

## Tropicalization of fish assemblages at temperate biogeographic transition zones

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*Marine Ecology Progress Series 504: 241–252 (2014)*

**Supplement.** This supplement includes information on the species and the environmental data used in the present study and information resulting from the best model adopted (see also ‘Materials and methods’ of the main text)

Table S1. Rocky reef fish species (or higher taxonomic levels) and corresponding families observed in the underwater surveys and included in the multivariate regression models. The biogeographic group affinity is indicated: CT = cold-temperate; T = temperate; WT = warm-temperate; Tr = tropical; E = eurythermic

Species	Family	Biogeographic group
<i>Ciliata mustela</i>	Phycidae	CT
<i>Gaidropsarus vulgaris</i>	Phycidae	CT
<i>Pollachius pollachius</i>	Gadidae	CT
<i>Entelurus aequoreus</i>	Syngnathidae	CT
<i>Nerophis lumbriciformis</i>	Syngnathidae	CT
<i>Taurulus bubalis</i>	Cottidae	CT
<i>Centrolabrus exoletus</i>	Labridae	CT
<i>Labrus bergylta</i>	Labridae	CT
<i>Symphodus melops</i>	Labridae	CT
<i>Gobiusculus flavescens</i>	Gobiidae	CT
<i>Zeugopterus punctatus</i>	Scophthalmidae	CT
<i>Zeus faber</i>	Zeidae	E
<i>Trigloporus lastoviza</i>	Triglidae	E
<i>Boops boops</i>	Sparidae	E
<i>Balistes capriscus</i>	Balistidae	E
<i>Conger conger</i>	Congridae	T
<i>Sardina pilchardus</i>	Clupeidae	T
<i>Gaidropsarus mediterraneus</i>	Phycidae	T
<i>Trisopterus luscus</i>	Gadidae	T

<i>Mugilidae n.id.<sup>a</sup></i>	Mugilidae	T
<i>Atherina sp.<sup>a</sup></i>	Atherinidae	T
<i>Belone belone</i>	Belonidae	T
<i>Syngnathus acus</i>	Syngnathidae	T
<i>Syngnathus typhle</i>	Syngnathidae	T
<i>Dicentrarchus labrax</i>	Moronidae	T
<i>Trachurus trachurus</i>	Carangidae	T
<i>Pagellus acarne</i>	Sparidae	T
<i>SpondylIOSoma cantharus</i>	Sparidae	T
<i>Mullus surmuletus</i>	Mullidae	T
<i>Coris julis</i>	Labridae	T
<i>Ctenolabrus rupestris</i>	Labridae	T
<i>Labrus mixtus</i>	Labridae	T
<i>Symphodus bailloni</i>	Labridae	T
<i>Lipophrys pholis</i>	Blenniidae	T
<i>Diplecogaster bimaculata</i>	Gobiesocidae	T
<i>Callionymus sp.<sup>a</sup></i>	Callionymidae	T
<i>Gobius niger</i>	Gobiidae	T
<i>Pomatoschistus sp.<sup>b</sup></i>	Gobiidae	T
<i>Thorogobius ephippiatus</i>	Gobiidae	T
<i>Scomber colias</i>	Scombridae	T
<i>Myliobatis aquila</i>	Myliobatidae	Tr
<i>Halobatrachus didactylus</i>	Batrachoididae	Tr
<i>Serranus cabrilla</i>	Serranidae	Tr
<i>Epinephelus marginatus</i>	Serranidae	Tr
<i>Diplodus puntazzo</i>	Sparidae	Tr
<i>Diplodus sargus</i>	Sparidae	Tr
<i>Oblada melanura</i>	Sparidae	Tr
<i>Pagrus auriga</i>	Sparidae	Tr
<i>Sarpa salpa</i>	Sparidae	Tr
<i>Chromis chromis</i>	Pomacentridae	Tr
<i>Parablennius pilicornis</i>	Blenniidae	Tr
<i>Sphoeroides marmoratus</i>	Tetraodontidae	Tr
<i>Raja undulata</i>	Rajidae	WT
<i>Muraena helena</i>	Muraenidae	WT
<i>Phycis phycis</i>	Phycidae	WT
<i>Hippocampus hippocampus</i>	Syngnathidae	WT
<i>Hippocampus guttulatus</i>	Syngnathidae	WT
<i>Scorpaena notata</i>	Scorpaenidae	WT
<i>Scorpaena porcus</i>	Scorpaenidae	WT
<i>Aspitrigla obscura</i>	Triglidae	WT
<i>Serranus atricauda</i>	Serranidae	WT
<i>Serranus hepatus</i>	Serranidae	WT
<i>Trachurus sp.<sup>a</sup></i>	Carangidae	WT
<i>Diplodus annularis</i>	Sparidae	WT

