The Lionfish Invasion!

Welcome

What is as graceful and beautiful as a butterfly,

as ferocious as the most dangerous predator,

and delivers a painful sting with its

venomous spines?

View Video Clip in Windows Media Player
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It is the lionfish, a native to coral reefs in the tropical waters of the South Pacific and Indian Oceans. But you don't have to travel halfway around the world to see a lionfish.

Perhaps you have seen one in a friend's home aquarium?

Lionfish are popular saltwater aquarium fish all over the world, but especially in the United States.

Nowadays, they also live in western Atlantic waters off the East Coast of the United States. These lionfish are what

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scientists call an **invasive species** or an "alien invader."

Discover & Watch: Run-ins with an Invader! A Chronicle of Lionfish Sightings in U.S. Waters

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Invasive species like the lionfish are becoming a major problem in many parts of the world. Scientists are using newly collected data and technology to try to answer the question :

How does an "alien invasion," like that of the lionfish, affect an ecosystem?

Learn about the environmental and economic consequences of invasive species, using the recent invasion of the lionfish as a case study.

Read on to find out more about the lionfish invasion!

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The Lionfish Invasion!

What is an Invasive Species?

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The predaceous Northern snakehead (*Channa argus*), native to China, is a recent alien invader of North America. Reproducing populations of snakeheads have now been discovered in Maryland, California, and Florida. ***Click on image*** for larger view and further details.

An "invasive species" is a species

- that is non-native (or alien) to the ecosystem it occupies and
- whose introduction causes or is likely to cause economic or environmental harm, or harm to human health.

Some scientists classify an alien species as an invasive species if it begins to reproduce and establish a population in its new ecosystem, which often happens very quickly after introduction. Invasive species can be plants, animals, and other organisms (such as microbes or fungi). Most alien introductions result from human activities. A well-known terrestrial example of an alien or exotic species is the red imported fire ant, a native of South America first introduced to the United States in 1930s. They entered the U.S. through Mobile, Alabama, probably in soil used for ships' ballast. The fire ant has infested more than 260 million acres of land in nine southeastern states, replacing large parts of the native ant community as it continues to spread. Another example of an invasive species is the Asian tiger mosquito, introduced to the U.S. from Japan in the mid-1980s and now spreading to many regions. This mosquito attacks more hosts than any mosquito in the world. It can transfer disease organisms from one species to another, including into humans.

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Invasive species affect all regions of the United States and every nation in the world. People, too, pay a high price, measured in billions of dollars for damaged goods and equipment, a degraded environment, disease, and even death. Alien species invasions can result in the loss of native species and biological diversity at a rate that ranks second only to habitat destruction. Some of the most serious and costly alien invaders include human, animal, and plant diseases (such as West Nile virus), agricultural pests (such as the Africanized honeybee, Russian thistle, and the imported red fire ant), and a host of seemingly harmless species whose sheer numbers overwhelm native ecosystems (such as zebra mussels, purple loosestrife, European green crabs, and hydrilla).

An adult lionfish trolls a wreck about 40 miles off the North Carolina coast. This specimen is about 6 inches long. ***Click on image*** for larger view and further details.

In the United States alone, approximately 50,000 alien species are known, and the number continues to grow. By some estimates, the major environmental damages, losses, and control measures for invasive species cost the nation an average of $138 billion per year. Invasive species also threaten nearly half of the species currently protected under the Endangered Species Act.

The introduction and spread of invasive species are caused by many factors, including, but not limited to:

- expanded global trade,
- the harvesting of exotic marine species to satisfy the popular aquarium trade,
- the use of non-native species in agriculture to control unwanted pests.

Invasive species also are introduced into coastal waters when large ships exchange their ballast water. It is important to study invasive species to learn about the effects they may have on native organisms and the physical environment.

Controlling invasive species is difficult because scientists know little about when new aquatic alien invaders arrive in our

waters. The introduction and viability of lionfish along the U.S. East Coast are leading to new perspectives on how fish invasions may pose threats to marine ecosystems. Many scientists, like Paula Whitfield and Jonathan Hare (2003), believe that scientists must expand their research on invasive species and develop plans to manage, mitigate and minimize their effects on ecosystems that are already stressed due to other human activities (often called stressors).

Lionfish are highly visible, recognizable, and distinctive. Many other less recognizable invasive invertebrates and freshwater fish are causing real problems, too. Recent research on lionfish raised potentially troubling questions with no clear answers, such as:

How many other invasive fish species have established themselves along our coasts without being recognized?

What effects are they having on the nation's resources?

Continuing research will provide more answers to these important questions.

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Lionfish Invade U.S. Waters!

The red and black dots are locations in the Atlantic Ocean where lionfish have been reported as of May 2003. ***Click on image*** for larger view and further details.

Local divers off the coast of North Carolina were not expecting to see what they found one day in August 2002--the exotic and beautiful lionfish, common to the warm waters of the western Pacific, but unknown at that time as residents of the Carolina coast. They provided the first solid evidence that lionfish were in the Atlantic--an actual specimen that they collected. A year later, scientists had documented 19 lionfish sightings at eight locations along the North Carolina continental shelf. By then, lionfish were also being observed off the coasts of Florida, Georgia, and South Carolina. Juvenile lionfish were also showing up off Bermuda and even as far north as Long Island, New York! Since then, many more United States divers have reported sightings of the distinctive fish. Between 2000 and 2003, 49 lionfish sightings were reported at 16 different shipwrecks and natural hard bottom locations. During a summer 2004 research expedition, NOAA scientists collected 155 lionfish at 19 different locations off the North Carolina coast alone. The jump in numbers and distribution over such a short time, plus sightings of juveniles smaller than those sold for aquaria, strongly indicate that the lionfish is reproducing in the Atlantic Ocean. If this is true, it's the first time that a western Pacific fish has populated the waters of the U.S. Atlantic coast.

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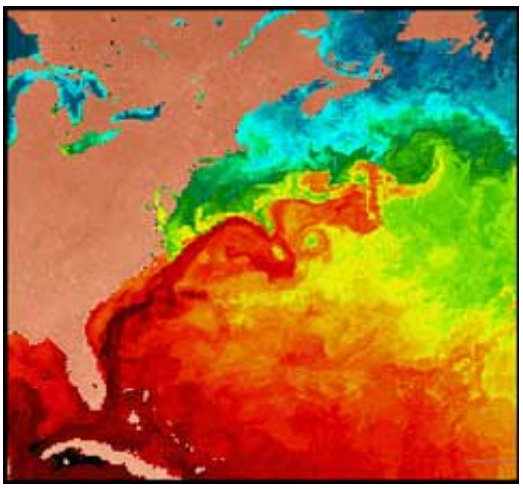
How did lionfish get into the Atlantic Ocean?



The warm Gulf Stream current (in red) may have dispersed lionfish as far as North Carolina and Bermuda, where water temperature is similar to their native habitat. Lionfish larvae may have been carried in the Gulf Stream to the northeast in a similar way.

Reportedly, six lionfish were accidentally released in Biscayne Bay, Florida, when a beachside aquarium or nursery broke open during Hurricane Andrew in 1992. It's likely that even more have been released on purpose when people no longer want them as aquarium pets because they grew too large for the aquarium, or they learned the hard way that lionfish will eat their other fish! The swift and warm Gulf Stream, which likely transported buoyant lionfish eggs and larvae from Florida northward, helped the lionfish's Atlantic journey.

It's pretty unusual for non-native, tropical marine fishes, like the lionfish, to establish themselves at this latitude. In Florida waters and along the continental shelf near the Gulf Stream the temperatures are very similar to the lionfish's native waters.

However, from north Florida upward, the waters along the coastline are too cold in the winter for lionfish to survive. Scientists expect them to survive the winter only at water depths greater than 120 ft because this is where the Gulf Stream has influence all year long. Very importantly, the types of **predators** and competitors present in the

Lionfish swimming near the wreck of the *Cedar Pride* , a Lebanese freighter purposely sunk in 1986. This popular dive site is located in the Sea of Aquaba, which is in the northern part of the Red Sea (Jordan). ***Click on image*** for larger view and further details.

marine community in the Atlantic are very different from the native range of the lionfish. These are a couple of the reasons why scientists are paying so much attention to the lionfish invasion. Generally, species like the lionfish have not been perceived to pose a significant threat to marine ecosystems because they were not likely to survive long. Research on this topic has been minimal, however, so it is hard for scientists to answer questions such as:

- ***Is this new discovery a cause for concern?***
- ***Should something be done about it?***

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The Lionfish Invasion!

Is the Aquarium Trade to Blame?

A lionfish juvenile roams its aquarium after being collected off Long Island, New York. ***Click on image*** for larger view and further details.

The aquarium trade appears the most likely vector for the introduction of lionfish into U.S. waters, but the lionfish's introduction into the Atlantic remains something of a mystery. Recent research indicates that a number of other tropical aquarium fish are currently surviving off the coast of Florida. Also, the color patterns of lionfish sighted off the Atlantic coast of the U.S. are similar to those from the Philippines, where many lionfish are collected for the aquarium trade.

Scientists say it is impossible to determine if the lionfish released in 1992 account for the species invasion of Atlantic Ocean.

Some scientists have suggested that lionfish entered Atlantic waters when larvae or juvenile fish were trapped in ships moving from the Pacific to the Atlantic and were released when the ballast water was pumped out.

However, there is no evidence to support ballast water as the source for the lionfish invasion, although it is a common source of aquatic alien species introductions generally. Further, although lionfish have been introduced into the western Mediterranean, probably through the Suez Canal, there is no evidence that they crossed the Atlantic or that they entered the Atlantic through the Panama Canal. Besides, it is very unlikely

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that the tropical lionfish could survive a journey across the cold water between the two oceans.

An adult lionfish on display in a home aquarium. (Photo credit: Hiroshima University, Graduate School of Biosphere Science)

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The Lionfish Invasion!

Some Lionfish Biology

Profile of a lionfish showing the distinctive fleshy tentacles above the eyes and below the mouth. ***Click on image*** for larger view and further details.

The lionfish (scientific name *Pterois volitans*) is a popular saltwater aquarium fish with distinctive maroon (or brown) and white stripes, fleshy tentacles above the eyes and below the mouth, and an imposing fan of prickly venomous spines. Although not fatal, the sting of a lionfish is extremely painful. Because these fish are not aggressive toward people, contact and poisoning is usually accidental. The species of lionfish now found in U.S. waters produce a mild poisoning. Relatives of the lionfish, including the scorpionfish and stonefish, produce a much more severe poisoning; in fact, the sting of the stonefish can be fatal to humans. Today, a person with a home aquarium is more likely to be stung by a lionfish than a diver or fisherman, but they could be placed at risk if lionfish increase in large numbers along the heavily populated East Coast.

