Progress Report October 25, 2012

Effects of climate change on inland fishes of California: tools for adaptation

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California's 129 native fishes are mostly (80%) endemic to California; they have no place to go as streams become warmer and more variable due to climate change. Many of the 51 alien fishes, however, are likely to benefit from these changes. The goal of this project is to synthesize information on California's fishes gathered systematically since the release of the book *Inland Fishes of California* in 2002. The information includes status (75% of endemic fishes in decline, 25% in danger of extinction), population and distribution trends, life history traits, and climate change adaptability of all inland fishes in the state. A major product of this work is the analysis of climate change effects on fishes with different vulnerabilities based on statewide climate change predictions.

Brief status of current project:
Since October 2011, we have made good progress on all but one of the deliverables. The database of the status of California fishes has been posted on an interactive website at UC Davis (access by permission only). This data base is currently under review by the CA Fish and Game and will be more widely posted, including links to agency websites, once it is finalized. Distribution maps of fishes in public lands with their descriptions have also been posted on the UCD website. Distribution maps are currently being made for the rest of the state. Maps are continuously being updated as new information is available. An early version of the climate change vulnerability database has been posted on the California Energy Commission website (Moyle et al. 2012) and the data is currently being reviewed and updated, with expected completion by December 1, 2012. We have also begun assessments of climate change vulnerabilities of fish species in specific regions. Projections from the project will be coupled with these analyses to evaluate species response at multiple geographical scales. Preliminary results of the vulnerability assessments were presented in April 2012 at the US International Association for Landscape Ecology conference in Rhode Island. Since April, findings have been expanded and are detailed below. The only incomplete product is the project page on the California Fish website which has yet to be created. We are waiting for other products to be finalized first but we expect the website page to be completed by January or February 2013.

Climate change vulnerabilities of fishes at different geographical scales – subprovince analysis:
Because climate change effects will differ in scale and magnitude according to location, a large part of the effort in 2012 was placed in deciphering trends of fishes in different geographical areas. We analyzed the status, threats, baseline vulnerability, climate change vulnerability, and overall vulnerability of native fishes in zoogeographic subprovinces based on Moyle 2002 (Table 1). Of the subprovinces designated by Moyle (2002), the Klamath-Pit, McCloud River, Great Basin, and Surprise Valley subprovinces were not included in our analysis due to a lack or low diversity of fish fauna.

Table 1. Zoogeographical subprovinces and management units used in our analysis.

Upper Klamath River	Monterey Bay	Lahontan
Lower Klamath River	Kern River	Owens Valley
Pit River	North Coast	Amargosa
Clear Lake	Eagle Lake	Mojave
South Coast	Colorado River and Salton Sea	Goose Lake
Central Valley	San Francisco Bay	Sierra Nevada

In addition, the San Francisco Bay and Sierra Nevada management units were analyzed in the same manner. Results are summarized in the figures found in the appendix. Only species endemic to the subprovinces were used in the analyses in order for fish status and vulnerabilities to most closely reflect conditions in each location. Species were designated into subprovinces as listed in the Table 2 below.

Table 2. Native species endemic to specific zoogeographic subprovinces in California.

Amargosa

Amargosa Canyon speckled dace, *R. o. nevadensis*

Saratoga Springs pupfish, *C. n. nevadensis*

Amargosa River pupfish, *C. n. amargosae*

Shoshone Spring pupfish, *C. n. shoshone*

Salt Creek pupfish, *C. s. salinus*

Cottonball Marsh pupfish, *C. s. milleri*

Central Valley

Kern brook lamprey, *L. hubbsi*

Western brook lamprey, *L. richardsoni*

Southern green sturgeon, *A. medirostris*

White sturgeon, *A. transmontanus*

Lahontan redside, *Richardsonius egregius*

Sacramento hitch, *Lavinia e. exilicauda*

Central California roach, *L. s. symmetricus*

Red Hills roach, *L. s. subsp.*

Sacramento blackfish, *Orthodon microlepidotus*

Sacramento splittail, *Pogonichthys macrolepidotus*

Hardhead, *Mylopharodon conocephalus*

Sacramento pikeminow, *Ptychocheilus grandis*

Sacramento speckled dace, *Rhinichthys osculus subp.*

Lahontan speckled dace, *R. o. robustus*

Mountain sucker, *C. platyrhynchus*

Sacramento sucker, *C. o. occidentalis*

Longfin smelt, *Spirinchus thaleichthys*

Delta smelt, *Hypomesus pacificus*

Central Valley winter Chinook salmon, *O. tshawytscha*

Central Valley spring Chinook salmon, *O. tshawytscha*

Central Valley late fall Chinook salmon, *O. tshawytscha*

Central Valley steelhead

Central Valley fall Chinook salmon, *O. tshawytscha*

Clear Lake

Clear Lake hitch, *L. e. chi*

Clear Lake roach, *L s. subsp.*

Sacramento blackfish, *Orthodon microlepidotus*

Sacramento pikeminow, *Ptychocheilus grandis*

Sacramento sucker, *C. o. occidentalis*

Clear Lake prickly sculpin, *C. a. subsp.*

Inland threespine stickleback, *G. a. microcephalus*

Sacramento perch, *Archoplites interruptus*

Clear Lake tule perch, *H. t. lagunae*

Colorado River (including the Salton Sea)

Razorback sucker, *Xyrauchen texanus*

Desert pupfish, *Cyprinodon macularius*

Eagle Lake

Eagle Lake tui chub, *S. b. subsp.*

Eagle Lake rainbow trout, *O. m. aquilarum*

Goose Lake

Goose Lake lamprey, *Entosphenus sp.*

Goose Lake sucker, *C. o. lacusanserinus*

Goose Lake tui chub, *S. t. thalassinus*

Kern River

Kern River rainbow trout, *O. m. gilberti*

Little Kern golden trout, *O. m. whitei*

Lahontan

Cow Head tui chub, *S. t. vaccaceps*

Lahontan Lake tui chub, *S. b. pectinifer*

Lahontan stream tui chub, *S. b. obesus*

Mountain whitefish, *Prosopium williamsoni*

Paiute sculpin, *C. beldingi*

Lower Klamath River (including Smith River)

Klamath River lamprey, *E. similis*

Blue chub, *Gila coerulea*

Klamath smallscale sucker, *C. rimiculus*

Upper Klamath-Trinity fall Chinook salmon, *Oncorhynchus tshawytscha*

Upper Klamath-Trinity spring Chinook salmon, *O. tshawytscha*

Klamath Mountains Province winter steelhead*, O. mykiss*

Klamath Mountains Province summer steelhead*, O. mykiss*

Lower Klamath marbled sculpin, *C.k. polyporus*

Mohave

Mohave tui chub, *S. mohavensis*

Monterey Bay

Monterey hitch, *L. e. harengeus*

Monterey roach, *L. s. subditus*

Monterey sucker, *C. o. mnioltiltus*

North Coast

Russian River roach, *L. s. subsp*

Navarro Roach, *L. s. navarroensis*
Tomales Roach, *L. s. subspecies*
Gualala roach, *L. parvipinnus*
Humboldt sucker, *C. o. humboldtianus*
California Coast fall Chinook salmon, *O. tshawytscha*
Northern California coast winter steelhead, *O. mykiss*
Northern California coast summer steelhead, *O. mykiss*
Russian River tule perch, *H. t. pomo*

Owens

Owens tui chub, *S. b. snyderi*
Owens speckled dace, *R. o. subsp.*
Long Valley speckled dace, *R. o. subsp.*

Pit River

Pit River tui chub, *S. thalassinus subsp.*
McCloud River redband trout, *O. m. stonei*
Rough sculpin, *Cottus asperrimus*
Bigeye marbled sculpin, *C. klamathensis macrops*

South Coast

Santa Ana speckled dace, *R. o. subsp.*
Santa Ana sucker, *C. santaanae*
South Central California coast steelhead*, O. mykiss*
Southern California steelhead, *O. mykiss*

Upper Klamath (Oregon into California to Iron Gate Dam)

Klamath tui chub, *S. b. bicolor*
Klamath largescale sucker, *C. snyderi*
Lost River sucker, *C. luxatus*
Shortnose sucker, *Chasmistes brevirostris*
Upper Klamath marbled sculpin, *C. k. klamathensis*
Bull trout
slender sculpin
Klamath Lake sculpin

In general, we found that fishes in the southern (Mojave, Colorado River, Kern River) and eastern (Owens Valley, Eagle Lake) part of the state are the most threatened by the combination of their present status and climate change. In contrast, fishes in Monterey Bay appear to be the least vulnerable to these impacts. Non-parametric analysis (Kruskal-Wallis Z test) of vulnerability values between subprovinces showed significant differences (Z values > 1.96) among the most and least vulnerable fish faunas but not among subprovinces with intermediate values. Analysis between the two management units suggests that fishes in the Sierra Nevada are more threatened than those in San Francisco Bay.

Products proposed for year 2:

Year 2 (ending September 30, 2013)

1. Completed posting of all relevant materials and links on the California Fish website.

2. Final report on status and conservation of California fishes in relation to climate change that will include (1) ranked list of native species, by vulnerability, with brief narratives (or links to narratives) for each species; (2) ranked list of non-native species, by likelihood of increasing abundance in relation to climate change; (3) analysis by region of climate change vulnerability of native and alien species regional clusters of most vulnerable native species, (4) recommendations for a statewide conservation strategy; (5) regional lists of potential refuge waters, including streams where dam reoperation may benefit native fishes.

