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Evaluating changes in marine communities that provide ecosystem services through comparative assessments of community indicators

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Abstract :

Fisheries provide critical provisioning services, especially given increasing human population. Understanding where marine communities are declining provides an indication of ecosystems of concern and highlights potential conflicts between seafood provisioning from wild fisheries and other ecosystem services. Here we use the nonparametric statistic, Kendall's tau, to assess trends in biomass of exploited marine species across a range of ecosystems. The proportion of 'Non-Declining Exploited Species' (NDES) is compared among ecosystems and to three community-level indicators that provide a gauge of the ability of a marine ecosystem to function both in provisioning and as a regulating service: survey-based mean trophic level, proportion of predatory fish, and mean life span. In some ecosystems, NDES corresponds to states and temporal trajectories of the community indicators, indicating deteriorating conditions in both the exploited community and in the overall community. However differences illustrate the necessity of using multiple ecological indicators to reflect the state of the ecosystem. For each ecosystem, we discuss patterns in NDES with respect to the community-level indicators and present results in the context of ecosystem-specific drivers. We conclude that using NDES requires context-specific supporting information in order to provide guidance within a management framework.

Highlights

► This indicator gauges ability of an ecosystem to sustainably provide wild seafood. ► This indicator provides a simple way to focus on exploited species in an ecosystem. ► Multiple drivers of impact necessitate a suite of indicators to provide context.

Keywords : Ecological indicator, Comparative approach, Community metric, IndiSeas, Fishing impacts

Introduction

Oceans provide important ecosystem services for human well-being, including provisioning services (e.g., procurement of seafood and medicinal products), regulating services (e.g., moderation of climate fluctuations and protection against flooding and erosion), cultural services (e.g., aesthetic and spiritual benefits, and recreation), and supporting services (e.g., nutrient cycling, carbon storage, and trophic stability) (Worm et al. 2006, Daniel et al. 2012). The provision of seafood from wild capture fisheries is one of the most critical benefits that humans derive from the ocean and as such, the regulation of commercial harvests of fish stocks has become a priority. Additionally, there has been a concerted effort to measure and regulate other ecosystem services that may have negative impacts on fisheries (e.g., balancing conservation objectives underlying ecotourism) through marine spatial planning (Foley et al. 2010), better valuation (Börger et al. 2014) and analyses of the synergies and trade-offs (Halpern et al. 2012) of marine ecosystem services. However, while declines in some fisheries have been halted or some fish stocks have recovered due to precautionary fisheries management or reduced exploitation rates (Worm et al. 2009), many exploited stocks around the world are in decline due to a combination of stressors such as overfishing, pollution, habitat degradation, and climate change. These stock declines result in fisheries yields, which are less than optimal and ultimately can lead to stock collapse. This is of growing concern due to the direct impacts on food security for over three billion people who rely on fisheries to supply a significant portion of their animal protein (FAO 2014). Fishing represents one of the most significant human impacts on marine ecosystems and has led to many changes including alterations of the trophic structure, declines in the abundance of top predators, biodiversity, and overall resilience and biomass of some ecosystems (Pauly et al. 1998, Jackson et al. 2001, Christensen et al. 2003, Perry et al. 2010, Jackson et al. 2011). Additionally, the spatial footprint of fishing has continued to increase as fisheries have expanded offshore (Coll et al. 2008a, Swartz et al. 2010) and into deeper waters (Morato et al. 2006). These expansions have often been facilitated by the use of increasingly sophisticated fishing technology (Pauly et al. 2002). These remarkable technological improvements have resulted in fleets that are more efficient (Pauly & Palomares 2010) and more powerful (Anticamara et al. 2011) than at any time in the past. However, this has not led to increased catches but rather a stagnation or even slow decline in the overall global catch (FAO 2014), threatening the delivery of this critical ecosystem service.

Traditionally, fish stocks have been assessed and managed as single units, with little consideration for the linkages with other components of the ecosystem. However, there is a growing push to manage fish stocks cohesively as one aspect of an ecosystem-based approach to marine management (Link et al. 2002, Garcia 2009). This is in line with the objectives of several international conventions such as the Convention on Biological Diversity (CBD 2010) and regional legislations such as the European Marine Strategy Framework Directive (EU Directive 2008/56/EC) or the EU Common Fisheries Policy (European Commission 2013). An ecosystem approach to management requires the development of indicators and robust methods to gauge changes in marine ecosystems. This requires indicators of ecosystem change that are easy to interpret in order to measure the impacts of fishing, climate change, and other factors across ecosystems and to provide management guidance at an ecosystem level.

However, the development of robust and reliable marine indicators is still in its infancy, and multiple indicators may be necessary to capture changes in different components of the community and to provide a more complete understanding of ecosystem status (Shin et al. 2010b, Bundy et al. 2012). For example, trophic level indicators calculated for different portions of the ecosystem (e.g., surveyed biomass vs. landings) can provide differing views of the status of the ecosystem (Shannon et al. 2014) and highlight places where trophic instability may be affecting the delivery of provisioning and/or regulating ecosystem services. The need to interpret multiple ecosystem indicators to obtain a more complete understanding of the status of the system is particularly important in an ecosystem services framework since the majority of ecosystem indicators currently available are not comprehensive and are often inadequate to characterize ecosystem services when used alone (Liquete et al. 2013, Piroddi et al. In Review).

Here we test an indicator, which has been proposed as a 'simple community analysis' (Lynam et al. 2010), and which can be interpreted in terms of trends and correlations of multiple species at the community-level, for use as a gauge of the ability of an ecosystem to deliver provisioning services. This measure was originally developed and demonstrated using fish survey and phytoplankton count data from waters off the west coast of Ireland (Lynam et al. 2010). The indicator is based on a nonparametric test statistic, Kendall's tau (Kendall & Gibbons 1990), which is used to determine the strength of declining or non-declining trends in a set of time series of species biomass from the comparison of theoretical and observed distributions of the statistic. We also assess the proportion of non-declining species across several ecosystems.

Similar to Lynam et al. (2010), we use this statistic in a simple community analysis approach to explore biomass trends for exploited species within ecosystems and to estimate the proportion of non-declining exploited species biomass, the 'Non-Declining Exploited Species' (NDES) indicator. The rationale for exploring non-declining trends, rather than the proportion of declining trends, is to have an indicator that should have a lower value at higher levels of fishing pressure (i.e., more declining biomass trends with higher exploitation rates), in line with other ecological indicator formulations selected for comparing the effects of fishing across ecosystems (Shin et al. 2010b). Cross-ecosystem comparisons of the NDES indicator are possible because it accounts for the distinct number of species and differing length of the time series data available in each ecosystem. First, we illustrate, based on the full set of single exploited species trends for each ecosystem, the proportion of non-declining species and compare the indicator values between ecosystems. Second, in order to understand the patterns in NDES, which provides information specific to the exploited portion of the community, we compare NDES to three community-level indicators that provide a gauge of the ability of a marine ecosystem to function both in a provisioning role and as a regulating service (i.e., through maintenance of biodiversity, trophic stability, and reproductive potential): proportion of predatory fish (PPF), survey-based mean trophic level (TLsc), and mean life span (mLS), which were described by Shin et al. (2010b). In particular, the utility of trophic level indicators for capturing the health and status of different components of the marine community has been explored in detail by Shannon et al. (2014). We use these indicators to determine whether exploited species biomass is associated with other ecosystem-level changes. These particular indicators were selected because (a) data to compute the indicators for each ecosystem were available, (b) they are more integrative as they include all survey species as opposed to looking only at the exploited portion of the community, and (c) they are species-based like the NDES, but also account for different functional traits within the greater community. Each of these indicators is also formulated such that greater fishing pressures results in lower indicator scores.

Methodology

Ecosystems

We analyze 22 marine ecosystems spanning upwelling, high-latitude, temperate, and tropical marine habitats across the world's oceans (Table 1). They comprise the Barents Sea, the Bay of Biscay, the central Baltic Sea, the eastern Bering Sea, the eastern Scotian Shelf, the English Channel, the Guinean Shelf, the Gulf of Cadiz, the Irish Sea, the north Aegean Sea, the northern Humboldt Current, the north Ionian Sea, north-central Adriatic, the northeast U.S., the North Sea, the Portuguese coast, the south Catalan Sea, the southern Benguela, the Scottish west coast, the U.S. west coast, the west coast of Vancouver Island (hereafter referred to as Vancouver Island), and the western Scotian Shelf. The 22 ecosystems assessed here have been selected because multiple trends of species biomass from biological surveys or stock assessments are available through the IndiSeas international initiative (Shin et al. 2012; www.indiseas.org). The majority of these ecosystems were described and explored in a series of papers resulting from the IndiSeas project (Coll et al. 2010b, Shin et al. 2010b, Bundy et al. 2012). The number of species with biomass time series available for analysis and the average timespan over which the biological surveys and stock assessments were conducted vary greatly between ecosystems (Table 1). The northeast U.S. shelf has both the greatest number of available biomass time series (124) and the longest survey duration (47 years). Conversely, the north Ionian Sea has the fewest number of time series (5) and the north Aegean Sea has the shortest survey duration (4 years). The full list of species assessed in each ecosystem, length of time series, Kendall's tau correlation coefficient of exploited species biomass time series, and the relative proportional contribution of each species' average biomass to the overall average exploited biomass available in each ecosystem is presented in Table S1 in the Supplementary Information.

Calculating the Non-Declining Exploited Species (NDES) indicator

Lynam et al. (2010) used the Kendall's tau correlation coefficient to quantify the degree of association between the species biomass as measured from a biological survey (*X* variable) and the time series of years over which the survey was conducted (*Y* variable). Kendall's tau is a measure of the strength of the tendency of these two variables, *X* and *Y* to move in the same (or opposite) direction. That is, the estimates of tau in a set of species provide a probability of having a monotonic temporal trend in the biological data. Lynam et al. (2010) noted that one of the strengths of such a rank-based method over other parametric methods (e.g., Pearson's product moment correlation coefficient) is that the relationship between the measured variables does not have to be linear and does not rely on any assumption about the distribution of the variables.

Here, we take the same approach, calculating the Kendall's tau coefficient for each exploited species in an ecosystem with time series of biomass data (Table 1). The rationale is to build an indicator which would be simple to estimate, and easy to communicate, reflecting what proportion of exploited species have their biomass increasing or decreasing in each ecosystem, potentially as a result of fishing. Each tau is calculated by examining the difference between consecutive years and the corresponding consecutive biomass values (Lynam et al. 2010). If the differences are both positive, then this demonstrates an increase in biomass. By looking at all pairs in a time series within an ecosystem, one can determine whether the biomass over the time series is generally increasing or decreasing. The higher the proportion of concordant or discordant pairs, the stronger the increase or decrease, respectively. This procedure results in a measure of the probability of an increasing biomass trend (tau) for each exploited species from biological surveys or stock assessments in an ecosystem. A histogram of the resulting distribution of all Kendall's tau coefficients within an ecosystem allows a comparison of the observed distribution of tau with the theoretical expected distribution to assess whether there is a significant monotonic trend. An observed distribution of the statistic tau that is shifted to the left of the expected theoretical distribution indicates an ecosystem with more species with declining biomass than expected by chance alone. The converse is true for an observed distribution shifted to the right of the expected theoretical distribution.

Because we are interested in determining whether the NDES indicator is significantly high (i.e., more non-declining trends) or low (i.e., more declining trends), we formally test whether the observed distribution of the statistic tau is shifted to the right or left of the theoretical expected distribution with a two-tailed nonparametric Kolmogorov-Smirnov (KS) single-sample goodness-of-fit test. The null hypothesis tested is that there is no difference between the observed distribution and the expected distribution. The KS significance test takes into account the number of species and the differing length of the time series in the calculation of the theoretical expected distribution (red line in Figure 1). An ecosystem with few species trends, but a long time series will have a more leptokurtic distribution than an ecosystem with few species trends with short time series. The proportion of non-declining biomass of exploited species out of the total number of exploited species biomass trends in an ecosystem (as determined from this method) is taken to be the state indicator we call 'Non-Declining Exploited Species' (NDES).

Kendall's tau and associated analyses were conducted in R version 3.0.2 (R Core Team 2013) using the packages 'stats', and 'SuppDists' (Wheeler 2009).

Supplemental community-based indicators

We conducted several analyses to compare the NDES indicator directly with the status and trends of three other community indicators including proportion of predatory fish (PPF), average trophic level of the surveyed community (TLsc), and mean lifespan (mLS). These indicators were selected from the set of IndiSeas indicators chosen according to a carefully defined set of criteria (Shin et al. 2012) because they were available for the majority of the ecosystems presented here. Additionally, they are important indicators of ecosystem status and trend and have been noted to be effective at capturing different aspects of ecosystem functioning such as the state of turnover processes, predator-prey dynamics, and trophic composition (Shin et al. 2010b, Shin & Shannon 2010, Bundy et al. 2012, Shannon et al. 2014). The PPF is calculated as the ratio of the biomass of predatory fish species surveyed to the total biomass surveyed and TLsc is calculated as the biomass-weighted average trophic level of the total surveyed community. The PPF and TLsc are designed to capture the effect of fishing on larger and higher trophic level species in the ecosystem. The mLS is calculated as:

$$\sum_s (age_{MAX,s} \cdot B_s) / \sum_s B_s$$

where B_S is the survey biomass estimate for a given species s and $age_{MAX,s}$ is the maximum longevity of the species. This indicator is used as an inverse proxy for turnover rate and conveys the idea that fishing favors the emergence of species with a short lifespan (Shin et al. 2010b). The three indicators hence reflect changes in different facets of functional diversity (Bundy et al. 2010) and capture more of the ability of the ecosystem to act in a regulating role through the maintenance of biodiversity, trophic stability, and reproductive potential.

In contrast to the NDES indicator, which looks specifically at the biomass of the exploited component of the ecosystem, mLS, PPF, and TLsc, are calculated on the full suite of surveyed species biomass (i.e., surveyed biomass of exploited and non-exploited species) in a given ecosystem (Shin et al. 2010b). Because the indicators were designed to capture different components of the state of the ecosystem, we do not necessarily expect to find correlations between the indicators, but we illustrate similarities and differences between the indicators and provide some context for the patterns observed in each ecosystem.

First, for each ecosystem we compare the NDES indicator with the current state of each of the community indicators (PPF, TLsc, and mLS) using petal plots. The state for each of the three community indicators is calculated as the average of the most recent five years for which data were available (for most systems this was 2006-2010). Thus, the 'current state' of the ecosystem with regard to these three community indicators is compared directly with the NDES indicator (i.e., the proportion of exploited species with non-declining biomass in each ecosystem). For each of the 22 ecosystems the values for the four indicators are rescaled between 0 (worse state) and 1 (better state) in order to allow for comparison between indicators and between ecosystems. Each of the indicators used in the analyses presented here are designed such that higher fishing pressure should result in a lower indicator score (Shin et al. 2010b).

Next, for each ecosystem, we also evaluate the correlation over time of the three ecosystem indicators (PPF, TLsc, and mLS) with the biomass time series for each exploited species that were used to calculate the NDES. We perform this comparison again using the Kendall's tau correlation coefficient to quantify the degree of association between the times series of exploited species biomass from the survey (X variable) and each time series of ecosystem indicator values (Y variable). These comparisons are calculated for all years in which both biomass values and ecosystem indicator values exist. Here, in contrast to the Kendall's tau calculated for the NDES indicator, we used a two-tailed binomial test to assess the significance of the hypothesis that there are more positive or negative correlations between the biomass trends and the three community indicator values than would be expected by chance. Because we are looking at pairwise changes in the community indicator values and the biomass of an exploited species, we are assessing the trajectories of the time series, rather than correlating linear trends (i.e., slopes). A positive correlation indicates that the exploited biomass trends are following the same trajectory as the community indicator trends (i.e., increasing or decreasing). We present the proportion of positively correlated trends per ecosystem and term proportions greater than 0.5 'positively correlated' (i.e., more similar trajectories) and proportions less than 0.5 'negatively correlated' (i.e., more opposing trajectories). In order to determine whether the community indicators are positively or negatively correlated to biomass trends (i.e., decreasing/increasing community indicator associated with decreasing/increasing biomass trends), we calculate the slopes of each of the community indicators based on the complete time series of normalized indicator values (i.e., standardized by subtracting the mean and dividing by the standard deviation) for each ecosystem using generalized least-squares models with autoregressive errors following Blanchard et al. (2010). These slopes are used to further investigate the relationships between the trends in exploited species biomass and the community indicators.

Finally, in order to better understand the state and trend patterns in the NDES indicator and the three community indicators, we examine the biomass trends of the exploited species within an ecosystem with respect to the species trophic level (local values provided by IndiSeas experts or determined from FishBase, www.fishbase.org, see Table 1S). The rationale for this exploration is to evaluate whether there is a greater proportion and number of declining trends for lower or higher tropic level species. Thus, we compute the biomass-weighted average trophic level of the exploited species with declining biomass and compare that to the biomass-weighted average trophic level of the exploited species with non-declining biomass in a given ecosystem. Because each ecosystem will have a different composition of species with varying trophic levels that is related to factors specific to the particular ecosystem (e.g., levels of primary productivity, exploitation history, oceanography, etc.), we define 'lower' or 'higher' trophic levels on a relative basis within an ecosystem, and we do not compare these values between ecosystems. However, we explore whether ecosystems with a higher proportion of declines of higher trophic level exploited species tend to have lower scores for the ecosystem indicators.

