Wood SN (2006) Generalized Additive Models. An Introduction with R. Chapman & Hall, London

Zar JH (1985) Biostatistical Analysis. Prentice-Hall, London. 718 pp.

Zervakis V, Georgopoulos D (2002) Hydrology and circulation in the Northern Aegean Sea throughout 1997 and 1998. Medit Mar Sci 3:5–19

Zwolinski JP, Oliveira PB, Quintino V, Stratoudakis Y (2010) Sardine potential habitat and environmental forcing off western Portugal. ICES J Mar Sci 67: doi:10.1093/icesjms/fsq068

Table 1. Environmental satellite parameters and their characteristics.

PARAMETER	ABBREVIATION	SENSOR/MODEL	RESOLUTION	SOURCE
Sea Surface Chlorophyll-a	CHLO	MODISA	4 km	oceancolor.gsfc.nasa.gov
Sea Surface Temperature	SST	AVHRR	1.5km	eoweb.dlr.de:8080
Photosynthetically Active Radiation	PAR	SeaWiFS	9 km	oceancolor.gsfc.nasa.gov
Sea Level Anomaly	SLA	Merged Jason-1, Envisat, ERS-2, GFO, T/P	0.25° (interpolated to 1.5km using ArcInfo's topogrid)	www.jason.oceanobs.com
Sea Surface Salinity	SSS	NOAA NCEP EMC CMB GODAS model	0.5° (interpolated to 1.5km using ArcInfo's topogrid)	iridl.ldeo.columbia.edu

Table 2. GAM model results for adults and eggs: analysis of deviance for GAM covariates and their interactions of the final models fitted.

Parameter	Res. Df	Res. Deviance	Deviance explained %	AIC	P-value
Pooled Sicily Channel and N. Aegean Sea model (June)					
Null model	3496.00	4265.41		4267.41	
s(SST)	3492.10	3854.00	9.65%	3863.81	<<0.000
s(SST)+s(SLA)	3488.38	3675.45	13.8%	3692.69	<<0.000
s(SST)+s(SLA)+s(Depth)	3540.74	3515.56	17.6%	3484.41	<<0.000
s(SST)+s(SLA)+s(Depth)+s(CHLA)	3374.02	3341.17	21.7%	3480.57	<<0.000
s(SLA, CHLA)+s(SST)+s(Depth)	3461.42	2923.80	31.5%	2994.96	<<0.000
Total variation % explained			31.5%		
Adriatic Sea model (September)					
Null model	8286.00	8399.57		8401.57	
s(Depth)	8623.05	7287.97	13.2%	7289.87	<<0.000
s(Depth)+s(CHLA)	8259.24	6987.14	16.7%	7004.65	<<0.000
s(Depth)+s(SLA)+s(CHLA)	8255.63	6733.51	19.8%	6758.24	<<0.000
s(Depth)+s(SLA)+ s(SST)+s(CHLA)	8252.26	6647.02	20.8%	5951.47	<<0.000
s(Depth)+s(SST)+s(SLA,CHLA)	8230.23	5875.94	30.0%	5636.05	<<0.000
s(Depth,SST)+s(SLA,CHLA)	8209.94	5730.90	31.7%	5847.03	<<0.000
Total variation % explained			31.7%		
Spanish waters (December)					
Null model	5000.00	6926.87		6928.87	
s(Depth)	4979.64	5710.87	17.3%	5727.60	<<0.000
s(Depth)+s(CHLA)	4940.95	5444.28	20.7%	5478.39	<<0.000
s(Depth)+s(CHLA)+s(SLA)	4854.73	4963.30	26.6%	5013.83	<<0.000
s(Depth)+s(CHLA)+s(SLA)+s(SST)	4764.91	4712.16	29.1%	4780.33	<<0.000
s(Depth)+s(CHLA)+s(SLA, SST)	4766.67	4624.58	30.5%	4689.24	<<0.000
Total variation % explained			30.5%		
Spanish waters Sardine eggs' (December)					
Null model	834.00	1041.99			
s(SST)	770.71	793.11	17.5%	811.70	<<0.000
s(SST)+s(CHLA)	765.39	694.84	27.7%	724.06	<<0.000
s(SST)+s(CHLA)+s(SLA)	742.75	607.74	35.5%	644.25	<<0.000
s(SST)+s(CHLA)+s(SLA)+s(Depth)	740.13	574.37	39.1%	616.12	<<0.000
s(CHLA, SST)+s(SLA)+s(Depth)	729.13	537.56	43.0%	601.30	<<0.000
Total variation % explained			43.0%		

Table 3. Validation parameters for sardine adults' GAM models: estimated area under the Receiver Operating Curve (AUC), N=number of records per area and year. Bold indicates data from areas/or years not included in the model selection.

