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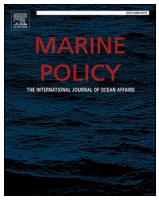

Governing the global fisheries commons

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ABSTRACT

Despite significant advances in understanding the biophysical and institutional causes of overfishing, we have yet to make progress in addressing the depletion of our global fisheries stock. Investigations of potential solutions tend to be too broad (mischaracterizing global fisheries as a singular commons problem to be addressed at the supranational level) or too narrow (focusing on improving management of small fisheries at the micro level). This article attempts to bridge the gap between our scientific understanding of our collective dilemmas and their pragmatic solutions. Building on insights from Nobel laureate Elinor Ostrom, we frame the depletion of global fisheries as a nested set of diverse and interconnected collective action problems organized at different horizontal and vertical levels, where decisions and actions of one jurisdictional unit reinforce and amplify problems (and solutions) for other units. We examine features of the global fisheries system, such as nonstationarity, nestedness, and prohibitive transaction costs. Then, we explore some potential solutions. The success of our conservation goals depends on our ability to craft institutional rules at the lower levels that are adaptive to local conditions, address incentive misalignment issues, and allow for the transfer of positive externalities to adjacent and higher levels.

1. Introduction

Since the industrialization of the fishing process began in the early 19th century, global fisheries have remained under persistent threat of population collapse [31]. However, geographical expansion and technological innovation have continually masked the decline, increasing access to previously unexploited fisheries [58]. Since the 1980 s, the depletion of marine ecosystems has intensified. Global marine fisheries landings have decreased by roughly 0.7 million tons each year. Of the world's fish stocks, 52% are deemed exploited, and 28% are overexploited or depleted [76]. Only about 15% of the world's fish stocks are underexploited or moderately exploited [28]. Overfishing has long been recognized as a chief explanation for the decline in fish populations, although environmental shocks such as El Niño events have played some role [58]. Despite commitments by governments and intergovernmental organizations to act swiftly, no tangible large-scale programs have been implemented to overcome overfishing challenges at the global scale meaningfully. Moreover, governments continue to subsidize large-scale fisheries, generating perverse economic incentives to overfish and undermining ongoing marine ecosystem preservation efforts [71].

The World Trade Organization (WTO) has attempted to address overfishing problems for over two decades by forging a global consensus. Still, the barriers to global collective action have proven to be insurmountable thus far. Although much emphasis has been placed on it, the WTO consensus is likely to be different from the panacea it is presumed to be. Even if the two-thirds consensus is achieved, it will likely remain a purely symbolic gesture. Without the necessary buy-in and backing of subnational stakeholders, such a high-level consensus is unlikely to sufficiently alter underlying economic incentives facing various actors [42], especially those participating in overfishing activities across different jurisdictions with varying levels of overfishing restrictions and enforcements. Given the unbending political stalemate, the insufficiency of fragmented solutions, and the prohibitive costs of meaningful global collective action, there is a dire need for institutional and technological

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innovations to overcome the global fisheries commons' social dilemmas.

The depletion of global fisheries has garnered significant scholarly attention [14,22,29,5,57,65,73,81]. Economists studying natural resource systems have long understood that global fisheries are susceptible to the commons problem. Gordon's [23] and Anthony Scott's [65] seminal papers attribute the fisheries' commons problem to fish stocks' common-property and open-access nature. Their analyses and subsequent bioeconomic literature rely on a model of a single fisheries stock, which is a "principally metaphorical" way of depicting a fundamental incentive mismatch [67]. The common ownership (or the absence of ownership) of the fisheries stock incentivizes fishers to maximize their catch through overcapitalization and disincentivizes them from investing resources toward preserving the total stock. Knowing that one person's actions are unlikely to be noticed or reciprocated by others, an individual fisher is unlikely to exercise restraint over others whenever using collective resources simultaneously. Thus, intensifying fishing activities beyond the system's regenerative capacity is expected in open-access fisheries, where property rights are either absent or unenforceable because of prohibitive exclusion costs.

Nobel laureate Vernon Smith [66] later expanded the model of a single fish species (with a fixed stock X_t and a natural regenerative capacity) to explore the dynamics of the open-access fishery under an open-access regime. Subsequent work has progressed well beyond the metaphorical single-species models of fisheries to account for spillovers across multiple species, the inter-seasonality of human and fish behavior, spatial heterogeneity, and the diversity of resource systems and institutions. Nevertheless, an expanding theoretical and empirical literature on fisheries has persistently recognized the common-property regime and its associated problems, such as the unenforceability of regulations, open access, and free-riding as the fundamental problems undergirding the tragedy of the fisheries commons.

Despite significant progress in our understanding of the biophysical and institutional causes of overfishing, curbing the depletion of global fisheries stock has proven to be—at best—an elusive goal [31]. The problem can be explained, in part, by the disconnect between vast scientific knowledge of diverse fish species and fisheries systems and socioeconomic models of human behavior and institutions. Even when the diagnostics of the scientific findings are accurate, proposed policy prescriptions tend to presume idealized human actors operating within perfect institutions. Ostrom and Cox [50] refer to this as the "panacea problem": any deviations from the perfect scenario are interpreted as aberrations, to be rectified presumably by an external authority (ibid., p. 451). Thus, scholarly prescriptions are often not implementable because of enormous transaction costs associated with imperfect real-world institutions vastly different from their idealized counterparts. In other instances, such prescriptions fail to adequately account for the costs of recommended institutional change and economic tradeoffs between choices.

Within the burgeoning literature examining the problem of overfishing, relatively small scholarship has been devoted to synthesizing scattered insights from studies of diverse fisheries systems in institutional economics, environmental studies, or political economy literature. Some recent studies have started linking the problems facing the global fisheries commons more directly to ideas from institutional economics and political economy ([4,37,40,77,82].). However, most studies in this vein focus on self-contained case studies or analyses of narrow empirical relationships. Thus, they have under-emphasized the nested and interconnected nature of the problems associated with the global fisheries commons. Our unique contribution is to unpack this nested governance nature and draw policy implications regarding the likely solutions. These implications include balancing top-down international efforts and bottom-up local approaches at various scales in markets, governments, and civil society.