Results & Discussion

The Non-Declining Exploited Species (NDES) Indicator

Histograms of Kendall's tau statistic indicate the distribution of negatively (decreasing; white portion of histogram bars) and positively (increasing; grey portion of histogram bars) correlated biomass trends for the exploited species in each ecosystem (Figure 1). Based on the proportion of non-declining trends (i.e., the NDES indicator), we find that in 10 out of the 22 ecosystems, more than half of the exploited species trends are significantly non-declining (Table 1; NDES > 0.5, p-value < 0.05). Most biomass trends are not declining for exploited species (i.e., higher NDES values) in the English Channel, the south Catalan Sea, the eastern Bering Sea, the southern Benguela, the western Scotian Shelf, the North Sea, the northeast U.S., Vancouver Island, the Portuguese coast, and the Barents Sea (ordered from lower to higher NDES values). We find that the observed values of the tau statistic in these ecosystems are shifted to the right of the expected theoretical distributions (red lines), indicating that there are fewer species declining in biomass than should be expected by chance alone.

Nine ecosystems have significantly more species that show declining biomass trends (Table 1; NDES < 0.5, p-value < 0.5), including the Guinean Shelf, the north Ionian Sea, the Gulf of Cadiz, the Bay of Biscay, the north-central Adriatic, the eastern Scotian Shelf, the Irish Sea, the U.S. west coast, and the north Aegean Sea (ordered from lower to higher NDES values). We find that the observed values of the tau statistic in these ecosystems are shifted to the left of the expected theoretical distributions (red lines), indicating that there are more species with a declining biomass than should be expected by chance alone. Note that the U.S. west coast and the north Aegean Sea ecosystems have relatively short time series (8 and 4 years, respectively), which results in expected theoretical distributions of the tau statistic that are broader and flatter compared with the rest of the ecosystems. It is expected that the variance of the expected distributions of the tau statistic should increase as the length of the time series of biomass decreases, which is a weakness of the indicator. The NDES indicator is non-significant in the central Baltic Sea, the northern Humboldt Current, and the Scottish west coast.

Comparison of the NDES indicator with community status indicators

The current status for the three community indicators and the NDES indicator vary greatly among ecosystems (Figure 2). In some ecosystems, the scores for all four indicators are relatively high (e.g., the eastern Bering Sea, the northeast U.S. and Vancouver Island) suggesting these ecosystems have a better ecosystem state overall. In other cases, the scores are all relatively low (e.g., the central Baltic Sea, the Gulf of Cadiz, the Irish Sea, the north Ionian Sea, the north Aegean Sea, and the northern Humboldt Current), suggesting a worse ecosystem state on average. For other ecosystems the NDES indicator contrasts with the results of the community-level indicators (e.g., the Bay of Biscay) suggesting that patterns in the exploited portion of the community are not reflected in the whole community.

The composition of the trophic levels of the species that are declining within an ecosystem can provide some insight as to why the NDES scores might be higher or lower than the status of the community indicators (Figure 3) and can help illustrate the similarities between the patterns in the exploited species versus the whole community. For example, the north-central Adriatic receives a high score for TLsc. However, the proportion of non-declining species is 29%, resulting in a low NDES score. This discrepancy can be explained by the fact that the biomass-weighted average trophic level of the declining species is lower (~3.1) relative to the biomass-weighted average trophic level of the species that are not decreasing (~3.75), indicating that lower trophic level species in the system are the ones declining and resulting in a higher TLsc. However, the fact that the average trophic level of these species is less than 4 suggests that large predatory fish are not abundant in the north-central Adriatic, which may point to why the scores for PPF and mLS are also lower (Coll et al. 2009, Coll et al. 2010a). Similar trophic level patterns are found for the Bay of Biscay, which is strongly over-exploited (Guénette & Gascuel 2012) and where the PPF status is high relative to the lower scores for the NDES indicator. These discrepancies can be explained by the fact that the biomass of lower trophic level species is declining.

The north Ionian Sea has the lowest status scores (i.e., 0) for the three community indicators and the NDES indicator. In this ecosystem, there are few exploited biomass trends, which are used to calculate the NDES indicator and all are declining according to the Kendall's tau statistic (Figure 1, Table 1). Additionally, the average trophic level of the exploited biomass is around 3.2, which is relatively low. This ecosystem, like many regions in the Mediterranean (e.g., south Catalan Sea: Coll et al. 2008b), is dominated by lower trophic level organisms (especially invertebrates and small pelagic fish) due to historic and current heavy fishing pressure (Piroddi et al. 2010). This situation also occurs in other heavily exploited Atlantic ecosystems, for example in the Gulf of Cadiz (Torres et al. 2013). The reduction in the trophic level of the overall ecosystem is reflected in the low status of the community indicators.

The Barents Sea provides an example of a higher score for the NDES indicator and a lower score for the community indicators. In the Barents Sea, nine out of 11 biomass trends are non-declining and the biomass-weighted average trophic level of the declining exploited species is lower. In this case, the NDES indicator does not reflect what is happening in the overall system. However, the Barents Sea is an ecosystem where stocks of short-lived small capelin (*Mallotus villosus*) and transient stocks of young herring (*Clupea harengus*, 0-4 years old) are major drivers for the top predators (Hjermann et al. 2010, Johannesen et al. 2012). These stocks show large natural fluctuations over relatively short time periods. During the 38 years of survey data analyzed here, capelin has fluctuated between very low biomass levels (Gjøsæter et al. 2009) and the highest peak in history (within the last 10 years) followed by natural declines one to two years after each peak. This pattern is likely causing a temporary reduction in the TLsc even if the long-lived, top predator species show a concurrent increase over the same period. Similar to the Barents Sea, the NDES scores for the Portuguese coast, southern Benguela, and the south Catalan Sea are also higher than the status of the community indicators, with fewer declining species trends. However, in these cases there are fewer declining exploited biomass trends, and it is mainly biomass of higher trophic level fish that is decreasing (Figure 3), corresponding to the lower scores for TLsc, PPF, and mLS, and in line with independent observations (e.g., the south Catalan Sea: Coll et al. 2008b).

For the English Channel and the western Scotian Shelf, there are more exploited species biomass trends that are not declining, but there is still a relatively large number of declining species compared to other ecosystems. In both ecosystems, the declining species have a lower average trophic level. For the western Scotian Shelf, the average trophic level of the species that are not declining is > 4, corresponding to a higher TLsc, which is at odds with the low scores for PPF and mLS. This is because Atlantic herring (*Clupea harengus*), a declining, exploited species with a relatively low trophic level, constitutes a large part of the surveyed biomass (~68%, Table S1). Conversely, for the English Channel, the PPF score is very high, especially given the fact that the average trophic level of the declining and non-declining species is lower and quite similar (~3.5 versus ~3.75). The fact that the average trophic levels of the declining and non-declining species are lower corresponds with the lower mLS and TLsc. Additionally, the English Channel is characterized by a regime shift that affected the fish community in mid-1990s, which was illustrated both by a declining biomass of small forage fish and an increasing biomass of large demersal fish (Auber et al. Submitted).

In some cases, the trophic level of the declining species does not adequately explain the discrepancy between the NDES indicator scores and the three community indicators. For example, on the U.S. west Coast, the biomass-weighted average trophic level of the declining species is close to that of non-declining species.

However, declining trends in biomass and mean trophic level of the surveyed species have been attributed to climate variability and attenuating mortality of a strong 1999 year class for multiple species targeted by the groundfish fishery (Keller et al. 2012, Tolimieri et al. 2013). Because overfishing is not the main driver of the trends in biomass, it is not surprising that the four indicators do not show perfect correlations. The score for mLS is very high due to long-lived rockfish species. In contrast the scores for the NDES, PPF, and TLsc indicators are lower compared to other ecosystems. Lower PPF and TLsc scores are due in part to the three most abundant species in the survey: Pacific hake (*Merluccius productus*), Dover sole (*Microstomus pacificus*), and longspine thornyhead (*Sebastolobus altivelis*). The diet of Pacific hake is dominated by euphausiids (Robinson 2000), while Dover sole and longspine thornyhead consume primarily benthic invertebrates (Gabriel & Pearcy 1981, Rooper & Martin 2009)—none of these species are considered predatory by the PPF index. For the Guinea Shelf, the scores for PPF are higher than the other indicators, although the scores across all indicators are quite low. The low score for the NDES indicator is a result of declines in all 20 biomass trends available. The biomass-weighted average trophic level of these declining species is just under 3.5, which corresponds to the low TLsc and mLS scores, but suggests that the PPF score should be lower.

There are three ecosystems for which the NDES indicator is not significant: the central Baltic Sea, the northern Humboldt Current, and the Scottish west coast. The NDES indicator for each of these ecosystems is close to 0.5, indicating that the proportions of increasing and decreasing exploited species are relatively even. In the central Baltic Sea and the northern Humboldt Current, the NDES indicator has a higher status than the community indicators. In the central Baltic Sea, lower trophic level clupeids (sprat and herring) are the dominant species in the system in terms of overall abundance (Eero 2012). In contrast, there is only one abundant higher trophic level predatory marine fish (Atlantic cod, *Gadus morhua*), which is also the most valuable and therefore heavily exploited species in the Baltic, and moreover subject to climate-related fluctuations (Eero et al. 2011). A possible explanation for the lower PPF and TLsc scores in the central Baltic is the climate-initiated regime shift in this ecosystem at the end of the 1980s, which resulted in a strong decrease in the cod population and a substantial increase in the abundance of clupeids likely due to reduced predation by cod (e.g., Möllmann et al. 2009, Eero 2012, Tomczak et al. 2013).

Similarly, for the Northern Humboldt, the decrease in mLS and TLsc during the study period responds to the recovery of the short-lived anchoveta (*Engraulis ringens*) after El Niño 1997-98. Because of the dominance of this species in this upwelling ecosystem, a reduction of mLS and TLsc likely corresponds to an increase in ecosystem health, highlighting the need for a context-specific approach to interpreting these indicators. In contrast, on the Scottish west coast, no regime shift has been identified, but large demersal fish (haddock: *Melanogrammus aeglefinus*, pollack: *Pollachius pollachius*, squids: *Lophius* species, flatfishes: Pleuronectiformes) and predators (rays and skates) have also shown an increase in the late 1990s

(Bailey et al. 2011, Alexander et al. In Press). These increases occurred in the absence of large declines in important small forage fish species such as herring and mackerel (*Scomber scombrus* and *Trachurus trachurus*), although sprat (*Sprattus sprattus*) and sandeels (*Ammodytes tobianus*) have declined.

Comparison of the NDES indicator with community indicator trends

Comparing the exploited single species biomass trends directly with the trends in the three ecosystem indicators, i.e., PPF (Figure 4), TLsc (Figure 5), mLS (Figure 6) we obtain insights as to which ecosystem indicators are positively or negatively correlated with the NDES indicator. An understanding of the direction of the correlation between the community indicators and the exploited species biomass trends allows us to determine whether the patterns in the exploited community are reflected in the overall community (i.e., a positive correlation). When there are negative correlations between the NDES and the community indicators, this may be an indication that different pressures or drivers (e.g., climate change) may be affecting different segments of the community. We explore this possibility in the context of the trophic structure of the exploited community (i.e., Figure 3). Additionally, we explore the overall significance of the temporal trend in each of the community indicators for each ecosystem. When we see significant trends in the indicator time series, we can directly infer the relationship between correlations in the exploited species biomass time series and the ecosystem indicator of interest, i.e., whether patterns in the exploited community are also picked up in the overall community.

The PPF is significantly positively correlated with the majority (i.e., more than half) of exploited species biomass trends in 16 ecosystems (Table 2, Figure 4). This suggests that the trajectory of exploited species biomass corresponds to the trajectory of the proportion of predatory fish in these ecosystems. These positive correlations occur in the Barents Sea, the eastern Bering Sea, the eastern Scotian Shelf, the English Channel, the Gulf of Cadiz, the Irish Sea, the north Aegean Sea, the northern Humboldt Current, the north Ionian Sea, the north-central Adriatic, the North Sea, the southern Benguela, the south Catalan Sea, the U.S. west coast, Vancouver Island, and the western Scotian Shelf. For three of these ecosystems, the Barents Sea, the English Channel, and the western Scotian Shelf, the trend in PPF is significantly increasing (Figure 7) and most of the exploited biomass trends are also increasing (Table 1, NDES: 0.82, 0.55 and 0.60 for the Barents Sea, the English Channel, and the western Scotian Shelf, respectively). Similarly, for the eastern Scotian Shelf, the northern Humboldt Current, the Gulf of Cadiz, and the north Ionian Sea, less than half of the exploited species biomass trends are declining (Table 1, NDES: 0.37, 0.40, 0.08, and 0, respectively). For the southern Benguela and the south Catalan Sea, the linear trend in PPF is significantly decreasing (Figure 7), but the majority of exploited species have positive biomass trends (Figure 1). This discrepancy is better explained by the fact that the exploited species with declining biomass in these ecosystems have higher average trophic levels than the non-declining exploited species (Figure 3). For ecosystems with a significant trend in the

NDES indicator based on the *p*-value of the Kendall's tau statistic (Table 1), but without a significant relationship in the PPF trend (the eastern Bering Sea, the Gulf of Cadiz, Irish Sea, north Aegean, and U.S. west coast), a signal may be present in the exploited portion of the community that is masked in the overall community. For example, in the eastern Bering Sea, changes in climatic patterns that have influenced summer bottom temperatures have been associated with declines in commercially exploited Alaska pollock (*Theragra chalcogramma*), and increases in predatory arrowtooth flounder (*Atheresthes stomias*), for which there is little commercial exploitation (Zador et al. 2011, Hunsicker et al. 2013).

Four ecosystems: the Bay of Biscay, the Guinean Shelf, the northeast U.S., and the Scottish west coast, have negative correlations between PPF and the available biomass trends (i.e., less than half of the exploited species biomass trends are positively correlated with PPF; Table 2, Figure 4). This suggests that the trajectory of exploited species biomass contradicts the trajectory of the proportion of predatory fish in these ecosystems. There is a significant decreasing trend in the PPF indicator over time for the northeast U.S. (Figure 7) and more exploited species that are not declining (Table 1, NDES: 0.75). Conversely, there is a significant increasing trend in PPF for the Scottish west coast (Figure 7) and more exploited species that are declining (Table 1, NDES: 0.45). The biomass-weighted average trophic levels corroborate these patterns (Figure 3). For the northeast U.S., although there are fewer species with a declining biomass, the average trophic levels of both the declining and non-declining species are relatively high (~4), suggesting that there is a greater proportion of higher trophic level predatory fish are experiencing declines. For the Scottish west coast, the biomass-weighted average trophic level of the declining exploited species is lower than the non-declining species, suggesting that higher trophic level species are being less affected by fishing or other drivers. This is likely due to the introduction of the cod recovery plan in 2004 (EU 2004), which reduced direct fishing mortality on demersal fish in the mixed fishery, although it did not have the intended effect of an increase in the cod stock on the Scottish west coast (Bailey et al. 2011, Alexander et al. In Press).

The trophic level of the surveyed community (TLsc) indicator is significantly and positively correlated with the biomass trends in 9 ecosystems (Table 2, Figure 5): the Bay of Biscay, the eastern Scotian Shelf, the English Channel, the Guinean Shelf, the Irish Sea, the north-central Adriatic, the south Catalan Sea, the U.S. west coast, and Vancouver Island. This suggests that the trajectory of exploited species biomass corresponds to the trajectory of the average trophic level of the surveyed community in these ecosystems. The NDES is higher in the English Channel, the south Catalan Sea, and Vancouver Island (Table 1, NDES: 0.55, 0.56, and 0.77, respectively). However, there are no significant trends in the normalized TLsc time series for these three ecosystems (Figure 7). There are significant negative correlations in the TLsc time series for the eastern Scotian Shelf, the north-central Adriatic, and the U.S. west coast, confirming the positive correlation between exploited species with declining biomass trends and declining TLsc. Additionally, for the eastern Scotian Shelf and the U.S. west coast, the biomass-weighted mean trophic level of the declining species is slightly higher than the biomass-weighted mean trophic level of the non-declining species (Figure 3).

The TLsc indicator is significantly and negatively correlated with the exploited species biomass trends in eight ecosystems: the eastern Bering Sea, the Gulf of Cadiz, the northern Aegean Sea, the north Ionian Sea, the northeast U.S., the North Sea, the southern Benguela, and the western Scotian Shelf (Table 2, Figure 5). This suggests that the trajectory of exploited species biomass contradicts the trajectory of the average trophic level of the surveyed community in these ecosystems. There are more exploited species with declining trends in the Gulf of Cadiz, the north Aegean Sea, and the north Ionian Sea (Table 1, NDES: 0.08, 0.44, and 0, respectively). The normalized time series trend in TLsc is significantly increasing only for the north Ionian Sea and the western Scotian Shelf. For the western Scotian Shelf, examining the biomass-weighted average trophic level does not provide an explanation for the negative correlation between the exploited biomass trajectories and the TLsc trajectories. In this case the average trophic level of the declining species is lower (Figure 3) due to the high proportion of herring in the biomass, which supports the significant declining slope of the TLsc trend in this ecosystem. There are significant declining trends in the normalized time series of TLsc for the southern Benguela and the North Sea, supporting the negative correlation between the exploited biomass trajectories (Table 1, NDES: 0.59) and the TLsc trajectories. Additionally, the biomass-weighted average trophic level of the declining species is higher than that of the non-declining species in both of these ecosystems, suggesting that the patterns in the exploited species are mirrored in the community indicator.

