SCIENTIFIC COMMITTEE
SEVENTH REGULAR SESSION

9-17 August 2011
Pohnpei, Federated States of Micronesia

Up-to-date CPUE for skipjack caught by Japanese distant and offshore pole and line in the western central Pacific Ocean

WCPFC-SC7-2011/SA-IP-13

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Abstract
Catch per unit effort (CPUE) indices for skipjack were evaluated and updated. The data used in 2010 were updated by one year and vessel ID was added before 1984. While the same methods were applied as proposed by Langley et al. (2010), final models in each region was determined by AIC, BIC and results from ANOVA. Indices in each region have been changed somewhat from results in 2010. Indices from the lognormal positive model especially in region2 (western equatorial area) were declined after 1985 as results from the 2010 analysis; however, updated indices in 2011 were flat throughout the study period. Other indices in each region were not largely changed from the last stock assessment in 2010.

INTRODUCTION

Standardized CPUE indices of the Japanese pole and line fisheries in WCPO have been incorporated to the skipjack stock assessment since 2000. The methodology of derivation of these indices has been improved in 2010 stock assessment as results of collaborative research between SPC and the National Research Institute of Far Seas Fisheries (NRIFSF) (Langley et al., 2010 and Kiyofuji et al., 2010). These improved indices and incorporated to the skipjack stock assessment as main index of skipjack stock abundance. In this study, CPUE were updated by the same methodology as in 2010 but model selection procedures were improved.

DATA and METHOD

The operational level of catch and effort data for Japanese pole and line between 1972 and 2010 with noon position in equidistant 1° x 1° grid cells was used. Dates, number of poles, catch in weight and vessel size in gross register tonnage (GRT) was employed. Japanese pole and line fishery are categorized into three licenses, which are inshore (< 20 GRT), offshore (from 20 to 200 GRT) and distant-water (> 200 GRT) (Ogura and Shono, 1999). There is no necessity for the inshore fishery to submit logbooks, and so any available data for this vessel class were excluded from this analysis. Individual vessel number was identified by the license number. Detail data descriptions were made in Langley et al. (2010) but one major change was that license numbers before 1984 were added. As a result of adding the license number, vessel data increased approximately three times in total from 2011.

The number of unique vessels was the highest in 1981 and decreased until 1990 (Figure 3). The time distribution of each unique vessel shows that several members of the fleet continued fishing activity from 1970s to the present in all regions (Figure 4).

A generalized linear model was applied for the MFCL region 1 defined in 2010 (Figure1) and the basic GLM model formulation applied in this study is shown as following equation.

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

Definitions of the predictor variables are shown in Table 1. Final models were chosen based on the results of reduction of parameters from the full model (included all devices) and model selection was made by the Bayesian information criterion (BIC) (Table 2). Parameters included in the final model are shown in Table 2. Note that any device information was not included as predictor variables in region 1 since these data are still in preparation.

The model was implemented separately for each region and both binomial and lognormal models were applied. These models address respectively:

1. The presence/absence of skipjack catches for a fishing day. The dependent variables were modeled using a binomial error structure to estimate probability of non-zero skipjack catch for a fishing day.
2. Non-zero skipjack catch for a fishing day after zero catch records have been excluded. The dependent variable was modeled assuming a lognormal error structure.

For the binomial model, the year/quarter indices indicating probability of capture (*p*) were derived using the inverse logit of the individual year/quarter factorial coefficients, with the average predicted value of p in the first 5 years constrained to equal the observed average p for the same period. For the lognormal model, the year/quarter CPUE indices were derived by exponentiation of the individual year/quarter factorial coefficients. Delta-lognormal indices were derived by multiplying the binomial *p* values and the non-zero lognormal indices (Lo et al., 1992).

Japanese offshore pole and line fishing activity near Japanese water (old MFCL region 1 and 2; Fig.1 (a)) mainly occurs during April – September, targeting both of skipjack and albacore. The absence of skipjack in the catch from targeting albacore trips is unlikely to be suitable for representing the relative abundance of skipjack. This is also a critical issue for derivation of relative abundance of albacore (e.g. Kiyofuji and Uosaki, 2010). To exclude such data from the analysis, those fishing trips that skipjack represented 75% of the combined skipjack and albacore were removed. The data set was limited to individual vessels that completed a minimum of 10 days fishing each year for a minimum of five years.

RESULTS

Region1 (northern part of WCPO)

The binomial model indicates that the probability of catching skipjack within region1 is between 0.4 and 0.8 during the analysis period and there were no any significant trends (Figure 5). The lognormal non zero model estimated the non zero daily catch of skipjack. There were also no particular trends in the year/quarter indices derived from the model (Figure 6). The year/quarter indices calculated by multiplying both year/quarter estimated by the binomial and lognormal non zero shows annual trend that it did not change largely until 2000 but decreased until 2005. Delta-lognormal indices increased gradually from 1990 to 2000 and then decreased until 2005 (Figure 7). There is a strong effect on earlier vessels in binomial model but not much effect in the lognormal model (Figure 8).

Region2 (Wesern Equatorial region of WCPO)

The year/quarter index estimated by the binomial model suggests that the probability of catching skipjack in region2 decreased from 1970' to date (Figure 9). The indices estimated by the binomial model were strongly influenced by both individual vessel effects and devices (sonar and birdradar) (Figure 12). Indices between include vessel id (model2) and excluded both device (final model) did not show large difference. Catch rate generally increased especially with the second generation of bird radar (Figure 14).

The index estimated by the lognormal non zero model are flat through study period but likely decreased after 2003 (Figure 10). The year/quarter index is also influenced strongly by the vessel effect, number of poles, and devices (bait tank and bird radar) after 1987 when started to deploy device (Figure 13). Non-zero skipjack catch generally increase with the number of poles fished, with bait tank, and bird radar (Figure 15). There was a strong vessel effect in the early period in the binomial model, but less so for the lognormal model (Figure 16). A step change is apparent in the lognormal indices in about 1984. This change may coincide with changes in data collection from the fishery. Indices by delta-lognormal also decreased constantly especially after 1990 (Figure 11).

Region3 (Eastern Equatorial region of WCPO)
Skipjack catch rates in region3 were between 0.6 and 1.0 and increased after 1985 (Figure 17). The indices estimated by the binomial model were influenced by the individual vessel effect and bird radar (Figure 20). Vessel ID and bird radar likely influenced after 1987. Catch rate was generally estimated to decrease with the first and second generation of bird radar (Figure 14). There is a strong effect on earlier vessels in the binomial model but not much effect in the lognormal model (Figure 24).

The index estimated by the lognormal non zero model fluctuated largely after 1990, with an overall declining trend on average (Figure 18). As in region 2, there appears to be a step change in about 1984. In this region, no large significant effect of pole and device on the indices was identified (Figure 21, 23). The delta-lognormal index shows similar variability to the lognormal non zero model (Figure 19).

DISCUSSION

In this document, CPUE indices for skipjack were evaluated and updated and the data used in 2010 were updated by one year and vessel ID was added before 1984. We implemented a generalized linear model (GLM) as suggested by Langley et al. (2010) to produce standardized time series for the full data set. This analysis was similar to analyses for the last stock assessment in 2010 but new vessel id information was added and the model selection procedure was improved. Some changes were apparent in the CPUE trends to those seen in 2010, mostly in the lognormal indices. Standardized catch rates increased quite substantially in 1984 for regions 2 and 3, and further investigation of the reasons for these changes is recommended in future.

While the same methods were applied as proposed by Langley et al. (2010), final models in each region was determined by AIC, BIC and results from ANOVA. In this analysis, standardizations provided clear benefits in the extraction of a reliable index. As results shows some predictor variables were excluded but birdradar were remained in all models in both region 2 and region3. This indicates that deployment of birdradar is considered as an important device to estimate reliable skipjack abundance indices.

In the northern region (region 1), delta-lognormal index shows some variability that gradual increases from 1990 to 2000 and decrease until 2005. It shows no decreasing trend in recent year; however, it is reported that decreased trend of skipjack population in this area (Uosaki et al., 2010; Kiyofuji et al., 2011). One cause of this is because any device information was not included as predictor variables since these data are still in preparation. This should be prepared in near future and conducted in same manner to provide more accurate and realistic abundance indices in this area. Furthermore, new abundance indices were presented derived from Global Positioning system (GPS) deployed to several middle sized offshore pole and line fisheries (Okamoto and Kiyofuji, 2011). This could also be one possibility to incorporate to the stock assessment model as one of abundance indices.

Reference

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

(a) JP PL offshore in region 1 (fleet <= 200 GRT)

Variable	**Data type**	**Description**
YearQtr	Categorical	Unique year and quater
LatLong	Categorical	5º of latitude and longitude spatial strata (midday position)
VesselID	Categorical	Unique vessel identifier
NumPoles	Continuous	Number of poles

(b) JP PL distant water in region 2 and 3(fleet > 200 GRT)

Variable	**Data type**	**Description**
YearQtr	Categorical	Unique year and quater
LatLong	Categorical	5º of latitude and longitude spatial strata (midday position)
VesselID	Categorical	Unique vessel category
NumPoles	Continuous	Number of poles
BaitTank	Categorical (2)	1. Vessel does not have LTLBT. 2. Vessel has LTLBT.
NOAA	Categorical (2)	1. Vessel does not have NOAA receiver. 2. Vessel has NOAA receiver.
Sonar	Categorical (2)	1. Vessel does not have sonar. 2. Vessel has sonar.
BirdRadar	Categorical (3)	1. Vessel does not have bird radar 2. Vessel has 1st generation bird radar. 3. Vessel has 2nd generation bird radar.

Table2-1. AIC, BIC and TYPE II ANOVA for each model in region 2(JPN PL DW).

(a) Binomial model.

