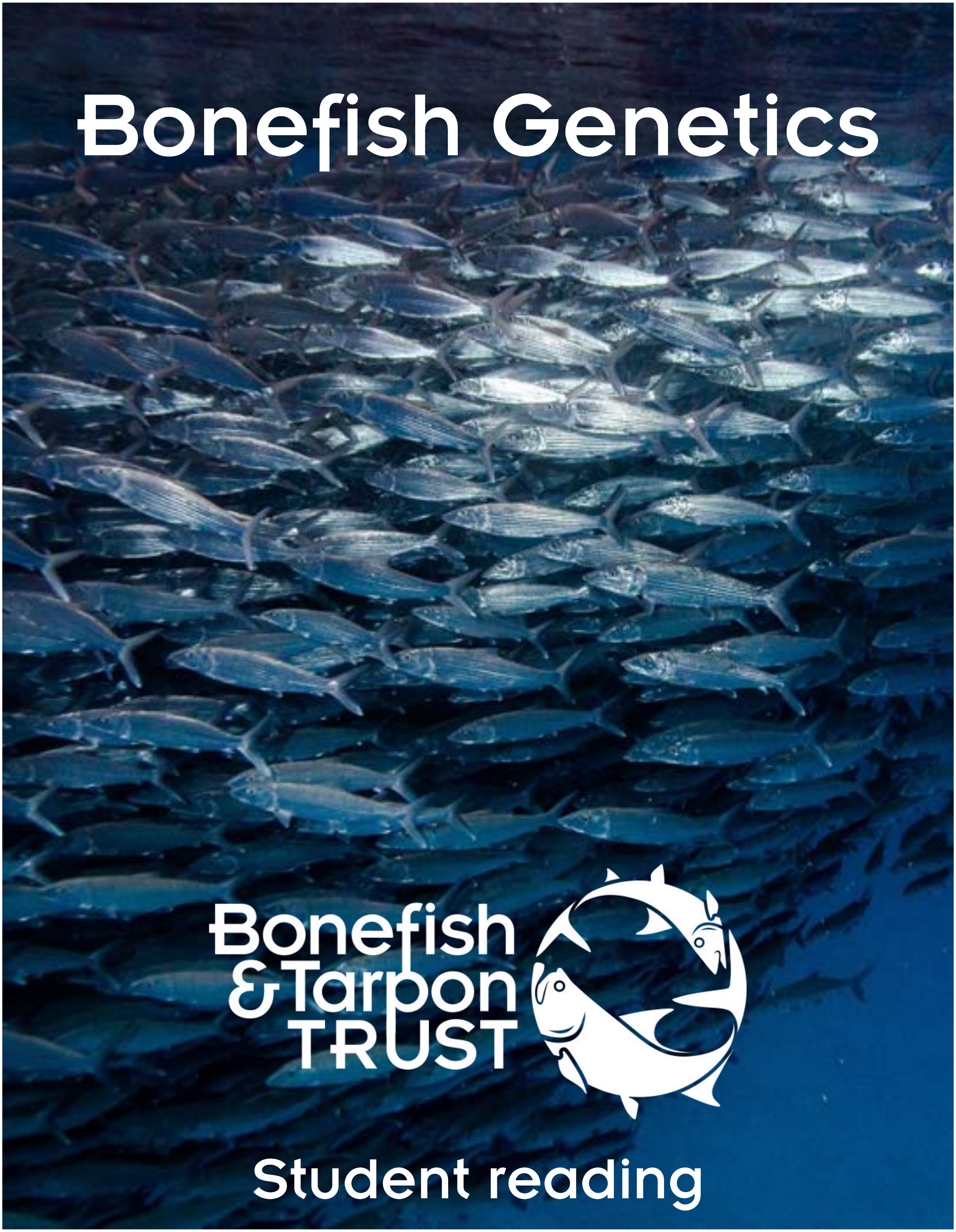
Bonefish Genetics



Bonefish & Tarpon TRUST

Student reading

Bonefish Genetics

A representation of the physical structure of DNA, the genetic material that determines your appearance and your traits.

