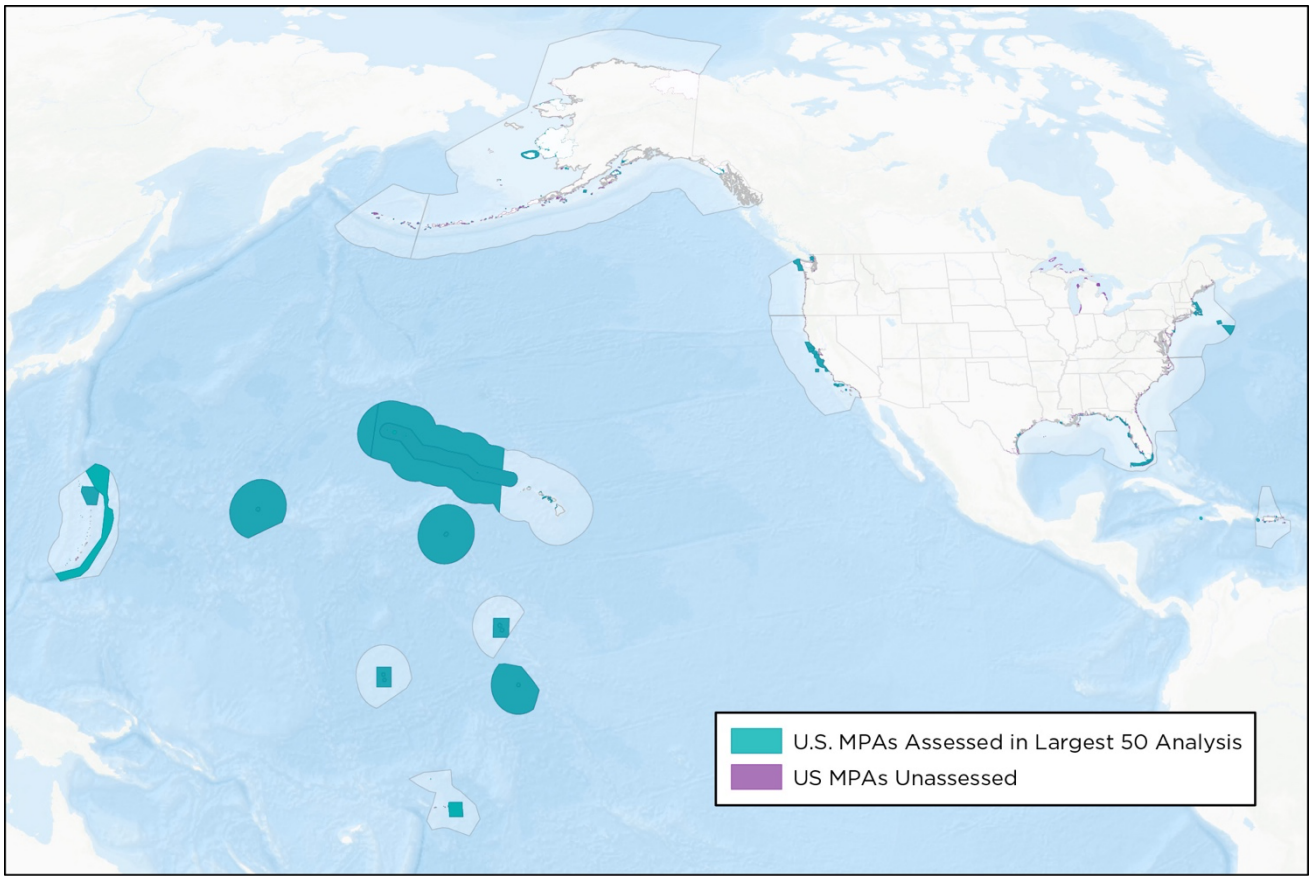
frontiers

Supplementary Material

Supplementary Figure 1. Map of 50 largest MPAs included in this analysis.



Supplementary Table 1. Types of areas in U.S. waters that may be considered MPAs.

MPA Type	Number	Total Area km^2 (marine)	Authority/Management
National Marine Monument	10	3,079,716	Designated by President through Antiquities Act; primarily located in remote Pacific; managed by NOAA and US Fish and Wildlife Service.
National Marine Sanctuary	15	104,572	Designated through National Marine Sanctuaries Act; multiple use MPAs; managed by NOAA.
National Parks	40	9,949	Designated through National Parks Organic Act; managed by National Parks Service
National Wildlife Refuges	155	242,518	Managed by the US Fish and Wildlife Service.
National Estuarine Research Reserves	29	2,920	Established and managed through partnerships between NOAA and state agencies.
State MPAs	572	28,220	State level authorities.
Territorial MPAs	62	2,885	Varies by territory.
Local MPAs	11	10	Varies by local context.
Partnership and Other MPAs	85	372,964	*Mostly partnership MPAs and other federal MPAs not captured above

Supplementary Table 2. Table of U.S. states or territories by marine area (km^2) in any type of implemented MPA in state waters.

