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VARs Explorer: An exploratory data portal for VARs

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ABSTRACT

Since its development in 2005 at MBARI, the Video Annotation and Reference System (VARs) has amassed over six million annotations, representing over 25,000 hours of recorded video. As this system has grown and evolved, the need for new ways to access and visualize the VARs dataset has become paramount. VARs Explorer is an updated, web-based platform that provides users an easy way to access data present in the VARs database. Divided into three parts, VARs Statistics provides a simple way to view global database statistics and monitor the overall state of the database, VARs Query provides an easy way to query the database for annotations or ancillary dive data, and VARs Visualizer provides a set of pre-defined visualizations allowing users to easily explore the VARs dataset. Built with a suite of modern web and backend technologies, VARs Explorer will be able to facilitate the analysis and visualization of the VARs dataset for years to come, and help provide new insight into the state of the world's oceans.

INTRODUCTION

VIDEO ANNOTATIONS AND REFERENCE SYSTEM (VARS)

Put into active use in 2005 at the Monterey Bay Aquarium Research Institute (MBARI), the Video Annotation and Reference System (VARS) is a software system that aids in the creation, storage, and retrieval of annotations made from video or images recorded by the MBARI fleet of remotely operated vehicles (ROVs), the i2MAP AUV, and stationary still imaging systems (such as Station M (3)) (1). At its inception, VARS held data from over 16,000 videotapes, equating to nearly 13,500 hours of recorded video, which was previously stored and catalogued using the Video Information Capture with Knowledge Inferencing (VICKI) system (1). VICKI was decommissioned in 2005 after becoming unmaintainable within MBARI's hardware, software, and database infrastructure. As of 2019, after 14 years of operation, VARS now holds over 6,300,000 annotations from over 26,000 hours of recorded video captured since MBARI began recording its ROV dives in 1989 (1).

VARS is a software system composed of two relational databases that work in conjunction with three Java-based, desktop applications: Annotation, Knowledgebase, and Query (1). The cornerstone of the system is the VARS Annotation application, which is designed for reviewing footage whether recorded as video files, video tape, or even while watching a real-time video feed as is done while the ROV's are deployed.

For each ROV dive that has been performed by MBARI vehicles, logistical details, metadata, and environmental information (or ancillary data) are recorded into the expedition database. This information includes navigational data, such as position, depth, altitude, and heading; environmental parameter data, such as light transmission, oxygen concentration, pressure, salinity, and temperature; and dive metadata, such as deployment date, principal investigator, and science team participants. Meanwhile, the annotation database holds annotation information about objects of interest observed in the recorded footage. This includes the name of the object or event (known and referenced as a 'concept'); any associative descriptions of the concept observed (known as 'associations'); and metadata related to the image or video from which the annotation

was produced. Video observations made in VARS are then merged with ancillary data contained within the expedition.

The VARS Annotation, Knowledgebase, and Query applications allow researchers to read and write data to the VARS database through the use of a shared application programming interface (API) (1). The Annotation application allows researchers to review video tapes, files, frame grabs, or still images and updates the underlying VARS database with new observational data. The Knowledgebase application displays a pre-defined hierarchy of concepts and phylogenetic relations, as well as a structured list of templates used to add descriptive properties about each concept. Meanwhile, the Query application allows researchers to query the annotations database for annotations based on user-specified criteria, allowing the user to retrieve data which has been filtered by a customized set of variables.

Since being put into service in 2005, VARS has helped facilitate the publication of hundreds of peer-reviewed publications (2) and VARS assets have been used in a variety of student projects (K-12, undergraduate, and graduate), government/agency reports (e.g., <https://deepseacoraldata.noaa.gov>), nonprofit campaigns (e.g., <http://www.californiaseamounts.org/photo-gallery/>), museums, exhibits, documentaries (e.g., BBC Blue Planet), and MBARI's own progress reports and outreach products. However, as the size of MBARI's digital collection and the VARS database has grown over the past 14 years, searching the database and making meaningful sense out of the rich dataset has proven difficult in some cases. This project aims to address the need of better data retrieval and analysis by utilizing modern, web-accessible tools to allow for easy searching, retrieval, and visualization of this one-of-a-kind archive of deep-sea observations.

