Windpower and Grey Seals:

An impact assessment of potential effects by sea-based windpower plants on a local seal population

by

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Summary

The impact of five sea-based windpower plants on two haulout sites for grey seals on south-western Gotland, in the Baltic Sea, was analysed. Data on seal numbers was collected on a regular basis during the initial stages of the project from summer 1996, continuing during the building (autumn 1997) and running of the windpower plants (from spring 1998) until the end of June 1999. Additional observational data from earlier years was also available.

Indications of lower occurrence and reduced number of seals in the area was found during periods of time in 1997 and 1998, times of construction and active running of the plants. However, no evidence on the windpower plants, per se, affecting the grey seals was found. Instead, several weather factors were found to affect the number of seals in the area, and periods of low occurrence and number of seals were more likely explained by i.e. unfavourable water levels and hard wind from certain directions. One important, short term, impact factor was however found. Human induced disturbances such as boat and helicopter traffic, some which were directly related to maintenance of the windpower plants, temporarily reduced number of seals and made them more restless. Disturbance thus constitutes a potential threat to seals.

A shift from one to the other of the two haulout sites was also noted, a shift which likely is due to disturbances. Future guidelines are given, including some restrictions in movements near the haulout sites. Continued observations and studies are suggested if more off-shore windpower plants will be raised in the area. A call for more stringent use of environmental impact assessments is thus made. Also, suggestions on measures to be taken in order to reduce the effect of human related disturbances are made. In order to create sustainable conditions for a continued population of seals in the area and in order to create opportunities for a reestablishment of the grey seal in the southern Baltic region, continued protection of the haulout sites in Burgsviken is essential.

Uppsala in December 1999

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Introduction

The Baltic Sea, including the Bothnian Bay and the Gulf of Finland, is within the distribution limits of three species of seals, the grey (*Halichoerus grypus*), ringed (*Phoca hispida*), and harbour seal (*Phoca vitulina*). Although formerly abundant in the Baltic region, the populations of all three seal species have undergone drastic declines during the 20th century. The grey seal is believed to have been very numerous a hundred years ago, with estimates of a population size of 100,000 individuals (Almquist et al. 1979, Hårding & Härkönen 1999). In the early 1970s the Baltic population was estimated to be as low as a few thousand individuals (Hårding & Härkönen 1999). There are likely many and interdependent reasons for the decline, but a strong hunting pressure, over fishing by humans and severe effects by pollutants are frequently quoted as important factors (e.g. Jenssen et al. 1969, Helle et al.1976, Olsson et al. 1992, Jenssen 1996). Due to the decline seals were protected from hunting in Sweden in 1974 (HELCOM recommendation 9/1). All Baltic seal species are classified in the Swedish Red Data Book (Ahlén & Tjernberg 1996), as vulnerable.

During the last decades the grey seal has shown signs of a population recovery. Population counts in 1999 yielded an estimate of at least 7,500 individuals in the Baltic (Baltic Seal 99). Other sources suggest a population size in the region of six to ten thousand individuals. This increase in population size has been most prominent in the northern Bothnian region, whereas in the southern Baltic the population has remained constant on a low number with only weak signs of recovery. The grey seal is still only a casual visitor in the southern Baltic area, such as in Poland and Germany where it formerly reproduced, but reintroduction programmes have been started. The reason for the absence of a recovery in the southern Baltic region is unknown. Seals are often killed in by-catches in fishnets, but this will not explain the regional differences (Baltic Seal 99). In the absence of a hunting pressure other reasons such as lack of adequate food resources and remaining high levels of pollutants have also been proposed. However, there is little evidence for these alternatives although there are signs of slower regress of pollutants in the Baltic proper (Bignert et al. 1999). Curry-Lindahl (1975) suggested that disturbance may have serious consequences for local populations and cause major "congregations" of grey seals to disappear, or be able to colonise, at certain sites. The southern Baltic region is a highly populated region with intense boat traffic, both leisure and commercial, and with high intensities of tourism along many parts of the coast. Seals are known to favour secure and isolated rocks and shores to haulout, and such sites may be in short supply in this southern Baltic region.

Seals are marine animals but spend considerable time on land (hauling out). This time is important for rest, and of paramount significance during moult (change of fur) which in the Baltic occurs in May and early June. The birth of young grey seals takes place on ice but also on land (Hook & Johnels 1972, Helander 1998).

Some of the southernmost haulout sites in the Baltic Sea still persist on the island of Gotland, where two out of three sites are located on the south-western part of the island. These two sites are unique, as they are located unusually close to the mainland. Clearly, the grey seal populations around Gotland may form a corner stone in a future recovery of the grey seals in the southern Baltic. Hence, good protection of these haulout sites is essential.

Windpower and windpower plants

The use of windpower has become an interesting source of energy. A continuous improvement in technique has opened up for the establishment of ever larger windpower plants (i.e. wind turbines) with production of energy competitive in comparison with more conventional production of electricity. Along with political intentions, a need of clean energy sources and for compensatory electric production, an increasing use of wind power is to be expected.

In Sweden, windpower has attracted increased attention in recent years. The first windpower plant was built in 1983, whereas constructions at a larger scale took place in mid 1990s, facilitated by governmental subsidiaries. Installations of new plants have continued according to information from the Swedish National Energy Administration (STEM) and Elforsk AB (Ltd.) (research and development by the Swedish Power Association, the Swedish Electricity Suppliers and the Swedish National Grid). The yearly reports of 1998 (STEM report ER 6:1999) show an increase from 348 plants to 428 by the end of 1998 (appr. 25% increase). The majority of the new plants had an effect of 600 kW, or more. From the monthly report of October 1999 (http://www.elforsk.se/varme/varm-vind.html) the number of installed plants had increased to 460, with a total capacity of 202 MW.

During the last years several governmental investigations and reports considering the suitability and opportunities for windpower have been produced (e.g. SOU 1988:32, SOU.1998:152, SOU 1999:75). In late 1996, STEM (formerly NUTEK) commissioned county administrations and authorities to investigate possible locations of sites suiTab. for large scale establishment of windpower. Along with meteorological data (the Swedish Meteorological and Hydrological Institute) several new localities for windpower were suggested, with more to come, with a majority being located along coasts or at sea. Naturally, the favourable wind conditions along coasts and at sea makes such sites particularly interesting for wind power locations.

In mid 1990s, the first plans of truly sea-based windpower plants in Sweden were formulated. Vindkompaniet, a Swedish windpower plant company based on Gotland (now a part of the NEG Micon group), applied for building permits to construct five sea-based windpower plants off the coast on south-western Gotland. Necessary authorisations for the plants were granted in 1996, but imposed with certain restrictions. These conditions were set by the Water Court (at the district court in Stockholm, and with special jurisdiction over disputes concerning the uses of water), and Gotland County Administration (Environmental unit). In particular, some restrictions were impaired in consideration of the potential influence of the windpower plants on local seal populations in the area of concern (Appendix 1). Vindkompaniet thus was claimed to make regular seal counts, visual observations and video recordings of the seals before, and during construction and subsequently some time during the running of the windpower plants. Such a study could potentially form a sufficient base for a future environmental impact assessment (EIA) study on the impacts of windpower plants on local seal populations. Consequently, the seal observations made have basically covered the periods of test drilling (October 1996), of drilling and construction of the five plants (late August to mid November 1997) and of running of the plants (from late March 1998 to June 1999).

Windpower and their environmental impact

The impact of windpower plants on the environment has to some minor extent been under study (e.g. SOU 1999:77). Especially, impact on birds have gained some attention (e.g. Montes & Jaque 1995, Guillemette et al. 1997). This includes the effect of disturbance under different situations, possible negative density effects and reduced reproduction and possibility of movements in the vicinity of windpower plants. Little or no negative effects are the general findings (Clausager & Nøhr 1995, Guillemette et al. 1997, Tydén et al 1998). It seems as if larger groups of plants more clearly show an impact and more easily detected problems (e.g. Orlof & Flannery 1992 in Montes & Jaque 1995, Kruckenberg & Jaene 1999, but see Percival & Percival 1998). A second issue concerns the risk for bird to collide with windpower plants. Again, birds have been found or modelled to risk collisions to some level, but results so far indicate low or little impact (Winkelman 1992, Dirksen et al. 1996, 1998). Additionally, some research has been directed to improve techniques such as to reduce impact on the environment (e.g. Tucker 1996a, b). Studies on large scale migratory bird movements in areas of planned windpower construction are still restricted to two pilot studies (Pettersson & Lindell 1998, 1999), but revealing potential of a massive negative impact.

The effect on mammals is hardly studied at all. Some unconfirmed studies on domestic animals are supposed to have had no impact by windpower plants (in SOU 1999:75). Finally, the effect on marine animals, and mammals in particular, in relation to sea-based wind power is practically unknown, partly because this is a new problem. The only studies, so far, are from Denmark where the impact of 10 off-shore windpower plants, located in Århus Bay, have been investigated (Guillemette et al. 1997, 1998). They found no or only weak effects on the local bird life, mainly sea birds and ducks resting in that area.

In general, investigating general impacts of windpower plants on the environment are faced with several problems. First, there are clear difficulties in obtaining results from earlier studies. This is partly due to that many of these studies are unpublished consult reports and therefore often not available to a general public. Referring to such studies is of great importance but will often rely on hearsay, making critical analyses of these studies impossible. Most studies until today have been performed around single wind turbines, or on groups up to a dozen, which is a second problem. Considering the plans for constructing wind power plants for the 21^{st} century, which at this point often include several hundreds of 100m high plants in parks, will make most earlier studies incomparable. Finally, the most frequently adopted EIA's (e.g. Underwood 1992, 1994), so called BACI (before, after, control impact), often requires relatively long time studies along with control sites. To undertake fully acceptable EIA'a thus requires a good portion of foresightedness, allowing long time s EIA studies.

In this impact study, thus, we deal with the potential impact of five sea-based windpower plants on two haulout sites for grey seal, located off the coast of south-western Gotland, Baltic Sea. The analysis mainly concerns the potential influence of the windpower plants on the seal population, i.e. possible impact by the windpower plants per se, and impact originating from activities related to the construction or maintenance of the plants. Based on the observational material available, a "before – during – after" study could be performed, where observations before the construction may function as a control. As the number of seals in an area were likely to fluctuate for several reasons, a thorough analysis of other extrinsic parameters, such as meteorological data, was included in our analysis. Finally, direct behavioural observations were added, in order to use behaviour, as an indicator of possible disturbance, and as behaviour can be a useful tool in detecting environmental stress (Shumway 1999).

Methods

Study area

The five windpower plants, "Bockstigen", are situated at the debouch of the bay of Burgsviken, on south western Gotland (57'02''N, 18'08''E, Fig. 1), Sweden. They are built in shallow water (appr. 7 m depth) and formed in a V-shaped pattern, with the tip pointing south-west. The two haulout sites, Killingholm and Näsrevet are within 2.5 km and 1.5 km, respectively, from the nearest plant.

The two haulout sites differ in some respects but are most certainly visited by the same seals, or seals from the same sub-population. Killingholm is an approximately 25 m long and narrow (ca 8 m) rock just off the coast south of Burgsviken, and only separated from the mainland by ca 50 m open shallow water. At Killingholm, counts and observations were possible from the shore north of the site (appr. 800m distance), or just inshore of the rock where a small pine groove constituted sufficient cover for close observations (ca 100m), without disturbing the seals. Näsrevet is a reef-like group of smaller rocks, formed at the end of an extension of the cape of Näsudden, and several smaller islands, west of the village Burgsvik. Observations of seals on Näsrevet were most often done from a small nearby island that was reached with boat, and where the seals could be observed from a distance of ca 250m. On days with windy weather the island could not be reached and

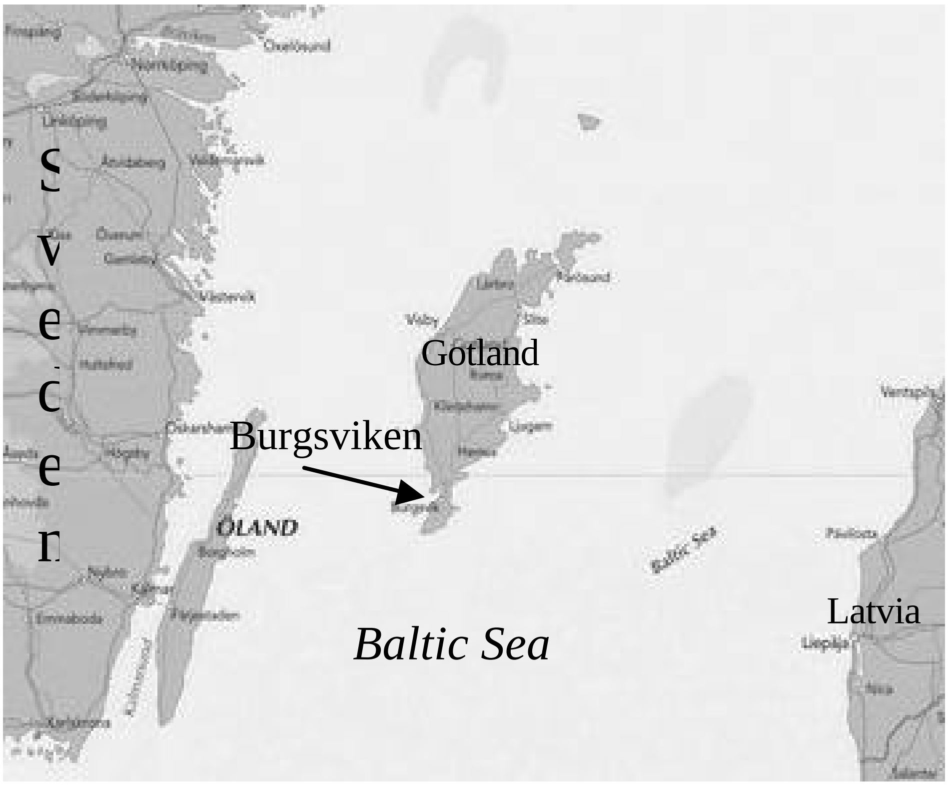

Figure 1. Map over the southern Baltic Sea, including the island of Gotland and denoting the site at Burgsviken.
Karta över södra Östersjön inkluderande Gotland och Burgsviken.

observations from land, using telescope (30X) was the only possibility. During the summer of 1999, behavioural observations and counts were made from the same island where the base of a lighthouse functioned as a base. The seals showed no apparent behavioural signs of disturbance towards our presence on the island but sometimes they reacted on the boat upon our arrivals and departures. Näsrevet is a bird refugee, with restrictions of landing on the island during spring and summer. Permit to land was obtained from the local authorities on Gotland.

