Paper

Traditional Fishing for Arctic Lamprey (*Lethenteron camtschaticum*) along the Sea of Japan Coast

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Abstract

Arctic lamprey (*Lethenteron camtschaticum*) constitutes an important fishery in Japan, but the catch has decreased. This study interviewed representatives of inland fishery cooperatives (FCs) along the Sea of Japan coast about lamprey fishing methods (gear, grounds, and season) and the fishers' local ecological knowledge (LEK). Lamprey fishing developed on the north and central coasts of the Sea of Japan in accordance with river size, environment, and lamprey behavior. The fishers used a variety of gear depending on the fishing ground. The fishing was classified into three types: 1) set-net fishing, 2) catching at artificial barriers, and 3) catching at spawning beds. The fishers' LEK provided insights into the migration behavior of Arctic lamprey in freshwater, including seasonal, lunar, diel, and habitat-related differences. However, the mean catch of Arctic lamprey has decreased to 1~10% of past catches and the number of lamprey fishers has decreased to only a few members in each FC. This information should be used to establish a conservation plan for Arctic lamprey and management of the traditional fishing culture.

Keywords：Lamprey ／ local ecological knowledge ／ inland fishery ／ local culture ／ conservation

Introduction

Arctic lamprey (*Lethenteron camtschaticum*) is an anadromous parasitic lamprey species distributed in Japan, Russia, and Alaska, where it is harvested and consumed (Kawanabe and Mizuno, 1989; Orlov et al., 2014). In Alaska, residents along the Innoko and Yukon Rivers harvest this species by ice-fishing and use it as source of food, oil, and skin (Brown et al., 2005). Traditional fishing and food cultures are found in Hokkaido and Ishikawa, Japan (Murano et al., 2008; Arakawa et al., 2018). However, the Arctic lamprey catch in Japan has decreased and it is listed as vulnerable in the Red Data Book of Japan (Ministry of the Environment, 2007; Arakawa et al., 2018). A further decline could threaten the sustainability of the local fisheries.

Traditional ecological knowledge is defined as the general cumulative body of knowledge, practices, and beliefs acquired by adaptive processes and handed down through generations by cultural transmission, about the relationships of living beings (including humans) with one another and their environment (Berkes et al., 2000). For fishing, these local practices can provide insight into the conservation of biodiversity and sustainable resource management. Information on aquatic organisms can be obtained from sources, such as indigenous people (Petersen, 2006; Sheoships, 2014) and local fishers (Lopes et al., 2019). Information from the latter resource is known as local or fishers' ecological knowledge (LEK or FEK) and is used to estimate fish distributions (Lopes et al., 2019). By using fisher's memories, their ecological knowledge can provide critical information for the management of fishery resources, including interannual, seasonal, lunar, diel, tide-related, and habitat-related differences in the behavior and abundance of target species (Johannes et al., 2000). However, several studies have reported that the loss of local and indigenous knowledge driven by globalization and modernization is likely to threaten the conservation of biodiversity (Aswani et al., 2018).

Information about the traditional lamprey fisheries in Japan has not been organized and the ecological knowledge developed through fishing might be lost. From scientific research, the occurrence of Arctic lamprey in rivers is limited to downstream of dams (Fukushima et al., 2007) and artificial barriers, including dams, culverts, weirs, and tide gates, threaten all anadromous lampreys (Clemens et al., 2020; Moser et al., 2020). Therefore, knowledge of their spawning migration behavior in

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freshwater is essential for restoring river connectivity for species conservation. However, the spatial distribution and the migration pattern are not known due to a shortage of long-term monitoring. Therefore, the ethnographical fishery relationship between inland fishers and spawning Arctic lamprey has the potential to provide critical, supplemental information for resource management.

This study interviewed members of inland fishery cooperatives (FCs) to organize information about Japanese lamprey fishing, including the distribution of fishing grounds, methods (gear and season), and practical knowledge. The FCs comprise local organizations of fishers. We interviewed fishers in the FCs since their information reflects the fishery status within each area. This current study describes the fishing methods and fishers' ecological knowledge to understand lamprey behavior and contribute to species management. We obtained details of the fishers' local ecological knowledge and temporal changes in the harvest and the number of fishers from face-to-face interviews and demonstrations on the fishing grounds.

Method

We conducted structured interviews with representatives of 111 inland FCs (62 river basins) along the Sea of Japan coast and 25 inland FCs (15 river basins) along the Pacific Ocean coast by telephone. The structured interview was conducted telephonically once for each FC office which managed all fishery activities within each specific area. A fisher or staff in each FC was asked about 1) the presence of fishing activity for Arctic lamprey in the past and present and 2) fishing methods (gear, fishing grounds, and season) if they reported fishing activity. In this study, we did not ask the respondents about attribution information such as age. We organized data to classify Japanese lamprey fishing based on its characteristics.

Additional face-to-face interviews were conducted with fishers of 10 FCs with active lamprey fishing. We asked the fishers about 1) the detailed techniques used and their knowledge of lamprey fishing, as a qualitative question, and 2) the total catch and the number of lamprey fishers in the past and present, in semi-constructed interviews. For six of the 10 FCs, we accompanied members while lamprey fishing. Both interviews were conducted throughout 2019.

Results

Arctic lamprey fishing

Along the Sea of Japan coast, Artic lamprey fisheries were recorded at 64 (30 river basins) of 111 FCs (62 river basins) in the past, while active fisheries had decreased to 15 FCs (nine river basins, Fig. 1). Along the Pacific coast, Arctic lamprey fishery was recorded at three (three river basins) of 25 FCs (61 rivers), in the past only. Of the FCs reporting past fishery activity, 39 FCs confirmed the fishing methods and the other 28 FCs were not sure (Fig. 2).

Of the 39 FCs, 17 FCs harvested lampreys by set net fishing using "*Dou*" (cone tubes), fyke nets, and baskets (Fig. 2) and 22 FCs caught lampreys using hooks, by hand, or with fishing nets (Fig. 2). Multiple methods were used in some FCs. The fishing grounds for set net fishing were mainly in the lower and middle reaches of large rivers (Figs. 1 and 2). The target in set-net fishing was harvesting migrating lampreys.

