



THE COASTLINES & FISHERIES
TEAM PRESENTS

THE DON YOUNG RESTORATION GRANTS FOR COASTLINES & FISHERIES ACT

FINAL REPORT



2023

STENZON COAST

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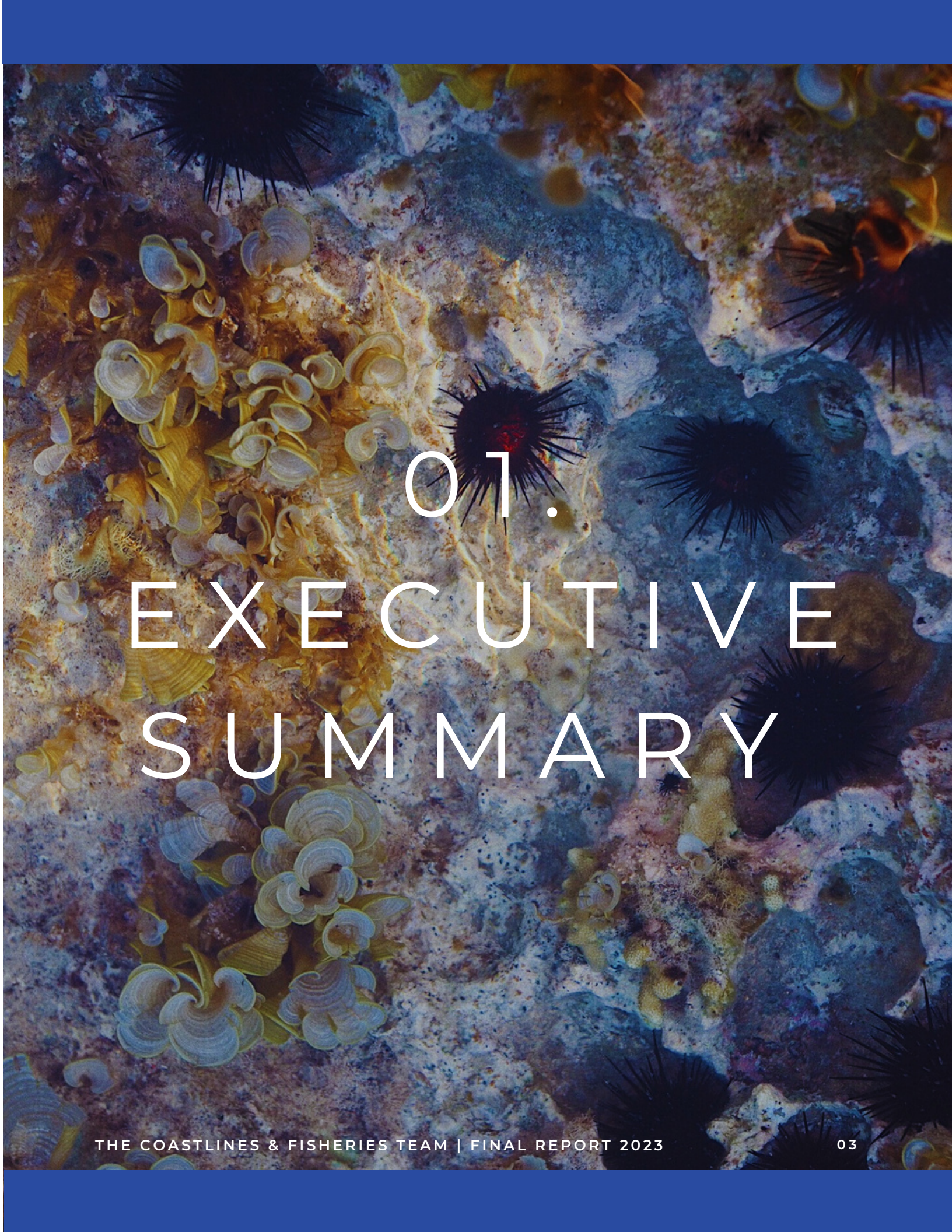
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An underwater photograph of a rocky seabed. The left side of the image is dominated by a dense cluster of yellow, spiral-shaped clams. Scattered across the dark, textured rocks are several black sea urchins with prominent spines. The water has a blueish tint, and the overall scene is a detailed view of marine life.

01. EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The Don Young Restoration Grants for Coastlines and Fisheries Act of 2023 (H.R. 1196) establishes a grant program through the National Oceanic and Atmospheric Administration (NOAA) for projects which rehabilitate damaged aquatic ecosystems, prevent climate change-induced coastline harm, and protect the industries and health of coastal communities. The bill was introduced by Rep. Stacey Plaskett (D-U.S. Virgin Islands) and Rep. Maria Salazar (R-Florida). It has been referred to two House committees for review.

The United States' aquatic ecosystems are in jeopardy. Marine and freshwater environments are suffering from a host of anthropogenic problems. Overfishing is devastating U.S. marine and freshwater fish populations through the use of unsustainable catch methods (i.e., bottom trawling, longlining) and the proliferation of Illegal, Unreported, and Unregulated (IUU) fishing events. The effects of these practices are only exacerbated by climate change which is shifting species' distribution patterns.

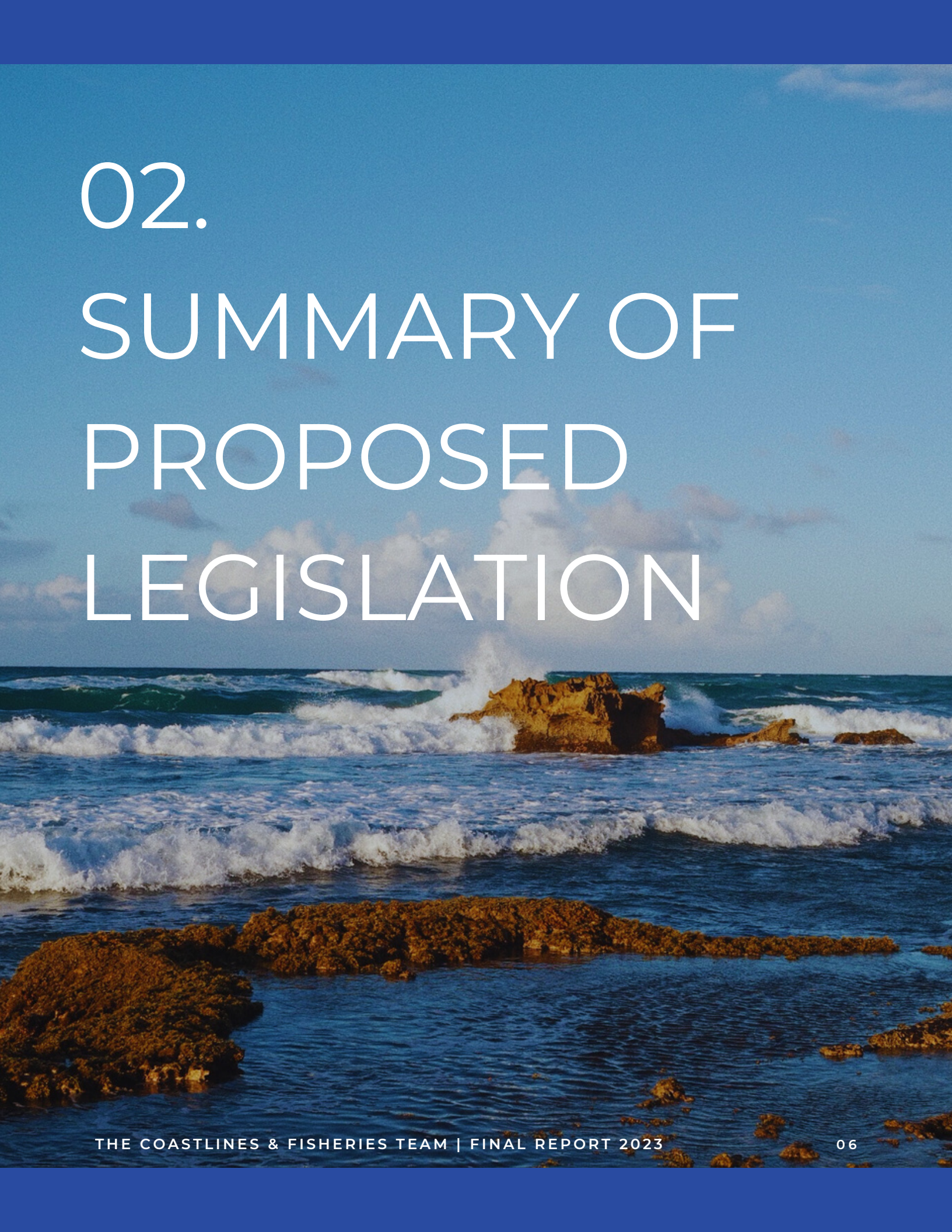
Water pollution is posing an equally dire threat. Industrial waste discharge, agricultural runoff, and plastics contamination are all present to some degree in U.S. water bodies. If left unchecked, entire ecosystems can disappear due to nitrate-induced eutrophic events or organism ingestion of toxins and plastics. Habitat decimation can be felt throughout the food web, sometimes even by humans.

Coastal degradation via climate change is the final threat to aquatic ecosystems and coastal communities and presents some of the most troubling problems. Part of the reason for this is due to the climate's global nature and the vast uncertainty surrounding its processes. Sea level rise and more intense storm systems are already degrading U.S. coastlines. Warming oceans and ocean acidification—both of which are caused by high levels of atmospheric carbon dioxide—are further damaging marine ecosystems.

There are solutions, however. Overfishing, water pollution, and coastal degradation represent complex problems so the solutions required must be holistic in their considerations. Sustainable management of fisheries promises to effect change in fishing practices, while mechanical and chemical removal of pollutants from water bodies has proven effective before. When it comes to climate change, investment in natural flood mitigation measures (i.e., living shorelines, floodplains) will aid local communities and ecosystems in their resiliency efforts.

This report acknowledges that no solution comes without its controversies and, to that extent, strives to identify potential complications following the implementation of a proposed solution. Some solutions are too expensive for local communities (i.e., reverse osmosis filtration) while others do not have enough research regarding full efficacy (i.e., oyster reefs). The solutions presented in this report, though, are representative of the best available science. What follows is a detailed documentation and analysis of the science behind the threats to aquatic ecosystems and their solutions, the controversies surrounding such solutions, and areas for additional research.





02. SUMMARY OF PROPOSED LEGISLATION

H.R. 1196

118TH CONGRESS (2023-2024)

Climate change is devastating aquatic ecosystems and coastal communities through occurrences such as sea level rise and extreme weather events. The coastlines and fisheries of the United States of America are vulnerable to these changes.

To address the adverse impacts of climate change and to fund adaptive solutions, H.R. 1196, The Don Young Restoration Grants for Coastlines and Fisheries Act of 2023, was introduced in the 118th session of the U.S. Congress. The sponsors are a bipartisan group of legislators, from geographical regions in the United States hit hard by climate change and worsening natural hazards. Representative Stacey Plaskett of the U.S. Virgin Islands wrote the original version of the bill with her team, titled “Shovel-Ready Restoration Grants for Coastlines and Fisheries Act”. She introduced the bill during the 117th Congress, garnering support and advocacy from the late Congressman Don Young of Alaska, with whom she would go on to introduce the bill (U.S. House, 2023).

During the 118th Congress, the bill was reintroduced and renamed the Don Young Restoration Grants for Coastlines and Fisheries Act of 2023, in memory of Congressman Don Young of Alaska, who passed away in March 2022.

The Don Young Restoration Grants bill is based on previous legislation passed to help create programs that called for the National Oceanic and Atmospheric Administration (NOAA) to identify, fund, and help implement projects that improve coastal habitats and economies, and increase resiliency (U.S. House, 2023).

Representative Stacey Plaskett of the U.S. Virgin Islands and co-sponsor Representative Maria Salazar of Florida introduced the bill on February 24, 2023 (U.S. Congress, 2023). They received the support of co-sponsors Representative Mary Peltola of Alaska and Representative Jennifer Gonzalez-Colon of Puerto Rico. The bill was referred to two committees for review: the House Natural Resources Subcommittee on Water, Wildlife, and Fisheries and the House Transportation and Infrastructure Subcommittee on Water Resources and Environment.

As written, the bill's summary states that H.R. 1196 is "to require the Administrator of the National Oceanic and Atmospheric Administration to establish a grant program to benefit coastal habitats, resiliency, and the economy, and for other purposes." The bill does this by creating and funding a 10-year government grant program administered by NOAA. It provides 1 billion dollars a year to fund projects focused on marine, estuarine, coastal, and Great Lake habitats. State, local, and tribal governments, nonprofit organizations, businesses, and institutions of higher education are all eligible to apply for grants under the bill if they are able to meet the objectives and priorities of the bill's ethos (U.S. Congress, 2023).

