How will climate change induced warming affect Delta smelt?

Larry R. Brown
U.S. Geological Survey
California Water Science Center

Funding: CALFED, DSP, USGS Environments (CASCaDE I and II)

Delta smelt
Hypomesus transpacificus

- Federal and State listed as threatened (1993)
- Granted endangered status
  - State 2009
  - Federal: 2010 warranted but precluded
- Annual (mostly) life cycle
- Endemic to the San Francisco estuary

This neighborhood has really gone downhill!

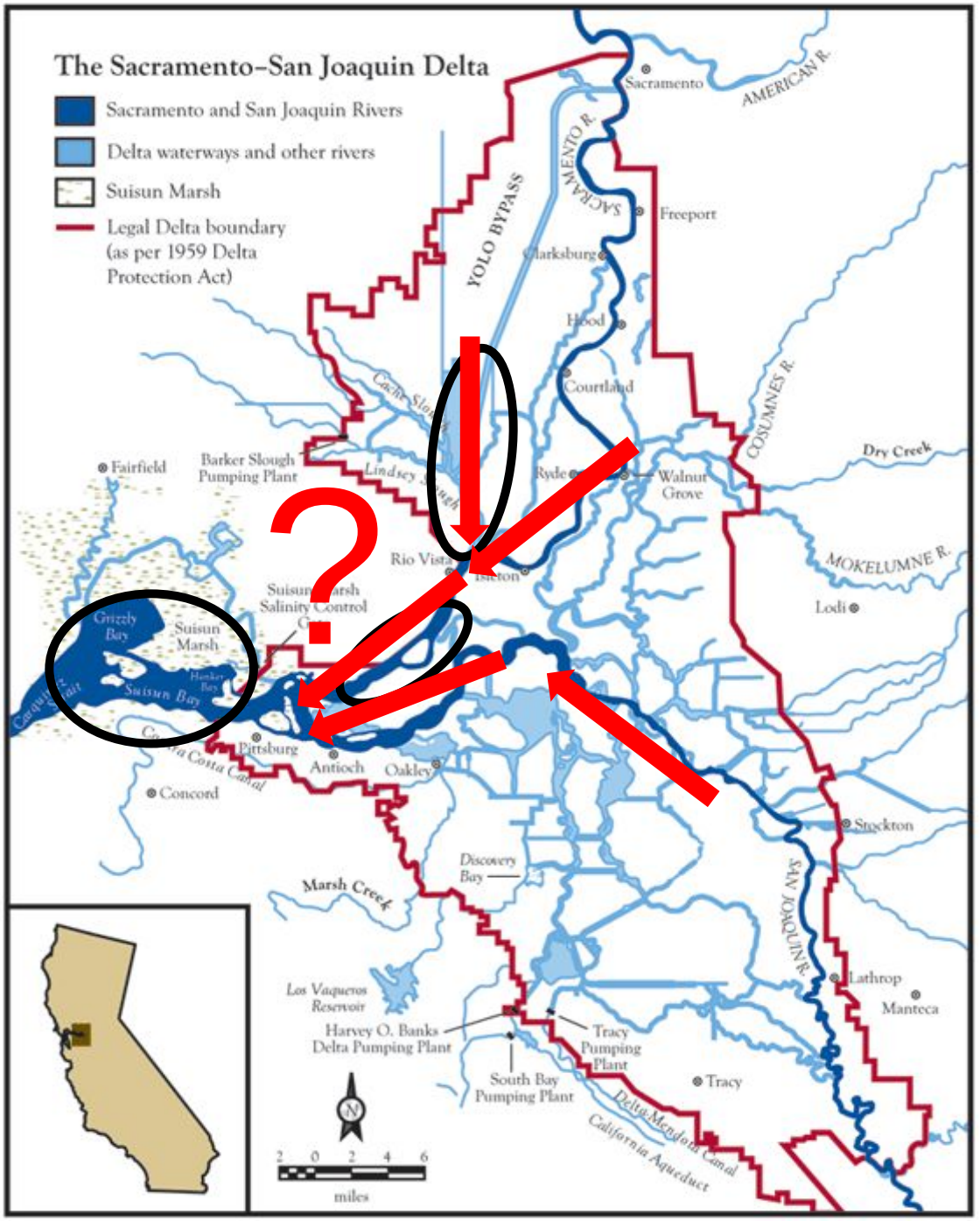
Third Year of Major Drought!
Hot Summers!
Politics!

How do I balance climate change with everything else going on in my life?!

And you thought there was stress in *your* life !

Not necessarily direct mortality

Large areas of current habitat may become unavailable or sub-optimal for long periods



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PLoS one

Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change

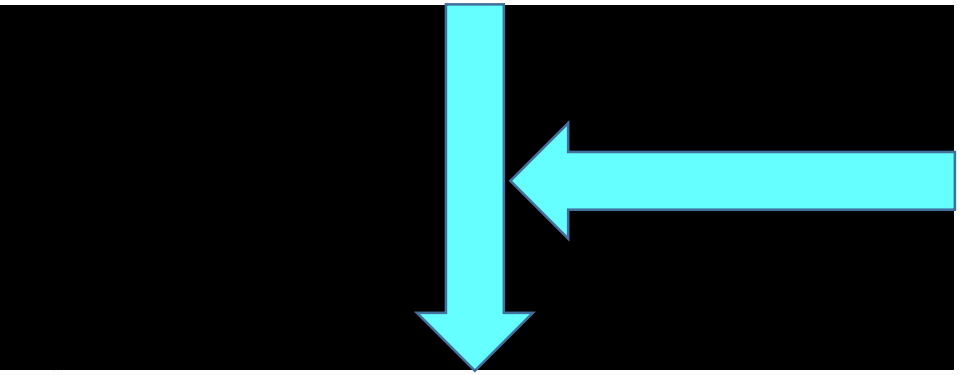
James E. Cloern[1]*, Noah Knowles[1], Larry R. Brown[2], Daniel Cayan[3], Michael D. Dettinger[3], Tara L. Morgan[2], David H. Schoellhamer[2], Mark T. Stacey[4], Mick van der Wegen[5], R. Wayne Wagner[4], Alan D. Jassby[6]

Estuaries and Coasts (2013) 36:754–774
DOI 10.1007/s12237-013-9585-4

Implications for Future Survival of Delta Smelt from Four Climate Change Scenarios for the Sacramento–San Joaquin Delta, California

Larry R. Brown · William A. Bennett · R. Wayne Wagner · Tara Morgan-King · Noah Knowles · Frederick Feyrer · David H. Schoellhamer · Mark T. Stacey · Michael Dettinger

Combine information on climate change with latest information on physiology



Conservation Physiology
Volume 2 • 2014
10.1093/conphys/cou008
SEB Society for Experimental Biology

