# Seeking to quantify contributions that fisheries operations can make to a global Nature Positive goal

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**ABSTRACT**

Amidst global efforts to address biodiversity loss, the concept of 'Nature Positive' has gained traction as a societal goal aligned with the Global Biodiversity Framework (GBF). While the goal is increasingly being embraced by businesses and governments, there has been little investigation into how fisheries, a key sector in the global economy and a major driver of marine biodiversity loss, could go beyond 'sustainable fishing' to contribute towards Nature Positive and the GBF. Here, we begin to fill this gap. We first draw on literature on the mitigation hierarchy and transformative actions for businesses to offer a conceptual framework outlining how fisheries' direct operations could contribute towards Nature Positive. We then use publicly available information from the Marine Stewardship Council's certification process and develop an example metric based on the UK's Biodiversity Net Gain metric, to work through the framework for three case study fisheries. Finally, we gain expert insights into stakeholder's perception of a Nature Positive approach to fisheries management to inform future avenues. Our findings offer a practical first step to support fisheries to contribute to nature recovery on a global scale as part of best practice fisheries management. We also highlight that pathways towards Nature Positive contributions will differ considerably between fisheries, with critical knowledge gaps hampering the potential for 'like-for-like' net positive outcomes in all fisheries. This study represents a first step towards Nature Positive pathways for fisheries, with implications for policy, business and research.

## 1. INTRODUCTION

The post-2020 Kunming-Montreal Global Biodiversity Framework (GBF) is an intergovernmental agreement under the Convention on Biological Diversity with the mission to “halt and reverse biodiversity loss by 2030” and the long-term vision of “living in harmony with nature” by 2050 [1]. Conceptually aligned with this vision is the emerging concept of ‘Nature Positive’, which is both a global societal goal for nature, and a widely used term to mainstream action towards the GBF. Like the GBF, Nature Positive envisions more nature in the future than there is now [2,3]. To realise this vision, it is imperative that the private sector takes ambitious action to contribute to broader societal transformation, because multi-national corporations and value chains are arguably the biggest source of pressure on nature globally [4]. Although corporations have historically published little on their nature-related impacts, Nature Positive initiatives are becoming widespread in private and public sectors [5], and expectations around corporate accountability for nature are also growing, for example via the Science-Based Targets (SBTs) for Nature, the Taskforce on Nature-related Financial Disclosures, and the EU Corporate Sustainability Reporting Directive [3].

To make a meaningful contribution towards Nature Positive, businesses will need to not only mitigate their new and on-going impacts, but also take proactive conservation and restoration actions beyond their operations and value chain [6]. This implicitly requires acceptance of net outcome approaches to nature goals, where some impacts on nature are inevitable and permissible, provided they are counterbalanced by restoration, compensation and regeneration [7]. Such net outcome approaches are currently incorporated – either implicitly or explicitly - into planning policy in over 100 countries worldwide [8]. The framework typically used for planning actions towards net outcome goals is the mitigation hierarchy, a stepwise precautionary framework that has been widely applied in terrestrial systems to balance conservation with economic development in pursuit of a clearly defined goal, such as ‘no net loss’ or ‘net gain’ of biodiversity [9].

There is also a growing recognition that, to drive positive outcomes at the societal scale, as is required to deliver a Nature Positive future, transformative change in how society operates is needed [3,10]. Such change will be critical to guard against leakage (i.e. where an individual company’s positive actions do not lead to positive outcomes on a societal scale due to market effects or the actions of others), and drive system-wide change [3]. This, by definition, requires extended accountability beyond any single company or economic actor [3].

The fishing industry is a high priority for defining pathways to Nature Positive. Despite constituting one of the largest sources of pressures on marine biodiversity globally, due to overexploitation of fish stocks, impacts on marine habitats and bycatch of non-target species [11,12], the fisheries sector remains far behind other sectors in terms of nature-related commitments. Although fisheries management strategies typically strive to achieve sustainable use of fishery resources [13], and therefore, in theory, achieve No Net Loss of biodiversity [14], this is rarely the case in practice [15,16]. Moreover, the global Nature Positive goal requires going above and beyond sustainable use to deliver nature recovery on a societal scale [3]. In addition, Nature Positive discourse has so far centred mainly around sectors where human activities cause effectively irreversible impacts that require mitigation, such as through land occupancy and land use change e.g., in mining and agriculture. Yet there is also a need to consider sectors where direct exploitation is a primary pressure on nature. Considering how fisheries could contribute towards Nature Positive may offer important lessons for other natural resource (such as timber and wildlife harvesting), where sustainable use is typically the management goal. How the uncertainties inherent in fisheries management can be addressed when developing a Nature Positive strategy adds another reason why fisheries are an interesting sector to explore.

Here, we explore how fisheries operations could contribute to the societal transition towards a Nature Positive future. We draw on literature on the mitigation hierarchy and transformative actions to offer a conceptual framework and real-world case studies illustrating how fisheries operations could contribute to the GBF's Nature Positive goal. This framework could be adapted for use in various ways by policy makers, fishery management agencies and fishing businesses. We then draw on expert opinion via key informant interviews to gain preliminary impressions on how a Nature Positive goal for fisheries might be received by industry and ways forward for operationalising it.

## 2. METHODS

The focus of the study is on the direct effects of fisheries operations on ocean ecosystems and target species. That is, the scope is the impacts of fishing between when fishing gear is cast into the ocean until it is removed, excluding business operations and value chains. While whole value chain approaches are critical to achieving the global Nature Positive goal, current methods for value chain analysis (such as life cycle assessment [17]) are just as applicable to fisheries as they are to other industries, so applying them requires less conceptual novelty.

### *2.1 Conceptual Framework Development*

To develop a conceptual framework for how fisheries operations could contribute towards a Nature Positive future, we conducted a literature review and key-informant interviews. The aim of the literature review was to gather insights from previous applications of net outcome approaches in other sectors, including methods for setting outcome-focused biodiversity goals and targets. To gain an insight into fisheries management and associated challenges, we conducted five interviews with experts from the Fisheries Standard Team in the Science and Standards Department of the Marine Stewardship Council (MSC). The interviews followed broad pre-determined discussion points centred around fisheries management approaches and challenges to implementing novel management measures. We used the information from the literature review and interviews to create a preliminary conceptual framework, which we iteratively updated as we gathered more information and tested it on case studies, to produce the final version.

### *2.2 Metric Development*

We developed an example metric to use as an illustration in our case studies. The purpose of the metric is to predict the ex-ante effectiveness of potential management measures within the mitigation hierarchy in mitigating risks to biodiversity and delivering the biodiversity gains required to compensate for losses. A metric of this kind is needed to help estimate the biodiversity impact of different actions taken by fisheries, but no such metric is currently available. The example metric we used was developed by translating the 'Defra Biodiversity Metric' (the UK government's Statutory Biodiversity Metric for Biodiversity Net Gain, Version 4.0 [18]) to the context of fisheries (Supplementary Material 2). We recognise that the Defra Biodiversity Metric was not designed for use in this context, therefore we only use it here as an illustrative example of a biodiversity metric being applied to fisheries.

We chose to use the Defra Biodiversity Metric as a model because it is a clear quantitative metric that was developed and tested over years using an iterative participatory approach, and has been widely adopted and used, not just by the UK government in their terrestrial

Biodiversity Net Gain policy [18], but also now by other countries [19]. Our version of the metric considers criteria that are relevant to seabed integrity and relative abundance of a species, two indicators for monitoring biodiversity outcomes. In short, the example metric uses various inputs to calculate separate scores for species and habitats which represent the impact the fishery is having on biodiversity. That score is then compared with a scenario where the mitigation hierarchy has been followed and additional positive actions taken for biodiversity, to predict ex-ante whether a fishery can deliver net gain. To address uncertainties in our version of the metric designed for fisheries, we conducted a sensitivity analysis and gained feedback from key-informants with expertise in biodiversity net gain (Supplementary Material 2). This version of the metric would require further research and expert elicitations before being used in the real world.

