Migration of late-fall Chinook and steelhead smolts relative to dredge removal and disposal sites in San Francisco Bay

LONG TERM MANAGEMENT STRATEGY (LTMS)

US Army Corps of Engineers

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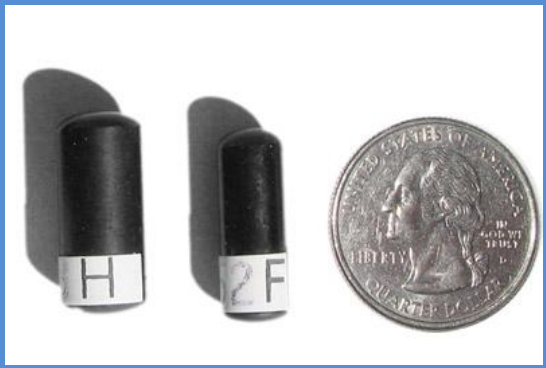
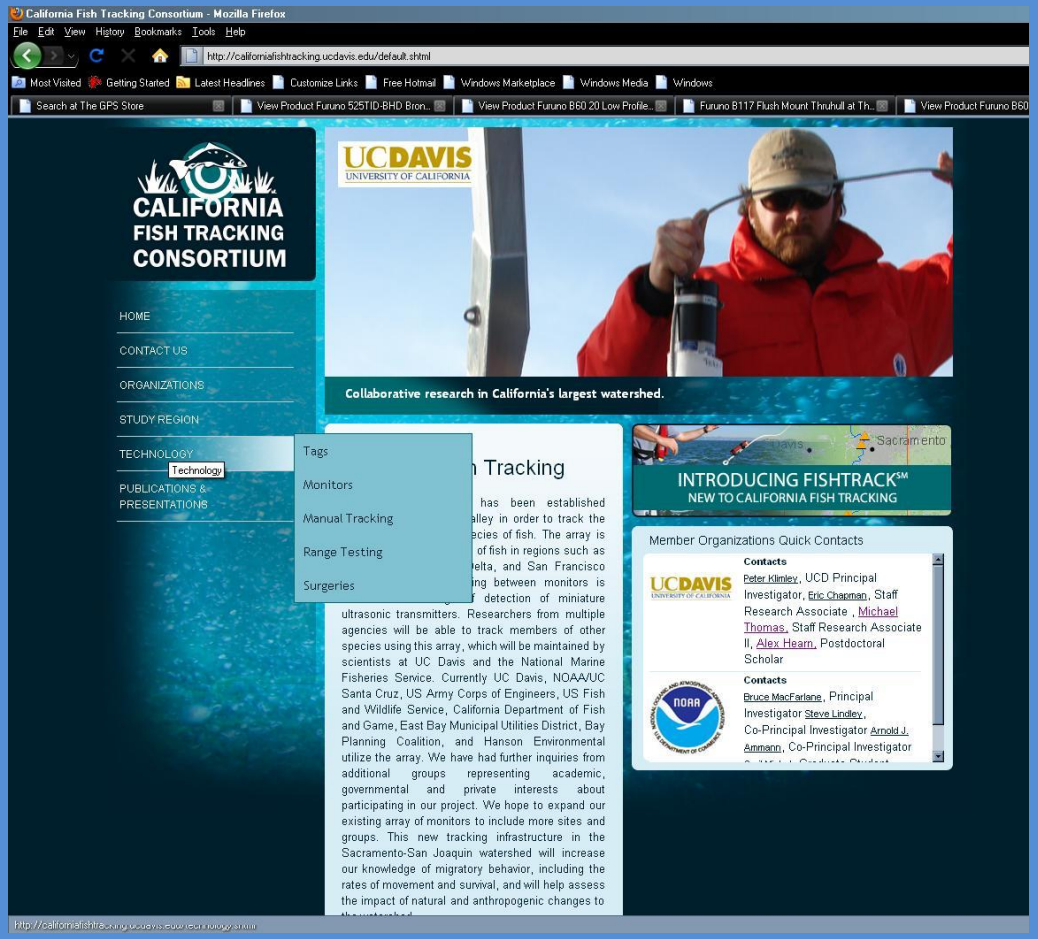
The California Fish Tracking Consortium

- 10 organizations
- 100s of monitors
- 1000s of fish tagged

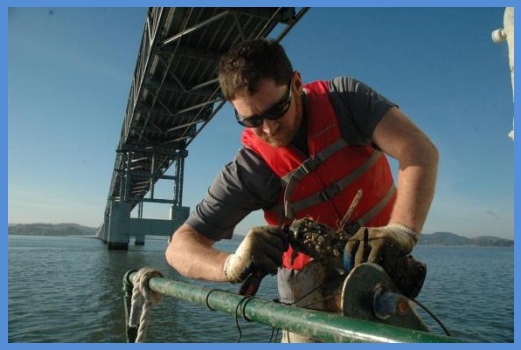


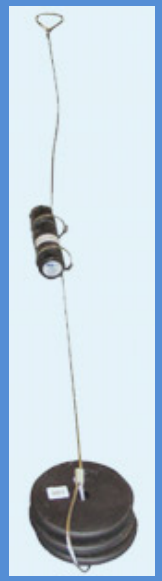


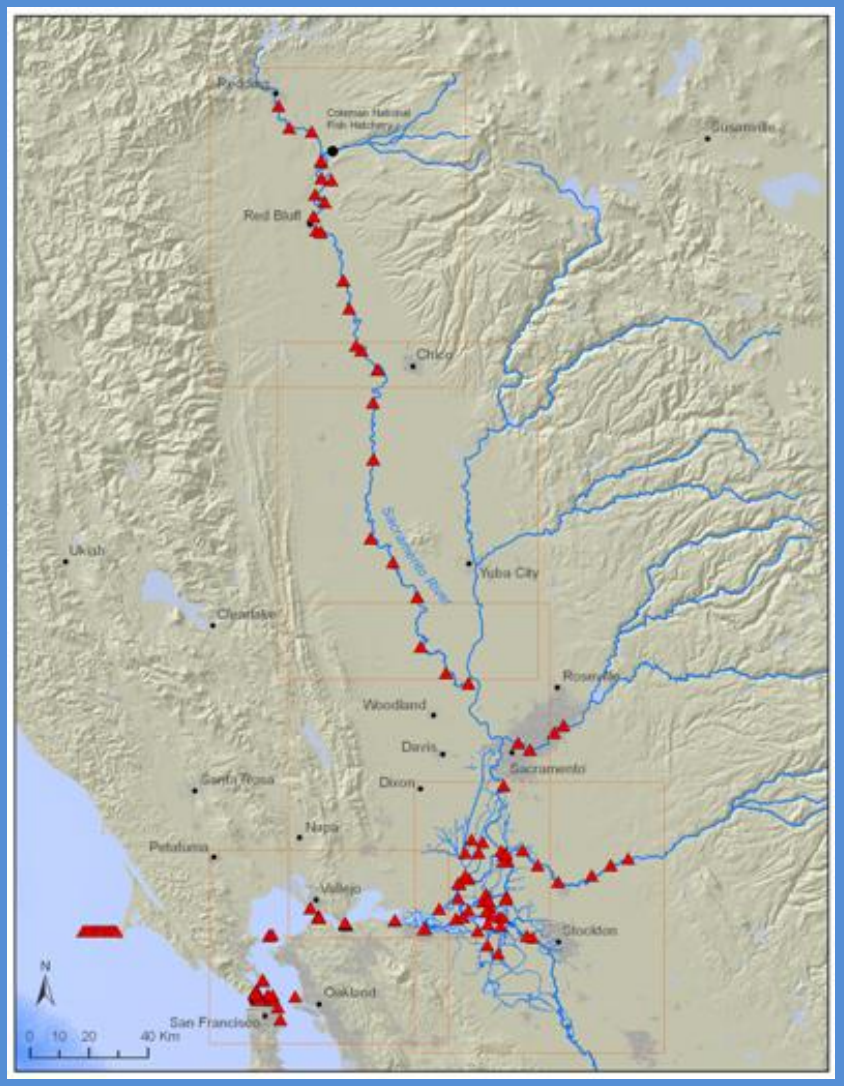
Range of studies

Spawning behavior, migrations, survival, juvenile movements, anthropogenic effects, restoration and climate change, niche partitioning…. And plenty more!

The array: Backbone of it all







Study Questions

1. What are the general migratory patterns of salmonid smolts through SF Bay in relation to dredge and dredge placement sites?

2. What is the residence time of these fish

   A) in particular reaches of the estuary (transit time) and

   B) at sites of interest (exposure time)?

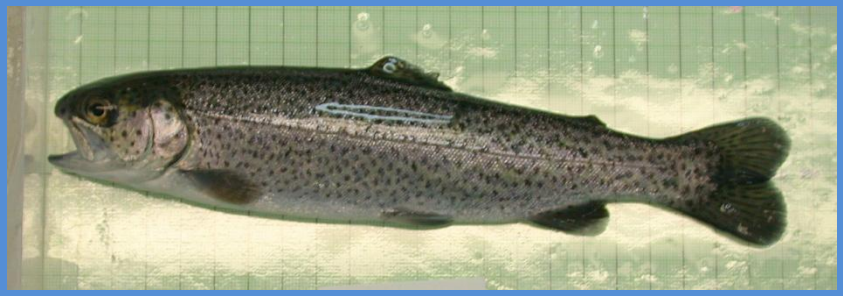
3. What are the spatial and temporal distribution patterns of green sturgeon in the estuary?