Model	AIC	BIC
Full model (include all device)		
Yrqtr + vesselid + latlong + pole + baittank + noaa + sonar + BR	79679	83938
Delete NOAA		
Yrqtr + vesselid + latlong + pole + baittank + sonar + BR	79678	83927
Delete NOAA and Baittank		
Yrqtr + vesselid + latlong + pole + sonar + BR	79678	83917
Delete NOAA, Baittank and pole		
Yrqtr + vesselid + latlong + sonar + BR	79676	83886

(b) TYPE2 ANOVA for selected binomial model.

factor	TYPE II SS	DF	F	Pr (>F)	
yrqtr	3778	143	25.727	< 2.20E-16	***
vesselid	3617	234	15.049	< 2.20E-16	***
latlong	746	50	14.535	< 2.20E-16	***
sonar	12	1	11.762	0.0006049	***
BR	37	2	17.83	1.81E-08	***

(c) Lognormal positive model in Region 2 (JPN PL DW).

Model	AIC	BIC
Full model (include all device)		
Yrqtr + vesselid + latlong + pole + baittank + noaa + sonar + BR	319896	552879
Delete sonar		
Yrqtr + vesselid + latlong + pole + baittank + noaa + BR	319894	324085
Delete sonar and NOAA		
Yrqtr + vesselid + latlong + pole + baittank + BR	319895	324075

(d) TYPE2 ANOVA for selected lognormal positive model in region2 (JPN DW).

factor	TYPE II SS	DF	F	Pr (>F)	
yrqtr	5192	141	39.3974	< 2.20E-16	***
vesselid	4010	234	18.3362	< 2.20E-16	***
latlong	1016	50	21.7462	< 2.20E-16	***
pole	200	3	71.4437	< 2.20E-16	***
baittank	14	1	14.623	0.0001314	***
BR	18	2	9.7149	6.04E-05	***

Table2-2. AIC, BIC and TYPE II ANOVA for each model in region 3 (JPN PL DW).

(a) Binomial model.

Model	AIC	BIC
Full model (include all device)		
Yrqtr + vesselid + latlong + pole + baittank + noaa + sonar + BR	56375	60053
Delete sonar		
Yrqtr + vesselid + latlong + pole + baittank + NOAA + BR	56375	60042
Delete sonar and NOAA		
Yrqtr + vesselid + latlong + pole + sonar + BR	56373	60031
Delete sonar, NOAA and Baittank		
Yrqtr + vesselid + latlong + pole + BR	56371	60020
Delete sonar, NOAA and Baittank and pole		
Yrqtr + vesselid + latlong + BR	56372	59992

(b) TYPE2 ANOVA for selected binomial model.

factor	TYPE II SS	DF	F	Pr (>F)	
yrqtr	2674	136	20.0996	< 2.20E-16	***
vesselid	2629	186	14.4508	< 2.20E-16	***
latlong	1070	53	20.6435	< 2.20E-16	***
BR	16	2	8.1584	0.0002865	***

(c) Lognormal positive model.

Model	AIC	BIC
Full model (include all device)		
Yrqtr + vesselid + latlong + pole + baittank + noaa + sonar + BR	273974	277627
Delete sonar		
Yrqtr + vesselid + latlong + pole + baittank + noaa + BR	273972	277615
Delete sonar and NOAA		
Yrqtr + vesselid + latlong + pole + baittank + BR	273972	277606

(d) TYPE2 ANOVA for selected lognormal positive model.

factor	TYPE II SS	DF	F	Pr (>F)	
yrqtr	7144	136	54.2076	< 2.20E-16	***
vesselid	2654	186	14.7224	< 2.20E-16	***
latlong	1266	53	24.6501	< 2.20E-16	***
pole	198	3	68.2226	< 2.20E-16	***
baittank	8	1	7.9744	0.0047452	**
BR	13	2	6.9559	0.0009534	***

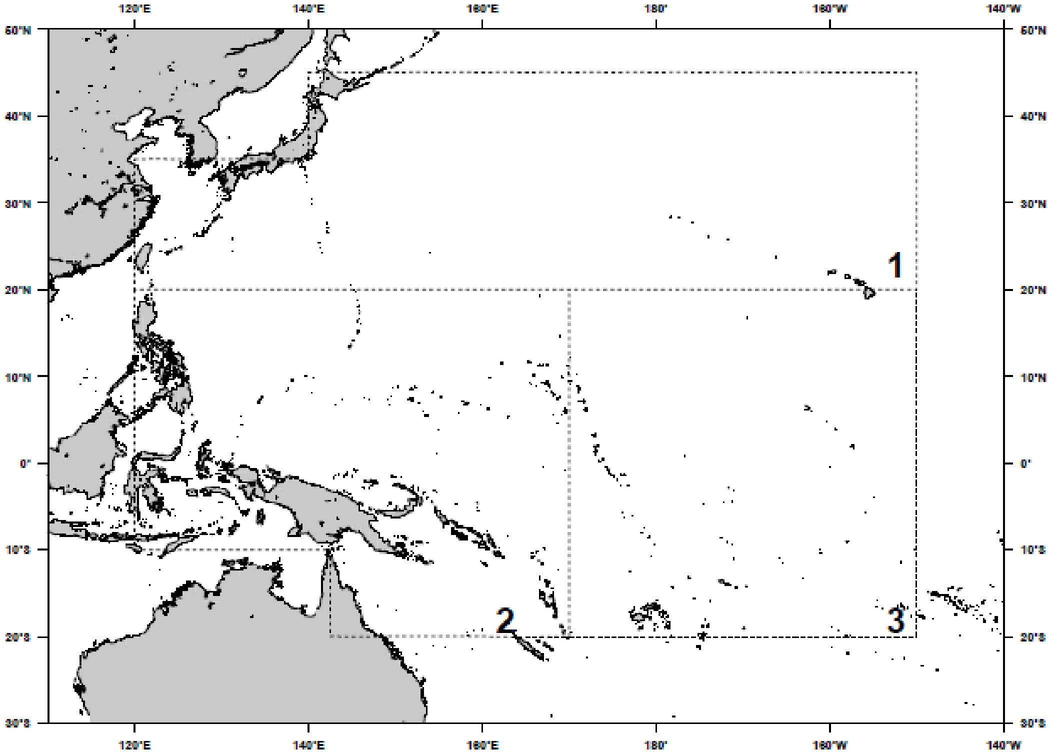

Figure 1. Spatial structure of the MFCL skipjack assessment model.

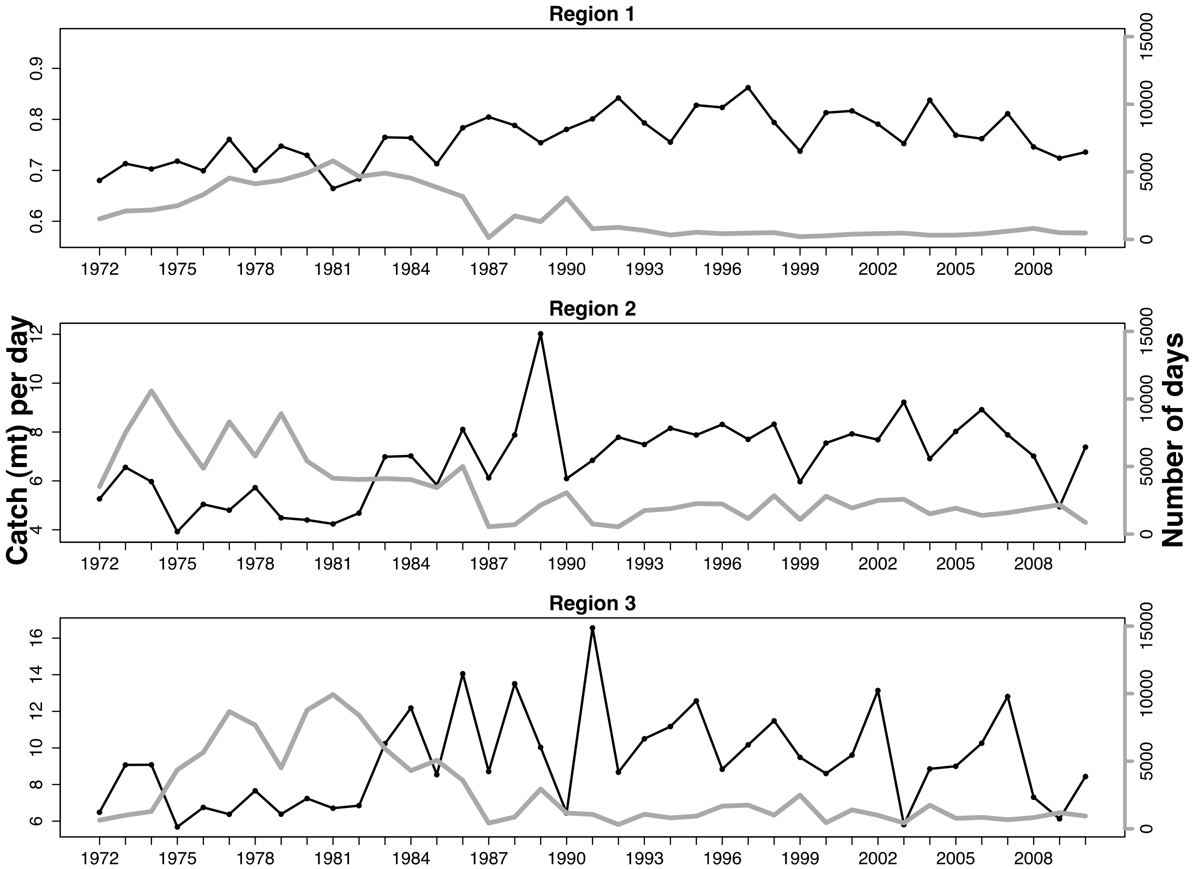

Figure 2. The annual number of days fished (gray line) by the distant-water pole and line fleet included in each region and the nominal skipjack catch rate (mt/day, black line). Note that data represents offshore pole and line in region1, distant water pole and line fisheries in region2 and 3, respectively.