### *2.3 Case Study Application*

To explore the utility of the conceptual framework and refine it, we worked through its first five steps for three real-world fisheries certified by the MSC. Using MSC-certified fisheries allowed us to use secondary data from the MSC for the case studies, along with other available literature on the fisheries and impacted biodiversity. The MSC data, readily available in online certification reports, is collected by third-party auditors and subjected to peer-review, which is also available online. Additionally, an MSC-certified fishery is a defined, geographically-limited operation that has already demonstrated commitment to sustainable practices, so the scope of the fishery's impact can be assessed, and the fishery is also more likely to be interested in aligning with Nature Positive.

To explore how the framework could be applied in various contexts, we chose three contrasting fisheries in terms of gears used and biodiversity impacts. This included: (1) a pelagic fishery, for Spanish bluefin tuna (*Thunnus thynnus*): a handline and rod, and greenstick fishery with negligible bycatch and habitat impacts; (2) a benthic fishery for Scottish king scallop (*Pecten maximus*): a dredge fishery with over 60 bycatch species and direct habitat impacts; and (3) a deep sea benthic fishery for New Zealand orange roughy (*Hoplostethus atlanticus*): a bottom trawl fishery operating in the deep sea with over 10 bycatch species and substantial direct habitat impacts [20,21,22].

### *2.4 Key-informant Perceptions*

To gain a preliminary impression of how the concept of a Nature Positive approach to fisheries management would be received by stakeholders, and how it could be operationalised, we conducted structured interviews with two groups of stakeholders; experts in fisheries management, and experts in developing a metric for measuring net outcomes for nature which we adapted for our case studies (the UK government's statutory Biodiversity Net Gain metric [18]). We purposively selected interviewees from our networks, to target specific areas of expertise. The key-informants included fisheries experts (n=7) and experts on biodiversity net gain (n=6) from diverse sectors both within the UK (n=10) and globally (n=3; Spain, Canada and New Zealand). The interviews lasted 30-40 minutes and were conducted online or in-person, depending on the location of the participant. Prior to the interviews, participants were emailed background information, which was discussed at the start of the interviews. We developed two structured interview questionnaires consisting of open-ended questions tailored to the expertise of the key informants (Supplementary Material 1). Ethics clearance for the interviews was obtained through Oxford University's ethics committee (reference number: R91741/RE001).

## 3. CONCEPTUAL FRAMEWORK FOR HOW FISHERIES OPERATIONS COULD CONTRIBUTE TO THE GLOBAL NATURE POSITIVE GOAL

### *3.1 Framework overview*

Our conceptual framework expands on existing mitigation hierarchy frameworks for bycatch [14,23,24,25] to consider the wider impacts of fisheries operations - encompassing not just bycatch but also target stocks and habitat. Because the framework aims to deliver outcomes aligning with the Nature Positive goal, it additionally includes a step for transformative actions for biodiversity. The proposed conceptual framework has seven steps: (A) define the system; (B) set a goal; (C) explore mitigation measures; (D) explore transformative actions; (E) evaluate the effectiveness of measures; (F) make a management decision; and (G) implement, monitor, and adapt (Fig. 1). Each of these steps are described in detail below.

The framework can be applied at different scales. At the global scale, the goal is to achieve a Nature Positive future (i.e., recovery in the abundance and diversity of species and ecosystems in absolute terms). At a smaller scale, since a fishery cannot deliver Nature Positive in isolation, a Nature Positive goal that allows fisheries to contribute towards this overarching goal can be set, such as achieving biodiversity net gain from fisheries operations. This goal can be established for a single fishery or for multiple fisheries operating in the same area or targeting similar species, such as a joint goal for Regional Fisheries Management Organisations (RFMOs), shared stocks, or the high seas [24]. Different sub-goals could be set for each fishery to account for varying socio-economic contexts, including dependence on fishing and adaptive capacity, to ensure fairness and distributive justice alongside delivery of the biodiversity goal [26]. For example, if a joint Nature Positive goal is set for a stock shared between high-value commercial fisheries and smaller-scale fisheries, the commercial fishing businesses could be required to take on a larger proportion of the costs (direct or opportunity) for delivering the goal than the smaller-scale fisheries [4,24,27]. This would be acceptable as long as the gains and losses across the stock as a whole combine to attain a net positive outcome for the impacted biodiversity.

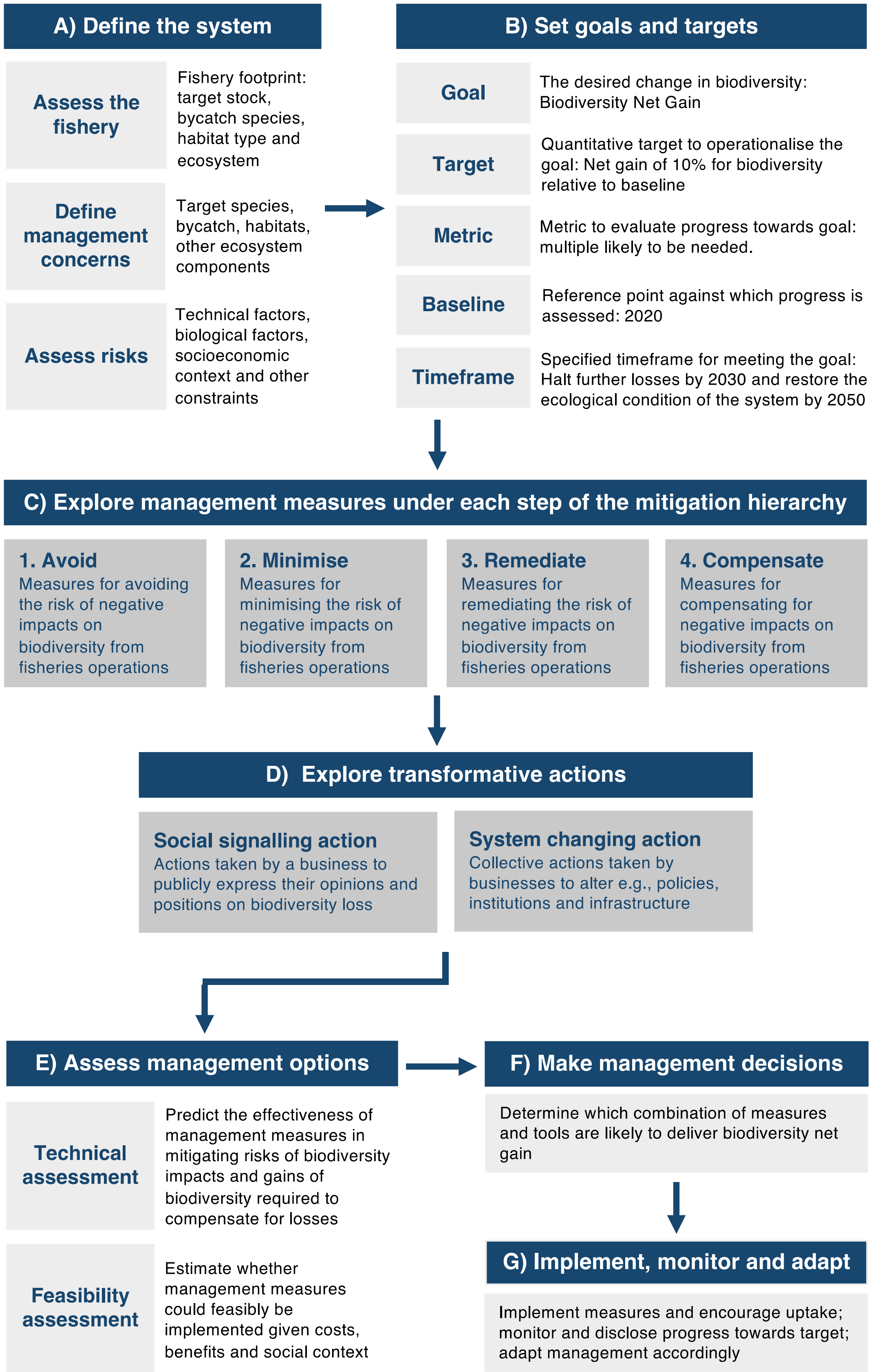


***Figure 1.*** *The proposed conceptual framework for actions towards Nature Positive fisheries operations. The framework prescribes using the mitigation hierarchy to deliver biodiversity net gain from direct fisheries operations and taking additional transformative actions to drive positive outcomes at the societal scale.*

### *3.2 Steps in the framework*

#### *3.2.1 Define the system (Step A)*

The first step of the conceptual framework is to collect background information about the fishery, through primary data collection or a review of available literature. The three sub-steps are: (i) assess the impact of the fishery on biodiversity; (ii) identify which biodiversity components are of management concern; and (iii) assess potential risks to biodiversity, including biological characteristics of impacted biodiversity, operational characteristics of the fishery, the socioeconomic context, and constraints such as the available budget for monitoring, enforcement and implementation.

