

The Future of Wild-Caught Fisheries: Expanding the Scope of Management

Kailin Kroetz^{*}, Linda Nøstbakken[†], and Martin Quaas[‡]

Introduction

Wild-caught fisheries,¹ also called capture fisheries, make significant contributions to human well-being, including by contributing to food security and alleviating poverty. However, poor management and external stressors can undermine the environmental, economic, and social sustainability of these fisheries.

In this article, which is part of a symposium on The Future of Seafood,² we examine potential gains from expanding the scope of management policies that impact wild-caught fisheries, focusing on market failures that go beyond those generally considered by economists in the fisheries management context. In particular, we view wild-caught fisheries from a perspective that is broader than the traditional single-species fisheries management paradigm. This is consistent with the recent change in the scope of fisheries management policy and economic research in developed countries, which has shifted from a single-fishery, single-species focus to a broader and more comprehensive approach called ecosystem-based fisheries management (EBFM); EBFM includes interactions between fished species and the surrounding ecosystem as well as interactions between the biophysical and human subsystems and complexities within the human system (Hilborn 2011; Marshall et al. 2018). We pay particular attention to fishers

^{*}School of Sustainability, Arizona State University; and Resources for the Future (email: kkroetz@asu.edu);

[†]Research Department, Statistics Norway; and SNF—Centre for Applied Research at NHH (email: linda.nostbakken@ssb.no); [‡]German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig; and Department of Economics, Leipzig University (email: martin.quaas@idiv.de)

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¹There is no single definition of a fishery. Throughout this article we use the term “fishery” generally to indicate a management unit, regardless of specific management unit attributes such as species, fishing gear, or geographic location.

²The other articles are by Abbott et al. (2022), who discuss the future of recreational fisheries; Asche et al. (2022), who focus on aquaculture; and Cojocaru et al. (2022), who provide a synthesis of the other three articles in the symposium and discuss key issues concerning the global seafood system.

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as an integral part of coastal communities, which in turn are linked to the broader economy and society.

With this broader socioenvironmental context in mind, we first provide some background on well-established market failures and management solutions in fisheries. Then we examine the various and interacting market failures that are endogenous and exogenous to the capture fisheries sector. Next, we discuss crosscutting market failures. This is followed by a discussion of the trade-off between efficiency and equity. Throughout these discussions, we highlight the trade-off between fully addressing all market failures through policy (which would be excessively costly) and adopting a narrower scope (which may fail to address costly market failures). In the final section, we recommend priorities for future policies and research aimed at supporting the sustainability of wild-caught fisheries.

Background

Over the past half century, economists have helped shift the policy debate concerning wild-caught fisheries management from focusing on ecological sustainability through limits on catch to maximizing the economic benefits from fisheries (Wilens 2000). In this section, we discuss catch shares as an approach to correcting market failures in fisheries and present a brief overview of the heterogeneity in fisheries regulation worldwide.

Catch Shares to Correct Fisheries Market Failures

It has been well established in the economics literature that market failures can lead to policy failures and reduce the economic efficiency of a fishery (e.g., Clark 1990). When there is no restriction on who can fish and fish are relatively easy to access, the well-known tragedy of the commons emerges, with too many boats racing to catch too few fish (Gordon 1954). Two common market failures in fisheries have been carefully studied: stock externalities and congestion externalities (Smith 1969). Stock externalities arise as a result of the actions of one fisher affecting the fish stock, which in turn affects the economic well-being of other fishers targeting the same stock because of the decreased availability of fish and the increased cost of fishing. A congestion externality arises when fishing costs increase because of crowding of the fishing grounds.

Lack of regulation can cause an erosion of the economic value of unregulated fisheries; this has led to the emergence of market-based policies such as catch shares, which can improve economic efficiency (Sanchirico and Wilens 2007). Catch share programs have been informed by economics research and include designs that allocate shares of the available catch to fishers, fishing communities, or other entities. The security of the allocated shares helps alleviate the race to fish. Individual transferable quota (ITQ) programs (a common type of catch share) set a cap on total catch, assign fishers a portion of the catch, and allow them to trade their allocations. This approach can substantially increase economic efficiency because trading allows quotas to flow to those that value them the most, thus resulting in an efficient allocation.

There are currently more than 200 catch share programs worldwide (figure 1), with many covering a single stock. Early on, only a few programs, such as those in New Zealand and Iceland, involved relatively comprehensive coverage across commercially caught species (e.g., Wilens 2000). Indeed, historically, fisheries management plans have focused on the management

