Task 2:
Relationship between wetland size and CRAM condition scores for depressional wetlands

Introduction

This study answers the question raised by Caltrans about the possible relationship between the size of depressional wetlands and their condition, as assessed using CRAM. This is the first study to investigate the relationship between wetland size and CRAM scores for any wetland type.

CRAM assumes that any size wetland of any type can have good condition. CRAM has therefore been designed to prevent correlation between CRAM scores and wetland size. One basic design decision was to exclude a size metric. The decision was based on the following assumptions:

- The relationship between the size of a wetland and the kinds and levels of its ecosystem services varies by wetland type and service in unknown ways; there is no certain rationale for scoring a wetland based on its size.
- For each wetland type, the standard AA size is designed to encompass the natural spatial variability in condition for that wetland type as assessed using CRAM, such that enlarging an AA beyond the recommended size should not result in significantly higher CRAM scores. For example, the cumulative number of co-dominant species or physical patch types encountered along a transect line that traces the diameter of an AA should asymptote before the AA is completely crossed (Figure 1).
- Wetland functions and services that might be strongly related to wetland size, such as ground water recharge, floodwater retention, or amount of waterfowl support, can be easily assessed using Level 1 metrics, such as wetland size-frequency or average wetland area; size does not need to be assessed using CRAM.

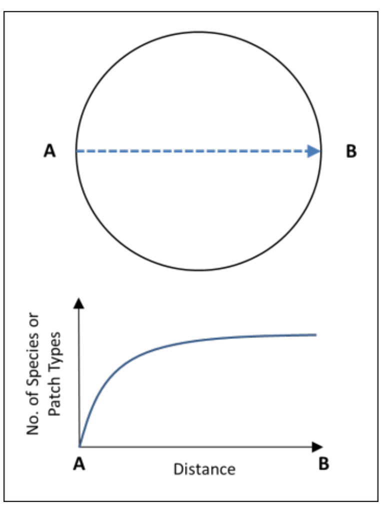

Figure 1: Hypothetical relationship between AA size (illustrated by traversing the AA circular area from A to B) and CRAM scores for physical patch richness or total number of codominant plant species (graph). For each wetland type, the standard AA is sized to encompass all the complexity of a typical wetland area, such that increasing the size of the AA does not result in higher CRAM scores.

Defining the optimal AA size for depressional wetlands has unique challenges. Using the statewide California Aquatic Resource Inventory (CARI), we find that more than 75% of depressional wetlands are smaller than the recommended AA size of 1 ha (Figure 2). Because it is assumed that the diversity of services increases with structural complexity and size, CRAM therefore favors larger, more structurally complex wetlands. This has raised a concern that CRAM might be biased against small depressional wetlands, despite efforts by the CRAM development team to prevent such bias.

