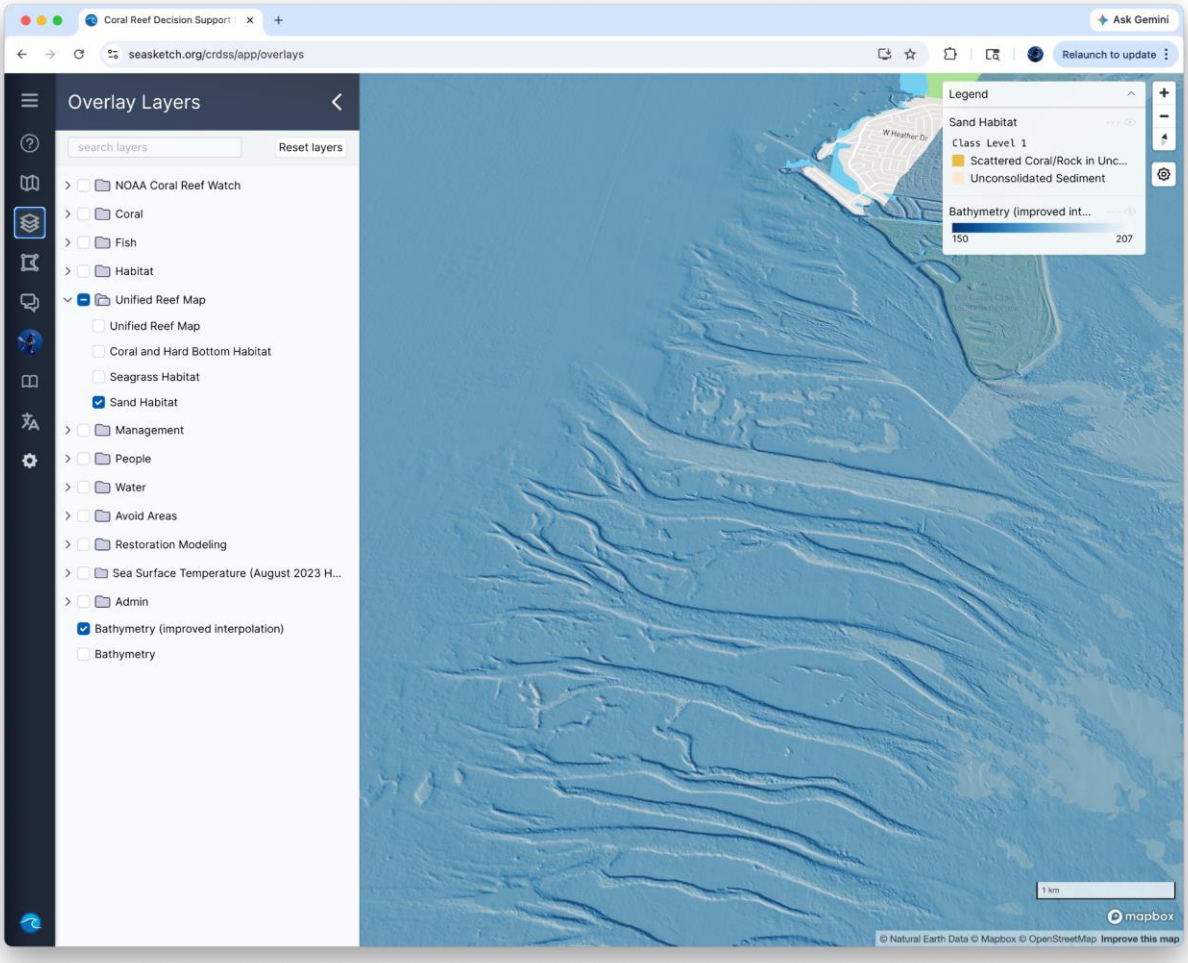
Coral Reef Decision Support System



Coral Reef Decision Support System

Year 2 Final Report

Prepared By:
Chad Burt and Will McClintock

The Spatial Collaborative, LLC
6237 Momouth Ave
Goleta, CA 93117

June 2026

Completed in Fulfillment of DEP PO# C5BC73 and FWC Agreement No. 24028 for

Florida Department of Environmental Protection
Coral Protection and Restoration Program
8000 N Ocean Dr.
Dania Beach, FL 33004

This report should be cited as follows: Burt, C. and McClintock, W. 2026. *Coral Reef Decision Support System (CRDSS) Year 2 Final Report*. The Spatial Collaborative, LLC. Prepared for the Florida Department of Environmental Protection, Coral Protection and Restoration Program. Dania Beach, FL. Pp. 1-15

This report was funded through a contract agreement from the Florida Department of Environmental Protection's (DEP) Coral Protection and Restoration Program. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the State of Florida or the Florida Department of Environmental Protection.

