博 士 論 文 の 内 容 の 要 旨
Abstract of Doctoral Dissertation

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Aquatic invasive species have spread globally and are a primary driver of native species decline and biodiversity loss in aquatic systems. In Japan, invasive freshwater fish have been introduced through a variety of pathways including aquaculture, aquarium trade, and sport fishing. These invasive fish are regarded as major social problem with many of the species listed in the 100 worst alien invasive species of Japan. The negative effects of these species on native fish are thought to include direct predation, resource competition and hybridization. Globally, the effects of invasive fish on native species have been studied nearly exclusively in experimental settings and an understanding of how these complex relationships play out in natural settings is lacking. Therefore, I designed four studies, all in natural settings, to elucidate the interspecific interactions between invasive and native fish species, and to determine the negative effects that native fish are experiencing.

In the following studies (1~4) I focused on the effects of smallmouth bass (*Micropterus dolomieu*) on native fish in rivers and lakes and the niche overlap of invasive trout (brown trout: *Salmo trutta* and brook trout: *Salvelinus fontinalis*) and native whitespotted charr (*Salvelinus leucomaenis*) in headwater streams located in central Japan. Smallmouth bass and salmonids are known to be some of the most destructive fish invaders and cause many issues related to predation, competition and hybridization with native fish throughout the world. In areas where smallmouth bass have invaded, native small-bodied fish species such as cyprinids often face decline due to predation. In addition, native piscivorous fish species also can face decline due to competition for fish prey resources. Similarly in areas where salmonids have been introduced, native salmonids generally decline, most often due to prey resource competition and hybridization. Although these generally trends are well studied, predominantly in laboratory setting, the specific mechanisms through which invasive smallmouth and salmonids displace native fish species are lacking, especially in complex natural habitat. Detailed examinations of these specific interactions are paramount and will provide concrete recommendations for management and conservation of native fish in systems where they coexist with these invaders.

Therefore, the goal of this study is to examine the detailed relationships between these invaders and native fish, while providing concrete recommendations on how management practices can enhance native fish survival.

(1) Microhabitat use and diets of smallmouth bass and native cyprinids were examined in a large river system where smallmouth bass were introduced in the early 2000s. In this system, smallmouth bass were found to have shifting effects on native cyprinids based on

habitat, with direct predation in slow flowing habitat to prey resource (aquatic invertebrate) competition in faster flowing habitat.

(2) In order to understand how these native cyprinids were responding and possibly adapting to the novel predator, smallmouth bass, the response of Japanese dace (*Pseudaspius hakonensis*) to vicinity smallmouth bass was studied in the lake where the two species have coexisted for ca. 30 years. Dace were found to recognize smallmouth bass as a predation threat and change their behavior accordingly, demonstrated by decreased foraging, a shift from benthic to water column foraging, and increased vigilance.

(3) Smallmouth bass populations continue in increase and spread into a variety of Japanese aquatic systems. To examine favorable spawning conditions, considered to be a driving factor in the continued spread of smallmouth bass, I conducted a two-year daily nest survey and determined egg predators by experimental removal of guarding males in the same lake as study (2). Spawning was found to be highly successful with nearly all nests proceeding to fry dispersal, gobies were the only egg predator observed, and the number of eggs predated was minimal.

(4) In headwater stream systems invasive salmonids are causing problems thought to stem from prey resource competition and direct predation of native species. The interspecific interactions between native whitespotted charr and two invasive salmonids (brown trout and brook trout) were examined in headwater streams. Brook trout and whitespotted charr have nearly identical foraging, diet and habitat niches, while brown trout are distinct and likely have terrestrial ecosystem impacts due to predation on terrestrial prey.

Throughout these examinations of a host of invasive and native species interactions, the effects of aquatic invasive species in the studied region were generalized to be negative but shifted based on habitat and species assemblage as follows: (1) smallmouth bass are not only direct predators of native cyprinids but also compete for prey resources in faster flowing habitat; (2) Japanese dace that have coexisted with these smallmouth bass utilized effective predator avoidance behaviors in response to the novel predator; (3) smallmouth bass may likely continue to increase and spread throughout Japan if favorable spawning habitat is present and native egg predators are lacking; (4) Similar issues were also found in headwater streams as invasive salmonids were competing with native charr for prey resources (primarily aquatic invertebrates) and habitat, while brown trout were found to directly predate on whitespotted charr, and likely also have terrestrial ecosystem impacts due to high rates of terrestrial insect predation.

Overall, this study is novel in that it examines interspecific interactions of invasive and native fish species exclusively in natural settings, and provides important insights for management of these species. Going forward managers should consider a variety of conservation techniques such as the introduction of underwater cover structure to provide complex habitat where native cyprinids can escape from smallmouth bass, especially in systems where a complete removal of the invasive species is unlikely, or where the invasive species is predicted to expand its' range due to climate change. In areas where native fish are showing behavioral adaptation to the novel predator, the genetic basis of these adaptations should be studied to possibly enhance these traits in native fish populations coexisting with invasive predators. In areas where the invasion range is still limited, targeted removal of invasive fish species and re-introduction of native species should also be undertaken.