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Ending overfishing can mitigate impacts of climate change

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Abstract

Marine fish stocks and the ecosystems they inhabit are in decline in many parts of our ocean, including in some European waters, because of overfishing and the ecosystem effect of fishing in general. At the same time, climate change is disrupting the physics, chemistry and ecology of the ocean, with significant consequences on the life it holds. While the positive effects of mitigating climate change on the ocean and marine life are currently being documented, papers that examine how ending overfishing could increase ocean resilience to climate change are less common. The goal of this paper is to review the current literature and conduct an analysis that demonstrate that ending overfishing and reducing other negative ecosystem effects of fishing would make fish stocks and marine ecosystems more resilient to climate change. Our findings suggest that fish are no different from people in that a healthy person is more likely to survive an epidemic than a person who is less healthy.

Introduction

We know the critical importance of the ocean for planetary function and life on Earth—mediating global weather patterns, cycling of carbon (i.e. biological carbon pump) and carbon sequestration (i.e. carbon sink), contributing almost half of the annual primary production on Earth, to name a few (Brierley & Kingsford, 2009). Marine ecosystem goods and services to human society are dependent on ocean health, yet there are many potential consequences of continuous human population growth and rising per capita consumption, in particular human-accelerated climate change and overfishing to meet global demands.

Fish is an important part of marine ecosystems and are a central part of the marine food web where predator-prey relations both within different fish species and between fish and other marine life keep the ocean thriving. An ocean full of life is also important as a source of food and livelihood for hundreds of millions of people worldwide. Unfortunately, fish and life in the ocean in general are facing a multitude of threats, two of the biggest being overfishing and climate change.

We adopt a dynamic and broad concept of overfishing as captured by the concept of fishing down marine food web of Pauly et al. (1998). This concept does not only capture the fact that we are taking too many fish than nature can sustainably yield annually, we are also taking too many high tropic level and valuable fish species thereby truncating the food web. While both of these are happening, we are also disturbing and, in some case, destroying ocean habitats through the use of harmful fishing gears (Chuenpagdee 2003). All of these three forms of overfishing combine to weaken the health of both fish stocks and the marine ecosystem as a whole. According to the FAO, overfishing and habitat destruction have resulted in the overfishing of about a third of fish stocks worldwide. Academic research has reported even higher levels of overfished stocks (e.g. Pauly and Zeller, 2015). For fisheries in the European Union (EU), estimates suggest that "at least 40% of fish stocks in the North East Atlantic and 87% in the Mediterranean and Black Seas, are currently subject to unsustainable fishing practices, … (STECF, 2019)" It should be noted that these numbers are averages and that some Atlantic EU stocks have seen improvements during the past decade. At the same time the situation in other European waters are worse than the averages.

The onset of rapid climate-related changes in these ecosystems are increasing pressure on fish stocks, with the potential of extinction for some fish species. Evidence of large-scale shifts in species' distributions to deeper and higher latitudinal waters has already been documented extensively in the past two decades (e.g. Parmesan & Yohe, 2003; Perry *et al.*, 2005; Dulvy *et al.*, 2008), and these effects have continued to manifest at the species (Montero-Serra *et al.*, 2015), ecosystem (Frainer *et al.*, 2017), and fisheries levels (Cheung *et al.*, 2013). Swift action is critical at this stage to ensure the long-term sustainability of marine ecosystems and fisheries (Gattuso *et al.*, 2018) and the varied and crucial benefits they provide (Rogers et al., 2014).

Here, we ask and address the question: How would the reduction of overfishing as broadly defined herein increase the ability of fish stocks to withstand the impacts of climate change, making the ocean more resilient to such changes. We conduct a selected literature review and carry out an analysis that reveals the links between reducing overfishing, improvements in fish stock and marine ecosystem health and increased resilience of marine ecosystems to the effects of climate change.

How eliminating overfishing can increase fish stock resilience under climate change

Climate-related impacts on marine environments are already impacting species, populations, and ecosystems (Pörtner *et al.*, 2014). Responses to environmental change for marine organisms is largely determined by physiological tolerance, and they respond with changes to physiological function and behaviour shaped by their evolutionary history (Doney *et al.*, 2012; Somero, 2012). For example, changes in temperature—e.g. ocean warming—that go beyond an organism's optimal range will initiate physiological responses that may affect biological performance including growth, reproduction, and survival. Climate-related impacts may also lead to shifts in phenology (timing of seasonal biological events). For example, in European waters we have observed shifts in the timing of zooplankton biomass formation in the North Sea (Schlüter *et al.*, 2010), juvenile Atlantic salmon migration (Kennedy & Crozier, 2010; Otero *et al.*, 2014), and general widespread ecosystem shifts across all major taxonomic groups in the UK (Thackeray *et al.*, 2010). These direct effects may translate into higher levels of biological organization, affecting population dynamics, and ecosystem structure, function, and diversity (e.g. tropicalisation of temperate reefs (Vergés *et al.*, 2019), localized species invasions and extinctions (Philippart *et al.*, 2011).