Acknowledgements

We gratefully acknowledge the guidance and support of Nick Alcaraz, staff of the Florida Fish and Wildlife Conservation Commission (FWC), Florida Department of Environmental Protection (DEP), and collaborators at Nova Southeastern University (NSU). We would also like to thank the reviewers and training participants whose insights helped improve the CRDSS.

Management Summary

The Coral Reef Decision Support System (CRDSS) is a modern, scalable, and interactive tool designed to support coral reef conservation and restoration planning along Florida's Coral Reef. Developed in collaboration with the Florida Fish & Wildlife Research Institute (FWRI), Nova Southeastern University, and The Spatial Collaborative using the SeaSketch platform, the CRDSS provides managers, scientists, and restoration practitioners with tools for viewing spatial data, filtering high-resolution planning units, digitizing potential restoration sites, and generating analytical reports.

During the second year of work, The Spatial Collaborative focused on maintaining and improving the operational CRDSS. Major accomplishments included continued infrastructure and Filter API support, updates to the HEX grid dataset, improved data visualization, refinements to the filtering interface, and expanded analytical reporting for restoration site evaluation. New report outputs included improved presentation of depth and vertical relief information, histograms, additional overlays, BCG scores, and a report summarizing the filters applied to grid-cell filtering outputs.

A major Year 2 advancement was the development of a data layer changelog and commenting system for SeaSketch administrators. This feature enables administrators to review changes to map layers before publishing, including information about what changed, who made the change, and when it occurred. This strengthens the governance and transparency of CRDSS data management workflows.

User feedback collected during training was generally favorable, with most system functions receiving high ratings. Survey responses also identified opportunities for future development, including improved printing and PDF export, personal data upload and visualization, larger legends, basic sketch annotation tools, additional report content, and incorporation of additional restoration-relevant datasets. These needs align well with the next planned phase of CRDSS development.

Executive Summary

Florida's Coral Reef (FCR) has experienced widespread disturbances from extreme temperature events, coral disease, pollution, and other stressors. Continued investment in restoration and management has created a need for decision support tools that help practitioners evaluate candidate restoration areas, compare spatial datasets, and document planning decisions in a transparent and collaborative manner. The Coral Reef Decision Support System (CRDSS) was developed to meet this need by building on lessons learned from the Our Florida Reefs Marine Planner and implementing a modern, flexible decision support system using SeaSketch.

The first year of the CRDSS project established the core system: a SeaSketch-based map portal, high-resolution grid-cell filtering tools, coral restoration site digitizing workflows, analytical reports, documentation, and training. The second year of work focused on maintaining and improving CRDSS as an operational platform, responding to feedback and identified needs. The Spatial Collaborative incorporated updated data, improved system reliability, refined user-facing workflows, and expanded administrative capabilities.

Year 2 improvements strengthened CRDSS in three principal areas. First, the project team continued to support the infrastructure, data delivery workflows, and filtering services that make the system available and responsive to users. Second, the restoration planning workflows were refined through updated HEX grid data, improved visualization, and expanded analytical reporting, making it easier for practitioners to interpret candidate restoration sites and document the criteria behind filtering results. Third, a new data-layer changelog and commenting system was developed to improve transparency and accountability in administrative data management. This was a major funded component of Year 2 work because CRDSS depends on authoritative, frequently updated spatial data, and administrators need a reliable way to review changes before they are published to users. The changelog system makes the data publishing process more transparent by showing what changed, who made the change, and when it occurred. It also provides a foundation for more rigorous review workflows as more partners contribute data layers, metadata, cartography, and restoration-relevant updates to the system.

Training and user feedback confirmed that the core CRDSS workflows are generally meeting user needs, while also identifying priorities for continued development. Users requested stronger output-sharing tools, options for uploading and visualizing project-specific data, improved legends and sketching tools, expanded report content, and additional restoration-relevant data layers. These suggestions align closely with the next funded phase of CRDSS development.

The work completed in Year 2 helped move CRDSS from an initial implementation toward a more mature decision support platform. The system is now better positioned to support ongoing restoration planning, partner data management, and future enhancements such as raster popups, selective publishing tools, Esri service synchronization, continued reporting improvements, and incorporation of additional datasets including Mission: Iconic Reefs information.

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1. Background

Florida's Coral Reef (FCR) stretches almost 350 miles from the Dry Tortugas to the St. Lucie Inlet, and is a vital ecological and economic resource, supporting biodiversity, coastal protection, and tourism. However, it faces acute and ongoing threats from coral disease, climate change, pollution, and other stressors. The Florida Fish and Wildlife Conservation Commission (FWC), in collaboration with the Florida Department of Environmental Protection (DEP), has prioritized coral reef restoration as a critical response strategy. Effective restoration efforts require comprehensive, up-to-date data and the ability to engage scientists, managers, and stakeholders in collaborative planning.