You have blue, brown or green eyes – because of the genes you inherited from your parents. Because of genes, your hair may be blonde or red, black or brown. And you may be tall and thin, or short and stocky because of your genes. A gene is the basic physical and functional unit of heredity – the passing on of physical or mental characteristics genetically from one generation to another. Genes consist of **deoxyribonucleic acid (DNA)**. DNA is a molecule composed of two chains that coil around each other to form a double helix that carries genetic instructions, or "codes," for the development, functioning, growth and reproduction of all known organisms and many viruses. They determine more about us than is fully understood, but genes "program" everything from physical characteristics to types of intelligence, athletic abilities, and certain diseases, and many other aspects that make you, well, you.

Perhaps you've heard of DNA in the context of criminal investigations, where detectives use hair, skin, or bodily fluids left at a crime scene to identify the genetic markers of the perpetrator. Or, perhaps your family decided to learn about its ancestry and provided DNA in the form of saliva to a company that conducts genetic research. DNA research has many applications, and it is so insightful because it is rarely misleading.

Did you know that DNA information also helps conservation biologists solve mysteries related to wildlife **population dynamics**? Population dynamics are a branch of knowledge concerned with the sizes of populations and the factors involved in their maintenance, decline, or expansion. Understanding the population dynamics of fish in an ecosystem as large and complex as our oceans is obviously challenging. So, with the help of professional and amateur fishermen, marine biologists have turned to DNA research to understand how geographically diverse populations of valuable fish species are related and connected. Such information can be used to inform management decisions that maintain healthy, diverse fish populations.

Much like us, every fish is slightly different from one another in their genetics. The reason for this is simple: if every fish was genetically identical and a disease swept through the population or an extreme environmental event – like a really cold spell – suddenly occurred, the entire population of fish would be wiped out. **Genetic diversity** in a population prevents wipeouts like this because variation in genes means that some fish will have resistance to things that other fish do not. The goal of every population is to be as diverse as possible so that the species will continue to persist, regardless of the challenges they face. High genetic diversity in a population shows that the population is healthy.

In determining the relative health and sizes of fish populations, scientists depend on several types of information including the number of fish that fishermen catch over time, the age structure of the population—the number of individuals in the population ranging from the young of the year to the oldest of fish—and the relative health of their habitats. Genetic information also helps to provide a much clearer picture of fish population dynamics. That's because, through the process of natural selection, individuals with certain genetic variants of a trait or traits tend to survive and reproduce more than individuals with other, less successful variants. That's how the population evolves and sustains itself. But if there are fewer and fewer individuals in the population to pass on the strongest genes, the gene pool's genetic diversity and resilience shrinks – along with numbers of fish being reproduced.

Spawning, Recruitment, & Citizen Science

Because **spawning** and **recruitment** of marine fish species is typically highly complex, DNA research is an essential tool in coastal and marine fisheries management. Species travel from their home ranges to reproduce in unknown locations, and spawning locations are usually situated next to strong ocean currents that will carry offspring varying distances until young fish find appropriate juvenile habitat where they settle and grow. This means that offspring may be carried far from the spawning location, and fish populations that are far apart may be very closely related. This is easily determined by looking at DNA of fish from different places. That's why, increasingly, scientists work with fishermen through **citizen science initiatives**. Fishermen are good at catching fish, so they can help collect enough DNA samples for scientists to get a picture of genetic connectivity and other information.

DNA research allows the researchers to use kinship—how closely two individuals may be related—as a way to understand how a given population of fish may contribute to populations nearby, or potentially even far away. This information is important for fisheries managers. Fisheries managers decide how many fish can be removed from a population without affecting the size of the population. Determining these numbers is a difficult task, even before considering that fish far away might be contributing to local populations. The population picture painted by DNA research can help fisheries managers understand how many fish are actually contributing to a population. This understanding can then help managers make informed decisions about how to keep the population healthy.

Let's take a look at this research in action in the context of the bonefish (*Albula vulpes*) research. To do that, we first need to understand the history of one of the most valuable fish in the sea, including how and where it reproduces. And we need to look at a recent genetics study conducted by the science-based conservation organization, Bonefish Tarpon Trust (BTT).

