Central Coast Wetlands Group

Development of New Tools to Assess Riparian Extent and Condition- A Central Coast Pilot Study

Final Report

USEPA Wetlands Program Development Grant CD- 00T83101

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Acknowledgments

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1. Introduction

Project Summary

Wetlands and riparian areas throughout the state are an incredibly rich resource, providing valuable services (foraging, refuge, and spawning grounds) to a plethora of flora and fauna. On the central coast, streams and wetlands improve water quality by filtering runoff before water reaches the Monterey Bay National Marine Sanctuary. Management of these riparian resources currently faces new opportunities (through new riparian protection policy development and new state resources for protection and restoration) and new threats (from food safety concerns and fear of additional liability by land owners). This project was designed to help the State of California develop the tools to conduct Level 1 and Level 2 assessments of riparian extent and condition.

Central Coast resource managers have identified that riparian resources are being lost due to impacts from adjacent land uses. Concerns within the agriculture and food distribution industry about the safety of vegetable crops have led to new guidelines in an attempt to ensure the safety of food crops. Unfortunately, many of these efforts have actually lead to misguided farm policies that are counter to sustainable land stewardship practices. Since 2006, the agriculture industry has removed significant areas of riparian habitat, a reversal in previous agriculture practices that prized riparian and wetland habitat for its water quality and erosion control values. Surveys of Central Coast famers indicate that a large number of the respondents actively eliminated water quality and wildlife habitat conservation practices. Conservation practices that were removed include riparian buffers (RCD of Monterey County, 2007). The total environmental implications of these actions are unknown due to a lack of baseline data on riparian resources.

This project was developed in part as a response to the Central Coast Regional Water Quality Control Board's (CCRWQCB) specific request to implement a riparian monitoring program that supports their "Vision of Healthy Watersheds." Protection of riparian areas, including protection of canopy cover, surface waters water quality and buffer condition is predicated on a comprehensive inventory of the resources. Protection of current resources and restoration of degraded riparian areas will be greatly enhanced through the creation of a regional riparian inventory and remote riparian condition assessment tool. RB3 has established several measurable goals that can be quantified through this effort:

- Healthy Aquatic Habitat: By 2025, 80 percent of Aquatic Habitat is healthy, and the remaining 20 percent exhibits positive trends in key parameters.

- Proper Land Management: By 2025, 80 percent of lands within a watershed will be managed to maintain proper watershed functions, and the remaining 20 percent will exhibit positive trends in key watershed parameters.

The CCRWQCB plans to develop a Riparian Protection Policy in parallel with other Regional Boards to the north. Staff and technical resources for this process have not yet been allocated and policy development is on hold while other priorities are addressed (TMDLs, Storm water, Agriculture). This project lays the groundwork for policy development to move forward by creating an inventory of riparian resources on the central coast and establishing methods to quantify condition of riparian resources in support of riparian protection policy development.

Without baseline data, future actions to protect and restore these resources will be hindered by a lack of information necessary to remedy impacts through negotiation or regulatory action. This project was designed to be a pilot effort to provide the CCRWQCB and regional resource managers a current inventory of the riparian extent on the central coast and a remote riparian assessment tool, allowing for the assessment of inaccessible stream reaches.

This project builds off of previous and current efforts of the Central Coast Wetlands Group:

- In 2003, staff at CCWG and the Morro Bay Estuary created a map of wetland and riparian resources using intensive aerial interpretation and field reconnaissance (104b3 grant).
- In 2007, the Morro Bay watershed wetland condition assessment project, conducted by CCWG, quantified the condition of riverine resources within that basin (O'Connor et al. 2008).
- In 2011, The Riparian Zone Estimator Tool, developed by SFEI, was used with the CCWG base map of riparian resources in Morro Bay to compare the mapping outputs of the two methods (GIS modeling and heads up digitizing).

CCRWQCB has a well-established regional monitoring program that provided the ambient data necessary to develop the riparian assessment protocol.

Riparian Areas

For the purposes of this project we used the National Research Council's definition of a riparian area:

> *Riparian Areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes and biota. They are areas through which surface and subsurface hydrology connect water*

bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems. Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes and estuarine-marine shorelines" (National Research Council 2002).

2. Mapping Central Coast Riparian Resources

Central Coast Riparian Map Using the Riparian Zone Estimator Tool (RipZET)

Purpose

The Riparian Zone Estimator Tool, or RipZET, is a GIS-based tool being produced by the California Water Resources Control Board (State Board) to help visualize existing riparian ecosystems and to assess their capacity to support the beneficial uses of the state's aquatic features, such as lakes, reservoirs, rivers, streams and wetlands. The intention is to provide a tool that Regional Water Quality Control Boards, other agencies, and the public can use to help implement the State Board's proposed Wetland and Riparian Area Protection Policy.

General Description of RipZET

RipZET is based on the concept of "functional riparian width." According to this concept, the kinds and levels of functions that a riparian area can provide depend on its width as well as its structure (e.g., topographic slope, density and height of vegetation, plant species composition). For any given structure, wider riparian areas tend to support higher levels of more kinds of functions, as compared to narrower areas (Wenger 1999). The concept is central to the riparian definition recommended by the National Research Council (NRC 2002) and is integral to many riparian design and management guidelines (e.g., *Johnson and Buffler 2008*).

RipZET has three main components: core code, modules, and output. The core code prepares the input data used by the modules. Each module generates a unique visual display (GIS coverage) of estimated functional riparian width based on site-specific vegetation, topography, and land cover characteristics, plus a tabular summary of spatial statistics derived from the displays. The displays are not regarded as maps because they do not depict areas with definite boundaries based on field indicators. Instead, they depict areas where selected riparian functions are likely to be supported based on the input data. Each module can be applied to any user-defined geographic area, from a single wetland or reach of stream to an entire watershed or region. The modules can be run separately or together, and the outputs from different modules can be conflated to estimate the maximum riparian extent for all the functions represented by all the modules. The modules can be revised, and new modules can be added to cover more functions.

During the time period of this project, RipZET consisted of the Vegetation Module and the Hillslope Module.

Technical Description of Vegetation Module

The vegetation module is designed to incorporate vegetation-related riparian functions into the estimates of riparian extent. The functions of particular interest are shading, bank stabilization, allochthonous input (i.e., vegetation, insects, and other organic matter that falls into an aquatic feature from its surroundings), and support of riparian vegetation and wildlife.

The vegetation module performs a series of discrete analytical steps to generate estimates of functional riparian width. The module first creates an intersection between a digital map of vegetation and a digital map of aquatic features that are provided by the user. Common vegetation data that can be used for this module include CALVEG produced by the U.S. Forest Service and VegCAMP produced through the CA Department of Fish and Wildlife. The VegCAMP data are preferred because of their greater spatial resolution and accuracy. Custom vegetation data can also be used. The vegetation is classified as trees, shrub-scrub, grasses and forbes, or bare ground. For each class of vegetation except trees, the module provides a default value for riparian width, termed a "Standard Buffer Distance" or SBD. Trees are treated differently because of their greater importance as sources of shade and allochthonous material. Levels of these particular functions are positively related to tree height, which varies with tree species and tree age. The module provides default values of expected heights for mature trees of each species. The user must join the vegetation data to the spreadsheet of default tree heights and SBD values. The user can edit the default values as needed to represent local conditions. The module also enables the user to make the functional riparian width equal to any multiple of tree height. This can be necessary to account for allochthonous input from trees at different distances away from aquatic features. For example, windthrow in the first two or three rows of trees along a stream can account for much of their input of large woody debris. There is a minimum riparian width of 1m for bare ground or pavement. There is no functional riparian width where the aquatic portion of one feature intersects that of another kind, such as where the flow from a river or stream enters a lake. The vegetation module estimates functional riparian widths independently for the left and right banks of a river or stream.

Technical Description of the Hillslope Module

The hillslope module is designed to incorporate hillslope processes into estimates of riparian extent. The processes of particular interest are landsliding, dry raveling, and other kinds of mass-wasting that can deliver sediment to an aquatic feature. The effects of sediment input can be positive or negative. For example, inputs of coarse sediment are generally expected to have positive effects on in-stream habitats, whereas the inputs of fine sediment are generally expected to have negative effects. In any case, the inputs are riparian in nature.

The module also accounts for the effect of hillslope steepness on inputs of allochthonous material, especially large woody debris. For example, the riparian width defined by the maximum distance a hillside tree can be from a stream and still fall into it decreases as hillslope steepness increases. This module is therefore especially applicable in steep terrain. It is also designed to estimate the minimum likely headwater source areas for rivers and streams. These areas are typically uphill of the ends of surface channels as mapped using LiDAR or aerial imagery.

The hillslope module estimates functional riparian width based on a series of analytical steps (Figure 1). First, the module calculates the area-weighted average hillslope gradient over a distance of 40m perpendicular to the stream bank or wetland edge. For hillsides with an area-weighted average gradient less than 20 degrees, the riparian width relating to hillslope processes is assumed to be zero, and the headward source areas for streams and rivers is assumed to be the same as the channel ends evident in LiDAR or aerial imagery. Where the hillslope gradient is greater than 20 degrees, the functional riparian width is estimated as the average hillslope gradient minus the threshold value, plus 1m for each 1 degree increase in average gradient greater than 20 degrees. For example, using the default threshold of 20 degrees, the functional riparian width for a stream reach bounded by a hillslope having an average gradient of 27 degrees would be 7m. The size of the headwater source area of a river or stream is similarly estimated. For example, if the area-weighted gradient around the end of a mapped channel is 27 degrees, the diameter of the circular area created to represent the source area would be 7m. The default threshold value of 20 degrees that triggers the module can be adjusted by the user.

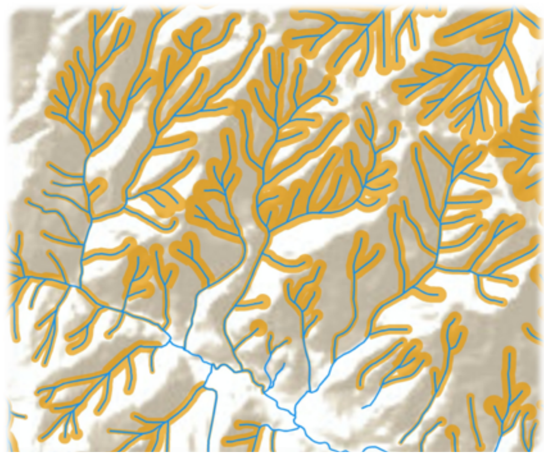


Figure 1. Example RipZET Hillslope Module display output

Visual and Analytical Output

Each module of RipZET generates a display of riparian areas and a summary chart of basic statistics developed from the display. The summary chart includes total riparian area by aquatic feature type for each module and for all modules combined, and the total riparian area shared by two or more types of aquatic features. All the data used to generate the final displays and summary statistics are maintained in the GIS. This includes estimated numerical values for riparian width, the names of associated aquatic features, the Strahler order of associated channels (Strahler 1952), names of associated vegetation types and land cover types, and values for area-weighted hillslope gradients.

Intended Uses of RipZET

The main intended uses of RipZET are to visualize existing riparian ecosystems and to assess their capacity to support the beneficial uses of adjoining state waters (Figure 2). To complete this kind of assessment, the user might develop a matrix that relates the riparian functions to the beneficial uses. The user can then define classes of riparian width that correspond to different kinds or levels of beneficial use, as represented by the riparian functions. The RipZET tabular output can then be used to calculate the relative abundance of the different classes of riparian width. Based on these calculations, the user can estimate spatial and temporal differences among riparian areas in terms of their likely capacity to support the beneficial uses.

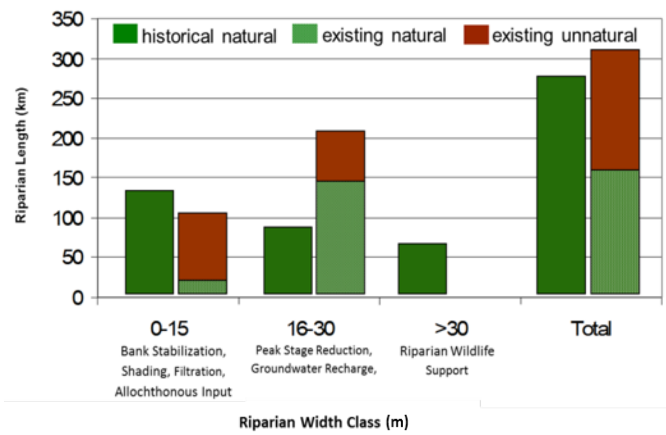


Figure 2. Example analysis if the relative abundance of different classes of functional riparian width.

The RipZET outputs have many additional uses. For example, they can be used to prioritize riparian restoration opportunities and to test the effects of alternative restoration projects on the total extent of riparian area by width class. They can also be used to create graphics that depict riparian areas in relation to other landscape features and land cover, and to educate the public about the values and likely locations of riparian areas.

Utilizing RipZET on the Central Coast of California

The Riparian Zone Estimator Tool (RipZET) was transferred from SFEI to CCWG in the summer of 2013. Staff at SFEI provided technical support to CCWG to work though creating a map of riparian function based on vegetation and slope for the central coast. It became clear early on that there was not sufficient GIS data coverage of the CALVEG vegetation maps for the central coast. As a result, the RipZET Vegetation output had several holes in coverage for the central coast (Figure 3), while the RipZET Slope output was complete for the region (Figure 4).

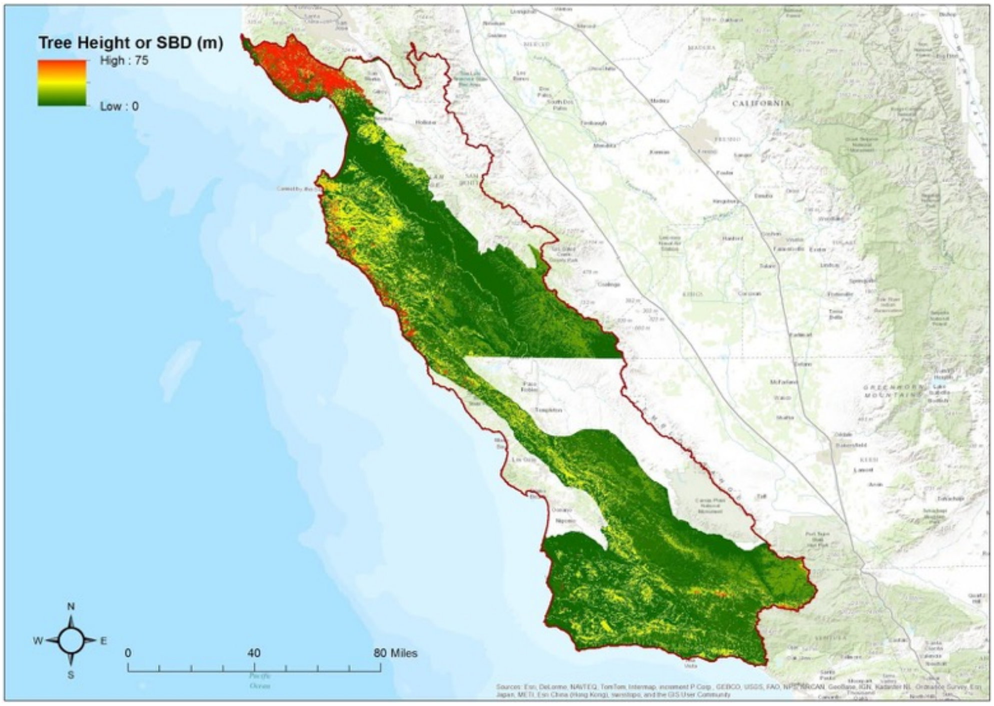


Figure 3. RipZET Vegetation Module output for the Central coast region

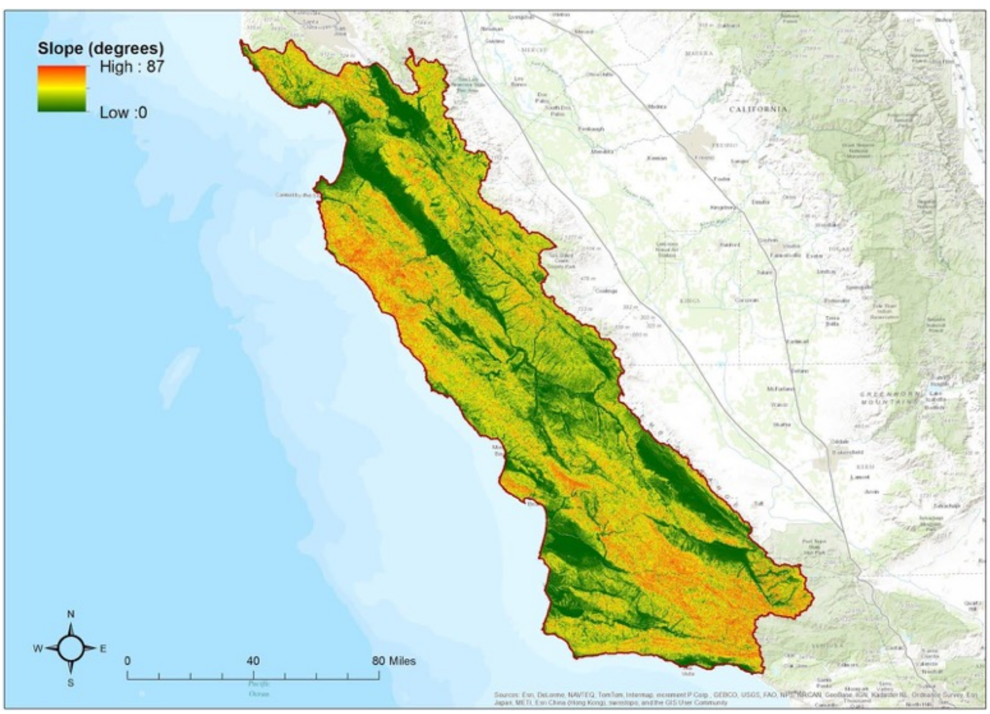


Figure 4. RipZET Slope Module output for the central coast region

The RipZET output was used to get an estimate of the dominant width of stream riparian zone function on the central coast, based on the two modules. The Vegetation Module showed a peak in area coverage for buffer widths between 36 and 45 meters, with a second peak of 136 to 140 meters of width (Figure 5). The Slope Module, as expected, showed a much smaller functional width, showing the highest area coverage in buffer widths ranging from 6 to 15 meters (Figure 6).

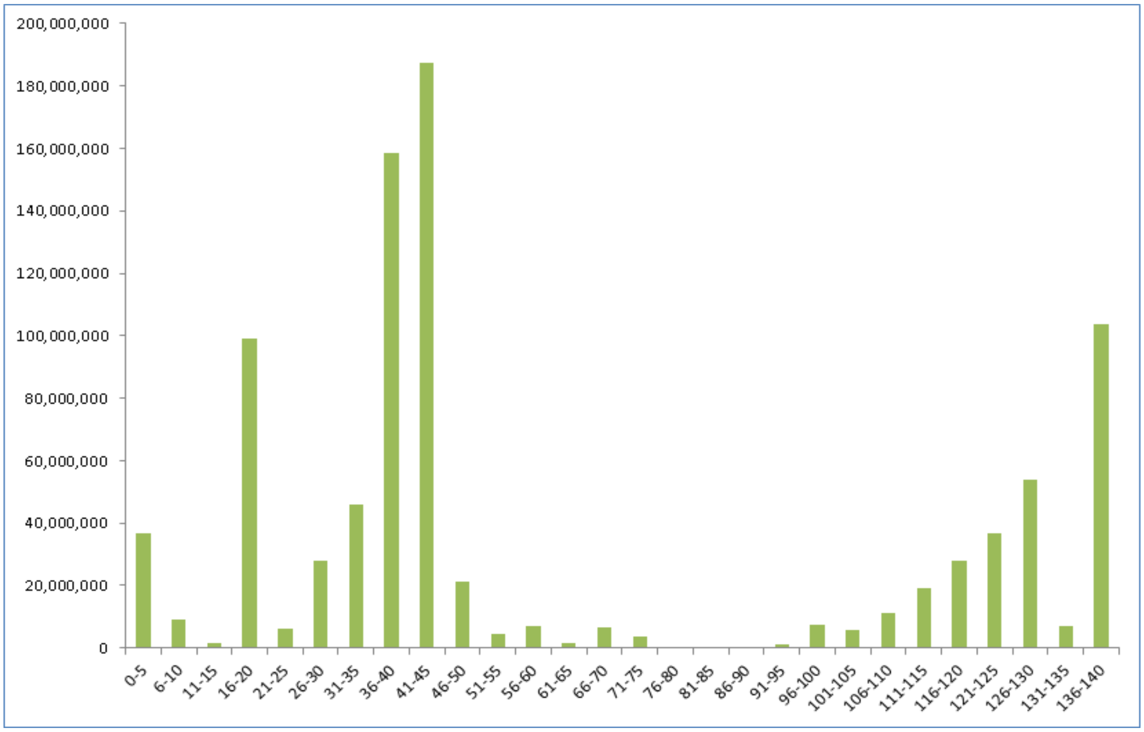


Figure 5. Total vegetation buffer area (sq. miles) by riparian buffer width (m) category

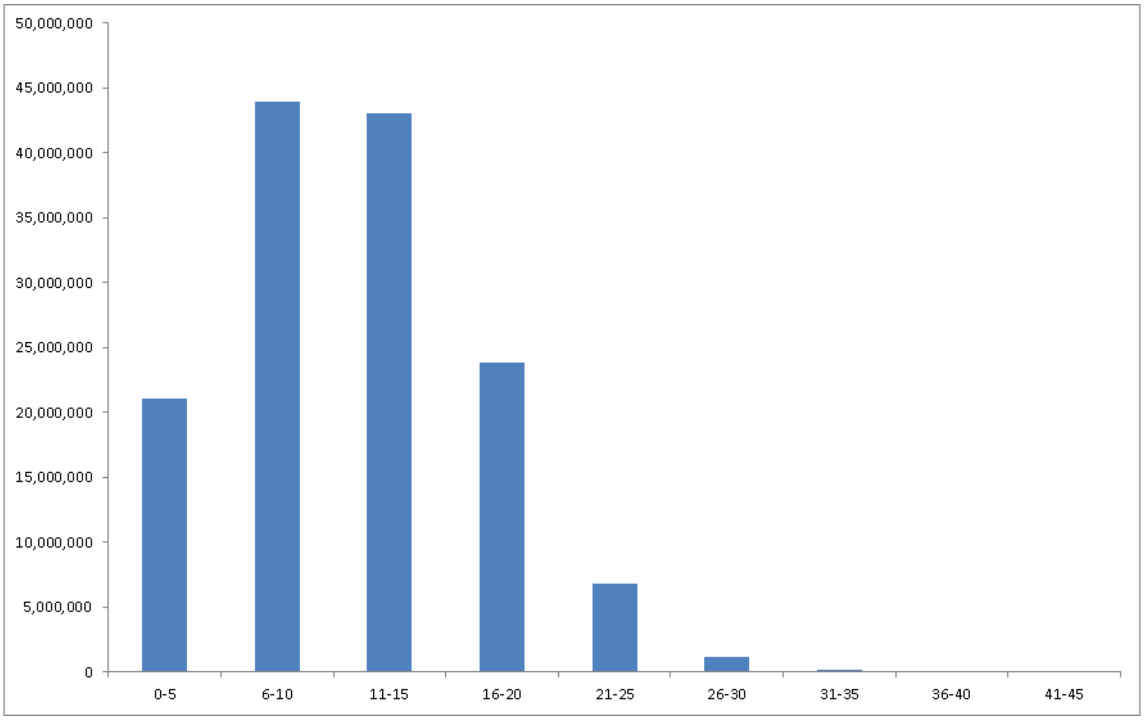


Figure 6. Total slope buffer area (sq. miles) by riparian buffer width (m) category

An attempt was made to use alternate GIS data for the Vegetation Slope Module allowing for a complete map of the central coast region. The best available data was determined to be the land use/land cover dataset of the central coast region developed by the Central Coast Watershed Studies at CSU Monterey Bay. This GIS data set has complete coverage of the Central Coast Water Board Region, but has very limited vegetation categories (Figure 7). The vegetation categories include grass, shrubs, oak woodland/mixed forest, and mixed conifer forest/montane.

CSUMB Land Use CALVEG

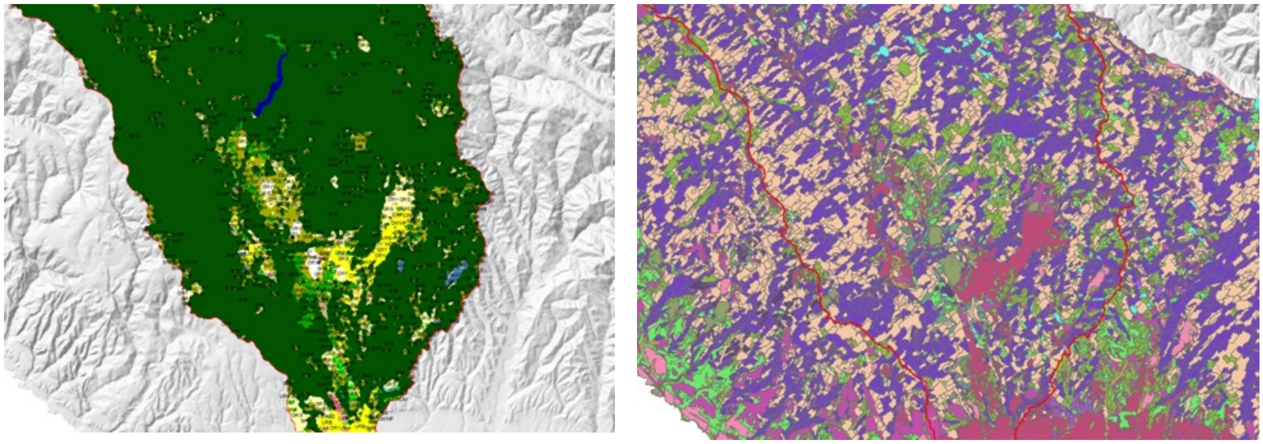


Figure 7. GIS vegetation maps used for the RipZET Vegetation Module analysis

An initial comparison was run in three central coast watersheds using CALVEG data set and the CSUMB land use data set as the source data for the Vegetation Module of RipZET. In addition, two different tree heights, 50 m and 70 m, were used for the mixed conifer forest/montane attribute of CSUMB land use dataset. This was done to see if varying the tree height of the CSUMB data set could make the results line up better with the CALVEG dataset (Figure 8). The three watersheds, San Lorenzo River, Carmel River, and Cuyama River headwaters, were chosen to represent different vegetation communities on the central coast. If it was determined that the CSUMB dataset produced data that was complementary to the CALVEG data, the plan was to run general a RipZET Vegetation Module output for the entire central coast region using.

