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# Abundance of Harbour Seals (*Phoca vitulina*) in Norway Based on Aerial Surveys and Photographic Documentation of Hauled-Out Seals During the Moulting Season, 1996 to 1999

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**Abstract**

The first nationwide aerial survey to count harbour seals (*Phoca vitulina*) in Norway was conducted between 1996 and 1999. Haulout sites were surveyed during the early moult period of the seals in the second half of August, and most of the known haulout sites along the Norwegian coast (excluding Svalbard) were covered. The haulout sites were photographed, and the films were subsequently analysed at the Institute of Marine Research (IMR), Bergen. The number of seals hauled-out and documented during aerial surveys numbered 7,272. Some haulout sites in fjords of the alpine landscape of western Norway were difficult to cover by aerial surveys, so 193 hauled-out seals counted from boat surveys in these fjords were added, and the total counted population was 7,465.

Applying a correction factor for estimating the total population from the number of hauled-out harbour seals in the adjacent Swedish Skagerrak, the total estimate was 13,000 seals in Norway. We assumed that this was possibly an overestimate of the true population, however, because the tidal amplitude and diurnal light variation differ significantly along the Norwegian coast and are reported to affect the haulout patterns of harbour seals. When correction factors based on regional studies in Norwegian Skagerrak, western Norway, and Finnmark in northern Norway of haulout behaviour in relation to tidal amplitude and diurnal light variation were applied, the total population was estimated at 10,000 harbour seals. Most sites were surveyed only once; consequently, there is no estimate of variance.

Because survey methods have changed from previous questionnaire studies and boat-based surveys, the current estimate cannot be used to assess trends in population size. Harbour seals in Norway are currently intensively hunted, however, and they are subject to high by-catch levels. A decline in numbers is expected under the current management regime, and there is an urgent demand for a new abundance estimate and improved survey design and methodology to account for bias, as well as the appropriate measures of uncertainty involved.

**Key Words:** Harbour seal, *Phoca vitulina*, aerial surveys, abundance, Norway

## Introduction

Counting seals at haulout sites is a frequently used method for monitoring harbour seal (*Phoca vitulina*) populations (Heide-Jørgensen & Härkönen, 1988; Reijnders et al., 1997; Frost et al., 1999; Huber et al., 2001). These hauled-out groups also are segregated by age and sex (Kovacs et al., 1990; Härkönen et al., 1999). The total number, age, and sex distributions of seals present at haulout sites are subject to change through the seasons (Thompson & Rothery, 1987; Thompson et al., 1989; Thompson & Harwood, 1990; Härkönen et al., 1999); therefore, the proportion of the total population counted at the haulout site will change in relation to the timing of a survey. If the age distribution within a population is known, and the haulout probabilities are established for the various population segments at a certain time of the year, the total population size can be estimated from haulout counts (Härkönen et al., 1999, 2002).

The first nationwide census of harbour seals in Norway was conducted by Øynes (1964, 1966) in the early 1960s. His estimate was based on questionnaires and interviews of lighthouse keepers, fishermen, and others with particular knowledge of seals. Øynes summarised the total contemporary population to be 4,040 harbour seals. He also postulated that harbour seals had suffered a severe decline, and that the species was disappearing from parts of their former range. His population estimate was not very different from later nationwide censuses such as that of Bjørge (1991), who recorded 3,629 harbour seals based on ground counts during the breeding season over the period of 1977 to 1989.

This paper presents the results of the first nationwide aerial survey of harbour seals in Norway, and a first attempt to estimate the true size of the Norwegian harbour seal population using actual counts of seals at haulout sites and correction factors for haulout behaviour.

