Eel River Watershed Conservation Solutions

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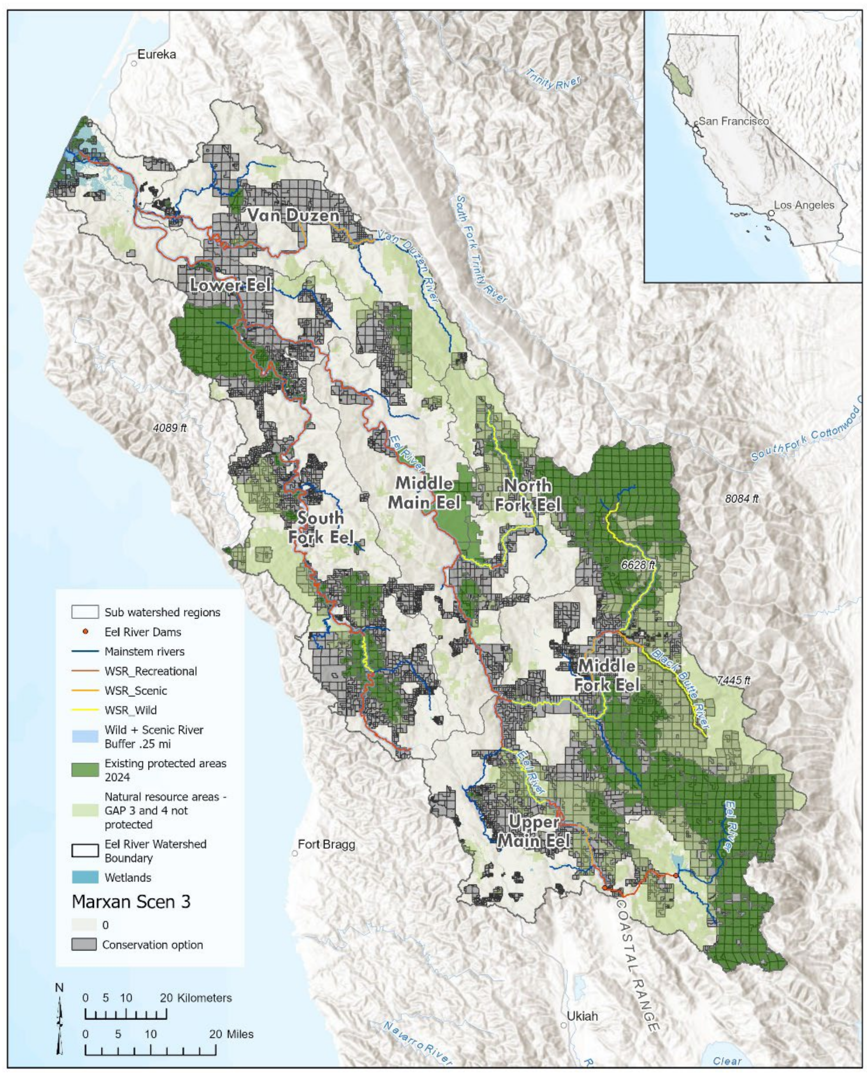
California Trout



The Eel River Watershed
RESTORATION AND CONSERVATION PROGRAM

Eel River Watershed Conservation Solutions:

A Resilience Strategy for the Eel River Watershed, Marxan Parcel Conservation Analysis

Goal: Create a strategic conservation plan to promote and prioritize climate resilience and biodiversity in the Eel River watershed. The strategic model and mapped conservation network results can be used to inform conservation planning goals in the North Coast region of California and beyond.

Contents

1. Abstract

Recent planning frameworks created to support conservation and restoration actions in California have identified the North Coast and Klamath regions as areas with some of the highest connectivity for species movement while simultaneously containing lands with the greatest risk to landscape conversion (Cameron et al., 2022; Schloss et al., 2022). If the patterns of land fragmentation continue, in turn connectivity for species movement will be impaired, making it more difficult for species to move to different locations as the climate shifts. The opportunity for improving the protected area network with strategic conservation planning in the North Coast of California, combined with the intent of California's 30x30 initiative to protect 30% of lands supportive of biodiversity and climate resilience by 2030, make the North Coast region in particular need of climate-informed biodiversity conservation strategy when choosing areas for conservation.

Conservation planning is a decision process of "when, where and how" to protect biodiversity and connectivity (Pressey & Bottrill, 2009). For connectivity planning in a watershed, a decision process is necessary because strategically identifying conservation suitability within connective riparian corridors

can result in protection of threatened biodiversity and connectivity at a landscape level (Krosby et al., 2018).

Biodiversity and landscape connectivity are two key pieces of this conservation plan. This strategic focus is necessary as climate impacts and land use practices threaten key habitat of anadromous fish and other species in the Eel River watershed. Here we identify a methodology to identify a connected network of riparian areas to promote the persistence of biological diversity and protection of existing connectivity, while considering the economic costs of conservation and the importance of climate refugia.

This report explains the methodology for defining where there are areas of high habitat value that are not yet protected. The result of this work is a spatial database of parcels that can be considered as a conservation network for the Eel River watershed. The protection and potential restoration of the strategic conservation network or "conservation solutions" within Eel River watershed riparian corridors, if implemented, may improve landscape resilience against future threats to biological diversity and connectivity.

The Eel River watershed is a fragmented landscape with many active land managers. Thus, it is imperative to work proactively with a systematic and repeatable planning process for protecting the proposed conservation network. The conservation network provides a starting point to organize multiple data into sets of maps and to begin agency and private landholder negotiations about how to implement conservation and restoration across the Eel River watershed. In this report, the conservation network results are analyzed further with a focus on the Upper Eel River sub watershed. This focused analysis provides a framework for how to use the conservation network for planning among the seven major sub watershed regions in the Eel River watershed.

Location

The planning region for this study is the Eel River watershed in Northern California. The watershed is the 3rd largest in the state of California and spans 3,682 square miles from the Yola Bolly mountains in Lake County to the mouth of the Eel River estuary in Humboldt County. There are seven major sub watersheds that represent regional habitats, resource management, and historical context. An analysis of each sub watershed was conducted separately. This report documents the resilience strategy analysis and resulting conservation network as applied to the entire Eel River watershed and highlights the results for the Upper Eel River watershed (Figure 1).

1. Lower Eel
2. Van Duzen
3. Middle Main
4. North Fork
5. Middle Fork
6. South Fork
7. Upper Eel

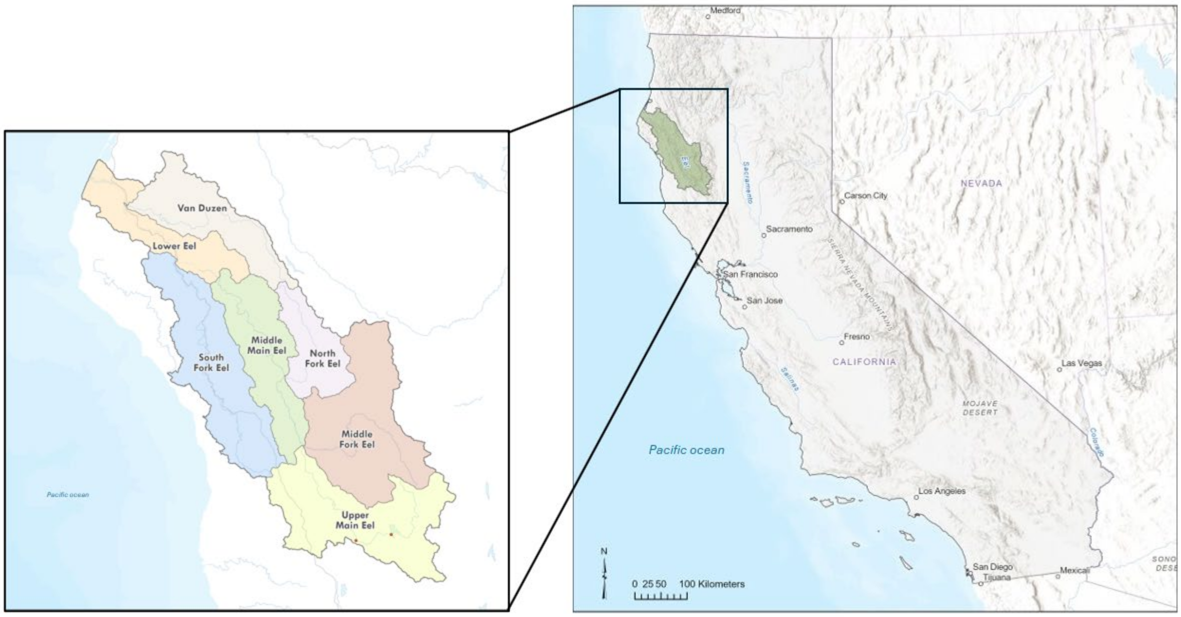


Figure 1. The Eel River Watershed, seven major sub watersheds in the context of the State of California. Map: Davis, March 2024.

2. Introduction

While there are many spatial planning tools available for protecting or conserving land in the United States, these tools focus on individual processes, are too broad to be downscaled for regional planning, or do not explicitly integrate climate resiliency strategies to ensure effective ecosystem resilience. For example, a common goal of increasing the percentage of protected areas in a region will not effectively protect ecosystem resilience (UNEP-WCNC & IUCN, 2016, CNRA 2023). Strategic planning on where those areas are located is critical to maintaining existing biodiversity and climate resilience in the watershed.

To build the strategic conservation network, adequate protection of connected habitat was leveraged to build a resilience strategy for effective conservation planning. The overarching goals of the resilience strategy are to strengthen and protect landscape resilience by 1. mitigating climate change impacts on biodiversity and 2. limiting destructive land use practices or conversion. The purpose of this study is to assess the representation of biodiversity features and recommend new conservation focal areas for a resilient Eel River watershed across the entire landscape scale. The term 'landscape scale' in conservation planning refers to the sub watershed level, but also refers to how the sub watersheds connect and share pathways for species movement.

2.1 Watershed impacts

Some notable impacts to the watershed include the two large dam complexes that make up the outdated Potter Valley Project (Cape Horn Dam and Scott Dam), grazing, industrial timber management, rural and residential development, gravel extraction, conversion of the estuary to agriculture, cannabis cultivation, and damage from the 1955 and 1964 floods. The impacts have caused extensive changes to much of the watershed, increased sediment supply, and resulted in the loss of riparian vegetation and altered hydrology.

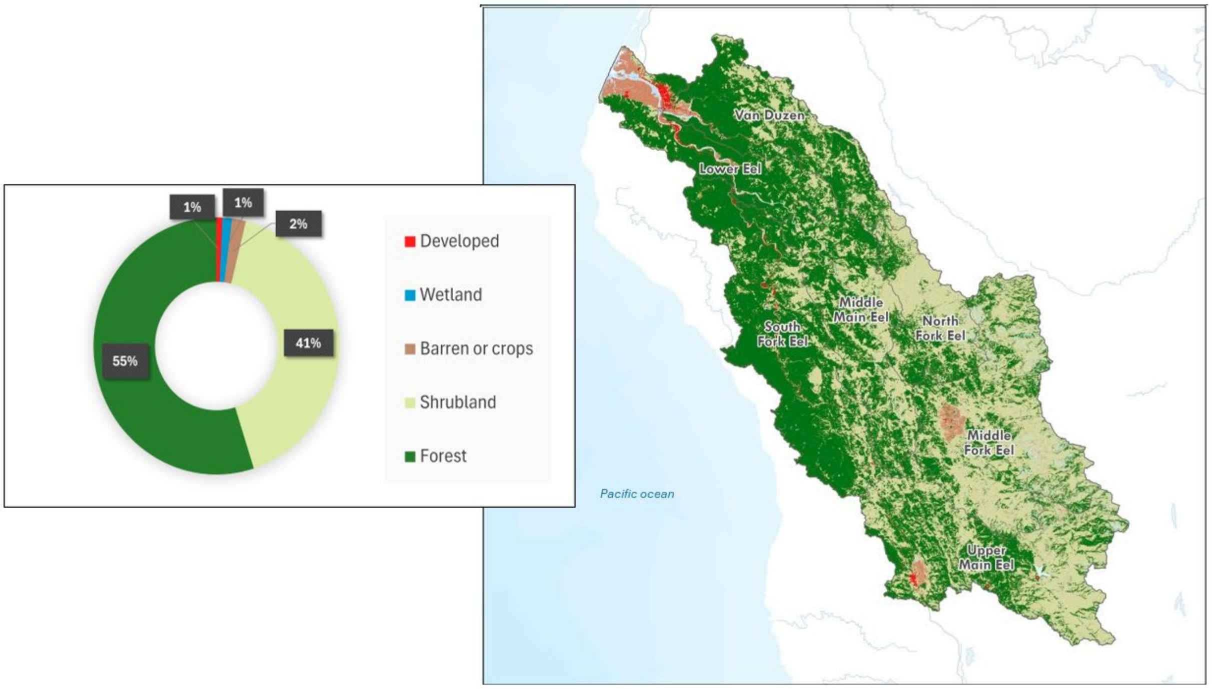


Figure 2. The Eel River watershed land use land classification (LULC 2021).

Defining and following a strategy to define a conservation network is one way we can support lessening these impacts. The strategic locations of the protected area network can flag areas that may give a higher ecological return if they are protected and restored. This is sometimes referred to as the effectiveness of conservation planning. We can effectively protect the landscape by incorporating knowledge of past impacts with the current landscape and identify through a strategic prioritization process, the most important areas for core habitat and climate resilience.

3. Resilience strategy

To understand the proposed resilience strategy, the phrase 'conservation strategy' must first be understood. A conservation strategy in conservation planning is a decision process of "when, where and how" to protect biodiversity and ecosystem services at least cost. The proposed resilience strategy is a conservation strategy that also incorporates climate and connectivity data in the analysis. The resilience strategy is necessary to plan for impacts beyond the river channel and consider future impacts to habitat in and around the riparian corridor.

There has not yet been a watershed wide conservation or restoration strategy for the Eel River watershed. Resilience has not been formally measured, nor has there been a landscape scale data review of how to incorporate the realities of the landscape, into a plan for action. For the Eel River watershed, the term 'resilience refuge' refers to a visionary statement. A resilience refuge must be pro-actively protected, restored, and managed. We still have a chance to protect and restore threatened habitats in the Eel River watershed, but the time to act is now.

Defined and explained in this report is the methodology for an enhanced conservation strategy, described here as the *resilience strategy* (Figure 3). This approach takes the framework of a classic conservation strategy and adds spatial data to a prioritization process to identify the best solutions that will result in a map of connected parcels that provide good options for not only conservation, but also improved resilience across the watershed. This is further highlighted with an examination of the results as applied to the Upper Eel River watershed in proximity to future dam decommissioning areas.

This analysis provides clarity to the research questions:

1. How much land needs to be conserved to protect at least 30% of habitat?
2. How can riparian corridors be better protected to facilitate species movement in a multi-use landscape?
3. To what extent can conservation areas be expanded for high returns of biodiversity and climate resilience?

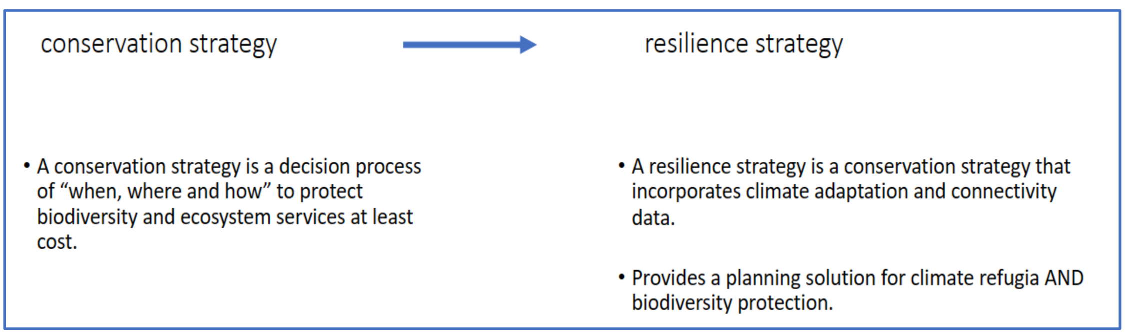


Figure 3. The difference between conservation strategy and the proposed resilience strategy used to create the conservation network for the Eel River watershed.

The resilience strategy provides a planning solution for climate refugia and biodiversity protection. The resilience strategy is built on the fundamental principles of:

- *The stressors of climate change and destructive land use practices necessitate proactive strategies to protect biodiversity.*
- *Finding the gaps where conservation is needed can result in improved landscape resilience.*
- *Strategically located and managed conservation areas can reverse impacts to habitat loss.*

In addition to the above fundamental principles, the resilience strategy for the Eel River watershed is built on the foundational basis that habitat representation and landscape connectivity are paramount for a conservation strategy. A conservation network built with strategy can protect core habitat for fish and other sensitive, threatened, and endangered species. In the past, business as usual conservation planning did not include specifically planning for protection of important areas that support ecosystem processes. The resulting lack of landscape connectivity and pathways for species to take shelter from climate impacts has had formidable consequences for biodiversity and thus, ecosystem resilience.

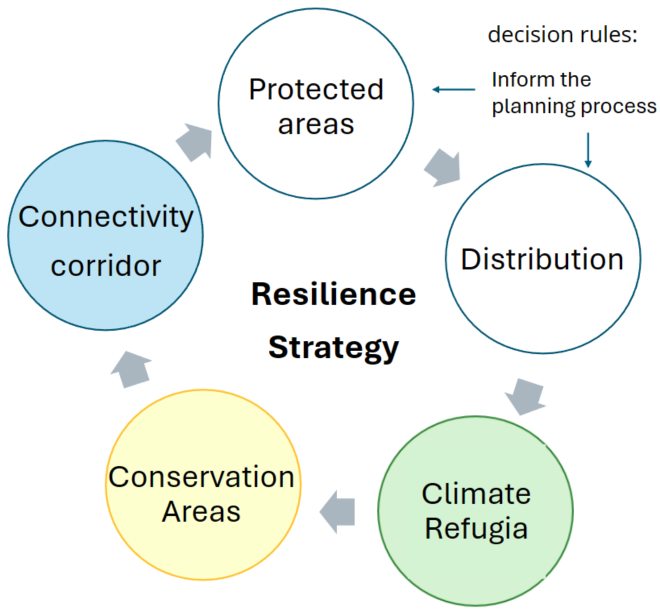


Figure 4. The five pillars of the resilience strategy

Within the five pillars of the resilience strategy are three colored circles, Connectivity Corridor, Conservation Areas, Climate refugia. Each of these circles represents a complete and separate analysis. Each of the analyses results in mapped spatial data which can be overlayed together to aid in making informed conservation investment decisions. When overlaid together, the result is a resilience strategy corridor map for the watershed (Figure 5).

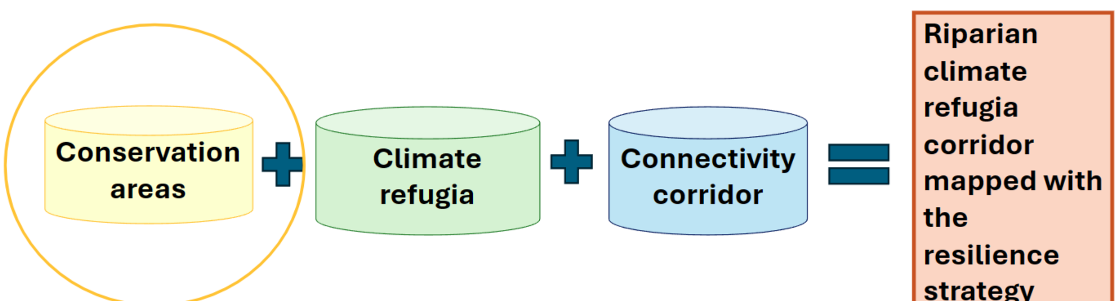


Figure 5. The three data analyses frameworks within the resilience strategy. The conservation areas (network) described in this report is one part of the resilience strategy that also includes climate refugia and connectivity corridor analyses and is informed by existing protected area proximity and distribution or representedness of habitats across the watershed.

Spatial planning framework

The basis of the strategic spatial framework for conservation planning is a combination of quantitative and qualitative design. We used Marxan to prioritize planning units at the county parcel scale. The resulting 'solutions' of prioritized polygons from the Marxan analysis can be combined or overlayed with other species-specific prioritization approaches. This approach prioritizes the landscape characteristics that support species movement across the landscape (Fremier et al., 2015). The data can be further informed by overlaying other spatial datasets of specific focal species distributions and ecosystem processes.

An increasingly important part of conservation planning is to identify what elements species will need as the climate changes and to strategically protect those ecological functions and features across the landscape (Heller et al., 2015; Lawler et al., 2015). To address climate impacts to the landscape and species, we also integrate landscape features supportive of biodiversity and climate resilience into the prioritization analysis. The approach is a multi-criteria, conservation target and structural connectivity systematic assessment (Cowling & Pressey, n.d.; Margules & Pressey, 2000). The analyses will be used to enhance the riparian corridor network and to recommend new conservation priorities for the Eel River watershed.

Elements of the spatial planning framework for the Eel River watershed:

1. Identify areas for conservation based on conditions of:
    a. Species presence
    b. Habitat quality
    c. Threat intensity
2. Choose specific protection and/or restoration actions.
3. Elevate biodiversity in the matrix surrounding core habitat and protected areas: GAP 3 and 4 status lands, agricultural, working forests, coastal areas, and cities.
4. Obtain protection status with a conservation plan for core areas needing protection.
5. Prioritizations need to consider the potential impacts of conservation activities on different environmental and social outcomes.

