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Evaluation of marine subareas of Europe using life history parameters and trophic levels of selected fish populations

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ABSTRACT

European marine waters include four regional seas that provide valuable ecosystem services to humans, including fish and other seafood. However, these marine environments are threatened by pressures from multiple anthropogenic activities and climate change. The European Marine Strategy Framework Directive (MSFD) was adopted in 2008 to achieve good environmental status (GEnS) in European Seas by year 2020, using an Ecosystem Approach. GEnS is to be assessed using 11 descriptors and up to 56 indicators. In the present analysis two descriptors namely “commercially exploited fish and shellfish populations” and “food webs” were used to evaluate the status of subareas of FAO 27 area. Data on life history parameters, trophic levels and fisheries related data of cod, haddock, saithe, herring, plaice, whiting, hake and sprat were obtained from the FishBase online database and advisory reports of International Council for the Exploration of the Sea (ICES). Subareas inhabited by *r* and *K* strategists were identified using interrelationships of life history parameters of commercially important fish stocks. Mean trophic level (MTL) of fish community each subarea was calculated and subareas with species of high and low trophic level were identified. The Fish in Balance (FiB) index was computed for each subarea and recent trends of FiB indices were analysed. The overall environmental status of each subarea was evaluated considering life history trends, MTL and FiB Index. The analysis showed that subareas I, II, V, VIII and IX were assessed as “good” whereas subareas III, IV, VI and VII were assessed as “poor”. The subareas assessed as “good” were subject to lower environmental pressures, (less fishing pressure, less eutrophication and more water circulation), while the areas with “poor” environment experienced excessive fishing pressure, eutrophication and disturbed seabed. The evaluation was based on two qualitative descriptors (“commercially exploited fish and shellfish populations” and “food webs”) is therefore more robust.

1. Introduction

Marine environments provide various essential ecological services to humans (Hattam et al., 2015), nevertheless, most of world's seas are threatened by pressures from numerous anthropogenic activities (Halpern et al., 2008). European marine areas are no exception and subject to degrade by invasion of non-indigenous species (Keller et al., 2011), excessive fishing, eutrophication (EEA, 2015), sea-floor degradation (Rice et al., 2012; Pieralice et al., 2014), contamination from hazardous substances (Tornero and Ribera d'Alcalà, 2014), marine litter (Galgani et al., 2014; Pham et al., 2014) and underwater noise (EEA, 2015; Korpinen et al., 2012). In response, the European Union introduced the Marine Strategy Framework Directive (MSFD) with the aim of achieving good environmental status (GEnS) in the European regional seas by 2020 (EU, 2008). GEnS is defined in the MSFD text as: “The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions” (EU, 2008), and

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Borja et al., (2013) give a scientific definition. GEnS is to be monitored and assessed through the use of 11 qualitative descriptors (EU, 2008; EU, 2010). EU has listed the criteria and indicators for each qualitative descriptor to use in environmental assessments (Borja et al., 2013; EU, 2010). However, EU member states find that the use of the 11 qualitative descriptors of GEnS as too complex, and this is hindering the implementation of the MSFD (Borja et al., 2013). There is no consensus as to whether each descriptor can be adopted individually or as part of an aggregate approach (Borja et al., 2013). The EU Member States (MS) must now improve the marine environment in various ways such as reducing nutrient inputs and reducing fishing pressure (EEA, 2015). Progress is to be monitored (Borja and Eliot, 2013; Borja et al., 2013; Carstensen, 2015) and assessed. Borja et al. (2013) raised an important timely question regarding "*how do we know when we have attained GEnS*"? The 11 qualitative descriptors have been used in numerous ways to answer this question (Brennan et al., 2014; Crise et al., 2015; O'Higgins and Gilbert, 2014).

Populations of commercially exploited fish/shellfish and marine food webs are D3 and D4 descriptors respectively out of the 11 qualitative descriptors (EU, 2008). Descriptor 3 (D3) states that commercial species should be "within safe biological limits, exhibiting a population age and size distribution that is indicative of healthy stock" (EU, 2008; Piet et al., 2010). Descriptor 4 (D4) concerns "all elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity" (EU, 2008). Both these descriptors have their own sets of indicators for assessing the marine environments (Piet et al., 2010; Rogers et al., 2010) and are often used in marine assessments (Borja et al., 2011; Probst et al., 2013). Also, Froese et al. (2015) have developed other indicators based on these descriptors to evaluate marine environments. Berg et al., (2015) suggested that it is necessary to rearrange the criteria and indicators of some qualitative descriptors described in MSFD in order to conduct the marine assessments in an efficient way.

The marine subareas are widely spread throughout different seas in Europe (Cardinale et al., 2013). Various approaches have been used to evaluate the environmental status of these subareas (Borja et al., 2011). Even though life history parameters of fishes have been used to measure the environmental status elsewhere (King and McFarlane, 2003), no attempts have been made to evaluate the area of FAO area 27 based on the life history parameters of fishes. In the study we attempted to evaluate marine subareas of European Seas using above mentioned qualitative descriptors, commercially exploited fish/shellfish populations (D3) and food web (D4). To investigate the latest trends of time series data, a comparatively short time period (1998–2013) was used, since data for many fish populations were available for this period. We considered a combined criterion for commercial fishes and food webs qualitative descriptors to assess marine environments of subareas in FAO area 27. Here, we used life history parameters and mean trophic level data (MTL) of some commercially important fishes in the subareas of FAO area 27 to assess the environmental status.

