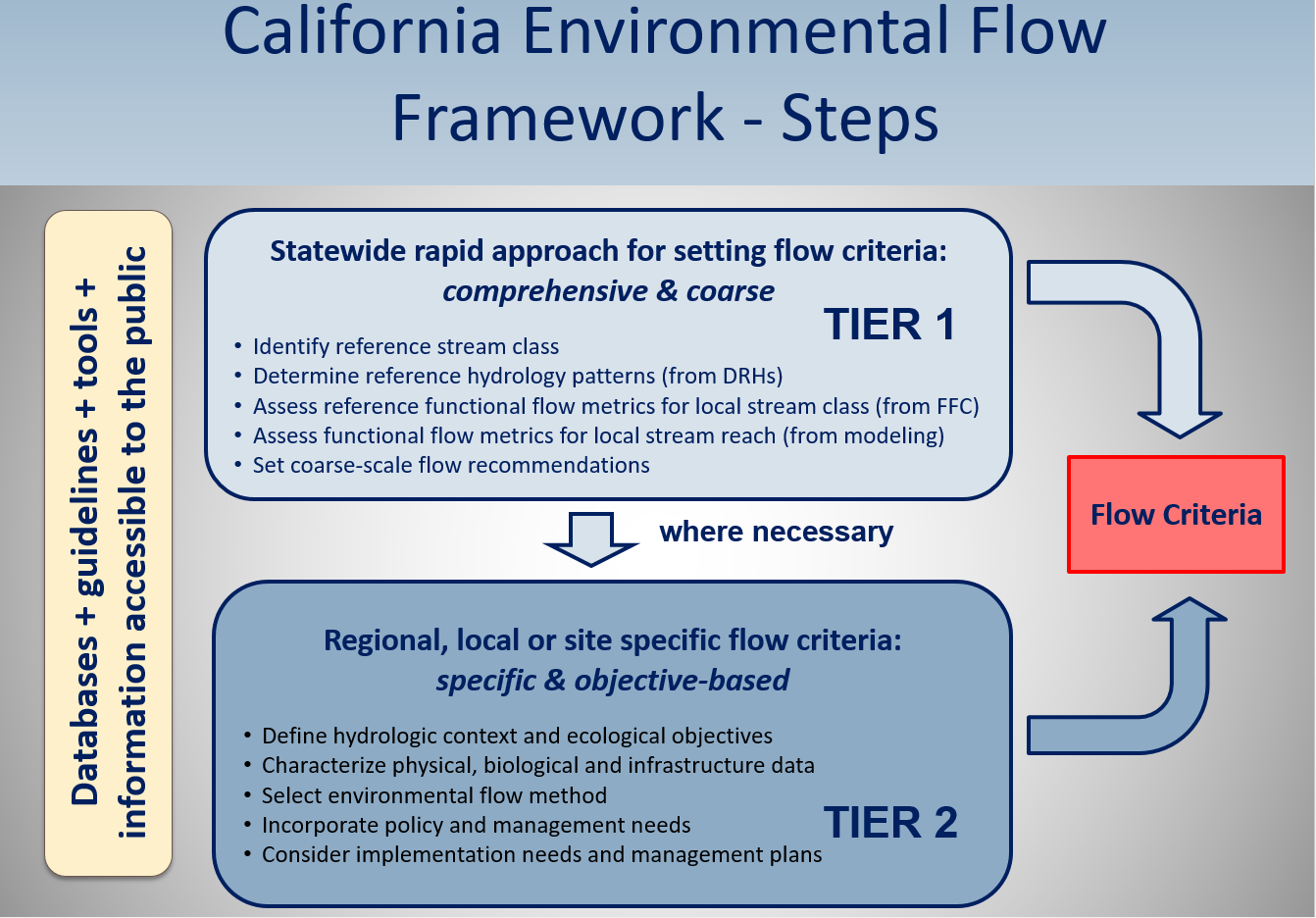
# Project Background

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 California Environmental Flows Framework (CEFF) 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, California 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 assemblages of species that are most distinct within a defined sub-region, based on their inherent geographic similarity and dissimilarity with other clusters within the region. Next, we will 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 boundaries 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 clustering are:

* **Central Valley & West Slope Sierra**
  + All HUC4s flowing out of the Central Valley, 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 the Bay, 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.

