Mining internet-based biodiversity data for application to conservation science

Biogeography, vol. 27, pp. 9–19 ISSN: 1880-8085

Mining internet-based biodiversity data for application to conservation science

Yusuke Miyazaki [1, 2, *], Atsunobu Murase [3, 4] & Hiroshi Senou [1]

[1] Kanagawa Prefectural Museum of Natural History, 499 Iryuda, Odawara-shi, Kanagawa 250-0031, Japan
[2] Department of Environmental Management, Faculty of Agriculture, Kindai University, 3327-204 Naka-machi, Nara-shi, Nara 631-8505, Japan
[3] Nobeoka Marine Science Station, Field Science Center, University of Miyazaki, 376-6 Akamizu, Nobeoka-shi, Miyazaki 889-0517, Japan
[4] Department of Marine Biology and Environmental Sciences, Faculty of Agriculture, University of Miyazaki, 1-1 Gakuen-kibanadai-nishi, Miyazaki-shi, Miyazaki 889-2192, Japan

Abstract: Citizens have uploaded numerous biodiversity images and movies with time and locality information to websites such as social networking services, blogs, and various personal websites. We identified such data scattered on the web as "potential museum collections of natural history" and have attempted to accumulate them as actual museum collections of the Kanagawa Prefectural Museum of Natural History (KPM), Japan. Based on this gathering of data, which is centered on the public natural history museum, we built a conceptual model for biodiversity data integration and public conservation awareness by systematizing (1) collection and accumulation, (2) survey and research, and (3) outreach and education. We applied the model to several case studies. First, suitable fish photographs from social media platforms such as Twitter (now rebranded as X) and a Japanese internet community, *WEB sakana-zukan*, were added into the Fish Image Database of KPM by obtaining the consent of the image owners (i.e., citizens). Second, the accumulated collections were used by scientific experts for studies on fish taxonomy, biogeography, ecology, and conservation biology. Finally, the identification and study results were made available to citizens, including the image providers, through volunteer programs, exhibitions and media applications such as newspapers, magazines, and TV programs. By synthesizing these three steps, it is possible to create a positive feedback mechanism for accumulating biodiversity data, and for increasing the participation of citizen scientists. In this article, we provide an overview of the conceptual model with some related issues (e.g., our main target is a citizen who did not intend to contribute to science) in order to consider the value, and contribute to the development, of digital citizen science for conservation efforts.

Key words: Ichthyology, mass communication, recreational fisher, science communication, scuba diving

Introduction

Social networking services, weblogs, and personal websites have developed and expanded rapidly since the early 2000s. It is now common for citizens to upload images and other information about their surroundings to online communities, particularly social media (e.g., Kitsuregawa & Nishida, 2010; Van Dijck, 2013; Toivonen *et al*., 2019). Biodiversity data are found through various jobs and hobbies, such as bird watching and fishing (e.g., Dickinson & Bonney, 2012; Miyazaki *et al*., 2014b).

Citizen science has also developed rapidly over recent years, in some cases influencing the development of information and communication technology (ICT). Many citizen science projects have applied various functions of social media platforms to applied various functions of social platforms to nature conservation and biodiversity studies (e.g., Silvertown, 2009; Silvertown *et al*., 2015; Kobori *et al*., 2016). For example, iNaturalist combines citizen science with nature observation targeting various taxa (iNaturalist, 2025). On this platform, users can upload records of plants, animals, fungi, and other organisms through an app or website. These observations are identified with the help of other users and experts, and the resulting data is utilized for scientific research and conservation efforts (e.g., Di Ciecco *et al*., 2021). Similarly, the widely used online ichthyological database FishBase (Froese & Pauly, 2000), to which fish images contributed by citizens such as scuba divers and fishermen, has substantially advanced our understanding of fish taxonomy

Received: 6 December 2024; Accepted 15 January 2025
Published online: 31 January 2025
https://doi.org/10.11358/biogeo.27.9
*Corresponding author: miyazaki@nara.kindai.ac.jp

and ecology. In addition to these intentional online scientific collections, useful data are available in the images and movies miscellaneously uploaded to social media that were not intended for scientific use (Miyazaki *et al*., 2014b; Toivonen *et al*., 2019).

"Citizen science" is defined as public participation in organized research efforts, while "citizen scientist" describes a person who has chosen to use their free time to engage in the scientific process (Dickinson and Bonney, 2012). Based on these definitions, data uploaded by citizens for purposes other than utilizing scientific research are not included in the concept of citizen science, but can still be used for such.

How broad is the scope of "citizen science"? Japanese researchers have discussed this issue based on Japan's culture of natural science. Sasaki *et al*. (2016) argued that "citizen science" is a broad concept. They concluded that it is not only a research approach directed towards the publication of scientific findings but also serves many other functions, all of which have significance for the citizen scientist who is actively engaged in this endeavor. After that, Miyazaki (2018a) compared the meanings of the words, "citizen", "science", and "research" between English and Japanese. The meaning of "science" corresponds in English and Japanese. However, while the English word "research" is important in denoting new findings, the corresponding Japanese word does not communicate novelty. East Asians, particularly those from Japan, tend to apply the word "citizen" to adults, whereas Europeans and North Americans apply the word to members of all generations including babies and children. Based on these findings, Miyazaki (2018a) pointed out that the new concept of "citizen science", as defined by Sasaki *et al*. (2016), is suitable for describing the process of becoming a scientist as well as indirect contributions to science (Fig. 1). This suggests that the development and definition of the concept of "citizen science" is affected by culture and language.

In Japan, citizen science has a high affinity to museum activities (Sasaki *et al*., 2016) as well as European regions (Sforzi *et al*., 2018), although in Japan, museums serve as a central venue, rather than online platforms. This reliance on museums may be partly because many citizen science projects conducted in Japan are managed by small research groups or individuals, making it challenging to allocate sufficient time for project operations (Ikkatai, 2020).

