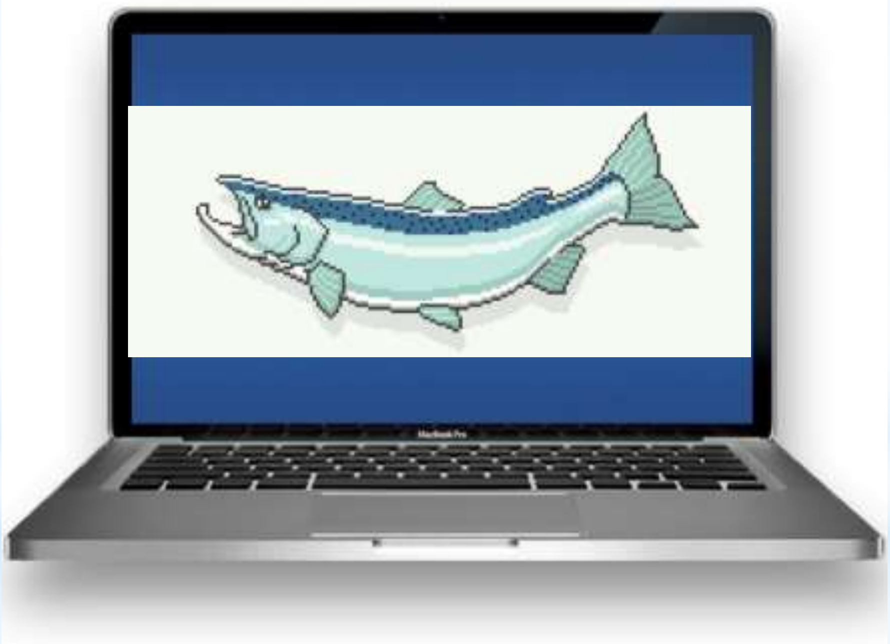
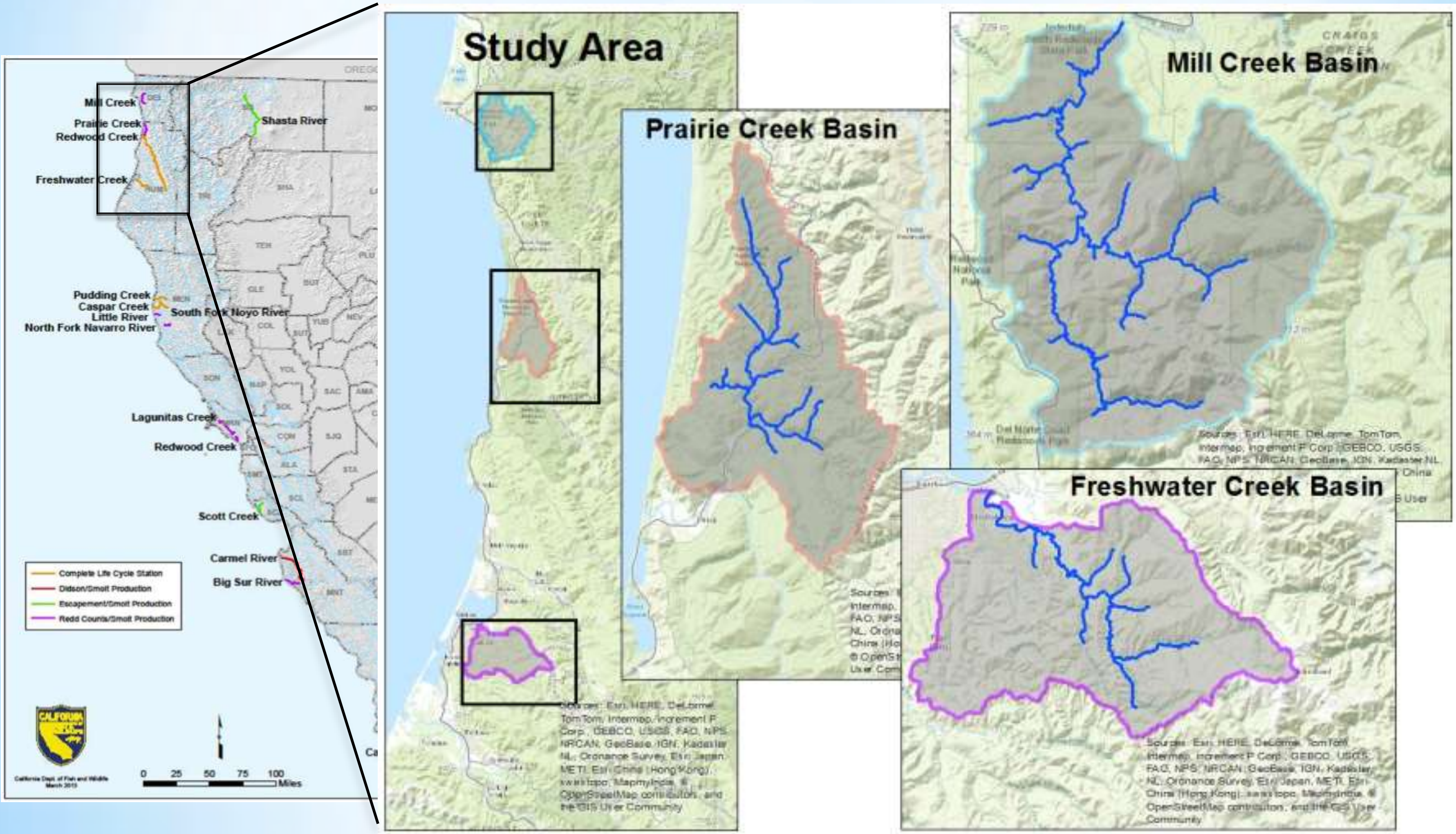
Coastal Coho Salmon Life Cycle Modeling