The mean life span (mLS) indicator is significantly positively correlated with the biomass trends in nine ecosystems (Table 2, Figure 6). This suggests that the trajectory of exploited species biomass corresponds to the trajectory of the mean life span in these ecosystems. In the eastern Scotian Shelf, the Guinean Shelf, the Gulf of Cadiz, the northern Humboldt Current, and the north Ionian Sea ecosystems the NDES indicator is lower (Table 1, NDES: 0.37, 0, 0.08, 0.40, and 0, respectively), and we see significant declines in the slopes of the trends for mLS for all of these systems, with the exception of a non-significant decline for the Guinean Shelf (Figure 7), confirming the positive correlations found with the Kendall's tau analyses. There are more non-declining trends in the English Channel, the northeast U.S., the southern Benguela, and the south Catalan Sea (Table 1, NDES: 0.55, 0.75, 0.59, and 0.56, respectively). In the northeast U.S., there is a lower proportion of declining exploited species (Table 1, NDES: 0.25) and the trend in mLS is increasing significantly (Figure 7), confirming the positive correlations found with the Kendall's tau analyses. However, for the Southern Benguela, there are more non-declining exploited species (Table 1, NDES: 0.60), but a significantly declining mLS trend (Figure 7). A possible explanation is that the exploited species with a declining biomass have higher trophic levels, corresponding to the decline in mLS over time, and possibly reflecting the observed declines in abundance of some K-selected species off South Africa's west coast (Atkinson et al. 2012).

The mLS is negatively correlated with biomass trends in eight ecosystems (Table 2; Figure 6). Six ecosystems have significant negative correlations: the eastern Bering Sea, the Irish Sea, north Aegean Sea, the north-central Adriatic, the North Sea, the Scottish west coast, the U.S. west coast, and the western Scotian Shelf. This suggests that the trajectory of exploited species biomass contradicts the trajectory of the mean life span in these ecosystems. In the eastern Bering Sea, the North Sea, and the western Scotian Shelf, the NDES is higher (Table 1, NDES: 0.59, 0.73, and 0.60, respectively). The linear slopes of the mLS are only significant for the north-central Adriatic, the Scottish west coast, and the western Scotian Shelf (Figure 7), and in each of these cases the slopes are positive. In the case of the western Scotian Shelf, where we have fewer declining exploited biomass trends (Table 1, NDES: 0.60) and a positive linear trend in mLS (Figure 7), we expect a positive correlation from the Kendall's tau analysis. However, the fact that the biomass-weighted average trophic level of the non-declining species is much higher (~4.2 versus ~3.3) could be contributing to longer life spans if higher trophic level species are correlated with higher life spans (Figure 3). For the north-central Adriatic and the Scottish west coast, the proportions of non-declining species are low (Table 1, NDES: 0.29, and 0.45, respectively). Similar to the western Scotian Shelf, the proportion of lower trophic level species is declining, which could be contributing to longer life spans. However, in the case of the Scottish west coast, another explanation is that there has been an increase in higher trophic level species due to reduced fishing (EU 2004).

Conclusions

The NDES allows us to assess the proportion of declining species in an ecosystem and provides a useful measure with which to gauge the ability of a marine ecosystem to sustainably provide wild seafood. Given the importance of seafood to provide critical sustenance for humans is of growing concern (Barrett 2010, Garcia & Rosenberg 2010, Srinivasan et al. 2010, Barange et al. 2014), the NDES may be used as a simple indicator to identify areas where the delivery of this food provisioning ecosystem service is declining or is already in jeopardy. Simple ecosystem indicators such as this have the potential to be used in regions with more robust fisheries management, as well as in regions that are considered to be data-limited and limited in resources and expertise to provide well-founded management advice. In regions with robust fisheries management, ecosystem indicators such as NDES serve an important role in providing a measure of overall ecosystem health, which is critical given that most fisheries management advice continues to be delivered on a single stock basis despite global rhetoric about intentions to adopt ecosystem based management. In regions with less robust fisheries management, the value of NDES cannot be understated. Such a simple indicator, even if calculated with only a limited number of trends, can provide some guidance on status where one may not have been previously available.

It is important to note that the number and length of available species biomass time series may influence the proposed indicator. The comparisons made here are over the length of the surveys or assessments that are available in each ecosystem. For the 22 ecosystems presented this represents an average of 27 years, but can be as many as 45 years (northeast U.S.) and as few as four (north Aegean Sea). One of the strengths of Kendall's tau is that the length and number of time series is accounted for in the significance test. However, there may also be situations where biomass trends are variable over the length of the time series. In the Bay of Biscay for example, horse mackerel (*Trachurus trachurus*) declined strongly from the early 1970s to the early 1980s where it remained stable until the early 2000s, when it began to strongly increase. In cases such as these, the determination of a declining trend will come down to the proportion of concordant versus discordant pairs, a result that may not be optimal in cases where there are opposing trends over the time series. Overall, the NDES may not always be an appropriate indicator, given that 1) longer time series data likely have a higher probability of containing opposing trends in species biomass and 2) shorter time series have a larger variance in the tau distribution and trends are more difficult to detect than for longer time series. However, a subset of years from a longer time series can be selected to best reflect the current status of the ecosystem.

Here we illustrate, through a direct comparison of the 'current status' of three community indicators and the NDES indicator, that many declining biomass trends can point to declining TL, lower mLS, and lower PPF (or the converse), highlighting similar patterns in the delivery of both provisioning and regulating services of the ecosystems. This may make intuitive sense if the exploited portion of the ecosystem is tracking what is happening at the community level. However, in some cases, the patterns among these community-level indicators do not agree (e.g., there is a low proportion of species with declining biomass but the mean trophic level of the surveyed community is low). This may be because the NDES indicator is calculated using the full time series available for each exploited species to provide a state indicator, whereas the current status for the community indicators is calculated over the most recent five years and for both exploited and non-exploited species. However, in cases where there is a difference in the status of the community indicators and the NDES indicator, we find it is critical to explore which components of the ecosystem are actually declining. One way to do this is to examine the proportion of declining species in the context of trophic level. Here, we find that in some cases, discrepancies between the directions of the indicators can be explained by looking at the biomass-weighted average trophic level of the declining component of the ecosystem. In general, many declines in higher trophic level exploited species correspond to lower scores for the proportion of predatory fish (PPF) and the trophic level of the surveyed community (TLsc), and to a lesser degree lower mean life span (mLS) suggesting that the pattern captured in the exploited biomass is also observed at the community level. In other cases, in ecosystems driven by lower trophic level fish rather than top-down predation pressure, a high score of NDES may occur with an increase in PPF and a relatively low TLsc (e.g., the north Ionian Sea). In some cases, this happens where lower trophic level species dominate the proportion of exploited species, such as in upwelling systems (e.g., several upwelling systems and many of the Mediterranean systems have low scores for current state of community indicators). Since the NDES and biomass trends of exploited species are species-weighted whereas mLs, PPF and TLsc are biomass-weighted indicators, we may expect to find some discrepancies in trajectories and seemingly inconsistent correlations.

Additionally, for some regions, stock assessment biomass estimates may provide a better indication of population trends than survey biomass estimates (i.e., some surveys were not designed to sample all species in the community with equal efficiency and some species are assessed using alternate survey data). For example, standard surveys were not conducted in the eastern Bering Sea until a few years after a regime shift. Thus, the survey time series captures the decline from the peak abundance of Alaska pollock that followed the regime shift, whereas the stock assessment, which incorporates alternate survey data, provides a time series of abundance that precedes the regime shift.

Similarly, using the Kendall's tau to examine the correlation between ecosystem indicators and the exploited biomass trends in a system allows one to understand whether patterns in exploited species biomass match trajectories in indicators designed to look at the fuller (exploited and non-exploited) community. Again, ancillary information, such as the average trophic level of the declining exploited species and the direction of significant trends in the ecosystem indicators, can explain what drives the relationships between the NDES indicator and other indicators.

A major finding of our analysis is that the multiple impacts of fishing (and other drivers) on marine ecosystems are difficult to track and assess concomitantly with any single indicator since multiple drivers from fishing to climate and habitat destruction are acting at multiple scales and on multiple processes in ecosystems. Therefore, it is important to explore a suite of indicators and their associations (Blanchard et al. 2010, Shannon et al. 2010, Shin et al. 2010b). The NDES indicator can provide a simple way to focus on exploited species and, through comparisons with community indicators, evaluate the significance of such trends at the community level. Furthermore, the indicator does not make naive assumptions that all species should be declining or increasing but compares the proportion declining against the overall pattern. In developing the NDES, we have included the assumption that in an 'healthy' ecosystem the number of species showing biomass declines should on average be balanced by species showing increases (over the relevant timeframe). It is also imperative to identify which key abiotic conditions and biological groups in the ecosystem are changing to determine the potential impact of the change on the food web. The use here of the community-level indicators provides information on the ability of the ecosystems to deliver regulating services such as maintenance of biodiversity, trophic stability, and reproductive capability. These results illustrate the need to understand the exploitation strategy and long-term dynamics of marine ecosystems and ocean and climate forcing and variability when interpreting such ecosystem indicators. This has been illustrated with trophic level-based indicators (Shannon et al. 2014, Gascuel et al. In press).

The ecological status of marine exploited resources is affected by fishing activity; it can also be strongly dependent on the environment. IndiSeas has collated information on several environmental and climate indicators, such as sea surface temperature (SST) and chlorophyll-a densities, which can help clarify the roles that climate and the environment play on the ecological status of marine exploited resources (Shin et al. 2012). These indicators are used to reflect the production potential of ecosystems and thus may reflect more of the supporting role of ecosystems. Additionally, IndiSeas uses human dimension indicators in order to evaluate the human side of fisheries activities, and benefits to society (Shin et al. 2012). The following are considered: 1) effectiveness of fisheries management and quality of governance; 2) contribution of fisheries to the broader society; and 3) wellbeing and resilience of fishing communities. While the focus here was on the development of a specific indicator to evaluate changes in a provisioning ecosystem service (and comparisons with indicators that capture more of the regulating role of ecosystems), it would be of great interest to explore the broader set of indicators in conjunction with NDES to evaluate the tradeoffs and synergies between other regulating, supporting, or cultural ecosystem services.

When multiple ecosystem indicators are used to evaluate patterns of change, it is important to recognize that some indicators are likely to reflect one aspect of the ecosystem more clearly (e.g. fishing), while others may respond to other processes (e.g., climate change, habitat destruction), and thus proffer confounding assessments (Shin et al. 2010a). In such cases, the use of expert judgment (such as that employed in this project in which local experts provide insights into interpretation of the indicator trends in the context of their ecosystems) to evaluate overall ecosystem health will be beneficial. Conversely, the NDES indicator and its associated histogram of tau scores can provide useful information to understand patterns in other trend-based community-level indicators. For example, if the mean trophic level of a community is increasing, it is useful to know if there is an unexpectedly large proportion of lower trophic level species declining, rather than the inferred increase in higher trophic level species. This has been already observed in ecosystems with a high exploitation level of small pelagic fish and invertebrates, such as in the Mediterranean Sea and the southern Benguela (Coll et al. 2010b, Piroddi et al. 2010, Shannon et al. 2010). Therefore, we conclude that using ecological indicators, including the NDES indicator, requires context-specific supporting information in order to provide guidance within a management setting, but that it can provide a valuable and relatively easy to understand indicator. Given its utility to measure the ability of the ecosystem to deliver seafood, further work will be necessary to explore this indicator in relation to the social, economic, governance, environmental, and other ecological attributes of exploited marine ecosystems to provide a more holistic analysis of their overall health and functioning.

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Tables

Table 1. Description of ecosystems used in the Non-declining Exploited Species (NDES) analysis, including the number of exploited species biomass trends and average length of the time series used to calculate the NDES in each ecosystem. Additionally, the significance of Kendall's tau statistic as determined by a two-sided *p*-value (bolded if significant), and proportion of non-declining species derived from the NDES indicator are provided. A significant Kendall's tau indicates more declining or increasing trends than could be expected by chance.

Ecosystem	Geographic area	Type of ecosystem	Number of biomass trends	Average time series length	Two-sided p -value of Kendall's tau	Proportion of non-declining species (NDES)
Barents Sea	NE Atlantic	High latitude	11	33	0.006	**0.82**
Bay of Biscay	NE Atlantic	Temperate	9	23	0.009	**0.22**
Central Baltic Sea	NE Atlantic	Brackish temperate	6	25	0.441	0.50
Eastern Bering Sea	NE Pacific	High latitude	22	29	0.003	**0.59**
Eastern Scotian Shelf	NW Atlantic	Temperate	30	41	<0.001	**0.37**
English Channel	NE Atlantic	Temperate	31	23	0.001	**0.55**
Guinean Shelf	East-central Atlantic	Upwelling	20	25	<0.001	**0.00**
Gulf of Cadiz	NE Atlantic	Temperate	13	18	<0.001	**0.08**
Irish Sea	NE Atlantic	Temperate	15	18	0.009	**0.40**
North Aegean Sea	NE Mediterranean	Temperate	57	4	<0.001	**0.44**
North Ionian Sea	NE Mediterranean	Temperate	5	45	0.013	**0.00**
North Sea	NE Atlantic	Temperate	30	28	<0.001	**0.73**
North-central Adriatic	Central Mediterranean	Temperate	17	25	<0.001	**0.29**
Northeast U.S.	NW Atlantic	Temperate	122	47	<0.001	**0.75**
Northern Humboldt Current	SE Pacific	Upwelling	10	19	0.055	0.40
Portuguese coast	NE Atlantic	Upwelling	10	26	0.003	**0.80**
Scottish west coast	NE Atlantic	Temperate	11	24	0.076	0.45
South Catalan Sea	NW Mediterranean	Temperate	16	34	0.037	**0.56**
Southern Benguela	SE Atlantic	Upwelling	59	29	<0.001	**0.59**
U.S. west coast	NE Pacific	Temperate	29	8	<0.001	**0.41**
Vancouver Island	NE Pacific	Temperate	22	31	<0.001	**0.77**
Western Scotian Shelf	NW Atlantic	Temperate	30	41	<0.001	**0.60**

Table 2. Correlation over time between the biomass time series of each exploited species and the three community indicators (proportion of predatory fish—PPF, and the average trophic level of the surveyed community—TLsc, and mean life span—mLS) for each ecosystem. The proportions of correlations greater than 0.5 are termed 'positively correlated' and proportions less than 0.5 are termed 'negatively correlated', referring to the preponderance of species-level biomass trends that are positively or negatively correlated with the particular community indicator. The proportions are bolded if the Kendall's tau is significant (i.e., based on the *p*-values).

Ecosystem	Proportion predatory fish (PPF)		Survey trophic level (TLsc)		Mean life span (mLS)	
	Two-sided p -value of Kendall's tau	Proportion positively correlated trends	Two-sided p -value of Kendall's tau	Proportion positively correlated trends	Two-sided p -value of Kendall's tau	Proportion positively correlated trends
Barents Sea	0.023	**0.73**	0.076	0.45	0.076	0.55
Bay of Biscay	0.037	**0.33**	0.037	**0.78**	--	--
Central Baltic Sea	0.441	0.50	--	--	0.441	0.50
Eastern Bering Sea	0.001	**0.64**	<0.001	**0.27**	<0.001	**0.27**
Eastern Scotian Shelf	<0.001	**0.70**	<0.001	**0.67**	<0.001	**0.63**
English Channel	<0.001	**0.61**	<0.001	**0.74**	<0.001	**0.61**
Guinean Shelf	<0.001	**0.05**	<0.001	**0.90**	<0.001	**0.95**
Gulf of Cadiz	0.015	**0.62**	0.015	**0.38**	<0.001	**0.85**
Irish Sea	0.028	**0.67**	0.028	**0.53**	0.028	**0.47**
North Aegean Sea	<0.001	**0.51**	<0.001	**0.49**	<0.001	**0.32**
Northern Humboldt Current	0.015	**0.70**	0.055	0.60	0.015	**0.70**
North Ionian Sea	0.013	**1.00**	0.013	**0.00**	0.013	**1.00**
North-central Adriatic	0.046	**0.53**	0.046	**0.53**	<0.001	**0.29**
Northeast U.S.	<0.001	**0.25**	<0.001	**0.34**	<0.001	**0.60**
North Sea	<0.001	**0.57**	<0.001	**0.40**	<0.001	**0.40**
Portuguese coast	0.055	0.70	0.055	0.40	0.055	0.60
Southern Benguela	<0.001	**0.61**	<0.001	**0.46**	<0.001	**0.59**
South Catalan Sea	0.013	**0.56**	0.013	**0.56**	0.004	**0.63**
Scottish west coast	0.023	**0.36**	0.076	0.64	0.023	**0.36**
U.S. west coast	0.001	**0.48**	<0.001	**0.59**	<0.001	**0.28**
Vancouver Island	0.001	**0.64**	0.003	**0.55**	0.008	**0.50**
Western Scotian Shelf	<0.001	**0.53**	<0.001	**0.47**	<0.001	**0.40**

