CONFLICTS BETWEEN RECREATIONAL AND COMMERCIAL FISHING IN LAKE TOYA, HOKKAIDO, JAPAN

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ABSTRACT

Recently, the number of recreational fishers has increased in Japan. Recreational fishers have caught larger numbers of fish than commercial fishers in some species. Formulating an appropriate management strategy that considers the recreational and commercial sectors is important. Sockeye salmon (*Oncorhynchus nerka*) have been caught in Lake Toya, Hokkaido, Japan, by both recreational and commercial fishers. The number of sockeye salmon caught in Lake Toya is decreasing and population management and regulation must be considered. While the number of sockeye salmon in commercial catches is reported, the number of fish caught in recreational fishing is not available, which is why an appropriate management strategy has not been made until now. In this study, we conducted a mail survey and access point survey from 1998 to 2003 (except 2000), to estimate catch numbers, the fishing effort of recreational fishers, and the population of sockeye salmon in Lake Toya. The mail survey questions in questionnaires distributed to recreational fishers with a recreational angling license included date of angling, caught fish species and size, and catch number. In the access point survey we also asked recreational fishers whether they had a license or not. The fish population was estimated using the DeLury method. The estimated total angling effort was 1,400-1,800 people in 1998-2002. The estimated recreational catch was 28,889 in 1998 and was rapidly decreasing. The recreational catch was two or four times larger than the commercial catch. The total exploitation rate was over 60%, except for 2003.

Keywords: Inland fishery; recreational fishing; Lake Toya; Angler survey; Population estimation

INTRODUCTION

Recently, the number of recreational fishers has increased all over the world including Japan. According to the fishery census in Japan, the population of recreational fishers has increased constantly and rapidly in this decade.[1] (Fig. 1) Recreational fishers have caught larger numbers of fish than commercial fishers in some species.[2] Formulating an appropriate management strategy that considers recreational and commercial sectors has therefore become more important.[3, 4]

Sockeye salmon (*Oncorhynchus nerka*) has been caught in Lake Toya, Hokkaido, Japan, by both recreational and commercial fishers. They are captured by commercial fishers using gill nets and by recreational fishers by angling.

Lake Toya at 42º36'N, 140º51'E is 84 m above sea level. (Fig. 2) The lake is oligotrophic of volcanic origin. The surface area is 70km^2, the volume is 8.19km^3, the maximum depth is 179m, the mean depth is 116m, the length of shoreline 36km, and the catchment area is 173km^2. Lake Toya is a caldera lake in the western part of Shikotsu-Toya National Park in southern Hokkaido. Toya Hot Springs and the Usu Volcano Group are on the southern shore. The lake is more or less circular in shape and has a group of islands at its centre. The bottom is covered by pyroclastic sediments. There are some 30 inflowing streams, but their discharge rates are very small except that of R. Horobetsu. R. Sibetsu is the sole outflowing river. However, after 1937, R. Oru became a new outlet through the diversion of the lake water for hydroelectric power generation and flood control. The lake water became acidic after 1937

owing to the inflow of mining wastewater until pH 5 was reached around 1970, but the acidity has recently been improved to pH 6.8-7.0 after neutralizing treatment in 1972. [5] The lake has sockeye salmon (*Oncorhynchus nerka*), masu salmon (*Oncorhynchus masou*), Japanese pond smelt (*Hypomesus transpacificus nipponensis*), rosy dace (*Tribolodon ezoe*), common freshwater goby (*Chaenogobius* sp.) and floating goby (*Rhinogobius* sp.)[6]

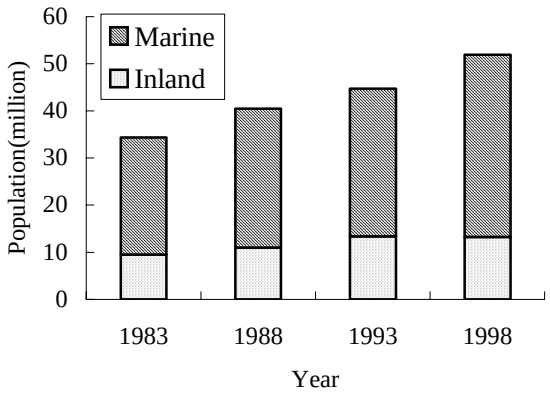


Figure 1. Population of recreational fishers in Japan according to the fishery census [1]

