Mapping the implications of low oxygen (hypoxia) on available habitat for select species of flatfish in Elkhorn Slough

Matt Levey[1] and Brent B. Hughes[2]

SeaSpatial Consulting[1]

UC Santa Cruz[2]

Ecological Question

Eutrophication

Ecological Question

Eutrophication

↓

Hypoxia caused by eutrophication

Ecological Question

Eutrophication

↓

Hypoxia caused by eutrophication

↓

Spatial and Temporal Variation

Ecological Question

Eutrophication

↓

Hypoxia caused by eutrophication

↓

Spatial and Temporal Variation

↓

Predicted Probabilities
and available habitat

English Sole
Parophrys vetulus

Speckled Sand Dab
Citharichthys stigmaeus

Ecological Question

Eutrophication

↓

Hypoxia caused by eutrophication

↓

Spatial and Temporal Variation

↓

Predicted Probabilities
and available habitat

↓

Fishery Impacts?

English Sole
Parophrys vetulus

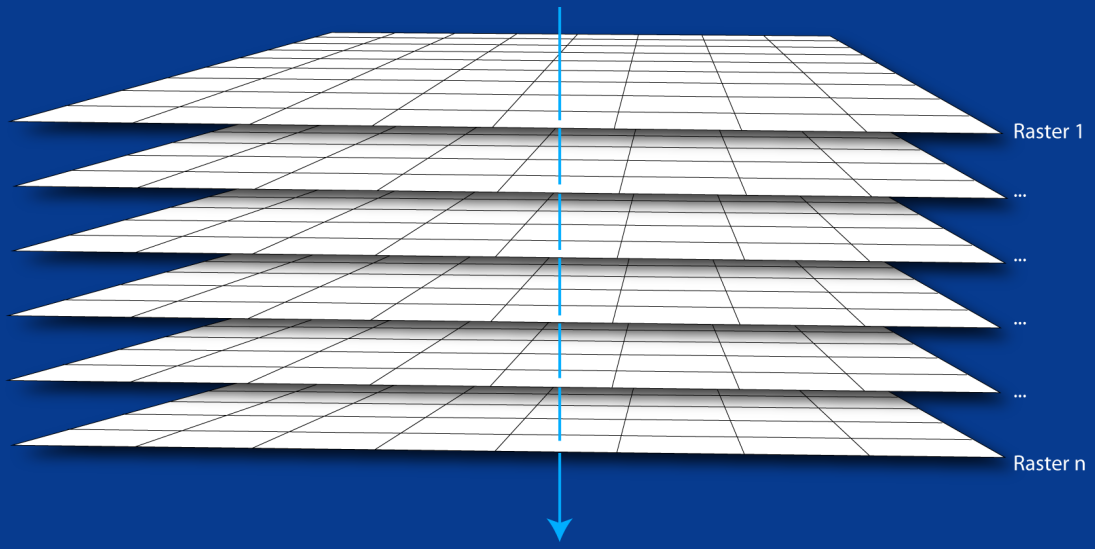
Speckled Sand Dab
Citharichthys stigmaeus

GIS Problem

Long term monitoring =
Really big Excel worksheet
How to filter, sort, and QA data?

GIS Problem

How to analyze 250+ rasters?
Calculate the 10^{th} percentile of DO



GIS Problem

How to detect influence of climate regimes on DO→ fish habitat?

GIS Problem

How to calculate fish probabilities of occurrence for different climate regimes?

GIS Problem

Is available habitat affected by the influence of ENSO condition on hypoxia?

Elkhorn Slough

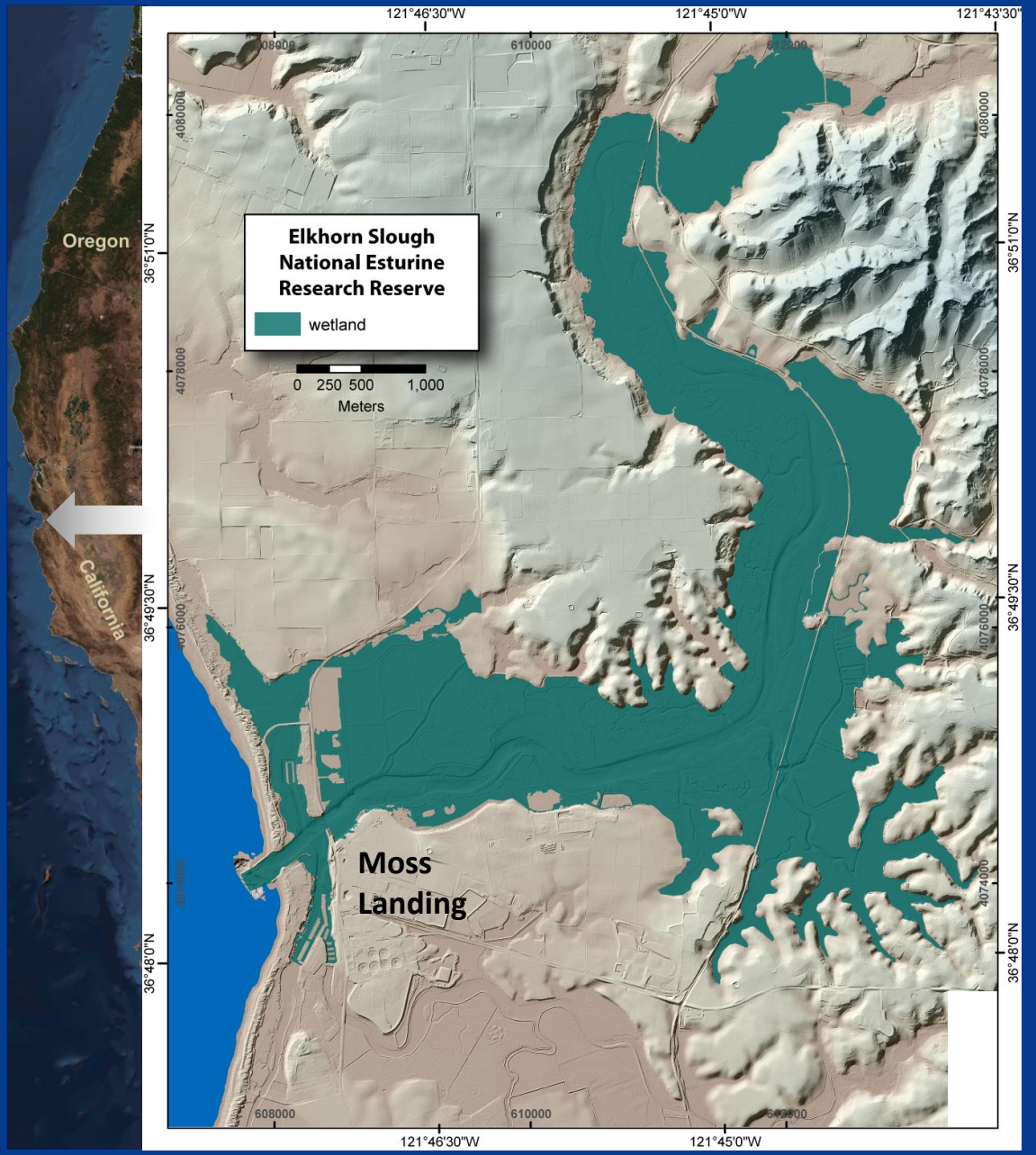
Elkhorn Slough

Part of the NERR system

Nutrient loaded

Moderately eutrophic

Important nursery for juvenile flatfishes



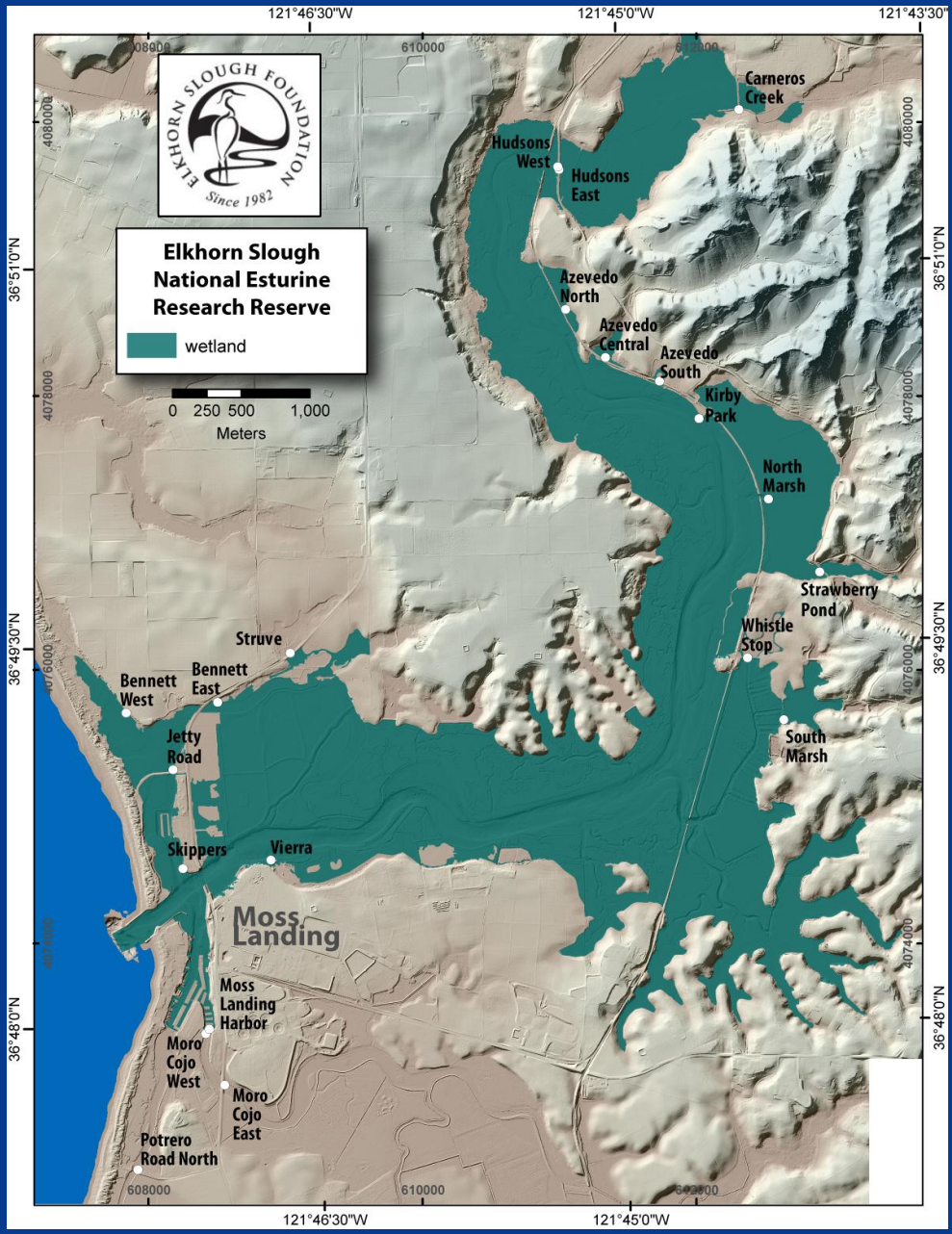
Heaps of data

The Elkhorn Slough Foundation

Monthly water quality monitoring

23 years + 22 sites ≈ 4,300 records

DO measured in $mg*L^{-1}$



Heaps of data

The Elkhorn Slough Foundation

Monthly water quality monitoring

23 years + 22 sites ≈ 4,300 records

DO measured in $mg*L^{-1}$

Climate condition added

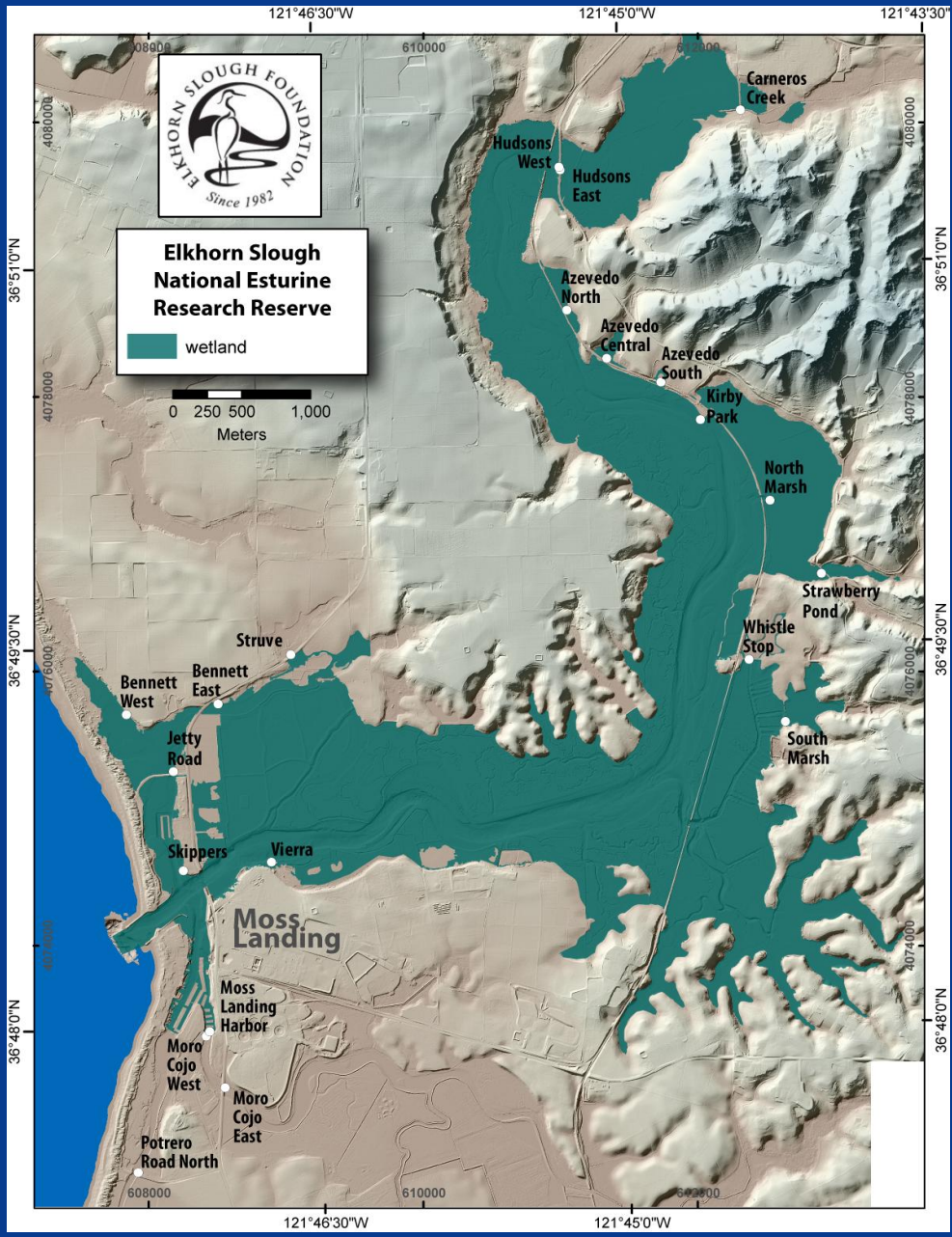
El Niño Southern Oscillation Index

12 month moving average

ENSO Index > 0.5 = El Niño

ENSO Index < -0.5 = La Niña

ENSO Index -0.5 – 0.5 = “La Nada”



