Aquatic Mammals 2021, *47*(5), 470-481, DOI 10.1578/AM.47.5.2021.470

Bycatch in Lake Ladoga Fisheries Remains a Threat to Ladoga Ringed Seal (*Pusa hispida ladogensis*) Population

Irina S. Trukhanova,[1] Elena M. Andrievskaya,[2] and Vyacheslav A. Alekseev[2]

[1]*Interregional Charitable Public Organization "Biologists for Nature Conservation," 3-7, 24 line V.O., St Petersburg, Russia*
E-mail: irina_trukhanova@yahoo.com
[2]*Marine Mammal Conservation Aid Fund "Baltic Ringed Seal Friends Fund," 12 Kolkhoznaya str., Solnechnoe, St Petersburg, Russia*

Abstract

Semistructured interviews were carried out between September 2019 and February 2020 with fishermen from fishing fleets in 23 locations on Lake Ladoga, northwest Russia. This was part of a multiyear Ladoga ringed seal (*Pusa hispida ladogensis*; Nordquist, 1899) bycatch monitoring program launched in 2007. According to the Federal Fisheries Agency, 306 fishing permits were issued in 2019 for a total of 222 fishing teams. Fishing gear that causes seal bycatch includes gill and fyke nets used in the Leningrad Region, and frame nets, gill nets, and stationary seines used in the Republic of Karelia. In 2019, we observed a general decline in fishing effort and catches throughout the lake compared with previous years. We noted a transition from large-scale to small-scale individual fisheries due to the cheaper operation and maintenance of a small boat fleet. Fishermen largely gave up fyke nets, trawls, and traps in favor of light gill nets and frame nets with thin netting. We estimated an overall decrease in annual seal bycatch rate from 700 seals in 2011 to around 250 seals in 2019, which is likely associated not only with the decrease in fishing effort but also with the transition to thin netting gear. This conclusion is also supported by a 65.9% decrease in the mean number of bycaught seals per fishing team. Nevertheless, this bycatch rate is still sufficiently high to remain a threat to the population, and the seal–fisheries conflict requires further mitigation.

Key Words: Ladoga ringed seal, *Pusa hispida ladogensis*, bycatch, fisheries, questionnaire survey

Introduction

Several species of pinnipeds have adapted to live in land-locked water bodies (Rice, 1998; Berta & Churchill, 2011). Such an adaptation may not only result in a unique diet (Filatov, 1978; Kunnasranta, 2001; Agafonova et al., 2007), breeding behavior, social interactions (Sipilä et al., 1996; Agafonova et al., 2007), and morphological traits (Tormosov & Filatov, 1973; Ambinder, 1980; Amano et al., 2002), but may also impose threats of greater magnitude than are typical for pinnipeds inhabiting the open ocean (Harwood, 2001; Kovacs et al., 2012). For instance, seal–fisheries conflicts are a global problem (Kovacs et al., 2012); however, in land-locked water basins, it may take on especially severe forms (Alekseev et al., 2012; Trukhanova et al., 2012; Dmitrieva et al., 2013).

Seal–fisheries conflict is a major problem in Lake Ladoga, the largest lake in Europe, located in the Republic of Karelia and the Leningrad Region in northwest Russia. The Ladoga ringed seal (*Pusa hispida ladogensis*; Nordquist, 1899) has inhabited Lake Ladoga for over 10,000 years at which time the lake separated from the Baltic Sea basin and the divergence of a land-locked form of ringed seal from its Arctic predecessor took place (Hyvärinen & Nieminen, 1990; Kunnasranta, 2001). The Ladoga subspecies was estimated to number around 20,000 individuals at the beginning of the 1900s (Chapsky, 1932); while later in the century, the population declined to 2,000 to 5,000 individuals (Sipilä et al., 1996; Verevkin, 2002; Medvedev et al., 2006). The most recent estimate suggested a recovery to 5,000 to 8,000 individuals (Trukhanova, 2013; Trukhanova et al., 2013). Apart from fisheries bycatch, the major threats to the population are climate-related breeding habitat deterioration and human-caused disturbance on breeding grounds and terrestrial haulouts in the summer (Sipilä, 2016). The recent revision of the *Red Data Book of the Russian Federation* (Decree No. 162; Ministry of Natural Resources and Environment of the Russian Federation, 2020) resulted in the Ladoga ringed seal being assigned Status 1 (Endangered), category CR (Critically Endangered), and Conservation Priority I, which is related to the need for immediate

conservation action, including the development and implementation of a conservation strategy.

The conflict between Ladoga ringed seals and commercial fisheries in Lake Ladoga has two major pillars—(1) seal mortality in fishing gear and (2) seal depredation on nets—and has had a long history in the region. In the mid-20th century, reported Ladoga ringed seals bycaught annually in fishing gear in different parts of the lake ranged from 25 to 190 individuals (Sokolov, 1958; Sorokin, 1970). These studies, for the first time, raised an issue of the impact of bycatch on the population.

However, commercial seal hunting in Lake Ladoga was well established in the mid-20th century; and because there was no conservation concern at the state level (Zubov, 1965), the problem seemed insignificant. The seal harvest itself contributed to seal mortality by removing, on average, 280 adult seals a year between 1944 and 1978 (Zubov, 1965; Tormosov & Filatov, 1973). Recreational and sport seal hunting was popular and encouraged in those years, bringing the total anthropogenic Ladoga ringed seal mortality to about 1,000 animals annually (Zubov, 1965). This mortality exceeded the estimated annual reproduction rate (20.5%) of the population (Antoniuk, 1975; Bychkov & Antoniuk, 1975). In 1984, the Ladoga ringed seal was included in the *Red Data Book of the Soviet Union* (Borodin et al., 1984) and then in the *Red Data Book of the Russian Federation* (Sokolov et al., 2001) due to the continuing serious decline in abundance (Filatov, 1990). At the same time, Finnish researchers in cooperation with Karelian scientists concluded that the annual bycatch was around 200 to 400 individuals, higher than previous estimates, which posed a major threat to the population (Sipilä & Hyvärinen, 1998).

In the 21st century, Verevkin and colleagues (Verevkin, 2003; Verevkin et al., 2006) started using anonymous questionnaires to collect bycatch data in Lake Ladoga. Continuation of this work in 2007-2008 showed that the rates of ringed seal bycatch had increased from an estimated 292 animals per year in 2003 to 442 animals per year in 2008 in the Leningrad Region alone (Verevkin et al., 2009). In 2012, bycatch for the entire lake, including both the Leningrad Region and the Republic of Karelia (Figure 1), was estimated at about 700 individuals (Alekseev et al., 2012).

Ladoga ringed seals prey on a variety of fish, including school fishes such as smelt (*Osmerus eperlanus*) and vendace (or European cisco; *Coregonus albula*), as well as larger species such as zander (*Sander lucioperca)*, European whitefish (*Coreogonus lavaretus*), or trout (*Salmo trutta*) (Sipilä & Hyvärinen, 1998; Agafonova et al., 2007; Trukhanova et al., 2012). In all survey years, fishermen typically reported high levels of seal depredation on these commercially important fish species caught in nets and associated significant economic losses due to seal-induced gear damage. Thus, many groups of fishermen requested the government, so far unsuccessfully, to consider de-listing the Ladoga ringed seal from the *Red Data Book*, permitting resumption of the seal harvest and allowing culls of individuals coming to feed on netted fish.

