Longfin Smelt Hatching Distribution and Entrainment Analysis

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Outline

- Longfin smelt background
- San Francisco Estuary hydrodynamic model
- Particle-tracking model
- Longfin smelt hatching distribution analysis

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Hatching distribution, abundance, and losses to freshwater diversions of longfin smelt inferred using hydrodynamic and particle-tracking models

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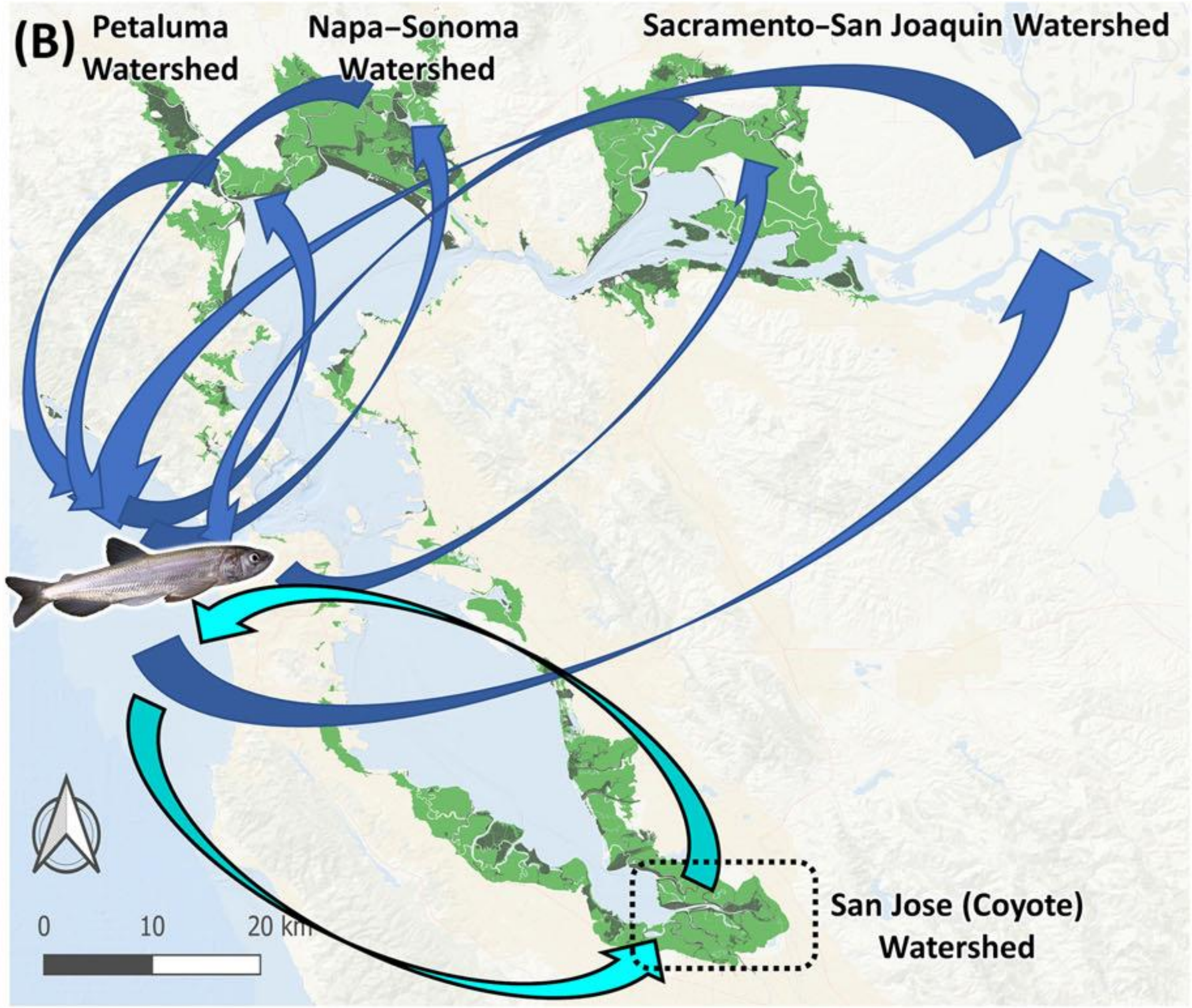
Longfin Smelt Life Cycle

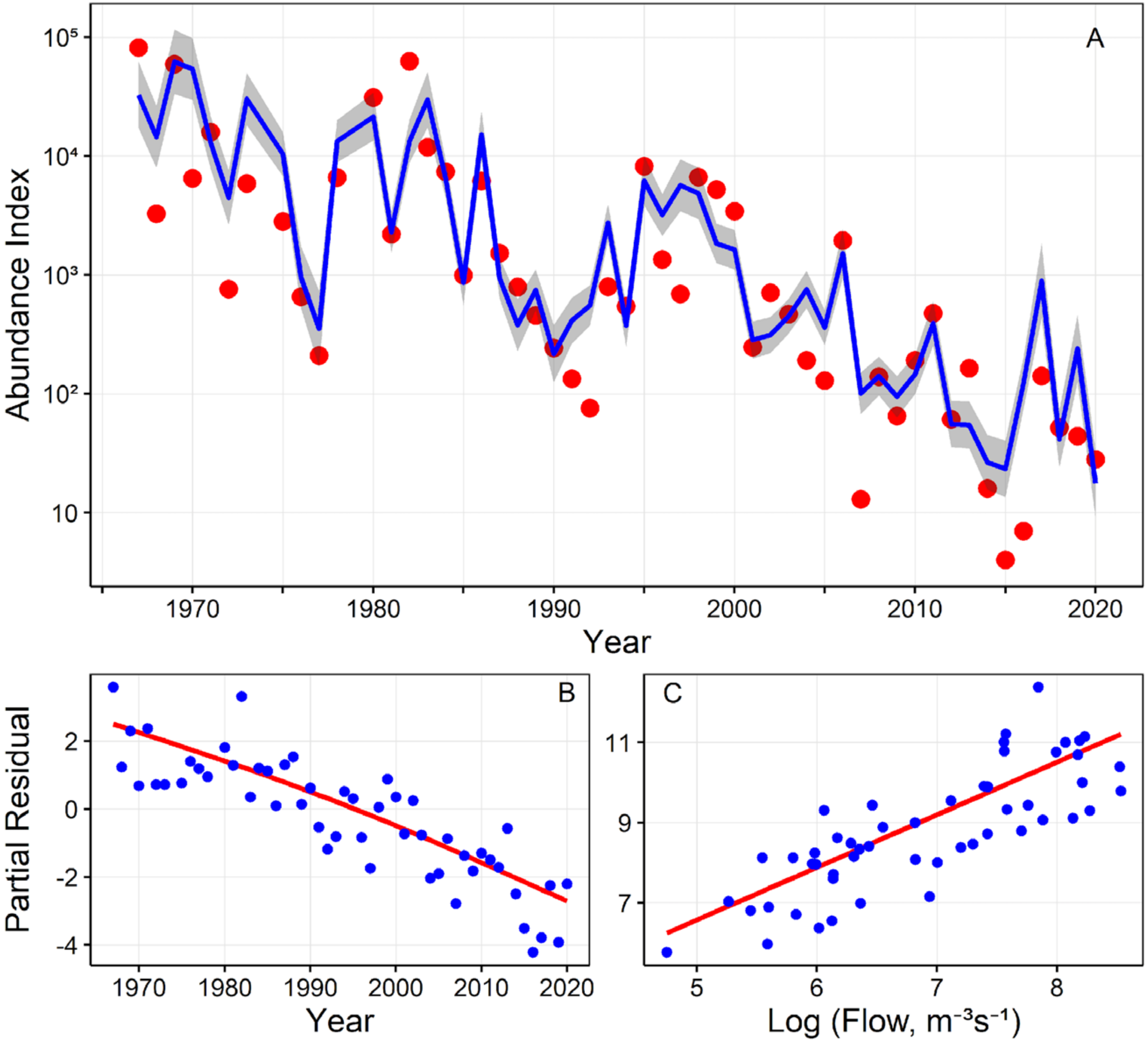
- Live up to 2 years
- Hatch in brackish and fresh water
- Rear in estuary and ocean
- Return to estuary to spawn at age 2



Lewis et al. 2019
The Scientific Naturalist

Long-term decrease in fall longfin smelt abundance index

At least partially related to abundance of prey (food)



Higher abundance in wet years.

