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Abundance indices of young Pacific bluefin tuna, derived from catch-and-effort data of troll fisheries in various regions of Japan

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1. Introduction

Japanese small-scale troll fisheries have historically fished young Pacific Bluefin tuna (PBF) in the western and southern coastal area of Japan (Yamada et al 2006, Yamada et al 2007). Because most of fish caught by the fishery are 0-age fish (Fukuda et al. 2012), abundance index derived from this fishery is considered to be particularly important to show relative trends of recruitment of this species. Yamada and Oshima (2007) provide 2 series of standardized CPUE of PBF derived from this fishery for potential use of stock assessment. One is derived from catch-and-effort data collected in Nagasaki prefecture (named S10JpnTrollChinaSea in the SS3 configuration conducted in the last stock assessment, Anonymous 2008) and Kochi prefecture (named S11JpnTrollPacific). Considering representativeness of each CPUE series, PBFWG decided to use CPUE from Nagasaki prefecture as sole abundance index representing Japanese troll fishery (Anonymous 2008). Since then, the CPUE in Nagasaki prefecture has been updated once (Abe et al. 2010) for the updated stock assessment conducted in 2010 (Ichinokawa et al. 2010a).

This document presents standardized CPUE derived from catch-and-effort data collected at various regions from the Japanese coastal troll fisheries, for the potential use of forthcoming stock assessment of PBF this May. Not only CPUE from Nagasaki prefecture, but also CPUEs from Kochi and Wakayama prefectures are analyzed and provided in this document. The catch-and-effort data used in this document have been collected and archived by National Research Institute of Far Seas Fisheries with cooperation from local fishery institutes, as a part the Marine Ranching project during 1980's (Secretariat of Forestry and Fisheries Research Council 1989) and Research Project on Japanese bluefin tuna (RJB) since 1994.

Fig. 1 roughly shows fishing grounds of troll fisheries in Nagasaki, Kochi and Wakayama prefectures. Troll fisheries in the three prefectures are different not only in geographical locations, but also characteristics of fisheries and quality of catch-and-effort data (Table 1). Troll fisheries in Nagasaki prefecture mainly target young PBF, originated from two spawning grounds, one each in the Pacific and in the Sea of Japan. On the other hand, troll fisheries in Kochi and Wakayama prefectures target mainly on skipjack and other species, and only occasionally on PBF, originated from spawning ground of Pacific, but not from the Sea of Japan. In addition, because data-recording formats are different among fishery associations and/or local fishery institutes conducting data collection, resolution and quality of the catch-and-effort data are different among the three prefectures.

Therefore, this document analyzed catch-and-effort data from the three prefectures separately with different data-selection processes and statistical methods for estimating standardized CPUE (Table 1). Next section introduces methods and results of standardization of CPUE separately from the three prefectures of Kochi (2-1), Wakayama (2-2) and Nagasaki (2-3). Each subsection has sub-subsection explaining <u>data</u>, <u>standardization of CPUE</u>, <u>model candidates</u> for sensitivity analysis and <u>results and discussion</u>. The sub-subsections of 'model candidates' provide alternative CPUE series calculated with different data sets or methods for standardization to check sensitivity of standardized CPUE to the process of data selection or statistical methods. In the section 3, how to choose these multiple indices of troll fishery for the use in the stock assessment of PBF is discussed by comparing the CPUE series derived from three prefectures. In the final section, general discussions and recommendations are presented.

2. Standardization of CPUE in Japanese troll fisheries

2-1 Kochi prefecture

Data

In Kochi prefecture, catch-and-effort data have been collected at the 6 fishing ports (Fig. 2-1-1, Table 2-1-1). Unit of the effort data is number of ship-landings per day (we call simply ‘landings’ in this document), which include even those without PBF landing. Because Japanese troll fishery is usually conducted by 1-day trip, number of ship-landings per day is approximately equal to number of trips, which can be applied to troll fisheries in Nagasaki and Wakayama prefecture, too. Note that the catch-and-effort data in Kochi prefecture exclude efforts for and catch of PBF for farming.

At Usa port, the data have been collected since 1980, while the data have been collected since late-1980’s or early 1990’s at the other ports (Table 2-1-1). Fishing efforts in 2010 is approximately half of recent year’s average, due to significant decreases of fishing efforts especially at Usa and Kan’no-ura ports. This is because poor catch of skipjack in 2010 caused fishers to refrain from operations especially from Usa and Kan’no-ura ports, which are located far from fishing the recent skipjack fishing area, i.e. Kuroshio-region (Niiya, pers. comm.). In addition, because of good catch of PBF in summer for farming in 2010, most of troll fishers switched their target to PBF for farming in summer, which is not recorded in this data-base (Niiya, pers. comm.).

The previous analysis by Yamada and Oshima (2007) didn’t use the data from Karyogo and Muroto, because of relatively small efforts of troll fisheries at these ports. This document added the data from the two fishing ports, and used all data from the 6 fishing ports. Sensitivity analysis without the 2 fishing ports of Karyogo and Muroto is conducted. This document used the data of all season, while Yamada and Oshima (2007) excluded the data from April to June because of large proportion of zero-catches. In standardizing CPUE, the data with less than 10 landings per each month and port are excluded from the analysis. Distributions of efforts and CPUE by year, month and fishing ports are shown in Fig. 2-1-2.

Standardization of CPUE

The previous analysis used simple generalized liner model (GLM) assuming lognormal error structure. The zero catch data are dealt by adding a small constant (1% of minimum CPUE) to the response variable of CPUE. However, because preliminary analysis with similar data-sets used by Yamada and Oshima (2007) revealed that the magnitude of annual fluctuation of standardized CPUE is sensitive to choice of the small constant value, this study didn’t use simple lognormal model for standardizing CPUE.

Instead of lognormal model, zero-inflated negative binomial (ZINB) model (Hall 2000, Minami et al 2007) is used for standardizing CPUE.

$$\Pr(Y=y)=\begin{cases}\omega+(1-\omega)(1+k\lambda) & \text{for } y=0\\ (1-\omega)\frac{\Gamma(y+1/k)}{\Gamma(y+1)\Gamma(1/k)}\frac{(k\mu)^y}{(1+k\lambda)^{y+1/k}} & \text{for } y=1,2,\ldots\end{cases}$$

As describing the above equation, this model has two components; one is zero with certainty (ω) expressed by binomial model, and another includes zeros and positive values of negative binomial distribution. By separating two components, the model can explain situation that there are more zero observations than expected by negative binomial distribution.

In this analysis, the first component to estimate zero probability with binomial model is modeled only with the effect of season because probability of zero catch is significantly changed by season in Kochi prefecture. Then, the second component using negative binomial is modeled by explanatory variables of year representing annual abundances and other variables selected by model selection with BIC. The response variable of second component is catch in weight with offset term of log(efforts, number of landings). The ZINB model is conducted by GENMOD procedure with zeromodel statement and znib as an assumed distribution in SAS 9.3. The standardized CPUE is calculated from least squares mean of year effect estimated in NB component.

Explanatory variables considered in ZINB model are listed below.

- ✓ Fishing year (fy); 1981-2010. Fishing year is starting from July and ending to June.
- ✓ Season; categorical variables with 5 classes of 1: July, 2: August-October, 3: November-January, 4: February-March and 5: April-June. This is determined by observation of nominal CPUE by month.
- ✓ Fishing ports (ports); 6 ports where catch-and-effort data collected.

Trying all possible combinations of main effects and 2-order interaction terms (Table 2-1-2), ZINB model without interaction term is selected as the best model by BIC. Vuong's test (Vuong 1989) always support ZINB rather than simple NB.

Model candidates

The base CPUE is estimated from data sets including 6 ports since 1980, with ZINB model without interaction terms. In addition to the base model, alternative models of K1-K3 listed below are also calculated.

- ✓ Base case; 6 ports since 1981 with ZINB no interaction terms
- ✓ K1; same data set with base case, but use simple negative binomial (NB)
- ✓ K2; 4 ports (exclude Muroto and Karyogo) since 1980, following Yamada and Oshima (2007)
- ✓ K3; 6 ports since 1993

Results and discussion

Anova table of type III analysis (Table 2-1-3) and residual distributions by year (Fig. 2-1-3) are shown. All explanatory variables are statistically significant in both models of negative binomial and zero-inflated. Fig. 2-1-4 shows zero-probability estimated in zero-inflated model. The zero-probability is expected to be high in April-June, and July. April to June is on season for skipjack, and out of season for PBF. In July, fishers target PBF for farming (not recorded in this data base). The estimated zero-probability could be reasonable to reflect actual situation of troll fisheries in Kochi prefecture.

The standardized CPUE and estimated CV are summarized in Table 2-1-4. The estimated CV is approximately 0.5 during 1981-1987, 0.3 during 1988-1992, and 0.2 after 1993. This tendency reflects the number of fishing ports where the data were collected, which gradually increased from sole port of Usa during 1980-1985 to 6 ports after 1993. Because the estimated CV is especially high in 1980, it is recommended to exclude the point of 1980 when using these data for stock assessment. The estimated CV is smaller than that by Yamada and Oshima (2007), 0.45-2.17 because of addition of data from 2 ports of Karyogo and Muroto in this analysis

The standardized CPUE fluctuates annually by approximately 4-fold (Fig. 2-1-5), while the magnitude of fluctuation is about 5-7-fold in the previous estimation by Yamada and Oshima (2007). This difference would attribute to the difference of the way to deal with zero-catch data. When comparing the standardized CPUE with nominal CPUE, standardized CPUE suggest strong cohort in 2004 although nominal CPUE didn't. Since the last stock assessment estimated that relatively strong cohort occurs in 2004 (Ichinokawa et al. 2010a), the standardized CPUE is considered to be better than nominal CPUE, to reflect relative abundance of 0-age PBF.

Fig. 2-1-6 shows results of sensitivity analysis on model structure (K1) or different data sets used (K2 and K3). Using NB instead of ZINB slightly magnified annual fluctuation. Excluding the data before 1992 reduced annual fluctuation. However, general trends are not different among those candidates, especially in recent years; all CPUEs indicating historical lowest in 2009, and relatively high in 2010.

2-2 Wakayama prefecture

Data

Catch-and-effort data of troll fishery in Wakayama prefecture have been collected at 4 fishing ports since 1994 at Gobou, Tanabe and Susami and 1995 at Kushimoto (Fig. 2-2-1, Table 2-2-1). Similarly to Kochi prefecture, fishing efforts in 2010 has significantly decreased, probably because of poor catch of skipjack in the coastal area in Japan.

Efforts of troll fishery in Wakayama prefecture is especially high during 8th to 11th fishing months (February to May) while CPUE of PBF is high during 4-7 fishing month (October to January) (Fig. 2-2-2). This mismatch of seasons with high CPUE and efforts reflects the fact that troll fishery in Wakayama prefecture target mainly skipjack and other species rather than PBF. Consequently, zero catch probability in the catch-and-effort data in Wakayama prefecture is high, 66% to the total number of data. We exclude the data from June to September because of particularly high proportion of zero-catch (>90%) in that season.

Standardization of CPUE

Because of large number of zero-catch data, we used same statistical model used for Kochi prefecture, ZINB for standardization of CPUE. The model for zero probability includes the effect of fishing month, instead of season used in Kochi prefecture. Explanatory variables incorporated into negative binomial component are listed below.

- ✓ Fishing year (fy); 1994-2010. Fishing year is starting from July and ending to June.
- ✓ Fishing month (fm); aligned to fishing year
- ✓ Fishing ports (ports); 4 ports where catch-and-effort data collected.

The interaction terms of fy*fm and fm*area are selected by BIC (Table 2-2-2). Vuong's test (Vuong 1989) always support ZINB rather than simple NB.

Model candidates

- ✓ Base case; fy*fm+fm*area with ZINB
- ✓ W1; simple NB

Results and discussion

Anova table of type III analysis (Table 2-2-3) and residual distributions by year (Fig. 2-2-3) are shown. All explanatory variables are significant in both models of negative binomial and zero-inflated. Fig. 2-2-4 show estimated zero-probability in the zero-inflated model of the base case. The zero-probability is constantly higher than 50%, except for December and January.

The standardized CPUE fluctuates annually by approximately 2-folds except for 2004, when extraordinary high CPUE, >4, is estimated (Table 2-2-4). Because catch-and-effort data in Wakayama prefecture is recorded daily, CV of the standardized CPUE is from 0.06 to 0.15, which is relatively small comparing with that of Kochi prefecture. The magnitude of annual fluctuations of standardized CPUE is smaller than the nominal CPUE (Fig. 2-2-5), and estimation by simple NB model (Fig. 2-2-6).

2-3 Nagasaki prefecture

Data

In Nagasaki prefecture, catch-and-effort data of troll fisheries have been collected intensively during 1980's at the 29 fishing ports shown in Fig. 2-3-1 as a part of Marine Ranching project (Secretariat of Forestry and Fisheries Research Council 1989). However, available catch-and-effort data are restricted to 5 fishing ports of Izuhara-are, Kamitsushima-honsyo, Kamiagata-honsyo, Ojika and Tomie after 1980's (Table 2-3-1). Total catch recorded in the catch-and-effort data covered more than 60% to the total catch of Japanese troll fisheries during 1982-1988 when the catch-and-effort data were intensively collected. On the other hand, total catch by the main 5 fishing ports contributed approximately 30-40% during 1980's, 20% during 1990's and 10-20% after 2000. Note that catch-and-effort data is missing even at the 5 main fishing ports in some years (ex. 1993-1996 in Kamitsushima, 2008 in Izuhara-are), because of various reasons, such as elimination and consolidation of fishery associations, transfer of scientists involved in data collection in the local fishery institute and errors associated with computerization of fishery data in fishery associations.

In the catch-and-effort data in Nagasaki prefecture, there are no records of efforts when PBF catch has not occurred. Consequently, the data are very sparse during the off-season of PBF (Fig. 2-3-2). This analysis selected the period of fishing season of PBF in each fishing port for standardization. The periods selected are different among fishing ports; from October to January for Are and Kami-agata, from October to December for Kami-tsushima and fishing ports other than 5 main ports, from November to February for Ojika, and from November to May for Tomie.

Because of the extremely unbalanced design of data sampling among fishing ports and decades, Yamada and Oshima (2007) didn't use the data from Kami-tsushima (the data of Kami-tsushima after 1993 were missing when previous study was conducted, but the data for several years have been recovered recently), and fishing ports other than 5 main ports. This study also doesn't use the data from 'other' fishing ports, too, as the base case, but try sensitivity using the data from all fishing ports.

