



Supplementary Materials for

The MPA Guide: A framework to achieve global goals for the ocean

Kirsten Grorud-Colvert *et al.*

Corresponding author: Kirsten Grorud-Colvert, gorudck@oregonstate.edu

Science **373**, eabf0861 (2021)
DOI: 10.1126/science.abf0861

The PDF file includes:

Figs. S1 and S2
Table S1
References

Other Supplementary Material for this manuscript includes the following:

MDAR Reproducibility Checklist

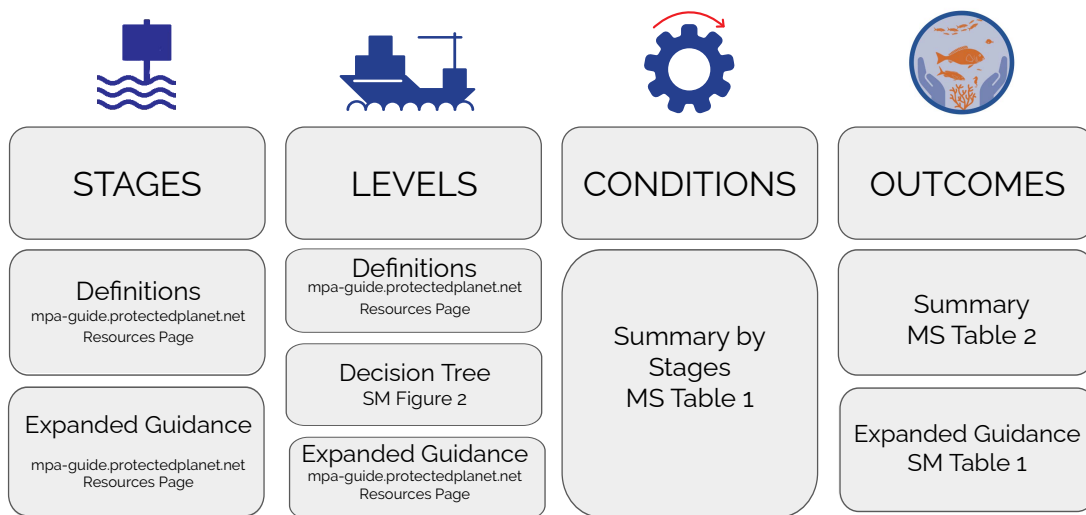


Fig. S1.

Quick Reference Directions to Additional Information about the MPA Guide’s Four Components. More in-depth information for each of the four components – STAGES, LEVELS, CONDITIONS, OUTCOMES – is provided either online at mpa-guide.protectedplanet.net/resources, in the primary paper (MS), or in these Supplemental Materials.

Key — Fully protected (dark blue) — Lightly protected (light green) — Incompatible with conservation (grey)
 — Highly protected (medium blue) — Minimally protected (medium green)

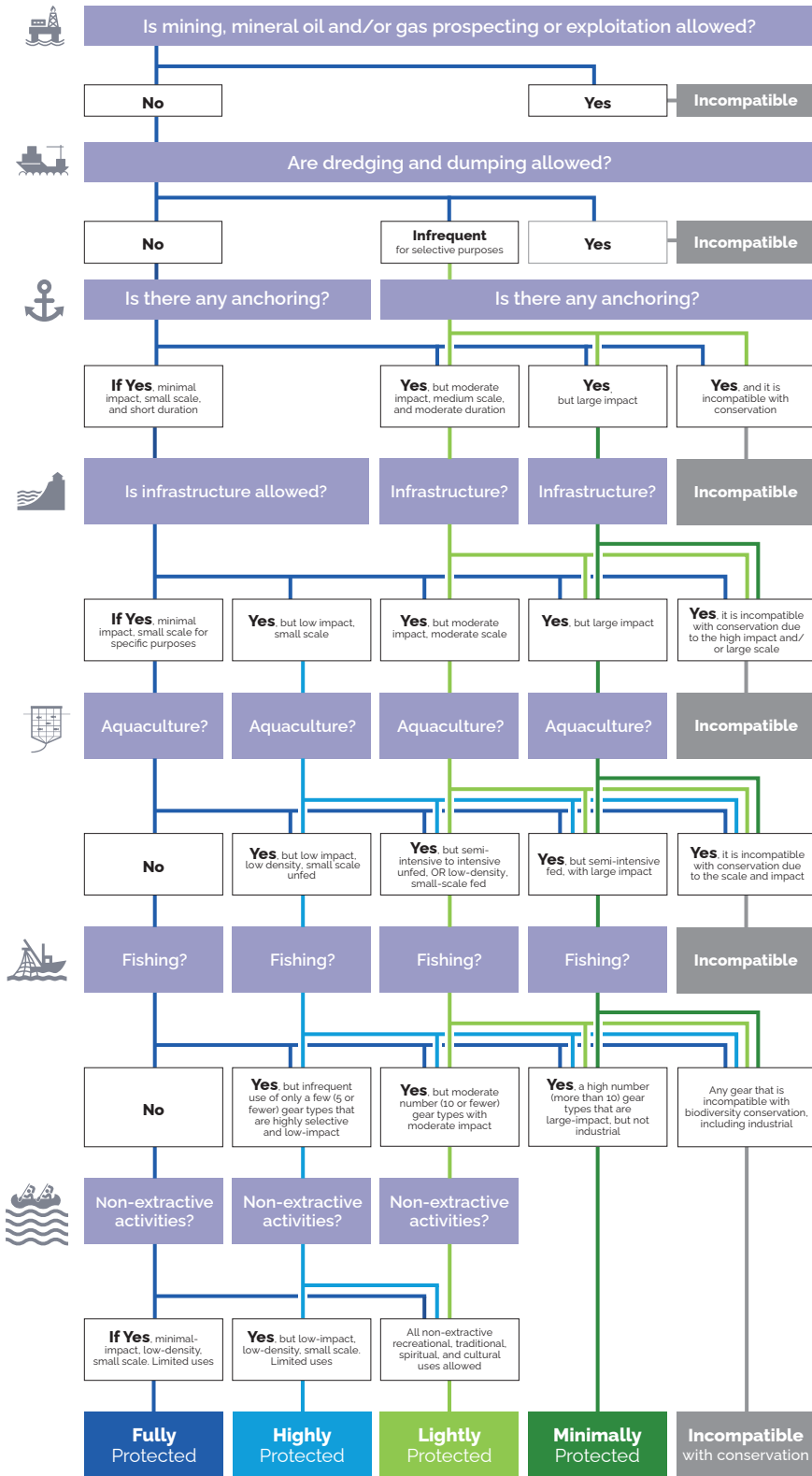


Fig. S2.

Decision tree to determine the protection LEVEL of an MPA, or zone within a multi-zone MPA, based on activities that are allowed or disallowed. Answers to questions in this decision tree lead sequentially to categorizing an MPA or MPA zone into one of four LEVELS of protection: Fully, Highly, Lightly, or Minimally, based on maximum allowed impact of seven different types of activities.

Table S1.

Expanded Ecological Outcomes of MPAs according to Level of Protection. The outcomes assume that best practices in Enabling Conditions (CONDITIONS) have been met, key threats are abatable by the MPA, and the system has had time to progress from a degraded state to one with relatively few fluctuations. While some ecological benefits occur quickly following protection (e.g., *I*), it can take time for many benefits to accrue. Levels of confidence in the outcome represent expert judgements based on available research (see References). Supporting references for each outcome are not exhaustive but are representative of this evidence.

Outcome	Level of protection				Confidence in effect / Supporting references
	Fully	Highly	Lightly	Minimally	
Biodiversity conservation					
Many attributes of individual organisms, their populations, and their communities contribute to the overall persistence and resilience of species and ecosystems, and the benefits they provide to people. The cells to the right of each outcome describe the extent to which different levels of protection are likely to protect or restore that attribute.					
<p><i>Abundance</i>: maintained at or increases towards pre-exploitation levels</p> <ul style="list-style-type: none"> • In general, protection results in increases in abundance of organisms within the MPA. • What increases, by how much, and when depend on the level of protection and degree of previous exploitation or impact. • Previously exploited species generally increase more 	Abundances are maintained in unimpacted sites or they increase towards unexploited / unimpacted levels, including many species highly vulnerable to depletion.	Abundances increase, including some species highly vulnerable to depletion, but for those still targeted to lower levels than with full protection.	Species that are given specific protections may increase in abundance. Vulnerable species may be present at low population levels.	Minimal change or continued decline of overexploited or impacted species.	High confidence Côté et al. 2001 (101); Lester and Halpern 2008 (102); Claudet et al. 2008 (35); Lester et al. 2009 (34); Giakoumi et al. 2017 (37); Zupan et al. 2018 (18)

<p>rapidly than other species.</p> <ul style="list-style-type: none"> • The prey of these previously exploited species will likely decrease in abundance as their predators recover, indicating that the ecosystem is recovering. 					
<p><i>Population age structure:</i> maintained at or extends towards natural age structure</p> <ul style="list-style-type: none"> • Once protected, previously exploited or impacted species (e.g., bycatch) live longer, particularly predators. • This shifts the population structure towards larger, older individuals that usually invest more in reproduction, are more experienced (e.g. in finding mates or favorable spawning areas), may produce higher quality offspring and 	<p>Older individuals will gradually return to the population, with timelines dependent upon growth rates of the species.</p>	<p>Older individuals will gradually return to the population if they are not exploited.</p>	<p>Species that are given specific protections live longer; exploited or impacted species will not.</p>	<p>Minimal difference in population structure compared to unprotected sites.</p>	<p>High confidence</p> <p>Roberts et al. 2001 (103); Claudet et al. 2006 (104); Ruttenberg et al. 2011 (105); García-Rubies et al. 2013 (106); Abesamis et al. 2014 (107); Malcolm et al. 2015 (108); Harasti et al. 2018 (109)</p>

can buffer the population through multi-year periods of environmental conditions unfavorable to replenishment.					
<p><i>Biomass</i>: maintained at or increases towards pre-exploitation levels</p> <ul style="list-style-type: none"> Protection generally results in increases in abundance and larger average body sizes, leading to large increases in biomass of previously exploited or impacted species. 	Biomass is maintained at unexploited /unimpacted levels or recovers towards this.	Biomass is maintained at unexploited / unimpacted levels or it increases. For exploited or impacted species, biomass is at lower levels.	Those species that are given specific protections will increase in biomass. Exploited or impacted species will stay at depleted levels or continue to decline.	Minimal difference in biomass compared to unprotected sites.	High confidence Lester and Halpern 2008 (102); Lester et al. 2009 (34); Sala et al. 2012 (110); Guidetti et al. 2014 (111); Giakoumi et al. 2017 (37); Giakoumi 2018 (112); Zupan et al. 2018 (18); Agnetta et al. 2019 (113)
<p><i>Species richness (no. of species)</i>: increases as populations recover</p> <ul style="list-style-type: none"> Protection results in an increase in the number of species as populations recover, rare species become more common, and vulnerable, previously absent, species recolonize. 	Richness is maintained in previously unexploited areas or it recovers towards unimpacted levels.	Richness is maintained (in previously unexploited areas) or it recovers to higher levels.	There is little difference in overall richness, although species with specific protections have an increased frequency of occurrence.	Minimal difference in richness compared to unprotected sites.	High confidence Lester and Halpern 2008 (102); Russ and Alcala 2011 (114); Nash and Graham 2016 (115)
<i>Reproductive output and replenishment</i> : increases as populations recover	Reproductive output of most previously	Reproductive output increases are	Some increases in reproductive output are	Minimal difference in reproductive	High confidence

<ul style="list-style-type: none"> Because bigger animals generally produce vastly greater numbers of young than do smaller animals, and because animals live longer when not exploited, far more young are produced in protected areas. Bigger animals may also be more successful at reproducing and producing higher quality offspring that survive better. 	<p>depleted populations can increase several times and in some cases by tens to more than a hundred times.</p>	<p>substantial for most previously depleted populations .</p>	<p>seen for those species given specific protections.</p>	<p>n compared to unprotected sites.</p>	<p>Nemeth 2005 (116); Kaiser et al. 2007 (117); Crec'hriou et al. 2010 (118); Taylor and McIlwain, 2010 (119); Díaz et al. 2011 (120); Hixon et al. 2014 (121); Barneche et al. 2018 (122); Marshall et al. 2019 (123)</p>
<p><i>Connectivity of populations:</i> higher self-replenishment and export of offspring as populations recover</p> <ul style="list-style-type: none"> In protected areas, the larger production of eggs or other propagules can lead to faster replenishment of the population within the MPA, but also higher export of offspring and therefore greater replenishment 	<p>Egg/larvae/propagule export is enhanced for most species.</p>	<p>Egg/larvae/propagule export is enhanced for many species.</p>	<p>Egg/larvae/propagule export is enhanced only for a few species.</p>	<p>Minimal difference in egg/larvae/propagule export compared to unprotected sites.</p>	<p>Moderate confidence</p> <p>Pelc et al. 2010 (124); Christie et al. 2010 (125); Di Franco et al. 2012 (126); Roberts and Hawkins 2012 (127); Andrello et al. 2017 (128); Roberts et al. 2017 (40); Manel et al. 2019 (129); Assis et al. 2021 (130)</p>

outside the MPA, sometimes over long distances.					
<p><i>Rare and endangered species protected:</i> increased protection allows populations to recover</p> <ul style="list-style-type: none"> Some species are more vulnerable to exploitation and damage than others, sometimes even at low intensities of human use. 	MPAs provide refuge for and enhance populations of many rare and endangered species, especially sessile, sedentary, or low mobility species.	MPAs provide refuge for and enhance populations of some rare and endangered species, especially sessile, sedentary, or low mobility species, but at lower levels than with full protection for these species.	Rare and endangered species given specific protections are present, especially if they are sessile, sedentary, or low mobility species, but at lower levels than with full or high protection	Minimal differences compared to unprotected sites.	Moderate confidence Mouillot et al. 2008 (131); Pichegru et al. 2010 (132); Gormley et al. 2012 (133); Goetze et al. 2015 (134); McLaren et al. 2015 (135); Dwyer et al. 2020 (136)
<p><i>Genetic diversity:</i> enhanced as populations recover and habitat heterogeneity increases</p> <ul style="list-style-type: none"> Large population sizes and increased environmental heterogeneity promote genetic diversity, although the effect may be limited for species that have been through population bottlenecks. 	Genetic diversity is maintained or enhanced for most species.	Genetic diversity is maintained or enhanced for many species.	Genetic diversity is maintained or enhanced for some species.	Minimal difference in genetic diversity compared to unprotected sites.	Moderate confidence Miethe et al. 2009 (137); Fidler et al. 2018 (138); Jones et al. 2018 (139); Sørvalen et al. 2018 (140)

