Environment International 147 (2021) 106324

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

The Baltic Sea: An ecosystem with multiple stressors

R. Dietz[a,*], C. Sonne[a], B.M. Jenssen[a,b], K. Das[c], C.A. de Wit[d], K.C. Harding[e], U. Siebert[f], M. T. Olsen[g]

[a] Department of Bioscience, Arctic Research Centre (ARC), Aarhus University, Faculty of Science and Technology, Frederiksborgvej 399, PO Box 358, DK-4000 Roskilde, Denmark
[b] Department of Biology, Norwegian University of Science and Technology, Høgskoleringen 5, 7491 Trondheim, Norway
[c] Freshwater and Oceanic sciences Unit of reSearch (FOCUS), Laboratory of Oceanology, University of Liege, Allée du six Août 11, Bât. B6C, 4000 Liège, Belgium
[d] Department of Environmental Science, Stockholm University, Svante Arrheniusvägen 8, SE-10691 Stockholm, Sweden
[e] Department of Biological and Environmental Sciences, Gothenburg University, Box 461, SE-40530 Gothenburg, Sweden
[f] Institute for Terrestrial and Aquatic Wildlife Research, University of Veterinary Medicine Hannover, Foundation, Büsum, Germany
[g] Evolutionary Genomics, Globe Institute, University of Copenhagen, Øster Farimagsgade 5, DK-1353 Copenhagen K, Denmark

ARTICLE INFO

Handling Editor: Adrian Covaci

Keywords:
POPs
Mercury
Health effects
Biomarkers
Baltic

ABSTRACT

This introductory chapter to our Environment International VSI does not need an abstract and therefore we just include our recommendations below in order to proceed with the resubmission. Future work should examine waterbirds as food web sentinels of multiple stressors as well as Baltic Sea food web dynamics of hazardous substances and how climate change may modify it. Also, future work should aim at further extending the new frameworks developed within BALTHEALTH for energy and contaminant transfer at the population level (Desforges et al., 2018, Cervin et al., 2020/this issue Silva et al., 2020/this issue) and their long term effects on Baltic Sea top predators, such as harbour porpoises, grey seals ringed seals, and white-tailed eagles. Likewise, the risk evaluation conducted for PCB in connection with mercury on Arctic wildlife (Dietz et al., 2019, not a BONUS BALTHEALTH product) could be planned for Baltic Sea molluscs, fish, bird and marine mammals in the future. Finally, future efforts could include stressors not covered by the BONUS BALTHEALTH project, such as food web fluxes, overexploitation, bycatches, eutrophication and underwater noise.

1. The Baltic Sea

The Baltic ecosystem has undergone drastic changes over the past century due to a combination of anthropogenic and environmental stressors. As such, it serves as a unique ecosystem model for the understanding of cumulative effects of stressors on marine top predators, birds, fish, invertebrates and plants, providing an early warning system for ecosystem health. Most Baltic Sea top predator species have undergone significant population declines due to factors including pollution, overexploitation, pathogens, eutrophication, climate change, shipping, underwater noise and offshore developments. At present, there is little information available to assess the cumulative impact of multiple stressors on single species in the Baltic Sea food web.

The aim of this special issue of Environment International is to update and review the current knowledge on selected stressors affecting the Baltic Sea ecosystem based on the BONUS (Baltic Organisations' Network for Funding Science) project *Baltic Sea multilevel health impacts on key species of anthropogenic hazardous substances BONUS BALTHEALTH* (https://projects.au.dk/bonusbalthealth/). Focusing on key Baltic Sea wildlife species such as grey (*Halichoerus grypus*), ringed seals (*Pusa hispida*), harbour porpoises (*Phocoena phocoena*), Eurasian otters (*Lutra lutra*), pink-footed geese (*Anser brachyrhynchus*), common eiders (*Somateria mollissima*) and white-tailed eagles (*Haliaeetus albicilla*), we highlight the need for understanding, identifying and quantifying powerful indicators of individual, population, and ecosystem health. In turn, this allows for an assessment of the impact of multiple anthropogenic and environmental stressors in space and time including inputs for risk assessment by Baltic Sea stakeholders such as BONUS, HELCOM, ICES, OSPAR, ASCOBANS, a.o.