Coastlines and fisheries play an integral role in the United States by providing and sustaining food, jobs, recreation, community identity, and physical protection from severe weather events. The objectives of the bill are to restore aquatic and coastal habitats by protecting fresh and saltwater biodiversity, including fisheries. Projects and activities that meet these objectives include those that focus on removing marine debris and toxic pollutants. The bill calls for a specific focus on projects that support climate change adaptation through nature-based solutions and promote ecological barriers to protect coastal communities from sea level rise, coastal storms, and flooding (U.S. Congress, 2023).

Priority will be given to projects that stimulate the economy, employ fishers, and help disenfranchised communities including low-income, minority, Indigenous, Tribal, and rural communities (U.S. Congress, 2023). The bill also calls for priority to be given to projects that have a regional focus on grant work being implemented to address coastal issues impacting National Parks, Marine Protected Areas (i.e. National Marine Sanctuaries), and National Wildlife Refuges.



The background of the page is a photograph of a coastal scene. In the foreground, there is a sandy beach. In the middle ground, three people are standing in the shallow water, using long poles to pull a large fishing net. In the background, a large suspension bridge with a tall central pylon spans across the water. The sky is a clear, bright blue.

03. OVERFISHING: PROBLEMS & SOLUTIONS

3.1

OVERVIEW OF PROBLEMS

3.2

MAXIMUM SUSTAINABLE YIELDS

3.3

MARINE SPATIAL PLANNING

3.4

ECOSYSTEM-BASED FISHERIES
MANAGEMENT

3.5

SUSTAINABLE FISHERIES TECHNIQUES

CASE STUDY: ATLANTIC SEA SCALLOPS



North Atlantic, New England Sea Scallops
Source: Getty Images

Atlantic sea scallops are found from the mid-Atlantic region to the U.S. / Canada border. Sea scallops grow quickly in the first few years of their life and can have life spans of up to twenty years (NOAA, 2022). While scallops can begin to reproduce as early as age 2, principle contributors to recruitment are those at or above age 5 (McGarvey et al., 1993). A single female sea scallop can produce hundreds of millions of eggs per year (NOAA, 2022). These biological factors allow for changes in fishing management practices to be quickly reflected in the species' population (NOAA, 2022).

From the beginning of the 20th century until 1970, sea scallop landings generally increased. This was a result of improvements in navigation, technology, and vessel power, which when combined, made each boat gradually more productive (Hart & Rago, 2006). A decline in commercial catch rates and scallop biomass began around 1970 as scallops began experiencing intense overfishing (Hart & Rago, 2006). A 1993 study also found that the average age of caught scallops was 3.25 years, lower than the peak reproductive age, and concluded that raising the minimum age would lead to higher yields (McGarvey et al., 1993).

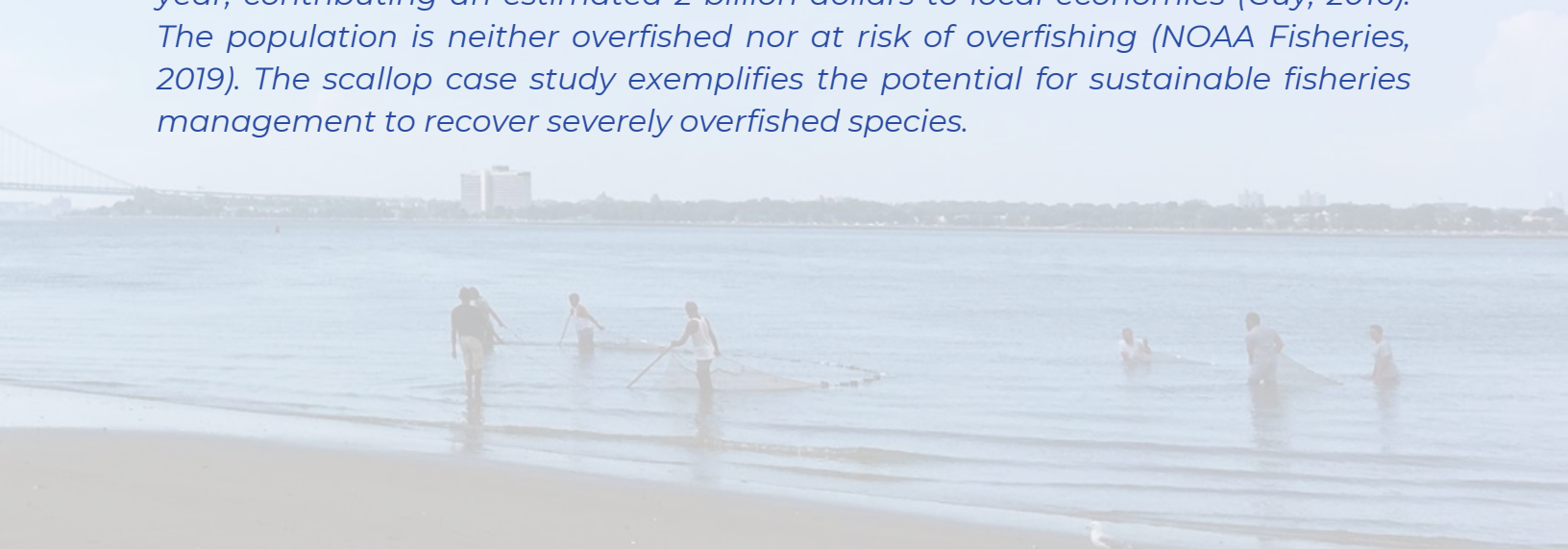
For the duration of the 20th century up until 1994, sea scallop fishing was open-access, meaning anyone with a boat and equipment could fish (Guy, 2016). In 1982, yield restrictions were put in place that limited scallopers by meat count (Hart & Rago, 2006).

In 1994, a series of sustainable measures were put in place to help the Atlantic sea scallops in the Georges Bank recover. NOAA designated zones in the Georges Bank as no-dredging zones, utilizing marine spatial planning to create marine-protected areas that let scallops recover (NOAA Fisheries, 2019). Marine-protected areas are especially effective at restoring biomass for sedentary, over-exploited species (Lester et al., 2009). Marine-protected areas can also benefit fisheries by the protected species spilling over to surrounding areas (Gell et al., 2003).

A moratorium on all new scallop permits was put in place, and days-at-sea limitations were instituted for existing permit-holders (NOAA Fisheries, 2019). Dredge ring sizes were increased from 3 to 3.5 inches, allowing more juvenile scallops to return to the seafloor and reproduce (NOAA Fisheries, 2019). Crew sizes were limited to seven, down from the previous average of thirteen (Hart & Rago, 2006). This was a subtle way to limit hours at sea: catch rates per vessel exceeded the shucking power of seven men, causing them to return to shore earlier in the day (Hart & Rago, 2006).

Sea scallops were officially declared “rebuilt” by 2001 (Hart & Rago, 2006). Their biomass was 18 times higher in 2005 than it was in 1994, and twenty-five times higher in the marine-protected areas during the same period (Hart & Rago, 2006).

Today, the Atlantic sea scallop fishery brings in 50 million pounds of scallops per year, contributing an estimated 2 billion dollars to local economies (Guy, 2016). The population is neither overfished nor at risk of overfishing (NOAA Fisheries, 2019). The scallop case study exemplifies the potential for sustainable fisheries management to recover severely overfished species.



3.1 OVERVIEW OF PROBLEMS

U.S. fisheries are a critical part of the U.S. economy: the sector makes up 1% of U.S. gross domestic product, provides 1.7 million jobs, and produces over 4.5 metric tons of meat per year (Link, 2021). **Overfishing** is a critical threat to the long-term sustainability of the fishing industry, yet the industry often lobbies for yield requirements that exceed sustainable thresholds.

In 1976, the Magnuson–Stevens Fisheries Conservation and Management Act, commonly referred to as the Magnuson–Stevens Act (MSA), was signed into law (Methot et al., 2014). It established a framework for fisheries management between the U.S. coastlines and 200 nautical-miles offshore, both to combat foreign fishing in U.S. waters and begin to manage U.S. fisheries (Methot et al., 2014). Eight regional Councils were established and tasked with developing fisheries management plans and regulations in compliance with federal law (Methot et al., 2014).

According to the MSA, an optimum yield (OY) is a yield that 1) provides the greatest benefit to the nation's food production, and 2) is prescribed on the basis of the maximum sustainable yield as modified by any relevant economic, social, or ecological factors (Methot et al., 2014). This practice of allowing economic considerations to factor into yield regulations has caused allowable yields to exceed **maximum sustainable yields** over time (Methot et al., 2014).

The MSA was reauthorized in 1996 and included ten national standards for fisheries management (Methot et al., 2014). These included somewhat contradictory priorities: while one standard ordered target yields to be framed based on “the best scientific information available,” another standard ordered the consideration of economic impacts on fishing communities (Methot et al., 2014). Thus, short-term economic interests were still appropriate determinants of yields, allowing for exceeding MSYs.

The Magnuson–Stevens Act was once again reauthorized in 2007, signed into policy by President George W. Bush (Methot et al., 2014). In contrast to the two previous versions of the MSA, the 2007 reauthorization put a greater emphasis on scientific consideration in the fisheries management process. When making fisheries management decisions, Councils were required to be briefed on stock status and health, habitat status, bycatch, and the biological sustainability of fishing practices (Methot et al., 2014). It also required Annual Catch Limits to reach a level that would comprehensively prevent overfishing (Methot et al., 2014). Over the following five years, 46 federal Fishery Management Plans were updated to implement Annual Catch Limits and associated accountability measures (Methot et al., 2014).

In addition to ecosystem and economic-based considerations for fisheries management, another key problem to account for is unreported landings. **Illegal, Unreported, and Unregulated (IUU)** fishing is a matter of global concern for fisheries managers (Lee et al., 2014). Driven by greed, IUU fishing circumvents regulations, paperwork, and operating costs, while still selling for the same price as legally-caught fish (Lee et al., 2014). In 2011, it was estimated that between 11 and 26 tonnes of landings were via IUU fishing (Lee et al., 2014). That mass is comparable to 14 to 33% of the world's total legal landings (Lee et al., 2014). This wide estimated range illustrates the difficulty that fisheries managers may have in accounting for a certain level of IUU fishing.

Recreational fishing is another contributor to overfishing (Coleman et al., 2004). A 2004 study found that, while recreational fishing only accounted for 4% of total U.S. fish landings, it accounted for 23% of the landings for overfished U.S. stocks (Coleman et al., 2004). In the Gulf of Mexico, that figure rose to 64% of overfished landings (Coleman et al., 2004).

Beyond exceeding sustainable yields, certain **harmful fishing methods and gears** can have dire consequences on aquatic ecosystems. Bottom trawling is the practice of towing a net along the ocean floor, which has a significant negative impact on seabeds (Palanques et al., 2014). The disruption associated with trawling leads to sediment resuspension, causing higher near-bottom turbidity (Palanques et al., 2014). Continuous scraping disturbs vulnerable organisms, which can lead to domination by more opportunistic organisms (Palanques et al., 2014). This also disrupts seafloor sediment records, which are an important historical record of earth conditions (McHugh, 2022).

Longline fishing is another harmful fishing method: hundreds of lines up to 1200 feet long are cast out behind a fishing boat, each carrying thousands of baited hooks (Fitzgerald, 2013). The lines are buoyed by styrofoam or plastic, meaning any animal above or below water could be caught (Fitzgerald, 2013). Since there is no way to bait a specific species with this method, it results in bycatch (non-target and unwanted species) in the form of birds, marine mammals, sea turtles, and sharks (Fitzgerald, 2013). These animals are often injured or killed by this method (Fitzgerald, 2013). Finally, if the gear is discarded into the ocean, it can continue to “ghost catch” marine life, disrupting their habitats and entangling species (Fitzgerald, 2013).

Overfishing is often discussed on a species-by-species basis, but that ignores profound indirect ecosystem effects. A trophic cascade occurs when large predatory species are removed from an ecosystem, disrupting the typical predator-prey dynamics (Scheffer et al., 2005). Removal of apex predators leads to an abundance of planktivorous fish, which results in a decline in zooplankton biomass (Daskalov, 2002). In certain ecosystems, this imbalance can have severe consequences, fostering blooms that lead to eutrophication (Daskalov, 2002). This same process can create coral-algal competition, disrupting coral reefs down to the microbial scale (Zaneveld et al., 2016).

Climate change is another threat to fish populations: as sea surface temperatures warm and sea levels rise, species’ distributions and potential ranges may shift (Link, 2021). Overfishing is likely to exacerbate the impacts of climate change (Link, 2021). When populations are already stressed under abiotic conditions (likely impacting their survival), maximum sustainable yields will not be the same as in normal circumstances (Link, 2021).