## Materials and Methods

The Institute of Marine Research (IMR), Bergen, conducted harbour seal aerial surveys during the period of 1996 to 1999 in the early moult season (i.e., the second half of August). The timing of the surveys was based on reports of an increase in number of harbour seals hauled out during the moult (e.g., Thompson et al., 1989; Thompson & Harwood, 1990). Known haulout sites were photographed, and the photographic material was subsequently analysed at the laboratory. The surveys were conducted in collaboration with the company FOTONOR A/S, Fornebu, that specialised in aerial photography. In 1996, a Parternavia P68TC Observer aircraft was used, and in 1997-1999, a Parternavia PA31 Navajo was used. Images were taken using an automatic camera of type WILD-RC30 (F: 15.3), hull-mounted for vertical exposures, and AGFA PAN 200 film was used.

A photo session started automatically when the aircraft entered the start position of a known haulout site and continued until the aircraft passed the haulout site. Thus, the survey tracks were predetermined and aimed at a complete coverage of known haulout sites. The observer onboard attempted to locate haulout activity outside the predetermined survey tracks. If new haulout sites were discovered, these were photographed with the same camera using a manually operated procedure. During photo sessions, flying altitude averaged 244 m, and photographs were taken automatically with 25% overlap between photographs, with each photograph covering approximately a 360 m x 360 m square.

The films were subsequently analysed using a light table with a binocular magnifier. Selected areas of the film (e.g., areas with high density of seals) were digitised, and further computer analysis allowed zooming and adjustment of light and contrast to optimize the counting procedure.

Typical harbour seal haulout habitat on the outer Norwegian coast (Figure 1) consists of rocks surrounded by shallow but difficult navigable waters, which provide shelter against breaking swells and disturbance from vessel traffic. The rocks may be exposed at high tide, but seals tend to haul out in the intertidal zone at low tide. Light and contrast manipulation and about 8 x magnification revealed 94 harbour seals in a small part of the area shown in Figure 1 and enlarged in Figure 2. The current method of aerial surveys and photographic documentation is, in principle, similar to methods used in adjacent areas of the west coast of Sweden, in the Wadden Sea, and in other areas as summarised by the International Council for the Exploration of the Sea (2003).

The Norwegian coastline is very convoluted with an outer coast fringed by numerous islands, islets, and intertidal rocks. The fjords penetrate more than 200 km into the alpine mainland. Some of the large fjord systems host resident populations of harbour seals. These populations are, in general, small and are separated by large distances from the more continuous distribution of seals at the outer coast. Some of these fjords constitute unique "ecosystems," and the seal populations

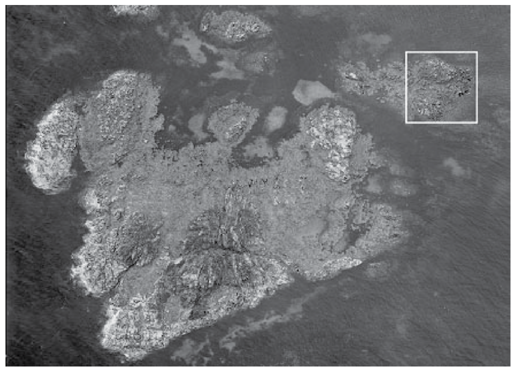

**Figure 1.** Black-and-white photographs of a typical rocky haulout habitat for harbour seals along the outer Norwegian coast; seals tend to haul out in the inter-tidal zone during low tide. The area within the frame is shown enlarged in Figure 2.

**Figure 2.** A detail of the haulout habitat of Figure 1 reveals 94 harbour seals after 8 x magnification and manipulation with light and contrast.

have a special conservation value. The topography (alpine landscapes with high risk of turbulence and other risk-associated factors such as electrical cables) makes aerial surveys in fjords difficult. Therefore, in some fjord systems with known haulout sites of harbour seals, the numbers of hauled-out seals were counted during moulting season from boats (inflatable boats with outboard engines). These counts were combined with aerial survey counts.