2. Materials and methods

2.1. Area, fish stocks and data sources

2.1.1. Study area

Sub areas of FAO fishing area 27 (Baltic and NE Atlantic) were selected for the present analysis. A map of the study area indicating the fishing areas of the regional seas is shown in Fig. 1. Table 1 describes the subareas considered in this analysis.

2.1.2. Selection of fish stocks and data sources

Commercially important fish stocks that are under the management of the International Council for the Exploration of the Sea (ICES) were selected namely cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), herring (*Clupea harengus*), sole (*Solea solea*), plaice (*Pleuronectes platessa*), whiting (*Merlangius merlangius*), hake (*Merluccius merluccius*) and sprat (*Sprattus sprattus*). These stocks represent about 25% of the fish stocks in the European region. They are considered as the most important in European commercial fisheries and these data are considered to be rich and reliable by ICES (Cardinale et al., 2013).

Data on life history parameters such as von Bertalanffy growth parameters (asymptotic length, L_∞ and growth constant, K), length at first maturity (L_m) and age at first maturity (A_m) of the fish populations were obtained from the Fishbase online database (www.fishbase.org; Froese and Pauly, 2014). These parameters are readily available for many fish stocks and known indicators for identifying *r* and *K* life history straits of fishes (please see Section 2.2.2).

Data on fish catch (C) of concerned fish stocks were gleaned from the ICES scientific advisory reports for 2014 (http://www.ices.dk/community/advisory-process/Pages/Latest-advice.aspx), which were accessed on 20.10.2014. In these reports, catch data were available up to 2013.

2.2. Data analysis

2.2.1. Interrelationships of life history parameters

Regression analysis was carried out to determine the relationships between K and L_∞ in stocks of each fish species in the subareas. Interrelationships of different life history parameters for the same fish species were also determined by linear regression analyses. For example for cod (*G. morhua*), linear regression analyses with different combinations of life history data such as L_∞ vs K, L_∞ vs L_m, L_m vs A_m etc. were performed.

2.2.2. Decision matrix analysis to evaluate marine subareas using life history data

The life history parameters with significant interrelationships were used to for comparative assessment of which marine ecosystems were "healthier" or less-stressed. Heavy fishing mortality tends fish populations towards an *r*-selected life history (Adams, 1980; Greenstreet and Rogers, 2006; Reznick et al., 2002). The *r*-strategists have low age/length at maturity, small body sizes with faster growth rates. The fish populations with opposite tendencies, which live in "healthier" or less-stressed environments, are generally *K*-strategists. They have a high age/length of maturity, larger body sizes and slower growth rates (Reznick et al., 2002). Based on these life history parameters, a simple decision matrix analysis was performed (For details, see Tauge, 2005) to categorize fish stock to *r* or *K* strategists in each subarea. The last three data points at both ends of each plot of the interrelationship of life history parameters were considered for this purpose. In each plot, *K*-selection end was given positive (+) scores, while *r*-selection end was allocated negative (−) scores. The highest weight (3 scores) was given to the data point at the extreme end of *K*-selection. The intermediate weight (2 scores) was assigned to the second/middle data point and the lowest weight (1 score) was allocated for the other data point of the three considered. Finally, the sum of scores was calculated to evaluate fishing subregions. The fish in sub regions that obtain scores of ≥ 0 have more *K* characteristics, and these regions were considered as having good environment status. The fish in subareas that obtain final scores below zero (<0) were considered as *r*-strategists and those regions were considered as having poor environment status.