Lionfish Biology Fact Sheet *- Find Out More About the Biology of Lionfish!*

The lionfish's sharp, slender spines are located on the dorsal, anal, and pelvic fins. A venom gland is located at the base of

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each spine. The venom is a combination of protein, a neuromuscular toxin, and a neurotransmitter called acetylcholine. After the fish's spine punctures the victim's skin, the venom travels up a groove in the spine and into the wound. The sting causes intense pain, redness and swelling around the wound site. Although the worst of the pain is over after an hour or two, some people report pain and tingling sensations around the wound for several days or weeks. On rare occasions, when the venom spreads to other parts of the body, people may experience headaches, chills, cramps, nausea, and even paralysis and seizures.

Look, but don't touch! Although not fatal to humans, the dorsal, anal, and pelvic spines of lionfish can deliver a painful sting, as well as cause headache, vomiting, and respiratory distress. (Photo credit: Stephen Vives)

Lionfish are native to coral reefs in the warm, tropical waters of the South Pacific and Indian Oceans. They prey on a wide variety of smaller fishes, shrimps and crabs, and have few predators in their native range, where they occupy the upper levels of the food chain. At present, little is known about how other coral reef species in the lionfish's "adopted" environment of the Atlantic Ocean might fare against them.

For now, reef communities in the western Atlantic Ocean are unlikely to be in much danger, since the number of lionfish is still relatively small. If the population grows large, though, lionfish could damage the native ecosystems. At the same time, other factors are already causing stress to these ecosystems, and these stress factors or "stressors" tend to favor the lionfish's expansion.

Lionfish also are believed to pose particular risks to the local environment. They are hungry predators that feed on practically anything that swims. They can easily devour the young of important commercial fish species, such as snapper, grouper and sea bass, many of which use the region's "live bottom" reefs as nursery grounds. Lionfish are ambush predators and may use their outstretched, fan-like pectoral fins to "corner" their prey. They don't sting their prey, though.

Their venomous spines are used mostly for defense. Scientists are concerned that lionfish could seriously reduce the numbers of prey species and/or compete with other reef predators. When a new species is introduced in an area, it can take over the niche, or role, of a native species in its ecosystem, thus squeezing it out--this process is called competition. Another important factor is that native prey species lack of experience in confronting the intimidating lionfish might make the lionfish a *more effective* predator.

In their native habitats in the Indian and South Pacific Oceans, lionfish are one of the top predators in the food chain, but there are often others like sharks. Therefore, lionfish have few, or no, predators in their native habitat, possibly because of the venomous spines. Another unknown piece of the lionfish puzzle is: what might prey on lionfish in its new Atlantic neighborhood? **NOAA** scientist Paula Whitfield has hypothesized that sand tiger sharks (*Carcharias taurus*) may be a possible predator of lionfish in the Atlantic. Still, questions abound on what the top marine predators in the Atlantic Ocean will make of this "new kid on the block."

Sand tiger sharks are possible predators of lionfish in the Atlantic Ocean, but this remains only a hypothesis. ***Click on image*** for larger view and further details.

(top)

The Lionfish Invasion!

Can We Stop the Invasion?

NOAA scientists collecting lionfish off the coast of North Carolina to take back to the laboratory for analysis. ***Click on image*** for larger view and further details.

Most scientists agree, it is unlikely that the lionfish's invasion of U.S. waters can be reversed. Any large-scale attempts to remove the existing lionfish from U.S. Atlantic waters appear impractical and would be very costly, because of the large geographic range and depths that the fish now occupies. Lionfish are now found along the entire southeast U.S. coastline at depths between 80 and 260 ft, making their complete removal all but impossible. Scientists point out that the introduction and spread of the lionfish illustrate the difficulty of managing introduced species in the marine environment. Lionfish now join the ranks of other aquatic invasive species that have taken up permanent residence in U.S. waters, such as European green crabs, Asian eels and zebra mussels.

Scientists are attempting to answer the following questions:

- ***How does an "alien invasion," like that of the lionfish, affect an ecosystem?***
- ***Are lionfish in the Atlantic a problem?***

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Although scientists don't know much about the ecological impact of lionfish in the Atlantic at this point, they know very well the impacts of many other invasive species. For example, scientists have studied one of the most infamous stowaways that has entered U.S. waters via ballast water, the zebra mussel. Originally from Europe, it now flourishes in the Great Lakes. Up to 700,000 zebra mussels may occupy only one cubic yard on the surfaces of boats, pilings and pipes. By 2000, these alien invaders had caused $5 billion damage to the infrastructure of industries, public utilities, ship navigation, boating and sport fishing.

Zebra mussels cover a water current meter in Lake Michigan near Michigan City, IN. ***Click on image*** for larger view and further details.

Another example of a well-studied aquatic invader is purple loosestrife, a plant now common in wetlands throughout the U.S. and Canada. It was brought to North America from Europe in the 1800s - both accidentally and on purpose. Because it has no natural predators in North America, purple loosestrife is able to rapidly invade wetlands. Once established, purple loosestrife out competes and displaces many native species

Purple loosestrife (*Lythrum salicaria*), an invasive wetland plant native to Europe and Asia, has spread throughout North America. ***Click on image*** for larger view and further details.

such as cattails. Because animals depend on native plants for food, nesting areas, and shelter, purple loosestrife invasions indirectly harm wildlife. Muskrats, bog turtles, and ducks are some of the species that suffer when purple loosestrife takes over.

So, what about the future of lionfish in U.S. waters?

Lionfish are often seen interacting with native species, like this squirrelfish, in their new Atlantic neighborhood. ***Click on image*** for larger view and further details.

Scientists predict that lionfish will continue to increase in abundance. In 2004, NOAA scientists collected 155 lionfish at 19 different locations. Some of these were juveniles and females ready to spawn (reproduce). These numbers far surpass their original expectations, and they now believe that lionfish are actually thriving in water depths over 120 ft off North Carolina. Scientists also predict that lionfish presence in United States waters, especially in the southeast, will become more noticeable, and more encounters between people and lionfish will probably lead to more stings. Because most observations of lionfish off the U.S. coast have been at depths of 100 ft or more, scuba divers are most likely to encounter them, but scientists caution that recreational and commercial fishermen will also be catching them in the future.

For now, scientists have five main suggestions:

• ***Track the lionfish population.*** Although more sightings in recent years suggest that more lionfish are present, that may not be the case. It could simply be that more public awareness has led to more reports. A monitoring program is needed to determine if the number of lionfish is actually growing.

• ***Conduct more research.*** Scientists' ability to predict the lionfish's future abundance, and its effects on the ecosystem is greatly hindered by a lack of knowledge. Research is needed to determine the lionfish's ability to survive, reproduce, and grow in the Atlantic Ocean.

During an August 2004 research expedition off the coast of North Carolina, NOAA scientists collected 28 lionfish on one shipwreck during a single dive. ***Click on image*** for larger view and further details.

• ***Educate the Public.*** People need to know that it can be harmful to release aquarium fishes into bodies of water. In the United States and throughout the Caribbean, people should be alerted to the presence of lionfish and encouraged to report sightings. At the same time, people should be cautioned against handling lionfish and made aware of the health risks from their stings.

• ***Notify physicians and other health care providers about venomous fish in U.S. waters.*** One study of reported lionfish stings, mostly involving aquarists, noted no fatalities. Most stings result in uncomplicated wounds with severe local pain that responds well to soaking treatment. A greater risk appears to be secondary infection resulting from the wound. In addition to medical personnel and health-care providers, boat operators and lifeguards also need to be advised about lionfish stings.

• ***Make regulations to control the introduction non-native marine species.*** Bermuda's approach, which is to enforce a strict ban on the importation of live fish, is proving an especially effective way to reduce the risk of aquarium releases. But scientists caution that the issue is more complex than simply limiting imports of non-native species. Some believe that such efforts will fail unless we learn more about how these species disperse once they are introduced into non-native waters. Although the lionfish invasion is probably here to stay, this dramatic event may prompt the development of effective strategies to reduce the ill effects of other marine invaders.

The Lionfish Invasion!

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Student Guide

Elsewhere on the Web

Glossary

An adult lionfish in all its glory! Note the fan-like pectoral fins and slender, straight dorsal spines. (Photo credit: John Randall; U.S. Geological Survey)

Glossary of Terms

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H | I | J | K | L | M | N |

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A

Acetylcholine—a neurotransmitter released at neuromuscular junctions and autonomic synapses.

Alien Species—any species, including its seeds, eggs, spores, or other biological material capable of propagating that species that is not native to that ecosystem (from Executive Order 13112 on Invasive Species). Also called an exotic species, non-native species, non-indigenous species or introduced species.

Anal fin—the fin on the median (i.e. middle) line behind the vent (i.e. the anus).

Anterior—relating to the front portion of an organism.

Aquarist—a person who keeps or maintains an aquarium.

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Aquarium Trade—the selling of aquatic life for public or private display.

Aquatic—growing or living in, or frequenting water.

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B

Ballast Water—water carried in special tanks (ballast tanks) of ships used to provide stability needed when carrying less than a full load of cargo and to keep the ship at the proper depth in the water. When the ship is loaded with cargo, the ballast water is released to surrounding waters; when the ship is empty, it takes on more water to keep it upright. Some vessels use sand as ballast rather than water.

Benthic—bottom-dwelling, living on the seabed.

Bilge—another term for ballast water.

Biodiversity (or **Biological Diversity)**—the variety of species, their genetic make-up, and the natural communities which they compose. All the different kinds of organisms living in an area.

Biological Classification—the hierarchical grouping of organisms into categories based on evolutionary relationships. Seven hierarchical levels (or taxa) are commonly used: kingdom, phylum, class, order, family, genus, and species.

Biological Control (or **Bio-control)**—using one kind of organism to help manage a harmful species. For example, certain beetles feed on purple loosestrife, an invasive species, and help control its spread.

Biome—major regional ecological community of plants and animals associated with a particular climate. Examples include: tropical rainforest biome, desert biome, lake biome, and estuarine biome.

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C

Community—an association of living organisms that have mutual relationships among themselves and with their environment, and thus function, to some degree, as an ecological unit.

Competition (or **Compete)**—any interaction that is mutually detrimental or harmful to both participants, occurring between

species that share limited resources such as food or space. The struggle for limited resources.

Competitor—a species that may compete with another species for the same resources, such as food, water or space.

Continental Shelf—the relatively shallow portion of the sea floor that adjoins and surrounds most parts of the continents.

