Efficient spatial allocation of fishing effort and partnership arrangement:
A managerial solution to overcome rising fuel cost and other hardships
for small-scale fisheries

Hirotsugu Uchida
Department of Environmental and Natural Resource Economics
University of Rhode Island
217 Coastal Institute, 1 Greenhouse Rd
Kingston, RI 02881 USA
uchida@uri.edu

August 24, 2007

PRELIMINARY DRAFT
DO NOT CITE WITHOUT PERMISSION FROM THE AUTHOR

Prepared for ICES Annual Science Conference 2007, held at Helsinki, Finland, on September 17-21, 2007.

Copyright 2007 by Hirotsugu Uchida.
Abstract

Adverse conditions hit particularly hard on small-scale fisheries and fishermen involved. Recent sharp rise in fuel cost is battering such fisheries already struggling from declining stocks and harvests. The threat of economical sustainability can potentially undermine the entire effort for achieving sustainable fisheries, and for this reason energy saving measures that can be adopted and affordable to small-scale fisheries are in urgent need. With this in mind, this paper investigates the management measures adopted by a group of coastal fishing communities in Hokkaido, Japan, targeting walleye pollack (*Theragra chalcogramma*). Faced with low stock level and surging fuel price, this group adopted a radical managerial measure that can be referred as “partnership arrangement.” Rather than permitting individualistic operations, as was the status quo, they adopted group-wide joint operations in aim to maximize the group’s aggregated revenue, and each participant receives a predetermined share of the total revenue. This allowed the group to adopt various cost saving measures, one being a spatially efficient allocation of vessels across the fishing grounds so as to minimize the vessels’ traveling distance. Last year their harvest volume declined but the profit increased slightly; a step forward to achieving sustainable fishery. While social characteristics are influential factors in community-based fishery management, the key success-factors and management objectives in this fishery are purely economical and thus universal. This paper shows lessons that can be learned from this fishery for achieving sustainable fisheries with rising costs, and the role of scientific information during the development phase of this management regime.
1. Introduction

Adverse conditions hit particularly hard on small-scale fisheries and fishermen involved. Recent sharp rise in fuel cost is battering such fisheries already struggling from declining stocks and harvests. The threat of economical sustainability can potentially undermine the entire effort for achieving sustainable fisheries. For this reason energy saving measures that can be adopted and affordable to small-scale fisheries are in urgent need.

The walleye pollack (Theragra chalcogramma) fishery in Hokkaido, northern Japan, is no exception. The retail gasoline price in the region has risen from 103 yen per liter in early 2000 to 156 yen per liter in late 2006, or roughly 50% increase (Oil Information Center 2007). Fuel cost constitutes about 18% of total cost for typical small-scale fishing household in Japan (Ministry of Agriculture, Forestry, and Fisheries 2005), and thus such increase in gas price is nontrivial. In the meantime, the stock level of walleye pollack in northern seas of Japan is estimated to be low and continues to decline (Uchida and Watanobe, forthcoming).

The Japanese government is taking some actions to mitigate the shocks of rising fuel cost to small-scale fishers. These include improving the efficiency of gasoline supply chain to reduce logistical costs, promoting fishers to reduce cruising speed of their vessels, and subsidizing costs related to implementing fuel-efficient technologies. At the same time, some local fishers’ groups are devising new ways of operation in aim to enhance efficiency in terms of harvesting and cost savings. These often involve shifting from individualistic and competitive operation to more coordinated fishing, which this paper refers to as fishery co-management.

This paper describes co-management of the walleye pollack fishery by a subgroup of fishers who belong to the Hiyama Fishery Cooperative Association (FCA), located at Hiyama region of Hokkaido. The Hiyama region is located in southwestern Hokkaido facing the Japan
Sea (Figure 1), and its near-shore area is known as the main spawning ground for the northern Japan Sea stock. Hiyama FCA consists of several “sections” defined according to geography, and each section co-manages its fisheries. This paper focuses specifically on the Nishi section, in the middle of the Hiyama fishery (light-shaded areas in Figure 1). The Nishi section produced 77% of total walleye pollack landings (by volume) in the Hiyama region in 2005 (Watanobe, 2007).