For example, one of Japan's natural history museums has documented an initial case of the development of a database with the participation of citizens. The Fish Image Database of the Kanagawa Prefectural Museum of Natural History (KPM), partly disclosed on the web as "FishPix" through a website of the National Museum of Nature and Science, Japan, was launched in 1994 (Matsuura & Senou, 2002). This database stores fish photographs and images as a museum collection, and has been utilized in several scientific fields such as ecology, biogeography and taxonomy (Miyazaki *et al*., 2014b). Contributors have consisted mainly of scuba divers, researchers and recreational fishers (Miyazaki *et al*., 2014a). The data are useful for scientific research despite being

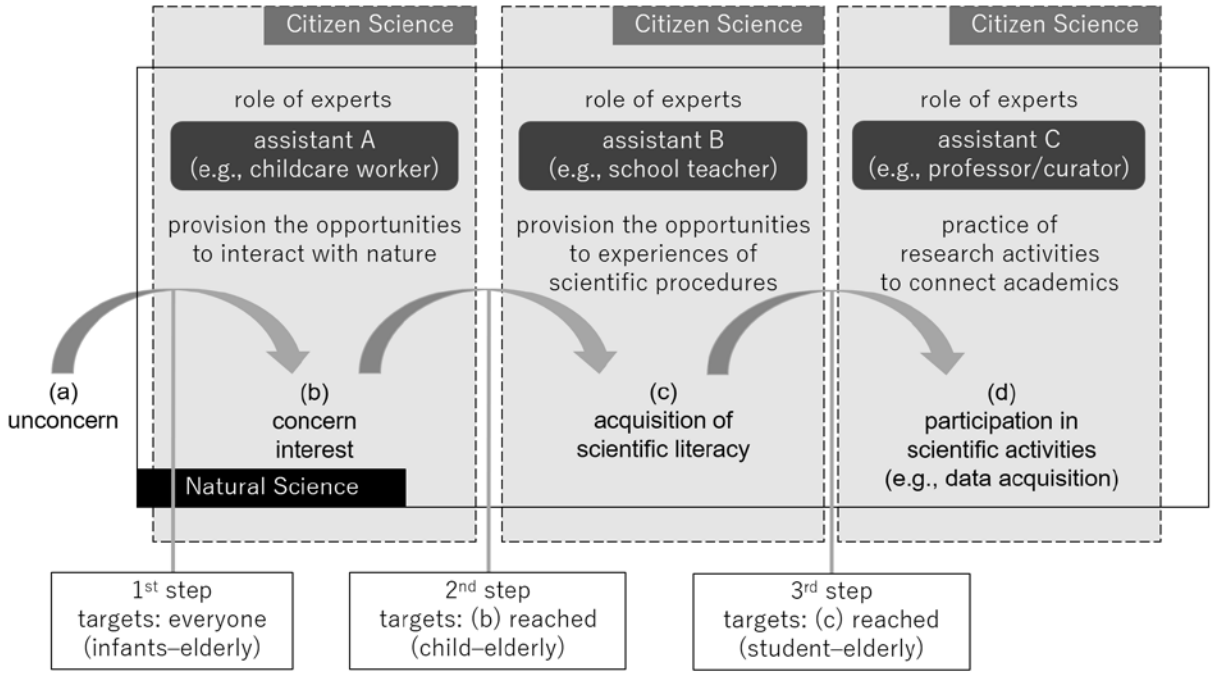

Fig. 1. The new framework of citizen science proposed by Sasaki *et al*. (2016). The process of 1st–3rd stages is limited by age and achievement, while the experts (assistants A–C) are also limited by their roles and achievements. This figure is translated from Miyazaki (2018a).

originally collected and shared for other purposes.

Although online citizen science projects, including for educations and/or public awareness, have been developed (Aristeidou & Herodotou, 2020), there remains a vast untapped resource of data that was unintended for scientific use. These "potential museum collections of natural history" are variously scattered across the internet. Whereas collections of museums of natural history consist mainly of specimens, biological images have also been targeted, as mentioned above. Photo images and movies, with attribute information such as locality and date, may function as vouchers of biodiversity data, particularly with respect to distributional information. However, these data do not fit the definition of "citizen science", and we therefore constructed a new conceptual model (Fig. 2). The model conforms to the definitions of "museum" by the International Council of Museums (ICOM) and the Museum Law of Japan. ICOM says "A museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing" and the Museum Law of Japan (Clause 2, Article 1) defines "museum" as follows "it is an institution that collects, stores, raises, displays and offers materials related to history, art, folklore, industry and natural science for general public use with consideration for education, conducts projects necessary for their education, research and recreation, and conducts research and study related to these materials." In other words, a museum gives back to society based on three pillars: (1) collecting materials, (2) conducting research and (3) education. Our new conceptual model described herein uses these three pillars to systematize the application of "potential museum collections of natural history" via implementation at a Japanese museum.

Applications of the Conceptual Model

(1) First step: integration to the database. The simple method to facilitate an addition to the database is for an expert to try and contact a citizen who uploaded a scientifically important image of a fish onto social media. If permission is obtained from the right holder, the image is registered to the database. It may be expected that individuals who give permission for their image to be used will continue to provide additional images, including of common species and phenomenon, in the future.

We attempted to integrate "potential museum collections of natural history", being mainly composed of fish images, scattered on the internet to the Fish Image Database of the Kanagawa Prefectural Museum, Japan. This database stores fish images with attribute information (e.g., locality and sampling date) in the same manner as collections of specimens (Miyazaki *et al*., 2014a). In this system (Fig. 3), a consent

