

Guide to
the Science of
**Marine
Protected Areas**
in The
Bahamas



This *Guide to the Science of Marine Protected Areas in The Bahamas* offers a synthesis of research findings on how marine protected areas (MPAs) can work to conserve the country's shallow coral reef ecosystems, including associated seagrass meadows, mangroves, and other lagoon habitats. Featured topics span the nature of Bahamian shallow marine habitats and seascapes, the ecological communities that reside in them, how reefs and populations across islands are ecologically connected, factors that contribute to reef health and resilience, what scientists have learned from the example of the Exuma Cays Land and Sea Park, and some of the social factors affecting MPAs in the country.

Most of the research cited in this *Guide* is the product of more than a decade of work by an international, interdisciplinary team of scientists, known as the Bahamas Biocomplexity Project. These scientists were influenced and inspired by The Bahamas' pioneering history of protecting marine resources in land and sea parks as well as through a newer system of fisheries replenishment areas.

Globally, coral reef ecosystems, including those in this country, are under assault from a suite of local and global threats. However, scientific research shows that reducing local pressures can help make reefs more resilient to some global stressors, such as climate change. By highlighting the significance of our research for ongoing marine conservation in The Bahamas, we hope to promote further policy discussion and action, so that healthy marine ecosystems will be as much a part of the Bahamian future as its past.

With this booklet, we seek to make this research more accessible for the Bahamian public, educators, and decision-makers. The Bahamas has a long history of supporting marine and coastal science, and this *Guide* represents both appreciation of the place and its people and a contribution to the dialogue between science and problem solving.



Summary of Key Scientific Findings



1. Scientists have classified the shallow reef and lagoon seafloors of The Bahamas into multiple habitat types. Each habitat type hosts different collections of species and provides different ecological functions that can be protected by marine reserves. *Pages 4-5*
2. Habitats and the biodiversity that they support can be mapped across seascapes, providing valuable information for management decisions about marine reserves. *Page 6*
3. Because the same habitat type may host different species in different parts of The Bahamas, it is important to protect each habitat type in more than one marine reserve. *Page 7*
4. It is essential for marine reserves to encompass combinations of habitats—such as mangroves, seagrass, and reefs—that are located near each other, since many fishes and invertebrates use more than one habitat. *Pages 6-7*
5. Many fish and invertebrate species produce tiny offspring called larvae that disperse among reefs, connecting different reef populations. Marine reserves should be located in close enough proximity that larvae can disperse among them. All reefs in The Bahamas rely to some extent on receiving larvae from other reefs. These connections are vital for long-term persistence of reef ecosystems. *Pages 8-9*
6. After suffering storm damage or other impacts, healthy reefs tend to recover to a coral-dominated state. Unhealthy reefs tend to be taken over by seaweeds and non-coral invertebrates, and that change can be difficult to reverse. From a management perspective, it is easier and less costly to prevent a coral reef from changing to a degraded state than it is to restore a degraded reef. Important management actions to keep coral reefs healthy and resilient include (a) preventing overfishing and (b) reducing inputs of nutrients and sediments from land into coastal waters. *Pages 8-9*
7. When fished species such as queen conch and Nassau grouper are protected in marine reserves, important Bahamian fisheries reap benefits, as shown at the Exuma Cays Land and Sea Park. *Pages 10-11*
8. Marine reserves support important ecological processes, such as herbivory by parrotfishes, that enhance the resilience of corals to impacts such as climate change. *Page 12*
9. By protecting large native predators such as Nassau groupers, marine reserves can help reduce lionfish numbers that threaten native reef fishes and invertebrates. *Page 13*
10. People want to be involved in determining marine management policies for their local areas. Their engagement in the decision-making process may lead to more local support and better management outcomes. Support for new no-take marine reserves varies within and among settlements in The Bahamas. People who are supportive of new marine reserves tend to be less dependent on fishing, more dependent on tourism, and have higher incomes, and they believe that local environmental conditions are poor, think that fishing is a top impact, and perceive current fishing regulations as poorly enforced. *Page 14*



Healthy Oceans Underpin Bahamian Livelihoods

In The Bahamas, the economy and many people's livelihoods are linked closely to the health of the ocean. Tourism contributes more than half of the gross domestic product (GDP), and tourists are drawn primarily by ocean-related activities and attractions. Fishing plays an important role in the Bahamian economy and way of life, involving 9,300 fishermen, producing annual exports valued at some \$82 million, providing food for many families, and serving as a cultural touchstone. Protecting the health of the ocean is important for the wellbeing and prosperity of the Bahamian people.

In many places around the world, fishermen and fishery managers have seen a dramatic decline in fish stocks because of factors such as overfishing, pollution, and habitat destruction. Overfishing can lead to fundamental ecological changes that result in the collapse of coral reefs and other coastal ecosystems.

Marine protected areas (MPAs) have gained wide acceptance as an important tool for preventing and reversing declines in ocean health, in addition to conventional fisheries management tools such as closed seasons, size limits, and fishing gear restrictions. In 2013, more than 10,000 MPAs have been established around the world, covering nearly 3% of the ocean. In addition to their conservation benefits, MPAs serve as important locations for marine research and education.

Marine protected area is a general term for areas of the ocean that receive any sort of protection, including marine parks, sanctuaries, and marine reserves. MPAs have a wide range of levels of protection. No-take marine reserves, which are fully protected from fishing and other extractive and harmful uses, offer the greatest benefits to fish stocks and biodiversity conservation. Only approximately 1% of the ocean is protected as marine reserves.

The Bahamas is a global pioneer in establishing MPAs, including marine reserves. In 1959, the Exuma Cays Land and Sea Park was established as one of the world's first MPAs, and in 1986 it was further protected as a no-take marine reserve. As part of the Caribbean Challenge, The Bahamas has committed to protecting at least 20% of its nearshore marine resources by 2020.

Scientific studies show that the creation and enforcement of marine reserves is a valuable approach to sustaining ocean health. Basing the design and management of marine reserves on a strong foundation of science is important to achieve the greatest benefits for sea life and the Bahamian people.



What's in a Seascape?

Analogous to ecological landscapes, seascapes are the mosaics of different habitat patches across the sea floor. Examples of habitats are fringing mangroves, seagrass beds, and patch reefs. Scientific information about habitats and species in Bahamian seascapes is essential for effective marine management.