DATA ANALYSIS AND EXTRACTION USING VARS

Since being brought online in 2005, the data stored within the VARS database has been accessible by one of two ways: the VARS Query application or a third-party database management tool. However, for the majority of users the VARS Query application is the only way to search and retrieve data from VARS. While useful, the

VARs Query tool requires Java, has limited computer operating system compatibility (macOS only), and has had limited data and image export capabilities (1).

For those individuals who opt to forgo use of the VARs Query application in favor of a dedicated database management tool, data analysis and extraction still presents challenges. Simply connecting to the database requires high-level login credentials. Once connected, an intimate knowledge of the complicated database structure, which contains more than twenty related tables and associated views is required. Once the data of interest is found, subsetting them in a useful manner requires a complete SQL query to be written. While not terribly difficult to learn, SQL has many quirks and nuances for the unfamiliar user. Most critically, this scenario introduces the risk of users accidentally, or incidentally, modifying or removing data from the database. And after all of this is done, few database management tools have good export options for exporting queries in common data file types, such as *.csv*.

The difficulties presented by using the VARs Query applications or a dedicated database management tool, has led many researchers at MBARI to begin interfacing with the database through an alternative means: using one or more programming languages. This solves the problem of getting data into a useable format, as many languages have libraries to handle the type of tabular data returned by relational databases like VARs, but fails to solve the issues of establishing a connection and writing SQL calls.

For those few individuals who have authentication credentials and familiarity with the database structure, interfacing using a programming language represents a great way to run the same queries repetitively including simple, dynamic display of certain queries for other researchers. Over the past several years, the MBARI Video Lab has done just this, creating a collection of Python scripts that can connect to the VARs database, pull certain information of interest, transform the data, and return data or a formatted HTML table for review as a standard web page. These skills have proven useful in that they have allowed for certain analyses to be done at any time, by any user regardless of skill, without the need to manually authenticate and write a SQL queries themselves. However, as the number of these programs has grown, several significant challenges have arisen including maintainability and accessibility.

VARs EXPLORER

The VARs Explorer is a new suite of web applications that aims to provide better access to the VARs database and facilitates the analysis of VARs data and Video Lab metadata and metrics. While other means of accomplishing these goals exist, none adequately scale to the appropriate size for an institution like MBARI. And with the amount of data being added to the VARs database every year, a more refined, consolidated, and maintainable solution was needed: the VARs Explorer. The new portal is composed of three distinct sub-applications: VARs Statistics, VARs Query, and VARs Visualizer.

VARs STATISTICS

VARs Statistics is composed of a series of web pages that displays tables and plots of various statistics about the state of the underlying VARs database. Intended largely for use by those researchers and technicians that maintain and contribute to the database regularly, this subsection of the explorer provides data about: the number of hours of video recorded each year; the total number of annotations added to the database annually; the total number of concepts present in the VARs Knowledgebase, and the number of annotations for each concept; the number and structure of unique concept associations; and the number and type of annotations that have missing data or values outside an expected range (known as “bad annotations”). While not directly useful for many researchers, this type of data is invaluable to system maintainers as it provides a quick way to evaluate the state of the database, monitor for the introduction of “bad annotations”, and efficiently search for regions of the database that can be improved.

A short overview of the functionality of the different pages is provided below:

- **Data accumulation** - This page displays a table and chart of number of hours of video annotated and recorded by the MBARI Video Lab each year since 1988 as well as the total number of hours of annotated and recorded video at the end of

each year. This allows for the Video Lab to monitor their progress and contributions throughout the year and on a year-over-year basis.

- **Annotation progress by group** - This page displays a set of table and charts displaying the number of hours of annotated and recorded video on a per lab basis. This allows the Video Lab to easily see, by MBARI lab, what remains unannotated and make decisions about how future resources should be allocated.
- **Annotations to review** - This page displays a table of ROV dives that have annotations that have bad recorded timestamps (i.e., outside of MBARI's expedition history) or are missing depth data. This provides a quick means for Video Lab staff to identify data that can potentially be corrected.
- **Knowledgebase concept counts** - This page displays a table of every concept present in the VARS Knowledgebase along with the number of annotations for each. This allows for the Video Lab to see how many Knowledgebase concepts are present in the database as well as which concepts are annotated most commonly.
- **Knowledgebase templates** - This page displays a table of association formats that have been created for attributing descriptors to annotations within VARS. This allows Video Lab annotators to quickly reference what association formats have been used in the past in order to make corrections and maintain consistency when adding new associations.

