



CONTRIBUTED PAPER

Bycatch in local fishery disrupts natural reestablishment of Eurasian otter in western Norway

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Research**Abstract**

Lack of proper estimates of nonreported bycatch has made it difficult to evaluate the actual impact of bycatch in many local fisheries. For the Eurasian otter (*Lutra lutra*), there are no published estimates on the extent to which bycatch is unreported, despite nonreporting being a well-known issue. Through public outreach efforts in local news and media we collected information from citizen scientists on nonreported otter mortalities of a small-scale fishery in western Norway along the recent natural expansion front of otters. We compared this to deaths that were properly registered by local authorities. In total, cause of mortality was determined from 218 otters between 2003 and 2018. We found that the chances of a mortality being properly reported varied between type of death. Drowning in fyke and gillnets were the most common cause of mortality, and at least 61 and 69% of these deaths were never reported, respectively. The high level of bycatch occurring in the otters' current region of expansion is likely to have demographic impacts and hinder otter reestablishment in the area. Banning the use of fyke nets and setting a minimum fishing depth for gillnets would enhance otter recovery and simultaneously alleviate bycatch of other nontarget species in the region, while having little economic impact on a fishery which is mostly noncommercial. The case of the otter is a classic example of lack of communication between government agencies which have so far failed to establish platforms where issues like this can be discussed and solved by adequate law implementation.

KEYWORDSbureaucratic barriers, citizen science, drowning, fisheries, law enforcement, *Lutra lutra*, management failure

1 | INTRODUCTION

Bycatch of nontarget marine fauna is a global conservation concern (Crowder et al., 2008; Crowder & Murawski, 1998; Hall, 1996). Many populations of marine vertebrates, including birds, reptiles, and mammals have been reduced

due to a tendency to become entrapped in various types of fishing equipment, significantly in some cases (Lewison, Crowder, Read, & Freeman, 2004; Read, Drinker, & Northridge, 2006). Even local, small-scale fisheries have the potential to harvest unsustainable levels of nontarget species (Campbell, Holley, Christianopoulos, Caputi, &

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Gales, 2008; Majluf, Babcock, Riveros, Schreiber, & Alderete, 2002; Peckham et al., 2007), especially concerning vulnerable species or those that have a low reproductive potential (Lowry, Pease, Graham, & Walford, 2005; Norse et al., 2005). However, in many cases there is no reliable way to measure bycatch due to a large amount of underreporting and therefore estimate its effects on a particular species (Poole, Rogan, & Mullen, 2007). In such cases, it can be helpful to rely on local citizen science to supplement official reports (Black, 2009; Black, Wampole, & Mayer, 2016; Kindberg, Ericsson, & Swenson, 2009; Loso & Roos, 2019).

Currently, most research concerning bycatch of non-target marine mammals is directed toward cetaceans and pinnipeds (Lewison et al., 2004). Although California sea otters (*Enhydra lutris*) received some attention during the mid-1970's through the early 1980's following a population decline due in part to high levels of bycatch (Estes, Hatfield, Ralls, & Ames, 2003). Bycatch is still a topic of concern for some local populations today (Hatfield et al., 2011). The Eurasian otter (*Lutra lutra*) is also affected by high levels of bycatch throughout its European range, significantly in some cases (Erlinge, 1971; Jefferies, Green, & Green, 1984; Madsen, 1991). However, even though this form of mortality can be important to local population viability, it is poorly quantified (McCafferty, 2011).

In western Norway, the bycatch of Eurasian otters is particularly high compared to other regions of the country and Europe in general (Reuther, 2002; van Dijk, May, Hamre, & Solem, 2016). However, official reports only offer a limited insight into the actual scale of the problem, as there is likely a large amount of underreporting throughout the region. This conceals the true extent to which bycatch is affecting local populations (Jefferies et al., 1988).

