# Thermal Thresholds Project

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# Introduction

- EPA thermal criteria developed for Pacific Northwest salmonids (EPA 2003)
- No such criteria in CA, so Pacific NW thermal criteria adopted
- Could California populations be more adapted to warmer temperatures?

**Table 1: Region 10 Guidance Criteria for Salmon and Trout**

| Salmonid Uses During the Summer Maximum Conditions | Criteria |
|---|---|
| Bull Trout Juvenile Rearing | 12°C (55°F) 7DADM |
| Salmon/Trout "Core" Juvenile Rearing<br><br>*(Salmon adult holding prior to spawning, and adult and sub-adult bull trout foraging and migration may also be included in this use category)* | 16°C (61°F) 7DADM |
| Salmon/Trout Migration plus Non-Core Juvenile Rearing | 18°C (64°C) 7DADM |
| Salmon Trout Migration | 20°C (68°F) 7DADM. Plus a provision to protect and, where feasible, restore the natural thermal regime |

| Salmonid Uses | Criteria |
|---|---|
| Bull Trout Spawning | 9°C (48°F) 7DADM |
| Salmon/Trout Spawning, Egg Incubation, and Fry Emergence | 13°C (55°F) 7DADM |
| Steelhead Smoltification | 14°C (57°F) 7DADM |

Modified from U.S. Environmental Protection Agency (2003). 1) "7DADM" refers to the Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, sockeye, pink and chum salmon; 3) "Trout" refers to steelhead and coastal cutthroat trout

**EPA Region 10 guidance**

# Introduction

## Thermal metrics for CV salmon not well defined

**Table 2.1: Thermal Metrics for Central Valley Anadromous Salmonids**

| Life Stage | Chinook Salmon: Fall CS | Chinook Salmon: Late-Fall | Chinook Salmon: Spring | Chinook Salmon: Winter | Steelhead Trout | Metric | Citations |
|---|---|---|---|---|---|---|---|
| Egg | 10-14°C[1] 13.3-13.9°C[2] | Unknown | Unknown | 13.3°C[2] | Unknown | Minimal Mortality (<10%) | [1] Richter and Kolmes 2005 [2] Myrick and Cech 2001 |
| Alevin | Unknown | Unknown | Unknown | Unknown | Unknown | Minimal Mortality (<10%) | |
| Juvenile | 17-20°C[3] 15.3°C[4†] | Unknown | Unknown | Unknown | 19-20.5°C[5] | Optimal Growth | [3] Myrick and Cech 2002 [4] Rich 1987 [5] Myrick and Cech 2005 |
| Juvenile | 28.8°C @ 19°C[6] | Unknown | Unknown | Unknown | 27.5-29.6°C @ 11-19°C[7] | Critical Thermal Maximum | [6] Cech and Myrick 1999 [7] Myrick and Cech 2005 |
| Smolt | <17°C[8,2] | Unknown | Unknown | Unknown | Unknown | Successful Smoltification | [8] Marine and Cech 2004 |
| Adult | 21-24°C[9†/] 19-21[10,11‡] | Unknown | 23°C[9 †/] | Unknown | Unknown | Migration Success | [9] Strange 2010 [10] Hallock 1970 [11] Williams 2006 |

Laboratory conditions (satiation rations, clean water etc.) should be assumed unless marked by a † representing 'field-like' laboratory conditions or ‡ representing date quantified from field observations. *f* represents populations tested were from the Klamath River Basin.

CWB Review of Literature regarding Thermal Tolerances of California Salmonids

UC Davis Agreement #: D16-15001

**Variation in Thermal Eco-physiology among California Salmonids: Implications for Management**

May 31st 2018

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Professor

# Introduction

- Ca State Water Resources Control Board funded project: **Quantifying thermal thresholds for Central Valley salmonids**

- Task 1: Improving and applying a framework for identifying numeric temperature targets
- **Task 2: Adult energy density study**
- Task 3: Temperature modeling

**Theory:** To successfully spawn, adult salmon must have enough energy at the initiation of their migration. An adult that uses too much energy will die prior to spawning.

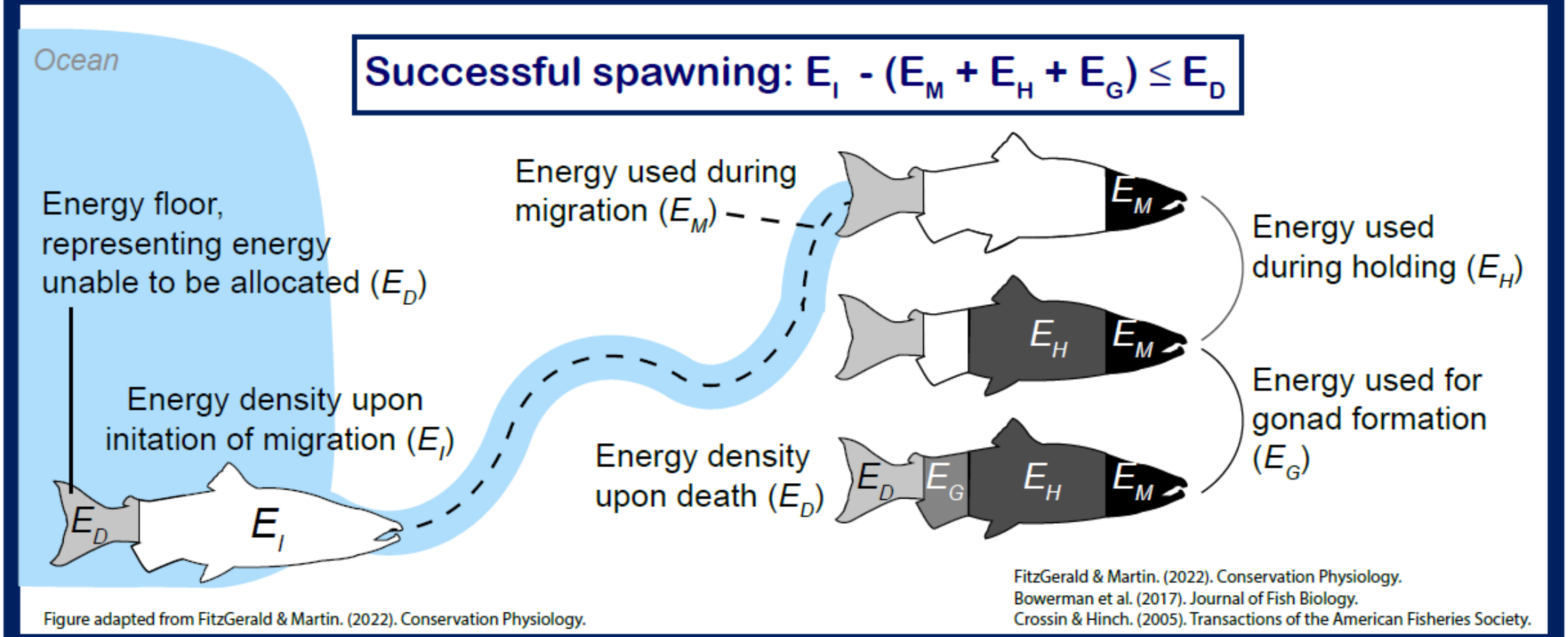



Figure adapted from FitzGerald & Martin. (2022). Conservation Physiology.

FitzGerald & Martin. (2022). Conservation Physiology.
Bowerman et al. (2017). Journal of Fish Biology.
Crossin & Hinch. (2005). Transactions of the American Fisheries Society.

**Question:** Do poor environmental conditions result in high energy use and increased pre-spawn mortality of adult Chinook salmon (*O. tshawytscha*) during migration and spawning?

-In the Central Valley, there is very little information on how environmental conditions impact energy use and pre-spawn mortality during migration.

Need measurements of energy content, reliable temperature measurements (or models), and migration routes!

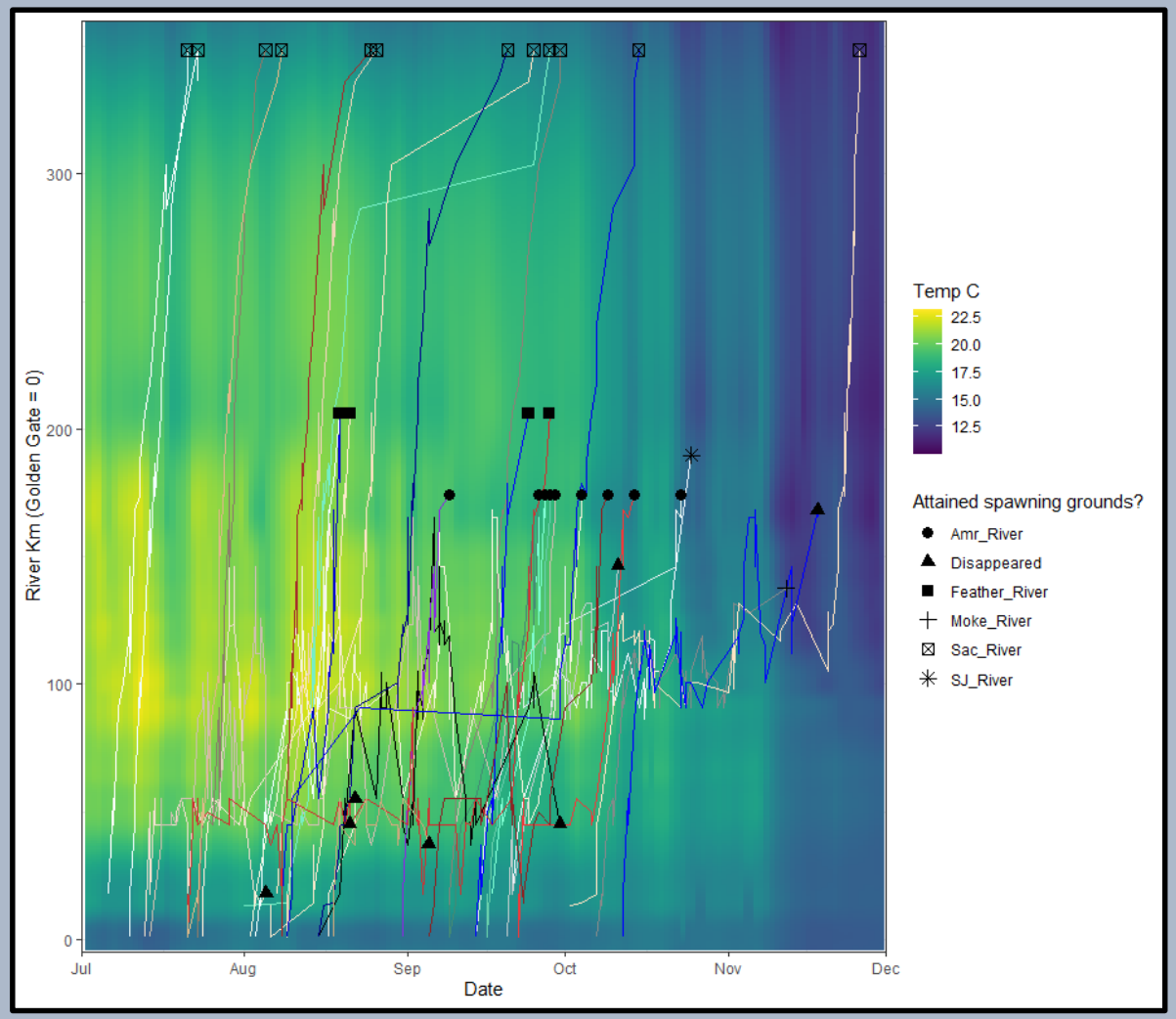
# Experimental design: Modeling and assessment

