Response: Commentary: Lake or Sea? The Unknown Future of Central Baltic Sea Herring

Joachim W. Dippner*

Department of Biological Oceanography, Leibniz Institute for Baltic Sea Research Warnemünde, Rostock, Germany

A Commentary on

Commentary: Lake or Sea? The Unknown Future of Central Baltic Sea Herring
by Meier, H. E. M., Börgel, F., Frauen, C., and Radtke, H. (2020). Front. Ecol. Evol. 8:55. doi: 10.3389/fevo.2020.00055

Recently (Dippner et al., 2019; hereafter D19) have applied the mediator concept (Dippner, 2006) to demonstrate that the mean weight of 3-year-old central Baltic Sea (BS) herring (*Clupea harengus*) is indirectly influenced by the Atlantic Multi-decadal Oscillation (AMO). The proposed mediator chain is increased sea surface temperature (SST) in the North Atlantic (NA), increased precipitation in the BS catchment area, increased river runoff, decreased surface layer salinity in the Baltic Proper, decreased marine zooplankton biomass of *Pseudocalanus acuspes* and herring weight. D19 addresses a comment (Meier et al., 2020; hereafter M20).

The reason for this comment is not clear because three of the four authors had recently published a paper (Börgel et al., 2018; hereafter B18) in which they showed that under anomalous warm NA SST, moisture is advected into the BS region leading to increased precipitation, increased river runoff, and decreased salinity in the BS. Aside from the biological aspect in D19, both papers B18 and D19 identify the same mechanism for the decrease in BS salinity, which has been identified by Vuorinen et al. (2015). The differences between B18 and D19 are first that B18 analyzed the output of a regional climate model run of 850 years whereas D19 analyzed observations. Secondly, the signal of climate variability occurred in different periods, on the decadal scale in D19 and on longer time scales in B18. The AMO index calculated from annual HadlSST data (Rayner et al., 2003) shows a peak around 64 years in the global wavelet spectrum and no significant peaks in shorter time scales (Figure 1 in M20). From this finding, the authors of M20 concluded that the time series in D19 are too short to verify a causal relationship between AMO and herring weight. This argument can be reduced to the simple question "What is wrong with the decadal scale?" and if we consider the Bjerknes hypothesis, to the extended question "Who drives whom?"

The AMO index is originally defined as monthly mean detrended NA SST anomalies in the region from 0° to 70°N (Kerr, 2000; Enfield et al., 2001). After filtering the AMO time series, a multi-decadal variation in SST with a period of 60–90 years appeared, which is of major interest for climatologists (e.g., Schlesinger and Ramankutty, 1994; Sutton and Hodson, 2005; Knight et al., 2006). However, this does not mean that no inter-annual or inter-decadal oscillatory modes exist. In fact, an examination of observed AMO data [Figure 2 in (Harris et al., 2014)] shows pronounced decadal variability with amplitudes in the same range as the 60–90 year oscillation. Lau and Weng (1995) presented a wavelet analysis of observed northern hemisphere SST and found significant oscillatory modes from inter-annual (2–5 years), inter-decadal (10–12, 20–25, and 40–60 years) and century to inter-century (90 and 180 years) scales at different periods of the data set. Furthermore,