Coral Reef (or **Reef)**—a massive, wave-resistant structure, built largely by coral, and consisting of skeletal and chemically precipitated materials.

Cycloid Scales—fish scales that are oval or elliptical in shape with a smooth edge. In this type of scale, the anterior part of each scale is usually overlapped by the posterior portion of the scale in front of it, giving the fish greater flexibility than fishes with other types of scales. There are four main kinds of scales (placoid, cosmoid, cycloid and ctenoid, and ganoid,) and numerous variations of each kind.

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D

Dispersal (or **Disperse)**—the spread of a species, population, or individual's offspring over time.

Distribution—where organisms live in an area; the geographical area (i.e., range) within which a species or other group of organisms occurs.

Dorsal—pertaining to the back or upper surface of an organism. In vertebrates, it means nearest to the spinal column. Dorsal is the opposite of ventral.

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E

Ecology—the study of the relationship among organisms and between organisms and their physical environment.

Ecologist—scientist who studies the interactions between species of organisms and their environment (studies the ecosystem).

Ecosystem—all organisms in a community and the associated non-living environmental factors (i.e. the physical and chemical environments) with which they interact.

Ecosystem Services—the fundamental life-support processes necessary for life, including human, to thrive. Ecosystems

provide "services" that:

• moderate weather extremes and their impacts
• disperse seeds
• mitigate drought and floods
• protect people from the sun's harmful ultraviolet rays
• cycle and move nutrients
• protect stream and river channels and coastal shores from erosion
• detoxify and decompose wastes
• control agricultural pests
• maintain biodiversity
• generate and preserve soils and renew their fertility
• contribute to climate stability
• purify the air and water
• regulate disease carrying organisms
• pollinate crops and natural vegetation

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Endangered Species Act—President Richard Nixon signed the Endangered Species Act (ESA) into law in 1973. The ESA provides broad protection for species of fish, wildlife and plants that are listed as threatened or endangered throughout all or a significant portion of their range and the conservation of the ecosystems on which they depend. "Species" is defined by the Act to mean a species, a subspecies, or, for vertebrates only, a distinct population. Provisions are made for listing species, as well as for recovery plans and the designation of critical habitat for listed species.

Endemic—restricted to a given region. A term applied to populations or species that are found in a particular locality, such as an island, and nowhere else.

Envenomation—the process by which venom is injected from a venom gland into the recipient.

Environment—the physical and biological conditions that surround an organism or a group of organisms.

Exotic Species—a species that has been transported by human activities, either intentionally or accidentally, into a region where it did not occur previously. Also called an alien species, non-indigenous species, or introduced species.

Extinct—the *complete* global disappearance of a species from existence.

Extirpate—the local disappearance of a species, as opposed to extinction, which is global disappearance.

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F

Food chain—the flow of energy and nutrients from sunlight to plants to predators.

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H

Habitat—the surroundings in which individuals of a particular species usually live (i.e. their address).

Hard-bottom Habitat—(or sometimes called "**Live-bottom" Habitat**) an area of rocky outcroppings, also referred to as ledges, which are surrounded by a relatively thin veneer of sand, which varies in vertical relief.

(back) | (top)

I

Introduced Species—another term for an alien species, exotic species or non-indigenous species.

Invasive Species—a species that has been transported by natural processes or human activities, either intentionally or accidentally, into a region where it did not occur previously, and reproduces and spreads rapidly into new locations, causing economic or environmental harm or harm to human health (from Executive Order 13112 on Invasive Species).

Invertebrate—an animal that lacks vertebrae (i.e., a spinal column).

(back) | (top)

J

Juvenile—a sexually immature organism that resembles an adult.

(back) | (top)

M

Mitigate—taking action to avoid or reduce damages or to make less severe or harsh.

(back) | (top)

N

Native Species (or **Indigenous Species)**—applied to a species that occurs naturally in an area, and therefore has not been introduced by humans either accidentally or intentionally.

Neuromuscular—relating to nerves and muscles; jointly involving or affecting nervous and muscular components.

Neurotransmitter—a substance that transmits nerve impulses across a synapse (i.e. the gap between two neurons or nerve cells).

Niche—the functional role of a species in an ecosystem. The sum of physical and biological factors necessary for an organism's or species' existence. The environmental factors that influence growth, survival and reproduction of a species.

NOAA—the National Oceanic and Atmospheric Administration (NOAA), a U.S. federal agency that conducts research and gathers data about the global oceans, atmosphere, space, and sun, and applies this knowledge to science and service that touch the lives of all Americans. NOAA provides these services through five major organizations: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, the National Environmental Satellite, Data and Information Service, and NOAA Research; and numerous special program units. In addition, NOAA research and operational activities are supported by the nation's seventh uniformed service, the NOAA Corps, a commissioned officer corps of men and women who operate NOAA ships and aircraft, and serve in scientific and administrative posts.

(back) | (top)

O

Overfishing—harvesting an aquatic population below its reproductive capacity to replenish itself.

(back) | (top)

P

Pectoral Fins—either of the two fins of a fish that correspond to the forelimbs of a quadruped (a four-legged animal). Pectoral fins are those situated on the chest.

Posterior—towards the hind end of the fish.

Predator—an animal that preys on others. [Also see Top Predator]

Prey—an animal that is preyed upon by a **predator**.

(back) | (top)

R

Ray—a jointed rod which supports a fin.

Reef (or **Coral Reef)** —a massive, wave-resistant structure, built largely by coral, and consisting of skeletal and chemically precipitated materials.

(back) | (top)

S

Species—a group of individuals or populations that are similar and are able to mate and have offspring.

Stressor—five stressors are identified as affecting coastal and marine ecosystems: pollution, invasive species, climate change, extreme events, and land or resource use.

(back) | (top)

T

Taxonomist—someone who studies the taxonomy, or orderly classification of plants or animals, according to their presumed evolutionary (natural) relationships.

Terrestrial—living on or in or growing from land (rather than in the air or water).

Top Predator—a species eaten by nothing else in the food web.

Toxin—a poisonous substance that is a product of an organisms metabolic activities and is harmful or fatal when introduced into tissues.

Transect—a line across an area to be sampled, marked by a tape measure. Often permanent markers at the ends of line are left so that the line is easily found upon return.

(back) | (top)

V

Vector—an organism or force of nature that spreads an organism to a new area; a path, or method, of invasion. For example, a major vector in zebra mussel invasion is ballast water; the zebra mussels travel from their native waters into

new regions when ballast water collected in their native ranges is discharged into non-native waters.

Venom (or **Venomous)**—poisonous matter normally secreted by some animals (snakes, scorpions, bees, and some fish) and transmitted to prey or an enemy chiefly by biting or stinging.

Viability—the capability of surviving outside the mother's womb. In the case of eggs or seeds, it means the capability to grow and develop.

(back) | (top)

Return To Welcome Page

Run-ins with an Invader!
A Chronicle of Lionfish Sightings in U.S. Waters

Expedition Background | Meet the Scientists

On August 1, 2002, a team of scientists exploring the ocean floor aboard the submersible *Johnson-Sea-Link II* happened across a strange fish that should *not* have been there. As pilot Dan Boggess "flew" the *Johnson-Sea-Link II* along Scamp Ridge off the South Carolina coast, scientists Scott Meister and Dan Russ videotaped their run-in with the invader!

Later, Scott Meister recalled the account of their strange discovery in his field journal:

Date: 2 August 2002
Time: 8:30 PM
Research Vessel:
R/V Seward Johnson
Location:
South Atlantic Bight
Latitude: 32° N
Longitude: 79° 30' W

We began our dive in the *Johnson-Sea-Link II* at about 4:30 pm. We'd been slowly hovering along the **reef** for a few hours when we came across a high rock ledge teeming with life. Schools of tomtate intermixed with vermilion snapper flashed above the feature, while small damselfish and wrasses darted in and out of the small holes in the reef.

View Video Clip in Windows Media Player
You may need to download Quicktime | Windows Media

Watch videotape evidence that lionfish had probably begun multiplying in the Atlantic Ocean by 2002. The scientists in the submersible did a double-take as a lionfish, native to the Pacific Ocean, pops out from around the coral they were studying! Click here for further details.

Soft corals and sponges adorned much of the face of the wall, and a spiny lobster could be seen

clinging upside down to a small overhang. Having been down on the reef for about two hours already, my eyes had become accustomed to the standard shapes and sizes of the **species** we'd seen throughout the dive.

We were on the prowl for a sponge sample to bring to the surface, when I spotted what I first believed to be an unusual coral outcrop of some type. Long, slender spikes peeked out from behind a small rock mound, and my interest was immediately piqued.

This lionfish was sighted off the coast of North Carolina in August 2002 during a submersible dive in water more than 180 ft deep. Although the scientists were excited about their exotic find, they were not pleased to see the lionfish in U.S. waters.

As we came closer and checked out the spines, an odd-looking fish rose above the mound and turned to see what all the commotion was about. My heart jumped into my throat as I realized it was a *lionfish*! Everything about this fish seemed out of place when compared to the species we had observed so far. Long, sharp spines ran up its back, nearly twice the height of its body. Its **pectoral fins** resembled wings, which were also lined with sharp, slender spines. Its color contrasted strongly with the surrounding reef, with a zebra-like pattern of brown-and-white vertical bars along its body and dark circles imprinted on a translucent tail. This invader didn't dive for cover as many other fish its size did, but instead seemed to assume a defensive posture and moved toward us. Maybe their poisonous spines present a formidable defense against potential **predators**, but they are no match for a 26,000-lb submersible!

This dive was an amazing opportunity. Unfortunately, we sighted the lionfish late in the dive, and the sub was low on battery power. This gave us only a few minutes to try to capture this noteworthy specimen. During a short and heated pursuit, we spotted a second lionfish. We attempted to capture both fish without success. Before we knew it, time was up, and we had to surface and leave the lionfish behind. Although we did not return to the surface with a physical specimen, we did return with proof of our unlikely encounter on videotape.

On the following day, members of the science team made another submersible dive on a similar reef approximately six miles away from our lionfish sightings. This time, sub pilot Craig Caddigan maneuvered the sub through the reef, while scientists **Josh Loefer** of SCDNR and **Jeremy Potter** of **NOAA's** Office of Ocean Exploration observed the surroundings.

Josh, seated in the front of the sub with Craig, had high hopes we would capture a live lionfish. We didn't have to wait long. Only 30 minutes into the dive, we sighted another lionfish. We had plenty of battery power this time, so the lionfish was as good as ours.

This 2002 lionfish sighting over the Outer Shelf Reefs off Cape Fear, North Carolina, was noteworthy because lionfish are not known to go this deep (~240 ft) in their native Pacific habitats.***Click on image*** for larger view and further deails.

