Galápagos Islands Testudinidae Macroevolution: Report, Findings, and Future Work

Paige Cherry,

Sara Cielaszyk,

Hubert Kasprzycki,

and Eleanor Tuck

College of Information Science, University of Arizona

ISTA 498: Senior Capstone

Dr. Cristian Román-Palacios

Dr. Kristen Martinet

May 5th, 2025

Overview

How large Galápagos tortoises are, and how has their size evolved? This question matters because Galápagos tortoises are not only iconic symbols of evolution but are also a key example of how species adapt to unique environmental conditions. Understanding how their size evolved can help scientists learn more about their adaptation, survival strategies and how to better protect them in the future. This research focuses on the relationship between tortoise body size and the size of the Galápagos Islands, as well as the diversification rates of the Testudinidae (the tortoise family). MiSSE (Missing State Speciation and Extinction) was used to obtain these diversification rates. The results are included in this paper as well as on a website which includes interactive visualizations and data summaries. The diversification rates which reveal just how quickly species accumulate or go extinct, were calculated using the MiSSE (Missing State Speciation and Extinction) model.

The results are presented in this paper and also featured on a website that includes interactive visualizations and data summaries (idk the word) to engage a broader audience.

The structure of this paper's body is organized into four main sections each authored by a different group member and reflecting on their individual contributions and learning outcomes. The four sections are: Data Analysis on Diversification and Body Size vs. Island Size, Paige section title, Frontend and Backend Web Development (Index and Diversification Rates pages), and Creating Website Frontend Development (Index, Island Data and Team Bios). Together these sections represent the collaborative effort that went into developing the final website and research product.

Through our research, we not only explored the evolutionary patterns of Galápagos tortoise size but also contributed to a broader understanding of how island environments influence species traits. Importantly, the Galápagos tortoise is currently endangered. Additionally, many of its species have been impacted by human activity and invasive species. Despite its iconic status, detailed evolutionary and ecological studies on these tortoises are still relatively limited. By connecting body size to island characteristics and diversification patterns, our findings offer insights that could inform conservation efforts. This project underscores the importance of integrating evolutionary biology with modern data visualization to raise awareness and support for endangered species.

Data Analysis on Diversification and Body Size vs. Island Size:

By Sara Cielaszyk

My focus for this project was data analysis performed on data from a previously published study from Cristian Román-Palacios (Román-Palacios and Wiens 2018). The data contains phylogenetic trees as well as body size and occurrence records with GPS points for tortoise species. After conducting analyses using the body size distribution and where the tortoises are found (island, mainland, shared), we concluded that island tortoises have a higher median and a larger variance of body size(cm) distribution. This pattern is an indicator of island gigantism.

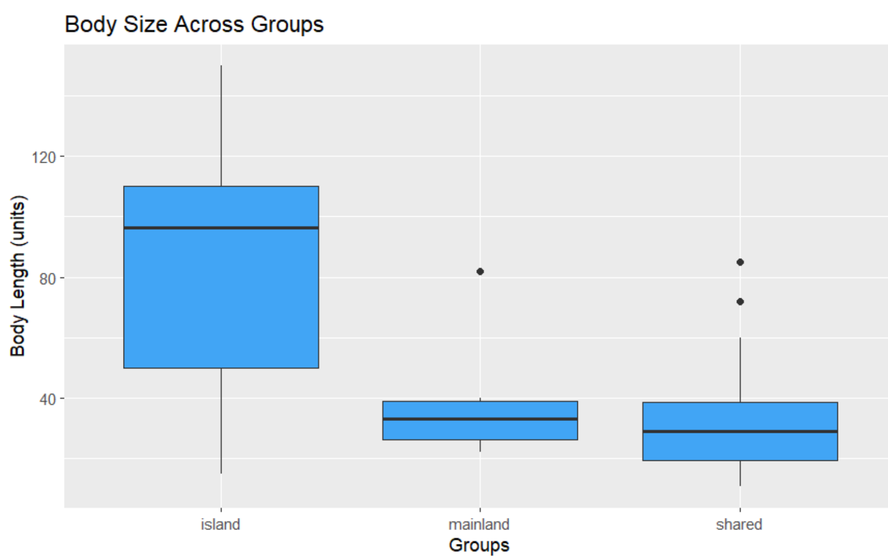


Figure 1. Boxplot of body size across groups. Island tortoises are generally larger than mainland or shared groups.

The diversification rates, which indicate the rate that species accumulate, were estimated using the HiSSE R package (Beaulieu and O'Meara 2016). A Missing State Speciation and Extinction (MiSSE) model was used to find diversification rates for each species. Results showed an average diversification rate of 0.34 events/Myr for Galápagos tortoises within the *Chelonoidis* genus, significantly higher than the 0.052 events/Myr average rate observed in other genera. This shows Galápagos tortoises are accumulating faster than other tortoise genera elsewhere in the world.