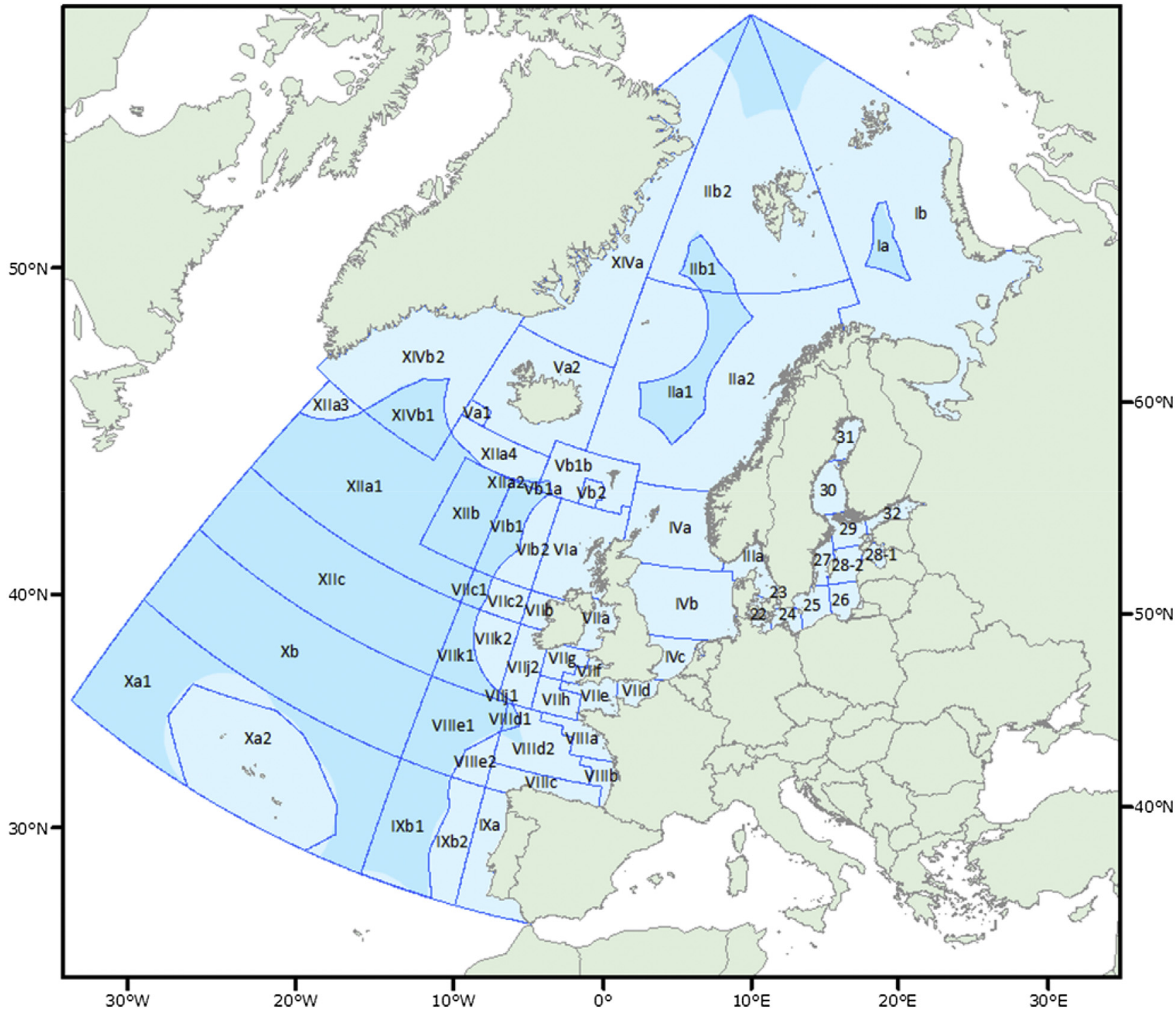

Fig. 1. Map of the FAO 27 area with the different fish stocks analysed (Cardinale et al., 2013).

2.3. *Mean trophic level analysis for different subareas*

Pauly and Palomares (2005) described a method to calculate mean trophic levels of aquatic environments mainly using the trophic level of fish species and commercial catch data. Following this method, mean trophic level (*MTL*) of fish communities in sub areas under the FAO area 27 were estimated.

Trophic level (TL_i) of a fish species can be estimated by

Table 1
Fishing subareas (FAO 27) considered for data gathering from FishBase online database, and ICES scientific advisory reports.

Subarea number (data labels in plots)	Area name
I	Barents Sea
II	Norwegian Sea (IIa); Spitzbergen, and Bear Island (IIb)
III	Skagerrak and Kattegat (IIIa); Sound, Belt Sea (III b,c) and Baltic Sea (IIId 24–32); the Sound and Belt (IIIc 22) together known also as the Transition Area
IV	North Sea (Northern IVa); (Central Vb); (Southern IVc)
V	Iceland (Va); Faroes Grounds (Vb)
VI	Northwest Coast of Scotland and North Ireland or West of Scotland (VIa); Rockall (VIb)
VII	Irish Sea (VIIa); West of Ireland (VIIb); Porcupine Bank (VIIc); Eastern (VIId) and Western (VIIe) English Channel; Bristol Channel (VIIf); Celtic Sea North (VIIg) and South (VIIh); and Southwest of Ireland – East (VIIj) and West (VIIk)
VIII	Bay of Biscay (North VIIIa); (Central VIIIb); South (VIIIc); Offshore (VIIId); (West VIIIe)
IX	Portuguese Waters (East IXa); (West IXb)
X	Azores Grounds
XI	North of Azores
XIV	East Greenland (North XIVa); (South XIVb)

Equation 1

$$TL_i = 1 + \sum_j (TL_j \cdot DC_{ij}) \quad (1)$$

where TL_j is trophic level of the prey j and DC_{ij} is the fraction of j in the diet of i. In the present analysis, TL_i values for cod (4.29), haddock (3.56), saithe (3.61), herring (3.29), sole (3.30), plaice (3.23), whiting (3.57), horse mackerel (3.84), hake (4.30) and sprat (3.01) were obtained from Fishbase online database (www.fishbase.org; Froese and Pauly, 2014).

Mean trophic level for year y (MTL_y) for an area or ecosystem was computed from 1998 to 2013 to observe whether there are any trends before and after the adoption of the MSFD in 2008. In this analysis, seven subareas (I + II, III, IV, V, VI, VII, VIII + IX) were considered based on the availability of ICES advisory reports. The fish stocks that were considered for each subarea for MTL analysis are shown in Table 2.

Subareas with a dominance of low trophic level species were identified following Christensen et al. (2003) with a reference level of MTL 3.75.

$$MTL_y = \frac{\sum_i (TL_i \cdot Y_{iy})}{\sum_i Y_{iy}} \quad (2)$$

where Y_{iy} is the catch of species i (obtained from ICES advisory reports) in year y.