The catch-and-effort data in Nagasaki prefecture include the information of catch in weight by size category. For example, size category of S, M and L is corresponding to 1-2 kg, 2-3 kg and 3-4 kg in Kamiagata port (Oshima et al. 2008). CPUE previously estimated by Yamada and Oshima (2007) and Abe et al (2010) used catch of PBF in the size category with <4 kg as an upper limit, supposing to extract abundance index of 0-age fish. However, because current configuration of SS can apply CPUE not only to age but also to fishery, creating age-specific CPUE is not necessarily required. Therefore, this document creates CPUE series to represent whole catch by troll fishery, without data selection on size category, as the base case CPUE. As sensitivity analysis, CPUE series only for fish less than 4 kg is also estimated. However, the CPUE less than 4 kg would include more uncertainty on data, because 1) catch-and-effort data by size category is not available in Tomie ports since 2005 because of change of data accumulation system in the port, 2) some size categories cross the boundary of 4 kg, such as 3-5 kg, and 3) definition of size category is unclear in some ports and years because the definition is different among ports and sometimes between years.

Standardization of CPUE

Because there are no zero-catch data, simple GLM assuming lognormal error structure is used for standardizing CPUE. Explanatory variables are fy (fishing year), ports (fishing ports), fm (fishing month) and interaction terms. All combinations of interaction terms are tried to calculate BIC (Table 2-2-2), which suggests that the best, second and third best models are ‘fy*fm+port*fm’, ‘fy*fm+port’ and ‘fy+fm*port’, respectively. Because of missing data at some strata of fy*fm (Fig. 2-3-2), it is impossible to calculate least squares mean by year with the model including the effect of fy*fm. Therefore, the third best model of ‘fy+fm*port’ is used for the base case for standardization. The standardized CPUE is calculated from least squares mean of the ‘fy’ effect. The GLM was conducted by GLM procedure of SAS 9.2.

Model candidates

As describing ‘data’ sub-section, the following alternative CPUEs with different data set from the base case are estimated.

- ✓ Base case; 5 main fishing ports, using all size categories
- ✓ N1; data from ‘other’ fishing ports are also used in addition to the data of 5 main fishing ports
- ✓ N2; catch weight in the size category with <4 kg of upper limit. In this data set, data from Tomie fishing port are missing after 2005.

Nominal CPUE calculated from the data set for N1 and N2 is shown in Fig. 2-3-3. Although incorporation of the data from ‘other’ fishing ports increased total number of data approximately from 9 thousands to 14 thousands, the nominal CPUE hasn’t changed so much from the nominal CPUE of base case. Excluding >4 kg catch made the nominal CPUE fluctuated more than the base case.

Results and discussion

Anova table of type III analysis (Table 2-3-3) and residual distributions by year (Fig. 2-3-4) are shown. R-squared value is not so large, 0.21, but residual distribution seems not to be generally well.

The standardized CPUE and estimated CV are summarized in Table 2-3-4. The CV of standardized CPUE ranges between 0.04-0.09, which is much smaller than that by Abe et al (2007), 0.27-0.40. This is because this analysis used original daily data instead of monthly aggregated ones which is used by previous studies.

The standardized CPUE fluctuates annually by approximately 2-fold, at most (Fig. 2-3-5). The standardized CPUE is estimated to be higher than the nominal CPUE before 1994, while the tendency has reversed after 1994: the standardized CPUE is lower than the nominal. This is probably because fishing efforts in recent years after 1994 tend to be concentrated when CPUE of PBF is high. Consequently, although the nominal CPUE seem to increase by year (0.58 of coefficient of correlation to year), the tendency become not clear in the standardized CPUE (0.36 of coefficient of correlation to year). The estimation of previous analysis shows greater fluctuation of CPUE than the base case, as observed in nominal CPUE in Fig. 2-3-3.

Sensitivity analysis on data-selection shows that incorporation of data from all ports has minor effects on standardized CPUE even during 1980's (Fig. 2-3-6), as observed when comparing with nominal CPUEs (Fig. 2-3-3). This fact might suggest that quantity of the catch-and-effort data from the 5 main fishing ports is enough to represent CPUE of troll fishery in Nagasaki prefecture.

3. Application to Pacific bluefin tuna assessment -

Fig. 3-1 compared 3 CPUEs estimated from Nagasaki, Kochi and Wakayama prefectures. Annual fluctuation of CPUE of Nagasaki prefecture (CV=0.35) is smaller than that of Kochi (CV=0.91) and Wakayama (CV=0.98). Focusing trends of recent 3 years, all 3 indices show drop of CPUE from 2008 to 2009, and then increase or stabilization from 2009 to 2010. However, the magnitudes of the drop and increase in CPUE are different among 3 indices. Indices from Pacific side (Kochi and Wakayama) show historically lowest value in 2009, while CPUE from Nagasaki prefecture in 2009 decreased from 2008 only slightly staying around the historical average (1.09). In addition, the CPUE level in 2010 is controversial among 3 indices; median (1.07), twice (1.97) and half (0.4) of historical average in Nagasaki, Kochi and Wakayama prefectures, respectively.

Then, which index is appropriate for the use in the next stock assessment? In this section, we discuss the issue from a stand point of (1) representativeness of Japanese troll fishery, and (2) fits to the current assessment model.

Catch in weight recorded in the catch-and-effort data from Nagasaki correspond to 25%, in average, to the total catch by Japanese troll fishery, although the proportion become lower than 20% after 2000 (Table 2-3-1). On the other hand, catch in weight recorded in catch-and-effort data in Kochi prefecture correspond to only 2.7% of Japanese total troll catch (Table 2-1-1), in Wakayama prefecture only to 1.5% (Table 2-2-1). This large gap of catch weight recorded in catch-and-effort data among prefectures reflect actual catch composition among prefectures: Nagasaki prefecture is the most dominant in PBF catch by troll fisheries, taking 66% of the total Japanese catch (Fukuda and Oshima, 2012). Considering the largest amount of catch-and-effort data in Nagasaki prefecture, to use CPUE from Nagasaki prefecture as representative of the troll fishery could be a reasonable solution.

Another solution could be to create combined CPUE by averaging three series weighted by the catch in the catch-and-effort data. Table 3-1 and Fig. 3-2 show the combined CPUE created by CPUE weighted by average catch (in weight) in the catch-and-effort data, 517, 62 and 21 MT in Nagasaki, Kochi and Wakayama prefectures, respectively. In addition, to create time series since 1980's, combined CPUE only from Nagasaki and Kochi prefectures is also calculated. Because of large contribution of catch in Nagasaki prefecture, the combined CPUEs are not so much different from original CPUE of Nagasaki prefecture alone.

However, estimation in 2004 when the highest CPUE is observed only in the Pacific side became higher in the combined series than the original Nagasaki CPUE. The combined CPUE is more consistent with the estimation by SS3 in the last stock assessment.

In order to check fits to the current assessment model of each CPUE series, root mean squared error (RMSE) between the standardized CPUE shown in this document and expected troll CPUE estimated in the most recent stock assessment (Ichinokawa et al 2010a) is calculated (Table 3-1). The RMSE can be an indicator to see how much each index is consistent with population dynamics estimated in the stock assessment model, originate from information of other data sources and fisheries. Smaller RMSE indicates better fits.

The RMSE calculated with CPUE from Nagasaki prefecture shows the smallest value of 0.27 among CPUEs from 3 prefectures, and combined CPUE of 2 prefectures of Nagasaki and Kochi is the smallest (0.25) among all CPUE (Table 3-1). The performance of these CPUE is better than the previous Nagasaki CPUE (Abe et al. 2010) with 0.51 of RMSE, even though the expected CPUE is made to fit the previous Nagasaki CPUE in SS3. Scatter plot between the CPUE and expected CPUE in troll fisheries (Fig. 3-2) visually show the high predictability of the two CPUE. The outlier is for 2007, when expected CPUE is much smaller than the Nagasaki or combined CPUE, which can be explained by negative retrospective bias of the terminal year in 2007 (Ichinokawa et al. 2010a). It is also noteworthy that RMSE from Kochi prefecture (0.66) become smaller than that in previous estimation by Yamada and Oshima (1.31). Those observations indicate that standardized CPUE estimated in this document have improved more or less than the previous estimations with respect to fits to the current stock assessment model.

4. General discussion and recommendation

This document shows candidates of CPUE derived from 3 regions where Japanese troll fishery is operating for the use in the next stock assessment of PBF. CPUE from Nagasaki prefecture, or weighted average of CPUEs from Nagasaki and Kochi prefectures could be prior to the other indices solely from Kochi or Wakayama with respect to representativeness and consistency with population dynamics currently estimated by SS3. The better performance of Nagasaki CPUE than Kochi and Wakayama would be attributed not only to dominant share of Nagasaki in PBF catch by troll fisheries, but also to geographical location of fishing ground in Nagasaki prefecture, where recruitments from the two spawning grounds of the Pacific and the Sea of Japan can be fished by the troll fishery. Using sole CPUE from Nagasaki prefecture has an advantage to make the data to be used in the stock assessment simple. On the other hand, using combined CPUE could incorporate information from the Pacific side, even though the contribution is 1/10 of that by Nagasaki. In either case, the index from troll fishery would be useful to give reasonable information especially on recent recruitments at the forthcoming stock assessment of PBF.

There are still many issues on collection of data and standardization of CPUE, to be solved in future. Collection of catch-and-effort data from troll fishery is always challenging and difficult, because troll fisheries are really small-scale fishery conducted in remote islands. In addition, many missing strata of year*month caused inability to estimate least squares mean when using the model including interaction effect of year*month, which is selected by BIC as the best and second best models. The fact that the model including the effect of year*month is selected by BIC as the best indicates that fishing season with high CPUE varied significantly among years. This analysis didn't incorporate the interaction effect into the model for base case, assuming that annual changes of fishing season are caused by random error. In future study, incorporation of explanatory variable to explain shift of fishing season would improve predictability of GLM for standardization of CPUE. There is an observation that fishing season of troll fishery in the East China Sea and the Sea of Japan is roughly related to sea surface temperature (Ichinokawa et al. 2010b), so sea surface temperature could be one candidate for explaining troll CPUE better. In addition, more effective use of catch-and-effort by size category would provide additional information on relative abundance of recruitments from the Sea of Japan and the Pacific, since they might be distinguished by individual weight and season (Itoh 2009).

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7. Figures and tables

Table 1. Summary of the data used and configurations for standardizing CPUEs of troll fisheries in Nagasaki, Kochi and Wakayama prefectures.

	Kochi		Wakayama	Nagasaki	
	This document	Yamada and Oshima (2007)		This document	Abe et al. (2010) updated from Yamada and Oshima
Data					
Spatiotemporal data resolution	Monthly & by port	Monthly & by port	Daily & by port	Daily & by port	Aggregated data by month & area (grouped fishing ports), from original daily and by port data
Data avairable period (in fishing year)	1980-2010	1981, 1983-2005	1994-2010	1980-2010	1980-2007
Fishing ports where catch-and-effort data are collected	6 ports of Kan-no-ura, Karyogo, Muroto, Saga, Tosa shimizu, Usa. Details are in Table 2-1-1. Both studies of this document and Yamada and Oshima (2007) basically used same data-base. However, Yamada and Oshima (2007) didn’t use the data from Muroto and Karyogo because of relatively low fishing efforts.		Kushimoto (1995-), Nansho, Susami and Tanabe. Details are in Table 2-2-1.	Main 5 fishing ports of Kami-agata, Kami-tsushima, Are, Tomie and Ojika (Table 2-3-1). In addition, data collected in other misllenious fishing ports during 1980's (Appendix I) are also avairable. Same data-base is used with that in Yamada and Oshima (2007) in this study, but some data are added by the efforts of update, recovery and re-format for this study.	
Zero-catch	15% in average (±9%) by year are zero-catch (per month). Zero-catch rate is especially high in May and June.		More than half of data are zero catch (per day). Zero catch rate is especially high (>90%) in June, August and	The data are recorded only when PBF catch has occurred (= no zero catch data), except for very few exceptional data	
Others				The data include catch in weight by rough size categories, such as small (1-2 kg), medium (2-3 kg) and large (3-4 kg). The definition of size categories is different	
Standardization					
Treatment of zero-catch data	Zero inflated negative binomial, where zer-catch probability is explained by the	GLM assuming log-nomrmal error distribution by adding a small constant to CPUE	Zero inflated negative binomial, where zer-catch probability is explained by the effect of month	No zero catch data	GLM assuming log-nomrmal error distribution by adding a small constant to CPUE
Data selection	All season. Remove the data with efforts <10 ships per month.	Exclude April, May and June	Exclude the data from March to June, because of high zero-catch probability and low efforts.	Use only the data from October to January in Are and Kmi-agata, October to Decmber in Kami-tsushima and other misllenious ports, November to February in Ojika and November to May in Tomie.	Exclude the data of May, Jun, July and August with low CPUE and efforts. Also, the catch more than 4kg, which is considered to correspond to >0 age, was excluded.
Error structure	Zero-inflated negative binomial	Lognormal	Zero-inflated negative binomial	Lognormal	Lognormal
Response variable	Catch in weight (/day) with offset term of efforts (number of landing ships)	log(CPUE + constant). Constant=1 % of the minimum CPUE than zero.	Catch in weight (/day) with offset term of efforts (number of landing ships)	log(CPUE). CPUE = kg /landing ships/day	log(CPUE + constant). Constant=1 % of the minimum CPUE than zero.
Explanatory vaiables in the base case	Year, season (grouped months), port for negative binomial, season for zero-inflation model	Year, season, port, port*season, year*season	Year, month, port, year*month, port*month	year, port, month, port*month	year, region (grouped ports)

Table 2-1-1. Total catch (MT), CPUE (number of landings per day, including zero PBF catch) and CPUE (kg/landing) by year and fishing ports, recorded in catch-and-effort data used for standardization of CPUE in Kochi prefecture. Percentages (%) to the total troll catch in Japan (Oshima, oral presentation #7 in PBFWG12-1) are also shown. Note that year is fishing year, starting from July ends to June.

