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Abundance of skipjack migrating to the Pacific coastal water of Japan indicated by the Japanese coastal troll and pole-and-line CPUE

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Abstract

Objective of this document is to investigate stock status of skipjack in the Pacific coastal water of Japan separately from the skipjack stock assessment at the WCPFC-SC. Skipjack catch per unit effort (CPUE) of coastal pole-and-lines fisheries around Kochi (KO) from 2003 to 2012 was standardized using GLM, and compared with those derived from coastal troll fisheries around south part of Wakayama (WK) and Hachijo-Islands of Tokyo (TKH). CPUE by the pole-and-line fisheries around KO decreased after 2005, remained at low level until 2009 and then slightly increased. This declining was similar trend that observed in WK troll fisheries. Abundance indices of TKH also shows declining trend and level between 2006 and 2013 were half of its level between 1996 and 2005. These results suggest that migration of skipjack stock to coastal area around Japan has been diminished since around 2006 possibly due to range contraction of this species in the WCPO. Although available data for estimating standardized CPUE in this study was until 2012 in KO and WK, recent catch in 2014 in these areas were extremely lower than recent 5 years average (16%) and recorded the historical lowest, indicating that coastal skipjack abundance remain low in recent year.

Introduction

To examine abundance trends of skipjack in Japanese coastal area, several analyses for the Japanese coastal troll fisheries in Wakayama (Kiyofuji et al., 2011) and in Tokyo (Kiyofuji et al., 2013) were conducted and reported in the previous WCPFC-SC. Okamoto et al. (2014) analyzed historical trend of skipjack CPUE in Tokyo and concluded that the recent (2006-2013) abundance of skipjack migrating to around Tokyo Hachijo-Island would be reduced to nearly half of that in the past years (1996-2005). In this document, data from small pole-and-line fisheries around Kochi where is located at the west of Wakayama was included to examine abundance trend of skipjack migrating to the Pacific coastal water of Japan. These analyses cover the entire range of the Pacific coastal fisheries for skipjack of Japan and develop an understanding of the whole picture of the coastal skipjack trend in Japan.

Skipjack in the Western Central Pacific Ocean (WCPO) was caught mainly by the pole-and-line until 1980's. Purse seine has been recruiting since 1980's and skipjack catch has been also increasing; yet stock status of skipjack is green area of Kobe plots (Hoyle, 2011). However, high catches in the equatorial region could result in range contractions of the stock (Anonymous, 2011). Species range and abundance relations are one of important issue for considering stock status in fisheries management. This topic likely has been discussed in territorial ecological research field (e.g. Brown et al., 1996) and on local or coastal scale (e.g. Jonson, 1998). Recent research article reported range contraction of large pelagic predators using historical longline CPUE (Worm and Tittensor, 2011). Their results shows skipjack in the Pacific may have increased its abundance and its range size, however it is consumed with suspicion that longline CPUE for skipjack is not representative because its fisheries is not main fisheries.

We address the following objectives. First, we describe about data and method for derivation of standardized CPUE for skipjack caught by the coastal pole-and-line fisheries in Kochi. All indices in the Pacific coastal water of Japan were combined and describe their trends. The second objective is to evaluate and hypothesize relationships between skipjack abundance and range size in the WCPO.

Data and Method

Coastal pole-and-line fisheries data in Kochi

Coastal Japanese pole-and-line operates in coastal areas categorized as small pole-and-line fisheries that basically correspond to vessel size less than 20 GRT. They operate mainly in the western coastal area (**Figure 1**). The size of vessel collected in this study is nearly equal to 19GRT. Those data were collected from 2003 and 2012. Data contains year, month, time, position (latitude and longitude), catch, recorded sea surface temperature (SST) and species of main catch. **Table 1** shows summary of total number of unique vessel, total number of records and skipjack record as main target species. We used those data for analysis.

Sea Surface Temperature

Monthly one degree grid NOAA Optimum Interpolation (OI) Sea Surface Temperature (SST) Version 2 (V2) from January 1982 to December 2012 were employed to investigate potential effect of environmental variables on catchability of coastal pole-and-line fisheries. NOAA_OI_SST_V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/. Averaged SST in each area was calculated.

Estimation of standardized Catch per unit effort (CPUE)

Since data contains zero catch, 10% of averaged CPUE were added. Explanatory variables were year, month, vessel ID and other species (small yellowfin, begeye and others). All variables except SST are considered as categorical and Akaike Information Criteria (AIC) were applied for model selection procedures. To keep seasonal consistency, data between February and June as spring fishing season were applied and data from only Area 1 were used because Area 1 is also important for the KO troll but there are no available data for those fisheries. Following equation was used for estimating of standardized CPUE of skipjack.

$$log(CPUE + const.) = \mu + year + month + vessel\ ID + other + SST + \varepsilon$$

where μ is overall mean, const. is 10% of overall mean of nominal CPUE and ε is error term with $N(0,\sigma^2)$. All explanatory variables were included as class variables and presence and absence of other species were included as 1 and 0 in the model, respectively.