Representedness (distribution of protected areas and habitats)

Restoration and conservation within the Eel River watershed to date primarily where research and conservation by groups such as SHaRP, CalPoly Humboldt, UC Davis, and California State Parks have focused efforts, and in the wilderness areas managed by the US Forest Service and Bureau of Land Management. In other cases, protected area parcels have been set aside in small pieces here and there or where the land is cheap or simply available for purchase or away from populated areas, without specific planning for biodiversity, connectivity, and watershed processes. A conservation prioritization process built on a resilience strategy for the entire watershed will aid in identifying areas which have historically been given less representation in strategic restoration and conservation and where opportunities for connectivity and protecting important habitat remain.

Globally, there are many studies reflecting values which can be applied in strategic conservation planning. For example, habitat representation needs equal attention across a landscape scale plan. Often protected areas are unproportionally weighted towards high elevation areas or places where land is not as desirable for agriculture or urban areas. A global review of the literature suggests that about 20% of species have adjusted their ranges towards lower elevations (Parmesan et al., 2003). Long-term downhill shifts in the optimal elevations of plant species have been shown for California, apparently in response to decreased climatic water deficit (Crimmins et al., 2011). While in general, lowlands are not well represented in protected area reserves, this analysis prioritizes habitat representation in the Eel River watershed by strategically planning across all elevations and within urban boundaries.

Adequate representation of protected areas

To analyze areas that still need protection, lands already considered as protected areas were located and identified in the watershed (CNRA, 2023). The spatial analysis of protected areas in the watershed showed that current protected areas are not representative of all seven major sub watersheds **(Figure 6).** We identified that a spatial strategy is needed to define a represented network of climate resilient habitat across the watershed (Naughton-Treves et al., 2005).

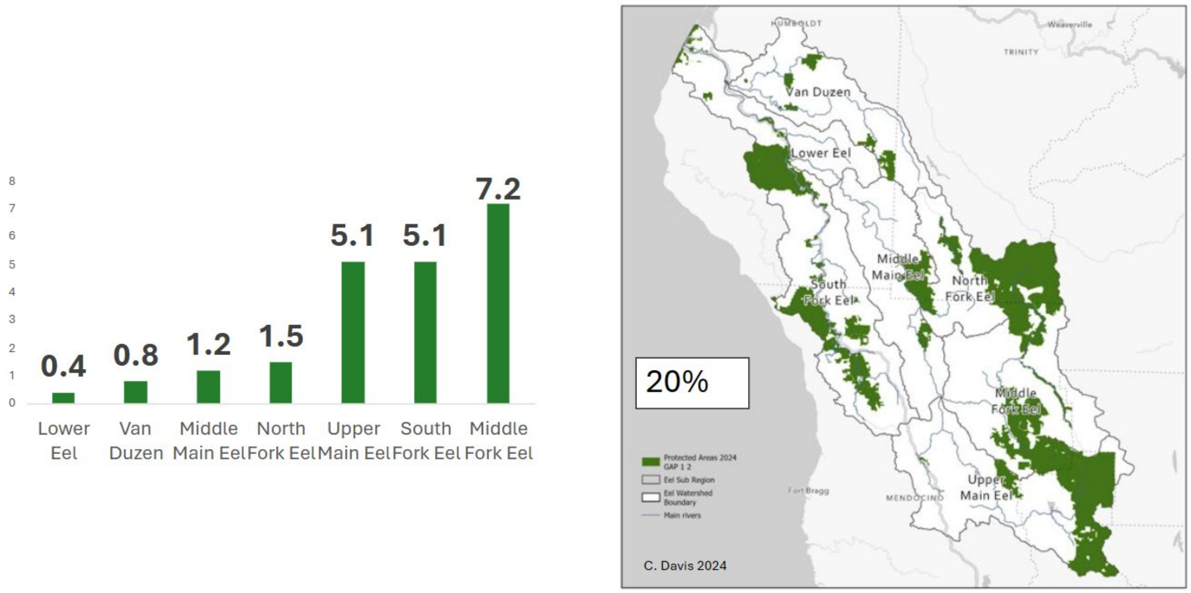


Figure 6. Percent of protected areas per sub watershed as of February 2, 2024. Protected areas in the Eel River watershed make up 20% of the total area but are not represented equally or effectively among the seven major sub watershed regions.

Connectivity

Species need connected habitats such as riparian corridors. A thorough review of strategies for improving landscape connectivity was essential to building this strategy. The resilience strategy integrates recommendations from other studies into the scale and conditions that will most benefit the goals of habitat and climate resilience for the Eel River watershed. For example, riparian areas that span climatic gradients might provide natural corridors that species could use to track shifting areas of climatic suitability and have been called riparian climate corridors (Anderson et al., 2023; Conservation Science & Nature Conservancy, n.d. TNC 2023; Krosby et al. 2018). A spatially explicit climate resilience analysis based on microclimates and connectedness identified riparian corridors as key landscape features because of the many climate options they provide, especially in relatively flat landscapes (Anderson et al., 2014).

To consider connectivity, it is helpful to consider the question: What are some easy ways that species might get from point A to point B in a watershed?

- Riparian areas ranging in elevation from cool to warm areas could provide natural corridors that species could use to move as temperatures shift: "riparian climate corridors" (Krosby et al. 2014).

- There are also species that will need to shift laterally, and some even downward (20% in California). Planning must include areas that are distributed across the watershed, but also along elevational gradients and corridors.

Connectivity, corridor planning

A corridor in ecology is a general term for a conduit or connecting group of features in the landscape. Corridors help maintain connectivity through the landscape. Whereas riparian corridors can provide connectivity but also complement existing protected areas by creating linkages which support species movement across a watershed.

To be effective, corridors must be strategically selected for their connective attributes at the watershed scale. These attributes are size > 1km, elevation gradients, degree of fragmentation, availability of habitat per species (many plants can't disperse at < 20% habitat), climate velocity, species dispersal capacity, and habitat preferences (Groves et al., 2012; Tallis et al., 2021). Corridors must also include prioritized sites for habitat restoration and conservation which include both biotic and abiotic parts (Anderson et al., 2014; Metzger & Brancalion, 2013).

Corridor design can become very specific when applied to a set of goals such as for the resilience strategy for the Eel River watershed. A simple method to refine corridor design with the goal of improving freshwater protection in a planning area is to extend the protection of rivers to the full length of their flow. This also addresses the need for protecting environmental gradients in the planning area (Nel et al., 2009).

Planning with riparian connections

Over time, there has been a preference in land management for preserving riparian forests over more valuable, farmable, or timber harvestable land (Krosby et al., 2018; Pressey & Bottrill, 2009b; Soule & Terborgh, 1999). This makes planning conservation networks around riparian corridors a natural fit for the availability of land and their inherent connectivity across a watershed.

Because riparian areas natural connectivity corridors with the potential to buffer the impacts of climate change, contain a higher percentage of threatened and endangered species (Watson et al., 2013), hold important ecosystem services such as water filtration and flood retention (Dale et al. 2001; Detenbeck et al., 1993), a key piece of the Eel River watershed resilience strategy is to establish riparian corridors through the watershed, name them and identify connective habitat blocks and prioritized parcels from the prioritized parcels branching from them. It is important to establish connectivity across the landscape for animal movement within their range needs and because of impacts to habitat from climate change. Most animals and plants will need to travel to different locations as the climate shifts. As a built-in system of pathways for movement and connectivity, riparian areas provide a natural framework to build connected networks (Salviano et al., 2021, Steidl, 2009). Many healthy riparian areas provide climate refugia naturally (Fremier et al., 2015). This is due to the environmental gradients of temperature, precipitation, elevation, and topographic complexity along riparian corridors.

Riparian Buffers

Riparian buffers on areas that connect to important habitat is a simple method for corridor design (Brost & Beier, 2012; Rouget et al., 2006). It is common practice to assign fixed-width buffers to riparian areas. For example, local planners in Humboldt County apply a standard 100-foot buffer to riparian corridors. A riparian corridor analysis and methodology created by Krause et al., 2015 (CDFW) for the California Wildlife Conservation Board provides a methodology for defining riparian corridors as continuous perennial streams with any riparian vegetation mapped along them and adding 500 meter fixed-width buffers. The image below shows a riparian corridor with little to no buffer within agriculture fields (Figure 7). Without clear management parameters, a fixed width riparian buffer would be better than no buffer. However, there are other methods to derive riparian buffers that provide more nuance and support the ecological processes of rivers as dynamically changing features in the landscape.

Figure 7. A riparian corridor with little to no buffer within agriculture lands.

Mapping 'Potential Riparian Area'

Instead of using standardized buffers to map riparian areas, CalTrout worked with Stillwater Sciences in 2024 to develop a Potential Riparian Area (PRA) spatial dataset using a geomorphons approach from Digital Elevation Model. This geomorphons method defines riparian area restrained by slope and valley bottom and is attached to the National Hydrography Data (NHD). Mapping riparian potential is useful because this method includes annual and intermittent streams as potential riparian area. Many streams in the Eel River watershed do not have continuous flows through the summer and dry periods, but rather provide important habitat for fish and other species intermittently. The resulting potential riparian area spatial data provides a tool to plan for protecting riparian corridors in places on the landscape where they have the potential to move, ebb, and flow to, even in changing climate conditions and flow regimes.

Connect riparian areas to wetlands.

Identify and connect all wetland types to riparian corridors (Figure 8). Wetland types to consider:

1. Riverine – Riverine wetlands depend on the flow of water conveyed by natural or artificial channels, including rivers, streams, ditches, and canals. They can form on floodplains, river terraces, and along channel beds, especially where the flows are seasonal or episodic. Very broad floodplains can contain wetlands that resemble depressional wetlands because they are confined to topographic depressions or hollows but are classified as riverine because they depend on riverine flooding.

2. Lake – a body of water surrounded by land, an inland body of water, small to moderately large, with its surface water exposed to the atmosphere and which may occasionally be saline

3. Freshwater Pond - Ponds are small and shallow waterbodies, with a maximum surface area of 5 hectares (12.35 acres), a maximum depth of 5 meters (about 5.5 yards) and less than 30% emergent vegetation.

4. Freshwater Forested/Shrubbed Wetland - are freshwater wetlands dominated by trees

5. Freshwater Emergent Wetland - Emergent wetlands are a transitional area between permanently wet and dry environments. It is a place where the land “emerges” from the water to join the forest and the plants that grow there “emerge” from the water. They are specially adapted plants called hydrophytes (“water plants”) that grow well in a wetland environment.

6. Estuarine and Marine Wetland - An estuarine wetland is a brackish habitat where freshwater meets saltwater. Estuaries contain nutrients and sediment from both the land and sea connecting the two and fueling an abundant assemblage of plants, animals, and invertebrates.

7. Estuarine and Marine Deepwater - DEEPWATER HABITATS are permanently flooded lands lying below the deepwater boundary of wetlands (see Section 2.2 for explanation of wetland limits). Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live, whether they are rooted in, or attached to the substrate.

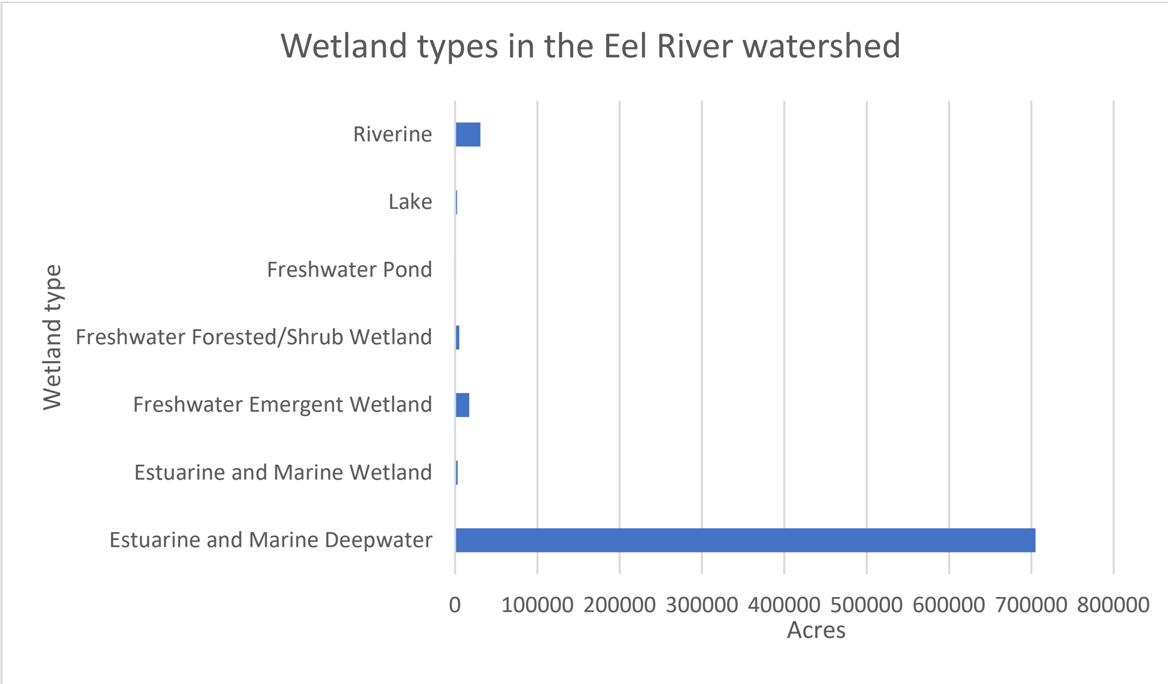


Figure 8. Wetland types in the Eel River watershed (USFWS, National Wetland Inventory database)

Description of the Key variables

Habitat and species variables are integrated into the resilience strategy as spatial data inputs. The variables are mapped across the planning area and used as conservation features for defining focal areas for conservation and restoration.

For the resilience strategy, conservation feature targets are set for each of the variables. For example, conservation targets are recommended by the Convention on Biological Diversity (CBD) and set at percentages based on international expert opinion and scientific reports. The standard 17% Aichi biodiversity target set in 2010, has been increased as of 2022 to 30% for terrestrial and aquatic biodiversity areas globally (IUCN, 2022; CNRA 2023). This study follows the recommendations outlined by the California Natural Resources Association (CNRA, 2023), which follow the Convention on Biological Diversity parameters for protecting 30% of California by the year 2030 (IUCN, 2022). In California, this is commonly referred to as the California 30x30 Initiative (CNRA, 2023). However, simply protecting 30% of California lands and oceans will not effectively protect the representative habitats, species, and climate refugia necessary to support biodiversity over time. Thus, targets were set for each of the following variables to establish an effective protected area network. The generalized framework presented here can be applied to other regions of California by adjusting the feature target variables and inputs for the specific ecosystem processes, species, and other analysis inputs relevant to those regions.

Rare, threatened, and endangered species

The CNDDB includes data on “special status taxa,” which is a broad term used to describe all plants, animals, and natural communities tracked by the CNDDB program, regardless of their legal protection status. The CNDDB data includes both global and state categories. However, for the conservation network solutions described in this report, only the State listed categories were used (Appendix II).

The State listed categories of special status taxa:

- SH- Possibly extirpated; known only from historical occurrences but there is still some hope of rediscovery.
- S1- Critically imperiled; at very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
- S2- Imperiled; at high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
- S3-Vulnerable; at moderate risk of extirpation in the jurisdiction due to a restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors

Vegetation

Canopy cover is a common variable in large landscape analysis planning. For the preliminary Marxan conservation solutions analysis, we used the LCMAP Forest Cover 2021 data for tree canopy cover. Other vegetation data needed extensive processing that we did not have time for during this project. However, future studies may discern that using either Normalized differentiation vegetation index (NDVI) or the forthcoming in 2025 updated VegCamp data are potential options for the vegetation layer in a weighted spatial analysis.

Normalized differentiation vegetation index (NDVI) gives a standardized range of values for vegetation density and health. NDVI can be used to define ranges of the index to be prioritized as representative vegetation densities. For example, the conservation target is to protect 30% of intact, dense vegetation. Vegetation data is needed because 'vegetation intactness' has been identified to be more important for habitat resilience than climate change impacts on the landscape (Watson et al., 2013). Climate strongly influences vegetation distribution (Cornwell et al., 2012).

NDVI were sampled for the entire Eel River watershed by CalTrout. Stillwater Sciences then analyzed the NDVI data in the Upper Eel River watershed and systematically edited and cleaned up those data to prepare them for use in future landscape analysis. This index, once it is edited for the rest of the watershed, may be used in replacement of the canopy cover variable that was used in this Marxan analysis. The NDVI values for dense vegetation, or the highest values, can be considered important to include as a spatial data layer in future prioritization analyses for the watershed.

As of the time of this report, mapped vegetation data are incomplete for the Eel River Watershed. Mapped VegCamp vegetation data are not scheduled to be completed for the North Coast region of California until 2025. For this reason, we recommend using Normalized Difference Variation Index (NDVI) or a proxy substitute such as tree canopy cover from the LULC data until complete vegetation community data are available for inclusion in a stratified representative conservation target approach for Marxan inputs.

Resilience index

Conserving a range of physical environments protects a diversity of species under current and future climates (Anderson et al., 2014). Because of this, connective properties of planning units as conservation features with set targets were used (Daigle et al., 2020). The TNC resilience index includes data on landscape heterogeneity including landscape diversity, local connectivity, fragmenting landscape features (roads etc), geology and soils, elevation, landforms, and migration space for tidal habitats. These data represent places where the effects of climate change are buffered by the natural properties of the site (Anderson et al., 2023).

Protected areas

The California Natural Resources Agency (CNRA) developed open-source spatial data available for download which were developed in collaboration with ESRI. The data provided for protected areas use the Protected Area Database (PAD-US) GAP 1 and 2 designations combined with other easement protected areas that have established management plans species protections. Proximity to protected areas (GAP 1 and 2 + easements) "protected areas" are often wilderness, managed forested areas, and croplands all lumped together (Watson et al. 2016). The CNRA data separates GAP 1 and 2 locations from GAP 3 and 4. It also adds other easements and conservation areas that may not be within the Protected Area Database (PAD) GAP dataset. Using the CNRA protected area data, we analyzed the percentage of protected area across the Eel Watershed. Further, we analyzed the representation of protected areas across the seven major sub watersheds (Map 1).

Proximity to natural areas (GAP 3 and 4)

Cost

Cost is integral to prioritization with Marxan conservation planning software. Cost may be set as null to help identify the conservation features without a cost penalty. However, a study on cost data for conservation planning equated planning without cost as "shopping without price tags" (Cawardine et al. 2008). To develop a real-world scenario for parcel acquisition and cost, the analysis in this report assigned cost with a designated value for each planning unit. We integrated cost data aligned with county parcel spatial data from the PLACES lab at Boston University into the analysis (Nolte et al. 2020). The indexed parcel cost estimates assign a cost range for parcel purchase.

There are other options to employ non-monetary alternative cost data which were not explored in this analysis. For example, it is possible to set a score for 'cost' based on parcel size and contribution to biodiversity. Larger parcels could have a lower 'cost' in the Marxan inputs. Develop other cost criteria with experts. For example, larger protected areas can sustain more biodiversity and have reduced edge effects (desiccation etc.) and fragmentation is detrimental to biodiversity and climate resilience.

4. Methods

4.1 Goal of this project

Identify a conservation network which results in a network of mapped parcels that meet specific conservation targets. Here, we show one part of the resilience strategy which is the proposed conservation network for the watershed. The other two data sets, climate refugia and potential riparian area, are standalone datasets that can be overlaid with the conservation network to provide additional information. The conservation network is built with a rigorous spatial data methodology described in this report. The results of the analysis show areas that have high value for conservation investment and can be prioritized for supporting landscape resilience.

4.2 Methods summary

Step 1. Analyze the amount of each of the data variables below in the 44,562 parcels within the Eel River watershed. Assign specific conservation target percentages per each item in the circles to be represented in the conservation solution.

<u>Variables analyzed:</u>

- Tree canopy cover (Landsat 2021)
- Observed areas of biodiversity – species of concern (CNDDB 2024 update) (endangered, threatened, and rare species)
- Observed beaver locations.
- Resilient lands index (Geophysical Diversity) TNC
- Areas of low-medium low solar radiation
- Cost – Places Lab 2020 cost of parcel acquisition data
- Connectivity – proximity to existing protected areas (CPAD 2023).

Step 2. Prioritize areas based on their value using Marxan software (section 3.3). Planning unit (parcel) value is defined by the percentage of each variable within each of the 44,562 parcel planning units.

4.3 Spatial planning

Flowchart

The prioritization framework →feature inputs → Marxan algorithm model outputs → corridor design → data overlay options (Figure 9).