Thus, this paper offers an analytical framework for understanding the global fisheries commons problem and investigating its potential solutions by synthesizing key insights from institutional economics, political economy, environmental economics, and environmental studies. The framework paves the way for fisheries scholars to investigate the problem of preserving the global fisheries commons as a nested governance challenge. We argue that the global fisheries commons pose a nested governance dilemma analogous to many challenges related to climate change, pandemics, and other complex externalities [49,54]. Although conveniently aggregated as a singular problem, the tragedy of the global fisheries commons is, in fact, a conglomeration of numerous tragedies, which are organized in multiple nested levels and involve different organizations, political jurisdictions, and authorities [52,53]. Thus, we contend that it is more fruitful to conceptualize complex, large-scale environmental challenges, such as the depletion of global fisheries stock, as nested externalities requiring multi-tiered governance [56]. Next, we sketch some pragmatic ways to improve the global governance of fisheries by using an entire menu of institutional and technological solutions.

Building on Ostrom's [48,49] and others' [40,52] analyses on the governance of large-scale nested externalities, we argue that there is a need for a plethora of distinct yet complementary solutions to manage the global fisheries commons. By acknowledging and enabling institutional diversity, intellectual and policy efforts can better match specific externality problems to appropriate institutions from the bottom up [56]. This bottom-up matching permits scaling up or down policies and solutions based on the scale of the problem and available institutional solutions, thus balancing the need for top-down national or international coordination and regulation with bottom-up organizational craftmanship. Specifically, this essay explores the role of four complementary solutions: i) market-based solutions such as Individual Transferable Quotas (ITQs), ii) government interventions such as rescinding fishing subsidies and redirecting public funds towards resource conservation at the local level, iii) encouraging community-based approaches that mobilize local knowledge and methods of mutual monitoring in the Exclusive Economic Zones (EEZs), which are areas formally under governmental jurisdictions, and iv) combining complementary private and governmental actions to innovate policies and technologies to curb overfishing in the high seas.

Importantly, homogenizing the global fisheries depletion as a singular problem in search of a panacea masks the crucial distinction between the governance challenges facing the high seas (which are ungoverned territories) and areas demarcated as Exclusive Economic Zones (EEZs) and Marine Protected Areas (MPAs) (which are formally regulated or protected by national or international laws and conventions). Most governments in the developed world have highly formalized fishing regulations within their EEZs and tend to comply with fishing restrictions within the MPAs. Although governments vary widely concerning the presence and implementation of their fishing regulations and marine conservation measures, many have succeeded in improving governance through property rights expansion and innovations in monitoring and sanctioning mechanisms [11,60,61].

The creation of EEZs has even been touted as "one of the most significant developments in the history of property rights" ([3], p. 1). Moreover, per the United Nations Convention on the Law of the Sea (UNCLOS), countries can designate and manage MPAs within their EEZs.[1] However, 58% of the ocean remains under an open-access regime [79]. That is, a significant portion of the world's waters are not under any government's jurisdiction, which presents a fundamentally different and more difficult challenge than the governance of the EEZs and MPAs. They pose different constraints and thus require different institutional solutions. Thus, we contend that a polycentric approach – that allows multiple decision-making units (governments, non-governmental entities, private actors) operating at different overlapping levels to

[1] MPAs were established with the goal of alleviating "the pressures on the international commons" by extending the EEZs to 200 nautical miles around a nation [37].

innovate, experiment with diverse solutions, and overcome nested challenges – is needed to avert the tragedy of the fisheries commons.

The remainder of the paper is organized as follows. Section 2 explains the nature of the commons problem, with a particular focus on the global fisheries commons. Section 3 argues that governing the global fisheries commons is a nested governance challenge. Section 4 explores and unbundles various aspects of nestedness to better understand the social dilemmas facing diverse participants in the commons and multi-leveled governance challenges. Section 5 examines existing institutions and organizations involved in the governance of global fisheries and explores how they interact with one another in a nested manner. This section also discusses potential and complementary solutions to the commons problem in light of its nested character. It paves a path toward improving the future of the global fisheries commons. Section 6 concludes.

1.1. The problem of the global fisheries commons

A *commons* refers to a resource system that many users share [63,69]. Although they are often conflated with open-access systems—and increasingly with common-pool resources (CPRs), following the work by Elinor Ostrom [43]—commons need not be either [19]. Open-access systems and CPRs can be understood as specialized types of commons (i.e., subsets). Open-access systems are defined by their lack of ownership or property rights, which precludes anyone from excluding others from accessing or appropriating the resource system. Whereas a CPR may or may not have defined property rights ascribed to it, it is difficult (but not impossible) to exclude others from benefiting from CPRs. The associated benefits are subtractable—that is, one person's use necessarily depletes the available stock, thus making the appropriated unit unavailable to others [43,51]. The distinction is crucial because open-access systems and CPRs lead to different collective action problems and have different policy implications [19,45]. Specifically, when analyzing problems associated with the fisheries commons, one ought to exercise caution not to conflate fisheries governed under a CPR regime with open-access fisheries.

The tragedy of the commons remains an influential analogy to describe the problem affecting global fisheries (Van Long & [75]). The idea is broadly credited to Garrett Hardin [24]. Hardin's bleak conclusions were refuted by natural resource economists, who showed that self-governing resource users can successfully avert the tragedy [2,43]. Resource users implement a variety of rules to monitor their resource extraction rates and exclude outsiders from exploiting the resource system. They do so by developing mutual monitoring, sanctioning, and conflict resolution mechanisms in case of violations. Thus, the tragedy is neither inevitable nor unsolvable, as resource users create and adapt diverse institutions to overcome their dilemmas.

Moreover, the creation of institutions is endogenous to the economic system and can occur in response to a perceived tragedy [2]. Since the commons are jointly owned (by definition) and investments to design institutions are typically large, some form of collective action is necessary to manage the commons. Thus, the management is a governance challenge involving the multilevel collective action problems of (i) creating a system of rules that allow, prescribe, or proscribe certain actions for specific actors and (ii) monitoring and enforcing the rules to distribute the costs and benefits to different actors. Such rules can be created through a top-down assignment, a bottom-up system of property rights and voluntary exchange, or some hybrid form that combines features of each [56,74]. The design of institutions (i.e., the institutional choice) has important implications for the sustainability of a resource system and the likelihood of a tragedy.

