Recreational fisheries as a conservation tool for endemic Dolly Varden *Salvelinus malma miyabei* in Lake Shikaribetsu, Japan

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Abstract

Recreational angling is a globally popular leisure, which can be a threat or a useful conservation tool depending on the management strategy. Miyabe charr *Salvelinus malma miyabei* is an endemic fish that inhabits Lake Shikaribetsu, and a management program was established to harmonize recreational fisheries and conservation. To examine the suitability of this program, a population assessment was conducted with cooperation of anglers. The population size in 2014 assessed by tag-and-release angling was estimated to be 105,300 (95%CI: 37,300–178,600), much higher than reported estimate in 1995. Further, angling mortality was estimated to be quite low. Moreover, no decreasing population trend was detected on analysing 8 years of angler's catch data. Consequently, angling has facilitated stock assessments of Miyabe charr under the current program. This case is a good example of recreational angling acting as a conservation tool under appropriate management.

Key words: angling, catch-and-release, conservation, Dolly Varden, Miyabe charr, recreational fisheries

Introduction

Recreational fisheries are an important use of fish resources in most parts of the world [1,2], particularly in inland waters of industrialized countries [3]. Because the catch of recreational anglers is not sometimes self-regulated, recreational fisheries may lead to the collapse of fish populations in the same manner as commercial fisheries [4]. Therefore, recreational fisheries management is essential for the sustainable use of inland fish stocks.

Various management tools and strategies, including bag limits, fishing gear restrictions and a limit on the number of daily anglers, have been introduced to facilitate sustainable recreational fisheries [5,6]. In addition to these fishing restrictions, catch-and-release can be an effective tool for maintaining fish populations if the after-release mortality is low, because anglers can receive pleasure from the activity in some kind of angling [5-7]. There are some instances where the establishment of appropriate fishing regulations, including catch-and-release, has resulted in sustainable recreational fisheries [8].

When recreational fisheries are managed sustainably, they function as a conservation tool rather than a threat to fish populations [8,9]. For example, recreational fisheries can monitor fish populations by collecting a standard suite of quantitative and qualitative data on the fish caught [9]. To evaluate recreational fisheries as a tool to conserve fish populations, it is important that 1) the angling impact is scientifically determined to be negligible, 2) the angling effort is monitored and regulated and 3) the condition of a fish population is continually determined by a monitoring program [8].

Miyabe charr *Salvelinus malma miyabei* is an endemic subspecies of the Dolly Varden that only inhabits Lake Shikaribetsu and its inlet streams, Japan [10]. Miyabe charr is a popular target for recreational anglers because of its beautiful appearance. Since Miyabe charr spawn in inlet streams from September to November, inlet streams of Lake Shikaribetsu are designated as fishing prohibited area by ordinance [11]. Thus, anglers target Miyabe charr in the lake during their feeding migration.

Since 1969, the Shikaoi town government has tried to use the Miyabe charr stock as a recreational resource[11]; however, the stock has declined due to recreational overfishing because they were not managed properly in the 1970s [12,13]. To facilitate the sustainable use of Miyabe charr as a recreational fisheries target, their management was entrusted to the non-profit organization ‘Hokkaido Tourism Union’ and the recreational fisheries management program ‘Great Fishing in Lake Shikaribetsu’ (GFS), initiated in 2005. Under this program, angling is only permitted for 50 days of the year, to only 50 persons/day and fishing gear is restricted. In addition, catch-and-release is required for all Miyabe charr and anglers are required to submit a daily catch report that describes the species and size of the fish caught and its capture location. These regulations were aimed at not only reducing fishing mortality, but also constructing a monitoring system of the Miyabe charr population using angler data.

In Lake Shikaribetsu, recreational fishers should be allowed to take on a role in the conservation of endemic Miyabe charr given that they had once been the reason for their endangered status. In order to achieve this goal, a scientific assessment is needed to evaluate angling mortality and the current state of the Miyabe charr population using angling data. Here this paper reports on a scientific assessment of the Miyabe charr population and determines whether recreational fisheries in Lake Shikaribetsu can be used in their conservation. First, a tag-and-release experiment was performed with recreational anglers to estimate the size of the Miyabe charr population. Second, catch-and-release mortality was estimated to evaluate the angling impact on the Miyabe charr population. Finally, long-term trends in their population levels were estimated by analysing the daily catch reports of recreational anglers over an 8-year period. Based on these results, a scientifically acceptable recreational fisheries management program was assessed as a conservation tool for endemic fish populations.

