Is thiamine deficiency a significant cause of declining bird populations in the Baltic Sea area?

Pilot study

Bo Söderström

Background

The Baltic Sea area is a highly disturbed ecosystem strongly affected by anthropogenic activities, which in turn impact more or less resident bird populations. Eutrophication of the Baltic Sea is often considered as the main factor behind the observed *increase* of eider populations in the Baltic until 1990. A surplus of nitrogen and phosphorous led to increased biomass of phytoplankton, which in turn benefited filtrating blue mussels that is the main food of eiders. In contrast, the eider has shown a dramatic population *decrease* between 1992-93 and 2007-09 (– 51%, Ottvall 2012). It should be noted that there are large regional differences in population trends within the Baltic Sea area: the population trend is similar in Sweden and Finland whereas the Danish eider population size has been constant since 1988 (Christensen and Bregnballe 2011).

Population trends of other bird species have shown a similar pattern of substantial population increases followed by decreases. For example, the Swedish population of the herring gull decreased by 20-29% between 1998 and 2008, but then from a historically high population size likely caused by the now discontinued use of open waste dumps (Ottvall et al. 2008). Moreover, overfishing of large predatory fishes, such as the cod, in the Baltic Sea has caused a predatory release[1] of sticklebacks and other smaller fish. In turn, this is a likely explanation for the significant population increases of fish-feeding bird species such as common tern, arctic tern and razorbill in the Baltic Sea area (Ottvall et al. 2008).

[1] Occurs when a predator species is removed from a prey species by, for example, a great reduction in the predator population size, which releases the prey from one of the factors limiting its population size.

Mussel-eating ducks other than eider have also shown dramatic population decreases since 1992-93: common scoter -48%, velvet scoter -56%, and long-tailed duck – 65%. A compilation of existing knowledge of reasons for population declines of mussel-eating ducks in the Baltic Sea area since 1990 was recently published (Ottvall 2012). It is concluded that most researchers agree that multiple, interacting factors are behind the observed population declines. These include:

1) Food shortage or reduced food quality, due to reduced eutrophication level of some parts of the Baltic Sea (e.g. in Denmark), leading to reduced breeding success and/or making ducks more susceptible to diseases (Skov et al. 2011).
2) Increased predation pressure on nesting eider females mainly due to a recovering population of the white-tailed eagle (Kilpi and Öst 2002).
3) Recurring oilspills in areas where many ducks congregate during winter (e.g., Hoburg bank south of Gotland where a large part of the long-tailed duck population overwinter; Larsson and Tydén 2005).
4) Fishery bycatches leading to the death of 200 000 birds per year (Zydelis et al. 2009).
5) Hunting causes the direct death of 65 000 eiders annually in the Baltic Sea area and may also indirectly lead to reduced physiological status due to lead poisoning (Hollmén et al. 1998).
6) Diseases have repeatedly been shown to increase both adult and juvenile mortality in the Baltic Sea area eider population (e.g., bird cholera in Denmark, reovirus in Finland). Lately, bird paralysis or so-called bird death in Sweden has received much attention. One of the main hypotheses is that thiamine (vitamin B1) deficiency may explain the paralysis syndrome (Balk et al. 2009a).
7) Persistent pollutants such as PCB and mercury that accumulate along food chains, leading to reduced breeding success through, for example, thinner egg shells (but see Franson et al. 2000).
8) Climate change affecting salinity and water temperature, in turn affecting eider food quality (blue mussel nutritional value) and/or time of breeding (Lehikoinen et al. 2006; Waldeck and Larsson 2013).

Thiamine deficiency as a significant factor behind bird population declines

Thiamine (vitamin B1) is involved in several basal metabolic processes. It is essential for many organisms, and in aquatic systems it is mainly produced by phytoplankton and transferred to top predators via zooplankton grazers and planktivoric fish. Stress factors such as salinity, temperature and light conditions can alter the thiamine content of phytoplankton. In a recent PhD-thesis, Sylvander (2013) suggested a pattern of trophic dilution of the thiamine content of the pelagic food web in the Baltic Sea. The higher the trophic level of an organism, the lower was its thiamine content. Thiamine deficiency has been reported in Baltic populations of the Atlantic salmon as early as in 1974 (Norrgren et al. 1993).