Given the continued uncertainty of the Ladoga ringed seal population status, persisting seal–fisheries conflict in the region, and limited data on the present-day rates of seal bycatch, we conducted an interview-based survey of Ladoga ringed seal bycatch in commercial fisheries during the 2019 fishing season (from January through December) and assessed its impact on the population.

Methods

We conducted semistructured interviews and distributed questionnaires between September 2019 and February 2020 in the coastal settlements and fishing ports of Lake Ladoga. These interviews were retrospective, with fishermen's reports covering their most recent fishing season between January and December 2019. In total, the study covered 13 main fishing locations in the Leningrad Region and 10 in the Republic of Karelia. State fisheries inspectors were interviewed in Priozersky, Kirovsky, Volkhovsky, Pitkyarantsky, Sortavalsky, Lahdenpohsky, and Olonetsky districts. Subsequently, for the purposes of the analysis, these locations were combined into six sectors (NW, NE, E. W, S, and SE; Figure 1)—these were the same lake divisions that had been used for questionnaire survey data analysis in 2007 and 2012 (Verevkin et al., 2009; Alekseev et al., 2012; Trukhanova et al., 2012).

We asked individual entrepreneurs in the fishing industry and members of fishing teams (where "team" refers to a crew of one fishing boat operating under one fishing permit) to answer questions regarding Ladoga ringed seal bycatch in fishing gear. The questions included an assessment of fishing effort, seal encounters, fishing efficiency, catch and gear damage frequency according to season, and the type of fishing gear used (see Appendix). Information on the total number of fishing teams registered in each region allowed us to calculate the percentage of fishermen who provided data for the survey. Due to a sufficiently complete and uniform coverage of all fishing areas of the lake, we were able to estimate the total number of animals ($\widehat{M}$) caught in fishing gear during the reporting period of January to December 2019 as

$$\widehat{M} = \frac{\sum_{i=1}^{n} m_i}{n} \times N$$

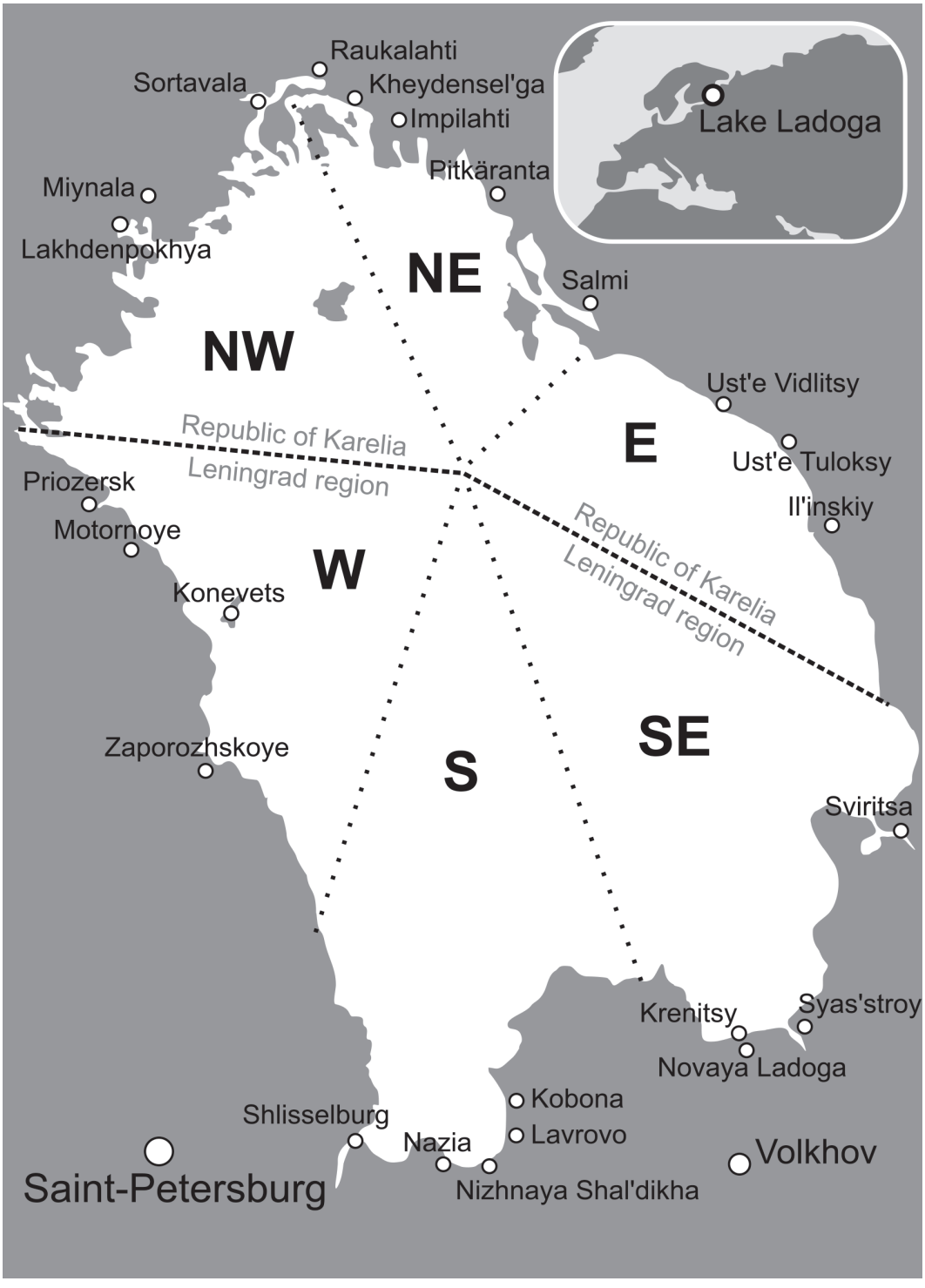

Figure 1. Locations of the interviews in 2019-2020 and division of the Lake Ladoga area into fishing sectors (dotted line) for analysis purposes. Dashed line indicates the border between the Republic of Karelia and the Leningrad Region.

and

$$CI\ 95\% = \widehat{M} \pm 1.96 \times \sigma(\widehat{M}),$$

where m_i = number of seals bycaught by team i, n = number of teams that provided bycatch information, N = total number of operating teams, CI = confidence interval, and σ = standard deviation.

We carried out the survey on the condition of anonymity. The Federal Fisheries Agency (FFA) and the Ladoga Lake Association of Fishermen facilitated data collection. In addition to in-person and telephone interviews, we posted on social media written data requests and sent copies of questionnaires (see Appendix) to state fisheries management units in each of the three districts adjacent to Lake Ladoga in the Leningrad Region and four in the Republic of Karelia, as well as to the North-Western division of the FFA. However, no response to the social media requests has thus far been received, so all information presented herein was collected verbally with the exception of the two FFA response letters which provided information on the total number of issued fishing permits for 2019.