State	Total Marine Area (km^2)	Area in Implemented MPAs (km^2)	Percent Marine Area in Implemented MPAs
Florida	38,051	16,432	43.2%
Alaska	180,788	16,227	9.0%
California	14,540	6,676	45.9%
Massachusetts	6,469	5435	84.0%
Hawaii	11,528	4,903	42.5%
Puerto Rico	13,498	3,258	24.1%
Washington	9,762	2,951	30.2%
Texas	16,258	981	6.0%
Louisiana	14,497	628	4.3%
Northern Mariana Islands	3,141	452	14.4%
Oregon	3,650	408	11.2%
American Samoa	1,329	323	24.3%
New Jersey	2,993	305	10.2%
Virgin Islands	1,535	297	19.3%
North Carolina	11,620	295	2.5%
South Carolina	2,809	248	8.8%
Mississippi	1,998	245	12.3%
Virginia	7,153	140	2.0%
New York	4,733	135	2.9%
Maryland	6,506	121	1.9%
Georgia	1,587	65	4.1%
Guam	915	47	5.2%
New Hampshire	225	28	12.7%
Alabama	2,003	20	1.0%
Rhode Island	1,182	13	1.1%
Maine	7,704	9	0.1%
Delaware	1,321	9	0.7%
Connecticut	1,504	1	0.1%

Supplementary Table 3. The four elements of *The MPA Guide* (Grorud-Colvert et al., 2021). Summary of Outcomes from http://mpa-guide.protectedplanet.net.

Element	Components	Summary Description
Stage of Establishment	Proposed/Committed	The intent to create an MPA is made public. - Site of importance identified for conservation - Conservation is the primary objective - Announced in some formal manner - Announcement is non-binding
	Designated	MPA is established/recognized through legal or traditional means. - Defined boundaries - Legal gazetting or equivalent recognition - Established for the long term - Clearly stated goals and process to define allowed uses and control impacts with associated regulations or rules
	Implemented	MPA is acknowledged to be "in force" on the water with plans for management activated. - MPA has plan for regulating activities - Existence of management body/team - Resource user is aware of MPA regulations - Plans for management activated.
	Actively Managed	Management of the area is ongoing with periodic review and changes made as needed to achieve conservation goals. There is: - ongoing monitoring - community engagement - management evaluation
Level of Protection	Fully Protected	No extractive or destructive activities are allowed, and all abatable impacts are minimized.
	Highly Protected	Only light extractive activities are allowed with low total impact, and all other abatable impacts minimized.
	Lightly Protected	Some protection of biodiversity exists but moderate to significant extraction and other impacts are allowed.
	Minimally Protected	Extensive extraction and other impacts are allowed, but site still provides some conservation benefit to the area.
Enabling Conditions	Across all Stages of Establishment	- Clearly defined vision and objectives - Long-term political will and commitment - Sustainable financing - Public participation with contextual and procedural fairness - Evidence-based decision-making - Knowledge integration, e.g., across academic disciplines, local, Indigenous, practitioner domains - Coordination with related governance institutions - Collaboration across jurisdictions - Transparency and communication

		- Upward and downward accountability to legal mandate and to stakeholders - Recognition and support of existing governance by Indigenous peoples and local rights-holders, including sovereignty, self-determination, and rights of access, use, and management - Conflict resolution mechanisms
	From Proposed/Committed to Designated	All the Enabling Conditions above, plus Ecological design principles: - Viability based on MPA location, size, spacing, shape, and permanence - Representativeness and replication of habitats - Incorporation of habitats and species of unique conservation value - Design for connectivity and resilience - Precautionary approach considering current and emerging threats - Consideration of existing threats and mitigation Social Design Principles: - Inclusion of social objectives for multi-dimensional human well-being - Recognition of pre-existing rights, tenure, uses: extractive and non-extractive - Consideration of pre-existing resource use and socio-economic status - Accounting for unequal costs and benefits to different social groups - Impact- and benefit-sharing with distributional fairness
	From Designated to Implemented	All the Enabling Conditions above, plus: - Sufficient and properly organized staffing and funding - Appropriate and adequate administrative structures and processes - Stakeholder engagement plan - Compliance and enforcement (including graduated sanctioning) - Education and outreach initiatives - Clarity of rules, rights, and boundaries
	From Implemented to Actively Managed	All the Enabling Conditions above, plus: - Ongoing monitoring, evaluation, and knowledge sharing - Adaptive management - Support for livelihoods, e.g. development programs, capacity building, hiring - Effective management of broader seascape and external pressures - Ongoing efforts to build trust, strong local leadership, partnerships with local users - Local collaboration in monitoring, enforcement, and management