2. This virtual special issue (VSI)

This VSI contain 12 key papers with results of the BONUS BALTHEALTH project conducted over the period 2016–2020. The additional

* Corresponding author.
E-mail address: rdi@bios.au.dk (R. Dietz).

https://doi.org/10.1016/j.envint.2020.106324
Received 24 November 2020; Received in revised form 1 December 2020; Accepted 2 December 2020
Available online 14 December 2020

published result as well as subsequent papers are available at: https://projects.au.dk/bonusbalthealth/publications/. The work packages include food web dynamics and persistent organic pollutants such as legacy and emerging contaminants and a wealth of health and biomarker endpoints as well as analyses of infectious diseases and finally modelling of population level effects (Fig. 1).

We have reviewed the state-of-the-art contaminant exposure and related health effects in Baltic Sea key species prior to the onset of BONUS BALTHEALTH. Contaminant exposure of Baltic wildlife species including grey seals and ringed seals, white-tailed eagles and otters resulted in massive population declines where Anthropogenic Hazardous Substances (AHSs) have been the major force behind the reduced numbers and health of the Baltic Sea. The exposure to legacy persistent organic pollutants, such as polychlorinated biphenyls (PCB) and dichlorodiphenyltrichloroethane (DDT), has been associated with significant population declines through effects on the reproductive system, survival and immunity in white-tailed eagles and seal species. In addition, our reviews show that Baltic high trophic level key species are exposed to multiple bacterial, viral and parasitic pathogens. The distribution of existing viral and bacterial pathogens, along with the emergence and spread of new pathogens, need to be monitored in order to assess the health status of key Baltic species. This is of special importance as some of the occurring pathogens are zoonotic and thus pose a potential risk for human health linked to climate change and pollutant exposure that all affect the immune suppression and subsequent inflammatory diseases. Altogether, this presents a comprehensive update of the health of the Baltic Sea including risks for wildlife and human health effects. However, as we also show, although many stressors causing effects in the 1960–2000s are now regulated, new stressors in the form of AHS, pathogens, noise and climate change are on the rise, posing continuous threats to the ecosystem. Thus, we recommend continuing the monitoring of sentinel species in the Baltic Sea.

3. Anthropogenic hazardous substances

Anthropogenic hazardous substances have shown to be a major driver of wildlife population declines in the Baltic Sea where for example high tissue concentrations of industrial and environmentally persistent chemicals in Baltic seals in the 1970–80s were associated with oviduct occlusions and stenosis due to repeated infections leading to sterility (Sonne et al., 2020a/this issue). Although environmental levels of legacy AHSs have declined since their international restriction in the 1970–80s, concentrations in high trophic predators of the Baltic Sea remain relatively high compared to other areas. The concentrations levels of especially PCBs and mercury are still within population level effects on reproduction as documented for certain marine mammals and white-tailed eagles (Dietz et al., 2021/this issue; Sonne et al., 2020a, 2020b/this issue, Sun et al., 2019a, 2020/this issue, de Wit et al., 2020/this issue). These studies adds to the understanding of increases and decreases of contaminant exposure in Baltic key bird and marine mammal species and how they affect their health and population dynamics. For example, concentrations of persistent organochlorines have decreased in Swedish white-tailed eagles during 1968–2011 except for chlordanes (Sun et al., 2020/this issue). In most species, levels of emerging contaminants, such as organophosphate esters (OPEs), chlorinated paraffins (CPs) and emerging halogenated flame retardants (HFRs) were generally similar or higher than those of legacy polybrominated diphenyl ethers (PBDEs) and/or hexabromocyclododecane (HBCDD) (de Wit et al., 2020/this issue). Organophosphate esters, CPs and HFRs concentrations were also similar to the legacy contaminants PCB and DDT concentrations in blue mussel (*Mytilus edulis*), viviparous eelpout (*Zoarces viviparus*) and Atlantic herring (*Clupea harengus*). In marine mammals and