After extensive hunting in the early 1900's reduced the historically widespread Norwegian otter population to just two remnant populations in Nordland and Hedmark (Figure 1a), the species started to recolonize much of its former range on the west coast following nationwide protection in 1982 (Christensen, 1995; Heggberget, 1988, 1996; Heggberget & Myrberget, 1979). As of 2019 the Norwegian otter population now ranges from the northern tip of the country to Rogaland County. Despite this initial success the otter long seemed to have stopped its expansion southwards along the coast around Bergen in Hordaland County due to excessive levels of bycatch in fyke nets (Heggberget, 2007). In early 2010 a tightening of fishing rules likely aided in the eventual movement of otters southwards. Such rules included a ban on fishing for eel, fewer number of traps and shorter fishing seasons to conserve the lobster (*Homarus gammarus*) population and a transition from using fyke

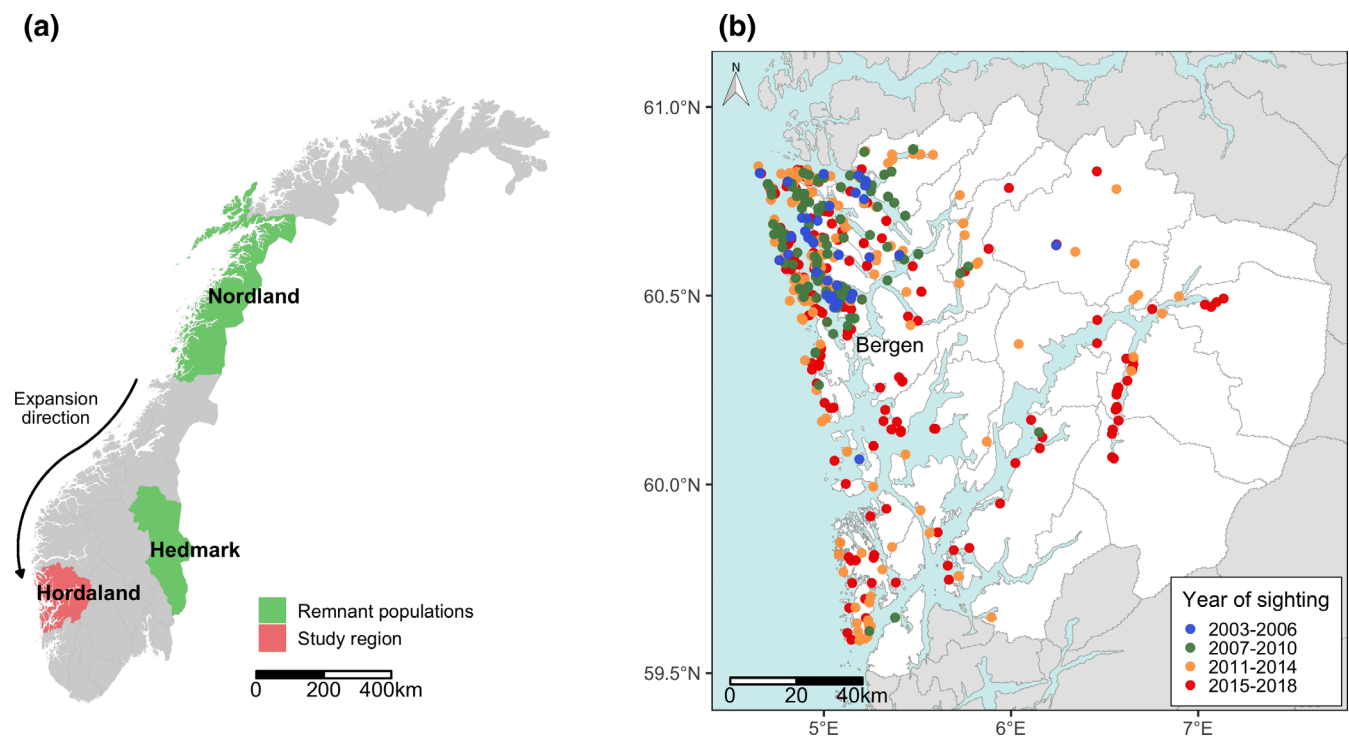


FIGURE 1 Areas of remnant otter populations and the general direction of expansion in Norway (a) and years in which otters established in the study region (b)

nets to pots in the wrasse (*Labridae* spp.) fishery. However, despite the aforementioned fishing restrictions, since 2009 the overall number of bycaught otters in Norway has increased (van Dijk et al., 2016), which is a direct result of otters trying to establish in Hordaland and falling victim to fishing gear (Heggberget, 2007).

