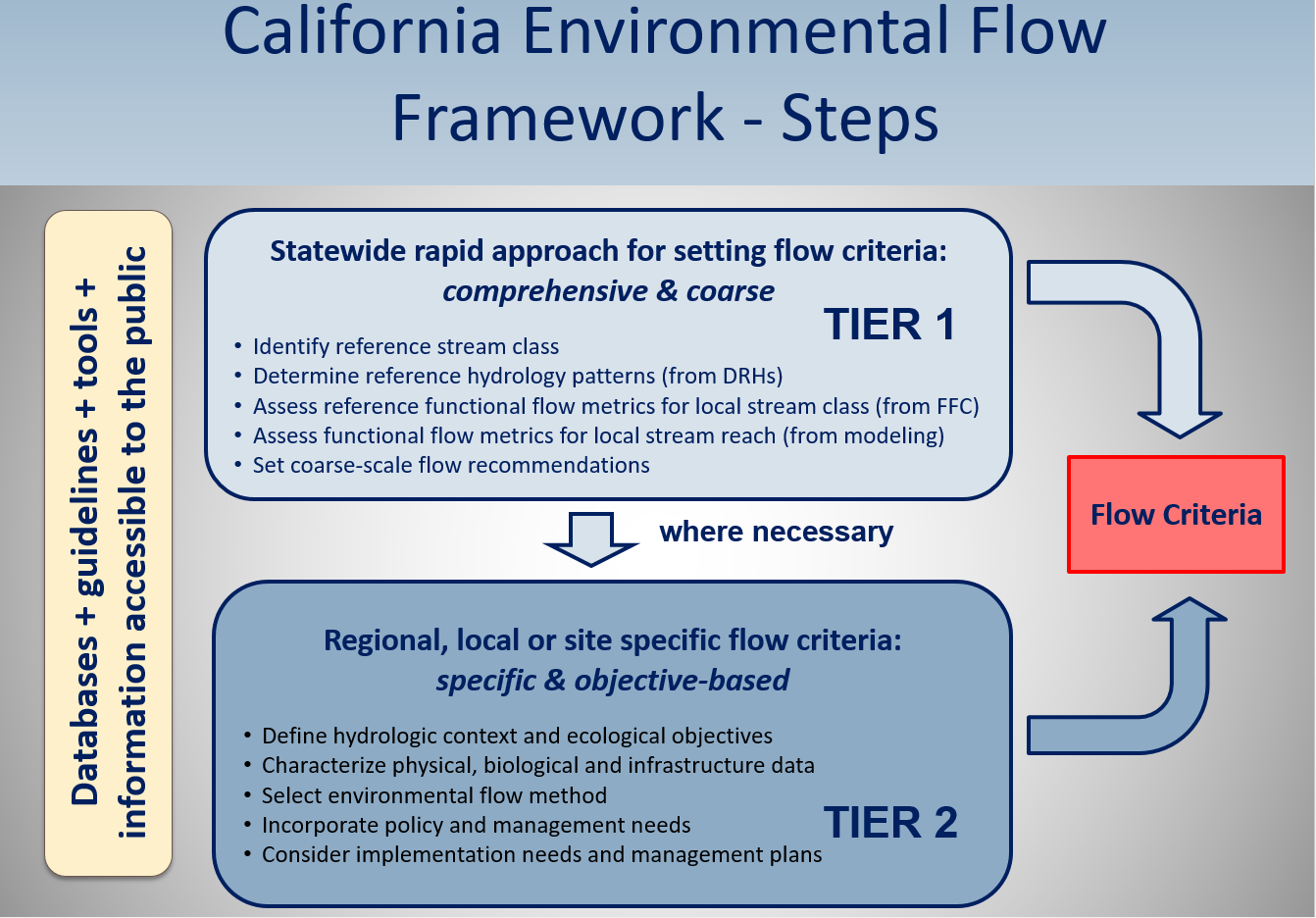
# Project Background

Flow alterations are a significant driver of species population declines and biodiversity loss in California and globally. Multiple state and local agencies across California share responsibility for setting flow criteria that protect and improve the ecological health of California’s water resources. These approaches historically have not been coordinated at the statewide level, resulting in fragmented and siloed flow management programs.

In 2016, a group of experts self-organized to pool knowledge and data, evaluate methods, and ultimately develop a statewide framework for determining environmental flow criteria for California. The strategy is organized into a two-tiered approach that varies in scale and detail.

