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Beyond the boundaries: How regulation-centered marine protected area information improves ocean protection assessments

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ABSTRACT

Comprehensive, spatially explicit data that include regulatory information are essential for evaluating the level of protection that marine protected areas (MPAs) and other marine managed areas (MMAs) provide to marine life, and to inform progress towards ocean protection targets. An analysis based on the ProtectedSeas database, which includes information on regulated activities, found that 85% of U.S. waters are in managed areas that restrict living resource extraction at some level above generally applicable regulations, with 52% managed at a low level of protection and 3% managed as highly protected no-take areas. States with the most state waters area in no-take MPAs are Hawaii (~25%), California (~9%), and Oregon (~3%). The majority of highly protected areas in U.S. waters exist in low-populated areas of the Pacific, such as the Papahānaumokuākea and Pacific Remote Islands Marine National Monuments. Under a quarter of U.S. waters are closed to bottom trawling, with the West Coast and Alaska each contributing one-third of trawl closures by area. Bottom trawling is prohibited in nearly 90% of West Coast waters. Focusing on waters off California showed that overlapping management and fishing gear restrictions can increase overall protection. In state waters, no-take MPAs account for roughly 9% of the area, while restricted take MPAs of different types cover 27% of the area. About 40% of California state waters are in some kind of MPA, while 13.4% of state waters have a high level of protection from fishing impacts. In federal waters off California, under one percent are in no-take areas while nearly all waters are subject to some kind of fishery restriction. Capturing regulatory information at the individual MPA and MMA level will improve assessments of current protection, inform planning of new protections, and provide ocean users a more accessible way to increase compliance through awareness.

1. Introduction

The designation of marine protected areas (MPAs) has been ramping up worldwide, driven by global conservation targets (e.g., Aichi Biodiversity Targets of the Convention on Biological Diversity) and growing concerns about declining ocean resources and loss of marine biodiversity [1,2]. With a goal of meeting these global conservation targets, many large MPAs have been designated by countries in their remote distant waters [3], resulting in significant logistical challenges in enforceability [4,5]. Further, MPAs are often designated without implementing actual regulatory protections (so-called paper parks) [6], or the siloed nature of the regulatory framework and the lack of transparency of regulations on activity restrictions within MPAs make both estimating protections and compliance by marine users difficult. Estimating progress towards national and global targets for ocean protection requires comprehensive, reliable, and accurate information on boundaries, governance, and allowed activities within MPAs [1,3,7–10]. These types of data are also necessary to identify spatial and regulatory gaps in protection in support of more systematic conservation planning to advance ocean conservation [11–13].

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Many factors impact MPA effectiveness at protecting marine life, including size, location, habitat representation, ecological connectivity, and, importantly, the degree to which extractive marine activities are restricted or prohibited [7,14–16]. Globally, MPAs vary from fully protected no-take areas to less protected areas that allow many types of resource extraction or other human disturbance. Positive conservation outcomes from MPAs are largely dependent on their stage of establishment (ranging from proposed to actively managed) and the level of protection afforded to marine life and habitats, ranging from minimally to fully protected [17]. While different types of MPAs with different levels of protection may be needed to balance biodiversity conservation and human needs, MPAs that allow for significant extractive uses are less likely to contribute towards global biodiversity protection goals than fully protected areas [3,15,17,18].

Estimates show that only about 2% of the ocean is within fully implemented and strongly protective MPAs [17]. However, our ability to assess how much of the ocean is truly protected is lagging due to insufficient information on allowed activities within designated MPAs and due to a lack of inclusion in existing databases of other types of marine managed areas (MMAs) that may contribute to conservation. Different global MPA databases have led to conflicting statistics for the amount of the ocean protected, the levels of protection afforded by those areas, and how those areas contribute to conservation goals at local, national, and global scales. The World Database on Protected Areas (WDPA), developed by the United Nations Environment Programme and the International Union for the Conservation of Nature (IUCN), is the primary state-sanctioned global database that is used to assess official progress towards U.N. Sustainable Development goals using the IUCN protected area categories (I-VI) (http://protectedplanet.net) [8,19]. The Atlas of Marine Protection (http://www.mpatlas.org) is an NGO-driven effort that aims to better characterize and visualize the level of protection and status of implementation of MPAs at the global scale. For U.S. waters, the MPA Inventory, developed by the National Oceanic and Atmospheric Administration (NOAA) (https://marineprotectedareas.noaa.gov/aboutmpas/), contains boundaries and associated classification attributes, including conservation objectives, protection level, governance, and related management criteria for federal and state waters.

The rapid development of online MPA databases, indicators, and indicator partnerships continues to improve the ability to quantify progress toward international biodiversity targets [20,21]. However, in order to fully understand the regulatory seascape and marine policy needs, a visual representation of the overlapping distribution of place-based regulations is needed. Most databases have been very useful for assessing general progress towards area-specific targets but did not focus on providing a full range of allowed or restricted activities within MPA and MMA boundaries. To date, the IUCN categories of protected areas (Ia, Ib-VII) have been based on the primary management objective of an MPA, but were not designed to characterize the diverse array of potential activities that may occur in an area, and therefore may not align with actual level of protection of ocean resources [5,10,22]. An effort to establish a framework that provides guidance on reporting MPAs to the WDPA and classifying MPAs within the IUCN categories is nearing completion (https://www.protectedplanet.net/en/resources/mpa-guide). Moreover, the amount of area covered by traditional MPAs only tells a small part of the marine conservation story, since many areas of the ocean are managed through other spatially explicit regulations on fisheries, energy extraction, and other ocean uses. This focus on total area protected in traditional MPAs disregards the importance of understanding which types of human activities are restricted or prohibited in MPAs and in other types of MMAs across the broader seascape [15,23]. Most global MPA databases do not include information on MMAs nor their regulated activities.

In an effort to develop activity-based protection categories, Horta e Costa et al. (2016) proposed a regulation-based classification system (RBCS) to more fully evaluate and score allowed activities (including fishing gear types, aquaculture, bottom exploitation, boating, anchoring) within MPAs. In an assessment of 54 MPAs, their assigned protection categories did not align well with globally recognized and accepted IUCN categories, indicating a need for a regulations-based framework to be a complementary approach to IUCN categories for assessing ocean protection [10,24]. The RBCS represents a significant advance in calling for more information on allowed activities in order to better classify levels of protection; however, it may be very resource intensive to implement globally as data on the full range of allowed and prohibited activities are often not available for areas in existing global MPA databases. Many MPA management plans and other regulatory documents fail to clearly define allowed and prohibited activities across a range of types of activities and ocean spaces, making it difficult to determine how protected a given area is.

