

Droughts, Climate Change and Dams, O My: Making a Future of California's Native Inland Fishes

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Droughts, Climate Change and Dams, O My: Making a Future of California's Native Inland Fishes

- Drought
- Predicted effects of climate change on aquatic habitats in California
- Climate change & native fishes
- What can we do: A conservation strategy
- Reconciliation ecology





The 2013-14 Drought

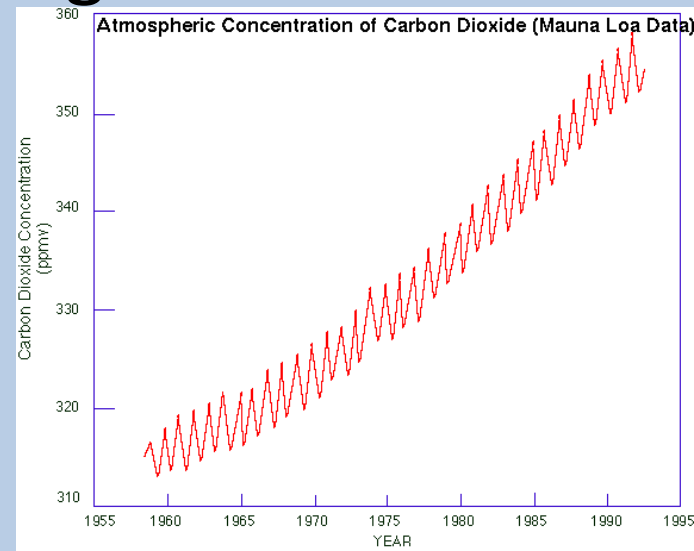
- 3rd dry year
- One year w/o significant rain
 - Until now...
- Reservoirs near-empty
- Fish vs people arguments arise again
- *Under climate change scenarios, these conditions are likely to become chronic*



CLIMATE CHANGE

- Is already happening
- CO₂ continues to rise
- Human populations continue to grow
- Models to 2100
- Not good news for fish
or people

IF PRESENT TRENDS CONTINUE



Predicted effects on aquatic ecosystems

- Sea level rise
- Changes in precipitation patterns
- Changes in stream flows
- Increases in water temperatures
- Increases in droughts and floods



Sea level rise

- 1.4- 1.7 meters by 2100 (conservative)

Rapid rise + hardened fringes =

Loss of estuarine habitat



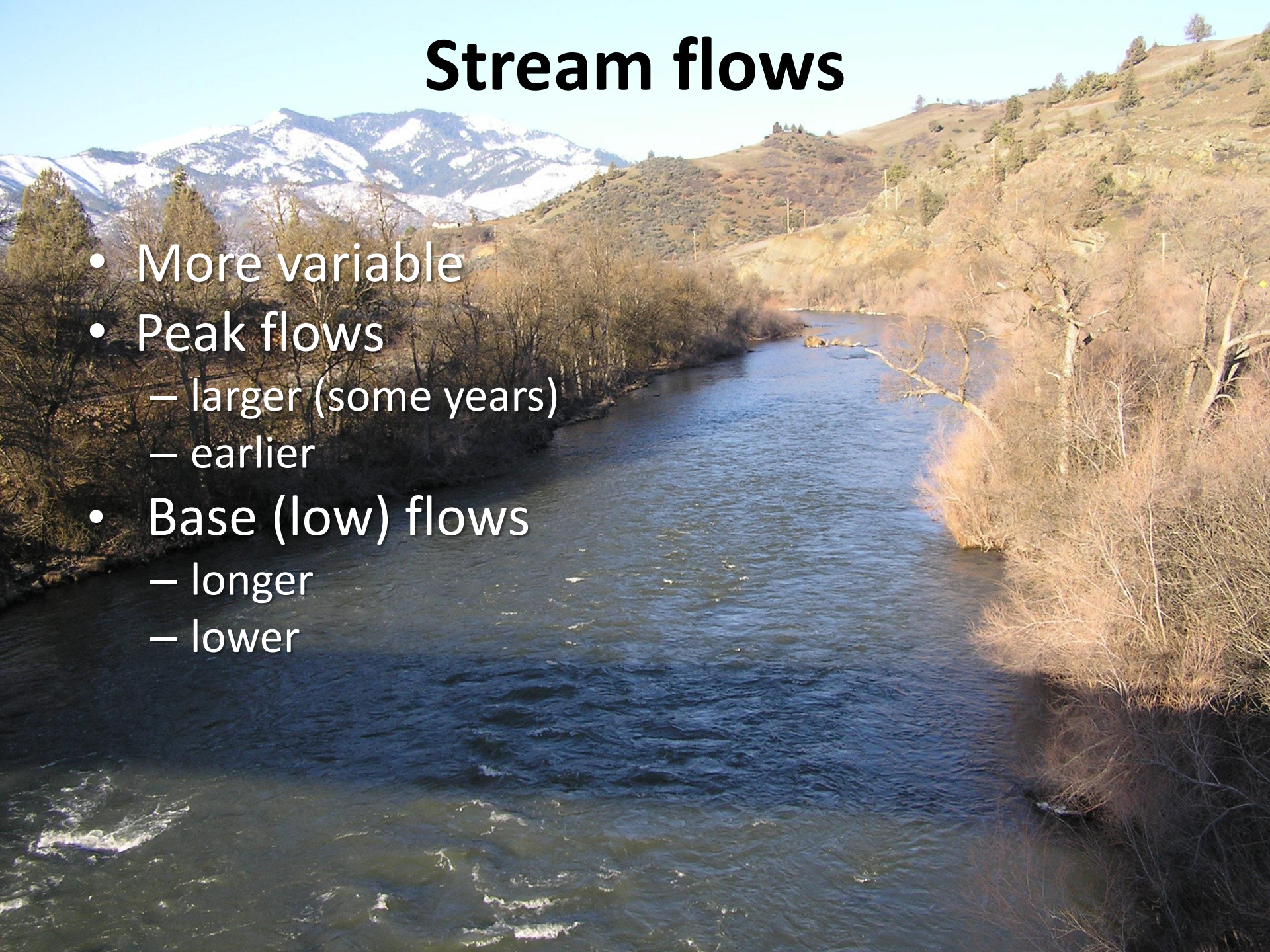
Precipitation

- Less annual precipitation, on average
 - but how much less??
- More variable
 - Mediterranean pattern
 - most precipitation in winter and spring
- More rain, less snow
 - 60-90% loss of snow pack in Sierra Nevada

= Big impacts to stream flows of snow-fed systems

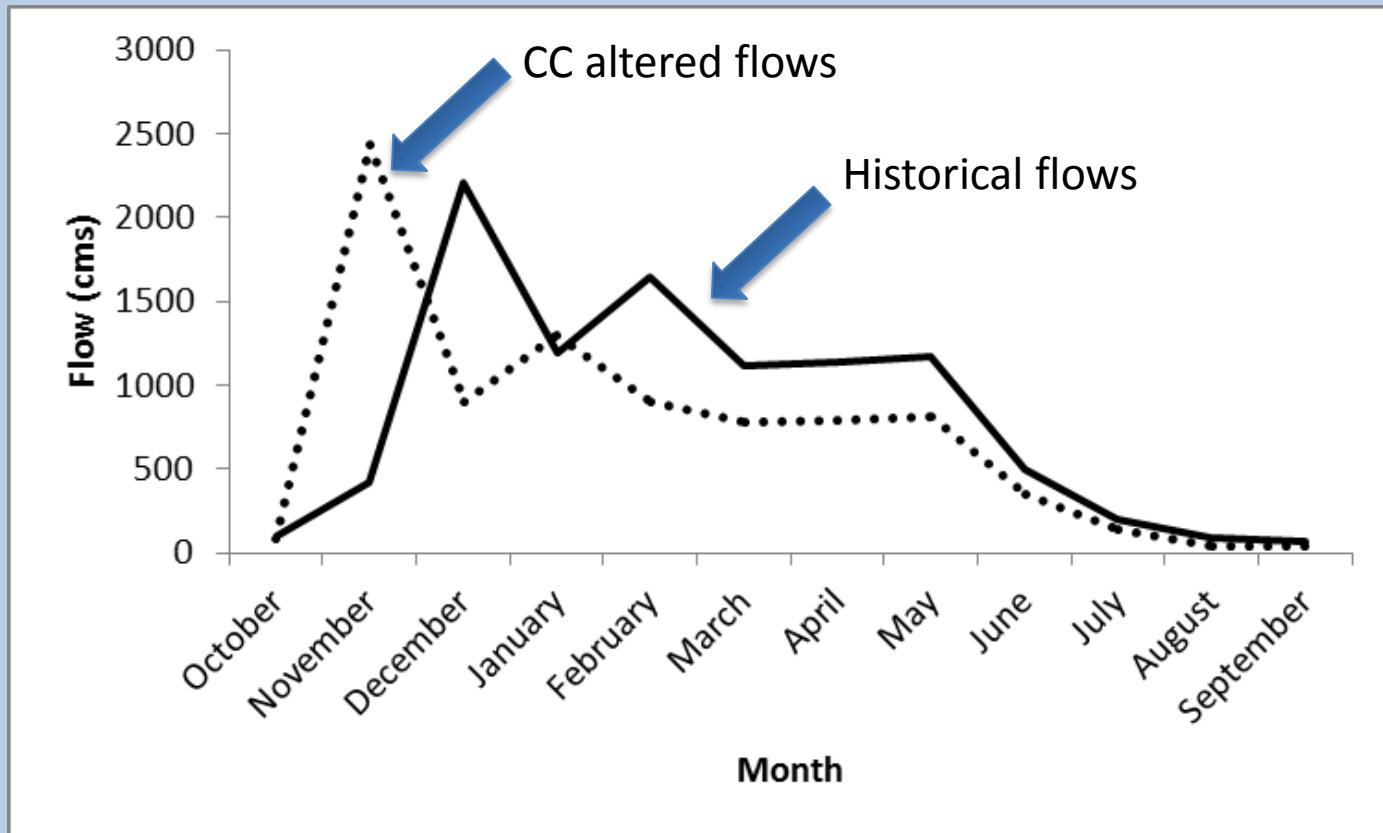
Stream flows

- More variable
- Peak flows
 - larger (some years)
 - earlier
- Base (low) flows
 - longer
 - lower