Research article

Ontogeny influences sensitivity to climate change stressors in an endangered fish

L. M. Komoroske[1], R. E. Connon[2], J. Lindberg[3], B. S. Cheng[4], G. Castillo[5], M. Hasenbein[2,6] and N. A. Fangue[1]*

PLOS | ONE

RESEARCH ARTICLE

Coupled Downscaled Climate Models and Ecophysiological Metrics Forecast Habitat Compression for an Endangered Estuarine Fish

Larry R. Brown[1]*, Lisa M. Komoroske[2,3], R. Wayne Wagner[4], Tara Morgan-King[1], Jason T. May[1], Richard E. Connon[5], Nann A. Fangue[3]

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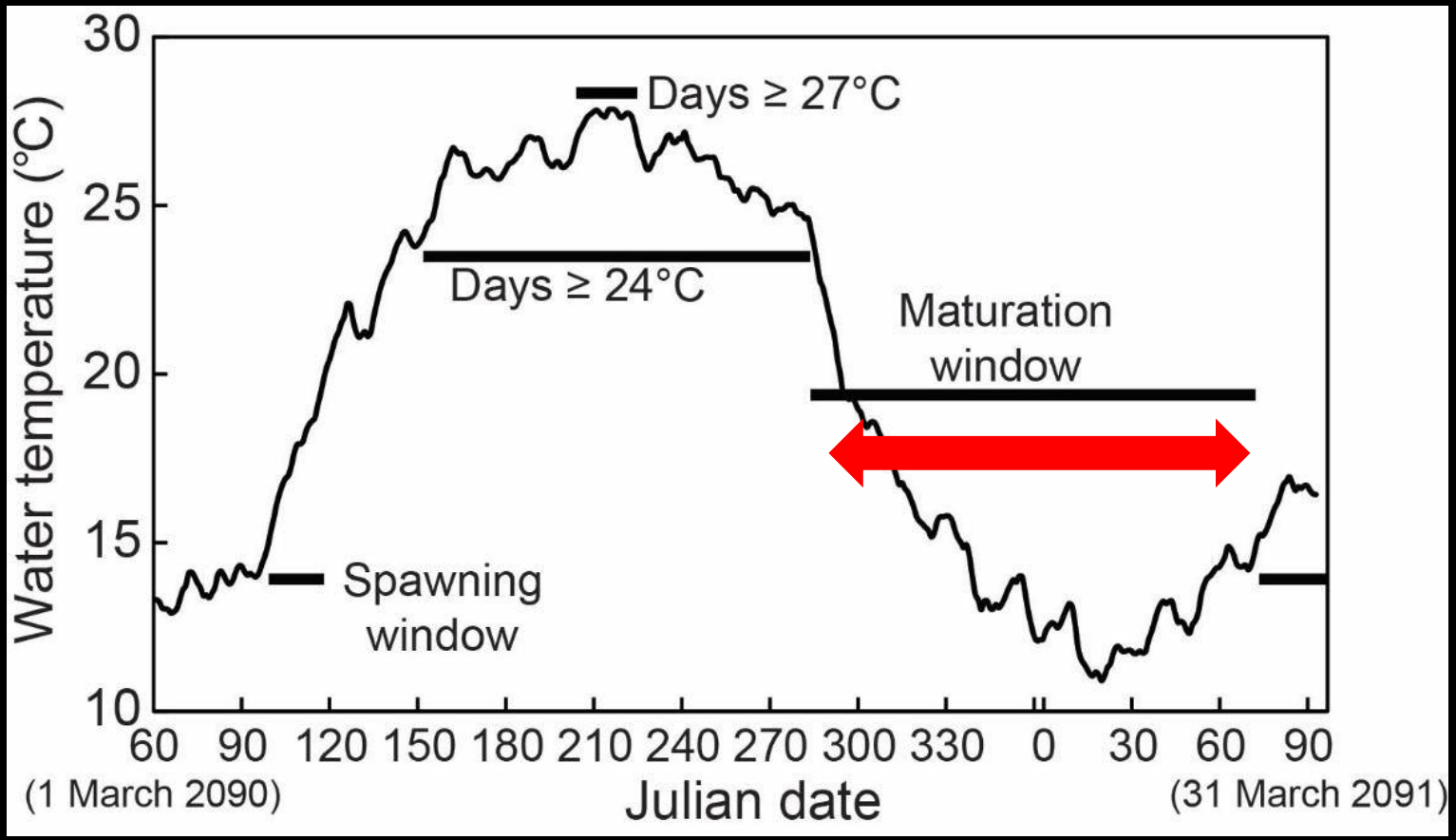
Thresholds		Adults	Post-spawn adults	Larvae	Juveniles
Physiological stress	Days ≥	NA	NA	NA	24
Chronic lethal thermal maximum (50%)	Days ≥	27	25	NA	27
Chronic lethal thermal maximum (95%)	Days ≥	27	27	NA	28
Critical thermal maximum	Days ≥	28	27	29	29
Time periods					
Days in optimal window	15 ≤ Days ≤ 18	NA	NA	X	X
Beginning of spawning window (15-20C)	Date	X	X	NA	NA
Duration of spawning window	15 ≤ Days ≤ 20	X	X	NA	NA