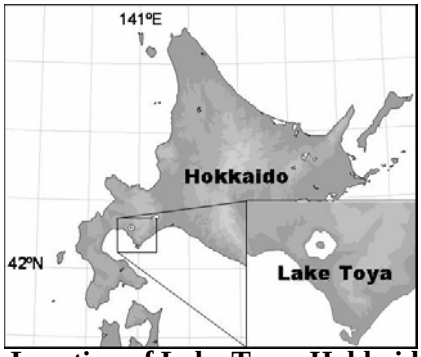


Figure 2. Location of Lake Toya, Hokkaido Japan.

The main fishing period is the month of June. Recreational fishers must buy a fishing license when they fish for recreational purposes in Lake Toya. There are two kinds of fishing license: a season-permit (20,000yen), and a day-permit (1,200yen). The permits allow a minimum length limit of 150 mm for sockeye salmon, a maximum of three rods and three hooks for each rod, and are based on authorized recreational fishing regulations.

According to the data of the Lake Toya Fishery Cooperative Association (FCA), annual commercial fishery catches of sockeye salmon in Lake Toya were 143 t in 1963, but they decreased markedly to 0.5 t in 1966 because of the acidification. After the neutralization treatment in 1972, the catch amount gradually increased and reached 12t in 1992 but it decreased after 1992 (Fig. 3). The sockeye salmon population in Lake Toya is partly sustained by stocking with hatchery-reared larvae released by the Toya FCA. In recent years, the cooperative association could not catch enough mature fish, and the number of released juveniles decreased.

Recently, ecosystem damage by invasion of alien species has been frequently reported in Japan [7-9]. However, few fish of alien species exist in Lake Toya, and their effect is considered to be negligible. The catch-and-release system is widely used by recreational fishers and in some cases the mortality caused by

angling is considerably small [10-13]. However, with the sockeye salmon in Lake Toya, most recreational fishers do not release the caught fish.

The number of sockeye salmon caught in Lake Toya is decreasing and population management and regulation must be considered. While the number of sockeye salmon in commercial catches is reported, the number of fish caught by recreational fishers is not available, which is why an appropriate management strategy has not been developed until now. The catching of sockeye salmon in Lake Toya is typical of the conflict between commercial and recreational fisheries.

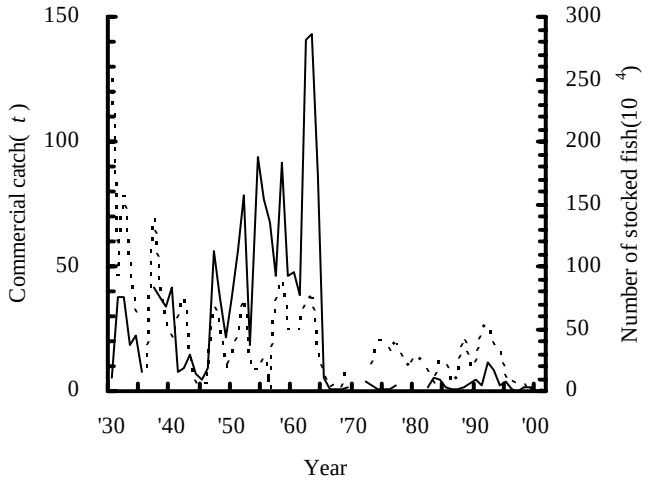


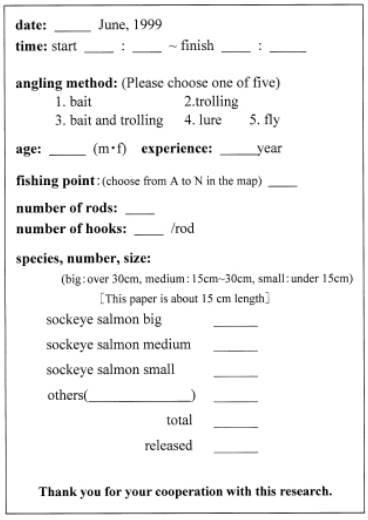
Figure 3. Commercial catch and number of stocked sockeye salmon.