<i>Diplodus bellottii</i>	Sparidae	WT
<i>Diplodus cervinus</i>	Sparidae	WT
<i>Diplodus vulgaris</i>	Sparidae	WT
<i>Pagellus erythrinus</i>	Sparidae	WT
<i>Pagrus pagrus</i>	Sparidae	WT
<i>Sparus aurata</i>	Sparidae	WT
<i>Spicara maena</i>	Centracanthidae	WT
<i>Symphodus cinereus</i>	Labridae	WT
<i>Symphodus mediterraneus</i>	Labridae	WT
<i>Symphodus ocellatus</i>	Labridae	WT
<i>Symphodus roissali</i>	Labridae	WT
<i>Symphodus rostratus</i>	Labridae	WT
<i>Tripterygion delaisi</i>	Tripterygiidae	WT
<i>Coryphoblennius galerita</i>	Blenniidae	WT
<i>Lipophrys canevae</i>	Blenniidae	WT
<i>Paralipophrys trigloides</i>	Blenniidae	WT
<i>Parablennius gattorugine</i>	Blenniidae	WT
<i>Parablennius incognitus</i>	Blenniidae	WT
<i>Parablennius rouxi</i>	Blenniidae	WT
<i>Parablennius sanguinolentus</i>	Blenniidae	WT
<i>Clinitrachus argentatus</i>	Clinidae	WT
<i>Apletodon dentatus</i>	Gobiesocidae	WT
<i>Lepadogaster candollii</i>	Gobiesocidae	WT
<i>Lepadogaster lepadogaster</i> <sup>c</sup>	Gobiesocidae	WT
<i>Gobius xanthocephalus</i>	Gobiidae	WT
<i>Gobius cobitis</i>	Gobiidae	WT
<i>Gobius cruentatus</i>	Gobiidae	WT
<i>Gobius paganellus</i>	Gobiidae	WT
<i>Gobius gasteveni</i>	Gobiidae	WT
<i>Zeugopterus regius</i>	Scophthalmidae	WT
<i>Pomatomus saltator</i>	Pomatomidae	WT

<sup>a</sup>*Trachurus picturatus* and *T. mediterraneus* were considered *Trachurus* sp. since they were not always distinguished and have the same biogeographic group. Similarly, *Atherina presbyter* and *A. boyeri* were considered *Atherina* sp., species from the family Mugilidae were aggregated to the family level (since the 3 most abundant species are from the same biogeographic group) and finally, *Callionymus lyra* and *C. reticulatus* were identified as *Callionymus* sp.

<sup>b</sup>*Pomatoschistus* sp. is most probably *Pomatoschistus pictus* but it was not possible to distinguish the species at all times

<sup>c</sup>As in Henriques et al. (2007), *Lepadogaster purpurea* was considered as *L. lepadogaster* since they were considered the same species until 2002

Table S2. Environmental predictors used for modelling purposes. Predictors (SST = sea surface temperature; WindStV = northward component of daily wind stress; WindStU = eastward component of daily wind stress; SSH = sea surface height; SWH = significant wave height; Chla = chlorophyll *a*; NAO = North Atlantic Oscillation), data source, temporal range, original resolution (in degrees), final data resolution after bilinear interpolation (in km; NA = not applicable), predictor type (RS = remote sensing; DO = direct observation), units and spatial scale considered. Metrics used are described below the table. Seasonal NAO dummy variables were also tested: 1 when NAO was positive, and 0 when it was negative

