# Population development and status of harbour seals *(Phoca vitulina)* in the Wadden Sea

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## ABSTRACT

An index for the condition of a population should include a measure of the recuperative power or resilience of the population in question. This measure needs to cover both the demographic and physiological condition of the population. Applied to the harbour seal population in the Wadden Sea we therefore address respectively the population development and distribution, and its health condition, and relate these to environmental conditions. The harbour seal population has been severely depleted by hunting in the first half of the 20th century. After hunting was stopped in the mid-1970s the population recovered gradually. This recovery was twice interrupted by Phocine Distemper Virus (PDV) outbreaks in 1988 and 2002. These PDV-epizootics reduced the population by 57% and 50% respectively. They also lead to changes in age and sex structure of the population, which gradually returned to a stable age-structure. Despite the reduction in population size by respectively 57% and 50%, the population showed a strong recovery with a growth rate close to the considered maximum possible for this species. The observed changes in the distribution of the population over the 4 sub-regions indicate that distribution is not a static phenomenon. Long term field and pathological investigations point out that the general health status of the population has improved, particularly that of newborn seals (0-6 months old). The increasing prevalence of parasites in lungs and intestine warrants continued monitoring of the health status of seals. This is especially relevant in view of the exponential increase of the population, which may finally approach the carrying capacity of the area. Concluding, we can state that the condition of the population in terms of demographic and health parameters is satisfactory. The best guarantee for maintaining such a favourable conservation status is to abstain from human interferences (*e.g.* rescue, rehabilitation and release) with natural population processes. However, in practice there is increasing exploitation of marine waters. This requires a continuous monitoring of the potential impacts on the population, particularly of the effect on foraging and migratory behaviour.

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## INTRODUCTION

The Wadden Sea is a shallow coastal part ofthe south-eastern North Sea and covers about 8,000 km2. It is characterised by a row of barrier islands, and tidal flats in the area between these islands and the mainland. The Wadden Sea area includes the sub-regions Denmark, Schleswig-Holstein, Niedersachsen and the Netherlands.

Marine mammals to be regarded as indigenous species in the Wadden Sea are the harbour seal *Phoca vitulina,* the grey seal *Halichoerus grypus*, and the harbour porpoise *Phocoena phocoena.* Several other marine mammal species, both pinnipeds and cetaceans, occur in the Wadden Sea and adjacent North Sea, either as stragglers or regular visitors. Stranding records show that occasionally 5 other species of seals are encountered in the Wadden Sea area and adjacent North Sea. These are the harp seal *Phoca groenlandica,* the hooded seal *Cystophora cristata*, the ringed seal *Phoca hispida,* the bearded seal *Erignathus barbatus* and the walrus *Odobenus rosmarus*, which all have a more northerly distribution. Cetacean specimens documented on the Wadden Sea coast are the white-beaked dolphin *Lagenorhynchus albirostris,* the white-sided dolphin *Lagenorhynchus acutus*, sperm whale *Physeter macrocephalus* (Reijnders *et al.* 2005), and relatively recently the bottlenose dolphin *Tursiops truncatus* and the humpback whale *Megaptera novaeangliae* (Camphuysen and Peet 2006, Camphuysen 2007).

The intention of this chapter is to describe the condition of the harbour seal population in the entire Wadden Sea since hunting was stopped in the mid-1970s. Such a measure for population condition should include a measure of the recuperative power or resilience of the population. This implies that both the demographic and the physiological condition need to be covered. We apply this here by addressing the developments in abundance and distribution of the population, its health condition, and relate these to environmental conditions.

## DISTRIBUTION

**General distribution**

For a long time harbour seals were considered to be largely restricted to the Wadden Sea and adjacent North Sea coastal waters. At the end of the 1990s, the deployment of satellite transmitters on seals became available and shed a new light on the seals' distribution. It appears that irrespective of the season, the animals travel hundreds of kilometres away from their haulouts. Though still based on a relative restricted number of animals, it is nevertheless clear that the seals from the Wadden Sea use the North Sea much more than had been realised before (Fig. 1). One can hypothesise whether the seals' range may have changed compared to some decades ago, and if so, whether this is because of the exponentially grown population and/or in response to *e.g.* decreasing fish abundance. Future research will show how different areas in the North Sea are utilised and how foraging opportunities may influence the spreading of the animals.

