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**Risks to North Sea fish
stocks and wildlife if post-
Brexit fishery negotiations
fail to reach agreement on
quotas and access to UK
waters**

SUMMARY REPORT

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Risks to North Sea fish stocks and wildlife if post-Brexit fishery negotiations fail to reach agreement on quotas and access to UK waters: SUMMARY REPORT

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SUMMARY AND KEY FINDINGS

“Taking back control of fisheries” became one of the totemic issues uniting supporters of the campaign to leave the EU. Having left, the issue is again high on the agenda in the ‘future relationship’ negotiations. The UK Government has indicated that getting a better deal for UK fishermen is a “red line” in the negotiations. This includes increases in quota for UK vessels, and restrictions on access to UK waters by foreign vessels. However, the EU has linked access to UK waters and maintenance of quotas enshrined in the Common Fisheries Policy (CFP) with securing tariff-free trade in fish and other products.

This report focuses on the North Sea and provides an assessment of the risks to stock and ecosystem conservation associated with the post-Brexit fisheries negotiations. The report first sets out the history behind the allocation of quota shares (Relative Stability) and compares the UK shares with those under proposed alternative rules based on the distribution of fish (“zonal attachment”). Unless a negotiated agreement can be reached to resolve these different views on quota allocation there is a risk that unilateral actions will result in the combined catches by all states exceeding the levels required for long-term maximum sustainable yields. The report sets out a narrative for the impact of such unilateralism on harvesting rates, and then presents results from models which show the risks that these would pose for key fish stocks and wildlife.

Key findings of the report

- It is the case that other EU and neighbouring nation states take more fish overall from UK waters than UK vessels take from theirs. However, this discrepancy is not universal across all fish stocks or regions.
- A combination of Relative Stability and national and international quota swaps and trades leave the UK with a preferential proportion of the quota for some species but an unfavourable proportion of others. For example, the UK took, on average, 87% of

the haddock landings from the North Sea during 2003-2013 which exceeds current estimate of the zonal attachment based quota.

- For other stocks such as scallop, crabs and lobster which are valuable to the UK, the CFP and Relative Stability plays little or no role as the fisheries are carried out almost exclusively within existing national jurisdictions.
- In fact, a high proportion of the apparent disparity between total UK share of catches, and reliance of EU vessels on UK waters, is due to just four species – herring, mackerel, blue whiting and sandeel.
- In the event of post-Brexit unilateralism on quota setting the likely outcome is increased overall fishing levels that would more than double the risk of overfishing herring, and increase the risk of North Sea cod stock collapse by 75% (with stock levels falling below sustainable limits).
- Reduced food abundance and increased by-catch in fishing gear in a post-Brexit unilateralism scenario are likely to be the main risks for wildlife, resulting in a projected decline in cetaceans and seabirds.

Key conclusions from the report

Overall, the report demonstrates the importance of international adherence to scientific advice on catch limits for shared fish stocks. It is vital that the UK, EU and other coastal states such as Norway reach an agreement that that preserves cooperation on fisheries, even in the face of political pressure to act independently for short term gain. Otherwise, the outcome will be overfishing, eventual collapse of key stocks, declines in seabird and cetacean numbers, placing further pressure on the UK's coastal communities that rely on a healthy marine environment to survive.

The potential risk to North Sea cod stocks identified in the report is of particular concern. The modelling indicates a 75% risk of cod stocks falling below sustainable limits if the UK and other nation states set their quotas unilaterally.

It is also concerning that a unilateralist outcome is expected to lead to declines in seabird and cetacean numbers. The UK Government has identified the conservation of marine wildlife for future generations as a key action. These populations are already under pressure from climate change and a diversity of human activities so it would be detrimental to add further pressure from overfishing.

The findings highlight the need for the UK to have an effective, independent environmental watchdog to ensure fishing limits are set at sustainable levels.

1. Background

The UK left the European Union on 31 January 2020 under the terms of the “New Withdrawal Agreement” [1]. This marked the start of a transition period during which the future relationship between the UK and EU will be negotiated, as outlined in the associated “Political Declaration”.

The Political Declaration makes specific provisions for the departure of the UK from the European Common Fisheries Policy (CFP) which regulates fisheries activities across European waters [2, 3, 4, 5, 6, 7, 8]. The Declaration states that new arrangements are to be sought regarding access to waters and quota shares, while at the same time ensuring fishing at sustainable levels to “promote resource conservation, and foster a clean, healthy and productive marine environment”. The Declaration envisages that these negotiations will be concluded by 1 July 2020 (Political Declaration page 14, Section XII; [1]).

Freedom of access to the UK Exclusive Economic Zone (EEZ) for foreign fishing vessels and objections to the CFP ‘Relative Stability’ rules were among the high-profile arguments for exiting the EU [2, 9, 10, 11]. Relative Stability is the fixed allocation key which, since 1983, has governed how the Total Allowable Catch (TAC) for each of the EU-managed fish stocks is shared out between the fishing industries of the Member States. The amount allocated to each Member State is referred to as ‘quota’ [12, 13, 14, 15, 16]. The UK fishing industry has argued that Relative Stability has become grievously unfair to the UK and should be re-negotiated, advocating that fishing opportunities for shared stocks should be divided according to ‘zonal attachment’ – of which there are several definitions but is generally taken to refer to the proportional distribution of stock between EEZs [7, 17, 18, 19, 20]. On this basis, it is argued that the evidence suggests that the UK should receive a larger quota, or proportion of the available TAC, for many of the species and stocks in its own EEZ.

It is clear that access to UK waters for EU vessels and the allocation of quotas will be a key strand of the transition-period negotiations regarding future relations [21, 22, 23, 24]. For example, the briefing document for the Lords stages of the UK Fisheries Bill 2020 states that:

"The EU is seeking continued reciprocal access to fishing waters and stable quota shares for the amount of fish that can be caught. The UK argues British fishing waters should primarily be for British fishing vessels, and opportunities for EU vessels should be negotiated annually on the basis of scientific data about sustainable catch levels, not based on historic quotas." [25].

There is thus a potential scenario under which there is no agreement on these issues before the deadline set by the Political Declaration, or at least not to the satisfaction of the UK fishing industry [7, 23, 26, 27, 28, 29, 30, 31, 32, 33]. The plausible worst case consequence would be that the UK is unable to effectively police harvesting in its EEZ after the transition period [34] and/or ends up unilaterally setting its own quotas within its EEZ in excess of

Relative Stability. Given domestic pressure the UK's aim (officially sanctioned or otherwise) would presumably be to take what it regards as its perceived "fair share" of the TAC for shared stocks [3, 25], although this carries the risk of retaliatory tariffs on exports of fish products to the EU [14, 22, 35, 36, 37]. If the remaining EU Member States adhere to their existing Relative Stability quota allocation then, instead of being harvested within the TAC limits advised by the International Council for the Exploration of the Sea (ICES), these stocks will be over-exploited.

It is to be expected that unilateralism as outlined above would have detrimental consequences for fish stock conservation and the principle of harvesting at Maximum Sustainable Yield (MSY – the largest yield (or catch) that can be taken from a species' stock over an indefinite period. There would also be consequences for wildlife that depend on there being sufficient fish in the sea to feed. However, there has been no risk assessment of these impacts of post-Brexit fisheries negotiations breaking down into unilateralism. The purpose of this report is to provide an assessment of these risks for the North Sea.

