White-tailed eagle productivity

Key message

The productivity of white-tailed eagle during 2007-2014 (2012-2014 for Polish areas) indicates that all the coastal areas in the Baltic Sea have achieved or are at least very close to achieving GES. The sub-GES evaluation for the Swedish coast of the Gulf of Bothnia and the Latvian coast is due to the nestling brood size parameter not reaching GES. The significantly higher occurrence of dead eggs in the Swedish Gulf of Bothnia compared to other areas might indicate a higher impact from hazardous substances. The sub-GES evaluation for the Archipelago Sea is due to the percentage of breeding success being slightly below the GES boundary.
After the bans of DDT and PCB were implemented in the Baltic region during the 1970s and 1980s the white-tailed eagle productivity began to recover and reached the pre-1950s reference level by the mid 1990s.

Relevance of the core indicator

As predators at the top-end of the aquatic food chain the white-tailed eagles are strongly exposed to hazardous substances that accumulate and magnify through the foodweb and can thus serve as sentinels for effects from harmful substances. The elevated concentrations of persistent chemicals in white-tailed eagles also give possibilities to detect new emerging pollutants that are below detection limits in other biota. The white-tailed eagle was the first species to signal for the effects from persistent chemicals in the Baltic environment already during the 1950s, and the detection of PCB in 1966 occurred in Baltic white-tailed eagles.

Reproduction in the white-tailed eagle population was reduced to one fifth of the pre-1950 background level in the 1970s due to contamination from hazardous substances. After measures were implemented to ban the use of DDT and PCB, the reproductive success began improving after a delay of approximately a decade. The productivity reached that of a reference level by the mid-1990s, clearly exemplifying a case where the effects of environmental management actions are reflected in an improved environmental status of an indicator.

Policy relevance of the core indicator

<table>
<thead>
<tr>
<th>BSAP Segment and Objective</th>
<th>Primary importance</th>
<th>Secondary importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity</td>
<td>Healthy wildlife</td>
<td>Biodiversity:</td>
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<td>Healthy wildlife</td>
<td>Concentrations of hazardous substances close to natural levels</td>
<td>- Thriving and balanced communities of plants and animals</td>
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<tr>
<td>Hazardous substances</td>
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<td>- Viable populations of species</td>
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</tbody>
</table>

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<thead>
<tr>
<th>MSFD Descriptors and Criteria</th>
<th>Primary importance</th>
<th>Secondary importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>D8. Contaminants</td>
<td>8.2. Effects of contaminants</td>
<td>D1. Biodiversity</td>
</tr>
<tr>
<td>1.3. Population condition (fecundity rates)</td>
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<tr>
<td>1.1. Species distribution (range, pattern, covered area)</td>
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<td>1.2. Population size (abundance)</td>
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<tr>
<td>D4. Food webs</td>
<td></td>
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<tr>
<td>4.1. Productivity of key species or trophic groups (productivity)</td>
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<td>4.3. Abundance/distribution of key trophic groups and species</td>
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Other relevant legislation:
- EC Birds Directive: listed in Annex I (species to be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution).
- Water Frame Directive: Chemical quality
- Washington Convention (CITES): listed in Appendix I (trade in specimens of these species is permitted only in exceptional circumstances).
- Bonn Convention: listed in Appendix I (endangered migratory species) and Appendix II (migratory species to be the subject of agreements).
- Bern Convention: listed in Appendix II (strictly protected species).

Cite this indicator

HELCOM [2015]. [Indicator name]. HELCOM core indicator report. Online. [Date Viewed], [Web link].
Indicator concept

Good Environmental Status

Good environmental status (GES) is evaluated using the reproduction of white-tailed eagles by evaluating the parameter ‘productivity’ and the two supporting parameters ‘brood size’ and ‘breeding success’. For an assessment unit to be evaluated as having achieved GES, all three parameters have to achieve GES. The GES boundary concept is based on acceptable deviation of the parameters from the target level determined during a reference period.

White-tailed eagle reproduction has been monitored on an annual basis around the Baltic Sea for decades. This available historical data of the three parameters is considered to increase the overall confidence of the indicator evaluation.

Reference level

The reference levels are based on actual reference status data collected from the Swedish Baltic coast (Helander 1994a, 2003a): breeding success data from 1915-1953, and nestling brood size data from the period 1858-1950. The target level for productivity is based on the combined data for breeding success and nestling brood size. The confidence of the GES boundary based on the reference levels is considered to be high as it has been determined based on carefully selected actual observations from the time period 1854-1953. It should be noted that the population in those times was much smaller than today and was most probably under no influence of density-dependent effects.

White-tailed eagle reproduction has been monitored on an annual basis around the Baltic Sea for decades. This available historical data of the three parameters is considered to increase the overall confidence of the indicator evaluation.

These reference levels are based on pre-1950s data from eagles nesting on the Swedish Baltic coastline and archipelagos and thus refer to birds in the coastal ecosystem (Helander 1985). Due to the lack of reference data from other parts of the Baltic Sea, the same reference level has been tentatively set for the core indicator in the entire Baltic coastal zone. Where possible, the applicability of the reference level and the resulting GES boundaries should be validated using data from other parts of the Baltic Sea.

Breeding success

The reference level of breeding success has been determined based on data from the period 1915-1953 (n=43 years). The data has been assembled as series of records over time periods of 3-10 years in succession from eight White-tailed eagle territories. The mean value of successful nests was 72 %, and the 95 % confidence interval ranges from 59 to 86 % based on binomial distribution.

