Webenizing Condition Reports
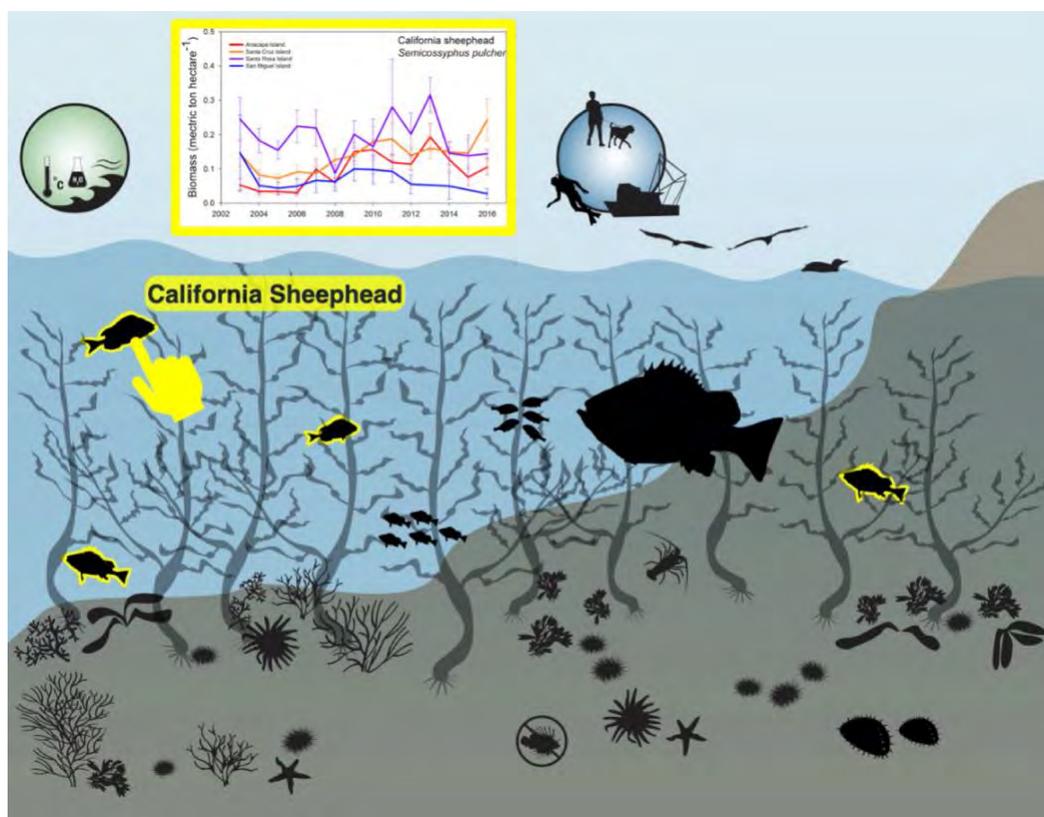
Communicating Data-Driven Ecosystem Indicators in a Visually Engaging and Interactive Online Platform

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Cover image: A stylistic representation of a kelp forest as viewed on the kelp forest page of the Channel Islands National Marine Sanctuary webenized condition report. A hand, representing the user interface, is clicking on a fish icon (California sheephead) and a corresponding graph **hovers above, illustrating the webenized condition report's functionality.**

About the National Marine Sanctuaries Conservation Series

The Office of National Marine Sanctuaries, part of the National Oceanic and Atmospheric Administration, serves as the trustee for a system of underwater parks encompassing more than 600,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our nation's maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sites range in size from less than one square mile to almost 583,000 square miles. They serve as natural classrooms and cherished recreational spots, and are home to valuable commercial industries.

Because of considerable differences in settings, resources, and threats, each national marine sanctuary has a tailored management plan. Conservation, education, research, monitoring, and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The National Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary System. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate. All publications are available on the Office of National Marine Sanctuaries website (sanctuaries.noaa.gov).

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Table of Contents

Abstract

The compilation and release of data-driven reports is one of the core functions of natural resource agencies and offices that support scientific investigations. Often, these reports contain **data and synthesis related to an ecosystem's "state" or the status** and trends of driving forces and the related condition of ecological indicators. These reports are often data and text rich and may be difficult for non-technical audiences to interpret. Further, because these reports may take years to compile and finalize, the data presented may be outdated by the time they are published. Status and trend reports, such as condition reports released by the Office of National Marine Sanctuaries, may need to target a wide swath of technical and non-technical audiences as sta**keholders with interests in a national marine sanctuary's resources. Here, we introduce the** webenized condition report (WebCR) as a digital companion to the published technical condition report (and similar reports) for increasing stakeholder engagement and accessibility while fostering timely understanding of ecosystem status and trends. The WebCR, built using open-source software, combines artwork depicting ecosystems, habitats, species, and human uses with related, data-driven content in the form of figures containing static or interactive charts, maps, and accompanying captions. The intuitive visual navigation combined with timely updates using a free and reproducible back-end system means that data providers and end users all benefit from this novel framework. Through an iterative process combined with stakeholder engagement, the WebCR has been made to specifically target the needs of a broad audience, including resources managers, educators, academic researchers and the general public. The **WebCR's desig**n is fully realized across a range of habitats and ecosystems, and can be applied broadly to disparate use cases. Here we describe the motivation for the WebCR, elements of its framework, a suite of examples for reuse elsewhere, the WebCR for Channel Islands National Marine Sanctuary, and next steps in a development pathway.

Key Words

Chapter 1:
Introduction

Ecological and environmental science agencies and resource managers face a critical communication challenge: how to effectively disseminate the status and trends of ecosystems to multiple stakeholders that would benefit from access to these data. Place-based managers often conduct assessments over the course of multiple years before detailed reports are released. While these reports offer a treasure trove of data and insights, they can also be long, dense, and difficult for non-technical audiences to interpret. Because these documents are compiled over many months to years, often involving consultation and review by multiple agencies, the data presented may be outdated by the time they are published.

To supplement these reports, we developed a novel platform to share and disseminate ecosystem status information: the webenized condition report (WebCR). The WebCR is a web-based platform that allows any user to easily navigate and interact with indicators for understanding the status and trends of the ecosystem, in conjunction with technical or scientific documents. The essential features of this platform are:

1. Navigation. Ecosystem components, such as species, habitats, ocean and climate drivers, or human dimensions, are all represented as icons in ecosystem illustrations. When one of these elements is "clicked," a popup window, hereafter "modal window," shows a figure, or multiple figures, with the latest associated data visualization (e.g., time series, map, chart).

2. Interpretation. To enhance stakeholder understanding, the platform supports interactive figures, a glossary of terms, and supplementary information, such as links to photographs, educational content, original data, and outward-pointing links to data providers. A simple caption, printed directly under an accompanying figure, image, or map, is intended for non-technical audiences. An expanded caption can be added to include more details targeted to scientifically and technically advanced users.

3. Timeliness. The platform supports automatic data updates (if relevant), especially from online sources such as data repositories, to display the latest information using free online services. For data that are not automated, project staff can easily update source data used to generate figures.

4. Open source. The website was constructed using free software (e.g., InkScape, Google Sheets, R, RStudio®) and is hosted for free (GitHub.com). This could lower the cost for other national marine sanctuaries and agencies to create similar interactive infographics and allow others to contribute improvements moving forward.