A greater focus on integrating information from national, subnational, and local regulations, including allowed or prohibited activities, would not only promote a more holistic and accurate evaluation of the status of legal ocean protection, it would also promote stakeholder understanding, compliance with regulations, and enforceability inside and outside of MPAs and MMAs. In this paper, the ProtectedSeas database, which is unique in its incorporation of additional regulatory attributes on allowed/prohibited uses across a range of activities, was used to assess the overall level of protection from fishing in U.S. waters based on restrictions on extraction of marine life. These analyses provide a broader understanding of the current level of ocean protection in U.S. waters through an analysis of existing spatial management areas, both MPAs and MMAs, at multiple scales (national, regional, and state).

Table 1
Attributes provided in the ProtectedSeas database, summarized by type.

Type	Specific attributes
Basic Info	Site ID code, Site Name, URL, Country, State, Managing Authority, Designation, Year Established, Seasonal/Year-Round, Protection Focus, Species of Concern
Summary Info[a]	Purpose, Restrictions, Allowed (activities)
Regulation Links[a]	Regulation Name, Regulation URL
Activity Restrictions[a]	Level of Fishing Protection, Entry, Speed, Discharge, Diving, Removal of Historic Artifacts, Stopping, Anchoring, Landing, Dragging, Dredging, Industrial or Mineral Exploration, Construction, Drilling, Overflight or Drones
Fishing Gear Restrictions[a]	Bottom Trawling, Gillnetting, Hook and Line, Trolling, Nets, Traps and Pots, Spear Fishing, Longlining, Miscellaneous Gear, Recreational Fishing, Commercial Fishing, Tribal Exemptions

[a] Not consistently available in other MPA datasets.

2. Materials and methods

2.1. The ProtectedSeas marine managed area database

The analyses described here utilized the ProtectedSeas database, an open-source database (available at https://protectedseas.net/mpa-download-data) with data accessible to the public in various formats and platforms, which was developed as part of a public-private partnership with NOAA. The data, which build upon the boundaries in the NOAA MPA Inventory, include geographic information system (GIS) boundary and regulatory information and were gathered from a range of management agencies, authoritative sources, and institutional repositories. Spatial boundaries were compiled in a geodatabase and assigned attributes based on thorough research of official legal texts, such as state and federal codes or site-specific management plans (Table 1). Spatial boundaries that were not readily available were digitized from the coordinates or descriptions found in legal texts. The data are provided as downloadable GIS files and web mapping services with customized views, available to query through online interactive mapping applications, and provisioned as overlays by a number of nautical charting applications (e.g., Garmin, etc.) and other marine-

Table 2
Activity-based restriction categories used in the ProtectedSeas database.

Restriction categories	Description
Allowed	According to regulations, the activity is expressly allowed
Prohibited	According to regulations, the activity is expressly prohibited, or belongs to an expressly prohibited group of activities (e.g., "all fishing" encompasses each individual fishing gear)
Restricted	According to regulations, the activity is neither explicitly allowed nor prohibited, but has specific control measures in place that restrict how the activity is pursued. This could be via gear, species, vessel size or type or seasonal restrictions
Unknown	The activity is not mentioned in regulations specifically applicable to the site

related maps (e.g., Global Fishing Watch). The MPA and MMA data used in these analyses were compiled and updated in January 2020 and represent the latest regulatory information on that date.

For each management area, data from legal texts were reviewed, summarized, and used to inform regulations-related attributes. Review was focused on marine-related activities, which also informed the restriction status (allowed, prohibited, restricted, unknown; see Table 2) of 20+ marine- and fishing-related activities (Table 1).

A Level of Fishing Protection (LFP) score was assigned to each area based on an analysis of restrictions on marine life extraction and coded on a Likert 1–5 scale (Table 3). Only area-specific regulations were considered in scoring each MPA or MMA. As a result, generally applicable restrictions, i.e., restrictions that are not specific to an MPA or MMA but apply to an entire EEZ or subnational region, did not inform the LFP score. Similarly, generally applicable restrictions also did not inform the activity restriction status categories (Table 2). For example, a jurisdiction-wide bottom trawl ban *would not* cause bottom trawling to be assigned the status of 'prohibited' in each MPA or MMA within the jurisdiction. However, a regulation specifically prohibiting bottom trawling in an MPA *would* cause bottom trawling to be assigned the status of 'prohibited' in that MPA. Following this same schema, restrictions that apply to an entire MPA are not necessarily reflected in a subzone within that area, unless specifically mentioned in the restrictions for that subzone.

Using the ProtectedSeas data for marine protection analyses reveals new information on actual levels of protection based on regulations affecting marine life removal. In any given marine area, protected or not, numerous legal instruments may apply, leading to a complex management regime across the seascape with overlapping fishing or other activity restrictions. The ProtectedSeas database individually maps place-based restrictions and therefore can help understand this confusing regulatory seascape.

Two case studies were developed, including a comparison of coverage of regulatory protections on marine fishing at the national, regional, and statewide scale for the U.S., as well as a focused analysis of waters off of California. The results of these case studies provide insight into the potential for a regulation-based approach for assessing the status of marine protection in U.S. waters and globally.

2.2. Assessing the protection status of U.S. waters based on restriction on removal of marine life

The first case study was designed to explore the seascape of managed

Table 3
Level of Fishing Protection Score based on legal restrictions on removal of marine life in the ProtectedSeas database.

Level of Fishing Protection Score	Level of Restriction on Removal of Marine Life	Description
1	Least restrictive	No known restrictions on marine life removal beyond national or subnational generally applicable restrictions
2	Less restrictive	At least one species- or gear-specific restriction applies (beyond permit requirements or generally applicable restrictions)
3	Moderately restrictive	Several species- or gear-specific restrictions apply, or: • Commercial marine life removal is prohibited • Both commercial and recreational marine life removal are heavily restricted • Recreational marine life removal is prohibited, and commercial marine life removal is restricted
4	Heavily restrictive	Marine life removal is mostly prohibited, with few exceptions, e.g., very limited or relatively non-intrusive recreational/sport or subsistence fishing
5	Most restrictive	Marine life removal is prohibited (or entry is prohibited)

Table 4
Types of MPAs and MMAs in California waters in the ProtectedSeas database.

