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Does extending days of searching fishing grounds and fishing operation add catch? Preliminary observations from the operations of Japanese coastal longline fisheires

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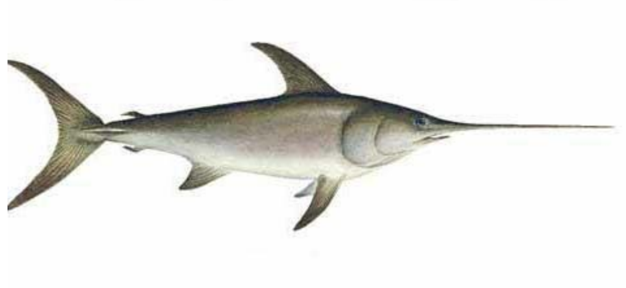

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Introduction

Decisions on the optimal length of fishing trips plays a significant role in the operation of distant-water fisheries. Under the spatial uncertainty of productive fishing grounds, additional days of searching for potential fishing grounds add opportunities of catch. On the contrary, they may also incur additional costs for searching activities, and deteriorate the market value of the fish already caught by losing its freshness premium, which is the amount of the market value lost due to an inverse effect on the premium lost for freshness.

By analyzing integrated landing and log-book data from the coastal longline fisheries based on Kesen-num, Japan (Figure 1), Ito *et al.,* (2009) demonstrated empirically that the freshness premium is a key determinant of the ex-vessel price of swordfish, but not for blue shark. They suggested that preserving the freshness of already caught swordfish by decreasing the days of a fishing trip would be one of the strategies to improve economic efficiency for these fishing vessels. In addition the recent dramatic increase in fuel prices suggests that the additional days in a fishing trip could add to operational costs. This fact encourages fishers to decrease the days for a fishing trip to maintain economic viability for these fishing vessels. Despite this rational to reduce the length of fishing trips, Ishimura and Yokawa (2009) found that these fishing vessels actually extended the length of their fishing trips from 27.7 days per trip in 1996 to 34.6 days per trip in 2006 (Table 1). Together with the fuel price increase, the share of fuel cost in the total annual cost per fishing vessel for the costal longline fisheries in Kesen-numa increased from 9 % in 1996 to 23% in 2006, and this results their hardships in financial operations (Figure 2). This contradictory fact would suggest that the economic rationality of incurring operational costs is not a dominated determinant of fishing operation decisions for the coastal longline fisheries in Kesen-numa.

We consider three possible reasons for this contradictory evidence. First, despite of the loss in the freshness premium and fuel cost, it can be profitable to extend fishing trips to explore additional fishing grounds. Second, fishers can benefit if marginal productivity, catch per unit effort (CPUE), in this case, is increasing in the days of fishing activities. Finally, fishers may simply fail to optimize the trip days to maximize the profits because of the opportunistic nature of marine capture fisheries, which often motivates fishers to extend the duration of searching fishing grounds and fishing operations to gain additional catch.

This study tests the first two hypotheses using log-book data from the coastal longline fisheries based in Kesen-numa in Japan, focusing on swordfish (*Xiphias gladius*) and blue shark (*Prionace glauca*). The following section describes the longline fishery in Kesen-numa. Secondly, we describe data sources. The third section shows descriptive evidence of our findings, and we conclude at the final section.

Background: Coastal longline fishery in Kesen-numa

This study focuses on the coastal longline fisheries ("*Kinkai Maguro Haenawa*") which accounted for about 30% of the 2007 total gross sales of fishery landings in Kesen-numa City, Japan. In 2006, 24 vessels were registered in this category, with 23 being active. From 2004 - 2007, the average total annual gross sales in this category was 3,064,944 USD per vessel. Swordfish landings at Kesen-numa represent 80% of the Japanese swordfish market, and blue shark landings at Kesen-numa represent 90% of the Japanese blue shark market (Kesen-numa City, 2005). While the expansion of the globalization for the seafood market is prominent, these dominations f two fish species in Kesen-numa market uniquely form a closed market structure for swordfish and blue shark, This means both swordfish and blue shark ex-vessel prices are dominantly determined by landings of these two species at Kesen-numa respectively. The 2004-2007 average gross sales from swordfish and blue shark consisted of 47% and 39% of the annual gross sales per a coastal longline vessel, respectively (Table 2). The remaining gross revenue from landings for the costal longline fisheries in Kesen-numa came from a variety of tuna species (e.g., bigeye tuna, northern blue fin tuna). The sum of the swordfish and blue shark landing values, therefore, dominate with their total landing value being 85% of average annual gross sales between 2004-2007 (Table 2). This fact justifies our focus on these two species for the analysis performed in this study.