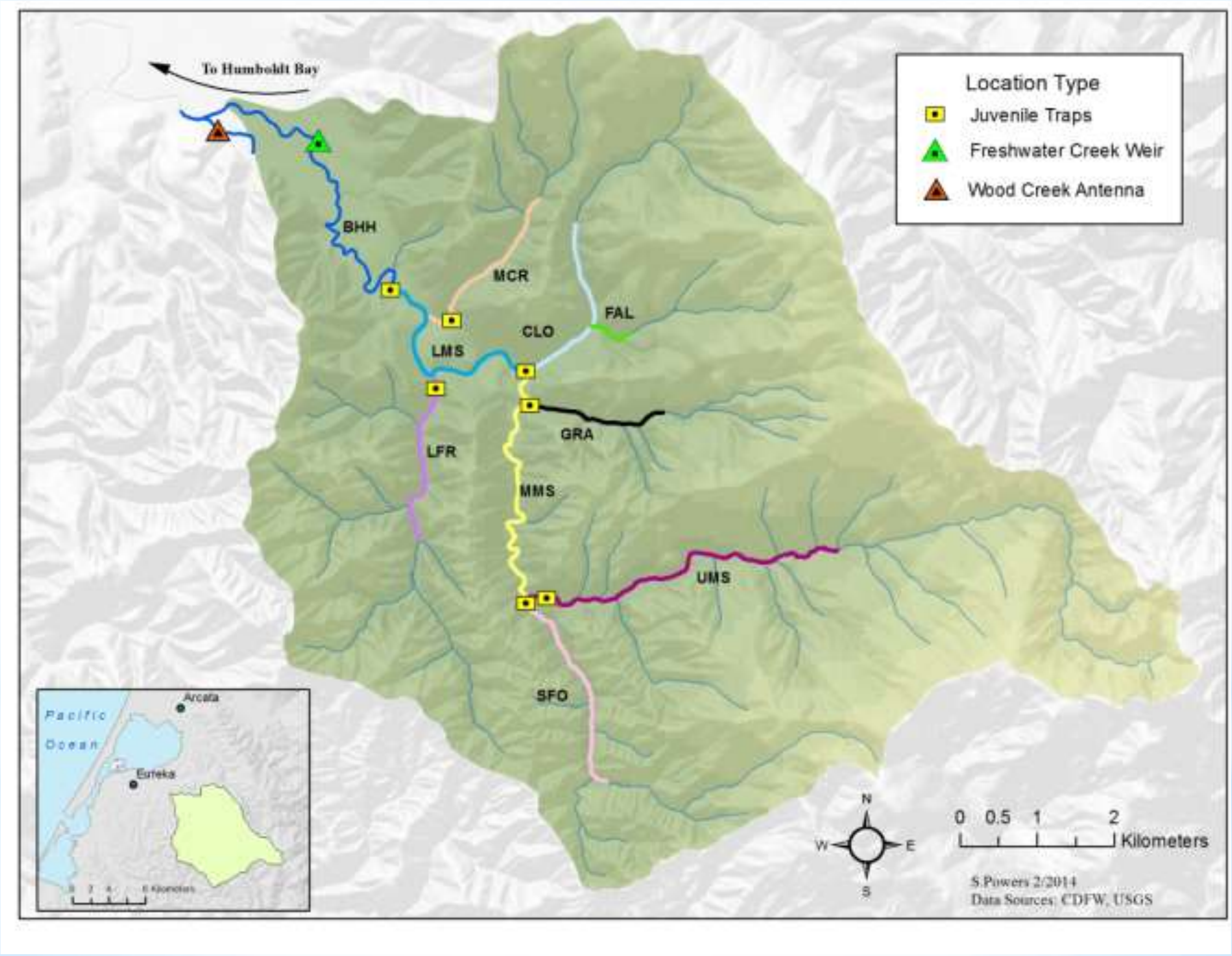


Gabe Scheer
Humboldt State University

Northern California Life Cycle Monitoring Stations

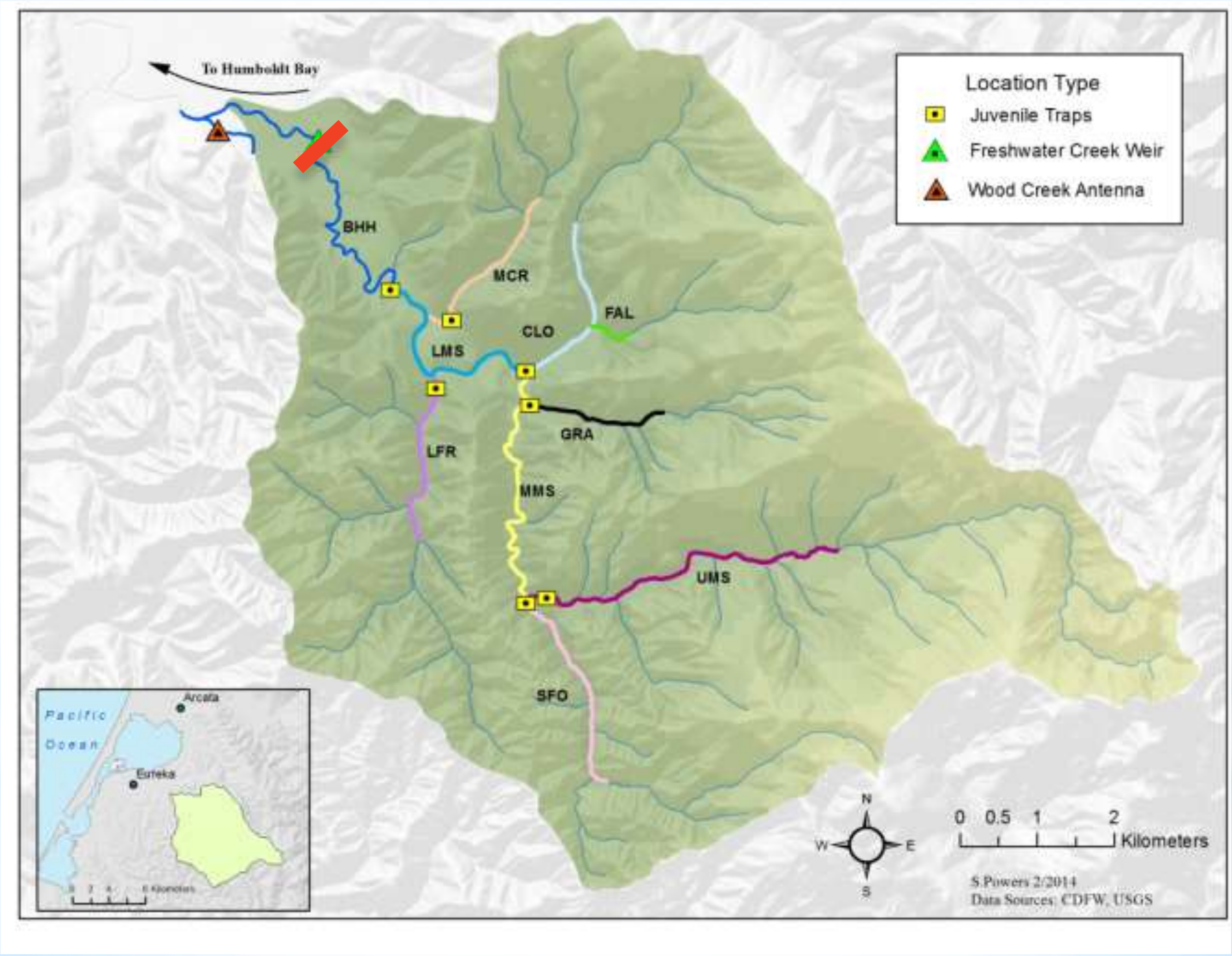


Freshwater Creek Life Cycle Monitoring Station



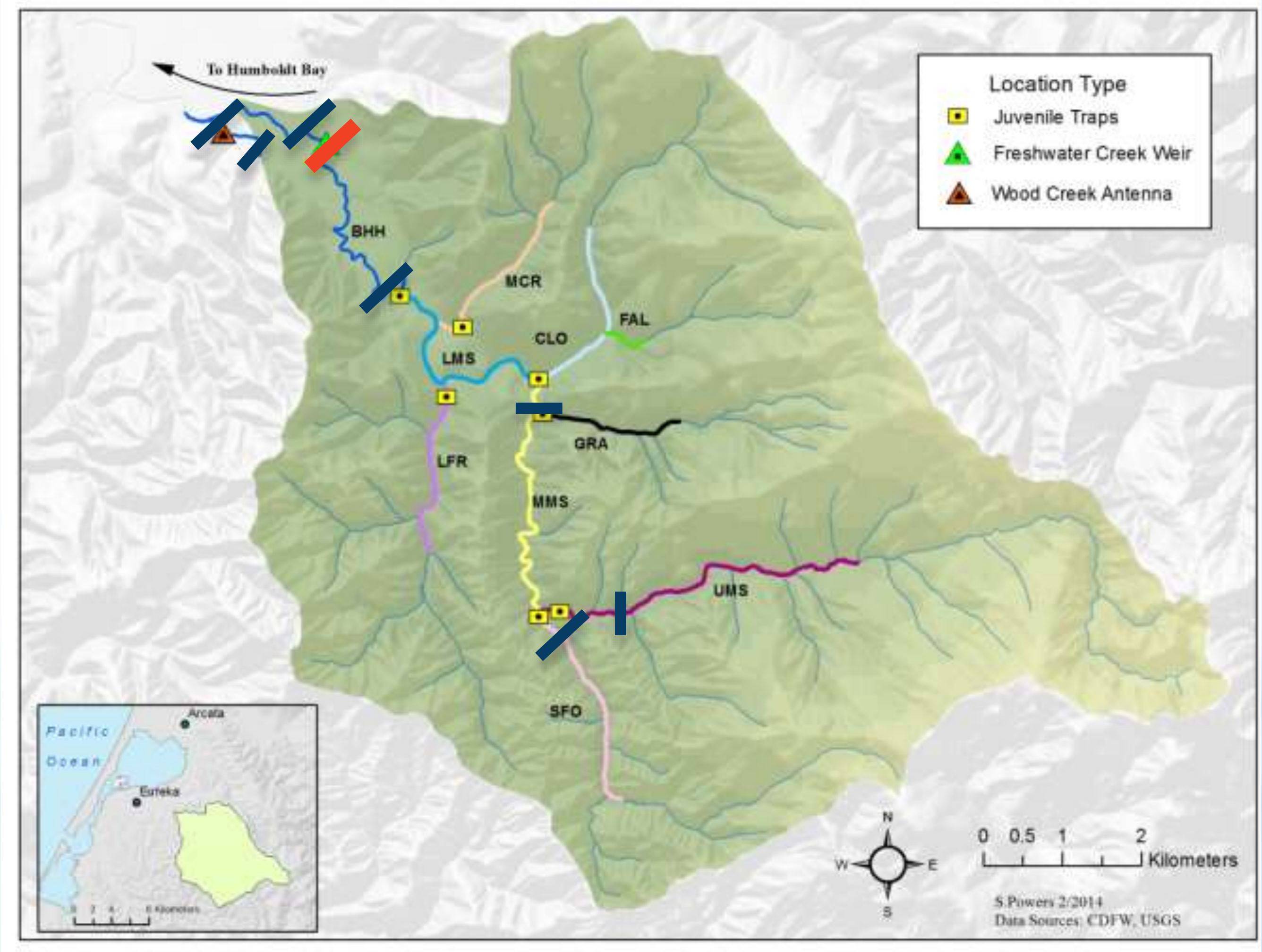
Area: 92 km^2 Anadromous habitat: 14.5 km