		- Ongoing consideration of cultural values, traditions, and activities in site management
Outcomes expected, assuming all Enabling Conditions are in place and MPA is Implemented or Actively Managed	Fully Protected	Fully Protected areas have the greatest potential to restore and protect biodiversity and healthy ecosystems, and the benefits they provide to people. Long-term recovery of species, habitats, ecosystem functioning, and resilience is most likely in Fully Protected areas. Population replenishment and high reproductive rates inside a Fully Protected MPA can lead to greater benefits to populations outside through spillover of adults, eggs and larvae. Spillover of targeted species can also benefit nearby fisheries, leading to increased catch, profit, and long-term sustainability of the fishery. Fully Protected MPAs can also help provide mitigation, adaptation, and resilience for climate solutions, including enhancing carbon sequestration and safeguarding carbon storage in sediments, enhancing productivity, mitigating local acidification, and providing coastal protection.
	Highly Protected	Highly Protected areas also have a high likelihood of restoring and protecting biodiversity and healthy ecosystems, and delivering benefits similar to those described for Fully Protected areas. However, outcomes for any species that are still exploited or adversely impacted by activities in the MPA will likely be lower than with Fully Protected areas. Highly Protected areas may provide cultural and subsistence benefits through support of specific, limited take for traditional or cultural reasons, using specific gears and by certain user groups. Protection can enhance these values through recovery of habitats and species and by providing opportunities for continuation of sustainable cultural practices.
	Lightly Protected	Lightly Protected areas can benefit species that are given specific protections, potentially leading to larger population and body sizes, biomass, reproductive output, and genetic diversity. However, exploited or impacted species may not experience outcomes that are different from unprotected areas. Likewise, overall species diversity is unlikely to increase, except with respect to species given specific protections. Recovery of ecosystem functioning and resilience is likely to be limited and incomplete. Thus, Lightly Protected areas are unlikely to deliver the benefits healthy ecosystems provide to people, including recovery and spillover of exploited species, climate change mitigation, adaptation, and resilience, and water quality improvement.
	Minimally Protected	Minimally Protected areas are unlikely to deliver substantial positive outcomes for species, habitats, or human communities. It is likely that impactful activities in these areas will result in continued decline of species and habitats, altered ecosystem functioning, and lowered ecosystem

		resilience. Minimally Protected areas are also unlikely to deliver other benefits that may be expected from MPAs with greater levels of protection, such as for water quality, climate resilience, and exploited species. In some cases the biodiversity conservation benefits may be negligible and thus difficult to discern from unprotected areas.

Supplementary Table 4. The 50 largest U.S. MPAs and zones there-in by level of protection and stage of establishment. MPA areas were obtained from the Marine Conservation Institute's Marine Protection Atlas (MPAtlas.org) database and NOAA's Marine Protected Areas Inventory (NOAA, 2020). Certain large MPAs also overlapped with other large MPAs of different jurisdiction; when this occurred we evaluated the level of protection of each management area individually, based on the activities happening in that specific area. This is reflected in the "Rank Size" column, where sites that overlap share the same rank. Areas within the same rank add up to the total size of the largest area. Some of these large MPAs also include smaller MPAs within their boundaries which may afford different levels of protection. We did not assess these here, as the total area coverage of these small MPAs was negligible relative to the large MPA in almost all cases. However, more than 20% of the Channel Islands National Marine Sanctuary is covered by a network of other smaller MPAs, many of which are fully and highly protected (see table S7). Stage of establishment and level of protection were assessed according to The MPA Guide (Grorud-Colvert et al., 2021). The MPA Guide level of protection is assigned using a decision tree that classifies each MPA zone based on impact of the activities (out of the seven that might be occurring in an MPA as the Guide assesses: mining, dredging/dumping, anchoring, infrastructure, fishing, aquaculture, and non-extractive activities) that are occurring within the area and impacting biodiversity, regardless of managing authority (see mpa-guide.protectedplanet.net for resources and an interactive decision tree). This information is summarized in the "Most Impactful Activity" and "Details on Level of Protection" columns below. To evaluate, we used the management plans, scientific literature, information from personal communications with managers, and overlaying regulations from overlapping jurisdictions to record information on management, regulations, allowed and active uses and their impacts, including fishing gear types in use, and current threats to biodiversity. These were identified via extensive online searches using management- and activity-based keywords. The level and stage of an MPA are best assessed by local experts, such as managers, with first-hand experience of the impacts to biodiversity in an area. We contacted individual MPA experts (e.g., the MPA manager or staff) to request information if needed, for example on active management and activity impacts. New information, regulations, or changes in human activities may affect these levels and stages. For areas marked "unknown", we did not find sufficient detail on impacts and/or establishment to evaluate a level of protection and/or stage of establishment.

Rank Size	Name	Designation	Zones	Marine Area (km^2)	Stage of Establishment	Level of Protection	Most Impactful Activity	Details on Level of Protection
1	Papahānaumokuākea	Marine National Monument	Papahānaumokuākea, excluding Midway Atoll National Wildlife Refuge, Hawaiian Islands National Wildlife Refuge, and Kure Atoll State Wildlife Sanctuary	358,447.0	Actively Managed	Highly	fishing	Limited, low-impact fishing by permit
			Papahānaumokuākea 2016 Expansion	1,146,564.8	Actively Managed	Highly	fishing	Limited, low-impact fishing by permit
	Midway Atoll	National Wildlife Refuge		2,349.7	Actively Managed	Highly	fishing	Limited, low-impact fishing by permit
	Hawaiian Islands	National Wildlife Refuge		1,031.4	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Kure Atoll	State Wildlife Sanctuary		332.0	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
2	Pacific Remote Islands	Marine National Monument	Pacific Remote Islands, excluding Baker, Howland Island, Jarvis Island, Kingman Reef, Palmyra Atoll, and Wake Atoll National Wildlife Refuges	1,245,266.9	Implemented	Highly	fishing	Limited, low-impact fishing by permit
	Baker Island	National Wildlife Refuge		1,650.1	Implemented	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Howland Island	National Wildlife Refuge		1,674.8	Implemented	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring

	Jarvis Island	National Wildlife Refuge		1,740.5	Implemented	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Johnston Atoll	National Wildlife Refuge		2,187.1	Implemented	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Kingman Reef	National Wildlife Refuge		1,955.2	Implemented	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Palmyra Atoll	National Wildlife Refuge		2,029.9	Implemented	Highly	fishing	Limited, low-impact fishing by permit
	Wake Atoll	National Wildlife Refuge		2,008.1	Implemented	Highly	fishing	Limited, low-impact fishing by permit
3	Mariana Trench	National Wildlife Refuge/Marine National Monument	Trench Unit – including Mariana Trench National Wildlife Refuge	204,500.0	Implemented	Seafloor: Fully	N/A	Benthic protections only.
	Mariana Trench	National Wildlife Refuge/Marine National Monument	Volcanic Unit – including Mariana Arc of Fire National Wildlife Refuge	221.3	Implemented	Seafloor: Highly	fishing	Benthic protections only. Only infrequent use of 5 or fewer selective and low-impact gear types (e.g., single line).
	Marianas Trench	Marine National Monument	Islands Unit	42,467.7	Implemented	Highly	fishing	Limited, low-impact fishing by permit
4	Rose Atoll/ American Samoa	Marine National Monument	Rose Atoll Marine National Monument/Muliāva Unit of American Samoa National Marine Sanctuary (excluding Vaiulu'u Seamount), excluding the Rose Atoll no-take zone/Rose Atoll	34,643.0	Actively Managed	Highly	fishing	Limited, low-impact fishing by permit

			National Wildlife Refuge					
			Rose Atoll [12nm no-take zone], Rose Atoll National Wildlife Refuge	157.6	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	American Samoa	National Marine Sanctuary	Muliāva Unit - Vaiulu'u Seamount	130.8	Actively Managed	Unknown	N/A	
			Swains Island Unit	135.4	Actively Managed	Unknown	N/A	
			Ta'u Unit	37.8	Actively Managed	Unknown	N/A	
			Aunu'u Unit	15.1	Actively Managed	Unknown	N/A	
			Fagalua/Fogama'a Unit	1.2	Actively Managed	Unknown	N/A	
			Fagatele Bay Unit	0.7	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
5	Monterey Bay	National Marine Sanctuary		15,780.7	Actively Managed	Minimally	fishing	Large-impact fishing gear types in use (e.g., trawls, purse seines, gillnets)
6	Northeast Canyons and Seamounts	Marine National Monument		12,713.4	Implemented	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (red crab and lobster commercial fishing, which will be phased out by 2023; recreational fishing using e.g., single line)
7	Yukon Delta	National Wildlife Refuge		12,527.7	Implemented	Lightly	fishing	Moderate-impact gear types in use (e.g., gillnet for salmon)
8	Florida Keys	National Marine Sanctuary	Florida Keys National Marine Sanctuary, excluding SPAs, Special Use Research Only Areas, Key West NWR, Great White Heron NWR, John Pennekamp Coral Reef State Park,	6,719.9	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use (e.g., longlines, beach seines, longlines, spearfishing by SCUBA and freediving, traps, nets, lines, gleaning)

			National Key Deer Refuge, and Dry Tortugas Ecological Reserves, National Park, and Research Natural Area					
			Sanctuary Preservation Areas (SPAs)	16.5	Actively Managed	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (bait fishing using cast nets by permit, trolling in some areas)
			Special Use Research Only Areas	2.1	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
	Key West	National Wildlife Refuge		842.8	Actively Managed	Lightly	fishing	Moderate number of moderate-impact gear types (e.g., beach seines, spearfishing by SCUBA)
	Great White Heron	National Wildlife Refuge		801.5	Actively Managed	Lightly	fishing	Moderate number of moderate-impact gear types (e.g., beach seines, spearfishing by SCUBA)
	National Key Deer Refuge	National Wildlife Refuge		463.0	Actively Managed	Lightly	dredging/dumping, infrastructure	Moderate-impact activities occurring (e.g., maintenance dredging, ports and harbors)
	Dry Tortugas - North	Ecological Reserves		282.5	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring
	John Pennekamp Coral Reef	State Park		239.3	Actively Managed	Lightly	anchoring, dredging/dumping, fishing, non-extractive	Moderate-impact activities occurring (e.g., fishing using moderate number of moderate-impact gear types; anchoring in sensitive seagrass habitats; dredging can occur by permit and dumping from live-aboard vessels has discharged sewage)
	Dry Tortugas - South	Ecological Reserves		187.2	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring
	Dry Tortugas	National Park		145.4	Actively Managed	Lightly	anchoring, fishing, non-extractive	Cumulative impact of activities is moderate (e.g., anchoring in sensitive habitats (coral, seagrass); fishing using moderate number of gear types with moderate impact)
	Dry Tortugas	Research Natural Area		119.4	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring

9	Greater Farallones	National Marine Sanctuary		8,539.2	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use, including large-impact (e.g., long lines, gillnets, seines, traps, bottom and mid-water trawls, single line)
10	Olympic Coast	National Marine Sanctuary		8,255.4	Actively Managed	Minimally	fishing	Large-impact fishing gear types in use (e.g., purse seines, trawls)
11	Channel Islands	National Marine Sanctuary	Channel Islands National Marine Sanctuary excluding Channel Islands National Park	3,797.8	Actively Managed	Lightly	fishing, anchoring, non-extractive	Moderate number of moderate-impact gear types in use (e.g., nets, traps, lines, spearfishing by SCUBA); some unregulated anchoring with moderate impact e.g., in sensitive habitats
	Channel Islands	National Park		482.8	Actively Managed	Lightly	fishing, anchoring, non-extractive	Moderate number of moderate-impact gear types in use (e.g., nets, traps, lines, spearfishing by SCUBA); some unregulated anchoring with moderate impact e.g., in sensitive habitats
12	Hawaiian Islands Humpback Whale	National Marine Sanctuary		3,528.8	Actively Managed	Minimally	fishing, anchoring	Large number (>10) of gear types in use (e.g., cast nets, lines, spearfishing (free diving and SCUBA), beach seines, gillnets, surrounding nets near shore, fish traps, lines, spearfishing, traps, longlines); some unregulated anchoring with high impact in sensitive habitats
13	Steller Sea Lion	Rookery Buffer Area		3,356.4	Implemented	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring
14	Cordell Bank	National Marine Sanctuary		3,330.4	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use, including high-impact gear types (e.g., trawl, gillnets, longlines)
15	Alaska Maritime National Wildlife Refuge	National Wildlife Refuge	Afognak Buffer Zone	1,567.4	Actively Managed	Lightly	anchoring, aquaculture, fishing, non-extractive	Some unregulated anchoring including on sensitive habitats; moderate-impact aquaculture at Kitoi Bay Hatchery; moderate-impact gear types in use (e.g., gillnets, type of purse seines, trawls)
			Semidi Buffer Zone	1,008.0	Actively Managed	Lightly	fishing	Moderate-impact gear types in use (e.g., type of purse seines, gillnets)
			Simeonof 1 Mile Buffer Zone	59.1	Actively Managed	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (bait fishing using cast nets, trolling in some areas)

			Karluk Fishing Reservation Zone	27.6	Actively Managed	Lightly	fishing	Moderate-impact gear types in use (e.g., purse seines, gillnets)
			Outer Womens Bay Zone	17.8	Actively Managed	Lightly	fishing	Moderate-impact gear types in use (e.g., purse seines, gillnets)
16	Cape and Islands	Ocean Sanctuary		2,774.7	Actively Managed	Minimally	fishing, dredging/dumping, infrastructure	Large-impact activities occurring (e.g., dredging, discharge from municipal wastewater treatment plants and vessels; fishing using high-impact gear types)
17	Big Bend Seagrasses	Aquatic Preserve		2,719.8	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use, including high-impact gear types (e.g., trawls)
18	Glacier Bay National Park and Preserve	National Park and Preserve	External Waters Zone	980.1	Actively Managed	Minimally	fishing	Large-impact fishing gears in use (e.g., dredges, longlines, purse seining)
			Proper Commercial Fishing Zone	882.4	Actively Managed	Lightly	fishing, anchoring	Moderate-impact fishing gear types in use (e.g., longlines, gillnets)
			Proper Non-Wilderness Zone	214.6	Actively Managed	Lightly	fishing	Moderate-impact fishing gear types in use (e.g., longlines, gillnets)
			Proper Wilderness Zone	173.9	Actively Managed	Lightly	fishing	Moderate-impact fishing gear types in use (e.g., longlines, gillnets)
19	Everglades	National Park		2,183.9	Actively Managed	Lightly	anchoring, dredging/dumping, non-extractive	Moderate-impact activities occurring (e.g., maintenance dredging, anchoring and recreational boating damage to sensitive habitats like seagrass beds)
20	Gerry E. Studds/ Stellwagen Bank	National Marine Sanctuary		2,190.8	Actively Managed	Minimally	fishing	Large impact fishing gear types in use (e.g., dredges, longlines, purse seines, trawls)
21	Isla de Mona Nature Reserve	Nature Reserve	Isla de Mona Natural Reserve - General Protection Zone	1,418.5	Actively Managed	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (single line)
			Isla de Mona Natural Reserve (No-Take Zone)	86.6	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring
22	Cape Cod Bay	Ocean Sanctuary		1,508.5	Actively Managed	Minimally	fishing, dredging/dumping, infrastructure	Large-impact activities occurring (e.g., dredging, discharge from municipal wastewater treatment plants and vessels; fishing using high-impact gear types)
23	Navassa Island	National Wildlife Refuge		1,468.0	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring

24	Pinellas County Aquatic Preserve	Aquatic Preserve		1,398.5	Actively Managed	Minimally	fishing, infrastructure	Large-impact activities occurring (e.g., docks, piers, boat ramps, dredging channels; fishing using a large number (>10) of gear types with large impact)
25	San Juan County/Cypress Island	Marine Biological Preserve		1,177.3	Actively Managed	Minimally	aquaculture	High-impact aquaculture activities
26	Kachemak Bay	National Estuarine Research Reserve		905.5	Actively Managed	Minimally	fishing	Large-impact fishing gears in use (e.g., dredges, longlines, gillnets, purse seines, trawling)
27	Walrus Islands State Game Sanctuary	State Game Sanctuary	Walrus Islands	446.6	Actively Managed	Unknown	N/A	
			Walrus Islands - Round Island	140.3	Actively Managed	Fully	N/A	Minimal/no impactful extractive and destructive activities occurring
28	Biscayne	National Park		672.7	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use, including high-impact gear types (e.g., trawling)
29	Atchafalaya Delta	Wildlife Management Area and Game Preserve		536.3	Implemented	Minimally	fishing, mining	Large-impact activities occurring (e.g., large number (>10) of gear types in use, including high-impact gear types (e.g., trawling, purse seining); oil and gas injection wells, as well as multiple mineral leases, are within the boundaries of the WMA)
30	Cape Cod	Ocean Sanctuary		490.1	Actively Managed	Minimally	fishing, dredging/dumping, infrastructure	Large-impact activities occurring (e.g., dredging, discharge from municipal wastewater treatment plants and vessels; fishing using high-impact gear types)
31	Mission-Aransas	National Estuarine Research Reserve		459.3	Actively Managed	Minimally	fishing, dredging/dumping, mining	Large-impact activities occurring (e.g., oil and gas exploration and production are allowed; dredging for shipping; high-impact fishing gears in use, e.g., dredging, trawling)
32	Apalachicola	National Estuarine Research Reserve		443.0	Actively Managed	Lightly	fishing, dredging/dumping, anchoring, non-extractive	Large-impact activities occurring (e.g., some unregulated anchoring in sensitive habitats (seagrass beds); dredging for navigational purposes)

33	Gulf Islands	National Seashore		443.4	Actively Managed	Lightly	dredging/dumping, anchoring, fishing	Moderate-impact activities occurring (e.g., some unregulated anchoring in sensitive habitats like seagrass beds; fishing using moderate-impact gear types, e.g. beach seines, spearfishing by SCUBA)
34	North Shore	Ocean Sanctuary		425.9	Actively Managed	Minimally	fishing, dredging/dumping, infrastructure	Large-impact activities occurring (e.g., dredging, discharge from municipal wastewater treatment plants and vessels, fishing using high-impact gear types)
35	Bering Land Bridge	National Park and Preserve		377.2	Implemented	unknown	unknown	
36	Gasparilla Sound - Charlotte Harbor	Aquatic Preserve		329.6	Actively Managed	Minimally	fishing, anchoring	Large-impact activities occurring (e.g., high-impact anchoring in sensitive habitats; large number (>10) of gear types in use)
37	La Parguera	Nature Reserve		324.6	Unknown	Unknown		
38	Cabezas de San Juan	Reserva Natural		305.9	Implemented	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (single line)
39	Apalachicola Bay	Aquatic Preserve		305.0	Actively Managed	Minimally	infrastructure, fishing	Large-impact activities occurring (e.g., high-impact marinas; large number (>10) of gear types in use)
40	Padre Island	National Seashore		311.9	Actively Managed	Minimally	mining	Large-impact activities occurring (mining prospecting and exploitation (gas wells (active and capped), pipelines))
41	Jacques Cousteau	National Estuarine Research Reserve		268.0	Actively Managed	Minimally	fishing	High-impact fishing gear types in use (e.g., dredging)
42	St. Joseph Bay	Aquatic Preserve		263.4	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use
43	Punta Yegüas	Reserva Natural		262.4	Unknown	Unknown		
44	Biscayne Bay	Aquatic Preserve		266.9	Actively Managed	Minimally	fishing, infrastructure	Large-impact activities occurring (e.g., high-impact marinas; large number (>10) of gear types in use, including some that are high-impact, that have a cumulative large impact (e.g., crab and