<p>(Environmental heterogeneity refers to the diversity of habitats which will increase as sensitive and vulnerable habitats recover.)</p> <ul style="list-style-type: none"> Genetic diversity may also be enhanced by the different selective environment MPAs provide compared to unprotected areas. 					
<p><i>Habitats:</i> recover over years to decades</p> <ul style="list-style-type: none"> Habitats will recover over timescales of years to decades as habitat-forming species (seaweeds, seagrass, coral, oysters, etc.) benefit from protection and produce cascading ecological effects of protection throughout the ecosystems. 	<p>Full recovery of all habitats is possible, but timescales depend on the types of habitats present or able to re-establish. Greater three dimensional complexity develops.</p>	<p>Many habitats recover fully or partially, but timescales depend on the types of habitats present. Greater three dimensional complexity develops.</p>	<p>Some habitats recover partially.</p>	<p>Minimal difference from unprotected sites in habitat condition or types of habitats present.</p>	<p>High confidence</p> <p>Guidetti 2007 (141); Babcock et al. 2010 (73); Costello 2014 (142); Williamson et al. 2014 (143); Turnbull et al. 2018 (144)</p>
<p><i>Ecosystem functioning:</i> natural interactions and processes recover</p>	<p>Full recovery of natural levels of</p>	<p>Partial recovery toward re-established</p>	<p>Food web effects of protection are quite</p>	<p>Minimal difference compared to</p>	<p>Moderate confidence</p>

<ul style="list-style-type: none"> As targeted species recover, they will re-establish interactions with other species in the community. This in turn alters other interactions that may reverberate throughout the community. Ecosystem-level changes will often be most dramatic when the targeted species were high-level/apex predators, habitat-forming or keystone species. 	<p>trophic structure and complexity for most species and habitats; partial recovery for those where key species are highly mobile or migratory.</p>	<p>levels of trophic structures and complexity.</p>	<p>limited and incomplete.</p>	<p>unprotected sites.</p>	<p>Guidetti 2006 (145); Claudet et al. 2010 (146); Babcock et al. 2010 (73); McClanahan and Graham 2015 (147); Russ et al. 2015 (148); Acuña-Marrero et al. 2017 (149); Selden et al. 2017 (150)</p>
<p><i>Ecosystem resilience</i> (ability to recover after disturbance): maintained at or increases towards pre-exploitation levels</p> <ul style="list-style-type: none"> Restoration of natural ecological interactions, higher population sizes, and associated increased genetic diversity will likely enhance the resilience 	<p>Resilience increases significantly.</p>	<p>Resilience increases.</p>	<p>Little apparent increase in resilience.</p>	<p>Minimal or no apparent increase in resilience.</p>	<p>Low confidence</p> <p>McLeod et al. 2008 (151); Ling et al. 2009 (152); Micheli et al. 2012 (153); Barnett and Baskett, 2015 (154); Mellin et al 2016 (71); Wilson et al. 2020 (155)</p>

of the community within the MPA.					
Effects on exploited species					
The level of protection of each MPA or zone can have important impacts on exploited species. The cells to the right of each outcome describe the extent to which different levels of protection are likely to protect or recover these populations, and the benefits they provide to people.					
<p><i>Spillover</i>: net movement of targeted mobile animals and some seaweeds to adjacent fishing grounds</p> <ul style="list-style-type: none"> Spillover typically to a maximum of a few kilometers away, as population densities rise and conditions become more crowded. Spillover is often first noticed as an increase in fishery catch rates just outside the MPA (or their no-take zone) boundaries. Level of spillover varies by species, and is highly dependent on species' mobility, habitat conditions and level of fishing 	<p>Spillover increases significantly with time as populations recover strongly inside MPAs. Bigger fish inside MPAs produce proportionally more larvae leading to potential spillover.</p>	<p>Spillover increases with time as populations recover inside MPAs. Rates of spillover and numbers of species showing the effect are lower than under full protection.</p>	<p>Spillover may increase for species given specific protections.</p>	<p>Minimal spillover to adjacent areas.</p>	<p>High confidence</p> <p>Abesamis and Russ 2005 (156); Halpern et al. 2009 (157); Russ and Alcala 2011 (114); Roberts and Hawkins 2012 (127); Di Lorenzo et al. 2016 (65); Di Lorenzo et al. 2020 (158)</p>

outside of the protected area					
<p><i>Larval export:</i> maintained at or increases towards pre-exploitation levels</p> <ul style="list-style-type: none"> Increased abundance and body size, plus reduced disturbance enhances reproductive output, usually results in the export of eggs and larvae from the MPA to surrounding areas. 	<p>Very high rates of egg and larval export are observed, and they increase with time. Bigger fish inside MPAs produce proportionally more larvae enhancing potential larval export.</p>	<p>High rates of egg and larval export are observed, and they increase with time, but at lower levels than with full protection.</p>	<p>Egg and larval export are higher for those species given specific protections, and they increase with time.</p>	<p>Minimal change in egg and larval export following protection.</p>	<p>High confidence</p> <p>Manríquez and Castilla, 2001 (159); Planes et al. 2009 (160); Christie et al. 2010 (125); Crec'hriou et al. 2010 (118); Pelc et al. 2010 (124); Harrison et al. 2012 (58); Di Franco et al. 2015 (161)</p>
<p><i>Insurance against management failure or stock collapse:</i> protects a portion of the population from exploitation</p> <ul style="list-style-type: none"> Increased abundance and body size, extended population age structures and increased reproduction reduce the likelihood that overfishing outside the MPA causes stock collapse, and they promote recovery following management 	<p>Insurance value potentially very high and rises with time since protection and with area protected.</p>	<p>Insurance value potentially high and rises with time since protection and with area protected.</p>	<p>Some insurance value for species given specific protections, but the effect is likely to be low.</p>	<p>Minimal or no apparent insurance value.</p>	<p>Moderate confidence</p> <p>Lauck et al. 1998 (162); Roberts et al. 2005 (163); Russ and Alcala 2011 (114); Krueck et al. 2017 (164)</p>

problems in fishing grounds.					
<p><i>Protection of vulnerable life stages:</i> enhanced via nursery grounds, spawning aggregations, etc., including for highly migratory species</p> <ul style="list-style-type: none"> • Protection promotes survival and growth and reduces impacts of overfishing. 	Benefits could be very high if key areas of vulnerability (e.g. spawning aggregations) are fully protected in MPAs.	Benefits could be high if key areas of vulnerability are highly protected in MPAs.	Some benefits evident for key areas of vulnerability given specific protection.	Minimal benefits.	High confidence Beets and Friedlander 1999 (165); Planes et al. 2000 (160); Rogers-Bennett and Pearse 2001 (166); Sala et al. 2001 (167); Mumby et al. 2004 (78); Garla et al. 2006 (168); Nemeth 2005 (116); Armsworth et al. 2010 (169); Grüss et al. 2014 (170); Erisman et al. 2017 (62); Farmer et al. 2017 (171); Sadovy de Mitcheson et al. 2020 (172)

Water quality

The level of protection of each MPA or zone can have important impacts on water quality. The cells to the right of each outcome describe the extent to which different levels of protection are likely to protect or restore water quality, and the benefits this provides to people.

<p><i>Eutrophication:</i> reduced, lower likelihood of dead zones, harmful algal blooms, etc.</p> <ul style="list-style-type: none"> • More intact pelagic and benthic food 	Possible	Possible	Unlikely	Unlikely	Low confidence Olds et al. 2014 (173); Alongi et al. 2015 (174);
--	----------	----------	----------	----------	---

<p>webs can increase grazing rates/nutrient cycling/detritivory, reducing adverse effects of nutrient enrichment.</p> <ul style="list-style-type: none"> • More intact pelagic food webs can reduce the probability of harmful algae species from blooming, although even for highly and fully protected MPAs, the effect likely to be offset if there is excessive nutrient pollution. 					<p>McKinnon et al. 2017 (175); Bergström et al. 2019 (176); Strain et al. 2019 (177)</p>
<p><i>Pathogens and pollutants</i>: reduced concentrations</p> <ul style="list-style-type: none"> • High densities of filter feeders may reduce nutrient and pathogen levels in overlying water and vegetated habitats have biocidal properties. • Disease mitigation for species such as corals through reductions in physical injury 	<p>Reduced pathogen levels likely compared to unprotected sites. Effects may also extend to adjacent areas.</p> <p>Evidence of reduced levels of coral disease in fully protected areas due to</p>	<p>Reduced pathogen levels likely compared to unprotected sites. Effects may also extend to adjacent areas.</p> <p>Minimizing impacts from other pressures (e.g. fishing) has been shown to increase</p>	<p>Reduced pathogen levels possible, especially where vegetated habitats are included.</p> <p>Impacts from fishing (e.g. abandoned fishing line) can exacerbate instances of coral disease.</p>	<p>Minimal difference from unprotected sites.</p>	<p>Moderate confidence</p> <p>Cotou et al. 2005 (178); Durrieu de Madron et al. 2005 (179); Lamb et al. 2017 (180); Pollack et al. (2014) (181)</p>

<p>in areas where human activities are reduced. May improve ecosystem resilience by preserving ecosystem function.</p> <ul style="list-style-type: none"> Mobile fishing gears can resuspend sediments and legacy pollutants (e.g. DDT, PCBs, heavy metals) at a higher rate than natural disturbances, reintroducing them to demersal and pelagic food webs. Protection from mobile gears increases longevity and efficacy of storage. 	<p>lower levels of coral damage and lower abundance of abandoned fishing line.</p> <p>Higher rates of uptake and sequestration of legacy chemicals by seabed invertebrates with longer sediment residence time.</p>	<p>resilience to coral disease.</p> <p>Higher rates of uptake and sequestration of legacy chemicals by seabed invertebrates with longer sediment residence time.</p>	<p>If protected from mobile fishing gears, higher rates of uptake and sequestration of legacy chemicals by seabed invertebrates with longer sediment residence time.</p>		
<p><i>Suspended sediment:</i> reduced levels</p> <ul style="list-style-type: none"> Re-establishment of dense populations of filter-feeding invertebrates will increase water filtration rates and reduce suspended sediment. In addition, improved water 	<p>Dense populations of filter-feeders re-establish on the seabed, increasing water clarity, and the abundance of rooted aquatic vegetation especially in semi-</p>	<p>Dense populations of filter-feeders re-establish on the seabed, increasing water clarity and abundance of rooted aquatic vegetation, especially in semi-enclosed</p>	<p>If protected from mobile fishing gears, dense populations of filter-feeders may re-establish on the seabed, increasing water clarity, and allowing</p>	<p>Minimal difference from unprotected sites.</p>	<p>Low confidence</p> <p>State of Queensland, 2018 (182); Powell et al. 2019 (183)</p>

clarity can foster an increase in rooted aquatic vegetation (such as seagrasses) which provides important fish nursery habitat.	enclosed water bodies.	water bodies.	for the persistence of rooted aquatic vegetation especially in semi-enclosed water bodies.		
---	------------------------	---------------	--	--	--

Climate resilience/adaptation/mitigation

The level of protection of each MPA or zone can play an important role in climate resilience, adaptation, and mitigation. There is high confidence in the first-principle knowledge about how marine systems sequester and store carbon; however, more studies are needed about how MPAs specifically contribute to the carbon budget. The cells to the right of each outcome describe the extent to which different levels of protection are likely to impact the changing climate, and the benefits this provides to people.

