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A standardized CPUE analysis of the Japanese distant-water skipjack pole-and-line fishery in the western and central Pacific Ocean (WCPO), 1972-2009.

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A. Langley [1], K. Uosaki[2], S. Hoyle[3], H. Shono[2], M. Ogura[2]

[1] Consultant, Secretariat of the Pacific Community, Noumea, New Caledonia
[2] National Research Institute of Far Seas Fisheries, Shimizu, Japan
[3] Secretariat of the Pacific Community, Oceanic Fisheries Programme, Noumea, New Caledonia

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Adam Langley[1], Koji Uosaki[2], Simon Hoyle[3], Hiroshi Shono[2] and Miki Ogura[2]

[1] Consultant, Secretariat of the Pacific Community, [2] National Research Institute of Far Seas Fisheries, [3] Secretariat of the Pacific Community.

ABSTRACT

Since 2000, stock assessments of skipjack tuna in the WCPO have incorporated standardized CPUE indices derived from the analysis of catch and effort data from the Japanese pole-and-line fishery. The resulting indices represent the principal index of stock abundance in each of the model regions and, consequently, are highly influential in the assessment. The methodology used to derive the skipjack CPUE indices was reviewed at the pre-assessment workshop held at SPC in April 2010. A key recommendation of the workshop was to initiate a collaborative study between SPC and the National Research Institute of Far Seas Fisheries (NRIFSF) to analyze the operational CPUE data and provide revised CPUE indices for inclusion in the 2010 skipjack stock assessment.

The study applied a delta-lognormal GLM approach to derive indices for the two equatorial regions of the WCPO from the distant-water fleet logsheet data. The resulting indices differ considerably from the indices incorporated in previous assessments. The indices for the western equatorial region exhibit a decline over the study period (1972-2009), although most of the decline in the indices occurs during the late 1980s and early 1990s. There is concern regarding potential sources of bias in the indices related to large changes in the operation of the pole-and-line fleet during that period. The indices for the eastern equatorial region are relatively stable from 1972 to 2001 and then tend to be lower for 2002-2009. Despite concerns regarding the reliability of the indices, it is concluded that the current indices represent the best available indices for incorporation in the 2010 WCPO skipjack assessment.

INTRODUCTION

Since 2000, stock assessments of skipjack tuna in the WCPO have incorporated standardized CPUE indices from the Japanese pole-and-line fishery (Shono & Ogura 1999). A GLM approach was used to standardize the catch and effort data, including information related to the adoption of new fishing technology that is likely to have increased the efficiency of the fleet. The methodology for deriving the indices is described in detail in Shono & Ogura (1999). The indices have routinely been updated for incorporation in the most recent assessments (Langley & Hampton 2008), although in the most recent assessment information regarding the fishing technology were not available for inclusion in the GLM. The indices represent the principal index of stock abundance in each of the model regions and, consequently, are highly influential in the assessment.

The methodology used to derive the skipjack CPUE indices was reviewed at the pre-assessment workshop held at SPC in April 2010 (Harley & Hoyle 2010). A key recommendation of the workshop was to initiate a collaborative study between SPC and the National Research Institute of Far Seas Fisheries (NRIFSF) to analyze the operational CPUE data and provide revised CPUE indices for inclusion in the 2010 skipjack stock assessment.

The collaborative work was undertaken at the NRIFSF in Shimizu during 10-21 May 2010. This report documents the results of the analysis.

DATA SETS

Data description

The Japanese distant-water pole-and-line fishery targets surface aggregations of skipjack tuna in the equatorial region and targets albacore tuna and/or skipjack tuna in the temperate waters off coastal Japan during the summer. The fishery relies on the location of surface aggregations of tuna, either unassociated schools (“free schools”) or schools associated with naturally occurring floating objects (log schools). The distant-water fishery does not deploy fish aggregation devices (drifting or anchored FADs).

The Japanese distant-water and offshore pole-and-line vessels have reported catch and fishing activity on daily logsheets since 1972. The logsheet data provides a high level of coverage of the fishing operations of the distant water pole-and-line fleet (more than 85% of fishing days in the 1990s and 100% thereafter) (Shono & Ogura 1999). Logsheet data were available to the end of 2009.

The logsheets record the daily fishing activity (searching and active fishing) of an individual vessel. The logsheet records the midday location (truncated to the nearest degree of latitude and longitude), the species catch in weight (estimated catches reported in 100 kg units; the minimum reported catch is 100 kg) for skipjack tuna, albacore tuna, yellowfin tuna, Pacific bluefin tuna, bigeye tuna, frigate mackerel, and other fish.

The number of poles used by the vessel is also recorded. The number of poles is recorded for almost all records (both non zero and zero catch records) and is relatively consistent for a vessel trip. Therefore, it is not possible to use this information to distinguish between an unsuccessful fishing event (i.e., locating an aggregation but catching no skipjack) and a day when no active fishing occurred (i.e. failure to locate a school during searching or navigating between fishing areas).

Individual vessels are identified by licence number. However, the licence number of individual vessels has changed on a regular basis (every five years; licence renewal occurred in 1992, 1997, 2002, and 2007). For the distant-water pole and line fleet, a reference table has been created that details the licence number of an individual vessel in each year for the period 1984 onwards. This table was used to create a unique vessel index in the logsheet dataset. The licence number was not changed between 1982 and 1984, enabling the vessel index to be extended to include the 1982 and 1983 years. For the years prior to 1982, all vessels were assigned to an aggregate vessel category. Similarly, for 1982-86, vessels with no associated record in the reference table were assigned to this aggregate vessel category. The few logsheet records from 1987-2009 that had no associated record in the vessel reference table were deleted from the data set.

The analysis was limited to the distant-water vessels only. This component of the fleet was defined as vessels larger than 200 gross registered tonnes. Information on the fishing technology used by the fleet has been collected via interview, as described in Shono & Ogura 1999. Vessel specific information details the implementation of five important technological innovations in the pole-and-line fishery: the low temperature live bait tank (LTLBT), onboard NOAA meteorological satellite image receiver (NOAA receiver), first and second generation bird radar, and sonar. The adoption and application of these components is described in detail in Shono & Ogura 1999. The individual logsheet records include the presence or absence of each component of the technology on board the vessel. Where no information is available it is recorded as unknown.

The LTLBT was first recorded in the fleet in 1981. For records prior to 1981 where the presence/absence of a LTLBT is recorded as unknown, it was assumed to be absent. Similarly, for records prior to 1987, it was assumed that sonar, first generation bird radar and NOAA receiver were absent if they were recorded as unknown. The second generation bird radar was introduced from 1991, and for earlier records it was assumed that the technology was absent (where recorded as unknown).

Individual logsheet records were assigned to a specific MFCL region (Figure 1) based on the location of the fishing activity. The regions are equivalent to those used in the most recent (2008) WCPO stock assessment (Langley & Hampton 2008). For each region, the data set was limited to individual vessels that completed a minimum of 10 days fishing each year for a minimum of five years ("core vessels"). While these selection criteria excluded a number of vessels from the final data sets, the core vessels accounted for a high proportion (greater than 90% ??) of the total fishing effort and catch.

Limited fishing activity has been recorded for distant-water vessels within the area of the Sea of Japan (MFCL region 1), and this region was excluded from the analysis.

Distant-water pole-and-line fishing activity in the other two northern regions (MFCL regions 2 and 3) principally occurs during May-September. During this period, the pole-and-line fleet targets both skipjack and albacore, although albacore is considered to be the preferred target species. The catch composition of fishing trips revealed that catch of an individual trip was generally dominated by one species, and few trips caught a significant quantity of both species. However, in years where a high proportion of trips were dominated by albacore, a relatively low proportion of trips were dominated by skipjack and vice versa. This is consistent with the assertion that albacore is the preferred species and skipjack is only targeted when albacore abundance is low.

The absence of skipjack in the catch from target albacore trips is therefore unlikely to be informative regarding the relative abundance of skipjack. On that basis, MFCL 2 and 3 data sets were limited to those trips that principally caught skipjack (i.e., those fishing trips where skipjack represented at least 75% of the combined skipjack and albacore catch from the trip) in the respective regions. In some years, this selection criterion resulted in the removal of a large proportion of the trips from the data set (quantify??).

Data summary

The historical trends in the fishery are described in detail in Shono & Ogura 1999.

The distant-water pole-and-line fleet operates throughout the western and central Pacific north of about latitude 20° S. However, fishing effort is concentrated between the equator and 10° N (0-10°N) and in the northern latitudes (35-45° N) off the eastern coast of Japan (Figure 2). The level of fishing effort declined considerably from the 1970s, particularly within the equatorial region. The eastern extent of fishing effort in the equatorial region also contracted in the 1990s and 2000s.

During the late 1970s, there was a northern shift in the distribution of pole-and-line fishing within the equatorial region, and since the late 1980s fishing effort has been concentrated along the higher latitudes of the equatorial region (see Appendix 1a).

The equatorial fishery operates throughout the year, but fishing effort is concentrated in this region during October-March (quarters 4 and 1) (Figure 3). Fishing effort in the northern latitudes principally occurs during the third quarter (July-September).

Fishing effort (number of days) in the equatorial region was relatively high in the 1970s and early 1980s, declined to a relatively low level by the late 1980s and has remained at that level for the subsequent period (Figure 4). The trend in fishing effort is generally comparable for the northern area of the fishery.

For all MFCL regions, the nominal catch rate of skipjack (catch per fishing day, including searching) increased during the mid 1980s and generally remained at a higher level until recent years. For most areas, nominal catch rates have been lower in the last few years (Figure 4).

For the equatorial regions (MFCL regions 5 and 6), the proportion of zero skipjack catch records is low in comparison to the northern fishery (Figure 5), although since the early-mid 1970s there has been a steady increase in the proportion of days recording a zero catch of skipjack in the equatorial regions from about 10% to 15% of fishing days. There has been a similar increase in the proportion of zero catch days in the subequatorial region (MFCL region 4). In the northern regions (MFCL regions 2 and 3), the proportion of zero catch days is considerably higher and much more variable among years (Figure 5).

The vessel registration data revealed that a considerable number of vessels retired from the fishery in the late 1980s-early 1990s, although some of the vessels continued to operate in the fishery throughout the next two decades. During the 1990s, new vessels continued to enter the fishery replacing vessels that retired from the fishery. A significant number of vessels ceased fishing in 1990, 1995 and 2000. In 1995-2005, about 30-40 vessels were operating in the equatorial region although the fleet has reduced to about 25 core vessels in the more recent years (2006-2009).

The data included in each of the regional analyses are summarized in Appendix 1.

METHODS

For each MFCL region, a generalized linear modeling approach was applied to define the relationship between the encounter rate or catch rate of skipjack and a range of dependent variables (Table 1).

Table 1. Definition of the predictor variables included in the model.

Variable	Data type	Description
YearQtr	Categorical	Unique year and quarter
Vesselid	Categorical	Unique vessel category
LatLong	Categorical	5° of latitude and longitude spatial strata (midday position).
NumPoles	Continuous	Number of poles used when engaged in fishing.
BaitTank	Categorical (3)	0 Unknown if vessel has LTLBT. 1 Vessel does not have LTLBT. 2 Vessel has LTLBT.
NOAA	Categorical (3)	0 Unknown if vessel has NOAA receiver. 1 Vessel does not have NOAA receiver. 2 Vessel has NOAA receiver.
Sonar	Categorical (3)	0 Unknown if vessel has sonar. 1 Vessel does not have sonar. 2 Vessel has sonar.
BirdRadar	Categorical (4)	0 Unknown if vessel has bird radar. 1 Vessel does not have bird radar. 2 Vessel has first generation bird radar.

3 Vessel has second generation bird radar.

The GLM model has the basic formulation.

CPUE = YearQtr + Vesselid + LatLong + NumPoles + BaitTank + NOAA + Sonar + BirdRadar + Error.

The continuous variable NumPoles was included as a third order polynomial function. All other variables were categorical.

The model was implemented separately for each region. Three alternative formulations of the CPUE dependent variable were initially considered.

1. The presence/absence of skipjack catch for a fishing day. The dependent variable was modeled using a binomial error structure to estimate the probability of non-zero catch of skipjack for a fishing day (binomial model).
2. The skipjack catch for a fishing day with the addition of a small constant. The dependent variable was modeled assuming a lognormal error structure. Zero catch records were assigned a nominal catch of 1 kg (lognormal, all data model).
3. The non-zero skipjack catch for a fishing day. The dependent variable was modeled assuming a lognormal error structure. Zero catch records were excluded (lognormal, non zero catch model).

The parameterizations of the variables included in the models were examined.

From the lognormal models, the year/quarter CPUE indices were derived by exponentiating the individual year/quarter factorial coefficients. For the binomial model, the year/quarter indices were derived by the inverse logit transformation ($\exp(x)/(1+\exp(x))$, where x is the sum of the yrqtr coefficient and the intercept term). The binomial indices were expressed relative to the average observed probability of catching skipjack during 1972-79.

The residuals of the fit to the Vesselid effects in the binomial models were examined by comparing the average annual observed encounter rate (number of non zero skipjack catch records/total number of records) for a vessel with the mean predicted probability of catching skipjack for the given vessel and year. The average residual (observed –predicted) for each vessel year was calculated and the difference in the residual between the last and first years of a vessel's activity was calculated. A positive value indicates that the vessels encounter rate declined less than the estimated decline in the annual indices, while a negative value indicates that the encounter rate of the individual vessel declined more than the overall annual indices. A similar approach was applied to investigate temporal trends in the fit to the LatLong effects.

Delta-lognormal indices were derived for the two equatorial regions by combining the binomial and the non-zero lognormal indices (following Lo et al 1992). The delta-lognormal indices are calculated by multiplying the two sets of indices.

RESULTS

Western Equatorial region (MFCL region 5)

Binomial model

The binomial model indicates that the probability of catching skipjack within MFCL region 5 is highest in the Bismarck Sea and the Solomon Sea and decreases in the northeastern area of the region (Figure 6). There is a temporal trend in the spatial distribution of the residuals indicating that the localized area north of the Solomon Islands has had a lower probability of catching skipjack than in the previous decades (Figure 7).

In general, the vessels entering the fishery in the late 1980s tend to have a higher probability of catching skipjack than the older vessels although there is considerable variation in vessel performance across the fleet (Figure 8). The number of poles is also a significant variable in the model with the probability of catching skipjack is predicted to generally decline with an increase in the number of poles (Figure 9). This is somewhat counterintuitive, although the variable is strongly related to the individual vessel effect as a single vessel will consistently report the same number of poles used over many years of operation. Further, there are a small number of events that conducted fishing with less than 15 fishing poles (see Appendix 1a) and the model predicts a relatively high encounter rate, although the encounter rate is very poorly determined at the extremes of the range.

The adoption of the LTLBT, second generation bird radar, and NOAA SST receiver are estimated to have increased the probability of catching skipjack (Figure 9).

The year/quarter indices derived from the model are relatively high for 1970-1988 (Figure 10). The high probability of catching skipjack during this period is consistent with the low proportion of zero catch records (see Figure 5). The indices are considerably more variable from 1988 onwards exhibiting both short-term variations in the probability of catching skipjack and an overall decline in probability of catching skipjack during the period. The decline was most pronounced over relatively short periods, most notably during the late 1980s-early 1990s, 2002-06 and 2008-09. The probability was very low in the most recent year (2009). The quarters with lower indices tended to have a higher uncertainty (standard error) associated with the indices (Figure 10).

The indices are strongly influenced by the inclusion of the individual vessel effect (vesselid) in conjunction with the four technology variables (baittank, sonar, NOAA, and BirdRadar) (Figure 11). Excluding the vessel effect from the model, while maintaining the technology variables, removes the decline in the indices from the late 1990s (*no vessel, tech* model). Adding the vessel effect and excluding the technology variables (*vessel, no tech* model) results in a comparatively small decline in the indices compared to the *no vessel, tech* model. Including both the vessel variable and the technology variables in the model (*vessel+tech* model) resulted in the lower indices from 1987 onwards (Figure 11). This corresponds to the year when the first generation of bird radar was first adopted by the fleet.

Lognormal model

The quarterly indices derived from the lognormal model were generally consistent with the indices described for the binomial model (Figure 12).

Lognormal non zero model

The lognormal non zero model estimated that the (non zero) daily catch of skipjack was generally higher in the southeastern area of the region and was lower north of latitude 5° N (Figure 13). The daily catch was predicted to increase with the number of poles used for fishing, while the introduction of the LTLBT, bird radar, and NOAA SST receiver are each estimated to have increased the daily catch of skipjack (Figure 14).

The year/quarter indices derived from the model were considerably higher during 1970s-early 1980s than from 1990 onwards with a sharp decline in the indices during the late 1980s. The indices were relatively low for 2009 (Figure 15).

Eastern Equatorial region (MFCL region 6)

Binomial model

The model estimated that within region 6 the probability of catching skipjack was highest to the north of Fiji and Vanuatu within latitude 5-15° S (Figure 16). The probability of catching skipjack was generally lower to the north of the equator.

The vessels entering the fishery since the late 1990s generally have a higher probability of catching skipjack than the vessels operating in the fishery during the earlier period (Figure 17).

Of the other variables included in the model, only the LTLBT has the expected increasing effect on the predicted probability of catching skipjack (Figure 18). A possible explanation for this relationship is that vessels equipped with a LTLBT are able to use more bait during active fishing of an aggregation, thereby, increasing the probability of catching skipjack.

The year/quarter indices reveal that the probability of catching skipjack tuna in region 6 has remained relatively high throughout the study period (Figure 19). However, there have been short periods of lower encounter rates (most notably 1989-1990, 2004, and 2009) and overall there has been a general decline in the indices throughout the study period (from a probability of about 90% in the 1970s to about 80% in the 2000s). There is a higher uncertainty associated with the indices from 1990 onwards and the highest uncertainty tends to be associated with the lower indices.

Lognormal model

The lognormal model estimates the daily catch of skipjack was relatively stable prior to 1987 (Figure 20). The indices were considerably more variable in the subsequent period.

Lognormal non zero model

The model estimated that daily (non zero) catches were relatively constant throughout the region, although they tended to decline in the northwest (Figure 21). Catch was predicted to be positively correlated with the number of poles used in fishing and catch was also predicted to increase following the adoption of LTLBT and both first- and second-generation bird radar (Figure 22). Vessels equipped with a LTLBT may be able to use more bait when fishing on an aggregation, thereby, increasing the catch from an aggregation of number of aggregations fished during the day. The use of bird radar may allow the preferential selection of fish aggregations that may yield higher catches. The more recent entrants to the fishery were generally more efficient than the older vessels in the fleet (Figure 23).

The annual indices were relatively low prior to the mid 1980s (Figure 24). The indices were more variable in the latter period, tended to increase in the late 1980s, remained relatively high from 1990 until about 2005 and then tended to decline.

Subequatorial region (MFCL region 4)

Binomial model

The binomial model estimates that there is a higher probability of catching skipjack in the Philippine Sea and off the east coast of Taiwan (Figure 25). The newer vessels in the fishery generally have a higher encounter rate than the older vessels (Figure 26), while encounter rates are also predicted to increase following the adoption of LTLBT and sonar, although the model did not predict an increase in fishing success with the introduction of bird radar (Figure 27). Nonetheless, there is likely to be significant confounding between the individual vessel effects and the technology variables that may obscure the relationship with an individual factor.

The year/quarter indices do not reveal a trend in the probability of catching skipjack tuna in region 4. However, the indices are very poorly determined from the late 1980s onwards (Figure 28). The low precision of the indices from 1985-2009 appears to be related to the lower number of logsheet records from the period (see Appendix 1c). The high standard error associated with the indices precludes the application of these indices as an indicator of stock abundance.

Lognormal model

The lognormal model, with zero catches included, predicts higher catch rates in the western, coastal areas of the region (Figure 29). There is a strong vessel effect with the newer entrants estimated to be considerably more efficient than the older vessels in the fleet (Figure 30). Catch rates were strongly correlated with the number of fishing poles and the adoption of bird radar (first and second generation) and LTLBT is also to considerably increase the daily catch (Figure 31).

The quarterly indices are relatively high during the 1970s and early 1980s, increase sharply during the mid 1980s and then generally decline throughout the late 1980s and early 1990s (Figure 32). The indices fluctuate about a low level throughout the remainder of the 1990s and 2000s.

Lognormal non zero model

The non zero daily catch of skipjack is estimated to increase eastwards within region 4 (Figure 33). Daily catch rates are also predicted to increase with the adoption of bird radar (first and second generation) and LTLBT and generally increase with the number of poles fished (Figure 34). The more recent entrants in the fishery also have a higher daily catch than the older vessels (Figure 35).

Catch rates tended to fluctuate throughout the period with higher catch rates in 1983-87, 1992, and 2004-07 and low daily catch rates in 2008-09 (Figure 36).

Western subtropical region (MFCL region 2)

Binomial model

The probability of catching skipjack is highest off the coastal area of Japan within the eddy of the Kuroshio Current (Figure 37). The encounter rate is low in the southeastern area of the region. The more modern vessels generally have a higher probability of catching skipjack than the older vessels in the fleet (Figure 38), while the introduction of LTLBT and NOAA receiver also had a positive effect (Figure 39).

The bird radar effects are counterintuitive with the encounter rates estimated to be higher without bird radar, although bird radar is not considered to be an important searching device in this region due to the prevailing sea conditions and behavior of the bird species.

The fishery is strongly seasonal and indices are only available for the second and third quarters on the year. Encounter rates were variable and poorly determined for the early 1970s until the mid 1980s (Figure 40). For the remainder of the period, the indices all approached the upper bound (1.0) but were extremely poorly determined partly due to the low sample size. Hence, there are no reliable indices available from the binomial model from the mid 1980s onward.

Lognormal non zero model

The daily non zero catch of skipjack is estimated to be relatively uniform over the region (Figure 41). Catch rates are predicted to be positively related to the number of fishing poles (Figure 42) and consistently higher for the more modern vessels in the fleet (probably also aliasing the adoption of new technology) (Figure 43).

Daily catch rates are estimated to have increased generally increased from the mid 1980s to the late 1990s and then tended to have declined (Figure 44). However, the indices for 1990-2005 are highly variable and poorly determined (high variance).

Lognormal model

The results from the all data lognormal model are similar to the non zero lognormal model and for brevity only the quarterly indices are presented (Figure 45).

Eastern subtropical region (MFCL region 3)

Binomial model

Insufficient data were available from skipjack pole-and-line fishing in region 3 to reliably determine the key parameters in the binomial model and derive reliable year/quarter indices.

Lognormal model

The catch of skipjack is predicted to be highest in the southwestern area of the region (Figure 46). Catch rates generally increase with an increase in the number of fishing poles and with the adoption of bird radar and the LTLBT (Figure 47). The more recent entrants in the fishery tend to have a higher catch rate than the older vessels (Figure 48).

The quarterly indices are available for the second and third quarters of the year only due to the seasonal nature of the fishery. The indices from 1972-85 are relatively consistent (Figure 49). However, the indices from the subsequent period are highly variable and poorly determined (high standard error).

Lognormal non zero model

The daily non zero catch of skipjack is estimated to be positively correlated with the number of poles fished (Figure 51). The introduction of bird radar, LTLBT and NOAA receiver are each estimated to have had a positive effect on the daily catch of skipjack (Figure 51).

The year/quarter indices were relatively constant through the 1970s and 1980s (Figure 53). The indices tend to decline over the subsequent period, although limited data are available from the fishery in recent years.

Delta-lognormal indices – Regions 5 and 6

Delta-lognormal indices were derived for MFCL regions 5 and 6 only. Indices were not computed for the other regions due to the high uncertainty associated with the binomial indices for at least a considerable proportion of the study period. The high uncertainty is associated with a relatively limited number of observations from the fishery and variability in the encounter rate attributable to factors not available for inclusion in the model. For some regions, particularly the northern regions, there was also a high level of uncertainty associated with the indices from the non zero lognormal GLM models reflecting the low sample size, particularly during the last two decades.

For the western equatorial region (region 5), the delta-lognormal indices are more pessimistic than the binomial indices (Figure 54); the decline in the binomial index is exacerbated by the incorporation of the lower indices from the non-zero lognormal model from 1990 onwards. The resulting delta-lognormal indices exhibit a large decline in the during the late 1980s following the marked decline in the non-zero lognormal index in this period.

For the eastern equatorial region (region 6) the delta-lognormal indices tend to fluctuate about a long-term average level during 1972-2001 with the fluctuations largely driven by the variation in the non-zero lognormal index (Figure 55). The slight decline in the binomial index during the 1990s is countered by the higher non-zero lognormal indices during the same period. The combined index is relatively high in 1983-84, 1987-89, 1991-95 and 2000-01. The delta-lognormal indices tend to be lower from 2004 onwards due to the combination of lower binomial and non-zero lognormal indices in 2003-04 and 2008-09.

DISCUSSION

This analysis is based on the equivalent data set used in the recent updates of the skipjack CPUE indices following the approach of Shono & Ogura (1999). For the equatorial regions, the CPUE indices derived following Shono & Ogura (1999) were comparable to the nominal CPUE indices; the indices increased during the 1980s and remained at the higher level throughout the 1990s and 2000s.

There are a number of key differences between the current standardized CPUE analysis and the approach of Shono & Ogura (1999). Firstly, the GLMs incorporate a vessel effect, whereby, the relative efficiencies of the individual vessels in the fleet are explicitly modeled. The analysis has shown that the newer entrants to the fishery have a higher probability of catching skipjack and/or a higher daily catch of skipjack. The inclusion of the vessel effect in the model, in conjunction with the technology variables (bird radar, LTLBT, sonar and NOAA receiver), was highly influential and, for the western equatorial region (MFCL region 5), resulted in a sharp decline in the indices in the mid-late 1980s. There was a more gradual decline in the indices over the subsequent period as new vessels continued to enter the fishery. These trends were much less pronounced for the eastern equatorial region (MFCL region 6).

The second main difference in approach was to conduct the analysis at the regional level rather than construct a single model for the entire WCPO while incorporating interaction terms in the GLM to derive the regional CPUE indices. The former approach is preferred as the GLMs have more freedom to estimate model parameters that are specific to the region rather than constraining the model to share parameters among the individual regions and/or estimate region-specific effects via first-order interaction terms. The sharing of model parameters among regions can introduce biases in the resulting region specific CPUE indices, particularly if the operation of the fishery differs considerably between regions. There are clear differences between the fisheries in the equatorial and northern regions, such as the seasonality of the fishery and the interaction with the albacore fishery in the northern area, and the differences in some of the parameter estimates from the region specific GLMs support the assertion that these areas should be analyzed separately.

In the northern regions (regions 2 and 3), there is a strong interaction with the albacore fishery. Albacore is considered to be the preferred target species and there is likely to be more targeting of skipjack when albacore is not available to the pole-and-line fleet. In years of high albacore abundance, the low probability of catching skipjack and/or the low daily catch of skipjack may simply be reflective of the preference for targeting of albacore rather than the abundance of skipjack. The current analysis endeavoured to address the interaction with the albacore fishery by excluding fishing trips that principally caught albacore. Nonetheless, the interaction between the two fisheries is not fully understood and warrants further consideration.

The current modeling approach also incorporated fine-scale area effects within each region (at the 5 degree spatial scale). For most regions, there is clear variability in the probability of catching skipjack and/or the daily catch of skipjack throughout the region. There has also been a considerable shift in the spatial distribution of fishing effort, particularly in the equatorial region, that could potentially bias the resulting CPUE indices if the "area effect" was not explicitly incorporated in the GLM.

A key difference from the previous approach is the consideration of what is the appropriate dependent variable in the GLM. Shono & Ogura (1999) expressed CPUE as the logarithm of the skipjack catch per day per fishing pole. Zero catches were included and a small, constant was added to all CPUE records to enable the zero catch records to be incorporated in the GLM. This most closely approximates the lognormal all data models in the current analysis, although in the case of Shono & Ogura the effort variable (number of poles fished) was incorporated in the dependent variable (CPUE) of the GLM.

In formulating a measure of CPUE that is likely to be indicative of stock abundance it is crucial to define an appropriate measure of fishing **effort** for the fishery and, secondarily, consider the appropriate approach to model the available data. The current analysis initially considered four alternative measures of CPUE.

1. The probability of catching skipjack (binomial model);
2. The magnitude of the catch of skipjack, including the zero catch;
3. The magnitude of the non-zero catch of skipjack; and
4. The combination of the probability of catching skipjack and the magnitude of the non-zero catch of skipjack (delta-lognormal model).

The abundance of skipjack (that is vulnerable to the pole-and-line fishery) can be considered as a function of the total number of surface aggregations of skipjack (schools) and the average school size (biomass). The measure of CPUE needs to incorporate the performance of the fishery with respect to both components; i.e. an encounter rate that is related to the density (and the total number) of schools and a catch rate that is related to the size of the school. At lower stock sizes, the number (and density) of schools is likely to be lower and, therefore, encounter rates would be lower, while the average size of the school may also be lower and support smaller catches (for the equivalent amount of effort).