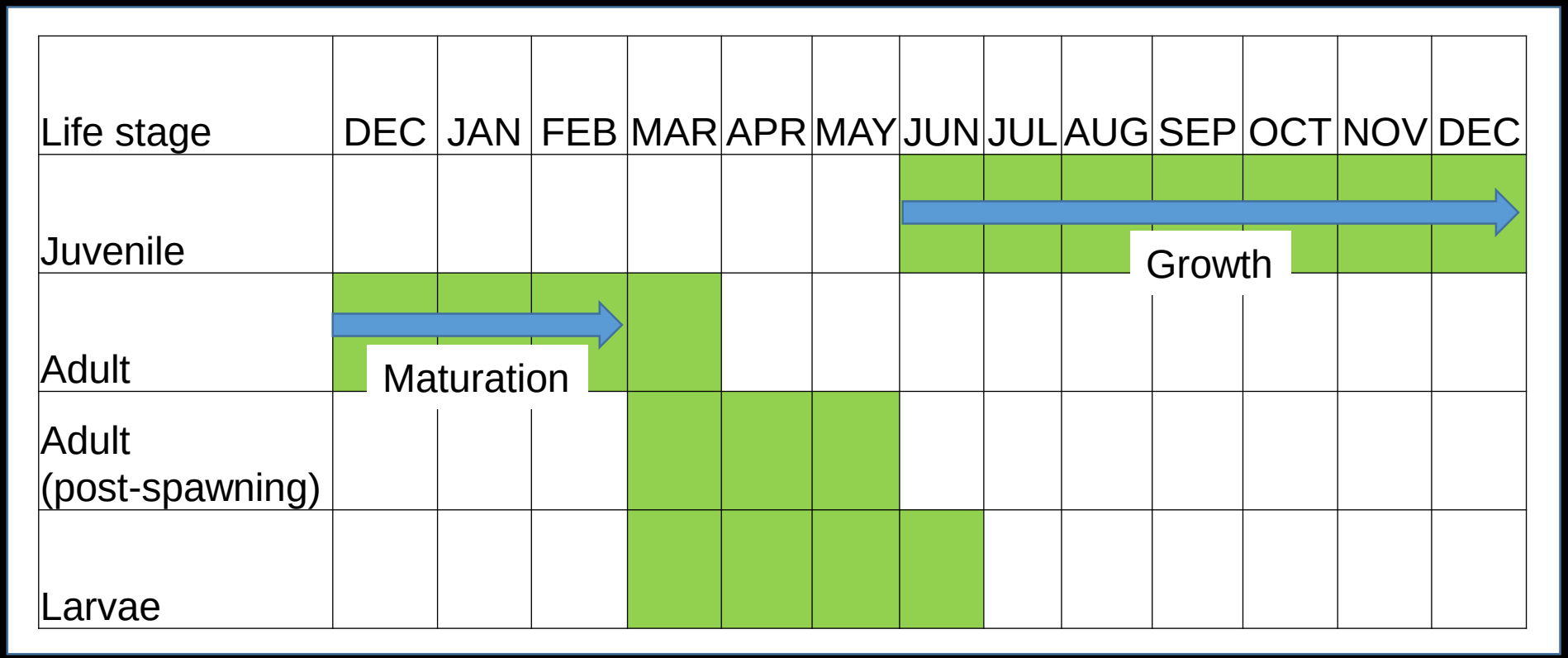
Definition of Maturation Window

(Assume this period needed for growth in length and development of eggs)



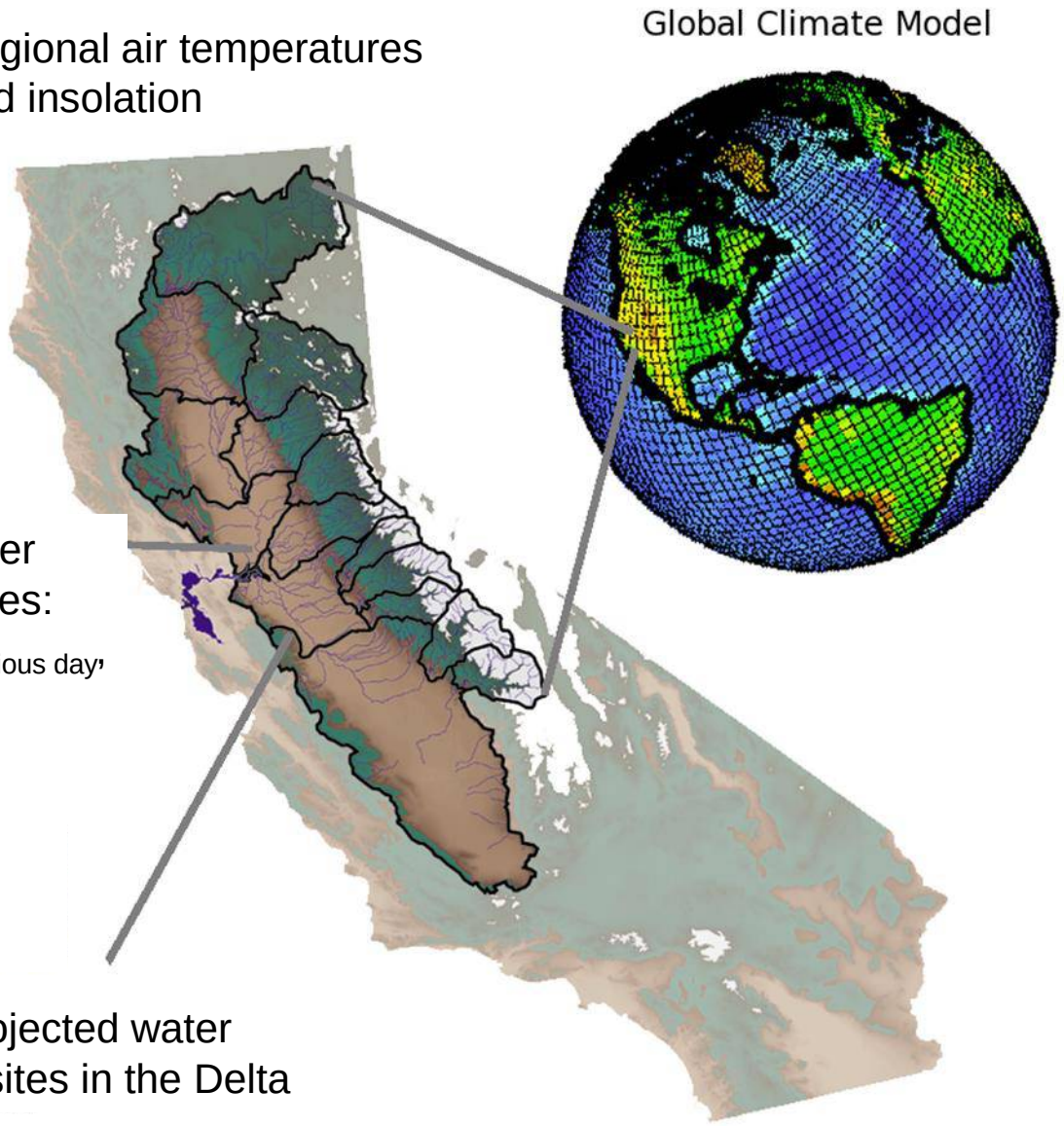
Maturation Window as Life Stages

- Baseline: juvenile phase to first spawn (272 days)