VARS Statistics aims to give its users an easy means by which to view and visualize the overall state of the VARS database and associated metadata. Each of the pages described above, as well as several additional pages, provide data in fully sortable, searchable, and sometimes filterable data tables that allow for additional analysis and efficient data subsetting. Where relevant, graphs and charts displaying visualizations of such data are also provided in a downloadable format (notably on the 'Data accumulation' and 'Annotation progress by group' pages).

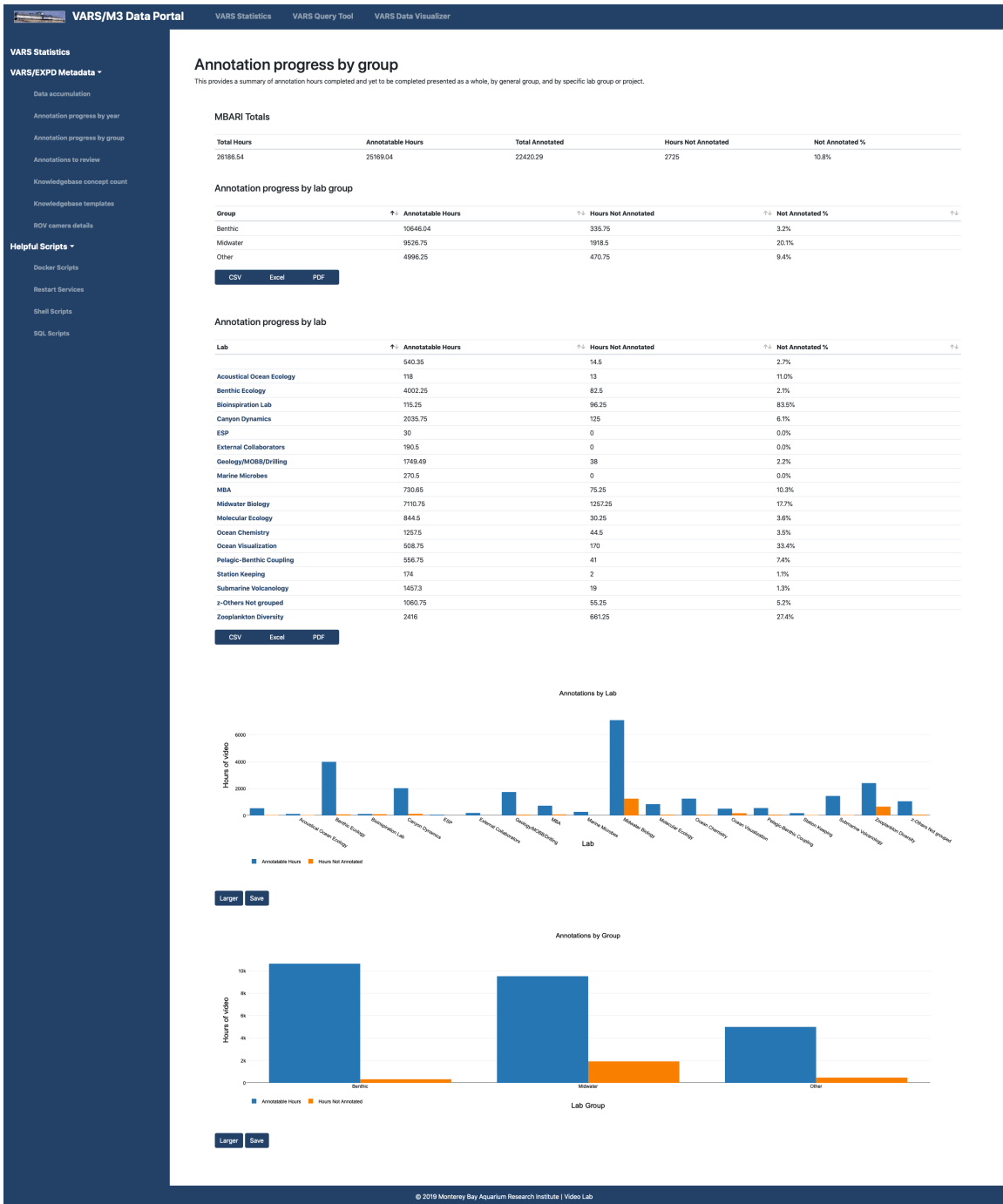


Figure 1: The ‘Annotations progress by group’ page of VARs Statistics provides users with an easy way to see the number of annotatable hours of video remaining for each MBARI lab as either a data table or interactive visualization.