Freshwater Creek Life Cycle Monitoring Station

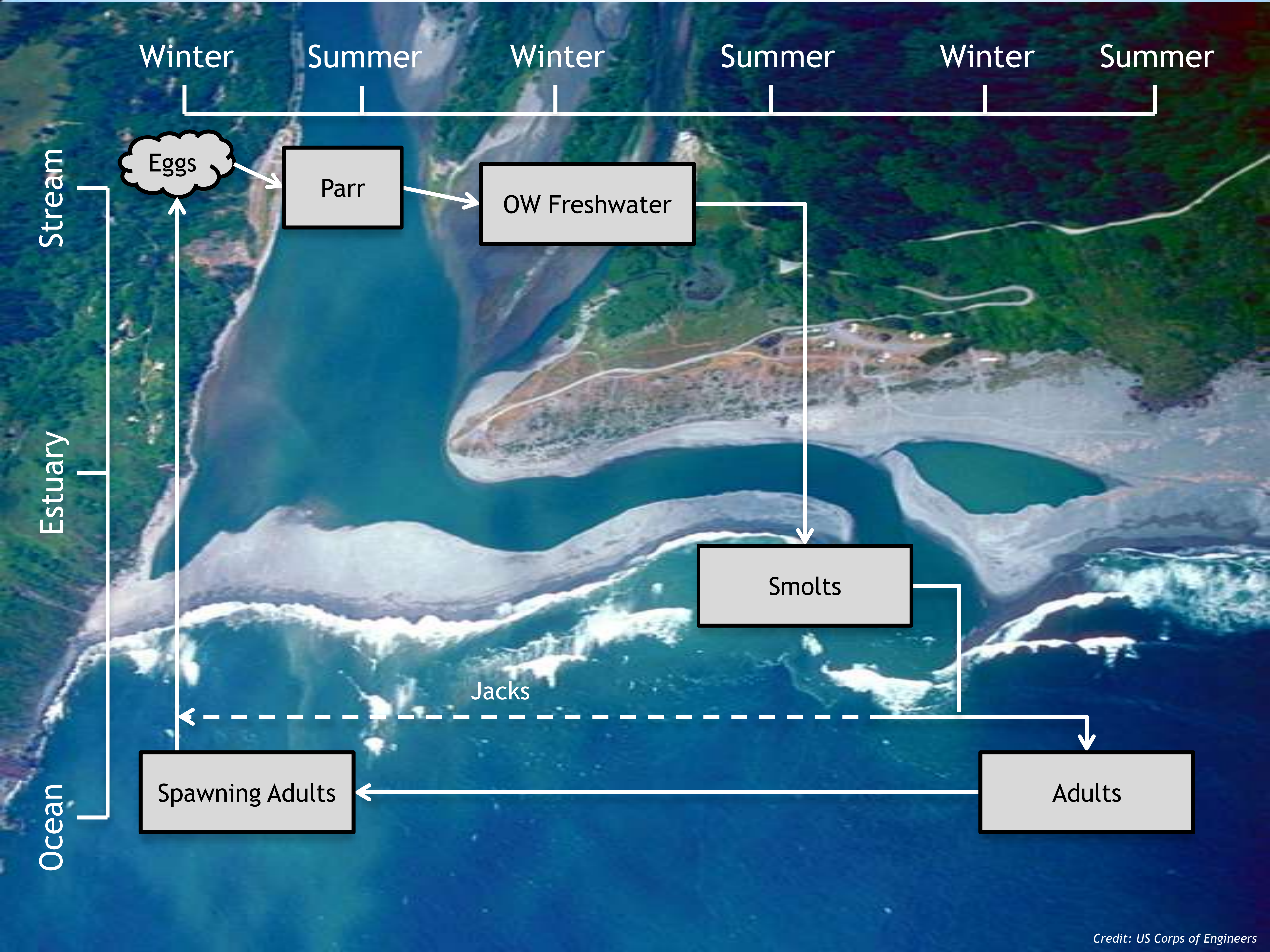


Permanent weir located near upper extent of tidally influenced habitat

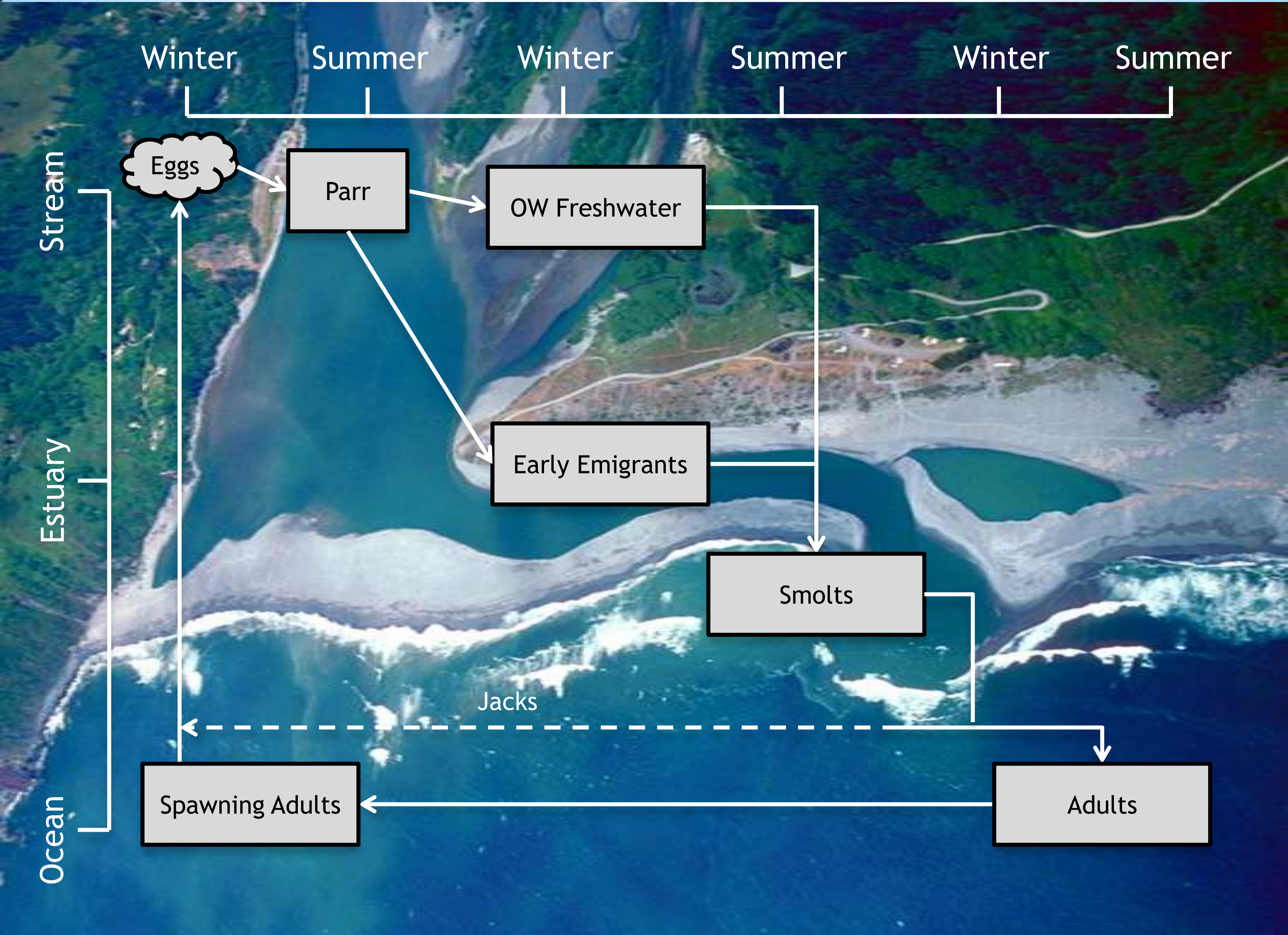
Freshwater Creek Life Cycle Monitoring Station



