

Electronic Supplementary material for Ecological Indicators research article:

Mapping benthic ecological diversity and interactions with bottom-contact fishing on the Flemish Cap (northwest Atlantic)

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Appendix A. Supplementary material

Table A1

Parametric coefficients and approximate significance of smooth terms in the GAMs. Avg, average; Min, minimum; edf, estimated degrees of freedom.

Parametric terms				
GAM 1A AIC = 1077 R ² (adj.) = 0.46	(intercept)	Estimate	SE	Probability
	Fishing effort	1.192	0.403	0.003
	Annual primary production avg range	-0.170	0.035	1.05x10 ⁻⁶
Approximate significance of smooth terms				
		edf		Probability
	s(Bottom salinity avg min)	7.13		< 2x10 ⁻¹⁶
	s(Surface temperature avg min)	2.70		4.54x10 ⁻⁴
Parametric terms				
GAM 1B AIC = 1235 R ² (adj.) = 0.45	(intercept)	Estimate	SE	Probability
	Fishing effort	2.394	0.169	< 2x10 ⁻¹⁶
	Surface temperature avg min	-0.192	0.033	4.86x10 ⁻⁹
Approximate significance of smooth terms				
		edf		Probability
	s(Annual primary production avg range)	2.719		3.59x10 ⁻⁴
	s(Bottom salinity avg min)	6.50		< 2x10 ⁻¹⁶
Parametric terms				
GAM 2 AIC = 1056 R ² (adj.) = 0.62	(intercept)	Estimate	SE	Probability
	Black corals	2.259	0.061	< 2x10 ⁻¹⁶
	Large gorgonians	0.016	0.056	0.770
	Small gorgonians	0.050	0.061	0.420
	Sea pens	0.376	0.092	4.48x10 ⁻⁵
	Soft corals	0.005	0.034	0.885
Approximate significance of smooth terms				
		edf		Probability
	s(Sponges)	3.165		3.17x10 ⁻⁵
	s(<i>Asconema foliata</i>)	1.994		0.002
Parametric terms				
GAM 3 AIC = 993 R ² (adj.) = 0.73	(intercept)	Estimate	SE	Probability
	Annual primary production avg range	1.506	0.251	1.81x10 ⁻⁹
	Small gorgonians	0.001	2.84x10 ⁻⁴	0.015
	Sponges	0.330	0.075	9.94x10 ⁻⁶
Approximate significance of smooth terms				
		edf		Probability
	s(Bottom salinity avg min)	5.99		7.90x10 ⁻¹³
	s(Fishing effort)	3.09		0.004
	s(<i>Asconema. foliata</i>)	1.49		3.09x10 ⁻⁵