The focus of this paper is to evaluate the impact of so-called partnership arrangement that was implemented by the Hiyama fishers in 2005 season, in response to further declining stock size and increasing fuel cost. To meet this objective, the daily operation data from 2004 and 2005 seasons are used. The results show that in 2005 season the harvest and fishing revenue per unit of fishing effort both increased significantly compared to 2004 season. Since fishing cost is
positively correlated with the level of fishing effort, this result implies the profitability has also improved. As it will be explained below, such improvements are result of cost rationalization such as minimizing traveling distance and use of fishing gear. What is remarkable about this particular case, however, is that all these cost saving efforts were made possible by a rather simple but radical change in the “rule of the game”, namely the partnership arrangement.

2. Background

2.1 The fishery

Walleye pollack are found in northern waters of the Japan Sea, the Pacific Ocean, the Okhotsk Sea, the Bering Sea, and along the Alaskan coast. The northern Japan Sea stock inhabits waters that extend from the southwestern tip of Sakhalin in Russia, along the western coast of Hokkaido, to Noto Peninsula in the Ishikawa prefecture. The fish are found from near the surface to a depth of 400 meters. Walleye pollack reach maturity at three to four years. Their life expectancy is unknown; most of the fish exceeding ten years of age have been found in the Hiyama region.

The walleye pollack’s spawning grounds once encompassed the western coast of Hokkaido, but major spawning activity during the past few years has been confirmed only in the Hiyama region. Overharvesting and depleted fish stocks are thought to be the cause of shrinking spawning grounds (Honda and Yabuki 2006). Hatchlings and juveniles are carried north by the current to an area known as the Musashi Bank and onto the continental shelf off northern Hokkaido, where they grow and mature. The majority of walleye pollack harvested near Musashi Bank and regions north of Shakotan Peninsula are between one and four years of age (mostly young and immature adults). As they mature and become reproductive, they migrate southward.
Young adults spawn for the first time around the Ishikari and the Iwanai region, which lies about 100 kilometers north of Hiyama (Figure 1). The migration continues until the pollack reach the Hiyama region, where fish that are five years or older predominate. The peak season tends to be earlier in southern areas and later in northern areas (Hokkaido Central Fisheries Experiment Station 2005).

Figure 2. Nishi section of Hiyama region, Hokkaido, Japan. Note: Circles show the distribution of walleye pollack as of February 2007. The area scattering strength (SA), measured by quantitative echo sounding, is used as a proxy for biomass distribution. The size of a circle represents the strength of the response and hence the density of the pollack school. Source: Hokkaido Hakodate Fisheries Experiment Station, 2006.

The geographical focus of this paper is Nishi section of Hiyama region (Figure 2). Otobe town, which is the source of data that is being analyzed, is located at the southern border of Nishi
section. Nishi section is further divided into three sections; labeled, from north, Top, Middle, and Bottom. These three sections are the basis of rotation scheme that these fishers adopted, which is explained below. As Figure 2 shows, the distribution of walleye pollack is very uneven. The thickest area is just offshore of Toyohama town, which are the main spawning ground and also the protected no-fishing zone (which was implemented voluntarily by the fishers). The fact that the Nishi section harbors the main spawning is an important advantage since the main target of walleye pollack fishery in Hiyama region is its roe.

According to a stock assessment report provided by the government, the stock level of northern Japan Sea walleye pollack is estimated to be low and continues to decline. Stock levels between 1987 and 1991 were high, with estimates ranging between 722,000 and 868,000 metric tons. The declining trend began in 1992 and, as of mid-2006, the stock level was estimated at 147,000 metric tons. The 1998 cohort was expected to yield a high level of stock, but in 2002 it was so extensively harvested that it ultimately produced no more fish than other cohorts. The recruitment per spawning stock biomass (RPS) has been declining since 1989, which resulted in 2003 posting the lowest recruitment level in more than twenty years (Honda and Yabuki, 2006).