The Norwegian mainland coast stretches from 58° N to 71° N and the landscape is very complex. Geographic differences in topography, climate, and oceanographic conditions influence the associated marine fauna. Roen & Bjørge (1995), who studied differences in haulout behaviour of harbour seals along the Norwegian coast, demonstrated significant relations between haulout pattern, tidal amplitude, and diurnal differences in ambient light in Norwegian Skagerrak, western Norway, and Finnmark in northern Norway. Three marine coastal zoogeographic sub-provinces (Skagerrak, western Norway, and Finnmark sub-provinces; Figure 3) are defined for the Norwegian mainland coast (Brattegard & Holthe, 1997) and used in the draft Norwegian national plan for Marine Protected Areas (Anonymous, 2004). We used information on different haulout patterns (from Roen & Bjørge, 1995) within the three sub-provinces to estimate corrected abundance of harbour seals from observed seals hauled out at low tide. The number of seals hauled out at any time during low tide is only a proportion of the total population. Based on studies of the haulout patterns of freeze-branded harbour seals at the west coast of Sweden (adjacent to Østfold haulout sites in Table 1), Härkönen et al. (1999) developed an overall correction factor of 1.75 (i.e., in average about 57% of the total population hauled-out during counting) for estimating total population from observed hauled-out seals counted during low tide. This correction factor was first applied for the entire Norwegian coast; however, the proportion of the population hauled out at any time, as well as the age and sex composition of hauled-out seals, changes with area and season (Thompson & Rothery, 1987; Kovacs et al., 1990; Huber et al., 2001; Daniel et al., 2003; Jemison & Kelly, 2003). Therefore, caution should be made when extrapolating such correction factors to other areas. The Skagerrak sub-province is characterised by small tidal amplitude (average of 21 cm) and large diurnal variation in ambient light during August (59° N) similar to the study site of Härkönen et al. (1999). At Sør-Trøndelag (in the central part of western Norway sub-province), the tidal amplitude is larger (average 135 cm), and the diurnal variation in light during summer is less due to the higher latitude (64° N). In Finnmark (Kongsfjord, in the central part of Finnmark sub-province), the tidal amplitude averages 208 cm, and there is only minor variation in diurnal light during summer due to the Arctic location (71° N). According to Roen & Bjørge (1995), the ratio between seals hauled out at low and high tides was 1.3 in the Skagerrak sub-province (at Østfold, next to the study site of Härkönen et al. [1999]). The ratio between number of seals hauled out at low and high tides increased with increasing latitude and was 2.27 in Sør-Trøndelag and 3.0 in Finnmark (Kongsfjord). In the three study sites, the seals were monitored throughout 13, 14, and 15 complete tidal cycles, respectively (Roen & Bjørge, 1995).

We assumed that the ratio between number of seals hauled out at low and high tides recorded for Østfold is representative for an area where a correction factor of 1.75 (Härkönen et al., 1999) can be applied for estimating the total population from counted numbers of hauled-out seals. Thus, this correction factor was applied to the Skagerrak sub-province. This correction factor is likely less correct for the two other sub-provinces due to the conditions mentioned above (tidal amplitude and diurnal light variations). To get estimates of the regional correction factors for the two other zoogeographic provinces, we arbitrarily assumed that there is a linear relationship between the ratios of seals hauled out at high and low tides and the ratios between seals hauled out at low tide and the total population size. To calculate this regression, we also made the assumption that if zero seals haul out at high tide, the entire population hauls out at low tide. This arbitrary assumption has little biological significance, and it will generate a conservative approximation of the total population. The correction factors generated for the western Norway and Finnmark sub-provinces from this regression were 1.35 and 1.25, respectively.

## Results

A total of 7,272 hauled-out harbour seals were counted on aerial survey photographs taken during the period from 1996 to 1999 (Table 1). Adding the number of hauled-out seals counted from boats in fjords where aerial surveys were not conducted due to topography brought the total to 7,465 harbour seals.

Applying the correction factor of 1.75 to the total number of seals gave a population estimate of 13,064. With the exception of the regional estimate of the Skagerrak population of 613 seals, we regarded this as a likely overestimate due to the observed differences in haulout behaviour of harbour seals along the Norwegian coast.