The Eurasian otter is listed as “vulnerable” in the Norwegian Red List for Species, and it is required by law to report any otter found dead or killed by fishing equipment to local game authorities. This likely results in slightly more accurate recordings of otter deaths than in other European countries such as Ireland, where there is no requirement to report mortalities (Poole et al., 2007). However, the number of otter deaths reported to local authorities, especially due to fishing equipment is at best largely underreported.

In this study, we aimed to find out how many otter killings go unreported in this region in order to advise policy decisions concerning fishing methods and otter bycatch in western Norway.

2 | MATERIALS AND METHODS

2.1 | Study area

The study area is located in Hordaland County (Figure 1a) on the west coast of Norway. The coastline of Hordaland is characterized as a fjord system where deep, saltwater inlets cut into the mainland. The shorelines are irregular and ascend steeply to high alpine habitat and mountain plateaus. Most of the shorelines are relatively sheltered by the thousands of barrier islands and clustered islets that dominate the topography of western Hordaland.

Most of the coastal zone in the county is well-suited for otters. Dense *Laminaria* spp. growth fringes rocky shorelines and fish taxa such as *Gadidae*, *Cottidae*, and flatfish are present in high concentrations, although varying throughout the year (Heggberget, 1993; Heggberget & Moseid, 1994). Otter recolonization followed a north-south direction, therefore the northernmost parts of the County will have naturally supported otter populations longer than those located further south and deep within the fjords (Figure 1b), with some regions being established as late as 2015.

The urban environment in Hordaland is characterized by small villages scattered throughout the valleys of the fjords and on the islands. The city of Bergen is the only large urban area (Figure 1b), with a population of roughly 280,000 in 2019 (StatBank Norway, 2019).

Fishing pressure is directed mostly toward large *Gadidae* spp., especially cod (*Gadus morhua*) through the

use of both fyke and gillnets. The commercial fyke net fishery is relatively insignificant though, and data provided by the Norwegian Directorate of Fisheries (fiskeridir.no) shows the fishery averaged around just \$13,000 per year between 2003 and 2018 (Figure 2). However, the vast majority of fyke netters in Hordaland do so on a recreational basis and do not market the catch. This, combined with the fact that fyke netters do not need to apply for fishing permits or register used nets makes quantifying fishing effort of the recreational fishery impossible, although it is significantly greater than the commercial fishery. The gillnet fishery is also predominantly conducted on a recreational basis, with the majority of catch being consumed locally instead of marketed. Data on market value of commercial gillnet catches in Hordaland was not available, although it is likely to be comparable to the fyke net fishery per year.

2.2 | Data collection

The assessment of the number of killings relied on two methods.

Given the otter is nationally protected in Norway, it is required to report any found dead otter to “local authorities,” such as game wardens or police. Information is then made publicly available on the website “artsobservasjoner.no,” which was developed and run by the Norwegian Biodiversity Information Centre on behalf of the Norwegian Environmental Agency. The portal also allows citizens to log information such as the date, place (GPS coordinates), size, sex, and cause of death and other relevant parameters. Using this information allowed us to track the expansion of otters throughout Hordaland County and locate mortalities. All otter mortalities collected by local authorities and registered on the species observations database were considered “properly reported” and are hereby referred to as such.