2.4. FiB (fishing-in-balance) index of marine subareas

Pauly et al. (2000) defined *FiB* (fishing-in-balance) index as a tool to evaluate ecosystem impact of fisheries. FiB index was calculated for above fishing subareas to investigate the future potential of the fisheries (Equation (3)).

$$FiB_y = \log\left\{\left[Y_y \cdot \left(\frac{1}{TE}\right)^{TL_y}\right] \middle| \left[Y_0 \cdot \left(\frac{1}{TE}\right)^{TL_{y0}}\right]\right\} \quad (3)$$

where, Y_y is the catch of year y, TL_y is the mean trophic level of the catch at year y; Y_o is the catch and TL_o mean trophic level of the catch at start of the series being analysed (Pauly and Palomares, 2005) here, 1998. TE (Transfer Energy) can be calculated from equation (4).

$$TL = a + b \cdot \log(Y_y) \quad (4)$$

where, $TE = 10^{1/b}$

Table 2
Fish stocks considered for mean trophic level analysis in each subarea.

Area	Fish stocks
I + II	Cod, Haddock, Saithe
III	Cod (SDs 22–24), Herring IIIa and (SDs 22–24) Herring IIId (SD 30), Herring IIId (SDs 25–29) Herring IIId (28.1), IIId (SD 31), Sole IIIa
IV	Cod (IV, VIId, IIIa), Haddock (IV, IIIa (West), Herring (IV, VIId, IIIa West), Sole, Plaice, Whiting (IV, VIId), Sprat
V	Cod, Haddock, Saithe, Herring
VI	Whiting (VIa), Herring (VIa North), Haddock (VIb)
VII	Cod (VIIe-k), Cod (VIIa), Herring (VIIa), Sole (VIId), Sole (VIIf,g), Plaice (VIIe)
VIII + IX	Sole (VIIIa,b), Horse Mackrel (IXa), Hake (VIIIc, IXa)

Note: fish stocks were categorized to each subarea following Cardinale et al. (2013) and ICES scientific advisory reports.

Pauly and Christensen (1995) and Pauly and Palomares (2005) reported a *TE* of 0.1 in marine environments and as such, we used this value.

2.5. Overall evaluation of marine subareas

Using the three methods (life history data analysis, MTL and FiB index analysis) we evaluated the overall environmental status of the marine subareas. Plus (+) signs were allocated to the subareas with fish of *K*-strategy, higher MTL (>3.75) and an increasing trend of the FiB Index. Negative (−) marks were given to the areas with fish stocks of *r*-strategy, lower MTL (<3.75) and a decreasing trend of the FiB index. Finally, the areas with at least two plus signs were evaluated as “good” while other areas (with two negative signs) were evaluated as “poor” environment status.

3. Results

3.1. Interrelationships between life history parameters and evaluation of marine subareas

3.1.1. Interrelationships between life history parameters

Significant relationships between K and L_∞ for haddock, saithe and plaice populations were found (Fig. 2a, b and c). In the North Sea (Area IV), haddock, saithe and plaice had higher growth rates with small body sizes (Fig. 2a, b and c).

Significant interrelationships of life history parameters were found in several fish populations. Cod and herring populations in subarea III (Baltic Sea) matured at early ages with low body lengths,

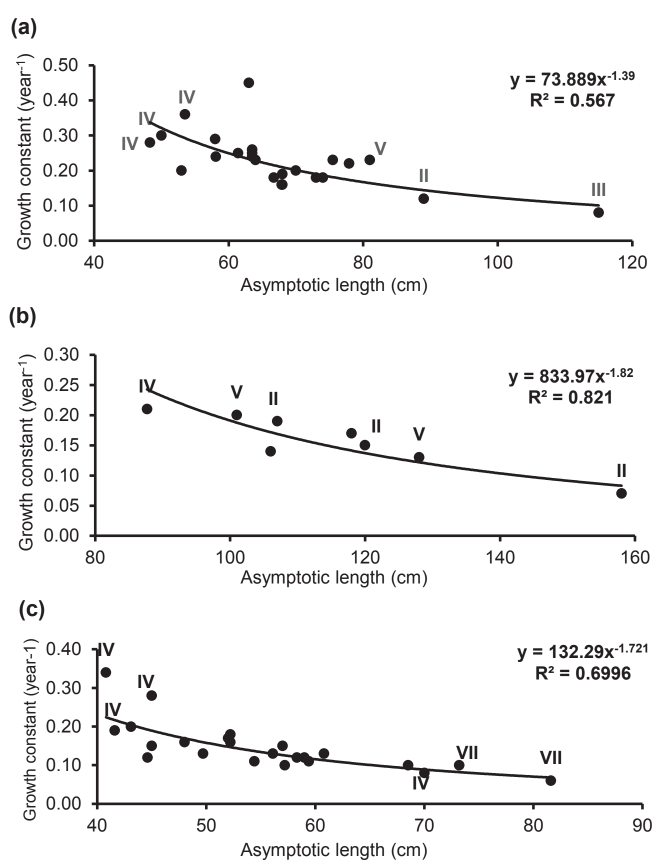

Fig. 2. Relationship between asymptotic length (L_∞) and growth constant (K) for haddock (a), saithe (b) and plaice (c). The stocks in two extremes are labeled (as given in Table 1) for easy reference.

while cod in the North Sea matured late with larger body sizes (Fig. 3a and c). The length of maturity of cod in the Baltic Sea was lower than in other marine subareas (Fig. 3b). Furthermore, length at maturity of herrings in the subareas VII, IV and III is smaller than in other areas (Fig. 3d). In addition, plaice in subarea VII matured at early ages with smaller body sizes compared to area IX (Fig. 3e). Cod and herring in subarea II have higher ages and lengths at maturity with larger body sizes Fig. 3b, c and d.

