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CPUE of skipjack for the Japanese offshore pole and line using GPS and catch data

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Abstract

To create the new CPUE based on the fishing effort for searching skipjack fishing ground or fish school, GPS data loggers were deployed on 7 Japanese pole and line vessels(< 200 GRT) from July to September 2010. The position and speed of vessels were logged in every 1 second. Start and end time of fishing (angling) and skipjack catch (ton) of each fishing activities were recorded on the field note by the fishing master. The characteristic of vessel behavior of cruising, searching, and fishing was investigated using these data. Then the daily distances for searching fishing ground were calculated and considered as a candidate of the fishing effort. The classical fishing effort (pole·day, derived from logbook data) was constant in each vessel, while the new fishing effort (distance·pole·day, in this study) varied several times from day to day. The variation and its pattern of the new CPUE were different from those of the classical CPUE. It is suggested from dataset in this study that the classical CPUE is more overestimated or underestimated when daily catch is from 10 to 25 ton. Therefore, new CPUE would be effective for the CPUE estimation particularly at its range of daily catch.

Introduction

Skipjack tuna (*Katsuwonus pelamis*) lives in wide area within almost whole of the Pacific Ocean (e.g. Matsumoto et al., 1984) and skipjack catches is largest in the tropical region (Williams and Terawasi, 2010). According to the last skipjack stock assessment in 2010, although stock status of skipjack tuna has declined somewhat in recent years, skipjack is not overfished and its stock keeps still safe level even though total catch has been increasing. On the other hand, recent skipjack catches near Japanese water north of 20°N has been decreasing, especially in 2009, it is lowest in 10 years. Therefore it is pointed out that the skipjack migrating seasonally to near the Japanese coastal waters may decrease (Uosaki et al., 2010). Japanese fishermen also have pointed out "the decrease of skipjack school which they can find near Japanese water", and they have been deeply concerned with the declining of skipjack stock. However, its indication is not reflected in the latest stock assessment because the fishing effort for finding skipjack school is not considered in CPUE used in the stock assessment. Current fishing efforts are the numbers of pole and day from logbook, which don’t include the fishing effort spent for searching fishing ground. In this document, we evaluated the new fishing effort for searching fishing ground using GPS and catch data of Japanese pole and line vessels after investigated vessel behavior, and estimated CPUE, which can reflect skipjack stock more, from its effort.

Data and Methods

GPS data loggers were deployed on 7 Japanese pole and line vessels (< 200 GRT) from July to November 2010 (Table 1). During this period the vessels had been fishing in the east of Japan (Fig. 1) and the total of fishing day was 61. The position and speed of vessels were logged in every 1-second. Start and end time of fishing and skipjack catch (ton) of each activities were recorded on the field note. We checked the GPS data against the field note, and identified the fishing position. To evaluate the new fishing effort, the characteristic of vessel behavior at fishing and searching fishing ground was investigated using these data. To smooth short-term fluctuations, we calculated the 1-minute running mean and 5-minute running standard deviation of vessel speed (RM_{speed} and RSD_{speed}, respectively), and 1-minute running standard deviation of bearing change per second ($RSD_{\Delta bearing}$). The daily averaged speed and total distance for searching fishing ground (D_{SFG}) were also calculated. The D_{SFG} was considered as new fishing effort, which also meant to consider the density of skipjack school because D_{SFG} should be short when the frequency of finding the school was high. Then the new CPUE (effort: distance·pole·day), $CPUE_{GPS}$, was calculated and compared with the classical CPUE, $CPUE_{classical}$, after normalized by mean and variance.

Results and Discussion

To investigate the vessel behavior at fishing and searching fishing ground, firstly the fishing trip trajectories from the GPS data were mapped with catch data from the field note. Figure 2 shows a trajectory of vessel “C” on August 4. On this day, fishing and searching fishing ground was started from 3:55 and finished at 14:03 before went to the port for catch landing. Fishing mostly continued for more than 5 minutes when some catches (e.g. from 4:17 to 6:30 in Fig. 2). While fishing time were less than about 5 minutes when no catch, only cast a bait (e.g. from 9:20 to 9:25 in Fig. 2), and the vessel quickly shifted to searching next fishing ground. When the vessel found and arrived at fishing ground, it rapidly slowed down (RM_{speed} < about 10 km/hr) and kept low speed with casting bait for fishing (upper line in Figure 3). After fishing it rapidly speeded up (RM_{speed} > 20 km/hr). RSD_{speed}, change rate of vessel speed, increased to more than 5 km/hr at the start and end of fishing (middle line in Figure 3). Using these characteristics of vessel speed, we will be able to extract "searching" and "fishing" automatically. $RSD_{\Delta bearing}$, change rate of vessel bearing, also had signals to determine the vessel behavior, which it was high (≥ about 10 °/sec) during "fishing" and low (< about 10 °/sec) during "searching" (lower line in Figure 3). And $RSD_{\Delta bearing}$ decreased exponentially with vessel speed obviously (Figure 4).

