Visualizing ESA-Listed Fish Research on the West Coast

Authors:
Alana Santana
Rory Spurr

Advisor:
Dr. Anne Beaudreau

Client:
Diana Dishman - NOAA Fisheries

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University of Washington

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Background on Capstone Process

Introduction

The West Coast Region research permits team (hereafter, 'permits team'), a part of the Protected Resources Division (PRD) within the West Coast Region of the National Marine Fisheries Service (NMFS), is responsible for issuing scientific research permits to work with fish species within their jurisdiction in Washington, Oregon, California, and Idaho. These permits are required to conduct research that involves "take" of species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). Take, as defined in section 3 of the ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect [a listed species] or attempt to engage in any such conduct" (16 U.S.C. 1531-1544). Ultimately, the results of this research are then used to inform conservation efforts and management strategies needed to support recovery of ESA-listed species. The permits team tracks information for their scientific research permits in the Authorizations and Permits for Protected Species (APPS) database (apps.nmfs.noaa.gov). Each permit request and subsequent authorization includes information on the research purpose, potential impact to listed species, organization or individual doing the research, research location, gear types and methods, and more. The permits team can only issue permits under specific criteria through the ESA, and must ensure that the permits they issue do not jeopardize the continued existence of listed species or their critical habitats, and that information gained from the research justifies the harm it may cause.

Client Request

Although the permits team has access to the data stored in APPS, they did not have a way to easily visualize and interpret the permitting data. Additionally, the permitting process can be difficult to understand for the general public due to nuances of specific ESA authorities, thus making the process of how permitting decisions are made relatively inaccessible to some. To solve this problem, the permits team came to the School of Marine and Environmental Affairs with a capstone project. The goals of this project were to create communication tools and data products that summarize research permit information visually across the areas where they work. These tools will be used to help communicate and provide more transparency on the permitting process to researchers, co-managers, and the public. Additionally, this product will be used internally to support the permits team in making decisions on permit authorizations in the context of other research happening across the landscape.

Project Development and Planning

To establish a project management workflow, the student capstone team began by creating a Github project. Github projects allow developers to upload, communicate, track changes, create issues or tasks, share code, and more. Through developing this Github project we were able to delegate tasks to reduce redundancy and document all code, changes, tasks, issues, and discussions that occurred during the length of the project.

We decided to develop an interactive web application using R Shiny Dashboard, to meet the needs of our client and create a communication tool that would be beneficial for multiple audiences. This also ensured that the products we created would continue to be useful as the inputs are updated, and would retain its utility for the client for years to come.

As the app was developed we went through several iterations of scoping the various kinds of content the app should include, planning how that information would be configured, and creating draft product components to share with the client for review. We shared draft layouts, storyboards, and alternative versions of data visualization options with the permits team and NMFS science communications specialists and refined our products based on their feedback. Careful consideration was also given to the app's ease-of-use, visual clarity, and accessibility for multiple audiences. Based on input from the client, other NMFS staff, peer review, and feedback from our advisor, the final product was assembled into an application with map and time series visualizations components, as well as educational content to contextualize the information.

Final Product Description

Map Component

One component of the app is an interactive map that displays the current amounts of take for each watershed in the West Coast Region. Within this component, the user can filter the data by life stage, species, origin (hatchery or natural), and evolutionary significant unit (ESU) or distinct population segment (DPS). The map is also accompanied by a dynamic data table that automatically updates based on selected inputs and filters, and displays data at the individual permit level. The map allows users to examine the data at a finer scale, while also allowing users to search for and focus on certain permits, locations, gear types, or other criteria.

Ultimately, the map component is necessary to visualize how much take is occurring in a species' range to better understand how research impacts to ESA-listed species are spread across the landscape. It can be used by the permit team to make more informed decisions on where to authorize research and how much take to authorize based on current impacts to species in specific watersheds. Outside of NMFS, this map can inform researchers and co-managers about how their project contributes to existing impacts to ESA-listed species, and can facilitate collaboration amongst researchers in various areas of interest to reduce impact to species.

Time Series Component

The second component of this application is the time series portion, which displays bar plots of authorized and reported take by year for both total take (lethal and non-lethal) and lethal take only. This component displays permit authorizations and annual reports over the last 10 years to visualize trends in authorized take in comparison to the take that was actually utilized by researchers. Similar to the map component, these bar plots can be manipulated to show data of interest by selecting filters for life stage, origin (hatchery or natural), and ESU/DPS (Appendix II, SS18). These plots were built in R and use the 'plotly' package that allows for plot

interactivity (Appendix II, SS20). The time series is also accompanied by a reactive data table (Appendix II, SS21) that updates with the plot filters to show the raw counts of authorized and reported take per year, again allowing for finer-scaled viewing of the data.

This component was specifically requested by the permits team to assist in informing permit managers on how much take to authorize. By showing the used and unused take (total authorized take minus the take that was reported), we can inform permit managers on where less take can be authorized while still providing researchers an adequate buffer. The purpose of closing the gap between used and unused take is to reduce the potential for harmful impacts to ESA-listed species, and allow for new research projects to be authorized in areas that might appear to already be highly impacted. By more accurately authorizing take based on what is actually used, over time we can allow more research to occur in a watershed or to an ESU/DPS without impacting the species' ability to recover.

Educational and Contextual Component

The descriptive components of the app serve to educate users on the background, context, limitations, and data display decisions of this project (Appendix I). This can allow users to better understand and apply the information displayed by the map and time series elements.

The contextual pieces consist of a background information section, a help video, a glossary page, and a uses and limitations section. The background section provides information on the ESA and the research permitting process, serving to educate those not familiar with the process in accessible language. The background also provides information on the motivations behind the project, creating more transparency concerning the project itself.

The help video provides a basic overview of the app in a visual form for those who prefer audiovisual instructions over written ones. This allows for more user accessibility and is optional for users to interact with (i.e., not the landing page) for those already familiar with the application.

The glossary section contains definitions for all the necessary terms and acronyms to increase user understanding as well as inclusivity for those who are not familiar with the jargon. Here, terms commonly used in the maps and time series components are defined to ensure that users are able to comprehend the information being displayed within the application. Additionally, a fish glossary defines the species included in this application and their scientific names. To provide more information regarding the species and their ranges, ESA-listing statuses, and general biology there are links to National Oceanic and Atmospheric Administration (NOAA) webpages.

The uses and limitations page includes information regarding our filtering and data processing decisions. Elements of the data were omitted or altered for better usage, and some limitations were inherent in the dataset. These are described for transparency about our methodology and to inform users about the caveats when using our application for informed decisions. Furthermore, there are data we cannot display due to privacy concerns. These records were suppressed in individual permit data tables to abide by these restrictions but included in

total counts and visual summaries. These are listed in the omissions section to provide transparency for users and clarity on why numerical summaries and disaggregated data may not always appear to align. The uses and limitations page also includes information linking to our metadata (Appendix III) and Github. Therefore, those who are interested in recreating our product or in the data used can find it there.

The purpose of including these sections within the web-based application is to fulfill our client's request to create a communication tool and data products that assist in informing the permitting process and provide more transparency for researchers, co-managers, and the general public in an accessible form. Users of this application can refer to these sections if they have any questions after interacting with the main data visualization components.

Github Repository

The github repository itself serves as a place to store not only the application, but also the input files and metadata related to this project. The repository landing page also provides detailed instructions for how anyone can download and run the application. In order to run the scripts within the repository, you must be working within the correct R project and working directory. In the first level of the 'ESAPermitsCapstone' folder there will be an R project file called 'ESAPermitsCapstone.Rproj'. It is important to first open the project by clicking on this file, and then you can run each of the individual scripts themselves. To be certain you are working in the correct project, you can look in the top right of the Rstudio window and you should see 'ESAPermitsCapstone'. To run the R Shiny application, open the PermitsApp.R file and click 'Run App'. The application should start running automatically and open in a new R tab. If it is not running, make sure you have all the correct R packages installed and loaded into your R session. A complete list of R packages used in this project can be found in the metadata folder in the GitHub. To access the full functionality of the application, click on the 'Open In Browser' button and run the application on your internet browser.

Additionally, the Github repository provides an easy mechanism by which the application can be shared with other users. Providing the product in this platform ensures all documentation stays with the application itself, and will make it easy for NMFS to continue to update and refine. All of the content described in this summary is publicly available at https://github.com/rory-spurr/ESAPermitsCapstone.

Next Steps

Throughout this iterative process, there were comments and suggestions provided by the permits team and NMFS science communication specialists regarding elements to add to this application. However, due to the limited scope of our project, we were unable to incorporate all of these comments and suggestions. Therefore, this section serves to document these elements for NMFS to consider for later implementation. Suggestions were to:

- Incorporate abundance data for comparative analysis on impact to species

- Expand filters to include more ESA-listed species protected under NOAA jurisdiction (i.e., marine mammals, turtles, sharks, invertebrates, and plants)
- Transform the application into an R package (not necessary if being deployed to NOAA R Shiny servers)
- Add the capability to upload new data from the application interface
- Add the capability to download selected data after viewing the table through the application

Appendix I: Application Text Content

The following section contains all of the text pieces within the application we created. Titles of tabs and subtabs are highlighted in gray.

Visualizing ESA-Listed Fish Research on the West Coast (Title of Application)

Home

Welcome (subtab)

Welcome to the ESA-Listed Fish Research Visualization App for West Coast Permits!

This platform summarizes and displays data collected by the National Marine Fisheries Service (NMFS) on the permits they issue for scientific research that may impact U.S. West Coast salmon, steelhead, eulachon, rockfish, and sturgeon that are listed under the Endangered Species Act (ESA).

[picture]

The app summarizes how much impact is authorized to occur to ESA-listed fishes in particular areas due to research. Users can choose what data to display to learn about projects on a particular species or in a region of interest, or look at trends over time. It was created to help NMFS staff see the 'big picture' view of research on the landscape, let researchers learn about each other's work, and make permitting decisions more transparent.

[picture]

How it works (subtab)

The following short video demonstrates how to use the various features of the app.
[video]

Background & Purpose (subtab)

What is the ESA and how does it affect scientific research? (tab title)

What is the ESA?
The Endangered Species Act (ESA) was enacted in 1973 to provide a policy framework for the protection and conservation of threatened and endangered species:

- Endangered species are species that are at risk of extinction throughout all or a significant portion of its range.
- Threatened species are those that are likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

The ESA prohibits “take,” which means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C. 1531-1544).

How does the ESA affect scientific research?

Research on ESA-listed species is important to understand their current extinction risk and threats to recovery. The ESA therefore outlines exceptions to the prohibitions on take where researchers can apply for permits to conduct studies on ESA-listed species:

- Under section 10(a)(1)(A) of the ESA, for studies conducted by any entity that have a bona fide scientific purpose and meet other key criteria limiting harm and justifying the data need; or
- Under section 4(d) of the ESA, for research that may take threatened species being conducted by state agencies or tribes.

Researchers apply for permits through the Authorizations and Permits for Protected Species (APPS) application, and NMFS personnel view this information and make permitting decisions based on the expected impacts of the research to the species relative to the value of the information that would be collected.

Why was this app developed?

Currently NMFS’ West Coast Region staff do not have an easy way to map and visually summarize their research permitting information for internal use, or to share with applicants and co-managers. Therefore, students from the School of Marine and Environmental Affairs (SMEA) at the University of Washington (UW) were contracted with the primary purpose of developing an application that would:

- Support the decision-making process for issuing scientific research permits in NMFS’ West Coast Region,
- Provide more transparency to researchers as well as state and tribal government co-managers about the permitting process, and
- Educate the public about the role of research to inform the management of ESA-listed species.

References:

Endangered Species Act. 16 U.S.C. 1531-1544 (1973). National Marine Fisheries Service (NMFS). (2019). Chapter 3: NMFS Pacific Marine/Anadromous Fish and Invertebrates Scientific Research Authorizations and Oregon Scientific Take Permits. National Marine Fisheries Service. 1315 East-West Highway Silver Spring, MD 20910.

Glossary (subtab)

Terms and Definitions (tab title)

Commonly used acronyms

- Department of Fish and Wildlife (DFW): State agencies tasked with the protection and conservation of the state’s fish, wildlife, and ecosystems for the benefit of their citizens. One DFW exists for each state in NMFS’ West Coast Region; Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fish and Wildlife (WDFW),

California Department of Fish and Wildlife (CDFW), and Idaho Department of Fish and Game (IDFG).

- Distinct Population Segment (DPS): a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species.[1]
- Endangered Species Act (ESA): United States federal legislation that outlines the protection and conservation of the nation's at-risk species.
- Evolutionarily significant unit (ESU): a Pacific salmon population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species.[1]
- Hydrologic Unit Code (HUC or HUC8): A HUC is a hierarchical land area classification system created by the United States Geological Survey (USGS).
- National Marine Fisheries Service (NMFS): Agency within NOAA responsible for the management, protection and conservation of United States marine resources.
- National Oceanic and Atmospheric Administration (NOAA): Scientific and regulatory agency in the United States that researches weather and atmospheric conditions as well as managing fisheries, marine mammals and endangered species. To learn more about NOAA look here.

Other key terms

- Dip Net: Method of capture where a long-handled fishing net (up to five feet in diameter) is dipped into the water to catch unsuspecting fish below.[1]
- Electrofishing: Method of capture where electrical current is used to inhibit or stun fish that can then be captured.
- Metadata: Represents data about data, enriches the data with information that makes it easier to find, use and manage.
- Nomenclature: The devising or choosing of names for things, especially in a science or other discipline.
- Take: Defined as any action that harasses, harms, pursues, hunts, shoots, wounds, kills, traps, captures, or collects listed species or attempting to engage in any such conduct.
- Trap: Various capture methods (minnow trap, screw trap, incline plane trap, etc.) that involve the setup of a device that passively catches fish and accumulates them into a live holding tank or compartment.
- Trawl: Capture method that involves pulling a large net through the water using one or more boats.
- Seine: A net with floats on top and weights on the bottom that encircles the fish. Can be used from shore (beach seine) or from a boat (purse seine).