The desert region, which included HUC4s from landlocked desert drainages, Great Basin HUC4s that contact California south of Mono Lake, and Colorado River HUC4s in the southeast portion of the state, was not subject to clustering due to the sparse number of fish species and fish presence in this area. Species occurring in this region should be managed for independently. Additionally, all HUCs that did not contain any flow-sensitive fish species were excluded from clustering.

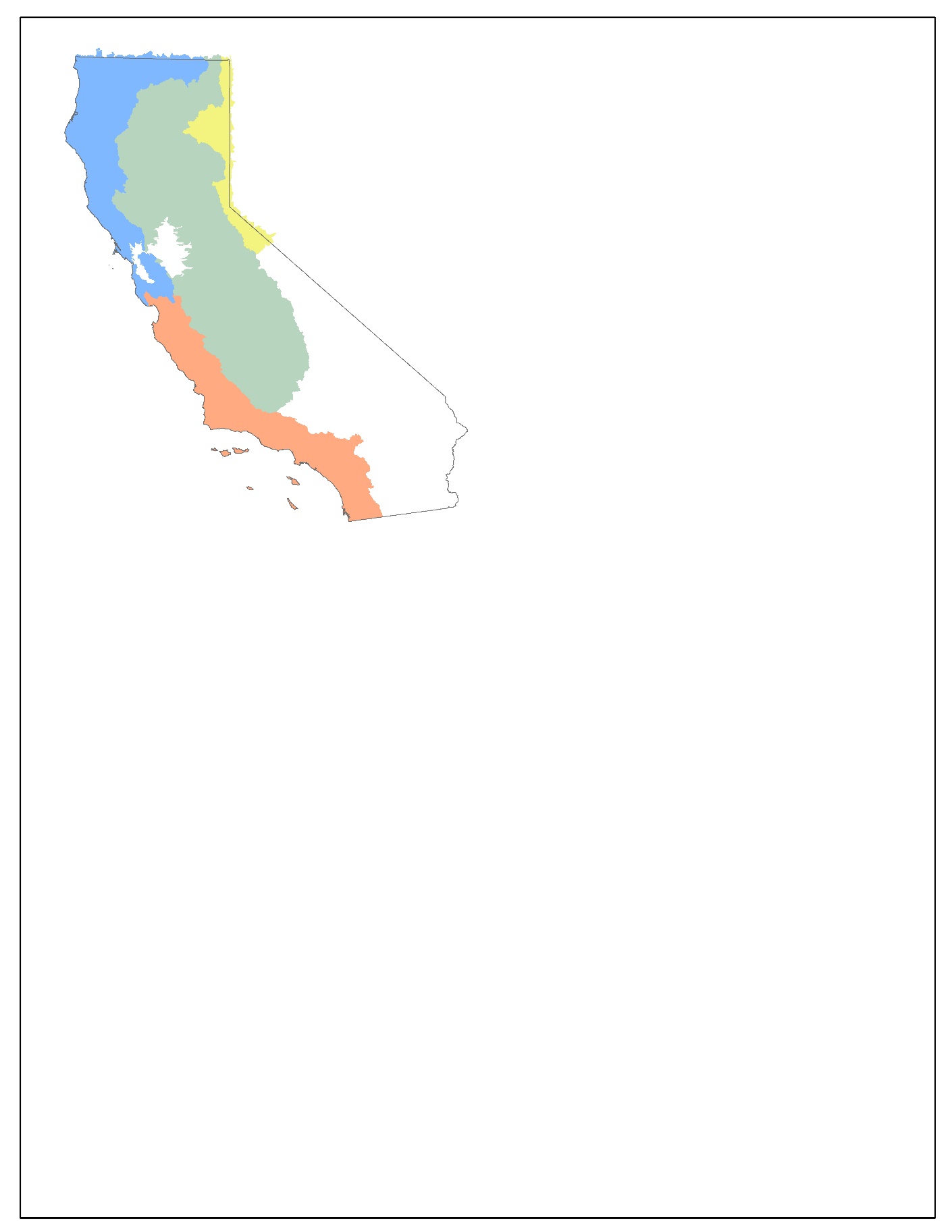
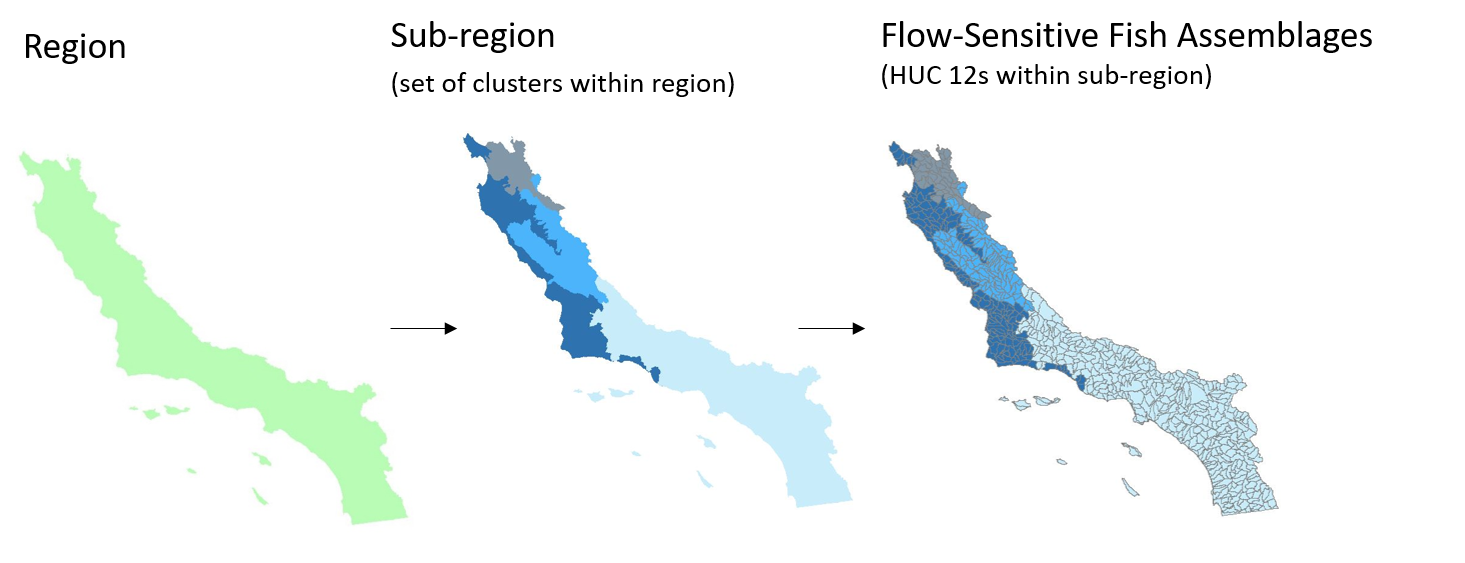