FIGURE 1 | Correlation between AMO and precipitation rate **(Upper)** and NAO and precipitation rate **(Lower)**. The correlation is based on un-lagged, unfiltered monthly mean anomalies for the period 1950–2000.
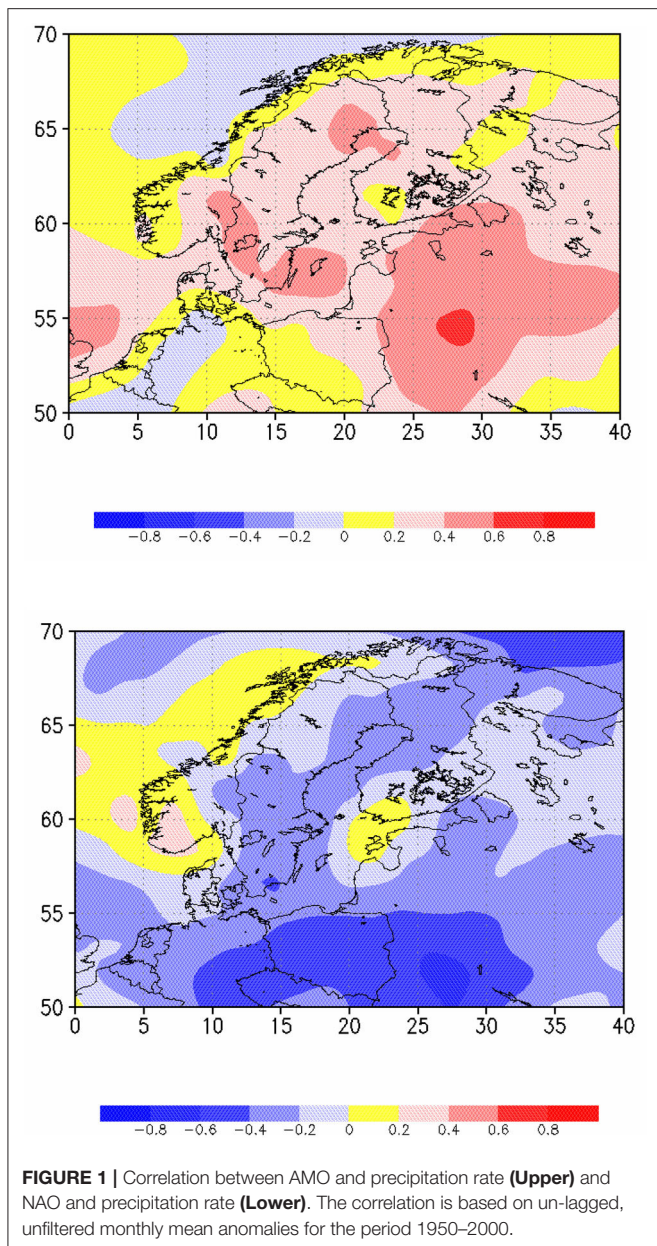
using the Comprehensive Oceans Atmosphere Data Set (COADS; Slutz et al., 1985; Woodruff et al., 1987), Chang et al. (1997) identified with a spectral analysis of the tropical Atlantic Ocean a dominant spectral peak at around 13 years.

Similar inter-decadal modes have also been identified in coupled ocean-atmosphere general circulation models. Zorita and Frankignoul (1997) identified in a 325-years integration of the ECHAM1/LSG model two distinct oscillatory modes in the NA SST with dominant periods of 10 and 20 years. The 20-years mode is the most energetic, but it is not seen in the atmosphere. The 10-years mode can be found in the temperature variation of the upper ocean and is also detected in the atmosphere, and thus appears to be a coupled ocean-atmosphere mode. Based on

results from another numerical model integration, Timmermann et al. (1998) detected a Northern Hemisphere coupled air-sea mode with a 35-years period.

This is evidence that inter-annual and inter-decadal variability exists in the NA SST, in observations as well as in model results. It is not clear why these periods do not exist in the global wavelet spectrum of M20. Furthermore, Mehta et al. (2000) demonstrated in an atmosphere only model, driven by observed SST and sea-ice boundary conditions, that the North Atlantic Oscillation [NAO, (Hurrell, 1995)] exhibits multiple variations from inter-annual to multi-decadal time scales. The quintessence of this paper is the existence of inter-annual, inter-decadal, multi-decadal, century, and inter-century periods in both modes, AMO and NAO, an aspect which is completely ignored by M20.

A complaisant consideration of the M20 argument leads to the Bjerknes "who drives whom" conjecture. Bjerknes (1964) suggested that the character of large-scale air-sea interaction over the mid-latitude NA differs with time scales, such that the atmosphere directly drives most short-term SST variability and the ocean contributes significantly to long-term SST and atmospheric variability. Gulev et al. (2013) have recently investigated the characteristic time scales over which these drivers dominate. They provide observational evidence that in the mid-latitude NA and on time scales longer than 10 years, surface turbulent heat fluxes are driven by the ocean and may force the atmosphere. On shorter time scales the opposite is true. From this confirmation of the Bjerknes hypothesis it can be concluded that AMO is the driver of the air-sea system on time scales longer than 10 years in the NA.

The following points in the M20 comment need a detailed inspection.

1) The authors of M20 argue that the observational records are too short, specifically mentioning the time series of herring weight. It is correct that the time series of herring weight covers 35 years. However, the authors ignore in their argumentation that most of the time series cover 63 years (see Table 1 in D19), which allows the resolution of oscillatory modes on the inter-annual scale of 2–5 years and inter-decadal modes around 10 and 20 years.

2) The authors of M20 picked out a sentence from the D19 abstract, "This observed trend is also projected for the future in regional climate change scenarios," and argue that "past correlations between multi-decadal climate variations and herring weight should not be extrapolated into the future." This is a misinterpretation. It is important to note that in D19 no extrapolation into the future is presented. The paper deals with climate variability only and not with climate change. In the D19 abstract, the sentence before reads, "Observations show that the mean weight of central BS herring, a quantity unbiased by fisheries, is indirectly influenced by the AMO via a complex mediator chain, in which a transition from a marine to a freshwater state plays a major role." That means that "the observed trend" is clearly related to salinity, i.e., the transition from a marine to a freshwater state. This aspect is further outlined in the discussion of D19: "The trend of reducing salinity might continue into the future. Different

climate change emissions scenarios (IPCC SRES A2 or B2) with regional climate models for the BS (Meier et al., 2006; BACC author team, 2008) project a decline in salinity of between 8 and 50%." These climate change projections were calculated by the first author of M20.