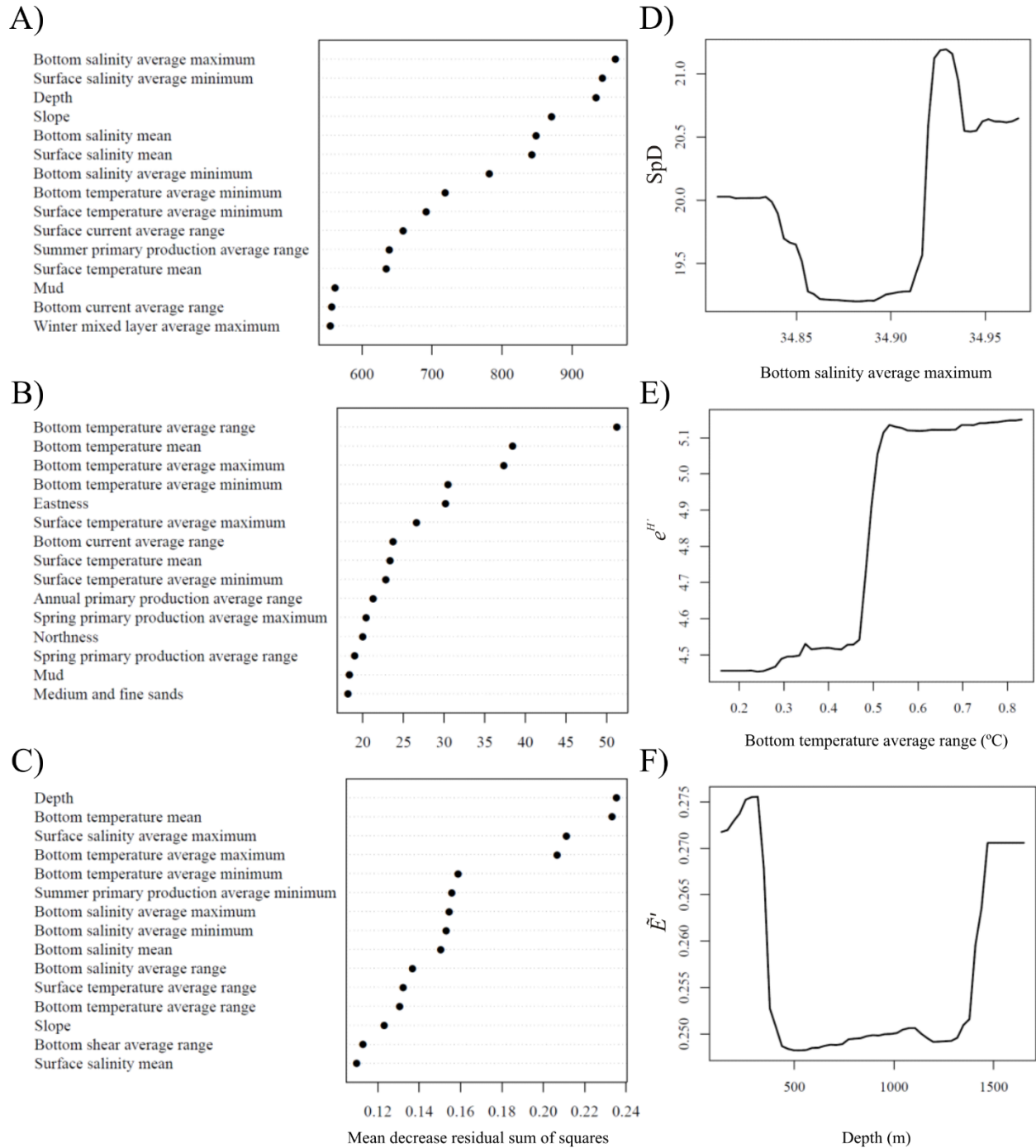


Fig A1. A–C) Importance of the top 15 predictor variables measured as the mean decrease in residual sum of squares of the regression random forest model of (A) sample SpD , (B) sample e^H and (C) E' . D–F) Partial dependence plot of the most important predictor while the rest of predictors are held constant at their mean observed values.

