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Marine biology

Ignoring discards biases the assessment of fisheries' ecological fingerprint

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Understanding the pressures of fisheries on the ecosystem is crucial for effective management. Fishery removals, or catch, are composed of both landings and discards. However, the use of discards data in studies investigating the effect of the fishing pressures is sparse. Here, we explore the individual contribution of both these catch components to the overall pressure of fisheries on the ecosystem metrics. Using Irish observer data, we compare the linear relationship between several ecological metrics calculated for landings and discards with those of catch. Our results show that in fisheries with high discarding rates, discards can drive the fisheries' ecological fingerprint and highlight the need to rectify landings-based estimates to make them representative of those of catch in order to gain a robust picture of the impact of fisheries.

1. Introduction

The most important impact of fisheries on the marine ecosystem is arguably the removal of individuals [1]. These removals, which constitute the catch, are composed of two components: (i) landings, which is the portion of the catch brought ashore and; (ii) discards, which is the portion of the catch returned to sea [2]. The catch increases the mortality rate of the target and non-target species, which can not only impact the biodiversity and productivity of the ecosystems but also destabilize the function and structure of ecosystems such as food web topology and community demographics [3]. As a consequence, the implementation of increasingly popular multi-species management frameworks, e.g. ecosystem-based management [4] or balanced harvesting [5,6], requires focus on the conservation of marine biodiversity, not just focus on single-species or fished stocks.

Though there is an ongoing debate on the suitability of fisheries data to assess ecosystem health [7], it has been suggested that catch, i.e. landings plus discards, reflects the fishing pressure in an ecosystem [8]. Here, we aim to provide empirical support to this suggestion by disentangling the biodiversity of landings and discards from the catch, and assessing the effect of omitting non-commercial species on the estimation of fishing impacts. Since fishers tend to be selective and only land a portion of their catch [6], we expect that discards will make a greater contribution to the ecological profile of catches than landings will. Our hypothesis might not seem surprising; however, the relationship between the biodiversity of catch and its components remains unknown as discards are typically omitted from such studies. Our study provides the first quantitative evidence of the consequences for the biodiversity estimation of overlooking non-commercial species. Furthermore, if confirmed, our study implies that studies based on only partial data are open to considerable misinterpretation. Given that it is estimated that the world fisheries discard around 8% of the total catch, with certain fisheries such as demersal fisheries in the European Union and Unites States discarding at