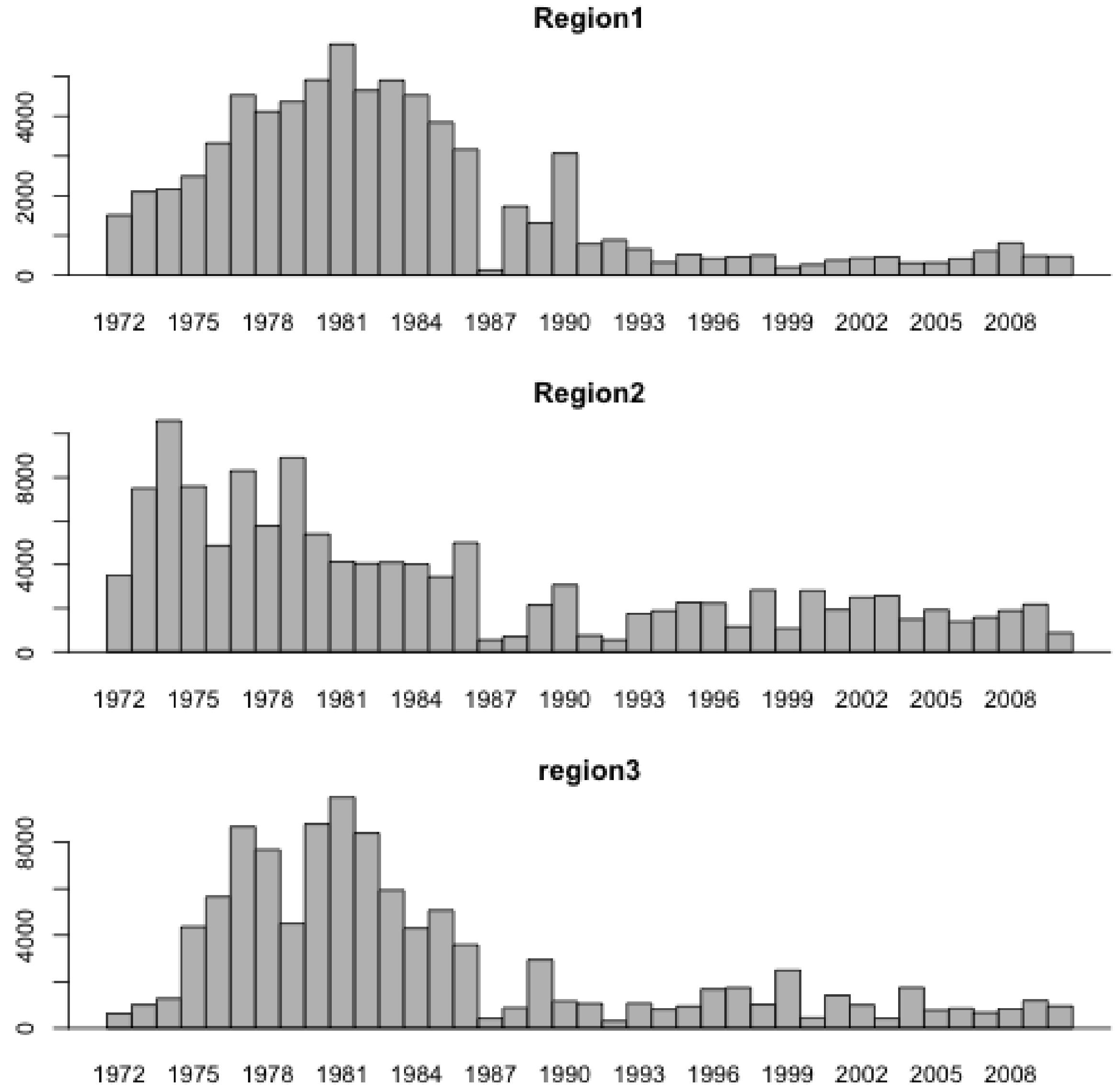

Figure 3. Number of unique vessel in each region.

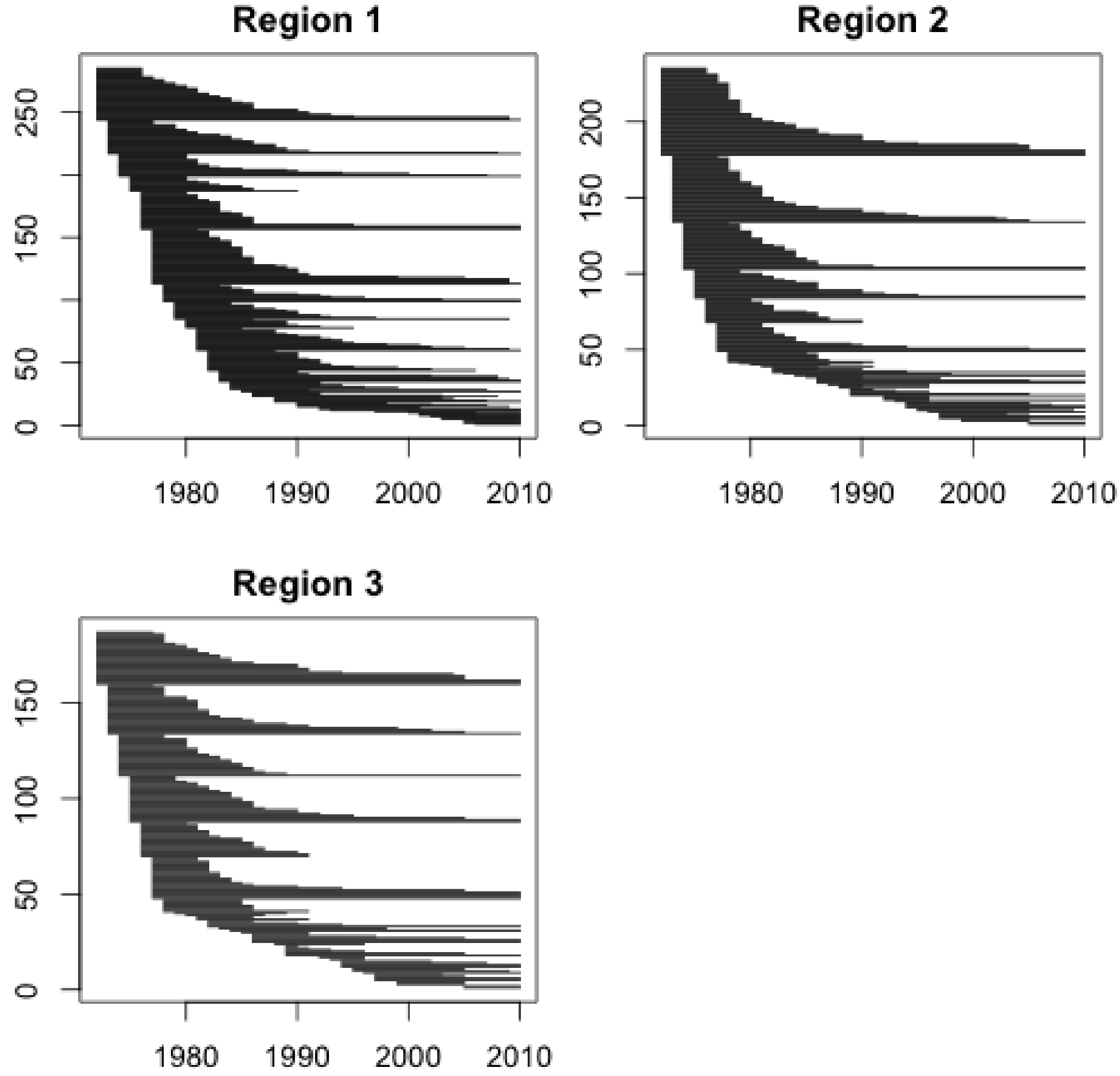

Figure 4. Time distribution of each unique vessel.

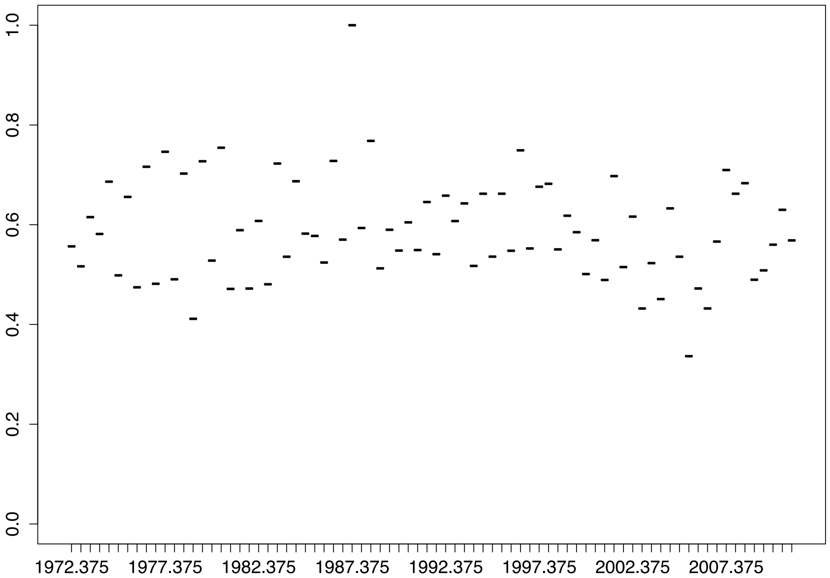

Figure 5. The year/quarter indices (catch rate time series) derived from the binomial model for MFCL region 1.