To indirectly assess the state of commercial fisheries as well as seal foraging, we collated and analyzed data published in official sources on catch trends in two principally harvested fish species in the lake: (1) zander and (2) European whitefish.

Results

Over the 6-month interview period (September 2019 to February 2020), we interviewed 64 fishing teams working in Lake Ladoga and talked to fisheries control officers in each of the six sectors of the lake. The fisheries in Lake Ladoga have the following structure: each individual entrepreneur (IE) manages several teams (from one to a max. of 17), and a team typically consists of one to four people and operates one fishing vessel. A fishing permit is obtained annually from a local division of FFA for each team, so one individual entrepreneur might obtain several permits at a time and redistribute them. Also, an IE might apply for various types of fishing permits throughout the year—for example, one IE/team might obtain a permit to fish for smelt in the beginning of the year and then apply for a permit for zander in mid-season. This complicates monitoring fishing effort. According to the FFA, they issued 306 permits (251 in the Leningrad Region and 55 in the Republic of Karelia) in 2019, including 125 permits for teams engaged in smelt ice-fishing only—such temporary teams are based exclusively in the Southeastern sector. Since number of fishing permits does not directly reflect number of fishing teams, we used the total number of fishing teams reported by the state fisheries inspector in each region instead of the number of fishing permits to estimate total effort and associated seal bycatch (Table 1).

Table 1. Lake Ladoga fisheries statistics and seal bycatch rate in the 2019 fishing season (number of teams registered in 2011 is provided for comparison)

Sector	Registered IE/ teams N (# of teams in 2011 and trend)	Interviewed IE/teams[1] n	Gear	Fish species	Bycatch reported $\sum_{i=1}^{n} m_i$	Bycatch estimated $\widehat{M}$
West	4/10 (14↓)	4/10	Gill nets	Vendace, zander, European whitefish	20	20
South	10/17 (21↓)	7/12	Fyke nets, gill nets	Zander, white fish, perch, bream, vendace, northern pike	45	64
Southeast	15/25 (39↓)	6/14	Fyke nets, gill nets, frame nets	Zander, white fish, perch, bream, smelt	30	54
East	3/16 (11↑)	2/8	Frame nets, zander (capron) nets, "bar" net (stationary seine)	Zander, European whitefish, salmonids (*Salvelinus lepechini*), northern pike	15	30
Northwest	12/17 (17)	9/12	Frame nets, gill nets	Zander, white fish, *S. lepechini*, northern pike	30	43
Northeast	6/12 (29↓)	3/8	Frame nets, gill nets	Zander, white fish, *S. lepechini*, northern pike	24	36
Total	50/97[2] (131↓)	31/64			164	247

[1]Number of individual entrepreneurs (IEs) interviewed/information provided for the following number of teams

[2]These numbers do not include 125 temporary specialized smelt teams operating only in April through June exclusively in the Southeast sector. These teams were not considered when estimating bycatch rate.

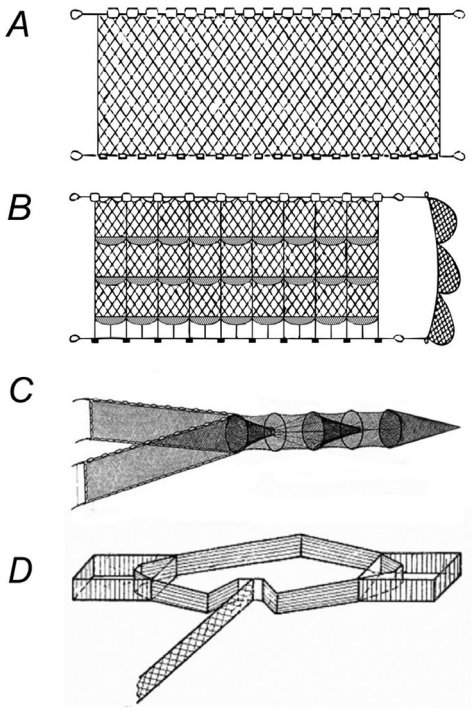

Figure 2. Types of fishing gear used in Lake Ladoga: (A) gill net, (B) frame net, (C) fyke net, and (D) stationary seine.

There are several types of gear currently used in the lake (see Table 1): frame nets, gill nets, and stationary seines are used in Karelia, while gill and fyke nets (or a similar gear—"kurlyandki") are used in the Leningrad Region (Figure 2A-D). Trawling was temporarily banned in the lake in 2018 because it was leading to a significant decline in European whitefish abundance over the last 50 years and was considered a threat to passive types of fisheries (Decree No. 328; Ministry of Agriculture of the Russian Federation, 2019b). However, the ban was lifted in 2020 due to bureaucratic delays in document processing, and four trawlers resumed working on the lake.

Without exception, all representatives of the fishing industry working with frame and gill nets reported frequent cases of damage to fishing gear and catch caused by Ladoga ringed seals. The teams that use fyke nets (mainly in the villages of Kobona and Nazia) did not consider damage caused by seals as significant since animals rarely damaged strong netting, and cases when an animal entered the fishing gear usually ended with the seal being unable to get back out and dying in the net. Moreover, the teams in Nazia began to use the entrance gates to prevent seals from entering their fyke nets and ruining the catch. It was noted, however, that the gates often get broken by the animals. No other seal-exclusion methods such as commonly used acoustics deterrents (e.g., Northbridge

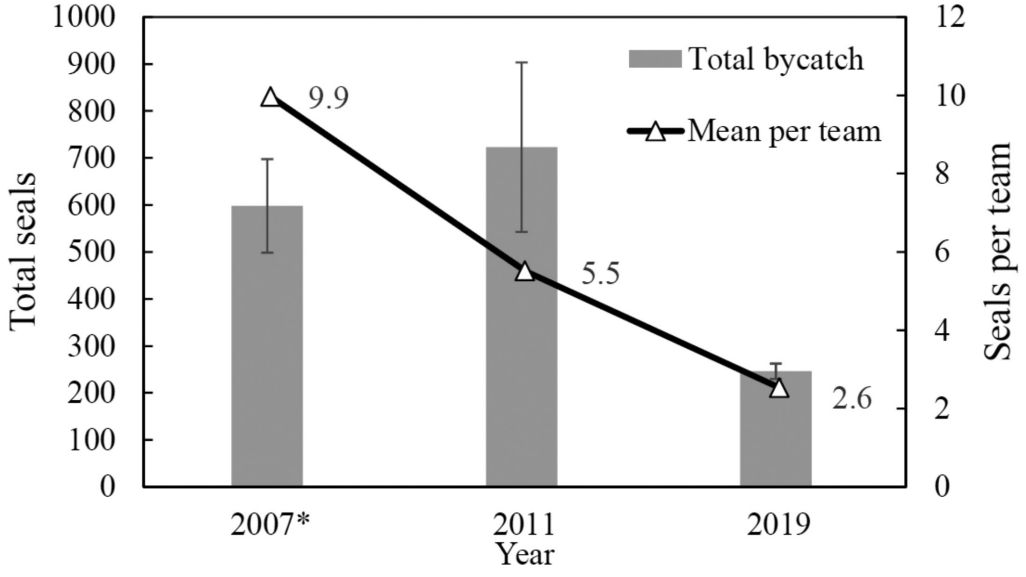

Figure 3. Bycatch trend in Lake Ladoga in 2007 through 2019. Mean bycatch rate is estimated for all registered teams except temporary smelt-specialized teams. *In 2007, the interviews were conducted only in the Leningrad Region, and the total bycatch was not estimated in the East, Northeast, and Northwest sectors.

