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Validation of the California Rapid Assessment Method (CRAM) Slope Wetland Module

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EXECUTIVE SUMMARY
Slope wetlands, one of the most numerous wetland types in California, are important regulators of downstream water supplies, and provide water storage functions, filtration and benefits to local biota. However due to anthropogenic actions, many Slope wetlands have become dewatered, thus degrading the wetland condition and providing lesser wetland functions. State and Federal agencies are charged with protecting wetlands and aquatic resources, and many are adopting the Wetland and Riparian Area Monitoring Plan (WRAMP) as a framework for coordinated monitoring and assessment. Level 2 of the framework is rapid assessment of condition, which is represented by the California Rapid Assessment Method (CRAM). The continued development of the CRAM methodology will improve the agencies' ability to support the protection of wetlands across the state.

The CRAM development process is prescribed, and includes a validation step, where CRAM data is compared against independent Level 3 data, or more intensive and detailed data that indicates ecological condition. The purpose of the CRAM Slope wetland module validation was to answer the question: "Does the Slope Wetland module correlate to more intensive measures of condition based upon independent vegetation data, and thus provide a meaningful, repeatable, and accurate measure of wetland condition?" (Sutula et al., 2006; Stein et al., 2009). This report presents the Validation of the Slope Wetland module of CRAM.

To validate the module, the development team completed multiple steps, including:
- Identifying the gradient of stress (dewatering),
- identifying appropriate detailed Level 3 data to validate the CRAM scores (vegetation data collected by USFS, NPS, and the development team following the NPS protocols),
- identifying the metrics that will be calculated from the detailed Level 3 data (Percent Native Cover; Percent Non-native Cover; Percent Early-, Mid-, and Late-Successional Plants; Percent Bare Ground; Native Species Richness; Non-native Species Richness; Shannon Plant Diversity Index; Shannon Evenness; Ratliff Vegetation Score; and Percent Decreasers),
- creating conceptual models that describe the expected relationship between the detailed data and CRAM scores,
- identifying field sites where the targeted Level 3 will be collected, or collect new data,
- and conducting new CRAM assessments.

In addition, data on wetland condition was collected using the American Rivers Scorecard, so that any potential correlation between the Scorecard and the CRAM Index Score could be developed.

CRAM assessment data was collected at a total of 40 sites during the spring and summer of 2015, including all five Slope wetland sub-types. Sites were located across the state, primarily on public lands, and primarily represented fair to good condition wetlands.

Results of the CRAM assessments revealed that modifications to the module were necessary, to improve its ability to differentiate between poor, fair, and good ecological conditions. The modifications included: creation of a fifth Slope wetland sub-type (Channeled Forested Slope wetlands), clarification of the Hydroperiod metric, rebinning of the Bank Height Ratio sub-metric, creation of a worksheet for the Percent Dewatered sub-metric, modifications to patch types within the Structural Patch Richness metric, separation between physical complexity and vegetation roughness in the Topographic Complexity metric, rebinning of the Number of Co-dominant Species sub-metric, removal of the Encroachment

Groups sub-metric, and addition of new life forms within the Life Forms metric. These modifications are captured in the updated Version 6.2 Slope Wetlands Field Book (October 2017).

Using the updated module, the development team explored findings and correlations between the detailed Level 3 vegetation data and CRAM scores. Results from the 40 Slope wetland assessments include:

- CRAM Index scores ranged from 56 to 91, with a median score of 73.
- CRAM Index and Attribute scores are normally distributed.
- Significant correlations exist between the CRAM Index score and Percent Native Cover, Percent Non-native Cover, Early Successional Plants, Late Successional Plants, Non-native Species Richness, Ratliff Vegetation Index, and Percent Decreasers.
- Significant correlations exist between the Biotic Attribute score and Percent Native Cover, Percent Non-native Cover, Early Successional Plants, Late Successional Plants, Non-native Species Richness, and the Ratliff Vegetation Index.
- A moderate correlation exists between the CRAM Index score and the Percent Bare Ground.
- As predicted by the conceptual models, no correlation exists for the Shannon Plant Diversity Index and Evenness, Percent Bare Ground, and Mid-successional plant species.
- A significant correlation exists between the CRAM Index score and the American Rivers Scorecard.
- The correlations between the Biotic Attribute score and each of the vegetation metrics are not as strong as the correlation with the Index Score.

Based upon these results, the development team believes that the Slope Wetland module *does* correlate to more intensive measures of condition, based upon independent vegetation data. The module *does* provide a meaningful, repeatable, and accurate measure of wetland condition that is applicable in Slope wetlands across the state. This module is an effective tool for rapidly assessing the overall condition of Slope wetlands, and should be incorporated into assessment and monitoring toolboxes as applicable.

INTRODUCTION

California is celebrated for the diversity of wetland types that exist within the state. Climate, geology, and land use control the types of wetlands and the locations of those wetlands on the landscape, as well as the abundance and persistence of wetlands. Despite the wide variety of wetlands across the state, wet meadows and other types of slope wetlands (forested slope and seeps/springs) are one of the most numerous types. Some Slope Wetlands, like the iconic Tuolumne Meadow in Yosemite National Park are cherished for their beauty. However, Tuolumne Meadow, along with the entire Slope Wetland class are more than just beautiful, they are also important centers of biodiversity and modulators of water resources, especially given climate change.

Slope Wetlands act as sponges, holding snowmelt and groundwater, and slowly releasing that water for many weeks or months that can extend into the Fall. This natural water storage, filtration, and delayed release benefits to the local biota, as well as the downstream receiving water bodies, including those that supply drinking water. However, despite their hydrologic importance, Slope Wetlands (especially wet meadows) have been affected over the past 150 years by a complex history of grazing, logging, ditching and agriculture. In many instances, these anthropogenic actions have negatively affected the condition and function by dewatering the wetlands. Because of the multiple beneficial uses and the historical and on-going degradation, Slope Wetlands are currently the focus of many restoration and enhancement projects.

State and Federal environmental policies protect wetlands and aquatic resources, and thus many agencies have dedicated significant public funds to protect, enhance, restore, mitigate and monitor these wetlands. The California Wetland Monitoring Workgroup (CWMW), a subcommittee of the California Water Quality Monitoring Council (CWQMC), provides oversight for the implementation of the Wetland and Riparian Area Monitoring Plan (WRAMP). The WRAMP recommends a coordinated monitoring and assessment strategy that supports California's Wetland and Riparian Protection Policy that is structured according to the US EPA's recommended 3-Level monitoring and assessment framework for wetlands. The framework includes GIS mapping of aquatic resources (Level-1), field-based rapid assessments of those mapped resources (Level 2), and discrete water quality or ecological field sampling (Level-3) that further investigates ecological condition or other regulatory requirements. Within this framework, Level 2, or rapid assessment of condition, is represented in California by the California Rapid Assessment Method for Wetlands (CRAM). CRAM is a cost-effective and scientifically defensible rapid assessment method for monitoring the conditions of wetlands throughout California. CRAM can be used to assess ambient conditions for any geographic scale of interest, or to assess the performance of compensatory mitigation projects and restoration projects. The continued development of the CRAM methodology will improve the agencies' ability to support the protection of wetlands across the state.

The procedures for developing individual CRAM modules for individual wetland types have been endorsed by the CWQMC, and peer reviewed by the California State Water Resources Control Board and the California Environmental Protection Agency. The development process is prescribed, and includes a *validation* step, where CRAM data is compared against independent Level 3 data, such as detailed vegetation data. Validation is an important step in module development because comparing CRAM scores to independent measures of wetland condition further establishes the validity of the CRAM module (Sutula et al., 2006; Stein et al., 2009).

This report presents the Validation of the Slope Wetland module of CRAM. A US EPA Wetland Program Development Grant (Region 9), which included the validation of three CRAM modules (the Depressional, Vernal Pool, and Slope Wetland modules), funded this project.

THE VALIDATION PHASE OF CRAM MODULE DEVELOPMENT

Validation provides confidence that a measurement method is working, or in other words, is robust and reproducible. Specific to CRAM, validation has been defined as "the process of documenting relationships between CRAM results and independent measures of condition in order to establish CRAM's defensibility as a meaningful and repeatable measure of wetland condition" (Stein et al., 2009).

Validation of a CRAM module is one step along the module development pathway. A CRAM module is developed in six steps, as described in Sutula et al., 2006 and outlined on the CRAM website (http://cramwetlands.org/about). The steps include:

1) a definition phase,
2) a basic design phase,
3) a verification phase,
4) a validation phase,
5) a module production phase,
6) and lastly, an ambient survey phase.

Development of the Slope Wetland module began in 2010/2011, when steps 1 through 3 were completed and produced the initial Wet Meadow CRAM module (Version 1.0c) that was employed in the Caltrans Willits Bypass Project in 2011. Further development occurred in 2012, and involved the formation of the Slope Wetland Technical Advisory Committee (TAC, consisting of 26 wetland scientists). Through the workgroup process, the initial Wet Meadow module was updated and released as the "Verification Version" of the Slope Wetland module (Version 2.0). Verification occurred at 15 sites in the Sierra Nevada in 2012, leading to the release of the "Validation Version" of the module in 2013 (Version 6.1). This version was used in 2013 in the Santa Rosa Plain, and in 2014 along the California coast (to provide additional coastal verification since most of the initial verification occurred in the Sierra). In September 2014, minor textual changes were made, and an updated Version 6.1 was released. During this time, the module production phase, or the on-line data entry of Slope Wetland assessment data on cramwetlands.org, was completed by generous funding supplied by the Department of Water Resources (DWR) to support their use of the module. Version 6.1 was used for the fieldwork completed in this validation effort. Any changes coming out of this effort will be incorporated into a new version (Version 6.2) of the fieldbook. It is important to note that the existing data entry is based upon Version 6.1; data entry for Version 6.2 will require updates to the on-line data entry website.

METHODS
Validation of the Slope Wetland CRAM module was consistent with previous module validation efforts (Stein et al., 2009) and involved that following tasks:

- identify the gradient of stress,
- identify appropriate detailed Level 3 data to validate the CRAM scores,
- identify the metrics that will be calculated from the detailed Level 3 data,
- create conceptual models that describe the expected relationship between the detailed data and CRAM scores,
- identify field sites where the targeted Level 3 will be collected, or collect new data,
- and conduct CRAM assessments at those sites.

Identify the gradient of stress
One of the primary negative impacts to slope wetlands is dewatering. Although dewatering can occur naturally, such as through changes in climate over time, dewatering often occurs through anthropogenic actions, such as overgrazing, ditching, or draining of a wetland. When a Slope wetland is dewatered, it provides lesser wetland functions. For example, soil disturbance through overgrazing causes soil compaction, destabilization of slopes, and increased surface runoff, which allows stream channels to incise and become entrenched, thereby lowering the water table. Similar water table lowering effects can be obtained through ditching and draining, which is often a result of agricultural practices or development pressure. Groundwater pumping can also lower the water table. In each of these examples, the water table in the slope wetland is lowered, reducing moisture in the root zone, which affects the vigor and survival of hydrophytic plant species, reduces wildlife support functions, and reduces the wetland's ability to filter, store, and slowly release water downstream throughout the year. Dewatering slope wetlands can significantly reduce wetland functions, habitat, and water regulation functions. Because most dewatering is due to anthropogenic actions, it is identified as a wetland stressor, and was selected as the key gradient of stress for this validation effort. Sites were selected so that they represented a range along the hydrologic stress gradient, from intact functioning slope wetlands to severely dewatered slope wetlands.

Identify Level 3 data
The selection of appropriate Level 3 data was guided by two questions:

> "What data sources should be used as independent ecological condition variables for slope wetland validation?"
> "What are the tradeoffs for using existing data, versus collecting new data?"

Previous validation efforts have shown that costs typically influence the ability to conduct calibration or validation studies. Due to the costs of collecting new intensive Level 3 data, very few assessment methods are calibrated or validated (Sutula et al., 2006). Thus, identifying an appropriate Level 3 dataset that is available for use can ensure success of the validation.

The ideal validation dataset includes statewide data, covers the full range of condition gradient, has been collected during the same year as the corresponding CRAM assessments, is standardized, and indicates the health or ecologic condition of the wetland. The development team explored many different intensive measures of condition, relying upon the expertise and suggestions of the Slope

Wetland TAC. Unfortunately, a single dataset that met all of these conditions did not exist. However, a dataset that met many of the criteria was identified.

The US Forest Service (USFS) has an established network of vegetation monitoring plots in slope wetlands on National Forest lands across the state. Many of the plots were monitored in 2015, the year field assessments were conducted for this validation. In addition, the National Park Service (NPS) had similar plots in National Parks in the Sierra. These two datasets together provided Level 3 vegetation data that would be collected during the same year as the CRAM assessments and they covered a wide range of condition gradient, were standardized, and reflected the ecological condition of the wetland. The only drawback to the dataset was the geographic range - although sites existed across the state, all sites were on National Forest land (typically mountainous terrain) or in the Sierra. No sites existed along the coast or in the Central Valley.