Sources:

1. https://www.fisheries.noaa.gov/laws-and-policies/glossary-endangered-species-act#:~:text=Take%20as%20defined%20under%20the,%2C%20but%20not%20unexpected%2C%20taking.

Fish Glossary

Below are the names of the fish species that are included within this app. They are the fish species under NMFS' jurisdiction for which an ESU or DPS is currently listed as threatened or endangered under the ESA.
Salmonids:

- Chinook Salmon (*Oncorhynchus tshawytscha*)
- Coho Salmon (*Oncorhynchus kisutch*)
- Chum Salmon (*Oncorhynchus keta*)
- Sockeye Salmon (*Oncorhynchus nerka*)
- Steelhead Trout (*Oncorhynchus mykiss*)

Find more information regarding salmonids, see here

Other species:

- Bocaccio (*Sebastes paucispinis*)
- Eulachon (*Thaleichthys pacificus*)
- Green Sturgeon (*Acipenser medirostris*)
- Yelloweye Rockfish (*Sebastes ruberrimus*)

Find more information regarding other species, see here

Uses and Limitations (subtab)

Uses and Limitations (tab title)

Things to know about this app

Users of this app should be aware of the following limitations and assumptions regarding the raw data and data summaries presented in this application:

These data are provisional, and are subject to change at any time. Additionally, this app is specifically for ESA-listed fish species in the West Coast Region under NOAA jurisdiction. Therefore, ESA-listed fish species under the jurisdiction of the U.S. Fish and Wildlife Service or protected under other state and international organizations are not represented here.

For the purpose of this project, some fields and data entries were modified to simplify analyses and provide consistency across the nomenclature. These include:

- Adjusting HUC 8 codes to encompass redrawn boundaries; see metadata for details

- Renaming and classifying water bodies in the 'WaterbodyName' field to allow for consistent nomenclature and inform users about the type of water bodies (saltwater or freshwater) these locations describe. Renaming practices were performed using best available data provided in the 'LocationDescription' field.

- Reclassifying 'Lifestage' and 'Production' fields to reduce the number of unique entries. For example:
    - 'Smolt' and ‘fry’ were replaced by 'Juvenile'
    - 'Listed Hatchery, Clipped and Intact', ‘Listed Hatchery Adipose Clip’, ‘Listed Hatchery intact Adipose Clip were replaced by ‘Hatchery'

Details of the rule sets used to create these fields can be found within the script files accessible through the Github repository.

Limitations and Omissions

Some data limitations were beyond the developers' control. These include:

- Take may have occurred which was not reported, and any take not submitted through the APPS system would not be captured.
- The input of incorrect HUC 8 codes by researchers applying for permits (for example: the ‘9999999’ HUC codes seen in the reactive data table) meant these data could not be accurately plotted with the other map data.

For the purpose of this project, the following data types were intentionally omitted:

- Unlisted hatchery fish
- Non-invasive take actions (e.g., snorkel surveys, dead tissue samples)
- Unknown take actions
- Permits that are expired or were never issued
- Research happening across a large geographic scope (whole states or coasts) were omitted from the map, but are included in time series.
- Tribal 4d permits were omitted from tables showing individual permit information for data privacy reasons, but included in the totals shown in the map and time series.

Metadata

For further information regarding the data source, data attributes, R packages used, and general metadata for this project, please visit the metadata folder of our Github.

License statement

[License Picture]

Citation

Spurr, R., & Santana, A. (2023). Visualizing ESA-Listed Fish Research on the West Coast (Version 1.0.0) [Computer software]. https://github.com/rory-spurr/ESAPermitsCapstone

Datasets Cited:
National Marine Fisheries Service and Oregon Department of Fish and Wildlife. Authorizations and Permits for Protected Species (APPS). Current authorizations for research under ESA Section 10(a)(1)(A) and Section 4(d), and reported take from 2012-2023, for fish species in Washington, Oregon, Idaho, and California. Available online at https://apps.nmfs.noaa.gov/. Accessed 02/09/23.

Acknowledgements
We thank Diana Dishman for her conceptualization of the project, expert technical guidance surrounding the permitting process and editing and critiquing drafts of the application. We also want to thank Anne Beaudreau for her help editing and critiquing drafts of the application, as well as the professional and technical guidance she has shown us throughout our time in grad school. We want to thank both NMFS's West Coast Region research permit and communications teams for taking the time to meet with us and help with the application. Funding for this project was provided through the NMFS West Coast Region Protected Resources Division, as well as the Jay Ginter Memorial Scholarship Fund at the University of Washington.

Authorized Take Map

About the Map
The map displays total authorized take (or total lethal take depending on what data is selected to display), for each Hydrologic Unit Code 8 (HUC 8). The black outline shows all the possible HUC 8's where these species may be encountered. Individual HUC 8's may be clicked on inside the map to reveal more information for the HUC, including specific authorized take values.

Build Your Map
Choose a life stage
- Adult
- Juvenile

Choose an origin
- Natural
- Hatchery

Choose data to display
- Total Take
- Lethal Take

Choose an ESU/DPS to view

About the Table
This table displays the raw data from the map above. The fields within this table are defined as:

Permit Code: The code automatically assigned by the APPS system and used in correspondence about the application. Can be searched on APPS to learn more about an individual permit.
Permit Type: Indicates the kind of permit or authority (more detail here).
Organization: Entity in charge of research operations.
HUC 8: Hydrologic Unit 8 (HUC 8) code where research is taking place.
Location: Name or description of research location.

Water Type: Whether the research is happening in freshwater (FW) or saltwater (SW).
Take Action: Action taken to capture/tag/kill animals.
Gear Type: Gear used to capture species.
Total Take: Total amount of take authorized. Includes both lethal and non-lethal take.
Lethal Take: Total amount of fish mortality authorized.

Time Series

Build Your Plot
Choose a life stage
    Adult
    Juvenile
Choose an origin
    Natural
    Hatchery
Choose an ESU/DPS to view

Time Series (plot)

Plot titles:
    Time Series
    Total Authorized Take (lethal & non-lethal)
    Lethal Authorized Take

Y-axis labels:
    Total Take (Number of fish)

About the plots
These plots display the authorized take and reported take of fish per year. Total take (number of fish) is the sum of reported take or what was actually used (yellow) and the remaining authorized take that was unused (blue). Note that the data is only showing what was reported through APPS and may not be complete due to unreported take by researchers.

Raw Data Table (table)
Caption: Note: Permits issued under the ESA 4(d) authority specific to Tribal Resource Management are not individually listed in the table because they are not considered public, but those data are included in the totals displayed in the map above.

Column headers:
Year; Report ID; Permit Number; Permit Type; Gear Type; Authorized Take; Reported Take; Unused Take; Authorized Mortality; Reported Mortality; Unused Mortality

About the table
This table displays the raw data from the plots above. The fields within this table are defined as:

- Year: The year field indicates the year that each permit was issued.

- Report ID: A five-digit unique code for each active project that reported take and mortality within their research.
- Permit Code: The code automatically assigned by the APPS system and used in correspondence about the application.
- Permit Type: Indicates the kind of permit or authority, more detail here.
- Gear Type: Gear used to capture species.
- Authorized Take: Predicted and allocated number of individuals the project expects to take as a result of research. Includes numbers from lethal and non-lethal take.
- Reported Take: The number of individuals reported taken as a result of research. Includes numbers from lethal and non-lethal take.
- Unused Take: The number of fish authorized to be taken that was allocated but went unused by the researcher. The difference between the authorized number and the reported number.
- Authorized Mortality: Authorized number of individuals that may be killed as a result of research. Includes ONLY lethal take.
- Reported Mortality: The number of individuals reported killed as a result of research. Includes ONLY lethal take.
- Unused Mortality: The number of fish authorized to be killed that went unused by the researcher. The difference between the authorized number and the reported number.

About Us

Alana Santana - Lead Developer

Alana Santana is a multifaceted individual, specializing in several areas including fish and marine biology, conservation, biomechanics, R coding, and ArcGIS. After Alana obtains her Master's, she is interested in pursuing a career that allows her to integrate coding and spatial analysis skills into her work for conservation purposes.

Contact info:
Github: asantan8
Email: asantan7@uw.edu

Rory Spurr - Lead Developer

Rory Spurr has worn many hats throughout his life, working as a fisheries scientist, in research and development for a fish passage company, and most recently as an R programmer. Rory will graduate with his Master's in March and is excited to see where his career will take him.

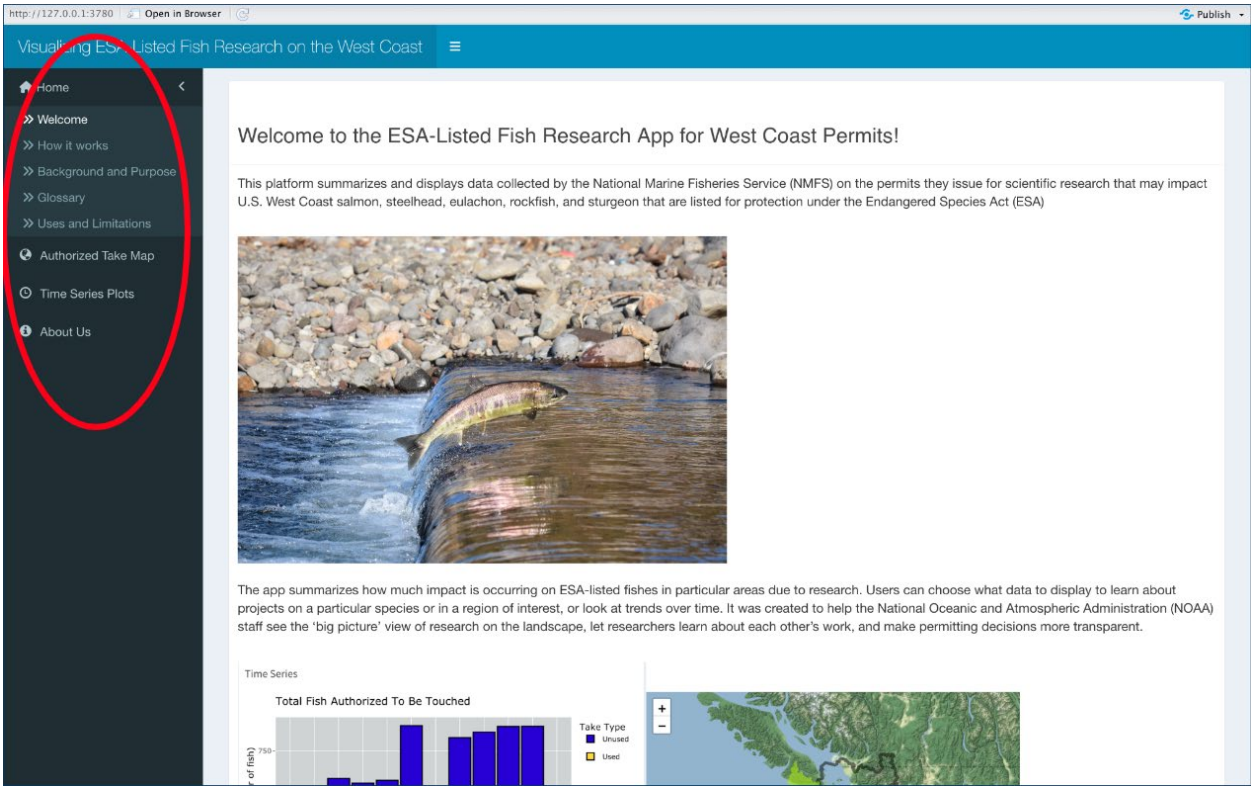
Contact info:
Website
GitHub: rory-spurr
Email: rjspurr5@live.com

Appendix II: Application Screenshots

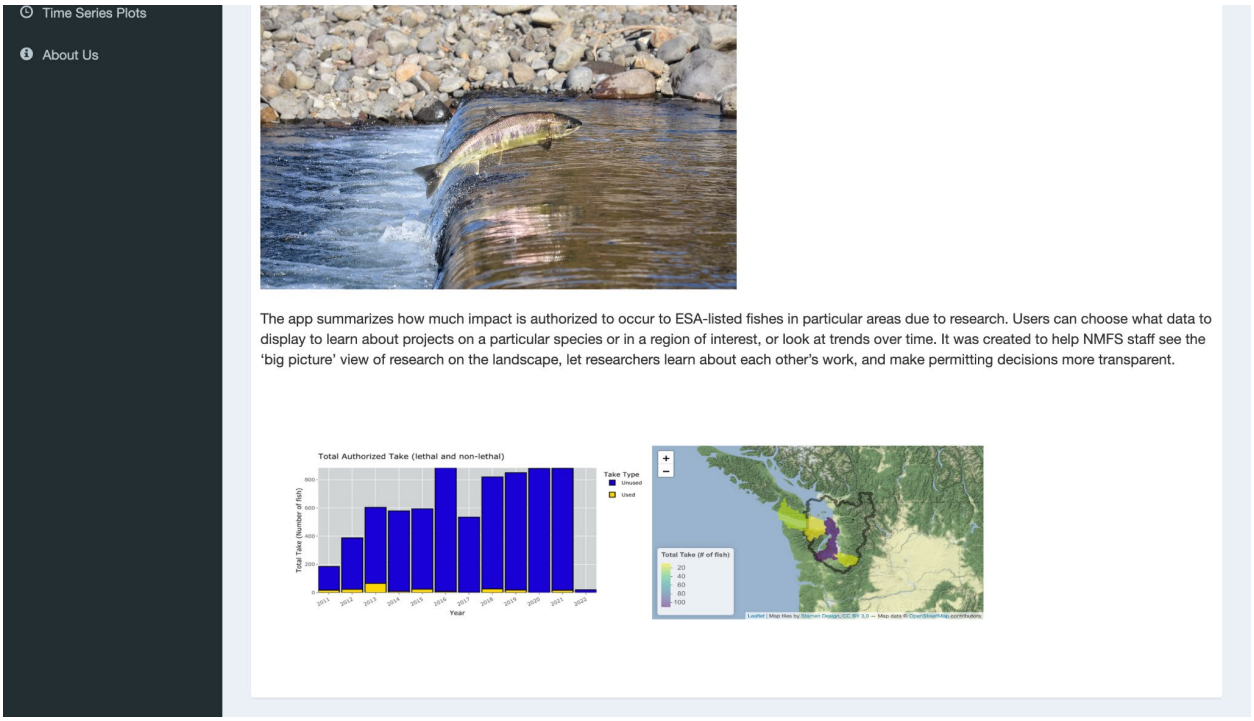
This section will show screenshots of the application, pointing out how they work and how they interact with the user's selections. Screenshots show pages in the order they appear in the app's menu.