Seal counts and observations
Seals have been counted and registered in the area since the early 1970s and Burgsviken is one of several localities included in an international program for monitoring seals in the Baltic. In Sweden, count of seals at traditional haulout sites has been programmed under the Swedish Museum of National History, as a part of a general monitoring programme, since mid 1970s (Helander & Lundberg 1998). From mid 1980s counts on Gotland have been performed at a more regular basis. Hence, observations prior to 1996 were either counting from land or boat, and occasionally from plane. Observations before 1996 were included in our analysis to a minor extent and then as an approximation of earlier population development.

Seal observations and counts, according to the conditions set upon the windpower project, started in June 1996 (see Tab. 2a-c for details on observation frequencies). These observations were set up as to monitor both of the haulout sites simultaneously, by two observers, in order to avoid double counts in case of seals moving between the sites. Thereby, countings were in most cases available from each of the two sites, separately, and a total count for the whole bay area was then obtained.

In some instances, in 1996 and 1997, a few days of observations were from one site only, or observations were not made simultaneously at both sites. A total count was hence not obtained. In a few cases, we increased the number of total counts by combining counts from Killingholm and Näsrevet for some dates when total counts were missing but observations from the two sites, respectively, were within 2 hours. Although seals may have been double counted by doing this, we considered this likelihood to be small based on our own observations of seal movements in 1999.

Time of observations for the regular counts (1996-1999) were from the early morning hours (see Appendix 1, requirements for observation protocol). During the darker months of the year (October to Mars) observations were done between 06.30 and 10.30, and during the rest of the year between 04.30 and 08.00. Hence, observation time was standardised to approximately two hours after sun rise and in our analyses a few observations made during later parts of the day were omitted.

Counts of seals were divided in two categories, number on land and number in water, adding up to a total count of seals at each site, respectively, and a total count for the whole bay area. These counts, seals on land, in water and total count showed strong significant positive relationships[1] (for superscript see further, Appendix 4), the number of seals on land usually accounting for more than 80% of the total count. Analyses of seal numbers, and factors affecting number of seals in the area, will mostly consider the total number for the whole area although in most cases, when differences between the sites were found, results from each of the two localities will be presented. When we analysed the number of seals hauling out, and factor related to haulout patterns, we only included seals counted on land.

The extended behavioural observations, made in summer 1999 (June 10 to July 7), were done at different times of day and lasted between 4 and 8 hours a day. Counts of number of seals during these observations were only included in the count data if they were obtained in the early morning hours (see above). Hence, these observations were done at a higher frequency than appears in some of the presentations. In fact, at Näsrevet seals were observed during every observation effort whereas at Killingholm observations decreased over the period. In spite of many observational attempts, seals were very rarely observed at Killingholm after June 20, wherefore most behavioural observations refer to Näsrevet. Behavioural observations included close classifications of the following behaviour: 1) resting on land; a seal peacefully resting with head down, 2) looking around; a seal with the head up apparently being observant, 3) vigilant; a seal that was paying attention to something more particular, head raised high up. The behavioural observations were done either as a) a close observation of one or a few seals within a larger group, where individual behaviours were recorded every 20 seconds during 10 minutes, or b) a whole group was scanned every 10 minute. The latter observations generated data on relative frequencies of the behaviours. In some cases, when number of seals exceeded 30, an observation took longer time and scans were done every at 15th minute.

Weather data

Seals are well known to vary in number according to several different parameters, including disturbance (Allen et al. 1984, Pauli & Terhune 1987, Teilmann 1992) and variable weather conditions (e.g. Pauli & Terhune 1987, Watts 1992, Grellier et al. 1996, Sjöberg 1999). Accordingly, several sets of meteorological data was used in our analyses. First, during the seal counts over the years the following data was recorded: wind direction in a 16 graded scale (e.g. NW and SSE), wind speed in m/sec, cloud cover and general weather conditions (i.e. cloudy, clear, foggy) and water level in a three degree scale (low, normal and high). These observations were estimated in the morning when the seal observations were done and thus reflect the current situation during the observations. However, at times and due to the close proximity to the meteorological station at Hoburgen (southern Gotland), meteorological observations were sometimes obtained from there, too, thus creating some inconsistencies. Second, during the drilling and construction of the five windpower plants, data was extracted from the logbook of the construction company (Seacore Ltd, and obtained through Vindkompaniet). This set of weather data contained information on wind direction and wind speed (as above), general weather conditions but also data on wave heights which was recorded at the beginning of the morning shift, around 08.00. Third, a large set of data was bought from the Swedish Meteorological and Hydrological Institute (SMHI). This information was derived from the nearest meteorological station, Hoburgen, on the southern tip of Gotland, 8 km and 11.5 km south of Killingholm and Näsrevet, respectively. This data included temperature (in C), air pressure (kPa), precipitation (mm), wind speed (m/sec), and wind direction (to the nearest 5 degree, i.e. N=0, E=90^{o}, S=180^{o}). All these observations used were from 06.00 apart from data on wind speed and wind direction, which also was obtained from 03.00. However, both these variables showed very high resemblance between 03.00 and 06.00 and the latter time was used consistently. The different meteorological data was cross-analysed in order to check for eventual differences and to obtain the best possible data set for the local conditions.

Data on absolute water level was also bought and used by permission from SMHI. Absolute water level was calculated from a station outside Visby, western Gotland, and approximately 66 km north of Burgsviken. The measure of water level we thus used is the a value of actual water depth in a local height system at Visby, based on 30 years of measurements (SMHI). This data can not be used as a precise value of the water level in Burgsviken. However, the relative closeness between the localities will validate the use of this measure on local water level conditions at Burgsviken. Corrections for land rise were not made. Land rise is a post glacial phenomena in Scandinavia but is less than 4 mm/year on Gotland and thus negligible considering the few years of observations included in the analysis and the much greater variation in water level caused by other meteorological factors. Likewise, tide do occur in this region to a very small extent, but is not of importance compared i.e. variation related to weather, and is thus neglected. Water levels was also noted by the seal observers, classifies as low, normal or high levels, and based on local experience.

Windpower and disturbances

The effect gained from the windpower plants was highly related to wind conditions[2] (Appendix 4). Therefore, wind speed per se could be used as a measure of their activity, unless temporarily at stand still. In order to test the potential effect of the windpower plants on the seal numbers, data on their running were obtained in two ways. First, during the observations in summer of 1999, we recorded the number of windpower plants running at each seal observations, i.e. every 10 or 15 minute. We then analysed eventual differences in seal numbers in relation to number of plants running. As all five plants were running only in one of the days, we categorised number of plants running from 0 to 4. Secondly, during the initial stages of our analysis we looked for two-week periods of time, of which one week was a period with high seal numbers and the other week with low numbers. In all, we found 9 two week periods (1998: end of March-early April, mid April-late April, late May-early June, late June-early July, early-mid August, early-mid September, early-mid October 1999: late April-early May and late May-early June). Thereafter, data on the produced effect (W) by the plants and average number of plants running during these periods were asked blindly from Vindkompaniet, i.e. without their knowledge of seal numbers in the actual periods in question. The produced effect was obtained from the local energy distribution company (GEAB) whereas Vindkompaniet calculated the average number of plants at work for each particular day. Other instances we recorded during summer of 1999 included presence of nearby boats, people etc. which was noted along with approximations of distance between seals and source (Appendix 2). In one analysis we separated disturbances into four categories, 1) sailing boats, 2) small motor boat, 3) larger motor boat, and finally 5) air planes and helicopters. Additionally, seal observers in earlier years noted some events on disturbance during seal counts (Appendix 3). These notes on disturbances and the effect on seal numbers were analysed.

A last set of data analysed was obtained from the log book of the construction company during drilling and building of the wind power plant during autumn of 1997. This data gave information on the work activity during specific days and nights. This activity measure was classified as 1) when the platform was present but no crew and no activity took place and 2) when crew was onboard but no activity was taking place. Category 3) was used when at least some activity was noted in the log, e.g. maintenance etc, and 4) when full activity could be interpreted, e.g. drilling or raising of fundaments. During night shifts, due to more sparse notes, only category 1 to 3 was used. The activity data was used a disturbance index where a higher categorical value indicated higher influence of disturbance. To some degree these values also did reflected transports by boat to and off the platform. Finally, in order to get an estimate of the 24-hour activity, categories obtained from day and night were subtracted, thus producing a 6-degree activity scale of the work at the platform.

Observational aid

During all observations binoculars (8x or more) were at hand. Counts and behavioural observations were done with help of telescopes (30X or 32X magnification). More than 30 hours of video recordings were taken between 1996 and 1999. These were requested in order to record special events, especially disturbances, according to the construction permits (Appendix 1), resulting in 8 occasions of recorded disturbances. However, in spite of the fact that they were recordings of disturbances, and of seal reactions in relation to those, they could not be compared or added to data obtained during summer 1999, and further analysed. This was mainly due to lack of necessary information belonging to each sequence, which could not be obtained. These video recordings were, however, in line with our findings in summer of 1999. During our observations in summer 1999 we used two video cameras in order to help keeping notes on numbers and behaviour.

Statistics

Tests and procedures will be presented separately in Appendix 4, where numbers in superscript appearing in text thus refer to respective test and result. In the text we will only present the generality of the results, as being significant ($P<0.05$) or non-significant ($P>0.05$).

With a few exceptions, all statistical analyses were performed on SAS (SAS Institute 1989). The data at stake, presence/absence of seals and number of seals, along with a great majority of external data, were not normally distributed but in some cases data could be transformed (log- or arcsin-transformation). Data of seal number were in many cases Poisson- or negatively binominally distributed. In such cases we used log-linear models or general models (SAS Inst. 1989, Stokes et al. 1995, Littell et al. 1996). Also, non-parametric tests were used I. In a few cases, in spite of possible violations, (ANOVA) General Linear Models (SAS Inst. 1989) were used, as GLM is rather robust against differences in variance and slightly skewed distributions of data.

Results and discussion

Presence/absence of seals and seal numbers

Based on all recorded observations available we found that the likelihood of observing seals in Burgsviken varied seasonally (Tab. 1). The highest chances of spotting seals were between April and October and the lowest during January to March. Moreover, there was a clear difference between the two haulout sites, Näsrevet showing a significantly higher probability of observing seals for all months[3]. From these figures, we suggest that seals are always present in the area from April to October whereas seals are at least regular in the area during the winter months, sometimes in greater numbers.

Table 1. Monthly overview of number of years with grey seal observations (1973-1999), number of observations over the years, days with grey seals found and percent days when seals were found. Data from Killingholm and Näsrevet, respectively.
Månatlig översikt av antalet år med gråsälsobservationer, antalet observationsdagar, antalet observationsdagar med säl samt den procentuella andelen dagar då säl påträffats. Data uppdelat på Killingholm respektive Näsrevet.

	Killingholm				Näsrevet			
Month	Years with obser-vations	Number of observation days (all years)	Days with seals	(%) Seal observations/ obs. day	Years with obser-vations	Number of observation days (all years)	Days with seals	(%) Seal observations/ obs. day
January	2	23	0	0	3	24	4	0.17
February	3	24	3	0.12	3	21	4	0.19
Mars	5	29	6	0.21	4	33	11	0.33
April	3	32	18	0.56	4	33	23	0.70
May	9	51	28	0.55	9	41	41	1.00
June	17	118	69	0.58	17	87	72	0.83
July	12	68	35	0.51	10	41	21	0.51
August	11	75	34	0.45	11	62	42	0.68
September	8	104	33	0.32	3	72	48	0.67
October	7	75	20	0.27	5	74	41	0.65
November	7	25	10	0.40	5	37	22	0.59
December	4	23	6	0.26	3	21	10	0.48

Using logistic regressions, which accounted for effects of both years and month ("season") in relation to seal presence, gave the following indications (Tab. 1, 2a-c). During January to June at Killingholm[4], there was no general difference in presence of seals in 1998 in relation to 1999. However, a significant combinatory effect between year and month was found, indicating seasonal differences between the years. Including data from before 1996, but omitting January, showed significant[5] yearly differences in seal presence at Killingholm. The difference between years was clearer during the later part of the year (July to October)[6], including a great variation between months and years. At Näsrevet, no differences between the spring of 1998 as compared to 1999 were found[7]. However, analysing presence between June and October (1997-1998)[8] showed both a seasonal differences in presence but also a significant difference between the two years. An analysis of the summer months[9] June and July (data prior to 1996 and 1997-1999) showed a barely significant year difference, 1998 being the year with the lowest frequency in seal presence.

The occurrence of seals clearly varied between the haulout sites, between different years and time of the year (Tab. 1, 2b-c). Several indications of a reduced occurrence of seals in 1998, i.e. after the windpower plants were erected and were in production, could be found. At Killingholm there was a large amount of data from prior to 1996, which we used for comparison. These figures indicate a negative trend in general at Killingholm, with low occurrence in most months during later years (Tab. 2b).

Table 2a. Observation frequency and number of grey seals observed in Burgsviken. Numbers refer to simultaneous counts at the two haulout sites Killingholm and Näsrevet, adding up to a total area count for Burgsviken. Figures are numbers of observation days (observations with seals), percent observations with seals, average number of seals/ month (±S.D.), and maximum numbers encountered each month, and in each year. For the period prior to 1996, number of year from which observations were included is added.
Observationsfrekvens och antal sälar i hela Burgsviken. Siffror hänvisar till simultana räkningar vid de två lokalerna Killingholm och Näsrevet, och är den summerade räkningen för hela Burgsviken. Siffrorna hänvisar till antalet observationsdagar (observationer med säl), andelen (%) dagar med säl, medelantalet sälar/månad (±S.D.) samt maximiantalet sälar observerat under respektive månad och år. För åren före 1999 anges även antalet år som inkluderas för respektive månad.