Collection of unregistered otter mortalities in Hordaland began in 2003 and lasted until 2018. Data was compiled in several ways. First, through local newspaper and online media companies we asked readers to submit knowledge of any otter mortalities they were aware of to the Norwegian Institute for Nature Research “oter@nina.no.” All submissions were urged to include relevant information such as location and depth of fishing equipment that the otter was found in, to avoid double counting. Submitters who did not include this information were contacted again. Second, radio and newspaper interviews, word-of-mouth and random encounters were conducted randomly throughout the course of the survey. From 2004 to 2018 we participated in a total of 34 local and national newspaper articles, two national television

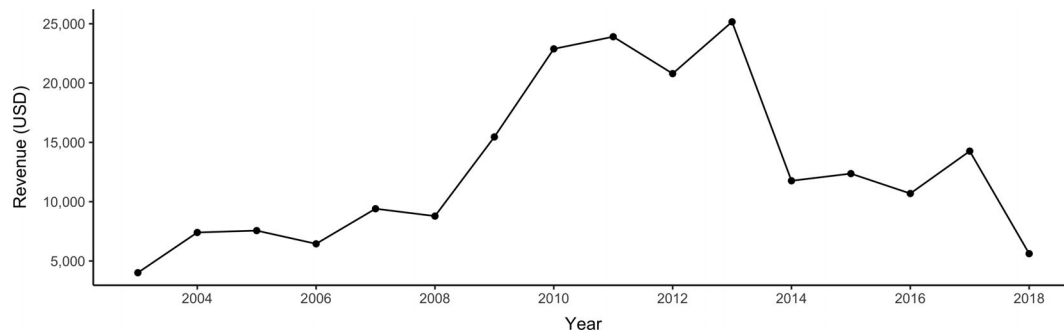


FIGURE 2 Revenue (US Dollars) of the fyke net industry over the studied timeframe in Hordaland County

programs and one national radio interview in which we asked for undocumented otter sightings and deaths to be reported. Although variation in awareness-raising effort may introduce a sampling bias, many reports included information on multiple instances of mortality, some times spanning over a decade. Any reported mortality which has not previously been reported to local authorities was then classified as “Improperly reported,” and is hereby referred to as such.

3 | RESULTS

Between 2003 and 2018 we collected 188 cases of otter mortality, for a total of 218 individuals. Usually, when more than one individual was netted at the same time they were females with pups. Six major causes of death were recorded (Table 1). Total annual mortality fluctuated throughout the studied timeframe, although an average of 14 (SD = 9) deaths occurred per year. In almost every year of the studied timeframe, the majority of the recorded deaths were not properly reported to local management authorities (Figure 3). A two-sample *t*-test revealed that the amount of improperly reported mortalities per year was not significantly greater, however ($p = .17$, $df = 29.62$).

The proportion of properly reported deaths varied between years, ranging from 6 ($n = 16$) to 87% ($n = 23$).

In total, only 39.0% ($n = 218$) of all registered mortalities were properly reported. However, this value drops to 36.4% when specifically examining human related mortalities, as the former figure also takes into account deaths in which the cause of mortality is unknown. The percentage of properly reported deaths exceeded that of unreported events only when the cause of death was filed as “unknown” (Table 1). Gillnet mortalities were properly reported significantly less than those that were unknown ($X^2 = 4.21$, $p = .04$, $df = 1$). Fyke net deaths had a similarly low chance of being reported compared to unknown deaths, although not significantly ($X^2 = 2.89$, $p = .09$, $df = 1$).

The largest amount of otter deaths was attributed to fyke nets, which made up 57.3% ($n = 218$) of the total mortalities in Hordaland. On average, mortalities due to fyke nets resulted in at least eight otter deaths per year in the County, of which only 39.2% were properly registered. Although fyke nets were by far the largest contributor to otter mortalities in Hordaland, deaths due to entanglement in gillnets were less likely to be reported by fishermen, with only 30.8% ($n = 39$) of otter drownings being reported.