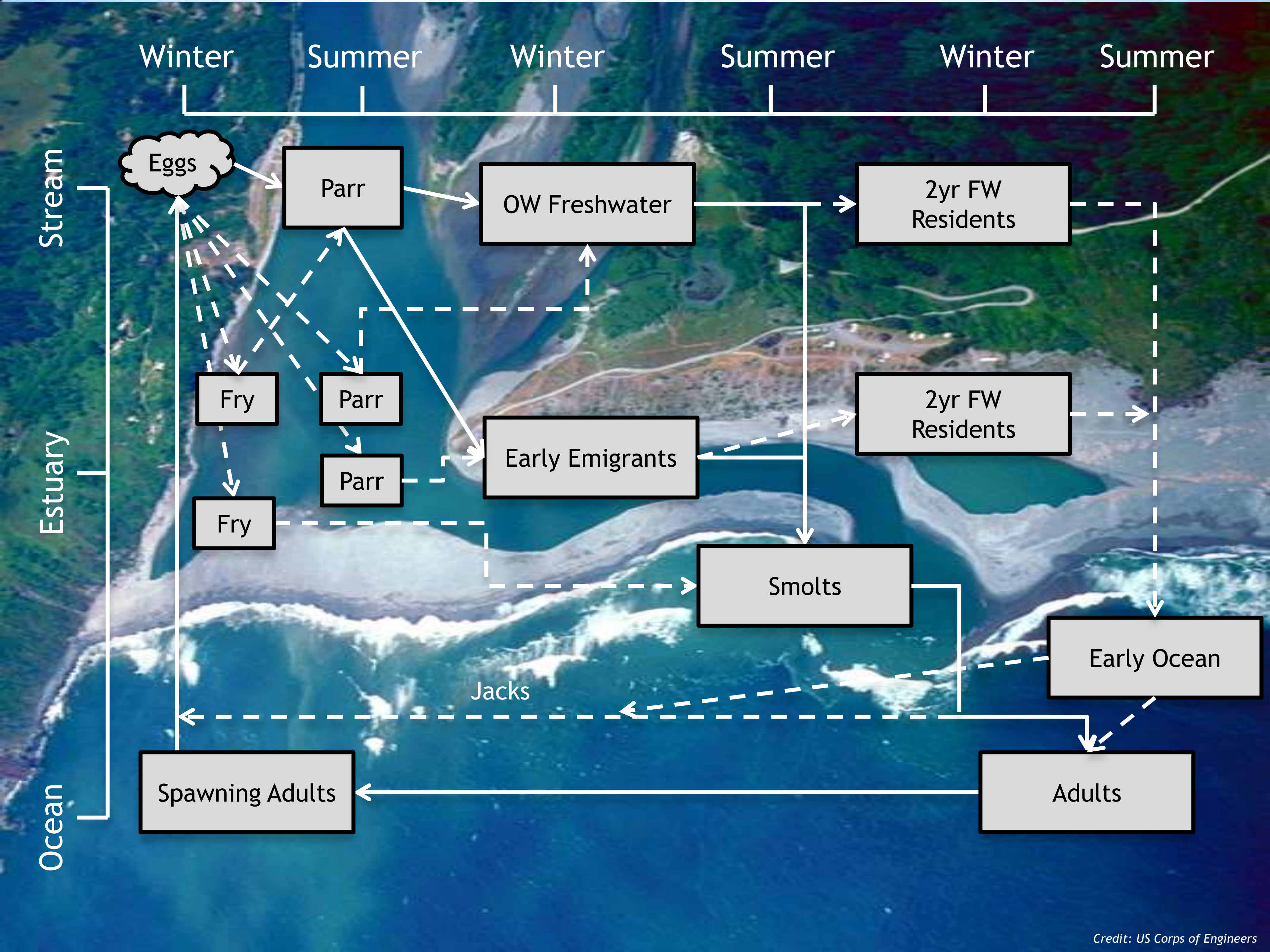
Antennas located throughout the basin and in wood creek marsh in the stream estuary ecotone

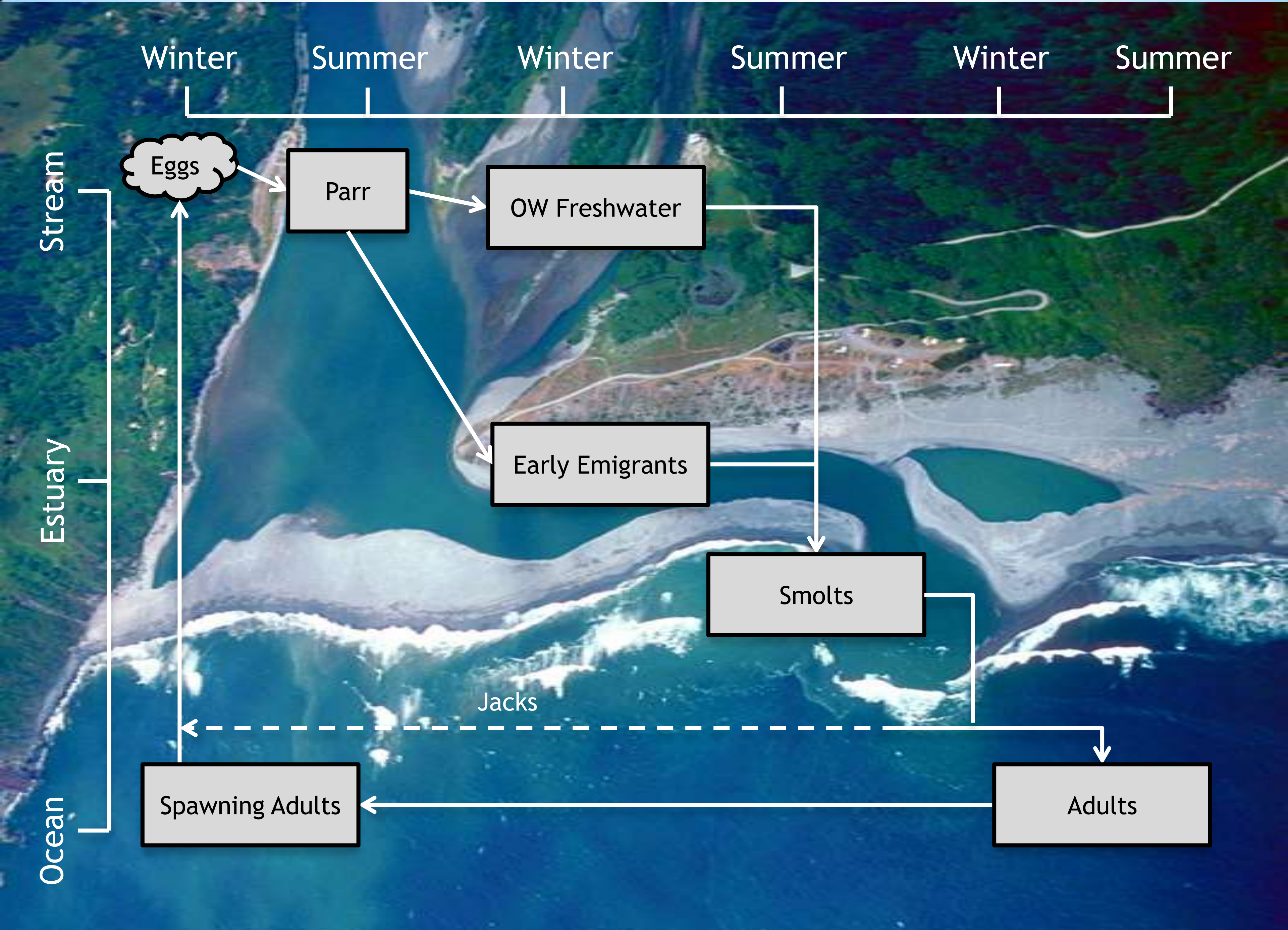


Winter
Summer
Winter
Summer
Winter
Summer
Stream
Estuary
Ocean
Eggs
Parr
OW Freshwater
Smolts
Jacks
Spawning Adults
Adults
Credit: US Corps of Engineers

