

BY-CATCH OF COMMON MINKE WHALES (*BALAENOPTERA ACUTOROSTRATA*) IN NORWEGIAN DEMERSAL TRAWL AND LONGLINE FISHERIES, 2011–2020

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ABSTRACT

The Norwegian High Seas Reference Fleet (HSRF) reported one minke whale (*Balaenoptera acutorostrata*) by-caught in demersal trawl fisheries and one in a longline in the period 2011–2020. The HSRF comprises 25–30 concurrent fishing vessels larger than 15 m total length, contracted by the Institute of Marine Research to provide detailed reports on fishing effort, catch, and by-catch. The HSRF is designed to be as representative as possible for large fishing vessels in all of Norway. By-catch per effort for demersal trawl and longline fisheries was calculated based on data from the HSRF and extrapolated using effort data from the corresponding non-observed fleet (vessels ≥ 15 m) to obtain fleet-wide total by-catch estimates. The total by-catch in demersal trawl and longline fisheries was 57 whales for the 10-year period (95% CI: 0–157). No by-catch of minke whales was observed in other gear types (purse seine, Danish seine, and gillnets), but information from various sources indicates that there is an unknown amount of cryptic minke whale by-catch in other gears that we cannot currently quantify. Pot and creel fisheries, for example, were not covered by the HSRF, and there is a need to quantify by-catch in these fisheries. Notwithstanding undocumented sources of by-catch, the results show that even if 100% of minke whale by-catches are fatal, documented by-catch in Norwegian fisheries is only about 0.5% of the PBR and can be considered negligible from a sustainability perspective. Even so, minke whale by-catch is still a serious animal welfare issue.

Keywords: cetacean, common minke whale, by-catch, by-catch estimates, PBR

INTRODUCTION

Fisheries by-catch is currently the most severe and acute threat to cetaceans worldwide, and is threatening several species, subspecies, and populations with immediate extinction (Brownell et al., 2019). By-catch mitigation is of the utmost importance for the conservation and sustained viability of many cetacean populations. Even for populations where by-catch is not a conservation concern, by-catch mitigation is urgently needed for animal welfare reasons (Dolman & Moore, 2017). This latter point is underscored by the fact that many cetaceans that are trapped in fishing gear do not drown but suffocate (asphyxiate) as oxygen levels in blood and muscles decrease and carbon dioxide concentration increases (Dolman & Moore, 2017; IJsseldijk 2021), entailing impairment of cardiac conduction (Cowan & Curry, 2002). It has been estimated that the time from entanglement to unconsciousness and to subsequent death in a minke whale can be considerably longer than the species' average dive times of 2–5 minutes (Leaper et al., 2006). Some cetaceans, such as the large baleen whales, may be strong enough to move and reach the surface despite being entangled in fishing gear, by pulling or dragging the gear along with them. In such cases, rather than suffocating or drowning in a relatively quick manner, the animals might instead carry the gear for days, weeks, or even months, before ultimately perishing from exhaustion (Moore & van der Hoop, 2012).

Norway initiated monitoring of marine mammal fisheries by-catches in 2005, when the North Atlantic Marine Mammal Commission (NAMMCO) established a working group to evaluate the extent of marine mammal by-catches. So far, this monitoring has resulted in published estimated by-catches of harbour porpoise, (*Phocaena phocaena*) (Moan et al., 2020), humpback (*Megaptera novaeangliae*) and killer (*Orcinus orca*) whales (Bjørge et al., 2022). In addition, preliminary estimates of by-catch of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals are available (Moan & Bjørge, 2021).

The common minke whale (*Balaenoptera acutorostrata*) is abundant in the Northeast Atlantic. The most recent abundance estimate for this region, based on the Norwegian shipboard mosaic surveys in 2014–2019, is 149,722 whales (CV = 0.152) (Solvang et al., 2021). The Northeast Atlantic is also an extensively fished area and Norway has been the second major global exporter of fish products since 2004 (FAO, 2020). Given this extensive overlap in time and space of minke whales and fishing activities, interactions between minke whales and fishing gear in Norwegian waters can therefore be expected. In this paper, we use data from a fleet of reference vessels to estimate minke whale by-catch rates in different fisheries and apply those rates to fleet-wide effort to estimate total minke whale by-catch.