In Each Habitat, a Unique Mix of Species

In a study of shallow coral reefs and lagoons of The Bahamas, scientists looked at a total of 277 fish species and 260 bottom-dwelling species, such as corals, sponges, and seaweeds. Most of these species dwell in particular areas, or habitat types, within the larger seascape. Every habitat is home to a unique assortment of species because each habitat offers different kinds of foods, shelter, and environmental conditions. The scientists found that star coral reefs, for example, hosted 182 fish species and 197 bottom-dwelling species.

All Habitat Types Provide Benefits

Research shows that a quarter of fish and invertebrate species of The Bahamas live in only one habitat type. Moreover, every habitat type provides ecosystem services that contribute to the overall functioning of the reef ecosystem and that benefit people. For example, some habitats serve as important nursery areas, and others play a major role in fueling the food web through primary production. All species and the full array of ecological functions can be sustained only if adequate areas of each habitat type remain intact and healthy.



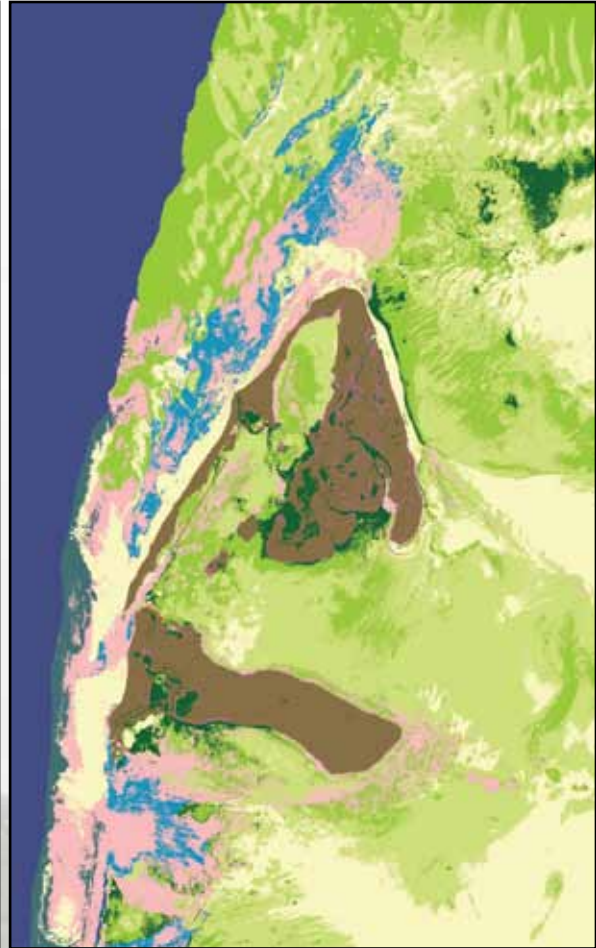
	Habitat Type	Description	Examples of Ecological Functions	Examples of Ecosystem Services
Land-sea edge	Fringing Mangrove	 Outer edge of red mangrove stands. Found along shorelines, tidal creeks, offshore islands.	Habitat for spiny lobster, Nassau grouper, and invertebrate-eating fishes. Moderate contributions to primary productivity.	Protects shore from waves. Contributes to lobster and grouper fisheries. Provides building resource (wood) and pharmaceutical material (sponges). Easily accessible for educational activities.
Lagoon	Dense Seagrass	 Dominated by turtle grass but may contain manatee grass.	Converts atmospheric nitrogen into biologically useable form (nitrogen fixation). Habitat for spiny lobster, queen conch, and invertebrate-eating fishes.	Contributes to conch, lobster, and other fisheries. Easily accessible for educational activities.
	Medium-density Seagrass	 Dominated by turtle grass but may contain manatee grass and shoal grass.	Converts atmospheric nitrogen into biologically useable form (nitrogen fixation). Habitat for spiny lobster, queen conch, invertebrate-eating fishes, and Euchema seaweed.	Contributes to conch and lobster fisheries. Provides material for jewelry and curios. Easily accessible for educational activities.
	Sparse Seagrass	 Dominated by manatee grass and shoal grass.	Habitat for queen conch and Euchema seaweed.	Contributes to conch fishery.
	Sand and Sparse Algae	 Sand with sparse algal community.	Habitat for queen conch.	Contributes to conch fishery. Good place for bonefishing, snorkeling, swimming.
	Patch Reef	 Dominated by massive corals and dense sea fans (gorgonians).	Habitat for surgeonfishes, long-spined sea urchin, stoplight parrotfish, threespot damselfish, young coral, invertebrate-eating fishes, and spiny lobster.	Good place for bonefishing, snorkeling, swimming. Provides material for jewelry and curios. Easily accessible for educational activities.
Lagoon and Outer Reef	Seaweed Plain	 Relatively smooth, rocky bottom with seaweeds and few sea fans (gorgonians).	Habitat for spiny lobster and Nassau grouper. Fuels food web through primary productivity. Converts atmospheric nitrogen into biologically usable form (nitrogen fixation).	Contributes to lobster and grouper fisheries.
Outer Reef	Elkhorn Coral	 Reef-crest areas between depths of 1-5 meters.	Fuels food web through primary productivity. Habitat for surgeonfishes, long-spined sea urchin, and stoplight parrotfish. Forms reef structure (calcification). Converts atmospheric nitrogen into biologically usable form (nitrogen fixation).	Highly valuable area for fishing. Protects shore and lagoon from waves. Produces building resource (sand).
	Dense Gorgonians	 Densely covered with sea rods, fans, and other gorgonians with little hard coral. More than 10 gorgonians per square meter. Often just seaward of elkhorn coral reef; also in shallow, wave-swept areas.	Fuels food web through moderate levels of primary productivity. Habitat for spiny lobsters, Nassau grouper, reef-grazing organisms, plankton-eating fishes, and invertebrate-eating fishes. Moderately vulnerable to bleaching and disease.	Contributes to lobster and grouper fisheries. One species of gorgonian is harvested for anti-inflammatory use in medicines and cosmetics.
	Gorgonian Plain	 Sparse sea rods, fans, and other gorgonians on hard, rocky bottom with some seaweed.	Habitat for Nassau grouper, surgeonfishes, long-spined sea urchin, and invertebrate-eating fishes. Vulnerable to disease.	Contributes to grouper fisheries. One species of gorgonian is harvested for anti-inflammatory uses in medicines and cosmetics.
	Star Coral	 Dominated by star coral. High structural relief. Typically in areas relatively sheltered from waves.	Habitat for stoplight parrotfish, threespot damselfish, surgeonfishes, invertebrate-eating fishes, young coral, long-spined sea urchin, spiny lobster, and Nassau grouper. Forms reef structure (calcification). Converts atmospheric nitrogen into biologically usable form (nitrogen fixation).	Highly valuable area for fishing. Good place for bonefishing, snorkeling, swimming. Helps protect shore from waves. Produces building resource (sand). Provides material for jewelry and curios. Produces pharmaceutical material (sponges).