A key determinant of fishing success is the ability of a vessel to locate a surface aggregation. The logbook data does not record whether or not an aggregation (or multiple aggregations) was detected during the day. Instead, a zero catch may represent either the failure to locate an aggregation or a nil catch when the aggregation is actively fished by the vessel. Consequently, the proportion of records that report a catch of skipjack cannot be considered as a direct measure of the encounter rate; instead, the metric may be considered to be proportional to the encounter rate if the probability of a catch from a detected aggregation remains relatively constant over time and the probability of detecting subsequent aggregations remains constant over time.

The zero catch records can be incorporated in a GLM approach by explicitly modeling the probability of catching skipjack using a binomial error structure or by inflating the zero catch records with a small, nominal value and assuming a lognormal error structure. The former is the preferred approach as it more explicitly models the encounter rate, while ignoring the magnitude of the non zero catch, although it is recognized that the binomial indices may be positively biased if the average size of the fish aggregation has declined (and detecting an aggregation is independent of the size of the aggregation).

The second approach, the all data lognormal model, is somewhat sensitive to the value assumed for the zero catch records and, more crucially, allows the magnitude of the non-zero catch to influence the key model parameters. As a result, the zero catch component of the model is often poorly determined (as indicated by the violation of the assumption of a normal distribution of the model residuals). On that basis, the all data CPUE indices should be rejected.

The third approach involves modeling the catches obtained on days when some catch was taken. For catches on a single aggregation, the catch may be independent of the ability to locate that aggregation. While the size of an individual aggregation may influence the catch or catch rates achieved, the catch is also likely to be affected by the size of the vessel (number of crew and number of poles vs. mobility of smaller vessels) and the ability of the vessel to remain in contact with the aggregation. For sufficiently large aggregations, the fishing effort is likely to become saturated; i.e. the catch is limited by the number of fishing poles and the length of time the school stays with the vessel rather than the abundance of fish in the aggregation. This may explain why the CPUE indices from the non-zero (i.e. zero catches excluded) lognormal models tend to be relatively stable.

CPUE on a single aggregation does not incorporate a key component of the fishing activity (i.e. searching) and the resulting indices are likely to be exhibit “hyperstability”. Nonetheless, the indices from the non-zero lognormal model may provide some information regarding the size of the aggregations fished (as well as the ability to locate more than one school during a day). That is the basis for combining these indices with the binomial indices to derive the delta-lognormal model, essentially combining the probability of encountering an aggregation (binomial) with an index of the size of the aggregation (non-zero lognormal). However, the delta-lognormal approach does assume that the two sets of indices are independent. This assumption could be violated if, for example, the ability to locate an aggregation was related to the size of the aggregation.

For the two equatorial regions, the binomial models tended to estimate parameters that are broadly consistent with the understanding of the operation of the fishery (Figs 9, 19); the newer vessels in the fishery were estimated to have a higher fishing power and the adoption of the LTLBT and the second generation bird radar resulted in an improvement in the ability of the vessels to catch skipjack.

The indices from the non-zero lognormal model for the western equatorial region are characterized by two phases; the indices are high prior to the late 1980s, decline rapidly during the late 1980s and are relatively low from 1990 onwards (Figs 16, 25). A converse trend is apparent in the indices from the eastern equatorial region; the indices are relatively low before the late 1980s and are somewhat higher and considerably more variable from 1990 onwards. This may be indicative that the non-zero lognormal indices are influenced by a marked change in the operation of the fishery (i.e. a change in fishing strategy, fleet composition, etc). It is worth noting that from about 1990 onwards the equatorial fleet was dominated by the vessels in the largest size class (500 GRT) (see Appendix 1a and 1b).

The binomial indices also exhibit a shift at about the same time. The indices for the western equatorial region are relatively stable until the late 1980s; in the subsequent years the indices are more variable and exhibit an overall decline. The indices for the eastern equatorial region are also considerably more variable after the late 1980s, although the decline in the indices is relatively slight until the most recent years. The transition in the indices corresponded to a period of rapid expansion of the purse seine fishery and also a general northern movement of the pole and line fleet in the equatorial region, partly related to the declaration of the EEZs in 1986 and the subsequent loss of access to important fishing grounds, especially the Bismarck Sea. The shift in the distribution of fishing activity may be indicative of a negative impact of the purse-seine fishery on the performance of the pole and line fishery. A cursory examination of the interaction between the two fleets revealed that there was virtually no overlap in the operation of the fisheries at the resolution of fishing day and 1° of latitude/longitude. The lack of any significant overlap in the fishing distribution precluded modeling the interaction explicitly within GLMs. The higher variation in the binomial indices from the late 1980s onwards may also be attributable to fishing in more variable conditions beyond the core distribution of skipjack tuna.

For the western equatorial region, the delta-lognormal indices are more pessimistic than the binomial indices (Figure 54); the decline observed in the binomial index is exacerbated by the incorporation of the lower indices from the non-zero lognormal model from 1990 onwards. For the eastern equatorial region, the combined delta-lognormal indices tend to be slightly more optimistic than the binomial indices, particularly from 1990 onwards as the slight decline in the binomial indices in the 1990s is countered by an increase in the non zero lognormal indices (Figure 55). Nonetheless, the contrasting trends in the two sets of indices are suggestive that the indices are monitoring different signals from the fishery and, on that basis, it may not be appropriate to derive a composite (delta-lognormal) index.

The spatial contraction of the pole and line fishery in the equatorial region also means that the indices from the latter period are driven by the fishery performance in the northern areas of the equatorial regions. By default, these indices are also assumed to reflect the trend in area closer to the equator. However, the distribution of the total skipjack catch is concentrated south of 10° N and potentially the stock may be more depleted in this area. Conversely, the higher exploitation rates in the core area may reduce the dispersion of skipjack to the higher latitudes (where the pole and line fishery operates) and the contraction of the distribution of skipjack may result in a greater decline in the abundance of skipjack in the peripheral areas.

Another potential confounding factor is the decline in the number of vessels operating in the pole and line fishery and, consequently, a reduction in the searching power of the fleet. However, this was more likely to be a factor during the late 1970s-early 1980s when the number of vessels in the fleet declined substantially. The size of the fleet was relatively stable through the 1990s and early 2000s.

Binomial GLMs were run for three of the northern MFCL regions (regions 2, 3, and 4). However, the data were limited (MFCL region 3) or the resulting indices were poorly determined indicating that there was limited information content in the data sets to reliably predict the probability of catching skipjack. In regions 2 and 3, this may be partly related to the interaction with the target albacore pole and line fishery. Nonetheless, this means that there are no binomial indices available from the distant-water fleet for these northern regions. This may require some reconsideration of the existing boundaries of the WCPO skipjack stock assessment model. There are also logsheet catch and effort data from the Japanese offshore pole and line fishery, albeit without information regarding searching technology, which may be applied to derive an alternative set of indices.

In addition to the issues discussed above, there are a range of issues that could be more thoroughly investigated in future analyses of the catch and effort data from the Japanese pole and line fisheries, as follow.

1. The sensitivity of the annual indices to the criteria for selecting vessels for inclusion in the model data set should be examined. A preliminary analysis (for MFCL region 5) revealed that the CPUE indices were relatively insensitive to selecting vessels based on a minimum of 5-years or 10-years in the fishery, although the longer qualifying period resulted in somewhat more pessimistic indices.
2. For MFCL regions 5 and 6, the binomial models estimate very high quarterly indices for the 1973 year. This is consistent with the very low proportion of zero catch records in that year (2%) compared to the other years in the 1970s when approximately 10% of days recorded a zero catch. However, it is unknown whether this is due to a difference in reporting during that year.
3. If possible, the vessel license reference list should be extended to include 1972-81, thereby, enabling the vessel effects to be incorporated for the earlier period. This is important given the influence of the vessel effects in the GLMs and noting that there was a mass retirement of vessels (presumably the less efficient vessels) from the fishery during the late 1970s and early 1980s.
4. The sensitivity of the CPUE indices to the inclusion of a single vessel category in the early period should be examined. It may be worth considering splitting the CPUE index at 1982 thus creating two separate series (pre and post 1982).
5. In many cases, the parameterization of the covariates in the GLMs is generally consistent with the understanding of the fishery. However, for some variables, particularly those related to the various searching devices, the relationships are counterintuitive. This suggests a degree of confounding with other variables included in the model. The sensitivity of the resulting indices to the inclusion in specific variables should be examined in more detail. Some further error checking of the data set should be undertaken; for example, fishing records with a small number of fishing poles should be examined.
6. Information is available concerning vessel code groups (based on prefecture). This information was not included in the current GLMs and may provide some useful information regarding the sharing of information within sectors of the fleet. For the distant-water fleet, the vessels are considered to have operated as a single fleet from at least the 1980s and, therefore, such an analysis would be less relevant than for the offshore fleet.

7. Consideration of alternative approaches for modeling the data, including alternative error structures (e.g. Delta-Poisson and Delta-NegativeBinomial models).
8. Further analyses are required to improve the understanding of the nature and extent of the interaction between skipjack pole and line fishery and the purse-seine fishery (equatorial waters) and the albacore pole and line fishery (northern regions).

The current study represents considerable progress in the analysis the catch and effort data from the pole-and-line fishery and the resulting indices are likely to be more representative of the performance of the fishery (relative to previous studies). Nonetheless, the relationship between the CPUE indices and skipjack stock abundance is uncertain. For example, interpretation of the binomial component of the GLM as an index of stock abundance assumes that the probability of a non zero catch record (standardized by vessel, location, technology) is proportional to the density of fish aggregations, the distribution of the aggregations has remained relatively constant, the interest of fish in bait and hook has remained relatively constant, the average size of an aggregation has remained relatively constant, the probability of locating successive fish aggregations during a day has remained relatively constant and the indices are not biased by changes in the operation of the fishery. The index will also become saturated above a certain threshold of school density (and stock abundance) that corresponds to a high probability (approaching 1.0) of encountering and catching fish from at least one school each day. Insufficient data are available to investigate and validate these key assumptions.

The WCPO skipjack stock assessment is highly dependent on a time-series of relative biomass indices and, despite the uncertainty in the interpretation of the CPUE indices as indices of stock abundance, the CPUE indices from the distant-water pole-and-line fishery represent the most credible indices currently available. Conceptually, the delta-lognormal indices should provide a better index of stock abundance than the binomial indices. However, as discussed above, there is some concern regarding the reliability of the non-zero lognormal component of the delta-lognormal indices due to large changes in the operation of the fleet, particularly in the late 1980s and early 1990s. Such factors may also introduce biases to the binomial indices. There are also contrasting trends between the two sets of indices, particularly for the eastern equatorial region, suggesting that one (or both) of the indexes is not reliably monitoring the performance of the fishery.

For the 2010 WCPO stock assessment it is proposed that separate assessment models are formulated using the delta-lognormal indices and the binomial indices (Appendix 2). Delta-lognormal and binomial indices derived from distant-water logsheet data are only available for the two equatorial regions (region 5 and 6). In the absence of distant-water CPUE indices for the northern regions, it is proposed to compute delta-lognormal indices for the offshore pole-and-line fishery in region 2 following the GLM approach described in this paper. These indices will be incorporated in the stock assessment model as the principal relative abundance index for the northern region(s) (Appendix 3). It may also be appropriate to reconfigure the spatial structure of the WCPO assessment to be more closely aligned with the operation of the pole-and-line fishery.

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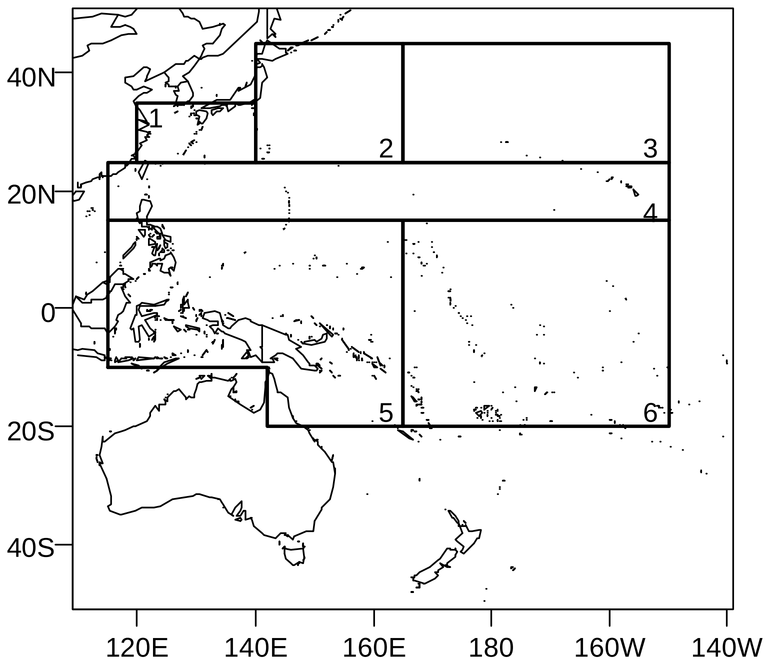


Figure 1. The spatial structure of the MFCL skipjack stock assessment model.

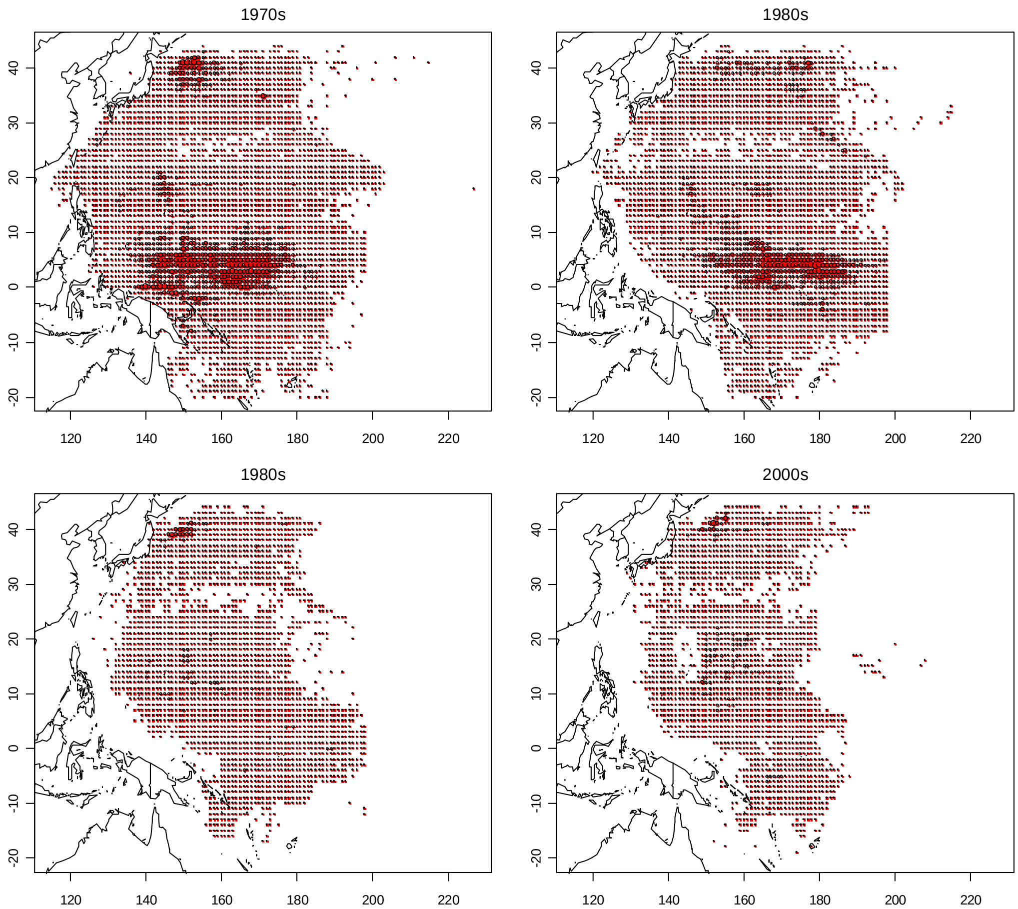


Figure 2. The spatial distribution of distant-water pole and line effort targeting skipjack tuna by decade. The circle size is proportional to the level of effort aggregated by degree of latitude and longitude. The bottom left panel is labeled incorrectly and should be labeled "1990s".

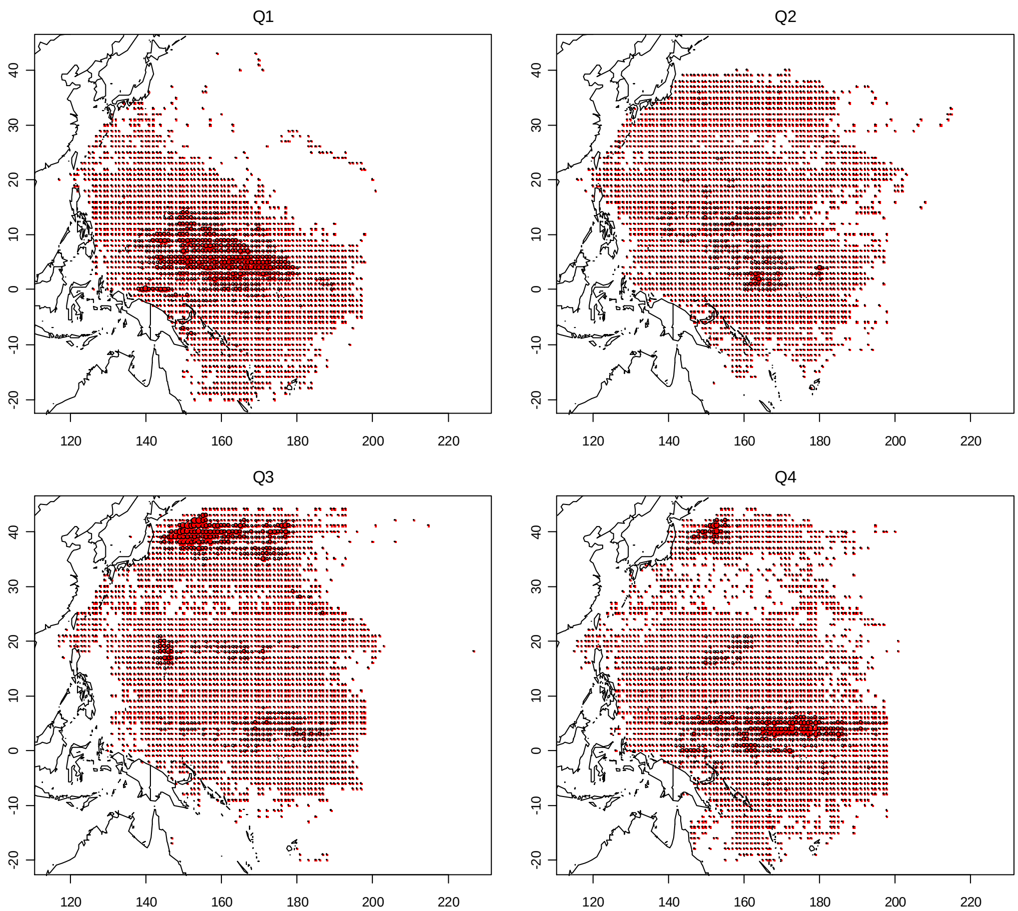


Figure 3. The spatial distribution of distant-water pole and line effort targeting skipjack tuna by quarter (all years combined). The circle size is proportional to the level of effort aggregated by degree of latitude and longitude.

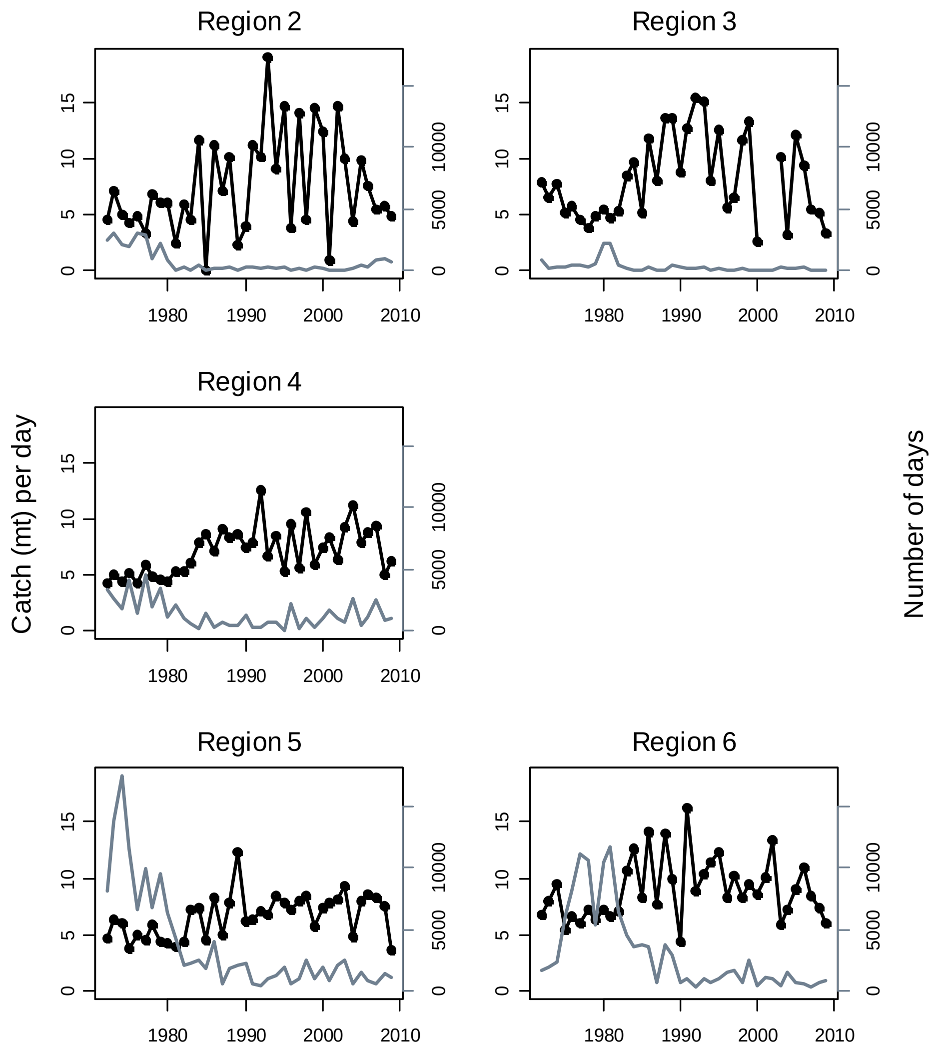


Figure 4. The annual number of days fished (grey line) by the distant-water pole-and-line fleet included in the final regional CPUE data sets and the nominal skipjack catch rate (mt per day, black line).

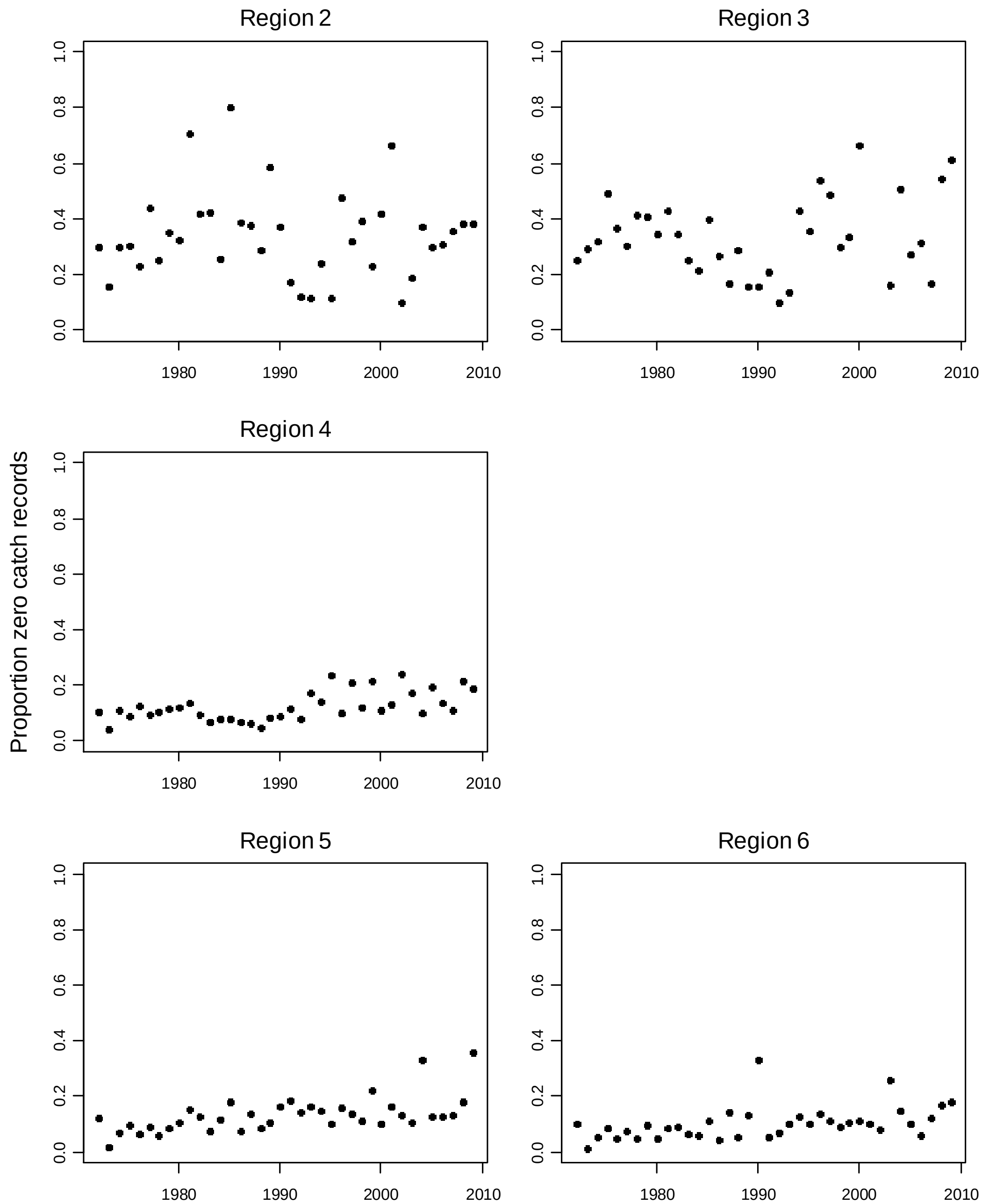


Figure 5. The proportion of zero skipjack catch records by year for the distant-water pole-and-line fleet included in the final regional CPUE data sets.

