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Do population and community metrics tell the same story about recent changes in Northern Mediterranean fish communities?

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Abstract

This document presents a comparative study of human impacts on the length-structure of fish communities across North-Mediterranean ecosystems. We use survey data to examine trends in length-based metrics and their consistency within and among the two levels of organisation populations and communities, and to suggest interpretations of observed trend combinations. We start from a set of population processes potentially affected by human pressures: fishing will induce mortality especially in target species, whereas the hydrological environment and eutrophication potentially affect recruitment and individual growth. How population changes will be reflected at the community level is expected to depend on community evenness. Based on this expectation, a tentative theory for predicting the joint response of a suite of population and community length-based metrics to potential changes in the environment is proposed. The trends in these metrics from survey data are then examined, focusing on the consistency with the above predictions. The potential causes suggested for the observed trends are then checked against independent evidence of environmental and human pressures on these communities. The approach is applied to the MEDITS survey data, which cover a series of neighbouring fish communities undergoing various human pressures, including fishing, coastal pollution and eutrophication, and a possible change in temperature and hydrology over the last decade.

Keywords

Community metrics; ecosystem approach to fisheries; fish community; length-based metrics; Mediterranean; survey data

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Introduction

For an ecosystem approach to fisheries management, we need to evaluate changes, especially those due to fishing, in i) target fish stocks ii) non-target fish populations iii) the whole fish community iv) fish habitats and the whole ecosystem. It is widely agreed that suites of metrics would be appropriate to describe the state and dynamics of fish communities and to give advice on management actions (Daan *et al.*, 2005a). The idea of combining trends in metrics to understand the causes of observed changes has recently been put forward (Rochet *et al.*, 2005). However, progress is still to be made in developing appropriate interpretations of given trend combinations, in particular for community metrics. This can be investigated either theoretically using ecosystem models, or empirically *e.g.* using survey data. The use of survey data is expected to give a consistent picture of components i to iii above, and to allow estimating metrics for populations and the impacted fish community.

The MEDITS groundfish surveys in the North Mediterranean Sea cover a series of neighbouring fish communities undergoing various human pressures, including fishing, coastal pollution and eutrophication, and a possible change in temperature and hydrology over the last decades (Bethoux, 1993; Diaz-Almela *et al.*, 2007). These surveys provide the opportunity to examine trends in metrics and their consistency within and among the two levels of organisation populations and communities, and to develop interpretations of observed trend combinations. The focus here is on length-based metrics, as they are widely recognised as sensitive, cost-effective and easy-to-understand indicators of ecosystem effects of fishing (Shin *et al.*, 2005). We start from a set of population processes potentially affected by human pressures: fishing will induce mortality especially in target species, whereas the hydrological environment and eutrophication potentially affect recruitment and individual growth. How population changes will be reflected at the community level is expected to depend on community structure. In communities dominated by a few species, community metrics will mainly reflect the changes in the most abundant species. In more even communities, community metrics will be responsive only to changes consistent across many populations. Based on these expectations, a tentative theory for predicting the joint response of a suite of population and community length-based metrics to changes in the environment is proposed. The time trends in these metrics across North Mediterranean communities over the period 1995 to 2006 are then examined, focusing on the consistency with the above predictions. Finally, the potential causes suggested for the observed trends are checked against independent evidence of environmental and human pressures on these communities.

Materials and methods

MEDITS surveys

The Medits surveys (International bottom trawl survey in the Mediterranean) cover all trawlable areas over the shelf and upper slope from 10 to 800 m depth in the North of the Mediterranean Sea from Gibraltar to the eastern Aegean Sea (Figure 1)(Bertrand *et al.*, 2000). A stratified sampling scheme with random selection of stations within strata is used, with a target sampling rate of one station per 60 square nautical miles. The sampling gear is a GOC 73 with codend mesh size 20 mm (stretched mesh) and vertical opening about 2 meters (Bertrand *et al.*, 2002). Medits surveys have been carried out annually since 1994 during the late spring-early summer period; data from the first year were not used here because sampling methods were not yet completely standardised. In this study data from six geographical units are used. Table 1 lists their characteristics in terms of surface area and sampling protocol details.

All macrofauna species are identified, counted and weighed by species, with special attention to a common list of 56 fish, cephalopod and crustacean species. For 30 of these, length, sex and maturity stages are recorded (Appendix 1). Rare, poorly sampled species (with average occurrence across years lower than 5 % of the hauls) were removed, with adjustments depending on the geographical unit. Only the data for species measured during the whole series were used. In some areas, the species effectively sampled and measured constitute a minor part of the total biomass caught in the survey (Table 1), which in turn might be a non-representative sample of the actual community due to species differences in catchability. As a consequence, the results of this study should not be over-interpreted as they might not depict changes in the total community, but only in the sampled and measured part. Still the data is suitable for examining consistency between population and community indicators.