We conducted a mail survey and an access point survey to estimate the catch numbers, the fishing effort of recreational fishers and the population of sockeye salmon in Lake Toya from 1998 to 2003. However we did not conduct this survey in 2000 because of the volcanic eruption of Mt. Usu which is adjacent to Lake Toya. We have already reported some of the results in 1998 and 1999. [3] In this study, we analyzed the data from 1998 to 2003, except 2000.

MATERIALS AND METHODS

Mail survey

Mail surveys were conducted using questionnaires (Fig.4) distributed with fishing licenses to recreational fishers every day in June from 1998 to 2003, except 2000. The questionnaires were collected mainly by business reply mail. Some of the questionnaires were collected by access point survey interviewers directly.



date: _____ June, 1999
time: start ____ : ____ ~ finish ____ : _____

angling method: (Please choose one of five)
1. bait 2.trolling
3. bait and trolling 4. lure 5. fly

age: _____ (m・f) **experience:** _____year

fishing point: (choose from A to N in the map) ____

number of rods: ____
number of hooks: ____ /rod

species, number, size:
(big: over 30cm, medium: 15cm~30cm, small: under 15cm)
[This paper is about 15 cm length]

sockeye salmon big _____
sockeye salmon medium _____
sockeye salmon small _____
others(_____) _____
total _____
released _____

Thank you for your cooperation with this research.

Fig. 4 The questionnaires used in the survey, originally in Japanese

In the questionnaire, we asked recreational fishers about the date fished, the starting and finishing time, fishing gear and method, the fishing site, the caught fish species, the size of caught fish, and the numbers of caught and released fish.

Access point survey

We also conducted access point surveys to estimate the proportion of recreational fishers having a fishing license and to find out if the mail survey had a bias. We also investigated more precisely the size and weight of fish caught.

We conducted the access point survey at a minimum of five main landing places for three days every year. We interviewed almost all recreational fishers whose boats returned to the landing places. Interviewers asked recreational fishers if they had a fishing license. We also asked the recreational fishers the same questions as the mail survey questionnaire in order to analyse the bias. We also measured the fork length and weight of the caught fish.

Estimations

We estimated fishing effort and the total catch of recreational fishers of Lake Toya in the season from the angling survey, and the population of sockeye salmon in Lake Toya from both the angling survey and the catch record of the Toya FCA, following the method of the previous report [3]. We also estimated the standard errors of the estimators, but these are not described in this paper.

1. Angling effort for 1998: As the number of licenses sold in 1998 was not available, we estimated the return rate from the access point survey. The questionnaire return rate $\hat{p}$ is estimated as,

$$\hat{p} = \frac{m}{\nu}, \tag{1}$$

where m is the number of recreational fishers who had completed the questionnaire before the interview, and ν is the number of recreational fishers interviewed by the access point survey. By using this estimated return rate, fishing effort (person ·day), X , is estimated as,

$$\hat{X} = \frac{M}{\hat{p}}, \tag{2}$$

where M is number of questionnaires collected.

2. Angling effort of season licensed recreational fishers in 1999 and after: The numbers of licenses sold were available both for day licenses and season licenses. The average number of days that a season license recreational fisher fished in the fishing season, $\hat{d}$, is calculated as,

$$\hat{d} = \frac{\sum_{i=1}^{M} d_i}{M}, \tag{3}$$

where d_i is the number of days that the season license recreational fisher i fished in the fishing season.

The total fishing effort of season license recreational fishers, X_s is estimated as

$$\hat{X}_s = S_s \cdot \hat{d}, \tag{4}$$

3. Fishing effort of recreational fishers: We estimated the probability that an recreational fisher held a license, $\hat{r}$, by access point survey as

$$\hat{r} = \frac{h}{\nu}, \tag{5}$$

where h is the number of recreational fishers interviewed who had a license.

We estimated the total fishing effort of recreational fishers without a season license, i.e., the fishing effort of recreational fishers licensed for a day and without a license in the fishing season, X_d, as

$$\hat{X}_d = \frac{S_d}{\hat{r}}, \tag{6}$$

where S_d is number of sold day license.

4. Total catch: The catch rate $\hat{R}$ is estimated as,

$$\hat{R} = \frac{\sum_{i=1}^{n} y_i}{n}, \tag{7}$$

where y_i is the number of catches by a recreational fisher in a day, the information regarding which was collected by questionnaire, and n is number of y_i data.