Reduction in fish catch and increasing fish biomass

Overfishing takes too much fish out of a renewable capital just like withdrawing more money out of a bank account than the savings can generate annually. And just like a bank account, taking more than the annual yield that a fish stock can generate makes the system more vulnerable; the fish stock and the marine ecosystem will be more vulnerable to change even without a stressor such as climate change. To overfish is a result of catching targeted species beyond sustainable levels, as well as incidental by-catch of non-targeted species. Overfishing has been widely accepted as a direct pressure and major risk to marine environments and ocean health, drastically reducing fish biomass in the ocean (Pauly *et al.*, 2002; Halpern *et al.*, 2015).

Human society has had considerable and far-reaching impacts on the global ocean (Halpern *et al.*, 2015), and overfishing has had lasting effects on marine ecosystems and continues to be one of the greatest threats to ocean health (Pauly *et al.*, 2002; 2005; Jackson *et al.*, 2007; Le Quesne & Jennings, 2012; Halpern *et al.*, 2015; Gattuso *et al.*, 2018). Overfishing often has major ecosystem effects (Coll *et al.*, 2008; Sumaila *et al.* 2000) and has even been linked as a driver of ecosystem regime shifts (Daskalov *et al.*, 2007). As a stressor, overfishing will have negative effects on many indicators of ocean health, including biodiversity, food security, and coastal livelihoods and economies (Halpern *et al.*, 2012). The direct impacts of overfishing can reduce fish biomass, affecting biodiversity and the sustainability of fisheries, as well as exacerbate the impacts of destructive fishing gear on marine ecosystems (e.g. bottom trawls). Where overfishing is a result of illegal, unreported, or unregulated fishing, these fishing operations are often conducted with destructive fishing gears—e.g. bottom trawls, dynamite (Bailey and Sumaila 2015)—that negatively affect benthic substrate.

In European waters, recent reports estimate that between 40% to70% of fish stocks are currently at an unsustainable level—either overfished or at their lower biomass limits (Froese *et al.*, 2018; STECF, 2019). In the Mediterranean Sea, it is estimated that over 90% of stocks are overexploited (Colloca *et al.*, 2017). Similarly, the Black Sea also sees high levels of exploitation, with continuing declines in catch (Tsikliras *et al.*, 2015). In contrast, some northern European are faring better—i.e. Norwegian Sea and Barents Sea—due to historically well-managed fisheries and the majority of stocks in these waters with a biomass that can produce MSY and not currently subject to overfishing (Gullestad *et al.*, 2014; Froese *et al.*, 2018). The January 1, 2020 deadline for the proposed plan to end overfishing in the EU is approaching. While there are some trends heading in the right direction, they are far from eliminating overfishing. In fact, on August 30, 2019, the EU proposed to continue overfishing past the deadline for January 1 2020, https://twitter.com/SeasAtRisk/status/1167458264566706176.

Reduction in the truncation of the marine food web

Overfishing has already done considerable damage to ecosystems and has resulted in trophic cascades (i.e. restructuring of the food chain). It takes too many large individuals from higher trophic levels and high value fish out of the marine ecosystem, going from the highest trophic level and most valuable species at the time they are fishing resulting in serial depletion and fishing down marine food webs (Pauly et al. 1998). These all serve to weaken fish stocks and make them vulnerable to all sorts of stressors including climate change. Climate-related impacts on marine ecosystems affect natural and human elements of ocean health. Changes in species' distribution and abundance will increase local invasions and extinctions, redistributing marine biodiversity and its composition (Cheung *et al.*, 2009; Pecl *et al.*, 2017; Sunday *et al.*, 2017). Subsequently, this will affect marine ecosystem goods and services, including food security and dependent coastal communities (Halpern *et al.*, 2012; Lam *et al.*, 2014; Sumaila *et al.*, 2019). Furthermore, the increased variability of environmental change will also increase the variability—and decrease the predictability and reliability—of goods and services to human society (IPCC, 2014).

Hence, the combination of overfishing and climate change is deadly for fish stocks and marine ecosystems, and just like climate change mitigation will help the long term sustainability of the marine ecosystem, ending overfishing would most likely enable more effective conservation and sustainable use of marine fish and ecosystems.

Reduction in ocean habitat disturbance and destruction

Indirect pressures of overfishing include habitat degradation (from destructive fishing gear) and pollution (i.e. plastic, oil). Overfishing has already resulted in habitat loss (Daskalov et al., 2007; Halpern et al., 2015). Maintaining the integrity of ocean habitat biodiversity is important for planetary function—e.g. carbon storage, coastal protection/erosion. Improving aspects of ocean health such as the condition of marine habitats (corals, seamounts, mangroves and seagrass) can benefit other components of the ecosystem including fish stocks and increase resilience to other pressures—in particular, climate change (Gaines *et al.*, 2018). While pressures and stressors will decrease fish stock abundance and marine ecosystem health, resilience counteracts these negative effects (Halpern *et al.*, 2012).