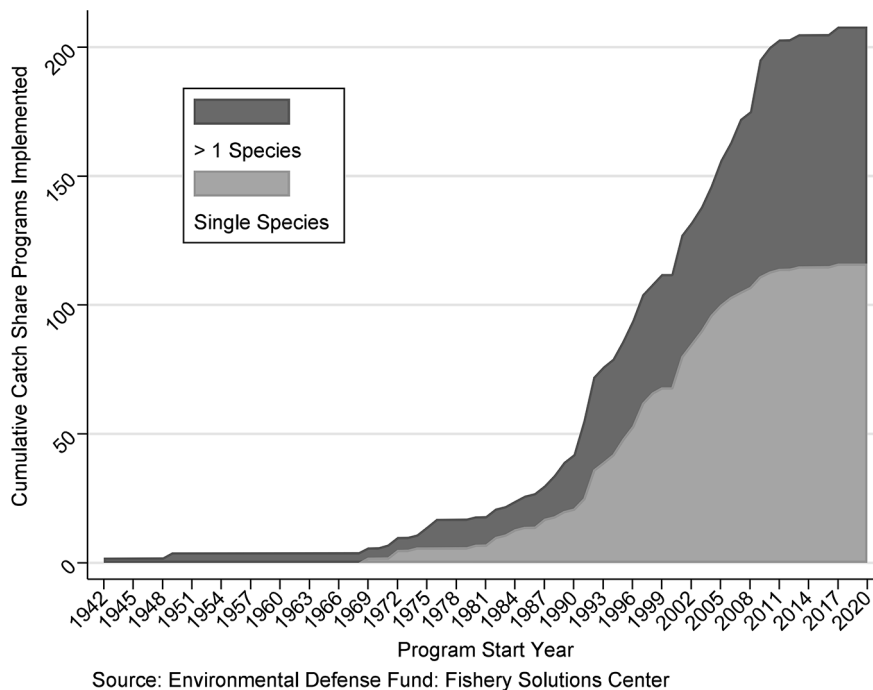


Figure 1 Cumulative count of catch share programs. The figure is based on data from the Environmental Defense Fund's Fishery Solutions Center database, accessed in February of 2021 (<http://fisherysolutionscenter.edf.org/database>). We did not include programs for which the start year was missing from the database or no estimated start year was available from supplementary sources. A color version of this figure is available online.

of a single fishery (e.g., Collie et al. 2016). Although multispecies catch share programs have become more common over time, about half of the documented catch share programs cover only a single species (figure 1).

Evaluation of catch share impacts has been somewhat limited, with past economics research on wild-caught fisheries management policies generally focusing on the impacts on fisheries within the catch share program. In particular, early research focused on biological outcomes in catch share fisheries (Costello, Gaines, and Lynham 2008). More recently, research has expanded to include economic and other social outcomes (e.g., Asche et al. 2018; Hoshino et al. 2020). For example, catch shares can increase fisheries profitability through mechanisms such as lengthening fishing seasons to allow fishers to catch fish when prices are high (Birkenbach, Kaczan, and Smith 2017) and enabling switching to more valuable fish products (e.g., Homans and Wilen 2005)—for example, by catching larger (and often more valuable) fish (Stoeven, Diekert and Quaas 2021). Additionally, catch shares that provide security concerning catch allocations can improve fisher safety (Pfeiffer and Gratz 2016) by providing fishers the opportunity to choose safe times to fish their allocations over a long season. There is also evidence that catch share management may be more expensive than alternatives such as closing the fishery when a catch limit is reached. However, Mangin et al. (2018) find that catch shares appear to increase net fisheries profitability even when these increased management costs are considered.

Although market-based programs such as catch shares have transformed fisheries management, they face considerable opposition, including from those not directly involved in the catch

share fishery, such as coastal communities. In fact, in the past decade, there has been a slow-down in the implementation of new catch share programs (figure 1). Moreover, recent work finds that there are still barriers to maximizing societal benefits from wild-caught fisheries (e.g., Marshall et al. 2018), suggesting an important role for economists in future fisheries management design.

Heterogeneity in Fisheries Regulation and Enforcement

To date, most catch share programs have been implemented and evaluated in developed countries (Jardine and Sanchirico 2012), where institutions are strong enough to support the required catch accounting, monitoring, and enforcement. Illegal and unreported fishing is a major challenge in global fisheries, particularly in countries with weak or no regulations and relatively weak institutions for monitoring and enforcement and on the high seas (Agnew et al. 2009). For example, Agnew et al. (2009) estimate that illegal and unreported catches accounted for 18 percent of reported catches in 2003.³ Moreover, they report big differences in the share of illegal and unreported catches across both fisheries and regions, with the Eastern Central Atlantic having the highest share (37 percent). While this is consistent with the results of other studies (e.g., Pauly and Zeller 2016), more research is needed to improve information about illegal fishing.

The heterogeneity in regulation and enforcement across countries, regions, and fisheries leads to different types of market failures and management challenges worldwide. While developed countries are moving toward more sustainable fisheries management, many developing countries are moving in the opposite direction, as they continue to struggle with overcapacity in terms of the number of vessels relative to the stock size, overexploitation of stocks, and declining stocks (Ye and Gutierrez 2017). These two trends can be linked. For example, in the short run, stricter regulations and enforcement of fish harvesting in some regions can reduce supply from those regions, but this can increase fish prices and create incentives to increase harvesting in other parts of the world where regulations are weaker.

Market Failures Endogenous to the Wild-Caught Fisheries Sector

In this section, we examine market failures that are endogenous to the wild-caught fisheries sector and potential management systems that have been used to address them. These market failures arise from multispecies catch, cases where multiple fisheries are regulated separately but target the same stock, and the potential for ecological or socioeconomic interconnections within an ecosystem (figure 2).

Multispecies Catch

It is common for catch to be composed of multiple species. However, this can result in externalities including impacts on nontarget species (bycatch) and unregulated species. Bycatch, which occurs when species other than the targeted species are incidentally caught,⁴ can negatively

³However, this is a slight drop from their estimates for the 1980s and 1990s.

⁴This may include both iconic species (such as dolphins) and less iconic species.

