

Bycatch of harbour and grey seals in Norway

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ABSTRACT

In this paper we compare information from three different sources (mark recapture data, data from a monitored segment of the coastal fishing fleet, and from modeling population trajectories) to elaborate on levels of bycatch of grey and harbour seals in Norway. The mark recapture data revealed bycatch of 555 harbour and 466 grey seals annually in the period 1997-2014. Data from a monitored segment of the coastal fishing fleet gave annual bycatch of 479 harbour and 84 grey seals in the period 2006-2014. However, it is possible that the species identification is incorrect in these data. A modeling approach to population trajectories of grey seals in Sør-Trøndelag and Nord-Trøndelag counties required an annual bycatch of 150 and 80 seals, respectively, in the two counties to explain a recent decline in observed pup production. Considering the different data sources, we assume that the mark recapture data set best reflected the true level of bycatch of grey and harbour seals in Norway. It is likely that the level of bycatches has been increasing in recent years north of 62°N due to an increase in fishing effort with large mesh gill nets. Data from the monitored segment of the coastal fishing fleet are likely to be the basis for future monitoring of marine mammal bycatches of marine mammals in Norwegian coastal waters.

INTRODUCTION

Norwegian populations of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals, are distributed in Norwegian coastal waters. The harbour seal population is distributed along the entire coast and numbers 7568 based on counts of moulting seals in 2011-2015 (Nilssen *et al.* 2016). The overall population has increased slightly since the previous count (2003-2006), but local depletions were observed. The grey seal has one small breeding colony in Rogaland and

the species is continuously distributed from Trøndelag to Varanger. The overall population has been slowly growing over the past two decades and the modelled population was estimated at 8740 (CI 7320-10170) in 2011 (Øigaard et al. 2012). However, recent surveys aimed at counting grey seal pups have revealed a dramatic decline in pup production in the recent five years in some areas (Nilssen & Bjørge 2015). Both species are harvested but the quota regulated harvest should not be the reason for dramatic decline in abundance in some areas. Both species are exposed to incidental bycatches in the coastal fisheries throughout their range in Norway (Bjørge *et al.*2002). The extent of these bycatches are not known, but they are believed to not be negligible.

In this paper we hypothesize that incidental fishery bycatch levels have the potential to significantly impact population trajectory of coastal seals in Norway. The objective of the paper is to explore the extent of the bycatch using three sources of information: mark-recapture data from flipper tagged seals; data on bycatch rates from the Coastal Reference Fleet (CRF); and a model approach to population trajectories.

INFORMATION DERIVED FROM MARK RECAPTURE DATA

Between 1975 and 1998, 3571 grey and 630 harbour seal pups were tagged along the Norwegian coast, and 259 (7%) grey and 80 (13%) harbour seals tags were returned (Bjørge *et al.* 2002). Incidental mortality in fishing gear accounted for the majority of these tag returns: 79% in grey and 48% in harbour seals. Therefore, 205 returned grey seal tags (5.7%), and 38 returned harbour seal tags (6.1%) were from incidental mortality in fishing gear. This is most likely an underestimate of the bycatch rate due to tag loss, underreporting of recovered tags, and tags returned to IMR without any information on the cause of death (6% and 34% of returned tags in grey and harbour seals, respectively).. We do not know the pup production of grey and harbour seal during the period 1975-1998 and can therefore not elaborate on the minimum number of seals taken as bycatch, but we can conclude that the bycatch exceeds about 6% of all pups born in both species.

For the period 1997-2014 we have statistics of the number of grey and harbour seals harvested from the populations. These statistics together with information on number of seals tagged, number of tags recovered from the hunt and number of tags recovered from fishery bycatches (Table 1) provide an opportunity to estimate the number of seals taken as bycatch.

Table 1. The total harvest of grey and harbour seals in the period 1997-2014, and the total number flipper tagged, the total number of tagged animals in the hunt, and the total number of returned tags from fishery bycatch during the same period.

Species	Total harvest 1997-2014	Total tagged	Total tagged harvest	Total tagged bycatch
Grey seals	4311	2642	73	142
Harbour seals	7991	174	7	9

We assume equal proportions of tagged animals among harvested seals and bycaught seals. Therefore:

$$\textit{Total harvest} / \textit{Tagged harvest} = \textit{Total bycatch} / \textit{Tagged bycatch}$$

This gives: $\textit{Total bycatch} = \textit{Tagged bycatch} \times \textit{Total harvest} / \textit{Tagged harvest}$.

For grey seals this resulted in a total bycatch of 8379 for the period 1997-2014, with an annual bycatch of 466 seals. The total bycatch of harbour seals for the period 1997-2014 was 9989 resulting in an annual bycatch of 555 seals. The bycatch of grey seals is about twice the annual harvest (240 seals) and the bycatch of harbour seals is about 125% of the harvest .

DATA FROM THE COASTAL REFERENCE FLEET

The Coastal Reference Fleet (CRF) constitutes a monitored segment of the Norwegian coastal fleet of fishing vessels < 15m. Reference vessels were selected from among the this segment of the fleet based on criteria such as fishing gears used, species targeted and geography (seeking at least two vessels in each of nine statistical areas), in an effort to ensure that the CRF as a whole should be as representative as possible for the entire coastal fleet of vessels less than 15m total length. In the nine-year period in this study, a total of 40 different vessels served in the fleet for various periods of time. The contracts were one-year engagements. Over time, some contracts were renewed, while others were not. Occasionally new vessels were contracted. At any time, the fleet was comprised of 16-22 vessels. These vessels were distributed across nine statistical fishing areas, collectively covering the entire Norwegian coastline (see Fig. 1). Each vessel was primarily associated with one specific fishing area, distributed so that there were two vessels associated with each fishing area (see map). The data shows, however, that vessels were also fishing outside their primary area. Cod and monkfish catch in bottom set gill nets of mesh size 75-105mm and 180mm, respectively, was used as a measure of fishing effort. Bycatch rates were calculated using general additive models (GAMs). The bycatch estimates were then applied to fish landing statistics for the same segment of vessels and the same gear category. Landing data were provided by the Norwegian Directorate of Fisheries. In contrast to the CRF data set, which included detailed information about each fishing station and catch item, the landing statistics data were aggregated by month, area and species.