Results and Discussion

Catch and Nominal CPUE trends

Figure 2 shows total skipjack catch (a) and effort (b) in 0.25 x 0.25 grid cells combining data from 2003 to 2012. Areas of high catch and effort were identified in south of Kochi (Area 1), south of Kyushu (Area 2). While skipjack catch shows two seasonal mode; one is in spring (April – June) and another is fall (October and November) in area 1,they operate through February to November in area 2. Small amount of catch and effort were seen in area 3 and they operate only in summer time (**Figure 3**). **Figure 4** shows annual trend of catch, effort and nominal CPUE from 2003 to 2012. It is interesting to note that catch and effort has decreased since 2005 and keep at the lower level.

Standardized CPUE trends

Standardized CPUE (divided by overall mean) by all possible configurations without any interaction terms in both areas are shown in **Figure 5** and AIC and BIC were summarized in **Table 2(a)**. ANOVA diagnostics of the final models were summarized in **Table 2(b)**. Overall standardized CPUEs show slightly different trends with the nominal CPUE. High CPUE was identified in 2004, decreased in 2005 and kept at lower level until 2009 when was the lowest All skipjack indices in the Pacific coastal water of Japan were combined and shown in **Figure 6** with nominal CPUE (see Figure 6 caption). Fig.6 (a) represent reported nominal CPUE (total landing/total number of vessels) by each prefecture. All nominal CPUEs have been declining gradually since 1990. Estimates abundance indices shows similar trend with reported nominal CPUE (**Fig 6b**.). Indices from TKH shows declining trend and level between 2006 and 2013 were half of its level between 1996 and 2005 (Okamoto et al., 2014). Trend around KO also decreased after 2005, remained at low level until 2009 and then slightly increased. Since longer data of Tokyo Hachijo troll were included to the analysis, skipjack indices likely have been decreasing since 2000 and recent skipjack abundance (2006-2013) is nearly half of that in the previous years. Although there were still not enough data for the coastal troll and pole-and-line, derived skipjack indices show similar trend. Collection of longer historical data still remains to show recent abundance trends migrating to coastal regions more clearly.

Possibility of skipjack range contraction in the WCPO

Figure 7 is conceptual representation of range contraction for skipjack in the WCPO (modified from Swain and Sinclair, 1994). It is commonly well known that abundance is positively related to range (Gaston and Blackburn, 2000). Assuming that center of skipjack distribution is in equatorial area, population is high in center and it decreases gradually towards the edge that is high latitude. Y-axis and X-axis in **Fig.7** is population density and geographical distribution, respectively. Each different color shows population in different decade due to changes of fishing pressure in the WCPO. **Fig.7 (a)** is simple to understand the case that increasing fishing impact in the center of range may cause population decline with uniformity across the range. It is reported that if species at risk, high-density areas would represent to see significant population decline (Shackell *et al.*, 2005). **Fig.7 (b)** is the case that range contraction occur only marginal areas. Fishing in center of range would have an impact directly to the marginal area. Another situation is that skipjack range is not wide spread to higher latitude but to subtropical area (**Fig.7 (c)**), in which case is based on the results of purse seine fisheries impact to spatial skipjack dynamics by the SEPODYM (Lehodey *et al.*, 2011). Although this case also may have impact on marginal area indirectly, other factors such as oceanographic environment should also have effect at some extent. Increasing fishing mortality in core area in any of three simple cases would have both direct and indirect repercussions on marginal area since remarkable impact on population does not occur especially latter two cases. Hence, observed downward trends of skipjack abundance in the Pacific coastal water of Japan would exhibit some signals of range contraction of this species due to increasing fishing mortality in the core area in spite of that the stock assessment results (Hoyle et al., 2011) did indicate the skipjack stock status in the western and central Pacific Ocean has not been at risk. Further researches for understanding its mechanism of range contraction with environment, movement, growth and maturity should be conducted.

Although available data in this study was until 2012 in KO and WK, recent catch in 2014 in these areas were extremely lower than its recent 5 years average (16%) and recorded historical lowest (**Figure 8**), indicating that coastal skipjack abundance remain lower in recent year.

Followings are summary of this document.

- Skipjack abundance demonstrate downward trend around the Pacific coastal water of Japan.
- Any of the simple conceptual models of range contraction due to increasing fishing mortality in core area may impact on higher latitude.
- Therefor observed downward trend of skipjack abundance in coastal water of Japan suggest that migration of skipjack stock to coastal area around Japan has been diminished possibly due to range contraction of this species in the WCPO.
- It is important to take into consideration of species-range and abundance relation for management of highly migratory species in the WCPO (e.g. SPC-OFP, 2013).

