

Predation in Marine Reserves: How Increases in Predator Populations Can Impact Diversity and Fisheries Goals

Studies of no-take marine reserves around the world have suggested that, on average, total biological diversity inside reserves is higher than outside. That said, within a designated marine reserve over time, each species or group of species can respond by increasing in population, decreasing in population, or having no response at all. The response depends on a range of factors, including predator-prey relationships. In cases where a reserve protects a predator species, an increase in predator abundance can in turn decrease the numbers of prey in the reserve — either through direct predation or predator-avoidance behavior by the prey. These shifts can have ecosystem-wide effects, with indirect impacts on biodiversity within reserves or, in theory, on fish stocks outside.

The complex linkages in ecological communities, particularly predator-prey relationships, make it challenging to predict the indirect outcomes of reserve creation. However, planners can gain an appreciation for potential effects by learning from what has occurred in reserves elsewhere. This month, *MPA News* examines how increases in predator populations can affect the goals of marine reserves, and how planners can prepare for these effects.

Impacts of predators on biodiversity reserves

A frequent goal of marine reserves is to increase biodiversity by removing exploitation pressure. Expecting increases in all species following reserve designation is unrealistic, owing to the various factors contributing to each species' response: the level of exploitation, life-history characteristics, potential for replenishment from surrounding areas, and abundance of predators and prey. The ecological interactions that play out in a reserve can yield unexpected results.

"It is certainly true that it can be difficult to predict the impact of protecting one group of animals on others elsewhere in the system," says John Pinnegar, a biologist at the UK-based Centre for Environment, Fisheries & Aquaculture Science (CEFAS) who has studied predatory interactions in MPAs and non-protected areas worldwide. In a review of research at 21 sites, he documented 39 cases of what he called "trophic cascades", in which the presence of primary carnivores

had suppressed herbivores, thereby increasing plant abundance. (Trophic cascades can occur in reverse in cases of overfishing; primary carnivores are removed, thus increasing herbivores and suppressing plant growth. They can also occur among levels of carnivores with little or no effect on plants.)

Pinnegar's study, which he conducted with a team of researchers from Mediterranean countries and published in *Environmental Conservation* (27:2[179-200]), pointed out that large predatory species are often the most susceptible to fishing. Therefore their recovery in reserves would be expected to have top-down effects on other species.

Examples of trophic cascades in reserves from around the world, cited in Pinnegar's study and elsewhere, include:

Malindi, Kisite, and Watamu Marine National Parks, Kenya: Triggerfish, considered the most important predator of sea urchins in Kenya, are protected in these national parks but depleted in adjacent fished areas. In the depleted areas, urchins have tended to become the dominant grazer. This has led to increases in urchin-resistant turf algae and decreases in hard coral cover, with the latter due in part to urchin grazing (coral damage from fishing gear is also a factor). The implication is that where Kenyan reefs are protected from fishing, triggerfish abundance will increase, sea urchin and turf-algal abundance on reef flats will decline, and coral cover will correspondingly increase.

Leigh Marine Reserve, New Zealand: Abundance of predatory fish and spiny lobsters is significantly higher inside this temperate reserve than in adjacent fished areas. Densities of sea urchins, a component in the diet of the fish and lobsters, have declined since the reserve's designation in the 1970s. As a result, kelp — which the urchins normally graze — has increased in cover.

Brackett's Landing Conservation Area, US: Over a seven-year time span, densities of predatory copper rockfish declined substantially in this reserve in Washington State, while densities of lingcod — a larger predator — increased. Each species is targeted by fishermen outside the reserve. Researchers suggest these patterns may have occurred due to direct predation by lingcod on rockfish

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(a known behavior) or lingcod outcompeting rockfish for prey items. (This cascade has had no significant effect on primary production.)

The simplicity of these examples may be deceptive. Rarely are trophic cascades the only factor dictating ecosystem effects. In the case of Brackett's Landing, evidence of the decline in rockfish became apparent in the late 1990s, a quarter-century after the reserve was designated. Until then, rockfish and lingcod had both been relatively abundant in the reserve. Why would this balance between lingcod and rockfish suddenly shift? Regional fisheries management may have played a role: fishing limits instituted for lingcod in the 1980s and '90s, along with improved recruitment, have helped its populations to increase region-wide. In the reserve, perhaps the growing lingcod population reached a tipping point past which rockfish could no longer co-exist as effectively. Researchers are unsure.