In 2013, we also plan to evaluate the traits that buffer or exacerbate species' vulnerability to climate change. Traits that will be considered include traits related to environmental tolerance and various life history traits, such as reproduction, longevity, habitat specialization, and dispersive capacity.

Appendix

Figure 1. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Amargosa zoogeographic subprovince, California.

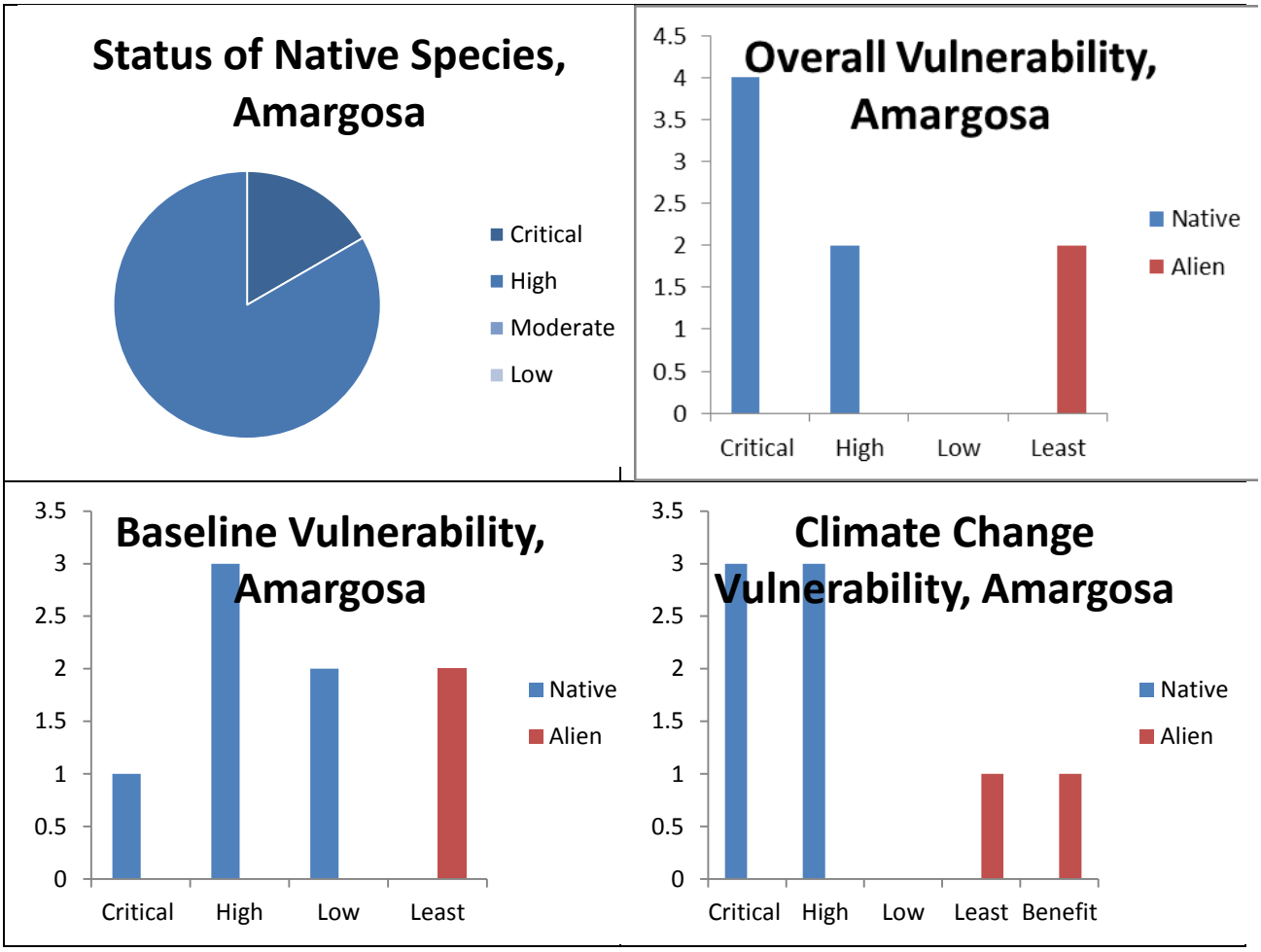

Figure 2. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Central Valley zoogeographic subprovince, California.

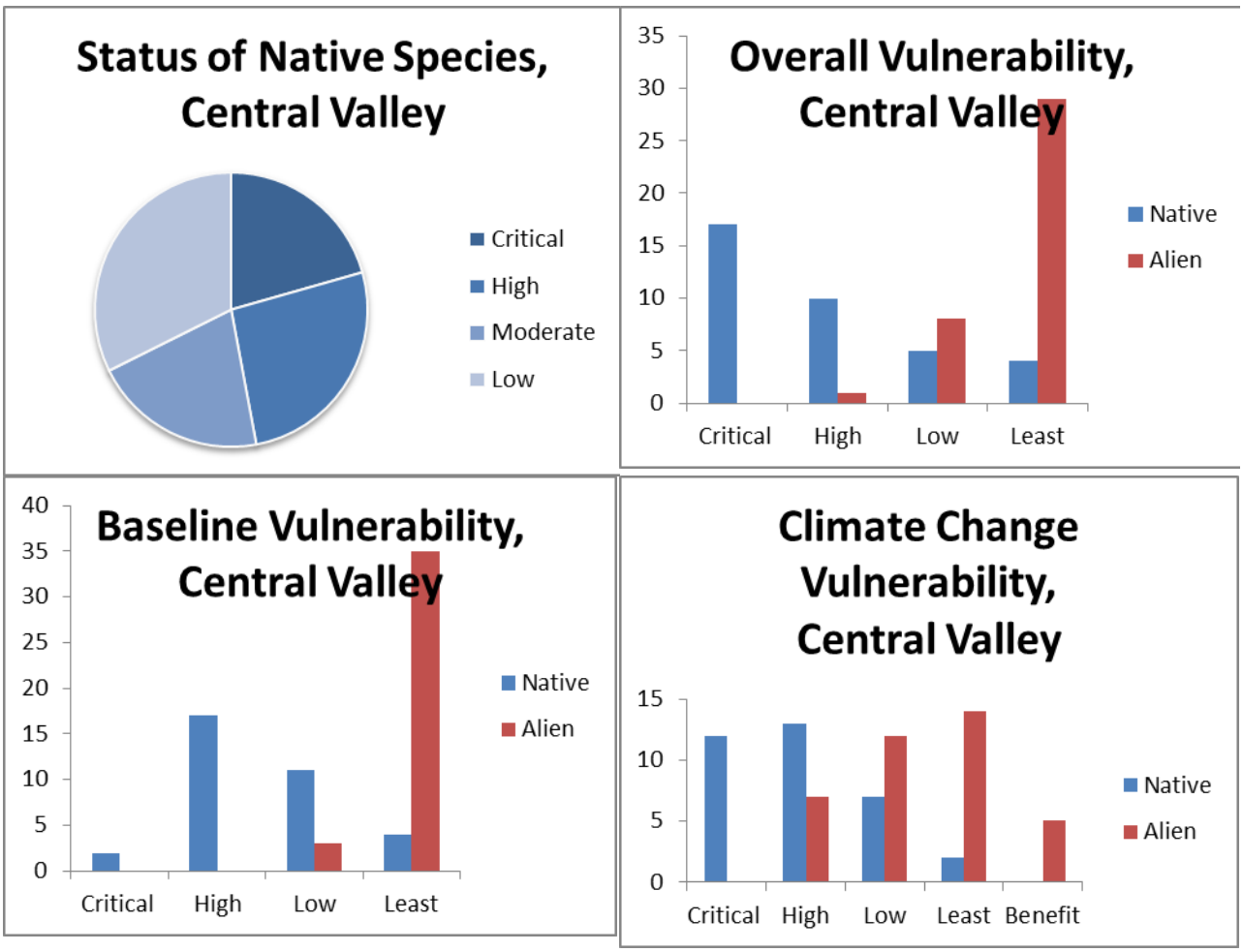

Figure 3. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Clear Lake zoogeographic subprovince, California.