Dealing with a large dataset

Excel too limiting and cumbersome

Dealing with a large dataset

Excel too limiting and cumbersome

Nicked from www.outsidethebeltway.com

Dealing with a large dataset

Excel too limiting and cumbersome

Batch processing too risky and time consuming

Dealing with a large dataset

Excel too limiting and cumbersome

Batch processing too risky and time consuming

Model Builder useful but limited to ArcGIS

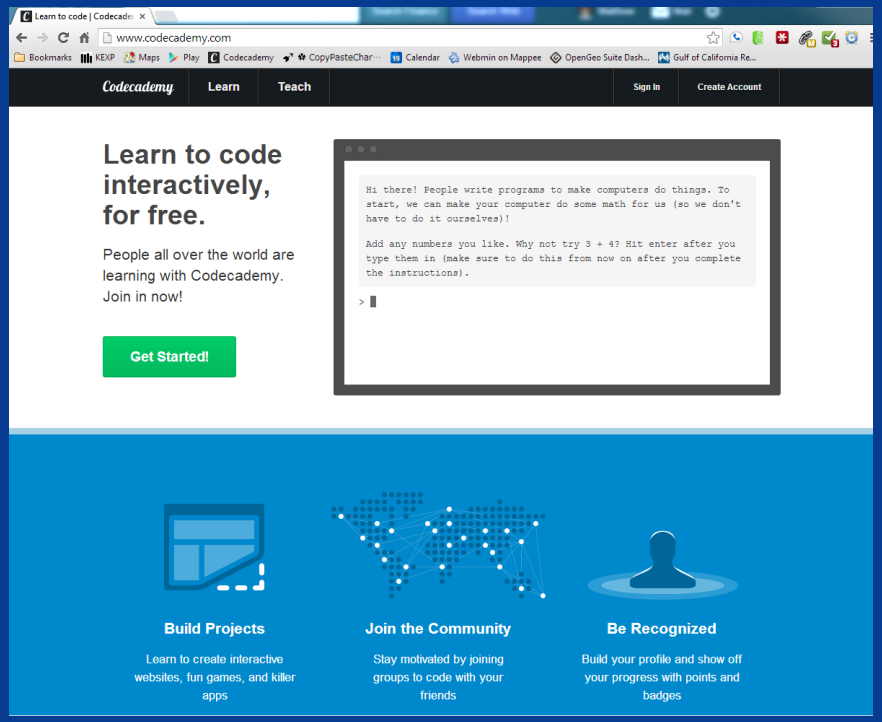
Solution: learn Python

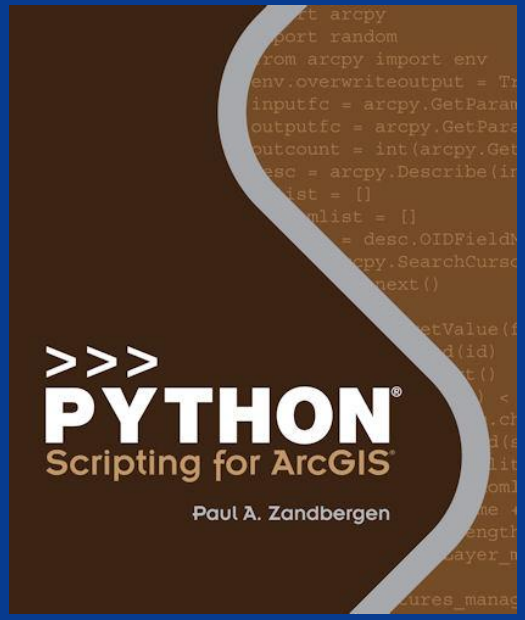