Or was it? The area was extremely rocky and provided many hiding places for our quarry. Nevertheless, the chase was on. At times, it appeared as though the lionfish was toying with us. It would allow the sub's suction nozzle to come within inches of its body, so close that we could see its fins ripple in the current created by the suction pump. Then it would dart away at the last moment and find cover. Several times we relocated the lionfish, flushed it from its hiding place and tried again to capture it. After a 30-minute chase in this fashion, the lionfish found a large rock overhang about 4 ft deep. It darted inside this well protected area, placing itself well out of reach of the submersible. Lionfish: 2; scientists: 0.

With our quarry out of reach, we reluctantly moved on and continued our scheduled dive activities. By the end of the dive we had spotted two more lionfish, but we had no time to pursue them. This brought the total number of lionfish sightings to five. Though it was exciting to see this many lionfish in such a short amount of time, these sightings suggest that they have established a foothold in this non-native environment, and may be actively reproducing in U.S. waters off North Carolina.

(top)

Expedition Background

NOAA's Office of Ocean Exploration supports expeditions all over the world to explore the Earth's last frontier: the ocean. One of these ocean expeditions, "Islands in the

Stream: Exploring Underwater Oases," took place on the NOAA Research Vessel *Seward Johnson* in July and August 2002. Scientists explored and investigated deep-water coral reefs, rocky outcrops, and hard-bottom habitats at the edge of the continental shelf off the U.S. southeast coast.

The purpose of the expedition was to conduct geological, biological, and ecological observations of these habitats, and to collect samples for further analysis to better understand these little known and poorly understood areas. Scientists on the expedition used a variety of methods to collect data and information, including the *Johnson-Sea-Link II*, a four-person submersible that completed 48 dives during 33 days at sea. It was during one of these dives that scientists came across the invasive lionfish and videotaped it from the window of the *Johnson-Sea-Link II*.

Click on PLAY to watch video

Watch a video of the *Johnson Sea-Link II* research submersible as Steve Ross chief scientist of the "Islands in the Stream" expedition describes the mission plan the day they videotaped a lionfish in U.S. waters.

Source location:
http://oceanexplorer.noaa.gov/explorations/02sab/logs/aug08/media/dive.html

View Video Clip in Windows Media Player
You may need to download
Quicktime | Windows Media

(top)

Click on PLAY to watch video

Transcript: Almost exactly one year after the first video documentation of the red lionfish in Atlantic waters, scientists diving in the *Johnson Sea-link II* stumbled upon another specimen. After watching the video, several scientists were surprised to see the fish living in an area with so little bottom

relief. Much like the fabled cartoon Roadrunner, the elusive fish seemed to be taunting the sub pilot as it easily pirouetted around multiple attempts to capture it. Given that this was our first dive anywhere in this area, seeing this lionfish was like hitting a bull's eye with the first dart.

This begs the question: ***"Just how many are out there?"***

Source Location:
http://www.oceanexplorer.noaa.gov/explorations/03bump/logs/aug07/media/lionfishvideo.html

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View Video Clip in Windows Media Player
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Meet The Scientists

Meet some of the scientists that provided evidence that lionfish were multiplying in the Atlantic Ocean, and were swimming much deeper in the Atlantic than in their native habitat!

Scott Meister
Biologist
Marine Resources Research Institute
South Carolina Department of Natural Resources

Scott Meister is a fisheries biologist for the Marine Resources Monitoring and Prediction (MARMAP) program, a co-operative between the South Carolina Department of Natural Resources and the National Marine Fisheries Service. His research background includes life history studies of black and bank sea bass, as well as the deeper-dwelling wreckfish. Scott also has a great interest in the movement patterns of offshore reef fishes and is currently wrapping up a 5-year mark/recapture study of gag grouper and greater amberjack in the Atlantic. Having been turned on to science at a young age, Scott enjoys working with local schools to promote awareness of the marine environment. Scott has a BA in environmental science from the University of North Carolina at Wilmington.

Joshua K. Loefer
Marine Biologist
Marine Resources Research Institute
South Carolina Department of Natural Resources

Josh Loefer is a marine biologist with the South Carolina Department of

Natural Resources. On the *Island in the Sea* expedition, he assisted with cruise logistics, data acquisition, GIS analysis, and sample collection. Josh earned a BA in biology from Furman University in 1996, and an MS in marine biology from the University of Charleston (SC) in 2000. His main research interests include the life history of sharks, snappers, and groupers; satellite telemetry tagging of billfishes and sharks; and the hydrography of the Charleston Bump complex.

(top)

Jeremy Potter
Sea Grant Fellow
NOAA Office of Ocean Exploration

Jeremy grew up in West Virginia and graduated from Davidson College in North Carolina. Immediately after college, he worked as an observer in Alaska's Bering Sea crab fishery, and later as an instructor at the Wallops Island Marine Science Consortium. In 1997, he spent oa year teaching English in rural Japan. Three years later, he returned home to pursue his interests in international environmental politics, facilitation, and negotiation. Jeremy is a master's student at the Duke University School of the Environment. His current research in international fisheries policy focuses on the Japanese pelagic longline industry. His fascination with the deep sea led him to NOAA's Office of Ocean Exploration, where he is a Dean John A. Knauss Marine Policy Sea Grant Fellow. Jeremy coordinated Web site contributions and assisted with database management for the *Islands in the Sea* expedition.

Dr. Steve W. Ross
Research Coordinator
North Carolina Coastal Reserve
Principal Investigator, Outer Shelf and Slope Project

Dr. Ross is a native of North Carolina and has spent most of his career involved in the marine sciences of that area. He earned a BS in zoology from Duke University, a master's from UNC-Chapel Hill, and a PhD from NC State University. He has been the research coordinator for the NC Coastal Reserve Program for 12 years. He holds adjunct faculty appointments at North Carolina State University and UNC-Wilmington. His area of specialization is ichthyology (the study of fishes), particularly in areas of ecology and life history (age, growth, feeding, reproduction) studies. He has conducted numerous, diverse projects in estuaries and offshore waters and has served as chief scientist on many cruises, including several using submersibles. On the *Islands in the Stream* expedition, Dr. Ross and his team assessed the fish communities of several unique deep-water habitats off the southeastern U.S. coast. In particular, they studied energy flow (trophodynamics) and relationships of animals to various habitats, including coral banks, canyons, and rocky areas. The ultimate goal of such studies is to provide information for these poorly known areas that will facilitate management and protection of productive habitats.

Dr. Pamela Cox Jutte
Marine Scientist
Marine Resources Research Institute
South Carolina Department of Natural Resources

Pam Cox Jutte grew up in central Ohio, and developed an interest in marine invertebrates during her undergraduate years at Duke University. After finishing her BS in biology in 1993, she began graduate work at the University of California at Berkeley. Upon the completion of her PhD in 1997, she came to work as a marine scientist for the South Carolina Department of Natural Resources. Her research projects have focused on the condition of nearshore hard-bottom reefs following ocean disposal, the biological and physical effects of beach nourishment, and habitat quality in tidal creeks and coastal waters. She also serves as adjunct faculty at the College of Charleston's Graduate Program and the Medical University of South Carolina's Marine Biomedicine and Environmental Sciences Program.

(top)

Return to Some Lionfish Biology

Lionfish Biology Fact Sheet

Behavior
Biological Classification
Common and Scientific Names
Conservation Status
Ecological Role
Economic Importance
Habitat
Identification
Native/Non-native Range
Special Precautions

Download Factsheet:
Microsoft Word version (*doc, 31Kb*), text only.
Full version (*pdf, xxKb*)

Biological Classification

- **Kingdom** – Animalia (all the animals)
- **Phylum** – Chordata (animals with a spinal cord)
- **Subphylum** – Vertebrata (animals with backbones)
- **Class** – Actinopterygii (**ray**-finned fishes)
- **Order** – Scorpaeniformes (scorpion fishes and sculpins)
- **Family** – Scorpaenidae (firefishes, goblinfishes, rockfishes, and scorpionfishes)
- **Genus** – *Pterois (*lionfishes, turkeyfishes, and zebrafishes)
- **Species** – *volitans* (meaning volatile or poisonous)

Common Names:

lionfish, zebrafish, firefish, turkeyfish, red lionfish, butterfly cod, ornate butterfly-cod, peacock lionfish, red firefish, scorpion volitans

Scientific Name:

Pterois volitans

(top)

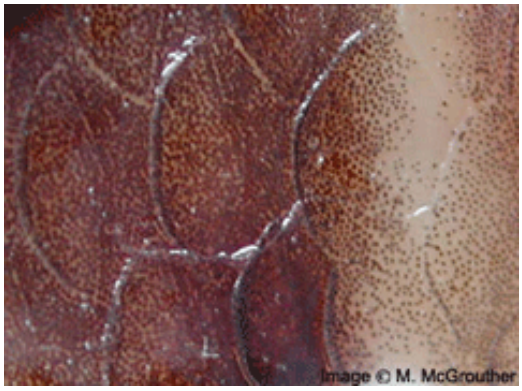
Identification:

Lionfish have distinctive brown or maroon, and white stripes or bands covering the head and body. Their body is 1.5 times the length of the head, with a total size range of 6 -12 inches. They have fleshy tentacles above their eyes and below the mouth; fan-like pectoral fins; long, separated dorsal spines; 13 dorsal spines; 10-11 dorsal soft rays; 3 anal spines; and 6-7 anal soft rays. An adult lionfish can grow as large as 18 inches, while juveniles may be as small as 1 inch or less. Lionfish have cycloid scales.

Native Range:

The South Pacific and Indian Oceans (i.e., the Indo-Pacific region). The range of the lionfish covers a very large area from western Australia and Malaysia east to French Polynesia and the United Kingdom's Pitcairn Islands, north to southern Japan and southern Korea and south to Lord Howe Island off the east coast of Australia and the Kermadec Islands of New Zealand. In between, the species is found throughout Micronesia.

Profile of a lionfish showing the distinctive fleshy tentacles above the eyes and below the mouth. ***Click on image*** for larger view and further details.



The cycloid scales of lionfish (*Pterois volitans).*
Click on image for larger view and further details.

Non-native Range: Lionfish have been reported along the southeastern United States coast from Florida to North Carolina. Juvenile lionfish have been collected in waters off Long Island, New York, and Bermuda. Lionfish were first spotted off the coast of North Carolina during summer 2000. During summer 2004, at least 155 lionfish were collected at 19 different locations off the coast of North Carolina, including hard bottom habitats and shipwrecks. Previous reports of lionfish include six that were accidentally released in Biscayne Bay, Florida, when a beachside home aquarium broke during Hurricane Andrew in 1992. Further intentional releases of aquarium pets into the Atlantic Ocean have very likely contributed to the Florida population. There are additional diver reports of lionfish off Palm Beach and Boca Raton, Florida, from the early 1990s.