Increasing numbers of wild birds dying from a paralytic syndrome around the Baltic Sea area have been reported from the southernmost part of the Swedish coast (from 2002 to 2008 in Skåne, and from 2000 to 2007 in Blekinge; Table S1 in Balk et al. 2009a). This disease has been observed in various bird species but predominantly in relatively large, colony-nesting birds such as the herring gull (Table S1 in Balk et al. 2009a). Fifty-four percent of 837 bird individuals from Skåne showed signs typical of different stages of the paralytic syndrome (first indication is difficulty in keeping wings folded, followed by the loss of ability to fly, complete paralysis, and finally death). Although the authors could not report any incident of adult eiders dying from paralytic disease in Skåne, they report occurrence of paralytic syndrome in adult eiders from Södermanland and/or Blekinge (number of individuals or proportion were not reported in Balk et al. 2009a). The authors also suggest that thiamine deficiency in egg yolk and newly hatched eiders could explain the near-absence of eider pulli in Södermanland between 2004 and 2007 (see also Balk et al. 2009b). The role of thiamine deficiency to explain the paralytic syndrome was purportedly evidenced by the improvement observed upon thiamine treatment of 9 out of 14 affected herring gull individuals over a 4-year period (but see Sonne et al. 2012).

The authors further suggest that thiamine deficiency is a cause of the recent decline of certain bird populations around the Baltic Sea area. Thiamine deficiency is “a possible cause for observed population declines” (Balk et al. 2009a),”most probably has contributed significantly to declines in many bird populations during the last decades” (Balk et al. 2011), and is “the dominating cause of the observed population declines in many bird spe-

cies during the last three decades" (Balk et al. 2012). Thus it seems as if their level of confidence has increased as time progresses despite a lack of new (published) data.

The thiamine deficiency hypothesis has attracted considerable attention, but the research behind it has also been questioned on several issues:

a) Rocke and Barker (2010) stated that many of the clinical signs of the paralytic syndrome are shared by other diseases such as avian botulism (see also Neimanis 2007). Balk et al. replied (2010) that they do not want to exclude botulism as a secondary effect of thiamine deficiency.

b) Sonne et al. (2012a) used a systematic approach to review the literature and found that paralysis in birds may be caused by a multitude of factors including intoxication (botulism, contaminants), deficiencies (vitamins, elements, minerals) or infectious agents (virus).

c) Sonne et al. (2012b) stated that simple population models are not adequate to make a case for the thiamine deficiency hypothesis. Data restricted in time and space were used to parameterize population models for long-lived and widely distributed species (i.e., herring gull and eider) that may be affected by different pressures between summer and winter, and between years (see also compilation by Ottvall 2012). Thus the link between population declines and thiamine deficiency is weak.

However, Tillitt et al. (2012) warned against a causal dismissal of thiamine deficiency as a plausible cause of excessive avian mortality and population declines. They drew a parallel to their work with salmonid predators in the Great Lakes, U.S.A., where thiamine deficiency could explain large-scale recruitment failure.

To conclude, thiamine levels are low in birds from the southern parts of the Baltic Sea area, and the causative agent(s) explaining low levels of thiamine in birds need(s) immediate research attention. But it is yet unclear whether this deficiency is a significant factor explaining the bird paralytic syndrome. Moreover, until further studies have been performed it is premature to suggest a causative link between the paralytic syndrome and declines in many bird populations in the Baltic Sea area. In fact, with the exception of Blekinge, monitoring performed by personnel from several county boards in southern Sweden has not

discovered more than a few new cases of birds with paralytic syndrome since 2009 (Ottvall, pers. comm.).

Search scoping

The thiamine deficiency hypothesis fulfills many of the mandatory and optional criteria for a systematic review: a) it deals with problem descriptions whose scientific support is insufficient, disputed or incompletely known, b) it is controversial and the subject of great public attention, c) it is seen as an environmental policy issue of high concern, and d) it deals with new forms of environmental pressures. However, it is *not* covered in the scientific literature to such an extent that a systematic assessment can be implemented. Only 7 hits are returned by the Web of Knowledge when using different combinations of Baltic, thiamine and bird (see below).