MATERIALS AND METHODS

Since 2005, the Institute of Marine Research (IMR) has contracted 25–30 concurrent fishing vessels larger than 15 m total length, to provide detailed reports on fishing effort, catch, and by-catch. These vessels, called the High Seas Reference Fleet (HSRF), are selected to be as representative as possible for large fishing vessels in all of Norway (Clegg & Williams, 2020). Pot and creel fisheries are known to have by-catches of minke whales in Scotland (Leaper et al. 2022), but such fisheries were not observed by the Norwegian HSRF. The crew on HSRF vessels are given training in reporting and taking biological samples. There are also extensive measures for data quality assurance and control in the HSRF. Data from the HSRF are regularly used as part of assessments of harvested fish stocks as well as by-catch of nontarget species and undersized fish.

In this study, we used data from the HSRF to calculate the minke whale by-catch rate, and multiplied those by-catch rate estimates with effort data from the corresponding non-observed fleet (vessels ≥ 15 m) to obtain fleet-wide total by-catch estimates. The reason we used data sampled by the HSRF rather than official fishery data from logbooks is because marine mammal by-catches are severely underreported in Norway (Basran & Sigurdsson, 2021). The low number of minke whale by-catches reported in the HSRF prevented more sophisticated approaches, e.g. stratification by vessel sizes, regions, seasons, or approaches based on generalised linear modeling, so instead we used a traditional ratio estimator (Cochran 1977), post-stratifying by gear type, and otherwise pooling all data. The by-catch rate, \hat{r}_i was calculated as the quotient of observed by-catch b_i and observed effort e_i , where i denotes the type of fishing gear. Fishing effort was defined as the product of fishing time (in decimal days) and either the number of tows (for demersal trawls), or number of hooks (for longlines) (Equation 1). The total by-catch in gear i , \hat{B}_i , was calculated as the product of \hat{R}_i and total effort E_i (Equation 2). Finally, total by-catch, \hat{B}_{total} , was calculated as the sum of by-catch \hat{B}_i (Equation 3).

$$\hat{r} = b_i / e_i \quad (1)$$

$$\hat{B}_i = \hat{r}_i \times E_i \quad (2)$$

$$\hat{B}_{total} = \sum \hat{B}_i \quad (3)$$

To assess the sustainability of minke whale fisheries by-catch in the Norwegian offshore fisheries, we compared the estimated total by-catch with the Potential Biological Removal, PBR (Wade, 1998), for minke whales in the Northeast Atlantic. The PBR for a marine mammal population is given by equation 4:

$$PBR = N_{min} \times 0.5 \times R_{max} \times F_r \quad (4)$$

Here, N_{min} is the 20th percentile of the abundance estimate, assuming a log-normal distribution, R_{max} is the maximum growth rate, and F_r is a recovery factor that can incorporate further information on the conservation status of the species in question. In this case, we used $R_{max} = 0.04$, according to recommendations by Wade (1998). We calculated N_{min} from the estimates reported in Solvang et al. (2021).

All analyses were done in R (R Core Team, 2020). Coefficients of

variation (CVs) and 95% confidence intervals (CIs) and were obtained through bootstrapping using the *boot* R package (Davison & Hinkley, 1997; Canty & Ripley, 2020). In the bootstrapping procedure, we resampled with replacement from haul-level HSRF data, and re-calculated total estimates from the bootstrap samples in the manner described above. CVs and bias corrected (BCa) CIs were obtained from the resulting distribution of 10,000 bootstrap estimates.