Table 1. *Geographical units included in this study. GFCM, General Fisheries Commission for the Mediterranean. Surface refers to the area covered by the survey (10-800 m depth).*

GFCM geographical UNITS	Code	Surface (km²)	Average ratio of measured to caught biomass (%)	Number of species retained in this study
1. Northern Alboran Sea	1	12753	45	19
6. Northern Spain	6	32506	71	26
7. Gulf of Lions	7	13860	71	26
8. Corsica Island	8	4562	40	23
20. Eastern Ionian Sea	20	16823	53	25
22. Aegean Sea (including Crete)	22	155674	55	27

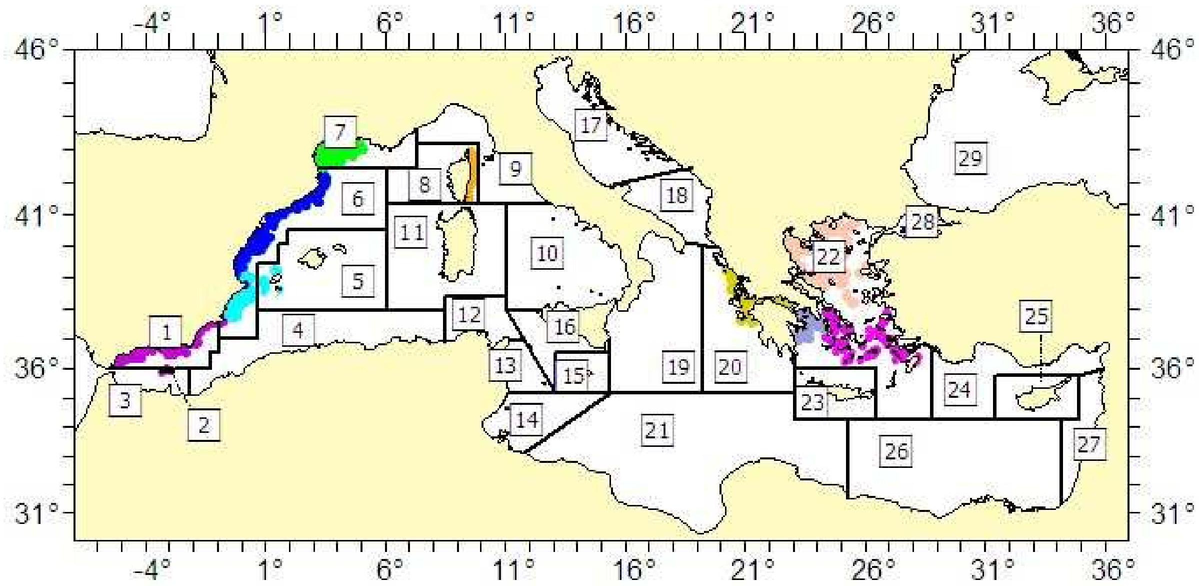

Figure 1 Map of the study area. Numbers refer to GFCM geographical units, the areas included in the present study are coloured.

Metrics

The following size-based metrics were used as they are expected to be sensitive to fishing (Shin *et al.*, 2005) and other human impacts: average length and the 95% percentile of the length distribution in populations, which provide a summary of the size distribution of fish, especially large fish. In addition, estimated log-abundance for the total area was used to help interpret the variations in these length-based indicators (Appendix 2). At the community level, three length-based indicators were calculated: average individual length in the community, the proportion of large fish, and a large population length percentile (95%) averaged across populations as a large fish index (Appendix 2). The proportion of large fish is agreed upon as an indicator of fishing impacts at the community level, but there is no consensus on how to define what a large fish is despite extensive discussion (ICES, 2006). Here 'large' was interpreted as larger than a fixed threshold to ease comparison across systems. A range of length thresholds was investigated (15, 20, 25, 30 cm) to determine which level was most appropriate in terms of sensitivity and representativeness. Too large a threshold would define a very small proportion of fish, which would be at risk of disappearing, whose variations would be difficult to interpret, and whose variance would not be properly estimated (the formula in Appendix 1 is valid only for proportions that are not too close to 1 or 0). Too small a threshold would include 'small' fish, that is recruits, in the proportion of large fish. In addition, two other community metrics were used, total abundance and a diversity index. Δ_l, interpreted as the probability that two individuals randomly picked up in the community belong to different species (Hurlbert, 1971), was used as a measure of species dominance in the community (Appendix 2).

Expected changes in metrics

Fishing induces mortality in target and by-catch species, especially in the large size-classes as most fishing gears are size-selective. Changes in temperature and hydrodynamics will result in changes in primary production timing, amount and quality, hence modify food available to various life stages of populations. This in turn will positively or negatively impact recruitment or individual growth, or both, depending on the biology of each species. Similarly, eutrophication will locally enhance primary production and thus should improve recruitment or growth in some populations relying on this local production. We gathered information on these factors and their changes over the last 10 years in the six study areas from published literature.

Human and environmental pressures in the areas of interest potentially affected adult mortality, growth, or recruitment within populations. Changes in these processes should in turn be reflected in metric time trends (Table 2) (Shin *et al.*, 2005; Trenkel *et al.*, 2007). For the sake of simplicity, metric trends in table 2 are ascribed to changes (increase or decrease, indicated by arrows) in processes. However, a consistently high mortality will result in decreased population abundance as well as an increasing mortality rate. Thus, for example "*R* ⬂" should be read "decreasing recruitment, or persistently low recruitment".