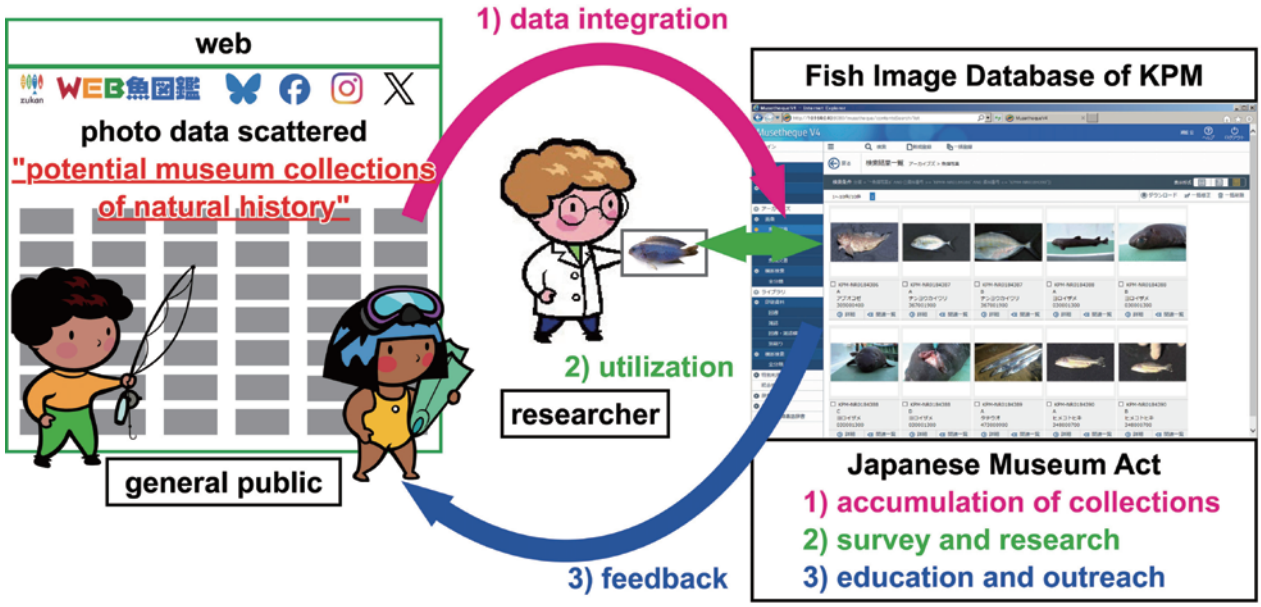

Fig. 2. The new concept model constructed according to the definition of "museum" described in the ICOM statement and the Japanese Museum Act, and implemented within the Fish Image Database (partly disclosed as FishPix on the web) of the Kanagawa Prefectural Museum of Natural History (KPM). By systematizing the information integration, utilization, and feedback, a large amount of biodiversity information will become available, and thus the general public will be able to contribute to not only research, but also sociological fields such as environmental education.

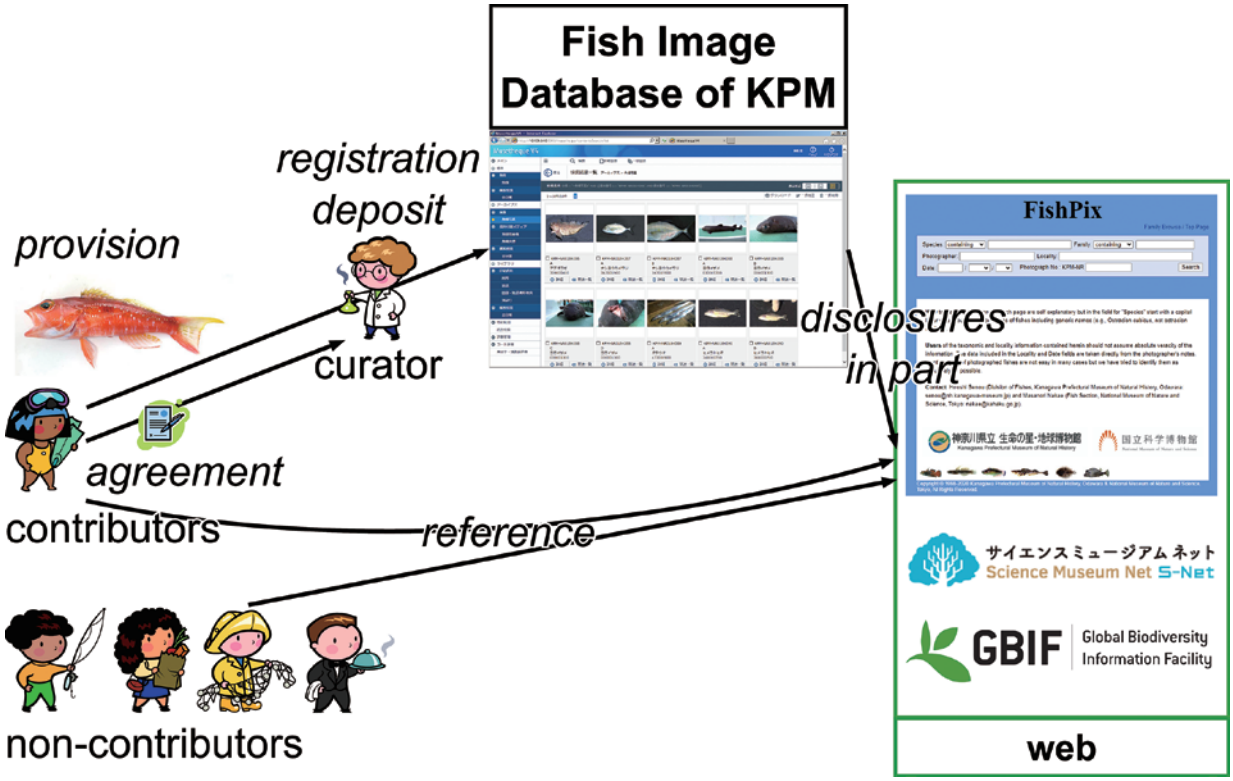

Fig. 3. The systems of the Fish Image Database of Kanagawa Prefectural Museum of Natural History (KPM). To register fish images into the database, a consent form from the image owner (or right holder) is required. This figure is modified from Miyazaki *et al.* (2014b).

form is required from the image owner or rights holder, and then the curator registers the image to the database. Part of this database has been disclosed on the web as FishPix, hosted by KPM and the National Museum of Nature and Science, Japan (Matsuura & Senou, 2002). Additionally, a subsection of the attribute information of this database has been shared at the Science Museum Net (S-Net) and Global Biodiversity Information Facility (GBIF) (Matsuura, 2009; Hosoya *et al*., 2018).

The early contributors to this photographic database were largely sourced from among readers of the journal, I.O.P. Diving News. This journal facilitated the registration of fish images by amateur scuba divers (Matsuura & Senou, 2002; Miyazaki *et al*., 2014b), publishing many new findings of fishes based mainly on underwater photographs (Senou, 2013).

A more systematic approach can be driven by a specific research aim. For example, *WEB sakana-zukan*, launched in 2002, is a large, private platform for recreational fishers in Japan (zukan.com, 2025). The website consists of a bulletin board system (BBS) where users are free to post comments and associated images, as well as a user-generated atlas of fishes (Miyazaki *et al*., 2014b). We tried to integrate important fish images (i.e., possible vouchers) from the BBS to the museum database. With this method, we could target fish images of non-native and red list species representing new records or range extensions.

Within this example (Miyazaki *et al*., 2020), permission was obtained from only 9 of 26 citizens (= 34.6%) who had uploaded images of non-native targets. Six of 26 citizens (= 23.1%) did not provide any contact information with their posts. The posts examined were 2–10 years old, and their addresses (10/26 = 38.5%) were not available, or one did not reply. Although we attempted to contact the only one poster whose record of a red list species provided new distributional information, their contact information had lapsed. We registered only 14 lots (32 images) to the museum's collection, although 31 lots were identified as potential vouchers (i.e., 14/31 = 45.2% success). In addition, Miyazaki *et al*. (2020) also found that 3/17 (17.6%) heavy users contributed new distributional information, while 15/2631 (0.6%) light users provided new distributional information. However, the heavy users contributed 23/50,325 (< 0.001%) posts and 8/30 lots (26.7% of all new distributional records), whereas the light users contributed 15/6569 (0.2%) posts and 15/30 (50.0%) lots. These results indicate that a community with fewer posts per user but many participants is better for identifying new distributional information for biodiversity conservation than a community with many posts from only a few users.