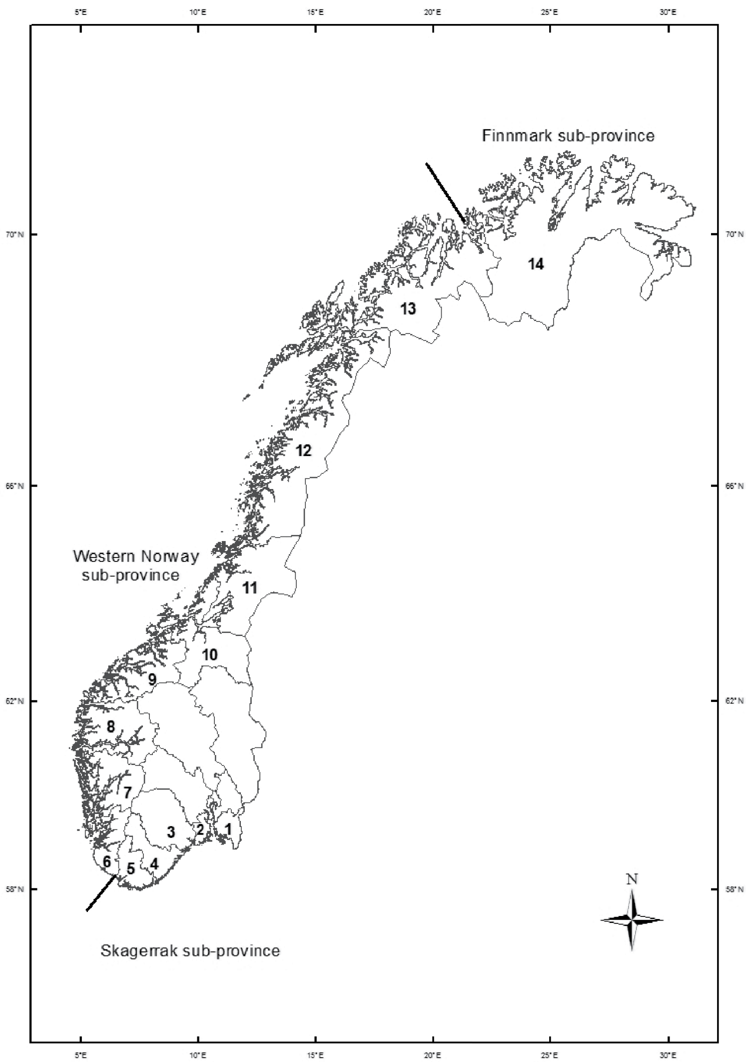


**Figure 3.** The Norwegian coast showing the three zoogeographic sub-provinces (Skagerrak, western Norway, and Finnmark) used for estimating abundance of harbour seals based on number of seals hauled out at low tide; the numbers on the maps relate to the counties covered by the survey (see Table 1).

Therefore, area-specific correction factors based on regional behaviour patterns were applied to the other two sub-provinces. In the western Norway sub-province, using the correction factor of 1.35, the population was estimated at 8,714. The Finnmark sub-province population was estimated at 826 harbour seals, using a correction factor of 1.25. Thus, using area-specific correction factors for the three zoogeographic sub-provinces, the estimated total population along the Norwegian coast was 10,153 harbour seals (Table 1).

## Discussion

Not all known haulout sites for harbour seals were covered by the surveys presented here. In particular, the eastern part of Finnmark sub-province (the Varanger area) was not well covered due to adverse weather during the survey period. It is unlikely that a complete survey in this area would result in a large increase in the number of counted seals, however. Øynes (1964) reported 180 harbour seals for the entire Finnmark County and claimed that the species had suffered a severe decline in this county. Bjørge (1991) reported 195 harbour

**Table 1.** Number of hauled-out harbour seals counted from aerial photographs along the coast of Norway during early moulting seasons, 1996 to 1999; numbers of harbour seals counted from boat-based surveys were added for fjord habitats where aerial surveys are difficult to undertake. For correction factors and estimate of total population, see text for explanation. Numbers in parentheses refer to location as coded on the map shown in Figure 3.