The Coral Reef Decision Support System (CRDSS) was developed in response to the Florida Department of Environmental Protection's goal of establishing a collaborative decision support tool for coral reef restoration and conservation efforts along Florida's Coral Reef. The system was built by The Spatial Collaborative, LLC using SeaSketch, a cloud-based decision support platform for marine spatial planning and conservation. During the first year of work, CRDSS was configured to support restoration site selection through map-based data exploration, a high-resolution H3 grid-cell filtering tool, coral restoration site digitizing workflows, and analytical reports that summarize key spatial information for proposed restoration areas.

The second year of work focused on supporting, maintaining, and improving this operational system. The Spatial Collaborative continued to maintain CRDSS infrastructure, update HEX grid datasets, refine filtering and reporting workflows, address bugs and usability issues, conduct training, and develop a major new data layer changelog system to support administrative review. Together, these efforts advanced the initial implementation toward a more mature data management and analysis system that is responsive to user feedback and evolving needs.

2. Continued CRDSS Support, Maintenance, and Data Updates

During Year 2, The Spatial Collaborative continued to support the CRDSS SeaSketch project and its related infrastructure. The system remained available to users at https://www.seasketch.org/crdss throughout the reporting period. The growing system now includes 5.3 gigabytes of vector and raster data across 98 layers. Ongoing support included maintenance of the Filter API server, data hosting workflows, application functionality, analytical reports, and other user-facing tools. The work also included troubleshooting and partner support related to data layer upload, management, cartography, and report reliability.

One of the most important responsibilities of The Spatial Collaborative is updates to the hex-grid dataset that drives the filtering tool. This tool enables restoration practitioners to set site selection criteria interactively and reveal which of 7.4 million locations match these criteria. As new data become available, and as users request additional filtering criteria, NSU collaborators encode additional layers into the canonical hex grid dataset. This product is then used by The Spatial Collaborative to update the

CRDSS. This dataset was updated twice during the reporting period, in October of 2025 and April of 2026. As this data product grows, issuing updates with the dataset in its entirety has become increasingly impractical. In response, The Spatial Collaborative streamlined hex-grid update workflows to allow for partial updates and improved data processing to reduce opportunities for introducing error. While still a semi-manual process, these updates make it possible to update the CRDSS much more quickly and reliably.

Another important data update deployed in fall 2025 was the addition of high-resolution bathymetry data. This multi-gigabyte raster dataset was provided by NSU, and was so large that it could not be processed by SeaSketch's standard upload handling system. Instead, this data was processed into tiles for optimal visualization on the web over several hours on a powerful workstation. This workflow was run multiple times to test different interpolation methods and yield a fast, accurate, and visually-effective representation of high-resolution bathymetry in the CRDSS. We anticipate that as new, higher-resolution LiDAR data become available across the state, the lessons learned from this initial data processing work can be applied.

