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Education and Outreach

A natural history museum as a platform for accumulating verifiable information on non-native fishes: a Japanese example

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Abstract

Natural history museums provide permanent storage for specimen collections, including non-native species. We extracted the records for specimens and photographs of exotic non-native fishes collected in Japan by experts and citizens at the Kanagawa Prefectural Museum of Natural History, Japan. The museum began operation in 1994. The records of alien species known to be established in Japan (FSAK) consisted of 1756 specimens (789 lots) belonging to 29 species and 611 photographs (494 lots) of 25 species. Additionally, there were records of alien species that were introduced to Japan but not known to be established (FSUK) consisting of 23 specimens (23 lots) belonging to 11 species and of 46 photographs (31 lots) of 17 species. The FSAK could be classified as 22 primary freshwater, six diadromous, and one marine species, whereas the FSUK were classified as 12 primary freshwater, one diadromous, and six marine species. We identified a significant difference in the life-cycle types of FSAK and FSUK suggesting that fluvial species are established more easily than marine species, which reflects the biogeography of Japan. In addition, the records of FSUK were probably caused by an increase of aquarium fish introductions due to dereliction of pet fish, ejectment for pleasure, or crime by traders. The museum collections were mostly provided by experts, followed by citizens and other institutions. We also discussed the functions of a public museum of natural history for accumulating information and for citizen participation.

Key words: FishPix, foreign species, museum collection, photograph, specimen, voucher

Introduction

Non-native fish invasions typically result from the intended or unintended introduction of aquarium and fishery fishes (e.g., Helfman 2007; Lucas and Southgate 2012; Mukai et al. 2013a). Intended introductions include releasing pet fish that aquarists can no longer keep and stocking species for sports fishermen. Unintended introductions can accompany intended introductions (hitchhikers) or involve fish that escape from aquafarms, are released from ballast water tanks (Okiyama 1985; Sasaki et al. 1989; Golani 2004), or spread via artificial canals (e.g., Bariche and Heemstra 2012).

In Japan, the introduction and invasion of non-native fish are often reported by mass media (Matsui 2009). Most of these reports have involved the participation of experts from fisheries research institutes, universities, aquariums, or museums. Some of the reports have included records of exotic species that have never colonised Japan (e.g., Kochi 1991; Toda 2002). However, scientific reports are rare, as few specimens are donated to appropriate institutes, so we are unable to re-evaluate the records of such exotic fishes. Scientific verification of the records of non-native species is essential. Public or university museums of natural history have a duty to store permanent collections. Some re-examinations of the records of fishes introduced into Japan have been published by museums researchers (e.g., Amaoka et al. 2001; Tashiro et al. 2010; Mukai et al. 2013b). These publications were based on museum specimens of specific non-native species. Such a review process by natural history

museums can verify the records of non-native species.

The Kanagawa Prefectural Museum of Natural History, Japan (KPM), one of the largest fish collections in Japan after the National Museum of Nature and Science (NSMT), and a part of former imperial university museums (NSMT has an extraordinarily large fish collection of more than 1 million specimens), is no exception. As well as specimens, this museum collects photographs of fish in the Image Database of Fishes (KPM-NR) as re-verifiable secondary sources. The fish images deposited in the KPM-NR are registered and numbered along with specimens (the collection lot number is given). During 1994–2014, more than 130,000 fish photographs and 35,000 fish specimens were deposited in the KPM (Miyazaki et al. 2014), including the records of non-native fish reported in the media. The KPM is supported by many individuals. For example, more than two-thirds of photographs deposited in the KPM-NR were provided by citizens (Miyazaki et al. 2014). Consequently, citizen participation plays an important role in the accumulation of natural history information.

This paper investigated the re-verifiable information (specimens and photographs) deposited in the KPM to reveal how the KPM integrates the information on exotic species provided by citizens. First, we compiled the information on introduced exotic fishes in the KPM with vouchers. Then, we discuss the function of natural history museums in accumulating data on non-native species.

Methods

The KPM-NR adopted the MusethequeV3 (Fujitsu Limited, Tokyo, Japan) computer system to manage the collection when it opened in 1994. To summarize the data on exotic non-native species registered from 1994 to 2014 from the system, the information on Japanese collections of native and non-native species was first distilled from the specimen (KPM-NI) and photograph (KPM-NR) collections.