Modeling Future Water Temperature

Regional air temperatures and insolation



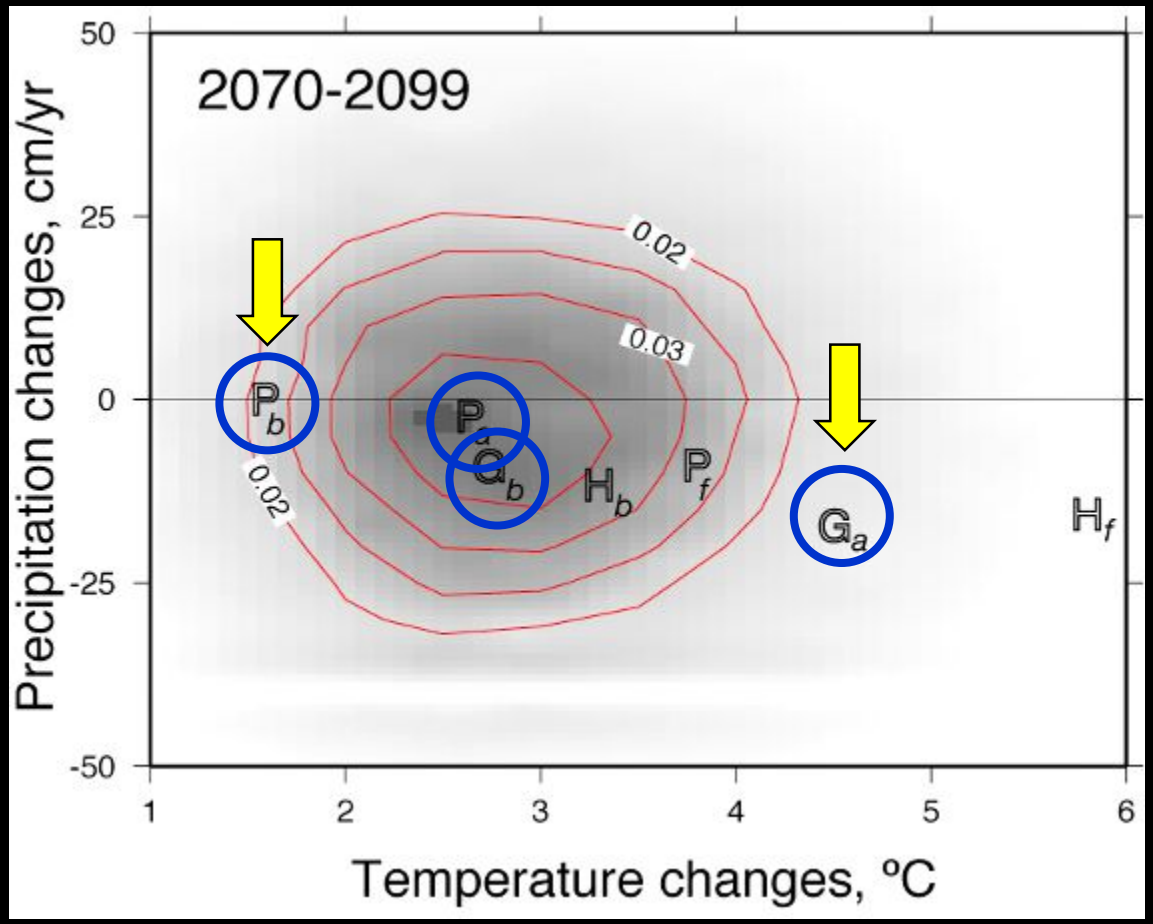
Regression models for water temperature at selected sites: f(Air Temp, Water Temp$_{previous\ day}$, insolation)

(Wagner et al. 2011)

Final output: 100 years projected water temperatures at selected sites in the Delta

Which Models to Use?

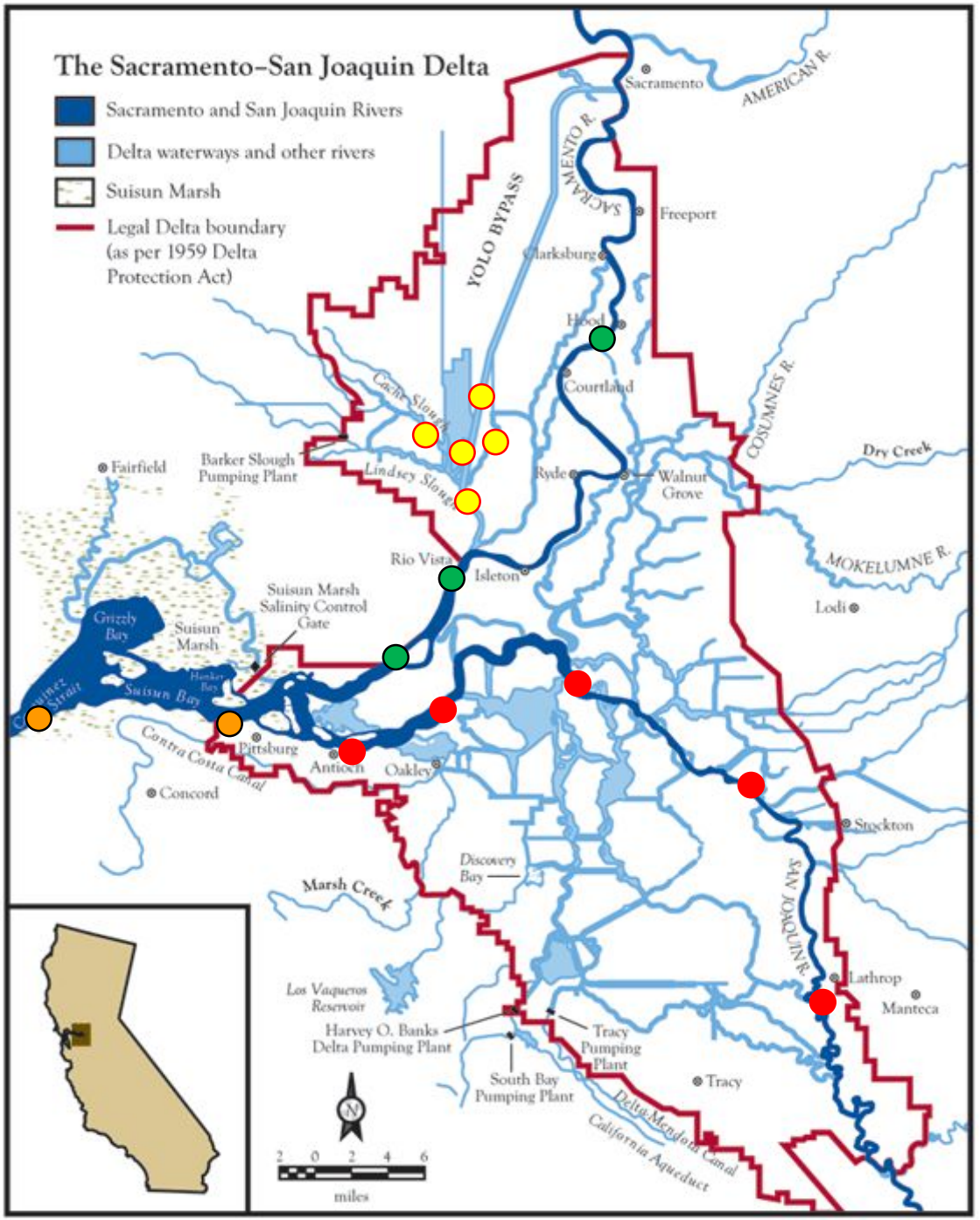
From 100+ recent climate-change projections, four scenarios chosen:



- PCM-B1: Little warmer with little ppt change
- PCM-A2: Medium warmer with little ppt change
- GFDL-B1: Medium warmer and drier
- GFDL-A2: Much warmer and drier **but no longer "extreme"**

Four regions:
(Brown et al. 2016)

- San Joaquin River
  - Warm already
- Sacramento River
  - Cool
- North Delta
  - Cool/warm
  - Food
- Bays
  - Cool



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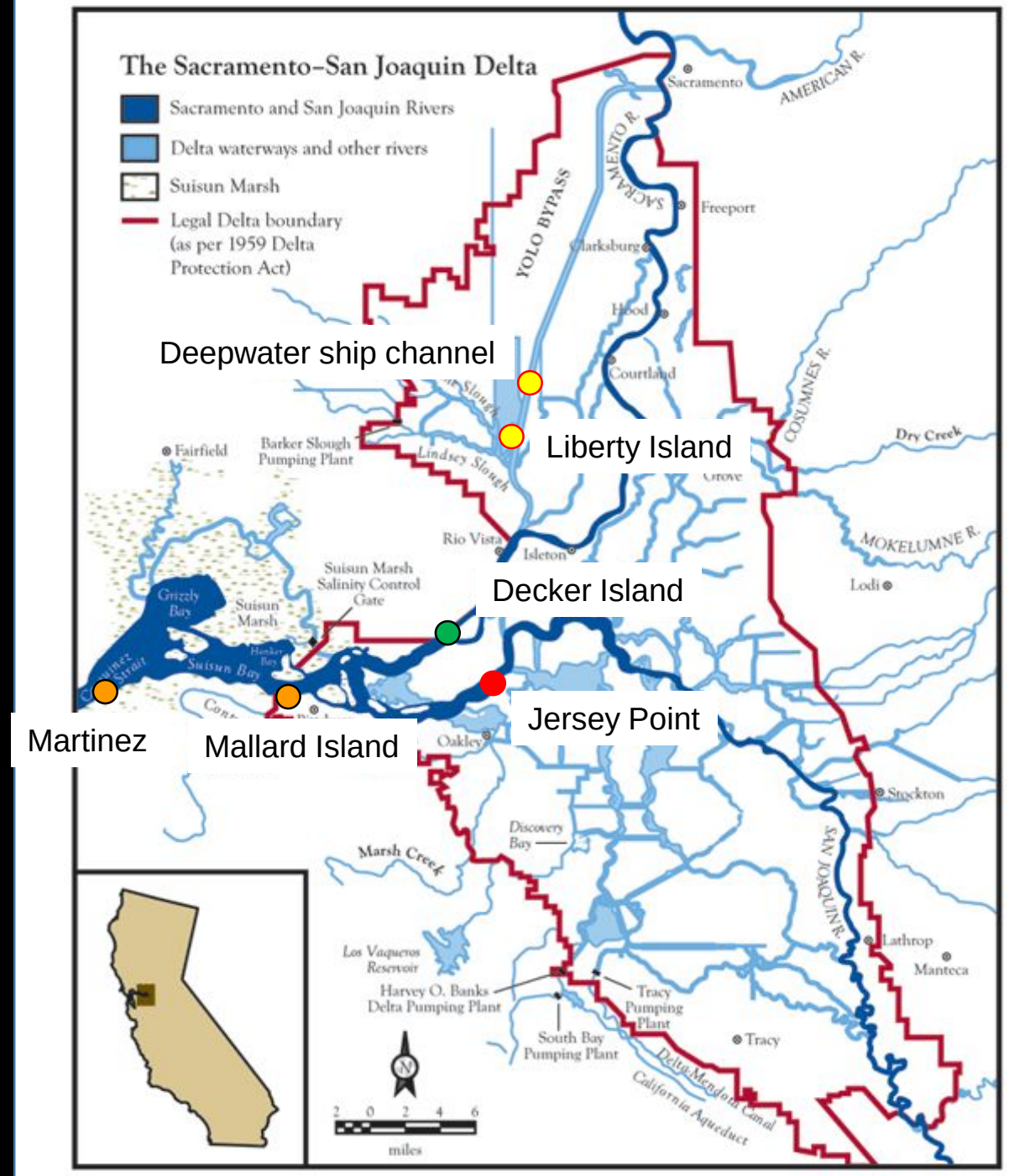
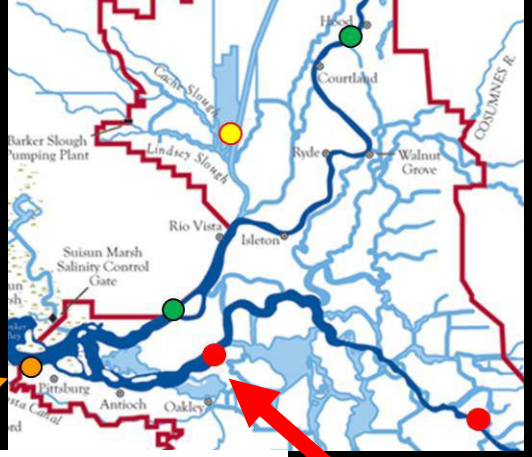
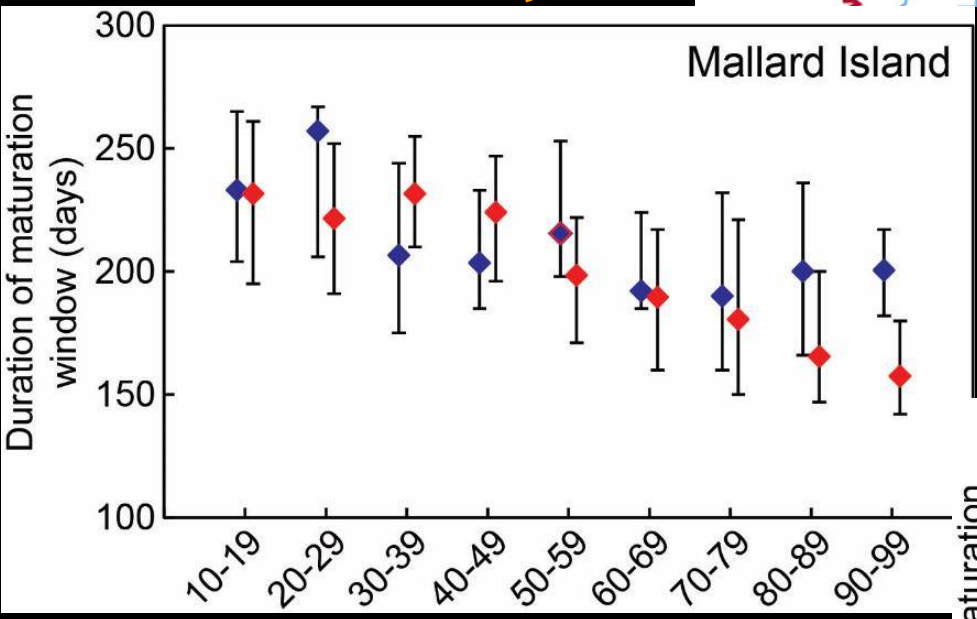
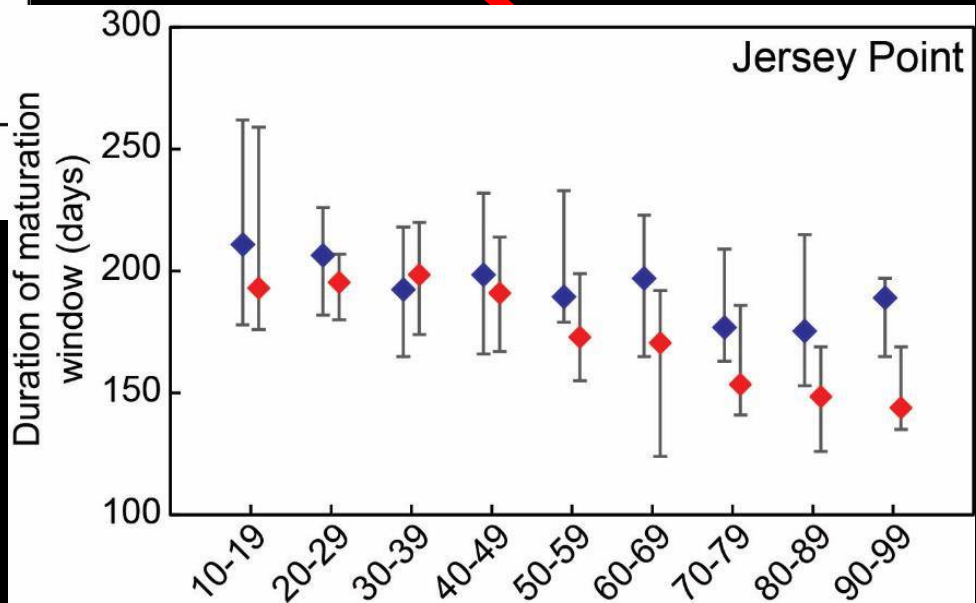
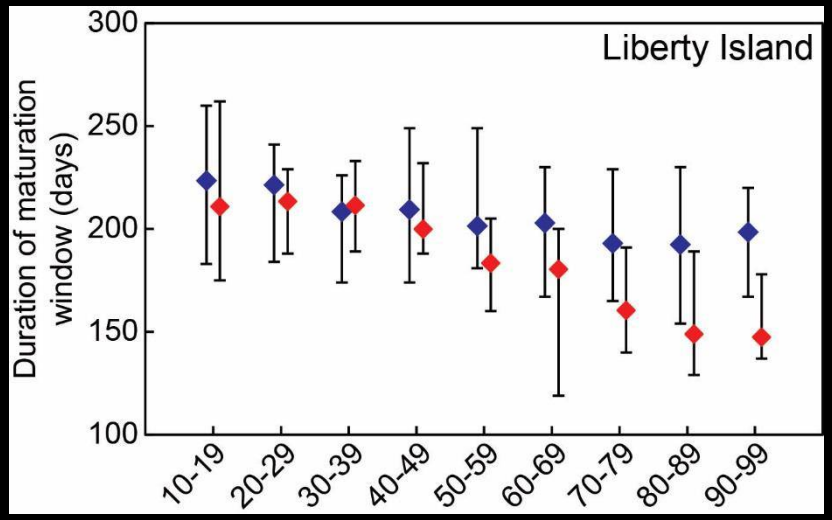