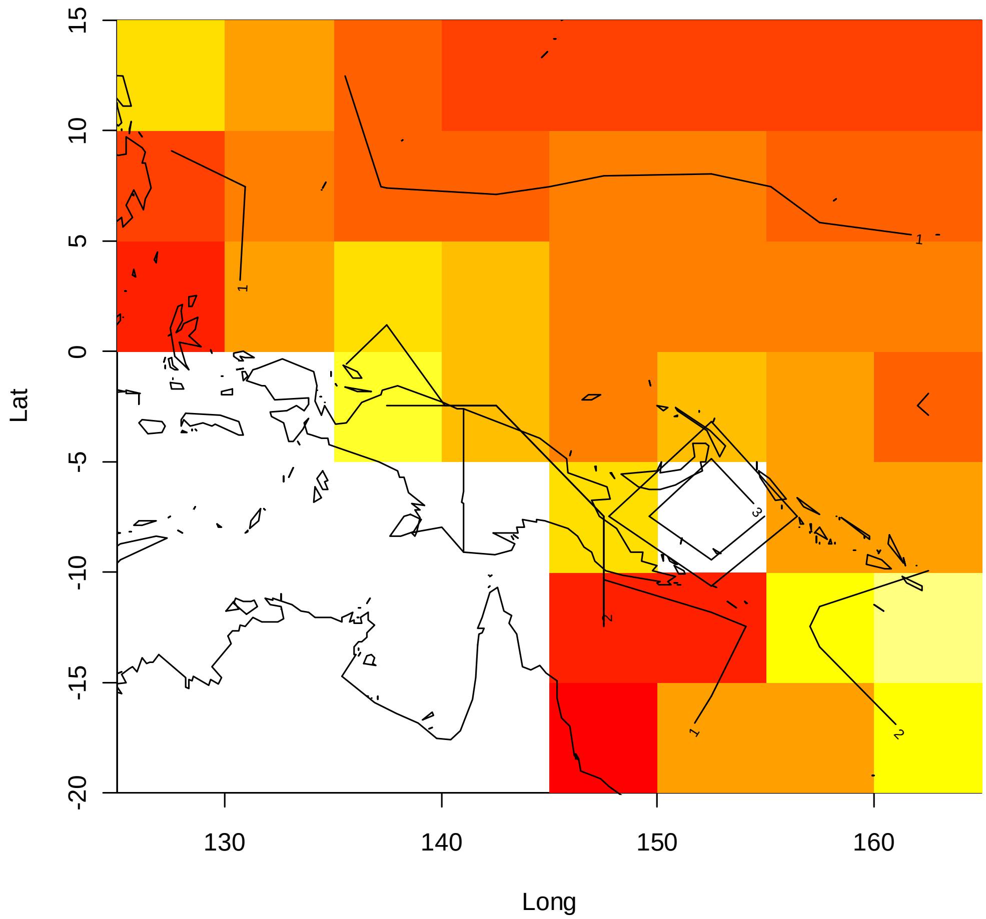


Figure 6. Latitude/longitude effects on the probability of catching skipjack (binomial model) for MFCL region 5 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

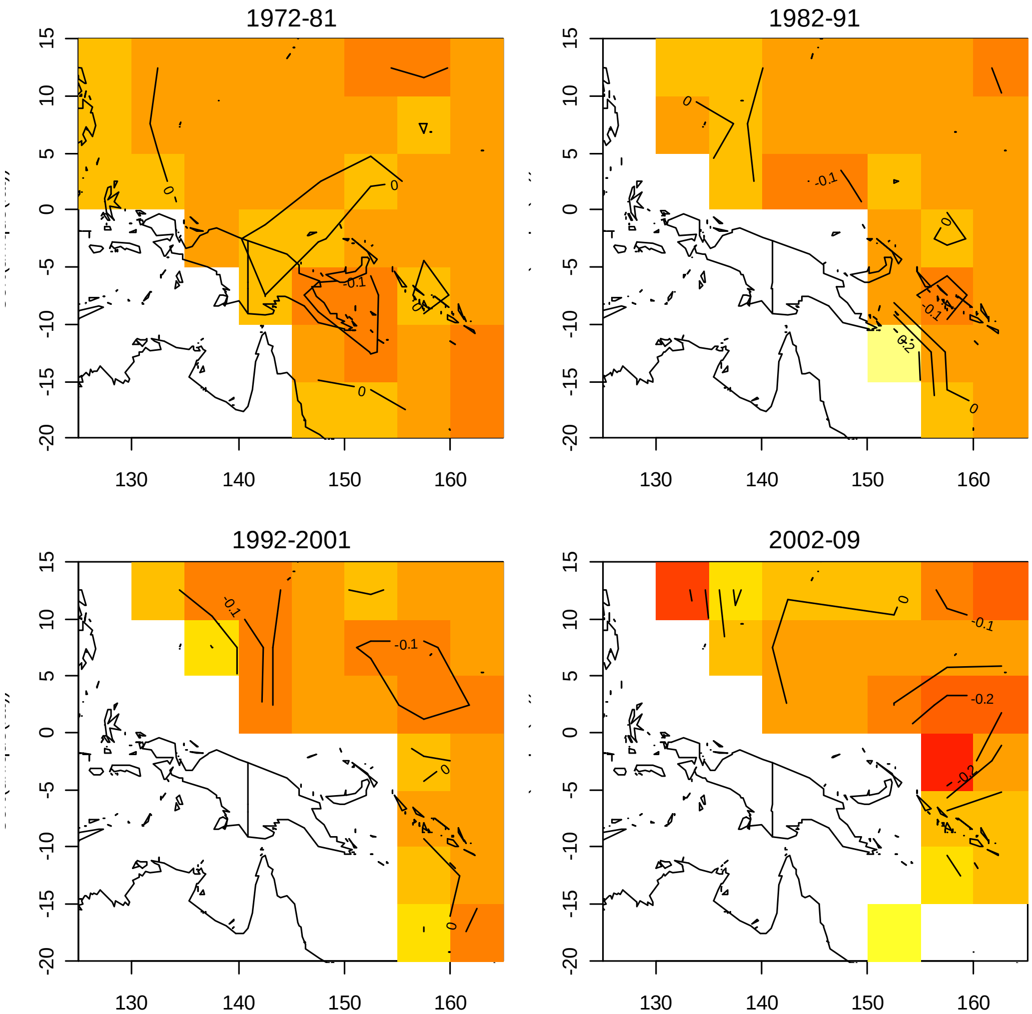


Figure 7. Mean residuals by ten year time intervals for the latitude/longitude effects on the probability of catching skipjack (binomial model) for MFCL region 5 (the colour scale denotes the magnitude of the residual from red (negative) to yellow (positive)).

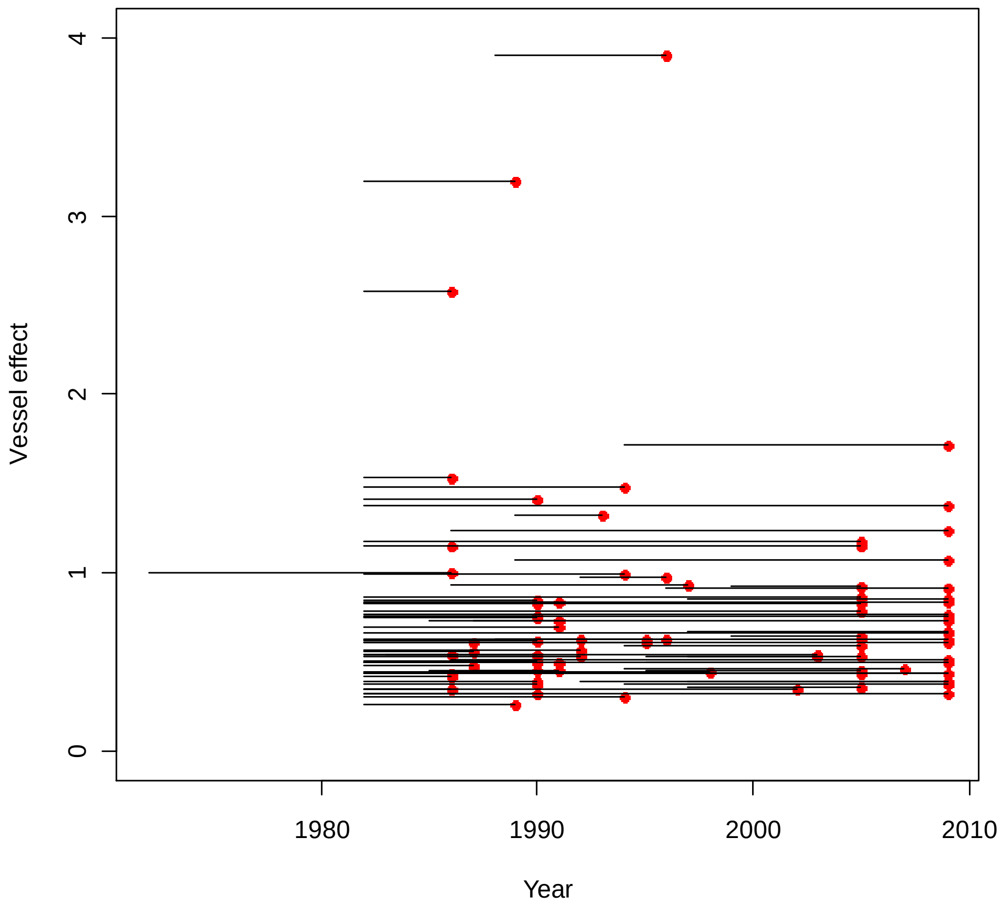


Figure 8. The individual vessel effects on the probability of catching skipjack (binomial model) for MFCL region 5 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

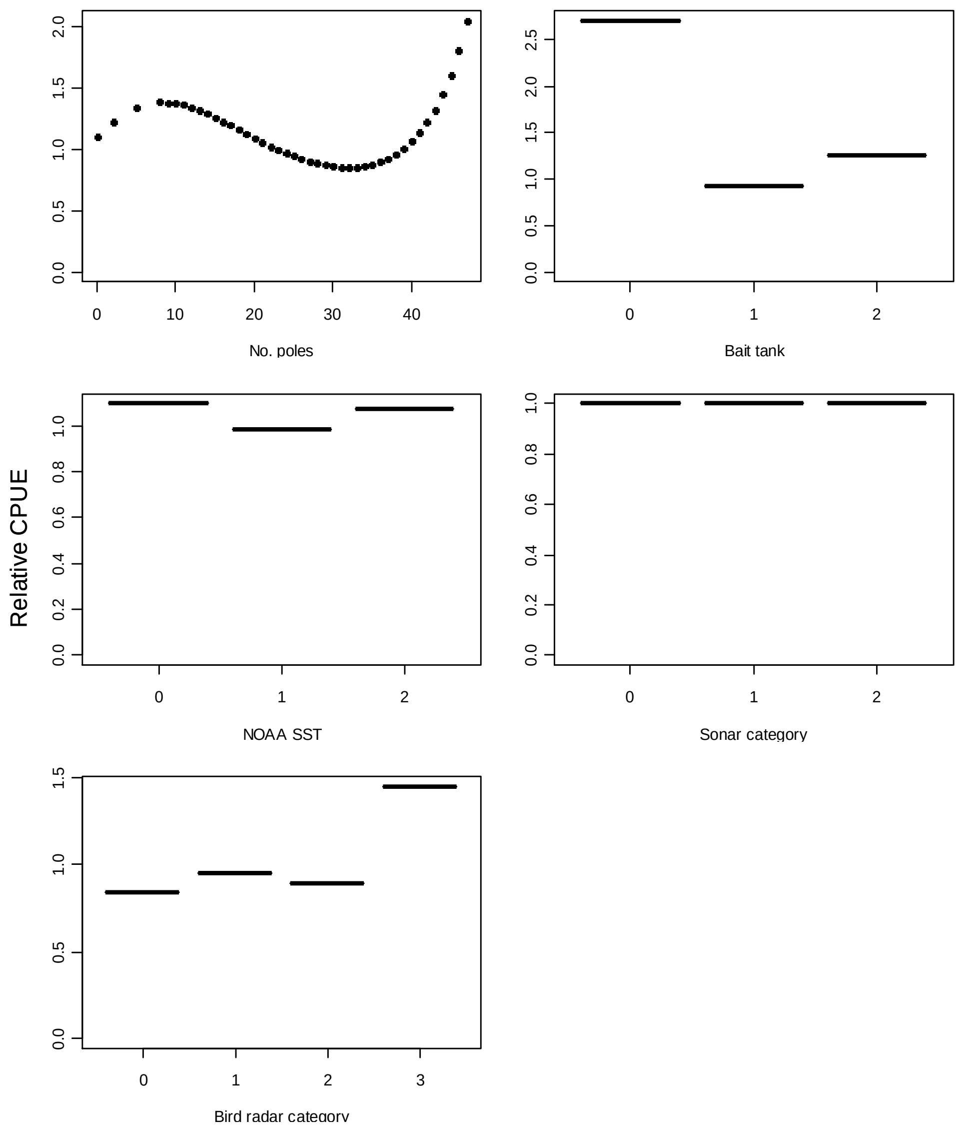


Figure 9. The relationship between the other model variables and the probability of catching skipjack (binomial model) for MFCL region 5.

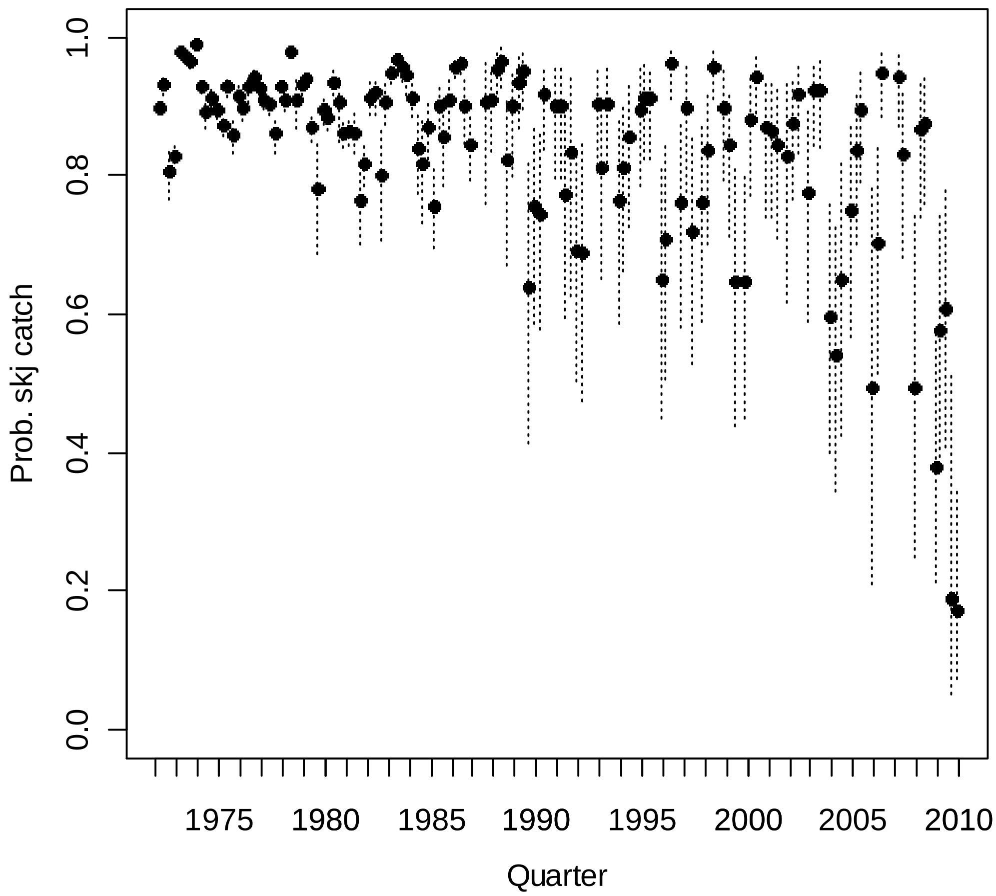


Figure 10. The year/quarter indices derived from the binomial model for MFCL region 5 (points). The vertical lines represent the 95% confidence intervals.

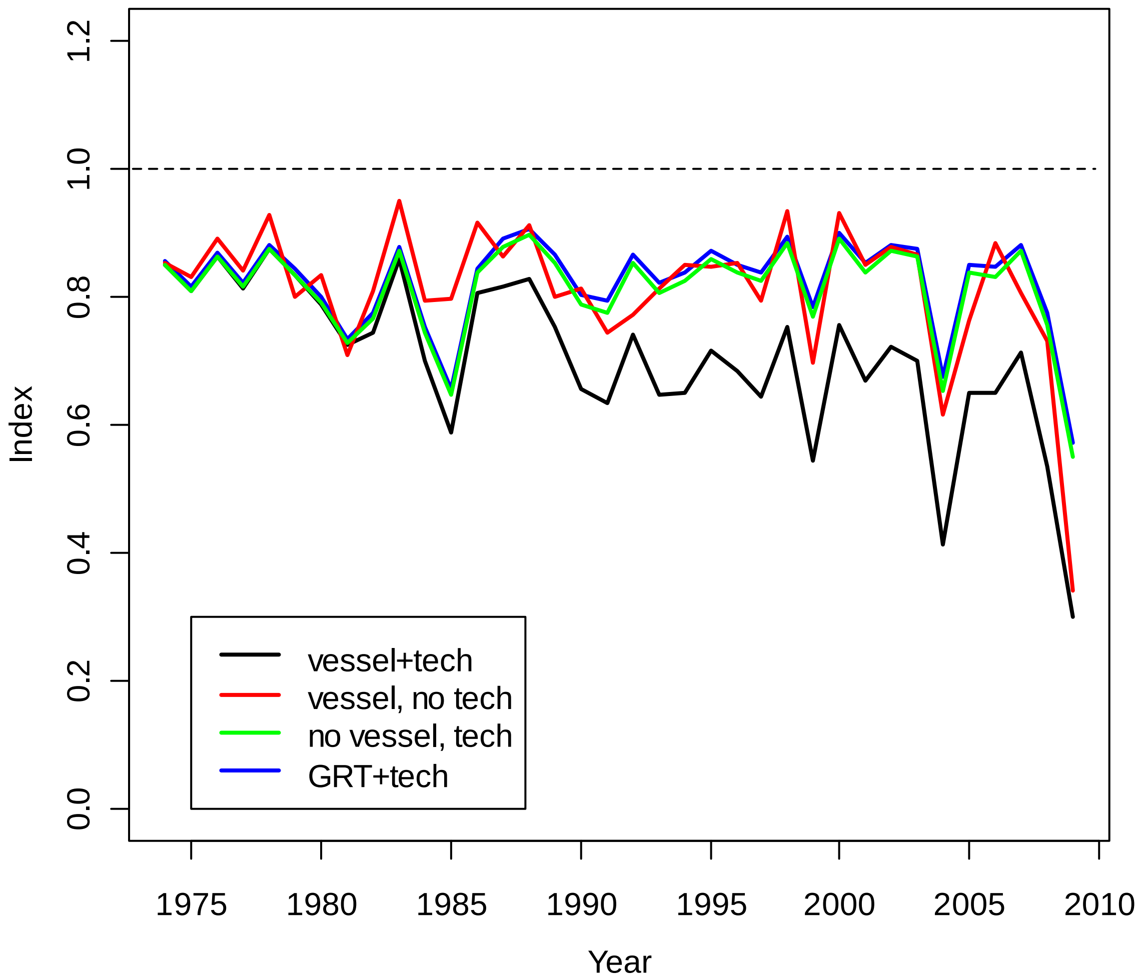


Figure 11. A comparison of annual indices derived from a range of binomial models for MFCL region 5 that investigate the influence of key variables, principally the individual vesselid (vessel) and the associated technology (tech) variables.

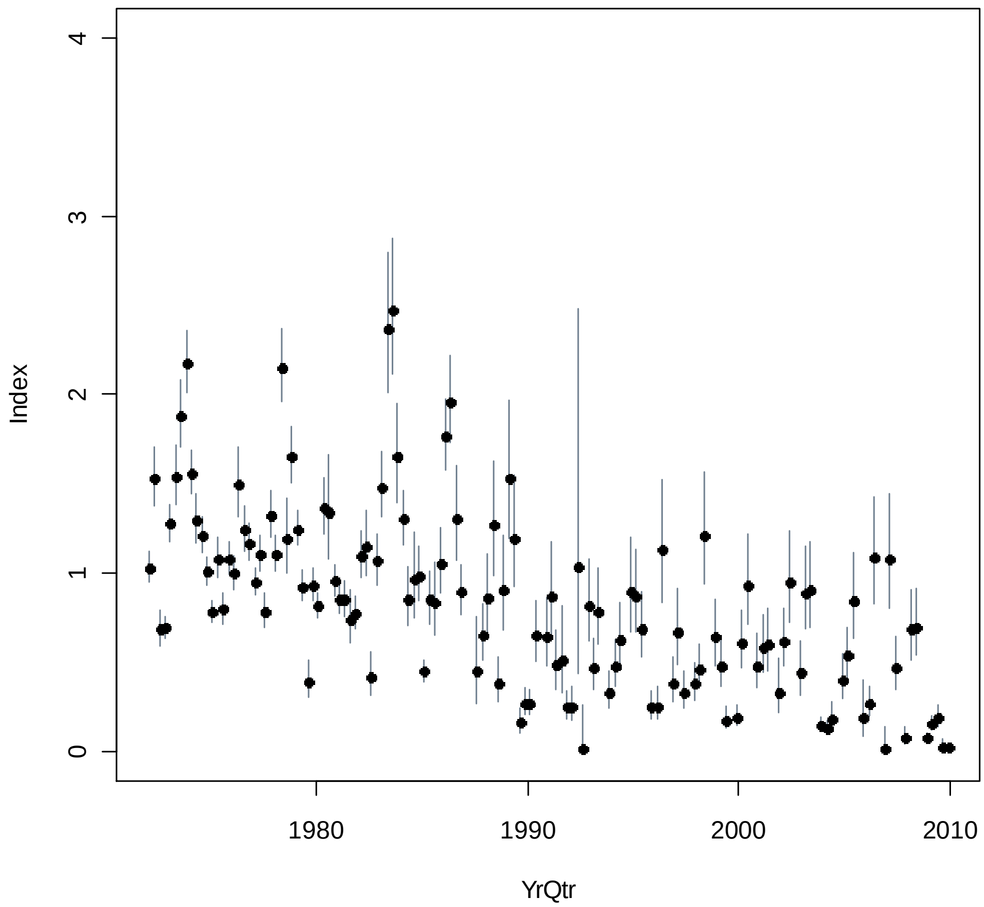


Figure 12. The year/quarter indices derived from the lognormal model for MFCL region 5 (points). The vertical lines represent the 95% confidence intervals.

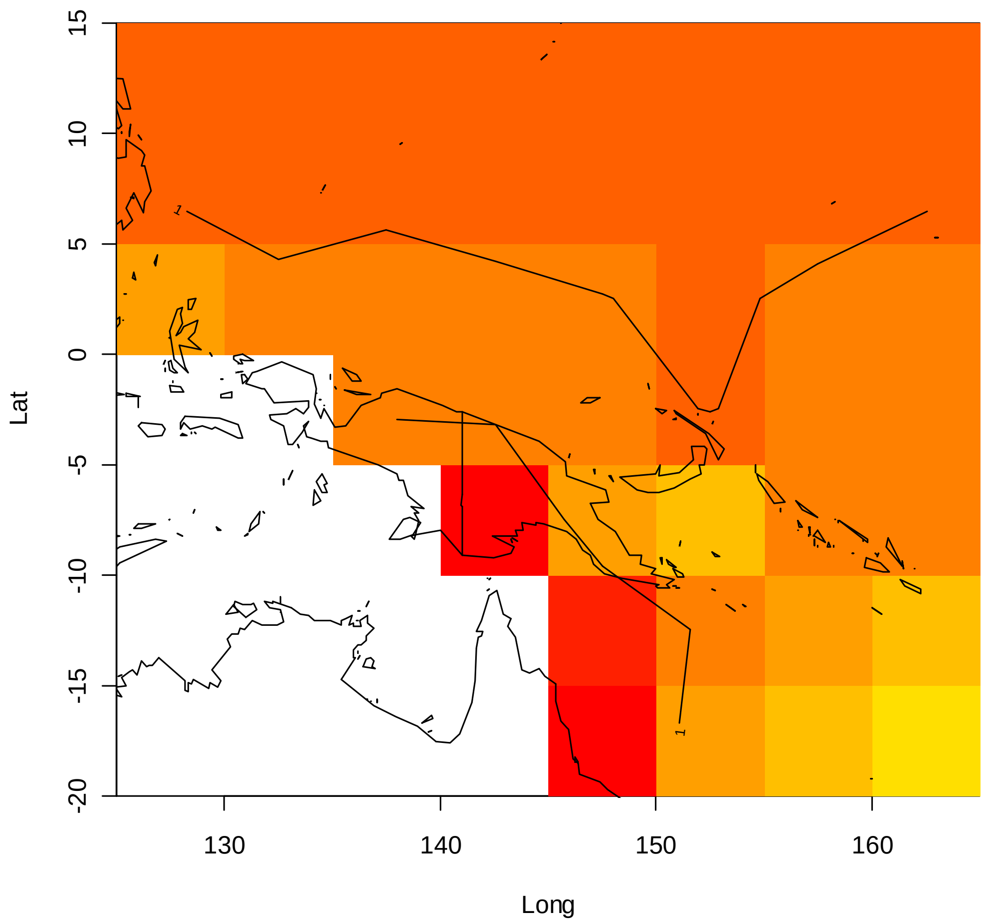


Figure 13. Latitude/longitude effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 5 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

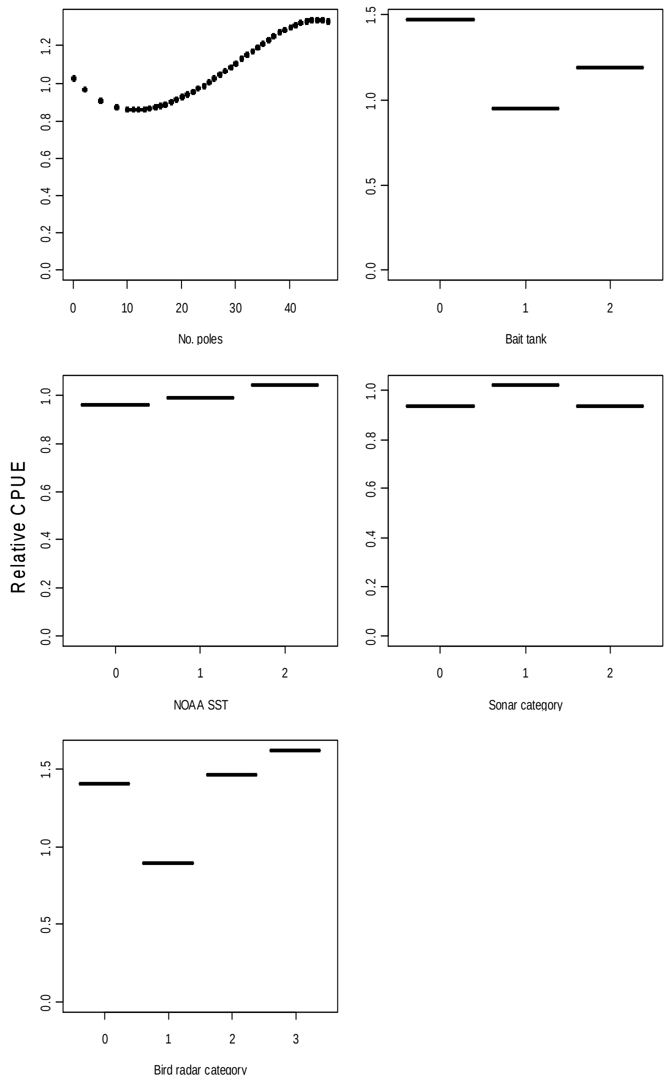


Figure 14. The relationship between the other model variables and the catch rate of skipjack (lognormal non zero model) for MFCL region 5.

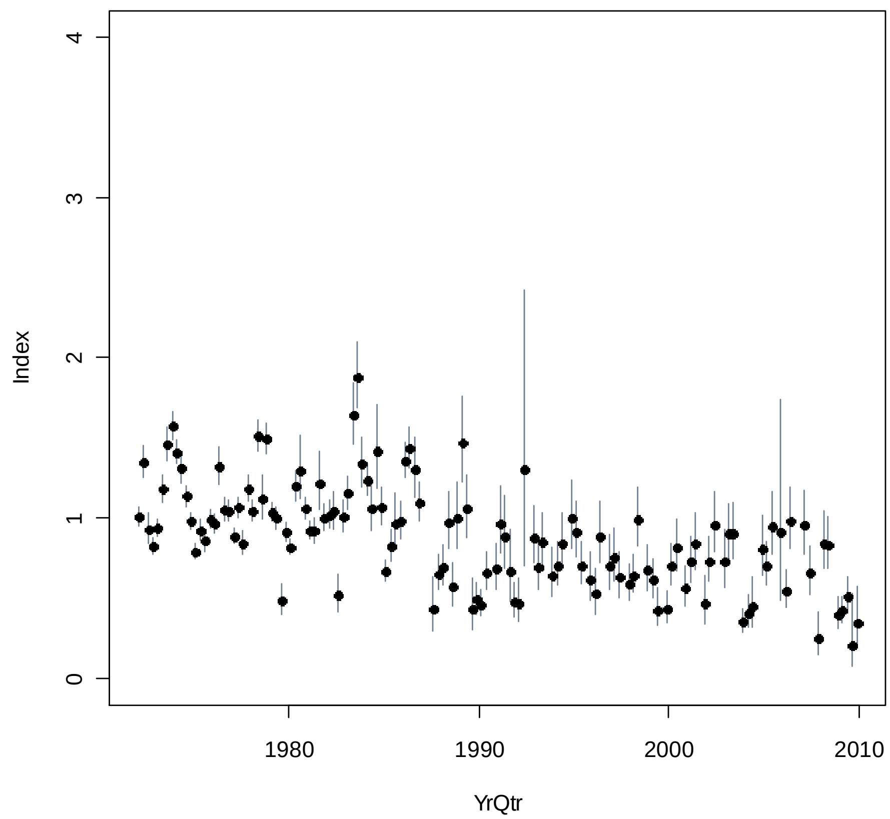


Figure 15. The year/quarter indices derived from the lognormal non zero model for MFCL region 5 (points). The vertical lines represent the 95% confidence intervals.