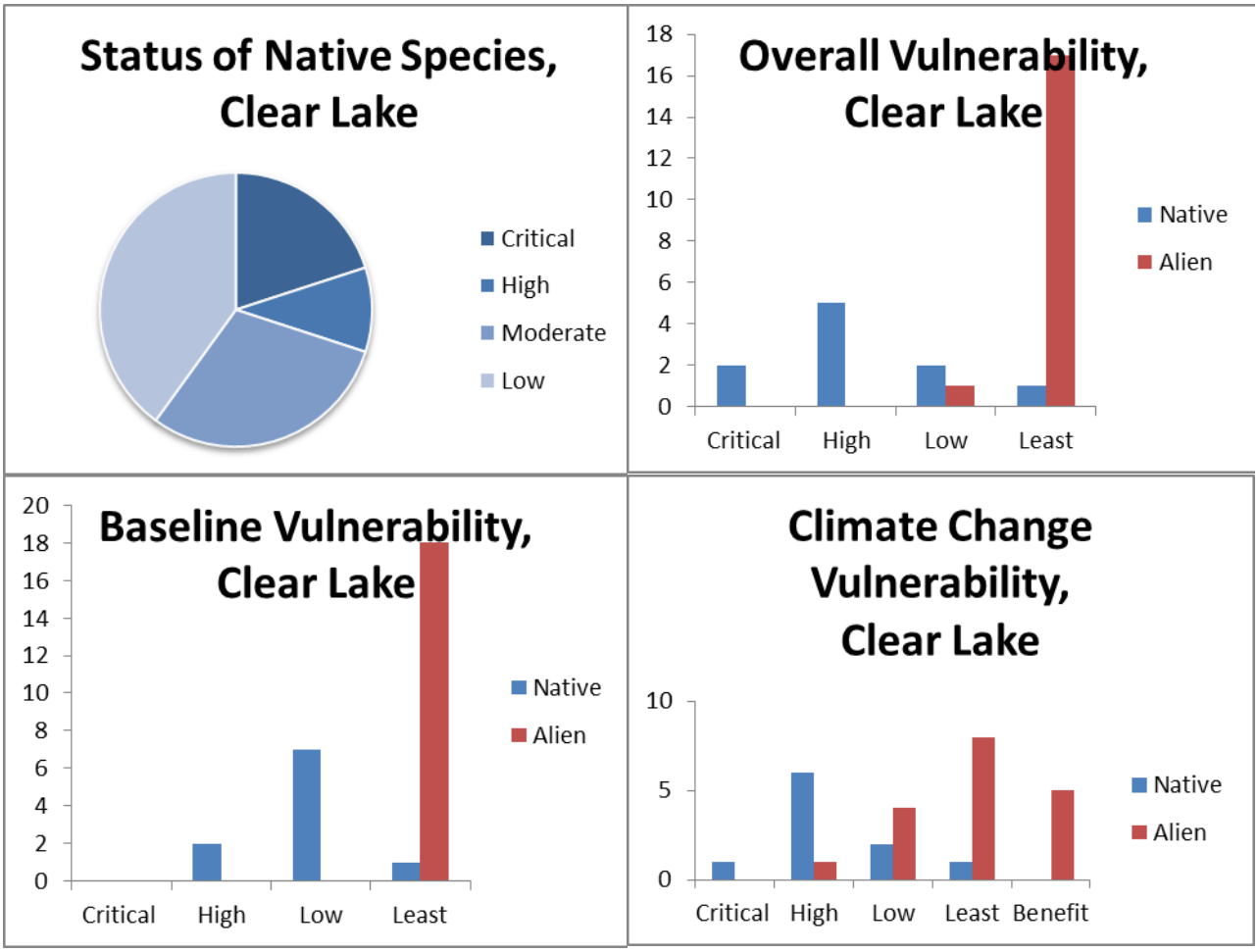

Figure 4. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Colorado River (includes Salton Sea) zoogeographic subprovince, California.

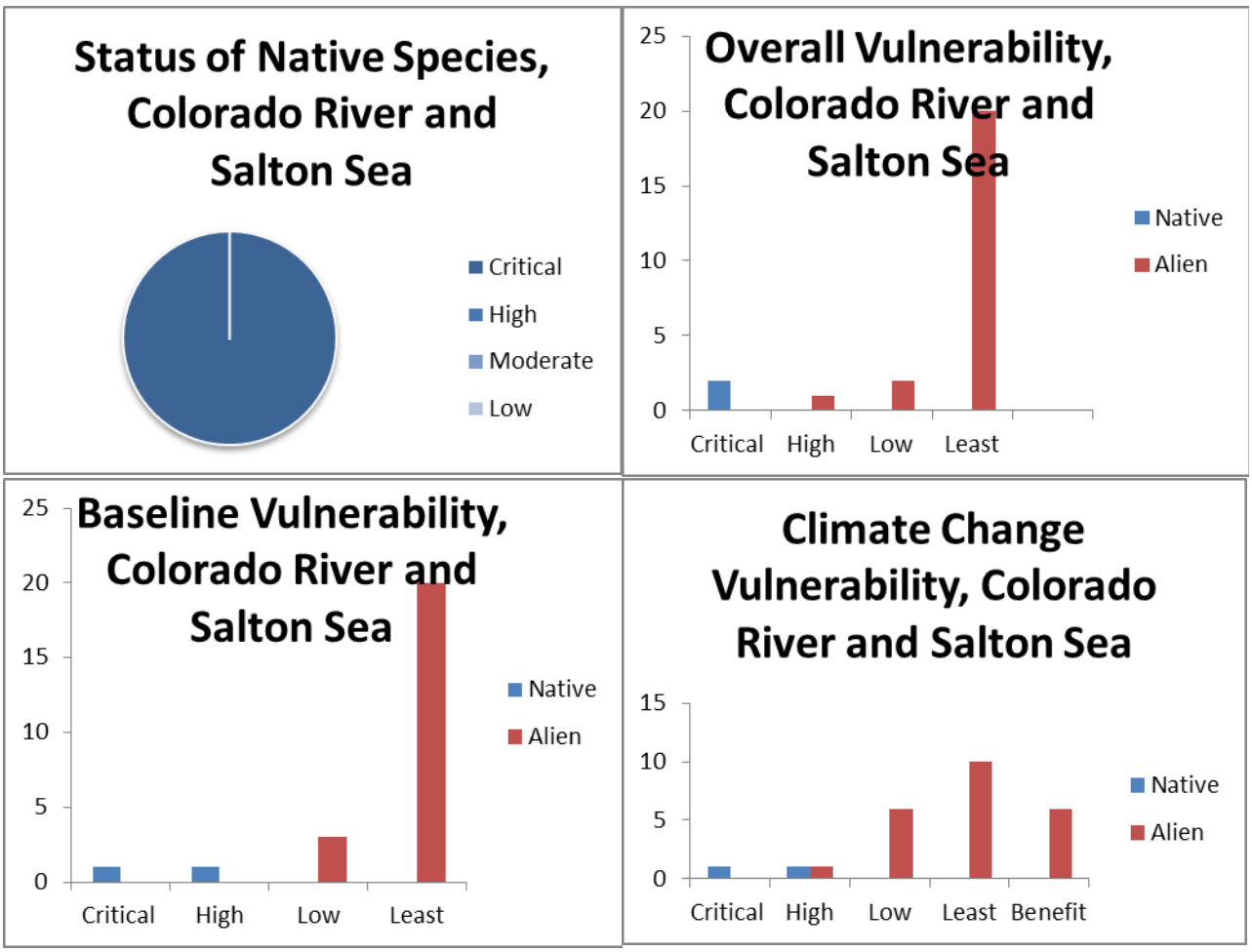

Figure 5. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Eagle Lake zoogeographic subprovince, California.

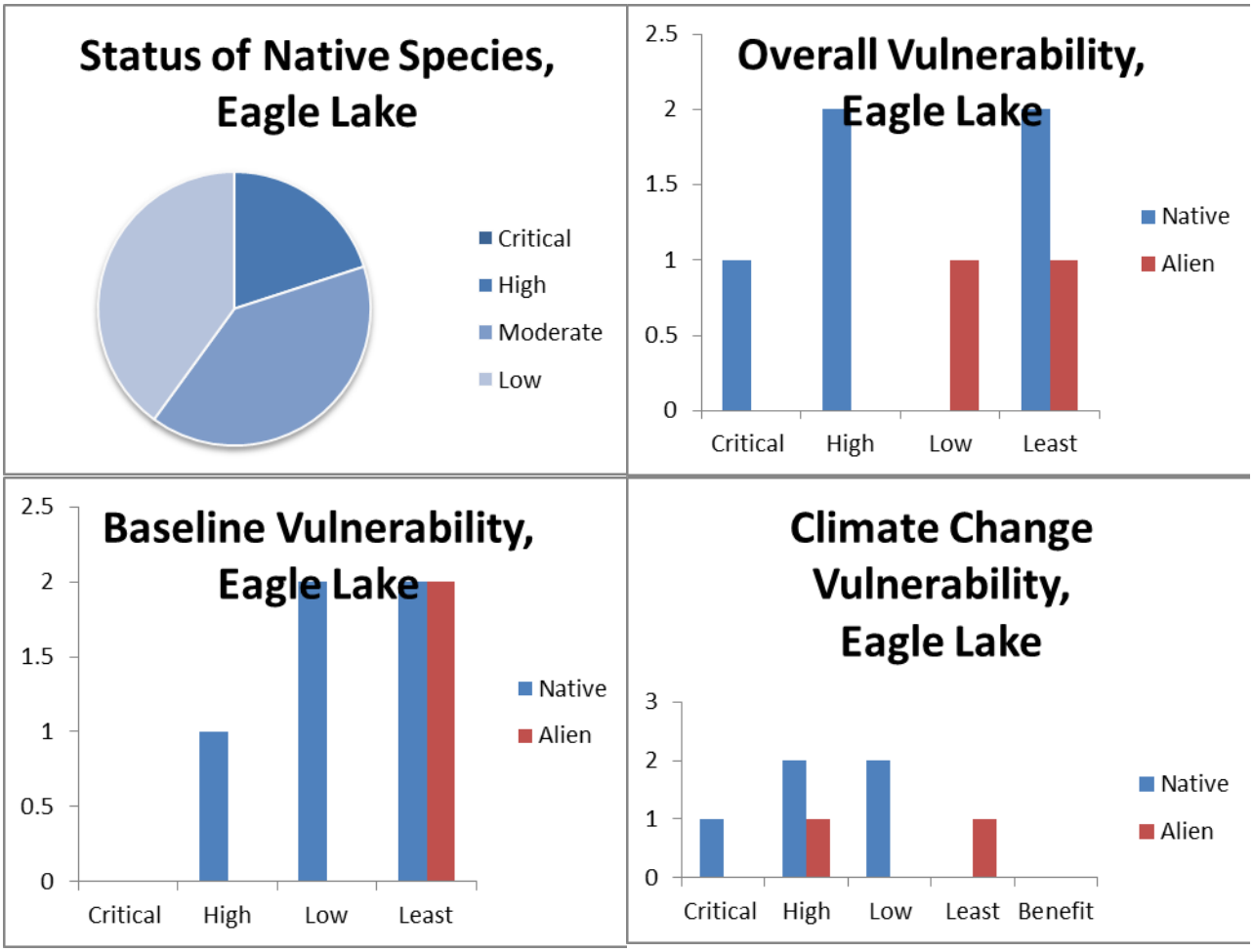

Figure 6. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Goose Lake zoogeographic subprovince, California.