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Table 1. Data summary for small PL.

Year	Number of Vessel	Total Number of Record	Total number of skipjack record as target species
2003	18	10,030	4,356 (43%)
2004	18	9,084	3,774 (42%)
2005	19	8,418	2,894 (34%)
2006	19	8,410	2,473 (29%)
2007	21	9,858	3,207 (33%)
2008	19	9,652	2,863 (30%)
2009	17	9,652	2,840 (29%)
2010	17	9,248	2,769 (30%)
2011	18	8,485	2,493 (29%)
2012	20	8,156	2,519 (31%)
Total	186	90,993	30,188

Table 2. (a) Model configuration and response variables used for standardizing catch per unit effort for the Japanese pole-and-line fisheries in Kochi and **(b)** ANOVA table for the selected model (m7 in (a)).

(a) Model configuration for the coastal pole-and-lines fisheries in Kochi

Model	Variables	n	AIC	BIC
Include 0 catch and add small number				
m1	Year	5476	20480.1	20552.8
m2	Year, Month	5476	20372.7	20471.8
m3	Year, Month, vesselID	5476	20293.2	20531.1
m4	Year, Month, vesselID, other species	5476	20266.3	20510.8
m5	Year, Month, SST (as polynomial function)	5476	20370.3	**20489.3**
m6	Year, Month, vesselID, SST (as polynomial function)	5476	20288.0	20545.7
m7	Year, Month, vesselID, SST (as polynomial function), other species	5476	**20258.9**	20523.3

(b) Result of ANOVA for model 7.

	DF	TYPE III SS	F Value	Pr > F
Year	9	175.7	8.3	< 0.0001
Month	4	141.1	15.0	< 0.0001
vID	21	297.1	6.0	< 0.0001
Other species	1	72.6	30.9	< 0.0001
SST	3	31.3	4.4	< 0.01

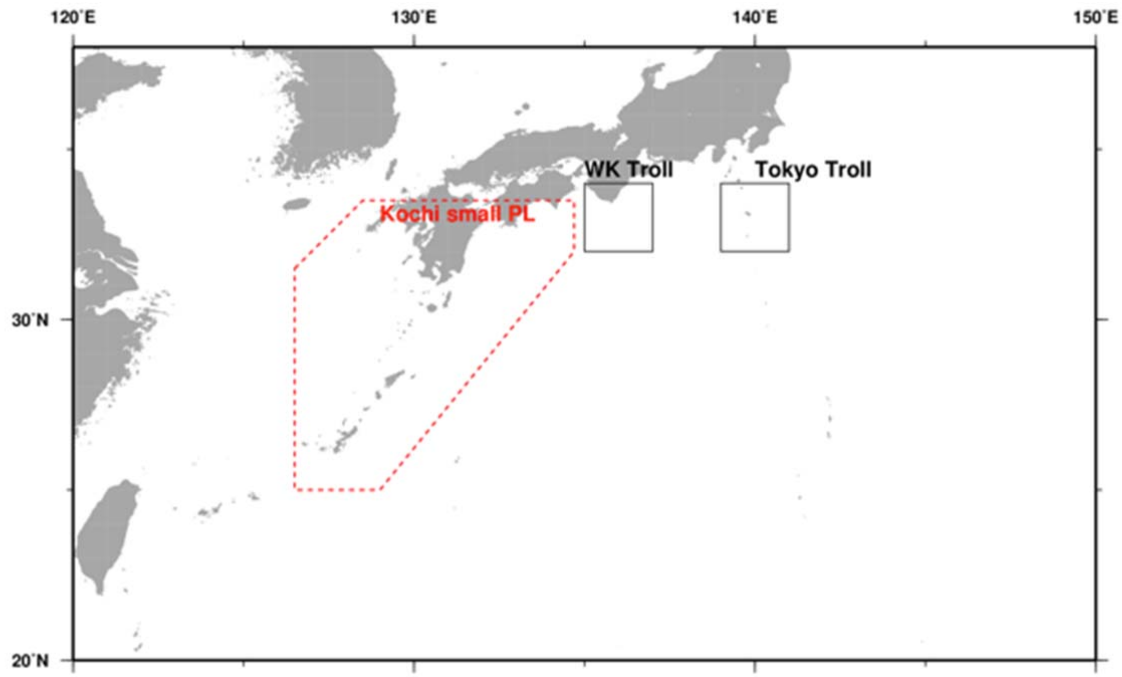
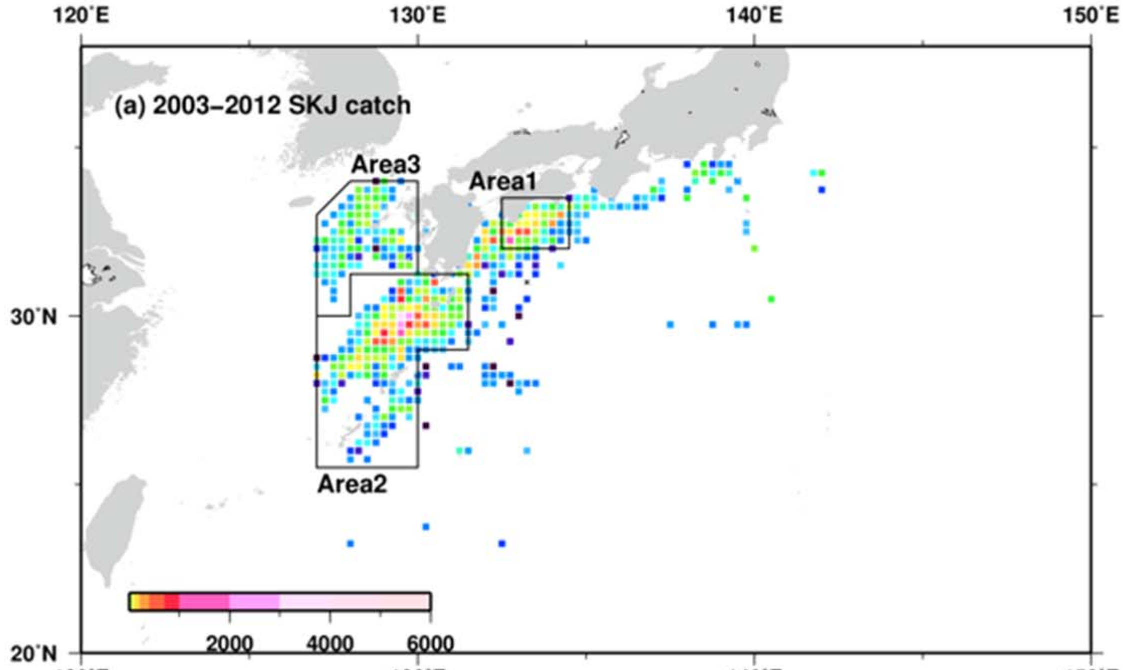