Model	**Year**	**Area**	**N**	**AUC**
June	2004	N. Aegean Sea	510	0.78
	2005	N. Aegean Sea	555	0.73
	2006	N. Aegean Sea	1044	0.73
	2008	N. Aegean Sea	358	0.76
	2003	**Sicily Channel**	**478**	**0.62**
	2005	Sicily Channel	514	0.78
	2006	Sicily Channel	516	0.78
September	**2004**	**West Adriatic**	**1005**	**0.82**
	2004	**East Adriatic**	**865**	**0.76**
	2005	**West Adriatic**	**1439**	**0.82**
	2006	West Adriatic	1425	0.94
	2006	East Adriatic	1094	0.85
	2007	West Adriatic	1399	0.87
	2007	East Adriatic	1088	0.89
	2008	West Adriatic	634	0.81
	2008	East Adriatic	1069	0.90
	2006	South-West Adriatic	404	0.83
	2007	South-West Adriatic	510	0.84
December	2003	N. & S. Spanish Mediterranean	1264	0.77
	2004	N. & S. Spanish Mediterranean	1090	0.81
	2005	N. & S. Spanish Mediterranean	1090	0.85
	2006	N. & S. Spanish Mediterranean	952	0.88
	2007	N. Spanish Mediterranean	669	0.87
	2008	N. & S. Spanish Mediterranean	998	0.77
December eggs	2006	N. & S. Spanish Mediterranean	281	0.82
	2007	N. Spanish Mediterranean	186	0.83
	2008	N. & S. Spanish Mediterranean	294	0.93

Table 4. Results of the analysis of variance of the suitable habitat area (A025, A050, A075) per study region. Significant differences are indicated in bold.

Study area	Suitable habitat area	Source	Sum of Squares	Df	Mean Square	F-ratio	p-value
Aegean Sea	A025	Month	69892.9	2	34946.5	3.62	0.076
		Year	16542.4	4	4135.6	0.43	0.785
		Residual	77178.4	8	9647.3		
	A050	**Month**	**772007**	**2**	**386003**	**10.81**	**0.005**
		Year	82483.1	4	20620.8	0.58	0.687
		Residual	285591	8	35698.8		
	A075	Month	96834.1	2	48417.1	1.55	0.269
		Year	63193.7	4	15798.4	0.51	0.733
		Residual	249372	8	31171.5		
Sicily Channel	A025	Month	34476.1	2	17238.1	1.38	0.304
		Year	24130.3	4	6032.57	0.48	0.747
		Residual	99600.5	8	12450.1		
	A050	Month	245636	2	122818	1.73	0.237
		Year	121782	4	30445.4	0.43	0.784
		Residual	567305	8	70913.1		
	A075	Month	20990.8	2	10495.4	1.89	0.213
		Year	9545.07	4	2386.27	0.43	0.784
		Residual	44404.5	8	5550.57		
Adriatic Sea	A025	Month	539593	2	269796	2.09	0.194
		Year	536375	4	134094	1.04	0.450
		Residual	902175	7	128882		
	A050	**Month**	**5048020**	**2**	**2.52E+06**	**4.85**	**0.048**
		Year	2199770	4	549943	1.06	0.443
		Residual	3640550	7	520079		
	A075	Month	967265	2	483633	1.75	0.242
		Year	1517520	4	379380	1.37	0.335
		Residual	1936660	7	276666		
Spanish Medit. waters	A025	Month	17353.7	2	8676.87	0.25	0.786
		Year	64679.7	4	16169.9	0.46	0.761
		Residual	279194	8	34899.3		
	A050	**Month**	**1947730**	**2**	**973864**	**9.84**	**0.007**
		Year	78033.7	4	19508.4	0.20	0.933
		Residual	792101	8	99012.6		
	A075	**Month**	**769491**	**2**	**384745**	**11.52**	**0.004**
		Year	138595	4	34648.8	1.04	0.445
		Residual	267213	8	33401.6		

Table 5. Results of analysis of the Tukey multiple range test for the suitable habitat area (A025, A050, A075) concerning the monthly differences per study region. * Denotes statistical significant difference.

Study area	Suitable habitat area	Contrast in Months	Difference from the mean	Limits
Aegean Sea	A025	June-September	-82.6	149.525
		June-December	***-167.2**	**149.525**
		September-December	-84.6	149.525
	A050	June-September	-231.0	296.321
		June-December	***-553.2**	**296.321**
		September-December	***-322.2**	**296.321**
	A075	June-September	-96.8	273.065
		June-December	-196.8	273.065
		September-December	-100.0	273.065
Sicily Channel	A025	June-September	52.2	171.804
		June-December	-65.0	171.804
		September-December	-117.2	171.804
	A050	June-September	203.6	405.445
		June-December	-104.6	405.445
		September-December	-308.2	405.445
	A075	June-September	74.0	113.446
		June-December	-9.8	113.446
		September-December	-83.8	113.446
Adriatic Sea	A025	June-September	-457.2	618.972
		June-December	-330.5	656.519
		September-December	126.7	656.519
	A050	June-September	-980.2	1247.17
		June-December	***-1564.25**	**1322.83**
		September-December	-584.05	1322.83
	A075	June-September	-301.8	959.139
		June-December	-719.25	1017.32
		September-December	-417.45	1017.32
Spanish Medit. waters	A025	June-September	81.8	286.414
		June-December	54.6	286.414
		September-December	-27.2	286.414
	A050	June-September	209.8	455.605
		June-December	***-637.6**	**455.605**
		September-December	***-847.4**	**455.605**
	A075	June-September	84.2	311.14
		June-December	***-432.8**	**311.14**
		September-December	***-517.0**	**311.14**