Based on combined trends in the three population indicators, populations can be classified into eight categories: those populations whose combined metric trends suggest increased (or decreased) growth, recruitment, or mortality, those with no detectable change, and those with no simple interpretable trend combination, probably reflecting the influence of several, or other non considered, factors. The effect of these factors at the community level will depend on whether they affected the most abundant populations in uneven communities (hereafter called dominant populations), or/and whether many populations in the community were affected by the same process changes (Table 3). In addition to the direct effects on the community taken as the sum of all populations, indirect effects might propagate through the community food web; *e.g.* fishing mortality selectively removing large, predator fish, might release smaller fish from predation and favour an increase in total abundance in the community (Shin *et al.*, 2005).

Analyses

Linear trends in population metrics were estimated by standard regression. A high α risk (0.1) was selected to increase the power of detecting effects; as the purpose of this analysis is to detect trends, rejecting the null hypothesis of no trend while it is true (α risk) is favoured over accepting it while it is false. Then populations were grouped into the eight process categories identified above (Table 3). Performing multiple tests on three indicators and many populations within each area will unavoidably lead to some results being statistically significant whereas the null hypothesis was actually true. The expected number of populations within each group under the overall null hypothesis that all populations were stationary, independent and the indicators were independent, was calculated to help interpreting the results (Table 3 last column). No overall test could be performed here owing to the difficult specification of an alternative hypothesis. The proportion of each process category relative to total abundance, averaged over the time-series, was also calculated to determine if the species groups with the same possible process explanation were made up of dominant populations or not.

Linear trends in community metrics were estimated by standard regression with a similar high α risk (0.1). Consistency between the trends in population and community metrics was examined based on expectations from Table 3. The proportion of population and/or of total abundance necessary for population metric trends to be reflected in community metrics was compared across areas. When consistent, the combined trends were ascribed to one or more plausible processes and potential factors. These inferences were compared with available knowledge of human pressures and environmental changes within each area.

Table 2. *Combinations of time trends in three population metrics suggesting major influence of changes in individual growth (g), recruitment (R), or adult total mortality (Z) for population i.* **↗↘** *significant metric trend in direction of arrow,* ↔ *no detectable trend.* ⬀(⬂) *increase (decrease) in process or consistently high pressure enhancing (impeding) this process. ? several or other processes. Population metrics:* $L_{0.95,i}$ *95% length percentile,* $\ln N_i$ *log-transformed population abundance and* L_{bar_i} *mean length.*

	$\ln N_i$ ↗			$\ln N_i$ ↔			$\ln N_i$ ↘		
	L_{bar_i} ↗	L_{bar_i} ↔	L_{bar_i} ↘	L_{bar_i} ↗	L_{bar_i} ↔	L_{bar_i} ↘	L_{bar_i} ↗	L_{bar_i} ↔	L_{bar_i} ↘
$L_{0.95,i}$ ↗	Z ⬂	Z ⬂	?	g ⬀	g ⬀	?	R ⬂	R ⬂	?
$L_{0.95,i}$ ↔	Z ⬂	?	R ⬀	g ⬀	No change	g ⬂	R ⬂	?	Z ⬀
$L_{0.95,i}$ ↘	?	R ⬀	R ⬀	?	g ⬂	g ⬂	?	Z ⬀	Z ⬀

Table 3. *Expected changes in community metrics, given changes in population processes, for two cases: 1) changes occurred in the dominant populations 2) changes occurred in many populations. Arrows read as in table 2. Last column: expected proportion of populations found in each process category (line in table) under the overall null hypothesis H_0 that populations are stationary and independent and population metrics are also independent for individual tests performed with $\alpha = 0.1$. Community metrics:* l_{bar} *mean inidividual length,* p_{large} *proportion of large fish,* $l_{0.95}$ *mean of populations' 95% length percentiles and* N *total community abundance.*

Major process underlying population changes	Expected direct effects on community metrics		Expected indirect effects	Expected proportion of populations under H_0
	Dominant populations affected	Many populations affected		
Z ⬀	l_{bar} ↘ N ↘ p_{large} ↘	$L_{0.95}$ ↘	l_{bar} ↘ N ↗	0.004625
Z ⬂	l_{bar} ↗ N ↗ p_{large} ↗	$L_{0.95}$ ↗	l_{bar} ↗ N ↘	0.004625
R ⬀	l_{bar} ↘ N ↗ p_{large} ↘	N ↗		0.004625
R ⬂	l_{bar} ↗ N ↘ p_{large} ↗	N ↘		0.004625
g ⬀	l_{bar} ↗ p_{large} ↗	$L_{0.95}$ ↗		0.08325
g ⬂	l_{bar} ↘ p_{large} ↘	$L_{0.95}$ ↘		0.08325
Multiple or other processes				0.086
No change				0.729

Results

Population metrics

There were much more population changes in the Eastern than in the Western Mediterranean over the 12 year (1995-2006) study period (Figure 2, Table 4). Few changes were detected in Spanish waters, mostly in combinations that have no direct interpretation in the present framework, and the notable exception of one species contributing 28% of community biomass which had increasing recruitment. No changes could be detected in Corsica. In the Gulf of Lions and mostly in Aegean Sea there were changes plausibly related to growth, whereas in the Eastern Ionian Sea five populations (34% of community biomass) showed signs of increased recruitment while 3 others (8% biomass) had signs of decreasing adult total mortality.