Figure 1. Study area and main fishing area for the Japanese coastal troll and small pole and line.



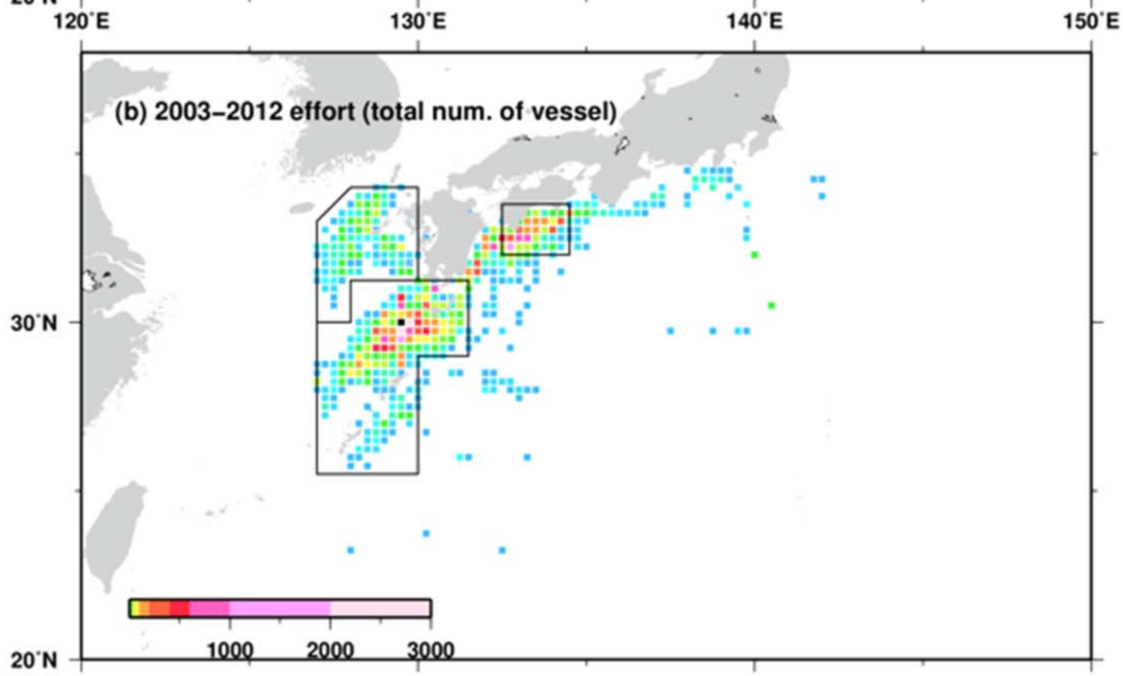


Figure 2. (a) Total skipjack catch and (b) total number of vessel in 0.25 x 0.25 grid between 2003 and 2012.