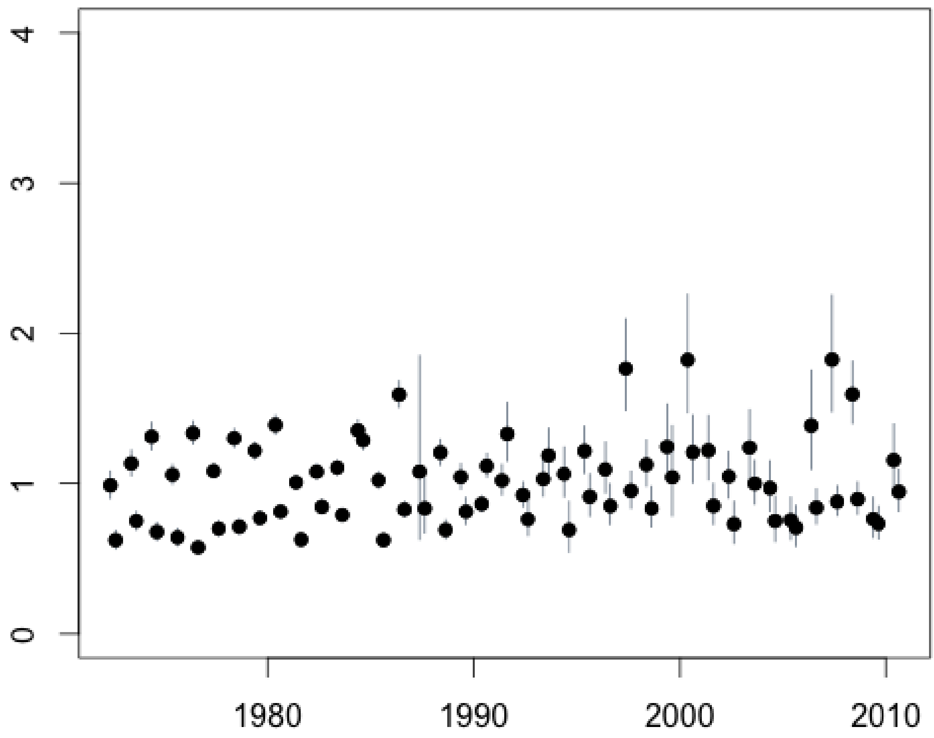

Figure 6. Time series of index derived by the lognormal non zero model for the offshore water Japanese pole and line fisheries in region 1.

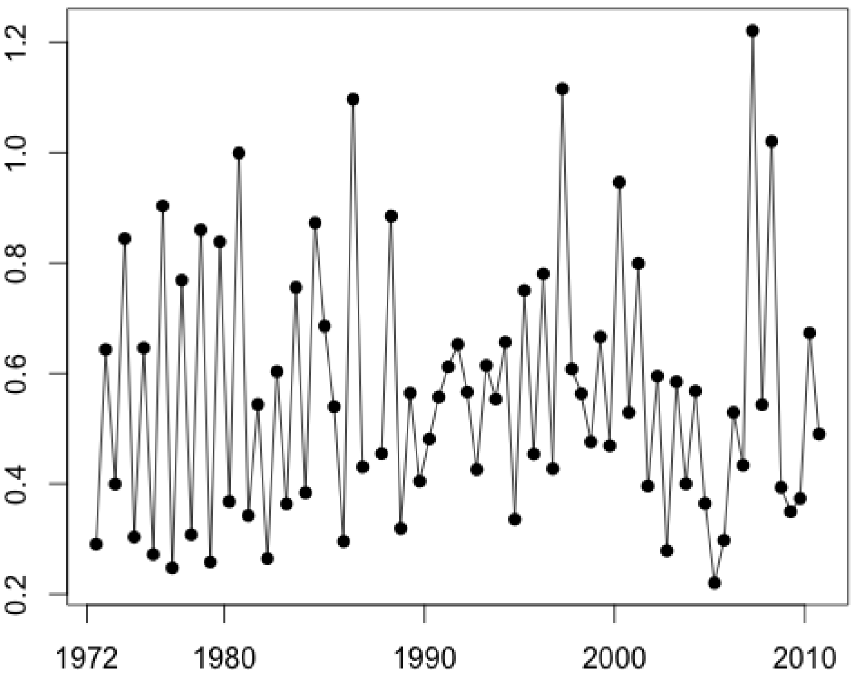

Figure 7. Time series of index derived by the delta-lognormal for the distant water Japanese pole and line fisheries in region1.

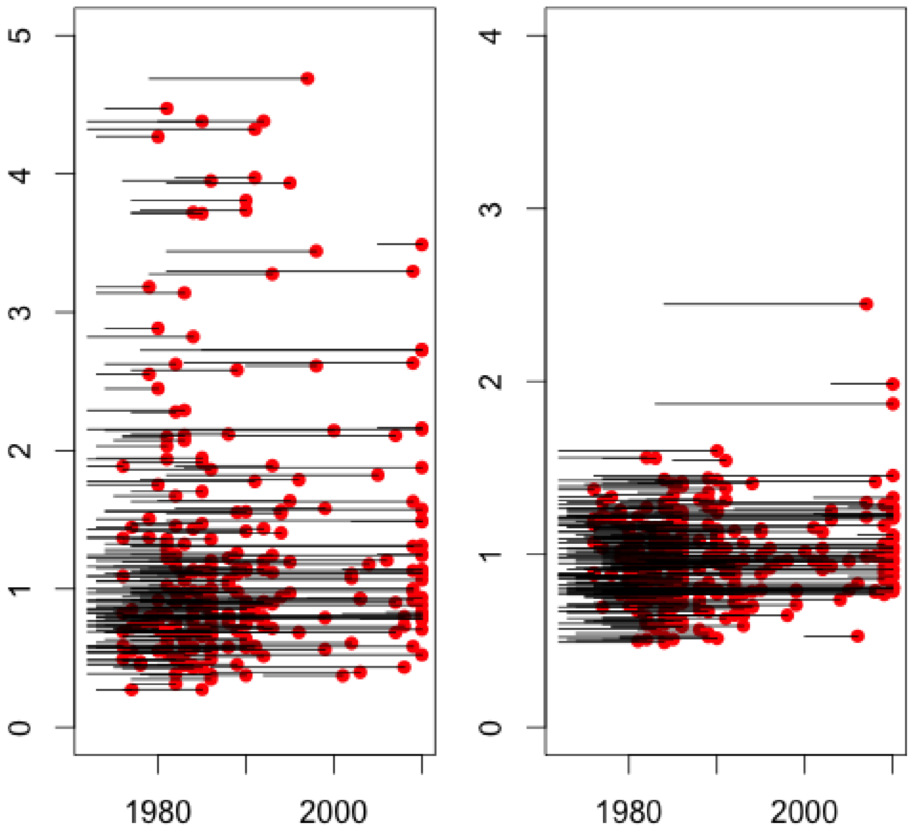

Figure 8. Individual vessel effects on the probability of catching skipjack (left: binomial model, right: lognormal positive catch) for region 1 (JP OS). Red points were plotted against the last year that the vessel was active in the fishery and the horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1972 onwards with the exception of the aggregate vessel category.

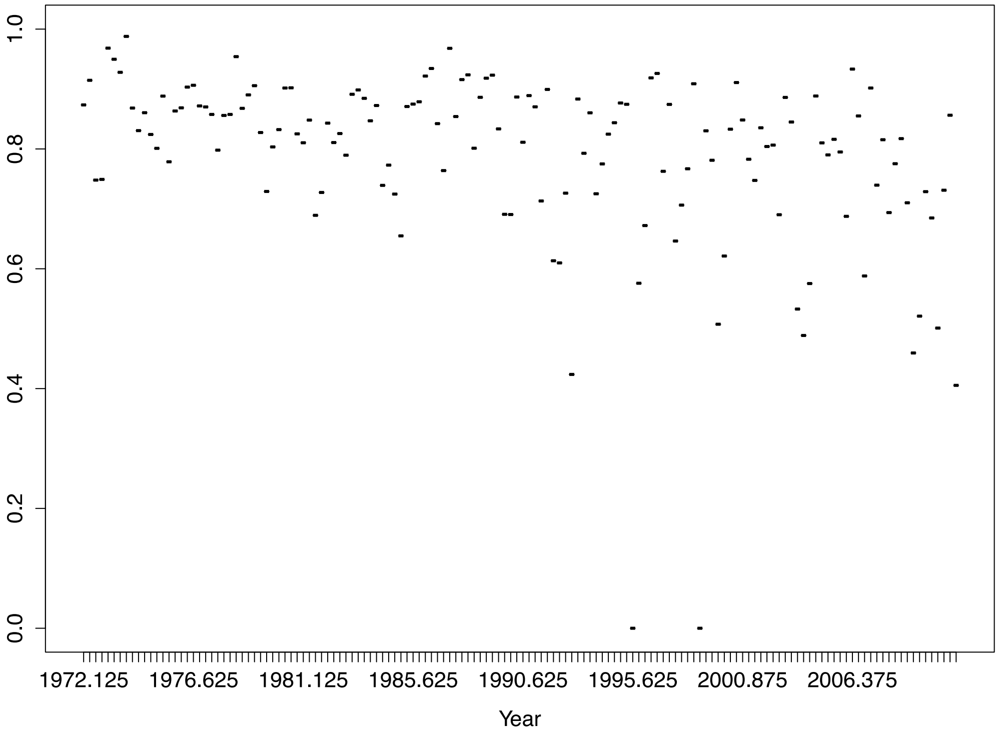

Figure 9. The year/quarter indices (catch rate time series) derived from the binomial model (final) for MFCL region 2.