2. Overall summary of the report

Relative Stability has been unpopular in the UK fishing industry which perceives that it provides the UK with a disproportionately small share of the available resource compared to the reliance of the international fishery on the UK EEZ [38, 39]. In any case, as the UK leaves the EU, the founding principle of the CFP – that fish stocks are a shared resource in shared waters – will no longer apply as the UK will become an independent nation state [6, 27, 40, 41]. Under the 1982 United Nations Convention on the Law of the Sea (UNCLOS) the independent UK will still have a responsibility to cooperate with the EU on the management of shared stocks and to minimise the economic impact of any changes on the coastal communities of States which have habitually fished in its EEZ or which have made substantial efforts in research and monitoring for management purposes [13, 27, 41]. On these grounds, the remaining EU Member States might be expected to argue for maintenance of the status-quo [26]. However, while the UK Government recognises its international commitments [42], the industry is pressing hard for a revision of Relative Stability [38, 39].

Unfortunately, the basis for negotiating alternative shares of TACs is extremely unclear and such negotiations are likely to take a number of years. The negotiating parties (The UK Government, The EU and, in the case of the North Sea and west of Scotland regions, the Norwegian and Faroese Governments) will be facing conflicting demands from across the negotiating table and from interested stakeholders within their own countries. The pressures on all of the parties to act unilaterally and claim catches which, when added together will exceed the TAC advised by the internationally recognised scientific assessment procedures, could become overwhelming. This may be particularly so for the UK since the expectation of a substantial boost to catching opportunities as a result of leaving the EU has been raised by the rhetoric of the Referendum Campaign [9, 29, 43, 44, 45, 46, 47, 48] and this could lead to the UK breaking its obligations under UNCLOS.

In order to understand how the UK ended up with the quota shares which became locked into the Relative Stability formula, we analysed the history of fishery landings from around the UK, and especially in the North Sea, since 1903. Data for this task were obtained from official FAO statistics [49], the EU Scientific, Technical and Economic Committee for Fisheries (STECF; [50]) and the Norwegian Directorate for Fisheries. The spatial distributions of landings from across the UK and non-UK EEZs in the North Sea, were then compared with estimates of zonal attachment for various fish species. Zonal attachment is an expression of the proportion of a shared stock which might be considered to be ‘owned’ by a nation based on the distribution of fish relative to its EEZ, and is likely to be a crucial factor in future negotiations [17, 19, 20]. However, the purpose here was to develop plausible narratives for what the UK might claim as its rightful catch for individual stocks or effort limit in the North Sea, in the event of the negotiations breaking down into unilateralism.

For the North Sea, the main element of the unilateralism narratives was a 50% increase in pelagic trawl and seine fishing effort, targeting a 70% increase in UK herring quota. The narratives also anticipate a smaller (~10%) increase in effort by demersal gears, targeting increased UK quota for cod, whiting, saithe and sole. The unilateralism narratives were then applied to two completely different types of mathematical models to predict the consequences for the food web and fish stocks in the North Sea. The first set of predictions involved the use of single species stock projection models - replicating those used by the International Council for the Exploration of the Sea (ICES) to provide fisheries advice to the EU [51] – to predict the probability of seven key stocks (herring, cod, haddock, whiting, saithe, plaice, sole) falling below their precautionary reference biomass (Bpa) within 5 years of the onset of unilateralism. The second set of predictions involved the use of a food web/ecosystem model of the North Sea. This model represented the whole network of interacting flora and fauna in the North Sea, from bacteria to whales, and their connections to the physical and chemical oceanography of the region, but at coarse taxonomic resolution [52, 53, 54]. This model did not resolve individual species, only aggregated groups of related types of species. However, it did capture the indirect effects of changes in one group on another as a result of predator-prey interactions.

The two modelling approaches produced convergent conclusions on the likely risks associated with unilateralism arising from a breakdown of fisheries negotiations. They both predict that the greatest risk is to stocks of plankton-eating pelagic fish, especially herring. Risks to demersal fish as a whole are much smaller, but within this group there is a significant risk to cod stocks. Among the indirect consequences of unilateralism are predicted declines in cetaceans and seabirds in the North Sea as a combined consequence of reductions in their main food supply (pelagic fish) and increased mortality due to by-catch in fishing gears.

3. Details of the research findings

3.1. Patterns of landings in relation to EEZs

The infamous fisheries statistic of the UK's EU Referendum Leave Campaign – that '80% of UK fish is given away to the rest of Europe' [10, 11, 55], or that other EU Member States take 8-times more fish from UK waters as we take from theirs [2, 56] – is generally supported by our analysis of landings data from, the waters around the UK. However, it is shown that this high-level generalisation is not applicable at the scale of individual sub-regions or stocks. A high proportion of the apparent disparity between UK share, and reliance on UK waters, is due to just four species – herring, mackerel, blue whiting and sandeel. In contrast, a combination of Relative Stability and national and international quota swaps and trades [7, 57] leave the UK with a preferential proportion of the TAC for some species. For example, the UK took, on average, 87% of the haddock landings from the North Sea during 2003-2013 which exceeds current estimate of the zonal attachment. For other valuable stocks such as scallop, crabs and lobster, the EU plays no role in setting TACs or quotas and the fisheries are carried out extensively within existing national jurisdictions.

In the case of the large-scale migratory species such as mackerel and blue whiting, which form around a third of the catch by weight from EU waters around the UK (North Sea, west of Scotland, Irish Sea, Southwest Approaches and English Channel), there are economic and biological reasons why a high proportion of the landings are taken in the UK EEZ. Similarly in the case of herring, especially in the North Sea, the stock is mainly harvested during a period of the year in which the fish are highly aggregated, and this happens to occur in the UK EEZ. In the case of sandeels, around half the annual catch is taken in the UK EEZ, but the UK has never had a significant commercial sandeel fishery – the majority of the market is as a natural resource for animal and aquaculture feed in Denmark and Norway, and not for direct human consumption. Accepting the founding principle of the Common Fisheries Policy – of shared stocks in shared waters - the allocation of significant quota shares of these species to other EU member states and Norway despite the reliance on UK waters may be understandable. However, as the UK leaves the EU and becomes an independent nation state these principles no longer hold [27, 58]. There will be an argument for abandoning Relative Stability and negotiating a new deal on the sharing out of the TACs for each of the stocks that are shared between the UK, EU and other neighbouring non-EU nations (especially Norway and the Faroe Islands). Since this is likely to be strongly resisted by the EU [26] there may be pressure in the UK to act unilaterally and claim a quota share in excess of Relative Stability. Such action could jeopardise the UK's international obligation under UNCLOS to collaborate with other States on the management of, and access to, shared stocks [13, 27, 41].

For the North Sea, the annual negotiations between the EU and Norway are an additional dimension to the sharing out of TACs (see [59] as an example). The EU and Norway operate on a principle of reciprocity regarding access to national waters in order to catch their assigned share of each TAC. However, the extent of Norwegian landings from the UK EEZ has received relatively little attention so far in the discussions on possible post-Brexit fisheries. This is partly because non-EU catch data are not included in the EU Scientific, Technical and Economic Committee for Fisheries (STECF) databases upon which most existing spatial analyses of landings and fishing effort have been carried out [45, 60, 61, 62]. Inclusion in this report of spatial data on Norwegian landings from the North Sea obtained

from the Norwegian Directorate of Fisheries shows that in terms of total landings both Norway and the rest of the EU are heavily reliant on the UK EEZ in the North Sea while the UK relies very little on access to waters outside its own EEZ (Norway takes 31% of its total North Sea landings of fish and shellfish from the UK EEZ, the rest of the EU 55%, and the UK 86%).