								lobster pots, seines, trawling, seines, nets)
45	South Essex	Ocean Sanctuary		223.0	Actively Managed	Minimally	fishing, dredging/dumping, infrastructure	Large-impact activities occurring (e.g., dredging, discharge from municipal wastewater treatment plants and vessels, fishing using high-impact gear types)
46	Pine Island Sound	Aquatic Preserve		216.9	Actively Managed	Minimally	fishing, anchoring, infrastructure	Large-impact activities occurring (e.g., high-impact anchoring in sensitive habitats; large number (>10) of gear types in use)
47	Kahoolawe	Island Reserve	Zone A	201.6	Actively Managed	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (single line, spearfishing)
			Zone B		Actively Managed	Highly	fishing	Only infrequent use of 5 or fewer selective and low-impact gear types (single line, spearfishing, trolling)
48	Merritt Island	National Wildlife Refuge		182.5	Actively Managed	Minimally	infrastructure	Large-impact activities occurring (e.g., construction of causeway bridges, maintenance of waterways)
49	Rookery Bay	National Estuarine Research Reserve		222.9	Actively Managed	Lightly	anchoring, dredging/dumping, non-extractive activities	Moderate-impact activities occurring (e.g., some anchoring in sensitive habitats like seagrass beds and overnight; dredging for navigational purposes)
50	Smith and Minor Islands	Aquatic Reserve		147.7	Actively Managed	Minimally	fishing	Large number (>10) of gear types in use, including high-impact gear types (e.g., purse seines, beach seines, gillnets, crab traps, geoduck harvest)

Supplementary Table 5. Area and percent of MPAs in each U.S. Commission for Environmental Cooperation (CEC) Marine Ecoregion (Wilkinson et al., 2009) that fall within this Largest 50 analysis.

CEC Marine Ecoregion	Non-MPA Area (km^2)	MPA Area (km^2) in Largest 50 analysis	Percent of Total MPA Area included in Largest 50 analysis
Acadian Atlantic	95,108	4,684	98.9%
Alaskan/Fjordland Pacific	1,694,900	6,295	95.9%
Aleutian Archipelago	180,854	2,057	93.2%
Arctic Basin	228,997	0	N/A
Beaufort/Chukchi Seas	278,357	289	44.0%
Bering Sea	1,284,701	12,683	100%
Caribbean Sea	207,257	3,925	77.8%
Carolinian Atlantic	123,689	169	16.2%
Columbian Pacific	433,766	9,501	91.7%
Gulf Stream	307,473	0	N/A
Hawaiian Archipelago	961,401	1,511,299	100%
Montereyan Pacific Transition	245,669	27,602	98.5%
Northern Gulf of Mexico	491,765	6,817	86.6%
Northern Gulf Stream Transition	194,857	12,599	100%
South Florida/Bahamian Atlantic	68,557	13,103	92.1%
Southern Californian Pacific	98,622	3,769	88.7%
Southern Gulf of Mexico	142,423	0	N/A
Virginian Atlantic	242,796	6,293	92.8%
Not in CEC Marine Ecoregion	1,802,012	1,556,756	99.9%
Grand Total	**9,082,766**	**3,177,840**	**99.7%**

Supplementary Table 6. Area (km^2) in Protected Areas in the U.S. waters of the Laurentian Great Lakes. Also includes other areas (fish refuges, de facto protected areas, and cultural protected areas) that may qualify as OECMs. Adapted from Parker et al. (2017) and updated to include the Wisconsin Shipwreck Coast NMS.

Designation	Lake Superior	Lake Huron	Lake Michigan	Lake Erie	Lake Ontario	Great Lakes (US)	
						Total	%
Total US Lake Area	54,248	24,286	60,769	13,790	9,407	162,500	
Total Protected Area	11	11,060	0	2	0	13,565	8.2%
Other: Fish Refuge	1,099	2,089	5,508	1		8,697	5.4%
Other: De Facto	1,085	1,179	3,273	206	3	5,746	3.5%
Other: Cultural	2,292	1,160	1,701			5,153	3.2%
Total Protected Area + Other	4,487	15,488	10,482	209	3	33,161	20.0%
% Protected	<0.01%	45.5%	0	<0.01%	0	8.2%	
% Protected + Other	8.3%	63.8%	17.2%	1.5%	0.0%	20.0%	

Supplementary Table 7. Level of protection and stage of establishment for the 21.9% of the Channel Islands National Marine Sanctuary that is covered by a network of other smaller MPAs. Stage of establishment and level of protection were assessed according to The MPA Guide (Grorud-Colvert et al., 2021). The MPA Guide level of protection is assigned using a decision tree that classifies each MPA zone based on impact of the activities (out of the seven that might be occurring in an MPA as the Guide assesses: mining, dredging/dumping, anchoring, infrastructure, fishing, aquaculture, and non-extractive activities) that are occurring within the area and impacting biodiversity, regardless of managing authority (see mpa-guide.protectedplanet.net for resources and an interactive decision tree). This information is summarized in the "Most Impactful Activity" and "Details on Level of Protection" columns below. To evaluate, we used the management plans, scientific literature, information from personal communications, and overlaying regulations from overlapping jurisdictions to record information on management, regulations, allowed and active uses and their impacts, including fishing gear types in use, and current threats to biodiversity. These were identified via extensive online searches using management- and activity-based keywords. The level and stage of an MPA are best assessed by local experts, such as managers, with first-hand experience of the impacts to biodiversity in an area. New information, regulations, or changes in human activities may affect these levels and stages.

