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Some expected impacts of the Common Fishery Policy on marine food webs

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ABSTRACT

For the ecosystem approach to fisheries management, understanding population dynamics and ecosystem resilience in response to the landing obligation acted by the reform of the European Common Fishery Policy (CFP) is currently an important avenue of research. This study attempts to assess the impact of the new CFP on marine food webs. Total carbon and nitrogen loss induced by a discard ban were estimated for the ecosystem of the Bay of Biscay based on French At-Sea Observer data and carbon and nitrogen content of discarded fish. Changes in predator diets were estimated by comparing two Bayesian mixing models, one mimicking the current situation and the second the application of the new CFP (removing the discarded species that would be landed from the model). Results illustrate a substantial shift in predation effort toward remaining available prey. The impact of changes in diet on individual and population health and on ecosystem functioning are important issues that remain to be assessed. A sister study could be carry out in another ecoregion, at a finer spatial scale in order to compare impacts and ecosystem responses. European monitoring programs such as DC-MAP and the Marine Strategy Framework Directive (MSFD) would help us to gain an understanding of how the food web would reorganize itself.

1. Introduction

Fisheries discards, corresponding to animals caught but returned to the sea due to minimum allowable landing size, quota restriction or low commercial value of species, are estimated at about 7 million tons per year [26]. North East Atlantic fisheries are identified as the second largest source of total removals [1,26], with some fisheries, like *Nephrops* trawlers, reaching discard rates of up to 50% [26]. Several tools are already being used to reduce discards, such as gear modifications [28,42], area closures (*e.g.* the plaice-box in [43]), acoustic and optical detection [8] or local discard bans [14] and have proved to significantly reduce discards in fisheries where they were tested. Despite these measures, the European Union reformed the Common Fishery Policy (CFP) and approved the landing obligation, implying that discarding any individuals of species under quota will be prohibited (Official Journal of the European Union, December 28th 2013).

It is well known that fishing activity is the most important major disturbance to marine ecosystems [22,24]. Among other changes, fishing modifies food web structure and stability by removing species from their environment [2,35]. However, some species have become quite dependent on fisheries activities by either feeding on dead or damaged fauna on the seabed [18,25], or feeding on discarded organisms [23,31,48]. Dead fishes that are not immediately eaten by predators but which fall on the seabed could also modify nutrient cycling processes through decomposition, and supply a significant proportion of the nutrients required for primary production [4]. Examples from aquatic ecosystems demonstrate that fish carcasses could provide up to 70% of a system's primary production [15]. In the North Sea, estimation of food production from damaged organisms or dead fish reaching the bottom revealed that a single passage of a beam trawl produced 8–24% of the food requirements of local scavengers [18]. So, in the same way that fishing perturbs the stability of trophic networks, the discard ban imposed in the reforms of the EU Common Fisheries Policy may have a significant impact on scavenger communities, as several population parameters such as reproductive success or growth are closely linked to food abundance and availability [33].

Research has also shown that some species survive the discarding process and that according to biological, environmental

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and technical parameters, survival could be substantial [41]. Following the implementation of the landing obligation, any individuals that would otherwise have survived the discarding process would no longer contribute to the stock, but to the overall fishing mortality.

In the context of an ecosystem approach to fisheries management, it is crucial to understand the impact of a discard ban on the food web. The present study is an attempt to assess the expected shortfalls of this fishing regulation in the Bay of Biscay (North-East Atlantic) in terms of inputs of organic matter for the ecosystem and predation reallocation to different prey species depending on the importance of the discard species for their diet. More precisely, stable isotopes of carbon and nitrogen, which are recognized as powerful tools for describing food web structure [37], and a Bayesian mixing model that makes it possible to characterize source contributions to predator diet [34], were used to make inferences on relative resources used among four examples of predatory fishes in the Bay of Biscay.

2. Methods

2.1. Sample collection

All the species under quota in ICES division VIII were considered except saithe *Pollachius virens,* which was absent from the sampling area and for which no discards were observed in 2014 or 2015 (Table 1). The other under-quota species were: boarfish Caproidae (Capr), roundnose grenadier *Coryphaenoides rupestris* (Crup), anchovy *Engraulis encrasicolus* (Eenc), cod Gadus morhua (Gmor), megrims *Lepidorhombus* spp. (Lepi), anglerfish Lophidae (Loph), haddock *Melanogrammus aeglefinus* (Maeg), whiting *Merlangius merlangus* (Mmer), hake *Merluccius merluccius* (Merl), blue whiting *Micromesistius poutassou* (Mpou), ling *Molva molva* (Mmol), Norway lobster *Nephrops norvegicus* (Nnor), plaice *Pleuronectes platessa* (Ppla), pollack *Pollachius pollachius* (Ppol), skate and ray Rajiformes (Raji), mackerel *Scomber scombrus* (Ssco), sole *Solea* spp. (Sole) and horse mackerel *Trachurus* spp. (Trac). Specimens of all these species were collected in 2014 onboard commercial vessels in coastal or shelf areas. A total of 95 specimens were sampled. The size range of each species was selected under minimum landing sizes in the ICES VIII division.