Predictors	Source	Temporal range	Original data resolution	Final data resolution	Type	Units	Spatial scale
SST	OSTIA <sup>a</sup> ; Donlon et al. (2011)	1992– 2011	0.05°	~9 km	RS, DO <sup>a</sup>	°C	Local-scale
SST	ICOADS 1°; Woodruff et al. (2011)	1960– 2010	1°	NA	RS	°C	Regional-scale
WindStV	Blended sea surface winds; NOAA; Zhang et al. (2006)	1992– 2011	0.25°	~9 km	RS	N m <sup>-2</sup>	Local-scale
WindStU	Blended sea surface winds; NOAA; Zhang et al. (2006)	1992– 2011	0.25°	~9 km	RS	N m <sup>-2</sup>	Local-scale
WindStV	ICOADS 1°; Woodruff et al. (2011)	1960– 2010	1°	NA	RS	N m <sup>-2</sup>	Regional-scale
SSH	AVISO; Schaeffer et al. (2012)	1992– 2011	0.33°	~9 km	RS	m	Local-scale
SWH	AVISO; Schaeffer et al. (2012)	1992– 2011	0.33°	~9 km	RS	m	Local-scale
Chla	MODIS AQUA; Huot et al. (2005)	1997– 2011	0.05°	~9 km	RS	mg m <sup>-3</sup>	Local-scale
NAO	NOAA: www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml	1960– 2010	North Atlantic region	NA	RS	Index	Large-scale

<sup>a</sup>OSTIA combines remote sensed satellite data provided by the GHRSSST project (<https://www.ghrsst.org>), with *in situ* observations, using a variant of optimal interpolation (OI) described by Martin et al. (2007)

Derived metrics for predictors SST, wind stress (V and U), SSH, SWH and Chla (Winter: DJFMA; Summer: JJAS):

1 = minimum winter; 2 = mean winter; 3 = maximum winter; 4 = minimum summer; 5 = mean summer; 6 = maximum summer; 7 = winter deviation from the monthly mean; 8 = summer deviation from the monthly mean; 9 = number of winter days above long-term monthly mean; 10 = number of summer days above long-term monthly mean; 11 = number of winter days below long-term monthly mean; 12 = number of summer days below long-term monthly mean.

Derived metrics for predictor NAO: 13 = mean winter; 14 = mean summer; 15 = dummy variable mean winter ( $\pm$ ); 16 = dummy variable mean summer ( $\pm$ )

Table S3. Species variance for the best multivariate regression tree of the presence/absence data of the rocky reef fish assemblage. The total species variance is partitioned by species, the whole tree, and the 3 splits of the tree. Selected predictors of the 3 principal splits obtained by the best model selected were the mean winter northward component of wind stress (MeanWint WindStV), the mean winter sea surface height (MeanWint SSH) and minimum winter significant wave height (MinWint SWH)