Year	Values	Jan.	Feb.	Mars	April	May	June
(1973)-	No. obs (obs w.seals)					4 (4)	16 (12)
1985-	% with seals					100	75
1995	Average (std)					18.8 (10.4)	17.2 (13.6)
	Maximum no.					28	46
	Years w.obs					2	6
1996	No. obs (obs w.seals)						3 (3)
	% with seals						100
	Average (std)						24.7 (11.0)
	Maximum no.						32
1997	No. obs (obs w.seals)						10 (9)
	% with seals						90
	Average (std)						17.4 (12.1)
	Maximum no.						37
1998	No. obs (obs w.seals)	17 (2)	16 (2)	16 (8)	16 (13)	14 (14)	30 (25)
	% with seals	12	12	50	81	100	83
	Average (std)	1.0 (3.6)	0.1 (0.3)	1.4 (2.1)	15.3 (10.4)	20.1 (8.8)	11.3 (8.7)
	Maximum no.	15	1	6	32	34	27
1999	No. obs (obs w.seals)	5 (0)	4 (1)	4 (1)	15 (12)	16 (12)	3 (3)
	% with seals	0	20	20	80	75	100
	Average (std)	0 (-)	0.25 (-)	1.0 (2.0)	10.3 (13.0)	13.2 (16.1)	18.0 (17.3)
	Maximum no.	0	1	4	45	47	37
Total	No. obs (obs w.seals)	22 (2)	20 (3)	20 (9)	31 (25)	34 (30)	62 (52)
	% with seals	9	15	45	83	86	84
	Average (std)	0.8 (3.2)	0.2 (0.4)	1.3 (2.0)	12.7 (11.7)	16.9 (13.2)	14.8 (11.5)
	Maximum no.	15	1	6	45	47	46

Year	Values	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
(1973)-	No. obs (obs w.seals)	3 (2)	4 (4)					27 (22)
1985-	% with seals	67	100					81
1995	Average (std)	9.3 (15.3)	12.5 (7.1)					16.0 (12.1)
	Maximum no.	27	20					46
	Years w.obs	3	4					11
1996	No. obs (obs w.seals)		1 (1)	6 (6)	18 (18)			28 (28)
	% with seals		100	100	100			100
	Average (std)		19.0 (-)	12.2 (7.5)	15.9 (10.8)			16.2 (10.2)
	Maximum no.		19	24	40			40
1997	No. obs (obs w.seals)	14 (13)	23 (21)	30 (19)	19 (10)	10 (9)	14 (10)	119 (91)
	% with seals	93	91	63	53	90	71	76
	Average (std)	12.0 (10.3)	21.1 (15.6)	6.8 (7.6)	6.9 (10.4)	3.5 (3.2)	5.6 (6.4)	10.6 (11.9)
	Maximum no.	32	56	32	38	11	19	56
1998	No. obs (obs w.seals)	14 (3)	24 (9)	30 (25)	21 (6)	5 (4)	4 (0)	207 (111)
	% with seals	21	38	85	29	80	0	54
	Average (std)	1.3 (3.4)	2.2 (4.3)	9.8 (9.4)	4.7 (9.7)	1.4 (0.9)	0	6.7 (9.3)
	Maximum no.	12	13	38	36	2	0	38
1999	No. obs (obs w.seals)	1 (1)						48 (32)
	% with seals	100						67
	Average (std)	20 (-)						9.5 (13.5)
	Maximum no.	20						47
Total	No. obs (obs w.seals)	32 (19)	52 (35)	66 (50)	58 (34)	15 (13)	18 (10)	429 (284)
	% with seals	59	67	76	59	87	56	66
	Average (std)	6.7 (9.3)	11.8 (14.2)	8.7 (8.5)	8.9 (11.2)	2.8 (2.8)	5.1 (6.8)	9.2 (11.2)
	Maximum no.	32	56	38	40	11	19	56

Table 2b. Observation frequency and number of grey seals observed at Killingholm. Figures are number of observation days (observations with seals), percent observations with seals, average number of seals/month (±S.D.), and maximum numbers encountered each month, and in each year. For the period prior to 1996, number of year from which observations were included is added.
Observationsfrekvens och antal sälar vid Killingholm. Siffrorna hänvisar till antalet observationsdagar (observationer med säl), andelen (%) dagar med säl, medelantalet sälar månad (±S.D.) samt maximiantalet sälar observerat under respektive månad och år. För åren före 1996 anges även antalet år med observationer som inkluderats för respektive månad.

Year	Values	Jan.	Feb.	Mars	April	May	June
(1973)-1985-1995	No. obs (obs w.seals)		4 (3)	9 (5)	1 (1)	32 (27)	60 (12)
	% with seals		75	55	100	84	20
	Average (std)		7.2 (7.6)	1.4 (1.8)	25 (-)	14.2 (11.1)	14.8 (12.5)
	Maximum no.		18	5	25	31	44
	Years w.obs		1	3	1	7	13
1996	No. obs (obs w.seals)						5 (5)
	% with seals						100
	Average (std)						18.0 (5.0)
	Maximum no.						23
1997	No. obs (obs w.seals)						18 (8)
	% with seals						62
	Average (std)						10.7 (10.6)
	Maximum no.						25
1998	No. obs (obs w.seals)	18 (0)	16 (0)	16 (2)	16 (13)	15 (5)	30 (2)
	% with seals	0	0	12	81	33	7
	Average (std)	0 (-)	0	0.1 (0.3)	10.8 (8.7)	3.4 (7.6)	0.6 (3.1)
	Maximum no.	0	0	1	28	28	17
1999	No. obs (obs w.seals)	5 (0)	4 (0)	4 (0)	15 (4)	16 (7)	8 (3)
	% with seals	0	0	0	27	44	38
	Average (std)	0 (-)	0	0	2.8 (6.7)	2.1 (3.1)	2.6 (2.4)
	Maximum no.	0	0	0	25	10	10
Total	No. obs (obs w.seals)	23 (0)	24 (3)	29 (7)	32 (18)	63 (39)	121 (30)
	% with seals	0	12	24	56	62	25
	Average (std)	0	1.2 (3.9)	0.5 (1.2)	6.7 (8.6)	8.3 (10.5)	10.0 (11.8)
	Maximum no.	0	18	5	28	31	44

Year	Values	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
(1973)-1985-1995	No. obs (obs w.seals)	38 (30)	22 (11)	13 (6)	9 (2)	6 (2)	4 (4)	199 (103)
	% with seals	79	50	46	20	33	100	52
	Average (std)	9.6 (11.2)	4.3 (6.5)	3.2 (4.9)	2.6 (5.6)	3.7 (5.7)	16.5 (9.9)	10.2 (11.2)
	Maximum no.	41	20	16	15	12	23	44
	Years w.obs	9	8	5	4	4	2	15
1996	No. obs (obs w.seals)		4 (4)	30 (15)	26 (12)	4 (0)	3 (0)	72 (36)
	% with seals		100	50	48	0	0	50
	Average (std)		10.5 (4.9)	3.6 (5.8)	4.6 (6.8)	0	0	4.9 (7.0)
	Maximum no.		17	22	25	0	0	25
1997	No. obs (obs w.seals)	14 (6)	24 (18)	30 (3)	19 (2)	10 (7)	14 (10)	124 (54)
	% with seals	43	75	10	11	70	71	44
	Average (std)	5.4 (7.6)	10.0 (9.6)	0.3 (1.1)	0.4 (1.6)	1.8 (1.8)	4.4 (6.2)	4.4 (7.5)
	Maximum no.	19	29	6	7	5	18	29
1998	No. obs (obs w.seals)	14 (0)	24 (0)	30 (9)	21 (4)	3 (3)	4 (0)	209 (38)
	% with seals	0	0	30	19	100	0	18
	Average (std)	0	0	1.3 (2.6)	3.2 (8.7)	1.7 (0.6)	0	1.7 (5.2)
	Maximum no.	0	0	10	32	2	0	32
1999	No. obs (obs w.seals)	2 (0)						
	% with seals	0						
	Average (std)	0						
	Maximum no.	0						
Total	No. obs (obs w.seals)	68 (36)	74 (33)	103 (33)	75 (20)	23 (12)	25 (14)	604 (231)
	% with seals	53	45	32	27	52	56	38
	Average (std)	6.2 (9.7)	5.2 (7.8)	1.9 (4.1)	2.7 (6.4)	1.9 (3.1)	4.2 (7.1)	5.0 (8.7)
	Maximum no.	41	29	22	32	12	23	44

Table 2c. Observation frequency and number of grey seals observed at Näsrevet. Figures are number of observation days (observations with seals), percent observations with seals, average number of seals/month (±S.D.), and maximum numbers encountered each month, and in each year. For the period prior to 1996, number of year from which observations were included is added.

Observationsfrekvens och antal sälar vid Näsrevet. Siffrorna hänvisar till antalet observationsdagar (observationer med säl), andelen (%) dagar med säl, medelantalet sälar månad (±S.D.) samt maximiantalet sälar observerat under respektive månad och år. För åren före 1996 anges även antalet år med observationer som inkluderats för respektive månad.

Year	Values	Jan.	Feb.	Mars	April	May	June
(1973)-1985-1995	**No. obs (obs w.seals)**	1 (1)	1 (1)	2 (2)	2 (2)	9 (8)	31 (23)
	% with seals	100	100	100	100	89	74
	Average (std)	4.0 (-)	4.0 (-)	4.0 (2.8)	3.5 (2.1)	5.4 (3.6)	6.0 (8.7)
	Maximum no.	4	4	6	5	12	34
	Years w.obs	1	1	2	2	7	13
1996	**No. obs (obs w.seals)**						3 (3)
	% with seals						100
	Average (std)						7.0 (5.3)
	Maximum no.						11
1997	**No. obs (obs w.seals)**						10 (8)
	% with seals						80
	Average (std)						9.9 (12.0)
	Maximum no.						35
1998	**No. obs (obs w.seals)**	18 (3)	16 (2)	16 (8)	16 (9)	16 (16)	30 (25)
	% with seals	17	12	50	56	100	83
	Average (std)	1.1 (3.5)	0.1 (0.3)	1.2 (1.9)	4.5 (4.5)	16.9 (8.4)	10.7 (8.1)
	Maximum no.	15	1	6	12	30	27
1999	**No. obs (obs w.seals)**	5 (0)	4 (1)	4 (1)	15 (12)	16 (12)	10 (10)
	% with seals	0	25	2.5	80	75	100
	Average (std)	0	0.2 (0.5)	1.0 (2.0)	7.5 (8.2)	11.1 (15.2)	20.8 (16.8)
	Maximum no.	0	1	4	22	47	56
Total	**No. obs (obs w.seals)**	24 (4)	21 (4)	22 (11)	33 (23)	41 (36)	84 (69)
	% with seals	17	19	50	70	88	82
	Average (std)	0.8 (3.1)	0.3 (0.9)	1.2 (1.9)	5.8 (6.4)	12.2 (11.5)	10.1 (10.4)
	Maximum no.	15	4	6	22	47	56

Year	Values	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
(1973)-1985-1995	**No. obs (obs w.seals)**	12 (7)	12 (11)		2 (2)	3 (2)		75 (59)
	% with seals	58	92		100	67		79
	Average (std)	3.5 (6.8)	7.5 (7.6)		3.5 (0.7)	2.3 (2.1)		5.3 (7.0)
	Maximum no.	24	23		4	4		34
	Years w.obs	7	8		2	3		18
1996	**No. obs (obs w.seals)**		1 (0)	6 (6)	19 (18)			29 (27)
	% with seals		0	100	95			93
	Average (std)		0	3.5 (2.4)	11.5 (6.4)			9.0 (6.5)
	Maximum no.		2	7	22			22
1997	**No. obs (obs w.seals)**	14 (13)	24 (22)	30 (18)	31 (17)	29 (19)	16 (9)	154 (106)
	% with seals	93	92	60	55	66	56	69
	Average (std)	6.6 (4.6)	10.8 (8.8)	6.6 (7.6)	4.7 (7.9)	4.3 (7.1)	1.2 (1.9)	6.1 (7.9)
	Maximum no.	16	33	32	38	22	7	38
1998	**No. obs (obs w.seals)**	14 (3)	24 (9)	30 (24)	21 (5)	5 (1)	4 (0)	210 (105)
	% with seals	21	38	80	24	20	0	50
	Average (std)	1.3 (3.4)	2.2 (4.3)	18.5 (9.1)	1.4 (3.3)	0.2 (0.4)	0	5.0 (7.5)
	Maximum no.	12	13	36	13	1	0	36
1999	**No. obs (obs w.seals)**	1 (1)						55 (37)
	% with seals	100						67
	Average (std)	20 (-)						9.5 (13.3)
	Maximum no.	20						56
Total	**No. obs (obs w.seals)**	41 (24)	61 (42)	66 (48)	73 (42)	37 (22)	20 (9)	523 (335)
	% with seals	59	69	73	58	59	45	64
	Average (std)	4.4 (6.1)	6.7 (8.0)	7.1 (7.9)	5.7 (7.5)	3.6 (6.4)	1.0 (1.7)	6.1 (8.5)
	Maximum no.	24	33	36	38	22	7	56

With the exception of April, May and September, the presence of seals was very low at Killingholm in 1998, compared to previous years[10]. In fact, from June to August 1998, seals were only observed on two occasions in spite of 68 observations days (3%). This should be compared with an average observation rate of at least 50%. This low presence of seals at Killingholm appeared to have continued in the summer of 1999, although seals were seen rather frequently in early 1999, especially in May (44% of observations). Seal presence during September and October also differed between years. These two months in 1997, when the drilling and construction of the windpower took place, showed a significant deviation compared to 1996 but also to 1998[11]. Including data prior to 1996 resulted in similar results. The development at Näsrevet showed a different pattern (Tab. 2c). Data from April and May showed no difference in presence of seals when comparing 1998 and 1999 with data prior to 1996 (no observations were made in May in 1996-97)[12]. However, presence of seals from June to October differed significantly between years[13]. In 1998, seals were present in 54% of the cases, to be compared to an average of 74% of the observations in all the other years. Presence of seals at Näsrevet was, as at Killingholm, unusually low during July and August 1998, differing significantly from 1997[14], as well as from 1997 and observations before 1996[15].

