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Photographic evidence from a recreational angler of the northernmost record of the bull shark *Carcharhinus leucas* (Elasmobranchii: Carcharhinidae) in the western Pacific Ocean

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Abstract

Photographs of a single shark specimen (1040 mm in total length) caught in the Oyodo River estuary, Miyazaki Prefecture, Kyushu, Japan, by a recreational angler and uploaded to the social networking service Facebook, were identified as a juvenile specimen of the bull shark *Carcharhinus leucas*. The photographic record, now deposited in the Kanagawa Prefectural Museum of Natural History collection, represents the northernmost record of this species in the western Pacific Ocean. Although *C. leucas* is known to utilize primarily tropical estuarine habitats as nursery grounds, a few reports exist regarding the utilization of subtropical and warm-temperate latitude estuaries, as in this case. From the perspectives of species conservation and shark-bite mitigation in warm-temperate latitudes, further information on *C. leucas* occurrence around its northern distribution limit is required.

Introduction

The bull shark *Carcharhinus leucas* Valenciennes, 1839, is circumglobally distributed, occurring mainly in tropical, subtropical, and warm-temperate latitudes in shallow continental and shelf waters. This species has a high tolerance of low-salinity environments, such as estuaries and rivers, which are often utilized as essential habitats, especially during early *C. leucas* life stages (Ebert *et al*., 2021; Gausmann, 2021). However, such habitats have often been subjected to depletion, degradation, modification, and pollution due to human activities (Costanza *et al*., 1997; Lotze *et al*., 2006; Barbier *et al*., 2011). In addition, *C. leucas* has been overfished throughout its range for fins, flesh, skins, and liver oils (Last and Stevens, 2009), despite a warning that a decline in population numbers would require a long recovery time due to slow maturation of individuals (15–20 years) and low birth rate (1–14 pups at one time after 10–11 months of gestation; Nevill *et al*., 2013; Ebert *et al*., 2021). Accordingly, the *C. leucas* population is considered to be declining on a global scale; it is assessed in the IUCN Red List as 'Vulnerable' (Rigby *et al*., 2021). Any conservation strategy requires an understanding of distribution patterns and habitat utilization, especially in the case of threatened taxa (Lamoreux *et al*., 2006; Mota-Vargas and Rojas-Soto, 2012; Moore, 2018). In the western Pacific Ocean, *C. leucas* has been recorded primarily from tropical and subtropical latitudes, the only reliable record from a warm-temperate latitude in the region was of a juvenile male specimen (729 mm in total length) collected off the coast of Shanghai, China, at approximately 31°N (Catalogue No. BMNH 74.1.16.63; Garrick, 1982; Gausmann, 2021). Clearly, information on the western Pacific warm-temperate latitude occurrence and habitat utilization of *C. leucas* is extremely limited.

The recent frequency of reported unprovoked shark-bite incidents has increased around the world (McPhee, 2014), presumably due to an increase in the number of ocean users. A number of species have been implicated, including (most commonly) the great white shark (*Carcharodon carcharias*), the tiger shark (*Galeocerdo cuvier*), and the bull shark (*C. leucas*; McPhee, 2014; Chapman and McPhee, 2016). Although shark-bite incidents attract a great deal of public and media attention (Neff, 2012), many large shark species, including those mentioned earlier, are legally protected or threatened (Ebert *et al*., 2021). Therefore, public policies considering both public safety and the responsibility for protecting endangered predators, such as *C. leucas*, are needed (Neff, 2012). In addition, the actual risks to humans from sharks need to be re-assessed, based on the most up-to-date scientific knowledge of shark abundance and distribution (Simpfendorfer *et al*., 2011; Chapman and McPhee, 2016).

In recent years, the general public has contributed to scientific knowledge in many ways, with so-called 'citizen science' becoming widespread in many fields (Devictor *et al*., 2010; Dickinson *et al*., 2010; Kobori *et al*., 2016; Eitzel *et al*., 2017). It is considered a useful tool for clarifying the distribution and population ranges of species in ichthyology, recording, for example, a new distribution location of a species (Miyazaki *et al*., 2017; Heard *et al*., 2019), movement ranges of individuals (Armstrong *et al*., 2019; Araujo *et al*., 2020;