While swordfish products are limited to direct human consumption (e.g., sashimi or fillet for steak or other cooking), blue shark products have a variety of uses. Fins go to a high value food market in China and Japan. After being processed in Kesen-numa, skins are exported to Italy for leather products. Meats go to surimi. Bones are used for raw materials for medicine and cosmetics. There is almost no waste from the blue shark harvest.

Data

This study uses the logbook data of coastal longline fishing vessels registered with the Kesen-numa City from 1995 – 2006, compiled by the Fishery Research Agency of Japan. The logbooks include species-specific harvest data for tuna (e.g., bigeye, blue marlin), tuna-like species (e.g., swordfish), and sharks (e.g., blue shark), and operational descriptions (e.g., number of hooks, gear configurations, locations) for each operational day.

Empirical Analysis

Consider a simple profit maximization model of coastal longline fisheries. Assume that their catch (Q), cost (C), and the market price of the fish (P) are the function of days for a fishing trip (d), which is an aggregated days for searching fishing grounds, fishing operations and return to port. Then, assuming the concavity of the profit function for coastal longline fisheries, the fisher's optimization problem with respect to the trip length is;

(1) $\underset{d}{Max} \quad \pi = P_s(d) \cdot Q_s(d) + P_B(d) \cdot Q_B(d) - C(d)$

This model assumes aggregated production and price. In the auctions at Kesen-numa, only one or two coastal longline vessel are allowed to land their harvest at Kesen-numa port. The reveled information on each fish at the auctions is limited to a location of fishing grounds. The information on the day individual fish caught is not given to buyers who bid by price on swordfish and blue shark. Although buyers can estimate the freshness premium by the distance to the locations where the fish was caught, for simplification, here we assume the aggregated and homogenized catch over fishing days is the same as the location where the fish were caught. The first order condition can be expressed as follows;

(2-1) $$P_S \cdot \frac{\partial Q_S}{\partial d} + Q_S \cdot \frac{\partial P_S}{\partial d} + P_B \cdot \frac{\partial Q_B}{\partial d} + Q_B \cdot \frac{\partial P_B}{\partial d} = \frac{\partial C}{\partial d}$$

The marginal cost of operation can be constant for aggregated fishing activities for a trip. Ito *et al.,*(2009) estimated the freshness premium of swordfish and blue shark, concluding there is a freshness premium for swordfish, however, the price of blue shark does not indicate correlation with freshness premium. Equation 2-1 is now;

(2-2) $$P_S \cdot \frac{\partial Q_S}{\partial d} + Q_S \cdot \frac{\partial P_S}{\partial d} + P_B \cdot \frac{\partial Q_B}{\partial d} + Q_B \cdot P_B = C$$

Under the assumption of convexity, the first order condition of Equation 2-2 suggests that the conventional relationship between marginal price and marginal cost with respect to *d.* The marginal productivity by extending the operation days, $\frac{\partial Q}{\partial d}$, is expected to be positive, but the second derivative, $\frac{\partial^2 Q}{\partial d^2}$, can be either positive or negative. The term $\frac{\partial P}{\partial d}$ shows how an extra operation day affects the ex-vessel price of the catch in the market, which includes the effect of the freshness premium, essentially, the amount of the market value lost due to an inverse effect on the premium lost for freshness, discussed in Ito *et al.,* (2009). Again Ito *et al.,* (2009) found that the freshness premium of swordfish is negatively significant, $\frac{\partial P_S}{\partial d} < 0$. Note that the price elasticity of swordfish and blue shark against to the amount of supply are not significant mostly due to landing control at the Kesen-numa port. If the second derivative of catch is positive, $\frac{\partial^2 Q}{\partial d^2} > 0$, extending trip days may be profitable even if the marginal price change is negative, $\frac{\partial P_S}{\partial d} < 0$, due to the freshness premium. As a preliminary analysis, this study focus on finding empirical evidence of the relationship between the catch by effort at fishing grounds and operation days, $\frac{\partial Q}{\partial d}$

Method

A fishing trip of coastal longline fisheries can be divided into three parts (Figure 2); *Phase I*) days of searching for fishing grounds, *phase II*) days in fishing operation at the fishing grounds, and *phase III*) days spent returning to port after fishing. The coastal longline fishing vessels can spend several days searching a fishing ground in the Pacific Ocean, carry fishing activities for multiple days around a fishing ground, then return to the Kesen-numa for landing catches. The production of a fishing trip can be defined by the first and second parts; searching and the fishing operation.