The other parameter of importance we analysed was actual number of seals in the area (Tab. 2a-c). It is clear that number of seals varied considerably (Fig. 2), at both sites and in the total area count, (Fig. 3) ranging from many days with zero seals to a maximum of 56 seals, recorded in August 1997 (total area count) and in May 1999 (Näsrevet). Average daily counts of 10 or more seals per day, including the whole area, seems to be a rule from April on to September with occasional high counts both later and earlier in the year.

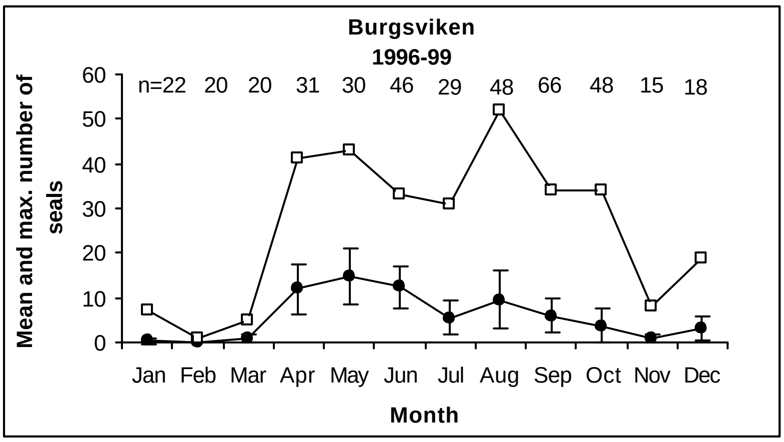

Figure 2. Monthly variation in grey seal numbers (mean ±S.D., and maximum) in the whole Burgsviken area based on observation in 1996-1999. Numbers above denotes number of observation days in each month, respectively.
Månatlig variation av antalet gråsälar (medel ±S.D., och maxvärden) i hela Burgsviken baserat på observationer 1996-1999. Numren i ovankant hänvisar till antalet observationsdagar i respektive månad.

In order to analyse populations trends we choose to use the total count, i.e. the combined count of seals in the water and on land of the whole area, as well as for each of the two haulout sites, respectively. A crude measure of average annual number of seals, (using 1980's, 1990-1995, 1996, 1997, 1998, 1999 as categories of time) indicated unusually low numbers of seals in the area in 1998[16a]. A similar pattern emerged from Näsrevet[16b], although here the numbers of seals seemed to be higher in the late 1990s compared to counts before 1996. At Killingholm[16c] a different trend was found, where the number of seals appeared to have been higher in earlier years. Still, counts made before 1996 were irregular and from varying times of day and some caution should be taken when interpreting long time changes in population size.

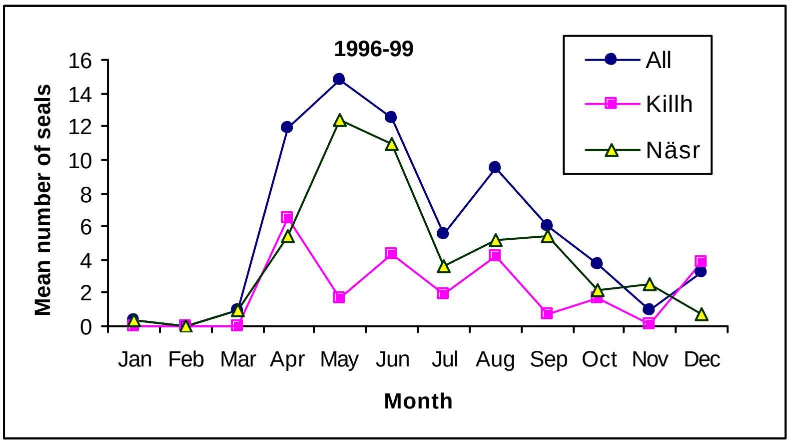

Figure 3. Monthly mean number of grey seals in the total Burgsviken area (all) and at Killingholm and Näsrevet, respectively, during 1996-1999.
Månadsmedelvärden av gråsäl 1996-1999 i hela Burgsviken (all) samt vid Killingholm respektive Näsrevet under 1996-1999.

Using each daily count in each year as an independent observation from 1996 to 1999 showed a significant difference in total number of seals in 1998[17a], compared to the two previous years, but not compared to 1999. Moreover, the numbers observed in 1999 were significantly lower compared to 1996. The same pattern was found at Killingholm[17b], except here 1999 showed significantly lower numbers compared to 1997 as well. At Näsrevet[17c], the only significant difference was the constant low numbers found in 1998 compared to the high counts in 1999. Clearly, significant year effects were found when analysing total area counts, as well as the two haulout sites separately, including strong significant interaction effects between month and year. Again, caution should be taken due to yearly differences in observation efforts.

Analysing the daily total counts for the summer month's only, i.e. April to September revealed somewhat different patterns (Tab. 2a-c). Total counts from the area differed between years but only barely on the level of significance[18a], 1998 still being the year with the lowest counts followed by 1999. Killingholm[18b] still showed very low counts both in 1998 and in 1999, both years being significantly different from 1997 and 1998 being different from 1996. At Näsrevet[18c], summer of 1998 was also the year with the lowest total counts and significantly different from 1999. Again, both the total area count and counts at Killingholm differed between years, whereas at Näsrevet

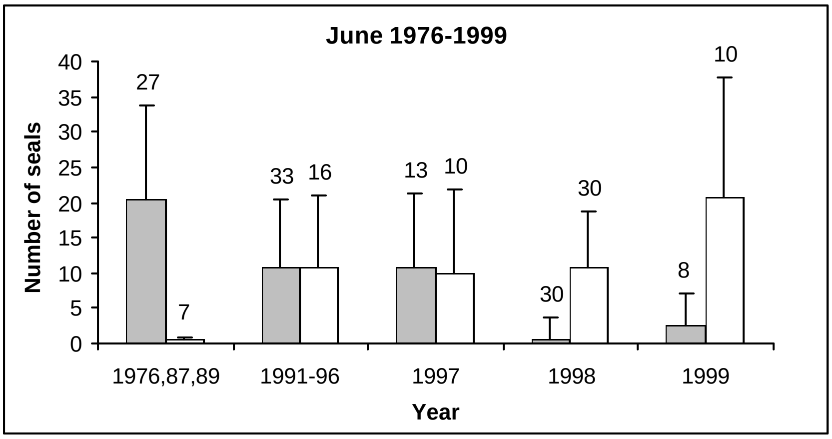

Figure 4. Average number of grey seals (±S.D) in June (1976-1999) at Killingholm (filled bars) and Näsrevet (open bars) divided into five periods of time. Numbers above bars indicate number of observation days in each category.
Medelantalet gråsäl (±S.D) i juni (1976-1999) vid Killingholm (fyllda staplar) och Näsrevet (öppna staplar) under fem olika tidsperioder. Numren ovan staplarna anger antalet observationsdagar i respektive kategori.

only a tendency of year effects were found in later years. The local long-term trends and the shift between the two sites is illustrated in Fig. 4, using data from June only.

We also tested the differences in monthly means of number of seals, thereby reducing the dependence that daily observations consisted of, since seals counted one day are likely to be counted the day after. However, by doing that no year differences were found, neither in total counts for the whole area or at the two sites separately.

Differences in numbers during wintertime, i.e. October to March (Tab. 2a-c), suffered greatly from unevenness in time and dates of observations, but showed significantly decreasing numbers of seals over the years, in the total count as well as when analysing the two sites separately[19a-c].

As the likelihood of observing seals, as well as the number of seals (Tab. 1, 2a-c), varied seasonally such facts has to be taken into account when performing tests, making comparisons but foremost when interpreting the results. Moreover, another problem to consider was the variable observation effort between different months and years. Low number of observations in certain months may not be representative. Further, older observations were often observations from the afternoon and evenings, i.e. other times of day compared to those we restricted our main analyses on. A final consideration is that data from before the 1990s likely represent observations of a seal population, which were smaller than the present.

In summary, both the data on presence-absence and the counts of actual seal numbers in the area indicated strong yearly and monthly variation, and more prominently suggests 1998 to be an exceptionally bad year for the seals in the area. Also, the data from Killingholm strongly show a continuous negative trend, a trend that seems to persist. The question that arises is what are the cause, or causes, of these patterns of variation in seals in the area? Several options are at hand. First, a large fluctuation in population size (Baltic) or population movements may also cause local variation. Secondly, disturbance from human activities may cause the seals to move. Finally, other extrinsic factors such as variable weather conditions may, and are known from other seal species and populations, to make seal number fluctuate. Next we will look into the latter factors, disturbance and weather conditions.

Figure 5. Mean number of grey seals in Burgsviken (total counts) in 1996-1999, by month. The three periods of impact, test drilling, construction and active running of the five windpower plants are denoted. N.B. that total count for the whole area differs in time slightly from counts from the respective haulout sites.
Medelantalet gråsäl i Burgsviken (totalsumma) under 1996-1999, månadsvis. De tre perioderna av störning, provborrning, uppbyggandet och själva driften av de fem verken är angivna. Observera att totalsumman för hela området till del avviker från räkningarna från respektive lokal

Disturbances – Windpower

We had some means of investigating potential effects of the windpower plants, or their construction, on the seals (Fig. 5). First, during summer of 1999, at each count of seals we also noted the number of windpower plants at work, resulting in five categories from zero to four plants. We did not find any differences in seal numbers between the five categories of distrubance[20]. The number of seals varied independently of the number of plants running at both Killingholm and at Näsrevet (Fig. 6).

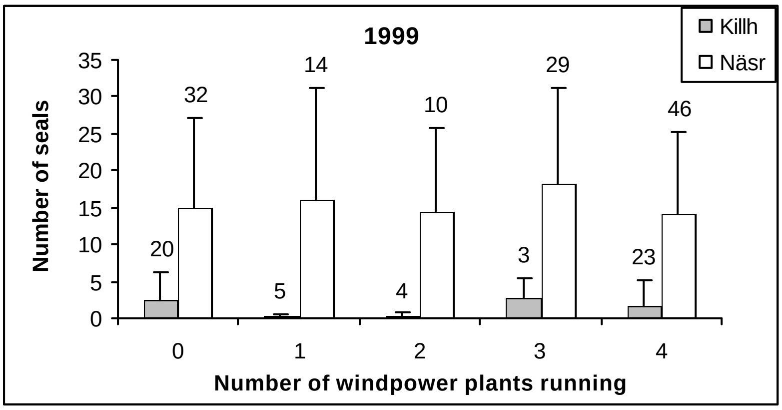

Figure 6. Number of grey seals (mean ±S.D.) at Killingholm (filled bars) and at Näsrevet (open bars) in relation to number of running windpower plants during summer of 1999 (June-July). 4 plants running include one day of five plants running.
Antal gråsäl (medel ±S.D.) vid Killingholm (fyllda staplar) och Näsrevet (öppna staplar) i relation till antalet vindkraft i drift. Fyra verk inkluderar en dag med 5 verk i drift.

The second way of analysing potential effects of the plants was obtained from the data on the production and plants running. This data showed that, as expected, number of seals differed significantly between the high and low seal densities[21]. During the same periods, no differences were found in either the effect gained from the plants or differences in mean number of plants running (Fig. 7a-f). Neither could we find any differences in the most important weather variables (see further), the speed and direction of wind or water level. Looking at the number of plants running, most observations referred to either all five plants or none running. Combining the fewer cases of 1 to 4 plants running to one category, thereby using no (0), intermediate (1-4) or 5 plants running as categories, did not reveal lower numbers of seals when all plants were running[22]. The intermediate group, however, showed signs of lower number of seals, differing from both zero and five plants running. The cause of that is due to unknown factors. The effect gained, number of plants running and wind speed were all highly positively inter-correlated[23].

We analysed the possible effect of disturbance during the construction phase, from late August to mid November 1997 (Fig. 5), which was caused by the high human activity in the area, by relating a gradient of work activities on the platform with number of seals in the area. Number of seals varied significantly in relation to different work activities on the platform[24], with seals counts ranging from 0 to the highest number observed in the area, 56 individuals. However, and surprisingly, we found that activity was positively related to seal numbers[25]. This pattern was found when looking at Näsrevet and in the total area count. At Killingholm, this relationship was negative indicating possible local effects. However, at Killingholm only a few seals were found there during this period, never exceeding 12 individuals. Also, this period showed unusual weather conditions (see further) which might explain the observed pattern.