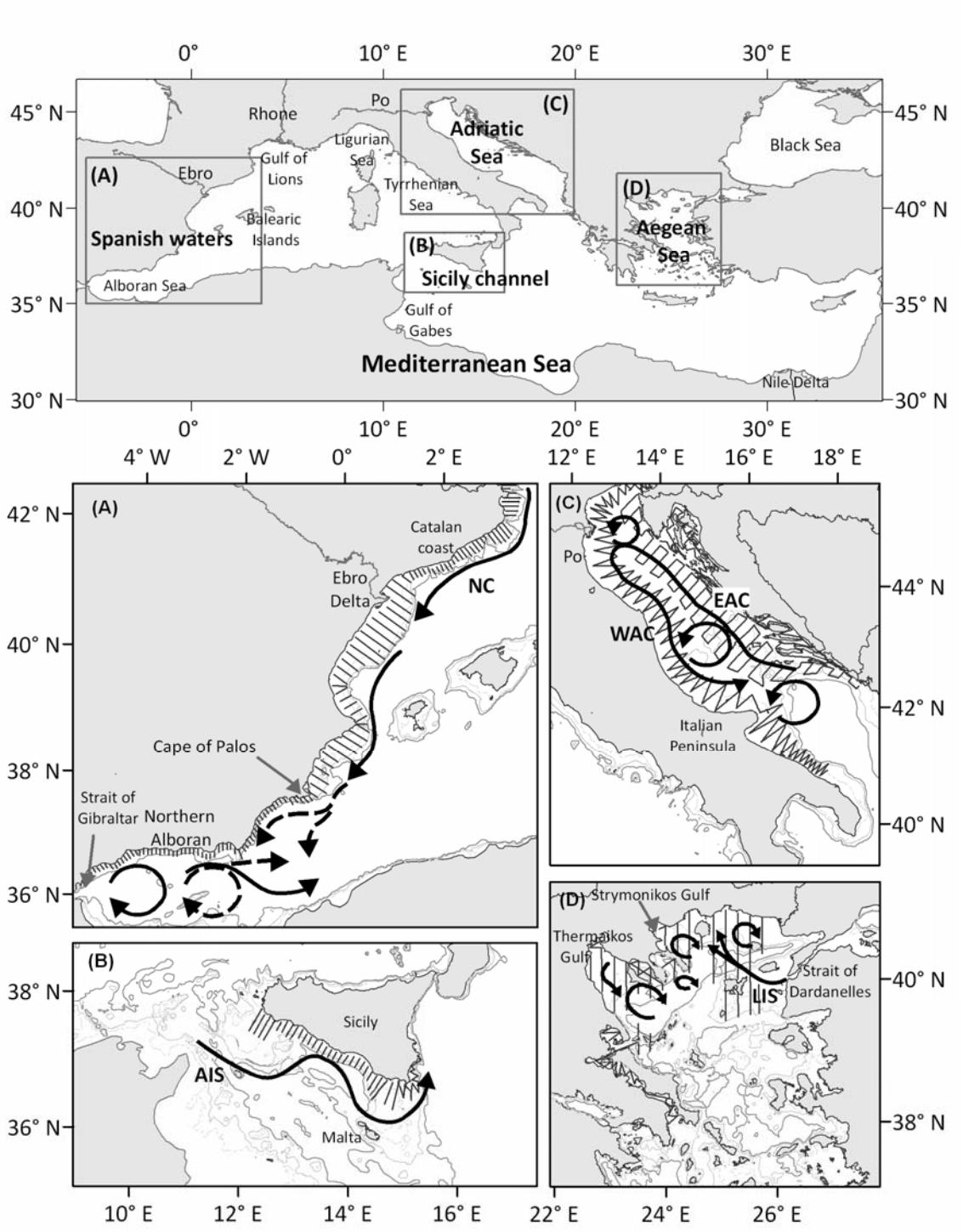

Fig. 1. Map of the study areas where also transects of acoustic sampling are shown. Water circulation is also shown. Arrows indicate the presence of fronts and gyres (redrawn from Millot 1990, Somarakis *et al.*, 2002, Artegianni 1997, Patti *et al.*, 2004). LIS: Limnos–Imvros Stream, NC; Northern Current, AIS: Atlantic Ionian Current, WAC: West Adriatic Current, EAC: East Adriatic Current. Positions of the main rivers in the area are also shown. Bathymetry is also indicated. Toponyms mentioned in the text are also indicated.

