Bull. Fac. Fish. Hokkaido Univ.
39(3), 180-186. 1988.

The Harvest Efficiency of the Sardine Fishermen of Kushiro

Anne VÉZINA*

Abstract

North American fisheries are mainly managed by a quota system. As much of the emphasis in fisheries management is on stock estimation, the dynamics of fishing fleets have received little attention. However, an understanding of fleet dynamics is important, especially if new management strategies are to be implemented. One of the regulation under consideration is the limited entry system. In Japan, where it is easier to control the number and tonnage of fishing vessels than the catch of individual vessels, a limited entry system is the norm for most fisheries. One of them is the sardine purse seiner fleet fishing in the coastal waters of Kushiro, Hokkaido. The harvest efficiency of this fleet, that is the fishing and searching processes, are examined for the years 1983 to 1986. Although the total annual catch is relatively constant for those four years, there is a noticeable decrease in the catch per unit effort and catch rate. In terms of total catch the fishermen have been able to offset a smaller CPUE, and catch rate, by increasing the time spent fishing, but this may be done at the detriment of the resource. The searching pattern of the purse seiners also indicates that the sardine population may be on the decline.

Introduction

The world-wide development of stock assessment methods and the implementation of quota systems has helped restore certain fish stocks dangerously depleted after years of unregulated fishing. Yet, despite increases in biological knowedge of many species, the fishing industry is not immune to crises. A recent example is the Canadian domestic coastal fisheries. At the beginning of the 1980's, Canadian fisheries were examined in detail to determine the cause of the poor economic state of the salmon and cod industries in spite of good harvests. Reports by the Royal Commission on Pacific Fisheries Policy (Pearse, 1982) as well as the Task Force on the Atlantic Fisheries (Kirby, 1982), came to the conclusion that the problems of the industry were not due to a lack of fish, but instead to other factors such as over-expansion of fishing fleets and processing facilities, poor prices and escalating costs.

Canada's situation is far from unique. Hillborn (1985) argues that the collapse of the Peruvian anchoveta and the Norwegian herring, were not due to a poor understanding of fish biology, but to a poor understanding of fishermen dynamics; how they fish and how they invest. Hillborn divides fisheries science into four components; population dynamics, fleet dynamics, processing and marketing. The field of fleet dynamics has recently been given more attention as managers and fishery scientists recognize the need to consider the behavior of fishermen when implementing new regulations.

In the search for new management strategies it is worthwhile to examine

* *Laboratory of Fishing Gear Engineering, Faculty of Fisheries, Hokkaido, University*
(北海道大学水産学部漁具設計学講座)

existing limited entry fisheries. Japan is a good example, especially since the fishing industry commands a major share of the national economy. In Japan, entry into nearly all fisheries is limited. The only significant fishery where entry is still open is the coastal angling fishery using small boats (Asada, 1983). The primary management strategy is the control of fishing effort, i.e. limitation of the number and size of fishing vessels. Additionally, when required, restrictions on the fishing ground, fishing season and/or gear are imposed. The only harvest which is regulated by a quota are salmon and whales since Japan is obliged, through international agreements, to limit the catch of those species. From a resource point of view, the Japanese system of controlling fishing effort may be less effective than a maximum catch quota but it is less likely to fall into the problem of over-investment (Asada, 1983). Since the quota system encourages competition between fishermen to appropriate for themselves a bigger part of the quota, the incentive is to invest heavily in fishing gear, sometimes expanding the industry beyond the limits that can be sustained by the resource.

Determination of the most efficient system is beyond the scope and intent of this paper since the effectiveness of any system is dependent upon many local factors. This paper will examine the dynamics of a fishing fleet operating under a limited entry system. The fleet under consideration is the sardine purse seiner fleet fishing in the coastal waters of Kushiro, Japan. The primary objective is to study the harvest efficiency of the individual fishermen and of the fleet. The efficiency of fishermen should reflect, not only on their ability to harvest the fish but also on the status of the stock.

Materials and Methods

The Sardine Fishery

Prior to 1975, the purse seiners operating in the coastal waters of Kushiro, harvested pacific mackerel (Fig. 1). Between 1960 and 1968 the number of purse seiners increased from 9 to 24 and has remained the same since. When the harvesting of sardine started after 1975, the capacity of carrier boats, which transport the fish from the fishing grounds to port, was augmented. This increased transport capacity accounts for the sharp rise in sardine catch since 1975. Since 1983 however, the fleet size and tonnage has been nearly constant with little turnover in the boats. Presently each purse seiner is associated with one fish finder boat and two carrier boats that can carry up to 300 tons of fish each. The fishing season extends from July to October, and the fishing ground is restricted to an area south east of Kushiro which covers approximately 2,500 km^2.