VARS QUERY

VARS Query, implemented as a part of VARS Explorer, now referred to as *VARS Query (web)*, is a web-based, updated version of the original VARS Query application, now referred to as *VARS Query (desktop)*. It provides a more manageable and straightforward interface for querying the VARS Annotations database, as well as the means to query the VARS Expedition database where environmental and navigational data for all MBARI vehicle dives are stored.

A short overview of each of the three query tools is provided below:

- **Annotation Query Tool** - Composed of a complex query form and a subsequent “query results” page, this tool provides users a direct means of querying the VARS Annotations database for observations matching any number of possible query filters. Users have the ability to filter the database by one or more concepts as well as their phylogenetic relations, a geographic region or bounding box, a range of dates, a range of depths, an activity type, one or more chief scientists associated with the annotations, one or more distinct dive numbers, and one or more concept associations. Results are presented to the user in tabular format, and include taxa (or other concept) name, abundance, basic ancillary data, and any associated image. Results can be downloaded as a *.csv* or *.xls* file and images can be downloaded in bulk.
- **Location Query Tool** - This simple form allows users to select a predefined geographic region, or manually enter a geographic bounding box, and a depth region in the water column (midwater or benthic) and returns a listing of all of the VARS Knowledgebase concepts and their associated abundances for that region and depth. Like the other tables in VARS Explorer, this data is fully sortable and searchable, and can be saved as one of several file types.
- **Expedition Query Tool** - Composed of a very simple form allowing the selection of one of MBARI’s three ROVs (*Doc Ricketts*, *Ventana*, and *Tiburon* (decommissioned)) and the entry of a specific dive number, this tool provides users with navigational data (geographic position, depth, altitude, and heading)

for the specified dive at two second intervals. This data is also available for download in standards formats.

VARS Query (web) is a natural evolution of the initial VARS Query (desktop) application. Where as VARS Query (desktop) required extra software and a specific operating system to work properly, the new VARS Query is completely system agnostic and works perfectly fine on any computer with a modern web browser. VARS Query (web) also possesses a more refined user interface and makes more of the data in the annotations and expedition databases accessible to researchers (the ability to query the expedition database is not completely new functionality but was not previously a part of VARS Query (desktop)).

The screenshot displays the VARS Query Tool interface. At the top, it is titled "VARS Query Tool" and includes a disclaimer: "These data are from the internal VARS database and, therefore, contain some data that are embargoed and may require additional approval prior to distribution outside of MBARI. Please refer to the Data Use page to learn more about these data. Contact Nancy Jacobson Stout (nans@mbari.org) for further information." Below this, there are several filter sections:

- Concept:** A dropdown menu set to "Octopodidae" with an "Add a Concept" button. To the right are radio buttons for "Parent", "Siblings", "Children", and "Descendants".
- Location:** A section with "Region:" set to "Monterey Bay" and "Upper Left Coordinates:" with fields for Latitude (37.0538) and Longitude (-122.5073). "Lower Right Coordinates:" has fields for Latitude (36.4458) and Longitude (-121.7805).
- Date:** "Start Date" is 2010-01-01 and "End Date" is 2015-12-31.
- Depth:** "Start Depth" and "End Depth" fields.
- Activity:** "Activity Type" dropdown and "Chief Scientist:" field with an "Add a scientist" button and a "Remove" button.
- Dive Information:** "Dive Vehicle" dropdown, "Dive Number:" field, and "Add a dive" / "Add a dive range" buttons.
- Associations:** "Dive Association:" field and "Add an association" / "Remove" buttons.

At the bottom, there is a "Data Columns:" section with a list of fields: Concept, Video Sequence Name, Recorded Timestamp, Observation Timestamp, Latitude, Longitude, Depth, Image, Associations, Observer, Observation UUID, Activity, Chief Scientist, Oxygen Concentration, Salinity, Temperature, and Light Transmission. Below this are "Submit" and "Clear Form" buttons.

