Flowing Forward: Advancing Eel Conservation Through Technology and Community Science

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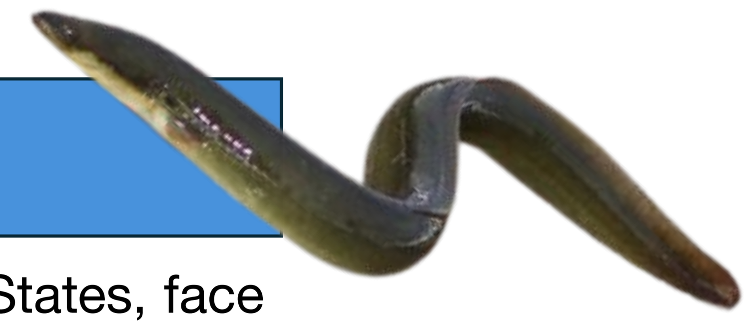

Introduction

Eel populations, particularly *Anguilla rostrata* in the northeastern United States, face a range of environmental and anthropogenic pressures that influence their behavior, distribution, and abundance.[1] This past summer, Project True students conducted research on eels in the Bronx River at two locations: Twin Dams at the Bronx Zoo and the 182nd Street Dam at River Park. They evaluated how the river's water quality impacts macroinvertebrates and the abundance of *A. rostrata*.[2] The current studies build on this summer's work, further investigating the factors influencing eel populations. This collection of three interrelated research projects explores the challenges and methodologies associated with understanding and tracking eel populations in the Hudson River and New York State (NYS) over the past decade (2014-2024).

Monitoring and Conservation

This year, we have continued our long-standing partnership with the NYC Parks Department to monitor eel populations within the Fishway Dam. These monitoring projects play a crucial role in protecting the species by identifying early signs of low abundance and enabling timely interventions. Additionally, long-term monitoring helps us track population trends, such as the specific eel life stages present at the dam during different times of the year, thus contributing to our understanding of the behavior and ecology of these elusive creatures. The three studies presented provide insights that can improve monitoring and conservation efforts.

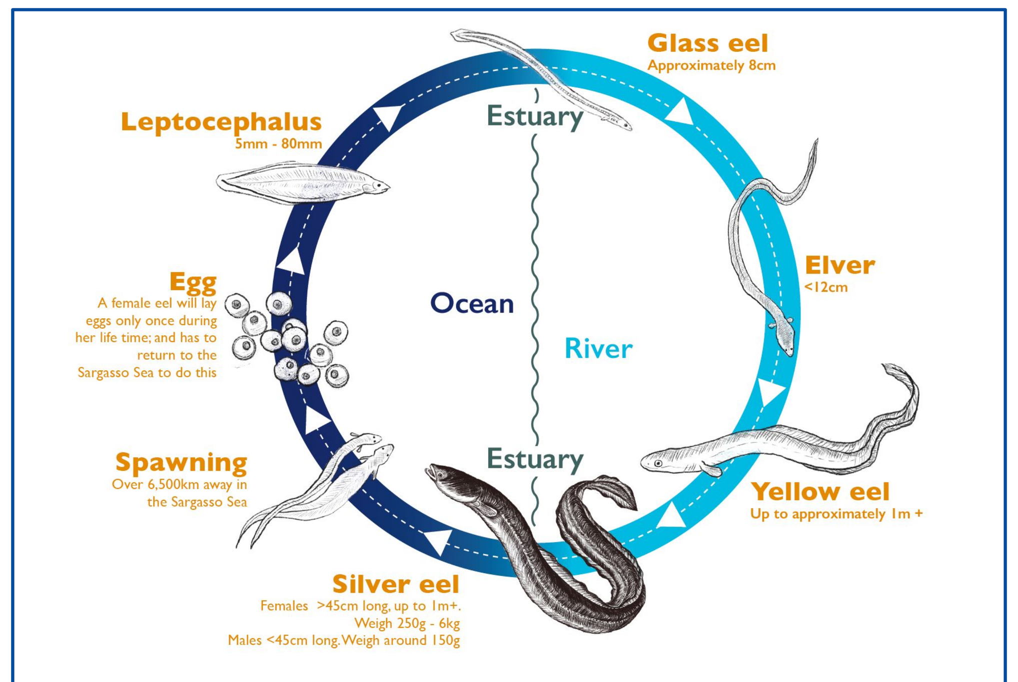

Figure 1. *(left)* Stages of the American eel over the course of their lives, beginning at the egg stage.[3]

Image 1. *(right)* Project True Mentee holding a silver eel caught while electrofishing during the 2024 Summer Session.
Photo Credit: Yandel Ramirez

Project Focus Areas

Collectively, these projects aim to provide a comprehensive understanding of the spatial and temporal dynamics of eel populations. There is a strong emphasis on the importance of technological advancements and community-based monitoring in eel conservation and research. Altogether, the findings from these studies highlight how environmental changes and data collection methods impact our understanding of eel ecology. This is crucial for developing educated conservation strategies in the face of ever-present environmental challenges.

Eel-ing the Pressure: The Effects of Salinity and Temperature on Juvenile Eel Abundance in the Hudson River

Sanaii Wilks & Ava Lopez

Question: How does the water temperature from 2014-2024 and salinity from 2016-2024, during winter and spring affect eel abundance at the Hudson River?

Hypothesis 1: As water temperature increases, glass eel abundance decreases and elver eel abundance increases

Hypothesis 2: As salinity increases, glass and elver eel abundance increases

Eel-Volved Science: Assessing Citizen Science in Observing Eel Stages

Stephanie Galva Feliz & Luna Langford

Questions: How do the stages of *Anguilla rostrata* observed on iNaturalist differ between the years 2019 and 2024 in New York State? Additionally, what is the correlation between the number of observers reported annually and the quantity and quality of these observations?

Hypothesis 1: As the years progress and the eels from 2019 develop, more later stage eels will be observed.

Hypothesis 2: The quantity of iNaturalist eel observations will increase due to the growing recognition of the importance of community research.