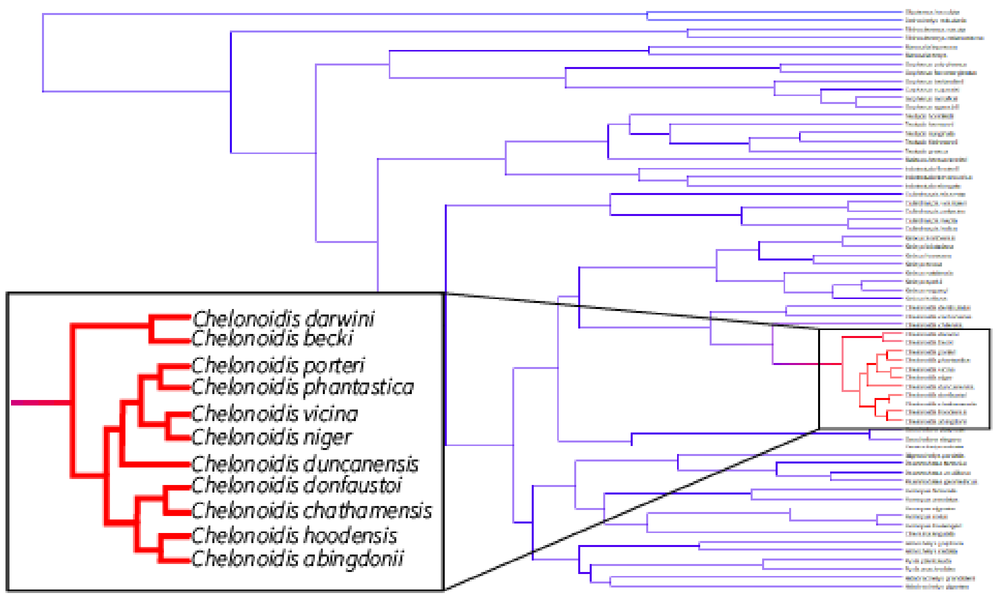


Figure 2. Phylogenetic tree colored coded for the diversification rates of species. The red is correlated to high diversification rates. The zoom box highlights the Galápagos species in the phylogenetic tree.

The last analysis completed was looking at the relationship between the body length(cm) and the size of the island (Km^2). The island and tortoise data was collected just for Galápagos species (Galápagos Species Database).The linear regression model showed a .42 correlation coefficient which is positive and moderately strong. The regression equation:

$\widehat{Body\ Length} = 87.61 + 0.007423\ (Island\ Size)$ shows that for every 1 Km^2 increase, we expect a .007423 cm increase in body length. The body length variable has a p value of 0.115, this means that at a significance level of 0.15 the coefficient for island size would be statistically significant. However that would be a large significant level, at a standard significance level of 0.05 the coefficient for island size is not statistically significant and we would accept the null hypothesis of a zero coefficient. This means that island size is not a significant predictor for tortoise body size. This trend was visualized with an interactive map of the Galápagos Islands,showing tortoise body size in relation to geographic location.

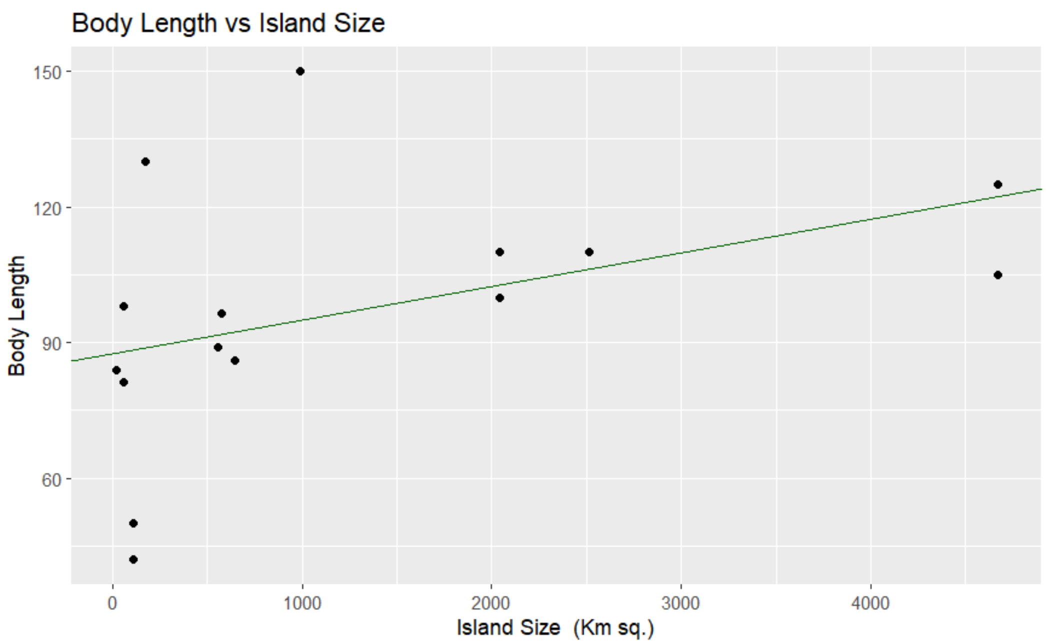


Figure 3. Regression plot for island size and body size, as well as the line of best fit in green.