Brood size

The reference level for brood size has been determined based on data on WtE nestling brood size retrieved from banding records and from literature, comprising a total of 91 broods from 1858-1950 (Figure 6). The recorded brood size can only result in a discrete number (1, 2 or 3 nestlings). Up to 1950, the arithmetic mean for nestling brood size was 1.84. The sample distribution for samples taken from such a population cannot be expected to be normal distributed. In order to investigate the true sample distribution, for estimation of a confidence interval around the mean value for brood size, samples of 25 individual brood sizes were randomly taken from the population, 1858-1950. This was repeated 1000 times (bootstrapping). The estimated sample distribution deviates significantly from the normal distribution (p<0.03). An estimated 95 % confidence interval for a sample size of 25 was between 1.64 and 2.04.
Productivity

The reference level for productivity has been derived by combining the reference levels for brood size and breeding success. This gives a reference level for mean productivity of $1.84 \times 0.72 = 1.32$, with confidence limits from $1.64 \times 0.59 = 0.97$ up to $2.04 \times 0.86 = 1.75$. This estimate of confidence interval has been used in previous assessments. A more stringent estimate based on frequency distributions was derived from the dataset for nestling brood size ($n = 91$, all successful breeding attempts) with the addition of 35 ‘fictive’ unsuccessful breeding attempts, based on the mean value of 72 % breeding success in the population. The 95 % confidence interval around the mean value of 1.32 was estimated with the same method as for nestling brood size above (bootstrapping) and is then from 1.15 to 1.50. This confidence interval is built from a population that was probably under no influence from density dependent mechanisms. Under current conditions, it might be more appropriate for reference to apply the wider interval given above, and setting the lower end at 0.97.

GES boundary

The target applying to the good environmental status sensu EU Marine Strategy Framework Directive is set to the lower 95% confidence limit of the observations during the reference period. The data for the three parameters are presented as time trends. Observations should be measured as averages for a recent 5 to 10 year-period (depending on sample sizes). The current GES evaluation is based on an 8-year assessment period.

Productivity

The GES boundary for productivity is 0.97 nestlings.

Brood size

The GES boundary for brood size is 1.64 nestlings.

Breeding success

The GES boundary for breeding success is 0.59 (59%).

Anthropogenic pressures linked to the indicator

<table>
<thead>
<tr>
<th>General</th>
<th>MSFD Annex III, Table 2</th>
</tr>
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<tbody>
<tr>
<td><strong>Strong link</strong></td>
<td>The most important anthropogenic threat to White-tailed Eagle in modern times has been effects of toxins affecting population health (reproduction).</td>
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<tr>
<td></td>
<td>Contamination by hazardous substances introduction of synthetic compounds</td>
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<tr>
<td><strong>Weak link</strong></td>
<td>Enhanced mortality from collisions (trains, wind farms etc)</td>
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<tr>
<td></td>
<td>Enhanced mortality from secondary poisoning by lead ammunition.</td>
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<tr>
<td></td>
<td>Vulnerable to direct persecution (now illegal)</td>
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<tr>
<td></td>
<td>- Habitat loss and prey depletion are potentially serious future threats</td>
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The productivity of the white-tailed sea eagle is affected by several anthropogenic pressures that affect the nestling brood size (number of nestlings) and the breeding success (success in raising at least one nestling per pair).
Contaminant burdens

The anthropogenic pressure that has most clearly affected white-tailed eagles after it was legally protected is the introduction of hazardous substances to the environment. The effects on white-tailed eagle reproduction by hazardous substances have been clearly documented over the years. Chemical analyses of samples of the contents from collected dead eggs have e.g. provided possibilities to study relationships between the concentrations of contaminants and reproduction.

Tissue- and egg samples of white-tailed eagles have contained among the highest residue concentrations of persistent organochlorine contaminants (e.g. DDTs and PCBs) and heavy metals in the Baltic and the world ever documented (Henriksson et al. 1966, Jensen 1966, Jensen et al. 1972, Koivusaari et al. 1980, Helander 1994b, Helander et al. 1982, 2002, 2008, Olsson et al. 2000, Nordlöf et al. 2010). Furthermore, studies of individual eagles over time showed that females that were exposed to high concentrations of contaminants during the 1960s and 1970s remained unproductive after residue concentrations in their eggs had declined, indicating persistent affects from previous exposure (Helander et al. 2002).

Trends in productivity and residue concentrations of DDE and PCBs show that residue concentrations of DDE have now generally declined below an estimated critical threshold level for affecting reproduction (Figure 2), but exceptions with very high concentrations have turned up during 2009-2013 among sea eagle eggs from the Gulf of Bothnia.
Predatory birds are highly exposed to persistent chemicals and are useful in detecting the presence of ‘new’ pollutants that are potentially harmful, as illustrated by the discovery of PCBs in 1966 in a Baltic white-tailed sea eagle (Jensen 1966), and the discovery of the flame retardant congener PBD-209 in peregrine falcon eggs in 2004 (Lindberg et al. 2004).

Residue concentrations of brominated flame retardants have been investigated in eagle egg samples from Sweden (Nordlöf et al. 2010). Concentrations in the Baltic samples were three and six times higher than from inland samples from southern Sweden and Lapland, respectively.

