Extermination of invasive alien fish species during water level drawdown of dam reservoirs

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ABSTRACT: In Japan, an increasing number of invasive alien fish species, such as largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*), are exerting significant impact on dam reservoir ecosystems, causing declines in native species in the lake. The Government of Japan has initiated a number of programs in line with a 2004 law aimed at controlling invasive alien species.
A growing number of alien fish live in dam reservoirs nationwide, and extensive work is needed to evaluate various measures to control these invasive alien fish, which can spread to other water systems through river channels, posing a wide-scale threat to freshwater ecosystems.
This study focuses on methods to exterminate largemouth bass and bluegill, which has a great impact on native ecosystems. In the case of dams for flood control, water levels are periodically lowered to maintain flood-control storage capacity. These drawdown operations has proved to be effective at exterminating largemouth bass in dam reservoirs by either drying out bass eggs in spawning beds or capturing and removing largemouth bass and bluegill using fixed shore nets in dry areas created by the drawdown operations.

1 INTRODUCTION

In the rivers, lakes (including dam reservoirs), and other freshwater systems of Japan, populations of invasive alien fish species, including largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus*, are increasing, resulting in decreasing numbers of native aquatic insects and fish, as well as other serious impacts on indigenous freshwater ecosystems (Azuma 1992, Iguchi 2004, Maezono et.al. 2005).

To conserve native ecosystems from the threat of alien species, the "Invasive Alien Species Act" was enacted in June 2004. As of August 2007, 13 fish species, including channel catfish largemouth bass and bluegill, had been classified as invasive alien species (Nhisizawa et.al. 2006, Washitani 2004).

Travel restrictions, extermination of invasive alien fish species, and other measures have been enacted. Although such measures increasingly are applied to small lakes and irrigation ponds, they have seldom been applied to large dam reservoirs. A methodology to assess the impact of invasive alien fish species and to exterminate these species in large dam reservoirs is urgently needed.

Generally, dam reservoirs have a large water surface area compared with irrigation ponds. Water moves through the dam from upstream to downstream. Thus, if alien fish increase populations in dam reservoirs, they may expand their distribution by moving upstream or downstream with water discharged from the dam reservoir. Because alien fish in dam reservoirs have environmental impacts on rivers both upstream and downstream, the investigation of methods to control them in dam reservoirs is very important.

This study analyzed the distribution of alien fish species in dam reservoirs and factors affecting their habitat using survey data from the National Census on River Environments (NCRE) in dam reservoirs that are controlled by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Japan Water Agency (JWA). Case studies of removal and extermination of alien fish were also investigated as effective methods for dam reservoirs.

We also report results of experiments, launched in 2007 in conjunction with drawdown operations, on two methods of exterminating largemouth bass and bluegill in Miharu Dam reservoir, located upstream of the Abukuma River. The first technique involved drying out bass eggs on spawning beds, and the other was the capture and removal of alien fish using fixed shore nets in dried areas.

2 SELECTION OF INVASIVE ALIEN FISH SPECIES FOR EXPERIMENTAL FIELD SURVEYS, BASED ON THEIR PRESENCE IN DAM RESERVOIRS

In many dam reservoirs, alien fish were identified according to the 1990–2004 NCRE fish survey results. In 94 target dam reservoirs, controlled by MLIT and JWA fish surveys were conducted between 1990 and 2004.

Five invasive alien fish species were confirmed to inhabit 49 dam reservoirs (Tab. 1), and largemouth bass and bluegill were chosen for this study because of their presence in many of these dam reservoirs nationwide, except in Hokkaido and Okinawa.

Table1. Invasive alien fish identified in NCRE survey.

Species name	Number of dams inhabited
Channel catfish	1
Topminnow	2
Bluegill	33
Largemouth bass	45
Smallmouth bass	2
Total: 5 species	49

3 HABITAT FACTOR ANALYSIS OF THE TWO ALIEN FISH SPECIES

A habitat factor analysis was conducted to clarify the characteristics of dam reservoirs inhabited by largemouth bass and bluegill.