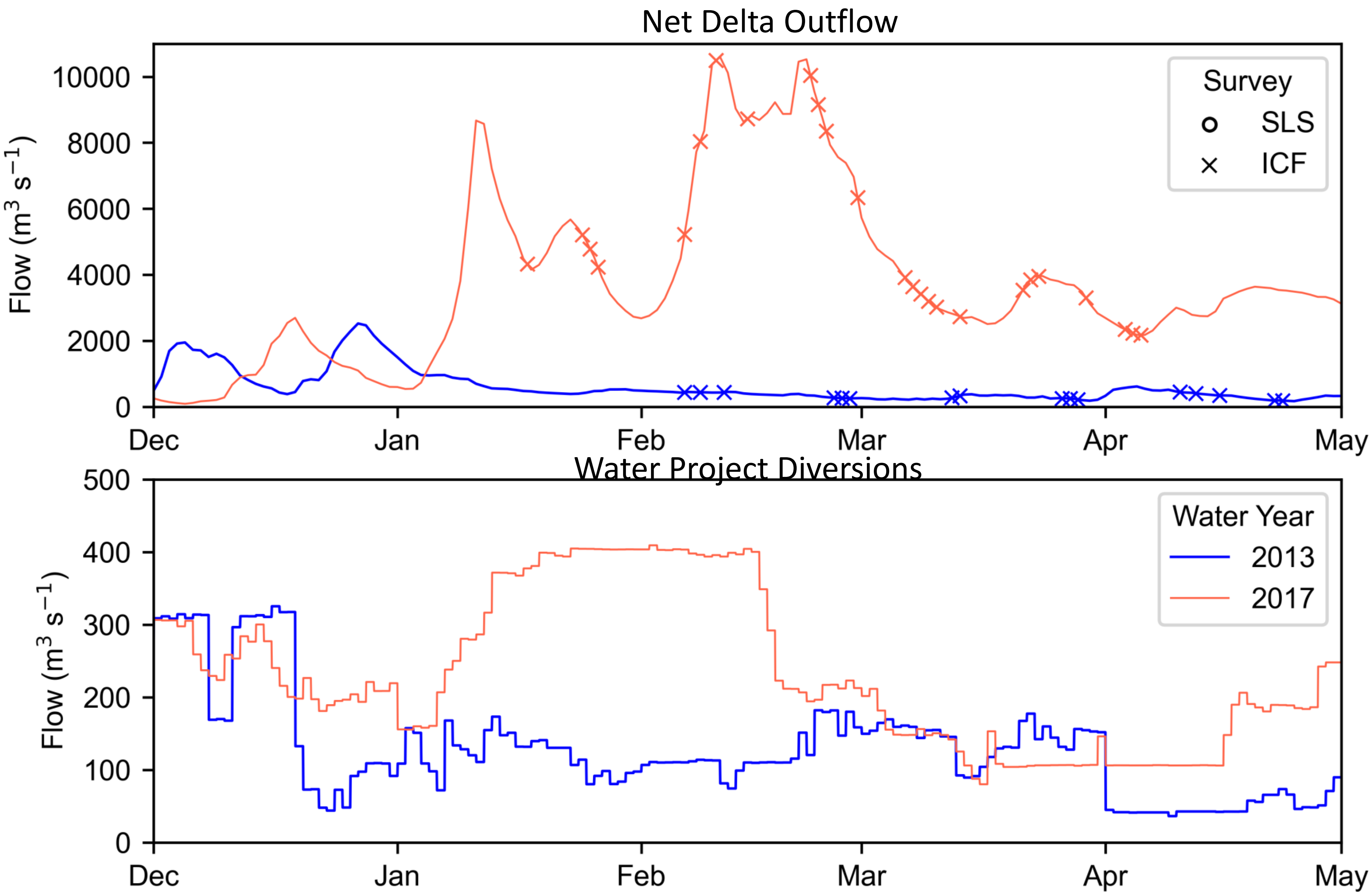
Relationship to log flow or X2.

Reasons unknown but entrainment losses have been hypothesized to be a contributor

Longfin Smelt Analysis Ingredients

- Data
  - Catch data by length
  - Size at hatching, growth rate
- Modeling and analysis
  - Hydrodynamic modeling
  - Movement from hatching to trawl (particle tracking)
  - Inference of hatching rates

Key Flows, 2013 and 2017

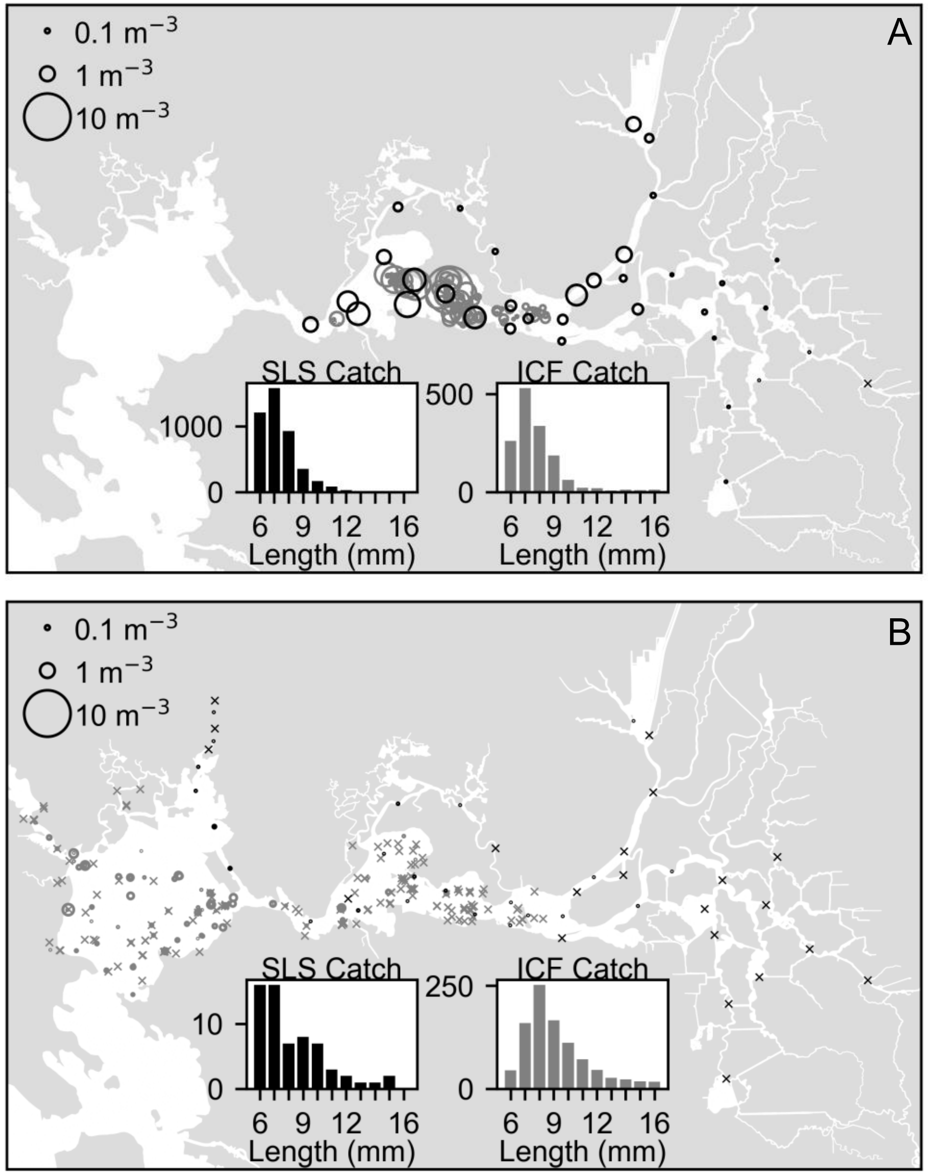


Larval Longfin Smelt Catch and Size Distribution

SLS – Smelt Larva Survey (CDFW)