A recent study comprising data from the time period 1965-2011 showed that mean WtE productivity was significantly negatively correlated with DDE in egg content, and with sPCB, sDDT, sPCDD/F as exposure index (Faxneld et al. 2014). No correlation between productivity and concentrations of PBDEs in the eggs was found. In North American ospreys (Pandion haliaetus) reproduction was adversely affected at concentrations of PBDEs in the eggs exceeding 1000 ng/g (Henny et al. 2009) which is 2-3 times higher than the concentrations found in the white-tailed eagle eggs from the Baltic. No negative correlation was found between productivity and PFOS in the eggs (Faxneld et al. 2014). However, the PFOS concentrations were in the same range as reported for eggs of great cormorant (Phalacrocorax carbo sinesis) from Lake Vänern for which a risk assessment indicated the possibility of effects on embryo survival (Nordén 2013).

Of special interest in the context of anthropogenic pressures on white-tailed eagles is the incidence of lethal poisoning connected with consumption of lead ammunition. Out of 11 investigated specimens from Finland 1994-2001, two (18%) died of lead poisoning (Krone et al. 2006). In Germany, reports from three
overlapping time periods may indicate an increasing trend: 12 % 1990-2000 (Krone et al. 2002), 23 % 1996-2007 (Krone et al. 2009, 27 % 1999-2010 (Herrmann et al. 2011). From Sweden, the results of analyses of heavy metals in archived samples of sea eagle liver and kidney tissue for lead contamination revealed no decrease in lead concentrations over the period 1981 – 2004, and indicated that a minimum of 14% of investigated specimens were lethally poisoned from ingestion of lead ammunition during that period (Helander et al. 2009). Preliminary results from a follow-up study on eagles from 2005 - 2012 indicate no improvement, despite a partial ban on lead ammunition since 2002; 20 % of the eagles from the core area on the coast were lethally poisoned (Helander et al. 2012). Analyses of 90 sea eagles found dead in Finland 2003-2013 indicated that 30 % had died from lead poisoning (Isomurso et al. 2014). Altogether these investigations imply that lead poisoning is an important death cause in white-tailed eagles within the HELCOM area that has so far not been fully recognized.

Other factors
The massive development of wind power parks can lead to a significant increase in mortality among white-tailed eagles and be seen in a reduction in breeding success and productivity (Dahl et al. 2012), but not in nestling brood size. Weather condition can affect the breeding success and productivity, and with possible effects from climate change it will be of interest to follow. It will also be possible to evaluate the influence from the natural density dependent conflicts between eagle pairs. A recent study in Germany showed a significant density dependent effect on breeding success (and thus on productivity), but no significant effects on nestling brood size (Heuck & Albrecht 2012).

In theory, also effects of food shortage affect brood size and breeding success, but this has so far not been observed in the Baltic population, where there has been, so far, plenty of food. Body mass can be indicative of food stress and health and such data can usually be easily obtained when assessing reproductive output in the nests and handling nestlings.

Assessment protocol
For the assessments of GES, a mean value based on data from a recent 5-10 year period for each of the three parameters is evaluated against its GES-boundary (and when appropriate, tested with the chi-square or equivalent method). Simple log-linear regression analysis is carried out to investigate average changes over time. To check for significant nonlinear trend components, a LOESS smoother is applied and an analysis of variance is used to check whether the smoother explains significantly more than the regression line (Cleveland 1979, Nicholson et al. 1995). Statistical power analysis is used to estimate the minimum annual trend likely to be detected at a statistical power of 80% during a monitoring period of 10 years.

Methodology of data analyses
In the following three paragraphs, n1 denotes the number of nests containing 1 young (etcetera).

Productivity
The mean number of nestlings of at least three weeks of age, out of all occupied nests:

\[
\frac{(n1 + [n2x2] + [n3x3])}{(n0 + n1 + n2 + n3)}
\]
For nests with young that were observed only from the ground, the numbers of nestlings is underestimated since sometimes not all nestlings are visible. A correction is necessary before the total number of nestlings from such observations can be incorporated with the total number of nestlings from climbed nests, to make up the total number of nestlings for the productivity assessment. A correction is calculated based on the mean number of nestlings in climbed nests divided by the mean number of nestlings observed from the ground, or by applying the mean nestling brood size in climbed nests to all successful nests that were observed only from the ground.

**Brood size**

The mean number of nestlings of at least three weeks of age in nests containing young:

\[
\frac{(n1 + n2 + n3)}{(n1 + n2 + n3)}
\]

For the calculations of mean brood size only data obtained from nests that have been climbed are included. Even big nestlings that are lying down in the nest are easily overlooked when observations are made from the ground. Data received from observations made from the ground in Germany underestimated the real number of nestlings by 11% (Hauff & Wölfel 2002), using an extended data set (updated until 2014) the difference was 14% (Herrmann, unpublished).

**Breeding success**

The proportion of nests containing at least one nestling of at least three weeks of age, out of all occupied nests:

\[
\frac{(n1 + n2 + n3)}{(n0 + n1 + n2 + n3)}
\]

**Assessment units**

White-tailed eagles are presently breeding in coastal areas of the whole Baltic Sea, and are since many years monitored in a network of national projects with harmonized methodology (Helander 1990).

Unit level 3 is proposed as most accurate for this indicator. Where the subpopulation within a coastal strip of a sea-unit is too small from a statistical point of view, data from coastal strips of adjacent sea-units can be combined. However, since the assessment of GES is based on data over at least a 5-year period it will yield a reasonable sample size even for small subpopulations.

The subpopulation on coastal strip # 15 (Russian part of Gulf of Finland) has been reported to be only 6 pairs. Over a 5-year period this would yield a potential sample size of 30, provided that data from all pairs can be collected in all years. This is not the case so far, and the currently available samples are useful only for calculations of mean nestling brood size (Figure 6).