Stein et al., 2009 contend that in an ideal situation, intensive data should be collected concurrently with the rapid assessment data. However, this is often cost-prohibitive, leaving validation efforts to solely rely upon existing data. In this case, the existing data was geographically limited. Fortunately this validation project included funding for collecting new Level 3 data at a subset of sites in order to expand the climatic and topographic gradient of the validation dataset. Using the detailed USFS/NPS vegetation data protocol, the development team collected new vegetation data that is comparable to the existing monitoring plots data. Thus, the validation uses data gathered at both the long-term monitoring sites and the subset of additional sites, greatly improving the validation due to a greater geographic range of field sites.

The USFS data was provided by Dave Weixelman, a Range Ecologist in Forest Service Region 5, and described in Weixelman and Zamudio (2001). The data collected at each long-term monitoring location was focused on addressing the ecological status of the wetland, and included plant frequency sampling and a number of soil characterization variables. At each location, a total of 60 10x10 cm quadrats were established nested within a 30x20 m macroplot, with data on rooted frequency of occurrence by species, percent bare soil, and rooting depth collected and reported by macroplot. Across the state, more than 850 monitoring locations have been established, however only a subset of those locations are monitored in any given year. The development team selected field site locations from the list of sites that were scheduled to be monitored in 2015, ensuring that the data would be collected the same year as the Slope Wetland CRAM assessments. At the end of the 2015 season, Dave Weixelman provided a spreadsheet with the summary data to the development team. The summary reports: Percent early-, mid-, and late-successional plant species; Percent bare soil; Species richness; Plant diversity index (Shannon Index and Shannon Evenness); and the Ratliff vegetation score.

The NPS data were provided by Jonathan Nesmith, an Ecologist with the National Park Service, Inventory and Monitoring Program. The vegetation data collected by NPS is described in Gage *et al.* (2014). The NPS data was collected using a nested plot design with a 10x10 m largest macroplot, with smaller plots nested within. Percent cover of species was visually estimated in microplots, and estimated using cover classes in the macroplots. Ground cover (including bare ground) was also estimated within each plot. Vegetation data was collected in 2015, with the exception of one site, Drosera Meadow (the data was last collected in 2009). Drosera Meadow is very remote and in good condition, thus the development team did not expect any significant changes to have occurred between 2009 and 2015. At the end of the season, Jonathan Nesmith provided a spreadsheet with the summary data to the development team.

For the sites located outside of the USFS or NPS monitoring programs, the development team collected data following the NPS protocols. Then, for both the NPS and the new self-collected data, the team calculated the same vegetation summary data as was reported in the USFS data.

There was some concern about selecting detailed vegetation data as the validation dataset due to potential auto-correlation between CRAM scores and the vegetation data, since one-quarter of the CRAM Index score is based upon vegetation. However, many other RAMs have conducted validation using floristic data. For instance, the Ohio Rapid Assessment Method (Mack, 2001), a RAM developed for the Juniata Watershed in PA (Wardrop et al., 2007), and many Hydrogeomorphic Approaches (HGMs) (Stein et al., 2009) have all successfully utilized vegetation data for validation.

Identify detailed Level 3 data metrics

The development team identified specific Level 3 vegetation metrics for correlation analyses with CRAM scores based on consultation with the vegetation data authors (Dave Weixelman, USFS and Jonathan Nesmith, NPS). The metrics include:

- Percent Native Cover
- Percent Non-Native Cover
- Percent Early-, Mid-, and Late-successional Plants
- Percent Bare Ground
- Native Species Richness and Non-native Species Richness
- Shannon Plant Diversity Index and Evenness
- Ratliff Vegetation Score and Percent Decreasers

Percent Native and Non-Native Cover were calculated as the cover class sum for all identified native (or non-native) species divided by the total cover class sum, and converted into a percentage. Percent Early-, Mid-, and Late- Succession was calculated by first assigning a successional stage to each identified plant species. Next, the sum of cover for all identified species in that successional stage was divided by the total cover, and converted into a percentage. Percent Bare Ground was calculated as the midpoint percentage of the cover class identified as bare ground in the macro (10 x 10 m) plot. Native and Non-Native Species Richness was calculated as simply the numeric sum of all native plant species, or separately, all non-native plant species identified within the vegetation plot. The Shannon Plant Diversity Index calculation began by taking the cover class midpoint for each identified species, and dividing by the total cover to calculate pi. Next, the natural log (ln) of pi was calculated, then pi and ln(pi) were multiplied. The sum of the products was calculated, and the absolute value of the sum was reported as the Index. The Shannon Evenness was calculated by dividing the Shannon Index by the natural log of the species richness for the site. The Ratliff Vegetation Score was calculated by first assigning a Ratliff status (Increaser, Decreaser, Invader) for each identified species, then dividing the total number of Increasers and Decreasers by the total number of species, and converting to a percentage, following methods developed by Ratliff (1985). The Percent Decreasers metric included only the total number of Decreasers divided by the total number of species multiplied by 100 to represent the percentage.

Create Conceptual Models

The development team created conceptual models before the CRAM assessments were conducted to predict the expected relationships between the CRAM scores and each of the calculated vegetation metrics. The paragraphs below describe the conceptual model for each vegetation metric described above.

Percent Native Cover and Percent Non-Native Cover: These vegetation metrics represent the proportions of vegetative cover within the vegetation macroplot composed of either native vegetation or non-native vegetation. Sites with higher proportions of native vegetation cover are assumed to represent more intact plant communities within the wetland and less disturbance or stress. Therefore, it is expected that sites with a high percent of native vegetation cover will also have higher CRAM scores (a positive relationship, Figure 1a). Sites that have a high percent of non-native vegetation cover are assumed to represent less intact wetland conditions with more disturbance and stress and are expected to have lower CRAM scores (a negative relationship, Figure 1b).

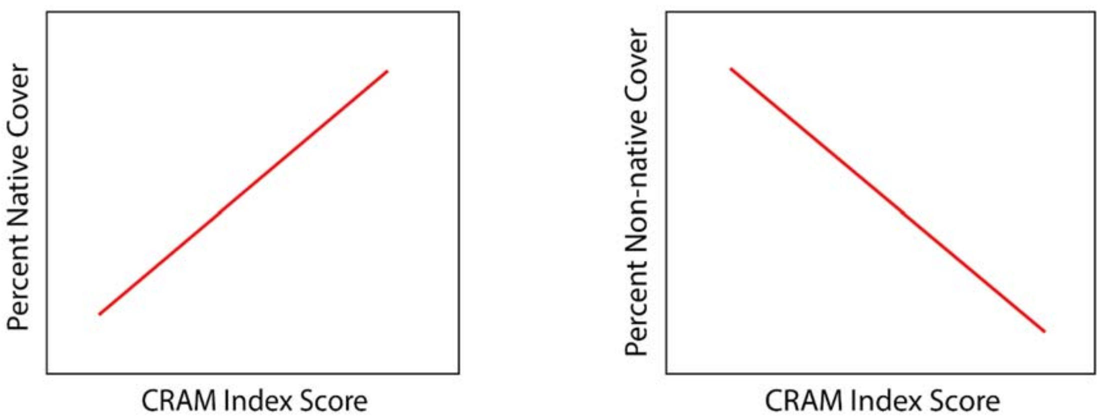

Figure 1. a) A positive relationship is expected between CRAM Index score and Percent Native Cover. b) A negative relationship is expected between CRAM Index score and Percent Non-Native Cover.

Percentage of Early-successional, Mid-successional and Late-successional Plants: Plant succession describes species of plants that come into a wetland after a disturbance. Early-successional plants are the first to arrive, immediately following the disturbance, followed by Mid-successional plants, and finally, Late-successional plants that arrive much later and represent a well-established and stable wetland. We expect Slope wetland sites with a high percentage of Early-successional plants to be disturbed. They would also exhibit other signs of disturbance and would therefore have low CRAM condition scores which would result in a negative relationship between Early-successional plants and CRAM Index scores (Figure 2a). Sites with a high percentage of Mid-succession plants would not have a strong correlation with CRAM scores because those wetlands are in transition and we expect them to recover at different and irregular rates. Additionally, transitioning wetlands are likely to exhibit aspects of poor condition, due to the original disturbance, and high condition as the wetland recovers. Therefore, we expect no relationship between Mid-successional plant species and CRAM Index scores (Figure 2b). And finally, sites with a high percentage of Late-successional plants represent more stable, intact, and higher functioning wetlands, and therefore we expect them to have high CRAM scores - a positive relationship with CRAM Index scores (Figure 2c).

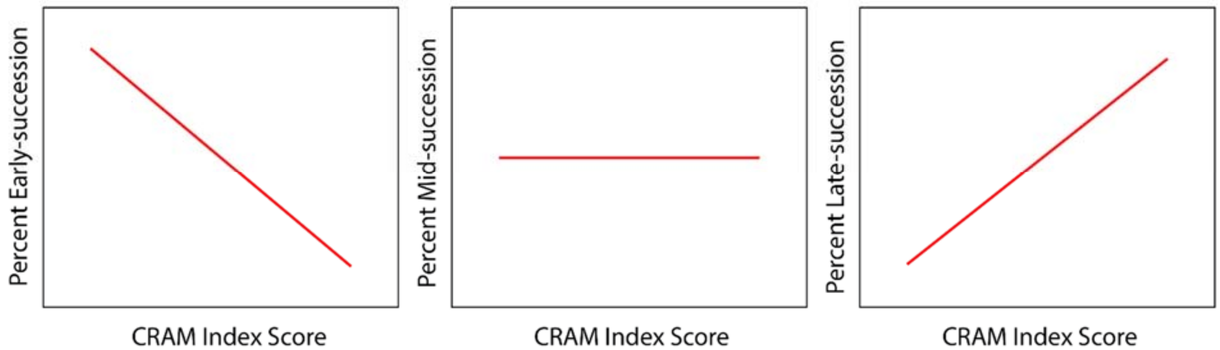

Figure 2. a) A negative relationship with CRAM Index scores is expected for Percent Early-successional plants. b) No relationship with CRAM Index scores is expected for Percent Mid-successional plants. c) A positive relationship with CRAM Index scores is expected for Percent Late-successional plants.

Percent Bare Ground: Slope wetlands, and in particular wet meadows, are subject to disturbance from voles and gophers, which leave mounds of bare soil from the tunnels they dig. In addition, sediment splays on the meadow surface from channel flooding, intense grazing, or loss of plants from dewatering of the meadow can also cause patches of bare ground. In all of these instances, bare ground is an indicator of reduced ecological condition in the meadow. Sites with higher percentages of bare ground are expected to have lower CRAM scores (Figure 3).

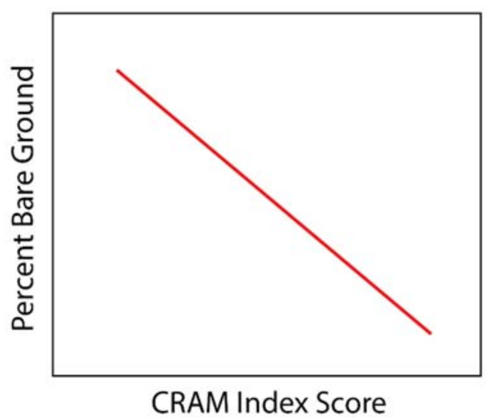

Figure 3. A negative relationship is expected between CRAM Index scores and Percent Bare Ground.

Native Species Richness and Non-native Species Richness: Relationships between species richness and CRAM Index scores can be complicated due to successional effects and the trajectory of species diversity. We expect no relationship between Species Richness and Index score because of this complexity. However, grouping species by their native or non-native status might improve the correlations because recently disturbed wetlands typically have a high number of non-native species, while undisturbed wetlands have relatively few. Considering species richness by native or non-native status should improve the relationships by removing the variability in the transition between disturbed and undisturbed states.

The relationship between Native Species Richness and CRAM Index score is expected to be positive, reflecting a high number of native species in the undisturbed and good condition sites (Figure 4a). A negative relationship is expected between Non-native Species Richness and CRAM Index score, reflecting the high number of non-native species in the recently disturbed and poorer condition sites (Figure 4b).