**Relative importance of the four Wadden Sea regions**

The first epizootic somewhat changed the distribution of the population throughout the Wadden Sea regions. As shown in Table 1, in 1987, Schleswig Holstein housed most of the animals (43%), and still does so nowadays. The relative growth of the Netherlands' population, where by 2001, 20% of the total population was counted compared to 12% in 1987 is interesting. In particular, improved reproductive success has been noted in this region (Reijnders *et al.* 1997). Denmark apparently has lost importance. This is demonstrated by the lower than average population growth in Denmark from 1989 onwards. In addition, the total number dropped in 1999 below the 1998 level because of the relocation of a large group. Due to topographic changes several sandbanks disappeared. They harboured almost a quarter of all "Danish" seals, which moved from a haulout site just north of the Danish-German border into the Schleswig Holstein area.

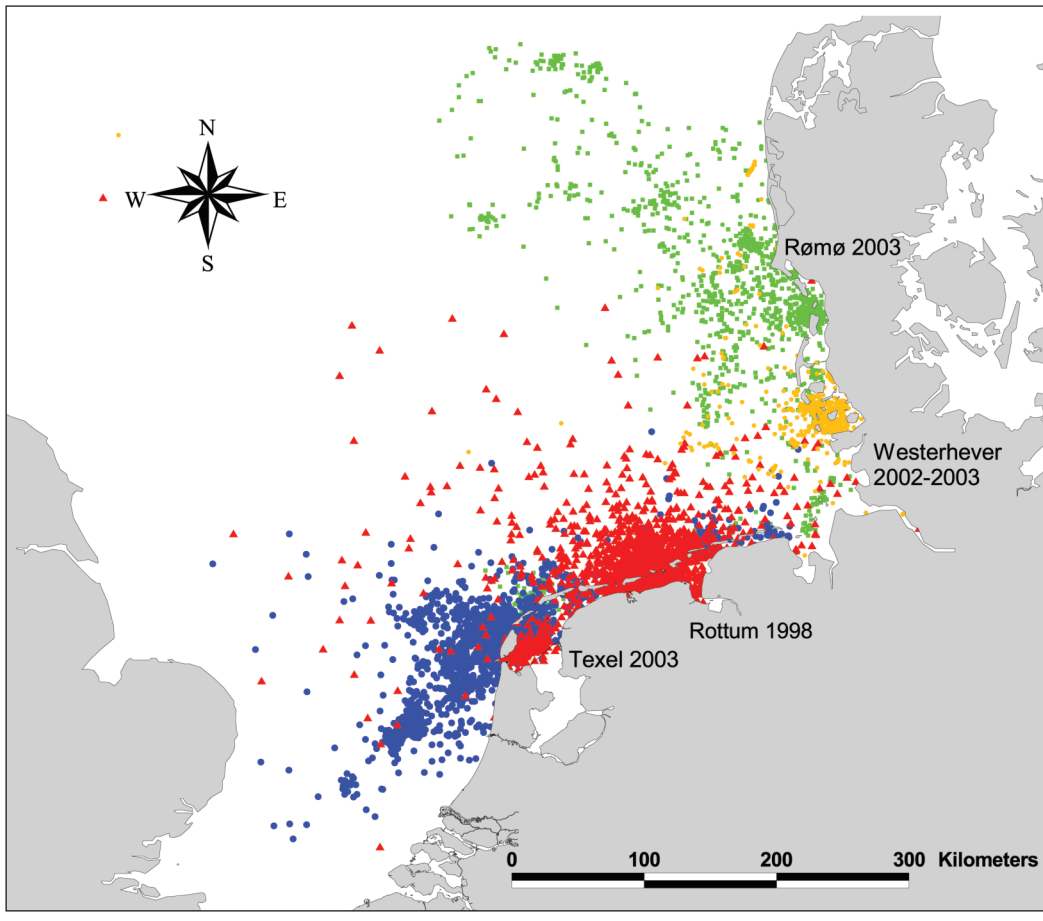


***Fig. 1.*** *Locations of harbour seals revealed through satellite telemetry studies. Blue: seals tagged close to Texel in 2003; red: seals tagged at Rottum in 1998; green: seals tagged at Rømø in 2002; yellow: seals tagged close to Westerhever in 2002/2003. Note that the tracking methods in these studies differed slightly; the map therefore indicates rather locations than representing the actual distribution.*

## DEVELOPMENTS AND TRENDS

In the last 3 to 4 decennia, 3 periods can be distinguished in the population developments. The period mid-1970s until 1987, the year before the first epizootic amongst harbour seals; the period 1988 until 2001, the year before the second epizootic, and the post 2002 epizootic until present.