Type of restricted area	Types of MPAs and MMAs included
No-Take MPAs	State level: State Marine Reserves, No-take Marine Conservation Areas, Special Closures, Marine Recreational Management Areas, and Marine Life Refuges; Federal level: Federal Marine Reserves, No-Take National Wildlife Refuges
Restricted Take MPAs	State level: Restricted Take State Marine Conservation Areas, State Marine Parks, Fish Refuges, Restricted Take Marine Life Refuges, State Marine Recreational Management Areas, Restricted Take or Seasonal No-Take Special Closures, University Research Reserves; Federal level: Restricted Take National Marine Sanctuaries, Marine Conservation Areas, Wildlife Refuges, National Seashores, Essential Fish Habitat Conservation Areas, National Estuary Research Reserves, Restricted Take National Monuments, National Parks
Other MPAs	State level: State Water Quality Protection Areas, Other non-restricted Marine Life Refuges, Federal level: National Marine Sanctuaries, Other National Monuments, National Recreation Areas, National Seashore Closure Areas
MMA Area-based fishery restrictions, Species or Gear-Based Area Closure	State or federal level: Gear Restricted Areas, Fishery Management Areas, Special Closures, Groundfish Conservation Areas, Pacific Essential Fish Habitat Areas, Groundfish Conservation Areas, Cowcod Conservation Areas, Coastal Pelagic Species Closures and Restricted Areas, Deep-sea Ecosystem Conservation Area
Areas limiting other marine activities	State or federal level: Energy Development Restrictions, Vessel Speed Reduction Zones, Watercraft Restricted Areas, Recreational Areas, Restricted Entry Areas, Mineral Leasing Restricted Area (BOEM Ecological Preserve)

areas at a nation-wide scale in U.S. marine waters[1] with respect to protection. The U.S. region (with the exception of the Great Lakes) was chosen because of the comprehensive collection of MPAs and MMAs available which has been well reviewed for completeness via ProtectedSeas' public-private partnership with NOAA.

To resolve any complications resulting from overlapping managed areas with varying LFP assignments, all U.S. ocean areas were assigned the most restrictive or highest LFP wherever overlaps occurred. Then, area and percent coverage of each LFP score was calculated and summarized for national, regional, and statewide scales.[2]

In order to calculate LFP statistics for each region of interest, spatial layers for each LFP score (1–5) were first dissolved to remove overlap and prevent double counting, then clipped to the region of interest's boundary to remove any land components, and, finally, symmetrically differenced from the greater protection level layer(s) to isolate coverage of the lowest protection level in each iteration. This method is similar to the method the WDPA uses to calculate protected area coverage (https://www.protectedplanet.net/c/calculating-protected-area-coverage).

An additional analysis, using the calculation methods described above, focused on area and percent coverage of areas where bottom trawling is prohibited in U.S. waters (excluding the U.S. Pacific Remote and Caribbean).

2.3. Assessing the protection status, gear restrictions, and management overlap in California waters

A second case study focused on California state and federal marine waters to provide a more detailed view of MPA and MMA coverage and the cumulative protections resulting from an aggregation of overlapping gear restrictions and management areas. California was chosen due to the state's comprehensive MPA network in state waters, the number of other types of state and federal MPAs, and the extensive spatial fishery management areas (e.g., essential fish habitats, rockfish conservation areas, etc.) in state and federal waters [25]. To date, there has not been an analysis of LFP, number of gear restrictions, and overlap of all types of MPAs and MMAs off California.

First, to understand proportional contributions to marine protection from traditional MPAs versus other kinds of spatial regulatory measures, areas were categorized as either (1) no-take MPAs, (2) restricted take MPAs, (3) other types of MPAs, (4) other types of managed areas restricting fishery activities or gear, and (5) managed areas limiting other marine activities (Table 4). Coverage and percent area statistics per type of restricted area were calculated and reported for state waters (0–3 NM), federal offshore waters (3–200 NM), and overall (0–200 NM).

Next, three different analyses were conducted for a highly managed subregion in Central California, from Point Arena (north) to Cambria (south) and summarized on a hexagonal grid (10 km^2). First, each grid cell was assigned the highest LFP score amongst all MPAs and MMAs that overlapped the cell. For a second analysis, cumulative fishing gear prohibitions were derived from separate GIS layers, created to capture the prohibited area for each of eight gear types: bottom trawling, hook and line, gillnetting, trolling, nets, traps and pots, spearfishing, and longlining. Each of the eight gear layers were spatially joined to the hexagonal grid (10 km^2) and summed to derive the total number of gears (0–8) prohibited in each grid cell. Lastly, MPA and MMA boundaries were spatially joined to the grid and summed to yield a count of overlapping management areas in each grid cell. Each analysis was plotted as a heat map.

3. Results

3.1. The status of protection in U.S. waters based on restriction on removal of marine life

While only 3% of U.S. waters are restricted at the most restrictive level (LFP5 no-take; Fig. 1), extraction of living marine resources beyond generally applicable regulations (LFP2+) is restricted to some degree in approximately 85% or 10.4 M km^2 of U.S. marine waters (0–200 NM, excluding the Great Lakes). The majority of the 10.4 M km^2 within restricted U.S. waters (~61% or 6.4 M km^2) is managed as less restrictive (LFP2), with the remainder shared between 9% (900 K km^2) moderately restrictive (LFP3), 26% (2.7 M km^2) heavily restrictive (LFP4), and 3.5% (370 K km^2) most restrictive (LFP5 no-take).

At a regional scale, the Pacific Islands region is clearly notable for hosting both the largest overall marine waters (nearly 6 M km^2) and the highest percentage of marine area (6%) protected as most restrictive or no-take (LFP5) (Table 5), due almost entirely to the Papahānaumokuākea and the Pacific Remote Islands Marine National Monuments. The Pacific region is also the most strongly protected region, with over 50% of its marine area protected as heavily or most restrictive (LFP4 and 5). Conversely, the Caribbean region has the smallest marine waters area and the lowest percentage (29%) of marine

[1] U.S. marine waters included all ocean areas from 0 to 200 nautical miles (NM) (excluding the Great Lakes); boundary data was sourced from Marine Regions. State waters included all waters within state jurisdiction as defined by NOAA's maritime boundary vectors. Shared marine jurisdiction of U.S. EEZ were included. (e.g. Navassa, Puerto Rico).

[2] Area calculations can vary substantially based on projection and datum. For the analysis of U.S. waters, Cylindrical Equal Area projection with WGS84 projection was used. For the analysis of California waters, California (Teale) Albers projection with NAD83 datum was used. For both analyses, coastal bays and estuaries were included in the calculations.