Table 4. *Observed and expected (under the null hypothesis that all populations are stationary, independent and indicators are independent) number of populations in each process category, in six MEDITS study areas.*

	N- Alboran	N- Spain	Lions	Corsica	E- Ionian	Aegean
Observed and (expected) number of populations						
Z ⬀	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)
Z ⬂	0 (0)	1 (0)	0 (0)	1 (0)	3 (0)	0 (0)
R ⬀	1 (0)	0 (0)	0 (0)	0 (0)	5 (0)	2 (0)
R ⬂	0 (0)	0 (0)	0 (0)	1 (0)	1 (0)	1 (0)
g ⬀	1 (2)	2 (2)	4 (2)	2 (2)	1 (2)	0 (2)
g ⬂	1 (2)	1 (2)	4 (2)	1 (2)	1 (2)	8 (2)
Other	4 (2)	7 (2)	3 (2)	2 (2)	3 (2)	5 (2)
No change	12 (14)	15 (19)	15 (19)	16 (17)	11 (18)	10 (20)
Percentage of observed total biomass						
Z ⬀	0	0	0	0	0	1
Z ⬂	0	2	0	6	8	0
R ⬀	28	0	0	0	34	5
R ⬂	0	0	0	8	1	1
g ⬀	2	4	6	4	1	0
g ⬂	3	3	17	2	4	24
Other	13	20	4	3	15	11
No change	54	72	73	76	37	58