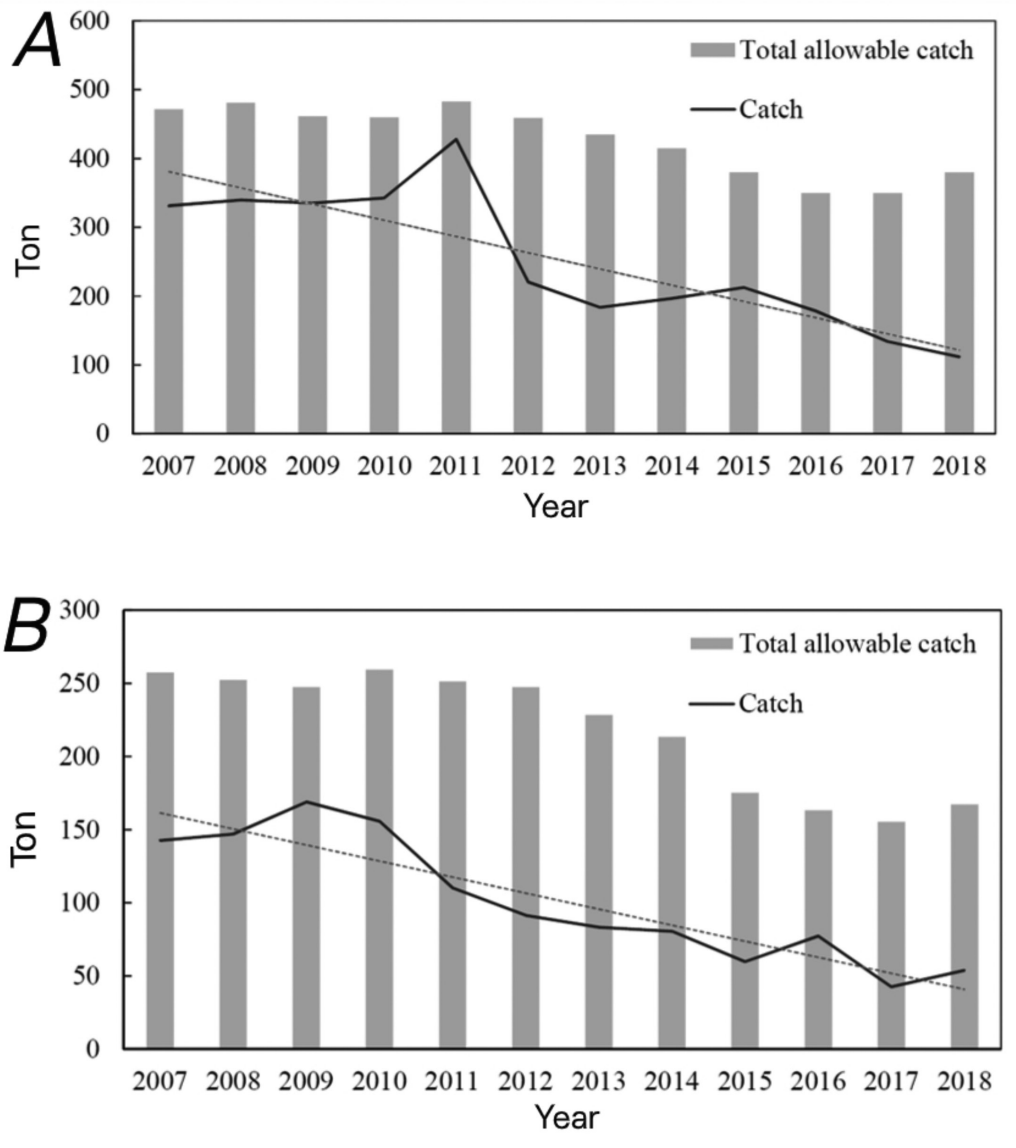

Figure 4. Total allowable catch and actual catch of zander (A) and European whitefish (B) in Lake Ladoga in 2007 through 2018 (Federal State Budgetary Establishment "Berg State Research Institute on Lake and River Fisheries" [FSBSI "GosNIORH"], 2016a, 2016b, 2017a, 2017b, 2019a, 2019b; Glushenko, 2019; Ministry of Agriculture of the Russian Federation, 2018, 2019a, 2019b; Ministry of Natural Resources and Environment of the Russian Federation, 2020). Dotted line = linear trend in catch.

et al., 1999; Barlow & Cameron, 2003) or seal-safe gear (e.g., Calamnius et al., 2018) were reported to be used anywhere in the study area, consistent with Trukhanova et al.'s (2012) findings.

The respondents reported bycatch in all parts of the lake between May and October. The first spike in bycatch frequency occurred during May and June after ice melted and seals transitioned from annual molt to foraging, and the second occurred from September through November. From June to August, there was a reported decline in fishing effort, mainly by small-scale fisheries for pike, pike perch, catfish, common carp, *Carassius* spp., *Pelecus cultratus*, etc., and for other low-value fishes, which reduced the overall frequency of seal–fisheries interactions.

The fishing effort in the lake has declined over the past 8 years from 131 registered teams to 97, not including temporary smelt-oriented units fishing exclusively in April and May. The number of teams declined in four out of the six sectors and remained unchanged or increased in the remaining two. Out of 64 teams that took part in the survey, 59.3% used gill nets exclusively; 26.6% used a combination of gill and fyke nets; 10.9% used gill and frame nets; 1.6% used gill, frame, and fyke nets; and 1.6% used stationary seine in addition to gillnet fishing. We recorded 164 reported bycatch cases and estimated the overall mean bycatch rate at 2.56 (SD = 1.65) seals per team per year. In teams using fyke nets in addition to other types of gear, mean bycatch rate was significantly higher compared with those that do not use fyke nets—3.65 (SD = 2.17; Wilcoxon test: W = 578; $p = 0.012$) seals per team per year. Total bycatch estimated for all fishing teams was $\widehat{M} = 246$ (CI 95% = 229 to 262), which is 2.9 times lower than the numbers reported for 2011 (Figure 3).

Based on official statistics collated for the two principally harvested fish species, official catches of zander declined between 2007 and 2019, on average by 7.2% each year (SD = 19.89%) as shown in Figure 4A, and the European whitefish catch decline rate was 5.7% (SD = 23.22%) a year during the same period (Figure 4B). Both zander and whitefish were reported to be damaged by seals in nets. Other species recorded among harvest losses were smelt, vendace, northern pike (*Esox lucius*), perch (*Perca fluviatilis*), and bream (*Abramis brama*).