ICF – ICF International trawls

2013



Relatively high catch in Suisun Bay

No data in San Pablo Bay

Median length ~ 7 mm

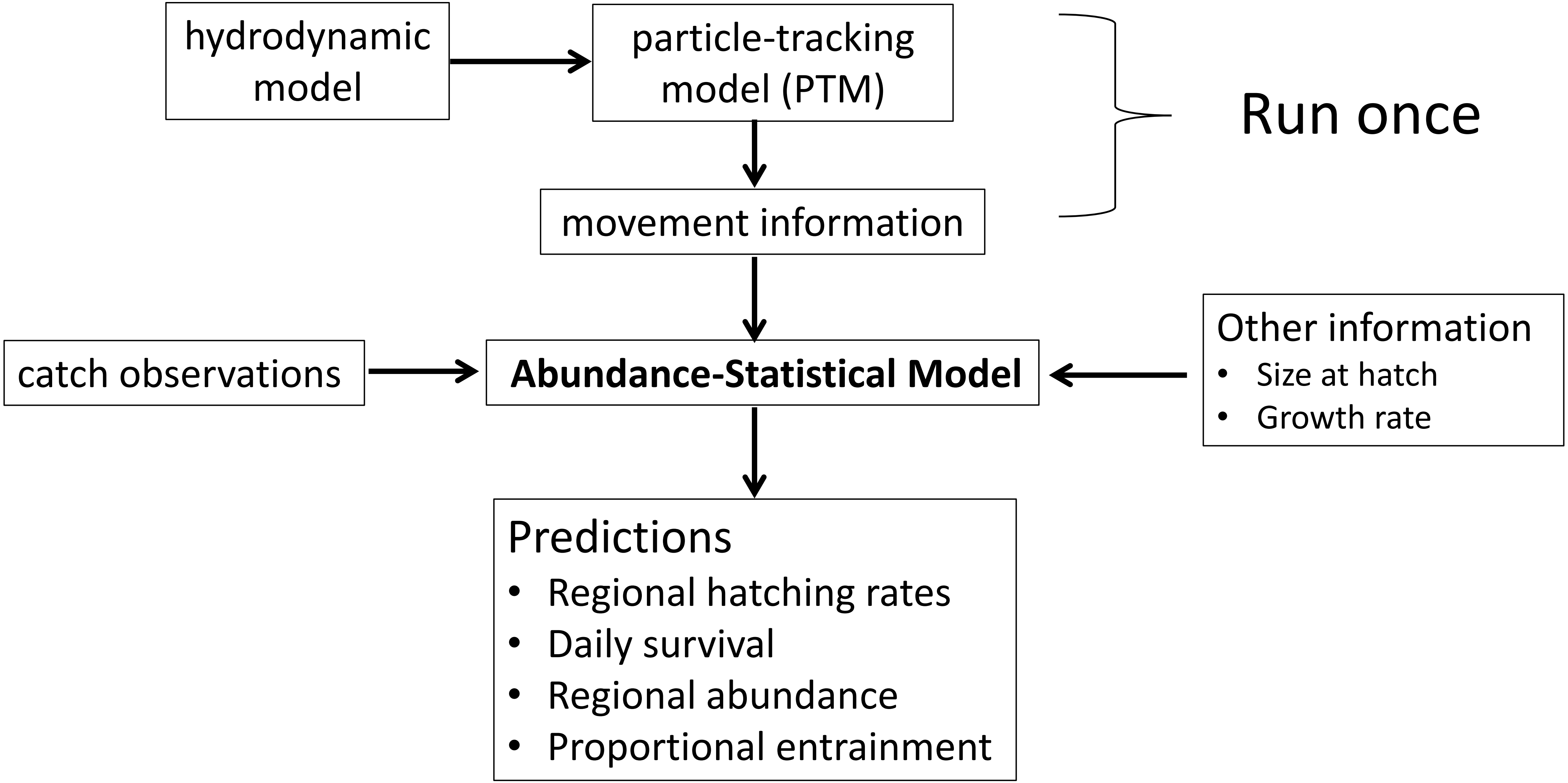
2017

Relatively low catch in Suisun Bay

Most catch in San Pablo Bay

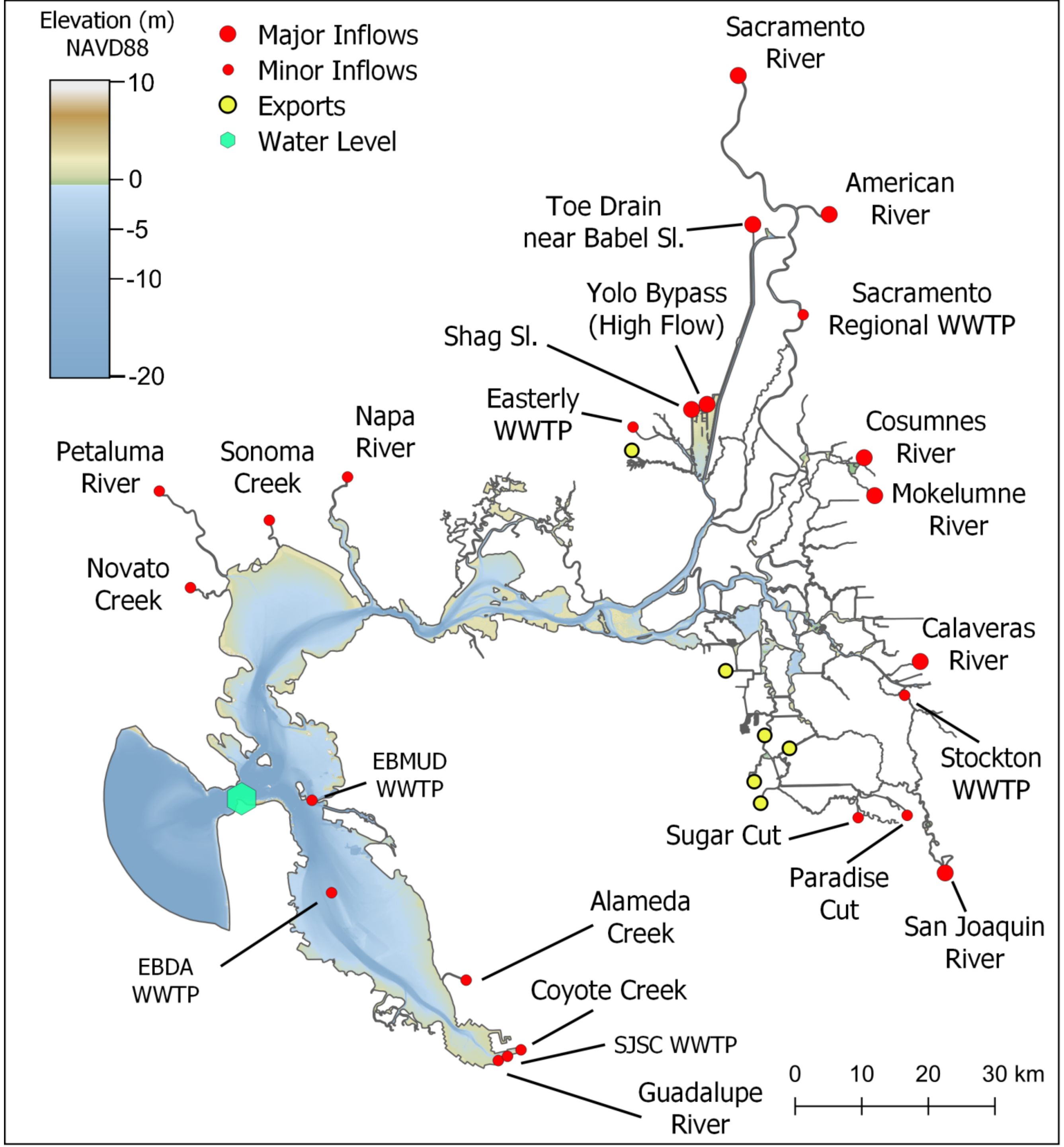
Median length ~ 7 mm

Analysis Approach

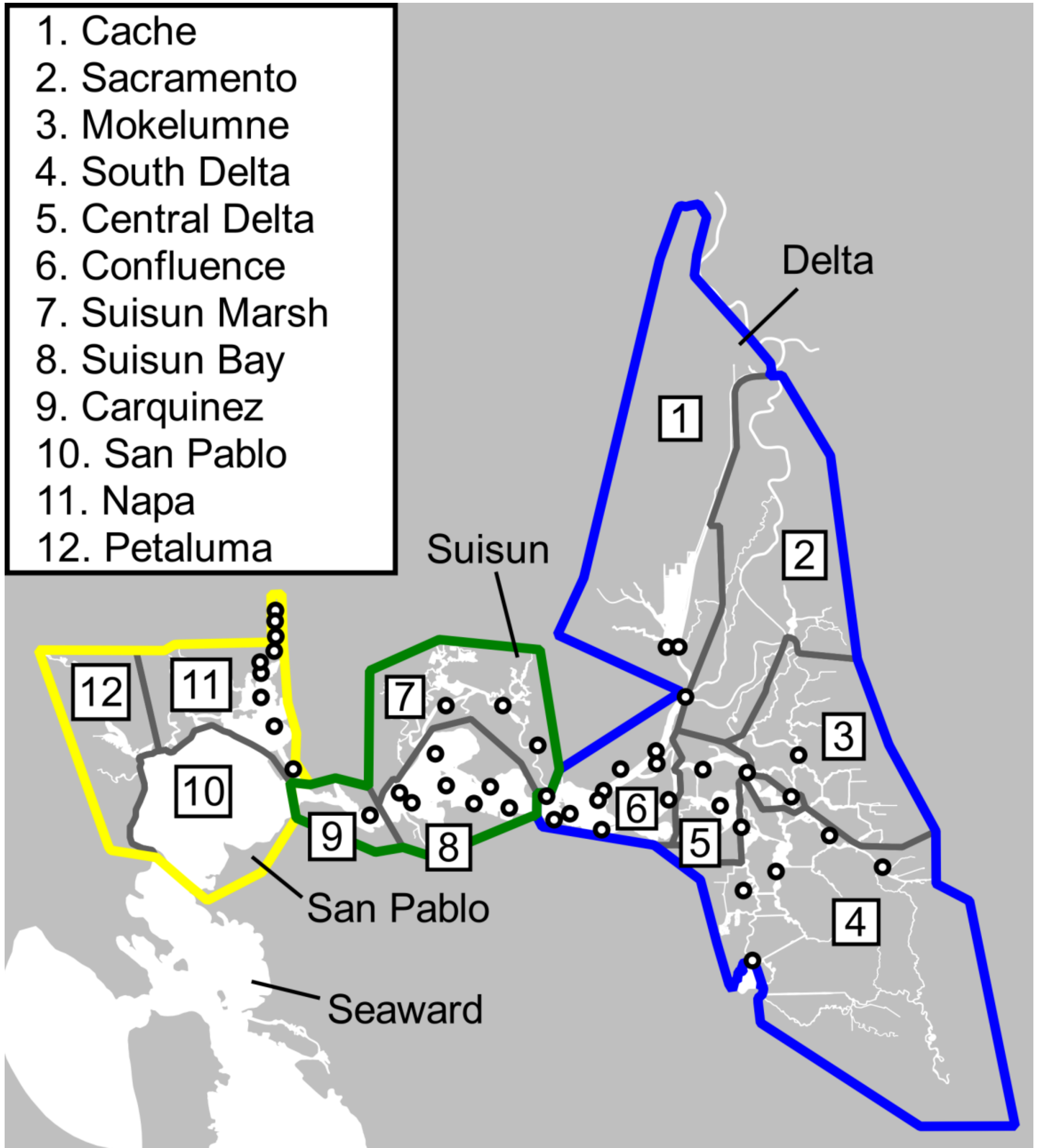