There were two fishing grounds for catching lamprey: at artificial barriers such as weirs or at spawning beds in the upper-middle reaches and tributaries. Ten FCs caught lampreys below barriers while 16 FCs caught lampreys in spawning beds. Accidental lamprey catches while fishing

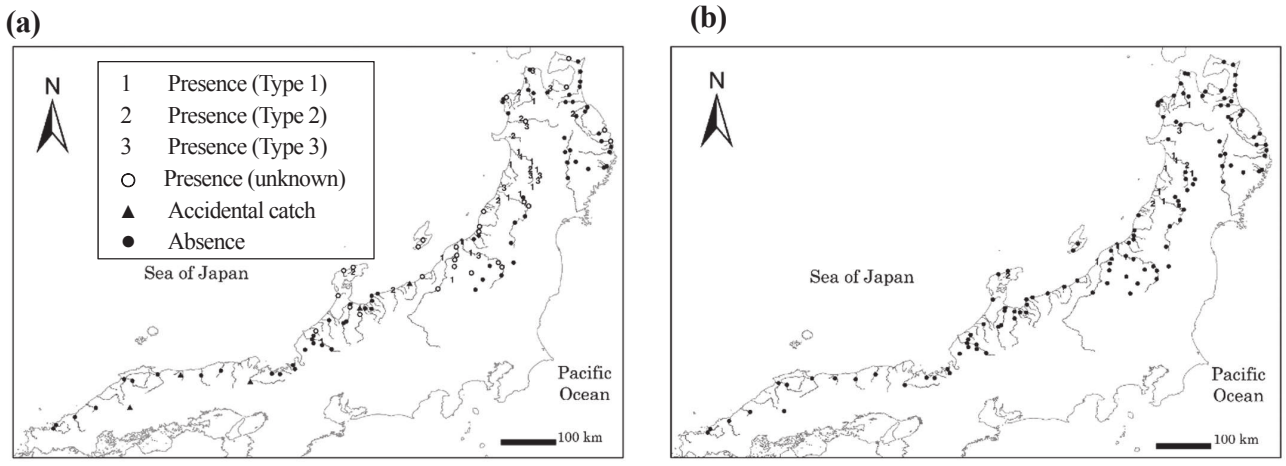

Fig.1 Distributions of Arctic lamprey fishing in the FCs in the (a) past and (b) present

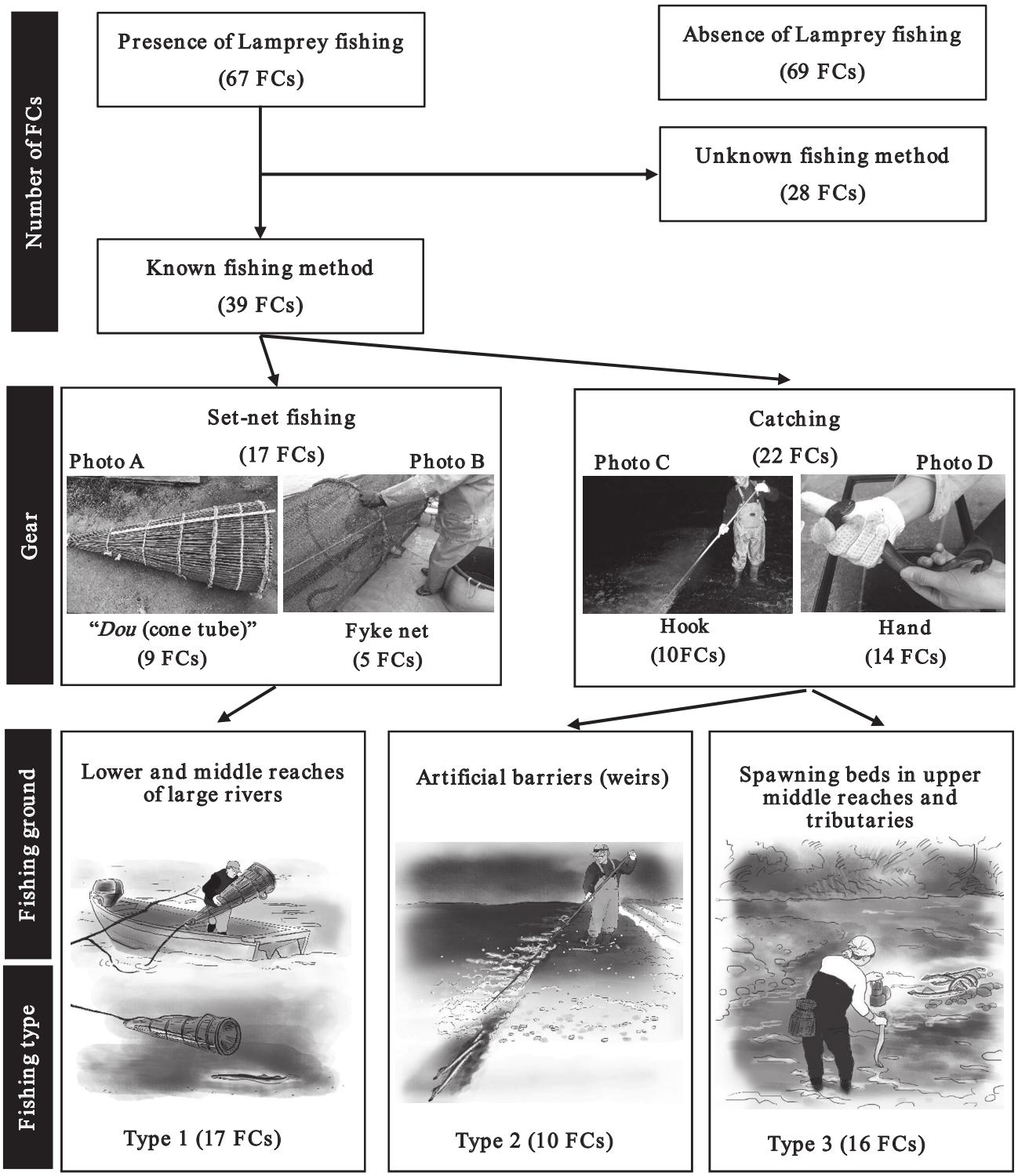

Fig.2 Flowchart classifying Japanese lamprey fishing in the inland FCs

Note: The mismatched numbers between all FCs and gear used by FCs arise because some FCs use multiple fishing methods.