Discussion

Seal entanglement in fishing gear has been a serious problem all over the world for centuries (e.g., Wilson, 2003; Fjälling, 2006). Animals of all ages die in traps and gill nets, and it has been noted that yearlings are the most vulnerable category. Seals entrapped in nets were not necessarily trying to feed from them (Wilson, 2003); however, fishermen worldwide consider these animals as direct competitors for fish resources, causing significant economic losses to the industry (e.g., Gulland, 1987; Bowen & Lidgard, 2013).

The seal–fisheries conflict in Lake Ladoga is not a new phenomenon either. Fishermen have struggled to keep their catch and gear safe for decades, whereas seals have taken advantage of easy prey already caught in the nets (Sokolov, 1958; Sipilä et al., 1996; Verevkin et al., 2006; Alekseev et al., 2012; Trukhanova et al., 2012). Conflict intensity depends on the prevailing fishing gear, lake productivity cycle (Kudersky, 2009), and the economic situation in general. Alekseev et al. (2012) reported a number of teams working in the South sector of Lake Ladoga halting fishing effort during July and August because losses were exceeding revenues. The fuel costs alone could not be covered as the amount of intact catch was negligible.

The bycatch rate differs from season to season. The 2011 survey showed that more than 57% of the total number of Ladoga ringed seals caught per year were entangled in fishing gear in May and June (Alekseev et al., 2012). This, in our opinion, is related to the end of the lactation period and weaning of pups who transition to independent habitat exploration and foraging. Fishermen reported a large percentage of animals under 20 kg in their nets, which would correspond to young of the year (Alekseev et al., 2012; Trukhanova et al., 2012). The second spike of seal bycatch was observed in October (about 15% of total annual catch in 2011). Similar to 2011, no bycatch cases between December and February were recorded in the interviews; in November, March, and April, bycatch was characterized as "occasional," primarily due to very little fishing effort in all areas of the lake.

The respondents reported bycatch in all parts of the lake between May and October. Similar to past surveys in 2007 and 2011, we identified two seasonal spikes in bycatch in 2019. The first occurred during May and June after the ice melted and seals were transitioning from annual molt to foraging. The second spike occurred in autumn when a major part of the population comes to the south and southeastern parts of the lake and stays there until the ice begins to form (Bychkov & Antoniuk, 1975; Filatov, 1978). There, Ladoga ringed seals often gather in coastal haulouts, may enter artificial channels in the Novaya Ladoga area, and are sometimes seen resting on the banks of the Volkhov River, resting on shore a considerable distance from the lake. This coincides with a period of active fishing of European whitefish and pike perch in the river mouths with strong netting gear, resulting in an increased bycatch rate. In April and May, smelt fishing takes place in all ice-covered areas of the lake—from the shoreline up to 10 km from shore. During the 2019 smelt season, the number of fishing teams increased temporarily from 97 to 222. Small mesh gill nets and fishing rods are used in this type of fishery, which does not seem to cause major problems to the seals as the nets are constantly monitored, and the netting is generally very weak and can be torn apart by seals.

According to this study's results, fyke nets pose the primary threat to Ladoga ringed seals among all other types of gear used in the lake. The teams using fyke nets are based mostly in the South sector of the lake and contribute almost 1.5 times more to the overall bycatch compared with the lake-wide mean bycatch rate.

It is hard to assess whether the negative changes in fish catches in 2007 through 2018 were caused by declines of stocks of certain fish species, which, in turn, could cause Ladoga ringed seals to start raiding nets. Fish stock assessments are typically based on the reported catch and quota fulfillment from the previous year (see Figure 4). Both are believed to be largely unreliable—unreported catch by commercial fisheries alone was estimated at a minimum of 20% of the reported catches for 1999 through 2007 (Georgiev & Cherepanova, 2011), while the amount of fish caught illegally by poachers and unlicensed fishermen is unknown. Assumed decline in fish stocks might be associated with the natural cycle of the lake system (Kudersky, 2009) in addition to being a consequence of hidden overfishing or effort decline.

The ban on trawling in Lake Ladoga, which occurred in 2018 (Decree No. 328; Ministry of Agriculture of the Russian Federation, 2019b)—that is, between the 2011 survey and the present study—likely had a positive impact on schooling fishes such as smelt and vendace, which were thought to have been previously overfished (Shurukhin, 2018). Consequently, the whitefish and zander foraging base started to restore without the trawling. These two factors might be advantageous for Ladoga ringed seals who might be less likely to feed exclusively on nets during certain months in certain areas. However, the trawling resumed in 2020, and it is not yet clear when the permanent ban will be in place.

We observed a general transition from large-scale to small-scale individual fisheries that most people explained by the cheaper operation and maintenance of small boats compared with larger vessels. Transition from fyke nets, trawls, and traps to light gill nets and frame nets with thin monofilament netting is also largely associated with a lower cost as such gear can be replaced every year which avoids expensive and labor-consuming repairs. Thin netting is easily torn apart by seals, thus reducing the bycatch and limiting it to young animals.

Although ice fishing is relatively harmless to the Ladoga ringed seals in terms of bycatch, it is nevertheless considered to be a major disturbance factor during the seal's spring breeding season. This occurs because much of the ice that is potentially suitable for female seal birth lairs is occupied by fishermen or used for transportation (Trukhanova et al., 2013). However, this type of fishery is currently extremely unprofitable because of the high cost of logistics and the complexity of setting fishing gear in the winter. This might result in an eventual reduction of human presence on the ice during the spring.

All of these trends are indicative of economic problems in the lake fisheries sector. They nevertheless suggest a possible trend towards reduction of seal–fisheries conflict. The 65.9% decrease in seal bycatch rate compared with 2011 is clearly not only associated with the decline in number of teams on the lake because there has been an overall 54% decrease in the mean number of bycaught seals per fishing team between 2011 and 2019. Unfortunately, there are no reliable data on trends in seal-induced economic losses since these are assessed subjectively by each fishing team.

Based on our experience, it is difficult to obtain reliable information from fishermen about their interactions with Ladoga ringed seals since the animals are red-listed and respondents fear fines for incidental catches or harm to the species. Moreover, fishermen are reluctant to cooperate with the interviewers as they do not see any practical benefit in this collaboration. This is why a long-term bycatch monitoring program, enabling a trusting relationship to develop with representatives of the fishing industry through years of meetings and conversations, is essential to monitor the level of threat coming from bycatch and to take steps towards mitigation of seal-induced gear and catch damage. For the purpose of our survey, we made an assumption that the fishing teams who agreed to participate in the study provided reliable data or, at the very least, reported the minimum bycatch rate which allowed us to indicate the existence of the problem in any given area. The overall 2019 bycatch estimate might be biased low due to the above-mentioned reasons, but so are the estimates from the early 2000s. Therefore, we can assume that the bycatch monitoring program allows us to capture the general trend in this parameter, even taking into account a certain level of underreporting. Moreover, an interview-based study proved to be an effective approach to reveal the nature of seal–fisheries interactions.

