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Balancing protection and production in ocean conservation

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With the acceleration of the global biodiversity and climate crises, the need to protect and sustainably manage ocean resources has never been greater. However, the science needed to integrate ocean protection (through marine protected areas and OECMs) and sustainable production in the blue economy (particularly pelagic fisheries) remains underdeveloped and contested. The scientific divide and the knowledge gaps still remaining have created serious real-world challenges for practitioners seeking to reconcile protection and production approaches, and is hindering progress in achieving global conservation targets. Here, we identify the vital science necessary to bring together the "twin pillars" of protection and production, integrating mutually reinforcing meaningful protections at scale, while also driving management of production systems to internationally accepted sustainability standards. The research community must rapidly develop this new horizon of ocean science – particularly in pelagic ecosystems - to aid countries and practitioners in achieving global conservation and sustainable development targets.

The recent adoption of the Kunming-Montreal Global Biodiversity Framework[1] and the High Seas Treaty[2] has increased the impetus for the establishment of more marine protected areas (MPAs) and other effective area-based conservation measures (OECMs) to reach the global "30 by 30" target. As a response, more than US$ 1 billion has been committed by private and public funders to reach this goal. At the same time, there is increased interest and investment in the blue economy[3], fueled by the recognition of the unrealized potential of ocean sectors as economic drivers[4], as well as the interest among ocean-dependent countries to develop more resilient economies as they recover from the pandemic.

These two imperatives — the need for increased protections in the form of MPAs and OECMs, and sustainable production in the blue economy — are often in tension with each other. In many ways, this is one of the oldest problems in conservation[5], pitting economic development priorities and human rights issues against biodiversity protections[6]. This issue is now coming to the fore in the ocean realm[7].

These issues are particularly pressing in pelagic ecosystems that cover the majority of the world, where a proliferation of large-scale "blue water" MPAs (which primarily encompass open-ocean, pelagic ecosystems) is colliding with longstanding efforts to manage pelagic migratory fisheries that are vital for global food security, and the livelihoods and economies of many developing countries (Box 1). This area is a relatively new horizon for ocean conservation and presents distinct challenges compared to coastal seas, where MPAs and sustainable fisheries interventions have benefited from investments in science, finance, and policy for more than two decades.

These tensions are not uncommon in conservation, but the need to reconcile protections alongside sustainable production systems – particularly fisheries – has gained new impetus as countries have grappled with the sustained impacts of the global pandemic and the economic vulnerability it has generated for developing economies. For the practitioner community, this puts an increased emphasis on the need to reconcile the economic development needs of countries with the opportunity costs of putting protected areas in place as essential safeguards of biodiversity and natural capital. This critical task has been exacerbated by current global economic stresses, which overlay an ongoing biodiversity and climate crisis.

Now, the burgeoning interest in the establishment of blue water MPAs calls for a robust and interdisciplinary scientific effort to understand how to design and integrate large-scale protected areas with the sustainable development of the blue economy – particularly pelagic fisheries. Unfortunately, the areas of science for protection and production in the blue water realm remain largely in separate siloes, promulgated by separate communities. At best, these two fields have very little integration and at worst, they have been

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antagonistic in terms of their findings[8–11]. As a result, the solutions required to integrate protection and production thus far remain out of reach.

Here, we highlight three research fields that must be prioritized by the scientific and practitioner community, in order to simultaneously reach the global ambitions of the "30 by 30" target, while also securing the vital food, livelihood, and economic benefits of the blue economy through sustainable production. Our overarching goal is to initiate increased scientific attention to integrated solutions that bring together the best of protected area planning and management and sustainable development of vital ocean economy sectors.

Resolving the science underpinning blue water MPAs and pelagic fisheries management

First, there needs to be rapid and meaningful investment by governments, philanthropic foundations, development banks, and research funds in the science underpinning blue water MPAs and the integration with pelagic fisheries management. Achieving the global "30 by 30" target for ocean protection cannot be done without blue water MPAs. Blue water MPAs, which primarily encompass pelagic, open-ocean ecosystems, are proliferating in number[12]. Over the past 20 years, 38 large-scale (>100,000 km^2) blue water MPAs have been established, representing a total area of more than 20 million km^2.

Currently, the establishment of blue water MPAs is outpacing the available scientific evidence of conservation impact and threat reduction for biodiversity in pelagic habitats. For coastal seas, the original scientific rationale underpinning the 30% protection target required significant effort to bring together insights from a broad range of disciplinary fields including population biology, reserve modeling and design, fishery science and other scientific research[13,14]. These early interdisciplinary scientific efforts set a strong foundation in place and inspired decades of ongoing research to inform the design and implementation of coastal MPAs[15] together with fisheries management efforts[16,17], with myriad examples from the scale of entire regions[18] to large-scale multi-use managed areas[19].