First, this study calculates the average catch per unit effort (CPUE: catch per hook) by fish trips to test how extending days for searching fishing grounds can affect the marginal productivity, $\frac{\partial Q}{\partial d}$, defined as CPUE. For each species, swordfish and blue shark, and for each trip i ,we calculate the total catch (kg) divided by the number of hooks used for a fishing trip, and compute the average CPUE for j days of searching for fishing grounds, fish , w (swordfish or blue shark), $\theta_{s,w}$, as follows;

(3) $$\theta_{s,w} = \frac{1}{k_j} \cdot \sum_{i \in j} \frac{1}{d_{o,i}} \frac{h_{i,w}}{E_i}$$

k_j is the number of the data which has j days of searching for fishing grounds. $d_{o,i}$ is the days for fishing activities given data set i. h_i is catch and E_i is efforts (hooks). Note that this average CPUE does not standardize the effects of days (length) for fishing operations.

Second, we study the average CPUE given n-th days of the fishing operation to test whether extending operation days increases the marginal productivity, $\frac{\partial Q}{\partial d}$. In addition to search days, the fishers need to determine the number of days for fishing operations at the fishing grounds. For each fishing trip, starting with the 1st day of fishing operation for the trip, we define the 2nd, the 3rd, and the n-th date of the fishing operation. For example, for the 2nd day of the operation, we calculate CPUE for the 2nd day of the operation for each trip, and take the average among these values.

(4) $$\theta_{o,w} = \frac{1}{k_n} \cdot \sum_{i \in n} \frac{h_{i,w}}{E_i}$$

Finally, to see the effect of adding days of searching fishing grounds and fishing operations for CPUE, this study employ two linear regression analysis.

(5) $$\theta_w = f(d_s, d_o)$$

A log-linear functional form is assumed for *f* and the following equation is separately estimated for each fish type by the method of ordinary least squares (OLS).

(6) $$\ln\theta_w = \alpha \ln d_s + \beta \ln d_o + \varepsilon$$

Result

Figure *4-a* shows the total days of a fishing trip, which ranges from less than 10 to over 50 days, having a median value of 35 days (mean=33.69). Figure *4-b* shows the days for searching for fishing grounds per trip; this study defines search days for as the days between the departure date and the first fishing operation day. The median is 6 days (mean=6.81). Figure *4-c* presents the fishing operation days in a trip. The median is 20 days (mean=19.97) and most vessels operate less than 30 days in a trip. Some vessels start fishing right after the departure while others spend more than 10 days to searching and reaching fishing grounds. Figure *4-d* presents the days for returning the port per trip. The median is 6 days (mean=6.6). The days of searching fishing grounds and retuning a port are the almost same. This suggests that fishers may predetermine potential location for fishing grounds before depart from a port rather than wondering around the Pacific Ocean.

Figure *5-a* shows the smooth mean and 95% confidence intervals of CPUE given search days for swordfish. The CPUE slightly increases with the duration of search days, up to four days. After four days of searching, an additional search does not improve the productivity. In fact, the productivity shapely decreases with extended days of searching. Figure *5-b* shows the same statistics for blue shark. The marginal productivity increases with more search days added up to four days, but it starts moderately declining after that then show sudden drops as the days for searching exceeds eight days.

Figure 6-*a* shows the smooth mean and 95% confidence intervals of CPUE for swordfish given the *n*-th day of the fishing operation. The CPUE gradually increases with operation

days and starts to decrease when the days of fishing operation exceeds a cutoff date around 23. Figure *6-b* shows the same statistics for blue shark. The marginal productivity increases with operation days, but starts to decline after the operation days exceed about 28. The difference of increase and decrease of CPUE given *n*-th day of the fishing operation for swordfish and blue shark may be the result of the different schooling behavior of swordfish and blue shark. A schooling behavior of swordfish would be scatter, then additional days of operations increase the marginal productivity by fishing activities moving toward the hot spot for swordfish. A schooling behavior of blue shark would be tight, then additional days of operations suddenly decrease the marginal productivity.

The first two columns in Table 3 show statistically estimated relationships between swordfish/ blue shark CPUE and the days of searching for fishing grounds and fishing operations. Both species suggested that increase searching days decrease CPUE and increase days for fishing operations increase CPUE. This maybe the result of linear fit of OLS. For the days of searching for fishing grounds, the models fit to the decline trend after four days. Further considerations on the model forms (*e.g.,* polynomial) are necessary.