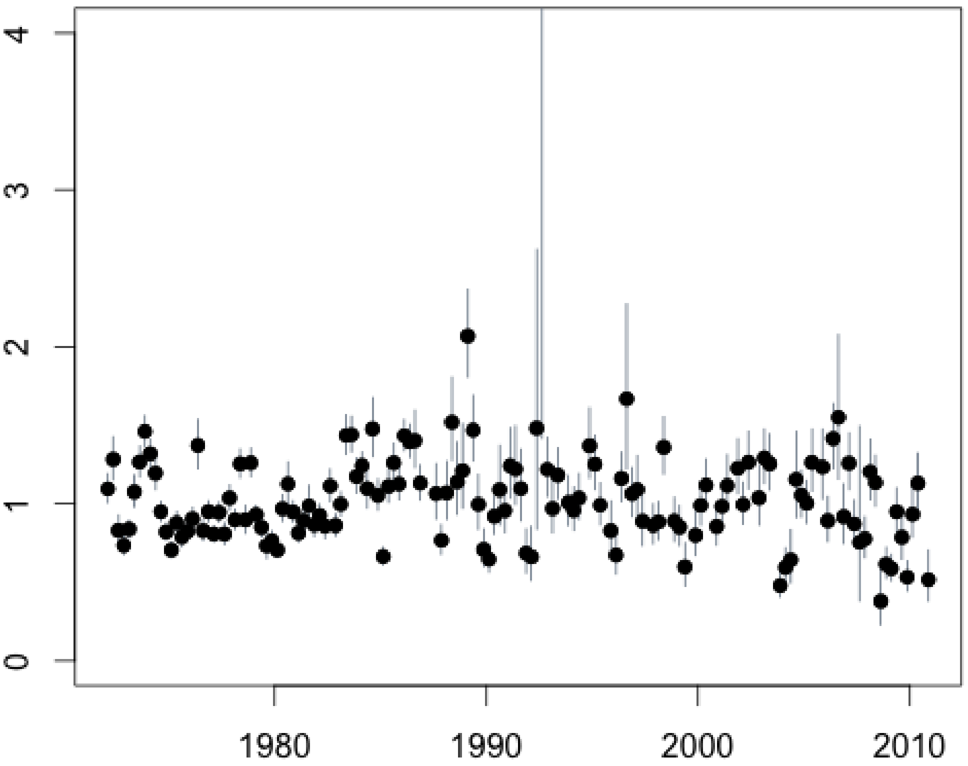

Figure 10. Time series of index derived by the lognormal non zero model for the distant water Japanese pole and line fisheries in region 2 (final model in Table 2-2).

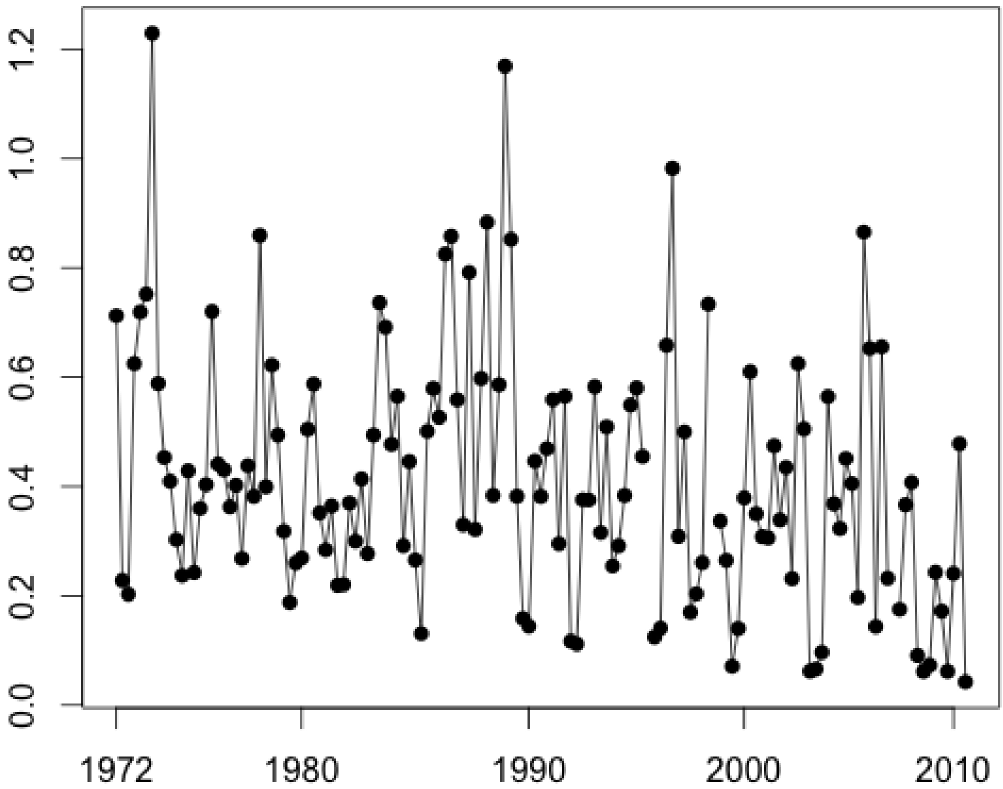

Figure 11. Time series of index derived by the delta-lognormal for the distant water Japanese pole and line fisheries in region2. (final model in Table 2-2).

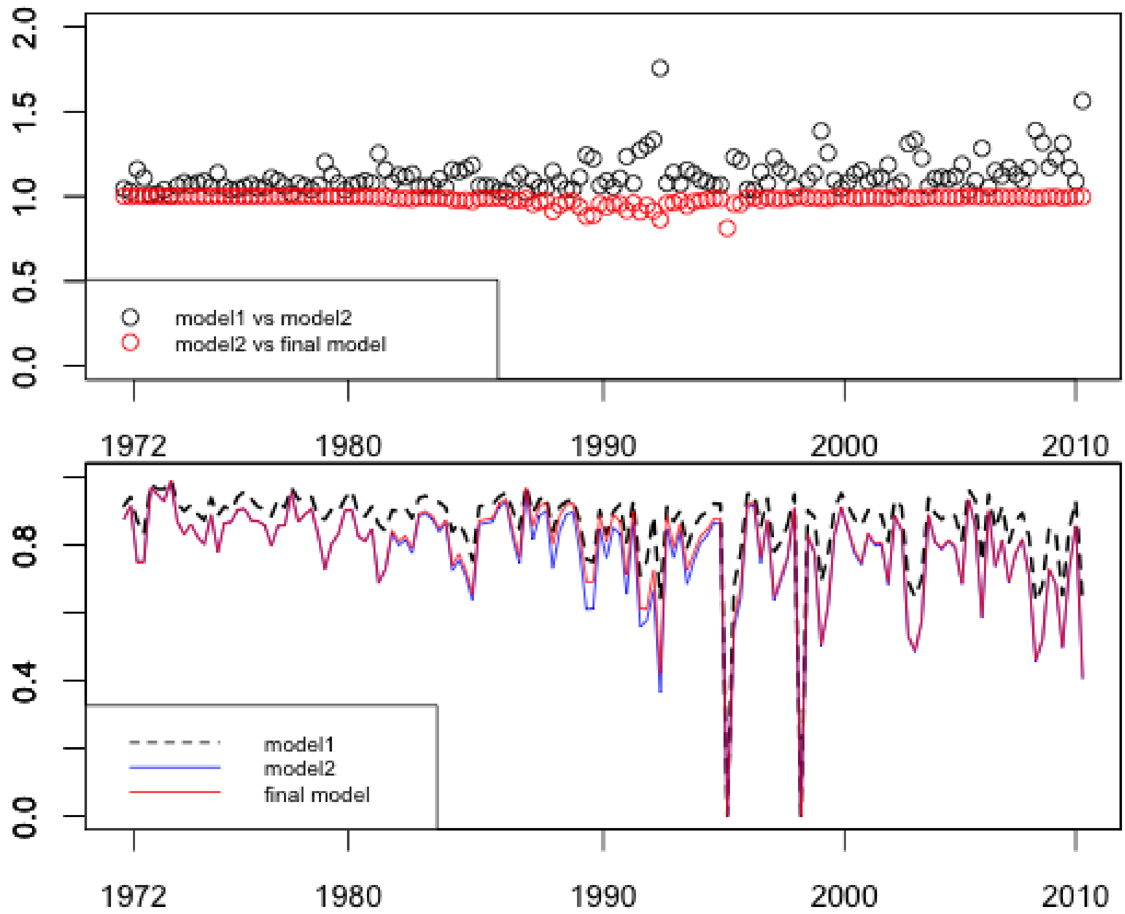

Figure 12. Ratio of coefficients (above) and zero-catch rate of the binomial model in region 2 (model1: yrqtr+latlong, model2: yrqtr+latlong+vesselid, model3: final model).