A concomitant effort to develop the fundamental science to guide the design and implementation of blue water MPAs must be a focus for the research community, which will surely be a challenging but rewarding endeavor (Box 2).

Although there have been advances in the science of large-scale MPAs[7–11], the implementation field is relatively young, and the key science to evaluate and understand the impacts of these interventions remains largely under-developed and contested, in terms of understanding the effects on habitats, key species, ecosystem services, ecological processes and socio-economic performance[20,21]. Additionally, many blue water MPAs have been established in areas with little human activity[22,23] and management authorities often have limited capacity to address existing concerns (such as illegal or unreported fishing), both of which limit collective understanding of the potential benefits of these protected areas[24]. Initial investments have also been made in the social science agenda for blue water MPAs, making progress in this important area of research that has myriad implications for management and therefore must remain a priority for research (see below)[25].

In contrast, there is far more development of science on production in blue water systems, owing to the significant research investment that fisheries management institutions have made. Pelagic fisheries management relies on a sophisticated set of methods and models to predict the impacts of various management measures on the population dynamics of target species. More than two decades ago, the field expanded to focus on ecosystem-based fisheries management[26] – broadening the research field to incorporate interactions among target species and other populations[27].

However, even with these developments in pelagic ecosystem science, there are major data gaps that exist, which stymie efforts to integrate fisheries management efforts with blue water MPAs. For example, the number, distribution and size of self-replenishing populations of the major targeted migratory fish stocks including the locations of key spawning and nursery sites are largely unknown[28]. Another example concerns minimizing impacts

Box 1 | Kiribati and the Phoenix Islands protected area

In November 2021 the Pacific Island nation of Kiribati announced they would open the Phoenix Islands Protected Area — an MPA the size of California — to industrial fishing. Under strict protection for 7 years, the Phoenix Islands were prime fishing grounds for the tuna industry prior to its closure. Under stress from the pandemic and other economic factors, the government made its position clear: the protected area's value could not match the perceived revenue Kiribati would make from licensing foreign fleets to extract fish. The protected area was subsequently opened to fishing in January 2023[61].

Box 2 | Confronting the challenges of blue water MPA science

Developing the scientific foundation for integrating MPAs and fisheries management in pelagic zones will not be an easy task. The ecology and physical environment of blue water ecosystems differs significantly from coastal seas[62]. Pelagic ecosystems encompass static features of the open ocean (e.g. seamounts, shelf systems, ridges) as well as mobile and dynamic habitat types (fronts, eddies, upwelling zones), and extreme vertical habitat stratification from the surface to the deep seafloor. Migratory species such as tunas, sharks and billfishes can move vast distances, transcending multiple jurisdictional scales, complicating both fisheries management and the benefits of area-based approaches to protect biodiversity[63]. Further, the biodiversity in deep-water and pelagic habitats remains largely unknown and undescribed[64,65] further complicating conservation.

Additionally, as oceans warm due to climate change, habitats are shifting and species are on the move[66,67], which presents further challenges for existing management approaches for both fisheries and protected areas[68,69]. Re-distribution of ocean resources is also expected to exacerbate the potential for conflict among countries, eroding incentives for collaborative management of shared stocks and endangered and threatened species[70]. New approaches for blue water MPAs and fisheries may need to be explored, including mobile and dynamic protections that may increase the efficiency of conservation benefits as well as fisheries management objectives[71,72].

In recognition of this, key knowledge gaps have been identified by several multi-stakeholder initiatives drawing on a multitude of disciplinary fields. These efforts have identified several key research areas deserving more attention, including understanding the efficacy of blue water MPAs for threat abatement and biodiversity protection throughout the water column (including the deep sea), design attributes and planning for blue water MPA effectiveness, outcomes of blue water MPAs on fishery performance, effort displacement, and conservation measures, human dimensions issues, and other key topics. (See Appendix F in ref. 73 for a full assessment of previous efforts in this space). As researchers develop initiatives in this space, building on this nascent foundation will need to be a priority.

on non-target species such as sharks, turtles, marine mammals and seabirds, which are a focus for both fisheries management and blue water MPAs, and require additional science to understand the relative efficacy of different measures applied by regional fisheries agencies to conserve these vulnerable species[29].

Research on blue water MPAs and pelagic fisheries continue, for the most part, operating in separate communities, with little overlap. There is, however, some emerging evidence for how blue water MPAs and management measures for pelagic fisheries could be harmonized to produce social and ecological benefits[30]. For example, some large-scale MPAs are sizeable enough to protect spawning zones for fished migratory species, even through ENSO cycles[31], and some highly mobile species may exhibit more site fidelity than perhaps has been previously known[32–34]. The nascent science on large-scale MPAs creates an important opportunity to further understand how these protections benefit ecosystem biodiversity and impact both targeted and non-targeted species[35].