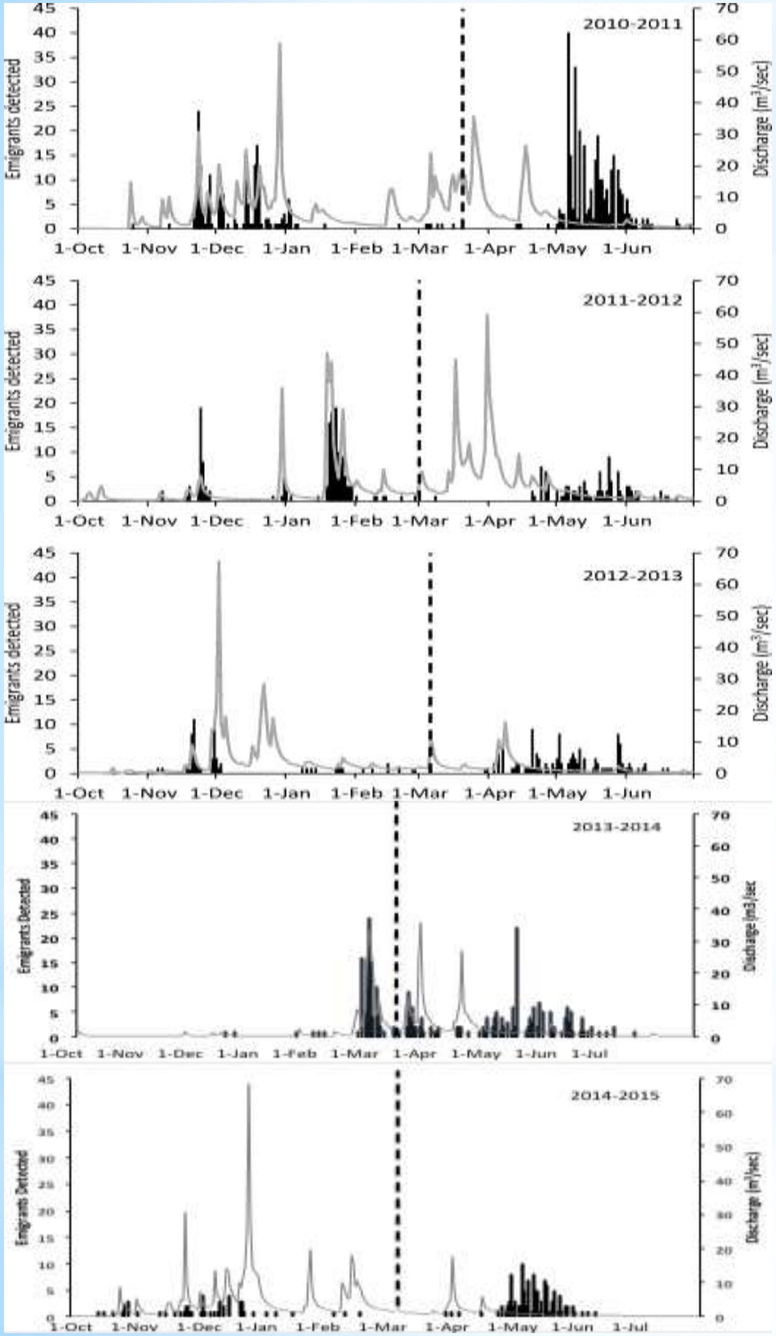


Credit: US Corps of Engineers


Winter
Summer
Winter
Summer
Winter
Summer
Stream
Estuary
Ocean
Eggs
Parr
OW Freshwater
2yr FW Residents
Fry
Parr
Parr
Early Emigrants
2yr FW Residents
Fry
Smolts
Early Ocean
Jacks
Spawning Adults
Adults
Credit: US Corps of Engineers



Credit: US Corps of Engineers



Early Emigrants

- Missed by spring migrant trapping
- Early emigrants account for up to 29% of fall tagged fish (2010-2015)
  - Up to 70+% in some Washington streams (Bennett et. al. 2014)
- Many rear in the estuary and associated tidally influenced habitat

Study Goals

1. Build a stage structured population model for Freshwater Creek CA

1. Quantify early emigration contribution to population dynamics

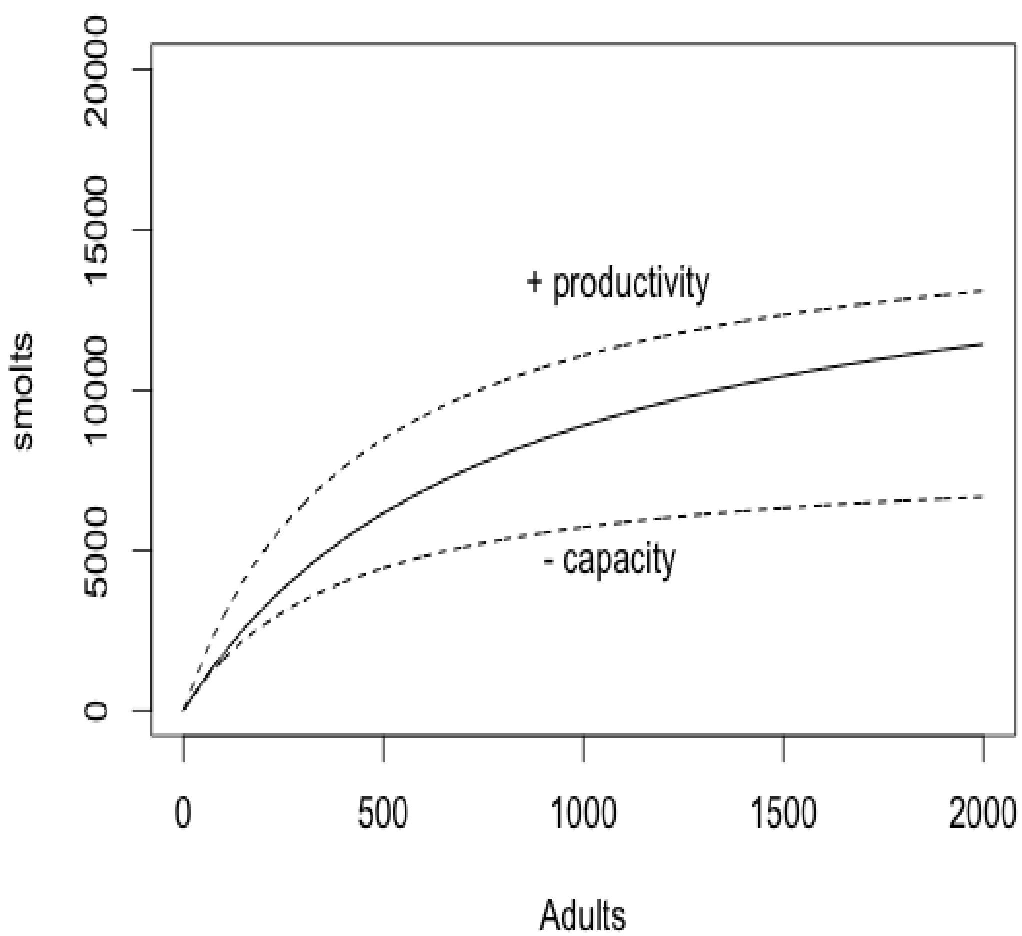
1. Identify limiting stages

1. Quantify population response to alternative restoration scenarios

Credit: Jessica Newley

Basic Model Framework

- Modified Leslie matrix design
- Survival and early emigration quantified at the reach scale
- 6 reaches and estuary included
- Density dependent functions to model changes in productivity and capacity
- Life stage survival quantified by data from Freshwater Creek LCM