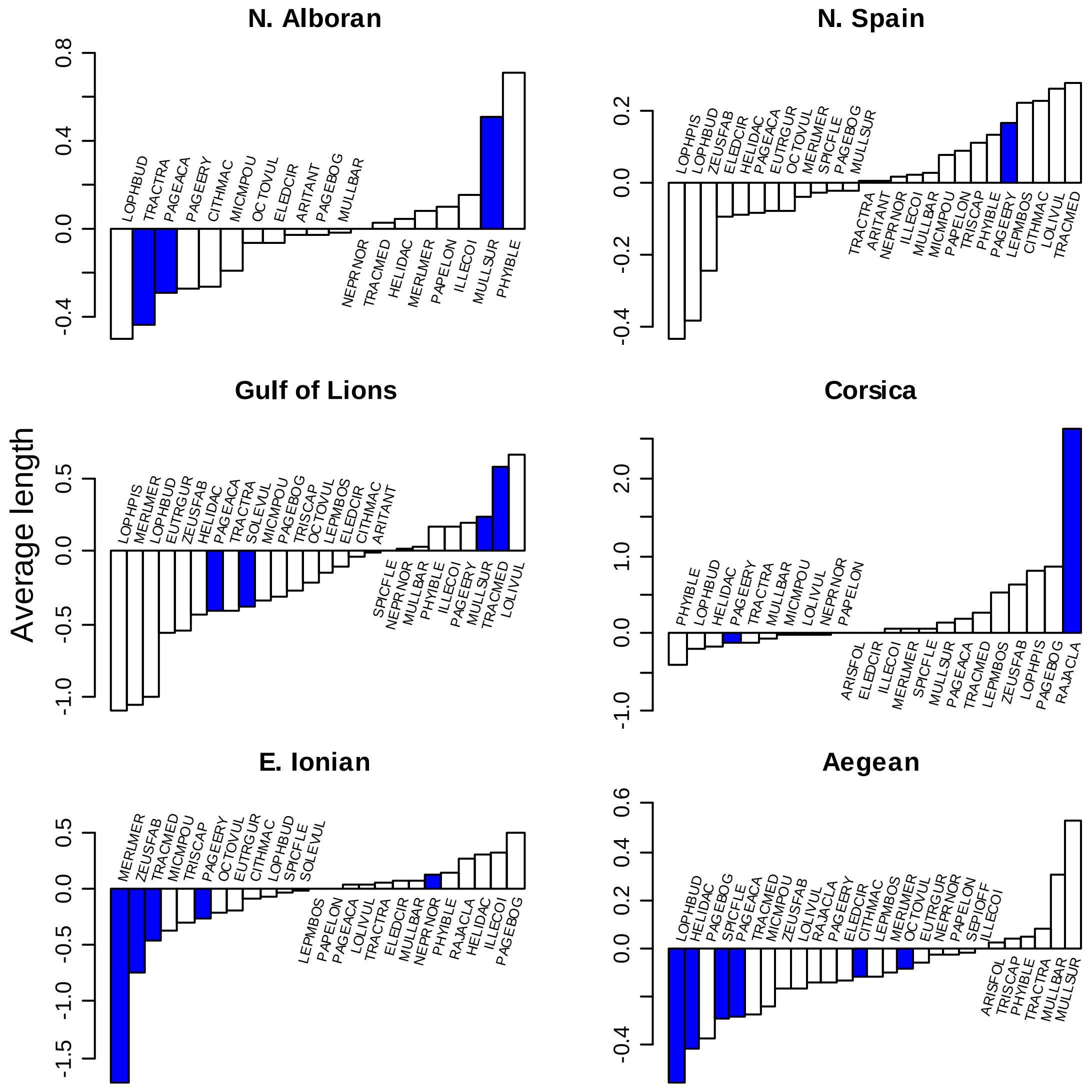

Figure 2. *Slopes (cm.y^{-1}) of time trends in population average lengths in MEDITS surveys, ranked by increasing order. Coloured bars are for slopes significant at* α *= 0.1. Species codes are listed in Appendix 1.*

Community metrics

There was no significant time trend in the diversity index Δ_1, so the average for each area is reported in Table 5. The most dominated communities were the most Eastern ones, whereas evenness was higher around Corsica and in Greek waters. The proportion of large fish when using a small size threshold (15 or 20 cm) was largely fluctuating between years, probably following fluctuations in recruitment of the dominant species in the communities (Figure 3). The largest threshold (30 cm) proved inadequate too as the corresponding proportions were lower than 2% in all areas and as low as 0.3% in Northern Spain (Figure 3). Thus the most pertinent size threshold for comparing these Mediterranean communities seems to be 25 cm. This metric decreased in all four French and Greek communities. By contrast, there were much less changes in the other community length-based metrics, average length (which did not change in any area), and the large fish index, which increased in Corsica and decreased in the Aegean Sea. Total abundance increased in all areas except the North Alboran Sea, and the change was significant in both Corsica and the Eastern Ionian Sea (Table 5).

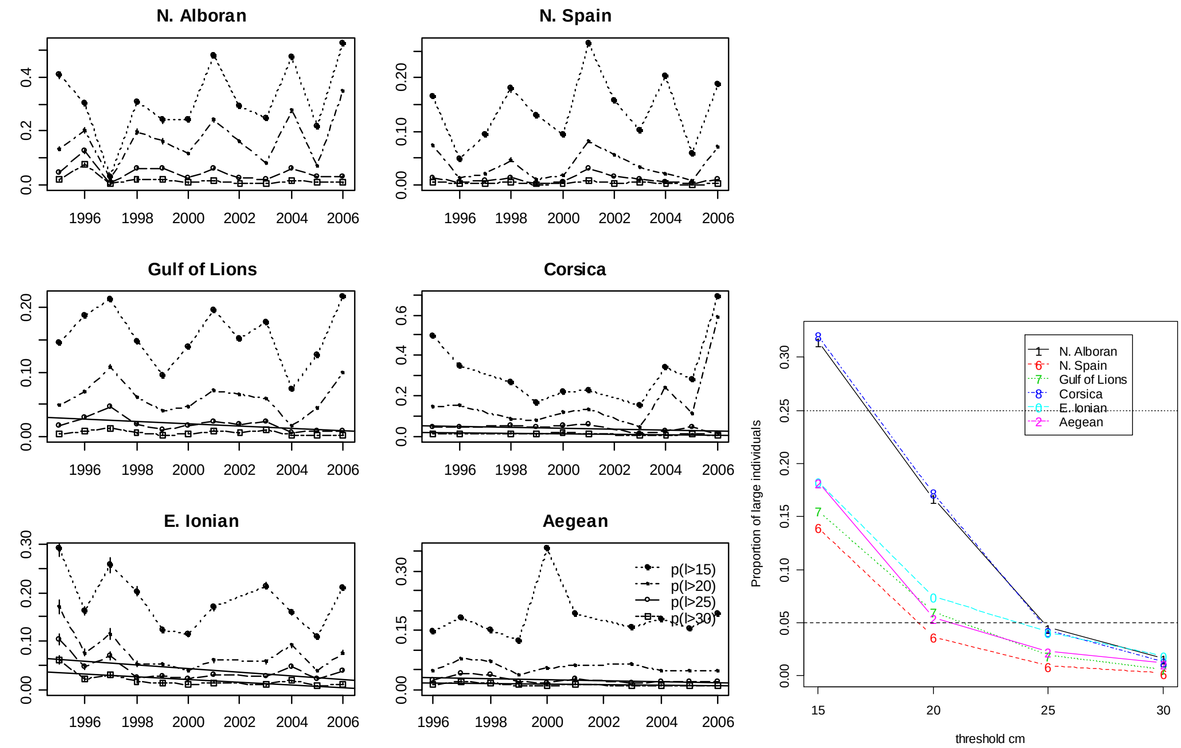

Figure 3. Time-series of the proportion of large fish in the community for MEDITS surveys. Dashed lines: observed fluctuations in metrics. Black bars: 95% confidence intervals. Continuous lines: fitted linear trend when P≤0.1. Right panel: Comparison of average proportion of large fish among communities with different length thresholds.