The presence of largemouth bass and bluegill was examined with regard to factors that could affect the habitat and populations of the alien fish, including elevation, age of dam, dam operating system, range of water level fluctuation, water temperature, and number of anglers.

In dam reservoirs, which were inhabited largemouth bass or bluegill, the water temperature tended to be above the suitable spawning temperature for long periods throughout the year. It shows as number of months, the water temperature tended to be higher than that optimal for spawning (16°C, largemouth bass; 20°C, bluegill) during the spawning period (largemouth bass, April–August; bluegill, May–July) (Fig. 1).

As elevation of dam reservoirs tends to be higher, the percentage of reservoirs, which were inhabited two alien species, decreased. (Fig. 2). It is thought that, as elevation of dam reservoirs is higher, water temperature decrease.

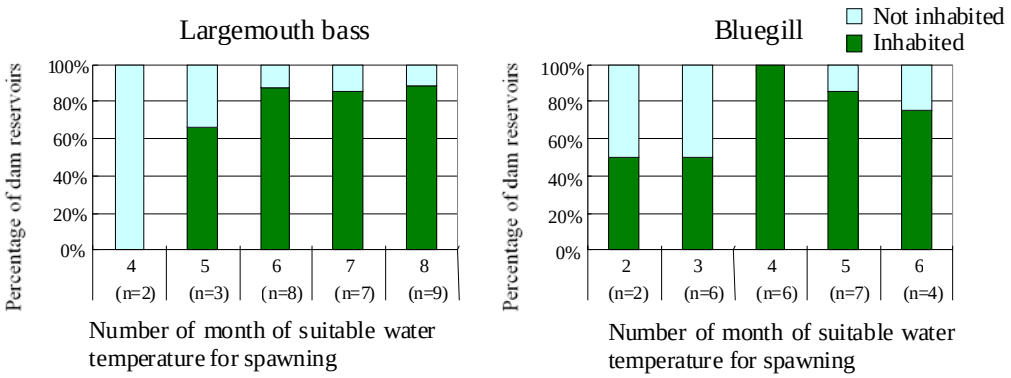

Figure1. Inhabited dam reservoirs percentage by number of months of suitable water temperature for spawning.

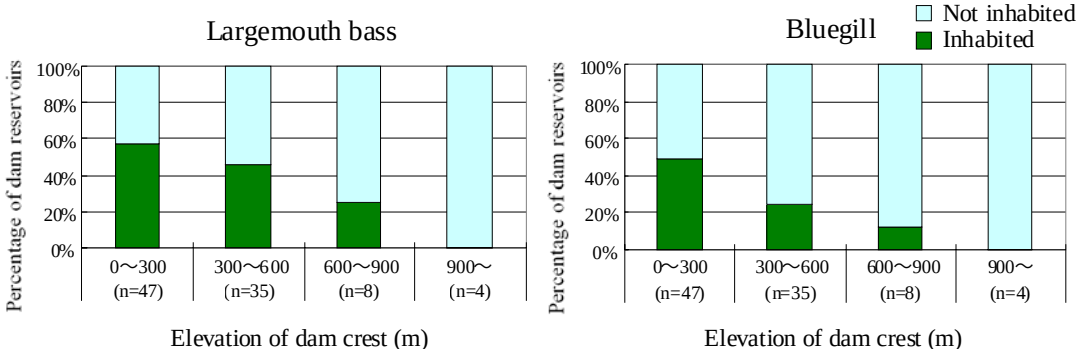

Figure 2. Percentage of dam reservoirs where bluegill or largemouth bass were confirmed and elevation of dam crest.

4 DEVELOPMENT OF OPTIMAL REMOVAL METHODS OF ALIEN FISH FROM DAM RESERVOIRS

4.1 *Literature search of alien fish removal methods*

A literature research of measures used to remove alien fish was conducted. Many case studies have been conducted on removing alien fish from ponds, number of studies of dam reservoirs is almost equal to those of natural lakes. Largemouth bass was the major species studied, and adult largemouth bass, smallmouth bass, and bluegill were usually the targets of removal.