Flows in Salmon River, Klamath basin

Projected shift due to climate change



Solid line = historical flows; **dotted line** = predicted flows with 10% increase in winter flows, 30% reduction in spring and summer flows, and 30 day shift in peak flows (as in Leung et al. 2004, Kim 2005, Stewart et al. 2005)

Temperatures



- 4-6°C increase in average air temperature by 2100
- 3-5°C increase water temps
 - Depends on stream elevation and size
- Lethal temperatures more frequent
 - Higher air temperature
 - Lower flows in late summer

Temperature shifts & fish

- large loss of cold water (<math><18-20^{\circ}\text{C}</math> in summer) habitats
- Shift northward & upward of cool water streams
- Warmer streams favor non-native species



Photo: E. Yokel

Effects of climate change on native fishes

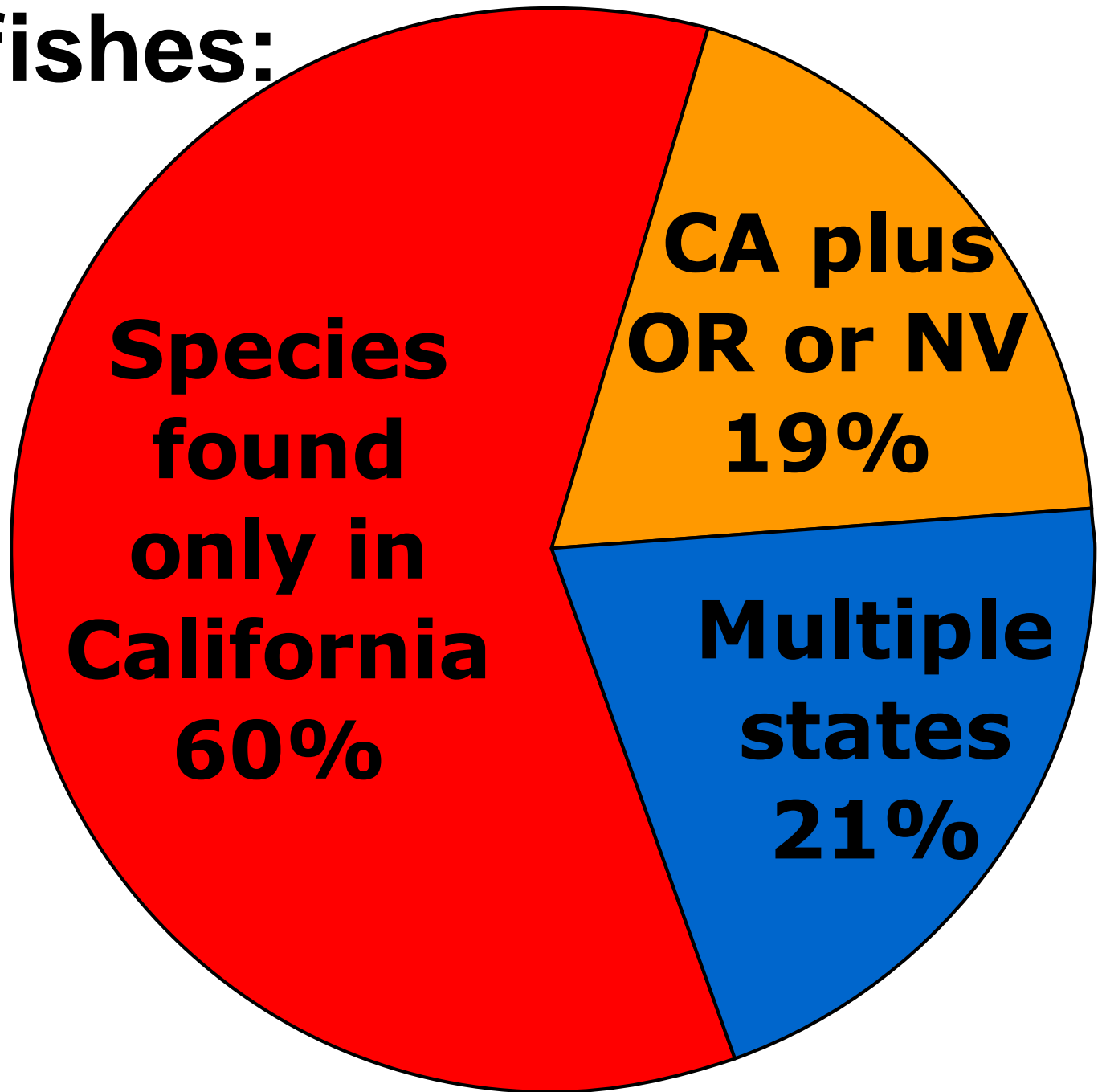


Native fishes:

79% are
found
only in
CA
Region

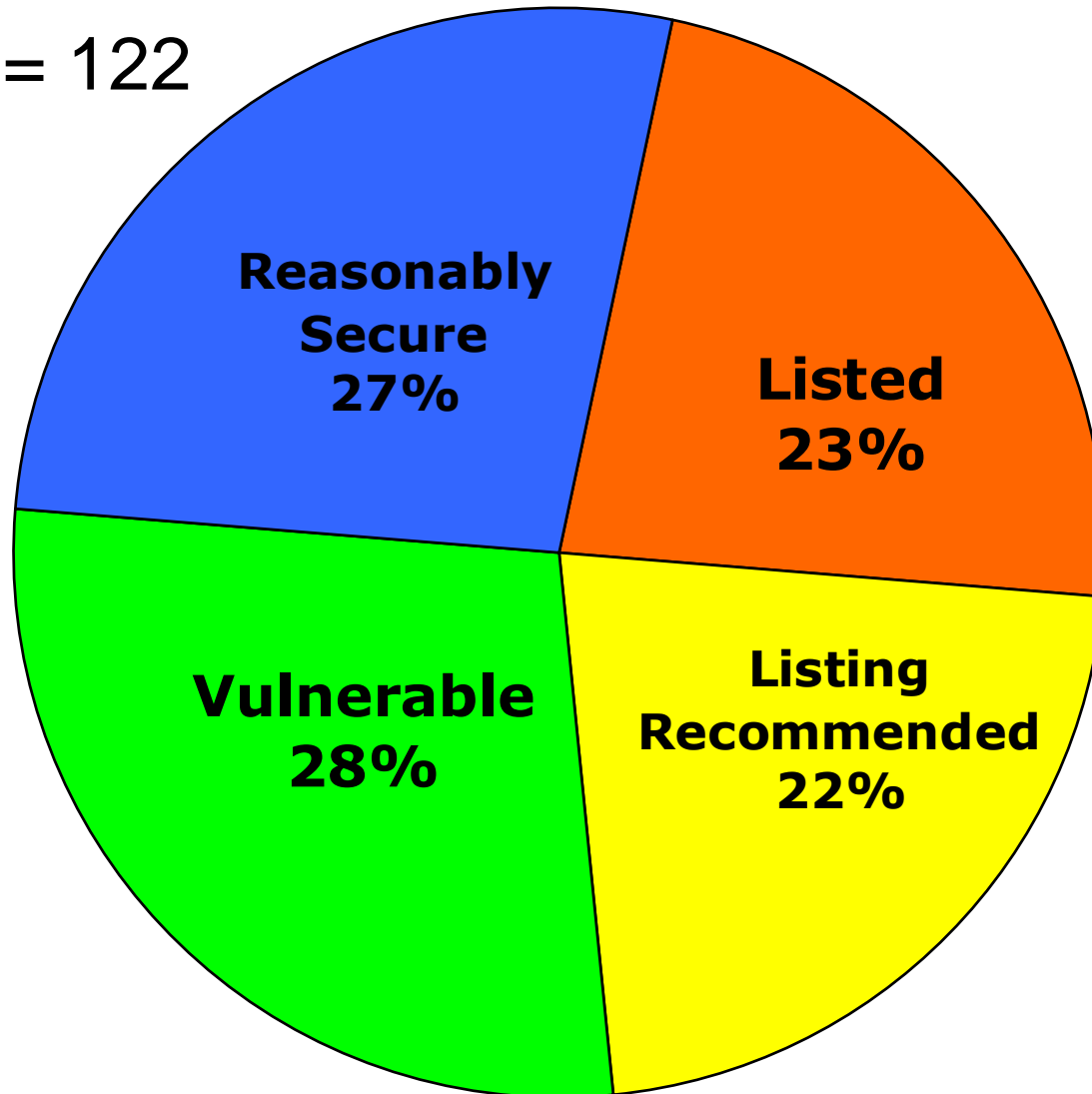
% increasing

N = 129

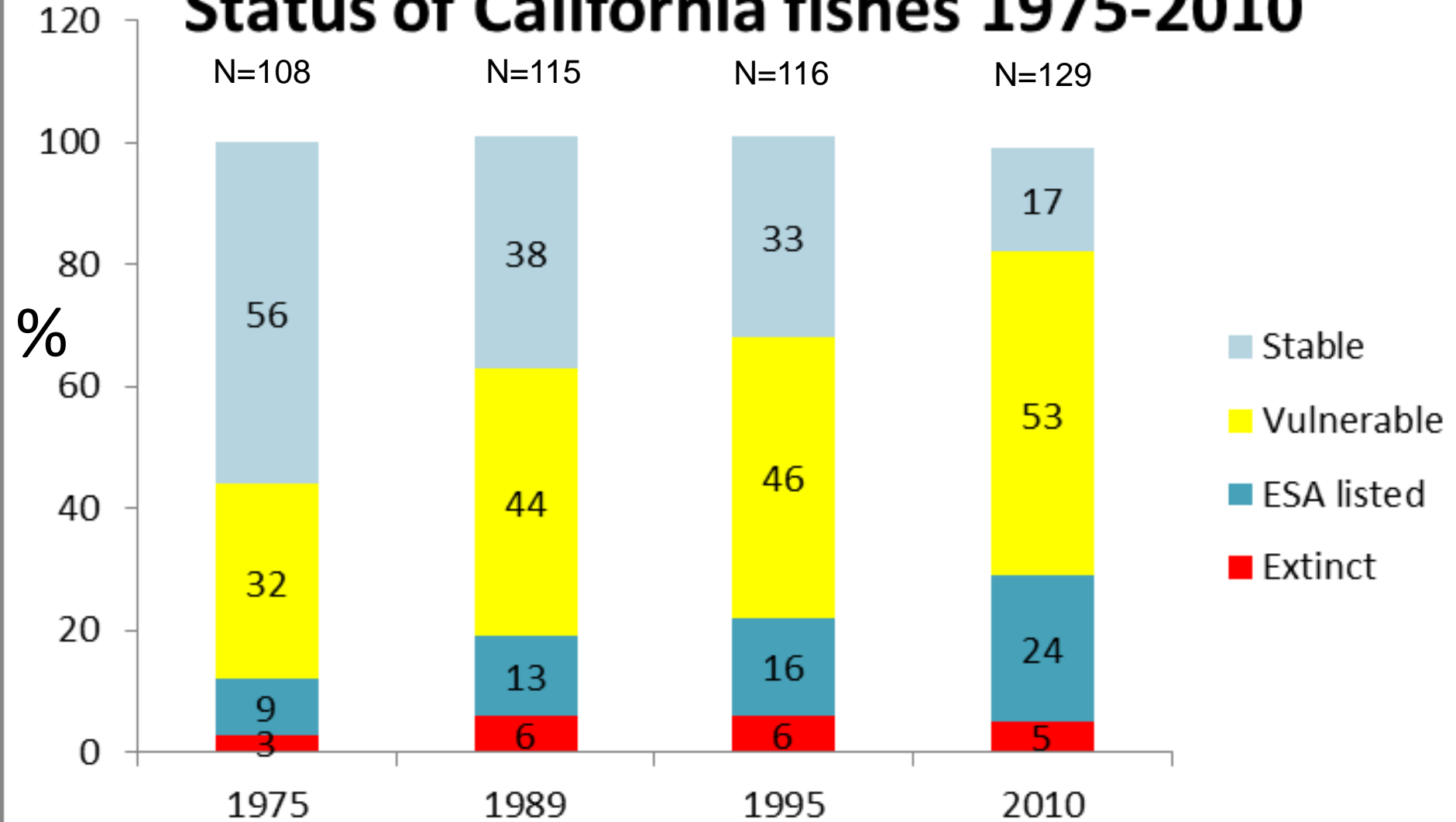


80% of native fishes in decline

N = 122



Status of California fishes 1975-2010



Listed species, 2014 = 28

FISH SPECIES OF SPECIAL CONCERN IN CALIFORNIA

Out soon, California Dept of Fish & Wildlife

Peter B. Moyle, Rebecca M. Quiñones, Jacob Katz, and Jeff Weaver

70 species of special concern

28 species already listed

7 species extinct

24 species OK

Based on systematic scoring methods
in Moyle et al. (2011)

DRAFT so

Status numbers subject to change

Globally extinct
1950s →



EXTINCTION HAPPENS!

7 species lost from CA



Extinct in California 1970s

Causes of native fish declines (the 1-2 punch)

#1 Habitat loss and degradation



Shasta Lake in 1977 when it hit its lowest point ever. (Courtesy: Bureau of Reclamation)





#2 Alien fishes

Favored by altered habitats



Climate change: an additional stressor

- Climate change vulnerability study
 - California Landscape Conservation Cooperative
 - Evaluated vulnerability to extinction
 - 100 years
 - 121 native fishes
 - 43 alien fishes



Moyle PB, Kiernan JD,
Crain PK, Quiñones RM.
2013. PLoS One
8:e63883.

Methods

- Compile literature and observations
- Determine baseline vulnerability to extinction
 - 10 metrics
- Determine climate change vulnerability
 - 10 metrics
- Goal: repeatable, verifiable score for each species

Moyle PB, Kiernan JD,
Crain PK, Quiñones RM.
2013. PLoS One
8:e63883.

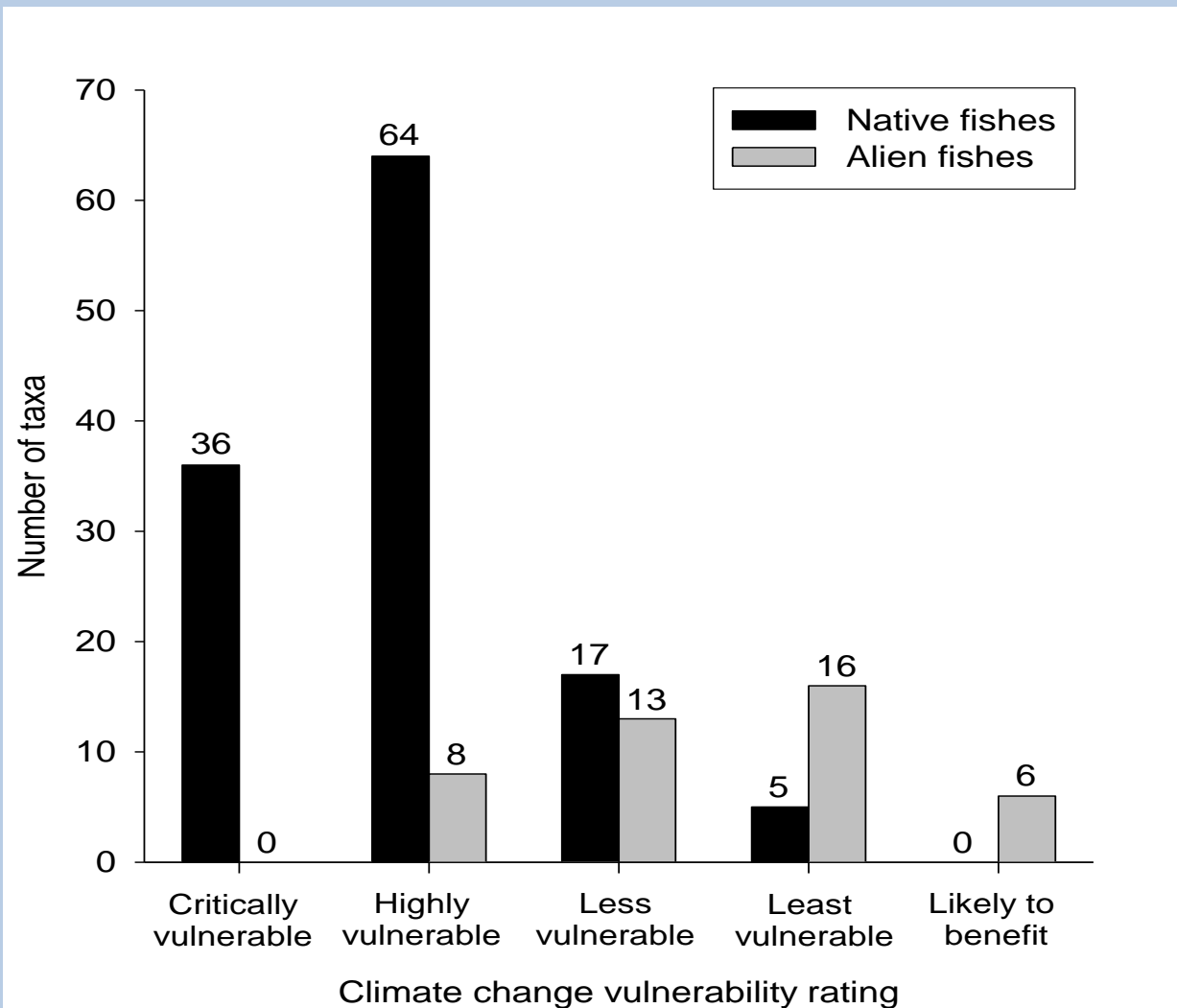




Baseline Vulnerability

- ~49% of 121 native species rated as already critically or highly vulnerable to extinction (without climate change)
- All non-native species rated as low vulnerability to extinction

Climate change vulnerability



**critical or high
vulnerability to
extinction**

Natives = 82%

vs.