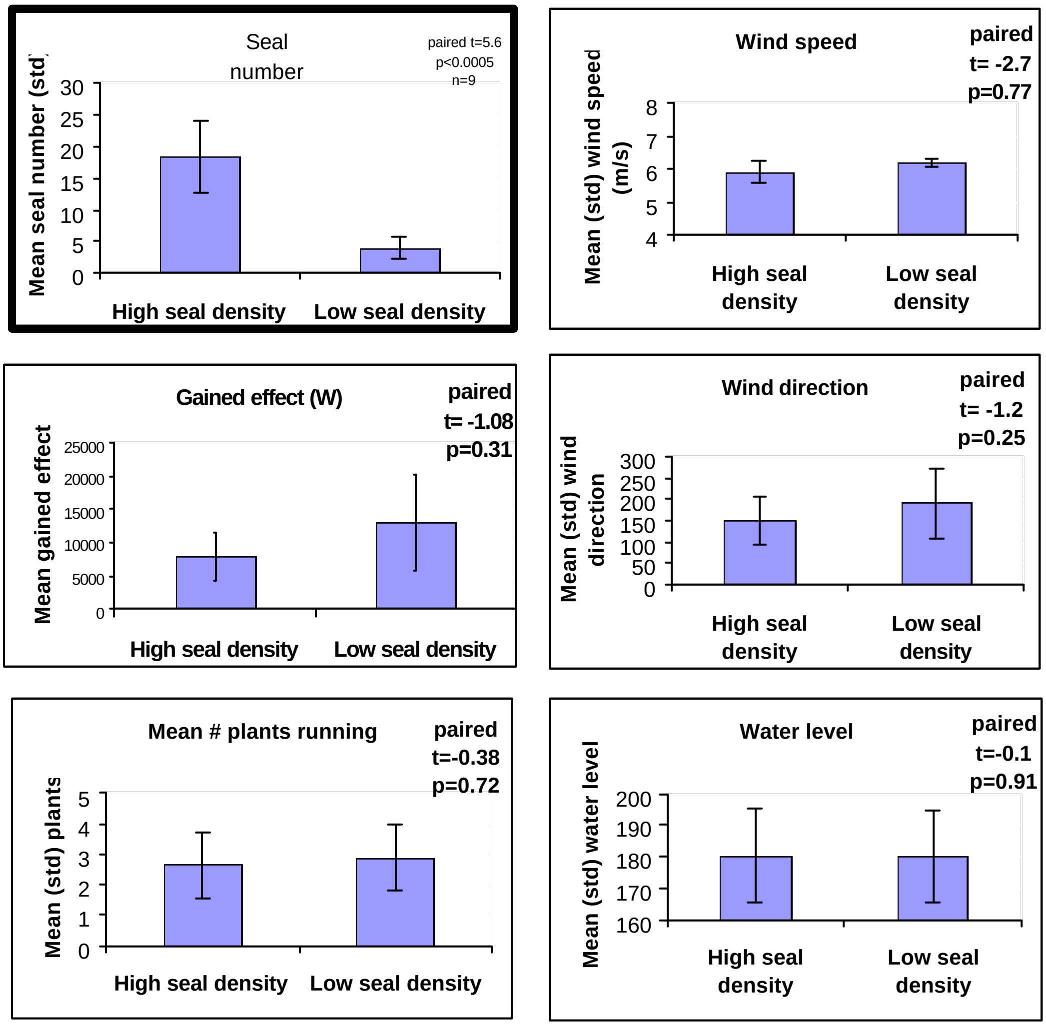

Figure 7. Number of grey seals (mean ±S.D.) in Burgsviken (total count) during high and low seal density periods. The five additional factors, effect gained and average number of running, plus the weather factors wind speed, wind direction and water level, were added but showed no difference between high and low seal density periods.
Antal gråsäl (medel ±S.D.) i Burgsviken (totalsumma) under perioder av hög respektive låg säldensitet. De fem faktorerna producerad effekt och medelantalet vindkraftverk i drift, samt väderfaktorerna vinhastighet, vindriktning och vattenstånd visade ingen skillnad under de två perioderna låg respektive hög säldensitet.

Other disturbances

Direct observations from summer 1999 gave strong indications on the seal's sensitivity towards disturbances, in the number of seals hauling out, and their behavioural responses. In all, 37 occasions of possible disturbances were recorded (Appendix 2). Number of seals hauling out differed before, during and after a disturbance[26], where number of seals after disturbance was significantly different from before and during an incident. Of these disturbances, 61% caused all seals to go into the water when originating from actions within 1.5 km, i.e. within the distance from the nearest plant at Näsrevet. Consequently, number of seals decreased significantly after a disturbance, indicating that such events are important short-term determinations of number of seals hauling out. Similar results could be found in the older seal count data, which included 12 notes of disturbances (from summers 1987 to 1991, most from an unknown source (Appendix 3). The number of seals decreased significantly[27] from the observation prior a disturbance compared to after. In 42% of the cases all seals left the haulout (Killingholm) and in 82% of the cases less than half the original number of seals were back on land after one hour.

No difference was found in proportion of seals leaving a haulout between the four different categories of boats and air plane disturbances[28]. However, the distance between the source of disturbance and the seals had an effect on the proportion of seals going into the water. Disturbance closer than 500m resulted in a significantly[29] higher percentage of seals going into the water than did disturbance sources between 500m and 2000m. Time to recovery, i.e. a measure of when animals feel secure again and counted as the time it took 50% of the seals to regain their haulout, did not differ in relation either source type[30] or distance[31]. We found a strong but non-significant tendency[32] for a higher proportion of seals being vigilant before and during after a disturbance compared to after (Appendix 2).

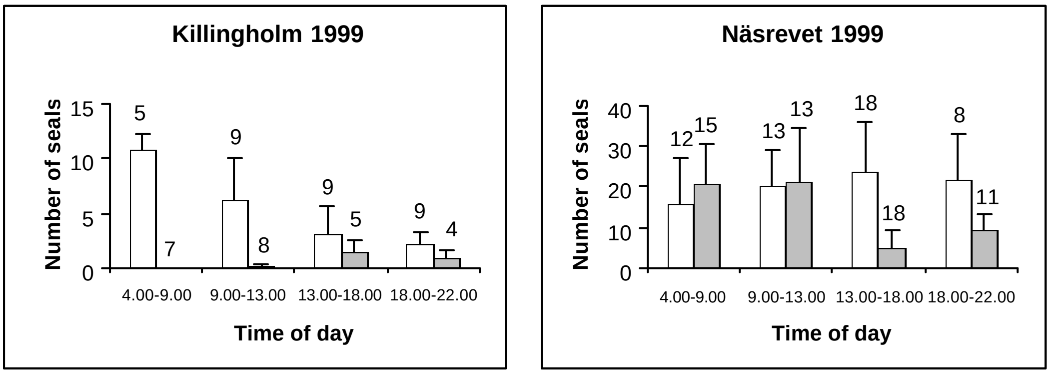

Figure 8. Mean number of seals (±S.D.) per day during different times of day before (period 1, 10-24 June: open bars) and after midsummer (period 2, June 25-July 7: filled bars) at Killingholm (left) and Näsrevet (right).
Medelantalet sälar (±S.D.) per dag under olika tidunkter av dagen före (period 1, 10-24 juni: öppna staplar) och efter midsommar (period 2, 25 juni - 7 juli: fyllda staplar) vid Killingholm (vänster) samt Näsrevet (höger).

From parts of the data we were able to obtain figures on daily changes in seal numbers, i.e. from days with more than 6, and the number of seals hauling out was rather constant. The highest average numbers were usually found in the early morning, with a slight drop during the midday and a slight recovery during evenings (Söderman 1999). During summer 1999, we found differences in the haulout pattern when comparing the daily haulout pattern before and after June 25th (midsummer). After midsummer at Killingholm, the mean number of seals hauling out was significantly lower in the afternoon after midsummer[33] (period 2) compared to numbers before noon before midsummer (period 1, Fig. 8).

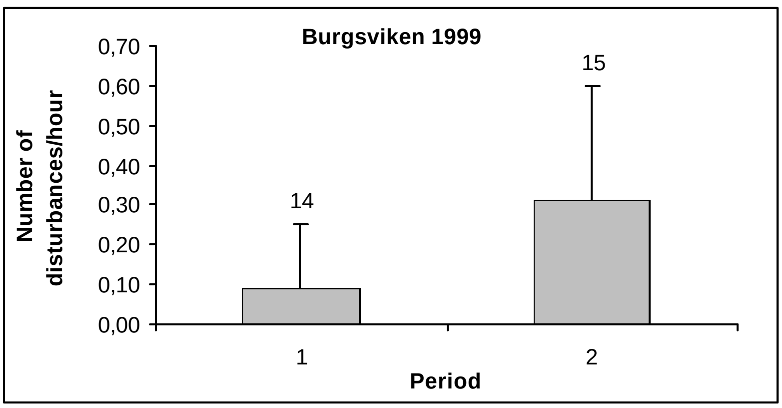

Figure 9. Mean (±S.D.) disturbances/hour before (period 1, 10-24 June) and after midsummer (period 2, June 25-July 7) at Burgsviken.
Medelantalet störningar/timme före (period 1, 10-24 juni) och efter midsommar (period 2, juni25-juli 7) vid Burgsviken.

However, seals were hardly seen at Killingholm after midsummer in spite of regular observations at different times of days. We found a similar pattern at Näsrevet[34] where number of seals was more or less constant over the whole day before midsummer whereas after midsummer the number decreased in the afternoon (Fig. 8). Looking at the afternoon only, however, number of seals was significantly lower after midsummer as compared to before midsummer[35]. Although other causes may explanation this change in daily haulout pattern after midsummer, we found that disturbances rate, per hour, was significantly higher after midsummer[36] (Fig. 9). Of all the observed disturbances (33 instances) at Näsrevet 73% took place in the latter period. Of these, 13 took place in the afternoon (Appendix 2).

Seal behaviour also changed after midsummer. A higher proportion of seals was vigilant at Näsrevet after midsummer[37a] and significantly so in the afternoon[37b], as compared to the same time of day before midsummer. As this increase in vigilance may be a consequence of the lower number of seals during the later period we then controlled for group size. This resulted in no differences in vigilance[38] before and after midsummer. We also tested the proportion of vigilant seals in relation to observation with or without disturbance at Näsrevet. We then found that the frequency of vigilant seals was higher[39] during observations related to disturbance incidences, compared to disturbance free observations (Fig. 10). No difference in group size was found in this comparision[38].

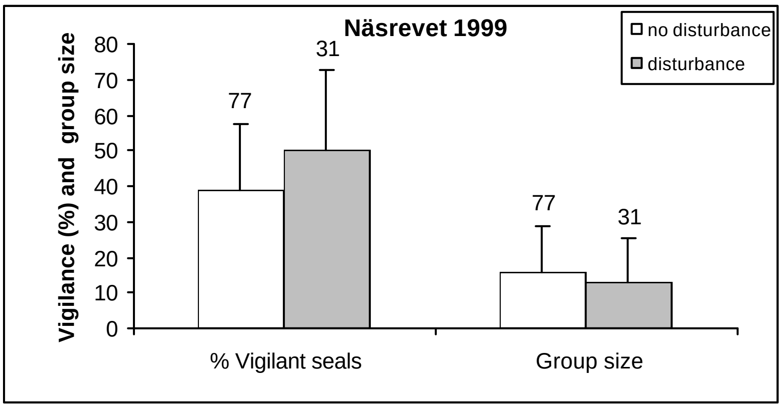

Figure 10. The percentage grey seals being vigilant (left), and group size (right) during observations without disturbance (open bars) and during observations when disturbance occurred (filled bars).
Andelen vaksamma gråsälar (%, vänster) och gruppstorleken (höger) under observationer utan (öppna staplar) respektive med störning (fyllda staplar).

Extrinsic factors

Several weather factors were included in our analyses, using data obtained from SMHI, the seal observers and from notes in the logbook of the company constructing the windmills. The latter source only included data from late August to mid November 1997. The meteorological data included air temperature, air pressure, precipitation, cloud cover, wind direction, wind speed and water level (see also methods). Several of these measurements were obtained simultaneously from each of the sources. A last variable, wave height, was also obtained through the logbook but covered only the restricted period given above.
The different sets of meteorological data were cross analysed in order to check for discrepancies. Wind speed data from SMHI (06.00) showed high positive relationship with wind speed data noted by the seal observers[41]. Also, wind direction showed a strong resemblance between the two data sets[41] but not as strongly as that of wind speed. A possible explanation for that may be that the meteorological station at Hoburgen is less affected by land cover, being situated on the southern point of Gotland, whereas Burgsviken and the two haulout sites do have more land cover which

might affect the degree of exposure. Although the local data may be more accurate in terms of local conditions we still used the SMHI data. In a similar way, the wind data obtained from the construction logbook showed strong positive relationship with corresponding data from SMHI. Moreover, data on wave height[42], measured around the drilling platform was highly positively correlated with wind speed data (SMHI). Thus, in most case wind speed is a good estimate of wave conditions. Comparing log data and seal observer data also showed good similarities[43]. Clearly, local weather data collection is not only the simplest way of obtaining useful data, but is likely best considering local conditions if obtained under standardised and well organised forms.

We used a stepwise logistic regression when investigating which factors were of importance in affecting seal presence in the area[44]. Our analysis showed strong significant effects by wind speed, water level, temperature, cloud cover and a slightly weaker affect by precipitation and wind direction. No effects of year and month were found indicating that seals sometimes were missed in the counts independent of year and month.

Using a similar approach, employing a generalised model we analysed factors affecting numbers of seals[45]. This analysis revealed all of the factors highly influenced numbers of seals, namely year, month, water level, wind speed, wind direction, temperature and precipitation. Yet, another way of analysing the data was to omit all observations without seals[45]. We then found that only month, wind speed, cloud cover and temperature were highly important, whereas precipitation was barely significant, in determining seal numbers. A tendency of a year effect was found but not significantly so. Water level and wind direction was not affecting seal numbers when observations without seals were excluded. This was not surprising as these two variables were found to be important in the stepwise regression and it might be concluded that days without seals hauling out are to a great extent due to certain wind directions and high water levels. In this case wind speed was still affecting number of seals hauling out.

Using a rank correlation[46], where relationships between the monthly means of total number of seals in the area were tested against the monthly means of the extrinsic variables, we found similar results. Water level, wind direction, wind speed, precipitation and air pressure showed strong negative relationships with seal numbers. Temperature showed strong positive relationship and air pressure a somewhat weaker but still significant relationship in the same direction. Wind direction and precipitation showed non-significant relationships. The same variables were not always found to be of importance at both of the two sites, and as a predictor of the total area, suggesting that local features may be of outmost importance in determining haulout patterns. A summary of categorised weather variables and their effects on seal numbers in Burgsviken, in summer, is given in[47].

Clearly, several meteorological variables were important, determining both seal presence and variation in numbers in the area (Fig. 11a-d). Season per se is also important, being related to life the cycle of seals. A variable such as temperature may thus be of importance during a season but is also a reflection of time of year, indirectly coupled both to high seal numbers during the summer months. A variable such as air pressure is unlikely to affect the seals directly. However, as air pressure is highly linked to water levels in the Baltic it is understandable that a relationship between air pressure and seal numbers was found.