Fishing year	a. Tosa-shimizu	b. Saga	c. Usa	d. Karyogo	e. Muroto	f. Kan'no-ura	Total	(%)	Total troll catch in Japan
1980			1.6				1.6	0.1	1479
1981			27.2				27.2	1.4	1982
1982			8.4				8.4	1.8	456
1983			1.1				1.1	0.1	2234
1984			18.9				18.9	0.8	2260
1985			1.1				1.1	0.1	1401
1986			1.6				1.6	0.1	1613
1987	0.2		1.1				1.3	0.2	600
1988	21.0		4.9				25.9	2.0	1321
1989	0.7		18.7	0.1			19.5	2.2	874
1990	53.0		1.9	6.0			60.9	3.4	1789
1991	2.1		13.5	7.2			22.7	1.5	1546
1992	3.6	0.0	0.3	5.9	0.0		9.7	1.2	820
1993	10.1	8.2	0.9	1.4	0.1	1.2	21.9	4.9	450
1994	26.0	119.7	76.8	19.0	1.7	68.9	312.1	4.3	7237
1995	10.4	16.9	3.0	3.4	0.7	10.1	44.5	2.5	1763
1996	7.1	92.1	17.4	1.6	0.3	19.7	138.1	2.9	4843
1997	14.3	9.7	1.7	0.1	0.0	1.5	27.4	1.1	2464
1998	1.0	17.5	13.4	13.9	1.1	7.1	53.9	1.9	2902
1999	6.7	12.5	1.5	0.1	0.0	5.5	26.3	0.6	4455
2000	0.8	7.2	1.4	0.2	0.2	16.2	25.8	0.6	4295
2001	53.0	106.5	52.1	14.3	0.6	10.4	236.8	6.5	3616
2002	18.5	24.5	2.9	0.0	0.0	7.6	53.6	2.6	2085
2003	15.5	16.9	3.5	0.0	0.1	10.1	46.2	6.3	732
2004	6.3	18.8	17.6	10.3	0.0	27.7	80.8	2.0	4025
2005	81.5	27.8	4.1	3.8	1.3	38.4	156.9	8.1	1925
2006	31.4	8.2	15.3	0.7	0.1	14.8	70.6	5.7	1245
2007	44.3	57.2	52.3	40.1	0.5	21.5	215.9	7.4	2925
2008	14.2	15.9	39.2	2.9	0.1	1.8	74.1	3.2	2344
2009	1.0	1.8	0.0	0.0	0.0	3.6	6.5	0.6	1067
2010	26.7	36.5	27.8	21.5	0.6	0.8	113.9	6.5	1761

Table 2-1-1. Continued

	Efforts							CPUE						
	a. Tosa-shimizu	b. Saga	c. Usa	d. Karyogo	e. Muroto	f. Kan'no-ura	Total	a. Tosa-shimizu	b. Saga	c. Usa	d. Karyogo	e. Muroto	f. Kan'no-ura	Total (total catch/total efforts)
1980			390				390			1.6				4.1
1981			3028				3028			27.2				9.0
1982			2369				2369			8.4				3.5
1983			1596				1596			1.1				0.7
1984			2357				2357			18.9				8.0
1985			1604				1604			1.1				0.7
1986			1319				1319			1.6				1.2
1987	3112		1350				4462	0.2		1.1				0.3
1988	4587		1952				6539	21.0		4.9				4.0
1989	5965		2779	880			9624	0.7		18.7	0.1			2.0
1990	6475		2191	4145			12811	53.0		1.9	6.0			4.8
1991	3809		2863	1910			8582	2.1		13.5	7.2			2.6
1992	5099	232	737	1440	1096		8604	3.6	0.0	0.3	5.9	0.0		1.1
1993	4209	702	522	1242	1487	1239	9401	10.1	8.2	0.9	1.4	0.1	1.2	2.3
1994	5742	4792	5484	1524	847	4496	22885	26.0	119.7	76.8	19.0	1.7	68.9	13.6
1995	1953	1892	803	513	1704	2640	9505	10.4	16.9	3.0	3.4	0.7	10.1	4.7
1996	5414	4869	2444	1122	1807	3361	19017	7.1	92.1	17.4	1.6	0.3	19.7	7.3
1997	5454	2293	1418	1106	882	1364	12517	14.3	9.7	1.7	0.1	0.0	1.5	2.2
1998	3179	2812	1639	981	859	1784	11254	1.0	17.5	13.4	13.9	1.1	7.1	4.8
1999	4837	3039	1471	918	1281	2498	14044	6.7	12.5	1.5	0.1	0.0	5.5	1.9
2000	2757	3341	1497	1216	1118	3606	13535	0.8	7.2	1.4	0.2	0.2	16.2	1.9
2001	3558	5210	3585	1335	1432	3642	18762	53.0	106.5	52.1	14.3	0.6	10.4	12.6
2002	3297	2951	1785	74	752	2449	11308	18.5	24.5	2.9	0.0	0.0	7.6	4.7
2003	3776	3434	2066	369	708	3093	13446	15.5	16.9	3.5	0.0	0.1	10.1	3.4
2004	6250	1960	2472	699	491	2970	14842	6.3	18.8	17.6	10.3	0.0	27.7	5.4
2005	5561	2178	2175	854	691	4036	15495	81.5	27.8	4.1	3.8	1.3	38.4	10.1
2006	4643	876	2918	326	443	2859	12065	31.4	8.2	15.3	0.7	0.1	14.8	5.9
2007	8105	3365	4587	1898	344	3645	21944	44.3	57.2	52.3	40.1	0.5	21.5	9.8
2008	3672	2162	3746	325	305	2426	12636	14.2	15.9	39.2	2.9	0.1	1.8	5.9
2009	3985	2777	1320	619	335	2219	11255	1.0	1.8	0.0	0.0	0.0	3.6	0.6
2010	2541	1640	549	686	140	246	5802	26.7	36.5	27.8	21.5	0.6	0.8	19.6

Table 2-1-2. Results of model selection. Underlined models have minimum value in each model. ZINB: zero-inflated negative binomial, NB: simple negative binomial.

	BIC	
	ZINB	NB
fy+season+area	21234.6	21043.8
fy*season+area	21724.5	21472.0
fy*area+season	21698.8	21436.2
fy+area*season	21269.1	21052.5
fy*area+fy*season	22209.8	21898.8
fy*season+area*season	21707.8	21444.3
fy*area+season*area	21713.3	21447.2
fy*area+season*area+fy*season	22171.2	21847.0

Table 2-1-3. Type 3 analysis table of the explanatory variables in the base case model for standardization of CPUE in Kochi. The table shows the hypothesis tests for each of the variables in the model individually.

Negative binomial model

Effects	Df	Chisq	Pr>ChiSq
fy	30	267.43	<.0001
season	4	319.85	<.0001
ports	5	108.63	<.0001

Zero-inflation model

Effects	Df	Chisq	Pr>ChiSq
season	4	91.02	<.0001

Table 2-1-4. Standardized CPUE in Kochi prefecture, comparing with estimation by Yamada and Oshima (2007) and nominal CPUE. All CPUEs are normalized by each average.

	Nominal	Standarzied CPUE				Yamada and Oshima	
	CPUE	Estimation	CV	Lower 5%	Upper 5%	Estimation	CV
1980	0.8	3.72	1.02	0.70	19.85		
1981	1.8	0.82	0.51	0.35	1.90	0.145	1.60
1982	0.7	0.25	0.51	0.11	0.59		
1983	0.1	0.21	0.58	0.08	0.55	0.01	2.17
1984	1.6	1.14	0.51	0.49	2.64	6.91	1.56
1985	0.1	0.77	0.49	0.34	1.74	0.97	1.31
1986	0.2	0.28	0.49	0.13	0.63	0.43	1.07
1987	0.1	0.16	0.46	0.08	0.34	0.04	1.72
1988	0.8	0.58	0.33	0.34	0.99	2.31	0.67
1989	0.4	0.32	0.32	0.19	0.54	0.09	0.70
1990	0.9	0.64	0.28	0.41	1.01	0.91	0.67
1991	0.5	0.58	0.31	0.34	0.97	0.26	0.75
1992	0.2	0.30	0.31	0.18	0.49	0.26	0.75
1993	0.5	0.51	0.24	0.34	0.75	0.17	0.53
1994	2.7	3.20	0.19	2.35	4.36	4.52	0.45
1995	0.9	1.04	0.21	0.74	1.47	0.74	0.45
1996	1.4	0.90	0.19	0.65	1.24	1.78	0.44
1997	0.4	0.48	0.23	0.33	0.71	0.33	0.49
1998	0.9	1.54	0.22	1.07	2.22	0.27	0.46
1999	0.4	0.33	0.21	0.23	0.46	0.19	0.45
2000	0.4	0.32	0.21	0.23	0.46	0.09	0.49
2001	2.5	2.11	0.20	1.52	2.94	1.40	0.44
2002	0.9	0.83	0.21	0.58	1.17	0.65	0.45
2003	0.7	0.40	0.23	0.27	0.58	0.17	0.45
2004	1.1	3.47	0.23	2.37	5.08	0.42	0.45
2005	2.0	0.99	0.19	0.73	1.36	0.92	0.45
2006	1.1	0.93	0.21	0.66	1.32		
2007	1.9	1.47	0.20	1.06	2.04		
2008	1.1	0.66	0.23	0.46	0.96		
2009	0.1	0.08	0.25	0.06	0.13		
2010	3.8	1.97	0.22	1.36	2.83		

Table 2-2-1. Total catch (MT), CPUE (number of landings per day, including zero PBF catch) and CPUE (kg/landing) by year and fishing ports, recorded in catch-and-effort data used for standardization of CPUE in Wakayama prefecture. Percentages (%) to the total troll catch in Japan (Oshima, oral presentation #7 in PBFWG12-1) are also shown. Note that year is fishing year, starting from July ends to June.

	Catch (MT)						
	a. Gobou	b. Tanabe	c. Susami	d. Kushimo	Total	(%)	Total troll catc
1994	4.5	20.8	22.0	-	47.4	2.4	1982
1995	0.0	2.1	0.4	0.5	3.1	0.7	456
1996	13.7	20.2	5.6	5.4	45.0	2.0	2234
1997	2.8	4.9	0.9	1.1	9.6	0.4	2260
1998	4.6	4.2	0.4	9.3	18.5	1.3	1401
1999	1.0	3.0	0.4	0.9	5.3	0.3	1613
2000	1.6	2.5	0.6	1.4	6.1	1.0	600
2001	2.9	5.9	2.9	3.6	15.4	1.2	1321
2002	8.3	15.7	4.1	0.6	28.7	3.3	874
2003	2.1	3.3	0.1	0.2	5.7	0.3	1789
2004	8.2	26.0	31.4	18.1	83.6	5.4	1546
2005	1.4	7.4	3.7	4.6	17.2	2.1	820
2006	4.8	7.6	1.9	1.5	15.8	3.5	450
2007	3.4	7.0	4.4	2.9	17.7	0.2	7237
2008	0.9	7.1	5.1	10.0	23.1	1.3	1763
2009	0.2	0.7	0.4	0.7	2.0	0.0	4843
2010	0.7	2.3	0.9	1.5	5.4	0.2	2464

	Efforts (number of landings)					CPUE (kg/landing)				
	a. Gobou	b. Tanab	c. Susam	d. Kushim	Total	a. Gobou	b. Tanab	c. Susam	d. Kushim	Total (total c efforts)
1994	471	3581	8083	-	12135	9.6	5.8	2.7	-	3.90
1995	262	1467	4357	6696	12782	0.2	1.4	0.1	0.1	0.24
1996	1193	4473	8116	11315	25097	11.5	4.5	0.7	0.5	1.79
1997	661	4291	6937	8530	20419	4.2	1.1	0.1	0.1	0.47
1998	519	2297	4258	5269	12343	8.8	1.8	0.1	1.8	1.50
1999	331	2963	4820	8087	16201	3.0	1.0	0.1	0.1	0.33
2000	464	3551	5399	8431	17845	3.4	0.7	0.1	0.2	0.34
2001	685	3314	6357	10256	20612	4.3	1.8	0.5	0.4	0.74
2002	1755	3575	6593	7829	19752	4.7	4.4	0.6	0.1	1.45
2003	1112	2336	4321	6056	13825	1.9	1.4	0.0	0.0	0.41
2004	760	1975	3187	4647	10569	10.8	13.1	9.9	3.9	7.91
2005	2715	2458	3683	6342	15198	0.5	3.0	1.0	0.7	1.13
2006	3207	2012	3808	5826	14853	1.5	3.8	0.5	0.3	1.06
2007	4204	2621	4289	9130	20244	0.8	2.7	1.0	0.3	0.88
2008	3923	2275	4174	10775	21147	0.2	3.1	1.2	0.9	1.09
2009	3654	3005	5096	14413	26168	0.1	0.2	0.1	0.0	0.08
2010	1735	240	3111	8841	13927	0.4	9.5	0.3	0.2	0.39

Table 2-2-2. Results of model selection.

	BIC	
	ZINB	NB
fy+fm+ports	72687.0454	74809.1385
fy*fm+ports	72347.6301	74831.9727
fy*ports+fm	72780.2055	74971.878
fy+ports*fm	72536.0948	<u>74544.0896</u>
fy*ports+fy*fm	72409.1628	74958.0801
fy*fm+ports*fm	<u>72274.8942</u>	74586.3375
fy*ports+fm*ports	72573.2561	74694.9
fy*ports+fm*ports+fy*fm	72344.5559	74662.0687

Table 2-2-3. Type 3 analysis table of the explanatory variables in the base case model for standardization of CPUE in Wakayama. The table shows the hypothesis tests for each of the variables in the model individually.

Negative binomial model

Effects	Df	ChiSq	Pr > ChiSq
fy	16	763.45	<.0001
fy*fm	112	1298.17	<.0001
port*fm	24	759.57	<.0001

Zero-inflation model

Effects	Df	ChiSq	Pr > ChiSq
fm	7	451.86	<.0001

Table 2-2-4. Standardized CPUE in Wakayama prefecture.　All CPUEs are normalized by each average.

Fishing year	Nominal CPUE	Standardized CPUE			
		Estimation	CV	Lower 5%	Upper 5%
1994	2.01	1.40	0.09	1.20	1.63
1995	0.24	0.78	0.11	0.65	0.94
1996	1.79	1.26	0.06	1.14	1.41
1997	0.47	0.71	0.08	0.62	0.81
1998	1.50	0.55	0.15	0.44	0.70
1999	0.33	0.18	0.11	0.15	0.22
2000	0.34	0.53	0.09	0.46	0.61
2001	0.74	0.94	0.07	0.84	1.06
2002	1.45	0.62	0.08	0.55	0.71
2003	0.41	0.30	0.13	0.24	0.37
2004	7.91	4.37	0.08	3.81	5.02
2005	1.13	1.08	0.07	0.96	1.20
2006	1.06	1.04	0.09	0.90	1.21
2007	0.88	1.51	0.08	1.33	1.71
2008	1.09	1.20	0.10	1.03	1.41
2009	0.08	0.13	0.14	0.10	0.16
2010	0.39	0.40	0.11	0.33	0.48

Table 2-3-1. Total catch (MT), CPUE (number of landings per day, excluding zero PBF catch) and CPUE (kg/landing) by year and fishing ports, recorded in catch-and-effort data used for standardization of CPUE in Nagasaki prefecture. Percentages (%) to the total troll catch in Japan (Oshima, oral presentation #7 in PBFWG12-1) are also shown. Note that year is fishing year, starting from July ends to June.