Besides breeding in coastal areas, white-tailed eagles also breed inland within all Contracting Parties. The boundaries for coastal areas where this indicator applies are here set in accordance with HELCOM Article 1 (Convention Area) to include landward internal waters (lagoons and estuaries). The inner landward boundary is set in accordance with the Guidelines for the identification of coastal ecosystems, proposed by EC Nature (EC Nat 2-5, 1993) and approved by EC 4, stating under point 1.2: ‘For practical reasons in cases
where the extension of coastal ecosystems is difficult to define according to a) – c), a strip in a width of at most 10 kilometers inland from the coastal mean water line is taken for a working area of Art. 15.’

Figure 3. Only white-tailed eagle pairs breeding within the 10 km zone are considered in the indicator.

**Relevance of the indicator**

**Policy Relevance**

The white-tailed sea eagle has faced strong persecution in the 19th and early 20th century causing severe population declines and even extermination from many countries in Europe in the early 1900s. Protection measures made the population increase again.
A second decline began in the 1950s’ and continued into the 1960s-70s. The second decline occurred due to organic pollutants, mainly DDE (a metabolite of DDT), that caused structural changes and thinning of egg shells, and PCB causing embryo mortality, and hence, wide-spread failure in reproduction. Reproduction in the Baltic eagle population in the 1970s was reduced to 1/5 of the pre-1950 background level. Following bans of DDT and PCB during the 1970s around the Baltic eagle productivity began to recover from the mid-1980s, and since the mid-1990s is largely back to pre-1950 levels. The population on the Swedish Baltic coast has increased at 7.8% per year since 1990.

The improvement in reproduction of the Baltic white-tailed sea eagle populations came no earlier than 10 years after most countries around the Baltic had implemented bans of DDT and PCB. This is a clear reminder of the potentially long-term effects from persistent pollutants. The subsequent recovery, from an 80% reduction in reproductive ability in the 1970s, is nevertheless an important evidence of successful results from wise political decisions.

The maintenance of viable populations of species is one of the biodiversity objectives of the HELCOM Baltic Sea Action Plan. EU Birds Directive (79/409/EEC) lists the white-tailed sea eagle in Annex I, binding member states to undertake measures to secure reproduction and survival of the species.

The species is listed in the following international conventions:

- Bern Convention Annex II (strictly protected species),
- Bonn Convention Annex I and II (conservation of migratory species),
- Washington Convention (CITES) Annex I (regulating trade).

As a top predator in aquatic ecosystems in general the white-tailed sea eagle is relevant for the Water Framework Directive (2000/60/EC) in relation to the objective Chemical quality, as indicator for detrimental effects of pollutants. As a top predator in the marine ecosystem, white-tailed eagle is also being assessed by the EU Marine Strategy Framework Directive (2008/56/EU), which requires good environmental status (GES) of marine ecosystems by 2020. Particularly the following GES criteria apply to this core indicator:

- Species distribution,
- Population size,
- Population condition (fecundity rates),
- Productivity of key species or trophic groups,
- Effects of contaminants (“Contaminants are at a level not giving rise to pollution effects”).

Monitoring of sea eagle population health as environmental indicator, as well as monitoring of contaminants in eagles and their prey, is recommended in an international Species Action Plan adopted under the Bern Convention in 2002. In Sweden, reproductive parameters of white-tailed eagle are since 1989 included in the national environment monitoring program as indicators for harmful effects of contaminants. White-tailed eagle productivity, and eggshell thickness of white-tailed eagle and guillemot, is used in the Swedish implementation of the WSFD as indicators for effects from harmful substances (HVMFS 2012:18, 8.2.A and 8.2.B)
Role of white-tailed eagles in the ecosystem

Relevance of the indicator for describing developments in the environment

The white-tailed eagle is the ultimate top predator of the Baltic ecosystem, feeding on fish, sea birds, and seals, and is thus strongly exposed to persistent chemicals that magnify in the food web. It was the first species that indicated deleterious effects from environmental pollutants in the Baltic Sea.

The white-tailed eagle is positioned at the top end of food webs in aquatic ecosystems. Within the Convention area, white-tailed eagle preys primarily on waterfowl and fish, and to some extent on mammals, largely as carrion (seals) (Table 1). The white-tailed eagle is an opportunistic hunter and the food largely reflects the availability of potential prey. Fish that dwell in shallow waters or close to the surface are particularly vulnerable to predation. Common fish prey species in the Baltic coastal ecosystems are pike (Esoc lucius), bream (Abramis brama), ide (Leuciscus idus) and perch (Perca fluviatilis). A species that has increased strongly as prey in recent years in the Baltic Proper is the garfish (Belone belone), probably as a result of increased availability but possibly also as a substitute for local decreases in the abundance of pike. Most common among bird prey are eider (Somateria mollissima), mergansers (Mergus merganser, M.serrator), mallard (Anas platyrhynchos), cormorants (Phalacrocorax carbo), gulls (Laridae spp.), great-crested grebe (Podiceps cristatus), and coot (Fulica atra). A clear shift from a dominance of fish prey near the mainland shore to a dominance of bird prey in the outer archipelago has been observed (Helander 1983). This also showed a shift among bird species, reflecting differences in availability from mainland to outer coast. A decrease in the abundance (and thus availability) of eider has been compensated for by the increase in abundance of cormorants. The prey distributions seem to be largely similar in different parts of the Baltic Sea, but the proportions of the prey species have not been studied in all sub-basins.