We found that the output produced by the RipZET Vegetation Module was not comparable with the two different source datasets (Figure 8). In the Carmel watershed, dominated by oak woodland and scrub/shrub vegetation communities, the CALVEG dataset resulted in a much lower estimate of overall riparian acreage as compared with the CSUMB dataset. The opposite was true for the San Lorenzo and Cuyama River watersheds.

It was decided by the TAC that the most appropriate path forward would be to obtain funding to complete the CALVEG maps for the central coast region. The complete dataset would serve as a good baseline for vegetation mapping and monitoring in the region, and allow for a complete map of riparian vegetation function.

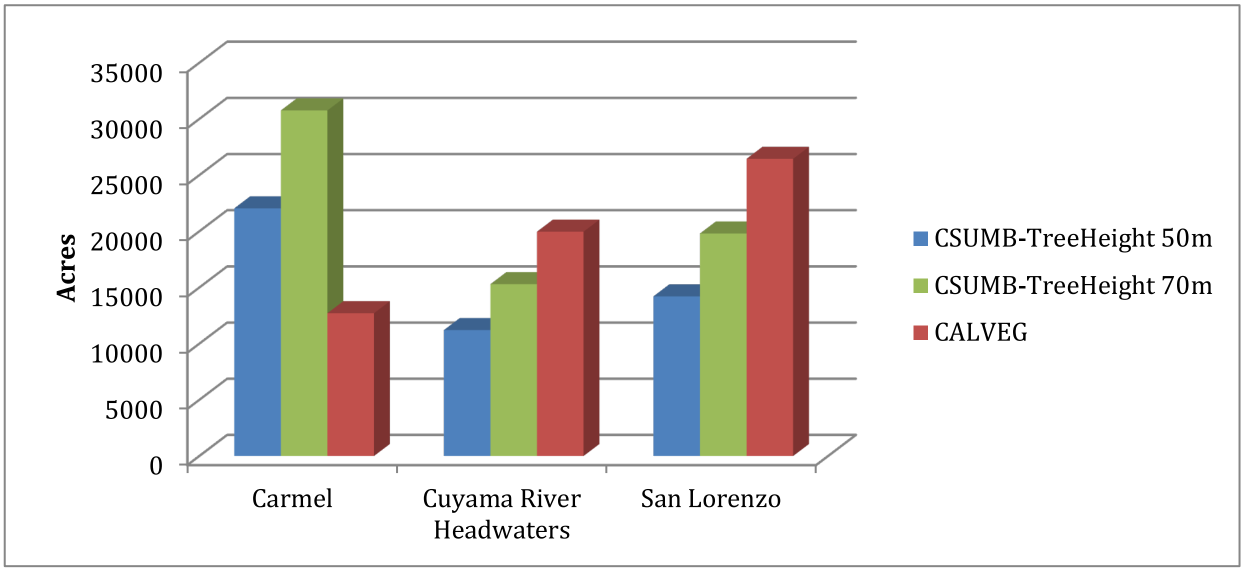


Figure 8. Estimated total acres of riparian area based on two differnt source GIS data sets for the RipZET vegetation Module

Remote Mapping of Reference Riparian Widths on the Central Coast

The study area for the analysis focused on three locations within the state water board RB3 zone; Pinnacles National Park, Fort Hunter Liggett Military Reservation, and Montaña de Oro State Park (Figure 9). The three study sites were chosen based on the lack of urban development, few roads, and relatively undisturbed watersheds that could provide intact riparian corridors. A remote sensing analysis of intact riparian corridors will provide a reference dataset of metrics with which we can compare other riparian corridors throughout the RB3 zone. The riparian metrics recorded for each of the three study sites included total riparian width, stream order, mean percent slope, and percent cover of trees. Methods for estimating each of the metrics are discussed in detail. Additionally, we investigated the potential of assessing riparian metrics within areas of the RB3 zone where the presence of dense tree canopy limited our ability to digitize riparian zones using aerial imagery. In this report we discuss various mapping methods that worked, those that did not work, and further ways to improve our analysis. Finally, we present a summary of our riparian reference metrics.

Methods

All geospatial analyses were performed using ESRI ArcGIS for Desktop Advanced, v.10.2.2 on a computer running Windows 7 Professional, 64-bit operating system, Service Pack 1, with an Intel® Core™ i7-3720QM CPU @ 2.60 GHz processor, 8.00 GB of RAM, and an Intel® HD Graphics 4000 video card.

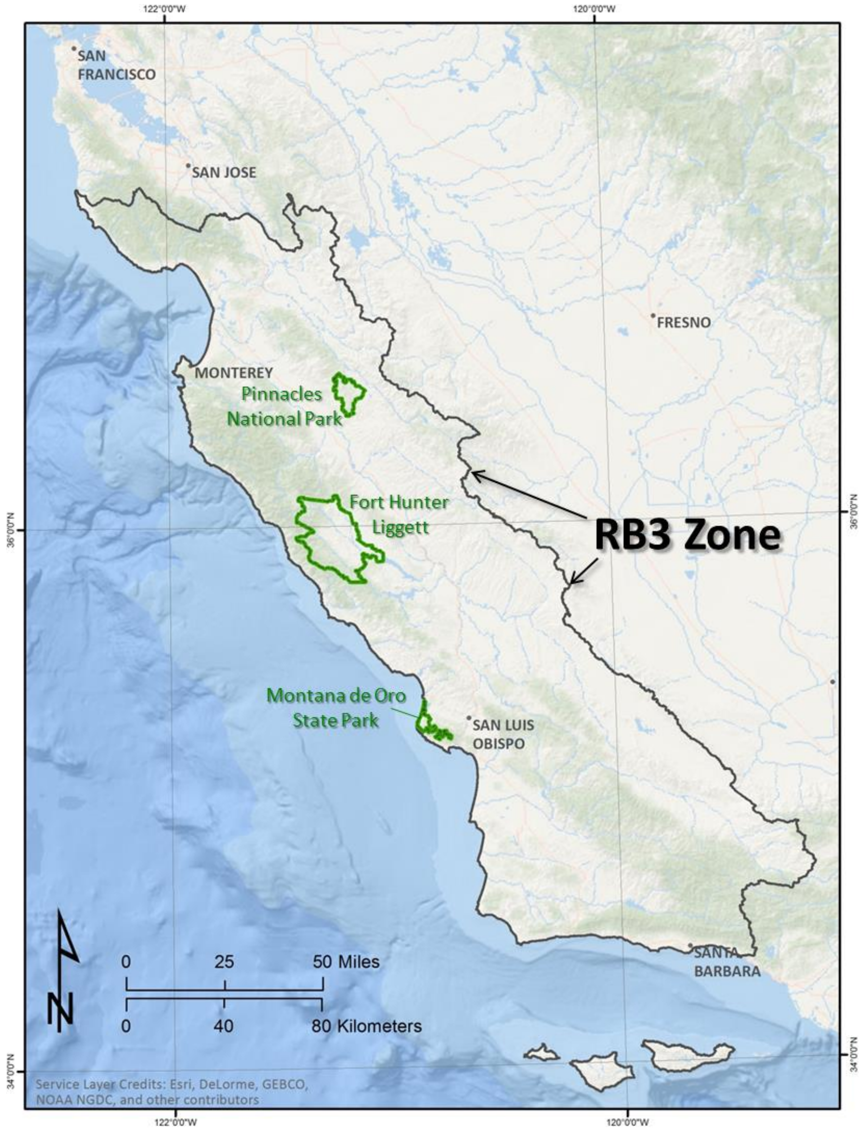


Figure 9. The study area located within the State Water Quality Board's RB3 zone. The GIS analysis focused on 3 study sites: Pinnacles National Park, Fort Hunter Liggett, and Montaña de Oro State Park.

One of the first objectives of the project was to determine the best and most efficient way of identifying and digitizing the riparian corridor. San Francisco Estuary Institute's (SFEI) Riparian Zone Estimation Tool (RipZET) produces estimates of functional riparian width along stream channels, lakes, and wetlands using three modules: hillslope, vegetation, and hydrologic connectivity. RipZET module outputs include a visual display of the boundaries of estimated functional riparian area based on field indicators (SFEI, 2015). In other words, RipZET modules are depicting areas where riparian functions are likely to be supported based on the available data, and not the observed boundaries based on direct observation. Our goal was to identify riparian boundaries based on an analysis of different sources of remote sensing data, principally aerial imagery. We chose the 4-band aerial imagery collected by the USDA National Agriculture Imagery Program (NAIP) due it's broad coverage (nation-wide), frequent updates (2 years), and collection during the growing season (typically April to June in California). Another advantage of NAIP imagery is the 4th color band, infrared, offers the ability to generate Normalized Difference Vegetation Index (NDVI) layers which provide an index of a plant's "greenness" or photosynthetic activity. This is a useful metric that can assist in both identifying the active riparian zone and estimating total tree coverage.

The sections below present a graphical outline of the steps we used in identifying the boundaries of the riparian corridor, followed by the extraction of data metrics for Fort Hunter Liggett Military Reservation. Unless noted, identical methods were employed in our analysis for both Montaña de Oro State Park and Pinnacles National Park.

Classifying Stream Order

Stream order is a measure of the relative size of streams and can be used to compare riparian metrics across broad geographical distances. Although the 1:100,000-scale USGS National Hydrography Dataset ("NHD-Plus") contains a Strahler stream order record for all streams, we decided against using this dataset due to the low resolution and lack of higher tributary streams. Instead, the 1: 24,000-scale "NHD-Hi" dataset was chosen as a better higher resolution alternative. Since this dataset does not contain a record of stream order, we modified an existing Watershed Delineation Model (using ArcGIS Model-builder) to delineate watersheds and create an ordered stream network based on a USGS National Elevation Dataset (NED) 10 m digital elevation model (DEM). The tool assigns stream networks within a watershed based on a set threshold value; the threshold value defines the minimum number of upland cells from a DEM that are required to empty into the network for the stream to be identified. For this project, the threshold value was set to approximately 750 cells. Through trial and error, this value was adjusted in order to achieve a stream network as similar to the NHD-Hi dataset as possible (Figure 10). After establishing the stream network, multiple streams from each order were selected randomly in order to locate stream segments that would be digitized for riparian corridor metrics.

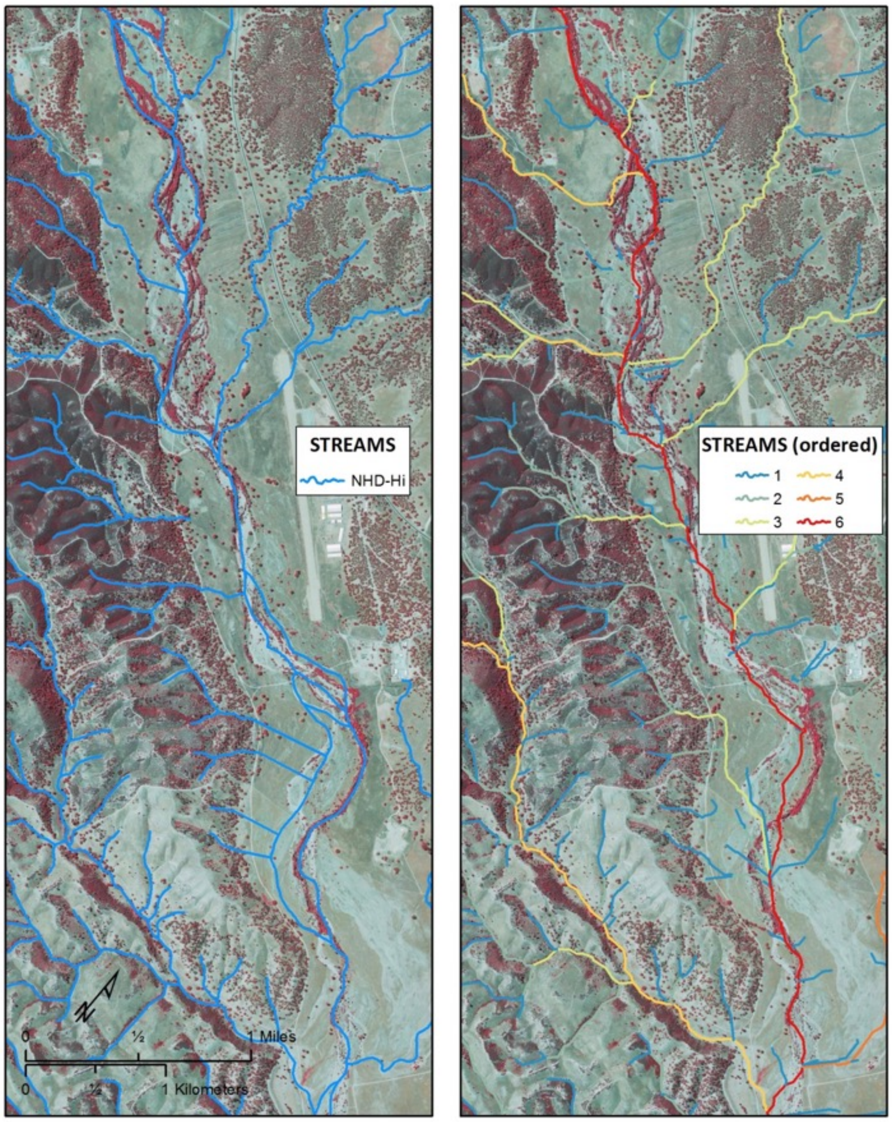


Figure 10. a) Stream network (non-ordered) from the 1:24,000 NHD-Hi dataset. b) Ordered streams created from a 10 m DEM in a custom ArcGIS toolset.

Digitizing Riparian Corridors

Initially, we investigated whether the FEMA 100 yr. flood layer and the National Wetlands Inventory (NWI) wetland layer could serve as potential baseline datasets for the digitized boundaries of riparian corridors. Since both the FEMA flood layer and the NWI wetlands inventory have broad coverage throughout California for most streams, our goal was to assess the different datasets for accuracy against the 2014 NAIP imagery. Upon further investigation we concluded that the FEMA flood layer did not contain nearly as many upper tributary streams as the NWI dataset. Additionally, the FEMA flood stage boundaries did not appear to match well with the riparian vegetation in the NAIP imagery (Figure 11). Therefore, we excluded the FEMA flood layer as a potential riparian baseline dataset.

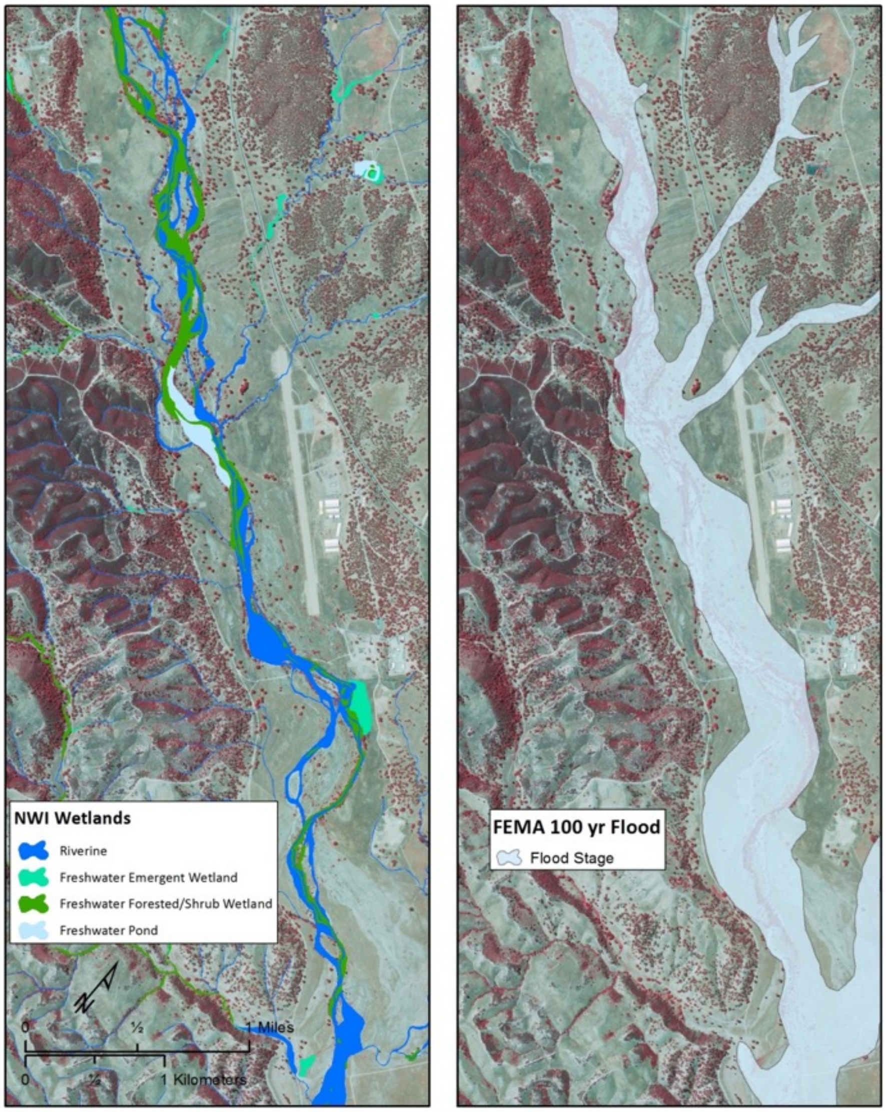


Figure 11. A comparison of digitized wetlands from the National Wetlands Inventory dataset vs. the FEMA 100-yr flood layer.

Based on a visual inspection of the NAIP imagery and NDVI we determined that, in most cases, the NWI layer accurately identified the active riparian corridor and would be useful as a draft base layer. Most low order NWI streams, however, were mapped using a standard buffer width (2-4 meters) whereas the higher order streams appeared hand-drawn and accurate with respect to the observed width of the riparian corridor. Although we recognized this as a potential problem when tallying the riparian width statistics, there was no alternative to re-draw many of the low order streams since there was a general lack of vegetation or any identifiable features that could assist digitizing. Using the NWI layer, we merged the “Riverine” and “Freshwater Forested/Shrub Wetland” classes and modified the boundaries (using Arc Editor) in areas where the riparian corridor and NWI boundary did not match (Figure 12).

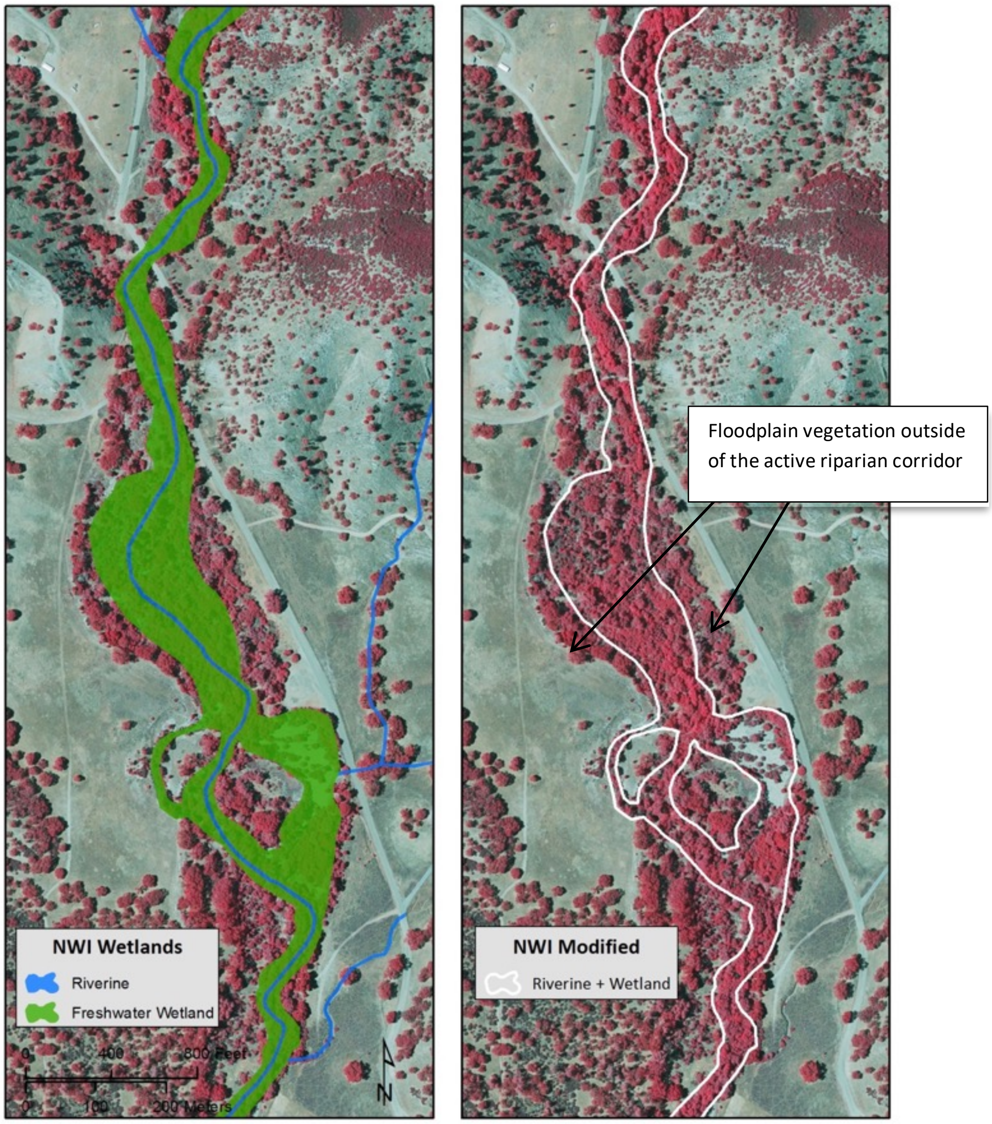


Figure 12. Example of a riparian corridor with a modified NWI polygon layer. Only the active riparian corridor was included in the modified polygon boundary.

Riparian Cross-sections

Next, at the locations of the randomly selected stream orders, NWI polygons were selected and processed with the Polygon to Centerline toolset (ArcToolbox add-in) to create a polyline dataset of centerlines. The centerlines were cleaned and assigned order values based on the ordered stream network. We chose to create new centerline polylines, in lieu of using the ordered stream network polylines, simply because the ordered stream network was based on a 10 m DEM that did not accurately match the center of polygons drawn by the NWI dataset, which was based on 1 m imagery. Also, it was important that each polyline segment be generally parallel to the outer boundaries of the polygon so that the line segments drawn perpendicular to the centerline (described in the next section) reflected an accurate cross-sectional distance of the riparian corridor. If a line was skewed relative to the riparian corridor, this would result in a larger cross-sectional distance value. Figure 13a shows a comparison of the newly created centerline versus the NHD-Hi and Ordered Streams (10 DEM) datasets. The centerline dataset clearly best represents the longitudinal center of the NWI riparian polygon.

All centerlines were then segmented every 20 m and assigned bearings. The bearings were used in a custom-built model to create perpendicular segments that spanned at least the width of the riparian corridor (Figure 13b). Next, all cross-section lines were clipped to the boundaries of the NWI riparian corridor polygons in order to calculate cross-section length (or riparian width) (Figure 14a). Lastly, the clipped cross-section lines were buffered 5 meters (10 m total width) and used as a mask to extract statistics from the slope and NDVI raster datasets (Figure 14b).

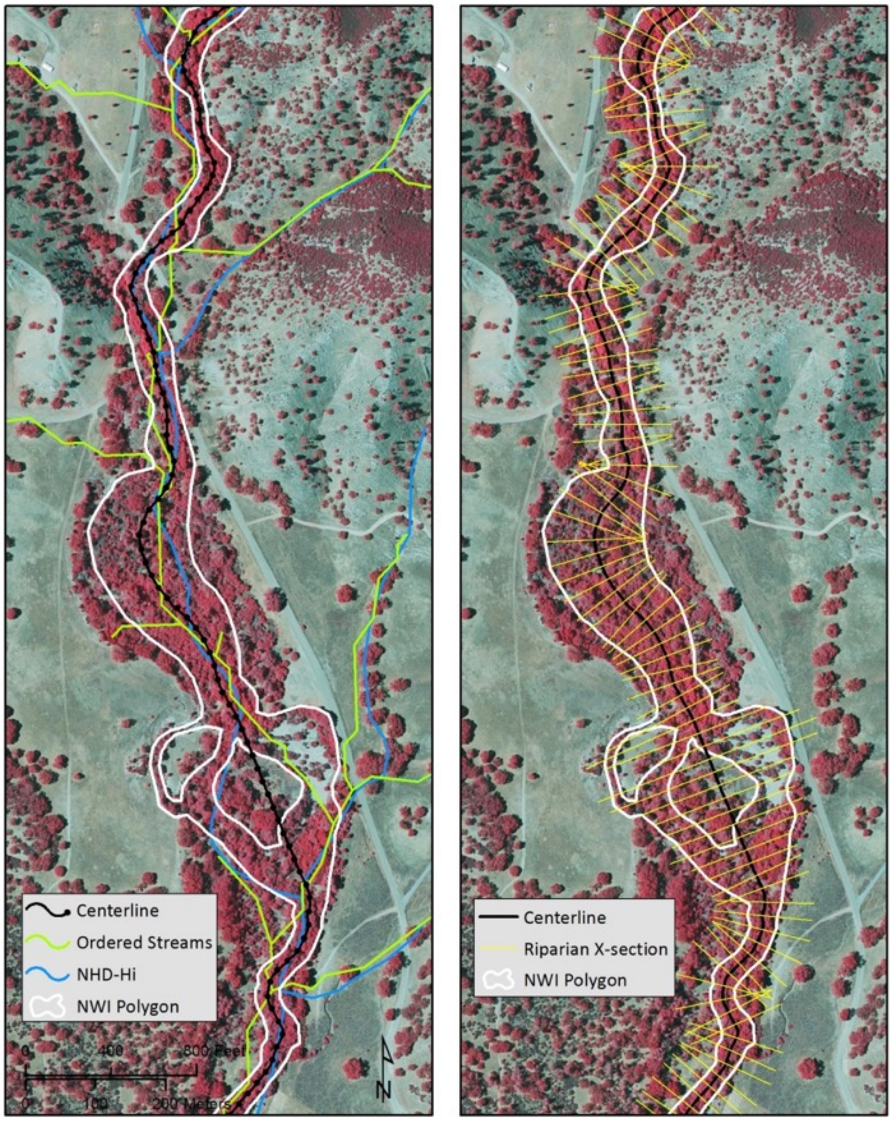


Figure 13. a) Example of a comparison of a newly created centerline (black) versus the NHD-Hi and the ordered streams dataset (created from a 10 m DEM). The new centerline dataset best represents the longitudinal center of the NWI riparian polygon. b) The centerline dataset was segment every 20 m and used to create perpendicular cross-sections (yellow).