Figure 1. Map of regions used for clustering analysis. Note, white areas indicate areas excluded from our analysis. These areas either do not contain flow-sensitive species, or were manually excluded because they have unique management considerations and should be managed separately (desert, San Francisco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

## Clustering Analysis

We used k-means clustering to determine sub-regional flow-sensitive fish assemblages. 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 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.

The goal of this analysis is to provide a unit of 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

The following web map displays the results of the clustering analysis. It includes the four broad geographic regions, the number of clusters within the region, and the HUC 12s within each cluster.

Appendix B includes tabular results of the data included in the web map. For each region, results are displayed as a table of the species present within each sub-regional cluster (the flow-sensitive fish assemblage), listed from most dominant to least dominant. Note, dominance here does not imply abundance, this dominance count only indicates the number of HUCs a given species is present in within a cluster. Each table also includes information about the proportion of the total current range of the species that falls within that cluster.

Some clusters have identical species assemblages which is due to differences in species distributions across HUC 12s within each cluster. See figure 3 below for visual representation.

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Figure 3. Fictional example of two clusters with identical assemblages (Sucker, Riffle Sculpin, Coastal Roach, Speckled Dace) that were broken up into different clusters.

# Questions for Experts

We would like your expertise in answering the questions below, and welcome other general comments on methodology or results of this analysis.

1. Do the **fish species** within these assemblages and **cluster boundaries** make sense from an ecological and management perspective? For example, while the Klamath system may have unique management recommendations, clustering did not result in it being distinguished as its own cluster.
2. Do the **number of clusters** for each region make sense from a species and management perspective? Should there be more or less clusters in a given region?

Please address the three questions above, and email your responses back to anobester@ucdavis.edu 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

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# 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