

Estimates of numbers of masu salmon caught by recreational fishermen in the coastal area off Iburi, Hokkaido, Japan

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ABSTRACT: Recreational fishing for masu salmon *Oncorhynchus masou* has recently become popular in coastal areas of south-western Hokkaido, including the Iburi district. We sampled recreational party boats in the Iburi district in the winters of 1998–1999 and 1999–2000. Daily numbers of anglers and catches of masu salmon were provided by the captains of the fishing boats. On average, anglers caught approximately four masu salmon per day each year, and peak catches occurred from late January to early February. Estimated numbers (standard errors in parentheses) of masu salmon caught by recreational anglers in the Iburi district were 66 844 (11 685) in 1998–1999 and 57 454 (6559) in 1999–2000, equivalent to 12–13% of the total annual commercial catches of masu salmon in Hokkaido. High recreational catches illustrate the importance of evaluating this fishery in the assessment and management of masu salmon in Hokkaido.

KEY WORDS: angling, Hokkaido, masu salmon, party boat, recreational fishing.

INTRODUCTION

To enhance fishery resources, stock enhancement programs using hatchery-reared fish are commonly undertaken. When techniques to produce larvae have been established and, consequently, many larvae can be stocked, programs to assess the success of stocking are required to improve the stocking technologies. Recoveries of stocked fish are usually estimated by reports from commercial or recreational fishermen; however, this approach can have severe problems because of high non-reporting and overlooking rates.¹ Recently, the sampling survey in which researchers checked the recoveries of stocked fish at fish markets has been paid attention as a reliable assessment method.² An approach to estimate stocking effectiveness under random sampling at fish markets is proposed.³ Using the sampling survey method, unbiased estimates of recovery rates of hatchery-reared

fish by commercial fisheries can be obtained and the precision of the estimates can be evaluated.

However, fish supplemented by hatchery stocking programs are often caught by recreational fishermen; for example, numbers of red sea breams *Pagrus major* caught by recreational anglers are nearly equal or exceed the numbers caught by commercial fishermen in various districts in Japan.^{4,5} Recreational catches for various enhanced fish species are so high that they have to be properly assessed to evaluate stocking success.^{4–7} In Japan, catch statistics for recreational fisheries are usually not available. Therefore, when recreational catches are to be estimated, sampling and/or questionnaire surveys are conducted.^{8–10} When estimating the catches, it is important to evaluate precision; however, in Japan, only a few reports have estimated recreational catches with precision.^{7,11–13}

Masu salmon *Oncorhynchus masou* is an important commercial fish species in northern Japan. However, commercial catch of masu salmon in Hokkaido is gradually decreasing. To restore and maintain masu salmon stocks, intensive research on stocking techniques has been conducted. For example, Miyakoshi *et al.*¹⁴ conducted a two-stage sampling survey at fish markets over an extensive

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area in western Hokkaido, and estimated recovery rates of hatchery-reared masu salmon smolts by coastal commercial fisheries. Their study revealed that masu salmon smolts stocked from the Sea of Japan side were exploited widely in coastal waters of Hokkaido including the Pacific Ocean side. In contrast, recreational fishing for masu salmon is becoming popular in coastal areas, and more reports on recreational fishing for this species are frequently published in papers and journals for anglers.¹⁵ Masu salmon is caught at various life stages by recreational anglers, and an evaluation of recreational fisheries is important to properly assess and manage masu salmon stocks.¹⁶ Recent publications showed estimates of juvenile masu salmon caught in freshwater by recreational fishermen;^{12,13} however, any quantitative survey to estimate numbers of masu salmon caught in recreational fisheries in coastal areas has not been conducted.

From December to March in 1998–1999 and 1999–2000, we sampled recreational party boats in the coastal area of the Iburi district, on the Pacific Ocean side in south-western Hokkaido, and estimated the number of masu salmon caught by the anglers.