Despite scholarship disproving the inevitability of the tragedy of the commons, the notion tends to resurface in various forms in contemporary global commons discourse. It is easy to see the appeal of the analogy. It offers a simple and compelling explanation for otherwise convoluted and seemingly intractable problems. Many of our global problems indeed share some essential elements underlying the logic of the tragedy of the commons—namely, that these problems are caused by individuals' maximizing their private gains and/or minimizing their private costs. The logic suggests that when rationally self-interested individuals encounter a commons, they will attempt to appropriate the private benefits from it but will try to 'socialize' the costs of maintaining and preserving the resource system as much as possible. They internalize a significant personal benefit while bearing only a small part of the costs. When all actors behave this way, the commons get overexploited, and no one benefits, resulting in a tragedy.

Economists have long recognized that global fisheries provide archetypal cases of the tragedy of the commons. Property rights are incomplete and difficult to implement, especially in the high seas and large, jurisdictionally ambiguous bodies of water. As a result, many fisheries resemble open-access systems and are highly susceptible to tragedies comparable to Hardin's pasture. Overexploitation can occur because of three main reasons.

First, marine systems are vast geographical areas that follow an open-access logic. They belong to no one, or rather to anyone, who can access them through maritime technology. Because they lie outside the purview of any government, fishers are free to extract unlimited quantities of fish, with the only limits posed by technology, gear, and the environment. Even in inland systems that are sufficiently large, more than formal laws will likely be required to deter violators. Second, even when *de jure* rules are in place to prevent over-extraction, monitoring resource use and sanctioning rule breakers entail high costs. Such systems can remain open access, in fact, despite being technically restricted. Third, fish species' migratory and fugitive nature makes enforcing de jure and de facto property rights challenging over most fish stocks. So, the rule of "first come, first capture" prevails, incentivizing rational fishers to race to overexploit the resource [38]. Empirical evidence suggests that the race is more intense in systems where more fish migration is possible. For example, shared stocks in marine systems and international waters are more prone to overexploitation than smaller and more contained fisheries [37]. Thus, these factors make the problem of global fisheries highly complex and multilayered.

2. Global challenges as nested collective action problems

One critical insight from Nobel laureate Elinor Ostrom's work on natural resource management is that large-scale externalities spanning multiple governmental jurisdictions should be viewed as nested collective action problems rather than singular problems [48,49,55,59]. According to Ostrom, externalities are nested if one decision-making unit's choices and actions produce costs or benefits for other units at different scales ([49], p. 356).

Global externalities, such as those involving global fisheries, fit the above description. They involve different countries, states, cities, municipalities, cultures, firms, and organizations. Actions of each unit (a fisher, firm, or government) generate costs and benefits that percolate to other units. For example, once in effect, an environmental policy targeting large-scale fisheries in Nova Scotia province in Canada will immediately affect fishing communities in Maine in the United States. Similarly, because of their 'fugitive' (i.e., mobile or migratory) nature and the interconnectedness of their habitats, poor management of a lobster fishery by communities in southern Maine will directly affect the size and health of the available stocks in northern Maine [64]. Highly migratory species, such as tuna, billfish, and sharks, can swim between the high seas and areas demarcated as exclusive economic zones (EEZs) by different jurisdictions, making them highly susceptible to overexploitation [37]. Such species can be affected by decisions and actions taken by governments and private actors from distant regimes. Even the choices made by secondary actors—such as processors, marketers, supporting industries, and consumers—have implications for the overall sustainability of fisheries [77].

Nestedness is a feature that is not unique to large-scale externalities

[56]. A society itself can be described as a nested system. There are small social orders embedded within other larger social orders. For example, [34] conceptualizes nested arrangements as cooperative systems that encourage the autonomous functioning of smaller, more exclusive units operating within broadly agreed-upon principles. Thus, the nestedness of externalities can be thought of as a byproduct of the nestedness of the social orders within which they materialize. The larger a problem is, the higher the chances are that it presents a higher-order nested externalities challenge. In other words, in dealing with a small-scale problem, smaller jurisdictional units can often govern themselves insofar as the problem does not spill over to neighboring jurisdictions. When the challenge is grander, two or more smaller units can agree on objectives and rules consistent with their mutual interests. When the number of affected parties rises beyond a certain threshold, the costs of collective decision-making as a singular unit can grow exponentially because of diverging interests and hold-out problems [8]. Thus, although aggregation is still technically feasible, it will be more complex and may require clustering at multiple centers.

For tractability and other reasons, analysts and policymakers often ignore the costs of collective decision-making and implementation, presume homogeneity and linearity, and aggregate multiple small problems into a larger singular unit. Analysts may find it convenient—for analytical purposes—to assume a static and singular governmental body that can twist policy levers through regulation, taxation, subsidies, or other behavioral nudges. However, such perspectives have significant blind spots concerning subnational institutions, geographical variation, and dispersed knowledge prevalent at the local level [43]. Aggregating problems into a singular decision-making unit does not make these decision-making costs go away. They are simply arbitrarily suppressed to zero (by assumption) and tend to resurface in other forms, such as high implementation costs, high noncompliance rates, and even societal instability.

Consequently, miscalculations of the costs and benefits become inevitable because the nested nature of specific socioeconomic and ecological problems is ignored, thereby generating unintended and counterproductive outcomes for communities and the resource or economic system. Higher-level decision-makers who hand down policies to local jurisdictions and communities are unlikely to carefully consider the diversity and heterogeneity of communities, their interconnectedness, and the nestedness of their collective problems [50]. Thus, misaligned incentives and institutional mismatch are the inevitable outcomes of policies that homogenize a nested set of collective action problems and aggregate them into a singular large-scale problem.