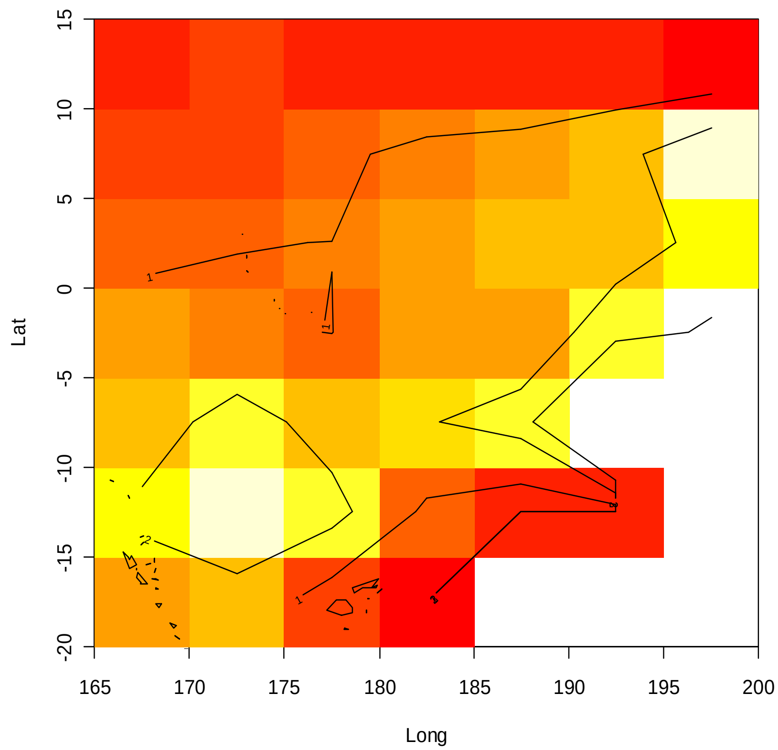


Figure 16. Latitude/longitude effects on the probability of catching skipjack (binomial model) for MFCL region 6 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

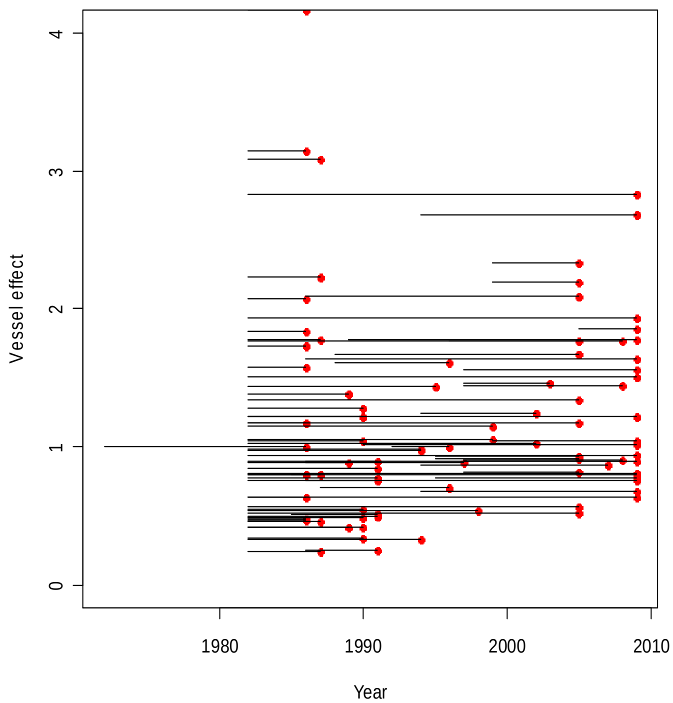


Figure 17. The individual vessel effects on the probability of catching skipjack (binomial model) for MFCL region 6 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

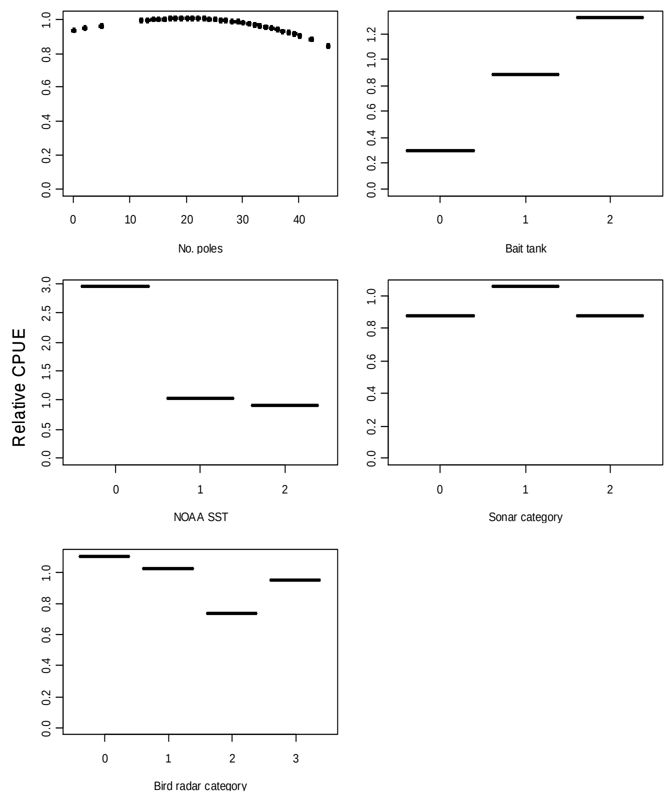


Figure 18. The relationship between the other model variables and the probability of catching skipjack (binomial model) for MFCL region 6.

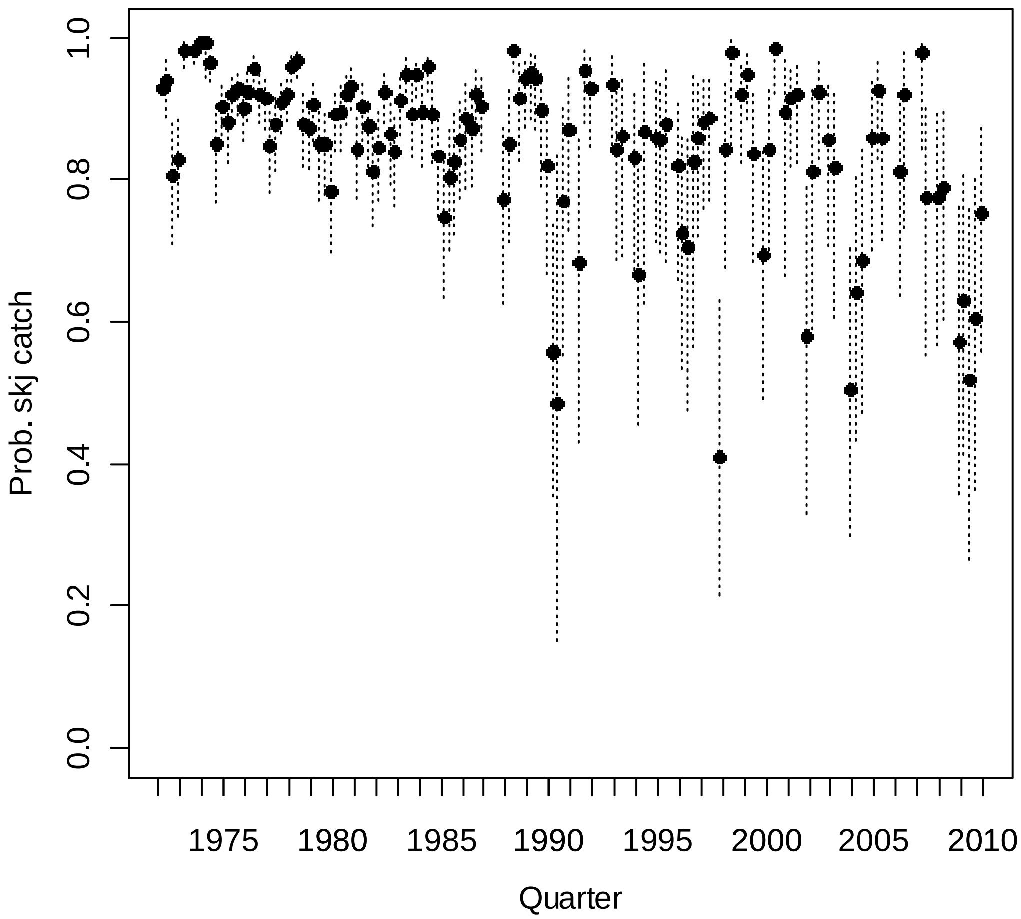


Figure 19. The year/quarter indices derived from the binomial model for MFCL region 6 (points). The vertical lines represent the 95% confidence intervals.

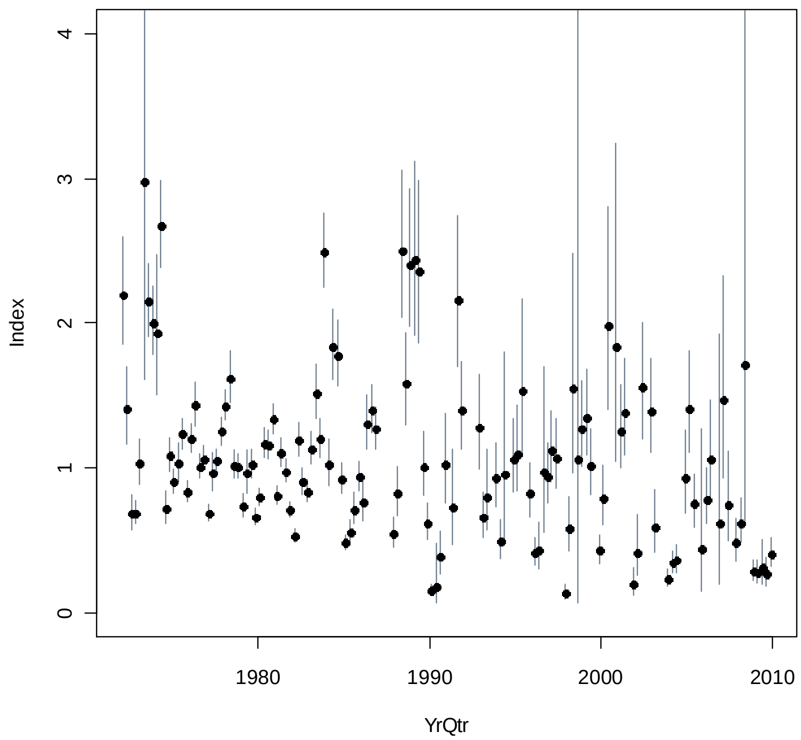


Figure 20. The year/quarter indices derived from the lognormal model for MFCL region 6 (points). The vertical lines represent the 95% confidence intervals.

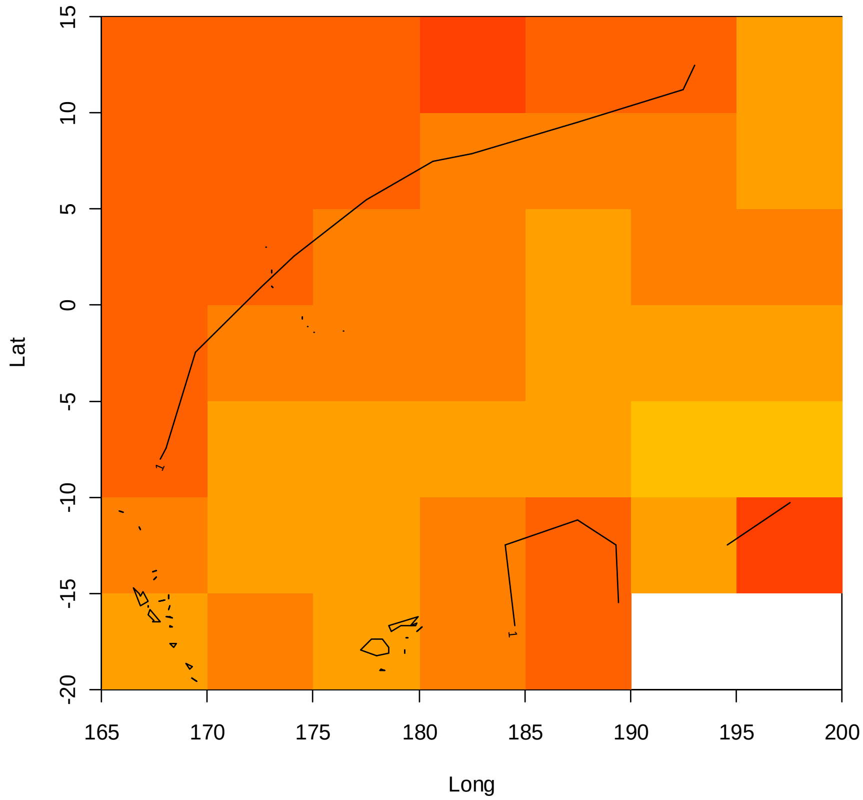


Figure 21. Latitude/longitude effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 6 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

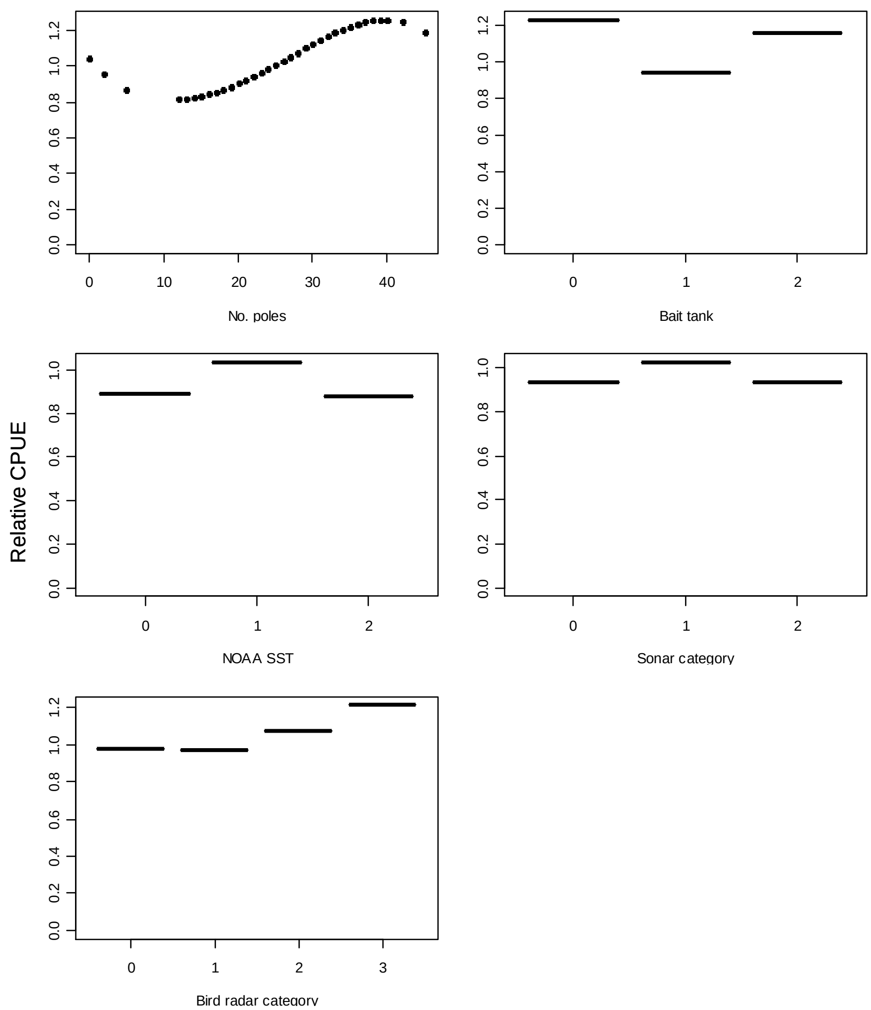


Figure 22. The relationship between the other model variables and the catch rate of skipjack (lognormal non zero model) for MFCL region 6.

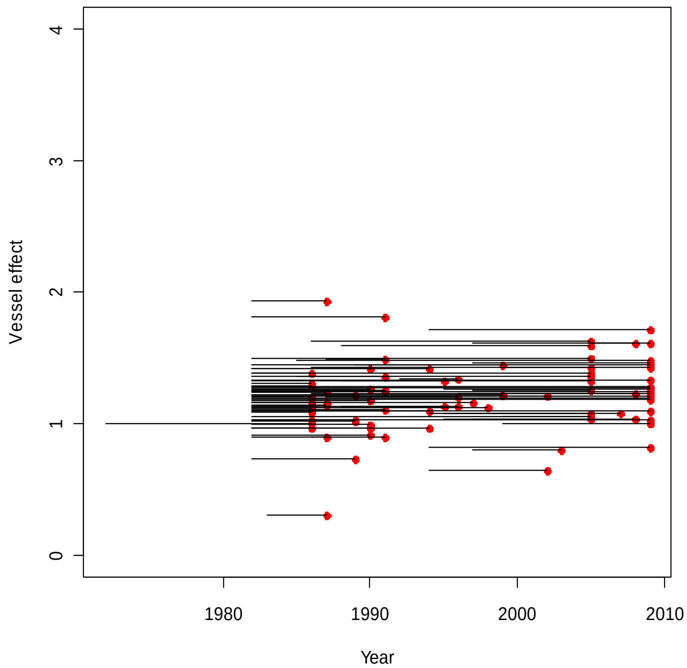


Figure 23. The individual vessel effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 6 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

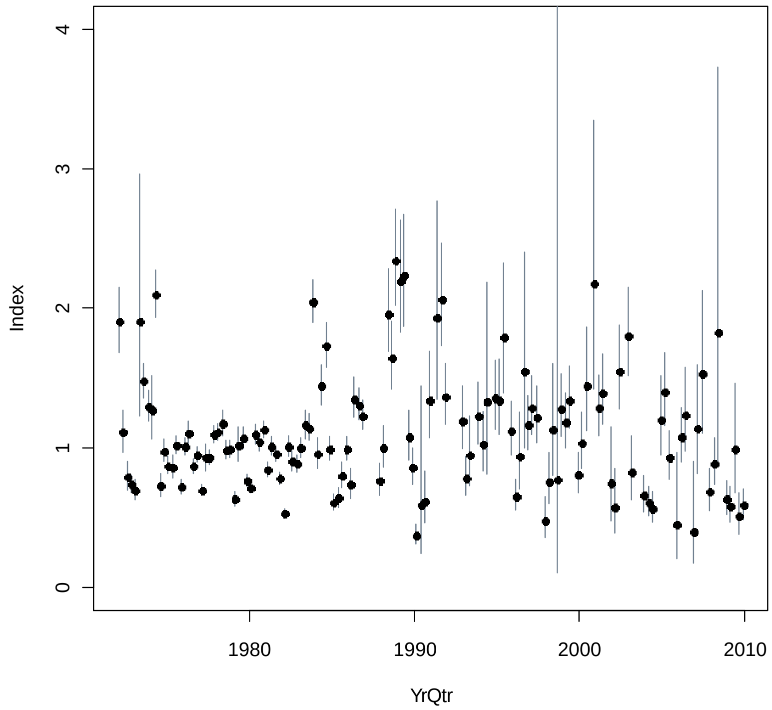


Figure 24. The year/quarter indices derived from the lognormal non zero model for MFCL region 6 (points). The vertical lines represent the 95% confidence intervals.

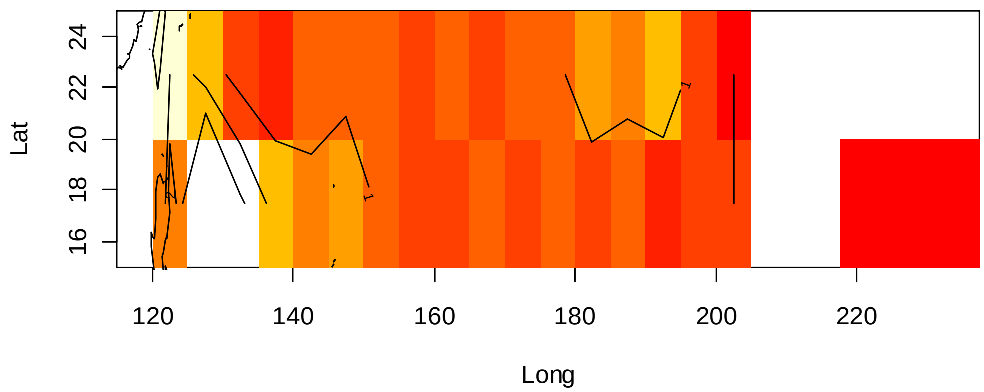


Figure 25. Latitude/longitude effects on the probability of catching skipjack (binomial model) for MFCL region 4 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

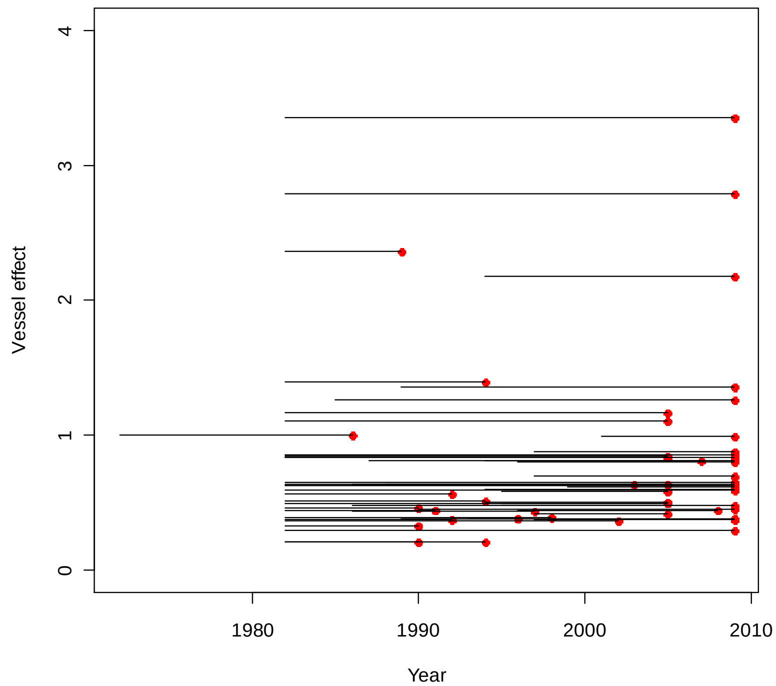


Figure 26. The individual vessel effects on the probability of catching skipjack (binomial model) for MFCL region 4 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

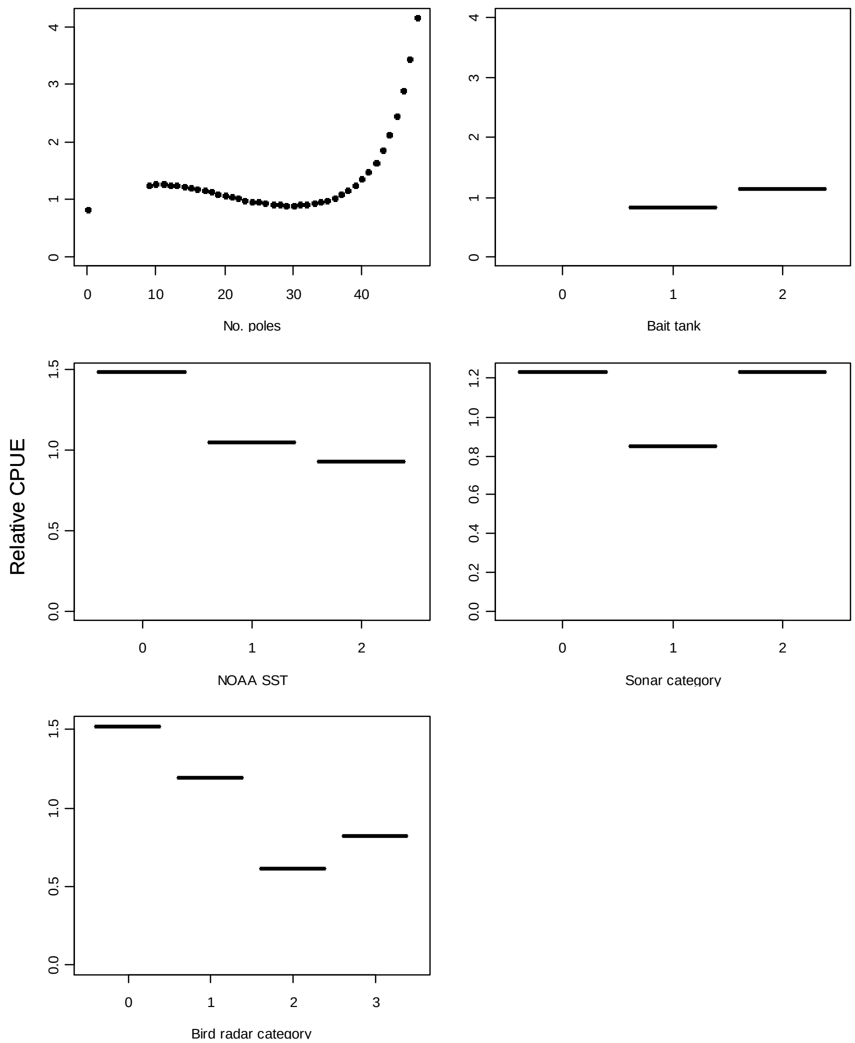


Figure 27. The relationship between the other model variables and the probability of catching skipjack (binomial model) for MFCL region 4.

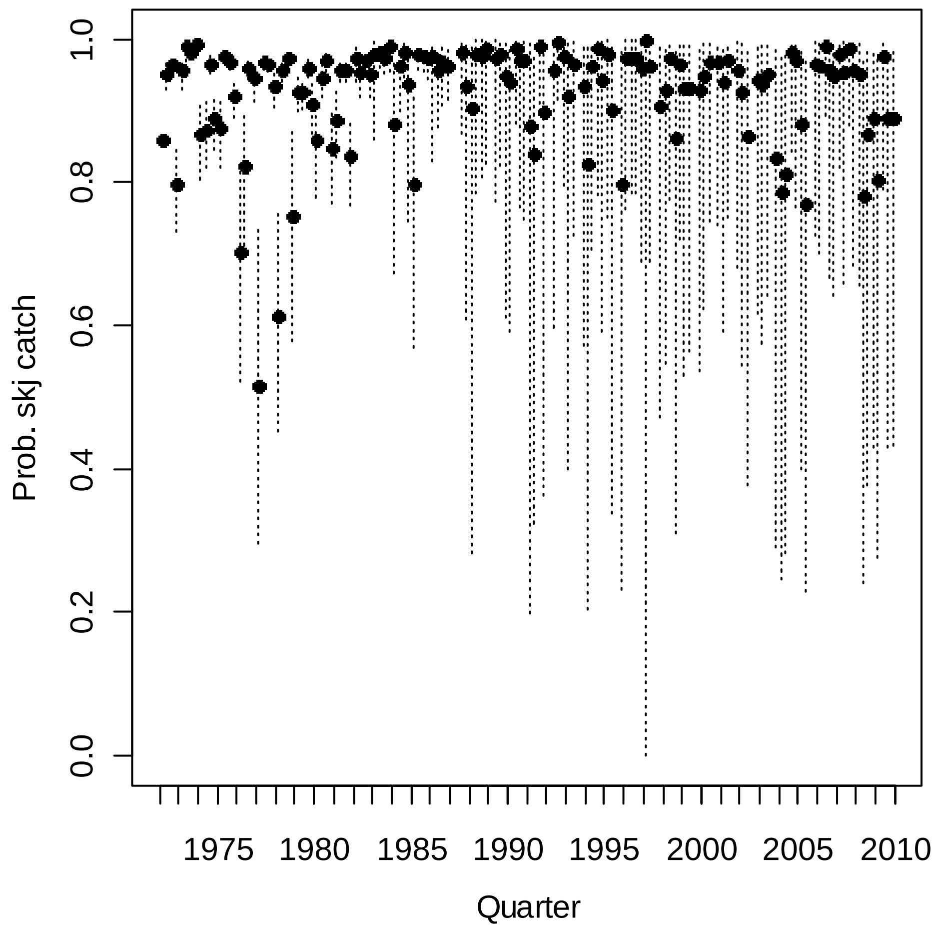


Figure 28. The year/quarter indices derived from the binomial model for MFCL region 4 (points). The vertical lines represent the 95% confidence intervals.