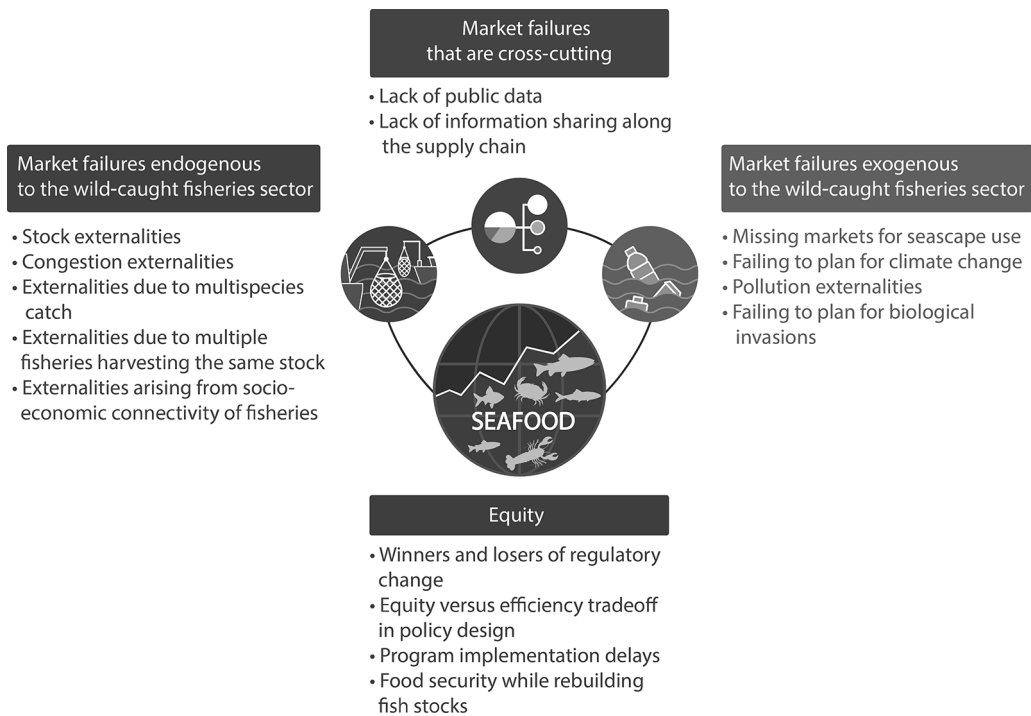


Figure 2 Conceptual framework for considering key market failures involving wild-caught fisheries. Market failures endogenous to the capture fisheries sector, market failures exogenous to the capture fisheries sector, and crosscutting market failures are interlinked. Equity issues underpin these various components. A color version of this figure is available online.

impact the ecological health of the incidentally caught species population. This is a common and well-studied fisheries problem (see, e.g., Smith 2012 for a review).

In addition to the issue of bycatch, **fishers often jointly target groups of species, particularly in multispecies groundfish complexes. However, this can lead to market failures through inefficient catch of some or all species. In some cases, the species group may be managed jointly (e.g., the Norwegian cod, haddock, and saithe trawl fisheries), but in other cases, only one or a subset of species is managed, which has implications for the type of market failure that arises.** Birkenbach et al. (2020) explore the case of the joint management of a species group and find that even in a multispecies fishery that is regulated through individual vessel catch limits for all species, the regulations as well as the market and biological conditions of one species can influence outcomes for other species. **Quaas and Requate (2013) find that when one or a subset of total fished species is managed, there can be increased incentives to fish other species (e.g., through interactions in fish markets).** In Norway's pelagic purse seine fisheries, reducing quotas for a subset of species targeted by a fleet was found to increase pressure on other species targeted by the fleet (Asche, Gordon, and Jensen 2007). Similarly, in the case of rockfish species in the US West Coast groundfish trawl fishery, Holland (2010) finds that a small catch limit on one species (relative to limits for other species) results in rare and uncertain catch of that species, which potentially constrains catches of other species with larger catch limits.

Harvesting of nontarget species, either unintentionally as bycatch or intentionally, results in a similar choice between two potential solutions: broadening the scope of management by

bringing the nontarget species under the same management program as the target species and then determining the efficient catch for all species simultaneously or adopting a solution that may be less costly to implement but may not fully resolve the externality (Smith 2012).

Future technological advances may enable fishers to be more selective in what they catch and may reduce the externality (or externalities) associated with a narrower management scope. For example, O'Neill et al. (2019) examine how the fishing industry can improve selectivity (i.e., reduce impacts on nontarget and unregulated species) by using the latest available technologies to better understand the interaction of fish and fishing gears. However, as we will discuss in the final section, more research is needed to identify potential gains from a broader management scope and to design policies that take advantage of such gains.

Separate Regulation of Multiple Fisheries That Target the Same Stock

It is relatively common for fishers in multiple separately managed fisheries to target the same stock. However, this can lead to market failures when the allocation of catch between fisheries is not efficient. More specifically, this type of market failure can arise when fishers are divided into fisheries based on type of activity (e.g., recreational or commercial fishing), fishing gear used, or the age or size classes of the fish species targeted. In more well-managed fishing regions, a total allowable catch (TAC) for a species is generally set and then allocated among the fisheries to ensure that the total catch is sustainable. In this case, an allocation to one fishery directly reduces what is available to the other(s). Moreover, one fishery can affect another through habitat impacts.⁵ This means that an economically efficient allocation among fisheries requires efficient allocation both across fisheries and within each fishery.

One way to improve the efficiency of cross-fishery allocations of catch is to implement a catch share program that allows trade between participants across fisheries or that allows gear switching (e.g., from trawl to hook and line) so that quota flows to users that place the highest value on access to the catch. However, this approach could be costly in the short run because of factors that go beyond direct management costs (e.g., capital adjustment costs associated with purchasing new fishing gear) and could be difficult to implement from a political economy perspective. Indeed, recreational and commercial allocations of the TAC have historically been contentious in many fisheries (Abbott et al. 2022), as have allocations between types of fleets (e.g., trawl vs. longline). In addition, an efficient management approach would need to account for different impacts on the habitat and the ages of the fish targeted, both of which are generally difficult to assess and incorporate into management programs.

Potential for Ecological and Socioeconomic Interconnections within an Ecosystem

Within an ecosystem, fished species and the fishers and communities that rely on them are connected in multiple ways. One way an externality can arise in such connected systems is if the interactions between species in the food web are not considered during the quota setting process, which causes decisions in one management unit to impose externalities on others.⁶

⁵For example, trawl gear dragged across the seafloor can damage the habitat on which species depend, thus impacting both the fish stock and other fishers.

⁶Ecologists have collected data and developed models to demonstrate these interactions (e.g., Collie et al. 2016).

Accounting for these interactions can lead to changes in catch limits that both support the ecological sustainability of the overall system and maximize system-wide economic yield (e.g., Sanchirico, Smith, and Lipton 2008).