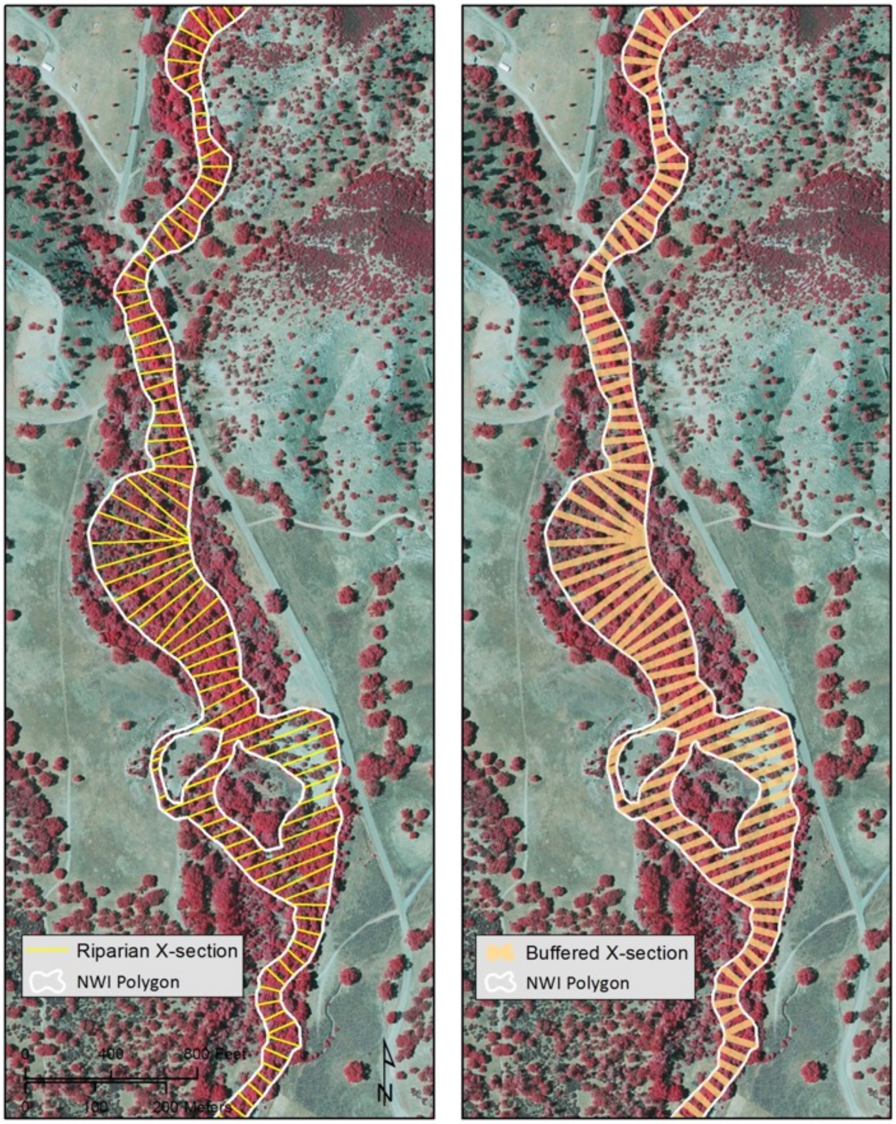


Figure 14. a) All cross-section lines were clipped to the boundaries of the NWI riparian corridor polygons in order to calculate cross-section length, referred to as "riparian width." b) Clipped cross-section lines were buffered 5 meters (10 m total width) and used as a mask to extract statistics from the slope and NDVI raster datasets.

Slope and NDVI Data Extraction

Normalized Difference Vegetation Index (NDVI) is a measure of the photosynthetic activity in vegetation. Red light is strongly absorbed by photosynthetic pigments (i.e. chlorophyll a), whereas near-infrared light (NIR) is reflected by live leaf tissue (Figure 15).

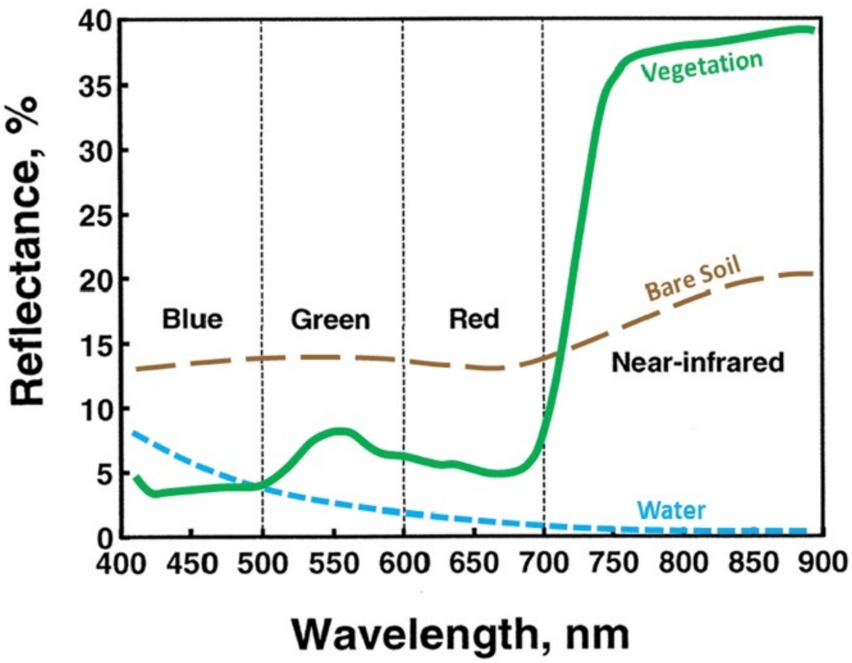


Figure 15. Plot of light reflectance vs. wavelength showing how differences in % reflectance of vegetation, bare soil, and water are amplified in the near-infrared wavelength spectrum.

By isolating the near infrared reflected light from the background light, we're left with an index of vegetation health. In the formula below, the differences in reflectances of NIR light (Band 4) and Red light (Band 1) is divided by the sum of the two reflectances.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

This compensates for different amounts of incoming light and produces a number between -1 and 1. Higher values closer to 1 indicate more dense, healthy vegetation; negative values typically indicate impermeable surfaces or shadows.

NAIP imagery (4-Band), available through the CA Dept. of Fish and Wildlife ArcGIS server, is easily converted to NDVI raster format using the NDVI Processing tool in the Image Analysis toolset (Figure 16a). We then reclassified the NDVI values into three classes:

Shadows/Grassland (-1 - -0.1), Grassland/Scrub-shrub (-0.1 - 0.2), and Trees (0.2 - 1) (Figure 16b). The reclassified raster enabled us to extract tree percent cover per transect using the buffered cross-sections as a mask. Similarly, we used the buffered cross-sections to extract average percent slope per transect (Figure 17a-b).

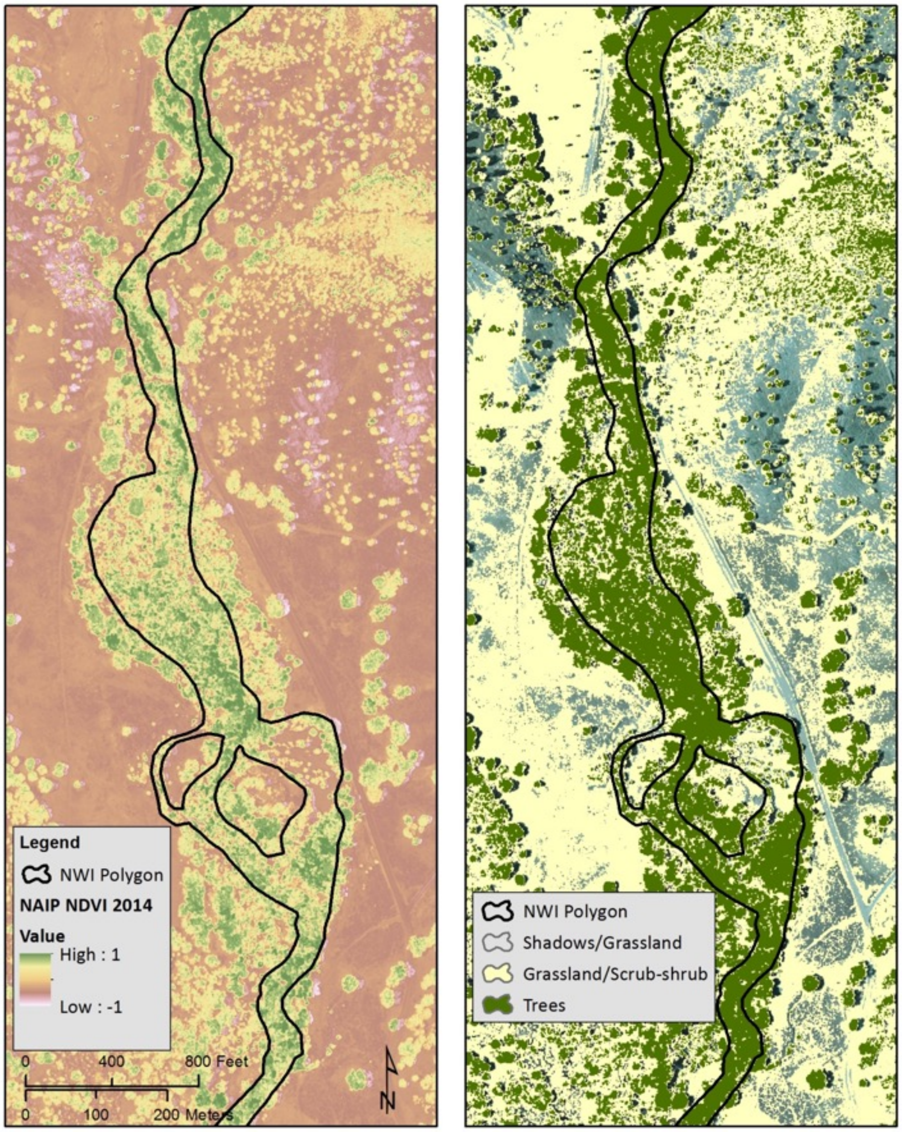


Figure 16. a) Normalized Difference Vegetation Index (NDVI) converted from the NAIP 2014 imagery. Higher values close to 1 indicate more dense, healthy vegetation; negative values typically indicate impermeable surfaces or shadows. b) NDVI raster dataset reclassified to identify different vegetation types.

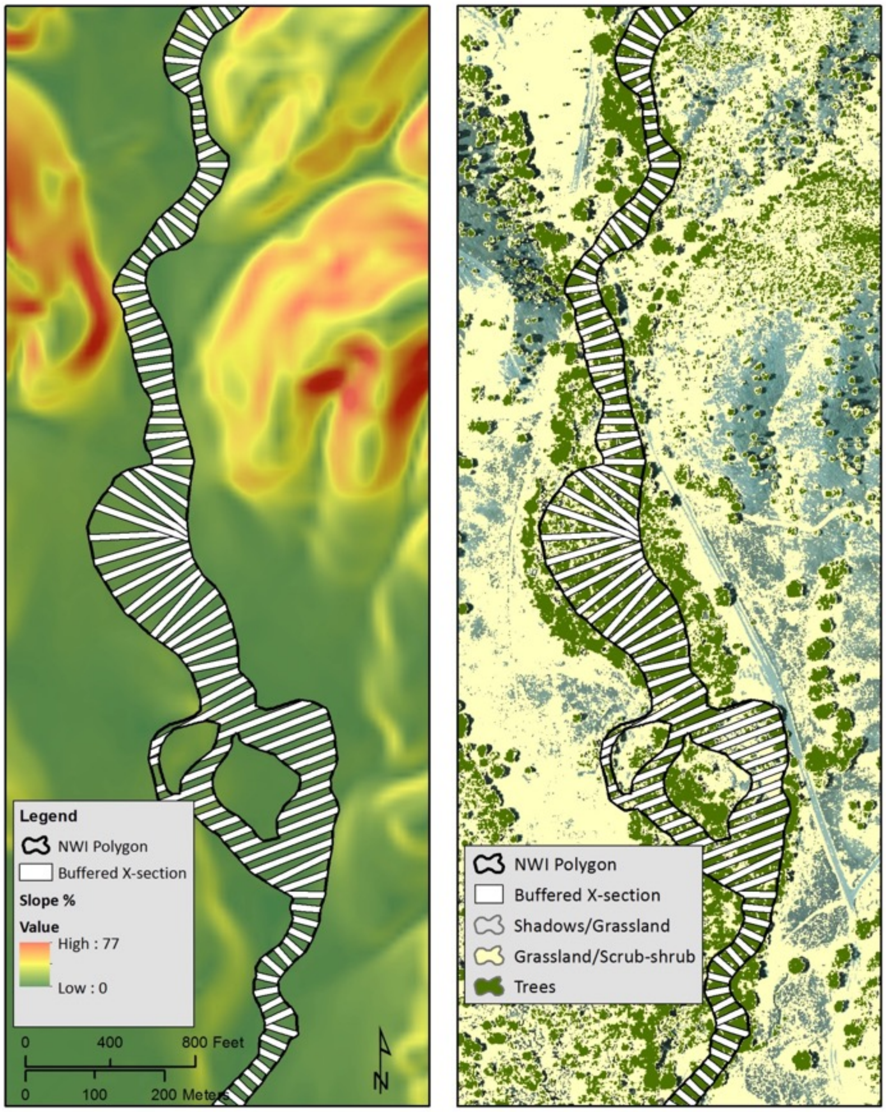


Figure 17. a) Buffered cross-sections used to extract average percent slope per transect from a slope raster dataset. b) Buffered cross-sections also used to extract percent tree coverage per transect from the reclassified NDVI dataset.

Results

A total of 1,838 cross sectional data records, including riparian width, stream order, average slope percent, and average tree percent were produced for Fort Hunter Liggett from 27 streams. We also extracted 1,749 data records from 23 streams at Pinnacles National Park and 1, 145 data records from 13 streams at Montaña de Oro State Park. A single data record included the stream order value, total riparian width, mean percent slope, and percent cover of trees. All data records were grouped by location and then averaged with respect to stream order values.

All three study sites show an increase in riparian width with increasing stream order (Figure 18). Riparian widths for stream orders 1 through 4 at Montaña de Oro, however, are significantly higher than those at Fort Hunter Liggett and Pinnacles National Park. This is likely due to the fact that nearly all the NWI-mapped streams in Montaña de Oro were digitized using standard buffer widths that did not accurately reflect palustrine habitat. Therefore, we had to re-digitize nearly all the streams in order to capture areas that appeared to match our criteria for riparian zones, which resulted in much higher widths than the standard buffer. In contrast, rarely did we need to re-digitize any of the standard buffer lower order streams at both Pinnacles and Fort Hunter Liggett.

Average tree percent cover generally increases with increasing stream order at each location, while average percent slope generally decreases with increasing stream order. Overall, the most obvious pattern appears to be higher values measured for each metric in all 4 stream orders at Montaña de Oro State Park versus Fort Hunter Liggett and Pinnacles National Park.

Frequency plots of riparian width for all stream orders within the three study sites were also produced (Figures 19-21). Pinnacles NP and Fort Hunter Liggett have mean riparian widths of 19 m and 24 m, respectively, whereas mean riparian width at Montaña de Oro is much greater, equaling 45 meters. Slope % averaged at each cross-section vs. riparian width is again similar at both Pinnacles NP and Fort Hunter Liggett (Figure 22). Generally, results show that riparian width does not exceed 50 m on any slopes above 15-20%. In contrast, results from Montaña de Oro do not indicate a strong correlation between slope and riparian width.

Conclusion

The differences observed in the results among study sites may be explained by a number of factors such as local climate, hydrologic differences based on local geology, slope aspect, etc. The three study sites, separated by approximately 50 miles, each contain unique differences that preclude us from creating a one-size-fits-all riparian reference framework. However, further riparian mapping and analysis of other watersheds or individual streams scattered across the RB3 zone will help identify a range of riparian metrics within specific “eco-regions” that may serve as references when assessing other local streams. Late in the project we began using the California Stream Condition Index (CSCI) as a means of assessing the degree of alteration of streams. This dataset could prove to be an excellent reference for the initial selection of streams and/or watersheds to be used in further analyses.

In summary, our research indicates that the base data layers used in this study (e.g. NAIP, NWI wetlands, DEM’s), all of which are publicly available and contain broad geographic coverage, were adequate for our analyses. Through the use of custom-built models in ArcGIS, we were able to create additional products (e.g. ordered stream networks, NDVI-derived tree layers) that can be used to assess riparian conditions with consistent and repeatable techniques.

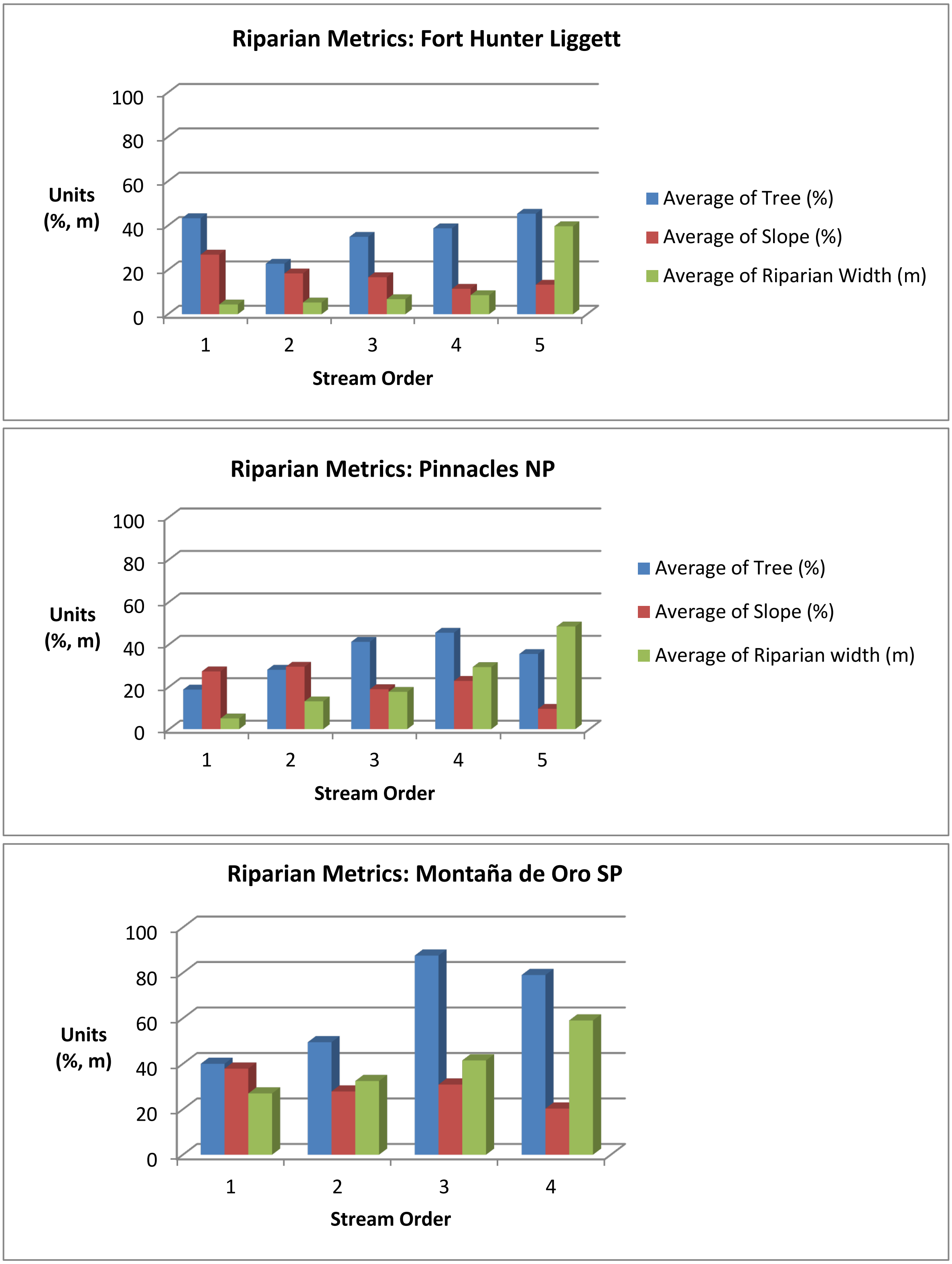


Figure 18. A comparison of all stream metrics with respect to stream order at each study site.

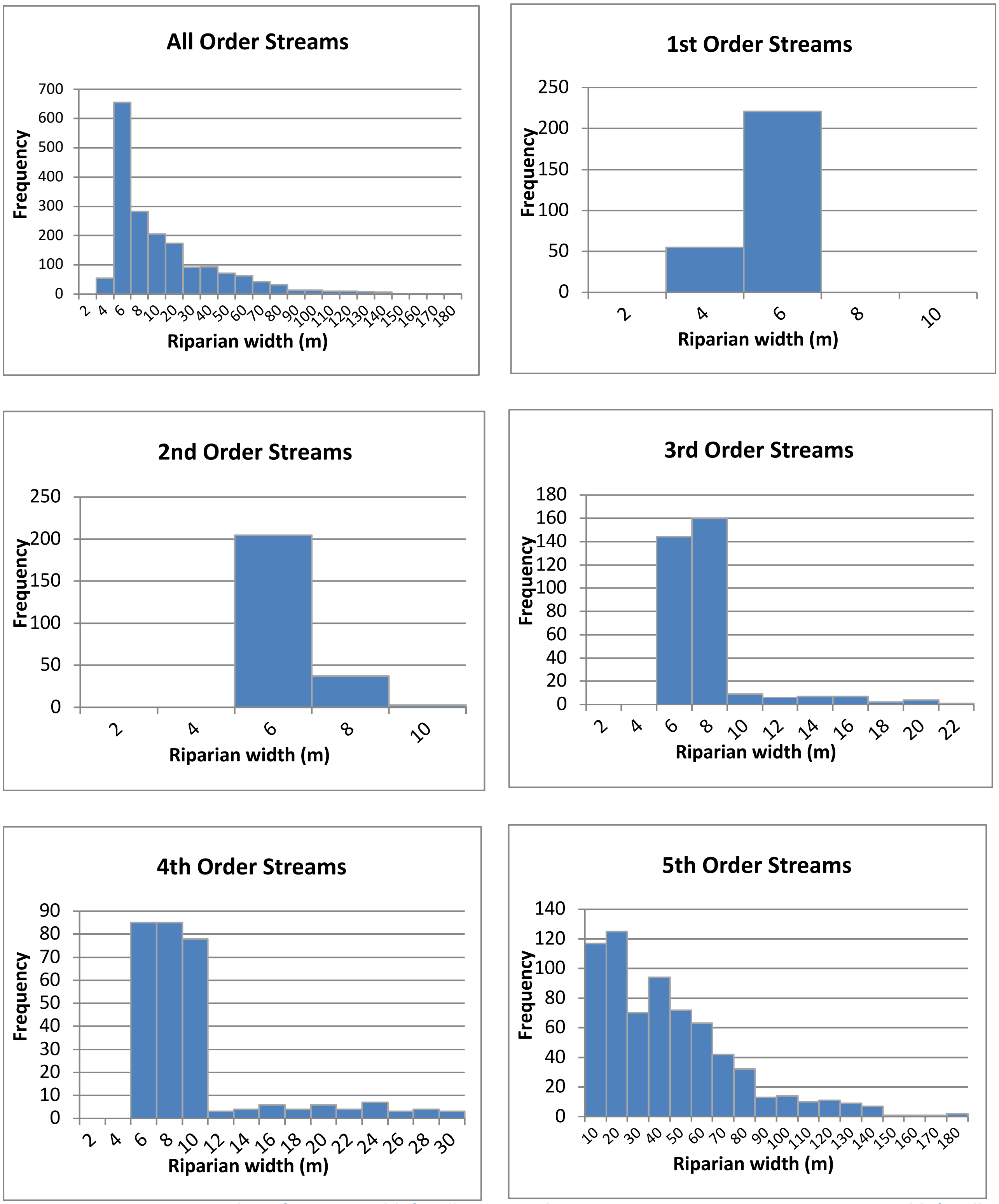


Figure 19. Frequency plots of riparian width for all stream orders at Fort Hunter Liggett. Mean riparian width for all streams equals 19 meters.