The governance literature that accounts for the nestedness of global externalities is growing [40,56]. Thus far, the most analyzed cases of nested global externalities are related to climate change [32,48,49] and natural resource systems such as water [21,33,72]. Ostrom [49] emphasized that the challenge of climate change is particularly difficult to tackle because it is rife with free-riding and coordination problems across all levels, from the international politics and nation-state level at the top to private firms, corporations, families, local communities, and individuals all the way down. Actors at all levels emit carbon into the atmosphere in small or big ways and are thus all positioned to contribute toward mitigating net carbon emissions. However, public discourses remain fixated on the nation-state- or global-level solutions, ignoring the nestedness of associated externalities. As Ostrom argues:

> The literature on global climate change has largely ignored the small but positive steps that many public and private actors are taking to reduce greenhouse gas emissions. A global policy is frequently posited as the only strategy needed.… Positive actions are underway at multiple, smaller scales to start the process of climate change mitigation. Researchers need to understand the strength of polycentric systems where enterprises at multiple levels may complement each other. Building a global regime is a necessity, but encouraging the emergence of a polycentric system starts the process of reducing greenhouse gas emissions and acts as a spur to international regimes to do their part. ([49], p. 353)

Polycentricity offers a useful analytical device for understanding large-scale nested externalities. A system is polycentric if it comprises many autonomous and overlapping decision centers, each representing heterogeneous units linked through different exchange relationships (collaborative, competitive, or hybrid forms). Within such a system, citizen preferences can be aggregated and organized within multiple governing authorities at different scales to match private incentives with the collective agenda. For instance, the users of a common-pool resource would have significant authority to devise many rules regarding the resource's management, use, and preservation ([46], p. 283). Recent scholarship has begun to examine large-scale externalities, such as those associated with climate change, through the lens of polycentric governance [32]. At the heart of the polycentric perspective is the acknowledgment that climate change poses a set of nested global-scale externalities that a singular governing authority cannot solve because of epistemic and incentive-related difficulties. Solving problems of this type often requires efforts from all governmental levels. However, governmental efforts alone are insufficient to address them. They also require meaningful participation and input from nongovernmental actors such as private firms, nonprofit organizations, and civil society.

This implies that the focus of public policies must be on generating sufficient incentives for private actors to innovate disruptive technologies and to improve efficiency through institutional innovations. The specific contents and provisions of such policies are likely to vary across jurisdictions and contexts, and they cannot be determined ex-ante without adequate consideration of institutional context, geographical peculiarities, and a host of other factors. Instead, policy design and implementation should be viewed as a dynamic process with built-in provisions to adapt to feedback and institutional change. In other words, despite our political and academic obsession with optimal policy design, there is no panacea to solve our existing environmental and ecological problems [50]. One should be wary of proposals that prescribe a singular one-size-fits-all solution to nested challenges such as climate change or global fisheries.

A vital strength of the polycentric approach to governing global fisheries is that it facilitates emergent outcomes that are socially desirable but not centrally planned (or plannable) [49]. Although it offers no readily implementable silver bullet to halt the depletion, it fosters an environment where commercial and institutional entrepreneurs can experiment with different potential technological and institutional solutions, test them at smaller scales, abandon ideas and solutions that do not work, and scale up those that do work. Moreover, solutions that work at smaller scales but lead to perverse outcomes when scaled can still be replicated at smaller scales, allowing multiple solutions to compete and/or coexist. Thus, many smaller-scale actions taken by governments (at different levels), private firms, non-profit organizations, professional associations, and civil society can generate sufficient positive outcomes and make a significant difference. Moreover, emergent solutions resulting from cooperation and contestation among low-level entities are likely more robust than those designed by high-level government officials, who often face severe coordination challenges, knowledge problems, and misaligned incentives [50]. However, this does not mean that large-scale entities and national governments have no positive role to play. High-level political and bureaucratic entities are crucial to solving coordination problems by providing relevant technical and scientific information where the information gaps exist, connecting donors and resource suppliers to communities that can put them to use, and realigning economic incentives through regulations, conventions, and treaties with the common goal of preserving the fisheries commons. They can further explore other co-productive avenues to enable the emergence of bottom-up creative solutions from lower-level entities [42,43].

Thus, through competition and collaboration between various

entities at diverse levels, the polycentric approach can help us avoid the impossible task of forging a global-level consensus and still produce many workable solutions that can jointly prevent overexploitation. Ultimately, different solutions may resolve small parts or fractions of the large-scale commons and jointly contribute to alleviating the problem at different scales and under different contexts. For instance, at the meta-level, solutions such as climate clubs (of nations) may effectively introduce incentives through joint resolutions and trade treaties [42]. A wide range of novel institutions may coexist locally to promote climate adaptation while respecting local conditions [17]. Market mechanisms such as pollution permits and other economic incentive-based devices could stir innovation and entrepreneurship and promote wider adoption of cleaner goods and services.

3. The global fisheries commons

This essay explores the essential features of the global fisheries system and its associated externalities that make it susceptible to overexploitation and depletion. Global fisheries share three critical characteristics with large-scale externality challenges such as climate change and pandemics.

First, the resource system is nonstationary. Stocks of different fish species move globally across national and international waters. Although it may be technically feasible to contain fish stocks by assigning and enforcing property rights, such endeavors tend to be prohibitively costly, especially on the high seas. The costs of technology and resources needed to implement property rights are substantial. Such efforts are also rife with free-riding problems that make it extremely cumbersome to generate sufficient political consensus and overcome uncertainties associated with collective decision-making. Those difficulties are akin to the problem of curtailing greenhouse gas emissions, which are also fugitive externalities whose origins are nearly impossible to trace once they are released into the atmosphere. Thus, the nonstationary nature of the resource makes it challenging to assign rights and responsibilities to individuals, firms, and organizations.

Second, the problems associated with global fisheries are nested. Each fish species is part of the vast marine ecosystem, which is an aggregation of numerous interconnected sub-ecosystems. Each fish species relies on other fish species, eggs, plants, crustaceans, and a variety of food sources for its survival. All fish species are part of a complex, delicate, and interconnected ecosystem in which one species can profoundly affect others. Any human intervention in the nested marine ecosystem will generate positive or negative effects throughout the nested ecological systems. These effects also naturally extend to human societies in the form of costs and benefits, which are distributed unpredictably and pose governance challenges. Hence, the governance of fish stocks is complex because it involves many institutional and organizational arrangements at different levels and scales, ranging from sparsely populated rural communities to vastly populated coastal cities. Within and across these communities are small-to-large private businesses, local nonprofits, corporations, sub-national and national entities, and large international nonprofit organizations. Programs and policies enacted at one political, jurisdictional level will affect outcomes at other levels, either directly by producing external costs and benefits or indirectly by influencing institutions and underlying economic incentives. Moreover, actions taken by individuals, communities, businesses, and organizations in one unit will have repercussions for actors in other units. These dynamics stem from the nestedness of externalities and were most apparent during the recent COVID-19 pandemic [54,55].

Third, global fisheries face steep monitoring and exclusion costs, which must be overcome if natural resources are to be managed sustainably [44]. The costs can be outright prohibitive without enforceable property rights on the high seas. Even when property rights are defined and technically enforceable, devising monitoring and exclusion mechanisms may remain economically inviable because of the high costs of associated technology and capital. Global fisheries span vast geographical areas, transcending national and continental boundaries. Diverse types of international waters—such as oceans, large marine ecosystems, enclosed or semi-enclosed regional seas and estuaries, rivers, lakes, aquifers, and wetlands—are home to a vast share of global fisheries.