Common Reef and Lagoon Habitats. This table describes eleven habitat types that are common in the shallow coral reefs and lagoons of The Bahamas. Adapted from Mumby et al. 2008.

Mapping the Mosaic

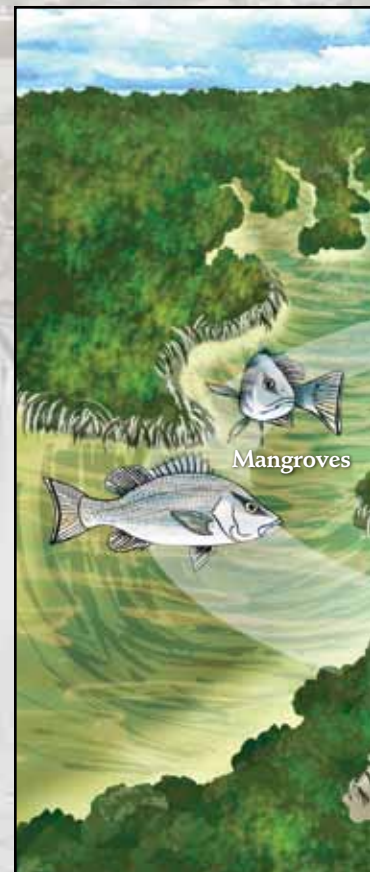
Information about the locations of different habitat types is critical for planning and designing marine reserves. Through technical analysis of high-resolution satellite images and field studies to confirm the image analysis, scientists can create detailed maps of habitats in reefs and lagoons of The Bahamas. Because certain species are associated with each habitat type, the habitat maps provide valuable information about where fish and invertebrate species are likely to be found—and where they could be protected in marine reserves.

Bimini Seascape. Left: This satellite image shows the island of Bimini and surrounding reefs and lagoons in January 2003. Right: Scientists created this detailed map based on analysis of the satellite image. Each color represents a type of reef or lagoon habitat.



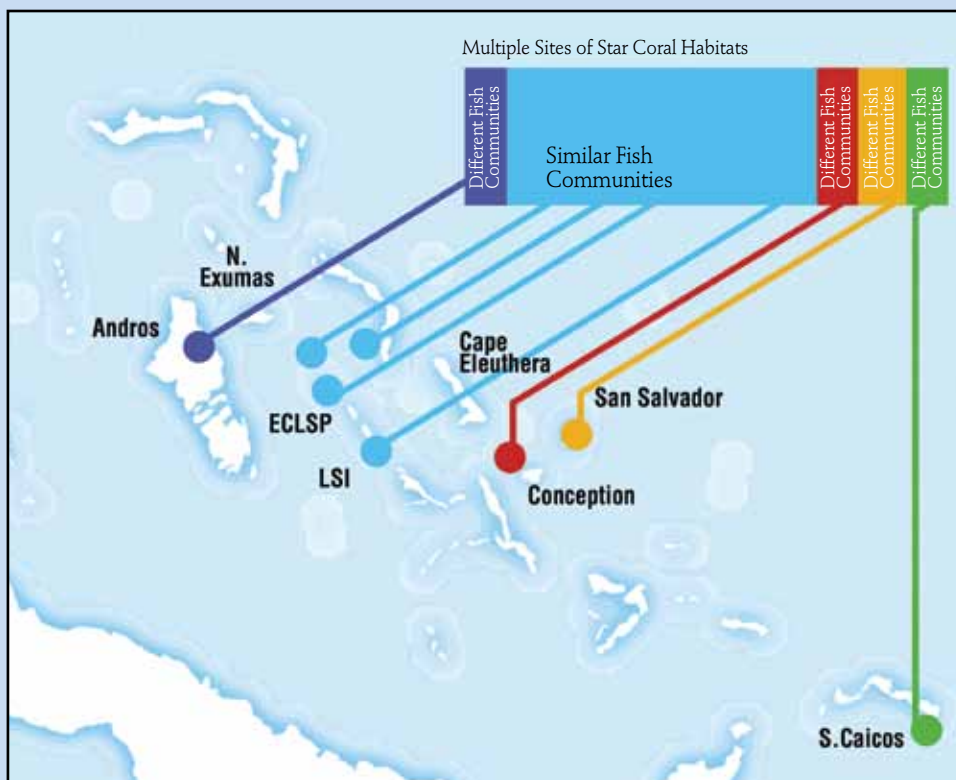
Around the Neighborhood

Many marine species need more than one habitat during their lives, and they need to be able to move among these habitats. For example, gray snapper is an important fishery species that uses mangroves, sea grass, coral reef, and open-water habitats at different stages of its life. Similarly, queen conch and many other Bahamian invertebrates and fishes rely on several habitat types during their lives. As a result, it is essential for marine reserves to encompass nearby combinations of habitats and the connections among them.