MATERIALS AND METHODS

Study area and fishing for masu salmon in the coastal area

A sampling survey was conducted in the Iburi subprefecture, on the Pacific Ocean side in south-western Hokkaido (Fig. 1). The recreational party boats sampled were based in six cities (Muroran, Noboribetsu, Shiraoi, Tomakomai, Atsuma and Mukawa) facing the Pacific Ocean; party boats based in three cities facing Funka Bay were not included because they rarely fished masu salmon. The Iburi district is within easy access to Sapporo, the capital of Hokkaido prefecture, and has fewer

stormy days in winter than other fishing areas for masu salmon in Hokkaido, which is convenient for recreational fishermen. The fishing season for masu salmon in the Iburi coastal area is from December to March, and the peak of timing usually occurs in January and February. The main fishing area for masu salmon is 10–20 km offshore between Noboribetsu and Tomakomai (Fig. 1), at depths of approximately 100–130 m. Fishing usually begins at dawn and is virtually finished at 13.00 h. When masu salmon is targeted, anglers normally use a rod, an electric reel, a line with five to seven flies, and a wedge-shaped weight (called *ba-ke*). Masu salmon is fished between 10 and 120 m. When fishing for masu salmon in the Iburi coastal area, walleye pollock *Theragra chalcogramma* is often caught, and also arabesque greenling *Pleurogrammus azonus*, Pacific cod *Gadus macrocephalus*, pinthead flounder *Hippoglossoides pinetorum*, black edged sculpin *Gymnocanthus herzensteini* and chinook salmon *Oncorhynchus tshawytscha* are sometimes caught.

In the coastal area off Iburi in winter, there is no commercial fishery that targets masu salmon. Most of the masu salmon landed in the commercial fishery are caught by gill-nets that target walleye pollock. Numbers of masu salmon landed by the commercial fishery in Iburi from December to March in the past three fishing seasons (from 1995–1996 to 1997–1998) ranged from 7255 to 14 844 fish with a mean of 10 557 fish.¹⁷

Sampling survey for recreational party boats

In the survey area, 256 party boats were registered with the Hokkaido prefectural government and most of them belonged to one of the associations of recreational party boats. With the cooperation of the Iburi recreational party boats association, the Tomakomai fishermen's cooperative association and the Mukawa fishermen's cooperative association, 27 party boats were randomly sampled during

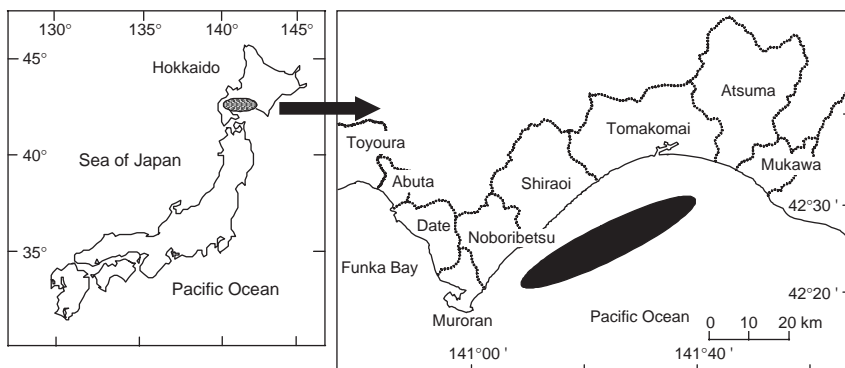


Fig. 1 Location of the main recreational fishing area in the coastal area off Iburi, south-western Hokkaido.

1998–1999, and 42 party boats during 1999–2000 (samples were chosen by the association managers regardless of fishing days for masu salmon in the past seasons). Captains of the sampled boats received logbooks and recorded the number of anglers and numbers of masu salmon caught by each angler on each fishing day. That is, our sampling scheme was single-stage cluster sampling¹⁸ with the recreational party boat as a sampling unit. When the fishing season was finished, logbooks were collected from the captains of party boats and used to estimate masu salmon catches.