| County | 1996 | 1997 | 1998 | 1999 | Boat-based surveys | Best count | Correction factor | Estimated population |
|---|---|---|---|---|---|---|---|---|
| Østfold (1) | | | 176 | 289 | | 289 | 1.75 | 506 |
| Vestfold (2) | | | 35 | 61 | | 61 | 1.75 | 107 |
| Telemark (3) | -- | -- | -- | -- | | | | |
| Aust-Agder (4) | -- | -- | -- | -- | | | | |
| Vest-Agder (5) | -- | -- | -- | -- | | | | |
| Rogaland (6) | | | 417 | | | 513 | 1.35 | 693 |
| • Lysefjord | | | | | 96* | | | |
| Hordaland (7) | -- | -- | -- | -- | | | | |
| Sogn og Fjordane (8) | 292 | | 617 | | | 714 | 1.35 | 964 |
| • Indre Sognefjord | | | | | 48** | | | |
| • Nordfjord | | | | | 49*** | | | |
| Møre og Romsdal (9) | 871 | | | 1,072 | | 1,072 | 1.35 | 1,447 |
| South-Trøndelag (10) | | 690 | | 1,296 | | 1,296 | 1.35 | 1,750 |
| North-Trøndelag (11) | | 173 | | 44 | | 173 | 1.35 | 234 |
| Nordland (12) | | | | | | 2,129 | 1.35 | 2,874 |
| • Nordland, south | | 849 | | | | | | |
| • Nordland, north | | | 1,280 | | | | | |
| Troms (13) | | | 557 | | | 557 | 1.35 | 752 |
| Finnmark (14) | | | 661 | | | 661 | 1.25 | 826 |
| Totals | | | | | | 7,465 | | 10,153 |

* Bjørge, unpub. data, 1998; **IMR, Internal Report SPS9805; ***IMR, Internal Report SPS9806

seals for the entire county based on ground counts about 20 years later.

Most of the haulout sites were surveyed only once. Therefore, no attempt was made to consider the variance associated with the results. The correction factors used were based on the ratio of the number of hauled-out seals at low and high tides. The seals were monitored during 13, 14, and 15 complete tidal cycles in Østfold, Sør-Trøndelag, and Finnmark, and the mean numbers of hauled-out seals at low tide were associated with large coefficients of variance (i.e., 87.1%, 68.7%, and 54.3%, respectively) for the three areas (Roen & Bjørge, 2005). The declining coefficient of variation (CV), with increasing tidal amplitude at the study sites, supports the fact that the tidal cycle and the amplitude of the tide influence the haulout pattern of harbour seals. We assumed that the precision of survey results increases with declining variance of the mean number of seals hauled out at low tide; however, survey results were probably most vulnerable to stochastic disturbance immediately prior to the time of the survey. Disturbance at the haulout sites just prior to low tide contributed to the CV in all areas studied by Roen & Bjørge (1995), underlining the necessity of repetitive surveys for abundance estimation.

Because the methods used to survey harbour seals in Norway have changed over the last 50 years (Øynes, 1964, 1966; Bjørge, 1991; the current survey), it is not possible to interpret differences in reported abundance as accurate trends in population size. A comparison between ground counts and aerial surveys conducted in a small area on 21 August 1998 resulted in 43% more seals counted in the aerial survey (Bjørge & Øien, 1999). A similar experiment in a smaller area, but repeated on three successive days, resulted in a three times higher number of seals from the aerial survey compared to ground counts (Juel Gulliksen, 2001). The topography of the Norwegian coast where harbour seals haul out on a large number of relatively steep intertidal rocks can possibly contribute to these apparently large differences between results from different survey methods.