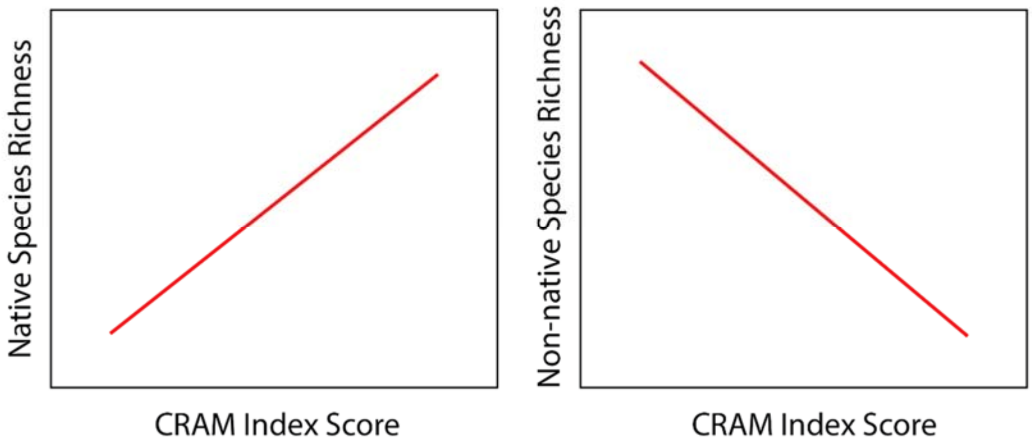

Figure 4. a) A positive relationship between CRAM Index scores and Native Species Richness is expected. b) A negative relationship between CRAM Index scores and Non-native Species Richness is expected.

Shannon Plant Diversity Index and Evenness: The Shannon Diversity Index looks at both the diversity of species and the distribution among those species. The highest scores result from samples with high diversity and an even spread among the samples. In the case of plant community this means that sites with both higher numbers of species and a more even distribution of plant cover will get higher Shannon Index scores. The expected relationship with CRAM is somewhat confounded (similarly with the species richness metric), as they both are based on the absolute number of unique species found at a site. We might expect sites with a low Shannon Index value to have low CRAM scores, and sites with intermediate Shannon Index values to have higher CRAM scores. However, there is likely a peak in condition at some intermediate level, where sites with the highest Shannon Index values would actually have lower CRAM scores. Due to this complexity, we expect no relationship between CRAM Index scores and the Shannon Diversity Index (Figure 5a) or Shannon Evenness (Figure 5b).

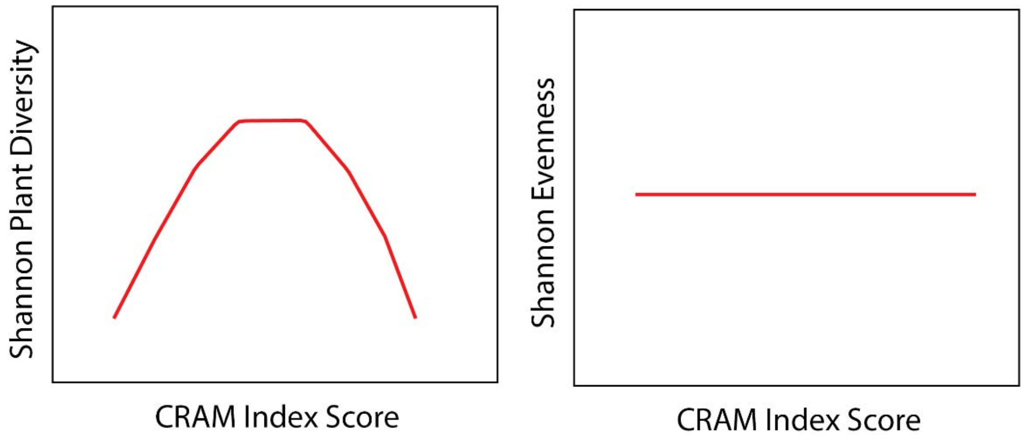

Figure 5. a) A relationship between CRAM Index scores and Shannon Plant Diversity is not expected. b) A relationship between CRAM Index scores and Shannon Evenness is not expected.

Ratliff Vegetation Score and Percent Decreasers: The work by Ratliff (1985) focused upon assessing the condition and management of a number of Sierra Nevadan wet meadows. He argues that species composition and ecological position indicate vegetative condition. To assess vegetative condition, Ratliff focused on the idea of a climax community, and used the species composition method to look at the percentages of Decreaser, Increaser and Invader species, to determine condition. Decreasers are plants that would decrease in cover in the face of overgrazing, and are generally more sensitive species. Increasers are hardy plants that may expand and increase under a regime of overgrazing. Invaders are the species that were not present before a disturbance (i.e. overgrazing) and subsequently colonized and invaded the area. Following his proposed generalized vegetative condition standards for meadow sites, the Ratliff Vegetation Score was calculated as the percentage of Decreaser and Increaser species as compared to the total number of species. In this index, sites with a greater percentage of Decreaser and Increaser species will have a higher score, and reflect a better condition wetland. Thus, we expect a positive relationship between CRAM Index scores and Ratliff scores (Figure 6a). Additionally, we wanted to look at any potential relationships with only the Decreaser species, since they are more sensitive. We would also expect a positive relationship between CRAM Index scores and Percent Decreasers (Figure 6b). We acknowledge that Ratliff's use of the climax community concept is dated, but the concept of vegetation community response to disturbance is still valid. And Ratliff's work focused on wetlands across a gradient of stress, in this case overgrazing which likely caused dewatering, and captured a vegetation response across that stress gradient.

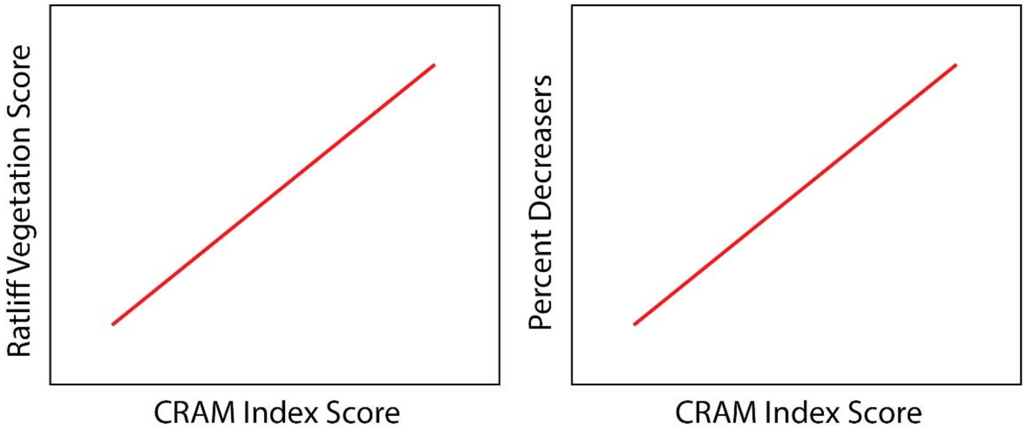

Figure 6. a) A positive relationship between CRAM Index scores and Ratliff Vegetation scores is expected. b) A positive relationship between CRAM Index scores and Percent Decreasers is also expected.

Select Field Site Locations

Thirty field sites were targeted in the Slope Wetland validation project. To select the site locations, the development team began by inspecting the list of the 2015 USFS and NPS vegetation monitoring plot sites. The sites were mapped so that the geographic distribution could be evaluated in order to select sites that were distributed across the state, were fairly easy to access (within a mile from an access road), included as many types of slope wetlands as possible, and that could be grouped into reasonable field trips. With these site selection criteria in mind, a number of candidate sites were inspected on GoogleEarth and selected. For the USFS monitoring sites, there was no data to indicate the ecological condition of the 2015 sites so aerial imagery and best professional judgment was used to select sites across the gradient of dewatering. The NPS monitoring sites did have data on the ecological condition, allowing the team to select some of these sites to increase the spatial distribution and ensure that some very high condition sites were included in the validation.

The USFS and NPS sites represented locations where detailed vegetation data would be collected in 2015 through the existing monitoring programs and would be available for the validation. To include more Slope wetland sub-types (including forested slopes and seeps/springs) the development team identified 19 additional sites that would provide more geographic coverage and fill-in the distribution of slope wetland sub-types for the validation dataset. New sites were selected based upon previous knowledge of particular slope wetlands, the ability to gain permission to access the sites, and consideration of topographic and climatic gradients across the state. Level 3 vegetation data were collected at these sites by the development team who employed the NPS sampling protocol.

American Rivers Data

The American Rivers (AR) Mountain Meadow Scorecard has been in use in the Sierra by various environmental monitoring groups since 2011 (and possibly earlier). Similar to CRAM, the AR Scorecard characterizes the ecological condition of Sierran meadows based on multiple field observations (although less holistically than CRAM), which include bank height, channel stability, gullying, vegetation cover and composition, amount of bare ground, and conifer/upland shrub encroachment. The Slope

Wetland TAC recommended that the development team collect concurrent AR Scorecard data at all CRAM assessment sites for comparison. The TAC was interested in learning how well the two methods correlate and if it was possible to extrapolate CRAM scores from AR Scorecard results. It was expected that there would be a positive relationship between the AR Scorecard results and CRAM Index scores, although it was likely to be variable since the AR method focuses on different aspects of ecological condition than CRAM.

Field Assessments

A total of 40 Slope wetlands were assessed using the CRAM Slope Wetland module (version 6.1) between May and October of 2015, including all five Slope wetland sub-types (Figure 7). The sub-types included 15 Channeled, 16 Non-Channeled, 5 Forested (Channeled Forested Slope and Non-channeled Forested Slope), and 4 Seep/Spring wetlands. Assessment Areas (AAs) ranged in size from .007 ha (each of the four seep/springs sites assessed were <0.1 ha) to 3.7 ha.

The sites were located in 17 different counties across the state, and were situated on both public and private land. All the assessments were completed by Sarah Pearce (SFEI) and Cara Clark (MLML), who are lead CRAM trainers, and members of the Level 2 Committee of the California Wetland Monitoring Workgroup (CWMW) of the California Water Quality Monitoring Council. April Robinson (SFEI, and also a CRAM trainer) accompanied the team at several sites. USFS, NPS, and self-collected Level 3 vegetation data was paired with each CRAM assessment: 17 sites used USFS data, 4 sites used NPS data, and 19 sites used self-collected data that employed the NPS protocols. All but two of the 40 CRAM assessments are available through EcoAtlas (www.Ecoatlas.org); two remain private due to landowner privacy concerns.

Despite efforts to target sites across a wide range of dewatering stress gradient, the overall population of CRAM assessments represent slope wetlands in fair to good condition. 35 of the 40 assessment sites were located on public lands, which typically have better condition, as opposed to private lands which may be more intensively used and modified. It is generally difficult to identify and gain access to slope wetlands on private property, as compared to public lands. This bias towards fair and good condition within the validation dataset should be kept in mind when interpreting the validation results presented below. Although not many poor sites were assessed in this project, highly degraded and poor condition slope wetlands exist within the state.

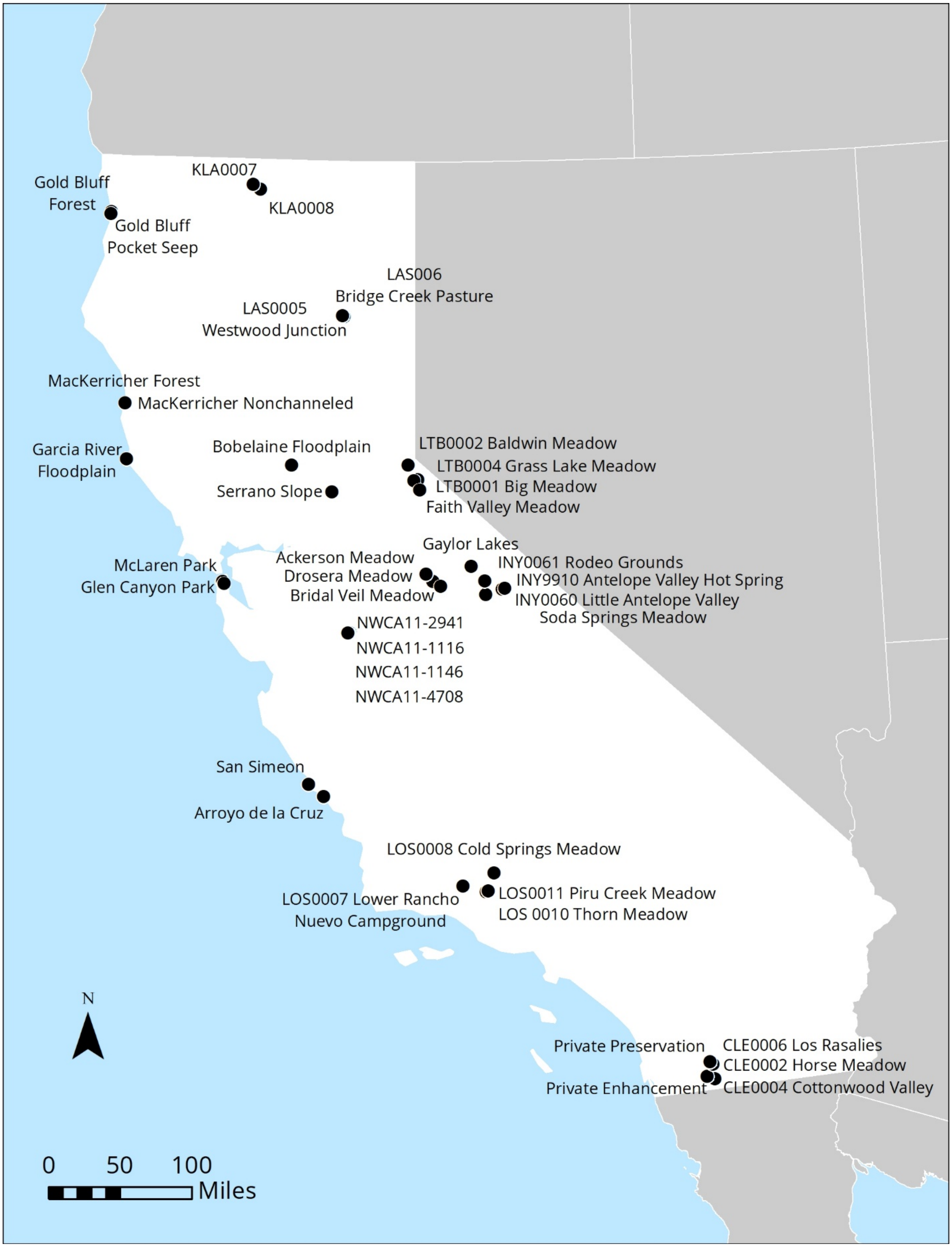

Figure 7. Map illustrating the location of the 40 Slope wetland validation sites.