Figure 2: The query form for VARS Query allows users to easily query the VARS Annotations database as a number of various filters. Above, the database would be queried for all annotations of the phylogenetic family ‘Octopodidae’ and all of its descendent taxa, found in Monterey Bay during the years 2010 to 2015 at a depth of between 500 and 1500 meters.

Database Query Tool
Location Query Tool
Expedition Query Tool

VARs/M3 Data Portal VARs Statistics VARs Query Tool VARs Data Visualizer

VARs Query Results

Your query was as follows:

- Concept: Octopodidae
- Location: 38.4458, 37.6538, -122.5073, -121.7805
- Date Range: 2010-01-01 -> 2019-08-16
- Depth Range: 500 -> 1500
- Dives: None
- Associations: None
- Scientists: None

Query Results
Graneledone boreopacifica (601), Enteroctopus defleini (180), Graneledone (64), Benthoctopus (13), Octopus (6), Octopus californicus (5), Octopus rubescens (2)

Show SQL

Show 10 entries Showing 1 to 10 of 871 entries Search:

Concept	Video Sequence Name	Recorded Timestamp	Latitude	Longitude	Depth (m)	Image	Associations	Salinity (psu)	Temperature (°C)
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:15	36.7029	-122.0475	1396.7200		comment self brooding eggs, identity-reference self 1, comment self Female G1, upon rock outcrop nil	34.5220	2.9800
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:25	36.7029	-122.0475	1396.1700		comment self brooding eggs, comment self Female G1, upon rock outcrop nil, identity-reference self 1	34.5210	2.9900
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:39	36.7030	-122.0476	1396.7300		comment self Female G1, upon rock outcrop nil, comment self brooding eggs, identity-reference self 1	34.5200	2.9840
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:43	36.7030	-122.0476	1396.8400		identity-reference self 1, upon rock outcrop nil, comment self Female G1, comment self brooding eggs	34.5190	2.9840
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:47	36.7030	-122.0476	1397.1000		comment self Female G1, comment self brooding eggs, upon rock outcrop nil, identity-reference self 1	34.5180	2.9840
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:55	36.7030	-122.0477	1397.2500		comment self Female G1, identity-reference self 1, comment self brooding eggs, upon rock outcrop nil	34.5210	2.9930
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:16:57	36.7030	-122.0477	1397.2500		identity-reference self 1, upon rock outcrop nil, comment self Female G1, comment self brooding eggs	34.5150	2.9850
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:17:03	36.7030	-122.0477	1397.2900		comment self Female G1, identity-reference self 1, upon rock outcrop nil, comment self brooding eggs	34.5210	2.9790
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:17:21	36.7030	-122.0477	1397.7500		identity-reference self 1, comment self Female G1, upon rock outcrop nil, comment self brooding eggs	34.5190	2.9860
Graneledone boreopacifica	Doc Ricketts 0181	2010-08-29 03:17:23	36.7030	-122.0477	1397.7500		identity-reference self 1, comment self brooding eggs, upon rock outcrop nil, comment self Female G1	34.5160	2.9920

Showing 1 to 10 of 871 entries

Previous 1 2 3 4 5 ... 88 Next

CSV Excel

Download Images

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Figure 3: The query results page for the query performed in Figure 2. The datatable allows for users to easily search and sort the results, as well as download the results in .csv and .xls format, as well as download all of the images that were returned by the query. The unique taxa and the number of annotations for each is also returned to the user, as is the actual SQL query string that was run against the database to produce the results.

VARS VISUALIZER

VARS Visualizer is a fully interactive data visualization dashboard that provides a set of pre-defined, simple visualizations of VARS data matching the query filters input by the user. Intended to be a quick data exploration tool and a “first stop” for researchers interested in using these data, VARS Visualizer provides a simple query form and a series of different visualization plots, showing the distribution of annotations across depth, date, and activity type; the distributions of various environmental parameters; and the geographic distribution and abundance of annotations through space.