Table 1. Prey of white-tailed eagle in the Baltic Sea sub-basins.

<table>
<thead>
<tr>
<th>Waterbirds</th>
<th>Fish</th>
<th>Mammals</th>
<th>Other</th>
</tr>
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<tbody>
<tr>
<td>Gulf of Bothnia</td>
<td>55%</td>
<td>34%</td>
<td>11% (carrasses)</td>
</tr>
<tr>
<td>Åland Sea + Archipelago Sea</td>
<td>58–66%</td>
<td>28–36%</td>
<td>no data</td>
</tr>
<tr>
<td>Gulf of Finland</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Northern &amp; Central Baltic Proper + Gulf of Riga</td>
<td>58%</td>
<td>36%</td>
<td>seal carcasses</td>
</tr>
<tr>
<td>Southern Baltic Proper</td>
<td>waterfowl, geese</td>
<td>yes</td>
<td>carcasses of deer and wild boar</td>
</tr>
<tr>
<td>Danish Straits and German Bights</td>
<td>waterfowl, geese</td>
<td>yes</td>
<td>carcasses</td>
</tr>
<tr>
<td>Kattegat+ Limfjorden</td>
<td>waterfowl, geese</td>
<td>yes</td>
<td>carcasses</td>
</tr>
</tbody>
</table>

The distribution of white-tailed eagle populations in many countries also includes inland freshwater habitats. The monitoring of the inland populations in Sweden has shown big differences in concentrations of hazardous substances in the eggs compared to the coastal population, resulting in significant differences in observed effects on eggshell and reproductive parameters. The access to data from populations that are exposed to different pressures in this way is a favourable and useful condition for interpretations of observed differences to coastal eagles in reproductive and other population parameters.
Life history traits

In addition to being a top predator, the white-tailed eagle has other features that are favourable from a monitoring perspective. Territorial adults on the Baltic Sea coast are mainly sedentary and thus reflect the regional contaminant situation. Mating pairs generally pair for life, and remain at the same breeding site, with sites commonly used over many generations of eagles. This provides very good opportunities for long-term monitoring and detailed studies. A large portion of breeders in the Baltic region are currently ringed, improving possibilities for study of individual birds over time.

Relevance of the concept

The concept of using white-tailed eagle productivity as core indicator for GES in relation to hazardous substances relies on the experience of effects on this species from the exposure to persistent contaminants over five decades on the Baltic Sea coast. If white-tailed sea eagle reproduction had been monitored in the Baltic Sea earlier during the 20th century, then the negative impact of DDT could have been noticed already in the 1950s. Retrospective studies have shown a significant drop in white-tailed eagle breeding success and nestling brood size already in the 1950s, with a further decrease during the 1960s and 1970s (Helander 1985). High concentrations of DDTs and PCBs in white-tailed eagle eggs were reported early from Finland (Koivusaari et al. 1980) and Sweden (Helander et al. 1982) and significant relationships were shown between productivity and residue concentrations of DDE and PCB in white-tailed eagle eggs (Helander et al. 1982, 1994b, 2002, 2008).

The productivity parameter

The productivity of white-tailed eagle in the coastal zone of different parts of the Baltic Sea is an indicator describing not only effects from the biomagnification of contaminants, but also persecution, disturbance of nest sites, food availability and availability of suitable nesting sites. Thus, it describes in reproductive terms the condition of the population and indirectly indicates the potential for increased abundance and distribution. This indicator combines the breeding success and brood size into a single indicator and assesses the reproductive output of the population. It is a useful indicator in studies on relationships between reproduction and anthropogenic pressures and also a vital parameter in assessments of the state of populations in management perspectives.

Brood size and breeding success as supporting parameters

Brood size is a precise parameter following the number of nestlings produced per nest containing young. This is a good indicator for impacts of hazardous substances because as top predators, white-tailed eagles accumulate persistent toxins which in turn can cause egg mortality. Breeding success (per cent pairs in the population that produce young) is another indicator for egg mortality, including effects from contaminants and also other anthropogenic disturbance as well as natural factors such as weather, and density dependent breeding failures.
Results and confidence

Productivity

The mean annual productivity during 2007-2014 reaches good environmental status (GES) in all studied areas (Figure 4 and Figure 5). The assessments in this report include all HELCOM contracting parties except Poland (data not yet submitted). The time series since the 1970s, available for some countries, indicate a great increase in productivity as well as for nestling brood size and breeding success since the mid-1980s, and GES was reached or nearly reached for all three parameters mainly during the last 10 years. In some of the studied areas the increase in productivity has stabilized at the lower end of the estimated reference level, possibly as an effect from density-dependent competition for nest sites, as has been observed in Germany (Figure 4 and Figure 5).

Figure 4. The status of productivity of the white-tailed eagle 2007-2014 in the Baltic Sea (10 km coastal zone around the sea). The productivity score indicates the number of nestlings per checked territorial pair in the population (8-year average). Germany is represented by data from Mecklenburg- Western Pomerania. Polish data 2012-2014.
Figure 5. Mean annual productivity (number of nestlings per checked occupied territory) of coastal subpopulations of white-tailed eagles around the Baltic Sea. The blue line in the graphs represents a locally weighted scatterplot smoothing (LOESS). A pre-1950 reference level (black line) given with a range (yellow) based on 95% confidence limits for breeding success according to Helander (2003a) is given in each graph. Germany is represented by data from Mecklenburg-Western Pomerania.