Daily D_{SFG} were calculated and considered as new fishing effort. Temporal variability in the fishing effort including D_{SFG}, E_{GPS} (distance·pole·day), was investigated. Figure 5 shows the time-series in E_{GPS} of vessel "D" as an example. The ratio between the maximum (4.43 on September 5) and minimum (1.72 on August 20) values of E_{GPS} was 2.6 and its coefficient of variation was 26%, while the classical fishing effort, $E_{classical}$ (pole·day), was constant. Then $CPUE_{GPS}$ was calculated using E_{GPS} and compared with $CPUE_{classcail}$ after normalized by mean and variance (Figure 6). Trends in two CPUEs look similar, however some differences were observed in them variations. For example, on August 5, $CPUE_{GPS}$ was fourth-largest in all $CPUE_{GPS}$ while $CPUE_{classical}$ was second-largest in all $CPUE_{classical}$ (Figure 6). $CPUE_{GSP}$ of all vessels were also compared with $CPUE_{classical}$ (Figure 7). There was a positive correlation between two CPUEs (r^2 = 0.90, $p < 0.0001$). The relationship was strong especially when $CPUE_{classical}$ was less than 1, however, its relationship was not shown when $CPUE_{classical}$ was from 1 to 3. Simply thinking, this was because $CPUE_{GPS}$ should be more influenced by variation in D_{SFG} (denominator of $CPUE_{GPS}$) when catch (numerator of CPUE) was higher (i.e. when $CPUE_{classical}$ was higher). It should be highly possible that $CPUE_{classical}$ is more overestimated or underestimated when catch is higher. Focusing on this point, we investigated the relationship between D_{SFG} and catch (Figure 8). Although there may be a bias of sample number, D_{SFG} tended to be narrowly distributed with catch. This would roughly make sense because D_{SFG} might decrease with catch which was positively correlated with fishing time (Figure 9) and a certain amount of D_{SFG} (> about 70 km in Fig. 8) is commonly needed for a certain amount of catch (about > 8 ton in Fig. 8). To examine its relationship quantitatively, the distributions of D_{SFG} were statistically processed at every 10 ton (Figure 10). The 95% upper prediction limits linearly decreased with catch, and the lower limit of that was smallest at a class from 10 to 20 ton and increased to the higher catch class. Using the probability distribution of D_{SFG}, the predicted distribution of CPUE was estimated roughly (Figure 11). When catch is more than 30 ton, although $CPUE_{GPS}$ cannot be statistically predicted because of only one sample, it is assumed that the lower limit of CPUE would not greatly decrease (e.g. one-half) because D_{SFG} would not greatly increase (e.g. twice) at high catch. On the contrary, it is assumed that the upper limit of CPUE would be higher at high catch because the lower D_{SFG} could well occur. Especially when catch is from 10 to 25, it would be highly significant to estimate $CPUE_{GPS}$ because the predicted $CPUE_{GPS}$ was distributed widely in Fig. 11. However, it is necessary that GPS research are more conducted in peak season for fishing because samples at more than 5 ton catch are particularly not enough to analyze statistically.

In the next step, we are planning to estimate the efforts for searching fishing ground from past data. We will use the data based on the onboard catch information exchange between vessels and fuel consumption as a function of “searching”, and recalculate the past CPUE based on the effort for searching fishing ground. And we will be able to estimate the near real-time spatial distribution of skipjack school density around the main fishing ground by extracting the “fishing” pattern of vessel behavior and its duration time using only GPS data.

Acknowledgement

We thank the crews of the Japanese pole and line vessels and the National offshore Tuna Fisheries Association of Japan for cooperating in the GPS research.

References

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Uosaki, K., Kiyofuji, H., Hashimoto, K., Okamoto, S. and Ogura, M. (2010) Recent status of Japanese skipjack fishery in the vicinity of Japan. WCPFC-SC6-2010, Nukualofa, Tonga. SA-WP-07.

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Table 1. Period of GPS research and the number of fishing day in each vessel.

Vessel ID	Start day	End day	No. of fishing day (No. of sample)
A	7/15/2010	7/28/2010	8
B	7/29/2010	7/30/2010	2
C	8/4/2010	8/5/2010	2
D	8/1/2010	9/8/2010	19
E	9/3/2010	9/8/2010	3
F	9/4/2010	10/28/2010	11
G	10/6/2010	11/6/2010	16