Tracing the Untraceable: A Comparative Review of Eel Tracking Methods

Yandel Ramirez & Raihan Bhuiya

Questions: How does the success rate of peer-reviewed eel studies from 2017 to 2022 vary based on tracking method and duration? Which eel species were most frequently studied in these papers?

Hypotheses: Among peer-reviewed eel studies from 2017 to 2022, *Anguilla rostrata* will be the most frequently studied species. Acoustic telemetry will exhibit the highest success rate among the various tracking methods, demonstrating greater reliability and effectiveness in tracking eel migrations over extended durations.

Acknowledgments

This study was made possible due to generous support from The Pinkerton Foundation, the New York City Science Research and Mentorship Consortium, and the Wildlife Conservation Society. I would also like to thank Max Falkenberg and Lowell Iporac for their unwavering support.

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Eel-Volved Science: Assessing Citizen Science in Observing Eel Stages

Stephanie Galva Feliz and Luna Langford
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Introduction

Anguilla rostrata, often known as the American eel, is an endangered catadromous fish whose presence is crucial to the equilibrium of freshwater ecosystems. *A. rostrata* regulates the population of other organisms such as macroinvertebrates in addition to serving as food for large fishes and birds.

A. Rostrata life cycle begins in the Sargasso Sea where they spawn as eggs. Once entering the leptocephalus stage, they travel oceanic currents and reach estuaries along the east coast of the United States as glass eels. After migrating upstream as elvers, and spending most of their life in the yellow eel stage, they undergo physical changes in preparation to return to the Sargasso Sea to spawn as silver eels. As an endangered species, scientists have sought alternative methods of researching eels and working towards their conservation; one of which being citizen science.

Citizen science involves collecting data through community observations to gather a wide variety of information. iNaturalist, like many citizen science resources, enable users to upload images of various species, which are then verified and made accessible to the public. Such data offers insights on biodiversity and relative abundance of species in specific regions, allowing for the visualization of population changes over time.[1] Prior research indicates that many iNaturalist users who report eel sightings reside along the east coast of the United States.[2] It has also been shown that glass eels are the most observed stage during January - March due to colder environmental conditions, which are optimal for glass eels.[3] However, there lacks information regarding what the most common eel stages reported on community science platforms and the frequency of activity observers. The present study aims to address this gap by studying the stages of eels reported on the community science platform iNaturalist and the activity of observers within New York state.

Methods

Data was collected by downloading research grade iNaturalist observations for 2019-2024 in New York State. Each iNaturalist observation contains an image of the eel reported, which were individually analyzed and identified for life stage. Each search was filtered by year in order to view the individual quantity of observers, observations, and eel stages. Once downloaded, this data was inserted to a Google Sheet ascending by year containing each observation and image link alongside the total quantity of observers and observations that year. It was then converted to graphs using pivot tables in order to assess trends in life stages, observer quantity, and yearly observations.

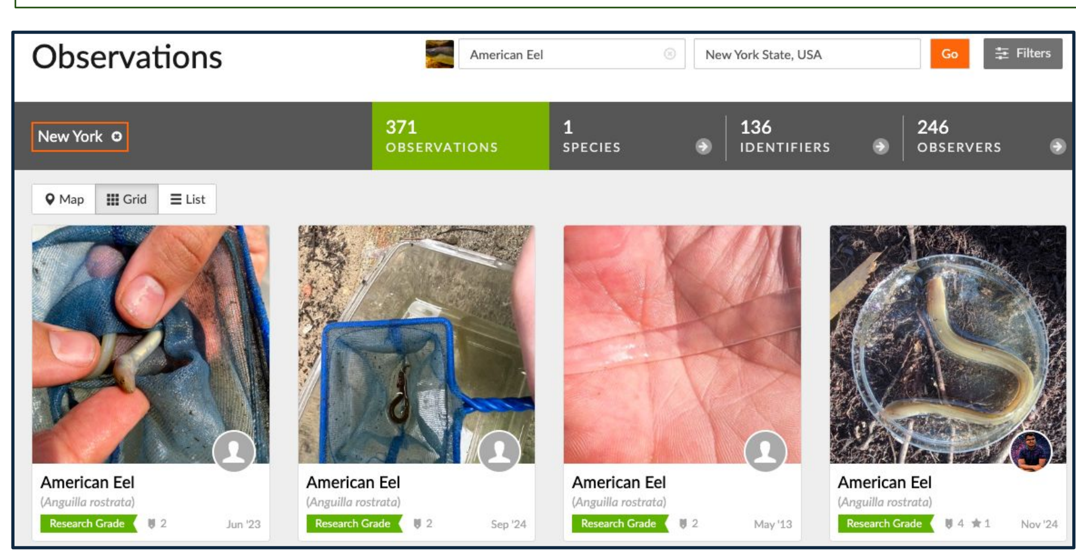

Image 1. Search results for *A. rostrata* submissions from New York State on iNaturalist.

Abstract

The American eel (*Anguilla Rostrata)* is an endangered catadromous fish whose conservation has recently been supported through the growing usage of community science involvement. This study uses iNaturalist to assess the changes in American eel abundance per life stage in New York State from 2019 to 2024. Data was collected from iNaturalist by downloading research grade observations from each year. The lifestage of the eel from each iNaturalist observation was recorded and assessed individually. Google Sheets was used for data analysis and visualization. There was a direct correlation between the number of active iNaturalist observers and the number of submitted observations. As the number of observers increased, so did the number of submissions. In 2023, glass eels experienced a notable spike whilst the number of elver observations fluctuated, that of yellow eels increased, and silver eels underwent a slight decrease.

Questions and Hypotheses

Questions: How do the stages of *Anguilla rostrata* observed on iNaturalist differ between the years 2019 and 2024 in New York State? Additionally, what is the correlation between the number of observers reported annually and the quantity and quality of these observations?

