PIT Antenna Technology: An Array of Applications in the Russian River Watershed

Sea Grant California

Sonoma Water
ENVIRONMENTAL RESOURCES

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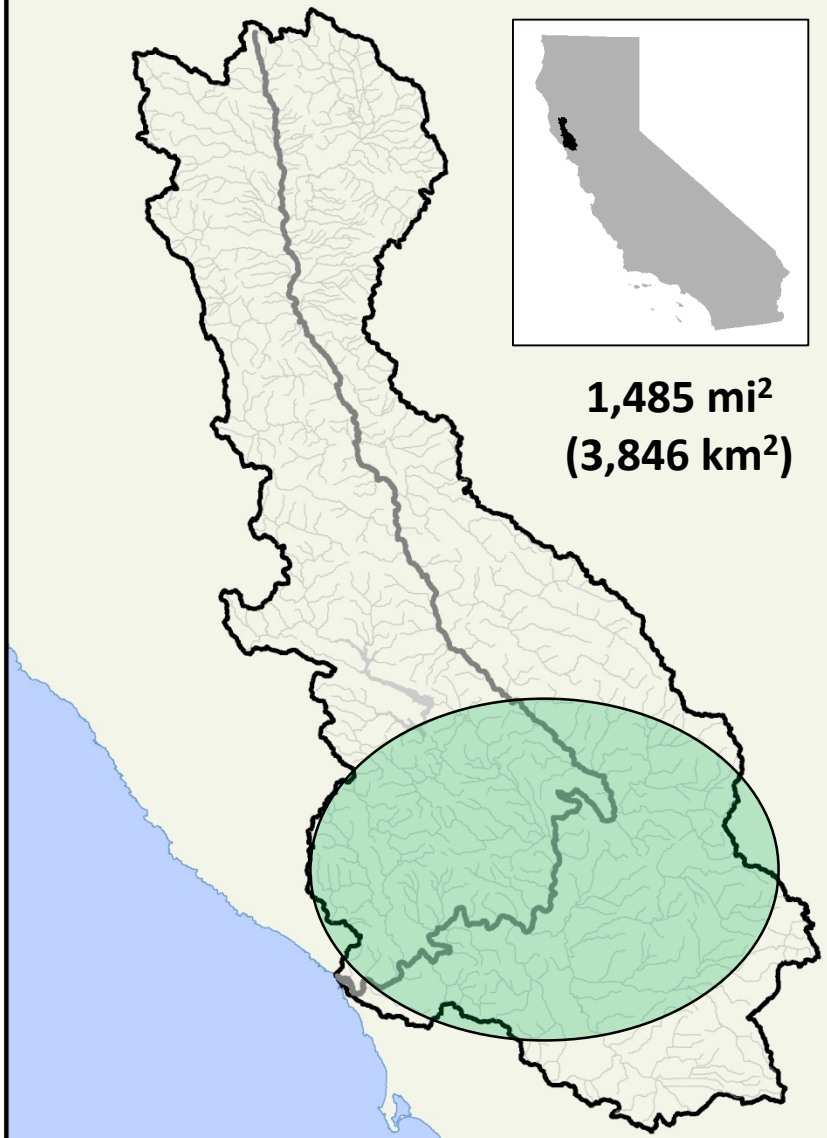
Resources Agency California Department Fish & Game