<p><i>Carbon:</i> sequestration and storage enhanced and safeguarded</p> <ul style="list-style-type: none"> • Greater primary production by vegetated habitats such as mangroves, salt marshes, and seagrasses protected in MPAs leads to greater carbon capture (e.g., blue carbon). • Existing stores of carbon in sediments in MPAs are protected from disturbance from mobile fishing gears and other sources. • Untrawled and undredged seabed habitats promote carbon uptake by 	High, if MPA protects blue carbon coastal habitats such as mangroves, salt marshes and seagrasses, other marine communities that sequester carbon, and/or protects sediments from mobile fishing gears or other sources of disturbance	High, if MPA protects blue carbon coastal habitats such as mangroves, salt marshes and seagrasses, other marine communities that sequester carbon, and/or protects sediments from mobile fishing gears or other sources of disturbance	Moderate, but only if MPA provides some protection to vegetated coastal habitats, and/or to sediments from mobile fishing gears and other sources of disturbance	Minimal difference compared to unprotected sites.	<p>Moderate confidence</p> <p>High confidence in first principle-based knowledge of carbon sequestration and storage in marine systems.</p> <p>Pendleton et al. 2012 (184); Atwood et al. 2015 (185); Mineur et al. 2015 (186); Zarate-Barrera and Maldonado 2015 (187); Krause-Jensen and Duarte 2016 (188);</p>
--	--	--	--	---	---

<p>richer communities of filter feeding organisms and plants, and storage in sediments.</p> <ul style="list-style-type: none"> ● Pelagic habitats with high abundance of mesopelagic species promote carbon shuttling from surface to deep water. ● High abundances of animals that feed deep and excrete nutrients at the surface enhance surface productivity, some of which is eventually stored in deep sea sediments. 					<p>Howard et al. 2017 (189); Roberts et al. 2017 (40); Duarte et al. 2020 (190); Mariani et al. 2020 (191); Saba et al. 2021 (192); Sala et al. 2021 (6)</p>
<p><i>Acidification:</i> local effects mitigated</p> <ul style="list-style-type: none"> ● Vegetated areas may reduce local acidification. This may benefit local shellfish or other economically or culturally important species. ● Carbonate excretion at 	<p>Vegetated habitats increase in extent and quality, especially if supplemented by active restoration/coastal realignment, mitigating local acidification.</p>	<p>Vegetated habitats increase in extent and quality, especially if supplemented by active restoration/coastal realignment, mitigating local acidification.</p>	<p>Given specific protection, vegetated habitats may increase in extent and quality, especially if supplemented by active restoration, mitigating local acidification.</p>	<p>Minimal difference from unprotected sites. However, MPAs supporting seaweed aquaculture may have benefits in ameliorating local acidification.</p>	<p>Low confidence</p> <p>Unsworth et al. 2012 (193); Roberts et al. 2017 (40); Duarte et al. 2017 (194); But see Koweek et al., 2018 (195)</p>

<p>surface by vertically migrating fish may buffer surface acidity.</p> <ul style="list-style-type: none"> Seaweed aquaculture may reduce acidification. 	<p>Protection of vertically migrating species facilitates surface buffering.</p>	<p>Protection of vertically migrating species can facilitate surface buffering.</p>	<p>Protection of vertically migrating species can facilitate surface buffering.</p>		
<p><i>Productivity</i>: declines from climate change offset</p> <ul style="list-style-type: none"> Greater potential for adaptation and sustained productivity due to higher genetic diversity. Climate change is reducing marine productivity. With MPAs, primary productivity may be maintained by a greater abundance of marine life playing key roles in the nutrient pump (shuttling of nutrients from depth to epipelagic zone), which promotes primary production. Expanded area of coastal vegetated 	<p>Maintained or increased productivity.</p>	<p>Maintained or increased productivity.</p>	<p>Maintained or increased productivity if specific protections target key ecosystem components promoting productivity.</p>	<p>Minimal difference from unprotected sites.</p>	<p>Low confidence</p> <p>Grémillet and Boulinier 2009 (196); Reed et al. 2016 (197); Kelly et al. 2017 (198); But see Rogers-Bennett and Catton 2019 (199)</p>

<p>habitats increases productivity and nutrient subsidy to adjacent ecosystems.</p> <ul style="list-style-type: none"> Secondary productivity declines can be countered by increased populations of previously exploited species. 					
<p><i>Coastal protection:</i> disturbances offset, maintained, or enhanced</p> <ul style="list-style-type: none"> Protection of biogenic habitats, such as mangroves, seagrasses, saltmarsh, coral reef and oyster beds, can protect coasts even as sea levels rise. This has benefits to human health, safety and security, and economies. 	<p>Natural coastal defenses are maintained or enhanced, especially if supplemented by active restoration/ coastal realignment .</p>	<p>Natural coastal defenses are maintained or enhanced, especially if supplemented by active restoration/ coastal realignment .</p>	<p>Natural coastal defenses are maintained or enhanced if given specific protection, especially if supplemented by active restoration/ coastal realignment .</p>	<p>Minimal difference from unprotected sites.</p>	<p>High confidence.</p> <p>Luo et al. 2015 (200); Miteva et al. 2015 (201); Narayan et al. 2016 (202); Roberts et al. 2017 (40); Harris et al. 2018 (203); Powell et al. 2019 (183); Duarte et al. 2020 (190)</p>

References and Notes

1. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), “Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services,” E. S. Brondizio, J. Settele, S. Díaz, H. T. Ngo, Eds. (IPBES secretariat, 2019).
2. United Nations, Ed., *The First Global Integrated Marine Assessment: World Ocean Assessment I* (Cambridge Univ. Press, 2017).
3. J. Lubchenco, S. D. Gaines, A new narrative for the ocean. *Science* **364**, 911–911 (2019). [doi:10.1126/science.aay2241](https://doi.org/10.1126/science.aay2241) [Medline](#)
4. A. M. Friedlander, Marine conservation in Oceania: Past, present, and future. *Mar. Pollut. Bull.* **135**, 139–149 (2018). [doi:10.1016/j.marpolbul.2018.05.064](https://doi.org/10.1016/j.marpolbul.2018.05.064) [Medline](#)
5. Intergovernmental Panel on Climate Change (IPCC), “IPCC Special Report on the Ocean and Cryosphere in a Changing Climate,” H.-O. Pörtner et al., Eds. (IPCC, 2019).
6. E. Sala, J. Mayorga, D. Bradley, R. B. Cabral, T. B. Atwood, A. Auber, W. Cheung, C. Costello, F. Ferretti, A. M. Friedlander, S. D. Gaines, C. Garilao, W. Goodell, B. S. Halpern, A. Hinson, K. Kaschner, K. Kesner-Reyes, F. Leprieur, J. McGowan, L. E. Morgan, D. Mouillot, J. Palacios-Abrantes, H. P. Possingham, K. D. Rechberger, B. Worm, J. Lubchenco, Protecting the global ocean for biodiversity, food and climate. *Nature* **592**, 397–402 (2021). [doi:10.1038/s41586-021-03371-z](https://doi.org/10.1038/s41586-021-03371-z) [Medline](#)
7. IUCN, WCPA, “Applying IUCN’s Global Conservation Standards to Marine Protected Areas (MPAs). Delivering effective conservation action through MPAs, to secure ocean health & sustainable development. Version 1.0.” (IUCN, 2018).
8. J. Lubchenco, K. Grorud-Colvert, OCEAN. Making waves: The science and politics of ocean protection. *Science* **350**, 382–383 (2015). [doi:10.1126/science.aad5443](https://doi.org/10.1126/science.aad5443) [Medline](#)
9. E. Sala, J. Lubchenco, K. Grorud-Colvert, C. Novelli, C. Roberts, U. R. Sumaila, Assessing real progress towards effective ocean protection. *Mar. Policy* **91**, 11–13 (2018). [doi:10.1016/j.marpol.2018.02.004](https://doi.org/10.1016/j.marpol.2018.02.004)
10. J. A. Kawaka, M. A. Samoilys, M. Murunga, J. Church, C. Abunge, G. W. Maina, Developing locally managed marine areas: Lessons learnt from Kenya. *Ocean Coast. Manage.* **135**, 1–10 (2017). [doi:10.1016/j.ocecoaman.2016.10.013](https://doi.org/10.1016/j.ocecoaman.2016.10.013)
11. D. Vilas, M. Coll, X. Corrales, J. Steenbeek, C. Piroddi, D. Macias, A. Ligas, P. Sartor, J. Claudet, Current and potential contributions of the Gulf of Lion Fisheries Restricted Area to fisheries sustainability in the NW Mediterranean Sea. *Mar. Policy* **123**, 104296 (2020). [doi:10.1016/j.marpol.2020.104296](https://doi.org/10.1016/j.marpol.2020.104296)
12. D. Laffoley, N. Dudley, H. Jonas, D. MacKinnon, K. MacKinnon, M. Hockings, S. Woodley, An introduction to ‘other effective area-based conservation measures’ under Aichi Target 11 of the Convention on Biological Diversity: Origin, interpretation and emerging ocean issues. *Aquat. Conserv.* **27**, 130–137 (2017). [doi:10.1002/aqc.2783](https://doi.org/10.1002/aqc.2783)

13. J. M. Reimer, R. Devillers, J. Claudet, Benefits and gaps in area-based management tools for the ocean Sustainable Development Goal. *Nat. Sustain.* **4**, 349–357 (2020). [doi:10.1038/s41893-020-00659-2](https://doi.org/10.1038/s41893-020-00659-2)
14. S. Woodley, B. Bertsky, N. Crawhall, N. Dudley, J. M. Londono, K. MacKinnon, K. Redford, T. Sandwith, Meeting Aichi Target 11: What does success look like for Protected Area systems? *Parks* **18**, 1 (2012).
15. E. S. Nocito, C. M. Brooks, A. L. Strong, Gazing at the crystal ball: Predicting the future of marine protected areas through voluntary commitments. *Front. Mar. Sci.* **6**, 835 (2020). [doi:10.3389/fmars.2019.00835](https://doi.org/10.3389/fmars.2019.00835)
16. B. C. O’Leary, M. Winther-Janson, J. M. Bainbridge, J. Aitken, J. P. Hawkins, C. M. Roberts, Effective coverage targets for ocean protection. *Conserv. Lett.* **9**, 398–404 (2016). [doi:10.1111/conl.12247](https://doi.org/10.1111/conl.12247)
17. K. R. Jones, C. J. Klein, H. S. Grantham, H. P. Possingham, B. S. Halpern, N. D. Burgess, S. H. M. Butchart, J. G. Robinson, N. Kingston, N. Bhola, J. E. M. Watson, Area requirements to safeguard Earth’s marine species. *One Earth* **2**, 188–196 (2020). [doi:10.1016/j.oneear.2020.01.010](https://doi.org/10.1016/j.oneear.2020.01.010)
18. M. Zupan, E. Fragkopoulou, J. Claudet, K. Erzini, B. Horta e Costa, E. J. Gonçalves, Marine partially protected areas: Drivers of ecological effectiveness. *Front. Ecol. Environ.* **16**, 381–387 (2018). [doi:10.1002/fee.1934](https://doi.org/10.1002/fee.1934)
19. J. Claudet, C. Loiseau, M. Sostres, M. Zupan, Underprotected marine protected areas in a global biodiversity hotspot. *One Earth* **2**, 380–384 (2020). [doi:10.1016/j.oneear.2020.03.008](https://doi.org/10.1016/j.oneear.2020.03.008)
20. UNEP-WCMC, World Database on Protected Areas. *Protected Planet* (2020); www.protectedplanet.net/marine.
21. Marine Conservation Institute, The Atlas of Marine Protection, (2020); <http://mpatlas.org>.
22. M. D. Barnes, L. Glew, C. Wyborn, I. D. Craigie, Prevent perverse outcomes from global protected area policy. *Nat. Ecol. Evol.* **2**, 759–762 (2018). [doi:10.1038/s41559-018-0501-y](https://doi.org/10.1038/s41559-018-0501-y) [Medline](#)
23. B. Horta e Costa, J. Claudet, G. Franco, K. Erzini, A. Caro, E. J. Gonçalves, A regulation-based classification system for Marine Protected Areas (MPAs). *Mar. Policy* **72**, 192–198 (2016). [doi:10.1016/j.marpol.2016.06.021](https://doi.org/10.1016/j.marpol.2016.06.021)
24. M. Pieraccini, S. Coppa, G. A. De Lucia, Beyond marine paper parks? Regulation theory to assess and address environmental non-compliance. *Aquat. Conserv.* **27**, 177–196 (2017). [doi:10.1002/aqc.2632](https://doi.org/10.1002/aqc.2632)
25. B. Horta e Costa, J. M. S. Gonçalves, G. Franco, K. Erzini, R. Furtado, C. Mateus, E. Cadeireiro, E. J. Gonçalves, Categorizing ocean conservation targets to avoid a potential false sense of protection to society: Portugal as a case-study. *Mar. Policy* **108**, 103553 (2019). [doi:10.1016/j.marpol.2019.103553](https://doi.org/10.1016/j.marpol.2019.103553)
26. J. Claudet, C. Loiseau, A. Pebayle, Critical gaps in the protection of the second largest exclusive economic zone in the world. *Mar. Policy* **124**, 104379 (2021). [doi:10.1016/j.marpol.2020.104379](https://doi.org/10.1016/j.marpol.2020.104379)