Recently, there have been calls from researchers and policy makers to use an ecosystem-scale approach to examine fisher decisions, including where, when, and what species they will fish, as well as the broader socioeconomic outcomes of fisheries management. Such holistic EBFM approaches are intended to account for the connections within and between the human and natural systems (Marshall et al. 2018). This broader scope explicitly recognizes that fishers may consider many fisheries when deciding where, when, and how much to fish. In the remainder of the discussion, we describe three key issues to consider when broadening the scope of management from a single-fishery to an ecosystem-scale approach: cross-fishery participation spillovers, diversification of fishing portfolios, and costs of ecosystem-scale management.

Cross-fishery participation spillovers

One market failure that a broader management scope may be able to address is the efficiency of fishers' adjustments to their allocation of effort across fisheries in response to management or other changes in a single fishery. Economists have studied the effect of catch shares on fisher decisions about fishery participation, and the results suggest that the impacts are often not confined to the catch share fishery. In particular, Holland et al. (2017) find that catch shares may decrease diversification of fishing portfolios, which could be a sign of consolidation of the fleet, increased specialization, and efficiency. However, consolidation within the catch share fleet may have impacts beyond that fishery. For example, spillovers have been found to occur with fishers moving from a catch share fishery to another fishery (e.g., Cunningham, Bennear, and Smith 2016; Kroetz et al. 2019). In these cases, the catch share program may increase the economic efficiency of the target fishery but intensify harvesting pressure in other fisheries and thus reduce their economic efficiency. In addition, spillover of effort into fisheries with poorer stock regulation could result in negative consequences for stock sustainability.

Diversification of fishing portfolios

Another market failure can arise as a result of fishers' efforts to mitigate risk. One unique characteristic of fisheries as a natural resource is that there is no insurance available to fishers to protect them in bad years. This creates an incentive for risk-averse fishers (who are willing to trade off expected profit from fishing for a decrease in variability of profit) to diversify effort across fisheries to essentially self-insure. Empirical evidence supports the argument that fishing portfolio diversification can smooth income (e.g., Kasperski and Holland 2013). However, this individual behavior can be viewed as a market failure because it can reduce aggregate system profit. Similarly, fishing communities or regions may aim to diversify catch portfolios to smooth income, an outcome that is supported by empirical evidence at the community level (e.g., Cline, Schindler, and Hilborn 2017).

Costs of ecosystem-scale management

Despite the potential for an EBFM approach to address market failures related to effort spillovers and portfolio diversification, there are few examples of such an ecosystem-scale perspective influencing fisheries management in practice (DePiper et al. 2021). This raises questions about

the feasibility and cost of EBFM and whether the potential benefits (in terms of market failure reductions) exceed the costs.

In general, the potential benefits of resolving market failures need to be weighed against both the potential management costs of an EBFM approach and equity concerns.⁷ Although this broader approach increases the extent to which market failures can be addressed in policy design, the gains in efficiency (from internalizing externalities and accounting for other market failures across species and within ecosystems) may be lower than the costs of collecting data, designing models, and implementing management programs for such a large and complex system (e.g., Hilborn 2011). Thus, additional research is needed to develop an accounting of costs and benefits that includes future management costs under various management scopes. Management costs include the data and modeling efforts needed to understand both the complexities of system linkages and the responses of the system to shocks. There are also challenges to designing and administering such large management systems. However, as discussed below, cheaper data storage and computing power, with further advances expected in the future, are likely to mitigate some of these costs.

Market Failures Exogenous to the Wild-Caught Fisheries Sector

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services' global assessment report on biodiversity and ecosystem services, the most important drivers of biodiversity decline in marine ecosystems are (in order of importance) direct exploitation, changes in seascape use, climate change, pollution, and invasive alien species (IPBES 2019). This suggests that although endogenous market failures are important, because they determine patterns of direct exploitation (discussed above), exogenous market failures also play a key role in wild-caught fisheries outcomes. Thus, it is important to understand these exogenous stressors and their interactions with wild-caught fisheries. In this section, we examine the market failures associated with the latter four exogenous stressors, focusing on their impacts on the wild-caught fisheries sector and their implications for management of the sector (figure 2).

Changes in Seascape Use

Seascape uses other than wild-caught fisheries, including shipping, energy production, mariculture (i.e., fish-farming in marine waters), and conservation, are expanding. Most commodities and goods are currently shipped over the oceans, with the volume of goods shipped globally increasing (UNCTAD 2021). Offshore wind energy is also growing rapidly and is projected to continue to expand in the future (IEA 2020). Furthermore, mariculture is emerging as a competing use of seascapes (Asche et al. 2022), and the share of seascape area covered by marine protected areas (MPAs) has increased and is expected to expand further (UN 2015).

Given the finite nature of the seascape, these trends suggest that there are trade-offs between competing uses. Because there are no markets for seascape use that mirror land markets, there is a potential for market failures; that is, actual seascape uses might not reflect the most economically efficient pattern. Governing institutions such as state and country governments

⁷We discuss equity issues below.

can address these market failures through policies that support efficient allocation of the seascape to each use. While such policies may be effective when institutions have explicit control over the space, they are not as effective in cases where the marine space is effectively a commons (such as when the seascape falls outside country territory) or where territorial governance is weak. Moreover, marine spatial planning entails costs and often faces political challenges (Ehler 2021). Given the economic significance and projected growth in alternative seascape uses and the finite nature of the seascape, it appears likely that the optimal allocation of space for wild-caught fisheries will be a reduction from current levels.

In terms of determining optimal seascape use, MPAs are particularly relevant for fisheries because they can increase fish population growth over the entire area (i.e., both within and beyond the MPA) and increase profitability through spillovers of fish from reserves to fished areas. MPAs have been extensively studied in the fisheries literature and have been found to be effective in restoring fish populations, especially if they are well enforced, long lasting, and large (Edgar et al. 2014). However, if the fishery is unregulated, the extent to which protecting an area can improve economic returns will depend on fish movement ecology (e.g., Sanchirico and Wilen 2001) and fisher behavior (Smith and Wilen 2003).