Photos: A (Arakawa, 23 March 2019), B (Arakawa, 30 January 2019), C (Yanai, 30 March 2015), D (Arakawa, 19 April 2019).

for other species were reported in five FCs. We did not classify the accidental catches as fishing for lamprey since they did not reflect continuous fishing activity and did not involve a long-term relationship between fishers and lamprey. Fishing for Arctic lamprey was classified into 1) set-net fishing or catching lamprey at 2) artificial barriers or 3) spawning beds. Details of the fishing methods and knowledge of lamprey fishing are described in the next section based on 10 face-to-face interviews.

The three types of lamprey fishing

Type 1

The Iwamigawa FC is downstream in the Omono River, Akita, and has harvested lampreys from the estuary near

the sea by longline fishing using multiple cone tubes. The trap consists of 60 plastic cone tubes [large diameter (LD) 39 cm, opening diameter (OD) 3 cm, length (L) 100 cm, Fig. 3a] connected to a 200 m mainline by 3 m branch lines. This trap was set across the river and the cone tubes opened downstream. The traps were checked once every 4 to 7 days. In the past, the cone tubes were made of bamboo (LD 30 cm, OD 3 cm, L 120 cm, Fig. 3b). The fishing season is from October to next February (main season Oct-Dec). A local fisher said that Arctic lamprey was rarely caught when water was clear or at low tide, while there were many lampreys in the traps after rain. In the past, 60 lampreys/fisher·day (L/F·D) were harvested, and the traps were checked every day; at present, 10 L/F·D are collected. The total catch during the main 3-month season was 6000 L/F in the past and 50-100 L/F at present. The catch fell below 1000 L/FM in 2000 and has been decreasing since then. While there were previously eight fishers, there are only three at present.

The Senboku Seibu FC also conducts longline fishing, but in the middle of the mainstream of the Omono River, Akita. They use 20-30 cone tubes (LD 30 cm, OD 3 cm, L 70 cm) made of polycarbonate resin connected to the mainline (Fig. 4). The fishing season is from October to the next April (main season Oct-Nov). The line is installed in 1-m-deep water, with the traps at a depth of about 0.5 m. A fisher said that if the cone tubes were placed on the bottom of the river, they would fill with sediment. In the past, the fishers used cone-shaped woven-rush mats filled with willow branches. However, since there was no funnel-shaped entrance, the fishers had to lift the traps carefully so that the lampreys would not escape. There were numerous lampreys in the traps when river flow increased, but the flow could be too high for fishing. The daily catch was 200-300 L/F·D in the past and 10 L/F·D at present. The total catch during the season reached 2000-4000 L/F. In the past, there were more than 30 fishers, while there is one at present. In a conservation effort, the FC releases some of the harvest above the weir in spring.

The Mogamigawa Dai Hachi FC is in the middle reach of the Mogami River, Yamagata, and conducts lamprey fishing using cone tubes made of plants. The cone tubes are not connected to a longline, but are roped to poles. The fishers work from a boat to place the traps into the river and collect them the next day. There are two fishing seasons: from September to the next spring and from April 10 to May 5. The daily catch was 200-300 L/F·D in the past and is 10 L/F·D at present. There were over 30 fishers in the past and only two at present. As a conservation effort, for 60 years the FC has released larvae they propagate.

The Iwakigawa FC fishing ground is the middle and lower mainstream of the Iwaki River, Aomori. In the past, the fishers used cone tubes made of plants, but now use

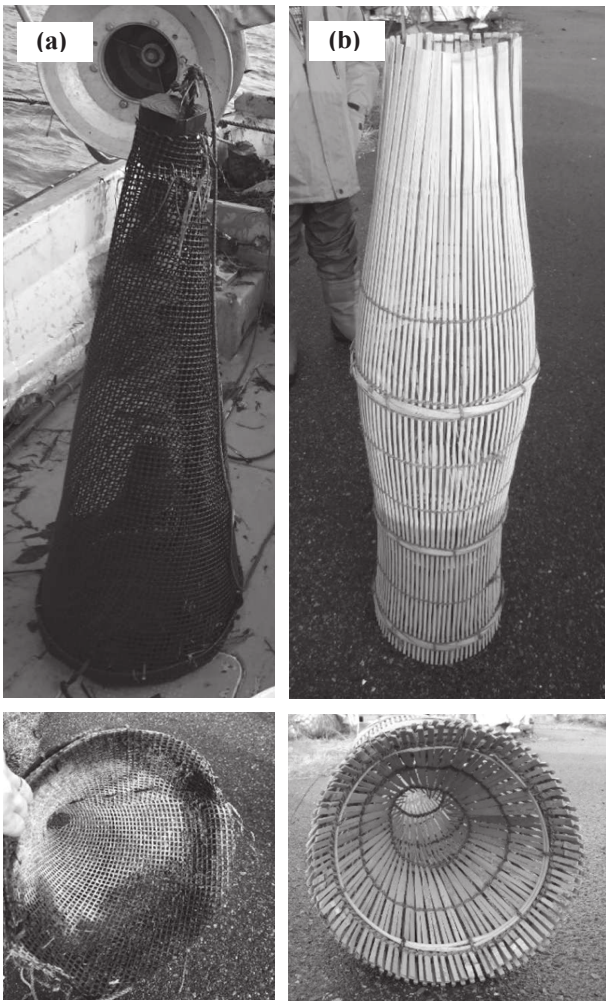

Fig.3 Present (a) and past (b) cone tubes
Photo (Arakawa, 11 December 2019)

Fig.4 Longline fishing using cone tubes
Photo (Arakawa, 10 December 2019)

metal trapezoidal baskets (LD 30-40 cm, OD 3 cm, L 70 cm). The entrance to the basket is square and it narrows to a 3 cm quadrangle at the opening. Baskets are roped to poles and installed on the river bottom at a depth of around 60 cm. The entrance faces downstream and the opposite end is inclined upward to buffer the water. The fishing season is from the end of April to May. The daily catch was 300-400 L/F·D in the past and is 4-5 L/F·D at present. In the past, type 3 fishing using hooks was also conducted and the catch exceeded 100 L/F·D. Presently, there are 5-10 fishers, while there were many (both type 1 and 3) in the past.