Most of removal methods are drying out the pond or capturing the fish using a gill net without water-level drawdown. The number of captures via beach seine and fishing were almost equal, and few techniques involved removing spawning beds.

4.2 *Optimal removal methods of alien fish from dam reservoirs*

We investigated efficient measures to remove largemouth bass and bluegill from dam reservoirs. In selecting countermeasures from previous removal methods, we focused on the following three criteria: 1) high applicability to dam reservoirs, 2) efficiency, and 3) low damage to native fish captured. We selected two methods that used water-level drawdown operations: suppression of reproduction by drying out spawning beds during drawdown operations and capture by fixed shore net during drawdown operations (Figure 3).

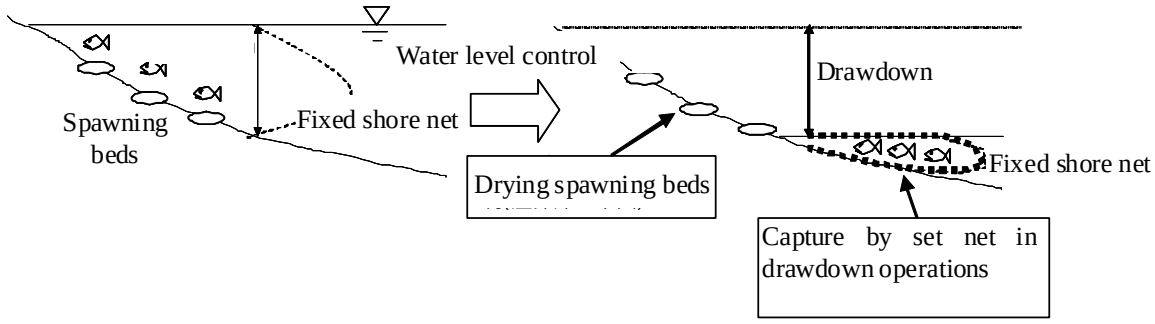

Figure 3. Two methods to remove alien fish using drawdown operations in dam reservoirs.

5 RESEARCH AT MIHARU DAM

5.1 *Created status of fish inhabiting in Miharu Dam*

Before the initial impoundment of the Miharu Dam reservoir, the presence of Japanese dace (*Tribolodon hakonensis*), Ginbuna crucian carp (*Carassius gibelio langsdorfi*), and other fish were confirmed. After impoundment began in 1997, population of dace, species those inhabited in running water, decreased, and pale chub (*Zacco platypus*) and common freshwater goby (*Rhinogobius sp. OR*), which prefer stagnant water environments, increased. The invasive alien largemouth bass was observed. Bluegill was also confirmed in 1999 and subsequently formed stable populations in the dam reservoir.

All sizes of largemouth bass and bluegill, from juveniles to adults were found at 2007 survey. On the other hand, large size class of Ginbuna crucian carp, the dominant native fish, was observed, and small size classes of the next generation of the native fish were very few (Fig. 4).