Figures

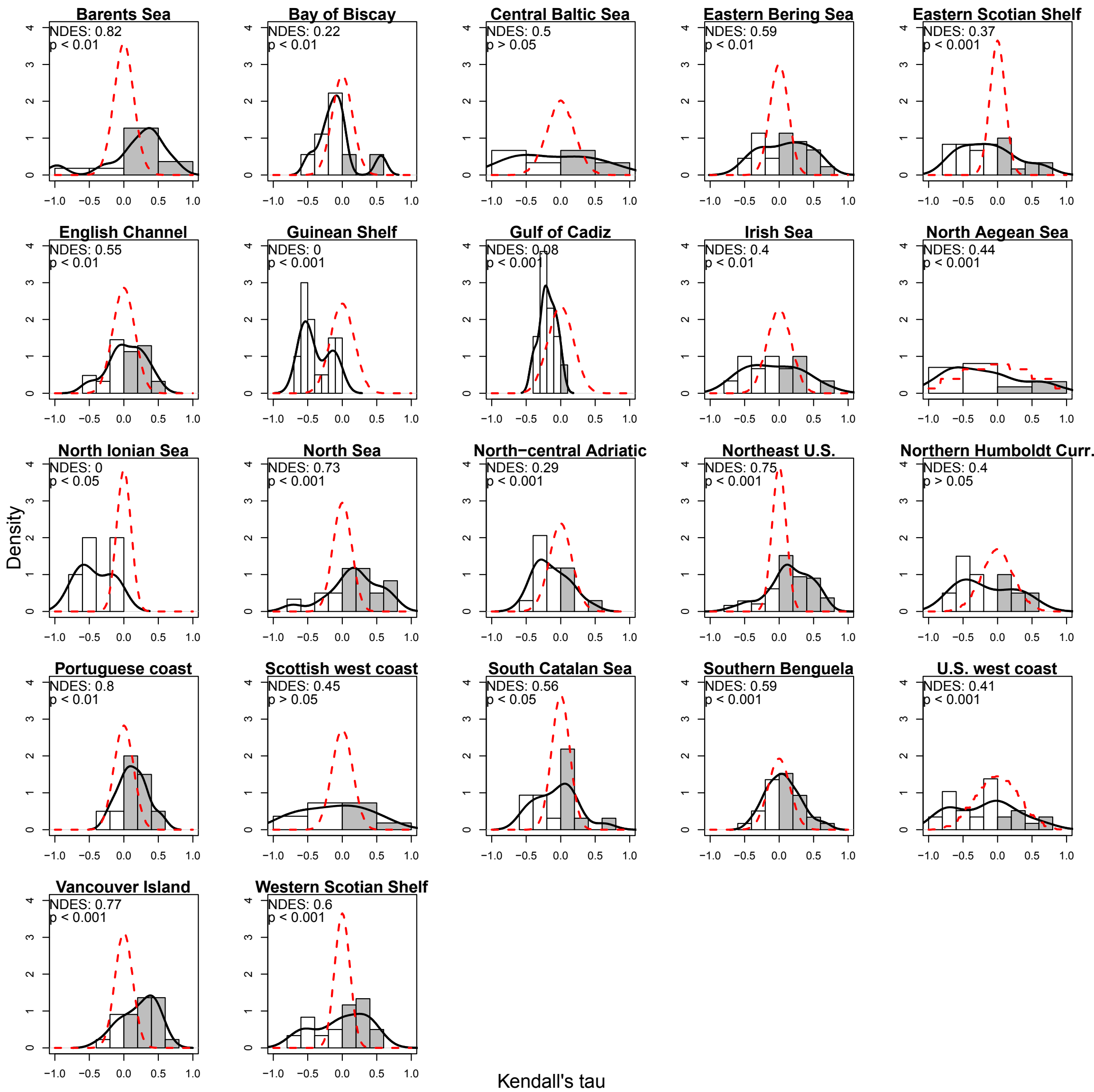

Figure 1. True histograms (bars) of Kendall rank coefficients (tau) by ecosystem with Kernel density smooth functions (solid black lines) contrasted with the theoretical expected distribution of tau by ecosystem (red dashed lines). Shifts in the solid line to the left or right of the dashed line, or histogram bars to the left or right of zero that are taller than the red line, indicate more temporal decreases or increases in the biomass of exploited fish species in the community than would be expected by chance (two-tailed p-value categories are listed in the top left corner of each graph). The white area in the histograms (negative correlations, Kendall's tau < 0) illustrated the proportion of declining exploited species and the grey area in the histograms (positive correlations, Kendall's tau > 0) illustrates the proportion of non-declining exploited species in each ecosystem. The number of non-declining exploited species out of the total is the indicator we call the 'Non-declining Exploited Species' indicator (NDES). NDES values are listed in the top left corner of the graphs with the associated significance level of the indicator (two-tailed p-value categories) for each ecosystem.

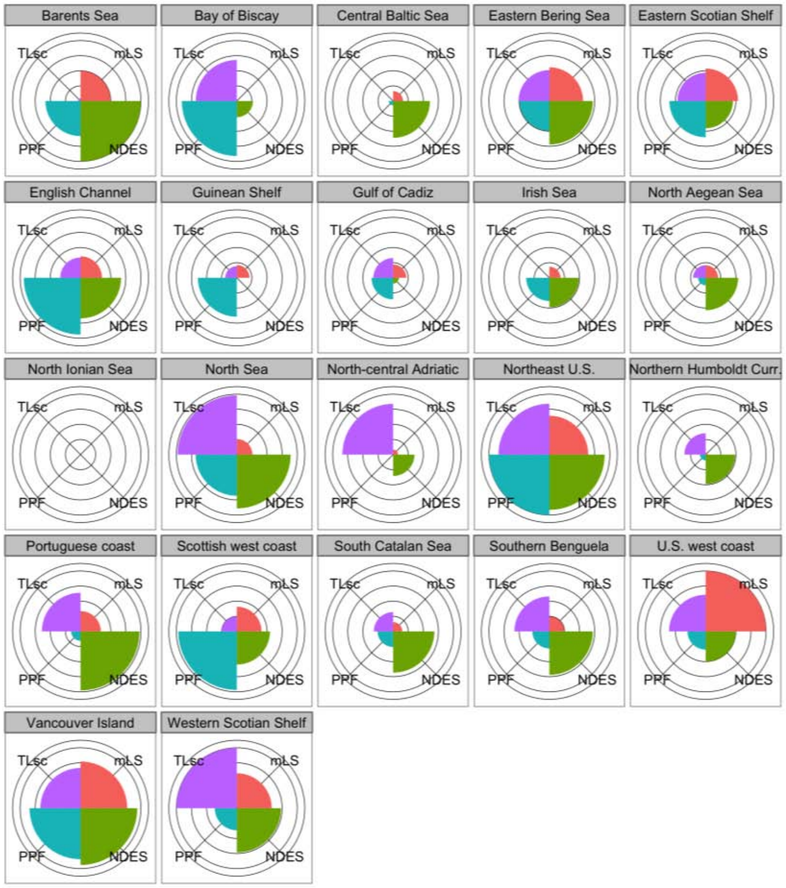

Figure 2. Petal plot of current state for each of the NDES indicator and the three community indicators (mean life span—mLS, proportion of predatory fish—PPF, and the average trophic level of the surveyed community—TLsc) for each ecosystem. Each indicator is scaled from zero to one, with a score of one indicating a 'better' status. A larger petal corresponds to a higher score. Note that the blank plot for the north Ionian Sea ecosystem reflects the fact that all indicator scores were the lowest in comparison to the other ecosystems.

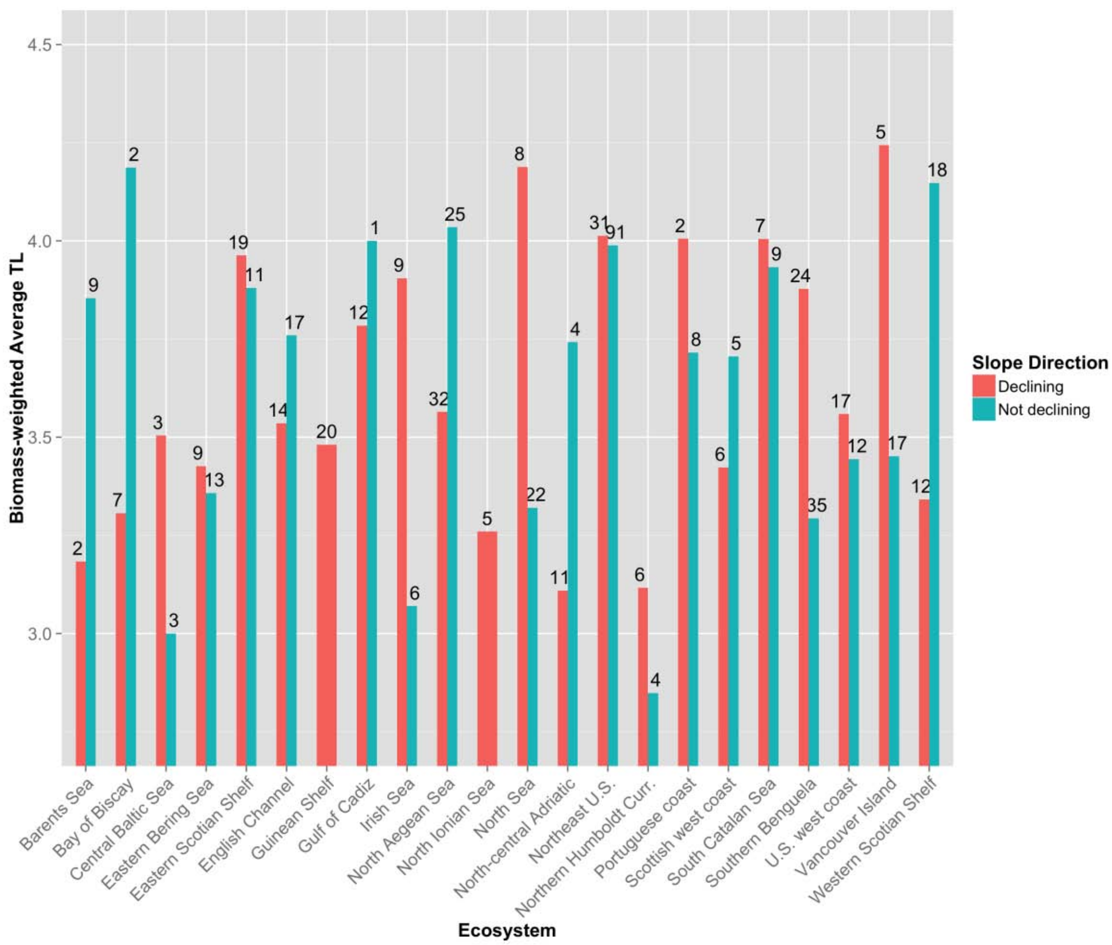

Figure 3. Biomass-weighted average trophic levels of the exploited species trends that are declining (red) and not declining (blue) for each ecosystem. Numbers on the top of each bar correspond to the number of biomass trends of exploited species for each category and ecosystem. Note that the y-axis has a lower truncation at 2.75.

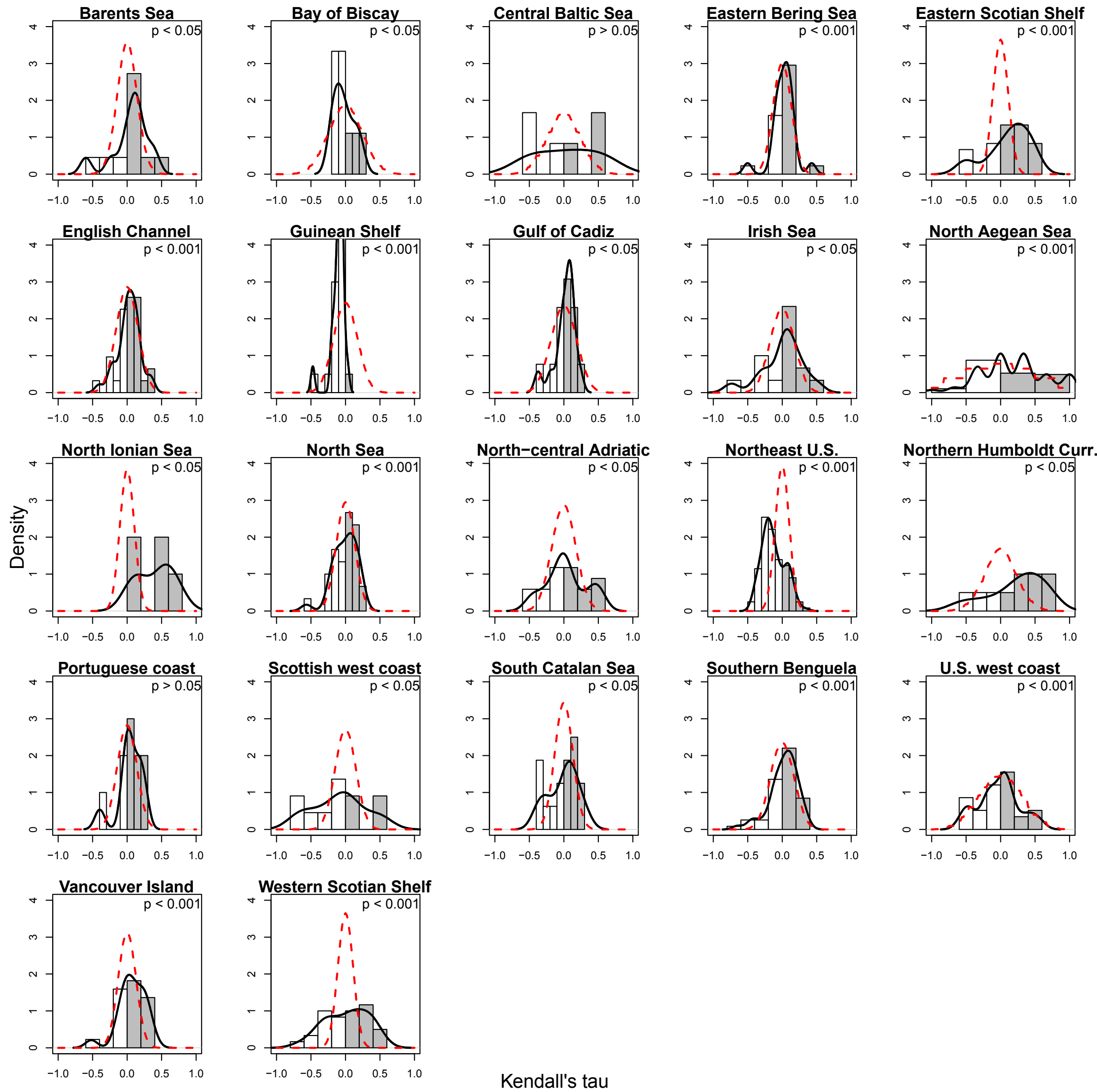

Figure 4. True histograms (bars) of Kendall rank coefficients (tau) by ecosystem indicating the correlation of the exploited species biomass time series with the trend in the community indicator, proportion of predatory fish (PPF), over the whole time series in which both indicators are available. Kernel density smooth functions (solid black lines) are contrasted with the theoretical expected distribution of tau by ecosystem (red dashed lines). A shift in the solid line to the left or right of the dashed line, or histogram bars to the left or right of zero that are taller than the red line, indicates more negative (non-shaded area of histogram) or positive (grey shaded area of histogram) correlations between the PPF and the trends in the exploited species biomass in the community than would be expected by chance (two tailed p-values are listed above each graph).

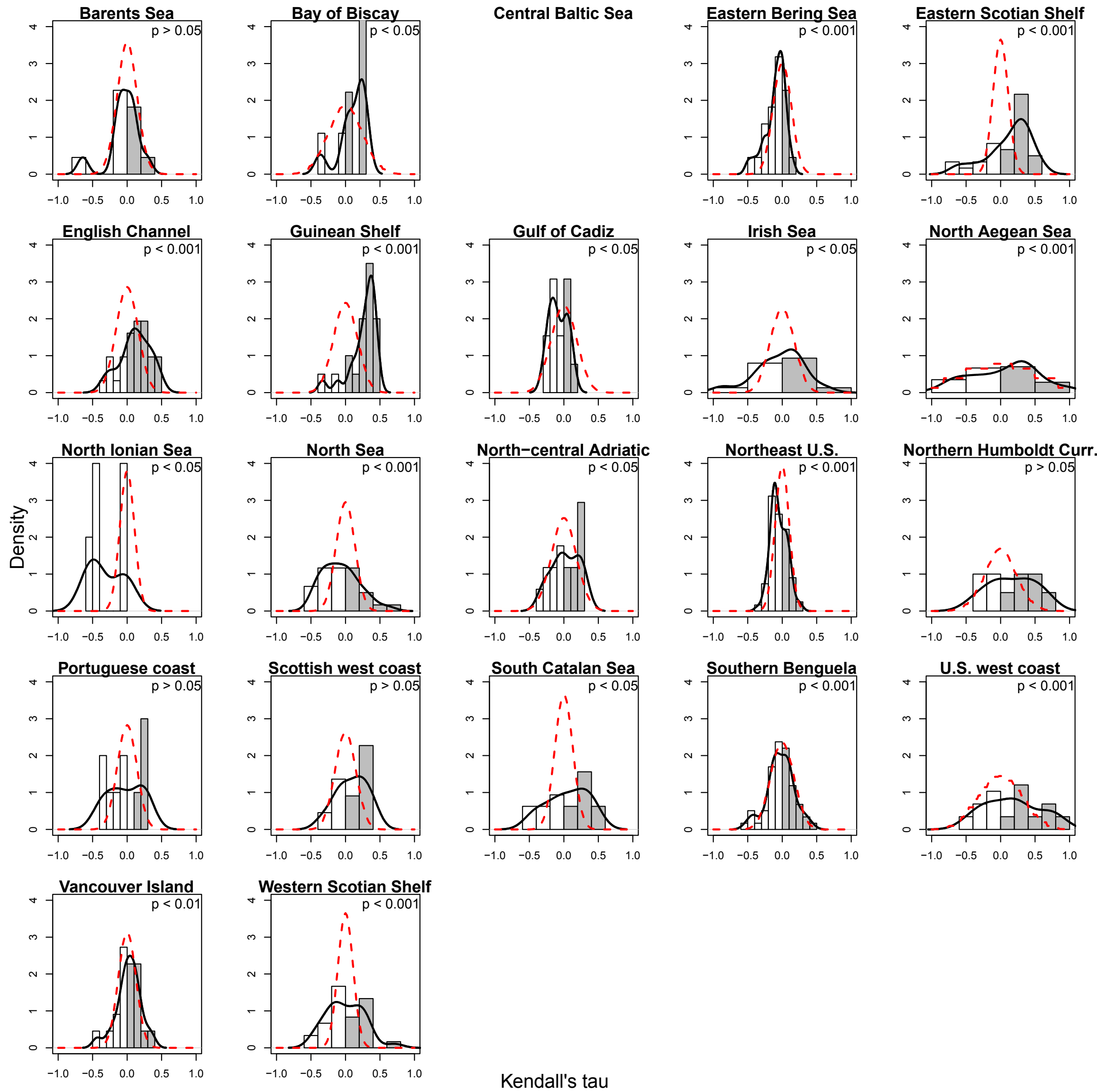

Figure 5. True histograms (bars) of Kendall rank coefficients (tau) by ecosystem indicating the correlation of the exploited species biomass time series with the trend in the community indicator, average trophic level of the surveyed community (TLsc), over the whole time series in which both indicators are available. Kernel density smooth functions (solid black lines) are contrasted with the theoretical expected distribution of tau by ecosystem (red dashed lines). A shift in the solid line to the left or right of the dashed line, or histogram bars to the left or right of zero that are taller than the red line, indicates more negative (non-shaded area of histogram) or positive (grey shaded area of histogram) correlations between the TLsc and the trends in the exploited species biomass in the community than would be expected by chance (two tailed p-values are listed above each graph). The TLsc indicator was not available for the central Baltic Sea ecosystem.