The Matsuhama FC harvests lamprey using a fyke net in the Agano River Estuary, Niigata. The fyke net consists of a guide net and bunt attached to a pole fixed in the riverbed in water 3-3.5 m deep. The traps face downstream. All of the fishing work is done from a boat (Fig. 5). The fisher said that the traps should be placed on an inclined riverbed, since lampreys prefer this geographical feature for migration. The fishing season is from December to the middle of January. The fisher said that they could harvest many lampreys at night with a new moon, but not with a full moon. The daily catch was 100-150 L/F·D in the past and is presently 5-6 L/F·D. There were 10-20 fishers in the past and only one at present.

The Teradomari FC fishes for lamprey in the estuary in the Ookoudzu flood control channel of the Shinano River. The fisher places an "*Otoshidamo*", a kind of fyke net without a guide net, from the riverside (Fig. 6). The entrance frame is a 2-m-high, 0.5-m-wide rectangle and the bunt is composed of multiple 8-m-long funnels. This trap needs to be placed at an appropriate site and depth due to the lack of a guide part. The fisher said that the traps were set beside the riverbank, since lampreys tended to migrate nearer the bank than in the line of maximum depth. The depth of the fishing ground was 3-4 m and the traps were set at a depth of 1.5-2 m. In the past, they also harvested lampreys by sinking a scoop net in the river for several tens of minutes. The fisher said that many lampreys were captured at night when the water was choppy, but very stormy weather limited the placing of the traps safely. There were two fishing seasons: from October to the next January and from March to April 10 (main season Oct-Dec). In the past, the size of the catch was unknown, but so many lampreys were harvested that they were crushed in the traps due to the high physical pressure. The present daily catch was only 10 L/F·D. There were 4-5 fishers in the past and only one at present. As a conservation measure, the FC released 20% of the harvest in the mainstream of the Shinano River.

Fig.5 Fyke net fishing
Photo (Arakawa, 30 January 2019)

Fig.6 "*Otoshidamo*" fyke net without a guide net
Photo (Yanai, 29 January 2019)

Type 2

The Senboku FC is located in the middle mainstream of the Omono River, Akita. The fishers catch lampreys at weirs using hooks. The river is around 100 m wide and high water volumes prevent fishers from entering the river. Therefore, fishers use a 3-m-long rig made of three fishhooks and a fishing pole (Fig. 7). The fishers stand at the riverside of the lower weir and jig the hooks up and down at night. The fishing season is from October to the

next May. Many lampreys have been captured at night with a new moon or when the river water rose and became muddy. In the past, fishers worked from 17 PM to 4 AM, but with the decreasing lamprey harvest, they now work from 17 PM to 21 PM. The daily catch was 150 L/F·D in the past and is presently 20 L/F·D. There were 20-30 fishers in the past and are 2-3 at present. As a conservation effort, the FC has released part of the harvest in the upper reaches of tributaries.

The Yanagida Kasen FC catches lampreys in the middle mainstream of the Machino River, Ishikawa. The fishers used a 3-m-long "Kanko" hook made of wood and hooked piano wire. At night, they stand above the weir in the river and jig for lampreys below the weir (Fig. 8). The fishing season is from December to the next March. A fisher said that lampreys were caught when the temperature started to get warmer and the river flow rose due to rain. The daily catch was 100 L/F·D in the past. At present, they sometimes harvest a few lampreys (1-2 L/F·D). There were 20~30 fishers in the past and are 1-2 at present. In the past, type 3 fishing was also conducted using a short version of the same type of hook (length 1 m). The spawning beds are found in riffles in knee-deep water. The type 3 fishing is done from dusk to 19-20 PM. To find spawning lamprey, the fishers walk in the river holding a carbide lamp.

The Akagawa FC used a unique fishing technique in the lower mainstream of the Aka River. In the past, the fishers got into the water up to their shoulders below the groundsill at night, facing downstream. They waited for a lamprey to attach to their bodies and grabbed them by hand with cotton or rubber gloves. A wooden board was also used to weaken the river flow and attract lampreys by holding it in front of them. Since the fishing was conducted in the cold-water season (autumn to early winter), the fishers warmed at a fire beside the river and by drinking alcohol. This method is no longer used. Now fishers do not get into the river, but grab lampreys at shallow sites close to the shore using wooden boards (Fig. 9). There are two fishing seasons: from September to November and from April to May 10. Lampreys are not harvested with bright moonlight or after agrochemical spraying upstream. The fishing is done for 2–3 hours after sundown. The daily catch averaged 500 (max 1000) L/F·D in the past and is 20–30 (max 100) L/F·D at present. There were more than 10 fishers in the past and three at present.