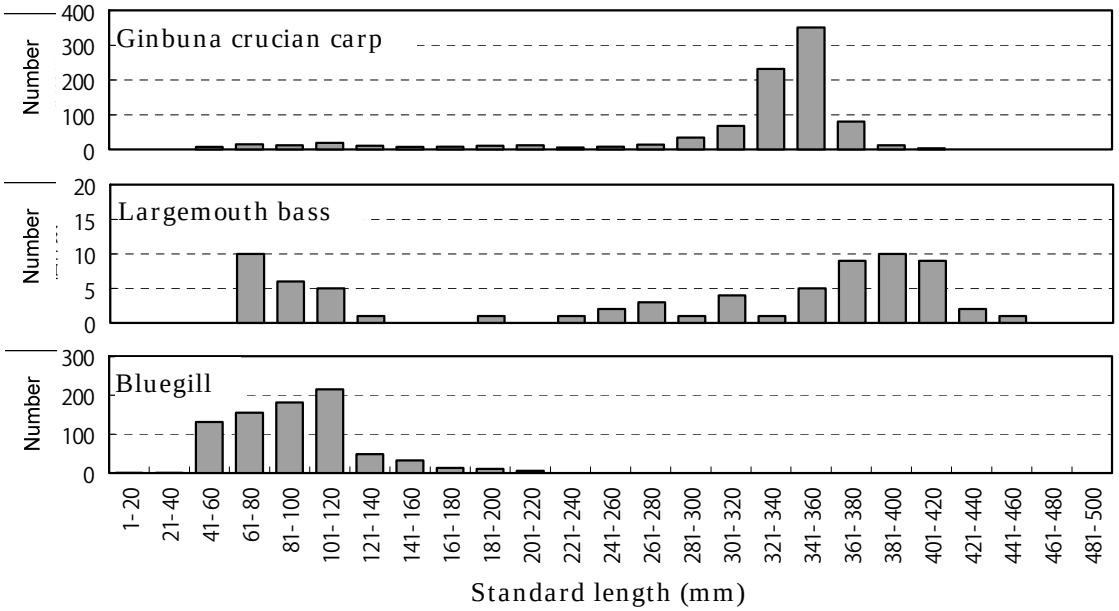

Figure 4. Size class composition of three species in Miharu Dam.

Figure 4 indicates the strong possibility that eggs and fry of native fish, such as Ginbuna crucian carp, were preyed by fish-eating largemouth bass and egg-eating bluegill. Thus, the normal generational progression of native fish was at high risk. If the large size class of Ginbuna crucian carp was to crash, the extinction risk would become high, leading to concern about the biodiversity loss of native fish fauna.

Thus, the impact on native ecosystems was confirmed at Miharu Dam reservoir, where the increase in alien fish induced a decrease in a native fish population. To protect native ecosystems in dam reservoirs, the removal of invasive alien fish is necessary.

5.2 *Study area and survey methods*

The study area at Miharu Dam reservoir is located on a tributary of the Abukuma River. The survey was conducted during May–August over three years, 2007–2010, in the two front reservoirs, Hebisawagawa and Ushikubirigawa, which were constructed at the end of tributaries of Miharu Dam reservoir as water-quality conservation (Fig. 5).

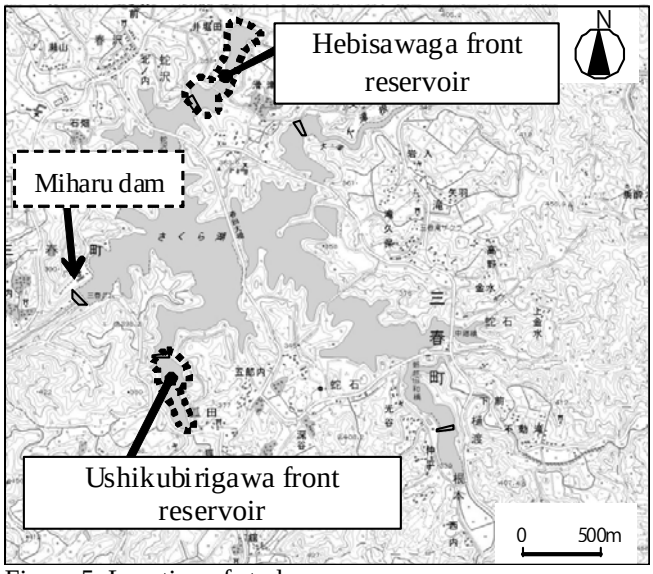

Figure 5. Location of study area

(1) Summary of method to remove alien fish using a fixed shore net during drawdown operations

The net was set near the flood season water level (limited water level during flood season) during drawdown operation from May to June of Miharu Dam reservoir. All fish that entered the fixed shore net were captured during drawdown operation. The lengths of all captured individuals were measured. Largemouth bass and bluegill were removed, and native indigenous fish were released alive. The total number of fish was recorded in the area enclosed by the fixed shore net.