Study Species

Late-fall Chinook Salmon

Year	Fish tagged
2006/7	49
2007/8	50
2008/9	500
2010	500

Steelhead



Year	Fish tagged
2006/7	49
2007/8	50
2008/9	500
2010	500

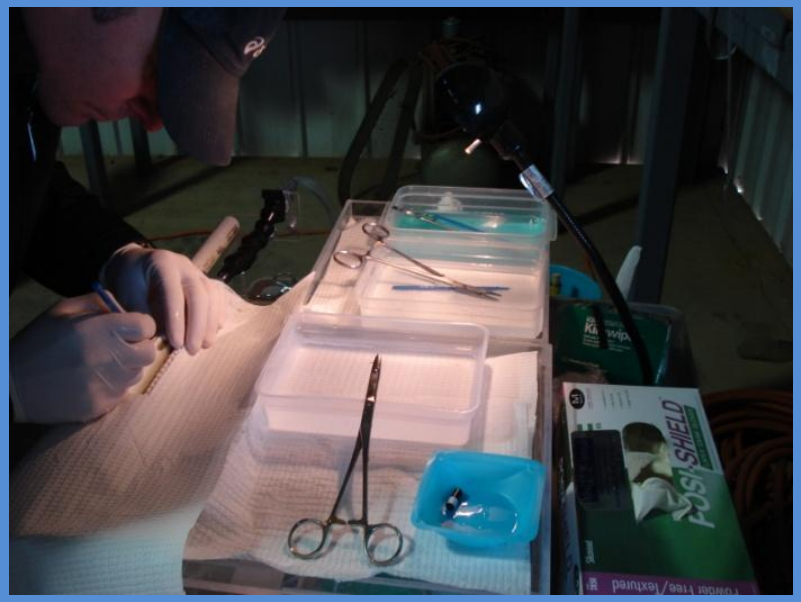
New Species: Green Sturgeon

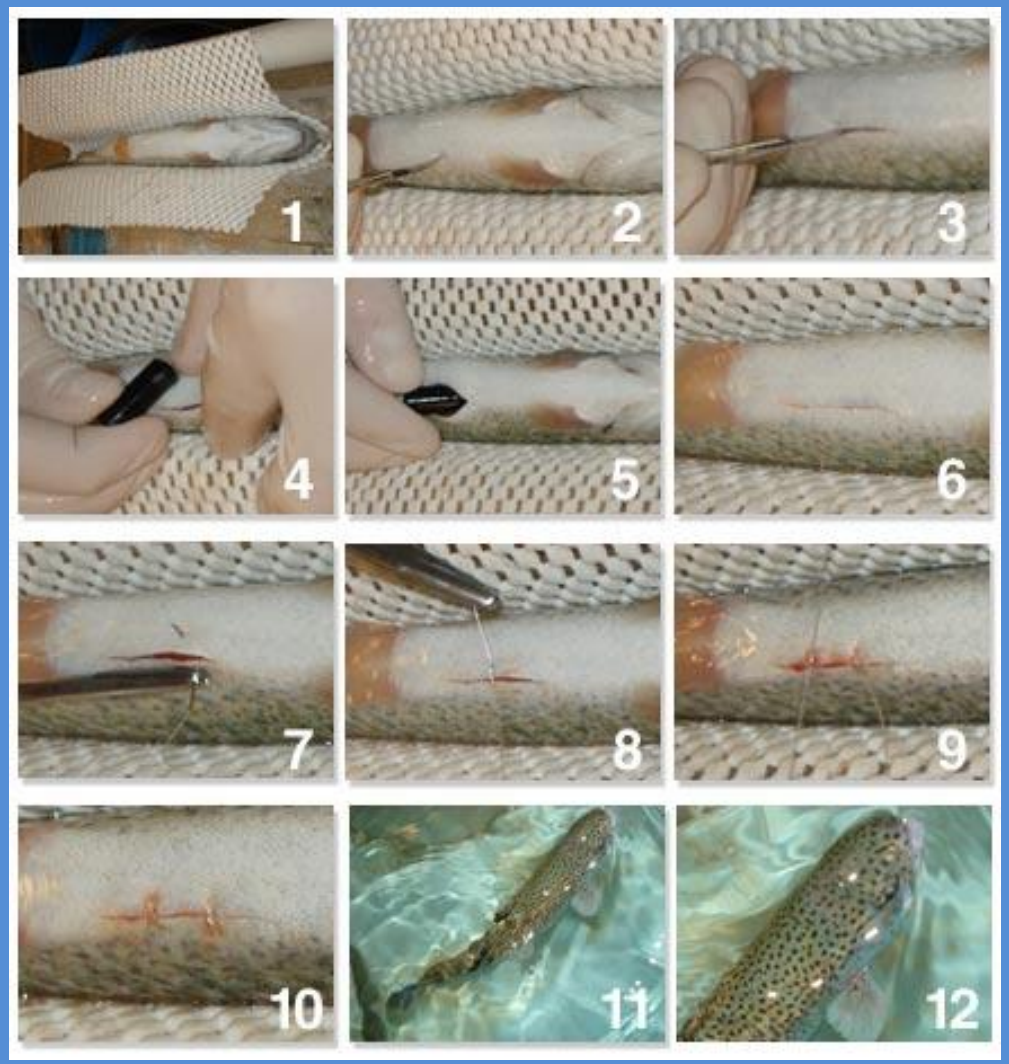
Over **300** green sturgeon tagged in the last 5 years. Tagging ongoing (six last week!)

Several projects look at effects of Red Bluff Dam, migration upriver, juvenile habitat use etc.

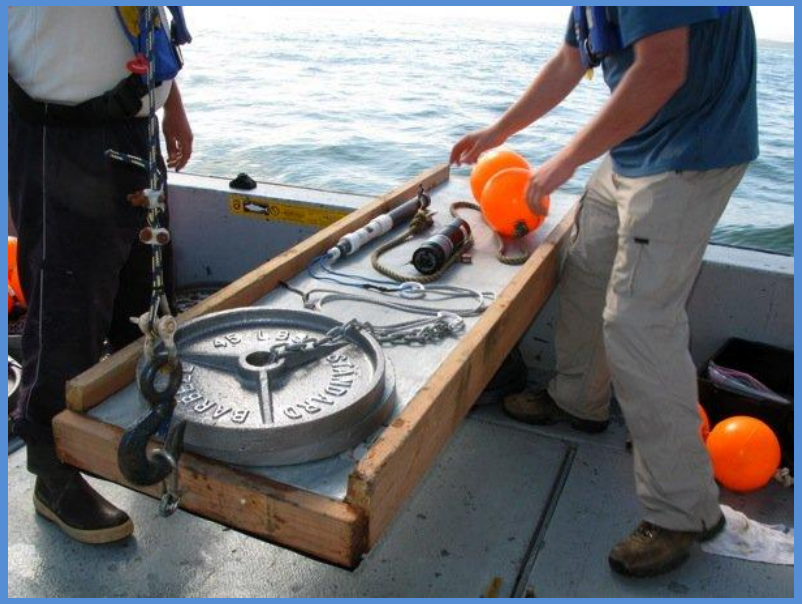
Current perception that adult green sturgeon are in the estuary all year round and over the entire area.