The framework establishes targets for environmental flows on all streams in California  
based on their natural reference flow conditions (Tier 1), and then provides guidance on  
further refining these statewide flow criteria using site-specific hydrologic, geomorphic  
and ecologic conditions (Tier 2).



CEFF provides a process for evaluating existing conditions of flows, identifying potential limiting factors, and developing recommendations for establishing ecologically relevant flow targets in light of competing water uses, statewide. CEFF has been developed in collaboration with the State Water  
Resources Control Board, CA Department of Fish and Wildlife, federal resource agencies, academic institutions and non-profit organizations within the Environmental Flows Workgroup, a sub-group of the California Water Quality Monitoring Council.

# Biological Endpoints and Environmental Flow Recommendations

The identification of priority biological endpoints across the state is a key step in refining  
environmental flow recommendations under Tier 1. Based on a literature review of documented relationships between aquatic species and flow conditions, we found that data directly linking individual species to quantifiable flow metrics is lacking (Yarnell et al.?). Therefore, we needed to more broadly relate stream flow conditions directly to aquatic species community composition and to specific life history requirements for taxa of concern. To do this, we developed an approach for determining regional fish assemblages across California that are geographically distinct and thus are assumed to have evolved under local hydrologic conditions.

# Methods

We used fish distribution data and a clustering analysis to group species assemblages geographically within four broad regions across California. This approach allowed us to determine sub-regional assemblages of species that are most distinct within a defined sub-region, based on their inherent geographic similarity and their dissimilarity with other clusters within the region. We will then relate these assemblages to hydrologic conditions and flow metrics to determine sub-regional environmental flow recommendations.

## Fish Distribution Data

Fish distribution data were obtained from the PISCES database (Santos et al, 2014). Distribution data used in this analysis only included current species ranges, and did not include historic ranges or areas where translocations have occurred. We focused on the 74 native flow-sensitive species identified by Grantham et al 2014 (See Appendix A for complete list of species), which are known to be susceptible to altered flow regimes, and thus will directly benefit from improved environmental flows.

## Regional Boundaries

We sought to determine appropriate regional divisions within the state for clustering that would be large enough to encompass broad geographical areas, but not so small as to limit the usefulness of clustering. We defined four regions that were created by combining complete HUC4 units so that watersheds remained connected in general geographic regions.

The four regions used in our analysis are:

* **Central Valley & West Slope Sierra**
  + All HUC4s flowing out of the Central Valley via the San Francisco Bay, including the west slope of the Sierra Nevada, the Coast Range HUC4s flowing into the valley, and the Pit River system. The San Francisco Bay and HUCs immediately draining into it as well as the legal Delta were removed from this region, as these areas have unique management considerations and should be managed independently.
* **North Coast**
  + All HUC4s flowing out the Klamath river, as well as all HUC4s from Klamath river to south of San Francisco Bay to the north end of Monterey Bay along the west coast.
* **South Coast**
  + All HUC4s from Monterey Bay south to the US-Mexico border along the west coast.
* **Great Basin**
  + HUC4s flowing from the eastern Sierra/Modoc Plateau into the Great Basin north of Mono Lake.
* **\*Desert, not included in clustering analysis**
  + HUC4s from landlocked desert drainages within California and any great basin HUC4 that contacts California south of Mono Lake (in order to keep contiguous regions), as well as Colorado River HUC4s in the southeast portion of the state. However, due to the sparse number of fish species and fish presence in the desert, this region was **not** subject to clustering. Species occurring in this region should be managed for independently.

Additionally, all HUCs containing no flow-sensitive fish species were excluded from clustering.

*(Map of regions with areas grayed out that weren’t part of the analysis.)*

Figure 1. Map of regions used for clustering analysis. Note, gray areas indicate areas excluded from our analysis. These areas either do not contain flow-sensitive species, or were manually excluded because they have unique management considerations and should be managed separately (desert, San Francisco Bay, the Delta)