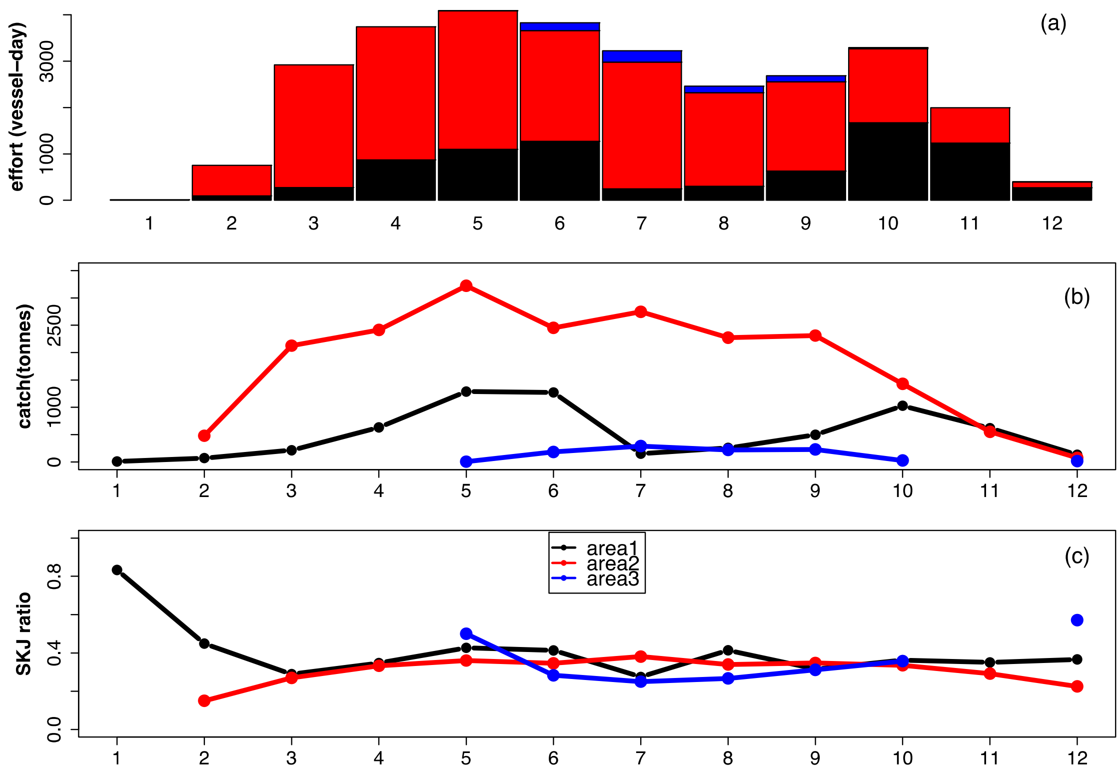


Figure 3. Seasonal changes of (a) effort (vessel-day), (b) total skipjack catch and (c) skipjack catch ratio in each area between 2003 and 2012 (black: area1, red: area2, blue: area3).