Type 3

The Anigawa FC is one of a few FCs still conducting Type 3 fishing. The fishing ground is in the tributaries of the Yoneshiro River. The fishers catch spawning lampreys by hand or with hooks. The 1-1.4-m-long hooks are made of cedar wood or plastic (a ski pole) with a metal hook. The 1.4-m-long hooks are used from a boat with a boxed water glass to jig for lampreys on the bottom of the river at depths over 1 m. In shallow water at depths of around 15

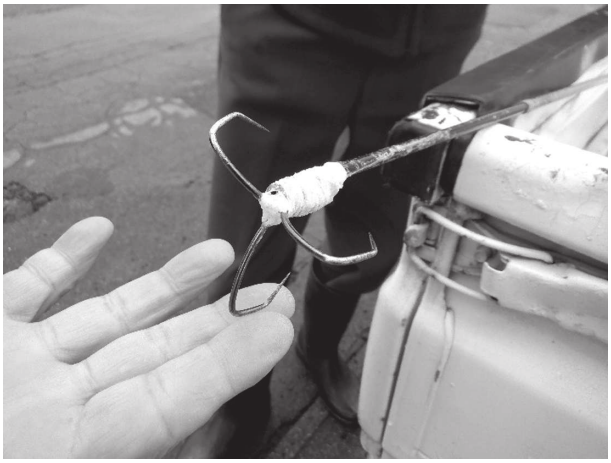

Fig.7 A hook for type 2 fishing
Photo (Arakawa, 10 December 2019)

Fig.8 Jigging lampreys at a weir
Photo (Yanai, 30 March 2015)

Fig.9 Grabbing lampreys from behind a board
Photo (Arakawa, 23 March 2019)

cm, fishers wearing waders walk closer to spawning beds and jig using a 1-m-long hook or grab lampreys by hand. A fisher said that the lamprey spawning beds tended to be at the heads of riffles and they needed to catch male lampreys before catching female lampreys because the males dispersed if the females were collected first. The fishing season is from middle April to May at present and was from June to July in the past. The catch throughout the season was 300 L/F/hour in the past and 200-300 L/F at present. There were 30-40 fishers in the past who rarely had boats and there is only one at present.

Summary of the three fishing types

The harvest had decreased in all FCs, with the maximum declines in the Iwamigawa, Iwakigawa, and Yanagidakasen FCs to 1% of past levels and the minimum decline in Senboku FC to about 10%. The number of lamprey fishers has also decreased, and few members remain in each FC. Four FCs also conducted conservation efforts independently. One FC artificially propagated and released larvae and three FCs released some of the adult lampreys in the upper reaches or tributaries

Discussion

Characteristics of Japanese lamprey fishing

A variety of lamprey fishing methods has been used along the Sea of Japan coast as determined by river size, the aquatic environment, and lamprey behavior. Type 1 set net fishing was conducted in the lower and middle mainstream reaches by longline fishing with cone tubes, fyke nets, and baskets. The same method using cone tubes and basket traps or *Dou* is common for Arctic lamprey fishing in Hokkaido, Japan (Murano et al., 2008). Set-net fishing using fyke nets is common in the Scandinavian Peninsula, Baltic States, and Iberian Peninsula (Sjöberg, 2013; Araújo et al., 2016). Historically, small baskets made of plants were used in Finland but, since 2000, these have been replaced by large metal and plastic fishing gear, such as fyke nets (Sjöberg, 2011). In Japan, the use of large fyke nets was less common than the use of cone tube traps because of geographical restrictions. Rivers in mountainous areas of Japan flow rapidly due to the steep topography. In addition, the inland fishing season for lamprey is from winter to spring when the water volumes are increased because of the melting snow. These features restrict the use of large set net fishing gear. By contrast, cone tubes fixed by longlines and floats are easy to manage, which might promote their utilization downstream and in mainstreams. The depths at which the nets are set can be controlled by weights in the traps and the water current (Nashimoto and Sato, 1985). Sea lampreys do not migrate in the surface layer (< 1 m) (Holbrook et al., 2015). At the bottom of the streambed, the fishing efficiency deteriorates due to debris flow. In Hokkaido, lamprey traps are set at intermediate depths (Murano et al., 2008). Japanese type 1 set-net fishing has developed in accordance with the topography to harvest lampreys efficiently.

In type 2 fishing, fishers catch lampreys concentrated below artificial barriers in the middle reaches, and in second-class rivers with smaller water volumes. Similarly, indigenous people on the west coast of the USA and New Zealand catch lampreys concentrated at falls by hand or with nets (Close et al., 2002; Jellyman et al., 2002). The Japanese lamprey fishing grounds are at weirs constructed for irrigation and flood control. The type 2 fishing gear mainly consists of a rod and fishhooks. The shapes of the hook are similar, but the rod lengths differ depending on the environment in the fishing ground. Hooks are also used for type 3 fishing, but are shorter (1 m) for use in shallower rivers. In the Iberian Peninsula, wounding gear called “Galheiro” is used, with longer versions for jigging from riverbanks and smaller ones for use in the water (Araújo et al., 2016). Shorter hooks are also used in the Klamath River Estuary, in the USA, to hook Pacific lampreys by casting from the shore (Petersen, 2006). The Japanese gear used for catching Arctic lamprey was developed depending on the river size and environment.

Type 3 fishing to catch lampreys in spawning beds was conducted in the upper reaches and tributaries. However, fishing at spawning beds is not common in other countries because harvesting spawning lampreys has a negative impact on their reproduction and lampreys caught in spawning beds taste different from those captured in estuaries. The energy is expended as the anadromous lamprey migrate upstream and spawn (William and Beamish, 1979). A sensory evaluation of migrating chum salmon reported that their flavor deteriorated with a corresponding decrease in lipid content (Hatano et al., 1987). After a long migration, lampreys also consume body lipid contents and might be preferred less. However, Arctic lamprey contains many essential fatty acids (DHA and EPA) and vitamins and was described as medicine for preventing night blindness in a book published in 1712 (Yazawa, 2007). In Japan, marine stingrays were eaten historically in mountain areas because they were nutrient-rich, and not perishable when transported inland (Tomioka et al., 2010). Therefore, Arctic lampreys that migrate

upstream might be important food resources throughout river basins. The fishers interviewed said that Arctic lampreys containing less fat after swimming in rivers were easy to eat and more delicious. Residents of the Noto Peninsula, Ishikawa, consumed spring Arctic lampreys as seasonal food (Arakawa et al., 2018). Therefore, Arctic lamprey with different tastes might be enjoyed as medicines or as traditional dishes.