http://www.codeacademy.com

ESRI Press: *Python Scripting for ArcGIS*

ArcGIS Help

Numpy and Scipy

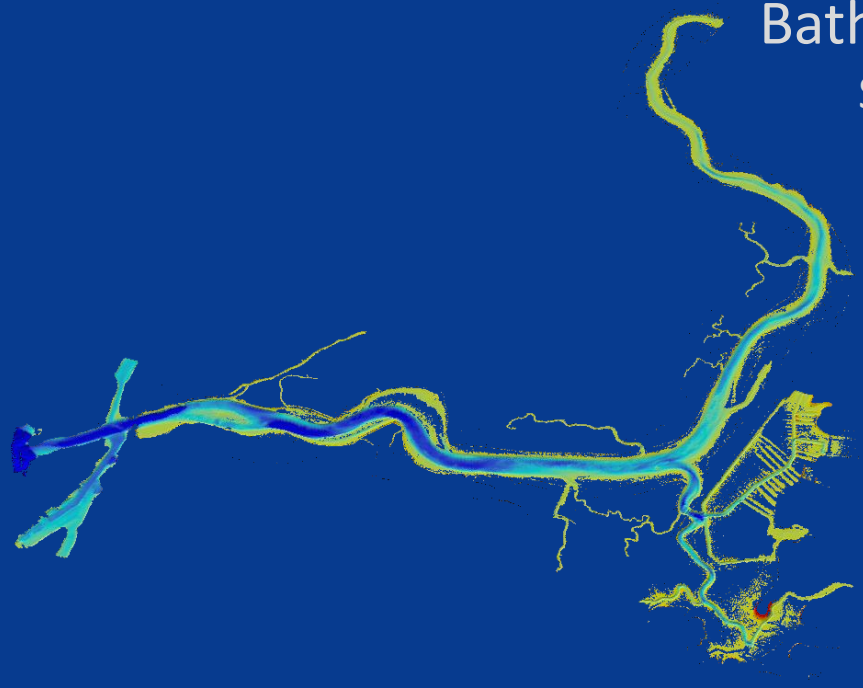




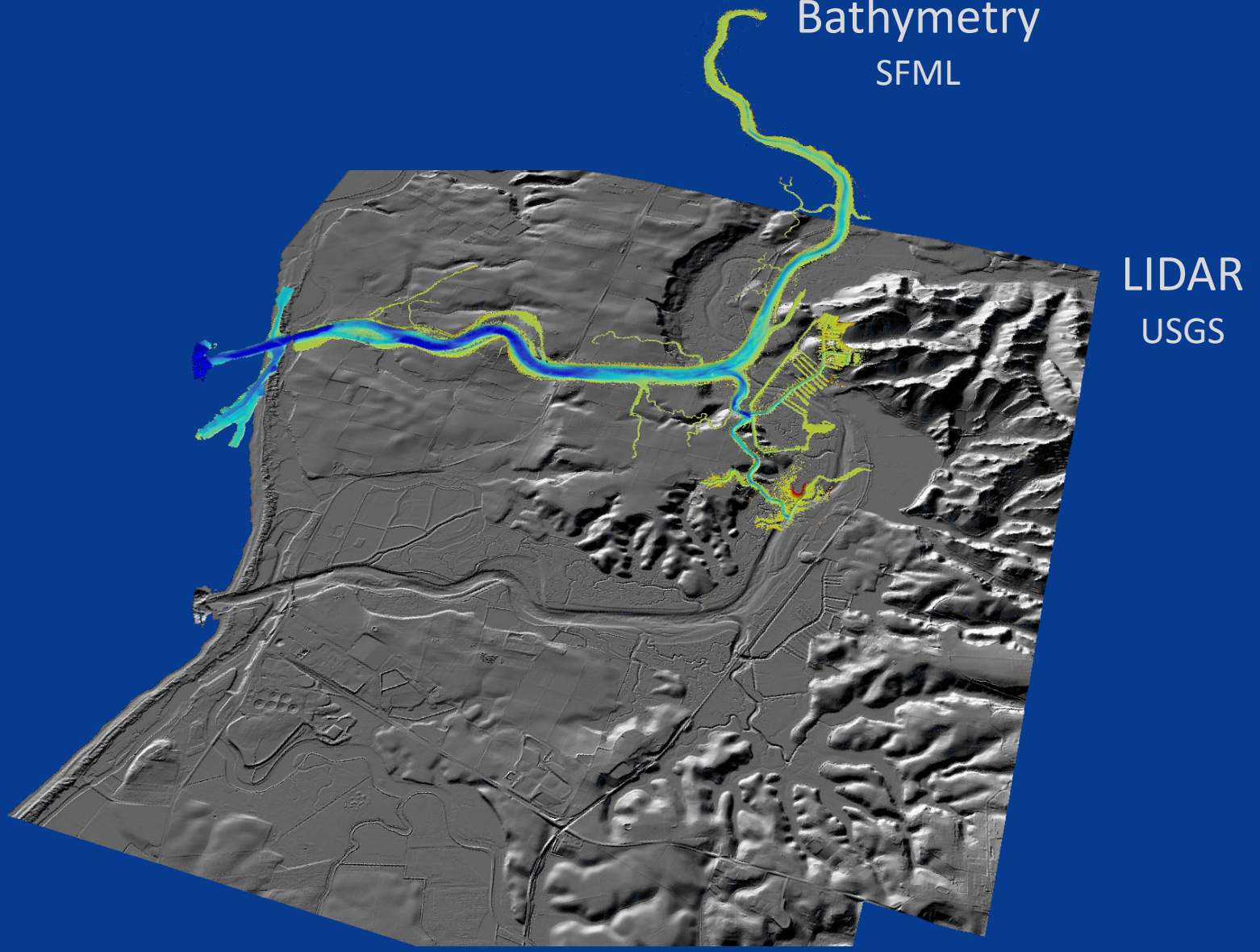
Base DEM

Bathymetry

SFML

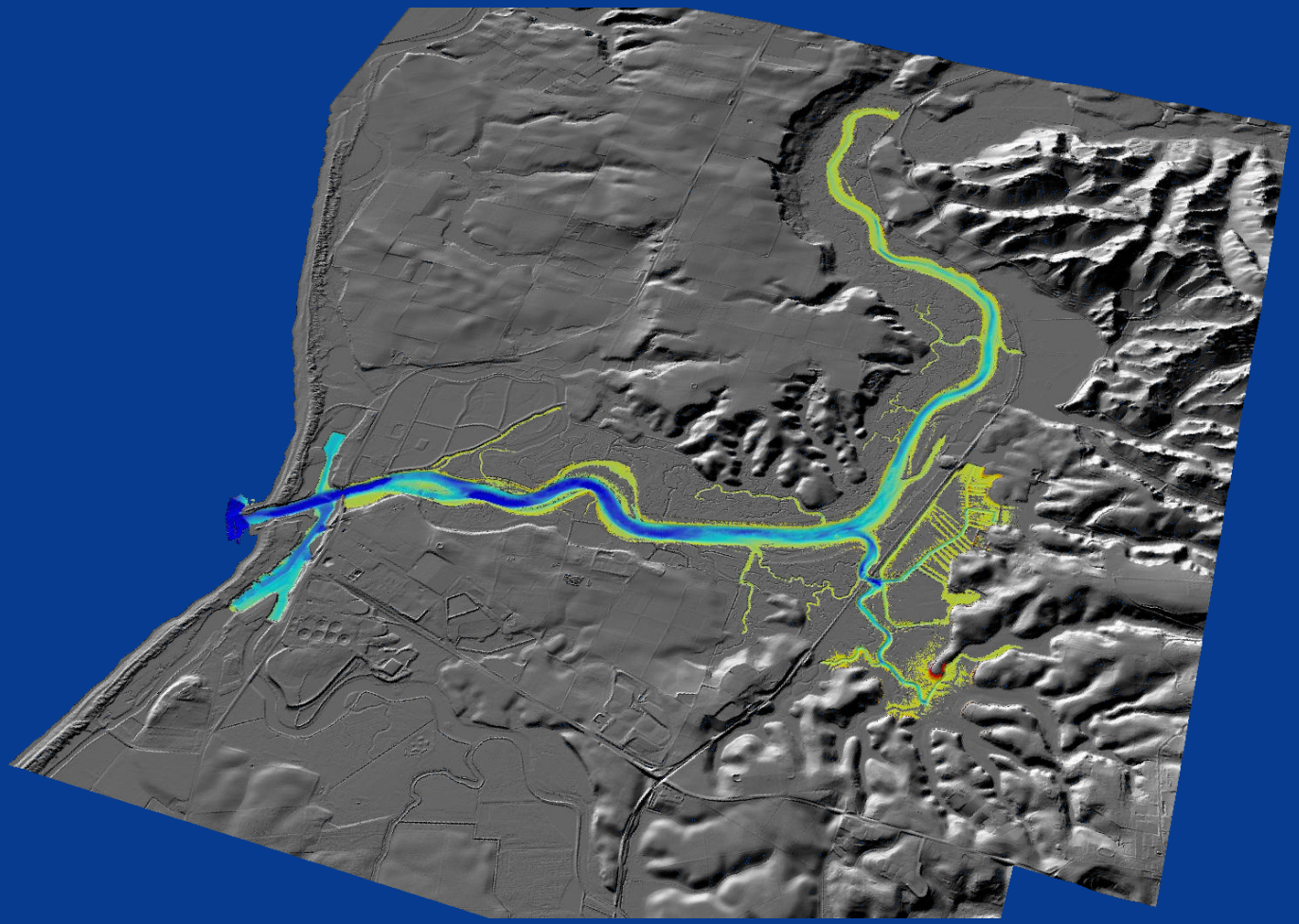


Base DEM



Base DEM

Resolution: 1m x 1m
Vertical datum: NAVD 88

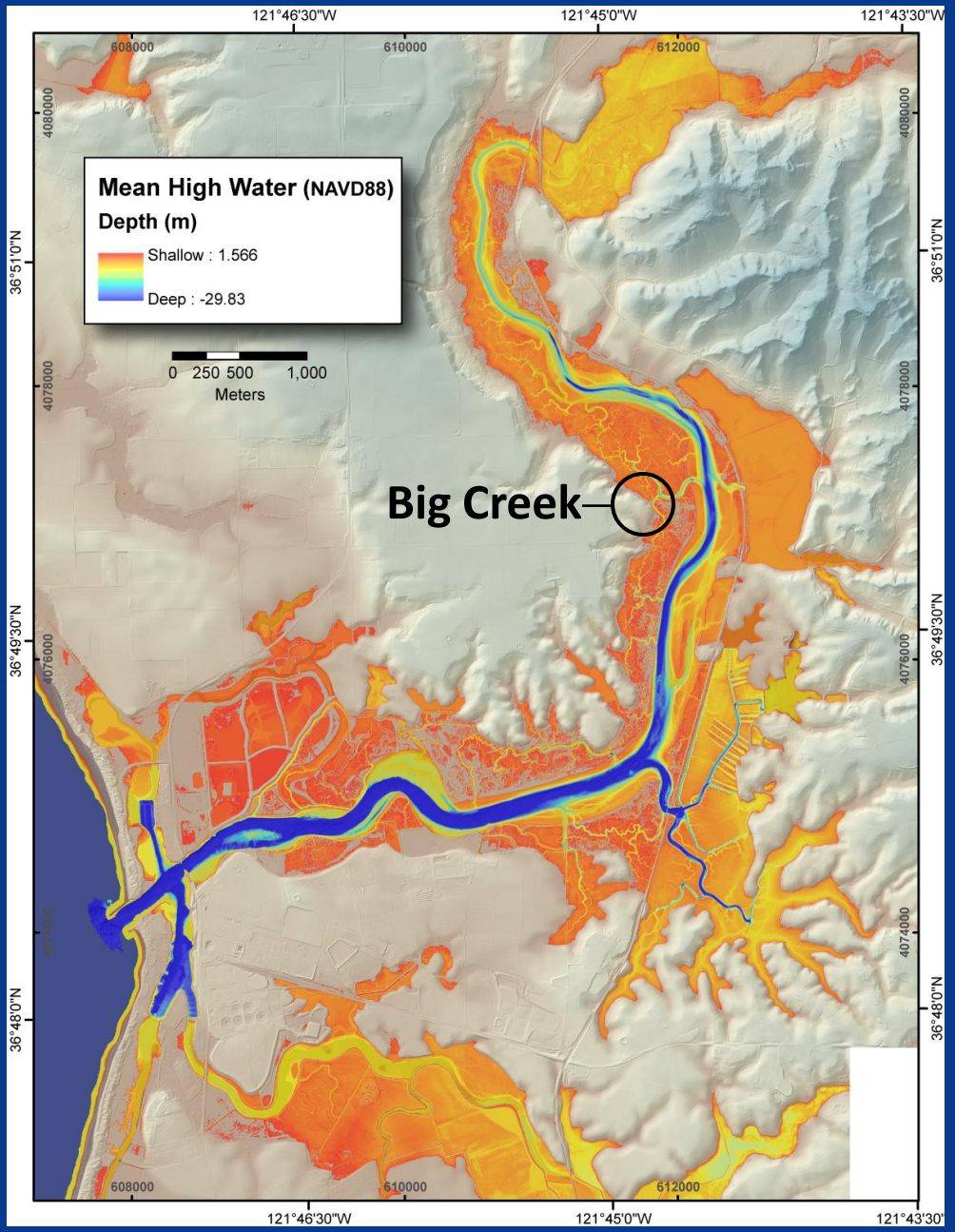


Base DEM

To determine available fish habitat

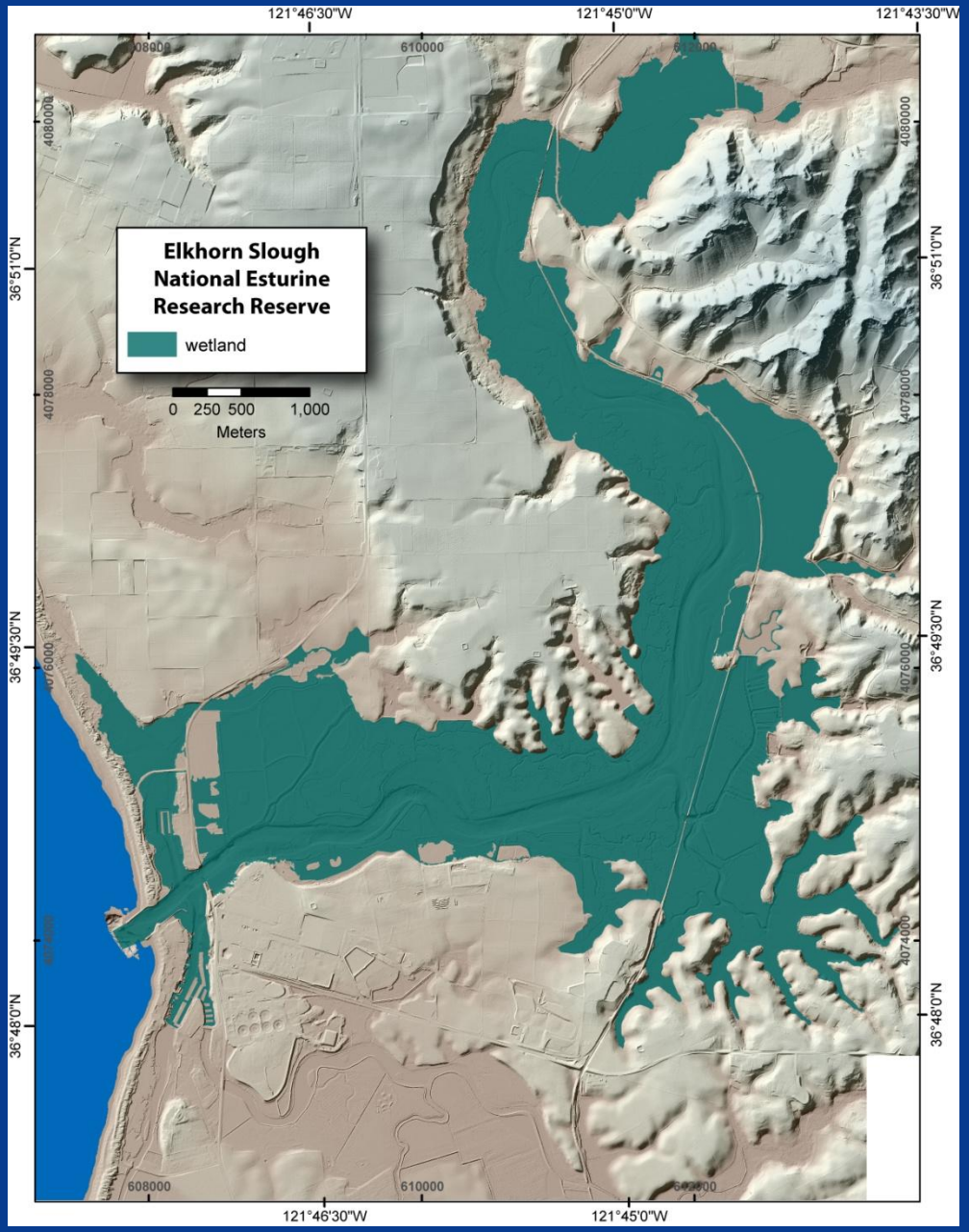
Extracted depths below MHW (Van Dyke et. al 2012)

