



HAL
open science

Absence of an internal multidecadal oscillation in the North Atlantic has consequences for anticipating the future of marine ecosystems

Gregory Beaugrand, R Faillettaz, R. R. Kirby

► To cite this version:

Gregory Beaugrand, R Faillettaz, R. R. Kirby. Absence of an internal multidecadal oscillation in the North Atlantic has consequences for anticipating the future of marine ecosystems. *Climate Research*, 2021, 85, pp.107-111. 10.3354/cr01676 . hal-04290771

HAL Id: hal-04290771

<https://hal.science/hal-04290771>

Submitted on 17 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **The recently suggested absence of an internal multidecadal oscillation in the**
2 **North Atlantic has consequences for anticipating the future of marine**
3 **ecosystems**

4

5

Opinion Piece

6

7 **Running head: future of North Atlantic marine ecosystems**

8

9

10 G. Beaugrand^{1*}, R. Faillettaz², R. R. Kirby^{3,4^}

11

12 1. Centre National de la Recherche Scientifique, Laboratoire d'Océanologie et de
13 Géosciences, Station marine de Wimereux, Université de Lille, 28 avenue Foch,
14 62930 Wimereux, France

15 2 Robin Faillettaz, Ifremer, STH, Laboratoire de Technologie et de Biologie
16 Halieutique, 8 rue François Toullec, 56100 Lorient, France

17 3. The Secchi Disk Foundation, Kiln Cottage, Gnaton, Yealmpton, Devon PL8 2HU,
18 United Kingdom

19 4. Ronin Inst, Montclair, NJ 07043 USA

20 Authors for correspondence

21 * gregory.beaugrand@univ-lille.fr

22 ^ richard.kirby@planktonpundit.org

23

24

25

26

27 **Abstract**

28

29 The North Atlantic marine ecosystem was expected to adjust imminently to a
30 negative phase of the Atlantic Multidecadal Oscillation (AMO). Recent results
31 suggest however, that the AMO is not a regular internal source of variability but has
32 been driven by both volcanism and sulphate aerosol emissions that have influenced
33 temperature negatively and a period of greenhouse gas accumulation causing
34 temperatures to be higher than normal. The demise of the AMO removes the
35 expected and imminent cyclical change from the current warm phase to a negative
36 cool phase in the North Atlantic. Here, we discuss the implications of this new finding
37 for the near-future of North Atlantic marine ecosystems in a context of rapid climate
38 warming.

39 **Main text**

40 For centuries, humans have tried to recognise patterns in natural systems and
41 determine their controlling mechanisms, not least in marine ecosystems (Cheung et
42 al. 2009, Rombouts et al. 2012, Raybaud et al. 2013, Schickele et al. 2021) where it
43 helps to enhance predictability and especially, with regard to commercial fisheries,
44 e.g. the European herring Bohuslän periods (Alheit & Hagen 1997) or the
45 multidecadal fluctuations of sardines and anchovies in different oceans (*Chavez et*
46 *al. 2003*).

47

48 Until now, an inherent large-scale oceanic phenomenon called the AMO was thought
49 to explain periodic changes observed in key physical and biological systems in the
50 North Atlantic, with a periodicity of ~60 years (Mann et al. 1995, Kerr 2000, Enfield et
51 al. 2001, Edwards et al. 2013). Climate change biologists have documented
52 significant correlations between the cyclical nature of the AMO index and North
53 Atlantic biological systems to try to understand the ecosystem and how it might
54 evolve, even postulating that the next negative AMO phase could alleviate or
55 momentarily reverse the current warming trend (Frajka-Williams et al. 2017). For
56 example, in the English Channel, the Russell Cycle that describes an alternation of
57 periods dominated by cold-water (i.e. herring, *Clupea harengus*, and the

58 chaetognath *Sagitta elegans*) and warm-water species (i.e. pilchard, *Sardina*
59 *pilchardus*, and the chaetognath *S. setosa*) has been related to the AMO (Russell et
60 al. 1971, Edwards et al. 2013). Sardine (and *S. setosa*) dominates during positive
61 phases and herring (and *S. elegans*) during negative phases of the AMO. In the
62 North Atlantic, bluefin tuna has been shown to exhibit a long-term, quasi-cyclical,
63 north to south, seesaw-like population movement and changes in abundance driven
64 by climatic variation that correlates with the AMO: when the AMO phase is positive
65 or negative, bluefin tuna are distributed further north or further south, respectively
66 (Faillettaz et al. 2019).