In the CRF data set, catches obtained using gears corresponding to bottom set gill nets with unspecified mesh sizes and mesh sizes between 75 – 105 mm were classified as cod fishery and mesh size 180mm as monkfish fishery. The CRF data were aggregated by year, month, area and fishery, so that the data set derived was in a format identical to the landing statistics data. The resulting data set consisted of 9 years × 12 months × 9 areas × 2 fisheries = 1944 data points, and was greatly zero-inflated due to the low number of observations. Therefore, neighboring areas were combined into a factor variable *region*, with four levels according to the following scheme. Region 1 consisted of areas 03, 04 and 05; region 2 consisted of area 00; region 3 consisted of areas 06 and 07; and finally region 4 consisted of areas 08, 28 and

09. In modelling grey seal bycatch, regions 3 and 4 were combined into a single region 3 because of the low number of grey seal bycatches in regions 3 and 4. Cod and monkfish fisheries followed a distinct seasonal trend, with most cod landings occurring during the first half of the year (January – June) and monkfish in the second half of the year (July – December). To account for this seasonal shift, a factor variable *season* was used, with two levels, one for each half of the year.

GAMs were used to model bycatch rates from the CRF data. The modelling approach followed from that of Bjørge *et al.* (2013), with some small modifications. A number of different model formulations were attempted, as indicated by Table 2. In each case, bycatch rates were input as a response variable and assumed to follow a Poisson distribution. Landings were entered as an offset and a log link function was used. The AICc information criterion was used to select the best model variation. Bycatch in the commercial fleet was then estimated based on statistics for cod and monkfish landings using the bycatch rates from the best models. The `predict.gam` function from the `mgcv` package (`mgcv` package 1.8-4, R 3.1.1, R Development Core Team, 2011) was used in this extrapolation. Using the fishery definitions specified above, cod catches accounted for 74% of total cod catches and monkfish catches 91% of total monkfish catches. Since the landing statistics data did not contain gear information, cod and monkfish catches in the landing statistics were scaled down by the corresponding proportions.

CVs were obtained by bootstrapping, in the same manner as in Bjørge *et al.* (2013). In each bootstrap iteration, 1944 observations were sampled at random with replacement from the CRF data. The best model was applied on the bootstrap sample and extrapolated using landing statistics data data. This selection was replicated 1000 times for each seal species, and the CVs were calculated from the resulting distribution of predicted values. All data manipulation and analyses were conducted in R version 0.99.484 (R Core Team 2014).

Harbour seal bycatch was significantly correlated with monkfish landings (Pearson's $r = 0.39$, $p < 0.001$), and cod landings (Pearson's $r = 0.16$, $p < 0.001$). Grey seal bycatch was significantly, but weakly correlated with monkfish landings (Pearson's $r = 0.15$, $p < 0.05$) and weakly correlated with cod landings (Pearson's $r = 0.05$, $p = 0.1$).

Model formulations and fit statistics are given in Table 2. The two best harbour seal models (1.9 and 1.10) included region and the interaction fishery \times region. Model 1.10 also included the interaction fishery \times season. Both models accounted for 57% of the deviance, but with scale value of 0.22 while the scale values for the other models ranged from 0.25 to 0.5, which suggests that the data may not fit a Poisson distribution very well (underdispersion?).

The best grey seal model (2.10) included region and two interaction terms: fishery \times region and fishery \times season. Only 28% of the deviance was accounted for by this model. The model scale was only 0.10.