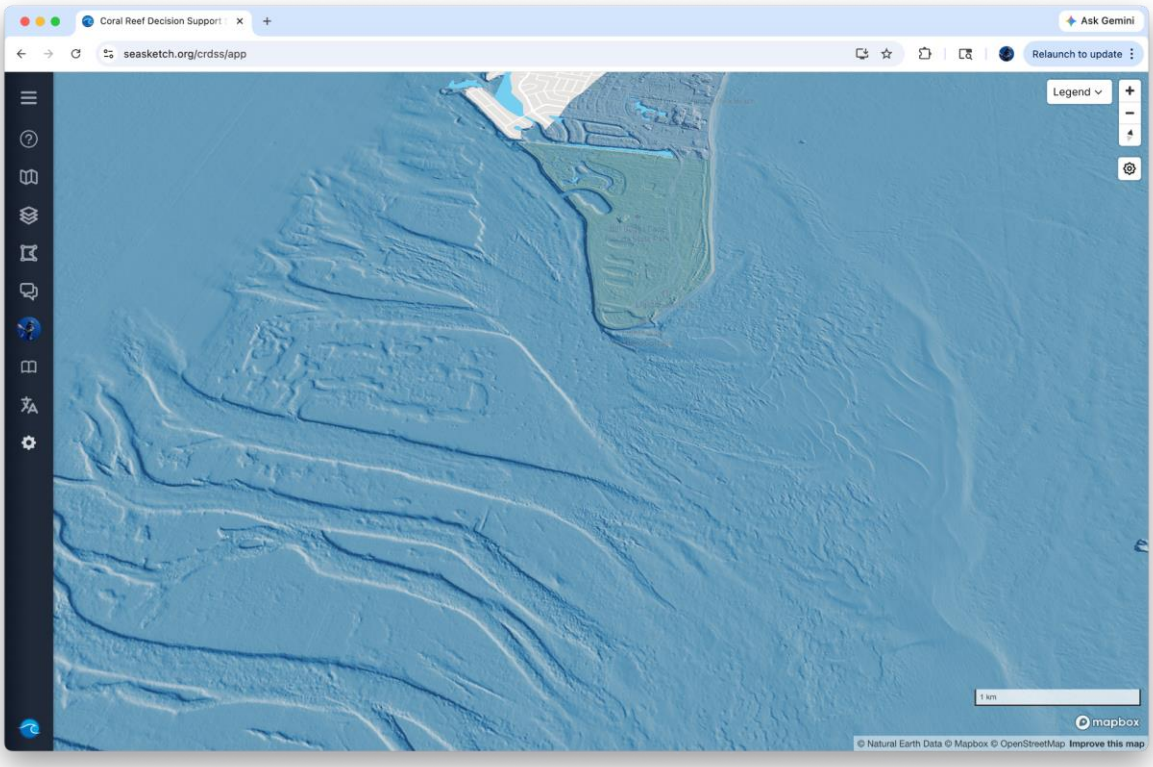

Figure 1: Despite the high resolution, tiled bathymetry data is very fast to load. Many iterations of the tiling process were tested in order to ensure interpolated details are clear at all zoom levels.

Beyond these data updates and major feature additions, The Spatial Collaborative continued to make small improvements, bug fixes, and adjustments to the system as requested by project collaborators and users. These included:

- Improved layer stacking and z-order settings to ensure datasets of different geometry types, filter tool outputs, and restoration sites could be more easily compared on the map.
- Fixes for analytical report reliability issues related to expiring authorization tokens.
- An added opacity slider for the Filter Tool user interface so that users can easily see habitats and other data layers underneath hex grid cells on the map.
- Improved SeaSketch project visitor statistics data collection processes to extend historical data access to up to 6 months.
- Improved instructions for working with complex inputs in the Filter Tool user interface.
- Added documentation on how to use new SeaSketch features such as the AI Cartographer and Data Layer Changelogs.

Taken together, these Year 2 maintenance and refinement tasks made CRDSS more stable, useful, and easier to use. Many of these improvements were not large standalone features, but they are the type of work required to keep an operational decision support system responsive to changing data, user needs, and management priorities. In addition, because SeaSketch is actively supported by other funding sources and projects, CRDSS also benefited from broader platform improvements made available to all SeaSketch projects during the reporting period. Highlighted improvements are listed in Appendix 2.

3. Coral Restoration Site Reporting Improvements

The coral restoration site reports are one of the most important user-facing components of the CRDSS. While the filtering tools help users identify broad areas that meet selected criteria, the reporting tools help users evaluate specific restoration sites. Users draw a polygon representing a proposed restoration area and receive analytical feedback based on spatial overlap with key CRDSS datasets and attributes from the high-resolution HEX grid.

During Year 2, these reports were improved based on partner feedback and continued use. Three significant revisions included updated datasets and improved presentation of key metrics. Habitat, organism, and human activity report content was updated to better reflect the data available in the CRDSS and the needs of restoration practitioners. These changes continued the iterative approach established during Year 1, where reports were refined as data layers changed and users identified improvements to make report outputs more understandable and useful.