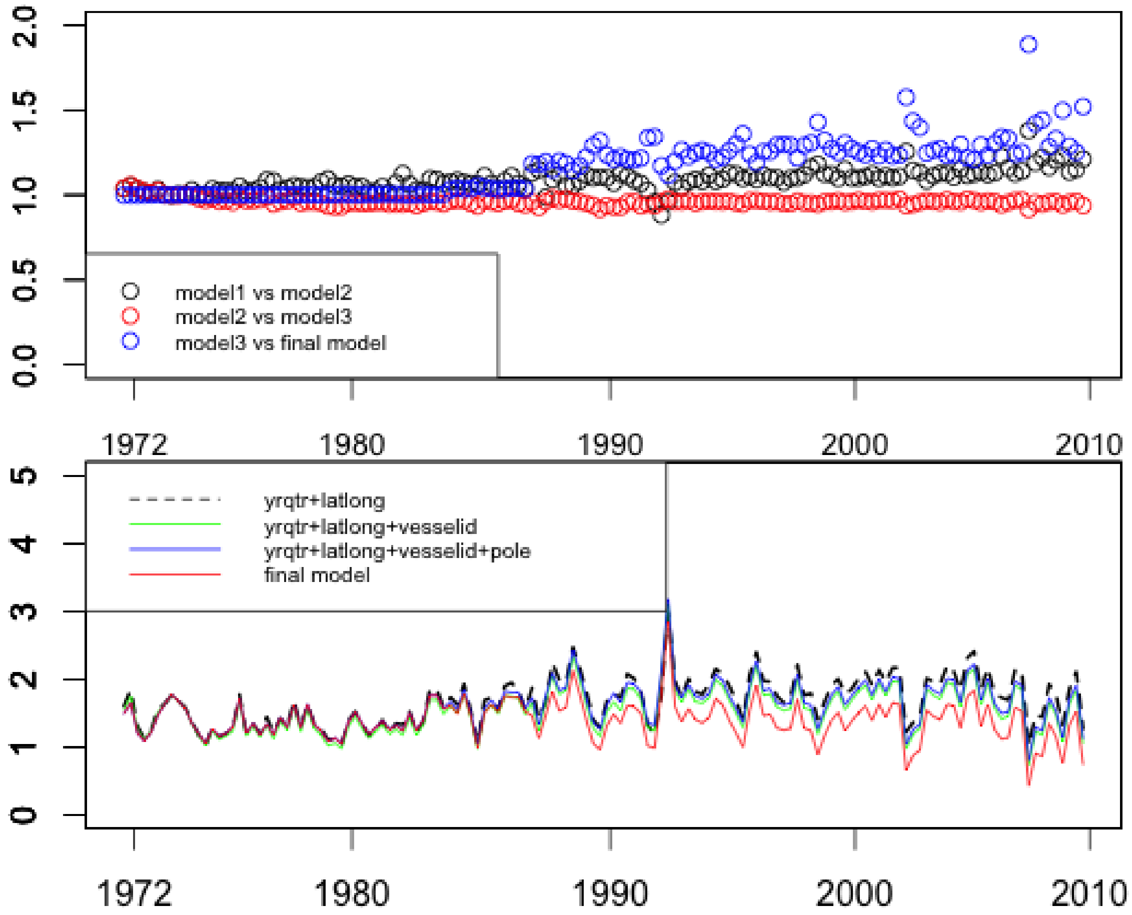

Figure 13. Ratio of coefficients (above) and indices of lognormal positive model in region2. (model1: yrqtr+latlong, model2:adding vesselid to model1, model3: adding pole to model2).

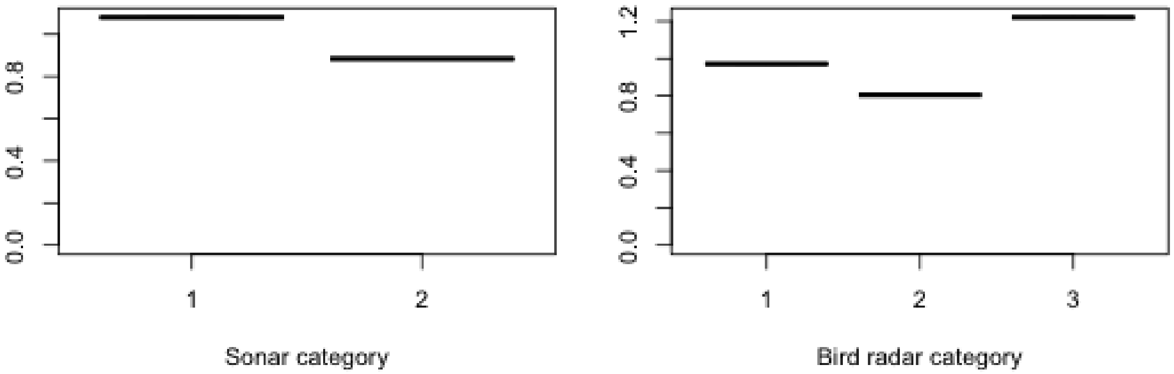

Figure 14. The relationship between the other model variables and the probability of catching skipjack (binomial model) for MFCL region 2. Other model variables of the final model were sonar and birdradar.

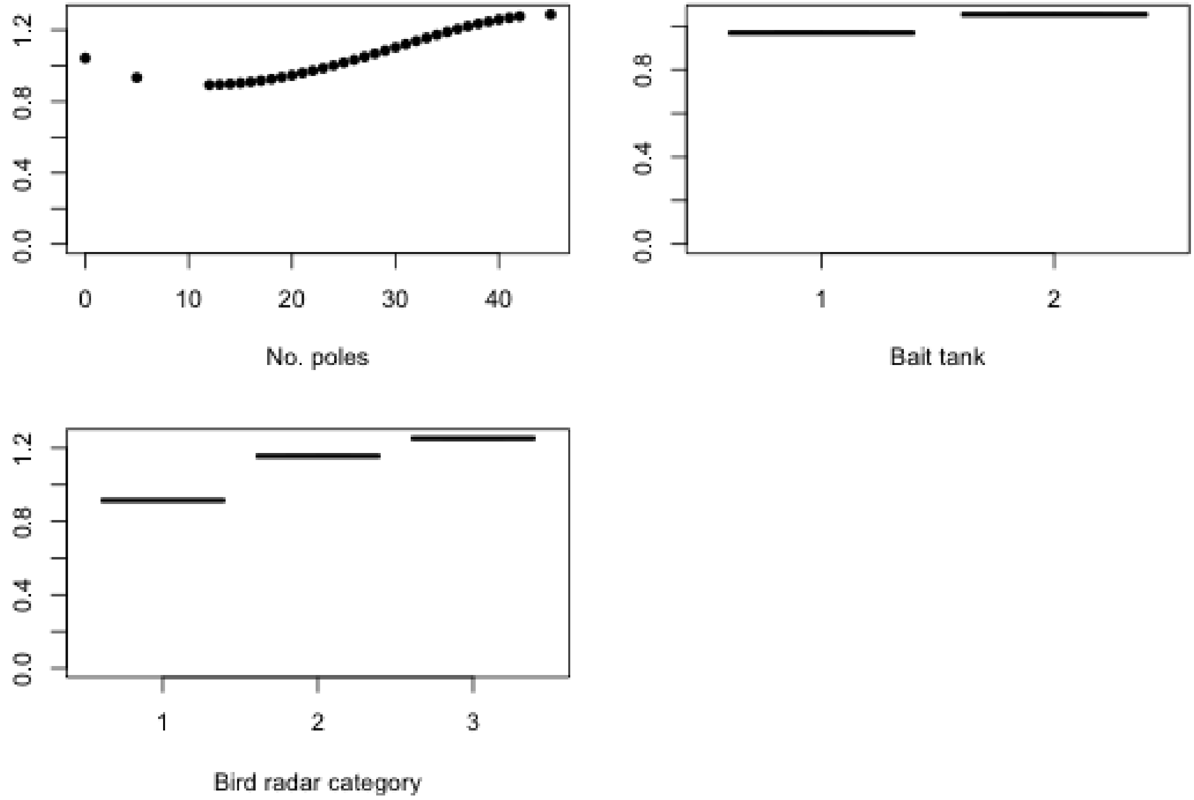

Figure 15. The relationship between the other model variables and the probability of catching skipjack (lognormal positive model) for MFCL region 2. Other model variables of the final lognormal positive model were bittank and birdradar.

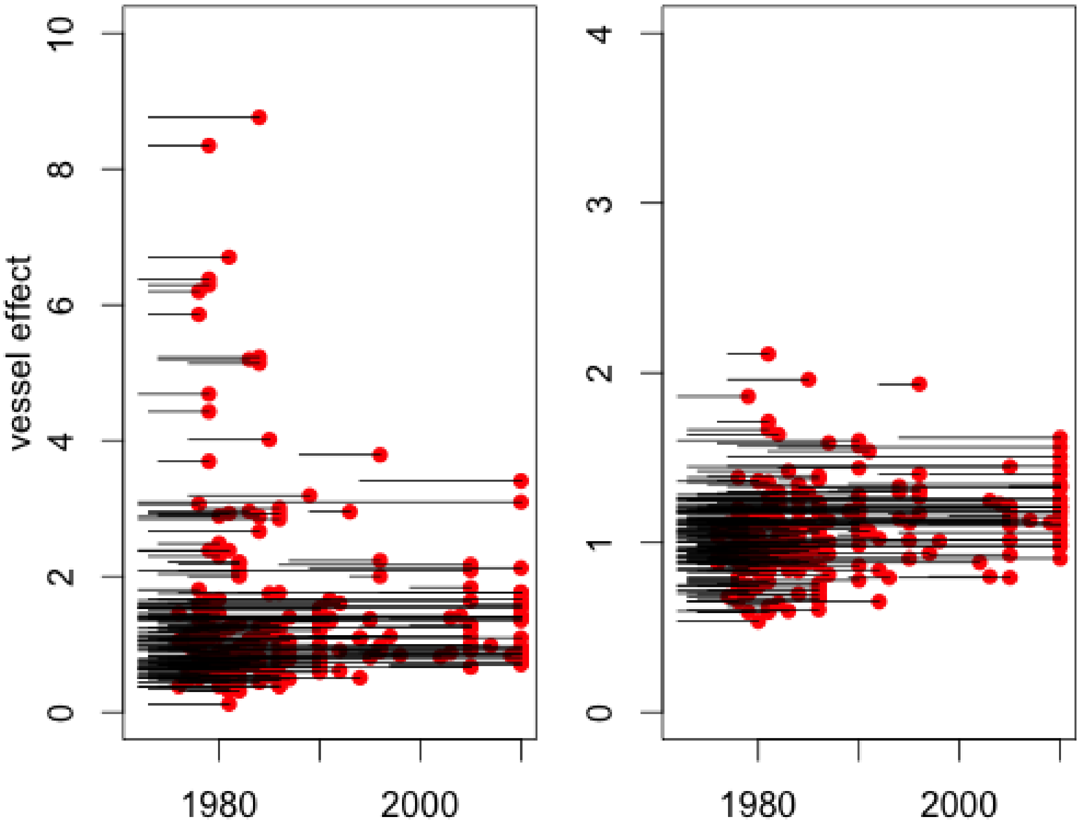

Figure 16. Individual vessel effects on the probability of catching skipjack (left: binomial model, right: lognormal positive catch) for region 2 (JP DW). Red points were plotted against the last year that the vessel was active in the fishery and the horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1972 onwards with the exception of the aggregate vessel category.