Materials and methods

Study site

Lake Shikaribetsu is located in the mountainous area of central Hokkaido Island, Japan, at a latitude of 45.3° N and longitude of 143.1° E (Fig. 1). Its area is 3.4 km^2 and average depth is 56.1m [14]. The lake has three small inlet streams and one outlet stream, but outlet stream was dammed in 1953 to regulate the water level [10]. Lake Shikaribetsu contains masu salmon *Oncorhynchus masou* and rainbow trout *O. mykiss,* both of which were introduced [15], and are targeted by recreational anglers.

The fishing season of 50 days per year is divided into two seasons: early June to early July, called the ‘first stage’ (approximately 33 days), and late September to early October, called the ‘second stage’ (approximately 17 days). In addition, the northern part of the lake and all of its inlets are designated as no-fishing areas throughout the year [16](Fig. 1). Angling gear is also restricted to only lure or fly fishing, one fishing rod per person and only one single barbless hook per a rod can be used.

In addition to these fishing gear restrictions, anglers also required reporting their daily all catch to submit catch report sheet by fishing regulation. In catch report sheet, anglers report about species, size and capture place of all individuals that they captured. Anglers can approach to Lake Shikaribetsu through only one way-in, which enables stock manager to collect catch report sheet from all anglers.

Life history of Miyabe charr

Miyabe charr has two types of life history: the lake-run type and stream-resident type [10]. Lake-run fish usually inhabit the lake and feed mainly on zooplankton [15,17]. During September–November, mature lake-run fish migrate to inlet streams and spawn, after which they return to the lake and start their feeding migration again [10]. On the other hand, stream-resident group live their entire life in stream [10,15]. Thus, recreational anglers target adult lake-run Miyabe charr during their feeding migration and immature fish that remain in the lake during the spawning season. In the open fishing area, anglers from onshore or on boats target Miyabe charr. Since the shoreline where angling from onshore is allowed is away from way-in, all anglers have to rent or bring their boat regardless they are going to angle from onshore or on boat. Thus, on-boat angler and onshore angler are indistinguishable.

Tagging study of Miyabe charr

A tag-and-release experiment was conducted over the first 10 days of the first stage season from 7 to 16 June 2014. Once fish were caught and the hook was removed, the fish were anaesthetized using 2-phenylethanol and the fork length (FL) was measured. A red, yellow or blue numbered anchor tag (35 mm, Toska-Bano'k Co., Ltd., Tokyo) was attached to the base of the dorsal fin; the tag colour represented the capture site. The tagged fish were released at their point of capture (Table 1, Fig. 2), after their recovery from anesthesia [7]. All angled Miyabe charr were tagged-and-released except for severely injured fish (5 fish). FL of tagged fish was 272 ± 28.4 mm (mean ± SD).

To obtain recapture reports of tagged fish from anglers, recapture report sheets were distributed to anglers with their licence tickets and catch report sheets. When tagged fish were recaptured, the anglers recorded their length, recapture position, tag number and colour on the recapture report sheet and then released them.

Estimation of population size based on tagging and angling data

To estimate the population size based on tag-and-release data, tagging mortality and tag loss were assumed negligible [18]. In our study, a pen experiment was conducted using tagged Miyabe charr to assess the validity of these assumptions. Nine or ten Miyabe charr were caught, tagged and kept in a pen (37 cm long × 52 cm wide × 30 cm high) and the same number of untagged Miyabe charr were kept in an alternative pen as a control. The pen experiments were conducted with experimental periods of 24 h (4 trials using a total of 39 fish) and 17 days (1 trial using 10 individuals). FL of tagged Miyabe charr was 277 ± 29.1 mm and 268 ± 34.4 mm for the control. Severely injured fish was also excluded from pen experiment following tagging study. In addition, natural mortality during first stage was also assumed negligible because natural mortality of adult Miyabe charr occur mainly after spawning [19].

The population size was estimated using the Schnabel method with an adjustment for the small sample size as follows [18]:

$$N_f = \frac{\sum M_i n_i}{\left(\sum m_i\right) + 1} \quad (1)$$

$$\mathrm{SE} = N_f \sqrt{\frac{1}{\sum m_i + 1} + \frac{2}{\left(\sum m_i + 1\right)^2} + \frac{6}{\left(\sum m_i + 1\right)^3}} \quad (2)$$

where N_f is the population size of the first stage, M_i is the total number of tagged-and-released fish on day i, m_i is the number of recaptured tagged fish on day i and n_i is the total number of fish caught by a recreational angler on day i. 95% confidence interval (95%CI) was also calculated as follows:

$$N_f - 1.96 \times \mathrm{SE} < N_f < N_f + 1.96 \times \mathrm{SE} \tag{3}$$

Validation of estimated population size

To assess the accuracy of the estimated population size, population size in first stage was also estimated using recapture data during second stage, under the assumption that tagging ratio at second stage was equal to that in first stage. estimated population size using data during second stage $N_f^{'}$ was calculated as follows:

$$N_f^{'} = \frac{(M_f + 1)(n_s + 1)}{(m_s + 1)} \tag{4}$$

$$\mathrm{SE} = \sqrt{\frac{(M_f + 1)^2 (n_s + 1)(n_s - m_s)}{(m_s + 1)^2 (m_s + 2)}} \tag{5}$$

where M_f is total number of taged-and-released fish during the first stage, n_s is total number of fish caught by recreational anglers in the second stage, and m_s is total number of recaptured tagged fish during the second stage. The result of equation (4) was compared with that of equation (1) to assess the accuracy of the estimated population size.