Home

Welcome (subtab)

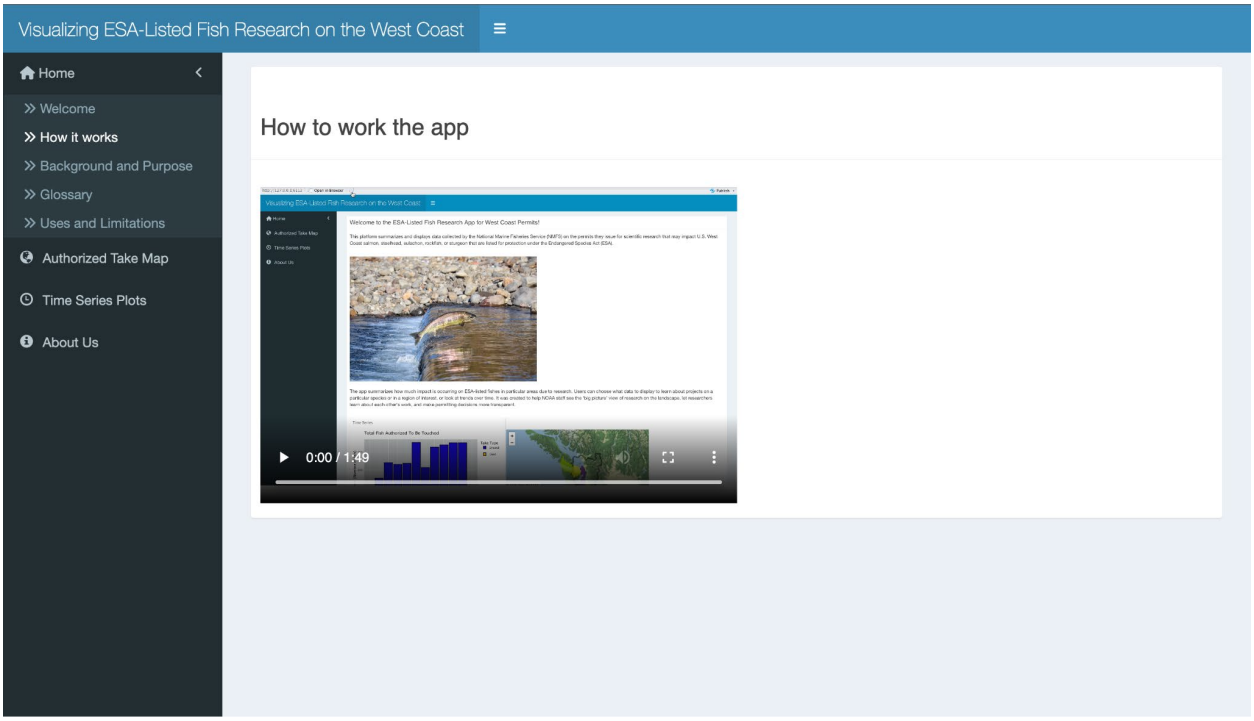


SS1: Welcome tab introduces the user to the app. The menu panel (circled) allows users to navigate to different sections of the application.



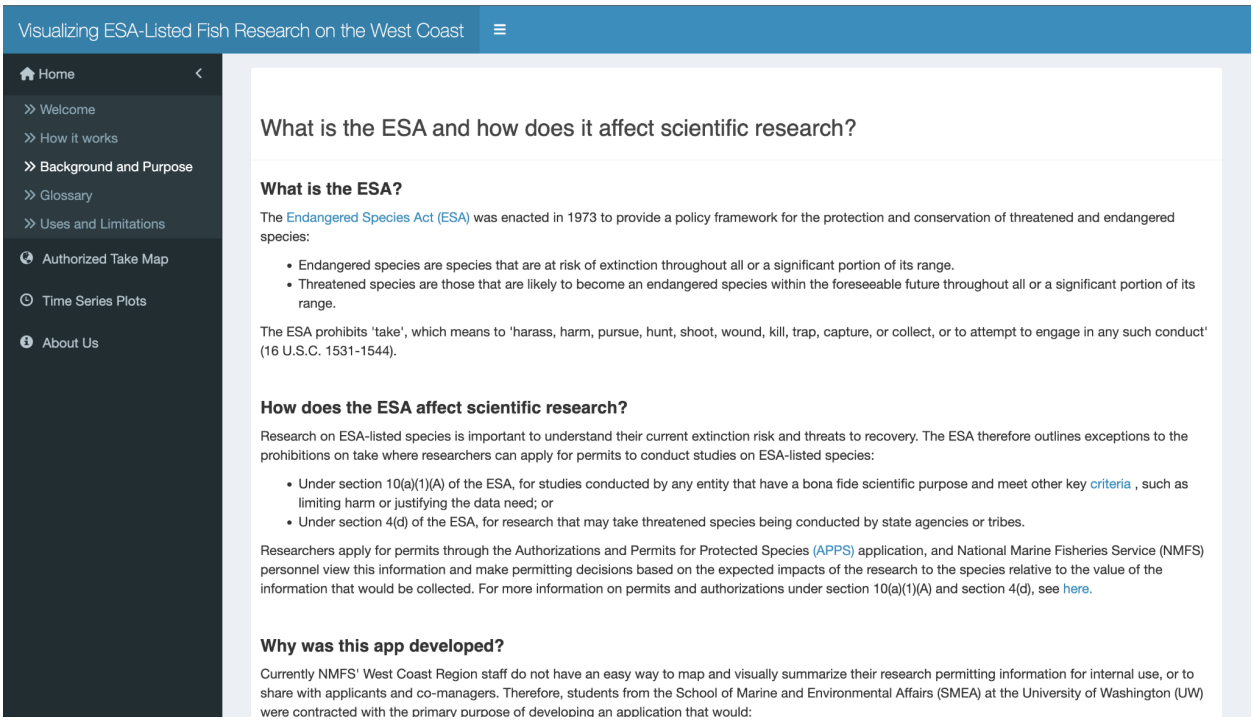
SS2: Bottom side of the welcome tab.

How it Works (subtab)

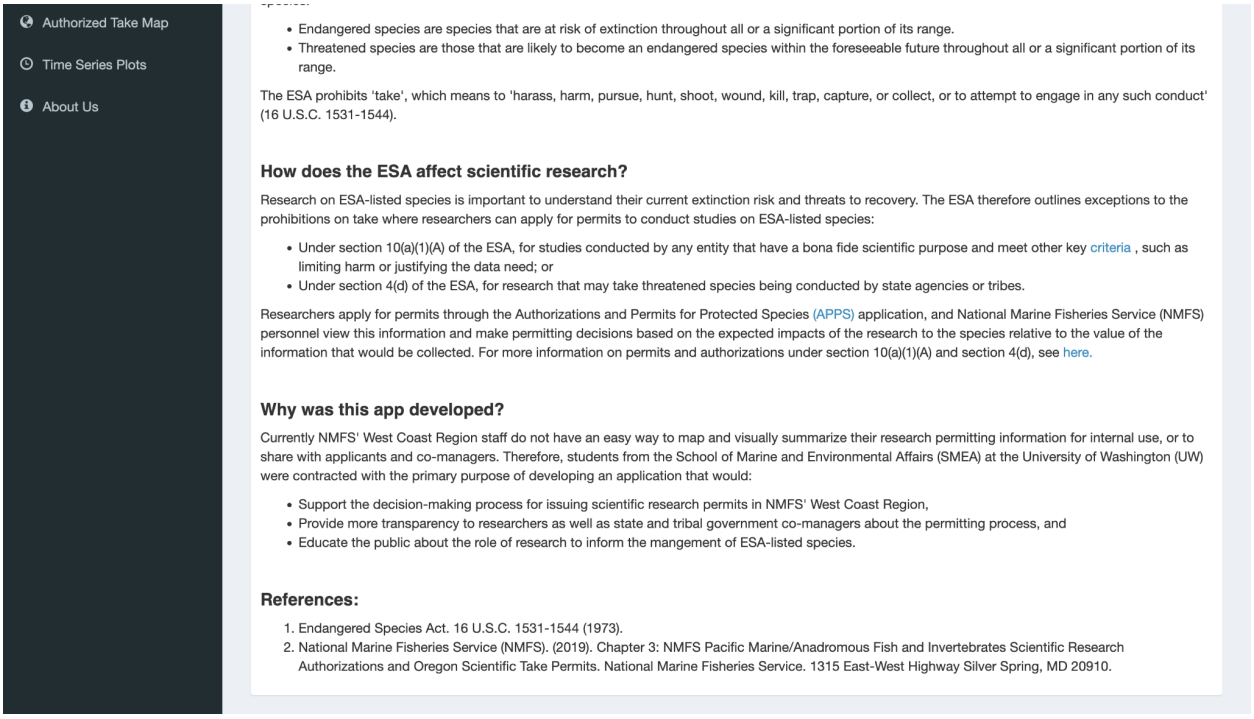


SS3: This tab displays a video instructing the user on how to work the application.

Background and Purpose (subtab)

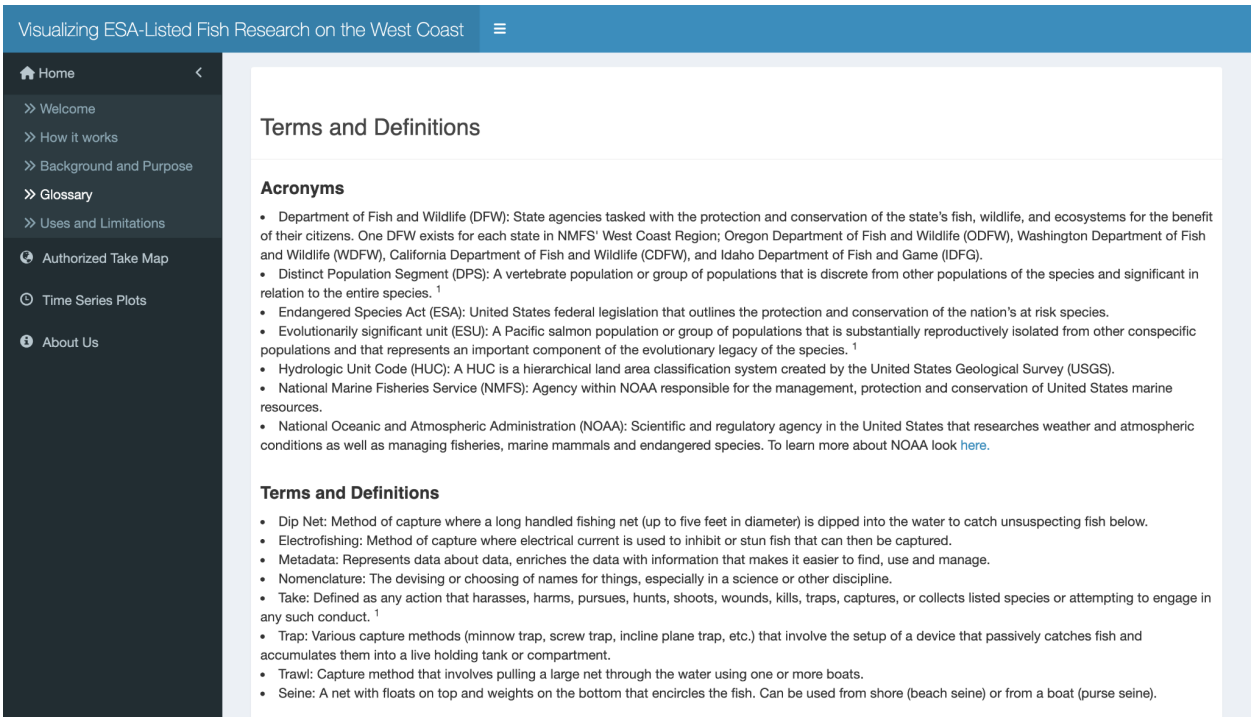


SS4: Background and purpose section, gives users background on app information.