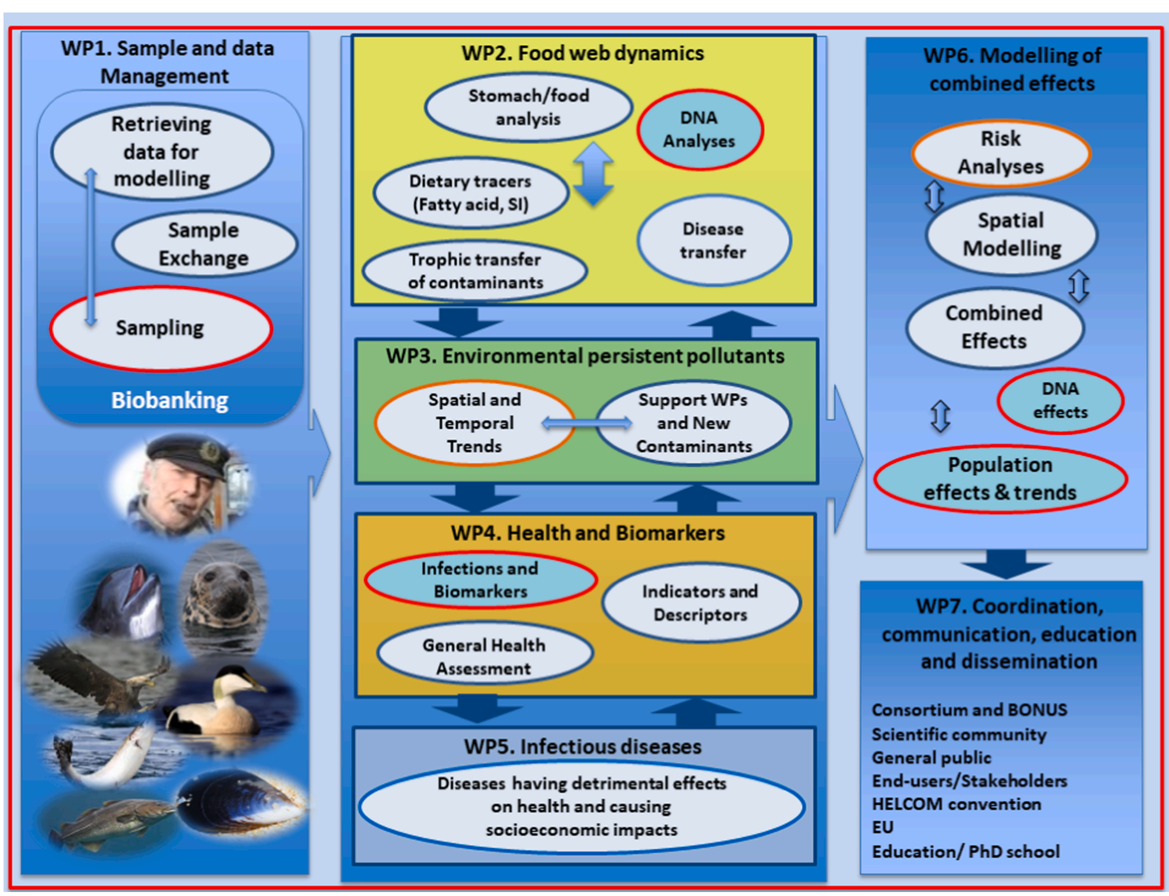

Fig. 1. Work packages and themes addressed under the BONUS BALTHEALTH programme 2017–2020.

birds, however, the PCB and DDT concentrations remained orders of magnitude higher than those of the emerging contaminants OPEs, CPs, HFRs and per/polyfluorinated alkyl substances (PFAS). Comparing representative predator-prey species indicated that OPEs have low biomagnification potential, some CPs show potential biomagnification, and several HFRs and PFAS show high biomagnification potentials. These results add to weight of evidence that the targeted compounds are of environmental concern and that their continued spatiotemporal monitoring is warranted.

