Mediterranean demersal resources and ecosystems:
25 years of MEDITS trawl surveys
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Size-dependent survival of European hake juveniles in the Mediterranean Sea

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Supplementary material

MATERIAL AND METHODS SUPPLEMENTARY TEXT

Estimation of fishing pressure index based on multi-criteria decision analysis

Given that primary data on fishing vessel locations were not available for all spatial and temporal scales, a methodological approach based on GIS-based multi-criteria decision analysis (GIS-MCDA) was used to estimate a fishing pressure index (FPI) for bottom trawl in the Mediterranean Sea. For the current work average FPI values per GSA for the years 1994, 2004 and 2014 were used.

This method produces a fisheries footprint by taking into consideration several interactions with other anthropogenic or environmental factors. The methodology is further described in Kavadas et al. (2015) and is considered as a modified work based on data from 1994 to 2014. The method is applied to three categories of vessel length: a) 0-12 m, b) 12-24 m and c) 24-40 m.

The analytic hierarchy process (AHP) and fuzzy logic were applied in an effort to estimate the FPI which was perceived as the fuzzy product of two indices: the fishery suitability index (Sc) and the activity index (Ac) based on the spatial distribution of registered fishing vessels in the Mediterranean Sea:

$FPI = Sc \times Ac$

To this end, we identified the most influential components and criteria affecting bottom trawlers. Each criterion was assigned a rank of order of importance by expert judgement. The final rankings used for all criteria under study are presented in Table A1. The criteria were the following:

Bathymetry (source: EMODNET).

Distance from coastline (estimated by ARCGIS proximity tool “near”. ESRI, 2011).

Annual chlorophyll *a* concentration (average for the period 2002-2014; source http://oceancolor.gsfc. nasa.gov/ cms/).

Fisheries restricted areas (legislation; source MEDISHEH).

No-take zones: based on depth and annual restrictions.

Sc estimation from the investigated criteria was carried out as follows: (i) creation of spatial information and calibration of each criterion according to a scale of evaluation and formation of the hierarchical structure of the multiple criteria problem; (ii) implementation of the AHP to estimate the relative importance of the evaluation criteria; (iii) application of the weighted linear combination method using the weights (priority vectors) to estimate the suitability index; (iv) standardization on a scale from 0 to 1 with linear fuzzy membership.

The Ac for each fishing category and length segmentation by registration port (VAIp) was based on vessel length and gross tonnage for the years 1994, 2004 and 2014. The methodology used to estimate Ac consisted of the following steps: (i) implementation of the optimal interpolation method on VAIp to estimate values at a spatial cell level (VAIc); and (ii) implementation of the optimal fuzzy membership in VAIc to represent numerically the degree to which a given measure of criteria within a grid cell belongs to a fuzzy set. The study area was gridded with a spatial resolution of 0.01×0.01 decimal degrees. Each of these cells was assigned the corresponding values for each of the MCDA-modelled criteria.

Table S1. – Ranking of the criteria taken into account in MCDA per length overall (LOA) segmentation. The higher the grade, the more favourable the area is for trawl fishing activities. The model includes the following no-take zones: a) banned areas (annually), b) depth >500 m, for LOA 0-12 m, and c) depth >800 m for LOA >12 m.

Bathymetry (m)	Grade		
	LOA 0-12	LOA 12-24	LOA 24-40
0-50	3	3	3
50-100	5	5	5
100-200	4	5	5
200-500	1	4	4
500-800	0	1	2

Chlorophyll *a* (mg m^{-3})	Grade All classes of LOA
>1	1
0.73-1	4
0.46-0.73	5
0.23-0.46	4
0.1-0.23	2

Distance from coastline (nautical miles)	Grade		
	LOA 0-12	LOA 12-24	LOA 24-40
1.5	0	0	0
1.5-3	5	5	5
3-6	5	5	5
6-12	4	5	5
>12	3	4	5

Legislation (total months of banning)	Grade All classes of LOA
available areas	5
ban <2	4
ban 2-6	3
ban 6-11	2
ban 12	0