Within the North Sea, dependence on the UK EEZ varies across the fishery sectors. The UK takes more than 95% of its North Sea landings of pelagic (herring, sprat, sandeel) and migratory fish (mackerel, blue whiting, horse mackerel) and shellfish from its own EEZ. However, somewhat less (71%) of its North Sea demersal fish landings come from its own EEZ. Conversely, the rest of the EU catches over 60% of its total North Sea pelagic and migratory species landings from the UK EEZ, but only 30% of demersal fish and 2% of shellfish. Norway takes 47% of its landings of demersal fish from the UK EEZ, and 34% and 22% respectively of pelagic and migratory species.

Within the UK North Sea EEZ, the UK takes the largest share of demersal fish (49%), while the rest of the EU catches the largest share (73%) of pelagic fish (herring, sprat, sandeels). Landings of migratory fish (mackerel, blue whiting, horse mackerel) from the UK EEZ are roughly evenly divided between the UK, rest of the EU and Norway. For the shellfish species (scallop, prawns, shrimps, crabs, lobster), over 98% of the landings from the UK EEZ taken by the UK (Fig. 1).

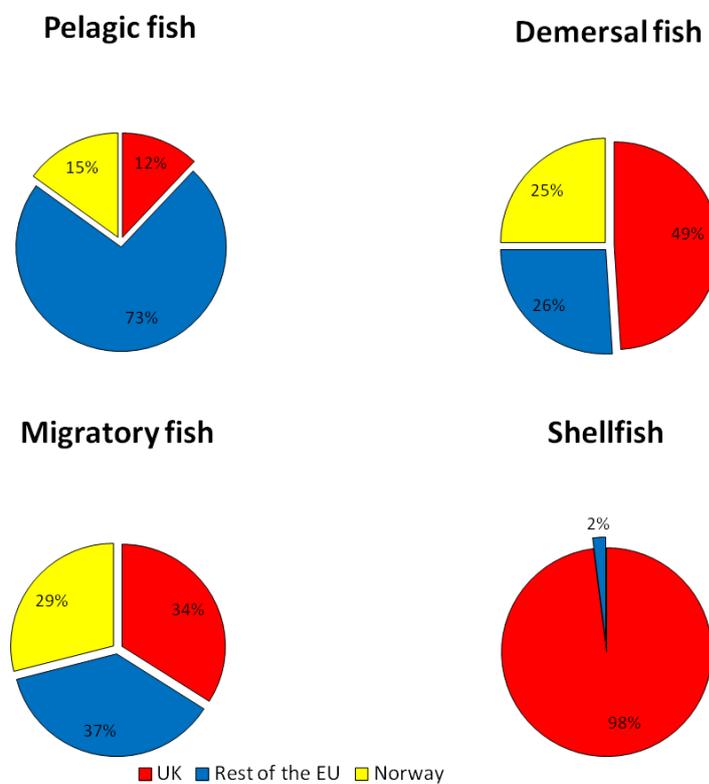


Figure 1. Annual average proportions of the total landings of different groups of fish and shellfish from the UK EEZ sector of the North Sea (FAO area 27.4) during 2003-2013, attributable to the UK, rest of the EU, and Norway.

The main conclusion from this section of the project is that the pattern of reliance on the North Sea UK EEZ for fishery harvest is extremely disparate across stocks and nation groups, including Norway. The infamous statistic - that 80% of UK fish is given away to the rest of Europe – is not a general rule that can be applied in all regions and to all stocks.

3.2. Development of plausible narratives for unilateralist outcomes of fisheries negotiations

Against the backdrop of disparate existing distributions of catches, negotiating an equitable share of the available TAC for each species and stock is likely to be extremely challenging. The basis for an agreement revolves around the concept of zonal attachment, which represents the proportion of living resource, or asset, which is rightfully ‘owned’ by each nation state which has EEZ within the geographic distribution of the fish. However, there is no consensus on the details of how this should be calculated. The White Paper on Defra’s vision for a future fisheries policy once the UK is no longer part of the EU [2] contains three different and conflicting approaches to estimating zonal attachment, illustrated by examples for a few selected stocks. Two of the proposed approaches (proportional distribution of historical landings, and proportional distribution of habitat defined by bathymetry (seabed depth), latitude and longitude) seem invalid as measures of zonal attachment. Historical distributions of where landings have originated from cannot be regarded as equivalent to the distribution of fish abundance. Fishers make complex decisions on where to fish based on the likely revenue generated by catches relative to quota availability, expenditure on fuel and passage times. The second approach based on distribution of habitat is only a crude measure of potential, not actual distribution of fish, and in addition seabed depth is insufficient to define the habitat of fish. A variety of other factors are associated with fish habitat distributions such as prey, seabed sediments, salinity and temperature [63]. The third measure in the White Paper – swept area biomass – should provide an indication of the distribution of the stock from fishery-independent scientific surveys, but there are several alternative and disputed approaches to deriving a figure from these data [17, 20]. Other EU Member States are also investigating measures of zonal attachment [8].

Based on the detailed analysis of all the available landings and zonal attachment data, two plausible narratives were developed for UK unilateralism following a hypothetical breakdown of post-Brexit negotiations on fisheries in the North Sea. The first narrative is based on TACs for individual stocks in the North Sea, specifically herring, cod, haddock, whiting, saithe, plaice and sole. Plausible changes in the fishing mortality of each of these species are defined based on the UK claiming an increased share of the TAC for those species where the current share of total landings is less than the estimates of zonal attachment (Fig. 2). Note that the baseline for these changes is not Relative Stability, but the currently (pre-Brexit) realised share after taking into account existing quota swaps and trades. The rest of

the EU and Norway are assumed to adhere to their existing share of the total landings, so the resulting total exceeds the recommended TAC (Fig. 3). In this narrative, the concern is with the overall effect, not with where the catches are taken, though the underlying assumption is that non-EU vessels are excluded from the UK EEZ. Based on these criteria, our unilateralism scenarios for individual species involve increased claims of quota by the UK for herring (+72%), saithe, (+37%), sole (+26%), cod (+16%) and whiting (+14%). The scenario envisages no change in UK quota for haddock or plaice in the North Sea since the data on recent share of landings are equivalent to, or exceed the estimates of zonal attachment.

Changes in quotas for North Sea fish species claimed by the UK

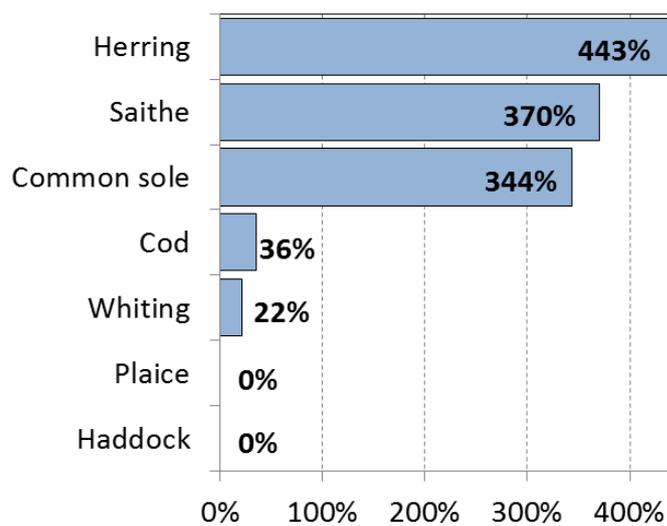


Figure 2. Percentage changes in quota for key fish species in the North Sea which might be plausibly sought by the UK in post-Brexit fisheries negotiations. Values are based on estimates of zonal attachment and pre-Brexit Relative Stability shares adjusted by quota trades and swaps. In the case of haddock, zonal attachment leaves the UK with an 8% deficit of quota share after taking account of quota trades and swaps, so we assume that the UK defends status-quo on haddock. In the case of plaice, there are no zonal attachment data available, but the proportion of total landings taken in the UK EEZ is close to the UK's Relative Stability share so we assume that the UK defends status quo for plaice too.