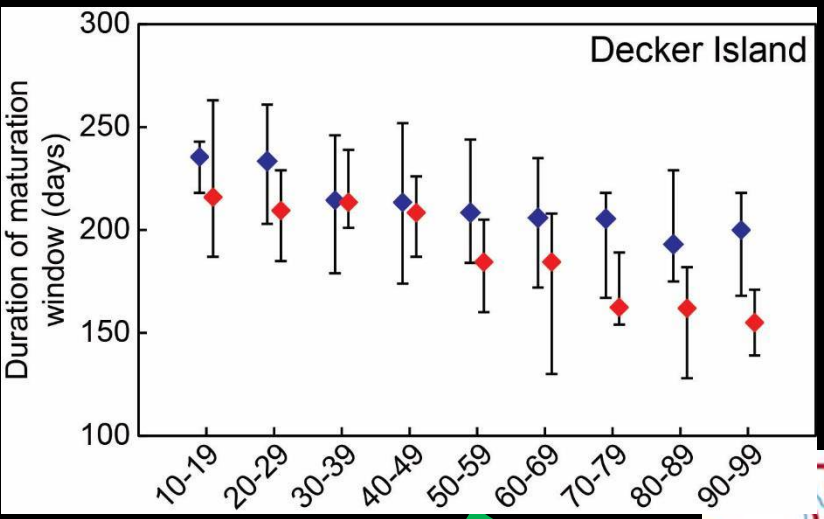


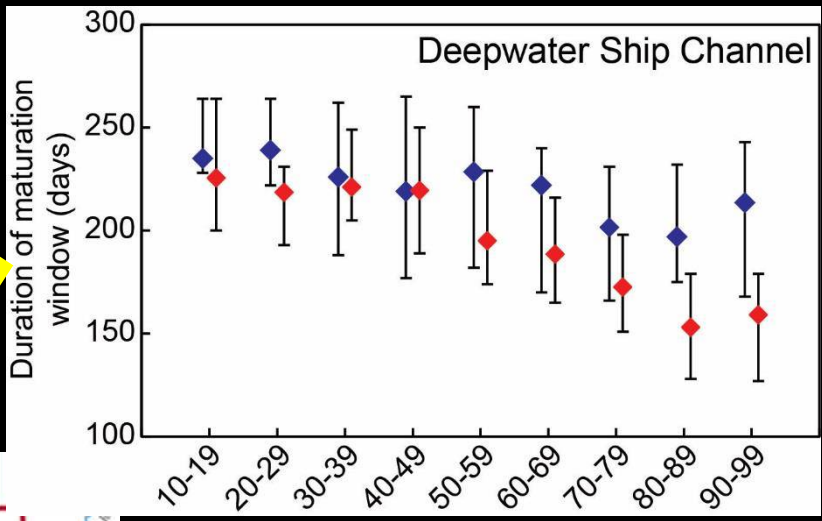
Maximum
Median
Minimum
GFDL-A2 scenario
PCM-B1 scenario