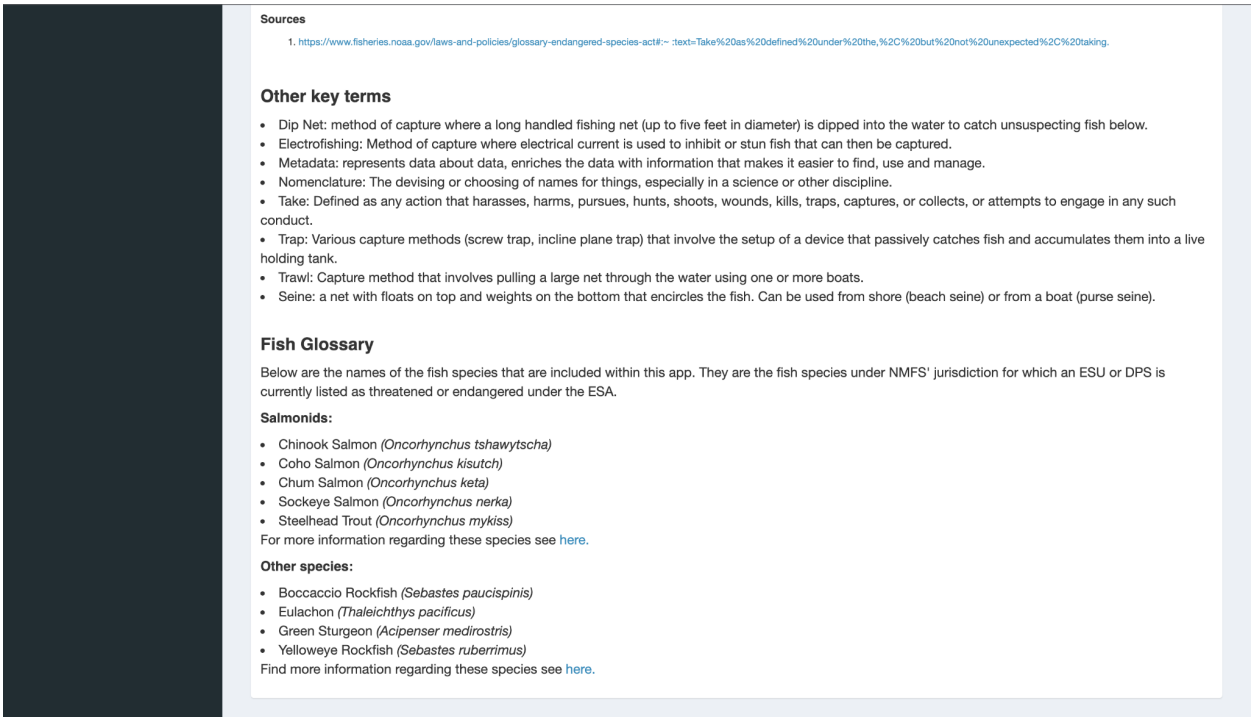


SS5: Bottom section of background and purpose section.

Glossary (subtab)

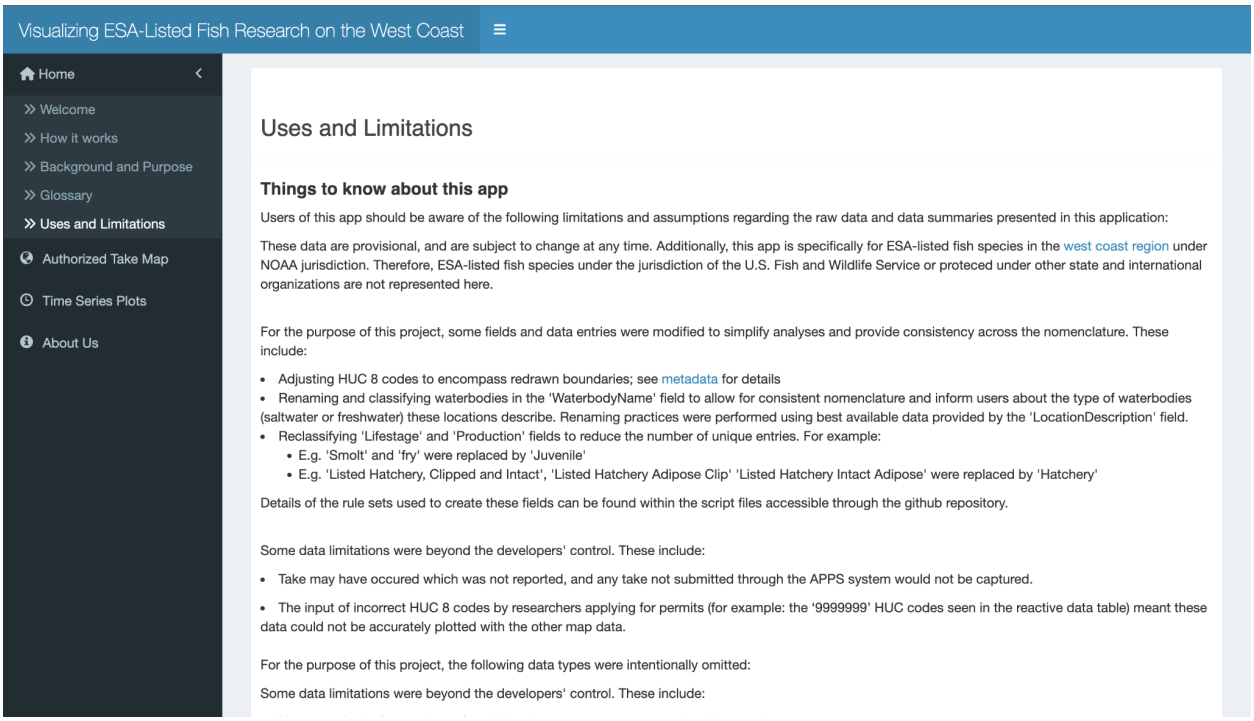


SS6: Top of terms and definitions page.

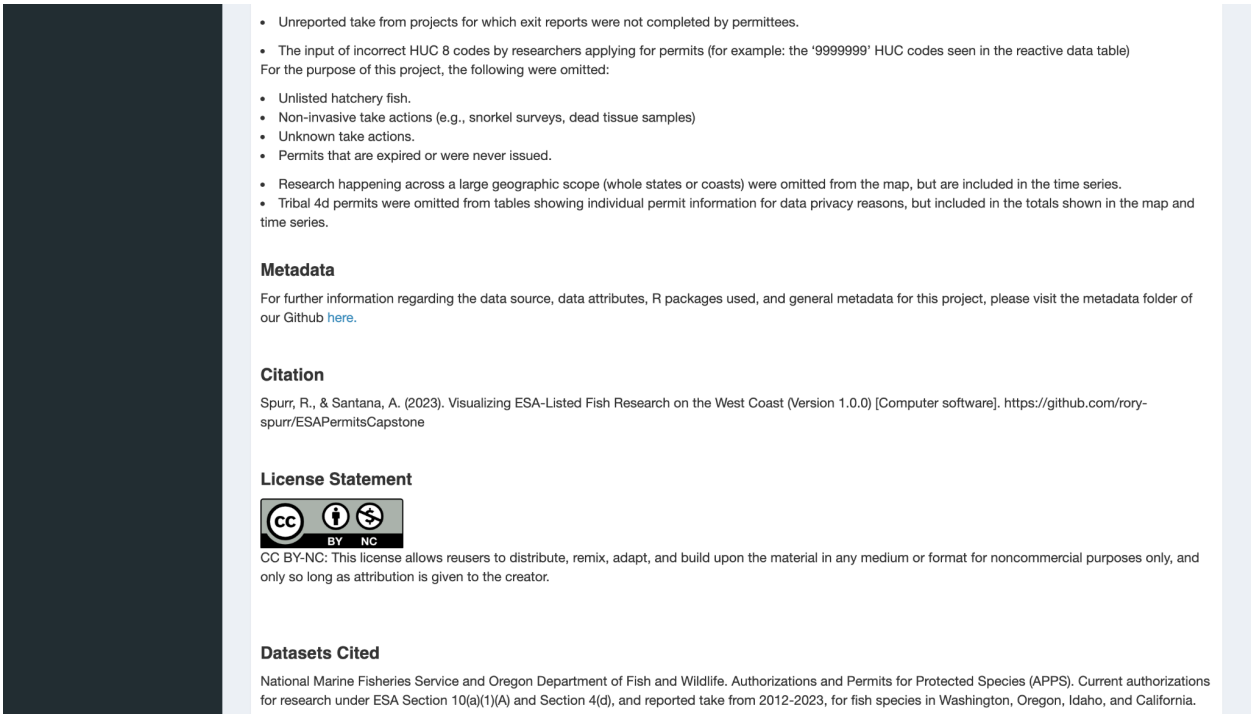


SS7: Bottom of terms and definitions page.

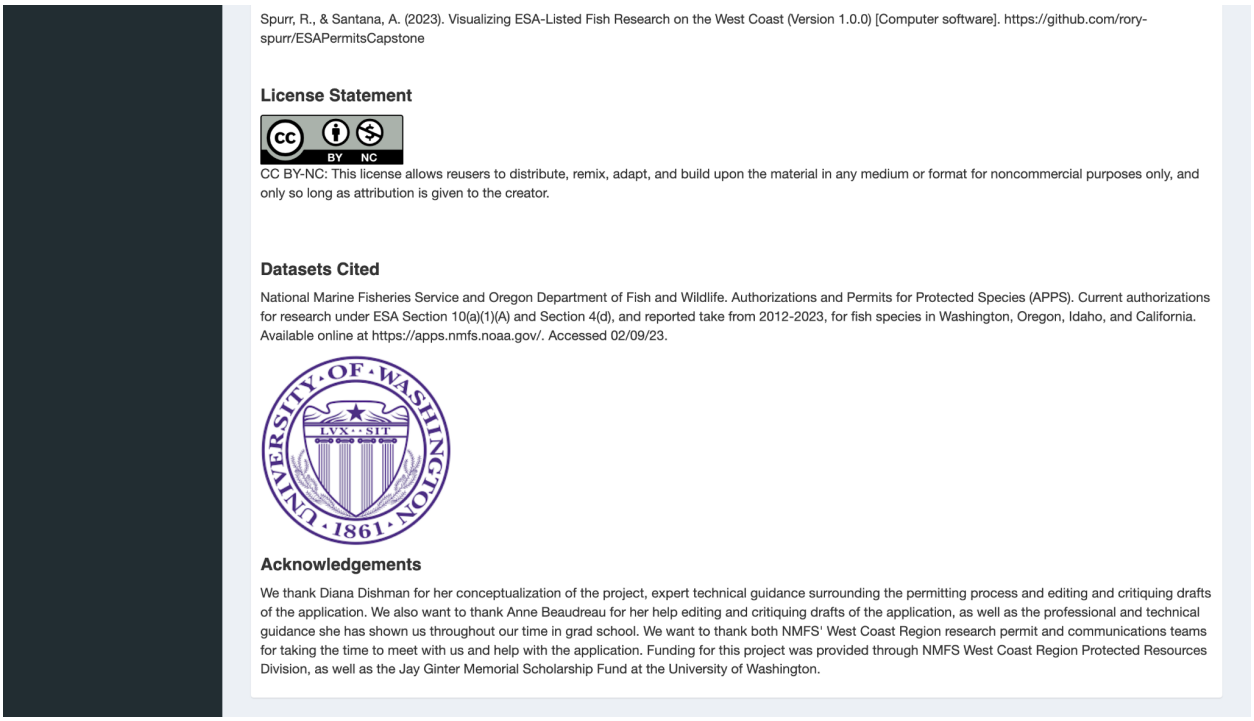
Uses and Limitations (subtab)



SS8: Top of uses and limitations page

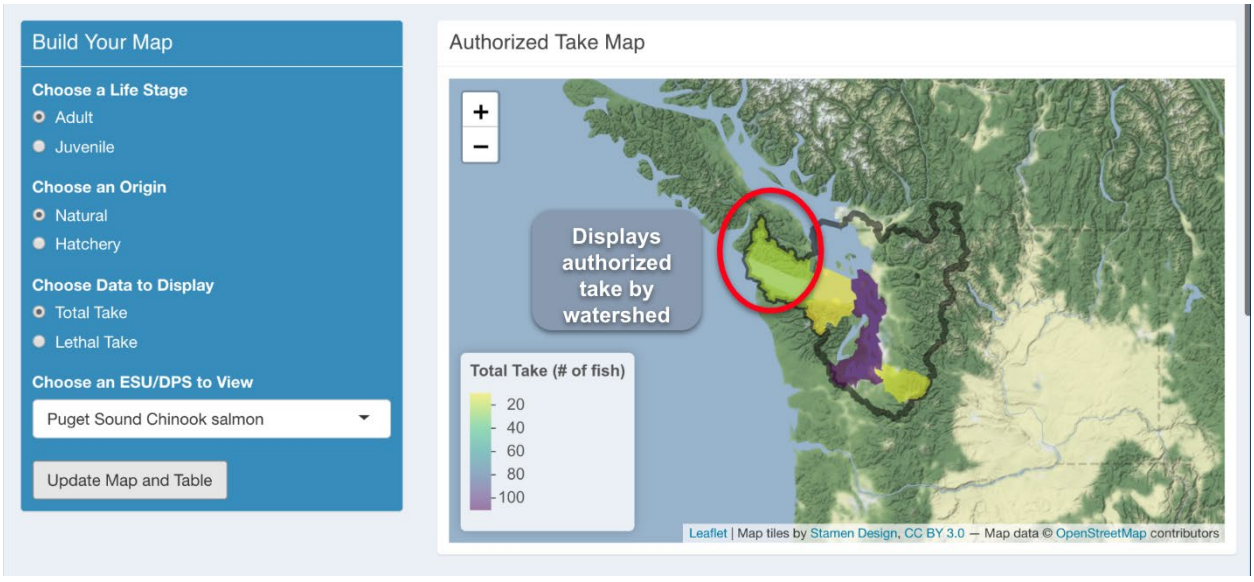


SS9: Middle section, includes license statement and citation.