Catch (MT)											
	Main 5 ports										
Fishing ye	Are	Kami-tsu	Kami-ag	Ojika	Tomie	Other port	Total 5 po	(%)	Total all po	(%)	Total troll catc SS)
1980	7.2	11.2	18.2	11.4	210.4	71.7	258	(17)	330	(22)	1479
1981	-	-	118.1	125.7	423.0	236.8	667	(34)	904	(46)	1982
1982	14.3	8.9	45.9	17.9	62.5	158.1	150	(33)	308	(67)	456
1983	51.3	153.4	350.9	102.4	242.9	546.5	901	(40)	1447	(65)	2234
1984	72.8	63.5	355.0	132.6	482.2	408.2	1106	(49)	1514	(67)	2260
1985	78.3	85.0	130.8	91.4	182.7	468.7	568	(41)	1037	(74)	1401
1986	67.0	24.0	130.5	77.3	378.5	564.2	677	(42)	1241	(77)	1613
1987	14.3	23.2	132.3	15.1	115.1	173.3	300	(50)	473	(79)	600
1988	6.0	37.3	150.3	51.1	281.2	313.5	526	(40)	839	(64)	1321
1989	17.4	36.1	81.2	24.8	119.5	27.2	279	(32)	306	(35)	874
1990	46.3	145.4	173.2	-	240.9	57.8	606	(34)	664	(37)	1789
1991	44.0	95.5	111.7	127.1	79.0	36.2	457	(30)	494	(32)	1546
1992	1.9	23.1	12.9	15.1	66.4	3.2	119	(15)	123	(15)	820
1993	17.8	-	60.1	4.9	42.4	-	125	(28)	125	(28)	450
1994	105.3	-	874.2	426.3	464.1	-	1870	(26)	1870	(26)	7237
1995	-	-	243.4	41.0	104.6	-	389	(22)	389	(22)	1763
1996	104.5	-	507.1	127.6	340.5	-	1080	(22)	1080	(22)	4843
1997	23.4	59.1	138.8	39.5	90.4	1.2	351	(14)	352	(14)	2464
1998	45.4	196.0	268.8	21.5	234.3	14.8	766	(26)	781	(27)	2902
1999	101.8	-	355.9	74.7	202.0	1.9	734	(16)	736	(17)	4455
2000	113.4	207.2	318.3	48.2	48.4	-	736	(17)	736	(17)	4295
2001	76.4	163.8	159.3	48.0	87.5	-	535	(15)	535	(15)	3616
2002	34.5	44.4	69.1	24.6	105.5	1.0	278	(13)	279	(13)	2085
2003	30.0	68.5	8.1	13.0	18.0	0.3	138	(19)	138	(19)	732
2004	83.4	188.2	324.1	40.0	117.5	2.5	753	(19)	756	(19)	4025
2005	15.2	125.9	68.2	23.6	22.5	2.3	255	(13)	258	(13)	1925
2006	9.5	30.7	20.0	0.4	-	-	61	(5)	61	(5)	1245
2007	22.6	91.8	163.8	29.8	5.3	-	313	(11)	313	(11)	2925
2008	-	142.0	53.8	60.9	179.7	-	436	(19)	436	(19)	2344
2009	35.7	75.6	-	5.3	97.3	-	214	(20)	214	(20)	1067
2010	14.7	76.7	171.9	6.5	115.3	-	385	(22)	385	(22)	1761

	Efforts (N of landings)								CPUE (kg/landing)							
	Main 5 ports								Main 5 ports							
Fishing ye	Are	Kami-tsu	Kami-ag	Ojika	Tomie	Total 5 p	Other port	Total all	Are	Kami-tsu	Kami-ag	Ojika	Tomie	Total	Other port	Total
1980	670	142	339	723	5330	7204	1770	8974	10.7	78.7	53.7	15.7	39.5	35.9	40.5	36.8
1981	-	-	1633	2952	9740	14325	3064	17389	-	-	72.3	42.6	43.4	46.5	77.3	52.0
1982	694	274	1503	725	1301	4497	5074	9571	20.7	32.4	30.5	24.7	48.1	33.3	31.2	32.1
1983	1756	2012	3958	2278	6264	16268	8971	25239	29.2	76.2	88.7	45.0	38.8	55.4	60.9	57.4
1984	1591	1130	6715	3381	12383	25200	9262	34462	45.8	56.2	52.9	39.2	38.9	43.9	44.1	43.9
1985	1753	1035	2470	1787	6932	13977	9317	23294	44.6	82.1	53.0	51.1	26.4	40.6	50.3	44.5
1986	1729	338	2420	2367	11457	18311	11365	29676	38.7	70.9	53.9	32.6	33.0	37.0	49.6	41.8
1987	500	447	2502	658	4406	8513	4710	13223	28.6	51.8	52.9	23.0	26.1	35.2	36.8	35.8
1988	283	555	2465	1079	9115	13497	6890	20387	21.1	67.3	61.0	47.3	30.8	39.0	45.5	41.2
1989	776	696	1583	868	5744	9667	676	10343	22.4	51.8	51.3	28.6	20.8	28.9	40.2	29.6
1990	903	1537	1739	-	6733	10912	972	11884	51.3	94.6	99.6	-	35.8	55.5	59.5	55.8
1991	865	1008	1603	2195	1546	7217	1188	8405	50.9	94.7	69.7	57.9	51.1	63.4	30.5	58.7
1992	234	630	446	953	2416	4679	126	4805	8.0	36.7	29.0	15.9	27.5	25.5	25.6	25.5
1993	986	-	2040	487	1810	5323	-	5323	18.0	-	29.4	10.1	23.4	23.5	-	23.5
1994	1343	-	5719	3668	5363	16093	-	16093	78.4	-	152.9	116.2	86.5	116.2	-	116.2
1995	-	-	2055	1116	2981	6152	-	6152	-	-	118.4	36.7	35.1	63.2	-	63.2
1996	1543	-	4793	2065	6134	14535	-	14535	67.7	-	105.8	61.8	55.5	74.3	-	74.3
1997	761	690	2605	767	2334	7157	23	7180	30.7	85.6	53.3	51.6	38.7	49.1	50.7	49.1
1998	1236	2348	3908	399	4525	12416	223	12639	36.7	83.5	68.8	53.9	51.8	61.7	66.4	61.8
1999	1167	-	2691	833	4294	8985	31	9016	87.3	-	132.3	89.6	47.1	81.7	62.6	81.7
2000	1213	1353	2216	668	2571	8021	-	8021	93.5	153.1	143.6	72.2	18.8	91.7	-	91.7
2001	1111	1682	1729	776	1582	6880	-	6880	68.8	97.4	92.2	61.8	55.3	77.8	-	77.8
2002	902	951	1495	806	2725	6879	60	6939	38.3	46.7	46.2	30.5	38.7	40.4	17.1	40.2
2003	631	842	239	357	853	2922	62	2984	47.6	81.3	33.8	36.4	21.2	47.1	4.6	46.2
2004	923	1478	3101	692	2304	8498	103	8601	90.4	127.3	104.5	57.7	51.0	88.6	23.8	87.9
2005	365	1014	721	354	550	3004	26	3030	41.8	124.1	94.6	66.5	40.9	85.0	87.1	85.0
2006	231	437	490	28	-	1186	-	1186	41.3	70.4	40.8	16.0	-	51.2	-	51.2
2007	376	753	1920	393	64	3506	-	3506	60.1	121.9	85.3	75.9	82.6	89.4	-	89.4
2008	-	854	760	792	2668	5074	-	5074	-	166.3	70.8	76.9	67.3	86.0	-	86.0
2009	743	693	-	175	1339	2950	-	2950	48.0	109.1	-	30.1	72.7	72.5	-	72.5
2010	439	806	2350	135	2119	5849	-	5849	33.4	95.1	73.2	48.4	54.4	65.8	-	65.8

Table 2-3-2. Results of model selection with using BIC. The third best model, surrounded by a square is the model used for base case.

	BIC
fy+fm+ports	26236.3
fy*fm+ports	26137.0
fy*ports+fm	26444.9
fy+ports*fm	$\boxed{26217.9}$
fy*ports+fy*fm	26509.4
fy*fm+ports*fm	26114.5
fy*ports+fm*ports	26393.7
fy*ports+fm*ports+fy*fm	26395.3

Table 2-3-3. Type 3 analysis table of the explanatory variables in the base case model for standardization of CPUE in Nagasaki. The table shows the hypothesis tests for each of the variables in the model individually.

Effects	Num DF	Type III SS	Mean Square	F value	Pr > F
Model	51	2238.3	43.9	47.28	<.0001
Error	9279	8613.3	0.9		
Corrected Total	9330	10851.6			
				R squared value	0.206

Effects	Num DF	Type III SS	Mean Square	F value	Pr > F
fy	30	1130.59	37.69	40.6	<.0001
fm*ports	21	899.97	42.86	46.17	<.0001

Table 2-3-4. Standardized CPUE in Nagasaki prefecture, comparing with estimation by Abe et al (2010) and nominal CPUE. All CPUEs are normalized by each average.

	Nominal CPUE	Standarzied CPUE				Abe et al. (2010)	
		Estimation	CV	Lower 5%	Upper 5%	Estimation	CV
1980	0.62	0.64	0.06	0.57	0.72	0.88	0.379
1981	0.80	1.11	0.06	0.99	1.25	1.86	0.33
1982	0.57	0.57	0.07	0.49	0.66	0.65	0.36
1983	0.95	0.87	0.05	0.78	0.97	0.94	0.33
1984	0.75	0.88	0.05	0.80	0.96	1.10	0.35
1985	0.70	0.82	0.05	0.74	0.90	1.14	0.36
1986	0.64	0.93	0.04	0.85	1.02	0.47	0.33
1987	0.61	0.67	0.06	0.60	0.74	0.75	0.35
1988	0.67	0.76	0.05	0.69	0.84	0.81	0.33
1989	0.50	0.61	0.05	0.55	0.68	0.80	0.32
1990	0.95	1.20	0.05	1.08	1.34	1.35	0.36
1991	1.09	1.29	0.06	1.15	1.45	0.65	0.40
1992	0.44	0.55	0.06	0.50	0.62	0.40	0.36
1993	0.40	0.46	0.05	0.42	0.51	0.53	0.31
1994	2.00	1.93	0.05	1.76	2.12	2.67	0.28
1995	1.09	1.05	0.06	0.93	1.18	0.62	0.37
1996	1.28	1.57	0.05	1.43	1.72	1.80	0.27
1997	0.84	0.89	0.06	0.79	1.00	0.41	0.32
1998	1.06	0.81	0.05	0.73	0.89	0.69	0.28
1999	1.40	1.47	0.06	1.31	1.64	1.85	0.29
2000	1.57	1.14	0.06	1.01	1.28	1.74	0.31
2001	1.34	1.15	0.06	1.02	1.29	1.10	0.32
2002	0.69	0.73	0.06	0.65	0.81	0.77	0.30
2003	0.81	0.64	0.07	0.55	0.73	0.84	0.35
2004	1.52	1.27	0.05	1.15	1.41	1.09	0.29
2005	1.46	1.35	0.06	1.19	1.53	0.84	0.32
2006	0.88	0.70	0.09	0.58	0.85	0.20	0.293
2007	1.53	1.38	0.06	1.22	1.55	1.07	0.35
2008	1.48	1.41	0.06	1.26	1.57		
2009	1.25	1.09	0.07	0.95	1.24		
2010	1.13	1.07	0.05	0.96	1.19		

Table 3-1. Summary of standardized CPUE estimated in Kochi, Wakayama and Nagasaki prefecture, and combined indices (simple and weighted by average catch), comparing previous indices of Nagasaki and Kochi and estimation in SS. Root mean squared error (RMSE) between each index and expected troll CPUE estimated in the last stock assessment is also shown.

Fishing year	Estimated recruitment in SS (Ichinokawa et al. 2010)	Troll expected catch in SS (Ichinokawa et al. 2010)	Previous Nagasaki troll (Abe et al., 2010)	Previous Kochi troll (Yamada and Oshima 2007)	Nagasaki	Kochi	Wakayama	Simple average of 3 prefecture	Simple average of Nagasaki & Kochi	Average of 3 prefectures weighted by catch	Average of Nagasaki and Kochi, weighted by catch
1980	0.38	0.60	0.88		0.64	(*1)					
1981	0.90	0.63	1.86	0.14	1.11	0.82			1.01		1.08
1982	0.76	0.61	0.65		0.57	0.25			0.43		0.54
1983	0.65	0.64	0.94	0.01	0.87	0.21			0.56		0.80
1984	1.03	0.92	1.10	6.91	0.88	1.14			1.05		0.90
1985	0.77	0.77	1.14	0.97	0.82	0.77			0.83		0.81
1986	0.80	0.75	0.47	0.43	0.93	0.28			0.63		0.86
1987	0.46	0.55	0.75	0.04	0.67	0.16			0.43		0.61
1988	0.81	0.77	0.81	2.31	0.76	0.58			0.70		0.74
1989	0.65	0.82	0.80	0.09	0.61	0.32			0.48		0.58
1990	1.46	1.46	1.35	0.91	1.20	0.64			0.96		1.14
1991	1.08	1.35	0.65	0.26	1.29	0.58			0.97		1.22
1992	0.28	0.55	0.40	0.26	0.55	0.30			0.44		0.53
1993	0.22	0.35	0.53	0.17	0.46	0.51			0.50		0.47
1994	2.34	1.88	2.67	4.52	1.93	3.20	1.40	1.94	2.67	1.77	2.07
1995	1.33	1.37	0.62	0.74	1.05	1.04	0.78	0.85	1.09	0.90	1.05
1996	1.49	1.43	1.80	1.78	1.57	0.90	1.26	1.11	1.28	1.29	1.49
1997	0.80	0.92	0.41	0.33	0.89	0.48	0.71	0.62	0.71	0.73	0.84
1998	1.05	1.04	0.69	0.27	0.81	1.54	0.55	0.86	1.22	0.76	0.88
1999	1.64	1.49	1.85	0.19	1.47	0.33	0.18	0.59	0.93	1.13	1.35
2000	1.31	1.15	1.74	0.09	1.14	0.32	0.53	0.59	0.76	0.89	1.05
2001	1.47	1.35	1.10	1.40	1.15	2.11	0.94	1.25	1.70	1.07	1.25
2002	1.17	1.26	0.77	0.65	0.73	0.83	0.62	0.64	0.81	0.63	0.74
2003	0.66	0.80	0.84	0.17	0.64	0.40	0.30	0.39	0.54	0.52	0.61
2004	1.99	1.81	1.09	0.42	1.27	3.47	4.37	2.70	2.47	1.39	1.51
2005	0.98	1.22	0.84	0.92	1.35	0.99	1.08	1.01	1.22	1.13	1.31
2006	0.80	0.86	0.20		0.70	0.93	1.04	0.79	0.85	0.64	0.73
2007	0.71	0.63	1.07		1.38	1.47	1.51	1.29	1.48	1.20	1.38
2008					1.41	0.66	1.20	0.97	1.08	1.14	1.33
2009					1.09	0.08	0.13	0.39	0.61	0.82	0.98
2010					1.07	1.97	0.40	1.02	1.58	0.99	1.17
RMSE from expected troll CPUE			0.51	1.31	0.27	0.66	0.75	0.44	0.33	0.28	0.25

Table 3-2. Summary of CV estimated in standardized CPUE.