#### *3.2.2 Set goals and targets (Step B)*

The background information can then be used to set a biodiversity management goal and targets, such as biodiversity net gain for the operations of the fishery. Once a biodiversity goal has been set, it must be operationalised through quantitative targets and associated baselines and metrics [23]. The target could be defined as a minimum 10% net gain in biodiversity, for example. This goal would then need to be operationalised for different elements of biodiversity, including abundance and diversity of species and extent and condition of ecosystems. Following the timeframe of the GBF, the baseline for measuring progress could be set to 2020, with the 10% net gain to be delivered by 2030.

#### *3.2.3 Explore management measures under each step of the mitigation hierarchy (Step C)*

The next step is to explore potential management measures to achieve biodiversity net gain. This can be achieved by adhering to the mitigation hierarchy, which prescribes four sequential action steps [9,28]: 1) avoidance of impacts on biodiversity as much as possible (e.g. no-take MPAs), 2) minimisation of unavoidable impacts (e.g. change gear type or reduce fishing effort), 3) remediation of impacts that cannot be avoided or minimised (e.g. improve post-capture handling practices of bycatch and do on-site habitat improvement efforts), and lastly 4) compensation for any residual impacts (e.g. habitat and species restoration actions that offset species mortality and habitat impacts). Compensation measures must ideally benefit the same biodiversity components as those affected, i.e. ‘like-for-like’ [6]. However, as discussed by Milner-Gulland et al. [23], there are grey areas between the four steps and different ways mitigation measures could be categorised.

#### *3.2.4 Explore transformative measures (Step D)*

Once the mitigation hierarchy has been followed to ensure biodiversity net gain from a fishery’s operations, transformative measures should be explored. As transformative change and a Nature Positive future are inextricably linked, this step is critical for fisheries aiming to deliver outcomes that align with Nature Positive. The range of possible transformative actions can be divided into three classes of actions: private actions, social signalling actions, and collective actions [3,29]. In the context of fisheries, private actions include actions by a fishing business aiming to reduce their own impacts on biodiversity, such as ensuring biodiversity net gain as described above. Social signalling actions are those a fishing business carries out to signal their actions and position on biodiversity to others. This could include publicly sharing biodiversity goals and strategies, impacts and progress towards delivering goals (e.g. via the Science Based Targets Network, https://sciencebasedtargetsnetwork.org/), and making public corporate pledges (e.g. via joining the Nature Positive Initiative, naturepositive.org). Finally, collective actions refer to those a fishing business undertakes in collaboration with others to address structural barriers and opportunities. This includes action to drive changes to laws, policies, institutions or sectors. For fisheries, this could, for instance, involve collaborating with other fisheries to drive new policies and regulations that establish novel Marine Protected Areas or a new status quo for biodiversity management, or engaging in cross-sectoral collaborations to address Illegal, Unregulated and Unreported (IUU) fishing. As discussed by Booth et al. [3], these transformative actions will need to be scaled up within sectors and across seascapes and value chains to decrease the potential for leakage.

#### *3.2.5 Assess management options: Technical assessment (Step E)*

A key step in the conceptual framework is a technical assessment of potential management measures, to provide guidance to fisheries on which actions might be most effective on the pathway to biodiversity net gain. For fisheries with sufficient data on the impacted biodiversity, and how it is likely to be affected by mitigation measures, a quantitative technical assessment comparing predicted losses and gains in biodiversity under different scenarios could be conducted.

Data gaps are prevalent for many species-fisheries combinations and information on the effectiveness of established technical measures and impacted biodiversity is often lacking. For example, predicting the effectiveness of compensatory and transformative measures is particularly challenging, due to a limited understanding of how such actions quantitatively influence biodiversity and how outcomes can be attributed to a single fishery operation. For example, the impact of habitat- and species restoration efforts for many marine habitats and species has not been studied and as a result it is difficult to reliably predict their effectiveness in improving the state of biodiversity [30]. Even when measures are quantified, the observed or tested effectiveness may be limited to the specific conditions under which they were originally observed or tested [31, 24]. Until these knowledge gaps have been addressed, expert elicitations and fisher knowledge may need to be used instead to help inform the technical assessment. To account for uncertainties, precautionary risk multipliers that capture elements such as the risk of project failure should also be applied [32].

*3.2.6 Assess management options: Feasibility assessment (Step F)*

To account for the socio-economic complexity of fisheries when exploring management measures, the conceptual framework includes a feasibility assessment. Such assessments can highlight opportunities and barriers to implementation, and help identify where there might be scope for economic incentives to facilitate implementation [23,33], Different approaches to socio-economic feasibility assessments have already been described in the literature which could be adapted for this step of the framework, such as those discussed by Gupta et al. [25] for shark fisheries in India. As with goal and target setting, the feasibility assessment can be adapted to suit the level of data, capacity and budget available for each fishery.

*3.2.7 Make a management decision; implement, monitor and adapt (Step G)*

Finally, the information gathered needs to be synthesised to make and implement management decisions. This should ensure that the measures undertaken provide sufficient biodiversity benefit to more than compensate for estimated impacts, determined by the technical assessment. It should also explicitly consider the socio-economic context and practical constraints of implementing the measures, as identified in the feasibility assessment. Robust monitoring, research and ongoing stakeholder engagement will be critical; continually assessing progress, building knowledge, and adapting accordingly will be particularly important for first attempts at implementing the framework.

## 4. CASE STUDIES: APPLYING THE CONCEPTUAL FRAMEWORK

To explore the utility of the conceptual framework and refine it, we worked through the first five steps of the framework for three distinct MSC-certified fisheries targeting bluefin tuna, king scallop and orange roughy respectively (Fig. 2).

*4.1 Case study results for steps A-D*

At step A (define the system; Fig. 2), the three fisheries were found to have a very different impact on biodiversity. The bluefin tuna fishery primarily impacts the tuna stock, with minimal direct benthic habitat impacts, and negligible bycatch attributed to the use of selective fishing gear [20]. Conversely, both the orange roughy and king scallop fisheries have multiple bycatch species and use fishing methods that directly damage the seabed [21,22]. The orange roughy fishery operates over a larger benthic area than king scallop and operates in the deep-sea where recovery times for impacted seabed features are poorly understood [22]. Consequently, while the primary concern in the tuna fishery is the tuna stock, we found that habitat, target species and bycatch are all of concern in the orange roughy and king scallop fisheries. Risks to biodiversity across these fisheries include biological risks (e.g. the long life-history of orange roughy) and technical risks (e.g. encounterability of bycatch species for scallop and potential for overfishing due to insufficient information for tuna [20,21,22]). Socio-economic risks and other constraints, particularly related to monitoring and budgets, may also exist but we could not adequately assess these due to limited information.

Step B involves setting biodiversity goals, quantitative targets, a baseline, and timeframe for each case study (Figs. 1, 2). Because the information used for the case studies was based on their latest MSC certification report, we had to adjust the baseline year for the goal for each fishery. To monitor future biodiversity outcomes, indicators for population growth rate and range, species richness and relative abundance, and seabed integrity are proposed as potentially applicable metrics.