2.2. Stable isotope analysis

Stable isotopes of carbon and nitrogen are commonly used to examine consumer trophic ecology, providing a time-integrated measure of trophic position and energy sources. The basic rationale of the stable isotopes approach is that the isotopic composition of consumer tissues reflects that of their diet, which in turn depends on the relative proportions of prey species assimilated over a specific time period [13,30,36]. Nitrogen stable isotope ratios in consumers are useful for defining trophic positions of consumers [38] and carbon isotope ratios are typically used to define diet compositions or sources of energy [13]. From each individual, a small piece of muscle tissue was dissected and kept freeze-dried until further analysis. All samples were oven dried (60 °C for 48 h) and ground into a homogeneous powder using a mixer mill. Determination of δ^{15}N, δ^{13}C and % content of C and N were undertaken at the Stable Isotopes in Nature Laboratory (University of New Brunswick, Canada) using a Carlo Erba NC2500 Elemental Analyzer. Isotope ratios were reported in delta notation in accordance with international standards: Pee Dee belemnite carbonate for δ^{13}C and atmospheric nitrogen for δ^{15}N. Data were corrected using working standards (bass muscle, bovine liver, nicotinamide; SD < 0.2‰ for both δ^{13}C and δ^{15}N) that had been previously calibrated against the International Atomic Energy Agency (IAEA) standards.

2.3. Data analysis

2.3.1. Carbon and nitrogen loss

In order to estimate potential carbon and nitrogen loss for food webs, discard estimates for the main fisheries of the Bay of Biscay were obtained from the French At-Sea Observer Program for 2012 and 2013 [11,12]. The fleets concerned were bottom trawlers (targeting either fish or *Nephrops*), trawlers targeting small pelagic fish, netters, Danish seiners and long liners (Table 1).

The total carbon and nitrogen loss for the ecosystem were estimated as follows:

$$C_{loss} = \sum_{i=1}^{19} \sum_{j=1}^{6} W_{ij} * CC_i$$

and

$$N_{loss} = \sum_{i=1}^{19} \sum_{j=1}^{6} W_{ij} * NC_i$$

where W is the weight of discarded species i in fleets j and CC_i and NC_i are the carbon and nitrogen content of species i, respectively (Table 2).

2.3.2. Discard contribution to predator's diet

In order to establish whether discarded fish species are potential prey for piscivorous organisms, their stable isotope values were compared with stable isotope values of predators from Chouvelon et al. [9] in the Bay of Biscay.

First, trophic groups of discarded species were identified by hierarchical clustering analysis on δ^{15}N and δ^{13}C values using Ward's minimum variance method [49]. This method is based on the linear model criterion of least squares and its objective is to define groups that minimize the within-group sum of squares. Computation of within-group sums of squares is based on a Euclidean model. Given that sample size varied between taxa, but that the intention was to account for within-sample variation in isotopic ratios, hierarchical clustering was performed on a bootstrapped matrix of distances between species, which was computed as follows: since the minimum sample size was three, three individuals per species were sampled with replacement. The isotopic ratios of these samples were then used as coordinates to compute a Euclidian distance matrix between species after standardizing coordinates to 0 mean and unit variance. This procedure was repeated 500 times, and the resulting distance matrices were averaged to obtain the bootstrapped distance matrix on which clustering was performed. The number of resamplings was sufficient to stabilize the values of the bootstrapped distance matrix. After clustering, the optimal number of clusters was assessed by visual inspection of the resulting dendrogram and confirmed using graphs of the fusion level [6].

Then the Bayesian mixing model SIAR (Stable Isotope Analysis in R) developed by Parnell et al. [34] was used to determine the contribution of potential prey from the Bay of Biscay to a predator's diet. SIAR is a mixing model that is not constraint by the number of sources and takes into account the variability of input parameters like consumer and source isotopic signatures and trophic enrichment factor. Fractionation factors between resources and consumers were assumed to be 1 ± 0.5 for δ^{13}C and 3.4 ± 1 for δ^{15}N, values which fall within the range most often reported for consumers analyzed in terms of their muscle [29,36,46,47].

The groups of discarded species identified by cluster analysis were used as potential groups of prey as well as other potential