27. CBD, “Decisions Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Eighth Meeting (Decision VIII/15, Annex IV),” Convention on Biological Diversity, Curitiba, Brazil, 2006.
28. IUCN, “Guidelines for applying the IUCN protected area management categories to marine protected areas” (IUCN, ed. 2, 2019); www.iucn.org/content/guidelines-applying-iucn-protected-area-management-categories-marine-protected-areas-0.
29. CCAMLR, “Proposal to establish an East Antarctic Marine Protected Area,” CCAMLR-38/21 (2019); www.ccamlr.org/en/ccamlr-38/21.
30. CCAMLR, “Proposal to establish a Marine Protected Area across the Weddell Sea region (Phase 1),” CCAMLR-38/23 (2019); www.ccamlr.org/en/ccamlr-38/23.
31. D. Faure, Speech on the occasion of 30% of Seychelles’ EEZ Designated as Marine Protected Area (2020); www.statehouse.gov.sc/speeches/4786/speech-by-president-danny-faure-on-the-occasion-of-30-of-seychelles-eez-designated-as-marine-protected-area.
32. J. C. Day, R. A. Kenchington, J. M. Tanzer, D. S. Cameron, Marine zoning revisited: How decades of zoning the Great Barrier Reef has evolved as an effective spatial planning approach for marine ecosystem-based management. *Aquat. Conserv.* **29** (S2), 9–32 (2019). [doi:10.1002/aqc.3115](https://doi.org/10.1002/aqc.3115)
33. Department of Agriculture, Forestry, and Fisheries, “Niue Moana Mahu Marine Protected Area Regulations 2020,” no. 2020/04 (2020); https://old.mpatlas.org/media/filer_public/bc/95/bc959065-13b7-42d7-97dd-507503fc4b01/reg_2020-04_niue_moana_mahu_marine_protected_area_regulations_1.pdf.
34. S. Wells, P. F. E. Addison, P. A. Bueno, M. Costantini, A. Fontaine, L. Germain, T. Lefebvre, L. Morgan, F. Staub, B. Wang, A. White, M. X. Zorrilla, Using the IUCN Green List of Protected and Conserved Areas to promote conservation impact through marine protected areas. *Aquat. Conserv.* **26**, 24–44 (2016). [doi:10.1002/aqc.2679](https://doi.org/10.1002/aqc.2679)
35. Marine Conservation Institute, BlueParks (2020); <https://blueparks.org>.
36. G. G. Gurney, E. S. Darling, S. D. Jupiter, S. Mangubhai, T. R. McClanahan, P. Lestari, S. Pardede, S. J. Campbell, M. Fox, W. Naisilisili, N. A. Muthiga, S. D’agata, K. E. Holmes, N. A. Rossi, Implementing a social-ecological systems framework for conservation monitoring: Lessons from a multi-country coral reef program. *Biol. Conserv.* **240**, 108298 (2019). [doi:10.1016/j.biocon.2019.108298](https://doi.org/10.1016/j.biocon.2019.108298)
37. G. N. Ahmadi, L. Glew, M. Provost, D. Gill, N. I. Hidayat, S. Mangubhai, H. E. Purwanto, H. E. Fox, Integrating impact evaluation in the design and implementation of monitoring marine protected areas. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **370**, 20140275 (2015). [doi:10.1098/rstb.2014.0275](https://doi.org/10.1098/rstb.2014.0275) [Medline](#)
38. S. Murray, T. T. Hee, A rising tide: California’s ongoing commitment to monitoring, managing and enforcing its marine protected areas. *Ocean Coast. Manage.* **182**, 104920 (2019). [doi:10.1016/j.ocecoaman.2019.104920](https://doi.org/10.1016/j.ocecoaman.2019.104920)

39. S. E. Lester, B. S. Halpern, K. Grorud-Colvert, J. Lubchenco, B. I. Ruttenberg, S. D. Gaines, S. Airame, R. R. Warner, Biological effects within no-take marine reserves: A global synthesis. *Mar. Ecol. Prog. Ser.* **384**, 33–46 (2009). [doi:10.3354/meps08029](https://doi.org/10.3354/meps08029)
40. J. Claudet, C. W. Osenberg, L. Benedetti-Cecchi, P. Domenici, J.-A. García-Charton, A. Pérez-Ruzafa, F. Badalamenti, J. Bayle-Sempere, A. Brito, F. Bulleri, J.-M. Culioli, M. Dimech, J. M. Falcón, I. Guala, M. Milazzo, J. Sánchez-Meca, P. J. Somerfield, B. Stobart, F. Vandeperre, C. Valle, S. Planes, Marine reserves: Size and age do matter. *Ecol. Lett.* **11**, 481–489 (2008). [doi:10.1111/j.1461-0248.2008.01166.x](https://doi.org/10.1111/j.1461-0248.2008.01166.x) [Medline](#)
41. P. P. Molloy, I. B. McLean, I. M. Côté, Effects of marine reserve age on fish populations: A global meta-analysis. *J. Appl. Ecol.* **46**, 743–751 (2009). [doi:10.1111/j.1365-2664.2009.01662.x](https://doi.org/10.1111/j.1365-2664.2009.01662.x)
42. S. Giakoumi, C. Scianna, J. Plass-Johnson, F. Micheli, K. Grorud-Colvert, P. Thiriet, J. Claudet, G. Di Carlo, A. Di Franco, S. D. Gaines, J. A. García-Charton, J. Lubchenco, J. Reimer, E. Sala, P. Guidetti, Ecological effects of full and partial protection in the crowded Mediterranean Sea: A regional meta-analysis. *Sci. Rep.* **7**, 8940 (2017). [doi:10.1038/s41598-017-08850-w](https://doi.org/10.1038/s41598-017-08850-w) [Medline](#)
43. M. Zupan, F. Bulleri, J. Evans, S. Frascchetti, P. Guidetti, A. Garcia-Rubies, M. Sostres, V. Asnaghi, A. Caro, S. Deudero, R. Goñi, G. Guarneri, F. Guilhaumon, D. Kersting, A. Kokkali, C. Kruschel, V. Macic, L. Mangialajo, S. Mallol, E. Macpherson, A. Panucci, M. Radolovic, M. Ramdani, P. J. Schembri, A. Terlizzi, E. Villa, J. Claudet, How good is your marine protected area at curbing threats? *Biol. Conserv.* **221**, 237–245 (2018). [doi:10.1016/j.biocon.2018.03.013](https://doi.org/10.1016/j.biocon.2018.03.013)
44. M. Sciberras, S. R. Jenkins, R. Mant, M. J. Kaiser, S. J. Hawkins, A. S. Pullin, Evaluating the relative conservation value of fully and partially protected marine areas. *Fish Fish.* **16**, 58–77 (2015). [doi:10.1111/faf.12044](https://doi.org/10.1111/faf.12044)
45. C. M. Roberts, B. C. O’Leary, D. J. McCauley, P. M. Cury, C. M. Duarte, J. Lubchenco, D. Pauly, A. Sáenz-Arroyo, U. R. Sumaila, R. W. Wilson, B. Worm, J. C. Castilla, Marine reserves can mitigate and promote adaptation to climate change. *Proc. Natl. Acad. Sci. U.S.A.* **114**, 6167–6175 (2017). [doi:10.1073/pnas.1701262114](https://doi.org/10.1073/pnas.1701262114) [Medline](#)
46. J. Claudet, France must impose strict levels of marine protection. *Nature* **570**, 36–36 (2019). [doi:10.1038/d41586-019-01750-1](https://doi.org/10.1038/d41586-019-01750-1) [Medline](#)
47. A. C. Alcala, G. R. Russ, No-take marine reserves and reef fisheries management in the Philippines: A new people power revolution. *Ambio* **35**, 245–254 (2006). [doi:10.1579/05-A-054R1.1](https://doi.org/10.1579/05-A-054R1.1) [Medline](#)
48. Palau International Coral Reef Center-PICRC, “Palau National Marine Sanctuary Act Overview”; <https://picrc.org/picrcpage/wp-content/uploads/2019/12/PNMS-Act-Overview-2019AUG20.pdf>.
49. K. Kikiloi, A. M. Friedlander, ’Aulani Wilhelm, N. Lewis, K. Quioco, W. ’Āila, S. Kaho’ohalahala, Papahānaumokuākea: Integrating culture in the design and management of one of the world’s largest marine protected areas. *Coast. Manage.* **45**, 436–451 (2017).

50. M. B. Mascia, C. A. Claus, A property rights approach to understanding human displacement from protected areas: The case of marine protected areas. *Conserv. Biol.* **23**, 16–23 (2009). [doi:10.1111/j.1523-1739.2008.01050.x](https://doi.org/10.1111/j.1523-1739.2008.01050.x) [Medline](#)
51. National Oceanic and Atmospheric Administration, United States Fish and Wildlife Service, Hawai‘i Department of Land and Natural Resources, “Papahānaumokuākea Marine National Monument Management Plan” (2008); https://nmspapahanaumokuakea.blob.core.windows.net/papahanaumokuakea-prod/media/archive/management/mp/vol1_mmp08.pdf.
52. Great Barrier Reef Marine Park Authority, Interpreting zones; www.gbrmpa.gov.au/access-and-use/zoning/interpreting-zones.
53. International Union for the Conservation of Nature, “Motion 066–Guidance to identify industrial fishing incompatible with protected areas” (2020); www.iucncongress2020.org/motion/066.
54. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration, United States Department of Commerce, State of Hawai‘i, Hawai‘i Department of Land and Natural Resources, “Hawai‘ian Islands Humpback Whale National Marine Sanctuary Management Plan” (2020); <https://nmshawaiihumpbackwhale.blob.core.windows.net/hawaiihumpbackwhale-prod/media/docs/2020-hihwnms-management-plan.pdf>.
55. L. M. Petruny, A. J. Wright, C. E. Smith, Getting it right for the North Atlantic right whale (*Eubalaena glacialis*): A last opportunity for effective marine spatial planning? *Mar. Pollut. Bull.* **85**, 24–32 (2014). [doi:10.1016/j.marpolbul.2014.06.004](https://doi.org/10.1016/j.marpolbul.2014.06.004) [Medline](#)
56. C. Bracciali, D. Campobello, C. Giacoma, G. Sarà, Effects of nautical traffic and noise on foraging patterns of Mediterranean damselfish (*Chromis chromis*). *PLOS ONE* **7**, e40582 (2012). [doi:10.1371/journal.pone.0040582](https://doi.org/10.1371/journal.pone.0040582) [Medline](#)
57. D. A. Gill, M. B. Mascia, G. N. Ahmadi, L. Glew, S. E. Lester, M. Barnes, I. Craigie, E. S. Darling, C. M. Free, J. Geldmann, S. Holst, O. P. Jensen, A. T. White, X. Basurto, L. Coad, R. D. Gates, G. Guannel, P. J. Mumby, H. Thomas, S. Whitmee, S. Woodley, H. E. Fox, Capacity shortfalls hinder the performance of marine protected areas globally. *Nature* **543**, 665–669 (2017). [doi:10.1038/nature21708](https://doi.org/10.1038/nature21708) [Medline](#)
58. M. Lockwood, Good governance for terrestrial protected areas: A framework, principles and performance outcomes. *J. Environ. Manage.* **91**, 754–766 (2010). [doi:10.1016/j.jenvman.2009.10.005](https://doi.org/10.1016/j.jenvman.2009.10.005) [Medline](#)
59. N. J. Bennett, T. Satterfield, Environmental governance: A practical framework to guide design, evaluation, and analysis. *Conserv. Lett.* **11**, e12600 (2018). [doi:10.1111/conl.12600](https://doi.org/10.1111/conl.12600)
60. IUCN-WCPA, “Establishing marine protected area networks–Making it happen” (IUCN World Commission on Protected Areas, National Oceanic and Atmospheric Administration, and The Nature Conservancy, 2008), p. 118.
61. R. L. Pressey, M. C. Bottrill, Approaches to landscape- and seascape-scale conservation planning: Convergence, contrasts and challenges. *Oryx* **43**, 464–475 (2009). [doi:10.1017/S0030605309990500](https://doi.org/10.1017/S0030605309990500)

62. H. E. Fox, M. B. Mascia, X. Basurto, A. Costa, L. Glew, D. Heinemann, L. B. Karrer, S. E. Lester, A. V. Lombana, R. S. Pomeroy, C. A. Recchia, C. M. Roberts, J. N. Sanchirico, L. Pet-Soede, A. T. White, Reexamining the science of marine protected areas: Linking knowledge to action. *Conserv. Lett.* **5**, 1–10 (2012). [doi:10.1111/j.1755-263X.2011.00207.x](https://doi.org/10.1111/j.1755-263X.2011.00207.x)
63. M. Hockings, S. Stolton, F. Leverington, N. Dudley, J. Courrau, *Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas*, Best Practice Protected Area Guidelines Series (IUCN, 2006).
64. B. Spergel, M. Moye, *Financing Marine Conservation a Menu of Options* (World Wildlife Fund, Center for Conservation Finance, 2004).
65. P. Guidetti, J. Claudet, Comanagement practices enhance fisheries in marine protected areas. *Conserv. Biol.* **24**, 312–318 (2010). [doi:10.1111/j.1523-1739.2009.01358.x](https://doi.org/10.1111/j.1523-1739.2009.01358.x) [Medline](#)
66. N. J. Bennett, A. Di Franco, A. Calò, E. Nethery, F. Niccolini, M. Milazzo, P. Guidetti, Local support for conservation is associated with perceptions of good governance, social impacts, and ecological effectiveness. *Conserv. Lett.* **12**, e12640 (2019). [doi:10.1111/conl.12640](https://doi.org/10.1111/conl.12640)
67. V. R. Kamat, “The ocean is our farm”: Marine conservation, food insecurity, and social suffering in southeastern Tanzania. *Hum. Organ.* **73**, 289–298 (2014). [doi:10.17730/humo.73.3.f43k115544761g0v](https://doi.org/10.17730/humo.73.3.f43k115544761g0v)
68. H. B. Harrison, D. H. Williamson, R. D. Evans, G. R. Almany, S. R. Thorrold, G. R. Russ, K. A. Feldheim, L. van Herwerden, S. Planes, M. Srinivasan, M. L. Berumen, G. P. Jones, Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Curr. Biol.* **22**, 1023–1028 (2012). [doi:10.1016/j.cub.2012.04.008](https://doi.org/10.1016/j.cub.2012.04.008) [Medline](#)
69. K. Grorud-Colvert, J. Claudet, B. N. Tissot, J. E. Caselle, M. H. Carr, J. C. Day, A. M. Friedlander, S. E. Lester, T. L. de Loma, D. Malone, W. J. Walsh, Marine protected area networks: Assessing whether the whole is greater than the sum of its parts. *PLOS ONE* **9**, e102298 (2014). [doi:10.1371/journal.pone.0102298](https://doi.org/10.1371/journal.pone.0102298) [Medline](#)
70. A. Di Franco, J. G. Plass-Johnson, M. Di Lorenzo, B. Meola, J. Claudet, S. D. Gaines, J. A. García-Charton, S. Giakoumi, K. Grorud-Colvert, C. W. Hackrad, F. Micheli, P. Guidetti, Linking home ranges to protected area size: The case study of the Mediterranean Sea. *Conserv. Biol.* **221**, 175–181 (2018). [doi:10.1016/j.biocon.2018.03.012](https://doi.org/10.1016/j.biocon.2018.03.012)
71. S. M. Maxwell, K. M. Gjerde, M. G. Conners, L. B. Crowder, Mobile protected areas for biodiversity on the high seas. *Science* **367**, 252–254 (2020). [doi:10.1126/science.aaz9327](https://doi.org/10.1126/science.aaz9327) [Medline](#)
72. B. Erisman, W. Heyman, S. Kobara, T. Ezer, S. Pittman, O. Aburto-Oropeza, R. S. Nemeth, Fish spawning aggregations: Where well-placed management actions can yield big benefits for fisheries and conservation. *Fish Fish.* **18**, 128–144 (2017). [doi:10.1111/faf.12132](https://doi.org/10.1111/faf.12132)
73. C. M. Hernández, J. Witting, C. Willis, S. R. Thorrold, J. K. Llopiz, R. D. Rotjan, Evidence and patterns of tuna spawning inside a large no-take Marine Protected Area. *Sci. Rep.* **9**, 10772 (2019). [doi:10.1038/s41598-019-47161-0](https://doi.org/10.1038/s41598-019-47161-0) [Medline](#)