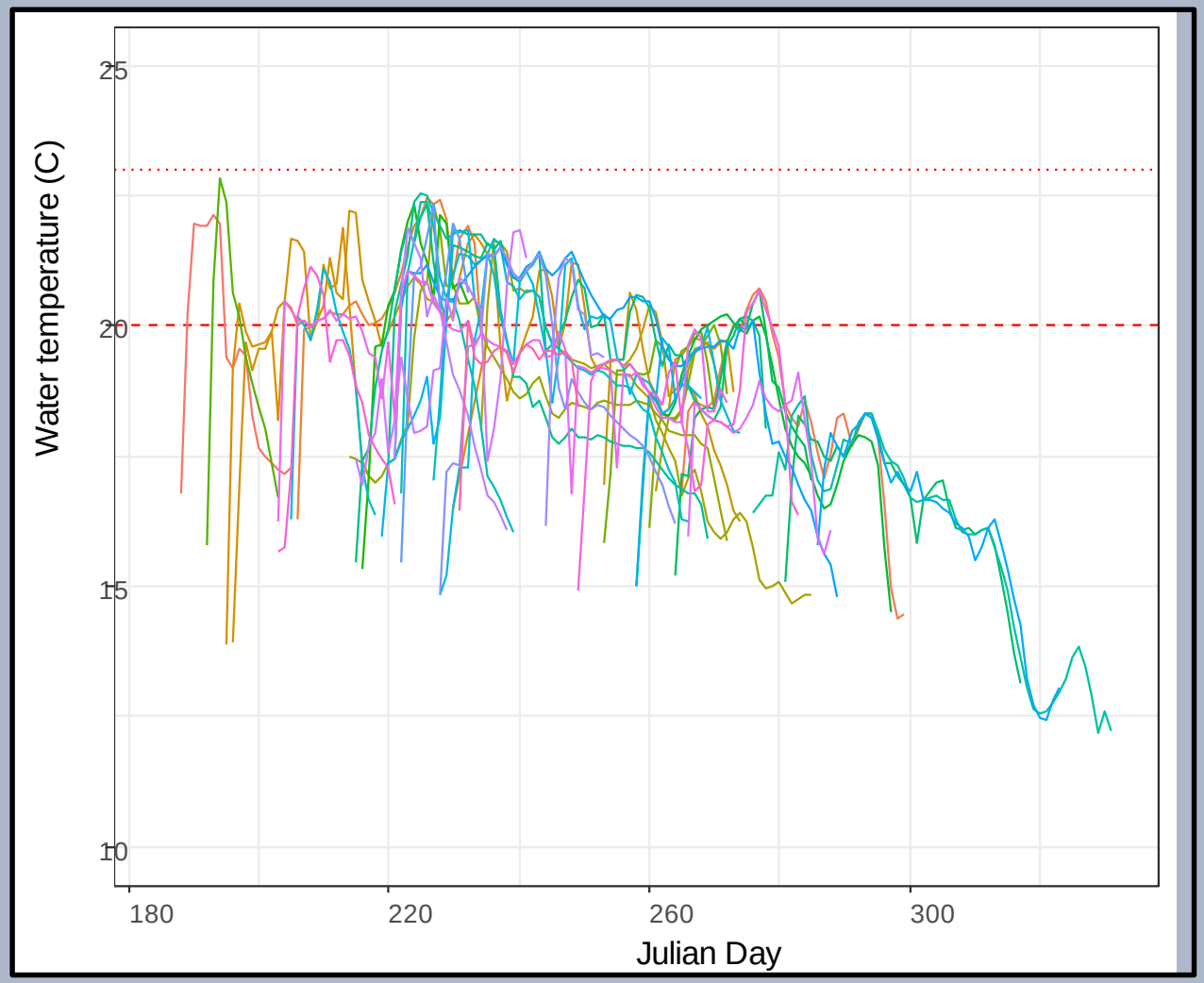
-We will link empirical measurements of fish energy density, migration and travel time, size, and pathogen prevalence to environmental factors, especially water temperature.

-Water temperature will be obtained from high-resolution stream temperature models as well as from a subset of adults tagged with archival temperature tags.

# Methods – Infer temperatures based on telemetry and temperature models

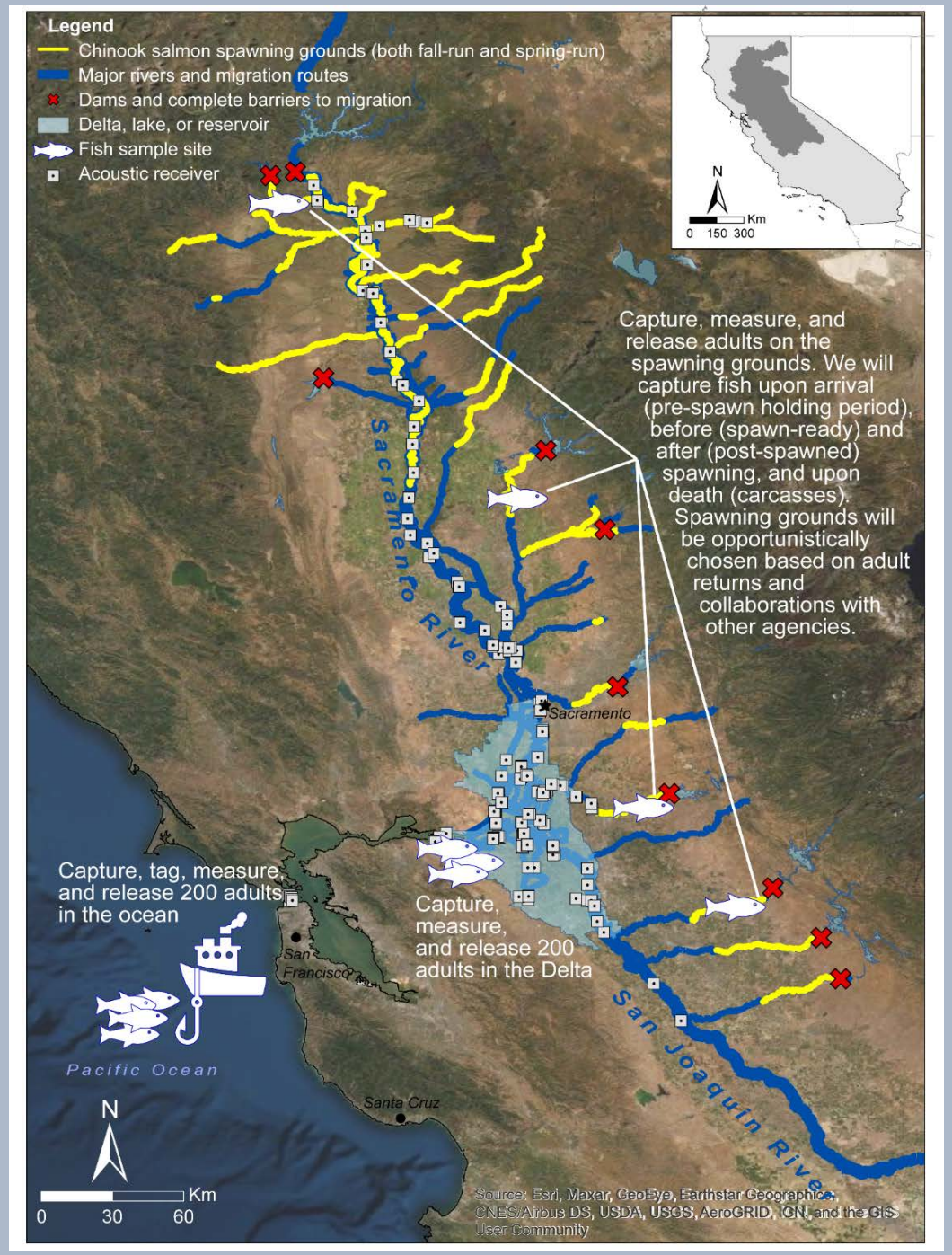
## Use individual tracks of tagged salmon for temperature histories



# Methods – Archival temperature tags

- Innovasea Acoustic Data Storage Tags: “**ADST tags**”
- Transmits current tag temperature and depth as well as stores archive of all recorded temperatures and depths
- Retreiving tag archive requires physical tag recovery
- Bright red and floats, increasing odds of being found and returned




# Methods

$$E_I \geq (E_M + E_H + E_S + E_D)$$

$E_I$ = energy at initiation of migration
$E_M$ = energy used during migration
$E_H$ = energy used during holding
$E_S$ = energy used for spawning
$E_D$ = energy at death

- **Ocean ($E_I$)**: tag 150 adults, measure with fatmeter and PA, gill tissue for pathogen assessment
- **River entry ($E_{M.1}$)**: CDFW traps in delta, fatmeter
- **Spawning ground arrival ($E_{M.2}$)**: Hatcheries / surveys, fatmeter
- **Prespawn fish ($E_{H\ or\ S}$)**: Hatcheries / surveys, fatmeter
- **Spawned out fish ($E_D$)**: Hatcheries / surveys, fatmeter