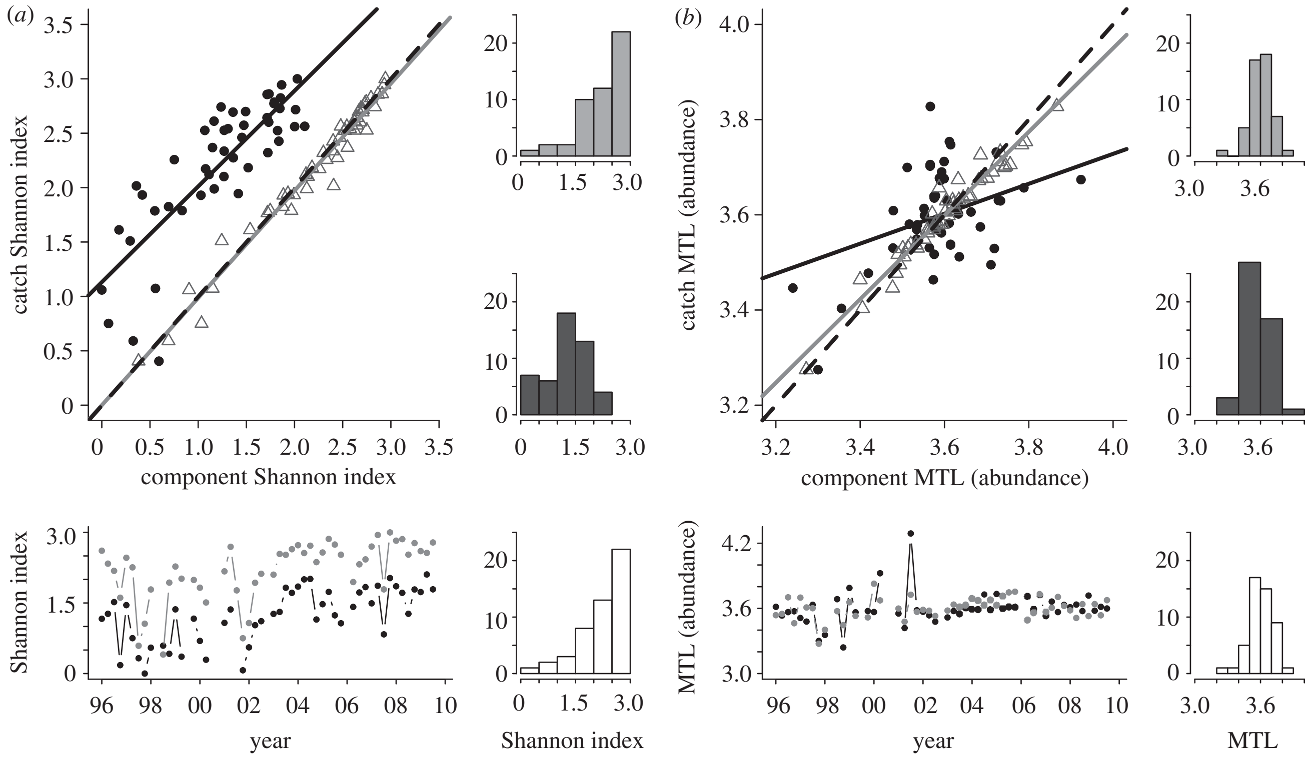

Figure 1. Shannon (*a*) index and MTL in abundance (*b*) calculated quarterly for catch (*y*-axis) against those of its two components (*x*-axis); upper plots. The black and grey lines correspond to the linear regression of catch (*y*-axis) against landings (dots) and discards (triangles) (*x*-axis), while the dotted line is the null model of intercept 0 and slope 1; all *p*-values < 0.05. The lower plots correspond to the quarterly time series of the metrics estimated for landings (black) and catch (grey). The time series of discards was omitted for clarity as it overlaps with catch. Adjacent, to the right, are histograms of the frequency of each correspondent metric for catch (grey), landings (black) and discards (white).

a much higher rate (e.g. up to 96% for prawn fisheries; [2]), understanding the contribution of discards to the impact of fishing is essential.

2. Material and methods

(a) Data

We used Irish observers' data collected quarterly from 1996 to 2009 onboard commercial fishing vessels, as part of the Marine Institute discards sampling programme for demersal fisheries. The data consisted of species-specific biomass and abundance caught per haul. In total, data from 2875 hauls from all around Ireland were used in this study. Further details are available in the electronic supplementary material.

(b) Methods

Rochet & Trenkel [9] have suggested that investigating fishing effects is mainly looking for changes in indicators of assemblages. Although the individual use of some of these indices have been questioned [9,10], the coupling of different diversity estimators is still the most pragmatic way of assessing the pressures of fishing.

We explored the importance of the different catch components in two ways: (i) we compared the frequency distribution of eight key ecological metrics calculated quarterly for catch, landings and discards. The metrics used were Shannon and Simpson indices, mean trophic level (MTL) in both abundance and biomass (g), species richness, total log biomass and total log abundance. (ii) We regressed those same eight ecological metrics calculated quarterly for catch against those calculated from landings and those calculated from discards. In addition to the regression coefficients and *p*-values, we compared the Akaike information criterion (AIC) of these models in order to compare the relative performance of landings and discards in predicting catch metrics. A difference of at least two is considered a significant improvement of the model fit [11]. Additionally, we compared the accuracy of each regression by subtracting these AIC values from those of the respective null model. This difference indicates which model is closer to the scenario of perfect prediction.

Finally, to explore the similarity of the quarterly compositions, we calculated the Bray–Curtis dissimilarity and Euclidean distance between the proportional composition of catch and landings and catch and discards. We used Welch *t*-tests on these values to assess whether landings or discards were closer in composition to catch.

As rare species are thought to affect the performance of many of the ecological metrics used [12], and rare species are typically discarded, we performed the analyses on (i) the full dataset comprising all species caught during the 14-year period investigated (163 species) and (ii) a subset of the data comprising only the 40 most frequently caught species.

Further details of the methods can be found in the electronic supplementary material.

3. Results

Our results suggest that not including discards in the assessment of marine biodiversity can bias our estimates of fishing pressures. The linear regressions for both the full and partial datasets were all significant with a *p*-value < 0.004. However, figure 1 and the electronic supplementary material, figure S1, tables S1 and S2, show that even though there is always a significant relationship between the characteristics of catch and landings, discards always yield both more accurate (see coefficients closer to one and AIC values in the electronic

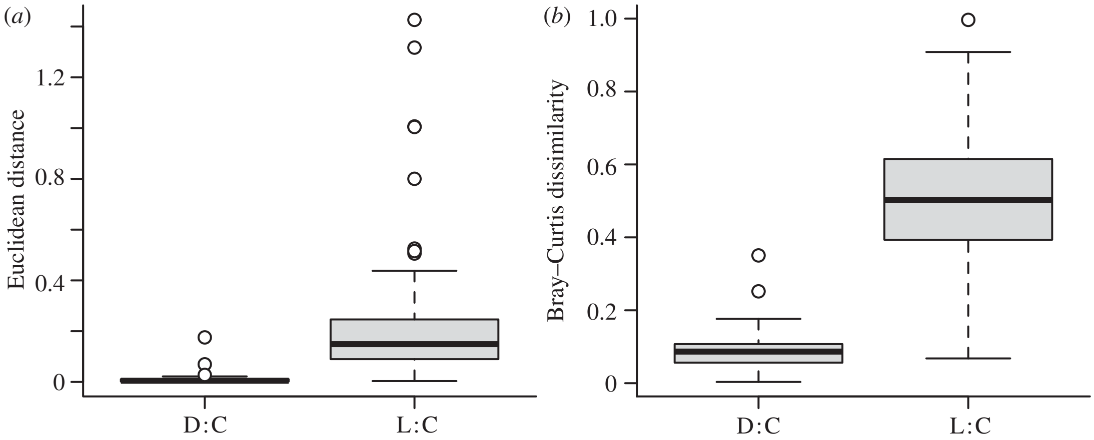

Figure 2. Euclidean distance (*a*) and Bray–Curtis dissimilarity (*b*) between the proportional compositions of catch and landings (L : C) with those between catch and discards (D : C). The means are significantly different based on a Welch *t*-test with *p*-values < 0.0001.