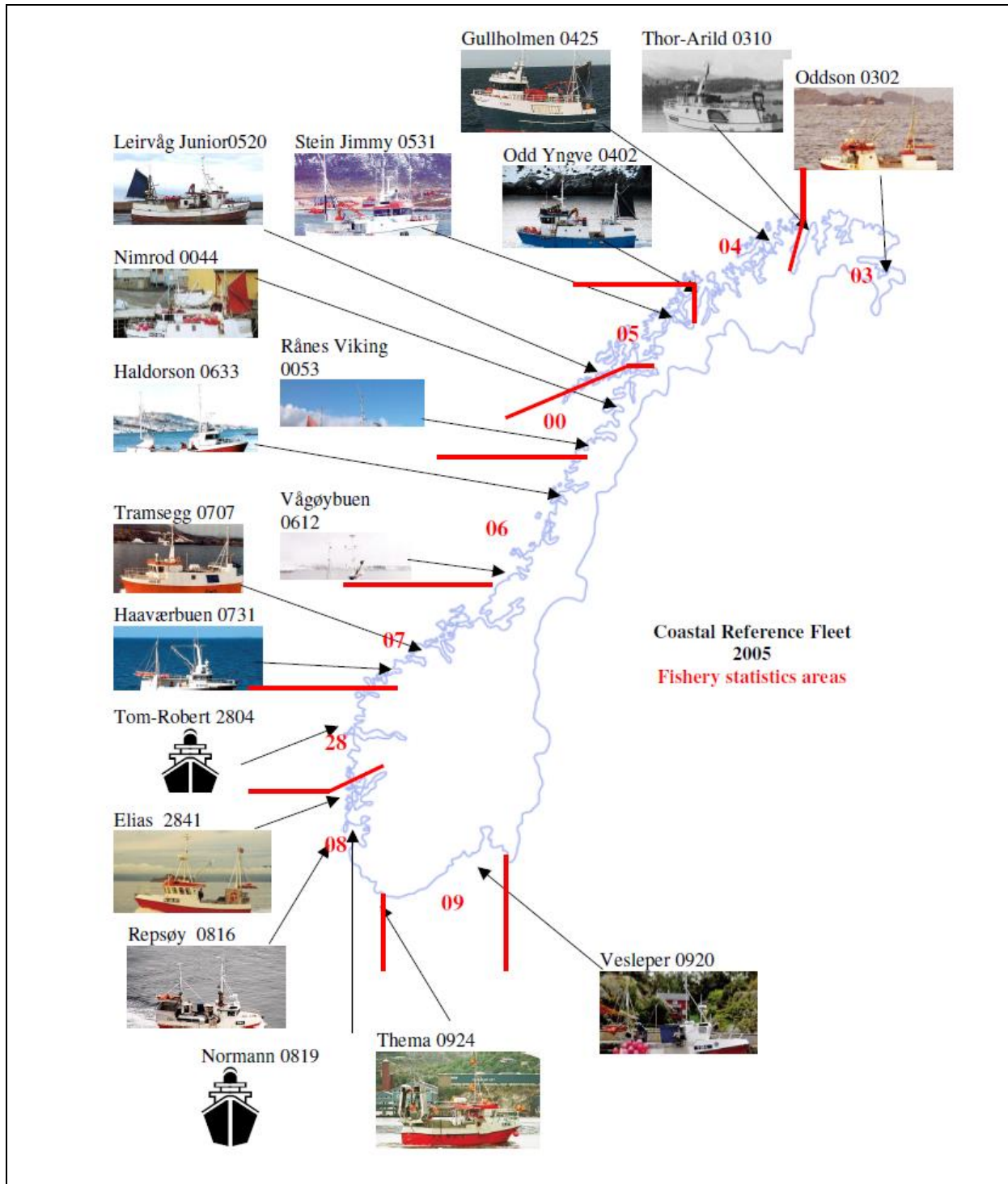


Figure 1. The nine coastal fishery statistics areas (red) and the 18 vessels constituting the Coastal Reference Fleet in 2005-2006.

Table 2: Model fit statistics for various model formulations. Note that the definition of the REGION parameter is different for the harbour seal and the gray seal models. Models in bold have the lowest AICc scores.

Model	DF	Dev. Expl.	Scale	AICc	
<i>Harbour seal models</i>					
1.1	offset(LOG.CATCH)	1	0.00	0.50	1143.32
1.2	offset(LOG.CATCH) + factor(REGION)	4	0.23	0.39	926.49
1.3	offset(LOG.CATCH) + factor(SEASON)	2	0.29	0.35	859.00
1.4	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON)	3	0.47	0.27	686.08
1.5	offset(LOG.CATCH) + factor(FISHERY) + factor(REGION)	5	0.53	0.23	630.00
1.6	offset(LOG.CATCH) + factor(SEASON) + factor(REGION)	5	0.45	0.28	709.61
1.7	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION)	6	0.54	0.23	627.68
1.8	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(SEASON)	7	0.54	0.23	625.33
1.9	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(REGION)	9	0.57	0.22	602.01
1.10	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(REGION) + factor(FISHERY) : factor(SEASON)	10	0.57	0.22	603.47
<i>Gray seal models</i>					
2.1	offset(LOG.CATCH)	1	0.00	0.13	291.80
2.2	offset(LOG.CATCH) + factor(REGION)	4	0.05	0.13	284.84
2.3	offset(LOG.CATCH) + factor(SEASON)	2	0.12	0.12	262.99
2.4	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON)	3	0.16	0.11	255.16
2.5	offset(LOG.CATCH) + factor(FISHERY) + factor(REGION)	5	0.16	0.11	258.06
2.6	offset(LOG.CATCH) + factor(SEASON) + factor(REGION)	5	0.15	0.11	260.98
2.7	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION)	6	0.17	0.11	256.37
2.8	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(SEASON)	7	0.25	0.10	237.50
2.9	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(REGION)	9	0.20	0.11	251.72
2.10	offset(LOG.CATCH) + factor(FISHERY) + factor(SEASON) + factor(REGION) + factor(FISHERY) : factor(REGION) + factor(FISHERY) : factor(SEASON)	10	0.28	0.10	234.42

The relationships between observed and fitted values for the two best models are shown in Fig. 2. The observed and the fitted values predicted by model 1.9 were significantly correlated (Pearson's $r = 0.52$, $p < 0.001$), and while this may be a tolerable fit, there is still substantial variation between observed and fitted values.. No such correlation was found for model 2.10 (Pearson's $r = 0.07$, $p < 0.05$). Figs 3 and 4 show the total predicted harbour seal and gray seal bycatch by area and month. Model 1.9 predicted the highest harbour seal bycatch in the three neighboring areas 00, 06 and 07. In areas north and south of this region, a large drop in bycatch was predicted. Model 2.10 predicted the highest grey seal bycatch in the neighboring areas 06 and 07. Predicted bycatch south of this region was greatly decreased, while predicted bycatch north of this region remained at an intermediate level. Predicted bycatches by both models increase greatly in the second half of the year. These increases reflect the fact that 63% of bycaught seals were caught in monkfish nets.