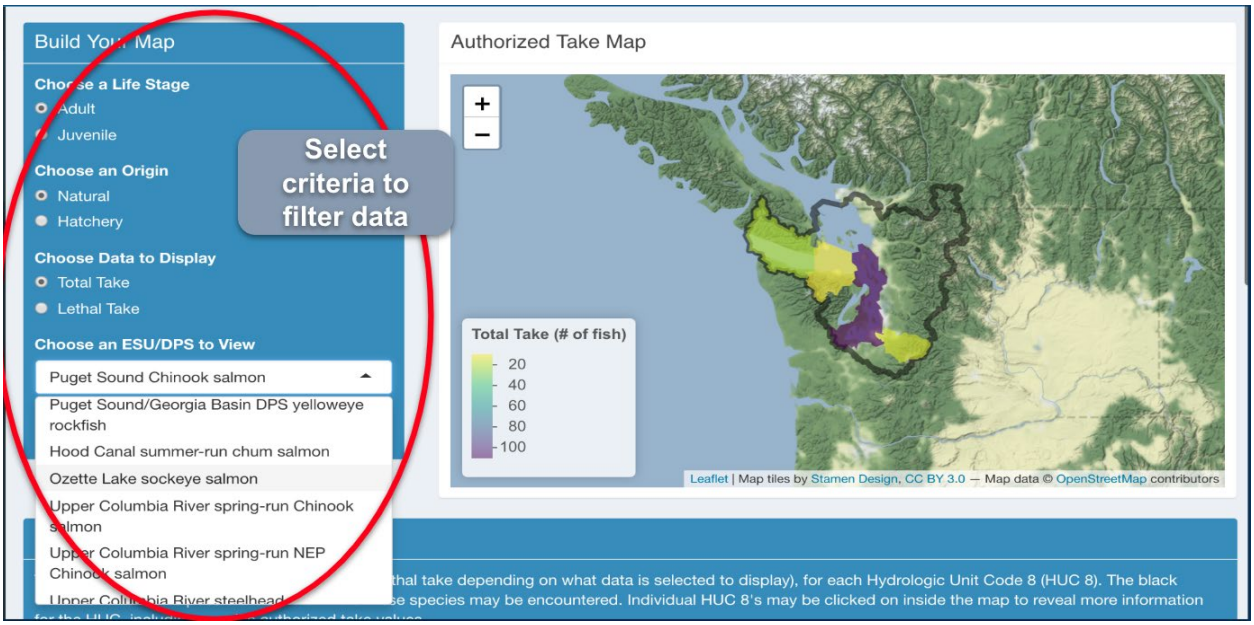


SS10: Bottom section of uses and limitations. Includes help and funding acknowledgements.

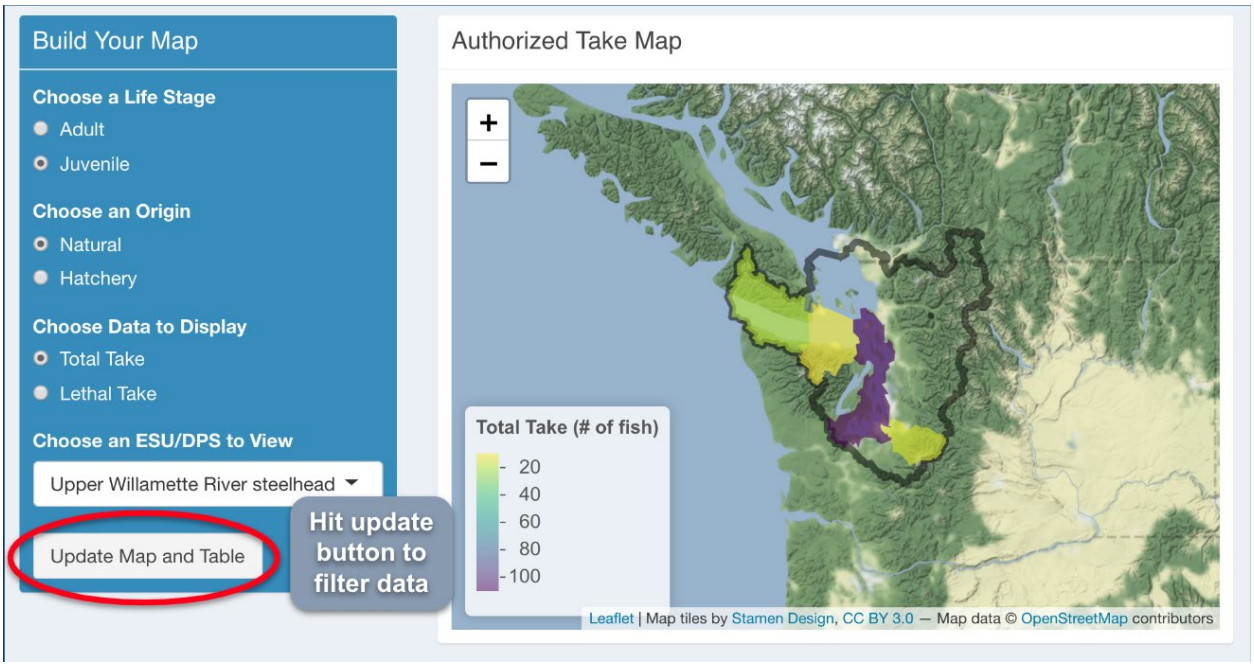
Authorized Take Map



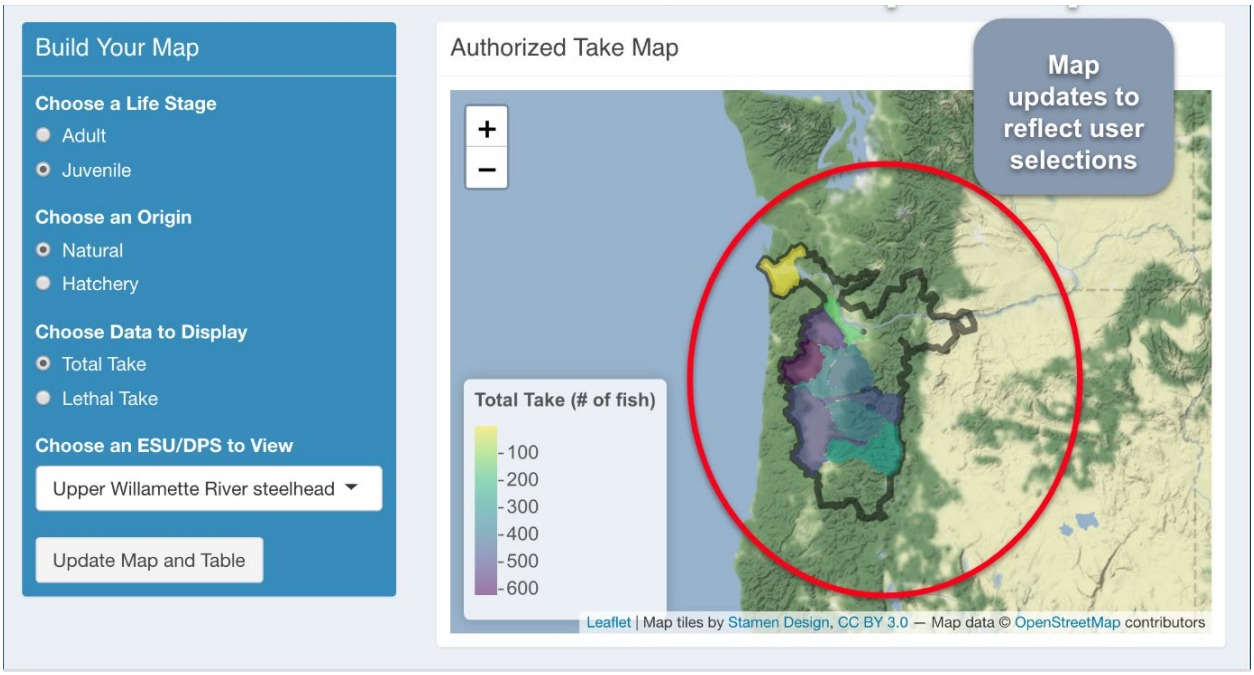
SS11: Authorized take map that displays take data by watershed. All permits within a watershed are aggregated for a total amount of take per watershed.



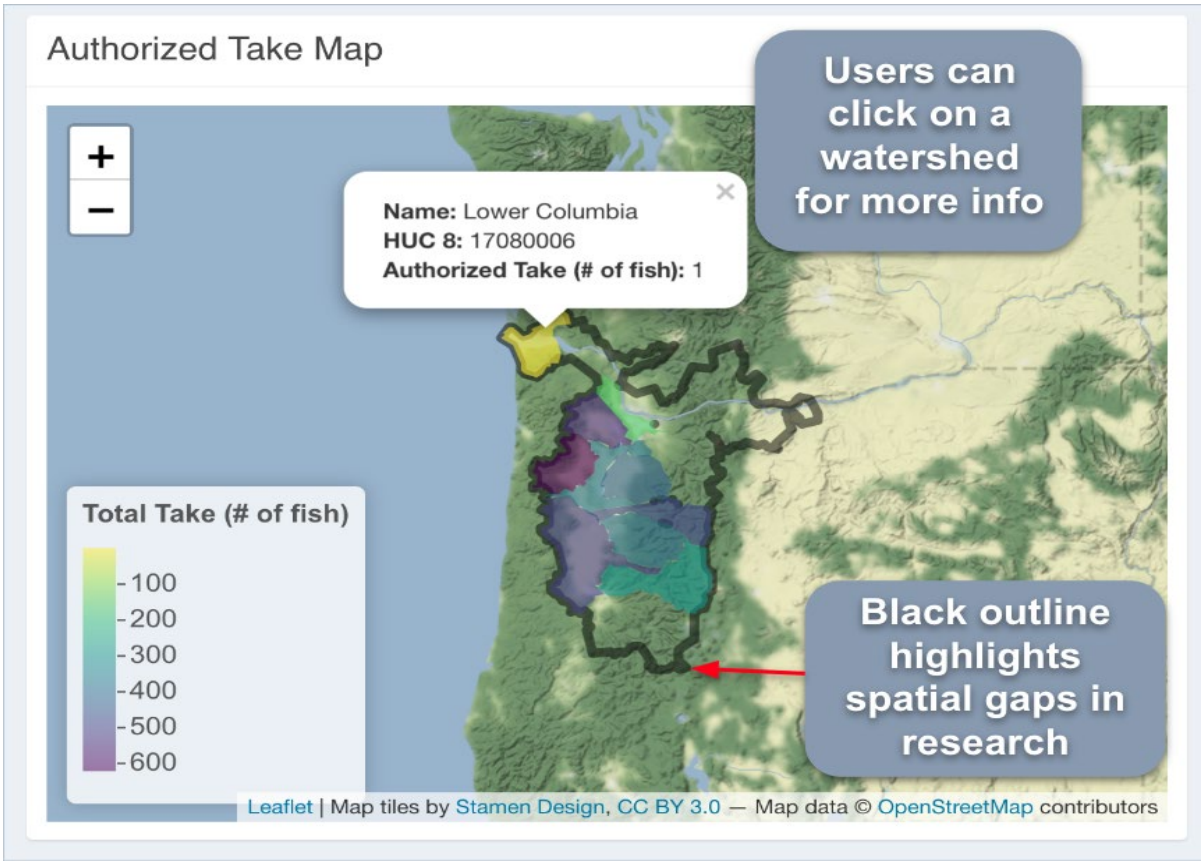
SS12: Users can use the control panel on the left side of the map to select filters they wish to apply to the underlying data. Choices include life stage, origin, whether to display total take or lethal take, and ESU/DPS.



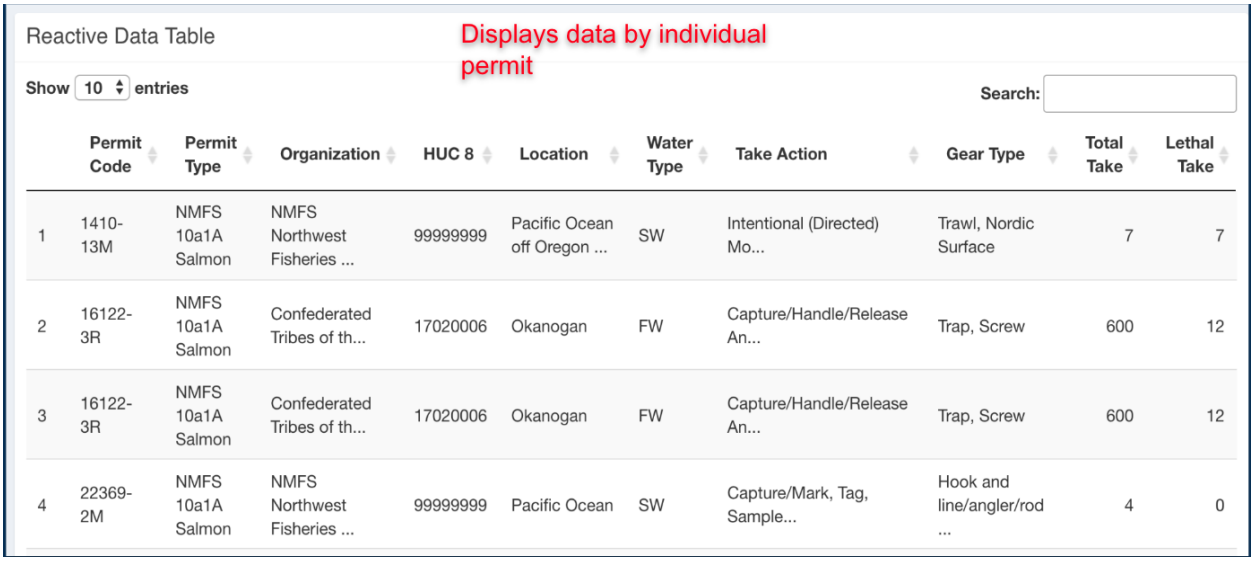
SS13: Map and table will update after the button is hit.