Developing economic science and financing solutions for integrating protection and production

Second, the economic science and conservation finance innovations to support blue water MPAs and pelagic fisheries need to be developed, so that communities and governments can support management actions for both protection and production in their jurisdictions over the long-term. The global Covid-19 pandemic made the opportunity costs of protected areas more visible as countries have had to grapple with severe financial pressures and face stark choices to rebuild their economies[36]. For many countries, the decision to set large areas of their sovereign waters aside in MPAs, particularly no-take zones, will be highly influenced by the extent to which these protections generate tangible economic or other benefits for communities[37,38]. In other words, it has become harder in the short term for countries to adopt MPAs if it involves economic loss, even if these protection measures may build long-term resiliency.

For ocean-dependent nations, no-take closures may result in short-term direct loss of revenues from licensing of fishing vessels and related revenue streams (e.g., taxes, fees), as well as the potential for future opportunity costs associated with regional arrangements for fishing quota or access, or for other blue economy sectors that may develop in the future. Pacific small island developing states are a prime example. These countries have limited opportunities for economic diversification and their governments depend heavily on tuna fishing access fees[39], but there is interest in alternative opportunities for financing.

Unfortunately, the economic science and financial dimensions of blue water MPAs remain under-developed and poorly understood[40], relative to current understanding of the direct revenue generated from pelagic fisheries and other blue economy sectors. Existing research suggests the costs of establishing large MPAs can be significant[41], on the order of >USD 1–10 M[42], with management costs for staffing, programs, and other management needs ranging from ~1 M to >10 million USD per year, depending on the context[43,44]. Whereas start-up costs are often supported by short-term philanthropic financing or direct development aid[45], there are limited mechanisms for long-term support except by the governments themselves, which forces the costs of protection into competition for finite budget resources that may be needed to support other government priorities. Compared to coastal MPAs, which can impose tourism entry fees and other mechanisms for revenue generation, the options for blue water MPAs currently appear more limited. However, there may be new and emerging economic opportunities associated with the benefits of closure such as improved foreign aid or other novel financial instruments stemming from protecting ecosystems and biodiversity.

These short-term opportunity costs have more visibility in governmental budgets than the long-term values protection may generate (Box 3). For example, protected areas may preserve key biological mechanisms that sequester carbon in the deep sea and open ocean[46] and may also keep intact key food chain dynamics and processes that are vital to ecosystem function[47,48]. Diminishing these services can be expected to create future liabilities for countries. Research that uncovers the processes and mechanisms that successfully maintain biological communities, and their time scales, will be essential to understand and implement more effective protections and how these conservation actions may benefit production systems in the longer-term.

A new set of conservation financing approaches holds promise to support implementation of integrated protection and production solutions for countries. Most of these approaches are based on development of the blue economy, such that countries capture more value from their ocean resources and utilize that increased value to support both improvements in their fisheries management and other blue economy sectors, as well as to finance protected areas in the long-term. These conservation finance approaches will need to be tailored to the unique context for regions where they are applied, and involve key stakeholders to ensure success.

A promising model, for example, has emerged in the Republic of the Marshall Islands, where the government has entered into a commercial relationship with Walmart to source sustainable tuna, creating more value for both partners and supporting conservation initiatives in the country[49]. Under this arrangement, the country licenses the harvesting and processing functions but maintains ownership of its tuna commodity, selling directly to the buyer. If successful, this will generate more value from the fishery than the more common model of licensing foreign fleets to catch the fish. Additionally, a portion of the revenue generated is dedicated to supporting conservation initiatives, including MPAs, which can in the long-term create the conditions for self-financing both fishery improvements and protected areas[50].

Another conservation finance solution, blue bonds, are being trialed in several countries to finance protection and production. In the Seychelles, for example, international investors provided USD 15 M to finance the expansion of protected areas, sustainable fisheries initiatives, and a diversified blue economy[51]. Other approaches, such as the Project Finance for Permanence (PFP) model[52], may also be worth exploring in ocean conservation initiatives. The PFP approach has gained momentum in terrestrial applications as a model to finance long-term durability by mobilizing significant funding to support the establishment of protected areas, creating a spend-down fund that is replaced in the long-term by new sources of revenue from production to ensure long-term durability of the conservation initiative.