67

68 While previous studies attributed the AMO to internal climatic processes, a recent
69 study by Mann *et al.* (Mann et al. 2021) showed that positive (warm) and negative
70 (cool) phases of the AMO have been due to external forces, such as volcanic
71 activity, sulphate aerosol cooling, and greenhouse-gas-induced warming. The last
72 negative AMO phase was mostly caused by the negative forcing exerted by the
73 increasing sulphate aerosol emission, and the current warm phase by the
74 predominant effect of increasing greenhouse gases at a time of diminishing sulphate
75 aerosol emission (Mann et al. 2021). The AMO-like pattern has therefore, never
76 been governed fully by internal hydro-climatic variability and this new knowledge is of
77 profound importance for our understanding of the regional climate and marine
78 ecosystems.

79

80 To illustrate the strong influence of multidecadal changes in temperature on extra-
81 tropical North Atlantic marine resources, we have updated a previous Principal
82 Component Analysis (PCA) on Sea Surface Temperature (SST) (Beaugrand et al.
83 2002) for the region 20°N-65°N and 100°W-20°E using SST data from the COBE
84 interpolated 1°x1°dataset from 1891 to 2020 (Ishii et al. 2005). Expectedly, this
85 analysis shows two cold and two warm phases superimposed on a long-term
86 positive SST trend for most areas of the North Atlantic except for the central and
87 south-western regions (Figure 1a-b). Detrending the first principal component (PC1,
88 49.8% of the total variance) gives a pattern similar to the classic AMO index, albeit

89 the AMO index is usually based on a larger area than the one we considered here
90 (Enfield et al. 2001, Mann et al. 2021, Murphy et al. 2021).

91

92 When we include long-term changes in an index of phytoplankton concentration in
93 the North Sea (Reid et al. 1998), Norwegian spring spawning herring (Toresen &
94 Østvedt 2008) and bluefin tuna distribution in the north-east Atlantic (Faillettaz et al.
95 2019), we see that changes across three trophic levels in different regions correlate
96 with long-term changes in North Atlantic SST, exhibiting a clear oscillation (Fig. 1c-
97 e). High North Sea phytoplankton concentration, high Norwegian Sea herring and
98 north-east Atlantic tuna abundance are observed during a positive (warm) phase of
99 the AMO and inversely. Because the AMO is considered to cause these changes in
100 addition to other factors (e.g. overfishing of North-east Atlantic tuna and Norwegian
101 Spring-Spawning herring at the beginning of the 1960s) (Lorentzen & Hannesson
102 2004, Fromentin et al. 2014, Cort & Abaunza 2015), and because the nature of the
103 phenomenon was cyclical, a reversal of the AMO was soon expected to occur
104 (Frajka-Williams et al. 2017) with its putative consequences for the marine
105 ecosystem and its exploited resources. Results from Mann et al. (Mann et al. 2021)
106 imply that an imminent reversal to a cool period is now unlikely and so we should not
107 expect an imminent shift in the North Atlantic marine ecosystem and provisioning
108 services.