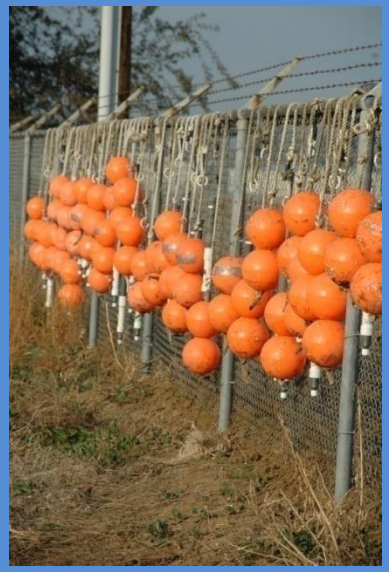
Fish Tagging

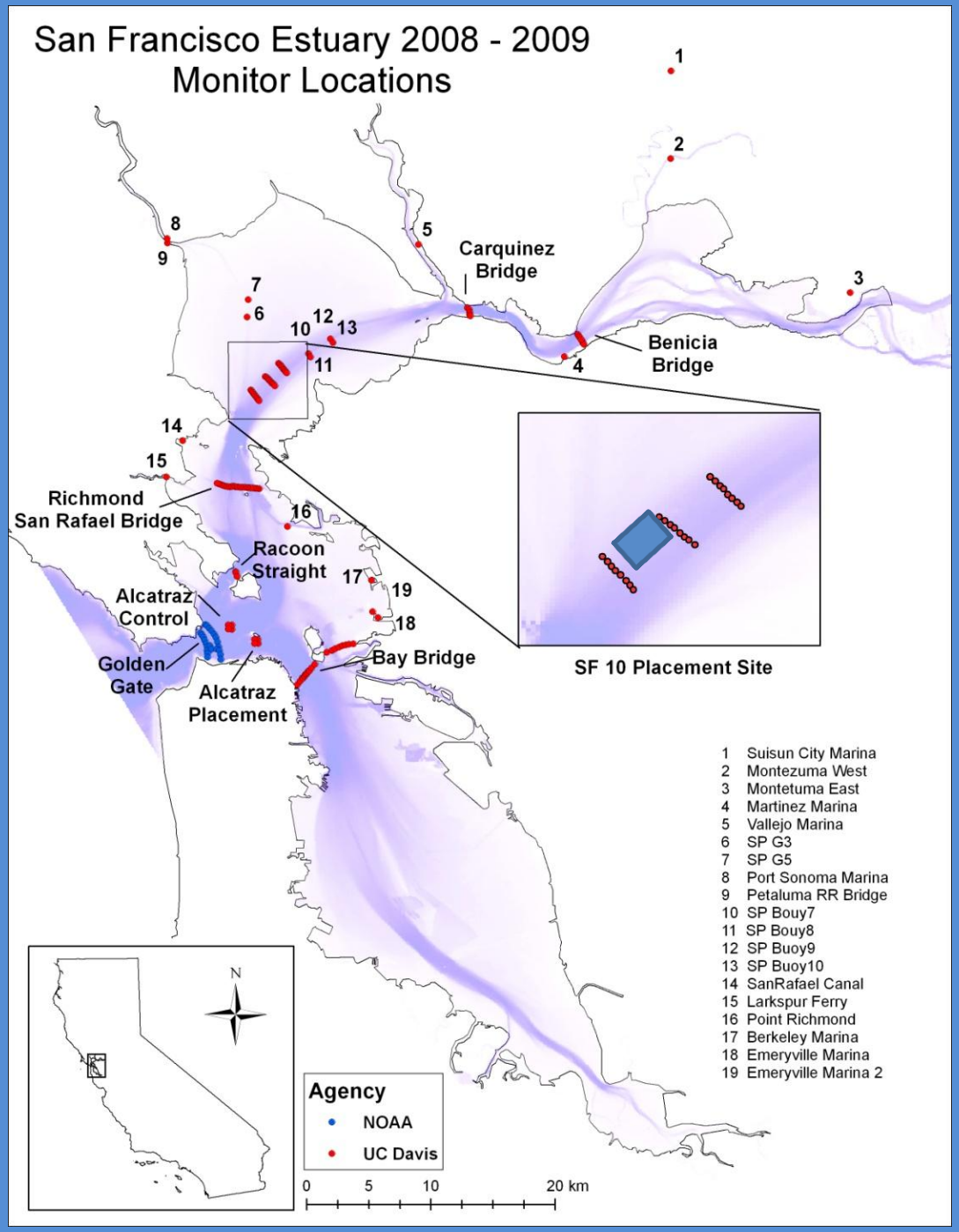




Study Array

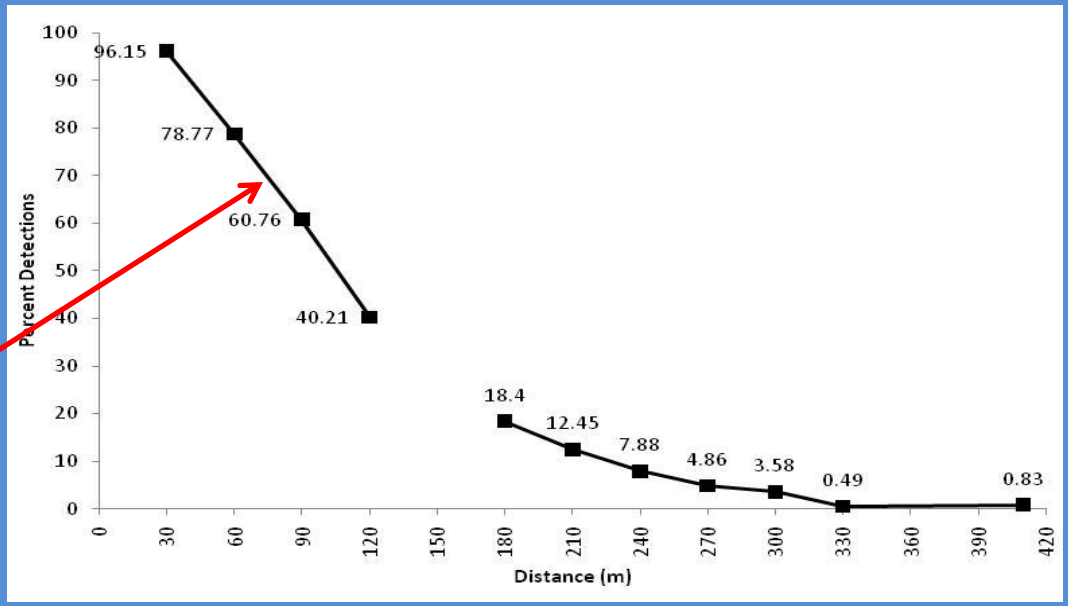


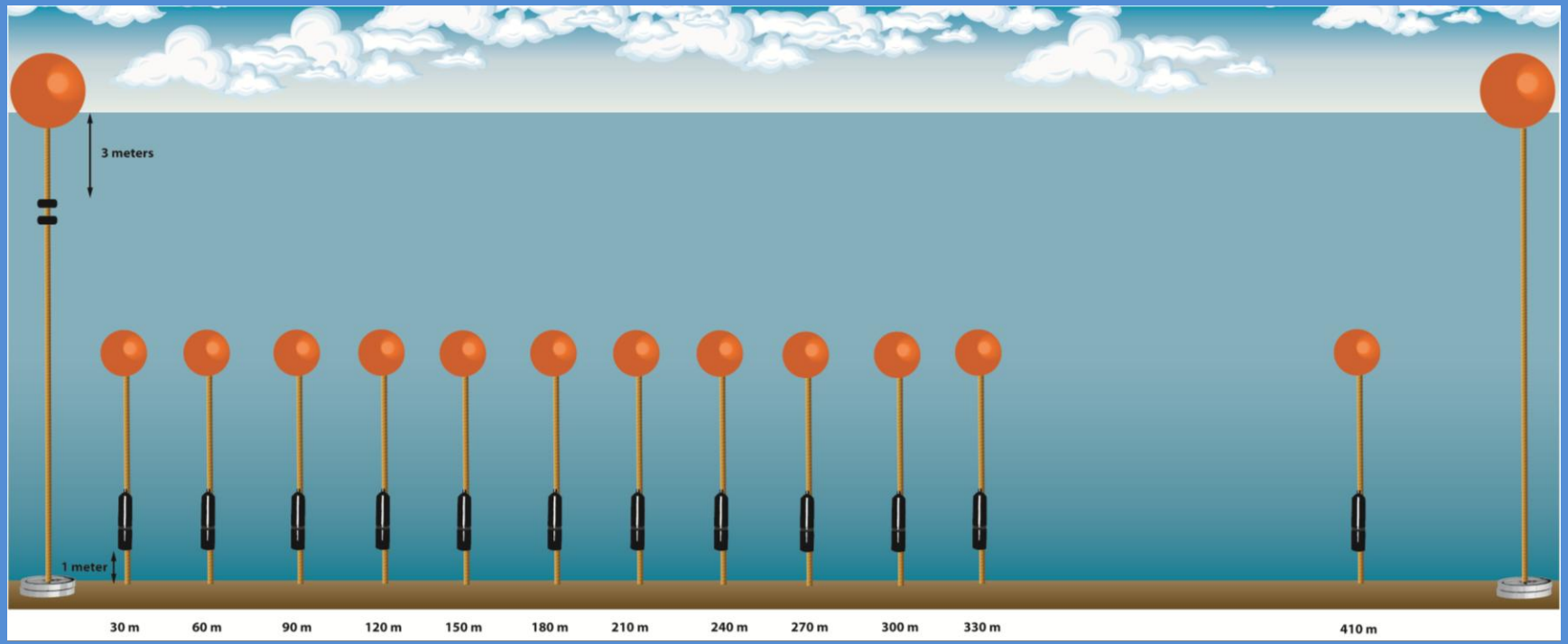



San Francisco Estuary 2008 - 2009
Monitor Locations
Carquinez Bridge
Benicia Bridge
Richmond San Rafael Bridge
Racoon Straight
Alcatraz Control
Golden Gate
Alcatraz Placement
Bay Bridge
SF 10 Placement Site
1 Suisun City Marina
2 Montezuma West
3 Montetuma East
4 Martinez Marina
5 Vallejo Marina
6 SP G3
7 SP G5
8 Port Sonoma Marina
9 Petaluma RR Bridge
10 SP Bouy7
11 SP Bouy8
12 SP Buoy9
13 SP Buoy10
14 SanRafael Canal
15 Larkspur Ferry
16 Point Richmond
17 Berkeley Marina
18 Emeryville Marina
19 Emeryville Marina 2
N
Agency
NOAA
UC Davis
0 5 10 20 km