Converted to a polygon



Python Scripting

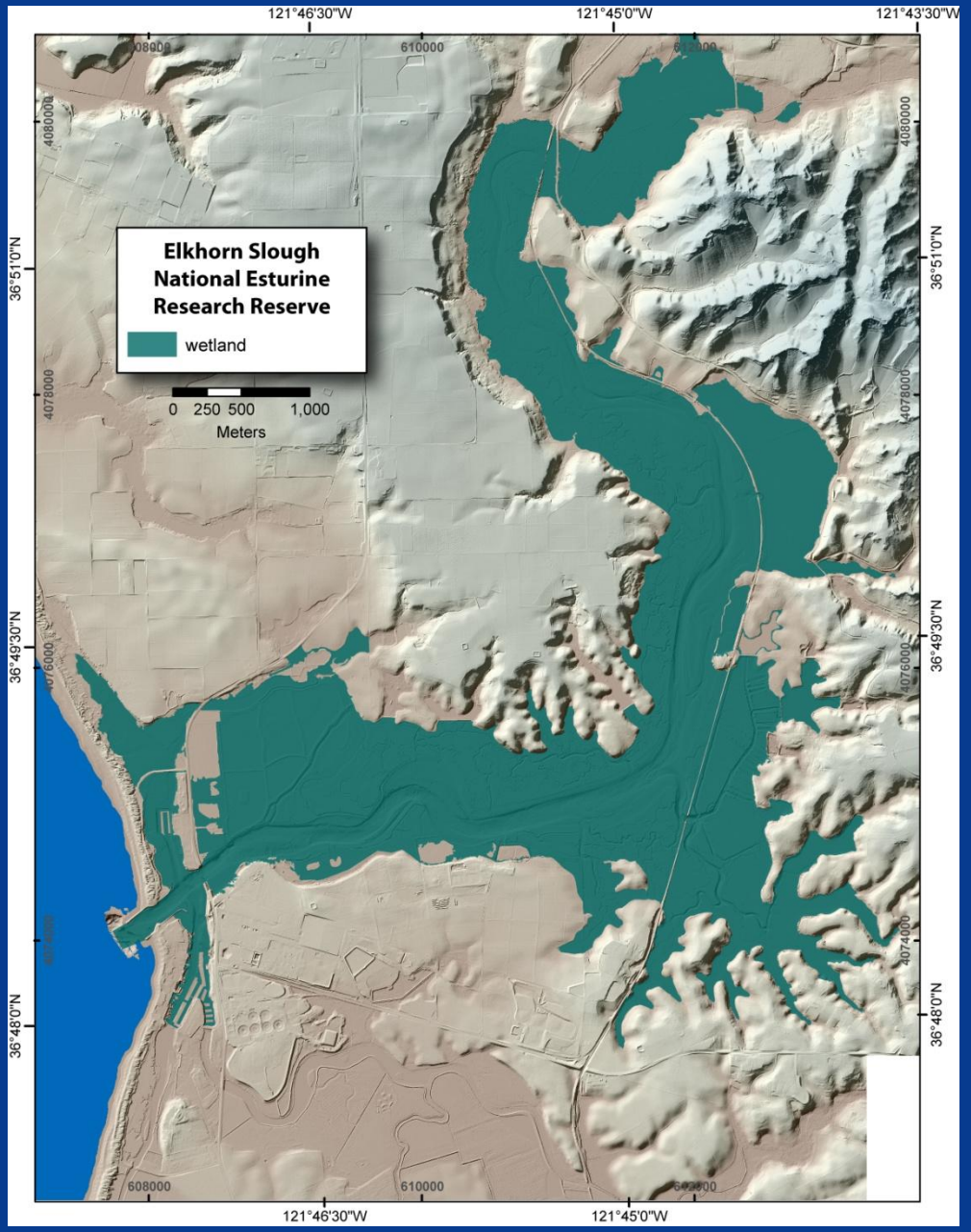
Parse data into
257 text files



Python Scripting

Parse data into
257 text files

Filter text files
and create
252 shapefiles



Python Scripting

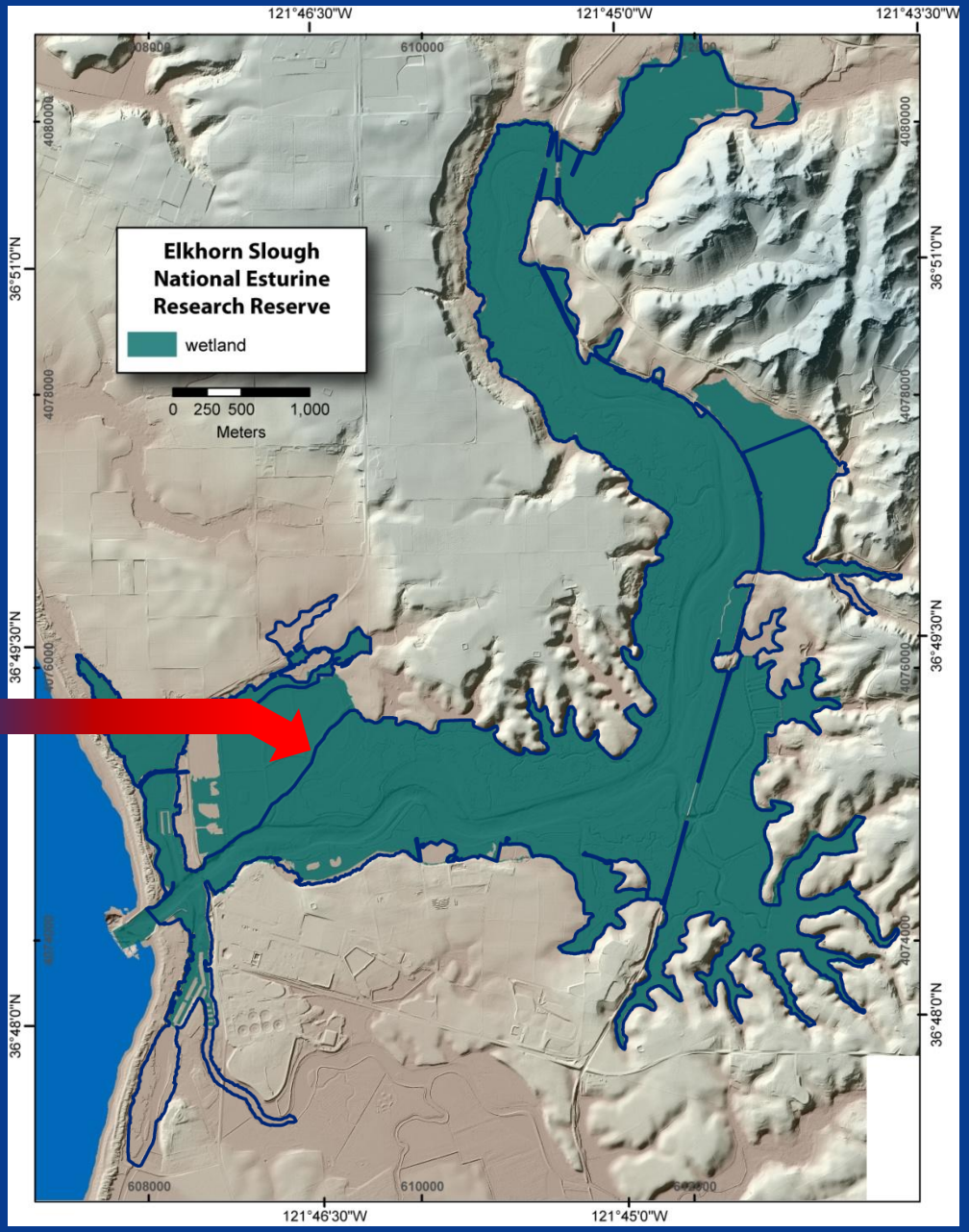
Parse data into
257 text files

↓

Filter text files
and create
252 shapefiles

↓

Interpolate using
Spline with Barriers
20m cell size



Python Scripting

Parse data into
257 text files

↓

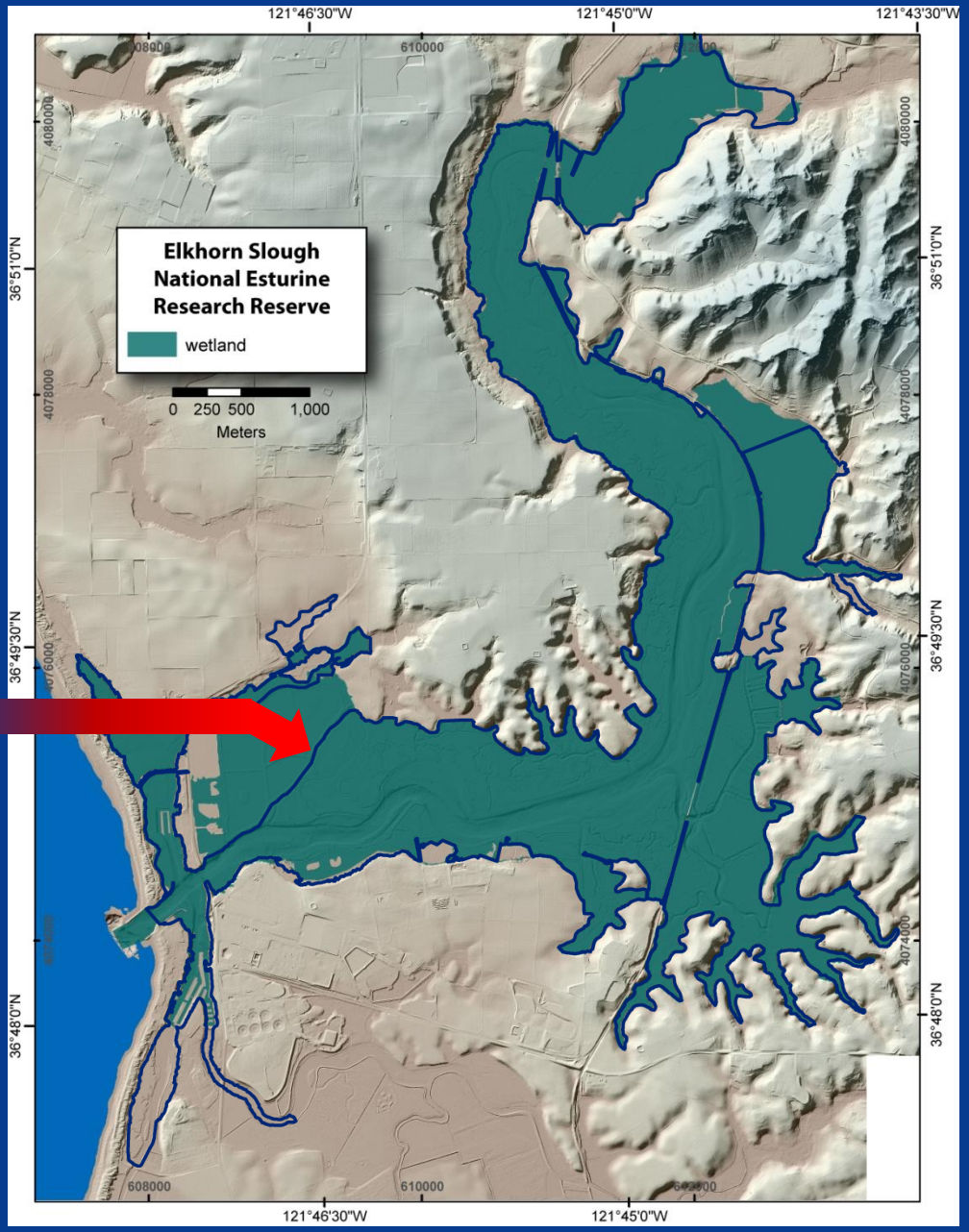
Filter text files
and create
252 shapefiles

↓

Interpolate using
Spline with Barriers
20m cell size

↓

And more converting and
filtering stuff!



Python Scripting, cont.

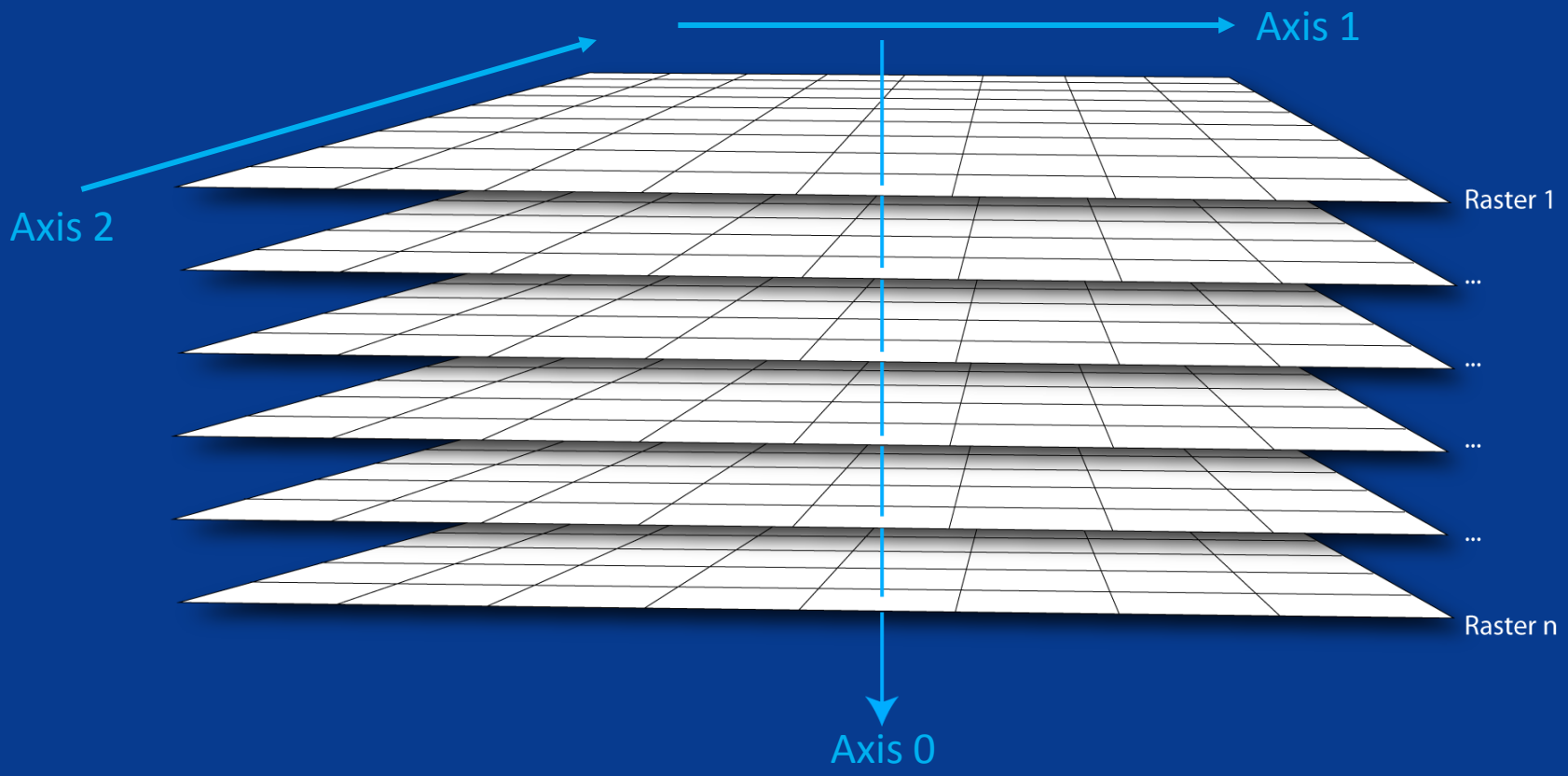
Calculate 10th percentile DO and create a raster for each climate regime

Python Scripting, cont.

Convert to numpy array using arcpy.RasterToNumpyArray

Python Scripting, cont.

Use numpy.percentile function along axis 0 (3rd dimension)