The second narrative is not concerned with quotas and catches of individual species, but with the distribution of fishing effort by different gears. The basis for this narrative is that the UK denies access to its EEZ for all Norwegian and EU vessels. Norway and the EU reciprocate by denying access to UK vessels. The UK then increases fishing effort within its own EEZ to absorb the difference between UK effort repatriated from EU and Norwegian waters, and the effort vacated in UK waters due to exclusion of EU and Norwegian vessels (except for the vacated scope for sandeel trawling in which the UK has no historic interest). EU and Norwegian vessels then attempt to catch their existing quota in non-UK waters. Based on

these criteria, our unilateralism scenario involves overall increases in pelagic effort (pelagic trawling and seine netting (+58%), mackerel long-lining (+20%), and sandeel/sprat trawling (+6%), rather smaller (5-10%) increases in effort targeting demersal fish (demersal beam and otter trawls and gillnets and lines), and very small (<1%) changes in effort targeting shellfish (Fig. 3).

The effort re-distribution scenario was combined with two realisations of the Landing Obligation, to which the UK officially remains committed [2]. The first realisation was based on perfect implementation, and second on a probably more realistic partial implementation where undersize fish continue to be discarded but there is no over-quota discarding of marketable sized fish.

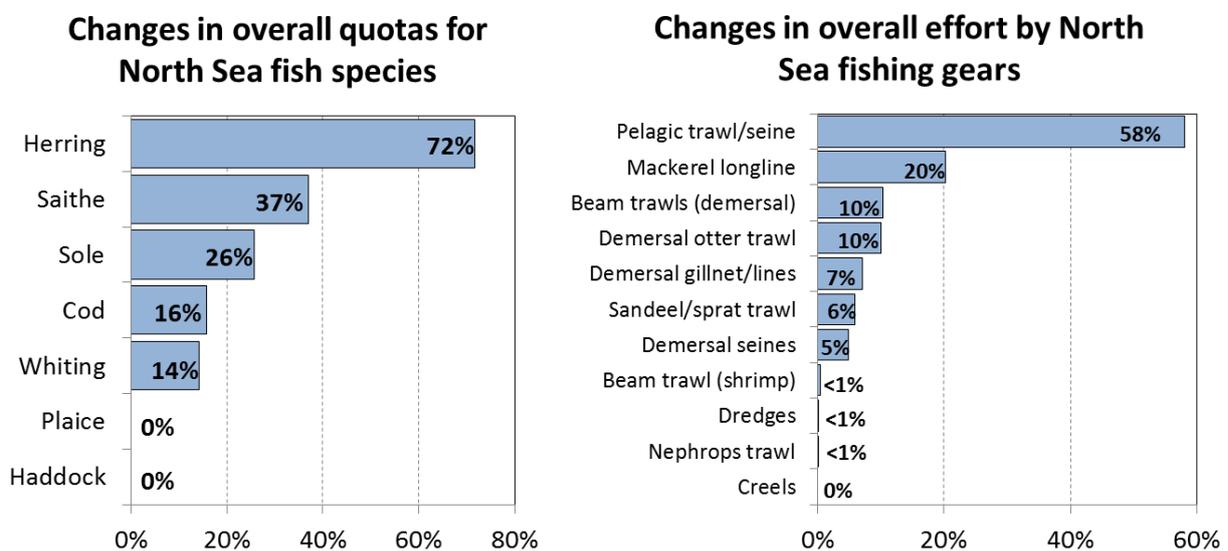


Figure 3. Percentage changes in overall quota for key fish species, and overall effort by fishing gears in the North Sea as a result of a unilateralist outcome from post-Brexit fisheries negotiations. Left panel shows the change in the combined quotas of all fishing nations in the North Sea as a result of unilateralism. The increases are a result of the UK claiming quota increases (Figure 2) and the remaining nations adhering to their Relative Stability shares of the TAC. Right panel shows changes in overall fishing effort in the North Sea by different gear groups as a result the UK denying access to the UK EEZ for EU and Norwegian vessels, with reciprocal action against UK vessels. The figures include an element for increased effort required by EU and Norwegian vessels to take their Relative Stability quotas in their own waters where catch per unit effort is lower than in the UK EEZ.

3.3. Results from modelling the consequences of unilateralism narratives

The single species stock projections suggested that of the seven species examined (herring, cod, haddock, whiting, saithe, plaice and sole), the post-Brexit unilateralism scenario would affect herring and cod significantly (Fig. 4). These two stocks have a comparatively high

probability of being below their precautionary biomass reference points (Bpa) which trigger management action even at current rates of fishing. Elevated rates of fishing mortality projected under the post-Brexit scenario more than double the risk of falling below Bpa for herring, and increase it by 75% for cod. Both stocks have a history of depletion and are known to be vulnerable to collapse [64, 65]. The risks are even higher in the short term, especially for cod where the current spawning stock biomass (SSB) is already below Bpa according to ICES advice [51].