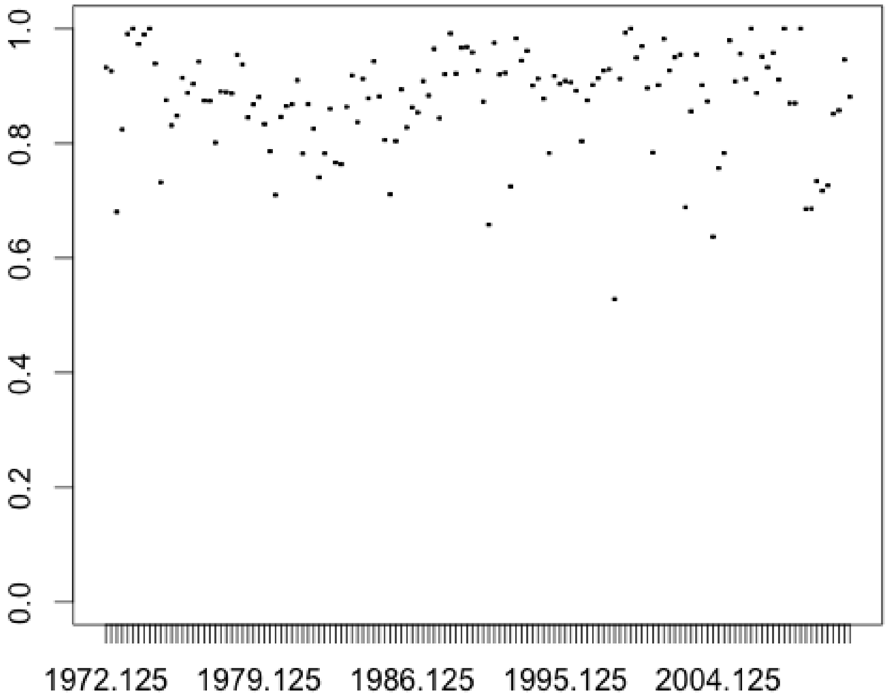

Figure 17. The year/quarter indices derived from the binomial model (final) for MFCL region 3.

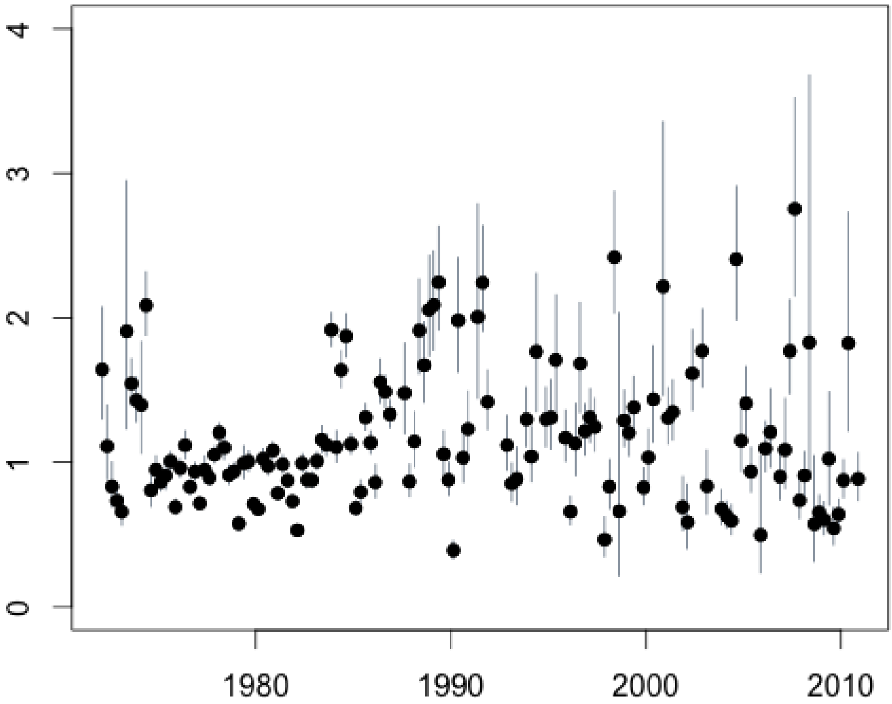

Figure 18. Time series of index derived by the lognormal non zero model for the distant water Japanese pole and line fisheries in region 3 (final model in Table 2-2).

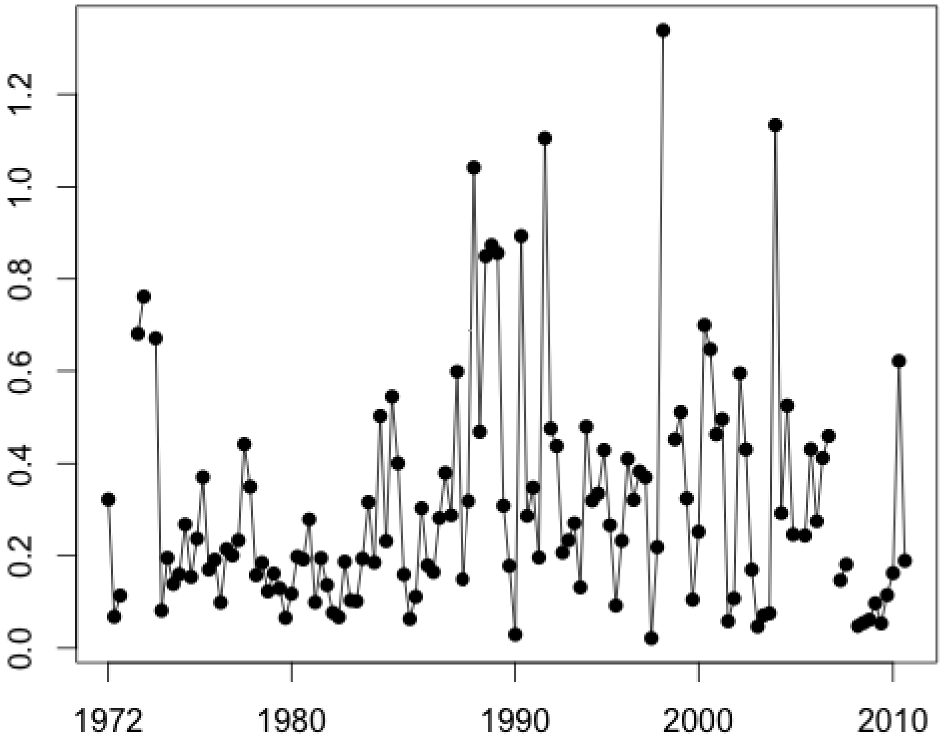

Figure 19. Catch rate time series by the different methods (lognormal non zero (above) and delta-lognormal (bottom)) for the distant water Japanese pole and line fisheries in region3.

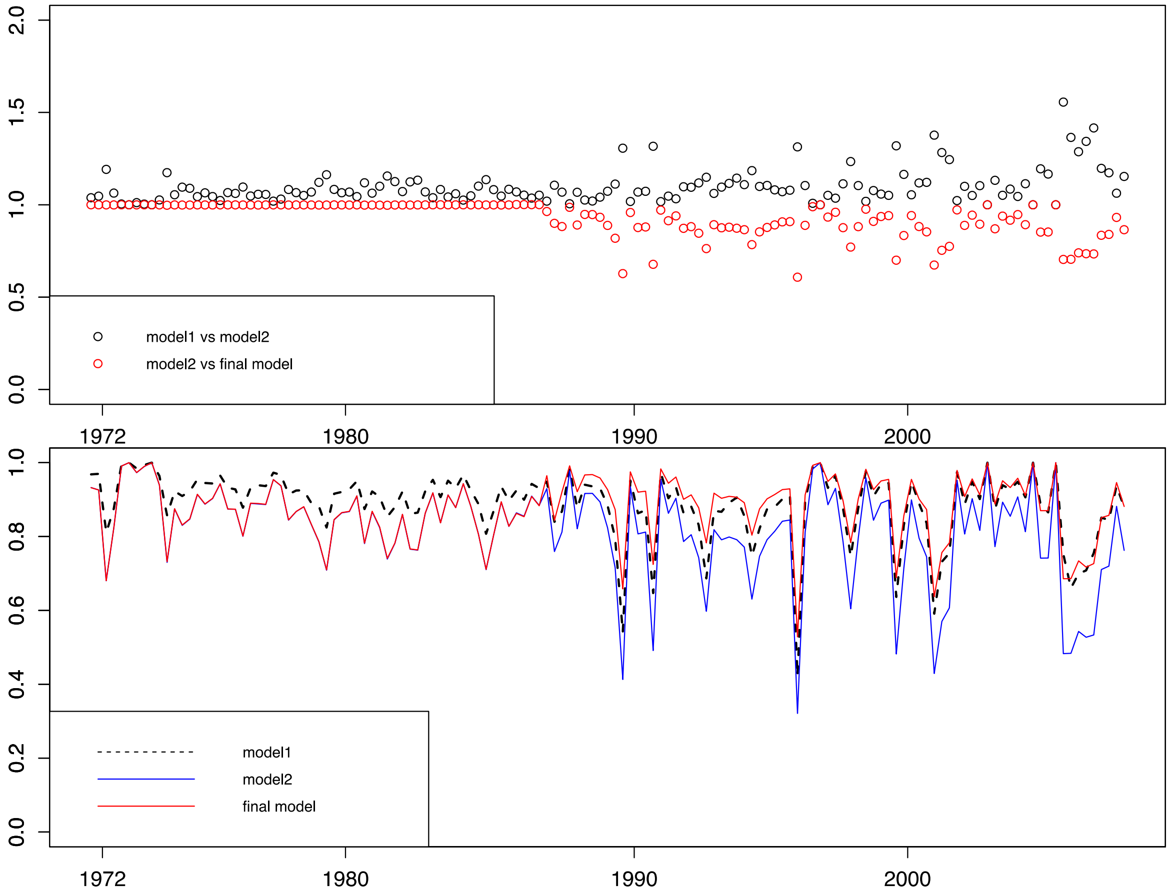

Figure 20. Ratio of coefficients (above) and zero-catch rate of the binomial model in region 3 (model1: yrqtr+latlong, model2: yrqtr+latlong+vesselid, model3: final model).