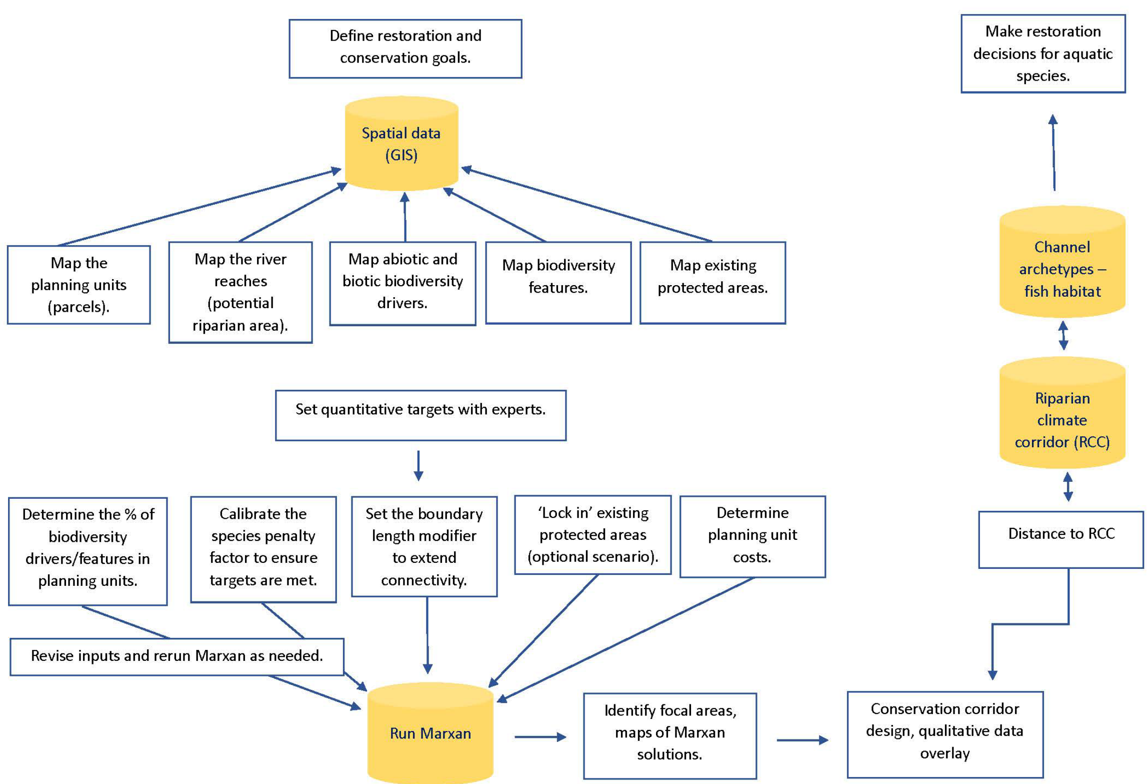


Figure 9. Marxan analysis flowchart shown with other analysis overlay options.
Flowchart of steps to identify focal areas for recommendations to protect climate resilience and biodiversity. The steps for the Running Marxan are generalized by Margules & Pressey, (2000) as 1. Define conservation targets, 2. Map spatial data for the planning area, 3. Set quantitative targets 4. Identify focal areas from the prioritized parcel solutions (Marxan results = conservation network). Additional databases "Channel Archetypes – fish habitat" and "Potential Riparia Area" are associated analyses in process and scheduled for release soon. These can be used as overlay data to the Marxan scenario results for adjusting protected area network to aquatic species habitat restoration decisions and parcel acquisition focused on climate resiliency values in the riparian corridors and surrounding habitat.

Planning scale

The Eel River watershed needs a landscape or "watershed scale" plan because the aquatic species which are the focus of restoration planning use habitats across the entire watershed throughout their lives. Additionally, a watershed scale plan is needed for terrestrial and riparian conservation planning because species need continuous landscapes to track to different locations as anthropogenic impacts and climate change alter the connectivity and quality of habitat across the landscape. The scale of the conservation strategy is the entire Eel River watershed. The conservation network analysis results are not limited to the riparian corridor, although we are recommending that the riparian corridor be the focus of a future connected protected area network.

4.4 Running Marxan

Marxan is a spatial conservation prioritization tool which uses an algorithm to identify areas which represent good options for sets of planning units within a network design. To output results, Marxan requires spatial data inputs of habitat features across the planning units. Conservation feature target percentages to be protected within each feature and relative cost per planning unit are established by the user. For example, a stated goal may be "protect 20% of all important bird areas" or "100% of all wetlands". The solution contains a selection of parcels that meet those criteria or conservation feature targets. The amalgamation of parcels in the Marxan result would represent 20% of important bird areas and all wetlands in the total solution.

Basic steps for running Marxan for this conservation analysis:

1. Pre-processing of data

2. Setting up the input files and the scenario parameters

3. Running Marxan

4. Viewing and interpreting the results

Identify Marxan goals and objectives.

- Increase the size of existing protected areas, adding new protected areas, protecting representative habitats across the landscape (Keeley et al. 2018).
- Prioritize connectivity to existing protected areas and link protected areas with riparian corridors or other natural areas where landscape resistance is low. These strategies will benefit many species when they need to expand their ranges as climate impacts their habitat. (Collingham and Huntley 2000, Donald and Evens 2006).

- Analyze the effectiveness of existing protected areas by running separate Marxan analyses with protected areas locked in and not locked in. Locking in an area, means that the area will always be included in the solution. Locking out the area means the area will always be excluded from the solution. To be effective as part of the conservation solution, locked in protected areas must be representative of the different habitats in the watershed.
- Focus on physical landscape level ecological processes that will support resilience to climate change. For example, "corridors that follow temperature and precipitation gradients to support species movement with or without climate change impacts (Pearson and Dawson 2005). Map environmental gradients such as upland to lowland interfaces" (Keeley et al. 2018).

Divide the area into planning units

The planning units in this analysis are county parcels from the five counties within the boundary of the Eel River watershed. Among Humboldt, Trinity, Mendocino, Lake and Glenn counties, there are a total of 44,642 planning unit parcels. Each of these is one planning unit, thus there are 44,642 planning units used to run the Marxan solution.

Creating the Planning Unit (PU) files to run Marxan:

"PU" shapefile + pu.dat is the text file
Create pu.dat file after the shapefile is created in ArcMap
Create a unique ID for each planning unit (pu)
Enter the cost of each planning unit (set to null = "1", or PLACES parcel value data from 2020)
Identify the status of each planning unit
0 = always available for selection
2 = lock in area (See solution for Targets 3, Table 1. existing protected areas, always include these in the selection to see where protected area expansion can occur)
3 = lock out (urban or pervious areas) We did not lock out urban areas in this analysis.

Identify and map variables

<u>Vegetation</u> – for the analysis, tree canopy cover from 2021 Landsat satellite Land Use Land Class (LULC) was used as the vegetation variable. For future analyses, a more refined vegetation variable, such as normalized differentiation vegetation index (NDVI) may be used from Landsat Satellite data downloaded from August – September 2022 imagery. The NDVI data require editing. At the time of this report, Stillwater Sciences are contracted to edit and prepare the NDVI data for the Upper Eel River sub watershed. The methods they used to edit the NDVI data can be applied to the other six sub watersheds to prepare the full data set to be used as the vegetation variable in future Marxan analyses. The NDVI data edited for the Upper Eel River sub watershed are available for download on the CalTrout / CalPoly Humboldt Eel River watershed data portal: caltrout.reclaim.hosting/dataportal/

> NDVI variable approach - protect a "representative sample" of major vegetation communities: forest, grassland, shrubs, agriculture (Venter et al. 2014). The vegetation class needs to be calculated per area. Do not just prioritize the densest vegetation. Choose to represent NDVI vegetation at different stratified levels. For example, plants need 20% of habitat minimum for dispersal (Pervious surfaces and very low NDVI values are excluded *ie.* blocked out). Other approaches recommend taking this a step further and categorize vegetation communities with climate gradients. For example, cool to hot grasslands within a region can be categorized to define climate gradients (Heller et al., 2015).

- Species biodiversity – CNDDB California Natural Diversity Database (CNDDB) Management Framework Presence / absence of rare, threatened, or endangered species. CNDDB version December 2023. Note: The occurrences used for the analysis represent the known locations of the species listed as of the date of this version. There may be additional occurrences or additional species within this area which have not yet been surveyed and/or mapped. Lack of information in the CNDDB about a species or an area cannot be used as proof that there is an absence of special status species in an area (Figure 10).

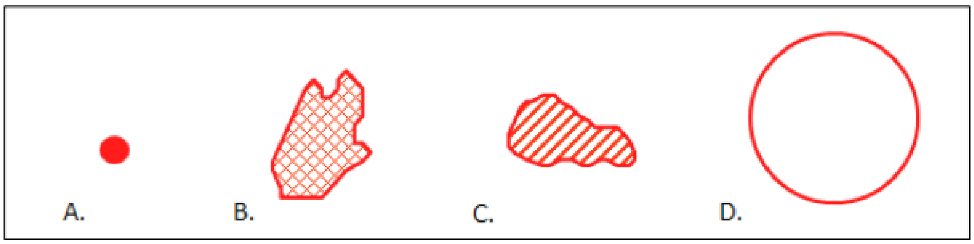


Figure 10. CNDDB layer data. Non-specific polygons and nonspecific circles (c and d) were represented with a smaller conservation target per area as they are identified areas of importance for species persistence but with less certainty as to the exact area as mapped areas of importance specific 80-meter radius circles and specific polygons (a and b).

- Resilience index
  Treat the connectivity properties of planning units as conservation features with set targets. Include connectivity strengths among planning units as spatial dependencies with the objective function. The presence / absence of high resilience index values, or targets of high-low is based on the indexed values 1-6 (TNC data).
- Proximity to protected areas (GAP 1 and 2 + easements) Protected areas are often wilderness, managed forested areas, and croplands all lumped together (Watson et al. 2016). The CNRA data separates GAP 1 and 2 locations from the GAP 3 and 4. It also adds other easements and conservation areas that may not be within the Protected Area Database (PAD-US 4.0) GAP dataset. Protected Areas with GAP 1 and 2 status were "locked in" to the Marxan algorithm. In this way, the protected areas are always included in the conservation solution. Suggested conservation parcels have higher value if they are connected to existing protected areas.
- Cost estimated range of parcel acquisition cost can be included if using the updated PLACES parcel cost data. The PLACES data reflect monetary cost and does not include the value or benefit of restoration and conservation. The method for applying PLACES cost range estimates to planning unit (parcel) data is as follows:
  - Create point layer to represent each polygon
  - Extract raster value for parcel value to point layer
  - Spatial join raster value of PLACES parcel value to County Parcel polygon layer
  - The indexed cost is assigned to each planning unit

Tally the amount of each feature in each planning unit.

Conservation feature amount per planning unit. See biodiversity features **Table 1**.

Set conservation targets for each feature.

For example, conservation target options: 10, 20, and 30% intact habitat for species diversity. See section 2.4 for a general description of conservation targets.

Conservation feature target % per variable

Table 1. Biodiversity features for Marxan conservation feature targets and analysis planning. Comparison of conservation feature target scenarios for Marxan run results: Targets 1 = Scenario 1, Targets 2 = Scenario 2, and Targets 3 = Scenario 3.

Biodiversity variables Climate change mitigation and nature conservation both require higher protected area targets (Roberts et al. 2020)	**Targets 1**	**Targets 2**	**Targets 3** *This report highlights Targets 3.*
Vegetation features Canopy cover 30m LULC 2021	20%	20%	20%
State ranked beaver habitat CNDDB data	30%	20%	20%
Observed State ranked endangered and threatened species locations. sensitive species data CNDDB data.	30% (biodiversity target set by CBD & CNRA, 30x30) S1 = 50% S2 = 30% S3 = 30%	30% (biodiversity target set by CBD & CNRA, 30x30) S1 = 50% S2 = 30% S3 = 30%	30% (biodiversity target set by CBD & CNRA, 30x30) S1 = 50% S2 = 30% S3 = 30%
Other variables			
Potential solar radiation index 30m modeled for entire watershed, Lowest values selected only. Lowest solar 1 Medium low solar 2 Somewhat low solar 3	1 = 30% 2 = 20% 3 = 10%	1 = 20% 2 = 10% 3 = 10%	1 = 20% 2 = 10% 3 = 10%
Resilience index (TNC), Geology, topographic heterogeneity. 30m. "A site's Resilience Score estimates its capacity to maintain species diversity and ecological function as the climate changes. It was determined by evaluating and quantifying physical characteristics that foster resilience, particularly the site's landscape diversity and local connectedness. The score is calculated within ecoregions based on all cells of the same geophysical setting and is described on	30% of the "more resilient" indexed value. Note: Did not use the tidal complex values as they were not as extensive in coverage as the California wetlands data.	20% of the "more resilient" indexed value. Note: Did not use the tidal complex values as they were not as extensive in coverage as the California wetlands data.	20% of the "more resilient" indexed value. Note: Did not use the tidal complex values as they were not as extensive in coverage as the California wetlands data.

a relative basis as above or below the average. For example, cells of granite bedrock were compared with all other cells of granite bedrock, and coastal plain sands were compared with other coastal plain sands. Our goal was to identify the places most resilient to climate change for each geophysical setting within each ecoregion." TNC web tool, 2022.			
Proximity to natural and restoration areas (GAP 3 and 4)	Did not treat this value differently than other land in the analysis. GAP 3 and 4 have no guaranteed protections. Thus, these areas should be available for restoration and conservation.		
Protected areas (GAP 1 and 2)	NA	NA	100% (locked in)
Post processing Marxan calibration:			
Boundary length modifier (BLM) calibrated	.66	.88	.22
Feature penalty factor (FPF or SPF) Calibrated	5	6	.11

Set conservation targets in Marxan and visualize the results in Zonae Cogito (Figure 11).

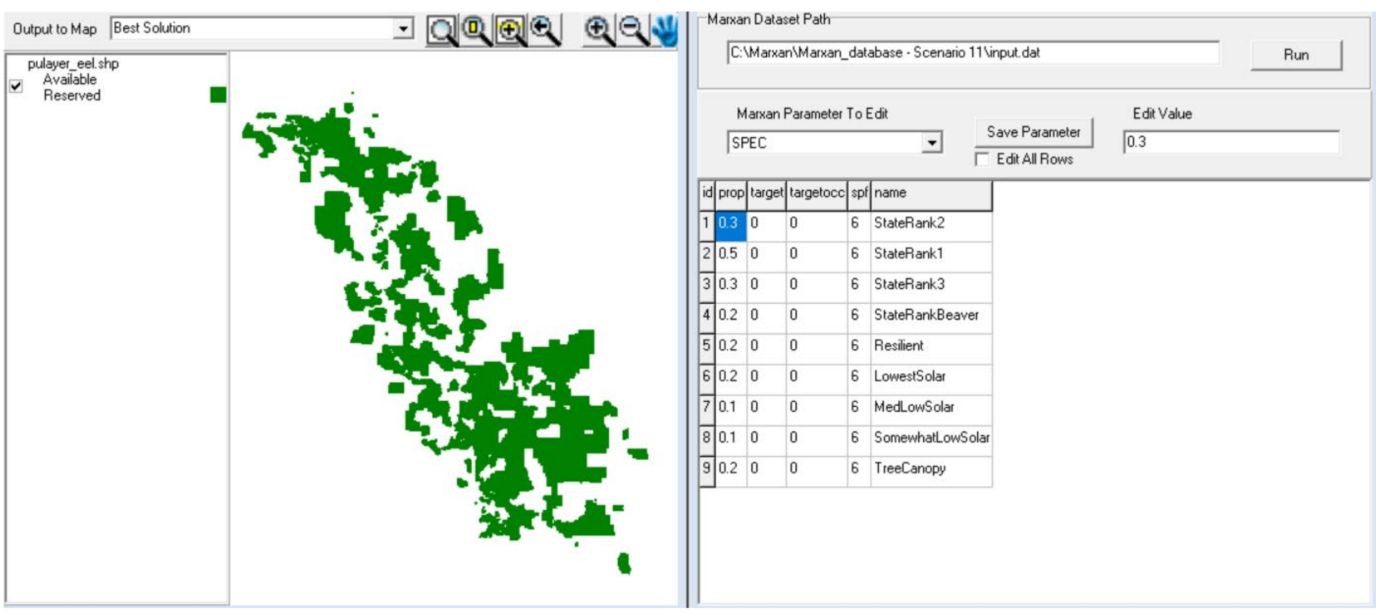


Figure 11. Zonae Cogito visualization of a Marxan best solution iteration of 100 algorithm prioritization runs for the Eel River watershed. The left panel shows the best solution for Marxan run with the boundary length modifier (BLM) and Feature Penalty Factor (FPF) calibrated and with % conservation targets shown in table to the right and reflects the target % as shown the planning **Table 1.**

Table 2. Alternate conservation targets example.

id	prop	target	targetocc	spf	name
1	0.3	0	0	1	StateRank2
2	0.5	0	0	1	StateRank1
3	0.3	0	0	1	StateRank3
4	0.2	0	0	1	StateRankBeaver
5	0.2	0	0	1	Resilient
6	0.2	0	0	1	LowestSolar
7	0.2	0	0	1	MedLowSolar
8	0.1	0	0	1	SomewhatLowSolar
9	0.2	0	0	1	TreeCanopy

4.5 Calibrating Marxan

Set Boundary Length Modifier (BLM)

Table 3. The Boundary Length Modifier (BLM) sets connectivity priorities, use for proximity to GAP 1 and 2, GAP 3 and 4.

test	BLM	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	5003.3103	2636.7298	1115.27	2814982.2	2366.5799	844641100	1
2	0.222222222222222	863883.33	75044.598	8206.61	3549752.5	4.9161522	7900	0.18
3	0.444444444444444	1724272.7	103541.994	10818.81	3646635.2	3.9742844	3200	0.1
4	0.666666666666667	2586967.9	120762.324	12430.03	3699307.9	0.5584057	300	0.02
5	0.888888888888889	3421114.1	124288.442	12686.7	3708916.8	10.915274	4400	0.08
6	1.11111111111111	4244940.3	129144.067	13122.93	3704216.1	1.08505	350	0.01
7	1.33333333333333	5088735.8	135352.55	13675.73	3715037	0.371952	100	0.02
8	1.55555555555556	5956444.6	136574.11	13838.42	3741337.8	11.064236	2550	0.05
9	1.77777777777778	6810899.2	139821.06	14109.58	3752464.3	30.737987	6200	0.04
10	2	7584539.6	140107.96	14137.59	3722205.6	20.077453	3600	0.04

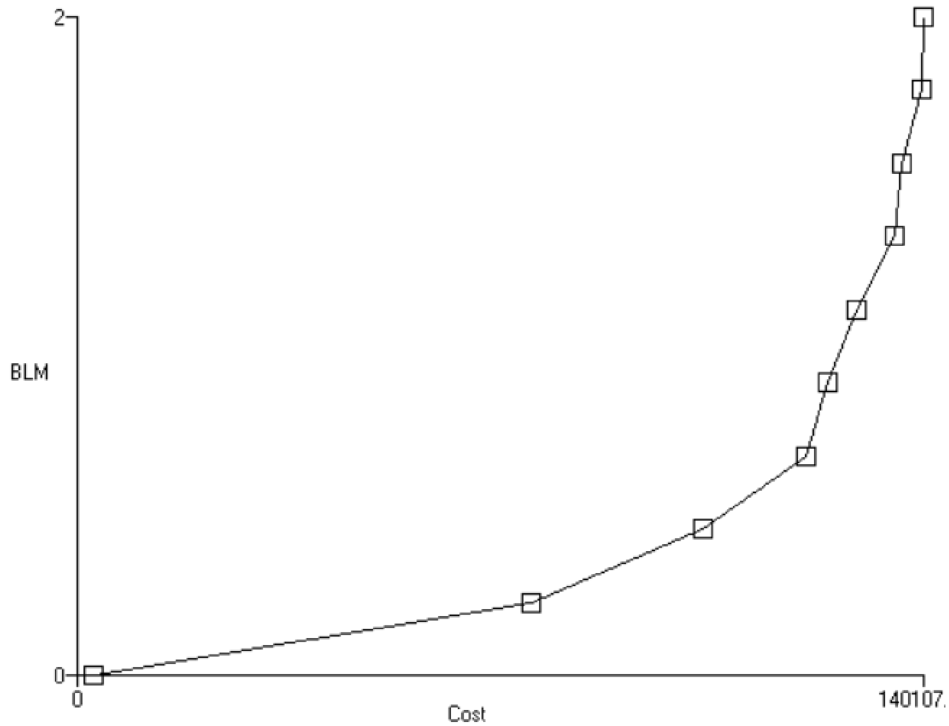


Figure 12. Test run BLM Calibration report 5 (10, 0-2): BLM set to .66

Calibrate Species Penalty Factor (SPF)

The Species Penalty Factor (SPF) is a part of the calibration process. This is also called the Feature Penalty Factor (FPF). The goal of the SPF is to find the balance between the species penalty and the missing values of the variables. Here, the cost and score are also considered to derive the best SPF to apply to the algorithm. After the SPF is chosen, the value is entered into the algorithm and Marxan is run again.

Table 4. The Species Penalty Factor results. The best SPF value is chosen from a review of all the fields.

test	SPF	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	1	2570509.8	119744.295	12300.84	3713258.9	14.3735732	7800	0.06
2	3.11111111111111	2638339.3	119206.082	12242.83	3816868.3	0.286653	50	0.01
3	5.22222222222222	2669554.1	118124.977	12179.67	3865796.3	3.849348	400	0.02
4	7.33333333333333	2684766.7	116068.456	11949.84	3891967	0	0	0
5	9.44444444444444	2724297.4	122918.253	12606.03	3941483.3	0	0	0
6	11.5555555555556	2718794.1	120326.978	12348.08	3937071	0	0	0
7	13.6666666666667	2721602.7	116082.155	11932.71	3947758.9	0	0	0
8	15.7777777777778	2744306.4	117719.96	12098.87	3979676.8	0	0	0
9	17.8888888888889	2743635.4	121163.731	12472.03	3973439.3	1.64826	50	0.01

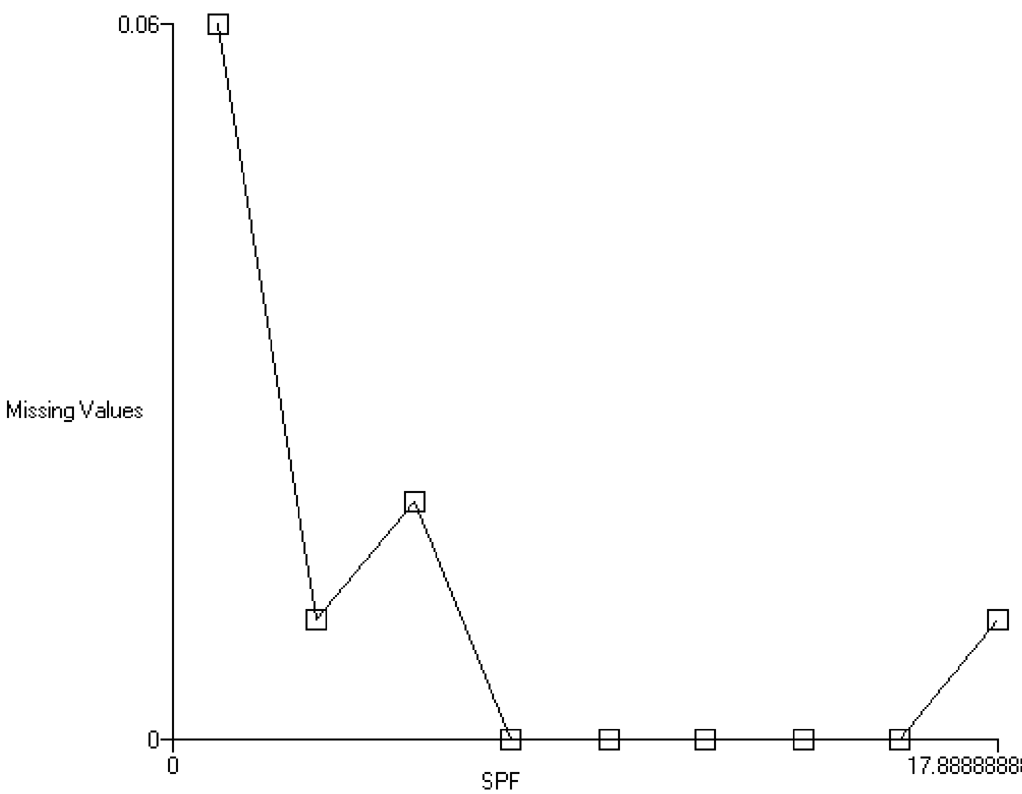


Figure 13. Calibration plot for SPF (FPF): Missing values (average number of features that missed their target for 100 solutions) versus the FPF value applied. Species Penalty Factor of 7.33 from line 4 in above SPF table graphed to show all tested calibration values. SPF of 7.33 calibration has the least cost per planning unit and contains no missing values of conservation feature targets in scenario 1.