Data Collection

The data used in this study came from the information given by each purse seiner on every fishing day, and was provided by the Kushiro Experimental Fisheries Station. Every hour, all fishing masters report position, surface water temperature, current speed and direction, the stage of the fishing process, as well as an estimate of the catch if in the process of setting the net. Fishermen also indicate whether they are searching or traveling.

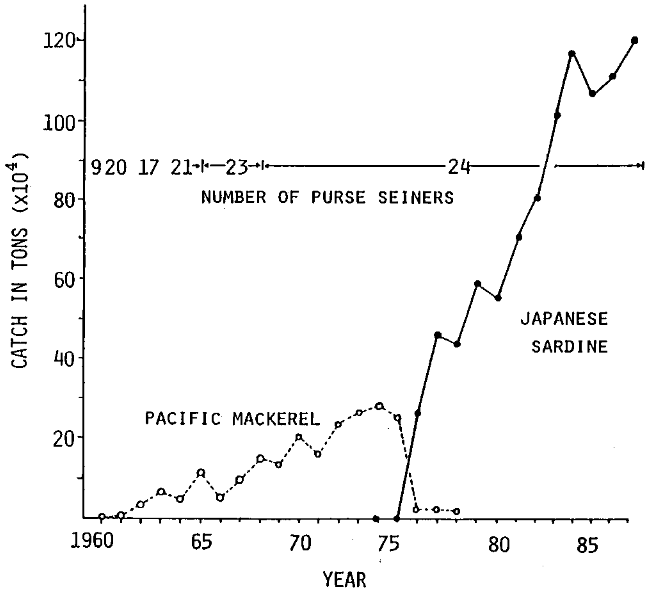

Fig. 1. Catch of Japanese sardine and Pacific Mackerel by purse seine fishery in the coastal region of Kushiro, Hokkaido from 1960 to 1982 (Asada, 1983) and from 1983 to 1987 (Kushiro Experimental Fisheries Station).

Data Analysis

The date, the boat number, the number of the area where the net was set (the fishing area is divided into 257 units/10 km^2 area), the estimated catch for each haul and the number of hours spent fishing on that day were retained for analysis. Since it is impossible to estimate the exact searching time for each haul from these data, only the interval between the initiation of the search in the morning and the termination in the evening, is evaluated. This estimate of the total fishing time is used in the calculation of catch rate, which is the number of tons caught per hour per boat. The catch per unit effort (CPUE) is simply taken as the number of tons caught every time the net is set (also referred to as a "haul"). The term "effort" used below refers to the "number of hauls". A failed haul is defined as an empty net, or a catch of zero tons.

Results and Discussion

For the four years under study, if all the boats managed to capture the maximum capacity of the carrier boats, which is 600 tons, the total catch for that day was 14,400 tons. In 1983-1984 the total catch per day oscillated around that value for most of the season, whereas in 1985 and 1986 there was more fluctuation, especially towards the end of the fishing season (Fig. 2). These above-normal catches represent days when the fishermen kept fishing for 20 hours or more. However there is no statistical difference in total catch for those four years. A

Table 1. Description of the fishing by the purse seiner fleet for the years 1983 to 1986

	1983	1984	1985	1986
Total Catch (tons)	918,455	920,084	869,169	963,930
Number of Fishing Days	82	74	79	84
Total Fishing Time (hours)	25,044	23,364	27,555	29,652
Number of Hauls	3,925	3,495	5,227	5,586
Proportion of Failed Hauls	.078	.105	.102	.097

two-way Analysis of Variance without replication, parformed on catch versus area indicates effect of the year on the catch (F=0.12). As expected, catch differed by area (F=6.12, p<.001) but unfortunately the interaction between year and area could not be tested because of lack of replication of these data.

The annual catches for the years 1983 to 1986 calculated from fishermen reports (Table 1) are slightly lower than the landing values shown in Fig. 1. It appears that the fishermen underestimate, intentionally or not, the number of tons they catch. Since there is no way to account for that bias it must be assumed that it is constant. The number of fishing days does not vary greatly, however, compared to