Nestling brood size

As illustrated in Figure 6 and Figure 9, nestling brood size reached or is very close to GES in 2007-2014 in all coastal areas of the Baltic Sea. Nestling brood size during that time period was in GES in all areas except for the Swedish coast of the Gulf of Bothnia and the coastal area of Latvia (Figure 6), but the scores were quite close to the target for several areas.
Figure 6. The status of nestling brood sizes of the white-tailed eagle 2007-2014 in the Baltic Sea (10 km coastal zone around the sea). The nestling brood size score indicates the number of nestlings per checked reproducing pair (8-year average for climbed nests). Red color indicates score below the target for good environmental status (GES). Germany is represented by data from Mecklenburg-Western Pomerania. Polish data 2012-2014.

The smaller average nestling brood size on the Swedish Gulf of Bothnia coast 2000-2009 was linked to a significantly higher frequency of nests with young that also contained dead eggs: 7.1% as compared to 2.9% in the Baltic Proper (n = 461 and 932, respectively) (Figure 7). This can imply an influence of hazardous substances on the hatching success in the Gulf of Bothnia. This case also indicates that nestling brood size is a more sensitive indicator specifically for hazardous substances than productivity.
Figure 7. Mean white-tailed sea eagle nestling brood size in sub-areas around the Baltic Sea in 2000 – 2010. Sample sizes given in brackets. Nestling brood sizes below 1.60 are highlighted (red) in the map. Data from Finland are from Stjernberg et al. (2003). Germany is represented by data from Mecklenburg- Western Pomerania.

Nestling brood size has improved strongly since the 1970s but still has not reached the level of GES in all parts of the Baltic. Brood sizes began to increase in the studied areas from the 1980s (Figure 8), roughly in synchrony with the increase in breeding success (Figure 11). This is inherent with an improvement in the hatching success of the eggs, affecting both these indicators parameters in parallel. Brood size in the Baltic Proper reached into the lower end of the pre-1950 reference level in the late 1990s (Figure 8). The huge fluctuations that show in some of the graphs in Figure 9 can be an artefact of small and varying sample sizes of climbed nests.
Figure 8. Mean brood size (number of nestlings per successfully breeding pair) of white-tailed sea eagle on the Swedish Baltic coast 1854-2013. Sample size for each time period is given in brackets. A reference level (solid black line) with 95% confidence limits (shaded grey) is based on data from 1854-1950 (blue bars) according to Helander (2003a).
HELCOM core indicator report
White-tailed eagle productivity

A) Denmark  B) Estonia  C) Latvia  D) Lithuania

E) Germany  F) Finland, G.of Finland

[Graphs showing brood size by year for different countries]
Breeding success

The breeding success has reached GES in nearly all areas along the Baltic Sea during 2007-2014 (Figure 10). Retrospective studies have shown that breeding success along the whole Swedish Baltic coast decreased
from an average of 72% in the early 1950s, down to 47% between 1954–1963, and 22% between 1966–1982 (Figure 11) (Helander 1985).

Figure 10. The status of breeding success of the white-tailed eagle 2007-2014 in the Baltic Sea (10 km coastal zone around the sea). The breeding success score indicates the percentage nests with young out of all checked pairs (8-year average). Red color indicates score below the target for good environmental status (GES). Germany is represented by data from Mecklenburg- Western Pomerania. Polish data 2012-2014.

Figure 11. Breeding success (% reproducing pairs) in the population on the Swedish Baltic Sea coast. The upper dot and the blue line indicate the background reference mean value with 95% confidence interval (grey) for a time period 1915-1953, based on data from eight eagle territories (n=43). The lower dot indicates a mean value for the time period 1954-1963 based on data from 14 territories (n=68).
Breeding success increased significantly from the early 1980s (Germany, Sweden) and has generally reached GES by the mid- to late 1990s (Figure 11). The development in the southern Baltic (Germany) is similar to that in the central Baltic (Sweden, Baltic Proper and Finland, Åland-Åboland). Impacts of intraspecific competition in areas with a high density of breeding pairs in Mecklenburg-Western Pomerania have been discussed as a possible reason for lower breeding success (Hauff 2009; Heuck & Albrecht 2012). In densely populated areas also in Sweden and Finland, fatal territorial fights have been recorded more frequently in recent years. It may be that intraspecific competition in densely populated areas could explain why breeding success in several areas seems to have stabilized at levels slightly below the mean value for the estimated reference level in Figure 11. A lower breeding success also inherently affects productivity. The reference level was based on data from a more sparse population during the first half of the 20th century.
Figure 12. Breeding success in % (proportion of successfully reproducing out of all checked territorial pairs) of coastal white-tailed sea eagle subpopulations around the Baltic Sea. The blue line in graphs represents a locally weighted scatterplot smoothing (LOESS). A pre-1954 reference level (black line with 95% confidence limits indicated in yellow) according to Helander (2003a) is given in each graph. Germany is represented by data from Mecklenburg-Western Pomerania.

Confidence of the indicator status evaluation

The confidence of the indicator status evaluation is considered to be high. Annual data is currently available from nine countries, covering almost the entire Helcom coastal zone. There is no bias in the spatial distribution of the data. The parameters are robust and the comparability of data from different areas is high. Annual sample sizes are big for countries with long stretches of coastline and are adequate for other countries based on averages for 5-10 year periods. The national focus is generally on whole-population monitoring.
Monitoring requirements

Monitoring methodology

HELCOM common monitoring relevant to the indicator is described on a general level in the HELCOM Monitoring Manual in the sub-programme: Marine bird health.