These specimens and photographs included records of foreign species that are already known to be establishments in Japan (FSAK hereafter) and those are not known to be established (FSUK hereafter). Matsuzawa and Senou (2008) compiled lists of non-native fishes, particularly those already established in Japan. Murakami and Washitani (2002) compiled lists of exotic organisms in Japan, but whether the species are actually established is difficult to judge based on their information. Therefore, we classified the species, registered in KPM-NI and/or KPM-NR, as FSAK or FSUK, following Matsuzawa and Senou (2008). Also, Nakabo (2013) compiled a list of Japanese fishes that included established exotic fishes and revealed several new FSAK. We used this information to assess recent status changes from FSUK to FSAK.

Furthermore, to examine the characteristics of the individuals who donated specimens and photographs stored at the KPM, the sources of the specimens and photographs were classified into three groups: experts who work at a research institute or have published a scientific paper as the corresponding author; institutions that specialise in fisheries or natural history; and citizens who do not work at a research institute and have not published a scientific paper as the corresponding author. Incidentally, the material from other institutions included collections made by both researchers and citizens.

Results

From the specimens and photographs registered in KPM-NI and KPM-NR, we identified 29,853 lots of specimens and 82,699 of photographs collected or taken in Japan. From these, 1779 (812 lots) specimens and 657 (525 lots) photographs of alien species were identified. Of these, 256 lots were registered to both KPM-NI and KPM-NR. Overall, there were 1081 lots representing 48 species and 24 families. The species represented in the most lots was *Micropterus salmoides* (Lacepède, 1802) (184 lots, 17.0% of the non-native species) and was recorded in all Japanese prefectures (Matsuzawa and Senou 2008), followed by *Micropterus dolomieu* Lacepède, 1802 (144 lots, 13.3%), *Poecilia reticulata* Peters, 1860 (107, 9.9%), *Gambusia affinis* (Baird and Girard, 1853) (104, 9.6%), *Oncorhynchus mykiss* (Walbaum, 1792) (91, 8.4%), *Rhodeus ocellatus ocellatus* (Kner, 1866) (80, 7.4%), *Lepomis macrochirus* Rafinesque, 1819 (79, 7.3%), *Oreochromis mossambicus* (Peters, 1852) (36, 3.3%), and other species (30, 2.8% or less). Among the other species, there were many re-verifiable first records of introductions into Japanese natural waters; i.e., *Polypterus endlicheri* Heckel, 1847, *Acipenser ruthenus* Linnaeus, 1758 × *Huso huso* (Linnaeus, 1758),

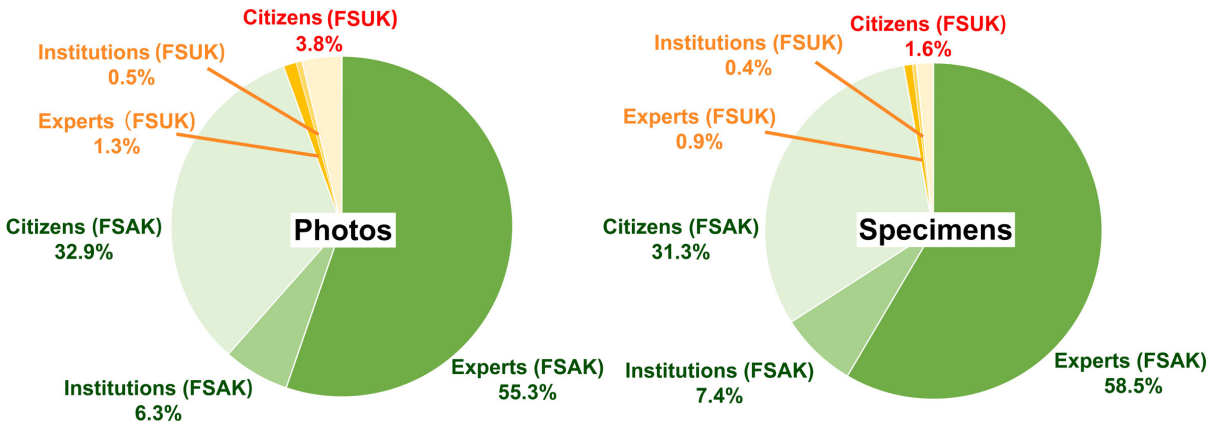

Figure 1. Frequencies of donors classified as experts, institutions and citizens contributing to museum collections (FSAK and FSUK lots) registered to the KPM. (A): photographs (KPM-NR); (B): specimens (KPM-NI).