74. M. H. Carr, S. P. Robinson, C. Wahle, G. Davis, S. Kroll, S. Murray, E. J. Schumacker, M. Williams, The central importance of ecological spatial connectivity to effective coastal marine protected areas and to meeting the challenges of climate change in the marine environment. *Aquat. Conserv.* **27**, 6–29 (2017). [doi:10.1002/aqc.2800](https://doi.org/10.1002/aqc.2800)
75. M. Di Lorenzo, J. Claudet, P. Guidetti, Spillover from marine protected areas to adjacent fisheries has an ecological and a fishery component. *J. Nat. Conserv.* **32**, 62–66 (2016). [doi:10.1016/j.jnc.2016.04.004](https://doi.org/10.1016/j.jnc.2016.04.004)
76. “Reef 2050 Water Quality Improvement Plan 2017-2020” (State of Queensland, 2018), p. 63.
77. J. E. Duffy, J. S. Lefcheck, R. D. Stuart-Smith, S. A. Navarrete, G. J. Edgar, Biodiversity enhances reef fish biomass and resistance to climate change. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 6230–6235 (2016). [doi:10.1073/pnas.1524465113](https://doi.org/10.1073/pnas.1524465113) [Medline](#)
78. S. D. Gaines, C. Costello, B. Owashi, T. Mangin, J. Bone, J. G. Molinos, M. Burden, H. Dennis, B. S. Halpern, C. V. Kappel, K. M. Kleisner, D. Ovando, Improved fisheries management could offset many negative effects of climate change. *Sci. Adv.* **4**, ea01378 (2018). [doi:10.1126/sciadv.a01378](https://doi.org/10.1126/sciadv.a01378) [Medline](#)
79. L. Sheehan, E. T. Sherwood, R. P. Moyer, K. R. Radabaugh, S. Simpson, Blue carbon: An additional driver for restoring and preserving ecological services of coastal wetlands in Tampa Bay (Florida, USA). *Wetlands* **39**, 1317–1328 (2019). [doi:10.1007/s13157-019-01137-y](https://doi.org/10.1007/s13157-019-01137-y)
80. G. W. Allison, S. D. Gaines, J. Lubchenco, H. P. Possingham, Ensuring persistence of marine reserves: Catastrophes require adopting an insurance factor. *Ecol. Appl.* **13** (sp1), 8–24 (2003). [doi:10.1890/1051-0761\(2003\)013\[0008:EPOMRC\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2003)013[0008:EPOMRC]2.0.CO;2)
81. C. Mellin, M. Aaron MacNeil, A. J. Cheal, M. J. Emslie, M. Julian Caley, Marine protected areas increase resilience among coral reef communities. *Ecol. Lett.* **19**, 629–637 (2016). [doi:10.1111/ele.12598](https://doi.org/10.1111/ele.12598) [Medline](#)
82. M. J. Emslie, M. Logan, D. H. Williamson, A. M. Ayling, M. A. MacNeil, D. Ceccarelli, A. J. Cheal, R. D. Evans, K. A. Johns, M. J. Jonker, I. R. Miller, K. Osborne, G. R. Russ, H. P. A. Sweatman, Expectations and outcomes of reserve network performance following re-zoning of the Great Barrier Reef Marine Park. *Curr. Biol.* **25**, 983–992 (2015). [doi:10.1016/j.cub.2015.01.073](https://doi.org/10.1016/j.cub.2015.01.073) [Medline](#)
83. R. C. Babcock, N. T. Shears, A. C. Alcala, N. S. Barrett, G. J. Edgar, K. D. Lafferty, T. R. McClanahan, G. R. Russ, Decadal trends in marine reserves reveal differential rates of change in direct and indirect effects. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 18256–18261 (2010). [doi:10.1073/pnas.0908012107](https://doi.org/10.1073/pnas.0908012107) [Medline](#)
84. A. M. Friedlander, M. K. Donovan, H. Koike, P. Murakawa, W. Goodell, Characteristics of effective marine protected areas in Hawai‘i. *Aquat. Conserv.* **29** (S2), 103–117 (2019). [doi:10.1002/aqc.3043](https://doi.org/10.1002/aqc.3043)
85. O. Aburto-Oropeza, B. Erisman, G. R. Galland, I. Mascareñas-Osorio, E. Sala, E. Ezcurra, Large recovery of fish biomass in a no-take marine reserve. *PLOS ONE* **6**, e23601 (2011). [doi:10.1371/journal.pone.0023601](https://doi.org/10.1371/journal.pone.0023601) [Medline](#)

86. P. Guidetti, M. Milazzo, S. Bussotti, A. Molinari, M. Murenu, A. Pais, N. Spanò, R. Balzano, T. Agardy, F. Boero, G. Carrada, R. Cattaneo-Vietti, A. Cau, R. Chemello, S. Greco, A. Manganaro, G. Notarbartolo di Sciara, G. F. Russo, L. Tunesi, Italian marine reserve effectiveness: Does enforcement matter? *Conserv. Biol.* **141**, 699–709 (2008). [doi:10.1016/j.biocon.2007.12.013](https://doi.org/10.1016/j.biocon.2007.12.013)
87. M. Kaplan-Hallam, N. J. Bennett, Adaptive social impact management for conservation and environmental management. *Conserv. Biol.* **32**, 304–314 (2018). [doi:10.1111/cobi.12985](https://doi.org/10.1111/cobi.12985) [Medline](#)
88. N. C. Ban, G. G. Gurney, N. A. Marshall, C. K. Whitney, M. Mills, S. Gelcich, N. J. Bennett, M. C. Meehan, C. Butler, S. Ban, T. C. Tran, M. E. Cox, S. J. Breslow, Well-being outcomes of marine protected areas. *Nat. Sustain.* **2**, 524–532 (2019). [doi:10.1038/s41893-019-0306-2](https://doi.org/10.1038/s41893-019-0306-2)
89. D. A. Gill, S. H. Cheng, L. Glew, E. Aigner, N. J. Bennett, M. B. Mascia, Social synergies, tradeoffs, and equity in marine conservation impacts. *Annu. Rev. Environ. Resour.* **44**, 347–372 (2019). [doi:10.1146/annurev-environ-110718-032344](https://doi.org/10.1146/annurev-environ-110718-032344)
90. D. A. Gill, H. A. Oxenford, P. W. Schuhmann, in *Viability and Sustainability of Small-Scale Fisheries in Latin America and The Caribbean*, S. Salas, M. J. Barragán-Paladines, R. Chuenpagdee, Eds. (Springer, 2019), pp. 295–328.
91. M. Schratzberger, S. Neville, S. Painting, K. Weston, L. Paltriguera, Ecological and socio-economic effects of Highly Protected Marine Areas (HPMAs) in temperate waters. *Front. Mar. Sci.* **6**, 749 (2019). [doi:10.3389/fmars.2019.00749](https://doi.org/10.3389/fmars.2019.00749)
92. G. G. Gurney, J. Cinner, N. C. Ban, R. L. Pressey, R. Pollnac, S. J. Campbell, S. Tasidjawa, F. Setiawan, Poverty and protected areas: An evaluation of a marine integrated conservation and development project in Indonesia. *Glob. Environ. Change-Hum. Pol. Dimens.* **26**, 98–107 (2014). [doi:10.1016/j.gloenvcha.2014.04.003](https://doi.org/10.1016/j.gloenvcha.2014.04.003)
93. C. E. Hattam, S. C. Mangi, S. C. Gall, L. D. Rodwell, Social impacts of a temperate fisheries closure: Understanding stakeholders' views. *Mar. Policy* **45**, 269–278 (2014). [doi:10.1016/j.marpol.2013.09.005](https://doi.org/10.1016/j.marpol.2013.09.005)
94. R. Chuenpagdee, J. J. Pascual-Fernández, E. Szeliánszky, J. Luis Alegret, J. Fraga, S. Jentoft, Marine protected areas: Re-thinking their inception. *Mar. Policy* **39**, 234–240 (2013). [doi:10.1016/j.marpol.2012.10.016](https://doi.org/10.1016/j.marpol.2012.10.016)
95. H. S. Macedo, R. P. Medeiros, P. McConney, Are multiple-use marine protected areas meeting fishers' proposals? Strengths and constraints in fisheries' management in Brazil. *Mar. Policy* **99**, 351–358 (2019). [doi:10.1016/j.marpol.2018.11.007](https://doi.org/10.1016/j.marpol.2018.11.007)
96. C. Leisher, P. van Beukering, L. Scherl, "Nature's investment bank: How marine protected areas contribute to poverty reduction" (The Nature Conservancy, 2007).
97. E. Sala, C. Costello, D. Dougherty, G. Heal, K. Kelleher, J. H. Murray, A. A. Rosenberg, R. Sumaila, A general business model for marine reserves. *PLOS ONE* **8**, e58799 (2013). [doi:10.1371/journal.pone.0058799](https://doi.org/10.1371/journal.pone.0058799) [Medline](#)
98. M. D. Smith, J. Zhang, F. Coleman, Effectiveness of marine reserves for large-scale fisheries management. *Can. J. Fish. Aquat. Sci.* **63**, 153–164 (2006). [doi:10.1139/f05-205](https://doi.org/10.1139/f05-205)

99. K. Hogg, T. Gray, P. Noguera-Méndez, M. Semitiel-García, S. Young, Interpretations of MPA winners and losers: A case study of the Cabo De Palos- Islas Hormigas Fisheries Reserve. *Marit. Stud.* **18**, 159–171 (2019). [doi:10.1007/s40152-019-00134-5](https://doi.org/10.1007/s40152-019-00134-5)
100. G. G. Gurney, R. L. Pressey, J. E. Cinner, R. Pollnac, S. J. Campbell, Integrated conservation and development: Evaluating a community-based marine protected area project for equality of socioeconomic impacts. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **370**, 20140277 (2015). [doi:10.1098/rstb.2014.0277](https://doi.org/10.1098/rstb.2014.0277) [Medline](#)
101. S. M. Alexander, D. Armitage, P. J. Carrington, O. Bodin, Examining horizontal and vertical social ties to achieve social-ecological fit in an emerging marine reserve network. *Aquat. Conserv.* **27**, 1209–1223 (2017). [doi:10.1002/aqc.2775](https://doi.org/10.1002/aqc.2775)
102. C. G. McNally, E. Uchida, A. J. Gold, The effect of a protected area on the tradeoffs between short-run and long-run benefits from mangrove ecosystems. *Proc. Natl. Acad. Sci. U.S.A.* **108**, 13945–13950 (2011). [doi:10.1073/pnas.1101825108](https://doi.org/10.1073/pnas.1101825108) [Medline](#)
103. M. Gustavsson, L. Lindström, N. S. Jiddawi, M. de la Torre-Castro, Procedural and distributive justice in a community-based managed Marine Protected Area in Zanzibar, Tanzania. *Mar. Policy* **46**, 91–100 (2014). [doi:10.1016/j.marpol.2014.01.005](https://doi.org/10.1016/j.marpol.2014.01.005)
104. E. G. Oracion, M. L. Miller, P. Christie, Marine protected areas for whom? Fisheries, tourism, and solidarity in a Philippine community. *Ocean Coast. Manage.* **48**, 393–410 (2005). [doi:10.1016/j.ocecoaman.2005.04.013](https://doi.org/10.1016/j.ocecoaman.2005.04.013)
105. J. E. Cinner, T. Daw, C. Huchery, P. Thoya, A. Wamukota, M. Cedras, C. Abunge, Winners and losers in marine conservation: Fishers’ displacement and livelihood benefits from marine reserves. *Soc. Nat. Resour.* **27**, 994–1005 (2014). [doi:10.1080/08941920.2014.918229](https://doi.org/10.1080/08941920.2014.918229)
106. G. J. Edgar, R. D. Stuart-Smith, T. J. Willis, S. Kininmonth, S. C. Baker, S. Banks, N. S. Barrett, M. A. Becerro, A. T. F. Bernard, J. Berkhout, C. D. Buxton, S. J. Campbell, A. T. Cooper, M. Davey, S. C. Edgar, G. Försterra, D. E. Galván, A. J. Irigoyen, D. J. Kushner, R. Moura, P. E. Parnell, N. T. Shears, G. Soler, E. M. A. Strain, R. J. Thomson, Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**, 216–220 (2014). [doi:10.1038/nature13022](https://doi.org/10.1038/nature13022) [Medline](#)
107. E. Northrop, Manaswita Konar, Nicola Frost, Elizabeth Hollaway, “A Sustainable and Equitable Blue Recovery to the COVID-19 Crisis” (World Resources Institute, 2020); www.oceanpanel.org/bluerecovery.
108. K. Kelautan dan Perikanan, Management of marine protected areas in Indonesia: Status and challenges (Ministry of Marine Affairs and Fisheries and Yayasan WWF Indonesia, 2021); [doi:10.6084/m9.figshare.13341476.v1](https://doi.org/10.6084/m9.figshare.13341476.v1).
109. K. Grorud-Colvert, V. Constant, J. Sullivan-Stack, K. Dziedzic, S. L. Hamilton, Z. Randell, H. Fulton-Bennett, Z. D. Meunier, S. Bachhuber, A. J. Rickborn, B. Spiecker, J. Lubchenco, High-profile international commitments for ocean protection: Empty promises or meaningful progress? *Mar. Policy* **105**, 52–66 (2019). [doi:10.1016/j.marpol.2019.04.003](https://doi.org/10.1016/j.marpol.2019.04.003)
110. H. Österblom, C. Wabnitz, D. Tladi, E. Allison, S. Arnaud-Haond, J. Bebbington, N. Bennett, R. Blasiak, W. Boonstra, A. Choudhury, A. Cisneros-Montemayor, T. Daw, M.