**Development of the population from 1975 - 1987**

After the hunting - aimed at pups particularly-

**Table 1.** Distribution of the entire harbour seal population over the different Wadden Sea regions in different periods, based on counts during the moult (August).

| Year | NL | NS | SH | DK | Total count |
|---|---|---|---|---|---|
| 1987 | 12% | 28% | 43% | 17% | 8,296 |
| 1988 | 1st PDV-epizootic | | | | |
| 1989 | 13% | 28% | 38% | 21% | 4,000 |
| | | | | | |
| 2001 | 20% | 30% | 37% | 13% | 17,900 |
| 2002 | 2nd PDV-epizootic | | | | |
| 2003 | 22% | 28% | 39% | 11% | 10,817 |

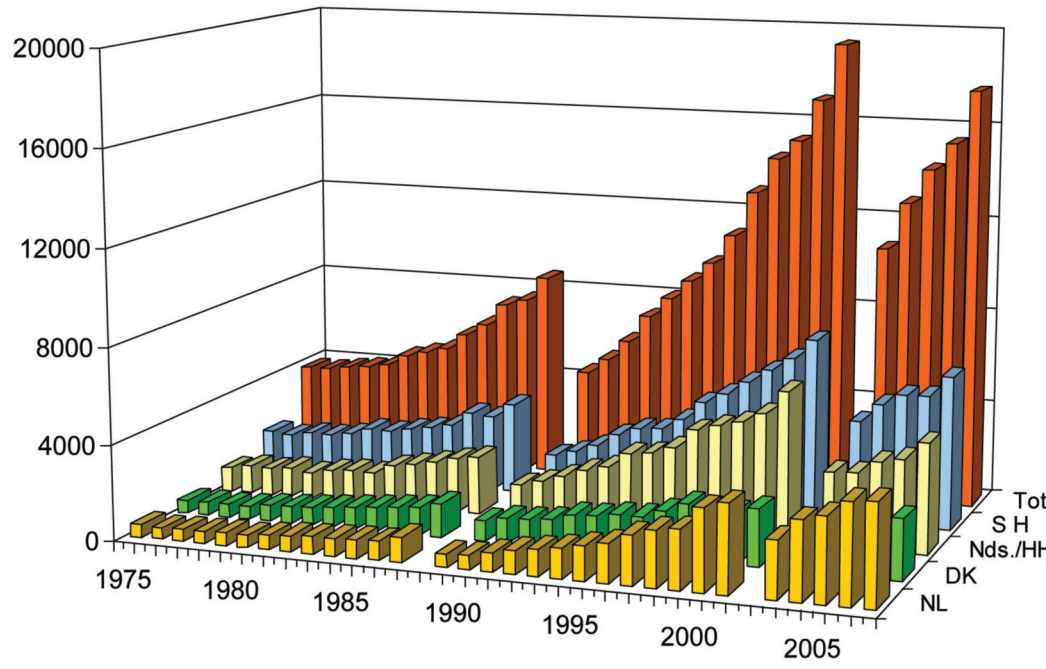


***Fig. 2.*** *Number of harbour seals counted in the different Wadden Sea regions: Denmark (DK), Schleswig Holstein (SH), Lower Saxony (Nds) and The Netherlands (NL).*

was banned in the mid-1970s in the entire Wadden Sea, the population started growing (Reijnders 1981). It was gradual in the beginning, but grew steadily until the first epizootic outbreak amongst harbour seals in 1988. Data obtained through aerial survey counts showed that the number of seals counted increased from 4,380 in 1975 to 10,425 in 1987. This represents an average growth of 7.5% per year (Fig. 3). However, in the first part of this period through 1980, the average annual increase was only 4.1% compared to 9.3% in the second part. This difference is considered to be related to an increased recruitment caused by the extra cohort of pups that were no longer hunted, and which when reaching the age of 4 years started to contribute to the population. The absence of disturbance connected to the ban of hunt during the pupping season, presumably lead to a better pup survival as well.