Range Tests

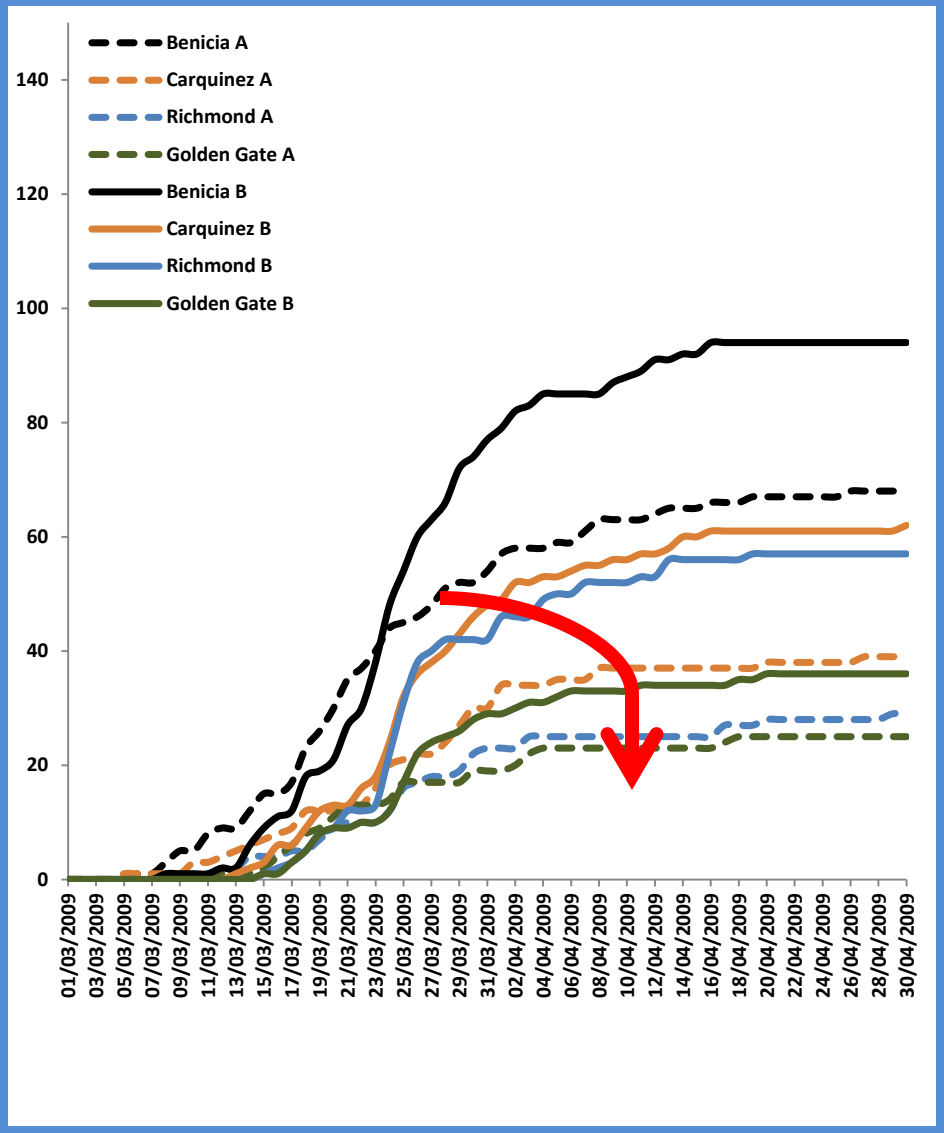
70% at 75 m radius



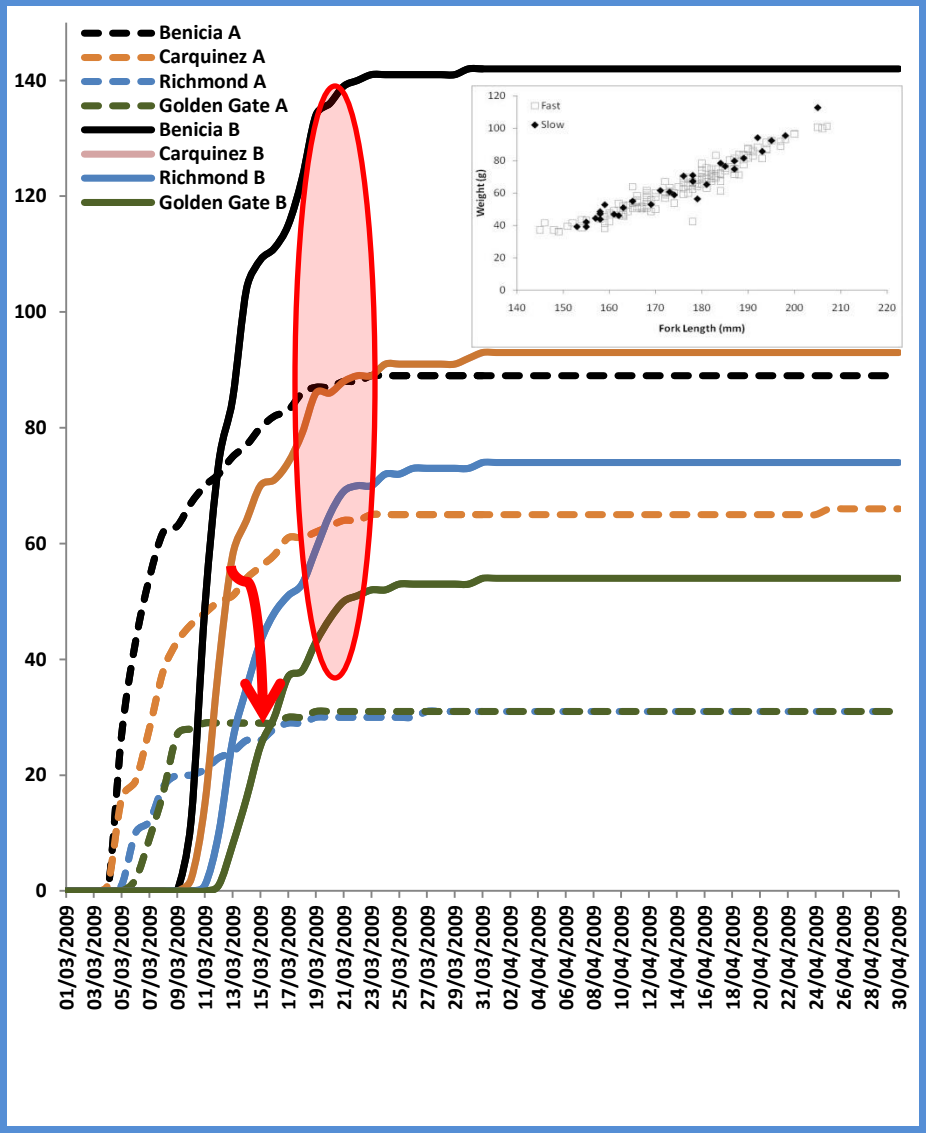


Q1: What are the general migratory patterns of salmonid smolts through SF Bay in relation to dredge and dredge placement sites?

Dispersal and Survival

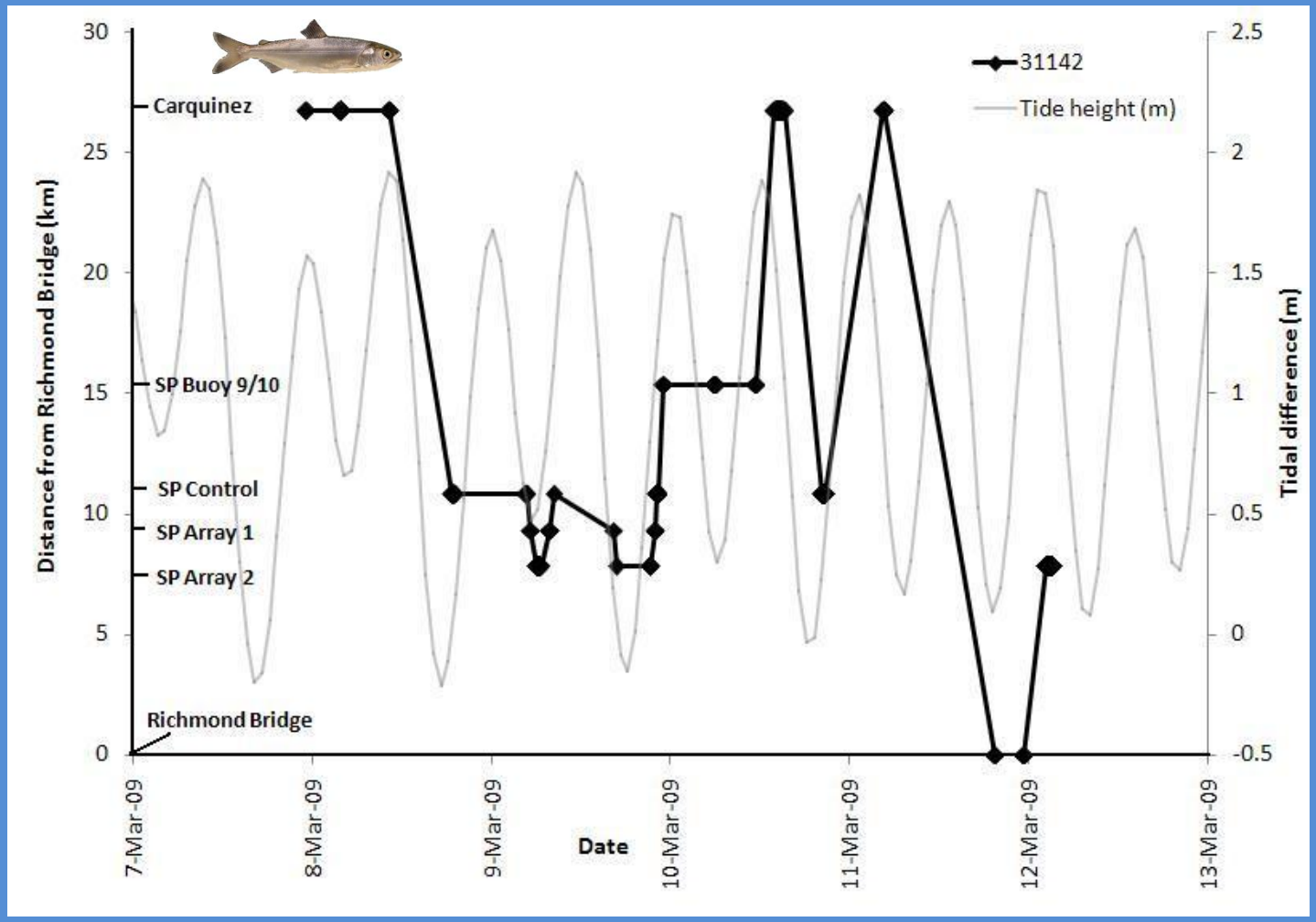


Steelhead



Late Fall Chinook

Sloshing



Many fish (both species) display repeated upstream-downstream movements, coinciding with tidal flows

Direct Routes?