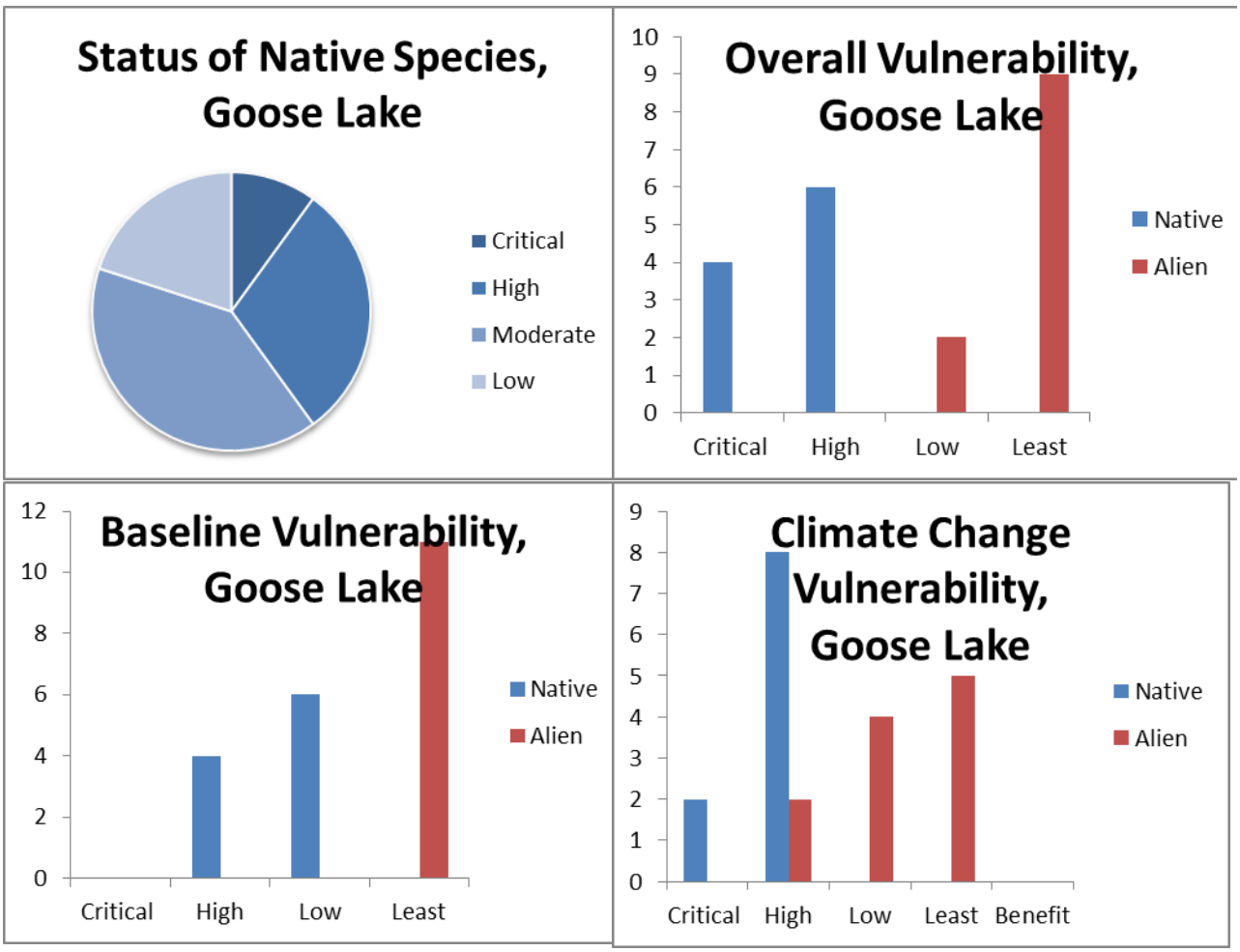

Figure 7. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Kern River zoogeographic subprovince, California.

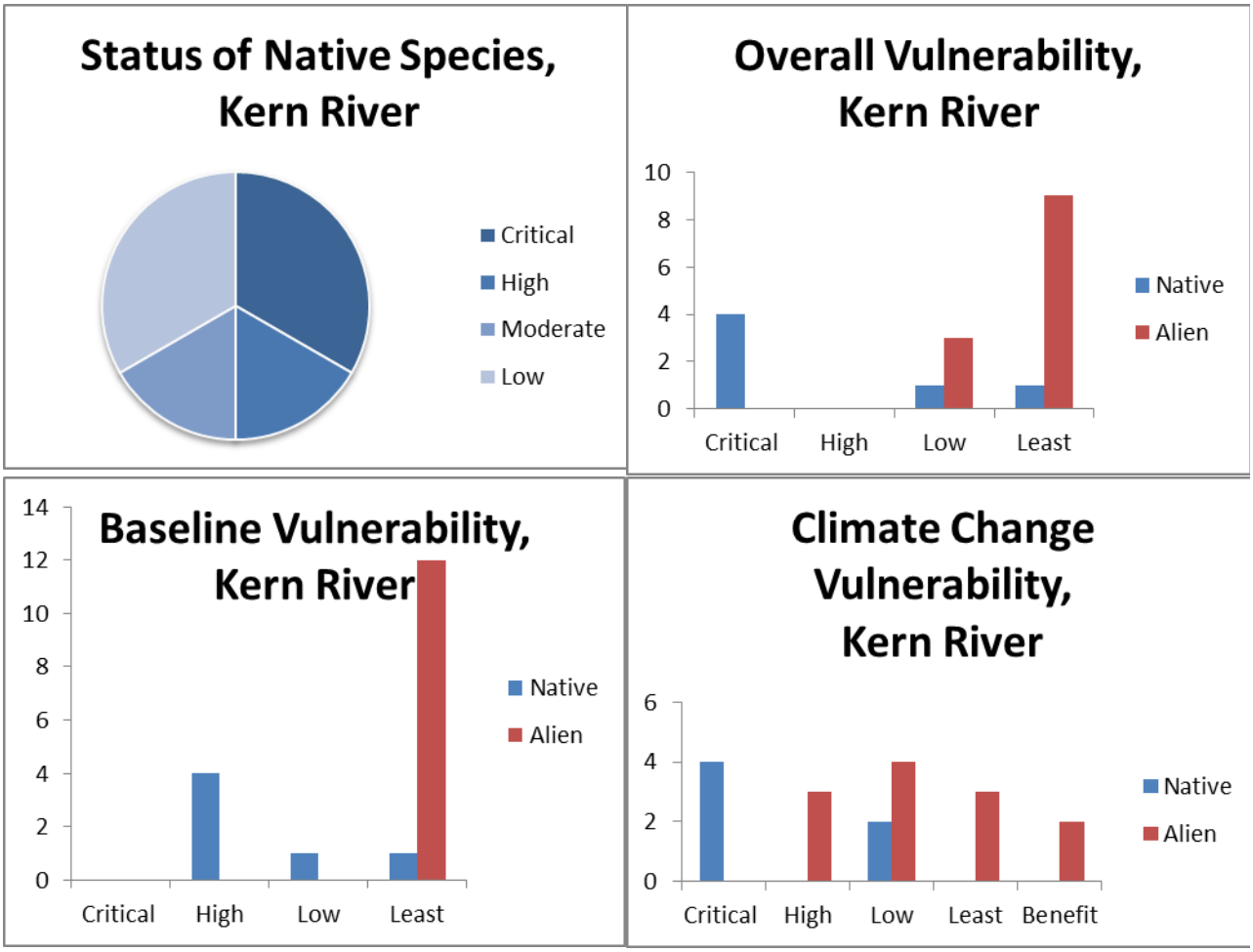

Figure 8. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Lahontan zoogeographic subprovince, California.