(2) Summary of method to remove alien fish by drying spawning beds during drawdown operations

Both largemouth bass and bluegill establish bottom spawning beds in shallow water during the breeding season. In fact, the spawning beds of the two fish in Miharu Dam reservoir were concentrated in less than 1.8m water depth.

The drawdown operations period at Miharu Dam reservoir, which occurs during flood season, when the dam reservoir water level must be decreased to secure the flood control capacity of the lake, overlaps with the breeding season of largemouth bass.

During the May-to-August breeding seasons of largemouth bass and bluegill, we surveyed areas that had emerged and dried out when the water level was lowered, as well as the near shore area in the two front reservoirs, and investigated the distribution of juveniles and spawning beds. We recorded spawning beds, their locations, fish species, physical environment (size, slope, sediment, etc.) and lengths and population sizes of juveniles.

6 SURVEY RESULTS

6.1 *Effect of removal of alien fish via fixed shore net during drawdown operations*

Using a fixed shore net in Hebisawagawa front reservoir, we removed 68 largemouth bass and 809 bluegills in 2 years (Tab. 2).

Numbers of removed fish are less than total number of captured fish, because some individuals are released with marking to estimate the population size of each species.

Table 2. Removal of largemouth bass and bluegill, Hebisawagawa front reservoir.

Year	Largemouth bass		Bluegill	
	Total numbers captured	Numbers removed	Total numbers captured	Numbers removed
2007	72	54	839	266
2008	30	14	739	543
2009	17	5	268	99
Total	119	73	1846	908

The population of captured yearling Ginbuna crucian carp individuals with lengths less than 150 mm increased in 2010 after the removal of alien fish (Fig. 6). In addition, the population of Japanese native fish species increased from about 400 before the removal in 2007 to about 900 after the removal in 2010 too (Fig. 7). It was thought that populations of small size classes of these native fish species were increased because the predation pressure on small native fish populations was decreased by removal of alien fish.

However, number of large size class of Ginbuna in 2008 and number of captured of all species in 2009 were decreased. We considered each reason was as below, decrease of number of large size class of ginbuna in 2008 was caused by the motile aeromonad disease, on the other hand, decrease of numbers of captured of all species in 2009 was caused by the reduction in activity of fish by a water temperature fall by the rain just before investigation day.

Thus, we confirmed that removing invasive alien fish increased populations of native fish species.