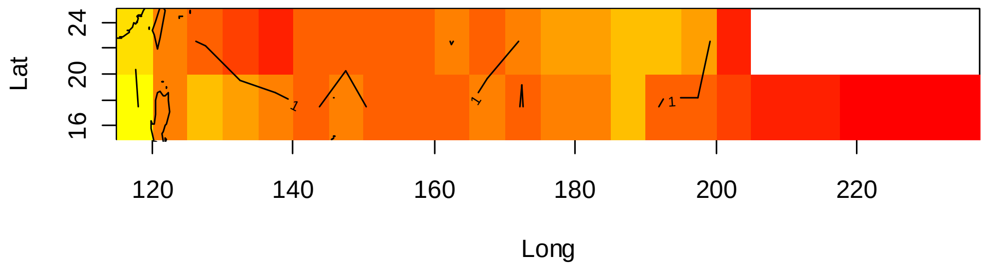


Figure 29. Latitude/longitude effects on the catch rate of skipjack (lognormal all data model) for MFCL region 4 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

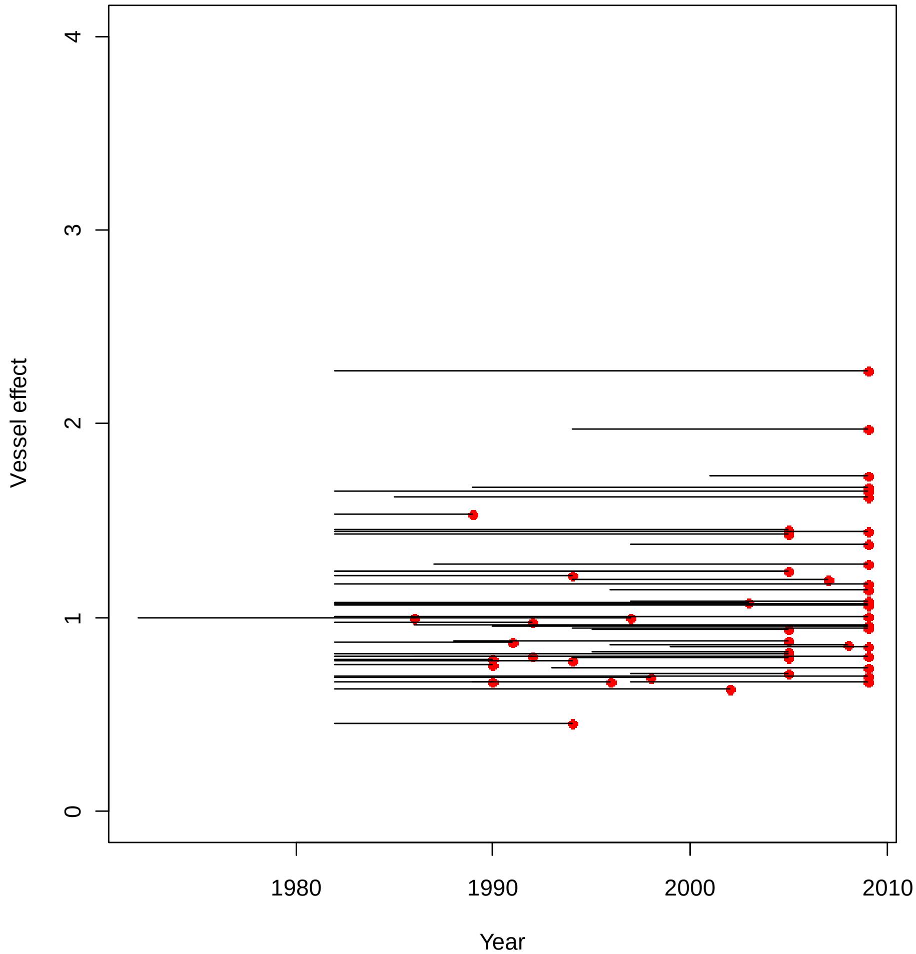


Figure 30. The individual vessel effects on the catch rate of skipjack (lognormal all data model) for MFCL region 2 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

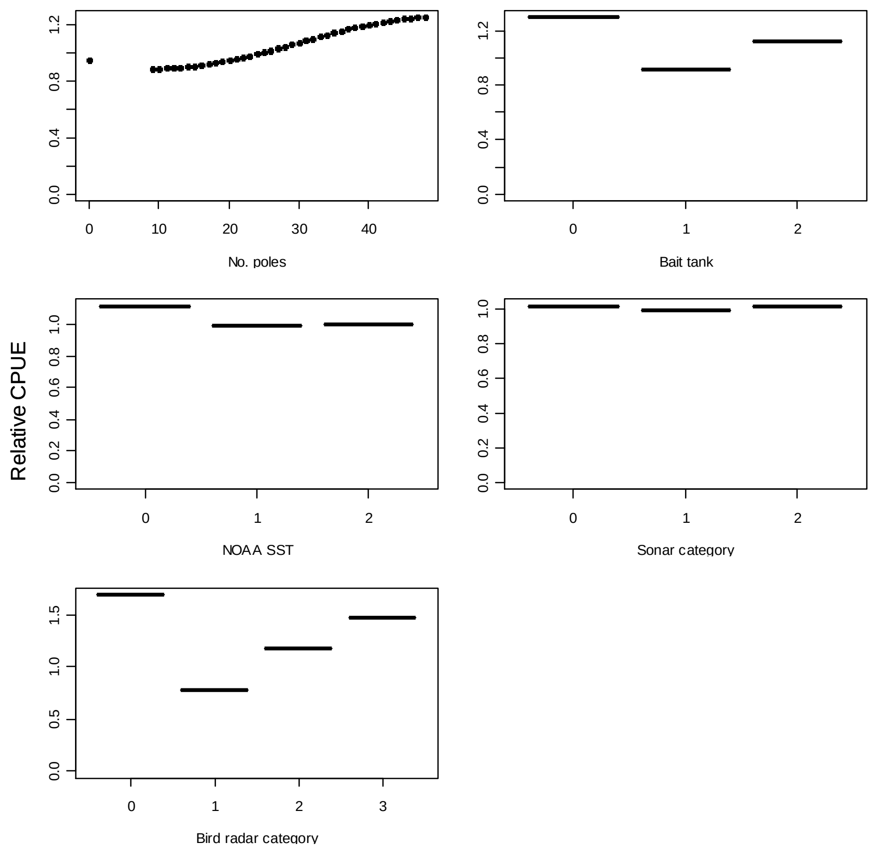


Figure 31. The relationship between the other model variables and the catch rate of skipjack (lognormal all data model) for MFCL region 4.

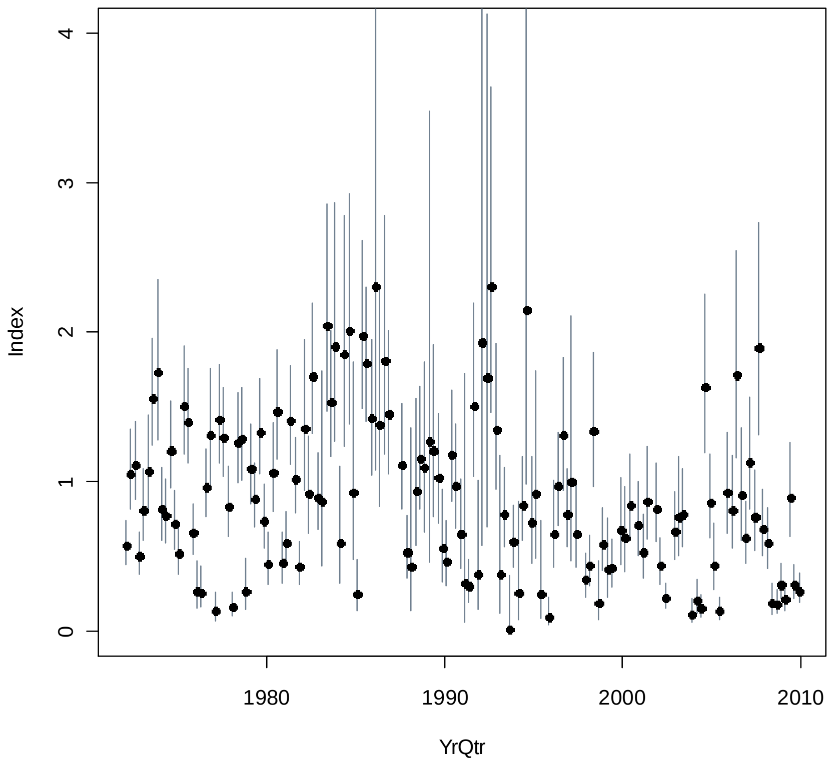


Figure 32. The year/quarter indices derived from the lognormal all data model for MFCL region 4 (points). The vertical lines represent the 95% confidence intervals.

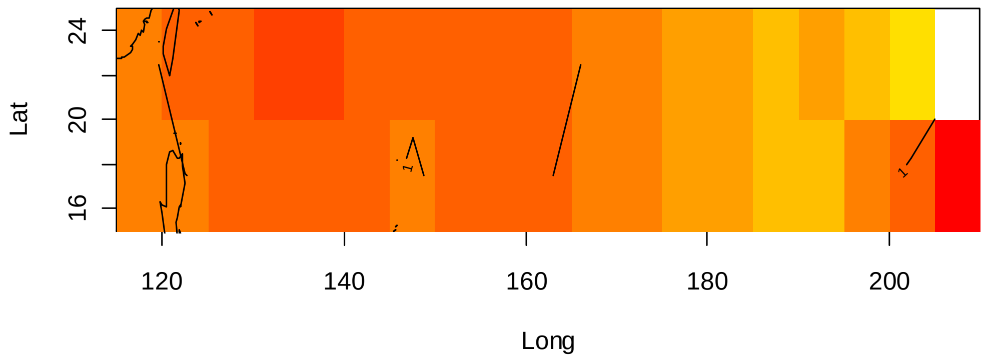


Figure 33. Latitude/longitude effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 4 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

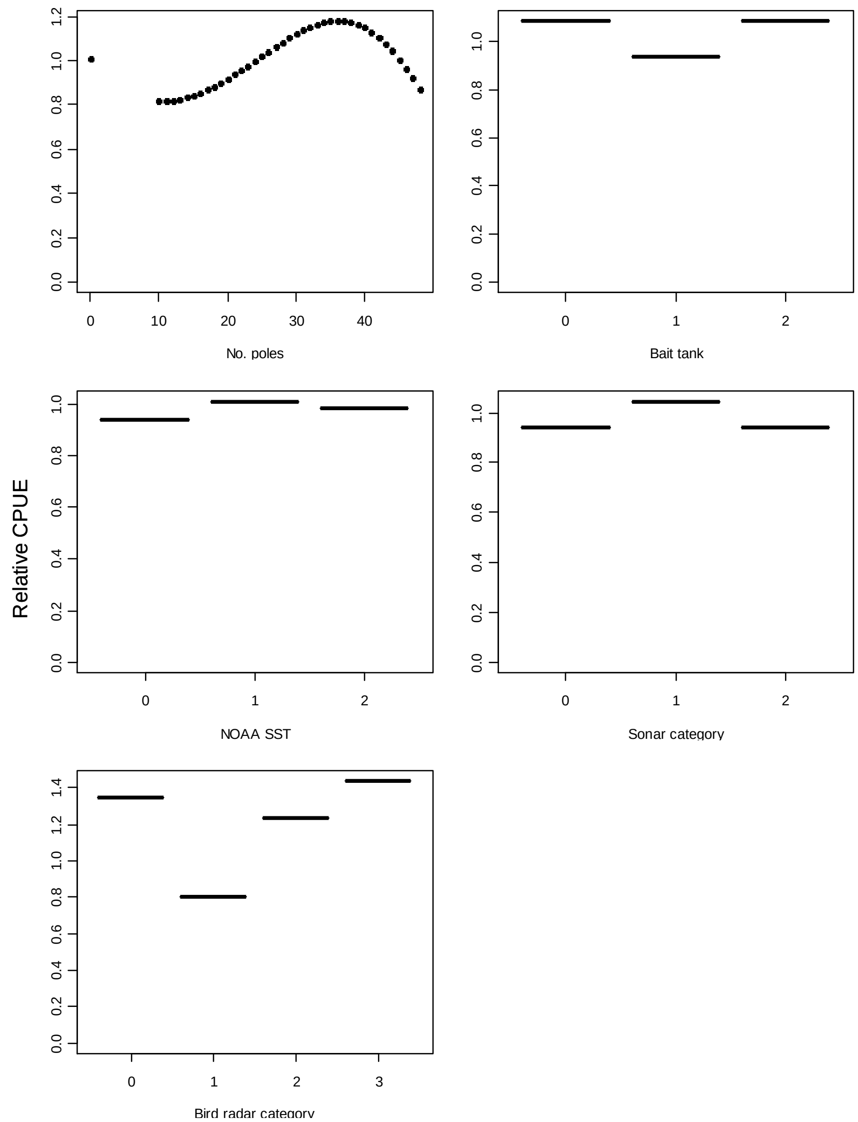


Figure 34. The relationship between the other model variables and the catch rate of skipjack (lognormal non zero model) for MFCL region 4.

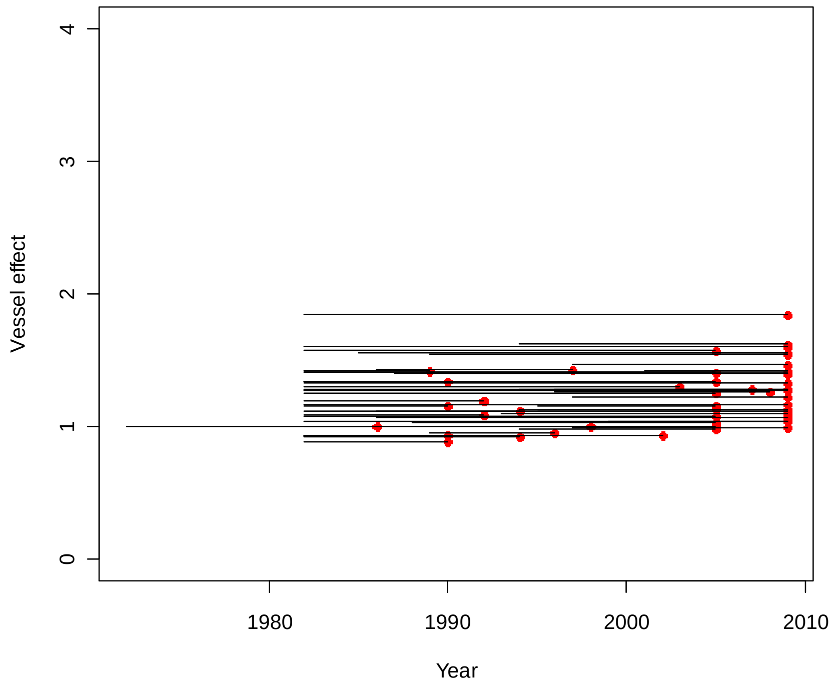


Figure 35. The individual vessel effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 4 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

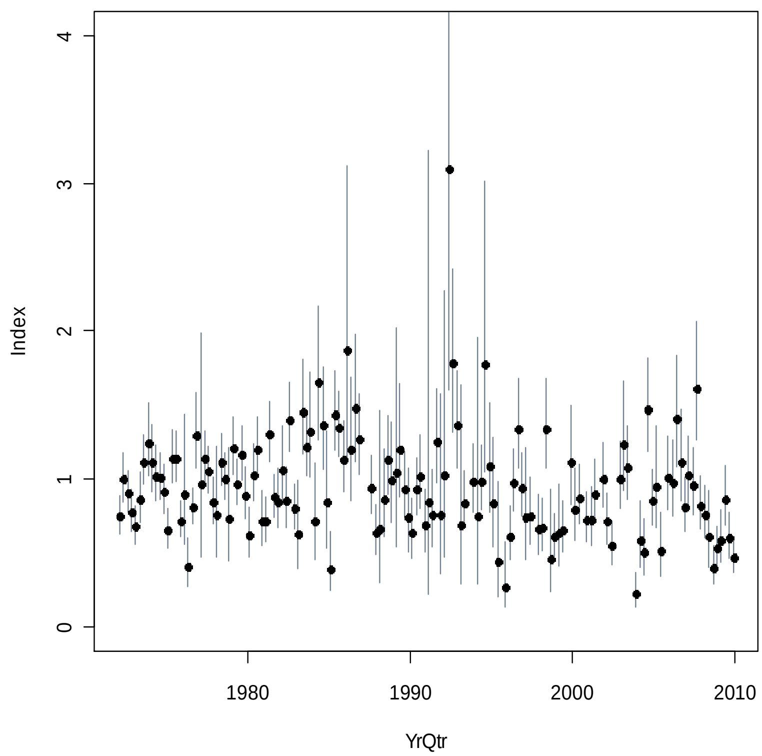


Figure 36. The year/quarter indices derived from the lognormal non zero model for MFCL region 4 (points). The vertical lines represent the 95% confidence intervals.

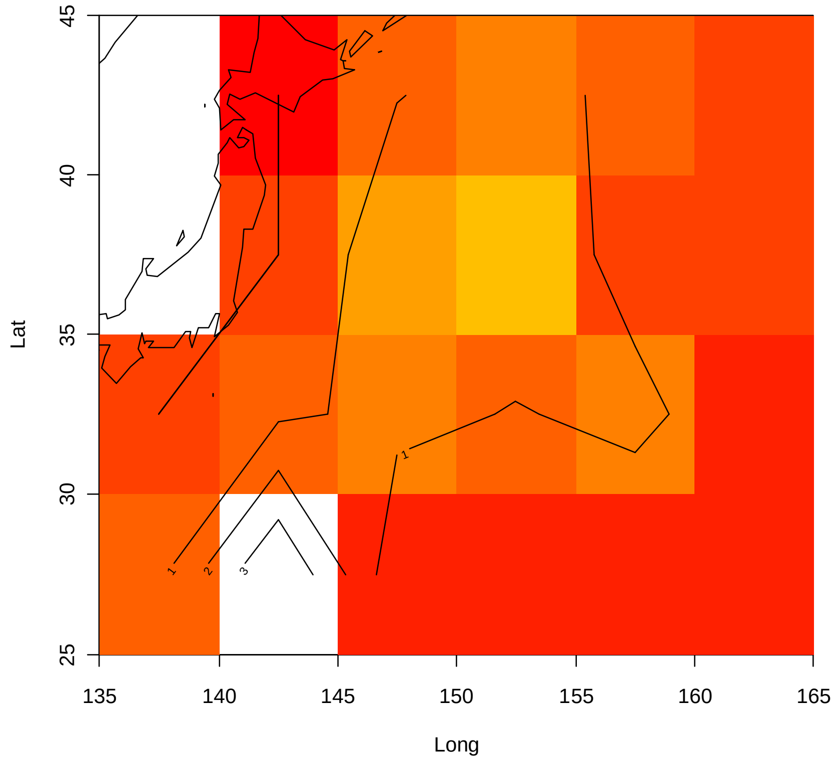


Figure 37. Latitude/longitude effects on the probability of catching skipjack (binomial model) for MFCL region 2 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

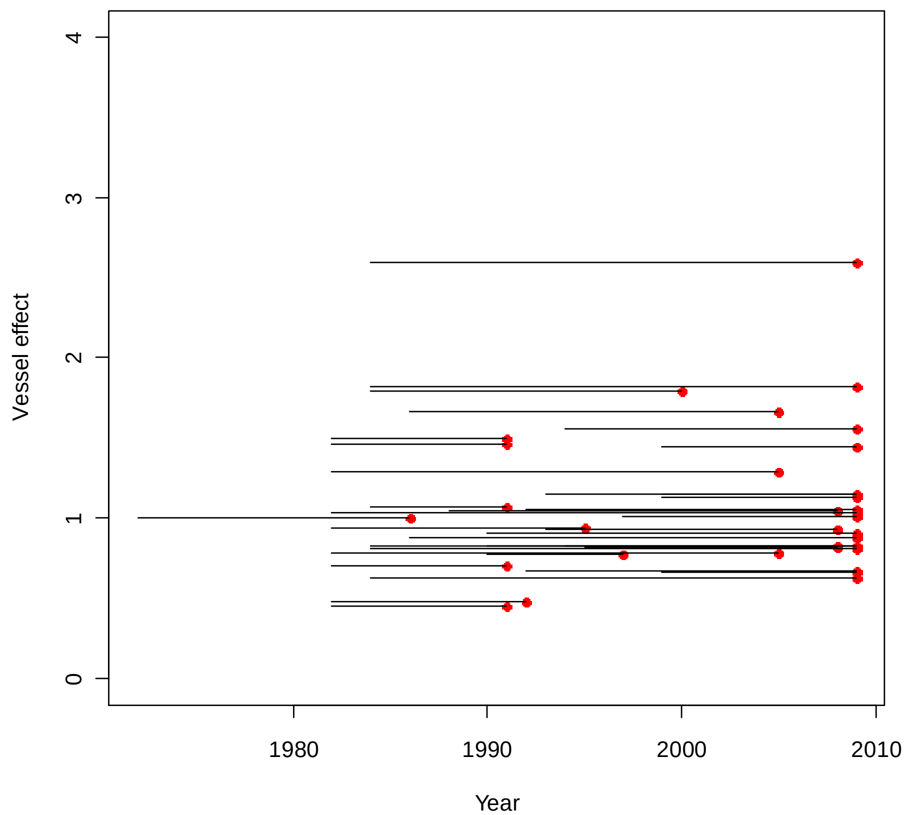


Figure 38. The individual vessel effects on the probability of catching skipjack (binomial model) for MFCL region 2 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

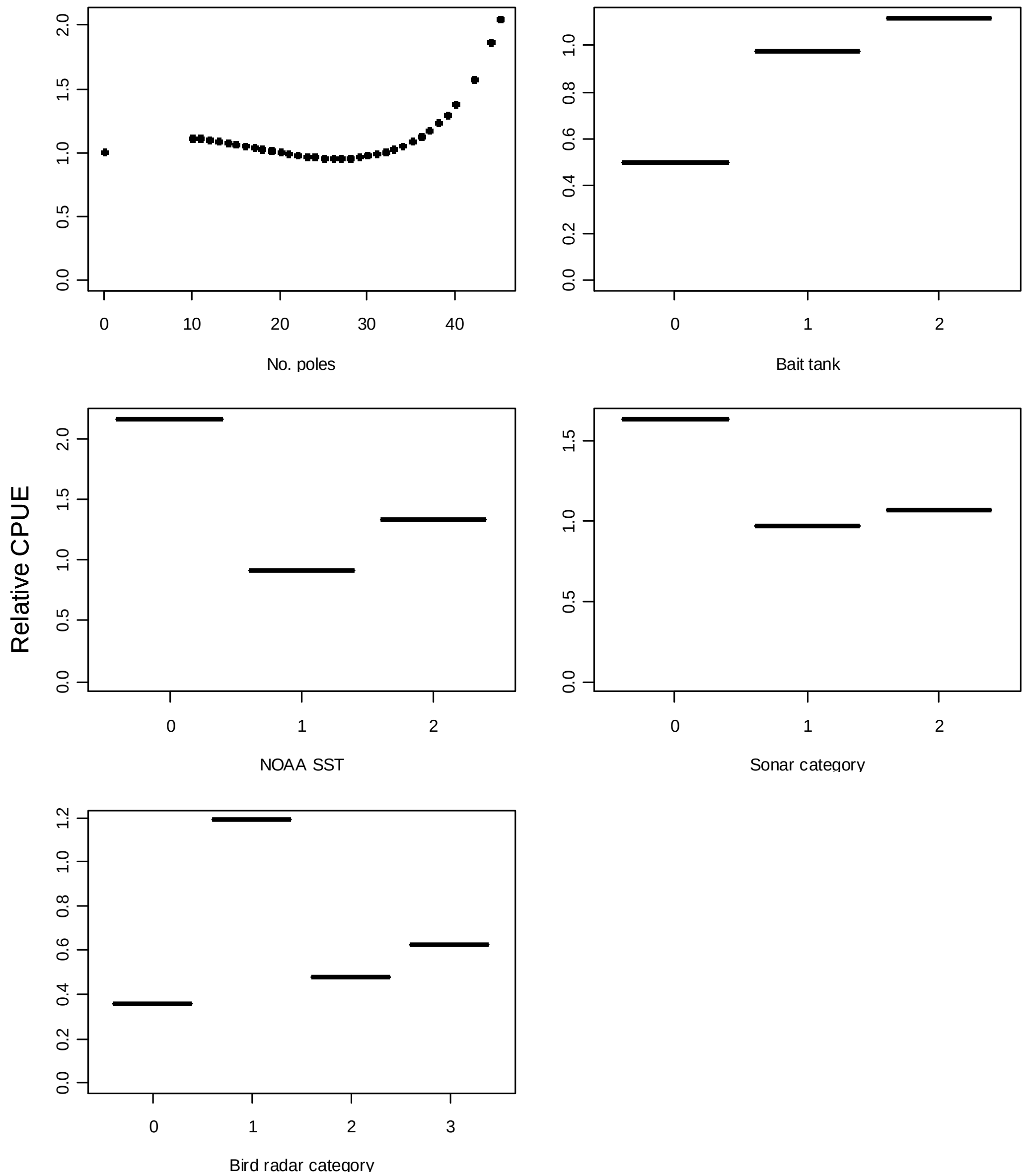


Figure 39. The relationship between the other model variables and the probability of catching skipjack (binomial model) for MFCL region 2.

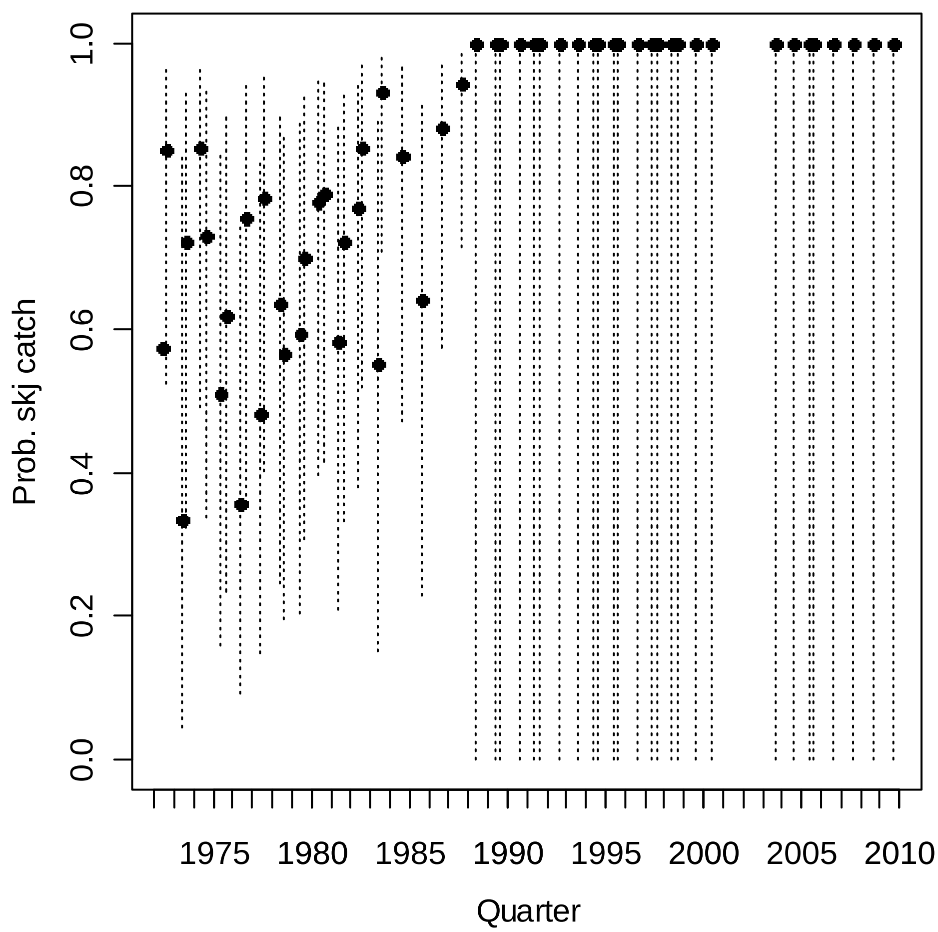


Figure 40. The year/quarter indices derived from the binomial model for MFCL region 2 (points). The vertical lines represent the 95% confidence intervals.

