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Marine and terrestrial food chain links: the case of large-billed crows *Corvus macrorhynchos* eating stranded sharptail sunfish *Masturus lanceolatus* in Fukui Prefecture, Japan

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(Abstract)　On 1–14 January 2019, the stranding of some individuals of *Masturus lanceolatus* was observed on the coast around Matsushima, Tsuruga, Fukui Prefecture, Japan, and it was also observed that dead fishes were eaten by some individuals of *Corvus macrorhynchos*. This is the first report of a pelagic fish, *M. lanceolatus* used directly as food by a land bird, *C. macrorhynchos*. This observation is an example of a rare food chain connecting directly a marine fish to a land bird, contributing to the study of marine and terrestrial food chain interactions.

Key words : *Corvus macrorhynchos*, Fukui Prefecture, food habits, *Masturus lanceolatus*, stranding

Pelagic animals and terrestrial animals live in very different environments. Therefore, it seems that there is almost no connection between the two. However, aquatic animals and land animals are interconnected within the complex food web, as stated in the phrase “the forest is longing for the sea, the sea is longing for the forest” (LFOO, 2017). An example of an event in which pelagic animals come in contact with land animals is the stranding of pelagic animals. The carcasses of the stranded pelagic animals are made available in the terrestrial ecosystem as food for land animals. But, because the stranding of pelagic animals is sporadic, it presents a rare feeding event for land animals.

In early 2019, the unusual stranding of some individuals of the pelagic fish, the sharptail sunfish *Masturus lanceolatus* (Liénard, 1840) occurred along coastal areas of Fukui Prefecture, Japan, and it was observed that these carcasses were grazed upon by the land bird, the large-billed crow *Corvus macrorhynchos* Wagler, 1827. We have initially reported these briefly (Yoshida & Sawai, 2019), but it was only now that stranding records of many individuals *of M. lanceolatus* in Fukui Prefecture and direct consumption of *M. lanceolatus* carcasses by *C. macrorhynchos* are recorded for the first time. Since the relationship between *M. lanceolatus* and *C. macrorhynchos* observed in Yoshida & Sawai (2019) was considered to be a rare example of a food chain linking a pelagic fish to a land bird, the present report is an elaboration of this phenomenon that is more common than previously thought.

Masturus lanceolatus belongs to the family Molidae (order Tetraodontiformes) and it is often confused with similar looking species of the genus *Mola*. However, this species can be distinguished from *Mola* morphologically based on the following points: body shape is more oval than that of *Mola*, the central clavus (a fin that looks like a caudal fin) protrudes posteriorly, and lower jaw is slightly protruding anteriorly at the level of the upper jaw (Sawai, 2017; Sawai *et al*., 2019). The occurrence of this species is high in tropical waters (Chang *et al*., 2018; Nyegaard *et al*., 2018), but low in cooler Japanese waters (Sawai, 2017; Sawai *et al*., 2019). However, it is known the stranding of multiple individuals of this species occurs during the winter months in the Sea of Japan (Kawakami, 2002). The stranding phenomenon of this species in the Sea of Japan during winter is based on the following

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hypothesis: this species enters the Sea of Japan along with the Tsushima warm current flowing northeastward from points further south of Japan and individuals are weakened by the decrease in water temperature, and subsequently transported to the Japanese coast by the drift current generated by the northwest seasonal wind (Nishimura, 1965; Kawakami, 2002; Sawai *et al*., 2019).