National Marine Sanctuary Condition Reports as the Motivating Use Case

Formed in 1972, the National Marine Sanctuary System now encompasses 15 national marine sanctuaries and two marine national monuments, and covers more than two million square kilometers. National marine sanctuaries protect both cultural and natural resources, and can be productive fishing grounds as well as economically and culturally important sites. Each sanctuary prepares a condition report (CR) approximately every ten years, typically prior to reviewing and updating its management plan. These reports focus on 16 questions related to five topics (drivers/pressures, water quality, habitat, living resources, and maritime heritage resources), which can be answered using a "status and trends" reporting system (see Office of National Marine Sanctuaries [ONMS], 2021a). Typically, CRs serve as informational tools for resource managers, researchers, and policy makers. These groups may use these reports to support management decisions, including identifying and proposing specific management actions that align with sanctuary management plans.

To create the *Channel Islands National Marine Sanctuary 2016 Condition Report* (ONMS, 2019), Channel Islands National Marine Sanctuary (CINMS) staff led a process to identify indicators of condition for the six major habitats found within the sanctuary that address ONMS's standardized CR questions (see Brown et al. [2019] for a description of this indicator development process). Over the course of roughly 18 months, CINMS staff worked with data providers to compile status and trend data for as many of these indicators as possible, then presented the data to regional science experts during a series of workshop sessions to assess sanctuary condition. The status and trend assessments, as well as all the compiled data, were collated and published in the lengthy 2016 CINMS CR (ONMS, 2019). Although the data are available in this downloadable report, this format is a cumbersome way to find specific indicator data; by the time the 2016 CR was published in 2019, the data in the report were no longer current.

The CINMS WebCR (National Oceanic and Atmospheric Administration [NOAA], 2021) was built as a proof of concept for how to make this wealth of status and trend data from a CR more readily available through a website and to provide a platform to support periodic updates to the data. CINMS project staff worked with the U.S. Integrated Ocean Observing System (IOOS) and the National Oceanic and Atmospheric Administration (NOAA) Integrated Ecosystem Assessment (IEA) to secure the funds needed for this project. WebCR project staff also engaged with the Marine Biodiversity Observation Network (MBON; Duffy et al., 2013; Muller-Karger et al., 2014), a global initiative composed of regional networks of scientists, resource managers, and end users, who are also major funders of this initiative. Through an iterative process, IOOS, IEA, and MBON worked with project staff to identify deliverables and outline the website design, which is pivotal to providing an accessible look and feel for end users.

The landing page of the CINMS WebCR provides a site overview. It contains an illustration depicting the major habitats found within the sanctuary to quickly orient a viewer to the CINMS ecosystem. These habitats are clickable icons, as are icons depicting ocean and climate drivers and human activities and impacts (Figure 1A). When the cursor hovers over an icon, both the

icon and its name are highlighted. Icon names are also listed in a table of contents on the right of the overview page and in the upper navigation bar. Clicking on a habitat or species icon or name navigates to a habitat page (e.g., kelp forest habitat, Figure 1B), which then displays **associated species icons that, when "clicked," open species**-specific modal windows (Figure 1C). A modal window displays figures and supporting information for the selected icon. In cases when more than one figure is available for an icon, the modal window contains descriptive headers that are navigable as tabs (Figure 1C).
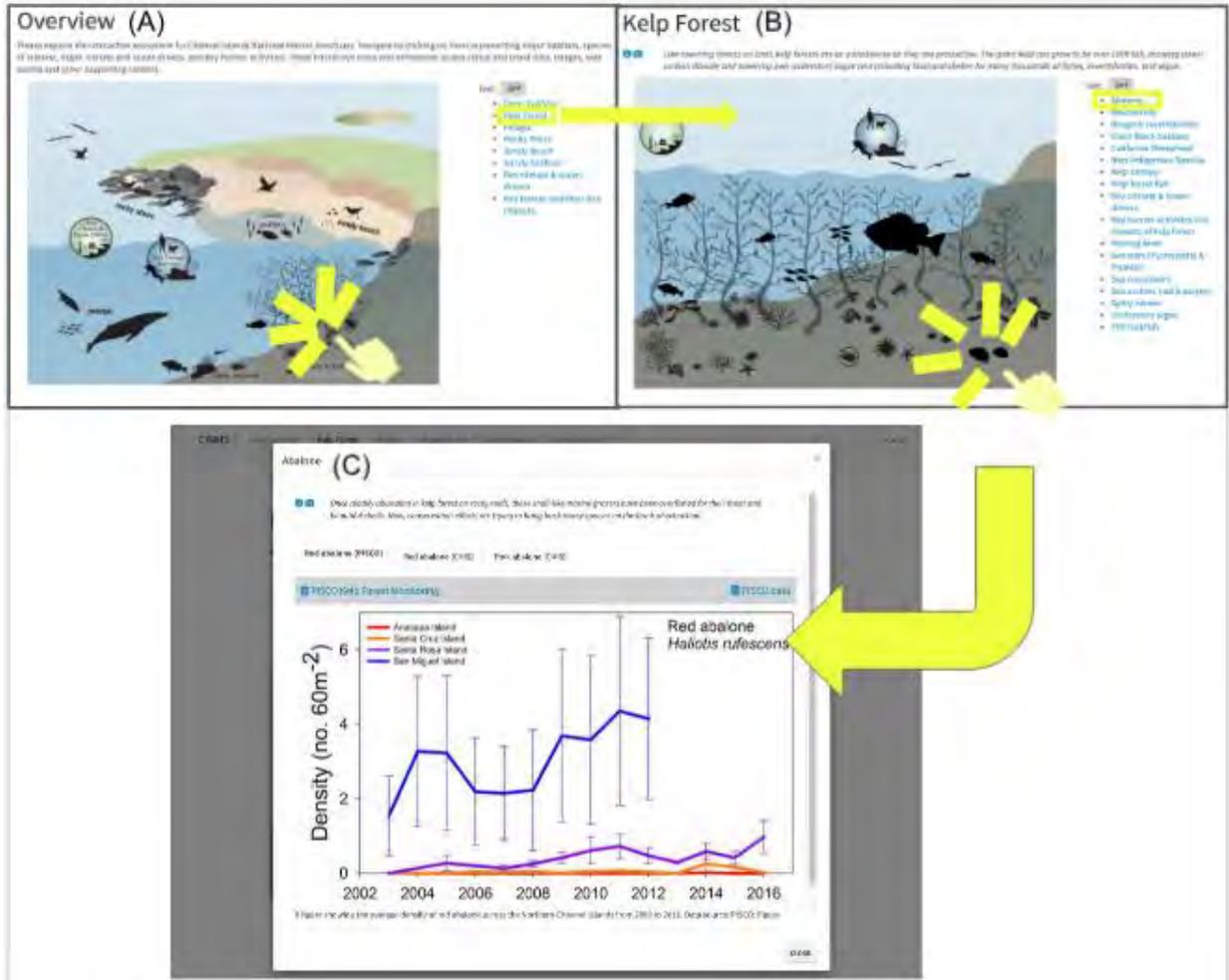

Figure 1. Example of sequential views in the CINMS WebCR site. (A) The overview page is the landing webpage for the CINMS WebCR. (B) The kelp forest habitat page can be opened by clicking either the interactive kelp forest icon on the overview illustration, the right-hand table of contents on the overview page, or kelp forest in the upper navigation bar (always visible at the top of the CINMS WebCR site. (C) Example of a modal window that opens on top of a habitat-level scene by clicking on an icon or an icon name in the right-hand table of contents. In this example, clicking on the abalone icon or the abalone name opens a modal window that displays a time series of abalone density at multiple islands in the sanctuary. Multiple tabs can be nested within a modal window to display multiple data products for the same indicator, for example maps and time series from different data providers. The specific features of the modal window are described in more detail in Figure 2.