Hypothesis 1: As the years progress and the eels from 2019 develop, more later stage eels will be observed.
Hypothesis 2: The quantity of iNaturalist eel observations will increase due to the growing recognition of the importance of community research.

Results and Figures

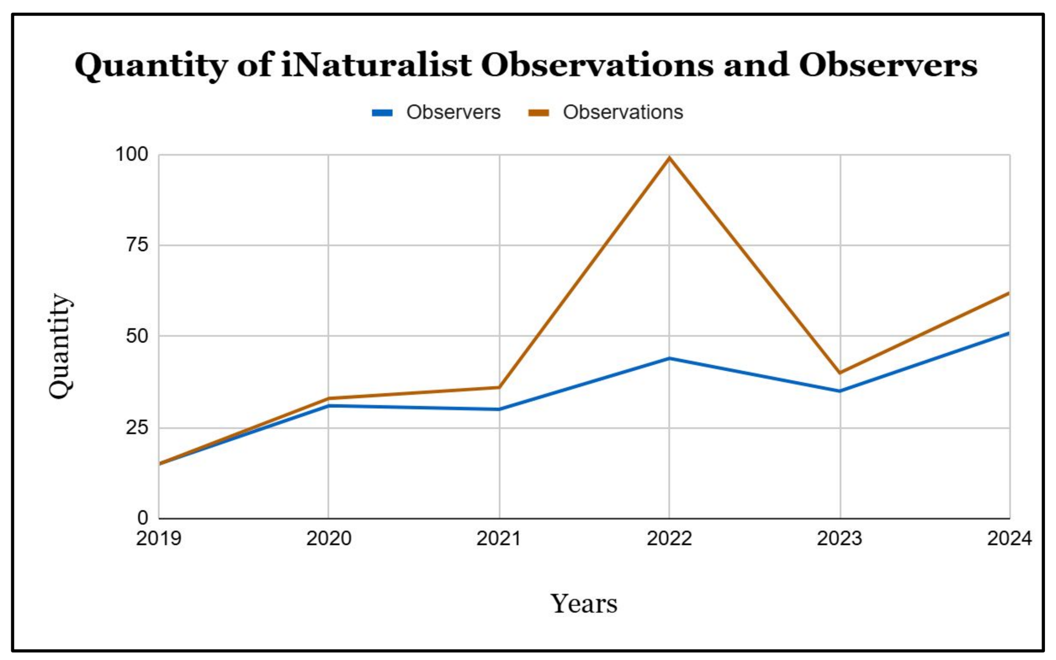

Figure 1. The number of New York State observations versus observers between 2019 and 2024.

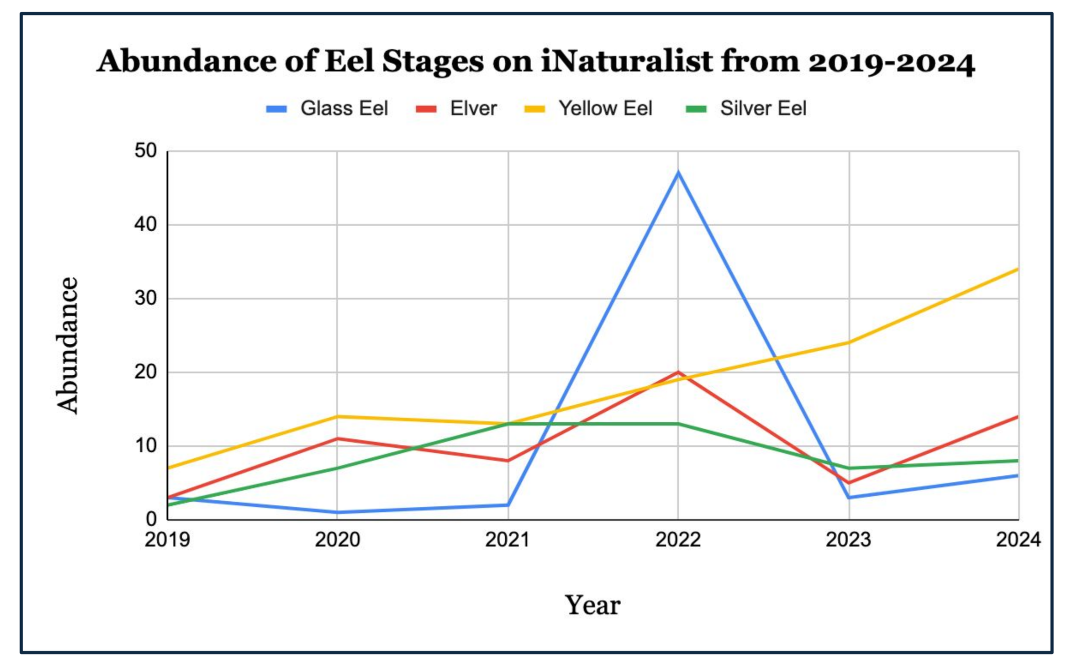

Figure 2. Visualization of Figure 2. The relative abundance of eels at each stage in New York State, based on iNaturalist submissions.

	Glass	Elver	Yellow	Silver
2019	3	3	7	2
2020	1	11	14	7
2021	2	8	13	13
2022	47	20	19	13
2023	3	5	24	7
2024	6	14	34	8
Total	62	61	111	50

Figure 3. The yearly count of eels observed at each stage and the grand total number of eels per stage from 2019-2024.

Summary of Results

The number of observers and observations showed some correlation, following similar trends over a six-year period. In 2022, both reached a notable spike, with observations peaking at 90, these results were significantly higher compared to previous years. From 2019 to 2024, the number of observers steadily increased, while observations also rose consistently from 2019 to 2021 (**Fig. 1**). However, there was a sharp increase in observations between 2021 and 2022, followed by a rapid decline in 2023. Despite a sharp decline in both observers and observations between 2022 and 2023, both factors rebounded in 2023-2024. The abundance of glass eels mirrored this pattern, peaking at 47 observations in 2022, compared to the typical 2-6 observations in the previous years (**Fig. 3**). While the yellow eel population showed a steady increase, both elver and silver eel abundances fluctuated (**Fig. 2**).