Aliens = 19%

Taxa about = to species

Most native fishes face severe decline or extinction in next 100 years



Alien fishes will become increasingly abundant



If present trends continue...

Managing California's Water

From Conflict to Reconciliation

So....

What can we do?

Ellen Hanak, Jay Lund, Ariel Dinar
Brian Gray, Richard Howitt, Jeffrey Mount, Peter
Moyle, Barton "Buzz" Thompson



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PUBLIC POLICY
INSTITUTE OF CALIFORNIA



Managing California's Water

From Conflict to Reconciliation

BE WELL INFORMED ON
WATER ISSUES

Ellen Hanak, Jay Lund, Ariel Dinar
Brian Gray, Richard Howitt, Jeffrey Mount, Peter
Moyle, Barton "Buzz" Thompson



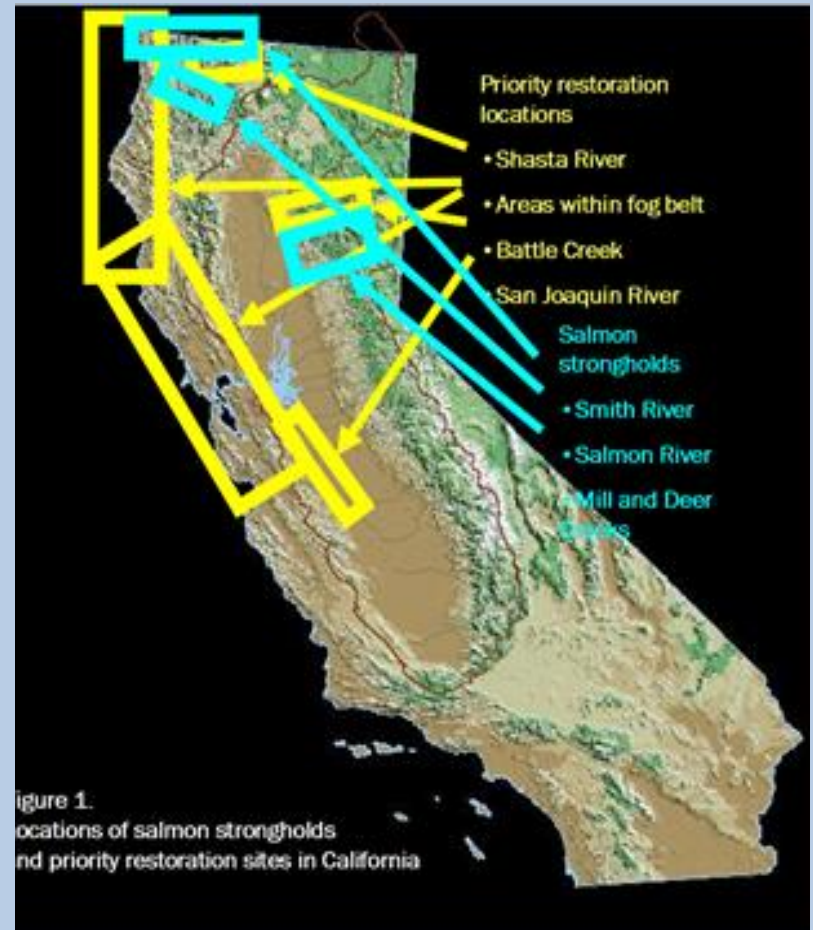
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Statewide strategy for aquatic conservation is needed

- GOALS:
- Protect examples of all major habitats
- Self-sustaining populations of all native species



Some key components

- Native fish rescue facilities
- Database (PISCES)
- Protect best of what's left
- Environmental flows below dams
- Dam removal
- Manage floodplains
- Manage estuaries



Native Fish Rescue Facilities

- “Emergency rooms” for fish
 - Drought
- Proposed Rio Vista facility for Delta fishes
- “Re-purposing” trout hatcheries
 - e.g., Mt Shasta Hatchery
- Ponds and other facilities statewide
 - Need for Clear Lake facility

PISCES: a Programmable geographic Information System for Cataloging and Encoding Species observations

Center for Watershed Sciences, University of California, Davis

Nick Santos, Joshua Viers, Jacob Katz, Peter Moyle



PISCES is a software system developed in Python that uses ArcMap, Arcpy, and Microsoft Access to standardize, store, map, and analyze data on fish species distributions.

STANDARDIZATION AND STORAGE

PISCES processes spatial and tabular coordinate observations and expert opinions on the location of fish taxa. PISCES standardizes all data to its own database by using Arcpy to join data to USGS 12 digit Hydrologic Unit Codes (HUC 12s).

PISCES process occurrence data in any spatial or tabular format with minimal human input. We add new data to the database by indicating a dataset, a code class, and a species translation table. We can also manually add or correct data in ArcMap 10 by passing selected HUC 12s through our custom Python script tool.

While it handles most data formats with no additional coding, PISCES can be extended with new data processing code via Python classes or function overloading to adapt to small inconsistencies in familiar datasets.

DATA SOURCES

Species occurrence data is the foundation of PISCES. Currently, PISCES includes data from Moyle and Randall 1998, Moyle and Katz 2011 in prep, United States Forest Service field data, and the California Natural Diversity Database.

DATA COMPONENTS

Species Occurrence Data Standardized data on which species are present in each HUC.	Spatial Attributes Data for each HUC on key indicators and correlates, such as road density, lake area, dams, stream miles and designations, and more.
Species Attributes Relevant data about each species - designations, classifications, and traits - that could be important variables for analysis of a HUC or a species.	Mapping Configurations Stored queries to convert data into rangemaps, run analyses, and generate new ArcGIS data layers.

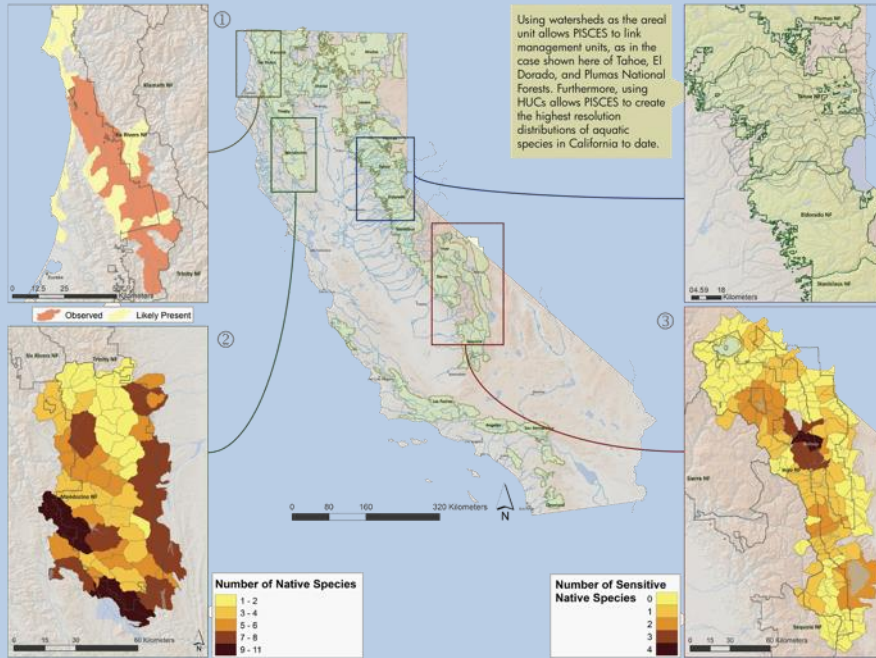
REPORTING

We preloaded PISCES with expert information on the distribution, history, and sensitivities of each native species. We use this data to produce reports on each species, but it is also accessible for use by map producing SQL queries (see below).