109

110 While overfishing has been an important component of the collapse of North-east
111 Atlantic tuna or Norwegian Spring-Spawning herring and so management actions
112 may have played an important role in the rebuilding of the different stocks (Lorentzen
113 & Hannesson 2004, Toresen & Østvedt 2008, Fromentin et al. 2014, Cort & Abaunza
114 2015), it often interplayed with changing environmental conditions (Beaugrand et al.
115 2003, Faillettaz et al. 2019). A shift in the state of the AMO from positive to negative
116 could have caused another rapid retreat of bluefin tuna southwards as was observed
117 notoriously at the beginning of the 1960s together with another biological shift in the
118 Russel cycle bringing a new period of high productivity to the English Channel. So,
119 while the demise of the AMO does not negate the climatic modulation of North

120 Atlantic biology, it does have significant implications for our understanding of the
121 drivers of change and how ecosystems and provisioning services may change in the
122 future. Consequently, the recent northward shift of bluefin tuna is likely due to
123 greenhouse gas-induced global warming and the well-known Russell Cycle is not
124 necessarily a cycle anymore (McManus et al. 2016), and there is now, no *a priori*
125 reason that the North Atlantic region will return soon to the negative AMO phase that
126 has been anticipated (Frajka-Williams et al. 2017, Mann et al. 2021).

127

128 The latest IPCC report includes the influence of anthropogenic and volcanic activity
129 on Atlantic multidecadal variability (Masson-Delmotte et al. In press). Climatologists
130 now also use the term Atlantic Multidecadal Variability (AMV) instead of the AMO
131 because multidecadal variability in the Atlantic may result from broad, low-frequency
132 signals (Lapointe et al. 2020, Murphy et al. 2021, Masson-Delmotte et al. In press).
133 The AMV includes the influence of the North Atlantic Oscillation (NAO) that is a
134 natural source of atmospheric variability (Hurrell 1995) and which interacts with the
135 AMOC, although the mechanisms involved and their relative strengths are still
136 unclear (Masson-Delmotte et al. In press). As a result, we also think it is better to
137 replace the AMO by AMV in climate change biology and to therefore recognise that
138 the oscillatory behaviour of Atlantic multidecadal variability observed during the last
139 two centuries may not continue. Consequently, we cannot predict a return to a lower
140 temperature regime with all that entails, i.e. rapid shift in the marine ecosystems with
141 its consequences for exploited resources.

142

143 A fundamental question in ecology is, why is what where? (Berry 1989). Sea surface
144 temperature is a key determinant of the abundance and distribution of marine pelagic
145 species. Of course, knowing that an anticipated and imminent climate reversal in the
146 North Atlantic will not now occur due to the AMO neither invalidates previous
147 environment-driven, cyclical variation seen in species such as bluefin tuna (Faillettaz
148 et al. 2019) nor helps predict the future direction of marine ecosystems, but it does
149 help us focus on those drivers of change that are important. While climatic surprises
150 remain possible (e.g. the slow-down of the Atlantic Meridional Overturning

151 Circulation and its negative influence on North-east Atlantic climate (Boers 2021,
152 Caesar et al. 2021)), if the results of Mann et al. (Mann et al. 2020, Mann et al. 2021)
153 are confirmed, and recent works suggest, at least in part, that they are (Murphy et al.
154 2021, Masson-Delmotte et al. In press), they have now eliminated the AMO as one
155 variable thereby simplifying a complex world where ecosystem shifts are moving
156 towards a warmer dynamic regime in response to anthropogenic climate change
157 (Beaugrand et al. 2002).