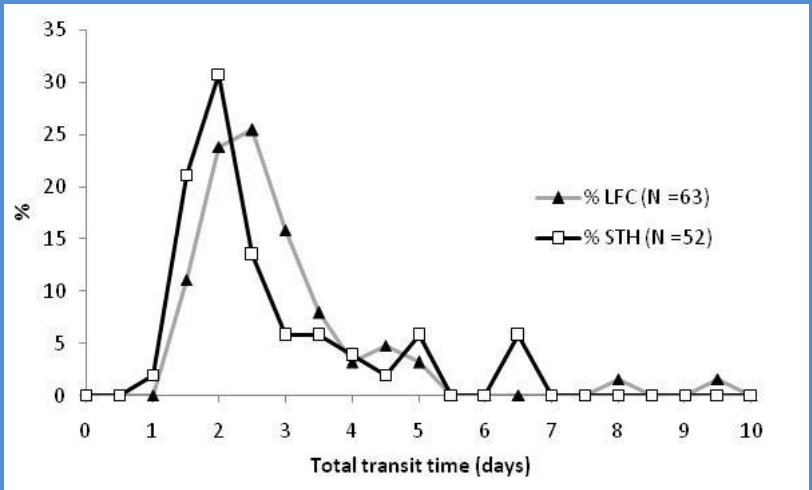
- Instantaneous rates of transit through experimental array were **faster** than overall transit through reach (Paired t-test, $p<0.001$)
- Why? (flats, back-forth washing, pausing?)

Tag ID	Carquinez-Richmond	SP Control - SP Array 1	SP Array 1 - SP Array 2
31284	0.38	2.05	1.90
31289	0.45	1.82	1.84
31376	0.35	2.53	0.09
31386	0.44	1.81	1.50
31389	0.41	1.68	0.12
31496	0.17	1.24	1.00
31578	0.61	1.31	0.06
31589	0.43	0.88	0.06
31618	0.39	1.40	1.41
31628	0.49	1.38	1.26
31636	0.47	1.70	1.22
31260	0.47	1.76	
31392	0.36	1.37	
31426	0.54	1.30	
31454	0.44	1.21	
31466	0.29	1.55	
31500	0.55	2.42	
31501	0.61	1.95	
31570	0.49	1.93	
31579	0.39	1.31	
31619	0.53	1.22	
31415	0.32		1.93
Average transit rate	**0.44**	**1.61**	**1.03**

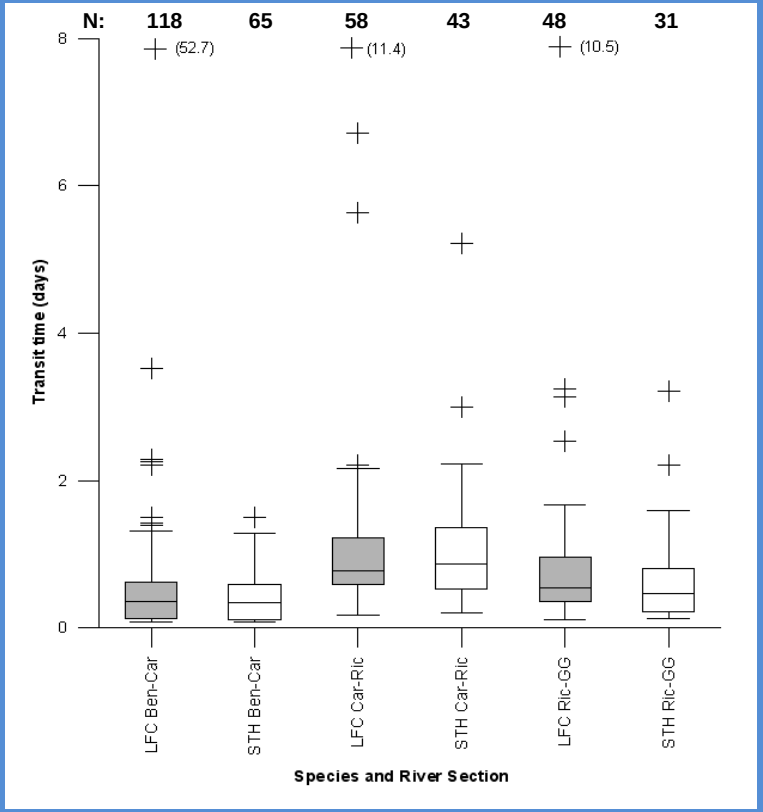
Chinook salmon

Q2a: What is the residence time of salmonid smolts in particular reaches of the estuary (transit time)?

Results to Date

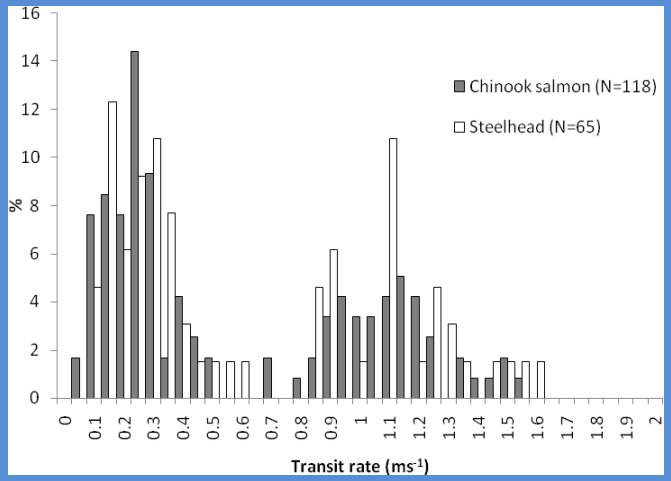


Transit time from Benicia to the Golden Gate

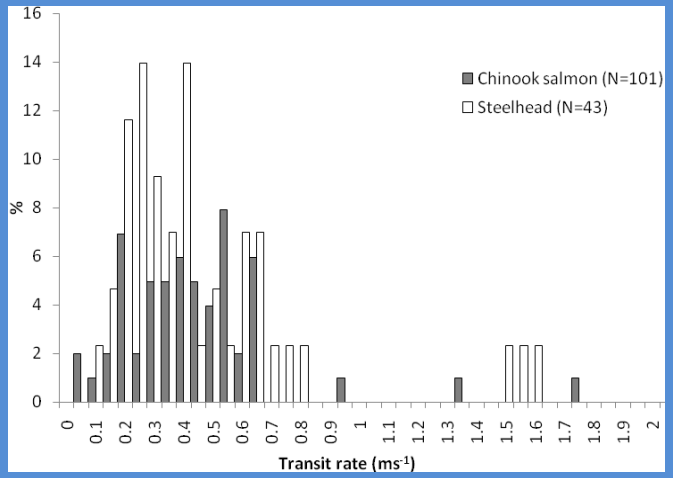


Transit time of Chinook salmon (LFC, grey) and steelhead (STH, white) in three sections of the Sacramento River system: Benicia (BEN) –Carquinez (CAR), Carquinez (CAR)–Richmond (RIC), Richmond (RIC) –Golden Gate (GG).

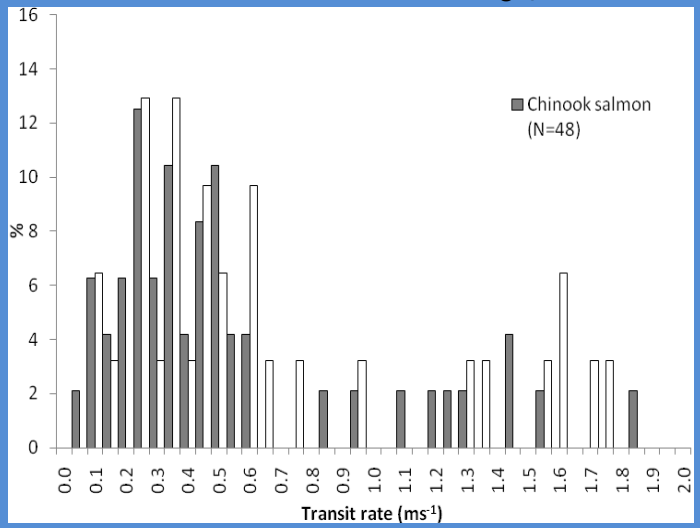
Results to Date



Transit rates (ms-1) for Chinook salmon (filled bars) and steelhead (white bars) from Benicia Bridge to Carquinez Bridge, 2009.