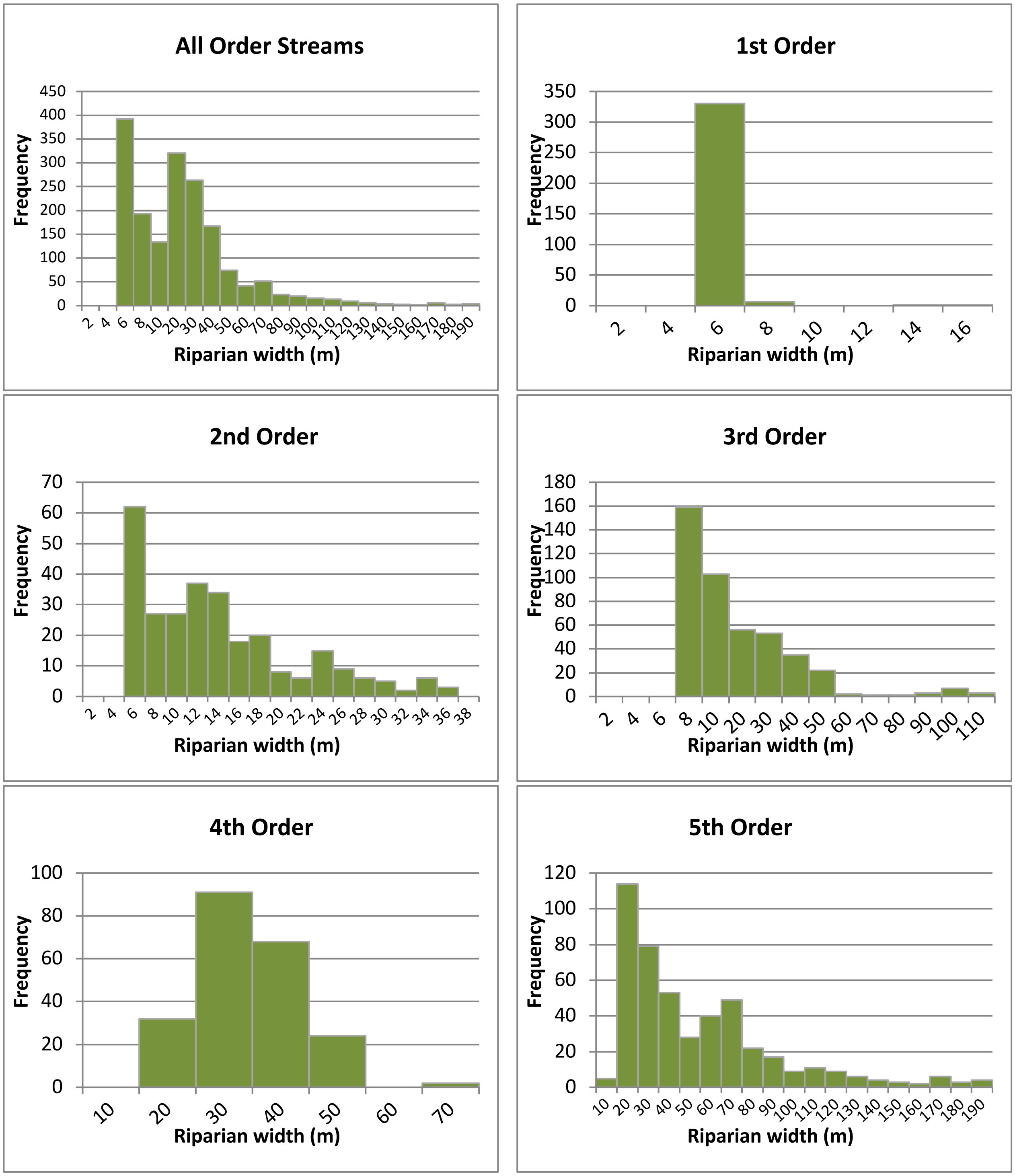


Figure 20. Frequency plots of riparian width for all stream orders at Pinnacles National Park. Mean riparian width for all streams equals 24 meters.

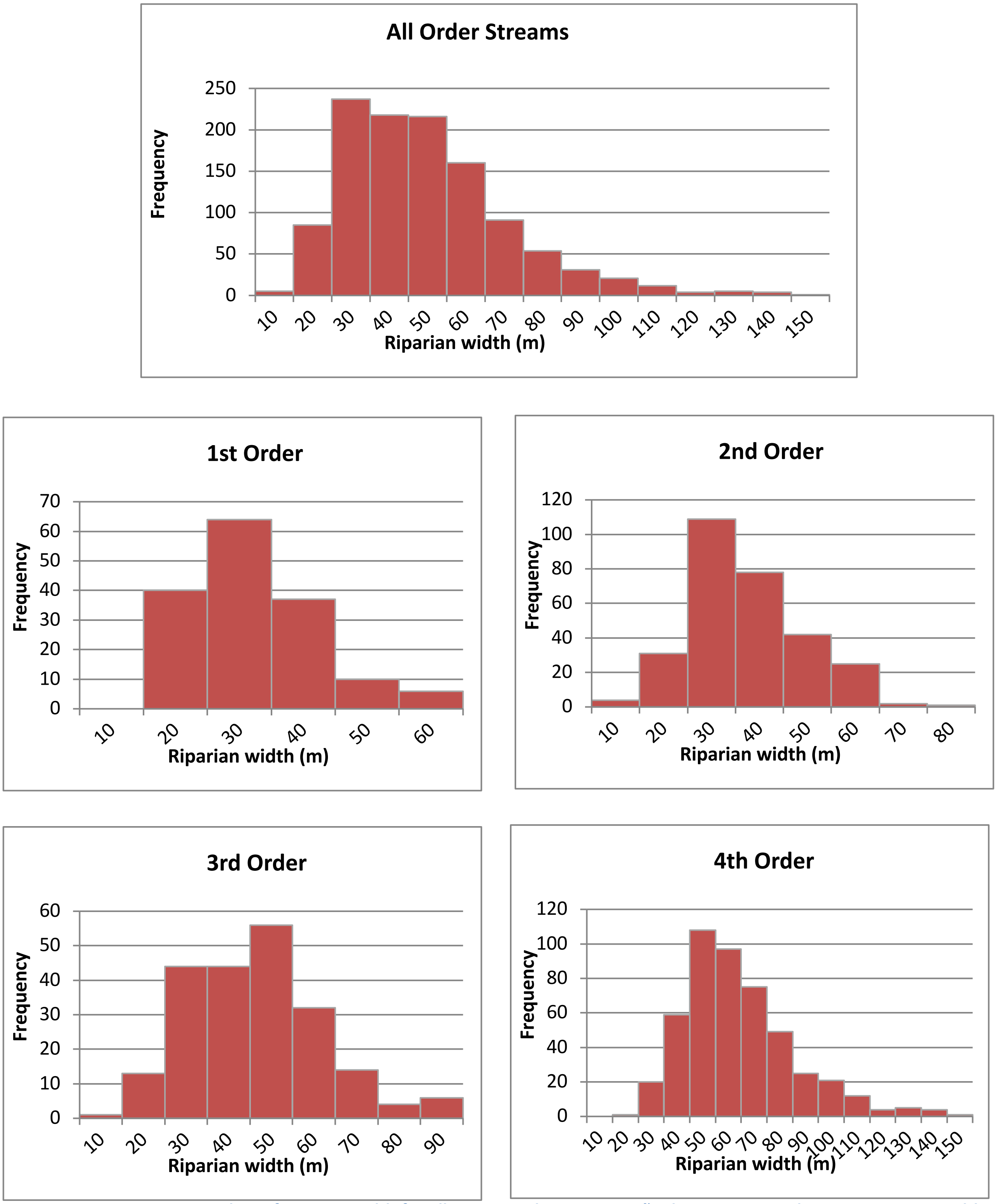


Figure 21. Frequency plots of riparian width for all stream orders at Montaña de Oro State Park. Mean riparian width for all streams equals 45 meters.

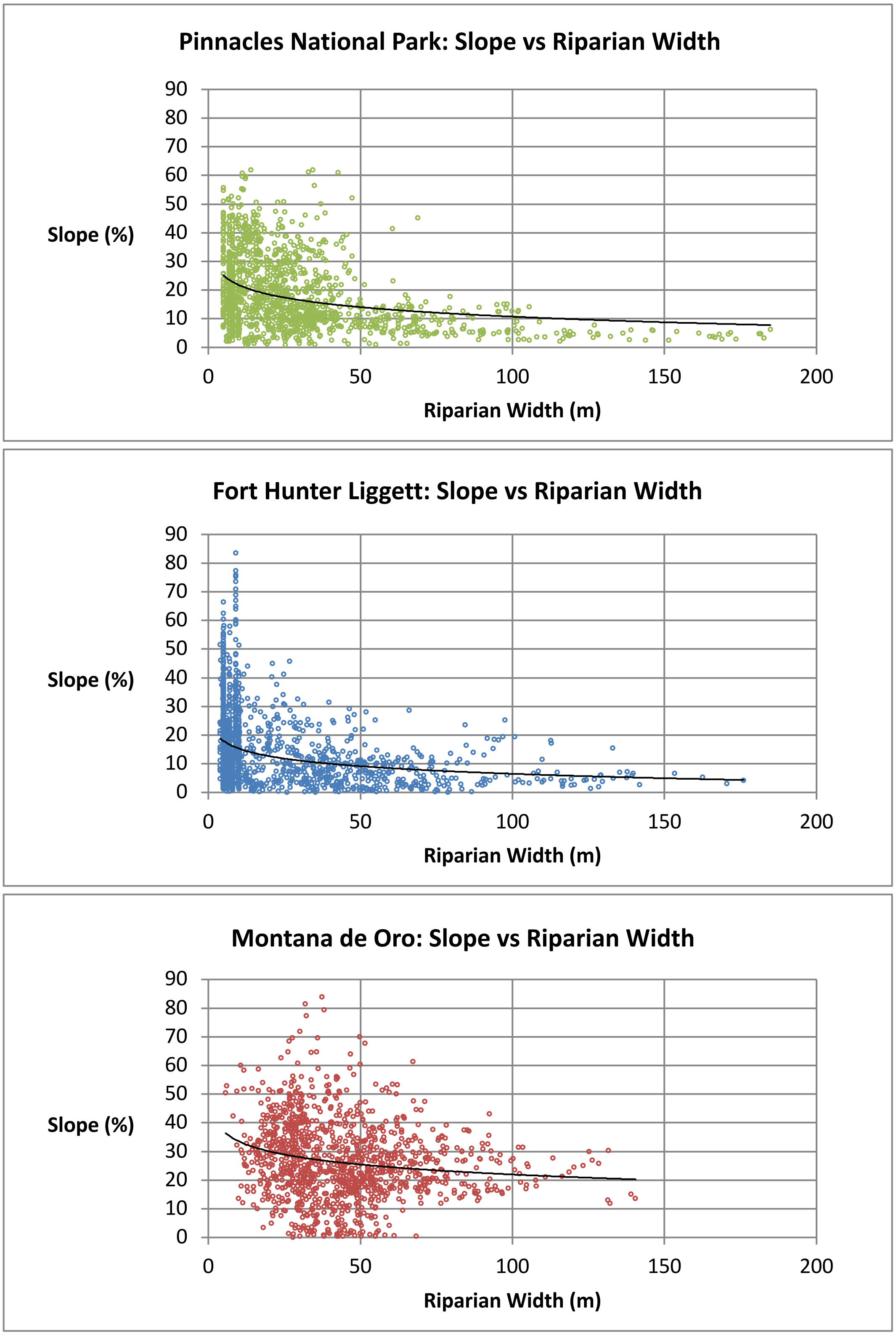


Figure 22. Scatter-plots of slope % averaged at each cross-section vs. riparian width for all study sites.

3. Development of a Riparian Rapid Assessment Method

Overview of RipRAM

The Riparian Rapid Assessment Method (RipRAM) relies on visual indicators to reliably assess physical and biological complexity, which is then used to infer ecological functioning and benefits (i.e. condition). We developed the Riparian Rapid Assessment Method specifically to assess the condition of the stream riparian zone in the Central Coast Region of California.

The objective of the SOP is to provide practitioners and regulatory agencies with a Level 2 rapid assessment tool to assess the condition of riparian resources along a stream reach. Due to potential limitations in access to a site, the SOP has been developed so that it can be used either from a bridge crossing or down in the stream and riparian zone. RipRAM enables two or more trained practitioners working together in the field to assess the overall health of a riparian area by choosing the best-fit set of narrative descriptions of observable conditions ranging from the worst commonly observed to the best achievable for a particular area being assessed. RipRAM yields an overall score for each assessed area based on the component scores of the eight metrics. RipRAM is a cost-effective ambient monitoring and assessment tool that can be used to assess condition on a variety of scales, ranging from individual stream reaches to watersheds and larger regions.

Methods of Development Process

Study sites

We selected 40 of the Central Coast Water Board's Central Coast Ambient Monitoring locations distributed throughout the Central Coast Region to develop and verify the Riparian Rapid Assessment Method (Figure 23). Sites were selected to represent a variety of habitats (including redwood forest, oak woodland, and grasslands), elevation, hydrologic regime, confinement, as well as different levels of potential stress (urban, agriculture and rural landscapes). Sites were selected to represent a wide range of condition to ensure that RipRAM can properly assess the full range of riparian condition across California's Central Coast.

Santa Cruz County Sites

Monterey County Sites

San Luis Obispo County Sites

Santa Barbara County Sites

Figure 23. RipRAM development sites along the central coast.

Riparian Assessment Method Review Matrix Testing

A thorough literature search of riparian assessment methods from around the globe was conducted in the fall of 2013. A total of thirteen assessment methods were then selected for review in a matrix format which recorded a standard suite of information about each method and tallied the number of riparian functions each assessment method addressed (Table 1). This was completed for 2 levels of access: full and adjacent (bridge).

Table 1. a) List of wetland assessment techniques investigated for use in developing a new riparian rapid assessment method (with tested methods in italics), and b) riparian functions considered in the development of the new riparian rapid assessment method.

Wetland and Riparian Assessment Methods*	Riparian Functions
• British Columbia Riparian Assessment and Prescription Procedures • Combined Habitat Assessment Protocols • *Index of Riparian Quality (QBR) and Ohio-QBR* • Montana Wetland Assessment Method • New Mexico Rapid Assessment Method • NRCS Riparian Assessment Method • *Ohio Rapid Assessment Method* • Proper Functioning Condition • *Rapid Appraisal of Riparian Condition* • *Rapid Stream/Riparian Assessment* • *Riparian Quality Index* • SWAMP-Physical Habitat (Phab) • Unified Stream Assessment • *Visual Assessment of Riparian Health* • Washington State Wetland Rating System	• Bank/Channel Stabilization • General Biodiversity and Vegetation Species Complexity • Habitat/Riparian Wildlife Support • Human Benefits: Flood Attenuation • Human Benefits: Recreation • Human Benefits: Water Quality (nutrient and sediment capture) • Large Wood Input to Stream • Leaf Litter Input to Stream • Stream/Wildlife Corridors and Habitat Connectivity • Structural Shading in Stream • Tree Shading (water cooling and microclimate control)

*See reference section for full citations

Riparian Assessment Method Testing

We settled on six methods to test on the central coast region of California. Two were from Spain (Index of Riparian Quality-QBR and Riparian Quality Index), one was from Australia (Rapid Appraisal of Riparian Condition), and three were from the U.S. (Rapid Stream-Riparian Index, Visual Assessment of Riparian Health, and an Ohio version of the Index of Riparian Quality). All six methodologies, along with CRAM, were tested at 20 sites throughout the central coast region of California. At each site, all assessments were performed first from the bridge and then in-stream during both the initial creation phase and the verification phase. This allowed us to determine whether RipRAM could be reliably used at sites with varying levels of access. This was a high priority of the Regional Board Staff during the initial drafting of the proposal for this project due to the high amount of private property and limited access on the central coast.

RipRAM Creation

A selection of the metrics from each of the 6 methodologies was selected to form the Riparian Rapid Assessment Method for California (RipRAM) v.1.0. Eight metrics were selected to represent a wide suite of riparian functions, to be easily reproducible, and to show similar values from both the bridge assessment and the in-stream assessment (Table 2).

Table 2. List of RipRAM Metrics, the source assessment methods and the name of the metric in the source method.

RipRAM Metric name	Source Method	Source full name
Metric 1: Total Riparian Cover	Ohio version of Index of Riparian Quality (QBR)	Total Riparian Cover
Metric 2: Vegetation Cover Structure	Ohio version of Index of Riparian Quality (QBR)	Cover Structure
Metric 3: Vegetation Cover Quality	Ohio version of Index of Riparian Quality (QBR)	Cover Quality
Metric 4: Age Diversity and Natural Regeneration	Riparian Quality Index	Age Diversity and Natural Regeneration of Woody Species
Metric 5: Riparian Vegetation Width	Riparian Quality Index	Dimensions of Land With Riparian Vegetation
Metric 6: Riparian Substratum Condition and Vertical Connectivity	Riparian Quality Index	Substratum and Vertical Connectivity
Metric 7: Macroinvertebrate Habitat Patch Richness	Visual Assessment of Riparian Health	Macroinvertebrate Habitat
Metric 8: Anthropogenic Alterations to Channel Morphology	NA	NA

RipRAM Verification

A second round of testing was then performed on the central coast at a new set of 20 CCAMP sites to complete the verification phase of development. The verification phase was used to determine if the draft metrics and the narrative descriptions of alternative states were (1) clear and understandable; (2) comprehensive and appropriate; (3) sensitive to obvious variations in condition; (4) able to produce similar scores for areas subject to similar levels of the same kinds of stress; and (5) tended to foster repeatable results among different practitioners.

RipRAM scores were then compared to EPA Level 3 data collected at the CCAMP sites (BMI-IBI, Vegetation, etc.) to complete the initial verification of the RipRAM.

Verification analyses

Range and representativeness

Range and representativeness describes the ability of an assessment method to characterize the entire range of conditions that exist in the real world (Stein et al. 2009, Hennesey 2007). Our first step to ensure representativeness of RipRAM was to select 40 sites across as wide a range of condition as possible using our best professional judgment and guidance of the technical advisory committee and local experts. To investigate representativeness a posteriori we initially conducted a general comparison of RipRAM Index Scores between score bin categories, best professional judgment, basic categories of stress, and hydrologic regime. This was done to look at any potential bias in the method early and to ensure the results were meeting initial expectations. We then examined the range of RipRAM metrics and the Index score in comparison with the range of Level 3 data variables collected at the CCAMP sites (BMI-IBI, Vegetation, etc.). Where necessary, we adjusted the thresholds of method's categorical bins to normalize distributions and better represent the distributions of Level 3 data (Stein et al. 2009).

Responsiveness

We tested responsiveness, a measure of the ability of an assessment method to discern good vs. poor condition (Stein et al. 2009), using Spearman's rank correlations. We examined correlations of the RipRAM Index score and several of the RipRAM metrics to multiple Level 3 data variables collected at the CCAMP sites by Regional Board Staff as well as the California Rapid Assessment Method.

Comparison Between Levels of Access (Bridge and Stream)

A correlation analysis was performed on each metric and the Index Score for RipRAM between the assessment data taken from the bridge and the assessment data taken in the stream. This was done to determine how reliable scores are that are taken from the bridge and to help with the refinement of metric scoring descriptions.

Verification Analysis Results

Range and representativeness

RipRAM Index scores showed a full range condition in the 40 sites assessed on the central coast (Figure 24). The lowest scoring site was Quail Creek near Salinas, while the highest scoring site was in the upper watershed of Scott Creek near Davenport.

RipRAM index score=0-20 RipRAM index score = 50-70 RipRAM index score =80-100

Figure 24. Example sites and associated index scores using RipRAM.

The average score for the central coast was 61, while the score bin with the most sites was 61-80 (Figure 25a). RipRAM performed well when compared to an assessment of riparian condition using best professional judgement on Google Earth prior to a field visit, showing a significant difference between the high, medium and low BPJ categories (Figure 25b). For the higher BPJ classified sites, RipRAM showed no bias for perennially flowing streams compared to intermittently flowing streams (Figure 25d). RipRAM showed a significant difference in the condition of riparian sites grouped by adjacent land use. Land use categories which in general put higher stress on riparian areas (agriculture, urban) showed lower condition than land use categories which in general put lower stress on riparian areas (grazing, open, and rural) (Figure 25c).

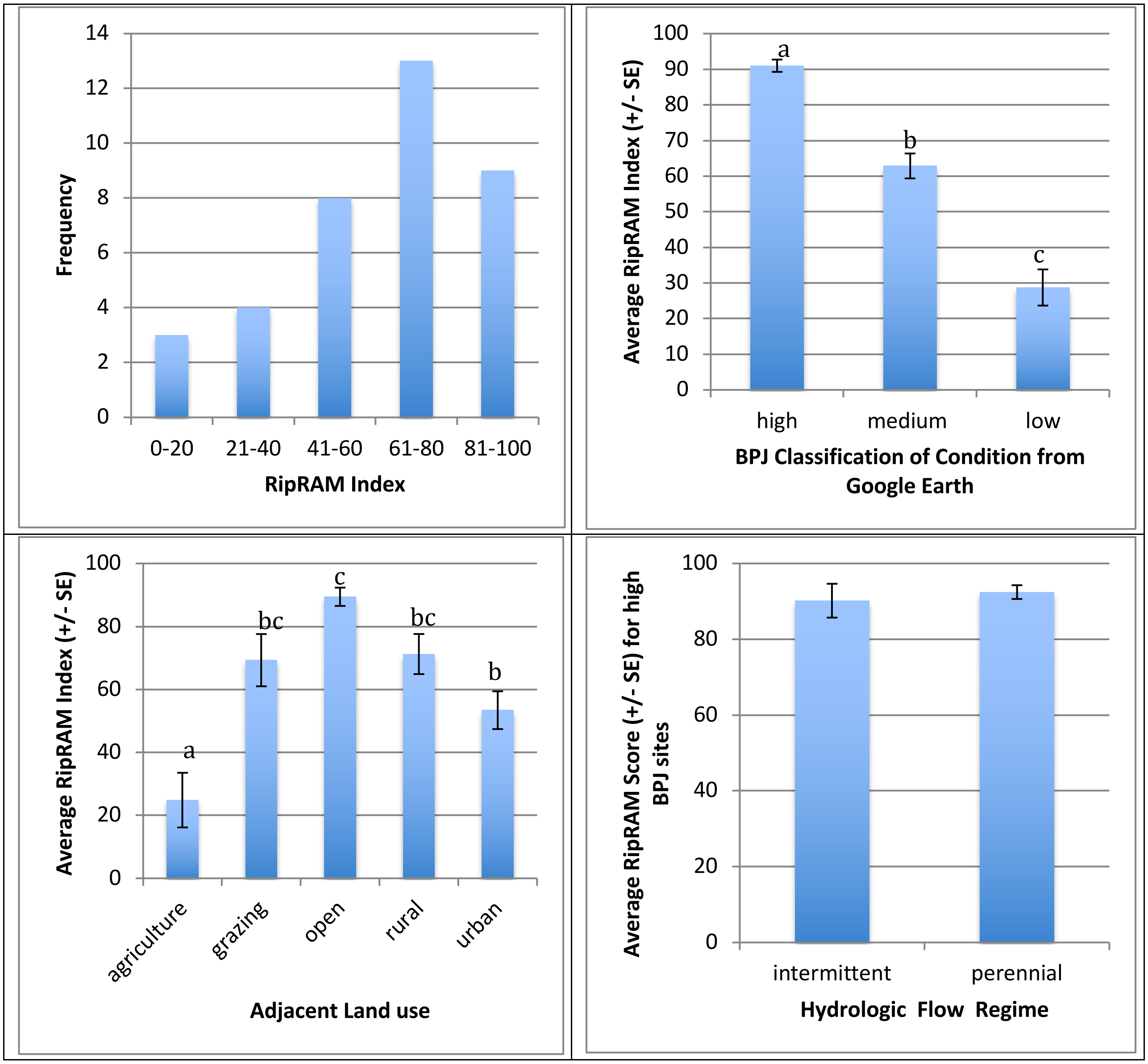


Figure 25. a) Frequency of RipRAM Index scores be scoring bin, b) Average RipRAM Index score by BPJ classification, c) Average RipRAM Index score by adjacent land use, and d) Average RipRAM Index score and high BPJ sites in perennial and intermittent streams.

Responsiveness

The L3 data variables were grouped into categories, including vegetation, shade, stress and in-stream habitat. The RipRAM Index score as well as several metrics showed significant correlations as hypothesized with Level 3 measures (Table 2). For example, the RipRAM Index Score (Figure 26a) and Metric 1 (Total Riparian Cover) were significantly positively correlated with Mean Lower and Upper Canopy Cover, while the RipRAM Index Score (Figure 26b) and

Metric 5 (Riparian Vegetation Width) were significantly negatively correlated with the Riparian Human Disturbance Index, a known measure of stress.

Table 3. Correlation values between RipRAM Metric and Index scores and independent measures of riparian area condition at the selected assessment locations.

RipRAM	L3 Variable (CCAMP)	Category	R^2 value	p value	Direction of relationship
Metric 1- Total Riparian Cover	Mean Lower (Mid-Layer) and Upper Canopy Cover	vegetation	0.24	0.01	positive
Metric 3- Vegetation Cover Quality	Mean Mid-Channel Shade and Canopy cover	shade	0.49	0.00	positive
Metric 4- Age Diversity and Natural Regeneration	Mean Upper Canopy Trees and Saplings	vegetation	0.32	0.00	positive
Metric 5- Riparian Vegetation Width	Riparian Human Disturbance Index	stress	0.46	0.00	negative
RipRAM Index	SoCal BMI IBI	in-stream habitat	0.19	0.02	positive
RipRAM Index	Mean Live tree roots cover	in-stream habitat	0.19	0.02	positive
RipRAM Index	Big Shelters cover	in-stream habitat	0.18	0.02	positive
RipRAM Index	Mean Mid-Channel Shade and Canopy cover	shade	0.41	0.00	positive
RipRAM Index	Riparian Human Disturbance Index	stress	0.34	0.00	negative
RipRAM Index	Percent Fines	stress	0.23	0.01	negative
RipRAM Index	Percent Stable Banks	stress	0.17	0.03	positive
RipRAM Index	Mean Filamentous Algae Cover	stress	0.16	0.03	negative
RipRAM Index	Percent Eroded Banks	stress	0.12	**0.07**	negative
RipRAM Index	Mean Lower (Mid-Layer) and Upper Canopy Cover	vegetation	0.49	0.00	positive
RipRAM Index	Mean Upper Canopy Trees and Saplings	vegetation	0.42	0.00	positive
RipRAM Index	Mean Lower (Mid-Layer) Canopy Vegetation	vegetation	0.36	0.00	positive
RipRAM Index	Mean Woody Shrubs Ground Cover	vegetation	0.24	0.01	positive
RipRAM Index	Mean Herbs/Grasses Ground Cover	vegetation	0.17	0.03	negative

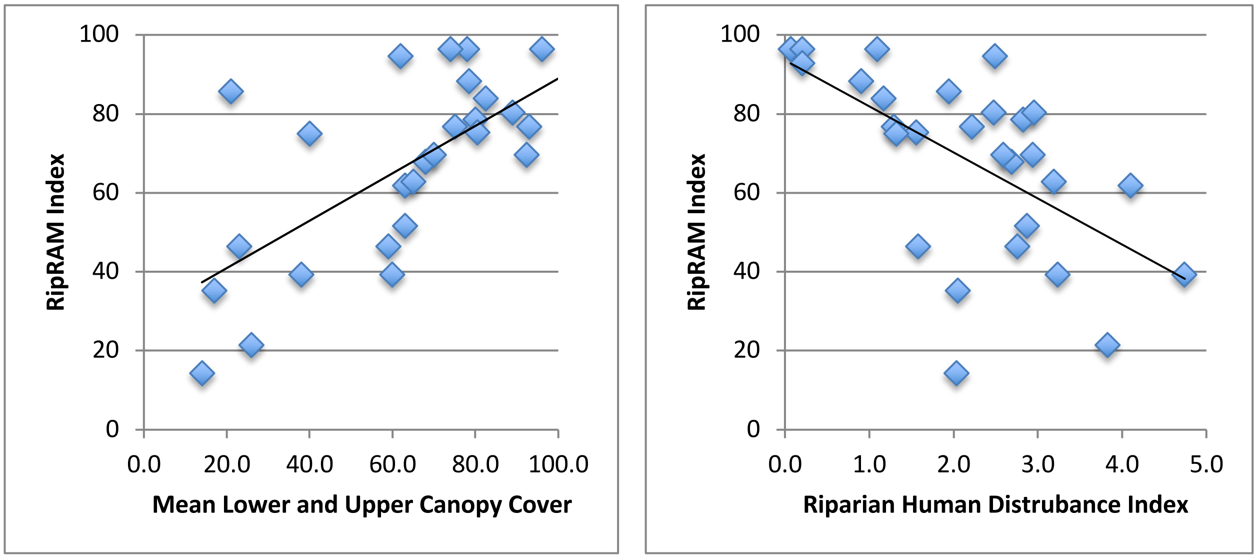


Figure 26. a) Significant correlation of RipRAM Index score to Mean Lower and Upper Canopy Cover. b) Significant negative correlation of RipRAM and the Riparian Human Disturbance Index.