Table 5. SPF calibration table test results.

test	SPF	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	1	2545537.7	119596.315	12292.17	3675630.6	25.1538218	13650	0.09
2	2	2618145.3	119369.69	12287.17	3786018.7	3.316987	900	0.02
3	3	2649534.2	118016.233	12158.76	3835630.7	1.105663	200	0.02
4	4	2649389.9	115395.074	11896.69	3839385.3	0.368554	50	0.01
5	5	2676340.2	117341.324	12069.54	3877271.2	0	0	0
6	6	2675994.6	119070.914	12227.03	3874125.2	1.105664	100	0.02
7	7	2688857.3	118078.372	12137.88	3895119.5	0	0	0
8	8	2707375	119059.129	12211.73	3921689.4	0.737109	50	0.01
9	9	2721736.8	120866.966	12432.08	3940711.1	0	0	0
10	10	2716607.7	119247.26	12245.12	3935394.5	0	0	0

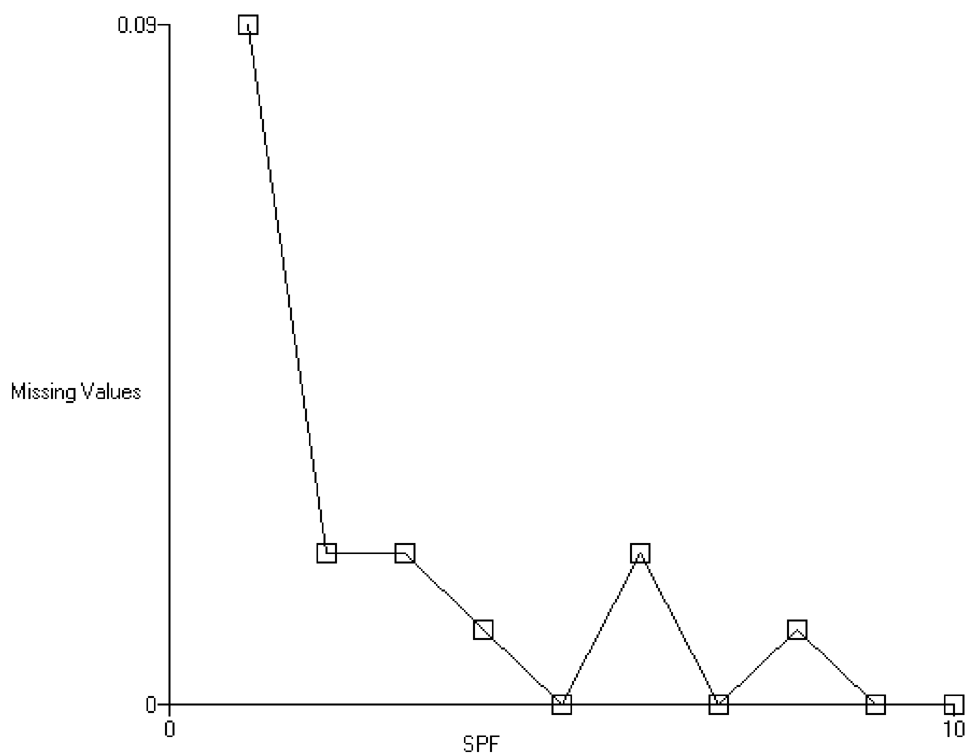


Figure 14. Calibration plot for SPF (FPF): Missing values (average number of features that missed their target for 100 solutions) versus the FPF value applied. Species Penalty Factor of 5 from line 5 in above SPF table graphed to show all tested calibration values. SPF of 5 calibration has the least cost per planning unit and contains no missing values of conservation feature targets in scenario 2.

Zonae Cogito: Rerun the analysis with new updated data and adjust targets if needed.

Conservation target percentages can be adjusted by manually changing the percent of each variable within the Zonae Cogito software that is used to view the results of the Marxan algorithm processing (Figure 15).

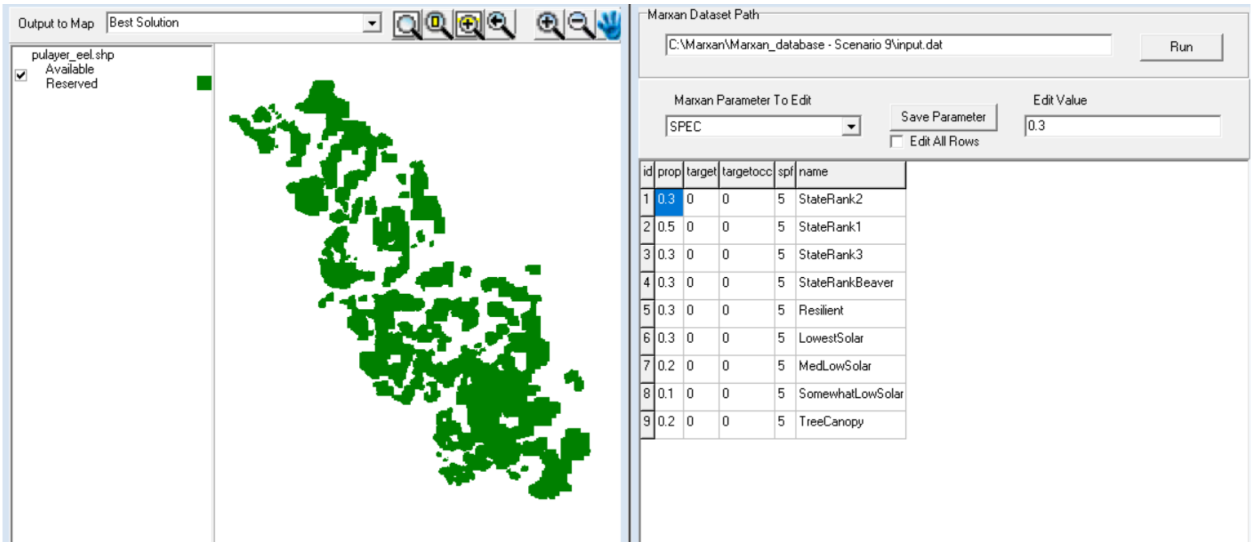


Figure 15. Zonae Cogito view panel. This is used to view the spatial results in a map of the Marxan algorithm processing. The percentage of each variable can be adjusted manually by editing the Prop column (proportion).

Internal review of Marxan results

- Review the achievement of targets: Review how well the project's objectives have been met through the achievement of targets;
- Review the efficiency of the conservation network: Consider how well solutions that meet targets do so for minimal cost / area, as well as how the clumping of sites suits the planning purposes;
- Conduct sensitivity (calibration) analyses: Measure how much influence each parameter has on the solutions and evaluate the potential effects of poor parameter estimates or weak assumptions.

4.6 Network and corridor planning

(see also section 5.2: Next Steps)

To build representative, connected corridors, we considered planning and connectivity elements such as proximity to existing protected areas, riparian buffers, riparian corridors, connectivity corridors, and climate corridors. To create structural connectivity, we included the connectivity needs of many species and overlaid these with important biodiversity areas, and representative landscape resiliency data for environmental gradients known to assist species persistence during climate change (4.4 in Conservation Targets).

5. Results

5.1 Marxan Solutions

Explore Targets 3 (Solution 3) conservation network spatial data on the web map. The layer in the web map is called "Conservation Solutions": https://caltrout.maps.arcgis.com/apps/webappviewer/index.html?id=7157121b86314342bbf0de8a6b6ccc78

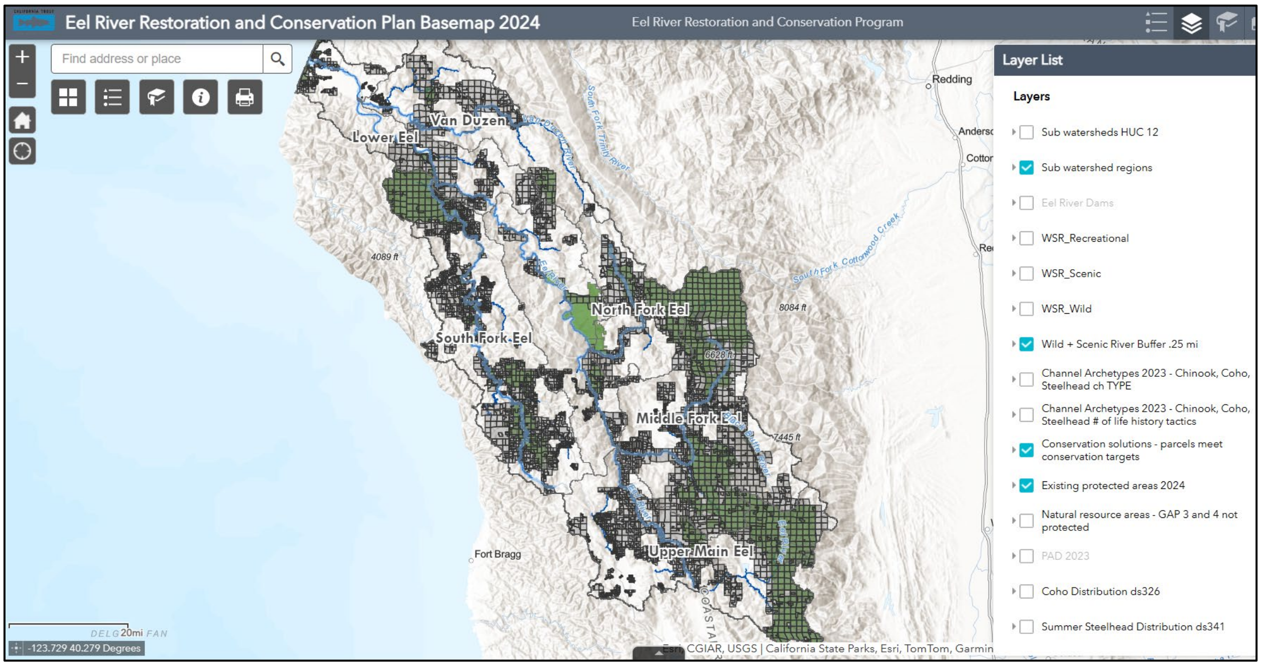
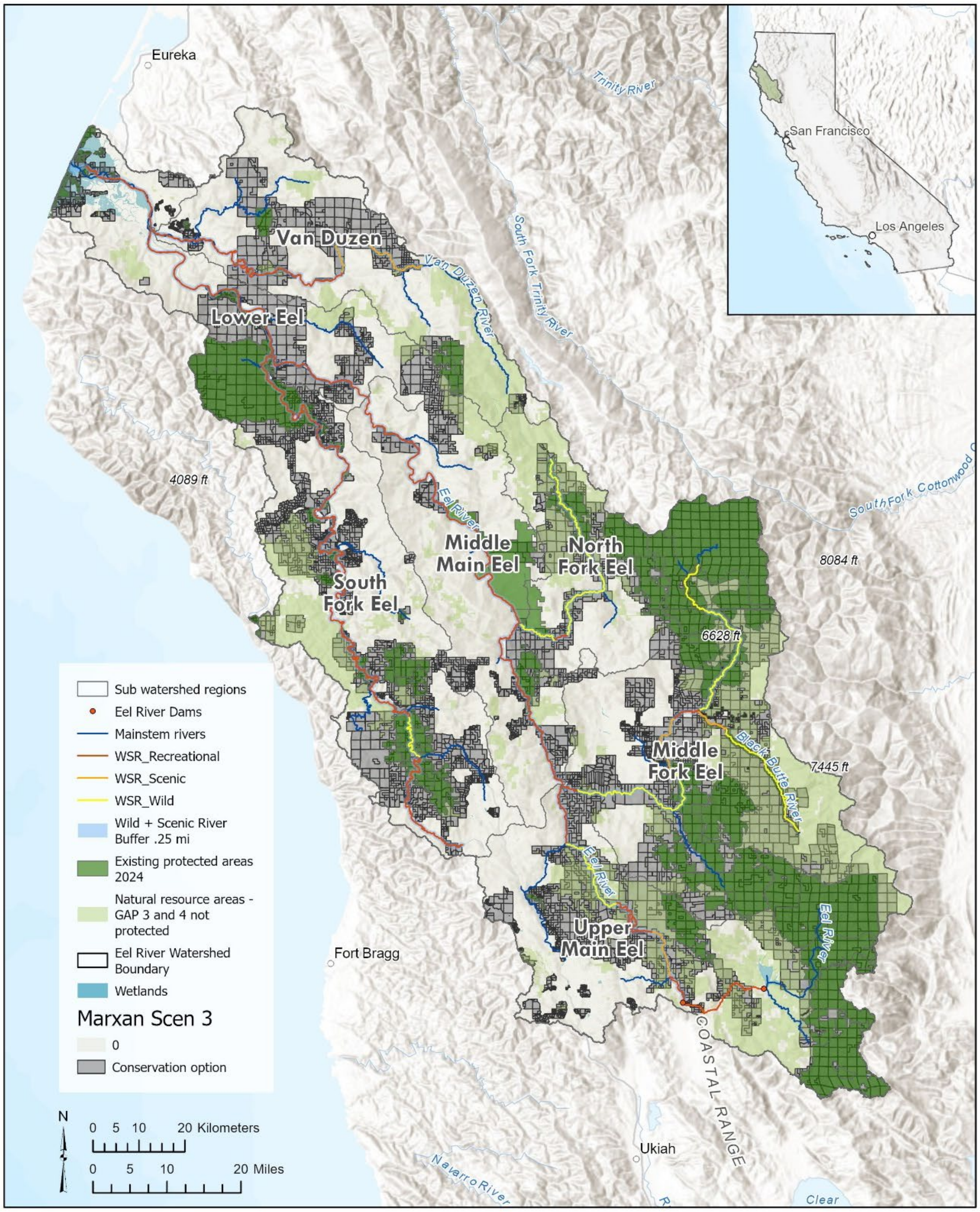


Figure 16. Results of the conservation solution and other data sets compiled and analyzed for the Eel River watershed can be explored by visiting the The Eel River Restoration and Conservation Plan base map (web map).



Map 1. Marxan conservation solution results (Scenario 3 from Targets 3) are shown with the existing protected areas, GAP 3 and 4 areas, wetlands, mainstem rivers and Wild and Scenic River segments.

Conservation feature targets

The Marxan analysis was run with different percentages assigned to represent each variable (feature). These percentages function as the feature targets for the algorithm to meet for the overall solution. The results of the analyses are shown here for Scenarios 1, 2, and 3. **Scenario 3 is the result that is referred to within this report** to define the results of the conservation network for the Upper Eel River watershed. Scenario 3 is also displayed on the Eel River Restoration and Conservation Program web map. Scenario 3 was chosen because it provides a conservation network with the highest values for land protection, connectivity, and climate resilience. Scenarios 1 and 2 are shown here for reference. See Methods section 3.2 for the full description of the variables for each Scenario.

Scenario 1

Conservation feature targets Scenario 1

The Boundary Length Modifier (BLM) calibration is run to ensure conservation features are met with the Marxan solution. This below table shows the test run of the BLM Calibration report. For Scenario 1, the BLM value within the report that best represents a balance among the Cost, Penalty, Shortfall and has the lease amount of missing values from the conservation target percentage is **BLM = .66**

Table 6. The BLM calibration table.

test	BLM	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	5003.3103	2636.7298	1115.27	2814982.2	2366.5799	844641100	1
2	0.222222222222222	863883.33	75044.598	8206.61	3549752.5	4.9161522	7900	0.18
3	0.444444444444444	1724272.7	103541.994	10818.81	3646635.2	3.9742844	3200	0.1
4	0.666666666666667	2586967.9	120762.324	12430.03	3699307.9	0.5584057	300	0.02
5	0.888888888888889	3421114.1	124288.442	12686.7	3708916.8	10.915274	4400	0.08
6	1.11111111111111	4244940.3	129144.067	13122.93	3704216.1	1.08505	350	0.01
7	1.33333333333333	5088735.8	135352.55	13675.73	3715037	0.371952	100	0.02
8	1.55555555555556	5956444.6	136574.11	13838.42	3741337.8	11.064236	2550	0.05
9	1.77777777777778	6810899.2	139821.06	14109.58	3752464.3	30.737987	6200	0.04
10	2	7584539.6	140107.96	14137.59	3722205.6	20.077453	3600	0.04

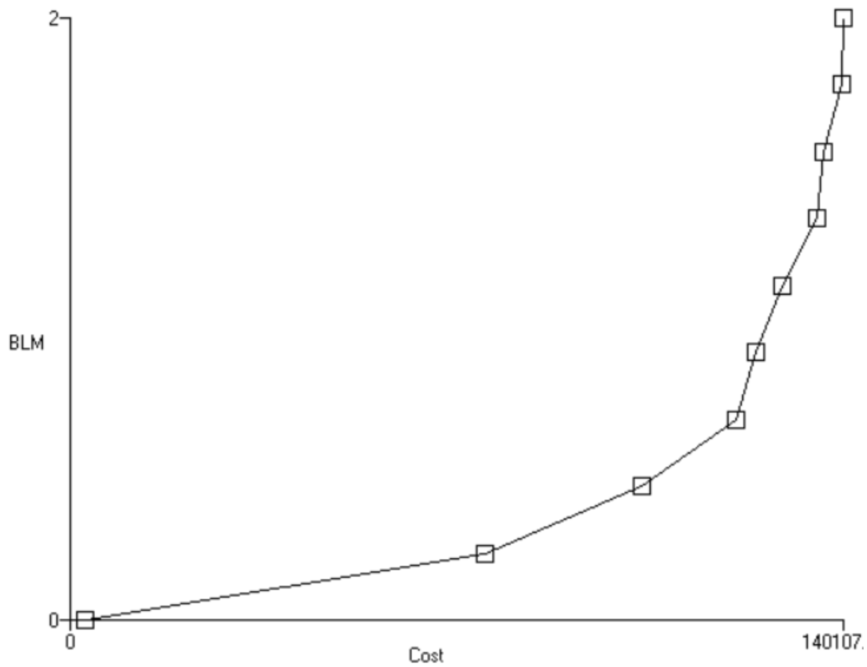


Figure 18. Targets Scenario 1 - Test run BLM Calibration report graph: **BLM = .66**

Mapped result of Scenario 1

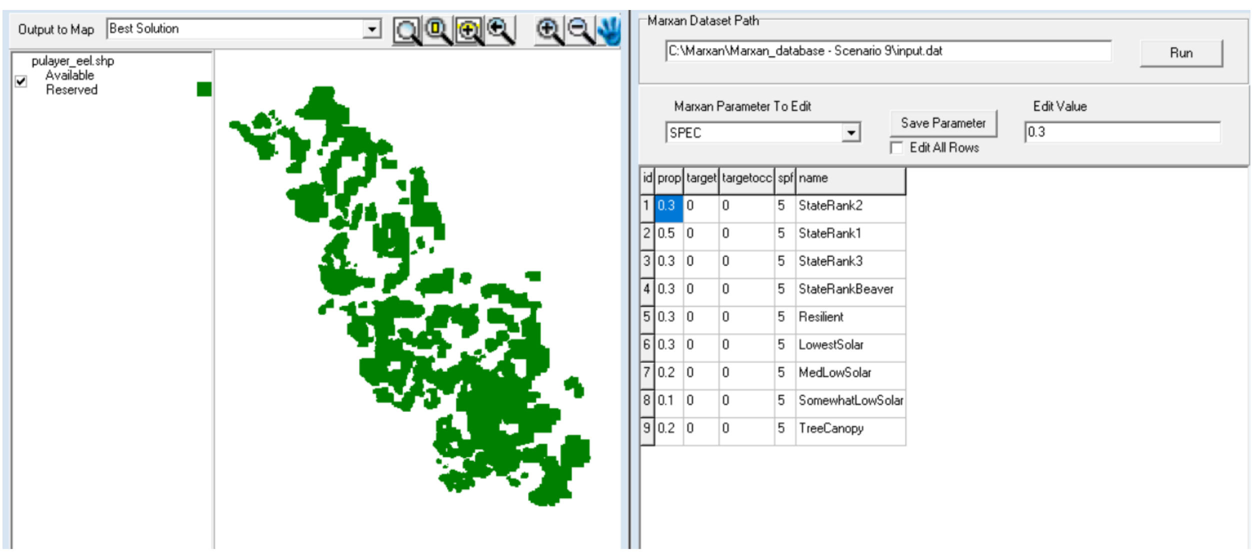


Image 19. FPF Targets Scenario 1 – mapped result, refined the FPF to “5” combined with the above BLM Calibration of “.66” to ensure all conservation targets are met.