"Nature is complicated, and we should not expect to predict the response to reserves in all situations," says Tim McClanahan, a biologist with the US-based Wildlife Conservation Society who conducted the Kenyan research on coral, urchins, and triggerfish. Nonetheless, he adds, it is possible to draw some generalizations about recovery. "Reserves will often produce fairly fast recovery for some of the key target fisheries species, so it should not be hard to see early recoveries for these species," he says as an example. "There are, however, a number of species and groups that are slow to recover and may take more than 10 years to reach their undisturbed levels."

McClanahan suggests that it is nature's complexity itself that necessitates the designation of no-take reserves. "Reserves provide the pieces for nature's self-organization," he says. Without unfished areas — which theoretically allow an ecosystem to re-approach its original, "natural" state over time — there would be little way for researchers to avoid the sliding baseline phenomenon, in which expectations of what is natural are skewed because many of the original components of the system are reduced or absent. Marine reserves — including the unforeseen effects they can exhibit — change the benchmarks for environmental and fisheries management, reflecting a natural state that managers and researchers may not have observed in their lifetimes.

The naturalness of reserves was part of the rationale behind plans to re-zone the Great Barrier Reef Marine Park, says Leanne Fernandes, manager of the park's Representative Areas Program (RAP). RAP resulted in greatly expanded no-take areas for the park, effective 1 July (*MPA News* 5:10). "One of the reasons for the increased level of protection was to move the system as a whole — especially within the no-take areas — toward a higher level of natural integrity," she says. "Preventing the take of target species, and of bycatch, has the flow-on effect of helping to restore the natural

integrity of the local food webs." That integrity, she says, will hopefully provide resilience to other pressures on the system, such as climate change. Monitoring the effects of the new reserves will require study of target and non-target species and habitat changes over time.

Fernandes acknowledges that trophic cascade effects are significant but poorly understood, and that implementing the new network of no-take areas on the Great Barrier Reef may have unforeseen impacts on the system as a whole. But that is part of returning the system to a more natural state. "In this way, trophic cascade effects were an integral part of considerations in the planning process, but it didn't mean that the design was specifically altered in some way to accommodate the concept," she says. "It was inherent."

Impacts of predators on fishery reserves

Where a reserve is designed to support fisheries through sustained spillover of adults into fished areas, increased abundance of predators within the reserve can limit the site's effectiveness. If predators are consuming the same target species the fishermen are harvesting, they essentially become competitors for that prey source. Spillover of the target species decreases, and the fishermen may suffer reduced catches.

Marine mammals provide some of the best examples of this kind of predator impact. Their impact is increased where the marine mammals themselves are off-limits to hunting: in these cases, their populations are largely limited by the food resource. Around the world, it is not unusual for fishermen to complain that seals, sea lions, whales, and other marine mammals are taking their fish. In Atlantic Canada, the Canadian government expanded its harp seal hunt this year to its highest take in nearly 50 years, in part to try to limit the impact the seals are having on Atlantic cod. The Canadian cod fishery has been drastically reduced in the past decade due to overfishing, and the increased seal populations have been accused of hindering the fishery's recovery.

Scientific understanding of competition between predators and fishermen is murky. John Pinnegar, the researcher who reviewed trophic cascades in reserves worldwide, is now studying predator-prey interactions in the North Sea and cites several studies in which changes in model configuration provided different conclusions on the utility of seal hunts for protecting fisheries. In one study, when two prey species were aggregated in the model, a seal hunt was recommended; then, when the prey species were considered separately, complete *protection* of seal stocks was recommended. "This was because of indirect predator-prey and competition effects," he says. "You have to be very careful about the assumptions of your models." In his current research, Pinnegar is studying whale-fishery interactions and the problems encountered with different model formulations.

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Inspired by a proposed marine national park off the coast of Brittany in France, Jean Boncoeur, an economist at the Université de Bretagne Occidentale, modeled potential interactions not only among fish, seals, and fishermen in the area, but also their interaction with tourists. He wanted to determine the economic consequences of creating a marine reserve in which fishing adjacent to the reserve and ecotourism (seal watching) were both considered, and how these consequences could inform the size of the reserve.