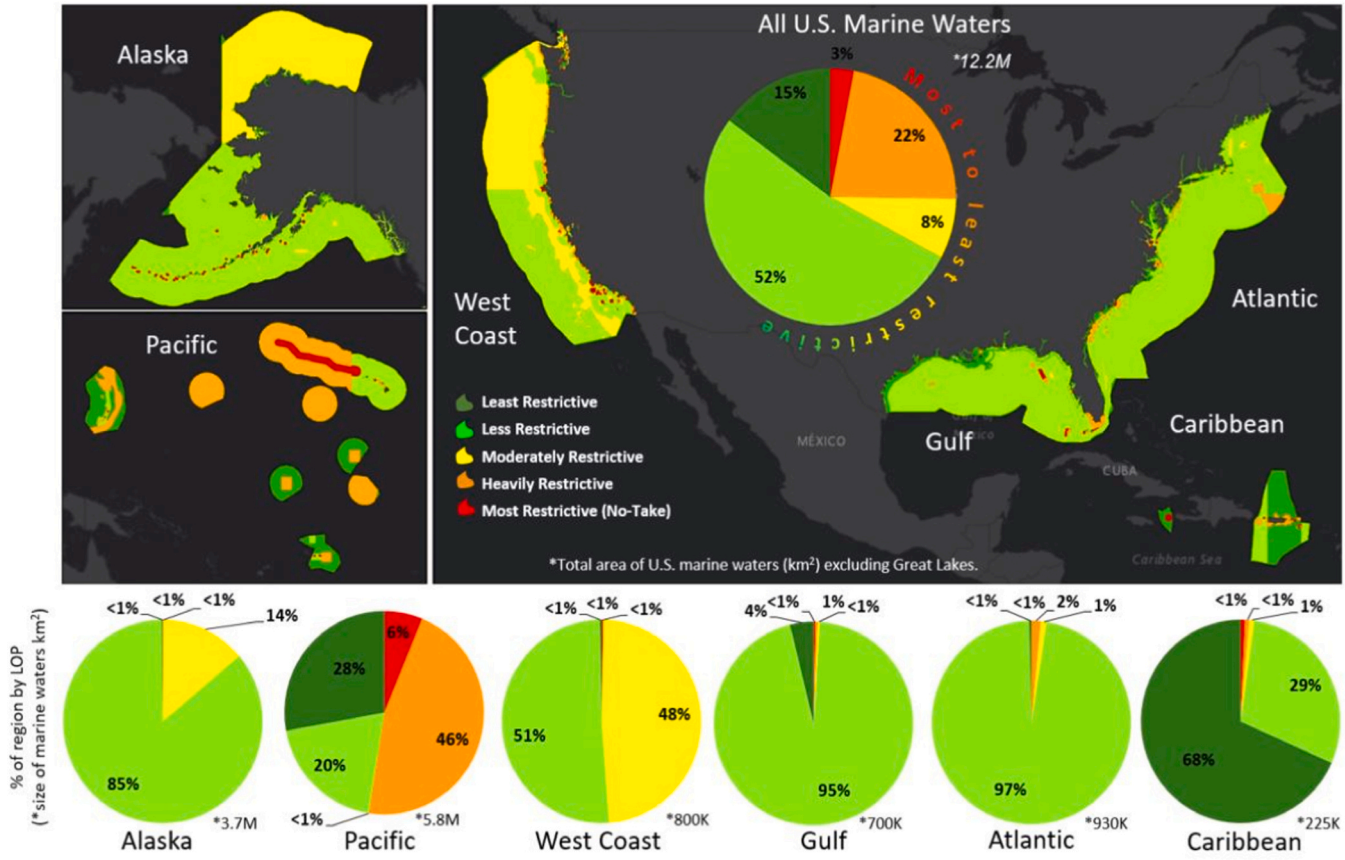

Fig. 1. Map and insets show LFP distribution across all U.S. waters with pie chart (top center) reflecting LFP categories as proportional contributions across all of U.S. waters. Regional pie charts (bottom) depict LFP categories as proportional contributions across each region's total marine water area. *Dark Gray Canvas Basemap courtesy of Esri and partners.

area that is restricted to marine resource extraction of some kind (Fig. 1). Most of the marine waters of the U.S. Atlantic (97%), Gulf of Mexico (95%) and Alaska (85%) regions are classified as less restrictive (LFP2), so while a species or gear-type restriction may be in place across these large areas, they are considerably less regulated. While the West Coast region is second to the Pacific region for overall LFP, it is not nearly as protected, with a near even split between moderately (LFP3) (48%) and less restrictive (LFP2) (51%).

All regions other than the Pacific Islands have less than 1% of their marine area classified as most restrictive or no-take (LFP5), with the smallest coverage area of no-take (< 0.01%) found in the Atlantic region. Looking more closely at state level statistics (Table 6), the highest *occurrence* of no-take area is in state waters of Alaska, Hawaii, California and Oregon, while the highest *percent* of no-take area in state waters is in Hawaii (24.7%), attributed largely to the inclusion of all state waters around the Northwestern Hawaiian Islands (Papahānaumokuākea Marine National Monument). Interestingly, while the West Coast regional statistics show < 1% no-take area, the no-take percentage in the state waters of California and Oregon, 8.7% and 2.7% respectively, show that these states have higher overall LFP in state waters than the regional level statistics might suggest.

Almost a quarter of U.S. waters is off-limits to bottom trawling (Table 7). Bottom trawling is prohibited in almost 90% of West Coast marine waters, accounting for about one third of bottom trawling prohibited areas, while other regions prohibit bottom trawling in 20% or less of marine waters. While Alaska prohibits bottom trawling in less than 20% of its waters, these waters account for another third of U.S. bottom trawling prohibited areas. The Atlantic generally has lower LFPs (Fig. 1); however, bottom trawling is still prohibited in approximately 20% of marine waters[3] (Table 7; Fig. 2).

3.2. The status of protection in California waters based on restriction on removal of marine life, gear restrictions, and management overlap

Calculating proportional contributions from traditional MPAs versus other kinds of spatial regulatory measures shows that restrictions on fishing through the combination of MPAs and MMAs cover nearly all marine waters off California (Table 8), with very little area remaining where only general EEZ-wide fishing restrictions apply. In state waters, no-take MPAs account for roughly 9% of the area, while restricted take MPAs of different types cover 27% of the area. About 40% of state waters are in other kinds of MPA, including the National Marine Sanctuaries that do not restrict fishing. Considering state waters as a whole, 13.4% are fully or highly protected from fishing (LFP 4 and 5) and 27.9% are moderately to fully protected (LFP 3, 4 and 5). In all, about 10.2% of state waters are closed to commercial fishing, while 25.3% of state

[3] This calculation includes the commercial fishing prohibition in the Northeast Canyons and Seamounts Marine National Monument, which contributes significantly to the bottom trawling prohibited area in the Atlantic. This prohibition was lifted by presidential proclamation on June 5, 2020, which is currently subject to litigation.