Scenario 2

Conservation feature targets Scenario 2

Calibration

Targets Scenario 2, BLM calibration to .88 to ensure conservation features are met with Marxan solution.

The Boundary Length Modifier (BLM) calibration is run to ensure conservation features are met with the Marxan solution. This below table shows the test run of the BLM Calibration report. For Scenario 2, the BLM value within the report that best represents a balance among the Cost, Penalty, Shortfall and has the lease amount of missing values from the conservation target percentage is **BLM = .88**

Table 6. BLM calibration table for Scenario 2.

test	BLM	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	4997.5838	2630.7761	1114.74	2807485.7	2366.8078	844722420	1.02
2	0.222222222222222	863431.14	74914.937	8174.69	3548270.5	11.6369557	18700	0.14
3	0.444444444444444	1715964.5	103487.212	10844.49	3628054.3	8.7558356	7050	0.13
4	0.666666666666667	2566549.5	116721.228	12004.99	3674726.1	10.6097177	5700	0.04
5	0.888888888888889	3374905.1	124304.609	12696.16	3656920.4	4.961491	2000	0.02
6	1.11111111111111	4266511.1	132217.64	13396.25	3720853.7	11.005514	3550	0.03
7	1.33333333333333	5092081.8	134448.84	13589.96	3718224.6	0.185976	50	0.01
8	1.55555555555556	5931389.7	137695.56	13920.86	3724447.6	109.55813	25250	0.03
9	1.77777777777778	6812630.3	139793.12	14085.31	3753467	7.932387	1600	0.02
10	2	7596361.1	144080.92	14470.57	3726137.3	5.019351	900	0.04

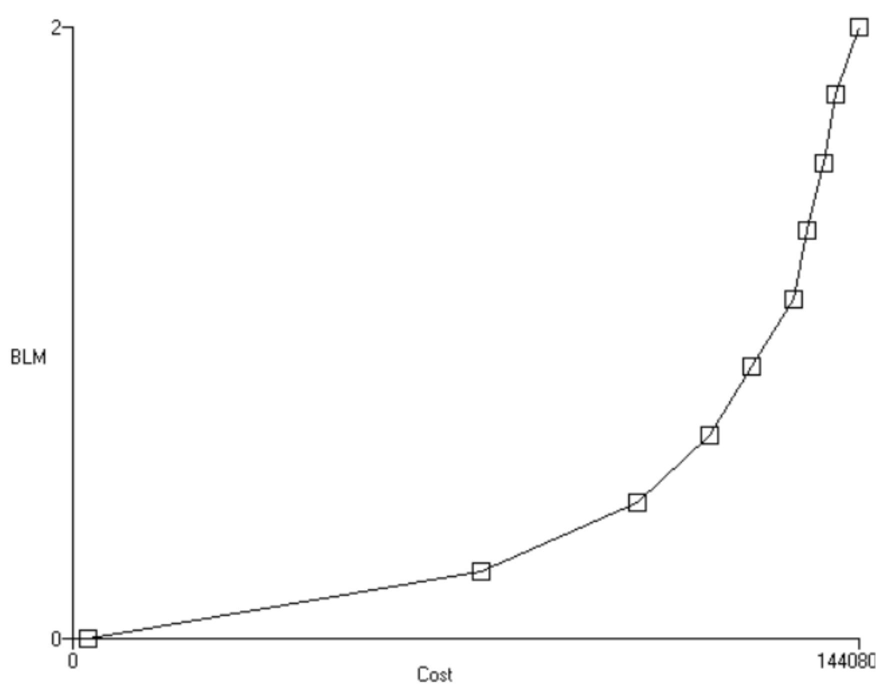


Figure 20. Targets Scenario 2 - BLM calibration to '.88' achieves the goal of least missing values, ie, conservation targets are met to the best degree possible and at least cost for Marxan targets scenario 2.

FPF Targets Scenario 2 – refine the FPF to “6” combined with the above BLM Calibration of “.88” to ensure all conservation targets are met.

Table 7. SPF/FPF calibration table for Scenario 2.

test	SPF	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	1	3372287.1	124823.83	12738.96	3690277.8	18.911004	7700	0.08
2	2	3445589.9	127191.241	12963.25	3770899.9	6.876711	1400	0.02
3	3	3496646.2	126428.78	12908.26	3829786.9	4.78914	650	0.01
4	4	3536914	128033.02	13028.22	3873728.5	0.491194	50	0.01
5	5	3549855.4	128258.949	13071.02	3888177	0.613992	50	0.01
6	6	3549410.1	127898.8	13041.03	3888080.9	0	0	0
7	7	3563128.4	129824.757	13200.91	3901480.2	0.859589	50	0.01
8	8	3582071.5	129898.797	13249.43	3922899.3	21.612564	1100	0.06
9	9	3603934.3	124640.82	12720.47	3953741	1.10519	50	0.01
10	10	3599765.9	130120.638	13276.1	3942778.8	0	0	0

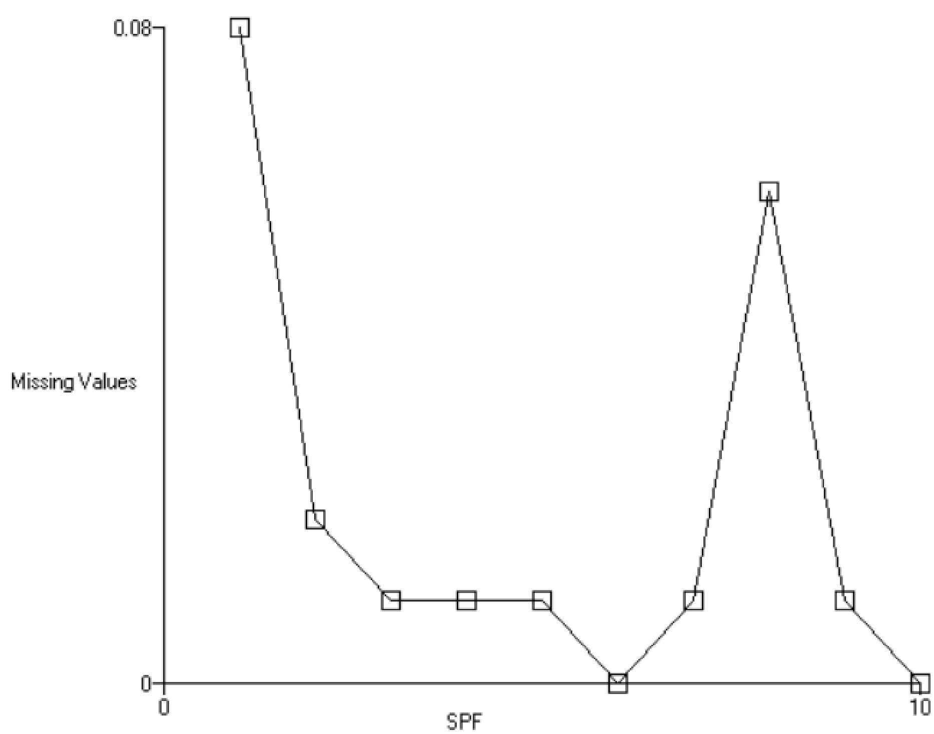


Figure 21. Targets Scenario 2**,** SPF calibration to ‘6’ achieves the goal of no missing values, ie, all conservation targets are met and at least cost for Marxan targets scenario 2.

Mapped result of Scenario 2

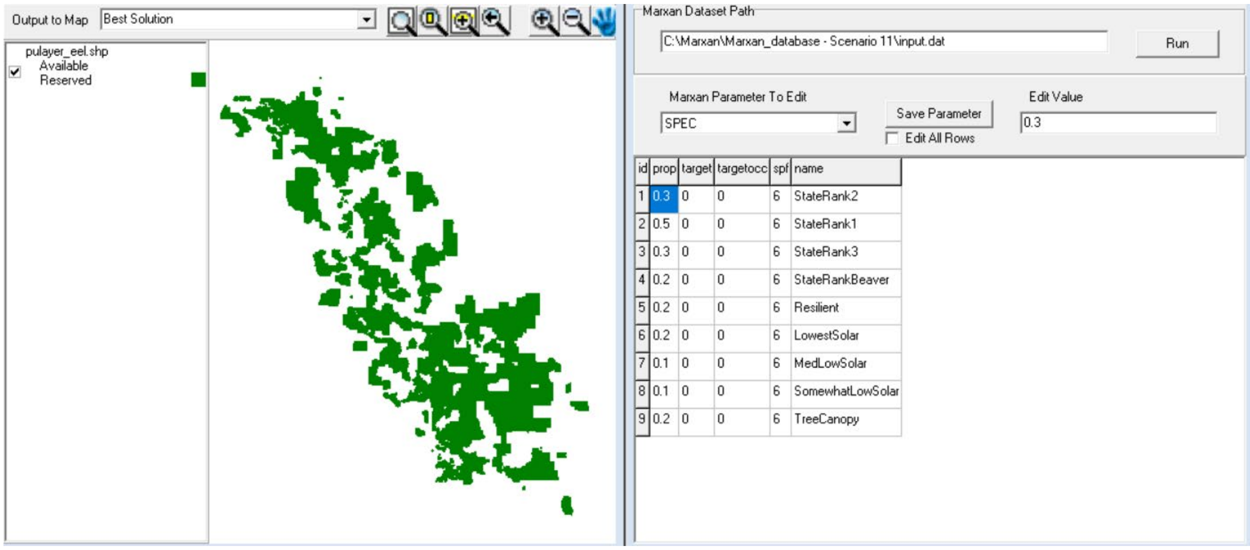


Image 22. FPF Targets Scenario 1 – mapped result, refined the FPF to “6” combined with the above BLM Calibration of “.88” to ensure all conservation targets are met.

Scenario 3

Conservation features Scenario 3

BLM Calibration

The Boundary Length Modifier (BLM) calibration is run to ensure conservation features are met with the Marxan solution. This below table shows the test run of the BLM Calibration report. For Scenario 3, the BLM value within the report that best represents a balance among the Cost, Penalty, Shortfall and has the lease amount of missing values from the conservation target percentage is **BLM = .22**

BLM = .22

Table 8. BLM calibration table for Scenario 3.

test	BLM	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	27404.172	27401.611	3951.22	5543056	2.563134768	396600	0.78
2	0.222222222222222	917010.39	96504.964	10659.93	3692274.3	0	0	0
3	0.444444444444444	1841579	126711.72	13513.41	3858450.8	0	0	0
4	0.666666666666667	2738715.2	143776.49	15051.76	3892408.9	0	0	0
5	0.888888888888889	3653665.9	150461.94	15657.84	3941104.4	0	0	0
6	1.11111111111111	4504355	155469.28	16092.97	3913997.5	0	0	0
7	1.33333333333333	5426356.4	162084.12	16758.18	3948204.5	0	0	0
8	1.55555555555556	6324579.5	166472.83	17151.24	3958782.7	0	0	0
9	1.77777777777778	7209933.8	169565.57	17427.54	3960207.3	0	0	0
10	2	8044407.9	170020.55	17467.36	3937194.4	0	0	0

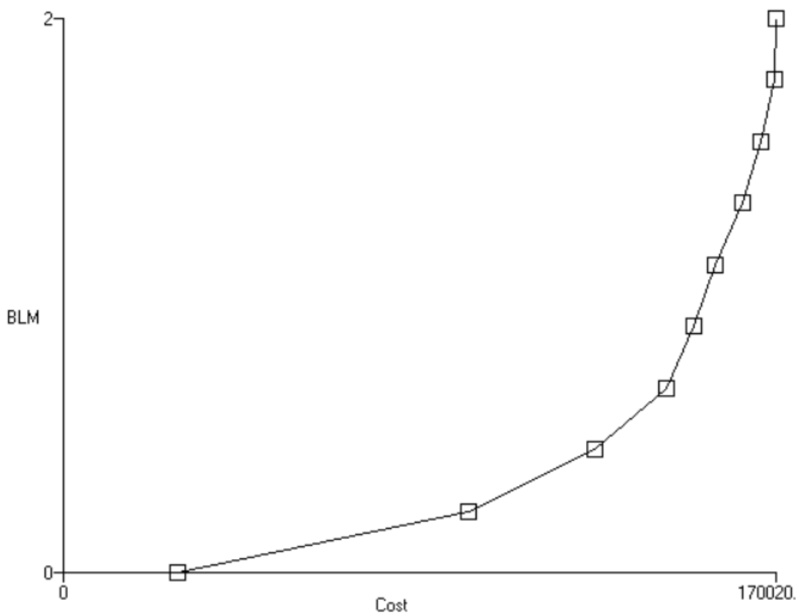


Figure 23. Targets Scenario 3 - BLM calibration to '.22' achieves the goal of least missing values, ie, conservation targets are met to the best degree possible and at least cost for Marxan targets scenario 3.

Table 9. SPF/FPF calibration table for Scenario 3.

test	SPF	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	877799.67	95800.557	10590.88	3554541	0	1594600	0.02
2	0.111111111111111	893549.52	96754.851	10679.73	3621794.2	0	0	0
3	0.222222222222222	901843.01	97002.79	10717.17	3658364.8	0	0	0
4	0.333333333333333	911062.09	97905.334	10796	3696167.5	0	0	0
5	0.444444444444444	900241.85	96501.122	10659.44	3653367.5	0	0	0
6	0.555555555555556	907924.08	97412.522	10753.73	3684143.1	0	0	0
7	0.666666666666667	910295.04	96810.262	10706.24	3697657.7	0	0	0
8	0.777777777777778	910064.33	97119.652	10722.42	3695202.6	0	0	0
9	0.888888888888889	907587.12	96754.599	10694.73	3685602	0	0	0
10	1	913468.18	96817.472	10685.8	3712048.9	0	0	0

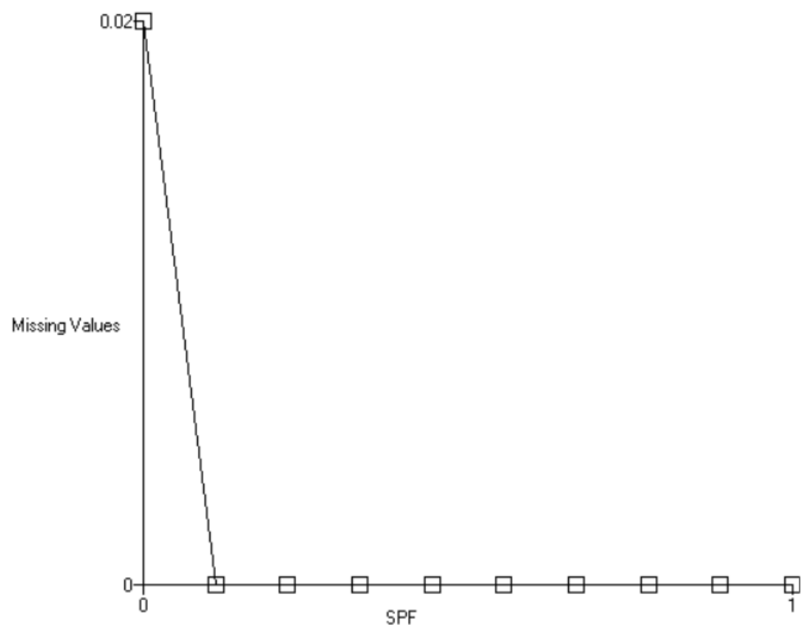


Figure 24. Targets Scenario 3**,** FPF calibration to '.11' achieves the goal of no missing values, ie, all conservation targets are met and at least cost for Marxan targets scenario 3.

Mapped result for Scenario 3

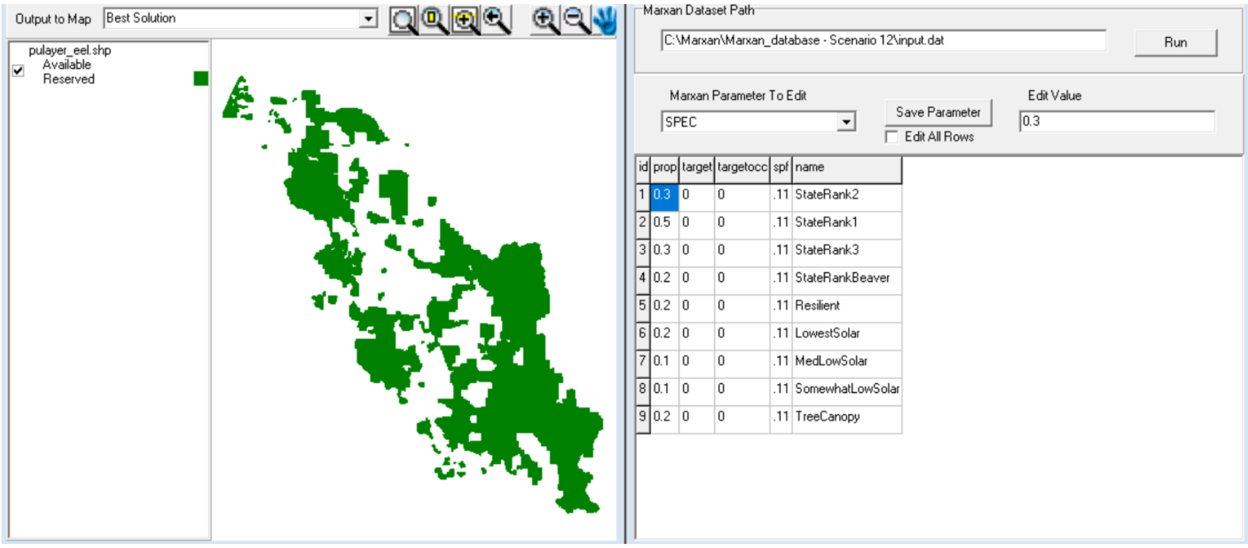
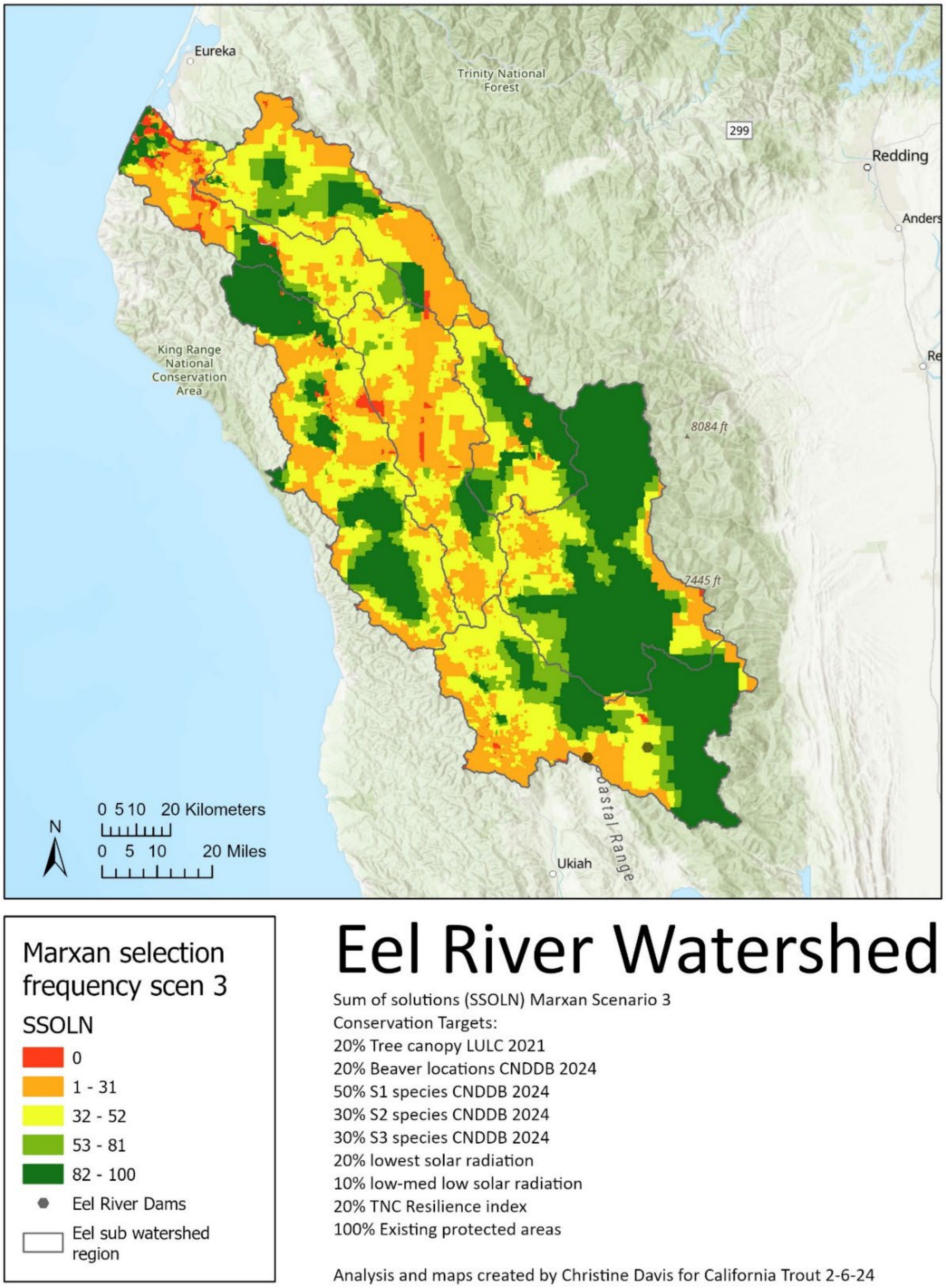


Figure 25. Scenario 3, the final result for the Conservation Solution used in the Eel Restoration and Conservation Plan web map, viewed here in the Zonae Cogito software.