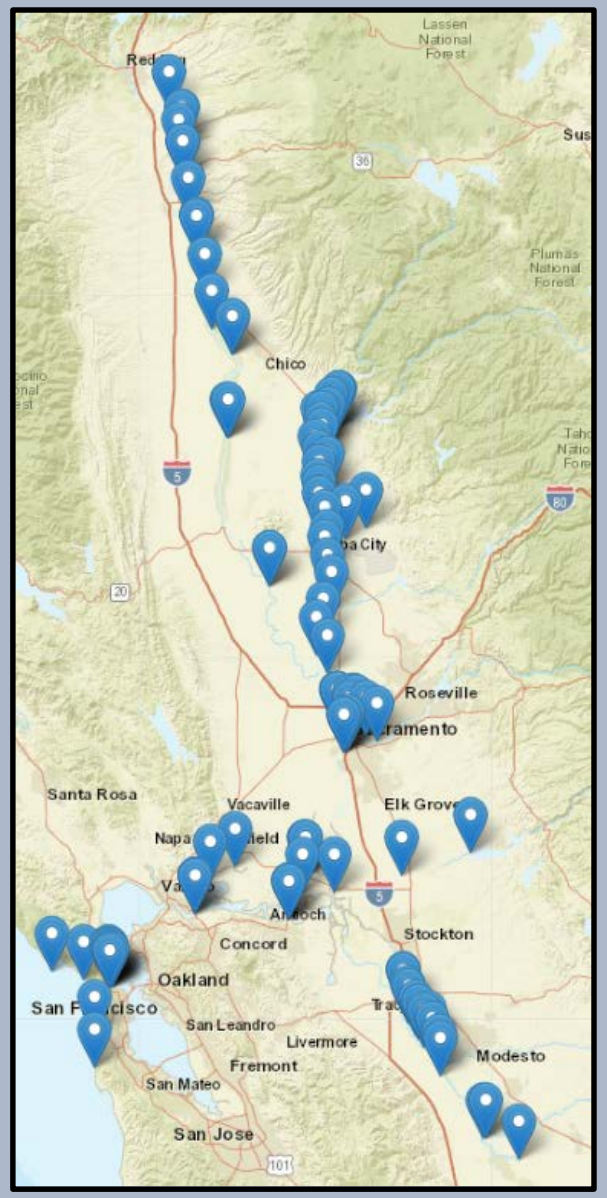
# Methods

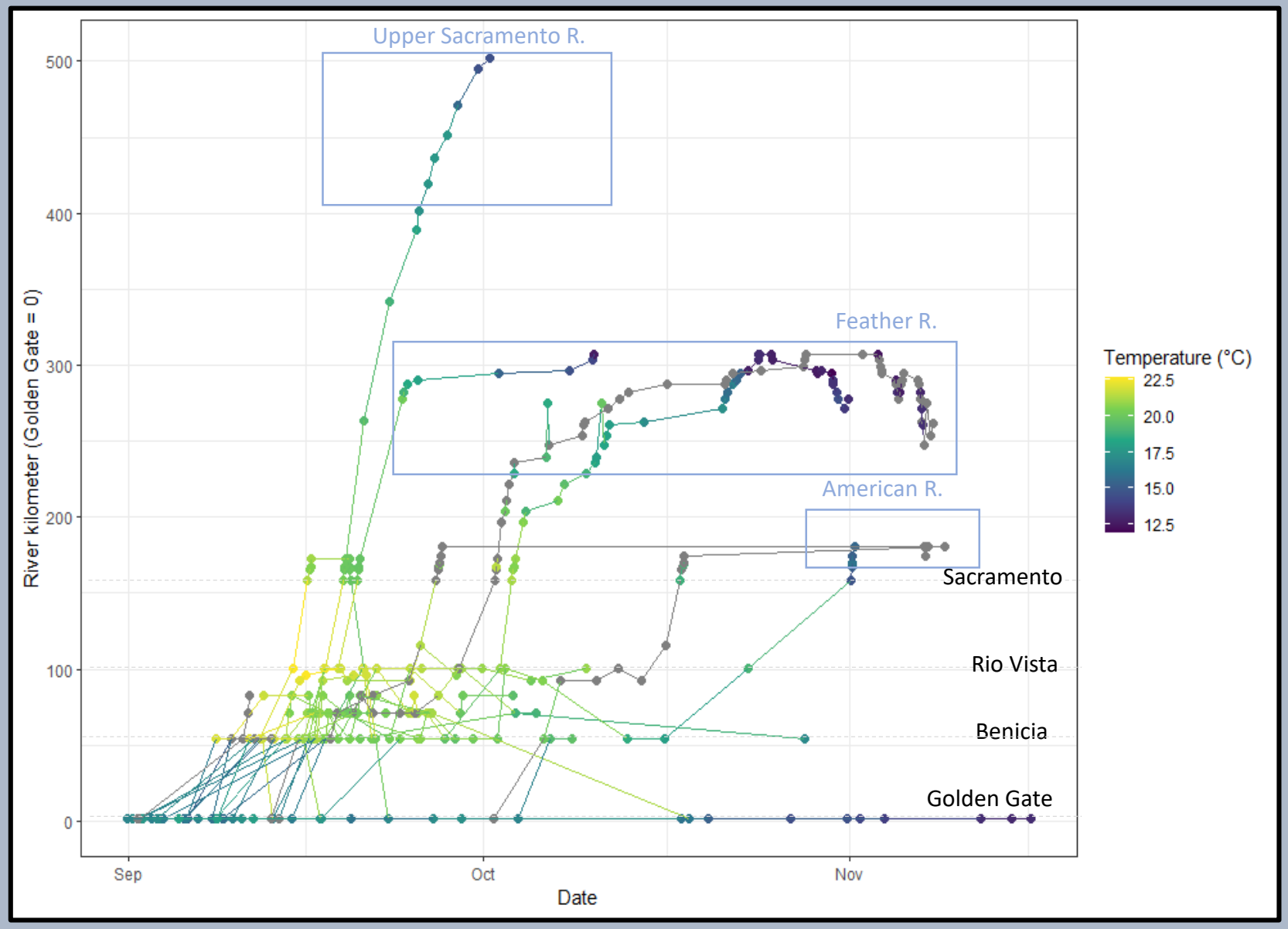

2022: n= 110

2023: n= 131

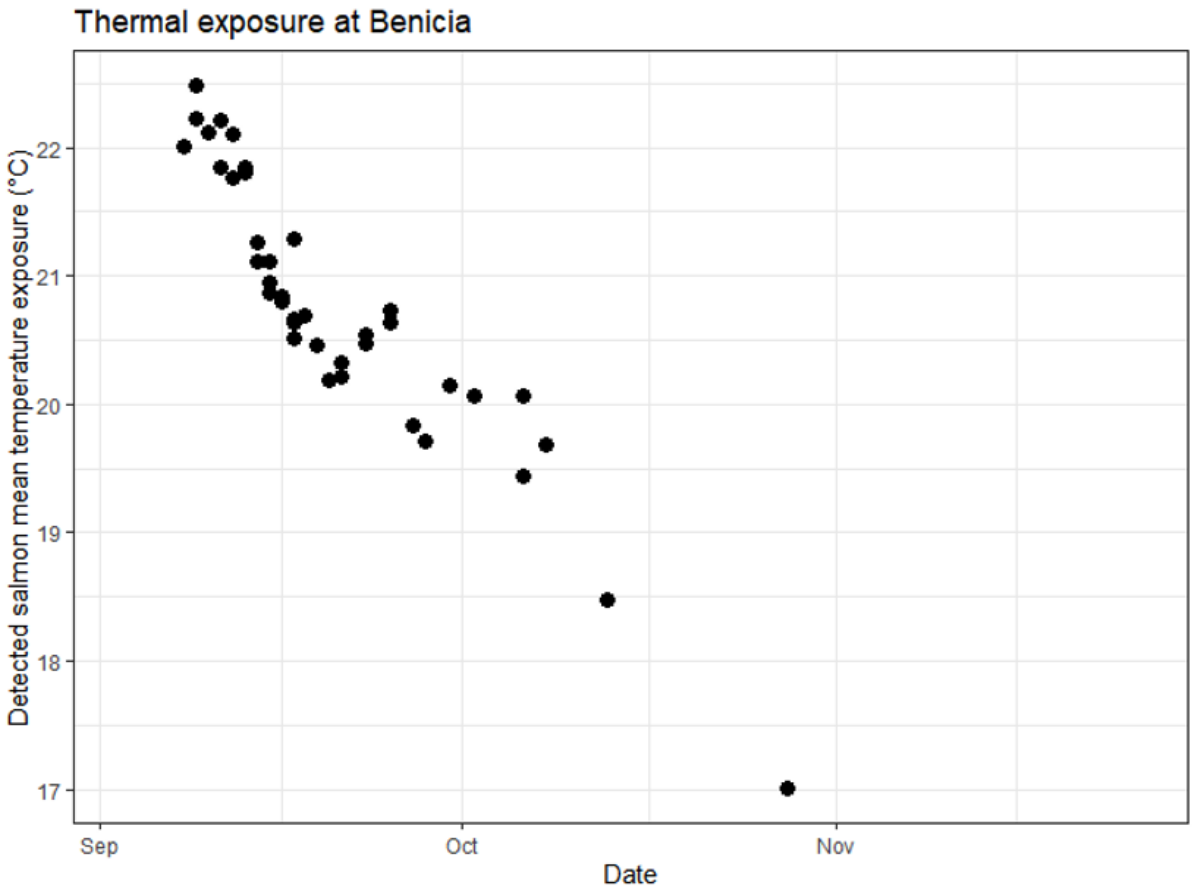
# 2022 Telemetry data

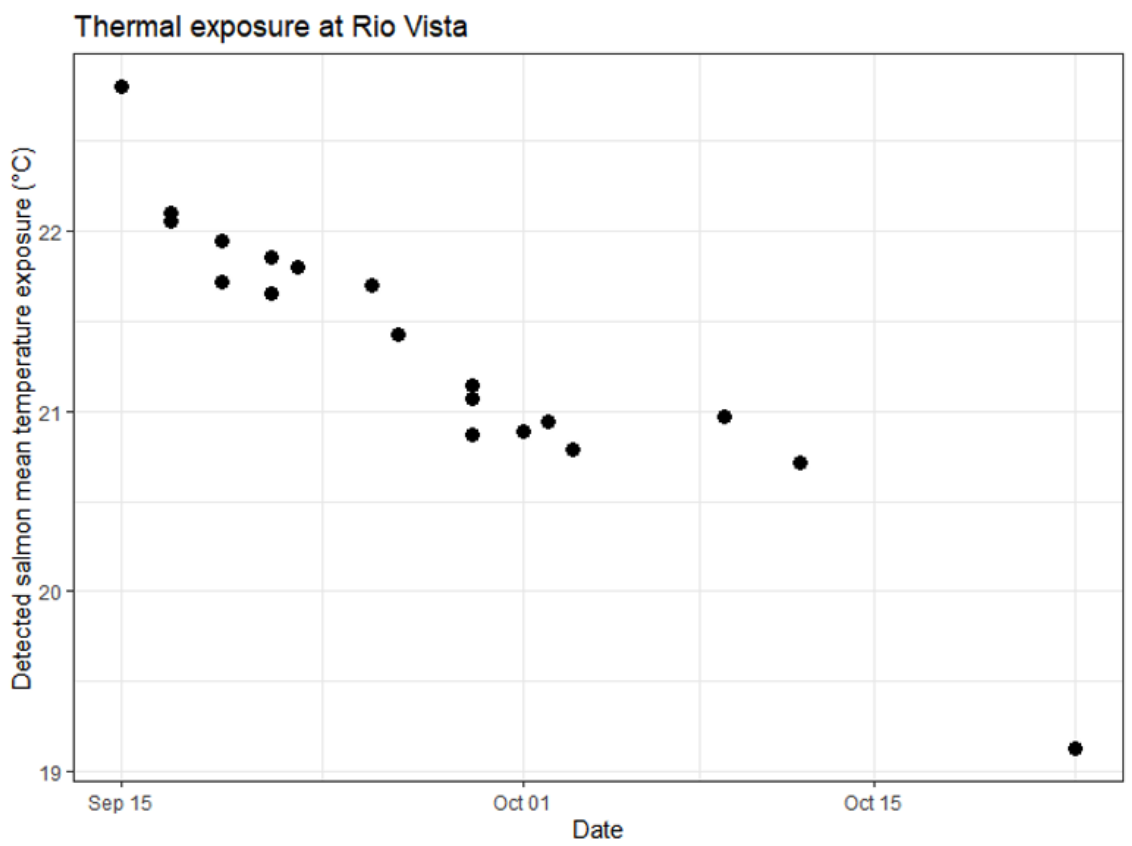
110 tagged and released in Ocean



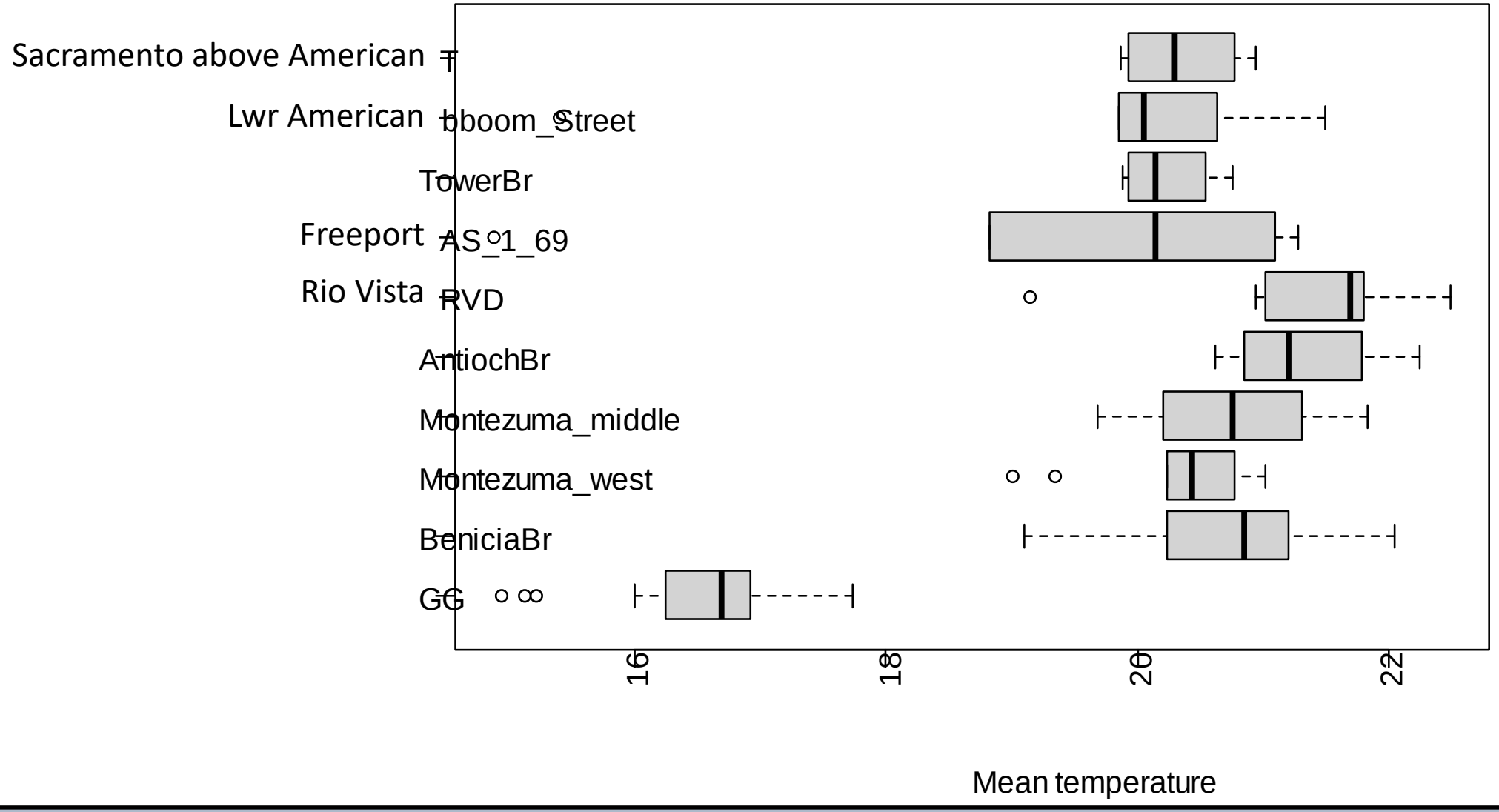



# 2022 Telemetry data

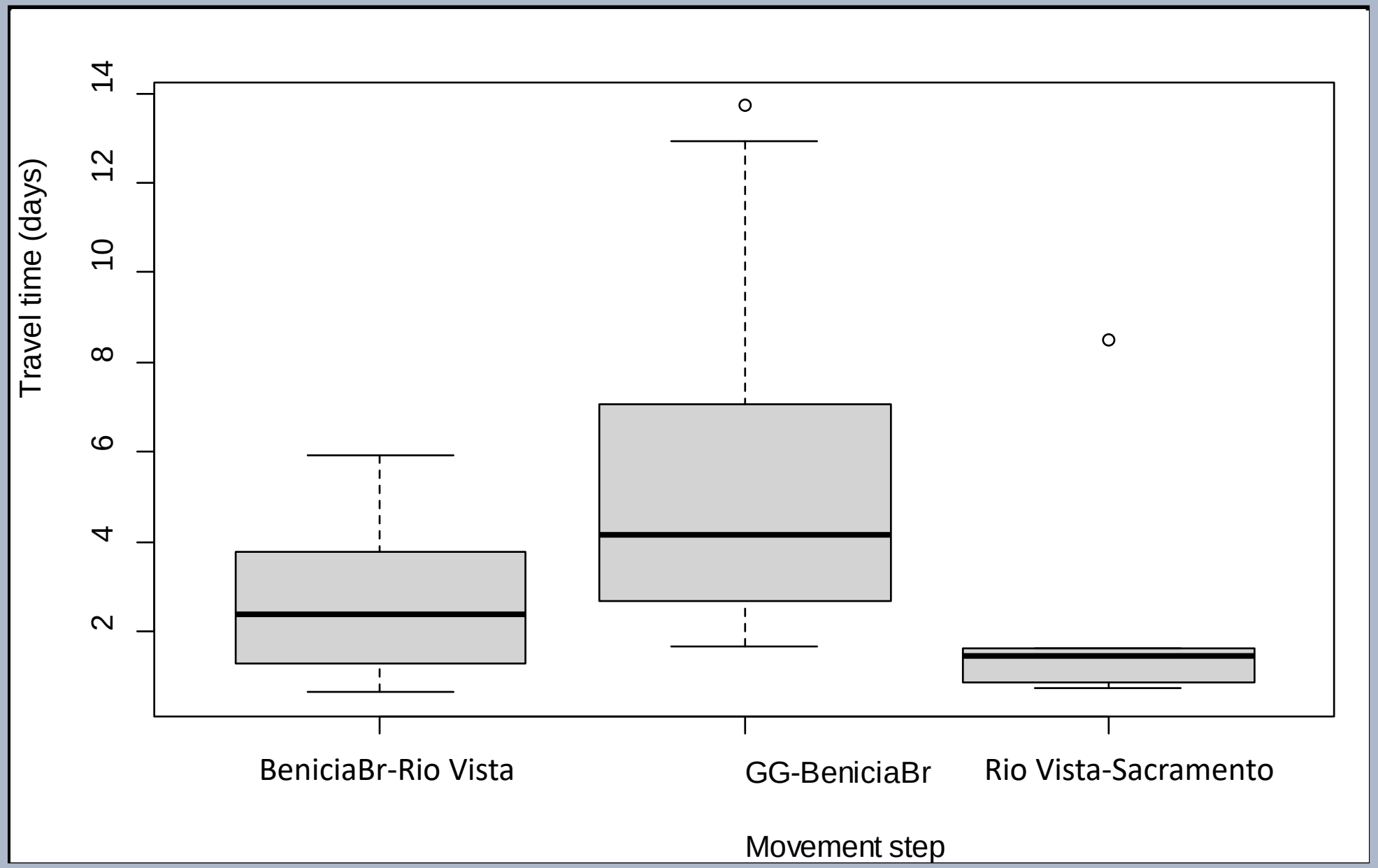


# 2022 Telemetry data



# 2022 Telemetry data



# 2022 Telemetry data

- Unfortunately, ADST tags had a programming error and most shut off within 7 days of initiation
- Some limited data from ocean residence was recorded
- On the bright side: Innovasea warrantied all 2022 ADST tags so 2023 season possible!