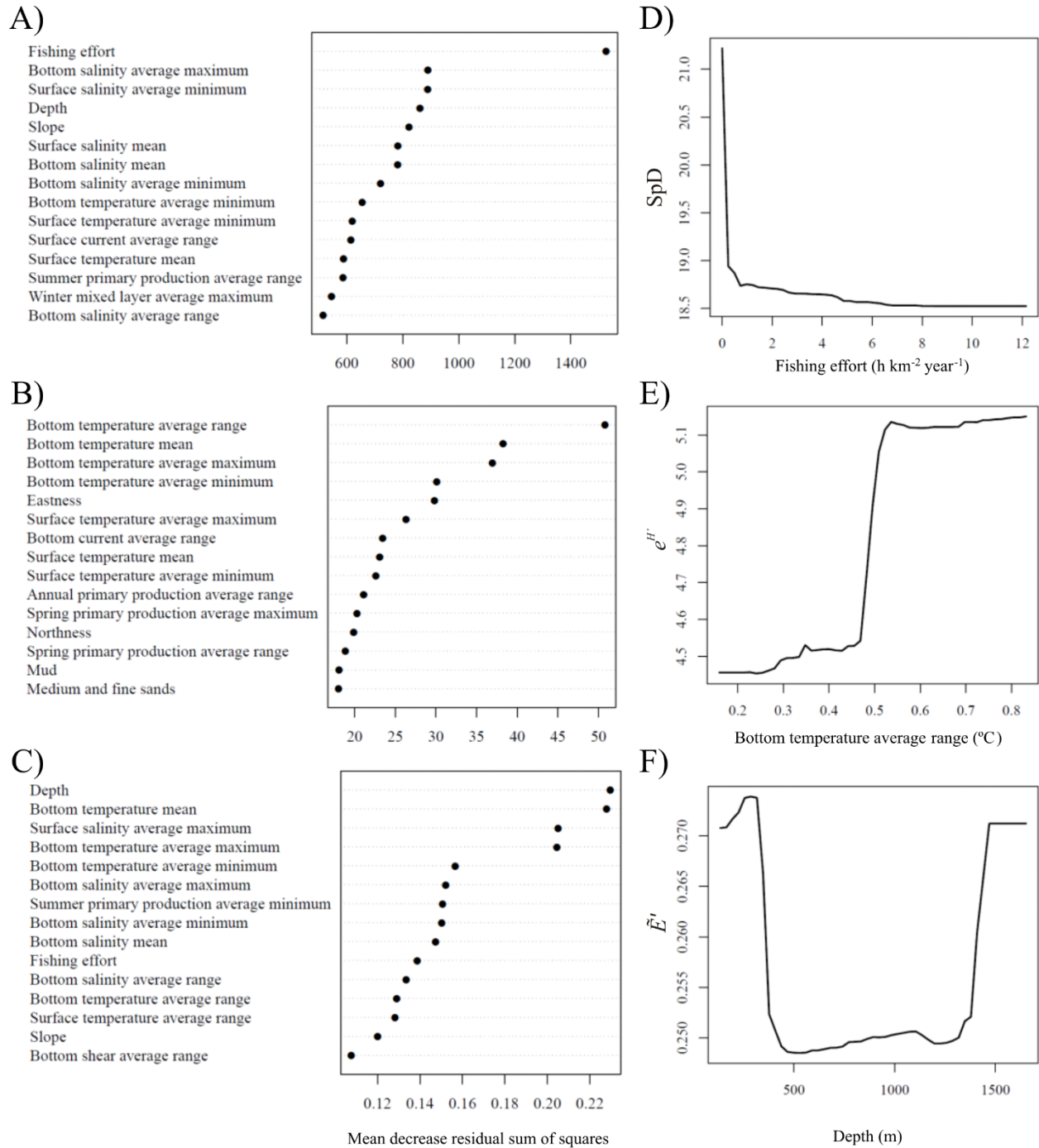


Fig A2. A–C) Importance of the top 15 predictor variables measured as the mean decrease in residual sum of squares of the regression random forest model including fishing effort as predictor of (A) sample SpD, (B) sample e^H and (C) E' . D–F) Partial dependence plot of the most important predictor while the rest of predictors are held constant at their mean observed values.