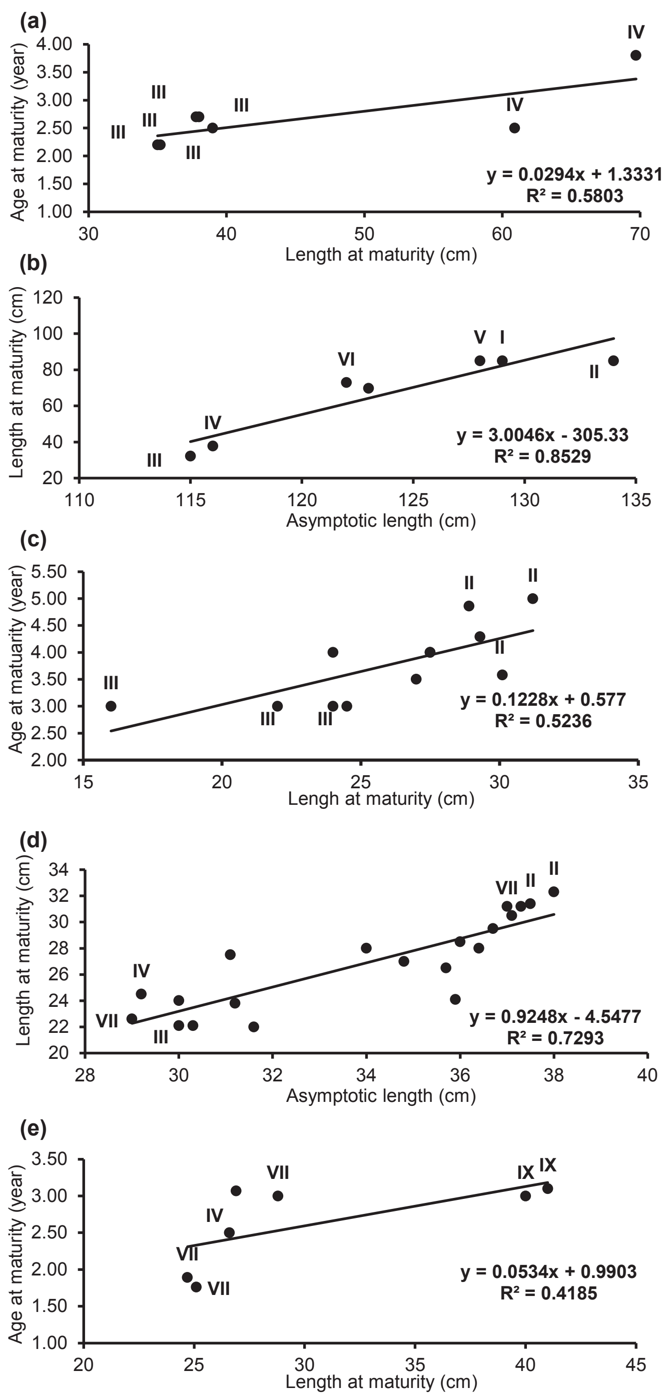

Fig. 3. Linear relationships between the length at maturity (L_m) and age at maturity (A_m) for cod (a); asymptotic length (L_∞) and length at maturity (L_m) for cod (b); length at maturity (L_m) and age at maturity for herring (c); asymptotic length (L_∞) and length at maturity (L_m) for herring (d); length at maturity (L_m) and age at maturity (A_m) for plaice (e). Data labels are as given in Table 1.

3.1.2. Classification of marine subareas based on life history parameters

The tendency of life history trends of fish stocks in the subareas of FAO fishing area 27 was determined (Table 3) based on the decision matrix analysis. Positive values for the sum of the decision matrix analysis scores were obtained for marine subareas I, II, V and IX, indicating that the fish species that inhabit these areas have *K*-characteristics (Table 3). Negative values for the sum were obtained for subareas III, IV, VI and VII, indicating that the fish in these subareas are *r*-strategists (Table 3).

3.2. Mean trophic level

Changes in mean trophic levels (MTL) for subareas (I + II, III, IV, V, VI, VII, VIII + IX) are illustrated in Fig. 4. The mean MTL for the subareas I + II, V and VIII + IX was higher than the reference level (3.75), indicating these areas are dominated by higher trophic level species. The highest MTL was in subareas I + II. Furthermore in subareas I + II, there was a gradual decline from 1998 to 2008 and an increasing trend after 2008. MTL below the reference levels in the subareas III, IV and VI indicate that high trophic value species were fished out. Although the MTL of subarea VII was below the 3.75 reference level, the values were always in greater than the areas III, IV and VI. Considerable fluctuations in subarea VII were marked and there was a decreasing trend throughout the years.

3.3. FiB index

The calculated values for the FiB index for the subareas I + II changed from negative values to positive values after 2010 (Fig. 5a). Additionally, there was a remarkable increase in the FiB index after 2008 in these two subareas (Fig. 5a). Fig. 5b shows that annual FiB values were negative in the Baltic Sea (except 2000) and the lower values were recorded after 2010. FiB values for the North Sea (Subarea IV) were also negative, except in 2002–2003 (Fig. 5c) and the FiB index for subarea V was negative for many years. However, there was an increasing trend of the FiB index from 2010 (Fig. 5d). Nevertheless, the FiB values always remained negative and there were no increasing trends during recent years for subareas VI and VII (Fig. 5e and f). FiB values for were negative from 1998 to 2007 but became positive after 2008 in subareas VIII + IX.