RESULTS

The purpose of the CRAM Slope wetland module validation was to answer the question: "Does the Slope Wetland module correlate to more intensive measures of condition based upon independent vegetation data, and thus provide a meaningful, repeatable, and accurate measure of wetland condition?" (Sutula et al., 2006; Stein et al., 2009).

Results from the validation effort initially focused on making modifications to the module to improve its ability to differentiate between poor, fair and good ecological conditions in slope wetlands across the state. Then, using the updated module, the development team explored correlations between the detailed Level 3 vegetation data and CRAM scores. Finally, the development team reported the findings to the Level 2 Committee of the California Wetland Monitoring Workgroup for review and feedback. Updates and additional analyses were performed based on that review and are presented here.

Updates to Version 6.1 Slope Wetland module

The development team carefully studied the data from the 40 validation field sites, along with notes and comments from previous slope assessments and experience from other expert CRAM practitioners, to evaluate the performance of the Slope Wetland module (Version 6.1). This effort focused upon improving the distribution of scores, so that the full range of condition that exists was adequately reflected in the scoring, and updating/modifying any metrics that were not working properly. Changes are described below and include modifying the scoring bins in instances where the binning did not allow for the full range of scores, or when it produced a non-normally distributed set of scores. For other metrics, the wording was modified to more accurately capture the intent of the metric. And finally, one metric was dropped, with the concept moved into a different metric, because the development team believed that the metric did not belong in that Attribute. The resulting updated Slope Wetland module is Version 6.2 and will be released when approved by the Level 2 Committee.

In Version 6.1, the Slope Wetland sub-types included Channeled Wet Meadow, Non-Channeled Wet Meadow, Forested Slope, and Seeps/Springs. However, Forested Slope wetlands can exist both with and without a channel. Because those Forested Slope wetlands with a channel are strongly controlled by a hydrologic regime that is linked to the channel, the development team thought that the Forested Slope sub-type should be split into Channeled Forested Slope and Non-Channeled Forested Slope Wetland sub-types. With this change, Channeled Forested Slope Wetlands would score Hydrologic Connectivity similarly to Channeled Wet Meadows, that is, including the Bank Height Ratio sub-metric. The Topographic Complexity metric and the Horizontal Interspersion and Zonation metric would be scored using the Channeled cartoons. This change prompted the addition of a figure into the fieldbook to help practitioners define and select the appropriate sub-type for the wetland that they are assessing. This change will also require updating the eCRAM data entry portal.

In the Hydroperiod metric, the wording was clarified, helping practitioners to understand instances where "more water" and "less water" is being added/removed from the wetland. However, no changes to the scoring were made.

In the Hydrologic Connectivity metric, the Bank Height Ratio sub-metric binning created a distribution of scores that did not include any As. Because the binning numbers were created for a bank erosion index, the development team decided to use the actual ratios collected during 2015 to help create new bins for scoring. This created a full distribution of scores, and more accurately accounts for the hydrologic effects caused by different channel bank heights within a wetland. In addition, the Percent Dewatered sub-metric was also modified, so that the practitioner will determine if the wetland has "Intact Hydrologic

Connectivity" or "Degraded Hydrologic Connectivity" using a worksheet. The worksheet includes common indicators of dewatering, including the presence of encroaching upland species. After completing the worksheet, the practitioner determines the percentage of the wetland that is experiencing dewatering.

In the Structural Patch Richness metric, the development team decided to separate the patch type "Abundant wrack, organic debris, or thatch" into two separate patch types, "Abundant wrack or organic debris" and "Thatch". Especially in Slope Wetlands, the structure created by thatch plays a large role in habitat value and movement of surface water through the wetland. These benefits are different than those provided by wrack or organic debris, which are loose, and can be floated within the wetland. Testing showed that this change did not create an unfair bias, nor significantly change the distribution of scores. The patch type was added, however the binning remained unchanged. In addition, the development team removed the patch type "Concentric or parallel high water marks", as this is a patch type more applicable to depressional wetlands.

In Version 6.1, the Topographic Complexity metric combined the assessment of physical complexity (the ground surface) and the vegetation roughness (on the ground surface) into a single score. This resulted in a "low bar" for scoring based upon the wording, as the wetland only needed to have complexity in either the physical or the vegetative roughness to score well. Instead, the development team has separated the scoring of these two components; the metric will be scored using the average of the two components. A new rating table has been added to allow practitioners to appropriately score this metric.

For the Number of Co-dominant Species sub-metric within the Plant Community Composition metric, the scoring bins for Non-Channeled Wet Meadows was adjusted. The data revealed a good distribution of the actual number of co-dominant species, however with the existing bins, it did not translate into a good distribution of scores. New binning was created, which sets more realistic expectations for the number of co-dominant species expected in this wetland sub-type. In addition, the scoring bins for Channeled Wet Meadows, Forested Slopes, and Seeps/Springs was also adjusted because it had unrealistic expectations for the number of species, and thus was adjusted slightly down.

The Encroachment Groups sub-metric within the Plant Community Composition metric was heavily discussed amongst the Level 2 Committee, and ultimately it was removed. The concept of "upland" species, or those species more adapted to drier conditions, is familiar to those working in Sierra Wet Meadows. As those meadows dry, species such as Lodgepole Pine (*Pinus contorta*) or sagebrush (*Artemisia tridentata*) encroach upon the meadow, as they take root and become established. However these species can become established due to other factors, such as fire suppression or natural conversion from meadow to upland due to sediment supply to the wetland surface. In other areas of the state, wetlands simply do not have these same iconic species that encroach into the wetland. Plants, regardless of their wetland rating (e.g. FAC, FACU) will grow wherever they can become established, and are not necessarily limited to growing inside or outside of a wetland. In addition, this was a new sub-metric added only for the Slope Wetland module, and does not exist in other modules. For these reasons, the sub-metric was removed. However, the concept of encroaching species was carried over into the Hydrologic Connectivity metric, where the development team felt that it was more appropriate. In the assessment of drying of the wetland, the practitioner is asked about the presence of various types of encroachment groups, as one of many indicators that the wetland may be drying.

The Life Forms metric originally had eight life forms that were captured and scored, however based upon the statewide fieldwork, the development team added three additional forms. By adding Evergreen Broadleaf trees, ferns, and vines, the metric becomes more inclusive of life forms that are observed in Slope wetlands across the state, especially along the coast and in the Central Valley. But adding these forms required updating the scoring bins, to maintain an even distribution of scores.

Patterns within CRAM Index and Attribute Scores of the validation dataset

The CRAM Slope Wetland validation dataset was updated to Version 6.2 and the Index and Attribute scores were inspected to see if the full range of scores had been generated, and if those scores were normally distributed, as opposed to skewed high or low. Figure 8 displays histograms showing the frequency of occurrence of the CRAM Index score and the four Attribute scores for the validation dataset (n=40). Visually the Index and Attribute scores all appear to be normally distributed, and are not strongly skewed high or low. The one exception is the Hydrology Attribute, where the scores are all 75 or higher; this is likely due to the overall fair to good population of sites included in this analysis. For instance, no sites that would have scored a C or D for Hydroperiod were visited, and no non-channeled sites were visited that would have scored a C or D for Hydrologic Connectivity. However, in previous verification efforts or project assessments, sites have received these lower scores, indicating that wetlands with degraded condition do exist.

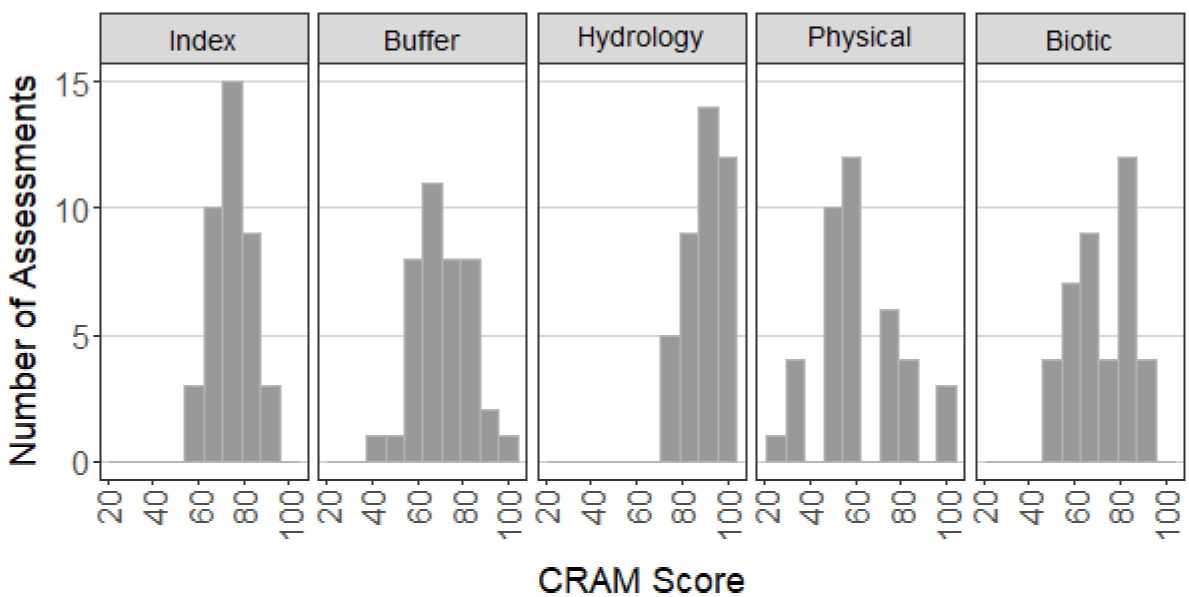

Figure 8. Histograms showing the distribution of data within a) the Index score, b) the Landscape and Buffer Attribute score, c) the Hydrology Attribute score, d) the Physical Structure Attribute score, and e) the Biotic Structure Attribute score.

Index Score

The CRAM Index score represents the overall ecological condition of the assessed wetland, and is an average of the four component Attribute scores. The Index score can range from very poor to excellent condition (25-100), should capture the full range of conditions that exist in nature, and should be normally distributed. For the 40 validation sites, CRAM Index scores ranged from 56 to 91, with a median score of 73 (Figure 9). Ideally the dataset would include scores lower than 50, but again, that is a function of the sites that were selected for validation.

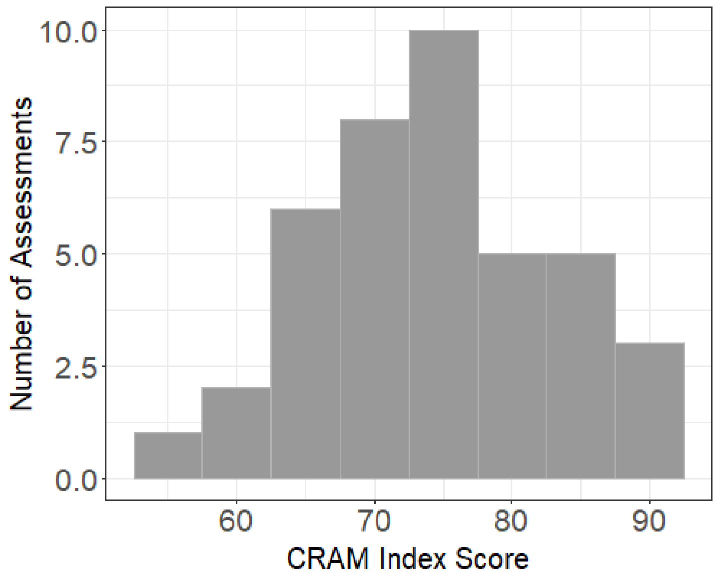

Figure 9. Histogram of CRAM Index scores with 8 bins (n=40).