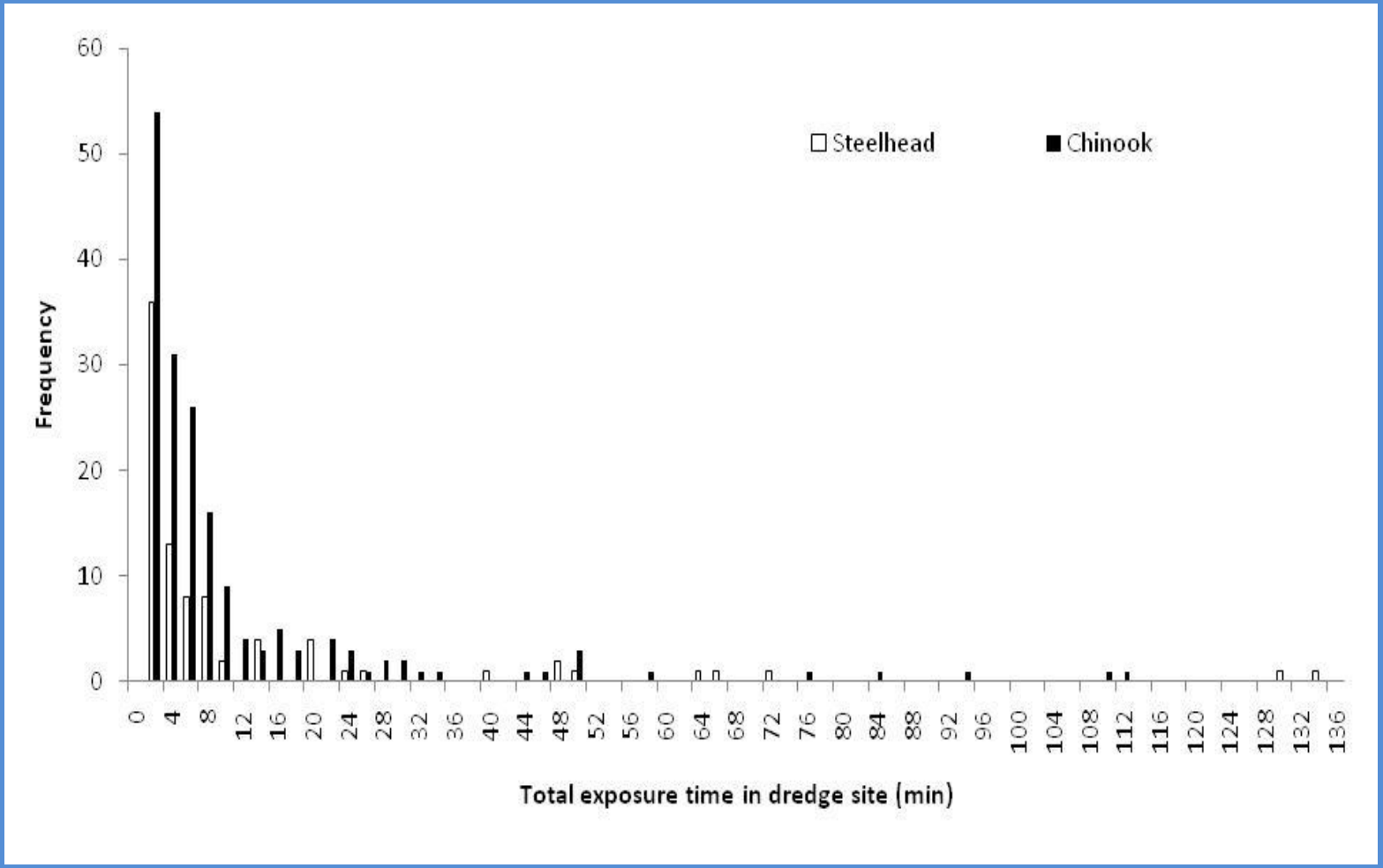
Transit rates (ms-1) for Chinook salmon (filled bars) and steelhead (white bars) from Carquinez Bridge to Richmond Bridge, 2009.



Transit rates (ms-1) for Chinook salmon (filled bars) and steelhead (white bars) from Richmond Bridge to the Golden Gate, 2009.

Q2b: What is the residence time of salmonid smolts at sites of interest (exposure time)?

General Exposure Time



Total exposure time at a dredged site (marina or channel) by salmonid smolts in San Francisco Bay Estuary.

Fish Presence at Dredged Sites

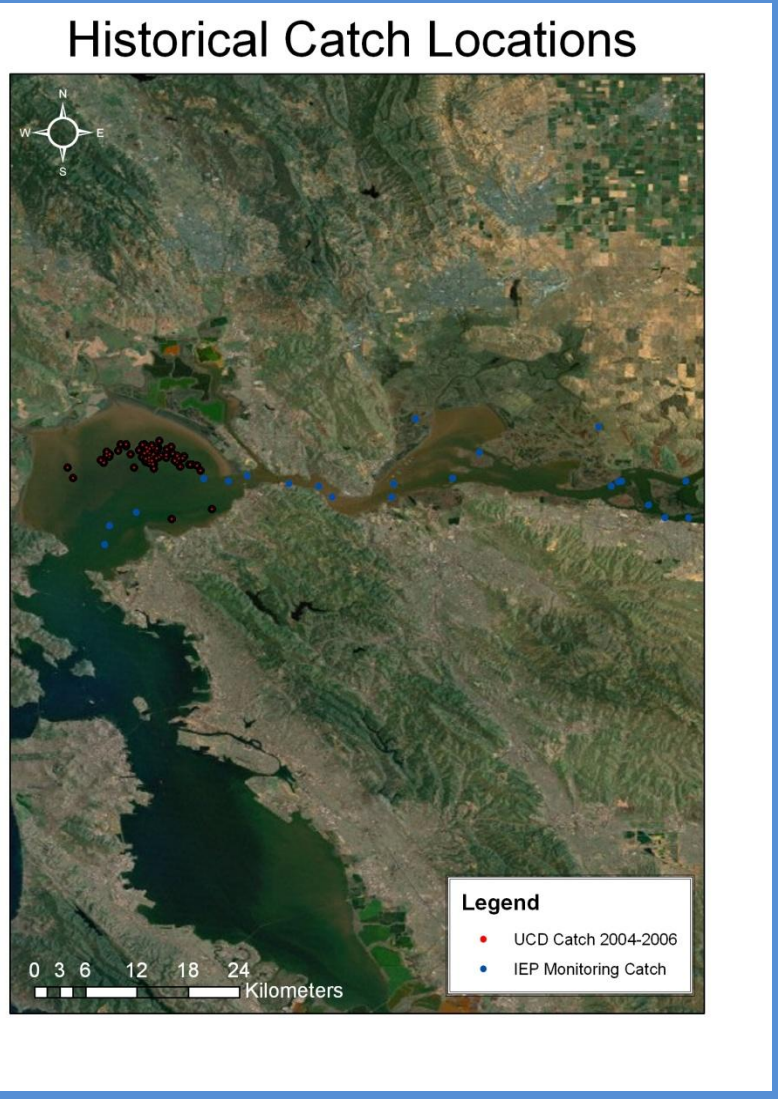
Station Type	Station Name	Chinook salmon # Fish	Chinook salmon # Detection	Steelhead # Fish	Steelhead # Detection
Marina/ Shoal	Berkley Marina				
	EmeryvilleA				
	EmeryvilleB	1	2		
	G3	5	160	2	22
	G5			1	1
	Larkspur Ferry 15			5	112
	MartinezMarina	156	1152	64	162
	MontezumaEast	4	308	4	149
	MontezumaWest	4	103	2	22
	PetalumaRRBridge	5	192	5	206
	Point Richmond			2	30
	PortSonomaMarina	4	50	3	7
	San Rafael Can 6				
	Suisun City Marina				
	Vallejo Marina C	12	36		
	Total	**168**	**2003**	**77**	**711**
Channel	SPBuoy7			1	1
	SPBuoy8	50	331	38	163
	SPBuoy10	38	240	2	5
	SPBuoy10b	3	7		
	Total	**80**	**578**	**39**	**169**

Summary

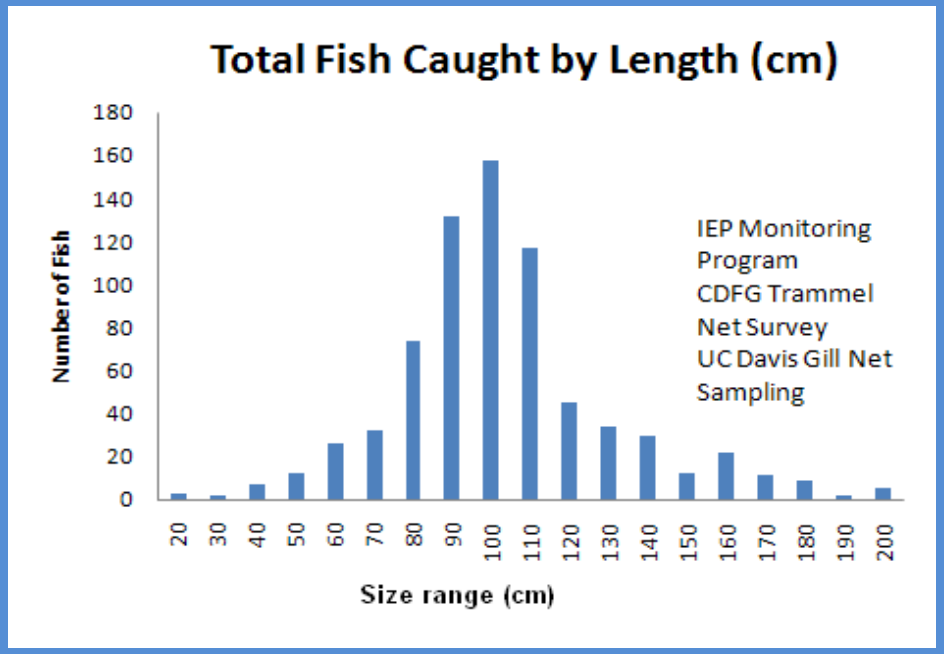
- Bay movements of salmonids affected by tidal influences, leading to a washing effect up and down stream
- Instantaneous transit rates > overall transit rates; movements may not be entirely directional within channels, but may include use of flats
- Overall transit times through the Bay is relatively short; less than 10 days
- Reach specific transit rates variable for both species and range from 0.1-1.9 ms^{-1}
- Cumulative exposure at dredge site monitors was low for both species; less than 12 minutes for most individuals

Q3: What are the spatial and temporal distribution patterns of green sturgeon in the estuary?