## Clustering Analysis

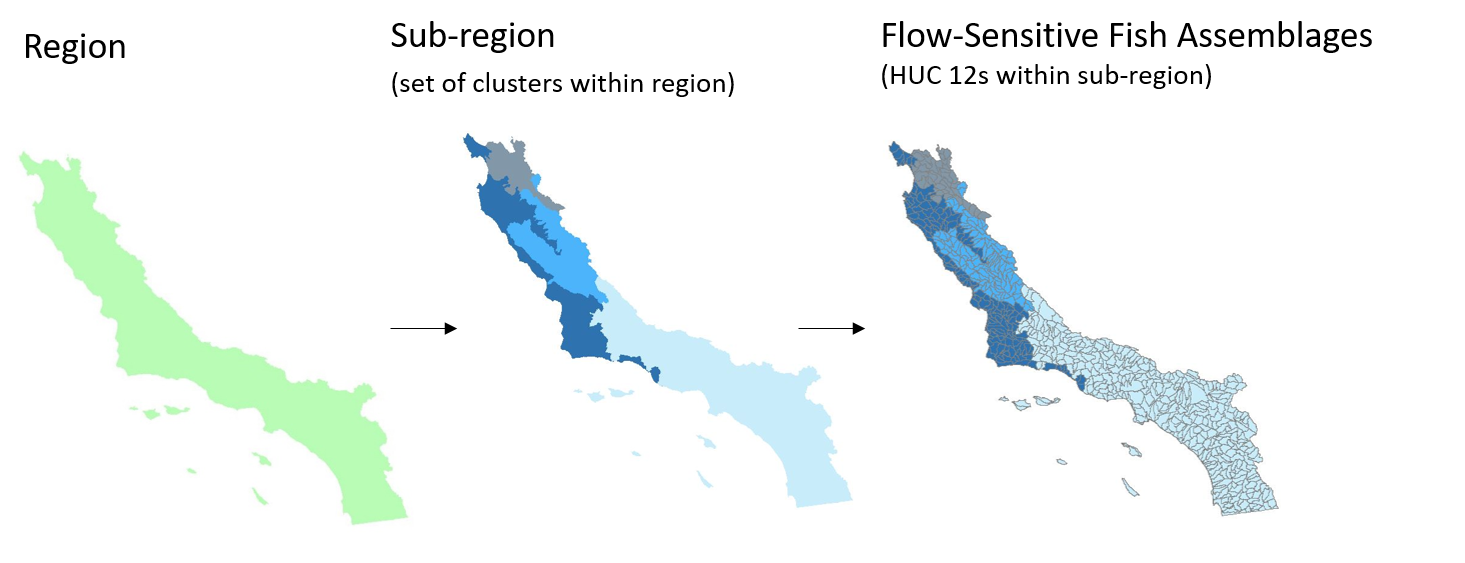
We used k-means clustering to determine sub-regional flow-sensitive fish assemblages across the state. We evaluated a range of cluster sets (2-8 clusters) for each of the four regions, where each cluster set was made up of a HUC12-scale species assemblage (Figure 2). UC Davis ecologists reviewed the cluster sets for each region and selected the set (hereby referred to as a regional flow-sensitive fish assemblage) based on groupings that were the most geographically-pertinent and ecologically- relevant for management of environmental flows.

Figure 2. Hierarchy of units used in clustering analysis.

The goal of this analysis is to provide a unit for management of environmental flows at an intermediate spatial scale, rather than a broad regional or a local scale. Additionally, it is important to note that the results of this analysis will be used to inform a community approach to flow management, and are not intended for managing individual species or ESUs.

# Results

Explain what’s in fancy map

Tables are in an appendix, describe what’s in them and how to interpret (count relative to region (ie. this species occurred in 6 out of 20 HUCs), dominant species are at the top of the table, proportion of current range . no info in here about the abundance of a species

Explain why we see groups with the same assemblages, include schematic of this

# Questions for Experts

Do the fish species within these assemblages make sense from an ecological and management perspective and based on geographic boundaries we have established? (ex. Klamath)

-think of 2-3 more questions for everyone to answer

Please email your responses back to XX by XXX.