Meet the Bonefish

Globally, scientists have identified twelve species of bonefish. Though subtle physical differences can distinguish the species, genetic information provides concrete proof of different species, as well as indications of kinship between sub-populations of the same species.

The most popular bonefish species in Florida and around the Caribbean is *Albula vulpes*, known as "the white fox."

There are two species commonly encountered in Florida and throughout the Caribbean: *Albula vulpes*, (the 'white fox'), which are most commonly encountered in the Florida Keys and Biscayne Bay, as well as *Albula goreensis*, the "channel bonefish," which is typically caught off the coasts of peninsular Florida.

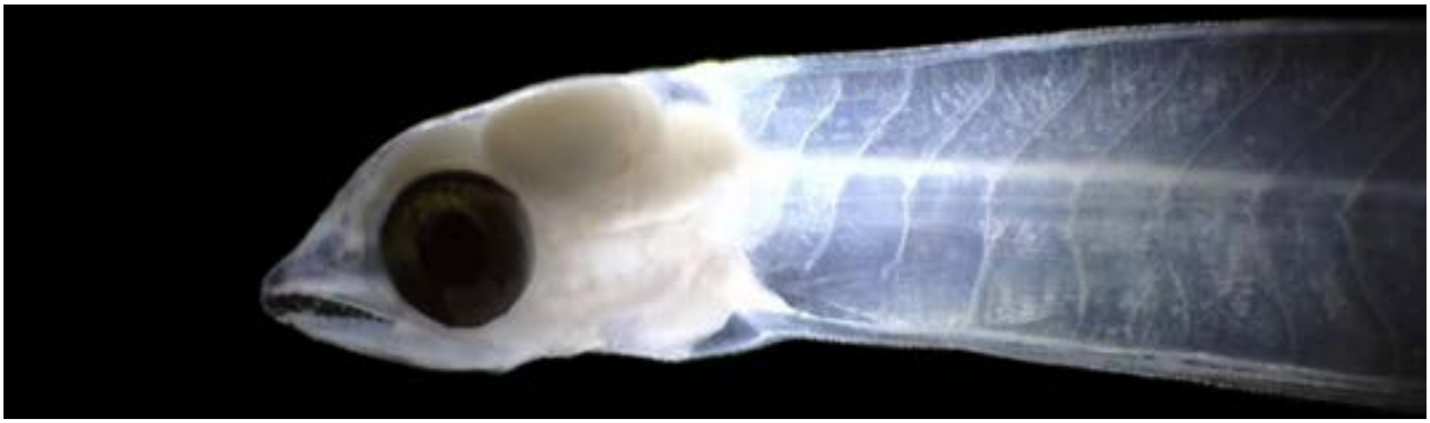
Albula vulpes is the species that draws anglers from around the world to flats in destinations such as Florida, The Bahamas, and Belize, as well as Cuba and Puerto Rico. Flats are shallow-water ecosystems that support seagrasses, mangroves and other essential fish habitats that support populations of these and many other prized fish.

This bonefish species is one of the most difficult of fish to catch fly fishing or with light tackle. They aren't very good eating. Instead, anglers target them for fun and excitement, since they present one of the greatest challenges in the sport. Many millions of dollars are spent in Florida and other tropical destinations in pursuit of this remarkable fish. Yet in Florida, and in other places, bonefish are extremely vulnerable to pollution, fishing pressure, and habitat loss, which can lead to shrinking genetic diversity and fewer fish.

Open Ocean Broadcast Spawning

Like all animals, bonefish undergo **ontogenetic migrations**. Ontogeny is the development or course of development of an individual organism. For bonefish, it means it will occupy several different habitats. Bonefish begin life as a fertilized egg and then undergo a series of metamorphoses as larvae – including a stage as a transparent, eel-like larva called a leptocephalus. Eventually, they transform into a young fish, then grow into sexual maturity within a year or two. They spend most of their adult lives feeding in the shallows, and in creeks and channels along the flats.