His findings: the optimal reserve size, according to a global cost-benefit analysis, was larger than the one that would be optimal if fisheries management were the only objective. This was because the growth in the seal stock generated by a larger reserve increased the opportunity to make money through ecotourism (the number of tourist visits was assumed to be an increasing function of the seal stock). In fact, because the model also assumed tourism to generate more net regional income than fishing, any and all increases in reserve size and seal stocks resulted in improved overall efficiency of the reserve, although much of the improvement was realized to the detriment of the fishing industry (from decreased fishing area and increased competition with seals). Boncoeur submitted the research results to planners of the Iroise Sea National Park in 2000. The park is still under development.

In research published in *Conservation Biology* in 2003 (17:1[273-283]), a US research team studied several MPAs along the California coast to compare the effects of a top predator — sea otters — with the effects of human recreational harvest on red abalone, a commercially valuable mollusk eaten by otters. What they sought was insight on whether MPAs intended to conserve ecosystems, including sea otters, were compat-

ible with the use of MPAs for abalone fishery sustainability. (Abalones have been prone to boom and bust fisheries, while otters are recovering from severe hunting pressure in the 18th and 19th centuries. The geographic range of red abalone is wholly within the historic range of sea otters, although otters have not yet returned to their entire range in the state.)

The research team found that where sea otters were present, abalones were constrained to densities and sizes that were most likely inadequate for regional fishery sustainability. The conclusion was that MPAs off California could not enhance abalone fisheries if, in the interest of ecosystem integrity, they also contained sea otters. Thus, the researchers recommended the designation of two categories of spatially segregated, single-use MPAs: one focusing on ecosystem restoration and one on fishery development. “Species recoveries may be pleasing to ecologists and environmental advocates who yearn for the biological integrity of ecosystems but may be costly to human communities and economies,” wrote the researchers. (A change in the relative economic value of sea otters versus abalone fisheries — such as from establishment of otter-based ecotourism — could affect management decisions, akin to Boncoeur’s above-mentioned model.)

The concept of otter-free reserves for abalones begs the question of what should be done if otters found their way into these sites — as they most likely would over time. Managers would need to remove them, such as with culls, relocation, otter-scaring devices, or other methods. The researchers admit this would not be easy. “Such methods are either politically controversial or are of questionable effectiveness,” says Glenn VanBlaricom, a study co-author and biologist with the US Geological Survey.

Samantha Fanshawe, who collected the abalone data for the study and is now director of conservation for the UK-based Marine Conservation Society, says zoning the California coastline according to spatially explicit uses — ecosystem restoration, fishing, and other activities — would involve identifying which areas had the highest natural value, which ones had the highest fisheries value, and so on. This could have benefits beyond just otters and abalones, she says. “Identifying and mapping the distribution of these areas and where they overlap — and agreeing on where activities would be allowed or where nature takes precedence — would benefit industry as well as conservationists,” she says. “Everyone could plan their developments on a more strategic and long-term basis.” 

Notes & News

Germany: 38% of marine waters proposed as MPAs

More than one third of Germany’s total marine area could consist of MPAs under a national plan to designate 10 sites in the country’s Exclusive Economic Zone (EEZ) as protected areas. Designed in part to bring Germany into compliance with the EU Birds and Habitats Directives, the plan would raise the protected percentage of all of Germany’s marine waters (its EEZ and territorial sea combined) to 38 percent. Germany nominated the 10 sites — located in the Baltic Sea and North Sea — to the European Commission in May.

Two of the sites, designed specifically to protect birds, took effect immediately upon nomination. The remaining eight sites — protecting fauna, flora and/or habitats — must be approved by the European Commission, a process that could take “a couple of years”, says Henning von Nordheim, head of marine and coastal nature conservation for the German federal

agency for nature conservation. Germany will set regulations for each site as Commission approval comes.

The EU Birds and Habitats Directives aim to maintain biodiversity through conservation of species and natural habitats, including development of a coherent European ecological network of protected zones — the Natura 2000 network. Germany is also a contracting party to OSPAR (the convention for the protection of the marine environment in the north-east Atlantic) and HELCOM (the Baltic marine environment protection commission), each of which has set a goal to create a network of well-managed MPAs by 2010. Von Nordheim says states within Germany are expected next year to nominate more MPAs within the territorial sea, raising the protected percentage of German waters beyond 40 percent. 