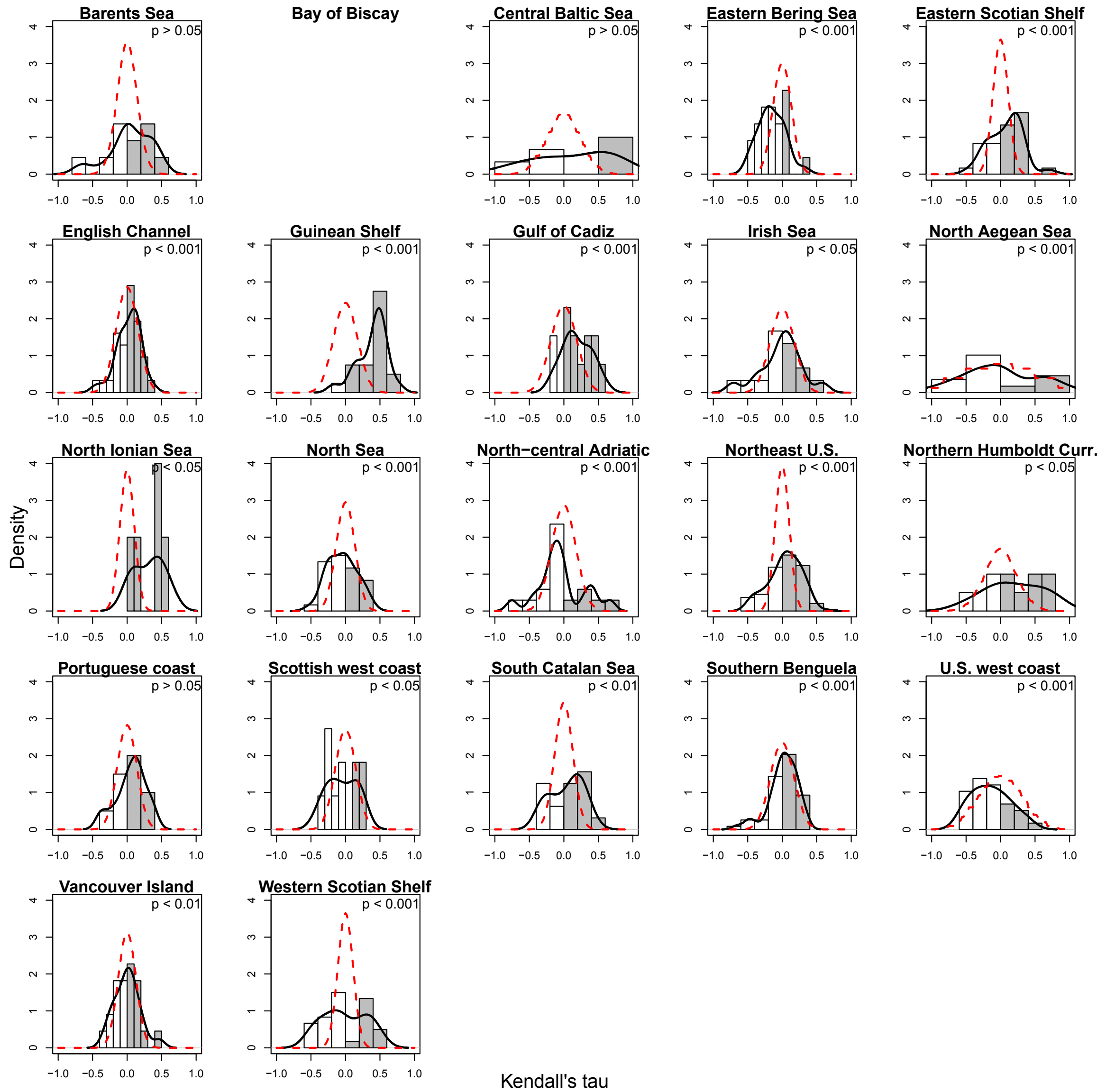

Figure 6. True histograms (bars) of Kendall rank coefficients (tau) by ecosystem indicating the correlation of the exploited species biomass time series with the trend in the community indicator, mean life span (mLS), over the whole time series in which both indicators are available. Kernel density smooth functions (solid black lines) are contrasted with the theoretical expected distribution of tau by ecosystem (red dashed lines). A shift in the solid line to the left or right of the dashed line, or histogram bars to the left or right of zero that are taller than the red line, indicates more negative (non-shaded area of histogram) or positive (grey shaded area of histogram) correlations between the mLS and the trends in the exploited species biomass in the community than would be expected by chance (two tailed p-values are listed above each graph). The mLS indicator was not available for the Bay of Biscay ecosystem.

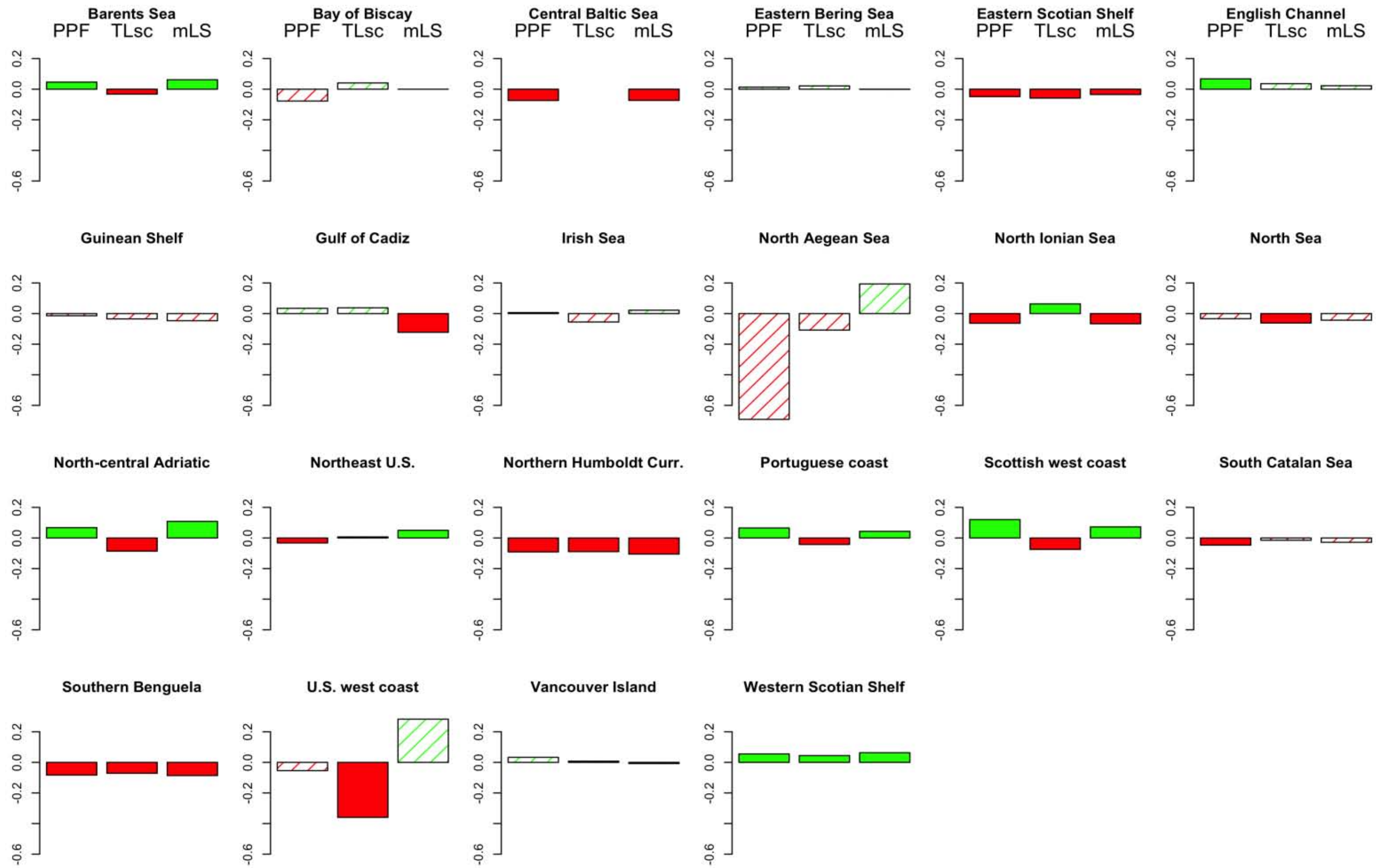

Figure 7. Histograms of slopes of the three independent indicators, proportion of predatory fish (PPF), trophic level of the surveyed community (TLsc), and mean life span (mLS). Solid red indicates a significant decreasing slope and green indicates a significant increasing slope. Striped lines indicate a non-significant trend. These slopes were calculated from standardized time-series using generalized least-squares with autoregressive errors.

Supplementary Information

Table S1. Species time series assessed for each ecosystem, with the length of the time series, the trophic level of the species (from www.fishbase.org or local estimates from ecosystem experts), the Kendall's tau correlation coefficient of the biomass with years, and the relative proportion that each species' average biomass contributes to the overall average exploited biomass available for a given Ecosystem. A negative or positive correlation indicates that the biomass is decreasing or increasing, respectively. An asterisk (*) indicates a proportional contribution to total exploited biomass less than 0.0001.

Ecosystem	Scientific name	Common name	Length of time series	Trophic level	Correlation	Proportional contribution to total exploited biomass
Barents Sea	Boreogadus saida	Polar cod	25	3.10	0.5800	0.0941
Barents Sea	Clupea harengus	Atlantic herring	38	3.23	0.4264	0.1122
Barents Sea	Gadus morhua	Atlantic cod	38	4.42	0.1750	0.1730
Barents Sea	Mallotus villosus	Capelin	38	3.15	-0.2774	0.3394
Barents Sea	Melanogrammus aeglefinus	Haddock	38	4.09	0.4054	0.0459
Barents Sea	Micromesistius poutassous	Blue whiting	27	4.01	0.3333	0.0420
Barents Sea	Pandalus borealis	Northern prawn	38	2.46	0.0128	0.0002
Barents Sea	Pollachius virens	Saithe	38	4.38	0.3826	0.0716
Barents Sea	Reinhardtius hippoglossoides	Greenland halibut	38	4.48	0.1465	0.0129
Barents Sea	Sebastes marinus	Ocean perch	25	4.08	-0.9699	0.0126
Barents Sea	Sebastes mentella	Beaked redfish	19	3.65	0.7310	0.0961
Bay of Biscay	Engraulis encrasicolus	European anchovy	24	3.11	-0.1159	0.0918
Bay of Biscay	Lepidorhombus whiffiagonis	Megrim	22	3.58	0.0130	0.0146
Bay of Biscay	Lophius budegassa	Black-bellied angler	22	4.48	-0.0211	0.0151
Bay of Biscay	Lophius piscatorius	Angler	21	4.49	0.5619	0.0291
Bay of Biscay	Merluccius merluccius	European hake	33	4.42	-0.3068	0.0445
Bay of Biscay	Nephrops norvegicus	Norway lobster	23	2.88	-0.1621	0.0250
Bay of Biscay	Scomber scombrus	Atlantic mackerel	29	3.18	-0.0542	0.6107
Bay of Biscay	Solea solea	Common sole	27	3.17	-0.4815	0.0378

Bay of Biscay	Trachurus trachurus	Atlantic horse mackerel	39	3.64	-0.2173	0.1314
Central Baltic Sea	Clupea harengus	Atlantic herring	37	3.23	-0.7658	0.4445
Central Baltic Sea	Gadus morhua	Atlantic cod	37	4.42	-0.5646	0.1331
Central Baltic Sea	Platichthys flesus	European flounder	13	3.53	-0.4000	0.0001
Central Baltic Sea	Pleuronectes platessa	European plaice	13	3.26	0.7179	*
Central Baltic Sea	Psetta maxima	Turbot	13	3.05	0.1961	*
Central Baltic Sea	Sprattus sprattus	European sprat	37	3.00	0.2793	0.4223
Eastern Bering Sea	Anoplopoma fimbria	Sablefish	29	3.83	-0.3022	0.0056
Eastern Bering Sea	Atheresthes evermanni	Kamchatka flounder	29	4.45	0.5598	0.0010
Eastern Bering Sea	Atheresthes stomias	Arrowtooth flounder	29	4.26	0.6158	0.0268
Eastern Bering Sea	Chionoecetes opilio	Snow crab	29	2.30	-0.2315	0.0239
Eastern Bering Sea	Chionoecetes bairdi	Tanner crab	29	2.30	-0.0148	0.0047
Eastern Bering Sea	Clupea pallasii	Pacific herring	29	3.15	0.1429	0.0208
Eastern Bering Sea	Enteroctopus dofleini	North Pacific giant octopus	29	3.33	-0.2611	0.0023
Eastern Bering Sea	Gadus macrocephalus	Pacific cod	29	4.01	-0.5025	0.0830
Eastern Bering Sea	Glyptocephalus zachirus	Rex sole	29	3.24	0.3744	0.0008
Eastern Bering Sea	Hippoglossoides elassodon	Flathead sole	29	3.64	0.3645	0.0285
Eastern Bering Sea	Hippoglossus stenolepis	Pacific halibut	29	4.13	0.5172	0.0060
Eastern Bering Sea	Lepidopsetta polyxystra	Northern rock sole	29	3.30	0.5862	0.0801
Eastern Bering Sea	Limanda aspera	Yellowfin sole	29	3.24	-0.3300	0.1096
Eastern Bering Sea	Microstomus pacificus	Dover sole	29	3.27	0.1968	*
Eastern Bering Sea	Oncorhynchus	Pacific salmon	29	3.95	0.1162	0.0042
Eastern Bering Sea	Pleuronectes quadrituberculatus	Alaska plaice	29	3.10	-0.4729	0.0239
Eastern Bering Sea	Pandalidae	Northern shrimps	29	2.70	0.2808	0.0695
Eastern Bering Sea	Paralithodes camtschaticus	Red king crab	29	2.82	0.1527	0.0043
Eastern Bering Sea	Pleurogrammus monopterygius	Atka mackerel	29	3.33	0.3674	0.0045
Eastern Bering Sea	Reinhardtius hippoglossoides	Greenland halibut	29	4.48	0.0049	0.0149
Eastern	Thaleichthys	Eulachon	29	3.24	-0.0739	0.0063

Bering Sea	pacificus					
Eastern Bering Sea	Theragra chalcogramma	Alaska pollock	29	3.45	-0.2906	0.4792
Eastern Scotian Shelf	Anarhichas lupus	Atlantic wolffish	41	3.24	-0.6220	0.0052
Eastern Scotian Shelf	Argentina silus	Greater argentine	41	3.31	-0.4195	0.0027
Eastern Scotian Shelf	Brosme brosme	Tusk	41	4.00	-0.6683	0.0022
Eastern Scotian Shelf	Chionoecetes opilio	Queen crab	41	2.30	0.7023	0.0049
Eastern Scotian Shelf	Clupea harengus	Atlantic herring	41	3.23	0.5925	0.0534
Eastern Scotian Shelf	Gadus morhua	Atlantic cod	41	4.42	-0.4366	0.1551
Eastern Scotian Shelf	Glyptocephalus cynoglossus	Witch flounder	41	3.14	-0.2195	0.0084
Eastern Scotian Shelf	Hippoglossoides platessoides	American plaice	41	3.65	-0.5976	0.0756
Eastern Scotian Shelf	Hippoglossus hippoglossus	Atlantic halibut	41	4.53	0.1902	0.0058
Eastern Scotian Shelf	Illex illecebrosus	Northern shortfin squid	41	3.98	-0.1195	0.0331
Eastern Scotian Shelf	Limanda ferruginea	Yellowtail flounder	41	3.22	-0.4512	0.0411
Eastern Scotian Shelf	Lophius americanus	American angler	41	4.49	-0.6073	0.0104
Eastern Scotian Shelf	Melanogrammus aeglefinus	Haddock	41	4.09	0.1171	0.1842
Eastern Scotian Shelf	Merluccius bilinearis	Silver hake	41	4.26	0.0756	0.0612
Eastern Scotian Shelf	Myoxocephalus octodecemspinosus	Longhorn sculpin	41	3.50	-0.1146	0.0086
Eastern Scotian Shelf	Myxine glutinosa	Hagfish	41	3.45	0.2962	0.0001
Eastern Scotian Shelf	Pandalus borealis	Northern prawn	41	2.46	0.6212	0.0228
Eastern	Phycis chesteri	Longfin hake	41	3.20	-0.3927	0.0010