This WebCR for CINMS provides information on the status and trends of sanctuary resources and points users to available data sources and streams. In this way, the WebCR can be used to

communicate which indicators were considered the most useful for condition assessment while enabling users to access the data used to generate these assessments. The framework is free to use and extensible to other natural resource assessments for reaching a broader, non-technical audience in a timely fashion.

Extending to a General Audience

Researchers and scientists in both academia and across government sectors often have difficulty locating data that are both openly accessible and available to meet their needs. These issues are also faced by many staff at other entities, such as NGOs and nonprofits, who wish to develop status and trend reports that reflect their activities and findings in a meaningful and engaging way. While report writing is a staple of management agencies and the scientific community, these documents are generally intended for a limited audience and therefore are often less accessible or convenient for non-technical readers.

The WebCR extends the intended audiences for condition reports as well as the associated data to be more inclusive of educators, members of the interested public, and other interested parties. Like most status and trend compendiums, readers of CRs follow a structured, linear pathway through the document. With a table of contents at the beginning, readers can skip to relevant sections within CRs. However, with a diversity of audiences in mind, the WebCR was designed to be navigable via visual cues rather than as a text-heavy, cross-referenced document.

Process for Building the Channel Islands National Marine Sanctuary WebCR

Translating the static, PDF-based CR to the webenized version was an iterative, multi-staged process in which icons were matched to indicators and the available data products for those indicators. For some indicators with available underlying data, interactive figures were generated. Furthermore, for indicators linked to data that are updated through vetted online sources (such as the Environmental Research Divisions Data Access Program [ERDDAP]), generation of interactive figures was automated to capture updates in the WebCR beyond the original static CR.

The layout of the WebCR included the six major habitats identified for indicator development (Brown et al., 2019) and described in the 2016 CINMS CR (ONMS, 2019). An illustration of the major habitats in the sanctuary became the landing page and allows for visual navigation to each habitat of interest, all of which are also accessible from the top menu (Figure 1A). Illustrations for each habitat were also designed to include icons of species, climate and ocean drivers, or human uses and impacts that corresponded with indicators for periodic assessment or ongoing tracking of sanctuary condition. Each habitat illustration was constructed with background elements and vector-based icons representing each of the habitats. This process required many **iterations in which icons were matched to indicators and the available data product's underlying** data and feedback from sanctuary staff. An online spreadsheet relating icons to static figures and available data was crucial for flagging gaps and needs for clarification. Further, affiliated monitoring programs that have data sets covering many indicators were identified. In some cases, static figures from the CR were used where the underlying data were not easily available

or the derivation process was too complicated to recreate. Otherwise, data were obtained, ideally through an online web service such as ERDDAP where future updates will become available, and reworked to generate an interactive version of the indicator.

A modal window template (Figure 2) was developed to include specific features. An Info icon, located at the top left of the window, links to an online resource with more detailed information on the subject of the modal window, such as a specific page on an associated website (e.g., Sanctuary Integrated Monitoring Network [SIMoN] species database [SIMoN, 2021]). An Images icon, located to the right of the info icon, links to an online image or gallery of images for that subject when available. The Data collector icon and Data collector title, located in a gray bar above the figure, give credit to the data provider and link to their program website when available. The Data icon and Data link title provide more information and a link to the dataset displayed in the figure if the data source is available online. Because modal windows are species- or indicator-specific, multiple tabs can be nested within a given modal window (e.g., Maps: Subject and Trends: Subject, shown in Figure 2). The Simple caption is intended for a general audience and contains a brief description of the displayed figure as well as the source/attribution. An Expanded caption, containing more technical information, can be displayed by toggling "Click for Details." Either the simple or expanded caption can include terms found in a Glossary, populated by project staff, which provides the term's definition when clicked or hovered over. All content found within a given modal window must be populated into the appropriate cell within a specified spreadsheet by project staff. If the corresponding information is not provided, the feature will not be displayed (e.g., if a data link is input into the spreadsheet, the data link icon will not appear in the related modal window).
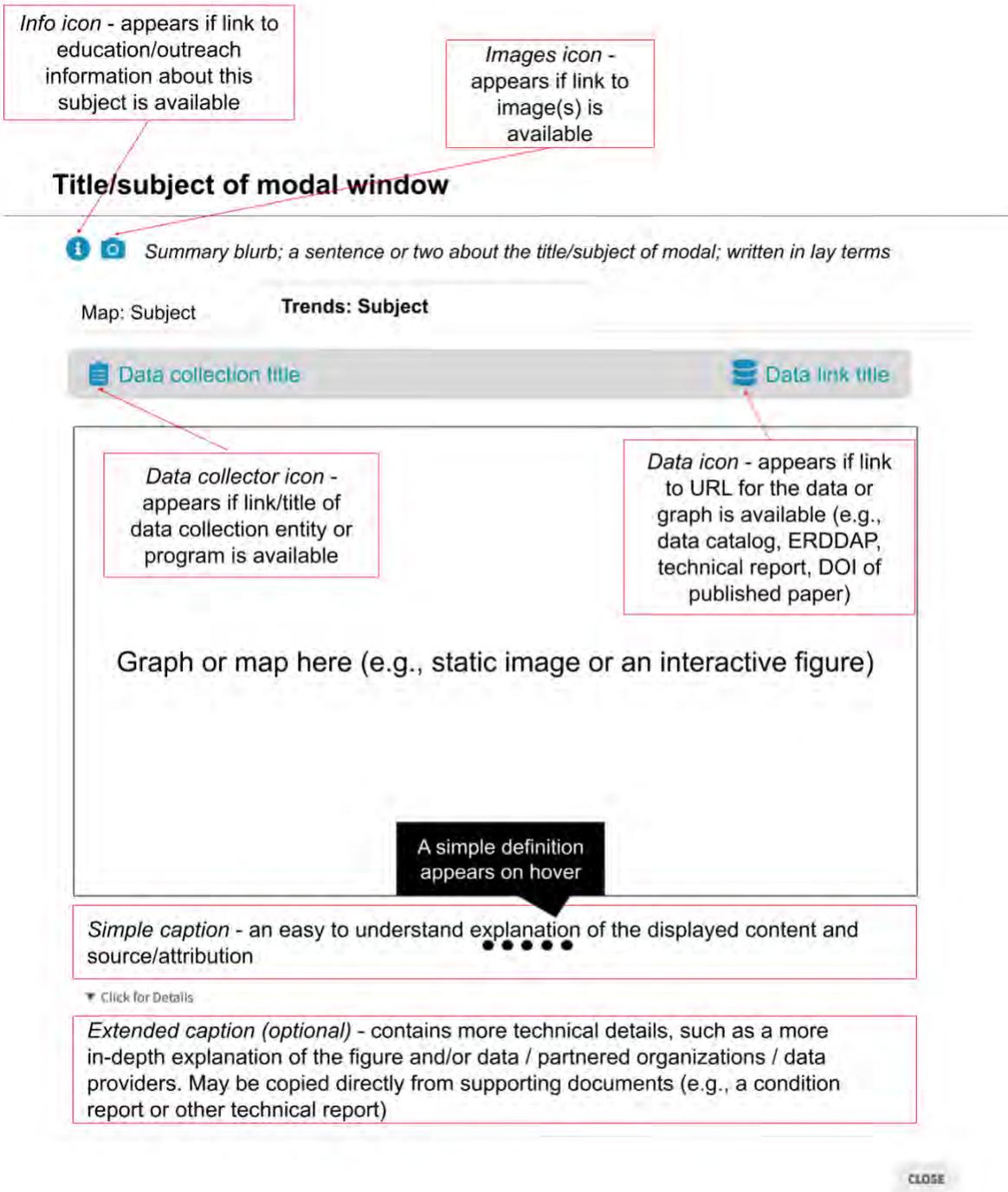
Figure 2. A modal window template showing available features. The **Info icon** links to an online resource providing more detailed information about the modal window, such as a species page on a partner website. The **Images icon** links to an online image or gallery of images for the subject. The **Data collector icon** and **title** provide credit to the monitoring entity that collected the data displayed in the figure and a link to their website. The **Data icon** is used to provide a link to the details of the dataset in the figure if that data source is available online. The **Simple caption** interprets the figure for a general audience. "Click for Details" expands an **Expanded caption** targeted to scientifically and technically advanced users. Terms found in the **Glossary** have a dotted underline to indicate that a definition will be displayed on hover.