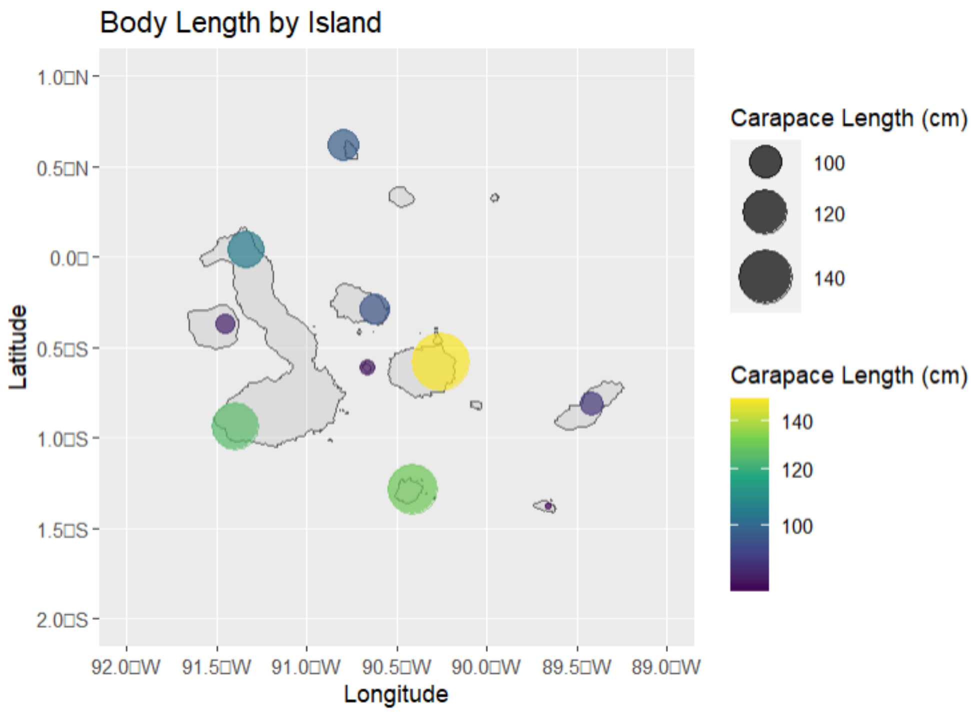


Figure 4. Map showing average tortoise carapace lengths across Galápagos Islands. Circle size and color indicate tortoise body size, with larger yellow circles representing bigger tortoises, etc. (R Graph Gallery 2025)

Questions

How large are Galápagos tortoises? How does their size compare to tortoises elsewhere in the world? How does body size vary by island size and is there a relationship between the two?

Tasks

I conducted data analysis using R and tools such as ggplot2 and plotly for visualizations, giscoR for mapping, and the MiSSE (Missing State Speciation and Extinction) model in the HiSSE package to estimate the diversification rates. I fit a linear regression model to test the relationship between island size and body size. This association was also shown in an interactive map. I used a color coded and annotated phylogenetic tree to highlight the high diversification rates of tortoises in the Galápagos region and better show the Galápagos tortoise species names. I utilized Canva to present my visualizations to be understood by a broad audience of varying backgrounds. The interactive map, diversification rate phylogenetic tree, Galápagos vs. other region boxplot, and the body size across groups boxplot were customized for the poster and website.

Tools/Resources

- ggplot2. Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.
- HiSSE. Beaulieu, J.M., and O'Meara, B.C. (2016). Detecting hidden diversification shifts in models of trait-dependent speciation and extinction. Systematic Biology, 64(4), 583-601.
- giscoR. Hernangómez, D. (2025). giscoR: Download Map Data from GISCO API - Eurostat. doi:10.32614/CRAN.package.giscoR
- Plotly. Sievert, C. (2020). Interactive Web-Based Data Visualization with R, plotly, and shiny. Chapman and Hall/CRC Florida.
- R. R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Discussion

For the interactive plot I could have implemented Leaflet (Cheng, Schloerke, Karambelkar, and Xie 2025) to complete the map and interactivity with more engaging backgrounds. For example satellite view would make the map more interesting, add more detail and also showcase the islands landforms. For the linear regression if there were more observations or features, other regression techniques might have been helpful to determine the underlying relationship. Regression techniques such as transformations of either variables using logarithms or square roots or including interaction terms. If the underlying relationship with more observation proved to be nonlinear a polynomial regression model would have been beneficial.

For the MiSSE model, changes to the estimated proportion of extant species could have been added to change the rates, or other parameter changes in the MiSSE model, such as turnover for the suspected rates of turnover, and eps for the suspected rates of extinction. Without using MiSSE, BAMM (Bayesian Analysis of Macroevolutionary Mixtures)(Rabosky, Grundler, Anderson, Title, Shi, Brown, Huang, and Larson 2014) might have been another solution for finding the diversification rates. My initial research shows that state data is not required for this method.