Estimation of total catch

From the logbook data, the number of masu salmon caught by recreational anglers was estimated by multiplying the catch rate (mean catch per fishing boat per day) by the total number of fishing days. To estimate periodic catch trends, estimates and variances were generated for every 10-day period (i.e. 1–10, 11–20, and 21–last day of each month) using the equations in Kitada and Tezuka.¹¹ Notations were defined as follows:

N : total number of recreational party boats in the sampling population;

n : number of recreational party boats sampled;

M_k : total number of fishing days in the population in the k th period (to be estimated);

m_{ik} : total number of fishing days in the k th period of the i th sampled fishing boat;

\bar{m}_k : mean number of fishing days per fishing boat in the k th period (to be estimated);

y_{ik} : number of fish caught by the i th fishing boat in the k th period;

R_k : catch rate of the k th period (to be estimated);

Y_k : total catch in the k th period (to be estimated).

Here, catch rate R_k is the number of fish caught by a fishing boat per day. The estimate and variance for the catch rate are estimated:

$$\hat{R}_k = \frac{\sum_{i=1}^n y_{ik}}{\sum_{i=1}^n m_{ik}} \quad (1)$$

$$\hat{V}(\hat{R}_k) \equiv \left(\frac{N}{M_k} \right)^2 \frac{N-n}{N-1} \frac{\sum_{i=1}^n (y_{ik} - m_{ik} \hat{R}_k)^2}{n(n-1)}. \quad (2)$$

In equation (2), M_k is unknown; hence, we estimated M_k by

$$\hat{M}_k = N \bar{m}_k = \frac{N}{n} \sum_{i=1}^n m_{ik}. \quad (3)$$

The number of fish caught in the k th period is estimated by

$$\begin{aligned} \hat{Y}_k &= \hat{M}_k \hat{R}_k = N \bar{m}_k \hat{R}_k \\ &= \frac{N}{n} \sum_{i=1}^n m_{ik} \frac{\sum_{i=1}^n y_{ik}}{\sum_{i=1}^n m_{ik}} = \frac{N}{n} \sum_{i=1}^n y_{ik}. \end{aligned} \quad (4)$$

As shown above, when the total number of fishing days M_k is unknown, the ratio estimator is the same as the unbiased estimator.^{2,11} The variance estimator is evaluated by

$$\hat{V}(\hat{Y}_k) = N^2 \frac{N-n}{N-1} \frac{\sum_{i=1}^n (y_{ik} - \bar{y}_k)^2}{n(n-1)} \quad (5)$$

where

$$\bar{y}_k = \frac{\sum_{i=1}^n y_{ik}}{n}. \quad (6)$$

Total annual catches were estimated by applying annual data to the above equations as one period, rather than by summing the periodic estimates of catches and variances. When data are collected from the same samples throughout the fishing season, the sampling is not independent in each period and estimates of periodic catches are autocorrelated.¹¹ When we used the simple estimation procedure to apply annual data as one period, we could avoid the need to consider autocorrelation. In this case, because the total number of recreational party boats and the sampled party boats were the same throughout the fishing season, the estimates of numbers of masu salmon caught were the same when either estimation procedure was applied.

RESULTS

The mean number of recreational anglers on a party boat was 4.8 in both fishing seasons. The number of anglers on a fishing boat is normally restricted to five to six persons because the lines are often tangled up if more anglers fish together in a boat. Numbers of anglers on a boat ranged from one to nine, and the number of boats with less than six anglers accounted for 88% and 95% of the total numbers in 1998–1999 and 1999–2000, respectively (Fig. 2).

On average, approximately four masu salmon were caught per angler in both seasons; 4.1 fish in 1998–1999 and 3.9 fish in 1999–2000. Numbers of anglers who caught five fish or less accounted for