These innovative approaches hold much promise for making protection and production mutually beneficial and economically durable in the long-term, unlocking the potential for larger-scale financing for countries. Such approaches are developing rapidly, thanks to increased development of these approaches by private sector partners, multilateral funders and philanthropic organizations. Most of these models derive from terrestrial

Box 3 | Emerging science for blue water MPAs and pelagic fisheries

Some emerging scientific insights from blue water MPAs and pelagic fisheries are already finding their way into practice. The Galapagos Marine Reserve, for example, protects an important oceanic habitat where juvenile tuna aggregate, which may serve to build long-term resilience in tuna stocks[74]. Similarly, the Pacific island of Niue has applied an integrated approach across its sovereign waters that includes a no-take MPA (Niue Moana Mahu) covering 40% of its maritime domain, and five managed marine resource use zones that sustain production from its vital fisheries. The Niue approach incorporated a robust assessment of stakeholder values for the blue water realm, built on traditional knowledge and culture, scientific and socio-economic assessments, and collective leadership which formed the foundation of a balanced, whole-domain management initiative that balances protection and production[75].

applications, and need to be further accelerated and diversified to aid countries to achieve the long-term economic security and natural capital benefits of well-managed MPAs and the blue economy.

Increased social science is key to support equity and justice

Third, social science is also needed to enable social equity and justice as MPAs and fisheries interventions continue to develop in the pelagic realm. Large blue water MPAs have and continue to be predominantly established in the sovereign waters of countries from the global south and overseas territories[53]. These developing coastal States therefore carry a disproportionate burden for the global implementation of "30 by 30," sparking debates and apprehensions regarding social justice[54].

The Pacific Islands, for example, have a tradition of marine management and conservation, and have become the global focus for blue water MPAs, with support from international actors, including nonprofit organizations, multilateral institutions, and philanthropic foundations[44]. Research in the region finds that equity and proportionality concerns ranked high in the list of challenges perceived by local ocean stakeholders[55]. These concerns are exacerbated by a mixed record with respect to the processes, engagement approach among actors, and outcomes of these efforts, pointing to the need for more robust consultative approaches and science-based planning efforts, led by indigenous peoples and local communities. For this region, and others, this dynamic is not new for developing countries. The global demand for fish has required developing nations to manage the pressures from larger, more powerful interests for decades, creating power mismatches and driving inequitable outcomes for coastal communities[56,57].

Without consideration of these equity dimensions, the disproportionate burden can translate into inequitable benefit-sharing between local communities and global actors. This issue featured prominently, for example, in the negotiations on the High Seas treaty, where issues of equitable benefit sharing for marine genetic resources was a major focus among countries, and stalled progress on the treaty progress until the treaty language was reconciled. Eventually, countries agreed to develop a multilateral benefit-sharing mechanism for marine genetic resources and digital sequence information for marine biotechnology ventures operating in the high seas, which enabled the necessary language to be finalized to progress the High Seas treaty to completion. Similar concerns about equity and disproportionate burden in coastal MPAs have resulted in calls to establish codes of conduct for marine conservation[58], which requires robust social science data and analysis.

More social science and innovative methodologies are needed to assess the equity dimensions of blue water MPAs, particularly given the diverse social, economic and cultural interests of countries, industries and organizations that have a stake in the pelagic zone[59]. This is a major need, given the global push to establish blue water MPAs and OECMs, and the socio-economic ramifications of these protections (e.g., loss of revenue, access to resources, and other social impacts) on the economies of developing countries, and the equity concerns of the global south shouldering the disproportionate burden of these protections. Given the strong interaction between no-take closures and fisheries in these zones, the integration of social science into planning and implementation processes is an absolute imperative to balance equity and justice concerns[60].

Further development of social science initiatives to understand key issues relevant to stakeholder engagement, community perspectives and priorities, and other key social parameters is necessary. The development of this research may help practitioners avoid incoherent conservation and management frameworks, and to support the design, implementation and monitoring of effective management approaches in blue water ecosystems that optimize protection of biodiversity and sustain production benefits from fisheries and other vital economic sectors.

Conclusions

At the Our Ocean meeting held in April 2022 in the Republic of Palau, H.E. President Surangel Whipps Jr opened the conference by highlighting the plight of small island developing nations in dealing with the crisis of the pandemic, and outlined an ambitious plan to ensure the prosperity of his ocean nation by investing in a whole-domain management approach that balanced protection and production. It was a bold step that encompassed a new vision for conservation to prioritize, and balance, the development of the blue economy and protection of vital biodiversity and ecosystem health. To make this vision a reality, the scientific and practitioner community will need to work together to develop and integrate the science to support protection and sustain production at scale, addressing key knowledge gaps that are preventing progress in conservation in practice. The pandemic has exposed the vulnerabilities countries face in balancing these priorities, but it has also created an opportunity for a broader community of practice to come together to support the global need for a healthy ocean.

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Author contributions

JNK concieved of the research study, and all authors contributed equally to the development of the manuscript.

Competing interests

The authors declare no competing interests.

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