Correlations between CRAM scores and the Level 3 detailed vegetation metrics

Correlation results between CRAM scores and the detailed vegetation data are presented below along with a comparison of the results to the conceptual models. Ideally the results will match the conceptual models. However, in instances where they do not match the conceptual models, the results should be closely inspected to decide if a modification to the metric is warranted, or if we simply need to better understand the processes occurring in the wetland, making adjustments in the expected relationships.

Rapid assessment methods (RAMs) should be *responsive*, that is, the method should appropriately reflect the distribution of ecological conditions that exist in nature (Stein et al., 2009). Responsiveness was evaluated using a Spearman's rank correlation analysis (Spearman's ρ or 'rho') to evaluate the relationships between CRAM scores and the detailed vegetation data. RAMs that are able to differentiate between a range of wetland conditions should also correlate with the conditions indicated by detailed vegetation data. Significant Spearman's ρ values that are close to 1 (either positive for positive relationships or negative for negative relationships) indicate a strong correlation. Spearman's ρ values that are close to 0 (either positive for positive relationships or negative for negative relationships) indicate a weak or no correlation. In biology, a significance level (P-value or 'probability-value') of 0.05 or less is often used to identify significant statistical tests. In this case as P-value <0.05 means that the risk of concluding that a correlation exists when it actually does not is 5% or less. In this validation study, Spearmans rank correlation analyses between CRAM scores and Level 3 vegetation metrics were conducted to evaluate if the Slope Wetland module is correlated with independently collected vegetation metrics. If the CRAM Slope wetland module is validated, it serves as another relatively fast and inexpensive, standardized ecological monitoring and tracking tool for assessing the overall ecological condition of wetlands in California.

Percent Native Cover and Percent Non-Native Cover
The Index score has a good correlation with Percent Native Cover (Spearman's ρ = 0.75, P = <0.001) and also with Percent Non-Native Cover (Spearman's ρ = -0.79, P = <0.001). This result follows the conceptual model, with Percent Native Cover having a positive relationship, and Percent Non-Native Cover having a negative relationship (Figure 10).

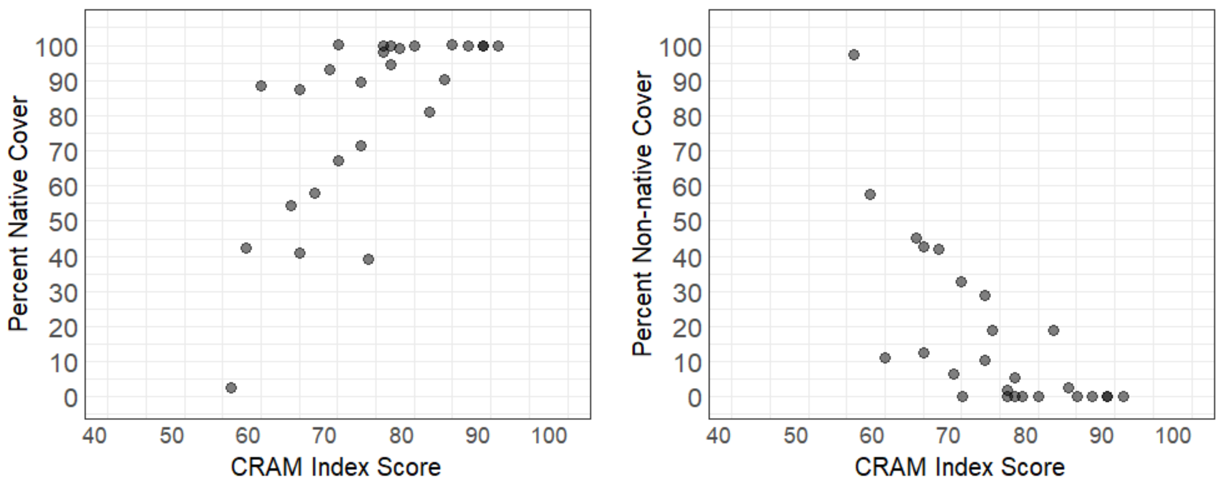

Figure 10. Correlation between CRAM Index score and a) Percent Native Cover, and b) Percent Non-Native Cover.

Percent Early-, Mid-, and Late-Successional Plants
The Index score has a good correlation with the Percentage of Early-Successional Plants and the Percentage of Late-Successional Plants, and matches the conceptual models (Figure 11). A negative correlation exists between Index score and Percentage Early-Successional Plants (Spearman's ρ = -0.59, P = <0.001). A positive correlation exists between Index score and Percentage Late-Successional Plants (Spearman's ρ = 0.53, P = <0.001). However, no correlation exists between Index score and Percentage Mid-Successional Plants (Spearman's ρ = -0.01, P = 0.949), as predicted by the conceptual model.

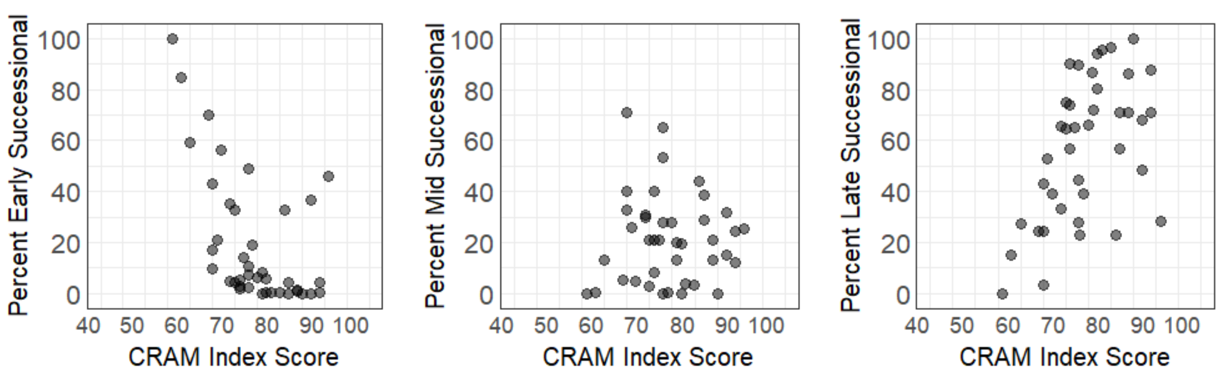

Figure 11. Correlation between CRAM Index score and a) Percent Early-Successional Plants, b) Percent Mid-Successional Plants, and c) Percent Late-Successional Plants.

Percent Bare Ground
The Index score has a moderate correlation with the Percent Bare Ground (Spearman's ρ = -0.44, P = 0.005) in agreement with the conceptual model (Figure 12). It appears that sites with poor CRAM Index

scores can have a wide range of bare ground, while sites with good Index scores typically only have low percentages of bare ground. The presence of bare ground in Slope Wetlands can be due to a variety of factors, ranging from the presence of burrowing animals, to the delivery of sediment from adjacent hillslopes, to dewatering of the meadow causing the loss of hydrophytic plants. Wetlands in poor condition may be in poor condition due to processes that create large areas of bare ground in the wetland, or due to other processes that do not. But wetlands in good condition appear to maintain high vegetation cover. This variability in the amount of bare ground present in poor condition wetlands likely creates the moderate correlation.

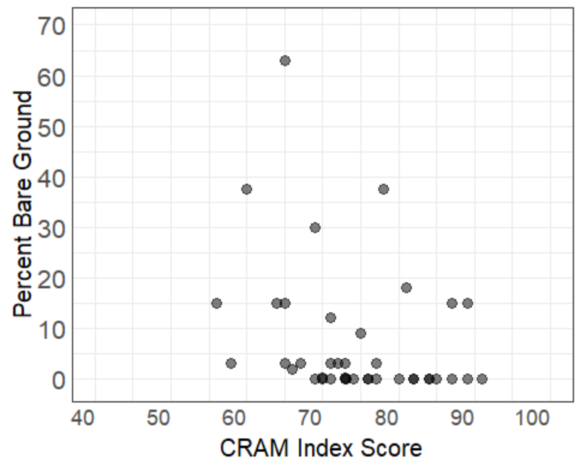

Figure 12. Correlation between CRAM Index score and Percent Bare Ground.

Species Richness

The CRAM Index score was not correlated with Native Species Richness (Spearman's $\rho = 0.33$, $P = 0.101$), however was correlated with Non-native Species Richness (Spearman's $\rho = -0.78$, $P = <0.001$) (Figure 13). We expected sites in good condition to have high Native Species richness, and sites in poor condition to have low Native Species richness. In general, the highest condition sites do have high Native Species richness, however sites across the broad range of fair condition have a wide variety of Native Species richness values. We believe that there was not a correlation because the CRAM Index score captures a number of variables that affect condition, including items like buffer and physical structure that may have little effect upon the number of native species present. In addition, natives can typically persist, even in wetlands that have experienced a disturbance and been colonized by a number of non-native species. For these reasons, we do not find a correlation with Native Species Richness. However, we do see a correlation with Non-native Species Richness; sites that are in poor condition typically have experienced a disturbance, which allows non-native species to become established. In contrast, the good condition sites typically have not been disturbed, and have a robust native plant community that is able to keep the non-native species from establishing. Thus, we see a significant correlation with Non-native Species Richness.

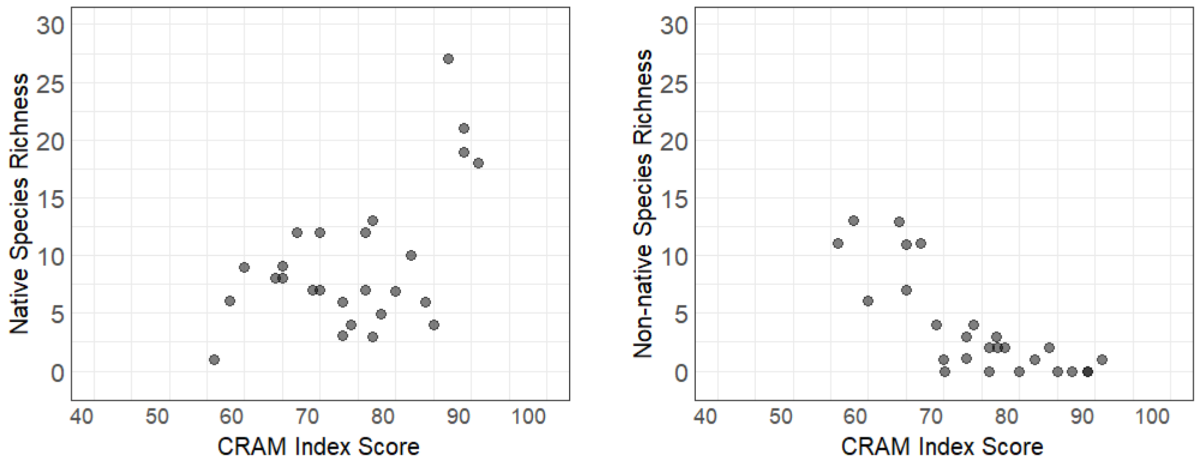

Figure 13. Correlation between CRAM Index score and Species Richness.

Shannon Plant Diversity Index and Evenness

The CRAM Index score was not well correlated with the Shannon Plant Diversity Index (Spearman's ρ = -0.06, P = 0.731). Nor was the Index score well correlated with Shannon Evenness (Spearman's ρ = 0.16, P = <0.316), as expected by the conceptual model (Figure 14). A strong correlation was not anticipated due to the structure of the Shannon Index and CRAM scoring. CRAM emphasizes diversity of dominant species, while the Shannon Index focuses on overall diversity, where the highest scores result from many species that are equally abundant. Shannon Evenness assigns high scores to sites with a lot of species that are all equally abundant, while CRAM scores wetlands based on the prevalence of particular dominant species.