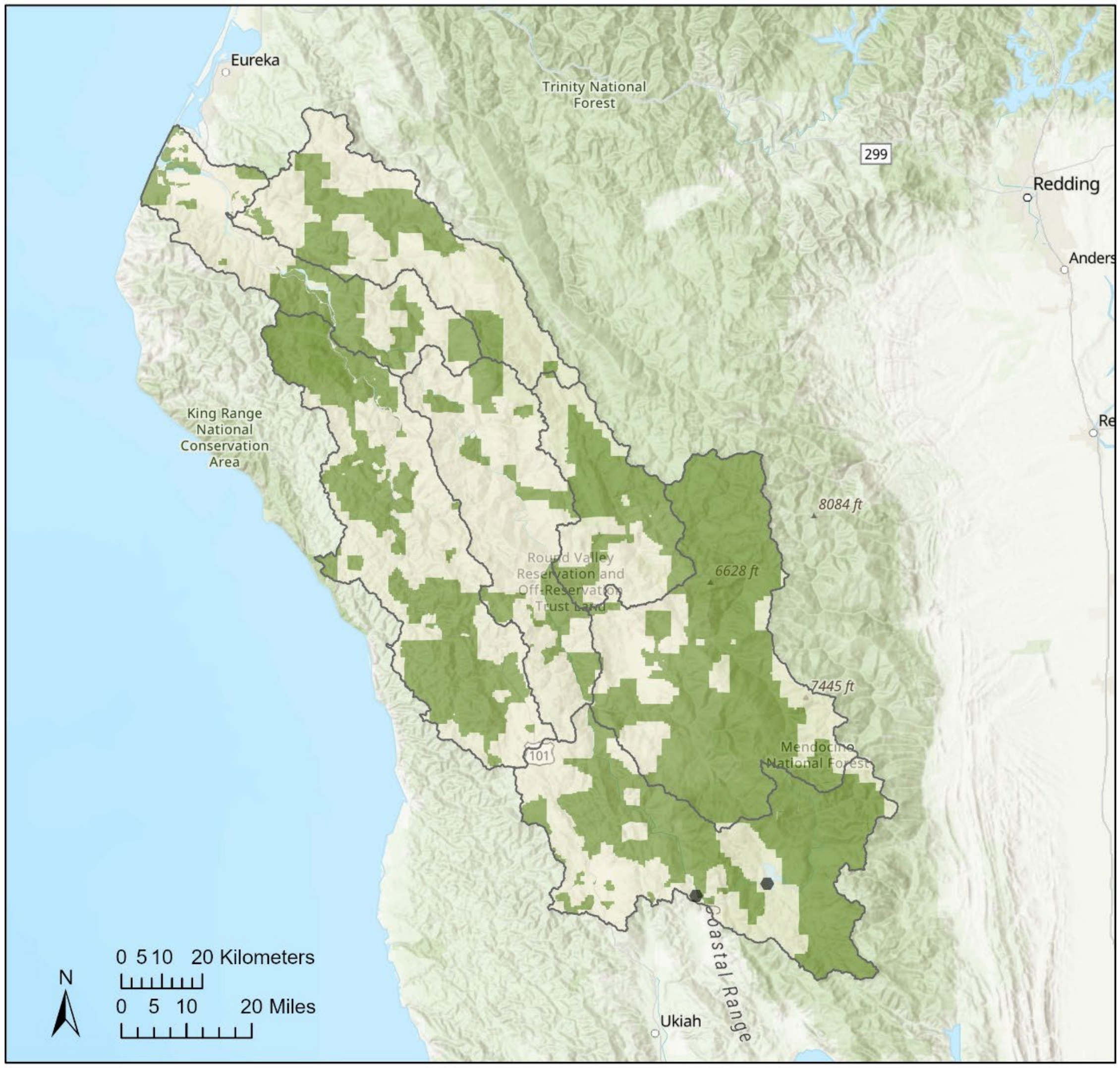
5.2 Map solutions, proposed conservation network (Scenario 3)

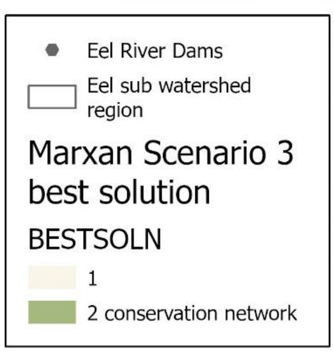


Map 2. Selection Frequency of parcels in the best solution for scenario 3 conservation targets. Parcels selected 82-100% of the time are suggested as the protected area network for the Eel River watershed. Parcels selected 53-81% are considered good options as back up solutions. The percentage correlates to how well the parcels meet the conservation targets as defined by the user. In this case, the conservation targets are listed on the map description.

Table 10. The parcel selection grid. The table shows the relative priority of parcels based on their selection frequency in the solution.

Number of times planning unit (parcel) is selected	**Marxan relative importance ranking**
1-25	Low priority
26-50	Medium low priority
51-75	Medium high priority
76-100	High priority





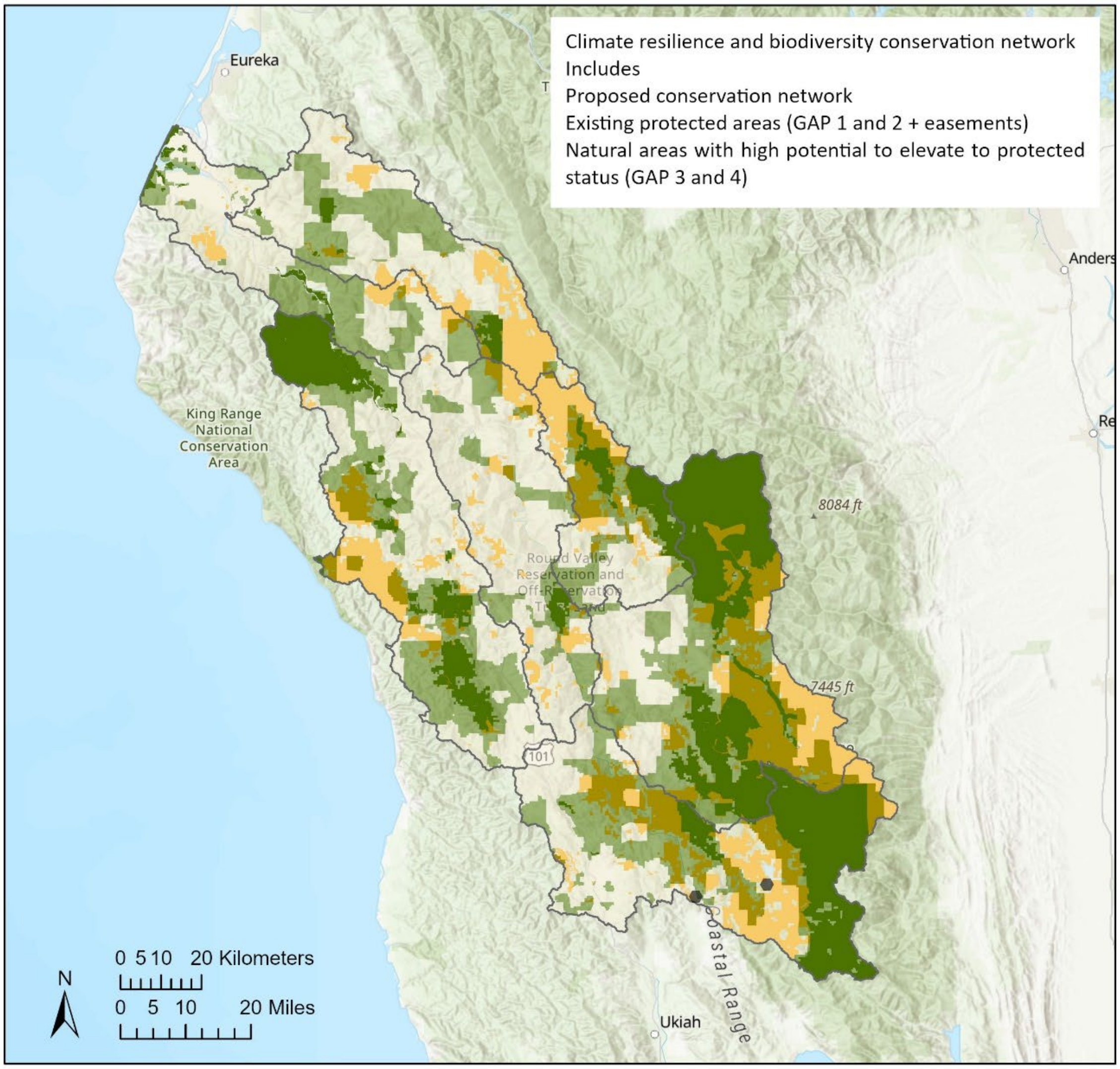
Eel River Watershed

Best solution from 1,000,000 iterations of Marxan Scenario 3
Solution meets all conservation targets:
20% Tree canopy LULC 2021
20% Beaver locations CNDDB 2024
50% S1 species CNDDB 2024
30% S2 species CNDDB 2024
30% S3 species CNDDB 2024
20% lowest solar radiation
10% low-med low solar radiation
20% TNC Resilience index
100% Existing protected areas

Analysis and maps created by Christine Davis for California Trout 2-6-24

Map 3. The Conservation Network solution.

To obtain the Conservation Network solution 3, Marxan was run by targeting 50% of all S1 species locations, 30% of all S2 and S3 species locations, 20% of the mapped beaver locations, 20% Tree canopy cover, 20% of the lowest potential solar radiation, 10% of the low-medium potential solar radiation, 20% of the The Nature Conservancy highest values of resilience, and included 100% of the existing protected areas (GAP 1 and 2). The Conservation Network is also called the Conservation Solutions layer, when viewed in the Eel River Restoration and Conservation Plan Web Map.



Conservation network solution

BESTSOLN

- 1
- 2 conservation network
- Eel sub watershed region
- Eel River Dams
- Existing Protected Areas
- Other natural areas (not protected)

Eel River Watershed

Best solution from 1,000,000 iterations of Marxan Scenario 3
Solution meets all conservation targets:
20% Tree canopy LULC 2021
20% Beaver locations CNDDB 2024
50% S1 species CNDDB 2024
30% S2 species CNDDB 2024
30% S3 species CNDDB 2024
20% Lowest solar radiation
10% Low-med low solar radiation
20% TNC Resilience index
100% Existing protected areas

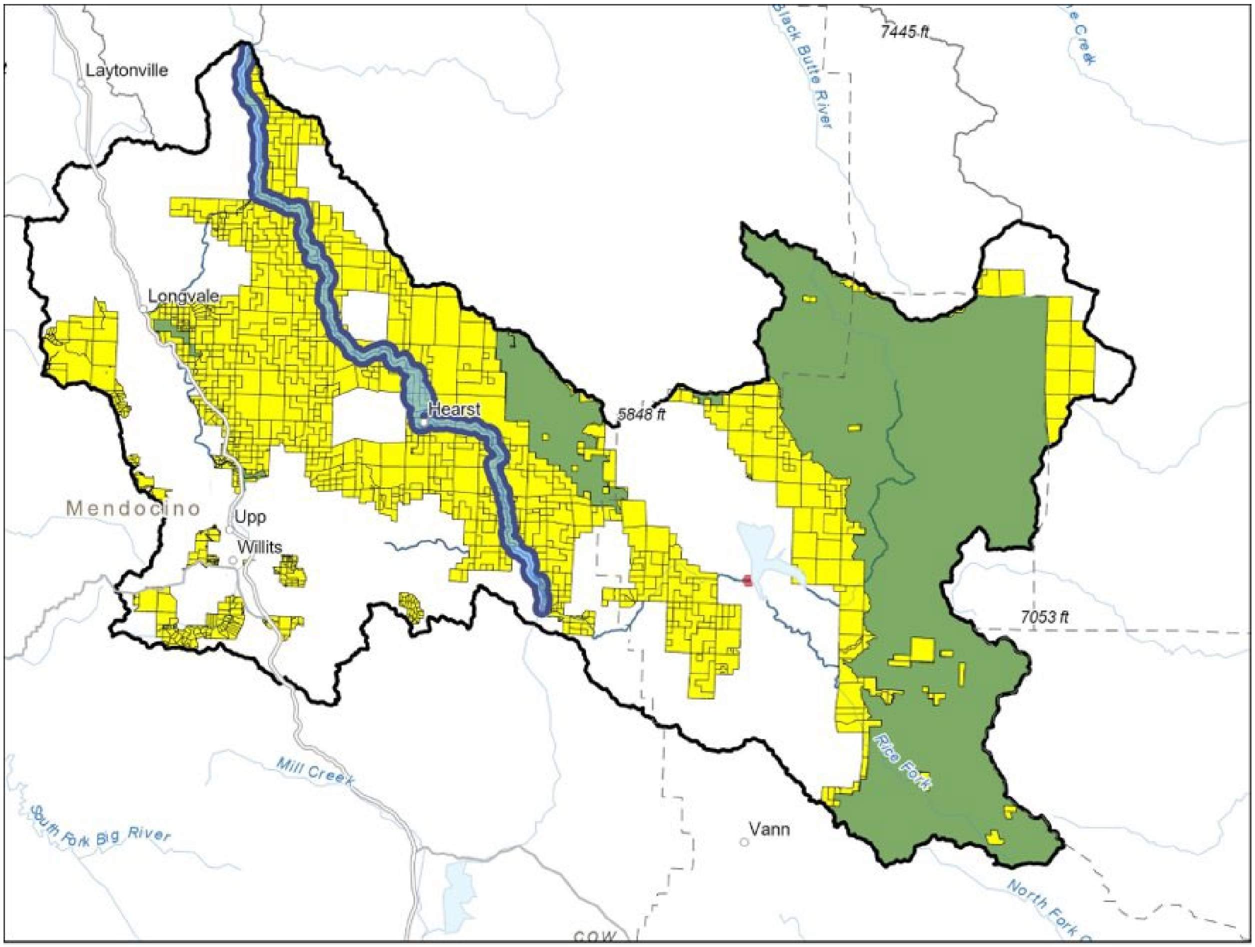
Analysis and maps created by Christine Davis for California Trout 2-6-24

Map 4. The Conservation Network solution is shown with other natural resources areas (GAP 3 and 4), existing protected areas (GAP 1 and 2 + easements).
Marxan was run by targeting 50% of all S1 species locations, 30% of all S2 and S3 species locations, 20% of the mapped beaver locations, 20% Tree canopy cover, 20% of the lowest potential solar radiation, 10% of the low-medium potential solar radiation, 20% of the The Nature Conservancy highest values of resilience, and included 100% of the existing protected areas (GAP 1 and 2), to achieve the proposed “Conservation Network”. The Conservation Network is also called the Conservation Solutions layer, when viewed in the Eel River Restoration and Conservation Plan Web Map.

5.3 Analysis of Solution 3 in closer detail for a sub watershed of the the Eel River watershed.
The Upper Eel River sub watershed

Figure 26. Upper Main Eel River sub watershed (Michael Weir).

The Upper Eel River sub watershed is connected to the larger watershed. A network of protected areas along riparian corridors and climate gradients will provide a mosaic of climate resilience and biodiversity protection. The conservation solution total is 56% of the sub watershed, while the area that meets the conservation feature targets but is not yet protected comprises 33% of the sub watershed. Thus, 33% of the Upper Eel River sub watershed is yet to be protected but contains high value for conservation acquisitions (**Figure 26**).

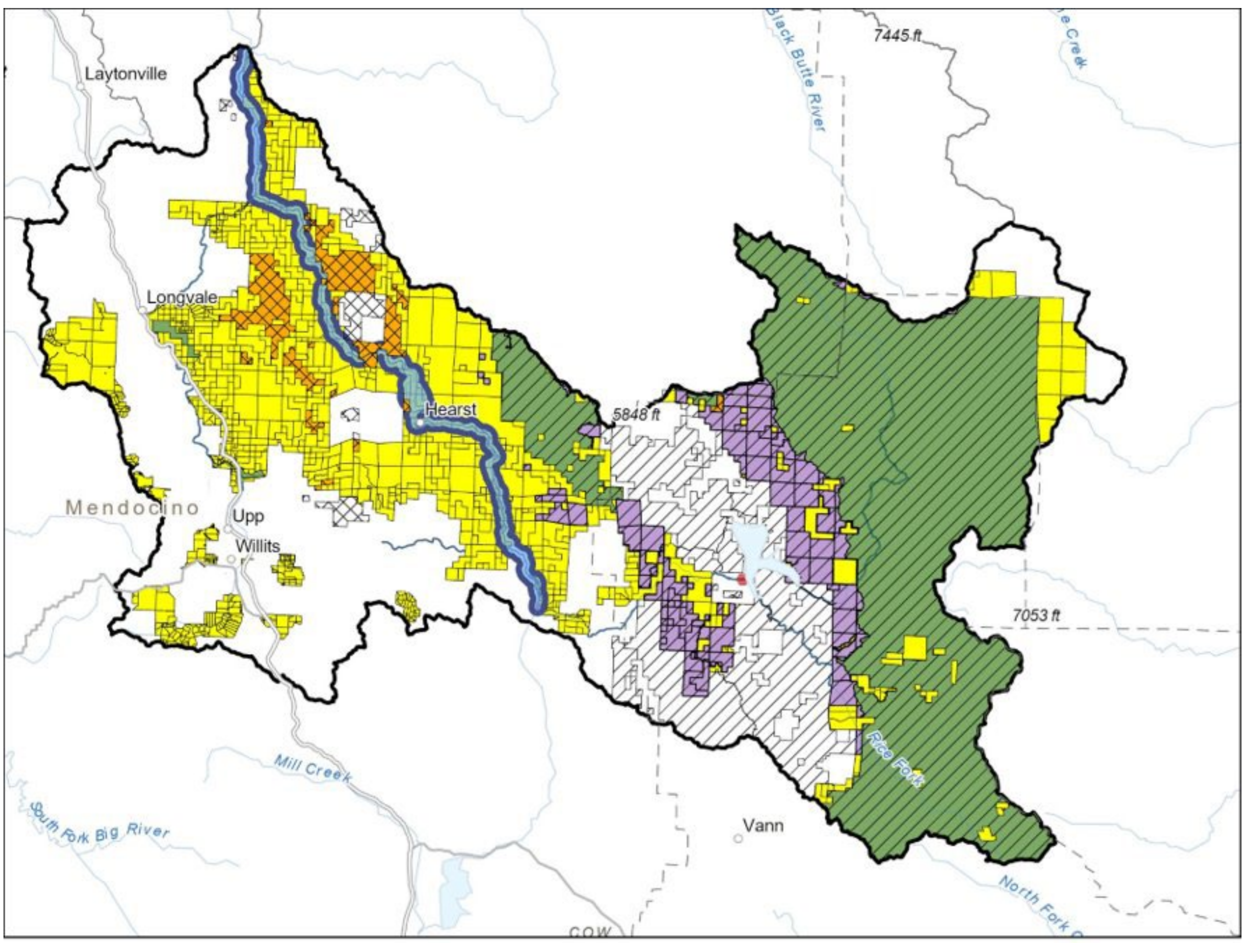


Map 5. The Upper Eel River sub watershed conservation solution.
The yellow parcels are not yet protected areas that meet the conservation feature targets. The green areas are existing protected areas. Both the green and the yellow parcels combined make up the conservation solution for the Upper Eel River sub watershed.

Table 11. The Upper Eel River sub watershed case study results per land management type.