Mature bonefish spawn offshore in the open ocean. Large schools called **spawning aggregations** leave the shallows for the open ocean and then release their eggs and sperm simultaneously into the water where the eggs are fertilized. This is a reproductive strategy called **broadcast spawning**, and it has many advantages.



Leptocephalus larvae are almost transparent, which is advantageous for a small bonefish drifting in the unprotected waters of the open ocean.

First, the large number of participating males and females encourages genetic diversity. Second, ocean currents may carry the offspring to multiple **settling areas** – typically shallow mud- or sand- bottomed habitats within lagoons and bays that offer shelter and food. Larval bonefish spend 42 to 72 days floating on ocean currents. One spawning aggregation of bonefish may be responsible for repopulating the fisheries in multiple places at various distances.

DNA testing allows researchers to piece together how populations of bonefish in one area support those in other areas. Without it, researchers can only get a sense of population connectivity by studying the speeds and trajectories of ocean currents.

Adult bonefish have silvery scales that help them mirror their environment, making it easier to blend in.

A fly fisherman and professional fishing guide look for bonefish on a shallow flat.

Bonefish Genetics Study

In a recently concluded study, scientists worked with professional fishermen called "guides" and recreational anglers to collect 5,000 bonefish (*Albula vulpes*) DNA samples in South Florida; the Florida Keys; The Bahamas; Mexico; Cuba; Honduras; Nicaragua; the Cayman Islands; and Puerto Rico. It was a complex, five-year undertaking requiring support from multiple partners, including the Bonefish & Tarpon Trust; Florida Fish & Wildlife Conservation Commission (FWC); the University of Massachusetts; and the Cape Eleuthera Institute.

The goal of this study was to learn about how bonefish around the Atlantic, Gulf of Mexico, and Caribbean are connected to each other. The scientists used two ways to answer this question: DNA analysis, and bonefish movement tracking.

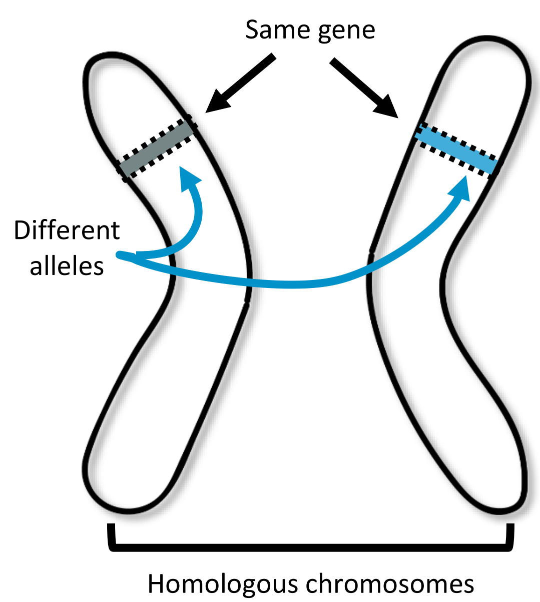
Methods & Materials

Every scientific investigation includes methods and materials, which become a formal section in the report the researchers produce after they arrive at conclusions.

DNA analysis

Scientists working on the BTT bonefish genetics study worked with fishermen using rod and reel fishing gear and seine nets to collect DNA samples. When fish were caught, the fisherman or researcher took small clips of tissue from the dorsal fin, leaving the fish in the water so it could properly breathe. These tissue samples were saved in vials of preserving solution, and sent to a laboratory at the Florida Fish & Wildlife Research Institute (FWRI) that

Genes vs. Alleles



All your DNA is raveled tightly into individual chromosomes that are paired together, called homologous chromosomes. On each individual chromosome, there are regions of DNA that code for very specific traits, such as hair color or eye color. These specific regions are genes. These genes can have different forms, just like hair can be red, brown, black or blonde. These different forms of the gene are called alleles.

analyzed the DNA from each sample.