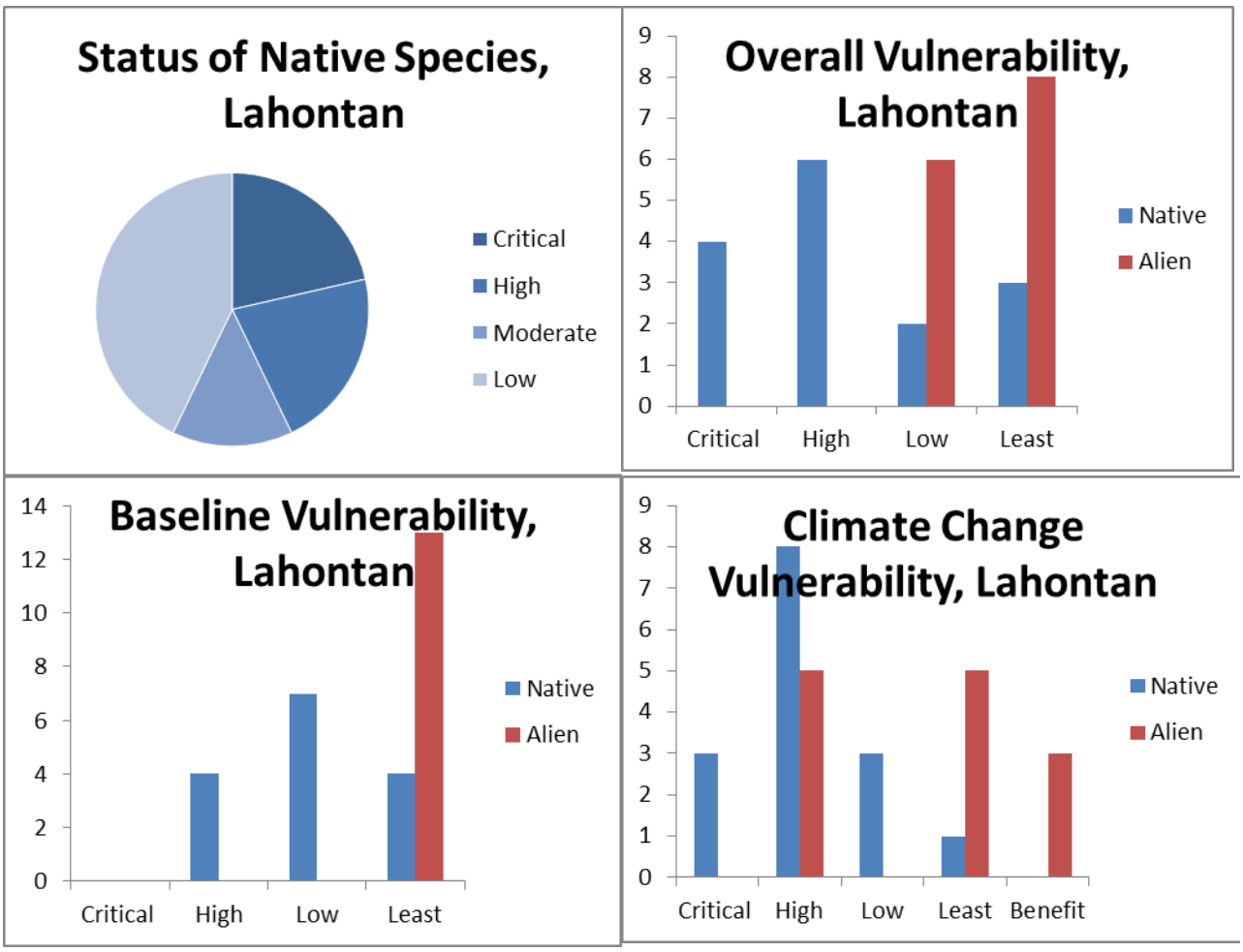

Figure 9. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Lower Klamath subprovince (includes Smith River), California.

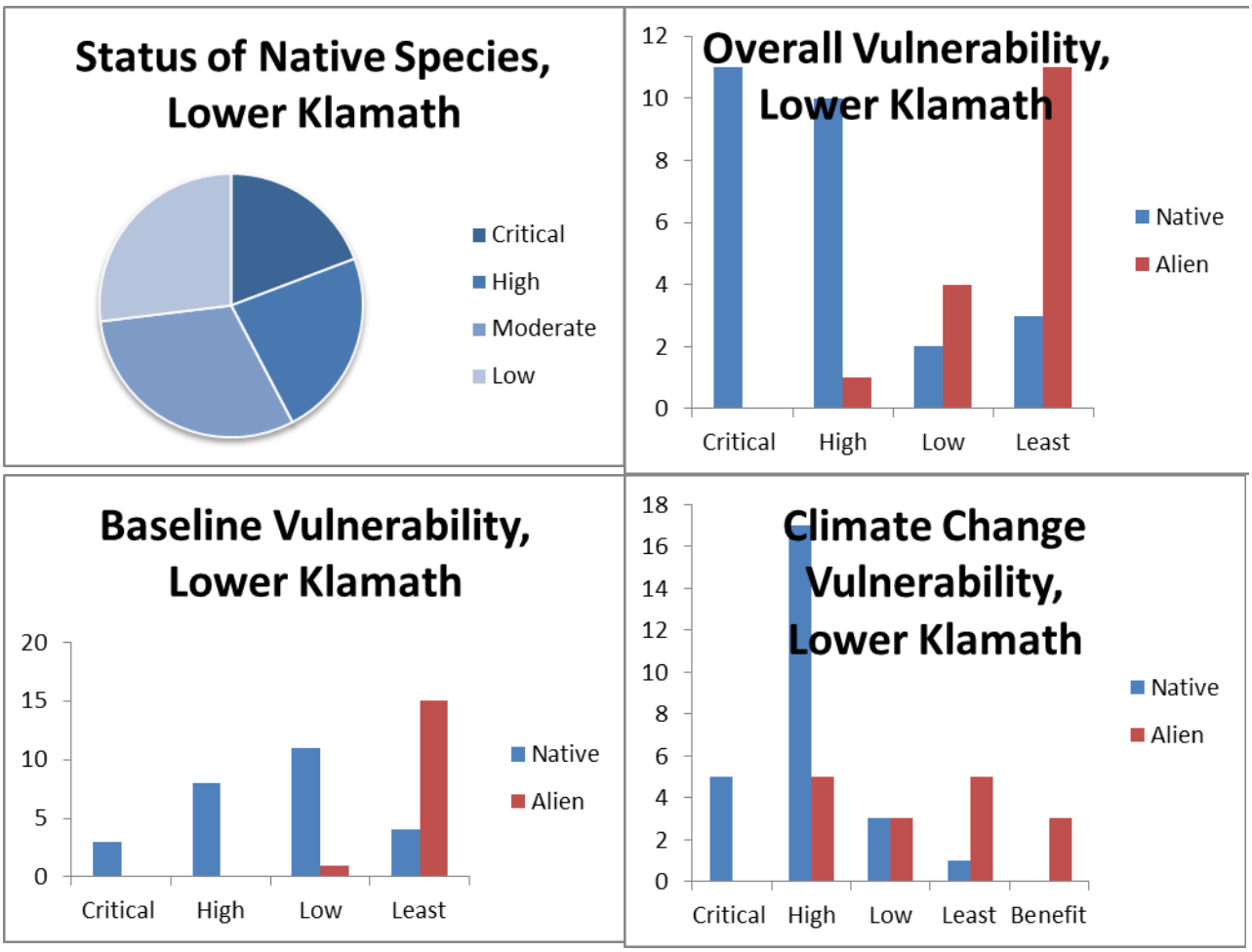

Figure 10. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Mojave subprovince, California.

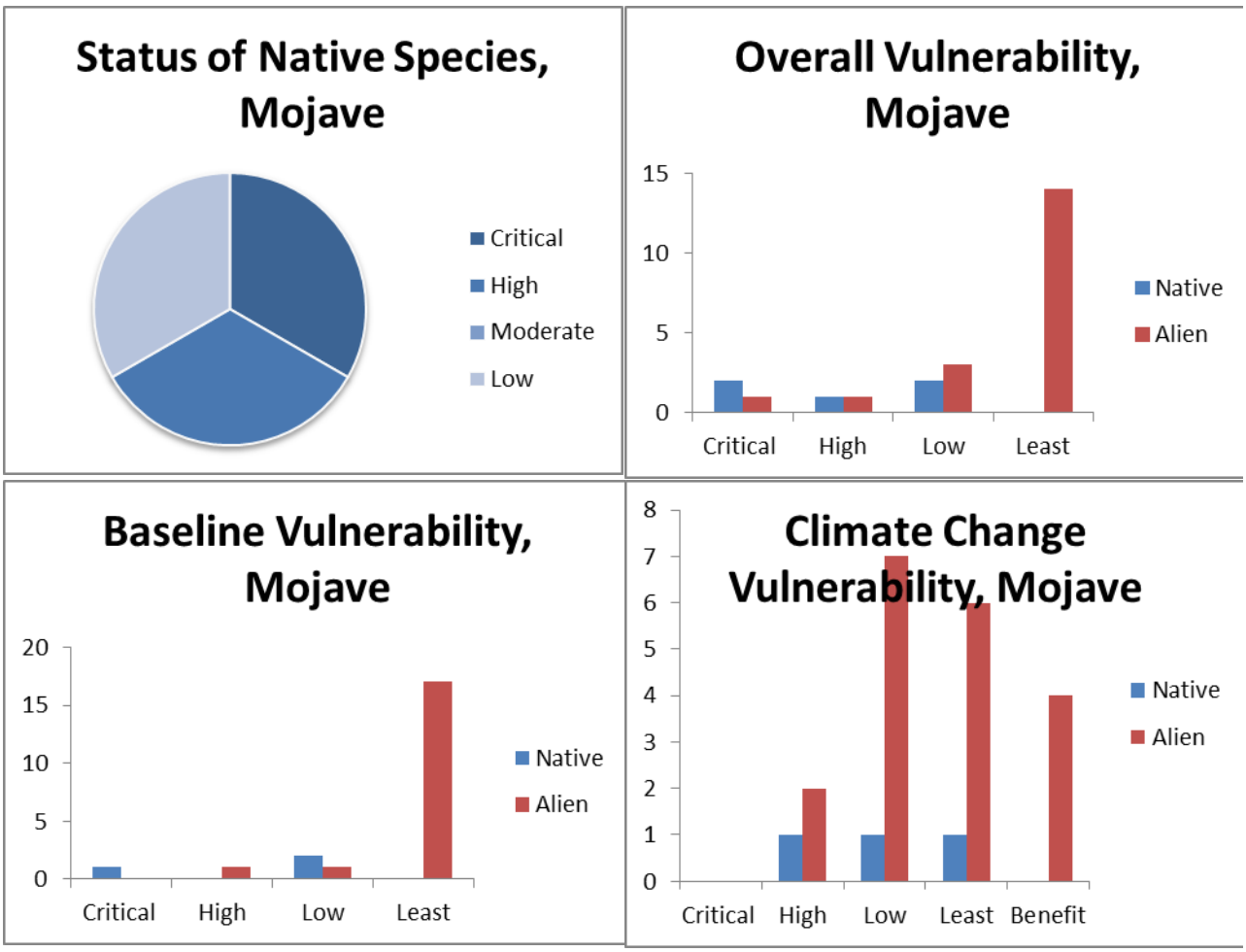

Figure 11. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Monterey Bay subprovince, California.