MAPPING

PISCES maps are, at their base, a set of SQL queries that return HUCs to be mapped. These queries are extended to produce sets of maps and process data in four significant ways:

- Iterators and Data Driven Pages:** Map iterators turn the values in a database column into bind variables on a map's SQL queries in order to create sets of maps from a single query. PISCES generates a map for each value in that column.
- Postprocessing Functions and Queries:** After a query's results have been retrieved, postprocessing functions in the form of code or simple SQL queries add additional attributes to each HUC's record. These attributes can then be symbolized or labeled according to a layer file associated with the query.
- Base MXDs:** PISCES adds generated data layers to a specified .mxd file at a known level in the Table of Contents. We use different mxd files in order to symbolize or highlight specific layers, provide extra data, or enable ArcGIS' Data Driven Pages.
- Layers:** Each generated layer can specify a .lyr file to copy symbology from. Combined with data added via a callback function, we can automatically generate and symbolize all of the maps on this poster and many more.



Using watersheds as the areal unit allows PISCES to link management units, as in the case shown here of Tahoe, El Dorado, and Plumas National Forests. Furthermore, using HUCs allows PISCES to create the highest resolution distributions of aquatic species in California to date.

Range Mapping ①
 PISCES was designed to create species rangemaps from presence data from varying sources and of varying quality (observations, expert predictions, etc.). The top map shows Chum Salmon distribution in California at the HUC 12 level. PISCES layers observations on top of expert-predicted range for the species.

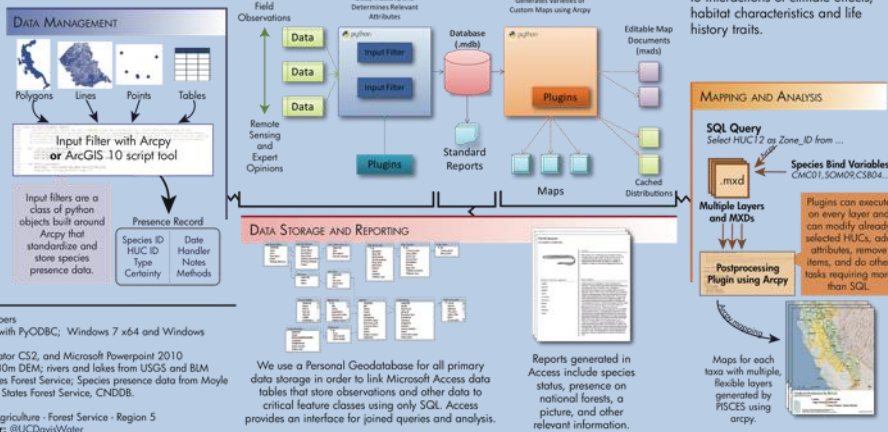
Diversity/Richness ②
 We configured PISCES to provide a count of species per HUC, giving us a quick measure of fish diversity. At bottom left is a species richness map of Mendocino National Forest showing HUC 12s, where deeper orange indicates more species. When mapped statewide, richness maps illuminate both data gaps and hotspots of fish diversity.

Sensitive Species by HUC ③
 PISCES stores auxiliary information about each species and each HUC, allowing for map generation that relates any number of environmental, human, or ecological variables. Results can be displayed as a map, or in tabular form as simple SQL queries, allowing us to rapidly answer complex questions in map form.

Other
 PISCES provides answers to questions in the form of maps and data tables. PISCES can answer most questions in the scope of its data with SQL statements or with a Python extension.

Future maps from PISCES will include better measures of diversity, species-specific habitat suitability modeling, and analysis of species distributional shifts due to interactions of climate effects, habitat characteristics and life history traits.

PISCES at a Glance



Data base: PISCES

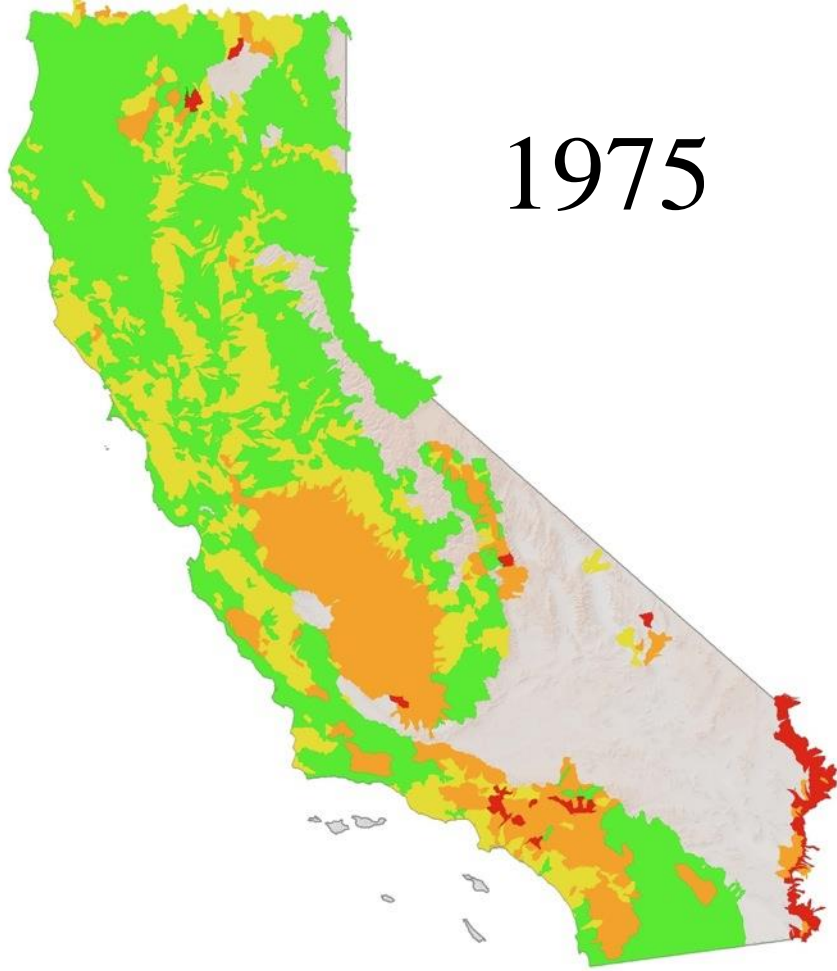
Programmable geographic Information System for Cataloging and Encoding Species observations

A database that tracks changes in fish distributions

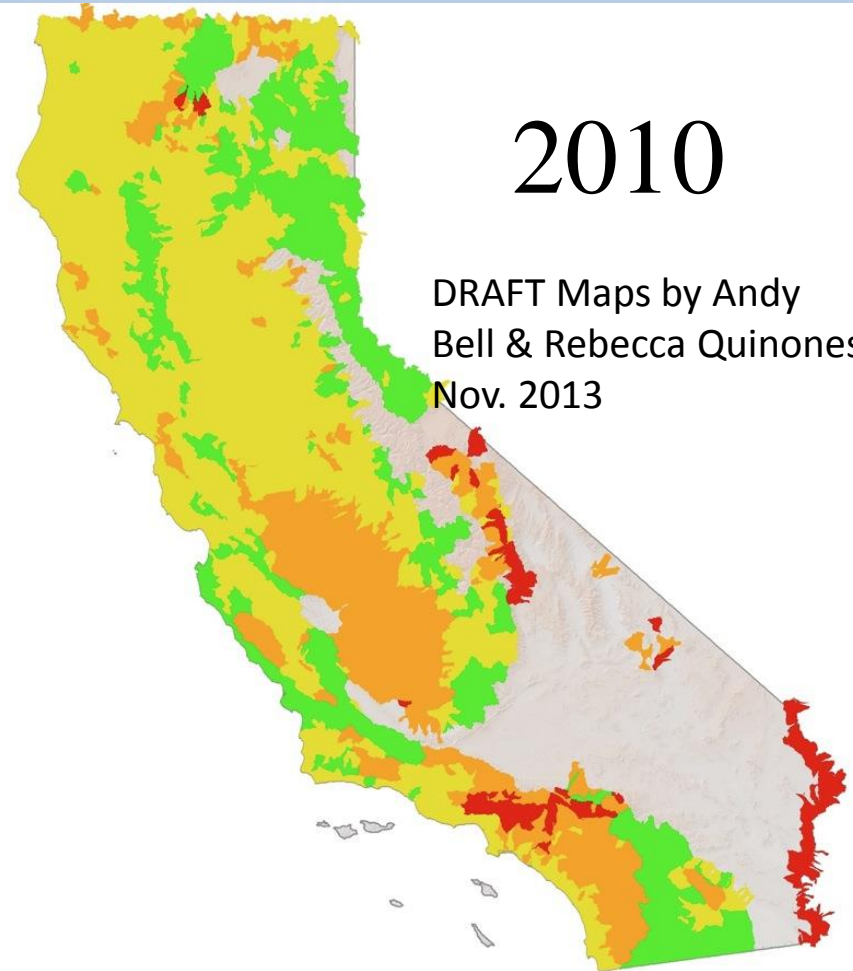


Metadata

1975



2010



DRAFT Maps by Andy Bell & Rebecca Quinones
Nov. 2013

Average Status Score by HUC12

0 - 1.0 1.1 - 2.0 2.1 - 3.0 3.1 - 4.0

Data Sources - Forest Service Boundaries: USDA Forest Service; Rivers/Lakes: USGS, HUCs: USGS; Hillshade: USGS, CWS, ESRI; State Boundary: CaSIL; Species Distribution: Various