The gear used in Hiyama walleye pollack fishing is longline. The longline is favored, rather than the trawl nets, because it is believed that longline is less damaging for the fish and thus better quality of the roe. The longline is set in a straight line, with its length varying from 3,472 to 5,788 meters, depending on the size of the vessel. There are 100 hooks per unit called “basket” and cut, frozen saury and squid are used as bait. The baits are hooked by hand, and because of this wasteful use of long line can be very costly. The average rate of catchability (the percent hooks that have fish) is approximately 50% but can rise to 70–80% when the catch is good.
2.2 Fishery self-management

Hiyama region’s walleye pollack fishery is also known for its sophisticated self-management scheme. This is in addition to government regulations; walleye pollack is one of seven species regulated under the national total allowable catch (TAC) system introduced in 1997. Other common self-imposed regulations include voluntary season closure (November through January), establishment of no-fishing zone, and gear restrictions (Uchida and Watanobe, forthcoming). The scheme that made this fishery famous, however, is the fishing ground rotation system.

The rotation scheme was implemented in the Hiyama region in the mid-1960s.\(^1\) The main objective is to avoid congestion at fishing grounds and the consequent costs, such as gear damage, while maintaining “fairness” defined as equal opportunity to fish at all fishing grounds throughout the season.\(^2\) There are three layers of rotation: groups, teams, and individuals. Nishi fishermen are divided into three groups based on town; Kumaishi, Toyohama, and Otobe. Recall that the Nishi section is divided into three segments of coastline from north to south (top, middle, and bottom). Each group rotates through the segments on successive days, so each group is granted access to all of the segments of coastline (the big rotation in Figure 3). Each group consists of several teams, and each team consists of several individual vessels. Within the big rotation, these teams also rotate within their group (the middle rotation). Furthermore, individual vessels rotate within a team (the small rotation).

This layered rotation equalizes fishing opportunities at the vessel level over the course of the season. In practice, the rotation scheme is more complicated still, because the rotation is

---

1. Similar system is also implemented in neighboring walleye pollack fisheries such as those in Iwanai region (Figure 1) (Hirasawa, et al. 1985).
2. Fairness is defined differently than it is in other fisheries in Japan, such as the system used by pink shrimp fishers in Suruga Bay (Uchida and Baba, forthcoming). In this shrimp fishery, fishers sought post-harvest fairness by sharing the group harvest equally. In the Nishi walleye pollack fishery, fishers sought pre-harvest fairness by rotating access to the fishing grounds.
sometimes adjusted to better equalize opportunities for individual vessels. However, even if the opportunity is equalized, the actual catch at the same location will differ depending on when one fishes. Hiyama fishers have long regarded such stochastic fluctuations, or luck, as part of fishery’s nature, and no further adjustments were made—until recently when the partnership arrangement was introduced.

![Diagram of rotation scheme](image)

**Figure 3. Schematic of rotation scheme adopted by Nishi fishermen in the Hiyama FCA.** Note: The number of teams and vessels are for illustration purpose only; the actual configuration may differ.

Harvest volumes in the Nishi section have fluctuated between 3,000 and 7,000 metric tons since 1979. Harvest volumes have remained near the 1979 level, although a decreasing trend is apparent in the years following 2001. (Figure 4 presents a scaled comparison of the trend in landings for two of Nishi’s three districts to landings in the northern Japan Sea area.) The Nishi section stands in stark contrast to a clear decreasing trend for northern Japan Sea walleye pollack. The total harvest in 2005 for Japan Sea pollack was only 16% of the total in
1979, while harvests for the Hiyama region remained at 80%. Hiyama region’s 2.8% share of the total harvest volume of Japan Sea pollack in 1979 has risen to an all-time high of 14.3% in 2005. While this difference may not be solely attributed to the management effort by Hiyama fishers, it certainly encouraged them to maintain the regime.

![Percentage change in total harvest volume (1979=100)
(For Otobe and Toyohama towns in Hiyama region)](image)

**Figure 4. Change in total harvest volume index with base year 1979 as 100.**
Source: Hokkaido Hakodate Fisheries Experiment Station, and Honda and Yabuki (2006).