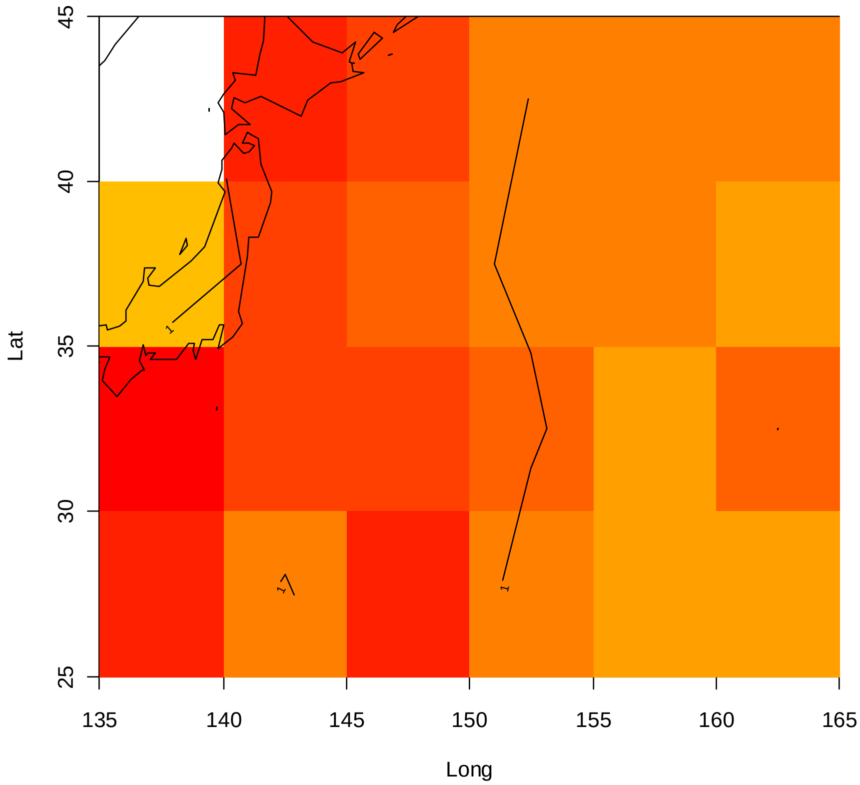


Figure 41. Latitude/longitude effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 2 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

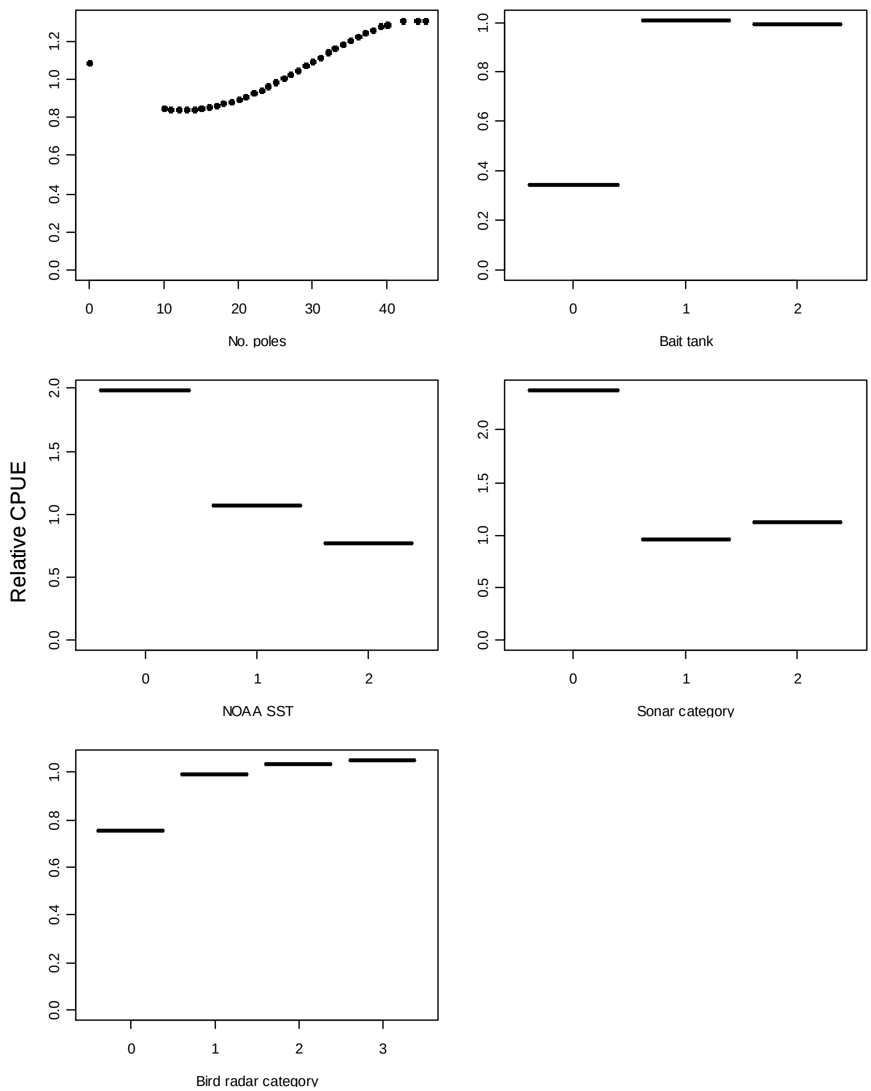


Figure 42. The relationship between the other model variables and the catch rate of skipjack (lognormal non zero model) for MFCL region 2.

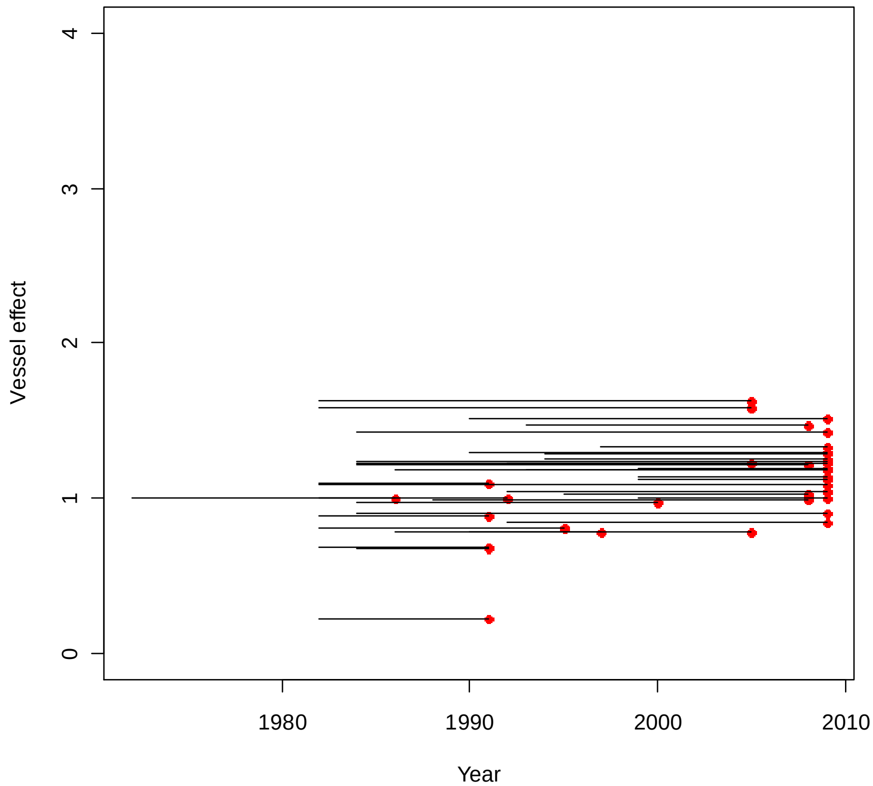


Figure 43. The individual vessel effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 2 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

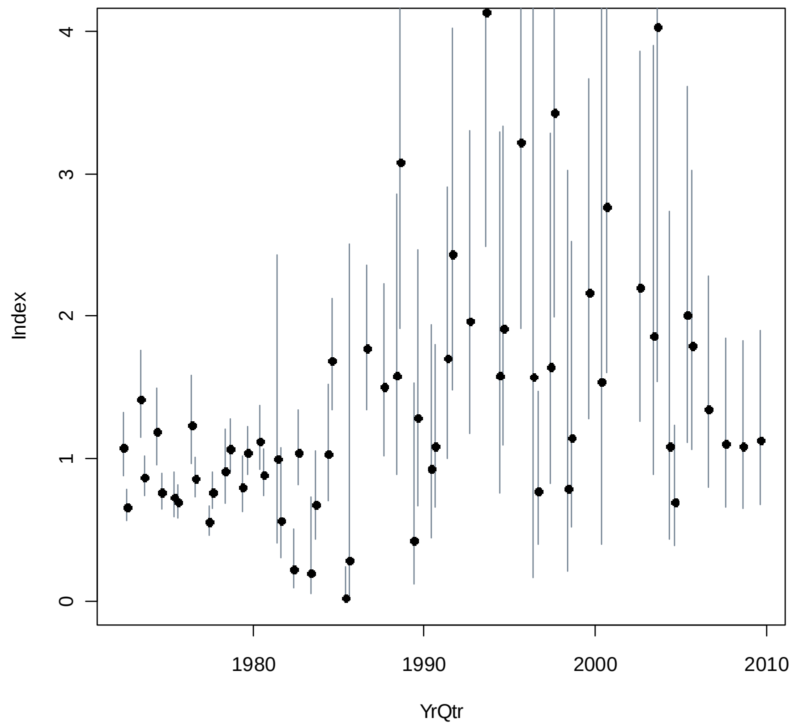


Figure 44. The year/quarter indices derived from the lognormal non zero model for MFCL region 2 (points). The vertical lines represent the 95% confidence intervals.

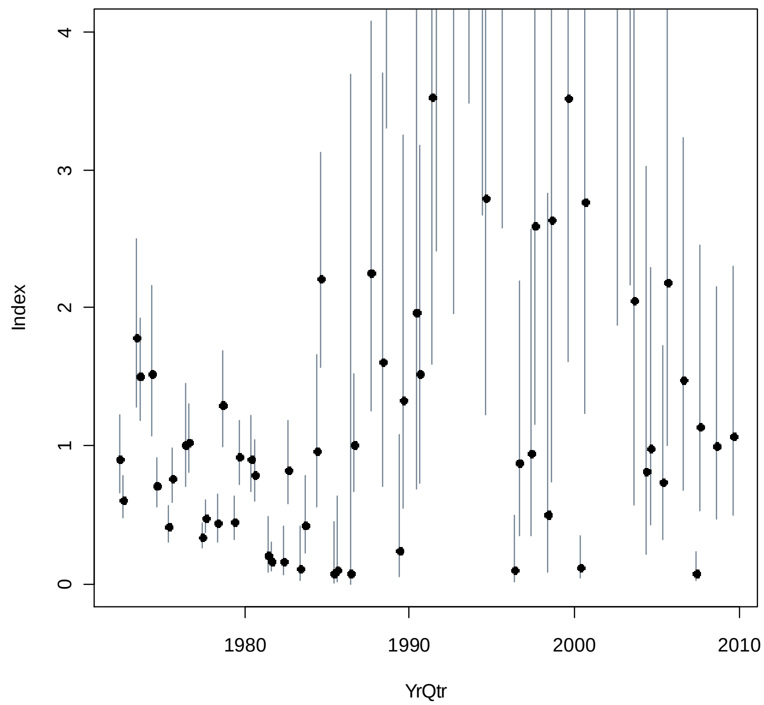


Figure 45. The year/quarter indices derived from the lognormal all data model for MFCL region 2 (points). The vertical lines represent the 95% confidence intervals.

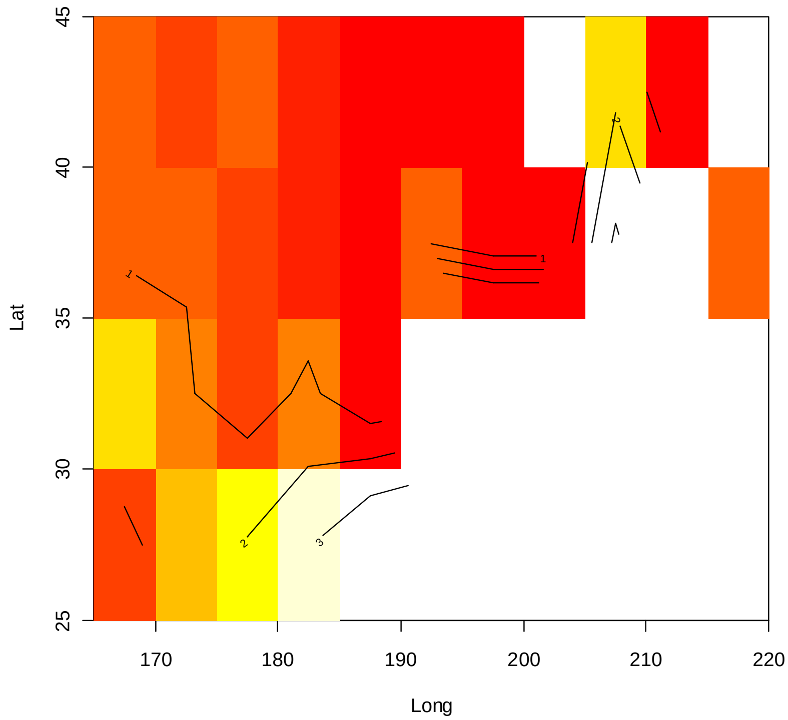


Figure 46. Latitude/longitude effects on the catch rate of skipjack (lognormal all data model) for MFCL region 3 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

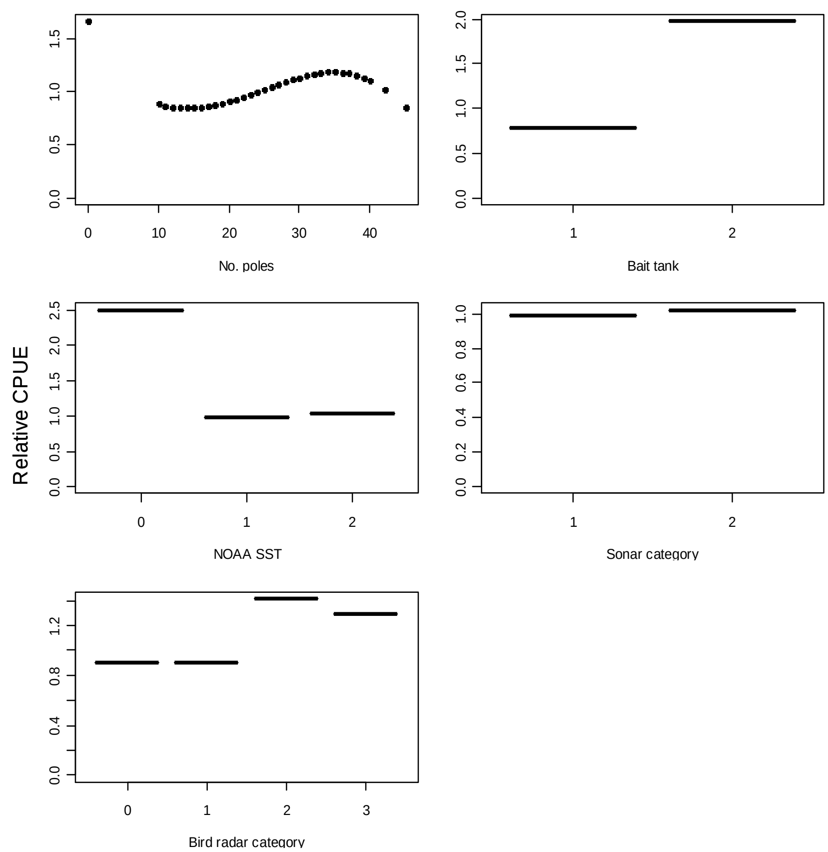


Figure 47. The relationship between the other model variables and the catch rate of skipjack (lognormal all data model) for MFCL region 3.

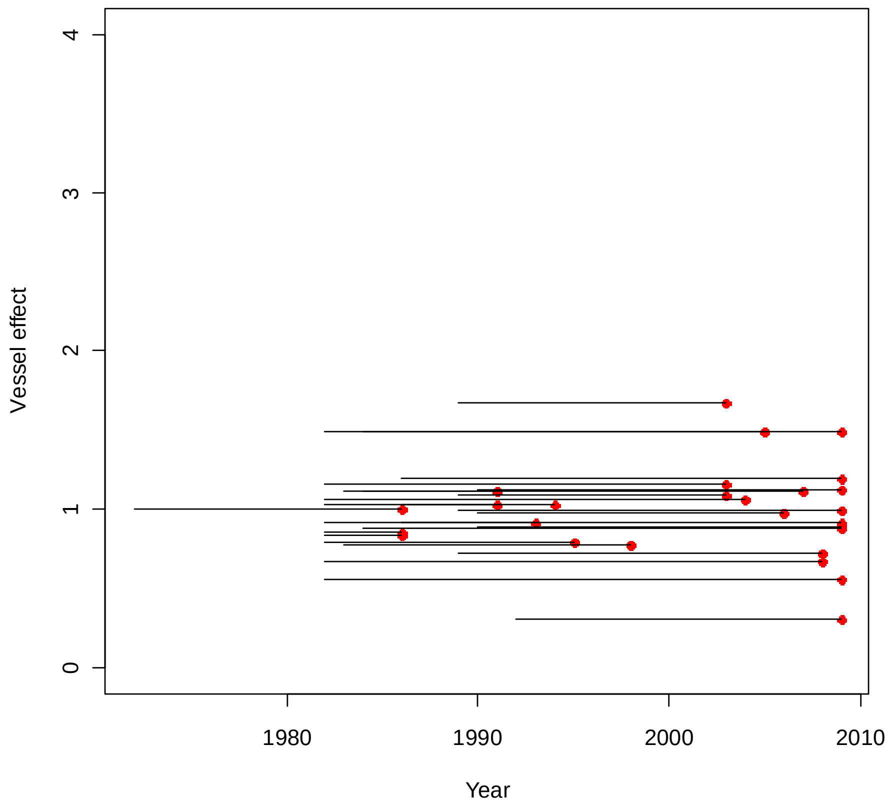


Figure 48. The individual vessel effects on the catch rate of skipjack (lognormal all data model) for MFCL region 3 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

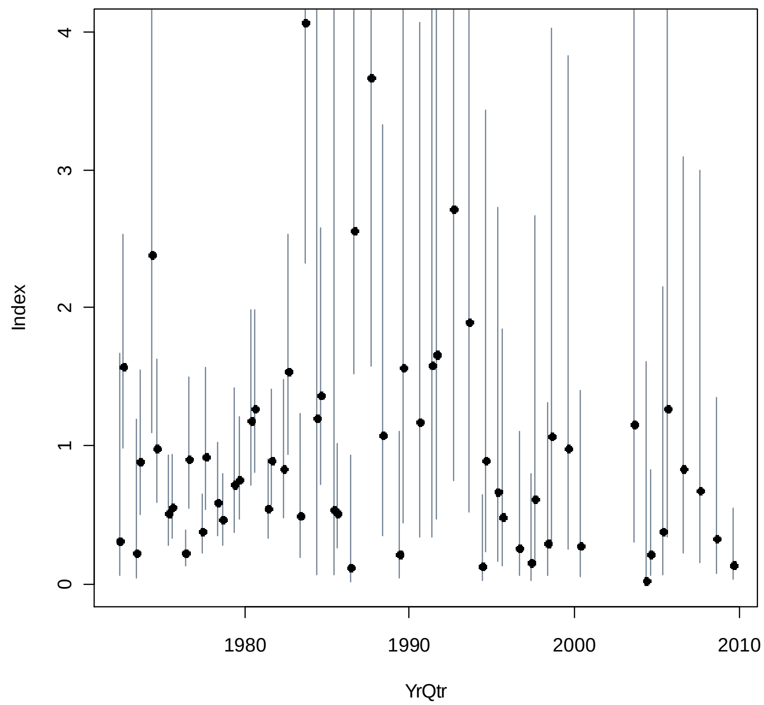


Figure 49. The year/quarter indices derived from the lognormal all data model for MFCL region 3 (points). The vertical lines represent the 95% confidence intervals.

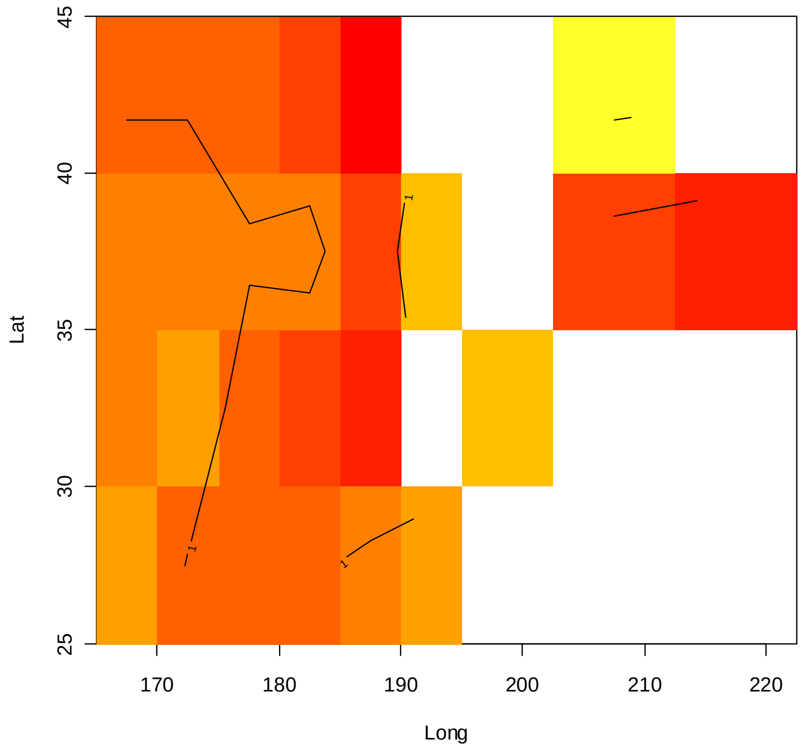


Figure 50. Latitude/longitude effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 3 (the colour scale denotes the magnitude of the effect from red (low) to yellow (high)).

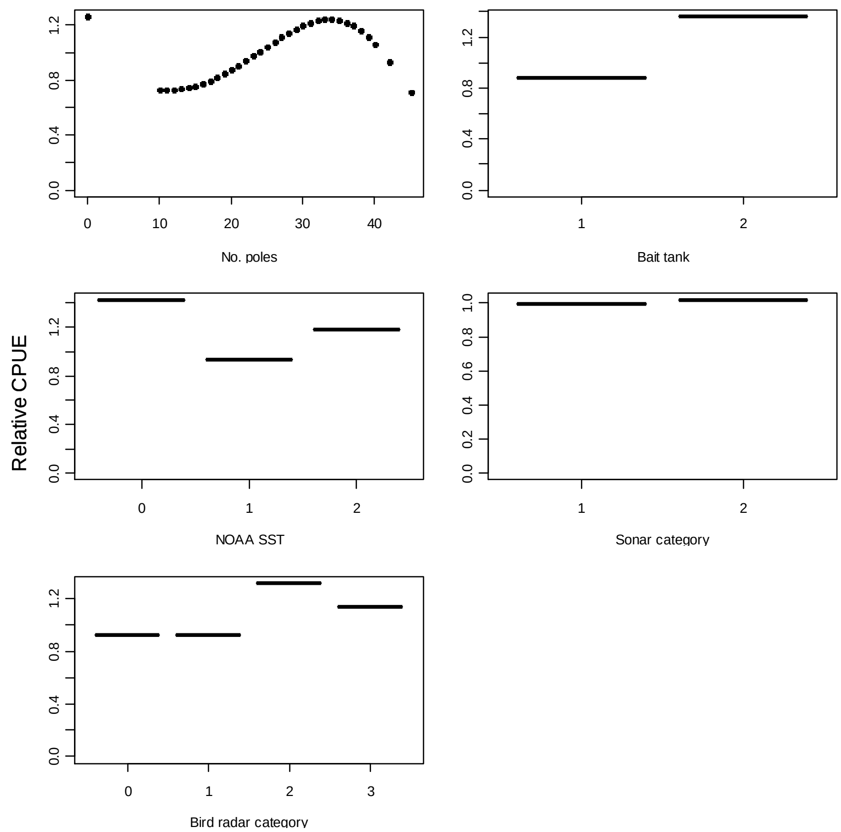


Figure 51. The relationship between the other model variables and the catch rate of skipjack (lognormal non zero model) for MFCL region 3.

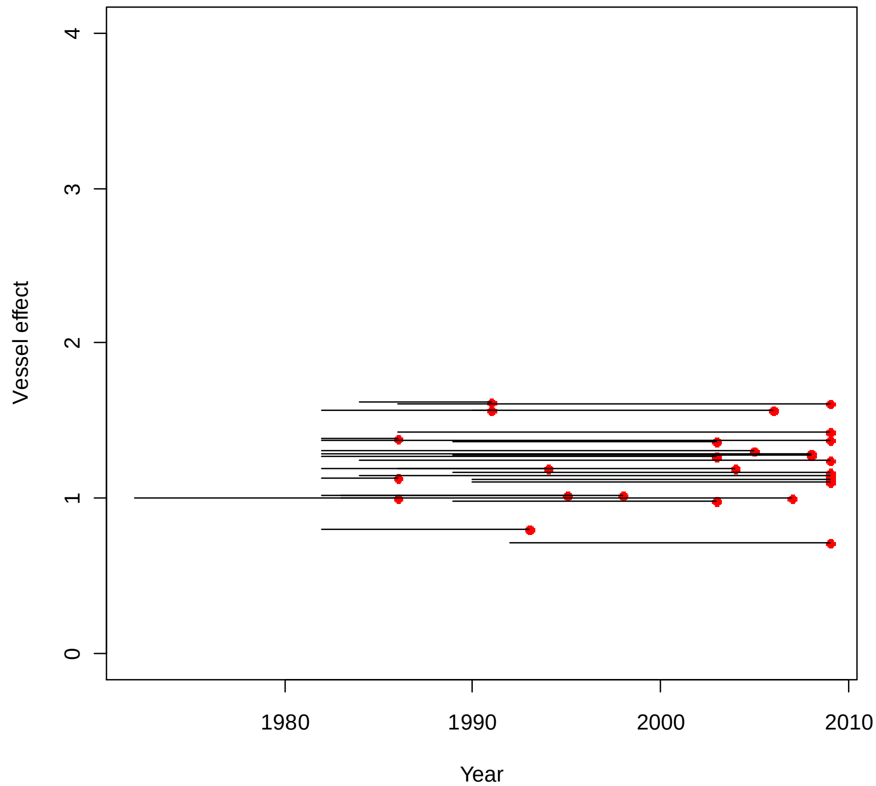


Figure 52. The individual vessel effects on the catch rate of skipjack (lognormal non zero model) for MFCL region 3 (red points) plotted against the last year that the vessel was active in the fishery. The horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1982 onwards with the exception of the aggregate vessel category.

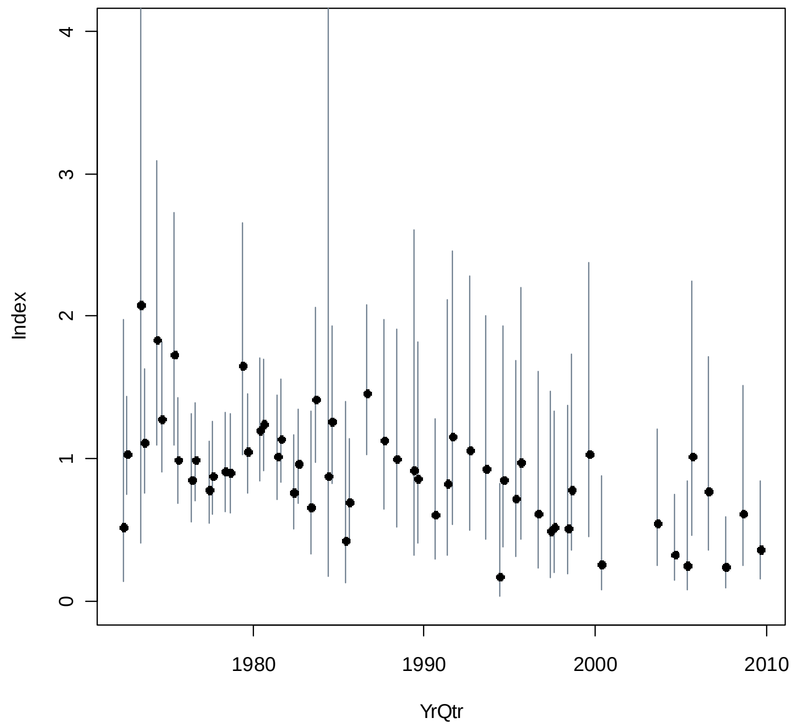


Figure 53. The year/quarter indices derived from the lognormal non zero model for MFCL region 3 (points). The vertical lines represent the 95% confidence intervals.