For step C, we used information from the fisheries' MSC certification reports and the wider literature to explore potential management measures for the fisheries. We then categorised the measures against the steps of the mitigation hierarchy. The measures proposed included: spatio-temporal closures (avoidance); gear changes (minimisation); improved release protocols for bycatch (remediation); and contributions toward habitat restoration (compensation). Additionally, each of the fisheries had uncertainties regarding the impacted biodiversity which would need to be addressed to better inform their management strategy.

Following Step D of the framework, recommendations for transformative actions were made for each fishery. These included sharing biodiversity goals and strategies, supporting measures to combat illegal, unreported, and unregulated fishing (IUU) of target species, and advocating for benthic protected areas. However, although transformative actions are imperative in driving fisheries towards the Nature Positive goal, their technical effectiveness could not be assessed for the case studies due to lack of quantifiable data on their impact for biodiversity.

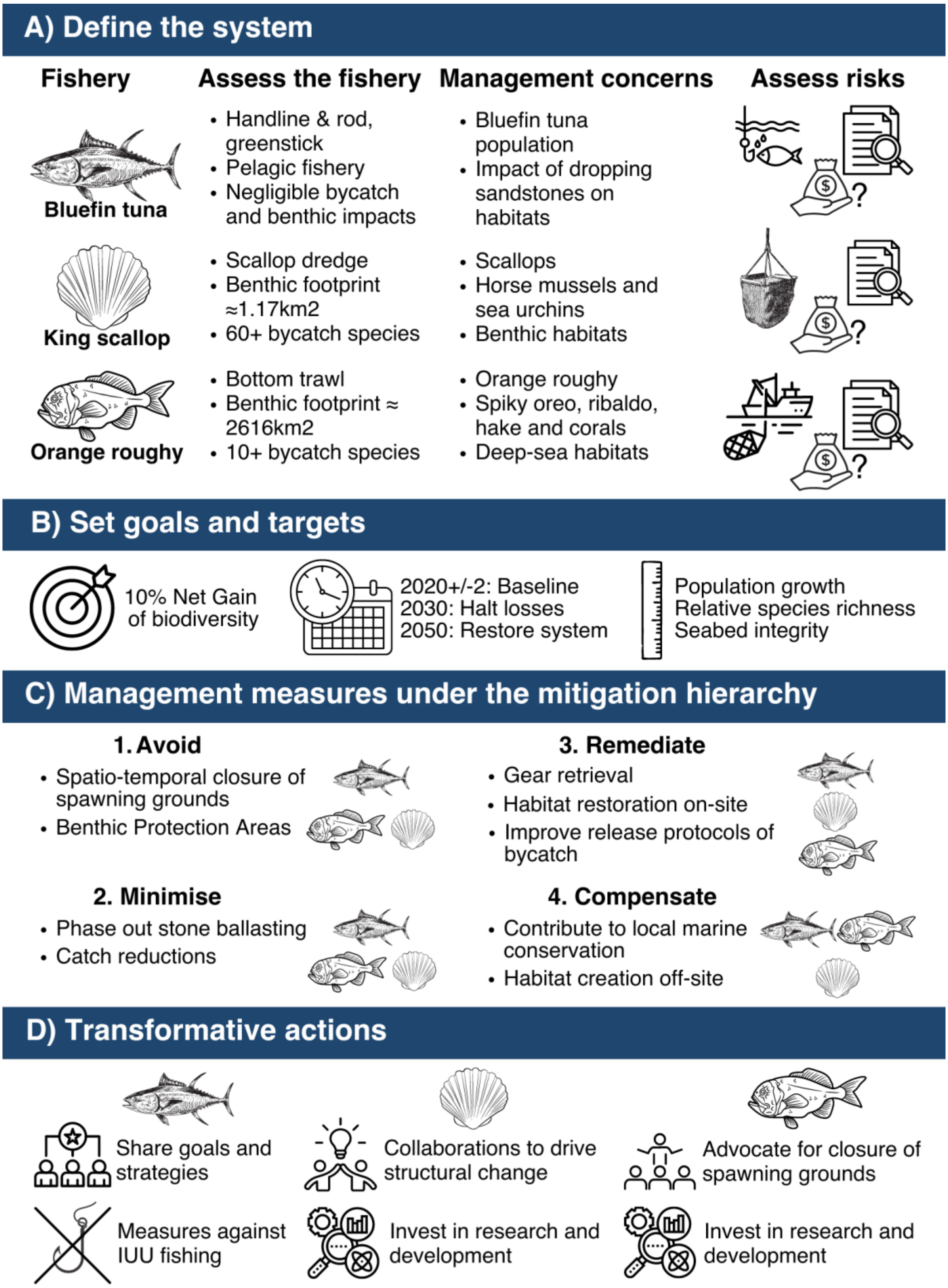


***Figure 2.*** *Overview of the results from steps A-D of the conceptual framework for the three fishery case studies in the following order: Bluefin tuna fishery, king scallop fishery and orange roughy fishery. IUU fishing is the acronym for Illegal, Unregulated and Unreported fishing. The icons under 'Assess risks' refer to some of the risks to biodiversity due to the fisheries operations for each case study. These include risk of encounter with fishing gear and overfishing (fishing gear icons), potential socio-economic risks ($ icons), and risks associated with uncertainties and knowledge gaps (magnifying glass icon). Figure created using canva.com.*

*4.2 Technical assessment: preliminary results using an example metric (step E)*

Using the example metric we developed based on the Defra Biodiversity Metric, we conducted a technical assessment of management measures for each of our case studies. This assessment involved predicting the ex-ante effectiveness of management measures in mitigating risks of biodiversity impacts and delivering the biodiversity gains required to compensate for losses.

*4.2.1 King scallop fishery*

The preliminary results from our metric predicted that the king scallop fishery could reach net gain for the primary impacted species and habitats by adopting management measures including benthic protection areas, catch reductions and habitat creation (Fig. 3). The fishery would also have to address uncertainties regarding impacted biodiversity to better inform their management strategy. Two specific compensation measures are proposed from which the fishery would choose one to reach net gain for their operations:

(1) Habitat creation within the current fishing area (on-site) of 280 hectares of good condition gravel habitat, including seeding for scallops. This compensation option is expected to benefit king- and queen scallops directly but not horse mussels and sea urchins.

(2) Habitat creation of 850 ha of maerl beds and 800 ha of horse mussel beds in an area adjacent to the current fishing area (off-site). This would require seeding of horse mussels and potentially also of king- and queen scallops. This compensation option is expected to benefit all directly impacted species, except sea urchins.

*4.2.2 Orange roughy and tuna fisheries*

In contrast, our analysis suggested that, based on currently available information, both the orange roughy and tuna fisheries are unable to deliver biodiversity net gain for the impacted species and habitats (Fig. 3). This stems from a lack of known compensation measures that could directly benefit the biodiversity affected by these fisheries. However, while 'like-for-like' compensation measures do not currently exist, this does not preclude fisheries taking other more general positive action for biodiversity to compensate for their impacts. For instance, both fisheries could take each of the following steps to deliver an overall positive contribution to biodiversity, even if they are not able to deliver biodiversity net gain in the strict sense:

(1) Prevent and remediate impacts on biodiversity as much as possible.

(2) Support research and development into potential compensation measures to address the knowledge gaps and reduce uncertainties.

(3) Take more general positive actions known to benefit marine biodiversity (e.g. contribute to nearby restoration projects focused on other biodiversity components) to

compensate for impacts. These do not represent net gain because they would not improve the status of the impacted species/habitats directly.