(2) Second step: application to scientific studies. Building on photograph collections of the museum obtained via the first step, we then explored their potential application to ichthyological studies. Unusual records or single findings such

as distributional range extensions (voucher specimens) are the most useful data for scientific publications, as mentioned below.

Senou *et al*. (2006) compiled the fish fauna of the Sea of Sagami based on voucher specimens and images collected by experts and by contributions from scuba divers and recreational fishers. Another typical example is that Wada *et al*. (2020) described a new species of perchlet, *Plectranthias ryukyuensis*, based on specimens and photographs, both of which were registered to the museum. This museum database has helped clarify the ichthyofaunas of major diving areas, provided a biogeographic key of the southern Japanese areas affected by the Kuroshio warm current, and listed the voucher specimens of various distributional records or color descriptions of fish species (Matsuura & Senou, 2002, 2012; Miyazaki *et al*., 2014a). In addition, Mabuchi (2003) revealed the differences in geographical distribution patterns between two closely related wrasses, *Pseudolabrus eoethinus* and *P. sieboldi*, on the Pacific and Sea of Japan coasts of southern Japan, based on a total of 724 minutes of diving observations, 586 specimens and 91 photographs. These specimens are stored at seven museums including the KPM, while all photographs are from the collections of the museum. Moreover, Okiyama *et al*. (2007) reported records of *Gibberichthys latifrons* from Japan with some suggestions for functional morphology and mimicry, based on not only specimens but also images of its larvae registered to the museum's database.

Similarly, individual reports of a rare triggerfish hybrid (Miyazaki *et al*., 2015b), an illegal introduction of an invasive fish (Miyazaki *et al*., 2016), and a species newly recorded from a country (i.e., Costa Rica; Miyazaki *et al*., 2017) were identified from the timeline of Twitter (now rebranded as X), a post at the BBS of *WEB sakana-zukan*, and via direct contact with a citizen respectively. The case studies also provide the chance for discussions of related issues such as language barriers caused by differences in Spanish and Japanese, copyright and permanent storage.

(3) Third step: trials of education or outreach. Steps 1 and 2 lead to the third Step of attempting to educate the general public about any new findings published in scientific literature. One simple method of achieving this to a small degree is to acknowledge the citizens' contributions and provide them with a reprint. This basic methodology is probably an ethical requirement for research studies (Miyazaki, 2018b).

Applied methods include a special exhibition of the Kanagawa Prefectural Museum of Natural History (e.g., Miyazaki *et al*., 2015a), and articles in a fishing magazine and museum newsletter (e.g., Miyazaki 2015a, b; Fig. 4). As a

Fig. 4. An example of the implementation of the new concept model to a case study. First, a fish image was posted to a bulletin board system by a recreational fisher (i.e., citizen). Then, it was registered to the Fish Image Database of Kanagawa Prefectural Museum of Natural History. A scientific article was published based on this museum collection by the experts and the contributor (Miyazaki *et al*., 2015b), representing the first record of this rare hybrid individual with a verifiable voucher. The rare hybrid was introduced in the color-feature series located at the end of the fishing magazine (Miyazaki, 2015a).

matter of course, the exhibition and newsletter of the museum are easy to reflect its members' works. On the other hand, the first author (YM) has also introduced our works at articles with color photographs of fishes in a fishing magazine, *Tsuri-joho*, published by Tatsumi Publishing Co., Ltd. or in a boat magazine, *Boat CLUB*, published by KAJI Co., Ltd.

It is considered that further effective methods could be applied by using mass media. When opportunities arise such as focusing on the use of citizen science or on the novel approach of the application of art for scientific purposes, mass media such as newspapers, radio, and television can be used to profile our publications. In fact, an example of extractions of fish distributional data from the *WEB sakana-zukan* BBS as mentioned before (Miyazaki *et al*., 2020) were introduced by the Japanese newspaper, *Nihon Keizai Shimbun* (Asanuma *et al*., 2020), to explain the importance of citizens' contributions to scientific discoveries, including conservation science (Miyazaki *et al*., 2020), meteorology (Araki, 2019), and public hygiene in particular regarding the participation of a company in the project of the Folding@home for preventing the spread of the COVID-19 pandemic (Frazer *et al*., 2020). In addition, Miyazaki & Murase (2020, 2022) reported that *gyotaku* sheets (fish rubbings) created and stocked by citizens could possibly help clarify historical biodiversity (and that the arts have potential for museum collections and science) was introduced by several domestic newspapers such as *Asahi Shimbun* (Kotsubo, 2020), *Asahi Shogakusei Shimbun* (Ekino, 2020), *Kyodo News* (more than 10 major and local newspapers) and foreign magazines such as *Forbus* (Amsen, 2020), *Spektrum der Wissenschaft* (Dönges, 2020) and *Hyperallergic* (Bishara, 2020). As a result, a few readers of the publications gained a new understanding of the importance of our research and sent us new *gyotaku* sheets (more than 300 sheets) as additional contributions. Further, YM received messages from some