3.4. Evaluation overall environmental status of marine subareas

Based on the 3 parameters studied, the subareas I, II, V, VIII and IX with *K*-selected fish populations, higher trophic values and an increasing trend of FiB index were assessed as being in “good” environmental status (Table 4). On the contrary, subareas III, IV, VI and VII were dominated with fish populations of *r*-selected characteristics, lower values of MTL and registered decreasing trend of FiB values and as such, these areas were assessed as having “poor” environmental status (Table 4).

4. Discussion

The analysis showed a wide range of life history traits for the fish stocks in different subareas of European maritime states. The status of the fish stocks can be understood on the basis of the life history strategies (Adams, 1980; Fudge and Rose, 2008). Generally, the fish populations in subareas III (Baltic Sea), IV (North Sea), VI (Northwest Coast of Scotland and North Ireland or West of Scotland) and VII (Irish Sea and areas around Ireland and Wales) showed features of *r*-strategies: low age of maturity, low length at maturity and small body sizes. In contrast, the fish populations in the subareas I (Barents Sea), II (Norwegian Sea, Spitzbergen, and Bear Island), V

Table 3
Determination of life history tendency in subareas using decision matrix analysis based on the interrelationships of life history parameters.

Life history relation	Figure number	Fishing subareas							
		I	II	III	IV	V	VI	VII	IX
L_∞/K	2a			+3	−3				
Haddock			+2		−2				
					−1	+1			
L_∞/K	2b		+3		−3				
Saithe						+2−2			
			+1−1						
L_∞/K	2c				−3			+3	
Plaice					−2			+2	
					+1−1				
A_m/TL	3a			−3	+3				
Cod				−2	+2				
				+1−1					
L_m/L_∞	3b		+3	−3					
Cod		+2			−2				
						+1	−1		
A_m/TL	3c		+3	−3					
Herring			+2	−2					
			+1	−1					
L_m/L_∞	3d		+3					−3	
Herring			+2		−2				
				−1				+1	
A_m/TL	3e							−3	+3
Plaice								−2	+2
					−1			+1	
Sum of scores		+2	+19	−12	−14	+2	−1	−1	+5
Life history tendency		*K*	*K*	*r*	*r*	*K*	*r*	*r*	*K*

Note: No decision was made for marine subareas VIII, X, XII and XIV due to non-availability of data; absence of significant relationships between life history parameters or absence of data points at the ends of the plots.

Table 4
Evaluation of overall environmental status of marine subareas.

Subarea	Life history strategy		MTL		FiB index trend		Overall environmental status
	K	*r*	High	Low	Increasing	Decreasing	
I	+		+		+		Good
II	+		+		+		Good
III		−		−		−	Poor
IV		−		−		−	Poor
V	+		+		+		Good
VI		−		−			Poor
VII	+			−		−	Poor
VIII			+		+		Good
IX	+		+		+		Good

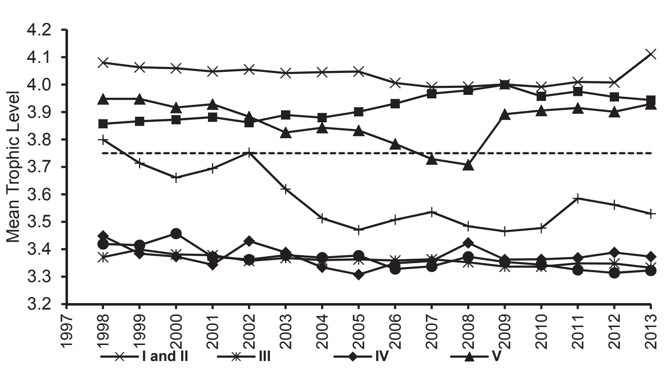

Fig. 4. Mean trophic level variations from 1998 to 2013 in subareas. The reference level (3.75) is indicated a broken line in the plot.

(Iceland and Faroes Grounds) and IX (Portuguese Waters) appear to be *K*-strategists with comparatively higher age and length at maturity, as well as larger body sizes. Multi-stressors affect the environmental conditions for the fish populations in the subareas III, IV, VI and VII, and are characterized by *r*-selected populations. Physical damage to the seafloor is one of the prominent environmental pressures in the subareas III, IV (EEA, 2015) and VI and VII (Foden et al., 2011). Damage to sea-floor integrity (Descriptor 6) causes heavy mortality and physical damage to benthic communities (EEA, 2015), destruction and fragmentation of natural habitats (Airoldi et al., 2008) and recovery takes very long time (EEA, 2015). In addition, pressures causing eutrophication (Descriptor 5) are a feature of the Baltic Sea, the North Sea (EEA, 2015; McQuatters-Gollop et al., 2009) and the seas around UK including subareas VI and VII (EEA, 2015). Excessive fishing pressure in the areas III, IV (Ducrotoy and Elliott, 2008; Piet et al., 2010) and East Atlantic areas (EEA, 2015) make the fish populations less robust. Overfishing of target species and change the predator-prey relationships are responsible for making the marine environments