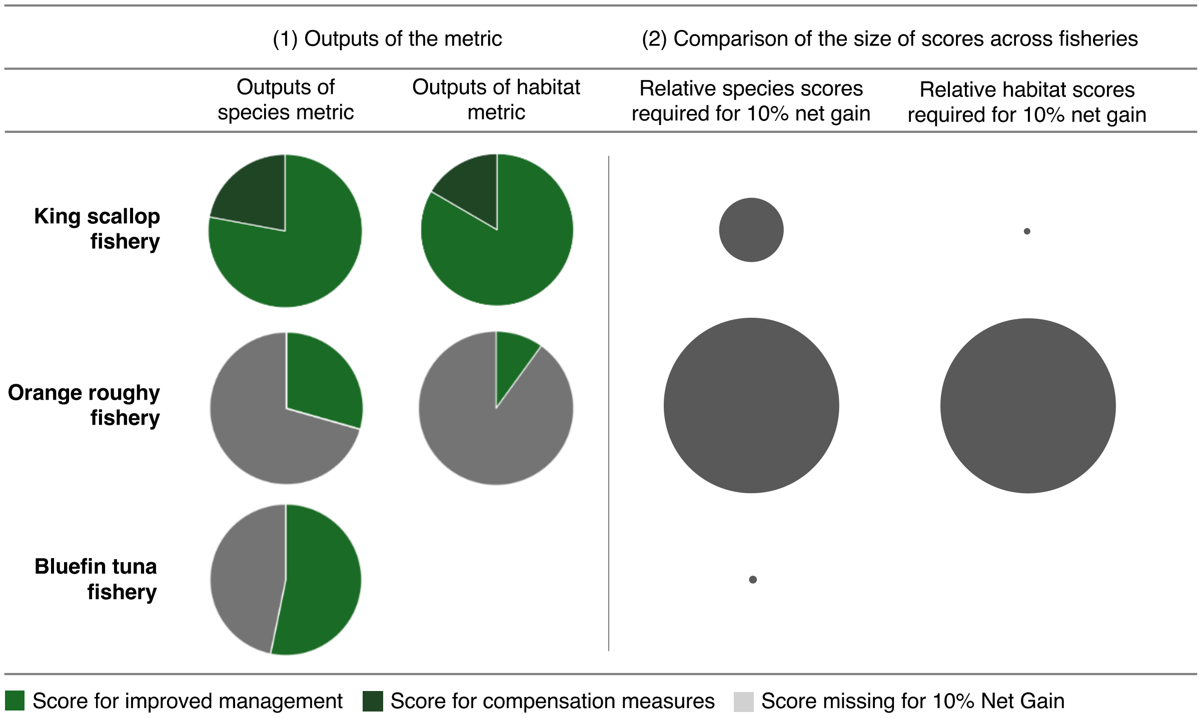


***Figure 3.*** *Metric results for the three fisheries. (1) Pie charts show the metric outputs for the species and habitat components, for each fishery. The total area of each pie chart represents the score required for 10% net gain for each respective fishery for either habitats or species, the lighter green shows how much of this score could be achieved through improved management (steps 1-2 of the Mitigation Hierarchy) the darker green how much could be achieved from compensatory actions (steps 3-4 of the Mitigation Hierarchy), and the grey how much impact remains uncompensatable. (2) The proportional area chart demonstrates how the size of the scores required for 10% net gain for habitats and species compare across the three fisheries. That is, the size of the circles is scaled across fisheries for habitats and species separately (because the two are based on different criteria), so the largest score for each (in both cases orange roughy) is 1 and the size of the other circles is relative to this score.*

*4.3 Feasibility assessment of management measures (step E)*

Following step E of the conceptual framework, the feasibility of implementing the proposed management measures was assessed (Table 1). Overall, most of the suggested measures were estimated as medium feasibility, with only one measure considered of low feasibility and three of high feasibility. The measures considered of high feasibility were transformative actions that do not involve high costs or effort from the fishery. The feasibility assessment was done for illustrative purposes, based on literature and consultation with MSC experts; before real-world implementation of our proposed approach best practice would include an extensive stakeholder consultation exercise.

| Case study | | Avoid | Minimise | Remediate | Compensate | Transformative actions | |
|---|---|---|---|---|---|---|---|
| **Atlantic bluefin tuna**  | **Potential measure** | **Spatio-temporal closure of tuna spawning grounds** | **Phase out stone ballasting** | **Habitat improvement efforts on-site (removal of sandstones dropped)** | **Fine/tax for impacts** | **Investment in research and development** | **Measures against illegal, unreported and unregulated fishing** |
| | **Feasibility assessment** | E: Some evidence of potential economic benefits; T: Costly monitoring and enforcement required but Spanish EM programmes may aid implementation I: Policy required; S: Reduction in catches expected, potential for fisher resistance | E: The fishery might be able to maintain the same catches using its other gear types; T: Additional monitoring or incentive may be needed; I: Policy could aid implementation; S: Potential fisher resistance, change required | E: Direct costs and/or time and resources required, but may be feasible; T: Additional monitoring and enforcement required, and potentially new technologies ; I: Administrative support needed; S: Novel measure, potential fisher resistance | E: The fishery may have enough resources to pay; T: Costly monitoring may be necessary; I: Policy and administrative support required for implementation; S: Potential fisher resistance to paying | E: The fishery may have enough resources, could support long-term sustainability; T: None expected; I: Collaborations with research institutes required; S: No specific issues identified | E: Requires resources but may be feasible; potential long-term benefits for bluefin tuna population if successful; T: ?; I: Administrative support necessary; S: No specific issues identified |
| | | √√ | √√ | √ | √√ | √√√ | √√ |
| **King scallop**  | **Potential measure** | **Spatio-temporal closure** | **Scallop catch reduction** | **Payment for biodiversity restoration on-site** | **Payments-in-kind** | **Collaborations to drive new more biodiversity-friendly policies** | **Share biodiversity goals and strategies with others** |
| | **Feasibility assessment** | E: Some areas open to the fishery remain unfished - potential for additional closures without significant cost; T: Current monitoring system applicable; I: Policy required; S: An already established measure, minimal change required if implemented in areas currently not fished | E: Short-term finanical losses anticipated; unclear comparison with long-term gains; T: Current monitoring system applicable; I: Policy ideally required; S: An already established measure, minimal change required | E: Costly for the fishery but may have revenues to pay; T: Current monitoring system applicable; I: Administrative support needed; S: Change requried, potential for fisher resistance | E: Fishers may be able to pay in kind, time and knowledge required. T: Current monitoring system applicable; I: Collaborations with relevant organisations required; S: Novel measure, potential for fisher resistance | E: Time and some resources required but may be feasible; T: Online or in-person meetings both possible; I: Goal is passage of policy by local administration; S: No specific issues identified | E: Low resource requirements; T: Online and/or in-person options feasible; I: Administrative support not expected to be required; S: No specific issues identified |
| | | √√ | √√ | √√ | √√ | √√ | √√√ |
| **Orange roughy**  | **Potential measure** | **Benthic Protection Areas** | **Orange roughy catch reduction** | **Best handling and release protocols for bycatch species** | **Contribute to nearby marine conservation efforts** | **Advocate for closures of spawning grounds** | **Investment in research and development** |
| | **Feasibility assessment** | E: Not all areas open to the fishery are currently fished, potential for additional protected areas at low cost; T: Current monitoring system applicable; I: Policy required; S: An already established measure, minimal impact on fishers if implemented in areas currently not fished | E: NZ$1.21m short-term loss; unclear comparison with long-term gains; T: Current monitoring system applicable; I: Quota recently increased, most cautious option suggested no change; S: Quota changes are common in this fishery but some resistance expected | E: No extra costs expected but time, knowledge and effort required; T: Current monitoring system applicable; I: Not necessarily required but could support implementation; S: Some change required, potential issues around compliance | E: Fishery may afford costs; T: Current monitoring and enforcement system applicable; I: Policy and administrative support required; S: Novel costly measure, potential fisher resistance | E: Requires time and resources, but may be feasible; potential long-term benefits if succesful; T: Advocating possible online or in-person; I: Ultimate goal is policy passage by local administration; S: No specific issues identified | E: The fishery may have enough resources to make a contribution, could support long-term sustainability; T: None expected; I: Collaborations with research institutes required, these may already exist; S: No specific issues identified |
| | | √√ | √√ | √√ | √√ | √√ | √√√ |