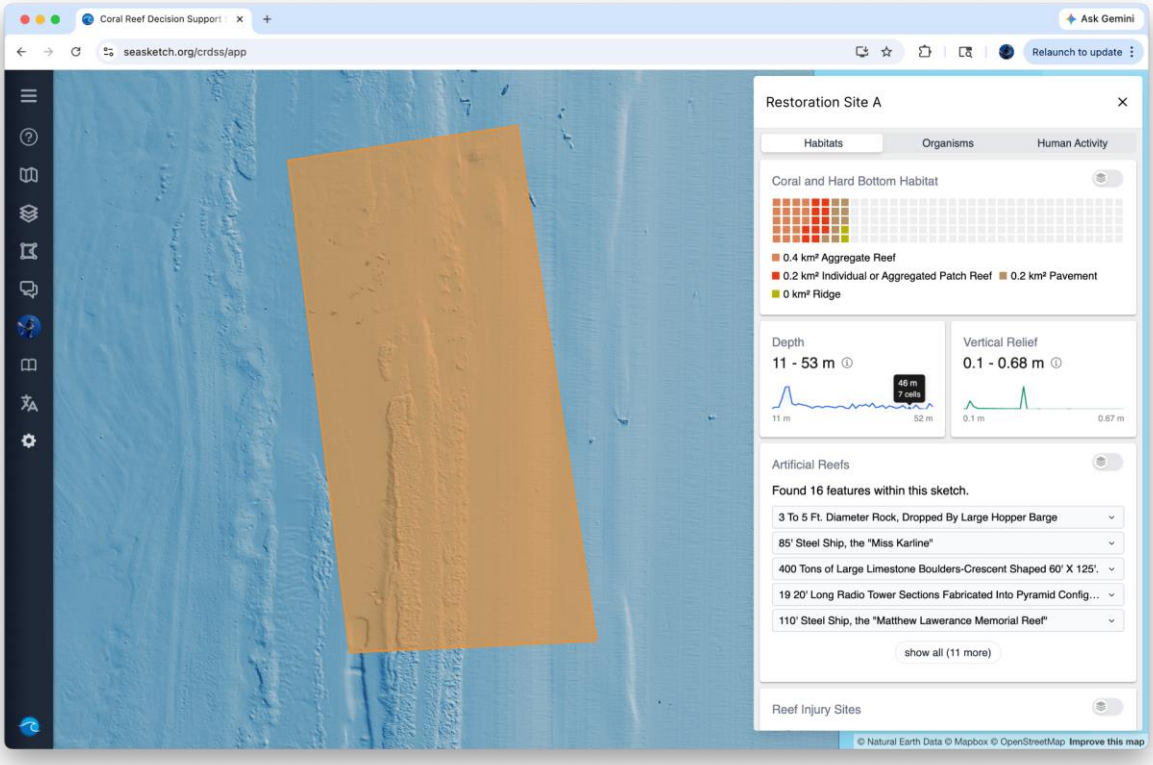

Figure 2: Restoration site reports were reorganized, then expanded to include depth and vertical relief outputs, including minimum and maximum values and distribution histograms.

New report outputs were developed for depth and vertical relief within restoration sites. These outputs include minimum and maximum values and histograms showing the distribution of values within the proposed restoration area. The addition of histograms is particularly useful because a single summary statistic may not adequately describe conditions across an irregularly shaped restoration site. Distributions provide a more complete picture of site conditions and can help users better understand whether a proposed site contains a narrow or broad range of depths or relief values.

BCG scores were also added to the updated HEX grid dataset and incorporated into analytical reports. This expands the set of restoration-relevant information available to users when evaluating proposed sites. The ability to include new indicators such as BCG scores demonstrates the value of CRDSS as a flexible reporting platform. As new data products become available, they can be incorporated into both the map interface and analytical outputs, allowing CRDSS to evolve with restoration science and management priorities.

The reporting system was also extended to support outputs from the filtering tool itself. Users can now generate a report that lists the filters applied to a filtering workflow. This is a useful addition because filtering results can be difficult to interpret without a record of the criteria that produced them.

These reports will continue to be revised over the life of the CRDSS, and appropriate funding for these revisions is included in the Task Assignment for Year 3 of the project. Already, surveys from participants in the April training, and feedback from practitioners have identified new useful outputs that are planned for addition in the near term. This includes the addition of Mission: Iconic Reefs buoy locations and data, warning of conflict with Coral Reef Evaluation and Monitoring Program (CREMP) sites, and overlap with Florida's Coral Reef Restoration and Recovery Initiative (FCR3) Tier II and Tier III locations.

4. Data Layer Changelog and Administrative Review Tools

A major Year 2 development is the addition of a new data layer changelog system for SeaSketch. This feature was one of the most significant components of the project year and was driven by a key challenge identified by CRDSS administrators during earlier use of the system. SeaSketch provided tools for collaboratively editing a draft version of the map layer list, including changes to data layers, cartography, metadata, and access control. However, when it came time to publish changes, administrators lacked a clear built-in way to review exactly what had been changed. In practice, this could require external spreadsheets or informal communication to track data maintenance work. This created a significant administrative challenge for FWC staff when deciding when to publish layer list updates to end users.

The new changelog system addresses this problem by recording changes to data layers and presenting them to administrators during the publishing workflow. It tracks who made a change, when the change was made, and what was changed. This can include data layer additions or removals, cartography changes, metadata updates, access control updates, and other modifications to the layer list. These changes are summarized for administrative review, allowing FWC staff and partners to better understand the state of unpublished edits before making them visible to users.