(top)

Habitat: Lionfish are primarily associated with coral reefs, but can be found in warm marine waters of the tropics. Lionfish have been found in water depths from 85 to 260 feet on hard bottom, coral reefs and artificial substrate (like sunken ships). They tend to glide along the rocks or coral during the night and hide under ledges or in crevices during the day.

Ecological Role: Lionfish are slow-moving and conspicuous, so they must rely on their

unusual coloration and fins to discourage would-be predators from eating them. Lionfish are one of the top predators in many coral reef environments. Lionfish are active hunters who ambush their prey by using their outstretched, fan-like pectoral fins to slowly pursue and "corner" them. Lionfish probably don't sting their prey; their spines are thought to be more defensive in nature. They may also be used in confrontations between male lionfish during spawning.

Lionfish are **native** to the warm, tropical waters of the South Pacific and Indian Oceans (i.e., the Indo-Pacific region), including the Red Sea. Their **native** range is shown in orange on the map. ***Click on image*** for larger view and further details.

Behavior: Lionfish are thought to be nocturnal hunters, but they have been found with full stomachs during the day in the Atlantic. They move about by slowly undulating the soft rays of the dorsal and anal fins. During the day, they often retreat to ledges and crevices among the rocks and corals. Although in the Atlantic, lionfish are often seen moving about during the day, both alone and in groups of 2-6. They may live alone for the majority of their lives, and will fiercely defend their home ranges from other lionfish and other species of fish. However, they may live in small groups when they are juveniles and during the spawning season. Male lionfish are more aggressive than females, especially during the mating season. Males will aggressively attack other males who attempt to invade their territory.

Economic Importance: Although lionfish have been used as a food source in their native range, economically, they are far more important in the aquarium trade. Lionfish are very popular and common aquarium fish, especially in the U.S. They are captured in their native range, or possibly raised in "lionfish farms" and sold as pets to dealers and private citizens.

(top)

Locations in the Atlantic Ocean where lionfish have been reported as of May 2003. ***Click on image*** for larger view and further details.

Conservation Status: Lionfish are not currently listed as threatened or endangered in their native range. However, the increase in pollution in coral reefs may negatively affect the lionfish's primary food sources (crustaceans and fish). If lionfish are unable to adapt to declines in their prey species, their numbers may decrease.

Special Precautions: The spines of this species deliver a venomous sting that can last for days and cause extreme pain, sweating, and respiratory distress. A venom gland is

located at the base of each spine. The venom is a combination of protein, a neuromuscular toxin and a neurotransmitter called acetylcholine (pronunciation: ah-see-toe-coe'-lean). After the spine punctures the skin, the venom enters the wound by traveling up a groove in the spine. There is evidence that commercially available stonefish anti-venom has detoxifying effects on lionfish venom.

Warning! Lionfish are beautiful but dangerous. Look, but don't touch!

(top)

The Lionfish Invasion!

Thinking Like a Scientist

So you want to chase invasive species?

Paula Whitfield has been chasing lionfish since they were first discovered in U.S. waters in 2000. Paula is a fisheries biologist at NOAA's Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina. We spoke to Paula about her work with the invasive lionfish. Here is what she had to say:

Profile of a Lionfish Chaser *- Click here to learn more about the early influences and career of Paula Whitfield.*

Interviewer:
When did you first become aware of the problem of lionfish in the Atlantic Ocean?

Paula Whitfield:
I first became aware that lionfish were in the Atlantic when one was sighted by a group of recreational divers in August 2000. They were exploring a shipwreck off the coast of North Carolina when they saw it. Although the divers did not bring back any solid evidence (like photos, video, or an actual

Click the filmstrip to view underwater footage of the beautiful but venomous lionfish, and the scientists who study them!

Learn More:

- **Thinking Like a Scientist**
- Student Guide
- Take the Quiz!
- For Teachers

1. Welcome
º run-ins with an invader

2. What is an invasive species?

3. Lionfish Invade U.S. Coastal Waters!

4. Is the Aquarium Trade to Blame?

5. Some Lionfish Biology
º biology fact sheet

6. Can We Stop the Invasion?

7. References

Ask an Expert

Report Lionfish Sightings

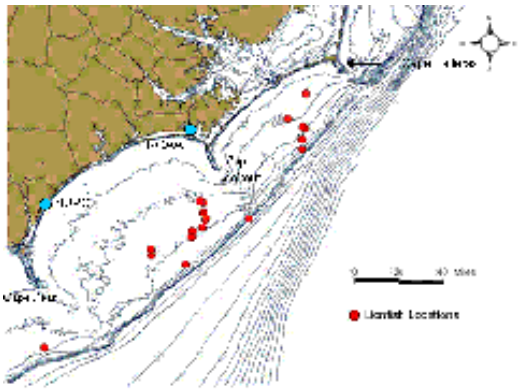
specimen), there was little doubt in my mind that they had indeed seen a lionfish. Lionfish are very distinctive in their coloration and posture, and nothing native to the Atlantic could be mistaken for a lionfish.

As a fisheries biologist, I immediately knew that lionfish in the Atlantic were going to be a big story. First, lionfish are exotic and beautiful. Second, the possibility of divers or fishermen getting stung by lionfish gave the whole story a sensational aspect. In fact, numerous newspapers, as well as TV and radio stations, have interviewed me in the past few years. I knew that once word got out, a lot of attention would be paid to the presence of lionfish off the East Coast—both in the popular press and among biologists.

Soon after the first report, other reports from recreational divers and commercial diving companies began coming in—it was clear that the first sighting was no fluke! I began keeping a log of all the sightings, including all the information I could get about it—location, how many, size, etc. So far, virtually all lionfish sightings have been in waters of 100 ft or deeper, and in coral reef or other hard-bottom habitats, or near shipwrecks.

(top)

Interviewer:
In your research with lionfish, what was the first question you wanted to answer?



A map of Paula Whitfield's study area in the Three Capes region off the coast of North Carolina. The red dots represent known lionfish populations. ***Click on image*** for larger view and further deails.

Paula Whitfield:
The first question that came to mind was, "*What will be the ecological impact of lionfish on ecosystems in the Atlantic?*" In other words, *how will the presence of lionfish affect other organisms living in the Atlantic?* I immediately realized that this would be a difficult question to answer. After doing a bit of research and reading, I learned that very little was known about the hard-bottom habitats and other areas in the Atlantic where lionfish were reported. As a result, there is nothing to compare the present situation to. It would have been nice to be able to do a "before and after" comparison, but it is not possible.

Interviewer:
How did you go about deciding how you would answer this question?

Paula Whitfield:
First, we assumed that we should not expect lionfish in the Atlantic to behave the same as those in their native habitats in the Pacific and Indian Oceans. The Atlantic Ocean off the coast of the southeastern USA is vastly different from the tropical Pacific. The Atlantic's community of organisms is very different from the lionfish's native tropical waters, which means that the lionfish may occupy a very different niche in the Atlantic than it does in the Pacific. For example, in their native habitats, lionfish are considered one of the top predators, with no known predators of their own. To say it another way, they are often the top dog in the food chain! It was entirely unclear whether this would be the case in the Atlantic.

Also, it was entirely possible that lionfish would **compete** for food and habitat with a different set of organisms in the Atlantic than in the Pacific. So, we needed to answer some basic questions about the natural history of lionfish in the Atlantic before we could even begin to understand their ecological impact there.

One assumption we made from the beginning of our research was that the impact of lionfish in the Atlantic was most likely related to their abundance, which is often the case with invasive species. So, the first question we asked was, *"How many lionfish are in the Atlantic?"* Our next question naturally followed. *"Are lionfish reproducing in the Atlantic?"* Ultimately, we hope that the answers to these two questions will begin to shed light on the impact of lionfish in the Atlantic.

(top)

Interviewer:
What are the some of the field methods you use to estimate the abundance of lionfish or whether or not they are present?

Paula Whitfield:
You might think that determining the number of lionfish in the Atlantic would be a fairly easy task,

except that lionfish are living in waters about 100-260 ft deep and perhaps even deeper! Many physical and physiological constraints come into play when people work in water this deep. In scuba diving, there are depth and time limits for the divers. In fact, recreational scuba diving has a maximum limit of 130 ft. Much of the time, we were working slightly beyond that depth. So, automatically, answering our two simple questions about the natural history of lionfish became very difficult. We were limited to two 30-minute dives each day. This is not much time to do our work. So we had to be very organized and know exactly what we were going to do when we got there.

NOAA scientists Christine Addison (foreground) and Paula Whitfield (in back holding the underwater video camera) decompress after one of their lionfish research dives. . ***Click on image*** for larger view and further deails.

At each site we visited, two teams of divers were deployed. One team was called the “lionfish observer team” and the other was the “hunter/gatherer team.” The observer team was responsible for conducting surveys to estimate the number of lionfish (i.e., their abundance) at the site. The hunter/gatherer team went in afterward to collect as many lionfish specimens as they could and bring them to the surface. Also, at the water’s surface, a chase boat with a safety diver followed the divers to help them if anything were to go wrong on the ocean floor below.

To determine the abundance of lionfish at each site, we did visual transect counts using teams of divers. We established transects, or survey lines, on the ocean bottom. As the divers swam, they measured a predetermined distance using a tape measure. We recorded every lionfish we saw along each transect. We also recorded the numbers of grouper and snapper, two predatory fish species that potentially compete with lionfish for food and habitat. We did this because we

wanted to know how many grouper and snapper there were in comparison to lionfish at that location. We used waterproof paper and pencils to record data, and hand signals to communicate. Later, we will use these counts to estimate lionfish abundance in the different habitats and locations that we surveyed.

(top)

Interviewer:
What are some of the other questions you are asking about lionfish in the Atlantic? How did you go about answering these questions?

Paula Whitfield:
Another question we asked was, *"Does temperature limit the distribution of lionfish in the Atlantic?"* At several locations where we counted lionfish, we also installed sensors to record the water temperature. These sensors will record the temperature every 30 minutes for the next year. We will retrieve them when we return in the summer of 2005. From the temperature data, we will test the prediction that cold-water temperatures at the ocean bottom limit the distribution of the tropical lionfish in the Atlantic.

We also asked: *Is the diet of lionfish in the Atlantic different from that of lionfish in the native Pacific range? What kind of prey organisms are they eating in the Atlantic, and how many? What is the size (or age) of the fish in their diet?* We dissected some of the lionfish specimens that we collected and examined their stomach contents to determine what they were eating (this is called a diet analysis). In general, we found that lionfish are voracious predators. The stomachs of most of the specimens we collected were full of small fish!