For the nine-year period 2006 – 2014, the total predicted harbour and gray seal bycatches were 4312 animals (model 1.9) and 755 animals (model 2.10), respectively. The bootstrap-generated CVs were 0.14 for model 1.9 and 0.47 for model 2.10. This yields an annual bycatch of 479 harbour seals and 84 gray seals.

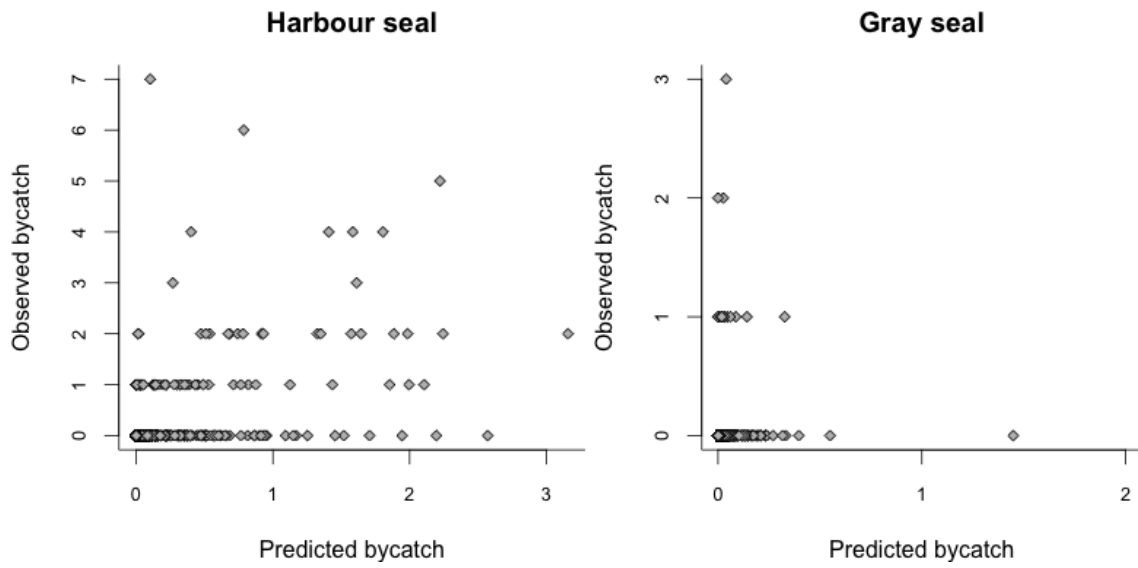


Figure 2: Observed versus predicted bycatch numbers for harbour seal (left) and grey seal (right). Predicted values for harbour seal and gray seal bycatch are from model 1.9 and 2.10, respectively.

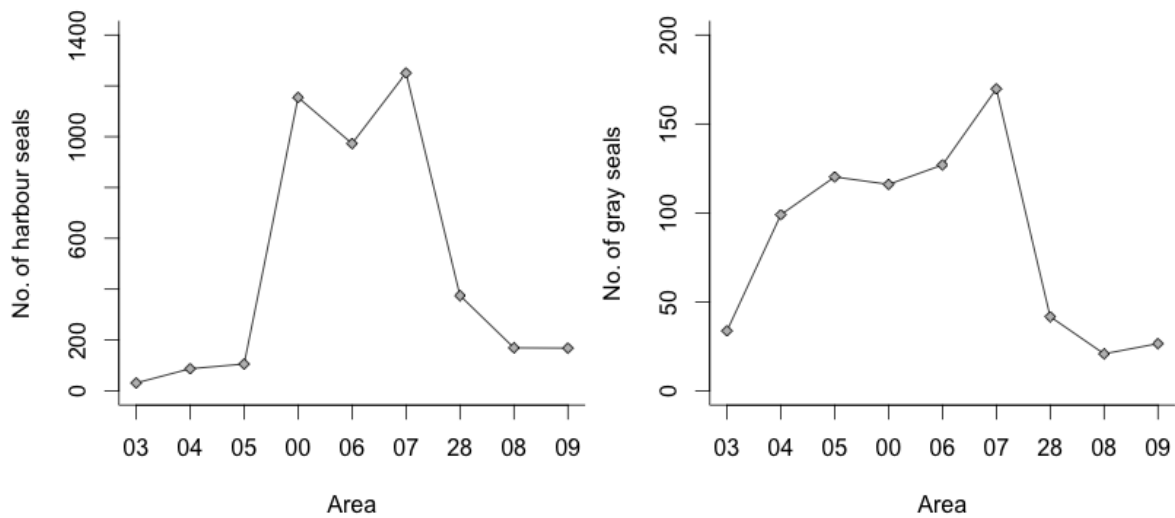


Figure 3: Predicted harbour seal (left) and gray seal (right) bycatch for the period 2006 – 2014 from models 1.9 and 2.10, respectively, aggregated by area.