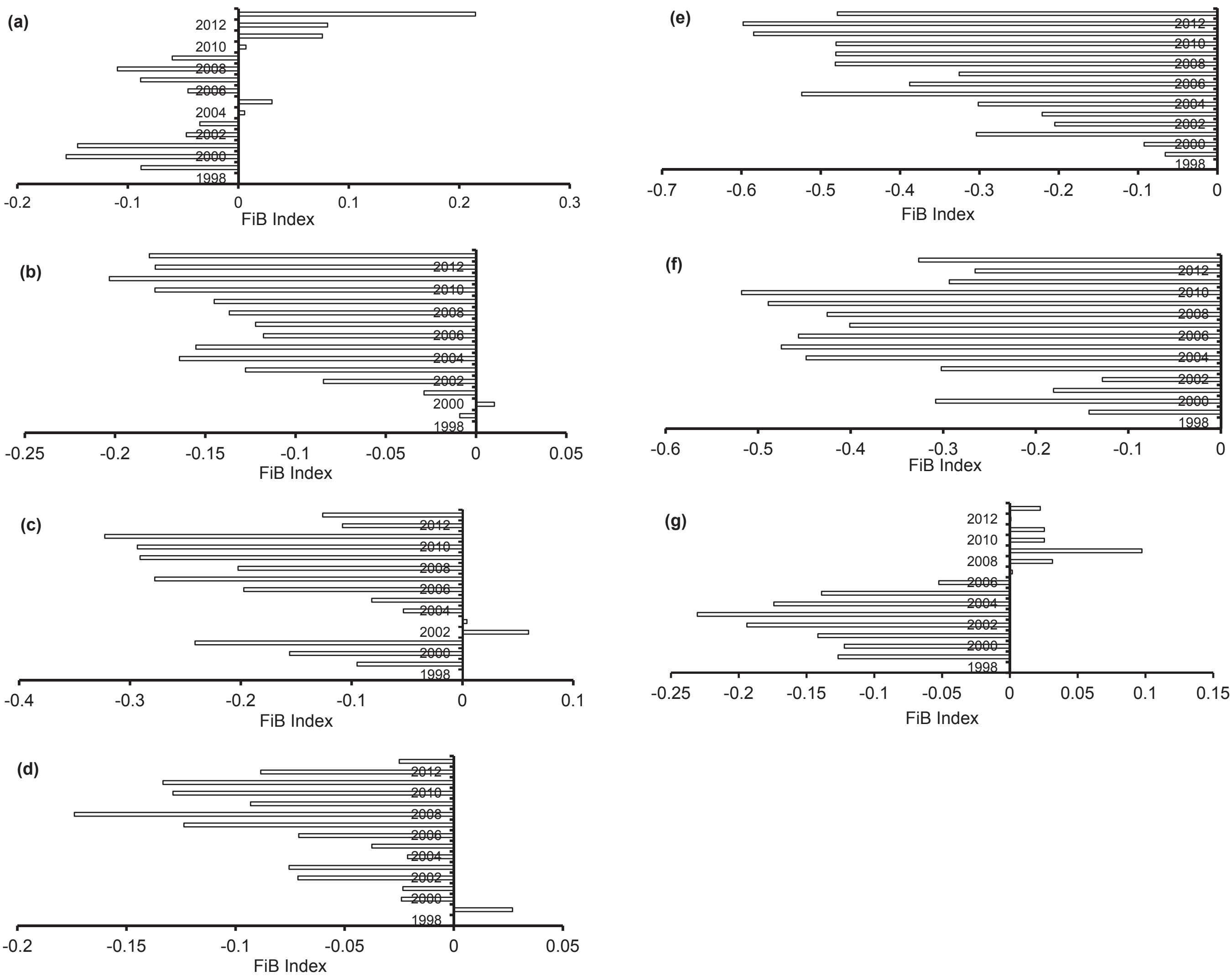

Fig. 5. Changes of values of FiB Index in fishing subareas I + II (a), III (b), IV(c), V (d), VI (e), VII (f) and VIII + IX (g) from 1998 to 2013.

unstable (Pauly et al., 1998; Jackson et al., 2001). Shipping also disturbs commercial species due to transport, release of contaminants and hazardous substances (Descriptor 8), as well as being a vector for non-indigenous species (Descriptor 2) in the Baltic Sea (Piet et al., 2010). Furthermore, the Baltic is a semi-enclosed sea with restricted water exchange (Ducrotoy and Elliott, 2008; McQuatters-Gollop et al., 2009; Tett et al., 2003) and majority of habitats in the seabed and in water column are considered as "unfavorable" status (EEA, 2015). Similarly, the English Channel (subarea VII) is subjected to multiple anthropogenic pressures including shipping, mineral extraction, over-fishing (Martin et al., 2009) contamination of heavy metals (Descriptor 8) and eutrophication (Descriptor 5) (Tappin and Millward, 2015). In the present analysis, *r*-strategists were found in the subareas of III, IV, VI and VII, where multi stressors are common. The subareas where *K*-strategists are found (I, II, V, and IX) experience less physical disturbances, no serious eutrophication, no excessive shipping and fishing (EEA, 2015). They are part of the open Atlantic Ocean, which may provide better environments (Borja et al., 2011; Cristina et al., 2015) for fish populations. Therefore, the fish in these areas (I, II, V, and IX) experience lower pressures and they tend to have *K*-strategists.

In Europe, attempts have often been made to reduce fishing pressure to restore many fish stocks (Villasante and Sumail, 2010), but quantification of the correct total allowable catch (TAC) for majority of fish stocks is still problematic (Proelss and Houghton, 2012). Furthermore, reducing fishing pressure only is not sufficient to recover a fish, (Hutchings and Reynolds, 2004; Hutchings et al., 2012) and it is important to consider the life history of fish stocks to assess their healthiness. The present analysis showed that the life history tendency of European fish stocks could be used in as an indicator for to assess the environmental health of European Seas.