One Isn't Enough

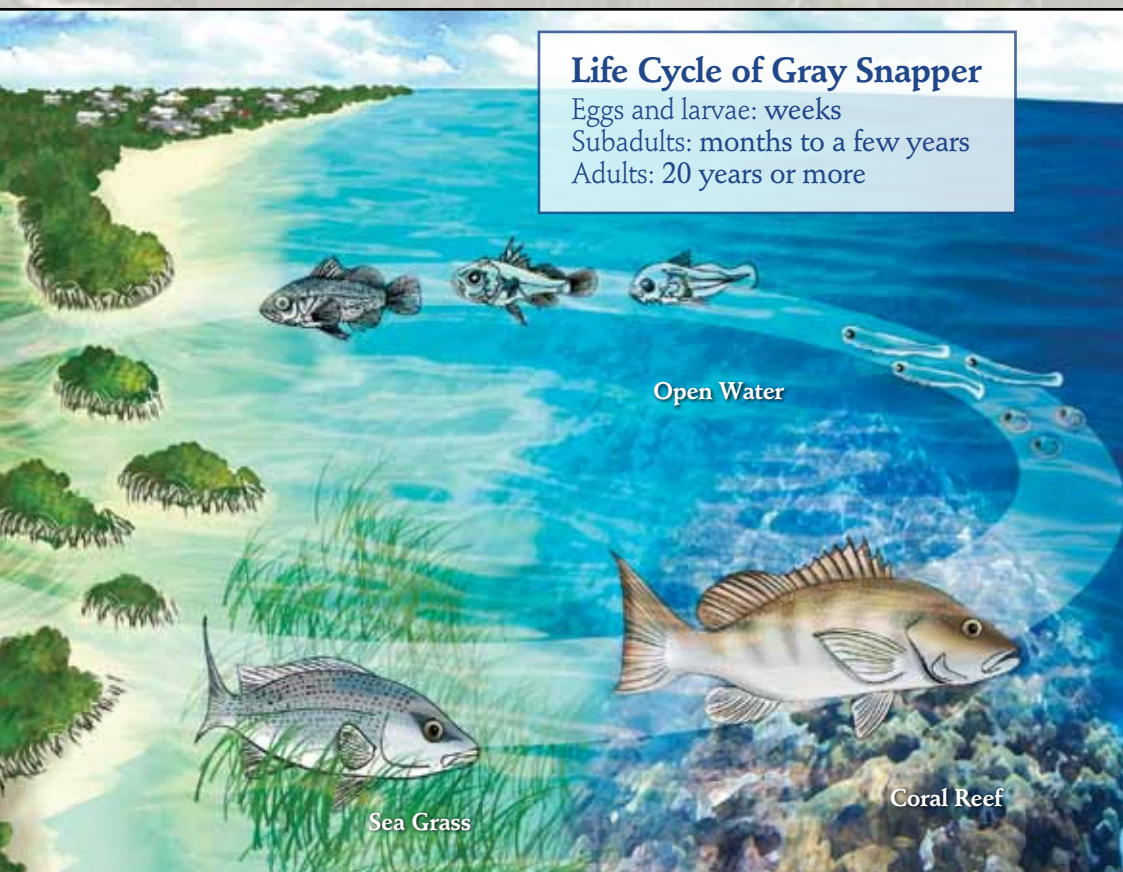
Usually, even if two coral reef locations are classified as the same habitat type, they have some different fishes and invertebrates inhabiting them. For example, star coral reefs on the eastern and western sides of an island may host some different species, and a star coral reef located hundreds of kilometers away is likely to have an even greater number of different species. The figure at right shows an example of this phenomenon. As a rule of thumb, multiple sites of each habitat type need to be included in marine reserves, rather than protecting each habitat type in only one marine reserve, so that more species can reap the benefits of protection.



Same Habitat Type, Different Fishes. Scientists surveyed fishes in star coral habitats and found that these fish communities vary across the Bahamian archipelago. On this map, places marked with the same color had similar fish communities in star coral habitats, while different colors indicate statistically significant differences in the fish communities. These types of differences tend to be consistent over time. Marine reserves would need to be located in areas of each color in order to protect each type of fish community associated with star coral habitats. Analysis by Alastair R. Harborne (Univ. Queensland).

Life Cycle of Gray Snapper

Eggs and larvae: weeks
Subadults: months to a few years
Adults: 20 years or more



How Are Reefs Connected?

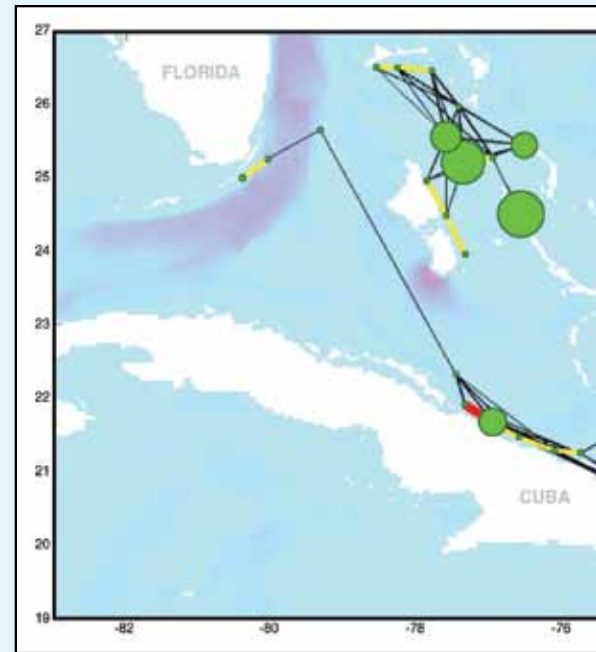
Coral reefs are connected to each other by travels of fishes and invertebrates. This means that human impacts such as overfishing on one reef affect other reefs. Planning marine reserves with these reef-to-reef connections in mind is an important way to increase the conservation benefits of reserves.

Leaving Home

Most species of fishes and invertebrates on coral reefs do not travel far when they are adults. They stay within a small area on the same reef, rather than going to other reefs. When they reproduce, however, they typically release large numbers of tiny offspring called larvae into the water, where ocean currents may transport the larvae for days or weeks. The larvae have the potential to travel long distances, eventually settling to live as adults at different reefs from their parents. The travels of larvae create important ecological linkages between reefs because the arriving individuals may help to sustain populations that they join. With an understanding of how coral reefs are connected through movement of young fishes and invertebrates, managers can design networks of marine reserves that work together to sustain biodiversity and fisheries.

Nearby Havens Needed

Research in The Bahamas reveals that larvae of corals and reef fishes typically travel tens or hundreds of kilometers, rather than thousands of kilometers as has often been assumed. In one study, scientists analyzed the genetic patterns of staghorn



How Can People Keep Reefs Healthy?

Coral reef ecosystems are fragile and can be lost suddenly. By taking steps to keep reefs healthy and resilient, people can help the reefs to survive.