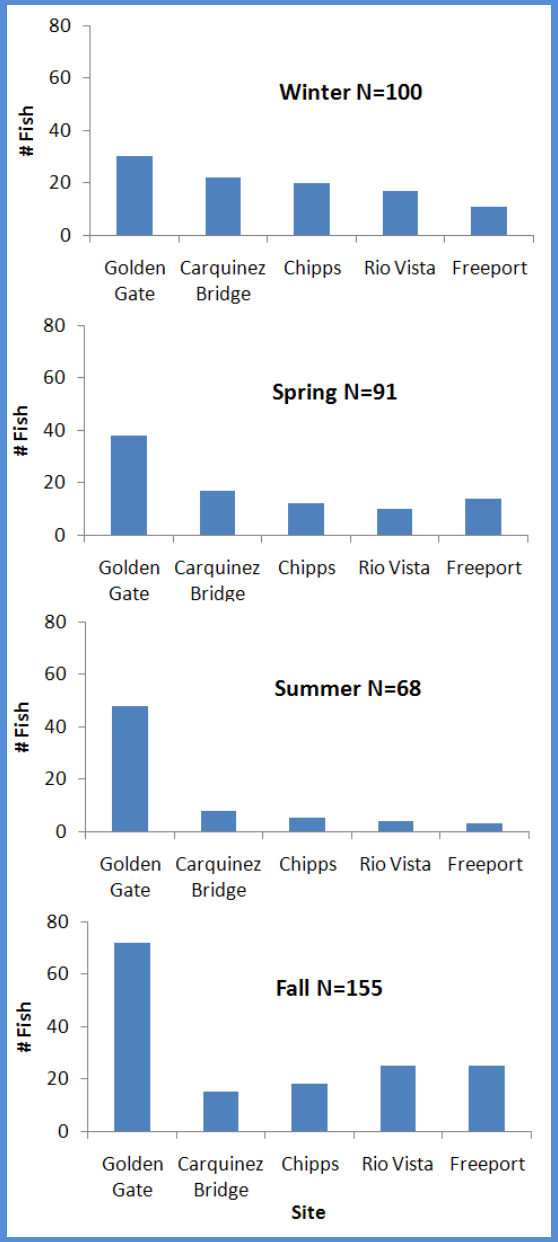
Distribution of Green Sturgeon in the Bay

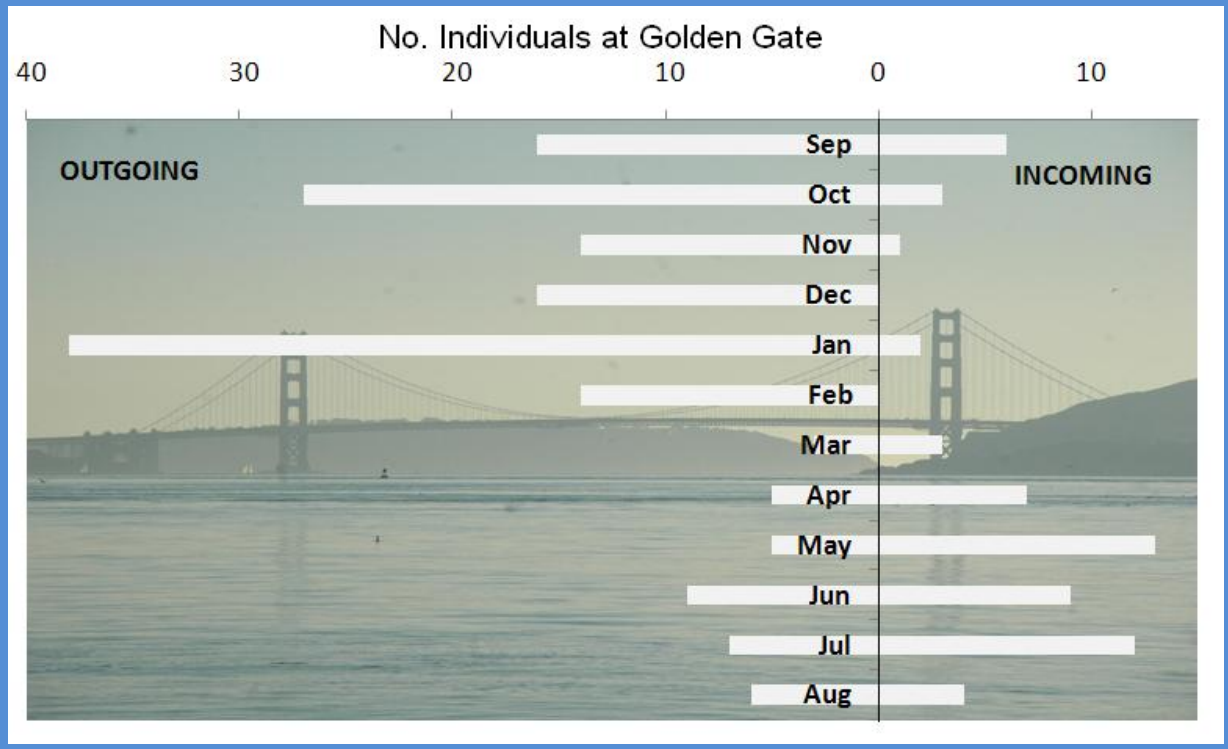


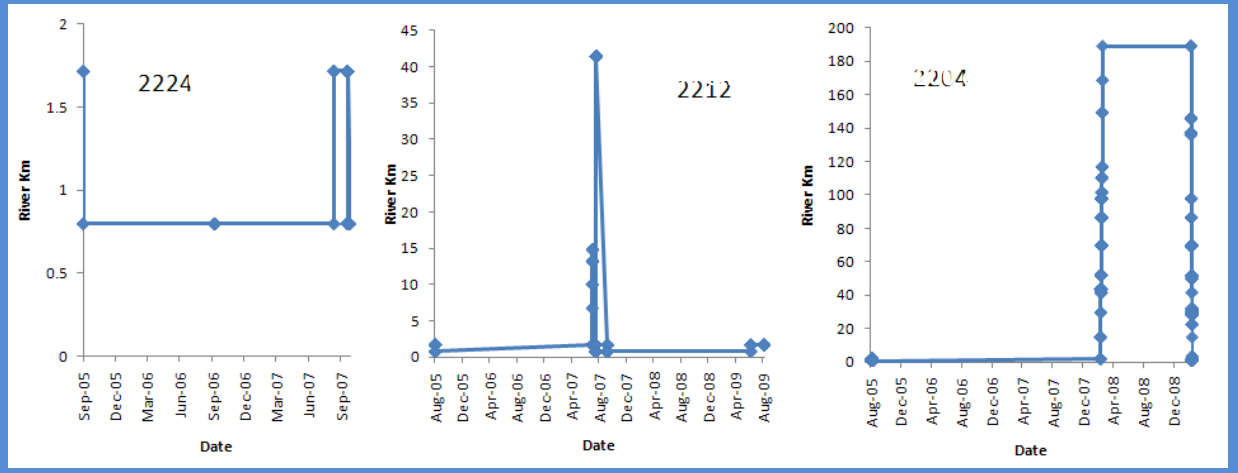
Program	Sampling Method	# Fish	Size Range (cm)
IEP Monitoring Program	Various	23	19-101
CDFG Trammel	Trammel Net	732	47-209
UC Davis	Gill Net	209	55-204