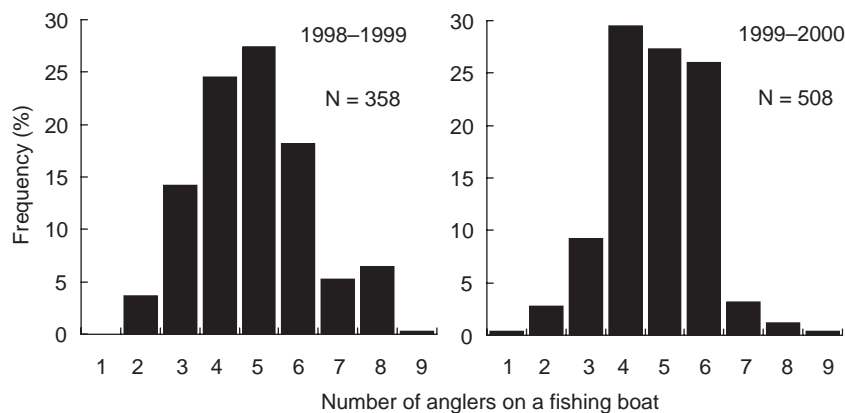


Fig. 2 Frequency distributions of numbers of recreational anglers per fishing boat.

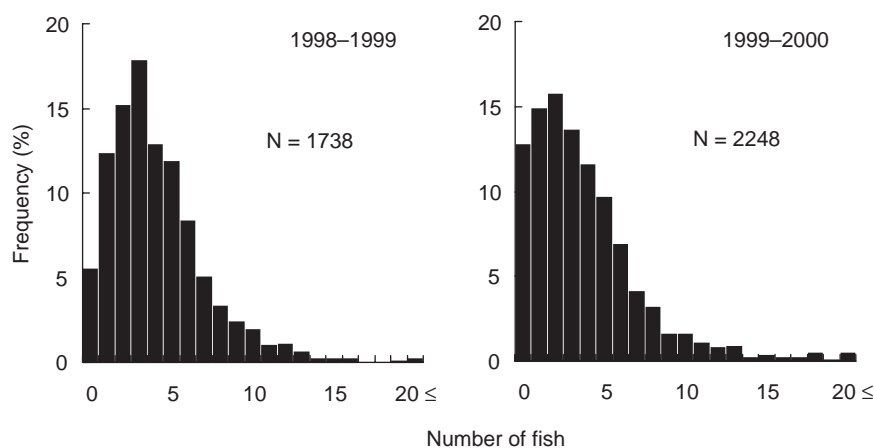


Fig. 3 Frequency distributions of recreational catches of masu salmon per angler in the coastal areas off Iburi, Hokkaido.

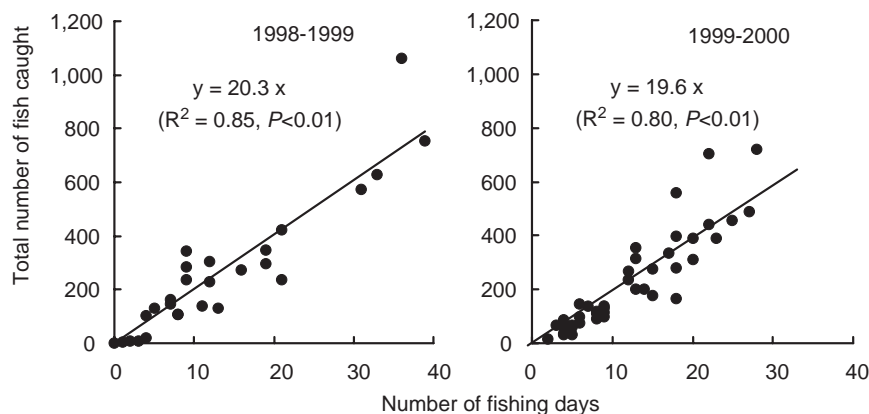


Fig. 4 Relationship between effort (number of fishing days) and catch (total number of masu salmon caught by each fishing boat) in the coastal area off Iburi, Hokkaido.