Systematic Review question: *Is thiamine deficiency a significant cause of declining bird populations in the Baltic Sea area?*

Web of Knowledge searches made September 4 and 9, 2013:

Thiamin*	11993 hits
Thiamin* AND deficienc*	2447 hits
Thiamin* AND deficienc* AND salmon*	95 hits
Thiamin*AND salmon*	296 hits
Thiamin*AND gull*	4 hits
Thiamin* AND Baltic AND (avian OR bird* OR eider* OR gull* OR waterbird*)	7 hits
Baltic AND (avian OR bird* OR eider* OR gull* OR waterbird*) AND (decline* OR decrease* OR change*) AND (population*)	81 hits
Baltic AND (avian OR bird* OR eider* OR gull* OR waterbird*) AND ("chronic disease*" OR contaminant* OR deficienc* OR "infectious disease*" OR mercury OR neurolog* OR nutrion* OR organochlorine* OR paralysis OR selenium OR thiamine OR "vitamin A"	

OR "Vitamin B" OR "Vitamin D" OR "Vitamin E" OR zinc)) 66 hits

Ongoing and future studies

Lennart Balk and colleagues at ITM, Stockholm University, are currently investigating factors explaining low levels of thiamine in eiders and blue mussels. The interactions between the benthic fauna and sea ducks in a changing Baltic environment are also being studied by Kjell Larsson, Högskolan Gotland. Furthermore, sea duck population sizes are monitored by Leif Nilsson, Lund University. To investigate the potential link between thiamine deficiency and bird population declines, a coordinated effort between researchers from different disciplines is needed. For example, it could be worthwhile to continue to monitor thiamine levels of eiders and herring gulls along different parts along the coast to the Baltic Sea. These two species could act as model species with different autecological strategies but sharing a similar population decline since the year 2000. If outbreaks of the paralysis syndrome occur, thiamine level tissue sampling should be done on both paralyzed individuals and those not showing any signs. Both are long-lived species so adult mortality is likely to be a more limiting factor on population sizes than reproductive success in single years (known to strongly vary between years in the eider). Therefore, sampling of thiamine levels in egg yolk may be a less successful strategy. Tissue sampling of adult individuals should be performed alongside long-term monitoring of population sizes in different locations along a north-south gradient (cp. Balk et al. 2009). It may then be possible to provide at least correlational evidence linking thiamine deficiency to population declines. Given the strong anthropogenic influence on bird populations in the Baltic Sea area other hypotheses should be explored simultaneously.

References

Balk, L., P.-Å. Hägerroth, G. Åkerman, M. Hanson, U. Tjärnlund, T. Hansson, G.T. Hallgrimsson, Y. Zebühr, et al. 2009a. Wild birds of declining European species are dying from a thiamine deficiency syndrome. *Proceedings of the National Academy of Sciences, U.S.A.* 106: 12001-12006.

Balk, L., P.-Å. Hägerroth, G. Åkerman, M. Hanson, U. Tjärnlund, T. Hansson, G.T. Hallgrimsson, Y. Zebühr, et al. 2009b. Tiaminbrist och överdödlighet i neurotoxiska

symptom hos ejder i Stockholms skärgård. Institutionen för tillämpad miljövetenskap, Stockholms universitet. Stockholms Stad. ISSN: 1653-9168. (in Swedish).

Balk, L., P.-Å. Hägerroth, G. Åkerman, M. Hanson, U. Tjärnlund, T. Hansson, G.T. Hallgrimsson, Y. Zebühr, et al. 2010. Reply to Rocke and Barker: The question is not whether birds are affected by thiamine deficiency or botulism, it is about the order of events. *Proceedings of the National Academy of Sciences, U.S.A*. 107: E37.

Balk, L., P.-Å. Hägerroth, T. Hansson, U. Tjärnlund, H. Gustavsson, T. Mörner, and G. Åkerman. 2011. Thiamine deficiency in the ecosystem. Swedish University of Agricultural Sciences (SLU) (43-43). Reproductive Disorders in Baltic Vertebrate Wildlife (BALTREP 2011), Uppsala, Sweden, December 7-8, 2011. ISBN: 978-91-576-9057-9.

Balk, L., P.-Å. Hägerroth, T. Hansson, U. Tjärnlund, H. Gustavsson, T. Mörner, and G. Åkerman. 2012. Lethal thiamine deficiency in several bird species in the Baltic Sea. Clin. Chem. Lab. Med. 50 (A64-A65). Advances and Controversies in B-Vitamins and Choline, Leipzig, Germany, March 5-8, 2012. ISBN: ISSN: 1434-6621.