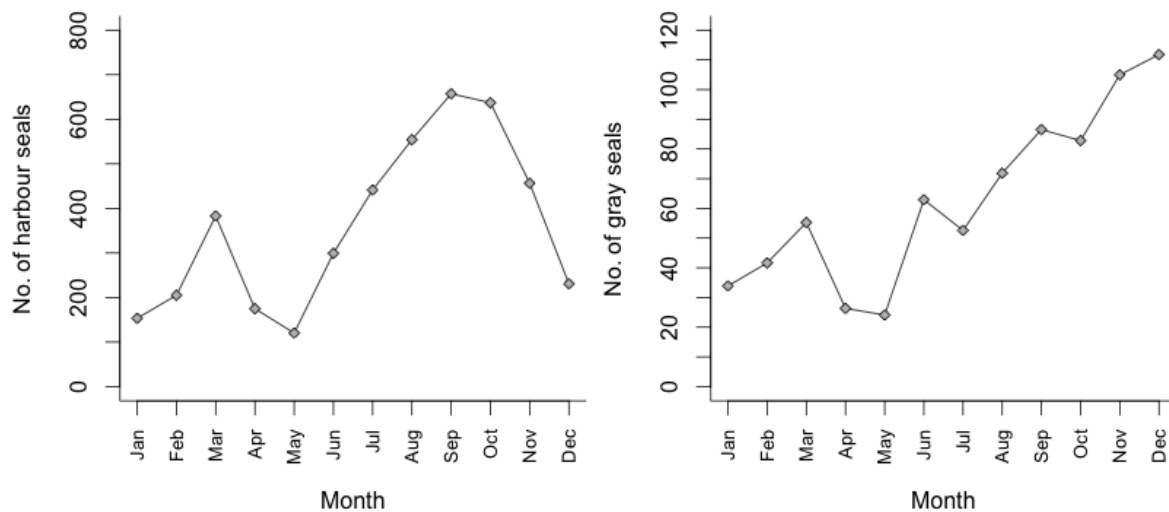


Figure 4: Predicted harbour seal (left) and gray seal (right) bycatch for the period 2006 – 2014 from models 1.9 and 2.10, respectively, aggregated by month.

A MODEL APPROACH TO POPULATION TRAJECTORIES

In 2011 an age-structured population dynamics model for the Norwegian grey seal was developed (Øigård *et al.* 2012). The model utilizes empirical data from pup counts and empirical data on hunting and estimated bycatch mortality. The model requires estimates of natural mortality and female reproductive rates, but since empirical data on these parameters are outdated or absent, they are estimated by the model using a Bayesian approach. Female reproductive rates are estimated using priors from data on Northwest Atlantic (NWA) grey seals, and available datasets from other grey seal populations are used to assess the general variability in parity curves in grey seal females. Natural mortality rates are estimated using uninformative priors.

Surveys aimed at estimating pup production have mainly covered whelping sites in different parts of the Norwegian coast each year. Available grey seal pup counts from each county are given in Table 3 and reported catch are found in Table 4.

Model predictions from 2012 suggested that the catch levels at that time would likely result in a reduction in the population size in the Sør-Trøndelag and Nord-Trøndelag counties, and an increase in the population size in Rogaland, Nordland, Troms, and Finnmark counties.

In Øigård *et al.* (2012) the model fit for the pup abundance corresponded well with the pup counts in the period 1979 – 2011. The adult natural mortality rate was estimated at 5–8% in most areas and at 13% in Sør-Trøndelag. The model indicated a slight reduction of the pup abundance in Sør-Trøndelag during the last 20 years, whereas the pup abundance in Nord-Trøndelag seemed to have stabilized.

In 2014 new pup counts were carried out in Sør-Trøndelag and Nord-Trøndelag. In Sør-Trøndelag 189 pups were counted in 2007 whereas 77 pups were counted in 2014 (Table 3), i.e. a drop of about 60%. In Nord-Trøndelag 135 pups were counted in 2007 whereas 47 pups were counted in 2014 (65% drop).

When including the new pup counts from 2014 the population dynamics model fit to the pup counts is poor as the model is not flexible enough to capture this sudden drop in the pup production in the period 2007 – 2014 (Fig. 5).

Table 3: Survey counts of grey seal pup production for all management areas along the Norwegian coast. From (Wiig, 1986; Wiig, 1987a; Røv *et al.*, 1990; Haug *et al.*, 1994, 1998; Lorentsen and Bakke, 1995; Bjørge and Øien, 1999; Nilssen and Haug, 2007; present study for 2006-2008). *481 pups counted along the mainland coast in Nordland. ** 138 pups counted at the Lofoten area. *** Only Helgeland in Nordland county was counted in 2014.

Year	Rogaland	Sør-Trøndelag	Nord-Trøndelag	Nordland	Troms	Finnmark
1979	-	228	47	140	-	-
1985	-	200	-	-	-	-
1989	-	230	-	-	-	-
1990	-	-	-	-	-	39
1991	-	-	-	171	17	-
1992	-	-	-	-	-	-
1993	-	226	-	-	-	-
1994	-	-	-	-	-	-
1995	-	-	-	-	-	-
1996	-	262	-	-	-	-
1997	-	-	-	-	-	-
1998	-	-	67	399	-	119
1999	-	-	-	-	-	-
2000	30	-	-	-	-	-
2001	30	-	84	-	-	142
2002	28	283	-	573	-	-
2003	35	-	-	-	41	143
2004	-	-	-	-	-	-
2005	31	-	-	-	-	-
2006	-	-	-	-	76	232
2007	-	189	135	619*	-	-
2008	43	-	-	**	-	-
2014	-	77	47	128***	-	-

There could be several potential reasons for the drop in the pup counts in these areas. One likely explanation could be a large amount of bycatch. We explored this by finding the bycatch level that would improve the model fit to the pup counts.

