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Abstract The potential invasiveness of 28 freshwater fishes in northern Kyushu Island, Japan, was evaluated using the Fish Invasiveness Scoring Kit. The five co-authors scored the level of invasiveness for each species and calculated the total scores, of which the maximum and minimum scores were eliminated, and the mean of the remaining three scores was used as the final score for each species. The mean scores ranged from 11.0 (*Hypomesus nipponensis*) to 31.0 (*Cyprinus carpio*). The receiver operating characteristics curve indicated that the threshold value between the invasive fishes of high risk and the other species were 19.8.

Keywords FISK · Alien · Hazard identification · Domestic invasion

Introduction

The negative effects of invasions by alien fishes on native fishes present serious problems throughout the world (Casal 2006), which has led to various studies on alien fishes. For example, in Japan, numerous studies have reported diverse information on alien fishes, such as reproduction and feeding (Azuma and Motomura 1998; Iguchi et al. 2004), genetic structure and diversity (Kawamura et al. 2006; Yonekura et al. 2007), competition (Taniguchi et al. 2000; Sahara 2005), hybridization (Kawamura et al. 2001; Konishi et al. 2003), and genetic homogenization between different populations (Horikawa and Mukai 2007; Horikawa et al. 2007). However, risk assessment and management studies of species invasions remain limited (Sato et al. 2010a, b). Recently, the Fish Invasiveness Scoring Kit (FISK) was developed and proposed as a tool for screening freshwater fishes (Copp et al. 2005a, b), with several studies reporting the utility of this kit to assess the potential invasiveness of alien freshwater fishes (Copp et al. 2009; Mastitsky et al. 2010) and invertebrates (Tricarico et al. 2010). Pre-screening of the potential invasiveness of existing and potential alien species and the information retrieved during such assessments could potentially, aid managers in determining the potential risks presented by alien fishes. In this study, we used FISK to evaluate the potential invasiveness of alien fishes in the northern Kyusyu Island of Japan.

Materials and methods

FISK was used for analysis of 28 freshwater fishes found in the northern Kyushu Island (Table 1, Fig. 1), of which 24 species are currently reported as alien species (Nakajima et al. 2008; Onikura et al. 2008) and four other species are confirmed to have different population

introduced from other regions of Japan or foreign countries based on genetic analysis (Horikawa et al. 2007; Matsuzawa and Senou 2008; T. Mukai, unpublished data). Thus, these fishes may be divided into two categories: alien species or different populations in same species (DP). Furthermore, alien species were classified into two groups based on whether they were introduced from domestic or foreign areas. Domestically introduced alien species from other regions of Japan are abbreviated as DAS. Alien species introduced from foreign regions were divided into three types: invasive alien species (IAS), adventive species (AS), and other unindentified alien species (UAS). The IAS are designated in the Invasive Alien Species Act (IASA), which is implemented by the government of Japan (Ministry of the Environment, Japan 2010a), while the AS are listed as species that require preventive measures or special attention, which has been complied by the Ministry of the Environment, Japan (2010a). The three IAS (mosquitofish, *Gambusia affinis*; bluegill, *Lepomis macrochirus*; largemouth black bass, *Micropterus salmoides*) were evaluated on the basis of their status before and after the IASA, while the other 25 species were evaluated based on their current status.

Several reports provide a detailed methodology and examples of case studies using the FISK tool (Copp et al. 2005a, b, 2009; Mastitsky et al. 2010). In brief, FISK questionnaires are classified into eight topics: domestication/cultivation (Number of questions: 3), climate/distribution (5), invasive elsewhere (5), undesirable traits (12), feeding guild (4), reproduction (7), dispersal mechanisms (8), and tolerance attributes (5), with each question having three possible answers (Yes/No/Don't know). The total FISK score is usually ranged from −11 to 54 (Copp et al. 2005a). However, we were unable to answer four specific questions because of the lack of information, such as the quality of climate match data by CLIMEX or GARP (Copp et al. 2005b) and the susceptibility of these species to piscicides Therefore, our final score ranged from –10 to 49.

The FISK assessments were undertaken independently by the five co-authors. Each person calculated the total FISK scores for each species. Subsequently, the maximum and minimum scores were eliminated from the five total scores for each species, and the mean score for each species was calculated from the remaining three scores.