# 2022 Season Recap

- 110 tagged and released in Ocean
- 15 tags recovered on beaches – mortality soon after release
- 34 known to have entered the bay
- 31 known to have passed Carquinez straits
- 10 known to have exited Delta into rivers
- 3 recaptured at Feather River hatchery
- 1 recaptured at Nimbus hatchery (American R)
- 1 caught at barge hole on Sacramento (mouth of Battle Ck)

Thousands of dead fish, killed by an algae bloom, float around Lake Merritt in Oakland, Calif., on Wednesday, Aug. 31, 2022. (Ray Chavez/Bay Area News Group)

- No recovered archival data

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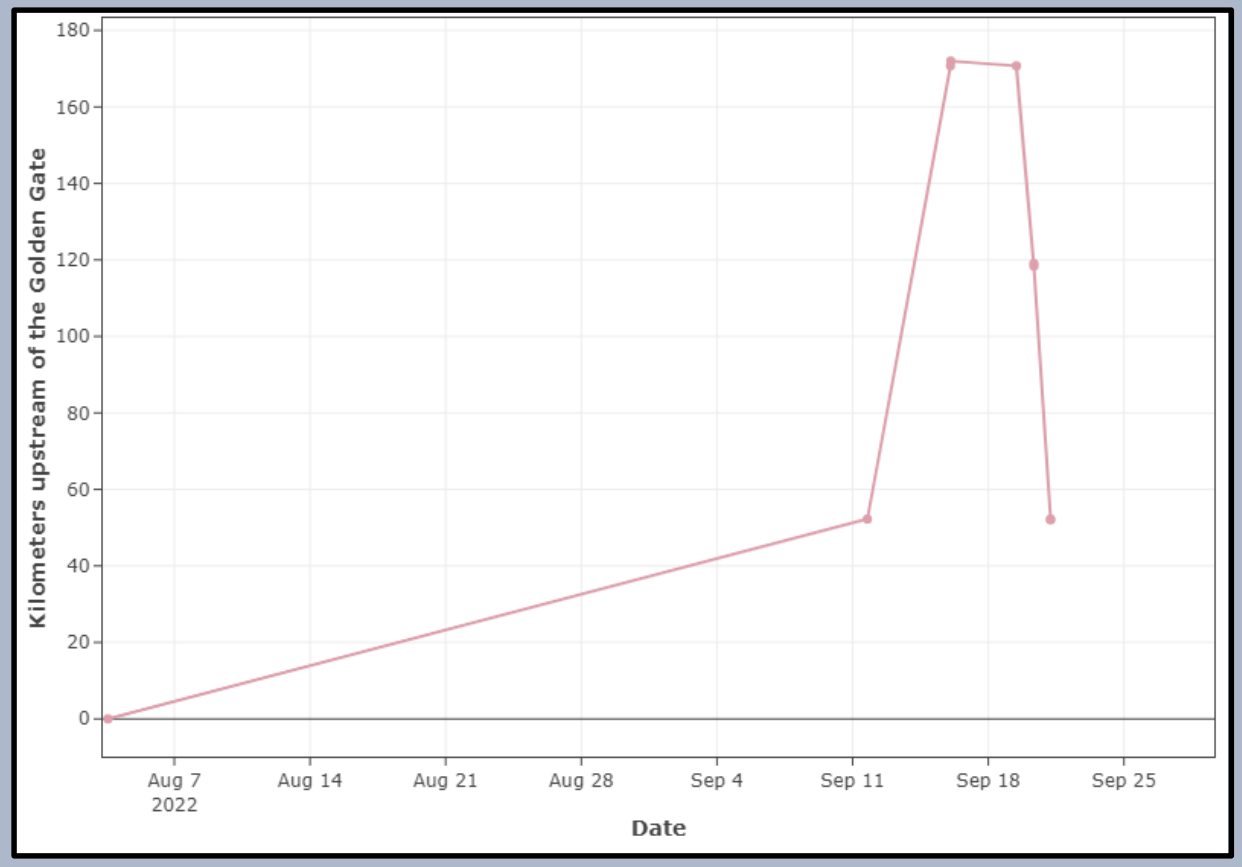
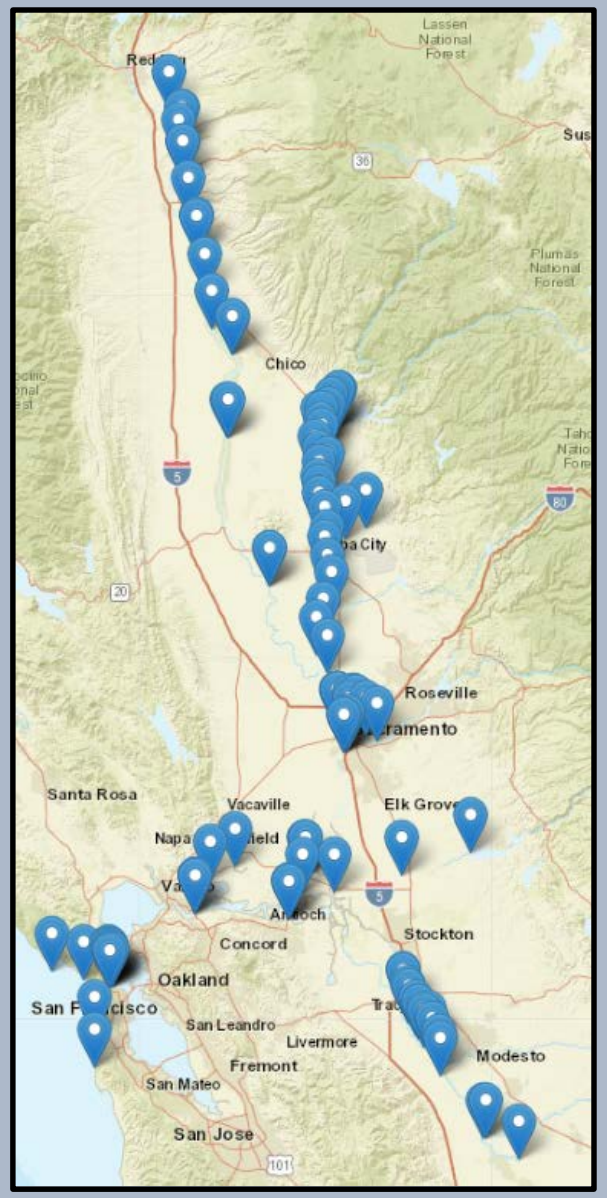
- 1 recaptured at Nimbus hatchery (American R)
- 1 caught at barge hole on Sacramento (mouth of Battle Ck)
- 1 caught at Benicia after going up to Sacramento!