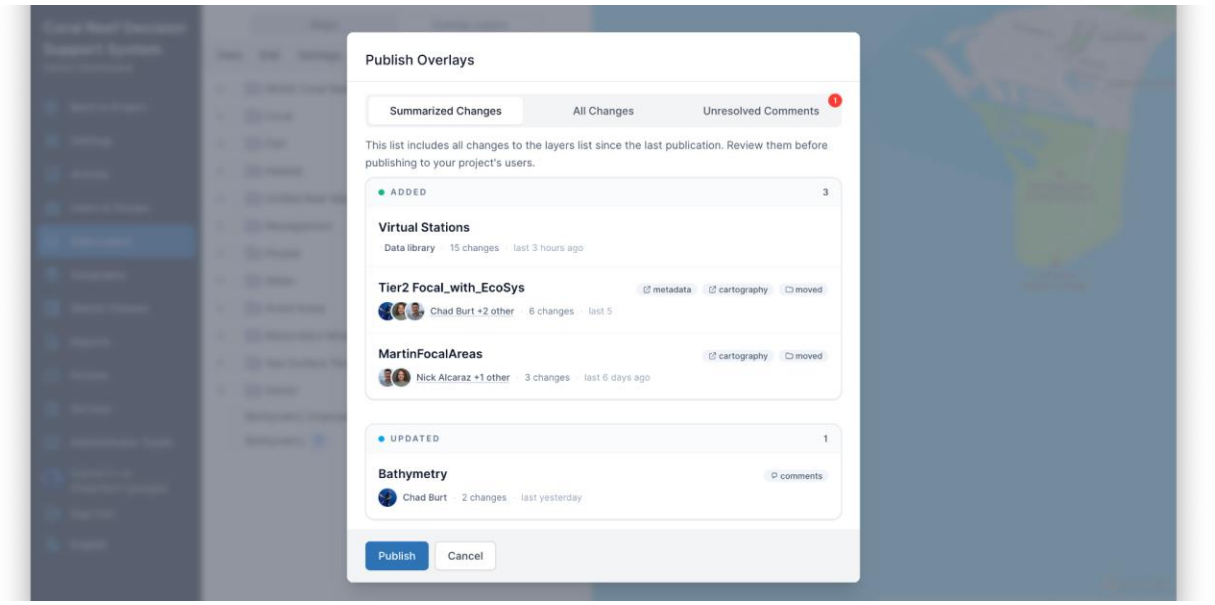

Figure 3: SeaSketch now summarizes unpublished data layer changes for review before publishing.

The system also provides detailed inspection tools. Activity badges can reveal exactly which settings were changed, showing their configuration both before and after the update. For more significant edits, such as cartography or metadata changes, detailed change history can be accessed and reviewed. Where appropriate, previous states can be restored, giving administrators a practical way to recover from mistakes or revisit earlier configurations.

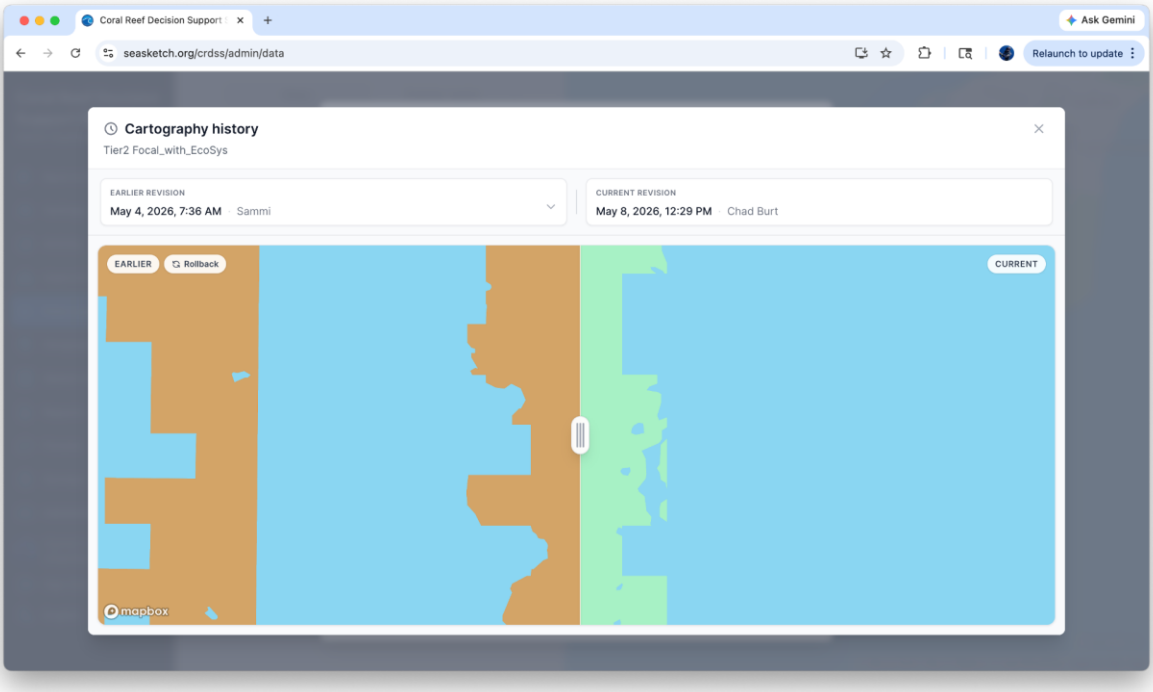

Figure 4: For cartography updates admins can view a complete history of changes, including a split-view map comparing a layer before and after each update. Undesirable changes can be rolled back if needed.