These water bodies outside the EEZs are considered ungoverned territories, as they do not fall under any state's jurisdiction. Under the doctrine of *mare liberum*, international waters are immune to claims of ownership and sovereignty owing to their fluid and seemingly limitless nature (Gümplová, 2023). This implies that states have unconstrained rights to engage in fishing (or overfishing), navigation, overflight, cable and pipe laying, and scientific research in international waters. Many of the planet's natural resources, including fish stocks, are located in areas "traditionally acknowledged to be beyond the exclusive legal jurisdiction of sovereign states" ([68], p. 1). For those reasons, the resources are deemed "global commons," susceptible to the tragedy of the commons, and they are similar to Hardin's open-access pasture in that they have no means of overcoming monitoring and excluding problems and no enforceable property rights [82]. To be clear, international waters are not entirely open access. The 1994 United Nations Convention on the Law of the Sea implemented exclusive economic zones (EEZs) in waters adjacent to all coastal nations, extending national-level property rights to 42% of the ocean and allowing coastal countries to manage fisheries within their jurisdictions and exclude foreign fleets. Per the convention, the remaining 58% of the ocean would still be under an open-access regime [79]. That said, the net conservation gains of decomposing the global commons into multiple national commons (i.e., complete privatization of the ocean) remain dubious [3], especially considering the fugitive nature of the resource system.

The three features described jointly make global fisheries governance extremely challenging. The nonstationary and migratory nature of the resource system, the nestedness of associated collective action problems, and the exorbitant monitoring and exclusion costs pose severe coordination challenges for institutions at all levels. As a result, property rights are either absent or are prohibitively costly to enforce, leading rational individuals to engage in a permanent race to fish beyond sustainable levels and act against their long-term mutual interests. In the next section, we will examine existing institutions and organizations involved in the governance of global fisheries and explore how they interact with one another in a nested manner.

4. A polycentric approach to governing global fisheries

Now that we have expounded the fundamental causes of the tragedy of the global fisheries commons, we can examine some potential solutions. Political economists and natural scientists have intensely debated ways to prevent the collapse of global fisheries and rebuild the stocks [12,80]. Economists have contributed to modeling and illustrating the fundamental incentive mismatch underlying the problem. However, their proposals (such as establishing private property rights) have been criticized by marine biologists, environmental scientists, and anthropologists for ignoring institutional contexts, geographical and ecological diversity, and complexity—maybe rightly so. However, economists' proposals are still valuable as first approximations, and there may be gains for us to make by improving upon and adding nuances. Moreover, economists' emphasis on realigning economic incentives with resource conservation goals gets to the heart of the problem and cannot be ignored. Hence, we propose that a polycentric governance framework can act as a bridge between (i) economists focusing on property rights and incentives in the abstract and (ii) environmental scientists focusing on applied matters of governance, local challenges, and geographical nuances.

The critics of the economic approach (narrowly conceived) are correct in the sense that the precise tools commonly proposed—namely, establishing and enforcing property rights and prices—are not meaningful in an institutional void. Many small-scale fisheries worldwide are

managed by communities using intricate traditional systems of rules without directly relying on private property rights and prices. Elinor Ostrom's [43] influential work examining the governance of small-to-medium-scale fisheries commons in various countries, where prices and property rights—at least in the narrowest sense of exchangeable ownership rights—are neither necessary nor sufficient to govern collectively owned resources. On the other hand, the criticism also applies broadly to non-economists who advocate for a global overseeing authority and a uniformly applicable regulatory approach to circumvent the economic forces at play. Proponents of nonmarket solutions similarly fall prey to panacea thinking that presumes away, in part or entirely, the very problem it purports to solve [47].

The polycentric thinking that we advance in this paper cautions against prescribing one-size-fits-all solutions of all kinds—including but not limited to market-based and government-oriented approaches—to govern global fisheries. *Global* need not connotate singular. As argued in the previous section, the problems facing global fisheries are not a single problem but rather a set of nested social dilemmas of varying scales organized across many horizontal and vertical levels. Although those dilemmas may share some features, each one has unique attributes corresponding to the characteristics of the fish species, local ecological conditions, geographical context, institutional setting, and socioeconomic background [4]. As Worm et al. [80] argue:

> [T]he feasibility and value of different management tools depends heavily on local characteristics of the fisheries, ecosystem, and governance system. For example, the most important element of small-scale fisheries success has been community-based management, … in which local communities develop context-dependent solutions for matching exploitation rates to the productivity of local resources…. Yet it is generally evident that good local governance, enforcement, and compliance form the very basis for conservation and rebuilding efforts…. Finding the best management tools may depend on the local context. ([80], pp. 583–584).

In other words, the key to crafting pragmatic solutions to governing the global fisheries commons going forward lies not in some optimally designed supranational overarching regulatory policy but in balancing top-down supportive and mediative roles with diverse small-to-medium-scale efforts from the bottom up. A significant degree of adaptability and flexibility is needed on the part of governmental authorities to "facilitate the development of institutions that bring out the best in humans" in a global fisheries context [47]. Likewise, scholars and policy analysts may benefit from regularly revising their theories using insights from individuals and communities on the ground tackling a wide range of problems. One implication of our analysis is that there are no panaceas for nested governance challenges. Both regulatory and property rights-based measures are only partial and imperfect means for averting the tragedy of the global fisheries commons. Hence, rather than insisting on one set of solutions, such as creating markets, a deeper appreciation of existing solutions and fruitful practices—combined with an openness to novel scientific and institutional innovations—is called for. A range of proven tools, such as ownership rights, alternative rights-based management, rules dictating catch restrictions, monitoring, gear, and vessel modification, the establishment of closed areas in the high seas, and ocean zoning, must all have a place in applicable contexts. Thus, a more fruitful and pragmatic path forward may be to match specific classes of collective action problems (based on their geographical scales, intensity, and other attributes) with an appropriate set of institutions from an array of feasible institutional arrangements [56].