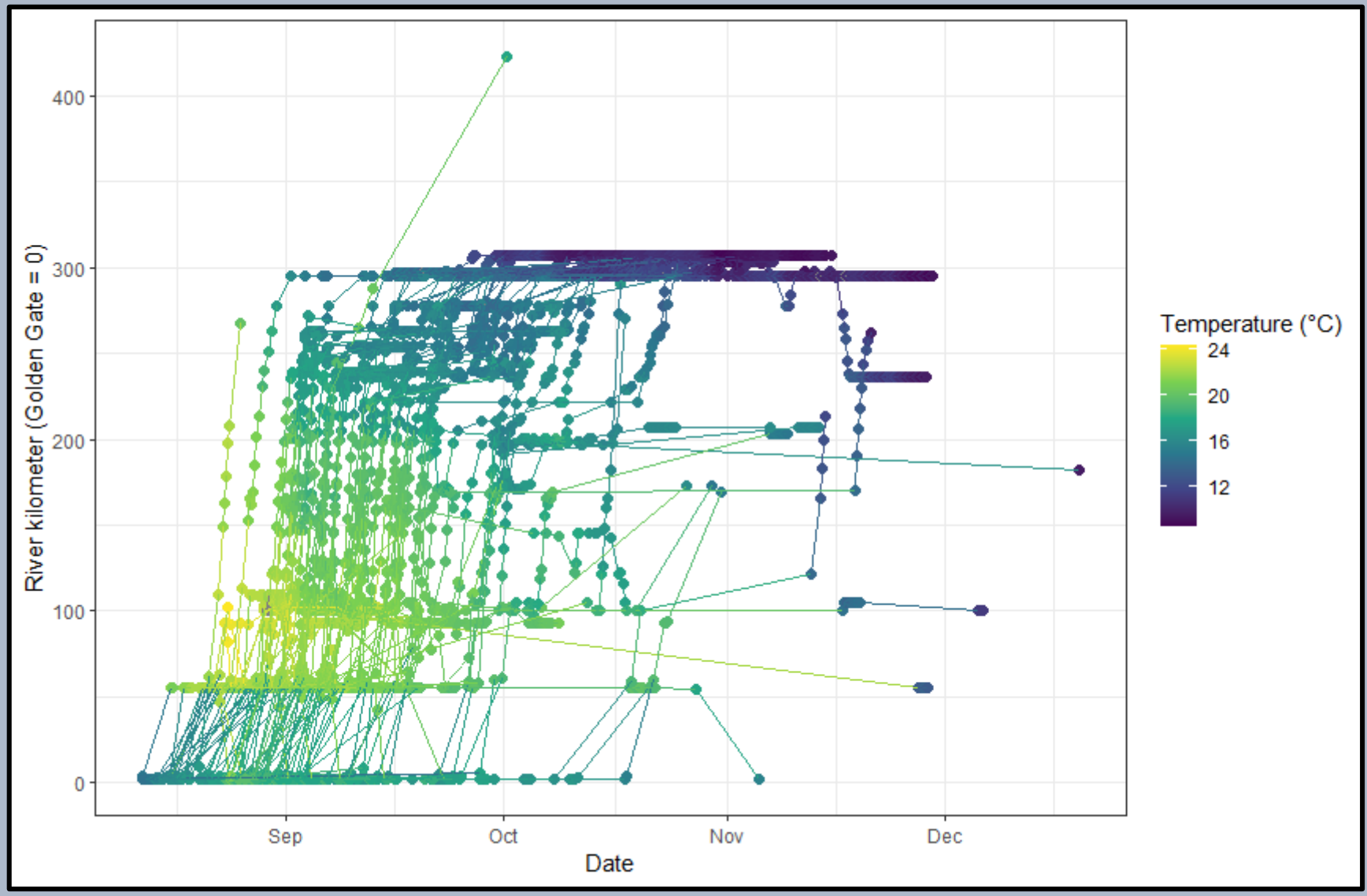
- No recovered archival data



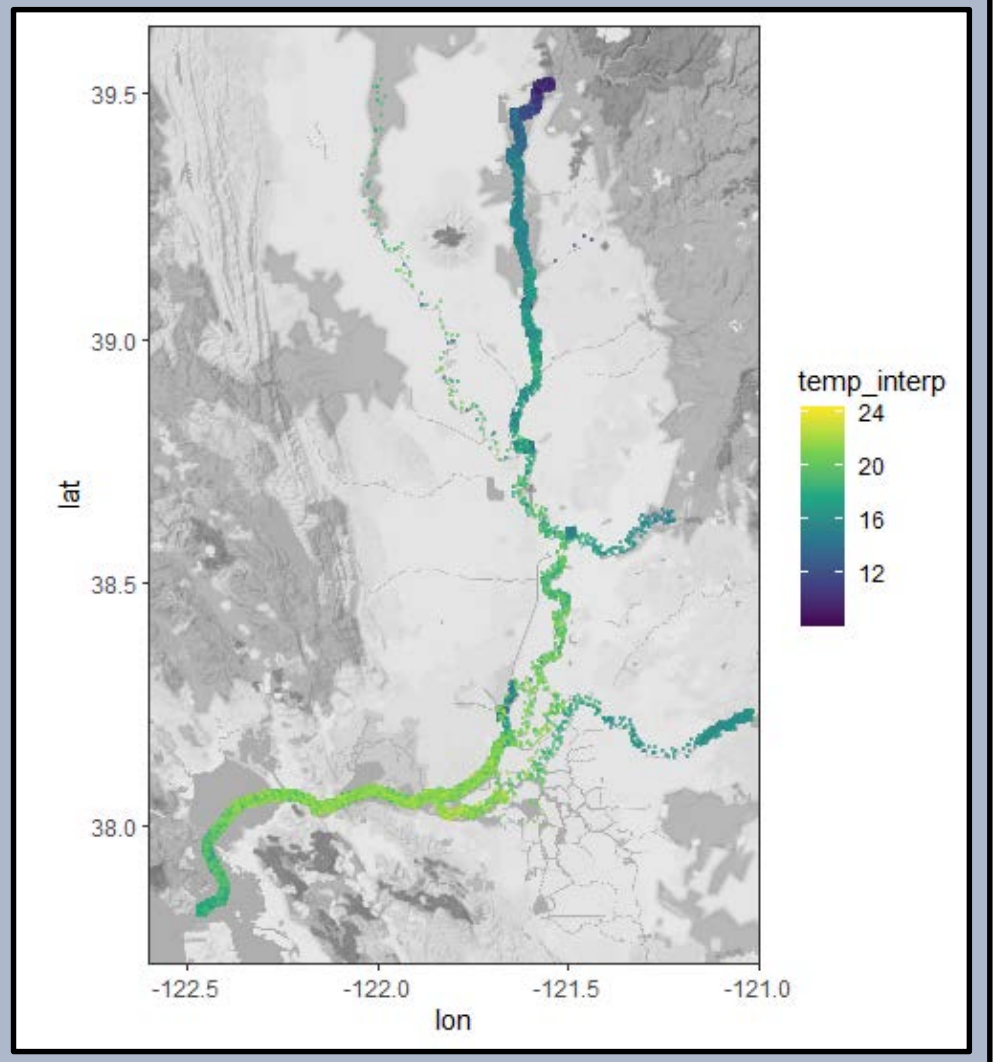
# 2023 Telemetry data

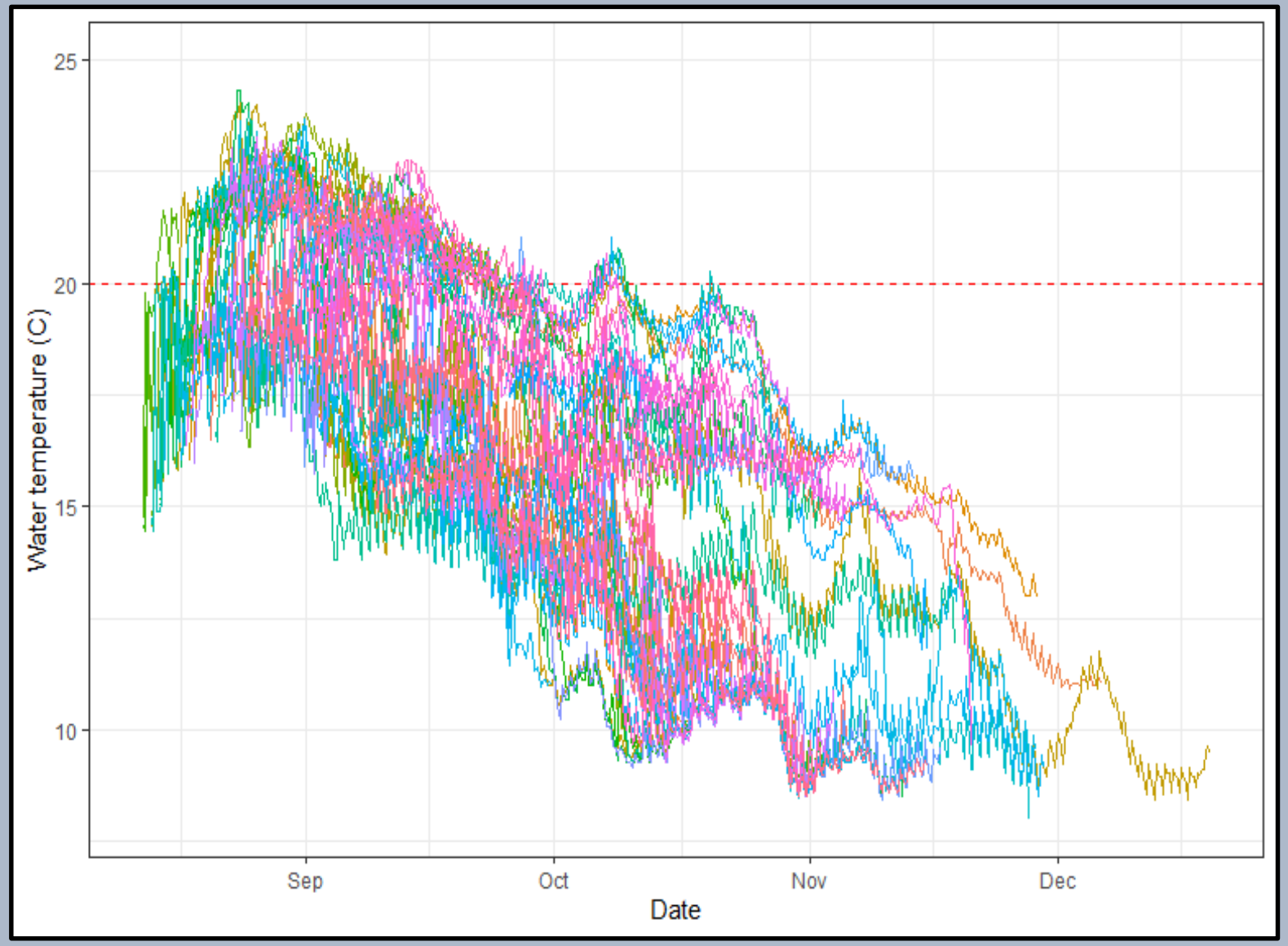
131 tagged and released in Ocean



# 2023 Telemetry data



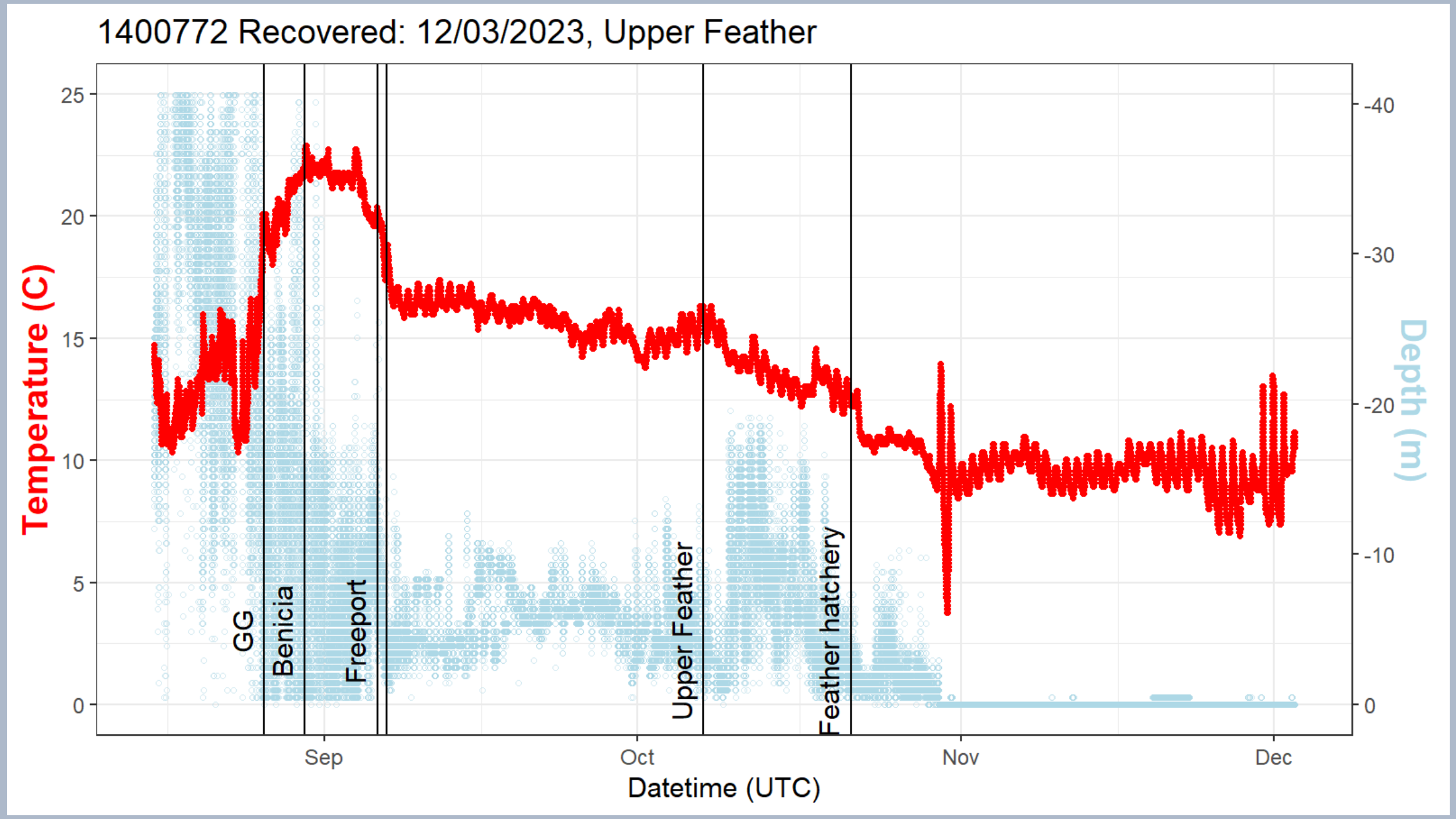



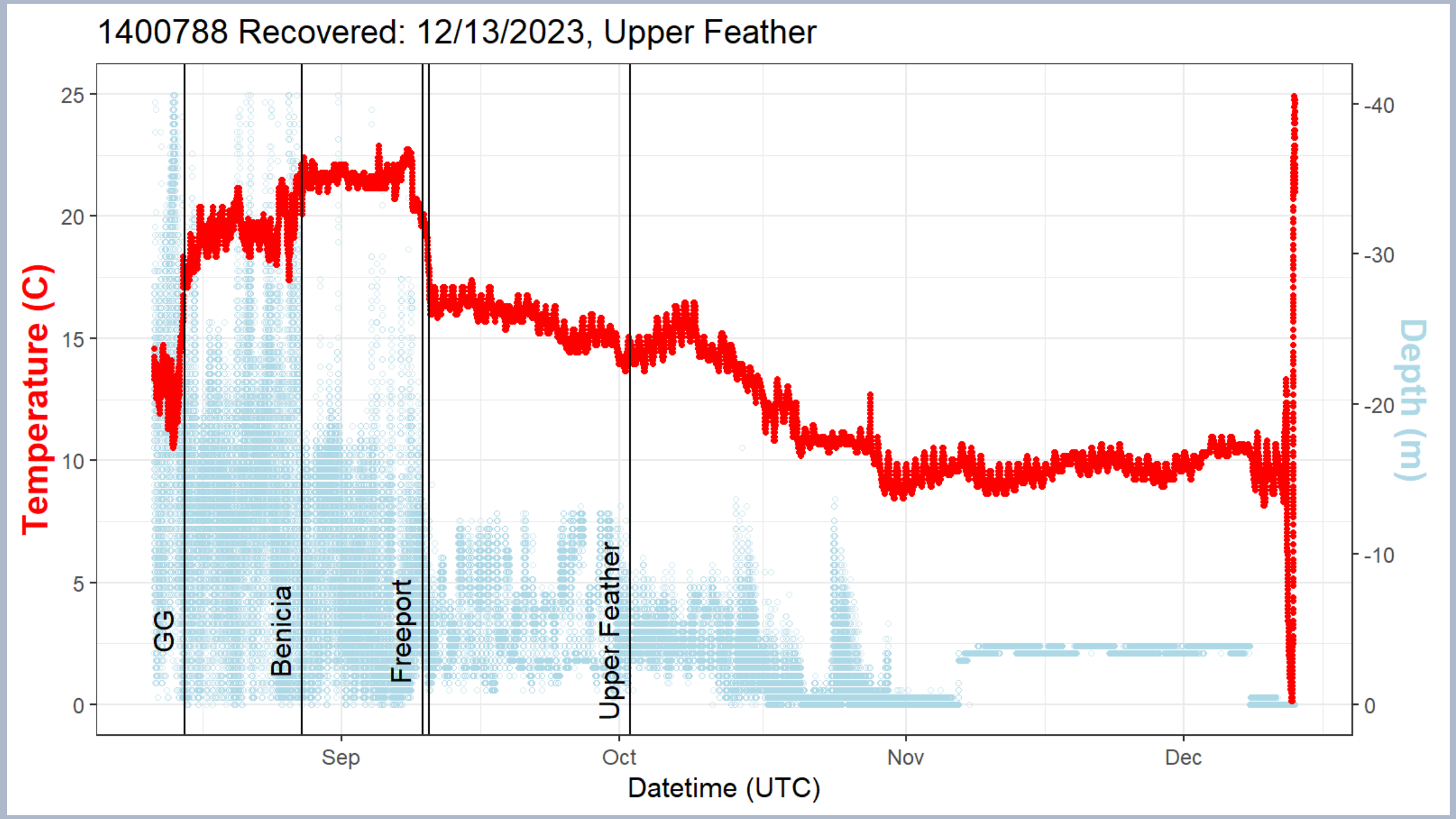
# 2023 Season Recap

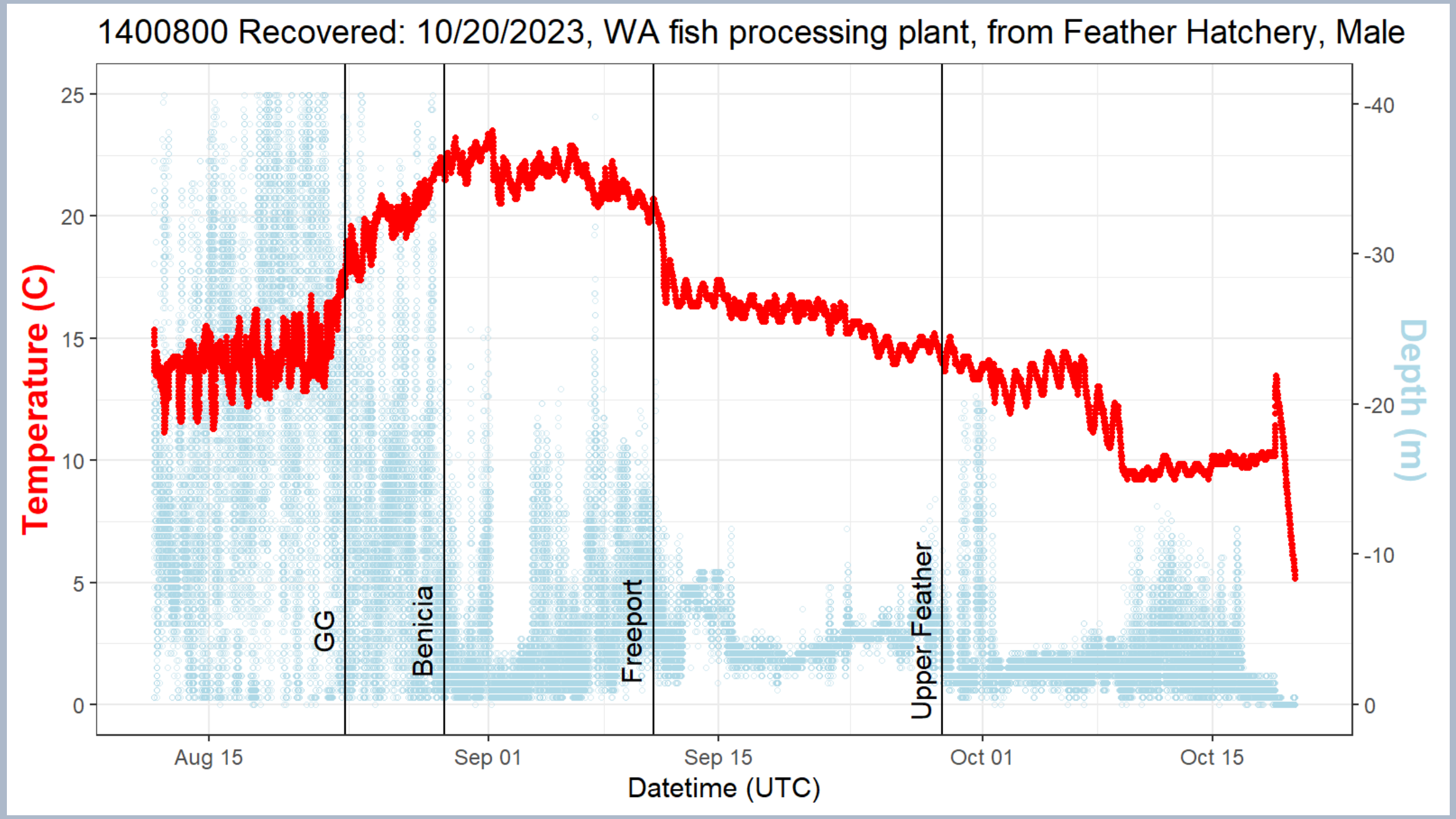
- 131 tagged and released in Ocean
- 7 tags recovered on beaches – mortality soon after release
- 109 known to have passed Golden Gate
- 89 known to have passed Carquinez straits
- 67 known to have exited Delta into rivers
- 50 made it to Feather/Yuba spawning grounds or hatchery
- 5 made it to Mokelumne River spawning grounds or hatchery
- 3 made it to Upper Sacramento River spawning grounds or hatchery
- 2 made it to American River spawning grounds or hatchery