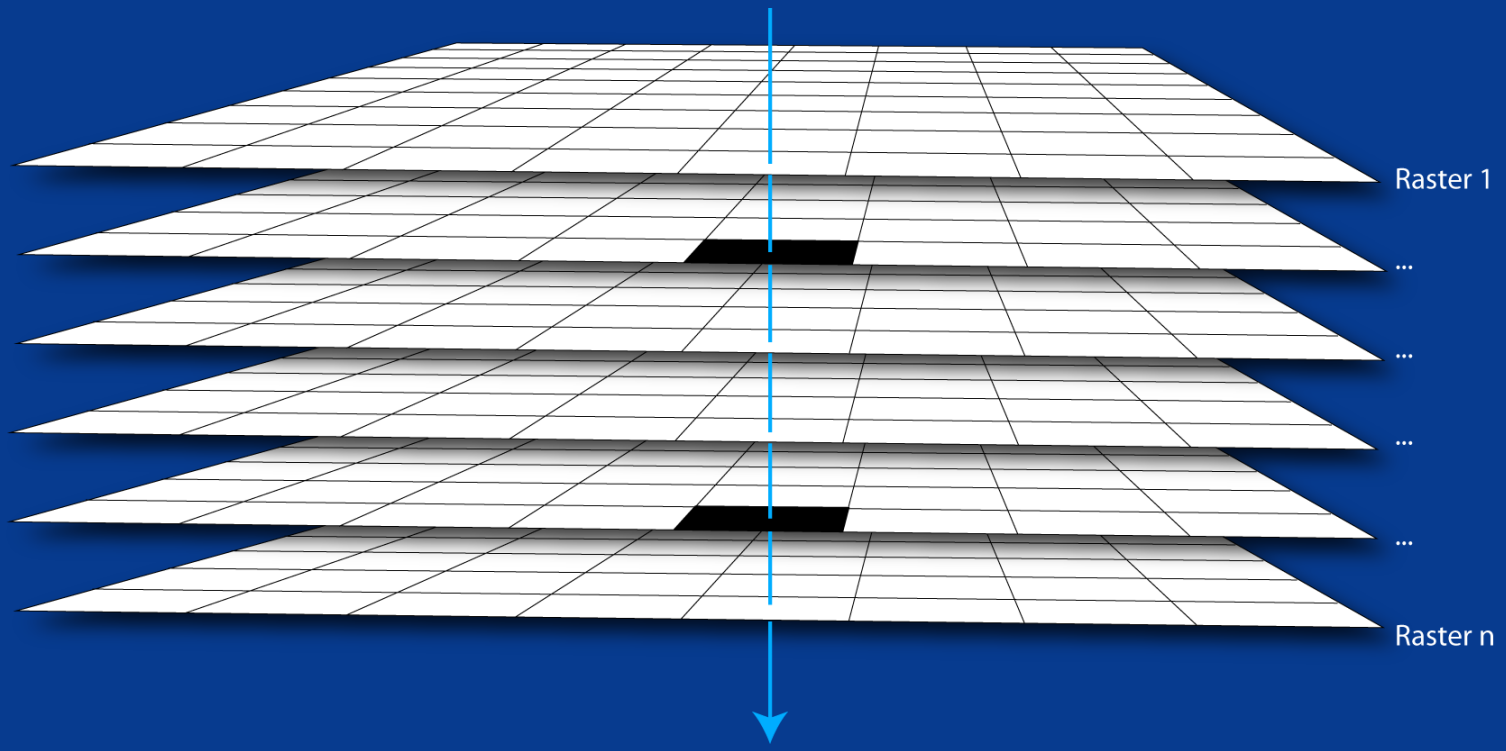
Paranoia not always bad

Bad results with NODATA cells

Paranoia not always bad

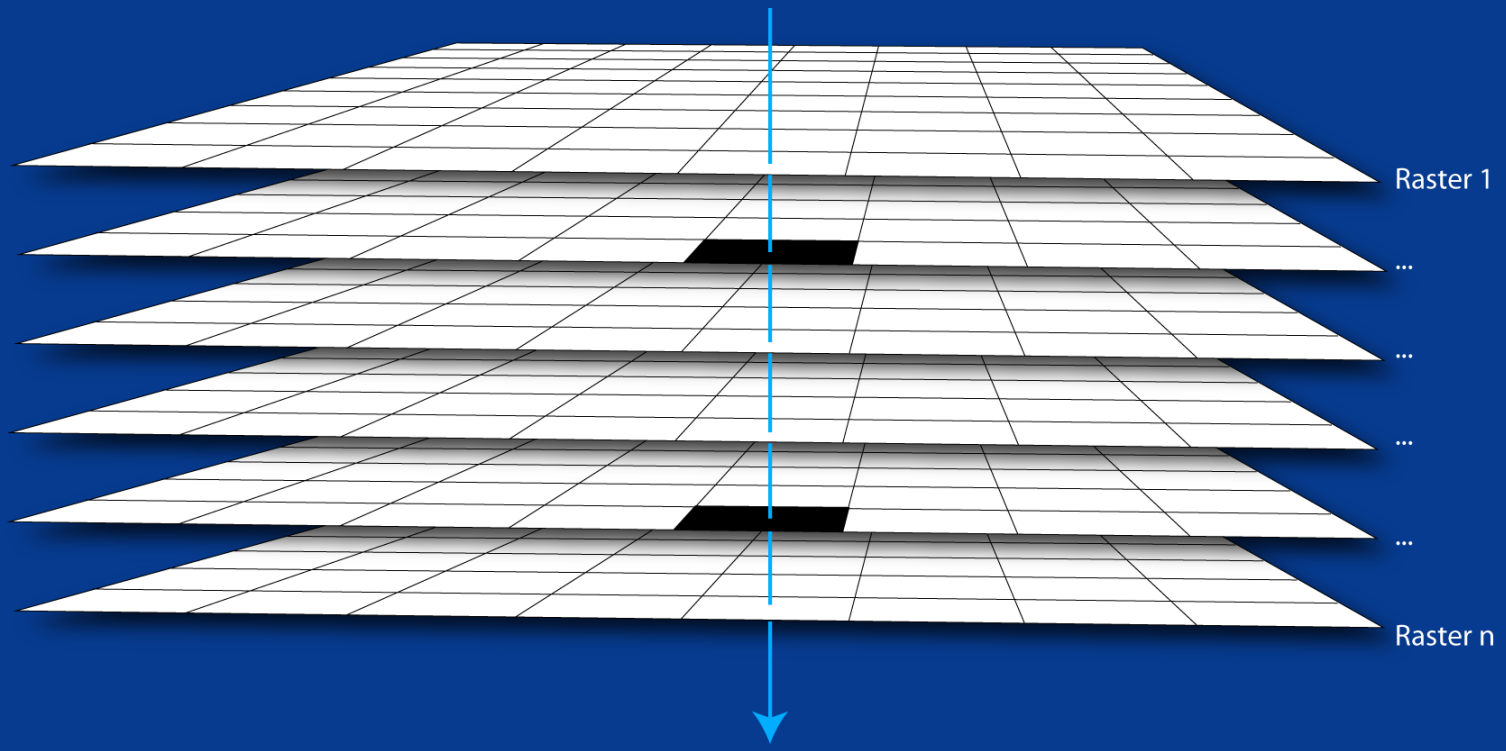
Numpy treats NODATA as valid data

= NODATA = -3.40282346639e+038



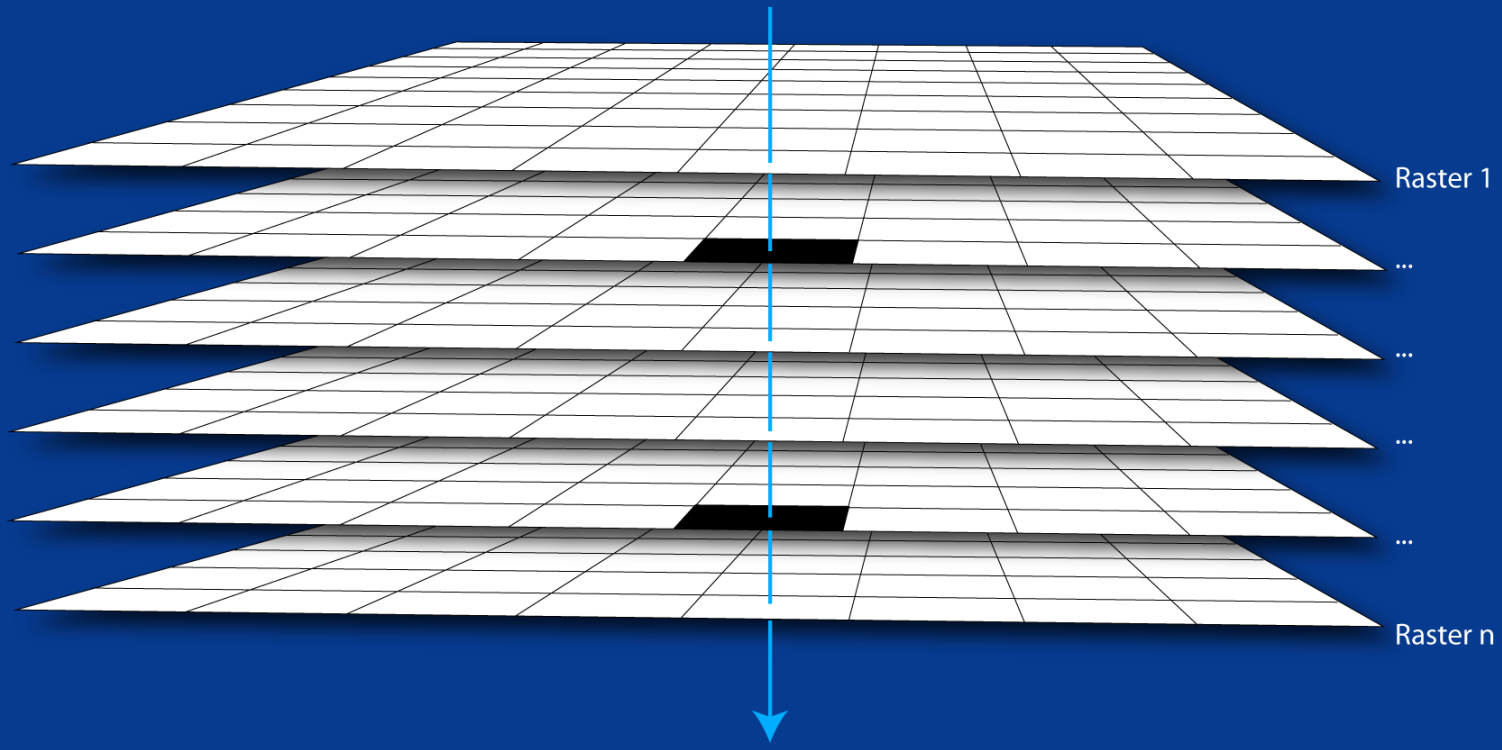
Paranoia not always bad

Masked arrays



Paranoia not always bad

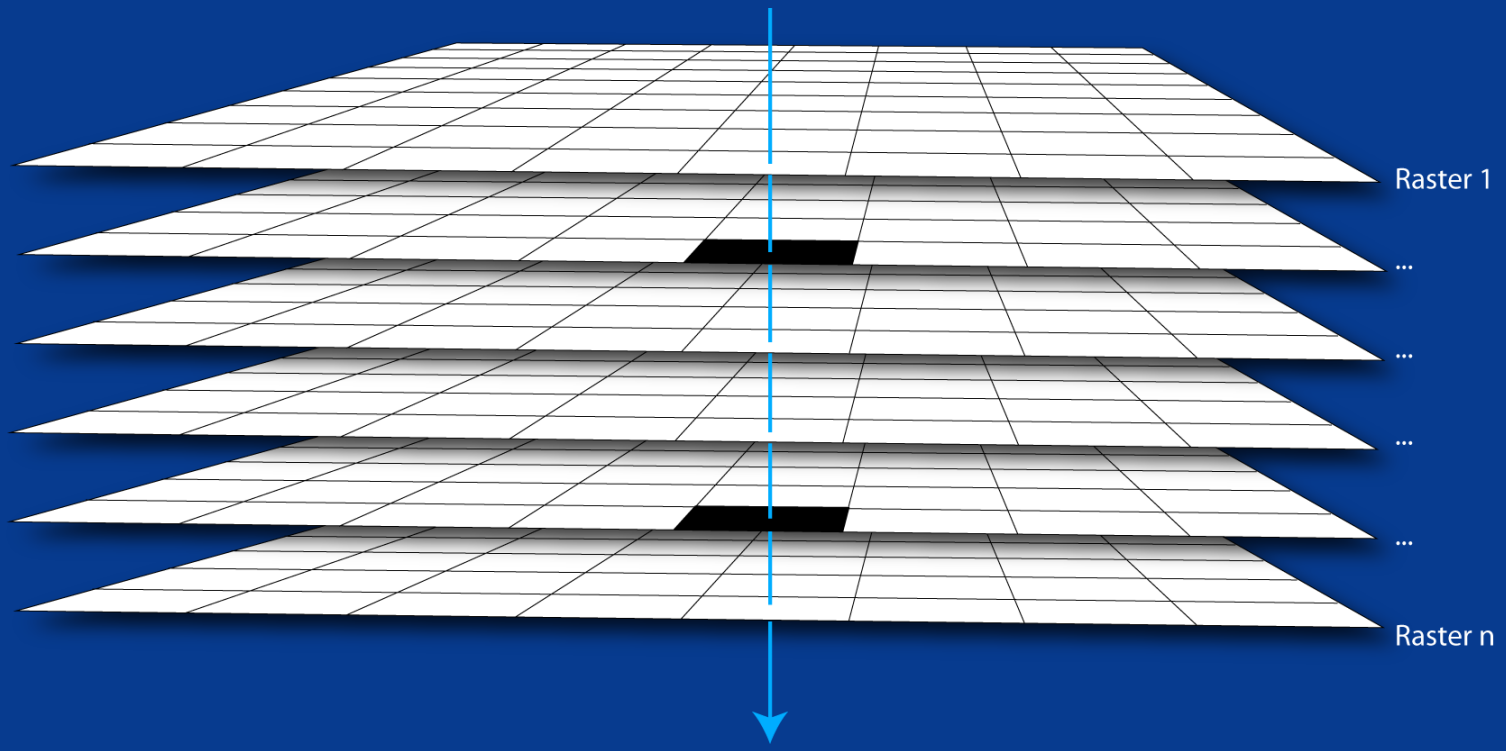
~~Masked arrays~~



Paranoia not always bad

Solution: convert NODATA to NaNs, run calcs, then convert back to NODATA

= NaN



Only code I will show, promise

```
        if el_nino:
            print "Adding %s to El Nino..." % (raster)
            eln_array = arcpy.RasterToNumPyArray(raster, "", 302, 421, -9.999)
            eln_array[eln_array == -9.9989996] = None
            elnino.append(eln_array)
```

NODATA to Nan

```
    # El Nino

    print "Working on El Nino"
    pct_eln = np.percentile(elnino, 10, axis = 0)
    pct_eln[np.isnan(pct_eln)] = -3.40282346639e+038
    stdev_eln = stats.nanstd(elnino, axis=0)
    stdev_eln[np.isnan(stdev_eln)] = -3.40282346639e+038

        # Convert back to rasters, project, and save

    pcteln = arcpy.NumPyArrayToRaster(pct_eln, point, 20, 20, "")
    pcteln.save("pct10_nino")
    arcpy.DefineProjection_management("pct10_nino", sR)

    std_eln = arcpy.NumPyArrayToRaster(stdev_eln, point, 20, 20, "")
    std_eln.save("stdv_nino")
    arcpy.DefineProjection_management("stdv_nino", sR)
```

Calculations and Nan to NODATA

Converting back to raster

Oh yeah, the fish!

Long-term fish monitoring dataset

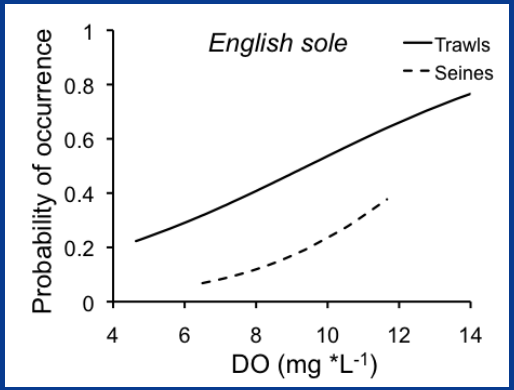
Monterey Bay National Marine Sanctuary's SIMoN program

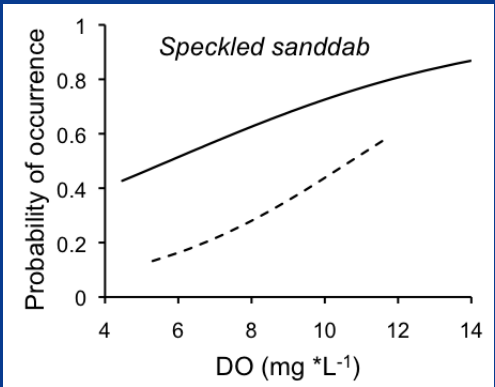
Oh yeah, the fish!