158

159

160

161 **References**

162

- 163 Alheit J, Hagen E (1997) Long-term forcing of European herring and sardine
164 populations. *Fisheries Oceanography* 6:130-139
- 165 Beaugrand G, Brander KM, Lindley JA, Souissi S, Reid PC (2003) Plankton effect on cod
166 recruitment in the North Sea. *Nature* 426:661-664
- 167 Beaugrand G, Reid PC, Ibañez F, Lindley JA, Edwards M (2002) Reorganisation of North
168 Atlantic marine copepod biodiversity and climate. *Science* 296:1692-1694
- 169 Berry RJ (1989) Ecology: where genes and geography meet. *Journal of Animal Ecology*
170 58:733-759
- 171 Boers N (2021) Observation-based early-warning signals for a collapse of the Atlantic
172 Meridional Overturning Circulation. *Nature Climate Change* 11:680-688
- 173 Caesar L, McCarthy GD, Thornalley DJR, Cahill N, Rahmstorf S (2021) Current Atlantic
174 Meridional Overturning Circulation weakest in last millennium. *Nature*
175 *Geoscience* 14:1-3
- 176 Chavez FP, Ryan J, Lluch-Cota SE, Niquen MC (2003) From anchovies to sardines and
177 back: multidecadal change in the Pacific Ocean. *Science* 299:217-221
- 178 Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Pauly D (2009) Projecting
179 global marine biodiversity impacts under climate change scenarios. *Fish and*
180 *Fisheries* 10:235-251
- 181 Cort JL, Abaunza P (2015) The Fall of the Tuna Traps and the Collapse of the Atlantic
182 Bluefin Tuna, *Thunnus thynnus* (L.), Fisheries of Northern Europe from the
183 1960s. *Reviews in Fisheries Science & Aquaculture* 23:346-373
- 184 Edwards M, Beaugrand G, Helaouët P, Alheit J, Coombs SH (2013) Marine ecosystem
185 response to the Atlantic Multidecadal Oscillation. *Plos One* 8:e57212
- 186 Enfield DB, Mestas-Nunez AM, Trimble PJ (2001) The Atlantic Multidecadal Oscillation
187 and its relationship to rainfall and river flows in the continental U.S. *Geophysical*
188 *Research Letters* 28:2077-2080
- 189 Faillettaz R, Beaugrand G, Goberville E, Kirby RR (2019) Atlantic Multidecadal
190 Oscillations drive the basin-scale distribution of Atlantic bluefin tuna. *Science*
191 *Advances* 5:eaar6993
- 192 Frajka-Williams E, Beaulieu C, Duchez A (2017) Emerging negative Atlantic
193 Multidecadal Oscillation index in spite of warm subtropics. *Scientific Reports*
194 7:11224
- 195 Fromentin J-M, Reygondeau G, Bonhommeau S, Beaugrand G (2014) Oceanographic
196 changes and exploitation drive the spatio-temporal dynamics of Atlantic bluefin
197 tuna (*Thunnus thynnus*). *Fisheries Oceanography* 23:147-156
- 198 Hurrell JW (1995) Decadal trends in the North Atlantic Oscillation: regional
199 temperatures and precipitations. *Science* 269:676-679
- 200 Ishii M, Shouji A, Sugimoto S, Matsumoto T (2005) Objective Analyses of Sea-Surface
201 Temperature and Marine Meteorological Variables for the 20th Century using
202 ICOADS and the Kobe Collection. *International Journal of Climatology* 25:865-
203 879
- 204 Kerr RA (2000) A North Atlantic climate pacemaker for the centuries. *Science*
205 288:1984-1986