In addition to change tracking, the system includes resolvable layer comments. These comments provide a lightweight workflow for documenting unresolved data maintenance tasks, review notes, or questions about specific layers. This is particularly useful in a collaborative administrative environment where multiple people may be responsible for preparing, reviewing, and publishing data layer updates

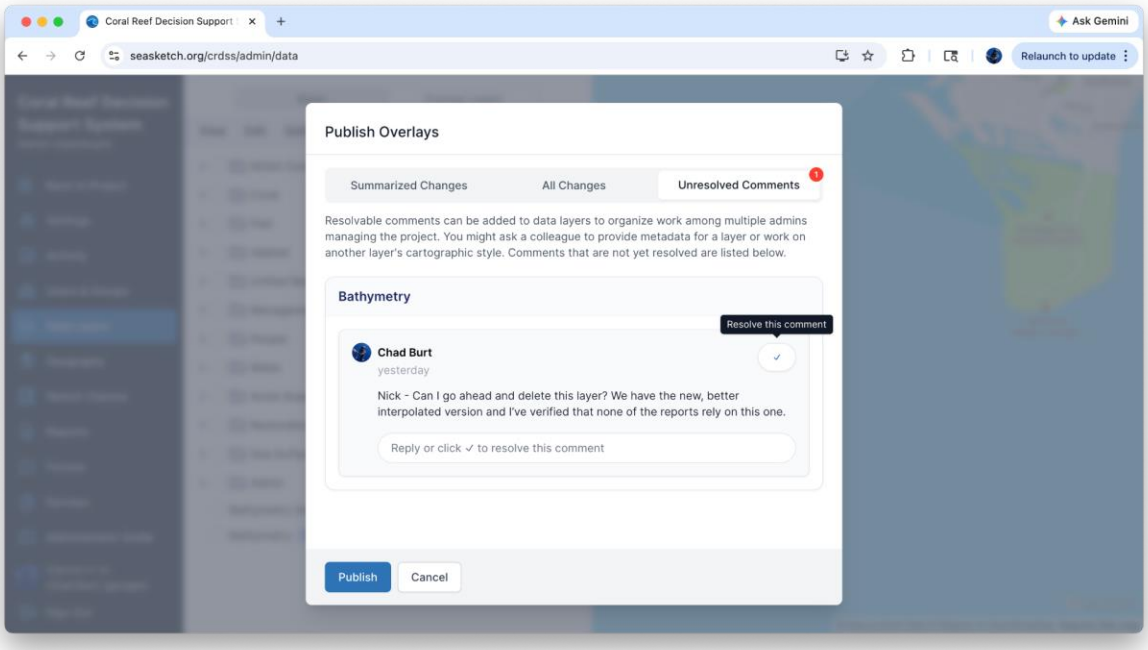

Figure 5: Administrators can add comments to facilitate collaboration among multiple editors of the data layers list. *Unresolved* comments are brought to the administrator's attention during the publishing process so that any unresolved issues with layers can be addressed.

The changelog system reduces reliance on external tracking methods, improves transparency, and supports more deliberate publication of data layer updates. Data access control updates, metadata revisions, and cartographic changes can now be reviewed as part of a deliberate administrative process. By making the history of layer changes visible to administrators, the changelog system strengthens trust in the CRDSS map library and supports more accountable collaboration among FWC, DEP, NSU, and other partners. Combined with many powerful new features released in the past year, SeaSketch has become a mature solution for managing spatial data.

5. Training, User Feedback, and Documentation

An online training was conducted on April 14, 2026 with FWC staff and partners involved in coral reef restoration site selection. Eighteen people expressed interest and were invited to participate. The training provided an opportunity to demonstrate the updated CRDSS, review key workflows such as map viewing, filter tools, restoration site creation, and analytical reporting, and collect structured feedback from users.

Although only five participants completed the feedback survey - with contributors from FWC, DEP, and NSU - responses were favorable for all major CRDSS features. On a scale of 1 to 5, the average rating across survey questions related to the usefulness and ease of use of features was 4.5, compared with 3.9

from the prior year's training survey. The only comparatively lower score was for the expected usefulness of forums, which averaged 3.4. This suggests that users found the core mapping, filtering, sketching, and reporting workflows useful and accessible, while the role of forums in restoration planning remains less clear. Better explanation of the forums in any future training may be needed.

Written comments reinforced these results. Respondents described the login process as easy, appreciated remaining logged in between sessions, and responded positively to map viewing features such as selectable basemaps and NOAA Coral Reef Watch layers. Comments on the filtering tool were also positive, with respondents noting that applied filters and sliders provided useful ways to narrow down cells. One respondent identified a usability issue where it should be clearer that a name is required before filters can be saved.