- Fabinyi, N. Franz, H. Harden-Davies, D. Kleiber, P. Lopes, C. McDougall, B. Resosudarmo, S. Selim, *Towards Ocean Equity* (World Resources Institute, 2020); www.oceanpanel.org/sites/default/files/2020-04/towards-ocean-equity.pdf.
111. I. M. Côté, I. Mosqueira, J. D. Reynolds, Effects of marine reserve characteristics on the protection of fish populations: A meta-analysis. *J. Fish Biol.* **59** (sa), 178–189 (2001). [doi:10.1111/j.1095-8649.2001.tb01385.x](https://doi.org/10.1111/j.1095-8649.2001.tb01385.x)
 112. S. Lester, B. Halpern, Biological responses in marine no-take reserves versus partially protected areas. *Mar. Ecol. Prog. Ser.* **367**, 49–56 (2008). [doi:10.3354/meps07599](https://doi.org/10.3354/meps07599)
 113. C. M. Roberts, J. A. Bohnsack, F. Gell, J. P. Hawkins, R. Goodridge, Effects of marine reserves on adjacent fisheries. *Science* **294**, 1920–1923 (2001). [doi:10.1126/science.294.5548.1920](https://doi.org/10.1126/science.294.5548.1920) [Medline](#)
 114. J. Claudet, D. Pelletier, J.-Y. Jouvencel, F. Bachet, R. Galzin, Assessing the effects of marine protected area (MPA) on a reef fish assemblage in a northwestern Mediterranean marine reserve: Identifying community-based indicators. *Conserv. Biol.* **130**, 349–369 (2006). [doi:10.1016/j.biocon.2005.12.030](https://doi.org/10.1016/j.biocon.2005.12.030)
 115. B. I. Ruttenberg, S. L. Hamilton, S. M. Walsh, M. K. Donovan, A. Friedlander, E. DeMartini, E. Sala, S. A. Sandin, Predator-induced demographic shifts in coral reef fish assemblages. *PLOS ONE* **6**, e21062 (2011). [doi:10.1371/journal.pone.0021062](https://doi.org/10.1371/journal.pone.0021062) [Medline](#)
 116. A. García-Rubies, B. Hereu, M. Zabala, Long-term recovery patterns and limited spillover of large predatory fish in a Mediterranean MPA. *PLOS ONE* **8**, e73922 (2013). [doi:10.1371/journal.pone.0073922](https://doi.org/10.1371/journal.pone.0073922) [Medline](#)
 117. R. A. Abesamis, A. L. Green, G. R. Russ, C. R. L. Jadloc, The intrinsic vulnerability to fishing of coral reef fishes and their differential recovery in fishery closures. *Rev. Fish Biol. Fish.* **24**, 1033–1063 (2014). [doi:10.1007/s11160-014-9362-x](https://doi.org/10.1007/s11160-014-9362-x)
 118. H. A. Malcolm, A. L. Schultz, P. Sachs, N. Johnstone, A. Jordan, Decadal changes in the abundance and length of snapper (*Chrysophrys auratus*) in subtropical marine sanctuaries. *PLOS ONE* **10**, e0127616 (2015). [doi:10.1371/journal.pone.0127616](https://doi.org/10.1371/journal.pone.0127616) [Medline](#)
 119. D. Harasti, J. Williams, E. Mitchell, S. Lindfield, A. Jordan, Increase in relative abundance and size of snapper *Chrysophrys auratus* within partially-protected and no-take areas in a temperate marine protected area. *Front. Mar. Sci.* **5**, 208 (2018). [doi:10.3389/fmars.2018.00208](https://doi.org/10.3389/fmars.2018.00208)
 120. E. Sala, E. Ballesteros, P. Dendrinou, A. Di Franco, F. Ferretti, D. Foley, S. Fraschetti, A. Friedlander, J. Garrabou, H. Güçlüsoy, P. Guidetti, B. S. Halpern, B. Hereu, A. A. Karamanlidis, Z. Kizilkaya, E. Macpherson, L. Mangialajo, S. Mariani, F. Micheli, A. Pais, K. Riser, A. A. Rosenberg, M. Sales, K. A. Selkoe, R. Starr, F. Tomas, M. Zabala, The structure of Mediterranean rocky reef ecosystems across environmental and human gradients, and conservation implications. *PLOS ONE* **7**, e32742 (2012). [doi:10.1371/journal.pone.0032742](https://doi.org/10.1371/journal.pone.0032742) [Medline](#)
 121. P. Guidetti, P. Baiata, E. Ballesteros, A. Di Franco, B. Hereu, E. Macpherson, F. Micheli, A. Pais, P. Panzalis, A. A. Rosenberg, M. Zabala, E. Sala, Large-scale assessment of

- Mediterranean marine protected areas effects on fish assemblages. *PLOS ONE* **9**, e91841 (2014). [doi:10.1371/journal.pone.0091841](https://doi.org/10.1371/journal.pone.0091841) [Medline](#)
122. E. Sala, S. Giakoumi, No-take marine reserves are the most effective protected areas in the ocean. *ICES J. Mar. Sci.* **75**, 1166–1168 (2018). [doi:10.1093/icesjms/fsx059](https://doi.org/10.1093/icesjms/fsx059)
123. D. Agnetta, F. Badalamenti, F. Colloca, G. D’Anna, M. Di Lorenzo, F. Fiorentino, G. Garofalo, M. Gristina, L. Labanchi, B. Patti, C. Pipitone, C. Solidoro, S. Libralato, Benthic-pelagic coupling mediates interactions in Mediterranean mixed fisheries: An ecosystem modeling approach. *PLOS ONE* **14**, e0210659 (2019). [doi:10.1371/journal.pone.0210659](https://doi.org/10.1371/journal.pone.0210659) [Medline](#)
124. G. R. Russ, A. C. Alcala, Enhanced biodiversity beyond marine reserve boundaries: The cup spillith over. *Ecol. Appl.* **21**, 241–250 (2011). [doi:10.1890/09-1197.1](https://doi.org/10.1890/09-1197.1) [Medline](#)
125. K. L. Nash, N. A. J. Graham, Ecological indicators for coral reef fisheries management. *Fish Fish.* **17**, 1029–1054 (2016). [doi:10.1111/faf.12157](https://doi.org/10.1111/faf.12157)
126. R. S. Nemeth, Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Mar. Ecol. Prog. Ser.* **286**, 81–97 (2005). [doi:10.3354/meps286081](https://doi.org/10.3354/meps286081) [Medline](#)
127. M. J. Kaiser, R. E. Blyth-Skyrme, P. J. Hart, G. Edwards-Jones, D. Palmer, Evidence for greater reproductive output per unit area in areas protected from fishing. *Can. J. Fish. Aquat. Sci.* **64**, 1284–1289 (2007). [doi:10.1139/f07-090](https://doi.org/10.1139/f07-090)
128. R. Crec’Hriou, F. Alemany, E. Roussel, A. Chassanite, J. Y. Marinaro, J. Mader, E. Rochel, S. Planes, Fisheries replenishment of early life taxa: Potential export of fish eggs and larvae from a temperate marine protected area. *Fish. Oceanogr.* **19**, 135–150 (2010). [doi:10.1111/j.1365-2419.2010.00533.x](https://doi.org/10.1111/j.1365-2419.2010.00533.x)
129. B. M. Taylor, J. L. McIlwain, Beyond abundance and biomass: Effects of marine protected areas on the demography of a highly exploited reef fish. *Mar. Ecol. Prog. Ser.* **411**, 243–258 (2010). [doi:10.3354/meps08672](https://doi.org/10.3354/meps08672)
130. D. Díaz, S. Mallol, A. M. Parma, R. Goñi, Decadal trend in lobster reproductive output from a temperate marine protected area. *Mar. Ecol. Prog. Ser.* **433**, 149–157 (2011). [doi:10.3354/meps09182](https://doi.org/10.3354/meps09182)
131. M. A. Hixon, D. W. Johnson, S. M. Sogard, BOFFFFs: On the importance of conserving old-growth age structure in fishery populations. *ICES J. Mar. Sci.* **71**, 2171–2185 (2014). [doi:10.1093/icesjms/fst200](https://doi.org/10.1093/icesjms/fst200)
132. D. R. Barneche, D. R. Robertson, C. R. White, D. J. Marshall, Fish reproductive-energy output increases disproportionately with body size. *Science* **360**, 642–645 (2018). [doi:10.1126/science.aao6868](https://doi.org/10.1126/science.aao6868) [Medline](#)
133. D. J. Marshall, S. Gaines, R. Warner, D. R. Barneche, M. Bode, Underestimating the benefits of marine protected areas for the replenishment of fished populations. *Front. Ecol. Environ.* **17**, 407–413 (2019). [doi:10.1002/fee.2075](https://doi.org/10.1002/fee.2075)
134. R. A. Pelc, R. R. Warner, S. D. Gaines, C. B. Paris, Detecting larval export from marine reserves. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 18266–18271 (2010). [doi:10.1073/pnas.0907368107](https://doi.org/10.1073/pnas.0907368107) [Medline](#)