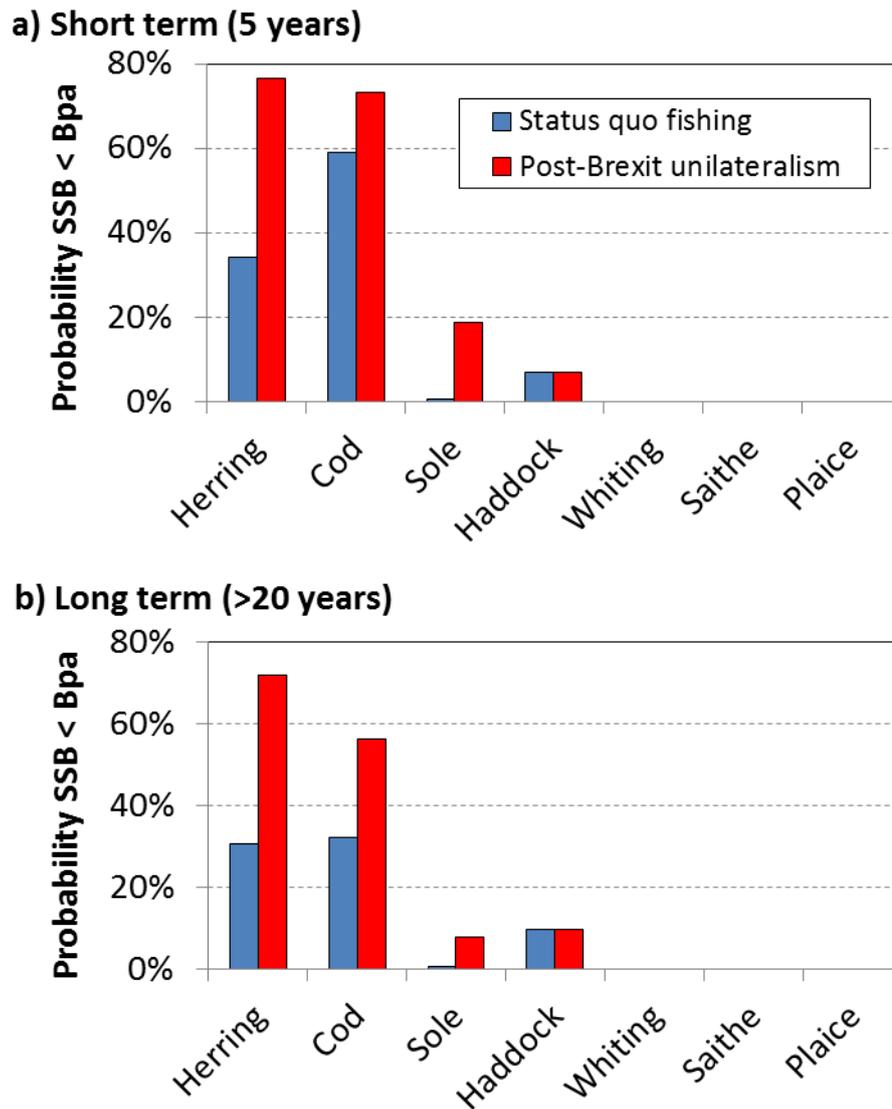


Figure 4. Percentage probabilities of the spawning stock biomass (SSB) of key species in the North Sea falling below their respective precautionary levels (Bpa). Upper panel, short term probabilities (5 years), lower panel, long term probabilities (more than 20 years). Blue bars indicate the probabilities assuming that status quo fishing conditions in 2017 continue unchanged into the future. Red bars indicate the probabilities under the post-Brexit unilateralism scenario.

The food web modelling suggested that if Brexit negotiations can be successfully concluded then fully implementing the Landing Obligation would lead to small increases in demersal fish in the North Sea over the coming 20 years (Fig. 5). The Landing Obligation implies improved selectivity of demersal fishing methods so that only marketable sizes of fish are captured. As a result, the current landings of demersal fish can be achieved with lower fishing mortality rates and higher stock biomass, which should be beneficial to the fishing industry. However, increased demersal fish biomass also implies increased predation mortality on pelagic fish as an indirect effect of the Landing Obligation, so their abundances decline slightly. This response has been exacerbated by the success of fisheries management in the past 20-30 years at reducing overall fishing mortality on demersal fish [66, 67, 68]. This means that predation mortality now represents a higher proportion of the overall mortality of pelagic fish compared to the past, and stocks become less resilient to changes in fishing mortality.

Critically, the food web model also indicates that post-Brexit unilateralism would negate any benefits of full implementation of the Landing Obligation, and lead to a substantial decline in the abundance of planktivorous fish. The effects of unilateralism on demersal fish in the food web model are predicted to be much smaller, consistent with the single-species model results.

Indirect consequences for non-target groups of species as a result of the changes in fishing under post-Brexit unilateralism, are significantly reduced biomasses of cetaceans and seabirds, and increased biomasses of pelagic invertebrates (krill, squid and other macroplankton), and of carnivorous and scavenge feeding benthos (mainly crustaceans such as shrimps, prawns and crabs). Declines in both cetaceans and seabirds in the model arise from the combination of decreasing food supply (planktivorous fish) and increased mortality due to by-catch in fishing gears [69]. Seals are predicted to be less vulnerable to the projected decline in planktivorous fish due to their greater feeding preference for demersal fish.

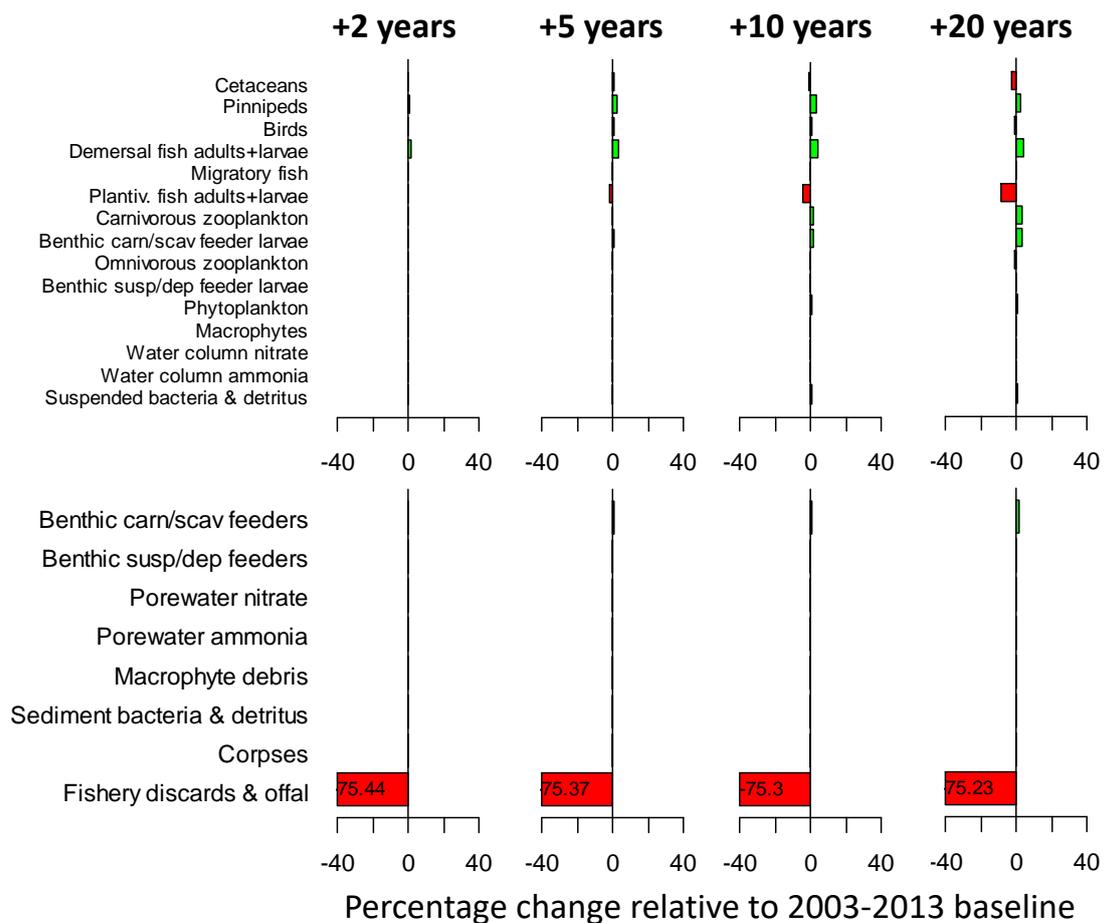


Figure 5. Simulated progression (years 2, 5, 10 and 20) of changes in the structure of the North Sea foodweb following the full implementation of the Landing Obligation ('improved selectivity') (beginning of year 1) with status-quo fishing effort (successful outcome of negotiations) relative to a baseline state in 2003-2013. Each bar represent the percentage change in annual average mass (for nutrients and detritus) and biomass for living components of the ecosystem relative to the baseline. Green bars indicate an increase, red bars a decrease relative to the baseline. Upper panel shows changes to nutrients, flora and fauna in the water column. Lower panel shows changes to nutrients and fauna in and on the seabed ('porewater' values refer to nutrient concentrations within the seabed sediments).