Quantifying Model Parameters

- Cormack-Jolly-Sebert modeling using Program Mark and standard statistical methods

- CDFW data:
  - Overwinter survival
  - Early emigration parameters
  - Marine survival
  - Carrying capacity
  - Spring/Summer survival
  - Fecundity + (Shapivalov and Taft 1954)

↓

- Literature values used for stages with incomplete/missing data:
  - Egg survival (Moring and Lantz, 1975)

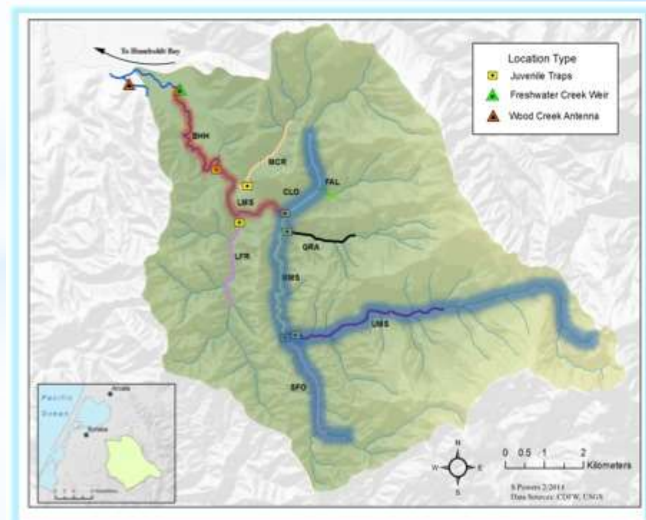
<°)))><

CJS Modeling Results

Overwinter Survival & Probability of Early Emigration:

- Both are highly variable between years
- Best fitting models vary from year to year
  - Multiple drivers: may be different from one year to the next
    - Length
    - Watershed area
    - Specific reach (habitat)
    - Mainstem vs. Tributaries

>



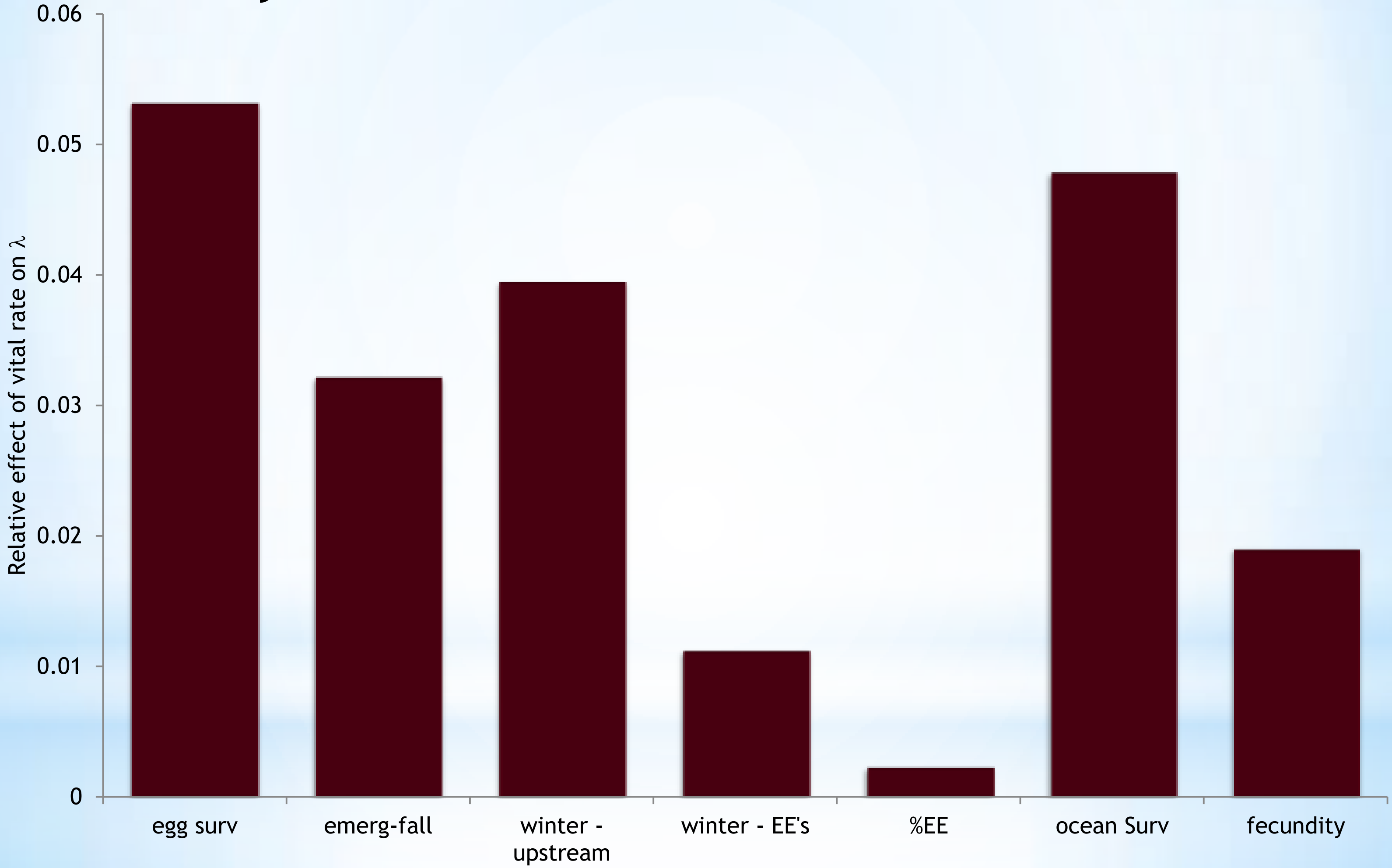
The Code Slide

```
cor.matrix <- matrix(0,nrow=6,ncol=6)
    for(i in 1:6){
      for(ii in 1:6){
        mod <- cor.test(ow.1[,i],ow.1[,ii])
        if(mod$p.value < 0.1){
          cor.matrix[i,ii] <- mod$estimate}
      }}
    names <- c("BHH","LMS","MMS","UMS","CLO","SFO")
    rownames(cor.matrix) <- paste(names)
    colnames(cor.matrix) <- paste(names)

    cor.matrix

    corrmx <- cor.matrix# correlation matrix

    eig <- eigen(corrmx) #get them eigens
    W <- eig$vectors # Makes matrix of eigen Vectors: W
    D <- eig$values # Makes matrix of eigen Values: D
    D12 <- sqrt(abs(matrix(diag(D),nrow=np))) # D12 is a matrix of the square
root of the eigen values on diagonal, the rest of the elements are zero

    C12 <- W%*%D12%*%t(W) # Generates the square root of correlation
matrix corrmx

results <- matrix(NA,nrow=tmax,ncol=np)
    colnames(results) <- paste(names)

    for( tt in 1:tmax){  # Loop for each years vital rates
      normvals <- matrix(rnorm(np))  #makes a set of random standard normal
values
      corrnorms <- C12%*%normvals #make them norms into correlated norms
      bhh.vr <- betaval(vrmeans[1],vrvars[1],normfx(corrnorms[1])) #converts
each normal into the beta equivalent via the Cumultive distribution value
      lms.vr <- betaval(vrmeans[2],vrvars[2],normfx(corrnorms[2]))
```

```
if(Nt[5]>10){
        total.ad <- round(Nt[5])  #this is the total number of adults returning to
spawn
        fems <- sum(rbinom(total.ad,1,0.5)) # This is the total number of those
that are female
        if(fems<1){fems<-1} # This is just so the code doesn't break down if by
statistical anomaly there are no females
        f.lengths <- rnorm(fems,66.90909,5.933774) #normally distributed
lengths of all the females
        egg.counts <- sapply(f.lengths,l.egg) #applying the length to egg function
to the length of each female
        f <- sum(egg.counts)/fems #getting the average egg count for the cohort
        scour<- sum(rbinom(fems,1,0.85))/fems # calculating the redd mortality
rate due to scour (nickelson and lawson 1998)
        if(scour==0){scour<-0.85}
        fem.pct <- fems/total.ad #percentage of the adults that are female
        Fert <- f*fem.pct*scour  #fertility rate
      }else{Fert <- f*0.5*.85}



      M <- matrix(data=c(0,    0,   0,   0,  Fert,
                    Y1,   0,   0,   0,   0,
                    0,  Y2n,   0,   0,   0,
                    0,  Y2e,   0,   0,   0,
                    0,    0,   Y3n, Y3e, 0

      ),
```