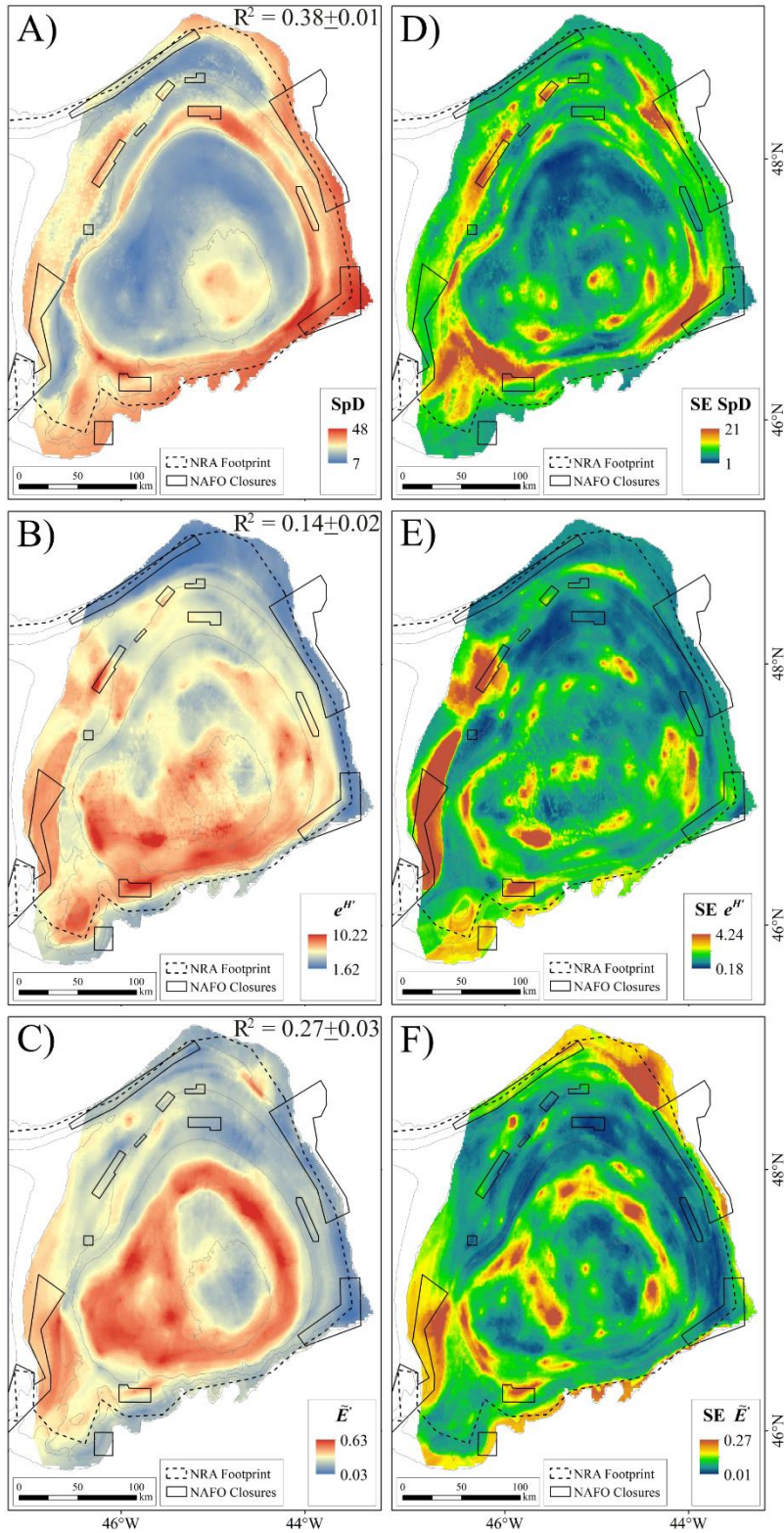


Fig. A3. A–C) Predicted maps and R^2 from random forest modelling including fishing effort as predictor of (A) sample SpD, (B), sample e^H and (C) E' . D–F) Standard deviation associated for each predicted surface. NRA footprint and Closed Areas indicated in outline.

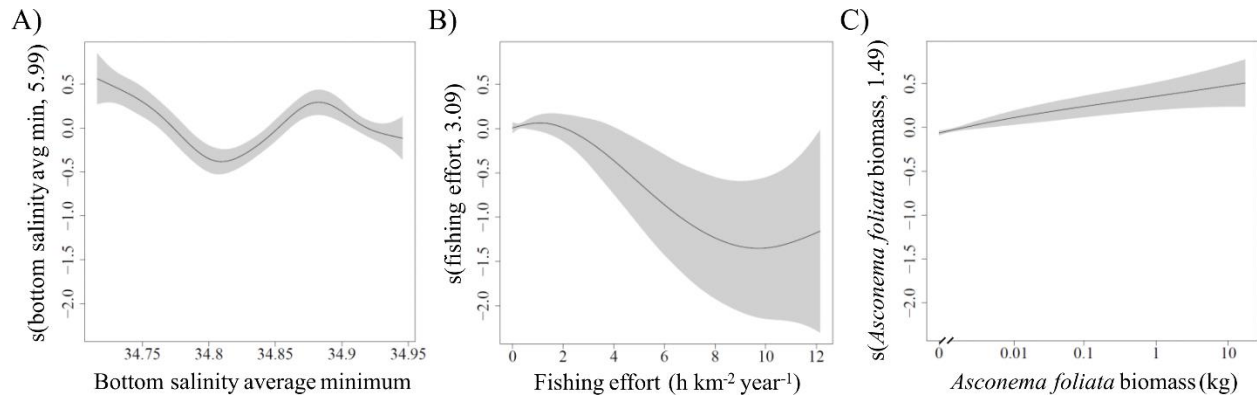


Fig. A4. Bivariate plots of the smooth terms of GAM 4 plotted against the corresponding input variable. A) Bottom salinity average minimum; B) Fishing effort; C) Biomass of *A. foliata* taken by the survey sets. The biomass is plotted on logarithmic scales, with zero offset. The grey areas represent 95% confidence intervals. Avg, average; Min, minimum.