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A Brief Guide to Regional MPA Projects in the Caribbean

Several international, inter-related projects are underway in the Caribbean to strengthen the region's MPAs and MPA networks. Comprising a mix of established and new initiatives, the projects together represent a boom for Caribbean protected area efforts. Below, *MPA News* presents a brief guide to these initiatives:

“Training of Trainers”: Teaching MPA managers

Educating MPA professionals on all aspects of planning and management, the fourth regional UNEP-Caribbean Environment Programme “Training of Trainers Course on MPA Management” was held in February 2004 in Long Key, Florida (US). Seventeen students attended from a dozen Spanish-speaking nations.

Designed to instruct managers who will in turn train their local personnel, the Training of Trainers (ToT) courses are held under the auspices of the United Nations Environment Programme–Caribbean Environment Programme (UNEP-CEP). The first ToT course, conducted in English, was in 1999; the second, in Spanish, was in 2000, followed by another English course in 2002.

The course features 14 days of lectures, interactive exercises, and field trips. All travel and lodging expenses are paid by UNEP-CEP and the United Nations Foundation through the International Coral Reef Action Network. The local follow-up sessions, in which trainees teach what they have learned to practitioners back in their communities, also receive partial financial support from UNEP-CEP.

The manual for the ToT course is available in English and Spanish, and is online at <http://www.cep.unep.org/issues/MPA%20manual.htm>. Georgina Bustamante of The Nature Conservancy, an international NGO, coordinated the 2004 and 2000 editions of the ToT course. She is updating the manual for the next class, scheduled for 2005 as funding becomes available.

SPAW: Regional, representative network of protected areas

In Gossier, Guadeloupe, in April 2004, regional experts met to review draft guidelines and criteria for the listing of protected areas under the Protocol on Specially Protected Areas and Wildlife in the Wider Caribbean (SPAW). The objective of this list is to create a representative network of protected areas to conserve natural heritage through regional cooperation. The list will eventually include marine reserves and other types of protected areas, including terrestrial ones. (Under SPAW, UNEP-CEP already offers a Small Grants Program to strengthen marine protected area management.)

The April workshop was organized by UNEP-CEP and the Regional Activity Centre for SPAW. Within the

MPA sessions at Caribbean conference this November

The upcoming meeting of the Gulf and Caribbean Fisheries Institute, to be held 8-12 November in St. Petersburg, Florida (US), will feature two special sessions on MPAs:

Ecological criteria for judging marine reserve performance: When is a coral reef ecosystem a “normative ecosystem”? (Co-hosted by the University of Puerto Rico and the [US] National Oceanic and Atmospheric Administration; for more information, e-mail ron.hill@noaa.gov or rich.appeldoorn@gcfi.org)

Caribbean spawning aggregations: Biology and management status (Co-hosted by The Nature Conservancy, The Ocean Conservancy, Environmental Defense, and the Society for the Conservation of Reef Fish Spawning Aggregations; for more information, e-mail pkramer@tnc.org)

Papers will be accepted on other MPA issues as well. Meeting and additional information is available at <http://www.gcfi.org/Conferences/57th/StPete2004.htm>.

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UNEP Regional Seas Programme, the Caribbean under UNEP-CEP is the second regional sea (after the Mediterranean) to initiate a regional representative MPA network.

The revised SPAW listing guidelines will be considered by the Third Conference of the Parties to the SPAW Protocol in September 2004 for further action. All working and meeting documents of the Guadeloupe workshop are online at <http://www.cep.unep.org/who/spaw.htm>. To learn more about SPAW in general, go to <http://www.cep.unep.org/pubs/legislation/spaw.html>.

CaMPAM: Networking MPA managers

Launched at the White Water to Blue Water Partnership Conference in Miami (US) in March 2004, the CaMPAM Network and Forum Partnership aims to network Caribbean MPA practitioners to exchange ideas and lessons learned. (CaMPAM stands for *Caribbean Marine Protected Area Management*.)

It is an overarching initiative, incorporating some of the above projects, including Training of Trainers and the UNEP/SPAW Small Grants Programme. Intended to develop synergy among existing efforts, CaMPAM involves UNEP-CEP, The Nature Conservancy, the Gulf and Caribbean Fisheries Institute, and an array of other international NGOs, national government agencies, and educational institutions.