A short overview of the five main visualizations is provided below:

- **Depth Histogram** - The depth histogram provides a simple vertical histogram displaying the number of annotations matching the query filters per depth bin. The number of bins is customizable by the user (default is 40 bins), as is the depth range to plot, which allows the user to more carefully inspect particular regions of interest. A vertical line plot displayed next to the histogram plots the space and time averaged value for a selectable environmental parameter for each bin, allowing the researcher to visualize the relationship between depth, annotation density, and an environmental parameter at once.
- **Time Series Chart** - The time series chart provides a simple bar chart displaying the number of matching annotations per year since 1988. An interactive slider allows the user to filter the chart, and the remainder of the plotted data, down to a specific range of years.
- **Activity Type Chart** - The activity type chart is another simple bar chart that displays the number of annotations for each of the possible VARS activity types. This chart helps give users an idea of what ROV activities yield the most annotations.
- **Environmental Parameter Box Plots** - The environmental parameter box plots show the distribution of five environmental parameters (depth, temperature, salinity, dissolved oxygen concentration, and light transmission) as box plots. Each box plot is linked to a set of options allowing the user to view all of the data

points alongside the box plot (as well as jitter said points), show or hide outlier points from the box plot, or forgo the box plot visualization altogether in favor of a violin plot.

- **Geographic Distribution and Density Plots** - The geographic density plot takes the form of a binned heat map displaying the areas of highest annotation density. This plot, which features a customizable number of bins, gives users an idea of geographic hot spots within the dataset. The geographic distribution plot, meanwhile, takes the form of a satellite map (provided by Mapbox), with points representing each annotation overlaid on top. Each point can be colored by any one of the five environmental parameters listed above.

VARS Visualizer aims to provide a set of easy-to-use visualizations that provide a general representation of the distribution of VARS data through space and time, and across different environmental parameters. It is not intended to be used to perform a complete statistical analysis of VARS data, and it will remain the user's job to perform further visualization and analysis work before drawing any conclusions from their dataset.