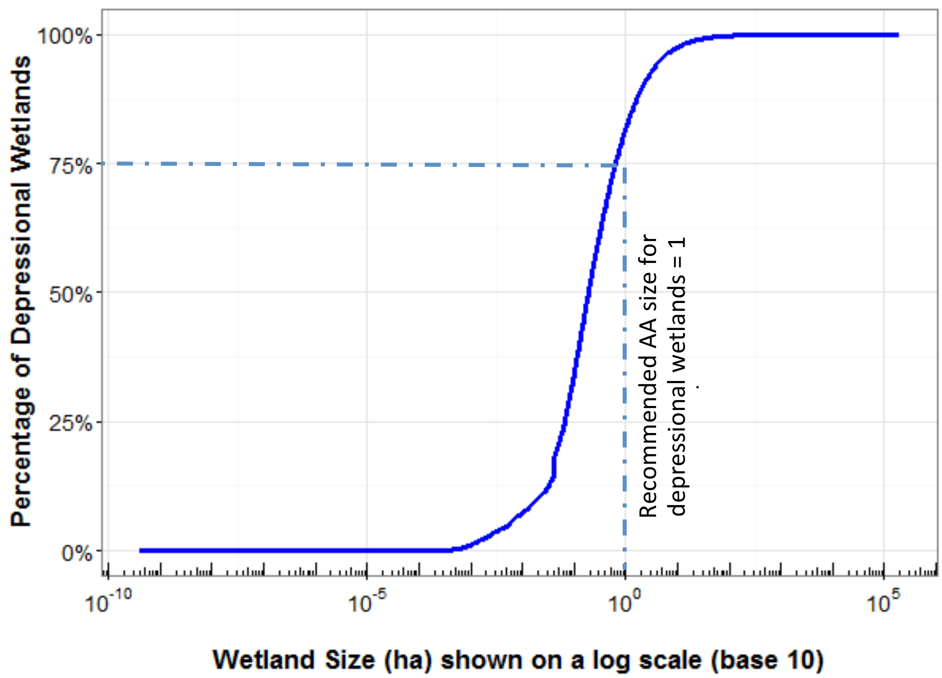

Figure 2. Statewide cumulative distribution function (CDF) plot of depressional wetland size, based upon California Aquatic Resource Inventory (CARI) data. More than 75% of all depressional wetlands are smaller than the recommended depressional wetland AA size of 1 ha (10^0 in base 10).

Dataset

An initial dataset of 393 CRAM scores for depressional wetlands assessed between 2007 and 2015 was compiled from the CRAM database (www.cramwetlands.org). This dataset represents depressional wetlands across California and includes assessments from ambient surveys and wetland projects. For this dataset, a project is defined as a purposeful change in topography and hydrology to create, restore, or enhance a depressional wetland. Compensatory mitigation is regarded as restoration.

CARI provides the most complete evidence of the total area and size-frequency of depressional wetlands statewide. A comparison of the size-frequencies of depressional wetlands for CARI and for the initial dataset reveals some important differences and similarities (Figure 3 and Table 1). In both datasets, the great majority of wetlands are less than 6 ha. Both datasets cover a very broad range of wetland sizes. However, unlike CARI, the initial dataset is not dominated by very small wetlands (i.e., <0.25 ha). This is due in part to the initial dataset having a much larger proportion of projects than CARI, and few of the projects are very small. The distribution of the assessed wetland sizes are representative of depressional wetlands found across the state.

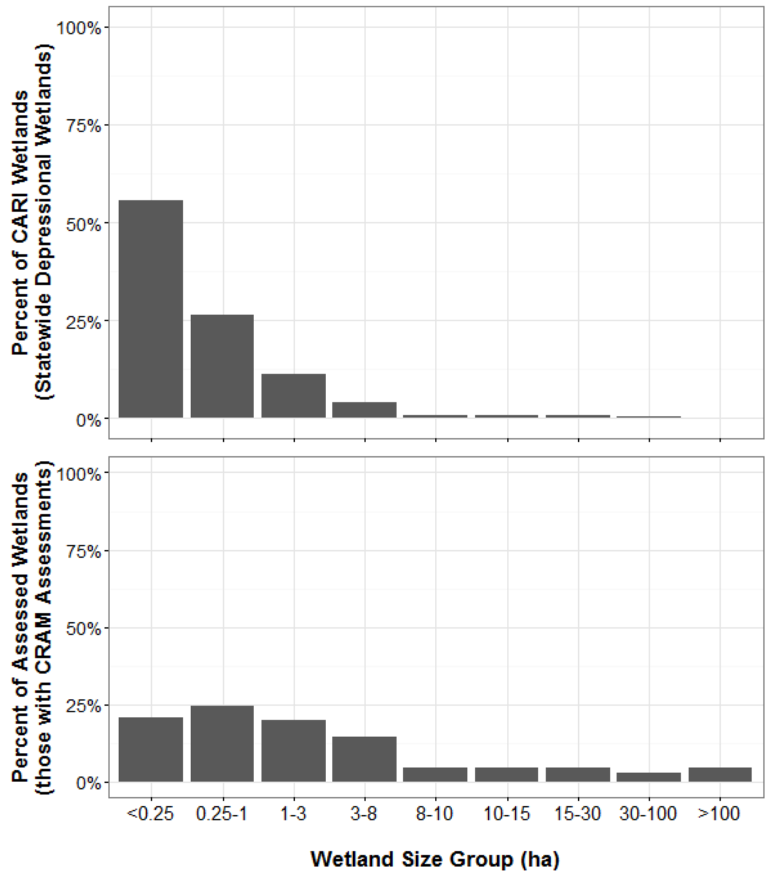

Figure 3. Bar charts showing the relative proportion of wetland sizes between the CARI statewide depressional wetlands (n=255,000) and all CRAM assessed depressional wetlands (n=300). The size groupings shown here have more groups for the smallest wetlands for visual resolution since most depressional wetlands in California are <1ha.

Table 1. Summary statistics of wetland size for CARI and the final dataset of CRAM assessments.