Table 5
Percent cover and area of U.S. regional marine waters for the highest level of fishing protection categories (3–5).

U.S. Marine Region (0-200 NM)	LFP	% of Region's Area	Area (km^2)	% of Total U.S. Marine Area (0-200 NM)
Pacific Islands	5	6.2	362,382	3.0
Alaska	5	0.1	3,390	<0.1
Gulf	5	0.3	1,938	<0.1
West Coast	5	0.2	1,824	<0.1
Caribbean	5	0.7	1,617	<0.1
Atlantic	5	<0.1	81	<0.1
Pacific Islands	4	46.2	2,687,997	22.0
Atlantic	4	1.6	14,710	0.1
Caribbean	4	1.4	3,159	<0.1
Gulf	4	0.4	2,799	<0.1
West Coast	4	0.2	1,274	<0.1
Alaska	4	<0.1	606	<0.1
Alaska	3	14.3	531,674	4.4
West Coast	3	48.5	399,777	3.3
Atlantic	3	0.9	8,666	0.1
Pacific Islands	3	0.1	4,188	<0.1
Gulf	3	0.3	2,243	<0.1
Caribbean	3	0.1	321	<0.1

waters are protected from longlining through no-take MPAs and fishery closures, including Essential Fish Habitat Conservation Areas, which make up 10.6% of state waters.

Less than 0.1% of federal waters off California are fully protected in no-take MPAs while restricted take MPAs, including Essential Fish Habitat Conservation Areas, make up 13.4%. Virtually all federal waters off California have some kind of area-based fishing restrictions, including large-scale management areas, such as the Deep-sea Ecosystem Conservation Area and Coastal Pelagic Species Closures and Restricted Areas.

Focusing in on a subregion in Central California from Point Arena (north) to Cambria (south), shows how highly managed this area is based on maximum LFP, cumulative gear prohibitions, and the cumulative overlap of management areas (Fig. 3). This geography covers over 300 miles of coast and 30,000 square miles of ocean and includes nearly 150 MPAs and MMAs. With three National Marine Sanctuaries, 64 state MPAs, and a host of spatial fishery management areas, this area has a highly complex management seascape with many different regulatory measures and management authorities governing the same ocean space for a range of intents.

In this subregion, all waters have some type of protection status, with the highest levels of protection in state waters adjacent to the coast achieved primarily through California's no-take MPAs and heavily restricted areas around key natural features (e.g., Farallon islands, Point Reyes; Fig. 3a). While gear *restrictions* are present throughout all of California waters (Table 8), gear *prohibitions* (Fig. 3b) are strongly concentrated nearshore in the state MPAs, select estuarine areas within San Francisco Bay, the continental shelf, and around the Farallon Islands and the Davidson Seamount. There are few gear restrictions for offshore waters beyond extensive restrictions on bottom trawl gear. The entire region has six or more management areas overlapping, with overlap hotspots of 16–20 areas found along the northern California coast, around the Farallon islands, and in the Monterey Bay, where state and federal MPAs and various fishery-specific management areas co-occur (Fig. 3c). In particular, the Farallon Islands area stands out as a 'most restrictive' area, with all eight gear types prohibited in some places among 15–20 overlapping MPAs/MMAs. Generally, offshore areas have fewer gear types prohibited, and less overlap of management areas.

In the U.S. many MPAs do not themselves regulate extractive uses, as these activities are often managed through other mechanisms by state fish and wildlife agencies and regional fishery management councils. For example, the three National Marine Sanctuaries (Fig. 3, Greater Farallones (A), Cordell Bank (B) and Monterey Bay (C)) off the central coast of California are assigned low LFP scores (2 = less, 1 = least, and 1 = least, respectively) because they have few to no restrictions on marine life extraction through their management or legal authorities. However, when looking *cumulatively* at the range of management approaches in place across these ocean spaces, they are actually highly regulated areas with four or more fishing gear types prohibited year-round across 43% of the Greater Farallones, 32% of the Cordell Bank,

Table 6
U.S. state waters no-take (LFP5) coverage, ranked by no-take area, highest to lowest.

State	Marine Area (0–3 NM), *(0–9 NM)** (km^2)	No-Take Area (km^2)	No-Take %
Alaska	189,855	3361	1.8
Hawaii (all)	11,895	2940	24.7
California	14,855	1296	8.7
Oregon	3832	103	2.7
Florida	37,430*(gulf side)	43	0.1
Washington	9876	37	0.4
Virginia	7131	6	0.1
Hawaii (main islands only)	8960	5	0.1
Georgia	1689	3	0.2
South Carolina	3099	2	0.1
Texas	15,967*	0.5	< 0.1
Massachusetts	6481	0.3	< 0.1
North Carolina	11,616	0.3	< 0.1
Connecticut	1613	0.2	< 0.1
Maine	7461	0.1	< 0.1
Maryland	6537	< 0.1	< 0.1
New York	4753	< 0.1	< 0.1
Mississippi	2016	< 0.1	< 0.1
Alabama	2102	0	0
Delaware	1315	0	0
Louisiana	18,388	0	0
New Hampshire	243	0	0
New Jersey	3044	0	0
Rhode Island	1170	0	0

and 25% of Monterey Bay National Marine Sanctuaries. These restrictions are tied to fishery management boundaries governed and enforced separately from the sanctuaries. So, while the sanctuaries themselves do not manage or enforce fishing regulations, the areas are managed for harmful fishing practices. This perspective, which tallies and accounts for restrictions across the seascape instead of within a boundary, suggests that ocean places like these where MPAs and other place-based management areas overlap, may have greater conservation contributions than the boundary-based LFP score would indicate.

These data on LFP, gear prohibitions and management overlap allow for analyses of protection level, existing restrictions, and management overlap at multiple scales of interest. At the local level, these data are valuable to fishermen and resource users to better understand allowed, restricted, or prohibited activities, and for resource management agencies to have a more comprehensive and multi-jurisdictional view of spatial management (Fig. 4).

4. Discussion

Accessible data on allowed and regulated marine activities at multiple scales are critical for estimating the current status of marine protections and to inform marine spatial planning for new protections and emerging marine activities (e.g., renewable energy). As the only resource that includes place-based regulatory information for MPAs and MMAs, the ProtectedSeas database enables large- and small-scale analyses based on the regulatory seascape. While *most* fishery management areas are not considered 'protected areas' under the IUCN definition (IUCN Guidelines 2017), they can have stronger restrictions (i.e., prohibit harmful gear) over larger areas, warranting consideration of their potential conservation impact and role in protected area frameworks.