4. Health and biomarkers

With respect to health and biomarkers, Siebert et al. (2020/this issue) show that older specimens of harbour porpoises have higher values of eosinophilic granulocytes, aspartate aminotransferase (AST) and alanin aminotransferase (ALT), which is important to take into account when assessing health. The highest eosinophil values are in free-ranging porpoises, most likely reflecting their higher parasitic burden. Free-ranging harbour porpoises are among the most exposed whales in the world to high concentrations of environmental contaminants including PCBs and mercury. Schmidt et al. (2020/this issue) examined skulls of ringed seals from the Baltic Sea and Greenland using museum samples using dual-energy x-ray absorptiometry to measure bone mineral density (BMD). Skull BMD of the Baltic seals was positively correlated with the historical polychlorinated biphenyls (PCB) contamination, showing potential effects on the constitution of bones. BMD fluctuated between the three study periods with the lowest BMD found between 1897 and 1957. The highest peak of the contaminant concentration in the Gulf of Bothnia was in the second period and the BMD levels increased with increasing PCB concentrations. The Greenland population showed significantly lower BMD concentrations than the Baltic population. This study also showed a higher BMD in males than in females. In conclusion, the variations between 1829 and 2019 may to a certain extent reflect normal fluctuations; however, this study revealed several factors affecting BMD including sex and PCB levels. Likewise, Schmidt et al. (2020/this issue) investigated the temporal trend in liver histological lesions over time in Baltic grey seals between 1981 and 2015 in the Gulf of Bothnia and northern Baltic Proper and correlated these with historical PCB contamination. Six histological features were evaluated showing statistically significant positive correlations between three of these lesions and age. Two of the lesions correlated with adipose tissue (blubber) concentrations of ΣPCB_{10} measured in 34 of the individuals. These results show that age is an important factor for the development of liver lesion and that PCB burdens may be a significant co-factor. Regarding common eiders, Ma et al. (2020/this issue) investigated the Baltic flyway population and found that blood concentrations of total mercury (THg) showed a significant increase from west to east with the lowest concentration at Hov Røn, medium concentration at Agersø and highest concentration at Christiansø. However, the health of eiders in the Baltic Sea is most likely not affected by mercury contamination. Lam et al. (2020a/this issue) showed that glucose, fructosamine, amylase, albumin and protein decreased significantly in eider blood from early to late incubation at Hov Røn and Christiansø, reflecting long-term fasting as supported by the decline in body weight. Untargeted metabolomics of Christiansø eiders revealed that 417 annotated metabolites changed significantly from the early to late incubation with vitamin B2 (riboflavin) significantly down-regulated. This reflects that while individual stressors are not yet identified Baltic eiders face multiple energy and nutritional related stresses during incubation, affecting their health and most likely their reproductive output.

5. Infectious diseases

Siebert et al. (2020/this issue) reported on autopsies of harbour porpoises in the Baltic Sea i.e. the western Baltic, Belt Seas and Kattegat and the Baltic Proper, respectively. Harbour porpoises throughout these areas are exposed to a large number of human activities causing direct and indirect effects on individuals that might also harm this species on a population level. From Latvia, Poland, Germany and Denmark, 385 out of 1769 collected dead harbour porpoises were suitable for extensive necropsy. The animals were collected between 1990 and 2015 and were either by-caught or found dead on the coastline. The respiratory tract had the highest number of morphological lesions and pneumonia caused by lungworms. The alimentary, hearing, and haematopoietic systems also had inflammatory lesions and parasitic infections while 20% to 100% of the animals had injuries or marks from nets following the by-catch. Inflammatory lesions, especially in the respiratory tract were in higher numbers when compared to control populations in areas with less human activities such as arctic waters. The high number of morphological changes in the respiratory tract and of bycatches especially among immature animals before reaching sexual maturity is of serious concern, as well as the low number of adult animals among the material. Data on health status and the causes of death are valuable for management. A next step in this regard will combine data from health and genetic investigations in order to detect differences between the two populations of the Baltic.

Lam et al. (2020b/this issue) studied the seroprevalence of specific avian influenza A antibodies to obtain information on circulating AI serotypes and exposure in Baltic eiders and pink-footed geese represent terrestrial, brackish and marine ecosystems spanning from the Western to the Eastern and Northern part of the Baltic Sea. Overall, antibody prevalence was 55% for the eiders and 47% for the pink-footed geese. Ca. 12% (22/183) of the eiders and 3% (12/427) of the pink-footed geese had been exposed to AI of the potentially zoonotic serotypes H5 and/or H7 virus. AI seropositive samples selected at random ($n = 33$) showed a low frequency of serotypes H1, H6 and H9. Future projects should aim at sampling and isolating AI virus to characterize dominant serotypes and virus strains (PCR). This will increase our understanding of how AI exposure may affect health, breeding and population viability of Baltic common eiders and pink-footed geese as well as the potential spillover to humans (zoonotic potential).