Conclusion and Further Issues

For both swordfish and blue shark, our empirical findings show that, although extending search days may improve productivity up to four days, searching for more than four days does not increase productivity. This finding contradicts the fishers' choice of search days – average days for searching (Figure *2-b*). The fishers tend to spend six days or more searching, although it may not improve their productivity. While the marginal productivity of swordfish shapely drops after more than four days searching, the productivity of blue shark stays high from 4 to 7 days. Further considerations are necessary to implication of these heterogeneous trends.

Our analysis shows that fishers perform better in the later days of their fishing operation. This is probably because they can find fish schools by learning-by-doing within the fishing ground they find. Note that most of the trips have operation days less than 30, with the median 20. Therefore, some fishers have a potential to improve their productivity by increasing days for fishing operation.

This paper tests two hypotheses: whether extending days of searching for fishing ground increases marginal productivity, and whether extending operation days improves productivity. These were tested by using the logbook data from a distant-water longline fishery based on Kesen-numa in Japan, focusing on swordfish (*Xiphias gladius*) and blue shark (*Prionace glauca*).

Our preliminary findings may reject the first hypothesis and support the second hypothesis: extending days searching first increases the productivity, but the marginal productivity with respect to the trip days quickly starts to decline at a certain cutoff point; on the other hand, extending fishing operation days almost certainly increases the productivity.

The next step of this research project is to 1) reveal the cross relationships of the productivity and days for searching fishing grounds and fishing operations at fishing grounds; 2) include the information on the production cost and the trade-off regarding the freshness premium by adding fishing opportunities in searching and fishing operations. The accounting data, including wages and fuel costs, would allow us to determine whether the fishers optimally choose the duration of their trip, search, and operation, taking into account the benefits from the productivity gains, as well as the losses from the freshness premium.

References:

K. Ito, G.Ishimura, K. Yokawa and Ishida, 2009, “The market value of freshness: Preliminary evidences from swordfish and blue shark market for a pelagic longline fishery,” International Scientific Committee for Tuna and Tuna like species in North Pacific (ISC)/09/BILLWG-1/12

City of Kensen-numa 2005. Recommendations for the costal longline fishery operations in Kesen-numa (*Kesen-numa kinaki haenawa ryou heno teigen*) *in Japaese.*

Table 1: Average days (total) and fishing operation days per trip for the coastal longline fisheries in Kesen-numa, Japan.

Year	Average days per trip	Average operation days per trip
1994	27.7	17.4
1995	29.3	18.3
1996	30.3	18.3
1997	30.4	18.2
1998	30.4	18.0
1999	31.1	18.6
2000	33.0	20.2
2001	35.3	20.7
2002	35.7	20.8
2003	34.3	20.0
2004	32.4	19.3
2005	34.0	20.0
2006	34.6	20.6

Table 2: Annual average sales for the coastal longline fisheries in Kesen-numa.

		2004	2005	2006	2007
Bluefin tuna	Landing(MT)	10.9	7.8	3.7	2.8
	Unit ex-vessel price (1000 USD/MT)	19.2	20.9	17.1	16.8
	Landing value (1000 USD)	209.9	161.7	63.8	47.3
	Species landing share in the value (%)	0.0	0.0	0.0	0.0
Bigeye	Landing(MT)	100.5	59.8	40.6	103.7
	Unit ex-vessel price (USD/MT)	13.4	16.6	18.4	15.4
	Landing value (1000 USD)	1,346.5	989.4	745.4	1,596.1
	Species landing share in the value (%)	0.0	0.0	0.0	0.0
Small bigeye	Landing (MT)	12.6	5.5	2.3	5.6
	Unit ex-vessel price (1000 USD/MT)	5.7	6.6	5.9	8.0
	Landing value (1000 USD)	1,343.2	840.2	282.2	4,152.9
	Species landing share in the value (%)	0.0	0.0	0.0	0.1
Swordfish	Landing (MT)	2,010.5	1,748.2	1,726.4	2,223.3
	Unit ex-vessel price (1000 USD/MT)	7.2	8.5	6.9	8.2
	Landing value (1000 USD)	14,495.0	14,825.0	11,927.3	18,222.7
	Species landing share in the value (%)	**0.47**	**0.46**	**0.49**	**0.49**
Striped marlin	Landing (MT)	58.5	66.3	59.6	48.4
	Unit ex-vessel price (1000 USD/MT)	4.8	5.3	4.0	4.7
	Landing value (1000 USD)	279.9	349.1	237.4	226.7
	Species landing share in the value (%)	0.0	0.0	0.0	0.0
Albacore	Landing (MT)	12.8	13.8	7.3	13.0
	Unit ex-vessel price (1000 USD/MT)	2.9	3.0	2.8	2.3
	Landing value (1000 USD)	510.6	595.2	298.6	319.7
	Species landing share in the value (%)	0.0	0.0	0.0	0.0
Blue shark	Landing (MT)	8,278.6	8,774.2	6,148.8	5,785.2
	Unit ex-vessel price (1000 USD/MT)	1.5	1.7	1.8	2.1
	Landing value (1000 USD)	12,591.4	14,673.8	10,804.3	12,255.5
	Species landing share in the value (%)	**0.41**	**0.45**	**0.44**	**0.33**
Total	Landing (MT)	11,770.7	12,182.5	8,897.1	9,458.0
	Landing value (1000 USD)	32,759.8	35,218.2	25,447.9	35,787.1
Swordfish+Blue shark	Landing value (1000 USD)	27,086.4	29,498.8	22,731.6	30,478.2
	Species landing share in the value (%)	**0.88**	**0.91**	**0.93**	**0.83**