Discussion and Conclusion

These findings indicate fluctuations in abundance of eel stages from 2019 to 2024. Contrary to the first hypothesis, silver eel numbers decreased, while yellow eel numbers increased (**Fig 2**). Glass and elver eels from 2019 were anticipated to develop into yellow and silver eels by 2024, but this likely did not occur due to the migration of silver eels to the Sargasso Sea. Additionally, the expected increase in elvers as glass eel numbers decreased was not observed, as both stages collectively increased and decreased between 2021 and 2023. This may be due to their similar temperature preferences (glass eels ~16°C, elvers 10°C-29°C).[4] Future research should examine how water temperature affects eel development and abundance.

Furthermore, these findings indicate a correlation between iNaturalist observations and the number of observers (**Fig. 1**). This finding partially supports the second hypothesis since the lines for both observations and observers increase together; however it also decreases together, which is not accounted for in the hypothesis. Despite a decline in observers from 2020 to 2021, active users, particularly in coastal areas, likely influenced the slight increase in number of observations.[5] Additionally, the sudden decrease in observers and observations from 2022 to 2023 contradicts the hypothesis, as a continuous upward trend was expected due to increased environmental awareness and internet access amongst citizens. Future research should explore the relationship between the specific location of data collection and number of observations to understand which communities in New York state are particularly involved in community science practices.

Acknowledgments

We thank The Pinkerton Foundation and the Wildlife Conservation Society for their generous support. We would also like to thank Max Falkenberg and Dr. Lowell Iporac.

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Tracing the Untraceable: A Comparative Review of Eel Tracking Methods

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Introduction

Eel migration, spanning freshwater and marine environments, is highly complex. Anguilla's genus travels long distances (**Fig. 1**) to obscure spawning grounds. As populations decline due to overfishing, habitat loss, and climate change, understanding their migrations is crucial for conservation and fisheries management[1].

Researchers have employed various tracking technologies (**Fig. 2**) to uncover eels migratory patterns. Acoustic telemetry, satellite tags, and archival data loggers have been developed to track eels' movements across different spatial and temporal scales.

Acoustic telemetry uses sound waves and underwater receivers to track aquatic animal movements[2]. PSATs (Pop-up Satellite Archival Tags) gather depth, temperature, and location data, detaching and transmitting information via satellite[3]. Pop-off data storage tags, or PDSTs, capture location information and send data when the tag comes into contact with the surface (**Fig. 5**)[4].

This review critically assesses methodologies adopted in the recent literature concerning eel migrations. It further compares the success rates of different tracking methods regarding transmitter longevity. By assessing the various methods applied in regard to their effectiveness and limitations, this review hopes to identify the most reliable method to study eel migration with a broader objective of enhancing current eel conservation efforts.

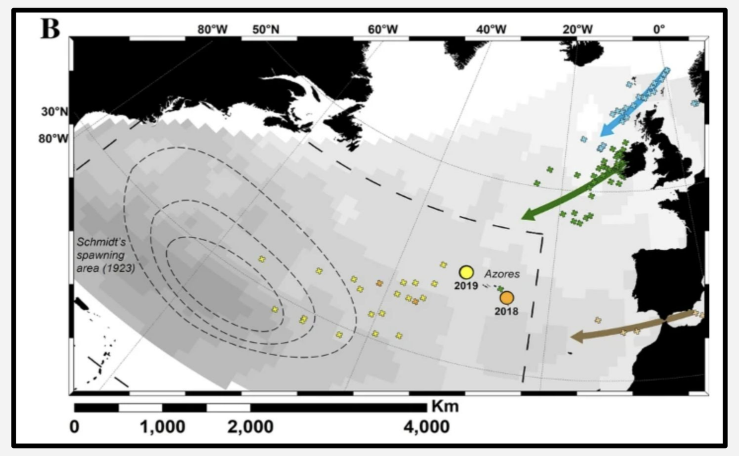


Figure 1: Map showing eel migration patterns.[5]

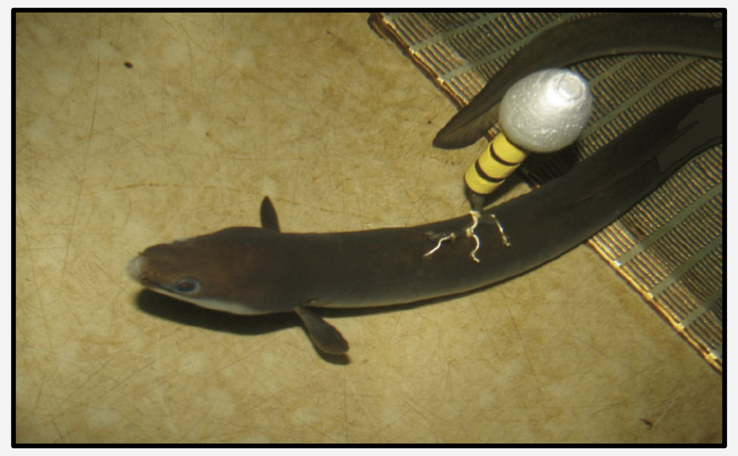


Figure 2: Pop-up satellite tag on an Eel.[6]

Methodology

Studies were identified using three primary databases, Google Scholar, Fordham University's OneSearch, and Web of Science. These platforms provided a broad and diverse range of sources, ensuring a thorough collection of relevant literature for this study. From this search, 42 studies were selected based on their focus on eel tracking methods and the availability of data on tracking success rates. For each study, key information was extracted, including the type of tracking method used and the eel species tracked. The tracking methods that our literature review focuses on were acoustic telemetry, pop-up satellite archival tags, and pop-up data archival tags, because they are not passive and provide a plethora of information. We aimed to look at a diverse range of species, which included *Anguilla anguilla, Anguilla australis, Anguilla bicolor pacifica, Anguilla celebensis, Anguilla dieffenbachii, Anguilla japonica, Anguilla marmorata, Anguilla rostrata*.