Marine biodiversity and habitat integrity contributes biomass to fisheries and non-food products such as aquarium fish (e.g. ornametnal: Livengood & Chapman, 2007), which has implications for global food security and coastal livelihoods and economies. Habitat loss has implications for marine life, but will also affect other aspects of ocean health such as coastal protection and carbon storage. Hence, the reduction of habitat degradation due to the elimination of overfishing would increase the health of marine ecosystems and the fish stocks they sustain.

Ending overfishing to increase ocean health and resilience to climate change

Climate change and overfishing are working together to accelerate the decline of ocean health, putting marine ecosystems and the goods and services provided to society at risk. Ending overfishing would reduce the cumulative pressures on the ocean and increase its resilience, potentially mitigating the effects of climate change. Current literature suggests that many possible mechanisms and solutions to adjust the current structure and narrative of fisheries to reduce the pressures on marine ecosystems as a mitigation tool against climate change (Cheung *et al.*, 2017, 2018; Gaines *et al.*, 2018; Gattuso *et al.*, 2018). Two broad solutions generally emerge to address overfishing: improving fisheries management and designating marine reserves.

Cheung et al. (2018) explored the extinction risk of overfishing and climate change using IUCN categories and spp distribution models. The authors found very high extinction risk for 60% of assessed species with business as usual (i.e., under RCP 8.5 scenario) and no fisheries management change. With improved fisheries management and climate change mitigation (RCP 2.6) the number of species with very high extinction risk is reduced by 63%. The authors further found that significantly improved fisheries management will lower extinction risk at all levels of climate change risk, but the most effective results need to occur with climate change mitigation (i.e. lower climate change risk, RCP 2.6 and RCP 4.5). Gaines et al. (2018) set out to understand whether reducing overfishing through fisheries management reform will increase fisheries catch, even under high climate change. They found that despite the negative effects of climate change on fish stocks, reducing fishing effort to ensure MSY will result in gains in catch based on the current state of overfished stocks.

Improving management would address current issues in many fisheries in the EU and around the world, including: negative capacity-enhancing subsidies (Sumaila *et al.*, 2010) and their distribution between small and large scale fisheries (Schuhbauer *et al.*, 2017); high quotas and catch rates (e.g. Froese *et al.*, 2018; STECF, 2019); and illegal, unreported, and unregulated, fishing (Sumaila *et al.*, 2006). For example, in EU fisheries many stocks (e.g., North Sea cod, Baltic Sea cod) are still currently overfished or at biomass levels below those which would produce maximum sustainable yield (Froese *et al.*, 2018). However, these stocks could be rebuilt if catch rates were reduced by 20-50% (Froese *et al.*, 2018), increasing future catch, revenues and jobs (Sumaila *et al.*, 2012, 2019). Furthermore, other strategies such as dynamic fishing rules based on measured changes in biomass could improve ocean health and subsequently increase resilience to climate change and scientific uncertainty (Kritzer *et al.*, 2019).

Designating marine reserves is a viable and effective strategy for tackling overfishing, and also providing many ancillary benefits to ocean health. Marine reserves that prevent fishing activities can protect important habitat refuges for fish populations and reducing the probability of overfishing (e.g. Afonso *et al.*, 2011). Furthermore, it protects habitats from destructive fishing gear (McLeod *et al.*, 2009; Green *et al.*, 2014), improving overall biodiversity and fisheries-related indicators of ocean health. Subsequently, marine reserves will improve other aspects of ocean health that directly address climate change mitigation (Roberts *et al.*, 2017), specifically: carbon sequestration and storage by protecting critical habitat (e.g. reefs, seagrass beds, kelp); and reducing coastal erosion due to sea level rise by preserving safeguarding habitats.

Concluding remarks

Reducing exploitation rates to end overfishing has been widely discussed as a viable climate change mitigation strategy (e.g. Cheung *et al.*, 2018; Gaines *et al.*, 2018; Gattuso *et al.*, 2018; Kritzer *et al.*, 2019). The MSY of fisheries is projected to generally decrease with climate change (Cheung *et al.*, 2016; Gaines *et al.*, 2018), yet some areas will face increases (i.e. temperate and polar regions) while others will see major declines (i.e. tropical regions) (Cheung *et al.*, 2010). Despite the historical global spatial expansion of fisheries and its extensive footprint on marine ecosystems (Halpern *et al.*, 2008; Swartz *et al.*, 2010), current fisheries catch are estimated to be underperforming due to inefficiencies with management, regulation, and compliance (Sumaila *et al.*, 2012; Froese *et al.*, 2018). Due to the current inefficiencies and operating at below MSY, improvements in management to achieve MSY would not only increase long-term catch, but actually offset some of the negative effects of climate change on catch (Gaines *et al.*, 2018). For overfished EU fish stocks, this could prove extremely valuable to increase catch by improving management as a climate change adaptation strategy.

Implementing strategies to increase resilience has been found to help with recovery from extreme climate impacts (O'Leary *et al.*, 2017; Roberts *et al.*, 2017). Therefore, overfishing and climate change are not mutually exclusive problems to be addressed separately, and it is imperative that we move forward with holistic comprehensive solutions to address these two challenges.

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