The initiative will provide several tools to MPA managers, including:

- An electronic discussion forum, now under development;
- Site visits and staff exchanges among MPAs;
- Technical assistance; and
- A comprehensive database on MPAs and their effectiveness.

At a CaMPAM meeting within the upcoming annual meeting of the Gulf and Caribbean Fisheries Institute (8-12 November 2004 in St. Petersburg, Florida, US), the initiative's partners will present a prototype of the CaMPAM database and initiate a three-month pilot phase to evaluate and finalize its design and applications.

To learn more about CaMPAM, go to <http://www.gcfi.org/Initiatives/CaMPAM.htm>, or <http://www.cep.unep.org/programmes/spaw/MPA/mpa.htm>.

MAREP: Advancing marine reserves in Caribbean

Released in September 2003, the Wider Caribbean Marine Reserves Regional Enhancement Plan, or

MAREP, aims to mainstream the use of marine reserves as a tool in biodiversity conservation and fisheries management in the region. Spearheaded by the IUCN World Commission on Protected Areas-Marine (WCPA-Marine), the MAREP identifies priority needs in fulfilling this goal, and proposes projects to help researchers, managers, and educators address those needs. It succeeds a similar plan for Southeast Asia, also led by WCPA-Marine (*MPA News* 5:2).

MAREP was developed through consultations among several national and international experts and institutions that included a review of existing regional initiatives and a request for proposals. The 16 approved projects — ranging from reserve design projects to public education to the CaMPAM partnership — have been submitted to potential donors for funding.

The 38-page MAREP plan provides an excellent overview of all MPA-related activities in the region. To download it in PDF format, or to learn more about the MAREP process, go to <http://ipo.nos.noaa.gov/mri/caribbean.html>. 

Study: Global MPA Network Would Cost \$12-14 Billion Annually

Managing a global network of MPAs in which 30% of each habitat type is protected would likely cost US\$12-14 billion annually — less than what is spent on international subsidies for commercial fishing, according to researchers. In a study published in June in the *Proceedings of the National Academy of Sciences*, a team of UK scientists surveyed the management costs of 83 well-managed marine parks worldwide, then used the findings to model costs for a global MPA system.

“Our purpose was to find the price tag of good management and to explore how costs scale up when extensive networks of MPAs are contemplated,” says study co-author Callum Roberts of the University of York. “The message from the figures is that MPAs are a bargain and that we should be putting our money into them rather than propping up unsustainable fisheries with subsidies.” The authors say US\$15-30 billion is spent each year on commercial fishing subsidies worldwide. If used for MPAs instead, they say, the funds would help fortify marine ecosystems, making them more productive and fisheries more sustainable.

The cost model in the study is principally based on MPA size: the researchers' global survey of MPA costs found size to be the primary determinant of management expenses. In other words, larger MPAs cost less per unit area than smaller ones. (Editor's note: The findings of this survey were described in “The costs of operating an MPA” in *MPA News* 5:5.) In the model, scenarios that essentially featured fewer but larger MPAs reduced the overall cost of the global network, accounting for variation in the final estimate.

At the World Parks Congress in September 2003, delegates recommended that MPA networks worldwide include at least 20-30% of each marine and coastal habitat in “strictly protected areas”, meaning these sites would be off-limits to fishing. The UK study used this recommendation as inspiration. The study model simplifies some factors. It does not account for the distribution of different habitats, assuming a homogeneous ocean. It also does not account for potentially higher management costs associated with the enforcement needs of no-take areas: the preliminary survey of management costs was conducted primarily on multiple-use MPAs. “But the evidence that no-take reserves cost more in our existing sample is only weak,” says co-author Andrew Balmford of the University of Cambridge.

The study appears in Vol. 101, issue 26, pp. 9694-9697 of the *Proceedings of the National Academy of Sciences*. Readers without access to the journal may e-mail Balmford for a copy of the paper at apb12@hermes.cam.ac.uk. 