From December of 2018 to January of 2019, the stranding events of *Masturus lanceolatus* occurred in a wide area (from Nagasaki Prefecture to Akita Prefecture) on side of the Sea of Japan (Yoshida & Sawai, 2019; Sawai *et al*., 2019; E. Sawai, personal communication). The stranding event of *M. lanceolatus* that occurred in the area around Matsushima, Tsuruga, Fukui Prefecture on 1–14 January 2019, is also considered to be a part of this population (Table 1). All seven fish found in this study were identified as *M. lanceolatus* because they had the above-mentioned morphological key characters (Fig. 1). Of these seven individuals, six individuals were stranded on the coast (Fig. 2), but one individual (sample code MaFu-2) was fished from the coast by rod and reel before it got stranded (Table 1). The body sizes of these individuals were not measured except for MaFu-6, but body size class of all individuals was visually similar, and they were estimated to be around 1 m total length (Fig. 1; Table 1). The direct stranding cause of these individuals is unknown. However, focusing on the meteorological information of Tsuruga city on the day before the discovery of each six stranded individuals, the relatively strong north wind blew (daily average wind speed 3.8–5.0 m/s; JMA, 2018–2019a), the daily sea surface temperature (14–16°C; JMA, 2018–2019b) was lower than the water temperature preferred by this species (≥20°C; Seitz *et al*., 2002; Nakamura, 2017; Nyegaard *et al*., 2018). These results suggest that stranded individuals possibly approached the coast about 24 h before actual stranding. This likely supports the above-mentioned stranding hypothesis. On the other hand, although it was not confirmed in this study, there were also two rare cases wherein an animal got stranded in the river (Awau & Sawai, 2018; Sawai *et al*., 2019).

The stranded *Masturus lanceolatus* may be dissected by humans (Fig. 3), but it has not been known until now that the stranded individuals are eaten by wild animals in nature, when Yoshida & Sawai (2019) documented that stranded *M. lanceolatus* carcasses are at least eaten by *Corvus macrorhynchos*. *C. macrorhynchos* belongs to the family Corvidae (order Passeriformes), and it can be distinguished from closely related species by a thick and slightly curved beak, and a domed head (e.g., Kanouchi, 2005; Fujita, 2016). *C. macrorhynchos* is a land bird that is distributed widely across Japan, and it appears in a wide range of places from alpine areas to coastal and urbanized areas (e.g., Kanouchi, 2005; Fujita, 2016). *C. macrorhynchos* is omnivorous, has a wide range of food items such as plants, insects, mammals, birds, crustaceans, and fishes, it also eats animal carcass in nature as well as kitchen and domestic garbage, thereby playing a role as scavenger in the ecosystem (Inukai & Haga, 1953; Halley, 2001; Kanouchi, 2005; Goto *et al*., 2015; Fujita, 2016).

When we observed the stranded *Masturus lanceolatus* from a distance, some individuals of *Corvus macrorhynchos* flocked around a carcass of *M. lanceolatus* and were pecking its body (Fig. 4A). Inspecting a carcass of *M. lanceolatus*, the fish eye and gill membrane were already lost (Fig. 1), and some holes were opened in the smooth

Table 1. Detail information of *Masturus lanceolatus* in this study.

Sample code	Date	Location	Catch method	Total length (cm)
MaFu-1	1 January 2019	35°39'24.2"N, 136°03'05.8"E	Stranding	No data
MaFu-2	1 January 2019	35°39'25.2"N, 136°03'29.8"E	Fishing	No data
MaFu-3	4 January 2019	35°39'25.1"N, 136°02'54.2"E	Stranding	No data
MaFu-4	4 January 2019	35°39'24.7"N, 136°02'57.0"E	Stranding	No data
MaFu-5	8 January 2019	35°39'24.1"N, 136°03'27.2"E	Stranding	No data
MaFu-6	8 January 2019	35°39'25.2"N, 136°03'31.3"E	Stranding	ca. 119
MaFu-7	14 January 2019	35°39'25.0"N, 136°03'31.0"E	Stranding	No data