TABLE 1 The total number of reported mortalities per cause of death, along with the depth at which otters were drowned, where applicable (2003–2018)

Cause of mortality	Properly reported		Total deaths	Depth				
	Yes	No		<i>n</i>	$\bar{x} \pm SD$	Med.	Min.	Max.
Fyke net	49	76	125	17	4.5 ± 2.4	3	2	10
Gillnet	12	27	39	13	8 ± 6	5	2	20
Lobster trap	0	3	3	2	6 ± 1.4	6	5	7
Roadkill	9	17	26	-	-	-	-	-
Other	1	1	2	-	-	-	-	-
Unknown	14	9	23	-	-	-	-	-
Σ	85	133	218	32	-	-	-	-

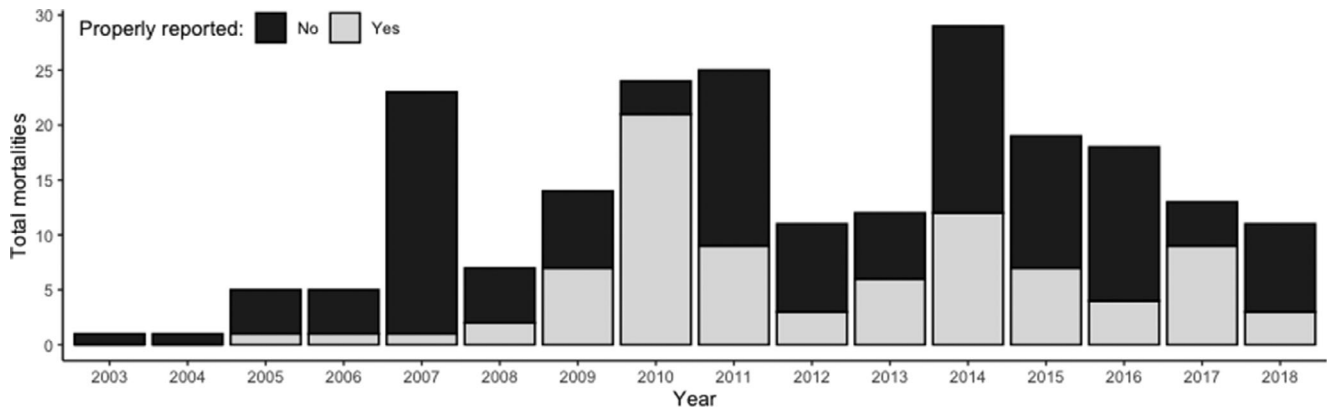


FIGURE 3 A comparison between the total number of otter mortalities that were properly reported and unreported to local management authorities during the studied timeframe

There are distinct regional differences with regard to where the majority of otter mortalities are concentrated throughout Hordaland (Figure 4). Of the 33 separate municipalities that make up County, just three combined made up 45% of all recorded mortalities and at least 50% of the total deaths due to drowning in fyke nets. All three of the municipalities are located in northwestern Hordaland.

The depth at which otters were drowned in various types of fishing equipment was seldom reported. Only 17% of the recorded cases of otters drowning in fyke nets included information on the depth that the animal was

found at, although this number increased to 39% for cases concerning bycatch in gillnets. Two of the three cases in which otters were drowned in lobster traps reported the depth at which the animal was found. In most cases otters were found in relatively shallow water, usually between 4 and 8 m. This was especially true for drownings in fyke nets, in which the average depth at which the trap was set was just 4.5 (SD = 2.4) meters (Table 1). Recorded cases of drowning in gillnets occurred less consistently in shallow water compared to fyke nets, with maximum depths at which bycaught otters were found reaching depths of up to 20 m.