***Table 1.*** *A semi-quantitative traffic-light categorisation to summarise the outcome of the feasibility assessment for the main suggested measures in each case study based on available information and expert opinion. Green colour and three "√" symbols indicate a high perceived effectiveness for that measure in that case study, whereas red colour and one "√" symbol a low effectiveness. E stands for the criteria for economic feasibility, T for technological feasibility, I for institutional feasibility and S for social feasibility. EM programme under bluefin tuna refers to electronic monitoring programmes. The measures in the table that follow the steps of the mitigation hierarchy are incorporated in the metric and need to add up to enough biodiversity benefit to more than compensate for calculated impacts to meet 10% net gain. The measures in the final two columns of the table, i.e. the 'Transformative actions', are additional steps required to move towards nature positive, but these cannot substitute for the impact mitigation steps.*

## 5. KEY INFORMANTS' VIEWS OF A NATURE POSITIVE GOAL FOR FISHERIES: PRELIMINARY IMPRESSIONS AND SUGGESTED STEPS FORWARD

### *5.1 Stakeholders' perception of a Nature Positive approach to fisheries management*

Overall, the fisheries experts we consulted were cautiously optimistic regarding a Nature Positive approach to fisheries management, recognising both its potential benefits and implementation challenges (Table 2). The potential benefits cited included its alignment with international agreements and the principles of ecosystem-based management, and the fishing industry's awareness of the importance of healthy ecosystems for fisheries. Conversely, the perceived challenges included that the approach might be too aspirational given the current state of fisheries and that fisheries already feel under pressure, making them likely to resist any new initiatives that might impede their activities. Some experts also suggested that the industry might be reluctant to adopt a Nature Positive approach due to previous exposure to similar initiatives that did not lead to change. Other potential barriers identified included knowledge gaps and monitoring issues, particularly given the dynamic and interconnected nature of marine systems.

***Table 2.*** *Responses of key informants relating to their perception of a Nature Positive approach to fisheries management, categorised as 'benefits' or 'challenges'. The reasoning articulated, and example quotes for each reasoning are also provided.*

| | Rationale | Example quotes |
|---|---|---|
| *Benefits* | Link to international agreements | *"Nature Positive fisheries is a concept that fits really well with the primary legislation and ambitions that the UK has signed up to globally"* |
| | Link to ecosystem-based management | *"Governance bodies are struggling with ecosystem-based fishery management, what it means, how to implement it and so on"* |
| | Importance of healthy ecosystems | *"I think everybody recognises that a healthy ecosystem is required to have a vibrant fishing industry"* |
| *Challenges* | Aspirational | *"It it's not something that would be easy to achieve I guess, in the sphere that I work in at least, because we're quite a long way from that."* |
| | Added pressure on industry | *"At the moment the most likely response from industry would be to resist anything that might impede their activities and their businesses"* |
| | Existence of related terms | *"I find the concept interesting, but there are many initiatives of this kind"* |

| | |
|---|---|
| Information gaps and monitoring issues | *"So I think there's another challenge around the level of monitoring of the different indicators and the information that's available to you"* |
| Marine connectivity | *"I guess whether or not it can be used is whether it fits in a fishery context, and it comes back to can you separate fisheries from everything else that's going on. The marine system is very different to the terrestrial, it's very dynamic and interconnected"* |

### *5.2 Suggested steps forward*

We prompted key informants to suggest how they thought these challenges could be addressed by future initiatives looking to operationalise a Nature Positive approach for fisheries. The most frequently cited theme in this context was the importance of a simple and positive framing of the Nature Positive goal that highlights potential benefits to fisheries. One specific suggestion for facilitating industry uptake was framing the goal as a step-by-step process that recognises milestones on the way towards Nature Positive contributions. Some informants also mentioned the value of aligning the goal with existing terminology familiar to industry. Additionally, to address issues related to marine connectivity, it was emphasised that interactions between fisheries and other sectors operating in nearby areas should be accounted for, as well as the importance of higher-level transformative actions, such as collaborations between different marine sectors.

To operationalise the approach for fisheries, most key informants believed that either regulatory or a combination of regulatory and voluntary measures, would be required. Nonetheless, they also recognised that the optimal approach to operationalising a Nature Positive goal would vary between fisheries, due to different regulatory environments and socio-economic contexts. The benefits of voluntary actions highlighted included that they typically have a faster implementation process than regulatory ones, and that voluntary sustainability certifications can be a strong driver for improving practice and performance as they can deliver market benefits to fisheries. One specific suggestion was that as a first step forward, the MSC could adopt the approach as an add-on for certified fisheries that aim to be leaders in this space.

However, it was frequently mentioned that voluntary measures in isolation would not be sufficient to drive Nature Positive outcomes for fisheries at a scale. Instead, policies and other regulatory actions by governments, RFMOs, or multilateral organisations, would be required in parallel to drive wide adoption of the approach. It was also suggested that since governments are the ones that have signed up to international treaties like the Global

Biodiversity Framework, they bear the responsibility for driving outcomes that align with the Framework and so should provide regulatory benefits to fisheries, such as financial incentives.

## 6. DISCUSSION

### *6.1 First step towards Nature Positive fisheries*

This study is the first to outline how fisheries could address the biodiversity impacts of their direct operations to take their first step towards the Nature Positive goal and contribute to the mission of the Global Biodiversity Framework. Although existing fisheries management strategies typically aim for sustainable utilisation of fishery resources, global evidence of fishery declines suggests that a different approach is needed to address fisheries' biodiversity impacts in the context of other drivers of change in marine systems [15]. Overall, the findings from the case studies suggest that the proposed conceptual framework could be applied to diverse real-world fisheries as their first step on a pathway towards Nature Positive contributions. Our proposed approach was not designed for use by a particular decision-maker, instead it should ideally be adapted for use by different fishery management agencies and companies working in collaboration. Promisingly, preliminary impressions from our key-informant interviews indicated that stakeholders are relatively positive about a Nature Positive approach to fisheries management. The key-informants also highlighted perceived challenges that might hinder Nature Positive outcomes for fisheries in the future. These insights have implications for future initiatives, research and policy in this area.

### *6.2 Biodiversity impacts of fisheries do not have a one-size-fits-all solution*

The case studies and key-informant interviews indicated that the path towards Nature Positive fisheries will vary between fisheries. This variability was expected, as we deliberately selected three fisheries with contrasting characteristics to test the framework. Given the immense diversity observed across global fisheries - encompassing differences in impacted biodiversity, gear types, socio-political context, and economic factors - it is evident that a one-size-fits-all management approach is unlikely to deliver desired biodiversity outcomes [34]. Instead, case-specific strategies will be necessary to address specific challenges and opportunities of each fishery. Net outcome approaches are a valuable tool in this context as they allow differentiated pathways towards a common goal. For some fisheries, such as the orange roughy and bluefin tuna, aligning with a Nature Positive ambition may be more challenging due to the size of their biodiversity impacts, and knowledge and innovation gaps. However, for fisheries like the king scallop fishery, which may have considerable impacts but has more readily available compensation measures for the most directly impacted biodiversity, the path towards Nature Positive operations may be more straightforward. Nonetheless, for all fisheries it will be imperative that there is strict compliance with the mitigation hierarchy, and compensation is only used as a last resort for unavoidable impacts [6].

The need to adapt specific management measures and policies to the context of specific case studies was also highlighted by key-informants pointing to diverse issues associated with the greater connectivity of marine systems compared to terrestrial ones. This observation is supported by existing literature, which suggests that, due to marine connectivity, indirect or cumulative impacts may be particularly dominant in the marine environment [35]. This can pose challenges for accurately attributing biodiversity impacts to specific activities or operations. This complexity is further compounded when multiple activities occur in the same or nearby areas, making it difficult to disentangle the causal relationship between a specific action and a biodiversity outcome. To address this issue, several key-informants highlighted the importance of considering interactions between fishery impacts and impacts of other sectors in the same geography. The value of taking interactions between fisheries and other sectors into account is also supported by existing literature [36]. This is likely to become increasingly important as demand for ocean resources expands across multiple sectors, such as European countries seeking a five-fold increase in the capacity of offshore wind farms by 2030 [37], which can have interacting effects on fishery impacts.