Given the economic, ecological, and climatic implications of overfishing, sustainable practices must be identified and implemented. In 2020, NOAA reported that of the 460 fish stocks actively managed in their fishery management plans, 70% had a known ‘overfishing’ status, while 55% had a known ‘overfished’ status (NOAA Fisheries, 2022). The former indicates that stocks are being overfished above their maximum sustainable yields, while the latter indicates that the stock population sizes are already too low to produce their maximum sustainable yield (NOAA Fisheries, 2022). In either case, the majority of U.S. fish stocks are in jeopardy if current patterns continue.

3.2 MAXIMUM SUSTAINABLE YIELDS

Given that fish stocks are diminished in a variety of ways (regulated commercial fishing, IUU fishing, recreational fishing, changes in abiotic conditions, etc.) sustainable fisheries management will account for all of these factors when regulating maximum yields. A **maximum sustainable yield (MSY)** is the largest catch (in number or mass) that can be repeated over an extended period (Maunder, 2008).

MSY relies on the ecological principle of carrying capacity, assuming that sustainable fishing would allow for the elimination of a surplus without impacting baseline reproduction (Maunder, 2008). While ‘optimal yields’ described in the prior section included short-term economic considerations, a true MSY would be scientifically determined based on the particular ecological and reproductive traits of a species (Maunder, 2008). This often requires a short-term trade-off (reducing fishing efforts) until a population has recovered, which often results in political pushback from fishers (Mesnil, 2012).

While MSYs can be difficult to precisely determine, their proximate range is known (Mesnil, 2012). One key misinterpretation of their concept is that an MSY for a given population would be a recurring limit on catches (Mesnil, 2012). Rather, managers should be monitoring population dynamics to ensure that fish stocks remain at levels “permitting them to produce MSY” (Mesnil, 2012). This requires decreasing yield limits if a species is below its carrying capacity. Essentially, a sustainable annual yield limit will always be at or below the MSY value.

MSYs are a critical part of sustainable fisheries management; however, they must be paired with other management methods that, when combined, fully protect a species’ continued proliferation.

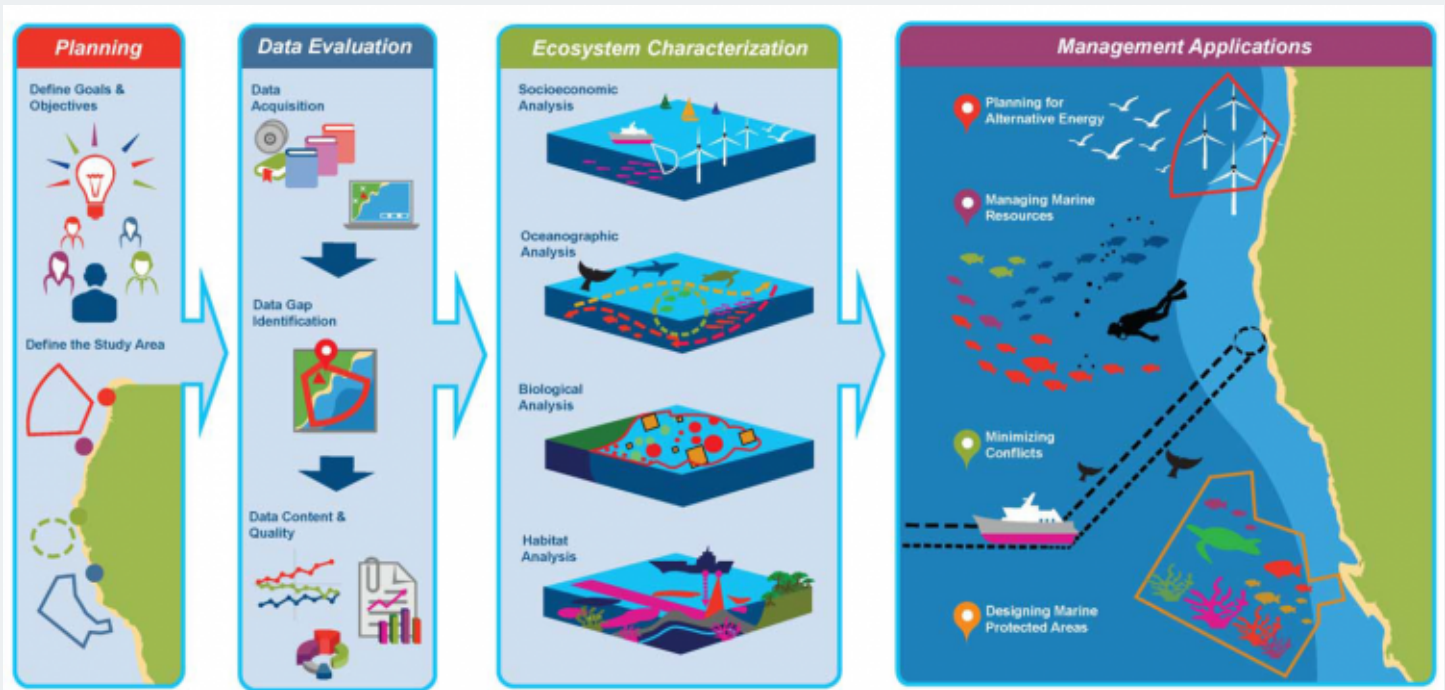
3.3 MARINE SPATIAL PLANNING

Marine spatial planning (MSP) incorporates considerations from diverse stakeholders such as communities, fishers, government entities, and other interest groups, as well as data on the ecological area (Frazão Santos et al., 2019). This solution can be applied in multi-use areas where the needs of fishing overlap with other human activities. The approach intends to maintain healthy marine habitats—which benefit coastal communities—while minimizing use conflicts in areas where sustainable fisheries are a priority (Ehler, 2009). Based on the area, the sustainable solution might be different but could include the creation of protected areas or species catch limits (SPREP, 2019).

The first step to implement MSP is to identify the area and its potential uses and establish objectives and priorities. Next, ecological data of the targeted areas needs to be collected. Analyzing how these different needs and uses can be applied within the area can be used to build consensus among diverse stakeholders. Once the plan is approved and implemented, further steps need to be taken to ensure the sustainable goals are achieved, including the provision of alternative use scenarios, forecasting future ecosystem conditions, and long-term adaptation plans (Caldow et al, 2015).

Managed under MSP, designated fishing areas can be established using **ecosystem-based principles**, which balance ecological, economic, and social goals and objectives toward sustainable development (Ehler, 2009). These can include no-take zones (areas where extractive activities are prohibited), seasonal restrictions, and acceptable fishing methods to support sustainable fisheries (Sala, 2017). When performed holistically, MSP will also include representatives of poor coastal fishing communities of color, thus addressing long-standing inequity issues (Koehn, 2022).

MARINE SPATIAL PLANNING DIAGRAM



National Centers for Coastal Ocean Science (NCCOS) Biogeographic Assessment Framework to support marine spatial planning. A logical sequence of steps in information synthesis: 1) Talking with managers to determine priorities; 2) assessing the data and identifying data gaps; 3) characterizing the ecosystem patterns and processes, including human activities across the area of interest; and 4) working with managers to support specific management applications. Source: NOAA.GOV

For more information, please visit:

<https://coastalscience.noaa.gov/news/innovative-management-approach-aids-marine-spatial-planning/>

3.4 ECOSYSTEM-BASED FISHERIES MANAGEMENT

Ecosystem-based fisheries management (EBFM) represents the evolution of Maximum Sustainable Yields and is directly related to fishery management practices applied in Marine Spatial Planning. Different from conventional resource management, EBFM defines management strategies for the entire ecosystem, not simply individual components (Levin et al., 2009). It takes into account the interplay among ecosystem components, management sectors, and impacts of various marine uses. A key aspect of EBFM is to balance the trade-offs between ecosystem services and management goals.

Integrated Ecosystem Assessments (IEA) provide the scientific foundation for EBFM. It is proposed as a framework for organizing science to inform EBFM on specific management measures to achieve sustainable goals (Levin et al., 2009). IEA uses integrated scientific understanding to feed into management choices and receives feedback from changing ecosystem objectives. An IEA process begins with identifying EBFM goals and challenges to achieve goals. Scoping involves management drivers, specific environmental stressors, and more importantly, the interests of multiple stakeholders. Afterward, indicators of ecosystem performance need to be developed. Indicators serve as proxies for ecosystem attributes such as resilience to changes and abundance of certain species. The next step is the evaluation of the risk to the indicators posed by human activities and natural processes.

Risk analysis enables decision-makers to understand inevitable uncertainties in ecosystem dynamics and their impacts. The next phase of the IEA is to evaluate how different EBFM management strategies will affect the status of natural and human system indicators. Lastly, ecosystem indicators and management effectiveness need to be continuously monitored and assessed (Levin et al., 2009). When taken together, the aforementioned practices are effective methods of fishing capacity management. A range of policies and technical measures must be deployed to strike a balance between finishing inputs and production from captured species (Cunningham, 2001).

CONTROVERSIES

There are some problems, however, with the reviewed solutions. Field data that informs the MSP process is typically difficult and expensive to collect. Accurately capturing the ecological and use features often requires expensive field studies on natural habitats, species, and other factors involved in multiple uses such as protected areas, industrial and recreational uses, and fisheries. In addition, MSP is not always attentive to the voices of multiple stakeholders (Said & Trouillet, 2020). Historically, local communities, especially poor communities of color, have been excluded from the decision-making though their livelihoods depend on coastal resources. In more recent times, organizers have worked to make the process more inclusive.

Ecosystem-based management is costly in time and human resources because it often involves an interdisciplinary team of investigators, scientific stakeholders, community stakeholders, and management coordinators (Wasson, 2015). Non-stationary ecosystems such as the Gulf of California system present additional challenges as influxes of migrants from coastal upwelling and climate shifts might radically change the dynamics of the ecosystem (Bakun et al., 2009).



© Photo: RA Cook 2019

Photo: Reyes Point, California coast

3.5 SUSTAINABLE FISHERIES TECHNIQUES

Beyond catch limits and spatial planning, fisheries management also includes **technical regulations** on fishing gear (Cunningham, 2001). These regulations are a critical component of sustainable practices because they can improve the selective properties of fishing gear, reducing bycatch as well as juvenile fish (Cunningham, 2001). This helps to safeguard marine ecosystems as well as spawning stock (Cunningham, 2001).

The Food and Agriculture Organization has published research on the ecosystem effects of various fishing methods (Cunningham, 2001). Categories covered include size selection, species selection, by-mortality, ghost fishing, habitat effects, energy efficiency, and catch quality, which are all averaged to an overall ecosystems effect index (Cunningham, 2001). Lowest-scoring gear included shrimp trawls, beam trawls, demersal trawls, and trammel nets, all of which performed poorly in size and species selection (Cunningham, 2001). Spears, purse seines, and traps were rated most favorably in their overall ecosystem effects (Cunningham, 2001). Of course, fisheries managers need to balance these impacts with socioeconomic considerations (Cunningham, 2001).

A study in Indonesia found that areas with restrictions on fishing gear exhibited 40% more fish biomass than areas without restrictions (Campbell et al., 2020). Further, a global analysis focused on coral reef fish populations found that various fisheries restrictions, including measures like gear limitations, effectively maintained total biomass above 50% of its pristine levels (NOAA Fisheries, 2022). Conversely, many open-access sites experienced biomass levels below this threshold (NOAA Fisheries, 2022).

One specific example of a sustainable gear modification is circle hooks (Oceana, n.d.). Unlike J-hooks, which are the more typical fishing hooks and can be lethally swallowed by bycatch like sea turtles, circle hooks simply snare animals, allowing them to be released (Oceana, n.d.). NOAA issued a gear regulation in July 2020 that requires the use of non-stainless steel circle hooks for fishing of all snapper and grouper species (NOAA Fisheries, 2022).

Sea turtle mortality can also be substantially reduced with turtle excluder devices, a grid of bars in the neck of a net, similar to an emergency exit for sea turtles (Oceana, n.d.). These modifications can reduce bycatch-related sea turtle mortality by as much as 97% (Oceana, n.d.). Modifying mesh sizes can also allow juvenile fish of the target species to escape, which is an important protection against removing individuals before they reproduce (Oceana, n.d.).

A study in the Spanish Mediterranean evaluated the performance of these kinds of mesh modifications on undersized fish catches (Carvalho & Humphries, 2021). Bottom trawling nets were modified to have a more selective grid for specific species, e.g. larger gaps in the mesh (Carvalho & Humphries, 2021). European hake was among the species studied, and sub-legal-sized catches declined by 35% with the gear modifications (Carvalho & Humphries, 2021).

Certain fisheries worldwide do set legal limits on fish size to protect juveniles, however, without gear modifications these individuals can still be caught and must be disposed of, sometimes having already died (Carvalho & Humphries, 2021). Sustainable fisheries management must include gear restrictions and modifications to accurately target mature fish and specific species.