Wind speed, and to some extent wind direction, were also variables being coupled indirectly to other factors of importance. First, wave height is known to affect seal haulout patterns (e.g. Sjöberg 1999). We could not obtain any wave data except for the estimates taken during the construction of the plants. However, it turned out that wind speed was a fairly good predictor of wave height and the effects of strong winds could in most cases be seen as a reflection of wave heights. Secondly, some cautions should be taken when analysing eventual effect of the running of the windpower

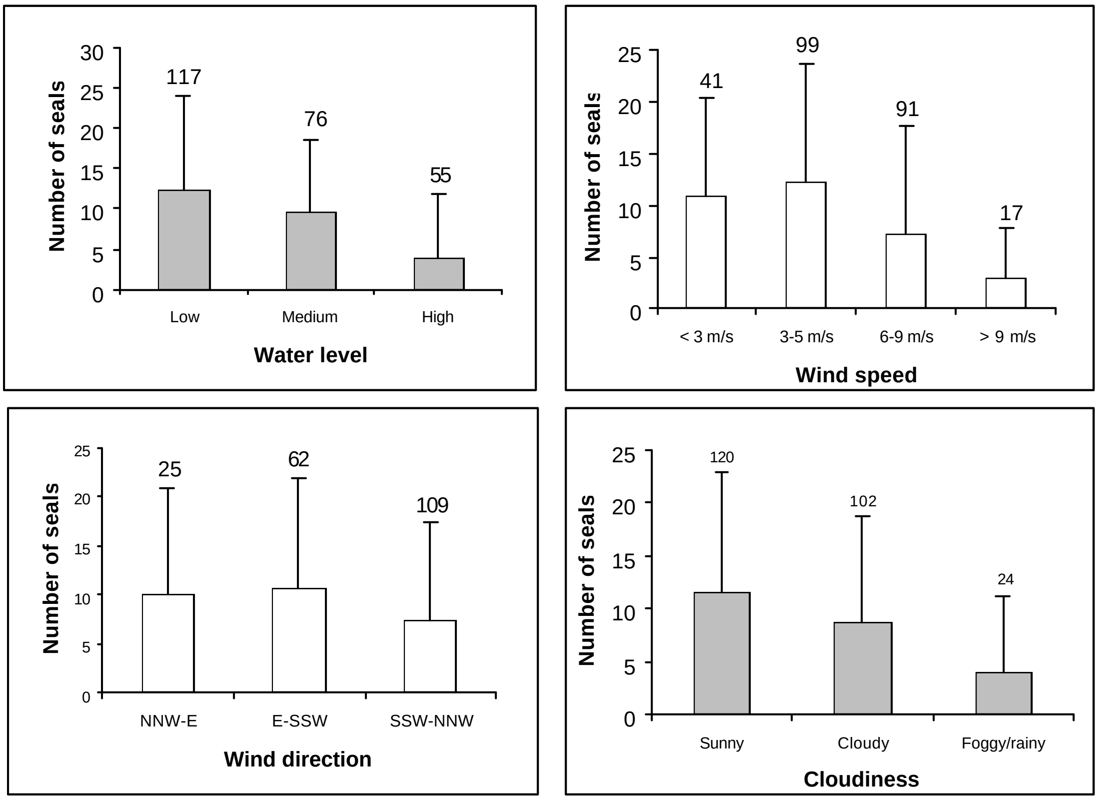

Figure 11. The influence of water level, wind speed, wind direction and cloud cover on average (±S.D.) grey seal numbers in Burgsviken (1996-1999).
Inverkan av vattenstånd, vindstyrka, vindriktning samt molnighet på medelantalet gråsälar (±S.D.) i Burgsviken (1996-1999).

plants. As wind speed was highly correlated with the effect gained from the power plants, and reasonably so, as well as being a factor influencing the seals, only careful experimental approaches can disentangle the true potential effects of the windpower plants, per se.

As some of the analyses above showed or indicated unusually low presence or number of seals during some periods of the construction of the windpower plants (autumn of 1997) or during the summer of 1998, we did some additional analyses of the weather conditions during these periods. Beginning with the weather conditions during the autumn of 1997, the period of construction of the windpower plants, an analysis[48] showed that this period had significantly higher water levels compared to both 1996 and 1998. Moreover, wind directions[48] were clearly more unfavourable in 1997, with prevailing winds from the SSW. This should be compared to the prevailing SE winds in 1996 and SSE winds in 1998, wind directions which the two haulout sites to some extent are covered from by land. Also, wind speed[48] varied significantly between years during this period, 1997 showing the highest mean wind speed, although only significantly different compared to 1996. The other variables tested showed no differences between the years. The low seal numbers during summer of 1998 (June to August) also appeared to be related to unusual weather conditions. In this case, however, we could only compare 1998 with data from 1997. Again, water levels were extremely high during 1998, significantly different to those in 1997 and comparable to the bad conditions during autumn 1997. In fact, all variables tested[49] (water level, temperature, air pressure, and wind speed and wind direction), except precipitation, were significantly different between the two years, indicating unfavourable weather conditions during summer 1998.

Conclusions

The observations showed considerable variation in seal presence and in number over the years. An essential question is if this variation was caused by human activities in the area? Alternatively, could the observed variation be due to influences of extrinsic factors such as natural variation in weather conditions, or, a consequence of a larger population fluctuation of grey seals in the southern Baltic area?

We found good evidence on the seals being affected, on a short term, by human activities in the area, but no or at the most only very weak evidence that the five wind power plants, per se, were affecting the seals. The occasional low numbers or presence's found in the area, during and after the construction, are much more likely attributed to unusual weather conditions. However, some cautions in the interpretations of the results need to be outlined. Moreover, there is nothing our material that with certainty can predict eventual future changes of the seal population in the area.

The grey seal population in the whole Baltic area has been undergoing a strong population decline earlier this century. It is not until the 1980s, or more strongly so in the 1990s, that the population trend for this species has turned into a positive trend. There are, thus, good evidence that the Baltic grey seal population is recovering in number, most prominently in the Bothnian Bay (Helander 1998, Sjöberg 1999, Hårding & Härkönen 1999, Baltic Seal 99).

We were not able to measure any eventual long time trends of the population in Gotland. However, it is evident that no decline in number of grey seals has occurred in the area since mid 1980s. On the contrary, the population appears to be at least stable with potential signs of a small increase, and thus in accordance with the general trend in the Baltic. However, if the total Baltic population is in an increasing phase, it would be much more difficult to detect negative trends in a local population, such as the one at Burgsviken. Such detection requires long time observations, as the sign of an effect has to be measured in differences in the rate of increase. Consequently, adequate comparative data from other haulout sites would have been needed (see also Härkönen et al. 1999).

Any apparent signs of negative effects caused by the windpower plants are not eminent. First, our own observations during the summer of 1999 gave no indication of the seals being disturbed by them. Neither have the observers responsible for the data collection, prior to our own, indicated any obvious signs of disturbance related to the constructions of the plants. There are, however, indications of increasing seal observations on the south-eastern side of Gotland (L. Tydén, pers. com), including observations and harm made by seals on fishing nets, but also observations of seals hauling out on rocks at a Raude Hund. Local movements may thus explain temporary changes in seal presence and numbers at Burgsviken.

There are several known cases where seals have accepted new and permanent constructions, such as lighthouses, and have set up new or re-established close to such constructions. This has been recorded in harbour seals (M.P. Heide-Jørgensen pers. com). A very recent example of such habituation comes from the straight of Öresund, between Sweden and Denmark. During the building of the new bridge between the two countries a new island, Saltholmen, has been constructed. In spite of the closeness to human activities, the harbour seals apparently accepts and take advantage of this novel situation and have established a new haulout site. Habituation is most likely a factor to take into account, but not haphazardly. Different species are likely to behave differently. Species specific histories and evolutionary events, plus earlier experiences and contact with humans are likely explanations to such differences. Grey seals have been hunted in a relatively recent time but reports on less cautious behaviour towards humans in present days are becoming frequent, especially when seals are in the water and feeling safe. Also, in Scotland, seals are known to be much more accepting towards humans, allowing approaches within 50 m, before they leave for shelter in the water (Bonner1989).

Another point of interest relates to the shift in the use of the two haulout sites, from Killingholm to Näsrevet (Fig. 6), and most prominently so during the last few years. This may give some further evidence in the direction of the seals not being severely affected by the power plants, or the activity around them. Näsrevet is in fact closer to the plants then is Killingholm and is likely more affected by the activities related to the plants, such as service and maintenance.

We did find some strong indications on the sensibility of the seals towards different kinds of disturbances. In some instances the disturbing activity was directly related to the windpower plants. It appeared that the boats used in the service and maintenance of the plants did cause the seals to leave the haulout sites temporarily although the recovery time, i.e. the time for the seals to re-enter land, usually was short. On several occasions we noticed that when service boats had anchored by a plant, the boat being still and work was being done at the plant, the seals did relax. During this time seals most often re-entered land for haulout, with no obvious signs of stress. Usually, the seals became vary again as soon as the transport boat started and headed back for land. This indicates that more frequent disturbances may prolong the time of recovery and thus, frequent disturbances may in the end increase the risk of a more permanent abandonment of a haulout site.

Environmental Impact Assessments and this study

The call for EIA's in various instances are global, and have been practised for some 25 years on an international basis (Baily 1997). On a national Swedish level, the use of EIA's in matters related to nature conservation are very limited. This may partly be due to a national tardiness both from the side of national conservation agencies and organisations as well as from the political and administrational sides. Since the Swedish entry into the European Union different and more stringent rules should apply, but still are not followed.

In a review of EIA's, made in Australia (Warnken & Bukley 1998), revealed a generally poor quality of EIA-studies made. Among the more critical points made included poor description of methods (needed to evaluate a study), lack of data in space and time (needed in order to detect true impacts and to make predictions), insufficient monitoring programs and ignorance of important parameters. The conclusion of Warnken & Bukley (1998) is that many IEA's do not follow the fundamental criteria for such studies.

The perhaps most practised EIA-method is a so called Before After Control Impact (BACI) (Underwood 1992, 1994, Ellis & Schneider 1997). A BACI includes monitoring and data collection before a possible impact that is to be compared to data collected after a potential disturbance. However, as all populations of all species vary in numbers over time, by natural causes, comparative data from undisturbed control sites are needed. This is the best and sometimes the only way of a true assessment of eventual impacts at the site at stake which strengthen all possible conclusions made.

In our analysis, we did not have access to control data, except perhaps for vague information on the general population trend of grey seals in the Baltic. Naturally, this has been a shortcoming. The time a monitoring program should run, in order to be able to provide sufficient and reliable information varies from case to case. Dealing with long-lived animals naturally requires long time spans of data collection. In spite of more than 450 observation days, and in some instances more than 600 days of observations generated over several decades, that we had to our disposal we cannot say anything about long term future effects. To some extent we have been able to assess the impact of disturbance during a construction, a relatively important partial factor of impact. On a greater scale, a disturbance may consist of different components of varying importance out of which detailed knowledge can been drawn. To conclude, in spite of the amount of data that at first site appeared comparatively large, a longer but also better planned time series of monitoring would have been desirable.

According to the requirements set upon the construction of the windpower plants, by Gotland County Administration and the Water Court, at the district court in Stockholm, observations were to be undertaken, based on a protocol provided by the Swedish Museum of Natural History, the Contaminant Research group (Appendix 1). Although it was an earnest consideration to set up such requirements it is surprising that no demands of an analysis of any kind was followed. In perspective, neither were some of the requirements realistic. To some extent, they illustrate the hollowness in our obligations to make thorough EIA's and, in the end, our refusal to respect conclusions that might result of such investigations. Clearly, unclear rules of financing are yet another cause of our unwillingness to avoid EIA's.

Guidelines for the future

Our analyses show no, or at the most, very minor short time effects of the five windpower plants on the seals in Burgsviken, SW Gotland. The population in the area did vary considerably between years but this was most likely due to highly variable external factors such as weather and wind. Other factors such as large-scale population trends and movements may also have influenced the local population. Based on the material at hand it is our view that the grey seals in the area are and will be unaffected by these five plants, but that caution should be taken regarding boat traffic and other human activity near the two haulout sites.

Thus, considerations about the future have to be close at hand. Plans for additional windpower plants in the near vicinity of the five plants at Bockstigen are already in progress, 20 sea based windpower plants that will be located slightly north of the present plants, at "Klasården". It is plausible, based on the findings from this analysis, that the seals in the area will remain unaffected even when additional plants will be raised in the vicinity of the haulout sites. However, there are several aspects not covered in our analysis, which might become more important when more and larger windpower plant parks are built. First, we have not looked into seal feeding behaviour. Little if any knowledge exist on what impact the windpower plants may have on the main food source of seals, the fish fauna. Moreover, we have no idea of how seals move and navigate around wind power plants, and weather they avoid the vicinity of the plants. Seals have been reported to come visiting boats nearby the plants, sometimes in larger numbers. However, from our sites of observation we only rarely could observe seals from that distance. Telemetric techniques could be used to disentangle questions concerning seal behaviour and foraging near windpower plants. This is recommended especially if a decrease of seals will be detected in the future. The techniques to radio-tag seals do already exist in the country (see Sjöberg 1999) and could be employed.

Another facts also need to be considered. The decrease of seal observations and numbers at Killingholm, which has become evident during the latter part of the 1990's, has to be reversed. This locality is unique in many respects. Likely, seals have previously been rather tolerant to disturbance at this site, making them easy to observe from a close distance, the close proximity being the second unique feature of the site. Here we recommend some kind of restrictions in movement along the beach, especially during the summer months. We have little reason to believe that the windpower plants are the cause of this local decline as it is likely that the decline started before their existence. From our observations made during summer 1999, and from talking to local people, we believe that increased human activities along the beach more likely are the cause. Yet, we have little data to support this notion. Our choice of midsummer as a breaking point of our observations during summer 1999 into two parts were only of convenience, but coincides with the start of summer vacation for many people. Another problem at this site is the close approachability of boats. Boats have at several occasions been observed to cause disturbance at this site and is likely an additional important source of disturbance. At the other site, Näsrevet, water is shallower and do not allow medium or large sized boats to approach as close. On the other hand, seals are reported to escape haulout sites with shallower surrounding water, such as Näsrevet, compared to haulout sites with deeper surrounding water, as they might feel less secure when they cannot escape by diving deep. Conclusively, some kind of restrictions of movements within several hundred meters, both at land and from the sea, might help the unique site at Killingholm to remain as an important haulout site for seals. Possibly, it could be worth considering a planned system of hiking tracks around the haulout site at Killingholm. Such tracking system/walk boards could be combined with an observational post, a platform, and be partly hidden among trees. This would enable the public to watch seals from a comparatively close distance and at the same time reduce the negative effect of unplanned strolling on the beaches closest to the rocks where the seals haulout.