RipRAM was also compared to a validated rapid assessment method for riverine wetlands, CRAM. A significant correlation was found, with an R^2 value of 0.67 (Figure 27).

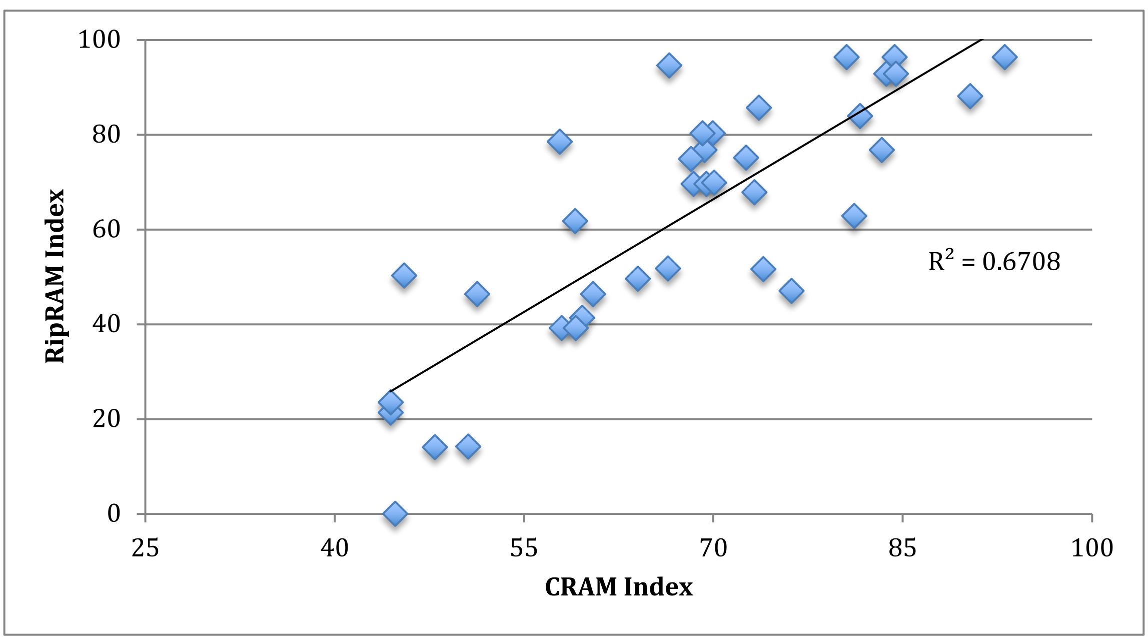


Figure 27. Significant correlation of RipRAM Index score to CRAM Index Score.

It is important to note that the assessment area of RipRAM compared to CRAM and the Benthic Macroinvertebrate Index of Biotic Integrity (BMI-IBI) are quite different. The BMI-IBI focuses on the wetted stream channel, while CRAM includes the immediate floodplain and all overhanging vegetation. RipRAM extends the assessment area even further to include the 100-year floodplain (Figure 28). As a result, the assessment methods are looking at different functions and services provided by riverine wetlands, but should demonstrate similar trajectories as our data has shown.

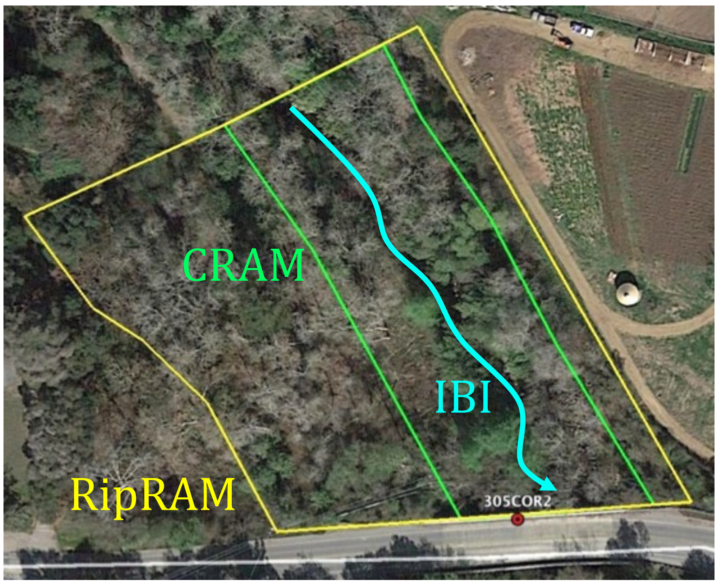


Figure 28. Comparison of the Assessment Area between an IBI, CRAM and RipRAM assessments.

Comparison Between Levels of Access (Bridge and Stream)

A comparison of results between different levels of access to a site was performed to determine how reliable scores are that are taken from a bridge crossing and to help with the refinement of metric scoring descriptions. We found strong correlations of all 7 metrics as well as the Index Score (Table 3, Figure 29). Metrics Showing the highest correlation values included Total Riparian Cover, Vegetation Cover Structure, Riparian Vegetation Width, and Macroinvertebrate Habitat Patch Richness. These metrics are often easier to interpret from a bridge or adjacent road, and can in some cases rely upon aerial imagery. Metrics showing lower correlation values included Vegetation Cover Quality, Age Diversity and Natural Regeneration, and Riparian Substratum Condition and Vertical Connectivity. This three metrics can be more variable over the course of an assessment area, so may not be visible from a bridge crossing. As we move forward with additional validation efforts for RipRAM we will work to refine the metric scoring descriptions for these three metrics in an effort to increase the reliability of scores assessed from a bridge crossing.

Table 4. Correlation values between RipRAM Index and Metrics when assessments we conducted first from a bridge and then down in the stream. All relationships were found to be significant (a= 0.05)

RipRAM Metric	**R^2 value between bridge and stream assessment scores**
Metric 1- Total Riparian Cover	0.73
Metric 2- Vegetation Cover Structure	0.71
Metric 3- Vegetation Cover Quality	0.48
Metric 4- Age Diversity and Natural Regeneration	0.54
Metric 5- Riparian Vegetation Width	0.71
Metric 6- Riparian Substratum Condition and Vertical Connectivity	0.43
Metric 7- Macroinvertebrate Habitat Patch Richness	0.63
Metric 8- Anthropogenic Alterations to Channel Morphology	Not assessed
Index score	0.90

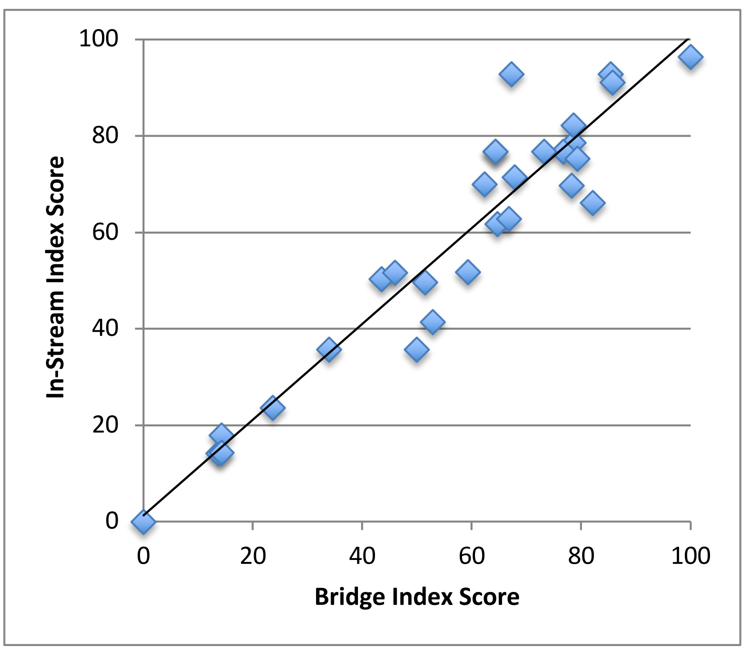


Figure 29. Significant correlation between the Bridge Index Score and the In-stream Index Score.

Evaluation

In order for a rapid assessment methodology to be trusted to provide a reliable representation of condition, the Metric and Index scores should correlate well with established Level 3 assessment protocols. RipRAM was found to correlate as predicted with many components of the CCAMP dataset, including measures of vegetation, shade, stress and in-stream habitat.

4. Morro Bay Intensification

Comparison of Automated Tree Canopy Mapping Techniques

SFEI-ASC provided technical GIS support to the Central Coast Wetlands Group (CCWG) at Moss Landing Marine Laboratory on a project titled *Development of New Tools to Assess Riparian Extent and Condition-A Central Coast Pilot Study* (SJSU acct. # 22-1508-5014). Task 2 focused on developing and evaluating a riparian mapping approach using image classification to identify trees along creeks, wetlands, and possibly floodplains, using the Morro Bay Watershed as a demonstration area. This analysis is necessary to compare multiple approaches to identifying riparian vegetation and functional extent.

The study area for this exercise was the Morro Bay watershed. Two types of imagery were used in this analysis: National Agriculture Imagery Program (NAIP) imagery and RapidEye multispectral imagery. All testing was done using ESRI ArcMap version 10.2 on a computer running Windows 7 Professional, 64-bit operating system, Service Pack 1, with an Intel(R) Core(TM) i5-3470 CPU @ 3.20GHz 3.20 GHz processor, 8.00GB of RAM, and an AMD Radeon HD 7570 video card.

It is important to understand the strengths and weaknesses of the two imagery datasets that were evaluated. The first type of imagery assessed was 4 band National Agriculture Imagery Program (NAIP) imagery, with a 1m spatial resolution. NAIP includes red, green, and blue bands as well as a near infrared band spectral resolution of 833 - 920 nm. NAIP imagery was chosen because it is publicly available at no cost and is typically used as a primary source for the California Aquatic Resource Inventory (CARI) mapping methodology. The second type of imagery assessed was RapidEye multispectral satellite imagery with a 5m spatial resolution. The RapidEye imagery has five spectral bands, including a red edge band and near infrared band with spectral resolutions of 690 - 730 nm and 760 - 850 nm respectively. RapidEye was chosen as the red edge and near infrared bands are known to be particularly useful for identifying vegetation.

Determining the type of pixel-based classification best to identify trees

The first method tested was an unsupervised classification. For this analysis we used "Iso Cluster Unsupervised Classification," an ArcGIS tool included in the Spatial Analyst extension. Preliminary unsupervised classifications were conducted on four-band NAIP Imagery, using the red, green, blue and near-infrared bands and on the RapidEye imagery, and all 5 spectral bands. During this preliminary testing, we ran the tool several times using different parameters for the number of classes, minimum class sizes, and sample intervals.

The second method tested was a supervised classification. Supervised classification relies on user-identified training points to help distinguish different classes. Training points were identified from the RapidEye Imagery. Between ten and forty points were selected for distinct land cover categories. These categories included the desired riparian tree cover class, other vegetation that we wanted to distinguish from riparian trees, and unvegetated features such as roads, oceans, and beaches. Each set of points was assigned a different value in a field called "HabitatNum", and this point feature class was used in the "Create Signatures" tool along with the RapidEye imagery. Output signatures were then used in conjunction with the RapidEye imagery in the "Maximum likelihood Classification" tool to classify the different pixels of the RapidEye imagery into the specified classes. After the first run of the classification, additional training points were added for a new class called "brown trees" in an attempt to better separate riparian from non-riparian trees. Supervised classification was also conducted on NAIP imagery. Roughly the same training points used for RapidEye were applied to the NAIP imagery to generate a signature file, although minor modifications were made to the training points to account for small differences in the georectification of the imagery. Initial classification efforts using the 1m resolution NAIP imagery resulted in "noisy" classification output, likely caused by shadows in the imagery and other spectral variation within tree stands. In an attempt to reduce misclassification, NAIP imagery was down-sampled to 5m resolution to match the spatial resolution of RapidEye imagery. Additional refinement of "training points" was conducted to improve results in an iterative fashion.

A qualitative assessment of unsupervised classifications of NAIP imagery revealed significant shortcomings. Within identifiable riparian tree groves, neighboring pixels were often classified as multiple classes (classification was "noisy"), and trees were not well distinguished from other vegetated areas. Frequently, trees were grouped into the same class as agricultural fields and vegetated or shadowed hillslopes.

Comparatively, a qualitative assessment of the unsupervised classification using RapidEye imagery reduced misclassification and "noise" relative to NAIP. However, even the RapidEye output still often grouped trees with agricultural areas and shadowed hills. Increasing the maximum number of classes allowed by the classification tool did not mitigate the misclassification.

Results from the supervised classification were of much higher quality than unsupervised classification, and consistently separated trees from other vegetated land cover types. Results clearly show that outputs from supervised classifications were able to be refined to produce significantly fewer false positive and negative classifications of trees.

Figure 30 illustrates the improved results of using RapidEye imagery (Left) for supervised classification (Right) compared with unsupervised classification of RapidEye imagery (Center).

Note the agricultural fields (A) in the eastern portion of the image are classified the same as riparian trees in the unsupervised output, but have been successfully omitted in the supervised output. The addition of training points for different tree classes improved classification results for both types of imagery.

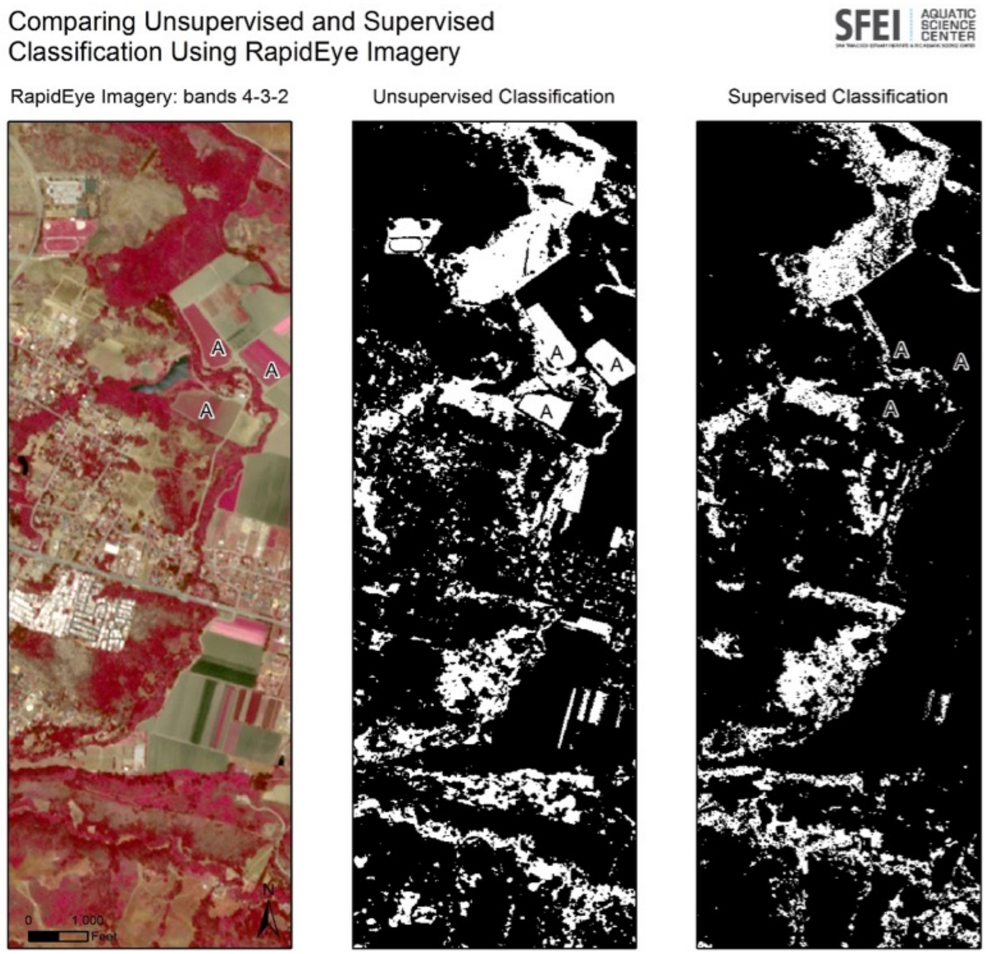


Figure 30. RapidEye imagery (Left) for supervised classification (Right) compared with unsupervised classification of RapidEye imagery (Center).

Supervised classification was performed on the original 1m resolution NAIP imagery, and on NAIP that had its resolution reduced to a 5m pixel. The reduced resolution NAIP imagery provided better classification results, possibly due to the reduction of the influence of shadows within the tree canopy. However, there was still a significant amount of noise and a number of misclassified zones within forested areas. Figure 31 compares supervised classification outputs of the RapidEye and NAIP imagery (reduced to 5m resolution). Overall, classification of NAIP tended to (A) under-classify forested areas (false negative classification) and to (B) over-classify agricultural fields and mountainous areas (false positive classification). A qualitative visual comparison indicated that supervised classification using RapidEye imagery produced the best results.

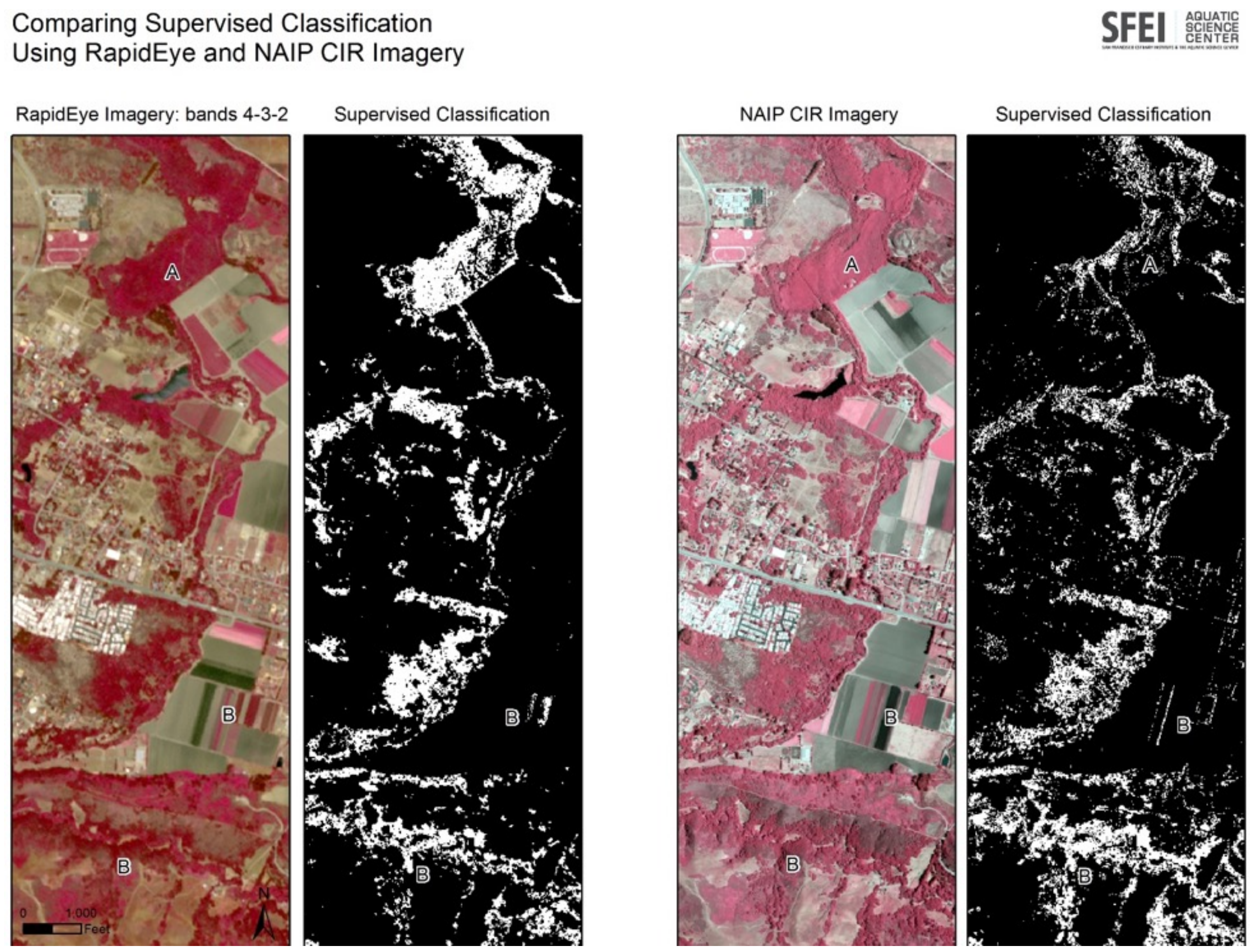


Figure 31. supervised classification outputs of the RapidEye and NAIP imagery (reduced to 5m resolution.

Based on the comparison of the RapidEye and NAIP imagery results, the team selected the supervised classification of RapidEye imagery to identify the distribution of trees in the entire Morro Bay Watershed. A 200ft buffer was then created along the stream network and used to clip out the pixels identified as trees in the supervised classification). Figure 32 shows the streams within the Moro Bay watershed within a 200ft buffer (blue outline), trees within the buffer (green), and trees outside the buffer (olive/tan) based on the RapidEye imagery.

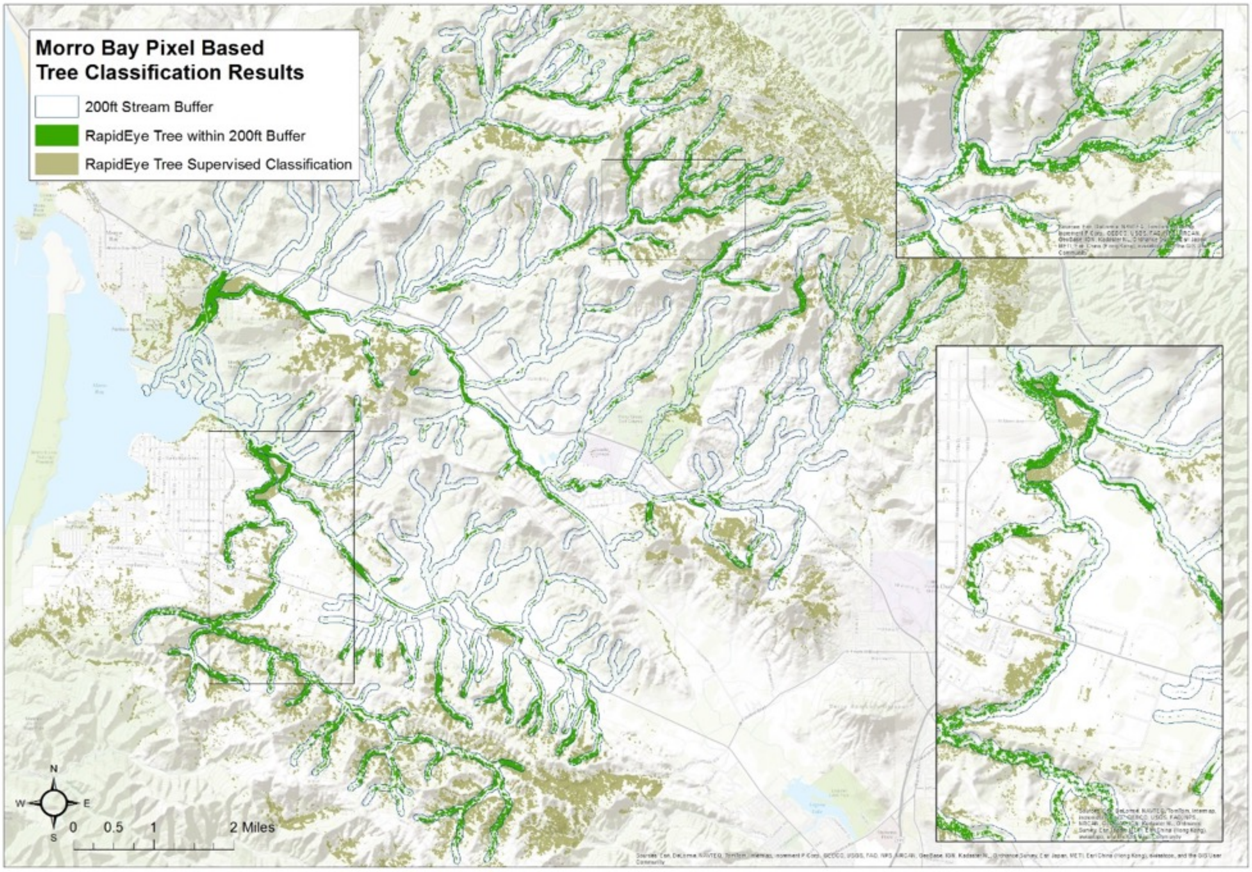


Figure 32. Streams within the Moro Bay watershed within a 200ft buffer (blue outline), trees within the buffer (green), and trees outside the buffer (olive/tan) based on the RapidEye imagery.

To further explore methods for estimating forested riparian extent, the same landscape area of the RapidEye imagery supervised classification was used to compare other estimates of riparian habitat, including the output from SFEI's Riparian Zone Estimation Tool (RipZET), and a simple, standardized 200ft stream buffer width (Figure 33).