**Development of the population from 1988 - 2001**

After a disastrous Phocine Distemper Virus (PDV)-epizootic in 1988, killing approximately 57% of the population (Reijnders *et al.* 1997), the population recovered from some 4,400 animals counted in 1989 to more than a fourfold in 2001: some 18,000 seals (Fig. 2).

The population growth during these 14 years, averaging at 12.6% per year (Fig. 3), was close to exponential (Reijnders *et al.* 2003a). There were no signs of density dependence *e.g.* in the form of delayed population growth. Apparently, the carrying capacity (K) of the area had not been reached yet. The total population size in 2001 has been estimated to amount to at least 26,000 animals, based on a correction factor accounting for unobserved seals (Ries *et al.* 1998), and is considered well below *K*.

The ratio of pups counted to total number of seals counted remained fairly constant during the period 1990-2002, and averaged 0.216 (SD = 0.019). Before the epizootic (1974-1987) that ratio had been on average 0.163 (SD = 0.009).

It is likely that survival and fertility of seals in the Wadden Sea were at their highest possible

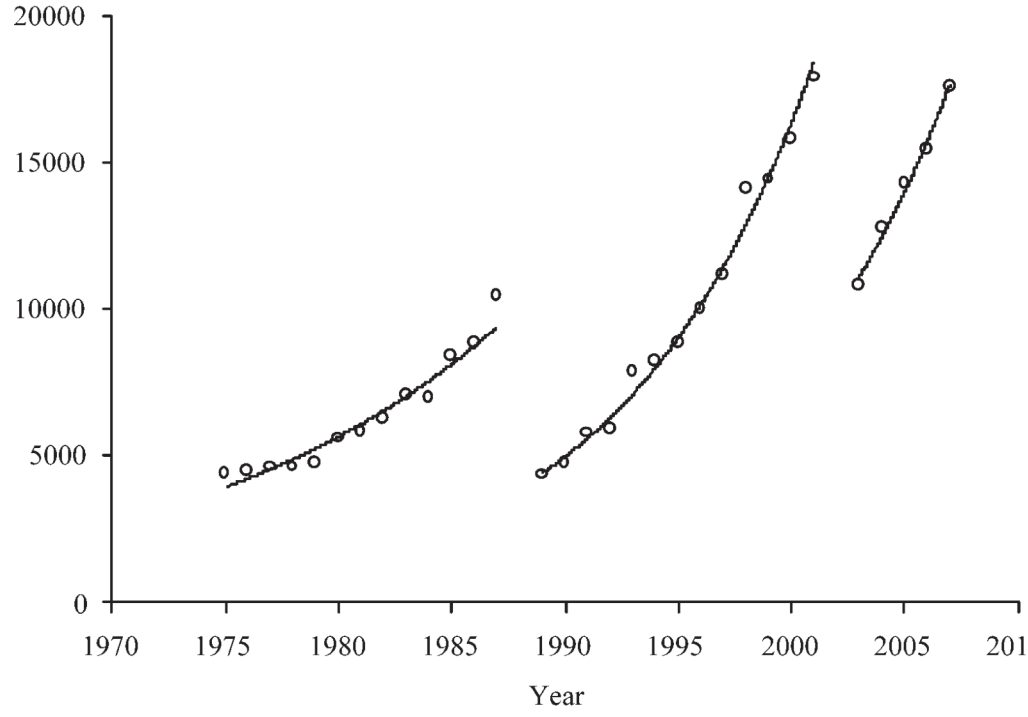


***Fig. 3.*** *Calculated population trend of harbour seals in the Wadden Sea ( ▬ ) for the periods 1975-1987, 1989-2001, 2003-2007, based on annual aerial counts (o) during the moult (August).*

values in the 1990s (cf. Härkönen *et al.* 2002). Therefore it is safe to conclude that from the population status in terms of demographic parameters, the population status of harbour seals in the Wadden Sea was satisfactorily. Compared to an annual decline of 2.8% in 1960-1973, it improved already to an increase of 7% per year from 1974-1987, and after the 1988 epizootic it further improved to an average of 12.6 % per year between 1989-2001 (Reijnders *et al.* 1997).