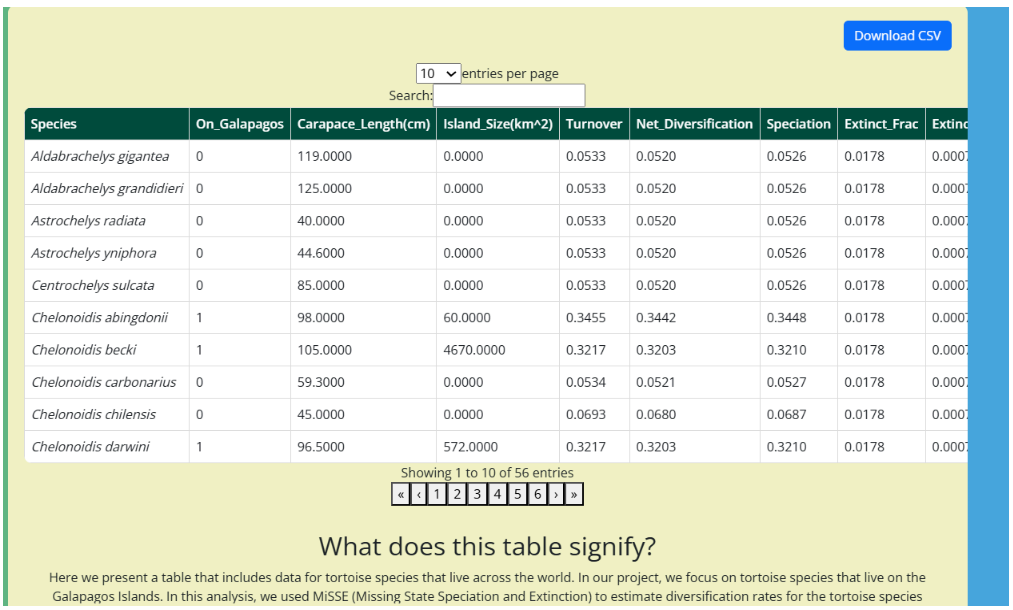
Conclusions and future work

The analysis of tortoise body size vs island size showed moderate positive correlation but more analysis would need to be done to find causation or other underlying factors. The diversification rates are higher in the Galápagos tortoises than in Testudinidae found elsewhere, meaning that species accumulate faster in the Galápagos compared to other regions in the world. It would be interesting to look into the morphological rates to see the evolution of body sizes.

Frontend and Backend Web Development (Index and Diversification Rates pages) By Hubert Kasprzycki:

Overview

Diversification rates quantify how quickly lineages gain and lose species, showing the total turnover (speciation + extinction) and net diversification (speciation - extinction). My focus for the project was to present the diversification rates estimated using MiSSE (Missing State Speciation and Extinction) with data from Román-Palacios and Wiens (2018) by converting the CSV output into a fully interactive web portal that helps to present the the findings with user-experience in mind. I created a server endpoint within an HTML file that routes data provided from the CSV file to the front end of the page upon request. This was done with the use of PapaParse (Holt, M. 2014) to help parse through the provided CSV data and Datatables (A. Jardine. 2008) to construct the interactive tables which allows users to sort, filter, and download the results on the front end of the website.



Species	On_Galapagos	Carapace_Length(cm)	Island_Size(km^2)	Turnover	Net_Diversification	Speciation	Extinct_Frac	Extinc
Aldabrachelys gigantea	0	119.0000	0.0000	0.0533	0.0520	0.0526	0.0178	0.000
Aldabrachelys grandidieri	0	125.0000	0.0000	0.0533	0.0520	0.0526	0.0178	0.000
Astrochelys radiata	0	40.0000	0.0000	0.0533	0.0520	0.0526	0.0178	0.000
Astrochelys yniphora	0	44.6000	0.0000	0.0533	0.0520	0.0526	0.0178	0.000
Centrochelys sulcata	0	85.0000	0.0000	0.0533	0.0520	0.0526	0.0178	0.000
Chelonoidis abingdonii	1	98.0000	60.0000	0.3455	0.3442	0.3448	0.0178	0.000
Chelonoidis becki	1	105.0000	4670.0000	0.3217	0.3203	0.3210	0.0178	0.000
Chelonoidis carbonarius	0	59.3000	0.0000	0.0534	0.0521	0.0527	0.0178	0.000
Chelonoidis chilensis	0	45.0000	0.0000	0.0693	0.0680	0.0687	0.0178	0.000
Chelonoidis darwini	1	96.5000	572.0000	0.3217	0.3203	0.3210	0.0178	0.000

Figure 5. Interactive table that features MiSSE output data of the diversification rates.

In addition to this, I created the navbar across all of the pages of the website that can be fully collapsed when on a mobile device utilizing Bootstrap's jQuery (Otto, M., & Thornton, J. 2011) for full mobile responsiveness. I was also in charge of creating the index page with the goal of greeting users with a summary of the project as well as an image carousel of photos taken in The Galápagos Islands provided by Kristen Martinet. The goal was making these web portals accessible for any user interested in the macroevolution of the Galápagos tortoises.