Before proceeding further, it is worth considering whether the existing system for governance of global fisheries commons is polycentric. Insofar as we conceive polycentricity as a multiple system of governance with many heterogenous and overlapping (both cooperative and competitive) centers of decisionmaking [46], then the current system could *prima facie* be deemed polycentric, although a fragmented and loosely coordinated one. However, as discussed in the previous sections, the current system has not been proven effective in governing the fisheries commons. Despite the apparent formal polycentric structure of the system, three broad classes of problems have hindered harnessing the benefits of polycentricity to preserve the commons: i) poor implementation of monitoring and surveillance mechanisms within many EEZs, resulting in illegal, unreported, and unregulated (IUU) fishing; ii) coordination difficulties in enforcement at the international level due to the lack of binding agreements regarding fishing restrictions, quotas, and conservation zones; and, iii) infeasibility of establishing property rights and exclusion mechanisms in the high seas available for governing fishing within it [18,77]. Thus, despite the external appearance of polycentricity, many crucial features of polycentricity are primarily absent – including institutions enhancing self-governance and fostering co-production and entrepreneurship from the bottom up. Therefore, the current system best resembles a poorly managed common pool resource (CPR) arrangement, artificially aggregated to a global scale and plagued with numerous tragedies.

That said, the relevant issue is not whether the current system conforms with the formal definition of a polycentric governance system. Instead, our focus is to use the tools of polycentricity to identify which parts of the system are underperforming or failing and why and to explore rules and methods to transform the existing 'tragedy of the commons' situation into one that resembles a sustainable CPR system (or systems). In the following subsections, we will explore some market-oriented solutions and some government- or community-based solutions and discuss contexts where they can be fruitful.

4.1. Market-based solutions: individual transferable quotas

One widely implemented market-based solution to the global fisheries commons problem is the individual transferable quotas (ITQs) system. Although implementing ITQs requires a substantial governmental role, ITQs rely on price mechanisms and voluntary transactions between buyers and sellers in the open market. ITQs work as follows: Scientists assist governmental authorities in setting the annual allowable catch, which is equal to the efficient catch based on the specific fishery's natural regenerative capacity.

Governments then either allocate or auction off catch quotas to fishers and companies. The catch quotas serve as tradable property rights that allow holders to extract a specified quantity of fish per year. The rights holders may extract the fish themselves or buy and sell their quotas in the secondary market [69,78]. Because the total quotas do not exceed the fishery's regenerative capacity, ITQs help to ensure that fishing levels are sustainable. ITQs are also welfare maximizing because they use a price system to direct resources to where they are most valued.

Seventeen countries—including Australia, Canada, Iceland, and New Zealand—have implemented different forms of ITQs in about 150 fisheries [41]. Of those countries, New Zealand uses ITQs to manage its entire commercial fishing industry ([41], p. 91). Mounting evidence suggests that ITQs render fishing less dangerous, increase supply, and improve the quality and quantity of fish for all consumers. ITQs can also be *self-enforcing* since fishers on site have incentives to take policing, monitoring, and reporting roles to ensure that everyone respects the quotas. Because each fisher is a partial owner of the fish stock and benefits from an increase in its value, fishers have an interest in properly managing the fishery to preserve the quantity and quality of the fish stock. ITQs' tradability guarantees that fishers who wish to catch more than their originally allotted quotas may purchase larger quotas in the open market rather than resorting to more costly and potentially dangerous measures. Even though this system gets the label of "privatization," the reality is that the shares are distributed by governments and based on a scientific body's advice while devolving part of those rights to local communities. Hence, they can also be granted to local communities, families, and cooperatives.

Costello et al. [12] analyzed data on more than 11,000 fisheries

worldwide from 1950 to 2003. They conclude that fisheries managed under the ITQ system were half as likely to collapse as fisheries under alternative management systems. Moreover, the longer a fishery used the ITQ system, the less likely it was to collapse and the more likely it was to rebuild. Strikingly, every time an ITQ system is adopted, management improves, and overfishing trends for the targeted fishery are halted and reversed. Subsequent studies have reached similar conclusions (see [80], p. 583).

Despite those benefits, ITQs are not the panacea some make them to be. They have technical and geographical limitations. Many countries lack the necessary scientific expertise and political will to implement the system credibly and effectively [13]. ITQs are a form of property rights, the applicability of which relies on the accountability of local governments. Economists have recognized that establishing property rights is not always welfare maximizing and can even be wealth destroying [30]. Crucially, for ITQs to enhance welfare, they must be tailored to the local ecological and geographical context. For countries that lack credible formal institutions, ITQs can transfer de facto communal rights from self-governing communities to extractive private organizations with the wherewithal to buy off corrupt political actors. That can lead to devastating consequences for the ecology and the communities that rely on the resource system. Consolidation caps and community-owned quotas have sometimes been implemented to prevent a single firm or entity from taking over a large fishery section. Such measures have been shown to increase competition and participation. Thus, the basic rule is not that private property is necessary but that "property rules must reflect the local conditions" ([10], p. 13). What are necessary are (i) a more nuanced and less ideologically driven analysis of property and property rights and (ii) institutions crafted to fit the micro granular conditions better.

Finally, ITQs have been used effectively in inland waters and within countries' EEZs. However, in the context of the high seas and the open ocean, where the underlying political institutions are absent, ITQs are unlikely to generate positive outcomes.[2] Likewise, international waters and contested territories present additional risks and challenges for ITQs or any system. Nevertheless, despite their limitations in scope, ITQs can be a valuable tool to reverse fisheries decline, especially when deployed with complementary governance strategies. With proper design, careful monitoring, and adaptation to changing environmental and local conditions, catch shares can lead to better global fisheries management.

4.2. Governmental action: rescinding government subsidies

Fisheries subsidies have become archetypal examples of well-intended government policies that have led to catastrophic consequences. In the United States, subsidies were put in place in the post–World War II years with the purported goals of stimulating regional economic development and supporting fishing communities. Instead, they have led to sustained capital overinvestment, overcapacity, and overfishing [15]. The economic effects of fishing subsidies vary, depending partly on the type of management regime adopted. Poorly designed and protracted subsidies can result in intergenerationally transmitted dependency for many fishing communities, whereas incentive-compatible subsidies may improve the economic well-being of some communities. Nonetheless, the effects of subsidies on *all* fish stocks have been detrimental, regardless of the management regime type adopted [39].