3) M20 mentioned that "correlations between high-pass filtered (or unfiltered) NA SSTs and precipitation or river runoff data are statistically not significant." However, based on unfiltered monthly observations, D19 showed significant correlations between these time series (Table 1 in D19). An obvious difference between D19 and M20 may result from the different precipitation data. M20 used the HiResAFF data set (Schenk and Zorita, 2012) for the area 9.6° to 32°E and 52.4° to 67.4°N. The disadvantage of this area is the northwest corner, which covers a part of the Norwegian Sea and the Norwegian coast. Both areas are characterized by high precipitation and do not belong to the BS catchment area. In contrast, D19 used NCEP/NCAR reanalysis data (Kalnay et al., 1996) of monthly mean precipitation rate. The area of BS catchment was constructed in a sophisticated way by dividing the catchment area into 10 slabs, which ensure the highest possible accuracy in resolution of the BS catchment area. Details were given in D19. The use of different data sets and areas might cause the different results.

4) M20 mentioned that "variations of precipitation and river runoff on time scales smaller than 35 years cannot be explained by variations of NA SST" and speculated that the driving mechanism, which transports moisture into the BS region, is the NAO. Using NCEP/NCAR reanalysis data (Kalnay et al., 1996), un-lagged and unfiltered monthly mean precipitation over the BS catchment area for the period 1950–2000 is correlated to the AMO index and the NAO index (**Figure 1**). Precipitation is significantly positively correlated to the AMO

index, indicating a link of positive NA SST anomalies to higher rainfall, whereas NAO is negatively correlated to precipitation. Both results do not support the argument of M20.

5) The authors of M20 avoid a discussion on the link between marine zooplankton and herring weight. Nevertheless, they present some arguments on declining weight-at age (Cardinale and Arrhenius, 2000), fishing gear selectivity, food web interaction, predation and competition (Casini et al., 2010). These arguments would be important if herring recruitment was being considered, but the subject of D19 is the mean weight of 3-years-old central BS herring. In contrast to recruitment, mean weight is an unbiased quantity. Furthermore, Casini et al. (2010) clearly stated that salinity is the main driver of herring growth variations and not competition. The mentioned declining weight-at-age (Cardinale and Arrhenius, 2000) is related to cod and not to herring.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

FUNDING

ACKNOWLEDGMENTS

REFERENCES

BACC author team (2008) *Assessment of Climate Change in the Baltic Sea Basin*. Regional Climate Studies. Heidelberg: Springer Verlag, 473. doi: 10.1007/978-3-540-72786-6

Bjerknes, J. (1964). Atlantic air-sea interaction. *Adv. Geophys.* 10, 1–82. doi: 10.1016/S0065-26870860005-9

Börgel, F., Frauen, C., Neumann, T., Schimanke, S., and Meier, H. E. M. (2018). Impact of the Atlantic multidecadal oscillation on Baltic sea variability. *Geophys. Res. Lett.* 45, 9880–9888. doi: 10.1029/2018GL078943

Cardinale, M., and Arrhenius, F. (2000). The influence on stock structure and environmental conditions on the recruitment process of Baltic cod estimated using a generalized additive model. *Can. J. Fish. Aquat. Sci.* 57, 2402–2409. doi: 10.1139/f00-221

Casini, M., Bartolino, V., Molinero, J. C., and Kornilovs, G. (2010). Linking fisheries, trophic interactions and climate: threshold dynamics drive herring *Clupea harengus* growth in the central Baltic Sea. *Mar. Ecol. Prog. Ser.* 413, 241–252. doi: 10.3354/meps08592

Chang, P., Ji, L., and Li, H. (1997). A decadal climate variation in the tropical Atlantic Ocean from thermodynamic air-sea interaction. *Nature* 385, 516–518. doi: 10.1038/385516a0

Dippner, J. W. (2006). Future aspects in marine ecosystem modelling. *J. Mar. Syst.* 61, 246–267. doi: 10.1016/j.jmarsys.2005.06.005

Dippner, J. W., Fründt, B., and Hammer, C. (2019). Lake or Sea? The unknown future of Central Baltic Sea

Herring. *Front. Ecol. Evol.* 7:143. doi: 10.3389/fevo.2019.00143

Enfield, D. B., Mestas-Nunez, A. M., and Trimble, P. J. (2001). The Atlantic multidecadal oscillation and its relation to rainfall and river flows in the continental U. S. *Geophys. Res. Lett.* 28, 2077–2080. doi: 10.1029/2000GL012745