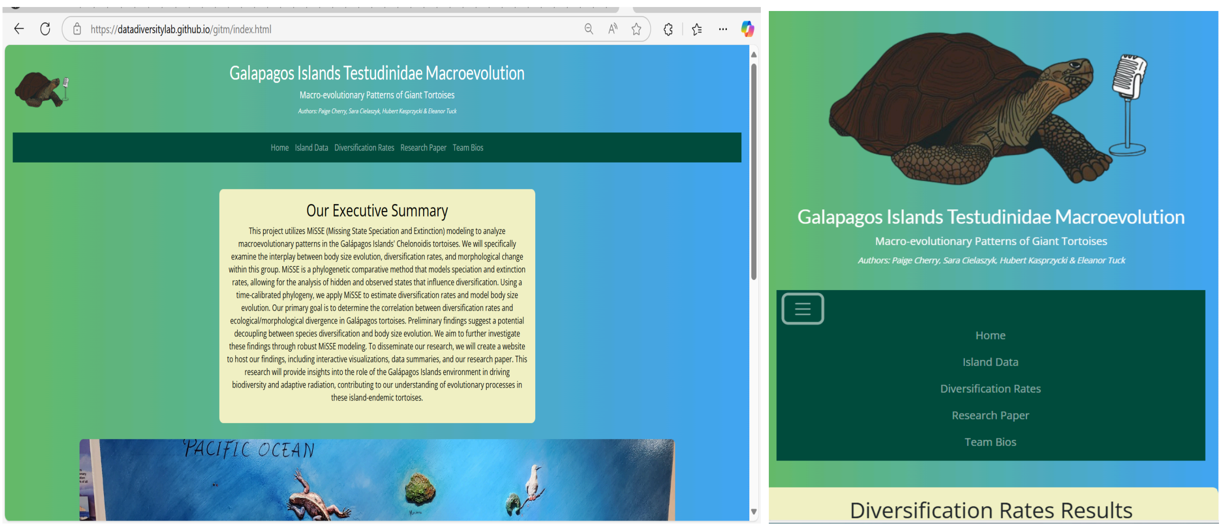


Figure 6,7. (Left) Index page that greets the user when going to https://datadiversitylab.github.io/gitm/index.html . (Right) Shows how the navbar looks when collapsed with a hamburger style button that the user can click that then drops down the full navbar.

Tasks

I focused on the full representation of the diversification rates data provided from the MiSSE model using a backend API (a server that sends data when the site asks for it) to create a fully interactive table that can be sorted, searched, and filtered upon user request. I also refined the website’s overall responsiveness with a navbar that can be collapsed for mobile devices and features a “hamburger” style button that shows all of the navbar links when pressed as well. In addition to this, I created the index page to be a welcoming first impression with an executive summary about the project, a scalable logo on the top left corner of the page, an image carousel with images from the Galápagos Islands, and was used as a reference point for the styling of the header and navbar across all of the pages of the website.

Approach

The development of the webpages was coordinated through a shared repository on Github.com at https://datadiversitylab.github.io/gitm/. I collaborated by forking the main branch, creating a dedicated branch for the diversification_rates.html and index.html pages, and submitting pull requests to be reviewed and eventually merged. Once the MiSSE analysis was conducted, the resulting CSV file was imported to the client with the use of PapaParse. PapaParse would get routed to a server based on parameters such as papa.parse(“Tips.rates.combo.csv”,{ download: true } which in this case would fetch the CSV endpoint. I used the transformheader callback to rename some of the columns for the interactive table on the website as the units of the columns, Carapace_Length (cm) and Island_Size (km^2), would simply be ignored when featured on the web page. In the original CSV, The columns Carapace_Length and Island_Size did not have units associated with them. Using the transformheader callback, this had renamed the columns to Carapace_Length(cm) and Island_Size(km^2) accordingly and completed the callback to obtain the parsed rows. Interactive tables were implemented using the DataTables jQuery plugin. After being parsed through, data from the CSV files would be initialized into a data table using a DataTables jQuery call that included options such as sorting and a download button, which allows the user to download the CSV file that is stored in the backend. During the parsing process, the species names in the 'Species' columns were italicized using a line of code associated with styling the resulting parsed data. I had also practiced a similar approach for rounding up all of the values, with the exception of the binary values within the 'On_galapagos' column, to the 4th decimal point which could enhance readability and comparability. For the Aesthetic enhancements, I used Bootstrap toggle attributes from Bootstrap 5's data-bs-toggle/data-bs-target (Otto, M., & Thornton, J. 2011), loaded only Bootstrap's bundle of java plugins that enhanced optimization and ensured consistent collapse behavior across devices using jQuery (jQuery, n.d.).For the index page, I developed the HTML and JavaScript for a responsive logo, welcoming header, carousel of images to introduce the project, and a favicon to the tab of the page using realfavicongenerator.net.

Tools/resources

- DataTables. A. Jardine. (2008-2014, 01 April). DataTables. Available: http://datatables.net
- GitHub. Wanstrath, C. (2008). *GitHub: Build and ship software on a single, collaborative platform*. Retrieved from https://github.com/
- RealFaviconGenerator (n.d.). RealFaviconGenerator: Generate your favicon for all platforms. Retrieved from https://realfavicongenerator.net/
- JQuery. Resig, J. (2006, August 26). A safe and modern home for JavaScript technologies. OpenJS Foundation. Retrieved from https://openjsf.org/
- PapaParse. Holt, M. (2014). Papa Parse: Powerful CSV Parser for JavaScript. Retrieved from https://www.papaparse.com/Rabosky, D. L., et al. (2014).

- Expressjs. Holowaychuk, T. J. (2010, November 16). Express: Node.js web application framework. Retrieved from https://expressjs.com/
- Bootstrap 5. Otto, M., & Thornton, J. (2011, August 19). Bootstrap: The most popular HTML, CSS, and JS library in the world. Retrieved from https://getbootstrap.com/

Discussion

Combining Bootstrap with the DataTables jQuery plugin allowed me to create user-friendly pages, however, there are many approaches that developers can use to create the same result. Instead of DataTables, I could have used JavaScript-based data grid libraries such as AG-Grid which provide advanced grid features like grouping and pivoting (Crosby, N. 2016). For some of the responsive components like the navbar I could have used Foundation (ZURB 2011) as a framework as they have intuitive tools for designing responsive elements in the context of web design. If the data somehow becomes significantly larger in the future, another option could have been to store the data acquired from analysis in an SQL database and have the server send back only the rows you need. This keeps the page fast and responsive when dealing with large datasets and doesn’t rely on a CSV file but this does require paying fees to keep the server running.