Séguigne *et al*., 2023), and the presence of non-native species (Miyazaki *et al*., 2016; Pentyliuk *et al*., 2023). In fact, several citizen groups have been formed in some regions, with initiatives for shark conservation (Bargnesi *et al*., 2020), there being a shift in perception from protecting humans from sharks to protecting sharks from humans (Simpfendorfer *et al*., 2011). Although the number of cases of records deriving from citizen science by recreational anglers is increasing (Gibson *et al*., 2019; Gausmann and Hasan, 2022), the amount of shark research involving citizen science remains still small, with most studies having been conducted by scuba divers (Bargnesi *et al*., 2020). Here, we provide photographic evidence of an immature specimen of *C. leucas* that was caught by a recreational angler which represents the northernmost record of this species in the western Pacific Ocean.

Materials and methods

In September 2015, a live fish caught by a local recreational angler (M. Oshikawa) and kept in the water on a long string was predated at the mouth of the Oyodo River, Miyazaki Prefecture, Kyushu, Japan (Figure 1). In addition, the angler's friend caught a shark of about 700 mm total length (TL) at the same location later that month. Subsequently, the remains of a carp (*Cyprinus carpio*[caudal part missing]) were found at the same place on 6 October 2015. Assuming both cases of predation were due to a feeding shark and that the shark might still be in the locality, the angler returned to the same place several times hoping to catch it. On 27 May 2016, the angler finally caught a shark specimen by lure fishing. The specimen was photographed and its TL measured after landed and given to a friend of the angler. Although the shark was not preserved as a scientific specimen, the angler's posts, including photographs, were later found on a social networking service (SNS: Facebook) by the first author (Figures 2, 3). The authors identified the shark as *C. leucas*. Subsequently, permission was granted to the authors for use of the photographs and collection data for this report on *C. leucas* from an estuarine habitat in the warm-temperate latitude of Japan, thereby adding to knowledge of the distribution of the species. This new record represents the northernmost record of *C. leucas* in the western Pacific Ocean region.

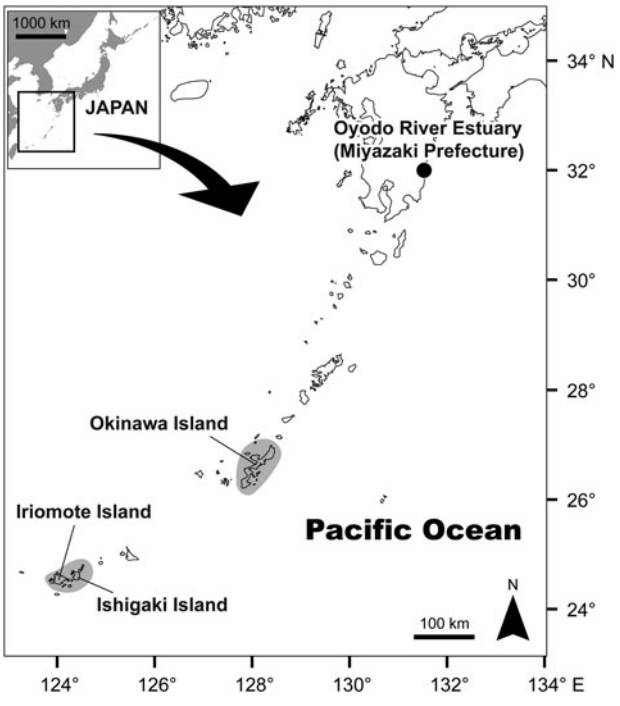

Figure 1. Distribution map of *Carcharhinus leucas* in Japan. Black spot and grey mesh indicate present and previous records, respectively.

Results

Colour photographs of the shark individual produced by the recreational fishermen were deposited by the authors in the image database of fishes at the Kanagawa Prefectural Museum of Natural History (KPM-NR), with the accompanying data: *Carcharhinus leucas*, collected and photographed by M. Oshikawa on 27 May 2016; collection method: hook and line with lure; location: mouth of Oyodo River, Miyazaki City, Miyazaki Prefecture, Kyushu, southern Japan (31°53'24.0"N, 131°27'19.2"E); registration number: KPM-NR 213016A–C. Note: KPM registration numbers are expressed as seven digits, including leading zeros (e.g. KPM-NR0213016), on the museum database, but the latter are omitted here. TL of the specimen was measured as the distance between the distal tips of the snout and the caudal fin.