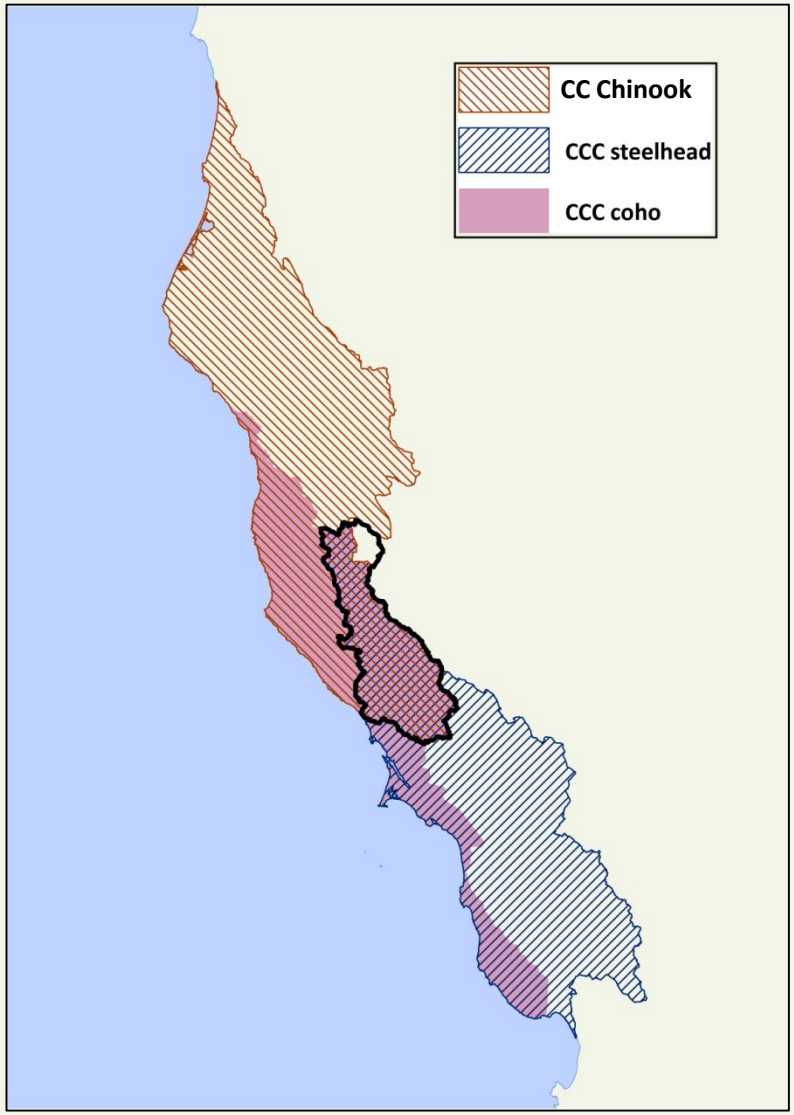
NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Russian River Watershed



1,485 mi^2
(3,846 km^2)

Central CA Coast ESU



Mill Creek Watershed

- 23 mi^2 (60 km^2) watershed, ~ 11 mi (18 km) long stream
- Life cycle monitoring to evaluate Coho broodstock program
- PIT tag a portion of hatchery Coho releases
- Track movement, growth and survival of several release groups from yoy to adult stage

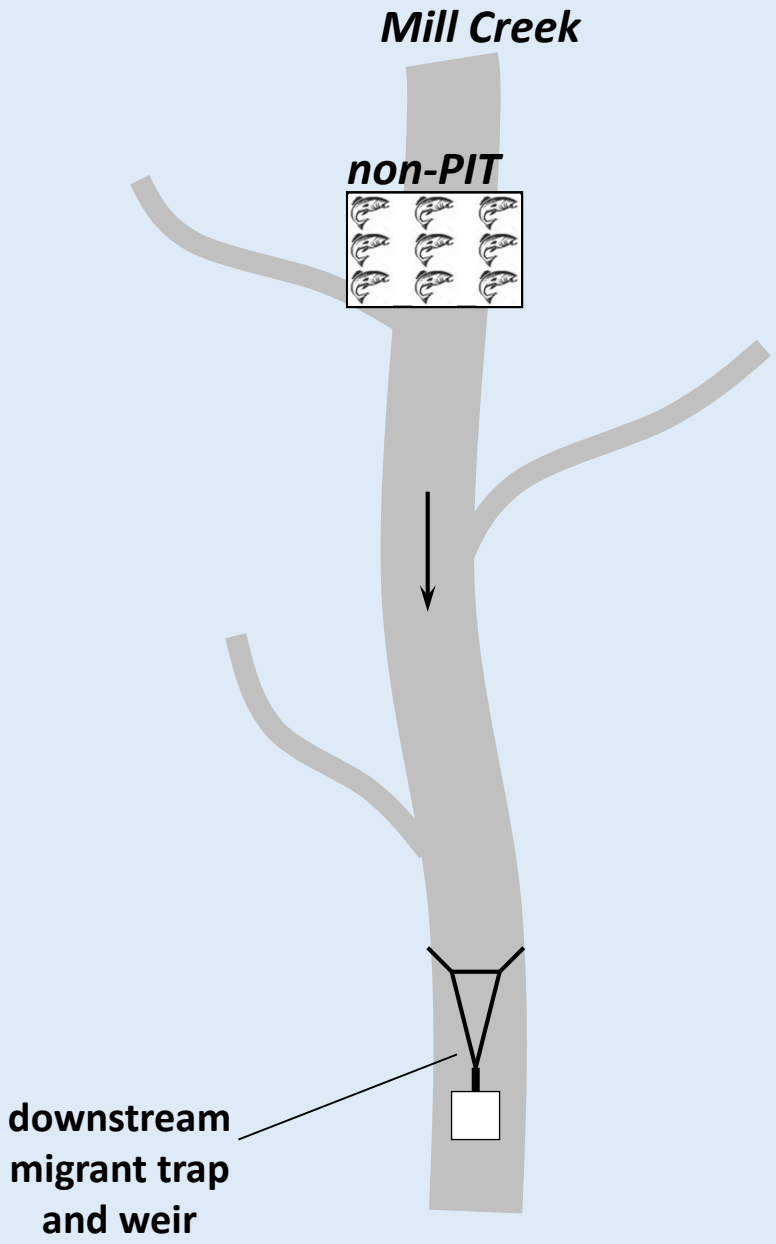
Started with traps as fixed counting stations