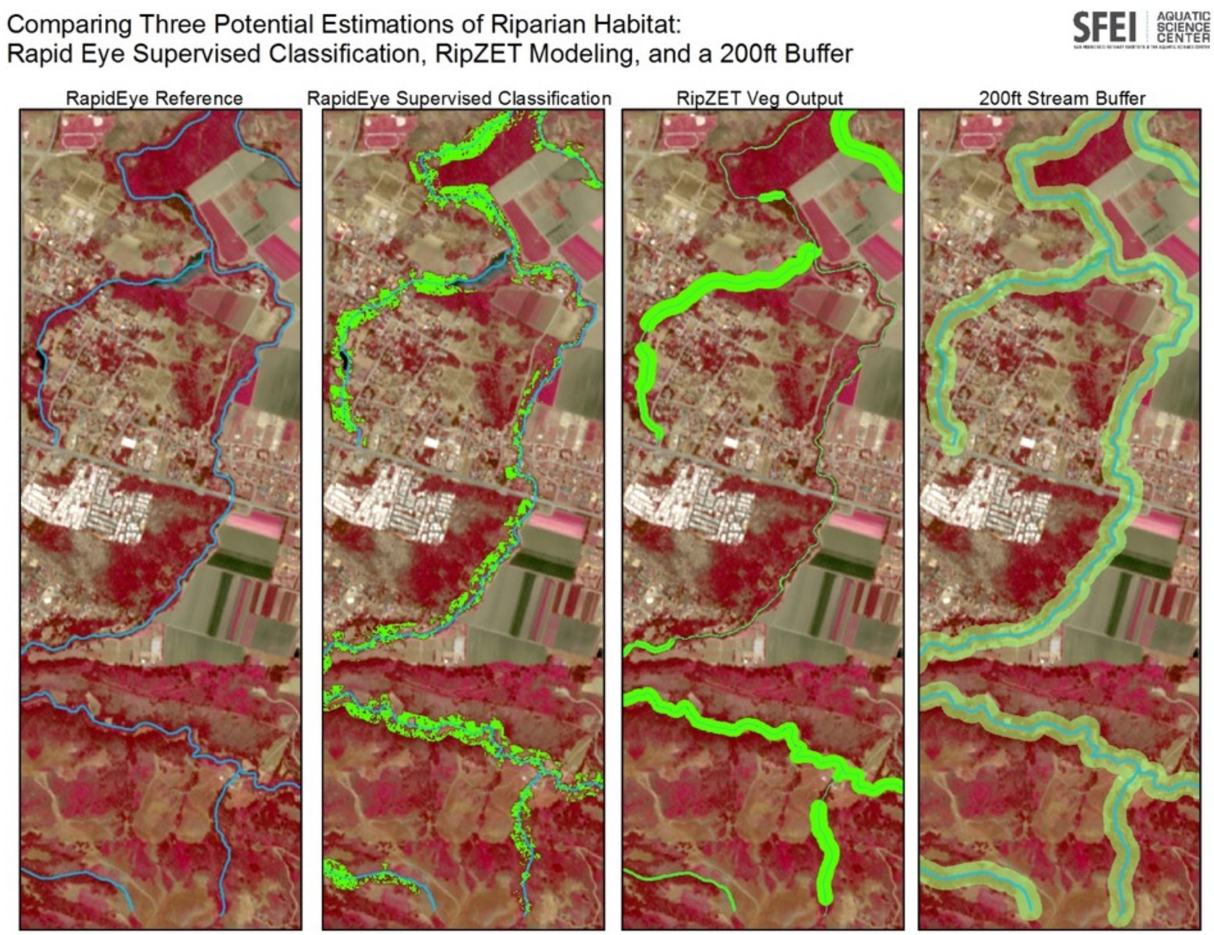


Figure 33. RapidEye imagery supervised classification compared to other estimates of riparian habitat, including the output from SFEI's Riparian Zone Estimation Tool (RipZET), and a simple, standardized 200ft stream buffer width.

It is important to note, that RipZET depends on the quality and detail of the mapped vegetation data available in ArcGIS. In this case the best available vegetation data for Morro Bay was provided by Charlie Endris from Moss Landing Marine Laboratory (MLML). This dataset was created from an expensive (and time consuming) approach of heads up digitizing and represent the best available ArcGIS map of vegetation in the Moro Bay watershed. However, this vegetation layer is still not perfect and doesn't match the high level of detail that one can see in the RapidEye or NAIP imagery. Thus, there are some areas of riparian habitat evident in the aerial imagery that are not represented in the RipZET output because of gaps in the mapped vegetation data layer. Figure 34 compares the RapidEye supervised classification imagery and the RipZET output based on the MLML ArcGIS base map.

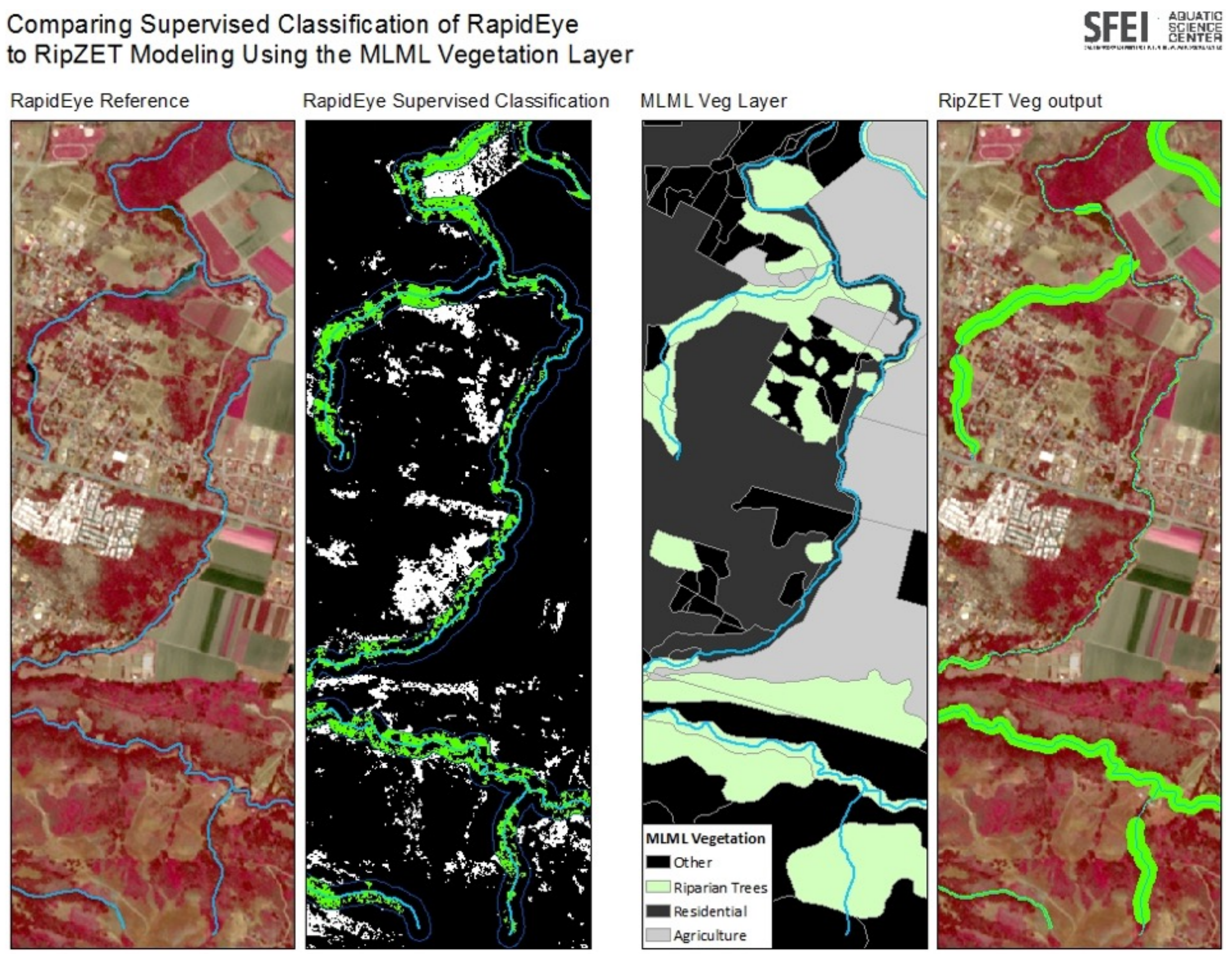


Figure 34. RapidEye supervised classification imagery and the RipZET output based on the MLML ArcGIS base map.

Because accurate, up-to-date, and complete vegetation maps are difficult to find (and/or expensive to build) in ArcGIS, accurate pixel-based classification could be particularly useful. If one could use a pixel-based, aerial imagery classification to accurately quantify trees and other types of vegetation, then riparian mapping could be improved (or updated) wherever suitable imagery is available. While RapidEye images produced superior results in this study it is costly (2012 price from EOTec was \$1.28/km^2 with a minimum order of a contiguous 500km^2 area). NAIP, on the other hand, is publicly available for multiple years. This makes NAIP a potentially attractive option despite the outputs of reduced quality.

In order to evaluate the trade-offs in data quality between NAIP and RapidEye aerial imagery, SFEI addressed a new set of questions by comparing the NAIP to RapidEye imagery using the Moro Bay Watershed as the case study area of interest. SFEI also summarized land use along the riparian corridor at 200m segments based on both sets of imagery. All analyses were conducted using the supervised classification outputs of the RapidEye and NAIP imagery (reduced to 5m resolution) as described above and depicted in Figure 31.

Comparison of tree cover between the NAIP and RapidEye supervised classification for different stream buffer widths based on area

In order to quantify and compare the pixel-based supervised classification of trees using RapidEye and NAIP imagery, the outputs of the classifications were clipped by a series of buffer widths from the stream network (5,10,15, 20, 30, 40, 70, 120, 160 m wide). The results were summarized by acres of trees identified for each buffer width and image type in a line chart (see Figure 35).

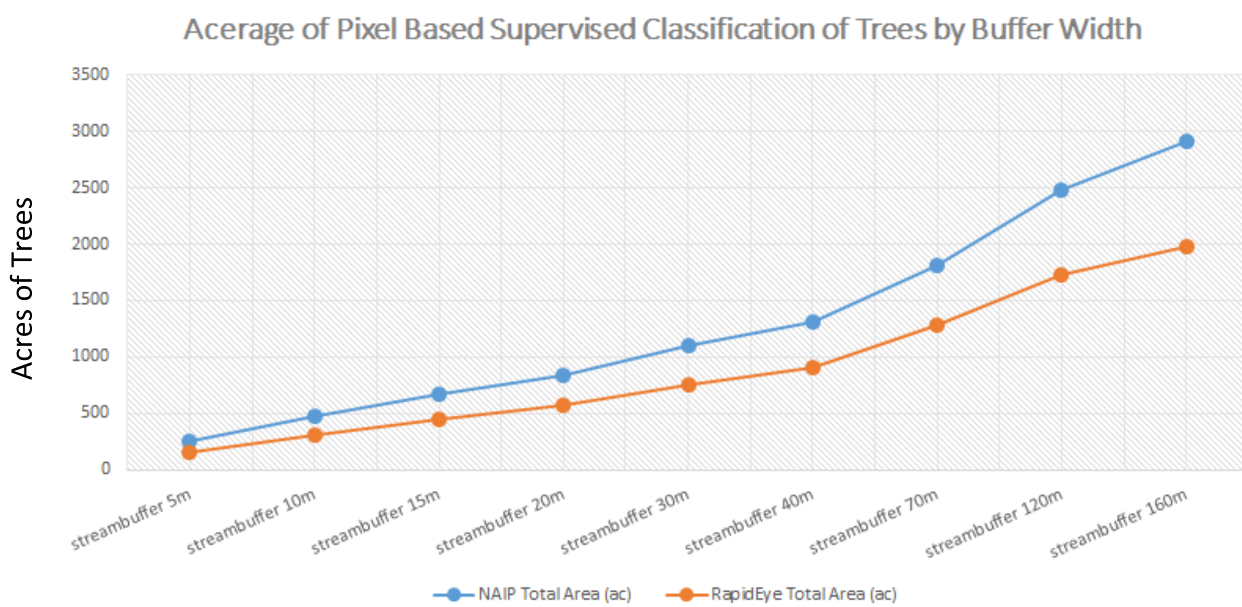


Figure 35. Comparison of the acreage of trees by various buffer widths using RapidEye and NAIP imagery.

Difference in amount of tree cover differ between the NAIP and RapidEye supervised classification for the buffered area from the RipZET vegetation output

The two pixel-based supervised classifications of trees were clipped to match the same width as the RipZET vegetation buffer extent, and the results plotted to show the acreage of trees for both sources of imagery (see Figure 36).

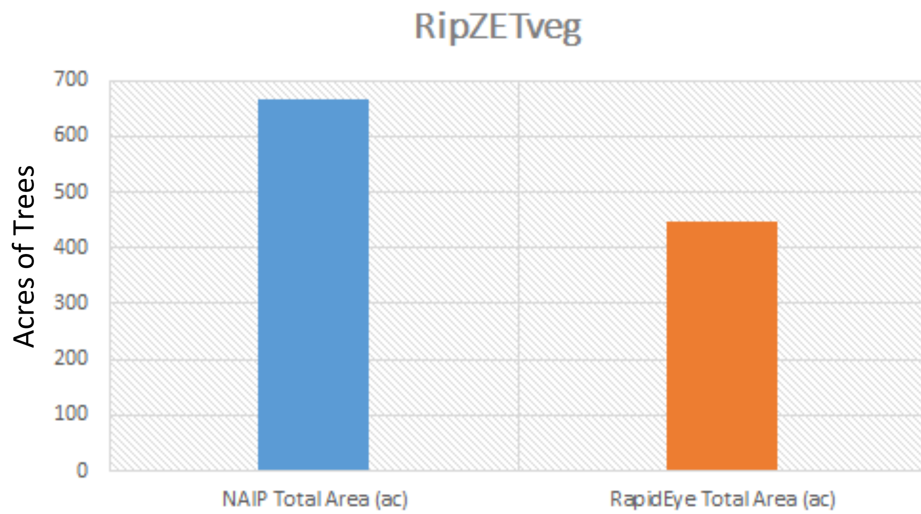


Figure 36. Comparison of the acreage of trees between NAIP and RapidEye imagery using the RipZET Vegetation Module output.

Comparison of the amount of tree cover between the NAIP and RapidEye supervised classification for the area of a stream buffer based on Strahler stream order

Buffers were created based on Strahler stream order by buffering stream reaches by their stream order multiplied by 10m. Thus, 1st order streams were buffered 10m and 5th order streams were buffered 50m. Both tree classifications were clipped by this Strahler buffer and resulting acreages of trees were graphed for both the NAIP and RapidEye imagery (see Figure 37).

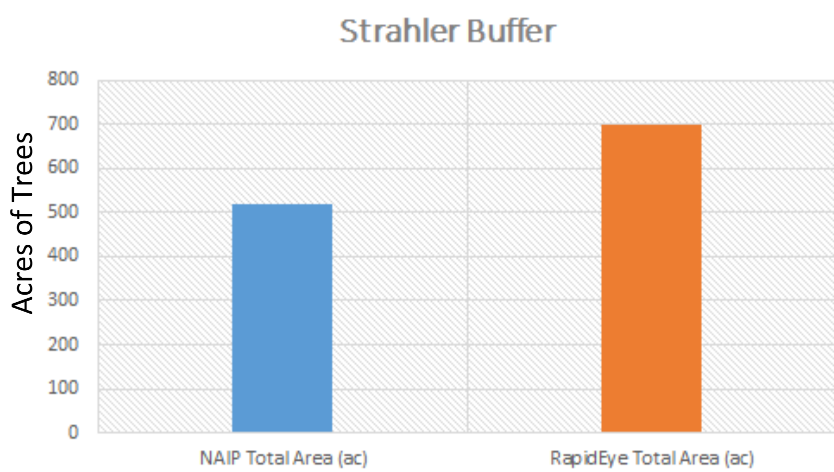


Figure 37. Comparison of the acreage of tree cover between the NAIP and RapidEye supervised classification for the area of a stream buffer based on Strahler stream order.

The acreages of trees within each Strahler stream order were also graphed for both imagery sources (see Figure 38).

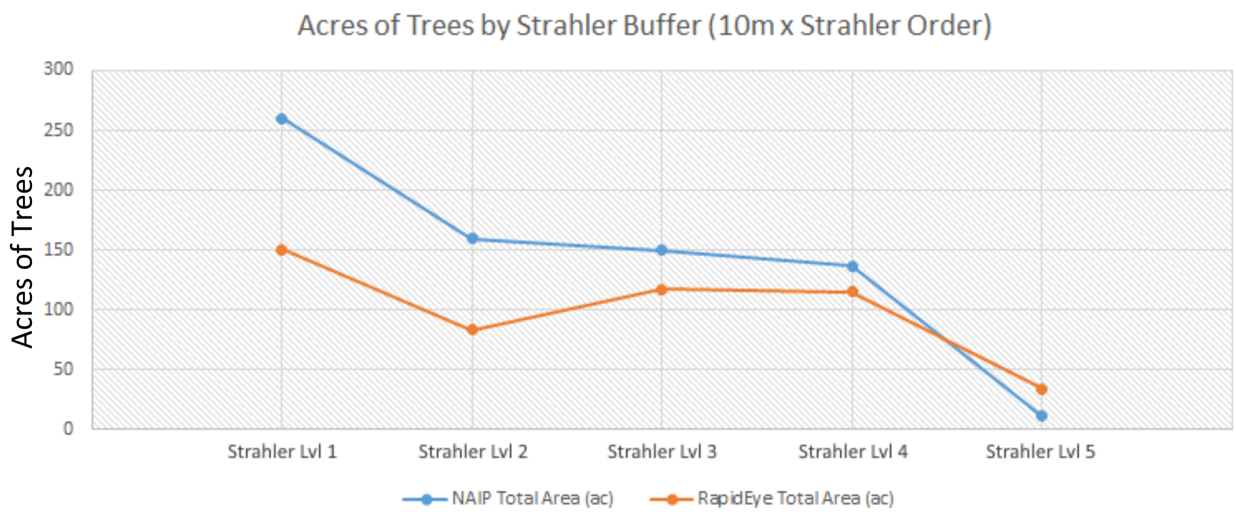


Figure 38. Comparison of the amount of tree cover between the NAIP and RapidEye supervised classification for the area of a stream buffer based on Strahler stream order.

The percent tree cover within each Strahler stream order buffer extent was also calculated and graphed (see Figure 39) in order to show differences in the aerial imagery masked (in Figure 38) by different size of buffer areas. In this Figure, as in Figures 37 and 38, Strahler stream order buffer widths were calculated by multiplying stream order level by 10m.

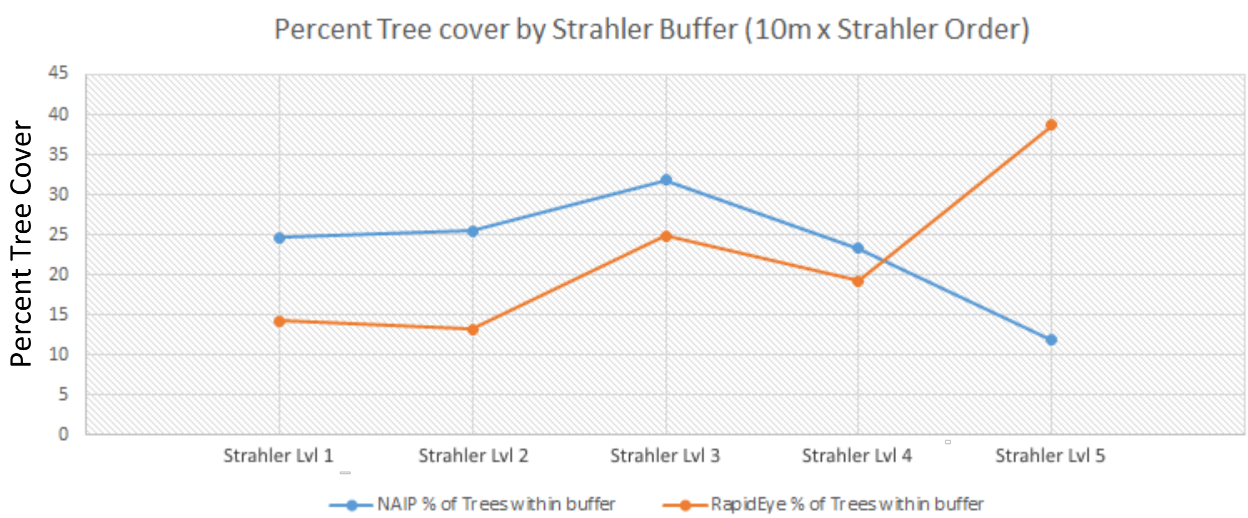


Figure 39. The percent tree cover within each Strahler stream order buffer extent.

Comparison of the percent tree cover between the NAIP and RapidEye supervised classification for 200m stream segments buffered 70m

Non-overlapping 70m stream buffer widths of 200m sections of the stream network were used to clip the pixel-based classified tree data. The results were then grouped into five categories according to the percent of tree coverage for both the NAIP and RapidEye pixel-based tree classifications. Figures 40 and 41 display the mapped results for each imagery classification: lighter shades represent lower percentage of tree cover while darker shades represent higher percentage of tree cover. A method using Thiessen polygons was used so that buffers did not overlap to ensure that they were representative of their corresponding stream segment and to avoid double counting trees where stream channels were less than 140m from one another.

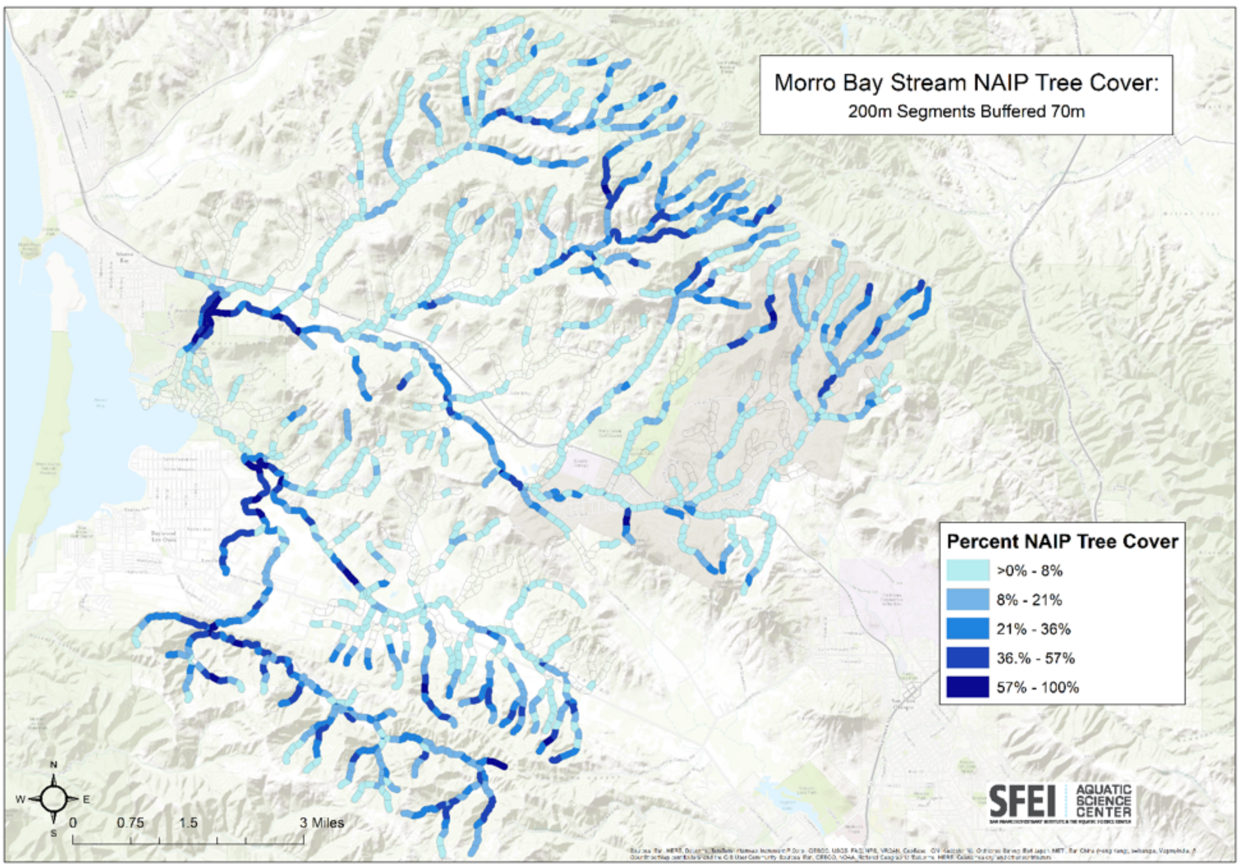


Figure 40. Percent tree cover using NAIP imagery within 70m wide, 2000m long buffer segments. Segements are color-coded into five categories.

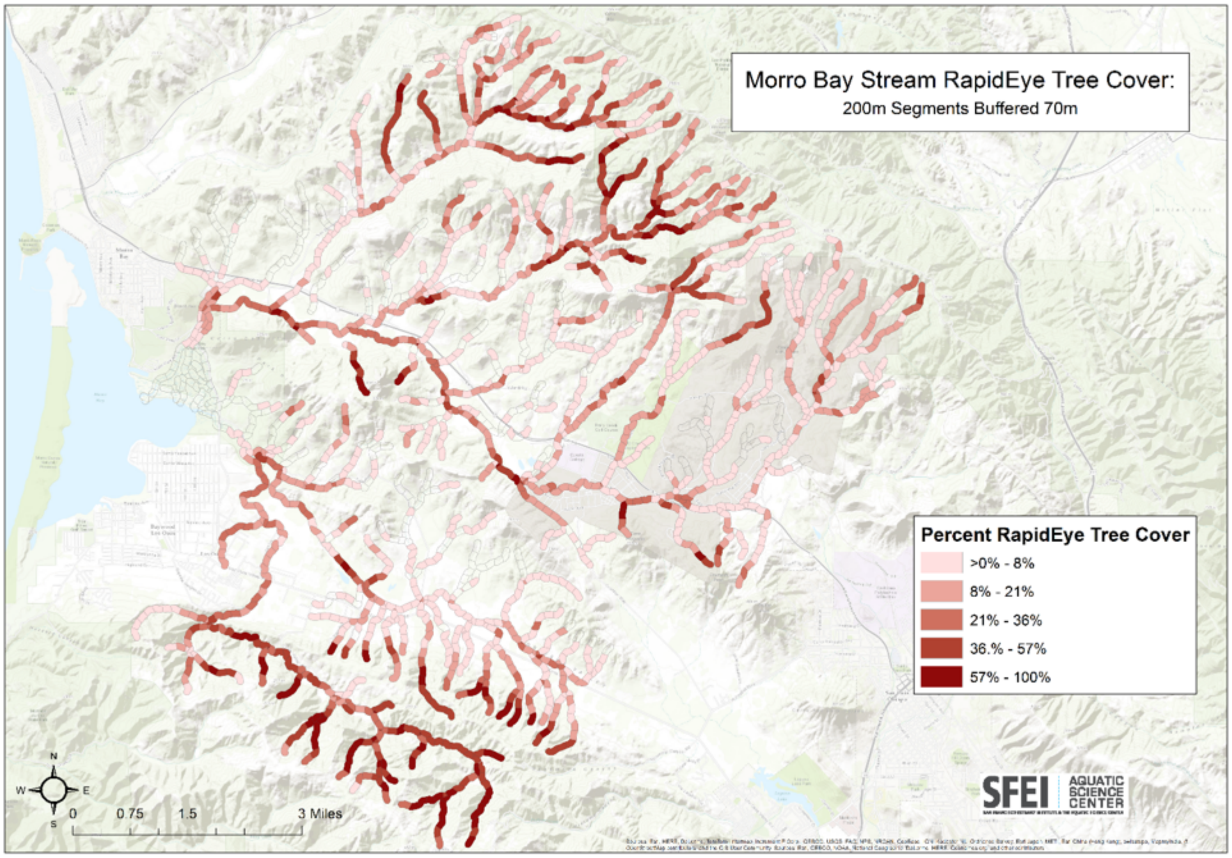


Figure 41. Percent tree cover using RapidEye imagery within 70m wide, 2000m long buffer segments. Segments are color-coded into five categories.