Dataset	Min Size (ha)	Max Size (ha)	Mean Size	Quantiles						
				5%	10%	25%	50%	75%	90%	95%
CARI (n=255,000)	0	18,490	2.3	0.01	0.02	0.1	0.2	0.6	2	5
CRAM Assessments (n=300)	0.005	591	20.2	0.05	0.1	0.3	1	6	22	57

The initial CRAM dataset was filtered through the following set of criteria intended to disqualify scores that did not contribute to an unbiased analysis of the relationship between wetland size and condition.

- Is the case a re-assessment? A re-assessment is a repeated visit to the same AA. Unless the time interval between re-assessments is large, they tend to have the same or very similar scores.

Therefore, in aggregate, the re-assessments of an AA could unjustifiably inflate its influence on the analyses. Twenty three re-assessments were dropped from the dataset leaving 370 scores.

- Is the case a clear statistical outlier? Initial summary boxplots of the dataset indicated that wetlands larger than ~15 ha were outliers (Figure 4). Additional review of these large wetlands revealed that they include diked baylands and large Central Valley refuges, many of which are intensively managed for a restricted number of services. Therefore, because these sites are statistical outliers and may be managed for a subset of their potential services, they were excluded from the dataset as outliers.

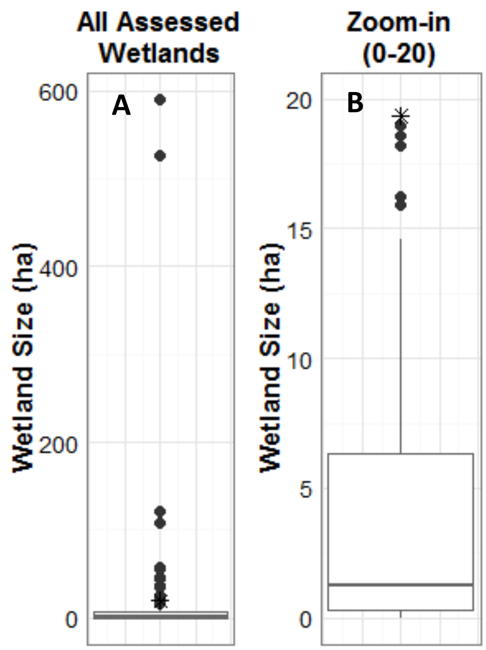

Figure 4. Box-and-whisker plots of wetlands size range for the initial CRAM dataset (n=393) with a zoom-in to wetland sizes <20 ha to show that wetlands larger than 15 ha are outliers. Dots represent sites that are statistical outliers, that is, they fall outside of 1.5x the interquartile range. At the lower end of the size range, the interquartile range (the "whisker") extends to near zero, with no smaller sites that are outliers.

After excluding the outliers and re-assessments, the final dataset consists of 325 assessments representing 300 depressional wetlands. 25 assessments are distributed among a few very large projects as replicates. They were sufficiently different from each other to warrant their inclusion in the final dataset. While most regions of the state are represented to some degree, the southeastern desert region is not represented, and the Bay-Delta region is abundantly represented (Figure 5).