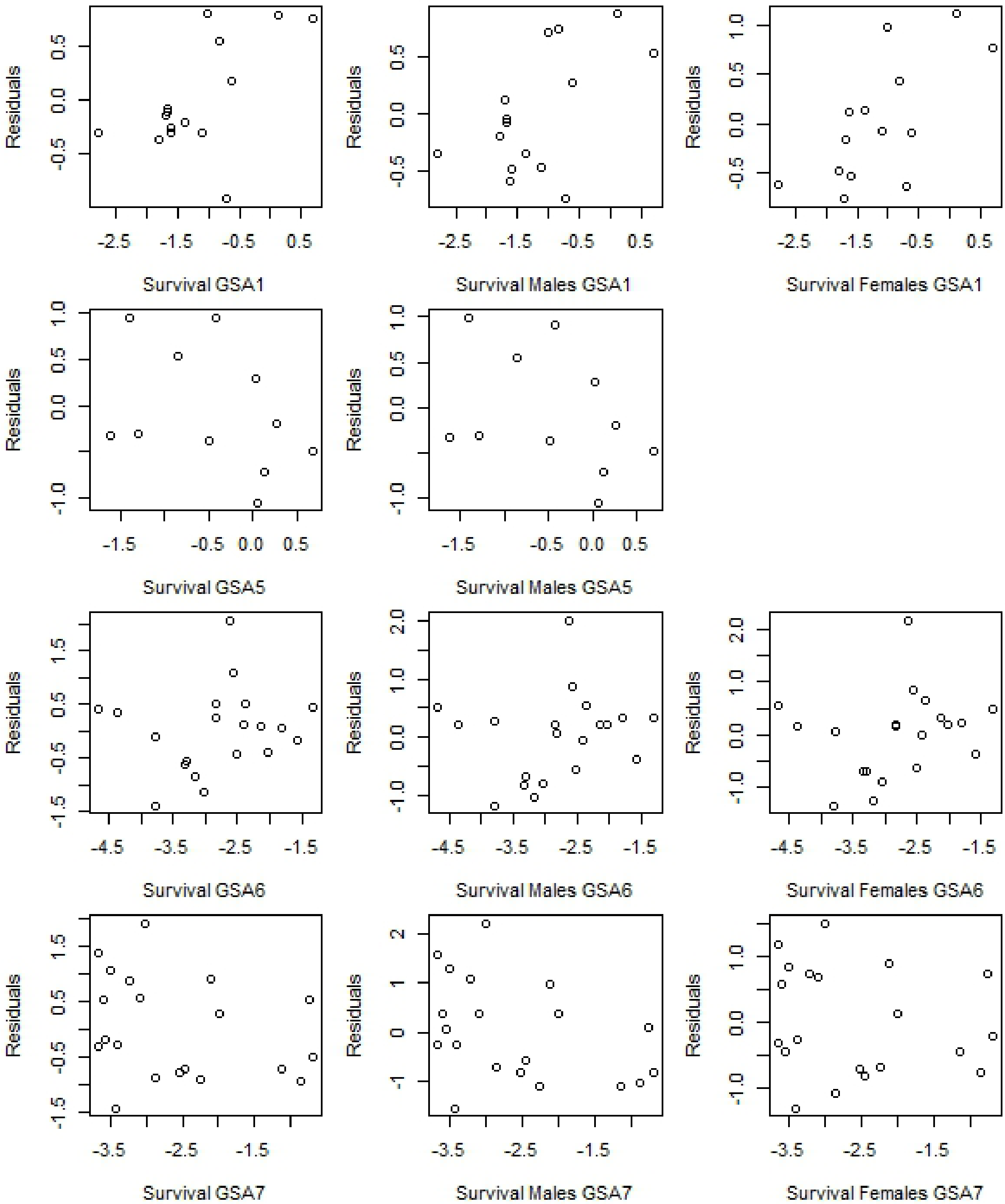


Fig. S1. – Model residuals against response variable for the best linear model obtained for each GSA (Table 1) for all individuals (left), males (centre) and females (right). Here, models for GSA-1, GSA-5, GSA-6 and GSA-7 are shown,