When viewing the U.S. national seascape under the lens of regulated activities, fishery management areas can play a big role in protecting marine life in both state and federal waters. This analysis showed that 85% of U.S. marine waters restrict some form of living resource extraction beyond general regulations (LFP2+), with only 3% managed at the most restrictive level (LFP5) and 22% at the heavily restrictive level (LFP4). This compares to statistics quoted in other sources on U.S. MPAs, such as: '26% of US marine waters in MPAs' (NOAA MPA Center, 2017), '23.2% of US waters in strongly protected MPAs' (MCI SeaStates 2017), or '41% of U.S. national waters protected' (WDPA Protected Planet 2017). Reporting discrepancies are relatively common due to inconsistent use of terminology and classification approaches, and differences in the area included. While none of these reported statistics is inaccurate, the differences lie both in the interpretation of the term 'protected area' and in what areas are considered for inclusion. This allows for significant confusion on how well the U.S. ocean is actually protected.

The greatest concentration of highly protected marine areas (LFP4+) in U.S. waters exists in low-populated and low-use areas of the Pacific Ocean. While remote uninhabited marine areas do face threats and do warrant protection, it is also important to increase protections closer to population centers that experience more fishing pressure [26]. Fishing restrictions of some type cover most U.S. waters, but in waters off the U.S. mainland only a very small percentage is highly protected from marine life extraction. Waters off the U.S. West Coast are more highly protected than waters off the remaining U.S. mainland coasts, such as the Atlantic and Gulf of Mexico which have limited protections beyond generally applicable regulations. As this study showed, marine waters off of California are highly managed with the types of managed areas and the level and distribution of protection varying greatly from the shoreline to the edge of the EEZ. Nearly 9% of California state waters are in no-take MPAs while only 0.3% of combined California state and federal waters are no-take. But nearly all state and federal waters off

Table 7
Percent cover and area of U.S. regional marine waters for bottom trawling prohibited areas.

Regional Bottom Trawling Prohibited Areas	U.S. Marine Area (0–200 NM)[a]	Regional Bottom Trawling Prohibited Areas	Regional Bottom Trawling Prohibited Areas/U.S. Marine Area	Regional Bottom Trawling Prohibited Areas/Total Bottom Trawling Prohibited Areas	Regional Bottom Trawling Prohibited Areas/Total U.S. Waters
Area name	in km^2	in km^2	%	%	%
Gulf of Mexico Bottom Trawling Prohibited Areas	697,794	65,958	9.5	3.2	0.8
Atlantic Bottom Trawling Prohibited Areas	927,387	188,505	20.3	9.3	2.2
West Coast Bottom Trawling Prohibited Areas	824,683	725,250	87.9	35.7	8.4
Alaska Bottom Trawling Prohibited Areas	3,682,950	690,433	18.7	34.0	8.0
Hawaii Bottom Trawling Prohibited Areas	2,474,714	362,252	14.6	17.8	4.2
Total	8,607,528	2,032,398		100	23.6

[a] Pacific Remote and Caribbean waters not included.

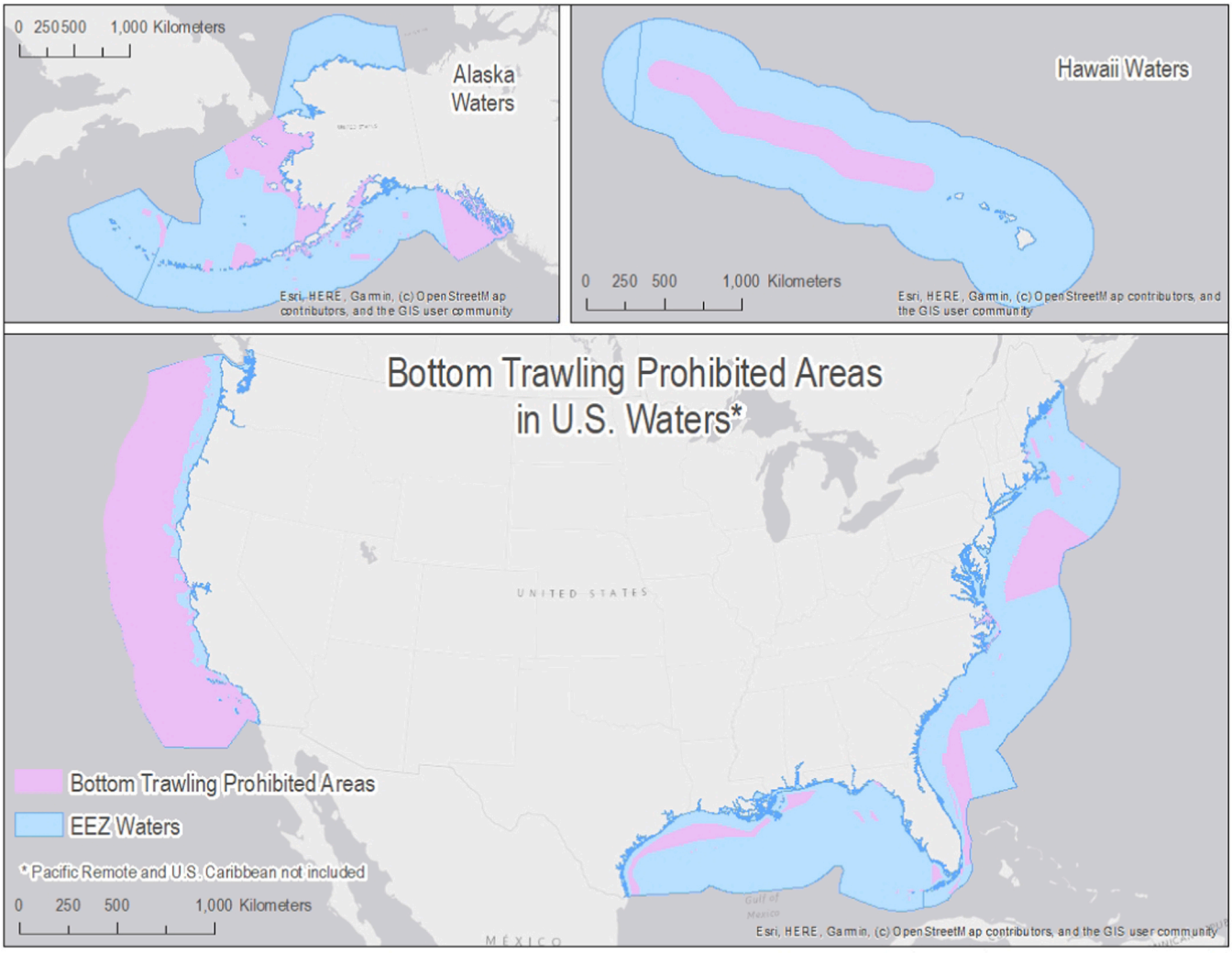

Fig. 2. Coverage of bottom trawling prohibitions in U.S. waters (excluding the Pacific Remote and Caribbean islands). Areas in purple represent areas where bottom trawling is prohibited. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 8
Coverage of spatial restrictions in California waters by type of restricted area (total area by type is not adjusted for overlapping areas of different classification).