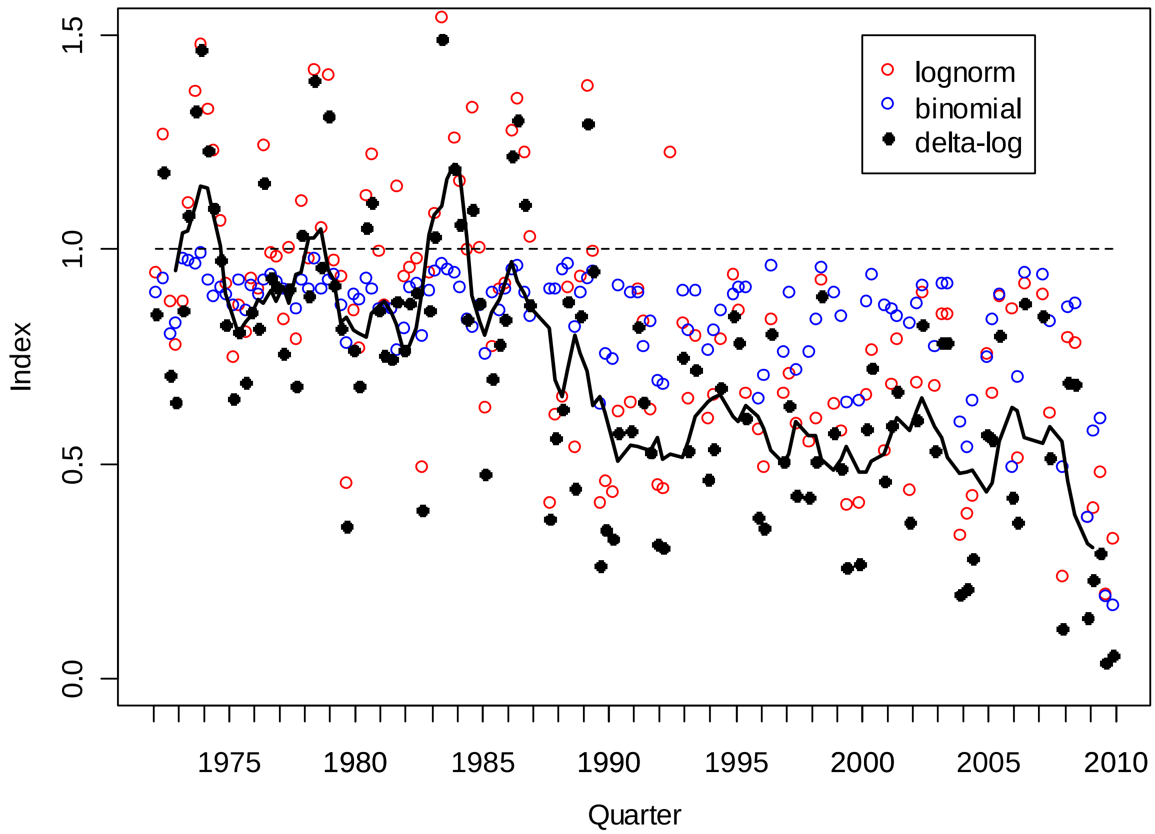


Figure 54. Comparison of the non zero lognormal, binomial and delta-lognormal CPUE indices for the western equatorial region (region 5). The black line represents a seven quarter running average of the delta-lognormal index.

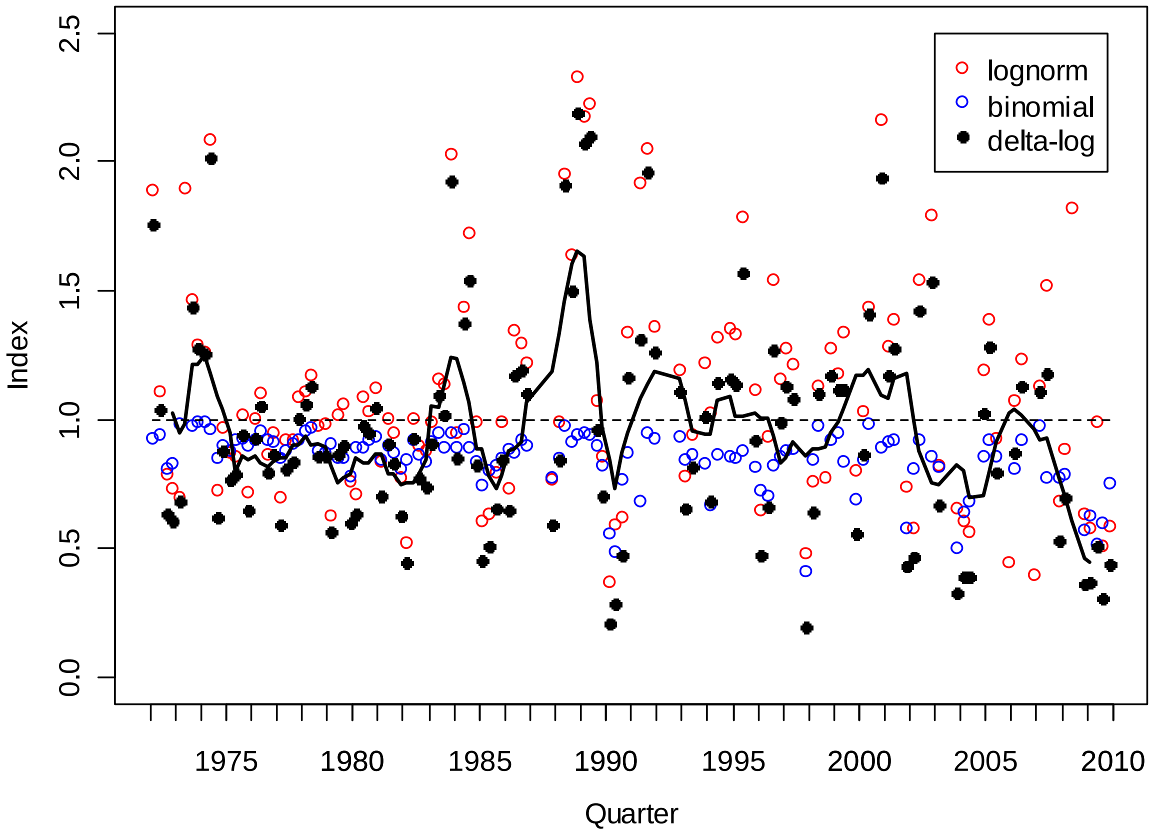
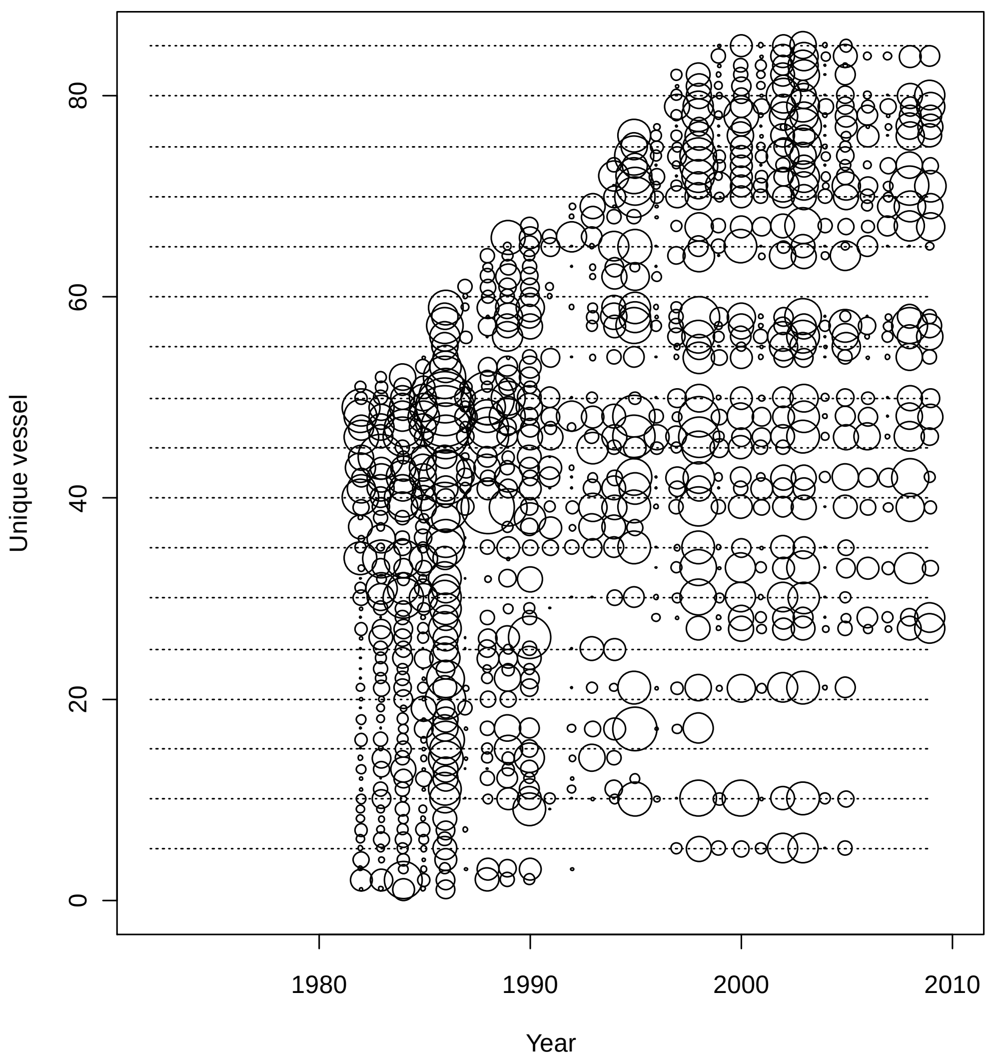
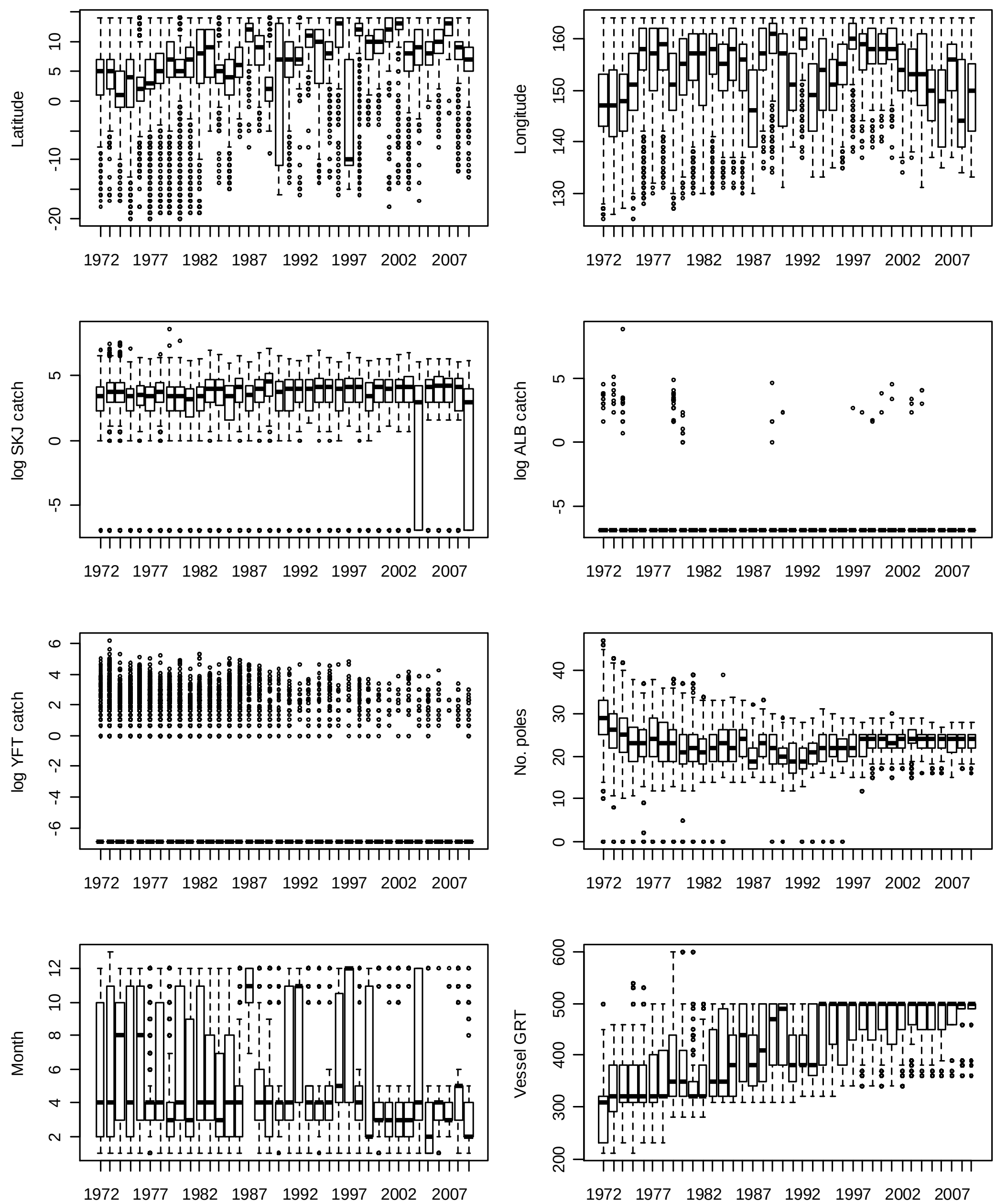


Figure 55. Comparison of the non zero lognormal, binomial and delta-lognormal CPUE indices for the eastern equatorial region (region 6). The black line represents a seven quarter running average of the delta-lognormal index.

Appendix 1a. Western equatorial region, MFCL region 5.



The annual number of days fished by each unique vessel (row) in the MFCL region 5 fishery data set. The area of the circle is proportional to the number of days fished. The aggregate vessel category, which includes all effort prior to 1982, is not included.



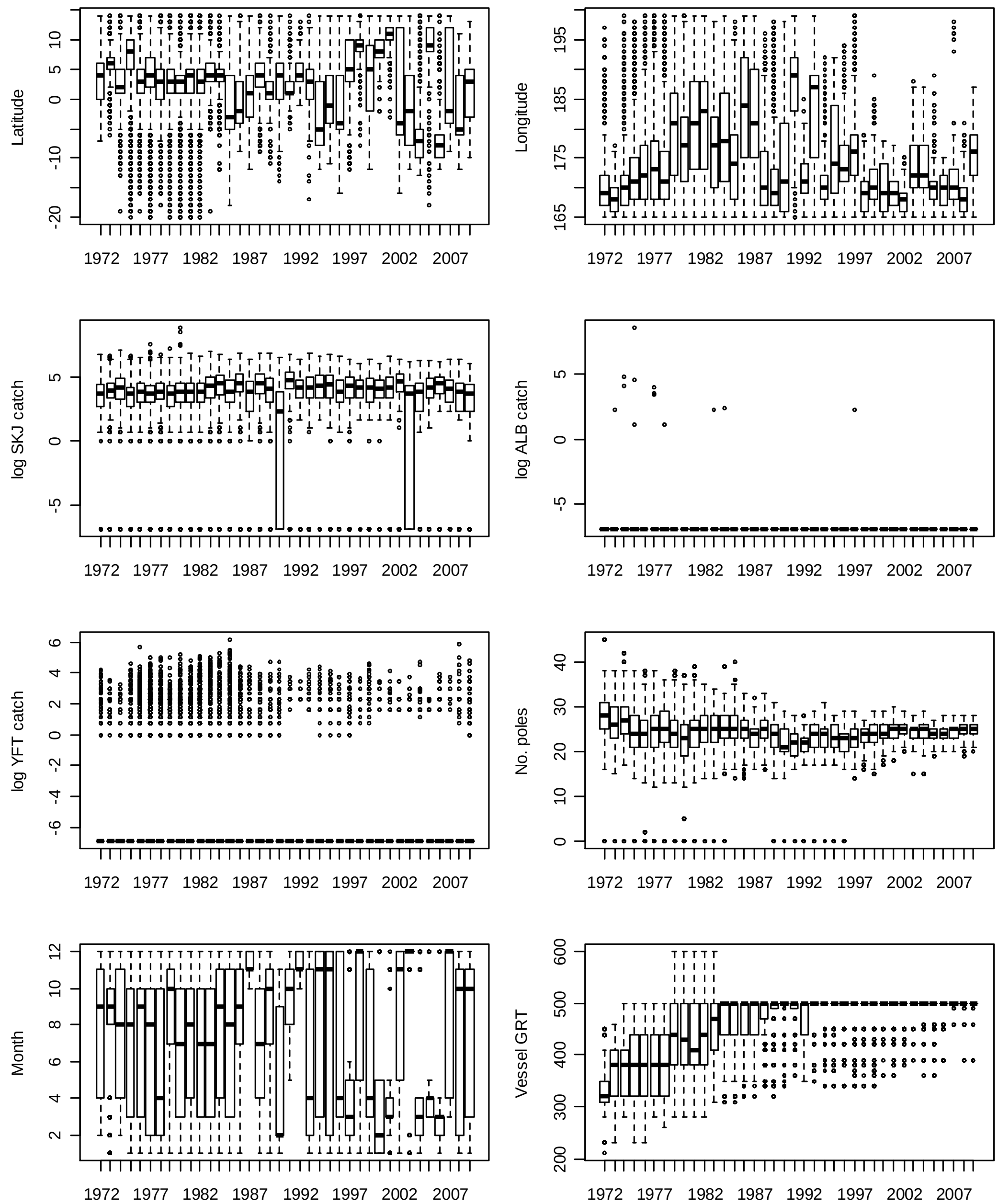
Boxplots of the key variables (aggregated by year) included in the data set included in the MFCL region 5 GLMs.

Summary of data (aggregated by year) included in the MFCL region 5 analysis. Annual catches for the five species are in tonnes.

Year	Days	Vessels	SKJ	YFT	BET	PBF	ALB
1972	8,147	205	38,393	716	882	6	48
1973	13,647	234	85,650	969	336	1	44
1974	17,335	239	103,886	624	253	62	718
1975	11,457	245	44,286	832	290	6	0
1976	6,566	231	32,535	1,328	401	80	0
1977	9,908	244	45,409	924	286	3	0
1978	6,715	237	39,373	283	120	0	0
1979	9,467	209	41,129	531	200	0	84
1980	6,267	182	26,471	599	251	0	3
1981	4,270	150	17,132	235	54	4	0
1982	2,033	78	9,050	371	212	0	0
1983	2,191	58	16,034	276	97	0	0
1984	2,496	53	18,616	225	71	1	0
1985	1,774	53	8,183	431	69	0	0
1986	4,025	61	33,142	472	129	0	0
1987	630	28	3,141	130	32	0	0
1988	1,745	39	13,828	212	36	0	0
1989	2,046	44	25,151	62	9	0	12
1990	2,220	47	13,723	93	47	0	4
1991	595	19	3,780	64	15	0	0
1992	417	25	2,970	40	11	0	0
1993	929	25	6,253	42	18	0	0
1994	1,251	28	10,590	107	27	0	0
1995	1,981	29	15,511	234	103	0	0
1996	544	31	3,913	30	11	0	0
1997	1,032	36	8,305	88	17	0	2
1998	2,462	35	20,841	99	16	0	1
1999	920	39	5,333	48	8	0	1
2000	1,959	37	14,546	32	6	0	6
2001	894	39	6,958	17	3	0	12
2002	2,083	39	17,048	17	5	0	0
2003	2,456	38	23,057	97	53	0	6
2004	514	36	2,486	25	13	0	14
2005	1,570	36	12,615	37	7	0	0
2006	797	24	6,911	33	18	0	0
2007	535	24	4,469	5	2	0	0
2008	1,391	23	10,542	27	10	0	0
2009	1,157	23	4,280	25	12	0	0

Appendix 1b. Eastern equatorial region, MFCL region 6.

The annual number of days fished by each unique vessel (row) in the MFCL region 6 fishery data set. The area of the circle is proportional to the number of days fished. The aggregate vessel category, which includes all effort prior to 1982, is not included.



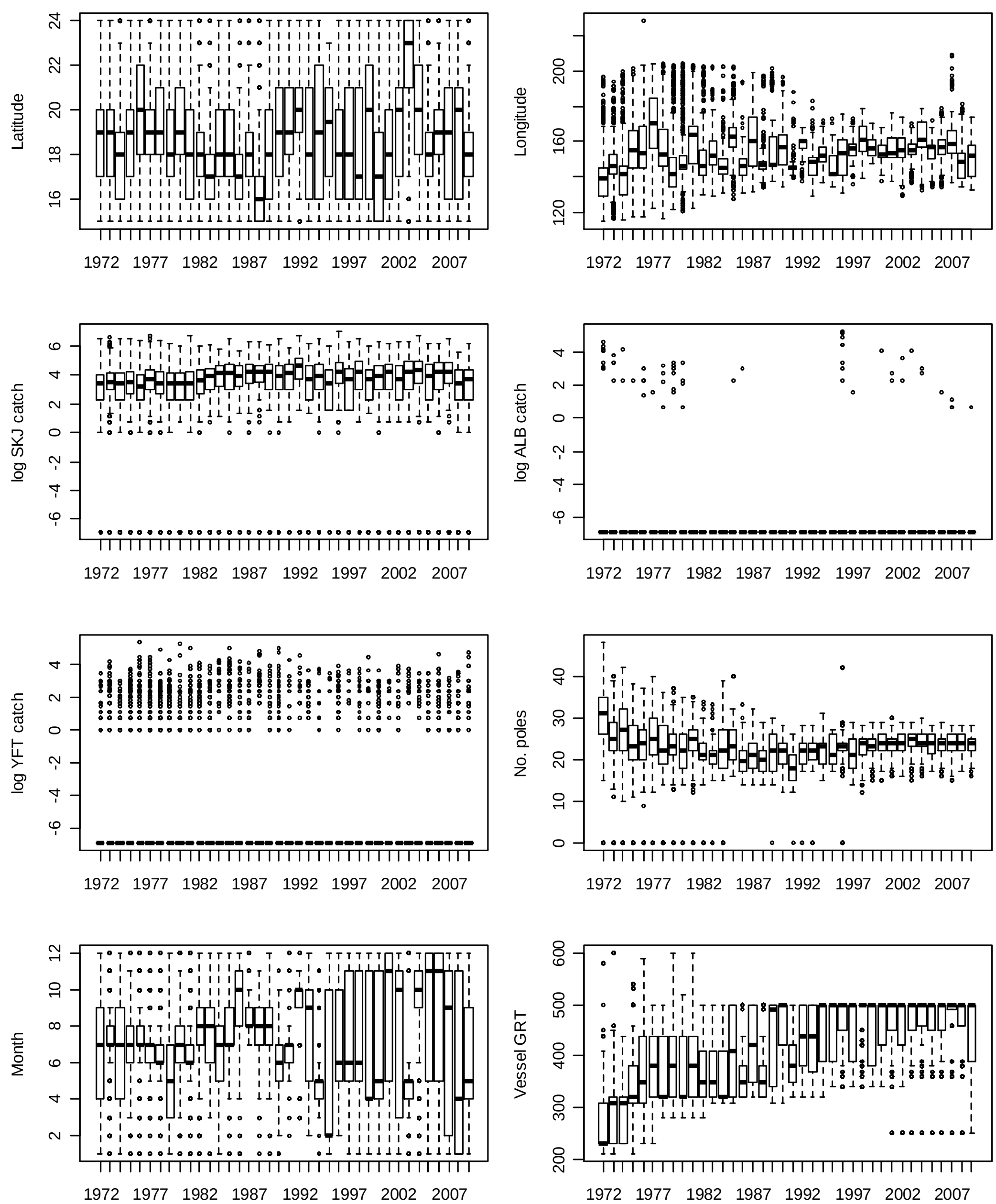
Boxplots of the key variables (aggregated by year) included in the data set included in the MFCL region 6 GLMs.

Summary of data (aggregated by year) included in the MFCL region 6 analysis. Annual catches for the five species are in tonnes.

Year	Days	Vessels	SKJ	YFT	BET	PBF	ALB
1972	1,672	104	11,463	255	104	33	0
1973	1,976	115	15,948	34	57	0	1
1974	2,321	121	22,000	16	13	0	18
1975	6,063	172	33,115	227	200	1	509
1976	8,154	217	53,794	548	218	101	0
1977	11,137	231	67,532	899	534	21	12
1978	10,541	235	76,174	459	272	29	0
1979	5,403	142	34,068	138	112	0	0
1980	10,421	179	75,199	481	162	0	0
1981	11,609	154	77,909	458	292	5	0
1982	6,447	82	45,337	975	565	1	0
1983	4,603	59	49,339	558	343	0	1
1984	3,527	54	44,878	245	152	0	1
1985	3,707	54	30,505	777	279	0	0
1986	3,540	59	50,110	215	81	0	0
1987	762	33	5,867	121	28	0	0
1988	3,728	37	52,101	146	97	0	0
1989	2,904	40	29,036	56	41	0	0
1990	750	36	3,275	77	58	0	0
1991	992	26	16,178	42	27	0	0
1992	299	16	2,666	11	1	0	0
1993	963	22	10,035	49	12	0	0
1994	694	26	7,974	116	25	0	0
1995	925	28	11,465	71	31	0	0
1996	1,517	29	12,529	32	13	0	0
1997	1,728	36	17,702	64	15	0	1
1998	674	33	5,587	35	9	0	0
1999	2,479	39	23,625	158	35	0	0
2000	436	28	3,749	13	1	0	0
2001	1,181	36	11,976	30	2	0	0
2002	919	36	12,390	27	27	0	0
2003	425	30	2,480	18	7	0	0
2004	1,511	34	10,883	63	46	0	0
2005	774	33	6,973	10	2	0	0
2006	623	21	6,873	39	36	0	0
2007	291	18	2,475	20	14	0	0
2008	770	21	5,690	136	32	0	0
2009	802	19	4,876	78	40	0	0

Appendix 1c. Northern subequatorial region, MFCL region 4.

The annual number of days fished by each unique vessel (row) in the MFCL region 4 fishery data set. The area of the circle is proportional to the number of days fished. The aggregate vessel category, which includes all effort prior to 1982, is not included.

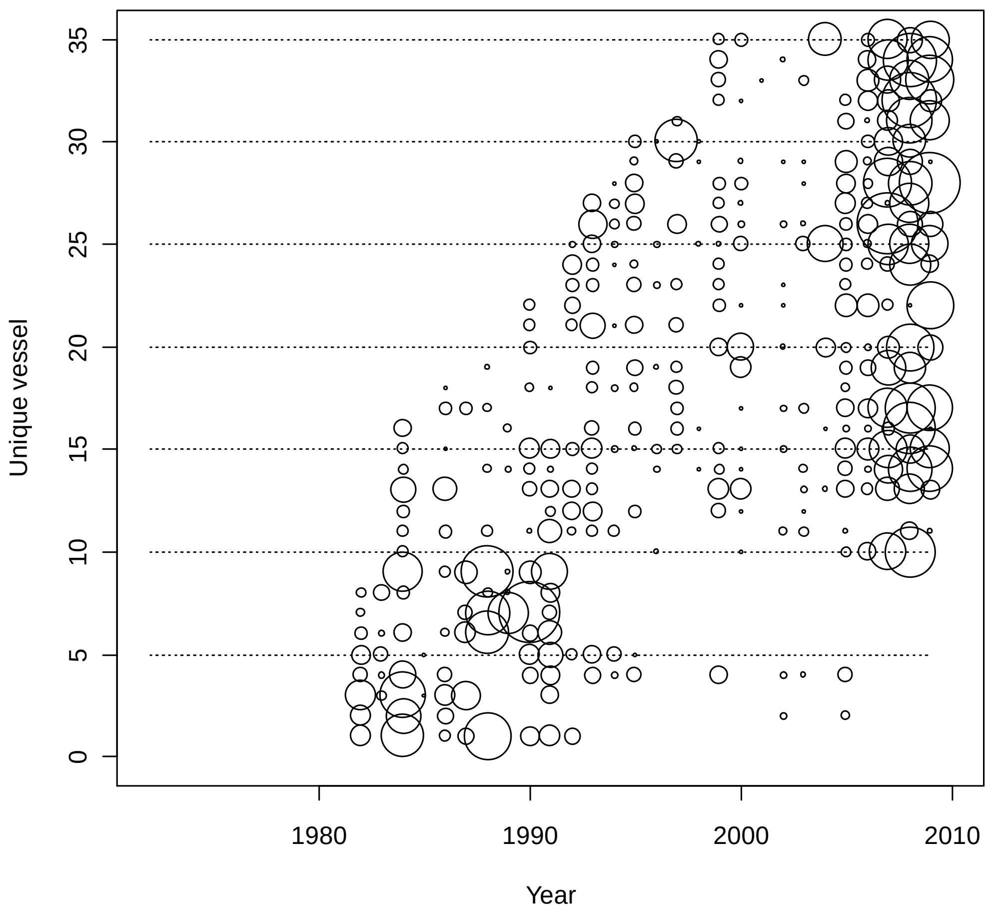


Boxplots of the key variables (aggregated by year) included in the data set included in the MFCL region 4 GLMs.