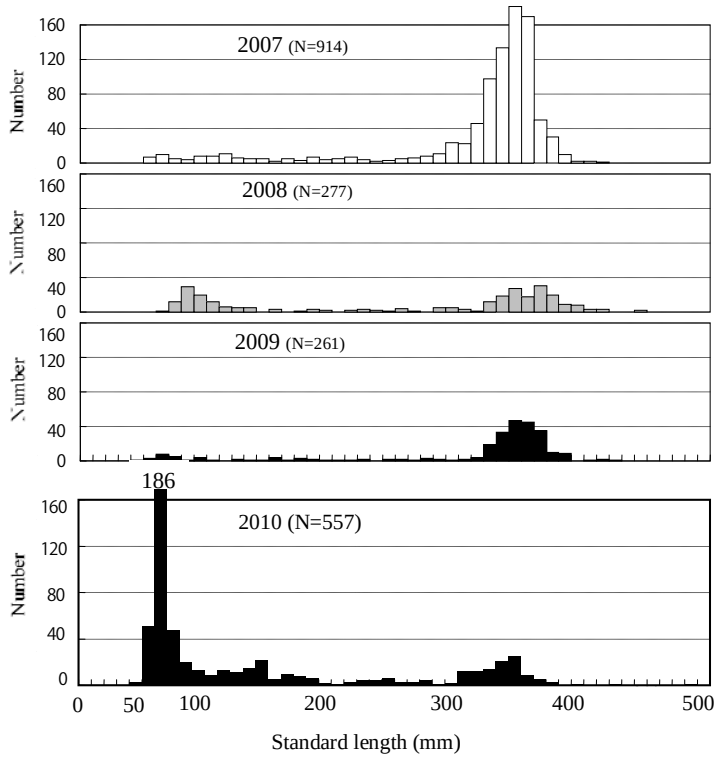

Figure 6. Number of each size classes of Ginbuna crucian carp.

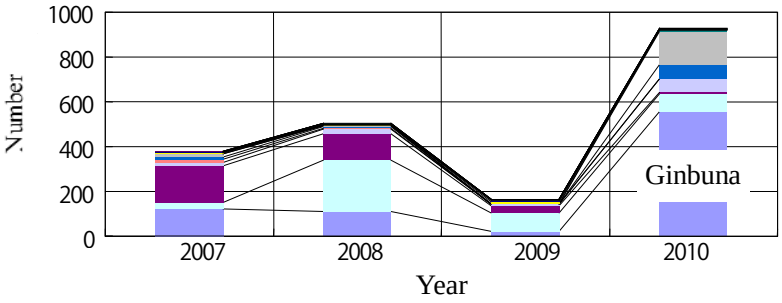

Figure 7. Number of all Japanese native fish species.

6.2 *Effect of removing alien fish by drying out spawning beds in drawdown operations*

In our survey of spawning beds, we found numerous spawning beds of largemouth bass that had dried out, but could not confirm any bluegill spawning beds. The surface water temperature of the reservoir before the drawdown on 16 May was about 15.2°C, whereas the temperature after the drawdown on 08 June was 19.4°C. Thus, the water temperature was above that suitable for largemouth bass spawning (16°C), but was not high enough for bluegill spawning (20°C). Table 3 shows the numbers of observed largemouth bass spawning beds: 45 in Hebisawagawamae front reservoir and 19 in Ushikubirigawamae front reservoir. The water depth of the spawning beds was similar in both front reservoirs.

Spawning beds were observed even after the water level reached a minimum in both reservoirs during the flood season, and we observed that largemouth bass continued to spawn even after drawdown operations.

Spawning bed sediments were mostly pebbles (100–200 mm), medium gravel (20–50 mm), fine gravel (2–20 mm) and sand (0.074–2 mm) and consisted partially of fish eggs on large stones and plant roots. Slopes of the locations varied from almost level to 5-25 degree.

All of the largemouth bass spawning beds, except 12 beds established after the water level was lowered, were completely dried out. Thus, it is possible to remove largemouth bass spawning beds by drying them out during drawdown operations.

Table 3. Status of observed largemouth bass spawning beds.

Study site (front reservoir)	Number of beds (beds with fish eggs)	Water depth (m)	Main sediments	Slope (degree)
Hebisawagawa	45 (9)	0.5–1.2	Sand, gravel, stone	Level to 5-25
Ushikubirigawa	19 (7)	0.4–1.0	Sand, gravel	Level to 5-20

7 CONCLUSION

The field trials at Miharu Dam reservoir confirmed that populations of native fish increase when alien fish are removed using fixed shore nets during drawdown operations and that the reproduction of largemouth bass can be controlled by drying out spawning beds during gradual drawdown operations.

However, largemouth bass eggs were still observed after the drawdown operations, and bluegill spawning beds could not be dried out because of the water temperature in the dam reservoir.

Because a dam controls the discharge of water that has flowed into a dam reservoir, the dam reservoir ecosystem exerts significant impacts on the river environment, both upstream and downstream.

Thus, conserving the ecological balance of the dam reservoir is very important.

Based on the results of this study, further research should be conducted on dam operations and reservoir management methods to conserve ecosystem balance, in addition to the original engineering purposes such as flood prevention and water supply.

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