The success rates of each method were calculated manually for each study. We did this by taking the number of eels that retained the tracker during the study period, and by dividing it by the total eels tagged. This success rate value allowed for a detailed and standardized comparison of tracking effectiveness across studies.

The success rates for each tracking method were then analyzed and visualized using box plots created with Rstudio. These plots were designed to display the distribution of success rates for each method and account for any variability or potential sources of error.

Abstract

Eel migration has remained one of the most mysterious processes in aquatic biology, particularly for the American eel (*Anguilla rostrata*), which has faced severe population declines due to overfishing, habitat destruction, and climate change. During our summer with Project TRUE at the Bronx Zoo, we helped monitor eel populations in the Bronx River, to highlight the challenges of studying these elusive creatures. We recognized a gap in the literature on eel tracking methodologies, so our project aimed to evaluate and compare tracking methods like acoustic telemetry and satellite tags from studies since 2017. We hypothesized that advancements in tracking technology had improved eel studies, with acoustic telemetry being the most efficient, but we expected satellite telemetry to surpass it eventually. We reviewed 42 studies from various sources, focusing on eel species like *Anguilla rostrata*. Data were analyzed using Google Sheets and R Studio to evaluate the reliability and success rates of tracking methods for eel migration, including acoustic telemetry, satellite tags, and archival data loggers. In the end, acoustic telemetry emerged as the most effective method; we found it had higher median success rates and lower variability across studies, as visualized through statistical box plots. This study aimed to enhance understanding of eel migration, supporting conservation efforts, and informing fisheries management policies, building on our work with Project TRUE.

Research Questions & Hypotheses

Research Questions:

1) How does the success rate of peer-reviewed eel studies from 2017 to 2022 vary based on tracking method and duration?
2) Which eel species were most frequently studied in these research articles?

Hypotheses:

1) Among peer-reviewed eel studies from 2017 to 2022, *Anguilla rostrata* will be the most frequently studied species.
2) Acoustic telemetry will exhibit the highest success rate among the various tracking methods, demonstrating greater reliability and effectiveness in tracking eel migrations over extended durations.

Graphs & Figures

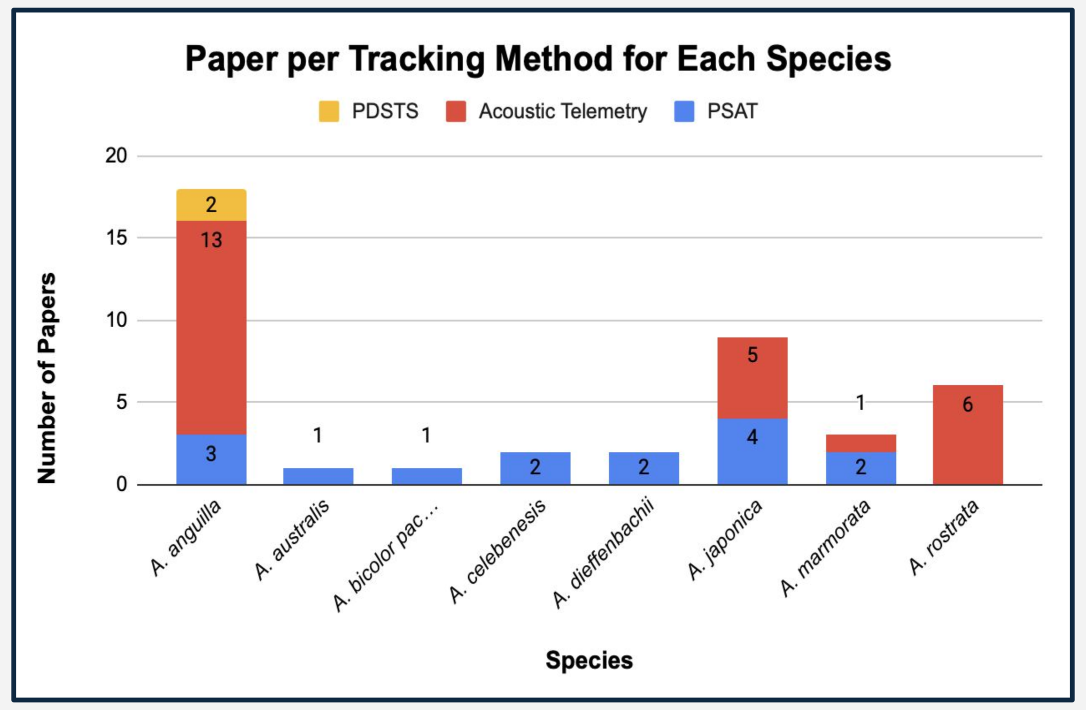


Figure 3: Number of papers analyzed for each tracking method for different eel species. *A. Anguilla, A. Australis, A. Bicolor Pacifica, A. Celebenesis, A. A.dieffenbachii, A. Japonica, A. Marmorata, A. Rostrata.*