**Development of the population from 2003 - 2009**

In 2002 a second PDV-epizootic struck the population, and in the following year, only 47% of the expected number of seals (if no epizootic had occurred) was counted: 10,800 animals. This number is comparable to the population size in 1996. Interestingly, the average pup to total ratio in this period, 0.271 (SD = 0.0312), is much higher compared to 0.216 following the former epizootic. This offers good prospects for a quick recovery (Reijnders *et al.* 2003b). Indeed the surveys for 2003 - 2007 showed that the numbers counted each year increased on average with 12.3% per year, demonstrating a prosperous recovery to 21,571 counted animals in 2009, which is over the pre-epizootic 2002 level (Reijnders *et al.* 2009).

A comparison of the population trends for the 3 distinguished periods is given in Fig. 3. The calculated instantaneous growth rate λ is successively: 1.075 for 1975-1987, 1.126 for 1989-2001, and 1.121 for 2003-2009.

## IMPACT AND CONSEQUENCES OF THE MOST RECENT PDV-EPIZOOTIC

**Short term trends**

Nearly 50% of the harbour seal population in the Wadden Sea was killed during the 2002 PDV outbreak (Reijnders *et al.* 2003c). First of all, this means that population size was pushed again far below the carrying capacity of the area. Based on the currently carried out counts, we conclude that the stocks had

recovered to pre-epizootic levels by 2008. However, absolute population recovery (total population) may have actually taken less time. This assumption is based on the following. Demographic data from distemper victims suggest that mortality was disproportionately high in adult males, and lower in adult females. The surviving population had therefore contained initially an elevated proportion of mature females (about 40% instead of 30%). This has two effects: an observed elevated productivity, and for some years an underestimation of the actual population level. The latter phenomenon is elucidated by Härkönen *et al.* (1999, 2002). They showed that changes in age and sex structure lead to biased estimates of population biologic parameters, through age and sex specific haulout behaviour. Both effects are reflected in the unusually high ratio of pups relative to total number of seals counted between 2003 and 2009. The demographic structure will gradually return to stable proportions. However, for a limited period, an elevated productivity may prevail, resulting in elevated rates of population increase (about 14–15% per year) and underestimation of population level. That means that the pre-epizootic level has been reached earlier than the observed numbers would suggest.

**Possible trends in case of recurrent PDV outbreaks**

What future may be expected for the seal population regarding recurring distemper epizootics? It is clear that the recovery and subsequent growth to carrying capacity levels would be severely disturbed. The shorter the interval between two epizootics, the lower the long term population growth would be. Assuming that seals do not die from a second PDV infection while those not previously infected are subject to an average mortality of nearly 50% (as observed in the 2002 epizootic), it would be expected that the long term population trend will probably be positive at any interval length. The shortest possible interval is calculated to be 2 years, because only then there are enough susceptible animals around to start a new epizootic (Grenfell *et al.* 1992). However, this scenario should be taken with caution. Although knowledge of PDV characteristics (behaviour and pathogenesis) has improved, data on *e.g.* transmission rates, seal-individual infection susceptibility, influence of genetic makeup, are still scarce (Harding *et al.* 2002, Härkönen *et al.* 2006, Hall *et al.* 2006). Moreover, factors not taken into account here, *e.g.* changes in environmental conditions in the seals' habitat, may lead to different mortalities than expected (Härkönen *et al.* 2006).

## HEALTH CONDITION

Describing the health status of harbour seals is complex because it is influenced by many different factors and moreover can be expressed in a wide variety of physiological parameters. Investigations on the health status of seals in the countries around the Wadden Sea included examination of live and dead individuals. Post mortem examination, histology, immuno-histochemistry, microbiology, serology and parasitology were performed from the first epizootic (1988) until now. The respiratory and alimentary tracts were the organ systems displaying the majority of pathological findings. The prevalence of these findings is compared here for the pre-1988 period, the period between the epizootics in 1988 and 2002, and the period 2002-2005.

With respect to the prevalence of parasites in harbour seals in the lung, stomach and intestine, it is concluded that both lungworm and intestinal parasites infestations were higher between the two epizootics compared to the period before 1988, and that continued after 2002. Contrary, lower acanthochephalan (intestine parasites) and heartworm prevalence was found (Lehnert *et al.* 2007, Siebert *et al.* 2007).