Table 3: estimated CPUE from the days of searching for fishing grounds and fishing operations.

log(days)	Swordfish log(CPUE)	Swordfish log(CPUE)	Blue Shark log(CPUE)	Blue Shark log(CPUE)
Days for searching fishing grounds	-1.52***	-	-1.58***-	-
	(0.048)	-	(0.067)	-
Days for fishing operation	-	2.66***	-	3.48***
	-	(0.067)	-	(0.091)

Note: Dependent variable, CPUE, is the log of the kg/hook. Statistical significance:1% ***, 5% **, and 10% *

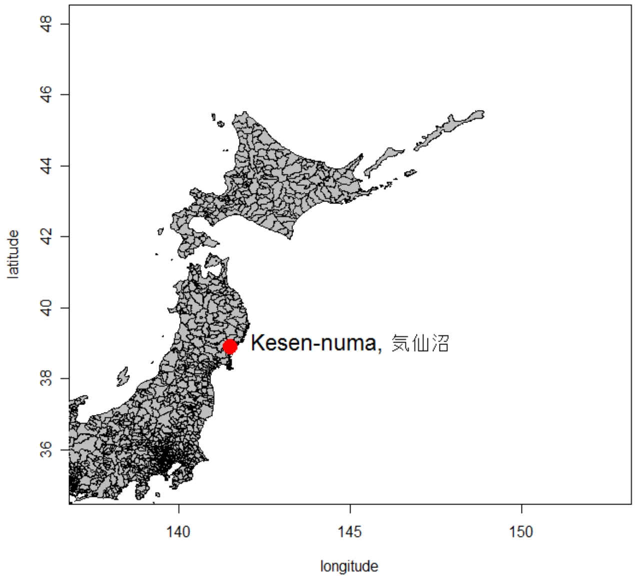
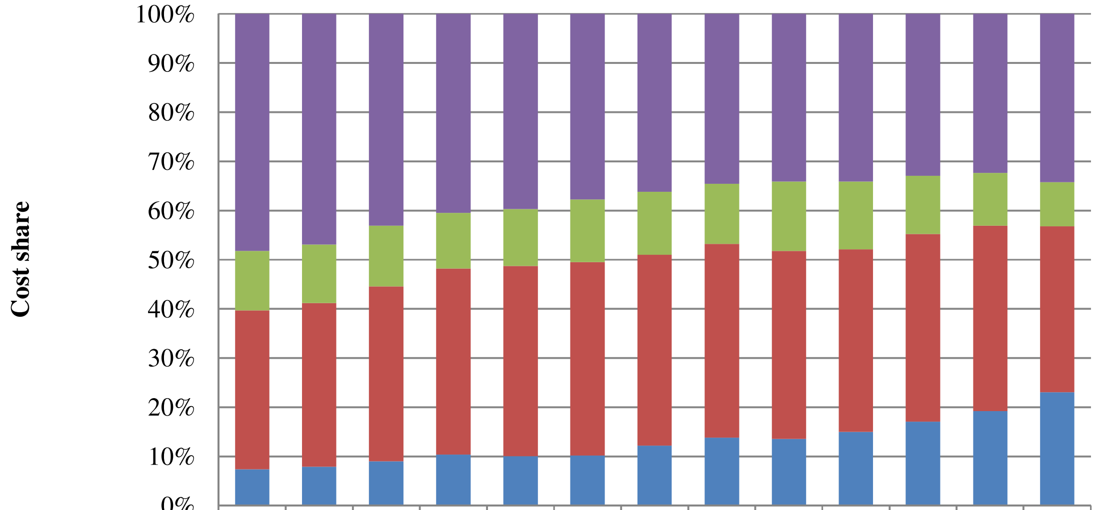