The R/V *Cape Fear*, an oceanographic research vessel, was home to Paula Whitfield and her research crew for several one-week research expeditions to study the lionfish in August 2004. ***Click on image*** for larger view and further details.

We also examined each specimen's reproductive status and sex. We have questions like: *What is their reproductive*

potential in the Atlantic? When do they spawn? Where are they spawning? This kind of "life history" information isn't well known for the lionfish even in its native habitat!

We also brought back some live lionfish to our laboratory so we could conduct growth and breeding experiments. By doing so, we hoped to learn how fast the populations in the Atlantic might grow, as well as learn more about lionfish reproduction: when breeding occurs, how often they breed, how many eggs are produced, how many eggs ultimately develop into fingerlings (i.e., baby fish), etc.

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Interviewer:
Is it possible to predict the future abundance and distribution of lionfish in the Atlantic?

Paula Whitfield:
I think it is difficult to estimate future abundance, but we have some ideas. Predicting lionfish distribution in the future is easier, so let me start with that. We have predicted that the minimum temperatures at the ocean bottom in the winter will limit lionfish distribution in the Atlantic. Tropical fish like the lionfish simply cannot tolerate water temperatures below a certain minimum. We hope to test this prediction with the temperature data we are collecting with the sensors we set up this past summer.

Except for low winter temperatures, overall conditions in the Atlantic Ocean are excellent for lionfish. For that reason, we think that where lionfish are found in the Atlantic, they will be just as abundant there as they are in their native habitats in the Pacific. At least that is our assumption. In other words, in the warmer waters of the Atlantic, where lionfish are able to live, we predict that they will be just as abundant as in the Pacific. So, one way to forecast their eventual abundance in the Atlantic is to determine their abundance in their native habitat and extrapolate those numbers to the Atlantic. Eventually, the Atlantic should have a similar number of lionfish per unit area as the Pacific. Until we have more accurate information about the reproductive potential and death rates of lionfish in the Atlantic, this is the best we can do.

Interviewer:
What are some of the challenges you face in conducting your research on lionfish?

Paula Whitfield:
As I mentioned before, the biggest challenge is getting to where the lionfish live on the ocean bottom. These depths are

at the edge of our current diving technology. Diving at these depths can be dangerous, and even potentially life-threatening. We have to be very careful not to return to the surface too quickly; otherwise "decompression sickness" can occur. In fact, we must surface as slowly as possible. We use time and depth tables that we strap to our arms, and wrist computers and stopwatches to time ourselves. For the same reason, we must severely limit the amount of time we spend at greater depths.

Diving specialist and research technician Jay Styron *carefully* captures a lionfish off the coast of North Carolina for later study. ***Click on image*** for larger view and further deails.

Instead of diving, we could have used remotely operated vehicles (ROVs) or submersibles, but these have their limitations. For example, it is not feasible to collect lionfish using the arms of ROVs or submersibles. Some have tried, but the technology isn't quite there yet. So we were left with using scuba gear.

The logistics of ocean research like mine are also quite challenging. I have no problems finding people to spend a week or two on a research ship to help me gather data. The hard part is scheduling space on the research ship, which is in very high demand. "Ship time" is also very expensive (thousands of dollars per day), as is the equipment that we use.

Then there's the ever-challenging Atlantic weather, which never seems to cooperate. This past summer, for example, we had to cut our expedition short by several days, courtesy of Hurricanes Alex and Charlie!

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Interviewer: What is the present (summer 2004) status of lionfish populations in U.S. waters? Were there any changes in the past year?

Paula Whitfield:
Unfortunately, lionfish sightings have increased over the past year. Reports have come in from Florida all the way up the coast to North Carolina. Of course, these reports are helpful to

us, but they represent what scientists call "anecdotal" information. In other words, they are observational and there is nothing systematic or consistent about how the observations of lionfish were made. Neither are they quantitative. From a report of a sighting, we know someone saw a lionfish in a particular location, but that's about it.

However, these reports from everyday citizens have helped us locate areas that lionfish might use for overwintering (i.e., places warm enough for lionfish to survive there through the winter). We targeted these locations for further study - in fact, many of the locations we visited this past summer were mentioned in citizens' reports. It is clear that lionfish are widespread along the North Carolina coast between Cape Fear and Cape Lookout. If fact, by the end of our studies in the summer of 2004, we were surprised if we did *not* see lionfish when we checked out a new location. Prior to our expedition, I never suspected that this would be the case.

The abundance of lionfish along the South Carolina, Georgia and Florida coasts is less clear, simply because no one has systematically looked, at least to my knowledge. Again, we know lionfish are there from citizen reports, but we don't know how many, whether they are reproducing, etc.

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Interviewer:
Do you still think the aquarium trade is the vector for the introduction of lionfish into the Atlantic Ocean? What is the evidence to support this hypothesis? Is there any evidence to refute this hypothesis?

Paula Whitfield:
Yes, in my opinion, the aquarium trade is the vector for the introduction of lionfish into the Atlantic. There is no absolute proof, but all of the evidence points to the aquarium trade as the vector. There is no evidence that lionfish entered the Atlantic by swimming over from the Pacific or that they were released in ballast water. We know for sure that a seaside aquarium in Key Biscayne Bay, Florida, broke during Hurricane Andrew in 1992, releasing six lionfish. In addition, thousands of lionfish are imported into the United States every year! It is very likely that their owners released some proportion of these lionfish either on purpose or by accident. There are many other examples of the introduction (and spread) of aquarium fish by their owners into Florida waters - so why not lionfish?

Interviewer:
Assuming lionfish are here to stay, what steps do you recommend to stop their further spread? Are regulations in place in the United States to control marine invasive species

like lionfish? If so, what are they?

Paula Whitfield:
I'm afraid that lionfish are here to stay. I don't believe there is any way to stop their spread throughout the warmer Atlantic waters. The broad geographic area that they have already colonized - from Florida all the way up the Eastern Seaboard to North Carolina - and the depths at which we are finding them, from 85 to 300 ft - makes it very difficult to remove them. Short of establishing a lionfish fishery and asking people to fish for them, I don't think there is a solution. But even this would be prohibitive because the lionfish's spines make it difficult to collect them without stinging incidents.

Another complicating factor is that there are people who actually want the lionfish in the Atlantic! Recreational divers want to see interesting and exotic sea creatures, and lionfish are certainly exotic. The charter companies that take people out to dive don't want to see the lionfish killed or removed because they are good for business. I would hope that if they were educated on the devastating effects of invasive species, they might think again...but probably not.

Also, lionfish are big business in the aquarium trade and I don't see the importation of lionfish slowing down or stopping. There are no federal or state regulations that prohibit the importation of lionfish, period. However, some states, like Florida, do have regulations that prohibit certain organisms from being released into native waters. Obviously, these regulations are not enforced very well.

In contrast to lionfish, it was fairly easy to halt the importation of snakeheads to the USA. They are rather ugly creatures and people can see and understand the devastating effects they have in ponds and other waterways in their own neighborhoods. Therefore, lawmakers were able to quickly stop snakeheads from being imported. Lionfish are different, though. They are attractive animals that people want to look at *and* they are found in rather remote locations off the coast, so they are "out of sight, out of mind" to the public. Snakeheads have a very low likeability factor, whereas lionfish are very charismatic. I don't anticipate that the importation of lionfish will slow down any time soon, so new releases are likely to continue.

Lastly, because lionfish eggs and larvae are "free-floating," water currents rapidly spread them to new areas. This is now the main way lionfish are spreading up and down the East Coast. There is just no way to stop this from happening.

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Some Lionfish Reading Material:

The following is a list of Paula Whitfield's publications that relate to her research on lionfish:

Hare, Jonathan A. and Paula E. Whitfield. 2003. An Integrated Assessment of the Introduction of the Lionfish (*Pterois volitans/miles complex*) to the Western Atlantic Ocean. NOAA NOS Technical Memorandum CCFHR 1 (available online at: http://shrimp.ccfhrb.noaa.gov/lionfish/lionfish_ia.pdf).

Whitfield, P.E., T. Gardner, S.P. Vives, M.R. Gilligan, W.R. Courtenay, Jr., G.C. Ray, and J.A. Hare. 2002. Biological invasion of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic Coast of North America. Marine Ecology Progress Series 235: 289-297 (for copies contact paula.whitfield@noaa.gov or available online at: http://www.int-res.com/abstracts/meps/v235/p289-297.html).

Whitfield, P.E., J. Hare, and D. Kesling. 2004. Dive operations plan for the assessment of the status and risk posed by the invasive lionfish in North Carolina hard-bottom communities. Accessed on September 20, 2004 at: http://www.uncwil.edu/nurc/research/cruise_plan_whitfield.pdf.

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Return To Thinking Like a Scientist Page

Profile of a NOAA Scientist: Paula Whitfield

Paula Whitfield is a fisheries biologist at NOAA's Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina. We talked to Paula about how she came to be a scientist, her career as a scientist at NOAA, and how she came to study lionfish. Here is what she had to say:

Paula Whitfield looks for lionfish! Paula is a NOAA fisheries biologist studying and tracking the lionfish invasion in the Atlantic. ***Click on image*** for larger view and further details.

Interviewer:
Can you tell us how you became interested in a career in science? Can you trace your interest in science back to a childhood experience, a favorite teacher or a favorite course?

Paula Whitfield:
I first became interested in the ocean when I was a kid. I couldn't get enough of "The Undersea World of Jacque Cousteau." It sounds kind of corny because this Cousteau show influenced so many of today's marine scientists, but it's true! It was my favorite TV show and I never missed it. It was today's equivalent to the Discovery Channel. The underwater footage was something very new when I was a kid—it was cutting-edge and exciting. I loved the water as a kid, too. I loved to swim, and I grew up on an island in Puget Sound in Washington State. So, being in the water and working around the water came naturally to me.

I didn't get interested in pursing a career in marine science until I went to college. I took Biology 101 during my freshman year at George Mason University in Virginia. From the start, I thought studying life was very cool. I also had the opportunity to go on an extended field trip to Costa Rica, a country in Central America that has nature reserves with amazing biodiversity. I saw how science was done by observing scientists in the field collecting data and interacting with each other and with students. It was great! I thought, "This would be a great life." That's when I decided to pursue a career in biology.

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Interviewer:
Tell us about your career at NOAA.What is your job title? What are your duties?