0 40 80 160 km

Map Generated: 2013/09/17

Average Status Score by HUC12

0 - 1.0 1.1 - 2.0 2.1 - 3.0 3.1 - 4.0

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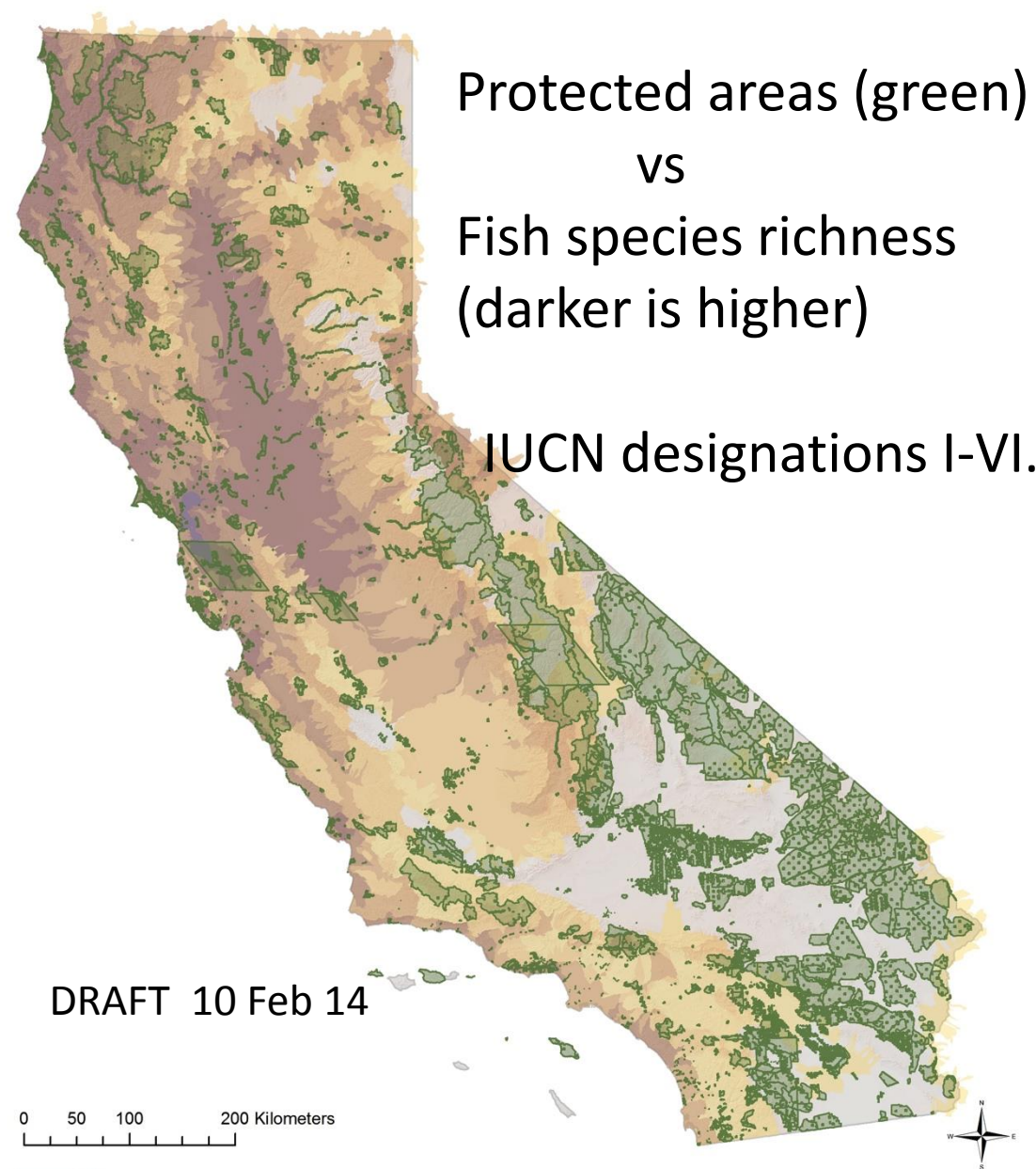
0 40 80 160 km

Map Generated: 2013/09/17

AVERAGE STATUS SCORES: NATIVE FISHES
GREEN – BEST RED - WORST

How much aquatic habitat is protected?

- Not much!



Native Species Richness and Protected Areas

Data Sources - Forest Service Boundaries: USDA Forest Service;
Rivers: USGS, HUC 12; USDA NRCS; Hillshade: ESRI;
State Boundary: CaSIL; Species Distribution: Moyle and Randall (1998)

Map Generated: 2014/02/10

Protect best of what is left



Blue Creek

Yurok Tribal Salmon Sanctuary



westernrivers.org



WESTERN RIVERS
CONSERVANCY

Big Springs Creek Restoration Shasta Valley



March 2009



September 2013



August 2009

Environmental Flows Below Dams



FOLSOM RESERVOIR, AMERICAN RIVER

JAN 2014



blog.kged.org

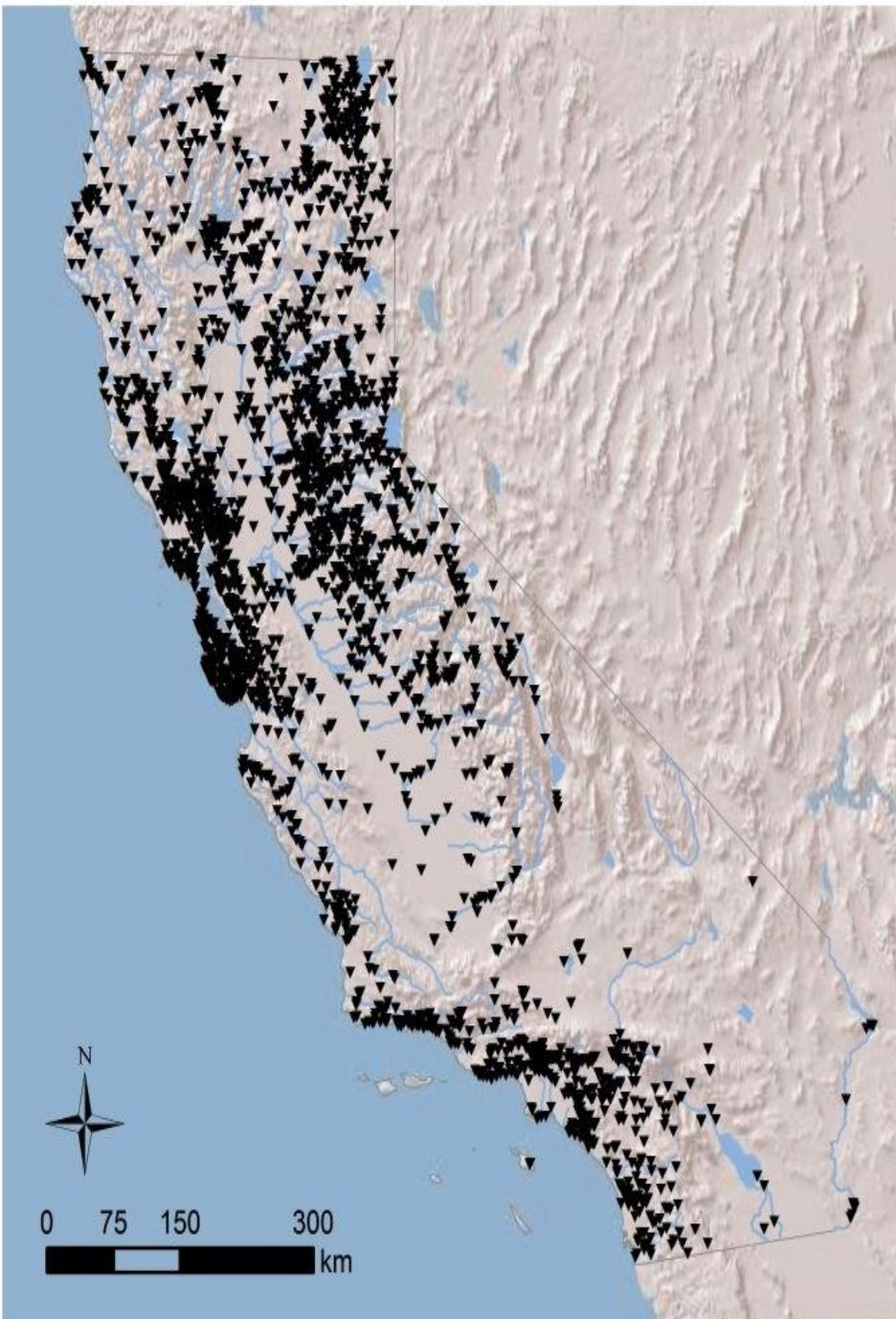
Dam Reoperation Study

By Ted Grantham,
CWS

1400 'large' dams



200 candidate dams
(20 case histories)