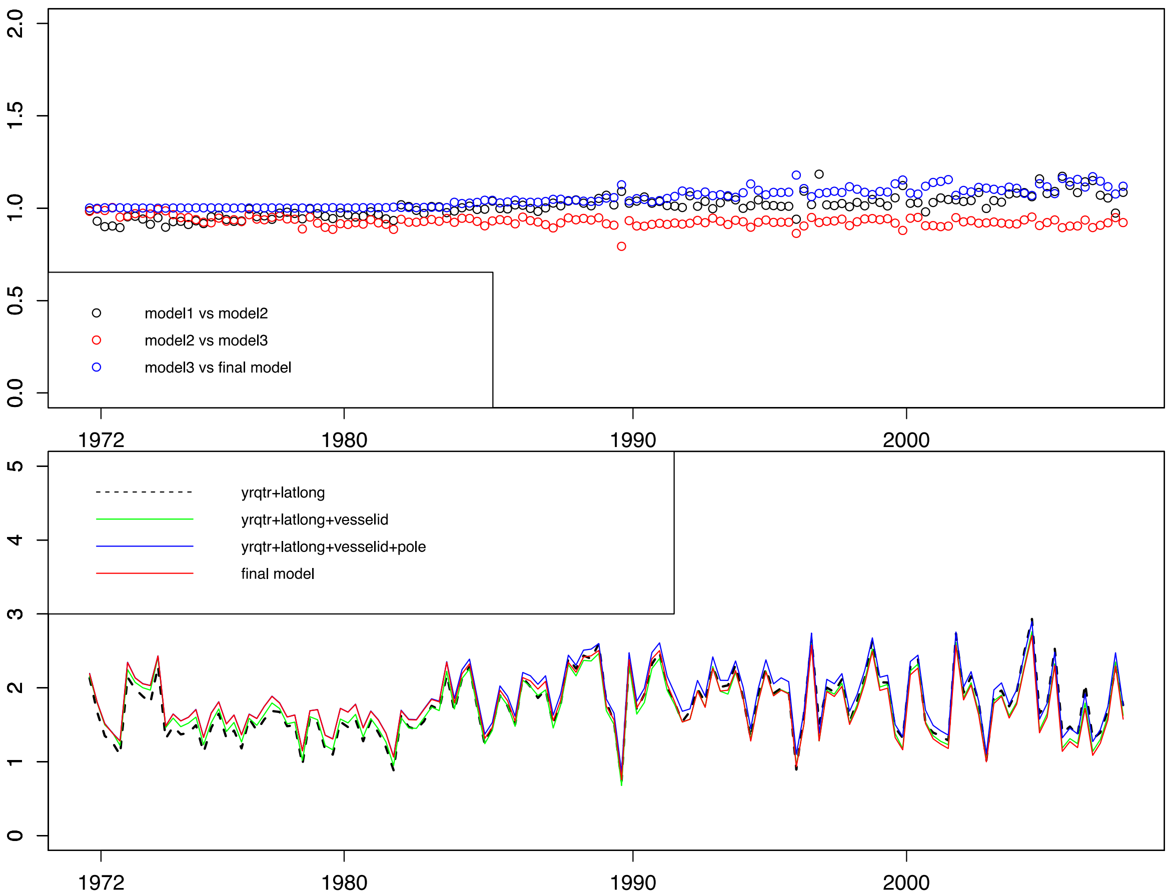

Figure 21. Ratio of coefficients (above) and indices of lognormal positive model in region3. (model1: yrqtr+latlong, model2:adding vesselid to model1, model3: adding pole to model2).

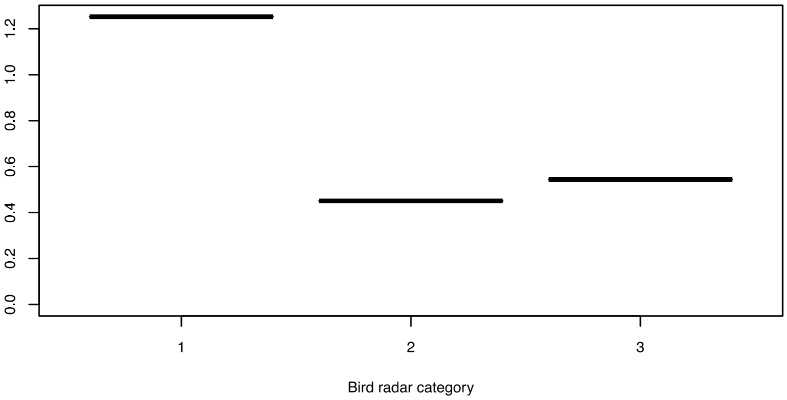

Figure 22. The relationship between the birdradar category and the probability of catching skipjack (binomial model) for MFCL region 3.

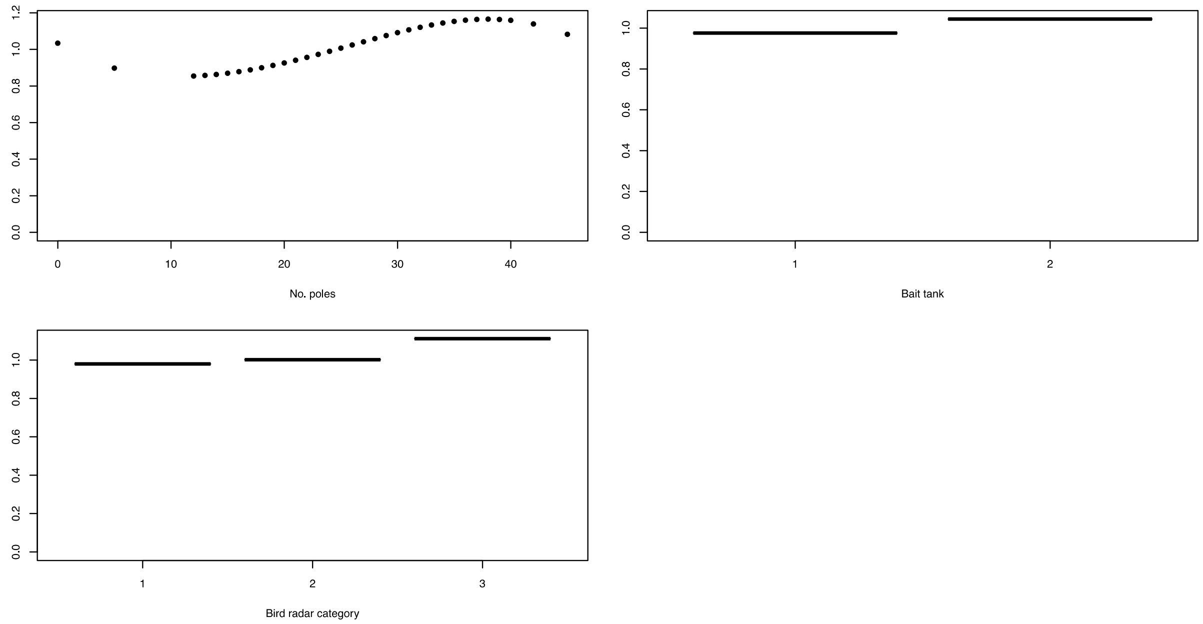

Figure 23. The relationship between the other model variables and the probability of catching skipjack (lognormal positive) for MFCL region 3.

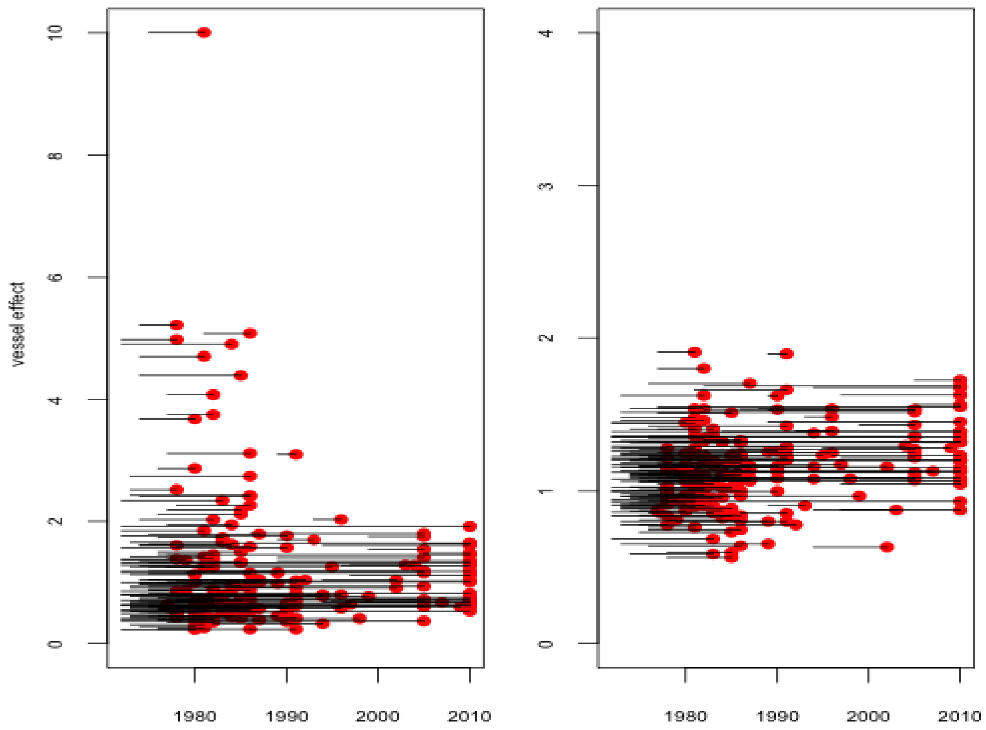

Figure 24. Individual vessel effects on the probability of catching skipjack (left: binomial model, right: lognormal positive catch) for region 3 (JP DW). Red points were plotted against the last year that the vessel was active in the fishery and the horizontal line represents the range of years that the individual vessel participated in the fishery. All vessel variables commence from 1972 onwards with the exception of the aggregate vessel category.