135. M. R. Christie, B. N. Tissot, M. A. Albins, J. P. Beets, Y. Jia, D. M. Ortiz, S. E. Thompson, M. A. Hixon, Larval connectivity in an effective network of marine protected areas. *PLOS ONE* **5**, e15715 (2010). [doi:10.1371/journal.pone.0015715](https://doi.org/10.1371/journal.pone.0015715) [Medline](#)
136. A. Di Franco, B. M. Gillanders, G. De Benedetto, A. Pennetta, G. A. De Leo, P. Guidetti, Dispersal patterns of coastal fish: Implications for designing networks of marine protected areas. *PLOS ONE* **7**, e31681 (2012). [doi:10.1371/journal.pone.0031681](https://doi.org/10.1371/journal.pone.0031681) [Medline](#)
137. C. M. Roberts, J. P. Hawkins, “Establishment of fish stock recovery areas” (European Parliament, 2012), p. 70.
138. M. Andrello, F. Guilhaumon, C. Albouy, V. Parravicini, J. Scholtens, P. Verley, M. Barange, U. R. Sumaila, S. Manel, D. Mouillot, Global mismatch between fishing dependency and larval supply from marine reserves. *Nat. Commun.* **8**, 16039 (2017). [doi:10.1038/ncomms16039](https://doi.org/10.1038/ncomms16039) [Medline](#)
139. S. Manel, N. Loiseau, M. Andrello, K. Fietz, R. Goñi, A. Forcada, P. Lenfant, S. Kininmonth, C. Marcos, V. Marques, S. Mallol, A. Pérez-Ruzafa, C. Breusing, O. Puebla, D. Mouillot, Long-distance benefits of marine reserves: Myth or reality? *Trends Ecol. Evol.* **34**, 342–354 (2019). [doi:10.1016/j.tree.2019.01.002](https://doi.org/10.1016/j.tree.2019.01.002) [Medline](#)
140. J. Assis, E. Fragkopoulou, E. A. Serrão, B. Horta E Costa, M. Gandra, D. Abecasis, Weak biodiversity connectivity in the European network of no-take marine protected areas. *Sci. Total Environ.* **773**, 145664 (2021). [doi:10.1016/j.scitotenv.2021.145664](https://doi.org/10.1016/j.scitotenv.2021.145664) [Medline](#)
141. D. Mouillot, J. M. Culioli, D. Pelletier, J. A. Tomasini, Do we protect biological originality in protected areas? A new index and an application to the Bonifacio Strait Natural Reserve. *Biol. Conserv.* **141**, 1569–1580 (2008). [doi:10.1016/j.biocon.2008.04.002](https://doi.org/10.1016/j.biocon.2008.04.002)
142. L. Pichegru, D. Grémillet, R. J. M. Crawford, P. G. Ryan, Marine no-take zone rapidly benefits endangered penguin. *Biol. Lett.* **6**, 498–501 (2010). [doi:10.1098/rsbl.2009.0913](https://doi.org/10.1098/rsbl.2009.0913) [Medline](#)
143. A. M. Gormley, E. Slooten, S. Dawson, R. J. Barker, W. Rayment, S. du Fresne, S. Bräger, First evidence that marine protected areas can work for marine mammals. *J. Appl. Ecol.* **49**, 474–480 (2012). [doi:10.1111/j.1365-2664.2012.02121.x](https://doi.org/10.1111/j.1365-2664.2012.02121.x)
144. J. S. Goetze, S. D. Jupiter, T. J. Langlois, S. K. Wilson, E. S. Harvey, T. Bond, W. Naisilisili, Diver operated video most accurately detects the impacts of fishing within periodically harvested closures. *J. Exp. Mar. Biol. Ecol.* **462**, 74–82 (2015). [doi:10.1016/j.jembe.2014.10.004](https://doi.org/10.1016/j.jembe.2014.10.004)
145. B. W. McLaren, T. J. Langlois, E. S. Harvey, H. Shortland-Jones, R. Stevens, A small no-take marine sanctuary provides consistent protection for small-bodied by-catch species, but not for large-bodied, high-risk species. *J. Exp. Mar. Biol. Ecol.* **471**, 153–163 (2015). [doi:10.1016/j.jembe.2015.06.002](https://doi.org/10.1016/j.jembe.2015.06.002)
146. R. G. Dwyer, N. C. Krueck, V. Udyawer, M. R. Heupel, D. Chapman, H. L. Pratt Jr., R. Garla, C. A. Simpfendorfer, Individual and population benefits of marine reserves for reef sharks. *Curr. Biol.* **30**, 480–489.e5 (2020). [doi:10.1016/j.cub.2019.12.005](https://doi.org/10.1016/j.cub.2019.12.005) [Medline](#)

147. T. Miethe, C. Dytham, U. Dieckmann, J. W. Pitchford, Marine reserves and the evolutionary effects of fishing on size at maturation. *ICES J. Mar. Sci.* **67**, 412–425 (2010). [doi:10.1093/icesjms/fsp248](https://doi.org/10.1093/icesjms/fsp248)
148. R. Y. Fidler, J. Carroll, K. W. Rynerson, D. F. Matthews, R. G. Turingan, Coral reef fishes exhibit beneficial phenotypes inside marine protected areas. *PLOS ONE* **13**, e0193426 (2018). [doi:10.1371/journal.pone.0193426](https://doi.org/10.1371/journal.pone.0193426) [Medline](#)
149. K. R. Jones, C. J. Klein, B. S. Halpern, O. Venter, H. Grantham, C. D. Kuempel, N. Shumway, A. M. Friedlander, H. P. Possingham, J. E. M. Watson, The location and protection status of Earth's diminishing marine wilderness. *Curr. Biol.* **28**, 2506–2512.e3 (2018). [doi:10.1016/j.cub.2018.06.010](https://doi.org/10.1016/j.cub.2018.06.010) [Medline](#)
150. T. K. Sjørdalen, K. T. Halvorsen, H. B. Harrison, C. D. Ellis, L. A. Vøllestad, H. Knutsen, E. Moland, E. M. Olsen, Harvesting changes mating behaviour in European lobster. *Evol. Appl.* **11**, 963–977 (2018). [doi:10.1111/eva.12611](https://doi.org/10.1111/eva.12611) [Medline](#)
151. P. Guidetti, Potential of marine reserves to cause community-wide changes beyond their boundaries. *Conserv. Biol.* **21**, 540–545 (2007). [doi:10.1111/j.1523-1739.2007.00657.x](https://doi.org/10.1111/j.1523-1739.2007.00657.x) [Medline](#)
152. M. J. Costello, Long live Marine Reserves: A review of experiences and benefits. *Biol. Conserv.* **176**, 289–296 (2014). [doi:10.1016/j.biocon.2014.04.023](https://doi.org/10.1016/j.biocon.2014.04.023)
153. D. H. Williamson, D. M. Ceccarelli, R. D. Evans, G. P. Jones, G. R. Russ, Habitat dynamics, marine reserve status, and the decline and recovery of coral reef fish communities. *Ecol. Evol.* **4**, 337–354 (2014). [doi:10.1002/ece3.934](https://doi.org/10.1002/ece3.934) [Medline](#)
154. J. W. Turnbull, Y. Shah Esmaeili, G. F. Clark, W. F. Figueira, E. L. Johnston, R. Ferrari, Key drivers of effectiveness in small marine protected areas. *Biodivers. Conserv.* **27**, 2217–2242 (2018). [doi:10.1007/s10531-018-1532-z](https://doi.org/10.1007/s10531-018-1532-z)
155. P. Guidetti, Marine reserves reestablish lost predatory interactions and cause community changes in rocky reefs. *Ecol. Appl.* **16**, 963–976 (2006). [doi:10.1890/1051-0761\(2006\)016\[0963:MRRLPI\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2006)016[0963:MRRLPI]2.0.CO;2) [Medline](#)
156. J. Claudet, C. W. Osenberg, P. Domenici, F. Badalamenti, M. Milazzo, J. M. Falcón, I. Bertocci, L. Benedetti-Cecchi, J.-A. García-Charton, R. Goñi, J. A. Borg, A. Forcada, G. A. De Lucia, A. Pérez-Ruzafa, P. Afonso, A. Brito, I. Guala, L. Le Diréach, P. Sanchez-Jerez, P. J. Somerfield, S. Planes, Marine reserves: Fish life history and ecological traits matter. *Ecol. Appl.* **20**, 830–839 (2010). [doi:10.1890/08-2131.1](https://doi.org/10.1890/08-2131.1) [Medline](#)
157. T. R. McClanahan, N. A. Graham, Marine reserve recovery rates towards a baseline are slower for reef fish community life histories than biomass. *Proc. Biol. Sci.* **282**, 20151938 (2015). [doi:10.1098/rspb.2015.1938](https://doi.org/10.1098/rspb.2015.1938) [Medline](#)
158. G. R. Russ, K. I. Miller, J. R. Rizzari, A. C. Alcalá, Long-term no-take marine reserve and benthic habitat effects on coral reef fishes. *Mar. Ecol. Prog. Ser.* **529**, 233–248 (2015). [doi:10.3354/meps11246](https://doi.org/10.3354/meps11246)
159. D. Acuña-Marrero, A. N. H. Smith, N. Hammerschlag, A. Hearn, M. J. Anderson, H. Calich, M. D. M. Pawley, C. Fischer, P. Salinas-de-León, Residency and movement

- patterns of an apex predatory shark (*Galeocerdo cuvier*) at the Galapagos Marine Reserve. *PLOS ONE* **12**, e0183669 (2017). [doi:10.1371/journal.pone.0183669](https://doi.org/10.1371/journal.pone.0183669) [Medline](#)
160. R. L. Selden, S. D. Gaines, S. L. Hamilton, R. R. Warner, Protection of large predators in a marine reserve alters size-dependent prey mortality. *Proc. Biol. Sci.* **284**, 20161936 (2017). [doi:10.1098/rspb.2016.1936](https://doi.org/10.1098/rspb.2016.1936) [Medline](#)
161. E. McLeod, R. Salm, A. Green, J. Almany, Designing marine protected area networks to address the impacts of climate change. *Front. Ecol. Environ.* **7**, 362–370 (2009). [doi:10.1890/070211](https://doi.org/10.1890/070211)
162. S. D. Ling, C. R. Johnson, S. D. Frusher, K. R. Ridgway, Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 22341–22345 (2009). [doi:10.1073/pnas.0907529106](https://doi.org/10.1073/pnas.0907529106) [Medline](#)
163. F. Micheli, A. Saenz-Arroyo, A. Greenley, L. Vazquez, J. A. Espinoza Montes, M. Rossetto, G. A. De Leo, Evidence that marine reserves enhance resilience to climatic impacts. *PLOS ONE* **7**, e40832 (2012). [doi:10.1371/journal.pone.0040832](https://doi.org/10.1371/journal.pone.0040832) [Medline](#)
164. L. A. K. Barnett, M. L. Baskett, Marine reserves can enhance ecological resilience. *Ecol. Lett.* **18**, 1301–1310 (2015). [doi:10.1111/ele.12524](https://doi.org/10.1111/ele.12524) [Medline](#)
165. K. L. Wilson, D. P. Tittensor, B. Worm, H. K. Lotze, Incorporating climate change adaptation into marine protected area planning. *Glob. Change Biol.* **26**, 3251–3267 (2020). [doi:10.1111/gcb.15094](https://doi.org/10.1111/gcb.15094) [Medline](#)
166. R. A. Abesamis, G. R. Russ, Density-dependent spillover from a marine reserve: Long-term evidence. *Ecol. Appl.* **15**, 1798–1812 (2005). [doi:10.1890/05-0174](https://doi.org/10.1890/05-0174)
167. B. S. Halpern, S. E. Lester, J. B. Kellner, Spillover from marine reserves and the replenishment of fished stocks. *Environ. Conserv.* **36**, 268–276 (2009). [doi:10.1017/S0376892910000032](https://doi.org/10.1017/S0376892910000032)
168. M. Di Lorenzo, P. Guidetti, A. Di Franco, A. Calò, J. Claudet, Assessing spillover from marine protected areas and its drivers: A meta-analytical approach. *Fish Fish.* **21**, 906–915 (2020). [doi:10.1111/faf.12469](https://doi.org/10.1111/faf.12469)
169. P. H. Manríquez, J. C. Castilla, Significance of marine protected areas in central Chile as seeding grounds for the gastropod *Concholepas concholepas*. *Mar. Ecol. Prog. Ser.* **215**, 201–211 (2001). [doi:10.3354/meps215201](https://doi.org/10.3354/meps215201)
170. S. Planes, G. P. Jones, S. R. Thorrold, Larval dispersal connects fish populations in a network of marine protected areas. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 5693–5697 (2009). [doi:10.1073/pnas.0808007106](https://doi.org/10.1073/pnas.0808007106) [Medline](#)
171. A. Di Franco, A. Calò, A. Pennetta, G. De Benedetto, S. Planes, P. Guidetti, Dispersal of larval and juvenile seabream: Implications for Mediterranean marine protected areas. *Biol. Conserv.* **192**, 361–368 (2015). [doi:10.1016/j.biocon.2015.10.015](https://doi.org/10.1016/j.biocon.2015.10.015)
172. T. Lauck, C. W. Clark, M. Mangel, G. R. Munro, Implementing the Precautionary Principle in Fisheries Management Through Marine Reserves. *Ecol. Appl.* **8**, S72–S78 (1998). [doi:10.2307/2641364](https://doi.org/10.2307/2641364)