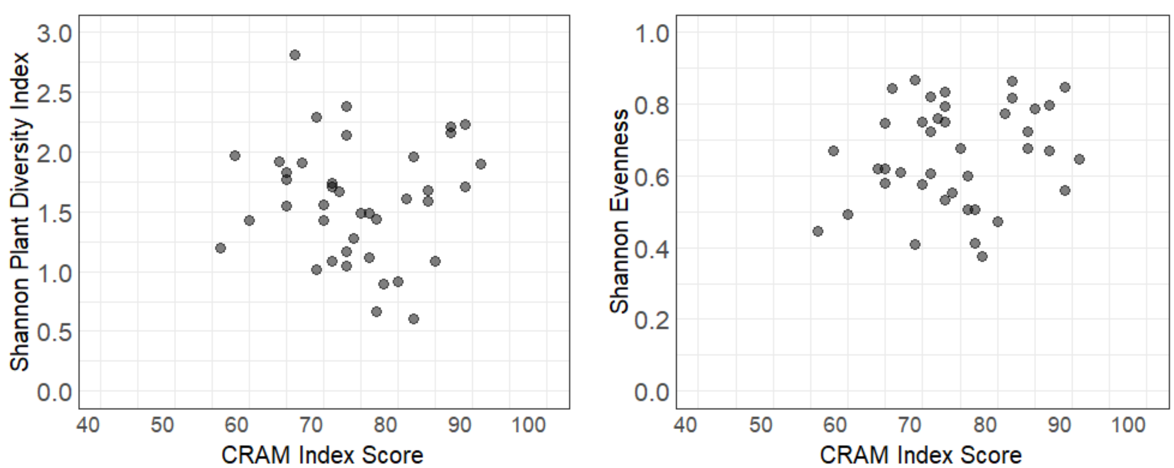

Figure 14. Correlation between CRAM Index score and a) Shannon Plant Diversity Index, and b) Shannon Evenness.

Ratliff Vegetation Score and Percent Decreasers

Despite the Shannon Index not correlating well, the Index score did correlate well with the Ratliff Vegetation Index (Spearman's ρ = 0.56, P = <0.001) (Figure 15). This is likely because sites with a lower Ratliff score have a greater proportion of Invader species, those that invade and colonize after a disturbance. Sites with lower Ratliff scores also have a lower proportion of Decreaser species, those that are sensitive to disturbance. For wetland sites that are disturbed, that disturbance would also be captured in many of the other CRAM metrics, leading to a lower CRAM Index score, and creating the expected correlation.

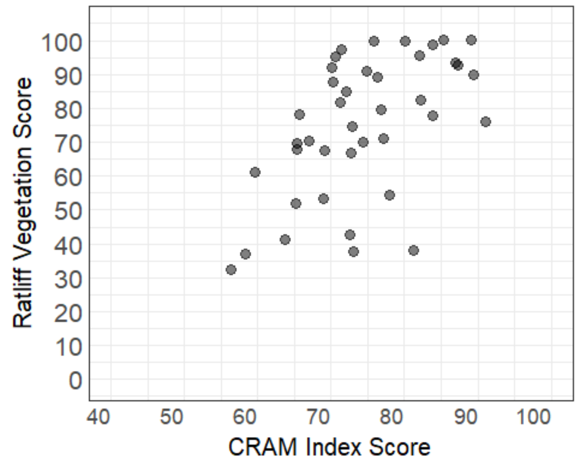

Figure 15. Correlation between CRAM Index score and the Ratliff Vegetation Score.

However, some of the disturbance signal is likely confounded by the complex relationships between plants that increase in cover or decrease in cover in response to a disturbance. Thus, in the Percent Decreasers metric we decided to focus only upon the sensitive species that would be lost due to a disturbance. The CRAM Index score correlated with the Percent Decreasers (Spearman's $\rho = 0.64$, $P = <0.001$), matching the expected relationship (Figure 16).

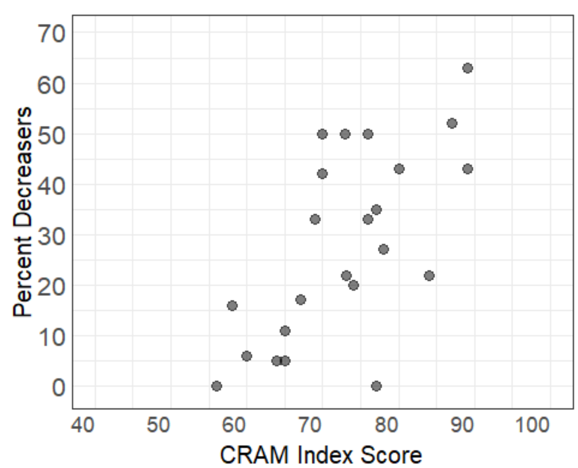

Figure 16. Correlation between CRAM Index score and the Percent Decreasers.

Biotic Attribute Score

Since CRAM Index scores are an average of four attributes of condition (Buffer and Landscape Context, Hydrology, Physical Structure, and Biotic Structure), it is important for the validation effort to explore correlations between the detailed vegetation data and only the Biotic Structure attribute. Because both measure condition based upon the vegetation community, we might expect stronger correlations than those calculated using the CRAM Index score. The same calculated vegetation metrics as evaluated against the Index score (above) are explored in this section. In addition, the conceptual models created for the Index score remain unchanged for the Biotic Structure Attribute, as we expect the same relationships to hold.

Percent Native Cover and Percent Non-Native Cover

The Biotic Attribute Score was well correlated with both the Percent Native cover (Spearman's ρ = 0.49, P = 0.011) and the Percent Non-Native cover (Spearman's ρ = -0.54, P = 0.004), similar to the correlations with the Index score (Figure 17). Both correlations are significant, however the ρ value is less than the correlations with the Index score.

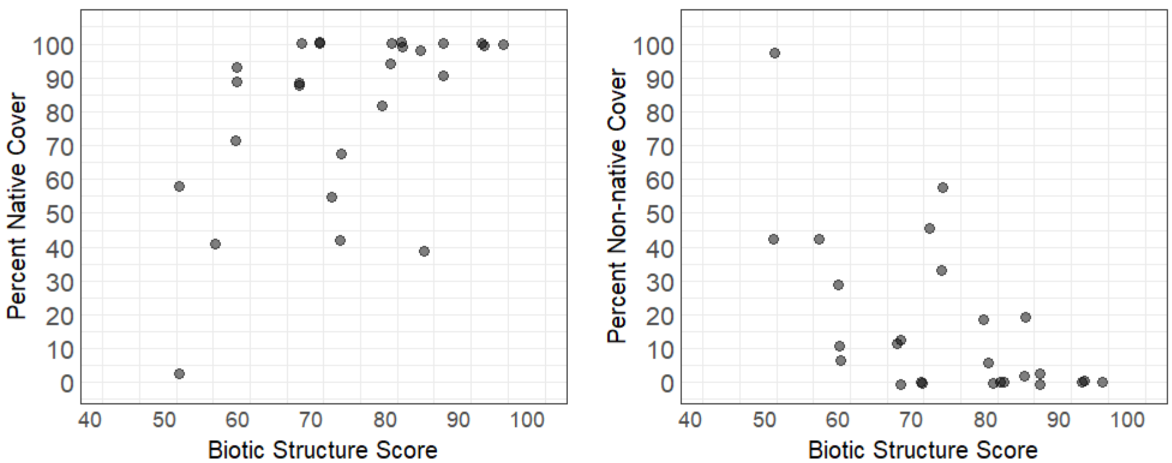

Figure 17. Correlation between CRAM Biotic Attribute Score and a) Percent Native Cover, and b) Percent Non-Native Cover.

Percent Early Succession and Late Succession

Similarly to the Index score correlation, the Biotic Attribute was also correlated with the Percent Early-Successional (Spearman's ρ = -0.48, P = 0.002) and the Percent Late-Successional (Spearman's ρ = 0.45, P = 0.003), but not with the Percent Mid-Successional (Spearman's ρ = -0.20, P = 0.205) (Figure 18).

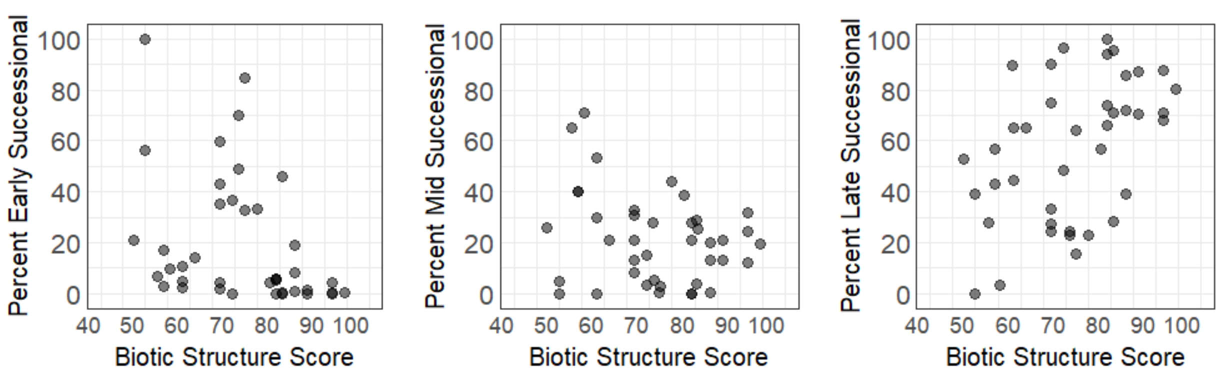

Figure 18. Correlation between the Biotic Attribute scores and a) Percent Early-Successional Plants, b) Percent Mid-Successional Plants, and c) Percent Late-Successional Plants.

Percent Bare Ground

The Biotic Attribute does not correlate with the Percent Bare Ground (Spearman's ρ = -0.24, P = 0.128), unlike the pattern observed with the Index score (Figure 19). This is likely because the Biotic Attribute score is based upon the plants that are present, regardless of the amount of bare ground that may or may not be present.

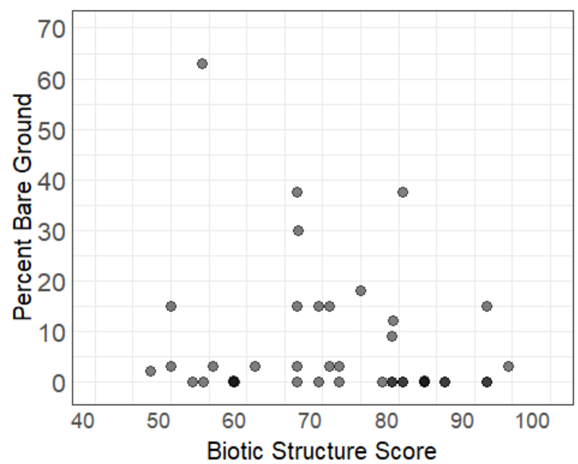

Figure 19. Correlation between the Biotic Attribute score and Percent Bare Ground.

Species Richness

For the same reasons as outlined in the correlation with the CRAM Index score, the Biotic Attribute does not correlate with Native Species Richness (Spearman's ρ = 0.24, P = 0.244), however does correlate with Non-native Species Richness (Spearman's ρ = -0.43, P = 0.030) (Figure 20).

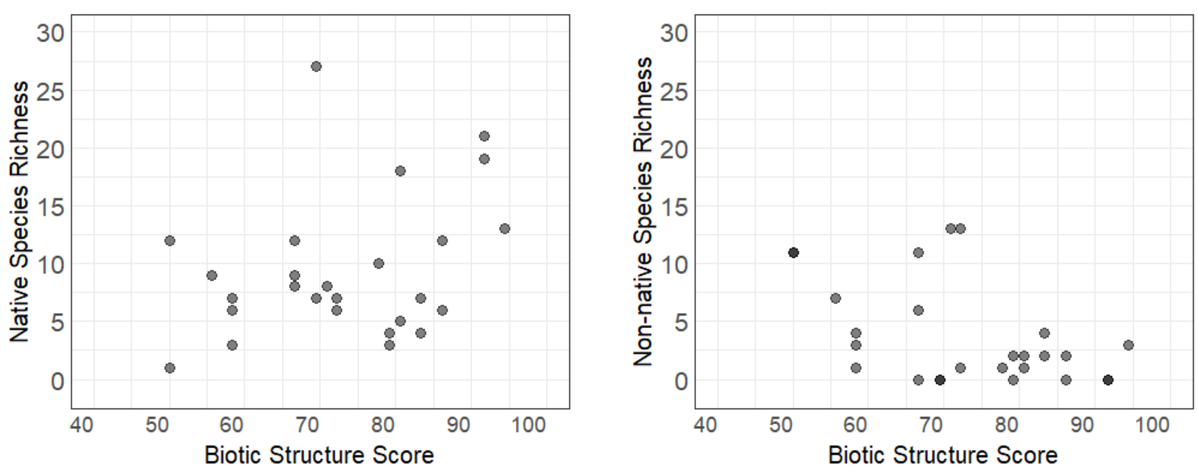

Figure 20. Correlation between the Biotic Attribute score and Species Richness.

Shannon Plant Diversity Index and Evenness

As with the Index score, the Biotic Attribute does not correlate with Shannon Plant Diversity (Spearman's ρ = -0.11, P = 0.515) or Shannon Evenness (Spearman's ρ = 0.00, P = 0.999) (Figure 21).