### *6.3 Future directions for encouraging industry uptake of a Nature Positive goal for fisheries*

#### *6.3.1 Real-life case study examples and further stakeholder engagement*

As suggested by some key-informants, the adoption of our approach by real-world fisheries would provide examples of successful implementation and tangible benefits to other fisheries. In this way, such examples could serve as a catalyst for driving uptake of the approach across the fisheries sector. In this way, such examples could serve as a catalyst for driving uptake of the approach across the fisheries sector. This should be done alongside robust monitoring of outcomes, both for biodiversity and fisheries, to enable ongoing reassessments of the approach and to ensure it delivers the desired outcomes. Such initiatives would also benefit from further stakeholder engagement. This could be implemented through interviews or workshops with more diverse groups in the fishing industry. Such efforts could provide valuable input on how a Nature Positive approach to fisheries could be operationalised in a way that would be most palatable to stakeholders while still delivering the outcomes desired for biodiversity. The benefit of stakeholder involvement in decision-making is also supported by the literature as being critical for creating fair and salient policies [38].

### *6.3.2 Suggested framing of the Nature Positive goal to industry*

Despite the small sample of key-informants, themes also emerged for framing the Nature Positive goal to increase uptake by industry. These have implications for future efforts, with the potential to address many of the reservations expressed by key-informants and encourage support within the fishing industry. For instance, relating the Nature Positive term to existing terms familiar to industry could facilitate greater uptake by making it more relatable and accessible to stakeholders. Similarly, framing the goal as a step-by-step process that acknowledges and rewards fisheries for major advancements along the way could help prevent the goal from being viewed as too aspirational. Presenting the goal in a straightforward and positive manner that emphasises potential benefits to fishing businesses (e.g. predicted increase in annual profits of the seafood industry from conserving marine stocks [39]) may also prevent it from being perceived as yet another regulation to comply with. Additionally, as there may be a role for consumer demand and market pressure to drive voluntary action by fishing businesses, it would be worth highlighting the various international regulatory pressures underway in this space and the potential benefits of getting ahead of the curve, including market premiums.

## 7. CONCLUSION: ONE PIECE OF THE PUZZLE FOR NATURE POSITIVE FISHERIES

This study presented a first step towards Nature Positive contributions for fisheries, by focusing on the direct impacts of fisheries operations. Future efforts will need to build upon the proposed approach to consider wider value chains and indirect impacts of fisheries activities (e.g. from fuel use and spread of invasive species on ship hulls). As fisheries progress towards aligning with a Nature Positive goal, transformative actions will also become increasingly important to deliver the desired outcomes for biodiversity on a societal scale. This is especially pertinent in the marine context, where connectivity may amplify the risk of impact displacement to other areas, undermining positive actions by particular fishing operations. Therefore, it is imperative that fisheries seeking to deliver positive outcomes for biodiversity also expand their actions into driving transformative sector-wide and cross-sectoral collaborations. This wider systems thinking, when founded on robust management of fisheries operations, could help to reconcile blue growth and biodiversity goals and achieve the Global Biodiversity Framework’s vision of living in harmony with nature.

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## 9. SUPPLEMENTARY MATERIAL

**Supplementary Material 1 - Interview questions:** The two structured interview questionnaires used in the key-informant interviews, each tailored to the expertise of the interviewees.

### A. Interview questions for experts in developing a metric for measuring net outcomes for nature

1) Were you familiar with the nature positive goal before I contacted you to do an interview?
2) Do you think the current management of the biodiversity impacts of fisheries is enough to ensure that fisheries are contributing towards the positive global goal? Please elaborate on your answer.
3) Based on this information, what is your initial feeling about this suggested extension of the UK government-prescribed metric to the fisheries context? Do you think a metric of this kind could be adapted for use by fisheries managers and operationalised in the real world? If not, why not?
4) Are there any additional factors that you think should be included in the metric or any currently used that you think should be excluded? If so, why?
5) Do you have any other suggestions for how the metric could be improved? Are there any changes that you think would make it more likely to deliver positive results for biodiversity?
6) Do you have any thoughts about other elements that should be taken into account alongside the metric, when assessing the contributions of fisheries towards a NP goal? Thinking just about the impacts of fishing operations on the ecosystem and target species, rather than the whole operations of a fishing business.
7) Who do you think might use a tool like this? Which types of fishery, and why? Do you think this is something a government like the UK might consider using?
8) Any further comments on whether this is a useful exercise, and any pitfalls, challenges, or opportunities you could envisage?

### B. Interview questions for experts in fisheries management

1) Were you familiar with the nature positive goal before I contacted you to do an interview?
2) Is nature positive fisheries a concept that resonates with you? How do you think it is generally likely to be perceived by fisheries managers or others working in the fishing industry?
3) Do you think the current management of the biodiversity impacts of fisheries is enough to ensure that fisheries are contributing towards the nature positive global goal? Please elaborate on your answer?

4) How do you think that the nature positive goal could be operationalised in the context of fisheries? Do you think it would primarily be driven by voluntary actions from industry, such as seeking MSC certification, or do you think regulatory action from governments will be needed?
5) Were you familiar with the nature positive goal before I contacted you to do an interview?
6) Is nature positive fisheries a concept that resonates with you? How do you think it is generally likely to be perceived by fisheries managers or others working in the fishing industry?
7) Do you think the current management of the biodiversity impacts of fisheries is enough to ensure that fisheries are contributing towards the nature positive global goal? Please elaborate on your answer?
8) How do you think that the nature positive goal could be operationalised in the context of fisheries? Do you think it would primarily be driven by voluntary actions from industry, such as seeking MSC certification, or do you think regulatory action from governments will be needed?

**Supplementary Material 2 - The Defra Biodiversity metric adapted to fisheries:** Further details about our adaptation of the Defra Biodiversity Metric to the context of fisheries which we used for illustrative purposes to work through our framework for three case studies. Includes an overview of our version of the metric, the equations incorporated in the metric, and feedback on the metric from key-informants.

### A. Overview of the adapted version of the metric

The metric we developed for fisheries adopts the principles of the Defra metric to predict whether an activity will deliver a 10% net gain. However, recognising ecological and contextual differences between terrestrial developments and fisheries operations, and knowledge gaps in marine systems, we made several adjustments and assumptions.

The metric calculates scores for both species and habitats, rather than just habitats as in the Defra metric. The literature supports the importance of including species as their response to biodiversity impact is not well captured in habitat-only metrics [1], including in marine systems [2]. Doing so also facilitates using the metric for fisheries with direct impacts on species but minimal habitat impacts, such as many pelagic fisheries, and ensures that compensation measures adequately mitigate impacts on species by mandating actions that directly benefit affected species. These actions may include prioritising habitat creation for impacted species and contributing to species restoration initiatives such as oyster seeding. Analogous to how the Defra metric does not combine scores for habitats, hedges, and watercourses because they are based on different criteria [18], the version of the metric for fisheries does not combine the scores for species and habitats. Instead, both components need to deliver 10% biodiversity net gain separately.

A key assumption of the fisheries metric is that fisheries operations are assumed to deliver no net loss of biodiversity if they meet the criteria for the maximum score against the MSC Fisheries Standard for the fishery's impacts on species and habitats. The MSC Fisheries Standard scores habitats and species separately on their status, management strategy and quality of available information. The assumption of a link between MSC scores and no net loss is, in turn, based on the assumption that sustainably managed fisheries deliver no net loss. However, it should be noted that, although the MSC Standard does require regulations focusing on avoidance and minimisation, the standard is not designed to deliver no net loss. Therefore, these assumptions would need to be scientifically tested and potentially replaced if the metric were to be implemented for real-world use.

The fisheries metric includes an additional step that predicts the biodiversity score of an improved management scenario. We added this step to predict the effectiveness of steps 1-3 of the mitigation hierarchy (avoid, minimise, and remediate) separately to step 4 (compensation). This score for improved management is subjected to a temporal multiplier to account for the time it would take biodiversity to recover after management has been improved. It is then combined with the score for on-site compensatory actions, and the two are compared to the required score for 10% net gain.

The criteria used to score the inputs of the habitat component of the metric are similar to the Defra metric. However, the criteria used for the inputs in the species component differ as follows: The distinctiveness category is based on the extinction risk of species, so it is more closely linked to threats to the species. Additionally, area size is replaced by annual catch of the fishery for each species in tonnes. The annual catch is required to allow quantification of how much species compensation is required. As seeking expert judgement and conducting site visits was not within the scope of this study, alternative information had to be used to score the inputs (Table 3).