Scotian Shelf						
Eastern Scotian Shelf	Pollachius virens	Saithe	41	4.38	-0.1220	0.0484
Eastern Scotian Shelf	Pseudopleuronectes americanus	Winter flounder	41	2.83	-0.0829	0.0030
Eastern Scotian Shelf	Leucoraja ocellata	Winter skate	41	4.40	-0.6171	0.0121
Eastern Scotian Shelf	Amblyraja radiata	Starry ray	41	4.00	-0.7317	0.0349
Eastern Scotian Shelf	Reinhardtius hippoglossoides	Greenland halibut	41	4.48	0.5122	0.0062
Eastern Scotian Shelf	Scomber scombrus	Atlantic mackerel	41	3.18	-0.2644	0.0071
Eastern Scotian Shelf	Scophthalmus aquosus	Windowpane	41	3.55	-0.1901	0.0001
Eastern Scotian Shelf	Sebastes	Redfishes	41	3.79	-0.2244	0.1706
Eastern Scotian Shelf	Squalus acanthias	Piked dogfish	41	4.30	0.1100	0.0154
Eastern Scotian Shelf	Tautogolabrus adspersus	Cunner	41	3.54	0.1335	*
Eastern Scotian Shelf	Urophycis chuss	Red hake	41	3.60	0.0341	0.0028
Eastern Scotian Shelf	Urophycis tenuis	White hake	41	4.20	-0.4780	0.0233
English Channel	Chelidonichthys cuculus	Red gurnard	23	3.85	-0.0988	0.0119
English Channel	Chelidonichthys lucernus	Tub gurnard	23	3.65	-0.2885	0.0038
English Channel	Clupea harengus	Atlantic herring	23	3.23	-0.5099	0.0401
English Channel	Dicentrarchus labrax	European seabass	23	3.80	0.4941	0.0228
English Channel	Eutrigla gurnardus	Grey gurnard	23	3.57	-0.1383	0.0036
English Channel	Gadus morhua	Atlantic cod	23	4.42	-0.0356	0.0489
English Channel	Galeorhinus galeus	Tope shark	23	4.21	0.0830	0.0350
English Channel	Hyperoplus	Sand lances	23	3.10	-0.2174	0.0018
English	Limanda limanda	Common dab	23	3.29	-0.0119	0.0251

Channel						
English Channel	Loligo	Common squids	23	3.99	0.1621	0.0284
English Channel	Maja squinado	Spinous spider crab	23	2.30	0.2632	0.0097
English Channel	Merlangius merlangus	Whiting	23	4.29	0.3202	0.0782
English Channel	Microstomus kitt	Lemon sole	23	3.22	-0.0909	0.0105
English Channel	Mullus surmuletus	Surmullet	23	3.35	0.2253	0.0073
English Channel	Mustelus asterias	Starry smooth-hound	23	3.71	0.4783	0.0274
English Channel	Mustelus mustelus	Smooth-hound	23	3.83	0.0095	0.0185
English Channel	Necora puber	Velvet swimcrab	23	2.60	-0.1429	0.0114
English Channel	Platichthys flesus	European flounder	23	3.53	0.1462	0.0137
English Channel	Pleuronectes platessa	European plaice	23	3.26	0.2174	0.0331
English Channel	Raja clavata	Thornback ray	23	3.60	0.1542	0.0251
English Channel	Sardina pilchardus	European pilchard	23	3.10	-0.4150	0.0106
English Channel	Scomber scombrus	Atlantic mackerel	23	3.18	-0.1383	0.0702
English Channel	Scyliorhinus canicula	Smallspotted catshark	23	3.58	0.3597	0.0704
English Channel	Scyliorhinus stellaris	Nursehound	23	4.03	0.3834	0.0227
English Channel	Sepia officinalis	Common cuttlefish	23	3.55	0.0119	0.0102
English Channel	Solea solea	Common sole	23	3.17	0.1542	0.0058
English Channel	Spondyliosoma cantharus	Black seabream	23	3.34	0.3202	0.0189
English Channel	Sprattus sprattus	Baltic sprat	23	3.37	-0.0514	0.0339
English Channel	Trachurus trachurus	Atlantic horse mackerel	23	3.64	-0.5494	0.1596
English Channel	Trisopterus luscus	Pouting	23	3.73	0.2253	0.1371
English Channel	Zeus faber	John dory	23	4.50	-0.0751	0.0043
Guinean Shelf	Alectis alexandrinus	African threadfish	25	3.60	-0.0526	0.0156
Guinean Shelf	Arius latiscutatus	Rough-head sea catfish	25	3.30	-0.5906	0.0347
Guinean Shelf	Brachydeuterus auritus	Bigeye grunt	25	3.03	-0.1345	0.0758
Guinean Shelf	Cararius heudelotii	Smoothmouth sea catfish	25	3.80	-0.4971	0.0143
Guinean Shelf	Chloroscombrus chrysurus	Atlantic bumper	25	3.21	-0.0877	0.1395

Guinean Shelf	Cynoglossus senegalensis	Senegalese tonguesole	25	3.60	-0.1579	0.0146
Guinean Shelf	Dasyatis margarita	Daisy stingray	25	3.40	-0.4386	0.0946
Guinean Shelf	Drepane africana	African sicklefish	25	3.10	-0.5439	0.0356
Guinean Shelf	Ephippion guttifer	Prickly puffer	25	3.60	-0.3333	0.0244
Guinean Shelf	Eucinostomus melanopterus	Flagfin mojarra	25	3.40	-0.5948	0.0162
Guinean Shelf	Galeoides decadactylus	Lesser African threadfin	25	3.57	-0.4737	0.1236
Guinean Shelf	Ilisha africana	West African ilisha	25	3.19	-0.2047	0.0763
Guinean Shelf	Pagrus caeruleostictus	Bluespotted seabream	25	3.60	-0.0292	0.0504
Guinean Shelf	Pentanemus quinquarius	Royal threadfin	25	3.56	-0.4503	0.0410
Guinean Shelf	Pomadasys jubelini	Sompat grunt	25	3.33	-0.5205	0.0350
Guinean Shelf	Pseudotolithus elongatus	Bobo croaker	25	4.06	-0.5439	0.0751
Guinean Shelf	Pseudotolithus senegalensis	Cassava croaker	25	3.84	-0.5556	0.0437
Guinean Shelf	Pseudotolithus senegallus	Law croaker	25	3.89	-0.6725	0.0229
Guinean Shelf	Pseudotolithus typus	Longneck croaker	25	3.70	-0.6023	0.0483
Guinean Shelf	Trichiurus lepturus	Largehead hairtail	25	4.45	-0.1930	0.0185
Gulf of Cadiz	Alloteuthis subulata	European common squid	18	4.00	-0.2680	0.0196
Gulf of Cadiz	Cepola macrophthalma	Red bandfish	18	3.20	-0.1111	0.0386
Gulf of Cadiz	Eledone cirrhosa	Horned octopus	18	3.70	-0.2288	0.0212
Gulf of Cadiz	Eledone moschata	Musky octopus	18	3.65	-0.3856	0.0947
Gulf of Cadiz	Illex coindetii	Broadtail shortfin squid	18	4.15	-0.1324	0.1255
Gulf of Cadiz	Liza aurata	Golden grey mullet	18	3.01	-0.3905	0.0059
Gulf of Cadiz	Liza ramada	Thinlip grey mullet	18	2.16	-0.2167	0.0254
Gulf of Cadiz	Lophius piscatorius	Angler	18	4.49	-0.2571	0.0129
Gulf of Cadiz	Micromesistius poutassou	Blue whiting	18	4.01	-0.0458	0.3238
Gulf of Cadiz	Scorpaena notata	Small red scorpionfish	18	3.50	-0.2288	0.0061
Gulf of Cadiz	Sepia elegans	Elegant cuttlefish	18	4.00	0.0065	0.0051
Gulf of Cadiz	Solea solea	Common sole	18	3.17	-0.0588	0.0030
Gulf of	Trachurus	Atlantic horse	18	3.64	-0.1503	0.3182

Cadiz	trachurus	mackerel				
Irish Sea	Clupea harengus	Atlantic herring	18	3.23	0.2680	0.1038
Irish Sea	Gadus morhua	Atlantic cod	18	4.42	-0.6993	0.0218
Irish Sea	Leucoraja naevus	Cuckoo ray	18	3.94	-0.4902	0.0042
Irish Sea	Melanogrammus aeglefinus	Haddock	18	4.09	0.1765	0.0015
Irish Sea	Merlangius merlangus	Whiting	18	4.29	-0.3464	0.0105
Irish Sea	Pleuronectes platessa	European plaice	18	3.26	0.6863	0.1065
Irish Sea	Pollachius pollachius	Pollock	18	4.15	-0.1774	0.0001
Irish Sea	Raja brachyura	Blonde ray	18	3.98	-0.0980	0.0026
Irish Sea	Raja clavata	Thornback ray	18	3.60	0.3987	0.0145
Irish Sea	Raja microocellata	Small-eyed ray	18	3.89	-0.3080	*
Irish Sea	Raja montagui	Spotted ray	18	3.57	0.3672	0.0065
Irish Sea	Scomber scombrus	Atlantic mackerel	18	3.18	-0.0141	*
Irish Sea	Solea solea	Common sole	18	3.17	-0.5948	0.0213
Irish Sea	Sprattus sprattus	European sprat	18	3.00	0.1443	0.7065
Irish Sea	Squalus acanthias	Piked dogfish	18	4.30	-0.4518	0.0001
North Aegean	Boops boops	Bogue	4	3.00	1.0000	0.0032
North Aegean	Citharus linguatula	Spotted flounder	4	3.97	-0.6667	0.0108
North Aegean	Conger conger	European conger	4	4.29	0.6667	0.0035
North Aegean	Dentex dentex	Common dentex	4	4.50	-0.3333	0.0005
North Aegean	Dentex maroccanus	Morocco dentex	4	3.85	0.0000	0.0017
North Aegean	Diplodus annularis	Annular seabream	4	3.40	-0.3333	0.0236
North Aegean	Diplodus vulgaris	Common two-banded seabream	4	3.24	0.6667	0.0016
North Aegean	Eledone cirrhosa	Horned octopus	4	3.70	0.0000	0.0235
North Aegean	Eledone moschata	Musky octopus	4	3.65	-0.6667	0.0470
North Aegean	Eutrigla gurnardus	Grey gurnard	4	3.57	-0.6667	0.0039
North Aegean	Gaidropsarus mediterraneus	Shore rockling	4	3.38	0.0000	0.0002
North Aegean	Helicolenus dactylopterus	Blackbelly rosefish	4	3.81	-0.6667	0.0007
North Aegean	Illex coindetii	Broadtail shortfin squid	4	4.15	0.0000	0.0521
North Aegean	Lepidopus caudatus	Silver scabbardfish	4	3.85	0.3333	0.0008
North Aegean	Loligo vulgaris	European squid	4	4.10	-0.6667	0.0022
North Aegean	Lophius budegassa	Black-bellied angler	4	4.48	-0.3333	0.0384
North Aegean	Lophius piscatorius	Angler	4	4.49	0.3333	0.0164

North Aegean	Merlangius merlangus	Whiting	4	4.29	-0.6667	0.0012
North Aegean	Merluccius merluccius	European hake	4	4.42	0.0000	0.0925
North Aegean	Micromesistius poutassou	Blue whiting	4	4.01	-0.6667	0.0489
North Aegean	Mullus barbatus	Red mullet	4	3.33	-1.0000	0.0425
North Aegean	Mullus surmuletus	Surmullet	4	3.35	0.6667	0.0016
North Aegean	Nephrops norvegicus	Norway lobster	4	2.88	0.3333	0.0045
North Aegean	Octopus vulgaris	common octopus	4	3.60	-0.6667	0.0747
North Aegean	Pagellus acarne	Axillary seabream	4	3.48	-0.6667	0.0174
North Aegean	Pagellus bogaraveo	Blackspot seabream	4	3.73	0.0000	0.0089
North Aegean	Pagellus erythrinus	Common pandora	4	3.40	-0.3333	0.0041
North Aegean	Pagrus pagrus	Red porgy	4	3.65	1.0000	0.0054
North Aegean	Parapenaeus longirostris	deep-water rose shrimp	4	3.30	-0.6667	0.1936
North Aegean	Penaeus kerathurus	Caramote prawn	4	2.10	-1.0000	0.0076
North Aegean	Phycis blennoides	Greater forkbeard	4	3.73	0.6667	0.0049
North Aegean	Phycis phycis	Forkbeard	4	4.26	-0.6667	0.0008
North Aegean	Raja clavata	Thornback ray	4	3.60	-0.3333	0.0258
North Aegean	Raja miraletus	Brown ray	4	3.80	0.0000	0.0020
North Aegean	Scomber scombrus	Atlantic mackerel	4	3.18	0.6667	0.0200
North Aegean	Scophthalmus rhombus	Brill	4	3.79	-0.3333	0.0013
North Aegean	Scorpaena elongata	Slender rockfish	4	3.86	0.0000	0.0002
North Aegean	Scorpaena notata	Small red scorpionfish	4	3.50	-1.0000	0.0152
North Aegean	Scorpaena porcus	Black scorpionfish	4	3.93	-0.3333	0.0031
North Aegean	Scyliorhinus canicula	Smallspotted catshark	4	3.58	-1.0000	0.0511
North Aegean	Sepia elegans	Elegant cuttlefish	4	4.00	-0.6667	0.0032
North Aegean	Sepia officinalis	Common cuttlefish	4	3.55	-0.6667	0.0063
North Aegean	Sepia orbignyana	pink cuttlefish	4	3.55	-0.3333	0.0017
North Aegean	Serranus cabrilla	Comber	4	3.35	-0.6667	0.0075
North	Spicara flexuosa	Blotched picarel	4	3.50	0.6667	0.0072

Aegean						
North Aegean	Spicara smaris	Picarel	4	3.00	0.0000	0.0028
North Aegean	Spondyliosoma cantharus	Black seabream	4	3.34	0.6667	0.0003
North Aegean	Squilla mantis	Spottail mantis squillid	4	2.60	0.0000	0.0040
North Aegean	Trachinus draco	Greater weever	4	4.18	0.3333	0.0067
North Aegean	Trachurus mediterraneus	Mediterranean horse mackerel	4	3.47	-0.3333	0.0058
North Aegean	Trachurus trachurus	Atlantic horse mackerel	4	3.64	-0.3333	0.0374
North Aegean	Trigla lucerna	Tub gurnard	4	3.65	-0.3333	0.0124
North Aegean	Trigla lyra	Piper gurnard	4	3.46	-0.3333	0.0022
North Aegean	Trigloporus lastoviza	Streaked gurnard	4	3.50	-0.6667	0.0046
North Aegean	Trisopterus minutus capelanus	Poor cod	4	3.65	-1.0000	0.0289
North Aegean	Uranoscopus scaber	Stargazer	4	4.38	0.0000	0.0022
North Aegean	Zeus faber	John dory	4	4.50	0.3333	0.0092
Northern Humboldt Current	Anchoa nasus	Longnose anchovy	13	3.30	-0.5152	0.0277
Northern Humboldt Current	Dosidicus gigas	Jumbo flying squid	11	4.20	0.4545	0.0413
Northern Humboldt Current	Engraulis ringens	Anchoveta	25	3.50	0.3800	0.4869
Northern Humboldt Current	Galeichthys peruvianus	Peruvian sea catfish	11	3.70	0.0909	0.0226
Northern Humboldt Current	Merluccius gayi	South Pacific hake	27	4.00	-0.3105	0.0161
Northern Humboldt Current	Normanichthys crokeri	Mote sculpin	11	3.00	0.1826	0.0022
Northern Humboldt Current	Prionotus stephanophrys	Lumptail searobin	17	3.60	-0.2222	0.0066
Northern Humboldt Current	Sardinops sagax	Pacific sardine	24	3.30	-0.6740	0.1394
Northern Humboldt Current	Scomber japonicus	Chub mackerel	27	3.70	-0.4758	0.0729
Northern Humboldt Current	Trachurus murphyi	Jack mackerel	27	3.90	-0.5442	0.1843

