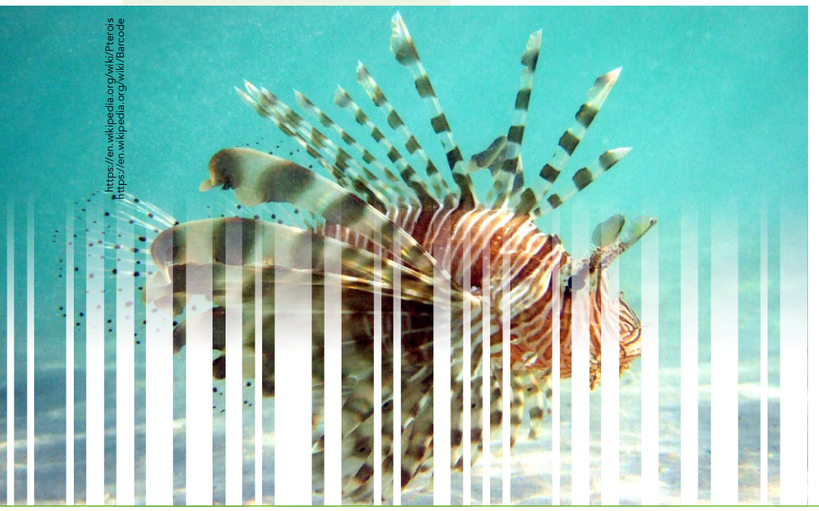
Citizen science DNA barcoding can help solve the riddle of invasive lionfish diet

Invasive lionfish in the Gulf of Mexico are a problem needing a solution, but it is challenging to collect the data needed. DNA barcoding can help by identifying prey species from gut contents. Citizen science can also help by producing data while teaching core scientific concepts to student-scientists. Professor Jeff Eble at Florida Institute of Technology and Professor John Pecore, University of West Florida, combined DNA barcoding with citizen science to form a hands-on learning experience for schools in Florida. Over 1200 students have helped to identify 16 native fish species at threat from lionfish in the Gulf of Mexico.

Conservation issues such as logging or pollution immediately capture our attention as a problem directly visible in our environment. However, some conservation problems, such as invasive species, present more of a challenge as the data needed to solve them is not immediately visible to the naked eye. For example, how do we know if an invasive predator is a problem if we do not know for certain what it is eating? Conservation scientists have used many molecular tools over the years, from microsatellite markers to eDNA, to try and collect the data they need. One such tool is DNA barcoding; this method can show us which species exist in a particular environment, without necessarily needing to observe the whole organism ourselves. Such molecular tools have an invaluable role in modern conservation science in helping to complete a picture not easily seen in nature.



https://en.wikipedia.org/wiki/Pterois
https://en.wikipedia.org/wiki/Barcode

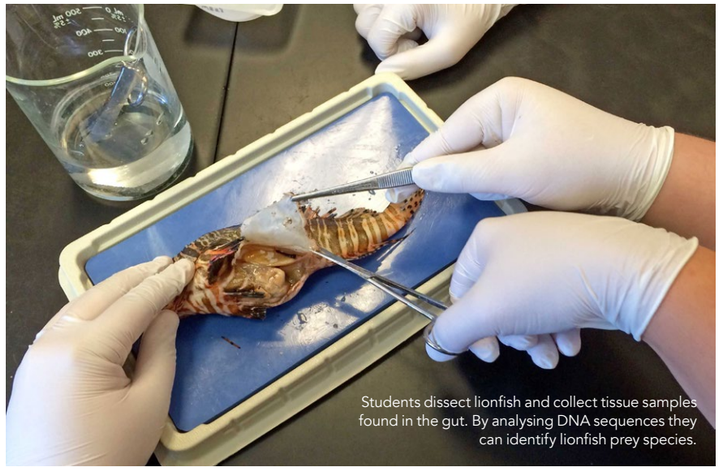
THE DNA BARCODE OF LIFE

When a plant or animal specimen is difficult to identify, either because there is not much of the specimen available, or key features of morphology and behaviour are missing, DNA sequences can be used as another means of identification. DNA is the material inside all living cells, and can be taken from any tissue, such as hair or nail clippings, plant cuttings or in some cases whole guts of a fish. The unique sequences of DNA (base pairs of adenine, guanine, cytosine, thymine, and uracil) in a particular region of the genome can be used as a 'barcode' of identity, in the same way that supermarkets use barcodes to identify each product they sell.

Since 2008, molecular scientists have deposited over 9 million 'barcodes' in The Barcode of Life Database, covering over 300,000 species of animals, plants, fungi, and microorganisms (International Barcode of Life Consortium, 2021). Animal species, such as lionfish, are commonly barcoded using the mitochondrial cytochrome oxidase subunit gene I (COI for short). Such barcodes are currently available for over 22,000 species of ray-finned fishes, making them an ideal resource for discovering exactly what predatory lionfish eat.