### 2.3 Fuel cost increase

The retail gasoline price increased sharply since 2004 (Figure 5). During the 2004 season (November 2004 to January 2005) the gas price actually declined a bit; the average per liter price during these three months was 120.7 yen (approximately U.S. $1.10).³ The gas price climbed up

³ Unless otherwise noted, the exchange rate used throughout this paper is U.S. $1 = 120 Japanese yen.
after the 2004 season, and by the time 2005 season came around the average price increased to 135.1 yen ($1.23), or 11.9% increase. This was one of the sharpest increases in recent years.

**Figure 5. Retail regular gasoline price of Hakodate city, Hokkaido.**
Source: Oil Information Center (2007).
Note: Months between red lines indicate the Hiyama walleye pollack fishing season.

The main components of fishing cost are fuel, depreciation, labor, and fees.⁴ Labor and fees share to total cost have remained relatively constant since 1996 at 13% and 10%, respectively (Ministry of Agriculture, Forestry, and Fisheries 2005). Depreciation cost share has actually decreased from 20% in 1996 to 16% in 2005. Fuel cost, on the other hand, increased its share from 12% in 1996 to 18% in 2005. Note that these figures are averages of all fishing

---

⁴ Fees include those paid to FCAs as sales fee, since an FCA provides services related to local exvessel markets and transactions.
vessels owned by small-scale fishing households. When restricted only to vessels of 10 to 20 tonnage, which is the majority in Nishi section walleye pollack fishery, the share was 22.8% in 2005, an increase from 20.1% in previous year. This increase corresponds to additional 264 thousand yen ($2,400) in fuel cost. In comparison, the average fishery income in 2005 for 10—20 tonnage vessel size class fishers was 4,632 thousand yen ($42,109).

2.4 Efficiency limit to rotation scheme

There are several limitations to the rotation scheme due to the rigidity of assigned locations. While schools of walleye pollack shift along the coastline from day to day, the location coordinates of the vessel rotations are largely fixed. In some cases the harvest could be better if the group adjusts its fishing location in accordance to where the fish schools are. Under the rotation scheme such adjustment was not allowed, since vessels adjusting their locations to areas where the fish schools are dense undermines the purpose of the rotation scheme and congests those areas.

A related inefficiency is that some vessels must travel long distances to reach the assigned fishing area. For example, the southern most Otobe vessels travel to northern top section once every three fishing days. This is not an efficient use of vessels and the cost of the inefficiency has become apparent and acute as fuel prices have soared. This led to adoption of a section-wide partnership arrangement in the Nishi section.

---

5 As of June 2006, there were 51 vessels in the Nishi section, of which three were small vessels (less than six tons), another three mid-sized vessels (seven to eight tons), and the rest exceeded 9.9 tons with some as large as nineteen tons.
3. Partnership arrangement

The essence of partnership arrangement is that each vessel’s harvest is collected and pooled at once, and then redistributed back to the vessels. There were 195 fishers’ group that implemented partnership arrangement nationwide as of 2003 (Ministry of Agriculture, Forestry, and Fisheries 2006). The redistribution rule varies among cases; some simply share equally while others weight the distribution according to the vessel size and/or fisher’s skill.

The important effect of partnership arrangement is that it alters the fundamental incentive structure of a fisher. Because of pooled and shared harvest, the return a fisher receives is no longer linked to his individual fishing effort. This could, on one hand, lead to shirking as one can, in principle, free ride on others effort. On the other hand, if one wishes to maximize his own return then the return to the group as a whole needs to be maximized. The objectives of an individual and a group are aligned (Uchida 2007), so that excessive competition is eliminated and avoid “the tragedy of the commons.” In this sense, individual fishers become partners and work together towards the common objective.

The Nishi section-wide partnership arrangement was implemented as a trial at the beginning of the 2005-06 fishing season. The Nishi section’s distribution rule incorporates the heterogeneity of the vessel size. The pooled harvest is distributed equally per unit of long line, and since larger vessels carry more units they get higher share. Harvest distribution is calculated daily, and only vessels that went out fishing that day get a share.