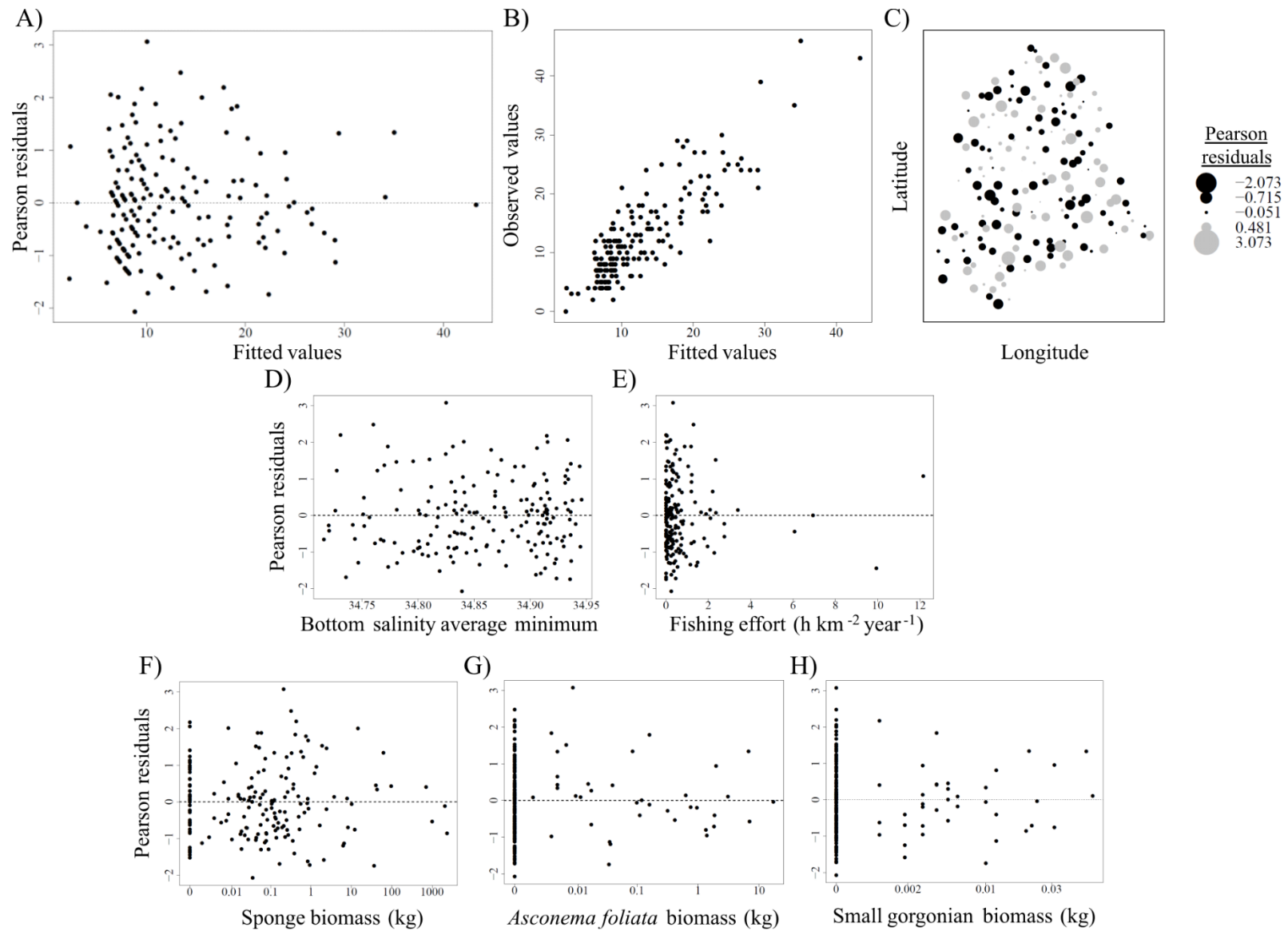


Fig. A5. Validation plots of GAM 3 (overdispersion = 0.97). A) Fitted values versus Pearson residuals; B) Fitted values versus observed values; C) Spatial autocorrelation of residuals; D-H) Residuals versus covariates included in the model.

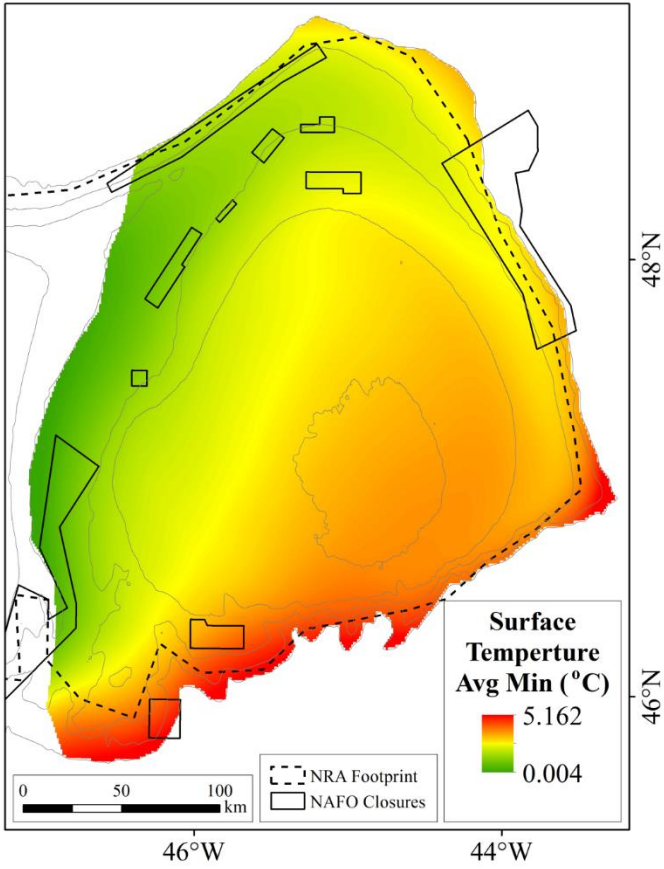


Fig. A6. Interpolated prediction surface of Surface Temperature Average (Avg) Minimum (Min) (°C).