Fishers' local ecological knowledge of lampreys

Seasonal cycle

There were two main fishing seasons for types 1 and 2 fishing: from autumn to winter, and in spring. Arctic lampreys have two migrating populations: a fall-run that enters rivers in fall, overwinters there, and spawns the next spring and a spring-run that enters rivers in spring and spawns immediately (Savvaitova et al., 2007; Sakashita, 2010). Yamazaki et al. (2014) investigated the population genetic structure of Arctic lamprey distributed from Japan to Russia, but the difference between the two run populations is unknown. The fishers' knowledge indicates the presence of a two-run population and it is necessary to exam their population structure and migrating behaviors for effective resource conservation in the future.

Lunar cycle

Lamprey fishers said that few Arctic lampreys were caught under a full moon. The migration activity of the European river lamprey is negatively associated with the night-time light intensity of the moon (Aronsuu, 2015) and fishers in Sweden reported low migratory activity near the full moon (Asplund and Sodergren, 1974). By contrast, the lunar cycle does not predict the migratory activity of sea lamprey. Low night-time light levels increase the migratory activity of lampreys (Hardisty and Potter, 1971). Cloud cover with a nearly full moon correlate positively with the European lamprey catch (Aronsuu, 2015). Lamprey migration activity might be regulated by the night-time light level and synchronized with the lunar cycle. We found that Arctic lamprey appear to be regulated by night-time illumination. Therefore, in rivers flowing through the urban areas, the influence of artificial light on migration behavior is a concern.

Diel cycle

The fishers set traps or caught lampreys at night. Lampreys actively migrate upstream in freshwater at night (Keefer et al., 2011; Arakawa et al., 2019), while they rest under rocks or along riverbanks from dawn to dusk (Hardisty and Potter, 1971; Almeida et al., 2002). Larval lampreys in freshwater follow the same diel pattern, and are active and change habitat at nighttime (Derosier et al., 2007). The nocturnal migration behavior of spawning lampreys could be related to the protection from predation afforded by darkness (Moser et al., 2015). In rivers, numerous predators consume spawning lampreys, including birds and large fish (Close et al., 2002). While adult Arctic lampreys show nocturnal migration behavior but it is not known what species consume Arctic lamprey there.

Habitat-related differences

The Arctic lamprey catch increased when the river flow increased and became muddy. In other lamprey species, the number of spawning lampreys increases below artificial barriers when the river flow increases (Binder et al., 2010; Keefer et al., 2011; Foulds and Lucas, 2013). By contrast, high flow limits the passage of river lampreys, which spend more time attached to substrate surfaces to hold their position (Keefer et al., 2013). The Arctic lamprey has a poor ability to ascend even small differences (20 cm) in water depth upstream and downstream of a weir (Arakawa et al., 2019). High flow conditions allow lampreys to pass low barriers by minimizing the depth difference (Moser et al., 2020). A decline in the quantity of light within rivers due to a rise in water depth and muddy water also regulates the migration behavior. Therefore, high flow conditions might be important for assessing the migration behavior of Arctic lamprey.

The fishers find the spawning beds of Arctic lampreys in riffles. The spawning beds of Arctic lamprey are about 30 cm in diameter (Murano et al., 2008) and constructed at the head of shallow, flat riffles where the riverbed is composed of pebbles and gravel (Shiraishi et al., 2018). The fishers' knowledge is consistent with field research and provides insight into the historical distribution of spawning sites. The original spawning habitat is difficult to assess at present since existing artificial barriers prevent natural migration. Therefore, information about the spawning site from fishers' memories can contribute to understanding the ecology of the lamprey life cycle and their historical distribution in freshwater.

Decline of the fishery and future conservation

The mean catch of Arctic lamprey has decreased to 1-10% of previous levels in coastal Honshu along the Sea of Japan. In the Ishikari River, Hokkaido, the catch began to decline in the 1980s and dropped to 1% after 2000

(HRO, unpublished data). A consistent reduction in the catch has been observed throughout Japan.

Overharvest is one threat to anadromous lampreys (Clemens et al., 2020). Ten Japanese inland FCs caught lamprey at artificial barriers, which prevent migration and have created new fishing grounds where many lampreys concentrate. Fishing in these areas has the potential for overharvesting. In Latvia, traditional lamprey fishing "*Pata*" is regulated and river traps are allowed to span only one-third of the river width (Sjöberg, 2011). The harvesting of spawning individuals has a negative impact on reproduction. To conserve fishery resources and preserve fishing culture sustainability, appropriate management, regulation, and conservation efforts are needed. However, only Hokkaido, Yamagata, and Niigata Prefectures regulate lamprey fishing at present. While Arctic lamprey fishing occurred along the coast of Japan widely in the past, there is a gap between utilization and resource management. Our study suggests two reasons why Arctic lamprey fishing is not regulated sufficiently.

First, little is known of the use of Arctic lamprey in Japan. Residents of the Noto Peninsula, Ishikawa, harvested Arctic lamprey for their own consumption (Arakawa et al., 2018). We found that lamprey fishing was limited by geographical features, but a variety of types of fishing have developed using gear that accommodates the river environment. The relatively small fishing culture might delay its management.

The second reason is related to the limited ecological information and lack of artificial propagation methods. If an inland fishery resource species were to be regulated, the FCs would have been required to conduct conservation efforts, such as releasing juveniles. However, the artificial propagation of this species was not well established until recently (Lampman et al., 2020; Arakawa and Yanai, 2018, 2019). Some FCs in Japan did perform artificial insemination and reintroduction independently. However, releasing propagated juveniles could cause a loss of genetic diversity and adaption in the population (Taniguchi, 2007). Habitat and river connectivity need to be restored for long-term conservation. In the future, we need to use our ecological knowledge to establish a conservation plan and adaptive management for Arctic lamprey and traditional fishing culture.