When comparing the DNA of each fish, the researchers looked at specific regions of the DNA called **genes**. Genes code for specific traits, but as we know, traits like eye color or hair color can differ between different subjects. These variations of a gene are called **alleles**. When two organisms reproduce using sexual reproduction, they pass down these alleles to their offspring. This means that most organisms have a pair of genes (and therefore a pair of alleles) – one from their mother, and one from their father. If both parents have alleles that code for red hair, the offspring will likely have red hair. But if one parent has red hair and the other has brown hair, the offspring will have brown hair because brown hair is known to be a stronger, or “dominant” trait. By looking at the alleles of different organism – in our case, bonefish – we can get a good idea of how closely or distantly two fish are related.

For this study, scientists looked at the alleles and other aspects of the DNA to ask four specific questions:

- How closely or distantly related are fish that live in different places in and around the Caribbean?
- Within one specific place, how closely or distantly related are those fish?
- Is it possible to identify parent-offspring relationships?
- Is it possible to identify sibling relationships?

Tagging studies

The second part of this study involved using two different types of tags to understand where the fish were moving around. This information helps to confirm the findings of the DNA analysis.

The first type of tag that researchers and fishermen used for this study was a spaghetti tag. Spaghetti tags are attached just under the skin of the fish next to the dorsal fin. These tags have unique numbers, and contact information of the researcher printed on them so that if/when the fish is recaptured, scientists can learn where it was caught.

Spaghetti tags are used for catch-and-release studies, where fishermen who catch the fish again will call the number listed on the tag and report information about where the fish was caught and how big is it. You can see where the name comes from!

The other type of tag used was an acoustic tag, which is surgically placed in the body of the fish. These tags work similarly to an EZ pass or SunPass you would use for a toll highway. There are “scanners,” called acoustic receivers, positioned all along the east coast of the US, around the Florida Keys, and around The Bahamas. Every fish that has an acoustic tag has a unique identification number that is “scanned” when it passes by an acoustic receiver. This means that if a bonefish swims up and down the coast of a Bahamian island, it may pass many different receivers, and scientists can use this information to piece together local migrations as well as home ranges for each fish. So far, this data shows that adult bonefish have fairly narrow home ranges except when they leave to spawn somewhere offshore. These tags record data for about 10 years, so scientists will keep getting more data from these tagged fish for years to come.

Conclusions

Bonefish (*Albula vulpes*) throughout the Caribbean, Gulf and Atlantic are all very genetically similar, meaning that bonefish in all of the locations that were sampled are part of a single genetic population. The study also showed that the distance between locations influences the degree of relatedness. For example, even though bonefish in the eastern Caribbean are genetically similar to bonefish in the western Caribbean and Florida, these groups are probably not immediate family, like parents or siblings. In other words, there are probably many generations between eastern and western Caribbean bonefish. How might this happen? We think that bonefish spawned down in Puerto Rico may travel on ocean currents west to Central American countries such as Honduras. When those larvae become adult bonefish and spawn in Honduras, some of their larvae ride ocean currents north to Mexico. And when those fish spawn, some of their larvae may drift northeast up to the Florida Keys.

At smaller geographic scales, the connections are more direct.

- Bonefish in Cuba and The Bahamas are closely related;
- Bonefish in Belize/Mexico and Cuba are closely related;
- Bonefish in Belize/Mexico and Florida are closely related;
- And bonefish in Cuba and Florida are related, but not too closely.
- When Belize, Mexico, Cuba, and Florida samples are all considered together, we can say that overall these bonefish are all pretty closely related.
- Bonefish within The Bahamas are all closely related.

Management Implications

Bonefish populations in one country clearly support populations in other countries in the western Atlantic Ocean. This information has big implications for how we manage bonefish populations, and brings up many more questions. How do we manage bonefish in Florida when ocean currents carry Florida bonefish larvae across international waters and to habitats that are managed differently? Is local conservation enough? Or do we also need to act at a larger scale – even if that means management agreements with other countries?

These questions are particularly important for bonefish in the Florida Keys, where bonefish populations have been declining at a fast pace. If larvae are being transported to the Keys from other places, it is harder to figure out what is causing population declines. It could be local issues in the Keys, but there could also be issues somewhere else that are causing fewer larvae to drift to the Keys.