supplementary material, tables S1 and S2, respectively) and more precise (see $AIC_{null}-AIC$ values closer to zero in the electronic supplementary material, table S2) estimates. The intercepts and slopes of the regressions on the metrics of catch against those of discards are closer to the perfect prediction of intercept 0 and slope 1 than those of landings. This is particularly visible from the change in the histograms showing the frequency of each metric calculated for catch, landings and discards (figure 1). In figure 1, we show the results for Shannon index and MTL in abundance as examples, but the results for the remaining biodiversity metrics can be found in the electronic supplementary material. Using landings data, some biodiversity metrics of catch such as species richness, Shannon (figure 1*a*) and Simpson indices biomass and abundance are underestimated. On the other hand, other metrics, for example MTL, are underestimated for lower trophic levels and overestimated for higher trophic levels as seen from regression lines of catch against landings crossing the null model line (figure 1*b*).

The removal of rare species from the analysis did not alter the relationships between discards and catch and landings and catch described above (see results for the partial dataset in the electronic supplementary material, table S1a,b).

The Welch *t*-tests (see electronic supplementary material, table S1a) used to compare the Euclidean distance and Bray–Curtis dissimilarity between the proportional compositions of catch and landings with those between catch and discards show that the composition of catch is significantly (p-values $<$ 0.0001) more similar to discards (lesser distances) than to landings (greater distances), as seen in figure 2.

4. Discussion

A key aspect of the pressure from catches is encompassed in the biodiversity 'fingerprint' [10] of the removals. Our results show that biodiversity 'fingerprint' should consider the total removals (landings plus discards) rather than just the landed component. At least in Irish demersal fisheries, discards are more representative of catch than landings are, and using landings alone can lead to incorrect inferences regarding the magnitude and types of pressures of fishing on the ecosystem.

In our study, 163 species were caught while only 55 were landed. Consequently, the resultant underestimation of the catch species richness, Shannon and Simpson indices, obtained from the landings component was expected. However, the results are different for the MTL analysis. Landings had higher MTL than the catches at high trophic levels and lower at low trophic levels, even though the overall frequency distributions of MTL were similar. This suggests that higher trophic level fish are being selected for landing and the lower trophic level fish are being preferentially discarded, which will tend to mask any 'fishing down' effect [8]. However, this relationship depends on the species discarded and landed, and their relative abundance. At smaller values of biodiversity, landings are more biodiverse than discards and the opposite occurs for higher diversity values. This indicates that there is no direct relationship between landings and discards, and hence it would be difficult to predict the level of impact of each, and that omitting one almost inevitably leads to incorrect estimation of fishing impacts.

As the mortality rate of discards often approaches 100% [13,14], ignoring discards risks omitting more than half of fishing-induced mortality in certain fisheries. Discards for the Irish demersal fisheries represent approximately 61% of the catch in biomass and over 84% in abundance. Other European and North American demersal fisheries may have similarly high discarding rates, commonly reported higher than 50% [2]. However, the proportion of the catch that comprises discards will vary temporally, geographically and by fishery [2,15,16]. Therefore, the discrepancies between landings and catch are similarly expected to vary. In fisheries where discards are proportionally low, one may expect to find landings to better correlate with catch compared with one where discards are predominant. The relative contribution discards make to the overall catch will not only depend on biodiversity in a given area, but also on fishing effort, market demand, fisheries regulations and gear type, including selectivity devices. This variation in discarding rate is particularly important to consider in large-scale or global assessments because the measure of fishing pressure will differ within the study region when using the whole catch or landings-only datasets. Existing global assessments of discards [2,13] could be used to ascertain the validity of using widely available landings data as a proxy for catch.

Ignoring one of the components of catch can therefore alter or conceal the need to establish conservation priorities, particularly if there are threatened species being discarded. The results also highlight the need to monitor a greater number of species that are affected by fisheries and the value of incorporating data from dedicated discards sampling programmes, when compiling catch datasets. The latter is particularly relevant for the forthcoming European discards ban because it is imperative that future analyses compare the same portion of the catch.

Our results provide strong evidence that depending on the fishery, discards can drive the ecological fingerprint of fishing and show that the different types of biodiversity measures will generate different relationships among them. While the utility of catch data as a measure of fishing pressure may be a matter for debate [7], our results provide a clear message: the component of the catch most frequently analysed (i.e. landings) may often be less representative of the whole catch than the component typically omitted (i.e. discards). It is important to note that the discards biodiversity metrics do not describe perfectly the catch biodiversity metrics. We must then conclude that if we wish to accurately assess fishing biodiversity as a proxy for fishing pressure, we must use total removals, i.e. catch.

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