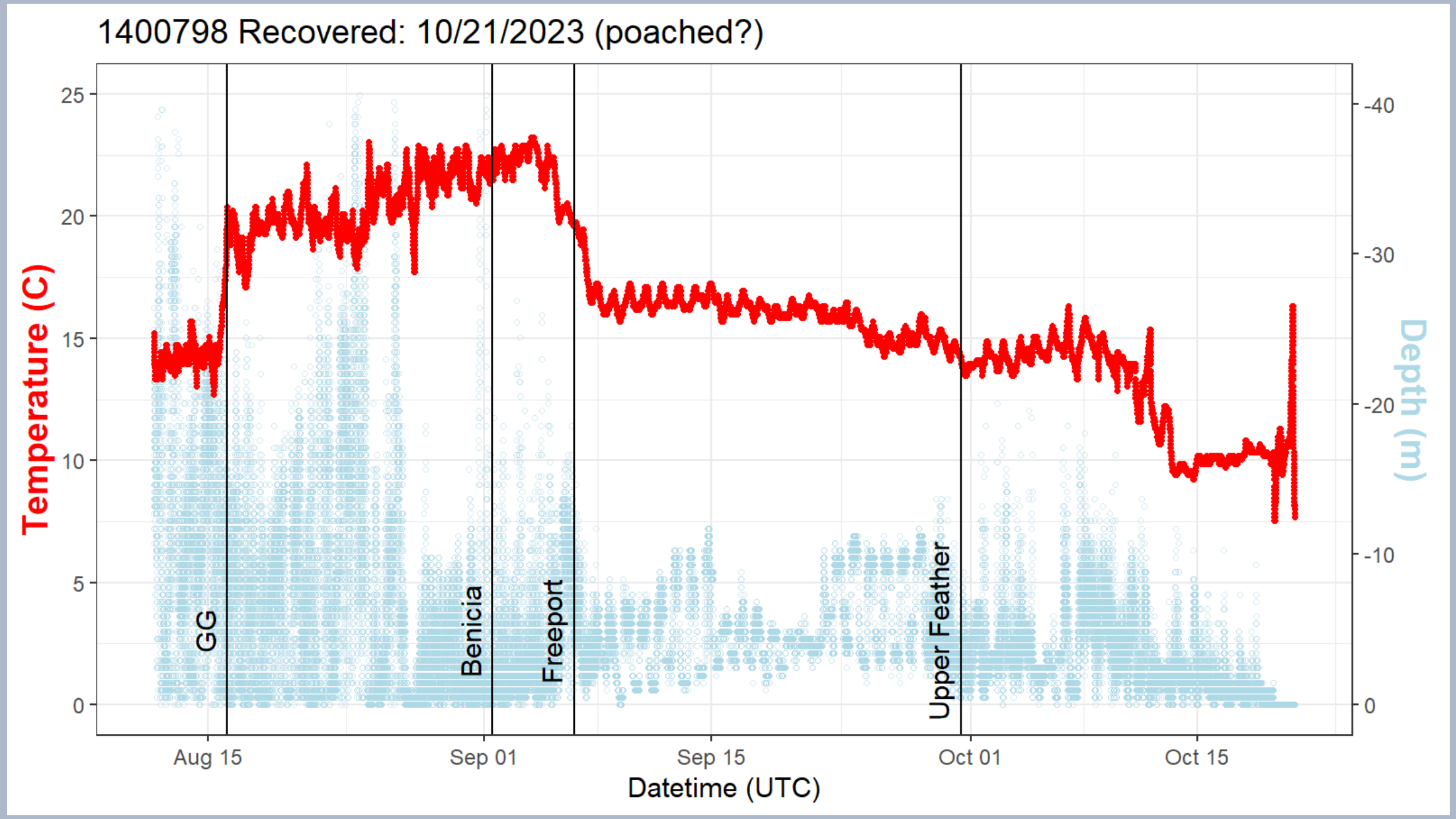
# 2023 Telemetry data

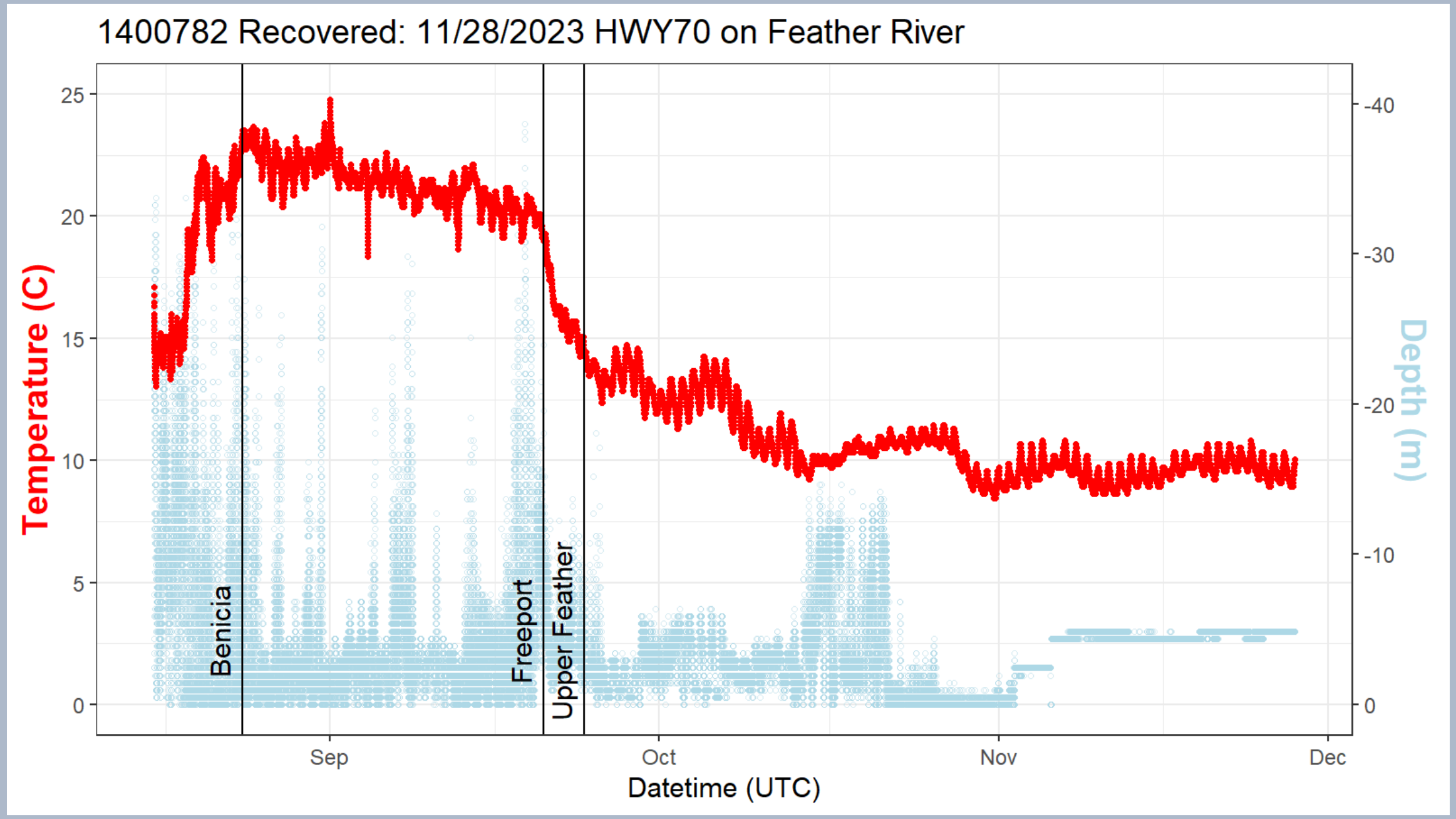

- ADST tags worked as advertised in 2023
- We recovered 16 in total
- 8 of these tags made it to the spawning grounds (all to the Upper Feather River)
- Here are 5 representative temperature exposure plots


1400772 Recovered: 12/03/2023, Upper Feather
Temperature (C)
25
20
15
10
5
0
-40
-30
-20
-10
0
Depth (m)
GG
Benicia
Freeport
Upper Feather
Feather hatchery
Sep
Oct
Nov
Dec
Datetime (UTC)


1400788 Recovered: 12/13/2023, Upper Feather
Temperature (C)
25
20
15
10
5
0
-40
-30
-20
-10
0
Depth (m)
GG
Benicia
Freeport
Upper Feather
Sep
Oct
Nov
Dec
Datetime (UTC)


1400800 Recovered: 10/20/2023, WA fish processing plant, from Feather Hatchery, Male
Temperature (C)
Depth (m)
25
20
15
10
5
0
-40
-30
-20
-10
0
GG
Benicia
Freeport
Upper Feather
Aug 15
Sep 01
Sep 15
Oct 01
Oct 15
Datetime (UTC)


1400798 Recovered: 10/21/2023 (poached?)
Temperature (C)
Depth (m)
25
20
15
10
5
0
-40
-30
-20
-10
0
GG
Benicia
Freeport
Upper Feather
Aug 15
Sep 01
Sep 15
Oct 01
Oct 15
Datetime (UTC)


1400782 Recovered: 11/28/2023 HWY70 on Feather River
Temperature (C)
25
20
15
10
5
0
Depth (m)
-40
-30
-20
-10
0
Benicia
Freeport
Upper Feather
Sep
Oct
Nov
Dec
Datetime (UTC)

# Results

- First direct measurements of CV salmon energy use during adult migration for 100 + years (Greene 1916 in Trans. Am. Fish. Soc.; n=9)

- Water temperatures experienced by adult salmon in both years indicate that CV salmon regularly experience high water temperatures (>20C) during return migration

- Evidence of pre-spawn mortality in 2022

- 2023 data should allow a wet year contrast to 2022 data

- Few fish returning to upper Sacramento and tributaries in both 2022 and 2023

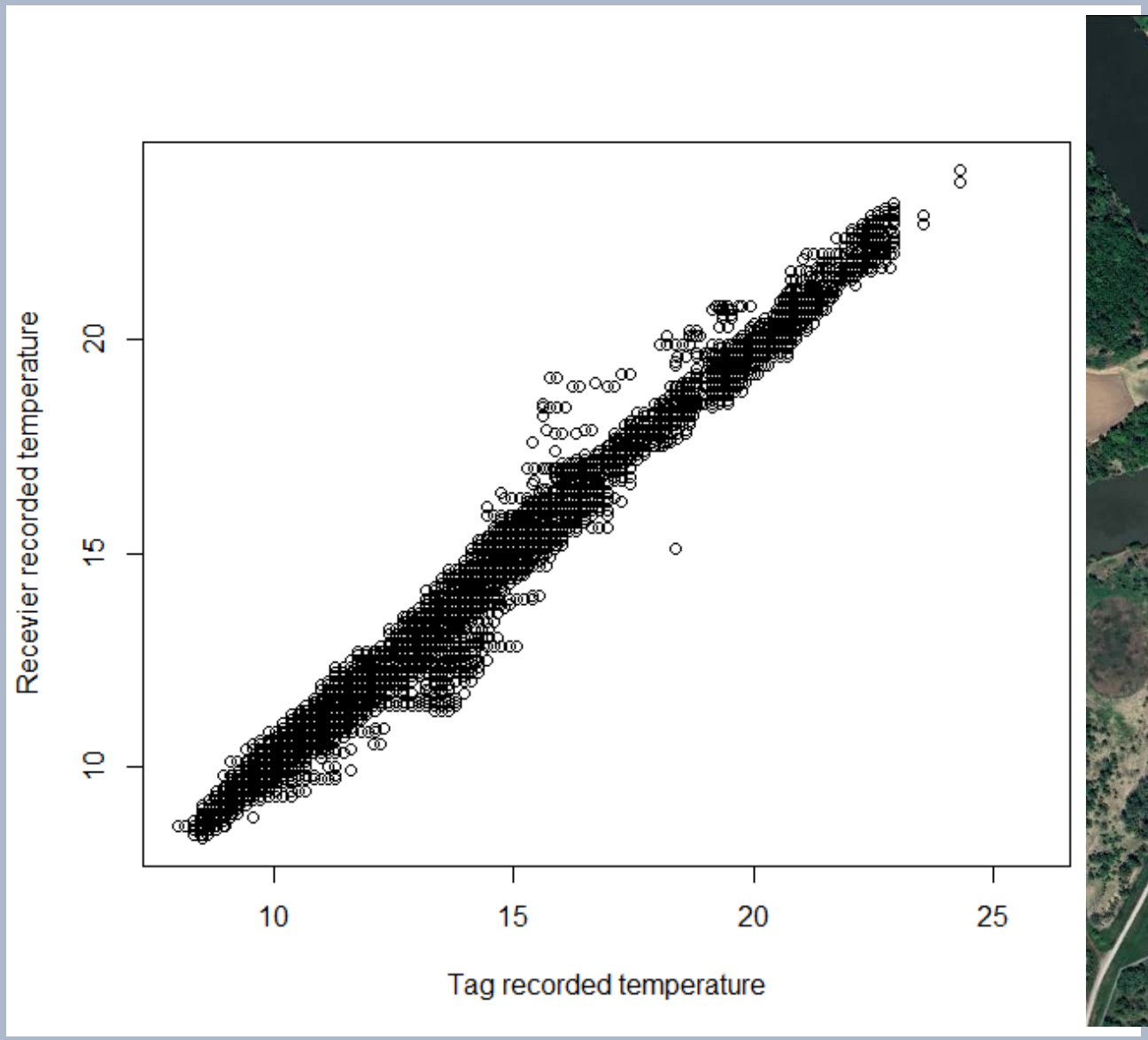
# Lessons learned

- Use of anesthetic (AQUI-S) was problematic. Fish were more lethargic at release and exhibited higher post-tagging mortality
- Tagging in ocean prior to freshwater entry allowed for tagging effects to dissipate before migration
- Quadruple-tagging fish (69kHz tag, JSATS tag, PIT, and FLOY) was useful to maximize detections and estimate tag loss
- Floating tags were very useful for tag recovery

# Acknowledgements


- Johnny and Matt from New Rayann Sportfishing
- Volunteer anglers, including many from CDFW, Fishbio, NMFS, UC Davis, Mokelumne Hatchery
- Bill Smith from Mokelumne Hatchery
- John Kelly and CDFW for surplus JSATS tags
- USFWS-Red Bluff for Vemco tag loan
- 69kHz telemetry researchers for deploying receivers


Thanks! Questions:
Cyril.Michel@noaa.gov


Recevier recorded temperature
10
15
20
10
15
20
25
Tag recorded temperature


Garden Hwy
Vernon Rd
Verona
Garden Hwy
Sacramento River
Garden Hwy
Rd 107
Rd 107
Rd 107A
38.7811960-121.612837
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