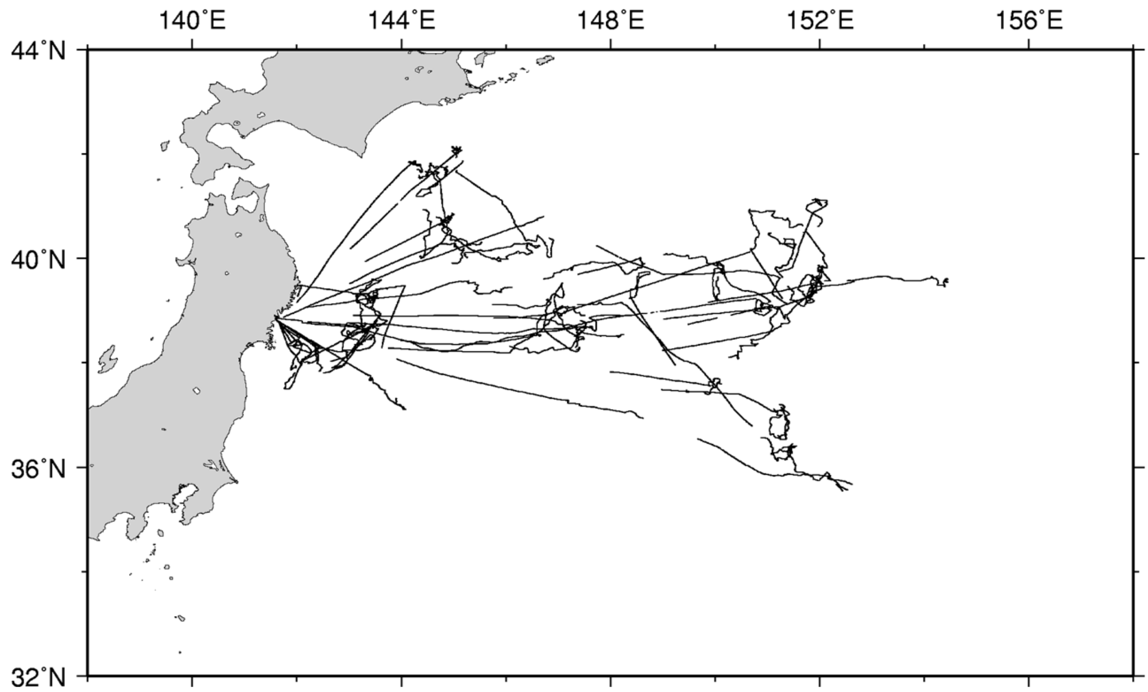

Figure 1. Fishing trip trajectory of all pole and line vessels in this document.

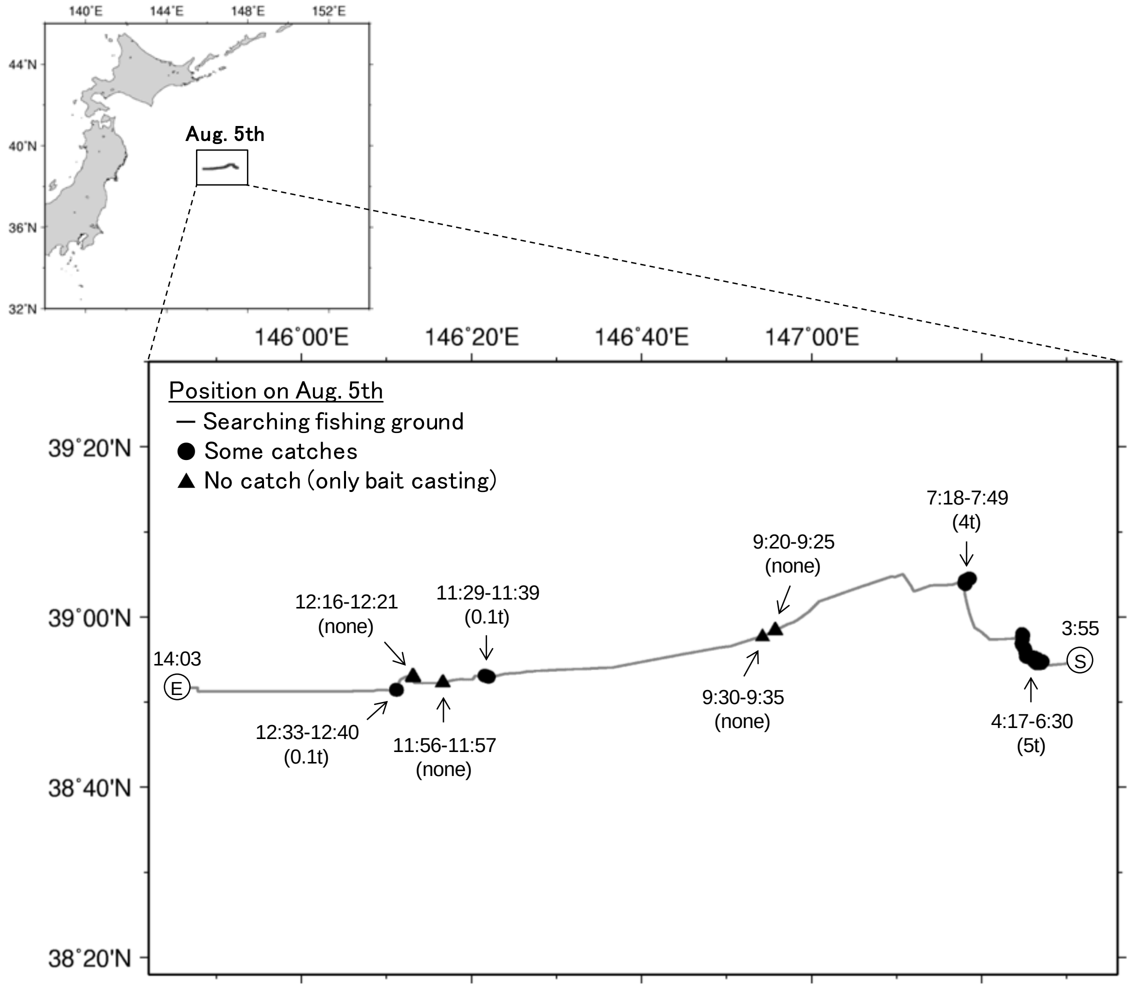

Figure 2. A fishing trip trajectory started from 3:55 and finished at 14:03 on August 5, 2010. Lines show the searching fishing ground. Circles indicate that there were some catches (ton) and triangles indicate no catch, only bait casting.