Hydrodynamic model: RMA San Francisco Estuary UnTRIM

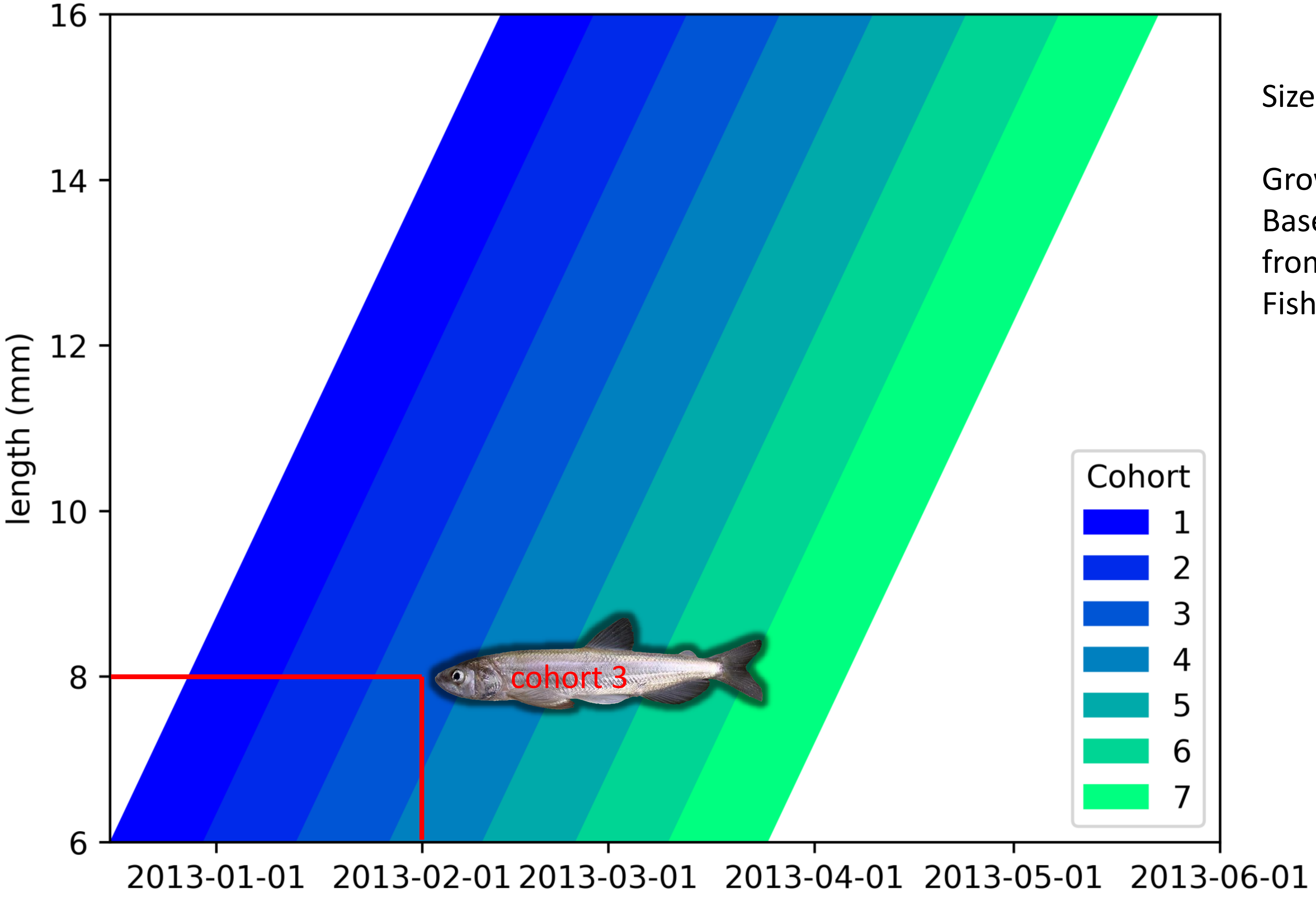
Boundary Conditions



Regions in Hatching Distribution Analysis



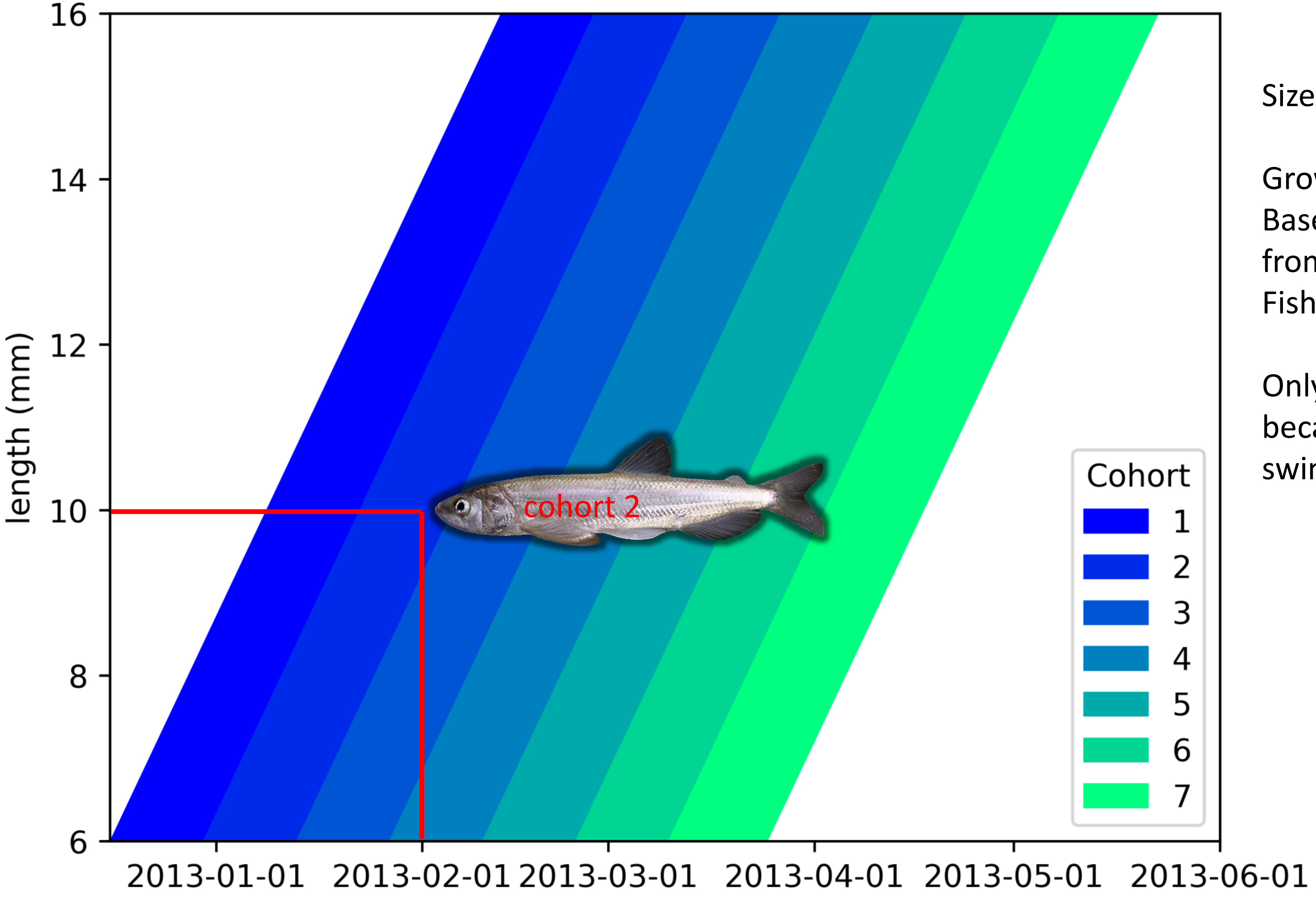
Cohort Definitions



Size at hatch = 6.2 mm

Growth rate = 0.2 mm/day
Based on otolith data for wild fish from Otolith Geochemistry and Fish Ecology Laboratory, UC Davis