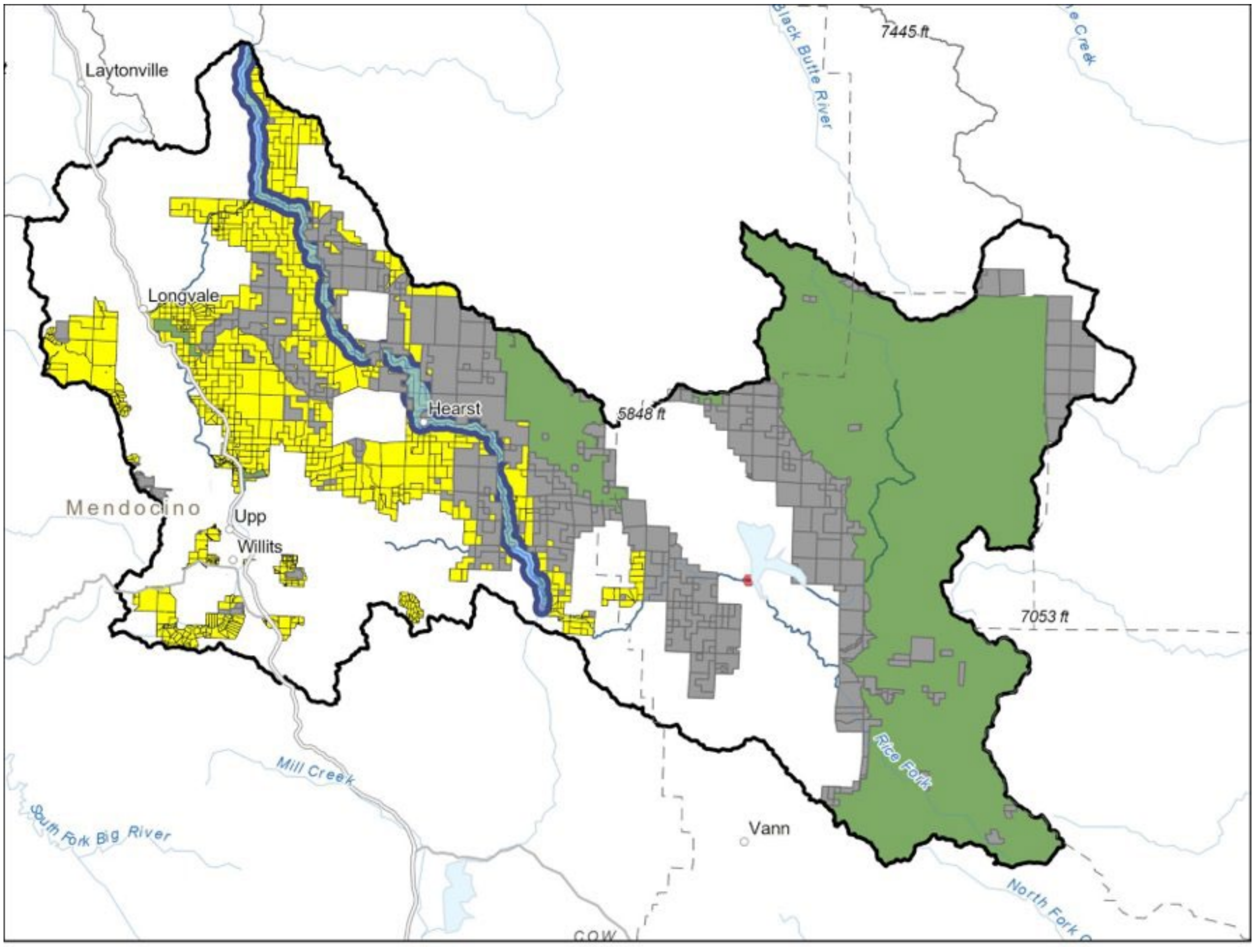
Upper Main Eel **sub watershed Total area: 1837 km^2**	
Solution total: 1094 km^2	56% of sub watershed
Solution not yet protected: **606 km^2**	**33% of sub watershed**
Existing protected areas within solution: 488 km^2	27% of sub watershed, 80% of solution

WSR not yet protected 46 km$^{2.}$ 228 parcels	75% of WSR
USFS not yet protected 106 km$^{2.}$ 166 parcels	10% of solution
BLM not yet protected 37 km$^{2.}$ 20 parcels	3% of solution
Public lands not protected: 319 km^2 ~700 parcels	29% of solution
Private lands not protected: 287 km^2 ~1000 parcels	26% of solution

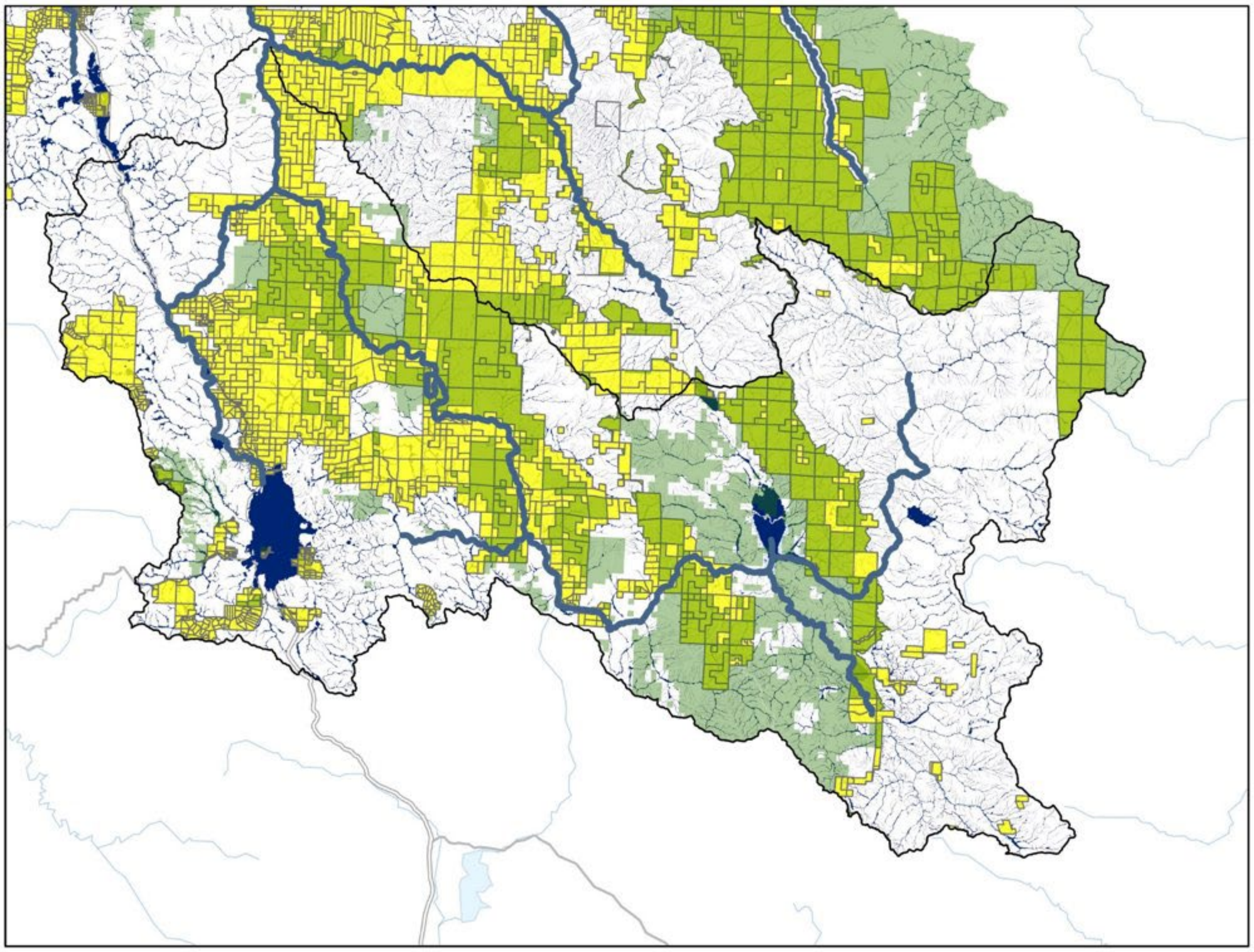


Map 6. The Upper Eel River sub watershed conservation solution shown colored as corresponding the results table above based on land management type.

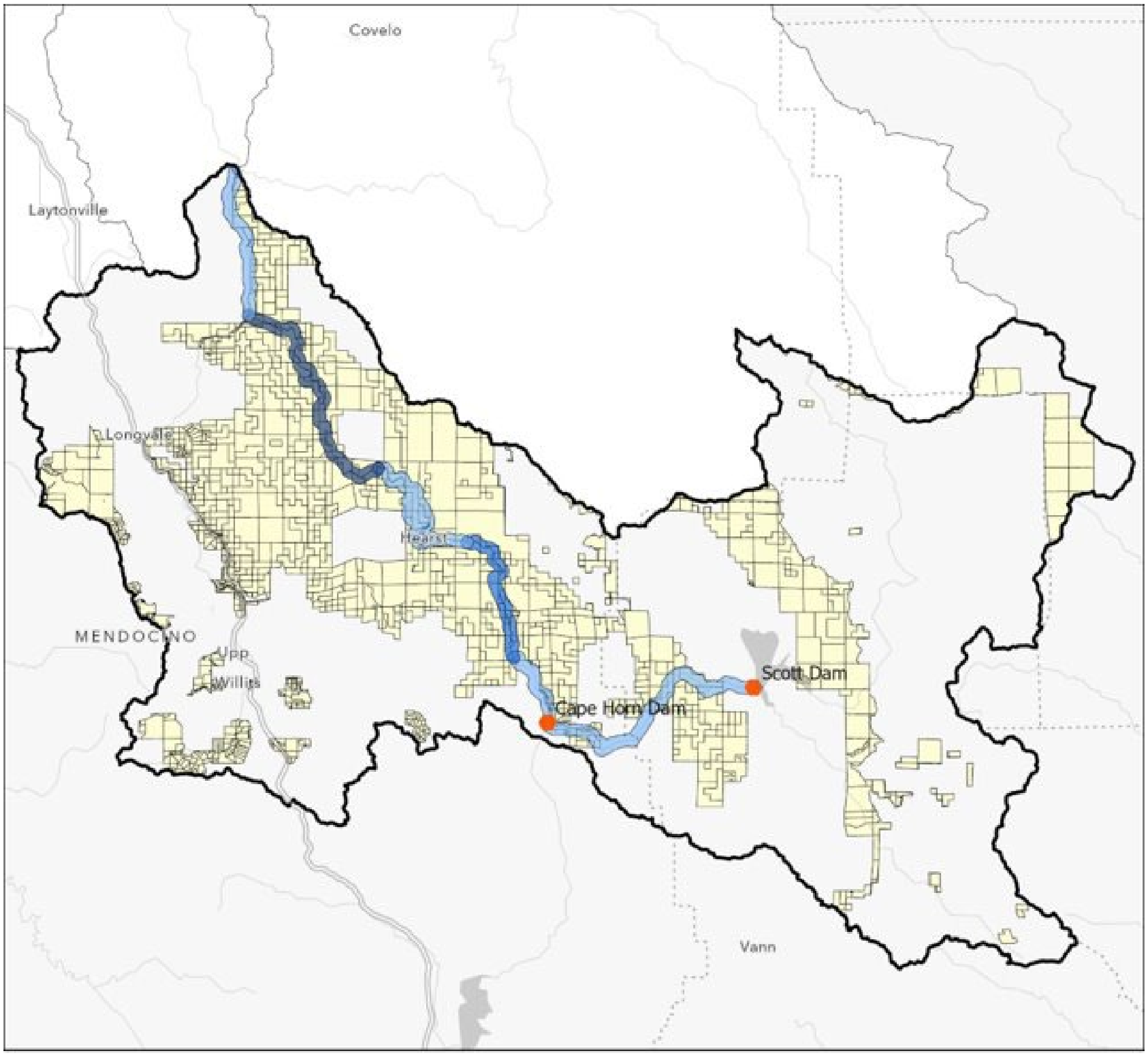
Green = existing protected areas within the conservation solution, grey striped = All US Forest Service lands, Yellow = other lands not yet protected within the conservation solution, orange = Bureau of Land Management parcels not yet protected within the conservation solution, Purple = US Forest Service lands not yet protected within the conservation solution.



Map 7. The Upper Eel River sub watershed conservation solution shown colored as green = existing protected areas within the conservation solution, grey = public lands not yet protected within the conservation solution, yellow = private lands not yet protected within the conservation solution. The total land area of the conservation solution is 56% of the sub watershed. The area that is not yet protected but meets the qualification criteria for high value conservation areas is 33% of the sub watershed.



Map 8. Conservation solutions for the Upper Eel River sub watershed are shown here in yellow. Existing protected areas are dark green. Other public lands/natural areas that are NOT protected, GAP 3 and 4 areas, are shown in lighter green. When the yellow areas which are not yet protected are overlaid onto the map, you can see the overlap where those not yet protected light green public lands also fit into the conservation solution. Thus, these parcels can be considered to provide a more effective resilient landscape if they are managed as protected areas.



Map 9. Conservation solutions for the Upper Eel River sub watershed are shown intersecting with the Wild and Scenic River corridor. 75%, 46 km^2 (228 parcels) of the Wild and Scenic River corridor within the conservation solution is not yet protected (February 2024). The conservation solutions are areas that are not yet protected yet have high investment potential for designation as future protected areas.

6. Discussion

6.1 Key conservation actions to implement conservation goals in the Eel River watershed.

Land acquisition.

- Establish new protected areas in federal lands. For example, elevate GAP 3 and 4 natural areas to protected status where core habitat can be increased, expanded, connected, and integrated into the existing protected area landscape.
- Conservation easements promoted and communicated as options and opportunities for landowners.
- Coordinate with local 30x30 groups to initiate strategic planning for acquisitions.
- Form a land trust alliance for the Eel River watershed.

- Actively contribute to or partner with Tribes in land back programs and capacity building to support Tribe strategic objectives for land acquisition.

Stewardship

- Invasive species control
- Private landowner incentive programs

Alignment and coordination with federal and state initiatives

- Support recommendations for the Northwest Forest Plan revision
- Support initiatives and make recommendations for Governor Newsom new protected areas.

Wild and Scenic River designations and expansions

- Conservation corridors built with WSR buffer guidelines, Potential Riparian Area (PRA) data, and prioritized parcels from the Marxan conservation solutions for the Eel River watershed.
- Improved management strategies (ie. management plans) for WSR in the Eel River watershed.

Advance equity and environmental justice

Establish a CalTrout Land Back support program for local Tribes, advance equity by adding options for conservation lands held by Tribes. Work with Tribe land trusts to identify their land back needs (Dickson-Hoyle et al. 2022). Use GIS analysis and build and maintain a web map planning tool to share information about conservation solutions for potential parcel acquisition. Support Tribes by working with natural resource staff to define capacity needs and provide support and partner with Tribes to apply for funding to help fill those capacity needs.

6.2 Next steps

Integration of Marxan solutions and corridor development:

Strategic conservation planning with Marxan can provide target informed connectivity solutions, but it cannot plan wildlife corridors. To expand on the conservation network created with the Marxan analysis, we recommend connecting the conservation solutions to a riparian corridor network to ensure that basin-wide processes are built into the resilience strategy (Rouget et al. 2006). This can be built by spatially defining, naming, and numbering riparian corridors + connective blocks of land between protected areas in the watershed and then integrating the Marxan solutions and goals into the corridor design.

1. Support the ongoing CalTrout collaboration with CalPoly Humboldt GIS department to complete the riparian climate refugia data. Goal: to establish core climate resilient habitat as indexed values in the potential riparian area.
2. Increase the size of the conservation network core areas to establish a buffer zone. A buffer zone will help mitigate edge effect and fragmentation impacts.
3. Identify potential areas for corridor extension into locations of upland habitat as shown by Marxan analysis results.
4. Overlay Potential Riparian Area (PRA) polygons with other spatial datasets (Stillwater & CalTrout analysis, 2024).
5. Continue to update the Eel River Restoration and Conservation Program web map to display key spatial data and planning resources.

6. Overlay Natural Landscape Block polygons from the California Essential Habitat Connectivity project (Spencer et al. 2010).

> "The Essential Connectivity Map depicts large, relatively natural habitat blocks that support native biodiversity (Natural Landscape Blocks) and areas essential for ecological connectivity between them (Essential Connectivity Areas). This coarse-scale map was based primarily on the concept of ecological integrity, rather than the needs of species. Essential Connectivity Areas are placeholder polygons that can inform land-planning efforts, but that should eventually be replaced by more detailed Linkage Designs, developed at finer resolution based on the needs of species and ecological processes. It is important to recognize that even areas outside of Natural Landscape Blocks and Essential Connectivity Areas support important ecological values that should not be "written off" as lacking conservation value. Furthermore, because the Essential Habitat Connectivity Map was created at the statewide scale, based on available statewide data layers, and ignored Natural Landscape Blocks smaller than 2,000 acres squared, it has errors of omission that should be addressed at regional and local scales" (Bios metadata - Conservation Biology Institute 2017).

The three major data sets that make up the Eel River watershed resilience strategy. These are stand-alone datasets that can be overlaid to support conservation planning decisions.

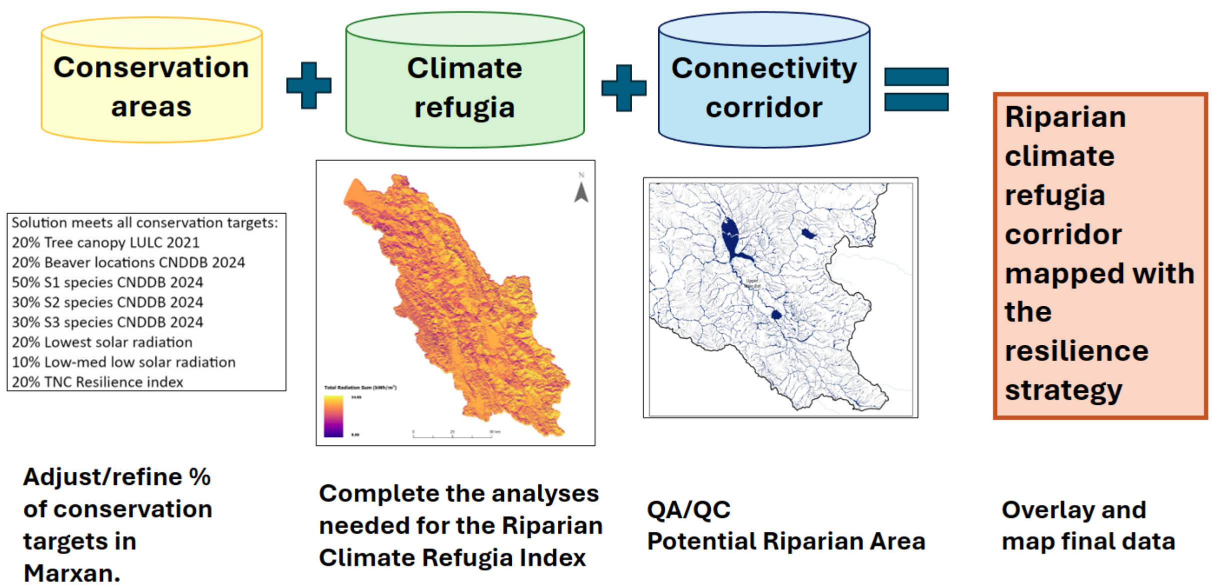


Figure 26. A visual generalization of the datasets within the Eel River watershed resilience strategy. Conservation areas refer to the conservation network solution result from the Marxan analysis, Scenario 3. The Climate refugia data set is in process with support from the CalPoly GIS department. The Potential Riparian Area data set was created in March 2024 with support from Stillwater Sciences.

Marxan conservation corridor analysis for each of the Eel River sub watersheds

This study emphasizes the need for a holistic watershed wide conservation strategy. However, results for the Upper Eel River watershed are highlighted due to the immediate need for conservation and restoration solutions before, during and after upcoming dam decommissioning projects in the Upper Eel

River sub watershed. Other sub watersheds may be analyzed similarly as individual units, so the total area recommended for conservation in each is set at biodiversity targets of 30%.

7. Overlay Potential Riparian Connections

   Named rivers and streams 30,000 feet or longer. (Analysis conducted by SC Wildlands 2003, retrieved 1/3/2024 https://wildlife.ca.gov/Data/BIOS).

Climate values

Climate values are an important addition to other vegetation distribution drivers, such as geology, soil type, topography, and precipitation in conservation planning (Heller et al. 2015). However, climate diversity is not the only driver of biodiversity patterns. Anthropogenic landscape changes significantly impact the strong correlation between climate ranges and biodiversity patterns (Want et al. 2018). Regardless of human impacts to the landscape, climate range dynamics, leading edges and trailing edges are important to consider when choosing priorities for climate resilience planning (Ackerly, 2003 & Morin and Lechowicz 2008). In the planning process, site resilience can be used to complement the needs for individual species resilience (Anderson et al. 2014).

Connected landscapes are considered as the best strategy for building climate resilience (Zavaleta, 2009). The climate flow data developed by the Nature Conservancy and Circuitscape represent connectivity and thus provide an important aspect for climate resilience. The dataset integrates the impacts of connectivity from land use and landscape features and environmental gradients (upslope, northward and riparian) which species are thought to use to move to different locations as the climate shifts. The range is presented in an index of seven categories ranging from low = far below average flow to high= far above average flow (Cameron et al., 2022).

Climate flow data are sampled at 250m which is much larger than the 30m scale we defined for the study area (Cameron et al 2022). Because The Nature Conservancy Resilient site data are sampled at 30m, we chose to use those data as an input to the Marxan analysis. Meanwhile the separate spatial analysis of the riparian climate refugia corridor index, in process by CalPoly Humboldt, are data that can be used as an overlay to add enhanced climate refugia information to conservation decisions.

Riparian Climate Refugia Corridor index

CalTrout in partnership with CalPoly Humboldt University is developing the riparian climate refugia corridor index based on Krosby 2018 by updating data inputs for the Eel River Watershed and the North Coast region of California. The riparian climate refugia corridor index will rank adaptation potential at 30m scale within the Potential Riparian Area (PRA). These data can be used for prioritizing riparian areas for climate adaptation. The variables within the model are temperature, width of riparian area, level of canopy cover, potential solar radiation, human footprint or landscape impacts. The datasets for the variables solar radiation and air temperature have already been created by CalPoly students in the GIS Program. The final datasets and flow analysis to create the riparian climate refugia corridor index will be completed by a CalTrout sponsored CalPoly graduate student in 2025-2026. Further GIS analysis can be done by using the Euclidean distance spatial analysis tool to show where the highest ranked climate resilience areas connect to existing protected areas (GAP 1 and 2 areas + easements, CNRA 2023).

The foundational datasets for the climate resilient corridor index being developed with CalTrout, Stillwater Sciences, and the CalPoly Humboldt GIS Program: CalTrout / CalPoly Data Portal.

A – Potential Riparian Area, modeled from DEM geomorphons approach for the North Coast, California (Built by Stillwater Sciences in 2023)

T – Temperature calculated average monthly temperature from 2020-2023 (analysis by CalPoly GIS students, 2023)

R – Potential Relative Solar Radiation, (modeled by CalPoly GIS students and faculty, 2023-2024)

C – Canopy cover, vegetation (indexed from the NDVI, Landsat satellite data 2022)

L – Landscape condition, human modification (may be indexed from the TNC resilient lands datasets)

Vegetation analysis

Vegetation such as grass, shrub, and tree canopy cover contribute to the riparian area corridor to different degrees. Normalized Difference Vegetation Index (NDVI) are data obtained through remote sensing that provide indexed numeric values at a range of high vegetation density to low density. The NDVI can be used as a proxy for Lidar data at the landscape level. NDVI were sampled for the entire Eel River watershed by CalTrout. Stillwater Sciences then analyzed the NDVI data in the Upper Eel River watershed and systematically edited and cleaned up those data to prepare them for use in future landscape analysis. This index, once it is edited for the rest of the watershed, may be used in replacement of the canopy cover variable that was used in this Marxan analysis. The NDVI values for dense vegetation, or the highest values, can be considered important to include as a spatial data layer in future prioritization analyses for the watershed.