***Table 3.*** *A comparison of the inputs and the information used to score the inputs for the Defra metric and the metric for fisheries (for both habitats and species). See Appendix III for more details.*

| Defra metric habitat inputs | Fisheries metric habitat inputs | Fisheries metric species inputs |
|---|---|---|

| | | |
|---|---|---|
| Habitat **distinctiveness**, based on expert judgement | Habitat **distinctiveness**, based on available literature | Species **distinctiveness**, based on the IUCN Red List category |
| Habitat **condition** based on judgements from ecological consultants | Habitat **condition**, based on the MSC habitat score | Species **condition**, based on the MSC species score |
| Size of the **area** of habitat impacted [ha], based on quantitative data | Size of the **area** of habitat the fishery impacts [ha], based on MSC reporting | Annual **catches** [t] of the species by the fishery based on MSC reporting |
| **Strategic significance,** based on location and habitat type (e.g. in Local Nature Recovery Network) | **Strategic significance,** based on whether the site is within or near a protected area or a buffer zone | **Strategic significance**, based on whether a species is considered a keystone species |

### B. Metric equations

#### 1. Habitat – calculating area habitat-based units (AHBUs)

Equation 1: Pre-impact ($t_0$) baseline biodiversity units

$$t_0 \text{ Baseline AHBU} = (A^{t0} \times D^{t0} \times C^{t0}) \times (SS^{t0})$$

Equation 2: Post-management intervention ($t_1$) biodiversity units for habitat:

$$t_1 \text{ Post management intervention AHBU} = \{[A^{t1} \times D^{t1} \times C^{t1}] \times [R_T] \times [SS^{t1}]\}$$

Equation 3: Biodiversity units required for 10% AHBU Net Gain:

$$10\% \text{ NG AHBU} = \{([A^{t1} \times D^{t1} \times C^{t1}] \times [SS^{t1}]) \times 0.1\}$$

Equation 4: Biodiversity units required for AHBU NNL:

$$\text{Units required for AHBU NNL} = \{[A^{t1} \times D^{t1} \times C^{t1}] \times [SS^{t1}]\}$$

Equation 5: Post-impact ($t_1$) biodiversity units for habitat creation:

$$t_1 \text{ Creation AHBU} = [\{A^{t1} \times D^{t1} \times C^{t1}\} \times \{R_D \times R_T \times R_{EU}\} \times \{SS^{t1}\}]$$

Equation 6: Area habitat biodiversity unit change on-site:

$$\text{Onsite AHBU change} = (\{t_1 \text{ Creation AHBU on-site} + t_1 \text{ Post management intervention AHBU}\} – \{\text{Units required for AHBU NNL}\})$$

Equation 7: Area habitat biodiversity unit change off-site:

$$\text{Offsite AHBU change} = [(\{ t_1 \text{ Creation AHBU off-site} + t_1 \text{ Post management intervention AHBU}\} - \{\text{Units required for AHBU NNL}\}) \times R_{OS}]$$

Equation 8: Total area habitat biodiversity unit change (total)

$$\text{Total AHBU change} = \text{Onsite AHBU change} + \text{Offsite AHBU change}$$

Equation 9: Total habitat biodiversity units missing for 10% NG:

$$\text{Total AHBU missing for 10\% NG} = \{10\% \text{ NG AHBU}\} – \{\text{Total AHBU change}\}$$

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| | | | |
|---|---|---|---|
| A | Area of habitat (hectares) | $R_D$ | Difficulty (a risk factor) |

| | | | |
|---|---|---|---|
| C | Condition | $R_T$ | Time to target condition (a risk factor) |
| D | Distinctiveness | $R_{OS}$ | Spatial risk (off-site risk factor) |
| SS | Strategic Significance | $R_{EU}$ | Uncertainties (a risk factor) |
| $T_0$ | Pre-intervention (baseline) | $T_1$ | Post-intervention |

**2. Species – calculating species-based units (SBUs)**

Equation 1: Pre-impact ($t_0$) baseline biodiversity units:

$t_0$ *Baseline SBU* $= (D^{t0} \times C^{t0} \times Ca^{t0}) \times (SS^{t0})$

Equation 2: Post-management intervention ($t_1$) biodiversity units for species:

$t_1$ *Post management intervention SBU* $= \{[D^{t1} \times C^{t1}] \times [R_T] \times [SS^{t1}]\}$

Equation 3: Biodiversity units required for 10% SBU Net Gain:

*10% NG SBU* $= \{([D^{t1} \times C^{t1}] \times [SS^{t0}]) \times 0.1\}$

Equation 4: Biodiversity units required for SBU NNL:

*Units required for SBU NNL* $= \{[A^{t1} \times D^{t1} \times C^{t1}] \times [SS^{t1}]\}$

Equation 5: Post-impact ($t_1$) biodiversity units for species through compensation:

$t_1$ *Onsite Compensation SBU* $= \{[D^{t1} \times A^{t1} \times AvD \times C^{t1}] \times \{R_D \times R_T \times R_{EU}\} \times [SS^{t1}]\}$

Equation 6: Species biodiversity unit change on-site:

*Onsite SBU change = {$t_1$ Onsite Compensation SBU + $t_1$ Post management intervention SBU} – {Units required for SBU NNL}*

Equation 7: Species biodiversity unit change off-site:

*Offsite SBU change = [{$t_1$ Offsite Compensation SBU + $t_1$ Post management intervention SBU} – {Units required for SBU NNL } × $R_{OS}$]*

Equation 8: Total area habitat biodiversity unit change (total)

*Total SBU change = Onsite SBU change + Offsite SBU change*

Equation 9: Total species biodiversity units missing for 10% NG:

*SBU missing for 10% NG = {10% NG SBU} – {Total SBU change}*

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| | | | |
|---|---|---|---|
| D | Distinctiveness | AvD = Average density of species/ha of habitat | |
| C | Condition | $R_T$ | Time to target condition (a risk factor |
| Ca | Catch [t] | $R_D$ | Difficulty (a risk factor) |
| SS | Strategic Significance | $R_{OS}$ | Spatial risk (off-site risk factor) |
| $T_0$ | Pre-intervention (baseline) | $R_{EU}$ | Uncertainties (a risk factor) |
| $T_1$ | Post-intervention | | |

**C. Metric feedback from key informants**

Key-informants were asked for their feedback on the adaptation of the Defra Biodiversity Metric used in this study. Most key-informants (9/12) expressed that they thought the translation of the metric was a useful first step towards achieving nature positive fisheries, or a useful exercise more generally. However, most informants (8/12) also identified potential areas for improvement, some of which overlap with critiques of the Defra Biodiversity Metric. These included lack of evidence supporting ecological assumptions of the metric and reservations about offsetting requirements.

We prompted key-informants to suggest additional elements that should be considered alongside the metric when assessing the contributions of fisheries operations towards a nature positive goal. Higher-level actions, such as collaborations between different marine sectors, were the most frequently suggested (6/12). Other frequently mentioned elements were addressing indirect and cumulative impacts on biodiversity (5/12) and additional indicators for monitoring biodiversity and resilience of marine systems (5/12). Two interviewees also suggested that, considering the broader policy context, including national targets as well as a global target would be important.

When key-informants were asked who they thought might use a metric of this kind, government entities were frequently identified (9/12). Other suggestions included multilateral inter-government bodies (4/12), standards organisations (1/12), and sustainability certification programmes (1/12). As for responses to which type of fishery might use the metric, these ranged from any fishery (3/12) to specifically benthic fisheries because of their direct habitat impacts (2/12), and aspiring leaders in sustainable fishing practices (2/12).

## SUPPLEMENTARY MATERIAL REFERENCES

[1] Hooper, T., Austen, M., & Lannin, A. (2021). Developing policy and practice for marine net gain. *Journal of Environmental Management 277*, 111387. https://doi.org/10.1016/j.jenvman.2020.11138.

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