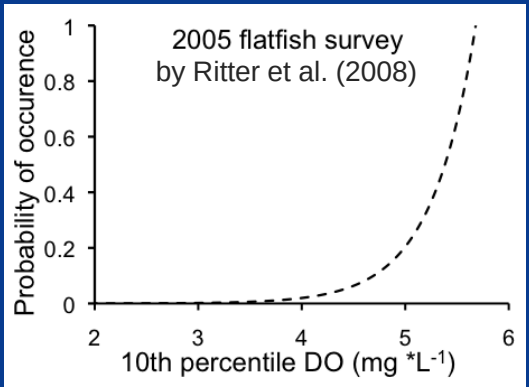
10th percentile DO rasters

↓

Logistic Regression equation from fish presence/absence







↓

Predicted fish probability of occurrence rasters

Determining available habitat

Reclassify

0 – 5	NODATA
> 5	1

Determining available habitat

Reclassify

Resample

0 – 5	NODATA
> 5	1

1m;
natural neighbors

Determining available habitat

Reclassify

Resample

Extract

0 – 5	NODATA
> 5	1

1m;
natural neighbors

MHW
polygon

Determining available habitat

Reclassify

↓

Resample

↓

Extract

↓

Convert to polygon and dissolve

Determining available habitat

Reclassify

↓

Resample

↓

Extract

↓

Convert to polygon and dissolve

↓

Add field and calculate area

Determining available habitat

Reclassify

↓

Resample

↓

Extract

↓

Convert to polygon and dissolve

↓

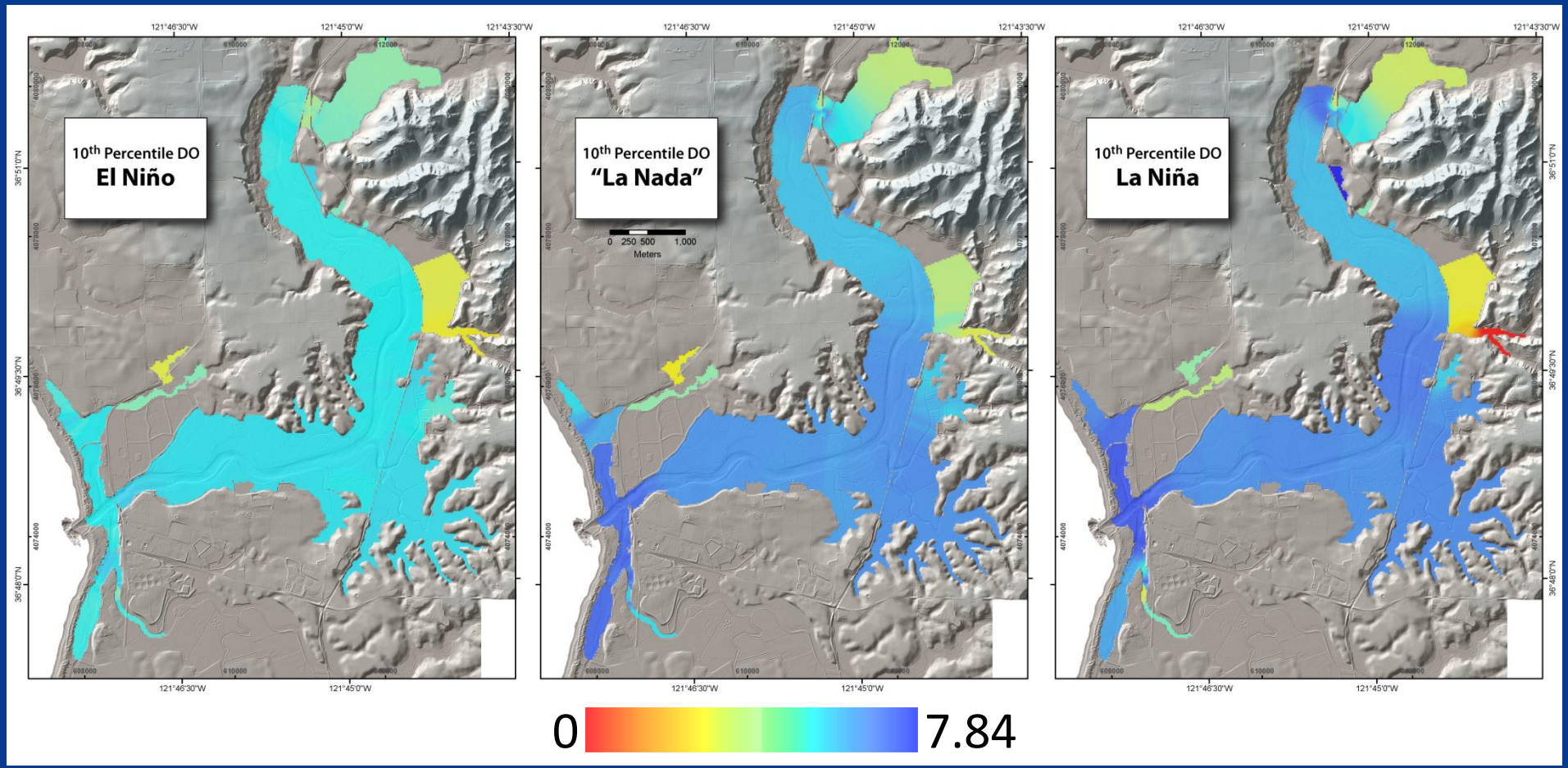
Add field and calculate area

↓

scipy.stats

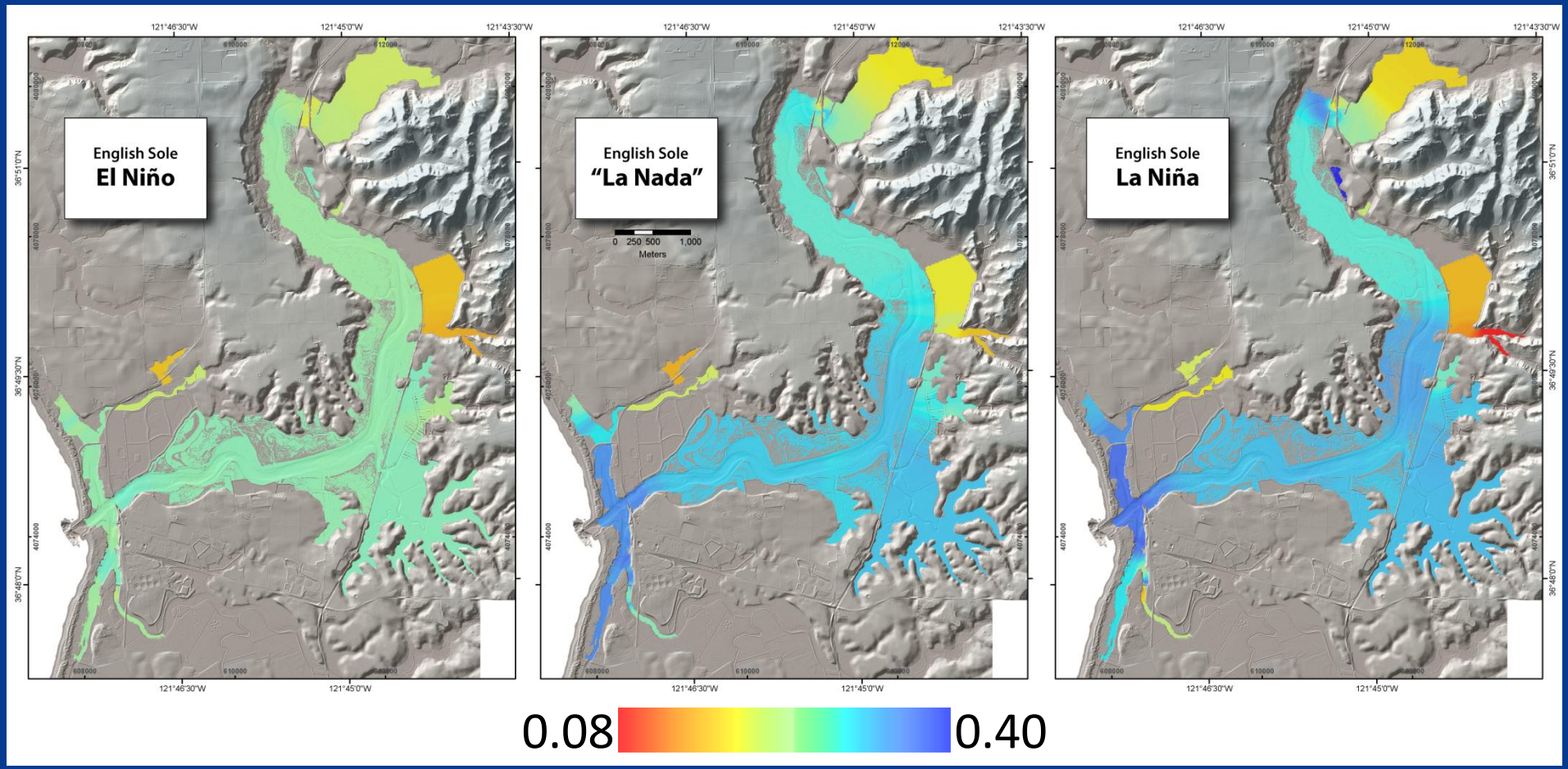
10th Percentile Dissolved O_2 in $mg*L^{-1}$