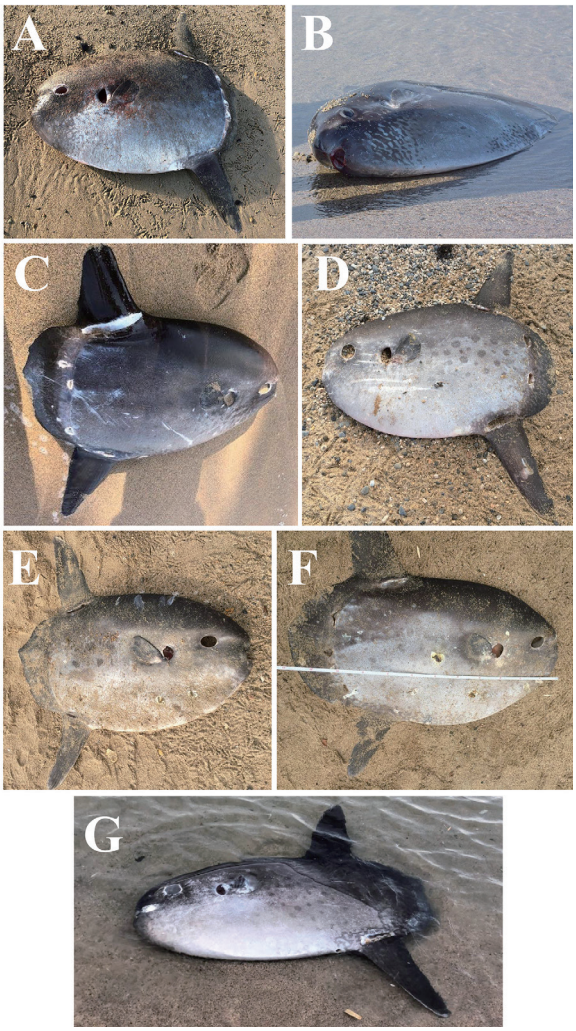

Fig. 1. Individuals of *Masturus lanceolatus* stranded or fished around Matsushima, Tsuruga, Fukui Prefecture, Japan on January 2019. **A**: sample code MaFu-1; **B**: MaFu-2; **C**: MaFu-3; **D**: MaFu-4; **E**: MaFu-5; **F**: MaFu-6; **G**: MaFu-7. *M. lanceolatus* was photographed by Tooru Tagawa (MaFu-1, MaFu-3), Shingo Tahara (MaFu-2) and Tomomi Kadono (MaFu-4–7). See Table 1 for details.

Fig. 2. An individual of *Masturus lanceolatus* (MaFu-4) which was stranded on the coast. This individual was photographed by Tomomi Kadono.

Fig. 3. An individual of dissected *Masturus lanceolatus* (MaFu-3) by someone at the stranding place. This individual was photographed by Hiroaki Uno.

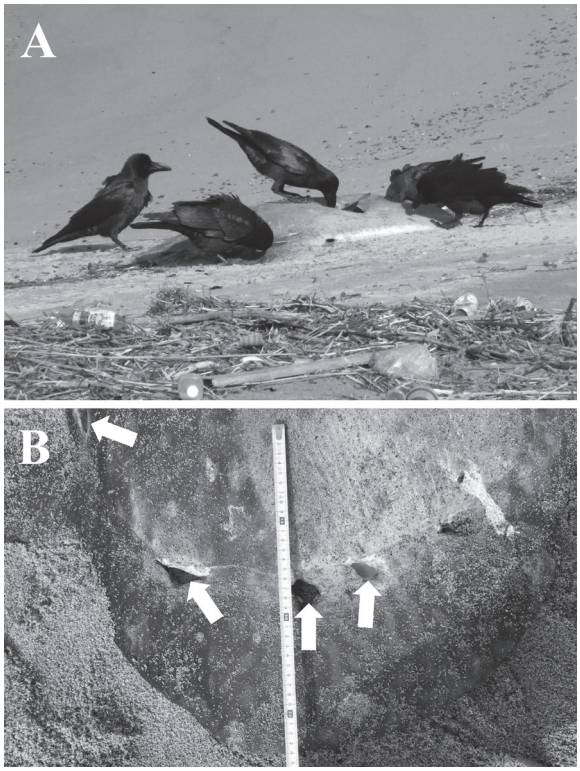

Fig. 4. *Corvus macrorhynchos* eating a stranded *Masturus lanceolatus* (MaFu-6). **A**: *C. macrorhynchos* eating MaFu-6; **B**: close-up of clavus (photographed by Tomomi Kadono). Arrows indicate scars that were pecked by *C. macrorhynchos*.