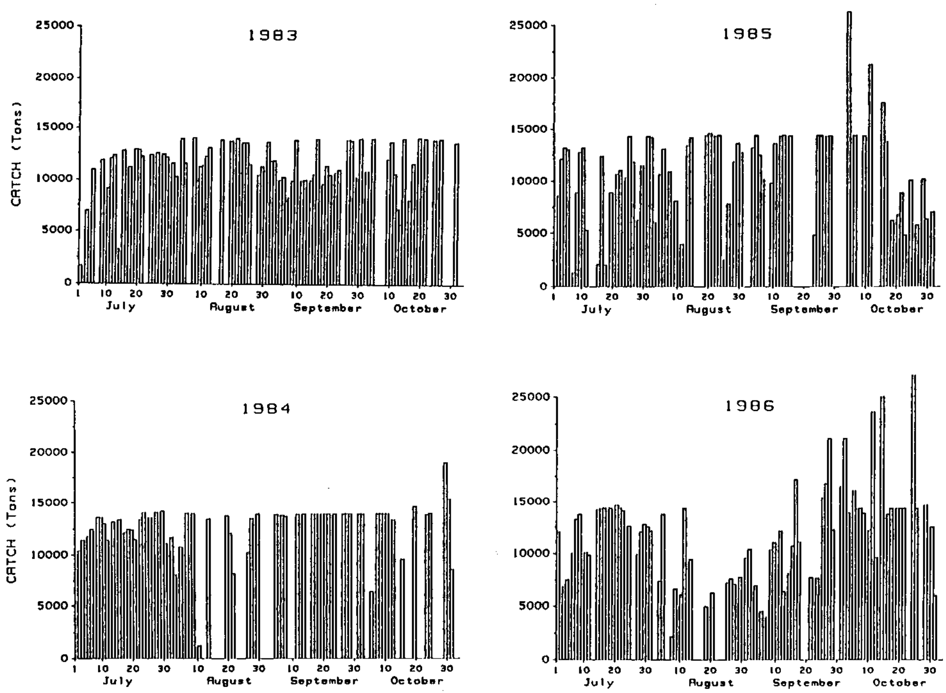

Fig. 2. Histograms of the daily catch of sardine by the Kushiro purse seiner fleet for the years 1983 to 1986.

1984, the number of fishing hours increased by 18% and 27% in 1985 and 1986, respectively. The increased time spent fishing is reflected in the greater number of hauls, an increase of at least 50% over 1984. The number of failed hauls also increased, but the proportion remained nearly constant between 1984 to 1986, while in 1983 the fishermen were somewhat less likely to bring back empty net. From these data it is obvious that the fishermen expanded fishing effort in 1985 and 1986. Those efforts however did not translate into a proportionally larger catch.

To determine whether this pattern was due to some inefficient fishermen who decreased the output of the fleeet, the catching power of individual vessels was calculated. The catching power of each boat is calculated by dividing its annual catch by the number of days fished times the average daily catch for the whole fleet. A value of the catching power greater than 1 means that the boat's catch was greater than the daily average catch, and that the boat was either more effective or luckier. The catching power of individual vessels is fairly similar, with little individual variation. The highest value observed is 1.11 while the lowest is 0.82, far less than the range of 0.3 to 2.7 that Hillborn (1985) observed in the salmon purse seine fishery. A two-way Analysis of Variance without replication performed on the individual catching power values over the years 1983 to 1986, indicates no effect of the boat ($F=2.28$), nor of the year ($F=0.27$), on the catching power. So it appears that the sardine purse seiner fleet functions as a fairly efficient unit, with no fishermen harvesting a disproportionately large quantity of sardines.

Over the years, however, the performance of the purse seiner fleet has changed, with the indicators for the paired years 1983-1984 and the paired years 1985-1986 seemingly different (Table 2). A one-way Analysis of Variance followed by a Tukey's Multiple Comparison test confirms this impression. The average CPUE is significantly lower in 1985 and 1986, than in 1983 and 1984, and the same results were obtained with the catch rate. It may be that the abundance has decreased, that the migration route has changed or both.

Table 2. Analysis of Variance of the performance indicators for the purse seiner fleet for the years 1983 to 1986

	1983	1984	1985	1986	F	
Average CPUE (tons/haul)	234.0 ±160.63 (n=3925)	263.3 ±183.44 (n=3495)	166.3 ±140.49 (n=5227)	172.6 ±150.53 (n=5586)	387.9	p<.001
Average Catch Rate (tons/hr)	39.8 ±15.59 (n=1894)	43.3 ±18.76 (n=1735)	31.9 ±15.17 (n=1884)	33.2 ±16.26 (n=1997)	198.7	p<.001
Average Number of Areas Visited/Day	5.2 ±2.35 (n=82)	5.1 ±2.37 (n=79)	6.9 ±3.04 (n=79)	8.5 ±3.68 (n=84)	22.5	p<.001

Tukey's Multiple Comparison Test:

CPUE: Significant difference between the log transformed means, for $\alpha=0.05$, except to the 1983-1984 and 1985-1986 comparisons.

Catch Rate: Significant difference between the log transformed means, for $\alpha=0.05$, except for the 1983-1984 and 1985-1986 comparisons.

Visited areas per day: Significant difference between the means, for $\alpha=0.05$, except for the 1983-1984 comparison.