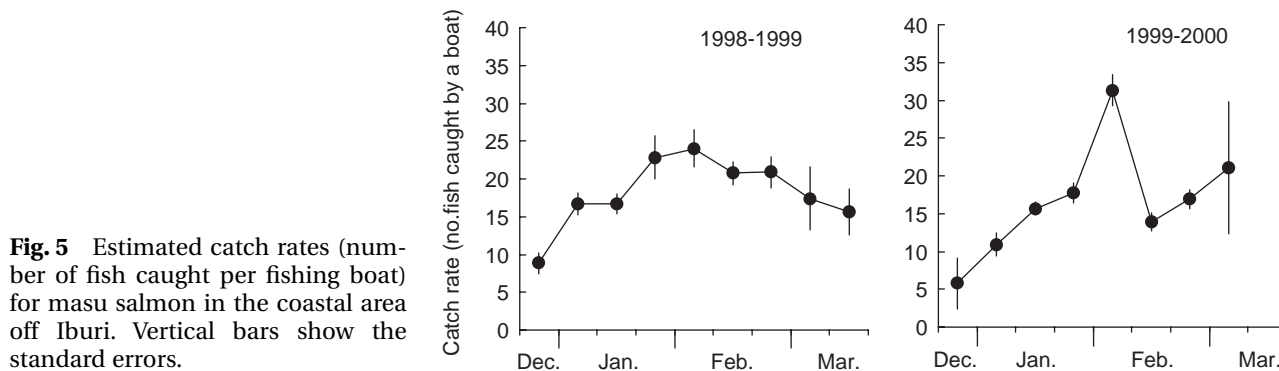
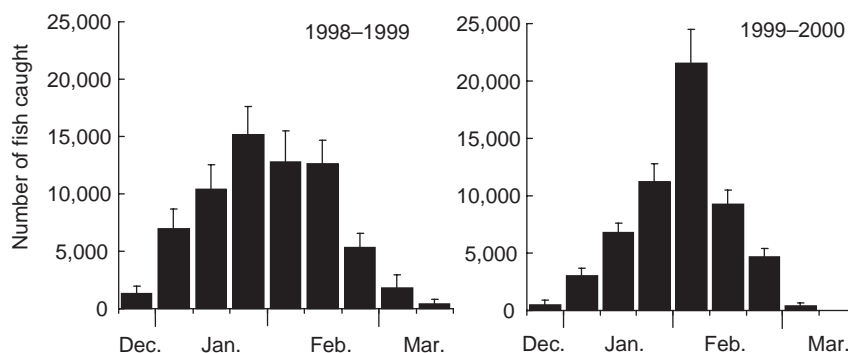
75.5% and 78.0% of the total numbers of anglers in 1998-1999 and 1999-2000, respectively (Fig. 3), and the number of anglers who did not catch a masu salmon was 5.5% and 12.7% of the total in 1998-1999 and 1999-2000, respectively. Conversely, a few anglers caught more than 10 fish; 3.5% in 1998-1999 and 4.6% of the total in 1999-2000. The maximum numbers of fish caught by an angler per day were 28 fish in 1998-1999 and 35 fish in 1999-2000.

Numbers of fishing days in a fishing season widely varied among party boats, from 0 to 39 days. The mean number of fishing days was 13.2 days in 1998-1999 and 12.1 days in 1999-2000. Positive correlations existed between numbers of fishing days and total numbers of masu salmon caught (Fig. 4).

The mean number of masu salmon caught per boat per day was 19.8 and 18.6 fish in 1998-1999 and 1999-2000, respectively (Table 1). The peak in

Table 1 Estimates of recreational catches from the sampling survey for recreational party boats and commercial catches of masu salmon in the Iburi district, Hokkaido

Year (December–March)	Catch rate (mean no. masu salmon caught per boat per day)			Total no. masu salmon caught by recreational party boats			Commercial catch
	Estimate	SE	CV	Estimate	SE	CV	
1998–1999	19.8	1.81	0.09	66 844	11 685	0.17	7 231
1999–2000	18.6	0.97	0.05	57 454	6 559	0.11	17 301

**Fig. 5** Estimated catch rates (number of fish caught per fishing boat) for masu salmon in the coastal area off Iburi. Vertical bars show the standard errors.**Fig. 6** Estimates of numbers of masu salmon caught by recreational anglers in the coastal area off Iburi. Vertical bars show the standard errors.

catch rate was in early February in both seasons (Fig. 5). Estimated catches of masu salmon peaked in late-January in 1999 and early February in 2000, and decreased after mid-February in both years (Fig. 6). In 1999, periodic estimates of recreational catches were over 10 000 fish for four periods from mid-January to mid-February. In 2000, catches increased abruptly in early February, but the good fishing did not last long. Estimates (standard errors) of recreational catches for the entire fishing season were 66 844 (11 685) fish in 1998–1999 season and 57 454 (6559) fish in 1999–2000 season (Table 1).