Cohort Definitions

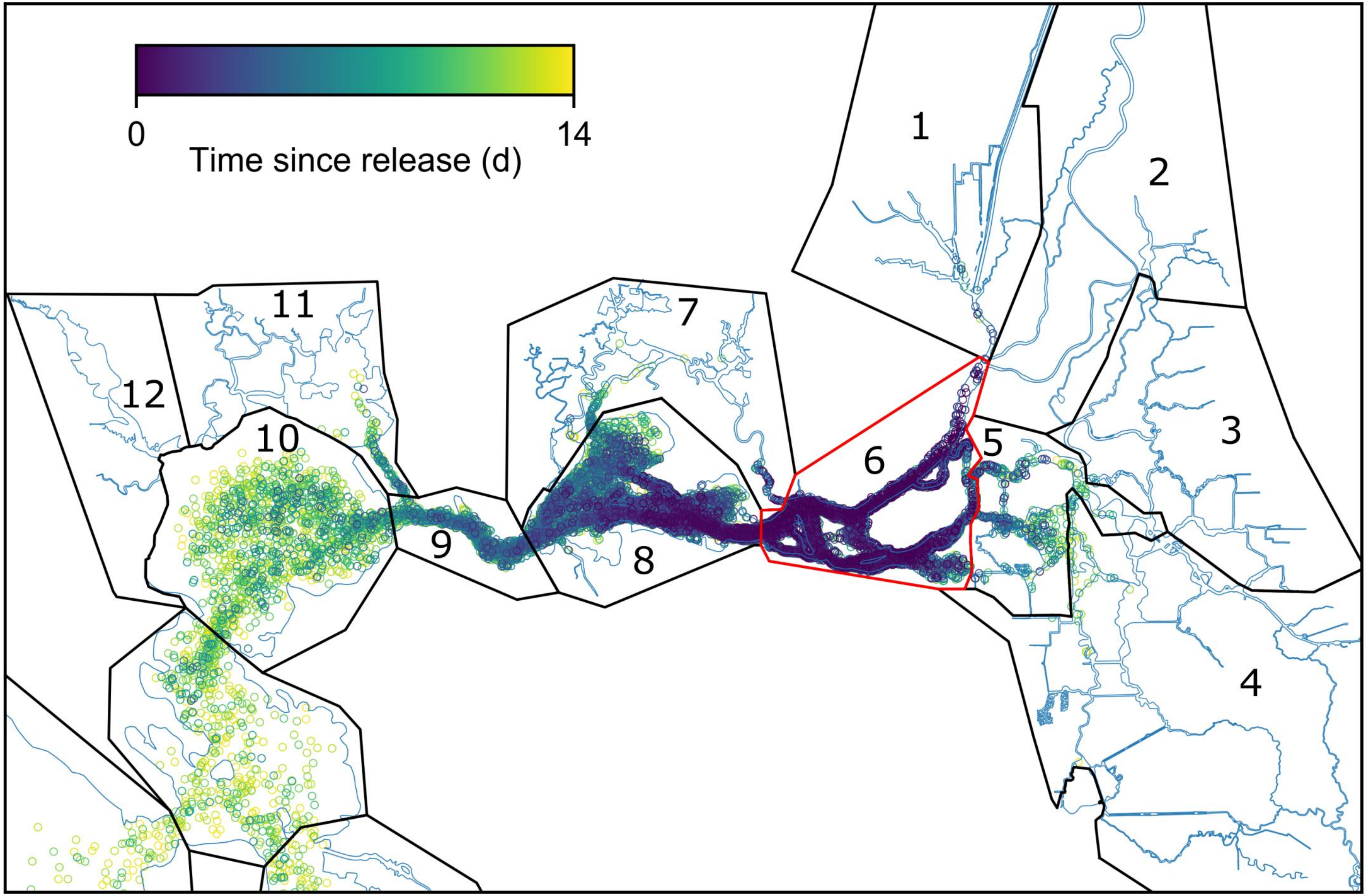


Size at hatch = 6.2 mm

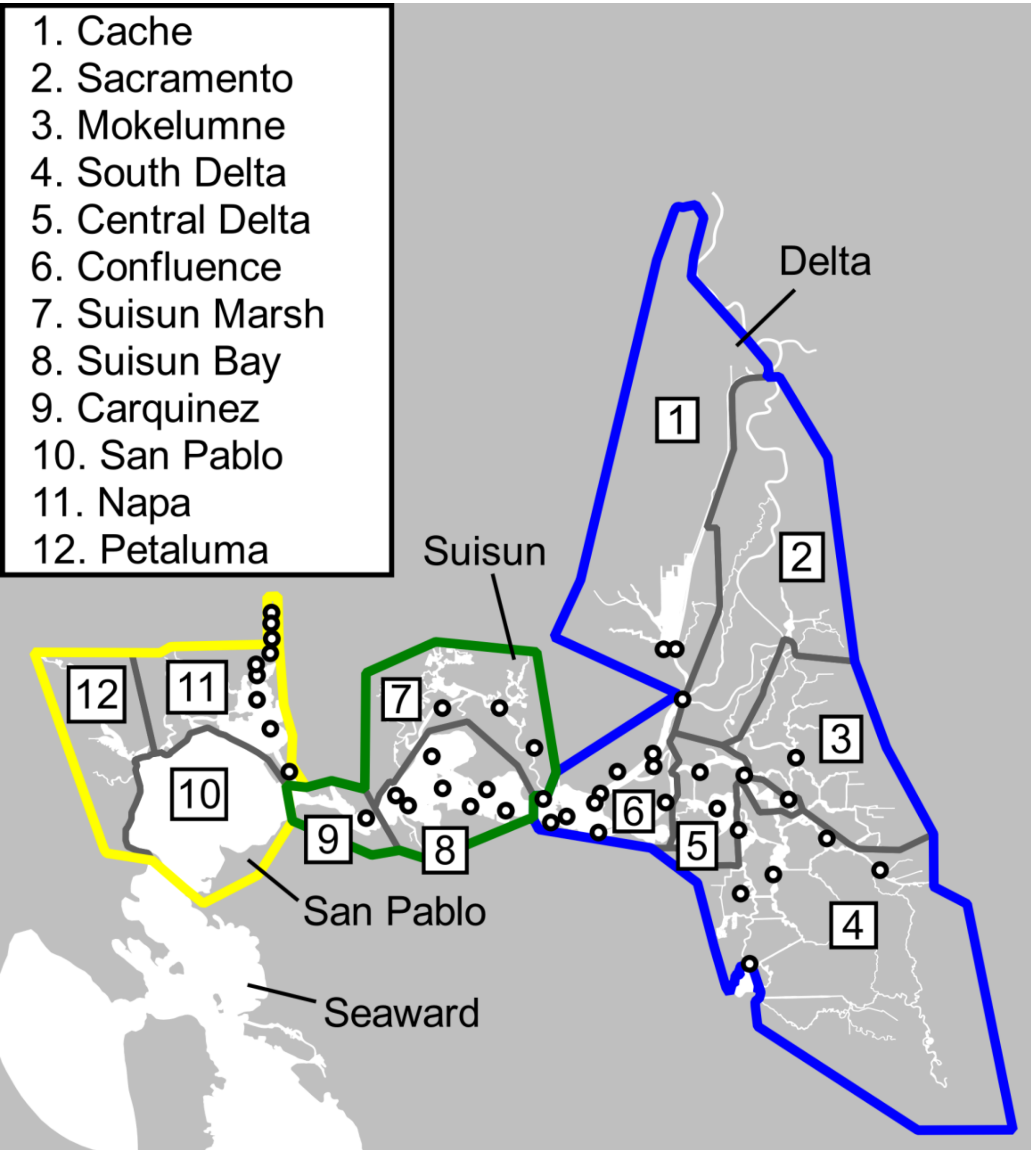
Growth rate = 0.2 mm/day
Based on otolith data for wild fish from Otolith Geochemistry and Fish Ecology Laboratory, UC Davis