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Peter Kareiva is a lead scientist for The Nature Conservancy, a US-based NGO, and has been a faculty member of five US research universities. He has conducted research in North America, Latin America, Asia, and Europe over the past two decades, including in the fields of insect ecology, landscape ecology, risk analysis, mathematical biology, and conservation science. This piece was adapted by *MPA News* from a longer essay by Kareiva, originally published this year in the journal *Frontiers in Ecology and the Environment* (1:9 [501-502]).

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MPA Perspective Lessons for MPAs from Terrestrial Conservation

By Peter Kareiva, The Nature Conservancy

Marine conservation lags behind terrestrial conservation in funding, science, and implementation. The sluggishness with which we have come to focus on marine conservation is inexcusable. However, there is some advantage to not being first. In particular, we can learn from the successes and failures associated with longstanding systems of parks and preserves on land. As we race to establish MPAs, we should pause to consider the following lessons that are gleaned from our experience with terrestrial conservation:

- Terrestrial parks have often been located in the wrong places — typically those places that are of little economic value. In the US, for example, we have many national parks in areas of snow and rock, with little productivity or biodiversity. If we take a similar approach to marine conservation and place MPAs where political forces offer the least resistance, we will end up with an ill-designed network.
- Global climate change is real and represents a serious challenge to the design of any protected area network. Parks that are fixed in space therefore risk becoming obsolete. Clearly, consideration of resilience in the face of climate change should be part of any plan for MPAs.
- Invasive species are the greatest threat to terrestrial protected areas, but have not figured prominently in discussions of marine conservation. However, invasive species often dramatically alter marine ecosystems. MPAs will require as much protection against non-indigenous species as against harvest or other human disturbances.
- All too often, terrestrial conservation has focused on collecting long lists of species in a certain area, with little attention paid to the maintenance of critical ecological processes. In terrestrial systems, these processes include natural disturbances such as fires and floods. In marine systems, they could include freshwater inputs and re-colonization following large disturbances such as hurricanes. Whereas a relatively small area may capture many species within its borders, it usually takes a much larger area to protect ecological processes.

- On a related note, a myopic focus on the accumulation of long lists of species within the smallest possible area (biodiversity hotspots) can fail to protect the diversity of ecosystems and ecosystem services. A focus on species protection will typically lead to a very different allocation of conservation effort than would a focus on the conservation of ecosystem diversity. Both species protection and ecosystem protection should be considered in plans for marine conservation.
- Corridors and connections between terrestrial reserves are widely embraced in theory, but poorly documented with data. The same mismatch between theoretical appeal and empirical support is evident in marine discussions of “connectivity”. Before rushing to invest in marine corridors, we should await some convincing evidence of their effectiveness.
- The ecological status of the matrix in which terrestrial reserves are embedded can be as important as the integrity of the parks themselves. It may be impossible to achieve our conservation goals if we focus too narrowly on marine reserves to the neglect of the surrounding human-dominated landscapes and seascapes.
- No nature reserve system can be sustainable without also making sure that local human populations are provided for. This principle will certainly hold for coastal fisheries, which many local communities rely on for livelihood and food.

The critical difference between marine and terrestrial conservation has less to do with biology than with the policy context and political justifications used when arguing that marine areas should be set aside as protected. Specifically, advocates of no-take marine reserves commonly argue that the spillover of fish from within these areas can supplement harvest in surrounding zones, and hence provide a win-win conservation tool (biodiversity protection and increased harvest). Meanwhile, on land, no one asks that terrestrial protected areas produce a surplus of wildlife that spills over and supports surrounding hunting communities. Perhaps we should think about MPAs in the same way we think about terrestrial parks — simply as secure havens for biodiversity. 

Notes & News

UNESCO World Heritage adds new marine sites

Three sites that combine sea and land components are among the newest additions to UNESCO's World Heritage List. Added to the list on 30 June 2004, these new World Heritage sites are:

- Ilulissat Icefjord, Greenland — sea mouth of one of the world's fastest-moving glaciers;

- Wrangel Island Reserve, Russia — an important bird-nesting site, major feeding ground for gray whales, and home to the world's largest population of Pacific walrus; and
- Pitons Management Area, St. Lucia (Caribbean) — featuring volcanic spires on land with coral reefs and more than 160 species of finfish in surrounding waters.

Ilulissat Icefjord and Wrangel Island Reserve are the first natural sites in the Arctic to be added to the World Heritage List.