Although those adverse effects are well documented, many countries continue to make significant fiscal transfers to the fishing industries within their territories and on the high seas. Sumaila et al. [70] estimate that the subsidies paid to bottom trawl fleets outside the EEZs are around US$152 million annually. Total government support to the fishing sector worldwide amounts to more than US$35 billion per year, roughly equivalent to 20% of the total value of the marine fish caught at sea and brought to port [35]. Sala et al. [62] concludes that the current rate of overfishing is enabled by public subsidies, without which 54% of high-seas fishing grounds would become unprofitable.

The economic rationale for disbursing fishing subsidies is that they directly help local fishing communities and boost the fishing industry. If the average cost to an individual taxpayer is small (or presumably negligible), the target population's positive outcome can be justified on efficiency grounds. However, as empirical observations of the effects of fishing subsidies show, economic calculus seems to have missed (or ignored entirely) the external ecological costs subsidies would generate in the form of depleted fish stocks and lost fish species. Fishers and businesses have faced many adverse effects: stock depletion, decreased yield, lower quality, and a gradual revenue decrease [35]. As public-choice theory would predict, instead of their purported beneficiaries, subsidies have helped large-scale fishers and well-connected companies at the expense of climatically vulnerable small-scale fishing communities [62]. Subsidies have also led to inequities in food security, as high-value species such as tuna and other deep-sea fishes are transported to markets in high-income countries and sold at subsidized prices, leaving less for subsistence-based fishing communities in developing countries ([62], p. 8).

The most harmful sorts of fisheries subsidies are the ones that encourage overfishing in the high seas, where large and well-capitalized fishers can conduct their operations using methods that would be proscribed in regulated environments. Those payments reduce such fishers' overall operating costs and increase profits by subsidizing fuel, gear, and shipping vessels. As fishers can obtain the required inputs at below-market prices, they overinvest and engage in overfishing, ultimately depleting fish stocks below sustainable levels. Given the structure of incentives and the de facto extra-legal, open-access logic of the high seas, overfishing in these areas is a likely and "rational" outcome [79].

In sum, government subsidies have increased the economic viability of overfishing. They have tragically countervailed relentless efforts by dedicated conservationists and stakeholders to curb the depletion of global fisheries. The scientific community has issued numerous calls to end fisheries subsidies, particularly in the high seas [39,58,71]. Some countries have taken constructive steps toward reducing fisheries subsidies. Norway set an encouraging example by eliminating fisheries subsidies at the national level [15]. The slow progress elsewhere is understandable, given the possibly high political costs of eliminating subsidies. One pragmatic way around those costs is to phase subsidies out over time by partly shifting subsidies to fisheries within the EEZs or inland fisheries whose activities are more compatible with preservation goals.

Finally, it is worth noting that getting rid of subsidies alone is insufficient to prevent overfishing. It may even have adverse short-term welfare effects for many fishing communities that rely on them. Thus, policies aimed at rescinding fisheries subsidies or reforming them to make them compatible with sustainability goals must be considered *in tandem with* ITQs, alternative property rights–based mechanisms, and improved management regimes. Gradual rescinding of subsidies may be supplemented by transitional support programs such as skill development and other opportunities for small-scale fishers and communities practicing subsistence fishing. Other promising programs include disaster payments, special income tax concessions, and seasonal employment insurance, which aims to increase fishers' incomes while shifting fishing away from the high seas and toward EEZs and inland fisheries [36]. Also, tradable catch and bycatch quotas can reasonably incentivize fishers to avoid the catch of threatened species [7].

[2] For a review on the benefits of ITQs, see Branch [6], Libecap [31], and Costello et al. [14]. In addition to ITQs, there are other property rights systems based either on common ownership, such as Territorial Use Rights in Fisheries (TURFs) and Individual Habitat Quotas (IHQs), that have positively contributed to conservation goals and also generated net economic benefits to local communities [1,25,26,31].

4.3. Community-based approaches: mobilizing social capital for collective action

Successes and failures of fisheries systems are typically assessed through the dichotomous lens of markets versus states. This view holds that failures stem either from uninternalized externalities leading to market failures or from governmental mismanagement and corruption (that is, governmental failure). Such a perspective presumes that governments and markets are the only relevant players in preserving the global fisheries stock. This is far from the truth. Fishing communities are integral parts of any fisheries system. As such, communities' productive roles are essential for the viability of fisheries. As [27] puts it, "viable fish stocks require viable fisheries communities." Fisheries systems exist not merely within the confines of formally organized markets and neatly demarcated political boundaries. They are enmeshed within fishing communities composed of individuals and families whose economic, cultural, and social lives are embedded in fishing. Thus, stressing the vital role of communities while analyzing the problem of overfishing is a crucial first step to overcoming collective action problems associated with the depletion of fisheries stock.

Because fishing communities' social and economic well-being depends critically on the health of their fisheries stock, the logic of collective interest dictates that those communities are naturally inclined to invest in efforts and resources to preserve their fisheries system. Those investments can form complex and adaptive institutions, often constituting elaborate operational, collective-choice, and constitutional-level rules to constrain individual fishers' expropriative behavior and incentivize them to contribute to fishery stock conservation. Where formal property rights are absent, communities often leverage their local knowledge and community social capital to devise informal rules and assign rights and responsibilities to different community members. Because the rules are created through extensive collective deliberations and are more likely to address local needs, they tend to elicit higher compliance rates. Moreover, institutions of this type tend to be self-enforcing because each member is invested in preserving the resource system and is thus likely to invest significant time and effort in monitoring and sanctioning mechanisms. Thus, these factors make community-based institutions better poised to succeed than formal rules handed down by formal authorities.

The famous case of the Maine lobster fishery, as documented by Schlager and Ostrom [64], illustrates an effective community-based solution to the problem of overfishing. The state government holds the de jure ownership rights to the lobster grounds off its coast. Lobstering businesses and fishers can obtain authorized user rights by obtaining licenses from the state. However, the prevailing system of public ownership was insufficient to manage and preserve the lobster fisheries. To fill this governance gap, fishing communities exercised de facto proprietor rights, which granted them all the privileges of ownership rights minus the rights to alienate the resource system. The de facto proprietor rights were enforced after being unbundled into several categories—access, withdrawal, management, exclusion, and alienation rights—and recombined in different configurations. Different fishing community members would then serve in different positions and exercise different bundles of rights granted to those positions. For instance, a fisheries manager would be granted the right to regulate the use of resources by other members. In contrast, authorized users could not exercise such rights but could still access and withdraw from the resource system, provided they followed the established appropriation rules. Thus, communities are not passive beneficiaries of efforts by private enterprises or public authorities but play active roles in fisheries management and contribute to overcoming the tragedy of the fisheries commons by crafting self-governing institutions.