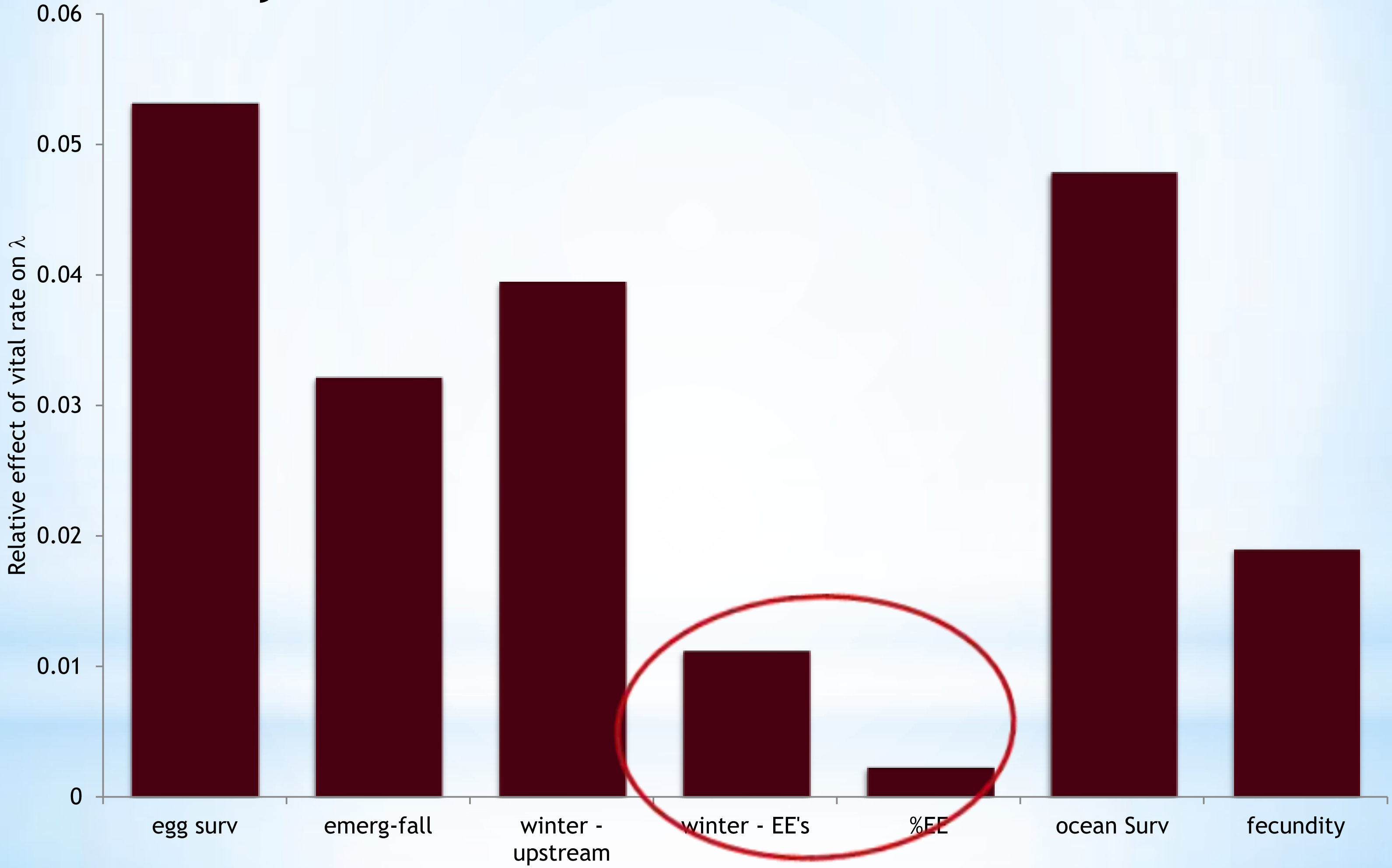
Sensitivity Analysis

- Life cycle simulation



Sensitivity Analysis

- Life cycle simulation



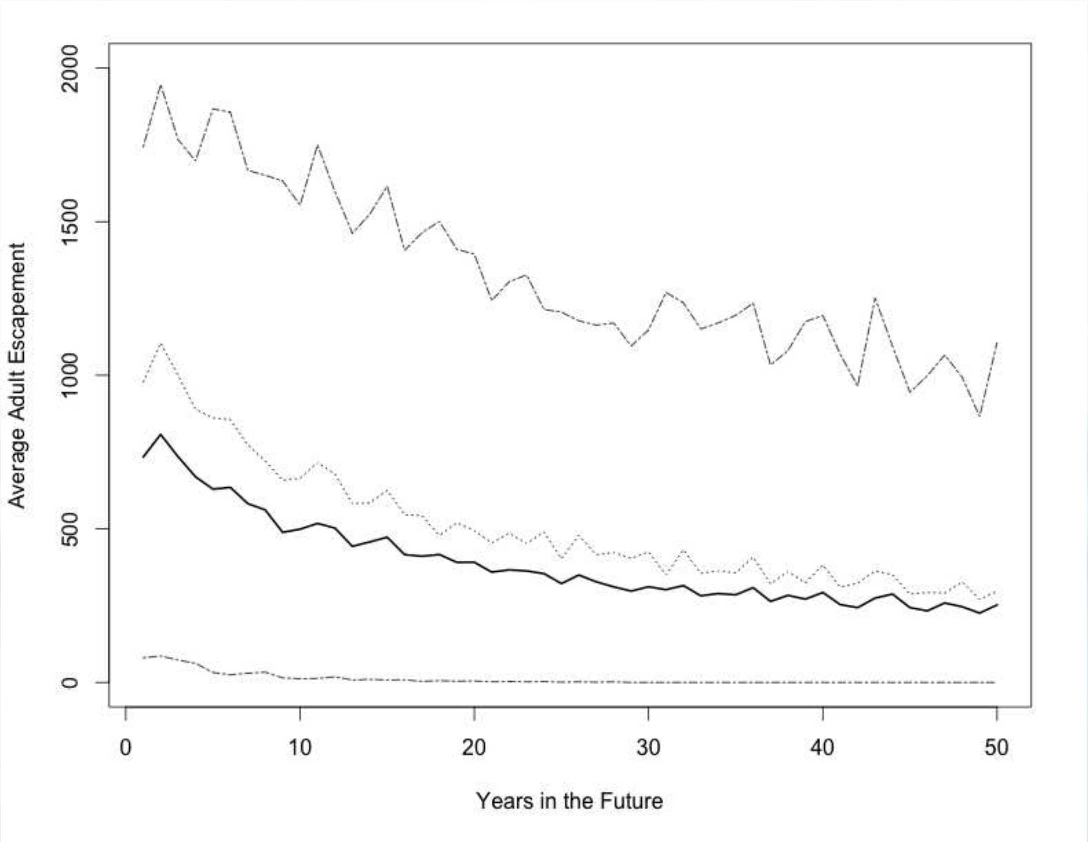
Minimal relative effect of EE parameters on population growth

Population Trajectory and Extinction Probability
Simulated population runs to 50 years