Name	Designation	Marine Area (km^2)	Stage of Establishment	Level of Protection	Most Impactful Activity	Details on Level of Protection
Santa Barbara Island	Federal Marine Reserve	113.9	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Richardson Rock (San Miguel Island)	State Marine Reserve	105.5	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Richardson Rock (San Miguel Island)	Federal Marine Reserve	82.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Harris Point (San Miguel Island)	State Marine Reserve	65.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Harris Point (San Miguel Island)	Federal Marine Reserve	61.2	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Footprint (Anacapa Channel)	Federal Marine Reserve	55.3	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Gull Island (Santa Cruz Island)	State Marine Reserve	51.6	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Gull Island (Santa Cruz Island)	Federal Marine Reserve	37.5	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
South Point (Santa Rosa Island)	State Marine Reserve	33.9	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Carrington Point (Santa Rosa Island)	State Marine Reserve	33.1	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Santa Barbara Island	State Marine Reserve	33.1	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring

Anacapa Island	State Marine Reserve	29.9	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Scorpion (Santa Cruz Island)	State Marine Reserve	25	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Scorpion (Santa Cruz Island)	Federal Marine Reserve	22.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Anacapa Island	State Marine Conservation Area	18.9	Actively Managed	Lightly	fishing	Moderate number of moderate-impact fishing gear types in use (e.g., spearfishing by SCUBA)
Footprint (Anacapa Channel)	State Marine Reserve	18.3	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Judith Rock (San Miguel Island)	State Marine Reserve	11.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Anacapa Island	Federal Marine Reserve	9.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Anacapa Island	Federal Marine Conservation Area	6.1	Actively Managed	Lightly	fishing	Moderate number of moderate-impact fishing gear types in use (e.g., spearfishing by SCUBA)
South Point (Santa Rosa Island)	Federal Marine Reserve	4.9	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring
Painted Cave (Santa Cruz Island)	State Marine Conservation Area	4.6	Actively Managed	Lightly	fishing	Moderate number of moderate-impact fishing gear types in use (e.g., spearfishing by SCUBA)
Skunk Point (Santa Rosa Island)	State Marine Reserve	3.8	Actively Managed	Fully	N/A	Minimal/no impactful extractive or destructive activities occurring

Box S1. Case Study: Biscayne National Park

Biscayne National Park (BNP) is the nation's largest marine National Park. Approximately 95% of its 700 km^2 are marine waters, which include fringing mangroves, seagrass beds, barrier islands, and coral reefs. The park is visited by more than half a million people annually, most of whom are recreational fishers and boaters. Fishing activities are managed under shared authority of the National Park Service (NPS) and the State of Florida. This is expressly stated in the park´s enabling legislation (16 U.S.C. sec. 410gg-2). The original General Management Plan (GMP) dates from 1983.
There has been depletion in BNP of various species of snapper and grouper, the principal fishes targeted by recreational fishers (Ault et al., 2020). NPS initiated development of a new GMP in 2001 with scoping meetings and the formation of a Fishery Management Council. NPS released its Draft GMP and Draft Environmental Impact Statement in 2011, which proposed a single fully protected MPA. NPS subsequently revised its proposal to increase coral reef protection.

After 12 public hearings and over 43,000 public comments, 90% of which supported creation of the fully protected MPA, the NPS approved the proposal in 2015. However, the Secretary of the Interior never gave approval to the fully protected area, and implementation never occurred. Despite the successful implementation of fully protected areas in the adjacent Florida Keys National Marine Sanctuary, opposition from certain sportfishing groups, charter boat captains, and the State of Florida remained strong in BNP. The Florida Fish and Wildlife Conservation Commission (FWC) called fully protected MPAs a “measure of last resort” and did not approve the concept. The South Florida congressional delegation (both Republicans and Democrats) was also united in opposition to fully protected MPAs, putting forth a Senate bill (S. 3099 in the 114th Congress) to ban the fully protected MPA in BNP, and a House bill (H.R. 3310) went one step further to prohibit the NPS from creating fully protected MPAs in State waters included in any national park or national marine sanctuary without the approval of the appropriate State fish and wildlife management agency. Nevertheless, neither of these bills progressed out of committee in the 114th Congress.

In 2020, the FWC approved new fishing rules for BNP and agreed to reconsider the fully protected MPA in five years if FWC´s increased size and bag limits fishery management tools failed to recover fish populations. In the meantime, destructive practices, including pollution from fishing vessels and fishing gear (derelict and otherwise) that damages corals are still permitted. These practices have the potential to degrade habitats in the BNP´s coral reef tract, issues that size and bag limits do not fully address.

References

Ault, J. S., Abdo, M. E., and McLaughlin, C. (2020). Biscayne National Park Fishery Management Plan Reef Fishery Regulations and Science Plan Analysis. National Parks Conservation Association.

Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B., Pike, E., et al. (2021). The MPA Guide: A framework to achieve global goals for the ocean. *Science*. doi:10.1126/science.abf0861.

Wilkinson, T. A. C., Wiken, E. B., Creel, J. B., Hourigan, T. F., Agardy, T., Herrmann, H., et al. (2009). *Marine ecoregions of North America*. Montréal, Québec: Commission for Environmental Cooperation.