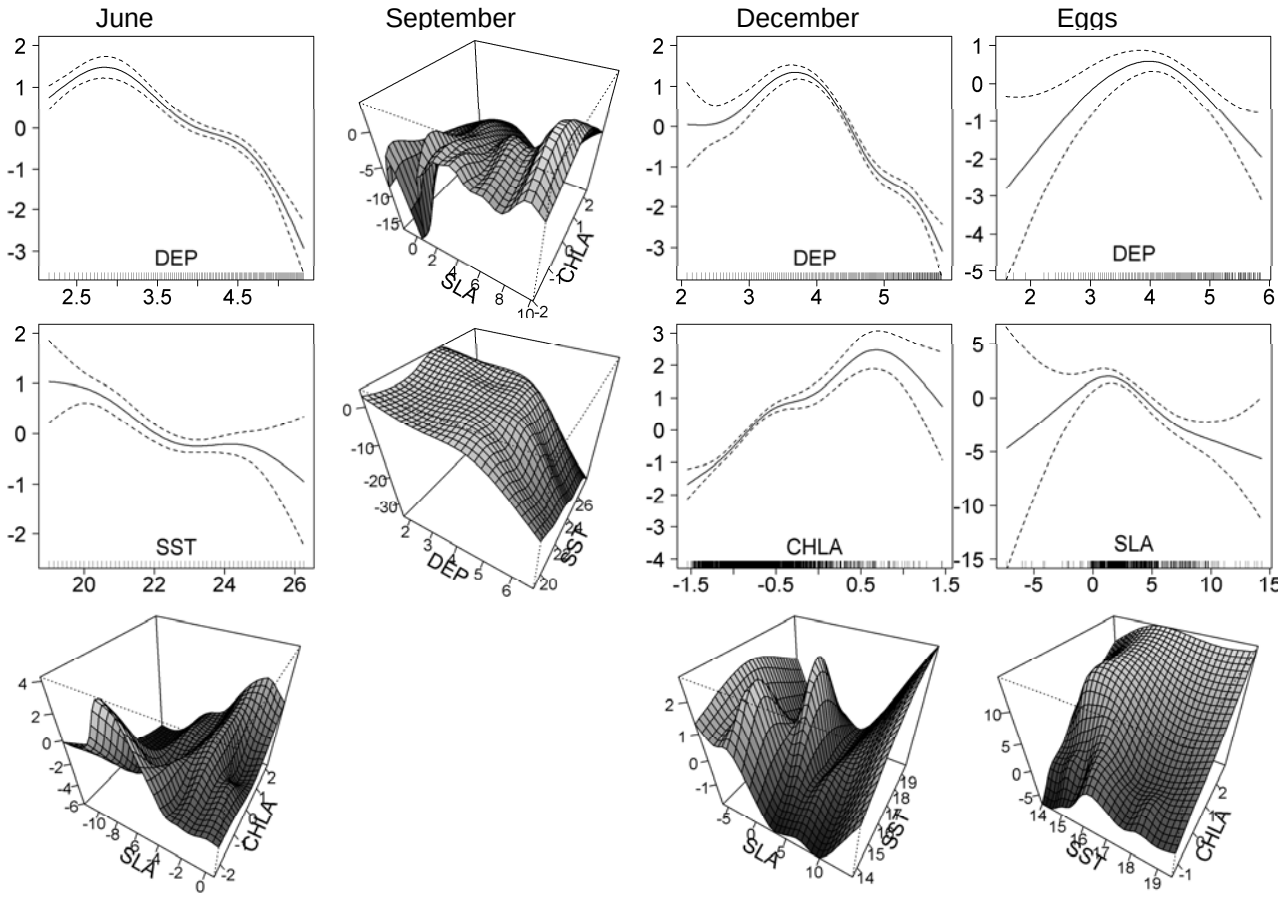

Fig. 2. Coefficients of the Generalized Additive Models (GAMs) for each model. The interaction plots are also shown. Black thick lines indicate the value of GAMs coefficient, dotted lines represent the confidence intervals at p = 0.05.