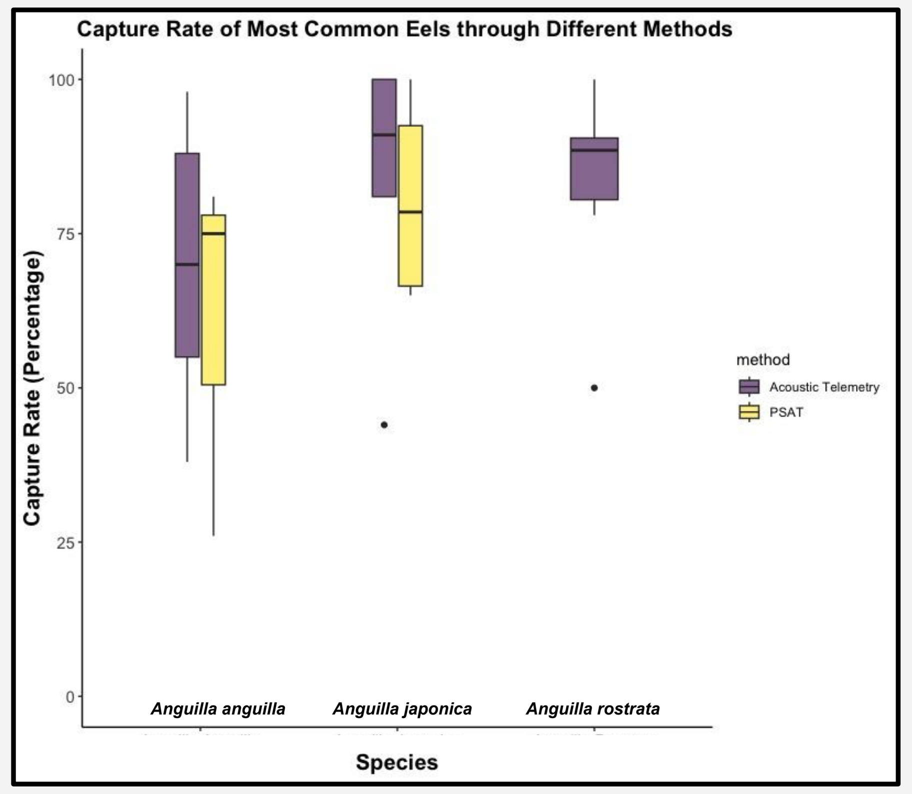
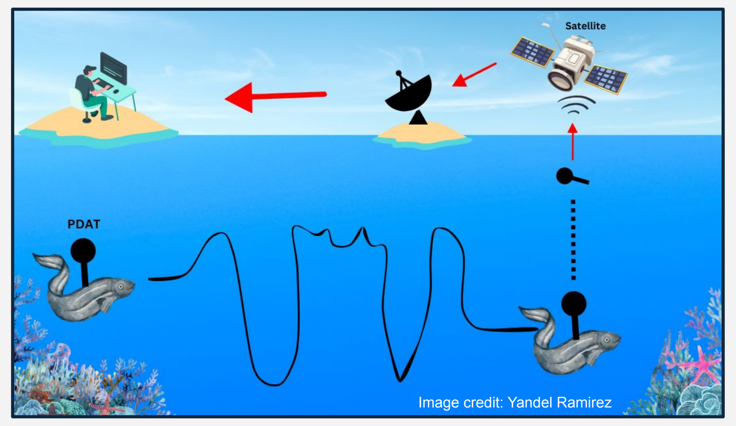


Figure 4: Success rates of methods, including PSAT, acoustic telemetry, and PDSTs, across different eel species. These species were analyzed as they were the most mentioned in the papers examined.

Results

Among the tracking methods analyzed, acoustic telemetry demonstrated higher success rates, particularly for *Anguilla anguilla, Anguilla japonica,* and *Anguilla rostrata,* with most rates exceeding 75%. Success rates were measured by the percentage of tags that provided consistent and usable data without significant limitations, such as early tag failure or insufficient tracking duration. In total, 42 studies were examined, 24 utilized acoustic telemetry, 13 used PSATs, and the remainder employed other methods. For *Anguilla anguilla,* 13 papers employed acoustic telemetry (compared to 2 using PSATs (**Fig. 3**). *Anguilla japonica* was studied in 9 papers, with 5 using acoustic telemetry and 4 using PSATs. For *Anguilla rostrata,* 6 studies utilized acoustic telemetry. PSAT methods generally showed lower success rates and higher variability across species.

Figure 5: The PDAT records eel movement and surrounding environmental data. Once the tracking period ends, the tag detaches, surfaces, and transmits the collected data to a satellite which can then be transferred to a database for further analysis.



Discussion

The results indicate that the tracking method most frequently employed for eel species is acoustic telemetry, which yields the highest success rates. A. Anguilla, A. japonica, and A. rostrata exhibit rates of 75% or more **(Fig. 4)**. The frequent use and reliability of acoustic telemetry are due to its durability and precision across diverse aquatic environments. In contrast, the PSAT method showed lower and more variable success rates, likely due to detachment issues or difficulties retrieving data from deep-sea environments. These findings support our second hypothesis: acoustic telemetry has the highest success rate for long-term monitoring. The initial prediction that Anguilla rostrata would be the most researched species, however, was not supported. A. rostrata was the focus of several investigations. Nonetheless, A. anguilla and A. japonica were also looked at significantly, indicating a wider interest in other species from different regions. This study highlights the importance of reliable tracking methods in understanding eel migration patterns and supporting conservation efforts by identifying key trends and challenges, such as limited databases and anthropogenic interferences. Future research should explore other variables that may affect eel tracking and expand its reach of sources.

Acknowledgements

This study was made possible due to generous support from The Pinkerton Foundation, the New York City Science Research and Mentorship Consortium, and the Wildlife Conservation Society. We would also like to thank Max Falkenberg and Dr. Lowell Andrew Iporac for their help.

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Given the large number of scientific articles used in this review, all cited sources can be accessed by via the QR code or the attached reference list.

Eel-ing the Pressure: The Effects of Salinity and Temperature on Juvenile Eel Abundance in the Hudson River

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Introduction

The *Anguilla rostrata*, also known as the American eel, starts its life in the Sargasso Sea and follows a catadromous cycle, moving to areas of freshwater to grow and develop before returning to the sea to reproduce and continue the cycle.[1] However, over the past few years, the American eel population has decreased drastically.

The International Union of Conservative Nature (IUCN) recently classified eels as an endangered species in 2014.[2] During the third and fourth stage of an eels life, known as the glass and elver stages, some American eels migrate to the Hudson River.[3] The increase in salinity in the river has led to increase in food availability, and has also resulted in growth rate changes for both elver and glass eels.[4] However, glass eels are very sensitive to temperature changes, which has also altered their growth and population rates; the ideal temperature for glass eels is 16.5°C.[5] Although previous research addresses how temperature and salinity affects the growth rate of glass and elver eels found in various freshwater areas, the effects on glass and elver eels that migrate through the Hudson River is left unexplained. The relationship between eel abundance and the rates of salinity and temperature in the Hudson river was explored in this study to determine if there was a correlation in the data collected from 2014 to 2024.