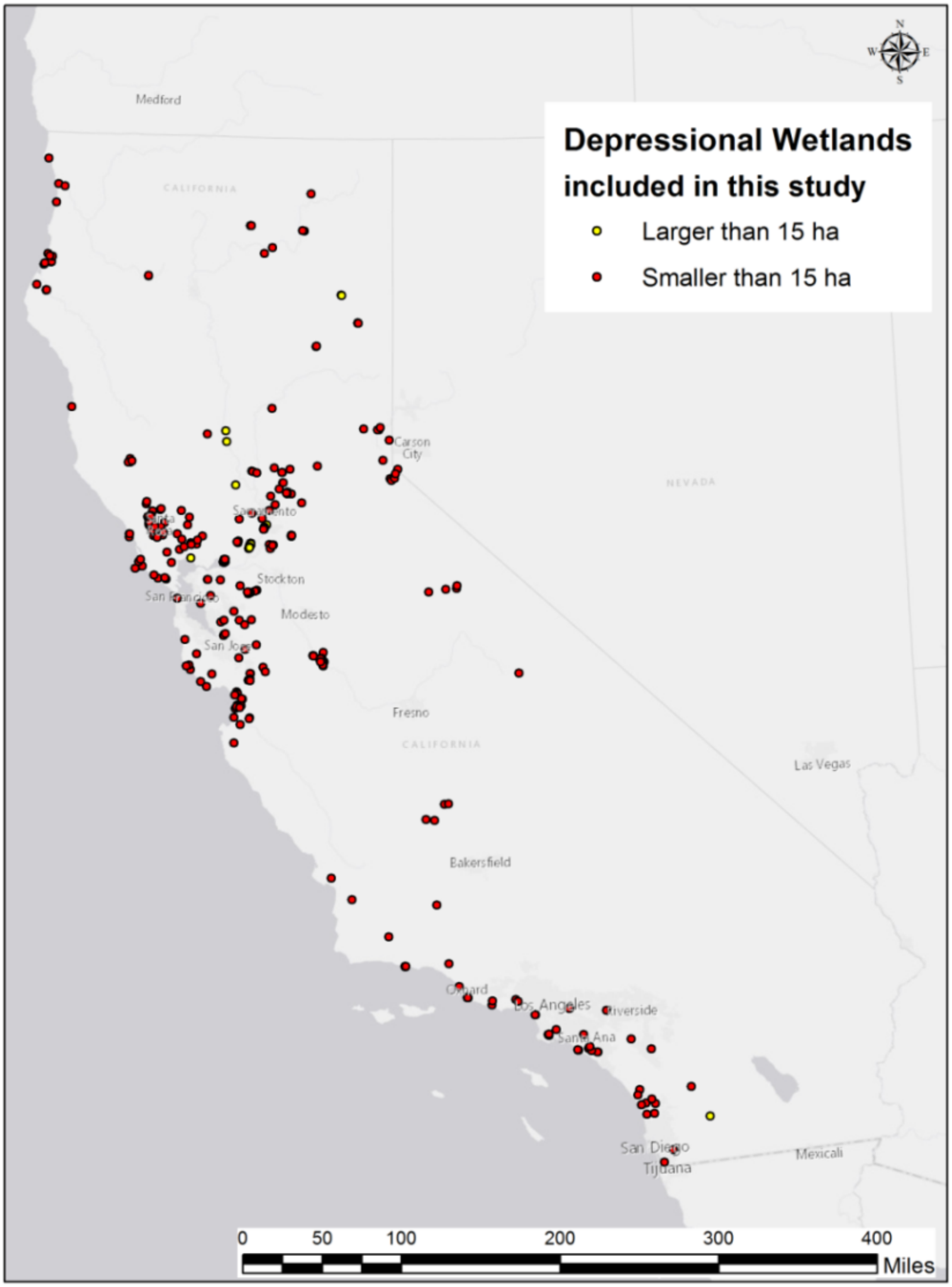

Figure 5. Locations of the CRAM assessments included in this study. Wetlands larger than 15 ha (shown in yellow) were excluded from analyses.

Results

Question 1: *Do larger depressional wetlands get higher CRAM Condition Index scores than smaller depressional wetlands?*

Null Hypothesis: There is no relationship between the size and condition of depressional wetlands.

Summary of Findings: The null hypothesis is not rejected. For all the purposes of CRAM, there is evidently no relationship between depressional wetland size and overall condition (Figure 6). However, the population of wetlands < 5 ha in size has a wider range of condition scores, including very low and very high scores, relative to the population of wetlands 5 to 15 ha in size. The population of these wetlands has a lower maximum score and a higher minimum score.

To explain this lack of correlation between wetland size and the CRAM index score, the relationships between wetland size and CRAM Attribute Scores was explored (see Question 2 below).

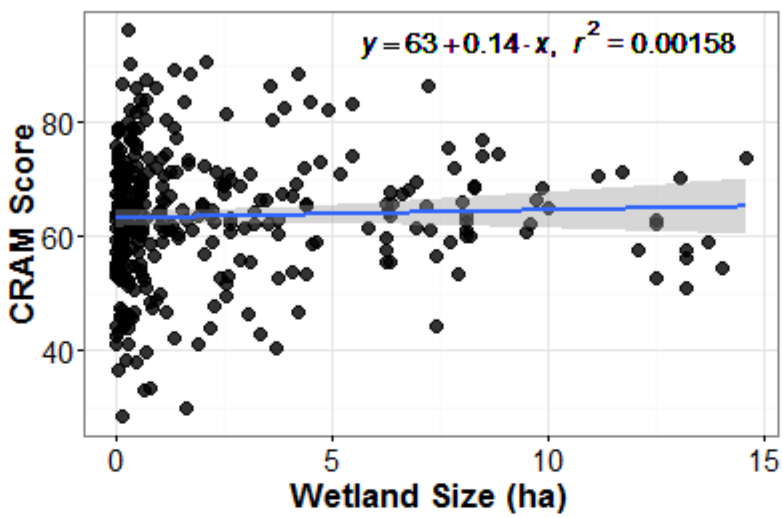

Figure 6. Wetland condition (CRAM Index Score) plotted against wetland size (ha) for the final dataset developed for this study (n = 325; R^2 = 0.001, p-value 0.5).