Fishing year	Previous Nagasaki troll (Abe et al., 2010)	Previous Kochi troll (Yamada and Oshima 2007)	Nagasaki	Kochi	Wakayama	Simple average of 3 prefecture	Simple average of Nagasaki & Kochi	Average of 3 prefectures weighted by catch	Average of Nagasaki and Kochi, weighted by catch
1980	0.38		0.06	(*1)					
1981	0.33	1.60	0.06	0.51			0.52		0.07
1982	0.36		0.07	0.51			0.52		0.08
1983	0.33	2.17	0.05	0.58			0.58		0.08
1984	0.35	1.56	0.05	0.51			0.51		0.07
1985	0.36	1.31	0.05	0.49			0.50		0.07
1986	0.33	1.07	0.04	0.49			0.49		0.06
1987	0.35	1.72	0.06	0.46			0.46		0.07
1988	0.33	0.67	0.05	0.33			0.33		0.06
1989	0.32	0.70	0.05	0.32			0.33		0.06
1990	0.36	0.67	0.05	0.28			0.28		0.05
1991	0.40	0.75	0.06	0.31			0.32		0.06
1992	0.36	0.75	0.06	0.31			0.31		0.06
1993	0.31	0.53	0.05	0.24			0.24		0.05
1994	0.28	0.45	0.05	0.19	0.09	0.21	0.19	0.04	0.04
1995	0.37	0.45	0.06	0.21	0.11	0.25	0.22	0.06	0.06
1996	0.27	0.44	0.05	0.19	0.06	0.21	0.20	0.04	0.04
1997	0.32	0.49	0.06	0.23	0.08	0.26	0.24	0.06	0.06
1998	0.28	0.46	0.05	0.22	0.15	0.27	0.23	0.05	0.05
1999	0.29	0.45	0.06	0.21	0.11	0.24	0.22	0.05	0.05
2000	0.31	0.49	0.06	0.21	0.09	0.24	0.22	0.06	0.06
2001	0.32	0.44	0.06	0.20	0.07	0.22	0.21	0.06	0.06
2002	0.30	0.45	0.06	0.21	0.08	0.23	0.22	0.05	0.05
2003	0.35	0.45	0.07	0.23	0.13	0.27	0.24	0.07	0.07
2004	0.29	0.45	0.05	0.23	0.08	0.25	0.24	0.05	0.05
2005	0.32	0.45	0.06	0.19	0.07	0.21	0.20	0.06	0.06
2006	0.29		0.09	0.21	0.09	0.25	0.23	0.08	0.08
2007	0.35		0.06	0.20	0.08	0.22	0.21	0.06	0.06
2008			0.06	0.23	0.10	0.25	0.23	0.05	0.05
2009			0.07	0.25	0.14	0.30	0.26	0.06	0.06
2010			0.05	0.22	0.11	0.25	0.23	0.05	0.05

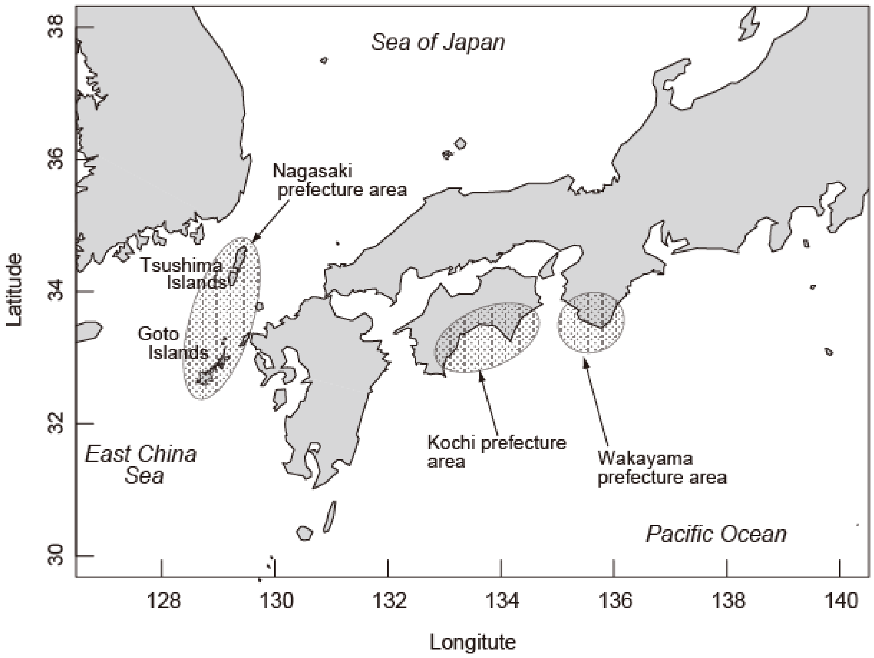

Fig. 1.　Location of fishing grounds of troll fisheries conducted in Nagasaki, Kochi and Wakayama prefectures in Japan.

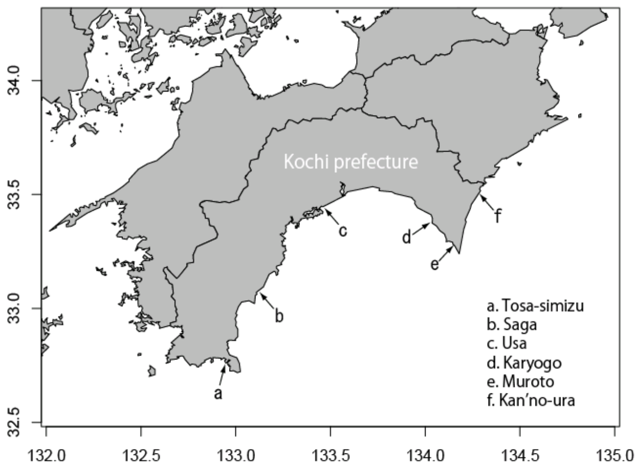

Fig. 2-1-1.　Location of fishing ports where catch-and-effort data of troll fisheries have been collected in Kochi prefecture

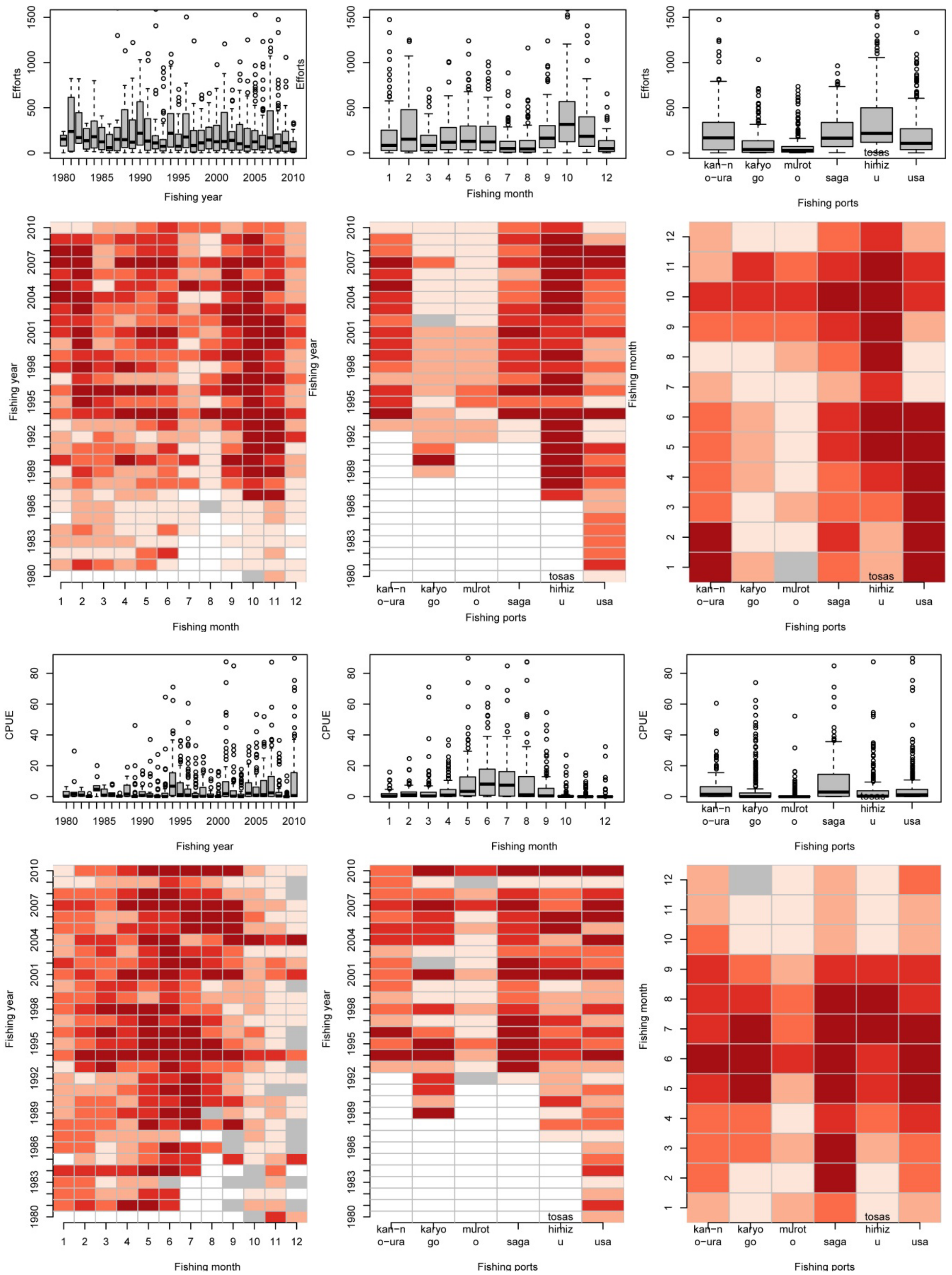

Fig. 2-1-2. Distribution of efforts (upper panles) and CPUE (lower panels) by year, month and ports in Kochi prefecture. 5 level colors of reds corresponds to 0-20, 20-40, 40-60, 60-80 and 80-100 percentiles of values, where deeper reds means higher value. White cells represent no records, and gray mean zero catch. Note that the data before data selection for standardization are shown.

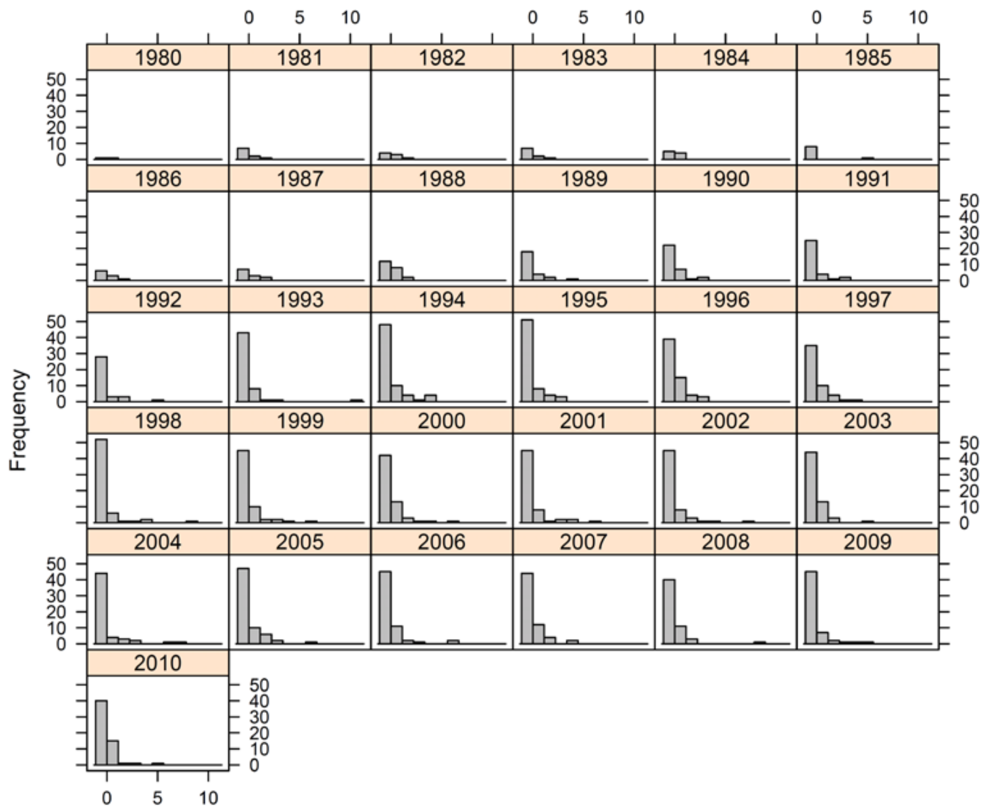

Fig. 2-1-3. Pearson residuals by year in base case model (K1, ZINB and no interaction).