6. Modelling population level effects

Dietz et al. (2021/this issue) investigated a wide range of species, including marine mammals, seabirds, birds of prey, fish and bivalves for potential population health risks resulting from contemporary (post-2000) mercury (Hg) exposure, using novel risk thresholds calculated on both literature and *de novo* exposure data. For marine mammals, 23% of the groups, each composing individuals of a specific sex and maturity from the same species in a specific study region, showed Hg-concentrations within the High-risk category (HRC) and Severe Risk Categories (SRC). The corresponding percentages for seabirds, fish and bivalves were 2.7%, 25% and 8.0%, respectively, although fish and bivalves were not represented in the SRC. Juveniles from all species showed to be at no or low risk. In comparison to the same species in the adjacent waters, i.e. the Greater North Sea and the North Atlantic, the estimated risk for Baltic Sea populations is not considerably higher. These findings seem to suggest that over the past few decades the Baltic Sea has improved considerably with respect to presenting Hg exposure to its local species, while it does still carry a legacy of elevated Hg levels resulting from high neighbouring industrial and agricultural activity and slow water turnover regime.

Silva et al. (2020/this issue) conducted a study where they developed a full lifecycle dynamic energy budget and individual based model (DEB-IBM) that captured Baltic grey seal physiology and life history, and showcase potential applications of the model to predict population responses to select stressors known to threaten grey seals and other marine mammals. The authors found that continuous incremental food limitation can be more detrimental than short random events of starvation and further, that the effect of endocrine disruptors on population growth and structure is delayed due to bioaccumulation, and that communicable infectious diseases significantly decrease population growth even when spillover events are relatively less frequent. One important finding of the study was that the delayed effect on population growth rate from some stressors, several years after the exposure period, resulting from a decline in somatic growth, increased age at maturation and decreased fecundity. Such delayed responses are being ignored in current models of population viability and can be important in the correct assessment of population extinction risks. The model provides a unique test bed on which effects of new hazardous substances and different scenarios of future environmental changes can be analysed. The importance of food availability and seasonal energetic demands can be investigated providing a tool for better understanding how diverse environmental stressors affect marine mammal populations and to guide scientifically based management.

Cervin et al. (2020/this issue) studied the Baltic Sea harbour porpoise population, which is genetically distinct, amounting to only about 500 animals and is classified as 'Critically Endangered' according to the IUCN red list. Data deficiency on nearly all demographic parameters have precluded systematic investigations of the relative importance of stressors affecting population viability. The authors took a comparative life history approach and investigated the phenotypic plasticity in somatic and demographic vital rates of seven larger, well studied North Atlantic harbour porpoise populations, enabling them to approximate the missing pieces of the life history of the Baltic population. Due to high levels of endocrine disruptive contaminants observed in Baltic harbour porpoises, Cervin et al. (2020/this issue) also investigated the effect of a possible reduction in fecundity. Subsequently, the combined effects of bycatches and reduced fecundity were investigated in terms of population growth rate and quasi-extinction risk. The Baltic harbour porpoise population is viable in the baseline scenario without anthropogenic stressors. However, even the lowest estimated bycatch level of 7 individuals per year will lead to a population collapse to $\leq$50 animals with high probability (0.4–1.0) over the next century, assuming an intermediate or low (<73%) fecundity. Adult survival is of critical importance and mitigation of fishery impacts and reduction of anthropogenic disturbances in the identified main breeding areas were recommended in the study.

7. Recommendations for future work

Future work should examine waterbirds as food web sentinels of multiple stressors as well as Baltic Sea food web dynamics of hazardous substances and how climate change may modify it. Also, future work should aim at further extending the new frameworks developed within BALTHEALTH for energy and contaminant transfer at the population level (Desforges et al., 2018, Cervin et al., 2020/this issue, Silva et al., 2020/this issue) and their long term effects on Baltic Sea top predators, such as harbour porpoises, grey seals ringed seals, and white-tailed eagles. Likewise, the risk evaluation conducted for PCB in connection with mercury on Arctic wildlife (Dietz et al., 2019, not a BONUS BALTHEALTH product) could be planned for Baltic Sea molluscs, fish, bird and marine mammals in the future. Finally, future efforts could include stressors not covered by the BONUS BALTHEALTH project, such as food web fluxes, overexploitation, bycatches, eutrophication and underwater noise.

CRediT authorship contribution statement

R. Dietz: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **C. Sonne:** Writing - review & editing. **B.M. Jenssen:** Writing - review & editing. **K. Das:** Writing - review & editing. **C.A. de Wit:** Writing - review & editing. **K.C. Harding:** Writing - review & editing. **U. Siebert:** Writing - review & editing. **M.T. Olsen:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Environment International for giving us the opportunity to publish the results of the BONUS BALTHEALTH project in this VSI. We thank Co-Editor in Chief Prof Dr. Adrian Covaci and Special Issue Editor Dr. Da Chen for professionally managing and handling our submissions in a timely matter. We are also grateful to the many laboratory technicians, field personal and others contributing to the BONUS BALTHEALTH project.