Climate Change

Climate change is an exogenous form of disturbance to marine ecosystems that has substantial and complex effects on wild-caught fisheries, which can lead to market failure. Our discussion of climate change focuses on its documented effects on fish and fisheries, how market failures can arise if management does not account for climate change, and the challenges of implementing fisheries management that does account for climate change.

Climate change can affect fish in many ways, including through its impacts on habitat and fish characteristics (such as maturation or growth), which in turn affect fisheries. While there are large uncertainties about how these effects will play out at the individual species level, it has been shown that fish species often have an optimal temperature at which they thrive and reproduce best (Hänsel et al. 2020). The fisheries science literature has also identified climate change effects on fisheries at the global level. Fish stocks move geographically and vertically in the ocean as climate change alters the conditions in marine ecosystems, with fished species shifting predominantly to higher latitudes and greater depths (Pinsky et al. 2020). This characteristic has implications for the consumer benefits derived from fisheries. In fact, Moore et al. (2021) estimate that the losses in present value consumer surplus due to climate change for 16 of the most important US fisheries are US\$2–US\$4 billion. Although the impacts of climate change on the productivity of marine living resources are dominated by the negative effects, climate change will lead to some regions of the world becoming better suited for valuable fish species (Free et al. 2019).

A failure to consider climate change in fisheries management can lead to several types of market failures. First, fisher behavior may deviate from what would be optimal if climate change had been considered in fisheries management program design. Market failures can also arise if there is inconsistency between the scope of management authority and the scope of the stock distribution. More specifically, fishing effort and harvest regulation will be inefficient if the stock is not fully within the manager's jurisdiction and if efforts to support sustainable stock use within the jurisdiction are undermined by fishing activity outside the jurisdiction.

The redistribution of fishing resources can be a problem at the local scale because stock shifts can impact groups of local fishers who may not be able to travel to follow the stock as it shifts northward or farther offshore; stock shifts can also have regional impacts through changes in the variability, timing, and/or availability of fish. Finally, climate change may pose a particular challenge to food security in countries in the tropics (Oremus et al. 2020), which suggests that it will also create challenges for equity in the fisheries sector.

Although there are benefits to designing management strategies that account for climate-induced market failures, such programs are difficult to implement; thus, overall efficiency requires that the benefits of new policy designs be weighed against the costs. Challenges to accounting for shifting stocks due to climate change include uncertainty over future stock sizes and distributions as well as political economy issues related to which fishers have access to the stock, those who fished the stock prior to the shift or those closest to the stock's current location (Hannesson 2007). Management strategy evaluation is one approach that can incorporate the limited data and uncertainty related to stock size and location; however, operationalizing it within EBFM contexts remains a challenge (e.g., DePiper et al. 2021).

Pollution

Many coastal marine environments suffer from pollution, including from agricultural runoff and marine plastics (Diaz and Rosenberg 2008; Abbott and Sumaila 2020), which can negatively impact fisheries. In addition, some species of fish, mussels, and mollusks filter water, which improves water quality and generates positive impacts beyond the fishery. In the discussion that follows, we focus on the potential for pollution to generate a negative externality for fisheries and for fisheries to generate positive externalities for coastal water quality and the management challenges of accounting for these externalities.

Agriculture and other upstream water uses have been shown to have negative impacts on nutrient runoff into marine waters; this can reduce water quality, which in turn can negatively impact fisheries (Diaz and Rosenberg 2008). Impacts on water quality include eutrophication (high concentrations of plant-available nutrients), which can lead to expanded zones of low oxygen concentrations. Smith et al. (2017) find that this increases the price of large shrimp relative to small shrimp in the Gulf of Mexico, which reflects the adverse effects of low oxygen concentrations on shrimp growth. Marine plastic pollution and toxic substances such as heavy metals also have negative effects on marine waters because such pollution directly diminishes the quality of fish products and affects the productivity of the natural resource itself (Abbott and Sumaila 2020).

Fisheries have also been shown to lead to positive externalities related to water quality. This is especially true for mussels and marine mollusks that live on food that they directly filter out of the water. Such positive externalities cause the long-run optimal harvest to be larger than it would be otherwise and have been documented in the Baltic Sea (e.g., Nielsen et al. 2019) and Chesapeake Bay (DePiper, Lipton, and Lipcius 2017).

Efficient management requires balancing the higher management costs associated with expanding the management scope to cover both the fisheries and the water-polluting sectors against the benefits of accounting for the cross-sector positive and negative externalities. This type of management strategy is a challenge to design because it requires an understanding of the linkages between the polluting sources and the fishery (or fisheries) to estimate the value

of the polluting activity and the value of water quality. Moreover, political economy issues are likely to arise because in many areas, fish and water resources have historically been managed separately (Kroetz, Kuwayama, and Vexler 2020).

Invasive Species

Human activities increasingly introduce new species into ecosystems, whether intentionally or accidentally. Often, these alien species are considered invasive, especially if they cause damage to humans and ecosystems. Some invasive species in marine ecosystems, such as jellyfish in the Black Sea (e.g., Knowler and Barbier 2005), cause harm to humans. The main approach to managing a damaging invasive species (if the invasion can be controlled at all) is to try to prevent the spread early on because containment later is costly (Frésard and Ropars-Collet 2014). Jardine and Sanchirico (2018) find that if the marginal costs of invasion control are constant then full eradication, rather than just containment, may be the economically optimal policy. Policies can also be implemented to prevent species from entering and invading new ecosystems (Finnoff et al. 2010).

However, not all biological invasions are detrimental from a fisheries profitability and consumer perspective. For example, despite their possible adverse ecosystem consequences, the king crab in Russian and Norwegian waters in the North Atlantic is a profitable fishery (e.g., Skonhøft and Kourantidou 2021). An ecosystem approach to fisheries management would include the management of such invasive species.