Estimation of catch-and-release mortality

Catch-and-release mortality was assumed caused by hooking injury. Generally, it is classified as immediate mortality (<24 h), short-term mortality (24–72 h), and long-term mortality (> 72 h), according to the time at which mortality occurred after release [20]. To estimate the immediate hooking mortality, we counted the number of Miyabe charr that died prior to release (458 fish). Short-term tagging mortality was estimated using the result of the control group in the pen experiments. Since it is known that most hooking mortality occur just after hook removal for charr *Salvelinus* sp. [21], only immediate and short-term mortality was examined as hooking mortalities in Miyabe charr in our study.

Standardized CPUE and estimation of population trends

A standardized CPUE was used to estimate changes in the population size of Miyabe charr in order to avoid potential bias due to environmental factors. Angler data (catch and number of daily anglers) were obtained from the catch report sheets collected by GFS staff between 2007 and 2014. In addition, surface water temperature, weather and wind speed data were included in the analysis, all of which were collected by GFS staff at the same time and location every day during the open season for the 8-year period. Weather and wind force were recorded as categorical data (weather: sunny/cloudy/rainy; wind: weak/little/strong). The relationship between Miyabe charr CPUE and these factors was then analysed using a generalized linear model with a negative binomial distribution. Model selection was performed on the basis of Akaike's information criterion (AIC). The model with the lowest AIC value was considered the best model, and any models whose AIC value was within 2 to the best model were also considered to be substantially supported models [22]. The following variables were included in the model:

$$Catch \sim Anglers\{\exp(Year + W.\,Temp + Weather + Wind)\} \quad (6)$$

where *Catch* is the daily total catch of anglers, *W. Temp* is the surface water temperature and *Anglers* is the number of daily recreational anglers. Data from the first and second stages were analysed separately because the abundance of fish during the second stage would be much lower since it coincides with the spawning season.

Results

Tagging study on Miyabe charr

A total of 310 Miyabe charr were tagged and released in the first 10 days of the first stage in 2014, nine of which were recaptured during the first stage at a rate of 0–2 fish/day (Table 2). In the first stage, four of these recaptured fish could not be identified because their tag number was not reported. The identified five recaptured fish in the first stage had moved in various range in the lake (Fig. 3). During the second stage, two tagged fish were also recaptured, one of which could not be identified.

Estimation of population size in 2014 based on tagging and angling reports

In the pen experiments using tagged fish, no tag-associated mortality nor lost tags were observed during the 24-h or 17-day containment (Table 3), and no mortality was observed in the control fish during any of the experimental periods. Therefore, tagging mortality and tag loss were assumed to be negligible in our study.

The number of captured, tagged-and-released, and recaptured fish that were used in the population size estimate are summarised in Table 2. The recreational catch ranged from two to 636 fish/day and the total catch was 4,865 fish in 33 days of the first stage in 2014. Thus, the population size of Miyabe charr in June 2014 was estimated to be 105,300 ± 37,400 (mean ± SE) fish. (95%CI: 37,300–178,600)

Validation of estimated population size

During the second stage, anglers caught 998 Miyabe charr and two tagged fish were recaptured. As a result, population size was calculated as 103,600 ± 51,700 (mean ± SE) fish. This result was similar to the result of equation (1).

Estimation of catch-and-release mortality

The catch-and-release mortality of Miyabe charr was estimated to be 1.8% (95% CI: 0.8–3.4%). Eight of the 458 fish died shortly after capture. However, no mortality was observed throughout the rest of the experimental period (Table 3). Thus, during the first stage in 2014, angler-associated mortality was estimated to be 88 (95% CI: 39–165) of the 4,865 fish caught, which is <0.1% of the estimated population size.

Standardized CPUE and estimation of population trend

The best model for predicting CPUE included surface water temperature and weather conditions as explanatory variables for both the first and second stages (Table 4). Standardised CPUE was calculated using the best model with the following conditions: water temperature = 12 °C and weather condition = sunny. These were assumed standardised conditions. The standardised CPUE ranged from 3.6 to 14.3 fish/angler-day in the first stage (Fig. 4a) and from 0.9 to 2.4 fish/angler-day in the second stage (Fig. 4b).