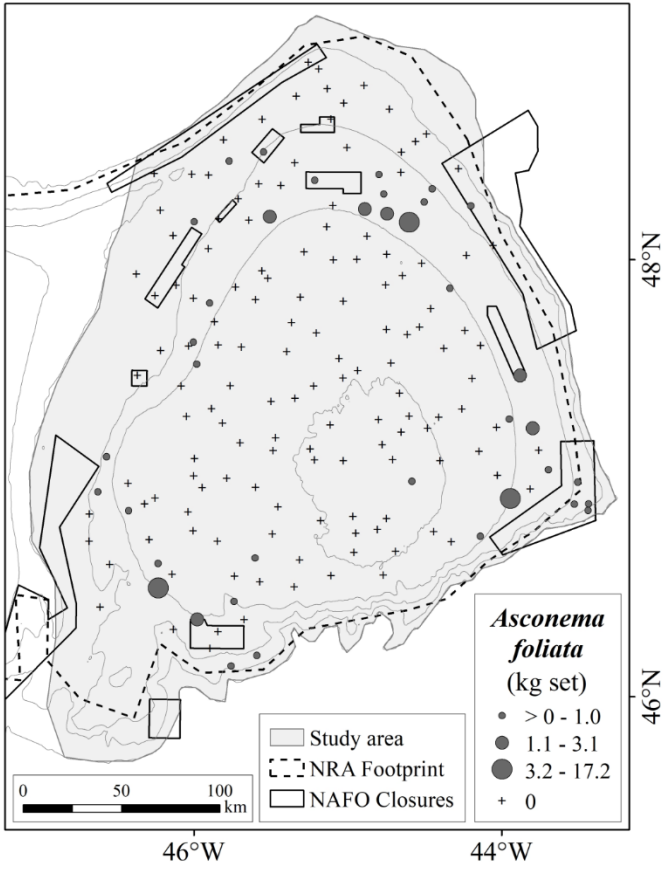


Fig. A7. *Asconema foliata* biomass distribution in the Flemish Cap area.

Appendix B.

Murillo et al. (2016) identified seven epibenthic assemblages on the Flemish Cap area each with relatively sharp faunal boundaries and unique species attributes. The heavily fished areas were characterized by an impoverished community (III.b.2) with no diagnostic species. The nearby presence of areas subjected to low fishing pressure and with similar species composition to the common fishing grounds (III.b.1), suggests that fishing activities have altered benthic biomass and species dominance rather than producing the extirpation of particular species, since the estimated species richness of assemblage III.b.2 was only 11% lower than III.b.1 (compared with the 40% reduction observed in species density). Comparing the species composition from both assemblages (Table B1), the decrease in species density is mainly caused by rarities present in III.b.1 which have a lower probability of being recorded in III.b.2 due to the lower benthic biomass caught. From the 71 species with occurrence below 30% in III.b.1, 47 were absent in III.b.2. Whereas species present in III.b.1 with percentage of occurrence above 50% were also present in III.b.2 but in lower occurrence and average biomass, except the blind lobster *Stereomastis nana* and the sea star *Mediaster bairdi* that were slightly more common in III.b.2. This decrease in percentage of occurrence and average biomass was especially notable for the sea pens *Funiculina quadrangularis* and *Halipterus finmarchica*, for the soft corals *Heteropolypus sol* and *Duva florida* and for the sea star *Bathybiaster vexillifer*.

References

Murillo, F.J., Serrano, A., Kenchington, E., Mora, J., 2016. Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. *Deep-Sea Res. I* 109, 99–122.

Table B1

List of non-encrusting benthic invertebrates found in assemblages III.b.1 and III.b.2 from Murillo et al. (2016) with number of trawl sets with taxon present (N), percentage of occurrence over these sets (%) and average biomass (Avg. B.) in kg for each taxon by assemblage. Taxa are ordered by percentage of occurrence in III.b.1.