Christensen, T.K., and T. Bregnballe. 2011. Status of Danish breeding population of Eiders *Somateria mollisima* 2010. *Dansk Ornitologisk Förenings Tidskrift* 105: 195-205.

Franson, J.C., T. Hollmén, R.H. Poppenga, M. Hario, M. Kilpi, and M.R. Smith. 2000. Selected trace elements and organochlorines: Some findings in blood and eggs of nesting Common Eiders (*Somateria mollisima*) from Finland. *Environmental Toxicology and Chemistry* 19: 1340-1347.

Hollmén, T., J.C. Franson, R.H. Poppenga, M. Hario, and M. Kilpi. 1998. Lead poisoning and trace elements in Common Eiders *Somateria mollisima* from Finland. *Wildlife Biology* 4:193-203.

Kilpi, M., and M. Öst. 2002. Summary: The effect of whitetailed sea eagle predation on breeding eider females off Tvärminne, Western Gulf of Finland. *Suomen Riista* 48: 27-33.

Larsson, K., and L. Tydén. 2005. Effekter av oljeutsläpp på övervintrande alfågel Clangula hyemalis vid Hoburgs bank i centrala Östersjön mellan 1996/97 och 2003/04. *Ornis Svecica* 15: 161-171.

Lehikoinen, A., M. Kilpi, and M. Öst. 2006. Winter climate affects subsequent breeding of common eiders. *Global Change Biology* 12: 1355-1365.

Norrgren, L., T. Andersson, P.A. Bergqvist, and I. Björklund. 1993. Chemical, physiological and morphological studies of feral Baltic Salmon (Salmo salar) suffereing from abnormal fry mortality. *Environmental Toxicology and Chemistry* 12: 2065-2075.

Ottvall, R., L. Edenius, J. Elmberg, H. Engström, M. Green, N. Holmqvist, Å. Lindström, M. Tjernberg, and T. Pärt. 2008. Populationstrender för fågelarter som häckar i Sverige. Naturvårdsverket Rapport 5713.

Ottvall, R. 2012. Ejderns och andra musselätande dykänders minskning i Östersjön. Rapport från Miljöforskningsberedningen. Statens Offentliga Utredningar. (in Swedish).

Rocke, T.E., and I. Barker. 2010. Proposed link between paralytic syndrome and thiamine deficiency in Swedish gulls not substantiated. *Proceedings of the National Academy of Sciences, U.S.A.* 107: E14.

Skov, H., S. Heinanen, R. Zydelis, J. Bellebaum, S. Bzoma, M. Dagys, J. Durinck, S. Garthe, G. Grishanov, et al. 2011. Waterbird populations and pressures in the Baltic Sea. TemaNord 2011: 550. Nordic Council of Ministers, Copenhagen.

Sonne, C., A.K. Olsen Alstrup, and O.R. Therkildsen. 2012. A review of the factors causing paralysis in wild birds: Implications for the paralytic syndrome observed in the Baltic Sea. *Science of the Total Environment* 416: 32-39.

Sonne, C., A.K. Olsen Alstrup, and O.R. Therkildsen. 2012. Reply to Tillitt et al. 2012: Thiamine deficiency: A viable hypothesis for paralytic syndrome in Baltic birds. *Science of the Total Environment* 433: 563-564.

Sylvander, P. 2013. Thiamine dynamics in the pelagic food web of the Baltic Sea. PhD-thesis. Stockholm University.

Tillitt, D.E., C.E. Kraft, D.C. Honeyfield, and J.D. Fitzsimons. 2012. Thiamine deficiency: A viable hypothesis for paralytic syndrome in Baltic birds. Commentary on Sonne et al., 2012. *Science of the Total Environment* 433: 561-562.

Waldeck, P., and K. Larsson. 2013. Effects of winter water temperature on mass loss in Baltic blue mussels: Implications for foraging sea ducks. *Journal of Experimental Marine Biology and Ecology* 444:24-30.

Zydelis, R., J. Bellebaum, H. Österblom, M. Vetemaa, B. Schirmeister, A. Stiepniece, M. Dagys, M. van Eerden, and S. Garthe. 2009. Bycatch in gillnet fisheries: An overlooked threat to waterbird populations. *Biological Conservation* 142: 1269-1281.