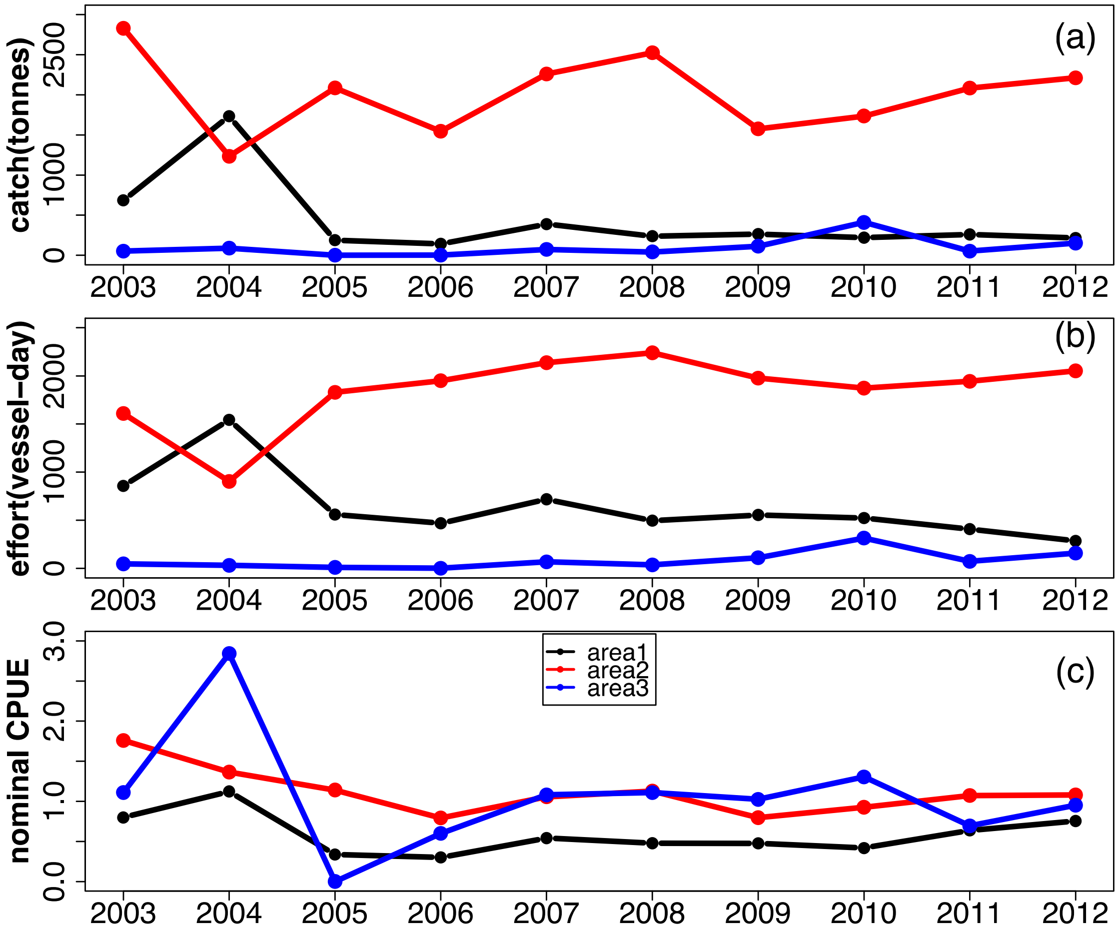


Figure 4. (a) Total skipjack catch (tonnes), (b) total number of vessels and (c) nominal CPUE in each area (black: area1, red: area2, blue: area3) between 2003 and 2012. Note that data are included all months.

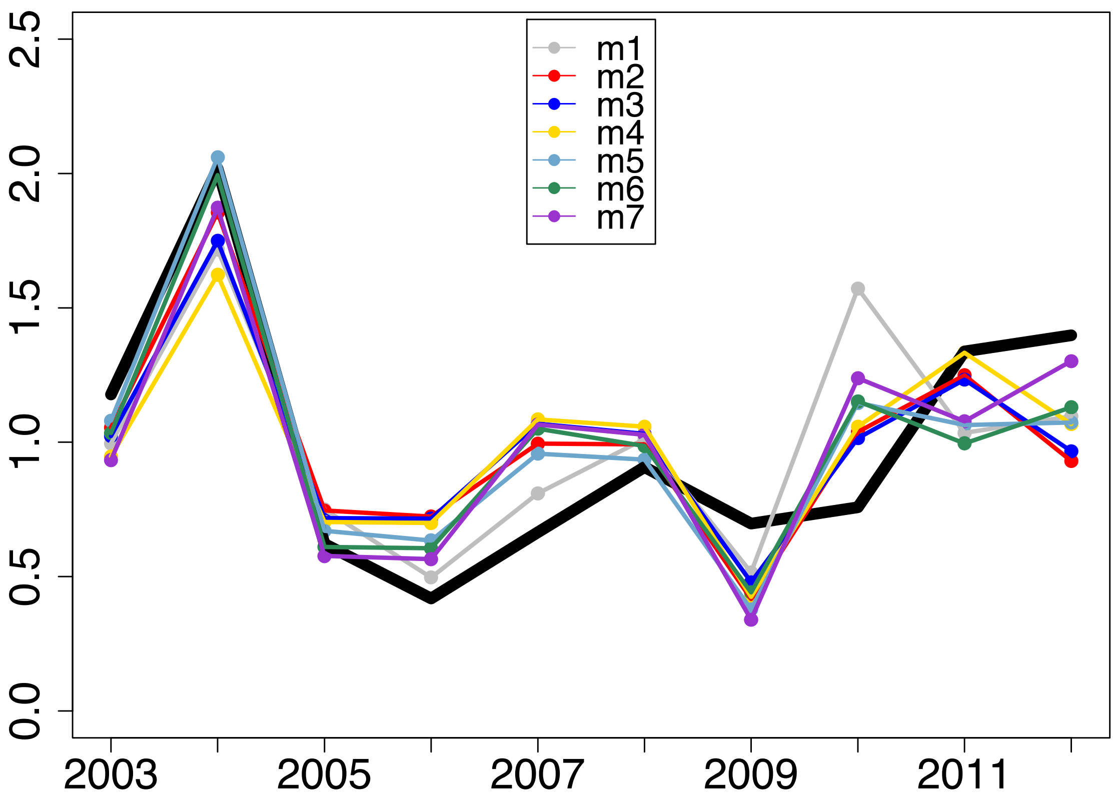


Figure 5. Relative CPUE derived from different model configurations shown in Table 2.