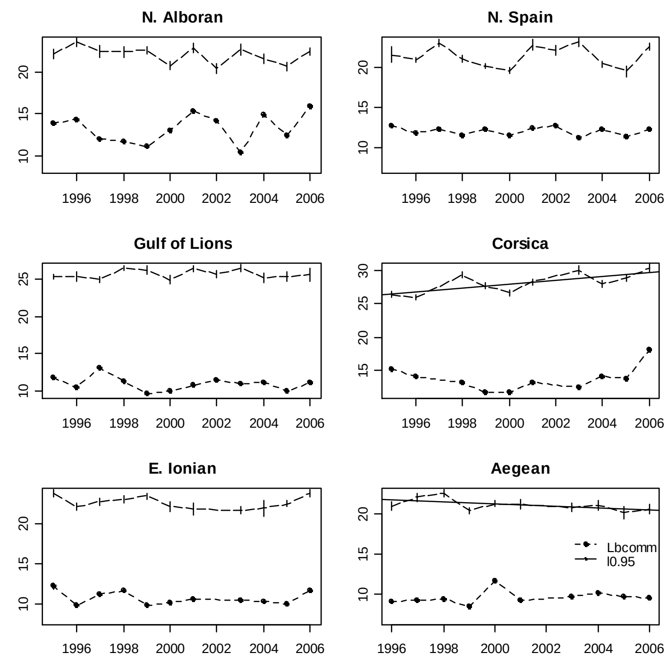

Figure 4. Time-series of mean length and length-percentile population metrics averaged across populations for MEDITS surveys. Lengths in cm. Dashed lines: observed fluctuations in metrics. Continuous lines: fitted linear trend when P≤0.1.

Fishing and environmental changes

Over the whole region, fishing effort is reported to have decreased in terms of fleet size and horsepower during the study period (Campillo, 1992; Berthou *et al.*, 2002; Papaconstantinou, 2005; García-Rodriguez *et al.*, 2006; Leblond *et al.*, 2007). However, fishing pressure might have remained stable owing to technical progress, which is consistent with stable catches over the recent period and continued diagnostics of overexploitation for the stocks that are formally assessed like red mullet and hake (Aldebert *et al.*, 1993; Stergiou *et al.*, 1997; Papaconstantinou and Farrugio, 2000; Jadaud *et al.*, 2006). The exception to this general rule is the Eastern Ionian Sea where coastal catches decreased by 37% between 1994 and 2006 (Source: Greek National Statistical Service).

Another general pattern in the Mediterranean is water warming over the last two decades, with higher increases in the Eastern compared to the Western Mediterranean at least for maximum surface temperature (Diaz-Almela *et al.*, 2007). In the Ionian Sea, in addition, recent changes in water circulation have contributed to an increase in biological production (Souvermezoglou and Krasakopoulou, 2005).

Overall pollution by metals and nutrients are widespread among the study regions and have remained stable or slowly decreased over the study period (Stergiou *et al.*, 1997; Galgani *et al.*, 2000; RNO, 2000). Only in the Aegean Sea increasing levels of eutrophication locally resulted in increased biological production in recent years (Papaconstantinou and Farrugio, 2000).

Based on these changes in environmental pressures we expect

A) no change in total mortality in all study areas, except the Eastern Ionian Sea where it might have decreased
B) pervasive changes in recruitment and/or growth due to water warming in all study areas, though the direction of change is difficult to predict because impacts will depend on temperature preferences of each species
C) increases in recruitment and/or growth in the Easter-Ionian Sea
D) increases in recruitment and/or growth in the Aegean Sea.

Consistency between population metrics, community metrics, and environmental changes

In all areas but Corsica some changes (or absence of change) were found in community metrics consistent with changes in population metrics (Table 5). In Spanish waters no significant change was detected, consistent with population trends not belonging to the major process groups in the Northern Alboran Sea, and the stability of populations in Northern Spain. In the Gulf of Lions and Aegean Sea there were signs of decreased growth, more important in the latter case. In the Eastern Ionian Sea the community changes were more consistent with increased recruitment than decreased mortality that were both detected in populations. As for Corsica the changes are rather difficult to interpret as there were few changes in populations, but community metrics changed, with an increase in total abundance and the large fish index, but a decrease in the proportion of large fish. These apparently contradictory trends are due to i) an increase in $L_{0.95}$ in several large species (*e.g.* hake, monkfish and thornback ray) which were not necessarily individually significant, were not accompanied by consistent trends in other indicators, but significantly affected the average $l_{0.95}$ across species; ii) an increase in numbers of several small-sized species (like red mullet or *Nephrops*), which contribute to decrease the proportion of large fish. Thus, there has been a change in the species- and size-structure of the community although populations did not show many significant trends; and this change is not easily interpretable within the present framework.

In summary:

A) Our results are consistent with expectation A as the only region with some sign of change in mortality is the Eastern Ionian Sea where three populations were found in this group.
B) We found no general change in growth or recruitment across all regions that would be consistent with expectation B. The only change consistent across two regions were the signs of decreasing growth translating into changes in size community metrics found both in the Gulf of Lions and Aegean Sea.
C) Consistent with expectation C, increased recruitment was detected at both population and community levels in the Eastern Ionian Sea.
D) By contrast, no sign of improved recruitment or growth was found in the Aegean Sea.