In the first stage, population was estimated as increasing trend during 2007–2014. In the second stage, the standardised CPUE fluctuated between 2007 and 2014 and was much lower than that during the first stage (Fig. 4), mainly due to the spawning migration to inlet streams. On the other hand, the total angler catch of Miyabe charr consistently increased over the 8-year period in both the first and second stages (first stage: $r = 0.88$, $t = 4.53$, $P = 0.004$; second stage: $r = 0.73$, $t = 2.60$, $P = 0.041$; Fig. 4c, d). Overall, standardized CPUE was stable or increasing although total catch was increasing consistently.

Discussion

Our study demonstrated a population assessment of endemic Miyabe charr using angling data. As a result, Miyabe charr recreational fisheries was assessed that it has been worked properly as a conservation tool of endemic fish populations under the current management program. First, angling had a negligible impact on fish populations because angling mortality was very low. Second, the current management program precisely checks and regulates angling effort. Third, the fish population was always monitored using angling data. In conclusion, Miyabe charr recreational fisheries in Lake Shikaribetsu should be encouraged to get involved in the conservation of this endemic fish population under the current regulations.

The population size of Miyabe charr was estimated to be 105,300 fish (95%CI:

37,300–178,600) in June 2014. This result was much higher than the previous estimation to be 13,880 fish (95% CI: 9,919–23,110) in 1995 and that to be 31,635 fish (95%CI: 21,708–58,291) in 1996 using a tagging method with a gillnet survey [23,24]. Although 120,000 Miyabe charr were harvested by anglers in 1979 [25], nowadays, the population size is higher than that recorded in 1995 and 1996, even if comparing lower limit of 95%CI of estimation population size in 2014. Furthermore, the standardised CPUE showed an increasing trend during 2007–2014 (Fig. 4) although total catch was increasing continuously, and fishing mortality was negligible. The standardised CPUE in the second stage was much lower than that in the first stage as the latter coincided with the spawning season of Miyabe charr [10], and thus, most of the mature fish were absent from the fishing area. Thus, recreational angling in Lake Shikaribetsu under the present regulations can be considered as sustainable fisheries management.

The hatchery program, which was carried out by Shikaoi town government, was thought to be ineffective to the population trends of Miyabe charr as far as the period of observation of the current study. During 2002–2011, approximately 130,000–245,000 yearling Miyabe charr were released into the lake per year. Since Miyabe charr targeted by anglers are mainly 4 or 5 year fish, number of released fish reflect population after 3 or 4 years. However, population trend during 2007–2014 was increasing despite number of released fish was slightly decreasing during 2004–2011 (Shikaoi town government, unpubl. data, 2016). After 2012, number of released fish was dramatically decreased to 79,186, thus continuing monitoring of Miyabe charr population after 2016 would detect the contribution of hatchery program.

Based on the findings of this study, the size of the Miyabe charr population is increasing and fishing mortality is negligible. It is believed that the fishing regulations have contributed to the recovery and sustainability of this endemic population. These regulations state that only lure or fly fishing using a single barbless hook is allowed in Lake Shikaribetsu, all of which have been well known to reduce hooking mortality in catch-and-release fisheries [5,6,26,27]. Hooking mortality of Miyabe charr was estimated to be 1.8% in our study, which was close to the result of previous study using anadromous Dolly Varden that was estimated to be 1.7% [28]. Thus, the present regulations have been effective in maintaining fishing mortality at a low level. This supports the previous finding that catch-and-release is an effective management approach for the sustainable use of white-spotted charr *S. leucomaenis* [21,29,30].

The tag-and-release method requires five main assumptions. The assumptions are as follows; 1) tagging mortality and tag loss does not occur, 2) all tag recaptures should be reported, 3) the study population is closed and no emigration nor immigration, 4) tagged fish and untagged fish have equal chance to be caught by anglers, and 5) vulnerability for angling is same for tagged and untagged fish [18].

First, tagging mortality and tag loss was confirmed by our pen experiments and was negligible. The second assumption was also confirmed because all anglers have to submit report sheets to GFS staff directly, including tag-recapture information. In addition, since anglers can approach to Lake Shikaribetsu through only one way-in, manager can collect catch report sheet from all anglers due to these geographical characteristics, although it is usually difficult to obtain the data about catch by anglers in other lakes [31].

Third, Lake Shikaribetsu can be assumed as a closed system during the study period. The estimation of fish population size was carried out on June, outside of the migration season from the lake to inlet streams [10]. In addition, the Miyabe charr stock is constructed of plural cohorts [23,24]. Furthermore, study period was 33 days, which was short for recruitment to fishing size (250 mm FL). These conditions weaken the effect of recruitment for estimated population size. Therefore, the recruitment and immigration can be assumed negligible.