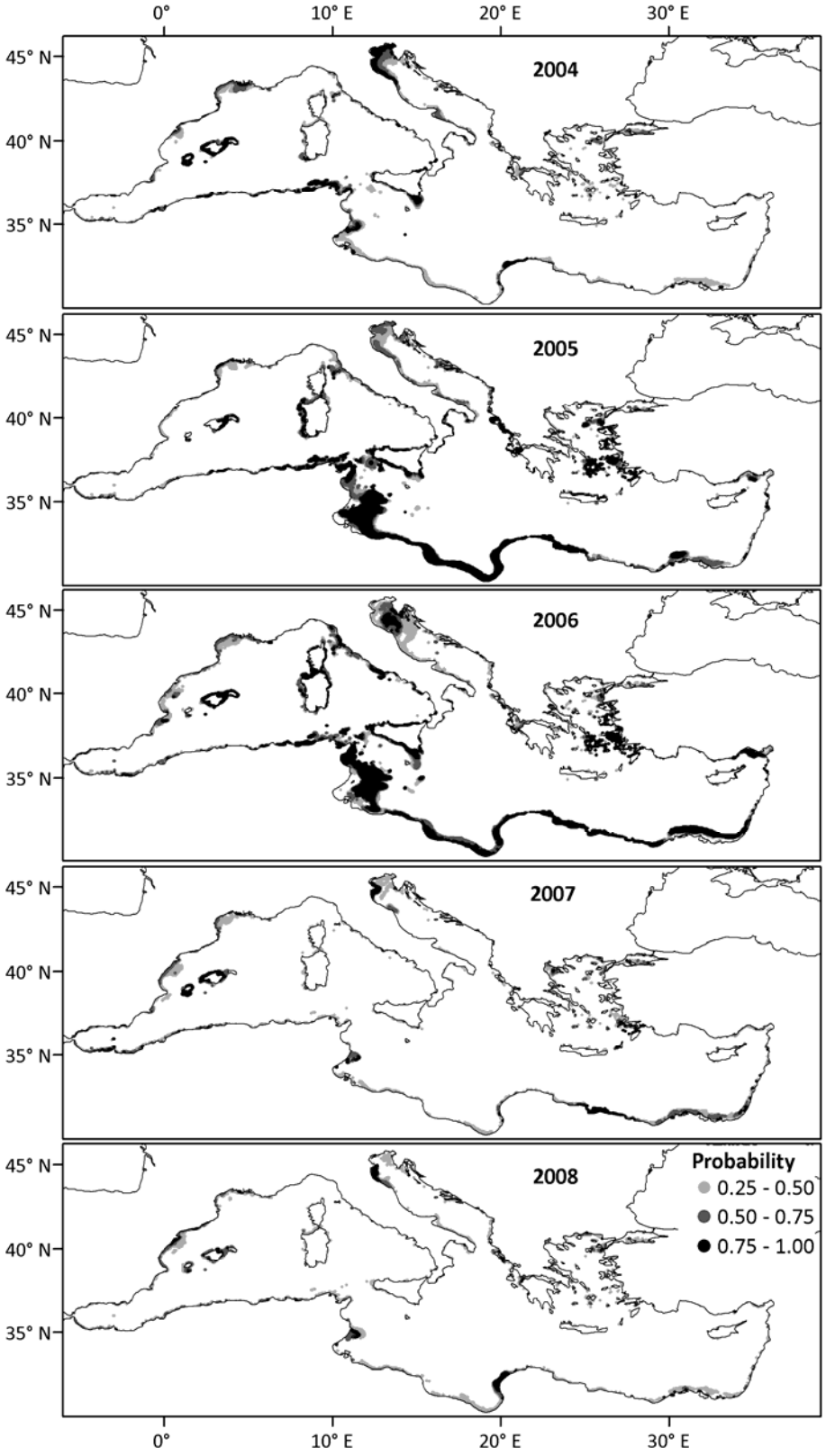

Fig 3. Habitat suitability maps indicating the probability of sardine presence in the Mediterranean Sea based on the selected GAM model in June. Spatial resolution used for prediction was 4 km of mean monthly satellite values from June 2004 to 2008. The scale indicates probability ranges