The number of bronchopneumonia, gastritis and enteritis increased after the 2002 epizootic when compared to the period 1988-2002, which may be influenced by the 2002 PDV epizootic (Lehnert *et al.* 2007, Siebert *et al.* 2007). Bronchopneumonia due to parasitic and/or bacterial infections was the most common cause of death during both time periods. The frequency of septicaemia as the cause of death or severe health problems increased significant-

ly after the second seal epizootic (Siebert *et al.* 2007). Bacteria most frequently causing *bronchopneumonia*, *gastroenteritis*, *polyarthritis, dermatitis, hepatitis, pyelonephritis, myocarditis* and *septicaemia* were identified as *α/β-haemolytic streptococci, Escherichia coli, Clostridium perfringens, Erysipelothrix rhusiopathiae, Staphylococcus aureus* and *Brucella maris.* (Siebert *et al.* 2007, Prenger-Berninghoff *et al.* 2008, Siebert *et al.* 2009). A comparison of bacteriological findings in harbour porpoises from different regions of the North Atlantic revealed that organs from animals originating from Greenlandic and Icelandic waters showed clearly less bacterial growth and fewer pathological lesions associated when compared to animals from the German North and Baltic Sea and Norwegian waters (Siebert *et al.* 2009).

No case of morbillivirus was reported after 2002. But a recent outbreak of disease leading to increased mortality of harbour seals in Europe began in 2007, again on the small Danish island of Anholt and spread to other major seal colonies in the Kattegat and Skagerrak over the next months (Härkönen *et al.* 2008). Clinical signs of diseased seals and gross pathological findings were similar to those observed in 1988 and 2002. Clinical observations included a dorsally misshaped silhouette with intermittent hump formation in the shoulder region, and restricted movement. In the final stage, animals showed respiratory distress and hemoptysis (Härkönen *et al.* 2008). Preliminary histopathological findings of four seals displayed multifocal acute catarrhal bronchitis, chronic interstitial pneumonia, severe atelectasis, moderate follicular hyperplasia and acute lymphocytolysis. It was suggested that an unknown virus was most likely the pathogen causing the epizootic. As harbour porpoises showed similar pathological findings, a cross-species infection could not be ruled out (Härkönen *et al.* 2008).

In conclusion, the general health status of harbour seals in the Wadden Sea appears to have improved compared with earlier decades. In particular the health of pups (0-6 months old) has improved after 2002 (Siebert *et al.* 2007). However, the increasing prevalence of lung and intestinal parasites warrants continued monitoring of the health status of seals.

## ENVIRONMENTAL CONDITIONS OF RELEVANCE TO THE STATUS OF THE POPULATION

**Anthropogenic interactions**

Human activities potentially influencing the status of the harbour seal population include pollution, fisheries, shipping, tourist activities and more recently the developments of more industrial activities such as building and operating of windmill farms and gravel extraction. Hunting of seals phased out in all Wadden Sea countries between 1962 and 1976.

Compared to the situation described in the 1970's (Reijnders 1980), the tissue levels of the classical chemical compounds such as PCBs and DDT analysed in samples from 1988 have decreased by about 60% and 90% respectively (Reijnders and Simmonds 2003). In samples from 2002, levels of PCBs and DDT continued to decrease and were about 50% and 65% lower compared to the 1988 levels (Reijnders unpubl. data). Evidently those pollutants have significantly less impact on the seal population than before the 1988 epizootic (*e.g.* Reijnders *et al.* 1997).
With respect to the other aforementioned activities, some new information has become available (Tougaard *et al.* 2000, Tougaard *et al.* 2003). Without ignoring the importance of the other factors, we consider it as a priority to address the aspect of adequate food availability both in and outside the Wadden Sea. Besides linking seal and fish distribution in order to assess associations in occurrences, molecular techniques (*e.g.* fatty acid and stable isotopes analyses) should be applied, to generate a more direct way of assessing diet composition.