Question 2: Do larger depressional wetlands get higher CRAM Condition Attribute Scores than smaller depressional wetlands?

Null Hypothesis: There is no relationship between the size of depressional wetlands and their Condition Attribute Scores.

Summary of Findings: There is a weak positive correlation between depressional wetland size and the Buffer and Landscape Context Attribute Scores (Figure 7A), a weak negative correlation between size and Hydrology Attribute Scores (Figure 7B), and no correlation between size and Physical Structure Attribute Scores (Figure 7C) or Biotic Structure Attribute Scores (Figure 7D).

The lack of correlation between wetland size and the CRAM Index score (see Figure 6) can be explained by the relationships between size and the Attribute scores. There is a lack of correlation between size and scores for either the Physical Structure Attribute or the Biotic Structure Attribute (see Figures 7C and 7D). Furthermore, the opposing correlations between size and scores for the Buffer and Landscape Context Attribute (Figure 7A) and between size and scores for Hydrology Attribute (Figure 7B) essentially cancel each other out when their scores are combined to calculate the Index score.

The weak negative correlation between size and the scores for the Hydrology Attribute (see Figure 7B) is due to the fact that most of the state is arid or semi-arid, such that larger wetlands tend to be unnatural, need larger amount of water from artificial sources, and need more water management to provide their intended ecosystems services. These artificial aspects of the hydrology of larger wetlands reduce their Hydrology Attribute scores.

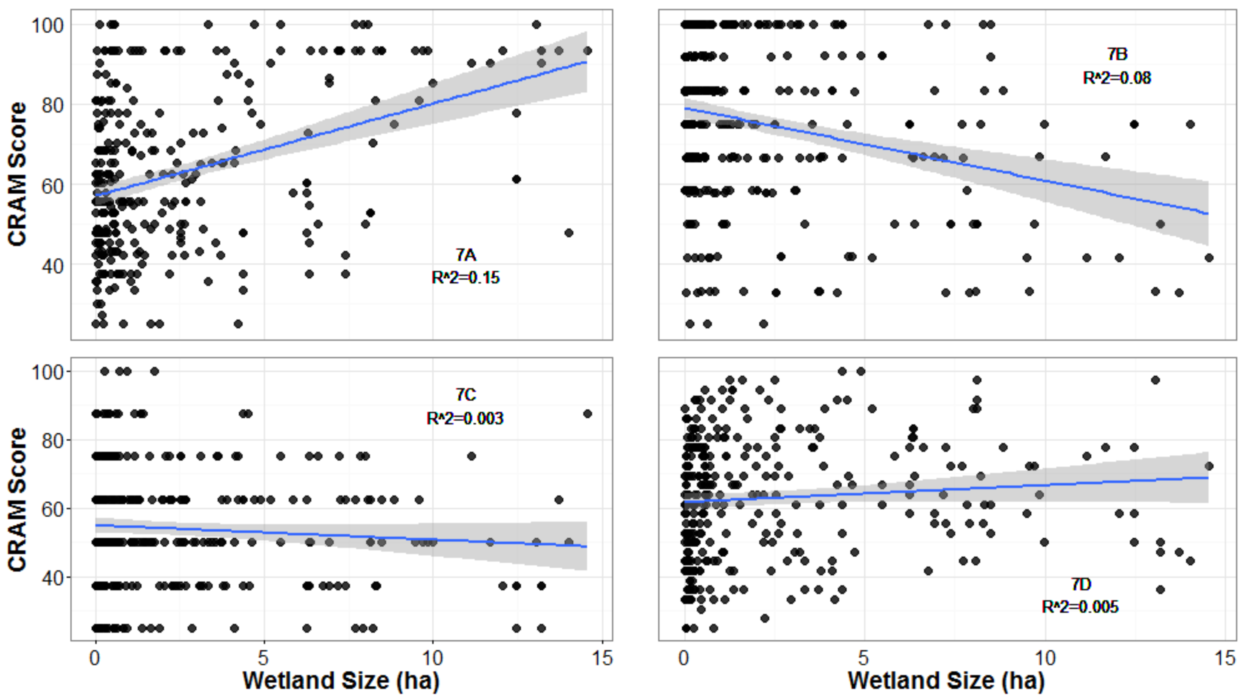

Figure 7. CRAM Attribute scores plotted as a function of wetland size (ha) for (A) the Buffer and Landscape Context Attribute, (B) the Hydrology Attribute, (C) the Physical Structure Attribute, and (D) the Biotic Structure Attribute.