Linking to Data Repositories and Supplemental Resources

The WebCR's user interface points users to accessible data repositories within NOAA (e.g., ERDDAP) and external data portals (e.g., IOOS, DataOne, the California Cooperative Oceanic Fisheries Investigation [CalCOFI], etc.; see Figure 2). In this way, project staff were able to directly integrate input by key stakeholders, who requested access to data sources and relevant documents, directly into the framework of the WebCR. To keep the user interface of the WebCR streamlined and user friendly, the users are also pointed to external "monitoring program" websites, such as ecosystem descriptions on the ONMS website and/or project databases on SIMoN. This approach allows curious users to explore relevant materials at their own pace without cluttering the look of the WebCR. Further, this promotes visibility for projects and programs associated with a given sanctuary to the benefit of users and project partners.

Accessibility by Design

Accessibility is at the heart of this project, and thus remains the focal point for continued development and implementation. To meet users' needs in the 21st century, project staff designed and implemented the WebCR to be accessible via desktop browsers (e.g., Chrome, Firefox, Safari) and mobile devices (e.g., smartphones and tablets). The look and feel of the WebCR is similar across platforms, performing equally well during desktop (e.g., using a mouse and/or keyboard/trackpad) or mobile browsing (e.g., fingers on a tablet or smartphone's touchscreen). Further, the needs of the visually impaired were considered in the design of the WebCR. This was done by ensuring that all elements of the WebCR met the Accessible Rich Internet Applications specification (Diggs et al., 2017), produced by the Web Accessibility Initiative.

In keeping pace with access and user interfacing, project staff designed the WebCR to capture the attention of audiences by creating a streamlined and visually appealing layout. Users can readily identify ecosystems and the organisms found within them, and engage with data-driven figures that facilitate synthesis of the information conveyed. Further, the WebCR is based on representations of the important components of the marine environment (e.g., a national marine sanctuary) for assessment and understanding. In its simplest conception, any WebCR can directly host static images that are presented concisely. Regardless of the type of data visualization, all figures on the WebCR can be used in conjunction with other reporting documents and are equipped with both a simple caption and an expanded caption to increase awareness and readability (Figure 2).

Chapter 2:
Framework for Developing the WebCR

Engagement with Intended Audiences

A core goal of the WebCR project is to make the data and information used in CRs, and similar assessment documents, accessible to a wider audience. To achieve this, target audiences, including those within the science and research communities, were engaged throughout the development process to ensure accessibility of the site layout and the content found within the site.

Intended audiences for the WebCR include: marine resource managers (state, federal, and tribal), scientists, educators (K–12), students (high school through college), and stakeholders from the general public (e.g., commercial fishers, volunteers, recreational users). For the CINMS WebCR, engagement with these groups took place mainly in the form of informal meetings, conference calls, and presentations to the CINMS Advisory Council. This level of engagement took place throughout the conception, drafting, and implementation of the WebCR, and helped guide project staff toward a finished product that is evergreen and easily updatable.

Partnership with Data Providers

During the drafting period of the 2016 CINMS CR, project staff worked within the science community (e.g., state and federal agencies, private entities, academics) to obtain the most recent status and trends information for target indicators. Data providers either sent project staff static images of rendered data or data files to be summarized and visualized for the site (i.e., CINMS). Project staff worked with data providers at Channel Islands National Park, CalCOFI, California Current Integrated Ecosystem Assessment program, and the Multi-Agency Rocky Intertidal Network (MARINe) to customize data analysis and presentation for the sanctuary. To better facilitate the dynamic nature of the WebCR, project staff worked with these partners to reconfigure these same data streams to create "interactive" figures embedded in the WebCR (where applicable), which allows users to: 1) see individual data values in a time series when hovering over them with a mouse, 2) dive down to a selected range of dates, or 3) zoom in to a map. To reconfigure the static images in the CR into interactive figures on the WebCR, project staff worked with data providers to streamline access to often large and complex datasets, thereby facilitating the implementation of interactive figures.

Components of a WebCR

At the core of the WebCR is reproducibility and an open access design. The WebCR's individual components blend back-end coding and user interface development (Figure 3). A combination of standard website coding (i.e., HTML, CSS, and JavaScript) rendered with a scientific programming language (i.e., R) was coded in an open-source integrated development environment (i.e., RStudio). Following this pathway, scripts were written to pull data from a data table (e.g., Google Sheets) and were then used to populate pages and modal windows with all the described content. Templates for web pages and modal windows (i.e., R Markdown) allowed project staff to develop a custom look and feel (Figure 2). Project staff utilized GitHub to