Taxa	Phylum	III.b.1			III.b.2		
		N	%	Avg. B. (kg)	N	%	Avg. B. (kg)
<i>Anthoptilum grandiflorum</i>	Cnidaria	19	100	0.5121	9	64	0.0113
<i>Phormosoma placenta</i>	Echinodermata	18	95	0.2319	10	71	0.0789
<i>Funiculina quadrangularis</i>	Cnidaria	14	74	0.0068	1	7	0.0006
<i>Halipteris finmarchica</i>	Cnidaria	13	68	0.0659	1	7	0.0034
<i>Stereomastis nana</i>	Arthropoda	13	68	0.0050	11	79	0.0210
<i>Bathybiaster vexillifer</i>	Echinodermata	11	58	0.1371	0	0	0
<i>Heteropolypus sol</i>	Cnidaria	11	58	0.0295	1	7	0.0002
<i>Duva florida</i>	Cnidaria	10	53	0.0333	1	7	0.0002
<i>Mediaster bairdi</i>	Echinodermata	10	53	0.0435	11	79	0.0211
<i>Flabellum (Ulocyathus) alabastrum</i>	Cnidaria	9	47	0.0174	0	0	0
<i>Pennatula aculeata</i>	Cnidaria	9	47	0.0025	0	0	0
<i>Zoroaster fulgens</i>	Echinodermata	7	37	0.1499	2	14	0.0041
<i>Munidopsis curvirostra</i>	Arthropoda	6	32	0.0005	6	43	0.0006
<i>Neolithodes grimaldii</i>	Arthropoda	6	32	0.4518	6	43	0.6020
<i>Ophiomusa lymani</i>	Echinodermata	6	32	0.0070	7	50	0.0084
<i>Stryphnus fortis</i>	Porifera	5	26	0.1381	0	0	0
<i>Actinoscyphia saginata</i>	Cnidaria	4	21	0.2358	0	0	0
<i>Mycale (Mycale) lingua</i>	Porifera	4	21	0.0307	0	0	0
<i>Phelliactis</i> spp.	Cnidaria	4	21	0.0503	0	0	0
<i>Pontophilus norvegicus</i>	Arthropoda	4	21	0.0011	2	14	0.0004
<i>Actinauge cristata</i>	Cnidaria	3	16	0.0364	0	0	0
<i>Arcoscalpellum michelottianum</i>	Arthropoda	3	16	0.0144	1	7	0.0021
<i>Ascidia</i> spp.	Chordata	3	16	0.0007	0	0	0
<i>Asteronyx loveni</i>	Echinodermata	3	16	0.0002	3	21	0.0004
<i>Drifa flavescens</i>	Cnidaria	3	16	0.0006	4	29	0.0006
<i>Kophobelemnion stelliferum</i>	Cnidaria	3	16	0.0002	1	7	0.0001
<i>Ophiochondrus cf. armatus</i>	Echinodermata	3	16	0.0003	0	0	0
<i>Pennatula grandis</i>	Cnidaria	3	16	0.0002	1	7	0.0001
<i>Pontaster tenuispinus</i>	Echinodermata	3	16	0.0011	3	21	0.0018
<i>Radicipes gracilis</i>	Cnidaria	3	16	0.0002	0	0	0
<i>Stauropathes arctica</i>	Cnidaria	3	16	0.0109	1	7	0.0010
<i>Turrisipho lachesis</i>	Mollusca	3	16	0.0013	0	0	0
<i>Actinauge</i> spp.	Cnidaria	2	11	0.0341	0	0	0
<i>Arrhoges occidentalis</i>	Mollusca	2	11	0.0010	0	0	0
<i>Astarte sulcata</i>	Mollusca	2	11	0.0005	0	0	0
<i>Bathypallenopsis mollissima</i>	Arthropoda	2	11	0.0002	0	0	0
<i>Buccinum hydrophanum</i>	Mollusca	2	11	0.0005	1	7	0.0013
<i>Hedingia albicans</i>	Echinodermata	2	11	0.0006	0	0	0
<i>Crella</i> spp.	Porifera	2	11	0.0007	0	0	0
<i>Eudendrium</i> spp.	Cnidaria	2	11	0.0002	1	7	7E-05
<i>Neptunea despecta</i>	Mollusca	2	11	0.0031	0	0	0
<i>Ophiacantha fraterna</i>	Echinodermata	2	11	0.0001	0	0	0
<i>Sabinea hystrix</i>	Arthropoda	2	11	0.0011	3	21	0.0024
Solenogastres	Mollusca	2	11	0.0001	0	0	0
<i>Ptychogena crocea</i>	Cnidaria	2	11	0.0004	2	14	0.0001
<i>Stephanauge nexilis</i>	Cnidaria	2	11	0.0015	0	0	0