Methodology and frequency of data collection

White-tailed eagles are resident and faithful to their territories throughout their lifetime. These features provide good opportunities for long-term monitoring of populations and breeding performance. Nest sites are checked annually for occupancy and the reproductive output is recorded for each occupied territory. Based on the frequency distribution in the population of occupied nests containing 0, 1, 2 or 3 nestlings, three reproductive parameters are assessed: the proportion of reproducing pairs in the population (Breeding success), the mean number of nestlings per successfully breeding pair (Nestling brood size) and the mean number of nestlings per checked pair in the population (Productivity).

Based on data from nests inspected by climbing the nest tree, and excluding nests checked only from the ground, nestling brood size is a precise standard. Nest trees are climbed for precise assessment of reproductive parameters. In connection with these nest visits, measurements and biological samples are taken. The following parameters are usually measured from the nestlings: wing chord (for estimation of age in days), tarsus width and depth (for estimation of sex; see Helander 1981, Helander et al., 2007), weight (for nutritional status) and in some areas feather and blood samples (for chemical analyses and genetic studies). The nestlings are ringed using an international colour ringing programme for identification, according to Helander (2003b). Dead eggs and shell pieces are collected for measurements, investigation of contents and chemical analyses, for studies on relationships with reproduction. Feathers shed from adults are generally collected at nest sites. In Sweden such samples are archived in the National Environmental Specimen Bank.

Eagles found dead in nature belong to the state in all countries around the Baltic Sea, except for Germany. In Germany, they are property of the hunting leaseholder; however, the leaseholders in most cases accept the analysis of dead eagles by governmental authorities. This provides good opportunities for investigations of the cause of death. State game is normally sent to the national authority for registration and examination of death cause, saving of samples and preparation for museum collections. Professional investigations of causes of death in white-tailed eagles are performed in Finland, Germany and Sweden (and possibly elsewhere). Before being opened, all white-tailed sea eagles are inspected macroscopically for body condition and signs of trauma, and x-rayed to assess the presence of lead shot, fractures etc. Distributions of cause of death of sea eagles from Germany, Finland and Sweden are presented in Herrmann et al. (2011). In Finland, Germany and Sweden, organ samples are archived from all reasonably fresh specimens. In Finland, white-tailed eagles undergo routine necropsy in the Finnish Food Safety Authority Evira, including chemistry and parasitology with histological, bacteriological and virological examinations when needed. Carcasses are x-rayed when shooting injuries are suspected. All tissue samples, skins and skeletons are sent to the Museum of Natural History for storage. For eagles from the the German Baltic coastal states (Mecklenburg-Western Pomerania and Schleswig-Holstein), necropsy is performed at the Institute for Zoo and Wildlife Research (IZW) in Berlin where tissue samples are also mostly stored, and skeletons and skins are mostly archived by the Müritzeum in Waren. In Sweden, all eagles undergo necropsy at the National Veterinary Institute (SVA) in Uppsala; skeletons and skins are archived by the
Swedish Museum of Natural History in Stockholm, and tissue samples archived in the National Environmental Specimen Bank and at the National Veterinary Institute.

**Description of optimal monitoring,**

During spring (February – April, incubation period) eagle territories are checked from a safe distance (to avoid disturbance) in order to locate occupied nests. Occupied nests are to be revisited during the nestling period (May – June) for assessment of breeding success and nestling brood size.

It is crucial for the assessment of breeding success and productivity that unsuccessful as well as successful breeding attempts are recorded equally well. Most breeding failures occur during the early phases of the breeding cycle. The early spring surveys are thus very important; later during the breeding season, there is an increasing risk that unsuccessful breeding attempts are overlooked. A very effective way to perform the early survey in spring is by helicopter. The importance of conducting a first check during the incubation period, to be followed by a second check during the nestling period, has been stressed previously by Postupalsky (1974, 1981, 1983), Steenhof (1987) and Steenhof & Newton (2007).

For the assessment of nestling brood size, it is crucial that the nest content is checked properly: by climbing to the nest (or a neighbouring tree) to be able to look into the nest. Nests checked only from the ground will not be used for assessment of nestling brood size. The number of nestlings in successful nests observed only from the ground is estimated by applying a correction factor before being used for calculation of productivity. For the future, UAS (Unmanned Airborne Systems) may provide good opportunities for the checking of unclimbed nest to assess actual nestling brood size.

**Current monitoring**

Current monitoring is considered adequate. Monitoring is done in the HELCOM Contracting Parties on the annual basis.

Currently, eagles are breeding along the coasts of almost the whole of the Baltic Sea, as well as in inland freshwater systems including drainage areas to the Baltic Sea. Populations and reproduction are monitored in a network of national projects that use the same methodology (Helander 1990). Monitoring of white-tailed eagle reproduction in Sweden has been included in the National Environment Monitoring Programme since 1989, as an indicator of effects from chemical pollutants. Pre-1954 background data on breeding success and pre-1950 background data on nestling brood size are available from the Swedish Baltic coastline (Helander 1994a, 2003a). These data are used as reference levels for evaluation of observations within the programme (see below). The current numbers of known territorial pairs in the Helcom coastal area are given below (}
Table 2). The coastal area is restricted to the 10 km Helcom coastal zone, with the majority of eagles breeding close to the coastline and in the archipelagos.
White-tailed eagle populations around the Baltic Sea have grown substantially during the last decades (Herrmann et al. 2011). The white-tailed eagle now inhabits coastal areas in all HELCOM contracting parties (states). White-tailed eagles also breed inland in freshwater habitats and are usually monitored in the same way as the coastal populations. Freshwater populations are much less exposed to contaminants and can be useful for reference to the coastal populations (Helander et al. 2002).