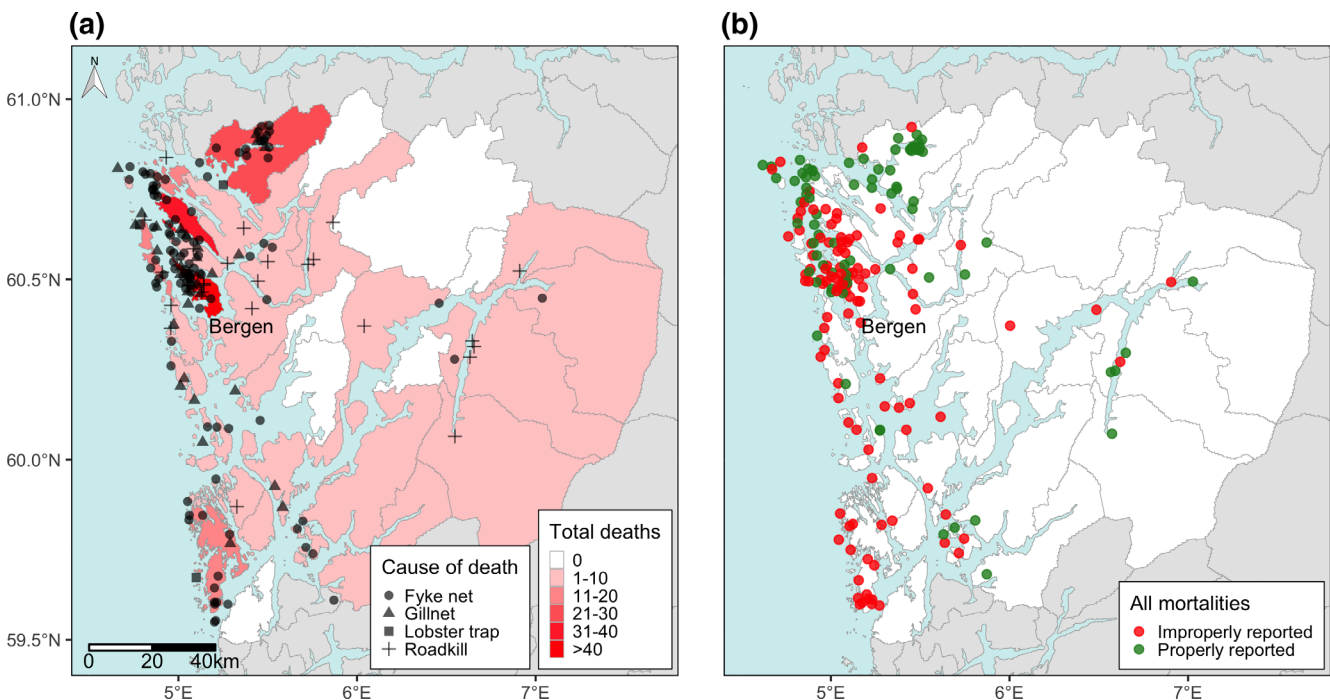


FIGURE 4 The total reported cases of mortality per commune in Hordaland, along with the cause of death (a) compared to the distribution of properly reported and unreported cases (b)

4 | DISCUSSION

As expected, we found that the majority of human related mortalities are never reported to local authorities, which is in agreement with an observer cited by Jefferies et al. (1984), who hypothesized that the amount of verified bycaught otters along the Solway coast in Great Britain was only 20–50% of the actual value. Despite our efforts to reach a large target audience, we believe that the proportion of unreported deaths may be even higher due to the fact that information on otter mortalities is often attained through random encounters, reports made in confidence or acquired through means that involve a significant amount of chance (Jefferies et al., 1984).

The difficulty in properly quantifying the actual amount of deaths due to fishing equipment is compounded by several factors. Namely, the fyke and shallow water gillnetting fisheries in western Norway are carried out on a mostly noncommercial, recreational basis, so fishermen using this equipment go unregistered. Also, fyke nets require no baiting or regular servicing, and are carried out between dusk and dawn, which makes policing of these fisheries both difficult and costly (Moriarty & Dekker, 1997; Poole et al., 2007). Another potential factor in the low rate of reported bycatch is that fishermen may feel that reporting an otter killed by fishing equipment may result in tighter restrictions for fishermen, and therefore such accidents should be concealed (Reuther, 2002). It is difficult to prove this assumption, but our finding that mortalities resulting from human interaction (i.e., fishing equipment and roadkill) were properly reported significantly less than instances in which the cause of death was assumed to be natural (i.e., “unknown” category) supports this hypothesis. Indeed, many cases in which otters were drowned in fishing equipment were reported not by the fishermen themselves, but by locals in the area. Last, as otter cubs are reliant on the mother for around 1 year before becoming independent (Kruuk, 2006), if the mother is drowned or killed by road traffic the pups will likely also die from malnourishment. This secondary effect is difficult to measure, although surely underestimated.