School of Menhaden, also known as Bunker Fish, in New York Harbor.
Source: Abby Jordan

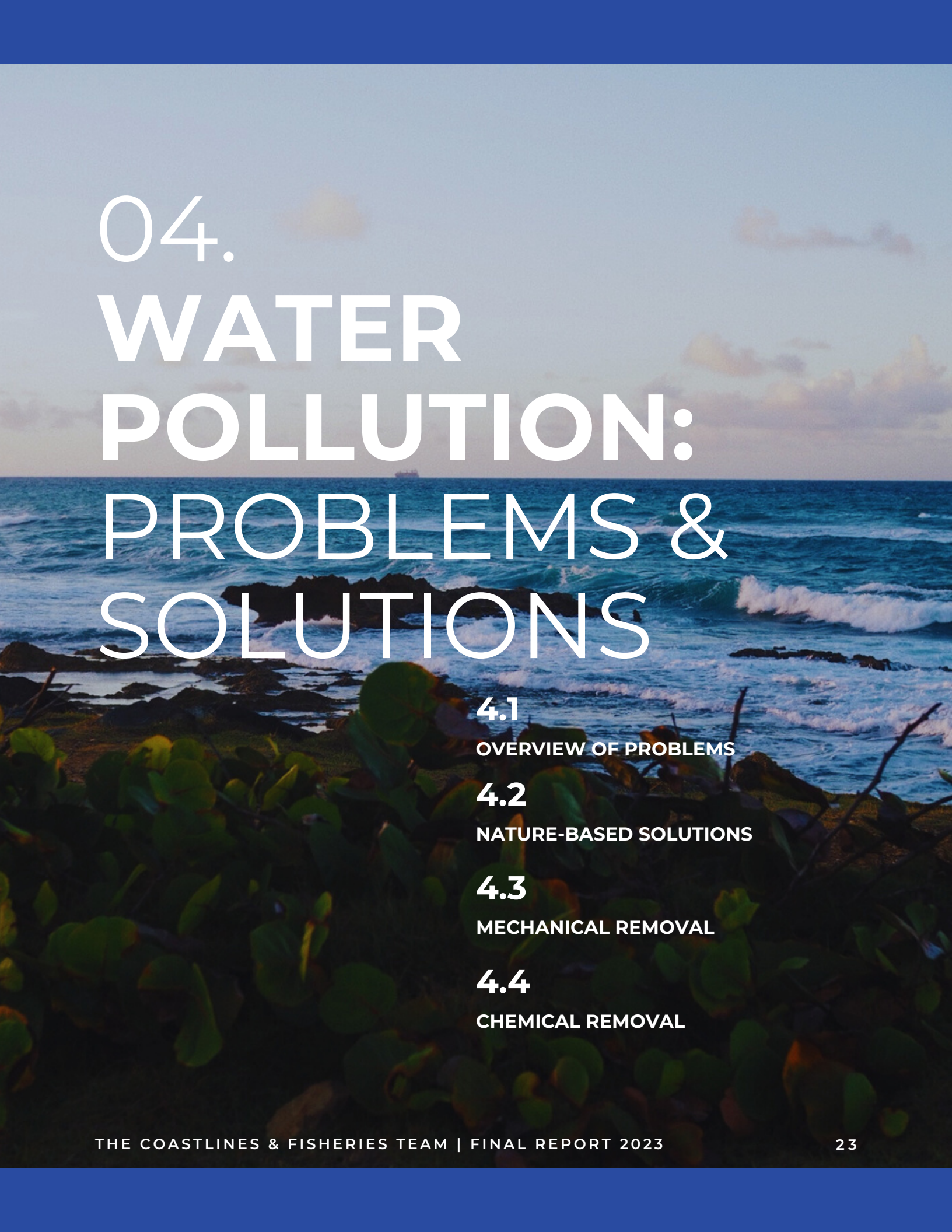
METRICS OF SUCCESS

Overfishing is a major challenge to the sustainable use of resources. To mitigate these effects, this report proposed purse seine fishing and marine spatial planning. The first method used to assess the health of fish stocks is MSY (Maunder, 2008), which, for a given fish stock, indicates the highest possible annual catch that can be sustained over time, by keeping the stock at the level producing maximum growth. An optimum over periods of time, it is the level at which fishers can catch the maximum amount of fish without a further decline in the population.

The overall health of the fish stock is a simple ratio: the biomass of the actual fish stock, divided by the biomass of the MSY. The biomass of the fish stock is the fish population multiplied by the average weight, and the population is based on samples of the population and their extrapolation. The biomass of the MSY is the MSY multiplied by the average weight. The ratio gives a simple comparison between the two and indicates how close our fish stocks are to the optimum.

Due to the dynamic nature of the fish population, monitoring and regulations are a periodic process. Data must be collected, stocks assessed, catch targets and limitations set, and new regulations made. Since this indicator is used for specific fish populations, regional and nation-wide comparisons should be made, determining the fraction of populations meeting healthy indicators.

MSY only considers the population of fish, and while this is reasonable in certain contexts, it is also important to look at the effects of fishing on the whole marine ecosystem. An extension of MSY, called Ecosystem-Based Fisheries Management, accounts for the effect of fishing on the whole ecosystem and proposes the equivalent of maximum sustainable yields for the populations of other species (Pikitch et al, 2004).



04. WATER POLLUTION: PROBLEMS & SOLUTIONS

4.1

OVERVIEW OF PROBLEMS

4.2

NATURE-BASED SOLUTIONS

4.3

MECHANICAL REMOVAL

4.4

CHEMICAL REMOVAL

CASE STUDY:

MICROPLASTICS IMPACT

ON MARINE SNAILS

*The Red-mouth rock shell (*Stramonita haemastoma*) and Crown conch (*Melongena corona*) are two types of snail living in intertidal habitats in Florida. Because the waters surrounding Florida are polluted with millions of microplastics, these two snail species were analyzed and characterized by the amount and types of microplastics they had ingested. Microplastics are known to cause damage to intertidal organisms, in some cases blocking digestive tracts and altering appetites. And hurricanes, common to Florida, can distribute even more microplastics from land to water, further exposing these organisms to contamination.*

Upon examination, it was found that the snails' tissues and surrounding seawater contained copious amounts of microplastics. Over 90% of identified microplastics were microfibers, which can come from a variety of sources: wastewater, clothing, fishing gear, etc.

Though the ultimate effects of this contamination on the two species are unknown, given known impacts on other organisms, it is possible that contamination could influence reproductive capabilities of the snails. In this scenario, snail populations will decline, the effects of which will be felt throughout the regional food web.



Florida Crown Conch (*Melongena corona*)
Source: iNaturalist

4.1 OVERVIEW OF PROBLEMS

Pollution is everywhere. It is in the clothes we wear, in the air we breathe, in the water we drink. And the problems it introduces are manifold. Regardless of whether one is speaking of human health or ecosystem health, pollution poses risks to all.

Aquatic pollution, though, is unique in its scope as it is known to settle in the smallest of organisms and the deepest of places. Pollution in water encompasses the discharge of organic and synthetic waste materials which can (and often do) result in the entanglement of animals and the consumption of these harmful materials by the same animals. And pollution within the food web directly threatens human health if such organisms are consumed (Pimentel, 2005). It is estimated that around 170 trillion pieces of plastic are floating in the world's oceans at any given time (Paddison, 2023).

But where does all of this pollution come from? In U.S. coastal waters, key contributors to pollution include industrial and extractive industry waste, agricultural runoff, and plastics (US EPA, 2015). Many bodies of water within the United States, including its coastal shorelines, suffer from some combination of these pollutants (NOAA, 2020).

Industrial waste stems from a wide range of manufacturing processes which can be broadly categorized into three: metallurgy, non-metallurgy, and food processing (Arockiam JeyaSundar et al., 2020). Though the dumping of many forms of industrial waste (i.e. sewage sludge) was outlawed in the United States by the Marine Protection, Research, and Sanctuaries Act of 1972, the vestiges of decades of unchecked dumping are still felt today. Researchers estimate that there are thousands of barrels of discarded Dichlorodiphenyltrichloroethane (DDT)—one of the most potent pesticides ever created—off California's southern coast alone (Xia, 2022).

Agricultural runoff is a critical water pollutant throughout the U.S. Nitrogen, phosphate, and potash in fertilizers (such as ammonium or rock phosphate) are essential for crop production and plant growth (Nwankwegu et al., 2019). These fertilizers, though, can be produced from petrochemicals which themselves are byproducts of fossil fuels, such as oil or coal (Nwankwegu et al., 2019). Excessive use of petrochemicals and chemical waste can increase nitrate levels in water and contribute to eutrophication (Nwankwegu et al., 2019).

Eutrophication is a process whereby harmful algal blooms erupt in water sources (Yang et al., 2008). These algal blooms proliferate due to high concentrations of nitrogen and phosphorus within agricultural byproducts. And if this algae proliferates to a large extent, a dead zone can result (US EPA, 2019).

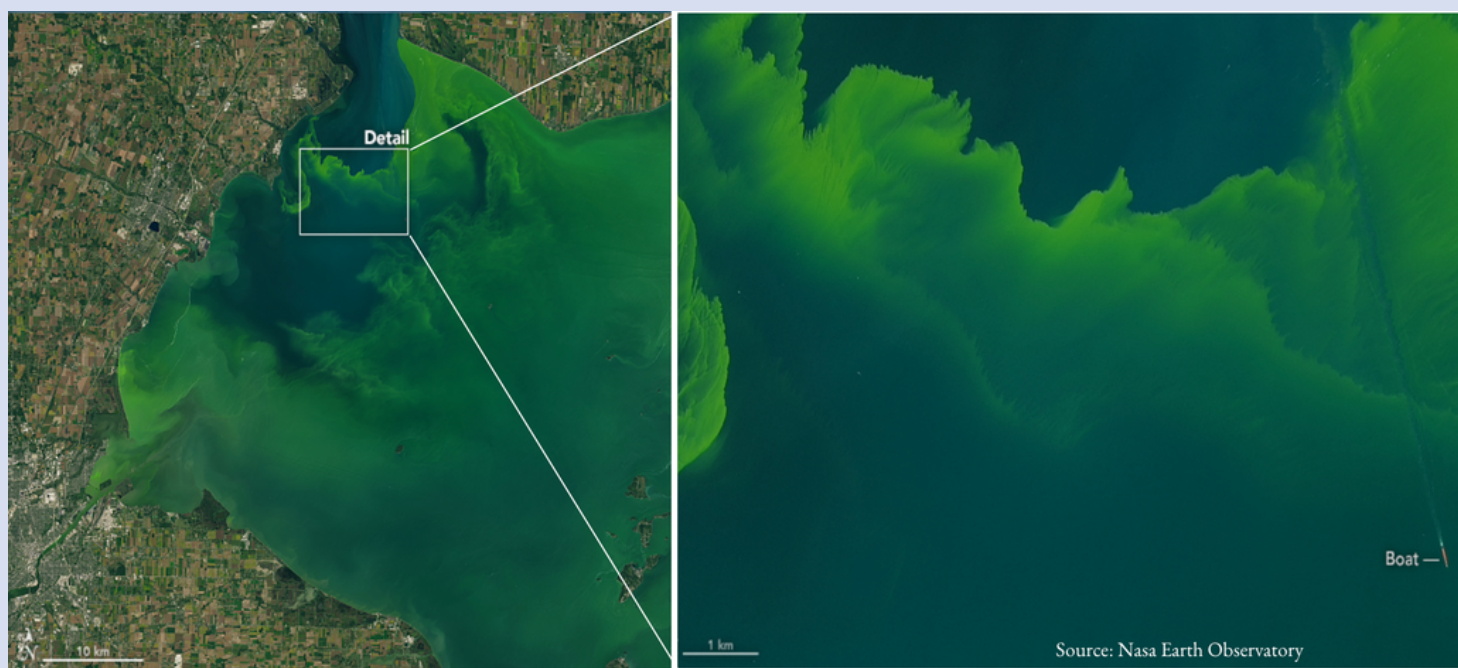
Dead zones are found in lakes or oceans where aquatic life can no longer be supported due to a lack of oxygen (US EPA, 2019). These zones are created when the algae die and sink to the bottom of the water body (Wurtsbaugh et al., 2019). Bacterial decomposition of the dead algal biomass then consumes oxygen within the water body and releases carbon dioxide as a byproduct (Wurtsbaugh et al., 2019). If enough oxygen is consumed in the decomposition process, fish populations can collapse and entire habitats can be destroyed (US EPA, 2019).

Fish populations are not only subject to excess agricultural runoff, though. **Plastic pollution** poses just as great a threat. Plastics are produced by combining fossil fuels (such as coal, oil, and gasoline) with diverse chemical additives to create the distinctive, long-lasting features associated with plastic (Williams & Rangel-Buitrago, 2022). Polyethylene, polypropylene, polyvinyl chloride, and polyethylene terephthalate are among some of the most widely used plastics (Williams & Rangel-Buitrago, 2022).