Our last, and perhaps most important consideration, concerns disturbances caused by boats and helicopters, both categories being used in the area in relations to constructions but foremost the maintenance of the windpower plants. The most important period for seals to have access to undisturbed haulout sites is during the moult, occurring in May and early June. According to the original requirements, no major work was to be permitted in the area during the seal moult. Whatever minor works may have been performed during this more critical period of time during the last years is unknown to us. According to the data we have, however, seal numbers and observation frequencies have been high during all recent spring seasons. Still, it is highly recommendable that such restrictions should be in force also in the future. Seals were earlier hunted in the area and this may partly explain their behaviour. Still, in some respect it is surprising that the seals were found to react so strongly towards disturbances. The relatively closeness between the two haulout sites on one hand, and a long historical activity of humans in the area on the other means that seals frequently have encountered human activities over the years, from land and bypassing boats. As mowing boats were found to be the major sources of disturbance to the seals we are still inclined to suggest that restrictions on more frequent boat transports to be set up. This may not be of great importance to the already existing plant but may be so when considering the planned plants at Klasården. A much more prolonged time for construction, followed by a larger traffic and transports during this time has to be considered. Moreover, an increase of service boat traffic is also likely to be a consequence along with more windpower plants in the area. Ideally, instead of using the harbour at Burgsviken we suggest that boat traffic to the new site, Klasården, will be directed through the harbour at Klintehamn, a larger harbour north of the planned site, thereby reducing the traffic and its disturbance on the seals at Näsrevet. Such restrictions are likely most important during the summer months, the period with most seals in the area.

A last restriction concerned any extra ordinary activities during the breeding period of seals. No regular reproduction of grey seals is known from Gotland in present time. However, two matters should be considered. The Baltic grey seal population is most likely under expansion after many years of decline but this increase is mainly found in populations north of Gotland. If political and environmental aims are to improve the grey seal population of the southern Baltic, safe breeding grounds at Gotland may be a necessity. Also, there are reports of earlier reproductions of harbour seals at Näsrevet from the 1980s. The Baltic harbour seal population is mainly found in south eastern Denmark and in the straight of Kalmarsund, between mainland Sweden and the island of Öland. The Baltic harbour seal population consists of an separate genotype, clearly separated from the populations on the Swedish west coast (Härkönen, pers. com). The importance of Näsrevet as a possible breeding ground for this species also needs consideration.

Finally, based on our findings we also suggest that some form of continued observation of the seals in the area has to be considered, especially if a plan for a continued exploitation will be finalised.

Seal counts, under the Swedish Museum of Natural History, are only performed once a year and cannot fully cover a continued monitoring, even if held at a lower level of ambition. However, data used in this report, along with our findings, can help in setting up a less time consuming and therefore less expensive monitoring programs, which can easily be used further in follow up studies. Ideally, a continued monitoring program need not only be focusing on seals but could also be combined with observations on other organisms such as birds, organisms that very well might be influenced by windpower plants and human activity related to windpower plants.

Acknowledgements

This study was financed by Swedish National Energy Administration (STEM), and performed by Anceps Ekologidata and the Department of Animal Ecology, Uppsala University. Seal counts made in 1996 to 1999 were financed by STEM and Vindkompaniet whereas counts prior to 1996 were supported and organised by the Swedish Museum of Natural History. We would like to send our gratitude to all seal observers over the years. Special thanks to Anna-Lena and Lars Tydén being responsible for the observations during the last years. We would also like to thank Göte Niklasson and the staff at Vindkompaniet for their enthusiasm and help with material. We are indebted to Delphine Melchior and Lars Hillström for observational aid during summer 1999. A special thanks to Björn Helander, Tero Härkönen, Torkel Lundberg, Olle Karlsson, Anna Roos, and Mikael Sjöberg for suggestions, help and discussions. Participation in the 6^{th} International Baltic Seal conference, held in Pärnu - Estonia in November 1999, enabled us to set the present study within the latest knowledge available on Baltic seals. We would also like to thank Staffan Ulfstrand and Lisa Shorey for constructive comments on our report.

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Appendix 1.

The major requirement related to the grey seal populations in Burgsviken and the control scheme concerning the impact on the seals at the two haulout sites, Killingholm and Näsrevet, set by Gotland County Administration. The requirements set by the Water Court were similar but not as extensive.
Några av de viktigare kraven, relaterade till gråsälspopulationen i Burgsviken, och det kontrollschema som närmast gällde inveran på sälarna vid de två kolonierna, i enlighet med beslutet från Länstyrelsen, Gotland. Vattendomstolens krav var liktydiga men ej så ingående.

A Control method:

1. Control shall be undertaken such as simultaneous counts can be made, according to the observation protocol by the Swedish Museum of Natural History, Stockholm, and counts are to be made by especially appointed observers.
2. Number of seals, on land and in water, shall be denoted at each observation. Further, notes on date, time, weather condition, water level, observation distance, species of seal, whether observations are made from land, boat or from plane shall be noted. Observations are to be documented on a pre-printed form, as determined by the by the Museum of Natural History.
3. If observations of special activities are made, related to the construction work on the windpower plants, and which are of great disturbance to the seals on the haulout sites, measures to reduce the disturbance shall immediately be taken in consultation with the County Administration.
4. If other possible sources of disturbance are noted, i.e. boat traffic, people bathing or strolling along the beaches, or animals which might incur threat to the seals, special notes shall be taken.
5. Documentation of seal behaviour shall done with help of black and white photographing. Photographs shall be taken regularly when weather permits but especially when construction work is markedly disturbing, i.e. through intense noise, boat traffic or other influence by the surroundings. Every photo occasion shall be denoted exactly with place and time.
6. If the observers do notice special behaviour among the seals which presumably may have connection to a special disturbance (independent of the source) such events shall, if possible, be video taped.
7. Observations shall be done at the same time of day at Killingholm and Näsrevet, in order to avoid double counts of seals which do swim between the two haulout sites. Best time for observation is early morning.

B Observation time and frequency:

1. From the first of June 1997, observations and counts shall be performed three times a week; Tuesdays, Thursday and Sundays.
2. Starting one week before the construction work begins, until the end of the month the work has been completed, observations and count shall be performed at a daily basis. Construction work is estimated to last from July 17 to August 31, 1997. Vindkompaniet will contact the observers and give information on the exact days.
3. After the time has passed, as the above 2, observations are to be continued and to be performed once every week during the ice free parts of the year, until the first of June 1999.

The Water Court further restricted work during the breeding period and during the moult of the seals, a period of time to be decided on by the County Administration, Gotland, and Vindkompaniet in consultation.

Appendix 2. Disturbances at Näsrevet (Näsr) and Killingholm (Killh) 1999

Place	Date	Time	Type of disturbance	Category	Distance (cat.)	Response	Seal totno.	No. bef.dist.(land)	No. afte dist.
Näsr	619	1900	Motorboat, high speed, 100m	2	1	panic	16	9	3
Näsr	622	1640	Aeroplane	4	2	panic	42	42	35
Näsr	622	1740	Aeroplane	4	2	no panic	49	43	39
Näsr	624	846	Motorboat windcompany, 100m	2	1	panic	33	31	10
Näsr	624	946	Motorboat	2	2	no panic	20	19	15
Näsr	624	1030	Motorboat	2	2	no panic	26	23	21
Näsr	624	1050	Aeroplane	4	2	no panic	24	21	20
Näsr	625	1100	Aeroplane	4	2	panic	43	37	17
Näsr	625	1535	Aeroplane	4	2	panic	34	34	20
Näsr	629	1345	Aeroplane	4	2	no panic	1	1	1
Näsr	630	650	Gulls	6	1	panic	24	23	11
Näsr	630	730	Windcompany ferry+gulls	3	2	panic	23	18	4
Näsr	630	810	Sailingboat, far away	1	2	no panic	11	8	7
Näsr	701	800	Motorboat windcompany	3	2	panic	26	23	2
Näsr	701	845	Motorboat windcomp. (seals in water)	3	2	panic	5	3	2
Näsr	701	858	Sailingboat with engine on	1	2	no panic	9	3	3
Näsr	701	1015	Helicopter	4	1	panic	9	5	3
Näsr	701	1130	Ferry windc., helicopter, ironboat	4	1	panic	10	3	0
Näsr	702	740	Ferry windc. arrives to wp	3	2	no panic	6	2	1
Näsr	704	1620	Fishingboat	3	2	no panic	2	2	1
Näsr	704	1920	Sailingboat closer than wp	1	2	panic	12	11	6
Näsr	705	1545	4 Sailingboats	1	2	panic	13	12	7
Näsr	705	1645	Sailingboat close, <500m	1	1	panic	12	11	4
Näsr	705	1805	Motorboat, 400-500m	2	1	panic	10	8	2
Näsr	705	1850	Sailingboat, 1000m	1	2	no panic	8	7	5
Näsr	706	1720	Small motorboat, sealtourists, 50-100m	2	1	panic	8	2	1
Näsr	706	1850	Boat leaving island	2	1	no panic	8	2	1
Näsr	706	1950	Boat coming to island, 300m	2	1	panic	7	2	1
Näsr	707	1520	Windcompany ferry at powerplants	3	2	zero seals	2	0	0
Killh	617	1200	Person walk on shore	5	1	no panic	8	8	8
Killh	617	1230	Person walk in water	5	1	panic	8	8	0
Killh	701	815	Boat windc. arrives to wp	3	2	zero seals	0	0	0
Killh	701	845	Boat windc. leaves wp	3	2	zero seals	0	0	0
Killh	701	1025	Helicopter at wp	4	2	zero seals	0	0	0
Killh	701	1100	4 pers. on horses looking for seals	5	1	zero seals	0	0	0
Killh	701	1115	Ferry windc. arrives to wp	3	2	zero seals	0	0	0
Killh	705	815	Ferry windc. arrives to wp, stay til 1015	3	2	zero seals	0	0	0

Appendix 3.

Disturbance incidences at Killingholm derived from observations in 1987-92. Number of seals before and after disturbances are noted including time of day, proportion of seals leaving land, numbers back after one hour and type of disturbance.
Störning vid Killingholm ur obervationerna gjorda 1987-1992. Antalet sälar före respektive efter störning anges och i övrigt tidpunkt, andelen sälar som lämnade land, andelen sälar som återkom inom en timme samt typ av störning.

Date	Time of day	Seal no. before dist. (on land)	Seal no. after dist. (on land)	% leaving site	% back after one hour	Disturbance type
28/06/87	1500	7	0	100	100	Sailingboat
30/06/87	600	20	13	35	100	Sailingboat
16/06/89	1400	16	0	100	0	Not noted
20/06/89	1300	12	4	67	50	Not noted
21/06/89	1300	20	3	85	20	Not noted
22/06/89	1000	36	5	86	30.5	Not noted
26/06/89	1645	16	1	94	31.3	Not noted
27/06/89	500	44	9	80	20.5	Not noted
06/07/89	2000	17	0	100	0	Not noted
07/07/89	400	28	0	100	0	Not noted
05/07/90	700	41	5	88	12.2	Not noted
07/07/91	600	25	0	100	0	Not noted

Appendix 4

Statistical test and test results. See superscripts in Results and Discussion for corresponding figures.
Values are given as mean (±S.D.).
Statistiska tester och testresultat. Se i Resultat och Diskussion för de korresponderande hänvisningarna. Värden anges som medelvärden (±S.D.).

1. Seals on land: 6.86 (9.88)
   Seals in water: 1.94 (3.39)
   Total 8.81 (11.01)

   On land - in water: r=0.18, n=404, P<0.0002
   On land - total: r=0.95, n=404, P<0.0001
   In water - total: r=0.47, n=404, P<0.0001

2. kW/24h: 11683kW (14132)
   Wind speed 6.24 m/s (3.21)
   KW/24h - wind speed: r=0.53, n=97, P<0.0001

3. Sign test: n=12, P<0.001

4. Maximum Likelihood ANOVA.
   Killingholm (January – June, 1998-1999)

Sourse	df	Chi-square	**P**
Seal*month	3	9.07	0.028
Seal*year	1	0.35	0.55
Month*year	5	5.40	0.37
Seal*month*year	2	12.70	0.002

5. Maximum Likelihood ANOVA.
   Killingholm (January – June, -1996, 1998-1999)

Sourse	df	Chi-square	**P**
Seal*month	4	32.36	<0.0001
Seal*year	2	12.58	0.0019
Month*year	8	40.32	<0.0001
Seal*month*year	4	18.72	0.0009

6. Maximum Likelihood ANOVA.
   Killingholm (July -October, -1996, 199-1998)

Sourse	df	Chi-square	**P**
Seal*month	3	25.70	<0.0001
Seal*year	2	6.92	0.0314
Month*year	6	25.08	0.0003
Seal*month*year	4	12.48	0.0141

7. Maximum Likelihood ANOVA.
   Näsrevet (January – June, 1998-1999)

Sourse	df	Chi-square	**P**
Seal*month	4	14.71	0.0053
Seal*year	1	0.76	0.38
Month*year	4	4.83	0.31
Seal*month*year	1	1.09	0.30

8. Maximum Likelihood ANOVA.
   Näsrevet (June - October, 1997-1998)

Sourse	df	Chi-square	**P**
Seal*month	4	17.31	0.0017
Seal*year	1	12.53	0.0004
Month*year	4	10.66	0.031
Seal*month*year	4	23.54	<0.0001

9. Maximum Likelihood ANOVA.
Näsrevet (June - July, -1996, 1997-1998)

Sourse	df	Chi-square	P
Seal*month	1	12.74	0.0004
Seal*year	2	5.72	0.057
Month*year	3	3.51	0.32
Seal*month*year	2	7.61	0.022