THE RIDDLE OF LIONFISH DIET

The Red Lionfish (*Pterois volitans*), which is native to the Pacific and Indian oceans,



Students dissect lionfish and collect tissue samples found in the gut. By analysing DNA sequences they can identify lionfish prey species.

was introduced into the waters near south-eastern Florida in the 1980s. Over the past 30 years it has extended its invasive range from the Caribbean Sea to the Gulf of Mexico (Dahl, 2017). While some introduced species can adapt and settle in a new habitat without creating much disruption to the ecosystem, predatory species like lionfish often cause problems as they inevitably encounter new local prey species that are naïve to the new predator. The naïve prey has no defences, such as instincts to hide, flee, or produce distasteful toxins in their body.

Conservation scientists have been monitoring invasive lionfish diets in the Gulf of Mexico to establish which species they are consuming, and to try and predict the future impact on extant fish populations in this area. However, determining what a whole population of lionfish eats, every day, over time is difficult, requiring many hours of underwater observation or visual examination of the gut contents of captured individuals. Inevitably, these methods provide only a partial picture of the true impact of lionfish on native fish communities. Scientists have used COI barcoding to fill in the gaps of unidentifiable prey recovered from the guts of captured lionfish. So far, the COI barcode has identified over 40 species of prey, in some cases doubling the previous estimates identifiedd by visual examination alone (Dahl, 2017). However, to form a longer-term picture, more data is needed.

While some introduced species can settle in a new habitat without creating much disruption to the ecosystem, lionfish often cause problems as they inevitably encounter naïve prey species.

SCIENCE FOR STUDENT-SCIENTISTS

Professor John Pecore from the University of Florida and Jeff Eble, Visiting Research Professor from the Florida Institute of Technology have brought lionfish DNA barcodes into the classrooms of school students in a citizen science project, funded by a University of West Florida Pace Academic Development Grant. The project has been established in multiple local schools with the aim of providing an authentic laboratory experience as a teaching method to understand broader concepts in ecology, evolution, genetics, and conservation.

In a five-part series of laboratory sessions under the tutelage of professional scientists from the Gulf Islands Research and Education Center, middle and high school students have produced the DNA barcodes that are helping to identify the prey items of lionfish in the Gulf of Mexico. For their part, students gain hands-on experience of advanced biotechnology, such as DNA extraction, Polymerase Chain Reaction (PCR), and analysis of sequencing data. In return, the scientists gain valuable data to solve the riddle of the invasive lionfish diet. Perhaps most importantly, students and scientists alike also practice one of the most important aspects of scientific research – interpretation and presentation of their findings to an audience in the form of reports, posters, school talks, and even newspaper interviews – making the experience more complete and personally engaging for everybody involved.

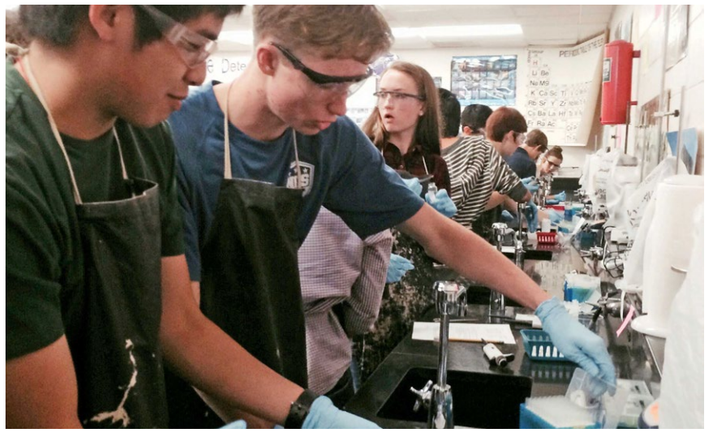
THE STORY SO FAR

To date, over 1200 students in 7 Florida schools have engaged in the Lionfish prey DNA barcoding citizen science project, with demonstrated

benefits to learning, such as increased understanding and enthusiasm for science and biotechnology, and even reduced anxiety over science (Eble & Pecore, 2019).

Some important findings from the project include the revelation that lionfish are much more generalist predators than previously thought – in one case consuming up to 16 different prey species. The students also identified the most abundant prey items as Vermillion Snapper and Round Scad, which are species targeted by the local commercial and sport fishermen.

In producing DNA barcodes of lionfish prey, citizen scientists are solving a significant piece of this conservation riddle.



Over 1200 students in 7 Florida schools have engaged in the Lionfish prey DNA barcoding project.

This contribution highlights a potential conflict between the invasive lionfish and local economic interests.

Another fascinating finding was a high degree of apparent cannibalism, as red lionfish were themselves among the 'prey' species identified, which is not common in conspecifics in their native Pacific habitats (Albins & Hixon, 2013). In other studies, DNA barcoding of lionfish diets significantly improved the catalogue of prey species and abundance in an otherwise unidentifiable major portion of gut contents (Dahl, 2017). Therefore, in producing DNA barcodes of lionfish prey, citizen scientists are solving a significant piece of this conservation riddle.

WHAT DOES THE FUTURE HOLD?

