

## Supplementary material

### Text S1. Random Forest model

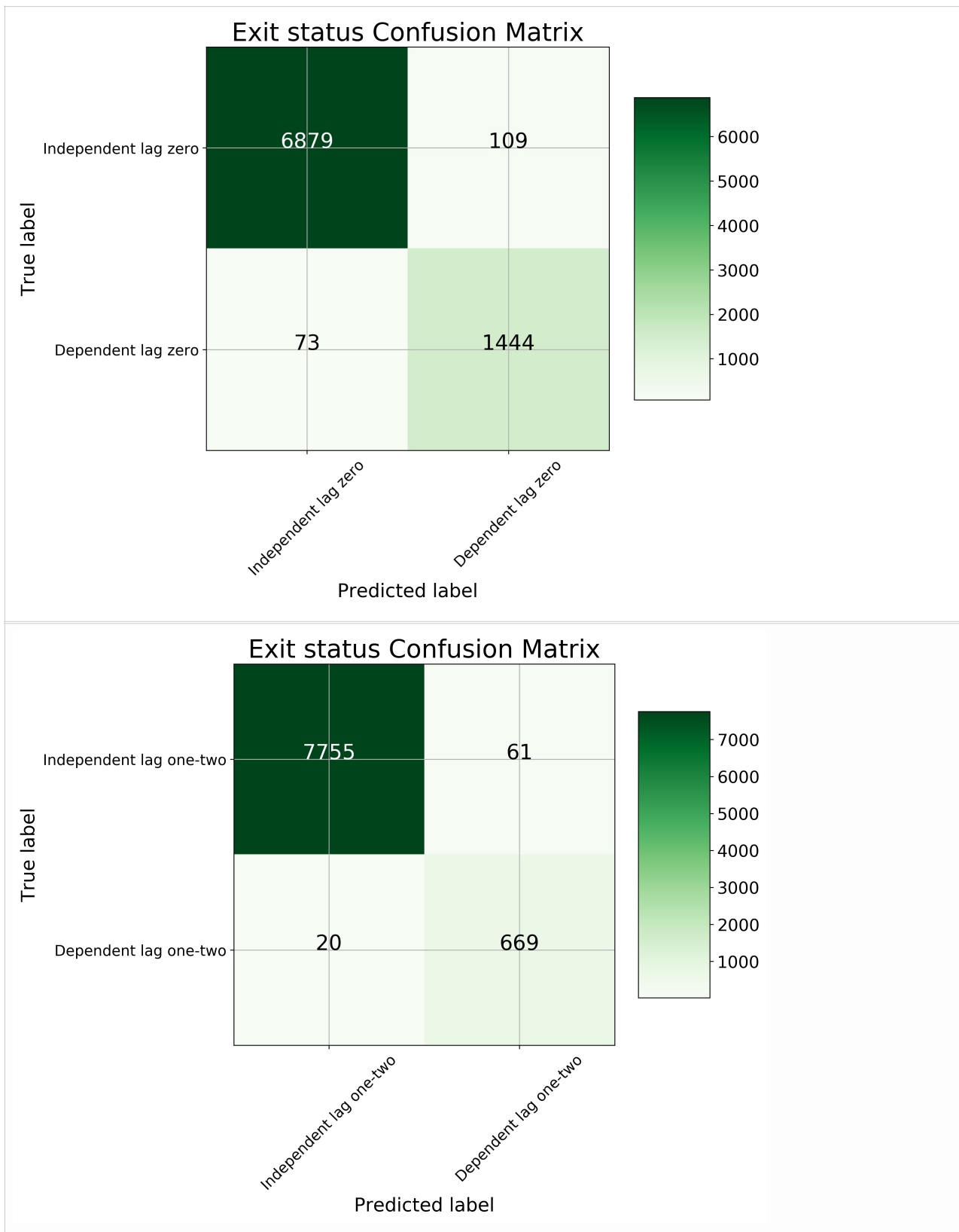
To gain more insight into the kind of life-history, population and environmental characteristics driving the observed relationships between seascapes and fish biomass in the North Sea we applied a Random Forest classifier (RFC). The objective of the RFC model was to correctly predict the presence of a causal relationship between seascapes at a time-lag of either zero or one-two years using 17 features (Table S1, Figure S1).