SS14: Map then updates to reflect user selections.

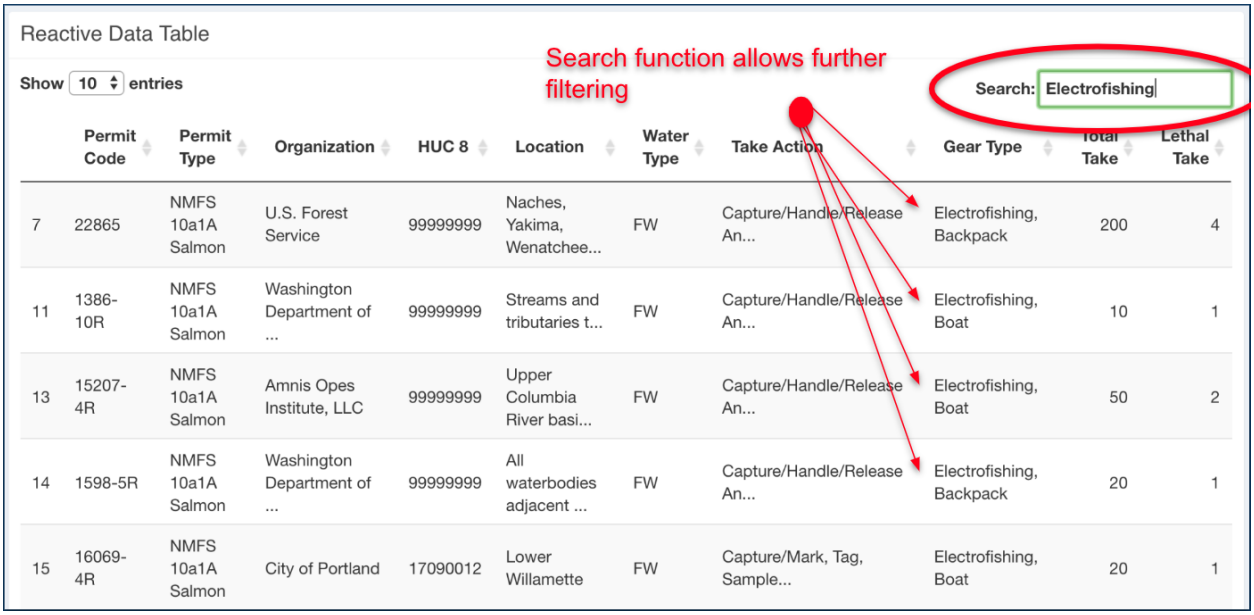


SS15: Users can click on a watershed for more information. Note that the black outline shows all watersheds where an ESU/DPS could be found.



	Permit Code	Permit Type	Organization	HUC 8	Location	Water Type	Take Action	Gear Type	Total Take	Lethal Take
1	1410-13M	NMFS 10a1A Salmon	NMFS Northwest Fisheries ...	99999999	Pacific Ocean off Oregon ...	SW	Intentional (Directed) Mo...	Trawl, Nordic Surface	7	7
2	16122-3R	NMFS 10a1A Salmon	Confederated Tribes of th...	17020006	Okanogan	FW	Capture/Handle/Release An...	Trap, Screw	600	12
3	16122-3R	NMFS 10a1A Salmon	Confederated Tribes of th...	17020006	Okanogan	FW	Capture/Handle/Release An...	Trap, Screw	600	12
4	22369-2M	NMFS 10a1A Salmon	NMFS Northwest Fisheries ...	99999999	Pacific Ocean	SW	Capture/Mark, Tag, Sample...	Hook and line/angler/rod ...	4	0

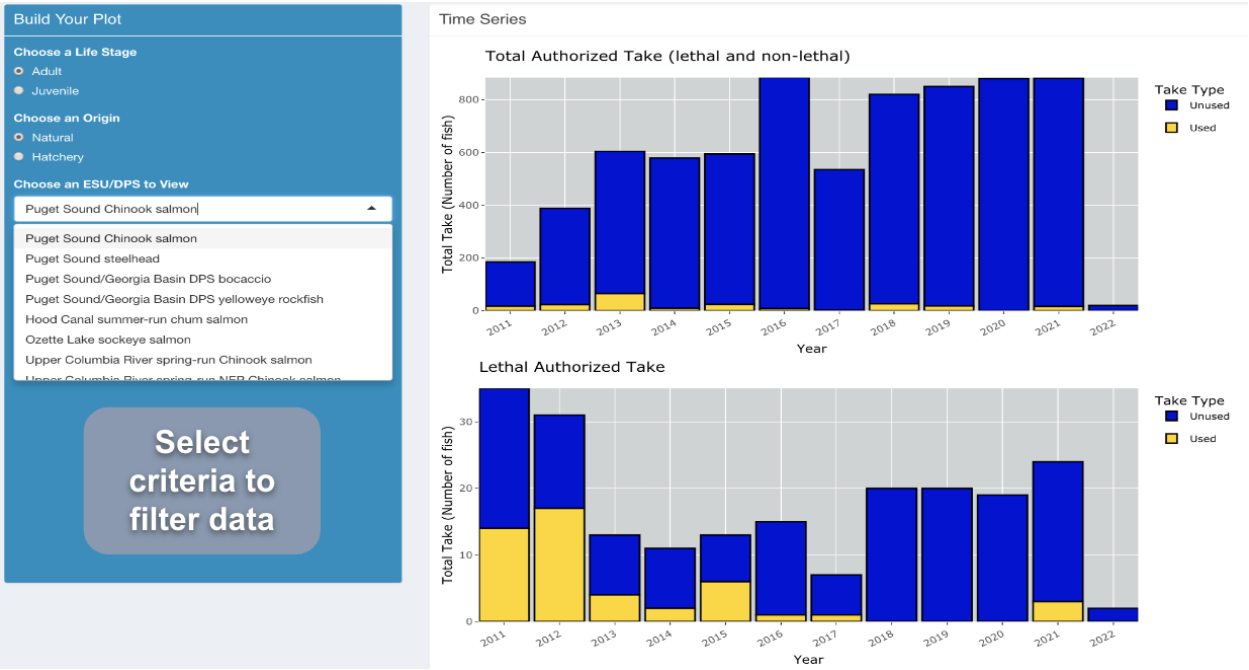
SS16: Table below map updates and is subject to the same filters as the map. Displays data by individual permit instead of aggregated by watershed.



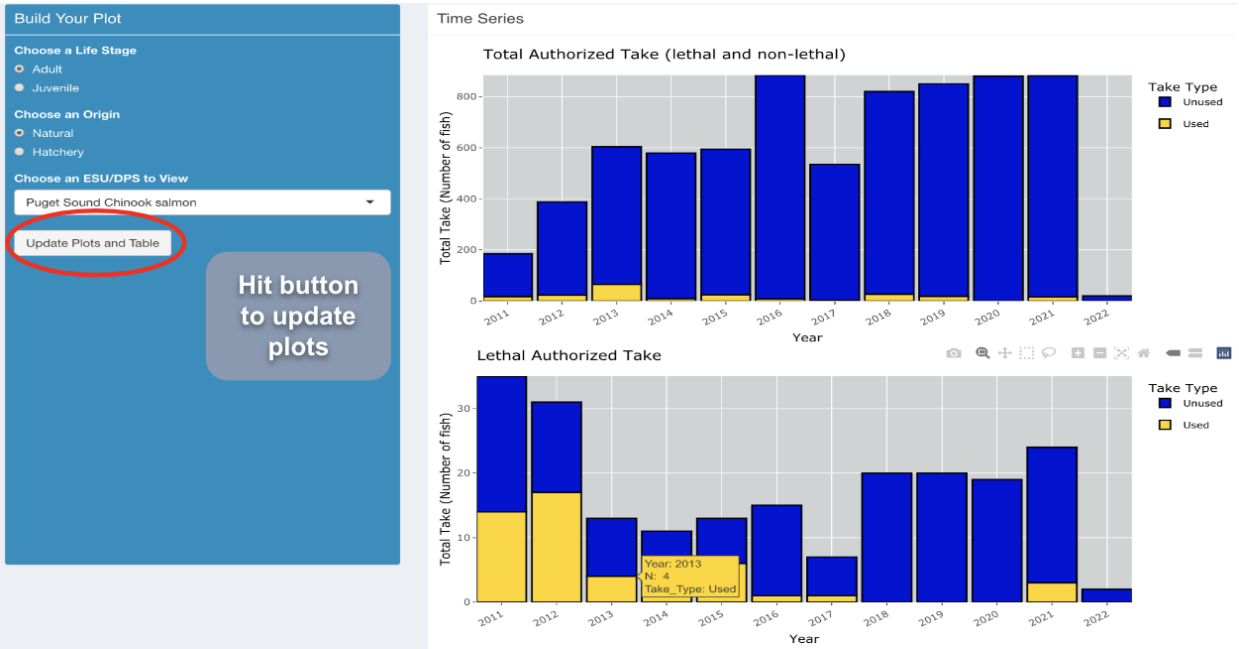
	Permit Code	Permit Type	Organization	HUC 8	Location	Water Type	Take Action	Gear Type	Total Take	Lethal Take
7	22865	NMFS 10a1A Salmon	U.S. Forest Service	99999999	Naches, Yakima, Wenatchee...	FW	Capture/Handle/Release An...	Electrofishing, Backpack	200	4
11	1386-10R	NMFS 10a1A Salmon	Washington Department of ...	99999999	Streams and tributaries t...	FW	Capture/Handle/Release An...	Electrofishing, Boat	10	1
13	15207-4R	NMFS 10a1A Salmon	Amnis Opes Institute, LLC	99999999	Upper Columbia River basi...	FW	Capture/Handle/Release An...	Electrofishing, Boat	50	2
14	1598-5R	NMFS 10a1A Salmon	Washington Department of ...	99999999	All waterbodies adjacent ...	FW	Capture/Handle/Release An...	Electrofishing, Backpack	20	1
15	16069-4R	NMFS 10a1A Salmon	City of Portland	17090012	Lower Willamette	FW	Capture/Mark, Tag, Sample...	Electrofishing, Boat	20	1

SS17: Table also has a search function that allows further filtering of data.

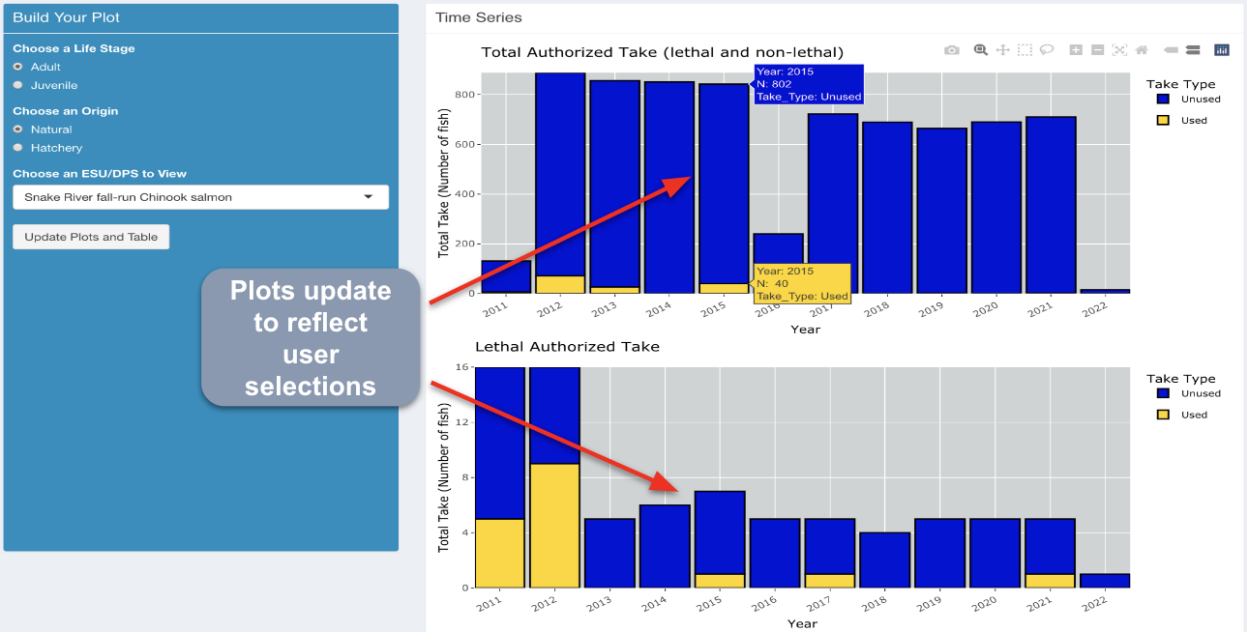
Time Series Plots



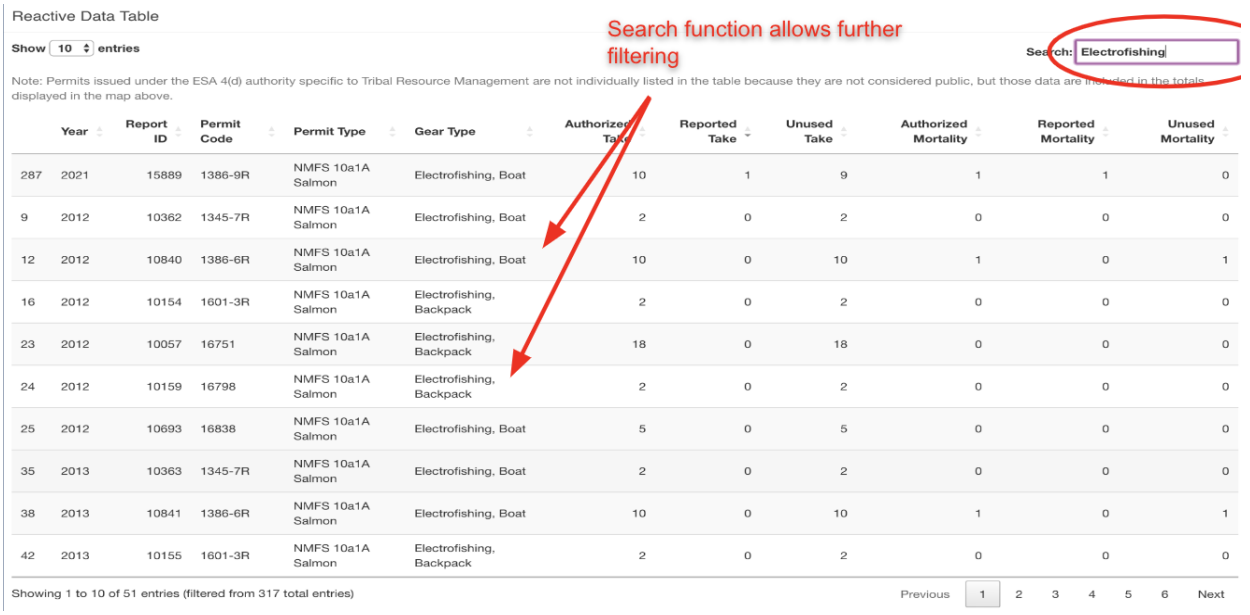
SS18: Filter selection display. Shows various filters you can manipulate to display data on plots.