Conclusions and future work

This project demonstrates how static phylogenetic CSV outputs can be transformed into a dynamic, user-friendly web portal. Users can now easily explore, sort, and download diversification data. The index page welcomes users with visually appealing fonts, colors, and images, while remaining contextually relevant to the project. Navigation through each of the navbar links is designed to be responsive, intuitive, and accessible on any device.

Future enhancements could include an interactive phylogenetic tree visualization using D3 tree layouts (Bostock, M., 2011), featuring clade filtering and the integration of additional trait data with dynamic charting. Another improvement could involve using an SQL database to store all output data. This would allow for more organized data management and enable efficient updates and modifications, eliminating the need to manually track multiple CSV files.

Creating Website Frontend Development (Index, Island Data and Team Bios):

By Ellie Tuck

Overview

This project involved building an interactive and informative website focused on the Galápagos Islands and the tortoises that inhabit them. Our goal was to present data, research, and team insights in a visually engaging way. My primary role was developing the front end of the site, focusing on layout, styling, and integrating data onto the pages.

Tasks

I was responsible for initiating and developing the frontend structure of the site. This included writing the base HTML and CSS for the homepage (index.html), designing a cohesive visual theme inspired by the natural greens and blues of the Galápagos, and ensuring layout consistency across the pages (W3Schools, n.d.-a; W3Schools, n.d.-b). I also developed the team_contact.html and island_data.html pages, where I integrated interactive and scrollable Plotly visualizations and styled each element for clarity and accessibility (Plotly Technologies Inc., 2015).

Approach

I started by creating a modular site layout using HTML and Bootstrap (Bootstrap Team, 2023). I defined reusable components such as a header, navigation bar, and footer, which I included on every page to maintain visual consistency. Bootstrap's grid system was used to ensure responsive design, along with components like the mobile collapsing menu (navbar-toggler) for smaller screens. For styling, I created a style.css file and applied a custom green and blue color scheme to reflect the Galápagos environment, using ColorHexa to choose accessible color combinations (ColorHexa, n.d.). I used CSS variables to manage the colors and adjusted typography using font-family, font-size, etc. for readability (W3Schools, n.d.-b). These styles are consistent across pages and implemented to ensure accessibility across devices.

On the Island Data page, I embedded three data visualizations that showcase trends in Galápagos tortoise size. The first box plot is a static image figure that compares Galápagos and non-Galápagos tortoise body sizes, showing that Galápagos tortoises tend to be larger. This box plot is followed by a descriptive caption.

The interactive Plotly map (Figure 1) was exported as a standalone HTML file and embedded using an iframe, preserving all Plotly interactivity such as hovering and zoom ability (Plotly Technologies Inc., 2015). This plot maps species and average carapace lengths across the Galápagos Islands. Circle size and color indicate tortoise body size: larger yellow circles represent bigger tortoises and smaller purple ones indicate smaller individuals. Users can hover over each island to view species names and body length values.

The third plot is a static image of a regression paired with a regression table. This plot displays the relationship between island size and tortoise body length. It includes a positive regression line suggesting that a possible ecological scaling pattern is present. I paired this with an HTML table presenting regression coefficients and p-values for additional analytical depth. Throughout development, I tested the site on different screen sizes and browsers to ensure visualizations remained legible across platforms (Visual Studio Code, n.d.; Bare Bones Software, n.d.).