host the versioned source code in a repository and serve the website for free. Art in the form of background images and icons (e.g., scalable vector graphic [SVG] files) was combined with data read from a Table to render the visual look and feel of the WebCR. Modal windows are then populated by Figure content before being rendered as HTML pages. For more information, see Appendix A: Technical Building Process and technical documentation (Best & Ranganathan, 2021).
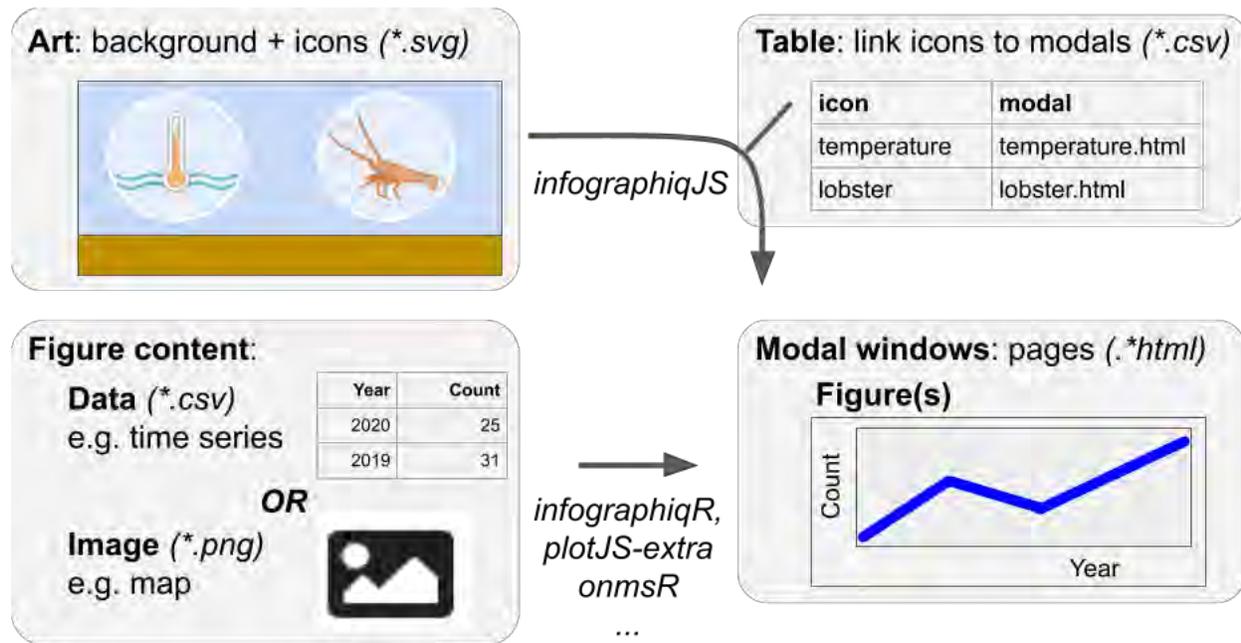

Figure 3. The main four components of a WebCR integrate art with content. The icons in **Art** are linked to the **Modal windows** with a lookup **Table**. The **Figure(s)** in the **Modal window** are populated by **Figure content** that is either a static **Image** or an interactive figure using the **Data**. The core JavaScript library was custom built into a package called infographiqJS, whereas other custom libraries used either just JavaScript (e.g., plotJS-extra) or R helper functions to output WebCR elements (i.e., infographiqR) or manipulate and visualize specific datasets (i.e., onmsR). The more general term of interactive infographics, or "intelligent" infographics, motivated the use of the prefix "infographiq" when naming the builder packages.

Component List for Generating a WebCR

Below is a set of basic components needed to develop a WebCR:

- Software
  - Scientific programming language: R (or Python)
  - Integrated development environment: RStudio (or Jupyter Notebook)
  - Versioned code repository and website hosting: GitHub (and GitHub Pages)
  - Artwork editor, such as Inkscape® (open source) or Adobe Illustrator® (proprietary)
- Components
  - Art
    - Background (raster or vector): embedded as SVG background to allow for navigation of the WebCR

- ■ Icons (vector): custom or borrowed from [phylopic](#), [University of Maryland Center for Environmental Science Integration and Application Network](#), [Font Awesome,](#) or similar; to be clicked by a user to further navigate the WebCR
  - ○ Table
    - ■ Table(s) in a comma-separated value (*.csv) format are used to link icons to modal windows
  - ○ Modal windows
    - ■ Web pages (*.html) store the content of the WebCR, generated from templates using R
  - ○ Figure content
    - ■ Static images (e.g., *.png or *.jpg) of data graphs and maps and/or
    - ■ Data to be used with interactive visualization functions (stored in *.csv form)

For more information, see Appendix A: Technical Building Process and technical documentation (Best & Ranganathan, 2021).

Chapter 3:
Design Layout

Figure Content Pathways

The inherently modular design of the WebCR means that future developers can select any combination of three types of data visualizations within each modal window, including different tabs in the same modal window. The three data visualization types are: static figures, interactive figures, and real-time updating figures. In this way, data visualizations can be modulated on a case-by-case basis to ensure the most scientifically accurate and visually appealing display for each data type. For example, if data providers prefer to supply a static image of a figure (e.g., a figure sourced from a publication), then that static image can be displayed within a modal window. If data are available, then the data may be displayed using an interactive interface. Finally, if an autonomous data stream is available (e.g., from ERDDAP), then the data may be displayed using an interactive interface that auto-refreshes on any discrete timescale. Regardless of visualization type, modal windows are built using the pathway described in Figure 3.

Static Figure

In its simplest form, the WebCR is a digital representation of the indicators and data in a physical CR. Therefore, with the code template already created by project staff, adding or updating content is a streamlined process. By using static images taken directly from a CR (Figure 4) or related document, project staff can simply add or swap an image file (e.g., a figure updated with more recent data) by replacing an outdated image file in the online repository. For example, project staff can render and download a figure from a relevant publication or partner report, save it to their local machine in the appropriate location, delete an old or outdated **image, and have these changes reflected online by simply rerunning the code and "pushing"** these changes to the GitHub repository. By streamlining the workflow in this way, individual WebCRs are readily updatable.
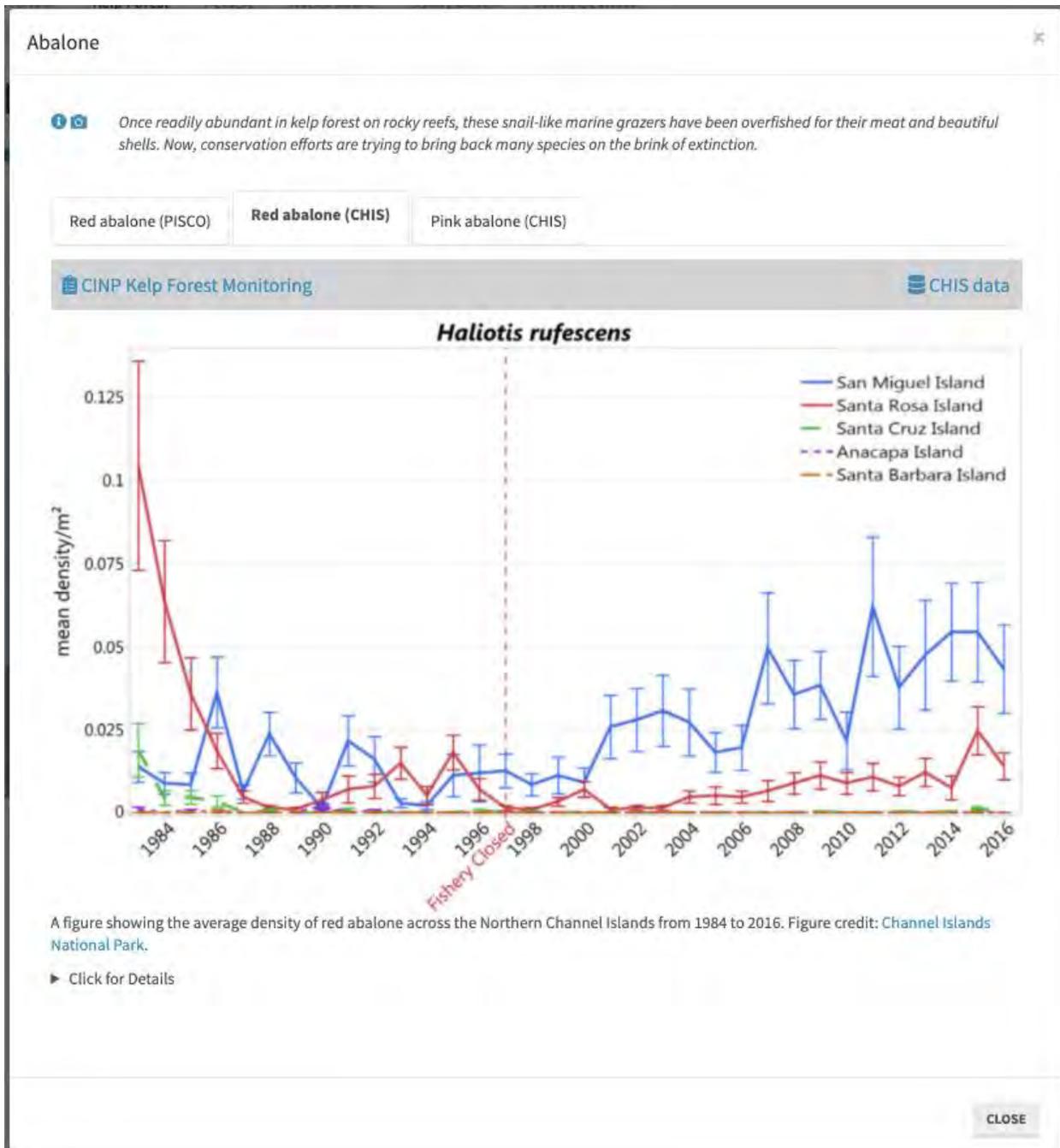
Figure 4. A static figure, along with supporting information (e.g., caption, data collector, and data links), populates the modal window template (see Figure 2). In this case, static figures from the 2016 CINMS CR (ONMS, 2019) for two abalone species and from two different data providers are navigable via tabs. To directly interact with this example, please visit CINMS Kelp Forest and click on abalone.