SS19: To update the plots, make sure to hit the update plots and table button to reflect new filters.

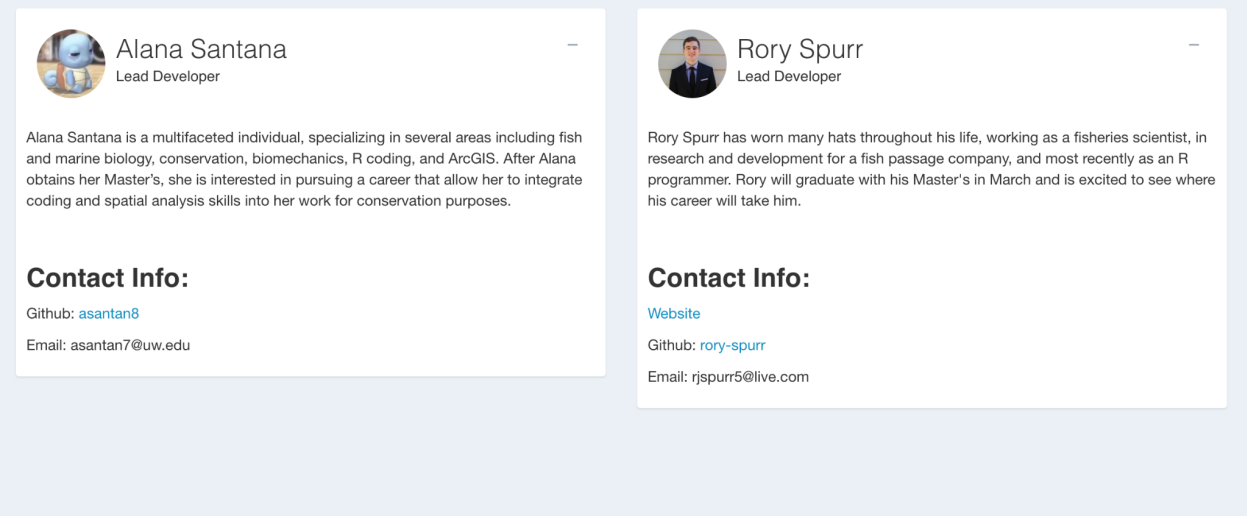


SS20: Plots update to reflect user inputs in two different displays - total authorized take (lethal and non-lethal) and lethal authorized take.



SS21: Reactive data take that accompanies the plots and updates to user filters.

About Us



SS22: Bios and contact information for each developer.

Appendix III: Data Biography

1. RESOURCE OVERVIEW (*what, why, who*)

1.1. Title of the dataset. *Descriptive title that usually includes data type, time period, location, and name of author, program, or institution.*

NOAA West Coast Region (WCR) Permitting Data, 2012 to 2023, U.S. West Coast (WA, OR, CA, ID), export from larger relational database maintained by NOAA WCR (Protected Resources Division).

1.2. Abstract. *One paragraph summary of the dataset in plain language. Include one sentence of broader context, followed by the dataset's origin/purpose, and briefly expand on the elements of the title. A length of 200-250 words is a good target.*

The NOAA WCR permitting database stores information about permits they issue for conducting research activities that may harm (purposefully or incidentally) species listed as threatened or endangered under the Endangered Species Act (ESA). The database collates information submitted by permit applicants through NOAA's online application system for Authorizations and Permits for Protected Species (APPS; https://apps.nmfs.noaa.gov/). The database is used by the Protected Resources Division (PRD) to store information on the amount of take being authorized for threatened and endangered species. This in turn allows the PRD to authorize permits that minimize harm to the species while maximizing the conservation benefit gained from the project. For example, the database provides information on the permit type, whether the permit was issued, where the research is occurring, what type of research will be conducted, what type of ESA-listed species are involved, and the amount of take authorized during the period of the project. Permit types can range from streamlined projects conducted on threatened species (4d and tribal 4d) to permits that allow research to be conducted on endangered species (10a1A permits). The portion of the dataset that the UW capstone team is working with is a subset that was queried from the larger relational database, and includes only permit types specific to scientific research actions.

1.3. Purpose. *Brief description of why the data were collected, including the goals and intended outcomes (this may or may not include application to decision-making).*

The NOAA WCR permitting dataset was collected as a form of record-keeping of current and past permits. The data is automatically stored in this repository to be reaccessed by anyone searching for past or current permits. The data is important for making decisions on issuing future permits, as NOAA can view the amount of take being authorized on an ESA-listed species, and determine if the amount of take being requested will put the species in jeopardy. Along with this, NOAA can review the methods and goals of the proposed study, and decide if it has a bona fide and desirable purpose in enhancing the viability of the species.

1.4. Contacts. *Provide contact info for the people who managed the project, collected the data, generated the dataset, and/or managed the data. Contact information should include name, organization, role in the project, email and/or phone.*

Agency: NOAA
Region: West Coast Region
Office Phone: (503) 230-5400
Website: https://www.fisheries.noaa.gov/about/west-coast-region
Address: 1201 Northeast Lloyd Boulevard, Suite 1100, Portland OR 97232

1.5. Sponsors. *Who or what organization sponsored collection of the data (e.g., NOAA as a part of a mandated monitoring program)? Who funded collection of the data (if applicable)?*

NOAA is the federal agency overseeing the Protected Resource Division through the Department of Commerce. Under the Protected Resource Division, the West Coast Region research permits team manages and allocates scientific research take permits. All data regarding permits applications, issuance, withdrawal, or denial is recorded and stored within a database. NOAA is the sponsoring organization for the collection of this data. As a federally mandated program, the collection of data is federally funded.

1.6. Citation for the dataset. *Use the citation format below and include a link to the data source.*

National Marine Fisheries Service (NMFS) and Oregon Department of Fish and Wildlife (ODFW). Authorizations and Permits for Protected Species (APPS). Current authorizations for research under ESA Section 10(a)(1)(A) and Section 4(d), and reported take, from 2012 to 2022, for fish species in Washington, Oregon, Idaho, and California. Available online at https://apps.nmfs.noaa.gov/. Accessed 11/29/22 and 02/09/23.

1.7. Keywords. *Include 3-5 keywords for the dataset. Think of these as search terms that someone might use to find the data.*

Research Permits, West Coast Region, NOAA Fisheries, ESA

2. TEMPORAL AND SPATIAL EXTENTS (*when, where*)

2.1. Temporal extent. *The entire time range (specific years) for observations included in the dataset.*

The dataset includes permitting data from October of 2010 to the present. However, the data made available for this project extends to November of 2022.

2.2. Temporal resolution. *The frequency at which data are collected or acquired. Be as specific as possible. Note whether measurements were taken at regular intervals or irregularly.*

The APPS database is continuously being updated and accessed by permit managers. However, the data we were provided shows a snapshot in time of the data that is ongoing in the APPS database. For each permit inquiry, the date was logged for the request, issuance, withdrawal, and/or denial.

Prior to the data export, permits are reviewed thoroughly at the time of application. However, the permit information is not reviewed unless there is an incident report or the annual report is submitted.

2.3. Spatial extent. *Boundaries of the data set. If possible, include both the (a) geographic description, and (b) coordinates describing north, south, east, and west boundaries of the area included in the data. You do not need to include granular geospatial data (e.g., survey tracks, buoy locations).*

The dataset includes permitting data from the U.S. west coast region, which includes anadromous and marine waters of California, Oregon, Washington, and Idaho. Below is a map regarding the extent of WCR and where the data on permits was collected.

Fig. 1 Spatial extent of NOAA's West Coast Region

2.4. Spatial resolution. *Specificity with which spatial data are recorded. For example, are locations of measurements recorded using GPS? Locality (place) names? Were measurements collected on a uniform grid and if so, at what spatial scale?*

Spatial resolutions vary between permits, with most of the permits containing a user inputted 8-digit Hydrologic Unit Code (HUC 8) describing where the project will be conducted. For some projects no HUC 8 code was provided (usually in projects encompassing a wide range of HUC 8's, or projects that are conducted in marine waters) the spatial resolution is larger than a HUC 8, and can generally be described by the waterbody or basin name, or the geographical range occupied by the Evolutionary Significant Unit (ESU) that the research is being conducted on.

3. RESOURCE CONTENT (*what*)

3.1. Digital context. *Names of data file(s), names of tables within data file(s), file format(s), and date the data were last modified. If you have multiple data files, describe any relationships among them (e.g., queried database tables saved as separate files and linked through an identifier?). For each data file and table within a data file, include a brief (1 sentence) narrative description of the contents.*

Data are queried by the data manager through the APPS interface.

Data are downloaded as a ".csv" file from the APPS interface.

The following SQL queries are used to download data as .csv files from the APPS database:

Authorized permit data: WCRpermitBiOp_allregns_all_years

```
SELECT DISTINCT
  pac.FileNumber,
  pac.ResultCode,
  pac.AccountStatus,
  pac.PermitStatus,
  pac.DateIssued,
  pac.DateExpired,
  pac.AnnualTimeStart,
  pac.AnnualTimeEnd,
  pac.ProjectTitle,
  pac.FirstName,
  pac.LastName,
  pac.Organization,
  loc.HUCNumber,
  loc.WaterbodyName,
  loc.BasinName,
  loc.StreamName,
  loc.LocationDescription,
  tak.CommonName,
  tak.Population,
```

```
    tak.Run,
    tak.Production,
    tak.LifeStage,
    tak.Sex,
    tak.TakeAction,
    tak.CaptureMethod,
    tak.ExpTake,
    tak.IndMort

  FROM dbo.PacificSection10a1AAnd4d_vw AS pac
    INNER JOIN dbo.Location_vw AS loc ON pac.ProjectID = loc.ProjectID
    INNER JOIN dbo.TakeInformation_vw AS tak ON loc.LocationID = tak.LocationID

  WHERE tak.SpeciesID IN (1,2,3,4,5,44,241,243,254,1028)
    AND pac.RegionID IN ('WA','OR','ID','CA')
    ORDER BY pac.FileNumber
```

Reported permit data: WCRPermitBiOp_Pass report data 4d and S10

```
SELECT DISTINCT
  rpt.FileNumber,
  rpt.ReportID,
  rpt.ResultCode,
  rpt.AnnualTimeStart,
  rpt.AnnualTimeEnd,
  rpt.DateReportPeriodEnd,
  rpt.RegionID,
  rpt.FirstName,
  rpt.LastName,
  rpt.Organization,
  rpt.ProjectTitle,
  lv.BasinName,
  lv.WaterbodyName,
  lv.StreamName,
  tv.CommonName,
  tv.Population,
  tv.Production,
  tv.LifeStage,
  tv.TakeAction,
  tv.CaptureMethod,
  tv.ExpTake,
  tv.ActTake,
  tv.IndMort,
  tv.ActMort
```

```
FROM dbo.RptPacSection10a1AAnd4d_vw AS rpt
  INNER JOIN dbo.RptLocation_vw AS lv ON rpt.ReportID = lv.ReportID
  INNER JOIN dbo.RptTake_vw AS tv ON lv.LocationID = tv.LocationID

WHERE rpt.AnnualTimeStart > '12/31/2010'
  AND rpt.RegionID IN ('OR','WA','ID','CA')
  AND tv.SpeciesID IN (1,2,3,4,5,44,241,243,254,1028)
  ORDER BY rpt.FileNumber, rpt.AnnualTimeStart
```

Abundance data are compiled from various sources including NOAA Fisheries' Northwest and Southwest Fisheries Science Centers, state hatchery management programs, and other fecundity, survival, and outmigration estimates assembled by NMFS. A file of compiled abundance data current as of March 2022 was provided by NMFS as Abundance_2022-03-17.xlsx. It is generated by an R script titled Compile_abundance.R saved within the permit team's Section 10 biological opinion Github repository.