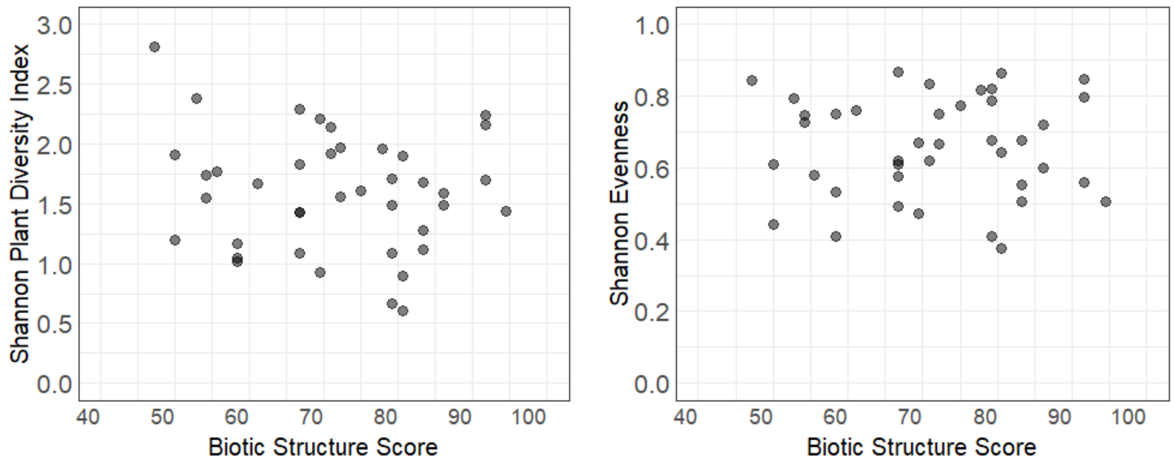

Figure 21. Correlation between the Biotic Attribute and a) Shannon Plant Diversity Index, and b) Shannon Evenness.

Ratliff Vegetation Score and Percent Decreasers

The Biotic Attribute does correlate with the Ratliff Vegetation Score (Spearman's $\rho = 0.44$, $P = 0.004$), however, unlike with the Index score correlation, it does not correlate with the Percent Decreasers (Spearman's $\rho = 0.39$, $P = 0.069$) (Figure 22).

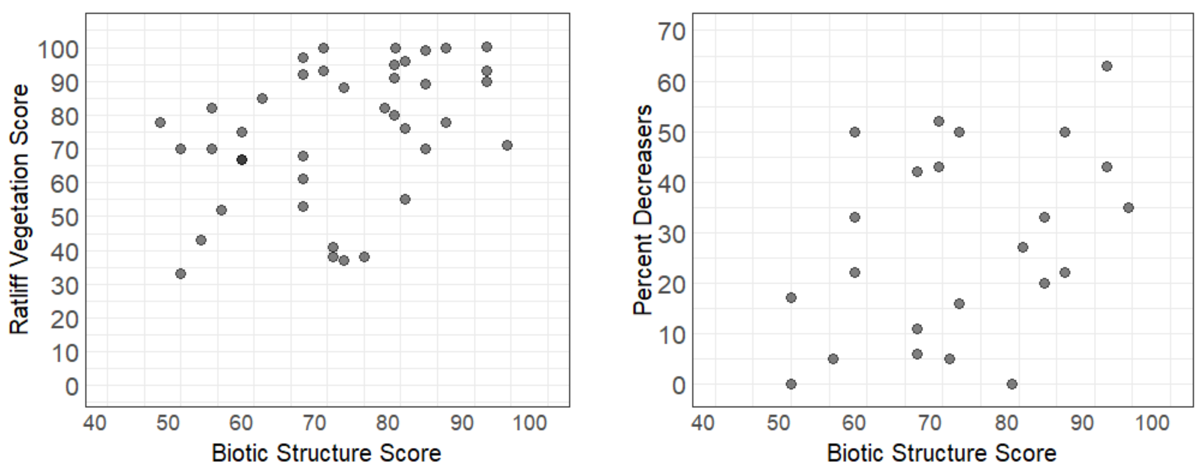

Figure 22. a) Correlation between the Biotic Attribute and the Ratliff Vegetation Score. b) Correlation between the Biotic Attribute and the Percent Decreasers.

Patterns within the Distribution of Scores

In addition to examining the correlations between CRAM scores and vegetation data, the range of scores for the Index and Attributes can be probed to identify any patterns/trends or biases (Figure 23). Inspecting the plots reveals that the Hydrology Attribute has the highest median score, while the Physical Attribute has the lowest median score, along with the lowest range of scores. During the site selection process, we utilized either our own knowledge of the site, or discussions with the land owner/manager to assign a rough best professional judgement (BPJ) estimate of site condition (high, medium-high, medium, medium-low, low) to ensure that a wide range of sites would likely be included. Inspecting the data now shows that very few sites with poor condition were included within the dataset, causing the scores to primarily indicate fair to good condition.

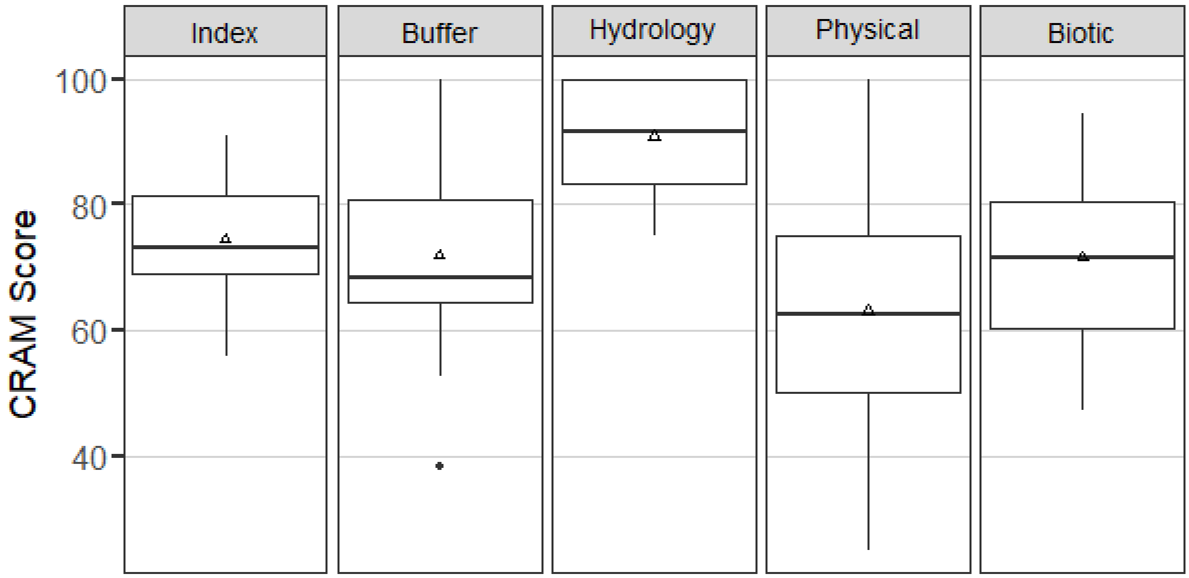

Figure 23. Box and whiskers plot showing the median score (line), mean score (triangle), 25th and 75th percentiles (the box), and one standard deviation (the whiskers) of the CRAM Slope wetland validation assessment results (n=40). Outliers are shown as individual dots.

Patterns within CRAM scores by wetland type

A comparison of Index and Attribute scores by wetland type can also reveal any potential biases within the method. Figure 24 illustrates that Channeled Meadows have the highest absolute value of Index scores (Index = 91), while Non-Channeled Meadows have the lowest value (Index = 56). Forested Slope wetlands have a very narrow range of scores (Index = 76 to 84), but have the highest median score (Index = 80). In addition, the distribution of scores for Forested Slope wetlands does not overlap with Seeps/Spring (Index = 58 to 74). Non-channeled wet meadows have the widest overall range of scores (Index = 56 to 89).

These patterns raise the question "Is there a bias in the method, or is the range of scores simply a function of the particular sites included in the study and the relatively small number of Forested (n = 5) and Seeps/Springs (n = 4)?" We believe that the range of scores is simply due to the relatively low number of sites included within the study, and the specific sites that were visited. In general, most of the sites were on publicly owned lands, managed by agencies responsible for maintaining their condition. In particular, each of the five Forested slope wetlands that were assessed were located on either publicly owned lands (USFS, State Parks) or lands specifically set aside and managed as preserved lands.

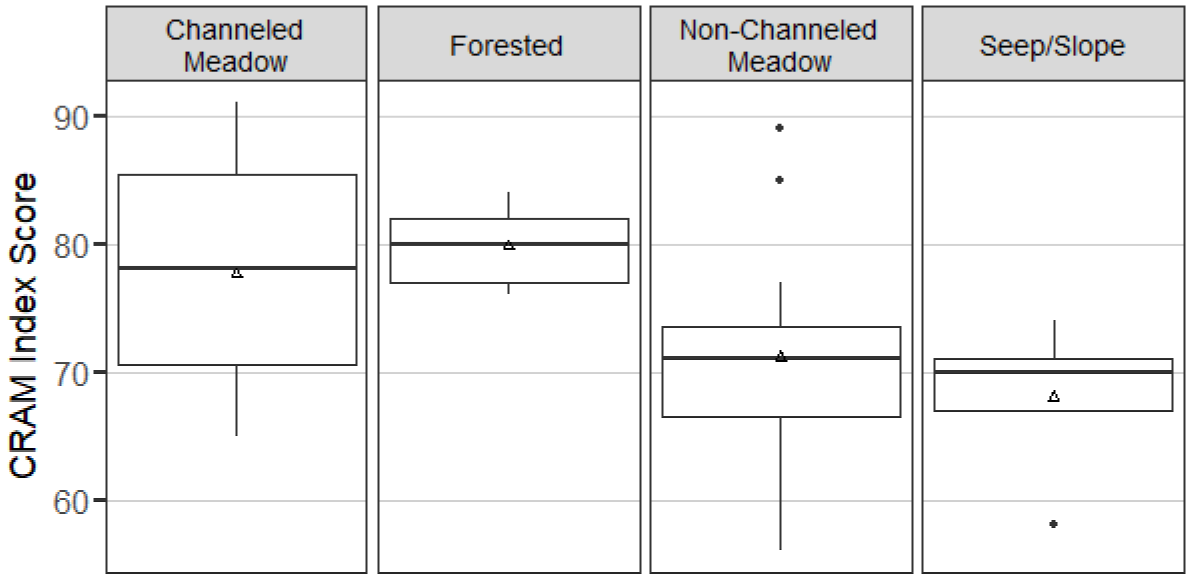

Figure 24. Range of Index scores by wetland subclass.

American Rivers Data Correlation

The American Rivers Scorecard data was collected to answer the question "Is there a correlation between CRAM scores and the AR Scorecard?". The CRAM Index score does correlate with the American Rivers Scorecard (Spearman's ρ = 0.36, P = 0.024) for the entire population of data (Figure 25). However, after conducting the Scorecard in all of the sub-types of Slope wetlands, the development team believed that the Scorecard is primarily intended for Channeled Wet Meadows, and is biased against the other Slope Wetland types that are included in the CRAM Slope Wetland module. For example, the Scorecard asks practitioners to assess bank height and channel stability. Thus, wetland types that do not have a channel automatically score higher, simply because they don't have a degrading/degraded channel. To address this, we have highlighted the Channeled Wet Meadow scores in blue, for comparison to the entire population. These data tend to plot lower on the Y-axis, as compared to other wetland sub-types. In looking only at these data, we see a positive correlation (Spearman's ρ = 0.68, P = 0.005), which we suggest represents the actual relationship between CRAM and the Scorecard.

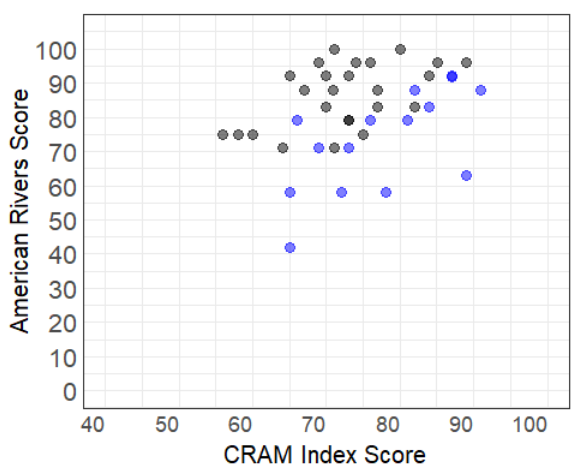

Figure 25. Correlation between CRAM Index score and the American Rivers Scorecard. The Channeled Wet Meadow data are shown in blue.

DISCUSSION

The development team's goal for this validation was to illustrate that the Slope Wetland module correlates to the more intensive measures of condition based upon the independent vegetation data. Exploring the correlations for both the CRAM Index score, as well as the Biotic Attribute score showed many significant correlations with the various calculated vegetation metrics. Most notably, the strongest correlations were with the CRAM Index score. The vegetation metrics with the strongest correlations were: Percent Native and Percent Non-native Cover, Percent Non-native Richness, Ratliff Vegetation Score and Percent Decreasers, and the Early-successional and Late successional plant species. These metrics are all responsive to disturbance of the wetland, which is also captured in many of the CRAM condition metrics. Based upon these results, the development team believes that the Slope Wetland module has been shown to be a meaningful, repeatable, and accurate measure of wetland condition.