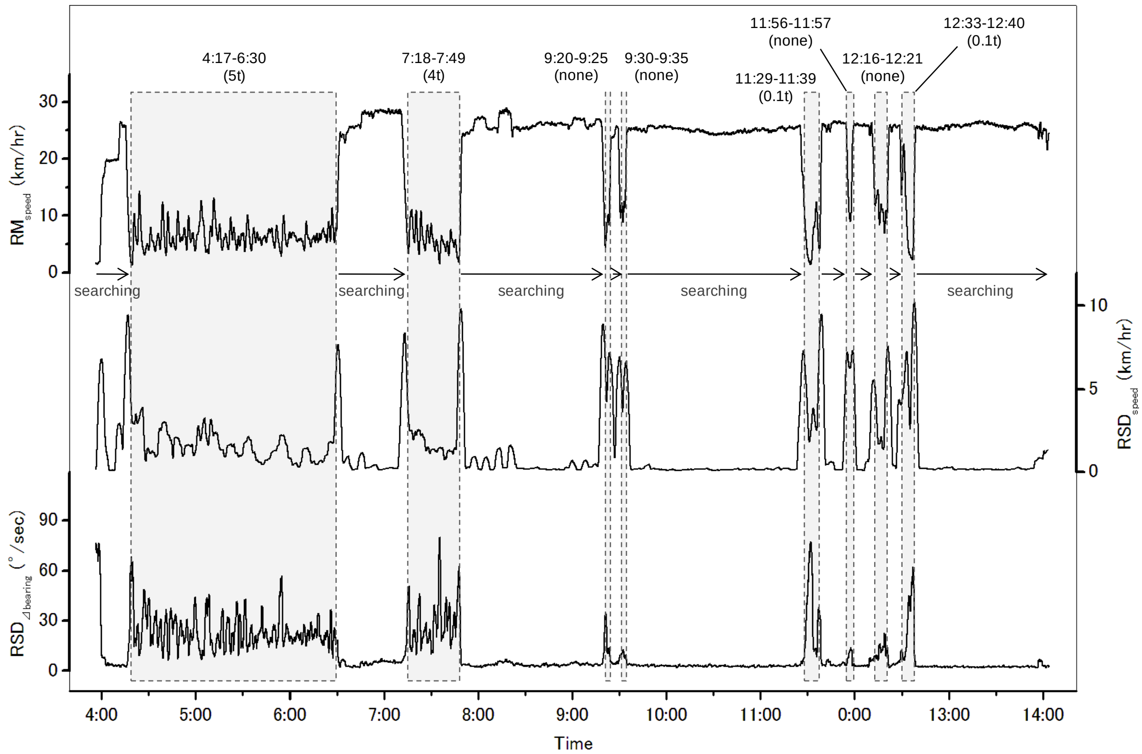

Figure 3. Time-series of the vessel behavior on August 5, 2010 (Fig. 2). Upper, middle and lower lines indicate the 1-minute running mean and 5-minute running standard deviation of vessel speed (RM_{speed} and RSD_{speed}), and 1-minute running standard deviation of bearing change per second ($RSD_{\Delta bearing}$), respectively. Shaded boxes and arrows indicate the time zones when fishing was operated regardless of catch, and when vessel was searching fishing ground, respectively.