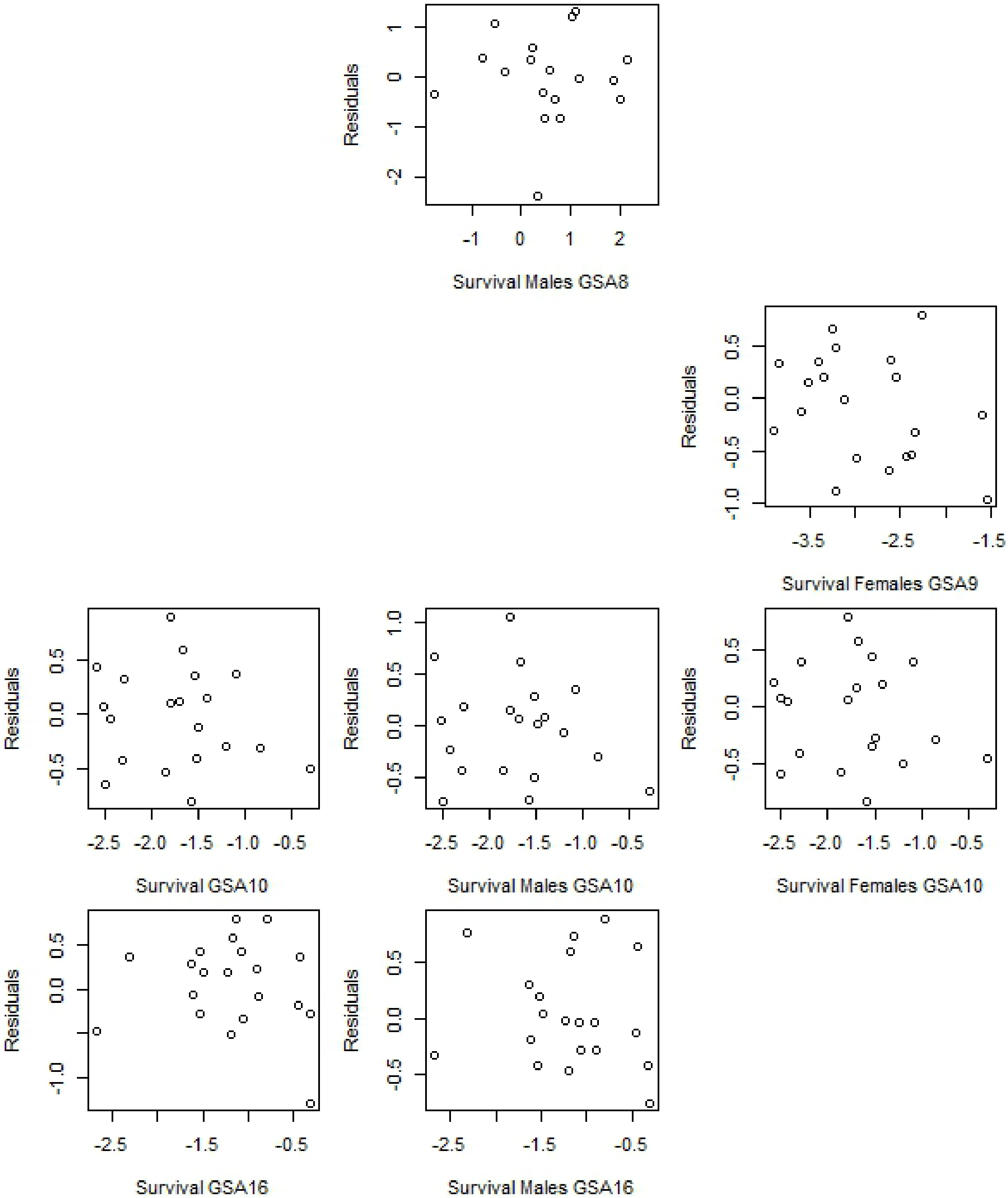
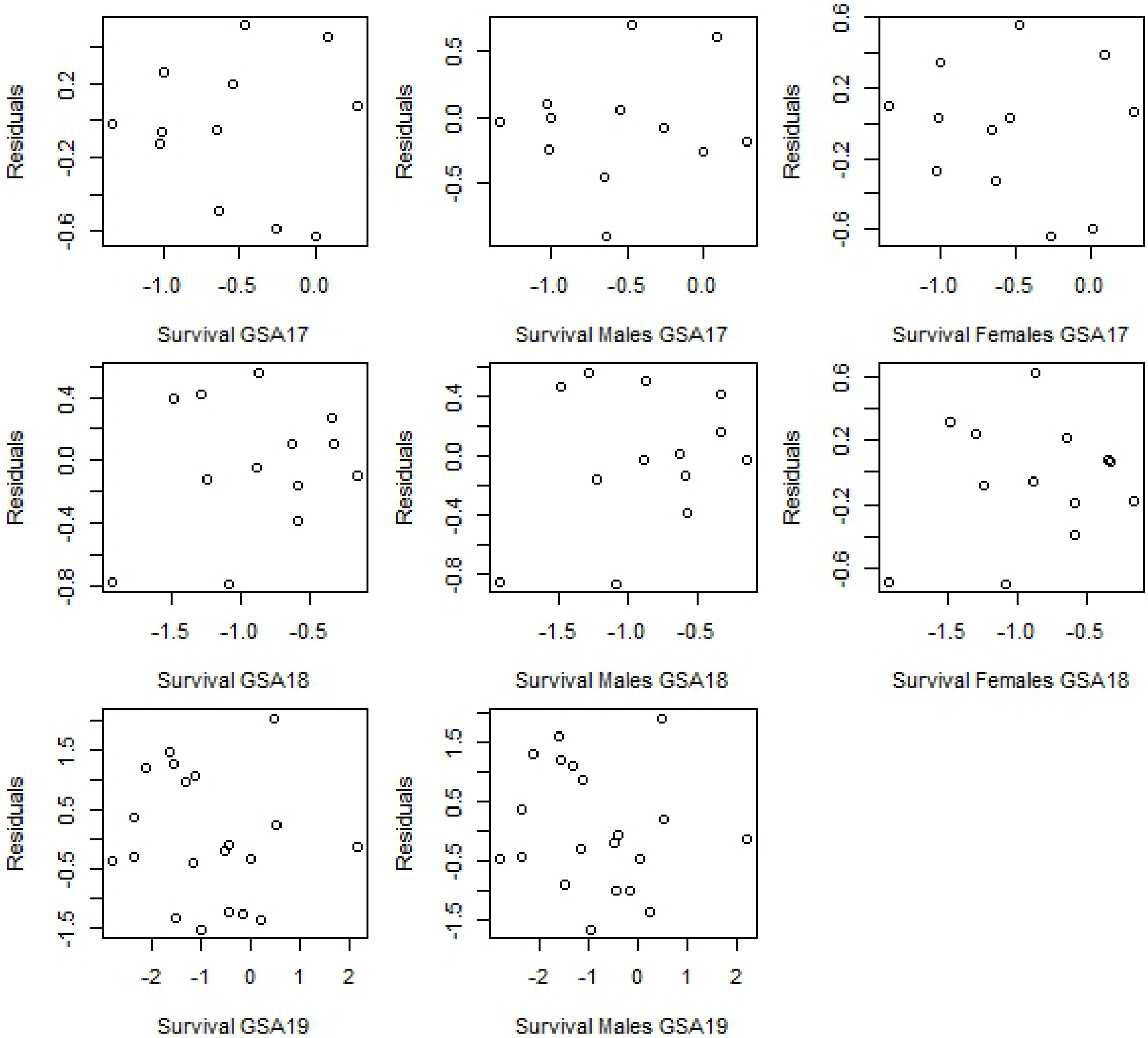