Fishing Pressure and Pollution Are Key

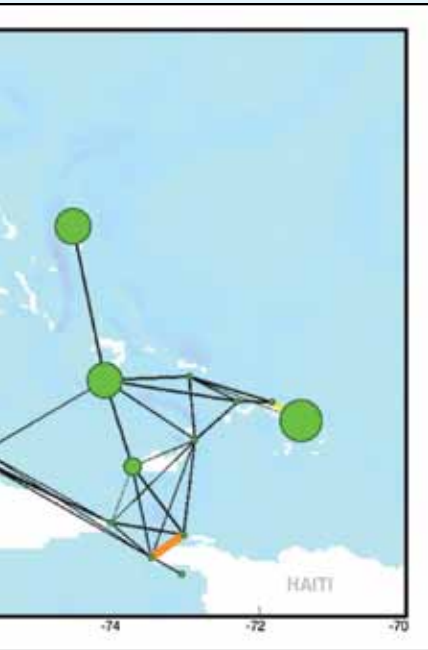
Three decades ago, scientists generally believed that coral reefs were very stable ecosystems, meaning that a coral reef was likely to remain a coral reef for thousands of years despite impacts such as hurricanes, fishing, and degraded water quality. Coral reefs seemed to have a natural, built-in resilience that enabled them to recover and persist



Factors in Healthy or Degraded Reefs

Seaweeds and sponges tend to dominate when seaweed-eating parrotfishes become scarce due to overfishing, nutrient pollution fuels seaweed and sponge growth, and excess sediment coming from land impairs coral growth.

- Overfishing
- Pollution
- Sedimentation



coral and determined that their larvae typically traveled relatively short distances of less than 500 kilometers. On some reefs, the movement of staghorn coral larvae was extremely limited—only some 2 kilometers. Some coral species even have populations with substantial amounts of self-recruitment, meaning that the larvae produced in that population come back to it rather than drifting elsewhere. The findings suggest that marine reserves should be located in relatively close proximity to each other, so that some larvae are likely to disperse from one reserve to another, rather than settling just in the unprotected areas between widely spaced reserves. These connections between marine reserves are vital to long-term survival of reef fishes and invertebrates.

Maintaining Connections

To protect biodiversity, marine reserves should be spaced at a variety of distances, so they protect species that travel different distances as larvae. Not only do species vary greatly in how far they disperse, but each population of a species has its own degree of connectivity with other populations. As an example, this figure shows ecological linkages among populations of a harvested, economically important sea plume. Each **green** dot represents a sea plume population. Northern Bahamian populations are linked only within The Bahamas, while southern Bahamian populations are linked with those in Cuba and the Turks and Caicos.

The color and thickness of the lines indicate the relative strength of linkages—created by traveling gorgonian larvae—between populations. **Red** lines indicate strong linkages, meaning that very high numbers of larvae move between the locations. **Orange, yellow, and black** lines indicate high, moderate, and weak linkages, respectively. Larger dots indicate more “self-seeding” (self-recruitment) of the population, meaning that larvae settle at the same reef as their parents. *Analysis by Claire B. Paris (Univ. Miami).*

after these impacts. In recent years, however, it has become evident that this resilience can become overwhelmed, so that seaweeds take over from coral and the coral reef ecosystem is lost. At the root of this phenomenon is intense competition for space on the reef among corals, seaweeds, and sometimes other invertebrate groups (see figure).

For management, the implications are clear. By preventing overfishing of parrotfishes and cutting down on pollution of coastal waters, managers can help coral to thrive, leading to long-term persistence of coral reefs. From a management perspective, it is easier and less costly to prevent a coral reef from changing to a degraded state than it is to restore a degraded reef. Establishing marine reserves is an important way to reduce fishing pressure.

Corals tend to dominate when seaweed-eating parrotfishes are abundant and unpolluted water enables high replenishment of coral populations without severe competition from seaweeds.

Healthy fish populations •
Good water quality •
Good coastal planning •



Case Study: Exuma Cays Land and Sea Park

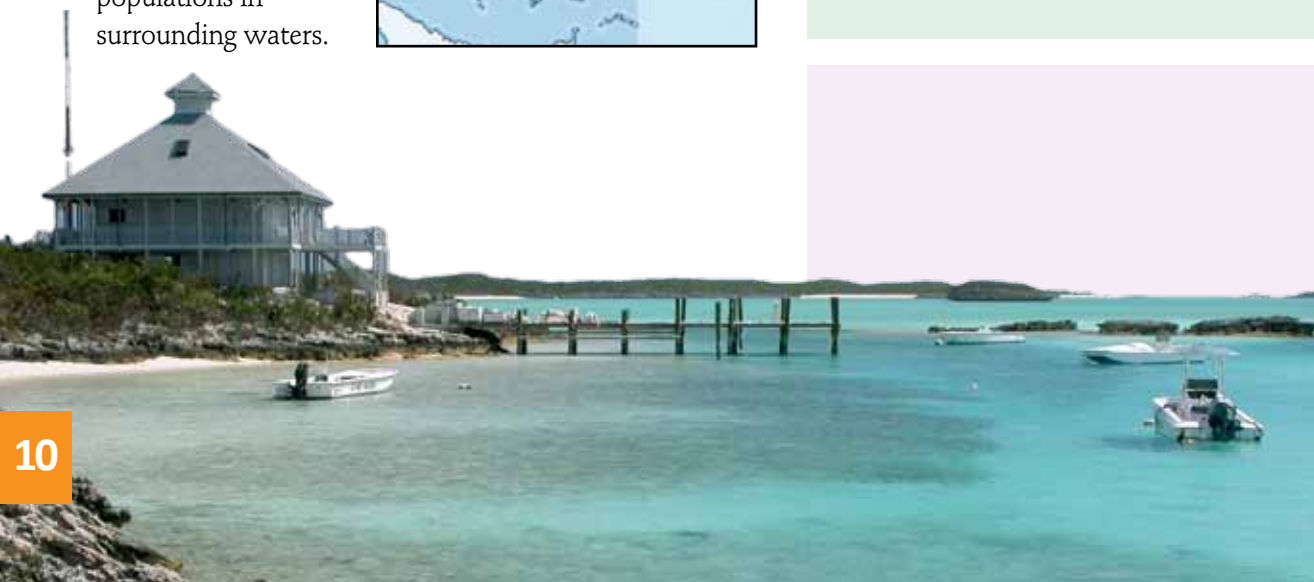
People and Marine Life Reap the Benefits

The Bahamas boasts one of the world's first and most successful marine protected areas (MPAs). Established in 1959 with a complete ban on fishing enforced since 1986, the Exuma Cays Land and Sea Park vividly illustrates the benefits of MPAs for marine life and fisheries. The Park is managed by the Bahamas National Trust and covers more than 400 square kilometers of coral reefs, seagrass beds, mangroves, and sand flats. The staff manage visitors, engage nearby residents, and conduct patrols to enforce rules prohibiting all fishing, conching, lobstering, and shelling within the Park's boundaries. Scientific studies show that these prohibitions have had dramatic, positive results for fishes and invertebrates both inside and outside the marine reserve, as well as for fisheries outside. Large numbers of conch, Nassau grouper, spiny lobster, and other marine species thrive within the Park's borders, and many of their offspring move outside to boost populations in surrounding waters.



