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Supplemental Information

A Climate-Driven Functional Inversion of Connected Marine Ecosystems

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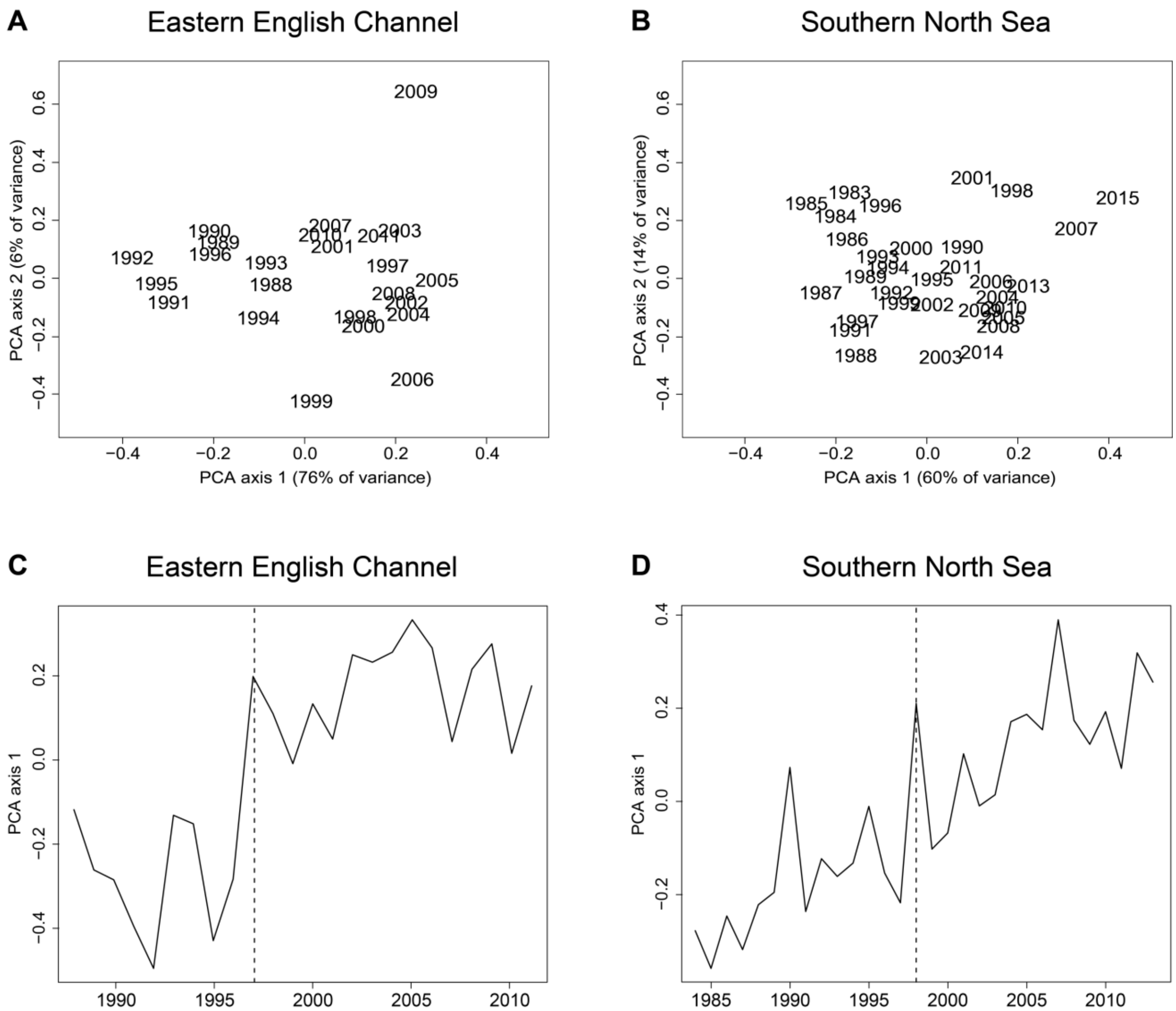

Figure S1. Temporal changes of fish functional structure in the Eastern English Channel (EEC) and Southern North Sea (SNS), related to Figure 4. Principal component plots showing temporal changes in fish functional structure in the EEC (A) and SNS (B). PCA axes 1 (C, D) were used for Granger causality analyses.