Question 3: Is there a relationship between wetland size and any of the individual metrics or sub-metrics of the Buffer and Landscape Context Attribute?

<u>Null Hypothesis:</u> There is no relationship between wetland size and any of the metrics or sub-metrics of the Buffer and Landscape Context Attribute.

Summary of Findings: The weak positive correlation between wetland size and scores for the Buffer and Landscape Context Attribute is driven by a weak positive correlation between size and scores for the Aquatic Area Abundance Metric. The Buffer Metric and its sub-metrics are not correlated to wetland size.

Of all the attributes, the strongest relationship existed between the Buffer and Landscape Context Attribute and wetland size. Thus, this Attribute warrants a closer inspection of its component Aquatic Area Abundance Metric and the sub-metrics of the Buffer Metric, which are Percent of AA with Buffer, Average Buffer Width, and Buffer Condition (Figure 8).

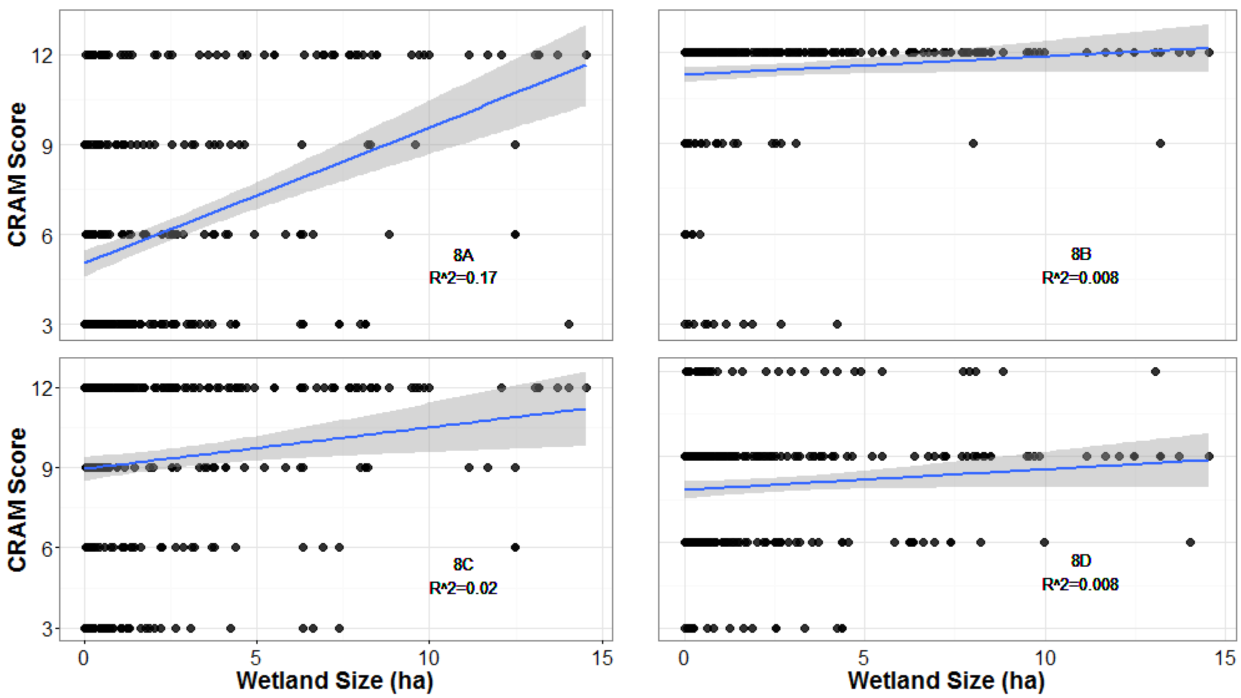

Figure 8. CRAM scores plotted as a function of wetland size (ha) for (A) the Aquatic Area Abundance Metric, (B) the Percent with Buffer Sub-metric, (C) the Average Buffer Width Sub-metric, and (D) the Buffer Condition Sub-metric.