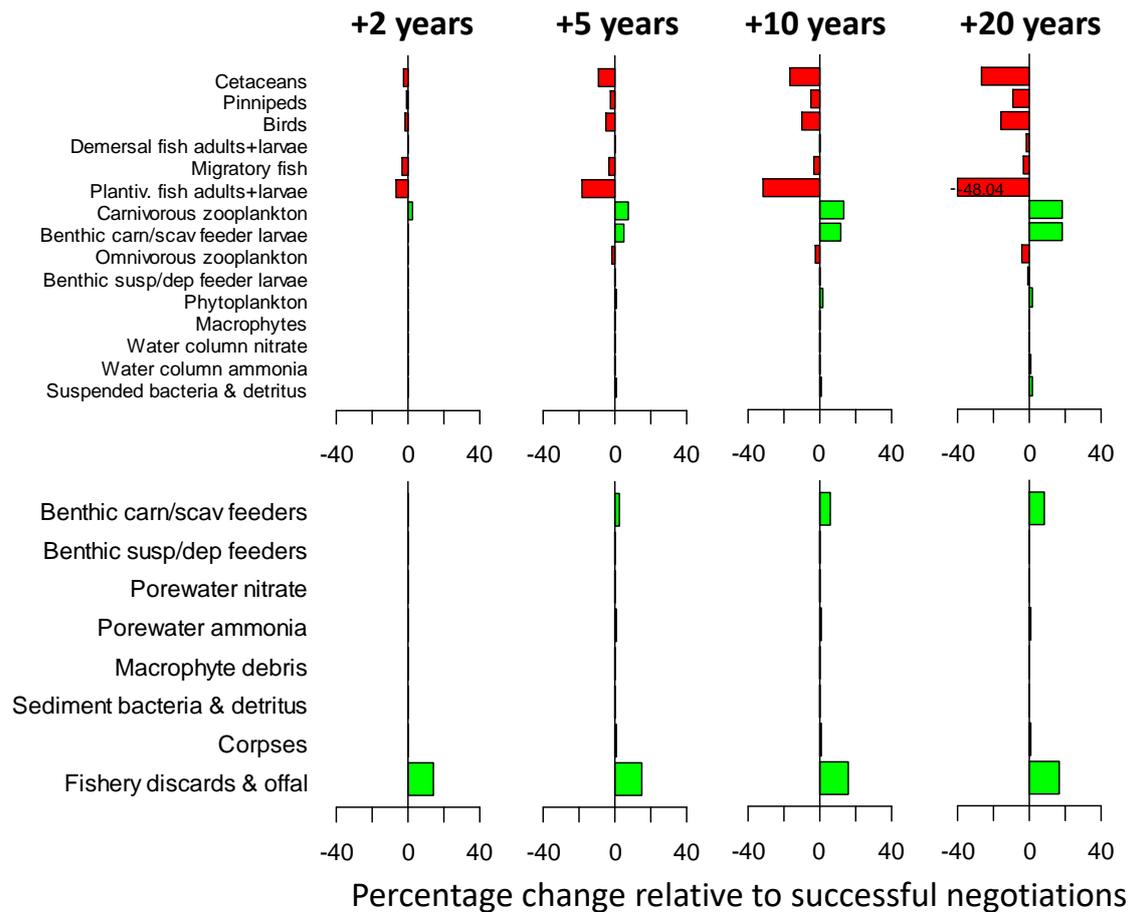


Figure 6. As Figure 5, but showing the simulated progression (years 2, 5, 10 and 20) of changes in the structure of the North Sea foodweb following the onset of unilateral actions due to a breakdown of Brexit negotiations(beginning of year 1). The results assume full implementation of the Landing Obligation ('improved selectivity') by all nations regardless of Brexit.

4. Conclusions

Most of the discrepancy between fishery quota assigned to the UK under Relative Stability rules, and either zonal attachments or the proportions of international landings taken in the UK EEZ, arise from four key species – North Sea herring and sandeels, and the migratory northeast Atlantic mackerel and blue whiting. For many other finfish species the UK's share under Relative Stability (with some adjustments through quota swaps and trades) is more in line with zonal attachment. The majority of shellfish species are not covered by Relative Stability since their management comes under national jurisdictions. Expectations of large across-the-board post-Brexit increases in fishery quotas, raised by the rhetoric of the Referendum, are thus misplaced. This is especially so in the North Sea where the bulk of the scope for negotiating quota increases is in the pelagic sector.

Based on a careful analysis of international landings and effort distributions (including Norwegian data) and zonal attachment estimates for fish and shellfish species, we identified plausible narratives for UK aspirations in post-Brexit negotiations on North Sea fishery quotas. Then, we envisaged what might happen in the event of being unable to achieve these goals through negotiation, with the UK under domestic pressure to act unilaterally. We developed narratives for changes in quotas and effort that could plausibly arise as a result of the UK excluding foreign vessels from its EEZ and setting quotas that, when combined with the existing Relative Stability shares of the EU and Norway, exceed the TACs for the species concerned, thus threatening conservation and Maximum Sustainable Yield objectives.

Simulations of the consequences for individual North Sea fish stocks and for the ecosystem as whole arising from the envisaged breakdown of post-Brexit North Sea fisheries negotiations and adoption of unilateralist positions on quotas, were carried out using two completely different mathematical models. Both of the modelling approaches were in agreement that the greatest threat would be to stocks of pelagic (planktivorous) fish, especially herring. Risks to demersal stocks as a whole would be smaller, though the sustainability of cod stocks would be significantly threatened. In terms of indirect consequences for wildlife, the main risks would be to cetaceans and seabirds which are projected to decline due to the combination of reduced food abundance (mainly planktivorous fish) and increased by-catch in fishing gear.

Our findings are contingent on the assumption that the UK does not attempt to establish a sandeel fishery in its EEZ following exclusion of foreign vessels from its waters. Currently, Norway and Denmark catch over 150,000 tonnes of sandeels per year (2003-2013 average) in the UK North Sea EEZ while the UK catches only 2000 tonnes. It seems unrealistic to suppose that the UK could develop the means to catch and process this resource in the short term, even if markets were available and it was supported by policy. Large areas of the UK EEZ are explicitly closed to sandeel fishing to protect wildlife, in particular breeding seabirds [70], and this will most likely remain a policy commitment. However, if we were to factor the establishment of a post-Brexit UK sandeel fishery into our models, in addition to the existing quota caught by Norway and Denmark continuing to be taken but outside UK waters, then the consequences for the ecosystem would clearly be significantly exacerbated and we could at least expect more severe impacts on pelagic (planktivorous) fish and indirect effects on cetaceans and birds.

In conclusion, the research findings emphasise the need for a negotiated agreement between the UK, EU and Norway on the post-Brexit distribution of fishery quotas. Unilateral quota-setting for shared stocks jeopardises adherence to the TAC advice provided by ICES. In the North Sea, unilateralist actions would threaten the sustainability of key stocks of fish, especially herring and cod, and wildlife.