El Niño | "La Nada" | La Niña



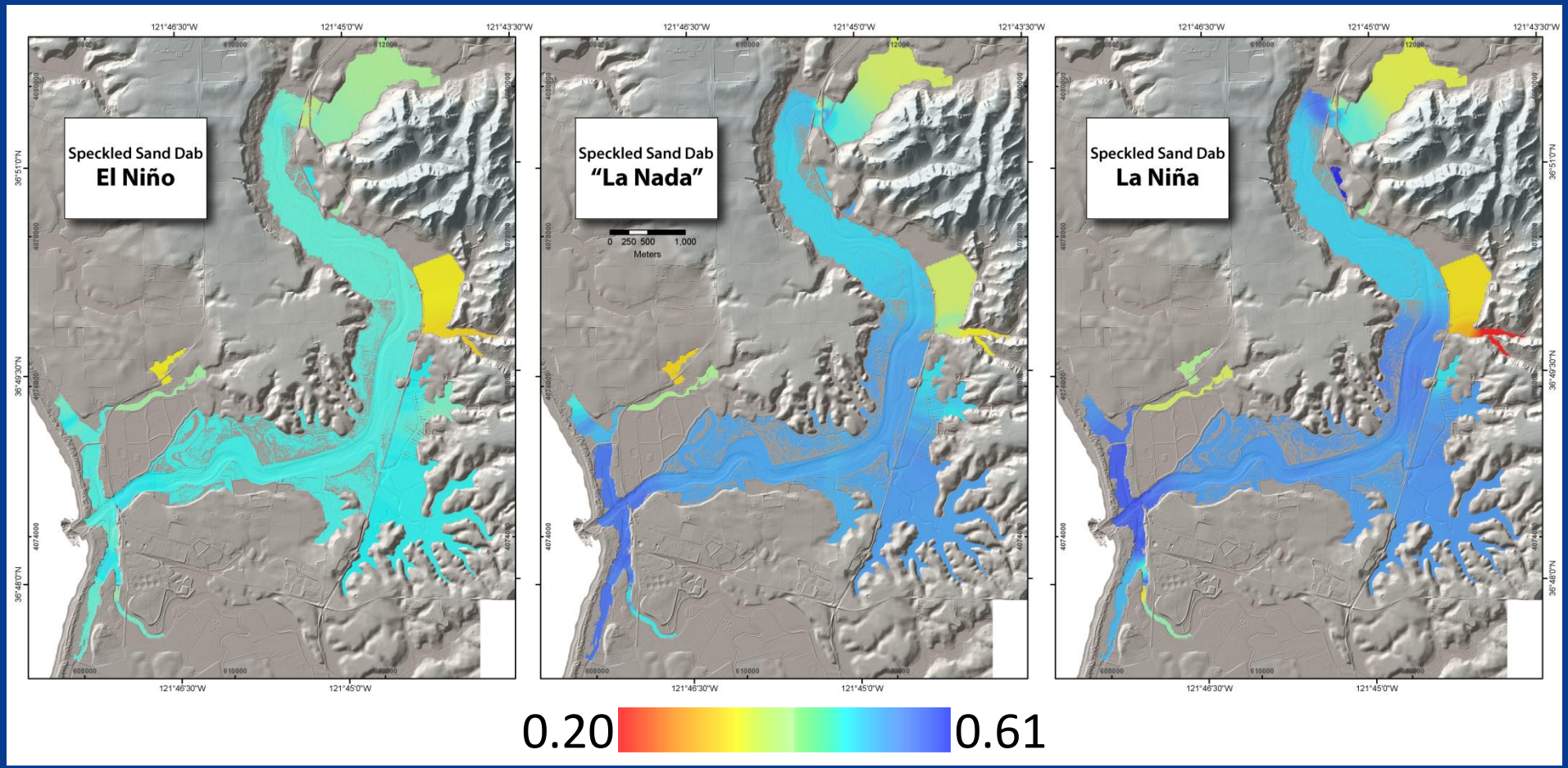
English Sole Probability of Occurrence

El Niño | “La Nada” | La Niña

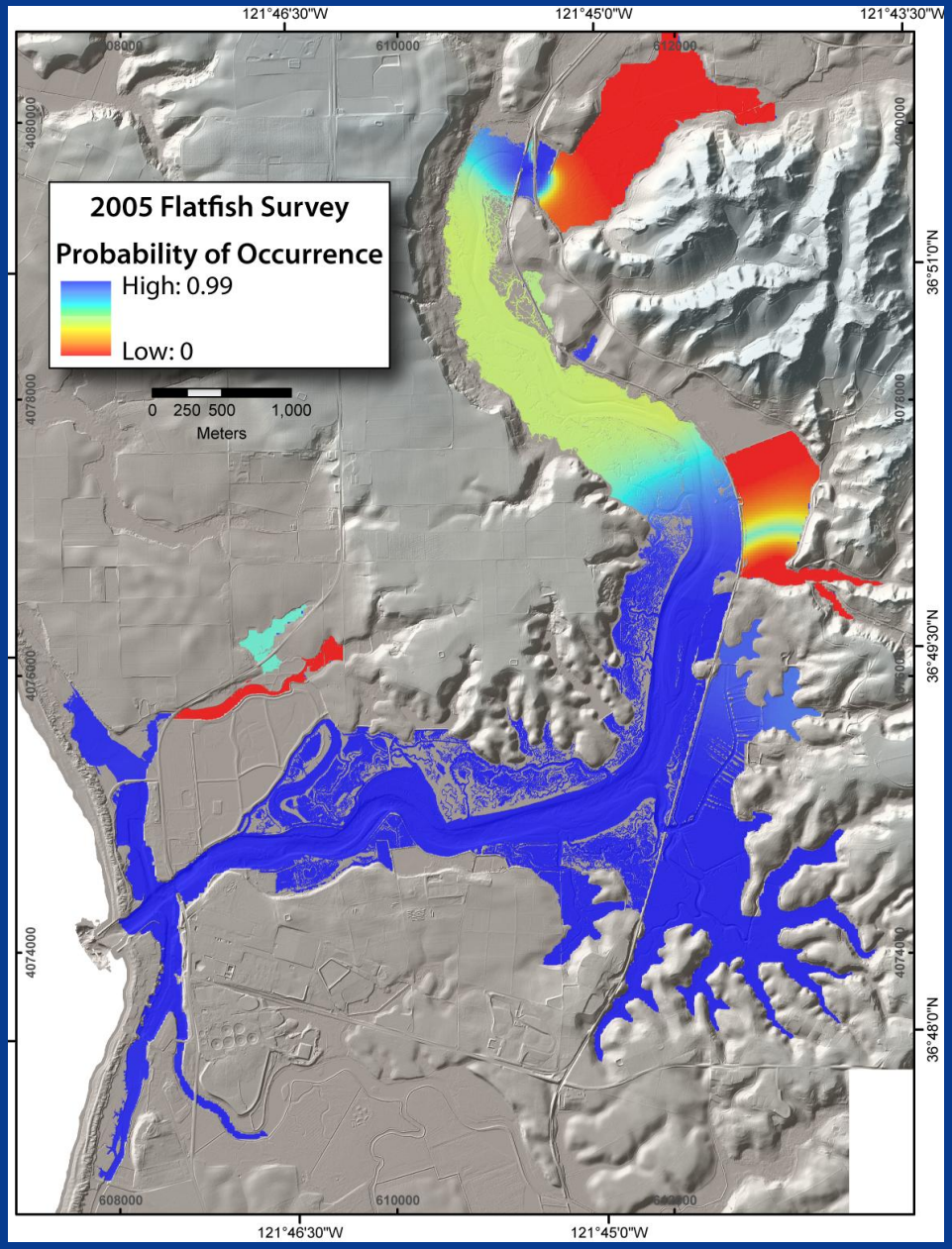


Speckled Sand Dab Probability of Occurrence

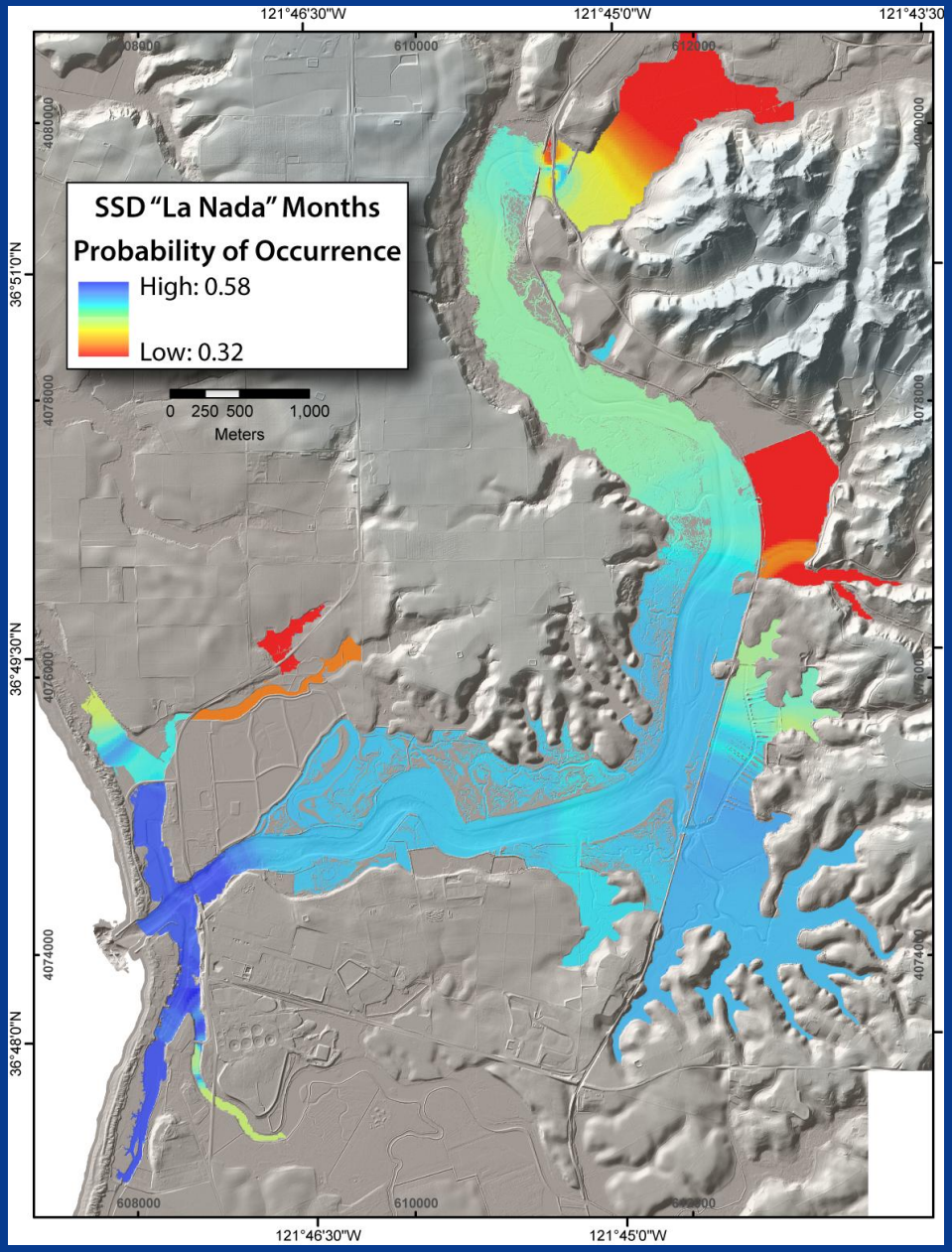
El Niño | "La Nada" | La Niña

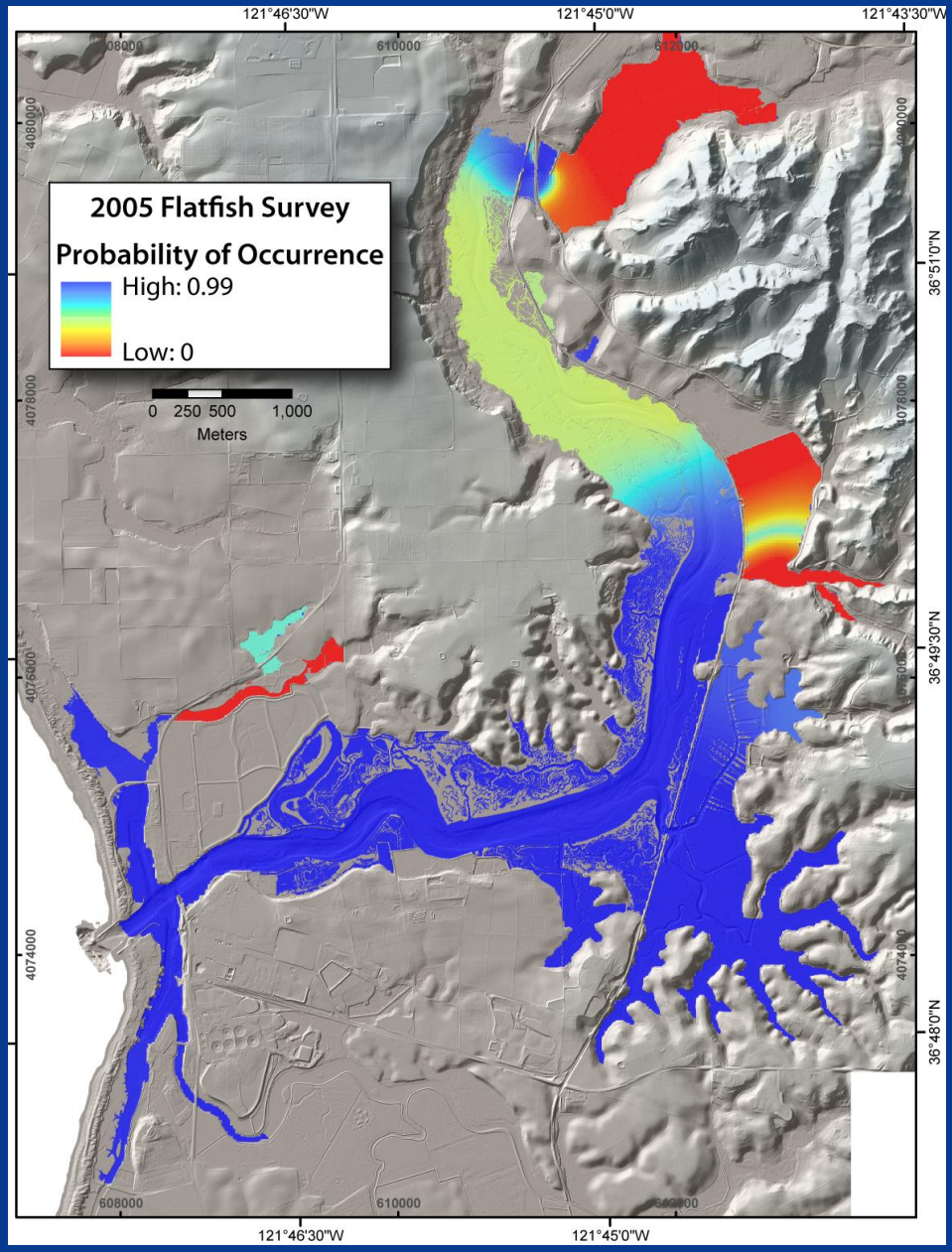


2005 Flatfish Probability of Occurrence



Results


SSD "La Nada" Months
Probability of Occurrence
High: 0.58
Low: 0.32
0 250 500 1,000
Meters
121°46'30"W
121°45'0"W
121°43'30"
36°51'0"N
36°49'30"N
36°48'0"N
608000
610000
612000
4080000
4078000
4076000
4074000


2005 Flatfish Survey
Probability of Occurrence
High: 0.99
Low: 0
0 250 500 1,000
Meters
121°46'30"W
121°45'0"W
121°43'30"W
36°51'0"N
36°49'30"N
36°48'0"N
608000
610000
612000
4080000
4078000
4076000
4074000

Available habitat

Total habitat = 9.287 km^2

Available habitat

Total habitat = 9.287 km^2

Regime	n	Mean (km^2)	sd
El Niño	88	8.322	1.43
La Nada	53	8.455	0.77
La Niña	111	8.475	1.17