North Ionian	Engraulis encrasicolus	European anchovy	45	3.11	-0.5758	0.3157
North Ionian	Katsuwonus pelamis	Skipjack tuna	45	4.35	-0.1414	0.0221
North Ionian	Merluccius merluccius	European hake	45	4.42	-0.1434	0.0702
North Ionian	Sardina pilchardus	European pilchard	45	3.10	-0.5152	0.5661
North Ionian	Xiphias gladius	Swordfish	45	4.49	-0.7192	0.0259
North-central Adriatic	Chlamys opercularis	Queen scallop	22	2.10	-0.3216	0.0005
North-central Adriatic	Conger conger	European conger	24	4.29	-0.0762	0.0001
North-central Adriatic	Engraulis encrasicolus	European anchovy	32	3.11	-0.5524	0.8075
North-central Adriatic	Lophius	Monkfishes	24	4.46	-0.3905	0.0005
North-central Adriatic	Merluccius merluccius	European hake	24	4.42	0.1238	0.0034
North-central Adriatic	Mullus	Western goatfishes	24	3.29	0.2000	0.0024
North-central Adriatic	Nephrops norvegicus	Norway lobster	24	2.88	-0.2762	0.0005
North-central Adriatic	Squilla mantis	Spottail mantis squillid	24	2.60	0.0667	0.0010
North-central Adriatic	Raja	Skates	24	3.82	-0.3333	0.0005
North-central Adriatic	Sardina pilchardus	European pilchard	31	3.10	-0.0882	0.1808
North-central Adriatic	Scomber	Mackerels	24	3.65	0.4381	0.0008
North-central Adriatic	Scophthalmus rhombus	Brill	24	3.79	-0.1167	*
North-central Adriatic	Spicara smaris	Picarel	24	3.00	-0.3333	0.0001
North-central Adriatic	Sprattus sprattus	European sprat	24	3.00	-0.0762	0.0014
North-central Adriatic	Trachurus	Jack and horse mackerels	24	3.70	-0.2667	0.0005

Northeast U.S.	Alosa aestivalis	Blueback shad	47	3.60	0.2174	0.0007
Northeast U.S.	Alosa pseudoharengus	Alewife	47	3.51	0.0694	0.0036
Northeast U.S.	Alosa sapidissma	American shad	47	3.19	0.3913	0.0004
Northeast U.S.	Amblyraja radiata	Starry ray	47	4.00	-0.7872	0.0110
Northeast U.S.	Ammodytes dubius	Northern sand lance	47	3.10	0.0102	0.0008
Northeast U.S.	Anarhichas lupus	Atlantic wolffish	47	3.24	-0.6540	0.0018
Northeast U.S.	Anchoa hepsetus	Broad-striped anchovy	47	3.33	0.3521	0.0012
Northeast U.S.	Anchoa mitchilli	Bay anchovy	47	3.46	0.3354	0.0010
Northeast U.S.	Antimora rostrata	Blue antimora	47	3.58	0.1700	*
Northeast U.S.	Arctica islandica	Ocean quahog	47	2.00	0.0811	*
Northeast U.S.	Argentina silus	Greater argentine	47	3.31	-0.4024	0.0006
Northeast U.S.	Aspidophoroides monopterygius	Alligatorfish	47	3.00	0.1230	*
Northeast U.S.	Bairdiella chrysoura	Silver perch	47	3.20	0.3950	0.0001
Northeast U.S.	Brevoortia tyrannus	Atlantic menhaden	47	2.25	0.3355	0.0002
Northeast U.S.	Brosme brosme	Tusk	47	4.00	-0.6559	0.0028
Northeast U.S.	Cancer borealis	Jonah crab	47	2.60	0.4695	0.0004
Northeast U.S.	Cancer irroratus	Atlantic rock crab	47	2.60	0.1900	0.0003
Northeast U.S.	Carcharhinus obscurus	Dusky shark	47	4.49	-0.2601	0.0003
Northeast U.S.	Carcharhinus plumbeus	Sandbar shark	47	4.49	0.2465	0.0008
Northeast U.S.	Carcharias taurus	Sand tiger shark	47	4.50	0.1613	0.0008
Northeast U.S.	Caranx crysos	Blue runner	47	4.40	0.5278	*
Northeast U.S.	Centropristis striata	Black seabass	47	3.98	0.3321	0.0012
Northeast U.S.	Centroscyllium fabricii	Black dogfish	47	3.90	0.0424	*
Northeast U.S.	Cephalopoda	Cephalopods	47	3.81	-0.4685	0.0003
Northeast U.S.	Cetorhinus maximus	Basking shark	47	3.20	0.0351	0.0006
Northeast U.S.	Chionoecetes opilio	Queen crab	47	2.30	0.1914	*
Northeast U.S.	Citharichthys arctifrons	Gulf Stream flounder	47	3.30	0.5541	0.0003
Northeast	Clupea harengus	Atlantic herring	47	3.23	0.5430	0.0135

U.S.						
Northeast U.S.	Coelorhynchus carminatus	Hollowsnout grenadier	47	3.60	-0.1689	*
Northeast U.S.	Conger oceanicus	American conger	47	4.50	-0.2050	0.0001
Northeast U.S.	Cyclopterus lumpus	Lumpsucker	47	3.89	0.1323	0.0002
Northeast U.S.	Cynoscion regalis	Gray weakfish	47	3.77	0.3497	0.0025
Northeast U.S.	Dasyatis americana	Southern stingray	47	3.50	0.0814	0.0019
Northeast U.S.	Dasyatis centroura	Roughtail stingray	47	3.81	0.1565	0.0076
Northeast U.S.	Dasyatis say	Bluntnose stingray	47	3.50	0.0727	0.0040
Northeast U.S.	Dibranchus atlanticus	Atlantic batfish	47	3.40	0.1186	*
Northeast U.S.	Dipturus laevis	Barndoor skate	47	3.50	0.3038	0.0031
Northeast U.S.	Enchelyopus cimbrius	Fourbeard rockling	47	3.53	0.1156	0.0001
Northeast U.S.	Etropus micorostomus	Smallmouth flounder	47	3.30	0.5768	*
Northeast U.S.	Etrumeus teres	Red-eye round herring	47	3.49	0.2073	0.0030
Northeast U.S.	Gadus morhua	Atlantic cod	47	4.42	-0.6059	0.0426
Northeast U.S.	Geryon quinquedens	Red deepsea crab	47	2.30	0.4241	0.0001
Northeast U.S.	Glyptocephus cynoglossus	Witch flounder	47	3.14	-0.4061	0.0043
Northeast U.S.	Helicolenus dactylopterus	Blackbelly rosefish	47	3.81	0.6133	0.0005
Northeast U.S.	Hemitripterus americanus	Sea raven	47	4.50	0.5301	0.0037
Northeast U.S.	Hippoglossoides platessoides	American plaice	47	3.65	-0.3636	0.0086
Northeast U.S.	Hippoglossus hippoglossus	Atlantic halibut	47	4.53	-0.1138	0.0008
Northeast U.S.	Illex illecebrosus	Northern shortfin squid	47	3.98	0.1175	0.0048
Northeast U.S.	Leiostomus xanthurus	Spot croaker	47	3.94	0.4223	0.0032
Northeast U.S.	Lepophidium profundorum	Blackrim cusk-eel	47	3.40	0.3099	0.0001
Northeast U.S.	Leucoraja erinacea	Little skate	47	3.40	0.6152	0.0460
Northeast U.S.	Leucoraja garmani	Rosette skate	47	3.60	0.5523	0.0002
Northeast U.S.	Leucoraja ocellata	Winter skate	47	4.40	0.4376	0.0402
Northeast U.S.	Limanda ferruginea	Yellowtail flounder	47	3.22	-0.1156	0.0131
Northeast U.S.	Doryteuthis pealeii	Longfin inshore squid	47	3.51	0.2784	0.0186

Northeast U.S.	Lophius americanus	American angler	47	4.49	-0.1082	0.0108
Northeast U.S.	Lopholatilus chamaeleonticeps	Great northern tilefish	47	3.45	-0.0697	0.0001
Northeast U.S.	Lumpenus lumpretaeformis	Snakeblenny	47	3.60	0.2285	*
Northeast U.S.	Macrorhamphosus scolopax	Longspine snipefish	47	3.47	0.4360	*
Northeast U.S.	Macrourus berglax	Onion-eye grenadier	47	3.62	-0.1148	*
Northeast U.S.	Zoarces americanus	Ocean pout	47	3.42	-0.0083	0.0081
Northeast U.S.	Malacoraja senta	Smooth skate	47	3.50	-0.1637	0.0012
Northeast U.S.	Mallotus villosus	Capelin	47	3.15	-0.1847	*
Northeast U.S.	Melanogrammus aeglefinus	Haddock	47	4.09	-0.2100	0.0631
Northeast U.S.	Menidia menidia	Atlantic silverside	47	3.18	0.4109	*
Northeast U.S.	Menticirrhus saxatilis	Northern kingcroaker	47	3.58	0.3140	*
Northeast U.S.	Merluccius albidus	Offshore silver hake	47	3.40	0.0231	0.0002
Northeast U.S.	Merluccius bilinearis	Silver hake	47	4.26	0.1637	0.0219
Northeast U.S.	Micropogonias undulatus	Atlantic croaker	47	3.31	0.5408	0.0107
Northeast U.S.	Morone americana	White perch	47	3.08	-0.1094	*
Northeast U.S.	Morone saxatilis	Striped sea-bass	47	4.34	0.7608	0.0013
Northeast U.S.	Mustelus canis	Dusky smooth-hound	47	3.70	0.3887	0.0142
Northeast U.S.	Myliobatis freminvillei	Bullnose eagle ray	47	3.20	0.4536	0.0024
Northeast U.S.	Myoxocephalus aenaeus	Grubby	47	3.70	0.3531	*
Northeast U.S.	Myoxocephalus octodecemspinosus	Longhorn sculpin	47	3.50	0.2248	0.0084
Northeast U.S.	Myoxocephalus scorpius	Shorthorn sculpin	47	3.90	0.0315	*
Northeast U.S.	Myxine glutinosa	Hagfish	47	3.45	0.0213	*
Northeast U.S.	Nezumia bairdii	Marlin-spike grenadier	47	3.60	-0.4215	*
Northeast U.S.	Ophichthus cruentifer	Margined snake eel	47	3.40	-0.1247	*
Northeast U.S.	Ophidion marginatum	Striped cusk-eel	47	3.50	-0.0130	*
Northeast U.S.	Opsanus tau	Oyster toadfish	47	3.60	0.0099	*
Northeast U.S.	Osmerus mordax	Rainbow smelt	47	3.00	0.2463	*
Northeast	Pandalus borealis	Northern prawn	47	2.46	0.6218	*

U.S.						
Northeast U.S.	Paralichthys dentatus	Summer flounder	47	4.49	0.5560	0.0067
Northeast U.S.	Hippoglossina oblonga	American fourspot flounder	47	4.20	0.6596	0.0056
Northeast U.S.	Peprilus triancanthus	American butterfish	47	3.97	0.1045	0.0148
Northeast U.S.	Peristedion miniatum	Armored searobin	47	3.70	0.1693	0.0001
Northeast U.S.	Petromyzon marinus	Sea lamprey	47	4.37	0.3702	*
Northeast U.S.	Placopecten magellanicus	American sea scallop	47	2.00	0.4579	0.0094
Northeast U.S.	Pogonias cromis	Black drum	47	3.89	0.1709	*
Northeast U.S.	Pollachius virens	Saithe	47	4.38	-0.4801	0.0251
Northeast U.S.	Pomatomus saltatrix	Bluefish	47	4.50	0.1212	0.0022
Northeast U.S.	Priacanthus arenatus	Atlantic bigeye	47	4.00	0.1228	*
Northeast U.S.	Prionotus carolinus	Northern searobin	47	4.10	0.0509	0.0085
Northeast U.S.	Prionotus evolans	Striped searobin	47	4.30	0.4487	0.0007
Northeast U.S.	Pseudopleuronectes americanus	Winter flounder	47	2.83	-0.0157	0.0091
Northeast U.S.	Raja eglanteria	Clearnose skate	47	3.70	0.6330	0.0051
Northeast U.S.	Reinhardtius hippoglossoides	Greenland halibut	47	4.48	0.4343	*
Northeast U.S.	Sarda sarda	Atlantic bonito	47	4.20	0.0833	*
Northeast U.S.	Scomber japonicus	Chub mackerel	47	3.09	0.1098	0.0002
Northeast U.S.	Scomber scombrus	Atlantic mackerel	47	3.18	0.5430	0.0118
Northeast U.S.	Scophthalmus aquosus	Windowpane	47	3.55	0.0398	0.0055
Northeast U.S.	Scyliorhinus retifer	Chain catshark	47	4.40	0.6707	0.0001
Northeast U.S.	Sebastes fasciatus	Acadian redfish	47	3.20	0.0324	0.0558
Northeast U.S.	Selene setapinnis	Atlantic moonfish	47	3.72	0.4337	*
Northeast U.S.	Selene vomer	Lookdown	47	4.30	0.1947	*
Northeast U.S.	Spisula solidissima	Atlantic surf clam	47	2.00	0.0072	*
Northeast U.S.	Squalus acanthias	Piked dogfish	47	4.30	0.6078	0.3999
Northeast U.S.	Squatina dumeril	Sand devil	47	4.50	-0.0148	0.0008
Northeast U.S.	Stenotomus chyrsops	Scup	47	3.90	0.2969	0.0074

Northeast U.S.	Synagrops bellus	Blackmouth bass	47	3.70	0.4031	*
Northeast U.S.	Syngnathus fuscus	Northern pipefish	47	3.20	0.2928	*
Northeast U.S.	Tautoga onitis	Tautog	47	3.33	0.0762	*
Northeast U.S.	Tautogolabrus adspersus	Cunner	47	3.54	0.1397	0.0003
Northeast U.S.	Torpedo nobiliana	Electric ray	47	4.50	0.0939	0.0004
Northeast U.S.	Trichiurus lepturus	Largehead hairtail	47	4.45	0.2514	*
Northeast U.S.	Triglops murrayi	Moustache sculpin	47	3.50	-0.5097	*
Northeast U.S.	Phycis chesteri	Longfin hake	47	3.20	-0.4727	0.0001
Northeast U.S.	Urophycis regia	Red hake	47	3.60	0.5282	0.0031
Northeast U.S.	Urophycis tenuis	White hake	47	4.20	-0.2766	0.0195
Northeast U.S.	Urophycis chuss	Red hake	47	3.60	-0.1822	0.0133
Northeast U.S.	Zenopsis conchifera	Silvery John dory	47	4.50	0.6441	0.0002
North Sea	Ammodytes tobianus	Small sandeel	28	3.10	0.2114	0.0001
North Sea	Anarhichas lupus	Atlantic wolffish	28	3.24	-0.7143	0.0007
North Sea	Chelidonichthys cuculus	Red gurnard	28	3.85	0.6331	0.0002
North Sea	Clupea harengus	Atlantic herring	28	3.23	0.1217	0.2581
North Sea	Dicentrarchus labrax	European seabass	28	3.80	0.6295	*
North Sea	Eutrigla gurnardus	Grey gurnard	28	3.57	0.7037	0.0305
North Sea	Gadus morhua	Atlantic cod	28	4.42	-0.7249	0.0439
North Sea	Glyptocephalus cynoglossus	Witch flounder	28	3.14	-0.3333	0.0006
North Sea	Hippoglossus hippoglossus	Atlantic halibut	28	4.53	0.3545	*
North Sea	Lepidorhombus whiffiagonis	Megrim	28	3.58	0.0899	0.0005
North Sea	Limanda limanda	Common dab	28	3.29	0.3333	0.0598
North Sea	Lophius piscatorius	Angler	28	4.49	-0.0106	0.0025
North Sea	Melanogrammus aeglefinus	Haddock	28	4.09	-0.0635	0.2509
North Sea	Merlangius merlangus	Whiting	28	4.29	-0.2804	0.1835
North Sea	Merluccius merluccius	European hake	28	4.42	0.2381	0.0006
North Sea	Micromesistius poutassou	Blue whiting	28	4.01	0.2381	0.0001
North Sea	Microstomus kitt	Lemon sole	28	3.22	-0.0899	0.0033
North Sea	Mullus surmuletus	Surmullet	28	3.35	0.7698	*
North Sea	Platichthys flesus	European flounder	28	3.53	-0.2116	0.0008
North Sea	Pleuronectes	European plaice	28	3.26	0.0106	0.0097

	platessa					
North Sea	Pollachius virens	Saithe	28	4.38	0.2275	0.0316
North Sea	Psetta maxima	Turbot	28	3.05	0.1534	0.0003
North Sea	Scomber scombrus	Atlantic mackerel	28	3.18	0.4550	0.0237
North Sea	Scophthalmus rhombus	Brill	28	3.79	0.1852	0.0001
North Sea	Solea solea	Common sole	28	3.17	0.2011	0.0001
North Sea	Sprattus sprattus	European sprat	28	3.00	0.5079	0.0179
North Sea	Trachurus trachurus	Atlantic horse mackerel	28	3.64	0.5344	0.0015
North Sea	Chelidonichthys lucerna	Tub gurnard	28	3.65	0.1201	*
North Sea	Trisopterus esmarkii	Norway pout	28	3.22	0.0899	0.0789
North Sea	Zeus faber	John dory	28	4.50	0.6113	*
Portuguese coast	Boops boops	Bogue	26	3.00	0.0954	0.0103
Portuguese coast	Conger conger	European conger	26	4.29	0.0215	0.0030
Portuguese coast	Lepidopus caudatus	Silver scabbardfish	26	3.85	0.2677	0.0099
Portuguese coast	Merluccius merluccius	European hake	26	4.42	0.5200	0.0888
Portuguese coast	Micromesistius poutassou	Blue whiting	26	4.01	-0.2062	0.6298
Portuguese coast	Pagellus acarne	Axillary seabream	26	3.48	0.2369	0.0348
Portuguese coast	Scomber scombrus	Atlantic mackerel	26	3.18	0.3108	0.0859
Portuguese coast	Trachurus trachurus	Atlantic horse mackerel	26	3.64	0.0215	0.1202
Portuguese coast	Trisopterus luscus	Pouting	26	3.73	-0.0954	0.0109
Portuguese coast	Zeus faber	John dory	26	4.50	0.1323	0.0064
Southern Benguela	Argyrosomus hololepidotus	Southern meagre	23	3.82	-0.3050	0.0002
Southern Benguela	Argyrozona argyrozona	Carpenter seabream	23	3.05	-0.2164	0.0004
Southern Benguela	Arnoglossus capensis	Cape scaldfish	23	3.60	-0.0409	*
Southern Benguela	Austroglossus microlepis	West coast sole	23	3.48	-0.1111	0.0001
Southern Benguela	Austroglossus pectoralis	Mud sole	23	4.03	-0.0526	0.0007
Southern Benguela	Brama brama	Atlantic pomfret	23	4.08	0.3333	0.0006
Southern Benguela	Callorhinchus capensis	Cape elephantfish	23	3.45	0.2281	0.0070
Southern Benguela	Chelidonichthys capensis	Cape gurnard	23	4.21	0.4503	0.0057
Southern Benguela	Chelidonichthys queketti	Lesser gurnard	23	3.90	-0.1579	0.0123
Southern	Chirodactylus	Bank steenbras	23	3.30	-0.1345	0.0001