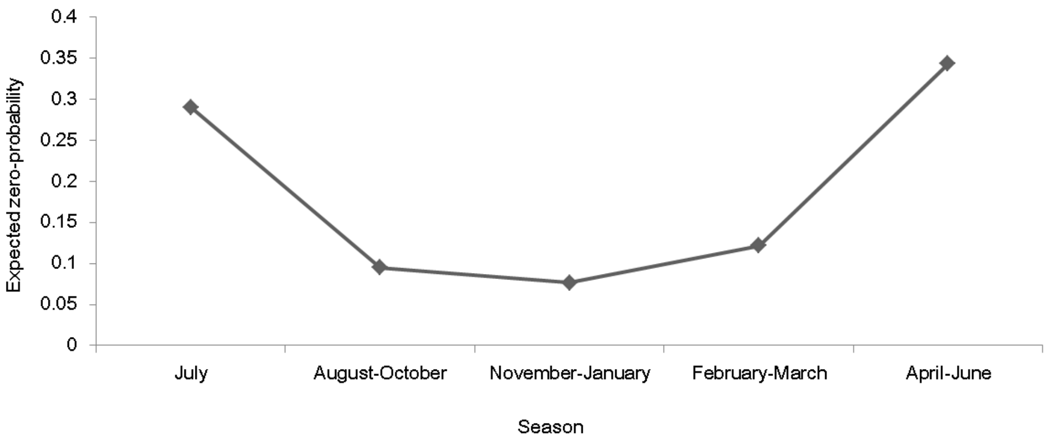

Fig. 2-1-4. Expected zero-probability by season estimated zero-inflated model.

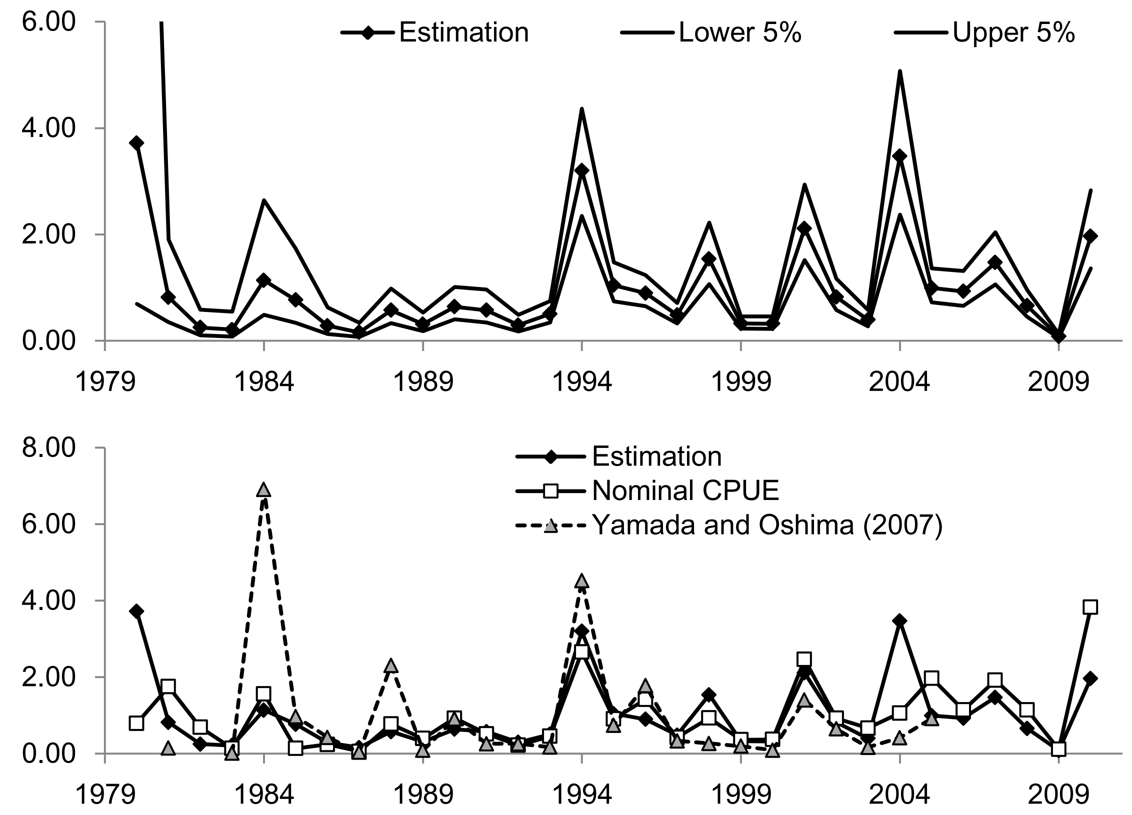

Fig. 2-1-5. Standardized CPUE with 90% confidence intervals (upper panel) and with nominal CPUE and estimation by Yamada and Oshima (2007).

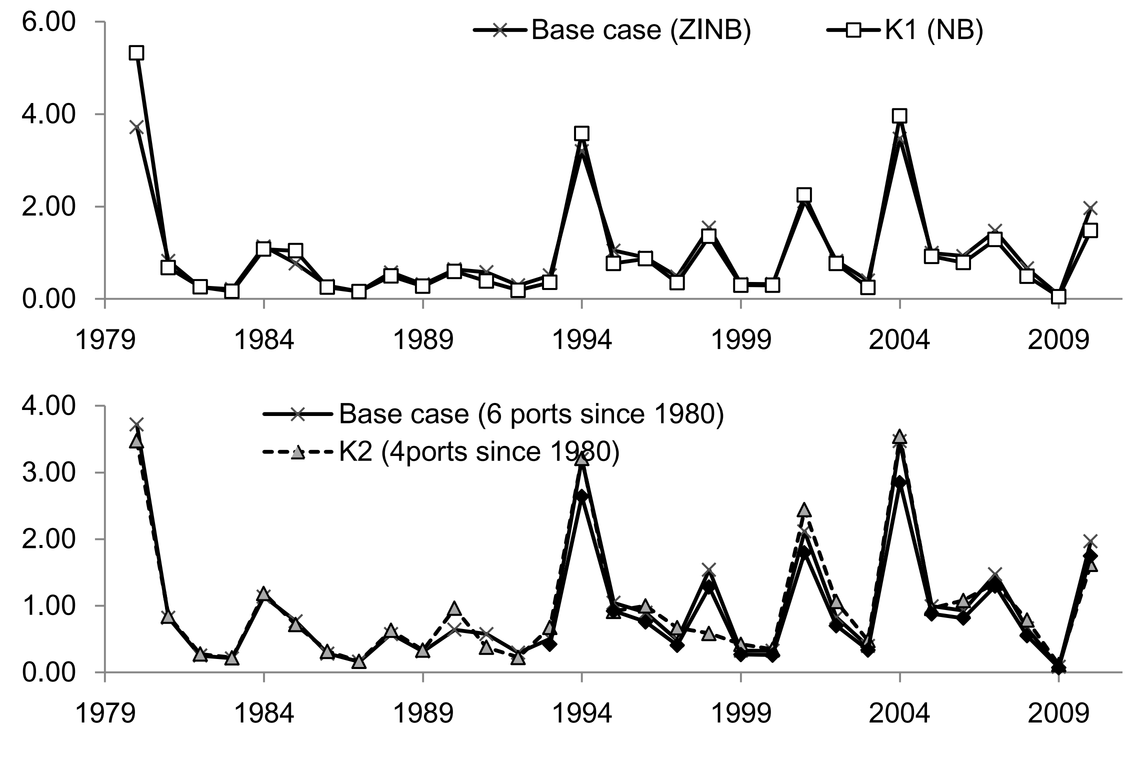

Fig. 2-1-6. Comparison of standardized CPUE in base case with alternative CPUEs estimated in sensitivity analysis.

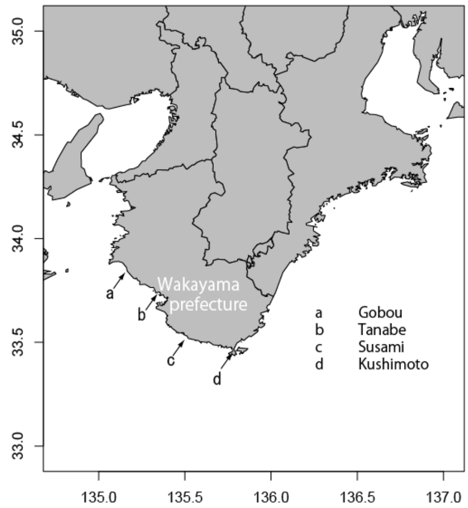

Fig. 2-2-1. Location of fishing ports where catch-and-effort data of troll fisheries have been collected in Wakayama prefecture

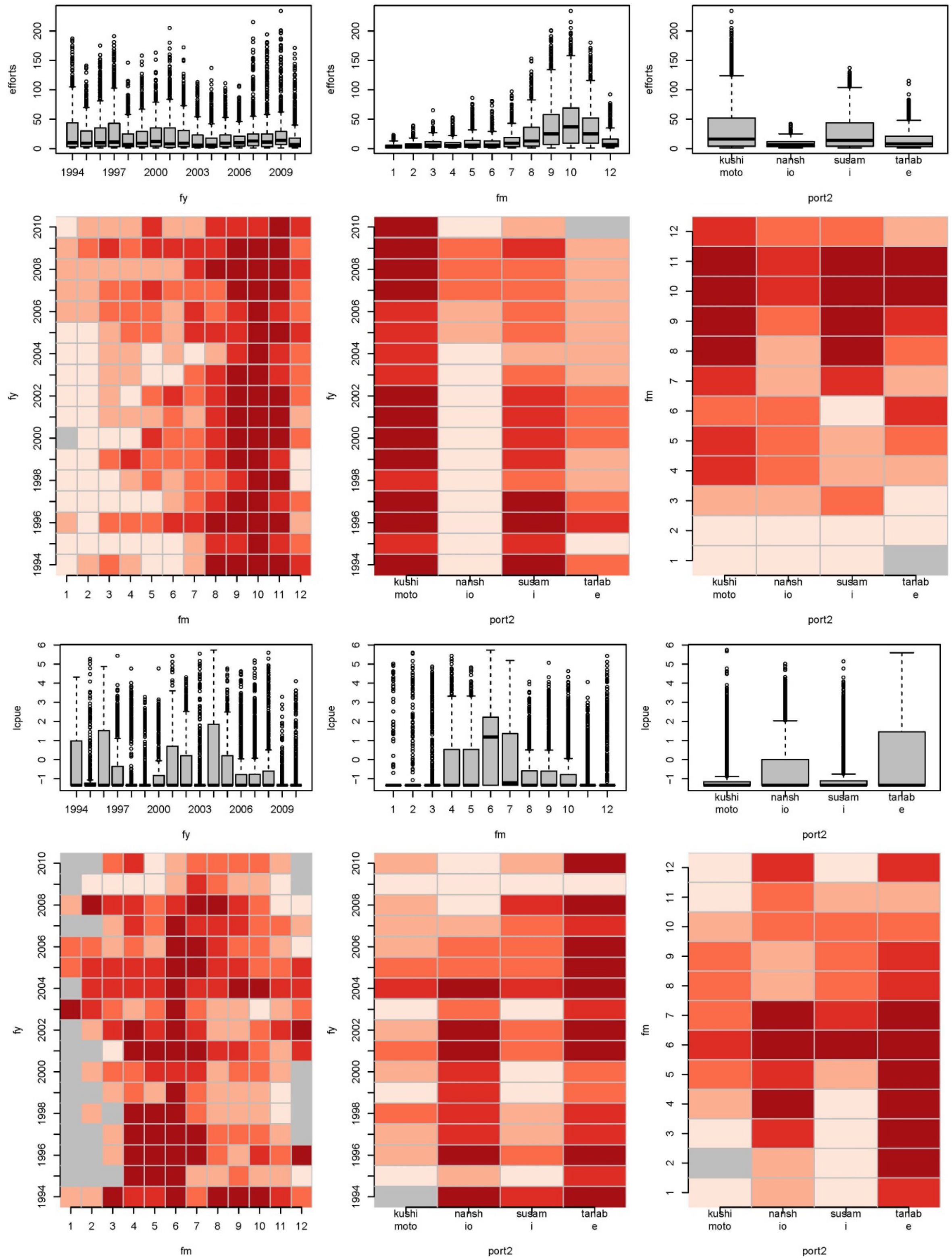

Fig. 2-2-2. Distribution of efforts (upper panels) and CPUE (lower panels) by year, month and ports in Wakayama prefecture. 5 level colors of reds corresponds to 0-20, 20-40, 40-60, 60-80 and 80-100 percentiles of values, where deeper reds means higher value. White cells represent no records, and gray mean zero catch. Note that the data before data selection for standardization are shown.

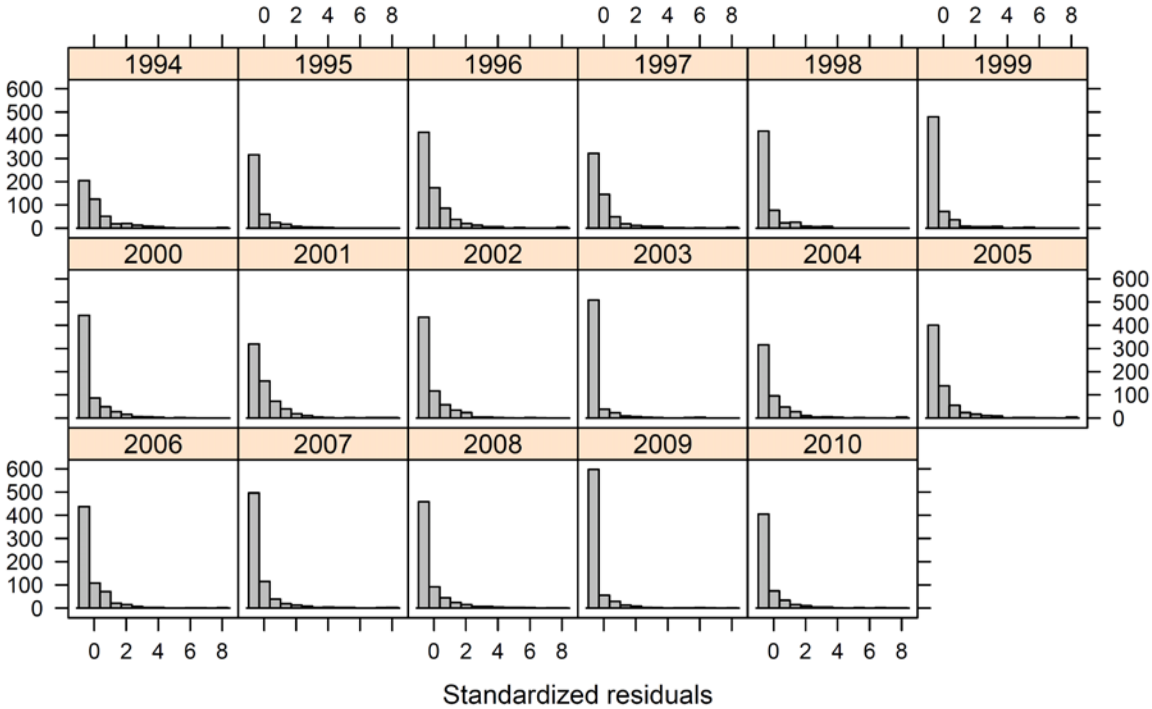

Fig. 2-2-3. Pearson residuals by year in base case model (K1, ZINB and no interaction).