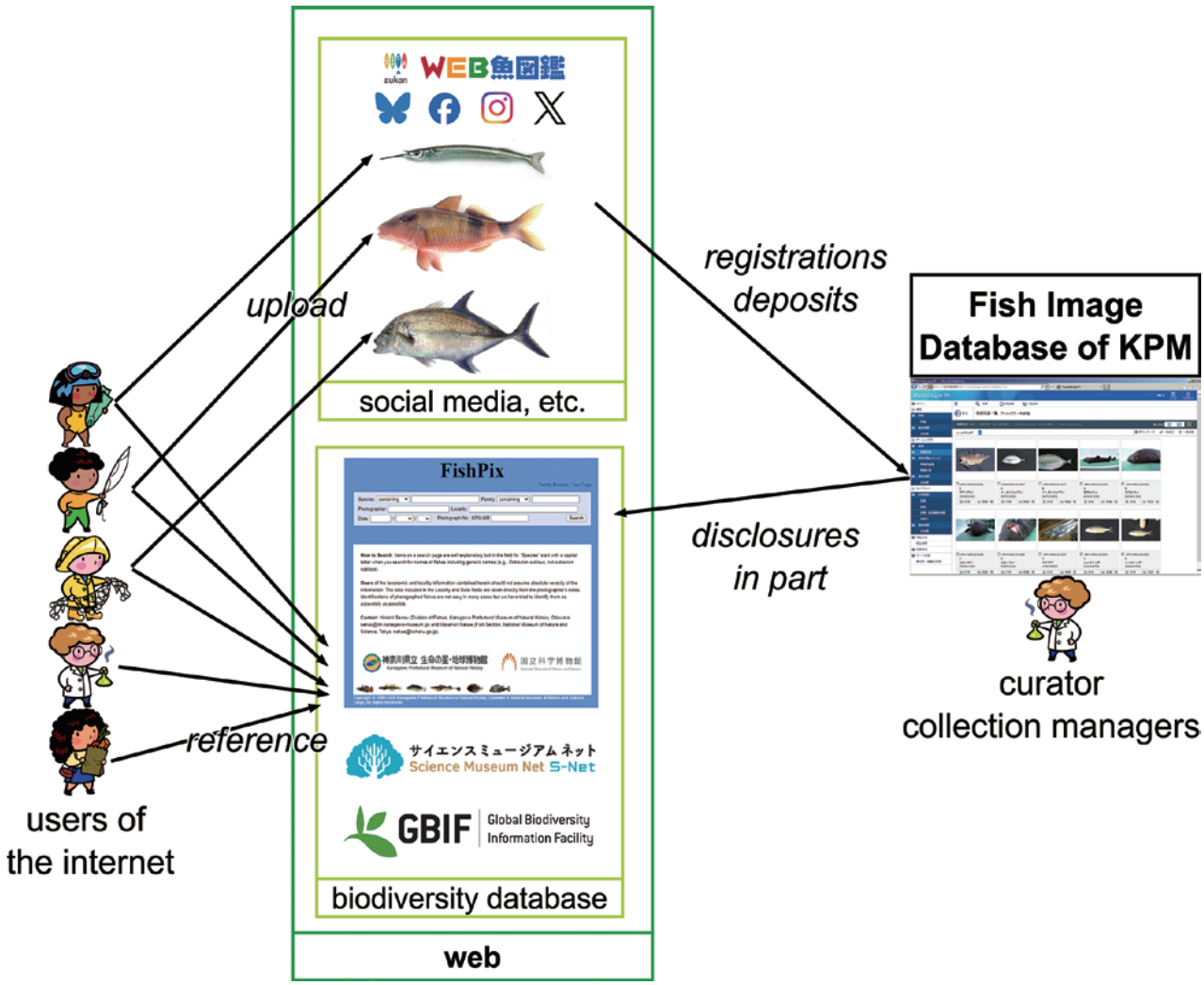

Fig. 5. Suggested improvements for the accumulation of fish images from the internet. If the museum is added as an exception to Japanese Copyright Law because of its high publicity (as is the National Diet Library of Japan), it will be legally able to copy and assemble its museum collections without permissions from copyright holders, and without collaborations between other databases and websites. This figure is modified from Miyazaki *et al*. (2014b).

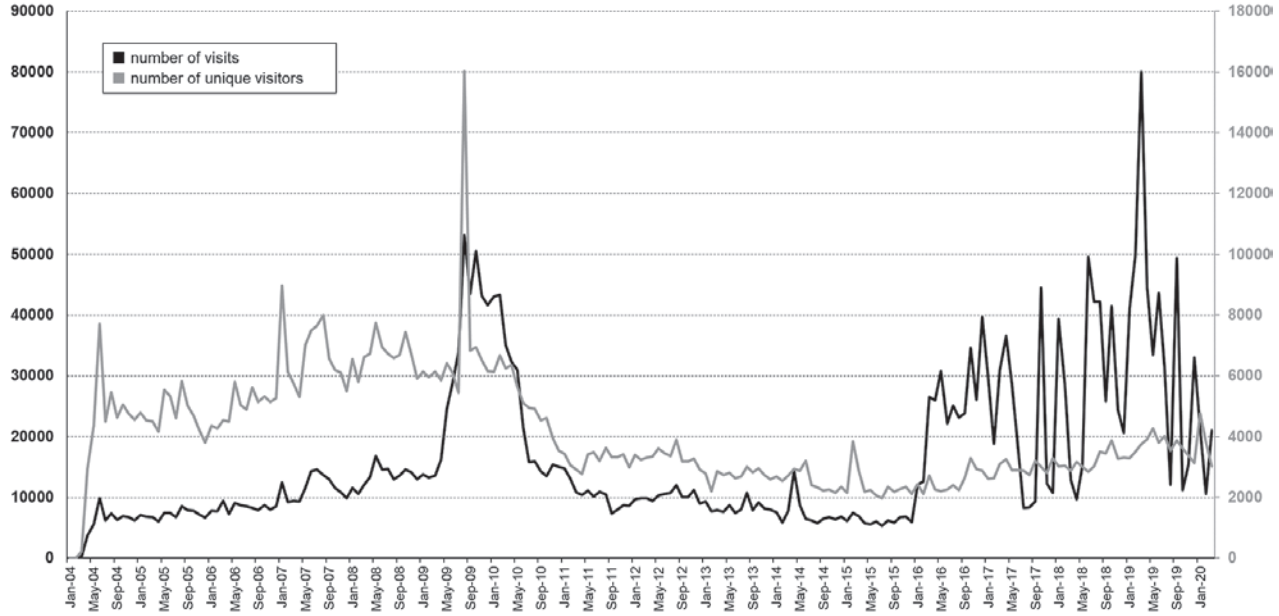

Fig. 6. The number of visitors to FishPix (part of the Fish Image Database of the Kanagawa Prefectural Museum of Natural History) since 2004. The black line indicates the number of total visitors (the left axis), while the grey line indicates the number of unique visitors (the right axis).

researchers, and collaborative research may result. However, the media focused on the unique research approach and the importance of citizens' contributions rather than the scientific results of the study. Media exposure requires popularity (Grossberg *et al*., 2006), and the utilization of mass media is often uncontrollable and unpredictable.

Other examples demonstrate that TV production teams sometimes provide specimens and images for museums and scientific discoveries. For example, based on the surveys conducted by an underwater photographer, a team comprising TV staff and ichthyologists, discovered that the pufferfish, *Torquigener albomaculosus*, was responsible for creating mystery circles (a spawning nest) on the seabed (Matsuura, 2015). In another example, a TV production crew provided their specimens and images taken for their program about deep-sea bycatch from Tokyo Submarine Canyon (Miyazaki *et al*., 2019). Mass media often have budgets far in excess of research budgets, so collaborations can provide unusual specimens and images that would be otherwise unobtainable, resulting in scientific findings at a more effective and larger scale (e.g., Grossberg *et al*., 2006; Wakefield *et al*., 2010).