Great for Groupers

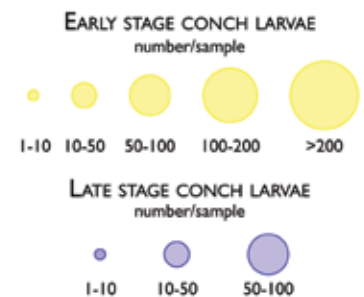
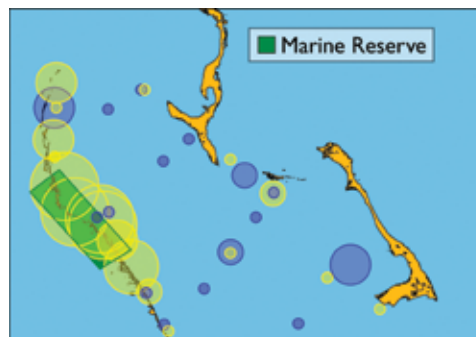
A study of Nassau grouper found that biomass of this ecologically and economically important fish was seven times greater inside the Exuma Cays Land and Sea Park compared to areas outside. Three lines of scientific evidence indicate that some grouper leave the Park and enter unprotected waters to support local fisheries: grouper abundance was highest in the reserve and declined with distance outside the reserve's boundary, grouper tagged inside the reserve were later caught as far as 220 kilometers away, and the number of grouper eggs produced per square kilometer was more than six times higher inside the Park and the eggs are likely carried outside by ocean currents.





► Conducive to Conch

In the past, scientists found that queen conch were up to 30 times more abundant inside the Exuma Cays Land and Sea Park compared to areas outside. Equally important, the Park appeared to be an important source of young conch, or larvae, that drifted outside and “seeded” the surrounding areas. The youngest larvae were most abundant within and nearby the Park, while older larvae were more abundant farther away. Based on this evidence and models of ocean circulation, the scientists concluded that adult conch inside the Park released large numbers of larvae that drifted away and eventually settled outside. More recently, declines in conch numbers inside the Park suggest that overfishing elsewhere may be affecting the current larval supply of conch coming into the Park. Marine parks can play an important role in supporting valuable marine resources like queen conch populations, but for long-term sustainability, ecologically connected networks of effective parks combined with active fisheries management of surrounding waters are necessary.



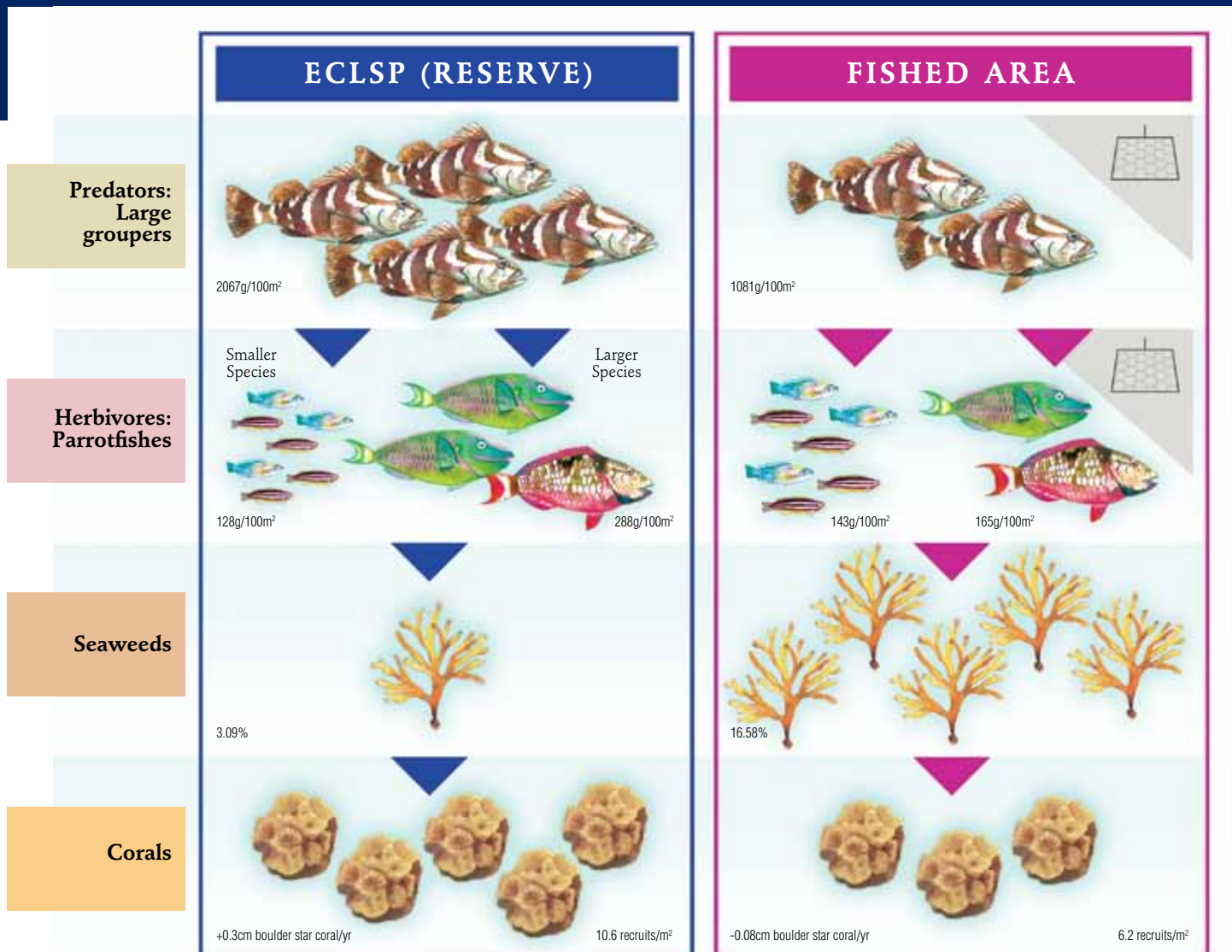
The youngest conch larvae were most abundant in and near the marine reserve. Slightly older larvae were found throughout the region. This finding suggests that most young conch were produced inside the reserve and were dispersed outside by currents. Data: Stoner et al. (1998) *Journal of Shellfish Research*