Respondents identified several opportunities for improvement. For map viewing, users requested support for newer aerial imagery where possible, and a larger legend or sidebar area. Users also requested printing or PDF export of reports so outputs can be saved and shared outside the CRDSS. One respondent requested basic annotation tools similar to Google Earth, including pins, simple text, and polygons. Several respondents requested the option to upload and privately visualize user-provided data such as outplanting sites or other project-specific layers. This is a feature request that has come up repeatedly.

Survey comments also identified report and data needs. One respondent suggested that restoration site reports include information on additional coral species beyond Acropora and DCYL where Tier 1 four-species zones are present. Another noted that filter outputs should help users understand whether areas are excluded because no data are available or because available data do not meet the selected criteria. Suggested data additions included NCRMP or DRM data where feasible, bleaching and disease hot spots, KJCAP terminology updates, FCR3 Tier II and Tier III locations, SECREMP and CREMP sites and buffers, and historic SAL permits or other permitted outplanting location layers. Respondents also noted the value of data related to Mission: Iconic Reefs, particularly for orienting users and understanding restoration context. These data updates, and related inclusion in reports, will be pursued over the next few months.

Documentation specific to the CRDSS continues to be available online at https://tinyurl.com/crdss-documentation. During Year 2, administrator documentation for SeaSketch was updated to include the new layer changelog system and other SeaSketch features introduced in 2026 such as the AI Cartographer.

6. Challenges, Opportunities, and Next Steps

The second year of CRDSS development demonstrated that the system is now an operational platform requiring continued maintenance, refinement, and adaptation. Regular calls with project collaborators to discuss user feedback have been invaluable, and a continual source of new data and functionality requests. Remaining responsive to these requests will be key in supporting user adoption. Feedback from the recent training will also be important to incorporate, along with follow-up to ensure users know their feedback has been heard.

A list of priorities has been created for the Year 3 Task Assignment which will focus development and maintenance efforts. This list of priorities includes:

- Continued updates to the hex-grid dataset, bug fixes, and improvements to the analytical reports.
- Support for querying raster data layers and displaying a popup with cell values. This is something that is currently only possible with vector layers and would be useful for inspecting Coral Reef Watch and bathymetry layers, among others.
- Automatic synchronization between SeaSketch and Esri services. Many useful authoritative datasets live in Esri systems. While SeaSketch can link to these services dynamically, users would benefit from hosting and tiling these data within SeaSketch for better performance. Synchronization would combine timely data updates from the source with the performance benefits of hosting on SeaSketch's infrastructure.
- More flexible layer list publishing options. Currently the draft layer list must be published entirely, but in many situations admins need to publish just a single priority layer, or publish the entire list while excluding a single layer that requires additional review.

One challenging feature that has been requested by users but has not been included in next year's priorities is the ability for non-admins to upload data layers. Restoration practitioners would benefit from being able to upload their own map layers (confidential or public) for visualization alongside the layers provided by the CRDSS for decision-making. Currently, doing so would require downloading this data from the CRDSS (if permitted), loading it into desktop GIS, applying their own cartographic styling, and only then visualizing it alongside their data. This is a highly technical and laborious workflow. Enabling users to upload data into their own personal workspace would enable them to visualize data such as their organization's outplanting sites directly within the CRDSS. Moreover, the CRDSS could support workflows where users may post their data to the discussion forums for sharing with other practitioners. These forums could also prove to be a workflow where practitioners submit data that administrators can consider for addition to the main map layers list. This feature would represent a significant development task and will require further scoping and consideration.

7. Closing Thoughts

The second year of the CRDSS project marked an important transition from initial system delivery to operational maturity. The first year established the core platform, high-resolution filtering tools, restoration site digitizing workflow, and analytical reports. The second year strengthened that foundation through data updates, report refinements, and new feature developments focused on improved data management and governance. As restoration priorities and datasets continue to evolve, CRDSS provides a flexible foundation for supporting data-informed decisions along Florida’s Coral Reef.

Appendix 1. Source Code

All source code related to this project is open-source licensed and available on GitHub.

- The complete SeaSketch source code can be found at: https://github.com/seasketch/next/
- The SeaSketch geoprocessing framework can be found at: https://github.com/seasketch/geoprocessing
- The API Server which performs grid-cell filtering can be found at: https://github.com/underbluewaters/crdss-api-server
- Analytical reporting source code can be found at: https://github.com/underbluewaters/crdss-reports

Appendix 2. Related New SeaSketch Features

SeaSketch is actively supported by other funding sources and projects, which have resulted in many significant improvements to the tool outside of the scope of the development contract with FWC. Below is an incomplete list of some of these new data management features introduced during the reporting period:

- An AI Cartographer feature can now optionally process administrator-uploaded data to clean up layer titles, assign attribution, and apply an appropriate cartographic style to new layers.
- Specialized Editor Views can now be used to very rapidly assess and update access control settings and data download permissions for all layers in a project.
- The Data Library has been expanded with new authoritative sources, including configurable iNaturalist observation layers.