5. Bibliography

- [1] Department for Exiting the European Union 2019. New Withdrawal Agreement and Political Declaration. <https://www.gov.uk/government/publications/withdrawal-agreement-and-political-declaration>, Published 19 October 2019.
- [2] Defra (Department of Environment Food and Rural Affairs) 2018a. Fisheries white paper: Sustainable fisheries for future generations. 60pp. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/722074/fisheries-wp-consult-document.pdf
- [3] Defra (Department of Environment Food and Rural Affairs) 2018b. Guidance: Commercial fishing if there's no Brexit deal. Updated 15 October 2018. <https://www.gov.uk/government/publications/commercial-fishing-if-theres-no-brexit-deal/commercial-fishing-if-theres-no-brexit-deal> (last accessed 22 October 2018).
- [4] Institute for Government 2018. Common Fisheries Policy (5 pp). <https://www.instituteforgovernment.org.uk/explainers/common-fisheries-policy> (last updated Tuesday, March 20, 2018).
- [5] Kenyon, W. 2017. Implications of leaving the EU – Fisheries. Scottish Parliament Information Centre (SPICe) Briefing 17/21. 16pp.
- [6] Marine Scotland 2019. Future of Fisheries Management in Scotland: National Discussion Paper. Scottish Government, 57pp.
- [7] Scottish Fishermen's Federation 2018a. Scottish industry position paper: Coastal State negotiations during and after Brexit. 14pp. <http://scottishpelagic.co.uk/wp-content/uploads/2018/06/SFF-Brexit-FINAL.pdf>
- [8] Sobrino Heredia, J M, 2017, Research for PECH Committee – Common Fisheries Policy and BREXIT - Legal framework for governance, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels. 164pp.
- [9] BBC 2015. Election 2015: Farage unveils UKIP fishing reform plan. 8 April 2015. <https://www.bbc.co.uk/news/election-2015-32220052> (last accessed 2 October 2018).
- [10] The Conversation 2015. Fact Check: is 80% of UK fish given away to the rest of Europe? 14 April 2015. <http://theconversation.com/fact-check-is-80-of-uk-fish-given-away-to-the-rest-of-europe-39966> (last accessed 2 October 2018).
- [11] YouTube 2015. Tony Blair can go to Hell! Nigel Farage speech in Grimsby. 8 April 2015. <https://www.youtube.com/watch?v=Yn4x-4RcGnY> Last accessed 2 October 2018.

- [12] European Commission 2016. Facts and figures of the Common Fisheries Policy. Basic Statistical data 2016. Office of the European Union. 56pp.
- [13] House of Lords Select Committee on Fisheries 2016. Brexit: fisheries. <https://publications.parliament.uk/pa/ld201617/ldselect/ldcom/78/7804.htm>
- [14] Phillipson, J. & Symes, D. 2018. 'A sea of troubles': Brexit and the fisheries question. *Marine Policy* **90**, 168-173.
- [15] Reeves, S A. & Davie, S L. 2017. FIS012A - Quota management and choke species under the landing obligation. A study commissioned by Fisheries Innovation Scotland (FIS) <http://www.fiscot.org/> 60pp.
- [16] Needle, C. 2015. FIS005 - Reconsideration of European Relative Stability quota shares and implications for the Landings Obligation. A study commissioned by Fisheries Innovation Scotland (FIS) <http://www.fiscot.org/> 30pp.
- [17] Fernandes, P.G. & Fallon, N.G. 2020. Fish distributions reveal discrepancies between zonal attachment and quota allocations. *Conservation Letters*. 2020;e12702. <https://doi.org/10.1111/conl.12702>
- [18] Hannesson, R. 2013. Zonal attachment of fish stocks and management cooperation. *Fisheries Research* **140**, 149-154.
- [19] Hannesson, R. 2018. Shared stocks, game theory and the zonal attachment principle. *Fisheries Research* **203**, 6-11.
- [20] University of Aberdeen 2017. The spatial distribution of commercial fish stocks of interest to Scotland in UK waters. Report prepared for the Scottish Fishermen's Federation, January 2017. 30pp. https://www.sff.co.uk/wp-content/uploads/2017/03/SFF_Report_v8-1.pdf
- [21] BBC 2019. Reality bites for the fishing industry. 18 December 2019. <https://www.bbc.co.uk/news/uk-scotland-50837190> (last accessed 19 December 2019).
- [22] BBC News 2020. Brexit: Is fishing the next big argument in the talks? By Chris Morris BBC Reality Check, 8 February 2020. <https://www.bbc.co.uk/news/46401558>
- [23] The Guardian 2020. Fishing: EU countries seek tough stance on access to UK waters. Jennifer Rankin, 6 Feb 2020. <https://www.theguardian.com/politics/2020/feb/06/fishing-eu-countries-seek-tough-stance-on-access-to-uk-waters>

- [24] The Telegraph 2019. Brussels to hit Britain with fishing ultimatum the day after Brexit (25 November 2019). <https://www.telegraph.co.uk/politics/2019/11/25/brussels-hit-britain-fishing-ultimatum-day-brexite/>
- [25] House of Lords Library 2020. Fisheries Bill [HL]: Briefing for Lords Stages. Published Thursday, February 6, 2020. <https://researchbriefings.parliament.uk/ResearchBriefing/Summary/LLN-2020-0051>
- [26] Fishing News 2017a. EU wants Hardball Brexit. Fishing news 23 February 2017, 4.
- [27] Owen, J. 2017. The Brexit Papers: Fisheries. Bar Council Brexit Working Group, Paper 23. Bar Council of England and Wales. https://www.barcouncil.org.uk/media/575232/brexit_paper_23_-_fisheries.pdf
- [28] Reuters Business News 2020. Britain to introduce bill to end automatic EU fishing rights in UK waters. January 29, 2020. <https://uk.reuters.com/article/uk-britain-eu-fishing-lawmaking/britain-to-introduce-bill-to-end-automatic-eu-fishing-rights-in-uk-waters-idUKKBN1ZS05S>
- [29] Scottish Fishermen's Federation 2018b. Brexit bonanza for fisheries – if we seize the Sea of Opportunity. <https://www.sff.co.uk/brexit-bonanza-fisheries-seize-sea-opportunity/> (last accessed 25 Sept 2018).
- [30] Scottish Fishermen's Federation 2018c. Fishing and Brexit – Briefing for Parliamentarians. <https://www.sff.co.uk/brexit/> (last accessed 25 Sept 2018).
- [31] The Express 2020. 'Never surrender!' Britons erupt at EU's fishing ultimatum 'taken blackmail for too long!'. By Oli Smith, published Fri, Jan 10, 2020 | UPDATED: 14:28, Fri, Jan 10, 2020. <https://www.express.co.uk/news/uk/1226567/EU-Brexit-trade-talks-Boris-Johnson-fisheries-fishing-waters>
- [32] The Herald Scotland 2020. Scottish fishing federation warns Johnson failure to take back control of UK waters would be 'colossal betrayal'. By Michael Settle UK Political Editor. 28th January. <https://www.heraldscotland.com/news/18192944.scottish-fishing-federation-warns-johnson-failure-take-back-control-uk-waters-colossal-betrayal/>
- [33] The-i 2020. Fishing in the Brexit era: What to expect as the UK tries to secure a greater share in Brussels. Josh Barrie. 27th January 2020. <https://inews.co.uk/news/environment/fishing-after-brexit-uk-share-leaving-eu-consequences-1377080>
- [34] Government Document, 2019. Operation Yellowhammer, HMG Reasonable Worst Case Planning Assumptions, as of 2 August 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data

[/file/831199/20190802 Latest Yellowhammer Planning assumptions CDL.pdf](#) (last accessed 14 October 2019).

[35] Harte, M. & Tiller, R. 2019. Trick or Treat: Brexit is a Halloween Horror Story for Europe's Fisheries. *Secure Fisheries*, 9 September 2019. <https://securefisheries.org/news/brexit-fisheries-horror> (last accessed 14 October 2019).

[36] Harte, M., Tiller, R., Kailis, G. & Burden, M. 2019. Countering a climate of instability: the future of relative stability under the Common Fisheries Policy. *ICES Journal of Marine Science*, doi:10.1093/icesjms/fsz109.

[37] Walmsley, S.F., Gasiorok, M., Smale, R., Pozas Franco, I., Roberts, C.A. & Rollo, J. 2018. Seafood trade modelling research project - Assessing the impact of alternative fish trade agreements post EU-Exit, Final Report, ABPmer Report. A report produced by ABPmer for Marine Scotland, April 2018.