Crosscutting Market Failures

We have examined endogenous and exogenous market failures in the context of wild-caught fisheries, but there are also market failures that cut across both the wild-caught fisheries sector and other sectors of the local and/or global economy. Such market failures include an underprovision of publicly available data and limited information and traceability within seafood supply chains (figure 2). We discuss each of these market failures in more detail below.

Underprovision of Public Data

Data are a public good, but they are often underprovided to stakeholders in the fisheries sector. Although in recent decades, there has been rapid growth in data on the oceans and human activity from new technology platforms such as satellites, autonomous vehicles, remote sensing, and mobile technologies, much of these data are controlled by governments, companies, and researchers and are not widely available. This underprovision of publicly accessible data can be viewed as a market failure that contributes to suboptimal resource use and management. Providing and making better use of existing data offer great potential for increasing the value creation from fisheries resources (Brett et al. 2020). This is particularly important in developing countries, where the potential for improved fisheries management is the highest, while digital competencies and access to new technologies are relatively low.

Maximizing the value of wild-caught fish requires supplying the right product with the right attributes to the right customer at the right time. This is a particularly challenging task in the case of wild-caught fisheries because they vary considerably over time and managing

supply requires coordinated effort along the supply chain, from the point of catch to consumption (Knútsson, Kristófersson, and Gestsson 2016). Data sharing among fishers, processors, and retailers can enhance this coordination. In particular, better data from the fishing grounds on the attributes of the wild-caught fish can enable processors and retailers to increase the value of the catch. In addition, better data on what customers want and when would enable fishers (particularly in well-regulated fisheries with longer seasons) to maximize value by catching the right fish at the right time.

Information Sharing and Traceability within Seafood Supply Chains

Market failures can arise because of a lack of information on the attributes of wild-caught seafood products along the supply chain; this has led to a recent focus on the traceability of fish (the ability to fully trace products, from point of sale back to point of origin). Attributes include whether the product is obtained through illegal, unregulated, and unreported fishing or mislabeled in terms of its characteristics, such as the specific species or region it is from (e.g., Kroetz et al. 2020). Market failures occur when retailers, consumers, or other seafood purchasers pay a higher price than what they would be willing to pay if they had full information regarding the product. Market failures may also occur when fishery regulators are not able to implement efficient regulations because they lack sufficient information about the production processes for the products they regulate.

Recently, wild-caught seafood supply chains have been characterized by increasing market orientation that focuses on the traceability of seafood products from the point of catch to consumption, which has helped to address some market failures. In particular, there has been progress in the provision of information about product origins to retailers and about the sustainability attributes of seafood products to consumers through third-party certification programs (see, e.g., Roheim et al. 2018). However, in their review of seafood markets, Roheim et al. (2018) also emphasize that further improvements in information sharing as part of seafood supply chain management are needed to reach sustainability goals. Better information management systems enable both seafood firms and control agencies to record and use information to improve decisions and performance, which can enhance traceability, ensure consistency in certification processes (such as those for health, catch, and point of origin), increase enforcement, and improve quota management in fisheries. Improved knowledge about seafood products can also benefit consumers by reducing health risks from consumption. In addition, by enabling more informed decisions about products, strong traceability systems can support socially responsible fisheries.

In the longer run, reliable end-to-end traceability will likely become a requirement for operating in many seafood markets because government regulation and commitments by the retail sector are already moving in this direction. However, the technologies needed to support traceability systems are only beginning to emerge. Indeed, Blaha and Katafono (2020) argue that there is currently a lack of standardization for the implementation of traceability systems both within and across countries. This suggests a need for closer cooperation across national agencies, such as health and fisheries control agencies, and for more international standardization. Blaha and Katafono (2020) present several recent examples of blockchain technology being used to track fish from capture to landing, processing, and distribution and all the way to the consumer. However, thus far, blockchain has primarily been used to track

high-value fish species such as tuna and Patagonian toothfish (Blaha and Katafono 2020); it has generally not been applied to more complex seafood value chains, suggesting a need for more research in this area. Ensuring a proper match between physical and digital assets will be even more challenging for lower-valued and smaller species like anchovy and herring because physically tagging each fish is prohibitively expensive with current technologies (Blaha and Katafono 2020). Although advanced traceability technology for seafood is still being developed, it clearly has the potential to significantly improve seafood sustainability.

Equity

Policies designed to correct market failures generally focus on achieving economic efficiency. However, in practice, societies are often concerned with issues of distributive justice and equity. Indeed, in the case of fisheries, policies often reflect goals that are broader than a narrow focus on maximizing sustainable catch or facilitating perfectly competitive quota markets (efficiency). These broader goals are often related to economic, social, and environmental sustainability (e.g., Hoshino et al. 2020). For example, both the Magnuson-Stevens Fishery Conservation and Management Act of 1976, which governs marine fisheries management in the United States, and the common fisheries policy of the European Union (Regulation [EU] 1380/2013) require consideration of social outcomes in addition to ecological and economic outcomes. Given these broader social concerns, in this section, we examine equity as a policy goal and its implications for the market failures we have discussed above. More specifically, we discuss the potential trade-off between equity and efficiency, the potential for fisheries policy to support equity objectives, the implications of equity concerns for program implementation, and the connections between equity and global production of wild-caught fish.

The Equity-Efficiency Trade-Off

One important issue for policy makers is whether social equity and economic efficiency should be considered jointly. Figure 3 presents a simplified example of the potential trade-off between equity and efficiency in fisheries management. In both panels, the solid lines represent the possibility frontier achievable without the option of redistributing returns from fishing after the policy has been implemented, and the arrows represent examples of policy change from the status quo. In both cases, when the status quo is located inside the solid line, there is the potential for an improvement in either equity or efficiency that has no impact on the other or an improvement in both outcomes.