Based on data collected in 2006-2008 from a monitored segment of the coastal fleet of gillnetters (CRF) the annual bycatch of grey seals were estimated at 100-200 animals per year along the Norwegian coast (Nilssen and Bjørge, 2009). It is assumed that the bycatch levels for each county is proportional to the population size in each county, i.e. the Sør-Trøndelag county has about 12% of the total population. Thus the bycatch level in Sør-Trøndelag is 12% of the total bycatch level. The historical population size varies so it is natural to expect that the bycatch level is higher in periods with larger population size. Since a bycatch estimate was available for the period 2006-2008 only, a time-dependent bycatch level was constructed by assuming that the bycatch level is proportional to the population size scaled relatively to the population size in 2008. Also the degree of bycatch is different for the various age groups. The proportion of bycatch in the various age classes are: 77.45% 0-12 months old seals,

7.35% 13-14 months old seals, 4.9% 25-36 months old seals, 4.9% 37-48 months old seals and 5.4% for seals aged 49 months and older, based on Bjørge *et al.* (2002). See Øigård *et al.* (2012) for more details on how bycatch has been implemented in the model.

Table 4: Grey seal catch data for all management areas along the Norwegian coast in the years 1980 - 2014. Catches in the counties Hordaland and Sogn og Fjordane are included in the Rogaland numbers, and catches in Møre og Romsdal are included in the Sør-Trøndelag numbers.

Year	Rogaland	Sør-Trøndelag	Nord-Trøndelag	Nordland	Troms	Finmark
1979	0	0	0	0	0	0
1980	0	0	14	8	3	55
1981	0	0	31	20	3	55
1982	0	80	10	65	3	55
1983	0	55	0	78	3	55
1984	15	200	8	146	3	55
1985	5	32	0	0	3	55
1986	5	10	0	16	3	68
1987	5	10	22	38	3	68
1988	5	10	5	20	3	68
1989	5	10	5	20	3	68
1990	5	10	5	20	3	68
1991	5	10	5	3	3	5
1992	5	10	5	3	3	5
1993	5	10	5	3	3	5
1994	5	10	5	3	3	5
1995	5	10	5	3	3	5
1996	5	10	5	3	3	5
1997	5	10	5	3	3	5
1998	5	10	5	3	3	5
1999	9	44	14	7	3	53
2000	70	45	5	31	3	22
2001	27	20	12	34	12	0
2002	23	24	19	20	5	19
2003	44	96	46	120	9	50
2004	30	67	51	94	42	54
2005	51	48	34	105	14	127
2006	60	51	27	69	39	129
2007	60	40	23	134	35	174
2008	60	40	72	103	37	203
2009	67	31	62	119	4	235
2010	38	19	38	41	20	208
2011	NA	12	12	12	NA	NA
2012	NA	8	14	16	NA	NA
2013	NA	14	20	59	NA	NA
2014	NA	11	21	41	NA	NA

To explore what bycatch level that would ensure a good fit to the observed pup counts we only fitted the population model to the survey counts in the period 1979 – 2007. Then we found an annual bycatch level that would ensure that the modeled pup abundance trajectory would include the 2014 survey counts. Reported catch levels up to 2014 was included in addition to the bycatch.

The starting point for the estimated annual bycatch level was 2005 for Sør-Trøndelag and 2007 for Nord-Trøndelag. The estimated bycatch level was 150 animals for Sør-Trøndelag and 80 for Nord-Trøndelag. If the hypothetical bycatch started in 2007 instead of 2005 in Sør-Trøndelag, the bycatch level increased to 190 animals. The new trajectory for the pup abundance is found in Fig. 6. The population trajectories for the modeled total population in Sør-Trøndelag and Nord-Trøndelag are found in Fig. 7.