Interactive Figure

The purpose of "webenizing" a CR or related document is to facilitate discovery of status and trend information and increase end user engagement. Static images taken directly from digital documents allow users to see a snapshot of the data being represented. However, as data

streams become more accessible, project staff may consider updating static images into interactive figures. By rendering data into appropriate interactive visualizations (e.g., time series plots), users can engage with status and trends in novel ways. The bulk of modern advancement in data visualization has occurred with web-based technologies (i.e., JavaScript libraries, especially based on d3). New frameworks such as htmlwidgets for R enable the creation of these highly interactive visualizations from source data with an easy-to-use function. Project staff can therefore summarize data to the place (e.g., CINMS), time step (e.g., month, year), and indicator of interest, then input this data into a visualization function within the coding editor (e.g., RStudio) and render these data into interactive figures. These figures allow end users to: 1) display individual points of data when hovering over them with a mouse, 2) select a time range of interest, or 3) zoom in to areas of interest. Further, these interactive figures can often be **downloaded to the user's local environment to be** used as needed (e.g., in a presentation or report).
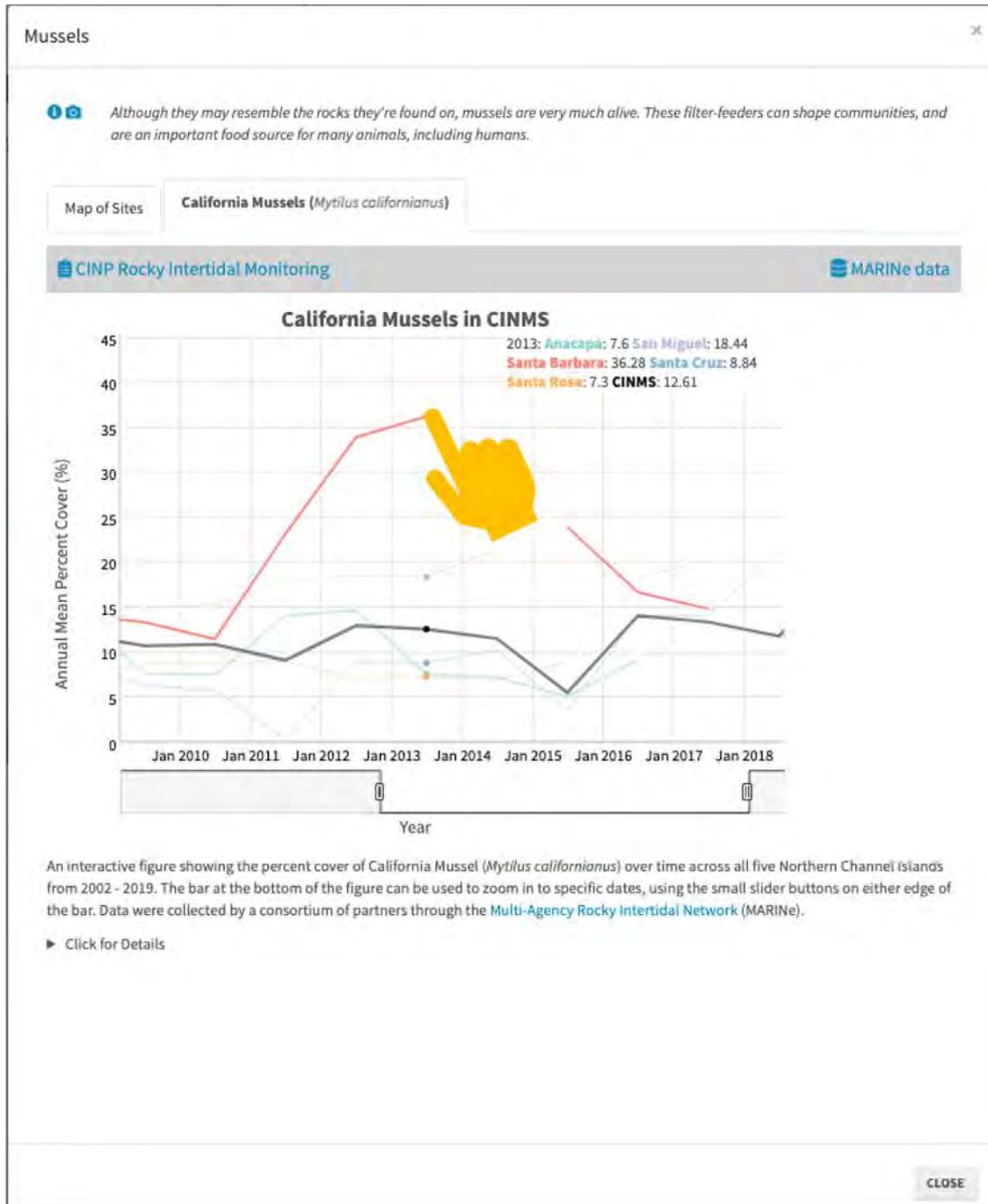
Figure 5. Interactive figures such as this time series example (using the htmlwidget library dygraphs) allow the user to zoom in to a time period of interest (e.g., by dragging the time sliders on the x axis) and see individual values within the series when hovering over a specific time (e.g., 2013 values displayed on hover with the cursor). To directly interact with this example, please visit CINMS Rocky Shore and click on mussels.