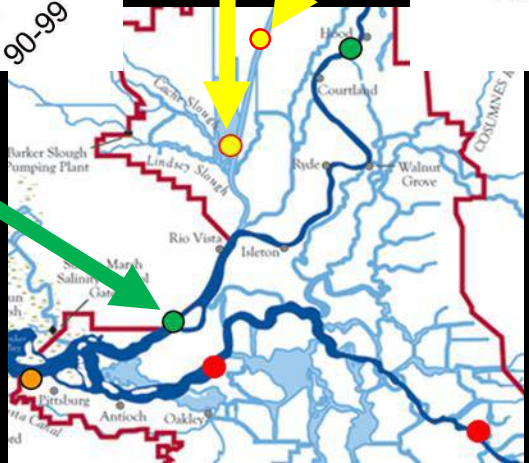





Liberty Island
Duration of maturation window (days)
300
250
200
150
100
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-99


Decker Island
Duration of maturation window (days)
300
250
200
150
100
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-99


Deepwater Ship Channel
Duration of maturation window (days)
300
250
200
150
100
10-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-99


Courtland
Lindsey Slough
Rio Vista
Isleton
Walnut Grove
Pittsburg
Antioch
Oakley

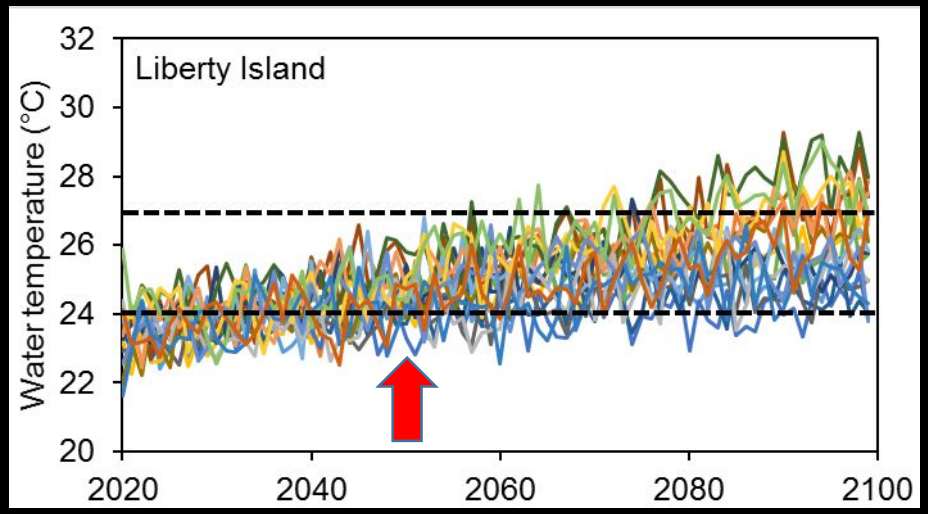

Maximum
Median
Minimum
GFDL-A2 scenario
PCM-B1 scenario

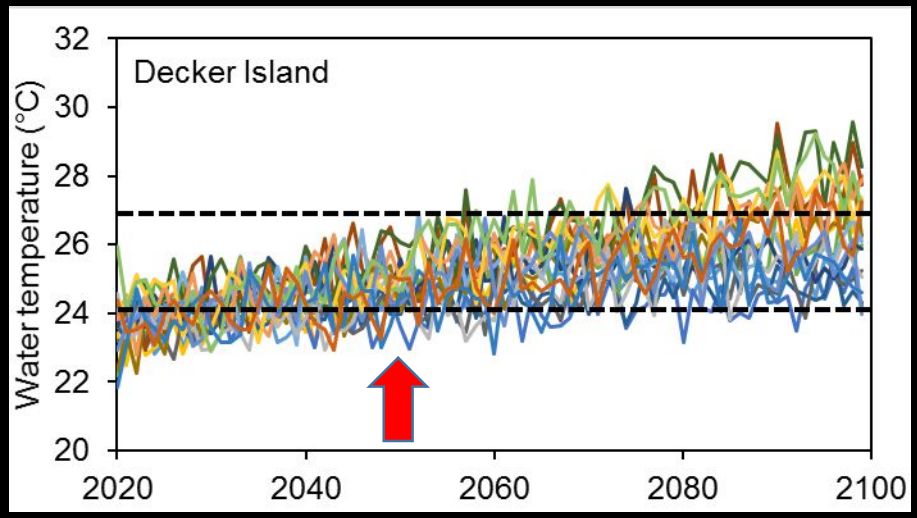
Maturation window (June-Feb=272 days)

	PCM-B1					GFDL-A2				
	Min	Max	Differ-ence	Percent loss	Trend	Min	Max	Differ-ence	Percent loss	Trend
San Joaquin River										
Mossdale	165.0	183.0	18.0	6.6	-1.90*	133.5	179.5	46.0	16.9	-5.77**
Burns Cut	157.0	177.0	20.0	7.4	-2.14**	136.5	176.5	40.0	14.7	-5.20**
Prisoners Point	181.0	208.5	27.5	10.1	-2.77*	142.5	198.5	56.0	20.6	-6.39***
Jersey Point	175.5	211.0	35.5	13.1	-3.56**	144.0	198.5	54.5	20.0	-7.46**
Antioch	180.0	212.0	32.0	11.8	-2.85*	143.5	203.5	60.0	22.1	-7.25**
Sacramento River										
Hood	197.5	245.0	47.5	17.5	-6.22**	160.0	237.0	77.0	28.3	-9.59***
Rio Vista	189.5	234.0	44.5	16.4	-4.37**	157.5	225.0	67.5	24.8	-8.59***
Decker Island	193.0	235.5	42.5	15.6	-4.82***	155.0	216.0	61.0	22.4	-8.54***
North Delta										
Upper Cache Slough	213.0	264.0	51.0	18.8	-5.28**	161.5	239.0	77.5	28.5	-10.8***
Miners Slough	213.0	249.5	36.5	13.4	-4.81**	163.0	240.0	77.0	28.3	-10.29***
Liberty Island	192.5	223.5	31.0	11.4	-3.74**	147.5	213.5	66.0	24.3	-9.48***
Deepwater Ship Channel	197.0	239.0	42.0	15.4	-4.3**	153.0	225.5	72.5	26.7	-9.84**
Lower Cache Slough	208.0	244.0	36.0	13.2	-4.72***	153.5	237.0	83.5	30.7	-10.98**
Confluence										
Mallard Island	203.0	249.0	46.0	16.9	-6.22**	157.5	231.5	74.0	27.2	-10.01***
Suisun Bay										
Martinez	221.0	255.0	34.0	12.5	NS	172.0	257.0	85.0	31.3	-11.83***