Fig. S1 (Cont.). – Model residuals against response variable for the best linear model obtained for each GSA (Table 1) for all individuals (left), males (centre) and females (right). Here, models for GSA-1, GSA-5, GSA-6 and GSA-7 are shown,



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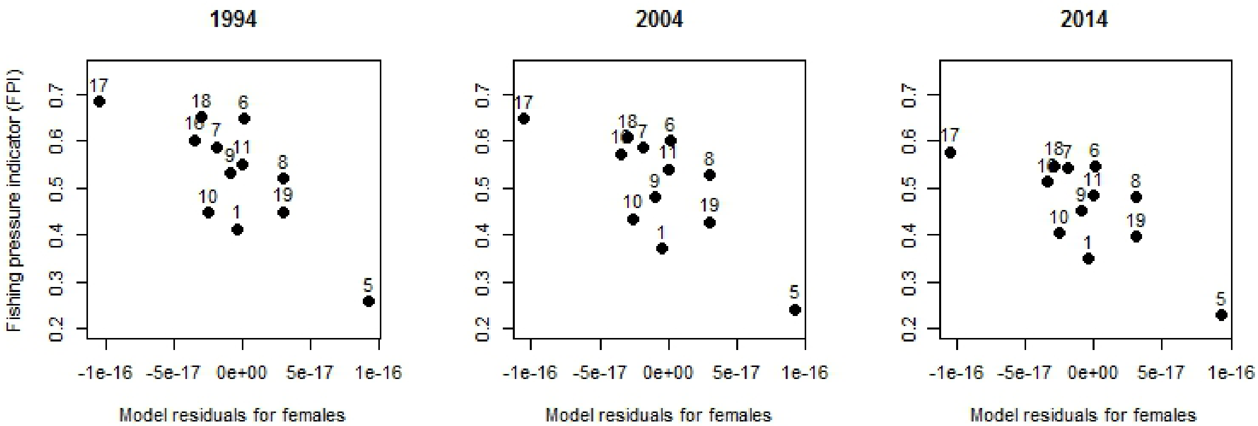

Fig. S2. – Scatter plot of the residuals of the global survival model for females applying a linear model on the standardized variables (mean 0 and variance 1) and the fishing pressure indicator for 1994 (left), 2004 (centre) and 2014 (right). While the negative correlations obtained between the fishing pressure indices and the residuals of the global model were very low (–0.23<rho≤0.17, right), those correlations for females were relatively high (–0.62<rho≤0.60, left). However, these high correlation values are forced by two extreme values of FPI: the lowest in the Balearic Islands (GSA-5) and the highest in the northern Adriatic (GSA-17).