Photographs of the captured specimen (Figure 3: 1040 mm TL) were identified by the authors as *Carcharhinus leucas*, based on the following morphological characteristics according to Compagno (1984), Last and Stevens (2009), and Ebert *et al*.'s (2021) observations were as follows: short, bluntly rounded snout; snout broader than long; internarial space less than preoral length; labial furrows inconspicuous; eyes small; large angular

Figure 2. A post on Facebook posted by a recreational angler on 6 October 2015. Main points of comments translated and summarized in English as follows: 'I found a recently predated carp at the mouth of the Oyodo River. My friend hooked a shark of about 700 mm total length at the same place a week ago, thus I believe the carp was predated by a shark.'

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Figure 3. A post on Facebook posted by a recreational angler on 27 May 2016. Main points of comments translated and summarized in English as follows: 'Finally, I caught a shark at the same place where I found the carp last year. Its length is 1040 mm total length. I don't know what species it is.' Photographs cropped by author.

pectoral fin; first dorsal fin broad, height about three times the second dorsal fin height; margin of second dorsal fin concave; both dorsal fins with short rear tips; no interdorsal ridge; caudal keels inconspicuous; and fin tips dusky. *Carcharhinus leucas* is most similar to the pigeye shark, *C. amboinensis*; both species have a short, broad, and blunt snout, the upper anterolateral teeth broad, triangular, and serrated, and lacking an interdorsal ridge (Compagno, 1984; Last and Stevens, 2009; Ebert *et al.*, 2021). However, the present specimen photographs differed from *C. amboinensis* in the following features: first dorsal fin height less than 3.1 times the second dorsal fin height (more than 3.1 times in *C. amboinensis*); second dorsal fin margin concave (nearly straight); fin tips, except for first dorsal fin, strikingly dusky [indistinct (Compagno, 1984; Last and Stevens, 2009; Ebert *et al.*, 2021)]. The comparison of the morphometrical characteristics of both species with the photographic material obtained from the fishermen ruled out *C. amboinensis* and left *C. leucas* as the only possible species.

Discussion

Carcharhinus leucas is a circumglobal shark found in tropical to warm-temperate latitudes of both hemispheres (Ebert *et al.*, 2021; Gausmann, 2021; Rigby *et al.*, 2021). In the western Pacific Ocean, however, the species has primarily been recorded from tropical and subtropical latitudes (Gausmann, 2021), with only a single warm-temperate latitude record off the coast of Shanghai, China (Garrick, 1982; Gausmann, 2021). In Japan, the species has been recorded previously only from the subtropical marine waters of Okinawa, Ishigaki, and Iriomote islands (Ryukyu Islands, Okinawa Prefecture) including freshwater habitats such as Iriomote´s Urauchi River (Tachihara *et al.*, 2003; Matsumoto *et al.*, 2006; Masunaga *et al.*, 2008; Shimose and Taira, 2014; Aonuma *et al.*, 2013 [Figure 1]). Thus, the photographed specimen from the Oyodo River mouth, Kyushu, mainland Japan, currently represents the northernmost record of the species in the western Pacific Ocean (31°53'24.0"N).

The specimen (1040 mm TL) was considered to have been a juvenile because newly born *C. leucas* are reported as 560–810 mm TL, with males maturing at 1570–2260 mm and females at 1800–2300 mm (Compagno, 1984; Ebert *et al.*, 2021). Juvenile *C. leucas* prefer lower salinity zones, often spending considerable time in such habitats (Simpfendorfer *et al.*, 2005; Heupel and Simpfendorfer, 2008; Werry *et al.*, 2011; Drymon *et al.*, 2014). In the tropical and subtropical latitudes, juveniles utilize estuaries as their main nursery habitat (Simpfendorfer *et al.*, 2005; Heupel and Simpfendorfer, 2008; Drymon *et al.*, 2014), whereas in the warm-temperate latitude, the limit of the species distribution, such environments are rarely utilized for that purpose (Whitfield, 1994; Gausmann, 2021). However, in recent years, a northward shift of the species' nursery habitat has been reported in the western North Atlantic Ocean which is the transitional zone between temperate and subtropical latitudes, associated with increased water temperature and salinity (Bangley *et al.*, 2018). Miyazaki Prefecture has a north–south open coast, defined as a warm-temperate latitude (Nishimura, 1992; Kai and Motomura, 2022), facing the Pacific Ocean, with the warm Kuroshio Current flowing offshore (Murase *et al.*, 2017; Miki *et al.*, 2018). However, the distance of the coast from the Kuroshio Current increases northward (Murase, 2020), resulting in a lower sea surface temperature off the northern coast of the prefecture (Akazaki *et al.*, 2010; Murase *et al.*, 2017). In addition, several tropical or subtropical fish species, represented by apparently adult specimens, have been reported along the southern coast of the prefecture (e.g. Miki *et al.*, 2018; Murase *et al.*, 2018; Sakamoto *et al.*, 2018; Shibuya *et al.*, 2020), suggesting a subtropical or similar environment. The Oyodo River mouth, where *C. leucas* was caught, is located on the southern coast of the prefecture. The water temperature data about once every three months at approximately 2 km upstream from the shark's landing site (31°54'02"N, 131°26'03"E) is available (Ministry of Land, Infrastructure, Transport and Tourism). According to this, the water temperatures are ranging from 26.1 °C in summer (22 August 2015) to 9.8 °C in winter (10 February 2016). These data indicate that water temperature of downstream of the river keeps around 20 °C or more except for winter season, being preferable condition for juveniles of *C. leucas* (Hueter and Tyminski, 2007; Gausmann, 2021).