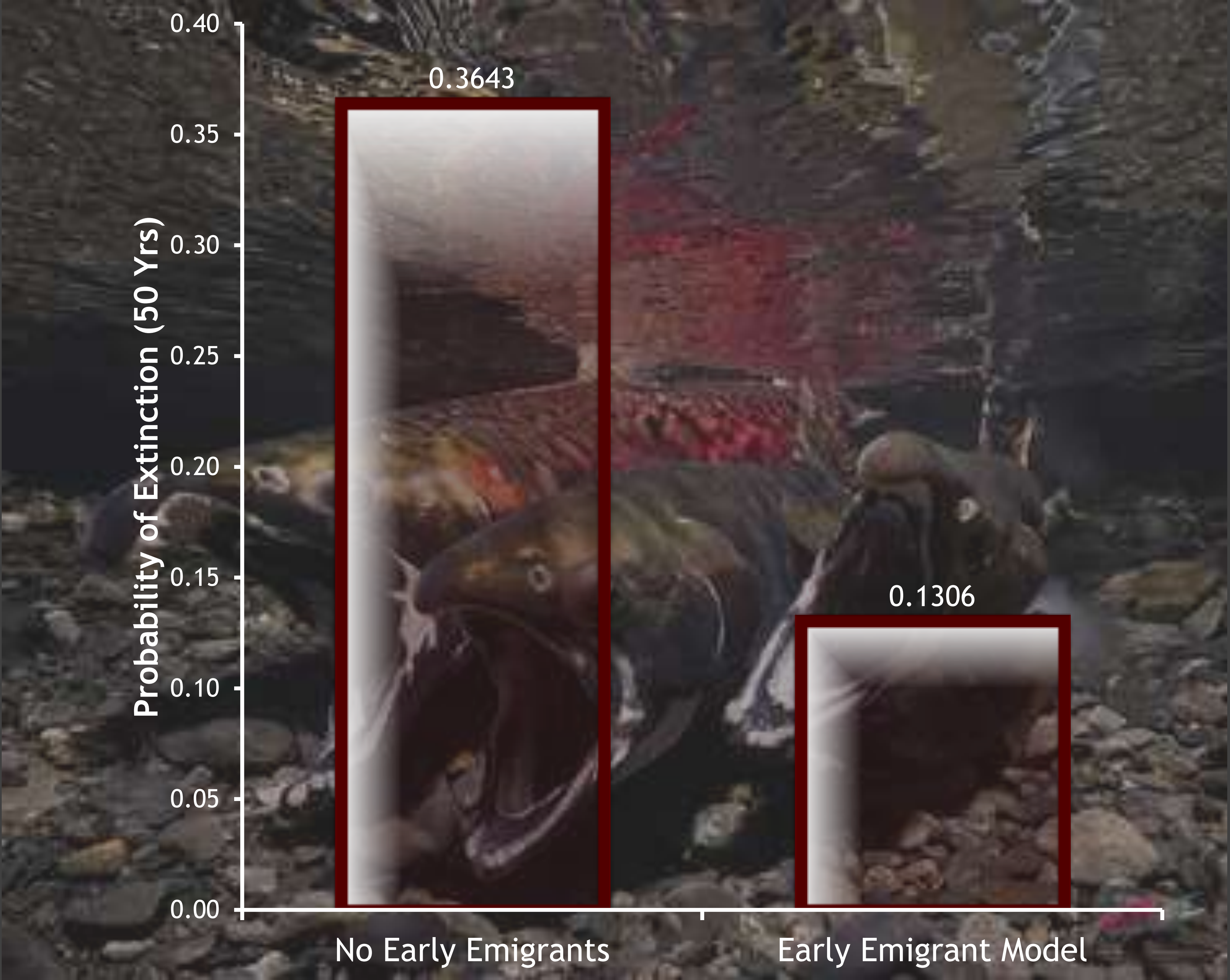
Metrics:

- Extinction Threshold= 20 > Spawners for 3 consecutive years

- Average spawner escapement over the last 10 years of simulation




500
450
400
350
300
250
200
150
100
50
0
Average Adult Escapement (40-50 Yrs)
361
436
No Early Emigrants
Early Emigrant Model
Credit: Paul Vecsei

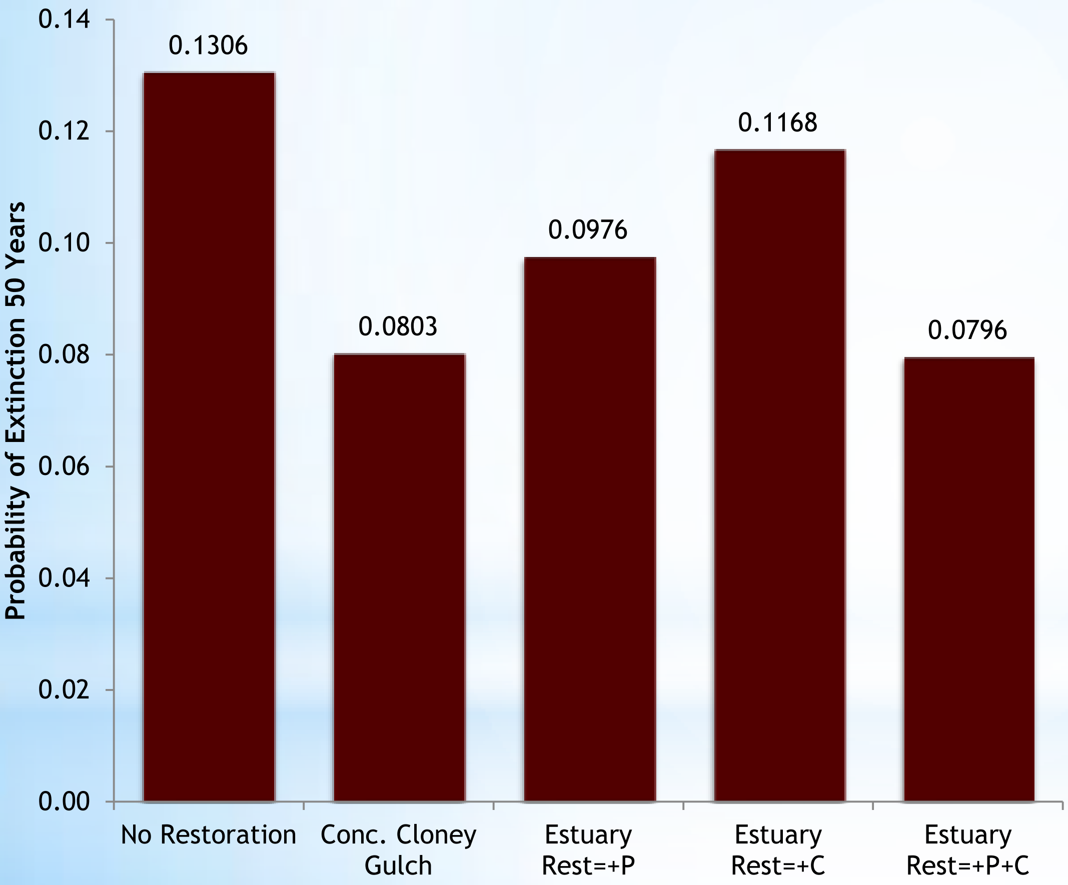

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Probability of Extinction (50 Yrs)
0.3643
0.1306
No Early Emigrants
Early Emigrant Model

Slow water – Survival Relationship and Restoration Scenarios

- Winter slow water habitat associated with overwinter survival (In prep: John Deibner-Hansen Masters Thesis)
- Incorporate additions of slow water habitat into modeling scenarios (Solazzi 2000)
- Variable configurations
- Little data for how estuary restoration affects early emigrants
  - Modeled under three scenarios:
    - + Productivity
    - + Capacity
    - +Productivity + Capacity

Credit: Molly Gorman

Simulated Restoration Scenarios



Conclusions:

Early emigrant life history is important for population viability

Managing for multiple life history patterns is important for individual populations ability to cope with annual variability and extreme environmental events

Early emigrant estimates represent minimums:

- Stream estuary ecotone provides productive habitat for smolt emigrants on their way to the ocean
- Estuary restoration efforts provide additional off channel refugia during winter high flows

Further study of coho usage of SEE needed to improve parameter estimates (+productivity? +capacity? Overwinter survival?)

Acknowledgments

- Darren Ward - HSU
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- John Deibner-Hansen - HSU
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Questions?