Regardless of the possible improvement of the situation around seal–fisheries conflict, bycatch continues to be a significant threat to the subspecies, and its effect can be aggravated even further by the warming climate and deterioration of the breeding habitat available to the Ladoga ringed seals each spring. It is clear that further mitigation of seal–fisheries conflict should be approached through an introduction of seal-safe fishing gear and spatial and/or temporal separation of conflicting parties but not by either a seal population cull or by eliminating individuals specializing in depredation on nets. Bycatch of young-of-the-year is viewed globally as a major threat to population growth (Härkönen et al., 2012; Jounela et al., 2019). Specific steps, therefore, need to be taken to protect juveniles, especially as they disperse from natal sites as the ice melts. At the same time, it is essential to take further practical steps to minimize fisheries losses, further reduce seal bycatch, and increase public understanding of the role of the Ladoga ringed seal in the ecosystem and its conservation needs.

Acknowledgments

We are grateful to all the anonymous respondents who contributed to this study, sharing their stories, concerns, and observations. We also thank Dr. Susan C. Wilson for her suggestions and edits which helped to improve the manuscript. Special thanks go to two anonymous reviewers who provided edits and valuable comments to the original draft. The study was conducted under Project KS1549, "CoExist: Towards Sustainable Coexistence of Seals and Humans," funded by the European Union, the Russian Federation, and the Republic of Finland within the South-East Finland–Russia CBC 2014-2020 programme.

Literature Cited

Agafonova, E. V., Verevkin, M. V., Sagitov, R. A., Sipilä, T., Sokolovskaya, M. V., & Shakhnazarova, V. Yu. (2007). *Kolchataya nerpa v Ladozhskom ozere i na ostrovakh Valaamskogo Arkhipelaga* [Ringed seal in Lake Ladoga and on the islands of the Valaam Archipelago]. Vammalan Kirjapaino Oy. [In Russian]

Alekseev, V. A., Trukhanova, I. S., & Andrievskaya, E. M. (2012, October). Towards an understanding of Ladoga ringed seal (*Pusa hispida ladogensis*) and fisheries conflict. *Proceedings of the Seventh International Conference "Marine Mammals of the Holarctic*," Suzdal, Russia.

Amano, M., Hayano, A., & Miyazaki, N. (2002). Geographical variation in the skull of the ringed seal, *Pusa hispida*. *Journal of Mammalogy*, *83*(2), 370-380. https://doi.org/10.1644/1545-1542(2002)083<0370:GVITSO>2.0.CO;2

Ambinder, E. M. (1980). *Kariologiya i evolutsiya lastonogih* [Karyology and evolution of pinnipeds]. Nauka. 152 pp. [In Russian]

Antoniuk, A. A. (1975). *Otsenka obshchey chislennosti popu-lyatsii tyulenya* Pusa hispida ladogensis *Ladozhskogo ozera* [Estimation of the total seal population of *Pusa hispida ladogensis* of Ladoga lake]. *Zoological Journal*, *54*(9), 1371-1377. [In Russian]

Barlow, J., & Cameron, G. (2003). Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. *Marine Mammal Science*, *19*(2), 265-283. https://doi.org/10.1111/j.1748-7692.2003.tb01108.x

Berta, A., & Churchill, M. (2011). Pinniped taxonomy: Review of currently recognized species and subspecies, and evidence used for their description. *Mammal Review*, *42*, 207-234. https://doi.org/10.1111/j.1365-2907.2011.00193.x

Borodin, A. M., Bannikov, A. G., & Sokolov, V. E. (Eds.). (1984). *Krasnaya kniga Sovetskogo Soyuza: Redkie i nahodyashiesya pod ugrozoy ischeznoveniya zhivotnih i rasteniy (2izd., Tom 1)* [Red data book of USSR: Rare and endangered species of animals and plants (2nd ed., Vol. 1)]. Lesnaya Promishlennost'. [In Russian]

Bowen, W. D., & Lidgard, D. (2013). Marine mammal culling programs: Review of effects on predator and prey populations. *Mammal Review*, *43*, 207-220. https://doi.org/10.1111/j.1365-2907.2012.00217.x

Bychkov, V. A., & Antoniuk, A. A. (1975). *Ladozhskaya nerpa i voprosy yeye okhrany* [Ladoga seal and questions of its protection]. *Zoological Journal*, *54*(9), 255-266. [In Russian]

Calamnius, L., Lundin, M., Fjälling, A., & Königson, S. (2018). Pontoon trap for salmon and trout equipped with a seal exclusion device catches larger salmons. *PLOS ONE*, *13*(7), e0201164. https://doi.org/10.1371/journal.pone.0201164

Chapsky, K. K. (1932). *Ladozhskiy tulen' and vozmozhnosti ego promysla* [Ladoga seal and the possibilities of its harvest]. *Izvestiya Leningrada*, *13*(2), 147-157. [In Russian]

Dmitrieva, L., Kondakov, A. A., Oleynikov, E., Kydyrmanov, A., Karamendin, K., Kasimbekov, Y., Baimukanov, M., Wilson, S., & Goodman, S. J. (2013). Assessment of Caspian seal bycatch in an illegal fishery using an interview-based approach. *PLOS ONE*, *8*(6), e67074. https://doi.org/10.1371/journal.pone.0067074.

Federal State Budgetary Scientific Establishment "Berg State Research Institute on Lake and River Fisheries" (FSBSI "GosNIORH"). (2016a). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov, otnesennykh k ob"yektam rybolovstva, v vodnykh ob"yektakh Leningradskoy oblasti, Ladozhskom ozere (v granitsakh Leningradskoy oblasti) na 2017 god* [Materials substantiating the total allowable catch of aquatic biological resources attributed to fisheries in water bodies of the Leningrad Region, Lake Ladoga (within the boundaries of the Leningrad Region) for 2017]. FSBSI "GosNIORH." [In Russian]

FSBSI "GosNIORH." (2016b). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov, otnesennykh k ob"yektam rybolovstva, v Onezhskom ozere, Ladozhskom ozere (v granitsakh Respubliki Kareliya) i vodnykh ob"yektakh Respubliki Kareliya na 2017 god* [Materials substantiating the total allowable catch of aquatic biological resources attributed to fisheries in Lake Onega, Lake Ladoga (within the borders of the Republic of Karelia) and water bodies of the Republic of Karelia for 2017]. FSBSI "GosNIORH." [In Russian]

FSBSI "GosNIORH." (2017a). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov, otnesennykh k ob"yektam rybolovstva, v vodnykh ob"yektakh Leningradskoy oblasti, Ladozhskom ozere (v granitsakh Leningradskoy oblasti) na 2018 god* [Materials substantiating the total allowable catch of aquatic biological resources attributed to fisheries in water bodies of the Leningrad Region, Lake Ladoga (within the boundaries of the Leningrad Region) for 2018]. FSBSI "GosNIORH." [In Russian]

FSBSI "GosNIORH." (2017b). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov, otnesennykh k ob"yektam rybo-*

lovstva, v Onezhskom ozere, Ladozhskom ozere (v granitsakh Respubliki Kareliya) i vodnykh ob"yektakh Respubliki Kareliya na 2018 god [Materials substantiating the total allowable catch of aquatic biological resources attributed to fisheries in Lake Onega, Lake Ladoga (within the borders of the Republic of Karelia) and water bodies of the Republic of Karelia for 2018]. FSBSI "GosNIORH." [In Russian]