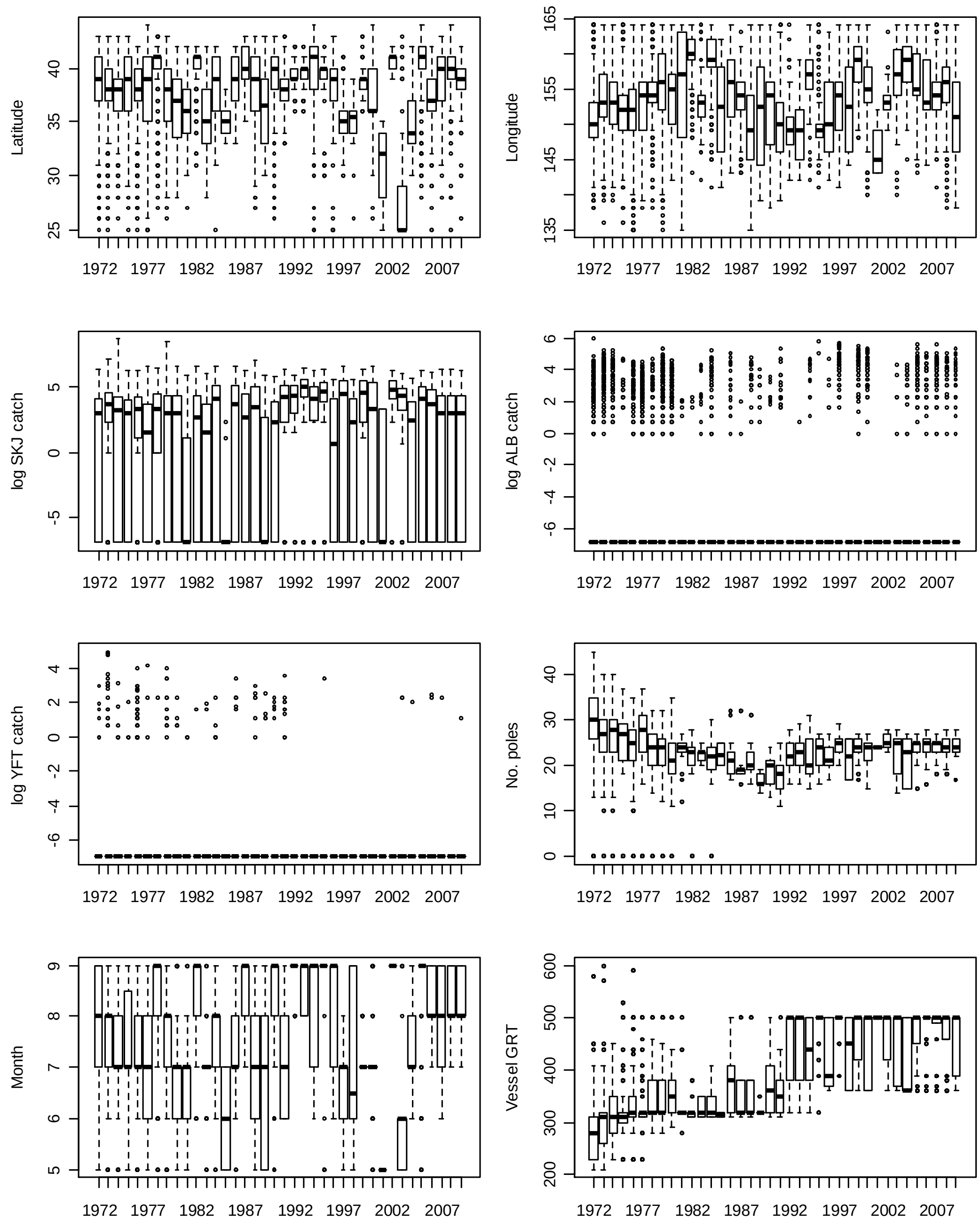
Summary of data (aggregated by year) included in the MFCL region 4 analysis. Annual catches for the five species are in tonnes.

Year	Days	Vessels	SKJ	YFT	BET	PBF	ALB
1972	3,262	138	13,777	70	32	10	53
1973	2,679	192	13,449	66	22	3	11
1974	1,876	178	8,313	25	11	0	8
1975	4,147	215	21,441	99	32	0	1
1976	1,469	173	6,326	122	141	0	4
1977	4,604	212	27,408	149	214	7	1
1978	1,992	173	9,669	87	66	0	5
1979	3,405	202	15,717	81	65	0	15
1980	1,085	119	4,714	47	24	0	5
1981	2,063	145	11,081	79	194	1	0
1982	978	50	5,146	68	67	0	0
1983	563	29	3,434	36	133	0	0
1984	225	23	1,783	79	62	0	0
1985	1,418	28	12,304	149	89	0	1
1986	278	26	1,958	41	10	0	2
1987	762	23	6,849	38	8	0	0
1988	422	21	3,481	107	38	0	0
1989	398	28	3,402	35	1	0	0
1990	1,278	28	9,488	73	12	0	0
1991	254	18	2,000	15	4	0	0
1992	277	15	3,465	33	1	0	0
1993	747	22	4,967	25	34	0	0
1994	713	23	6,000	16	7	0	0
1995	50	14	263	10	8	0	0
1996	2,177	29	20,824	48	17	0	74
1997	213	32	1,205	12	1	0	1
1998	1,004	34	10,615	52	13	0	0
1999	326	33	1,947	43	6	0	0
2000	975	35	7,196	48	34	0	6
2001	1,716	36	14,375	47	25	0	3
2002	1,033	36	6,495	27	4	0	5
2003	730	35	6,694	38	32	0	6
2004	2,574	34	28,843	53	40	0	4
2005	396	30	3,090	37	15	0	0
2006	1,131	25	9,843	52	20	0	1
2007	2,438	25	22,937	45	10	0	1
2008	838	23	4,158	32	14	0	0
2009	938	23	5,790	62	11	0	0

Appendix 1d. Northwestern subtropical region, MFCL region 2.



The annual number of days fished by each unique vessel (row) in the MFCL region 2 fishery data set. The area of the circle is proportional to the number of days fished. The aggregate vessel category, which includes all effort prior to 1982, is not included.

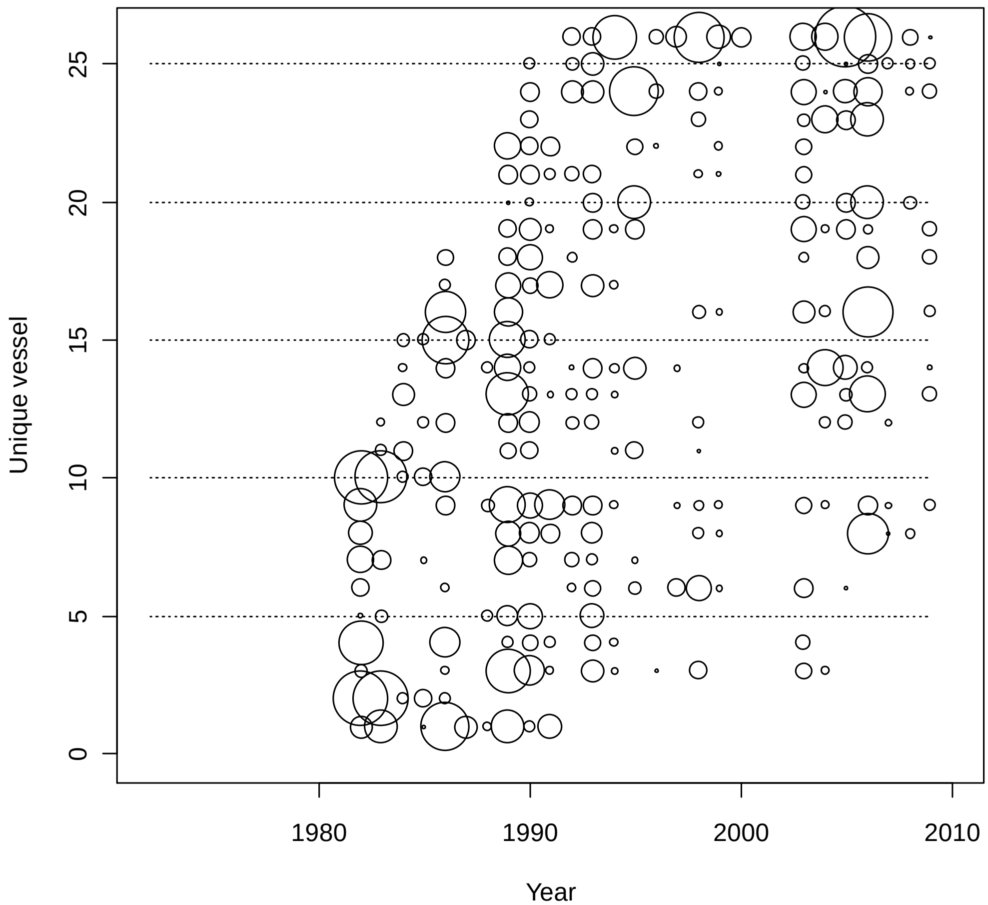


Boxplots of the key variables (aggregated by year) included in the data set included in the MFCL region 2 GLMs.

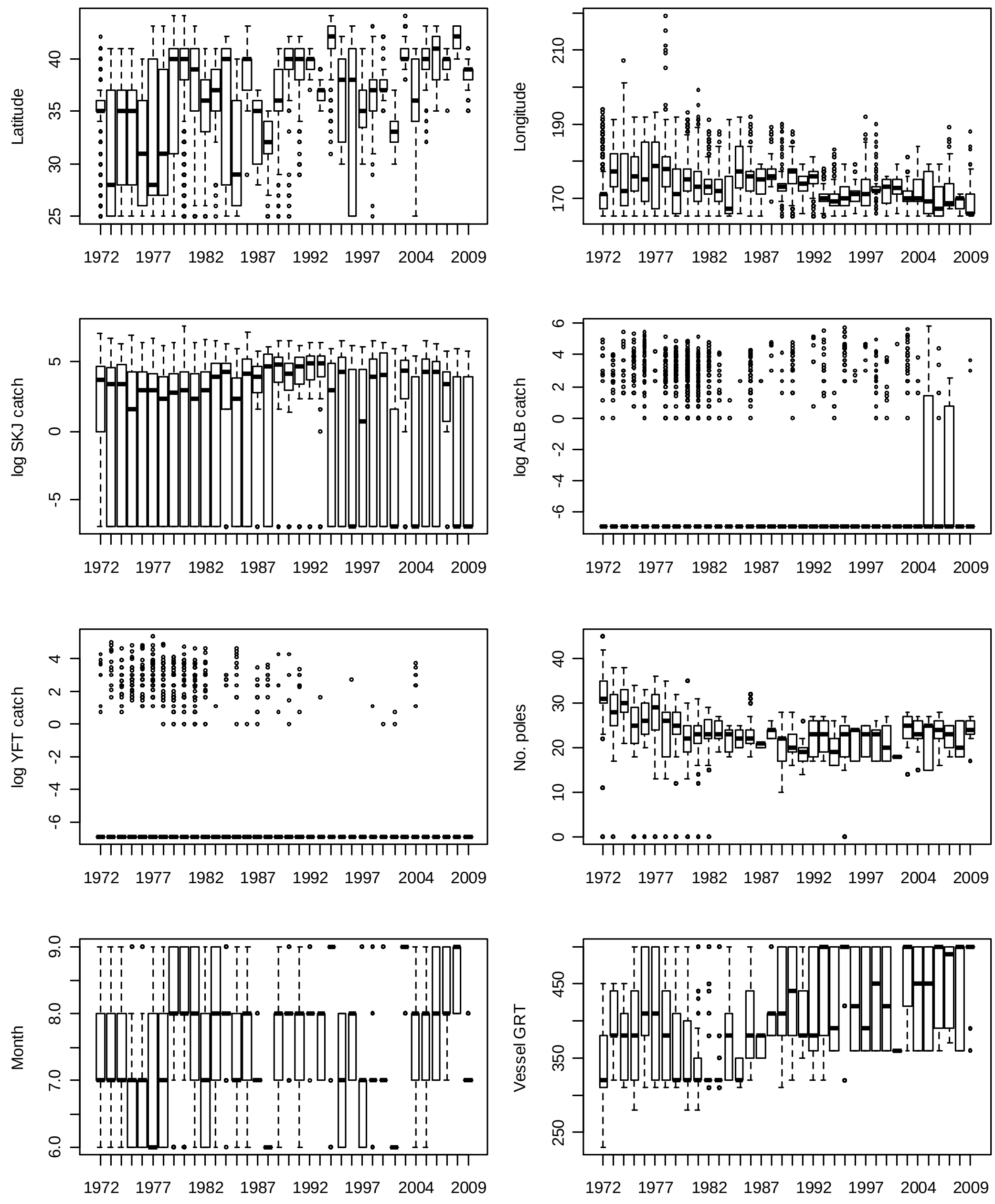
Summary of data (aggregated by year) included in the MFCL region 2 analysis. Annual catches for the five species are in tonnes.

Year	Days	Vessels	SKJ	YFT	BET	PBF	ALB
1972	2,509	116	11,547	4	38	0	380
1973	3,085	139	21,930	59	33	0	533
1974	2,091	114	10,509	3	2	0	350
1975	1,931	64	8,318	1	9	7	65
1976	3,097	124	14,954	24	88	14	186
1977	2,968	64	9,889	8	158	0	270
1978	957	80	6,512	1	43	0	124
1979	2,293	105	13,778	15	134	0	724
1980	936	53	5,745	2	73	0	404
1981	85	13	208	0	0	0	2
1982	273	14	1,619	1	1	0	2
1983	73	5	329	1	14	0	31
1984	498	16	5,784	2	5	0	151
1985	10	2	1	0	0	0	0
1986	215	13	2,405	7	9	0	100
1987	153	6	1,098	0	3	0	1
1988	298	9	3,008	6	20	0	103
1989	90	5	202	2	31	12	15
1990	337	14	1,335	4	3	0	17
1991	341	14	3,789	8	23	8	75
1992	200	11	2,038	0	0	0	0
1993	351	16	6,689	0	0	0	0
1994	116	11	1,055	0	11	0	82
1995	255	15	3,747	3	7	0	47
1996	61	7	232	0	0	0	17
1997	234	11	3,281	0	67	0	442
1998	28	5	128	0	0	0	0
1999	306	17	4,423	0	14	0	374
2000	210	16	2,612	0	14	0	321
2001	6	1	6	0	0	0	0
2002	88	11	1,283	0	0	0	0
2003	111	11	1,104	2	16	0	13
2004	127	5	556	1	57	0	68
2005	418	22	4,136	0	21	0	311
2006	387	21	2,926	2	164	0	140
2007	810	21	4,400	1	91	0	459
2008	1,059	22	6,137	0	28	0	203
2009	735	18	3,526	0	9	0	198

Appendix 1e. Northeastern subtropical region, MFCL region 3.



The annual number of days fished by each unique vessel (row) in the MFCL region 3 fishery data set. The area of the circle is proportional to the number of days fished. The aggregate vessel category, which includes all effort prior to 1982, is not included.



Boxplots of the key variables (aggregated by year) included in the data set included in the MFCL region 3 GLMs.

Summary of data (aggregated by year) included in the MFCL region 3 analysis. Annual catches for the five species are in tonnes.

Year	Days	Vessels	SKJ	YFT	BET	PBF	ALB
1972	933	67	7,352	26	52	19	56
1973	150	19	985	57	107	0	40
1974	302	25	2,319	45	102	0	79
1975	330	26	1,720	78	49	0	180
1976	487	40	2,830	109	113	0	337
1977	418	38	1,905	216	356	0	25
1978	365	29	1,413	140	249	0	134
1979	653	50	3,210	97	163	0	245
1980	2,295	105	12,564	133	373	7	423
1981	2,298	68	10,672	137	313	0	405
1982	491	20	2,641	40	123	0	125
1983	205	8	1,738	0	27	0	28
1984	89	7	862	14	22	0	1
1985	68	6	353	43	17	0	1
1986	346	15	4,062	0	26	0	98
1987	41	2	326	9	31	0	3
1988	45	4	609	16	21	0	40
1989	459	19	6,220	10	64	0	10
1990	372	21	3,248	10	19	0	93
1991	173	11	2,187	10	86	0	0
1992	149	11	2,298	0	2	0	51
1993	307	17	4,625	1	169	0	86
1994	105	9	839	0	2	0	1
1995	170	8	2,121	0	110	0	246
1996	39	4	219	2	0	0	5
1997	51	4	332	0	9	0	36
1998	180	11	2,099	0	0	0	73
1999	80	9	1,066	0	0	0	14
2000	18	1	48	0	19	0	11
2001	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0
2003	278	16	2,826	0	0	0	168
2004	141	9	459	17	261	0	8
2005	197	10	2,378	0	11	0	258
2006	332	12	3,122	0	9	0	12
2007	30	4	163	0	0	0	6
2008	57	5	294	0	0	0	0
2009	106	9	363	0	0	0	6

Appendix 2. The lognormal non zero indices (Logn), binomial indices (Bin) and delta-lognormal indices (delat-logn) from the MFCL regions 5 and 6 GLMs.

Year	Qtr	MFCL region 5			MFCL region 6		
		Logn	Bin	delta-logn	Logn	Bin	delta-logn
1972	1	0.947	0.898	0.851	1.892	0.929	1.758
1972	2	1.267	0.933	1.182	1.106	0.940	1.040
1972	3	0.879	0.806	0.708	0.788	0.808	0.636
1972	4	0.777	0.829	0.644	0.735	0.829	0.609
1973	1	0.880	0.978	0.860	0.696	0.981	0.683
1973	2	1.108	0.974	1.079	1.897		
1973	3	1.370	0.965	1.322	1.469	0.981	1.441
1973	4	1.479	0.990	1.464	1.288	0.993	1.279
1974	1	1.327	0.928	1.232	1.264	0.992	1.254
1974	2	1.231	0.892	1.098	2.086	0.965	2.013
1974	3	1.067	0.913	0.974	0.729	0.850	0.619
1974	4	0.922	0.896	0.826	0.974	0.904	0.880
1975	1	0.748	0.873	0.652	0.871	0.880	0.766
1975	2	0.871	0.929	0.809	0.857	0.920	0.788
1975	3	0.807	0.859	0.693	1.017	0.928	0.943
1975	4	0.932	0.916	0.854	0.718	0.903	0.648
1976	1	0.908	0.898	0.815	1.003	0.923	0.925
1976	2	1.241	0.930	1.155	1.104	0.956	1.055
1976	3	0.992	0.942	0.935	0.867	0.921	0.798
1976	4	0.983	0.927	0.911	0.947	0.916	0.867
1977	1	0.837	0.908	0.760	0.697	0.849	0.591
1977	2	1.003	0.903	0.907	0.925	0.879	0.813
1977	3	0.793	0.862	0.683	0.923	0.909	0.839
1977	4	1.114	0.929	1.035	1.089	0.921	1.004
1978	1	0.981	0.910	0.892	1.107	0.959	1.062
1978	2	1.420	0.981	1.392	1.172	0.967	1.134
1978	3	1.052	0.910	0.957	0.979	0.878	0.860
1978	4	1.406	0.931	1.309	0.985	0.874	0.861
1979	1	0.975	0.941	0.918	0.629	0.906	0.570
1979	2	0.937	0.870	0.815	1.017	0.852	0.866
1979	3	0.456	0.781	0.356	1.062	0.851	0.903
1979	4	0.856	0.895	0.766	0.763	0.784	0.598
1980	1	0.771	0.883	0.681	0.715	0.893	0.639
1980	2	1.126	0.934	1.052	1.090	0.896	0.976
1980	3	1.221	0.906	1.107	1.035	0.920	0.952
1980	4	0.996	0.862	0.858	1.126	0.933	1.050
1981	1	0.869	0.865	0.752	0.838	0.842	0.705
1981	2	0.864	0.863	0.745	1.007	0.903	0.909
1981	3	1.147	0.765	0.877	0.951	0.876	0.833
1981	4	0.939	0.817	0.767	0.776	0.813	0.631
1982	1	0.959	0.914	0.876	0.527	0.845	0.445
1982	2	0.978	0.921	0.900	1.006	0.925	0.930
1982	3	0.493	0.800	0.394	0.899	0.864	0.776
1982	4	0.947	0.906	0.858	0.880	0.840	0.739
1983	1	1.083	0.949	1.028	0.994	0.913	0.907
1983	2	1.541	0.967	1.490	1.158	0.948	1.098
1983	3	1.766	0.956	1.688	1.138	0.894	1.017
1983	4	1.258	0.946	1.190	2.031	0.949	1.928
1984	1	1.159	0.913	1.058	0.952	0.895	0.851
1984	2	0.999	0.839	0.838	1.435	0.960	1.378
1984	3	1.332	0.819	1.091	1.722	0.894	1.540
1984	4	1.003	0.871	0.874	0.990	0.836	0.828

1985	1	0.631	0.757	0.478	0.610	0.747	0.455
1985	2	0.776	0.900	0.699	0.637	0.804	0.513
1985	3	0.910	0.857	0.780	0.795	0.825	0.655
1985	4	0.920	0.909	0.836	0.991	0.855	0.848
1986	1	1.275	0.956	1.219	0.733	0.888	0.651
1986	2	1.350	0.962	1.300	1.344	0.873	1.173
1986	3	1.226	0.900	1.104	1.300	0.920	1.196
1986	4	1.031	0.844	0.871	1.224	0.903	1.106
1987	1						
1987	2						
1987	3	0.409	0.908	0.372			
1987	4	0.616	0.909	0.561	0.766	0.774	0.593
1988	1	0.657	0.955	0.627	0.992	0.851	0.844
1988	2	0.912	0.965	0.880	1.950	0.981	1.913
1988	3	0.540	0.823	0.444	1.638	0.916	1.500
1988	4	0.940	0.900	0.846	2.328	0.942	2.193
1989	1	1.381	0.935	1.292	2.179	0.951	2.072
1989	2	0.996	0.952	0.949	2.223	0.944	2.098
1989	3	0.413	0.639	0.264	1.074	0.898	0.964
1989	4	0.463	0.756	0.350	0.857	0.821	0.704
1990	1	0.438	0.745	0.326	0.374	0.558	0.209
1990	2	0.625	0.918	0.573	0.591	0.486	0.288
1990	3				0.619	0.770	0.477
1990	4	0.643	0.900	0.579	1.337	0.871	1.165
1991	1	0.910	0.902	0.821			
1991	2	0.834	0.774	0.646	1.918	0.684	1.312
1991	3	0.630	0.835	0.526	2.054	0.953	1.957
1991	4	0.453	0.693	0.314	1.359	0.929	1.263
1992	1	0.445	0.689	0.307			
1992	2	1.227					
1992	3						
1992	4	0.828	0.903	0.748	1.191	0.934	1.113
1993	1	0.655	0.812	0.532	0.782	0.842	0.659
1993	2	0.799	0.904	0.722	0.944	0.863	0.815
1993	3						
1993	4	0.608	0.764	0.465	1.219	0.832	1.014
1994	1	0.663	0.812	0.538	1.025	0.668	0.685
1994	2	0.791	0.856	0.677	1.321	0.869	1.147
1994	3						
1994	4	0.942	0.896	0.844	1.351	0.859	1.160
1995	1	0.858	0.912	0.783	1.331	0.855	1.139
1995	2	0.667	0.912	0.608	1.787	0.878	1.569
1995	3						
1995	4	0.582	0.651	0.379	1.120	0.821	0.919
1996	1	0.496	0.708	0.351	0.651	0.726	0.473
1996	2	0.837	0.963	0.805	0.935	0.706	0.660
1996	3				1.544	0.825	1.274
1996	4	0.667	0.762	0.508	1.157	0.859	0.994
1997	1	0.711	0.899	0.639	1.280	0.882	1.130
1997	2	0.594	0.720	0.427	1.215	0.889	1.079
1997	3						
1997	4	0.554	0.762	0.422	0.481	0.410	0.198
1998	1	0.607	0.837	0.508	0.758	0.844	0.640
1998	2	0.931	0.957	0.891	1.128	0.980	1.105
1998	3				0.772		
1998	4	0.640	0.898	0.575	1.277	0.919	1.174
1999	1	0.578	0.846	0.490	1.177	0.949	1.117
1999	2	0.406	0.646	0.262	1.337	0.837	1.119

1999	3						
1999	4	0.412	0.648	0.267	0.805	0.695	0.559
2000	1	0.660	0.881	0.581	1.030	0.844	0.869
2000	2	0.767	0.943	0.723	1.436	0.984	1.413
2000	3						
2000	4	0.530	0.870	0.461	2.164	0.897	1.941
2001	1	0.685	0.864	0.592	1.281	0.915	1.172
2001	2	0.791	0.846	0.669	1.387	0.920	1.276
2001	3						
2001	4	0.440	0.829	0.365	0.741	0.582	0.431
2002	1	0.690	0.877	0.605	0.577	0.812	0.468
2002	2	0.901	0.917	0.826	1.542	0.925	1.426
2002	3						
2002	4	0.683	0.777	0.531	1.794	0.856	1.536
2003	1	0.849	0.923	0.784	0.824	0.817	0.673
2003	2	0.851	0.922	0.785			
2003	3						
2003	4	0.334	0.597	0.199	0.657	0.505	0.332
2004	1	0.386	0.541	0.209	0.608	0.642	0.390
2004	2	0.430	0.650	0.279	0.568	0.688	0.390
2004	3						
2004	4	0.758	0.751	0.569	1.192	0.859	1.024
2005	1	0.665	0.838	0.557	1.390	0.925	1.286
2005	2	0.894	0.896	0.800	0.931	0.859	0.800
2005	3						
2005	4	0.863	0.493	0.425	0.451		
2006	1	0.515	0.704	0.363	1.072	0.813	0.871
2006	2	0.922	0.948	0.874	1.233	0.919	1.133
2006	3						
2006	4				0.401		
2007	1	0.896	0.943	0.845	1.133	0.979	1.109
2007	2	0.621	0.832	0.516	1.523	0.776	1.181
2007	3						
2007	4	0.238	0.496	0.118	0.682	0.777	0.530
2008	1	0.797	0.867	0.691	0.886	0.789	0.699
2008	2	0.784	0.875	0.686	1.820		
2008	3						
2008	4	0.377	0.379	0.143	0.633	0.571	0.362
2009	1	0.397	0.577	0.229	0.582	0.632	0.368
2009	2	0.481	0.609	0.293	0.989	0.518	0.513
2009	3	0.197	0.192	0.038	0.510	0.605	0.308
2009	4	0.329	0.172	0.057	0.586	0.754	0.442

Appendix 3. The lognormal non zero indices (Logn), binomial indices (Bin) and delta-lognormal indices (delat-logn) from the GLMs of the **offshore** pole-and-line logsheet data for MFCL **region 2**.

Year	Qtr	Bin	Logn	delta-logn	Year	Qtr	Bin	Logn	delta-logn
1972	2	0.537	0.876	0.470	1991	2	0.770	1.171	0.901
1972	3	0.524	0.770	0.403	1991	3	0.792	2.386	1.891
1973	2	0.651	1.185	0.771	1992	2		0.210	
1973	3	0.587	0.904	0.530	1992	3	0.719	1.633	1.175
1974	2	0.731	1.282	0.937	1993	2	0.365	2.693	0.982
1974	3	0.535	0.789	0.422	1993	3	0.678	1.445	0.979
1975	2	0.633	1.082	0.685	1994	2	0.792	0.886	0.702
1975	3	0.647	0.738	0.478	1994	3	0.451	0.791	0.357
1976	2	0.843	1.540	1.298	1995	2	0.610	1.774	1.082
1976	3	0.674	0.840	0.566	1995	3	0.619	0.598	0.370
1977	2	0.763	1.067	0.814	1996	2	0.474	1.669	0.791
1977	3	0.526	0.600	0.316	1996	3	0.667	1.255	0.837
1978	2	0.702	1.140	0.800	1997	2		4.408	
1978	3	0.594	0.785	0.466	1997	3	0.673	1.443	0.971
1979	2	0.802	1.390	1.114	1998	2	0.670	1.641	1.100
1979	3	0.644	0.833	0.536	1998	3	0.734	1.058	0.776
1980	2	0.816	1.475	1.203	1999	2	0.834	1.240	1.034
1980	3	0.627	0.862	0.540	1999	3	0.477	1.260	0.601
1981	2	0.640	0.747	0.478	2000	2			
1981	3	0.573	0.531	0.304	2000	3	0.545	2.442	1.331
1982	2	0.563	1.002	0.564	2001	2	0.342		
1982	3	0.554	0.916	0.508	2001	3	0.500	0.753	0.376
1983	2	0.720	1.231	0.886	2002	2	0.555	1.384	0.768
1983	3	0.662	0.976	0.647	2002	3	0.590	0.920	0.543
1984	2	0.556	1.240	0.689	2003	2	0.223	2.907	0.648
1984	3	0.739	1.622	1.198	2003	3	0.488	1.006	0.491
1985	2	0.501	0.899	0.451	2004	2	0.891	0.872	0.777
1985	3	0.556	0.677	0.376	2004	3	0.644	0.800	0.515
1986	2	0.692	2.025	1.401	2005	2		0.381	
1986	3	0.698	1.096	0.765	2005	3	0.574	1.606	0.921
1987	2		1.459		2006	2	0.245	2.020	0.494
1987	3	0.624	0.712	0.444	2006	3	0.545	1.529	0.833
1988	2	0.795	1.530	1.216	2007	2		3.394	
1988	3	0.680	1.062	0.722	2007	3	0.728	1.184	0.862
1989	2	0.560	0.930	0.520	2008	2	0.643	2.733	1.756
1989	3	0.558	0.699	0.390	2008	3	0.648	1.376	0.891
1990	2	0.618	1.181	0.730	2009	2		3.939	
1990	3	0.579	0.819	0.475	2009	3	0.604	0.755	0.456