Auto-Updating Figure

Reports may rely on data that are regularly updated. Therefore, a WebCR can similarly update itself with the latest values from the source data stream, thereby making it easier to revise

and/or update future reports. These data may be derived from *in situ* sensors, such as temperature or pH, or remotely via satellite (e.g., MODIS for chlorophyll or AVHRR for temperature). For the CINMS WebCR, staff produced interactive maps of the latest satellite data (e.g., chlorophyll and sea surface temperature) and an interactive time series figure summarized for the sanctuary over the timespan from the available satellite product. These satellite data continue to be automatically extracted and visualizations updated monthly for free using a GitHub Action. This automated update process facilitates the evergreen nature of the WebCR, which updates automatically as new data are published upstream.

Figure 6. The sea surface temperature (SST) data in this example interactive map (right) and interactive time series of SST climatic anomaly (left) continue to be automatically updated monthly from the source ERDDAP satellite dataset for free using a GitHub Action. To directly interact with this example, please visit CINMS Overview and click on "Key climate & ocean drivers" (which is updated using the update_oceano GitHub Action).

Community-Based Open-Source Adaptability

While the inaugural WebCR was built to supplement the 2016 CINMS CR, it exists as an updatable "living" site. Due to the nature of WebCRs in general, project staff can execute updates as appropriate at any time. All the necessary code, images, and content are publicly housed on GitHub, meaning anyone can see all the source files and 'under the hood' code. Anyone can suggest changes by simply creating an issue (see GitHub, 2021) or by submitting code revisions (see GitHub, 2017). Since all edits are versioned, every line of code is traceable

and revertible to past versions. This commonly used GitHub model for open-source software development lends itself well to community-based, collaborative online products and fosters transparency for enlisting stakeholder buy-in (Bastille et al., 2021; Lowndes et al., 2017).

By anticipating changes and updates to the WebCR, project staff can fully integrate feedback in real time from project partners (e.g., IOOS regions, MBON) and constituents (e.g., CINMS Advisory Council). This flexibility facilitates a rapport with the entities targeted by the WebCR. In most cases, project staff have been able to augment the content of the WebCR to meet end **users' needs, or to perform maintenance on the physical layout of the site to** enhance its accessibility. However, in some cases, project staff have had to overcome the challenges presented by integrating data from many different sources into the WebCR. This has been achieved, in part, through ongoing conversations with data providers. Through these conversations, project staff have streamlined data integration into the WebCR, to the benefit of data providers/partners and the constituents and stakeholders who use the WebCR.

Chapter 4:
Next Steps for WebCR Development

Project staff are engaged with ONMS, IOOS, MBON, and the IEA program to promulgate these techniques across places managed by NOAA. For instance, continued webenizing of CRs for Monterey Bay and Olympic Coast national marine sanctuaries, as well as applications to IEA regions and projects in the Northeast, California Current, Alaska, and Florida Keys (IEA, 2019), are currently underway. WebCR-like products are also in development elsewhere across NOAA (e.g., for ONMS sound monitoring efforts; see ONMS, 2021b).

Scrollytelling Ahead

In the future, interactive infographics could be laid out vertically and responsively to the user scrolling down in their browser by highlighting ecosystem icons and updating corresponding data figures side by side. This "scrollytelling" approach has become popular with the use of the scrollama JavaScript library in journalistic articles published in the New York Times and Washington Post; Esri StoryMaps has similar functionality.

For example, along the California coast, the marine heatwave of 2014–2016 led to a record number of humpback whale entanglements with crab pots, requiring mitigation management (Santora et al., 2020). The complexity of the trophic cascade could be explored and described sequentially with data using this scrollytelling approach for Monterey Bay National Marine Sanctuary (Figure 7). The "warm blob" led to a harmful algal bloom, releasing domoic acid and causing a closure of the Dungeness crab fishery at the beginning of the season, which compressed fishing effort toward the season's end. Krill declined offshore and forage fish redistributed nearshore, especially young-of-the-year anchovies. Humpback whales preyed upon these nearshore fish, resulting in unusually high entanglements. All these interactions are complicated but can be told in data-driven storyboard form using this technique. Enhancing the public's understanding of interrelated ecosystem processes with such a tool can increase public trust of regulatory agencies and acceptance of requisite management actions, such as fishery closures or crab pot modifications.
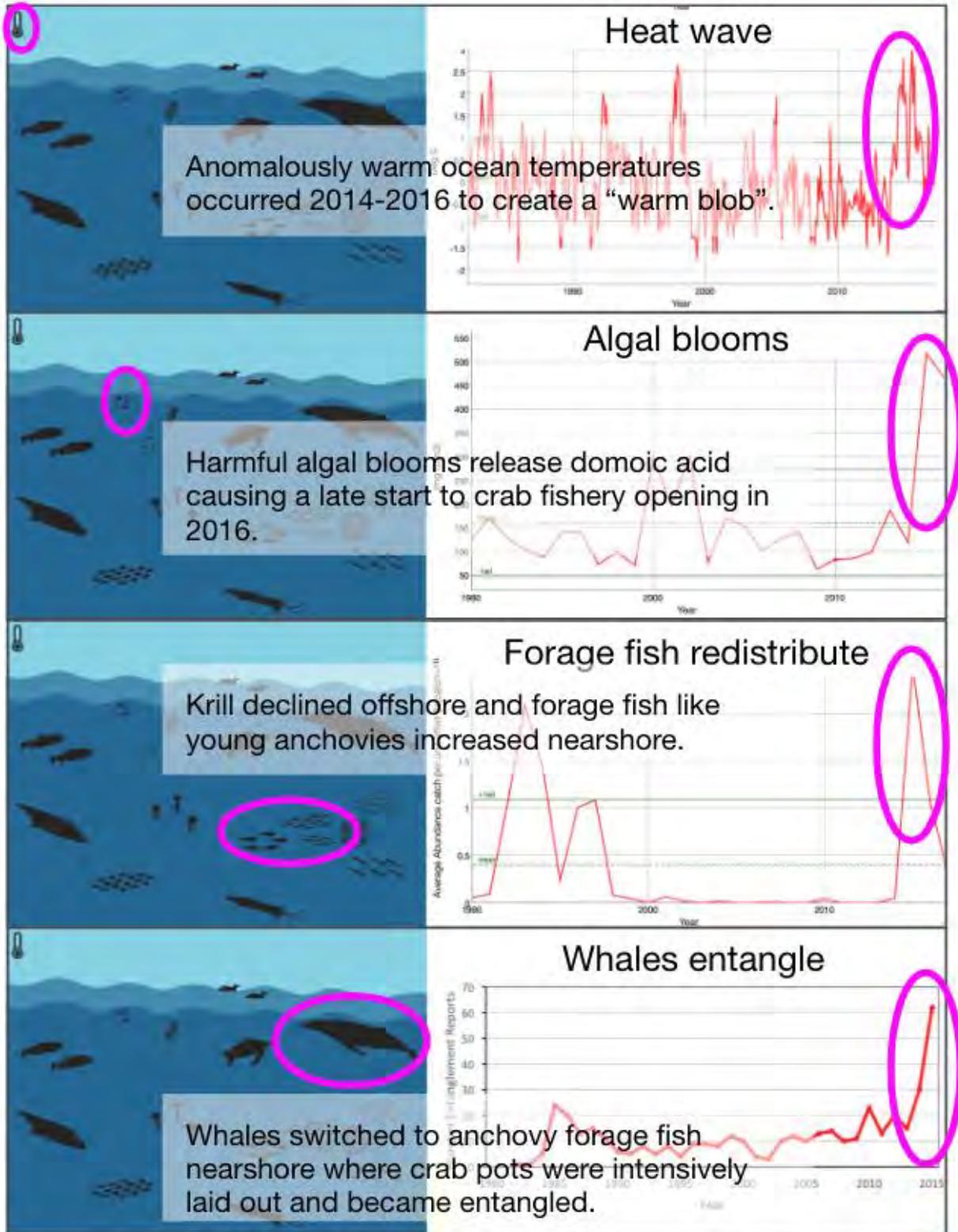
Figure 7. Example of information that could be presented in a scrollytelling format to promote interactive infographic data-driven storytelling. Ecological linkages, starting with the 2015 marine heatwave and ending with increased whale entanglement, are vertically oriented like a storyboard, meaning each pane is meant to be viewed one at a time with an icon highlighted and an associated figure displayed in sequence (see text for details.)