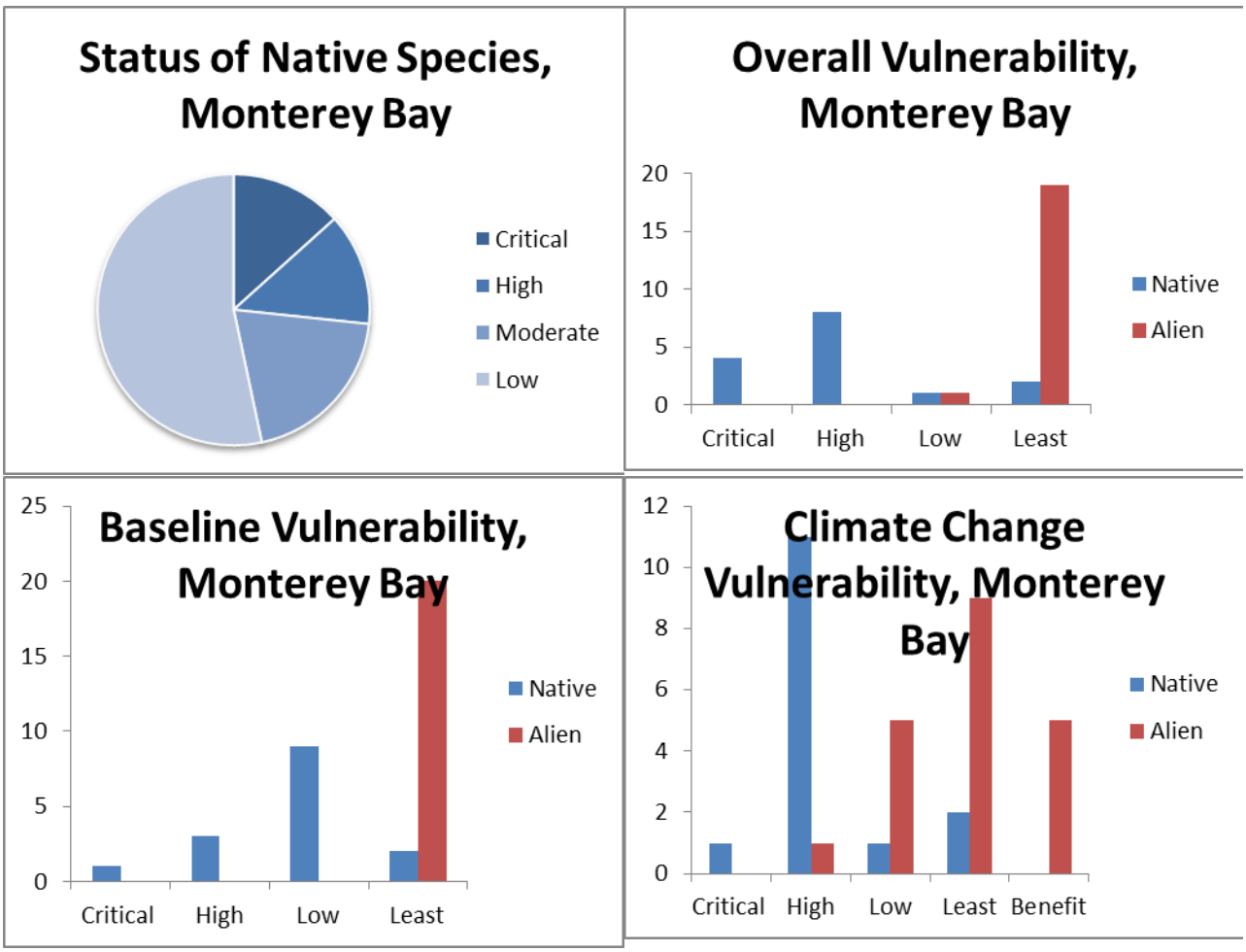

Figure 12. Status, overall vulnerability , baseline vulnerability, and climate change vulnerability for native and alien fish species in the North Coast subprovince, California.

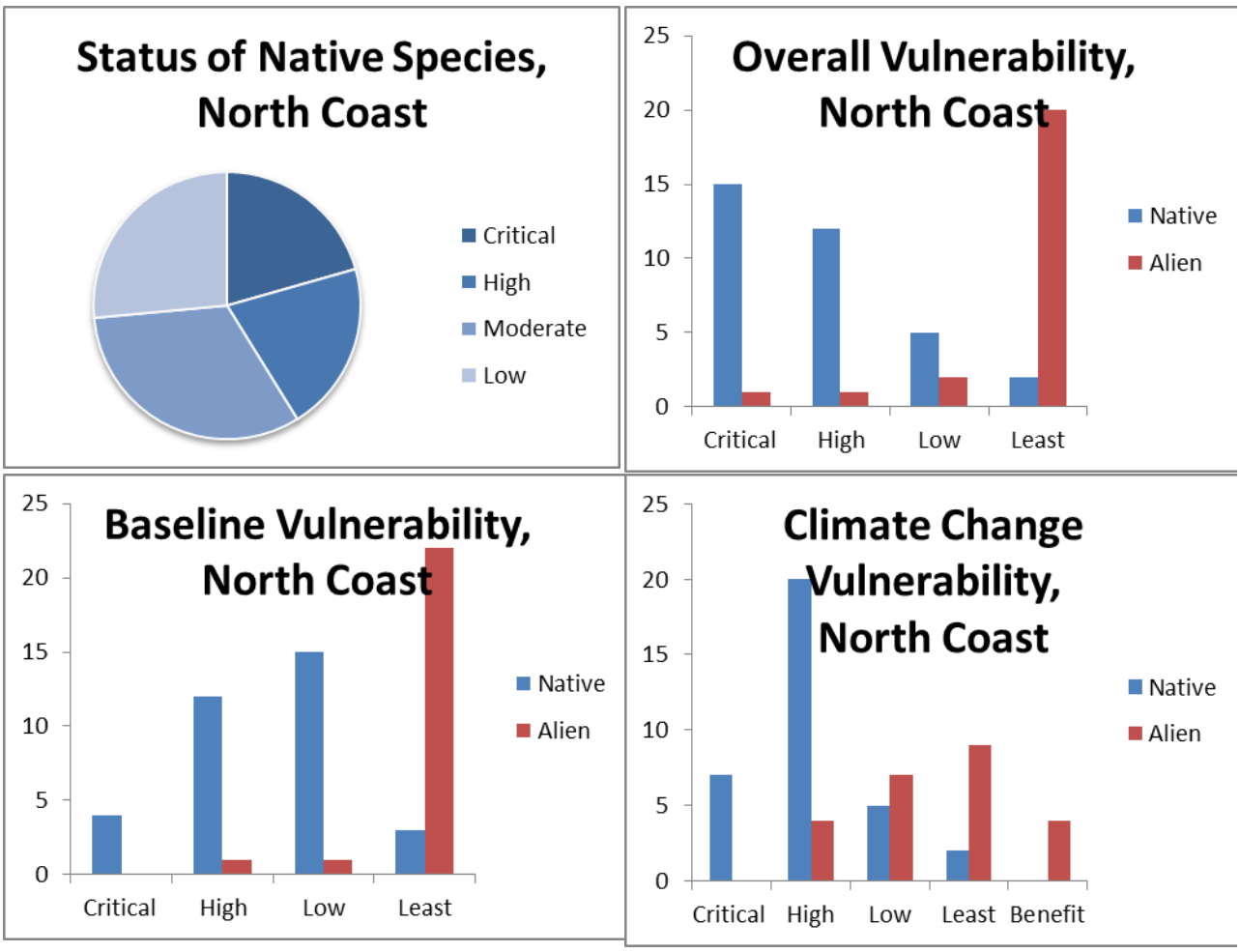

Figure 13. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Owens Valley subprovince, California.