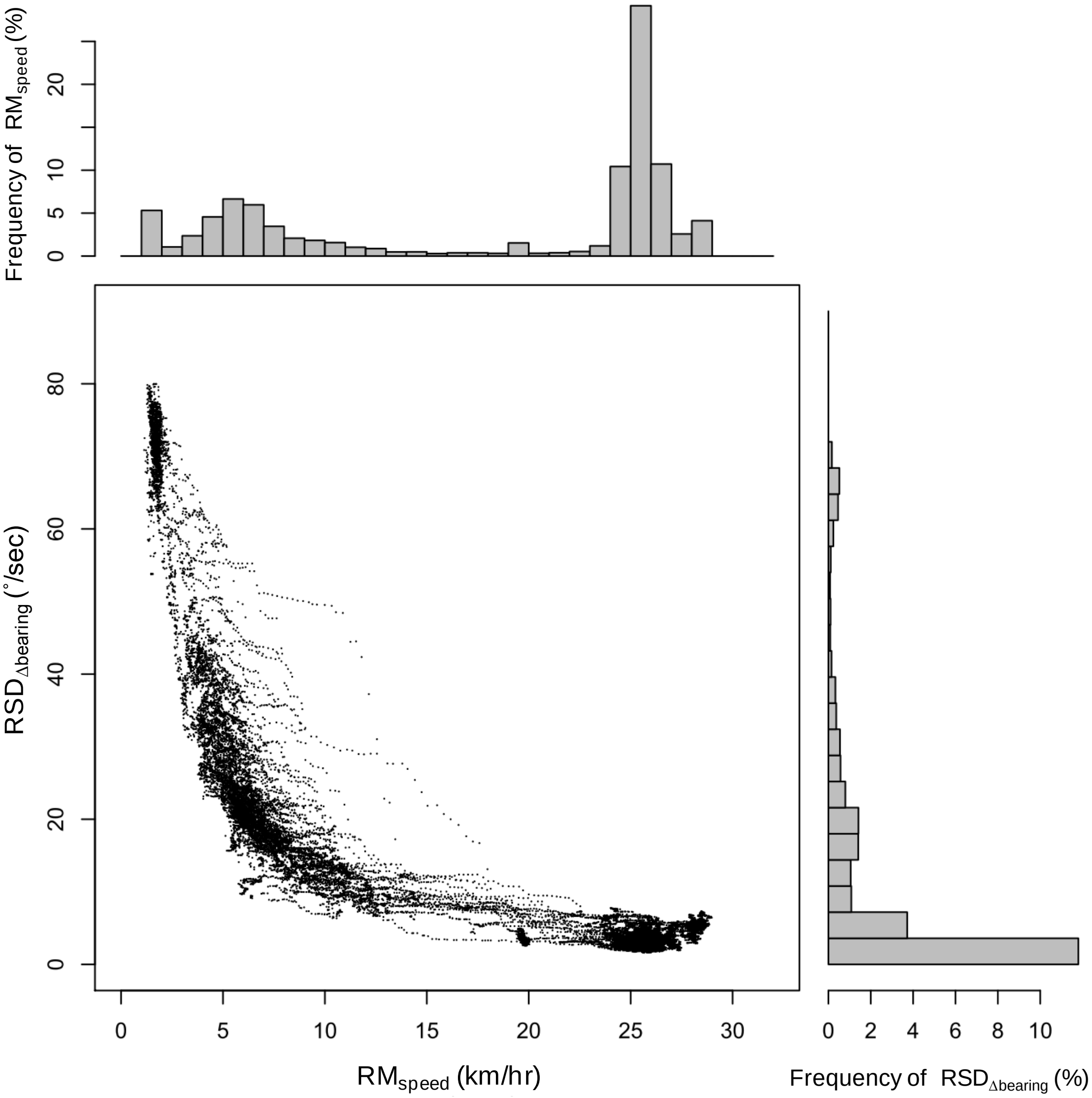

Figure 4. Relationship between the RM_{speed} and $RSD_{\Delta bearing}$ on August 5, 2010 (Fig. 2), with frequencies of those two parameters.

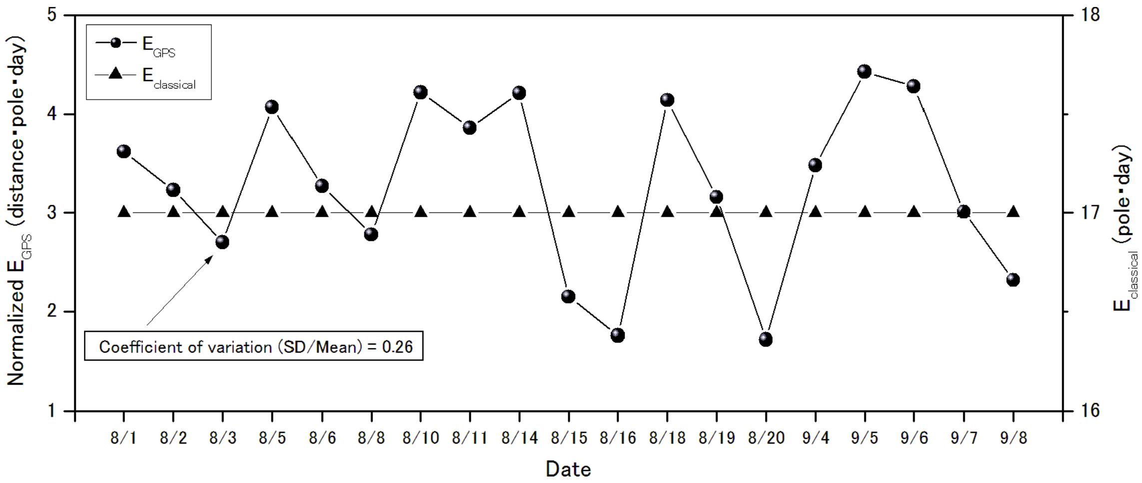

Figure 5. Comparison of temporal variability in the new fishing effort (distance·pole·day), E_{GPS}, and classical fishing effort (pole·day), $E_{classical}$, using vessel "D" data. E_{GPS} is normalized by mean and variance.