	State Waters [0–3 NM]		Federal Waters [3–200 NM]		Total California Waters [0–200 NM]	
Type of restricted area	Area (in km^2)	%	Area (in km^2)	%	Area (in km^2)	%
No-Take MPAs	1295	8.7	387	< 0.1	1683	0.3
Restricted Take MPAs	3992	26.9	74,167	13.4	78,160	13.7
Other MPAs	5892	39.7	21,336	3.9	27,228	4.8
MMA Area-based fishery restrictions	14,649	98.6	553,550	100.0	568,198	99.9
Areas limiting other marine activities	72	0.5	1694	0.3	1766	0.3

California are subject to area-based fishery management restrictions beyond LFP1 based on a long history of area-based groundfish fisheries management and state-level MPA designations [14].

Thus, in addition to MPAs, overlapping gear restrictions in MMAs can provide additional protection for marine life in a particular location, depending on the ocean governance system in place. In the U.S., fishery management has long-standing stakeholder support, is held to strict monitoring and enforcement standards, and is mandated to track and respond to effectiveness results, which goes well beyond many traditional MPAs. To this end, some countries, including Canada, consider some fishery management closures as integrated components of their nation's conservation seascape, nominating them as Other Effective Conservation Measures (OECMs) [27,28] and include them in their reporting on national marine conservation statistics. How this choice will be globally accepted and factored into level of protection calculations is yet to be determined [29]. In other countries, Mexico for example, fishery management areas and other managed areas do not overlap with MPAs and therefore provide no cumulative protection.

A boundary-based LFP analysis may not be sufficient to quantify actual protection at a given 'place' since it would not account for overlapping management regimes and the combined protections that this overlap may afford. The contribution of managed areas to marine protection may be undervalued and a given patch of ocean may be better protected than individual evaluations of the MPAs or MMAs might indicate. The combination of overlapping restrictions in MPAs and MMAs can inform long-term marine management plans, such as commitments to protect 30% of marine areas by 2030 [30].

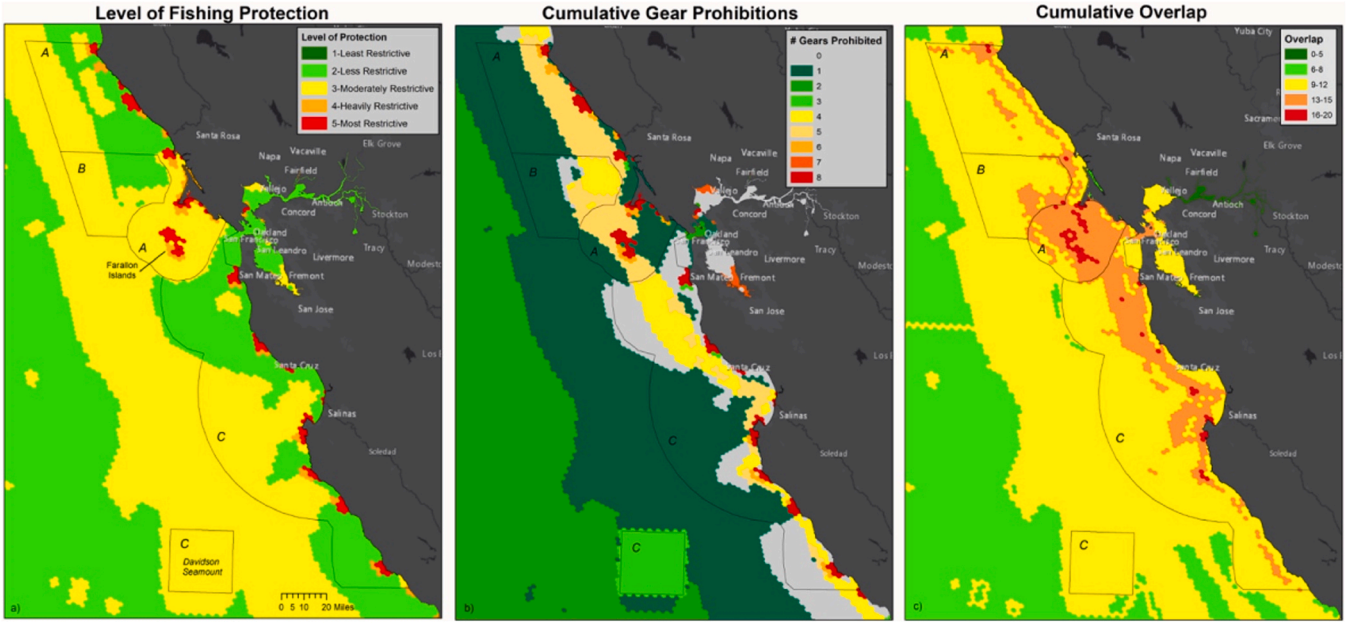

Fig. 3. Central California MPAs and MMAs. Map 3a depicts highest categorical LFP (1–5) assigned to a given ocean area; map 3b shows cumulative number of fishing gears prohibited (0–8); and map 3c shows total number of overlapping management areas (0–20). *National Geographic World Basemap courtesy of Esri, National Geographic and partners.