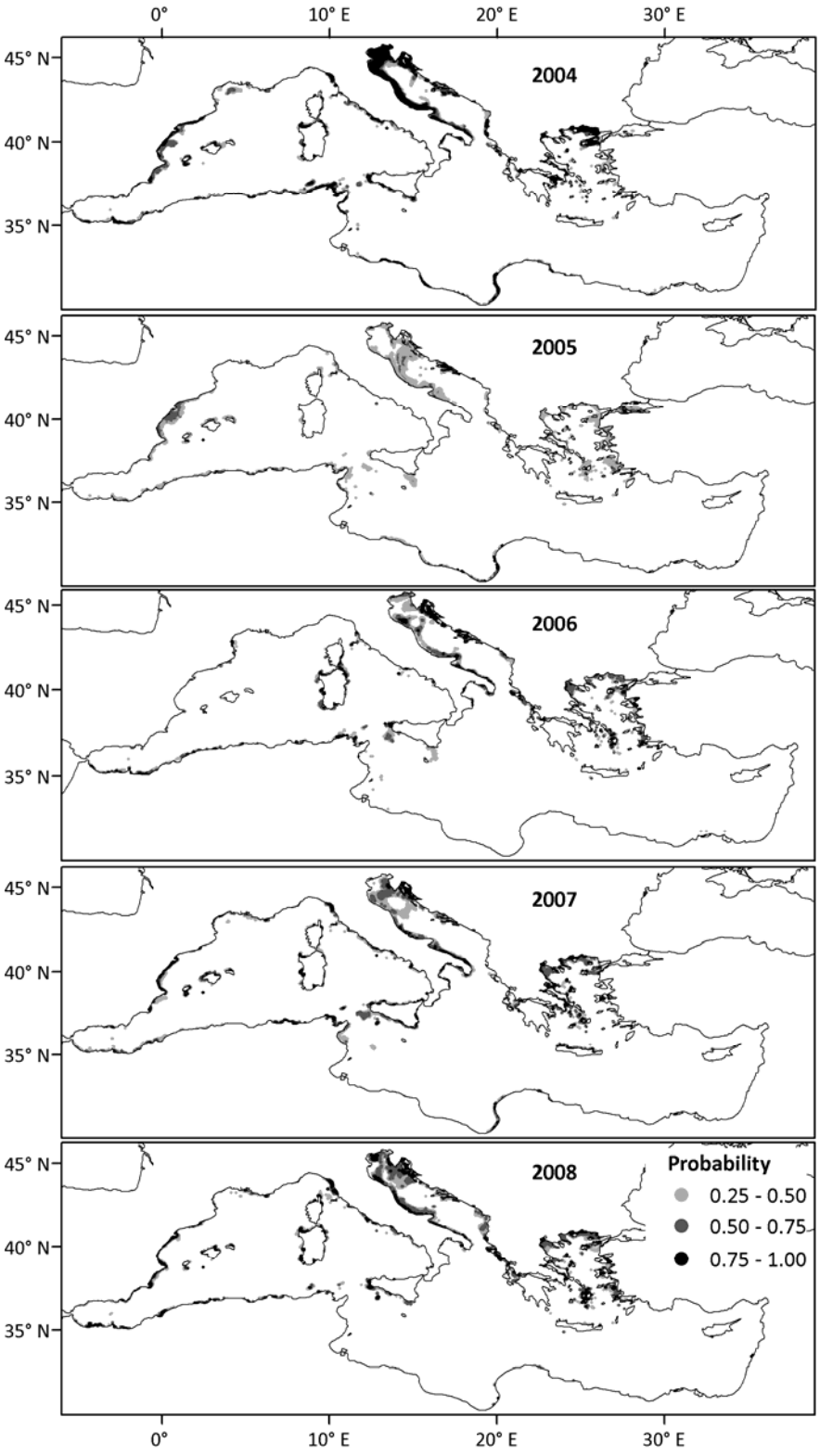

Fig 4. Habitat suitability maps indicating the probability of sardine presence in the Mediterranean Sea based on the selected GAM model in September. Spatial resolution used for prediction was 4 km of mean monthly satellite values from September 2004 to 2008. The scale indicates probability ranges.