[38] Fishing News 2017b. FFL sets out its Brexit stall. Call for complete control of EEZ and switch to days-at-sea. *Fishing News* 16 March 2017, 8-9.

[39] Fishing News 2017c. Eustice: UK wants Quotas that Reflect EEZ Resources. *Fishing News* 17 August 2017, 2.

[40] Appleby, T. & Harrison, J. 2017. Brexit and the future of Scottish fisheries: Key legal issues in a changing regulatory environment. *Journal of Water Law* **25**, 124-132.

[41] Ntona, M. 2016. A legal perspective on the value of Scotland's EU membership for sustainable fisheries. Strathclyde Centre for Environmental law and Governance, Policy Brief No. 5. September 2016. 9pp.

[42] Fishing News 2017d. Gove under Fire over Access Comments. *Fishing News* 17 August, 2017, 2.

[43] BBC 2018a. Fishermen protest over lack of control of UK waters post-Brexit. 8 April 2018. <https://www.bbc.co.uk/news/uk-england-43680686> (last accessed 2 October 2018).

[44] BBC 2018b. Brexit should create 'sea of opportunity' for fishing. 1 October 2018. <https://www.bbc.co.uk/news/uk-scotland-45703809> (last accessed 2 October 2018).

[45] Fishing for Leave 2017. The robbery of UK resources. 27pp/ <http://ffl.org.uk/wp-content/uploads/2017/11/Fishing-for-Leave-Robbery-of-UK-Resources-and-Correct-Minimum-TAC-Shares-PDF.pdf> (last accessed 2 October 2018).

- [46] Scottish Fishermen's Federation 2018d. Public strongly supports increase in quotas for UK vessels in own waters. <https://www.sff.co.uk/public-strongly-supports-increase-quotas-uk-vessels-waters/> (last accessed 2 October 2018).
- [47] The Express 2017. REVEALED: The 10 regions to hit fishing jackpot as Brexit to see industry boom 50 per cent. 13 November 2017.
<https://www.express.co.uk/news/politics/878449/brexit-news-uk-latest-eu-fishing-industry-economy-michael-gove-fish-region>
- [48] The Scotsman 2018. Fishing industry hails Brexit bonanza (6 June 2018).
<https://www.scotsman.com/news/politics/fishing-industry-hails-brexit-bonanza-1-4750049>
- [49] Lassen, H., Cross, D. & Christiansen, E. 2012. One Hundred Years of Catch Statistics for the Northeast Atlantic. *ICES Cooperative Research Report* **311**, 21 pp.
- [50] JRC (Joint Research Centre) 2018. Scientific, Technical and Economic Committee for Fisheries (STECF), Fisheries Dependent Information. <https://stecf.jrc.ec.europa.eu/dd/effort>
Last accessed 25 Sept 2018.
- [51] ICES 2018a. ICES Advice on fishing opportunities, catch, and effort. Greater North Sea Ecoregion Published 29 June 2018 cod.27.47d20, Version 2: 8 August 2018.
<https://ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/cod.27.47d20.pdf>
- [52] Heath, M.R. 2012. Ecosystem limits to food web fluxes and fisheries yields in the North Sea simulated with an end-to-end food web model. *Progress in Oceanography (Special issue: End-to-end modelling: Towards Comparative Analysis of Marine Ecosystem Organisation)* **102**, 42-66.
- [53] Heath, M.R., Cook, R.M., Cameron, A.I., Morris, D.J. & Speirs, D.C. 2014. Cascading ecological effects of eliminating fishery discards. *Nature Communications* **5**:3893 doi: 10.1038/ncomms4893
- [54] Heath, M., Wilson, R. & Speirs, D. 2015. FIS003 - Modelling the whole-ecosystem impacts of trawling. A study commissioned by Fisheries Innovation Scotland (FIS)
<http://www.fiscot.org/> 86pp.
- [55] ITV News 2016. "They're pinching our fish," @BorisJohnson said, as he recruited a live lobster to help him make his point. 16 June 2016.
<https://twitter.com/itvnews/status/743382380161835008> Last accessed 2 October 2018.
- [56] The Queen's Speech 2019. Prime Minister's Office, London, December 2019. 151 pp.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853886/Queen_s_Speech_December_2019_-_background_briefing_notes.pdf

[57] Hoefnagel, E., de Vos, B. & Buisman, E. 2015. Quota swapping, relative stability, and transparency. *Marine Policy* **57**, 111-119.

[58] Beukers-Stewart, B.D. & O'Leary, B.C. 2017, Post-Brexit Policy in the UK: A New Dawn? Fisheries, Seafood and the Marine Environment. University of York. DOI: 10.13140/RG.2.2.35329.76641

[59] European Commission 2017. Agreed record of Fisheries Consultations between the European Union and the Faroe Islands for 2017. Brussels, 7 December 2017. 14pp. https://ec.europa.eu/fisheries/sites/fisheries/files/docs/pages/2017-agreed-record-eu-faroe-islands_en.pdf

[60] Napier, I.R. 2016. Fish landings from the United Kingdom's Exclusive Economic Zone: By area, nationality and species, NAFC Marine Centre, University of the Highlands and Islands, Port Arthur, 2016. www.nafc.uhi.ac.uk/eez-reports

[61] Napier, I.R. 2017. Fish landings from the United Kingdom's Exclusive Economic Zone and UK landings from the EU EEZ. NAFC Marine Centre, University of the Highlands and Islands, Port Arthur, 2017. www.nafc.uhi.ac.uk/eez-reports

[62] Napier, I.R. 2018. The potential value to the UK fishing fleet of larger shares of the landings from the UK EEZ. NAFC Marine Centre, University of the Highlands and Islands, Port Arthur, 2018. www.nafc.uhi.ac.uk/eez-reports

[63] Rutherford, L.A., Simpson, S.D., Jennings, S. *et al.* 2015. Future fish distributions constrained by depth in warming seas. *Nature Climate Change* 13 April 2015 | DOI:10.1038/NCLIMATE2607

[64] Cook, R.M., Sinclair, A. & Stefansson, G. 1997. Potential collapse of North Sea cod stocks. *Nature* **385**, 521-522.

[65] Dickey-Collas, M., Nash, R. D. M., Brunel, T. *et al.* 2010. Lessons learned from stock collapse and recovery of North Sea herring: a review. *ICES Journal of Marine Science* **67**, 1875–1886.

[66] Cardinale, M., Dörner, H., Abella, A. *et al.* 2013. Rebuilding EU fish stocks and fisheries, a process under way? *Marine Policy* **39**, 43-52.

[67] Fernandes, P.G. & Cook, R.M. 2013. Reversal of fish stock decline in the Northeast Atlantic. *Current Biology* **23**, 1432-1437.

[68] Fernandes, P.G., Ralph, G.M., Nieto, A. *et al.* 2017. Coherent assessments of Europe's marine fishes show regional divergence and megafauna loss. *Nature Ecology and Evolution* **1**: 0170, 1-9.

[69] ICES 2018b. Report from the Working Group on Bycatch of Protected Species (WGBYC), 1-4 May 2018, Reykjavic, Iceland. ICES CM 2018/ACOM:25. 128pp.

[70] Daunt, F., Wanless, S., Greenstreet, S.P.R., Jensen, H., Hamer, K.C. & Harris, M.P. 2008. The impact of the sandeel fishery closure on seabird food consumption, distribution, and productivity in the northwestern North Sea. *Canadian Journal of Fisheries and Aquatic Sciences* **65**, 362-381.