Figure 1: Location of Kesen-numa City



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Other cost (%)	0.48	0.47	0.43	0.41	0.40	0.38	0.36	0.35	0.34	0.34	0.33	0.32	0.34
Bait cost (%)	0.12	0.12	0.12	0.11	0.12	0.13	0.13	0.12	0.14	0.14	0.12	0.11	0.09
Labour cost (%)	0.32	0.33	0.36	0.38	0.39	0.39	0.39	0.39	0.38	0.37	0.38	0.38	0.34
Fuel cost (%)	0.07	0.08	0.09	0.10	0.10	0.10	0.12	0.14	0.14	0.15	0.17	0.19	0.23

Figure 2: Annual average accounting share per fishing vessel for the coastal longline fisheries in Kesen-numa.

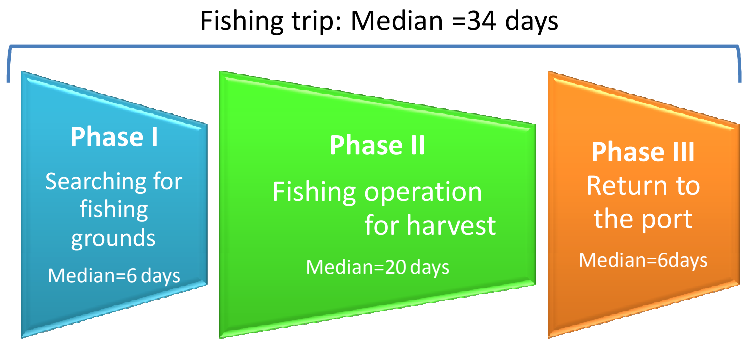
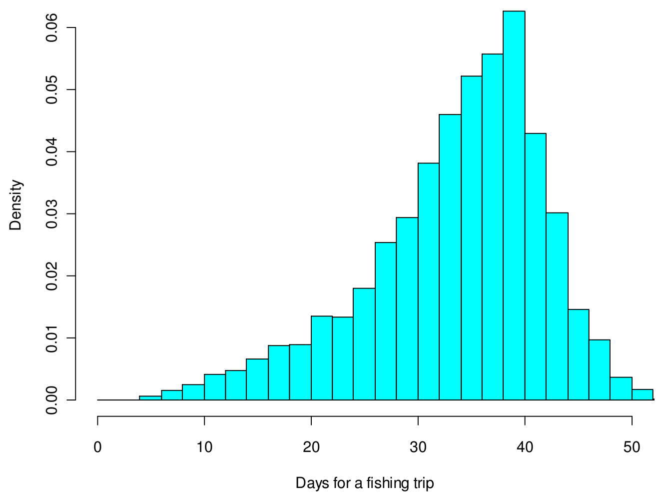


Figure 3: three phases of a fishing trip for the costal longline fisheries in Kesen-numa.

4-a) the histogram of the total days in a fishing trip with its median value = 35 days and average=33.69 days.



4-b) the histogram of days for searching fishing grounds per trip with its median value = 6 days and average=6.81 days.