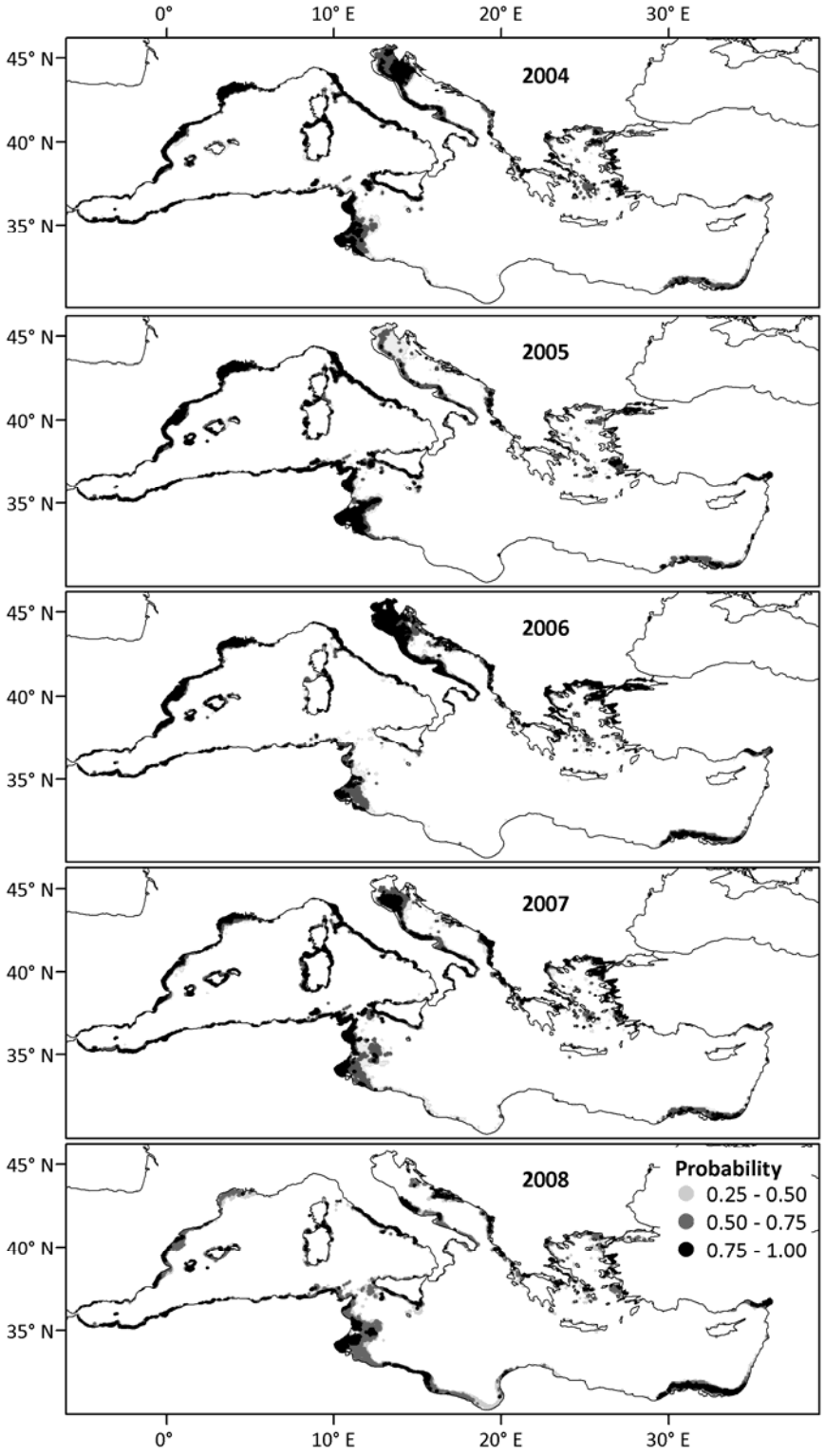

Fig 5. Habitat suitability maps indicating the probability of sardine presence in the Mediterranean Sea based on the selected GAM model in December. Spatial resolution used for prediction was 4 km of mean monthly satellite values from December 2004 to 2008. The scale indicates probability ranges.