A receiver operating characteristics (ROC) curve was analyzed to determine the threshold value for discrimination between invasive species of high risk and noninvasive species of medium and low risk (Gordon et al. 2008; Copp et al. 2009; Tricarico et al. 2010). As a priori classification, we organized these species into two categories, invasive and noninvasive fishes, on the basis of bibliographic information (Matsuzawa and Senou 2008; Nakajima et al. 2008; Table 1). We defined invasive fishes as species that had a probability of causing an ecological impact in northern Kyushu. In addition, we prepared two data sets based on two categories designated by the IASA: (1) IAS versus other species and (2) IAS plus AS versus other species (Table 1). We analyzed these three data sets by using SPSS ver. 15 (SPSS Japan Inc., Tokyo), and cut-off values were calculated as the threshold value between these data sets.

Results

FISK score. The mean FISK scores of the 28 species are shown in Fig. 2. The scores ranged from 11.0 to 31.0. The maximum score was recorded for common carp, *Cyprinus carpio* (DP in Table 1); followed by *Lepomis macrochirus* (IAS); and then rosy bitterling, *Rhodeus ocellatus ocellatus* (AS); Kara-dojou, *Paramisgurnus dabryanus* (AS); Japanese crucian carp, *Carassius cuvieri* (DS); piscivorous chub, *Opsariichthys uncirostris uncirostris* (DS); and freshwater minnow, *Zacco platypus* (DP). In contrast, low scores were observed in silver carp,

Hypophthalmichthys molitrix (UAS); rainbow trout, *Oncorhynchus mykiss* (AS); Asian swamp eel, *Monopterus albus* (UAS); and Japanese smelt, *Hypomesus nipponensis* (DS). With respect to the IAS, the scores obtained after regulation by the IASA were lower than those obtained before regulation.

The mean FISK scores indicated a negative correlation with their standard deviations (Spearman rank correlation test, $rs = -0.687$, $P < 0.01$), and their standard deviations had a negative correlation with the number of occurrence sites for each species that were shown in the current report (Nakajima et al. 2008; $rs = -0.457$, $P < 0.05$).

Threshold value. Based on bibliographic information, the area under the ROC curve was 0.749, indicating that FISK distinguished, to a moderate extent, between invasive and noninvasive species (Fig. 3, Table 2). The cut-off value was found to be 19.8, and the threshold value between invasive and other species was estimated to be 19.8. In this analysis, 14 species were indentified as invasive fishes.

Based on the IAS, the area under the ROC curve was 0.847, indicating that FISK distinguished, to a moderate extent, between the IAS and other species (Fig. 3, Table 2), and the threshold value was estimated to be 22.8. Nine species had values higher than the threshold value. When the AS was included, the area under the ROC curve was 0.600, indicating that the analysis could not distinguish between IAS + AS versus other fishes (Fig. 3, Table 2).

Discussion

Foreign alien species. The maximum FISK score for foreign species was recorded for

Rhodeus ocellatus ocellatus. This species has had a serious hybridization impact on the native Japanese rosy bitterling, *R. ocellatus kurumeus* (Kawamura et al. 2001), with a gradual expansion of its distribution in northern Kyushu Island (Miyake et al. 2008). Native populations of *R. ocellatus ocellatus* are primarily distributed in the continental East Asia (Matsuzawa and Senou 2008), under similar climatic conditions to populations in Kyushu Island (Peel et al. 2007). Because of this similarity in climatic conditions, the maximum FISK score was assigned to this species. High scores were also observed in *Paramisgurnus dabryanus*, which also originate from the continental East Asia and inhabit similar climatic conditions. This species has been regularly imported and cultivated as a source of fishing bait and food. As a result, this species has begun to reproduce in several regions of Honshu Island (Kanou et al. 2007). High scores were also obtained for *Gambusia affinis*, *Lepomis macrochirus*, and *Micropterus salmoides* which were selected as IAS. However, the scores obtained after regulation were lower than those obtained before regulation. This change in score before and after regulation which selected these fishes as IAS indicates that IASA regulations have positive effects on the cultivation and transportation of these species (Matsuzawa and Senou 2008).

In contrast, a low score was obtained for *Oncorhynchus mykiss*, which is designated as AS by the Ministry of Environment, Japan (2010a). One of the reasons for this result may be the difference in climatic conditions between northern Kyushu Island and the native distribution of this species, which is along the Pacific coastal area of the North American continent (Matsuzawa and Senou 2008). However, a high score would be obtained for this species if information about the freshwater fishes of Hokkaido Island were used, because of the similarity in climatic conditions. In addition, this species reproduces and competes with native chars on the island (Taniguchi et al. 2000). Hence, because of the several climatic divisions of Japan (Kotte et al. 2006), independent FISK screening should be conducted in

each region.