The total catch Y is estimated as

$$\hat{Y} = \hat{X} \cdot \hat{R}. \tag{8}$$

where,

$$\hat{X} = \hat{X}_d + \hat{X}_s. \tag{9}$$

5. Fish population The fish population number was estimated using the DeLury method [14, 15]. The population dynamics model is

$$N_j = N - \sum_{k=1}^{j-1}\left(\hat{C}_k^{(r)} + C_k^{(c)}\right), \tag{10}$$

where N_j is the population number at the beginning of day j, N is the population number at the beginning of the fishing season, $\hat{C}_j^{(r)}$ is the estimated catch number of recreational fishers on day *j*, $C_j^{(c)}$ is the reported catch number of commercial fishers on day *j*.

$\hat{C}_j^{(r)}$ is estimated as

$$\hat{C}_j^{(r)} = \sum_{i=1}^{I_j} \frac{y_{ij}}{\hat{a}}, \tag{11}$$

where y_{ij} is the catch number of recreational fishers *i* on the day *j*, $\hat{a}$ is the number of replies for the catch number

$$\hat{a} = \frac{Y}{\sum_{j=1}^{T}\sum_{i=1}^{I_j} y_{ij}}, \tag{12}$$

and I_j is the number of questionnaires collected on day *j*, *T* is the number of days in the fishing season. $C_k^{(c)}$was obtained from the Toya FCA.

The estimated catch number in each day is

$$\hat{y}_{ij} = qN_i \text{ for all } i, \tag{13}$$

where *q* is the catchability coefficient.

We estimated *q* and *N*, maximizing the likelihoods [16] of the model below;

$$L = \frac{1}{\sqrt{2\pi\sigma^2}} \prod_{j=1}^{T}\prod_{i=1}^{I_j} \frac{1}{y_{ij}} \cdot \exp\left[-\frac{\left(\ln y_{ij} - \ln \hat{y}_j\right)^2}{2\sigma^2}\right]. \tag{14}$$

We also examined an alternative model which assumes that the distribution of residuals of y_{ij} are a normal distribution instead of a log-normal distribution as this model, and found that generally this model fits better than the alternative model.[3]

6. Escapement We also estimated the number of fish caught neither by recreational angling nor commercial fisheries in the fishing season. The estimated escapement $\hat{E}$ is

$$\hat{E} = \hat{N} - \hat{Y} - C^{(c)}, \tag{15}$$

where

$$C^{(c)} = \sum_{j=1}^{T} C_j^{(c)}. \tag{16}$$

RESULTS

Fish species

From the mail survey, almost all fish caught were sockeye salmon. Only the catch reports of sockeye salmon were used for the analysis.

Angling effort

Table 1 shows the estimated angling effort. The efforts are fairly stable from 1998 to 2002 but dramatically decreased in 2003 because the sockeye salmon stock in Lake Toya had decreased.

Table 1 Estimated angling effort for sockeye salmon in Toya Lake from 1998 to 2003 except 2000.

Year		# Questionnaires collected	Return rate	Angling effort ±s.e.
1998	Mail Survey	213	0.156	1382 ± 472
	Access point survey	67	1	67 ± 0
	Angling association	311	1	311 ± 0
	Total	**591**	**0.336**	**1760 ± 472**
		# Licenses sold	**licenses holding rate**	**# days fished**	
1999	Day license	719	0.907	1	793 ± 17
	Season license	36	1	20.09	723 ± 68
	Total	**755**			**1516 ± 70**
2001	Day license	632	0.721	1	877 ± 25
	Season license	37	1	15.9	588 ± 90
	Total	**669**			**1465 ± 93**
2002	Day license	432	0.629	1	687 ± 16
	Season license	42	1	18.5	777 ± 42
	Total	**474**			**1464 ± 44**
2003	Day license	294	0.593	1	496 ± 6
	Season license	18	1	n.d.	n.d. ± n.d.
	Total	**312**			**496 ± 6**

Catch

Table 2 shows the total number of catches by recreational fishers from the angling effort and the catch rate estimated from questionnaires. The catch rate declined rapidly. The catch rate in 2003 was only 6.8% of the catch rate in 1998. Because the angling effort also decreased in 2003, the total catch in 2003 decreased to only 1.9% of that in 1998.