<u>Smolt abundance</u>:

- **downstream migrant trap (DARR- Darroch Analysis with Rank Reduction)**

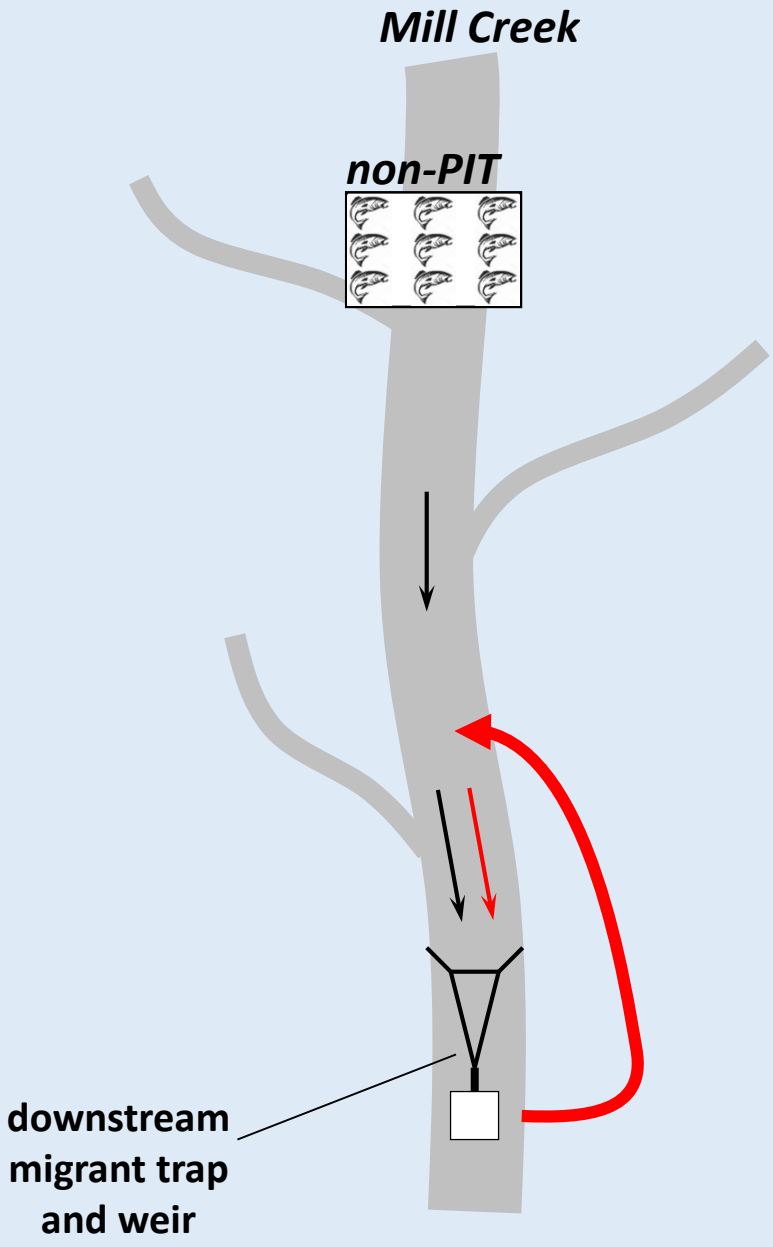
<u>Adult returns</u>:

- **adult trap in combination with spawner surveys (capture-mark-recapture)**



1-trap DARR (no PIT tags in early days)