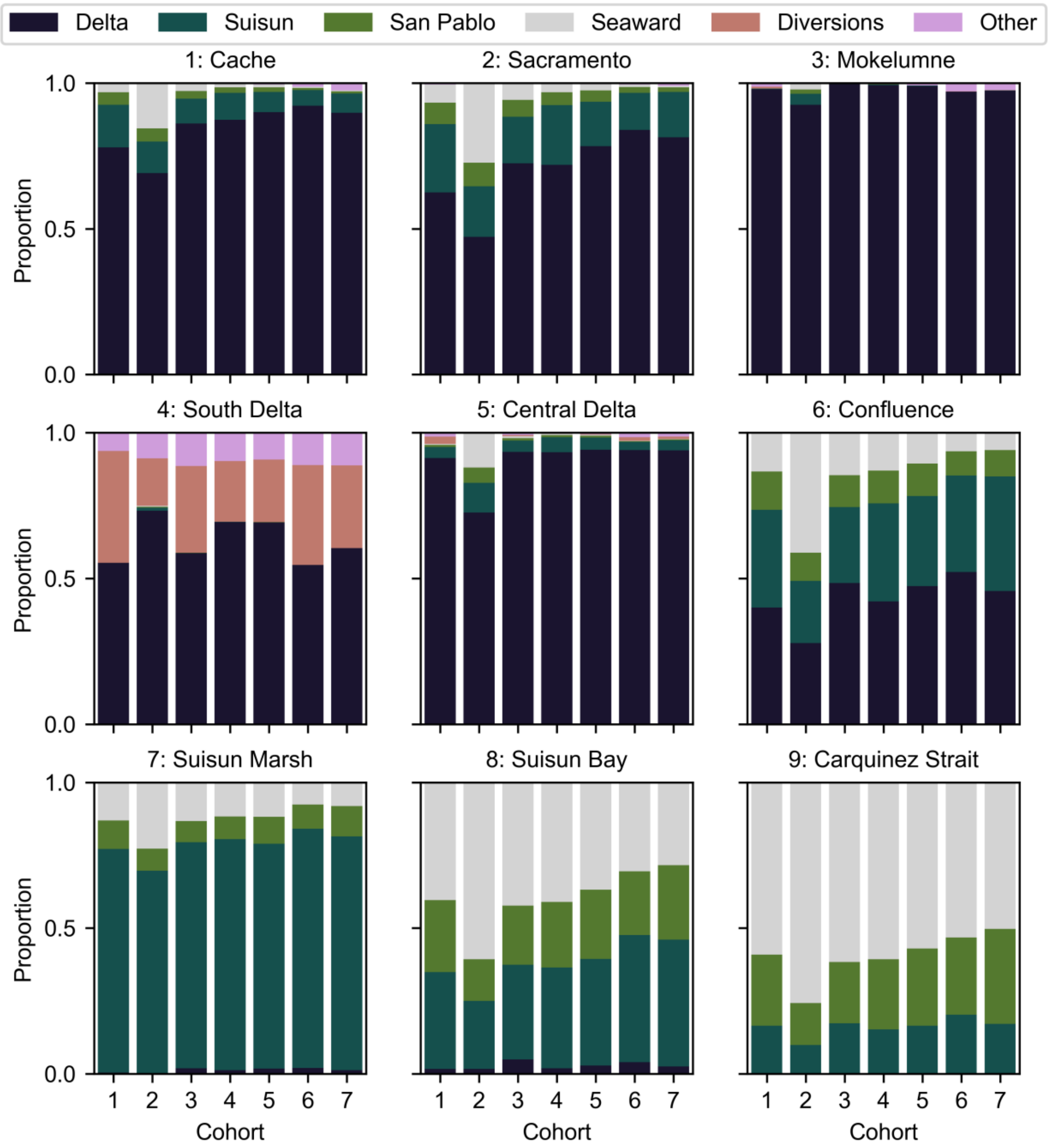
Only tracking fish to 16 mm because larger fish exhibit active swimming behaviors

Cohort 5
From Confluence
Starting Feb 24, 2013



Movement over each two week hatching period





Regional Abundance Model

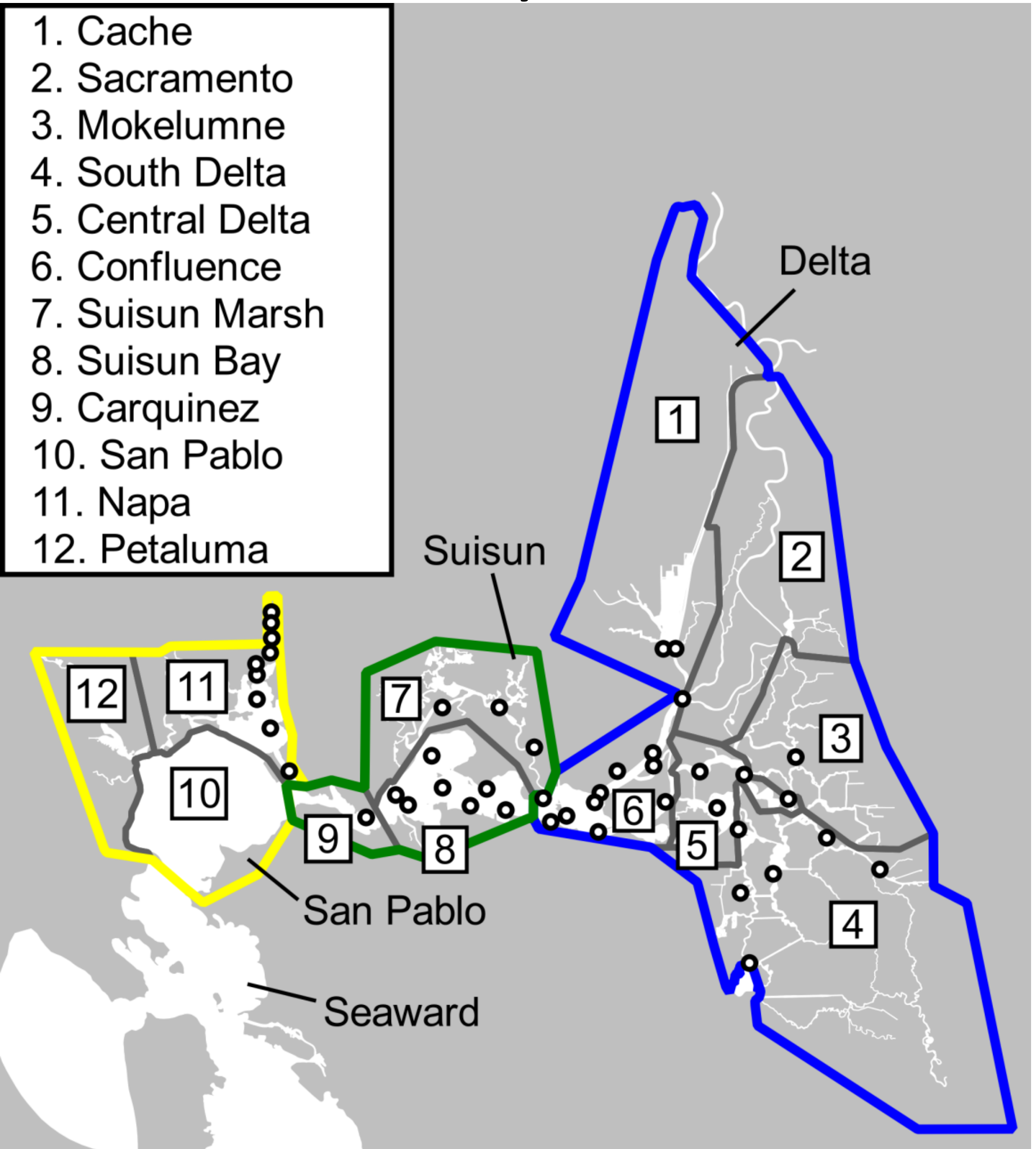
$$N_{n,i,d} = e^{\gamma_n}\Phi(\phi, d, s_n) \sum_{j}^{nsources} \theta_{n,j}\lambda_{n,j,i,d}\beta_{n,d-s_n}$$

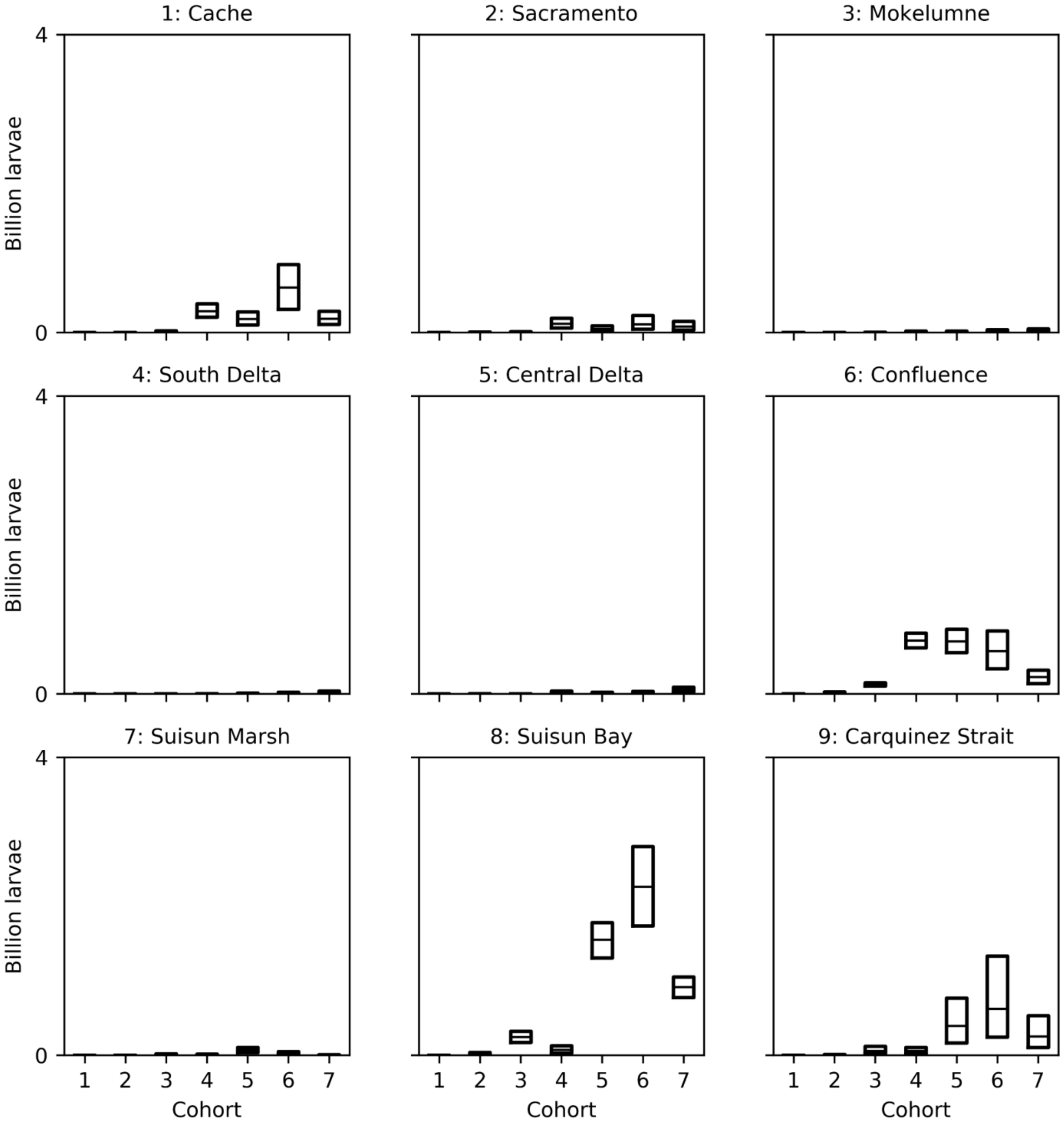
- n - cohort index
- i - region index
- j - source region index
- d - day index
- s_n - start date of hatching for cohort *n*
- $nsources$ – number of source regions
- $N_{n,i,d}$ - predicted regional abundance of cohort *n* in region *i* on day *d*
- $\lambda_{n,j,i,d}$ - fraction of larvae from cohort *n* and source region *j* located in region *i* on day *d*
- ϕ - daily survival
- e^{γ_n}- total number of larvae hatched in cohort *n*
- $\theta_{n,j}$ - fraction of the cohort *n* hatched in source region *j*
- $\beta_{n,d-s_n}$ - Fraction of hatched larvae in cohort *n* that remain larvae on day *d*