Furthermore, all authors of the present study have directly introduced our scientific activities face-to-face via lectures at universities/colleges, museums and other forums.

Implementation Issues of the Conceptual Model

Generally, copyright restrictions prevent the free use of images uploaded to social media platforms. To mitigate this issue, Miyazaki *et al*. (2014a) proposed that registrations of all fish images with time and locality data on the internet as cache or self-usage data (i.e., non-disclosures of the pictures themselves, but disclosure of distribution data) should be permitted because of its publicity. For similar example, the database "Fishes of Mainland Southeast Asia (FiMSEA)" (Kano *et al*., 2013), which has integrated with GEDIMAP (Watanabe *et al*., 2010) to currently operate as "ffish.asia (freshwater fish biodiversity of Asia)" (Kano, 2022), had a function of content curation. However, similar to the copyright of images, some people may believe that they also have the right to restrict others from using the attribute information. Even if there are no legal issues, this belief can often lead to potential conflicts in practical implementation. In Japan, only the National Diet Library is able to copy and assemble its library collections without consent forms from copyright holders by an exception of the Japanese Copyright Law (i.e., Item 3 of Clause 2 of Article 31). If copyrights have expired (e.g., 70 years after the author's death in one of Japanese cases), the works can be disclosed. Because images and their accompanying attribute information are more likely to be lost online, we believe that extending a similar exemption to public museums would be beneficial for their operations in the future (Fig. 5; see also Miyazaki *et al*., 2014a).

A closely related problem is that regional museums in Japan have difficulties applying for expressions of the Creative Commons License. In particular, CC-BY is recommended and popular for Open Science, but regional museums in Japan have faced the issue that a database itself is not evaluated by

their administrators such as governors and superintendents. Curators need to demonstrate the value of a particular database by quantifying its use but this is difficult when there is free usage without permission. This situation is incompatible with an application for a Creative Commons License.

In addition, the effects of education and outreach are difficult to quantitatively evaluate due to research ethics or their own complexity. The effects can be understood in part when readers and viewers of a feedback scheme directly express their thoughts, and it is considered that case studies are relatively easy to report, but quantitative analysis is problematic.

As a rough indicator of contributions to society, we show an example of the numbers of page views and unique visitors to the database (Fig. 6). It is considered that large numbers represent the general public, and we acknowledge that populations of scuba divers and recreational fishers have been rapidly declining in recent decades (i.e., scuba divers from 2.2 million in 2001 to 0.8 million in 2022; recreational fishers from 20.4 million in 1996 to 5.2 million in 2022: Japan Productivity Center, 2023). However, it is difficult to clarify the reasons for fluctuations over time due to the complexity of factors influencing people's engagement.

An international protocol of Access to genetic resources and Benefit-Sharing (ABS) (Secretariat of the Convention on Biological Diversity, 2011) may cause a problem to develop the conceptual model proposed in this paper. The abovementioned example of Costa Rica is part of the ecological surveys of the Japan International Cooperation Agency (JICA), an organization of the Japanese government. As such, the scientific publication was cleared with prior informed consent (PIC) and mutually agreed terms (MAT), and included a collaborative researcher of the other nation (see Miyazaki *et al*., 2017). However, it is not easy to replicate these arrangements for the image database because photographs and images of nature may be considered subject to the ABS protocol (Nakae *et al*., 2015); some countries' domestic laws may require individual correspondence with respect to the ABS.

Conclusions

This article introduces a new conceptual model for applying citizens' internet data, particularly social media posts, to conservation science based on Japanese Museum Law. We introduce case studies and demonstrate that the model is feasible. This model is not affected by whether citizens contribute deliberately or unintendedly to scientific endeavors.

However, focusing on the publication of papers is just one aspect of citizen science (Dickinson & Bonney, 2012), which has broader significance including education, experience of nature and public awareness (e.g., Bonney *et al*., 2009; Wals *et al*., 2014; Kobori *et al*., 2016; Aristeidou & Herodotou, 2020). To popularize citizen science and make it sustainable, it is important to redefine its concept. As discussed, Sasaki *et al*. (2016) concluded that citizen science is not only a research approach but also serves many other functions, all of which have significance for the citizen scientist who is actively engaged. Miyazaki (2018a) agreed that the words "citizen science" can also describe the process of becoming a scientist, but the definition of Sasaki *et al*. (2016) has not been widely accepted due to language barriers. That is, part of the new concept model of Japanese citizen science (i.e., Fig. 1) is similar to the conventional concept of citizen science or civic science in general in that one expects a bottom-up effect (see also Dillon *et al*., 2016). However, the conventional concepts focus on goals of actual new findings and publications of scientific articles, whereas the approach tailored to Japan's circumstances places an importance on raising more public awareness for science (Sasaki *et al*., 2016; Miyazaki, 2018a, b). The new and conventional concepts differ greatly in this respect.

Accumulating citizens' internet data for museums is beneficial to science, facilitating research and leading to publications in peer-reviewed journals. Of particular note is the identification of unusual phenomena such as the early detection of non-native species (Miyazaki *et al*., 2015a, 2016, 2020). It is important that human resources and funds equivalent to that provided for national projects be provided to maximize the benefits and ensure sustainability of the process.

With respect to education and outreach, individual researchers have limited ability to communicate to a broad public audience whereas cooperation with mass media allows for larger scale impact. When our new model is implemented in a society, it may be possible to replace contributors who are not cooperative with those who are. The feedback system proposed will contribute to an increase in citizen scientists, and to the bottom-up scientific education regarding disciplines such as biodiversity conservation, and to the further development of citizen science.

Acknowledgements

We are sincerely grateful to G. Yearsley (Ellipsis Editing), K. Matsuura (National Museum of Nature and Science, Japan) and anonymous reviewers for the critical reading on the manuscript. This work was supported by JSPS KAKENHI Grant Numbers JP13J11038, JP16K16225, and JP20K20008 to YM.