Fig. 1: American eel in glass stage

Fig. 2: American eel in elver stage

Methodology

The Center for the Urban River at Beczak (CURB) collected data on eels and other water metrics within the Hudson River, which was gathered from 2014 to 2024.[6] Data was extracted from their publicly available website and the all data was imported into Google Sheets for analysis. The data was used to create charts containing salinity, temperature, glass eel and elver eel populations from 2014 to 2024. The charts were then exported to Microsoft Excel to create a pivot table, which generated 4 graphs. The graphs compared the rates of temperature and salinity to the abundance of glass and elver eels per year.

Abstract

American eels are diadromous fish, meaning they have the ability to live in both saltwater and freshwater areas. Most fish are unable to survive in these conditions due to the salinity rates within the water. The American eel has varied distribution throughout its life, with its population spreading out after migrating from the Sargasso Sea to freshwater habitats. From 2014 to 2024, data was collected from the Center for the Urban River at Beczak (CURB), located on the Hudson River. Temperature, salinity, and eel abundance were collected and converted to graphical form to observe potential correlations between salinity and temperature on glass and elver eels. The results indicated that there was a correlation between abundance of glass and elver eels, and their populations showed a relationship to the amount of salinity and the temperature fluctuating within the Hudson River.

Research Questions & Hypotheses

Question 1: How does the water temperature from 2014-2024 and salinity from 2016-2024, during winter and spring affect eel abundance at the Hudson River?

Hypothesis 1: As water temperature increases, glass eel abundance decreases

Hypothesis 2: As water temperature increases, elver eel abundance increases

Hypothesis 3: As salinity increases, glass and elver eel abundance increases

Results & Figures

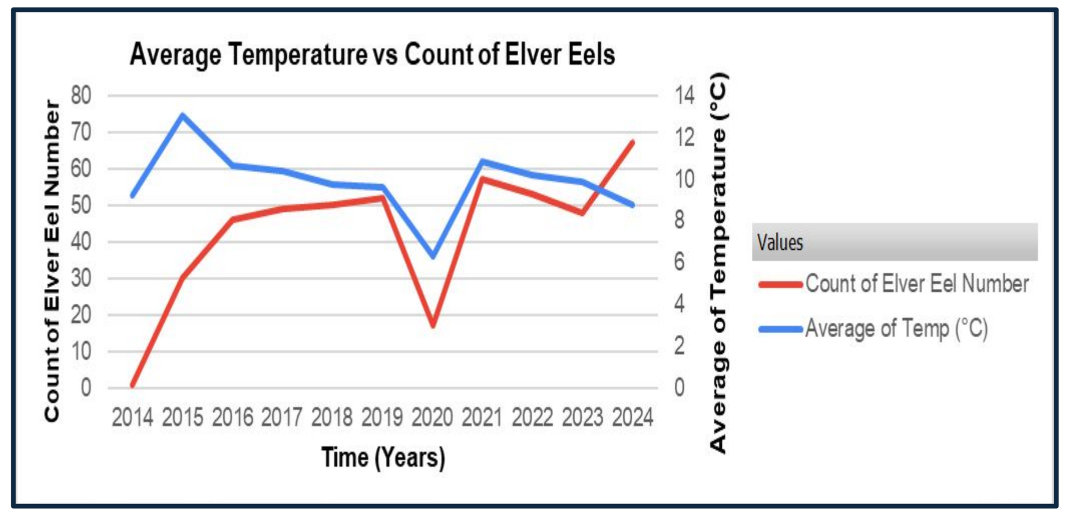

Fig. 3 represents the change in elver eel abundance from 2014 to 2024 in relation to the mean water temperature.

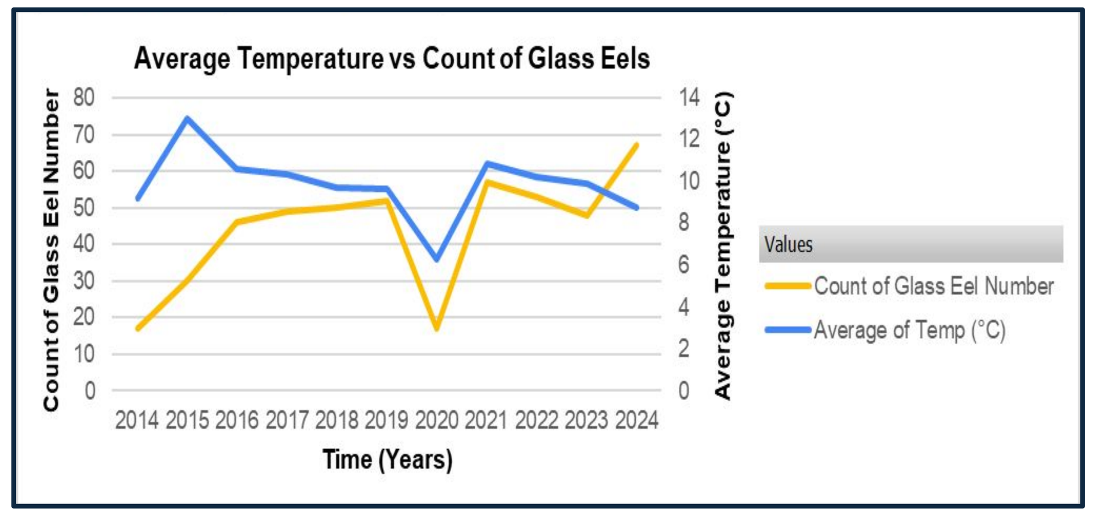

Fig. 4 represents the change in glass eel abundance from 2014 to 2024 in relation to the mean water temperature.