Paula Whitfield:
I started at NOAA even before I graduated with my bachelor's in biology from George Mason University. While in college, I was a part-time biological technician at the National Marine Fisheries Service. Most of my time was spent in the field assisting senior scientists with their research projects. I collected data, but also was in charge of making sure we had the proper supplies and equipment on hand, entering and analyzing data, etc. This got my foot in the door, and when I graduated, NOAA hired me full-time. Over the past 10 years, I have climbed the ladder to a professional biologist position and now have much more responsibility. Being promoted to a scientist position required that I have a master's degree. While I worked as a technician, NOAA allowed me time to go back to school to earn a master's in marine science from the University of North Carolina at Wilmington.

Paula Whitfield collects lionfish data onboard the R/V *Seward Johnson*. (Photo credit: Christine Addison)

Now, I am a fisheries biologist with the Center for Fisheries and Habitat Research, an office of NOAA's National Ocean Service in Beaufort, North Carolina. My job is to design and carry out ecological studies on marine fish and their habitats. So now, instead of working to help others with their research projects, I get to design, plan and carry out my own. This involves a lot of responsibility and requires much more creativity on my part. Now, I am very much in tune with the "big picture"—I can see how my research makes a difference—and that is very satisfying. Sometimes I get to choose my own questions (in the context of the NOAA mission) and sometimes my bosses assign me a question.

On a day-to-day basis, my work might seem fairly mundane. I actually spend most of my time behind a computer entering and analyzing data, planning research projects and logistics, writing grants to obtain money to do my research, and writing scientific papers. For me, the most difficult aspect of my job is writing. Although I find writing grants and research papers difficult, taking a research project from it beginning to its culmination as a publication that other scientists read is quite enjoyable. But, the 25 to 30% of my time that I spend in the field collecting data is why I am a scientist. It's what I enjoy most, and it happens to be the most glamorous and fun part of science, too.

In my work, I mostly use observations to try to answer questions, but sometimes I'm able to do an actual experiment. Doing experiments (that is, manipulating variables) is preferred, but often very difficult, so we count our lucky stars when an experiment is possible. As you might imagine, it is difficult to find ways to do experiments in the vastness of the ocean, so sometimes we are left with doing more observational research until more is understood about the system.

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Interviewer:
What kind of educational background would someone need to get a job like yours?

Paula Whitfield:
To work as a technician requires at least a bachelor's degree in a science related to the work you are being hired to do. A master's degree would make you even more competitive for these types of positions. However, these days, most professional scientists have PhDs in their fields. The exceptions are people like me who climbed up the ladder over many years. I am actually considering returning to graduate school to earn a PhD, which is required for me to get any further promotions. More importantly, a PhD would help make me more competitive for grants I wish to apply for to fund my research projects.

Paula Whitfield waits to dive. Note her deep-water diving gear, and the underwater videocamera she carrys. (Photo credit: Christine Addison)

Interviewer:
Besides your work with lionfish, what other research projects have you been involved in as a NOAA scientist?

Paula Whitfield:
Until I began studying lionfish, most of my research had to do with the disturbance and restoration of seagrass beds. I ask questions about how seagrass beds are damaged or disturbed by human activities or natural processes, and how they recover from damage. On a practical level, I try to find ways that damaged seagrass beds can be repaired so that their function in the ecosystem can be restored. Seagrass beds suffer from numerous types of insults from human activities, including poor water quality, severe damage from motorboat propellers, etc. Actually, I'm still very much involved with the restoration ecology of seagrass beds, but lionfish have been taking up most of my time lately!

Interviewer:
What are some other career options for people with a background like yours?

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Paula Whitfield:
There are many career options for someone with a bachelor's or master's in biology. The opportunities may be more limited for someone with a more specialized degree (especially a bachelor's) in marine science or marine biology. Even though I eventually

went into marine biology, I'm glad that I decided to get the more general biology degree, because it gave me a broader perspective and opened up more avenues for me in the end.

One option for someone with a bachelor's or master's is to start as a technician, like I did—assisting scientists in carrying out their research. All kinds of institutions hire research technicians, including universities, state and local governments, agencies of the federal government like the National Ocean and Atmospheric Administration (NOAA), the National Park Service, the United States Geological Survey (USGS) and the Environmental Protection Agency (EPA). There are also private research institutions like Moss Landing Marine Laboratories (CA), Woods Hole Oceanographic Institution (MA) and Mote Marine Laboratory (FL).

With a master's degree, there is also the option of teaching high school or community college. High school science teachers are in great demand and supply these days. Many school districts are willing to give bonuses and other incentives to attract young people to their schools.

Another option is to work as a professor at a university or college. This usually requires a PhD in your area of expertise, but it depends on the institution. Most professors spend part of their time doing scientific research and the rest teaching classes and supervising the research of graduate students who are working on their own masters and PhDs.

Interviewer:
What advice would you give to a high school student who would like to pursue a career similar to yours, say in biology or marine science?

Paula Whitfield:
I advise students to take as many science and math courses as they can, including biology, chemistry and physics. Not only will it prepare you for what is to come in college, it will help you figure out what you like and don't like, and what you are good at. I have found that my broad background in the sciences has benefited me tremendously in my career—and that started back in high school. What I didn't learn in high school, I had to learn later anyway, and believe me, it will be much harder when you are older.

NOAA scientist Paula Whitfield and NURC diving specialist Jay Styron after a dive during their August 2004 expedition to study lionfish. (Photo credit: Christine Addison)

I wasn't a very good student in high school. I wasn't focused on my schoolwork because I didn't understand how important it would be later on. Also, I was very intimidated by math, or at least I thought I was. I encourage students to get help at the first sign of problems in a math class—get a tutor, a study buddy, or ask the teacher for help. Doing nothing and just trying to struggle though is a big mistake. I know from experience!

For a while, I let my anxiety about math discourage me from pursuing a career in

science. When I got to college, I thought I couldn’t do math or anything that required working with numbers. Later, I realized that I would need to overcome my anxiety if I was going to be a scientist. In the end, I overcame my shaky background in math by seeking help from others and keeping my eye on the goal. Don’t let a fear or deficiency in math or any other subject discourage you from pursuing a career in science!

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The Lionfish Invasion!

For Teachers

- Ideas for the Classroom
- Printable Materials
- Links to Lesson Plans
- Online Resources for Teachers
- National Science Education Standards
- Scilinks Icon Information

An adult lionfish on a coral reef. (Photo credit: Paula Whitfield)

Ideas for the Classroom

Have students or student groups prepare one or more public education programs about invasive species. Encourage students to consider various media, including publications (e.g., flyers, posters or fact sheets), visual publications, videos, drama, music, etc.

Have students write a short essay on why knowledge about invasive species is (or might be) important in their own lives.

Have students investigate possible explanations for the introduction of an invasive species of local or regional concern, and prepare a written report outlining at least one hypothesis that explains how this invasive species was introduced into its non-native habitat. The report should also explain:

- The nature of the invasive species.
- The native range of the species.
- The new, non-native range of the species, as far as it is known.

Learn More:

- Thinking Like a Scientist
- Student Guide
- Take the Quiz!
- **For Teachers**

1. Welcome
   - run-ins with an invader
2. What is an invasive species?
3. Lionfish Invade U.S. Coastal Waters!
4. Is the Aquarium Trade to Blame?
5. Some Lionfish Biology
   - biology fact sheet
6. Can We Stop the Invasion?
7. References

Ask an Expert

Report Lionfish Sightings

- The ecological impact of this species, or its potential impact. For example, has this species or might this species alter the predator/prey relationships of its new environment? Is it likely to be a better competitor than native species, and thus displace them? Might this species introduce new diseases or parasites to its new environment?

- The possible economic impacts of this species, or its potential impacts. Is this species a direct threat to human health?

A good starting point for this research is the online resources in the “Student Guide” section. The “For Teachers” section also has some useful online resources. If possible, have each student or student group choose a different species. Lastly, lead a discussion of student’s research results.

Have students answer one or more of the following questions in a report or an oral presentation:

- Besides lionfish, are there other invasive species in the Atlantic Ocean threatening the ecosystems there?

- Are lionfish, as an invasive species, a problem in other parts of the world? Is the only lionfish invasion in the Atlantic?

- How might global warming affect the invasion of lionfish in the Atlantic?

- How can we increase public awareness of the potential harm to ecosystems done by invasive species such as the lionfish?

- Are there any introduced species that were thought originally to be harmful (invasive), that turned out to be beneficial to the ecosystem?

- Are there other examples of ecosystems that have been affected by invasive species? What were the effects and what solutions were tried? How would these solutions work for the lionfish invasion in U.S. Atlantic waters?

- What is the reproductive rate of lionfish? With no natural predators and based on the current numbers in the Atlantic, how long will it take before lionfish outnumber some of the natural species that live there?

Scientists have speculated that six lionfish were released from a flooded marine aquarium in Florida because of Hurricane Andrew in 1992. At least one of these individuals was seen alive several

days later. Have students speculate about the answers to the following questions, and then generate some hypotheses about how lionfish might have colonized the Atlantic.

- How did lionfish find their way to the Atlantic Ocean?
- Were the released aquarium lionfish the source of the population that lives in the Atlantic Ocean today?
- Why do scientists think that the aquarium trade is the vector for the introduction of lionfish? What kind of evidence would they need to support their hypothesys?

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Printable Materials

Click on the links to view or print for use as handouts. Includes all the text and images of the Web site content.

Chapters (with Glossary):

• The Lionfish Invasion! (pdf, *460Kb*), includes:

- 1. Welcome to *The Lionfish Invasion!*
- 2. What is an Invasive Species?
- 3. Lionfish Invade U.S. Waters!
- 4. Is the Aquarium Trade to Blame?
- 5. Some Lionfish Biology
- 6. Can We Stop the Invasion?
- 7. References
- Glossary

Chapter Supplements:

• Run-ins With an Invader! A Chronicle of Lionfish Sightings in U.S. Waters (pdf, *168Kb*)

• Lionfish Biology Fact Sheet - Microsoft Word text version (*doc, 36Kb*),
Adobe Acrobat version (*pdf, 128Kb*)

Supporting Resources:

• Thinking Like a Scientist (pdf, *232Kb*) - Includes the supplement page: Profile of a NOAA Scientist: Paula Whitfield

• Student Guide (pdf, *140Kb*), Glossary (pdf, *112Kb*)

• Take the Quiz! - Microsoft Word text version (doc, *40Kb*)

• Quiz Answers - Microsoft Word text version (doc, *44Kb*)

• For Teachers (pdf, *100Kb*)

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Links to Lesson Plans

Alien Invasion!
http://oceanservice.noaa.gov/education/classroom/lessons/06_coastal_alien.pdf

For Grades 9-12 (easily adapted for middle school students). This introductory lesson from NOAA's National Ocean Service introduces students to the broad concept of invasive species. Students prepare a written case study on an invasive aquatic species, followed by an oral presentation. The lesson plan provides a list of possible species to choose from, and information about their introduction, impact, and control. Suggestions for extensions are also provided.