Seasonal Presence of Tagged Sturgeon

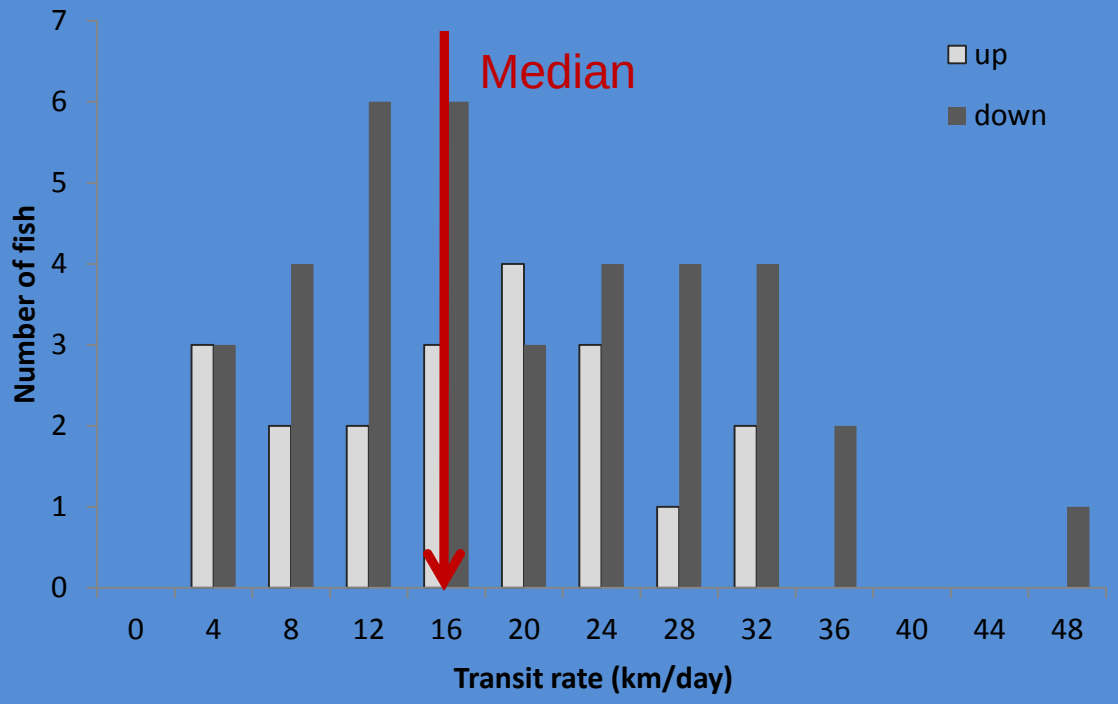




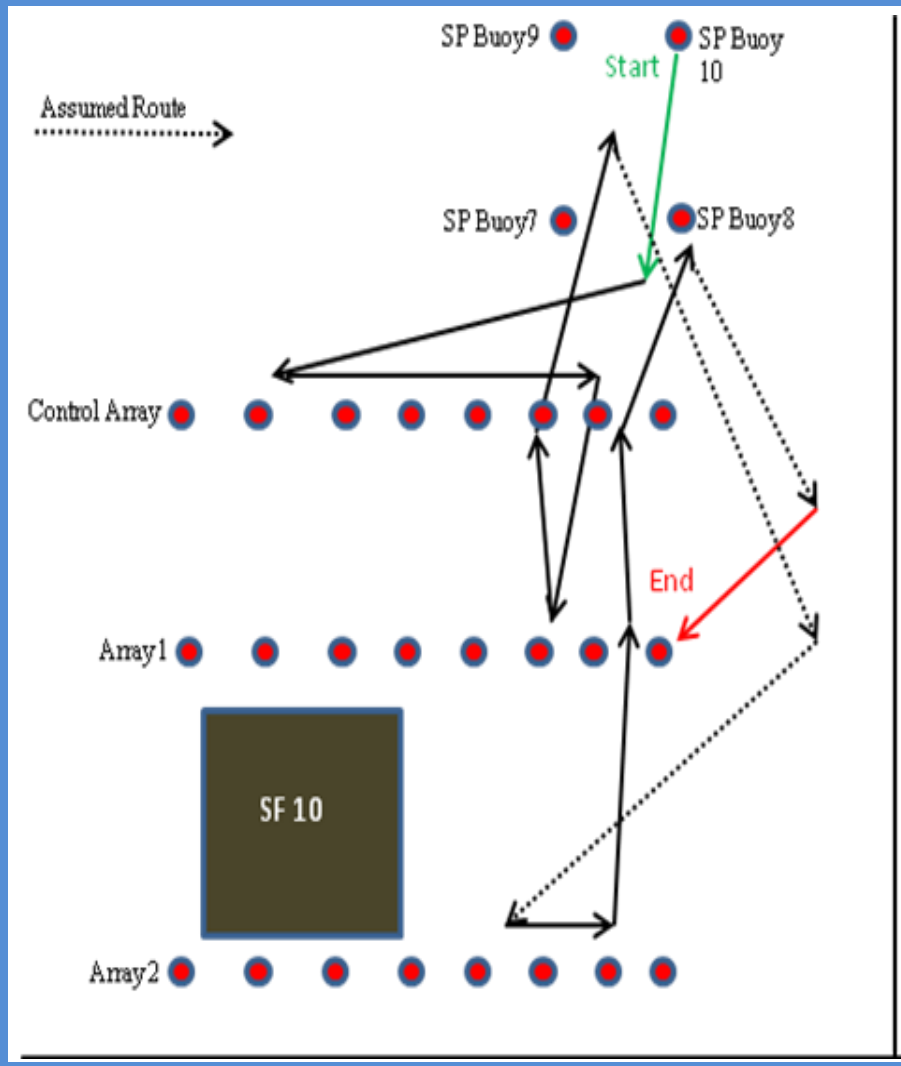


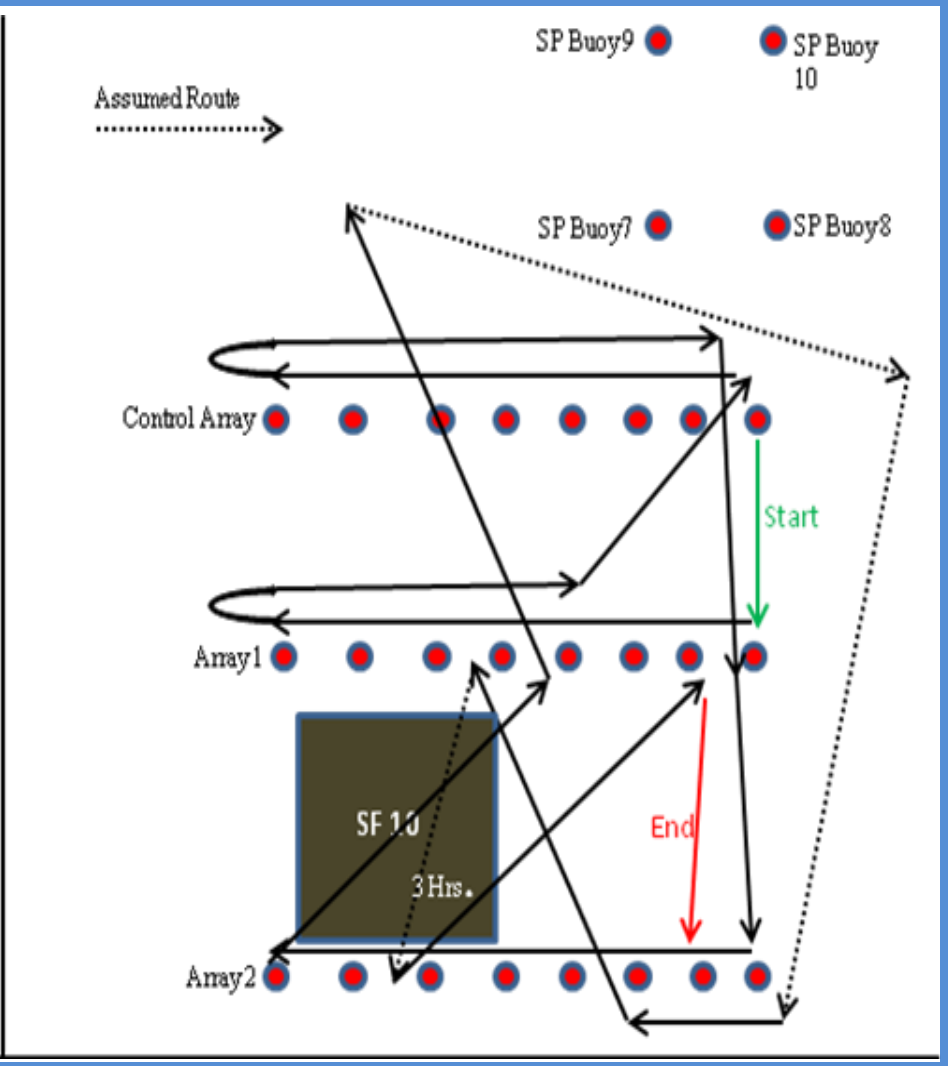
Transit Rates Through Bay

- Studied overall transit rates from Rio Vista to Carquinez and from Carquinez to Golden Gate
- Fish moved faster in winter than fall (P = 0.009)
- Fish moved faster downstream than upstream (P=0.032)
- No difference in transit rates by reach (upper and lower)



Movements Around Placement Site SF10





Exposure at dredged sites

From March-June 2009, 18 fish detected in Bay, 10 detected at dredged sites (exposure time [min])

Tag ID	Martinez Marina	Richmond Point	Vallejo Marina	G3 Channel	Total
217	34.3	20.2			54.6
219			682.5		682.5
224	18.6				18.6
2204	21.1			9.6	30.8
2237	7.1				7.1
2242		11.6			11.6
5447	252.7		149.8		402.5
5449	57.1				57.1
5450	30.7				30.7
10816	173.4				173.4
Average Minutes	**74.4**	**15.9**	**416.1**	**9.6**	**146.9**

(Two individuals (Tag IDs # 217 and 2237) were detected at the Alcatraz SE monitor for 21 minutes (13+8) and a single detection, respectively).

Expected Results 2010

- Describe frequency use of shallow flats/shoals for all three species
- Channel preference through SP Bay and Raccoon Strait.
- Transit time in relation to tidal state and currents (ADCP work)
- How much time do sturgeon spend in the estuary?
- Inter-annual variations (dry years vs. wet years?)
- Diel influence on behavior and movement patterns

Future Steps

- Towards an ecosystem-based management: suite of native species (including green sturgeon, sevengill sharks).
- Climatic influence on migratory behavior (wet vs dry years)
- Fine scale movements and avoidance behavior in relation to human activities.
- Transit time in relation to tidal state and currents (ADCP work)
- Integration of South Bay sites?

Acknowledgements

We would like to thank Mike McGill and Christina Slager at the Aquarium of the Bay for providing the boat time to deploy and maintain the monitors deployed on acoustical releases. Thanks to Dave Vogel for allowing us to present data on three green sturgeon tagged by his project. We would also like to thank Chuck Morton for scheduling boat time and assisting on the Caltrans vessel with the maintenance of the monitors deployed on the Bay Bridge and Richmond San Rafael Bridge. We greatly appreciate the help from everyone in the UC Davis Biotelemetry Laboratory (Denise Tu, Anna Stephenson, Taylor Chapple, Phil Sandstrom, Dennis Cocherell) for volunteering their time to assist with the surgical implantation of the tags. We would also like to thank Arnold Ammann and Cyril Michele at the Santa Cruz office of the NMFS for maintaining the database which made it possible to assemble detections from many different studies. We would like to acknowledge David Woodbury at the Santa Rosa office of the NMFS for his input into the design of the study. Finally, we would like to thank Pete Lacivita, Bill Brostoff, and Allison Bremner for their efforts in all aspects of the study.