Conclusion

Various lamprey fishing methods have been developed in north and central Honshu, Japan, along the Sea of Japan in accordance with river size, the aquatic environment, and lamprey behavior. The Japanese inland Arctic lamprey fishing can be classified into three types: 1) set-net fishing and catching at 2) artificial barriers and 3) spawning beds. The fishers have ecological knowledge about Arctic lamprey, including their migration behavior in freshwater involving their seasonal, lunar and diel cycles, and habitat-related differences. However, the mean Arctic lamprey catch has decreased to 1–10% of past levels and the number of lamprey fishers has decreased in parallel, with only a few members in each FC. This study reconstructed traditional Arctic lamprey fishing culture and fishers' local ecological knowledge in Honshu, Japan, and provides insights for understanding their ecological behavior and contributing to species management.

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References

Almeida P. R., Quintella B. R., Dias N. M. 2002. Movement of radio-tagged anadromous sea lamprey during the spawning migration in the River Mondego (Portugal). In Thorstad, Eva B., Fleming, I.A., Naesje, T. F. Aquatic Telemetry. Springer. 1-8.

Arakawa H., Ichion E., Nakano E., Yanai S. 2019. Factors that affect Arctic Lampreys' ascent behavior on fishway weirs. Journal of Rainwater Catchment System. 25: 15-21.

Arakawa H., Shima Y., Yanai S. 2018. Regional culture for Arctic Lamprey and its harvest change in rural rivers of Noto Peninsula, Ishikawa Prefecture, Japan. Bull. of Ishikawa Prefectural University. 1: 11-21.

Arakawa H., Yanai S. 2018. Maturation and Artificial Propagation of Arctic Lamprey *Lethenteron japonicum*. Noto Marine contact center research report. 24: 29-39.

Arakawa H., Yanai S. 2019. Optimal sediment particle size and rearing method for hatched larval Arctic Lamprey (*Lethenteron camtschaticum*). Noto Marine contact center research report. 25: 9-18.

Araújo, M. J., Silva, S., Stratoudakis, Y., Gonçalves, M., Lopez, R., Carneiro, M., Martins, R., Cobo, F., Antunes, C. 2016. Sea lamprey fisheries in the Iberian Peninsula. In Orlov, A., Beamish, R. Jawless fishes of the world: volume 2. Cambridge Scholars Publishing. 115-148.

Aronsuu K. 2015. Lotic life stages of the European River lamprey (*Lampetra fluviatilis*): anthropogenic detriment and rehabilitation. Jyväskylä studies in biological and environmental

science. 301.

Asplund, C., Sodergren, S. 1974. The spawning migration of River Lampreys (*Lampetra fluviatilis*) in the River Rickleå. Zoologisk Revy. 36: 111-119.

Aswani, S., Lemahieu, A., Sauer W. H. 2018. Global trends of local ecological knowledge and future implications. PLoS One. 13(4): e0195440.

Berkes, F., Colding, J., Folke, C. 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecological applications. 10(5): 1251-1262.

Binder, T. R., McLaughlin, R. L., McDonald, D. G. 2010. Relative importance of water temperature, water level, and lunar cycle to migratory activity in spawning-phase sea lampreys in Lake Ontario. Transactions of the American Fisheries Society. 139(3): 700-712.

Clemens B. J., Arakawa H., Baker C., Coghlan S., Kucheryavyy A., Lampman R., ... & Pequeño G. 2020. Management of anadromous lampreys: Common threats, different approaches. Journal of Great Lakes Research.

Close, D. A., Fitzpatrick, M. S., Li, H. W. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. Fisheries. 27(7): 19-25.

Derosier, A. L., Jones, M. L., Scribner, K. T. 2007. Dispersal of sea lamprey larvae during early life: relevance for recruitment dynamics. Environmental Biology of Fishes. 78(3): 271-284.

Foulds, W. L., Lucas, M. C. 2013. Extreme inefficiency of two conventional, technical fishways used by European river lamprey (*Lampetra fluviatilis*). Ecological Engineering. 58: 423-433.

Fukushima, M., Kameyama, S., Kaneko, M., Nakao, K., Ashley Steel, E. 2007. Modelling the effects of dams on freshwater fish distributions in Hokkaido, Japan. Freshwater Biology. 52(8): 1511-1524.

Hardisty, M.W., Potter, I.C. 1971. The general biology of adult lampreys. In Hardisty, M.W., Potter, I.C. The biology of lampreys. Academic Press. 127-206.

Hatano, M., Takahashi, K., Takama, S., Nakajima, T. 1987. Sensory Evaluation of Fresh Quality of Fall Chum Salmon. Hokkaido University Collection of Scholarly and Academic Papers. 38(3): 311-321.

Holbrook, C.M., Bergstedt, R., Adams, N.S., Hatton, T.W., McLaughlin, R.L. 2015. Fine-scale pathways used by adult sea lampreys during riverine spawning migrations. Transactions of the American Fisheries Society. 144(3): 549-562.

Jellyman, D.J., Glova, G.J., Sykes, J.R.E. 2002. Movements and habitats of adult lamprey (*Geotria australis*) in two New Zealand waterways. New Zealand Journal of Marine and Freshwater Research. 36(1): 53-65.

Johannes. R.E., Freeman, M.M., Hamilton, R.J. 2000. Ignore fishers' knowledge and miss the boat. Fish and Fisheries. 1(3): 257-271.

Kawanabe, H., Mizuno, N. 2001. Freshwater fishes of Japan. Yama to Keikoku sha.

Keefer, M.L., Peery, C.A., Lee, S.R., Daigle, W.R., Johnson, E.L., Moser, M.L. 2011. Behavior of adult Pacific lamprey in near-field flow and fishway design experiments. Fisheries Management and Ecology. 18(3): 177-189.