Table 5*. Summary of population (from Table 4) and community metrics trends, and major processes identified as the plausible causes of these trends. Significant changes (α = 0.1) are italicised and bold. Grey cells are conform to predictions from Table 3, while hatched cells are contradictory with predictions.*

Area	Pop-based scenario	Which populations affected	Average Δ_l	Slopes in				Overall process identified
				$l_{0.95}$ (cm.yr^{-1})	$l_{b.0.ar}$ (cm.yr^{-1})	N (10^6.yr^{-1})	p_{large} (%.yr^{-1})	
1	Other	Some non dominant	0.73	-0.11	0.1	-3.62	-0.3	—
6	Stable		0.6	0	-0.02	59.16	0	—
7	g ⬂	Some	0.75	0.02	-0.07	6.20	***-0.2***	g ⬂
8	Stable		0.81	***0.29***	0.13	***2.79***	***-0.2***	?
20	R ⬀	Many	0.87	-0.04	-0.05	***17.16***	***-0.4***	R ⬀
20	Z ⬂	Some						—
22	g ⬂	Many	0.81	***-0.12***	0.06	214.09	***-0.1***	g ⬂

Discussion

Generally there was good agreement between the patterns in population and community metrics, and these were also consistent with independent evidence for changes in environmental pressures. There are three exceptions to this general agreement. First, contradictory results were found between the stable population metrics and changing community metrics in Corsica, and clearly the present framework does not allow to ascribe a plausible cause to this situation. Second, we found no consistent evidence of changes due to water warming, except maybe decreases in individual growth in both the Gulf of Lions and Aegean Sea. However, the expected changes will depend on the life history of species present and their temperature preferences. Water warming may be an explanation why the number of populations in the 'Multiple or other processes' category was always higher than expected except for Corsica. Water warming might have weak effects or contradictory direct and indirect effects on the processes investigated here (*e.g.* warming may accelerate a species' growth but be detrimental to its main food resource). Third, no improvement in growth nor recruitment was found in the Aegean Sea. This suggests that the species sampled and measured in the survey do not benefit from the reported coastal eutrophication, in accordance with the hypothesis by Caddy *et al.* (1995) that enrichment will benefit to production of both pelagics and demersal but that the latter will be more affected by bottom anoxia, thus enrichment might be more beneficial to pelagic species. Thus, overall the method did meet expectation in five out of six areas. However, this was not a complete test for the theory, as the number of case-studies was small and the changes in the environmental factors were not very contrasted across areas. In addition, the areas with uneven communities (low Δ_I) were mostly stable, so that the expectations about community outcome depending on community dominance could not be tested. Further testing of the method is required before it can be used to interpret changes in population and community metrics. However, these first results are encouraging and outline the potential of examining and interpreting trends in several indicators rather than comparing their sensitivity and responsiveness independently like other studies (e.g., Piet and Jennings, 2005; Greenstreet and Rogers, 2006).

We found no change in fishing impacts in the investigated communities, except (weakly) in the Eastern Ionian Sea. For this reason we were also not able to examine the possibility of indirect fishing impacts that might be important on the size structure of exploited communities (Daan *et al.*, 2005b). This does by no way means that there are no fishing impacts, which are well known and documented in the region (Tudela, 2004), but there was no sign of release nor worsening of these impacts over the study period in most study areas. Rather, the strongest effects found here are consistent with Caddy's (2000) finding that biological productivity in the Mediterranean increased from 1970 to the end of the XXth century and caused an increase in fisheries catches. Thus marine catchment basin effects might be stronger than fishing impacts on the Mediterranean ecosystems (Caddy, 2000). On the time and spatial scale investigated here this was still true.

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Appendix 1. List of species included in the analysis for each area

Species name	Species code	1	6	7	8	20	22
Aristaeomorpha foliacea	ARISFOL				1		1
Aristeus antennatus	ARITANT	1	1	1			
Citharus linguatula	CITHMAC	1	1	1		1	1
Eledone cirrhosa	ELEDCIR	1	1	1	1	1	1
Chelidonichthys gurnardus	EUTRGUR		1	1		1	1
Helicolenus dactylopterus dactylopterus	HELIDAC	1	1	1	1	1	1
Illex coindetii	ILLECOI	1	1	1	1	1	1
Lepidorhombus boscii	LEPMBOS		1	1	1	1	1
Loligo vulgaris	LOLIVUL		1	1	1	1	1
Lophius budegassa	LOPHBUD	1	1	1	1	1	1
Lophius piscatorius	LOPHPIS		1	1	1		
Merluccius merluccius	MERLMER	1	1	1	1	1	1
Micromesistius poutassou	MICMPOU	1	1	1	1	1	1
Mullus barbatus	MULLBAR	1	1	1	1	1	1
Mullus surmuletus	MULLSUR	1	1	1	1		1
Nephrops norvegicus	NEPRNOR	1	1	1	1	1	1
Octopus vulgaris	OCTOVUL	1	1	1		1	1
Pagellus acarne	PAGEACA	1	1	1	1	1	1
Pagellus bogaraveo	PAGEBOG	1	1	1	1	1	1
Pagellus erythrinus	PAGEERY	1	1	1	1	1	1
Parapenaeus longirostris	PAPELON	1	1		1	1	1
Phycis blennoides	PHYIBLE	1	1	1	1	1	1
Raja clavata	RAJACLA				1	1	1
Sepia officinalis	SEPIOFF						1
Solea solea	SOLEVUL			1		1	
Spicara flexuosa	SPICFLE		1	1	1	1	1
Trachurus mediterraneus	TRACMED	1	1	1	1	1	1
Trachurus trachurus	TRACTRA	1	1	1	1	1	1
Trisopterus minutus	TRISCAP		1	1		1	1
Zeus faber	ZEUSFAB		1	1	1	1	1