► Super for Spiny Lobster

Scientists found more spiny lobster per square kilometer in Exuma Cays Land and Sea Park than in three other sites in Exuma Sound.





Healthier, More Resilient Reef in Park

Park—such as Nassau grouper, which eats parrotfishes as well as other reef animals—affect the parrotfish-seaweed-coral relationship? If Nassau grouper increase in the marine reserve, then do parrotfishes—and therefore corals—decrease?

Scientists recently conducted research at the Exuma Cays Land and Sea Park to answer this question. They found that an increase in grouper did not have a negative impact on corals. The reason is that within the Park some species of parrotfishes are able to grow so large that groupers cannot eat them. They effectively escape from predation by being too big. These large parrotfish graze reefs more effectively than smaller parrotfish do, so their increased numbers in the Park, due to their protection from fishing, more than compensates for the decreases in the size of the smaller parrotfishes, due to increased predation from groupers. In fact, overall grazing by all parrotfishes doubled inside the Park, causing a fourfold reduction in seaweed. Most importantly, the density of young corals nearly doubled in the Park. After two and a half years, the growth of coral was significantly higher inside the Park compared to outside.

These findings suggest that marine reserves can contribute to the resilience of coral reef ecosystems within their boundaries. This greater resilience could potentially help reefs to withstand climate change.

As discussed on page 8, corals and seaweeds compete for space on reefs. When parrotfishes graze heavily on reefs, they help keep it clear of seaweeds, and corals can settle in greater numbers and grow better. But how does the increased number of predators found in the

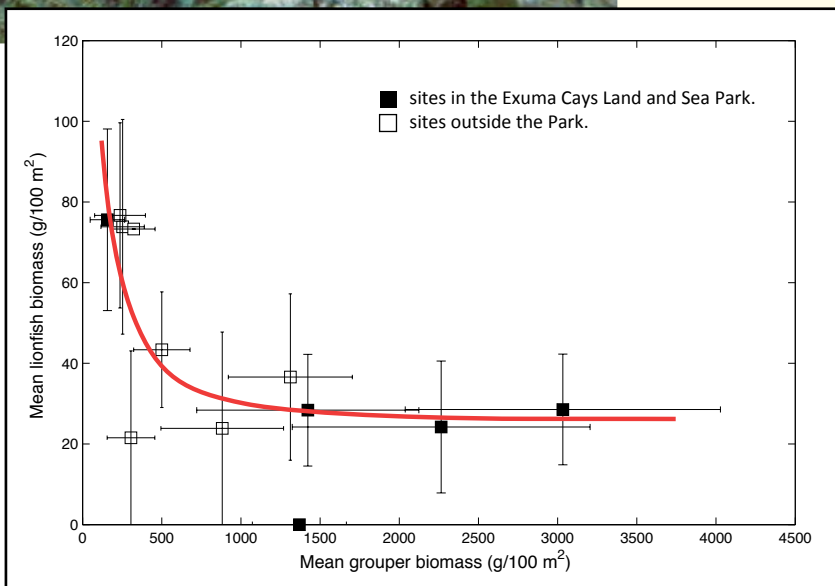
More Grouper... Less Lionfish

In a study of twelve reef sites in the Exuma Cays, sites with more grouper biomass tended to have less biomass of the invasive lionfish.



Battling the Lionfish Invasion

Native to the tropical Indo-Pacific Ocean, the lionfish has been invading the northwest Atlantic Ocean and the Caribbean Sea, apparently after being released or escaping from one or more aquaria in Florida. In 2007, the lionfish began to appear in the Exumas, and it poses a tremendous threat to native marine life. To date, no methods have been developed to eradicate this invasive species or to control its spread across large areas. Lionfish have been found occasionally in stomachs of Nassau groupers, raising the possibility that groupers might serve as a natural biocontrol. Scientists explored this possibility in research at the Exuma Cays Land and Sea Park, where there is an extremely high biomass of Nassau grouper. The study found a sevenfold decrease in lionfish biomass where Nassau grouper biomass was highest. This suggests that Nassau grouper has the capacity to act as a natural biocontrol of lionfish, but only in places where marine reserves and other management approaches are used to reverse overfishing of grouper.



The relationship between the amount of groupers and lionfish across twelve reef sites in the Exuma Cays. Solid points indicate sites within the ECLSP where groupers are protected and tend to be more numerous and larger. The red line suggests that a reef needs a grouper biomass of approximately 500-1000 g / 100m² to achieve the maximum observed decreases in lionfish biomass. Error bars are standard errors. Data: Mumby et al. 2011.

How Can The Bahamas Move Ahead with Marine Reserves?

In The Bahamas, social scientists have recently investigated cultural and economic factors related to planning, designing, and implementing marine reserves. These studies are examples of social scientific research that could be conducted to support management decision-making and enhance the long-term effectiveness of management efforts.



Perspectives of Local People

In a six-year study, researchers interviewed 193 people from six communities in the Exuma Cays.

- When asked who should design and control a local marine reserve, nearly two-thirds said they wanted a partnership between the national government and local people, rather than solely local or national control.
- Marine reserve efforts could either support or undermine the long-term resilience of local communities. For example, shifting a community to a cash-based economy would reduce resilience, according to the research.

- Establishing a no-take marine reserve may have greater negative impacts on subsistence fishermen, for whom fishing is central to their identity and lifestyle, than on commercial fishermen, who may shift to different fishing areas or sources of income.