Table 3. Chi-Square analysis of the strategy pay-off for the sardine purse seiner fleet for the years 1983 to 1986

Strategy		Proportion of catches higher than previous one	Proportion of catches lower than previous one	n	χ^2	
1983	Stay	.45	.55	758	7.6	$.005<p<.01$
	Move	.51	.49	1273	0.5	NS
1984	Stay	.56	.44	577	8.3	$.001<p<.005$
	Move	.47	.53	1183	4.3	$.025<p<.05$
1985	Stay	.42	.58	962	24.7	$p<.001$
	Move	.46	.54	2381	15.3	$p<.001$
1986	Stay	.47	.53	937	3.5	NS $.05<p<.10$
	Move	.44	.56	2672	38.5	$p<.001$

If it is assumed that the CPUE is related to the school size, then the resource is apparently decreasing. A decrease in CPUE variance with a decrease in the mean values for the years 1985 and 1986, is another indication that the school size may be smaller than before. The fishermen have compensated for the smaller school size by increasing fishing effort, so that at the end of the season the total catch is about the same for each year.

On a cost/benefit basis the fishermen are not doing as well in 1985-86 as in 1983-84. Not only do they spend more time fishing, but they also have increased searching effort. In 1983 and 1984, the fleet fished in an average of 5.2-10 km^2 areas per day, while in 1985 and 1986 this value increased to 6.9 and 8.5, respectively (Table 2). It is possible that sardine migratory patterns have changed, and that the fishermen search a wider area in order to find the schools. On the other hand, these results may also indicate that the fishermen are not willing to set a net on smaller schools and instead prefer to continue searching for larger schools. Since there may be fewer larger schools, fishermen may have to settle for smaller catches anyway.

Fishermen have the choice to remain in one area or move elsewhere. The consequences of either staying in the same 10 km^2 area or moving to another area were calculated by comparing two consecutive catches caught in the same or different areas (Table 3). In 1983, it was more profitable to move to a new area, since staying in the same area tended to result in a smaller catch. The slight improvement in moving, however, was not statistically significant using a Chi-Square. In 1984 it was more advantageous to stay in the same area where the net had been previously set. In 1985 and 1986 whatever the strategy, the subsequent catch was more often than not smaller than the previous one. It seems that whatever strategy the fishermen adopted in 1985 and 1986, it was bound to be less profitable.

Conclusion

Despite a decrease in efficiency in 1985 and 1986, the sardine fishermen are still formidable predators and in this instance, maintaining fishing power constant under a system of limited entry, did not preclude the possibility of increasing the effort. However, the consequences of increasing fishing effort on a possibly decreasing are not immediately apparent. So far, the year 1987 was the best fishing season so far, probably because of a good recruitment of the 1985 year-class (Mihara, Pers. Comm.), but this is not sufficient reason for thinking that the resource is stable. As seen in Fig. 1 the pacific mackerel fishery collapsed suddenly after a very good season. In a short lived species such as the sardine a repetition of this scenario is not unlikely.

Whether the management strategy is a quota system or a limited entry system, the behavior of the fishermen should not be ignored. A limited entry system alleviates tension between fishermen, but maybe to the detriment of the resource, whereas a quota system is better from the point of view of the resource but creates economic problems. Whatever the answer is, fisheries managers have much to gain by integrating fishermen in their models.

Acknowledgments

This analysis was performed while under a scholarship granted by the Japanese Ministry of Education. I would like to especially thank Drs. O. Sato and K. Nashimoto of the Hokkaido University Faculty of Fisheries, and Mr. A. Yoshida and Mr. Y. Mihara of the Kushiro Experimental Fisheries Station. J. Goodier made valuable comments on the manuscript.

References

Asada, Y. (1983). License limitation regulations: the Japanese system. *FAO Fisheries Report* No. **289** supplement 3, 307-318.

Hillborn, R. (1985). Fleet dynamics and individual variation: why some people catch more fish than others. *Can. J. Fish. Aquat. Sci.* **42**, 2-13.

Kirby, M. (1982). Navigating troubled waters: a new policy for Atlantic fisheries. *Report of the Task Force on Atlantic Fisheries, Ministry of Supply and Services, Ottawa, Ont.* 163 p.

Pearse, P. (1982). Turning the tide, a new policy for Canada's Pacific Fisheries. *Dept. of Fish. and Oceans, Ottawa, Ont.* 292 p.

Wada, T., Murata, M., Fujii, K., and Osako, M. (1983). Stock assessment of Japanese Sardine in coastal region off east Hokkaido with echo sounder-I. Distribution of relative density of Japanese sardine. *Bull. Hokkaido Reg. Fish. Res. Lab.* No. **48**, 79-91.