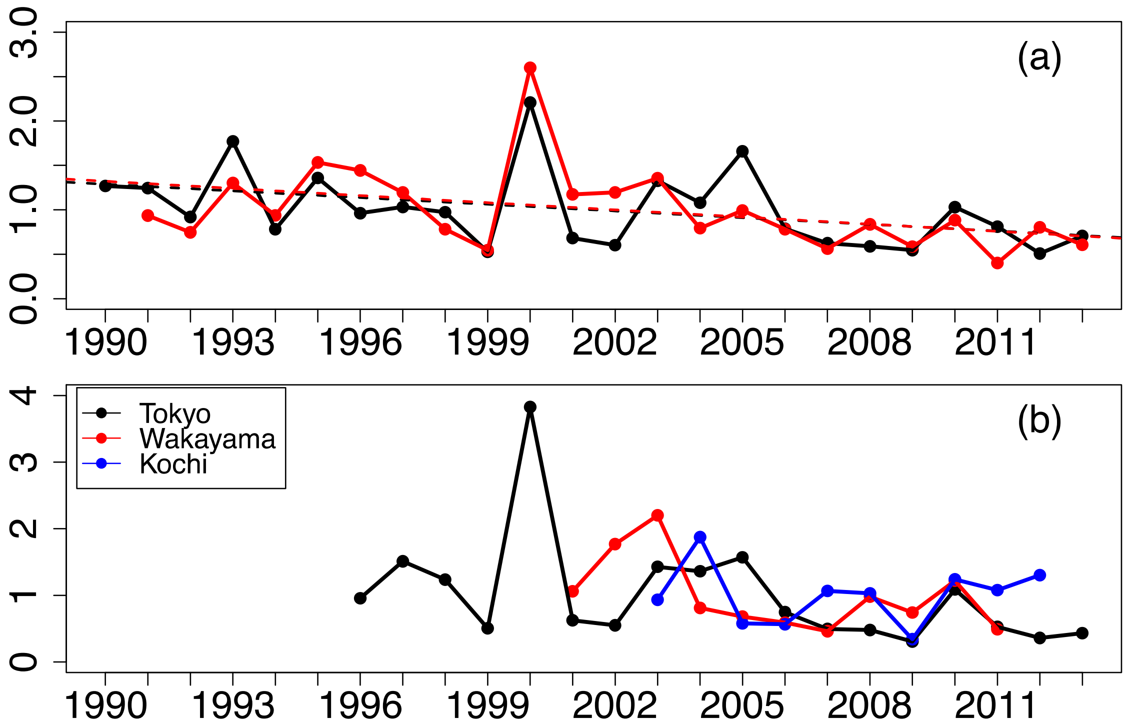


Figure 6. (a) Relative nominal CPUE reported by each prefecture. Temporal trends by year were estimated with a linear regression. Each dashed lines represent regression slopes. (b) Relative CPUE derived from the final model for Tokyo Hachijo troll (black solid line; Okamoto et al., 2014), Wakayama troll (red solid line; Kiyofuji et al., 2013) and Kochi pole-and line (blue solid line; this study).

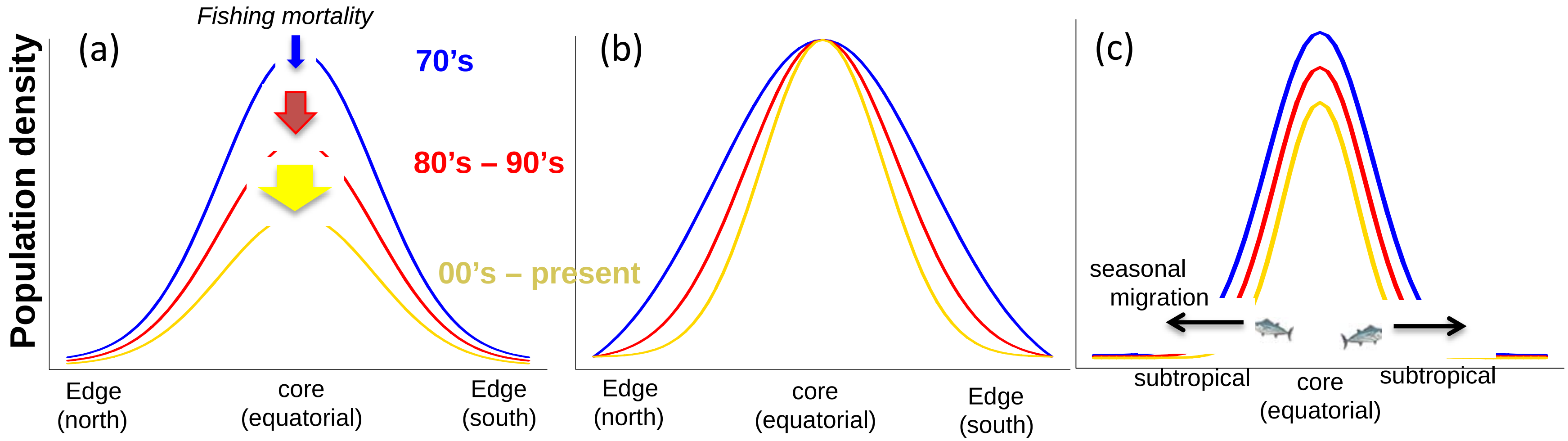


Figure 7. Schematic figures of skipjack range in the Pacific and range changes due to fishing mortality increase (modified from Swain and Sinclair, 1994).