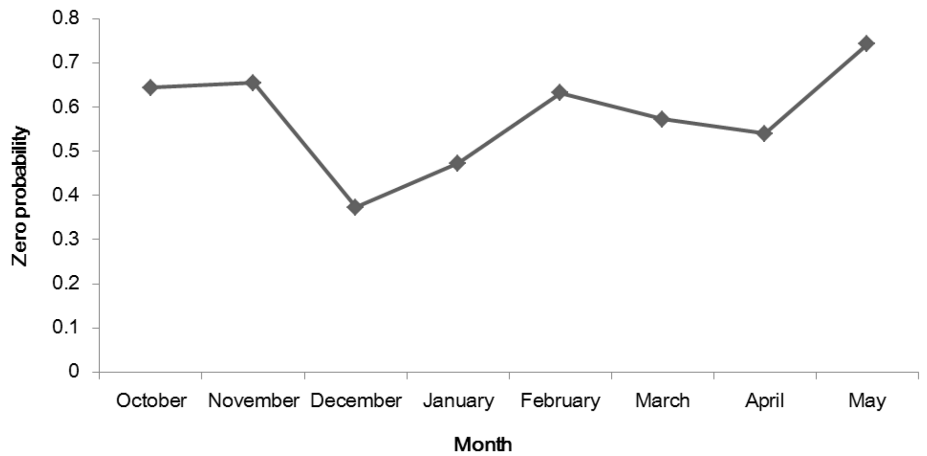

Fig. 2-2-4. Expected zero-probability by season estimated zero-inflated model.

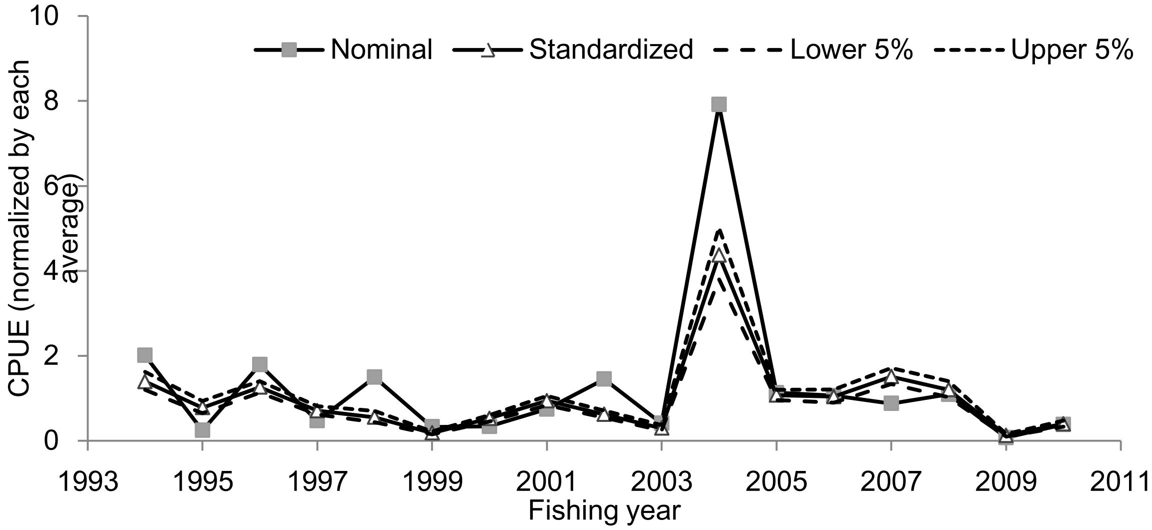

Fig. 2-2-5. Standardized and nominal CPUE estimated in Wakayama prefecture

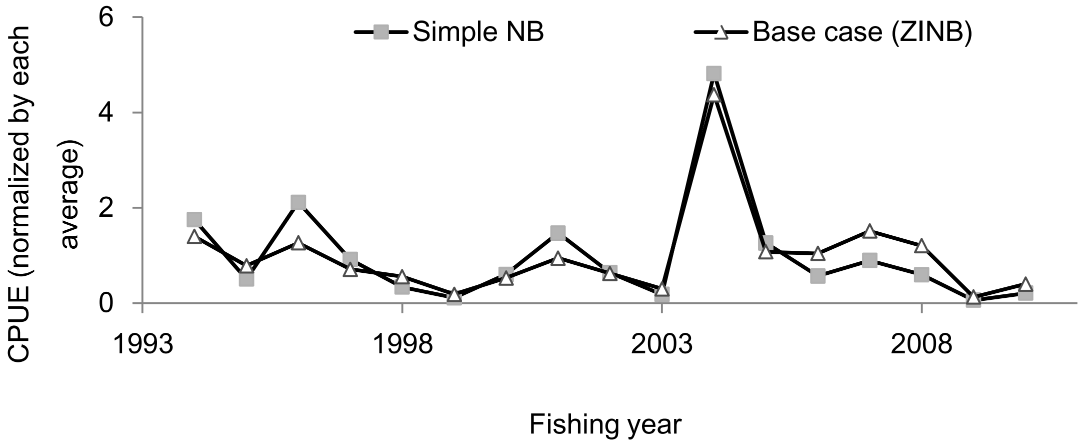

Fig. 2-2-6. Comparison of standardized CPUE in base case with alternative CPUEs estimated in sensitivity analysis.

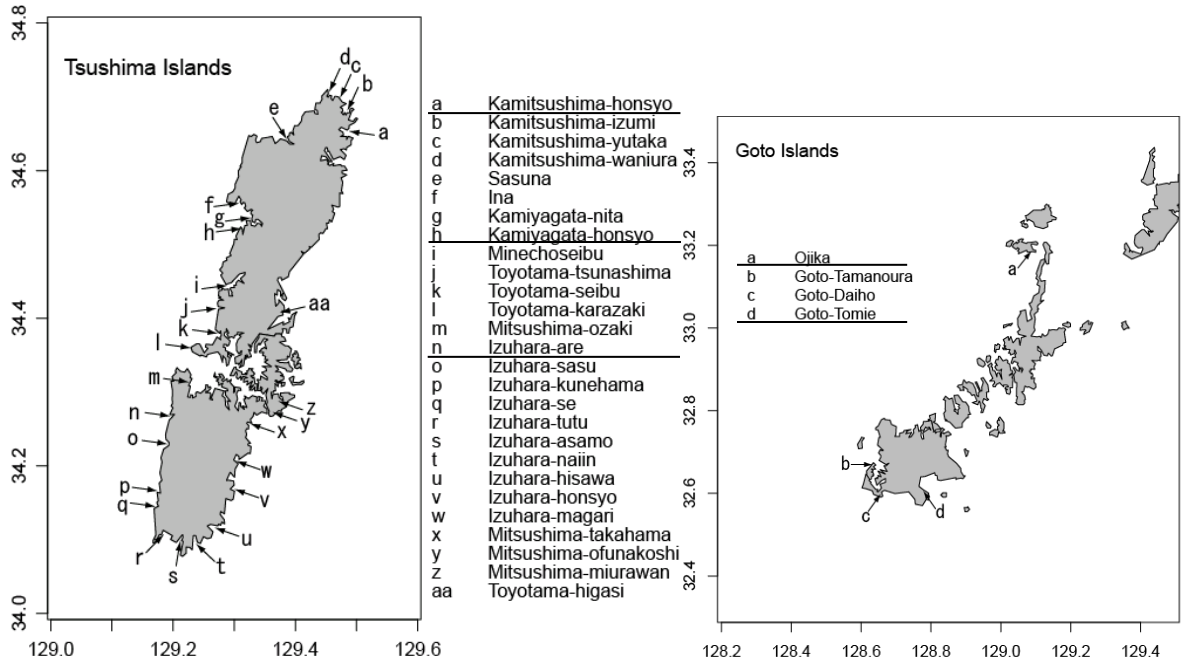

Fig. 2-3-1. Location of fishing ports where catch-and-effort data of troll fisheries have been collected in Nagasaki prefecture. Left: Tsushima Islands in Nagasaki prefecture. Right: Goto Islands in Nagasaki prefecture. The underlined fishing ports are main 5 fishing ports where catch-and-effort data have been collected still now.

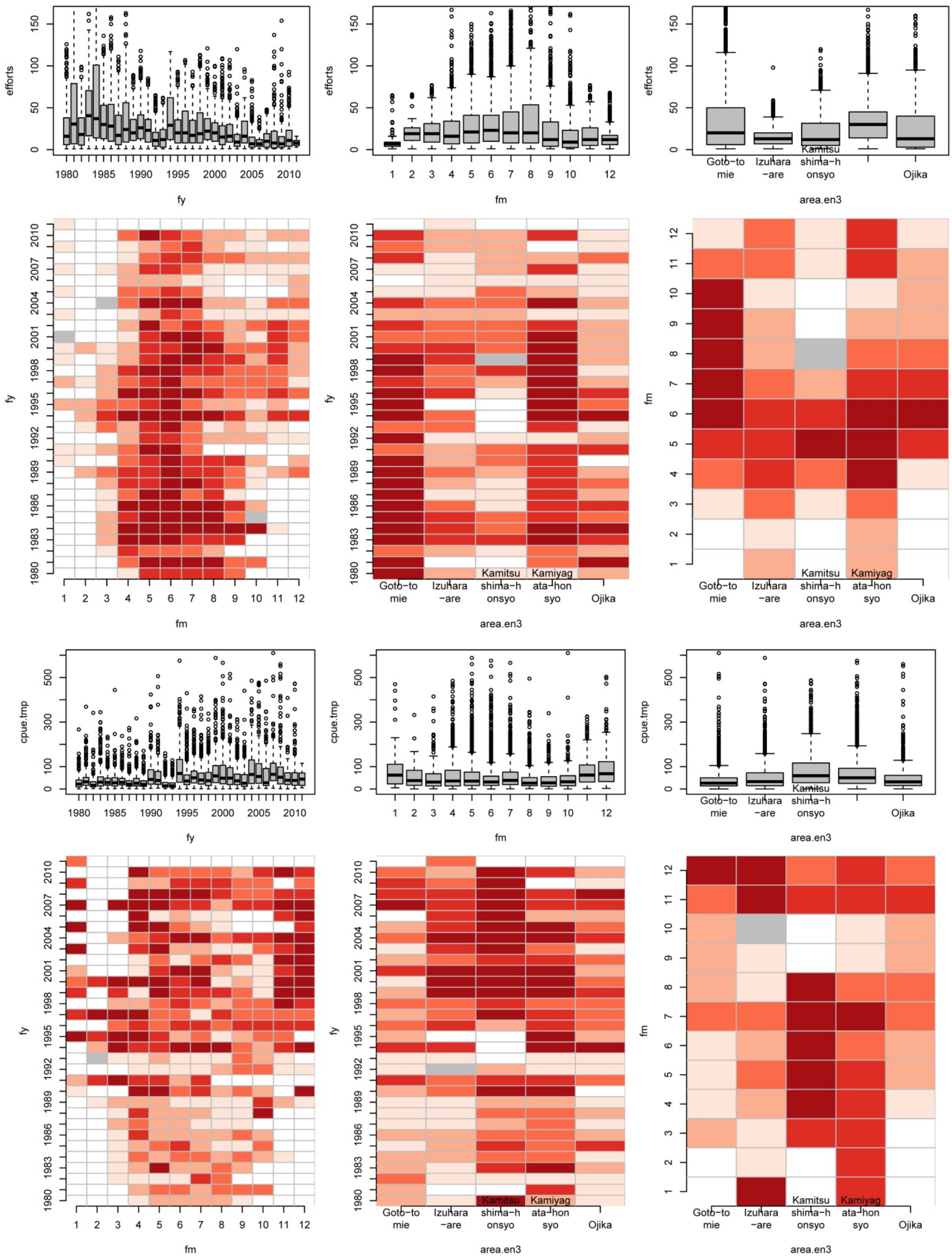

Fig. 2-3-2. Distribution of efforts (upper panels) and CPUE (lower panles) by year, month and ports in Nagasaki prefecture. 5 level colors of reds corresponds to 0-20, 20-40, 40-60, 60-80 and 80-100 percentiles of values, where deeper reds means higher value. White cells represent no records, and gray mean zero catch. Note that the data before data selection for standardization are shown.