Though population development is very well recorded in the area, distribution and habitat use off the haulout sites are still only understood at the level of individual seals rather than at a population level. In order to assess the impact of, *e.g.* the development of large scale wind farms, information is needed on the rel-

ative importance of the different areas, including haulout sites, feeding grounds and migration routes. To date only very few studies have been carried out addressing possible impact of wind farms on marine mammals (Teilmann *et al.* 2006, Wollny-Goerke and Eskildsen 2008). With respect to disturbance, information on "dose and effects" of disturbance, and on possible habituation is needed. Only then will it be possible to estimate cumulative effects of different activities in some areas and to determine when and how these activities would further affect the carrying capacity of the area for the seal population. Phrased differently: we need to find a way to assess how many new activities like windmill farms and/or gravel extraction can seals sustain in addition to the existing human use of their habitat such as recreation and shipping.

**Rescue, rehabilitation and release**

Rescue of live seals and their subsequent release after rehabilitation, can have negative effects on the wild population such as the risks of introducing resistant pathogens and interference with natural selection processes. Based on the observed growth as well as condition (reproduction, health, survival) of the populations, it was decided in 1991 and reconfirmed in 1994, by the responsible Authorities of the countries bordering the Wadden Sea, that rescue, rehabilitation and subsequent release of seals is not necessary from a biological and management point of view. The actual statements on this issue in the text of the "Seal Agreement" concluded under the Bonn Convention by the trilateral countries are: "The Parties shall prohibit the taking of seals from the Wadden Sea" (Seal Agreement Art. VI.1), but "the competent authorities may grant exemptions from the prohibition" (Seal Agreement Art. VI.2). The Seal Agreement text (Trilateral Wadden Sea Cooperation (CWSS)) and aforementioned decisions on rescue, rehabilitation and release can be found in CWSS (1996).

According to the Seal Management Plan 2002: "the number of seals taken from and released to the Wadden Sea should be reduced to the lowest level possible" (Trilateral Seal Expert Group-plus, 2002). This principle is translated into national legislation, which differs considerably between the trilateral countries: Denmark has forbidden rescue and release whereas it is at the highest in the Dutch part of the Wadden Sea. A future analysis of the data series regarding seal takes after 2002 will show if the implementation of the individual state agencies guidelines for handling seals resulted in a significant reduction of the number of animals taken, rehabilitated and released per total numbers in the respective (sub)populations.

Rehabilitation and release of seals on a very small scale can have a positive spinoff in terms of education and public awareness. However, given the fact that the primary objective in the management policy for the Wadden Sea is to achieve a natural and sustainable ecosystem in which natural processes should proceed in an undisturbed way, large scale rescue and release of seals can never be justified by connected socio-economic benefits whatsoever.

According to the SMP, all dead animals that are collected should be recorded in a database containing a trilaterally agreed minimum number of parameters to be measured, and forwarded to the responsible state agencies. Data collected should at least include: number, date and place found, length, age and sex. Together with post mortem examinations these data will assist in evaluating the health status of the population. It is essential that search effort is recorded as well.

## CONCLUSIONS

After hunting - particularly aimed at pups - was banned in the mid-1970s in the entire Wadden Sea, the population started growing, gradually at the beginning, but then steadily until the first epizootic outbreak amongst harbour seals in the Wadden Sea in 1988. After a prosperous recovery from that first PDV-epizootic, the harbour seal population in the Wadden Sea received another serious blow in 2002. Again a seal virus (PDV) struck the population and in 2003 the number of seals was only 47% of what was expected if no epizootic had occurred. Pup production (number of pups counted per total number counted) between 2003 and 2009 was higher than before the epizootic. This can partly

be explained by a skewed age and sex composition of the surviving population. The demographic structure will presumably return gradually to a stable composition. Continuation of the close monitoring of the population will enable assessment of its further recovery and future developments.

Recent research using satellite telemetry to investigate habitat use of harbour seals revealed that seals use the North Sea to a much larger extent, in terms of numbers as well as range, than thought before. It is therefore considered of importance to intensify studies focussed on foraging ecology (including diet composition and feeding grounds) to identify critical habitats for this species in the North Sea.

The increasing exploitation of marine waters by humans causes a new concern. In particular the booming wind farm industry in the North Sea, and to a lesser extent gravel extraction, may pose potential threats to harbour seals through interference with foraging and migratory behaviour. This issue is considered a research priority as well. A promising approach is to follow a 2-ways research track: a retrospective study to find out whether and how population changes can be related to changes in the environment (natural as well as human-induced), and to start collecting baseline data on population characteristics and environmental conditions, before new activities commence or existing ones are intensified.

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