173. C. M. Roberts, J. P. Hawkins, F. R. Gell, The role of marine reserves in achieving sustainable fisheries. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **360**, 123–132 (2005). [doi:10.1098/rstb.2004.1578](https://doi.org/10.1098/rstb.2004.1578) [Medline](#)
174. N. C. Krueck, G. N. Ahmadi, H. P. Possingham, C. Riginos, E. A. Treml, P. J. Mumby, Marine Reserve Targets to Sustain and Rebuild Unregulated Fisheries. *PLOS Biol.* **15**, e2000537 (2017). [doi:10.1371/journal.pbio.2000537](https://doi.org/10.1371/journal.pbio.2000537) [Medline](#)
175. J. Beets, A. Friedlander, Evaluation of a conservation strategy: A spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Environ. Biol. Fishes* **55**, 91–98 (1999). [doi:10.1023/A:1007404421518](https://doi.org/10.1023/A:1007404421518)
176. L. Rogers-Bennett, J. S. Pearse, Indirect benefits of marine protected areas for juvenile abalone. *Conserv. Biol.* **15**, 642–647 (2001). [doi:10.1046/j.1523-1739.2001.015003642.x](https://doi.org/10.1046/j.1523-1739.2001.015003642.x)
177. E. Sala, E. Ballesteros, R. M. Starr, Rapid decline of Nassau Grouper spawning aggregations in Belize: Fishery management and conservation needs. *Fisheries (Bethesda, Md.)* **26**, 23–30 (2001). [doi:10.1577/1548-8446\(2001\)026<0023:RDONGS>2.0.CO;2](https://doi.org/10.1577/1548-8446(2001)026<0023:RDONGS>2.0.CO;2)
178. R. C. Garla, D. D. Chapman, B. M. Wetherbee, M. Shivji, Movement patterns of young Caribbean reef sharks, *Carcharhinus perezi*, at Fernando de Noronha Archipelago, Brazil: The potential of marine protected areas for conservation of a nursery ground. *Mar. Biol.* **149**, 189–199 (2006). [doi:10.1007/s00227-005-0201-4](https://doi.org/10.1007/s00227-005-0201-4)
179. P. R. Armsworth, B. A. Block, J. Eagle, J. E. Roughgarden, The economic efficiency of a time–area closure to protect spawning bluefin tuna. *J. Appl. Ecol.* **47**, 36–46 (2010). [doi:10.1111/j.1365-2664.2009.01738.x](https://doi.org/10.1111/j.1365-2664.2009.01738.x)
180. A. Grüss, D. M. Kaplan, J. Robinson, Evaluation of the effectiveness of marine reserves for transient spawning aggregations in data-limited situations. *ICES J. Mar. Sci.* **71**, 435–449 (2014). [doi:10.1093/icesjms/fst028](https://doi.org/10.1093/icesjms/fst028)
181. N. A. Farmer, W. D. Heyman, M. Karnauskas, S. Kobara, T. I. Smart, J. C. Ballenger, M. J. Reichert, D. M. Wyanski, M. S. Tishler, K. C. Lindeman, S. K. Lowerre-Barbieri, T. S. Switzer, J. J. Solomon, K. McCain, M. Marhefka, G. R. Sedberry, Timing and locations of reef fish spawning off the southeastern United States. *PLOS ONE* **12**, e0172968 (2017). [doi:10.1371/journal.pone.0172968](https://doi.org/10.1371/journal.pone.0172968) [Medline](#)
182. Y. Sadovy de Mitcheson, P. L. Colin, S. J. Lindfield, A. Bukurrou, A decade of monitoring an Indo-Pacific grouper spawning aggregation: Benefits of protection and importance of survey design. *Front. Mar. Sci.* **7**, 571878 (2020). [doi:10.3389/fmars.2020.571878](https://doi.org/10.3389/fmars.2020.571878)
183. A. D. Olds, K. A. Pitt, P. S. Maxwell, R. C. Babcock, D. Rissik, R. M. Connolly, Marine reserves help coastal ecosystems cope with extreme weather. *Glob. Change Biol.* **20**, 3050–3058 (2014). [doi:10.1111/gcb.12606](https://doi.org/10.1111/gcb.12606) [Medline](#)
184. D. M. Alongi, N. L. Patten, D. McKinnon, N. Köstner, D. G. Bourne, R. Brinkman, Phytoplankton, bacterioplankton and virioplankton structure and function across the southern Great Barrier Reef shelf. *J. Mar. Syst.* **142**, 25–39 (2015). [doi:10.1016/j.jmarsys.2014.09.010](https://doi.org/10.1016/j.jmarsys.2014.09.010)

185. A. D. McKinnon, S. Duggan, M. Logan, C. Lønborg, Plankton respiration, production, and trophic state in tropical coastal and shelf waters adjacent to northern Australia. *Front. Mar. Sci.* **4**, 346 (2017). [doi:10.3389/fmars.2017.00346](https://doi.org/10.3389/fmars.2017.00346)
186. L. Bergström, M. Karlsson, U. Bergström, L. Pihl, P. Kraufvelin, Relative impacts of fishing and eutrophication on coastal fish assessed by comparing a no-take area with an environmental gradient. *Ambio* **48**, 565–579 (2019). [doi:10.1007/s13280-018-1133-9](https://doi.org/10.1007/s13280-018-1133-9)
[Medline](#)
187. E. M. A. Strain, G. J. Edgar, D. Ceccarelli, R. D. Stuart-Smith, G. R. Hosack, R. J. Thomson, A global assessment of the direct and indirect benefits of marine protected areas for coral reef conservation. *Divers. Distrib.* **25**, 9–20 (2019). [doi:10.1111/ddi.12838](https://doi.org/10.1111/ddi.12838)
188. E. Cotou, A. Gremare, F. Charles, I. Hatzianestis, E. Sklivagou, Potential toxicity of resuspended particulate matter and sediments: Environmental samples from the Bay of Banyuls-sur-Mer and Thermaikos Gulf. *Cont. Shelf Res.* **25**, 2521–2532 (2005).
[doi:10.1016/j.csr.2005.08.005](https://doi.org/10.1016/j.csr.2005.08.005)
189. X. Durrieu de Madron, B. Ferré, G. Le Corre, C. Grenz, P. Conan, M. Pujo-Pay, R. Buscail, O. Bodiot, Trawling-induced resuspension and dispersal of muddy sediments and dissolved elements in the Gulf of Lion (NW Mediterranean). *Cont. Shelf Res.* **25**, 2387–2409 (2005). [doi:10.1016/j.csr.2005.08.002](https://doi.org/10.1016/j.csr.2005.08.002)
190. J. B. Lamb, J. A. J. M. van de Water, D. G. Bourne, C. Altier, M. Y. Hein, E. A. Fiorenza, N. Abu, J. Jompa, C. D. Harvell, Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. *Science* **355**, 731–733 (2017).
[doi:10.1126/science.aal1956](https://doi.org/10.1126/science.aal1956) [Medline](#)
191. F. J. Pollock, J. B. Lamb, S. N. Field, S. F. Heron, B. Schaffelke, G. Shedrawi, D. G. Bourne, B. L. Willis, Sediment and turbidity associated with offshore dredging increase coral disease prevalence on nearby reefs. *PLOS ONE* **9**, e102498 (2014).
[doi:10.1371/journal.pone.0102498](https://doi.org/10.1371/journal.pone.0102498) [Medline](#)
192. State of Queensland, “Reef 2050 Water Quality Improvement Plan 2017-2022” (State of Queensland, 2018), p. 56.
193. E. J. Powell, M. C. Tyrrell, A. Milliken, J. M. Tirpak, M. D. Staudinger, A review of coastal management approaches to support the integration of ecological and human community planning for climate change. *J. Coast. Conserv.* **23**, 1–18 (2019). [doi:10.1007/s11852-018-0632-y](https://doi.org/10.1007/s11852-018-0632-y)
194. L. Pendleton, D. C. Donato, B. C. Murray, S. Crooks, W. A. Jenkins, S. Sifleet, C. Craft, J. W. Fourqurean, J. B. Kauffman, N. Marbà, P. Megonigal, E. Pidgeon, D. Herr, D. Gordon, A. Baldera, Estimating global “blue carbon” emissions from conversion and degradation of vegetated coastal ecosystems. *PLOS ONE* **7**, e43542 (2012).
[doi:10.1371/journal.pone.0043542](https://doi.org/10.1371/journal.pone.0043542) [Medline](#)
195. T. B. Atwood, R. M. Connolly, E. G. Ritchie, C. E. Lovelock, M. R. Heithaus, G. C. Hays, J. W. Fourqurean, P. I. Macreadie, Predators help protect carbon stocks in blue carbon ecosystems. *Nat. Clim. Chang.* **5**, 1038–1045 (2015). [doi:10.1038/nclimate2763](https://doi.org/10.1038/nclimate2763)
196. F. Mineur, F. Arenas, J. Assis, A. J. Davies, A. H. Engelen, F. Fernandes, E. Malta, T. Thibaut, T. Van Nguyen, F. Vaz-Pinto, S. Vranken, E. A. Serrão, O. De Clerck, European

- seaweeds under pressure: Consequences for communities and ecosystem functioning. *J. Sea Res.* **98**, 91–108 (2015). [doi:10.1016/j.seares.2014.11.004](https://doi.org/10.1016/j.seares.2014.11.004)
197. T. G. Zarate-Barrera, J. H. Maldonado, Valuing blue carbon: Carbon sequestration benefits provided by the marine protected areas in Colombia. *PLOS ONE* **10**, e0126627 (2015). [doi:10.1371/journal.pone.0126627](https://doi.org/10.1371/journal.pone.0126627) [Medline](#)
198. D. Krause-Jensen, C. M. Duarte, Substantial role of macroalgae in marine carbon sequestration. *Nat. Geosci.* **9**, 737–742 (2016). [doi:10.1038/ngeo2790](https://doi.org/10.1038/ngeo2790)
199. J. Howard, E. McLeod, S. Thomas, E. Eastwood, M. Fox, L. Wenzel, E. Pidgeon, The potential to integrate blue carbon into MPA design and management. *Aquat. Conserv.* **27**, 100–115 (2017). [doi:10.1002/aqc.2809](https://doi.org/10.1002/aqc.2809)
200. C. M. Duarte, S. Agusti, E. Barbier, G. L. Britten, J. C. Castilla, J.-P. Gattuso, R. W. Fulweiler, T. P. Hughes, N. Knowlton, C. E. Lovelock, H. K. Lotze, M. Predragovic, E. Poloczanska, C. Roberts, B. Worm, Rebuilding marine life. *Nature* **580**, 39–51 (2020). [doi:10.1038/s41586-020-2146-7](https://doi.org/10.1038/s41586-020-2146-7) [Medline](#)
201. G. Mariani, W. W. L. Cheung, A. Lyet, E. Sala, J. Mayorga, L. Velez, S. D. Gaines, T. Dejean, M. Troussellier, D. Mouillot, Let more big fish sink: Fisheries prevent blue carbon sequestration-half in unprofitable areas. *Sci. Adv.* **6**, eabb4848 (2020). [doi:10.1126/sciadv.abb4848](https://doi.org/10.1126/sciadv.abb4848) [Medline](#)
202. G. K. Saba, A. B. Burd, J. P. Dunne, S. Hernández-León, A. H. Martin, K. A. Rose, J. Salisbury, D. K. Steinberg, C. N. Trueman, R. W. Wilson, S. E. Wilson, Toward a better understanding of fish-based contribution to ocean carbon flux. *Limnol. Oceanogr.* **66**, 1639–1664 (2021). [doi:10.1002/lno.11709](https://doi.org/10.1002/lno.11709)
203. R. K. F. Unsworth, C. J. Collier, G. M. Henderson, L. J. McKenzie, Tropical seagrass meadows modify seawater carbon chemistry: Implications for coral reefs impacted by ocean acidification. *Environ. Res. Lett.* **7**, 024026 (2012). [doi:10.1088/1748-9326/7/2/024026](https://doi.org/10.1088/1748-9326/7/2/024026)
204. C. M. Duarte, J. Wu, X. Xiao, A. Bruhn, D. Krause-Jensen, Can seaweed farming play a role in climate change mitigation and adaptation? *Front. Mar. Sci.* **4**, (2017). [doi:10.3389/fmars.2017.00100](https://doi.org/10.3389/fmars.2017.00100)
205. D. A. Koweek, R. C. Zimmerman, K. M. Hewett, B. Gaylord, S. N. Giddings, K. J. Nickols, J. L. Ruesink, J. J. Stachowicz, Y. Takeshita, K. Caldeira, Expected limits on the ocean acidification buffering potential of a temperate seagrass meadow. *Ecol. Appl.* **28**, 1694–1714 (2018). [doi:10.1002/eap.1771](https://doi.org/10.1002/eap.1771) [Medline](#)
206. D. Grémillet, T. Boulinier, Spatial ecology and conservation of seabirds facing global climate change: A review. *Mar. Ecol. Prog. Ser.* **391**, 121–137 (2009). [doi:10.3354/meps08212](https://doi.org/10.3354/meps08212)
207. D. Reed, L. Washburn, A. Rassweiler, R. Miller, T. Bell, S. Harrer, Extreme warming challenges sentinel status of kelp forests as indicators of climate change. *Nat. Commun.* **7**, 13757 (2016). [doi:10.1038/ncomms13757](https://doi.org/10.1038/ncomms13757) [Medline](#)
208. E. L. A. Kelly, Y. Eynaud, I. D. Williams, R. T. Sparks, M. L. Dailer, S. A. Sandin, J. E. Smith, A budget of algal production and consumption by herbivorous fish in an herbivore

- fisheries management area, Maui, Hawaii. *Ecosphere* **8**, e01899 (2017).
[doi:10.1002/ecs2.1899](https://doi.org/10.1002/ecs2.1899)
209. L. Rogers-Bennett, C. A. Catton, Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens. *Sci. Rep.* **9**, 15050 (2019). [doi:10.1038/s41598-019-51114-y](https://doi.org/10.1038/s41598-019-51114-y)
[Medline](#)
210. S. Luo, F. Cai, H. Liu, G. Lei, H. Qi, X. Su, Adaptive measures adopted for risk reduction of coastal erosion in the People's Republic of China. *Ocean Coast. Manage.* **103**, 134–145 (2015). [doi:10.1016/j.ocecoaman.2014.08.008](https://doi.org/10.1016/j.ocecoaman.2014.08.008)
211. D. A. Miteva, B. C. Murray, S. K. Pattanayak, Do protected areas reduce blue carbon emissions? A quasi-experimental evaluation of mangroves in Indonesia. *Ecol. Econ.* **119**, 127–135 (2015). [doi:10.1016/j.ecolecon.2015.08.005](https://doi.org/10.1016/j.ecolecon.2015.08.005)
212. S. Narayan, M. W. Beck, B. G. Reguero, I. J. Losada, B. van Wesenbeeck, N. Pontee, J. N. Sanchirico, J. C. Ingram, G.-M. Lange, K. A. Burks-Copes, The effectiveness, costs and coastal protection benefits of natural and nature-based defences. *PLOS ONE* **11**, e0154735 (2016). [doi:10.1371/journal.pone.0154735](https://doi.org/10.1371/journal.pone.0154735) [Medline](#)
213. D. L. Harris, A. Rovere, E. Casella, H. Power, R. Canavesio, A. Collin, A. Pomeroy, J. M. Webster, V. Parravicini, Coral reef structural complexity provides important coastal protection from waves under rising sea levels. *Sci. Adv.* **4**, eaao4350 (2018).
[doi:10.1126/sciadv.aao4350](https://doi.org/10.1126/sciadv.aao4350) [Medline](#)