Assumptions

- Larvae are passive up to 16 mm length
- Constant in time and space survival
- Hatching uniform within each region
- Hatching rate is constant within each 14 day cohort period
- Negative binomial distribution of catch
- Multinomial for size distribution
- No size selectivity of trawls

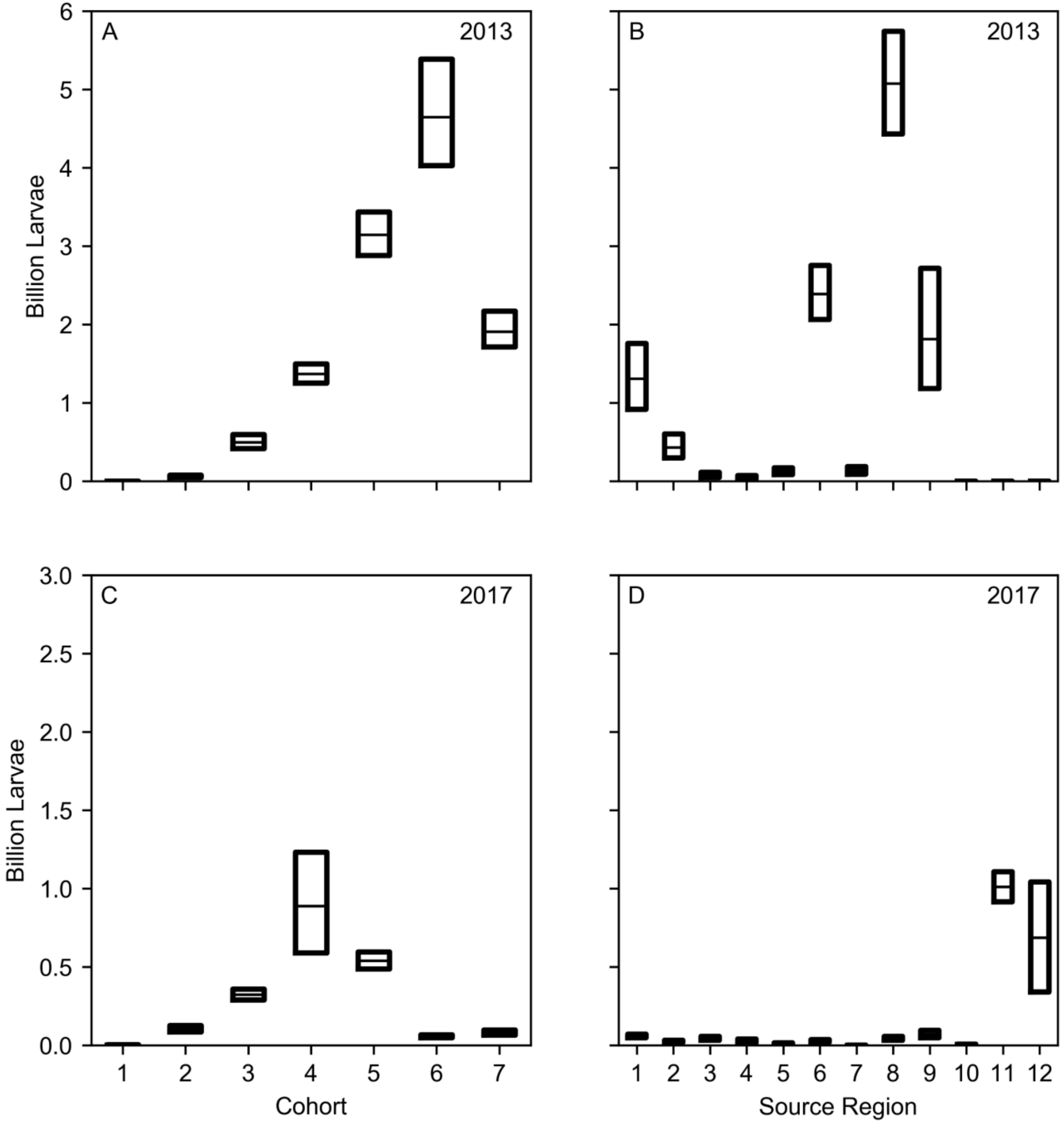
Where and when did they hatch?





When? Where?