Appendix 2. Definition of population (a) and community (b) metrics used in the analysis.

a) Population metrics	Definition	Required data	Estimator
$\ln N_i$	Abundance index for species i	Catch haul k stratum j $y_{k,j}$ Swept area $a_{k,j}$ Stratum area A_j	$N_i=\sum_j N_{i,j}=\sum_j A_j \sum_{k=1}^{n_j} y_{k,j} \Big/ \sum_{k=1}^{n_j} a_{k,j}$ $\ln N_i=\ln(N_i)-Var(\ln N_i)/2$ $Var(N_i)=\sum_j \frac{A_j^2}{n_j-1}\sum_{k=1}^{n_j}\left(\frac{y_{k,j}}{a_{k,j}}-\frac{\sum_{k=1}^{n_j} y_{k,j}}{\sum_{k=1}^{n_j} a_{k,j}}\right)^2$ $Var(\ln N_i)=\ln\left(\frac{Var(N_i)}{N_i^2}+1\right)$
L_{bar_i}	Average length in population	Catch per length class $y_{l,i}$	$L_{bar_i}=\frac{\sum_{l=1}^{L} y_{l,i}\, l}{y_i}$ avec $y_i=\sum_{l=1}^{L} y_{l,i}$ $Var[L_{bar_i}]=\left(\frac{\sum_{l=1}^{L} y_{l,i}\, l_2}{y_i}-L_{bar_i}^2\right)\Big/ y_i$
$L_{q,i}$ $q = 0.95$	Percentile of the population length distribution	Catch per length class $y_{l,i}$	$L_{q,i}=l_{q,i}\Big\vert \frac{\sum_{l=1}^{l_q} y_{l,i}}{y_i}=q$ $Var[L_{q,i}]=\frac{q(1-q)}{y_i\left(y_{l_q,i}/y_i\right)^2}$

b) Community Metrics	Required input	Estimator
Diversity Δ_1	N_i	$\Delta_1=\frac{N}{N-1}\left[1-\sum_{i=1}^{n}\left(\frac{N_i}{N}\right)^2\right]$ $Var[\Delta_1]\approx\sum_i^n Var[N_i]\left(\frac{2N_i}{N^2}-\sum_i^n\frac{2N_i^2}{N^3}\right)$ Confidence interval by parametric bootstrap
Total abundance N	Catch haul k stratum j $y_{k,j}$ Swept area $a_{k,j}$ Stratum area A_j	$N=\sum_j N_{i,j}=\sum_j A_j\sum_{k=1}^{n_j}\sum_i^n y_{ikj}\Big/\sum_{k=1}^{n_j} a_{k,j}$

b) Community Metrics	Required input	Estimator
		$Var(N)=\sum_{j}\frac{A_j^{\,2}}{n_j-1}\sum_{k=1}^{n_j}\left(\frac{\sum_{i} y_{i,kj}}{a_{k,j}}-\frac{\sum_{k=1}^{n_j}\sum_{i}^{n} y_{i,,}}{\sum_{k=1}^{n_j} a_{k,j}}\right)^2$
Community average length l_{bar}	Catch per length class y_l	$l_{bar} = \frac{\sum_{l=1}^{L} y_l\, l}{y}$ avec $y = \sum_{l=1}^{L} y_l$ $Var[l_{bar}] = \left(\frac{\sum_{l=1}^{L} y_l\, l^2}{y} - L_{bar}{}^2\right) \Big/ y$
Proportion of large individuals p_{large} larger than $lbig$ = 15, 20, 25, 30 cm	$y_l(t)$ catch per length class l $y(t)$ total catch (measured species) Large size threshold $lbig$	$p_{\text{large}}(t) = \sum_{l>lbig} y_l(t) \Big/ y(t)$ $Var[p_{\text{large}}] = \frac{p_{\text{large}}(1-p_{\text{large}})}{y(t)}$
Average population length percentiles $l_{0.95}$	Population length percentiles $L_{q,i}$ S number of consistently measured species	$l_q=\sum_{i=1}^{S} L_{q,i} \Big/ S$ $Var[l_q] = \sum_{i=1}^{S} Var[L_{q,i}]$