Fourth, tagged fish and untagged fish assumed to have equal chance to be caught by anglers because of our study design and dispersal of tagged fish. The tag-and-release procedure was conducted over as wide area as possible (Fig. 2). In addition, recaptured tagged fish were moved in various range in the lake (Fig. 3), mainly because lake-run Miyabe charr migrate all around the lake with feeding on plankton [17].

Fifth, the vulnerability to angling also would be the same between tagged and untagged fish. For white spotted charr, it is known that the angled experience was not related to angling vulnerability [29,30].

The sample size affect to the precision of estimated result. In our study, only nine tagged fish were recaptured, which seemed small. However, similar value was obtained when data in second stage was used to estimate population size in first stage. Therefore, our results have substantial meaning for stock assessments.

The two ecotypes is known for Miyabe charr, migration group and inshore-colonized group [17]. In this study, inshore-colonized group seem to be caught with migration group (Fig. 3). Considering such condition, both type of Miyabe charr are tagged without distinction. Thus, estimated population size in this study includes both type of Miyabe charr.

Cowx et al. [3] proposed some criteria for when anglers could contribute to the conservation of a fish population; 1) management scales are small, 2) threat to conservation originate from outside the fisheries sector, and 3) ecological awareness for the conservation problem is high. In the case of Lake Shikaribetsu, all of these criteria were met. First, Lake Shikaribetsu is small at only 3.4 km^2, in addition, it has only one way-in. Second, Habitat disturbance of inlet stream and/or environmental pollution of lake system can also be threat for Miyabe charr, both of them are outside of fisheries. In such case, monitoring research with anglers would be able to sense population decline at once. In addition, introduced species (masu salmon and rainbow trout) may become threat for Miyabe charr. In this case, introduced species are also monitored since catch of these species by anglers are also reported. In fact, CPUE of these species are lower than that of Miyabe charr during 2007–2014 in first stage (masu salmon: 0.7–3.2 fish/angler-day, rainbow trout: 0.2–0.4 fish/ anger-day, Yoshiyama T, unpubl. data, 2016), although catchability is quite higher than Miyabe charr. These results indicates that Miyabe charr is dominant to introduced species now. Monitoring by anglers can be available not only for conservation target but also for introduced species. Third, a consciousness of the conservation of Miyabe charr is high among all anglers because most anglers know that Miyabe charr only inhabits Lake Shikaribetsu [16]. Indeed, anglers are required to submit daily catch reports for stock monitoring, which may further enhance their awareness of the need for conservation. All of these factors should contribute to harmonising recreational fisheries and the conservation of endangered fish populations. Recreational fisheries give high social and economic value for fish population [32], and they should enhance the conservation of an endemic fish species under sustainable management [8]. Thus, recreational fisheries under an appropriate management program should be useful as a monitoring tool, since they provide not only effort for the research, but also a social and economic value.

To conserve an endemic species inhabiting a limited area such as the Miyabe charr, prohibiting fishing would be the usual conservation tool. However, Miyabe charr recreational fisheries indicate that, under a sustainable management program, recreational fisheries can be used as an alternative conservation tool. It should be noted that even if angling for an endemic species were prohibited, scientific stock assessments would still be needed for their conservation, which would require significant effort and financial resources. In addition, it would be hard to watch unregulated fishing due to effort and/or financial resource. On the other hand, the use of the fish stock as a recreational fishing target in combination with an appropriate management program should enable population assessment with less effort and cost than long-term academic studies would incur. Furthermore, recreational fisheries under appropriate management can work as a deterrent for unregulated fishing due to their own self and peer monitoring of anglers [9]. For successful recreational fisheries as a conservation tool, it should be important to enhance awareness for conservation of fish population among anglers [3,33]. Miyabe charr angling in Lake Shikaribetsu is a good example demonstrating that recreational fisheries programs can conserve an endemic fish population effectively rather than prohibiting fishing altogether.