If regional management is essential, **geopolitical** issues give rise to major conservation concerns. For example, given that there is some limited direct population connectivity between Cuba and the United States, it may be important but difficult for the two countries to enter into a management agreement – given the long history of animosity between a communist state and a democratic republic. Other political concerns, such as Cuba's strong economic dependence on Russia and Venezuela, may get in the way of meaningful negotiations designed to protect the integrity of bonefish in the Western Atlantic.

The principal investigators of the five-year bonefish genetics study have shared the results widely with scientists and resource managers in all of the countries where sampling occurred. The Bonefish and Tarpon Trust is now leading international discussions about policy particulars that could go beyond historic geopolitics and protect one of the most valuable fish species in the world wherever the bonefish occurs.

Permit Sidebar

Permit (*Trachinotus falcatus*) are another very exciting fish that anglers target on the flats fly fishing, or with light tackle. They occur in the waters of most of the same countries where bonefish are targeted. In fact, Florida's Biscayne Bay and the Florida Keys are famous permit fishing destinations.

Permit are a species of jack (Caringidae spp.), and like bonefish they typically feed in shallow water and spawn offshore. However, much more is known about the reproductive strategies of permit than bonefish. Adult permit are also commonly found on coral reefs and wrecks, in fairly deep water. They are also known to reproduce, generation after generation, at the same multi-species spawning aggregation sites, or "SPAGS." Multi-species spawning aggregation sites are typically towering reef structures on the edge of powerful currents that carry larvae to settling areas various distances from the spawning sites.

One of the best documented of SPAGS are a series of high-relief humps in the Dry Tortugas National Park, where permit, mutton snapper, groupers, and other species form spawning aggregations. These areas are so important that they're closed to fishing, are off-limits to the public, and are guarded by armed patrol boats. Originally, places including Riley's Hump in the Dry Tortugas were protected because mutton snapper were documented spawning there. Larval transport and genetics studies subsequently proved that the mutton snapper spawn taking place on Riley's Hump in the late spring provides offspring that settle throughout the Florida Keys and along the East Florida mainland. Later, similar studies proved that permit spawning at Riley's Hump also "seed" flats and reefs throughout the Keys and along East Florida.

By protecting one discrete area, fish populations and fishermen benefit. Without the technology to confirm this connectivity through DNA analyses, managers would not be able to demonstrate a clear need for such protections to the public.

Highlighted Vocabulary from Student Reading:

alleles:
A variant form of a given gene. Sometimes, the presence of different alleles of the same gene can result in different observable phenotypic traits, such as different pigmentation.

broadcast spawning:
When animals release their eggs and sperm into the water, where fertilization occurs externally.

citizen science:
Research conducted, in whole or in part, by amateur scientists. Outcomes are often advancements in scientific research, as well enhancement of the public's understanding of science.

deoxyribonucleic acid (DNA):
A nucleic acid molecule composed of two chains that coil around each other to form a double helix that carries genetic instructions for the development, functioning, growth and reproduction of all known organisms and many viruses.

genes:
A section of DNA that codes for specific characteristics and is passed down from parent to offspring.

genetic diversity:
Variation in genetic characteristics within a group, population, species or community.

geopolitical:
The study of the relationship among politics and geography, demography, and economics, especially with respect to the foreign policy of a nation.

homologous chromosomes:
A pair of chromosomes, each passed down from a parent, that are similar in length and contain genes in the same places.

ontogenetic migrations:
At different life stages, fish and many other organisms migrate to different habitats.

population dynamics:
The branch of life sciences that studies the size and age composition of populations as dynamical systems, and the biological, and environmental processes driving them (such as birth and death rates, and by immigration, and emigration). Example scenarios are aging populations, population growth, or population decline.

recruitment:
The number of fish surviving to enter the fishery or to some life history stage such as settlement or maturity.

settling areas:
The places where early juvenile fishes find suitable nursery habitats.

spawning:
The eggs and sperm released or deposited into water by aquatic animals.

spawning aggregations:
A group of fish of the same species that are gathered together for the purpose of spawning— releasing sperm or eggs for the purpose of reproduction. Spawning aggregation sites that attract more than one fish species are called 'multi-species spawning aggregation sites.'