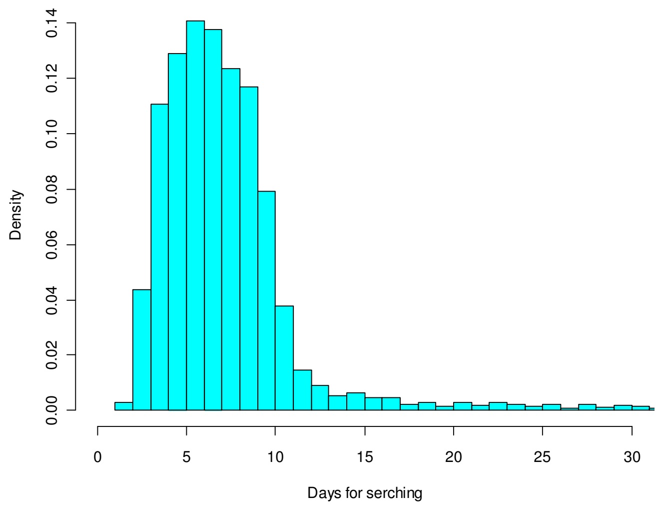
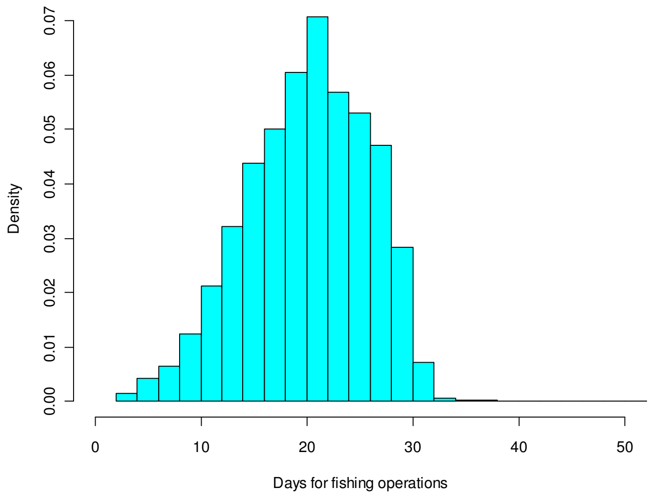


Figure 4-*a* and *b*: Histograms of the total days of a fishing trip, and days of searching for fishing grounds per trip. Total days for a fishing trip are defined as "departure date" – "arrival date" + 1. Days for searching for fishing grounds are defined as "first date of the operation" – "departure date" + 1.

4-c) the histogram of days of fishing operation per trip with its median value = 20 days and average =19.97 days.



4-d) the histogram of days for returning the port per trip with its median value = 6 days and average 6.6 days.

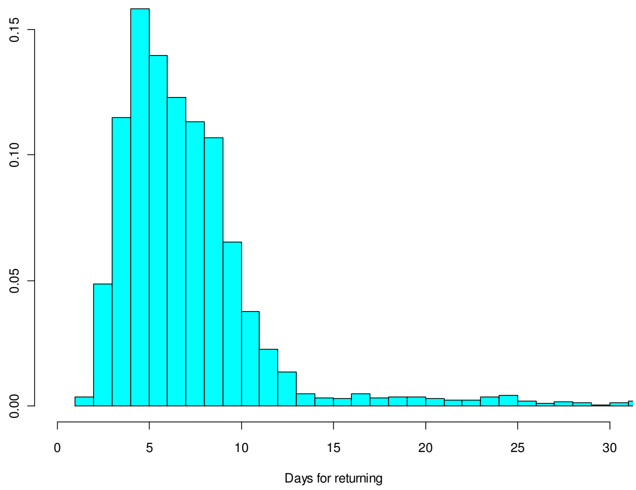
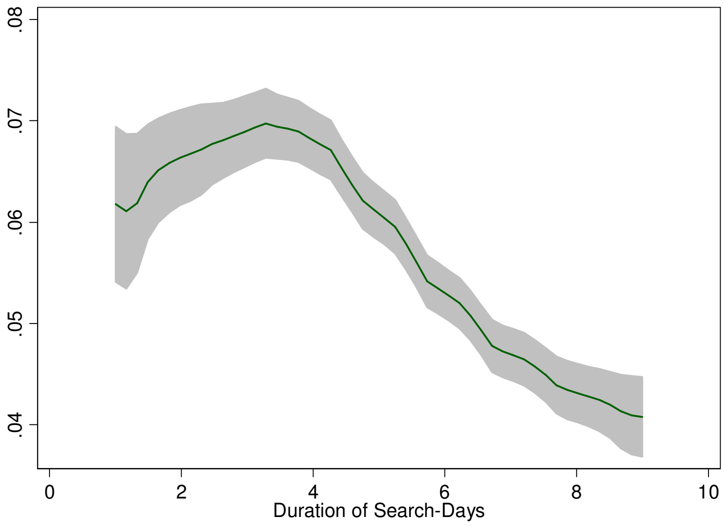


Figure 4-*c* and *d*: Histogram of days of fishing operations per trip and return to the port per trip.