10. June – October Killingholm (-1996, 1996-1998, see Tab. 2b)
X^2=42.8, df=3, P<0.001

11. September – October Killingholm (1996-1998, see Tab. 2b)
X^2=18.8, df=2, P<0.001

12. April – May Näsrevet (-1996, 1998-1999, see Tab. 2c)
X^2=1.0, df=2, P<0.60

13. June – October Näsrevet (-1995, 1996-1998, see Tab. 2c)
X^2=14.5, df=3, P<0.002

14. July – August Näsrevet (1997-1998, see Tab. 2c)
X^2=29.5, df=1, P<0.001

15. July – August Näsrevet (-1996, 1997-1998, see Tab. 2c)
X^2=32.0, df=2, P<0.001

16. ANOVA (GLM) See Table Y (1980's,1990-1995, 1996, 1997, 1998, 1999)
a) Total area $F_{5,426}$=7.46, P<0.0001
b) Näsrevet $F_{5,527}$=5.37, P<0.0001
c) Killingholm $F_{5,657}$=35.50, P<0.0001

17. ANOVA (GLM) See Table Y (1996-1999)
a) Total area $F_{3,376}$=4.31, P=0.005
b) Killingholm $F_{3,462}$=7.91, P<0.0001
c) Näsrevet $F_{3,452}$=5.34, P=0.0013

18. ANOVA (GLM) See Table Y (April – September 1996-1999)
a) Total area $F_{3,247}$=2.56, P=0.056
b) Killingholm $F_{3,289}$=6.65, P=0.0002
c) Näsrevet $F_{3,263}$=3.53, P=0.015

19. ANOVA (GLM) See Table Y (October - March 19996-1999)
a) Total area $F_{3,149}$=22.54, P<0.0001
b) Killingholm $F_{3,167}$=2.64, P=0.051
c) Näsrevet $F_{3,185}$=26.17, P<0.0001

20. Kruskal-Wallis ANOVA

	Killingholm		Näsrevet	
Windpower plants running	Mean (S.D) seal numbers	No. obs.	Mean (S.D) seal numbers	No. obs.
0	2.32 (3.84)	20	15.01 (12.00)	32
1	0.20 (0.45)	5	15.90 (15.29)	14
2	0.25 (0.50)	4	14.28 (11.54)	10
3	2.83 (2.57)	3	18.11 (13.18)	29
4/5	1.68 (3.49)	23	14.13 (11.02)	46

Killingholm: KW=2.65, df=4, P=0.62
Näsrevet: KW=1.90, df=4, P=0.75

21. Paired t-test, n=9 in all cases.

Source	High seal density Mean (S.D.)	Low seal density Mean (S.D.)	t	p
Seal numbers	18.39 (10.44)	3.97 (3.54)	5.63	0.0005
Effect (kW)	7950 (7400)	13012 (14296)	-1.08	0.31
No. plants running	2.65 (2.21)	2.89 (2.19)	-0.37	0.72
Wind speed (m/s)	5.91 (0.71)	6.19 (2.81)	-0.30	0.77
Wind direction	150.66 (57.98)	190.25 (81.06)	-1.23	0.25
Water level	180.31 (15.12)	179.87 (14.63)	-0.12	0.91

22. ANOVA (GLM)

	High density	Low density	Total
No. seals when no plants running:	19.89 (12.27)	5.41 (7.30)	14.10 (12.67)
No. seals when 1-4 plants running:	9.88 (6.27)	2.91 (4.47)	4.71 (5.78)
No. seals when all 5 plants running:	15.25 (14.51)	3.83 (4.37)	11.44 (13.20)

High densty: $F_{2,47}$=1.79, P=0.18
Low density $F_{2,44}$=0.88, P=0.42
Total: $F_{2,94}$=5.78, P=0.0043

23.
r_s =0.68, n=97, P<0.0001

24.

	Mean number of seals (S.D.) in the different activity categories (0-7) n= number of observations in each activity category							
	0	1	2	3	4	5	6	7
Killingholm	2.0 (1.7) n=3	3.0 (-) n=1	33.3 (4.0) n=9	0 (-) n=0	9.9 (12.6) n=7	0.2 (0.4) n=6	0 (-) n=0	0.1 (0.25) n=16
Näsrevet	2.0 (3.3) n=9	2.0 (-) n=1	3.7 (9.4) n=12	1.1 (2.8) n=10	12.5 (10.3) n=10	6.3 (4.5) n=7	4.2 (5.5) n=9	7.9 (8.3) n=25
Total area	5.3 (5.1) n=3	5.0 (-) n=1	5.6 (14.9) n=9	1.3 (3.4) n=7	20.7 (22.6) n=7	7.3 (4.3) n=6	6.0 (3.6) n=3	9.6 (8.8) n=16

ANOVA:
Killingholm: $F_{7,44}$=3.18, P=0.0082
Näsrevet: $F_{4,75}$=2.60, P=0.0185
Total area $F_{4,44}$=1.59, P=0.16

25.
Killingholm: Total activity – total seal numbers: r_s =-0.32, n=52, P=0.02
Näsrevet: Total activity – total seal numbers: r_s = 0.34, n=83, P=0.0015
Total area Total activity – total seal numbers: r_s = 0.35, n=52, P=0.011

26. Wilcoxon matched-pair test
before disturbance: 23.5 (11.6)
after disturbance: 3.3 (4.2)
W=208.5, n=12, P=0.0008

27. Friedman's ANOVA
before disturbance: 15.6 (13.4)
during disturbance: 13.9 (12.5)
after disturbance: 10.0 (11.2)
S=18.23, df=2, , n=26, P<0.0001

28. Kruskall Wallis ANOVA:
H=5.11, df=3, P=0.16

29. Wilcoxon rank test:
    <500 m.: 0.60 (0.27), n=12
    >500 m.: 0.33 (0.27), n=18
    W=246.0, P=0.01
30. Kruskall Wallis ANOVA: See Appendix 2
    H=0.56, df=3, P=0.91

31. Wilcoxon rank test: See Appendix 2
    W=194.5, P=0.73

32. Friedman's ANOVA

before disturbance:	0.67% (0.58)
during disturbance:	0.75% (0.50)
after disturbance:	0.43% (0.54)

S=5.33, df=2, P=0.07

33. Wilcoxon matched-pair test

period 1:	4.73 (4.39)
period 2:	0.01 (0.04)

T=-133, n=16, P=0.001

34. Wilcoxon matched-pair test

period 1:	17.8 (4.2)
period 2:	11.9 (7.6)

T=111, n=17, P=0.06

35. Wilcoxon matched-pair test

period 1:	20.1 (2.8)
period 2:	5.4 (3.6)

T=45, n=8, P=0.008

36. Wilcoxon ranks test

period 1:	0.09/h (0.16), n=14 (9 disturbances)
period 2:	0.31/h (0.29), n=15 (24 disturbances)

W=162.0, P=0.026

37a. Wilcoxon ranks test

period 1:	0.38% (0.12)
period 2:	0.45% (0.10)

T^+=112, n=17, P=0.09

37b. Wilcoxon ranks test

period 1:	0.50% (0.08)
period 2:	0.38% (0.10)

T^+=45, n=9, P=0.04

38. Wilcoxon ranks test

disturbance:	0.50% (0.23), n=31
no disturbance	0.39% (0.19), n=77

S=2057.5, z=2.49, P=0.01

39. Wilcoxon ranks test
    group size

disturbance:	13.0 (12.3) , n=31
no disturbance	16.0 (12.9), n=77

S=1558.0, z=-0.89, P=0.37

40. ANCOVA

Type I		
	Period:	F=8.19, df=1, P=0.006
	Vigilance:	F=5.19, df=1; P=0.027
Type III		
	Period:	F=0.25, df=1, P=0.62
	Vigilance	F=5.19, df=1, P=0.027

41.

Wind speed:	r=0.75, n=344, P<0.0001
Wind direction:	r=0.54, n=320, P<0.0001

42.

Wind speed – wave height:	r=0.74, n=80, P<0.0001

43.

Wind speed:	r=0.65, n=81, P<0.0001
Wind direction	r=0.59, n=76, P<0.0001
Wind speed (by seal observers) – wave height	r=0.62, n=77, P<0.0001

44. Stepwise regression

Weather parameter	Chi-square	P
Killingholm		
1. Water level	31.23	0.0001
2. Wind speed	7.08	0.0078
3. Cloudiness	4.26	0.039
Näsrevet		
1. Wind speed	56.03	0.0001
2. Cloudiness	30.46	0.0001
3. Water level	24.82	0.0001
4. Temperature	8.98	0.0027
5. Wind direction	6.09	0.014
Total area		
1. Wind speed	50.88	0.0001
2. Water level	27.98	0.0001
3. Cloudiness	29.85	0.0001
4. Temperature	14.54	0.0001
5. Wind direction	11.14	0.0027
6. Precipitation	4.77	0.029

45. Generalised model

Burgsviken Total area	Including all observations			Excluding observations without seals		
Parameters	d.f.	Chisq.	p	d.f.	Chisq.	p
Year	3	31.53	0.0001	3	8.99	0.029
Month	11	633.83	0.0001	11	220.79	0.0001
Waterlevel	1	26.26	0.0001	1	0.19	0.66
Wind speed	1	158.29	0.0001	1	28.57	0.0001
Wind direction	2	26.17	0.0001	2	2.16	0.34
Temperature	1	5.61	0.018	1	5.56	0.018
Precipitation	2	25.82	0.0001	2	7.34	0.026
Cloudiness	2	179.67	0.0001	2	24.91	0.0001

46. Relationship between monthly seal means and monthly means of six weather variables.
Samband mellan sälarnas månadsmedelevärden och månadsmedelvärden av sex väderfaktorer.

Site	Water level	Wind direction	Wind speed	Temperature	Precipitation	Air pressure
Killingholm	r=-0.72 n=32 p<0.0001	r=-0.64 n=29 p<0.0002	r=-0.54 n=29 p=0.0023	r=0.38 n=29 p=0.042	r=-0.29 n=29 p=0.13	r=0.49 n=29 p=0.0075
Näsrevet	r=-0.41 n=30 p=0.024	r=-0.12 n=29 p=0.55	r=-0.61 n=29 p=0.0004	r=0.65 n=29 p<0.0001	r=-0.09 n=29 p=0.64	r=0.39 n=29 p=0.037
Total area	r=-0.59 n=28 p=0.0008	r=-0.33 n=27 p=0.10	r=-0.74 n=27 p<0.0001	r=0.68 n=27 p<0.0001	r=-0.28 n=27 p=0.15	r=0.48 n=27 p=0.0105

47.
Mean number of seals at different weather conditions during April-September 1996-1999, Burgsviken (both sites). Kruskal-Wallis ANOVA shows occurrence of difference in seal numbers between classes for all weather parameters. Wilcoxon tests further show which classes that differed from each other.
Medelantalet sälar under olika väderförhållande under April-September 1996-1999 räknat på det totala antalet i Brugsviken. Kruskal-Wallis ANOVA påvisar avvikelser i förekomst inom de olika kategorierna medans Wilcoxon testerna ser till vilken/vilka grupper som avviker.

Burgsviken, i.e. Parallell obs.	Mean Seal number	S.D.	n	Chisq.	d.f.	p Kruskal-Wallis	Test between classes	p (Wilcoxon)
Windspeed				28.3	3	0.0001		
1. < 3 m/s	11.0	9.4	41				1 vs. 3	0.0021
2. 3-5	12.3	11.4	99				3 vs. 4	0.088
3. 6-9	7.3	10.4	91					
4. >9	2.9	4.9	17					
Waterlevel				35.9	2	0.0001		
1. Low	12.3	11.8	117				1 vs. 2	0.0001
2. Intermediate	9.7	8.9	76				2 vs. 3	0.23 ns
3. High	3.8	8.1	55					
Cloudiness				14.5	2	0.0007		
0. sunny	11.5	11.5	120				0 vs. 1	0.052
1. cloudy	8.8	9.9	102				1 vs 2	0.011
2. foggy/rainy	3.9	7.2	24				0 vs 2	0.0003
Temperature				16.1	3	0.0011		
1. <5^{0}C	10.3	9.3	17				1 vs. 4	0.46 ns
2. 5-12	10.9	11.2	94				3 vs. 4	0.0004
3. 13-17	6.5	8.7	94					
4. >17	13.1	12.7	43					
Precipitation				7.2	2	0.027		
0. 0 mm	9.8	10.6	180				0 vs. 2	0.0066
1. <5	10.2	11.5	58					
2. >4	2.3	4.1	10					
Winddirection				7.6	2	0.023		
1. NNW-E	10.0	10.8	25				1 vs. 3	0.12 ns
2. E-SSW	10.6	11.2	62				2 vs. 3	0.0092
3. SSW-NNW	7.5	9.8	109					

48. August 26 to November 24 1996-1998

Source	1996	1997	1998
Water level	172.0 (10.7)	199.1 (16.1)	193.4 (20.6)
Wind speed	5.2 (2.8)	6.1 (3.2)	6.1 (3.2)
Wind direction	177.1 (117.6)	204.8 (110.3)	159.8 (101.1)

ANOVA:

Killingholm:	Water level	$F_{2,179}=45.1$, $P<0.0001$
	Wind direction	$F_{2,179}=3.38$, $P=0.036$
	Wind speed	$F_{2,179}=1.72$, $P=0.18$
Näsrevet:	Water level	$F_{2,181}=28.71$, $P<0.0001$
	Wind direction	$F_{2,181}=6.58$, $P=0.0017$
	Wind speed	$F_{2,181}=3.22$, $P=0.042$
Total area	Water level	$F_{2,142}=19.12$, $P<0.0001$
	Wind direction	$F_{2,142}=4.96$, $P=0.0083$
	Wind speed	$F_{2,142}=2.11$, $P=0.12$

49. June to August 1997-1998

ANOVA's: $P<0.018$ in all cases (Killingholm, Näsrevet and Total count) except for precipitation $P>0.13$ in all cases, respectively.