We examined the difference in the catch rate reported by mail survey and access point survey. No significant differences were detected between the two surveys in either year. [3]

Table 2 Estimated number of fishing effort, catch rate and total catches of sockeye salmon by recreational fishers in Lake Toya from 1998 to 2003

Year	Angling effort	±s.e.	Catch rate	±s.e.	Total Catch	±s.e.
998	1,760	±472	16.41	±0.46	28,889	±7795
1999	1,516	±70	3.60	±0.22	5,455	±412
2001	1,465	±93	6.94	±0.25	10,173	±750
2002	1,464	±44	1.65	±0.08	2,413	±148
2003	496	±6	1.11	±0.11	548	±53

Fish population size

We estimated the population size of sockeye salmon at the beginning of the fishing season (Table 3). The initial population was estimated as 60,262 in 1998 and decreased to 2,958 in 2003, that is, only about 5% of the 1998 population.

Table 3 Estimated populations of sockeye salmon in Lake Toya. 95% confidence intervals are indicated in parenthesis.

Year	Population		Catchability coefficient	
1998	60,262	(51,673 ,71,776)	0.000321	(0.000240 ,0.000428)
1999	10,806	(10,300 ,11,359)	0.000434	(0.000387 ,0.000485)
2001	21,698	(20,439,23,072)	0.000289	(0.000262,0.000320)
2002	5,225	(4,797,5,681)	0.000298	(0.000264,0.000334)
2003	2,958	(2,378,3,595)	0.000252	(0.000196,0.000313)

The estimated initial population in recreational catch, commercial catch, and escapement are shown in Table 4. From our estimation, 68% (2002) to 78% (1999) of fish were caught in the fishing seasons from 1999 to 2002, except 2000, but only 22% were caught in 2003. Recreational fishers caught much more fish than commercial fishers, the amount being greater by 1.8 times (1999) to 4.4 times (2003).

Table 4 Estimated initial population numbers, estimated recreational catch, commercial catch, and escapement

Year	Population	Catch		Escapement
		recreational	commercial	
1998	60,262	28,889	8,426	23,947
	100%	48%	14%	38%
1999	10,806	5,455	2,983	2,368
	100%	50%	28%	22%
2001	21,698	10,173	3,546	7,979
	100%	47%	16%	37%
2002	5,225	2,413	1,126	1,686
	100%	46%	22%	32%
2003	2,958	536	121	2,301
	100%	18%	4%	78%

DISCUSSION

Because of the increase in numbers of recreational fishers [1], formulating an appropriate management strategy that considers both recreational and commercial sectors has become more important. In some cases, it was thought that the recreational fishery catches exceeded those of commercial fisheries[2], but recreational fishery catches are usually unavailable, which is why an appropriate management strategy has not been made until now[3, 4]. Thus quantitative information is important for management in order to formulate an appropriate management strategy. Although over fishing of sockeye salmon in Lake Toya has been discussed, no quantitative information has been available. The quantitative results of this study will provide important information in discussing the stock condition and fishery management of sockeye salmon in Lake Toya.

This study offers quantitative information of the Toya Lake sockeye salmon population based on interviews and questionnaires. The reliability of the results largely depends on the quality of data. In this study, we believed that reliable catch data were obtained, by courtesy of the recreational fishers and Toya FCA. In addition, one or more researchers stayed at Lake Toya in the fishing season and communicated with recreational fishers and Toya FCA, which makes the data more reliable. We also compared the reports of a mail survey and an access point survey, and these showed no significant differences, which suggests no bias in estimating the catch rate.

This study revealed that total catches of recreational fishers were 4.5 times (2003) greater at maximum in the years we surveyed. The exploitation rate was high at 79% (1999). It seems that the recreational fishery has an effect on the population dynamics of sockeye salmon in Lake Toya but as we showed in Fig. 1, the population fluctuates dramatically and the fluctuation is partly caused by environmental changes. The mechanism affecting the population dynamics of sockeye salmon in Lake Toya has to be investigated specifically. We are analyzing the age compositions of sockeye salmon samples obtained from non-selective gillnet sampling conducted by Toya Experimental Station, Hokkaido University, and we are estimating the population of sockeye salmon from the early 1990's. This investigation will reveal the stock-recruitment relationship, which can be utilized for future forecasts of population dynamics.

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