<table>
<thead>
<tr>
<th>Contracting Party</th>
<th>Sub-area if relevant</th>
<th>Number of breeding white-tailed eagle pairs within the 10km coastal strip</th>
<th>Number of pairs breeding and feeding inland/freshwater, given for reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td></td>
<td>&gt;30 pairs</td>
<td>c. 15 pairs</td>
</tr>
<tr>
<td>Estonia</td>
<td></td>
<td>&gt;100 pairs</td>
<td>35 pairs</td>
</tr>
<tr>
<td>Finland</td>
<td>Gulf of Bothnia (Quark)</td>
<td>&gt;100 pairs</td>
<td>c. 50 pairs</td>
</tr>
<tr>
<td></td>
<td>Åland &amp; Åboland</td>
<td>&gt;250 pairs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gulf of Finland</td>
<td>30 pairs</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Mecklenburg-Pomerania</td>
<td>&gt;110 pairs</td>
<td>c. 200 pairs</td>
</tr>
<tr>
<td></td>
<td>Schleswig-Holstein</td>
<td>&gt;20 pairs</td>
<td>c. 50 pairs</td>
</tr>
<tr>
<td>Latvia</td>
<td></td>
<td>10 pairs</td>
<td>c. 40 pairs</td>
</tr>
<tr>
<td>Lithuania</td>
<td></td>
<td>9 pairs</td>
<td>c. 50 pairs</td>
</tr>
<tr>
<td>Poland</td>
<td></td>
<td>88 pairs</td>
<td>&gt;500 pairs</td>
</tr>
<tr>
<td>Russia</td>
<td></td>
<td>6 pairs</td>
<td>Not known but believed to be large</td>
</tr>
<tr>
<td>Sweden</td>
<td>Gulf of Bothnia</td>
<td>&gt;120 pairs</td>
<td>&gt;75 pairs</td>
</tr>
<tr>
<td></td>
<td>Baltic Proper</td>
<td>&gt;200 pairs</td>
<td>&gt;150 pairs</td>
</tr>
</tbody>
</table>
Description of data and up-dating

Metadata

Data source
National. In most countries the monitoring and handling of data is carried out on a voluntary basis, often in national projects with devoted members. National data have been submitted from the contracting parties to the Swedish Museum of Natural History for storage and compilation of results in uniform format.

Description of data
The new reporting format is discriminating between controls of climbed nests and nests that have been observed only from ground level, in order to allow for calculations of a correction factor based on the data for each national population/subarea. The correction factor relates to nestling brood size for nests that has been checked only from ground level and is needed for correct estimates of productivity for such nests.


Spatial coverage includes the whole HELCOM Convention area, but with big differences in the size of national eagle populations. Monitoring of populations is annual. Examples of national monitoring performance and data handling:

Denmark: The monitoring and data storage is carried out on a voluntary basis within the national project “Örn” under the Danish Ornithological Society.

Estonia: The monitoring and data storage is carried out on a voluntary basis within the national “Eagle Club”.

Finland: In Finland surveys of breeding populations and reproduction, ringing of nestlings, sampling, are carried out by voluntary members of WWF Finland’s White-tailed Sea Eagle working group. Data are stored in a competent data base. Specimens found dead, DNA-samples from nestlings as well as addled eggs are stored in the Finnish Museum of Natural History, University of Helsinki.

Germany: In Western Pomerania, data are collected by voluntary ornithologists, co-ordinated by the “Project group for large bird species” under the auspices of the Agency for Environment, Nature Conservation and Geology. The country-wide white-tailed sea eagle data are compiled by Peter Hauff, who submits the annual reports to the mentioned governmental agency.

Sweden: Surveys of breeding populations and reproduction with sampling, sample preparation, storage in specimen bank and evaluation and storage of data are carried out by the Department of Environmental Research and Monitoring at the Swedish Museum of Natural History, Stockholm, and are commissioned by the national EPA. Surveys of breeding populations and reproduction of reference freshwater populations have thus far been carried out by the Swedish Society for Nature Conservation (“Project Sea Eagle”), Stockholm. Chemical analysis is carried out at the Institute of Applied Environmental Research at Stockholm University.
Strengths and weaknesses of data

Minimum detectable yearly trend (%) for a 10-year monitoring period at a statistical power of 80% has been estimated for Swedish data for different sample sizes, based on random sampling from data collected during 1991–2006 (Helander et al. 2008). Minimum detectable trends based on the raw data set between 1991–2006 (with a varying annual number of observations) was 1.3 % for brood size (Baltic Proper), 2.0 % for breeding success (Gulf of Bothnia) and 3.0 % for productivity (Gulf of Bothnia). The national survey methods are very similar but population size and thus sample sizes vary between the Contracting Parties.
Contributors, archive and references

Contributors

Main authors: Björn Helander, Christof Herrmann

Other recognized contributors: Lena Avellan, Anders Bignert, Tomasz Chodkiewicz, Deivis Dementavicius, Erik Ehmsen, Peter Hauff, Samuli Korpinen, Janis Kuze, Heikki Lokki, Tadeusz Mizera, Renno Nellis, Vasily Ptschelinzev, Minna Pyhälä, Torsten Stjernberg.

Archive

2013 Indicator report

HELCOM Baltic Sea Environment Fact Sheet 2011

References


Additional relevant publications