The difference between the percent Rapid Eye tree cover and the percent NAIP tree cover, within the buffered 200m sections (70m buffer widths), was also mapped to compare where RapidEye and NAIP detected more tree cover then the other (Figure 42). Yellow indicates where both imagery types detected about the same tree cover, red indicates where NAIP imagery detected more tree cover than RapidEye imagery, and green indicates were RapidEye imagery detected more tree cover than NAIP imagery.

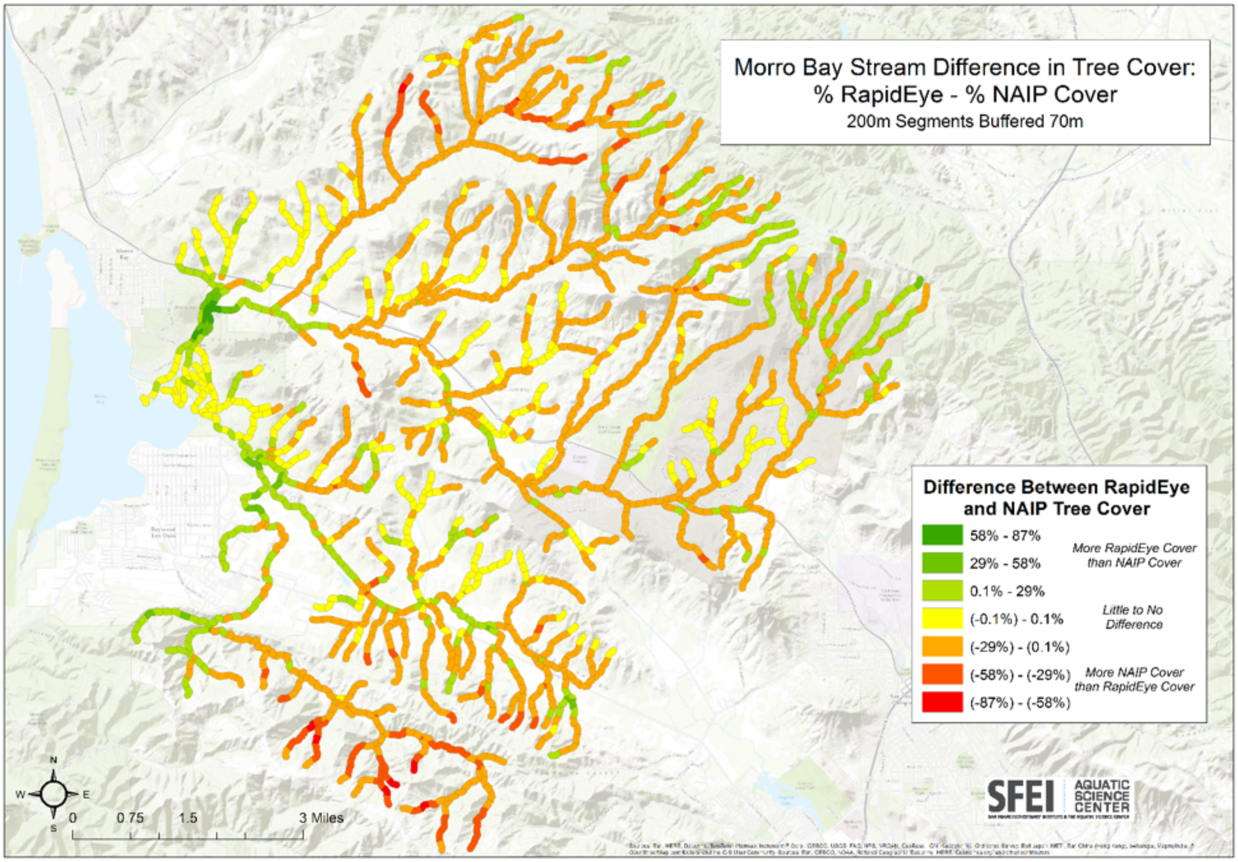


Figure 42. The difference between the percent Rapid Eye tree cover and the percent NAIP tree cover, within the buffered 200m long sections (70m buffer widths).

Comparison of the percent of tree cover compare between the NAIP and RapidEye supervised classification for 200m stream segments buffered according to their Strahler stream order

Stream segments were buffered by multiplying the Strahler steam order number by 10m. Figures 43 and 44 show the percent of tree cover, in 200m stream segments, employing variable buffer widths by Strahler stream order for the NAIP and RapidEye pixel-based tree classifications respectively. Lighter shades represent lower percentage of tree cover while darker shades represent higher percentage of tree cover.

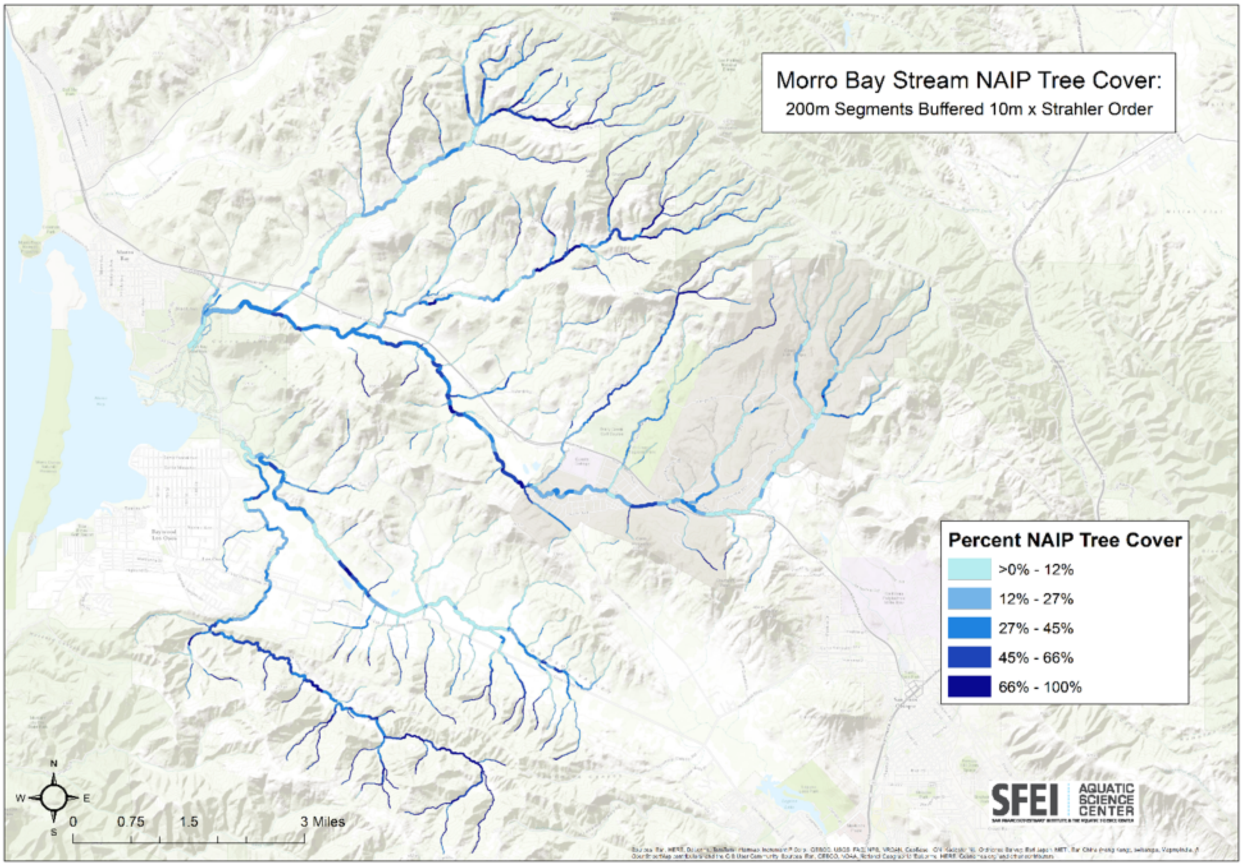


Figure 43. Percent of tree cover, in 200m stream segments, employing variable buffer widths by Strahler stream order using NAIP imagery.

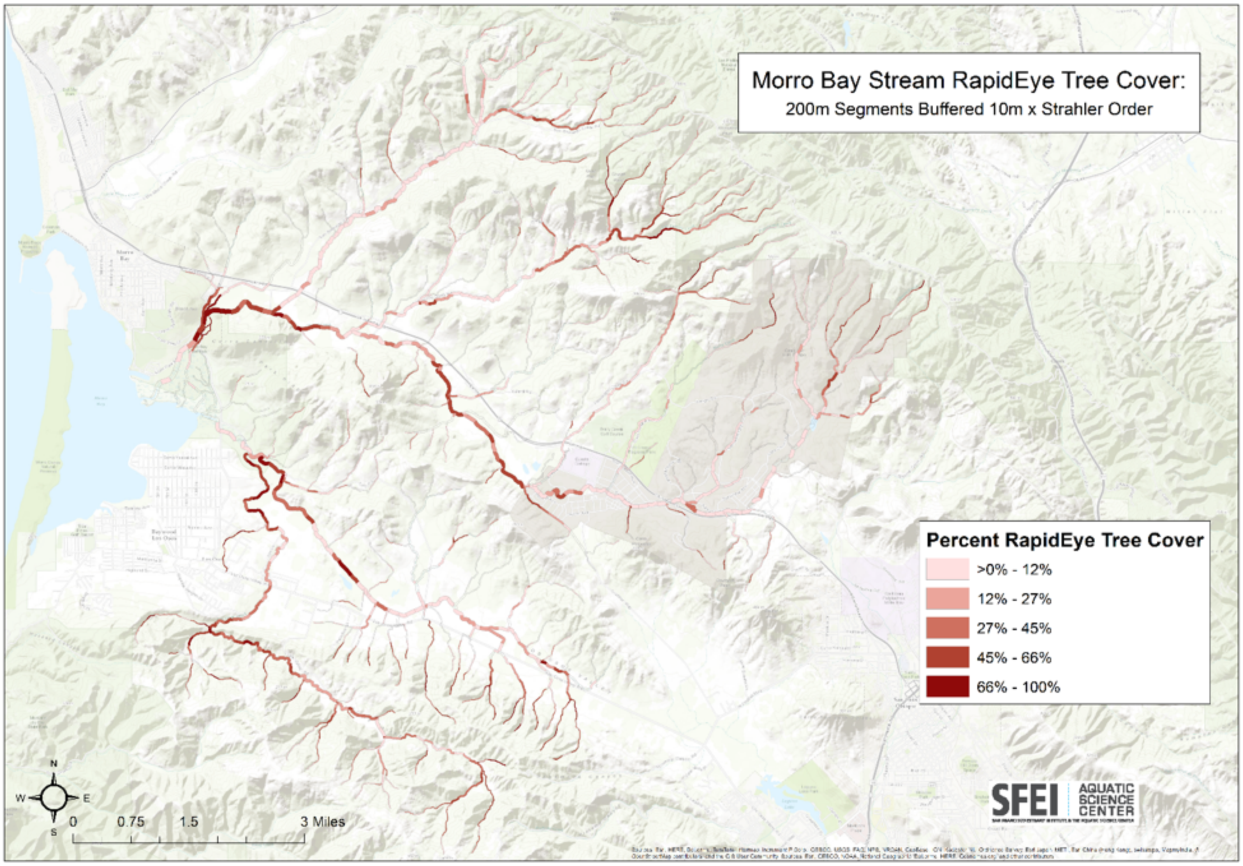


Figure 44. Percent of tree cover, in 200m stream segments, employing variable buffer widths by Strahler stream order using RapidEye imagery.

Determining the dominant land use for each 200m stream segment buffered to 70m

The same 200m stream segments buffered to a 70m width, were used to clip adjacent land use categories from Central Coast Watershed Studies dataset (CCOW). These segmented stream buffers were then attributed by the percent of each land use that they intersected and displayed based on the dominant land use within each buffered segment (Figure 45).

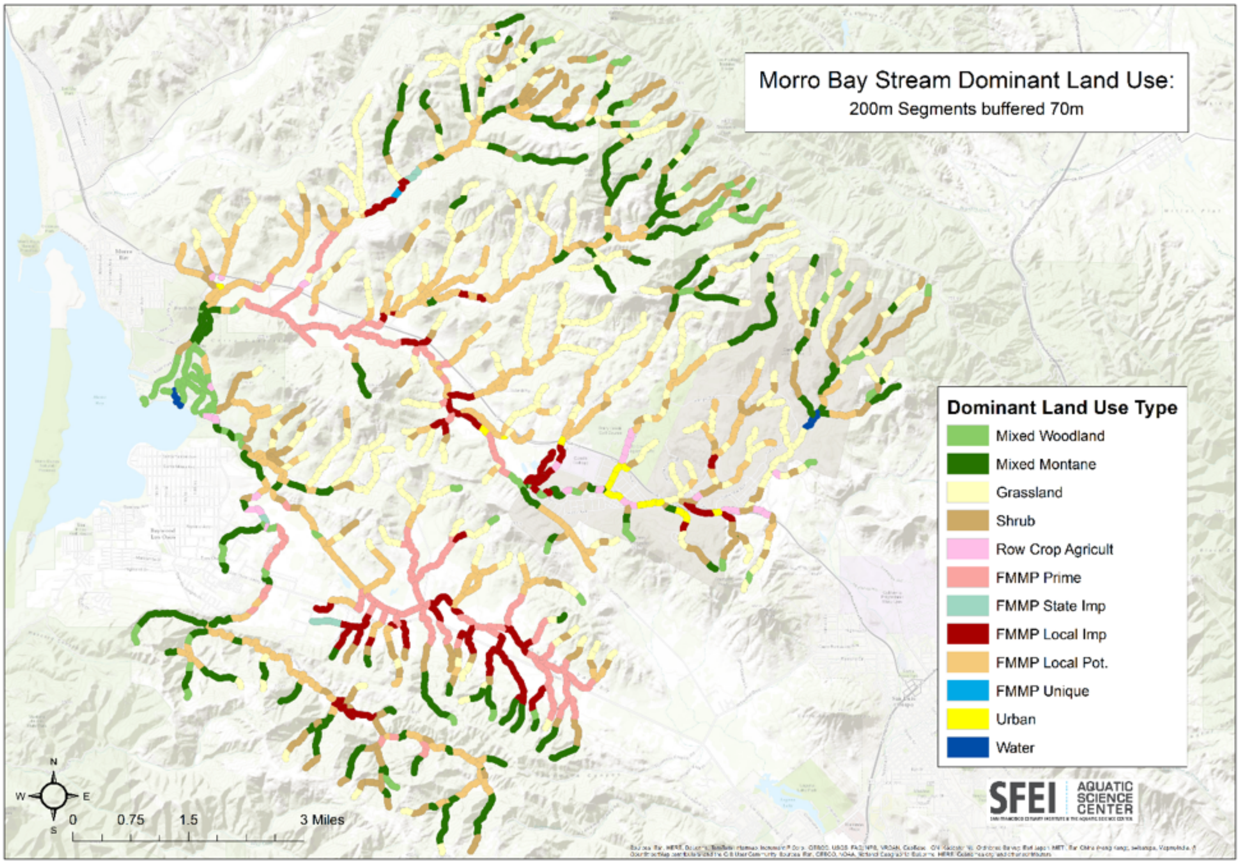


Figure 45. Stream segments color coded by the dominant adjacent land use.

Combining percent tree coverage with a land use disturbance score to rank each 200m stream segment that has been buffered to 70m

A single "score" was created for each 200m stream segment, based on dominant land use and percent tree cover for both the NAIP and RapidEye imagery. In order to accomplish this, land use types were assigned a score from 1-8, where 1 is a lowest score for more greatly stressed land use types and 8 is the highest score for land use types with lower ecological stress. These scores were then multiplied by the percent tree cover for both the NAIP and Rapid Eye pixel-based classification values to create a single score for both imagery types. Figures 46 and 47 show the resulting remote riparian condition scores, in 200m stream segments that were buffered to 70m, for the NAIP and RapidEye pixel-based tree classifications respectively. Lighter shades represent lower disturbance scores (or more highly disturbed areas) while darker shades represent higher scores (or less disturbed areas).

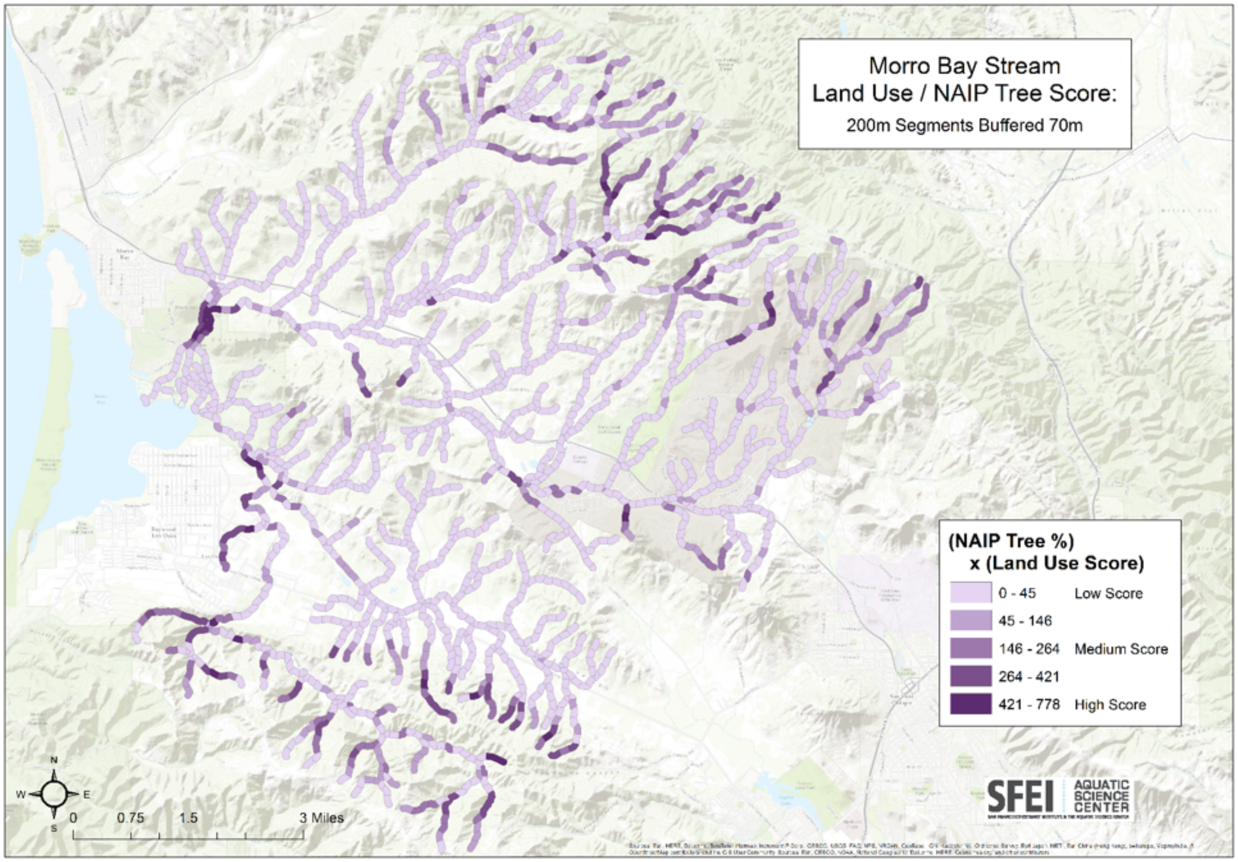


Figure 46. Stream segment scores based on a combination of percent tree cover using NAIP imagery and the adjacent land use category.

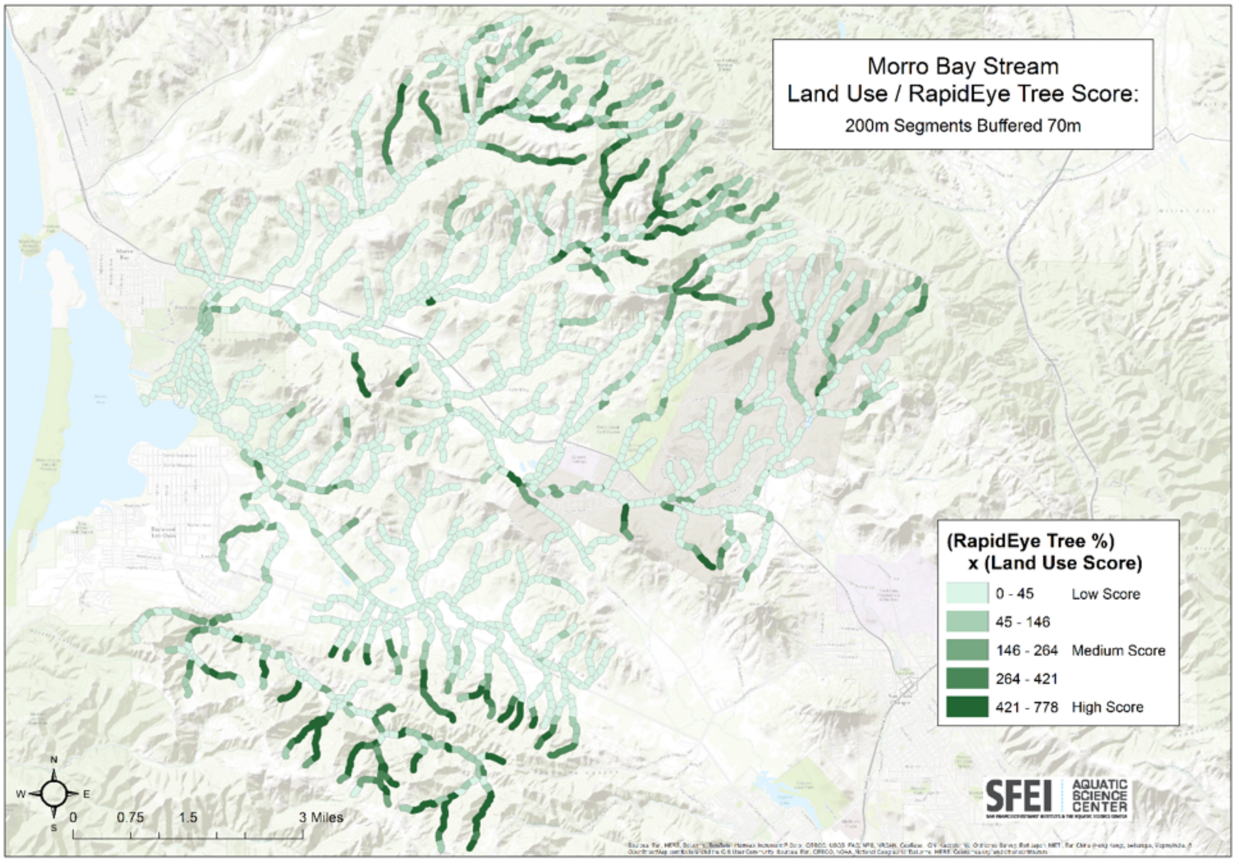


Figure 47. Stream segment scores based on a combination of percent tree cover using RapidEye imagery and the adjacent land use category.

Conclusions

This GIS-based analysis was able to draw a few conclusions about using aerial imagery to identify and map tree cover. Firstly, supervised classification of aerial imagery was found to yield better results than unsupervised classification; the refinement of training points through several iterations improved classification accuracy substantially. Supervised classification using 5-band RapidEye imagery produced better results than 4-band NAIP imagery. Supervised classification results for the vegetation classified in this study can be improved for NAIP imagery by down-sampling pixel resolution to 5m. For NAIP supervised classification results, misclassification remains an issue and significant effort may be needed for post-processing and quality control before it could be used to improve existing vegetation layers. However, there is potential for using pixel-based supervised classification outputs to improve existing vegetation layers.

Pixel-based classification should be explored further, particularly in study areas where there are no pre-existing GIS vegetation layers, or where those layers are not very detailed and less well vetted. Differences in percent tree coverage for NAIP and RapidEye results seemed to deviate more as buffer widths increased for the Morro Bay study area.

Comparison of L1 and L2 Riparian Assessment Methods in the Morro Bay Watershed

In the Morro Bay Watershed, an effort was made to evaluate the correlative relationship between visible indicators of riparian health from aerial imagery interpretation and field-collected data (RipRAM).

Site Selection and Assessment

We obtained a map of all streams and all roads in Morro Bay. We used ArcGIS 10.3 to run a quarry to identify all bridge and culvert crossings. Twenty-four stream crossing sites were then selected representing a range of scores from the Remote Riparian Assessment (Figure 46). In the event that a particular site could not be assessed, due to either access issues or incompatibility with our protocol, the nearest accessible site was chosen as a replacement. Prior to visiting the watershed, site maps were created using the FEMA flood map layer, which we used to establish the range of each AA. At each site, the riparian condition was assessed by two trained practitioners using the RipRAM protocol. When conditions permitted, the practitioners performed assessments from within the stream across the entire reach of the AA. In instances where conditions did not allow access to the stream (i.e. high flows, poison oak thickets/ thick vegetation, private property etc.) the assessments were done from the original stream crossing and surrounding vantage points. Sites took between 30-60 minutes to assess, and the entire watershed assessment was completed in 5 days.

Data Analysis

At each of the 24 assessment locations the RipRAM score was compared to four different remote riparian condition values. We used the tree interpretation map developed by SFEI and generated different buffer widths from the center line of the streams. We then determined the percent tree cover in each buffered area in a 200m long segment of the stream. The four buffer widths included:

- 30m
- 70m
- 10x Strahler stream order
- RipZET Vegetation and Slope module combined output

Correlation graphs were then generated for each buffer width to determine which width most closely aligns with the RipRAM Index Score.