<i>Stereomastis sculpta</i>	Arthropoda	2	11	0.0001	3	21	0.0006
<i>Terebratulina septentrionalis</i>	Brachiopoda	2	11	0.0011	0	0	0
<i>Thenea</i> spp.	Porifera	2	11	0.1019	0	0	0
<i>Umbellula lindahli</i>	Cnidaria	2	11	0.0026	2	14	0.0013
<i>Acanella arbuscula</i>	Cnidaria	1	5	0.0017	1	7	0.0001
Actinostolidae	Cnidaria	1	5	0.0004	2	14	0.0445
<i>Aglaophenopsis cornuta</i>	Cnidaria	1	5	0.0003	0	0	0
Alcyonacea	Cnidaria	1	5	5E-05	0	0	0
Aphroditidae	Annelida	1	5	0.0003	0	0	0
Aplousobranchia	Chordata	1	5	0.0003	0	0	0
<i>Asconema foliata</i>	Porifera	1	5	0.0019	0	0	0
<i>Beringius turtoni</i>	Mollusca	1	5	0.0036	1	7	0.0054
<i>Bolocera tuediae</i>	Cnidaria	1	5	0.0006	0	0	0
<i>Brisaster fragilis</i>	Echinodermata	1	5	0.0003	0	0	0
<i>Cladocarpus integer</i>	Cnidaria	1	5	0.0002	0	0	0
Clavulariidae	Cnidaria	1	5	5E-05	0	0	0
<i>Colossendeis angusta</i>	Arthropoda	1	5	0.0001	4	29	0.0003
<i>Colus stimpsoni</i>	Mollusca	1	5	0.0023	0	0	0
<i>Craniella</i> spp.	Porifera	1	5	0.0002	0	0	0
Didemnidae	Chordata	1	5	0.0008	3	21	0.0006
<i>Edwardsia</i> sp.	Cnidaria	1	5	5E-05	0	0	0
<i>Geodia barretti</i>	Porifera	1	5	0.1226	0	0	0
<i>Geodia macandrewii</i>	Porifera	1	5	0.1795	0	0	0
<i>Gorgonocephalus lamarckii</i>	Echinodermata	1	5	0.0002	0	0	0
Haplosclerida	Porifera	1	5	0.0003	0	0	0
<i>Harmothoe</i> spp.	Annelida	1	5	0.0006	1	7	7E-05
<i>Hippasteria phrygiana</i>	Echinodermata	1	5	0.0247	0	0	0
<i>Maldane sarsi</i>	Annelida	1	5	0.0002	0	0	0
<i>Modeeria rotunda</i>	Cnidaria	1	5	5E-05	0	0	0
Myxillina	Porifera	1	5	0.0021	0	0	0
Nereididae	Annelida	1	5	5E-05	0	0	0
Polynoidae	Annelida	1	5	5E-05	2	14	0.0001
<i>Protoptilum carpenteri</i>	Cnidaria	1	5	0.0001	0	0	0
<i>Pseudarchaster gracilis</i>	Echinodermata	1	5	0.0071	1	7	0.0026
<i>Pseudarchaster parelii</i>	Echinodermata	1	5	0.0017	0	0	0
<i>Psilaster andromeda</i>	Echinodermata	1	5	0.0003	1	7	0.0011
<i>Sagartiogeton</i> spp.	Cnidaria	1	5	0.0002	0	0	0
<i>Sarsiflustra abyssicola</i>	Bryozoa	1	5	5E-05	0	0	0
Sipuncula	Sipuncula	1	5	0.0004	1	7	0.0003
<i>Stelletta normani</i>	Porifera	1	5	0.0037	0	0	0
<i>Astarte montagui</i>	Mollusca	0	0	0	4	29	0.0006
<i>Limopsis affinis</i>	Mollusca	0	0	0	2	14	0.0001
<i>Aeolidiella</i> sp.	Mollusca	0	0	0	1	7	7E-05
<i>Anthomastus</i> spp.	Cnidaria	0	0	0	1	7	0.0024
Chaetopteridae	Annelida	0	0	0	1	7	0.0008
<i>Colus islandicus</i>	Mollusca	0	0	0	1	7	0.0036
Eunicidae	Annelida	0	0	0	1	7	7E-05
<i>Hanleya hanleyi</i>	Mollusca	0	0	0	1	7	0.0002
<i>Nymphon leptocheles</i>	Arthropoda	0	0	0	1	7	7E-05
<i>Nymphon tenellum</i>	Arthropoda	0	0	0	1	7	0.0001
<i>Ophioplinthus tessellata</i>	Echinodermata	0	0	0	1	7	0.0001
<i>Pentacheles laevis</i>	Arthropoda	0	0	0	1	7	0.0006
<i>Symplectoscyphus</i>	Cnidaria	0	0	0	1	7	7E-05
<i>Virgularia mirabilis</i>	Cnidaria	0	0	0	1	7	0.0001