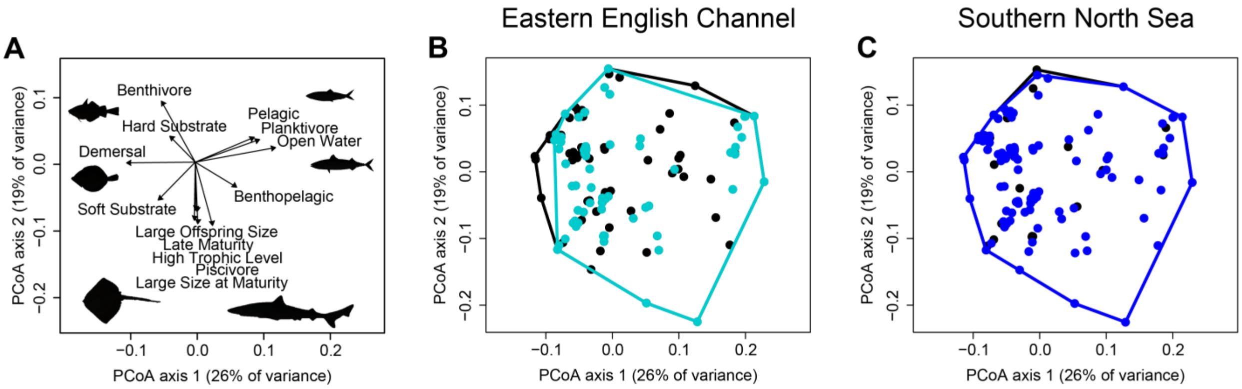

Figure S2. Multidimensional fish functional in the Eastern English Channel (EEC) (B) and Southern North Sea (SNS), related to Figure 2. (B, C). Points represent each species while polygons represent the functional space (i.e., convex hulls) containing all species in each ecosystem (EEC = light blue; SNS = dark blue; combined = black).

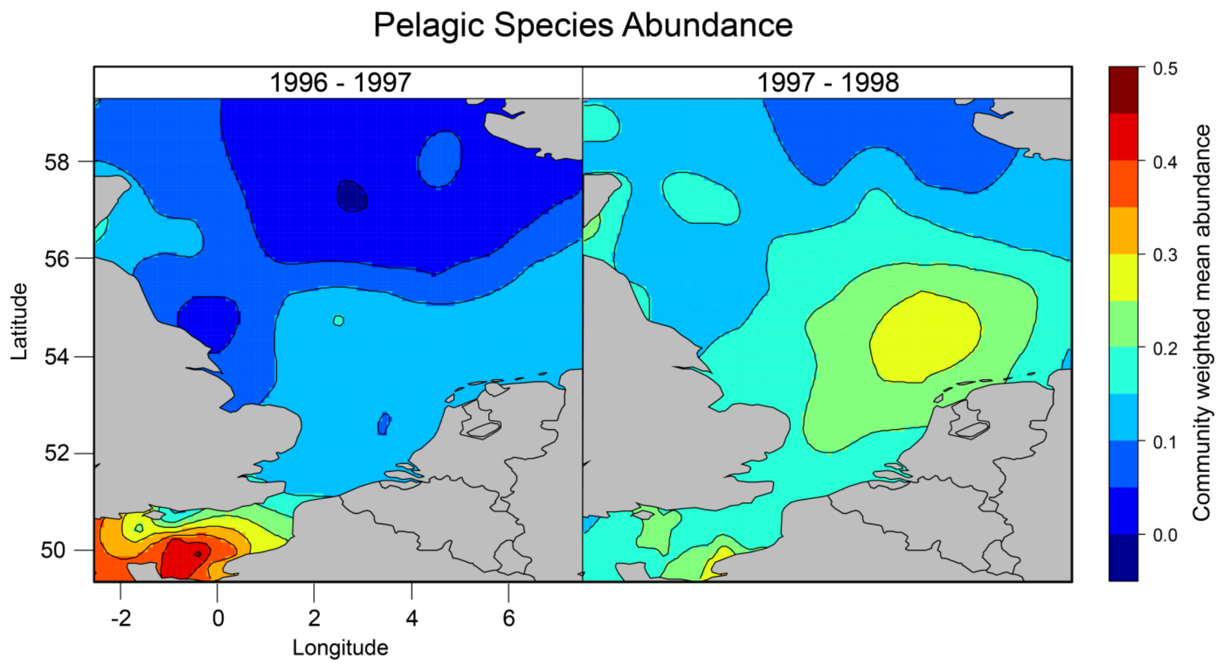

Figure S3. Kriging-interpolated map of the community-weighted mean abundance of all pelagic species in the Eastern English Channel (EEC) and Southern North Sea (SNS) for the years 1996 – 1997 and 1997 – 1998, related to Figure 2. For this figure the year 1998 in the SNS was combined with 1997 for the EEC, and 1997 in the SNS was combined with 1996 in the EEC to demonstrate the rapid northward shift of pelagic species, and because the SNS survey of a given year actually occurs only four months after the EEC survey of the year before.