Keefer, M.L., Caudill, C.C., Clabough, T.S., Jepson, M.A., Johnson, E.L., Peery, C.A., Higgs, M.D., Moser, M.L. 2013. Fishway passage bottleneck identification and prioritization: a case study of Pacific lamprey at Bonneville Dam. Canadian Journal of Fisheries and Aquatic Sciences. 70(10): 1551-1565.

Lampman, R., Maine, A.N., Moser, M.L., Arakawa, H., Neave, F.B. 2020. Lamprey Aquaculture Successes and Failures: A Path to Production for Control and Conservation. Journal of Great Lakes Research.

Lopes, P.F.M, Verba, J.T., Begossi, A., Pennino, M.G. 2019. Predicting species distribution from fishers' local ecological knowledge: a new alternative for data-poor management. Canadian Journal of Fisheries and Aquatic Sciences. 76:1423-1431.

Ministry of the Environment. 2007. Red Lists/red data books of fishes. https://www.env.go.jp/press/files/jp/9944.pdf . (Accessed January 20, 2021).

Moser, M.L., Almeida, P.R., Kemp, P.S., Sorensen, P.W. 2015. Lamprey spawning migration. In Docker, M.F. Lampreys: biology, conservation and control. Springer. 215-263

Moser, M.L., Almeida, P.R., King, J.J., Pereira, E. 2020. Passage and freshwater habitat requirements of anadromous lampreys: Considerations for conservation and control. Journal of Great Lakes Research.

Murano, N., Yagi, C., Sawada, T., Nagatsu, M., Kojima, E. 2008. Japanese lamprey *Lethenteron japonicum* in the Ishikari River - Filed work and the creation of a supplemental guide book-. Journal of Rakuno Gakuen University. 32: 183-220.

Nashimoto, K., Sato, O. 1985. Lamprey Fish pots used in the Ishikari River. Bulletin of the Faculty of Fisheries Hokkaido University. 36(1): 28-34.

Orlov, A.M., Baitalyuk, A.A., Pelenev, D.V. 2014. Distribution and size composition of the arctic lamprey *Lethenteron camtschaticum* in the North Pacific. Oceanology. 54(2): 180-194.

Petersen, R.S. 2006. The role of traditional ecological knowledge in understanding a species and river system at risk: Pacific lamprey in the lower Klamath basin. Master thesis of Oregon State University.

Savvaitova, K.A., Pavlov, D.S., Kuzishchin, K.V., Gruzdeva, M.A., Kucheryavyi, A.V. 2007. Ecological analogies in the

Pacific lamprey *Lethenteron camtschaticum* and the mykiss Parasalmo mykiss in Kamchatka. Journal of Ichthyology. 47(5): 341-347.

Sheoships, G. 2014. Pacific lamprey *Entosphenus tridentatus*: integrating traditional ecological knowledge and contemporary values into conservation planning, and stream substrate associations with larval abundance in the Willamette River Basin, Oregon, USA. Master thesis of Oregon State University.

Shiraishi, H., Toyobe, T., Kanaya, M. 2018. Civil Engineering Research Institute for Cold Region. https://thesis.ceri.go.jp/db/files/12256825095d22d6d61d6ec.pdf. (Accessed January 20, 2021).

Sjöberg, K. 2011. River lamprey *Lampetra fluviatilis* (L.) fishing in the area around the Baltic Sea. Journal of Northern Studies. 5(2): 51-86.

Sjöberg, K. 2013. Fishing Gear Used for River Lamprey *Lampetra fluviatilis* (L.) Catches: Documenting Rivers that Flow into the Baltic Sea. Part II, Finland, Latvia and Estonia. Journal of Northern Studies. 7(2): 7-74.

Taniguchi, N. 2007. Studies on conservation and utilization of genetic divergence in fish and shellfish population. Nippon Suisan Gakkaishi. 73(3): 408-420.

Tomioka N., Ohta A., Shigaki H., Fukumoto T., Fujita T., Mizutani R. 2010. Regional consumption of the Stingray in Japan. The Japan Society of Cookery Science. 43(2): 120-130.

William, F., Beamish, H. 1979. Migration and spawning energetics of the anadromous sea lamprey, Petromyzon marinus. Environmental Biology of Fishes. 4(1): 3-7.

Yamazaki, Y., Yokoyama, R., Nagai, T., Goto, A. 2014. Population structure and gene flow among anadromous Arctic lamprey (*Lethenteron camtschaticum*) populations deduced from polymorphic microsatellite loci. Environmental biology of fishes. 97(1): 43-52.

Yazawa, Y. 2007. Seasonal Change of Essential FFA and β-lipoprotein Contents in Lamprey, *Lampetra japonica*. Reports of Taisetsuzan Institute of Science. 41: 49-54.

日本海沿岸におけるカワヤツメ（*Lethenteron camtschaticum*）の伝統漁

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要　旨

カワヤツメ（*Lethenteron camtschaticum*）は日本国内で重要な水産資源であるが、その漁獲量は減少している。本研究は、カワヤツメ漁（漁具、漁場、漁期）と漁師が有する地域の生態学的知識（LEK）を体系化することを目的として、日本海沿岸における内水面漁業協同組合へのインタビューを行った。カワヤツメ漁は、川の規模や、地形環境、カワヤツメの生態的行動に応じて発達しており、過去には日本海沿岸の北部から中部にかけて分布していた。漁師たちは、漁場に応じて多様な漁具を使用しており、漁法は主にタイプ1（定置漁）、タイプ2（横断構造物での漁獲）、タイプ3（産卵床での漁獲）の3種類に分類された。また漁師の有する知識は、淡水におけるカワヤツメの移動として季節的、月周、日周、環境の違いによる行動パターンに関する生態的知見に関する洞察を提供した。しかし、カワヤツメの漁獲量は現在にかけて1～10％に減少し、その漁師の数も漁協内において数名にまで減少していた。今後は、カワヤツメと伝統的な漁業活動を守るために、漁師が有する情報を活用し保全計画や順応的管理を確立していく必要がある。

キーワード：ヤツメウナギ／地域の生態学的知識／内水面漁業／地域文化／保全