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Table 1 Summary of tagged-and-released Miyabe charr *Salvelinus malma miyabei* at each site

Date	Released site (Fig. 2)	Tag colour	Number of released fish
June 7	a	Red	50
	c	Red	49
June8	a	Red	18
	d	Yellow	65
	e	Blue	4
June 9	g	Yellow	12
June 10	j	Yellow	10
	g	Blue	2
June 11	a	Blue	5
	h	Blue	15
	i	Blue	8
June 12	h	Blue	5
	i	Blue	46
June 14	a	Red	3
June 16	f	Blue	19
		Total	310

The released site symbol corresponds to that in Fig. 2

Table 2 Summary of the tag-and-release data on Miyabe charr in 2014

Date[a]	Total catch by anglers	Tagged and released fish	Total tagged and released fish	Recaptured tagged fish
June 7	636	99	-	-
June 8	452	84	99	0
June 9	388	12	183	0
June 10	322	14	195	1
June 11	313	28	209	0
June 12	313	51	237	0
June 14	375	3	288	0
June 15-16	707	19	291	4
June 17–July 7	1,359	0	310	4
Total	4,865	310		9

Research and angling on June 13 were cancelled due to a strong storm

Table 3 Summary of the pen experiments used to assess tagging mortality in Miyabe charr *Salvelinus malma miyabei*

Trial		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Containment period		24 h	24 h	24 h	24 h	17 Days
Tagged	Number of fish	10	9	10	10	10
	Number of dead fish	0	0	0	0	0
Control	Number of fish	10	9	10	10	10
	Number of dead fish	0	0	0	0	0

Table 4 The best models for predicting CPUE based on the Akaike's information criterion (AIC) value

(a) First stage

Models	AIC	delta
Intercept + *Year* + *W. Temp*[a] + *Weather*	2214.0	-
Intercept + *Year* + *W. Temp* + *Weather* + *Wind*	2215.7	1.75

(b) Second stage

Models	AIC	delta
Intercept + *Year* + *W. Temp* + *Weather*	866.9	-
Intercept + *Year* + *Weather*	867.6	0.70
Intercept + *Year* + *W. Temp*	868.9	1.97

[a] *W. Temp*, surface water temperature

Figure captions

Fig. 1 Location of Lake Shikaribetsu and angling regulations. Inlet streams and the northern part of the lake were designated as fishing prohibited areas

Fig. 2 Tag-and-released sites in open area. The number of tagged-and-released fish at each site was provided in Table 1

Fig. 3 The movement of individually marked Miyabe charr. The tag number (#) and interval between the mark and recapture are shown. Number 390 (dotted line) was recaptured during second stage

Fig. 4 Time series of standardised CPUE and total catch of Miyabe charr, *Salvelinus malma miyabei*, during 2007–2014 in (a) the first stage and (b) second stage. The change in total anglers' catch in (c) the first stage and (d) second stage