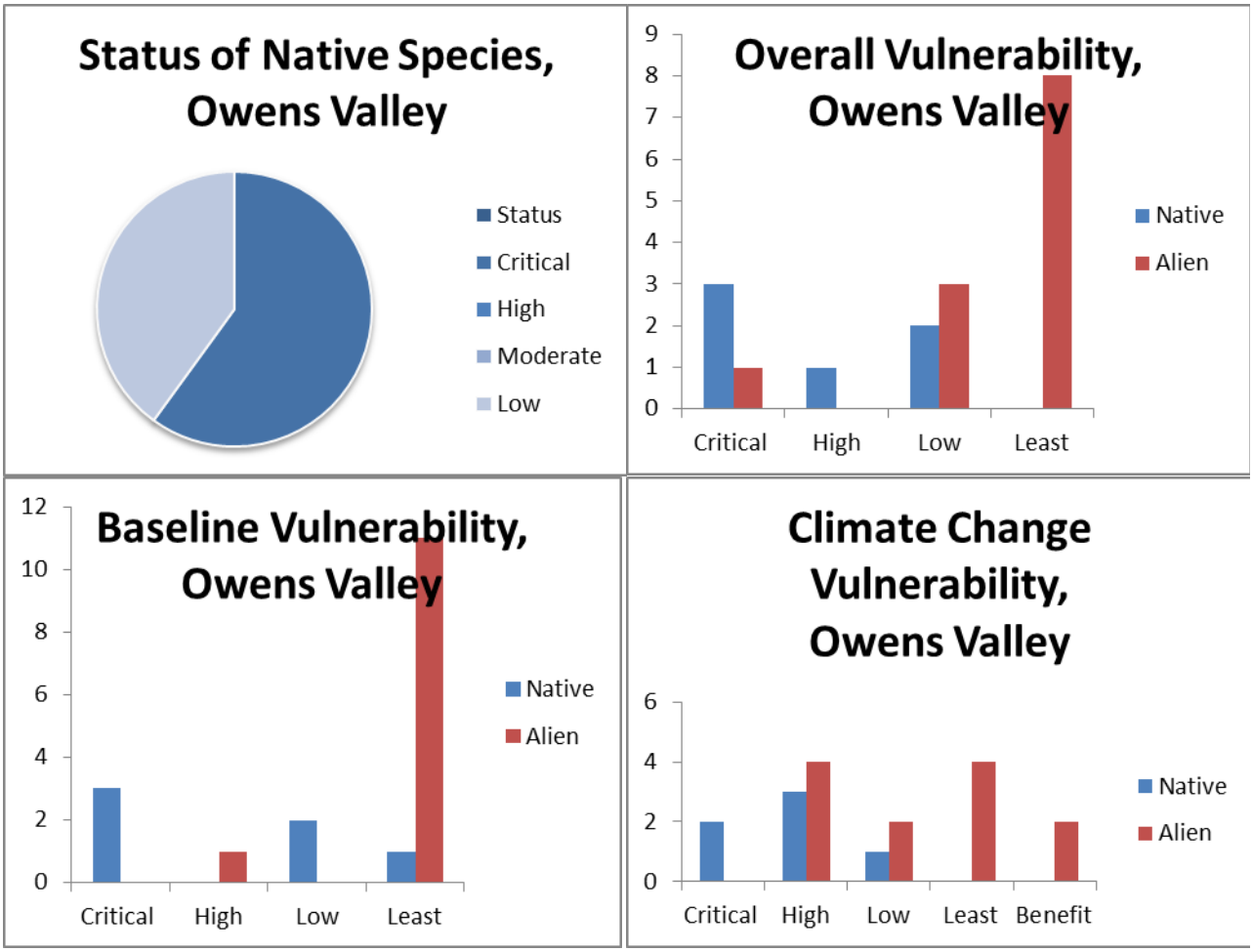

Figure 14. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Pit River subprovince, California.

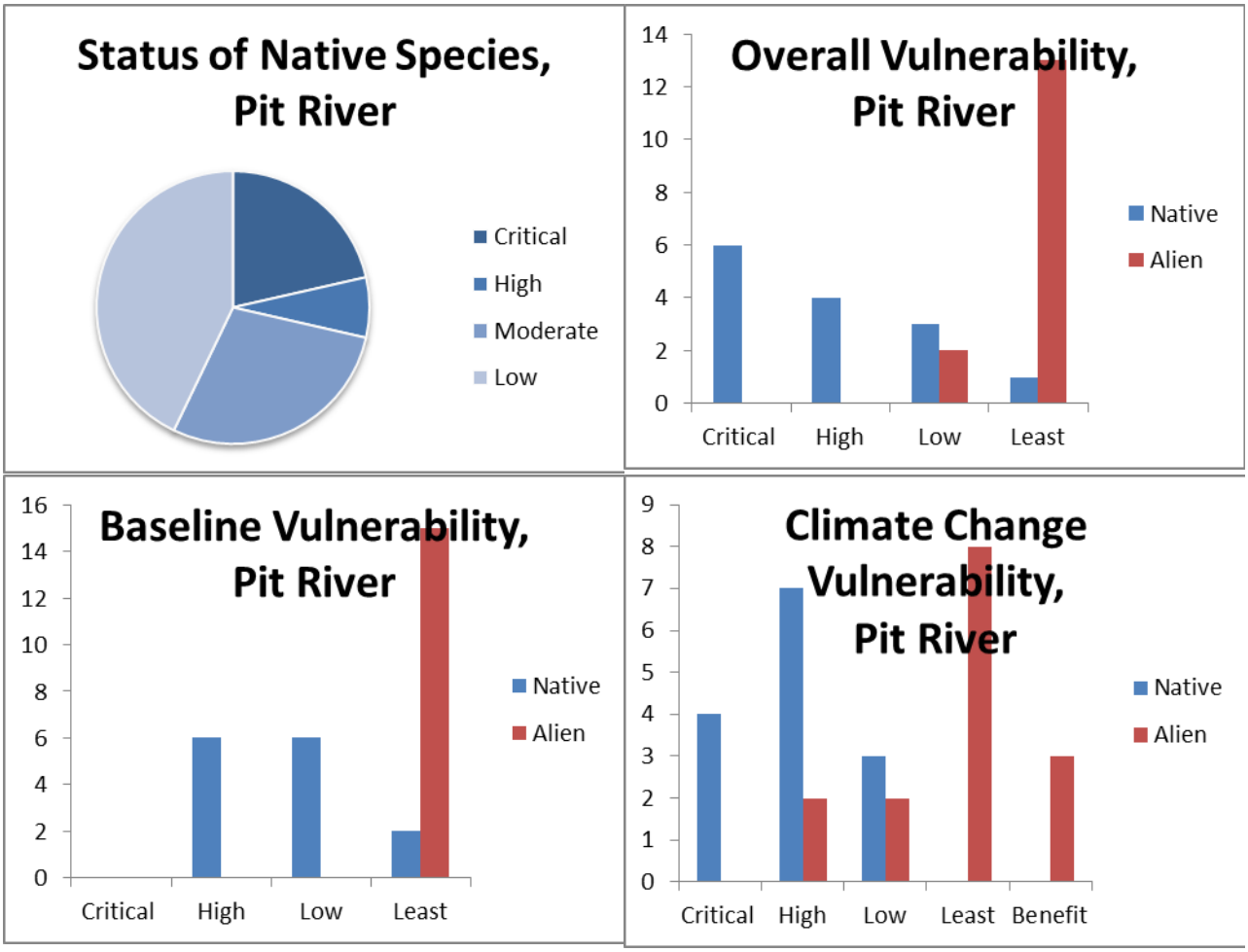

Figure 15. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the South Coast subprovince, California.