Atractosteus spatula (Lacepède, 1803), *Chitala ornata* (Gray, 1831), *Piaractus brachypomus* (Cuvier, 1818), *Corydoras aeneus* (Gill, 1858), *Sciaenops ocellatus* (Linnaeus, 1766), *Platax batavianus* Cuvier, 1831, *Apolemichthys xanthurus* (Bennett, 1833), *Pomacanthus asfur* (Forsskål, 1775), *Pomacanthus maculosus* (Forsskål, 1775), *Amphilophus citrinellus* (Günther, 1864) × *Vieja synspila* (Hubbs, 1935), *Otopharynx lithobates* Oliver, 1989, and *Premnas biaculeatus* (Bloch, 1790) (all are FSUK).

The FSAK records comprised 1756 specimens (789 lots) belonging to 29 species and 611 photographs (494 lots) belonging to 25 species. Of these, 244 lots were registered in both KPM-NI and KPM-NR, for a total of 1039 lots (3.5% in total) belonging to 29 species (0.8% in total) (Supplementary material Table S1). The remainder, FSUK, consisted of 23 specimens (23 lots) belonging to 11 species and 46 photographs (31 lots) belonging to 17 species. As 12 lots were shared by KPM-NI and KPM-NR, FSUK included 42 lots (0.1%) belonging to 19 species (0.5%) (Table S2).

The FSAK were classified as 22 primary freshwater, six diadromous, and one marine species (Table S1), and the FSUK were classified as 12 primary freshwater, one diadromous, and six marine species (Froese and Pauly 2014; Table S2). There was a significant difference in freshwater vs. marine habitat between FSAK and FSUK (two-sided Fisher's exact test: $p = 0.01$).

Of the donors contributing materials, experts contributed 475 lots of specimens and 302 photos of FSAK and seven lots of specimens and seven photos of FSUK, institutions contributed 60 lots of specimens and 29 photos of FSAK and three lots of specimens and three photos of FSUK, and citizens provided 254 lots of specimens and 163 photos of FSAK and 13 lots of specimens and 21 photos of FSUK (Figure 1). The citizen sources included 24 unique persons collecting specimens and 45 unique persons taking photographs of non-native fishes, although one person contributed more than half (55.5%) of the specimens provided by citizens.

All of the photographs in KPM-NR, except for unadjusted ones, are available on FishPix (online database of the KPM-NR: http://fishpix.kahaku.go.jp/fishimage-e/) (Matsuura and Senou 2002; Miyazaki et al. 2014).

Discussion

The information on non-native fishes accumulated in KPM-NI and KPM-NR consisted mostly of FSAK (96.1% of the total). The eight most frequent species (68.5% of the total) belong to FSAK, all of which are listed in the Invasive Alien Species Act, a Japanese criminal law that took effect in 2005, and in the lists of the 100 worst invasive species in Japan or in the world, except for *Poecilia reticulata* (Lowe et al. 2000; Murakami and Washitani 2002). This suggests that these species are widely settled invasive non-native fish in Japan. Hence, our results support the designations in the Invasive Alien Species Act.

Figure 2. The utilization of museum collections in the special exhibition at the Kanagawa Prefectural Museum of Natural History (KPM) from 19 July to 3 November 2014, titled "How is it going? How it is going! Non-native organisms: Try to get our virgin landscape." (A): example of the museum exhibition; (B): example of the practical guidebook.

In Japan, the FSAK were introduced for cultivation, aquariums, and sports fishing (Table S1; Matsuzawa and Senou 2008), whereas the FSUK likely originated through intended introductions via aquarium hobbyists (17 of 19 species), except for *Acipenser ruthenus* × *Huso huso* and *Sciaenops ocellatus*, which likely originated via unintended releases from fish farms (Table S2). Consequently, we need to pay attention to the introduction of non-native invasive fish by hobbyists who breed aquarium fish.