206 Lapointe F, Bradley RS, Francus P, Balascio NL, Abbott MB, Stoner JS, St-Onge G, De
 207 Coninck A, Thibault Labarre T (2020) Annually resolved Atlantic sea surface
 208 temperature variability over the past 2,900 y. *Proceedings of the National*
 209 *Academy of Sciences of the United States of America* 117:27171-27178
 210 Lorentzen T, Hannesson R (2004) The collapse of the Norwegian herring fisheries in the
 211 late 1950s and 60s crisis, adaptation, and recovery. In: SNF-Project No 5015.
 212 Institute for research in economics and business administration, Bergen
 213 Mann ME, Park J, Bradley RS (1995) Global interdecadal and century-scale climate
 214 oscillations during the past five centuries. *Nature* 378:266-270
 215 Mann ME, Steinman BA, Brouillette DJ, Miller SK (2021) Multidecadal climate
 216 oscillations during the past millennium driven by volcanic forcing. *Science*
 217 371:1014-1019
 218 Mann ME, Steinman BA, Miller SK (2020) Absence of internal multidecadal and
 219 interdecadal oscillations in climate model simulations. *Nature Communications*
 220 11
 221 Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y,
 222 Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK,
 223 Waterfield T, Yelekçi O, Yu R, Zhou B (In press) IPCC, 2021: Climate Change
 224 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth
 225 Assessment Report of the Intergovernmental Panel on Climate Change, Vol. Cambridge
 226 University Press, Cambridge
 227 McManus MC, Licandro P, Coombs SH (2016) Is the Russell Cycle a true cycle?
 228 Multidecadal zooplankton and climate trends in the western English Channel.
 229 *ICES Journal of Marine Science* 73:227-238
 230 Murphy LN, Klavans JM, Clement AC, Cane MA (2021) Investigating the Roles of External
 231 Forcing and Ocean Circulation on the Atlantic Multidecadal SST Variability in a
 232 Large Ensemble Climate Model Hierarchy. *Journal of Climate* 34:4835-4849
 233 Raybaud V, Beaugrand G, Goberville E, Delebecq G, Destombe C, Valero M, Davoult D,
 234 Morin P, Gevaert F (2013) Decline in Kelp in West Europe and Climate. *PLOS One*
 235 8:e66044
 236 Reid PC, Edwards M, Hunt HG, Warner AJ (1998) Phytoplankton change in the North
 237 Atlantic. *Nature* 391:546
 238 Reid PC, Hunt HG (1998) Are observed changes in the plankton of the North Atlantic
 239 and North Sea linked to climate change? In. Intergovernmental Oceanographic
 240 Commission, The Netherlands
 241 Rombouts I, Beaugrand G, Dauvin J-C (2012) Potential changes in benthic macrofaunal
 242 distributions from the English Channel simulated under climate change
 243 scenarios. *Estuarine, coastal and Shelf Science* 99:153-161
 244 Russell FS, Southward AJ, Boalch GT, Butler EI (1971) Changes in biological conditions
 245 in the English Channel off Plymouth during the last half century. *Nature* 234:468-
 246 470
 247 Schickele A, Leroy B, Beaugrand G, Goberville E, Hattab T, Francour P, Raybaud V (2021)
 248 Modelling European small pelagic fish distribution: Methodological insights. *Fish*
 249 *and Fisheries* 22:212-225

250 Toresen R, Østvedt OJ (2008) Variation in abundance of Norwegian spring - spawning
251 herring (*Clupea harengus*, Clupeidae) throughout the 20th century and the
252 influence of climatic fluctuations. *Fish and Fisheries* 1:231-256