**Table S1.** Random Forest Model Labels and Features

Feature	Description
Seascape-combination	Seascape combination identity. Categories include all 45 unique combinations: S1-S2, .. ,S9-S10.
Species	Species identity. Categories include all 9 species used in the research: <i>Amblyraja radiata</i> , <i>Callionymus lyra</i> , <i>Clupea harangus</i> , <i>Eutrigla gurnardus</i> , <i>Gadus morhua</i> , <i>Limanda limanda</i> , <i>Merlangius merlangus</i> , <i>Pleuronectes platessa</i> , <i>Sprattus sprattus</i> .
Family	Family to which the species belongs. Categories include: Gadidae, Pleuronectidae, Triglidae, Clupeidae, Rajidae, Callionymidae.
Year	The sampling year.
Diff LQL Juvenile	The difference in small juvenile (Lower Quartile Length) biomass between seascapes, as a proxy of recruitment.
Diff UQL Juvenile	The difference in large juvenile (Upper Quartile Length) biomass between seascapes.
Diff LQL Adult	The difference in small adult (Lower Quartile Length) biomass between seascapes.
Diff UQL Adult	The difference in large adult (Upper Quartile Length) biomass between seascapes
Seasonal migration	Presence of seasonal (spawning) migration in the species. Categories include: yes, limited.
Fecundity	The number of eggs spawned, as a proxy of reproductive output.
Age at maturity	Age of maturation as a proxy of the length of the juvenile stage.
Maximum age	The maximum observed age as a proxy of longevity.
Habitat	The preferred habitat. Habitat types include: benthopelagic, demersal, and pelagic.

Feeding mode	Feeding modes include: generalist, benthivorous, and planktivorous.
Body type	Body types include: fusiform, flat, elongated.
Length at maturity	Body size at onset of reproduction.

Feature	Description
Maximum length	Maximum body size.
Label	Description
Causal lag zero	Presence or absence of a causal relationship between seascapes at a time-lag of zero years. Categories include: yes, no.
Causal lag one - two	Presence or absence of a causal relationship between seascapes at a time-lag of one or two years. Categories include: yes, no.



**Fig. S1.** Confusion matrixes for assessing performance of Random Forest Classifier models trained to predict causal dependencies between seascapes at 0 year time lag (top) and 1-2 year time lag (bottom). The y-axis lists the true label of an observation and the x-axis the model prediction for that observation. Box color indicates the number of samples belonging to each category.

**Text S2. Data uncertainty**

The uncertainty in the input data for different species and seascapes (Table S2). Was calculated by computing the mean relative standard error in biomass density per species and seascape over all years (Table S2).

**Table S2 Average uncertainty in biomass density estimates per species and seascape (relative standard error)**

Species	MRSE S1	MRSE S2	MRSE S3	MRSE S4	MRSE S5	MRSE S6	MRSE S7	MRSE S8	MRSE S9	MRSE 10
<i>Amblyraja radiata</i>	32.90	46.80	28.89	35.74	28.96	54.18	45.41	51.04	52.49	31.71
<i>Callionymus lyra</i>	48.17	41.52	55.64	41.75	41.20	45.67	62.67	32.49	48.85	37.84
<i>Clupea harengus</i>	51.81	63.23	41.89	48.86	52.04	40.27	58.39	31.87	59.75	49.72
<i>Eutrigla gurnardus</i>	32.85	54.38	33.32	40.57	38.95	45.24	47.29	34.74	42.89	51.25
<i>Gadus morhua</i>	21.98	32.92	21.18	27.35	27.99	39.00	46.73	26.91	51.44	24.92
<i>Limanda limanda</i>	36.75	62.35	30.04	30.00	28.31	30.64	28.78	19.67	36.37	29.64
<i>Merlangius merlangus</i>	23.65	32.73	23.91	24.88	38.80	32.67	47.54	33.42	53.20	40.64
<i>Pleuronectes platessa</i>	37.03	65.26	32.37	34.96	28.69	30.59	33.80	17.23	32.95	29.33
<i>Sprattus sprattus</i>	63.34	62.42	60.08	50.90	53.70	39.08	61.12	29.32	58.71	34.75