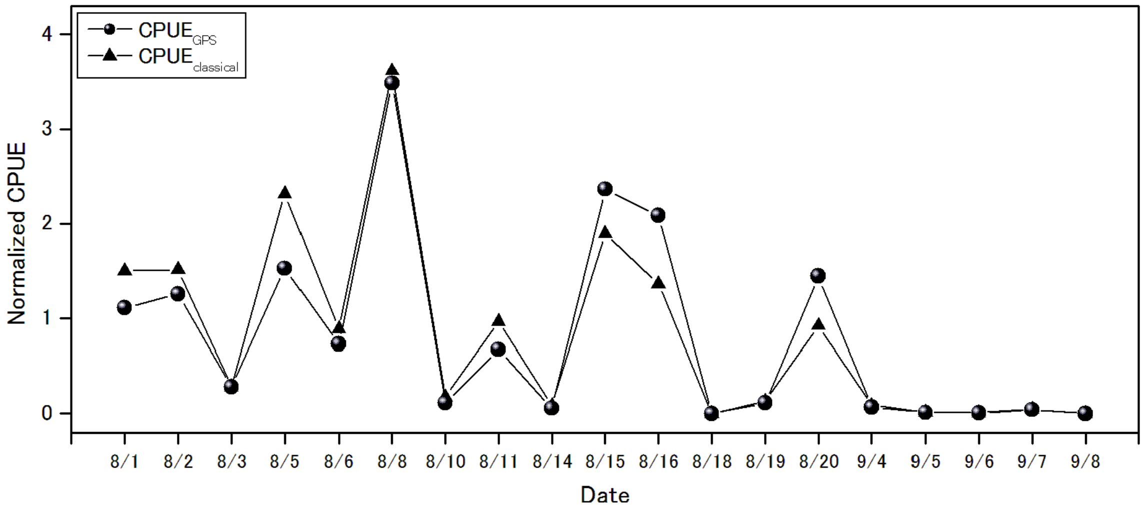

Figure 6. Comparison of trends in the new CPUE considered distance as fishing effort and classical CPUE, using one vessel's data. These CPUEs are normalized by mean and variance.

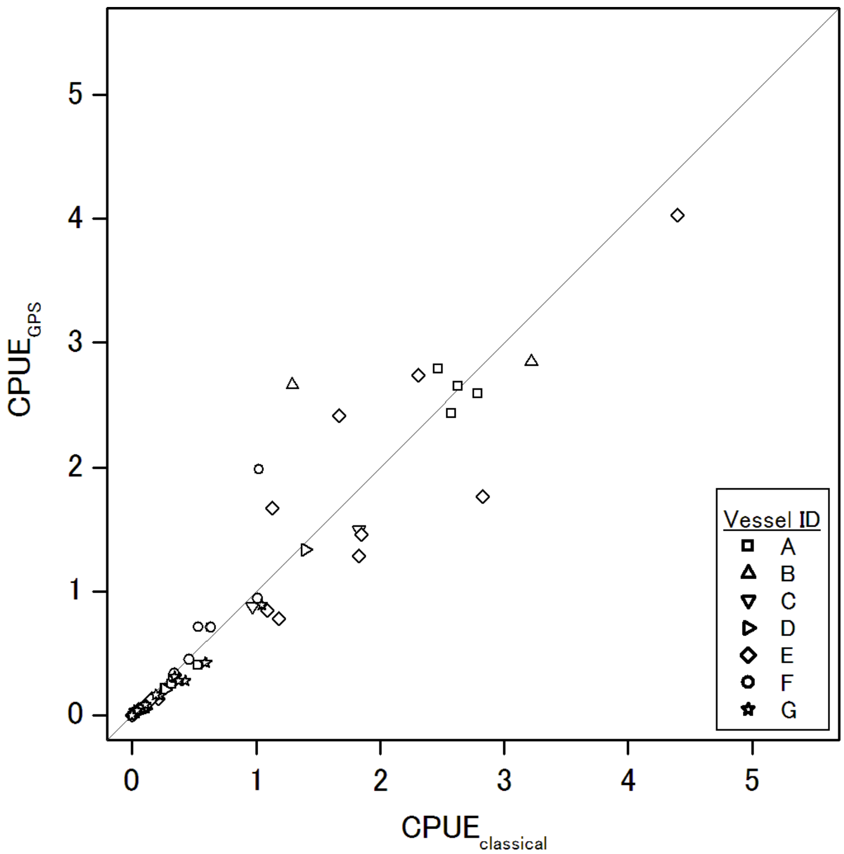

Figure 7. Comparison of normalized $CPUE_{classical}$ and $CPUE_{GPS}$ ($r^2 = 0.90$, $n = 61$, $p < 0.0001$). Linear line is the one-to-one line.