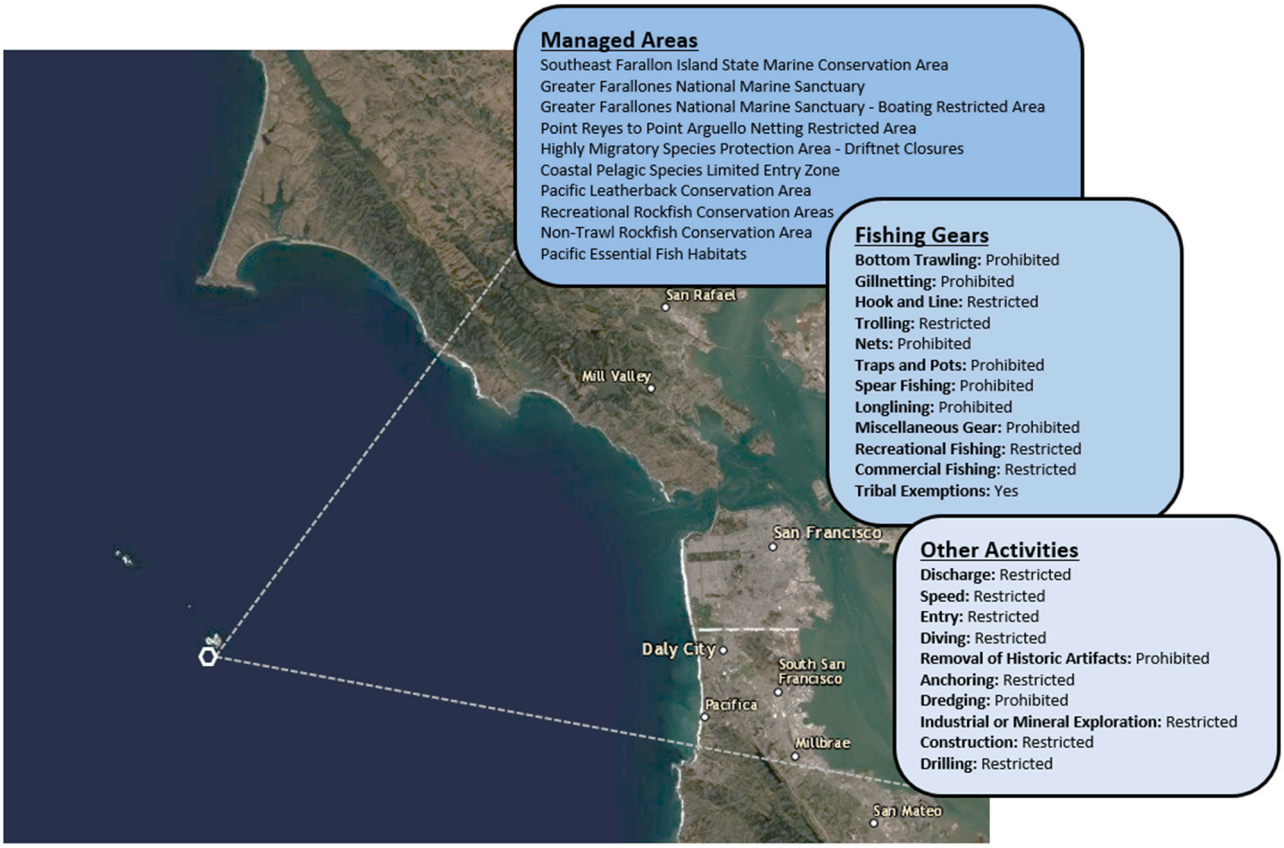

Fig. 4. Overlapping management areas and restricted fishing gears and activities within one selected 10 km^2 hexagon off the Farallon Islands, California (base map based on Google Earth image; regulatory data from ProtectedSeas database).

This highlights a need to assess cumulative/overlapping protections at an appropriate spatial scale and also implies the need for regulatory clarity and transparency for each contributing area. Better integration of MPA databases with spatially explicit resource extraction regulations (e.g., areas where different types of fishing gear or activities, ocean mining, aquaculture, energy development activities are allowed, restricted, or prohibited) would provide a fuller picture of allowed activities and level of protection to inform progress towards ocean conservation goals [10].

Providing access to accurate and readily available spatially explicit information on what are allowed and prohibited activities across the seascape (e.g., on maps, online, and through navigation software), particularly inside MPAs and MMAs, may also improve compliance. The International Hydrographic Organization recently published the S-122 Marine Protected Area product specification, which will provide a standardized method to provision MPA and MMA regulations onto large ship navigation displays in the future (S-122 Marine Protected Areas (MPAs); http://s100.iho.int/S100/product%20specification/introduction). Authoritative sources that capture the full spectrum of MPA and MMA restrictions are necessary inputs for these applications.

This study underscores the importance of global efforts to standardize MPA protection categorizations based on in-place laws and regulations, as well as incorporating MMAs or OECMs that contribute to ocean protection. These efforts are still in their nascency and promise a better understanding of how well the ocean is actually protected [17,31]. IUCN and NOAA's MPA Center offer frameworks for categorizing protected areas and evaluating coverage statistics, but challenges remain in gathering and accessing the essential information required to accurately apply them [24], especially as boundaries and management change over time. Databases that span the breadth of management approaches and integrate information on regulated activities will help inform consistent application of existing protected area frameworks. It will also be important to integrate protected area frameworks into a broader typology of human uses of the ocean [32,33]. Given significant management overlap and diversity of regulatory regimes, future work must also improve tools and methods to assess marine protection in a holistic fashion, relating cumulative management with data on human use, enforcement, biodiversity and other key indicators of ocean health [34].

5. Conclusion

Managing threats to ocean resources is largely about regulating the activities that occur within ocean spaces. Governance and categorically assigned level of protection within traditional MPAs are important for understanding seascape conservation, but alone tell only part of the story. The addition of information on regulated activities and other types of MMAs into protected area databases can improve our understanding of the true level of protection of ocean places and identify areas for improvement, as shown through use of the ProtectedSeas database. Given the large degree of management overlap already present, MPA assessment frameworks will need to develop new tools to explicitly measure cumulative management to obtain a true picture of protection status and better inform the creation of new protected areas. While progress toward conservation targets has historically relied on coverage statistics derived from protected area boundaries, this research illustrates the added value of looking beyond spatial boundaries to see protection potential through the lens of regulation-based LFP and spatially cumulative gear and activity restrictions.

CRediT authorship contribution statement

Jennifer Sletten: Formal analysis, Investigation, Resources, Supervision, Writing - original draft, Writing - review & editing. **Mimi D'Iorio**: Conceptualization, Formal analysis, Resources, Writing - original draft, Visualization. **Mary G. Gleason**: Conceptualization, Writing - original draft, Writing - review & editing, Supervision. **Alex Driedger**: Methodology, Formal analysis, Resources, Visualization, Software, Writing - original draft. **Timothé Vincent**: Methodology, Formal analysis, Resources, Data curation, Writing - original draft, Visualization. **Claire Colegrove**: Formal analysis, Investigation, Resources, Writing - original draft. **Dawn Wright**: Writing - review & editing, Funding acquisition. **Virgil Zetterlind**: Conceptualization, Software, Supervision, Project administration, Funding acquisition, Writing - review & editing.

Declaration of Competing Interest

ProtectedSeas is a part of the Anthropocene Institute. The database used for analyses in this article is the work product of the five authors affiliated with the Anthropocene Institute.

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