The weak positive correlation between wetland size and the Buffer and Landscape Context Attribute is evidently mainly due to the positive correlation between size and the Aquatic Area Abundance Metric (see Figure 8A). It is likely that this correlation is an artifact of the assessment methodology. For this metric, the practitioner is asked to place four 500m lines extending outward from the AA boundary along the cardinal compass directions, and measure the percentage of each line that coincides with an aquatic area. The size of the AA is not scaled to the size of the wetland. For wetlands that are not larger than the standard AA size, the metric pertains to the wetland setting (i.e., the area around the AA is the area around the wetland). However, for wetlands larger than the AA, the metric assesses the AA setting (i.e., the area around the AA includes the area of the same wetland outside of the AA). This means that, as wetland size increases, the amount of wetland surrounding the AA tends to also increase. Since wetlands are regarded as a type of aquatic area, the assessment of Aquatic Area Abundance tends to increase with wetland size. For the same reason, Average Buffer Width also tends to increase with wetland size (see Figure 8C). Percent of AA with Buffer is not correlated to wetland size (Figure 8B) because even the smallest wetlands are likely to have some amount of their perimeter with buffer of the minimum width. There is no relationship between wetland size and the Buffer Condition sub-metric (Figure 8D).

Conclusions

There is no strong relationship between wetland size and wetland condition based on the CRAM Index scores or Attribute scores. This finding has at least four important meanings with regard to the CRAM module for depressional wetlands.

- CRAM is not biased against small wetlands.
- There is no need for a size metric for CRAM Condition assessments.
- The standard Assessment Area (AA) adequately encompasses the natural spatial variability in physical and biotic structure.
- Wetlands of any size, including very small wetlands, can have good condition.

In this study, scores for the Aquatic Area Abundance Metric and the Buffer Width Sub-metric tend to be weakly correlated to wetland size. This is an artifact of the methodology. Since the size of the AA is constant, the amount of wetland surrounding the AA tends to increase with wetland size; therefore, since wetland areas qualify as buffer and aquatic areas, the scores for Buffer Width and Aquatic Area Abundance also tend to increase with wetland size. As a result, these two metrics are slightly biased against small depressional wetlands. This bias is removed by adding the scores for Aquatic Area Abundance and for Buffer Width to the other Buffer sub-metrics that are not correlated to wetland size, such that there is no bias for the Buffer Metric scores or for the Buffer and Landscape Context Attribute scores. Furthermore, the weak bias evident for the Aquatic Area Abundance Metric and the Buffer Width Sub-metric is unlikely to be evident for assessments of large individual wetlands, such as large wetland projects and mitigation banks, since they involve summarizing scores across multiple AAs that effectively increases the proportion of the wetland that is being assessed.

Discussion

Except for the montane areas of the Sierra and far northwest, annual potential evapo-transpiration (PET) exceeds annual precipitation in California by a factor of 2 or more, and PET exceeds precipitation throughout the state during the dry season[1]. As a result, natural depressional wetlands are uncommon statewide and most have a seasonal hydroperiod. This helps explain why the state's depressional wetlands tend to be small. It can also be hypothesized that the distance between depressional wetlands and other aquatic areas tends to be great, relative to wetter regions.

The wide natural dispersion of depressional wetlands throughout much of the state and their small average size has been countered by the construction of many artificial depressional wetlands for various purposes. Artificial depressional wetlands include mitigation and restoration projects, stock ponds, constructed wildlife ponds, small agricultural reservoirs, water hazards on golf courses, abandoned

[1] Barbour, M.G, T. Keeler-Wolf, and A.A Schoenherr. 2007.*Terrestrial vegetation of California*. University of California Press, Berkeley CA

swimming pools, and many water features build into public and private landscaping. Examples of relatively large artificial depressional wetlands include duck clubs, wildlife refuges, and poorly drained reclaimed tidal marshlands. Landscapes with abundant depressional wetlands, other than vernal pools, are usually unnatural and subject to extensive water management.

The native flora and fauna have adapted to the natural spatial distribution and hydrology of depressional wetlands. Depressional wetlands that are small, hydrologically isolated, and widely dispersed may nevertheless serve as feeding, resting, and breeding habitat for motile species of wildlife. They may, in aggregate, serve as dispersal and migration corridors. They may individually or collectively play important roles in runoff retention and groundwater recharge, depending on their landscape position. To the degree that they are ecologically isolated, they can promote speciation and thus contribute to regional and statewide biological diversity.

These considerations in aggregate suggest that small, hydrologically isolated depressional wetlands comprise a natural, integral component of California landscapes.