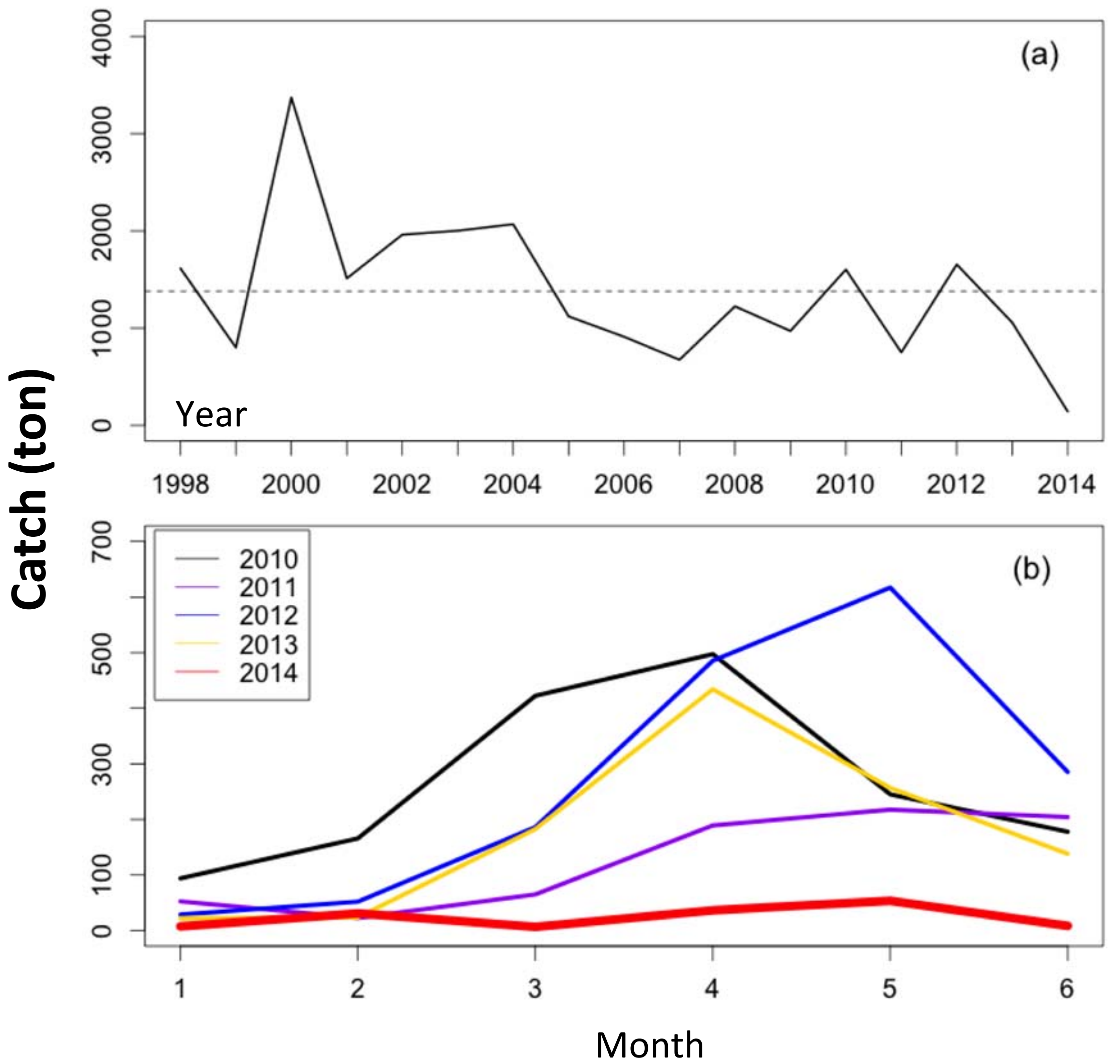


Figure 8. (a) Annual trend of skipjack catch (mt) caught by the coastal troll and pole-and-line in Kochi and coastal troll in Wakayama between January and March from 1998 to 2014. Dashed line represents average catch between 1998 and 2014. (b) Monthly trend of coastal skipjack catch from January to June in recent 5 years (gears are same as (a)).