While the creation of plastic is a problem in and of itself, it is the disposal of plastic that pollutes water bodies (Kunwar et al., 2016). Plastic waste can enter our bodies of water via methods such as waste control, littering, and runoff from land (Kunwar et al., 2016).

What can be done to stem the inflow into the U.S.'s water bodies? The problem is that plastic waste disposal is difficult—over 60% of plastic waste is discarded in landfills globally, and much less than 10% is recycled (Kunwar et al., 2016). The problem is magnified when such discarded plastic is exposed to the sun's UV rays; the waste can then break down into microplastics (defined as less than 5 millimeters across) which contain the same carcinogenic properties as larger plastic, but are easier to inadvertently consume.

If plastic of any size is consumed, the food web can be drastically altered. Larger plastic especially can cause mechanical blockages in the digestive tracts of large animals, starving them and making them more susceptible to death (Issac & Kandasubramanian, 2021). Despite the daunting nature of these problems, there are solutions. Water pollution is anthropogenic in its sources and so it must be in its solutions.



On September 26, 2017, the Operational Land Imager (OLI) on the Landsat 8 satellite captured these natural-color images of a large phytoplankton bloom in western Lake Erie. According to the National Oceanic and Atmospheric Administration, the bloom contains microcystis, a type of freshwater cyanobacteria. These phytoplankton produce toxins that can contaminate drinking water and pose a risk to human and animal health (skin irritant, respiratory distress) when there is direct contact. Blooms tend to thrive in Lake Erie during summer, sustained by warm water temperatures and nutrients from farm runoff. Source: NASA Earth Observatory

To learn more, please visit: <https://earthobservatory.nasa.gov/images/91038/lake-erie-bloom>

4.2 NATURE-BASED SOLUTIONS



Coastal Wetlands in Wrightsville Beach, North Carolina
Source: Hank Carter for NOAA

NATURE-BASED SOLUTIONS

When considering nature-based solutions, it's important to note that such solutions are best utilized in removing chemical pollutants like nitrogen and phosphorus. The ecosystem health of the natural solution is integral to its efficacy. As such, **wetlands** are extremely effective natural processors of harmful pollutants (Kadlec, 1995). The reason they are so effective is due to their anaerobic nature. An anaerobic ecosystem is one in which there is low oxygen content—in the case of wetlands, this low oxygen content is a result of the soil being perennially saturated with water. Because there is no oxygen available for bacteria and other microbes to respire, they must turn to less energy-efficient sources such as nitrates, phosphates, sulfates, and iron, all of which can be found in agricultural runoff (Inglett, et al., 2005).

The anaerobic microbes then neutralize chemicals like nitrate through denitrification (Crooks, et al., 2011). Nitrate, or NO_3 , is released into a wetland, and through the process of anaerobic respiration, the microbes convert this nitrate to NO_2 , or Nitrogen dioxide, and finally to N_2 , or molecular nitrogen. This molecular nitrogen can then be stored in the soil and converted into food by plants to produce proteins and nucleic acids. Unused nitrogen can remain stored in the soil with little to no gaseous exchange because the soil pores are filled with water (Inglett, et al., 2005). Storage of nitrogen, or any other chemical, prevents it from flowing into a nearby river source and inciting eutrophication.

Plastic in the ocean
Source: The Ocean Cleanup Project

MECHANICAL REMOVAL

As previously acknowledged, plastic pollution is an omnipresent and growing threat to the stability of aquatic ecosystems. Solutions to water pollution which revolve around mechanization are best applied to plastics. Before diving into the specifics, though, it must be addressed that the most effective way to mitigate, and ultimately solve, the plastic pollution crisis is through the **elimination of single-use plastics**. Single-use plastics include plastic bags, straws, sachets, and excessive product packaging, the elimination of which will reduce plastic waste significantly and contribute to lower levels of pollution on land and in waterways (Van Rensburg, Nkomo & Dube, 2016).

To achieve this, reuse systems wherein packaging can be collected and sanitized will help make strides toward a reduction of the overall circulation of plastic (Van Rensburg, Nkomo & Dube, 2016). In addition, extended producer responsibility places more responsibility on producers to decrease plastic pollution. This responsibility can manifest in a few different ways: using sustainable alternatives to plastics, manufacturing products that are truly recyclable and then recycled, and/or promoting reuse systems.

However, where economy-wide solutions fail, smaller-scale cleanup solutions can help. It is estimated that plastic pollution in waterways costs the U.S. economy anywhere from 6 to 9 billion dollars each year (Rochman, 2016). To reduce this expenditure, solutions like the **Ocean Cleanup Project** work to physically remove plastic waste from affected waterways. When deployed in oceanic settings, the Project uses computational modeling to predict where areas with high levels of plastics will be (Rochman, 2016). They then depart with two different boats that have a U-shaped retention zone following them (Rochman, 2016). The boats catch debris and once the retention zone is full, the net is then detached from the rest of the system, emptied onto the vessel, put back into place, and the process repeats itself (Sheppard et al., 2005). After the vessel is full, they head back to shore and recycle the debris they have removed (Sheppard et al., 2005).



The Ocean CleanUp Boats with U barrier system at sea
Source: The Ocean CleanUp Project for
United Nations, Sustainable Development Goals

The Project does not just focus on oceans, though. As rivers account for roughly 80% of ocean plastic pollution, the Project spends much time and effort in the nation's waterways (Ocean Cleanup, 2020). The process of plastic removal is slightly different for rivers as the navigable area is much smaller. Instead of the retention zone, they use a barrier system that collects plastic for disposal (Rochman, 2016). The Project's Interceptor Original model is placed in the river and is capable of extracting between 50,000 and 100,000 kg of trash per day depending on conditions (Ocean Cleanup, 2023). The barrier attached to the catamaran-style boat directs plastic floating on the water's surface toward the Interceptor. The water current is utilized to direct the plastic waste to a conveyor belt on the boat, which extracts the debris and automatically distributes it across six dumpsters on the boat.

Once the Interceptor sensors alert the system that the dumpsters are almost full, a message is automatically sent to local operators at the shore to retrieve the dumpster barge and take it to the riverbank. From here, it is sent to local waste management facilities, and the barge is returned to the Interceptor to repeat the process (Ocean Cleanup, n.d.). Interceptor Originals are currently deployed in Indonesia, Malaysia, Vietnam, Dominican Republic, and the United States. As of May 2023, they have prevented over 2 million kg of trash from reaching the oceans (Ocean Cleanup, 2023).

4.4 CHEMICAL REMOVAL



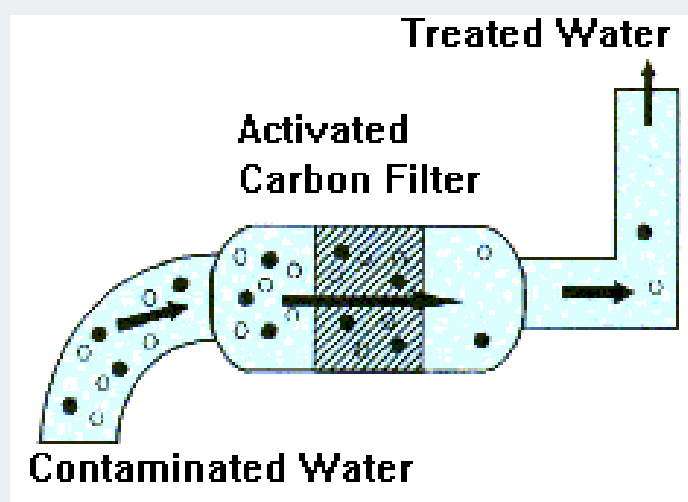
Tanks of granular activated carbon
Source: U.S. Environmental Protection Agency

CHEMICAL REMOVAL

As addressed earlier, though the Ocean Cleanup Project targets plastic debris, it does not have the capacity to target microplastics. Filtration systems such as **reverse osmosis**, though, can prevent the infiltration of microplastics into waterways. During reverse osmosis, water is pushed through a pressured membrane which treats and desalinates it (Joo & Tansel, 2015). The membrane filters out dissolved ions and solids using high pressure (100-800 psi) to force the water through (Joo & Tansel, 2015). This pressured membrane retains 95-99% of dissolved solutes so that the water passing through can be considered high-quality (Joo & Tansel, 2015).

Reverse osmosis membrane technology is often used in the treatment of water with high total dissolved solids or as a secondary treatment technology in wastewater treatment plants. For instance, reverse osmosis has been used in an Australian wastewater treatment plant and has been found to reduce microplastic from 0.28 to 0.21 per liter of wastewater (Tang & Hadibarta, 2021). Reverse osmosis plants are now used for a multitude of applications, such as semiconductors, food processing, power generation, desalination, etc. (Malaeb & Ayoub, 2011).

But reverse osmosis is not the only solution to chemical removal—activated carbon treatments are another way to mitigate industrial waste pollution in waterways. The EPA commonly utilizes this method to clean up Superfund sites and many towns use it to filter their water supply (Alves, et al., 2021). Activated carbon treatments usually consist of one or more columns (or tanks) filled with granular activated carbon (GAC) which has been processed to have a large surface area with a random porous structure (US EPA, 2012). Granular activated carbon is heavily used to process drinking water and treat wastewater due to its ability to remove low molecular weight compounds, such as phycotoxins and mycotoxins (Alves, et al., 2021).



Activated Carbon Treatment model

The first step in activated carbon treatments is generally the pumping of contaminated water or vapors through a column from the top down (though upward flow is possible) (US EPA, 2012). As the contaminated water or air flows through the GAC, the contaminants are absorbed into the outer and inner surfaces of the granules (US EPA, 2012). As a result, the water and air exiting the container will be cleaner (US EPA, 2012). However, regular testing of existing water or air must be conducted to check contaminant levels. The level of contamination determines how many cycles will be required before the water exiting the container is clean. If testing shows that some contaminants remain, the water or air may need to be treated again to meet treatment guidelines. When completed, the contaminated granules can then be disposed of in properly managed hazardous waste landfills (US EPA, 1992).

When the EPA implements activated carbon treatment to clean up polluted water at a Superfund site, it conducts **five-year reviews** to determine the success of its clean-up plan.

There are four primary objectives of the long-term groundwater monitoring program: (1) Verify the containment in groundwater; (2) Collect data to evaluate groundwater extraction system performance (this includes plume maps, annual monitoring reports, and monthly groundwater quality reports from the treatment plants); (3) Characterize the nature and extent of emerging compounds; (4) Characterize the nature and extent of the primary chemicals of concern to update the conceptual site model.

One example of success in this regard is the San Fernando Valley Superfund site, an area with contaminated groundwater in North Hollywood and Burbank, California. Burbank is operating a treatment facility where they remove the contaminants by mixing water with hydrogen peroxide, filtering the substance, and then passing it through ultraviolet reactors. The water then travels through a granular activated carbon filtration system. The most recent Five-Year Review of the cleanup plan in 2018 found that the plan is working as intended: it is protective of human health and the environment, and the post-treatment groundwater contaminant concentrations were below the regulatory cleanup goal (US EPA, 2022).

CONTROVERSIES

It must be acknowledged, though, that all of these solutions come with uncertainties attached. As **wetlands** are concerned, the primary problem with their restoration lies in their hydrological and geochemical processes. The anaerobic microbes that are so important to pollutant detoxification and storage emit methane as a byproduct (Inglett, 2005). Methane is a far more potent greenhouse gas than carbon dioxide and wetlands emit about a third of total global methane (Nasa's Goddard Space Flight Center, 2022). And as the climate changes, wetlands have the potential to emit even more methane due to increased flooding and rising temperatures (Nasa's Goddard Space Flight Center, 2022). It is of the utmost importance that policymakers ensure a wetlands restoration project does not offset any gains in pollution control with increased greenhouse gas emissions.

There are concerns too surrounding the design and effectiveness of **Ocean Cleanup** systems, concerns which could be applied to other aquatic plastic collection systems. When it comes to ocean cleanup efforts, the barriers of Ocean Cleanup systems only extend 10 feet under the water. Surface, or near-surface, floating plastic only accounts for 1% of the estimated ocean plastic budget while the remaining 99% not captured with floating systems ends up in the deep ocean or on the seafloor (Mohrig, 2020). Moreover, Ocean Cleanup's debris collection systems are not capable of addressing microplastic pollution. Most microplastics are found in the form of spheres, fibers, or fragments, which cannot be removed by net-like barriers (Andrady, 2015).

