RF-075 Evaluation of the Ecological and Genetic Disturbances Caused by the Internal Invasions and Modeling of Risk Assessments on these Invasions (Abstract of the Final Report)

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[Abstract]

We attempted to evaluate the ecological and genetic disturbances caused by internal invasions and develop a model for the risk assessments of these invasions. The studies were performed to determine the present distributions of exotic fish species in northern Kyushu Island, Japan, evaluate the ecological impact of internal invasions, investigate the habitat conditions of exotic fishes from internal regions, and detect the genetic disturbances caused by internal invasions.

We collected fish samples from approximately 1,100 sites on Kyushu Island, and we identified 7 exotic fish species causing foreign invasions and 7 exotic species causing internal invasions. Among the exotic species causing internal invasions, *Opsariichthys uncirostris uncirostris* was found to produce 2 ecological effects on the native species, i.e., feeding damage and hybridization. We performed single and stepwise logistic analyses; the data from Kyushu Island revealed that the presence of *O. uncirostris uncirostris* showed positive correlation with river length, and the data from the plains along the Sea of Ariake revealed that the presence of *O. uncirostris uncirostris* showed negative correlations with the altitude and the distance from the water intakes.

Genetic disturbances were confirmed by genetic analyses of native species such as *Biwia zezera*, *Pseudorasbora parva*, and *Zacco platypus*. In particular, in the case of *B. zezera*, the same mtDNA haplotypes caused genetic disturbances in multiple river systems on Kyushu Island. Therefore, we deduced that the native population of *B. zezera* was genetically disturbed by the nonnative population introduced from Lake Biwa, and the disturbed native population expanded to other regions on Kyushu Island. *O. uncirostris uncirostris*, which was introduced from Lake Biwa, exhibited different mtDNA haplotypes in each river system, suggesting that this species had been individually introduced in each system on Kyushu Island.

1. Introduction

Invaders have undesirable effects on native fish species: the population of the native species decreases; they are driven to seek alternative habitats; and their hatching success is reduced due to predation or depletion of food resources or due to other pressures resulting from the invader's presence. In Japan, most studies have evaluated the effects of invasions by nonnative fishes such as *Micropterus salmoides*, *Lepomis macrochirus*, and *Gambusia affinis* (Yodo and Kimura 1998; Maezono and Miyashita 2003) on native fish species and have recommended methods for the extermination of these nonnative fishes (Katano et al. 2005). Presently, the rearing, movement, and release of these fishes are regulated by legislation.

However, in Japan, there are other problems associated with invasions. In various environments, exotic fishes from other internal regions have been introduced for aquaculture and game fishing; these fishes commingle with the juveniles of *Plecoglossus altivelis*, which are released into rivers (Katano and Mori 2005). However, invasions by fishes from internal regions have not been as well investigated as those by fishes from foreign countries. Moreover, the effects of internal invasion on the natives need to be evaluated urgently.

2. Research objectives

We aimed to evaluate the ecological and genetic disturbances caused by internal invasions. The results obtained in this study will indicate the recommendation of risk-assessments models for internal invasions. We surveyed the distributions of all exotic fish species in northern Kyushu Island, Japan, and evaluated the ecological effects of internal invasions, such as feeding damage and hybridization. We also investigated the genetic disturbances caused by internal invasions. In particular, we intensively investigated the potential environmental threat posed by *Opsariichthys uncirostris uncirostris* (Fig. 1), and we analyzed the relationships between the distribution pattern of this species and the environmental factors.

Fig. 1. *O. uncirostris uncirostris* captured from the Chikugogawa River

3. Research methods

In order to determine the most recent distribution of exotic fish species, we performed fish sampling at approximately 1,100 sites in northern Kyushu Island, Japan (Fig. 2). In addition, to evaluate the feeding damage to the native fishes, we analyzed the gut contents of 490 *O. uncirostris uncirostris* individuals captured from the Futatsugawa River on Kyushu island. We primarily performed logistic regression analysis considering the presence or absence of this species as the objective variable and various environmental factors as the explanatory variables. *Biwia zezera*, *Pseudorasbora parva*, and *Zacco platypus*, which are naturally distributed in Lake Biwa as well as on Kyushu Island, were used to analyze the genetic disturbances in the Kyushu Island population that were caused by the populations in Lake Biwa. *O. uncirostris uncirostris*, which was introduced

on Kyushu Island from Lake Biwa, was used to confirm the routes of internal invasions in each river system. The molecular analyses of mtDNA were conducted using fishes captured from Lake Biwa and Kyushu Island.