Table S1. Functional traits used to characterize fish functional structure, related to Figure 2 and 3.

Functional Trait	Category	Type	Units
Length at maturity	Life history	Numeric	Total length (cm)
Age at maturity	Life history	Numeric	Years
Parental care	Life history	Ordered factor [S1]	1 = pelagic egg, 2 = benthic egg, 3 = clutch hider, 4 = clutch guarder, 5 = live bearer
Fecundity	Life history	Numeric	Number of offspring
Offspring size	Life history	Numeric	Total length or diameter (cm)
Trophic guild	Trophic ecology	Factor [S2]	Benthivore, benthopiscivore, carcinophage, detritivore, ectoparisite, piscivore, planktivore, scavenger
Trophic level	Trophic ecology	Numeric [S2]	Level (unit-less)
Water column position	Habitat use	Factor [S2]	Bathydemersal, bathypelagic, benthopelagic, demersal, epipelagic, mesopelagic, pelagic, reef-associated
Substrate preference	Habitat use	Factor	Soft, hard, or open-water
Thermal preference	Habitat use	Numeric	Degrees Celsius

Table S2. Changes in mean abundance before and after the shift for all species that co-occur in both ecosystems, related to Figure 2 and Figure 3.

	Eastern English Channel	**Southern North Sea**
Species	**ΔAbundance (Ind./km^2)**	**ΔAbundance (Ind./km^2)**
Agonus cataphractus	-2.30	22.03
Alosa spp.	0.06	5.90
Amblyraja radiata	0.08	5.66
Anguilla anguilla	-0.60	0.02
Arnoglossus spp.	1.14	19.47
Buglossidium luteum	12.30	160.80
Callionymus spp.	-56.82	9.95
Chelidonichthys cuculus	-92.34	-0.26
Chelidonichthys lucerna	-6.96	0.14
Clupea harengus	-827.46	11579.96
Dicentrarchus labrax	33.28	1.43
Engraulis encrasicolus	-225.51	235.84
Eutrigla gurnardus	-2.56	640.92
Gadus morhua	-12.37	-96.03
Galeorhinus galeus	-7.01	0.03
Hyperoplus lanceolatus	-48.09	7.70
Labrus bergylta	0.28	0.01
Leucoraja naevus	-0.25	0.03
Limanda limanda	-298.50	627.53
Liza ramada	0.28	0.01
Lophius piscatorius	0.15	0.10
Melanogrammus aeglefinus	0.01	-50.57
Merlangius merlangus	-406.82	266.26
Microchirus variegatus	-0.07	0.28
Micromesistius poutassou	3.73	0.01
Microstomus kitt	-17.38	17.38
Molva molva	-0.32	-0.14
Mullus surmuletus	54.61	1.34
Myoxocephalus scorpius	0.01	16.66
Platichthys flesus	3.83	-5.92
Pleuronectes platessa	-47.48	273.42
Pollachius pollachius	-4.51	-0.10
Raja brachyura	1.70	0.29
Raja clavata	9.11	-13.71
Raja montagui	-3.50	1.24

Raja undulata	0.08	0.00
Sardina pilchardus	-1207.36	17.11
Scomber scombrus	-1075.73	3.70
Scophthalmus maximus	1.32	0.49
Scophthalmus rhombus	0.92	0.08
Scyliorhinus canicula	105.76	40.89
Scyliorhinus stellaris	15.91	-0.02
Solea solea	0.72	-2.07
Spondyliosoma cantharus	81.95	-0.15
Sprattus sprattus	-3911.04	35611.78
Squalus acanthias	-0.77	-0.83
Syngnathus spp.	0.17	28.41
Trachinus draco	2.30	0.58
Trachurus trachurus	-24025.56	40.30
Trigla lyra	-1.64	-1.77
Trigloporus lastoviza	3.38	0.00
Trisopterus luscus	-2170.73	-46.86
Trisopterus minutus	-13835.40	-203.41
Zeus faber	5.62	0.13

Supplemental references

S1. Pecuchet, L., Lindegren, M., Hidalgo, M., Delgado, M., Esteban, A., Fock, H.O., Gil de Sola, L., Punzón, A., Sólmundsson, J., and Payne, M.R. (2017). From traits to life-history strategies: Deconstructing fish community composition across European seas. Glob. Ecol. Biogeogr. *26*, 812–822.

S2. Engelhard, G.H., Ellis, J.R., Payne, M.R., ter Hofstede, R., and Pinnegar, J.K. (2011). Ecotypes as a concept for exploring responses to climate change in fish assemblages. ICES J. Mar. Sci. *68*, 580–591.