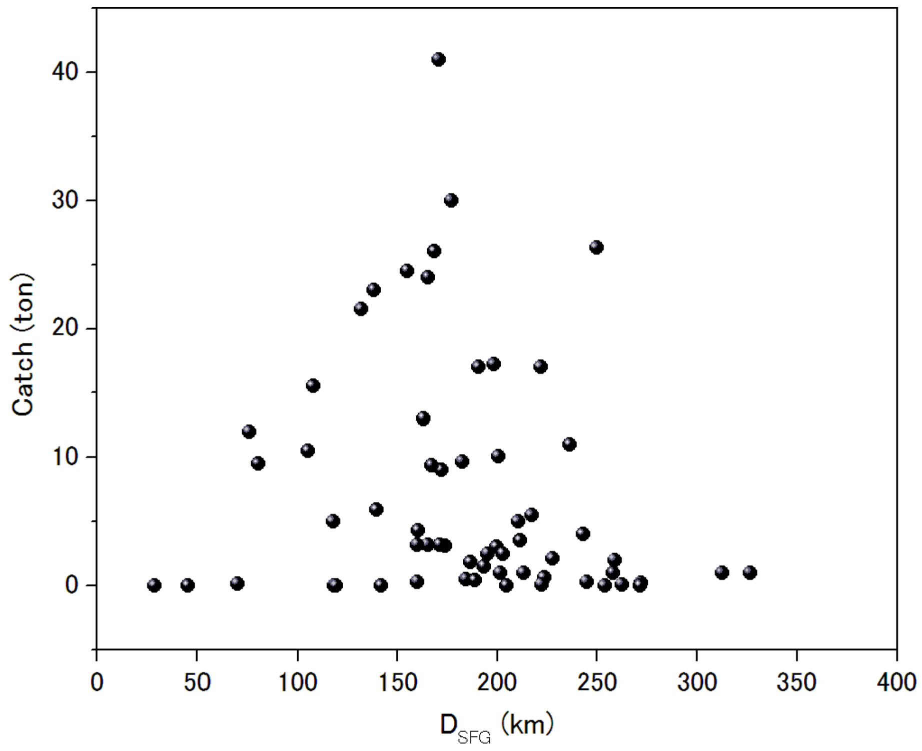

Figure 8. Scatter plot showing the relationship between daily D_{SFG} and catch.

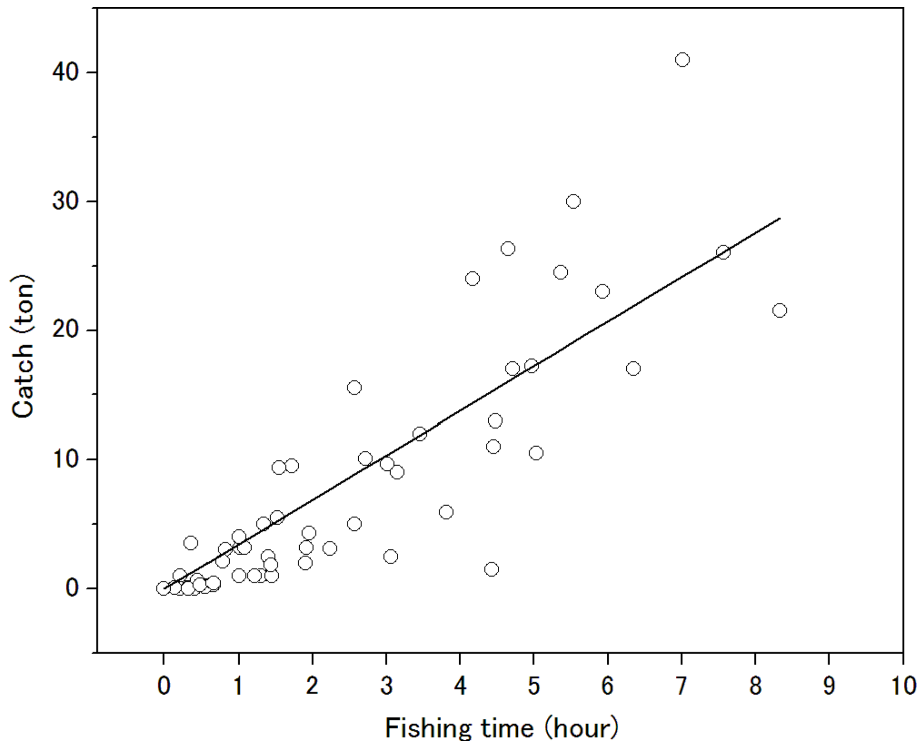

Figure 9. Linear regression describing the relationship between daily fishing time and catch ($r^2 = 0.75$, $n = 61$, $p < 0.0001$).