The museum FSAK collections rarely reveal the number of infested sites or the scale of the introduction at the prefectural level because they are already widespread in Japan. However, some specimens have been used as vouchers for introductions and invasions in the focal areas. Conversely, museum collections of the FSUK help to reveal the number of infested sites (usually one) and the scale of the introduction.

Additionally, our results show that freshwater species are more likely to become established than marine species. The oldest record of aquarium release in Japan is *Macropodus ocellatus* Cantor, 1842 in 1917 (Matsuzawa and Senou 2008), followed by *Poecilia reticulate* in ca. 1955 (Kochi 2001). Subsequently, aquarium release has rapidly increased, and FSUK in the present report are derived mostly from aquarium release (89.5%; see Table S2) due to dereliction of pet fish, ejectment for pleasure, or crime by traders. However, the number of identified Japanese marine fish species is still increasing (Senou 2013a). This increase is probably caused almost entirely by a combination of more extensive surveys, developments in taxonomy, the effects of sea surface temperature warming, and increased interest in saltwater aquarium keeping. One paper reported the introductions of exotic non-native aquarium species on the Japanese

coast (Ogihara et al. 2009), and similar introductions of exotic non-native fishes were reported from Florida, USA (Semmens et al. 2004). As it is difficult to learn of the existence of exotic non-native species in the marine environment, our re-examinable specimens and photographs should be applied to outreach activities such as publishing guide books, training volunteers, exhibiting and studying on biodiversity conservation. Therefore, the information on non-native marine fishes accumulating in museums has great potential utility for the early detection of invasive non-native marine species, as well as non-native freshwater and diadromous fish. Given that curators have much information on fish distributions, citizens' involvement in museum activities can contribute to the effective monitoring of exotic non-native species.

Note that our statistics probably reflect sampling bias, as the contributors are mainly researchers and scuba divers. We need to be aware of the possibility that sampling bias may result from aspects of the KPM or of Japanese biogeography (Miyazaki et al. 2014). To be able to crucially discuss the differences in the characteristics of FSAK and FSUK, specimens from other Japanese museums, such as National Museum of Nature and Science, which has a large collection, should be studied.

In general, early detection and removal of invasive non-native species is a fundamental component of preventing their establishment and spread (Puth and Post 2005; Blackburn et al. 2011). It is important to contain such species immediately after their introductions. From this perspective, it is also important to store voucher specimens in public museums and to use the voucher specimens to support information provided by citizens or the mass media. It is also necessary to formulate strategy to prevent the establishment of alien species and to monitor their biology based on this information. In fact, the two exotic *Xiphophorus* species, *X. hellerii* Heckel, 1848 and *X. maculatus* (Günther, 1866), mentioned here were recently determined to be established based on the specimens and photographs in the KPM (Senou 2013b; Nakajima and Kano 2014). Such information should be used to identify the need to remove alien species, such as Southern platyfish, *X. maculatus*, on Okinoerabu-jima Island (Nakajima and Kano 2014). In other words, regional biodiversity strategies and/or nature restoration committees should plan the removal of non-native fishes in target regions, based on information of non-native fishes published by experts.

The specimens and photographs of non-native fish species reported here are stored in the KPM permanently, along with additional information such as date and locality data, so that they can be re-verified, re-identified, and re-examined. They can be used in exhibitions and for other educational purposes (Nakai et al. 2003). In fact, the KPM collections of exotic fishes were used at the KPM's special exhibition on non-native organisms from 19 July to 3 November 2014 (Figure 2). The best way to record invasive non-native species is to deposit specimens in public or university museums as vouchers, and our results suggest that collaboration between citizens and experts is important for monitoring invasions and the spreads of non-native species, especially marine species. Although experts contributed most of the specimens, for FSUK, citizen's contributions outnumbered those of experts. This highlights the role of citizen scientists who voluntarily collect or process data as part of scientific enquiry (Silvertown 2009). The connection between a public museum and citizens plays an important role in fostering citizen scientists.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Alien fish species known to be established in Japan (FSAK) registered in the Kanagawa Prefectural Museum of Natural History (KPM).

Table S2. Alien fish species not known to be established in Japan (FSUK) registered in the Kanagawa Prefectural Museum of Natural History (KPM).

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