6.3 Tribe collaborations

Round Valley Indian Tribes

Prioritize offering program support to culturally sensitive areas or other areas that need to be restored as directed by the Tribe. The Wild and Scenic Rivers parameters may not be adequate to support the species that could potentially benefit from the corridors. In phase 2 of the Eel Program, support work to establish a data management plan with the Tribe natural resources staff and submit this for review to the Tribe Council.

Wiyot Tribe

Work with the Wiyot Tribe to offer support for the process to incorporate important areas to the Wiyot Tribe as described by the Tribe strategic plan. The focus of this work is to return areas of habitat type within ancestral territory. An action may be to prioritize a conservation network with more upland habitat and diverse forest types as directed by the Tribe. Share the results of potential conservation areas that align with Tribe strategic goals with the Tribe council for review. Look to the future and provide support where this is welcomed. Identify a good plan for the protection of connectivity and important river tributaries.

7. Conclusion

Strategically identifying conservation suitability within riparian corridors can result in protection of biodiversity and provide ecosystem services at a landscape level. While previous research has given quality scores to climate refugia areas along riparian zones in the Pacific Northwest, these assessments have not yet been defined for the parts of the Pacific Northwest that reach into Northern California, nor have the quality scores been integrated into conservation planning. Using a conservation planning algorithm, this research uses quantitative habitat data to identify high-quality riparian areas that can be combined with climate refugia data to inform on high priority areas for conservation and restoration. The resulting solutions are prioritized with habitat data and least cost estimates for parcel purchase. The results include the best areas for conservation opportunities within the watershed, thus contributing to regional climate adaptation strategies. This resilience strategy can be applied to other watersheds in Northern California and beyond to safeguard biodiversity and climate refugia.

8. Acknowledgements

This project is funded in part by grants from the California Department of Fish and Wildlife (CDFW), The Resources Legacy Fund (RLF), Larry Garlick, and the Nomellini Family. Thank you, CalPoly Humboldt GIS Department for solar radiation data used as a variable for the Conservation Solutions analysis. Thank you to Stillwater Sciences for potential riparian area analysis methods support and review. Heartfelt thanks to the North Coast California Trout team who have been supportive and encouraging throughout this project. The analysis results here are intended to guide conservation planning, but not to make definitive decisions about restoration and conservation actions. On the ground assessment and habitat analysis are needed to support any spatial data referred to in this report.

9. Project Timeline

The multi-step project spans 4 years. This report gives an overview of the project in Year 2.

- Year 1 (early 2023) – investigate data and create preliminary planning and identify data needs.
- Year 2 (2023-2024) –

  A. build foundational datasets for the Eel River Watershed as a prototype for the North Coast strategic planning (multiple spatial analyses, working).

  B. Write the resiliency strategy planning framework (this report).

  C. Test the initial Marxan runs for preliminary parcel solutions (spatial analysis).

  D. Build the Eel River watershed conservation corridor (spatial analysis after Marxan results).

- Year 3 (2024-2025) – build the climate corridor index flow data from the foundational datasets (2A above) with CalPoly graduate student. Finalize Marxan methodology and runs. Draft preparation to publish methods and results with CalPoly.
- Year 4 (2025-2026) – continue with publishing reports, online tools, and data modeling methods.

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10. Appendices

Appendix A. Running Marxan technical supplement

Marxan solutions

The solution file can be imported to GIS, to help visualize the Marxan output, although it is more common to only turn the best and summed solution (selection frequency) into spatial layers.

Best solutions

Users should not limit themselves to looking only at the “best solution” for a given scenario. There may be several other runs with very similar objective function costs that are virtually as good, and more easily implemented. The “best” solution may not be practical. Similarly, the “best” solution should never be communicated to stakeholders or decision-makes as such, but rather as a very good solution within a continuum of options. Practitioners should consider presenting more than one spatial output of areas required to meet targets. This will allow stakeholders/experts to use the flexibility of the Marxan analysis to compare several conservation options that may address their inherent concerns while meeting ecological objectives.

Sum of solutions

The "summed solution", also referred to as "selection frequency" or previously as "irreplaceability", represents the number of times a planning unit was selected as part of a good solution from all runs in a scenario. Practitioners can use this solution to consider how useful a planning unit is for creating an efficient reserve system. This in turn may contribute towards prioritization. In essence, if we lose a planning unit that has a selection frequency of 60% then we are roughly losing 60% of the good reserve network options.

The summed solution does not equal "irreplaceability" in the strictest sense. It is literally a measure of a unit's frequency of selection under a certain set of constraints. If a planning unit is selected in nearly every solution, it does not necessarily mean that it is irreplaceable; rather, the planning unit could be located geographically so that it is required to provide efficient solutions, even though the features it contains may be found in other planning units. The summed solution can therefore also be described as a "utility score" because it describes the utility of a planning unit in building efficient solutions within a given scenario. When interpreting and communicating summed solutions, it is very important to be clear that the summed solution output is not a reserve network fulfilling the criteria of a given scenario. To clarify the difference, the summed solution should be presented in conjunction with one or more of the better individual solutions.

Marxan technical information

- The Objective Function

  "The mathematical "heart" of Marxan is the objective function which evaluates and compares between potential reserve systems. This section provides information about how each of the components in the objective function are calculated.

  $\sum \text{pus} \text{Cost} + BLM \sum \text{pus}\ Boundary + \sum \text{convalue}\ FPF \times Penalty = \boldsymbol{Marxan\ Score}$"

  (Marxan user manual 2021)

- **Cost Boundary and Boundary Length Modifier (BLM)**
  The Boundary Length Modifier (BLM) controls the importance of reserve compactness, relative to reserve cost.
  BLM of 0 takes the BLM function out of the equation. Thus, boundary will not be considered in the algorithm. The higher the BLM the more compactness will be weighed in the results. With the Eel River watershed, the boundary of the external watershed perimeter was weighing as a reserve metric. We did not want the perimeter to reflect connectivity needs as this was skewing the overall output to make parcels at the perimeter of the watershed have more priority than biodiversity and other factors.

Image A1. Bar graph of missing values in best solution for Marxan run with boundary length modifier set to .66 (see Results for BLM values calibration). Note that State Rank 1 (endangered species and habitats) target was set to 50%, while other targets shown were set to 30%. The result graph shows that targets are met at 50% even though the algorithm was instructed to preserve at least 30% of the conservation features within its range. There is no existing reserve within this solution.

- **Features Penalty Factor (FPF)**

  "The Penalty component of the Marxan objective function is the penalty given to a reserve system for not adequately representing conservation features. It is based on the principle that if a conservation feature is below its target representation level, then the penalty should approximate the cost of raising that conservation feature up to its target representation level. For example, if the requirement was to represent each conservation feature by at least one instance then the penalty for not having a given conservation feature would be the cost of the least expensive planning unit which holds an instance of that conservation feature. If you were missing several conservation features, then you could produce a reserve system that was fully representative by adding the least expensive planning units containing each of the missing conservation features." (Marxan user manual 2021)

- Spatial feature penalties
- Cost Threshold Penalty
- Simulated Annealing

"Simulated annealing is based on iterative improvement but with stochastic (random) acceptance of bad moves to help avoid getting stuck prematurely at local minimum objective function value. A local minimum occurs at the point where simply adding one favorable planning unit or removing one unfavorable planning unit from a reserve system can no longer improve the objective function value. Such local minimum may well occur at an objective function value that is a long way from the true optima. Simulated annealing derives its name from a technique in metallurgy involving the heating and controlled cooling of a material to reduce defects. Initially high temperatures cause atoms to become unstuck and to move randomly. Slow cooling then increases the chance of the atoms finding configurations with fewer defects. By analogy, efficiency is achieved in a conservation area network whereby changes that apply additional costs in the conservation area network may be tolerated early in the selection process; however, as the process continues the temperature is cooled and only positive or effective changes in portfolio design are accepted. This allows the algorithm to escape local minima in early sampling rounds and the progressive refinement into efficient solutions in later sampling rounds."

- Iterative Improvement

Appendix B. Conservation feature inputs to Marxan.

State ranked species 1-3 occurrences by taxonomic group and habitats in the Eel River watershed.

S1	**112**
alpine crisp-moss	**1**
Tortella alpicola	1
Baker's meadowfoam	**20**
Limnanthes bakeri	20
Bolander's horkelia	**1**
Horkelia bolanderi	1
coast checkerbloom	**1**
Sidalcea oregana ssp. eximia	1
deep-scarred cryptantha	**1**
Cryptantha excavata	1
Humboldt marten	**10**
Martes caurina humboldtensis	10
Kneeland Prairie pennycress	**1**
Noccaea fendleri ssp. californica	1
Lake Pillsbury checkerbloom	**1**
Sidalcea hickmanii ssp. pillsburiensis	1
Lassics lupine	**2**
Lupinus constancei	2
Lassics sandwort	**2**
Sabulina decumbens	2
longfin smelt	**2**
Spirinchus thaleichthys	2
Milo Baker's lupine	**10**
Lupinus milo-bakeri	10
northern adder's-tongue	**3**

Ophioglossum pusillum	3
northern clustered sedge	**4**
Carex arcta	4
pygmy cypress	**1**
Hesperocyparis pygmaea	1
Red Mountain catchfly	**8**
Silene greenei ssp. angustifolia	8
Snow Mountain rockcress	**1**
Boechera ultraalsa	1
Tehama chaparral	**1**
Trilobopsis tehamana	1
three-fingered morning-glory	**7**
Calystegia collina ssp. tridactylosa	7
two-flowered pea	**1**
Lathyrus biflorus	1
Vine Hill ceanothus	**2**
Ceanothus foliosus var. vineatus	2
western bumble bee	**20**
Bombus occidentalis	20
western lily	**6**
Lilium occidentale	6
western yellow-billed cuckoo	**2**
Coccyzus americanus occidentalis	2
Whitney's farewell-to-spring	**1**
Clarkia amoena ssp. whitneyi	1
wolverine	**3**
Gulo gulo	3
S1.1	**1**
Sitka Spruce Forest	**1**
Sitka Spruce Forest	1
S1S2	**38**
obscure bumble bee	**20**
Bombus caliginosus	20
Siskiyou jellyskin lichen	**9**
Scytinium siskiyouense	9
small groundcone	**1**
Kopsiopsis hookeri	1
Ten Mile shoulderband	**1**
Noyo intersessa	1
Wawona riffle beetle	**2**
Atractelmis wawona	2
western pearlshell	**5**
Margaritifera falcata	5
S2	**338**

Anthony Peak lupine	**4**
Lupinus antoninus	4
Baker's navarretia	**9**
Navarretia leucocephala ssp. bakeri	9
beaked tracyina	**8**
Tracyina rostrata	8
Bolander's catchfly	**25**
Silene bolanderi	25
Cascade downingia	**6**
Downingia willamettensis	6
chinook salmon - California coastal ESU	**1**
Oncorhynchus tshawytscha pop. 17	1
Crotch bumble bee	**1**
Bombus crotchii	1
cylindrical trichodon	**2**
Trichodon cylindricus	2
drymaria-like western flax	**1**
Hesperolinon drymarioides	1
giant fawn lily	**6**
Erythronium oregonum	6
Hooker's catchfly	**1**
Silene hookeri	1
Howell's montia	**72**
Montia howellii	72
Humboldt Bay owl's-clover	**4**
Castilleja ambigua var. humboldtiensis	4
Humboldt County milk-vetch	**12**
Astragalus agnicidus	12
Kellogg's buckwheat	**7**
Eriogonum kelloggii	7
marbled murrelet	**25**
Brachyramphus marmoratus	25
marsh checkerbloom	**23**
Sidalcea oregana ssp. hydrophila	23
Mendocino gentian	**1**
Gentiana setigera	1
minute pocket moss	**1**
Fissidens pauperculus	1
North Coast semaphore grass	**12**
Pleuropogon hooverianus	12
northern meadow sedge	**1**
Carex praticola	1
Oregon fireweed	**2**
Epilobium oreganum	2

Oregon polemonium	**1**
Polemonium carneum	1
Pacific gilia	**15**
Gilia capitata ssp. pacifica	15
Point Reyes salty bird's-beak	**2**
Chloropyron maritimum ssp. palustre	2
Raiche's manzanita	**2**
Arctostaphylos stanfordiana ssp. raichei	2
rattlesnake fern	**2**
Botrypus virginianus	2
Rau's jaffueliobryum moss	**1**
Jaffueliobryum raui	1
Red Mountain stonecrop	**6**
Sedum eastwoodiae	6
red-bellied newt	**4**
Taricha rivularis	4
robust false lupine	**7**
Thermopsis robusta	7
saline clover	**1**
Trifolium hydrophilum	1
Siskiyou checkerbloom	**22**
Sidalcea malviflora ssp. patula	22
slender silver moss	**1**
Anomobryum julaceum	1
small-flowered calycadenia	**8**
Calycadenia micrantha	8
Snow Mountain buckwheat	**1**
Eriogonum nervulosum	1
Stebbins' harmonia	**1**
Harmonia stebbinsii	1
Stebbins' lewisia	**12**
Lewisia stebbinsii	12
steelhead - northern California DPS summer-run	**7**
Oncorhynchus mykiss irideus pop. 48	7
thin-lobed horkelia	**1**
Horkelia tenuiloba	1
Toren's grimmia	**1**
Grimmia torenii	1
Townsend's big-eared bat	**8**
Corynorhinus townsendii	8
tricolored blackbird	**1**
Agelaius tricolor	1
water howellia	**7**
Howellia aquatilis	7

western ridged mussel	**1**
Gonidea angulata	1
yellow rail	**1**
Coturnicops noveboracensis	1
Yolla Bolly Mtns. bird's-foot trefoil	**1**
Hosackia yollabolliensis	1
S2.1	**6**
Coastal Terrace Prairie	**1**
Coastal Terrace Prairie	1
Valley Oak Woodland	**5**
Valley Oak Woodland	5
S2.2	**1**
Northern Interior Cypress Forest	**1**
Northern Interior Cypress Forest	1
S2?	**6**
California floater	**1**
Anodonta californiensis	1
crinkled rag lichen	**1**
Platismatia lacunosa	1
Mad River fleabane daisy	**4**
Erigeron maniopotamicus	4
S2S3	**174**
angel's hair lichen	**1**
Ramalina thrausta	1
Fisher	**55**
Pekania pennanti	55
glandular western flax	**20**
Hesperolinon adenophyllum	20
Leech's skyline diving beetle	**1**
Hydroporus leechi	1
Nuttall's ribbon-leaved pondweed	**3**
Potamogeton epihydrus	3
Sanhedrin Mountain stonecrop	**14**
Sedum sanhedrinum	14
seacoast ragwort	**40**
Packera bolanderi var. bolanderi	40
Snow Mountain willowherb	**12**
Epilobium nivium	12
southern torrent salamander	**28**
Rhyacotriton variegatus	28
S3	**452**
American badger	**2**
Taxidea taxus	2
Baker's globe mallow	**1**

Iliamna bakeri	1
bald eagle	**2**
Haliaeetus leucocephalus	2
bank swallow	**5**
Riparia riparia	5
Butte County morning-glory	**1**
Calystegia atriplicifolia ssp. buttensis	1
coast cutthroat trout	**2**
Oncorhynchus clarkii clarkii	2
coast fawn lily	**35**
Erythronium revolutum	35
fringed myotis	**1**
Myotis thysanodes	1
golden eagle	**7**
Aquila chrysaetos	7
grass alisma	**4**
Alisma gramineum	4
grasshopper sparrow	**1**
Ammodramus savannarum	1
Jepson's dodder	**2**
Cuscuta jepsonii	2
Konocti manzanita	**9**
Arctostaphylos manzanita ssp. elegans	9
leafy reed grass	**1**
Calamagrostis foliosa	1
little willow flycatcher	**1**
Empidonax traillii brewsteri	1
long-eared myotis	**4**
Myotis evotis	4
long-legged myotis	**1**
Myotis volans	1
Lyngbye's sedge	**7**
Carex lyngbyei	7
maple-leaved checkerbloom	**45**
Sidalcea malachroides	45
McDonald's rockcress	**5**
Arabis mcdonaldiana	5
North American porcupine	**27**
Erethizon dorsatum	27
northern goshawk	**14**
Accipiter gentilis	14
northern red-legged frog	**33**
Rana aurora	33
Oregon coast paintbrush	**2**

Castilleja litoralis	2
pale yellow stonecrop	**6**
Sedum flavidum	6
pallid bat	**5**
Antrozous pallidus	5
purple martin	**1**
Progne subis	1
running-pine	**20**
Lycopodium clavatum	20
scabrid alpine tarplant	**12**
Anisocarpus scabridus	12
serpentine cryptantha	**1**
Cryptantha dissita	1
short-leaved evax	**3**
Hesperevax sparsiflora var. brevifolia	3
Sonoma tree vole	**45**
Arborimus pomo	45
steelhead - northern California DPS winter-run	**18**
Oncorhynchus mykiss irideus pop. 49	18
tidewater goby	**3**
Eucyclogobius newberryi	3
watershield	**5**
Brasenia schreberi	5
western pond turtle	**39**
Emys marmorata	39
western red bat	**4**
Lasiurus frantzii	4
western snowy plover	**1**
Charadrius nivosus nivosus	1
white-flowered rein orchid	**76**
Piperia candida	76
yellow warbler	**1**
Setophaga petechia	1
S3.1	**12**
Upland Douglas Fir Forest	**11**
Upland Douglas Fir Forest	11
Valley Needlegrass Grassland	**1**
Valley Needlegrass Grassland	1
S3.2	**2**
Northern Coastal Salt Marsh	**2**
Northern Coastal Salt Marsh	2
S3?	**17**
Oregon goldthread	**12**
Coptis laciniata	12

oval-leaved viburnum	**5**
Viburnum ellipticum	5
S3S4	**25**
American peregrine falcon	**9**
Falco peregrinus anatum	9
Pacific fuzzwort	**4**
Ptilidium californicum	4
Pacific tailed frog	**11**
Ascaphus truei	11
silver-haired bat	**1**
Lasionycteris noctivagans	1
SH	**1**
dwarf alkali grass	**1**
Puccinellia pumila	1
SNR	**9**
Humboldt mountain beaver	**6**
Aplodontia rufa humboldtiana	6
North Central Coast Fall-Run Steelhead Stream	**1**
North Central Coast Fall-Run Steelhead Stream	1
North Central Coast Summer Steelhead Stream	**2**
North Central Coast Summer Steelhead Stream	2
Grand Total	

Appendix C. Wild and Scenic Rivers analysis

Figure C1. Wild and Scenic Rivers shown by color categorization, mainstem rivers, and existing protected areas GAP 1 and 2 + other natural resources areas GAP 3 and 4.

As of October 2023, less than 14% of the Wild and Scenic River in the Eel River Watershed has a management plan (**Table C1**). The current management plans for WSR are all segments within USFS land management. However, the buffer for the USFS segments of WSR is derived from the center line, thus limiting the extent of the WSR total area which is typically analyzed from the high-water mark on either side of the river, rather than the center line.

Table C1. Wild and Scenic River calculations for the Eel River watershed.

Wild and Scenic River (WSR), Eel River watershed	**Miles**	**%**	**Miles without management plan (NPS/state oversight)**	**% without mgmt. plan**
Total Miles, rivers above 100cfs/USDA data	644 miles			
WSR total	432			
Remaining total miles not WSR (other river)	212 miles			
Eel WSR Recreation	283	66% of total WSR in Eel	283	100%
Eel WSR Scenic	36	8% of total WSR in Eel	32	88%
Eel WSR Wild	112	26% of total WSR in Eel	57	51%
SUM WSR	**432 (total WSR)**		**372**	**86% (WSR with no mgmt plan)**
			60 WSR miles with mgmt plan	9% of all river miles in Eel WS have a mgmt plan.
WSR GIS Data Excel: https://californiatroutinc.box.com/s/zsmavu8kx5s9aku1qk4vlgv1cx3rfg9s				

Recommendations for the Eel WSR systems are as follows:

i. Repair management linkages between NPS, county governments and CDFW for recreational areas in private lands
ii. Coordination with USFS and BLM on WSR management plans
iii. Increase protected buffer around riparian corridors in the Eel
iv. At minimum, map the buffer around the WSR to .25 mile on either side of the center line for all WSR, not just the <14% that falls within the USFS boundary.
v. Plan to remap the WSR boundary for effective and accurate boundary planning by mapping the high water mark in focal habitat areas, then analyzing and remapping the WSR boundary from the high water line on either side of the river.
vi. At minimum, establish a management plan for the Scenic and Wild (non-recreational) sections of the Eel River Watershed within NPS oversight which do not have a management plan.

Wild and Scenic River (WSR) additional tasks:

a. Map the accurate riparian buffer area for WSR using the Potential Riparian Area dataset created by Stillwater Sciences and CalTrout 2024. For example, in the USFS, WSR area is mapped only as the center line of the river channel.

b. Reanalyze, and update as necessary, the % of WSR in Recreational, Scenic, and Wild categories.

c. Reanalyze, and update as necessary, the length of WSR in Recreational, Scenic, and Wild categories.
d. Analyze, the amount of WSR in or adjacent to existing protected areas GAP 1+2
e. Analyze, the amount of WSR in or adjacent to existing protected areas GAP 3+4
f. Analyze, areas for recommendation for increased protection for WSR