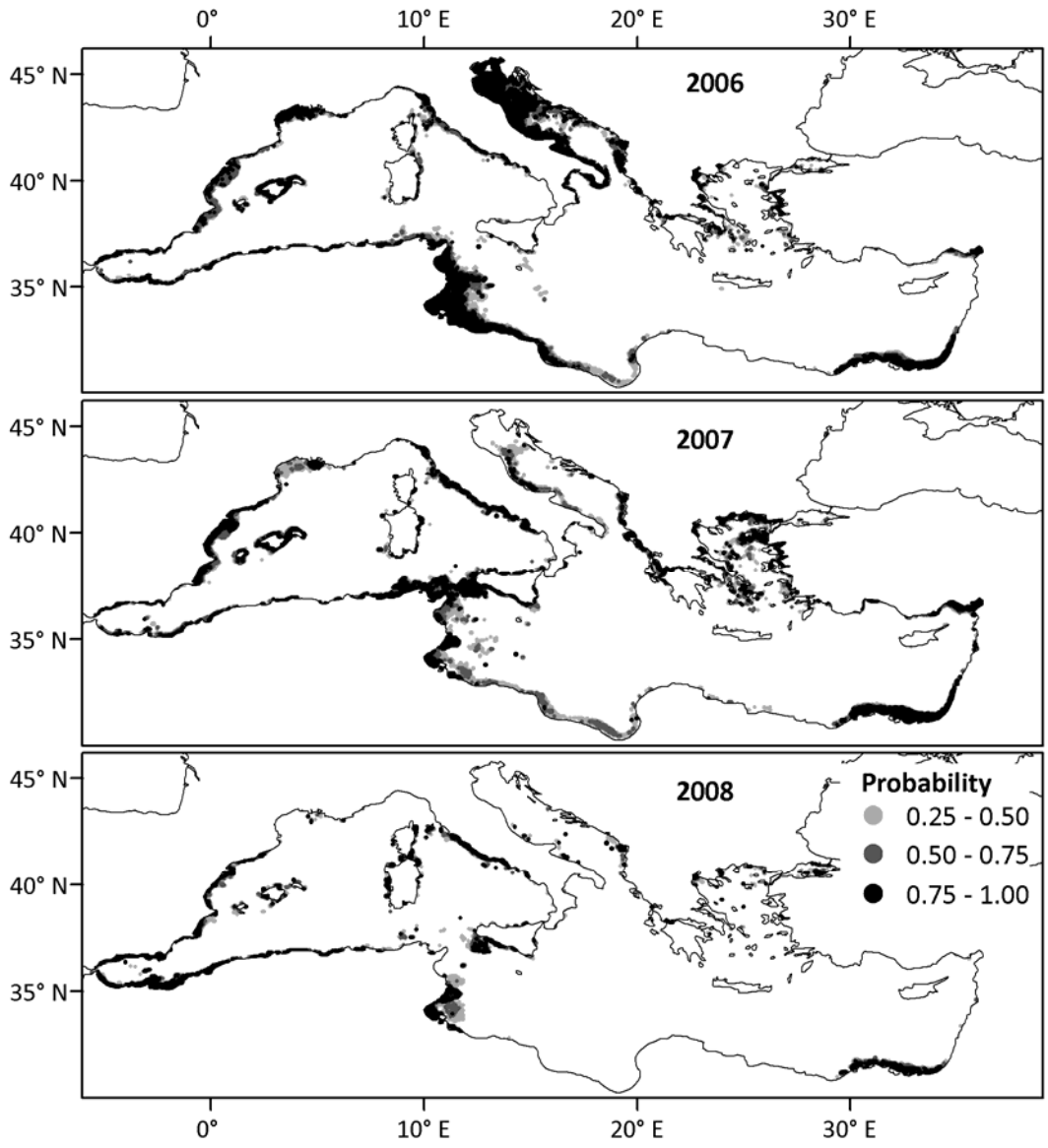

Fig. 6. Habitat suitability maps indicating the probability of sardine eggs' presence in the Mediterranean Sea based on the selected GAM model in December. Spatial resolution used for prediction was 4 km of mean monthly satellite values from December 2006 to 2008. The scale indicates probability ranges.

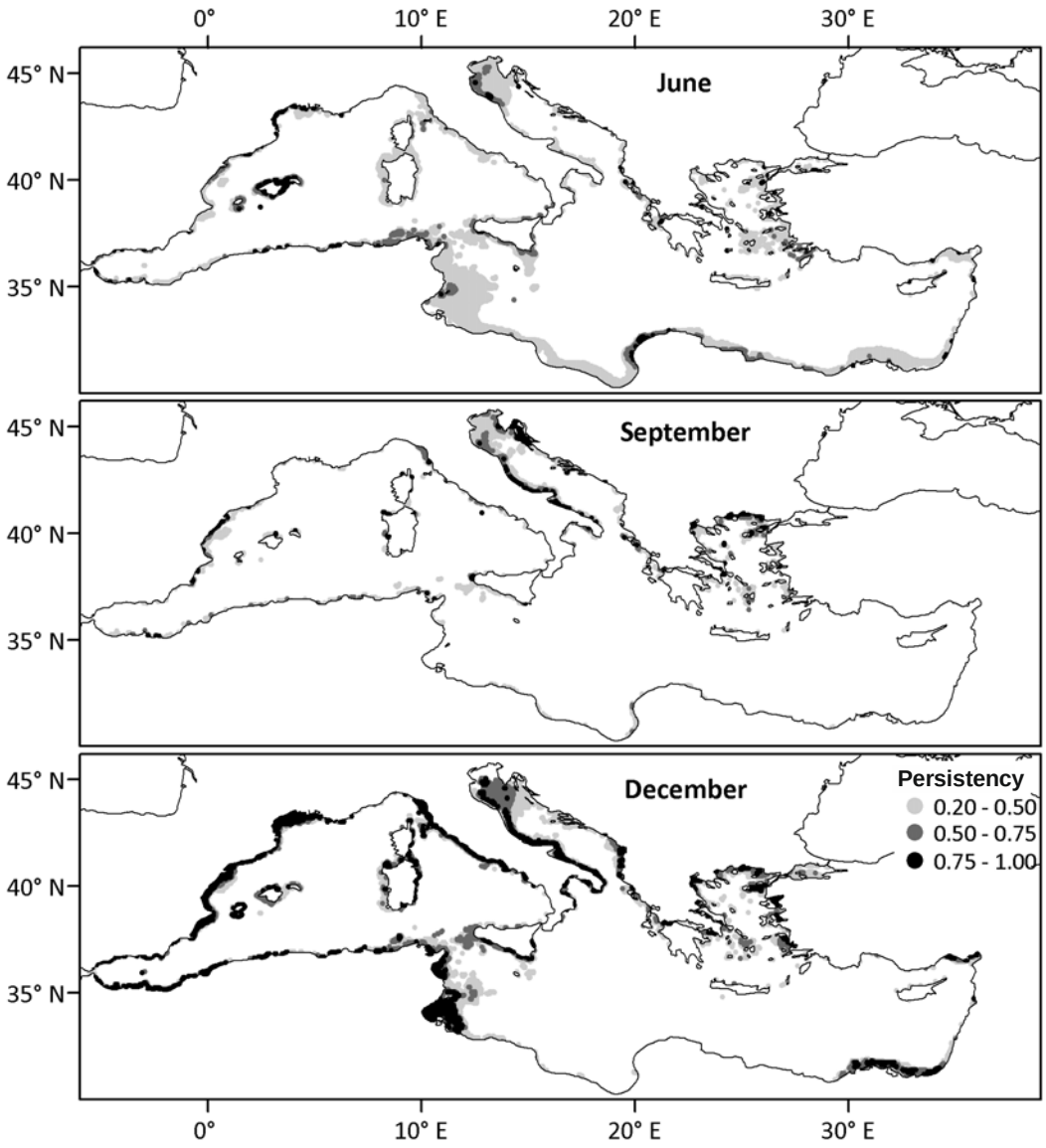

Fig 7. Potential habitat persistency maps for sardine in the Mediterranean Sea during June, September and December. Areas with low (PI: 0.20 to 0.50), medium (PI: 0.50 to 0.75) and high persistency (PI: >0.75) are shown in all cases.