DISCUSSION

In the Iburi district, south-western Hokkaido, we conducted a single-stage cluster sampling survey

with the party boat as a sampling unit to estimate recreational catches of masu salmon. Catch rate (number of masu salmon per fishing boat per day) peaked in early February and, in this period, number of fishing boats operated in the coastal area off Iburi increased. In the weekends in late January and early February, we counted 150–200 fishing boats concentrated in the main fishing area off Iburi. Number of fishing days varied greatly among fishing boats from 0 to more than 30 days. The fishing boats with only a few fishing days were not operated constantly for masu salmon fishing throughout the fishing season, but were operated only around peak periods. Commercial catches in the Iburi district during the same periods were 7231 and 17 301 fish in 1998–1999 and 1999–2000, respectively (Table 1). Recreational catches exceeded the commercial catches in both seasons;

however, masu salmon were only taken in the commercial fishery as bycatch. Annual commercial catches of masu salmon in Hokkaido were 557 084 and 437 815 fish in 1999 and 2000, respectively.¹⁹ In both years, commercial catches in the Iburi district in winter were approximately 12–13% of the total annual commercial catches in Hokkaido.

In Hokkaido, other than the Iburi district, recreational fishing for masu salmon is popular in south-western areas both on the Pacific Ocean and the Sea of Japan sides. Moreover, the number of privately owned boats recently is increasing, and they may catch many masu salmon, although we surveyed only recreational party boats that belong to the fishing boats associations. Therefore, our estimates of recreational catches are underestimated. Thus, the number of masu salmon caught in the recreational fishery in the coastal areas of Hokkaido is substantial and illustrates the importance of evaluating this fishery in the overall assessment and management of masu salmon stocks.

In the Iburi coastal area in winter, masu salmon stocked in various regions in Hokkaido, including the Sea of Japan side, have been landed by commercial fishery,¹⁴ and tagged masu salmon released from the Sea of Japan side have been recaptured also by recreational anglers.¹⁹ In evaluating the effectiveness of stock enhancement programs for masu salmon, it is important to assess the number of hatchery-origin fish caught by recreational anglers. When estimating catches of hatchery-origin fish, the number of marked fish landed should be estimated. Fin-clipping is commonly used to mark hatchery-reared masu salmon;²⁰ however, it is not realistic to expect to obtain accurate reports of recaptures of such marked fish from recreational anglers. In the present study, we estimate only the total number of masu salmon. To estimate the number of marked fish caught, marking techniques should be improved and/or a methodical sampling strategy should be undertaken.

For some fish species enhanced by stocking hatchery-reared fish, commercial fishermen pay fees for enhancement activities. In some regions in Hokkaido, a part of the landing values of masu salmon by commercial fishermen is charged for enhancement programs. In the Iburi area, a license system for masu salmon fishing, established by the Iburi region fishery regulation committee, has been in effect since December 2000. Fishing time (from dawn to noon) and the maximum number of fish caught by an angler (10 fish per day) is restricted (release is not permitted), and anglers are obliged to report the number of fish caught. Captains of licensed fishing boats pay license charges, which support the enhancement activities

for masu salmon. For sustainable fishery stock management, such a system monitoring the numbers of fish captured in both commercial and recreational fisheries is necessary and, moreover, commercial and recreational fishermen should obtain a common understanding of the conservation of fishery stocks.

This is the first report that has estimated the number of masu salmon caught by recreational anglers in the coastal area. Masu salmon spend 1–3 years in freshwater before migrating to the ocean.²¹ Fishing for juvenile masu salmon (called Yamame or Yamabe) in rivers is popular and fishing pressure is often high.¹² As the present paper reports, fishing pressure is also high in the coastal areas. To properly manage and enhance masu salmon stocks, it is necessary to assess and monitor the numbers of masu salmon captured in fresh and marine waters.

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