Recommendations

The following recommendations are provided to the Level 2 Committee of the California Wetlands Monitoring Workgroup (CWMW) for its consideration.

1. The relationship between CRAM scores and wetland size should be investigated for each CRAM module. The investigation should proceed as exemplified by this study, using the following approach.

   a. Conduct a statewide survey of wetland condition involving large numbers of wetlands throughout the full range of wetland size. The survey can be a combination of existing and new CRAM assessments.

   b. Using the statewide survey results, separately test for correlation between wetland size and the CRAM Index scores and Attributes scores.

   c. For any correlations, either positive or negative, between wetland size and scores for an Attribute, test for correlations between wetland size and the component Metric scores.

   d. Based on the CRAM User's Manual, field books, and conceptual models, determine if any correlations are due to systematic methodological bias.

2. For the CRAM Depressional Wetland Module, consider removing the weak bias of the Aquatic Area Abundance Metric against small wetlands by removing the correlation between its scores and wetland size. The correlation can be removed by adjusting the method for the Metric as follows.

   a. Assume that the purpose of the Aquatic Area Abundance Metric is to assess the potential ecological connectivity between a wetland and other aquatic areas, such that higher scores for this Metric indicate more connectivity and lower scores indicate greater ecological isolation.

   b. Extend the lines for assessing Aquatic Area Abundance from the edge of the wetland rather than from the boundary of the AA. This adjustment will remove the effect of the ratio between AA size and wetland size on the score for Aquatic Area Abundance, and thus it will remove the bias of this Metric against small depressional wetlands, while preserving the recommended standard AA size. Since the metric is assessed using aerial imagery, this adjustment does not incur additional time or expense.

3. For the CRAM Depressional Wetland Module, consider removing the weak bias of the Buffer Width Sub-metric against small wetlands by removing the correlation between its scores and wetland size. The correlation can be removed by adjusting the method for this Metric as follows.

   a. Assume that the purpose of the Buffer Width Sub-metric is to help assess the potential of the wetland to be buffered from external stressors. The corollary is that this sub-metric helps assess the vulnerability of the wetland. Furthermore, assume that the potential of a wetland to be buffered is related to its size. In other words, assume that the overall vulnerability of a wetland to stress decreases with wetland size because larger wetlands have larger interior areas relatively removed from external stressors.

   b. Extend the lines for assessing Buffer Width from the edge of the wetland rather than from the boundary of the AA. This adjustment will remove the effect of the ratio between AA size and wetland size on the score for Average Buffer Width, and thus it will remove the bias of this Metric against small depressional wetlands, while preserving the recommended standard AA size. Since the metric is assessed using aerial imagery, this adjustment does not incur additional time or expense.

4. Although we find no correlation between wetland size and wetland condition, we do hypothesize that a relationship exists between wetland size and vulnerability to stress. Given that the Buffer and Landscape Context Attribute may be used in the future to assess the effect of buffer on the relationship between stress and condition, it may warrant improving the performance of the Buffer Metric as much as possible. For the CRAM Depressional Wetland Module, consider improving the performance of the Buffer Metric by modifying its methodology to account for the effect of the size of a wetland on its vulnerability to external stress.

   a. Assume that the overall vulnerability of a wetland to stress decreases with wetland size because larger wetlands have larger interior areas relatively removed from external stressors.

   b. Develop a third metric for the Buffer and Landscape Context Attribute that scores wetlands for their size. The new Wetland Size Metric of the Buffer and Landscape Context Attribute should be estimated from the California Aquatic Resource Inventory (CARI) or from aerial imagery. The threshold sizes between metric scores should reflect new conceptual models relating wetland size to overall vulnerability for the dominant stressors for depressional wetlands. This new metric should reside within the Buffer and Landscape Context Attribute, rather than within the Stress Index, because it describes a wetland setting characteristic that may affect the amount of stress measured by the Stress Index. It, along with the other two buffer metrics helps to explain the relationship between stress and condition.

5. For the CRAM Depressional Wetland Module, develop a matrix relating wetland ecosystem services to wetland size. The purpose of this matrix is to summarize the likely differences in service between large and small wetlands that have good condition, as assessed using CRAM. The rationale for this matrix is as follows.

a. CRAM assumes that larger wetlands of any kind tend to provide higher levels of more kinds of intrinsic services.

b. However, based on the CRAM Depressional Module, depressional wetlands of any size can have good condition.

c. A summary of the likely functional differences between high-scoring large and small wetlands will help manage expectations about the potential performance of depressional wetlands of any size.