BONUS BALTHEALTH received funding from BONUS (Art. 185), funded jointly by the EU, Innovation Fund Denmark (grants 6180-00001B and 6180-00002B), Forschungszentrum Jülich GmbH, German Federal Ministry of Education and Research (grant FKZ 03F0767A), Academy of Finland (grant 311966) and Swedish Foundation for Strategic Environmental Research (MISTRA). In some of the work, studies were approved by the Danish Nature Agency (SVANA) and funding from the Danish Environmental Protection Agency (supported under the Wildlife Contract).

References

de Wit, C.A., Bossi, R., Dietz, R., Dreyer, A., Faxneld, S., Garbus, S.E., Hellström, P., Koschorreck, J., Lohmann, N., Roos, A., Sellström, U., Sonne, C., Treu, G., Vorkamp, K., Yuan, B., Eulaers, I., 2020. Organohalogen compounds of emerging concern in Baltic Sea biota: levels, biomagnification potential and comparisons with legacy contaminants. Environ. Int. 144, 106037. https://doi.org/10.1016/j.envint.2020.106037.

Desforges, J.-P., Hall, A., McConnell, B., Rosing Asvid, A., Barber, J.L., Brownlow, A., De Guise, S., Eulaers, I., Jepson, P., Letcher, R., Levin, M., Ross, P.S., Samarra, F., Vikingson, G., Sonne, C., Dietz, R., 2018. Predicting global killer whale population collapse from PCB pollution. Science 361 (6409), 1373–1376.

Dietz, R., Sonne, C., Albert, C., Bustes, J.O., Christensen, T.K., Ciesielski, T.M., Danielsen, J., Dastnai, S., Eens, M., Erikstad, K.E., Fort, J., Galatius, A., Garbus, S.-E., Gilg, O., Hanssen, S.A., Helander, B., Helberg, M., Jaspers, V.L.B., Jenssen, B.M., Kauhala, K., Kyhn, L.A., Labansen, A.L., Larsen, M.M., Lindstøm, U., Reiertsen, T.K., Rigét, F.F., Roos, A., Strand, J., Strøm, H., Sveegaard, S., Søndergaard, J., Sun, J., Teilmann, J., Therkildsen, O.R., Tjørnløv, R.S., Wilson, S., Eulaers, I., 2021. A risk assessment of the effects of mercury on Baltic Sea, Greater North Sea and North Atlantic wildlife, fish and bivalves. Environ. Int. 146, 106178.

Dietz, R., Letcher, R., Desforges, J.-P., Eulaers, I., Sonne, C., Wilson, S., Andersen-Ranberg, E., Basu, N., Barst, B.D., Bustnes, J.O., Bytingsvik, J., Ciesielski, T.M., Drevnick, P.E., Gabrielsen, G.W., Haarr, A., Hylland, K., Jenssen, B.M., Levin, M., McKinney, M.A., Nørregaard, R.D., Pedersen, K.E., Provencher, J., Styrishave, B., Tartu, S., Aars, J., Ackerman, J.T., Rosing-Asvid, A., Barrett, R., Bignert, A., Born, E. W., Branigan, M., Braune, B., Bryant, C.E., Dam, M., Eagles-Smith, C.A., Evans, M., Evans, T.J., Fisk, A.T., Gamberg, M., Gustavson, K., Hartman, C.A., Helander, B., Herzog, M.P., Hoekstra, P.F., Houde, M., Hoydal, K., Jackson, A.K., Kucklickt, J., Lie, E., Loseto, L., Mallory, M.L., Miljeteig, C., Mosbech, A., Muir, D.C.G., Nielsen, S. T., Peacock, E., Pedro, S., Peterson, S.H., Polder, A., Rigét, F.F., Roach, P., Saunes, H., Sinding, M.-H.S., Skaare, J.U., Søndergaard, J., Stenson, G., Stern, G., Treu, G., Schuur, S.S., Víkingsson, G., 2019. Current state of knowledge on biological effects from contaminants on arctic wildlife and fish. Sci. Total Environ. 696 (133792), 1–39.