Real-Life Aliens: Introduced Species
http://www.actionbioscience.org/lessonaccess/simberloff.html

Advanced/AP High School and undergraduate level. This lesson examines issues stemming from introduced and invasive species. Students can gather statistical information about local invasive species, interview animal and plant inspectors at an international airport, investigate the pet parrot trade, and more.

Aquatic Invaders
http://www.nationalgeographic.com/xpeditions/lessons/14/g68/invaders.html

For Grades 6-8 (easily adapted for lower high school level). In this activity from the National Geographic Society, students explore the ways that native species interact in a healthy Chesapeake Bay. They then learn how exotic and invasive species can threaten the balance of the ecosystem. Students discover how various elements of the Bay's ecosystems are interconnected and investigate some of the issues associated with invasive species.

Venom!
http://www.pbs.org/oceanrealm/intheschool/school3.html

For Grades 9-12. A classroom activity from PBS that is supported by the Secrets of the Ocean Realm episode "Venom!", which

investigates the behaviors of creatures that sting and those that are able to circumvent the use of venom (available from PBS on DVD). In this activity, students learn about the nature of venom and the treatment of envenomation. They conduct an experiment to demonstrate how proteins such as venoms can be denatured. For additional information on ocean creatures that are venomous (including lionfish), see this related Web page from PBS: http://www.pbs.org/oceanrealm/seadwellers/index.html

Discovery School Lesson Plan on Invasive Plants
http://school.discovery.com/lessonplans/programs/galapagos-beyonddarwin/

For Grades 6-8 (easily adapted for grades 9-12; standards given for all grade levels). Students investigate endemic and introduced species in the Galapagos Islands, and observe how one native species has been endangered by an invasive one.

Battlefield Earth
http://www.thirteen.org/edonline/ntti/resources/lessons/battle/index.html

For Grades 9-12. Using the Internet, students research the complications and environmental impact non-native species can have on ecosystems. Students conduct a Web quest to identify other regions of the world that are damaged due to the introduction of non-native species. Students create digitized posters that highlight their particular area of research, and discuss and draw similarities and differences between regions. Finally, students select an indigenous species that has been impacted by a non-native species and devise a population control method for restoring the indigenous species to its natural status in the ecosystem.

Environmental Inquiry: Invasive Species
http://ei.cornell.edu/ecology/invspec/

For Grades 9-12. Two great student field activities: 1) Early Detection Surveys and 2) Plot Sampling: Density. Click on the link titled “Invasion Ecology” at the very bottom of either activity to go to the downloadable student worksheets, peer review forms, assessment rubrics, test questions, background material, links and more.

Growing Native in Your Community/The Power of Invasion
http://www.wildlifehc.org/managementtools/backyard-growingnative.cfm

For Grades 6-8 (easily expanded and adapted for high school students). These three lesson plans from the Wildlife Habitat Council can be used in succession or alone. They introduce students to the concepts of native plant communities and the wildlife that inhabits them. Students study native and invasive

species in the classroom and learn to identify them in the wild. Some exercises can be done in the classroom.

Invasive Species Video and Lesson Plan
http://paipm.cas.psu.edu/invasiveplan.html

For Grades 9-12. This video, hosted and narrated by BugMobile, the famous talking Volkswagen, identifies the effects that people and their activities have on watersheds, explains species diversity, introduces species classified as pests in their new environments, and analyzes the benefits of Integrated Pest Management to the environment and society. Each video includes a lesson plan with pre- and post-tests, discussion questions and suggestions for related activities. There is a cost associated with the videos, but the lesson plans are available for free download at this Web site.

Pushy Plants and Alien Animals
http://www.naturalsciences.org/conservation/invasives/index2.htm

For Grades 6-12. A great interactive exercise on invasive plants and animals geared toward the fauna of North Carolina. The exercise could be adapted for most locations in the southeastern United States.

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Online Resources for Teachers

Invasivespecies.gov
http://www.invasivespecies.gov

This Web site is one-stop shopping for everything you ever wanted to know about invasive species and the gateway to Federal efforts to control them. Learn about the impacts of invasive species and the Federal government's response, read select species profiles, and find links to agencies and organizations dealing with invasive-species issues. Invasivespecies.gov is also the official site for the National Invasive Species Council, which coordinates Federal responses to the problem.

NOAA's National Center for Research on Aquatic Invasive Species
http://www.glerl.noaa.gov/res/Programs/ncrais/ncrais.html

An introduction to the National Ocean and Atmospheric Administration's (NOAA's) National Center for Research on Aquatic Invasive Species. The Center's mission is to understand, prevent, respond to, and manage aquatic species invasions in U.S. coastal ecosystems. The Center's broad goal is to foster, coordinate, and support aquatic invasive species research throughout and across

NOAA.

The Bridge
http://www.vims.edu/bridge/

The Bridge is a growing collection of the best marine education resources available on-line. It provides educators with a convenient source of accurate and useful information on global, national, and regional marine science topics. Resources are organized as indicated on the sidebar on the left side of the screen.

Aquatic Invasive Species: An Educators Information and Materials Guide
http://www.seagrant.umn.edu/exotics/ais_guide.pdf

A compilation of selected educational material on aquatic invasive species for K-12 teachers and informal educators. Entries include curricula, print materials, posters, videos, books, CDs and Web sites.

Invasion Ecology
http://ei.cornell.edu/pubs/ie.asp

Developed by the Cornell Environmental Inquiry Program, Invasion Ecology consists of a student edition and teacher's guide designed to enable high school students to carry out authentic research. By studying non-native invasive species such as purple loosestrife and Phragmites, students will learn about the links between biology and ecology—and explore how scientists are fighting these aggressors with biological controls. Invasion Ecology was published by the National Science Teachers Association.

Case Teaching Notes for "Exotics"
http://ublib.buffalo.edu/libraries/projects/cases/exotics/exotics_notes.html

These case notes examine the biological, ecological, social, political, and economic factors surrounding exotic species, as well as the role of resource managers in shaping public policy on environmental issues. Although aimed at the college level, this is excellent background reading for 9-12 teachers.

USGS—Nonindigenous Aquatic Species Web Site (includes a searchable database**)**
http://nas.er.usgs.gov/default.asp

This Web site is a central repository for accurate and spatially-referenced biogeographic information on nonindigenous aquatic species. It provides scientific reports, online/real-time queries, spatial data sets, regional contact lists, and general information. These data are for use by biologists, interagency groups, and the public. The geographical coverage is the United States.

Global Environmental Change: Introduced Species
http://nsta.tasco1.com/showItem.asp?product=PB138X04&session=F37615A549CE420792971A5EFA692978

Introduced Species is one of four books in NSTA Press's Global Environmental Change series, a joint project of NSTA Press and the U.S. Environmental Protection Agency. Seven inquiry-based activities--using pillbugs, the school grounds, species dispersal maps, and introductory genetics--provide students with the skills they need to address the problem of nonindigenous species.

Aliens in Your Neighborhood: Invasive Species and the National Parks
http://www.nps.gov/invspcurr/alienhome.htm

Aliens In Your Neighborhood is an introduction to the National Park Service's curriculum on invasive plants. It addresses key national strategies and enables students to become working partners with the National Parks System as citizen scientists.

Invasive Species Educational Resources
http://www.invasivespecies.org/resources/

A compilation of educational resources on invasive species and integrated pest management. This Web site is sponsored by the National Science Foundation Center for Integrated Pest Management.

The Impacts of Introduced Species to the United States
http://gcrio.gcrio.org/CONSEQUENCES/vol2no2/article2.html

An easy-to-understand article by Daniel Simberloff, a leading ecologist, about the status and biology of introduced species in the United States. Published in the respected online journal, Consequences: The Nature and Implications of Environmental Change.

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National Science Education Standards

SciLinks, a major product of the National Science Teachers Association (NSTA), identifies Web-based, educationally appropriate science content that provide useful background information to students and teachers. All Web pages cited in SciLinks adhere to rigorous NSTA criteria and have been formally evaluated by NSTA professionals. NSTA members may access this directly from NSTA's SciLinks Web site (www.scilinks.org) through a list of keywords. SciLinks also support most major textbook

publishers and is directly referenced in more than 45 science textbooks, and other publications as well, enabling all teachers and students to access its database of vetted resources.

Below, you will find the SciLinks Web site keywords featured on the SciLinks Web site that are appropriate to the topic of invasive species (*The Lionfish Invasion!*) and the corresponding National Science Education Standards arranged by subject, topic and concept:

SciLinks Keyword

- Subject
  - Topic
    - >Concept

SciLinks Keyword: Invasive Species

• **Subject:** Science in Personal and Social Perspectives

º **Topic**: Natural and human-induced hazards

> **Concept:** **Invasive species destroy ecosystems as surely as chemical pollution or human population growth with associated development. Whether they are called invasive, non-native, alien, exotic, or nonindigenous, introduced species are those that evolved elsewhere and have been purposely or accidentally relocated. Introduced species often find no natural enemies in their new habitat and therefore spread easily and quickly.

SciLinks Keyword: Human Impact

• **Subject:** Science in Personal and Social Perspectives

º **Topic**: Natural and human-induced hazards

> **Concept:** Human activities can enhance potential for hazards.

SciLinks Keyword: Ecology

• **Subject:** History and Nature of Science

º **Topic**: Science as a human endeavor

> **Concept:** ** Ecology is the study of relationships between living things and

their environment.

SciLinks Keyword: Aquatic Biomes

• **Subject:** Life Science

º **Topic**: Populations and ecosystems

> **Concepts:**

All populations living together and the physical factors with which they interact compose an ecosystem.

** Marine ecosystems cover almost three-quarters of the Earth's surface and contain about 97 percent of the Earth's water supply.

****Non Standard Web Page - NSES Concept Correlation:**

Some of the keywords featured in SciLinked publications don't have a perfect fit to the National Science Education Standards. These keywords may rely wholly or in part on customized Standards Concepts. NSTA educators have written these Concepts in the spirit of the Standards, but they don't appear in the official NSES publication.

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Scilinks Icon Information

The icons below are used on NSTA's SciLinks Web site (www.scilinks.org) to identify characteristics of the Web pages in its database. Resources available in *The Lionfish Invasion!* include:

- Lesson Idea
- Online Interactivity
- Graphics / Multimedia
- In the News
- Career
- Core Content
- Assessment