FSBSI "GosNIORH." (2019a). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov v vodnykh ob"yektakh Leningradskoy oblasti, Ladozhskom ozere (v granitsakh Leningradskoy oblasti) na 2021 god (s otsenkoy vozdeystviya na okruzhayushchuyu sredu)* [Materials substantiating the total allowable catch of aquatic biological resources in water bodies of the Leningrad Region, Lake Ladoga (within the boundaries of the Leningrad Region) for 2021 (with an assessment of the environmental impact)]. FSBSI "GosNIORH." [In Russian]

FSBSI "GosNIORH." (2019b). *Materialy, obosnovyvayushchiye obshchiy dopustimyy ulov vodnykh biologicheskikh resursov v vodnykh ob"yektakh respubliki Kareliya (v granitsakh Leningradskoy oblasti) na 2021 god (s otsenkoy vozdeystviya na okruzhayushchuyu sredu)* [Materials substantiating the total allowable catch of aquatic biological resources in water bodies of the Republic of Karelia (within the boundaries of the Leningrad Region) for 2021 (with an assessment of the environmental impact)]. FSBSI "GosNIORH." [In Russian]

Filatov, I. E. (1978). Dieta ladozhskogo tulenya [Diet of the Ladoga ringed seal]. *Proceedings of All-Union Congress "Morskie Mlekopitajuwie,"* Moscow, Russia. [In Russian]

Filatov, I. E. (1990). *Ladozhskaya kol'chataya nerpa* [Ladoga ringed seal]. *Proceedings of a meeting "Rare Species of Mammals of the Fauna of the USSR and Their Protection,"* Moscow, Russia. [In Russian]

Fjälling, A. (2006). The conflict between grey seals (*Halichoerus grypus*) and the Baltic coastal fisheries: New methods for the assessment and reduction of catch losses and gear damage. *Biology, Linköpings Universitet*, *8*.

Georgiev, A. P., & Cherepanova, N. S. (2011). *Rybnyy promysel v severnoy chasti Ladozhskogo ozera na sovremennom etape* [Fishing in the northern part of Lake Ladoga at the present stage]. *Proceedings of the Sixth International Scientific Conference "Biodiversity and Role of Species in Ecosystems,"* Dnepropetrovsk, Ukraine. [In Russian]

Glushenko, N. I. (2019). *Osobennosti dinamiki vylova tsennykh promyslovykh porod ryb Ladozhskogo ozera i rol' rybokhozyaystvennoy promyshlennosti po sokhraneniyu ikh zapasov* [Specifics of the dynamics of the valuable commercial fish species harvest on Lake Ladoga and the role of the fishing industry in preserving fish stocks] (Bachelor's thesis). Russian State Hydrometeorological University, St Petersburg, Russia. [In Russian] http://elib.rshu.ru/files_books/pdf/rid_ee43ee1c598b423f8cb8dc23249c10f9.pdf

Gulland, J. A. (1987). The impact of seals on fisheries. *Marine Policy*, *11*(3), 196-204. https://doi.org/10.1016/0308-597X(87)90056-X

Härkönen, T., Harding, K. C., Wilson, S., Baimukanov, M., Dmitrieva, L., Svensson, C. J., & Goodman, S. J. (2012). Collapse of a marine mammal species driven by human impacts. *PLOS ONE*, *7*(9), e43130. https://doi.org/10.1371/journal.pone.0043130

Harwood, J. (2001). Marine mammals and their environment in the twenty-first century. *Journal of Mammalogy*, *82*, 630-640. https://doi.org/10.1644/1545-1542(2001)082<0630:MMATEI>2.0.CO;2

Hyvärinen, H., & Nieminen, M. (1990). Differentiation of the ringed seal in the Baltic Sea, Lake Ladoga and Lake Saimaa. *Finnish Game Resources*, *47*, 21-27.

Jounela, P., Sipilä, T., Koskela, J., Tiilikainen, R., Auttila, M., Niemi, M., & Kunnasranta, M. (2019). Incidental bycatch mortality and fishing restrictions: Impacts on juvenile survival in the endangered Saimaa ringed seal *Pusa hispida saimensis*. *Endangered Species Research*, *38*, 91-99. https://doi.org/10.3354/esr00939

Kovacs, K. M., Aguilar, A., Aurioles, D., Burkanov, V., Campagna, C., Gales, N., Gelatt, T., Goldsworthy, S. D., Goodman, S. J., Hofmeyr, G. J. G., Härkönen, T., Lowry, L., Lydersen, C., Schipper, J., Sipilä, T., Southwell, C., Stuart, S., Thompson, D., & Trillmich, F. (2012). Global threats to pinnipeds. *Marine Mammal Science*, *28*, 414-436. https://doi.org/10.1111/j.1748-7692.2011.00479.x

Kudersky, L. A. (2009). *Sostav i promyslovoye znacheniye rybnogo naseleniya Ladozhskogo ozera* [Composition and harvest importance of the fish stocks of Lake Ladoga]. In G. M. Lavrentieva (Ed.), *Fisheries of European lakes in the north-western part of Russia* (Vol. 334, pp. 138-212). SPb. [In Russian]

Kunnasranta, M. (2001). *Behavioural biology of two ringed seal (*Phoca hispida*) subspecies in the large European lakes Saimaa and Ladoga* (Doctoral dissertation). University of Joensuu, Finland. https://www.researchgate.net/publication/260134247_Behavioral_ecology_of_the_Saimaa_ringed_seal-implications_for_conservation

Medvedev, N. V., Sipilä, T., & Verevkin, M. V. (2006, September). The distribution pattern of the Ladoga ringed seal (*Phoca hispida ladogensis*) over the lake in the ice season. *Proceedings of the Fourth International Conference "Marine Mammals of the Holarctic,"* St Petersburg, Russia.

Ministry of Agriculture of the Russian Federation. (2018). *Ob utverzhdenii obshchego dopustimogo ulova vodnykh biologicheskikh resursov vo vnutrennikh vodakh Rossiyskoy Federatsii, za isklyucheniyem vnutrennikh morskikh vod Rossiyskoy Federatsii, na 2019 god* [On approval of the total allowable catch of aquatic biological resources in the inland waters of the Russian Federation, with the exception of inland sea waters of the Russian Federation for 2019] (Decree No. 535). Ministry of Agriculture of the Russian Federation. [In Russian]

Ministry of Agriculture of the Russian Federation. (2019a). *O vnesenii izmeneniy v obshchiy dopustimyy ulov vodnykh biologicheskikh resursov vo vnutrennikh vodakh*

Rossiyskoy Federatsii, za isklyucheniyem vnutrennikh morskikh vod Rossiyskoy Federatsii, na 2020 god [On changes in the total allowable catch of aquatic biological resources in inland waters of the Russian Federation, except inland waters of the Russian Federation, 2020] (Decree No. 622). Ministry of Agriculture of the Russian Federation. [In Russian]

Ministry of Agriculture of the Russian Federation. (2019b). *Ob ustanovlenii ogranicheniya rybolovstva v otnoshenii otdel'nykh vidov vodnykh biologicheskikh resursov i v otnoshenii ispol'zovaniya otdel'nykh vidov orudiy dobychi (vylova) v 2019 godu* [On the establishment of a fishing restriction in relation to certain types of aquatic biological resources and in relation to the use of certain types of harvest (catch) gear in 2019] (Decree No. 328). Ministry of Agriculture of the Russian Federation. [In Russian]

Ministry of Natural Resources and Environment of the Russian Federation. (2020). *Ob utverzhdenii Perechnya ob"yektov zhivotnogo mira, zanesennykh v Krasnuyu knigu Rossiyskoy Federatsii* [On approval of the list of fauna objects listed in the *Red Data Book of the Russian Federation* (Registration 02.04.2020, No. 57940; Decree No. 162)]. Ministry of Natural Resources and Environment of the Russian Federation. [In Russian]

Northridge, S., Tregenza, N., Rogan, E., Mackey, M., & Hammond, P. (1999). *A sea trial of acoustic pingers in Celtic Shelf gillnet fisheries* (IWC SC/51/SM43). International Whaling Commission.