Once the partnership arrangement was implemented, the Nishi group made several changes to enhance efficiency. Joint surveillance of fishing grounds is conducted daily and the results are disclosed to all members. They also can adjust the location assignments while

---

6 Some researchers refer partnership arrangement as pooling system (Platteau and Seki 2001) and pooling arrangement (Uchida 2007).
fundamentally maintaining the rotation pattern. Additional adjustments were made based on the characteristics of each vessel type. For example, when operating in relatively high waves, larger vessels operate upwind of smaller vessels so that they block the high waves, making it safer for smaller vessels to operate.

The most prominent change in fishermen’s behavior has been efforts to reduce costs. In rough weather, vessels from each town fish at the nearest fishing grounds. When a low catch rate is anticipated, each vessel takes fewer units of long line.

4. Evaluation of partnership arrangement

Anecdotal evidence implies that partnership arrangement brought improvements in fishing efficiency on several fronts. The question, however, still remains: does the data support these claims? If so, what was the magnitude of the gain?

To answer these questions, a unique dataset collected from Otobe fishers’ group is used. This dataset has daily harvest volume and number of long line units used for each vessel. Data from 2005 fishing season, which is the first year of implementing the partnership arrangement, and 2004 season were used for comparison.

Descriptive statistics comparing the two fishing seasons are given in Table 1. For some figures the two seasons look astonishingly similar. For example, the number of fishing days at each fishing ground (top, middle, and bottom) is nearly the same considering the difference in total fishing days. Similar is also true for the number of days fished when the weather condition.

Both total catch and revenue increased, but at first sight this is not surprising because the total number of fishing days is higher in 2005 season. However, the data also shows that average
number of units of long line per fishing day was significantly lower in 2005 season, and consequently the catch and revenue per unit of long line much higher. These are consistent with anecdotal evidence and can be considered as positive change due to the implementation of partnership arrangement.

Table 1. Descriptive statistics of Otobe fishers for 2004 and 2005 seasons

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days at sea</td>
<td>53</td>
<td>59</td>
</tr>
<tr>
<td>Location (top)</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Location (middle)</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Location (bottom)</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>In bad weather</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Number of days smaller vessels stayed behind</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Total catch (tons)</td>
<td>1,794</td>
<td>1,894</td>
</tr>
<tr>
<td>Total revenue (thousand yen)</td>
<td>385,786</td>
<td>457,132</td>
</tr>
<tr>
<td>Average units of long line per day</td>
<td>1,731</td>
<td>1,538</td>
</tr>
<tr>
<td>Catch per unit of long line (kg)</td>
<td>19.2</td>
<td>20.9</td>
</tr>
<tr>
<td>Revenue per unit of long line (yen)</td>
<td>4,185</td>
<td>5,038</td>
</tr>
</tbody>
</table>

Simple regressions were ran to evaluate whether these difference between the seasons are statistically significant.

Total catch volume

\[ \text{Catch}_i = \beta_0 + \beta_1 \text{Gear}_i + \beta_2 \text{Location}_i + \beta_3 \text{Weather}_i + \beta_4 \text{Season}_i + u_i. \]  

(1)

Revenue per unit of long line

\[ \text{Unit}_i \text{Rev}_i = \beta_0 + \beta_1 \text{Location}_i + \beta_2 \text{Weather}_i + \beta_3 \text{Season}_i + u_i. \]  

(2)

Results are shown in Table 2. In both regressions the results are consistent with intuitions. The number of total long lines used is positive and significant when the dependent variable is the total catch. Location dummy is coded such that top is 1, middle is 2, and bottom is 3. Therefore, the negative sign implies the bottom as one goes from top to bottom fishing grounds the catchability decreases. This is intuitive considering the fact that major spawning ground for
walleye pollack and no-fishing zone are both located at north of Nishi section. The bad weather dummy is defined here as either wind speed of more than 10 meters per second, rain, or snow. The result shows that fishing in bad weather also reduces the total catch.

Season dummy is positive and statistically significant in both models after controlling for other factors that would affect total catch and revenue per unit of long line. As was shown in Table 1, there was no systematic difference between the two seasons except for the fact that 2005 season had Nishi section-wide partnership arrangement implemented. This implies that these results can be attributed to partnership arrangement.