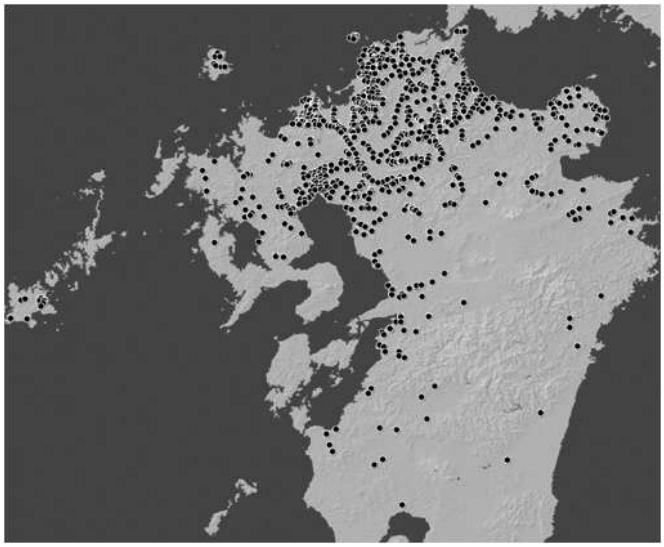

Fig. 2. Sampling sites of the fish fauna investigation in this study in Kyushu, Japan

4. Results and discussion

A total of 7 exotic fish species—*L. macrochirus*, *M. salmoides*, *G. affinis*, *Channa argus*, *Oreochromis niloticus*, *Tilapia zillii*, and *Poecilia reticulata*—introduced from foreign countries were captured from northern Kyushu Island. We also observed 7 exotic fish species that originated from other regions in Japan. *Carassius cuvieri*, *O. uncirostris uncirostris*, and *Ischikauia steenackeri*, which were probably introduced from Lake Biwa, appeared at 174, 74, and 36 sites, respectively. *Squalidus chankaensis tsuchigae*, *Gnathopogon elongatus elongatus*, *Acheilognathus cyanostigma*, and *Pseudobagrus nudiceps*, whose migration routes were unclear, appeared at 11, 45, 4, and 1 site(s), respectively.

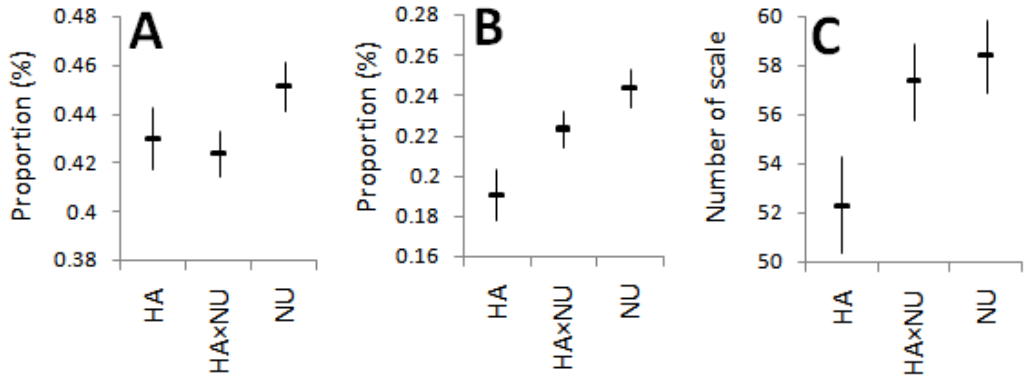

Fig. 3. Comparison of morphological characteristics among *O. uncirostris uncirostris* (exotic, HA), *Zacco sieboldii* (native, NU), and hybridized individuals (HA×NU)