4.4. All-hands-on-deck approach to governing the high seas

As discussed previously, most unregulated and unsustainable fishing occurs in the high seas, which are international waters beyond the exclusive economic zones (EEZs). High seas comprise roughly 58% of the world's waters. Thus, even if we successfully curb overfishing in the EEZs (remaining 42%) and inland fisheries, it will be inadequate to prevent the depletion of many fish species and the disruption of marine ecosystems. Thus, overfishing in the high seas remains the most critical factor, resulting in the tragedy of the global fisheries commons [3]. Governing fisheries on the high seas also remains the most challenging – so much so that some scholars have advocated for the complete "closing" of the high seas to fishing activities [79]. Leaving aside the discussion on the merit of such proposals, forging an international consensus – to close the high seas to fishing or to take any drastic measures – is extremely difficult and unlikely. Even if such an agreement is achieved, its implementation is infeasible due to prohibitive economic and political costs.

Moreover, the collective action problem concerning the governance of high-seas fisheries is akin to governing greenhouse gas emissions to mitigate climate change [42,48]. Because marginal contributions from each involved party only make a small impact (insufficient to prevent the tragedy), all involved parties have incentives to minimize their contributions and rely on the efforts of others. Thus, the lack of a governing entity and prohibitive exclusion costs make the high seas open access – free for all to exploit.

However, this does not mean that the tragedy is inevitable. Various measures can be undertaken to transform the high seas from open access to limited access or manageable commons. As discussed earlier, one measure can be rescinding expensive fishing subsidies, which have resulted in overinvestment in fishing activities on the high seas. Other measures can include introducing novel quasi-property rights systems that circumvent the lack of enforcement authority. For example, an individual habitat quota (IHQ) system – where individual quotas of habitat impact units (HIU) are allocated to fishers with a total quota fixed to maintain a sustainable target level – can be used to align individual economic incentives with habitat conservation goals [26]. Similarly, territorial use rights in fisheries (TURFs), which are a spatial form of property rights assigned to a collective group, can be used to convert open access to exclusive access systems [1].

Alongside these measures, some other complementary measures that can be implemented in tandem to alleviate pressures on the high seas commons include:

1) The private sector can be encouraged to intensify and expand sustainable aquaculture and offshore fish farming to partially offset the demand for fish stemming from the high seas [18].
2) Nonprofit organizations and private companies (such as supermarkets, restaurants, etc.) can be incentivized to promote consumer awareness regarding the impact of their consumption on the health of the global fisheries stock. They can take steps to promote more sustainable forms of fishing through better labeling methods and knowledge sharing. They can increase efforts to provide consumers with reliable information about companies and countries that practice sustainable fishing (and those that do not) so that they can make informed decisions. Various initiatives and organizations already exist that adopt similar strategies: for example, Alaska Sustainable Fisheries Trust, Center for Oceans, and Global Salmon Initiative. Such initiatives can benefit from more resources and publicizing.
3) National and international conservation agencies and nonprofit organizations can leverage new technologies, media, and diplomacy to promote sustainable fisheries management. For instance, new tools can track fishing boat movement, which can be utilized to detect illegal fishing activities. Such activities can then be reported to cooperating countries so they may take legal action to discourage future activities. Media and diplomacy can be adopted to influence or put pressure on non-cooperating countries, if necessary. An example of such an effort is the Global Fishing Watch (GFW) database, which uses automatic identification systems (AIS) and vessel monitoring

systems (VMS) to collect data on individual vessel behavior, fishing activity, and other characteristics in near real-time. GFW database provides vital services to states with less technical capacity and resources to prevent illegal and unsustainable fishing [20]. These efforts can be further legitimized and expanded using narrowly focused regional surveillance agreements and non-traditional maritime security cooperation [9].

4) When considered jointly with an entire menu of low- and mid-level efforts, global consensus, if achieved, can be pivotal in setting the stage for furthering conservation goals. Thus, efforts towards forming such global alliances can go hand in hand with all the other lower-level measures. One example of such an effort is the new "High Seas Treaty" signed on June 19, 2023, which has been described as "the watershed moment in global ocean management and marine conservation" [16]. Although the specific details of the treaty remain subjects of open discussion, to be determined by working groups of experts and country representatives, it marks, at least symbolically, the beginning of a long and difficult process of ending lawlessness on the high seas.

5. Concluding remarks

Analyses of the problem of global fisheries depletion suffer from the panacea problem [81]. Thus far, significant scholarly efforts have been expended in establishing the superiority of a specific solution and in refuting alternative solutions that are deemed suboptimal. As a result, the problem has been inappropriately aggregated, homogenized, and simplified, and the institutional context has been stripped away to comply with the assumptions and conclusions of academic exercises. Simple and elegant solutions derived from such exercises conducted within an institutional void, when implemented in the real world, either do not work or generate counterproductive results.

This paper offers an analytical alternative to move away from the panacea trap. Rather than viewing the global fisheries commons as a singular problem, we argue that it is a nested set of collective action problems of diverse scales and features, organized in different horizontal and vertical levels and affecting different parties across overlapping jurisdictions. Under this alternative framework, our perspective emphasizes the complementarity of diverse solutions at different levels. Market-based approaches such as ITQs that rely on price signals have proven their efficacies in many fisheries worldwide. However, their applicability is limited to contexts where effective and accountable political institutions exist. Where such institutions are absent, ITQs can serve as extractive tools that governments and external entities can use to remove de facto property rights from indigenous communities. The role of governments is also critical in addressing coordination challenges at the higher level. One achievable government action could be rescinding fisheries subsidies, which have led to massive declines in fisheries stock worldwide. Finally, we discuss the importance of community-based solutions in addressing the problem at the local level in a manner that can promote concerted efforts to solve the challenge of governing the "global fisheries commons" by partitioning it into more manageable local problems.

CRediT authorship contribution statement

Pablo Paniagua: Writing – original draft, Conceptualization. **Veeshan Rayamajhee:** Writing – original draft, Investigation.

Declaration of Competing Interest

The authors of this paper declare no conflicts of interest. No potential conflict of interest was reported by the author(s).

Data availability

No data was used for the research described in the article.

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