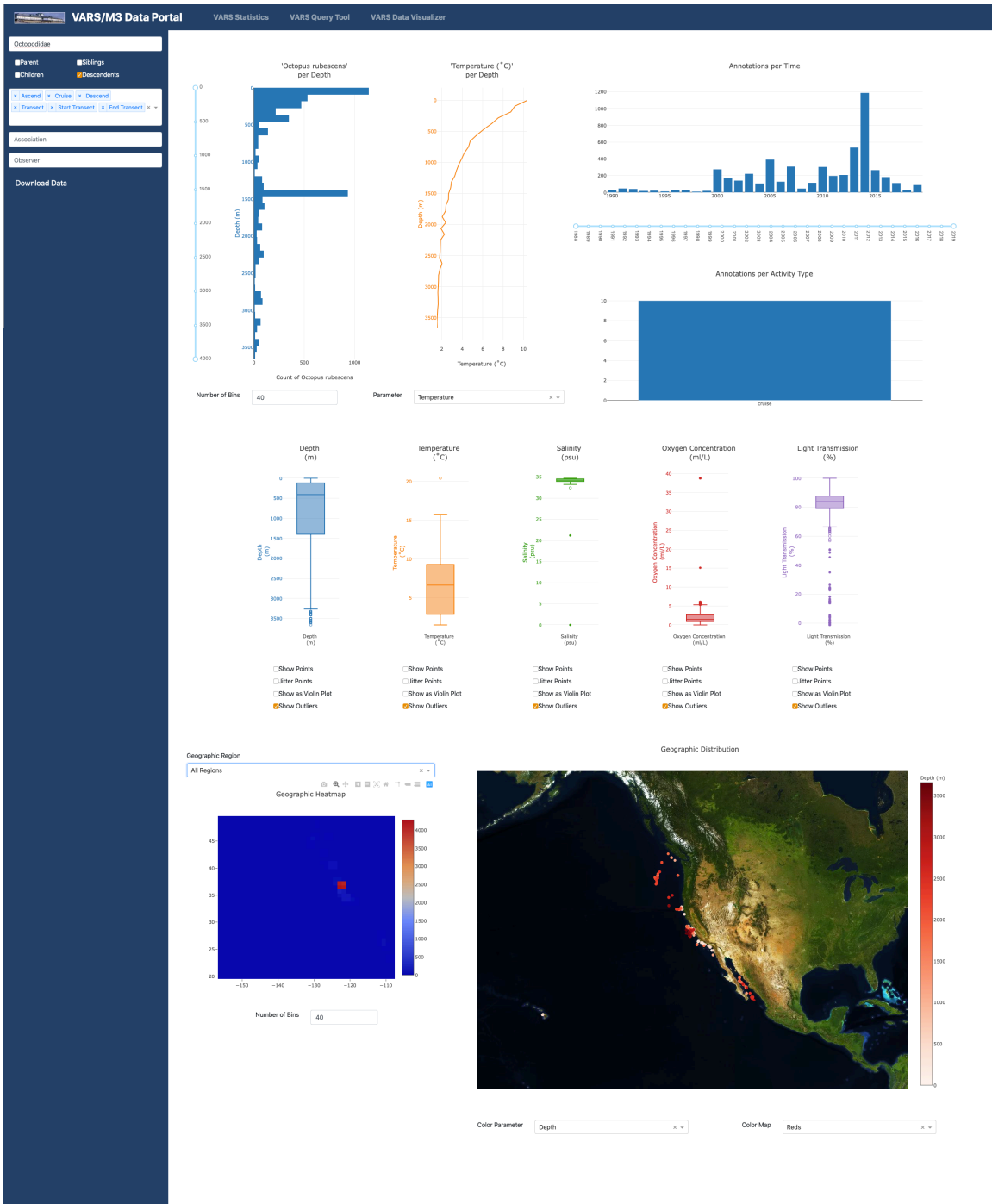


Figure 4: VARS Visualizer is an interactive dashboard displaying eleven unique visualization for VARS data including a depth histogram, environmental parameter vs depth line plot, timeseries chart, annotations per activity type chart, environmental parameter box plots, a geographic heatmap, and a geographic scattermap. All visualizations are completely interactive.

TECHNOLOGY STACK

VARs Explorer is deployed as a set of docker containers using ‘docker-compose’, which allows for easy separation of priorities for the four distinct subsections of the application: the front-end website, the VARs Statistics API, the VARs Query API, and the VARs Visualizer dashboard. The four services are brought online together with ‘docker-compose’, but can be taken down and updated individually without affecting users of the other systems.

The front-end website is run on an Apache web server that handles page routing and HTTP page requests. It uses PHP (Personal Home Page) as a server-side rendering language explicitly for its ability to separate and include frequently used components, such as the menu bar and footer, throughout the site. The remainder of the front-end site is standard HTML, CSS, and JavaScript (jQuery). The interactive data tables are produced using DataTablesJS and the interactive plots, using PlotlyJS, both open source JavaScript libraries. HTTP GET requests are sent to the backend APIs using asynchronous jQuery Ajax calls.

The backend VARs Statistics and VARs Query APIs are written in Python using the Flask micro web service. Flask is a simple light-weight web server that allows for defining custom HTTP routes and responses (4), and is commonly used for internal API creation. Flask does however require extra setup to be used in a production state, as it is singly threaded and can thus only handle a single web request at a time if run in its normal state. This is a significant problem when the API is being accessed by a multitude of people throughout a research institute like MBARI. To handle this, a proxy load balancer runs between the Apache web server running the front end and the backend APIs. This load balancer sends incoming requests to the API to one of several different server instances running the API, allowing multiple requests to be handled simultaneously. Data formatting is implemented through the use of the Python module, Pandas.

VARs Visualizer runs as an instance of Dash, a visualization dashboard framework created and maintained by Plotly (5). Dash is written in Python, but is compiled to interactive HTML, CSS, and JavaScript when viewed in a web browser.

Dash is implemented on top of the Flask web framework, the same one that was used to build the VARS Explorer APIs, and thus also requires special production-level deployment setup. This issue was solved as above with the load balancer.

While the above technology stack works well for internal use and is much more easily maintainable than previous similar software, somewhat significant restructuring would be advised prior to attempted release of VARS Explorer to the general public or other research institutions.

Primarily, it would be best to rewrite the backend APIs, specifically the VARS Query API, in a true server language, such as Scala or Go, that can better handle concurrent HTTP requests and provide faster database interactions. At the moment, a query returning ten-thousand annotations takes approximately thirty seconds to fully render on screen, and a query returning more than forty-thousand annotations is not rendered at all (though a link to a downloadable .csv file is provided to the user) due to render time. While much of this is due to the way the table is being iteratively built from the front end, a more efficient API could significantly decrease load times and provide a better user experience. Hooking into the already written APIs used internally by different components of the VARS system could also be beneficial.