Aside from the challenges posed by extraction efforts, there are also disposal problems. Ocean Cleanup claims that they recycle their collected plastic and turn it into new products, such as sunglasses. While this may be true, only plastic that contains less than 5% impurities can be recycled (Tombag, 2021), which is difficult to achieve for ocean-collected plastic due to its exposure to sun and aquatic chemicals. Most plastic is transported to landfills or incineration stations. Plastic in landfills can take hundreds of years to fully decompose and may carry with it toxins and invasive organisms. While landfills are required to have plastic lining by federal regulation, these liners are susceptible to leaks. A leak can contaminate nearby water sources, further damaging ecosystems (Vasarhelyi, 2015). Incineration of plastic is another option but this produces toxic emissions that pose threats to vegetation, human and animal health, and the environment as a whole (Verma et al., 2016).

There is also the potential for reductive marketing of such plastic removal projects. High-profile cleanup efforts by programs like Ocean Cleanup can be intrinsically good but often cannot begin to capture the amount of waste at the scale necessary. As valuable as they may be, they have the potential to draw public attention away from the overproduction of single-use plastic by fossil fuel petrochemical companies. Plastic producers may use ocean plastic cleanup projects as excuses to avoid their environmental responsibilities and to not reduce production of unnecessary plastic.

Reverse osmosis also comes with its drawbacks. In many applications of reverse osmosis, fouling occurs which is caused by membrane pores being clogged. Pretreatment of water is usually necessary to prevent this, a process that consists of chemical coagulation, fine filtration, and acidification in order to regulate pH. A number of things can contribute to fouling, including but not limited to: microbial growth, scaling, dissolved organic substances, or particulate matter forming compact cakes (Malaeb & Ayoub, 2011). Additionally, there are economic drawbacks. Despite the development of small hand pump units, they still have an incredibly high price and slow output (Malaeb & Ayoub, 2011). Most communities in need of reverse osmosis treatment are low-income neighborhoods which cannot afford this technology on any scale.

Activated carbon is promising as a commonly used method to remove toxins from polluted water and air, but there are issues with its production, disposal, and tendency to disproportionately impact minority populations:

- **Production:** An important raw material in the production of activated carbon is coal (Tuser, 2022). Coal mining releases methane and carbon dioxide gasses into the atmosphere, further exacerbating climate change. In the process of producing activated carbon, it must be subjected to significantly high temperatures, which also releases carbon dioxide.
- **Disposal:** Activated carbon must be disposed of once the treatment is done. Sending toxic activated carbon to landfills is a common method to dispose of it, but contaminants can leach out, leading to more pollution.
- **Impacts on minority communities:** Low-income and minority communities are often disproportionately located near hazardous waste facilities. An environmental justice report in Massachusetts shows that when the non-white population is above 25% in a neighborhood, the mean number of hazardous sites increases to 48.3 per square mile (Faber & Krieg, 2002).

METRICS OF SUCCESS

When evaluating projects like Ocean Cleanup, it is important to note that they self-report how much plastic they gather. According to the group, they have removed 4,775,896 kg of plastic since 2012, relative to the estimated 269,000,000 kg at the moment (Ocean Cleanup, 2023). To ensure program effectiveness, this paper recommends that measurements be monitored by government authorities.

Reverse osmosis removes 95-99% of microplastic particles (Joo & Tansel 2015). At present, the total effect on water bodies is not precise, but using the filtration rate and proper extrapolation, estimates can be made over the whole water body at hand. Ocean plastic quantities, for example, are notoriously imprecise. So to measure actual quantities of plastic in the ocean, the incorporation of a new indicator would be beneficial (Savoca et al. 2022). This indicator tracks plastic by referring to 12 crucial species of animals distributed along the north pacific. These consist of bivalves, seabirds, sea turtles, and fish. The indicator is derived from a meta-analysis of previous studies. For a species to be considered positive, a maximum of 10% of the population must have at least 0.1 g of plastic in their stomach, to be evaluated via dissections.

Industrial waste can be removed through activated water treatment. Where this happens, we suggest continuing with the EPA's method of conducting five-year reviews. These reviews consist of four steps (United States Army Corps of Engineers, 2018). First, they must verify the level of containment in the groundwater through chemical samples. Then, data is collected to evaluate the performance of the groundwater extraction system. This includes groundwater quality reports, which indicate the concentration of various chemicals in water, and maps of contaminated fluid flows. Then the characterization of the nature and extent of emerging pollutants must be undertaken. Last, characterized chemicals are updated into conceptual models that provide a visual representation of the site.



05. COASTAL DEGRADATION: PROBLEMS & SOLUTIONS

5.1

OVERVIEW OF PROBLEMS

5.2

OFFSHORE SOLUTIONS

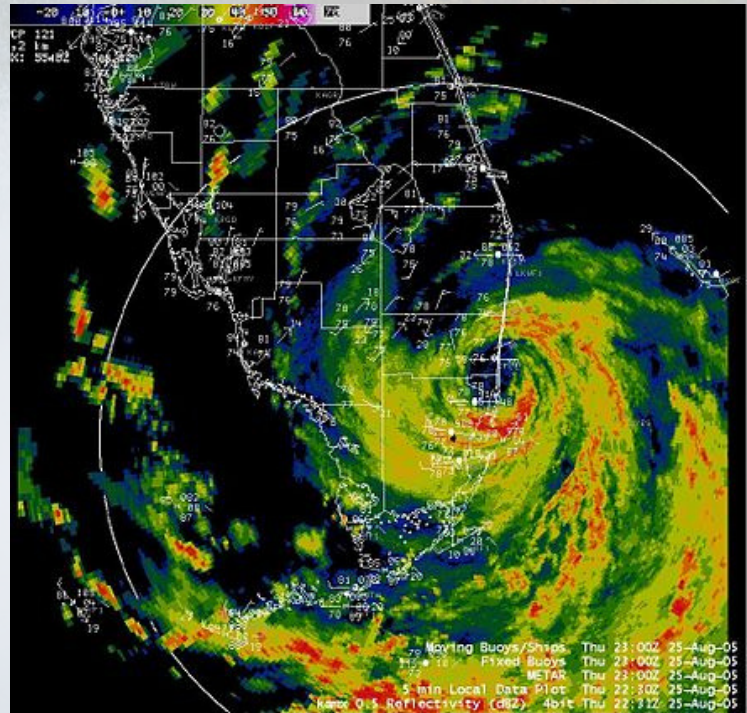
5.3

NATURE-BASED SOLUTIONS

5.4

FLOODPLAINS

CASE STUDY: HURRICANE KATRINA



Radar imagery of Hurricane Katrina moving onshore Southeastern Florida on August 25, 2005
Source: NOAA

Hurricane Katrina was one of the most devastating hurricanes in United States history. A study conducted in Biscayne Bay, Florida, found that Hurricane Katrina caused storm-induced fertilizer runoff in a nearby agricultural area (NOAA, 2023). This caused an increase in nitrate and soluble reactive phosphate concentrations to increase between 7 and 10 times the normal amount. It wasn't until three months after Hurricane Katrina that the nutrient concentrations went back to their normal rates.

This quick return was due to the area's large, shallow, lagoon-like structure. The area itself is an incredibly biodiverse ecosystem that includes coral reefs, seagrass beds, and mangroves that acted as natural filtration systems in addition to the riparian buffers helping filter out agricultural runoff contaminants before they reach the bay.

5.1 OVERVIEW OF THE PROBLEMS



Photo highlighting extreme storm damage
Source: Kelly, Pexels

OVERVIEW OF PROBLEMS

Climate change refers to long-term shifts in weather patterns (United Nations, 2023). The main cause of climate change since the 1800s has been anthropogenic activities, namely the emission of greenhouse gasses from burning fossil fuels (United Nations, 2023). Traditionally, the **greenhouse gas effect** has served an important role in maintaining Earth's radiative balance, trapping longwave radiation emitted by Earth's surface before it escapes back out into the atmosphere. However, the sharp increase in greenhouse gasses over the last two-hundred years has prevented the additional heat from escaping back into the atmosphere, warming the atmosphere, surface, and oceans.

These anthropogenic warming effects have several implications for the water cycle. According to the Clausius–Clapeyron relation, for every one degree Celsius increase in atmospheric temperature, the atmosphere increases its water-holding capacity by approximately 7% (Mathez & Smerdon, 2018). This means a warming atmosphere can hold infinitely more water vapor, which also increases the potential amount of precipitation during severe storms, such as hurricanes (Mathez & Smerdon, 2018). Water vapor functions as a greenhouse gas through its ability to inhibit infrared radiation emitted from Earth's surface to pass into the upper atmosphere (Held, 2000). In this way, water vapor contributes to the greenhouse effect. And since water vapor is a greenhouse gas, this has a positive feedback loop on global warming (Mathez & Smerdon, 2018).

Warmer water also expands. This thermal expansion accounts for approximately 34% of sea level rise (Ehlert & Zickfeld, 2018). Climate change is also melting ice sheets and glaciers throughout the northern and southern hemispheres, increasing the amount of liquid water in our oceans and further raising sea levels (Johnson & Lyman, 2020). This is causing the number and height of waves to increase, which leads to coastal erosion as shorelines are not adapted to receiving consistent high-energy waves. Sea level rise also affects the amount of nutrients plants can absorb from water (Bindoff et al., 2019).

Saltwater infringement and erosion are two common methods by which nutrient intake is affected by sea level rise. If left unchecked, the entire distribution of plants in a given area can be disrupted. For instance, intertidal plants which rely upon the daily ebb of tides to deposit nutrients in sodden soil may suffer from sea level rise and increased tidal coverage (Bindoff et al., 2019). When vegetation is depleted in aquatic ecosystems, it ceases to be a food source for other species which can adversely affect the entire food web (Bindoff et al., 2019).

Climate change is also increasing the **severity of storms**, such as hurricanes (Mathez & Smerdon, 2018). Hurricanes require warm ocean waters of at least eighty degrees Fahrenheit, low vertical wind shear, an unstable atmosphere driven by differences in temperature, and moist air near the mid-level of the atmosphere (Mathez & Smerdon, 2018).

The warm air surrounding a hurricane holds a tremendous amount of water vapor, which cools as it rises before condensing to form heavy rain (Mathez & Smerdon, 2018). These rains occur both at the coast and many miles inland, causing flooding that can continue for days or even weeks after a storm (Mathez & Smerdon, 2018).

One way to identify the impacts of hurricanes and flooding is through understanding the mechanisms behind **wave energy**. A wave's power is determined by its amplitude, which is the height it reaches above sea level. Frequency is determined by the number of oscillations per second. As waves move into shallower water, they contact the bottom and begin to move slower (Luo, 2021). As waves slow down, they get closer together; their wave period shortens. This process is called shoaling, and it causes the height of waves to increase. The steeper the bottom slope, the greater the increase in wave height (Luo, 2021). Waves with greater amplitude have the potential to devastate entire communities and ecosystems; even those species which live in estuarine systems usually have a sensitivity to salinity and can be threatened by massive storm surges.

A final impact of climate change is **ocean acidification**. Ocean acidification stems from atmospheric carbon dioxide and water reacting to create carbonic acid that can eat away at minerals in ocean water (Lindsey, 2018). This acidification reduces the pH in water, which can be detrimental to aquatic ecosystems through its impact on species sensitive to changes in abiotic factors (i.e. pH balance). Corals are one example of a species sensitive to acidification and the altered pH of seawater. Coral bleaching occurs in which coral reefs expel the algae upon which they depend, resulting in a bone-white color (NOAA, 2019b). Bleaching is as a result of multiple factors that stress the corals. These include acidification, as well as sedimentation, pollution and ocean warming. This bleaching is highly stressful for corals and often leads to mortality.

It is clear that climate change will have deleterious effects on coastlines and fisheries, but it is impossible to gauge the exact risk we will face. Even if we stopped emitting greenhouse gasses tomorrow, the Earth's atmosphere will continue to warm due to a phenomenon called inertia, which refers to the climate system's response time to reach a new equilibrium after changes in radiative forcing (Mathez & Smerdon, 2018). "Committed warming" is a term used to describe the amount of warming the Earth will undergo to find a new equilibrium based on the emissions released in the past, up to present day (Mauritsen, 2017). According to climate models, historical emissions should cause the Earth to warm by 2.4 degrees Celsius (Zhou, 2021). We have only warmed 0.8 degrees Celsius thus far, meaning our committed warming is another 1.6 degrees Celsius (Mathez & Smerdon, 2018).

While future emissions are not known, the federal government can still prepare for climate change by investing in resiliency solutions (U.S. Department of Commerce, 2023). Among coastal communities impacted by climate change, those that depend on coastal ecosystem services or that do not have adequate financial resources to address environmental issues are particularly vulnerable (U.S. Department of Commerce, 2023). Fishing communities are likely to be poor, have a more significant percentage of minority and tribal populations, and/or have residents with less capacity to respond to change due to higher unemployment rates or lower educational attainment (US EPA, 2023). In addition, low-income communities and communities of color are more likely to live in substandard housing less resistant to extreme weather. Such communities typically find it more difficult to recover financially from environmental damages (Ramey, 2022).