Rice, D. W. (1998). *Marine mammals of the world: Systematics and distribution* (Special Publication 4). Society for Marine Mammalogy. 231 pp.

Shurukhin, A. S. (2018). *Biologicheskoye obosnovaniye predlozheniy po zapretu na primeneniye tralov i donnykh nevodov v Ladozhskom ozere* [Biological justification proposals to ban the use of trawls and bottom seines in Lake Ladoga]. [In Russian] http://fisher.spb.ru/blogs/view.php?postId=1153

Sipilä, T. (2016). *Pusa hispida* ssp. *ladogensis*. In International Union for Conservation of Nature (Ed.), *The IUCN red list of threatened species 2016: e.T41674A66991648*. IUCN. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41674A66991648.en

Sipilä, T., & Hyvärinen, H. (1998). Status and biology of Saimaa (*Phoca hispida saimensis*) and Ladoga (*Phoca hispida ladogensis*) ringed seals. In M. P. Heide-Jørgensen & C. Lydersen (Eds.), *Ringed seals in the North Atlantic* (Vol. 1, pp. 83-99). The North Atlantic Marine Mammal Commission (NAMMCO) Scientific Publications. https://doi.org/10.7557/3.2982

Sipilä, T., Medvedev, N., & Hyvärinen, H. (1996). The Ladoga seal (*Phoca hispida ladogensis* Nordq.). *Hydrobiologia*, *322*, 192-198. https://doi.org/10.1007/BF00031827

Sokolov, A. S. (1958). *O pitanii ladozhskogo tyulenya i tselesoobraznosti yego promysla* [On the diet of the Ladoga seal and the profitability of its harvest]. *Fisheries*, *10*, 25-27. [In Russian]

Sokolov, V. E., Smelova, M. Ya., & Bychkov, V. A. (Eds.). (2001). *Krasnaya kniga Rossiyskoy Federatsii (Tom 1: Zhivotniye)* [Red data book of the Russian Federation (Vol. 1. Animals)]. AST, Astrel. [In Russian]

Sorokin, S. M. (1970). *Nekotoryye dannyye o popadanii ladozhskogo tyulenya v rybolovnyye orudiya* [Some data on the Ladoga seal entering fishing gear]. *Fisheries of Inland Water Reservoirs*, *5*, 35-36. [In Russian]

Tormosov, D. D., & Filatov, I. E. (1973). *O chislennosti ladozhskoy nerpy i ratsional'nom ispol'zovanii yeye zapasov* [On the abundance of the Ladoga ringed seal and the rational use of its stocks]. *Proceedings of a meeting "Rare Species of Mammals of the Fauna of the USSR and Their Protection,"* Moscow, Russia. [In Russian]

Trukhanova, I. S. (2013). The Ladoga ringed seal (*Pusa hispida ladogensis*) under changing climate conditions. *Russian Journal of Theriology*, *12*(1), 41-48. https://doi.org/10.15298/rusjtheriol.12.1.05

Trukhanova, I. S., Gurarie, E., & Sagitov, R. A. (2013). Spring density and distribution of Ladoga ringed seals (*Pusa hispida ladogensis*). *Arctic*, *66*(4), 417-428. https://doi.org/10.14430/arctic4328

Trukhanova, I. S., Sagitov, R. A., Verevkin, M. V., Alekseev, V. A., & Andrievskaya, E. M. (2012). *Ladozhskaya kol'chataya nerpa i rybnyy promysel: Pochemu voznik konflikt* [Ladoga ringed seal and fisheries: Background for social ecological and economical strain development]. *Terrahumana*, *23*(2), 232-238. [In Russian]

Verevkin, M. V. (2002, June). *Rezul'taty aviaucheta kol'chatoy nerpy na Ladozhskom ozere* [Results of aerial counting of ringed seals on Lake Ladoga]. *Proceedings of the III International National Symposium "Dynamics of Game Animals Populations of Northern Europe,"* Sortavala, Russia. [In Russian]

Verevkin, M. V. (2003). *Assessment of the state of the ringed seal population in the Russian part of the Baltic region: Interactions between seals and fishery (is there a conflict and how to resolve it)* (Technical report on Contract D.39.12/08/03.0063).

Verevkin, M. V., Medvedev, N., & Sipilä, T. (2006, September). Mortality of Ladoga seal (*Phoca hispida ladogensis*) in bycatch. *Proceedings of the Seventh International Conference "Marine Mammals of the Holarctic,"* St Petersburg, Russia.

Verevkin, M. V., Trukhanova, I. S., & Sipilä, T. (2009, March). Interactions between the Ladoga ringed seal (*Pusa hispida ladogensis* Nordquist, 1899) and fisheries on Lake Ladoga. *Proceeding of international meeting "Status of the Population, Problems and Conservation Avenues for Ladoga Ringed Seal (*Phoca hispida ladogensis*),"* St Petersburg, Russia.

Wilson, S. (2003). *Seal-fisheries interactions: Problems, science and solutions* (Report). British Divers Marine Life Rescue, UK.

Zubov, A. I. (1965). *Meropriyatiya po organizatsii promysla nerpy v Ladozhskom ozere i Finskom zalive* [Arrangements for organizing the seal harvest in Lake Ladoga and the Gulf of Finland]. *Fisheries*, *5*, 22-24.

Appendix: Anonymous Questionnaire Used in Fisheries Survey (Translated from Russian to English)

Study on the Impact of Seals on the Fishery in Lake Ladoga

The survey is completely anonymous, and the information collected will be used solely for scientific purposes!

Date	Location	ID

What fish species do you catch?

Which fishing gear do you use and in what quantity? (For nets, provide total length.)

What is the average depth for your gear deployment?

What months do you observe seals in your area?

What fish species do seals eat out of your fishing gear?

Which fish species are not damaged by the seals in the nets?

How many seals did you bycatch in the previous fishing season (2019)?

How would you assess your personal economic losses caused by seals (amount of spoiled catch in kg or %, number of damaged nets, costs for buying new nets or repairs, etc.)?

Additional comments or information

Full name, contact phone number, e-mail (optional)