3.2. Data components and data table attributes. *This section details the contents of each data table and/or data file and might be most effectively organized as a table (but it's up to you). For each data file/data table, provide the names, definitions, and units of the attributes of any data in tabular format (e.g., column headers in a CSV file). Depending on the nature of the data, this could include: parameter name, measurement units, instrument type, precision, accuracy, taxonomic details, definitions of codes used, and any other important information for an analyst (e.g., quality review notes, missing values). Indicate whether data are raw values (not modified in any way after collection), processed values (corrected or calibrated), or derived values (an index or summarized value calculated based on other data).*

WCRpermitBiOp_allregns_all_years__7Jan2022.csv
Note - data components that are italicized and bolded are unique to WCRPermitBiOp_Pass report data 4d and S10_22March22.csv data file.

Data Component	**Attributes**
FileNumber	File number automatically assigned by the APPS system; used in correspondence about the application
ResultCode	Permit type or authority
AccountStatus	Indicates the current status of the Application
PermitStatus	Indicates the status of the permit that was applied for. (ex "Issued", "In Review")
DateIssued	Month, day, and year of the permit issuance. (yyyy-mm-dd)

DateExpired	Month, day, and year of the permit expiry. (yyyy-mm-dd)
AnnualTimeStart	Window when applicants begin to send in reports. (yyyy-mm-dd)
AnnualTimeEnd	Window when applicants cease to send in reports. (yyyy-mm-dd)
ProjectTitle	Name of the research project being conducted.
FirstName	First name of the principal investigator.
LastName	Last name of the principal investigator.
Organization	Name of the organization sponsoring the research.
HUCNumber	Displays the Hydrologic Unit Code (HUC) where that take is expected to occur.
WaterbodyName	Name of the major waterbody where the take is expected to occur.
BasinName	Name of the water basin where the take is expected to occur.
StreamName	Name or names of the streams involved where the take is expected to occur. Can be general (“Lower Columbia River and its tributaries”) or specific (“Battle Creek”).
LocationDescription	Specific description giving location of sampling site/trap etc. where take is expected to occur. Can be general if take is expected to occur all along the stream/waterbody.
CommonName	Common name of the species on which take is expected to occur.
Population	Specific population on which take is expected to occur. Mainly defined by the river or geographic area.
Run	Specific run where take is expected to occur. Usually described as the time of year (Spring, Summer, Winter) when the salmon or other anadromous fish return to spawn.
Production	Indicates whether the fish are for hatchery production or wild.
LifeStage	Life stage of the species/individual the project expects to take.
Sex	Sex of the species/individual the project expects to take.
TakeAction	Description of the kind of take that is expected to occur (e.g., “Broodstock collection”, “Capture”, “Handle”).
CaptureMethod	Gear used to capture species.

ExpTake	Number of individuals the project expects to take as a result of research.
IndMort	Number of incidental mortality as a result of research.

WCRPermitBiOp_Pass report data 4d and S10_22March22.csv

Data Component	**Attributes**
FileNumber	File number automatically assigned by the APPS system; used in correspondence about the application.
ReportID	***Five-digit unique code for each active project that reported take and mortality.***
ResultCode	Permit type or authority.
AnnualTimeStart	Window when applicants begin to send in reports.
AnnualTimeEnd	Window when applicants cease to send in reports.
DateReportPeriodEnd	***Date in which the report on actual take and mortality is submitted/ends. Reported in YYYY - MM - DD format.***
RegionID	***State abbreviations for where permits are occurring. i.e. WA, CA, OR, ID.***
FirstName	First name of the principal investigator.
LastName	Last name of the principal investigator.
Organization	Name of the organization sponsoring the research.
ProjectTitle	Name of the research project being conducted.
BasinName	Name of the water basin where the take is expected to occur
WaterbodyName	Name of the major waterbody where the take is expected to occur
StreamName	Name or names of the streams involved where the take is expected to occur. Can be general (“Lower Columbia River and its tributaries”) or specific (“Battle Creek”).
CommonName	Common name of the species on which take is expected to occur.
Population	Specific population on which take is expected to occur.. Mainly defined by the river or geographic area.
Production	Indicates whether the fish are for hatchery production or wild.

LifeStage	Life stage of the species/individual the project expects to take.
TakeAction	Description of the kind of take that is expected to occur (ex. "Broodstock collection", "Capture", "Handle")
CaptureMethod	Gear used to capture species.
ExpTake	Predicted number of individuals the project expects to take as a result of research.
ActTake	***Actual number of individuals a project takes that occurred as a result of research.***
IndMort	Predicted number of incidental mortality as a result of research.
ActMort	***Actual number of lethal take that occurred as a result of research.***

APPS_HUCassignments_11Feb23.csv

Data Component	**Attributes**
speciesid	Unique code given to each species
populationid	Unique code given to each unique ESU/DPS of a species
Species	Common name of species
Population/Stock	Specific ESU/DPS of species
Status	ESA-listing status
HUC8	HUC 8 where species could be found
Basin Name	Name of basin containing the HUC 8

4. METHODS (*how*)

4.1. Lineage statement. *Provide a summary of the methods used to collect the data. Ideally, this is a brief narrative description that includes citations to standard operating procedures, field manuals, or other references.*

Data are collected and recorded when applications are submitted through the Authorizations and Permits for Protected Species (APPS) online application system. When researchers, hatchery managers, or other professionals wish to complete research on an ESA-listed species or plan on encountering ESA-listed species, they submit their

applications through the APPS online portal. Data on the type of species the research will be conducted on, the type of take occurring, where the take will be occurring, and how much lethal and non-lethal take is expected are then reviewed by the permits team and either approved, edited, or denied. For permits that are issued, if changes are made to permit information while it is active any approved changes to authorized take are immediately reflected in data exported from APPS.

After the end of each sampling season researchers also submit reporting information on what actually occurred in the field. This includes confirming where work was actually conducted, what gear was used, and recording how many fish of each type (species, life stage, and origin) were actually encountered, sampled, and killed. Permit team staff also review annual reports and correct any errors discovered during review. Any changes or corrections to reporting data are also immediately reflected in data exported from APPS.

4.2. Process steps. *The general process steps that occurred between data collection and its current form (brief narrative description or bulleted list). Depending on the dataset, processing might include digitization, removing or identifying outliers via computer scripts, file processing, data summarization, or data transformations. This does not need to be exhaustive, but should include information that would be important for an analyst to be aware of when they are using the data for research. Include relevant citations.*

The following steps were carried out by the UW capstone team to prepare the data for visualization and synthesis:

1. Created Reading and Filtering Computer Script
    a. Filtering out expired and non-issued permits.
    b. Filtering for specific and relevant permit types - NMFS 10a1A Salmon, 4d, NMFS BiOp DTA, Tribal 4d.
    c. Recoded all smolts, fries, larva to “juveniles” and subadults to “adults”.
    d. Recoded HUC numbers based on reclassification by USGS (see metadata folder of GitHub for details)
    e. Recoded and categorized species by production - Natural, Listed Hatchery, Unlisted Hatchery.
    f. Filtered out non-invasive, non-lethal take actions (i.e. Observe/Harass and Sampling dead animals)

2. Developing new fields within data files to:
    a. display ESU or DPS under “Species”
    b. recode and condense production type under “Prod”
    c. report total mortality that occurred.
    d. to report total authorized take under “AuthTake.

3. Map Component
    a. Setting up reactive data table (ReactiveDataTable.R)

i. Used functions from NMFSResPermits package to create new fields and organize data.
ii. Created a location field for the table. This is based on a hierarchical sort of different location based fields from the raw data. When researchers apply for permits they often use different fields to describe their location. The highest level (largest in terms of geographic scope) is used unless it is an NA value, then the next highest non-NA value is used. This hierarchy is WaterbodyName > BasinName > StreamName > LocationDescription.
iii. Created a water type column that uses keywords to identify a given location as freshwater or saltwater.

b. Setting up data frames for display in map (CreateDataFrames.R)
   i. Manually assigned HUCs to some marine areas in Washington (Puget Sound and Strait of Juan de Fuca area).
   ii. Aggregated both total take and lethal take data, and then joined to spatial data using HUC 8 codes.

c. Creating ESU/DPS boundaries (CreateBoundaries.R)
   i. Combine HUC assignment data with spatial data, and then loop through each ESU/DPS and join together all HUC polygons where that ESU/DPS can be found. End result is one large polygon showing the ranges for each ESU/DPS.

4. Time Series Component (TSPreAppCode.R)
   a. Setting-up time factor and performing a quality check on WCRpermit_reports_demo_20221129.csv
      i. Changing time factor so formatting and creating a new column for year using DateReportPeriodEnd field.
      ii. Using the totalmorts() function from the NMFSResPermits package to calculate the total mortalities, re-organizing the data using the order_table() function from the NMFSResPermits package, and replacing NA values with 0 using replace_na() function from tidyr on ExpTake, ActTake, TotalMorts, and ActMort fields to perform a quality check on the data file.
   b. Creating stacked bar plot
      i. Aggregating Authorized Take and Renaming Columns.
      ii. Summing each variable by year and grouping by ESU, Production, and Lifestage.
      iii. Performing another quality check by replacing NaN or NA or Inf with 0.
      iv. Taking the total authorized take and subtracting that by the reported take to get the unused take for both total take and incidental mortalities.
      v. Setting up data for plotting by filtering for just “Used” and “Unused” take.
   c. Creating dynamic table
      i. Aggregating Authorized Take and Renaming Columns.

ii. Summing each variable by year and grouping by ESU, Production, and Lifestage, FileNumber, CaptureMethod, ReportID, ResultCode.
iii. Taking the total authorized take and subtracting that by the reported take to get the unused take for both total take and incidental mortalities.

4.3. Quality assurance and quality control. *Note anything the data creators did to ensure the completeness and accuracy of their dataset (e.g., instrument calibrations, automated procedures, manual/visual tests for outliers).*

For the purpose of this project, some fields and data entries were modified to simplify analyses and provide consistency across the nomenclature. These include:

- Adjusting HUC 8 codes to encompass redrawn boundaries.
- Renaming and classifying water bodies in the 'WaterbodyName' field to allow for consistent nomenclature. Renaming practices were performed using best available data provided in the 'LocationDescription' field.

4.4. Data completeness and constraints. *Were any data excluded from the dataset? If so, why? What are known cautions or problems, such as sampling bias? Are there ways the data should not be used (according to the data creators)?*

Assumptions/Limitations:

1. *99999999 and Incorrect HUC Codes* - The input of incorrect HUC 8 codes by researchers applying for permits (for example: the '9999999' HUC codes) meant these data could not be accurately plotted or included, therefore serves as a limitation of this project.
2. *Changed HUC numbers* - Over time, HUC 8 codes have been rearranged and their boundaries redrawn. Many permits use old or outdated HUC 8 codes, causing issues when trying to map our permit data using the Watershed Boundary Dataset (USGS et al. 2022). Therefore, HUC 8 codes had to be updated to reflect any changes to their boundaries. Decisions were made using an unpublished document that summarizes HUC 8 code changes up until 2018 (Hanson et al. 2018). Some of these changes ran on assumptions using other fields (such as WaterbodyName or LocationDescription) and are detailed below:
    a. # 18020103 = 18020156 # very certain
    b. # 18020109 = 18020163 # very certain
    c. # 18020112 = 18020154 # very certain based on location descriptions
    d. # 18020118 = 18020154 # very certain based on location descriptions
    e. # 18040005 = 18040012 # very certain based on location descriptions
    f. # 18060001 = 18060015 # split between 18050006 as well, arbitrarily picked
    g. # 18060012 = 18060006 # chose this over Monterey Bay as population is South-Central Cal Coast
3. *Non-reported take* - Under the data file *WCRPermitBiOp_Pass report data 4d and S10_22March22.csv,* researchers are asked to report the actual take and

mortality that occurred to ESA-listed species during the duration of their study. However, some organizations or projects can neglect to report on the actual take and mortality. As a result, these projects are not included in our analyses due to lack of data. Thus, a limitation of this unreported data is we are missing total take and mortality data and therefore complicates further abundance data analysis.

4. *Tribal 4d permits* - Tribal 4d permits were omitted from tables showing individual permit information for data privacy reasons, but included in the totals shown in the map and time series. When using this data, be wary of these differences in counts due to this omission.
5. *Omission of "Unknown," "Unlisted," or "N/A" values* - in fields where input was necessary, inputs that included "Unknown," "Unlisted," or "N/A" were purposefully omitted. This was done to ensure data accuracy and includes fields such as Production and Take Action.

5. CITATIONS

1. U.S. Geological Survey (USGS), U.S. Department of Agriculture – Natural Resource Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA) (2022). USGS National Watershed Boundary Dataset in FileGDB 10.1 format (published 20220526). Accessed May 15, 2022 at URL https://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Hydrography/WBD/National/GDB/

2. Hanson, K., Daw, S., Davenport, L., Jones, K., Niknami, L., & Buto, S. (2018). Criteria for Legacy Name and Code Changes. [Unpublished]

Link to Github Repository

https://github.com/rory-spurr/ESAPermitsCapstone

SMEA CAPSTONE PROJECT COMPLETION FORM

Capstone Information

Capstone Project Title: Visualizing ESA-Listed Fish Research on the West Coast

Faculty Advisor: Anne Beaudreau Email: annebeau@uw.edu

Client Advisor: Diana Dishman Email: diana.dishman@noaa.gov

Students:

Name: Alana Santana Student ID#: 1874232

Name: Rory Spurr Student ID#: 1575371

Students listed above have completed the capstone research and analysis and submitted the deliverables as specified in- and agreed upon in the Capstone Project Management Plan dated 04/07/2022.

DISHMAN.DIANA.LYNN.1536335818 Digitally signed by DISHMAN.DIANA.LYNN.1536335818
Date: 2023.03.13 14:35:18 -07'00'

Signature of Client Advisor Date

3/10/23

Signature of Faculty Capstone Advisor Date

Due to SMEA Graduate Advising Office (MAR 107) on the final Monday of the student's graduation term. Please attach the completed capstone report.