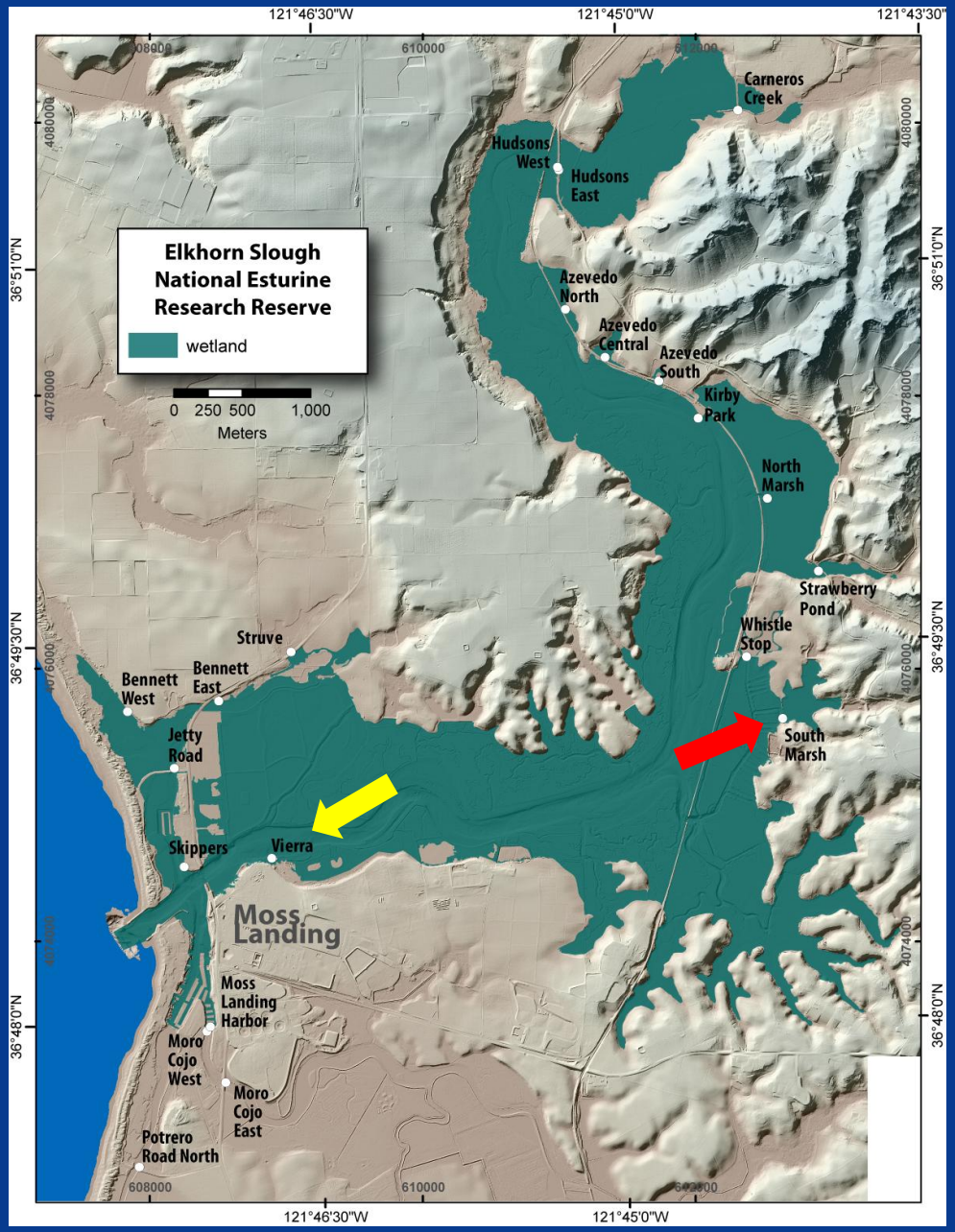
Available habitat

Total habitat = 9.287 km^2

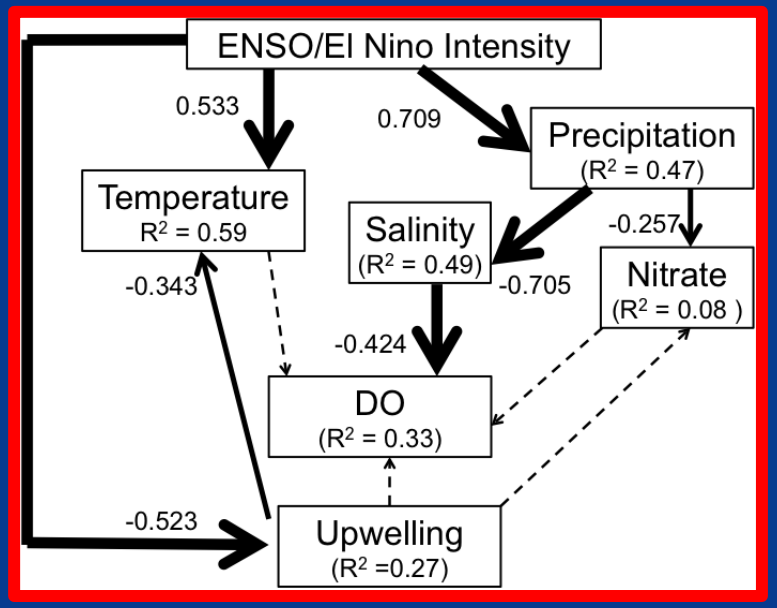
Regime	n	Mean (km^2)	sd
El Niño	88	8.322	1.43
La Nada	53	8.455	0.77
La Niña	111	8.475	1.17

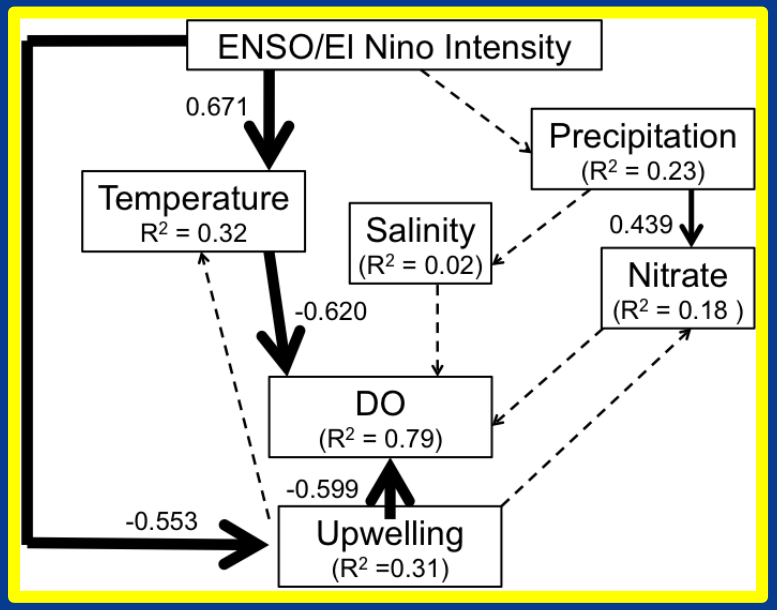
Kruskal-Wallace: p = 0.14

No significant difference



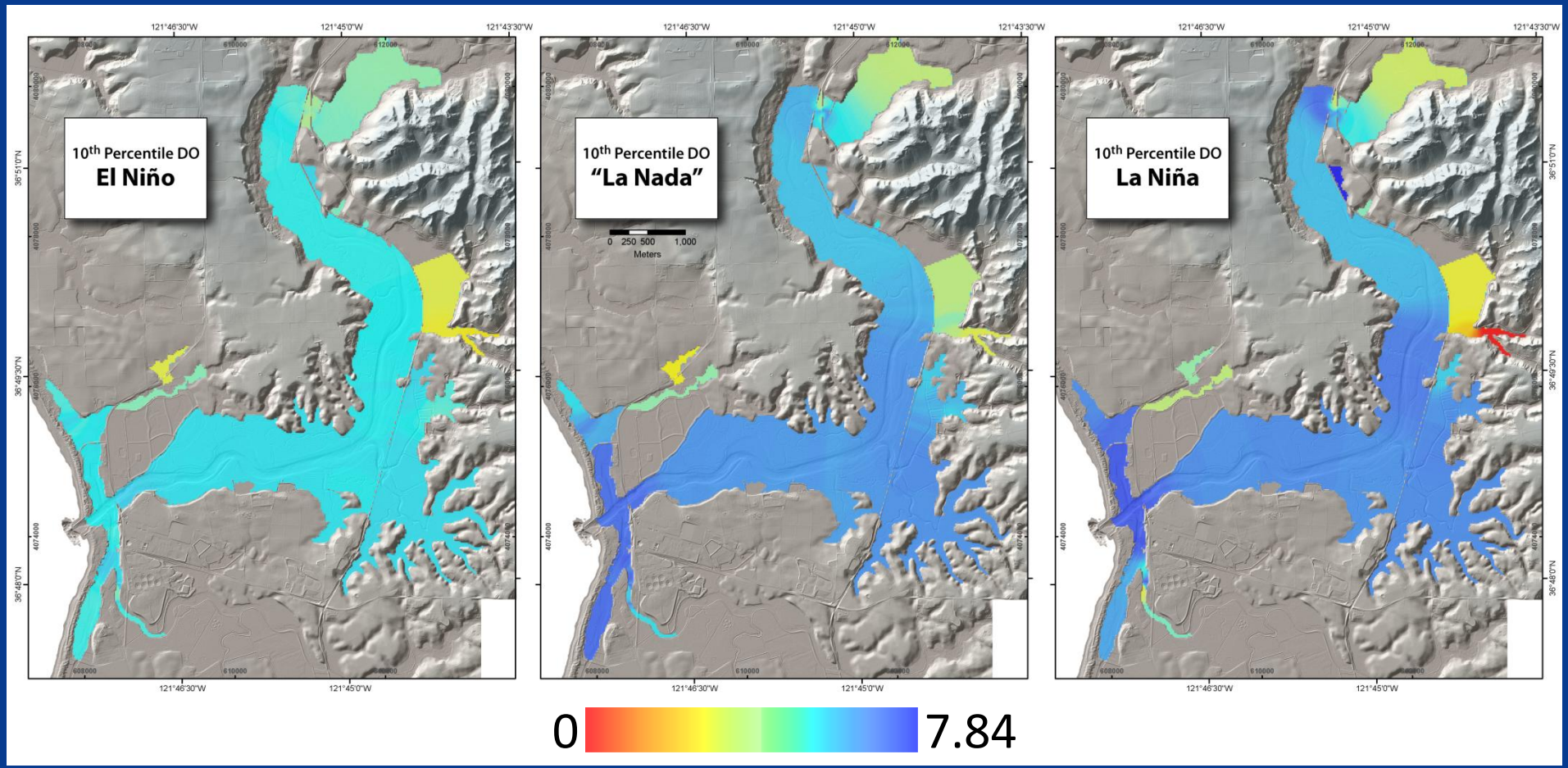
Path Analysis





10th Percentile Dissolved O_2 in mg*L^{-1}

El Niño "La Nada" La Niña



Available habitat

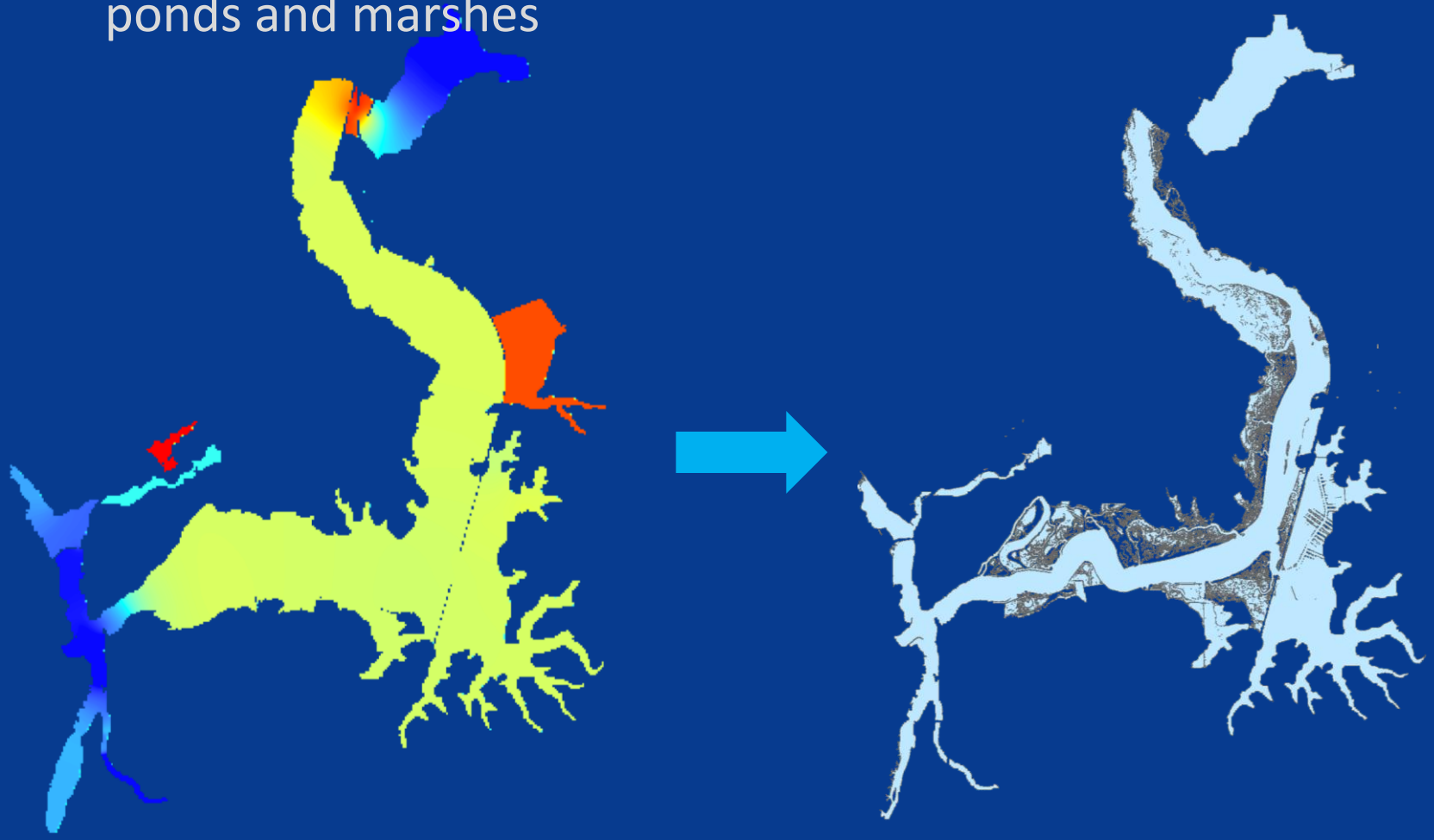
Climate regime does not have an effect on habitat availability

Available habitat

Hypoxic conditions mostly occurred in same areas, e.g.; ponds and marshes

Available habitat

Hypoxic conditions mostly occurred in same areas, e.g.; ponds and marshes



Python

For-loops and
list comprehension

Python

For-loops and
list comprehension
Arcpy

Python

For-loops and
list comprehension

Arcpy

Numpy and Scipy

Python

For-loops and
list comprehension
Arcpy
Numpy and Scipy

Acknowledgments