Domestic alien species. High scores were also recorded for a few DAS, such as *Carassius cuvieri*, and *Opsariichthys uncirostris uncirostris*. These fishes utilize similar climatic conditions in both native and non-native areas, resulting in the FISK "climate/distribution" section scores being high. Therefore, the questions in other sections tend to determine whether the fishes will obtain high or low scores. At Kyushu Island, *C. cuvieri* is subject to regular cultivation and release for the purposes of aquaculture and/or sport fishing (Nakajima et al. 2008). Populations of *O. uncirostris uncirostris* have expanded because of the fishery stocking of ayu, *Plecoglossus altivelis altivelis* (Matsuzawa and Senou 2008; Nakajima et al. 2008); this is one of the reasons for the high scores obtained for these species. Additional reasons include competition (Nakajima et al. 2008) and predation (Kurita et al. 2008) with native species.

Species with different population introductions. *Cyprinus carpio* and *Zacco platypus*, which are categorized into DP, also had high FISK scores. These fishes had high scores in the FISK "climate/distribution" section, which was similar to DAS. On Kyushu Island, the cultivation and release of these fishes has been conducted for aquaculture or resource management, which may provide one explanation for the high scores. In addition, *C. carpio* is known to have major direct and indirect impacts on nutrient dynamics, community structure and ecosystems (Matsuzaki et al. 2007, 2009).

Accuracy of low FISK scores. FISK scores had a negative correlation with their standard deviations. In addition, their standard deviations indicated a negative correlation with the number of sites of occurrence for each species. Dose FISK have a low level of accuracy with large standard deviation for alien fishes with low frequency distributions? *Hypophthalmichthys molitrix*, *Oncorhynchus mykiss*, *Monopterus albus*, and *Hypomesus*

nipponensis had low FISK scores and high standard deviations. Fish populations of these species were reported to be distributed or introduced in northern Kyushu more than 15 years ago (Tajima 1995), yet none was collected in the resent field study, despite approximately 900 sites in northern Kyushu were surveyed (Nakajima et al. 2008). We therefore regarded these species as "unestablished aliens" as defined by Occhipinti-Ambrogi and Galil (2004). An unestablished alien is an alien that lacks self-maintaining populations outside its natural range, either because settlement has not been possible or because its arrival is too recent. Hence, fishes with low FISK scores are deemed to have no or few habitats in which to settle in northern Kyushu.

Threshold value. Analysis of FISK scores of alien fish invasiveness in the United Kingdom resulted in a threshold value of ≥19 between high risk and others species (Copp et al. 2009). In this study, a threshold value of 19.8 was obtained in the analysis of alien fish with high risk invasiveness and other species with medium and low risk noninvasiveness in northern Kyushu, Japan. Hence, both studies obtained very similar values, suggesting that FISK may have global utility.

In this study, we were unable to obtain a threshold value for AS in the IASA. The IASA classifies AS into several different categories (Ministry of the Environment, Japan 2010a). AS classification may be useful for the following 2 categories: (1) the regulation of the species under consideration (*R. ocellatus ocellatus*, *O. mykiss*, and *Poecilia reticulata*) and (2) information about the species being collected (*Ctenopharyngodon idellus*, *Channa argus*, *Oreochromis niloticus*, and *Paramisgurnus dabryanus*). The FISK scores of the fishes in these categories were low and/or high. In fact, the FISK scores of AS ranged from 13.0 to 26.7, which may have led to the inability to designate an AS threshold value.

In contrast, we could obtain the threshold value for IAS, with the FISK scores of several fishes classified as AS, DAS, and DP exceeding IAS threshold value. This study

quantitatively demonstrated that these species present an equally high risk as IAS. However, several fishes in this group cannot be controlled under the IASA because the act only targets alien species introduced from foreign countries. Furthermore, a few DAS (*C. cuvieri* and *O. uncirostris uncirostris*) are ranked as threatened in the Red List (Ministry of the Environment, Japan 2010b) and must be conserved in their native habitats. Thus, different countermeasures must be taken for these species in their native and introduced areas. Therefore, the development of countermeasures for these fishes may be required at a local level in each region of Japan.