Furthermore, the bite-size of the predated carp was similar to the mouth size evident in the photo of *C. leucas*, the latter specimen having been caught using a lure (Figures 2, 3). The evidence suggests that young *C. leucas* utilize the estuarine zone of the Oyodo River as a nursery ground (at least temporarily). One-year-old juveniles of *C. leucas* utilize and stay in low-salinity zones as a nursery ground during the warmer months until water temperatures fall to about 21 °C (also found at 16.4 °C) and disappear during the colder months, and return to these areas next warm season (Hueter and Tyminski, 2007). It is assumed that juveniles of the species may undergo a similar seasonal migrating near the Miyazaki coastline, but any suggestion of seasonal occurrence, overwintering, or reproduction of bull sharks are presently unsupported. It is necessary to continue to monitor the occurrence of the bull shark not only in Miyazaki Prefecture but also near the boundaries of distributional ranges in order to elucidate the occurrence status (i.e. occasional visitor or resident) at known distribution limit for the avoidance of shark-bite incidents in temperate latitude under ongoing climate change. In addition, a recent molecular approach has also revealed that this species

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has a local population; the population of the Ryukyu Islands, including Iriomote Island, is genetically distinct (Devloo-Delva *et al.*, 2023). Bull sharks occurring in the temperate latitudes of Japan need to be genetically examined to reveal population matching from the viewpoint of future conservation in the western Pacific regions.

Various research approaches are necessary for information supporting future conservation management strategies for sharks and rays (Simpfendorfer *et al.*, 2011). Citizen science can also be expected to contribute to the accumulation of biological information on endangered sharks, such as the whale shark (*Rhincodon typus*; Araujo *et al.*, 2020), as well as observations of human and marine wildlife interactions (Pirotta *et al.*, 2022), being an information source not readily available to researchers or administrations (Miyazaki *et al.*, 2014; Eitzel *et al.*, 2017). As is the case with this study, the information or materials gained by recreational anglers could provide scientists with valuable evidence for fishery management and the critical habitat of sharks (Gibson *et al.*, 2019; Gausmann and Hasan, 2022). Especially in recent years, the magnitude of the contribution of those anglers for this topic in data-poor regions with some barriers to research such as financial limits and logistical difficulties has been emphasized (Gausmann and Hasan, 2022).

The 'accidental crowdsourcing approach' described here (i.e. a social network post, similar to Miyazaki *et al.* [2014]) is an example of the potential for scientists to work collaboratively with the general public, thereby filling gaps in shark distribution. In addition to changing human perception of sharks (Simpfendorfer *et al.*, 2011), it is likely that more data collected by members of the public will become available in the future with the development of camera technology and social networking services. Such data should be shared publicly in the discussion of future policies for more effective shark conservation management (Simpfendorfer *et al.*, 2011; Chapman and McPhee, 2016).

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Data availability. All relevant data are within the manuscript.

Author contributions. YO was the major contributor to the manuscript. AM supervised the study and revised the manuscript. Both authors read and approved the final manuscript.

Competing interests. The authors declare none.

Ethical standards. Not applicable.

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