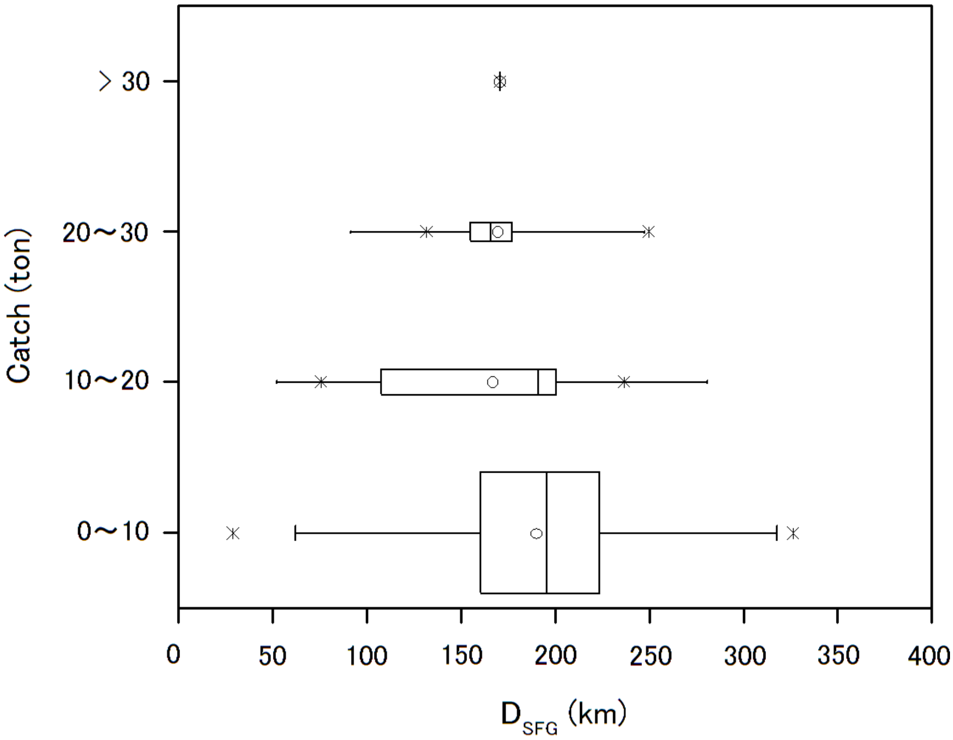

Figure 10. Box plot of daily D_{SFG} versus catch at every 10 ton. Boxes and vertical lines in the boxes show the 25th and 75th percentiles, and medians, respectively. Circles, asterisks and horizontal lines indicate means, 1st and 99th percentiles, and 95% prediction intervals, respectively. The width of the boxes shows the number of sample for the box.

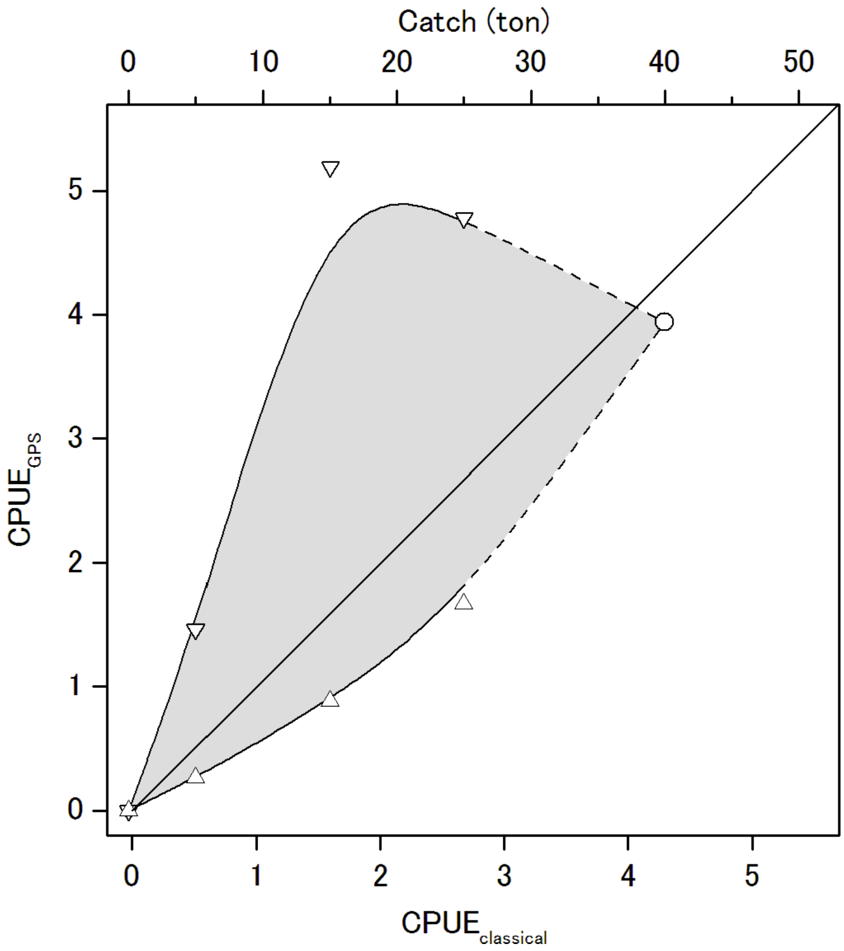

Figure 11. Predicted distribution of $CPUE_{GPS}$ against catch and $CPUE_{classical}$ estimated from the probability distribution of D_{SFG} in Fig. 10 (shaded zone). Upward and downward triangles show the catch and $CPUE_{classical}$ versus $CPUE_{GPS}$ at the 95% upper and lower prediction limits of D_{SFG}, respectively. Curve lines are B-spline curves. Circle indicates that sample is only one in the catch class (> 30 ton), and for that the curves connected to the circle are drawn by broken lines.