With the pilot phase complete, teachers and students continue to produce valuable DNA barcode data to improve understanding of invasive lionfish, although the protocols could easily be adapted to other scientific projects involving marine fish. Future projections of the impact of continued lionfish invasion are concerning; therefore, unique experiences of science, through citizen science project such as these, might be one route to fostering long-lasting student engagement with conservation science.

Q&A

Interviewee: Edward Bauer, Director of the Marine Science Academy at B. T. Washington High School (Florida, USA)

1. How do you think the lionfish DNA Barcoding project has influenced your students' perception of scientists and how we solve problems, e.g. the perception of science as 'too difficult' or 'not for people like me'?

The Marine Science Academy is an academic honours programme, so most students here are not intimidated by science. But the idea of doing hands-on research is foreign to many of my students. With the lionfish DNA barcoding project, the students are immersed in the whole scientific process, including presenting their research to local scientists and the community. This is perhaps what makes students the most nervous, because they feel like they don't know that much about the topic – but they gain more confidence during the project, and eventually they become experts.

The programme also gives students the opportunity to experience what fieldwork is all about. Many enjoy doing this hands-on work, but others come back to me and say they enjoy lab work much more than being out in the field. They also learn that there are failures and challenges in science, I think that is a very valuable lesson. Sometimes we grow more through our failures than we do when things go right. When they go on to college, they have a much better idea of what they want to do, and many of my former students are now pursuing science degrees.

2. Have you had any surprising developments from engaging students with a citizen science project?

I am pleasantly surprised by my students all the time! When they come to me with questions and I realise they really have a deep understanding of the process, that is awesome to me. They would often propose a new method or way of doing things that I hadn't thought about before. They are teaching me as well!

3. How did the DNA lionfish barcoding project come about? Have you been inspired to engage with other citizen science projects?

Dr Eble initially contacted me 8 or 9 years ago because he heard of the citizen science projects I was working on with my students. We then talked about his DNA barcoding idea and put together the lionfish project which we continued doing year after year. He was very instrumental, organising a workshop for teachers and pulling a bunch of different organisations together to collaborate. We are currently building a database of all the lionfish prey species we identified. There are also several other environmental studies we are working on right now, including Bringing Back our Bayous and the Shannon Diversity Study.

Behind the Research

Dr Jeff Eble

E: jeble@fit.edu **T:** +1 508-237-9551
W: https://www.fit.edu/faculty-profiles/e/jeff-a-eble/

Dr John Pecore

E: jpecore@uwf.edu **T:** +1 850-474-2303
W: https://bit.ly/3qlPXHn

Research Objectives

Drs Pecore and Eble have developed DNA barcoding protocols that allow high school and middle school students to investigate the impacts of invasive lionfish on native fish communities.

Detail

Address
Jeff Eble
Florida Institute of Technology
Ocean Engineering and Marine Science
150 W. University Blvd.
Melbourne, FL 32901

John Pecore
University of West Florida
Ocean Engineering and Marine Science
11000 University Pkwy
Pensacola, FL 32514

Bio

Dr Jeff Eble is a Visiting Research Professor at Florida Institute of Technology, Melbourne. His research investigates the evolution and conservation of marine biodiversity. Most recently this has included evaluating the use of environmental DNA to characterise biodiversity across trophic levels.

Dr John Pecore is Professor at the University of West Florida. His research focuses on innovative ways to engage students in science. Dr Pecore's scholarly interest includes situating learning in contextualised experiences with an emphasis in project-based learning and instruction. He has written about progressive education, experiential learning, teaching practices, and science standards.

Funding
University of West Florida Pace Academic Development Grant

Collaborators
Rick O'Connor, Capt. Andy Ross, Gulf Islands National Seashore, Charlene Mauro, Navarre Beach Marine Science Station, Booker T. Washington High School, Escambia High School, Gulf Breeze High School, Navarre High School, Pensacola High School, West Florida High School, Woodlawn Beach Middle School

References

Albins, A. and Hixon, M. (2013). Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities. *Environmental Biology of Fishes,* 96, 1151-1157.

Dahl, K., Patterson W., Robertson, A., and Ortmann, A. (2017). DNA barcoding significantly improves resolution of invasive lionfish diet in the Northern Gulf of Mexico. *Biological Invasions,* 19, 1917-1933.

Eble, J. and Pecore, J. (2019). The *American Biology Teacher,* 81(3), 169–174. Available at: https://doi.org/10.1525/abt.2019.81.3.169

International Barcode of Life Consortium. (2021). Available at: https://ibol.org/about/dna-barcoding/ [Accessed May 2021]

College of Education and Professional Studies
UNIVERSITY of WEST FLORIDA

FLORIDA TECH

Personal Response

Your collaboration brings together two very different fields of research – what made you team up?

As a research biologist and a STEM education researcher, we both have a passion for fostering an appreciation for science and empowering students to be leaders in conservation. We've seen how citizen science projects can help to advance student understanding of research methods and scientific thought while also encouraging support for environmental causes. And we've learned that creating sustainable citizen science projects requires a strong team that includes a research scientist with a suitable project, one or more teachers with aligned curriculum, and a university teacher educator to foster both the needs of the research scientist and the teachers.