Table 2. Robust OLS estimation results

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dependent variable</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total number of long lines</td>
<td>23.68</td>
<td>(10.35)***</td>
</tr>
<tr>
<td>Location dummy</td>
<td></td>
<td>-117.12</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Bad weather dummy</td>
<td></td>
<td>-4,380.80</td>
<td>(2.08)**</td>
</tr>
<tr>
<td>Season dummy</td>
<td></td>
<td>3,695.27</td>
<td>(1.89)*</td>
</tr>
<tr>
<td>Number of observations</td>
<td></td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td></td>
<td>0.500</td>
<td>0.073</td>
</tr>
</tbody>
</table>

Note: Robust t statistics in parentheses. Significance levels are indicated by * significant at 10%; ** significant at 5%; *** significant at 1%.

5. Conclusion

Walleye pollack co-management in the Nishi section of Hiyama has been successful thus far. The fishing-ground rotation, though schematically complicated, successfully meets a simple objective: maintain fairness and avoid congestion. The group also has shown remarkable
flexibility when faced with low stocks and increasing fuel costs. Members are actively working on both fronts: cost savings and revenue enhancement through marketing.

The objective of partnership arrangement was to eliminate the inefficiencies in their fishing operations. One of such inefficiencies was the rigidity of rotation scheme. However, data shows that although there was slight increase in incidents where Otobe fishers fished at the bottom section—the nearest from their harbor—but in light of an increase in total fishing days the difference does not seem significant. This could be partly explained by the fact that the top fishing ground is more productive than the bottom ground, and after all fishers were reluctant to forgo the opportunity to fish there.

Under Nishi section’s rotation scheme there was still an incentive to over-exert fishing effort because one’s return was directly linked to his level of fishing effort, and if he does not catch the fish someone else will. With partnership arrangement that direct link is broken, and even if other fishers catch fish that one left behind he will still get a share of that other’s catch. This allows each fisher to consider the efficient use of long line. The data supports this conjecture, as with partnership arrangement fishers are catching more pollack per unit of long line than before. Also, shorter long line means less use of fuel while fishing so it contributes to reducing fuel costs as well.

Partnership arrangement brought fishers in Otobe town, and Nishi section, a higher return from the fishery struggling from declining stock and soaring fuel cost. However, there are several issues and challenges facing these fishers. One is how to incorporate heterogeneity in the skill of skippers in the distribution of pooled harvest. The group could opt not to incorporate skill at all, but the group would probably need to further enhance profitability for that option to address the dissatisfaction with equal sharing. Alternative methods tend to reduce fairness in
other ways and/or induce excessively competitive behavior that would undermine the purpose of co-management.

There are also some external challenges, particularly the need to coordinate with neighboring regions that target the same walleye pollack stock. The ideal would be to merge the various management efforts into a single group with authority over the pollack throughout its migration range over the west coast of Hokkaido. The likelihood of establishing such an ideal institution, however, is small. Fishers in the southern region such as Hiyama, who mostly harvest for roe, argue that the collapse of walleye fisheries is due to overharvesting of juveniles by trawlers in the north. Fishers in the northern regions claim that southern harvesting for roe reduces the number of young fish that migrate northward to their fishing grounds. Both sides are caught in an endless chicken-or-egg argument. In the meantime the stock level can decline even further, and then even the cost saving effort by Nishi fishers may not be enough to keep their business afloat.

Co-management by fishermen in the Nishi section of the Hiyama region is notably successful, but the migratory nature of walleye pollack presents a restriction that Hiyama alone cannot overcome. Given the overall decline of walleye pollack stocks, especially in the northern Japan Sea stock, some kind of overarching management regime is needed. It will be a challenge for all stakeholders, as development of such a regime will require the cooperation among fishers, government officials, buyers, and scientists.
Acknowledgement

I would like to thank Mr. Masamichi Watanobe of Hokkaido Hakodate Fisheries Experiment Station, and the members of the Hiyama FCA at Otobe for their time and their generosity in providing the photographs. The fieldwork in Hiyama was funded by University of California Pacific Rim Research Program research grant (Ref. Num. 05-1477).

References


Oil Information Center. 2007. Data available online at http://oil-info.ieej.or.jp/price/price.html.