5-a) Average CPUE of swordfish over days of fishing operations against days of searching fishing grounds



5-b) Average CPUE of blue shark over days of fishing operations against days of searching fishing grounds

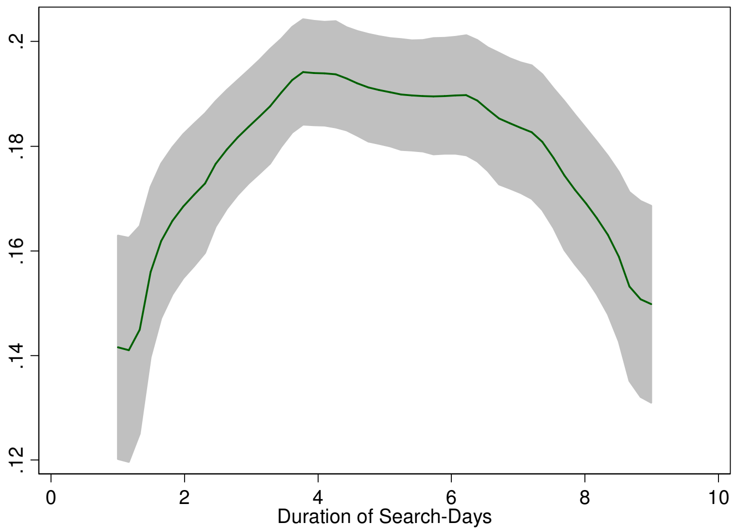
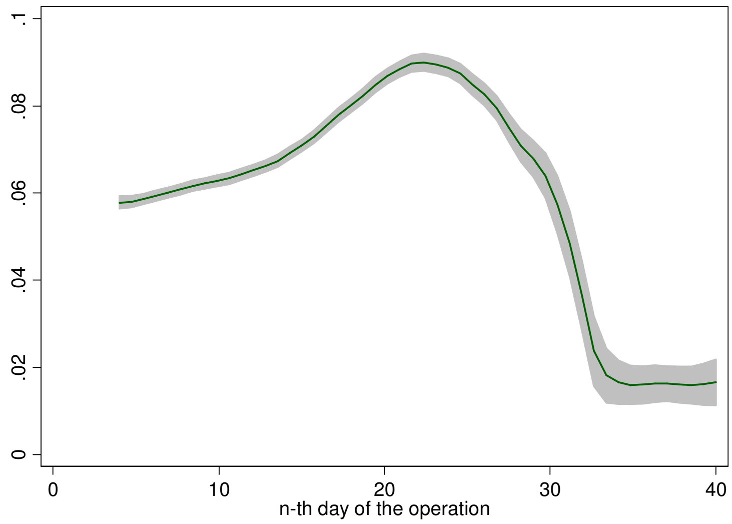


Figure 5: Average CPUE of swordfish (top) and blue shark (bottom) over days of fishing operations against days of searching fishing grounds. The graphs show smoothed mean and 95% confidence intervals of the catch (kg) / hooks for swordfish (top) and blue shark (bottom).

6-*a*) Average CPUE of swordfish given *n*-th day of fishing operation



6-*b*) Average CPUE of blue shark given *n*-th day of fishing operation

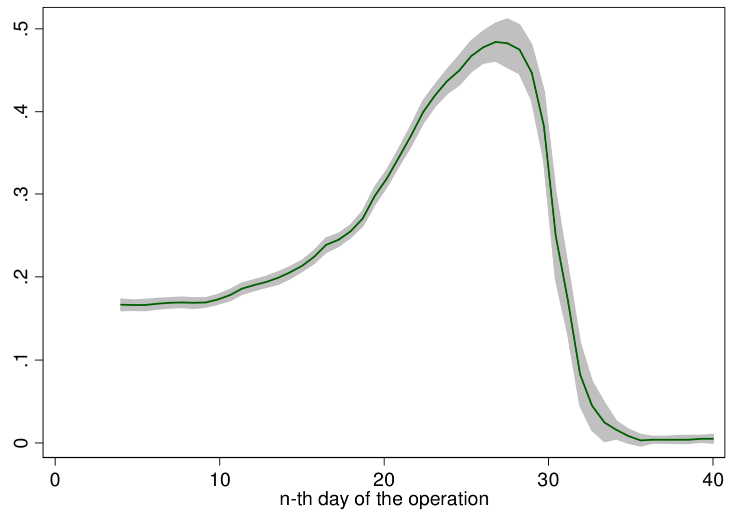


Figure 6: Average CPUE of swordfish (top) and blue shark (bottom) given *n*-th day of fishing operation. The graphs show smoothed mean and 95% confidence intervals of the catch (kg) / hooks for swordfish (top) and blue shark (bottom) for *n*-th day of the fishing operations.

Appendixes: the data distribution on *n*-th day fishing operation.