<b>Species</b>	<b>MeanWint WindStV &lt;-0.004</b>	<b>MeanWint SSH &lt;53.63</b>	<b>MinWint SWH &lt;1.29</b>	<b>Tree total</b>	<b>Species total</b>
<i>Ciliata mustela</i>	0.13	0.07	1.04	1.25	1.90
<i>Gaidropsarus vulgaris</i>	0.07	0.07	0.00	0.14	0.79
<i>Pollachius pollachius</i>	0.59	0.00	0.00	0.59	1.90
<i>Entelurus aequoreus</i>	0.45	0.29	0.46	1.20	2.22
<i>Nerophis lumbriciformis</i>	0.17	1.16	0.46	1.79	2.37
<i>Taurulus bubalis</i>	0.38	0.00	0.46	0.84	1.42
<i>Centrolabrus exoletus</i>	0.00	0.00	0.00	0.00	0.00
<i>Labrus bergylta</i>	0.00	0.00	0.00	0.00	0.00
<i>Symphodus melops</i>	0.00	0.00	0.00	0.00	0.00
<i>Gobiusculus flavescens</i>	0.00	0.00	0.00	0.00	0.00
<i>Zeugopterus punctatus</i>	0.52	0.07	0.26	0.85	2.37
<i>Zeus faber</i>	0.00	0.29	0.26	0.55	1.42
<i>Trigloporus lastoviza</i>	0.02	0.00	1.04	1.07	2.37
<i>Boops boops</i>	0.00	0.00	0.00	0.00	0.00
<i>Balistes capriscus</i>	0.04	0.07	0.12	0.23	1.90
<i>Conger conger</i>	0.01	0.29	0.03	0.33	2.22
<i>Sardina pilchardus</i>	0.21	0.65	0.12	0.98	2.22
<i>Gaidropsarus mediterraneus</i>	0.13	0.07	0.46	0.67	1.90
<i>Trisopterus luscus</i>	0.07	0.29	0.00	0.36	0.79
Mugilidae n.id.	0.00	0.00	0.00	0.00	0.00
<i>Atherina</i> sp.	0.00	0.00	0.00	0.00	0.00
<i>Belone belone</i>	0.45	0.29	0.03	0.76	2.22
<i>Syngnathus acus</i>	0.00	0.00	0.00	0.00	0.00
<i>Syngnathus typhle</i>	0.85	0.00	0.03	0.88	1.90
<i>Dicentrarchus labrax</i>	0.04	0.29	0.12	0.45	1.90
<i>Trachurus trachurus</i>	1.05	0.07	0.00	1.13	2.22
<i>Pagellus acarne</i>	0.01	1.16	0.03	1.20	2.22
<i>Spondylisoma cantharus</i>	0.00	0.00	0.00	0.00	0.00
<i>Mullus surmuletus</i>	0.00	0.00	0.00	0.00	0.00
<i>Coris julis</i>	0.00	0.00	0.00	0.00	0.00
<i>Ctenolabrus rupestris</i>	0.00	0.00	0.00	0.00	0.00
<i>Labrus mixtus</i>	0.00	0.00	0.00	0.00	0.00
<i>Symphodus bailloni</i>	0.00	0.00	0.00	0.00	0.00
<i>Lipophrys pholis</i>	0.00	0.00	0.00	0.00	0.00
<i>Diplecogaster bimaculata</i>	0.04	0.07	0.12	0.23	1.90
<i>Callionymus</i> sp.	0.00	0.00	0.00	0.00	0.00