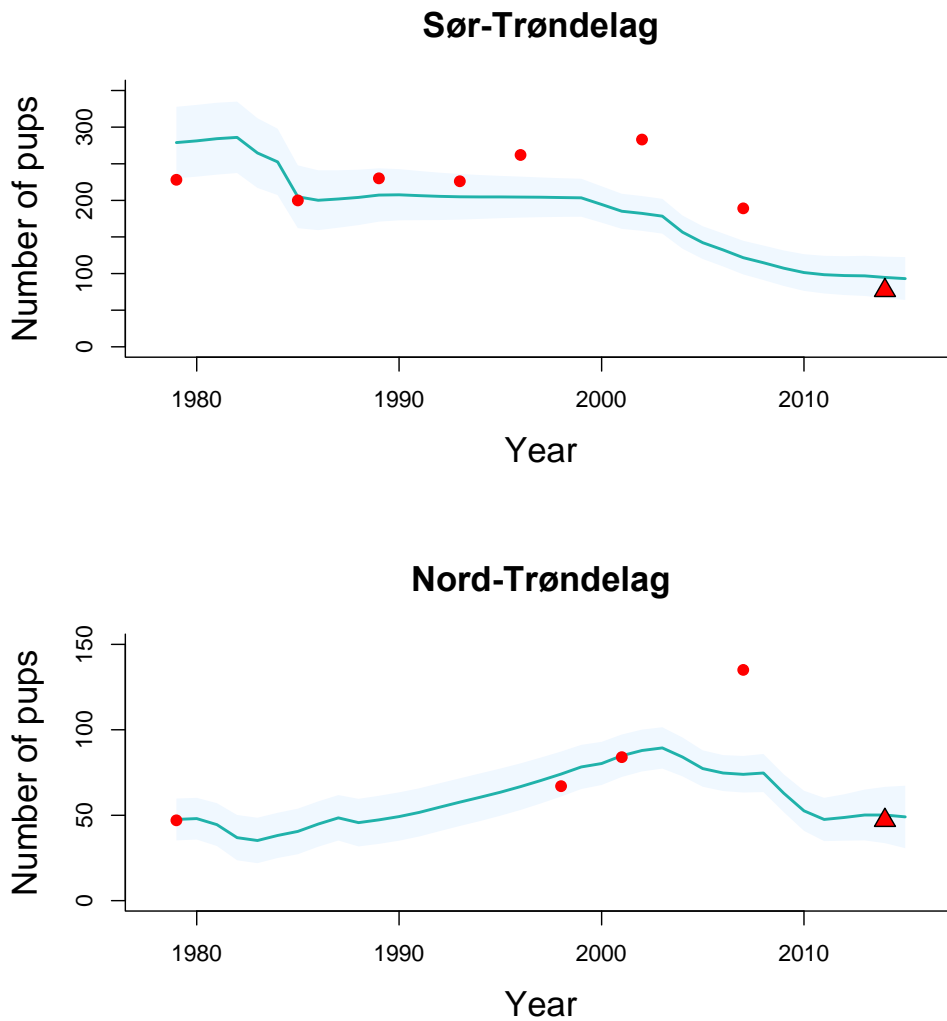


Figure 5: Model fits (full line) to the survey pup counts (red dots and triangle) for Sør-Trøndelag and Nord-Trøndelag.

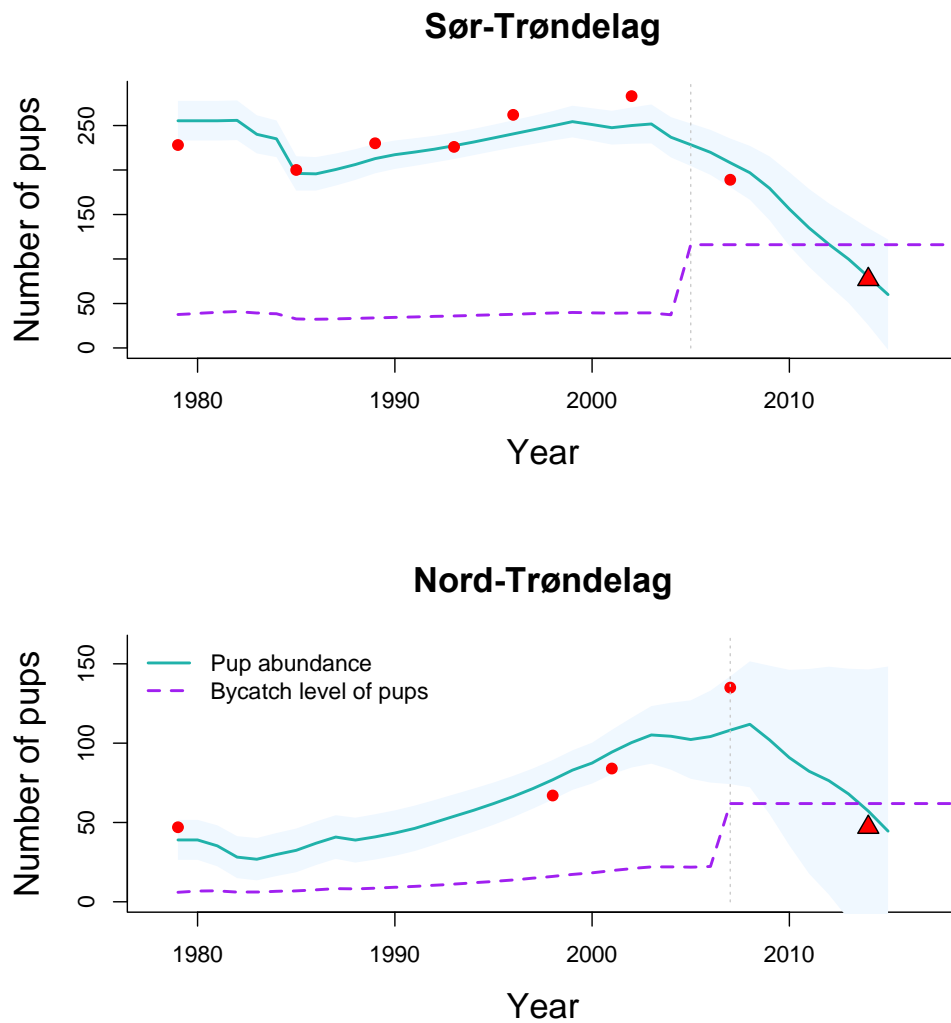


Figure 6: Model fits (full line) to the survey pup counts (red dots and triangle) for Sør-Trøndelag and Nord-Trøndelag. Dashed-line indicate bycatch level of pups. In Sør-Trøndelag the hypothetical bycatch level started in 2005 (vertical dotted line) and in Nord-Trøndelag it started in 2007.