Chatper 5:
Conclusion

The goal of WebCRs is to create products that are open source and easily accessible, using up-to-date ecological information that can be more readily communicated to managers and the general public for effective conservation and place-based management. Through an iterative design process, future WebCRs can easily accommodate location-specific needs while maintaining the **ethos of a host site's office or agency. As governments and agencies respond to social and** climatic changes, it is increasingly imperative that data and reports are easily accessible to a broad diversity of stakeholders and interested parties. Whether as a stand-alone website or a companion to a written report, the WebCR model can foster increased stakeholder engagement and synthesis.

Acknowledgements

Glossary of Terms

expanded caption

An expanded caption is an optional addition to the simple caption that includes a more detailed description of the figure targeted toward scientifically and technically advanced users.

figure

A figure is a visual representation of data, either in the form of a graph or map.

Git

Git is a command line utility to version code and synchronize with GitHub.

GitHub

GitHub is an online portal for hosting versioned code and websites using GitHub Pages and automated actions with GitHub Actions and project management with Issues and Projects.

Google Sheets

Google Sheets are online spreadsheets from Google.

habitat page

The habitat page is second-level navigation (under the overview page) that houses individual clickable icons of the WebCR.

interactive figures

An interactive figure is rendered using specific coding frameworks that allow users to manipulate the figure as appropriate (e.g., change the date range represented on the x-axis for time series data).

interactive infographic

An interactive infographic is the broader type of product linking artwork to data. The WebCR is the specific instance

Infographiq

Infographiq is a custom set of libraries for developing interactive infographics.

overview page

The overview page is the landing page, or home page, of the WebCR that houses all the individual habitats and/or clickable icons contained in the WebCR.

modal window

A modal window is a popup window that uses the Bootstrap JavaScript and CSS framework to prevent browser popup blocking.

RStudio

RStudio is an integrated development environment for programming in R and R Markdown.

scene

A scene is a web page containing an illustration (i.e., art background and icons) with a table of contents and other potentially templated elements like title, description, and links to images.

simple caption

A simple caption is a figure caption that contains a brief description intended for non-technical audiences that is always visible under the figure in a modal window.

webenize

    To webenize is to convert a static document, such as a report, to a web-enabled document with clickable navigation and an online, interactive user interface.

Glossary of Acronyms

CalCOFI – California Cooperative Oceanic Fisheries Investigation
CINMS – Channel Islands National Marine Sanctuary
CR – condition report
ERDDAP – Environmental Research Divisions Data Access Program
IEA – Integrated Ecosystem Assessment
IOOS – Integrated Ocean Observing System
MARINe – Multi-Agency Rocky Intertidal Network
MBON – Marine Biodiversity Observation Network
ONMS – Office of National Marine Sanctuaries
NOAA – National Oceanographic and Atmospheric Administration
SIMoN – Sanctuary Integrated Monitoring Network
SVG – scalable vector graphic
WebCR – webenized condition report

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APPENDIX A:
Technical Building Process

The development and implementation of the WebCR was executed using a combination of open-source software and digital platforms (Figure 3), with the exception of the SVG illustrations, which were generated using Adobe Illustrator®. However, SVG illustrations can also be generated using open-source alternatives like Inkscape. Project staff developed the code for the WebCR website in RStudio using R Markdown templates and R scripts that rendered the website files (HTML, JavaScript, and CSS). While other coding languages can be used to generate iterations of the WebCR, project staff were most familiar with R as the primary coding language. Image files stored in Google Drive with links and additional information entered into Google Sheets allowed for real-time online collaboration and were pulled with R scripts to render the WebCR website.

A GitHub repository was used to version all source and rendered web files of the WebCR. GitHub project management features **such as "Issues" and "Projects" were used to coordinate** collaborative technical development for implementing new features, troubleshooting bugs, and developing documentation. Through the Git interface in RStudio, project staff were able to easily **"pull" updates, "commit" edits, and "push" changes back to the GitHub repository. The use of** Rstudio and GitHub allowed project staff to work collaboratively and independently from spatially disparate locations.

Aside from building the foundation and framework for the WebCR in RStudio, project staff **utilized SVG "silhouettes" created by Su J. Kim, graphic designer and illustrator with the** Northwest Fisheries Science Center. Jennifer Brown and Ellen Spooner have begun developing an icon library for reuse across IEA and ONMS products. SVG images were created and edited using Adobe Illustrator®. Background images were overlaid with individual icons that were grouped and given an identifier (e.g., mussels, abalone). Files were saved in native Adobe Illustrator (*.ai) format for future editing and exported in SVG format. The icon identifiers were linked to output modal windows with a Google Sheet exported in CSV format. The SVG and CSV files become inputs to the core link_svg() function of the infographiqJS library.

The web pages and modals are rendered from R Markdown templates and R scripts (Figure 3). Web pages consist of the overview and habitat pages, along with their respective SVG files. The modals are similarly rendered from R Markdown as separate web pages and are viewed by the browser as an HTML iframe. R Markdown is composed of markdown, easy syntax for producing HTML-formatted text (headers, links, image references, bold, lists) and chunks of R code. The site itself is a compilation of this nested design, which is housed within an overview page that functions as the site homepage.

As project staff continue to develop the content of the WebCR, new and improved interactive figures have replaced static images when appropriate and resources allow. The data used by project staff to create these figures were accessed via data repositories such as ERDDAP, or accessed directly from project partners such as CalCOFI and MARINe.

For more information about the code behind the WebCR, the creation of a GitHub repository and GitHub functionality, project collaboration with multiple project staff, and the creation of the interactive figures, please see the technical documentation starting with the README in the CINMS repository. Please see infographiq with documentation on how to build websites for interactive infographics given a few common constraints: a) HTML only using the core infographiqJS, b) R-facilitated generation of pages and modals using infographiqR, and c) embedding with a content management system like Drupal. This infographiq site will also demonstrate use of dataset-specific summarization and visualization functions like in onmsR, use of a variety of htmlwidgets for interactive visualizations for maps and time series, and custom visualization functions for specific branded features and looks such as plotJS-extra.

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