Legal tools for dam reoperation

- Section 5937, California Fish and Game Code
- Public Trust Doctrine
- Endangered Species Acts (state and federal)

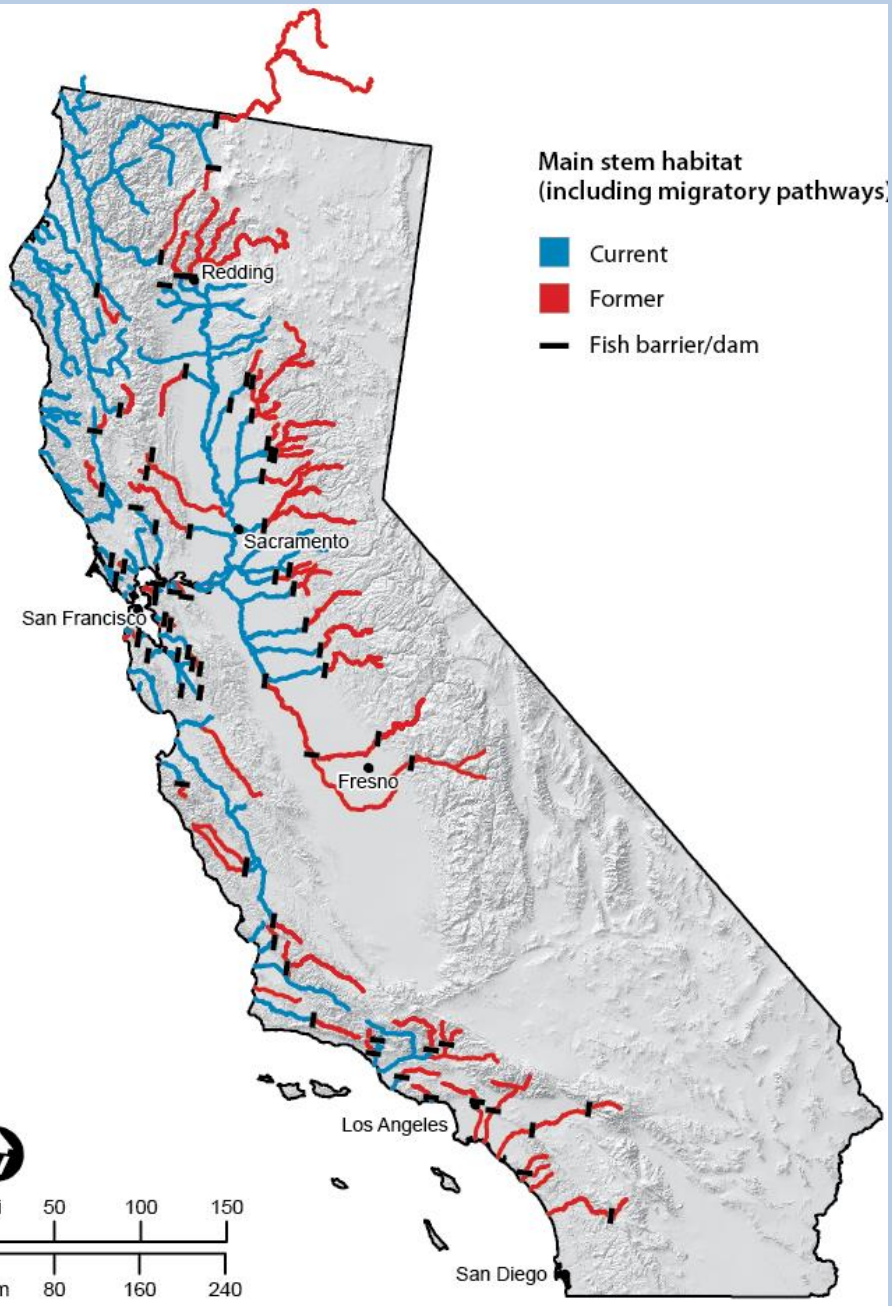


Dam Removal



Matilija Dam, Ventura River

Quiñones et al. in press



70+% of anadromous salmon habitat above dams

Manage Floodplains

for Floods, Fish, Wildlife and Farming.



Manage Estuaries

- Endangered statewide
 - Sea level rise
 - Decreased inflows
 - Habitat alterations



Delta

Where the Wild Things Aren't: Making the Delta a Better Place for Native Species



Peter Moyle, William Bennett, John Durand, William Fleenor, Brian Gray, Ellen Hanak, Jay Lund, Jeffrey Mount



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Edited by

Peter B. Moyle
Amber D. Manfree
Peggy L. Fiedler

Suisun Marsh

Ecological History and Possible Futures

Suisun Marsh

Ecological History & Possible Futures

UC Press,

March 2014

William F. Jackson. ca 1900

Suisun Marshes

Crocker Art Museum

Reconciliation Ecology

A basic approach to conservation

- Humans dominate all ecosystems
- Most ecosystems are novel ecosystems
- Alien species & altered habitats
- Climate change increases need
- What species do we want to save?



CASE STUDY

LOWER PUTAH CREEK

- Regulated by dams
- 30km Riparian “shred”
- Novel Ecosystem
- Model for reconciled aquatic/riparian ecosystems

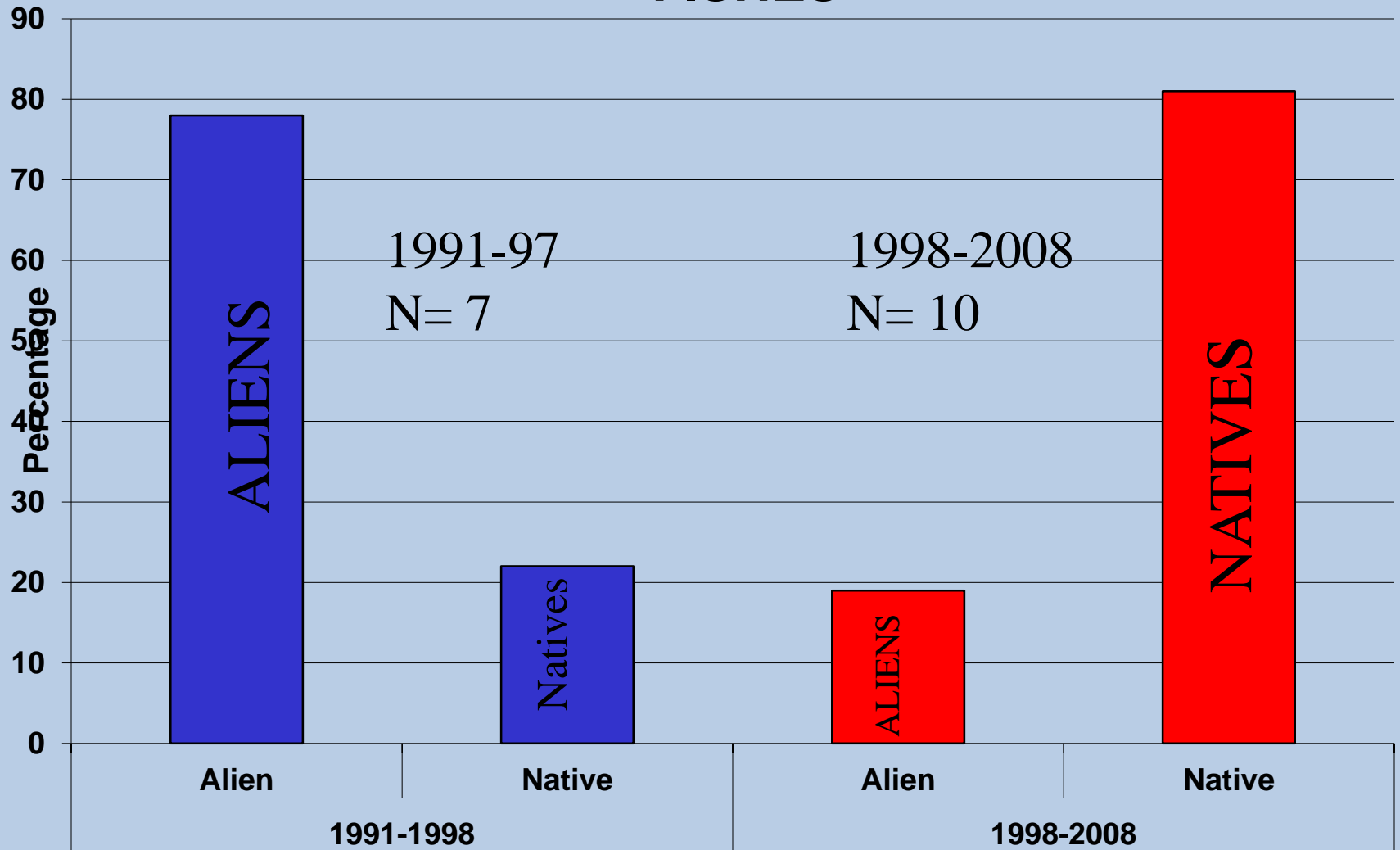




Species group (#)	Percent alien species
Trees (46)	35
Shrubs (39)	23
Herb. plants (198)	61
Butterflies (31)	25
Fish (35)	63
Amphibians (3)	33
Reptiles (10)	10
Birds (92 breeding)	3
Mammals (31)	11