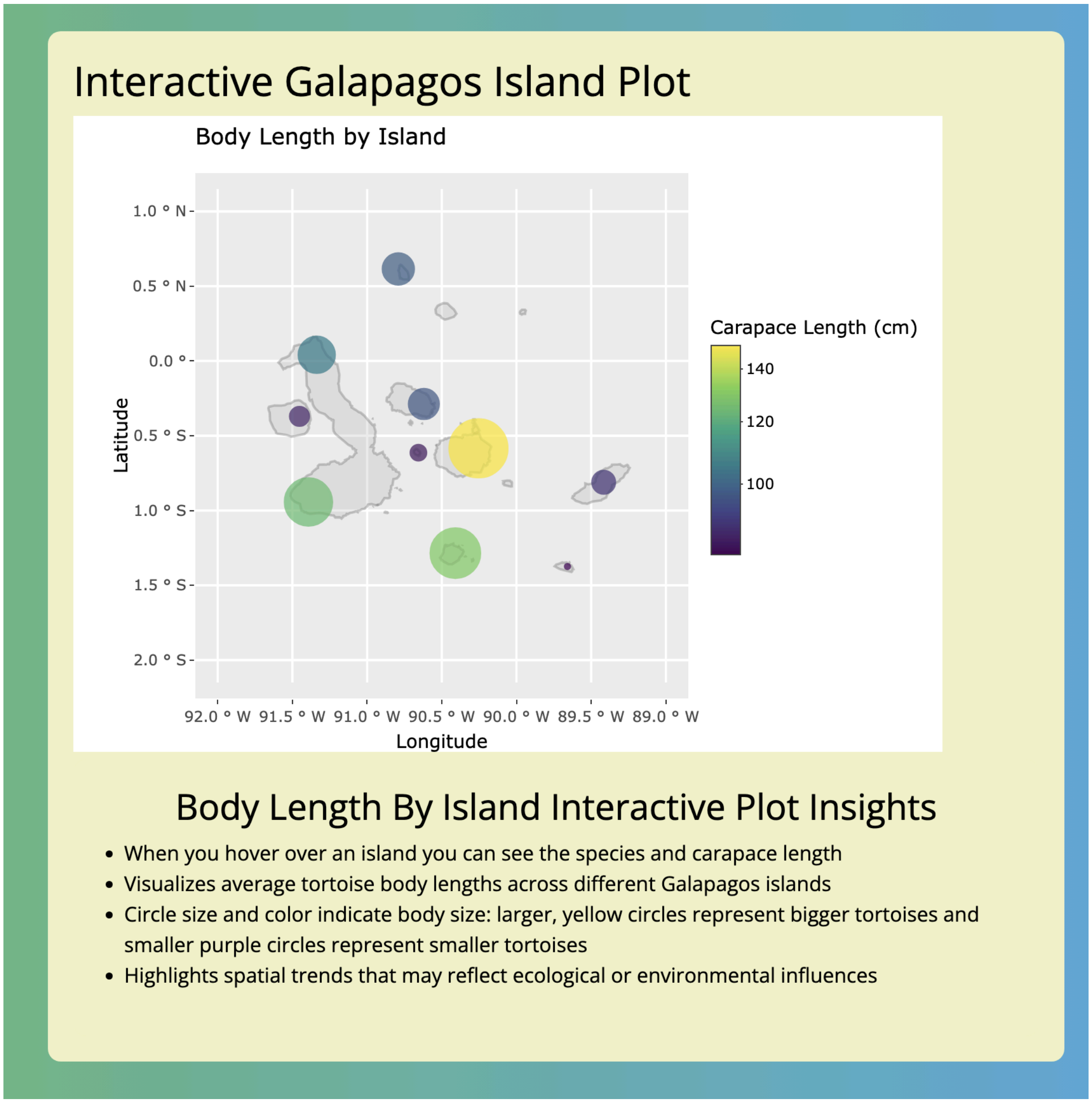


Figure 8. Interactive map showing average tortoise carapace lengths across Galápagos Islands. Circle size and color indicate tortoise body size, with larger yellow circles representing bigger tortoises, etc. Users can hover to view species names and average measurements.

Discussion

Our approach prioritized usability and clarity when emphasizing the ecological identity of the Galápagos Islands. We used plotly.js to implement an interactive map showing average tortoise body sizes across islands, which allowed users to engage with data via hover and visual encoding (Plotly Technologies Inc., 2015). While Plotly worked well for this purpose, other libraries like D3.js could have offered more customization, but would be more complex to implement (W3Schools, n.d.-c).

For frontend styling and responsiveness, we used Bootstrap to streamline layout creation and other components like the collapsible navigation bar (Bootstrap Team, 2023). Alternatives could have been Tailwind CSS, which offers similar functionality with a more utility-based approach (Tailwind Labs, 2023). Tailwind enables faster prototyping but requires more familiarity with its structure.

We implemented reusable components including the navbar and footer across all pages using consistent HTML snippets and Bootstrap classes. This route was chosen because it ensures consistency, reduces duplication, and simplifies future updates. If we were to scale this project using a JavaScript framework like React, we would be able to modularize components further and manage state more efficiently.

Conclusions and Future Work

Our site successfully presents ecological data related to Galápagos tortoises through static and interactive visualizations. It was designed with a focus on clarity and theme cohesion. In the future, we would like to add more interactive features such as filters for species or islands using JavaScript with dynamic DOM updates or D3.js for live filtering (W3Schools, n.d.-c). We could also improve mobile responsiveness by refining Bootstrap grid usage or adding media queries. Incorporating a searchable dataset feature using DataTables.js or custom JavaScript with input filters would be another valuable usability enhancement (DataTables, n.d.).

Future Work and Recommendations

To build upon the current functionality and impact of our web portal, several enhancements are recommended for future development.

First, interactivity can be expanded by incorporating filtering options for species or islands. This could be implemented using JavaScript with dynamic DOM updates or D3.js for real-time data filtering (Bostock, M., 2011). The use of DataTables.js or custom JavaScript input filters would enable a searchable dataset feature, significantly improving user experience and accessibility (A. Jardine. 2008).Improving mobile responsiveness is another priority. This can be achieved by refining the use of Bootstrap's grid system or adding custom media queries to ensure consistent design and usability across all devices.

The integration of an interactive phylogenetic tree using D3 tree layouts (Bostock, M., 2011) is also recommended. Features such as clade filtering and dynamic trait charting would enhance data exploration and better visualize evolutionary relationships. For more robust data, transitioning from static CSV file management to an SQL-based database would provide improved organization and allow for efficient updates and scalability.

From an ecological perspective, future analyses could explore the evolution of body sizes by examining morphological rates across species. While a moderate positive correlation was found between tortoise body size and island size, further investigation is needed to determine causation or other contributing ecological factors. Interestingly, the observed higher diversification rates in

Galápagos tortoises compared to other Testudinidae suggest a unique evolutionary trajectory worth deeper exploration.

These improvements would not only enhance the quality of the portal but also enrich its scientific insights and educational value for those especially interested in the macroevolution of the Galápagos tortoises.