Further research. In this study, we selected target fishes for FISK based on the current reports (Horikawa et al. 2007; Matsuzawa and Senou 2008; Nakajima et al. 2008; Onikura et al. 2008; Mukai, unpublished data). However, by considering the function of FISK as a pre-screening tool for invasiveness, we recommend that the analysis should include fishes that have not been introduced to the target area. In addition, it would be very important to analyze certain fishes, such as *P. altivelis altivelis* and masu salmon, *Oncorhynchus masou masou*, which are regularly stocked in target areas. The use of FISK for such additional analyses contributes to the management of invasive alien fishes within specific regions or countries, such as Kyushu Island and Japan.

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Figure legends

Fig. 1 Map of Japan and the target area of this study

Fig. 2 The mean scores for 28 freshwater fishes in the northern Kyushu Island, Japan, based on the Fish Invasiveness Scoring Kit (FISK). *Solid bar*, before regulation by the Invasive Alien Species Act of the Ministry of the Environment, Japan; *Open bar*, after regulation (IAS: specific invasive alien species) or current status (all species); *Acronyms*, abbreviated scientific name (shown in Table 1)

Fig. 3 The receiver operating characteristics (ROC) curve for the assessment of 28 freshwater fish species in the northern Kyushu Island based on bibliographic information (BI) of ecological impacts and the categories (IAS and IAS + AS) given by the Invasive Alien Species Act of Ministry of the Environment, Japan

Table 1 Introduction types and categorization based on the Invasive Alien Species Act (IASA) of the Ministry of the Environment, Japan (IAS: specific invasive alien species, AS: caution needed non-native species, UAS: uncategorized alien species) and bibliographic information (BI) on the ecological impact

Species	Acronyms	Category	
		IASA	BI
1. Introduction of alien species from foreign areas			
Gambusia affinis	Ga	IAS	Invasive
Lepomis macrochirus	Lm	IAS	Invasive
Micropterus salmoides	Ms	IAS	Invasive
Channa argus	Ca	AS	Noninvasive
Ctenopharyngodon idellus	Ci	AS	Invasive
Oncorhynchus mykiss	Om	AS	Invasive
Oreochromis niloticus	On	AS	Invasive
Paramisgurnus dabryanus	Pd	AS	Invasive
Poecilia reticulata	Pr	AS	Invasive
Rhodeus ocellatus ocellatus	Roo	AS	Invasive
Aristichthys nobilis	An	UAS	Noninvasive
Hypophthalmichthys molitrix	Hm	UAS	Noninvasive
Monopterus albus	Ma	UAS	Noninvasive
Tilapia zillii	Tz	UAS	Invasive
2. Introduction of alien species from domestic areas (DAS)			
Acheilognathus cyanostigma	Ac	–	Invasive

Carassius cuvieri	Ccu	–	Invasive
Gnathopogon elongatus	Ge	–	Noninvasive
Hypomesus nipponensis	Hn	–	Noninvasive
Ischikauia steenackeri	Is	–	Invasive
Opsariichthys uncirostris uncirostris	Ouu	–	Invasive
Pseudobagrus nudiceps	Pn	–	Noninvasive
Salvelinus pluvius	Sp	–	Noninvasive
Sarcocheilichthys variegatus microoculus	Svm	–	Noninvasive
Squalidus chankaensis tsuchigae	Sct	–	Noninvasive

3. Introduction of different population from domestic or foreign areas (DP)

Cyprinus carpio	Cca	–	Invasive
Biwia zezera	Bz	–	Noninvasive
Pseudorasbora parva	Pp	–	Noninvasive
Zacco platypus	Zp	–	Noninvasive

Table 2 Summary of the statistical results from the receiver operating characteristics curve analysis in selected cases

Cases	Area	Standard error	Significance	Cut-off value
Invasive versus noninvasive species	0.749	0.092	0.025	19.8
IAS versus other species	0.847	0.077	0.053	22.8
IAS plus AS versus other species	0.600	0.118	0.388	22.8