4.1 | Regional differences

There was a large amount of variation in human-caused mortality between the municipalities of Hordaland, with the majority of bycatch happening in northwestern Hordaland (Figure 3). However, this apparent phenomenon is probably biased by several factors, specifically, the time in which local populations of otters have been subjected to bycatch and how the density of human

inhabitation may affect chance of reporting (Loso & Roos, 2019). As otter recolonized the coastal, northern regions of the county first, municipalities in this area will have naturally accumulated more deaths than other regions which are newly established. Similarly, when examining total reported otter mortalities in Norway based on County (irrespective of cause of death), Nordland has more than double the mortalities of the next highest County (van Dijk et al., 2016), which is probably just a result of otters having boasted stronger populations there for longer amounts of time. As there is no evidence to suggest more use of fyke or gillnets in the northwestern regions of the Hordaland County compared to the others (excluding land-locked municipalities), the difference in reported mortalities could possibly be attributed to denser human populations in these areas, especially around Bergen. As the amount of people living in an area increases, the chances that news of a drowned otter reaching someone who would properly report it would logically increase as well.

4.2 | Demographic and ecosystem impacts

It is difficult to quantify to what extent high amounts of bycatch affect otter population dynamics such as dispersal and recruitment. Given that the otter has recently reestablished many parts of Hordaland, it is likely that population density is still low, especially in Southern Hordaland and within the fjord systems, and even the loss of a small number of individuals could have negative impacts (Bailey & Rochford, 2006). Moreover, otters tend to become transient at very low densities (Jefferies et al., 1988), increasing the chances of them coming into contact with fishing equipment.

Reestablishing otter populations may potentially out-compete invasive American mink (*Neovison vison*) in parts of Europe (Bonesi & Macdonald, 2004; Erlinge, 1972; McDonald, O'Hara, & Morrish, 2007), although some suggest that the minks' ability to adapt its diet and rhythmic activity under competitive pressure will allow for coexistence (Bonesi, Chantin, & Macdonald, 2004; Bueno, 1996; Clode & Macdonald, 1995; Harrington et al., 2009), similar to that seen with the North American river otter (*Lontra canadensis*) and mink (Ben-David, Bowyer, & Faro, 1996; Melquist, Whitman, & Hornocker, 1981). Nonetheless, in Norway the decline of the mink has been concurrent with the expansion of otter (Heggberget, 2001). The invasive mink are efficient predators of many ground-nesting riparian and seabird species (Craik, 1993, 1995; Ferreras & Macdonald, 1999; Clode & Macdonald, 2002; Nordström

et al., 2003) as well as certain rodent species such as the water vole (*Arvicola amphibious*) in Britain (Macdonald & Strachan, 1999; Woodroffe, Lawton, & Davidson, 1990). In Hordaland, mink share much of the blame, among other factors, for many of the failing seabird colonies in the County (Byrkjeland & Haugland, 2015). If otter do manage to outcompete mink over time from coastal areas in Western Norway, one could expect positive impacts on local seabird recruitment and chick survival. These benefits may be limited, however, by excessive levels of bycatch.

4.3 | Solutions

An extensive list of possible solutions to otter bycatch in fyke nets has been compiled by Jefferies et al. (1984). To date, the most successful solution appears to be mandating the use of otter excluder devices to either the opening of the net or the entrance of the first funnel. Such measures are now mandatory in Denmark and parts of Britain where freshwater fyke nets primarily target European eels (*Anguilla anguilla*) in river systems (Jefferies et al., 1984; Koed & Dieperink, 1999; Madsen & Søgaard, 1994). These excluder devices are impractical in Norway, however, as large-bodied target species such as cod and pollock (*Pollachius virens*) would be prohibited from entering the net, along with otters. A possible solution could be to set a minimum depth at which nets must be set (Jefferies et al., 1988). Our data supports previous findings which indicate rates of bycatch decrease with depth (Jefferies et al., 1984; Madsen, 1991; Reuther, 2002; Twelves, 1983). Setting nets deeper than 15 m could therefore be a possible solution to reduce bycatch in gill-nets. However, fyke netting in western Norway is traditionally conducted in shallow, coastal waters, and it is not known how fishing in deeper water may affect the catch rates of target species, or if this would be realistically possible to enforce.