The shape of the possibility frontier determines whether there is a trade-off between equity and efficiency once on the frontier. The left panel illustrates the extreme case, where maximum efficiency can be achieved simultaneously with maximum equity (left panel, solid line); that is, it is possible to achieve a large range of equity outcomes without reducing efficiency, with the policy that maximizes both equity and efficiency at the corner of the solid line. In the right panel, however, once on the frontier, achieving higher equity comes at the cost of lower efficiency. In this case, there is an equity-efficiency trade-off, and thus the optimal policy is an empirical question that depends on society's preferences. In this case, if society values equity but economists use economic efficiency as the main criterion for policy design, they will recommend a policy that is not socially optimal.

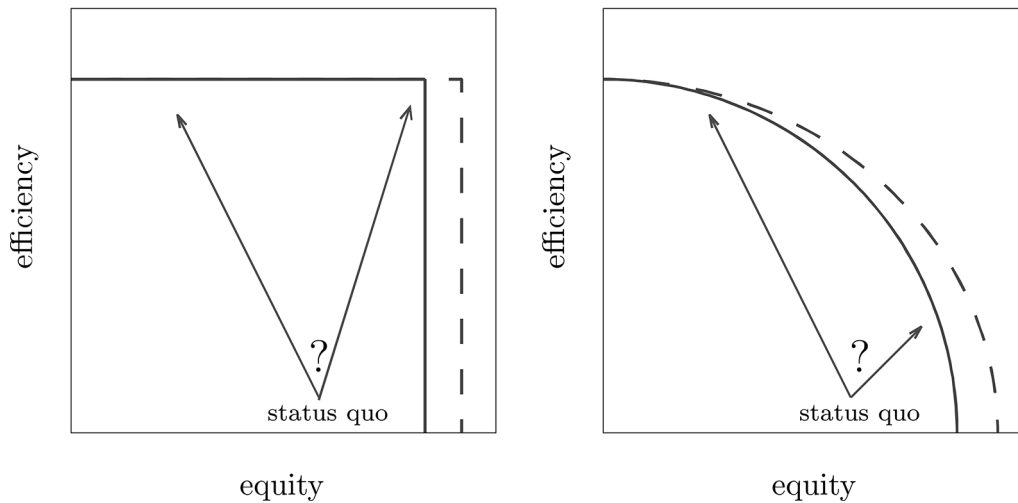


Figure 3 Equity versus efficiency trade-offs in fisheries management. In some circumstances, equity does not vary with the efficiency of policy options, which means that maximum efficiency can also be socially optimal (left panel, solid line). However, in other cases, there is a trade-off between the two objectives, and maximizing efficiency may not be socially optimal (right panel, solid line). It is also possible to address equity goals through redistribution (dotted lines), potentially allowing for improved equity for a given level of efficiency. Resource rent is an example measure of economic efficiency. The inverse of the Gini coefficient of resource rent distribution across fishing-dependent communities is an example of equity. A color version of this figure is available online.

Recent empirical work has explored the trade-offs between equity and other fishery outcomes. Asche et al. (2018) find that indicator scores for social, economic, and ecological outcomes across more than 100 fisheries are positively correlated, suggesting that in many fisheries, changes from the status quo can improve both equity and other outcomes. On the other hand, Hoshino et al. (2020) conclude that ITQ fisheries tend to perform better in terms of ecological and economic outcomes than social outcomes and argue that more careful policy design and better data on social indicators can improve social performance.

In practice, many equity outcomes that are important to society occur beyond fishery participants, thus increasing the chance that a market failure will arise under a traditional catch share program. Specifically, even if the catch share program balances equity and efficiency outcomes for program participants, social welfare may not be maximized. Like most other sectors, wild-caught fisheries have effects on local communities, such as through the generation of jobs and support for local economic activity (see, e.g., Watson et al. 2021). This means that the trading of quotas within market-based catch shares will affect individuals other than those directly involved in the transaction. Indeed, such market-based approaches to fisheries management have been shown to have employment impacts (Abbott, Garber-Yonts, and Wilen 2010). More broadly, increasing the efficiency of operations can lead to consolidation and concentration of the fishing industry (see, e.g., Gunnlaugsson, Kristofersson, and Agnarsson 2018), which can result in the returns to fishing benefiting fewer people, firms, and communities. Coastal communities that depend on fishing activities to survive can also be vulnerable to threshold effects associated with decreased fishing activity (such as minimum deliveries to keep processors open). This can lead to a form of market failure because members of the community who value

keeping the quota local may not actually participate in the quota market. Similarly, nonmarket values for the health and continued existence of fishing communities represent an externality in quota markets.

Fisheries Policy to Support Equity

Fisheries managers can take a variety of steps to strike a balance between efficiency and equity objectives. One option is to add safeguards to market-based management programs. For example, the transferable quota system in Norway restricts quota trade between geographical regions (north and south) and between different size segments of the fishing fleet to promote fishing activity and employment all along the coast and to maintain a diversified fishing fleet (Hannesson 2013). However, such safeguards may be costly if they reduce the economic efficiency of the fishery (Kroetz, Sanchirico, and Lew 2015), and this cost needs to be weighed against the benefits to society of a more equitable outcome.

Another option is for the government to implement an efficient program design, impose a special tax on fishing, and redistribute some of the profit to compensate those who would otherwise have been made worse off by the management program. Returning to figure 3, if we introduce the option of redistributing resource rent, the possibility frontier could shift to the right. Governments have also adopted this approach in practice. For example, in Iceland, the government has introduced a fishing fee on wild-caught catch and redistributed some of the resource rent to the public to increase public acceptance of the system (Gunnlaugsson, Kristofersson, and Agnarsson 2018). In contrast to a labor tax, where such redistributive taxation distorts behavior and lowers efficiency (Piketty and Saez 2013), fish resources generate resource rents, which could be taxed in a nondistortionary manner (Boadway and Keen 2015). This suggests that governments can achieve increased economic growth by shifting the tax burden from distortionary taxes to a resource rent tax. Although there is a large literature on optimal tax design in the context of nonrenewable resources (see, e.g., Boadway and Keen 2015), more research is needed on this issue in the fisheries context.