fig.1

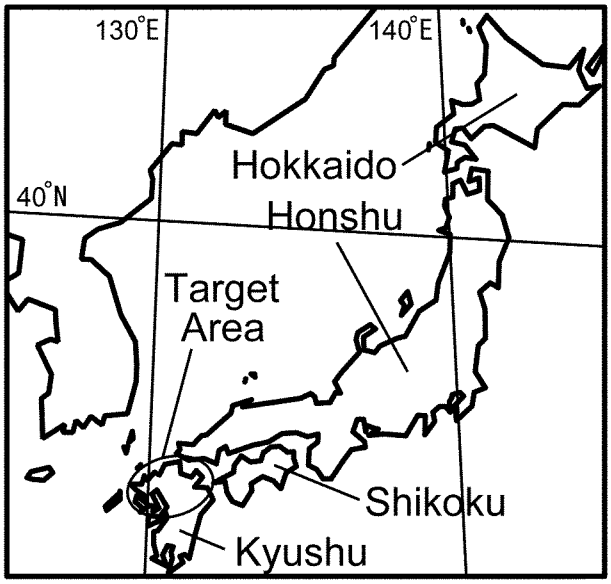
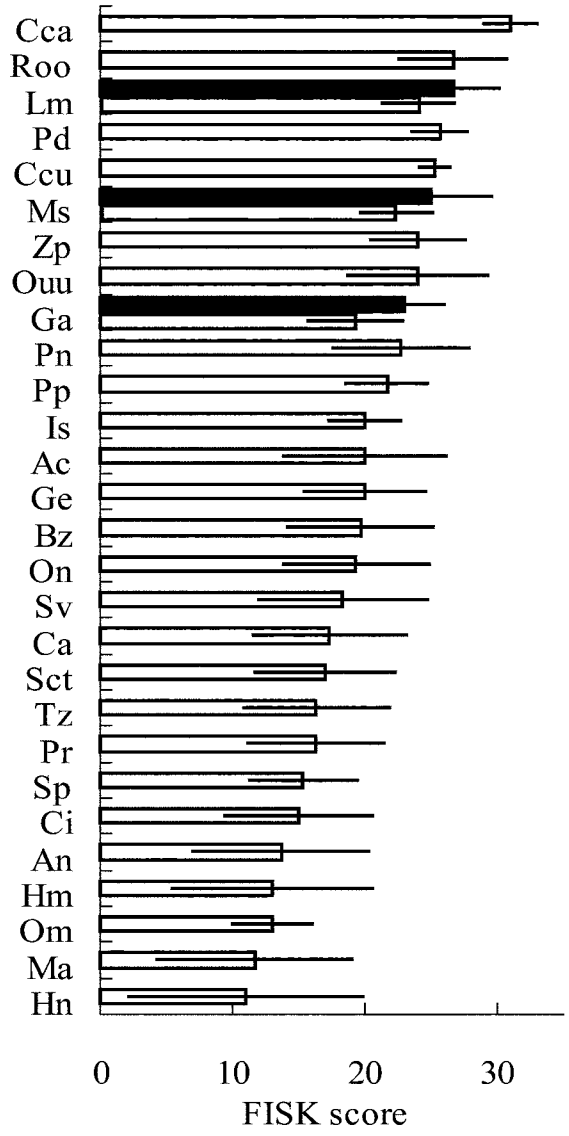


fig.2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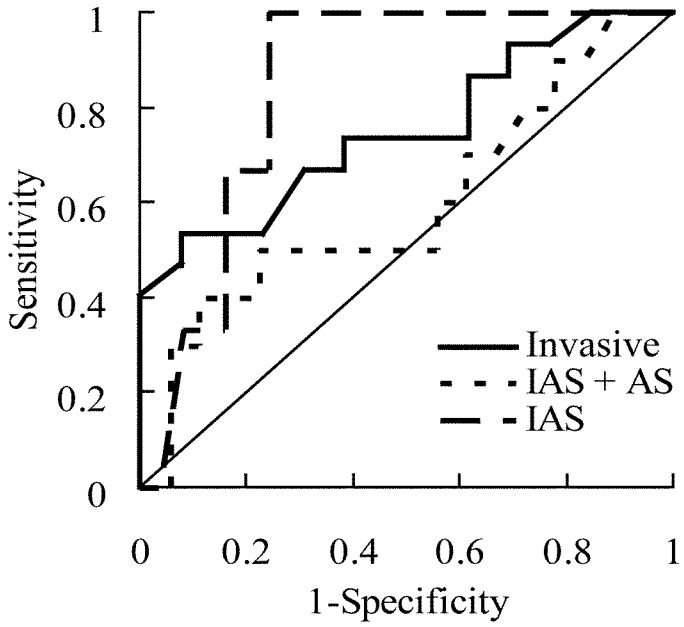
FISK score

Fig.3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