Other solutions proposed by Jefferies et al. (1984) include installing floating cod-ends, concealing the catch and shortening the fishing season, among others. Although all solutions may theoretically help to reduce bycatch, none of them would be capable of completely eliminating it. All alternatives considered, a closure to the fyke net fishery may be necessary to ensure the healthy reestablishment of otters in western Norway, at least until alternative methods of reducing bycatch become apparent. Considering the average annual revenue of the fishery is quite low, a closure of this fishery would not have large economic consequences for most fishermen. Stricter fisheries regulations would also reduce unwanted bycatch of local and migratory seabird

species in western Norway. Northern fulmars (*Fulmarus glacialis*) and black guillemot (*Cepphus grylleaso*) often fall victim to commercial gillnetting operations in Norway (Bærum et al., 2019; Fangel et al., 2015). Incidences of cormorants (*Phalacrocorax* spp.) and mink drowning in fyke nets have been anecdotally reported for decades (Bakken & Falk, 1998). However, like otters these are seldom ever reported.

To date, most of the conservation measures that have benefited otters in western Norway are a secondary result of restrictions on the lobster fishery. These fishing limitations have clearly not been enough though, and more consideration must be given specifically to otters. In Norway, the otter is a classic example of a species that has “fallen between two stools.” While the Norwegian Environmental Agency (Miljødirektoratet) provides legislation to protect vulnerable species like the otter, it has no authority over fishing equipment regulation; likewise, the Norwegian Directorate of Fisheries (Fiskeridirektoratet) can mandate measures to prevent bycatch, but the otter is offered little protection under the agency's current legislation. Similar bureaucratic barriers have hindered the recovery of the black-footed ferret (*Mustela nigripes*) (Clark, 1992, 1993) and California condor (*Gymnogyps californianus*) in the United States (Snyder, 1994). In order to more effectively manage bycatch of otters in Norway, a platform should be established to enhance communication between the Environmental and Fishing Directorates.

4.4 | Concluding remarks

The sheer number of bycaught otters in Hordaland throws into sharp relief the need for better preventative measures to reduce bycatch in western Norway. Our findings confirm previous estimates on the scale of the problem of purposeful nonreporting, and it is clear that the amount of properly reported drowned otters has been very underestimated. The continued exploitation of the otter, especially at the hands of a predominantly recreational fishery calls into question serious ethical concerns regarding the worth of otters and other nontarget semi-aquatic and avian species, not covered by our survey, compared to a fishery with little economic value. In order to quickly reduce the amount of otter bycatch happening in western Norway, an important first step should be to establish a means by which separate government agencies can effectively communicate and share information. Above all, conservation strategies should provide preventative measures for reducing bycatch not only in western Norway, but also any areas where the use of otter exclusion devices are not practical. Further research needs to be placed upon developing fishing gear that can exclude

otters, or allow them to escape once caught without compromising catch rates of large target fish. Until such equipment becomes available, the most effective means of reducing otter bycatch would be to place a ban on the use of fyke nets targeting large-bodied fish species. Any fyke nets targeting smaller fish species should be equipped with otter exclusion devices such as grids and ring guards.

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CONFLICT OF INTEREST

We have no conflicts of interest to declare. All research was done solely for the purpose of gathering more information on the scale of otter mortalities in western Norway and making the results publicly available.

AUTHOR CONTRIBUTIONS

Both authors made equal contributions to the manuscript. This includes all data compilation, calculation of results, drafting of the text, and revision.

ETHICS STATEMENT

All research was conducted and reported in a manner to ensure the highest quality and integrity of results possible. All participants in this study were informed and consented to their contributions being used toward research. Participation in this study was completely voluntary. We have respected the anonymity of all participants who made contributions to this study in confidence.

DATA AVAILABILITY STATEMENT

All data collected in this study has been made publicly available on the website “artsobservasjoner.no”. Datasets used specifically for the purpose of this study can be made available upon contact with the authors.

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