band at the base of the dorsal, clavus and anal fins (Fig. 4B). These holes in the bodies of *M. lanceolatus* and its lost parts considered to be scars pecked by *C. macrorhynchos*, as no other bird species were seen eating the carcass (Yoshida & Sawai, 2019). In addition, an unnaturally enlarged anus was also found and is believed to be a scar made by *C. macrorhynchos*. On the other hand, the elastic white and thick gelatinous collagen layer (subcutaneous gelatinous layer; Fig. 3) covering many parts of the fish body was not perforated. Based on these, it was presumed that *C. macrorhynchos* pecked only the soft parts of the body of *M. lanceolatus*. *C. macrorhynchos* was not able to get to the muscles under the thick subcutaneous gelatinous layer of *M. lanceolatus* on their own, but they ate the bare muscles of *M. lanceolatus* after being dissected by humans. It was thought that carcasses of *M. lanceolatus* have become a valuable food source for *C. macrorhynchos* during the winter months.

Links between marine and terrestrial food webs in the land-sea interface has also been documented although often constituting a longer as opposed to a direct food chain. Polis and Hurd (1995) found that spiders on the islands of the Gulf of California depend upon allochthonous marine inputs more than terrestrial resources. The main diet of spiders consists of detritus and seaweed consuming insects. On another hand, marine birds provide many avian parasites and scavengers as food for spiders, scorpions and lizards. In fact, marine birds are important contributors to the terrestrial food web through the provision of ectoparasites and guano particularly in isolated islands that are not vegetated in the Great Barrier Reef (Heatwole, 1971). Another study involved the food web interactions between the fauna of a very dry coastal desert in Peru and the rich upwelling region offshore (Catennazi & Donnelly, 2007). It was found that beach amphipods consume large amounts of seaweed, and these amphipods serve as food for geckos, beetles and scorpions. In a study probing the link of terrestrial fauna with marine biotic intertidal communities, Carlton & Hodder (2003) documented terrestrial mammals ("maritime mammals") such as raccoons, bears and foxes hunting and consuming mollusks, crabs and fish.

There are many unclear points concerning the use of stranded pelagic animals by land animals, and in particular, the relationship between *Masturus lanceolatus* with its rare occurrence in Japanese waters and land animals is not well understood. The relationship between *M. lanceolatus* and *C. macrorhynchos* observed in this study is considered to be an example of a rare marine-terrestrial food chain never before reported. It has also been shown for the first time that *M. lanceolatus* can constitute an available food item for land animals. This study is suggesting that the food web of marine ecosystems, which would normally be completed only in the sea, may also link the food web of terrestrial ecosystems by accidental stranding of pelagic animals.

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海洋から陸上へと繋がる食物連鎖：福井県に座礁したヤリマンボウを採食するハシブトガラスの事例

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（要旨） 2019年1月1－14日の間に，福井県敦賀市松島町周辺の海岸でヤリマンボウ数個体の座礁が観察され，座礁したヤリマンボウの死体はハシブトガラスによって採食されることも観察された．これは外洋性魚類であるヤリマンボウが陸上鳥類であるハシブトガラスに餌として直接利用された初めての報告である．本観察は外洋性魚類から陸上鳥類へと直接的に繋がった稀有な食物連鎖の事例であり，海洋と陸上の食物連鎖の相互作用の研究に貢献するものと考えられた．

キーワード：ハシブトガラス，福井県，食性，ヤリマンボウ，座礁