RESULTS AND DISCUSSION

The overall coverage of the HSRF as a sample of all fishing operations conducted by large Norwegian vessels was 1.9%. The coverage for individual years ranged from 1.4% to 2.7%. In the period 2011–2020, the HSRF reported one minke whale entangled in a longline in 2018 and one taken in a demersal trawl in 2020. Both incidents were lethal. Figure 1 shows the locations of both incidents, as well as total fishing activity for the relevant fisheries in the ten-year period. There were no reports in the HSRF data of by-catch of minke whales in other observed gear types (e.g. purse seines, Danish seines, and gillnets).

The total by-catch in demersal trawl fisheries for the entire period 2011–2020 was estimated to 45 minke whales (CV = 0.92; 95% CI: 0–129). The total by-catch in longline fisheries was estimated to 12 minke whales (CV = 0.96; 95% CI: 0–16). Based on these estimates, the total by-catch of minke whales in Norwegian fisheries between 2011 and 2020 was 57 whales (95% CI: 0–157). This corresponds to an average of about six whales per year, assuming similar by-catch rates and fishing effort throughout the 10-year period.

Given the rarity of minke whale by-catches recorded by the HSRF, it is possible that our sampling coverage may not be sufficient to capture the variance accurately. This is partly because the HSRF was not specifically designed for minke whale by-catch estimation. Thus, the estimates must be used cautiously. However, these results establish that by-catches of minke whales do occur in Norwegian fisheries and that such by-catches may be lethal. This is in contrast to the frequent entrapments of humpback and killer whales in purse seines set for herring (*Clupea harengus*), where most whales are released alive (Bjørge et al., 2022).

The by-catch estimate of 57 minke whales over the ten-year period (95% CI: 0–157) must be considered a minimum estimate of incidental anthropogenic mortality for this species, as there are also other sources of minke whale by-catch in Norwegian waters that are not part of this estimate. This includes an unknown amount of cryptic minke whale by-catch in gillnet fisheries, which is not evident from HSRF data but is known from anecdotal accounts (e.g., newspaper stories). By-catches of minke whales in pot and creel fisheries in Scottish waters (Leaper et al. 2022) may suggest that similar fisheries in Norway could also pose a risk to minke whales, although pot and creel fisheries are not monitored by the HSRF. Additionally, there are other causes of mortality that are not monitored by the HSRF. For example, minke whales have been reported to have died because of entanglements in fish farm moorings and gillnet buoy ropes.

The PBR for minke whales in areas covered by the Norwegian surveys (Figure 1), based on the latest full survey cycle and a