Percent aliens of recorded species, Putah Creek, UCD

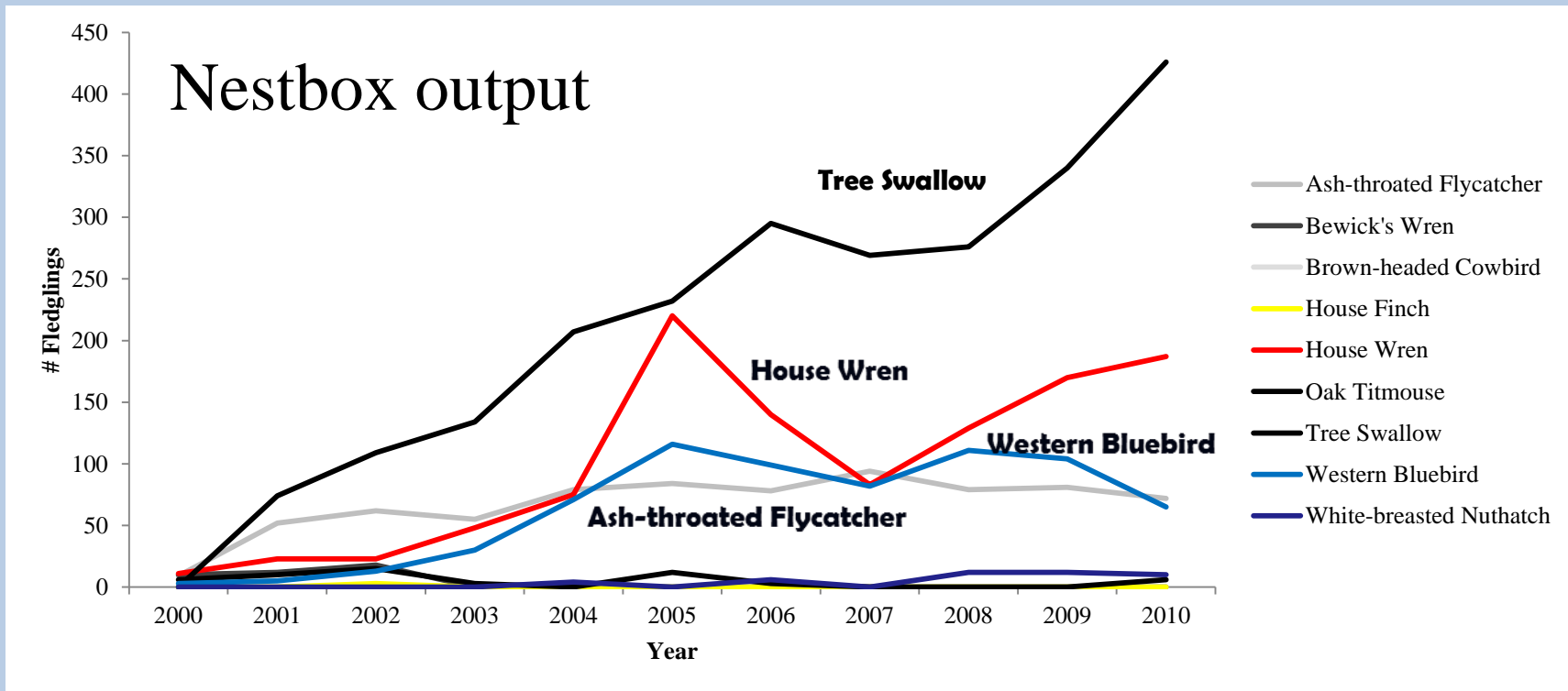
MANAGING THE FLOW REGIME FOR NATIVE FISHES



BEFORE

AFTER

Nestbox management & monitoring



>8000 fledglings produced so far . . .

What does it take to manage Putah Creek as a Reconciled Ecosystem?

- VISION
 - Accord
- WATER
- Water Agency Cooperation
- Streamkeeper
- Community involvement
 - Putah Creek Council
- Landowner co-operation
- Monitoring program



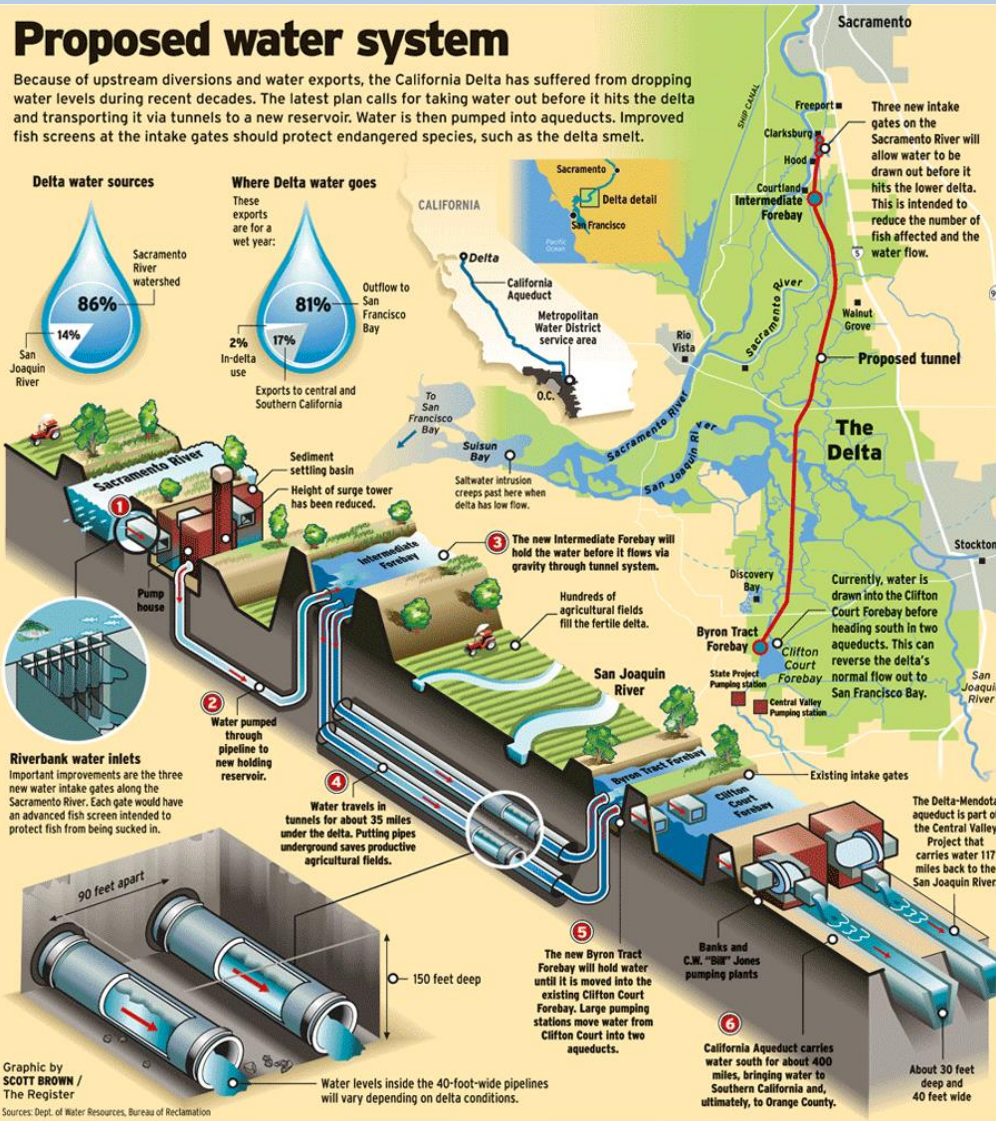
MONEY IS NEEDED (Lots of It)

Why give away fish flows for free during a drought?

Posted on [February 11, 2014](#)

By Jay Lund, Ellen Hanak, Barton “Buzz” Thompson, Brian Gray, Jeffrey Mount and Katrina Jessoe

California Water Blog



Conclusions

- Systematic actions needed to save California's endemic aquatic species
 - We can do it!
- Climate change is accelerating rate of declines
- 2014 drought –example of what is to come...
 - If we let present trends continue



Questions?



Further reading

- Moyle PB, Kiernan JD, Crain PK, Quiñones RM. 2013. Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach. *Plos One* 8:e63883.
- Katz JV, Moyle PB, Quiñones RM, Israel J, Purdy S. 2013. Impending extinction of salmon, steelhead and trout (Salmonidae) in California. *Environmental Biology of Fishes* 96:1169-1186.
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- Kiernan, J.D., P. B. Moyle, and P. K. Crain. 2012. Restoring native fish assemblages to a regulated California stream using the natural flow regime concept. *Ecological Applications*. 22:1472-1482.
- Quiñones RM and Moyle PB. In press. California's freshwater fishes – status and management. *Fishes in Mediterranean Environments*. Invited review.
- Moyle, P. B., and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: A five-tiered approach. *Fisheries* 19:6-18.