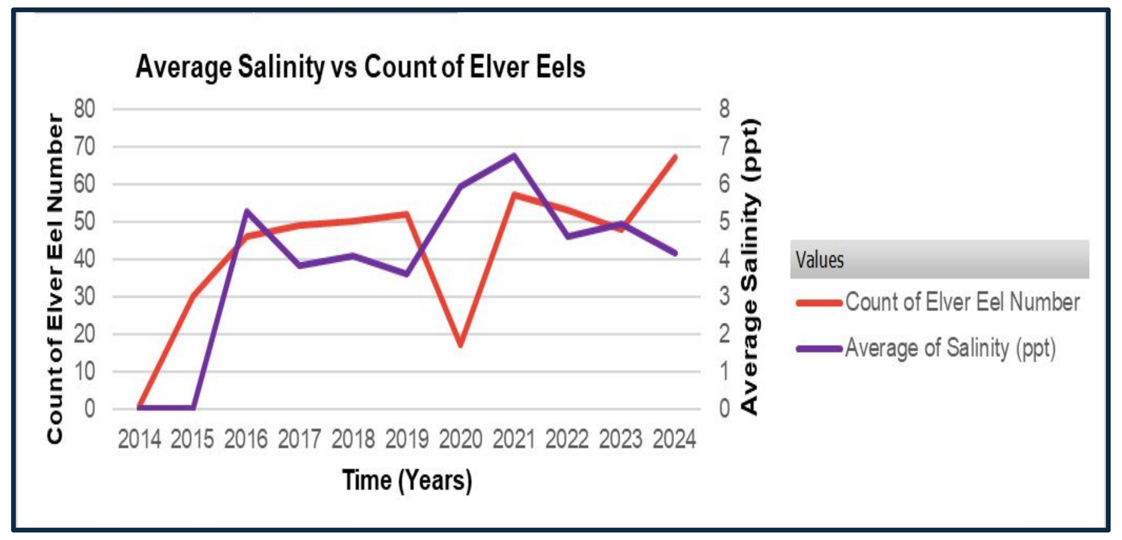

Fig. 5 represents the change in elver eel abundance from 2014 to 2024 in relation to the mean water salinity.

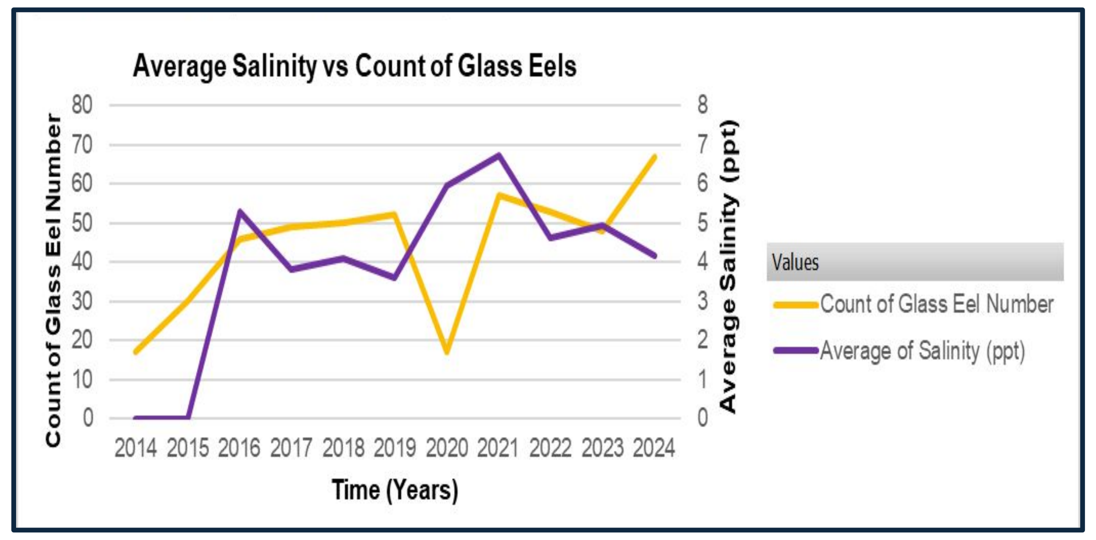

Fig. 6 represents the change in glass eel abundance from 2014 to 2024 in relation to the mean water salinity.

Results

The total abundance of glass eels peaked in 2024 with 5,777 glass eels. In contrast, both average temperature and glass eel abundance decreased in 2020. The average temperature peaked in 2015 at 13.2 °C. Interestingly, the glass eel population increased as the average temperature decreased in 2023 to 2024 (**Fig. 1**). The abundance of elver eels peaked in 2015 with 11 elver eels. However, following 2015, no elver eels were found between 2017 to 2020, despite the average temperature remaining steady during that period (**Fig. 2**). The average salinity peaked in 2021, with an average of 6.7 ppt. Following this, the abundance of elver eels and the average salinity both decreased from 2022 to 2024 (**Fig. 3**). However, as the average of salinity increased, the abundance of glass eels spiked repeatedly from 2014 to 2024, peaking in 2024 (5,777) as salinity decreased. (**Fig. 4**).

Discussion

The results of the study show significant patterns in glass and elver eel abundance in relation to the fluctuations of water temperature and salinity within the Hudson River. There were a few striking results in the data collected, such as the sudden rise in glass and elver eel abundance as water temperature decreased in 2024. This suggest that elver and glass eels might thrive better in waters with lower temperatures. Furthermore, elver and glass eels show an overall direct relationship to the change in temperature. In terms of salinity the fluctuations did not show a direct or inverse relationship. However, glass and elver eels seemed to prefer an average salinity between 50 and 60 ppt (parts per thousand), while their abundance decreased as salinity increased at some points between 2019 and 2022 (**Fig. 5 and Fig. 6 respectively**). The second hypothesis proposed supports the findings, and reveals a relationship between elver eel abundance and change in water temperature. Although previous research findings supports the direct relationship between glass eels and changes in temperature, it can be implied with the results that elver eels share the same relationship. Future research should further explore the nature of these trends, accounting for additional ecological variables that could clarify these relationships.

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