Results

The 24 assessment locations in the Morro Bay Watershed had an Index Score range of 17 to 91, with an average Index Score of 60. In general, sites higher up in the watershed scored higher, while sites on the valley floor and near development scored lower (Figure 48). However, there were several locations lower in the watershed that did have Index Scores above 80 and were associated with restoration projects (e.g. Chorro Flats) (Figure 48).

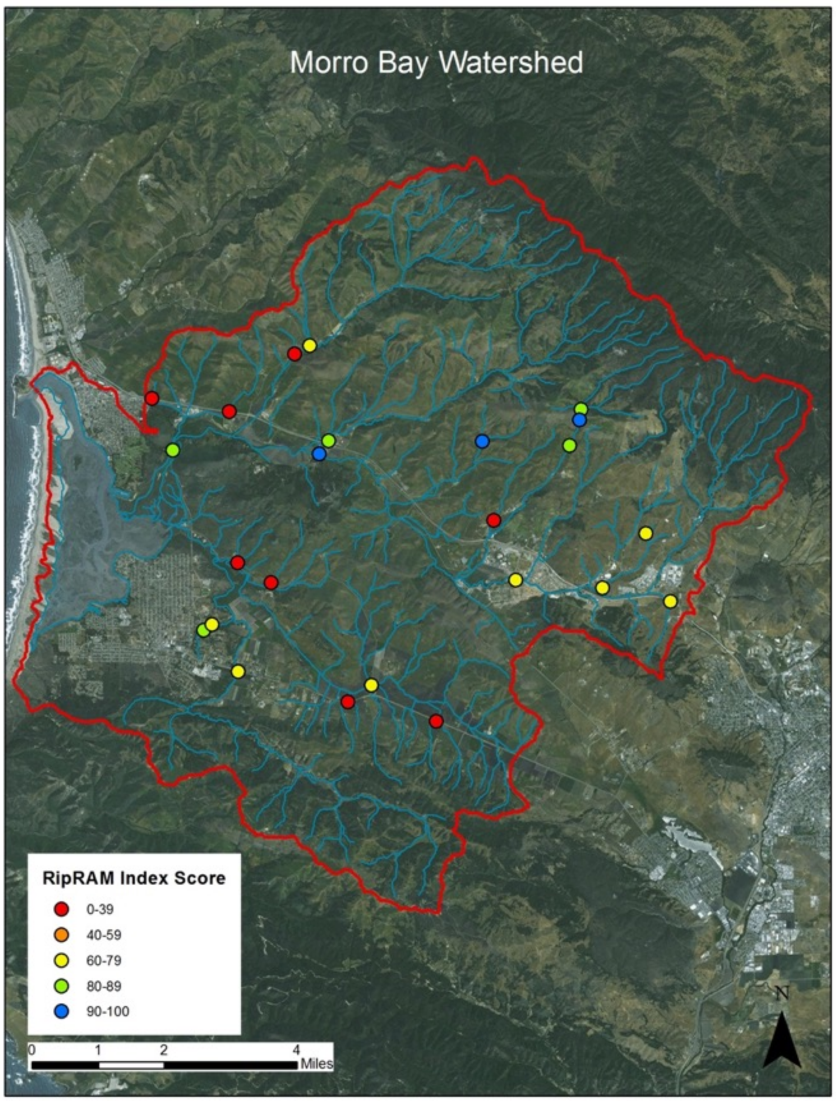


Figure 48. Riparian assessment locations in the Moro Bay watershed, color coded by RipRAM Index Score category.

The analysis of the RipRAM Index Scores compared to the percent cover of trees at 4 different buffer clips from the centerline of the stream showed the strongest relationship with the 30-meter standard buffer width. The buffer with showing the least relationship was the standard 70-meter width, while the RipZET Output and the width based on Strahler Stream Order were in the middle.

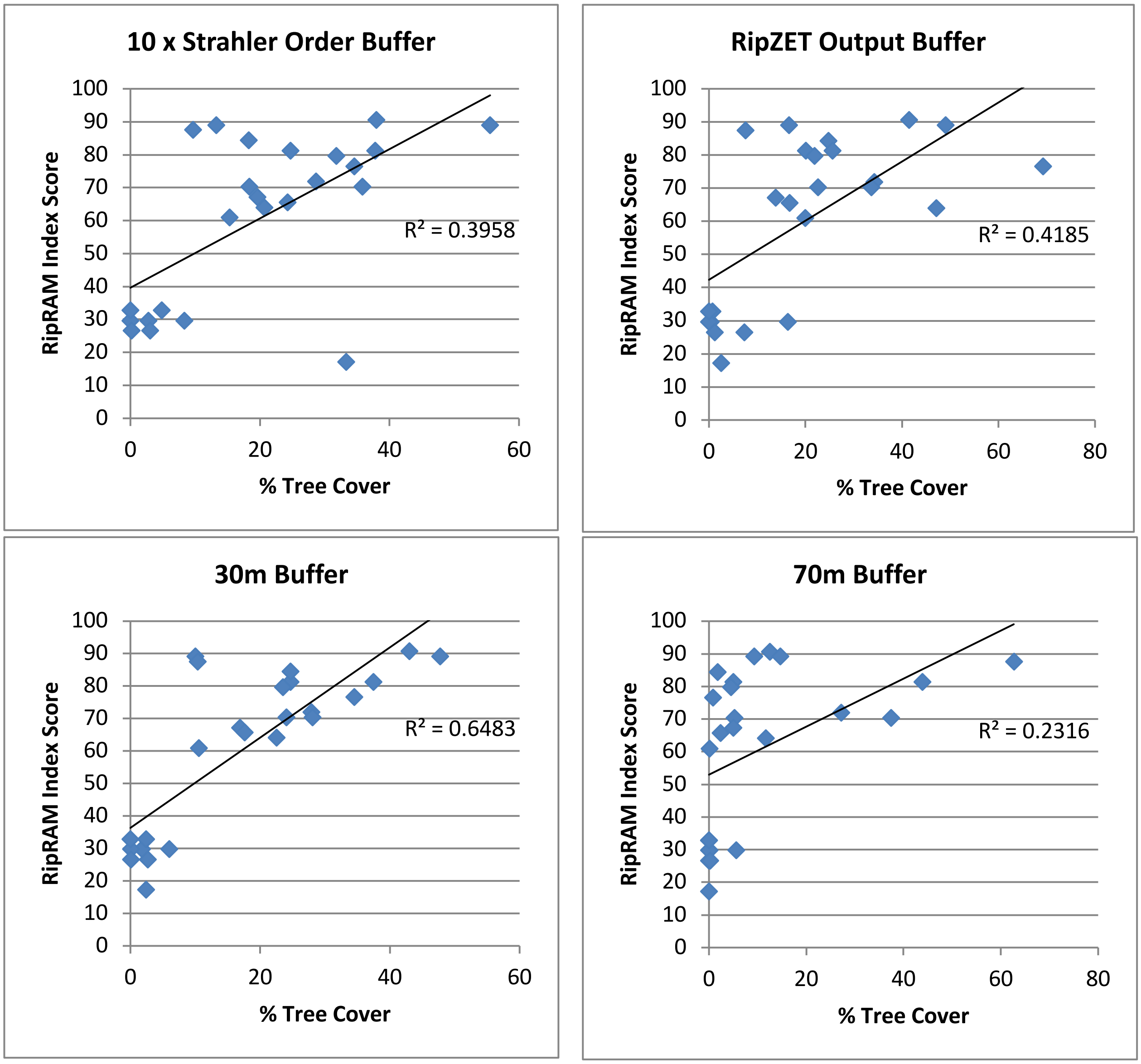


Figure 49. Correlation graphs and associated R^2 values comparing the RipRAM Index score and the percent cover of trees using NAIP Imagery classification for buffer widths based on a) 10x Strahler stream order, b) RipZET Vegetation Module output, c) a 30m buffer, and d) a 70m buffer.

Implications

Testing the relationship between visible indicators of riparian health from aerial imagery interpretation and field-collected data in the Morro Bay watershed takes the initial step in determining a reliable way to automate the projection of known scores upstream from an assessment location. It may be possible to assess strategic locations in a watershed using a field protocol, and then project those know scores upstream as long as the percent cover of riparian vegetation and landscape stressors do no change beyond a yet to be determined threshold.

5. Monterey Bay Area Watershed Assessments Using RipRAM

Introduction

In its infancy as an assessment tool, RipRAM has not yet been put to use in an applied context. In collaboration with the County of Santa Cruz and the Central Coast Water board, we piloted the use of this methodology to characterize the riparian condition of salmonid-bearing streams in four watersheds in Santa Cruz and Monterey counties in an effort to aid regulators and land managers in their prioritization and allocation of resources.

Methods

Site Selection and Assessment

In this study, four watersheds were assessed (Branciforte, Soquel, Corralitos and Carmel) in the winter of 2016. For each watershed we obtained a map of the salmonid-bearing streams, all streams, and all roads. We then used ArcGIS 10.3 to run a quarry to identify all bridge and culvert crossings. Twenty stream crossing sites were then selected from each watershed map based on accessibility and ability to represent riparian quality in the entire watershed. In the event that a particular site could not be assessed, due to either access issues or incompatibility with our protocol, the nearest accessible site was chosen as a replacement.

Prior to visiting each watershed, site maps were created using the FEMA flood map layer, which we used to establish the range of each AA. At each site, the riparian condition was assessed by at least two trained practitioners using the RipRAM protocol. When conditions permitted, the practitioners performed assessments from within the stream across the entire reach of the AA. In instances where conditions did not allow access to the stream (i.e. high flows, poison oak thickets/ thick vegetation, private property etc.) the assessments were done from the original stream crossing and surrounding vantage points. Sites took between 30-60 minutes to assess meaning an entire watershed could be completed, including data entry, in roughly one week.

Projecting Condition Upstream

An effort was made to determine how far the RipRAM score for a particular assessment area continued upstream. Practitioners traveled upstream via roadways and noted any differences in land use, hydrologic regime or density of invasive plant species that would significantly change the RipRAM score. If no roadway was available, locations of score change were estimated using Google Earth and ArcGIS. These score projection points allowed us to create maps characterizing the riparian quality for a large portion of the four watersheds.

Results

We created maps displaying the location and score of each assessed site, including the additional upstream reach the score applies to. These maps provide land managers and regulators with systematic data to describe riparian condition making it easy to identify both streams in need of restoration as well as those that are worth protecting.

In the four watersheds assessed, there were four sites with scores in the 0-39 range. All four of these low scoring sites had residential development adjacent to the stream edge (Figures 50a and 50b). Additionally, 10 out of the 15 sites that scored above 90 were the highest elevation locations assessed in their respective watersheds and had virtually no streamside development (Figures 50c and 50d). This suggests that land use immediately around the stream plays an important role in determining riparian condition when employing RipRAM.

Figure 50. A) Soquel creek mouth, index score of 24. B) An unnamed creek in Carmel, index score of 15. C) Branciforte creek, index score of 98. D) An unnamed creek in Corralitos, index score of 93.

In order to get a more complete characterization of each watershed, future watershed assessments using RipRAM should correlate the number of sites assessed to the size of the watershed being characterized. In this study, the maps for the smaller watersheds, Branciforte

(Figure 51) and Corralitos (Figure 52), show a much more complete picture than those of the larger watersheds Soquel (Figure 53) and Carmel (Figure 54).

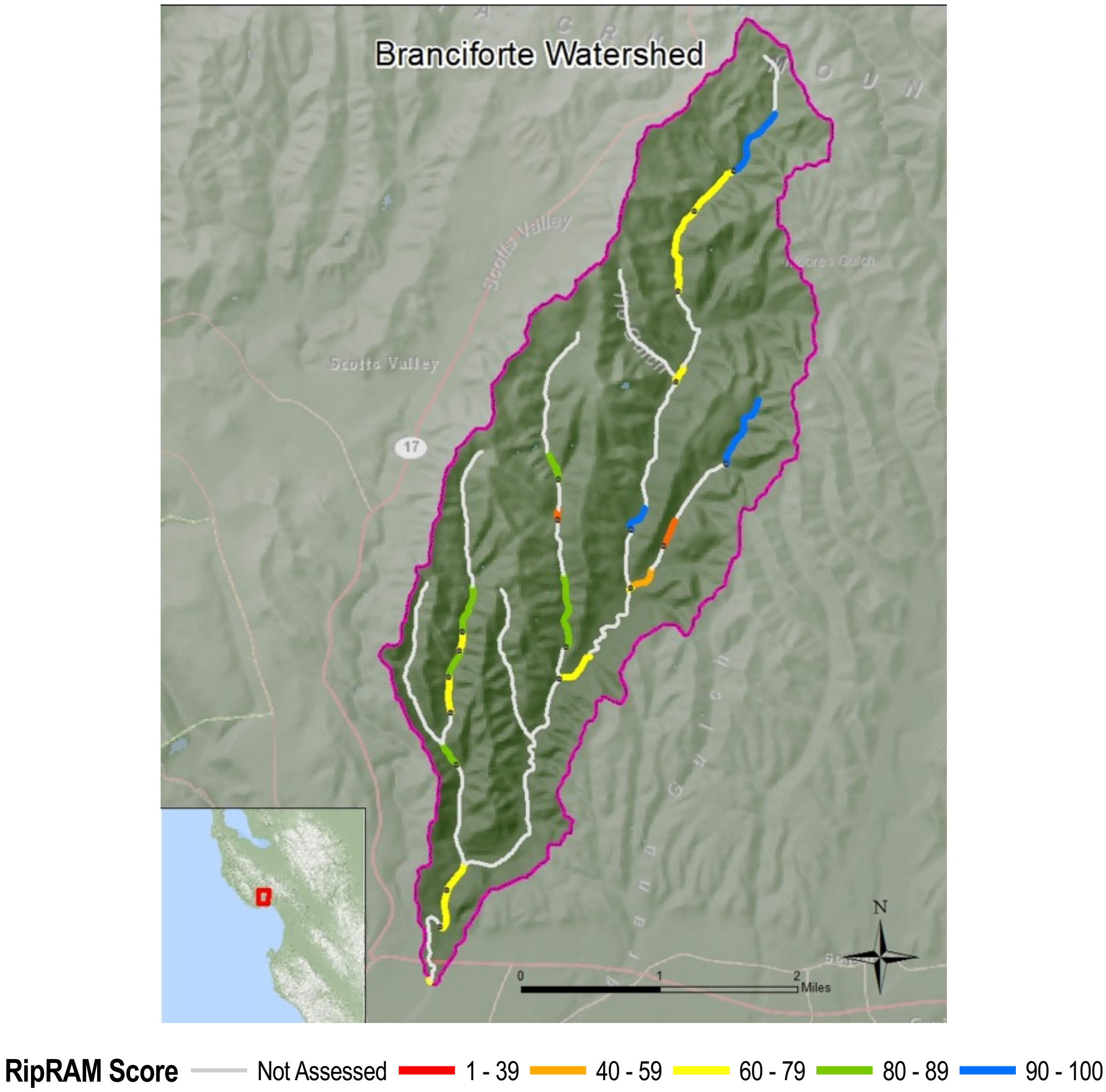


Figure 51. Branciforte Creek watershed map showing assessment locations (dots) and color coded stream lengths based on RipRAM Index score categories.

Figure 52. Corralitos Creek watershed map showing assessment locations (dots) and color coded stream lengths based on RipRAM Index score categories.

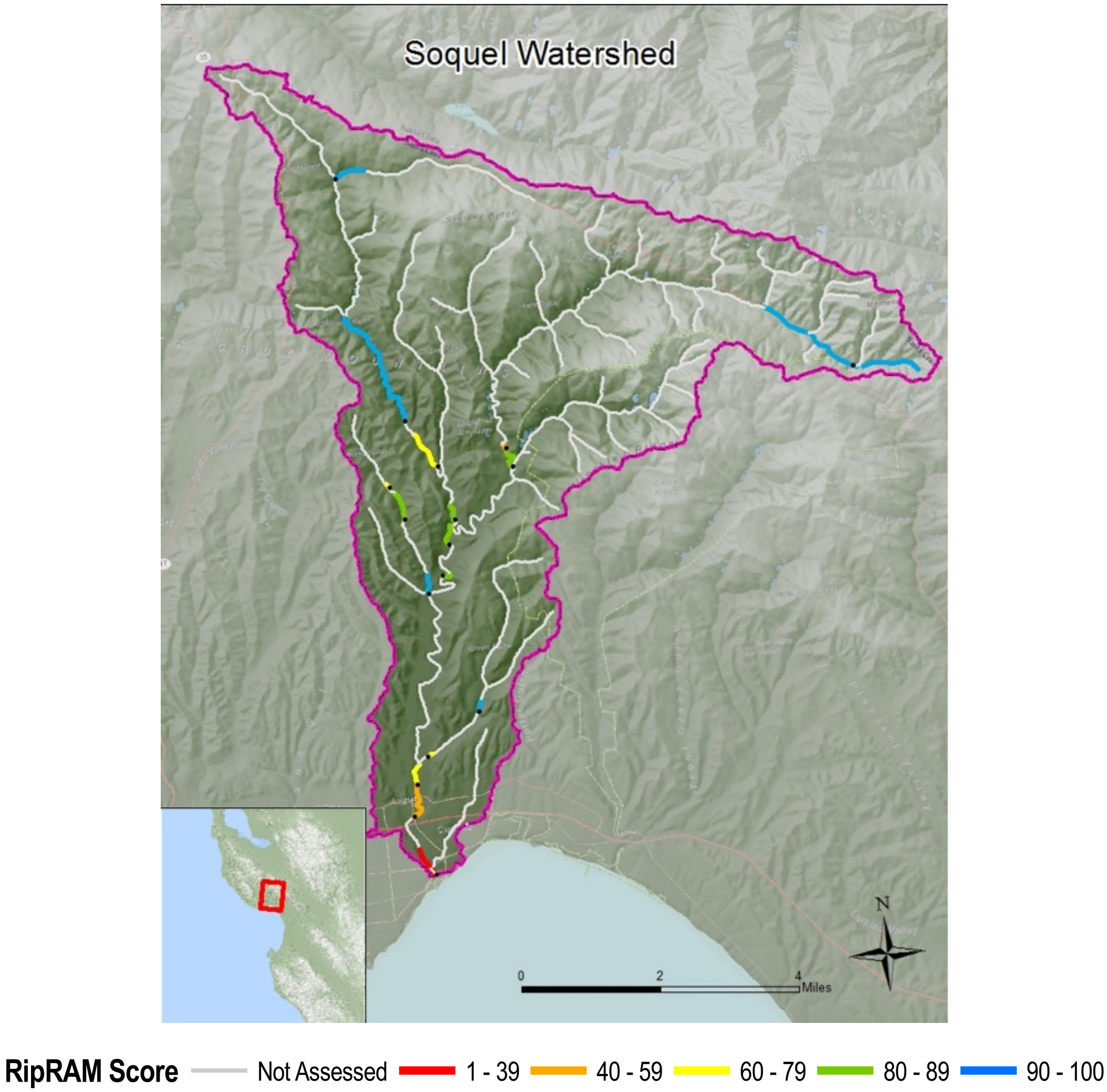
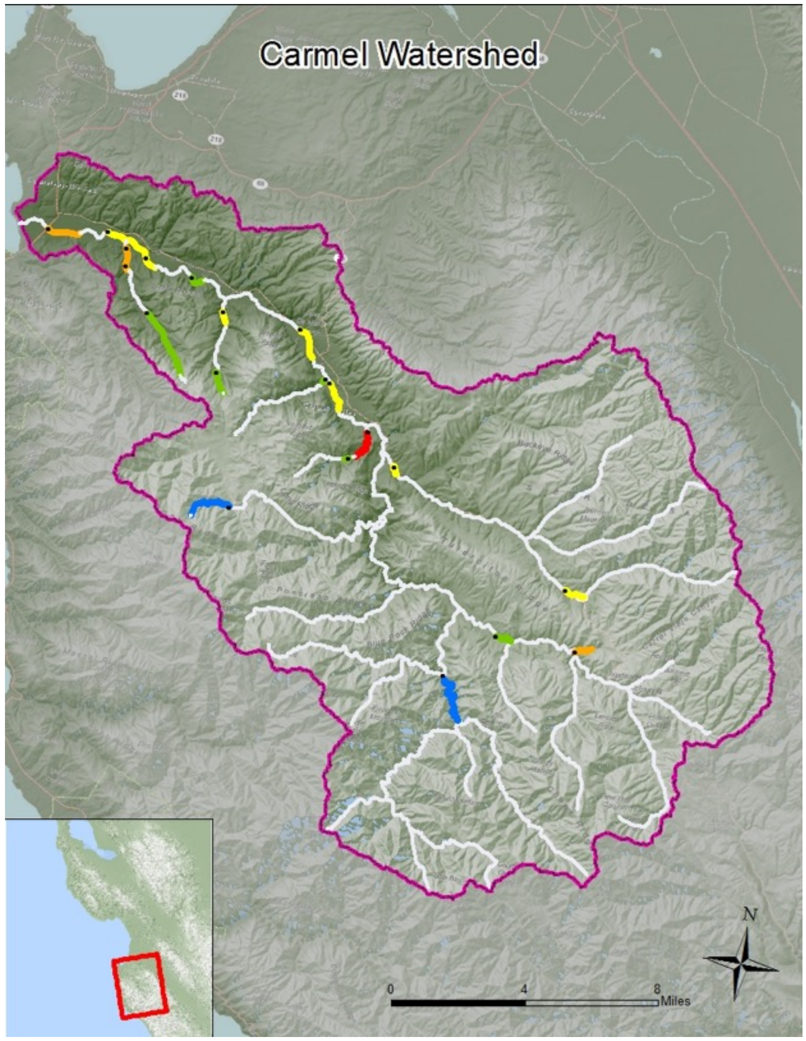


Figure 53. Soquel Creek watershed map showing assessment locations (dots) and color coded stream lengths based on RipRAM Index score categories.



RipRAM Score — Not Assessed — 1 - 39 — 40 - 59 — 60 - 79 — 80 - 89 — 90 - 100

Figure 54. Carmel River watershed map showing assessment locations (dots) and color coded stream lengths based on RipRAM Index score categories.

6. Project Outcomes

Outcomes

- This project supported consistency with the WRAMP through development of standardized assessment approaches (Riparian Rapid Assessment Method), information collection, and reporting on streams and associate riparian areas.
- This project built state capacity to measure and report on the extent, function, condition, and sources of significant stressors to the condition of streams and riparian areas in areas with different levels of access (in-stream, bridge, adjacent road, etc.).
    - Provide Regional Board 3 CCAMP staff with a tool for assessment of riparian health (RipRAM) to be implemented routinely during watershed rotational monitoring.
    - Adoption by RB3 of the RipRAM Index scores as the reported measure of riparian health on RB3's CCAMP data viewer website.
- This project supported the continued development of a watershed-based approach for wetland and riparian assessments to better address cumulative impacts and identify and protect critical watershed processes through development of an enhanced Riparian Mapping Tool for the Central Coast and the development of a Riparian Rapid Assessment Method.

A Note from the Central Coast Regional Water Quality Control Board

The Central Coast Water Board's Central Coast Ambient Monitoring Program (CCAMP) conducts routine water quality assessments on a five-year watershed rotational cycle in the Central Coast Region. CCAMP intends to continue partnering with the Central Coast Wetlands Group and CC Watershed Stewards Program to support a field team to conduct riparian assessments using RipRAM for each rotational assessment cycle. This will allow us to routinely assess riparian condition in the Central Coast Region, areas in need of restoration or protection, and over time, potentially also assess changes in condition.

In 2007, the Central Coast Water Board established a vision of "Healthy Watersheds", with three associated measureable goals of healthy aquatic habitat, proper land management and clean ground water. Water Board staff have established a Healthy Watersheds Report Card in a web mapping environment to assess the Vision goals. Aquatic habitat is assessed using several indices of health, including water quality, toxicity, biology, and habitat. Water Board staff are particularly supportive of the RipRAM concept, which provides a relatively rapid approach to assessing riparian health that can be visualized as "linear" assessments of stream reaches, because of the high applicability of this approach to the web mapping environment employed by the Report Card.

Karen Worcester and Central Coast Ambient Monitoring Program (CCAMP) staff participated in the RipRAM Technical Advisory Committee and observed that the RipRAM development staff made good use of technical input and suggestions and adapted the project based on input from the group. Development staff was receptive to suggested edits and amendments to the field methodology and adjusted it accordingly. Development staff also ensured that CCAMP field staff participated in testing the field methodology and again adjusted the methodology based on input from the CCAMP team.

CCAMP staff loaded RipRAM data into the Healthy Watersheds Report Card and color scored it according to a "20-40-60-80" scoring paradigm, where Very Poor (dark red) ≤ 20; Poor (red) ≤ 40; Fair ≤ 60; Good (lt. green) ≤ 80 and Excellent (dk. Green) ≤ 100. Where data co-occurs with other habitat data (from bioassessment surveys or CRAM), scores will be combined to assess habitat health at a reach scale. Next steps for CCAMP will be to extend mapped scores upstream to the field-estimated upstream extent, and then to compare that field determined extent with one determined using a modeled approach based on changes in upstream and adjacent land uses.

CCAMP will make use of satellite derived assessments of riparian health as those data become available on a broader geographic scale (assuming this work is followed by subsequent grant funding). The initial exploration of this approach in reference areas in the Central Coast Region are encouraging, but also make it clear that it will be important to undertake this analysis with an understanding of reference relative to specific habitat types within the Region. In order to complete the effort, we envision the National Wetland Inventory maps need to be extended to the entire Region (riparian delineation in NWI currently only covers 56% of the Region), and then satellite and photographic imagery needs to be evaluated for percent tree cover and riparian width within the defined NWI area. We think the Central Coast evaluation will encourage interest and adoption by other monitoring efforts elsewhere in the State and we intend to present the field method and the associated mapping approach at a meeting of the Surface Water Ambient Monitoring Program Roundtable.

Project Outreach

- Presentations to:
    - Presentation to California Bioassessment Workgroup (2014)
    - Presentations to California Wetlands Monitoring Workgroup (2015 and 2016)
    - Poster at Salmonid Restoration Federation Conference (2016)
    - Two Posters at the 2016 Moss Landing Marine Labs Open House

- Two field tests with CCRWQCB staff (once in San Luis Obispo, once in Pajaro)
- Assisted with the planning and development of the 2017 Riparian Summit at UC Davis (October 17-19, 2017)

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Appendix 1: Riparian Rapid Assessment Method for California Field Book