References

Amsen, E. 2020. Tracking fish art prints to monitor biodiversity. *Forbus*. https://www.forbes.com/sites/evaamsen/2020/03/26/tracking-fish-art-prints-to-monitor-biodiversity/ [Accessed on 4 December 2024]

Araki, K., 2019. Dense ground snow crystals observation by citizen science. *Met. Res. Note*, **241**: 551–555. [In Japanese]

Aristeidou, M. & Herodotou, C. 2020. Online citizen science: a systematic review of effects on learning and scientific literacy. *Citiz. Sci. Theory Pr.*, **5**: 11. doi: 10.5334/cstp.224

Asanuma, N., Kusashio, T. & Slevin-Ohama, H. 2020. Citizens' daily lives contribute to scientific research. *Nikkei Shimbun*, **May 10**: 26. [In Japanese]

Bishara, H. 2020. Historic prints made by Japanese fishermen help track endangered species. *Hyperallergic*. https://hyperallergic.com/545476/gyotaku/ [Accessed on 4 December 2024]

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V. & Shirk, J. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience*, **59**: 977–984.

Di Ciecco, G. J., Barve, V., Belitz, M. W., Stucky, B. J., Guralnick, R. P. & Hurlbert, A. H. 2021. Observing the observers: how participants contribute data to iNaturalist and implications for biodiversity science. *BioScience*, **71**: 1179–1188.

Dickinson, J. L. & Bonney, R., 2012. Introduction: why citizen science? In Dickinson, J. L. & Bonney, R. (Eds.) C*itizen Science: Public Participation in Environmental Research*: pp. 1–14. Cornell University Press: Ithaca.

Dillon, J., Stevenson, R. B. & Wals, A. E. J. 2016. Introduction to the special section moving from citizen to civic science to address wicked conservation problems. *Conserv. Biol*., **30**: 450–455.

Dönges, J. 2020. Gyotaku. Fischvielfalt in schwarz auf weiß. *Spektrum der Wissenschaft*. https://www.spektrum.de/alias/bilder-der-woche/gyotaku-was-die-japanischen-fischdrucke-ueber-biodiversitaet-verraten/1701740/ [Accessed on 4 December 2024] [In German]

Ekino, A. 2020. Proud certificate of fishermen: gyotaku fish rubbings reveals the natural history of fishes. *Asahi Shogakusei Shimbun*, **January 31**: 3. [In Japanese]

Frazer, J. S., Shard, A., & Herdman, J. 2020. Involvement of the open-source community in combating the worldwide COVID-19 pandemic: a review. *J. Med. Eng. Technol*., **44**: 169–176.

Froese, R. & Pauly, D. (Eds.) 2000. *FishBase 2000: Concepts, Design and Data Sources*. The International Center for Living Aquatic Resources Management, Los Baños.

Grossberg, L., Wartella, E., Whitney, D. C. & Wise, J. M. 2006. *MediaMaking: Mass Media in A Popular Culture, Second Edition*. Sage Publications, Thousand Oaks.

Hosoya, T., Jinbo, U., Nakae, M., Ebihara, A. & Mizunuma, T. 2018. The current status and challenges of the natural historical collection database "Science Museum Net." *J. Jpn. Soc. Digit. Arch*., **2**: 60–63. [In Japanese]

Ikkatai, Y. 2020. Current conditions and particular issues of online citizen science in Japan. *J. Sci. Technol. Stud*., **18**: 33–45. [In Japanese with English abstract]

iNaturalist, 2025. *iNaturalist*. https://www.inaturalist.org [Accessed on 6 January 2025]

Japan Productivity Center. 2023. *Leisure White Paper 2023: The Current State of Leisure and Trends in Industries and Markets*. Productivity Press, Tokyo. [In Japanese]

Kano, Y. 2022. Bio-photogrammetry: digitally archiving coloured 3D morphology data of creatures and associated challenges. *Res. Ideas Outcomes*, **8**: e86985. doi: 10.3897/rio.8.e86985

Kano, Y., Adnan, M. S., Grudpan, C., Grudpan, J., Magtoon, W., Musikasinthorn, P., Natori, Y., Ottomanski, S., Praxaysonbath, B., Phongsa, K., Rangsiruji, A., Shibukawa, K., Shimatani, Y., So, N., Suvarnaraksha, A., Thach, P., Thanh, P. N., Tran, D. D., Utsugi, K. & Yamashita, T. 2013. An online database on freshwater fish diversity and distribution in Mainland Southeast Asia. *Ichthyol. Res*., **60**: 293–295.

Kitsuregawa, M. & Nishida, T. 2010. Special issue on information explosion. *New Gener. Comput*., **28**: 207–215.

Kobori, H., Dickinson, j. L., Washitani, I., Sakurai, R., Amano T., Komatsu, N., Kitamura, W., Takagawa, S., Koyama, K., Ogawara, T. & Miller-Rushing, A. J. 2016. Citizen science: a new approach to advance ecology, education, and conservation. *Ecol. Res*., **31**: 1–19.

Kotsubo, Y. 2020. Monitoring records read by gyotaku fish rubbings. *Asahi Shimbun (Evening Ed.)*, **January 21**: 8. [In Japanese]

Mabuchi, K. 2003. Geographical distribution patterns of two *Pseudolabrus* (Perciformes: Labridae) species on the Pacific and Sea of Japan coasts of southern Japan. *Jpn. J. Ichthyol*., **50**: 103–113. [In Japanese with English abstract]

Matsuura, K. 2009. Contribution of natural history museums to GBIF project. *Bull. Plankton Soc. Jpn*., **56**: 169–173. [In Japanese with English abstract]

Matsuura, K. 2015. A new pufferfish of the genus *Torquigener* that builds "mystery circles" on sandy bottoms in the Ryukyu Islands, Japan (Actinopterygii: Tetraodontiformes: Tetraodontidae). *Ichthyol. Res*., **62**: 207–212.

Matsuura, K. & Senou, H. 2002. Fish databases in Japan with special reference to fish-image database and its role in

biodiversity study. *Res. Rep. Natl. Inst. Environ. Stud., Jpn*., **171**: 220–227.

Matsuura, K. & Senou, H. 2012. The Kuroshio Current and its fishes. In Matsuura, K. (Ed.) *Fishes in the Kuroshio Current*: pp. 3–16. Tokai University Press: Hadano. [In Japanese]

Miyazaki, Y., 2015a. A rare hybrid of *Rhinecanthus aculeatus* × *R. rectangulus*. *Tsuri-joho*, **38 (16)**: 162. [In Japanese]

Miyazaki, Y., 2015b. Utilizations of biodiversity information on the web for researches of natural history. *Newsl. Kanagawa Prefect. Mus. Nat. Hist*., **21(2)**: 10–11. [In Japanese]

Miyazaki, Y. 2018a. Citizen science in Japan: a consideration of the relationship between science and citizens among generations. *Jpn J. Conserv. Ecol*., **23**: 167–176. [in Japanese with English abstract]

Miyazaki, Y. 2018b. Scientific utilizations of citizens' data obtained via the information media. *Jpn. J. Plant Species Biol*., **2**: in press. [In Japanese]

Miyazaki, Y. & Murase, A., 2020. Fish rubbings, 'gyotaku', as a source of historical biodiversity data. *ZooKeys*, **904**: 89–101.