Gulev, S. K., Latif, M., Keenlyside, N., Park, W., and Koltermann, K. P. (2013). North Atlantic Ocean control on surface heat flux on multidecadal time scales. *Nature* 499, 464–467. doi: 10.1038/nature12268

Harris, V., Edwards, M., and Olhede, S. C. (2014). Multidecadal Atlantic climate variability and its impact on marine pelagic communities. *J. Mar. Syst.* 133, 55–69. doi: 10.1016/j.jmarsys.2013.07.001

Hurrell, J. W. (1995). Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. *Science* 269, 676–679. doi: 10.1126/science.269.5224.676

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., et al. (1996). The NCEP/NCAR Reanalysis 40-year Project. *Bull. Am. Meteorol. Soc.* 77, 437–471.doi: 10.1175/1520-0477(1996)077<0437:TNYRP>2.0.CO;2

Kerr, E. A. (2000). A North Atlantic pacemaker for the centuries. *Science* 288, 1984–1986. doi: 10.1126/science.288.5473.1984

Knight, J. R., Folland, C. K., and Scaife, A. A. (2006). Climate impact of the Atlantic Multidecadal Oscillation. *Geophys. Res. Lett.* 33:L17706. doi: 10.1029/2006GL026242

Lau, K.-M., and Weng, H. (1995). Climate signal detection using wavelet transform. How to make a time series sing. *Bull. Am. Meteorol. Soc.* 76, 2391–2402.doi: 10.1175/1520-047719950762391:CSDUWT2.0.CO;2

Mehta, V. M., Suarez, M. J., Mangello, J. V., and Delworth, T.L. (2000). Oceanic influence on the North Atlantic Oscillation and associated Northern Hemisphere climate variations: 1959–1993. *Geophys. Res. Lett.* 27, 121–124. doi: 10.1029/1999GL002381

Meier, H. E. M., Börgel, F., Frauen, C., and Radtke, H. (2020). Commentary: lake or sea? The unknown future of Central Baltic Sea herring. *Front. Ecol. Evol.* 8:55. doi: 10.3389/fevo.2020.00055

Meier, H. E. M., Kjellström, E., and Graham, L. P. (2006). Estimating uncertainties of projected Baltic Sea salinity in the late 21st century. *Geophys. Res. Lett.* 33:L15705. doi: 10.1029/2006GL026488

Rayner, N. A., Parker, D. E., Horton, E. B., Folland, C. K., Alexander, L. V., Rowell, D. P., et al. (2003). Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. *J. Geophys. Res. Atmos.* 108:4407. doi: 10.1029/2002JD002670

Schenk, F., and Zorita, E. (2012). Reconstruction of high resolution atmospheric fields for Northern Europe using analog-upscaling. *Clim. Past* 8:1681. doi: 10.5194/cp-8-1681-2012

Schlesinger, M. E., and Ramankutty, N. (1994). An oscillation in the global climate system of period 65-70 years. *Nature* 367, 723–726. doi: 10.1038/367723a0

Slutz, R. J., Lubker, S. J., Hiscox, D. J., Woodruff, S. D., Jenne, R. L., Joseph, D. H., et al. (1985). *Comprehensive Ocean–Atmosphere Data Set; Release 1.* Boulder, CO: NOAA Environmental Research Laboratories, Climate Research Program, 268.

Sutton, R. T., and Hodson, D. R. L. (2005). Atlantic Ocean forcing of North American and European summer climate. *Science* 309, 115–118. doi: 10.1126/science.1109496

Timmermann, A., Latif, M., Voss, R., and Grötzner, A. (1998). Northern Hemisphere interdecadal variability: a coupled air-sea mode. *J. Clim.* 11, 1906–1931. doi: 10.1175/1520-0442-11.8.1906

Vuorinen, I., Hänninen, J., Rajasilta, M., Laine, P., Eklund, J., Montesino-Pouzols, F., et al. (2015). Scenario simulations of future salinity and ecological consequences in the Baltic Sea and adjacent North Sea areas – implications for environmental monitoring. *Ecol. Indic.* 50, 196–205. doi: 10.1016/j.ecolind.2014.10.019

Woodruff, S. D., Slutz, R. J., Jenne, R. L., and Steurer, P. M. (1987). A comprehensive ocean–atmosphere data set. *Bull. Am. Meteorol. Soc.* 68, 1239–1250.doi: 10.1175/1520-047719870681239:ACOADS2.0.CO;2

Zorita, E., and Frankignoul, C. (1997). Modes of North Atlantic decadal variability in the ECHAM1/LSG Coupled ocean–atmosphere general circulation model. *J. Clim.* 10, 183–200.doi: 10.1175/1520-044219970100183:MONADV2.0.CO;2