SOLUTIONS TO COASTAL DEGRADATION

Solutions to climate change-related issues along coastlines will mostly be resiliency projects that adapt communities to survive these severe circumstances (Baskin, 2022). These include projects which decrease wave energy, projects which help shorelines bear the brunt of more wave energy (i.e. decreasing erosion), and projects which direct seawater overflows into areas that do not flood human or sensitive freshwater habitats (Baskin, 2022). The solutions touted in these projects will be explored in three different contexts:

- 1. Offshore solutions, including barrier islands*
- 2. Nature-based Solutions such as oyster and coral reefs*
- 3. Floodplains restoration and maintenance*



Photo source: River Partners, Dos Rios Ranch Preserve Floodplain in Modesto, California

5.2 OFF SHORE SOLUTIONS: BARRIER ISLAND

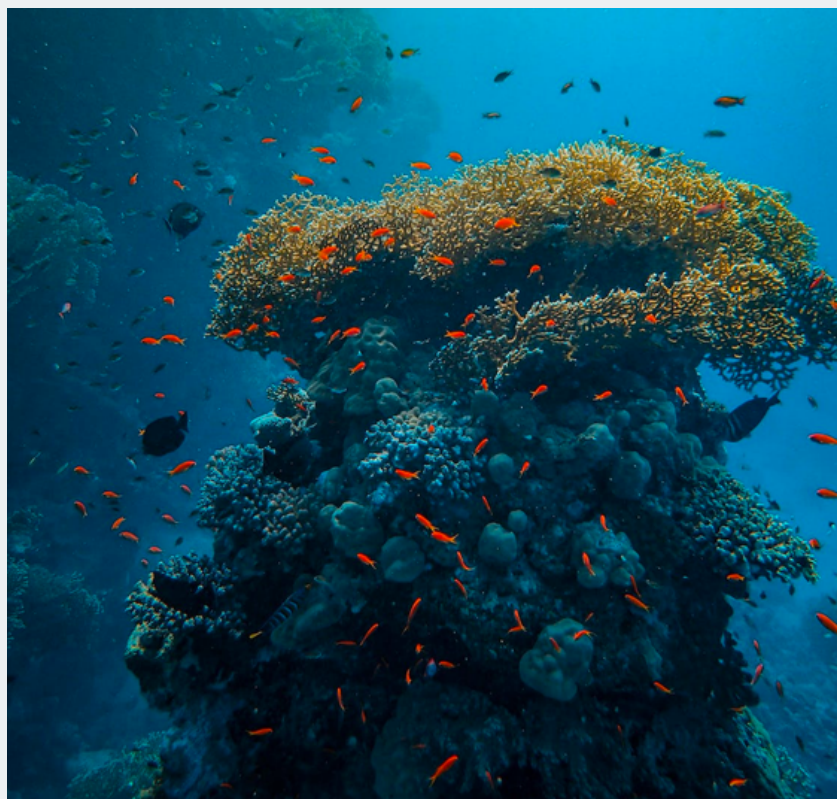
Barrier islands are a very effective offshore solution to storm surges and sea level rise. These islands form when wind and waves continually deposit sediment in one area parallel to the shoreline for an extended time (NOAA, 2023). They serve as protective barriers for shorelines exposed to wave action. Their ecosystems are also highly dynamic and variable, often serving as habitats for seabirds, fish and shellfish, and sea turtles (NOAA, 2023). Wave velocity and energy are diminished when hitting a barrier island due to the island's particular topography (namely, the presence of beach dunes and grasses) (Sallenger, 2000). This introduced friction has a direct impact on the amount of flooding inundating continental shorelines.

Barrier islands cannot just form anywhere, though. They usually form near river deltas and areas with low tectonic activity, which means that these islands are nearly nonexistent off the rocky and tectonically-active West Coast (NOAA, 2023). It is through a barrier island's interaction with the mainland that its true effects are noticed. Backbarrier lagoons formed by barrier islands decrease wave energy tremendously as compared to the open ocean (Oertel, 1985). Consequently, while the ocean-facing side of the barrier island incurs the brunt of the storm surge, the mainland directly behind the barrier island will be shielded from destructive waves. Barrier islands represent about ten percent of the world's coastlines (Durán Vinent & Moore, 2015).

5.3 NATURE-BASED SOLUTION: CORAL REEFS

Coral reefs are another prominent and effective solution to storm surges. Their adherence to the sea floor increases friction with waves, reducing the slope and extending into the water column. Serving as a wave break, they slow down oscillations which in turn decreases the amplitude of waves. One study found that coral reefs can reduce wave energy by up to 75% (Navarro, 2021). Economically, they save U.S. coastlines over 1.8 billion dollars annually in potential property damage due to flooding (Viehman, 2023).

Coral reefs are not just effective flood mitigators, though—they also help decrease coastal erosion. One study in Seychelles found that as reefs died off due to rising sea temperatures, wave energy and erosion on the coastline increased. These effects are expected to increase in the coming years due to rising temperatures induced by climate change (Sheppard, 2005).



Source: Batin Özen, Pexels



Source: Kelsey Williamson, The Coral Gardeners, United Nations Educational, Scientific and Cultural Organization (UNESCO)

Despite coral's susceptibility to climate change, there are methods to maintain and restore reefs. In the Florida Keys, NOAA undertook a reef restoration project which adhered to the following steps (NOAA, 2022):

- Site preparation: Remove nuisance and invasive species which compete with corals and coral larvae.
- Phase 1: According to NOAA, 25 percent coral cover is what is necessary to support a healthy reef. Restoring fast-growing species, such as elkhorn coral, can rapidly reach this quota. The goal was to reach 15 percent coral cover across the sites.
- Phase 2: Whereas some corals are notable for rapid growth, others are notable for improving the diversity of the reef (NOAA, 2022). This is why the project also restored star, brain, staghorn, and pillar corals. Species that eat coral-smothering algae, such as long-spined sea urchins and Caribbean king crabs, were also introduced. Coral cover was intended to be at 25 percent by the end of this phase.

As evidenced by NOAA's restoration efforts, corals can be reintroduced into damaged reefs to restore them to health (Navarro, 2021). Local efforts such as coral restoration will help not only with coastal resilience but also maintaining biodiversity, as critical habitat will be maintained (Hein, 2021).

CONTROVERSIES

Naturally, though, both barrier islands and coral reefs do not come without their controversies. As these pertain to barrier islands, one potential problem relates to their efficacy in the face of significant storm surges (IPCC, 2015). A heavy storm surge could erode a barrier island in a matter of hours or days, and natural recovery could take decades (Houser et al., 2015).

A second problem with barrier islands concerns their natural tendencies. Overwashing occurs with most barrier islands—it's a process by which sediment is delivered to the bay shores of these islands, allowing them to migrate toward land over time (National Academies of Science, 2014). Inlets can be periodically created in this process and if human facilities are situated atop such unstable landmasses, there are real threats involved (National Academies of Science, 2014). As it pertains to coral reefs, there are issues with their restoration. There are risks associated with restoration via sexual reproduction because mortality is common in the first few months after settlement (upward of 95% within the first four months) (Ligson, 2022). Moreover, logistical issues abound because each substrate bearing a coral recruit needs to be transplanted to the reef by hand (Ligson, 2022). This is incredibly time-consuming and not very cost-effective.

Coral reefs' resilience must also be taken into account. Given their susceptibility to climate change in aquatic environments, it is worth noting that declines in coral structure result in a negative feedback loop in which reef degradation decreases wave attenuation which in turn further reduces reef structure, etc (Cho, 2011). Coastal erosion then increases and communities find themselves more susceptible to storm surges (Cho, 2011).

5.3 NATURE-BASED SOLUTION: OYSTER REEFS

While shoreline ecosystems share the same water as their offshore counterparts, the conditions they offer are distinct enough to warrant entirely different solutions to oceanic climate change. One of these solutions is **oyster reefs**. Typically found in estuarine habitats with moderate salinity or along low-energy shorelines, oyster reefs are both more cost-effective than man-made seawalls and highly adaptive to local conditions in their native range (Hynes, 2022). High wave energy is a primary contributor to coastal erosion, but the vertical structure of oyster reefs is crucial in generating friction when an incoming wave passes through.

This friction weakens the wave and thus reduces shoreline erosion (Wallace, 2022). If a salt marsh is located behind an oyster reef, they too are shielded from incoming wave velocity and their sediments remain stable. Stable sedimentation is crucial for oyster reef longevity and oysters contribute to this stability through biodeposition (Mangi, 2021).

What is being done then to cultivate oyster reefs? Oyster beds are currently being re-established in suitable habitats within their historic range. If an area does not have an existing reef but does have a natural population of oysters, substrate (a mix of broken shells, limestone, and concrete) can be placed and existing oysters will populate the reef; if the area has a reef, but no living oysters, spat-on-shell juvenile oysters from hatcheries can be placed on the reef where they will grow and reproduce (Wallace, 2022).

Chesapeake Bay has seen substantial results after years of restoration efforts, which have included building substrate and planting spat-on-shell juveniles—more than 800 acres of oyster reefs have been restored in a region they once densely inhabited (NOAA, 2020). New York City has also implemented oyster reef restoration. The Billion Oyster Project aims to cultivate oyster reefs as a natural barrier to projected sea level rise (Janis et al., 2016). These oyster beds act as a natural breakwater to dissipate wave energy while simultaneously filtering out harmful pollutants from the city's bays. The reefs also serve as a habitat for hundreds of species which further promotes a more resilient ecosystem (Janis et al., 2016).

Living shorelines provide many of the same resilience benefits as oyster reefs. Living shorelines, as the eponymous phrase suggests, are biotic solutions in which wave-reducing plants and animals are used as natural breakers. Vegetation—such as planting riparian, marsh, and submerged aquatic vegetation—can break up low-energy waves and serve as a buffer to upland areas (NOAA, 2023). To make effective use of living shorelines, though, there has to be an edging structure (i.e. sand fills, stones) to hold vegetated areas in place (NOAA, 2023). Otherwise, they will be unable to withstand the effects of heavy storm surges.

Beach dunes can also serve as a buffer between ocean and inland areas by absorbing and reducing storm surges. Many native coastal plants atop beach dunes produce foliage and deep root systems that reduce wind velocity and anchor sand dunes (New Jersey Sea Grant, 2016). Dunes operate in much the same manner as living shorelines and oyster reefs in reducing wave energy.



Eastern oysters in South Carolina's Cape Romain National Wildlife Refuge
Source: The Pew Charitable Trust

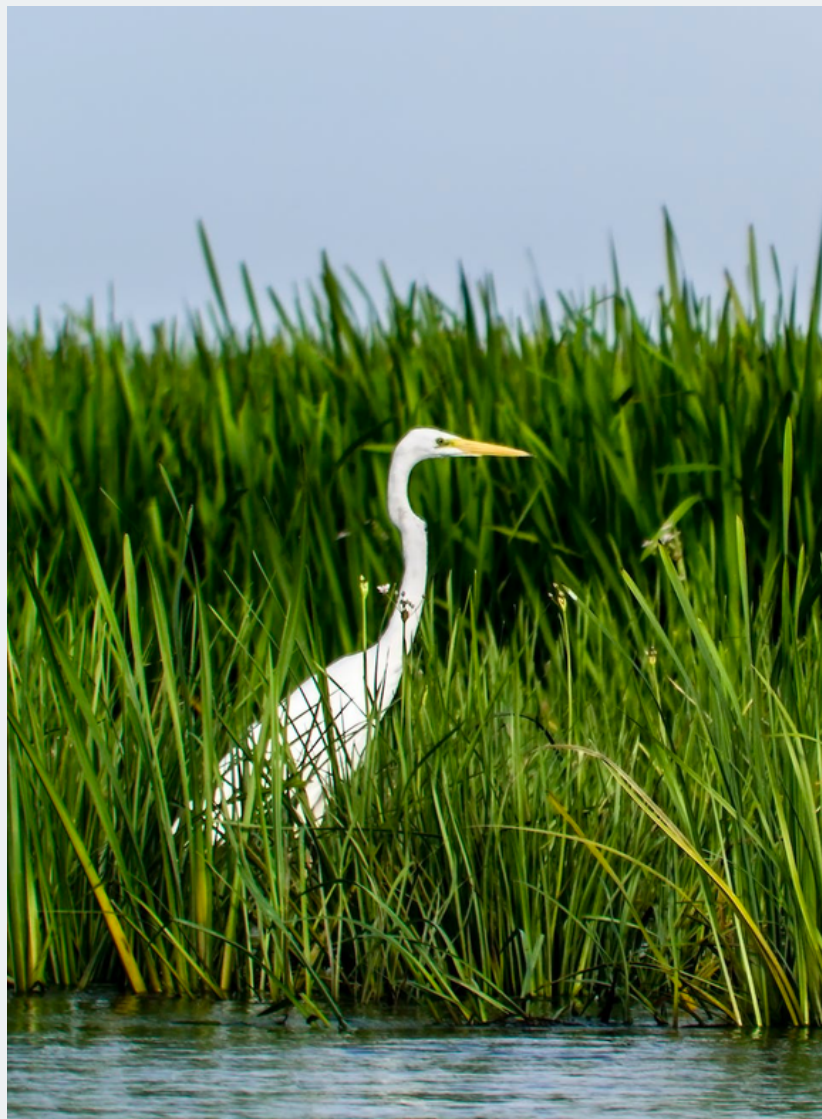
CONTROVERSIES

Oyster reefs do not come without their caveats, though. Their ability to shape environments depends on biological and environmental conditions (De Paiva et al, 2018). Oysters only thrive within a specific range of salinity (14-28 ppt), temperature (68 to 90 degrees Fahrenheit), and depth of water (2-26 feet deep) (MCNY, 2017). The strength of oyster reefs in stabilizing sediments also depends on biotic factors such as the density of oysters, as well as the length-to-width ratio of the reef (De Paiva et al, 2018). Longer and narrower reefs with higher oyster density tend to trap more sediment.