Support for Marine Reserves

In another study, scientists carried out more than 200 interviews with residents of five Family Island settlements. More than 60 percent of the respondents said they were familiar with the concept of marine reserves, and 13 percent had attended a meeting about marine reserves. The scientists determined that support for creation of new no-take reserves was highest among those residents who

- were less dependent on fishing and more dependent on tourism,
- had higher incomes,
- thought that local environmental conditions were poor,
- believed that fishing was a top impact, and
- perceived current fishing regulations as poorly enforced.

Scientific Monitoring and Research

Around the world, decisions about the planning, implementation, and management of marine reserves and other MPAs must be made based on available data, which typically lack the comprehensiveness, detail, and reliability that would be ideal for well-informed management. This challenge exists in The Bahamas as well. However, the relatively long history of marine reserves in The Bahamas provides a unique opportunity to create a strong scientific foundation for future adaptive management decision-making. As more is learned from studying reserves in comparison to more intensively used non-reserve areas of the ocean, this will help in two ways. First, monitoring the status of important indicators within the reserve can feed into regular, adaptive decision-making about the management of the reserves. In addition, because the reserves are reference areas for other non-reserve areas, research about reserves provides insights into how non-protected seascapes could be better managed to achieve more sustainable ecosystem processes and services.



Generous support for this project comes from **Lynette and Richard Jaffe, the Jaffe Family Foundation**, and **The Tiffany & Co. Foundation**. Major support for most of the original research was provided by the **US National Science Foundation** under Grant No. OCE-0119976.

MANAGING EDITOR

Daniel R. Brumbaugh

PRODUCTION ADVISOR

Meg Domroese

SCIENCE WRITER

Peter H. Taylor

DESIGN AND ILLUSTRATIONS

James Lui

SCIENCE ADVISORS

Craig P. Dahlgren, Alastair R. Harborne, Vanessa Haley-Benjamin, Eleanor Phillips

PHOTOS & OTHER IMAGES

Daniel R. Brumbaugh (**p2**: sea star, sunset; **p3**: diver with quadrat, fan worm, sea star, parrotfish, island development, red lionfish; **p4**: bonefishing, lighthouse, gorgonians; **p5**: mangrove, medium-density seagrass, patch reef, star coral; **p6**: mangrove, pillar coral; **p9**: gorgonian; **p10**: marine park, spiny lobster; **p11**: pillar coral; **p13**: Nassau grouper, red lionfish; **p14**: workshop participants, researchers on boat, diver with quadrat)

Craig P. Dahlgren (**p5**: seaweed plain, elkhorn coral, dense gorgonians, gorgonian plain; **p11**: Nassau grouper)

Alastair R. Harborne (**p5**: sparse seagrass, sand; **p6**: habitat map)

Katherine E. Holmes (**p2**: kids on dock; **p5**: dense seagrass; **p10**: queen conch)

NASA (**cover**: MODIS Terra image)

Claire B. Paris (**pp8-9**: connectivity analysis)

PISCO/Monica Pessino (**p10**: marine reserve map; **p11**: conch larval dispersal)

PISCO/Monica Pessino/Ryan Kleiner (**pp6-7**: snapper life cycle)

Eric A. Trembl (**p12**: elkhorn coral)

REFERENCES

- Bolden, SK. 2000. *Fish. Bull.* 98(3): 642-645.
- Broad, K and JN Sanchirico. 2008. *Ocean Coast. Manage.* 51(11): 763-771.
- Harborne, AR, *et al.* 2006. *Adv. Mar. Biol.* 50: 57-189.
- Harborne, AR, *et al.* 2008. *Ecol. Appl.* 18(7): 1689-1701.
- Harborne, AR, *et al.* 2008. *J. Appl. Ecol.* 45(4): 1010-1018.
- Jackson, JBC, *et al.* 2001. *Science* 293(5530): 629-638.
- Lipcius, RN, *et al.* 1997. *Mar. Freshwater Res.* 48(8): 807-815.
- Mumby, PJ, *et al.* 2006. *Science* 311(5757): 98-101.
- Mumby, PJ, *et al.* 2007. *Proc. Natl. Acad. Sci. USA* 104(20): 8362-8367.
- Mumby, PJ, *et al.* 2008. *Conserv. Biol.* 22(4): 941-951.
- Mumby, PJ and AR Harborne. 2010. *PLoS ONE* 5(1): e8657.
- Mumby, PJ, *et al.* 2011. *PLoS ONE* 6(6): e21510.
- Spalding, MD, *et al.* 2013. In: Chircop, A *et al.* (eds), *Ocean Yearbook* 27. Martinus Nijhoff, Leiden, The Netherlands: 213-248.
- Sluka, R, *et al.* 1997. *Proc. 8th Intl. Coral Reef Symp.* 2: 1961-1964.
- Stoffle, R and J Minnis. 2007. *Coral Reefs* 26(4): 1023-1032.
- Stoner, AW, *et al.* 1998. *J. Shellfish Res.* 17(4): 955-969.
- Stoner, AW, *et al.* 2012. *Mar. Ecol. Prog. Ser.* 460: 101-114.
- Stoner, AW and M Ray. 1996. *Fish. Bull.* 94(3): 551-565.
- The World Factbook*. 2013. U.S. Central Intelligence Agency, Washington, DC.
- Vollmer, SV and SR Palumbi. 2007. *J. Hered.* 98(1): 40-50.

SUGGESTED CITATION

Brumbaugh, Daniel R (ed.). 2014. *Guide to the Science of Marine Protected Areas in The Bahamas*. American Museum of Natural History, New York, NY, 16pp.



Central Park West
at 79th Street
New York, NY 10024 USA
Tel: +1 (212) 769-5742
Fax: +1 (212) 769-5292
Email: biodiversity@amnh.org
Internet: cbc.amnh.org/

For additional information and resources, go to <http://bbp.amnh.org/>

© 2014 American Museum of Natural History

Information in this publication may be reproduced for non-commercial, educational purposes, providing credit is given to the original work. For any other purposes, prior permission is required.

Printed on FSC certified sustainable (cover) and 100% post-consumer recycled (body) paper.



Lynette and Richard Jaffe

THE TIFFANY & CO. FOUNDATION

 AMERICAN MUSEUM
OF NATURAL HISTORY



The Nature
Conservancy 
Protecting nature. Preserving life.™