Figures

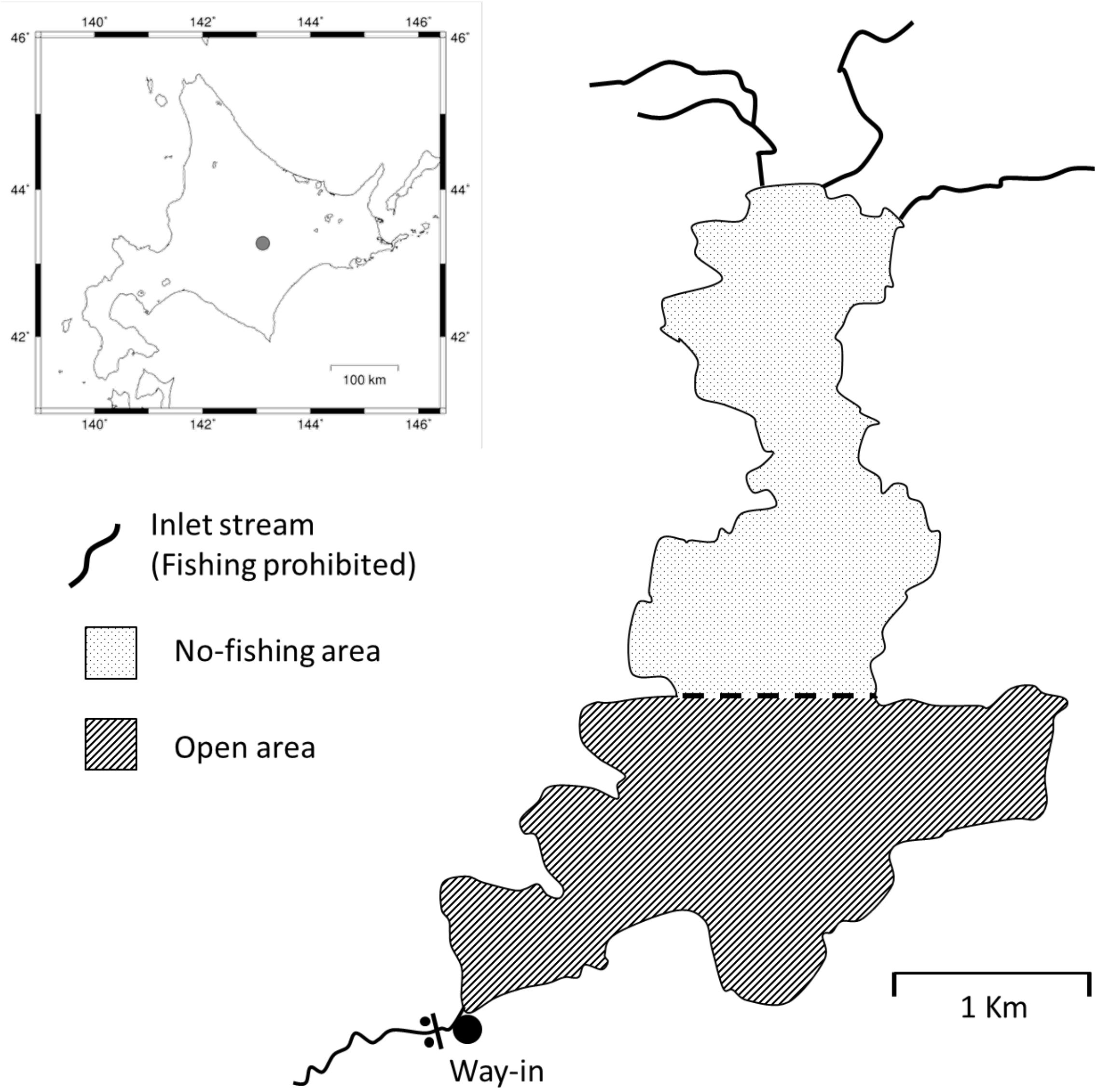

Fig. 1

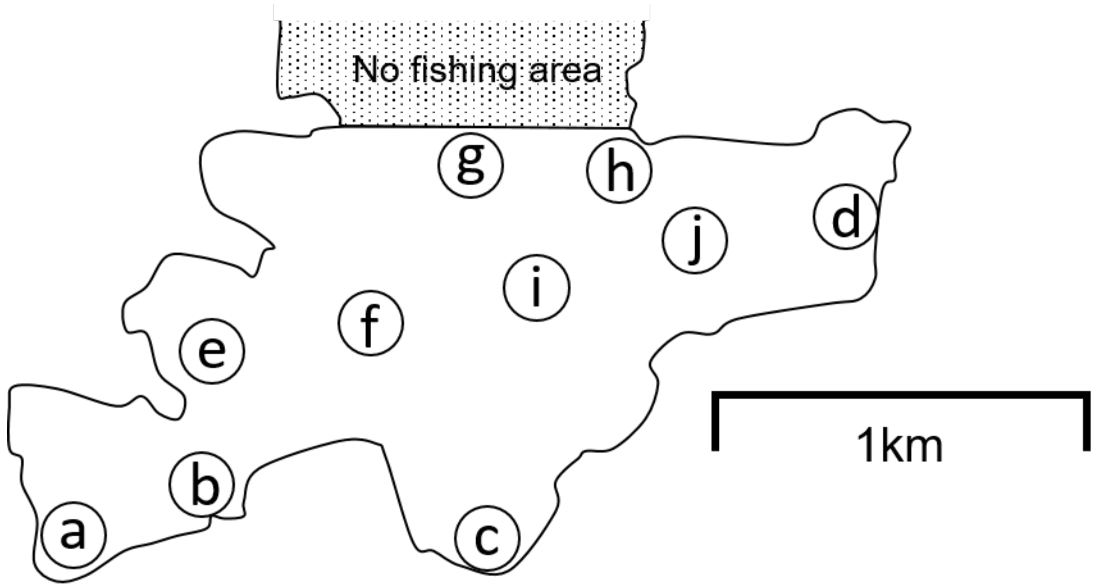

Fig. 2

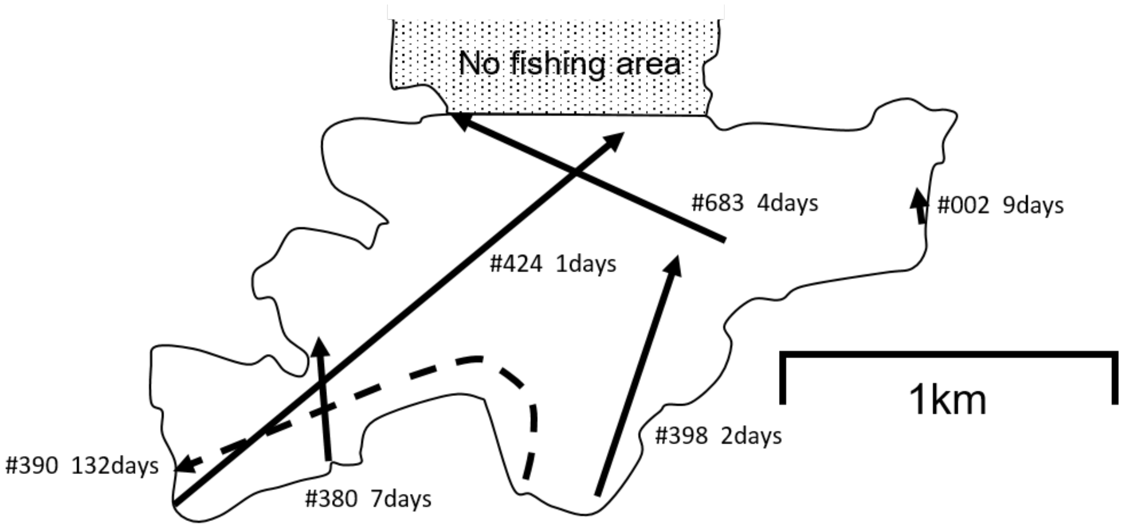
No fishing area
#683 4days
#002 9days
#424 1days
1km
#398 2days
#390 132days
#380 7days