Designing sustainable and efficacious oyster reefs requires an interactive ecological and engineering approach (Morris et al., 2019). Ecologically, restoration efforts aim to build a self-sustaining oyster reef. To determine sites most suitable for oyster growth and survival, an assessment of environmental conditions is required that includes parameters like salinity, temperature, and elevation. From an engineering perspective, focusing on reef structure and its ability to reduce wave height is essential to maximizing a reef's coastal defense abilities (Morris et al., 2019). However, there is currently insufficient engineering research on reef construction to effectively mitigate coastal erosion while also supporting the ecological needs to sustain oyster population growth.

The efficacy of living shorelines is also controversial. Coastal habitats are dynamic ecosystems. Unlike artificial coastal defense structures, the persistence and effectiveness of living shorelines are site-specific (Morris et al., 2018). A study on 17 living shoreline projects reported that some sites experienced an increase in erosion rates after the installation of living shorelines (Polk & Eulie, 2018). This may introduce uncertainty in coastal protection planning. In addition, living shorelines are more sensitive to human activities, including extraction of resources, contamination, and introduction of invasive species (Morris et al., 2018).

When it comes to beach dunes, coastal development is an unintended consequence. Waterfront green space may drive up real estate values and attract more upscale development (NRC Solutions). This may lead to reduced land space for beach dunes, inhibiting their implementation. The more their scale of implementation is reduced, the less effective existing beach dunes will be in coastal defense. Moreover, beach dunes are vulnerable to heavy storm surges. When dunes are submerged in high-energy storm waves, large amounts of sediments may be taken away or the dunes may be completely washed over (Penn State , n.d.).



Great Egret standing on marsh grass
Source: Ferenc Tibodi, Pexels

5.4 FLOODPLAINS

Next to heightened wave energy, **flooding** is a primary source of erosion and terrestrial degradation. To mitigate flooding, the restoration and/or expansion of floodplains is crucial as they are designed to receive excess water in the event of storm surges or excess precipitation (European Union, n.d.). Floodplains are low-lying areas adjacent to waterways where excess storm surge or precipitation-induced flooding accumulates naturally. They differ from wetlands in that the soil of wetlands is perennially saturated whereas floodplains can be dry for long periods, as their borders are characterized by the extent of floodwater distribution. When considering floodplain restoration or construction, flood bypasses are essential as they ensure excess water flows to the plains (European Union, n.d.).

Coastal floodplains often utilize mangroves and other wetland species adapted to higher concentrations of seawater (European Union, n.d.). Densely populated mangroves are especially beneficial to floodplain ecosystems as they are effective at distributing flood levels. But mangroves only thrive in certain latitudes and ecosystems so for those areas which cannot take advantage of mangroves, waterfront parks prove to be great flooding solutions.

These parks are naturally planted urban recreation areas that function as both floodplains or flood bypasses through the use of raised platforms, levees, rain gardens, and permeable sidewalks. Regardless of their exact design and efficacy in managing floods, waterfront parks benefit coastal communities in their flooding mitigation potential and recreational advantages (European Union, n.d.).

Identifying areas for potential floodplains involves the consideration of a multitude of components. Global Information Systems (GIS) software can be utilized to analyze hydrology, geology, vegetation, and climate-related factors that will make areas more vulnerable to flooding (Osiecki, 2022). Once identified, control measures can be instituted in these areas including relocating residents to higher ground, creating waterfront parks that can be used as recreational areas when not flooding, and restoring wetlands with plant species adapted to flooding and more saline storm surges (Osiecki, 2022).

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Floodplains have sometimes been associated with problematic social conditions. Often, undesignated floodplains become areas of low-cost housing, and these poor communities are usually most impacted by extreme weather events (Osiecki, 2022). One of the common approaches to reduce flood risks for communities is to relocate affected residents through government-led buyout projects. But buyout projects can be expensive. The U.S. Federal Emergency Management Agency (FEMA) sets standards and provides funding for 75% of the acquisition costs (Cardwell, 2021).

However, there is currently not sufficient funding for more comprehensive approaches to risk communication, community engagement, and relocation assistance (Curran-Groome et al., 2022). Consequently, the fragmentation of neighborhoods is a real threat.

Even if social factors were set aside and all residents safely and conveniently relocated, variations in hydrology and landscape features pose challenges for restoration efforts. Different landscape features of floodplain ecosystems—such as soil, watershed sizes, and differing elevations—exert a profound influence on water sources and options for restoration (King et al., 2009). In addition, the hydrological connections between river systems and their floodplains are often disrupted by continuous human activities like urbanization and agriculture. Water withdrawals from rivers reduce flows to estuarine areas, resulting in higher salinity levels in estuaries and upstream forested wetlands.

Floodplains are not so distinct from oyster reefs in the sense that increased salinity drastically affects the productivity of these systems (King et al., 2009). Changes in precipitation, temperature, and frequency/intensity of storms also cause functional and structural changes in floodplain ecosystems.

Despite the uncertainty surrounding disparate environmental conditions on floodplain productivity, these ecosystems are still worth cultivating. Their benefits are too numerous to ignore and often prove to be the difference between a moderate storm and years of rebuilding for many coastal communities.

METRICS OF SUCCESS

When considering the efficacy of oyster and coral reefs, it is necessary to measure the size, population, and spatial distribution of these ecosystems, and their overall health. The starting point for consideration would be total biomass. For oysters, this is done similarly to calculations of fish biomass. For coral reefs, the weight of each reef is inferred from previously estimated relations between weight and size.

After a whole quadrant is measured, the results are extrapolated (Pacey et al, 2023). Net primary productivity, which indicates how much biomass it generates, and how much it grows, is therefore also crucial (Dasgupta, 2021). For coral reefs, this is done by measuring differences in oxygen concentration from water that flows through the reef (Kohn et al, 2003).

Furthermore, coral reef resilience, or the ability to withstand disturbances, can be assessed by the variety and population of fish and is negatively related to the presence of algae (which are invasive and compete with corals) (Maynard, et al, 2017). As reefs and oysters are established, discerning their ability to reduce flooding incursions and wave attenuation through biomass calculations is crucial to success (Ferrario et al, 2014).



06.

ADDITIONAL RESEARCH

Aquatic ecosystems are fraught with uncertainties. While this report has tried to be as encompassing and in-depth as possible, there are still questions remaining.

NOAA is allocated 1 billion dollars a year to apportion to approved projects, but some problems are too global in scope. Ocean plastic pollution in U.S. coastal waters, for example, does not always come from U.S. shores. So it is an open question as to how much must be spent to address these wide-ranging problems.

The impacts of this report's proposed solutions on the social and economic fabric of communities are also an area for further exploration. It is undoubtedly the case that climate change and anthropogenic pollutants will destabilize many coastal communities. And while the science behind many of this report's solutions is well documented, there are knowledge gaps in the solutions' implementations. How will communities react to the restoration of hundreds of acres of wetlands near their properties? How will residents reply to increased costs associated with the implementation of reverse osmosis water treatments? These questions are examples of the uncertainties surrounding community reactions to solutions for coastal and aquatic degradation.

07. CONCLUSION

Overfishing, water pollution, and coastal degradation represent three distinct challenges for aquatic systems to overcome. Though global problems like climate change-induced weather events and plastics pollution may seem insurmountable, there are solutions to mitigate their effects. And more localized issues, such as unsustainable fishing practices within U.S. territory, are remedied through more rigorous implementation of solutions (i.e., sustainable fisheries management).

The solutions presented in this report do not come without their controversies, though. Floodplains, for example, are excellent mitigators of flood damage but have also historically been sites for low-income housing. Wetland restoration is efficient at chemical removal and detoxification, but wetlands are also among the world's largest natural emitters of methane, an incredibly potent greenhouse gas. There are trade-offs to be evaluated in any implementation of a solution.

Though the problems facing aquatic ecosystems are formidable, the Don Young Restoration Grants for Coastlines and Fisheries Act represents a significant step forward in addressing these challenges. Its establishment of a multi-billion dollar grant program through NOAA will allow organizations from across the public, private, and NGO sectors to execute efficient and effective solutions to the problems plaguing the U.S.' coastlines and waterways.

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H.R.1196 — 118TH CONGRESS (2023-2024)

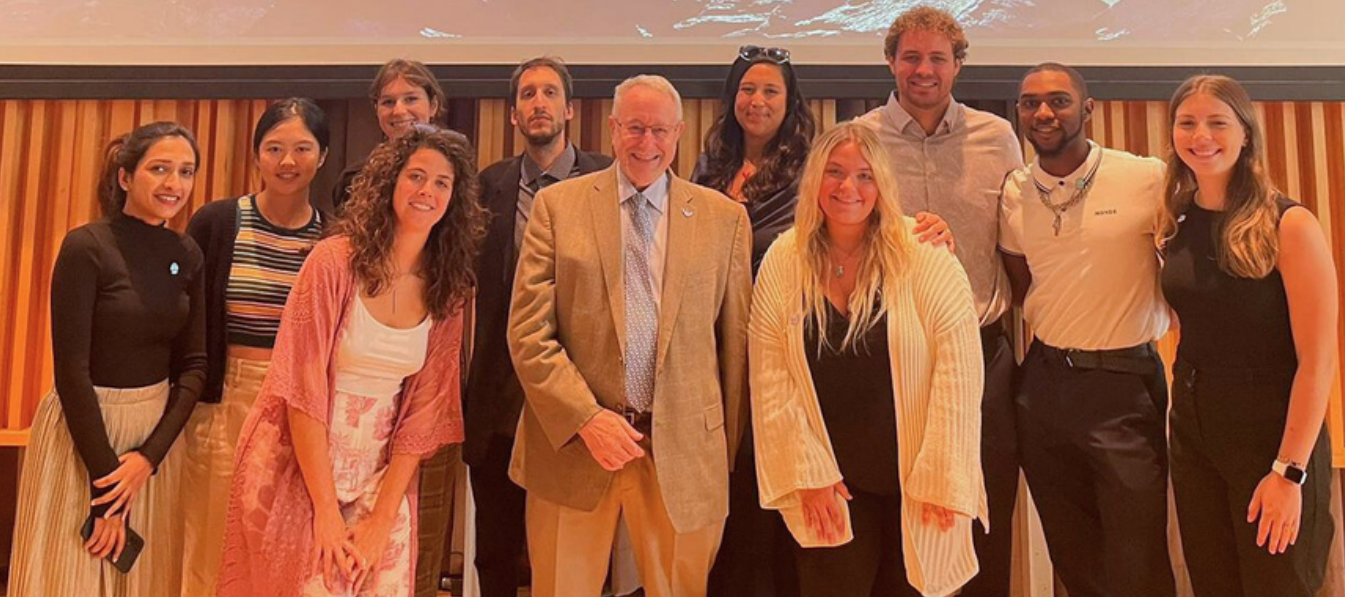
DON YOUNG RESTORATION GRANTS FOR COASTLINES & FISHERIES ACT

FINAL PRESENTATION

TASK LEAD: Abby Jordan

SUPPORT TEAM: Cristina Rocca, Christina Morano, Abby Austin, Yawen Zhang, Christina Van Dyke

ADVISOR: Dr. Bob Cook



THANK YOU FROM OUR TEAM SUMMER 2023

THE DON YOUNG RESTORATION GRANTS
FOR COASTLINES & FISHERIES ACT OF 2023



THE COASTLINES & FISHERIES TEAM
COLUMBIA UNIVERSITY
MPA - ENVIRONMENTAL SCIENCE & POLICY
CLASS 2024

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