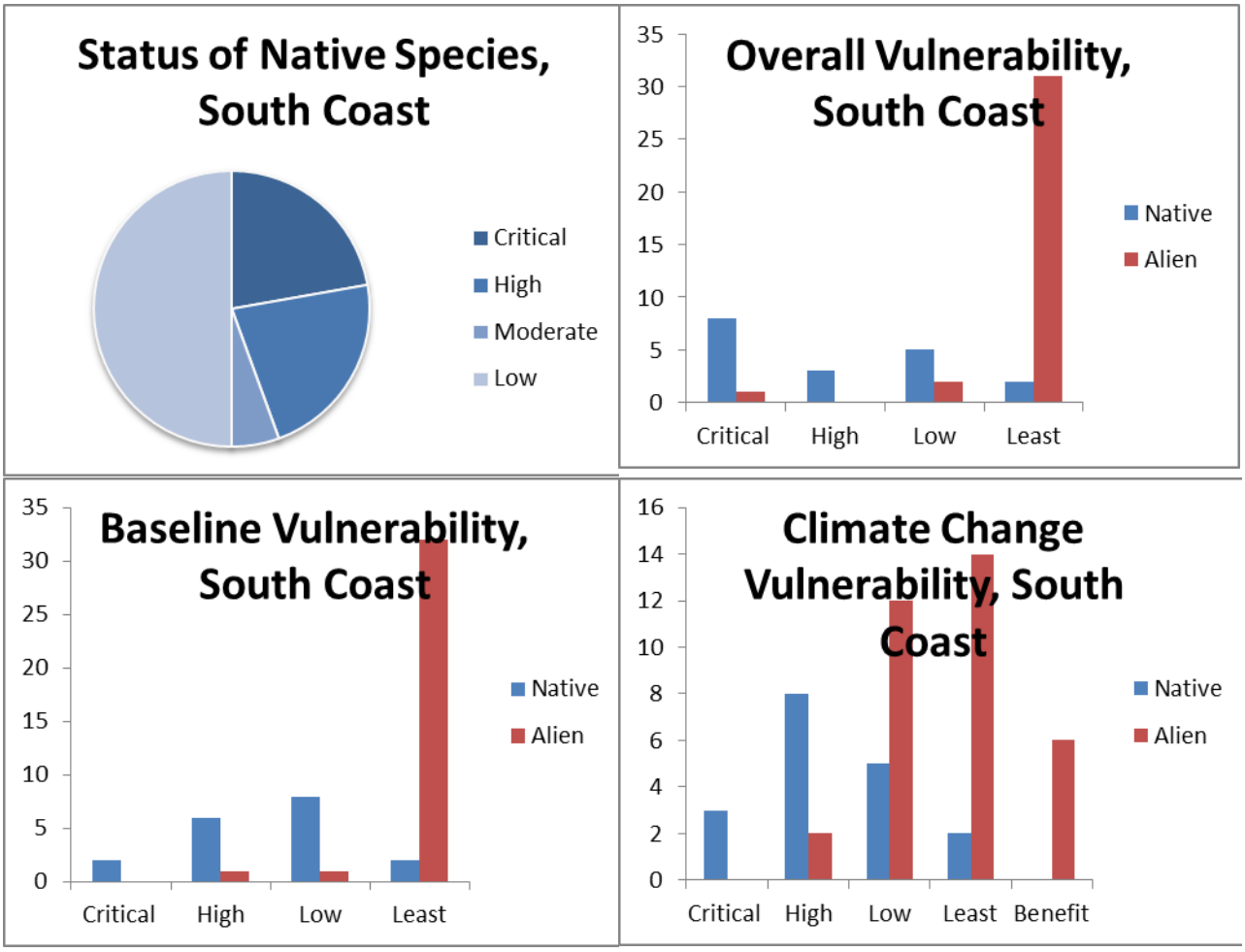

Figure 16. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Upper Klamath subprovince, California.

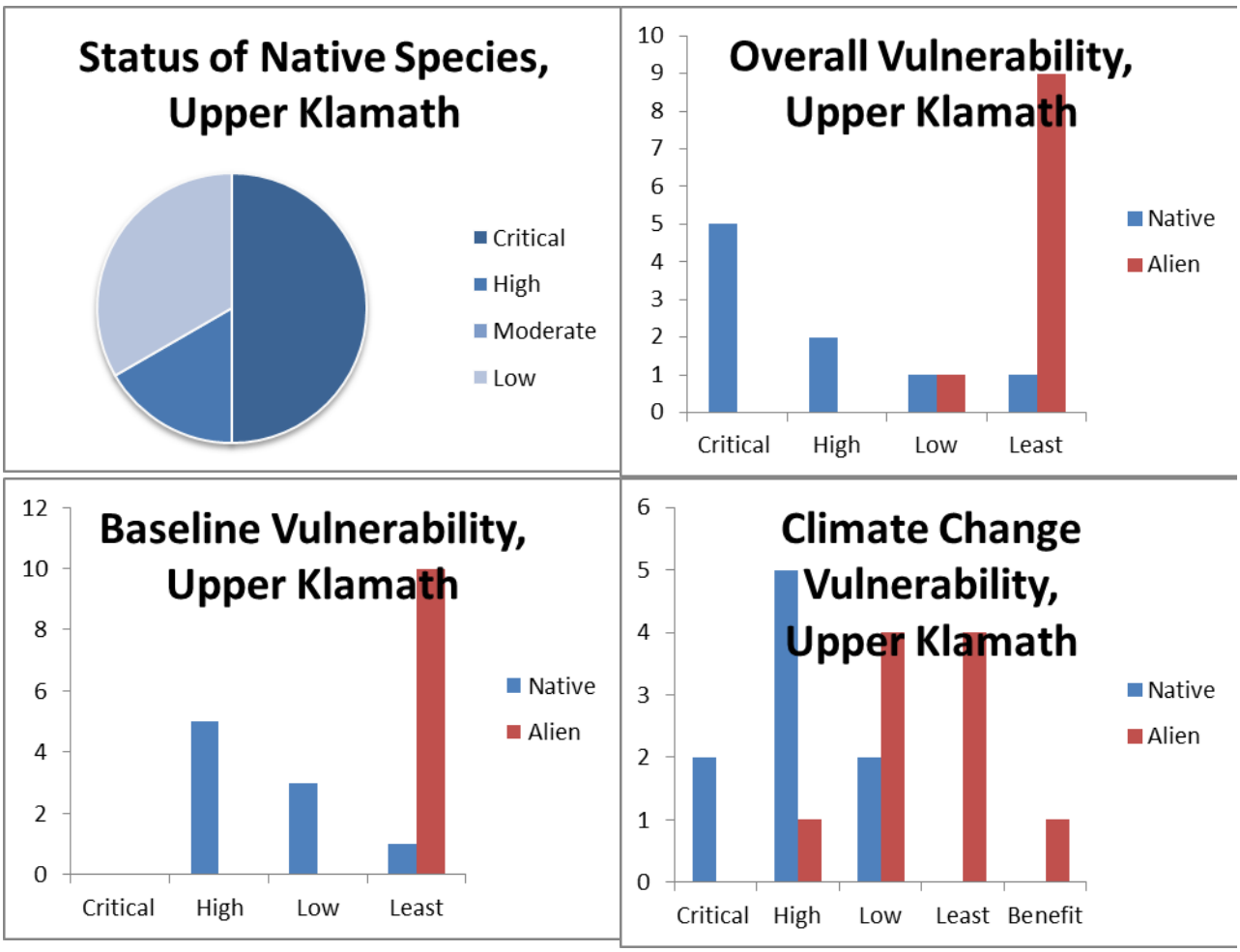

Figure 17. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the San Francisco Bay management area, California.

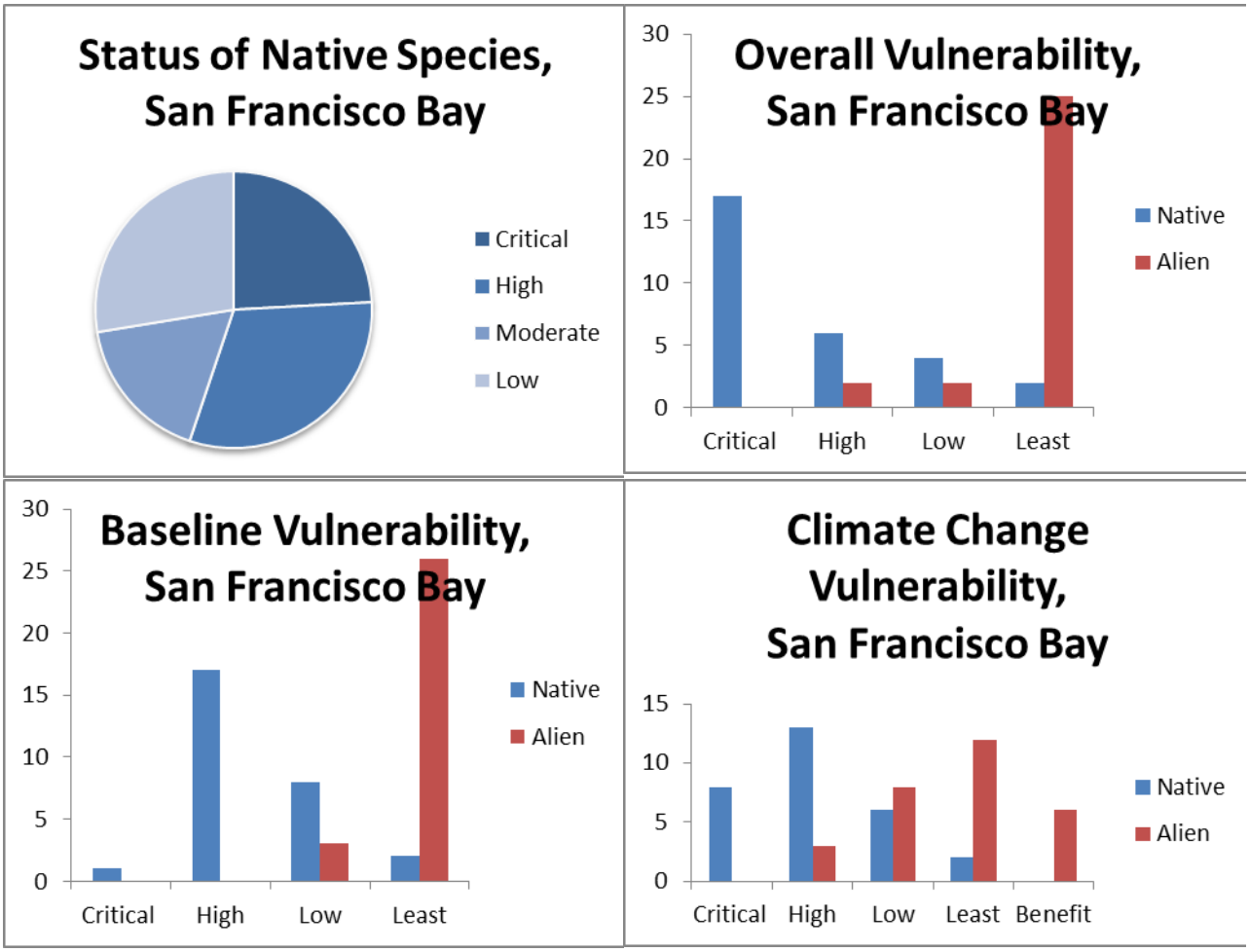

Figure 18. Status, overall vulnerability, baseline vulnerability, and climate change vulnerability for native and alien fish species in the Sierra Nevada management area, California.