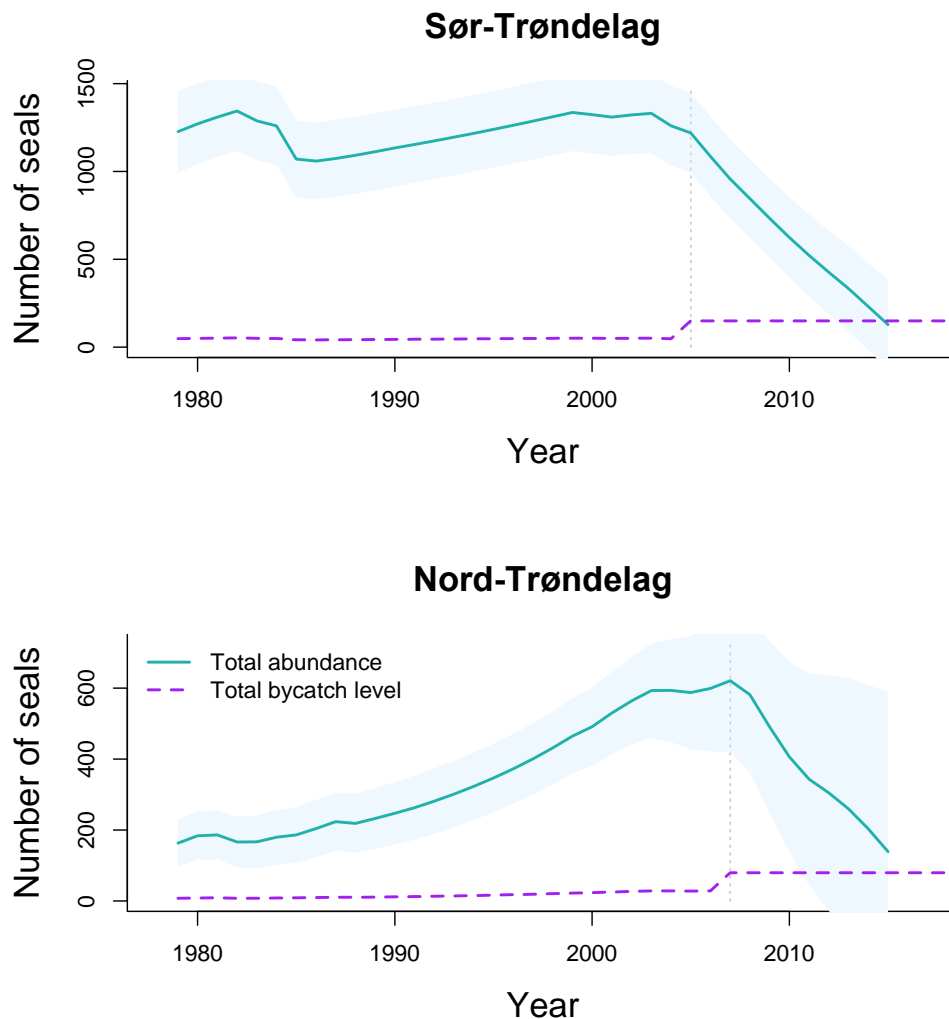


Figure 7: Population trajectory of the modeled total population (full line) for Sør-Trøndelag and Nord-Trøndelag. Dashed-line indicate total bycatch level. In Sør-Trøndelag the hypothetical bycatch level started in 2005 (vertical dotted line) and in Nord-Trøndelag it started in 2007.

DISCUSSION

Bycatch of grey and harbour seals in Norway occurs predominantly in coastal and inshore fisheries, while offshore fisheries have negligible bycatches of these species (Bjørge *et al.* 2006A): The Norwegian coastal and inshore fisheries are large and comprising about 5000 vessels less than 15m total length. The majority of these vessels are operating gillnets for part of the season and gillnets are identified as the gear type with highest risk of marine mammal bycatch (Bjørge *et al.* 2002; 2006B).

The mark recapture data revealed that about 45.6% of all seals taken as bycatch in the coastal zone are grey seals and 54.4% are harbour seals. Data from the CRF using gillnets for cod and monkfish gave an annual bycatch of 479 harbour and 84 grey seals. This species ratio is in contrast to the ratio derived from the mark recapture data. Most of the bycaught seals (77.45%) are taken before they are twelve months old (Bjørge *et al.* 2002). It is possible that young grey seals are incorrectly identified as harbour seals due to the body size. This is a question that will be discussed at the next annual meeting of CRF in December 2016.

If we assume the same ratio (45.6% grey and 54.4% harbour seals) in the CRF bycatch as in the mark recapture data set, the annual bycatches in gillnet fisheries for cod and monkfish are 257 grey and 306 harbour seals. These fisheries constitute only part of the fisheries with risk of bycatch of grey and harbour seals. In Bjørge *et al.* (2002), 82.8% of all bycaught grey seals were taken in set nets and 17.2% in other gear (mainly cod traps). This is a further indication that the bycatch estimated from the CRF data constitute only part of the total bycatch, and that the bycatch level revealed from mark recapture data is the most likely level of bycatches in Norway.

According to Nilssen and Haug (2007) the grey seal pup production at the Norwegian coast was 1159 pups in the period 2001-2003. Thereof were 283 pups (24.4%) recorded in Sør-Trøndelag and 84 pups (7.2%) recorded in Nord-Trøndelag. If we assume that the total annual bycatch of grey seals was 466 seals, and the bycatch in each county was proportional to the population size, the number of seals taken in Sør-Trøndelag would have been 114 seals and 34 seals in Nord-Trøndelag. This is lower than the modeled bycatch of 150 and 80 seals in Sør-Trøndelag and Nord-Trøndelag, respectively, required to cause the observed recent decline in pup production. However, the bycatch level have most likely increased north of 62°N in recent years because there have been a recent increase in fishing effort with large mesh gillnets for halibut (Berg 2015) and for monkfish (Bjelland 2015). This possible recent increase in bycatch level may not be fully reflected in the mark recapture data from 1997-2014.

In conclusion, based on a consideration of possible strengths and weaknesses in the different data sources, the mark recapture data do best reflect the true bycatch levels of grey and harbour seals. Therefore, the level of fishery bycatch in Norway was likely about 555 harbour and 466 grey seals annually in the period 1997-2014, with an increasing trend, in particular north of 62°N, due to an increase in fishing effort with large mesh gill nets for halibut and monkfish in recent years.

The mark recapture data seems to be suitable for monitoring bycatches of grey and harbour seals provided that the tagging effort continues. However, there has been little effort on flipper tagging coastal seals in recent years. Data from CRF are also suitable for monitoring bycatches of coastal seals, but the species identification has to be confirmed and possibly improved. The collation of data from the CRF is continuing and will most likely be the basis for future monitoring of bycatch of grey and harbour seals in Norway.

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