It would also be advisable to switch out the front end for a suite of more modern and flexible technologies. At the moment, each page of the front-end site, while following the same general structure, is hand written, which makes applying global changes to styling or page structure moderately difficult. Interactions with the server APIs are also completed using jQuery Ajax calls, which, while standard, are slowly being phased out in favor of more robust JavaScript request libraries. React, a component-based JavaScript library authored and updated routinely by Facebook, has gained popularity in recent years for its modular component-based architecture and may be a good choice for modernizing the front end. VueJS represents another JavaScript front-end alternative.

DISCUSSION

VARs Explorer is intended to be an exploratory data portal for research scientists and database contributors alike. As such, its applications in future oceanographic research are nearly limitless. Any number of patterns and trends may lie hidden within the six million annotations in the VARs database, and the immense amount of data collected every year by MBARI's fleet of scientific vehicles only adds more information for researchers to explore and analyze. VARs Explorer was created with the hopes of facilitating this exploration and analysis.

Exploratory data analysis is often considered to be the first step in any data science or data-driven research project. It is vitally important when working with data to understand what data is actually present, how it is distributed, and if there are any quirks or anomalies present. All of these things are much more easily accomplished using visualizations than by attempting to parse through raw data by hand. VARs Visualizer makes this process simple by providing common visualizations "out of the box". These visualizations can help scientists quickly determine how "clean" or "messy" some datasets are, whether or not certain datasets have large number of outlier data points that may make future analysis more difficult, or if there are any blatant patterns already present in the data. This can hopefully make the process of selecting or refining datasets to use in research much easier for scientists as well as speed up their analysis routines.

Outliers in data are often the source of much frustration for data scientists and researchers as they can skew statistical results or make certain statistical tests and techniques more difficult or ineffective. The ability to find and detect these outlier data points is usually done by hand, and the decisions about what to do with them are generally left up to the discretion of the researcher. While VARs Explorer does nothing to algorithmically locate outlier data points, the visualizations provided by VARs Visualizer do allow for scientists to quickly see if outlier data may be present in particular datasets. This allows them to more quickly decide whether they want to continue research with that dataset or maybe further subset the data in hopes of getting something more homogenous and easier to work with. The ability to quickly detect outlier data points may also be useful for database maintainers, as such outliers could be

the result of improper data collection, entry, or other database issues that may be correctable.

With a database housing over six million entries and available for a potentially large number of personnel to access and modify, it is inevitable that some data entered and committed to the database will be incorrect or missing. The ability to detect this data is often difficult. Portions of VARS Statistics, in conjunction with the VARS Visualizer, give database maintainers a new opportunity to see regions of the database where errors exist, as well as the ability to monitor the introduction of new errors into the database. This provides technicians the chance to more efficiently correct data errors and create a more accurate database of oceanographic data.

CONCLUSION

VARs Explorer is a means of centralizing, modernizing, and expanding how MBARI accesses and utilizes VARS data. For researchers, this means that extracting and analyzing VARS data, which previously would have required writing custom programs to first query, then visualize, the data, can now be accomplished utilizing VARS Query and VARS Visualizer. This frees up more time for analyzing data and thinking of novel ways to integrate VARS data into their research and less time forcing the data into a useable format. And for the MBARI Video Lab, this means that more time can be spent contributing annotations and enhancements to the database and less time attempting to locate and fix possible data errors.

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REFERENCES:

1. Schlining, B., & Stout, N. (2006). MBARIs Video Annotation and Reference System. *Oceans*. doi: 10.1109/oceans.2006.306879
2. Monterey Bay Aquarium Research Institute (2019, May 2). VARS Publications. Retrieved from <https://www.mbari.org/products/research-software/video-annotation-and-reference-system-vars/vars-publications/>
3. Hanrahan, C., & Salisbury, M. (2017, January 13). Station M long-term time series. Retrieved from <https://www.mbari.org/station-m-time-series/>
4. Welcome to Flask. Retrieved from <https://flask.palletsprojects.com/en/1.0.x/>
5. Plotly: Modern Analytic Apps for the Enterprise. Retrieved from <https://plot.ly/>