Although *O. uncirostris uncirostris* is known to be a fish-eating predaceous fish (Kawanabe et al. 2005), the analysis of the gut contents of the *O. uncirostris uncirostris* individuals that were captured in Futatsugawa River clearly revealed that this species fed on various animals such as freshwater fishes, shrimps, insects, and frogs. Furthermore, we captured a few individuals that showed morphological characteristics of both *O. uncirostris uncirostris* and the native species *Zacco sieboldii* (Fig. 3). This finding suggests that hybridization may have occurred between these 2 species. Therefore, it is highly possible that the introduction of *O. uncirostris uncirostris* on this

island produced a double ecological impact on the native fishes, i.e., feeding damage and hybridization.

The relationship between the occurrence rates (O) of *O. uncirostris uncirostris* and the river length (RL) was calculated by single logistic analysis by using all the research data in the following equation:

$$O = 1/[1 + EXP\{-(3.439 + 0.069RL)\}]$$

In addition, stepwise logistic analysis based on the data obtained from the plains around the Sea of Ariake indicated that the occurrence rates (O) of *O. uncirostris uncirostris* showed negative correlations with the altitude (A) and the distance from water intakes (D), and the model was expressed by using the following equation:

$$O = 1/[1 + EXP\{-(0.326 + 0.294D + 0.126A)\}]$$

We predicted the distribution of this invasive fish in the irrigation ditches of Kyushu, Japan, by using the regression model (Fig. 4).

The *B. zezera* individuals captured from Kyushu Island exhibited the same mtDNA haplotypes in multiple river systems, as determined by the analysis of our samples and previous sequence data (Horikawa et al. 2007). Therefore, we estimated that the native *B. zezera* population in a river on Kyushu Island was genetically disturbed by the nonnative populations introduced from Lake Biwa, and the disturbed native populations expanded from their present rivers to other rivers on Kyushu Island. In the case of *P. parva* and *Z. platypus*, we compared the mtDNA haplotypes of the samples obtained from these 2 areas, and these species were also found to show genetic disturbances due to internal invasion. *O. uncirostris uncirostris*, which was introduced from Lake Biwa, exhibited

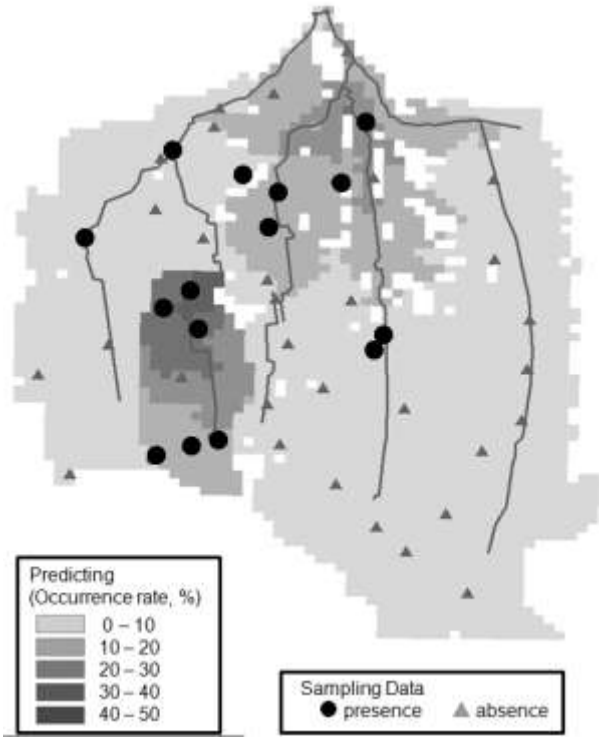

Fig. 4. Prediction of the occurrence rates of *Opsariichthys uncirostris uncirostris* on the basis of the stepwise logistic model, and the presence and absence data of this species on the basis of the field survey.

Fig. 5. Distribution of each mtDNA haplotype of *Opsariichthys uncirostris uncirostris* in Kyushu Island, Japan. We identified 11 haplotypes

different mtDNA haplotypes in each river system (Fig. 5), suggesting that this species had been individually introduced into each system on Kyushu Island.

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