# References

Grantham, T.E., Viers, J.H. & Moyle, P.B. (2014). Systematic screening of dams for environmental flow assessment and implementation. BioScience 64:1006-1018.  
https://doi.org/10.1093/biosci/biu159P.B

Santos, N. R., Katz, J. V. E., Moyle, P. B., & Viers, J. H. (2014). A programmable information system for management and analysis of aquatic species range data in California. Environmental Modelling and Software, 53. https://doi.org/10.1016/j.envsoft.2013.10.024

# Appendix A: Flow Sensitive Species

California native flow-sensitive species identified by Grantham et al 2014.

|  |  |
| --- | --- |
| Species | Common Name |
| Gasterosteus aculeatus | Stickleback |
| Cottus aleuticus | Coastrange Sculpin |
| Leptocottus armatus | Staghorn Sculpin |
| Cottus asper | Prickly Sculpin |
| Cottus asperrimus | Rough Sculpin |
| Lampetra ayersi | River Lamprey |
| Cottus beldingi | Paiute Sculpin |
| Siphatales bicolor | Tui Chub |
| Chasmistes brevirostris | Shortnose Sucker |
| Mugil cephalus | Striped Mullet |
| Pogonichthys ciscoides | Clear Lake Splittail |
| Oncorhynchus clarki | Cutthroat Trout |
| Gila coerulea | Blue Chub |
| Salvelinus confluentus | Bull Trout |
| Mylopharodon conocephalus | Hardhead |
| Siphatales crassicauda | Thicktail Chub |
| Richardsonius egregius | Lahontan Redside |
| Gila elegans | Bonytail |
| Lavinia exilicauda | Hitch |
| Entosphenus folletti | Northern California Brook Lamprey |
| Catostomus fumeiventris | Owens Sucker |
| Oncorhynchus gorbuscha | Pink Salmon |
| Ptychocheilus grandis | Sacramento Pikeminnow |
| Cottus gulosus | Riffle Sculpin |
| Lampetra hubbsi | Kern Brook Lamprey |
| Archoplites interruptus | Sacramento Perch |
| Oncorhynchus keta | Chum Salmon |
| Oncorhynchus kisutch | Coho Salmon |
| Cottus klamathensis | Marbled Sculpin |
| Pantosteus lahontan | Lahontan Mountain Sucker |
| Catostomus latipinnis | Flannelmouth Sucker |
| Lampetra lethophaga | Pit-Klamath Brook Lamprey |
| Ptychocheilus lucius | Colorado Pikeminnow |
| Catostomus luxatus | Lost River Sucker |
| Pogonichthys macrolepidotus | Sacramento Splittail |
| Cyprinodon macularius | Desert Pupfish |
| Acipenser medirostris | Green Sturgeon |
| Orthodon microlepidotus | Sacramento Blackfish |
| Catostomus microps | Modoc Sucker |
| Siphatales mohavensis | Mojave Tui Chub |
| Oncorhynchus mykiss | Steelhead |
| Cyprinodon nevadensis | Pupfish |
| Eucyclogobius newberryi | Northern Tidewater Goby |
| Eucyclogobius kristinae | Southern Tidewater Goby |
| Catostomus occidentalis | Sucker |
| Gila orcutti | Arroyo Chub |
| Rhinichths osculus | Speckled Dace |
| Thaleichthys pacificus | Eulachon |
| Hypomesus pacificus | Delta Smelt |
| Fundulus parvipinnus | California Killifish |
| Cottus perplexus | Reticulate Sculpin |
| Cottus pitensis | Pit Sculpin |
| Cyprinodon radiosus | Owens Pupfish |
| Lampetra richardsoni | Western Brook Lamprey |
| Catostomus rimiculus | Klamath Smallscale Sucker |
| Cyprinodon salinus | Salt Creek Or Cottonball Marsh Pupfish |
| Catostomus santaanae | Santa Ana Sucker |
| Entosphenus similis | Klamath River Lamprey |
| Catostomus snyderi | Klamath Largescale Sucker |
| Platichthys stellatus | Starry Flounder |
| Hesperoleucus symmetricus | Roach (Most Taxa) |
| Hesperoleucus symmetricus x venustus | Clear Lake Roach |
| Hesperoleucus venustus | Coastal Roach |
| Hesperoleucus mitrulus | Northern Roach |
| Hesperoleucus parvipinnus | Gualala Roach |
| Catostomus tahoensis | Tahoe Sucker |
| Xyrauchen texanus | Razorback Sucker |
| Siphatales thalassinus | Tui Chub |
| Spirinchus thaleichthys | Longfin Smelt |
| Acipenser transmontanus | White Sturgeon |
| Hysterocarpus traskii | Tule Perch |
| Entosphenus tridentata | Pacific or Goose Lake Lamprey |
| Oncorhynchus tshawytscha | Chinook Salmon |
| Prosopium williamsoni | Mountain Whitefish |

# Appendix B: Tabular Results of Clustering Analysis