Benguela	grandis					
Southern Benguela	Congiopodus spinifer	Spinenose horsefish	23	3.30	-0.1813	0.0005
Southern Benguela	Congiopodus torvus	Smooth horsefish	23	3.40	-0.0526	0.0004
Southern Benguela	Cynoglossus zanzibarensis	Zanzibar tonguesole	23	3.60	0.1579	0.0009
Southern Benguela	Emmelichthys nitidus	Cape bonnetmouth	23	3.61	-0.1579	0.0016
Southern Benguela	Engraulis capensis	Cape anchovy	27	2.96	0.2707	0.3658
Southern Benguela	Etrumeus whiteheadi	Whiteheads round herring	27	3.40	0.6752	0.1517
Southern Benguela	Galeichthys feliceps	White baggar	23	3.47	-0.0058	0.0009
Southern Benguela	Galeorhinus galeus	Tope shark	23	4.21	-0.3450	0.0013
Southern Benguela	Genypterus capensis	Kingklip	23	4.41	0.0058	0.0031
Southern Benguela	Halaelurus natalensis	Tiger catshark	23	4.20	-0.1228	0.0001
Southern Benguela	Haploblepharus edwardsii	Puffadder shyshark	23	3.80	0.0877	0.0001
Southern Benguela	Helicolenus dactylopterus	Blackbelly rosefish	23	3.81	0.0526	0.0051
Southern Benguela	Hoplostethus mediterraneus	Mediterranean slimehead	23	3.49	0.0409	0.0000
Southern Benguela	Jasus lalandii	Cape rock lobster	23	2.60	0.0409	0.0011
Southern Benguela	Lampanyctodes hectoris	Hectors lanternfish	23	3.17	0.0175	0.0001
Southern Benguela	Lepidopus caudatus	Silver scabbardfish	23	3.85	0.2632	0.0025
Southern Benguela	Loligo vulgaris	European squid	23	4.10	0.2982	0.0034
Southern Benguela	Lophius vomerinus	Cape monk	23	4.46	0.4152	0.0052
Southern Benguela	Merluccius capensis	South Pacific hake	23	4.26	0.0292	0.0555
Southern Benguela	Merluccius paradoxus	Deep-water Cape hake	23	4.66	0.2047	0.0809
Southern Benguela	Mustelus mustelus	Smooth-hound	23	3.83	0.0877	0.0006
Southern Benguela	Mustelus palumbes	Whitespotted smooth-hound	23	3.50	0.0526	0.0015
Southern Benguela	Octopus magnificus	Southern giant octopus	23	3.96	0.0994	0.0002
Southern Benguela	Pagellus bellottii	Red pandora	23	3.60	-0.2632	0.0018
Southern Benguela	Palinurus gilchristi	Southern spiny lobster	23	2.60	0.5789	*
Southern Benguela	Pomatomus saltatrix	Bluefish	23	4.50	-0.2698	0.0001
Southern Benguela	Pterogymnus laniarius	Panga seabream	23	3.68	0.1228	0.0134

Southern Benguela	Rostroraja alba	White skate	23	4.40	-0.1111	0.0024
Southern Benguela	Raja clavata	Thornback ray	23	3.60	-0.1228	0.0013
Southern Benguela	Rajella leopardus	Leopard skate	23	3.90	0.0877	0.0001
Southern Benguela	Raja miraletus	Brown ray	23	3.80	-0.4152	0.0001
Southern Benguela	Dipturus pullopunctatus	Slime skate	23	4.10	0.2865	0.0010
Southern Benguela	Raja straeleni	Spotted skate	23	4.00	-0.1228	0.0032
Southern Benguela	Leucoraja wallacei	Yellowspotted skate	23	3.90	0.2164	0.0013
Southern Benguela	Rhabdosargus globiceps	White stumpnose	23	2.87	0.0643	0.0002
Southern Benguela	Rhinobatos annulatus	Lesser sandshark	23	3.40	-0.4152	0.0003
Southern Benguela	Sardinops sagax	Pacific sardine	27	2.43	0.4473	0.1677
Southern Benguela	Scomber japonicus	Chub mackerel	23	3.09	0.2515	0.0024
Southern Benguela	Sphoeroides pachygaster	Blunthead puffer	23	4.20	0.1696	0.0004
Southern Benguela	Sphyrna zygaena	Smooth hammerhead	23	4.50	-0.1416	0.0002
Southern Benguela	Squalus acanthias	Piked dogfish	23	4.30	-0.1696	0.0001
Southern Benguela	Squalus megalops	Shortnose spurdog	23	4.30	0.1813	0.0268
Southern Benguela	Squalus mitsukurii	Shortspine spurdog	23	4.50	0.3333	0.0011
Southern Benguela	Thyrsites atun	Snoek	23	3.74	0.0877	0.0020
Southern Benguela	Todarodes angolensis	Angola flying squid	23	4.00	-0.0175	0.0002
Southern Benguela	Todaropsis eblanae	Lesser flying squid	23	4.00	0.6608	0.0015
Southern Benguela	Trachurus trachurus	Atlantic horse mackerel	23	3.64	0.0877	0.0575
Southern Benguela	Umbrina canariensis	Canary drum	23	3.37	-0.2463	0.0001
Southern Benguela	Zeus capensis	Cape dory	23	4.50	0.3216	0.0053
South Catalan Sea	Conger conger	European conger	35	4.29	-0.2874	0.0361
South Catalan Sea	Engraulis encrasicolus	European anchovy	32	3.11	-0.4444	0.0005
South Catalan Sea	Galeus melastomus	Blackmouth catshark	35	3.73	-0.4958	0.0197
South Catalan	Loligo	Common squids	35	3.99	-0.2437	0.0457

Sea						
South Catalan Sea	Lophius	Monkfishes	35	4.46	0.1731	0.0444
South Catalan Sea	Merluccius merluccius	European hake	35	4.42	0.0084	0.1887
South Catalan Sea	Micromesistius poutassou	Blue whiting	35	4.01	-0.5227	0.1823
South Catalan Sea	Mullus	Western goatfishes	35	3.29	0.1059	0.0582
South Catalan Sea	Octopus sp.	Octopuses	35	3.80	0.0286	0.2710
South Catalan Sea	Pleuronectiformes	Flatfishes	35	3.57	0.6370	0.0405
South Catalan Sea	Sardina pilchardus	European pilchard	32	3.10	-0.1589	0.0016
South Catalan Sea	Scomber	Mackerels	35	3.65	-0.2739	0.0092
South Catalan Sea	Thunnus thynnus	Atlantic bluefin tuna	26	4.43	0.0376	*
South Catalan Sea	Trachurus	Jack and horse mackerels	35	3.70	0.2269	0.0765
South Catalan Sea	Trisopterus minutus	Poor cod	35	3.60	0.1597	0.0255
South Catalan Sea	Xiphias gladius	Swordfish	26	4.49	0.0376	*
Scottish west coast	Clupea harengus	Atlantic herring	24	3.23	-0.8022	0.1877
Scottish west coast	Pleuronectiformes	Flatfishes	23	3.57	0.4387	0.0877
Scottish west coast	Gadus morhua	Atlantic cod	24	4.42	-0.8043	0.0080
Scottish west coast	Lophius	Monkfishes	24	4.46	0.1449	0.0099
Scottish west coast	Melanogrammus aeglefinus	Haddock	24	4.09	-0.1667	0.0259
Scottish west coast	Merlangius merlangus	Whiting	23	4.29	-0.1542	0.0149
Scottish west coast	Micromesistius poutassou	Blue whiting	24	4.01	0.6522	0.1812
Scottish west coast	Pollachius pollachius	Pollock	24	4.15	0.0870	0.0116
Scottish west coast	Scomber scombrus	Atlantic mackerel	24	3.18	-0.4565	0.1729

Scottish west coast	Trachurus trachurus	Atlantic horse mackerel	24	3.64	-0.4928	0.1849
Scottish west coast	Trisopterus esmarkii	Norway pout	23	3.22	0.2727	0.1154
U.S. west coast	Atheresthes stomias	Arrowtooth flounder	8	4.26	0.3571	0.0319
U.S. west coast	Sebastes aurora	Aurora rockfish	8	3.60	-0.0714	0.0034
U.S. west coast	Raja binoculata	Big skate	8	3.90	-0.0714	0.0072
U.S. west coast	Apristurus brunneus	Brown catshark	8	3.60	-0.5714	0.0077
U.S. west coast	Sebastes pinniger	Canary rockfish	8	3.80	0.0000	0.0145
U.S. west coast	Sabastes goodei	Chilipepper	8	2.00	-0.7857	0.0469
U.S. west coast	Sebastes crameri	Darkblotched rockfish	8	3.70	-0.4286	0.0085
U.S. west coast	Embassichthys bathybius	Deep-sea sole	8	3.30	0.6429	0.0065
U.S. west coast	Microstomus pacificus	Dover sole	8	3.27	0.0000	0.1959
U.S. west coast	Parophrys vetulus	English sole	8	3.45	-0.6429	0.0189
U.S. west coast	Parmaturus xaniurus	Filetail catshark	8	3.80	0.1429	0.0042
U.S. west coast	Sebastes elongatus	Greenstriped rockfish	8	3.60	0.3571	0.0106
U.S. west coast	Sebastes semicinctus	Halfbanded rockfish	8	3.50	-0.0714	0.0082
U.S. west coast	Ophiodon elongatus	Lingcod	8	4.32	-0.7143	0.0192
U.S. west coast	Dipturus oxyrinchus	Longnose skate	8	3.08	0.4286	0.0412
U.S. west coast	Sebastolobus altivelis	Longspine thornyhead	8	3.40	0.7143	0.1128
U.S. west coast	Coryphaenoides acrolepis	Pacific grenadier	8	3.80	-0.2143	0.0295
U.S. west coast	Merluccius productus	Pacific hake	8	3.56	-0.8571	0.0912
U.S. west coast	Sebastes alutus	Pacific ocean perch	8	3.50	0.0000	0.0090
U.S. west coast	Citharichthys sordidus	Pacific sanddab	8	3.45	0.0714	0.0486
U.S. west coast	Eopsetta jordani	Petrale sole	8	4.05	-0.0714	0.0144
U.S. west coast	Glyptocephalus zachirus	Rex sole	8	3.24	-0.7143	0.0347
U.S. west coast	Anoplopoma fimbria	Sablefish	8	3.83	-0.7857	0.0729
U.S. west coast	Sebastes zacentrus	Sharpchin rockfish	8	3.60	-0.7857	0.0169
U.S. west coast	Sebastolobus alascanus	Shortspine thornyhead	8	3.61	-0.2857	0.0372
U.S. west	Squalus acanthias	Spiny dogfish	8	4.30	-0.8095	0.0413

coast						
U.S. west coast	Sebastes diploproa	Splitnose rockfish	8	3.70	0.2143	0.0355
U.S. west coast	Sebastes saxicola	Stripetail rockfish	8	3.60	-0.4286	0.0146
U.S. west coast	Sebastes flavidus	Yellowtail rockfish	8	4.11	0.0000	0.0164
Vancouver Island	Alosa sapidissima	American shad	31	3.19	0.0947	0.0005
Vancouver Island	Anoplopoma fimbria	Sablefish	31	3.83	0.2602	0.0147
Vancouver Island	Atheresthes stomias	Arrowtooth flounder	31	4.26	0.3763	0.0913
Vancouver Island	Citharichthys sordidus	Pacific sanddab	31	3.45	0.2301	0.0165
Vancouver Island	Clupea pallasii	Pacific herring	31	3.15	0.1957	0.0608
Vancouver Island	Eopsetta jordani	Petrale sole	31	4.05	0.4151	0.0044
Vancouver Island	Gadus macrocephalus	Pacific cod	31	4.01	0.2129	0.0192
Vancouver Island	Glyptocephalus zachirus	Rex sole	31	3.24	0.4495	0.0459
Vancouver Island	Hippoglossoides elassodon	Flathead sole	31	3.64	0.0495	0.0127
Vancouver Island	Hippoglossus stenolepis	Pacific halibut	31	4.13	0.4366	0.0094
Vancouver Island	Lepidopsetta bilineata	Rock sole	31	3.21	-0.0989	0.0001
Vancouver Island	Lyopsetta exilis	Slender sole	31	3.40	0.6172	0.0381
Vancouver Island	Merluccius productus	North Pacific hake	31	4.35	0.3978	0.0361
Vancouver Island	Microstomus pacificus	Dover sole	31	3.27	0.5183	0.0273
Vancouver Island	Ophiodon elongatus	Lingcod	31	4.32	-0.1054	0.0329
Vancouver Island	Pandalus	Pandalus shrimps	31	2.60	0.0796	0.1646
Vancouver Island	Parophrys vetulus	English sole	31	3.45	0.3462	0.0087
Vancouver Island	Rajidae	Skates	31	3.82	0.4194	0.0133
Vancouver Island	Sebastes flavidus	Yellowtail rockfish	31	4.11	0.5312	0.0552
Vancouver Island	Sebastes pinniger	Canary rockfish	31	3.80	-0.1828	0.0319
Vancouver Island	Squalus acanthias	Pacific spiny dogfish	31	4.30	-0.0624	0.3092
Vancouver Island	Theragra chalcogramma	Walleye pollock	31	3.45	-0.3591	0.0072
Western Scotian Shelf	Anarhichas lupus	Atlantic wolffish	41	3.24	-0.5610	0.0019
Western	Argentina silus	Greater argentine	41	3.31	-0.2610	0.0036

Scotian Shelf						
Western Scotian Shelf	Brosme brosme	Tusk	41	4.00	-0.7024	0.0031
Western Scotian Shelf	Citharichthys arctifrons	Gulf Stream flounder	41	3.30	0.3770	*
Western Scotian Shelf	Clupea harengus	Atlantic herring	41	3.23	-0.5186	0.6821
Western Scotian Shelf	Gadus morhua	Atlantic cod	41	4.42	-0.5293	0.0166
Western Scotian Shelf	Hemitripterus americanus	Sea raven	41	4.50	0.0073	0.0015
Western Scotian Shelf	Hippoglossoides platessoides	American plaice	41	3.65	-0.5341	0.0020
Western Scotian Shelf	Hippoglossus hippoglossus	Atlantic halibut	41	4.53	0.1585	0.0011
Western Scotian Shelf	Illex illecebrosus	Northern shortfin squid	41	3.98	0.0049	0.0065
Western Scotian Shelf	Limanda ferruginea	Yellowtail flounder	41	3.22	0.3366	0.0006
Western Scotian Shelf	Lophius americanus	American angler	41	4.49	-0.5463	0.0020
Western Scotian Shelf	Melanogrammus aeglefinus	Haddock	41	4.09	-0.0805	0.0482
Western Scotian Shelf	Merluccius bilinearis	Silver hake	41	4.26	0.0317	0.0107
Western Scotian Shelf	Myoxocephalus octodecemspinosus	Longhorn sculpin	41	3.50	0.3585	0.0014
Western Scotian Shelf	Myxine glutinosa	Hagfish	41	3.45	0.3114	*
Western Scotian Shelf	Phycis chesteri	Longfin hake	41	3.20	-0.1845	0.0001
Western Scotian Shelf	Pollachius virens	Saithe	41	4.38	0.0268	0.0360
Western Scotian Shelf	Pseudopleuronectes americanus	Winter flounder	41	2.83	0.5780	0.0029
Western Scotian	Leucoraja erinacea	Little skate	41	3.40	0.3038	0.0006

Shelf						
Western Scotian Shelf	Leucoraja ocellata	Winter skate	41	4.40	-0.1073	0.0008
Western Scotian Shelf	Amblyraja radiata	Starry ray	41	4.00	-0.7293	0.0038
Western Scotian Shelf	Reinhardtius hippoglossoides	Greenland halibut	41	4.48	0.4825	*
Western Scotian Shelf	Scomber scombrus	Atlantic mackerel	41	3.18	0.1174	0.0003
Western Scotian Shelf	Scophthalmus aquosus	Windowpane	41	3.55	0.4348	*
Western Scotian Shelf	Sebastes	Redfishes	41	3.79	0.2317	0.0530
Western Scotian Shelf	Squalus acanthias	Piked dogfish	41	4.30	0.3732	0.1036
Western Scotian Shelf	Tautogolabrus adspersus	Cunner	41	3.54	0.0367	*
Western Scotian Shelf	Urophycis chuss	Red hake	41	3.60	0.3877	0.0009
Western Scotian Shelf	Urophycis tenuis	White hake	41	4.20	-0.2366	0.0165