253

254

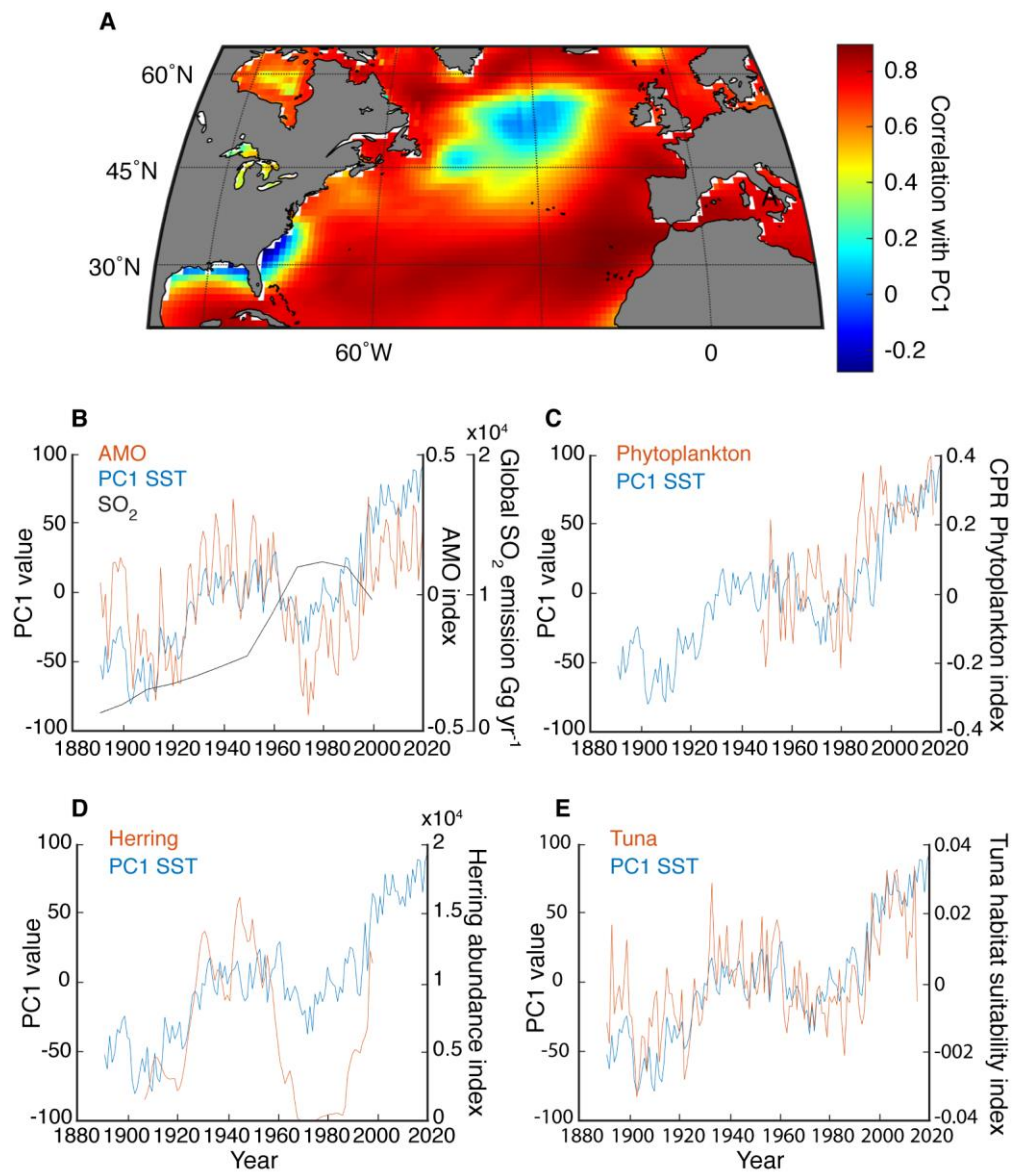
255

256 **Figure legend**

257 **Figure 1.** Relationships between changes in North Atlantic annual SST and pelagic
258 life. A) First standardised eigenvector (49.8% of the total variance) showing the long-
259 term changes in annual SST and the first principal component (SST PC1). B) The
260 long-term changes in SST PC1 and an AMO index (Spearman correlation r_{sp} 0.68,
261 $p < 0.01$), and long-term changes in global sulphate aerosol emissions. C) The long-
262 term changes in SST PC1 and the CPR phytoplankton colour index (PCI) in the
263 North Sea (r_{sp} 0.66, $p < 0.01$) (Reid & Hunt 1998). D) The long-term changes in SST
264 PC1 and Norwegian spring spawning herring (r_{sp} 0.43, $p < 0.01$) (Toresen & Østvedt
265 2008). E) The long-term changes in SST PC1 and a bluefin tuna occurrence index
266 (r_{sp} 0.75, $p < 0.01$) (Faillettaz et al. 2019). Although based on temperature, the
267 occurrence index has been validated with the observed changes in tuna abundance
268 that took place in the North-east Atlantic (Faillettaz et al. 2019). The given r_{sp} is the
269 coefficient of Spearman correlation and values are based upon a Montecarlo test
270 with 10,000 simulations.

271

272



273

274