Miyazaki, Y. & Murase, A. 2022. Using *gyotaku* to reveal past records of fishes including extinct populations. In Kai, Y., Motomura, H. & Matsuura, K. (Eds.) *Fish Diversity of Japan: Evolution, Zoogeography, and Conservation*: pp. 409–418. Springer, Singapore.

Miyazaki, Y., Murase, A., Honda, J., Yamaide, J. & Senou, H. 2020. Usefulness of a Japanese internet community for fish conservation. *Biodivers. Conserv*., **29**: 625–642.

Miyazaki, Y., Murase, A., Sahara, R., Angulo, A. & Senou, H. 2017. Adding fish images taken in other countries to the biodiversity database of a Japanese public museum, with report of range extension of *Labrisomus jenkinsi* from the Pacific coast of Costa Rica. *Ecol. Res*., **32**: 89–93.

Miyazaki, Y., Murase, A. & Senou, H. 2014a. Citizen participation in augmenting a museum database enhances fish monitoring and public awareness. *J. Aquat. Mar. Environ. Educ. Res. (Mem. Stud. Aquat. Mar. Environ. Educ.)*, **7**: 22–26.

Miyazaki, Y., Murase, A. & Senou, H. 2015a. A natural history museum as a platform for accumulating verifiable information on non-native fishes: a Japanese example. *Manag. Biol. Invasion*., **6**: 105–110.

Miyazaki, Y., Murase, A., Shiina, M., Masui, R. & Senou, H. 2015b. Integrating and utilizing citizen biodiversity data on the Web for science: an example of a rare triggerfish hybrid image provided by a sport fisherman. *J. Coast. Res*., **31**: 1035–1039.

Miyazaki, Y., Murase, A., Shiina, M., Naoe, K., Nakashiro, R., Honda, J., Yamaide, J. & Senou, H. 2014b. Biological monitoring by citizens using Web-based photographic databases of fishes. *Biodivers. Conserv*., **23**: 2383–2391.

Miyazaki, Y., Teramura, A. & Senou, H. 2016. Biodiversity data mining from Argus-eyed citizens: the first illegal introduction record of *Lepomis macrochirus macrochirus* Rafinesque, 1819 in Japan based on Twitter information. *ZooKeys*, **569**: 123–133.

Miyazaki, Y., Teramura, A. & Senou, H. 2019. Preliminary report on bycatch fish species collected from the Tokyo Submarine Canyon, Japan. *ZooKeys*, **843**: 117–128.

Nakae, M., Chiba, S. & Ohashi, S. 2015. Influences of Convention of Biological Diversity and Nagoya Protocol on ichthyological researches: you cannot be dismissed as ignorance about ABS issues. *Jpn. J. Ichthyol*., **62**: 84–90. [In Japanese]

Okiyama, M., Senou, H. & Kawano, T. 2007. Kasidoron larvae of *Gibberichthys latifrons* (Osteichthyes, Gibberichthyidae) from Japan. *Bull. Natl. Mus. Nat. Sci., Ser. A*, **33**: 45–50.

Sasaki, H., Ohnishi, W., & Osawa, T. 2016. Redefining "Citizen Science" from several perspectives. *Jpn. J. Conserv. Ecol*., 21: 243–248. [In Japanese with English abstract]

Secretariat of the Convention on Biological Diversity. 2011. *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity: Text and Annex*. Secretariat of the Convention on Biological Diversity, Montreal.

Senou, H. 2013. I.O.P. Diving News. In Senou, H. (Ed.) *Hajime Masuda and Japan's Ichthyology: A Dandy Devoted His Lifetime for Fish Photographic Books*: pp. 105–111. Kanagawa Prefectural Museum of Natural History, Odawara. [In Japanese]

Senou, H., Matsuura, K., & Shinohara, G. 2006. Checklist of fishes in the Sagami Sea with zoogeographical comments on shallow water fishes occurring along the coastlines under the influence of the Kuroshio Current. *Mem. Natl. Sci. Mus. Tokyo*, **41**: 389–542.

Sforzi, A., Tweddle, J., Vogel, J., Lois, G., Wägele, W., Lakeman-Fraser, P. & Makuch, Z. 2018. Citizen science and the role of natural history museums. In Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. (Eds.) *Citizen Science: Innovation in Open Science, Society and Policy*: pp. 429–444. UCL Press, London.

Silvertown, J. 2009. A new dawn for citizen science. *Trends Ecol. Evol*., **24**: 467–471.

Silvertown, J., Harvey, M., Greenwood, R., Dodd, M., Rosewell, J., Rebelo, T., Ansine, J. & McConway, K. 2015. Crowdsourcing the identification of organisms: a case-study

of iSpot. *ZooKeys*, **480**: 125–146.

Toivonen, T., Heikinheimo, V., Fink, C., Hausmann, A., Hiippala, T., Järv, O., Tenkanen, H. & Di Minin, E. 2019. Social media data for conservation science:a methodological overview. *Biol. Conserv*., **233**: 298–315.

Van Dijck, J. 2013. *The Culture of Connectivity: A Critical History of Social Media*. Oxford University Press, New York.

Wada, H., Suzuki, T., Senou, H. & Motomura, H. 2020. *Plectranthias ryukyuensis*, a new species of perchlet from the Ryukyu Islands, Japan, with a key to the Japanese species of *Plectranthias* (Serranidae: Anthiadinae). *Ichthyol. Res*., **67**: 294–307.

Wakefield, M., Loken, B. & Hornik, R. C. 2010. Use of mass media campaigns to change health behaviour. *The Lancet*, **376**: 1261–1271.

Wals, A. E. J., Brody, M., Dillon, J. & Stevenson, R. B., 2014. Convergence between science and environmental education. *Science*, **344**: 583–584.

Watanabe, K., Kano, Y., Takahashi, H., Mukai, T., Kakioka, R. & Tominaga, K. 2010. GEDIMAP: a database of genetic diversity for Japanese freshwater fishes. *Ichthyol. Res*., **57**: 107–109.

zukan.com, 2025. *WEB sakana-zukan*. https://zukan.com/fish / [Accessed on 6 January 2025]