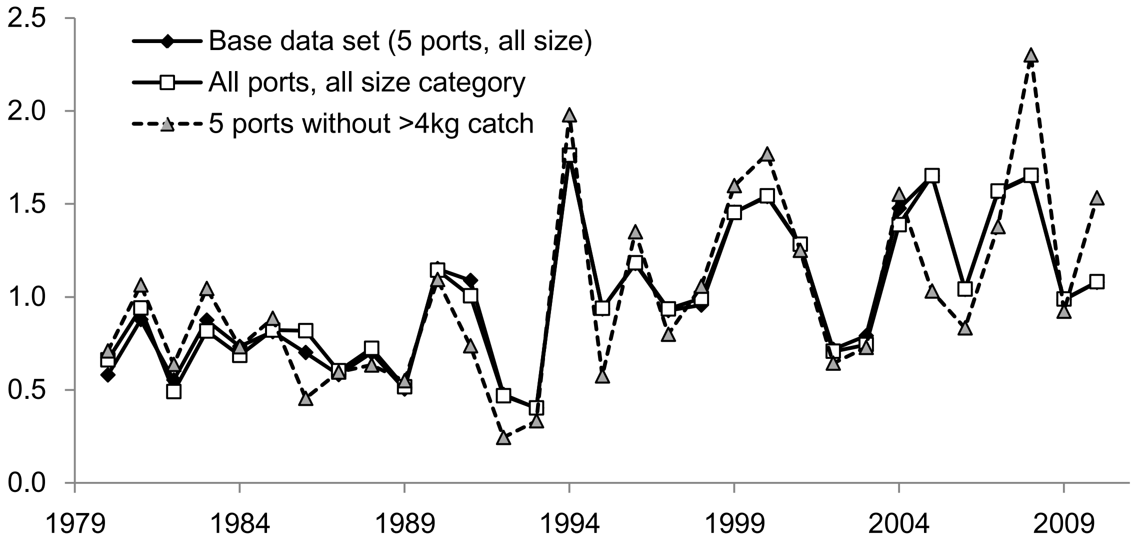

Fig. 2-3-3. Nominal CPUE of different data sets

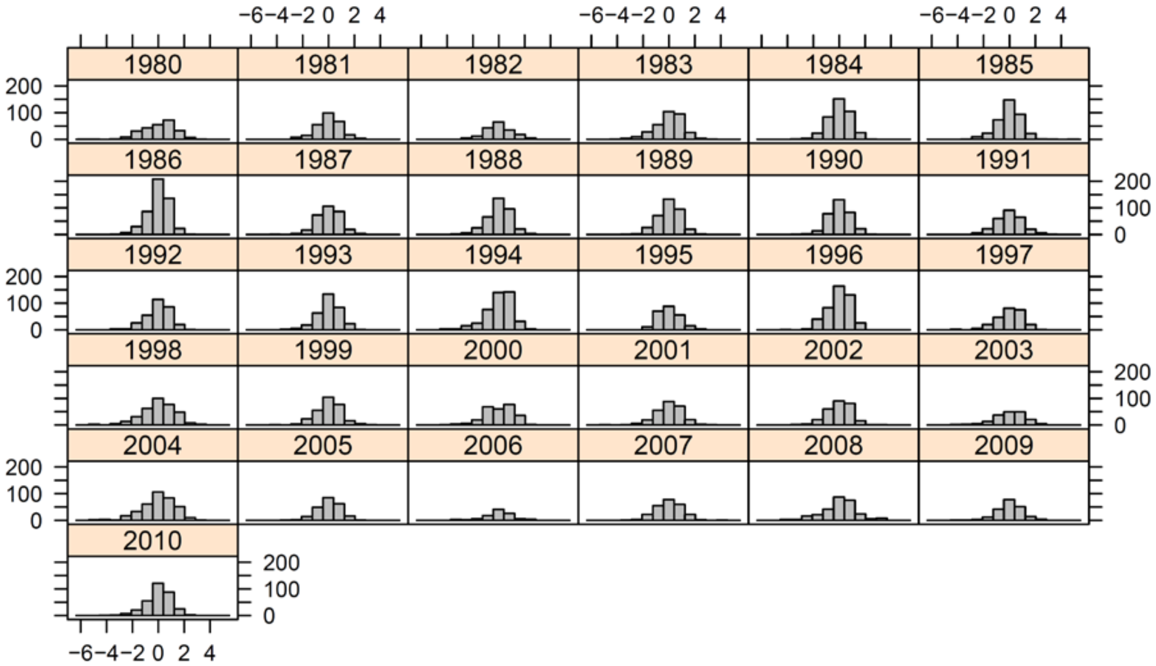

Fig. 2-3-4. Standardized residuals by year in the base case model

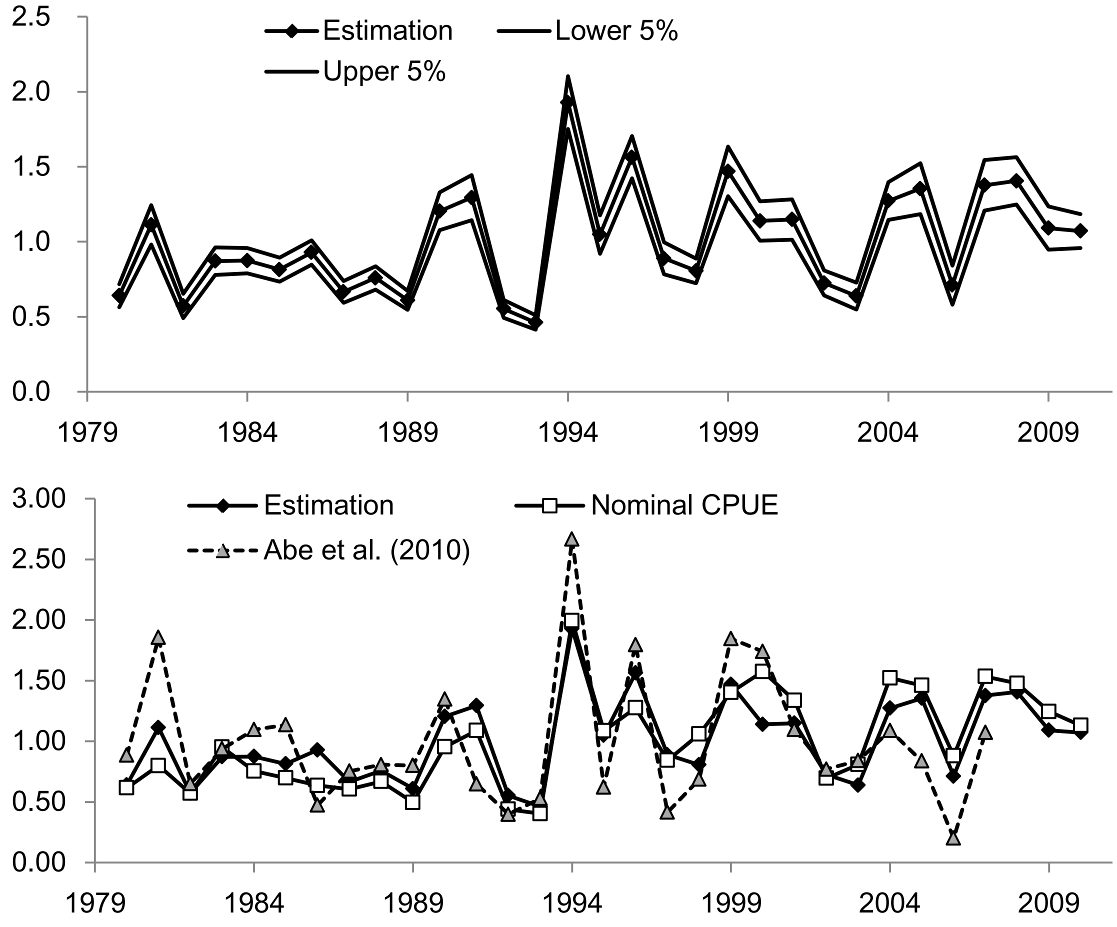

Fig. 2-3-5. Standardized CPUE with 90% confidence intervals (upper panel) and with nominal CPUE and estimation by Abe et al. (2010).

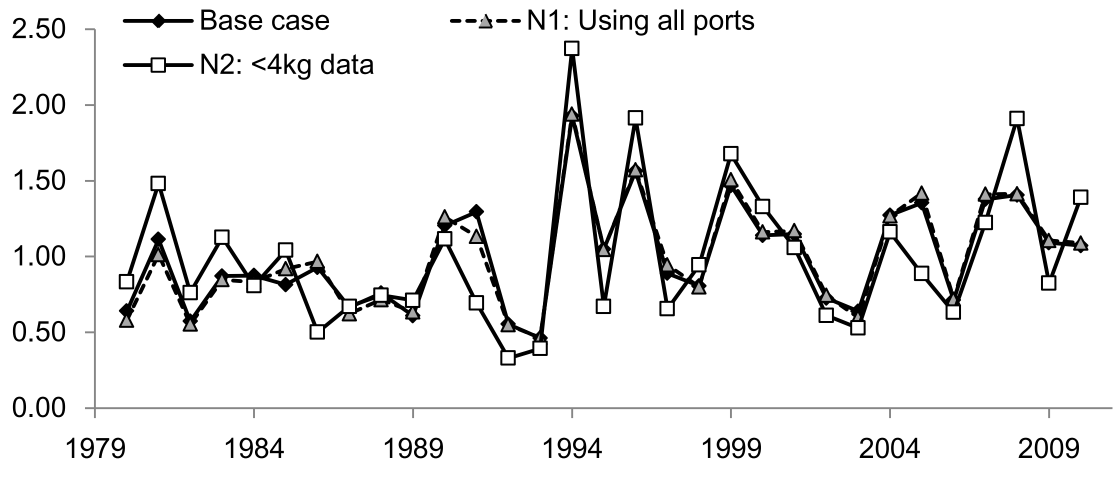

Fig. 2-3-6. Comparison of standardized CPUE in base case with CPUEs estimated in sensitivity analysis.

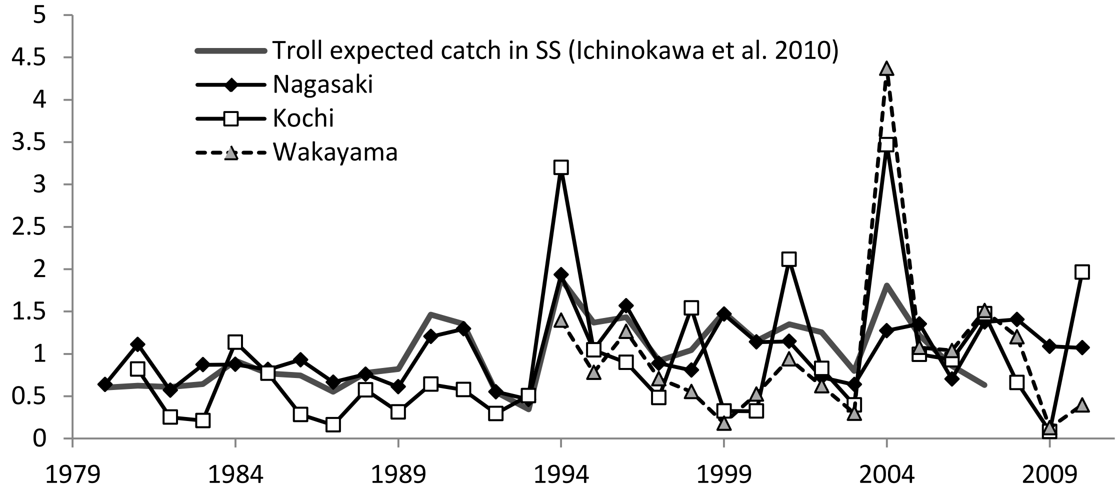

Fig. 3-1. Comparison of CPUEs from 3 prefectures of Nagasaki, Kochi and Wakayama with expected troll CPUE estimated by SS in the previous assessment.

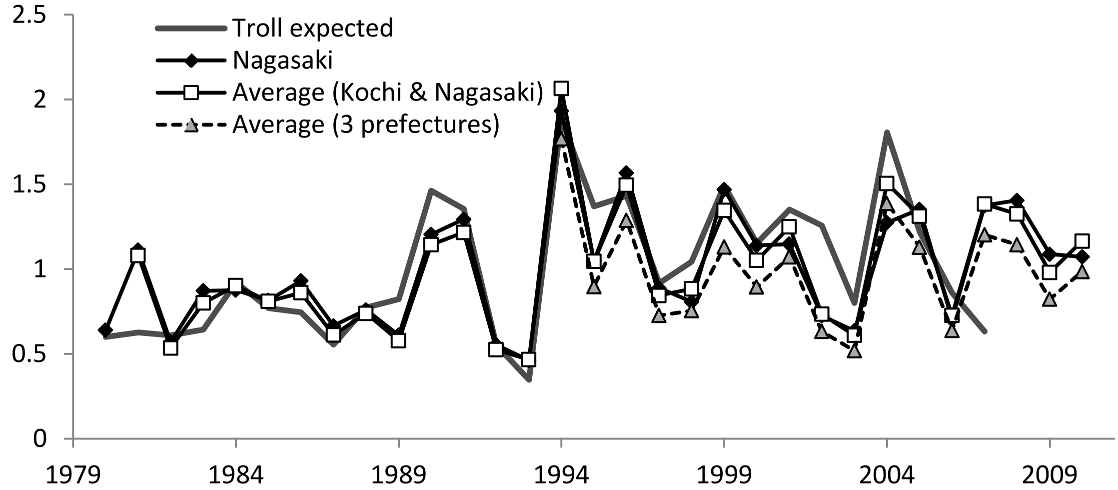

Fig. 3-2. Comparing 3 indices of Nagasaki, weighted average of 3 prefectures and weighted average of Kochi and Nagasaki.

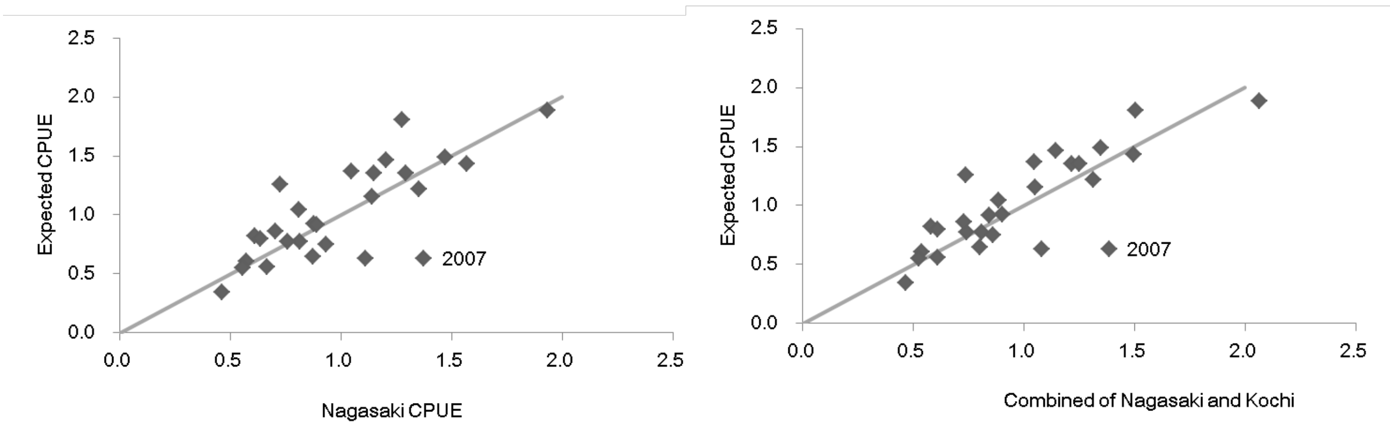

Fig. 3-3. Scatter plots of expected CPUE in SS vs. Nagasaki CPUE (left) and combined CPUE (right). The line of X=Y is also shown by the gray solid lines.