Equity and Program Implementation

Equity issues can affect the timing of program implementation and thus the overall efficiency of a program over its lifetime. Many proposed market-based solutions have failed as a result of political economy issues that cause stakeholders to oppose the proposed program (e.g., Guyader and Thebaud 2001; Grainger and Parker 2013; Kokorsch and Benediktsson 2018; Leonard, Costello, and Libecap 2019). Expanding the scope of program design increases the number of stakeholders and could further exacerbate delays. Thus, in the long run, implementing less efficient programs earlier may be a more efficient choice when the net present value of the full stream of rent changes is being considered.

Equity and Global Production

Equity is also an important issue when examining global production of wild-caught fish, especially production in developing countries. Generally, to improve fisheries outcomes in the long run, it is necessary to reduce fishing in the short run to allow depleted stocks to rebuild. However, this intertemporal trade-off can be difficult, especially in relatively poor areas, where fish tends to be an important food source or fishing is a source of income to buy food (Wilén 2013).

Thus, in the developing world, poverty itself is a source of fishery resource degradation (e.g., Ye and Gutierrez 2017). This highlights the importance of correcting market failures and compensating those who are adversely affected by a policy of reducing harvests today to have larger harvests in the future. Redistribution of harvest over time introduces additional challenges (e.g., those who gain might not be able to compensate those who lose), as well as costs, relative to the case where only economic sustainability and social sustainability in the present are at odds. Because land-based and sea-based economic activities are often linked, especially in developing countries, our understanding of fisheries outcomes and the development of new management approaches may also benefit from a broader perspective that considers the entire local economy and food system (e.g., Lindsay et al. 2020).

Conclusions: Policy Recommendations and Research Priorities

This article has examined the potential for gains from expanding the scope of management policies that impact fisheries, with our discussion framed around market failures beyond those traditionally considered by economists in the fisheries management context. As the problem of overfishing continues at the global scale (FAO 2020), more policy-oriented research is needed to address both the classic stock and congestion externalities and the additional complexities we have discussed in this article. As we have discussed, the shift toward expanding the overall scope of fisheries management beyond the traditional single-fishery approach provides an opportunity for economists to play a key role in identifying and meeting the broad range of policy challenges facing the fisheries sector. With this in mind, we conclude with some recommendations for policy and economics research priorities aimed at supporting the sustainability of wild-caught fisheries.

Pursue a Comprehensive Approach to Sustainable Fisheries That Considers Equity

Our primary recommendation is that there needs to be a more comprehensive approach to the socioeconomic goals of fisheries management that integrates social sustainability. To be successful, such an effort requires research and policy design initiatives that more thoroughly consider equity-efficiency trade-offs. A less comprehensive approach could result in potentially undesirable equity outcomes such as a loss of smaller-scale fishers and fishing communities and undermine the capacity of fisheries as a sustainable food source, thus posing a roadblock to further progress in implementing market-based management in global fisheries. Efforts to pursue a more comprehensive approach should include examining contributions that wild-caught fisheries can make that go beyond affecting the livelihoods of those directly involved in the sector, such as supporting communities and local economies. Furthermore, fisheries and fish products have historically been viewed in isolation; more research is needed to examine how fish and agricultural products can jointly contribute to a sustainable food system and support food security.

Encourage Technological Advances and Data Sharing

Recent technological advances such as increases in data storage, computing power, and satellite resolution provide new opportunities to collect and process data to support sustainable

fisheries, to improve enforcement and monitoring, and to expand research beyond the traditional single-fishery scope. However, policies are needed to encourage further technological advances, adoption of new technology, and data sharing in ways that support social goals.

Weigh the Costs and Benefits of Expanding the Scope of Marine Resource Management

EBFM has the potential to both address many of the market failures endogenous to the capture fisheries sector and improve fisheries sector sustainability. However, more economics research is needed to fully assess the benefits and costs of such an approach. Research in this area is especially timely because EBFM is still being tested in practice. In addition, rethinking management policy at an ecosystem scale may provide more flexibility to react to the consequences of climate change, especially changes in ecological conditions and the spatial distribution of fishery resources.

Our examination of exogenous and endogenous market failures suggests priorities for other economics research in this area. The future sustainability of fisheries will depend on exogenous market failures (such as biological invasions and climate changes) that are highly uncertain and cannot be overcome by fisheries policy alone. For example, climate change poses a challenge for the future of wild-caught seafood not only because of its predicted overall negative effect on the productivity of stocks but also because the issue of shifting fish stocks is generally not covered by current approaches to fisheries management. Other exogenous market failures such as competing seascape uses and cross-sector pollution must be addressed across sectors. In these cases, it is important to assess the costs and benefits of policies in a way that explicitly considers seascape use by multiple user groups and water quality outcomes and impacts across multiple sectors. For exogenous market failures that occur on a more local scale (such as impacts of agricultural pollution on fish populations), fisheries managers may be able to collaborate with the sectors generating the externality to develop efficient solutions. In all these cases, recommendations about the scale of management will need to be made based on limited data and under substantial and potentially deep uncertainty, suggesting the need for interdisciplinary research by economists and other researchers to provide input into a management design that addresses these conditions.

Pursue Integrated Research on Equity and Technology

There are also important points of nexus between exogenous and endogenous market failures and equity and emerging technologies. First, research is needed to identify socially optimal resource use that involves multiple groups of fishers and multiple sectors of the economy and to design policies that support improvements in resource allocation. Recent advances in data storage and computing power and satellite technologies can be used to both improve policies and decision-making (from fish production to consumption) aimed at supporting economic, social, and environmental sustainability and facilitate cross-sector resource allocation. To realize the full potential of these advances, there needs to be an emphasis on supporting technological knowledge and capacity building that strengthens developing countries' institutional and government capabilities. Additionally, although it is important to consider the costs of more complex management structures to address market failures, technological improvements

are likely to continue to reduce these costs, thus creating new opportunities for improved policy design and outcomes in the future.

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