<i>Gobius niger</i>	0.00	0.00	0.00	0.00	0.00
<i>Pomatoschistus</i> sp.	0.00	0.00	0.00	0.00	0.00
<i>Thorogobius ephippiatus</i>	0.52	0.29	0.26	1.07	2.37
<i>Scomber colias</i>	0.26	0.29	0.00	0.55	1.42
<i>Myliobatis aquila</i>	0.09	0.00	0.12	0.21	0.79
<i>Halobatrachus didactylus</i>	0.01	0.07	0.03	0.11	2.22
<i>Serranus cabrilla</i>	0.00	0.00	0.00	0.00	0.00
<i>Epinephelus marginatus</i>	0.07	0.07	0.00	0.14	0.79
<i>Diplodus puntazzo</i>	1.52	0.00	0.12	1.64	2.22
<i>Diplodus sargus</i>	0.00	0.00	0.00	0.00	0.00
<i>Oblada melanura</i>	1.52	0.00	0.26	1.78	2.22
<i>Pagrus auriga</i>	0.52	1.16	0.26	1.94	2.37
<i>Sarpa salpa</i>	0.00	0.00	0.00	0.00	0.00
<i>Chromis chromis</i>	0.52	1.16	0.12	1.79	2.37
<i>Parablennius pilicornis</i>	0.00	0.00	0.00	0.00	0.00
<i>Sphoeroides marmoratus</i>	0.07	0.07	0.00	0.14	0.79
<i>Raja undulata</i>	0.04	0.07	0.12	0.23	1.90
<i>Muraena helena</i>	0.00	0.07	0.26	0.34	1.42
<i>Phycis phycis</i>	2.37	0.00	0.00	2.37	2.37
<i>Hippocampus hippocampus</i>	0.00	0.07	0.12	0.19	1.42
<i>Hippocampus guttulatus</i>	0.04	1.16	0.12	1.32	1.90
<i>Scorpaena notata</i>	0.00	0.00	0.00	0.00	0.00
<i>Scorpaena porcus</i>	0.00	0.00	0.00	0.00	0.00
<i>Aspitrigla obscura</i>	0.07	0.29	0.00	0.36	0.79
<i>Serranus atricauda</i>	0.52	0.29	0.26	1.07	2.37
<i>Serranus hepatus</i>	1.52	0.00	0.12	1.64	2.22
<i>Trachurus</i> sp.	0.38	0.00	0.46	0.84	1.42
<i>Diplodus annularis</i>	0.21	0.00	0.12	0.33	2.22
<i>Diplodus bellottii</i>	0.26	0.07	0.00	0.34	1.42
<i>Diplodus cervinus</i>	0.00	0.00	0.00	0.00	0.00
<i>Diplodus vulgaris</i>	0.00	0.00	0.00	0.00	0.00
<i>Pagellus erythrinus</i>	0.07	0.07	0.00	0.14	0.79
<i>Pagrus pagrus</i>	0.00	0.29	0.26	0.55	1.42
<i>Sparus aurata</i>	0.21	0.65	0.26	1.13	2.22
<i>Spicara maena</i>	0.07	0.07	0.00	0.14	0.79
<i>Symphodus cinereus</i>	0.00	0.00	0.00	0.00	0.00
<i>Symphodus mediterraneus</i>	0.02	0.65	1.04	1.72	2.37
<i>Symphodus ocellatus</i>	0.09	0.00	0.12	0.21	0.79
<i>Symphodus roissali</i>	0.00	0.00	0.00	0.00	0.00
<i>Symphodus rostratus</i>	0.38	0.00	0.03	0.41	1.42
<i>Tripterygion delaisi</i>	0.00	0.00	0.00	0.00	0.00
<i>Coryphoblennius galerita</i>	0.00	0.00	0.00	0.00	0.00
<i>Lipophrys canevae</i>	0.00	0.00	0.00	0.00	0.00
<i>Paralipophrys trigloides</i>	0.00	0.00	0.00	0.00	0.00
<i>Parablennius gattorugine</i>	0.00	0.00	0.00	0.00	0.00

<i>Parablennius incognitus</i>	0.13	0.29	1.04	1.46	1.90
<i>Parablennius rouxi</i>	0.04	0.29	0.12	0.45	1.90
<i>Parablennius sanguinolentus</i>	0.26	0.07	0.00	0.34	1.42
<i>Clinitrachus argentatus</i>	0.07	0.29	0.00	0.36	0.79
<i>Apletodon dentatus</i>	0.85	0.00	1.04	1.90	1.90
<i>Lepadogaster candollii</i>	0.07	0.07	0.00	0.14	0.79
<i>Lepadogaster lepadogaster</i>	0.00	0.00	0.00	0.00	0.00
<i>Gobius xanthocephalus</i>	0.00	0.00	0.00	0.00	0.00
<i>Gobius cobitis</i>	0.00	0.07	0.12	0.19	1.42
<i>Gobius cruentatus</i>	0.00	0.00	0.00	0.00	0.00
<i>Gobius paganellus</i>	0.00	0.00	0.00	0.00	0.00
<i>Gobius gasteveni</i>	0.21	0.00	0.26	0.47	2.22
<i>Zeugopterus regius</i>	0.13	0.07	0.46	0.67	1.90
<i>Pomatomus saltator</i>	0.07	0.07	0.00	0.14	0.79
<b>Total species variance</b>	<b>18.43</b>	<b>13.34</b>	<b>12.53</b>	<b>44.30</b>	<b>100.00</b>

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