Fig. 3

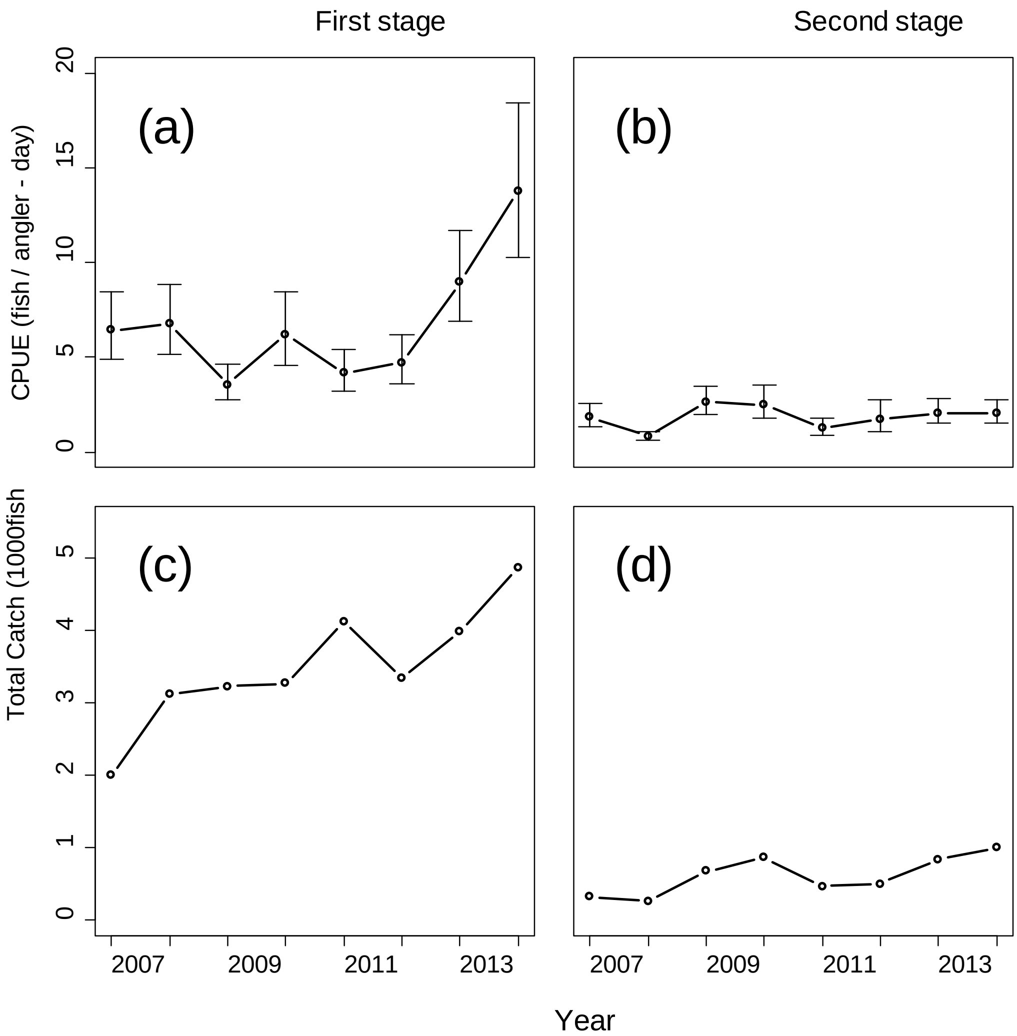
First stage
Second stage
(a)
(b)
(c)
(d)
CPUE (fish / angler - day)
Total Catch (1000fish
0
5
10
15
20
0
1
2
3
4
5
2007
2009
2011
2013
2007
2009
2011
2013
Year

Fig. 4