.

Conclusions

Our research explores how Galápagos tortoises have evolved in response to island environments, revealing patterns of large body size and rapid species accumulation. While we found a moderate link between island size and body size, more research is needed to confirm the relationship. Expanding the dataset or exploring additional ecological factors could provide deeper insights into the drivers of body size variation among island tortoises. Beyond biology, this project highlights the value of clear and accessible scientific communication. By developing an interactive website, we transformed complex data into engaging visualizations that allow users to explore key findings in an intuitive way. Using tools like Plotly and DataTables, we created an interface that enhances user experience, making evolutionary science more approachable for researchers, conservationists, and the general public. Future work could refine our models, expand analyses of evolutionary rates, and improve website features for better user interaction. Exploring alternative statistical approaches, such as more advanced regression models or machine learning techniques, may reveal additional evolutionary trends. Additionally, incorporating real-time data updates or user-driven filters could further enhance interactivity and accessibility. Ultimately, combining evolutionary science with digital accessibility helps deepen our understanding of species adaptation and supports conservation efforts for endangered tortoises. By bridging scientific research with technological innovation, this project serves as an example of how interdisciplinary collaboration can enhance both scientific discovery and public engagement in conservation initiatives.

References

A. Jardine. (2008–2014, April 1). *DataTables*. Available: http://datatables.net

Bare Bones Software. (n.d.). *BBEdit 14 User Manual*. https://www.barebones.com/products/bbedit/

Beaulieu, J.M., and O'Meara, B.C. (2016). Detecting hidden diversification shifts in models of trait-dependent speciation and extinction. *Systematic Biology, 64*(4), 583–601.

Bostock, M. (2011). *D3: Data-Driven Documents*. Retrieved from https://d3js.org/

Bootstrap Team. (2023). *Bootstrap v5.3*. https://getbootstrap.com/

Cheng, J., Schloerke, B., Karambelkar, B., and Xie, Y. (2025). *leaflet: Create Interactive Web Maps with the JavaScript 'Leaflet' Library*. R package version 2.2.2.9000.

ColorHexa. (n.d.). *ColorHexa – Color encyclopedia*. https://www.colorhexa.com/

Crosby, N. (2016). *ag-Grid: Enterprise-grade JavaScript Data Grid*. Retrieved from https://www.ag-grid.com/

DataTables. (n.d.). *DataTables: Table plug-in for jQuery*. https://datatables.net/

Galápagos Species Database. (n.d.). *CDF DataZone.* https://datazone.darwinfoundation.org/en/checklist/

GitHub. Wanstrath, C. (2008). *GitHub: Build and ship software on a single, collaborative platform*. Retrieved from https://github.com/

Hernangómez, D. (2025). *giscoR: Download Map Data from GISCO API - Eurostat*. doi:10.32614/CRAN.package.giscoR

Holowaychuk, T. J. (2010, November 16). *Express: Node.js web application framework*. Retrieved from https://expressjs.com/

Holt, M. (2014). *Papa Parse: Powerful CSV Parser for JavaScript*. Retrieved from https://www.papaparse.com/

Otto, M., & Thornton, J. (2011, August 19). *Bootstrap: The most popular HTML, CSS, and JS library in the world*. Retrieved from https://getbootstrap.com/

Plotly Technologies Inc. (2015). *Collaborative data science*. https://plotly.com/javascript/

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

R Graph Gallery. (2025) Bubble map with ggplot2. https://r-graph-gallery.com/330-bubble-map-with-ggplot2.html

Rabosky, D., Grundler, M., Anderson, C., Title, P., Shi, J., Brown, J., Huang, H., and Larson, J. (2014). BAMMtools: an R package for the analysis of evolutionary dynamics on phylogenetic trees. *Methods in Ecology and Evolution, 5*, 701–707.

RealFaviconGenerator. (n.d.). *RealFaviconGenerator: Generate your favicon for all platforms*. Retrieved from https://realfavicongenerator.net/

Resig, J. (2006, August 26). *A safe and modern home for JavaScript technologies*. OpenJS Foundation. Retrieved from https://openjsf.org/

Román-Palacios, C., and Wiens, J.J. (2018). The Tortoise and the Finch: Testing for island effects on diversification using two iconic Galápagos radiations. *J Biogeogr, 45*, 1701–1712.

Sievert, C. (2020). *Interactive Web-Based Data Visualization with R, plotly, and shiny*. Chapman and Hall/CRC Florida.

Tailwind Labs. (2023). *Tailwind CSS documentation*. https://tailwindcss.com/

Visual Studio Code. (n.d.). *Code editing. Redefined*. https://code.visualstudio.com/

W3Schools. (n.d.-a). *HTML <base> Tag*. https://www.w3schools.com/tags/tag_base.asp

W3Schools. (n.d.-b). *CSS Tutorial*. https://www.w3schools.com/css/

W3Schools. (n.d.-c). *JavaScript Tutorial*. https://www.w3schools.com/js/

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.

Wikipedia Contributors. (2019, March 11). *Galápagos Islands*. Wikipedia; Wikimedia Foundation. https://en.wikipedia.org/wiki/Gal%C3%A1pagos_Islands

ZURB. (2011, September). *Foundation: Fast and responsive front-end framework*. Retrieved from https://get.foundation/