February-March Peak in 2013



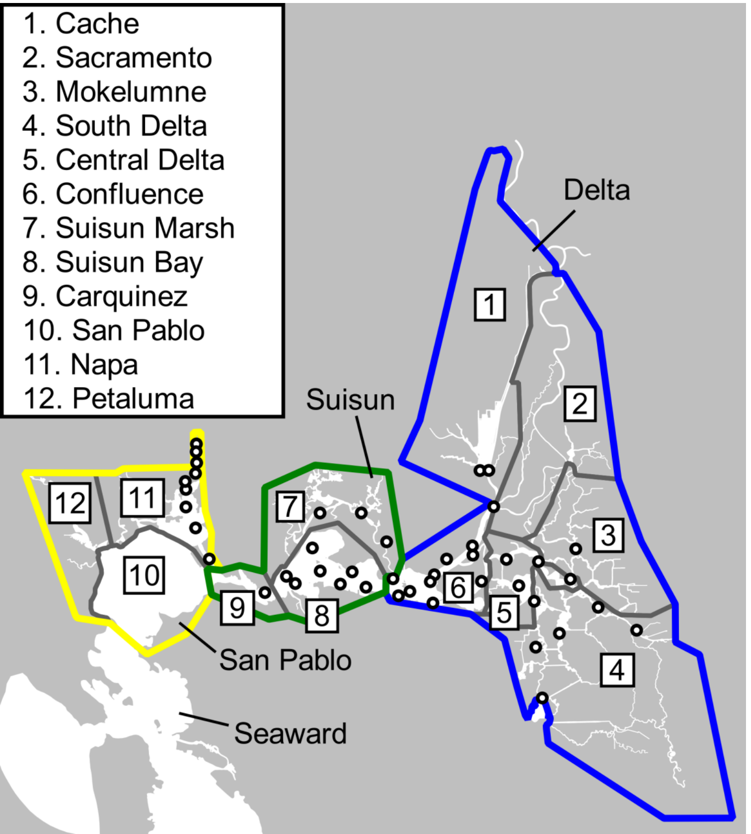
Dry: Suisun Bay

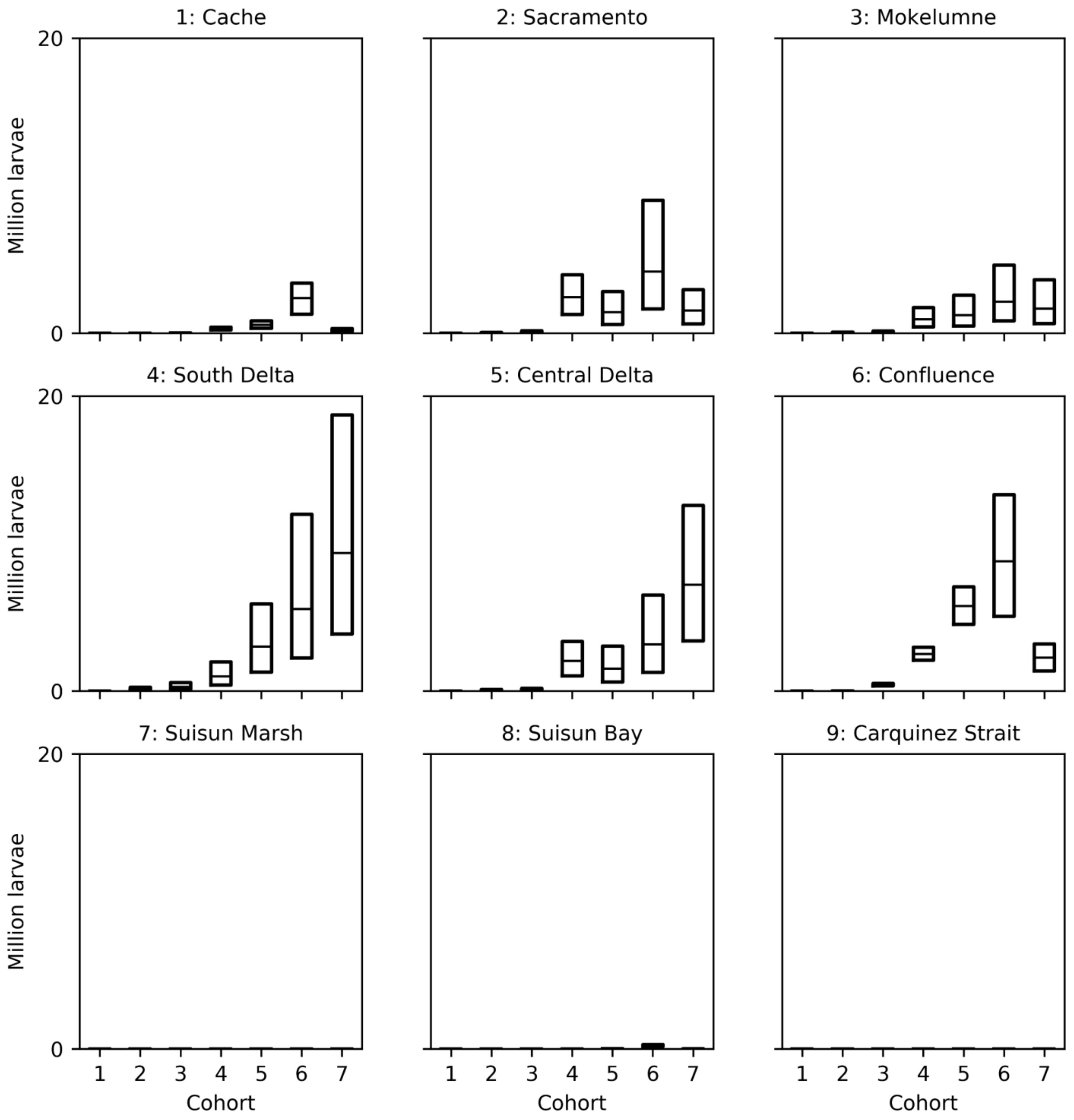
Early February Peak in 2017

Wet: San Pablo Bay

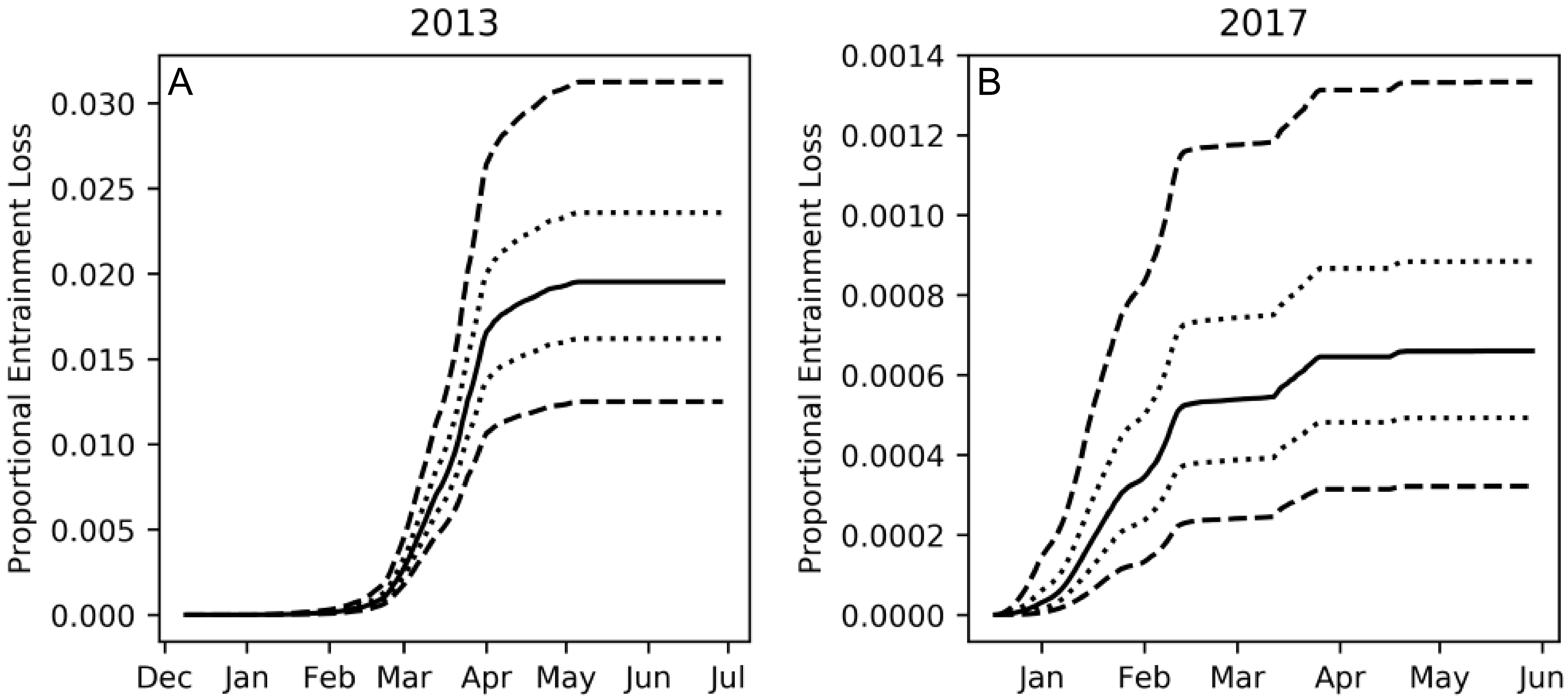
Which larvae were entrained?

South Delta contributed majority of entrained larvae despite limited hatching





Proportional Entrainment of Larvae



Conclusions

- Limited hatching in the central and south Delta
- Small entrainment losses
- Wet weather shifts hatching distribution seaward to San Pablo Bay
  - Smelt Larva Survey does not capture spatial extent of hatching during wet years
- Companion paper estimated that low entrainment was common

Estuaries and Coasts
https://doi.org/10.1007/s12237-022-01101-w

Population Abundance and Diversion Losses in a Threatened Estuarine Pelagic Fish

Wim Kimmerer[1] · Edward Gross[2]

Thank you!

- Funding from CDFW (Prop 1)
- Trawl Data from CDFW and ICF
- Hydrodynamic model development and application
  - Steve Andrews
  - Richard Rachiele

Extra Slides

Sensitivity Analysis Table

Growth Rate (mm d^{-1})	α	Hatching (billions)	Vertical Distribution	Fraction Hatched in Delta	Survival (d^{-1})	Proportional Entrainment Losses
0.19	1.106	11.8	well-mixed	0.385	0.964	0.0195
0.15	1.106	8.57	well-mixed	0.508	0.975	0.0285
0.22	1.106	17.8	well-mixed	0.623	0.924	0.0218
0.19	0.935	11.9	well-mixed	0.365	0.964	0.0155
0.19	1.304	11.8	well-mixed	0.403	0.963	0.0247
0.19	1.106	13.1	surface	0.336	0.958	0.0111

Estimating Regional Abundance from Catch

$$C_{k,s} \sim negbin(\widehat{N}_{i,s} * \frac{V_{k,s}}{V_i}, \alpha)$$

- i – region index
- k – station index
- s – survey index
- $\widehat{N}_{,i,s}$ - estimated regional abundance in region *i* at survey *s*
- $C_{k,s}$ - observed catch at station *k* (in region *i)* on survey *s*
- $V_{k,s}$ - tow volume at station *k* on survey *s*
- V_i - water volume in region *i*
- α - overdispersion parameter of negative binomial distribution

Estimating Regional Cohort Abundance

$$\tilde{C}_{*,k,s} \sim multinomial(f_{*,i,s}, \tilde{C}_{k,s})$$

- $*$ – all cohort indices
- i – region index
- k – station index
- s – survey index
- $\tilde{C}_{*,k,s}$- measured catch in each cohort at station *k* (in region *i)* on survey *s*
- $f_{*,i,s}$- fraction of abundance in each cohort for region i and survey *s*
- $\tilde{C}_{k,s}$- measured catch at station *k* (in region *i)* on survey *s*