Trophic level based indicators are useful for a more complete understanding of the effects of fishing on the trophic structure of ecosystems (Shannon et al., 2014). MTL is being used as an indicator for evaluating the effects of fishing on the trophic structure of marine ecosystems (Heath, 2005; Shannon et al., 2014). The present study revealed that MTL of fish stocks in subareas I, II, V, VIII and IX were higher than in subareas III (Baltic Sea) IV (North Sea), VI and VII (marine areas around Ireland and Scotland). Subareas III, IV and VI with poor environment quality were occupied by relatively high *r*-strategists according to the life history data analysis of the present study. The areas with low MTL (<3.75) are characteristic of fish communities with a dominance of low trophic level species (Christensen et al., 2003). This may be due to increased fishing pressure towards the high trophic level species in subareas, such as the Baltic Sea (Ojaveer et al., 2010) and the North Sea (Shannon et al., 2014). Since top predators play a vital role in the overall functioning of the food web (Rogers et al., 2010), removal of them systematically from the ecosystem affects all food web functions. Continued fishing pressure on low trophic level species negatively affects marine mammals, sea birds and commercially important fish species (Smith et al., 2011). Not only the fishing pressure, but also the above mentioned anthropogenic pressures (nutrients, contaminants, invasive species, seafloor integrity) directly or indirectly effect on marine food webs structure (Rombouts et al., 2013).

The FiB index (Pauly et al., 1998; Pauly and Palomares, 2005; Pauly and Watson, 2005) is an ecologically important tool to evaluate the exploitation by fisheries at different trophic levels. When there is an increasing trend of FiB, the fisheries can be expanded, whereas when the FiB index decreases, it indicates a geographical contraction of the fishery and/or collapse of the food web (Pauly and Palomares, 2005). Many subareas did not show an increasing trend in the FiB index, including the Baltic (Subarea III), North Sea (Subarea IV), English Channel (subarea VII); therefore those marine environments seem to be in a poor state. Negative trends of the FiB indices in the Arctic (subareas I and II) and Western Seas (VIII and IX) and subarea V from 1998 until 2008–2009 were replaced by more recent positive trends (decreasing negative values), indicating a recovery, perhaps due to concerted efforts by Member States to improve the quality of the environment to achieve GEnS. Guénette and Gascuel (2012) have analyzed the time series data (1950–2008) on fish populations in the Bay of Biscay (subarea VIII) and reported that most fish populations were in danger until 2008. In the present study, the FiB values were also negative until 2008 and thereafter, they changed to positive trends. Guénette and Gascuel (2012) found that, after the formal adoption of the precautionary approach in 1998, the conditions of fish stocks improved mostly after 2008. The adoption of the MSFD and the implementation of management plans may have improved the status of the environment and helped recovery of fish populations. This corroborates the findings of Cardinale et al. (2013) who have indicated that conditions of some of the fish stocks in European region have improved recently.

The effects of global climatic changes on the marine environment and fish populations are also known to occur (Stenevik and Sundby, 2007; Elliott et al., 2015). All the seas in Europe are threatened by climate change (Conversi et al., 2010; Reid and Valdés, 2011) and anthropogenic pressures are altering the key environmental variables supporting fish life, such as temperature, winds, water mixing, oxygen, pH and oxygen, (Brander, 2010; Gattuso et al., 2015). These alterations directly affect physiology, development rates, reproduction, behavior and survival rates of larvae and fishes (Brander, 2010; EEA, 2015). As such, life history parameters and fish catches, which are main data sources for the present analysis can also be affected by these altered climatic conditions. In addition, the marine food web structure and trophic levels may also alter due to climate change (Muren et al., 2005; Cury et al., 2008). However, the time series analysis for MTL in this study was done only for 1998 to 2013, which is insufficient to detect the impact of climatic change. Nevertheless, the above evidence suggests that future directions towards qualitative assessment of the status of European seas should be viewed through the climate change scenarios.

In the present analysis, the subareas of FAO Area 27 were evaluated by a combination of three approaches, which covers two qualitative descriptors of MSFD. This approach provided a clear assessment of the status of the environment of the subareas studied and enabled comparisons among them. Shin et al. (2010) have also used indicator-based marine assessments to evaluate and compare the environmental status in different areas. In addition, the present evaluation was carried out using some commercial fish stocks and we discussed the effect of fishing and other stress factors on fish stocks. Probst et al. (2013) explained the validity of combination of fisheries aspects, ecological interactions and environmental conditions in marine environmental assessments. Frose et al. (2015) also pointed out the necessity of combining anthropogenic pressures for evaluating the overall status of the marine environment. Furthermore, such approaches are useful for defining strategies for fisheries management in the context of ecosystem based fisheries management (Möllmann et al., 2014).

5. Conclusion

The environmental status of various marine subareas was assessed using a combined approach (life history characteristics, MTL and FiB index) and data of important commercial fish populations. The results indicated that the environmental status was good in subareas I, II, V, VIII, IX and poor in subareas III, IV, VI and VII. The present study has shown that the adoption of legal instruments (Water Framework Directive, MSFD and Common Fisheries Policy) and management plans may be improving environmental status, and may support the recovery of fish populations that are at risk.

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