Some of the vegetation metrics did not show correlations with the CRAM data. These included the Shannon Plant Diversity Index and Evenness, Percent Bare Ground, and Mid-successional plant species. The conceptual models for the Shannon Plant Diversity Index and Evenness and the Mid-successional plant species predicted that there would not be a correlation, and the results confirm that expectation. However, we did expect a negative correlation with Percent Bare Ground. After looking at each site that had a low CRAM score, the variety in percent of the wetland that has bare ground becomes evident. Because not every process that creates bare ground degrades the overall condition, no correlation is observed.

The validation of this module has benefitted from updates to the module made by the development team, stemming from analysis of the data collected during this effort. This set of 40 assessment sites represents the largest sample of statewide wetlands of various sub-types collected to date. Looking closely at the metrics revealed some instances where changes were necessary to better adapt the module for statewide use. Some metrics had binning that was carried over from previous versions of the module that were not producing a normal distribution of scores. Small modifications to the binning in some metrics improved this distribution, as well as elucidated the small differences in overall condition. And finally, removing the Encroachment Groups sub-metric within the Plant Community Composition metric, and inserting that concept into the assessment of dewatering of a wetland in the Hydrologic Connectivity metric has improved the module. This action again increases the scope of the module beyond just mountain meadows in the Sierra Nevada, and more adequately puts the concept in the correct Attribute.

Initial results of this validation effort were presented to the Level 2 Committee of the California Wetland Monitoring Workgroup in July, 2017. Extensive discussion of metrics, potential changes, and correlations significantly improved this analysis. The committee will again review the final validation results and updated Fieldbook (Version 6.2), and will approve them in October, 2017. The updated Fieldbook will be posted on the CRAM website (www.cramwetlands.org) for use starting Spring 2018. However the development team has not yet secured funding to update the online eCRAM database and data entry forms to Version 6.2.

CONCLUSIONS
Conducting validation of the Slope Wetland module was a very important step in the development pathway. The validation provides a chance to illustrate the relationship between the CRAM assessment and more intensive and independent measures of condition provided by detailed vegetation data.

The validation study has shown:

1) There is a significant correlation between both the CRAM Index score and the Biotic Attribute Score and the Percent Native Cover, as well as the Percent Non-native Cover.
2) There is a significant correlation between both the CRAM Index score and the Biotic Attribute Score and the Early Successional Plants and the Late Successional Plants.
3) There is a significant correlation between both the CRAM Index score and the Biotic Attribute Score and the Non-native Species Richness.
4) There is a significant correlation between both the CRAM Index score and the Biotic Attribute Score and the Ratliff Vegetation Index. However there is only a significant correlation between the CRAM Index score and the Percent Decreasers.
5) There is a moderate correlation between the CRAM Index score and the Percent Bare Ground.
6) There is a significant correlation between the CRAM Index score and the American Rivers Scorecard. A stronger correlation likely exists when only using the Channeled Wet Meadow assessments.

The Slope Wetland module *does* correlate to more intensive measures of condition, based upon independent vegetation data. The module *does* provide a meaningful, repeatable, and accurate measure of wetland condition that is applicable in Slope wetlands across the state. This module is an effective tool for rapidly assessing the overall condition of Slope wetlands, and should be incorporated into assessment and monitoring toolboxes as applicable.

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APPENDIX

Table 1. Location details for the 40 assessment sites.

Site Name	eCRAM ID	Wetland Subclass	Detailed Vegetation Data	Ownership	GPS Latitude	GPS Longitude	County
Arroyo de la Cruz	4112	Non-channeled meadow	Self collected	Public	35.712391	-121.306418	San Luis Obispo
LOS0007 Lower Rancho Nuevo Campground	4113	Channeled Meadow	USFS	Public	34.6956	-119.3978	Ventura
LOS0008 Cold Spring Meadow	4114	Non-channeled meadow	USFS	Public	34.82354	-119.0158	Kern
LOS0010 Thorn Meadow	4115	Channeled Meadow	USFS	Public	34.63155	-119.11303	Ventura
LOS0011 Piru Creek	4116	Channeled Meadow	USFS	Public	34.64177	-119.0901	Ventura
NWCA11-1116	4117	Non-channeled meadow	Self collected	Public	37.24183	-120.80929	Merced
NWCA11-1146	4118	Non-channeled meadow	Self collected	Public	37.23956	-120.81943	Merced
NWCA11-4708	4119	Non-channeled meadow	Self collected	Public	37.23928	-120.82344	Merced
NWCA11-2941	4120	Non-channeled meadow	Self collected	Public	37.2425	-120.838	Merced
San Simeon Slope	4121	Non-channeled meadow	Self collected	Public	35.592381	-121.123167	San Luis Obispo
Serrano Seep	4122	Seep/spring	Self collected	Private	38.66166	-121.06083	El Dorado
Grass Lake Meadow	4123	Non-channeled meadow	USFS	Public	38.78934	-119.95217	El Dorado
Baldwin Forested	4124	Forested	USFS	Public	38.9353	-120.07413	El Dorado
Big Meadow	4125	Channeled Meadow	USFS	Public	38.7786	-119.9983	El Dorado
Faith Valley Meadow	4126	Channeled Meadow	Self collected	Public	38.685	-119.92861	Alpine
Private Enhancement	4156	Channeled Meadow	Self collected	Private	na	na	San Diego
Private Preservation	4157	Non-channeled meadow	Self collected	Private	na	na	San Diego
Cottonwood Valley Meadow	4158	Non-channeled meadow	USFS	Public	32.72106	-116.49407	San Diego
Horse Meadow	4159	Non-channeled meadow	USFS	Public	32.84069	-116.42298	San Diego
Los Rasalies Meadow	4160	Non-channeled meadow	USFS	Public	32.86467	-116.45539	San Diego
Drosera Meadow	4198	Non-channeled meadow	NPS	Public	37.76689	-119.76191	Mariposa
Soda Springs Meadow	4199	Channeled Meadow	NPS	Public	37.62837	-119.08599	Madera
Bridal Veil Meadow	4200	Channeled Meadow	NPS	Public	37.71658	-119.66004	Mariposa
Gaylor Lakes Meadow	4201	Channeled Meadow	NPS	Public	37.91444	-119.26666	Tuolomne
Ackerson Meadow	4202	Channeled Meadow	Self collected	Private	37.836901	-119.843579	Tuolomne
INY00060 Little Antelope Valley	4203	Non-channeled meadow	USFS	Public	37.68021	-118.87736	Mono
INY009910 Antelope Valley Hot Spring	4204	Non-channeled meadow	USFS	Public	37.68916	-118.84277	Mono
INY00061 Rodeo Grounds	4205	Channeled Meadow	USFS	Public	37.76826	-119.09504	Mono
Bobelaine Forested	4416	Forested	Self collected	Private	38.92777	-121.58583	Sutter
LAS0006 Bridge Creek Pasture	4417	Channeled Meadow	USFS	Public	40.42656	-120.92441	Lassen
LAS0005 Westwood Junction	4418	Channeled Meadow	USFS	Public	40.43665	-120.94415	Lassen
KLA0008 Horsethief Meadow	4419	Channeled Meadow	USFS	Public	41.70042	-122.06379	Siskiyou
KLA 0007 Bull Meadow	4420	Channeled Meadow	USFS	Public	41.74571	-122.16507	Siskiyou
Gold Bluffs Seep	4421	Seep/spring	Self collected	Public	41.423697	-124.060472	Humboldt
Gold Bluffs Forested	4422	Forested	Self collected	Public	41.405981	-124.064364	Humboldt
MacKerricher Forested	4423	Forested	Self collected	Public	39.501	-123.77462	Mendocino
MacKerricher Meadow	4424	Non-channeled meadow	Self collected	Public	39.504463	-123.770637	Mendocino
Garcia River Forested Floodplain	4438	Forested	Self collected	Public	38.944674	-123.724147	Mendocino
Glen Canyon Seep	4587	Seep/spring	Self collected	Public	37.741829	-122.442691	San Francisco
McLaren Park Seep	4642	Seep/spring	Self collected	Public	37.722984	-122.419575	San Francisco

Table 2. CRAM assessment scores for the 40 assessment sites.

Site Name	eCRAM ID	Index Score	Buffer and Landscape Context	Hydrology	Physical Structure	Biotic Structure
Arroyo de la Cruz	4112	73	93.29	91.67	50.00	58.33
LOS0007 Lower Rancho Nuevo Campground	4113	81	62.50	100.00	87.50	75.00
LOS0008 Cold Spring Meadow	4114	65	62.50	91.67	50.00	54.17
LOS0010 Thorn Meadow	4115	82	62.50	95.83	87.50	80.56
LOS0011 Piru Creek	4116	72	75.00	87.50	62.50	61.11
NWCA11-1116	4117	64	72.88	75.00	37.50	70.83
NWCA11-1146	4118	73	72.88	100.00	62.50	58.33
NWCA11-4708	4119	56	72.88	75.00	25.00	50.00
NWCA11-2941	4120	60	60.38	75.00	37.50	66.67
San Simeon Slope	4121	77	77.79	100.00	50.00	79.17
Serrano Seep	4122	74	52.79	83.33	75.00	83.33
Grass Lake Meadow	4123	85	84.04	100.00	75.00	79.17
Baldwin Forested	4124	82	87.50	100.00	62.50	77.78
Big Meadow	4125	91	87.50	95.83	100.00	80.56
Faith Valley Meadow	4126	78	80.79	87.50	62.50	80.56
Private Enhancement	4156	65	68.29	75.00	50.00	66.67
Private Preservation	4157	67	68.29	100.00	50.00	50.00
Cottonwood Valley Meadow	4158	75	68.29	91.67	62.50	79.17
Horse Meadow	4159	73	62.50	83.33	75.00	70.83
Los Rasalies Meadow	4160	71	68.29	100.00	62.50	54.17
Drosera Meadow	4198	89	87.50	100.00	75.00	91.67
Soda Springs Meadow	4199	89	68.29	95.83	100.00	91.67
Bridal Veil Meadow	4200	76	54.54	91.66	75.00	83.33
Gaylor Lakes Meadow	4201	87	100.00	91.66	87.50	69.44
Ackerson Meadow	4202	65	80.79	75.00	50.00	55.56
INY00060 Little Antelope Valley	4203	71	68.29	100.00	50.00	66.67
INY009910 Antelope Valley Hot Spring	4204	71	68.29	100.00	37.50	79.17
INY00061 Rodeo Grounds	4205	87	68.29	87.50	100.00	91.67
Bobelaine Forested	4416	84	90.29	83.33	75.00	86.11
LAS0006 Bridge Creek Pasture	4417	84	75.00	91.66	87.50	83.33
LAS0005 Westwood Junction	4418	66	75.00	91.66	50.00	47.22
KLA0008 Horsethief Meadow	4419	69	55.79	91.66	62.50	66.67
KLA 0007 Bull Meadow	4420	73	80.79	95.83	62.50	52.78
Gold Bluffs Seep	4421	70	55.79	100.00	50.00	72.22
Gold Bluffs Forested	4422	80	87.50	100.00	62.50	69.44
MacKerricher Forested	4423	76	65.29	91.67	62.50	86.11
MacKerricher Meadow	4424	69	77.80	91.67	50.00	58.33
Garcia River Forested Floodplain	4438	77	68.29	83.33	62.50	94.44
Glen Canyon Seep	4587	70	68.29	83.33	62.50	66.67
McLaren Park Seep	4642	58	38.25	83.33	37.50	72.22

Table 3. Correlations between the CRAM Index score, the Biotic Attribute score, and the detailed vegetation metrics.

	Index Score		Biotic Attribute Score	
Vegetation Metric	**Spearman's ρ**	**P-value**	**Spearman's ρ**	**P-value**
Percent Native Cover	0.75	<0.001	0.49	0.011
Percent Non-Native Cover	-0.79	<0.001	-0.54	0.004
Percent Early-Successional Plants	-0.59	<0.001	-0.48	0.002
Percent Mid-Successional Plants	-0.01	0.949	-0.20	0.205
Percent Late-Successional Plants	0.53	<0.001	0.45	0.003
Percent Bare Ground	-0.44	0.005	-0.24	0.128
Native Species Richness	0.33	0.101	0.24	0.244
Non-native Species Richness	-0.78	<0.001	-0.43	0.030
Shannon Plant Diversity Index	-0.06	0.731	-0.11	0.515
Shannon Evenness	0.16	0.316	0.00	0.999
Ratliff Vegetation Score	0.56	<0.001	0.44	0.004
Percent Decreasers	0.64	<0.001	0.39	0.069