The population in the Skagerrak sub-province has suffered mass mortality due to the 1988 and 2002 Phocine Distemper Virus epizootics (Härkönen et al., 2006). In the eastern part of this sub-province (Østfold County), the mortality in 1988 was about 70% (Markussen, 1992). It is assumed that the population follows the pattern of recovery in adjacent Swedish waters as described by Härkönen et al. (2002). The epizootic was not reported to cause mass mortality in other parts of the Norwegian coast. The abundance of harbour seals in the western part of this sub-province (Aust-Agder and Vest-Agder Counties) remained low during the 20th century. Likewise, in Hordaland County in the western Norway sub-province, the numbers of harbour seals were low throughout the 20th century. Bounty hunting remained in force well into the early 20th century in these counties. Based on the pilot study to identify haulout sites prior to this aerial survey, there seems to be little sign of recovery in these counties since 1973 when harbour seals became legally protected in southern Norway (Royal Decree of 13 April 1973).

A new regulation (Royal Decree of 6 May 1996) allowed for quotas to be set in all counties in 1997. During the subsequent few years (up to 2001), the allocated quotas were coherent with an upper limit for removals suggested by scientists. In 2002, the politically decided quotas were about twice the maximum level recommended by scientists, and in 2005, the allocated quota was 989 harbour seals (Figure 4; Nilssen, 2006). The increased quotas were not always reached, but in 2006, a bounty system was introduced to encourage the hunt. Hunters get paid bounty for landed seals, and this system might encourage underreporting because hunters are reluctant to report shot but lost seals (because some seals sink in deep waters). In addition to the hunt, harbour seals along the Norwegian coast suffer high levels of incidental by-catch mortality in fishing gear. From 630 harbour seals flipper-tagged in the period from 1975 to 1998, 38 tags were returned from fishermen who reported that the seals were incidentally caught and drowned in fishing gear, and 15 tags were returned from shot seals. In addition, there were 27 tags returned with no information on the status of the seals or cause of death (Bjørge et al., 2002). These tag recoveries indicated that incidental by-catch mortality was higher than directed takes during that period. Preliminary results from recent monitoring of fisheries indicated that the by-catch mortality was in the low hundreds per year (Bjørge et al., 2006).

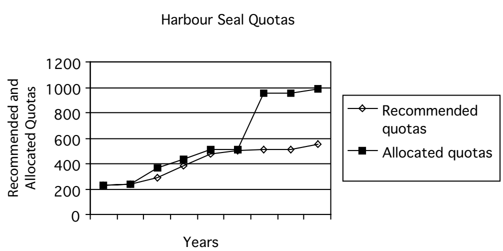


**Figure 4.** Maximum quotas recommended by scientists and actual quotas allocated by the Ministry of Fisheries for harbour seals at the Norwegian coast 1997 to 2005

The quota set for 2006 equalled 13% of the counted population and about 8% of our optimistic estimate of 13,000 seals. Even with the optimistic assumption of a population size of about 13,000 harbour seals, it is highly likely that the current level of anthropogenic removals is not sustainable (see Wade, 1998; Thompson et al., 2007). For a more conservative estimate of about 10,000 seals, the total anthropogenic removals are well above sustainable levels, and it is anticipated that the population will decline rapidly and that the species is at risk of extermination in some areas at the Norwegian coast unless the current management regime is changed. In the 2006 revision of the Norwegian Red List, the harbour seal was listed as vulnerable because of these high anthropogenic removals.

Due to the intensive hunting and high levels of by-catches, there is an urgent need for an updated abundance estimate of harbour seals in Norway and an improved survey method to monitor the population trends and the effects of the current management. The surveys presented here only had one photo-coverage per area and season. The number of hauled-out seals is very much affected by the degree of disturbance immediately before the time of the survey. Therefore, we advise that a number of repeated flights (see, e.g., Pitcher, 1990; Frost et al., 1999) are required to improve the reliability of abundance estimation and associated variances with the estimates. We suggest at least three repetitions, preferably spread over several low tides. Due to the very long and complex coastline of Norway, a complete coverage of the entire coast is very costly. More frequent surveys of selected transects might be a cost-effective alternative given that the population trends in selected transects are representative for wider areas. Modelling effects of tidal cycle and amplitude, wind direction, amount of ambient light, temperature, and precipitation might improve the reliability of abundance estimates (Frost et al., 1999; Boveng et al., 2003).

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