Cervin, L., Härkönen, T., Karin C. Harding, K.C. Accepted. Multiple stressors and data deficient populations; a comparative life-history approach sheds new light on the extinction risk of the highly vulnerable Baltic harbour porpoises (Phocoena phocoena). Environ. Int. 144, 106076. https://doi.org/10.1016/j.envint.2020.106076.

Lam, S.S., Tjørnløv, R.S., Therkildsen, O.R., Christensen, T.K., Madsen, J., Daugaard-Petersen, T., Ortiz, J.M.C, Peng, W., Charbonneaux, M., Rivas, E.I., Garbus, S.E., Lyngs, P., Siebert, U., Dietz, R., Maier-Sam, K., Lierz, M., Tombre, I. M., Andersen-Ranberg, E U., Sonne, C. Seroprevalence of avian influenza in Baltic common eiders (Somateria mollissima) and pink-footed geese (Anser brachyrhynchus). Environment International, vol. 142, pp. 105873.

Lam, S.S., McPartland, M., Noori, B., Garbus, S.E., Lierhagen, S., Lyngs, P., Dietz, R., Therkildsen, O.R., Christensen, Kjær T, Tjørnløv, R.S., Kanstrup, N., Fox, A.D., Sørensen, I.H., Arzel, C., Krøkje, Å., Sonne, C., 2020. Lead concentrations in blood from incubating common eiders (*Somateria mollissima*) in the Baltic Sea. Environ. Int. 137 (105582), 2020.

Ma, N.L., Hansen, M., Therkildsen, O.R., Christensen, T.K., Tjørnløv, R.S., Garbus, S.E., Lyngs, P., Peng, W., Lam, S.S., Krogh, A.K.H., Andersen-Ranberg, E., Søndergaard, J., Rigét, F.F., Dietz, R., Sonne, C., 2020. Body mass, mercury exposure, biochemistry and untargeted metabolomics of incubating common eiders (*Somateria mollissima*) in three Baltic colonies. Environ. Int. 142, 105866.28).

Schmidt, B., Sonne, C., Nachtsheim, D., Dietz, R., Oheim, R., Rolvien, T., Persson, S., Amling, M., Siebert, U., 2020. Variation in skull bone mineral density of ringed seals (Phoca hispida) from the Gulf of Bothnia and West Greenland between 1829 and 2019. Environ. Int. 143.

Siebert, U., Blanchet, M.A., Teilmann, J., Anderson Hansen, K., Kristensen, J., Bunskoek, P., Dietz, R., Desforges, J.-P., Sonne, C., Desportes, G., 2020. Haematology and clinical blood chemistry in harbour porpoises (*Phocoena phocoena*) from the inner Danish waters. Environ. Int. 143, 105937.

Silva, W.T.A.F., Harding, K.C., Marques, G.M., Bäcklin, B.M., Sonne, C., Dietz, R., Kauhala, K., Desforges, J.-P., 2020. Life cycle bioenergetics of the gray seal (*Halichoerus grypus*) in the Baltic Sea: population response to environmental stress. Environ. Int. 145, 106145.

Sonne, C., Lakemeyer, J., Desforges, J.-P., Eulaers, I., Persson, S., Stokholm, I., Galatius, A., Gross, S., Gonnsen, K., Lehnert, K., Andersen-Ranberg, E.U., Olsen, M. T., Dietz, R., Siebert, U., 2020a. A review of pathogens in selected Baltic Sea indicator species. Environ. Int. 137, 105565.

Sonne, C., Siebert, U., Gonnsen, K., Desforges, J.-P., Eulaers, I., Persson, S., Roos, A., Bäcklin, B.M., Kauhala, K., Tange Olsen, M., Harding, K.C., Treu, G., Galatius, A., Andersen-Ranberg, E., Gross, S., Lakemeyer, J., Lehnert, K., Lam, S.S., Peng, W., Dietz, R., 2020b. Health effects from contaminant exposure in Baltic Sea birds and marine mammals: a review. Environ. Int. 139, 105725.

Sun, J., Covaci, A., Bustnes, J.O., Jaspers, V., Helander, B., Bårdsen, B.-J., Boertmann, D., Dietz, R., Labansen, A.L., Lepoint, G., Schulz, R., Govindan, M., Sonne, C., Thorup, K., Tøttrup, A., Zubrod, J., Eens, M., Eulaers, I., 2020. Temporal trends of legacy organochlorines in different white-tailed eagle (*Haliaeetus albicilla*) subpopulations. Environ. Int. 138, 105618.