New Scenarios from IPPC 5th Assessment 2014

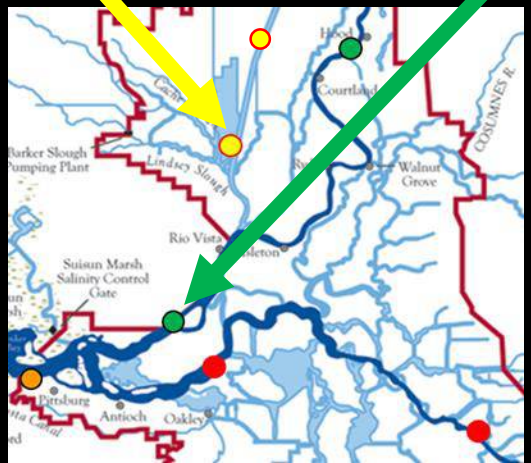
- 10 climate change models
- 2 greenhouse gas emission scenarios
- Calculated water temperatures using models
- Looked at average of daily average temperature July-September
- Plotted 2020-2099
- Compared to:
  - 24°C = stress
  - 27°C = mortality





Summer conditions (Jul-Sep)

- ≥ 24°C = stress
- ≥ 27°C = mortality



Data are preliminary and subject to revision. Do not cite.

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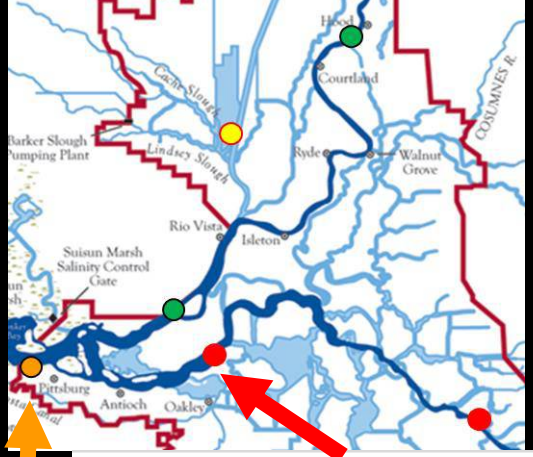

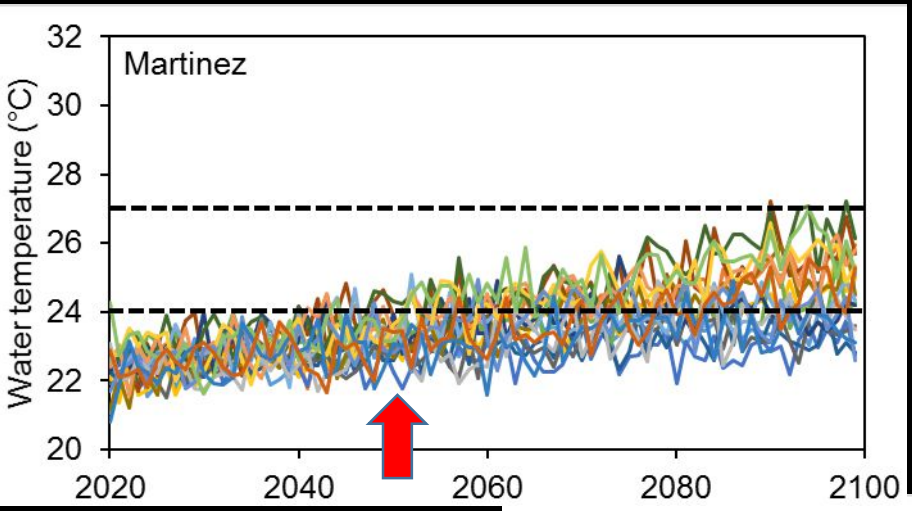

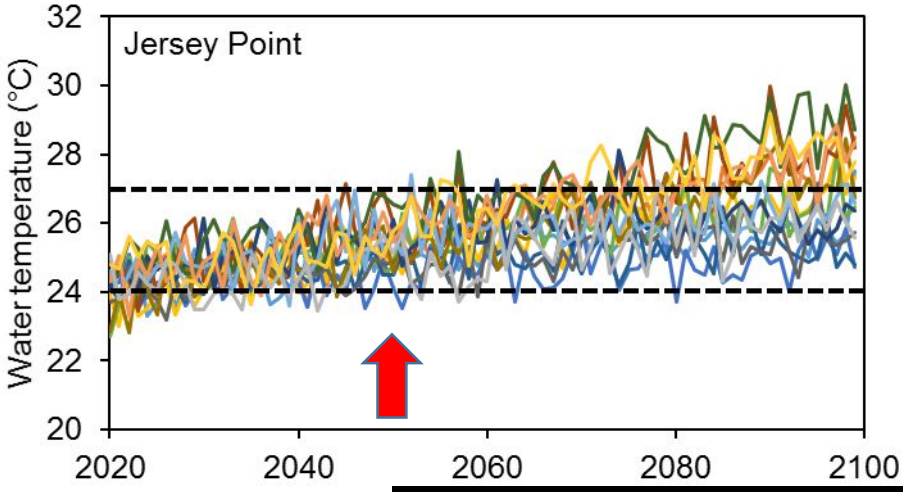

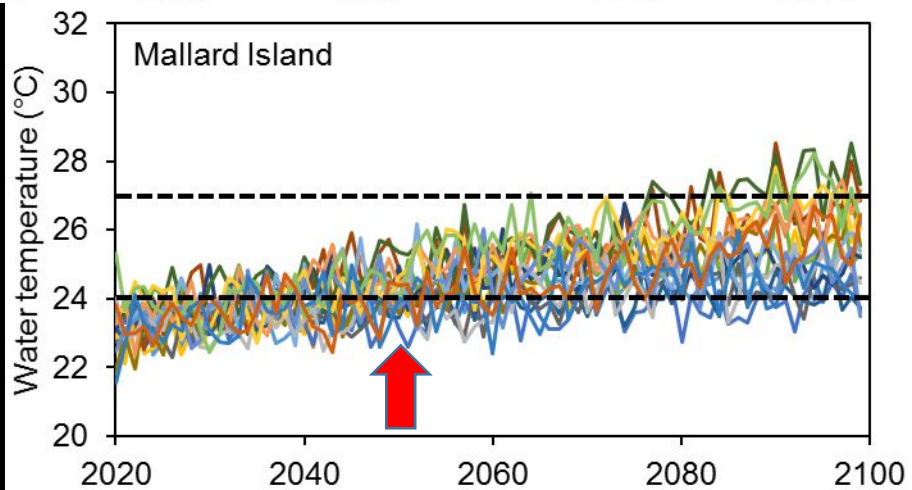

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Conclusions

- Significant changes in the maturation window occurred at all Delta sites examined
- New scenarios show no non-stressful habitat in Delta by mid-century
- Adaptation?
  - Temperature pushing seaward
  - Salinity pushing landward
  - Turbidity? Food? Other factors?

Questions?