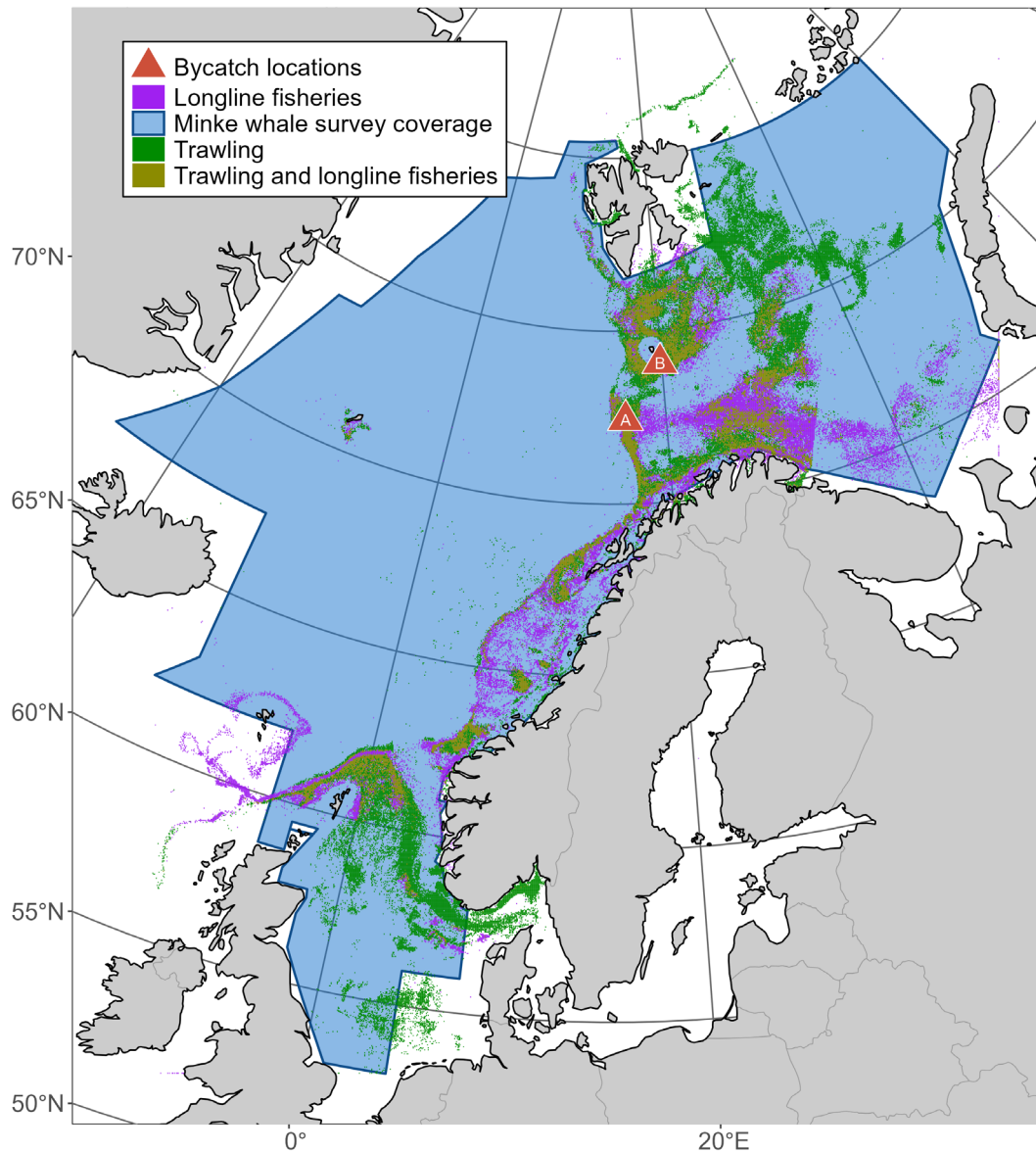


Figure 1: Minke whale survey coverage and trawl and longline fishing activity from 2011–2020. The red triangles indicate the locations of the two reported by-catch incidents, in trawl (A) and longline (B) fisheries.

recovery factor $F_r = 0.5$, is 1,319 whales per year. We used $F_r = 0.5$ because, even though the common minke whales in the Northeast Atlantic are regarded as one panmictic population (Quintela et al., 2014), the CVs of our by-catch estimates are all greater than 0.3. This is in line with applications by NOAA (2022) and Leaper et al. (2022). Thus, even if 100% of the total estimated minke whale by-catches reported here were fatal, this mortality, on average, would only amount to about 0.5% of the PBR. This, by itself, can be considered negligible from a sustainability perspective. In a more wholistic perspective, including an annual by-catch of 30 minke whales in Scottish creel fisheries (Leaper et al 2022) (even though most Scottish by-catches are on the west coast, outside the Norwegian survey area) and an annual average catch of 537 minke whales from the quota-regulated Norwegian harvest, the estimated total anthropogenic removals would be about 44% of the estimated PBR. However, as discussed above, there are other sources of anthropogenic mortality that we have not accounted for here. There is a need for research on by-catch of cetaceans in pot and creel fisheries in Norway, and for improved data of by-catch in

gillnets. These uncertainties, as well as the large CVs of estimates reported here, call for firm application of the precautionary principle when assessing the impact of human activities on minke whales and when making management decisions for this species. This suggests, for example, that by-catch estimates should be taken into account by Norwegian management authorities when setting national harvest quotas for minke whales. Finally, it is important to remember that regardless of sustainability perspectives, by-catch of cetaceans is a serious animal welfare issue.

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