- **Capture fish in trap**

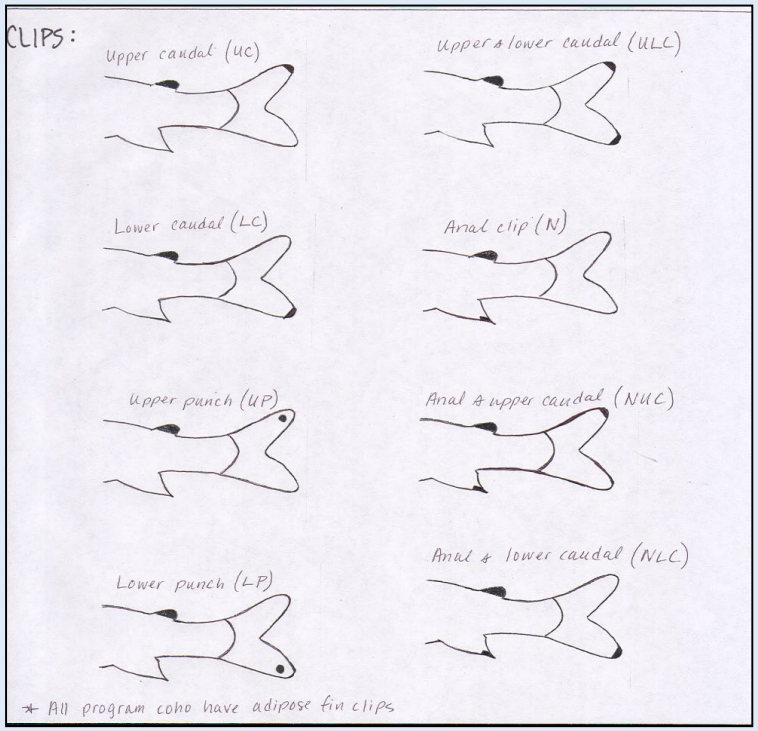


1-trap DARR (no PIT tags in early days)

- **Capture fish in trap**

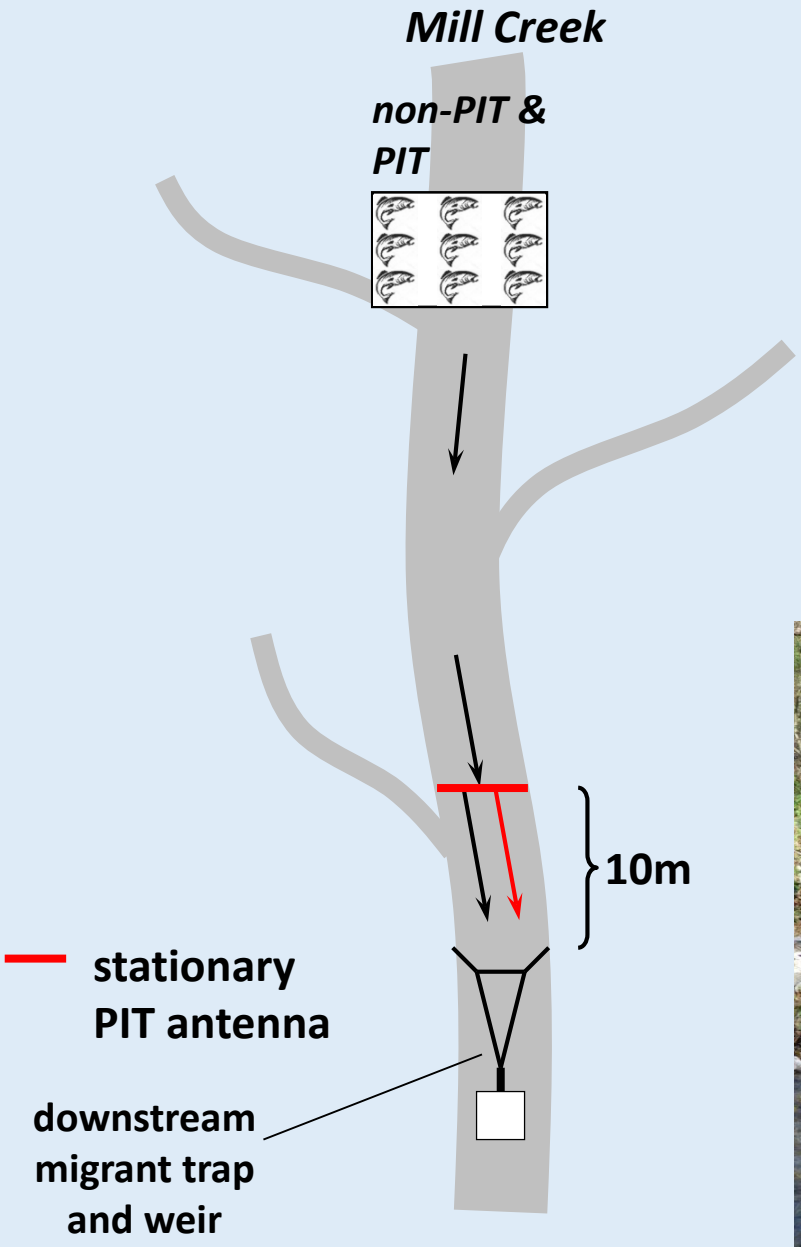
  M **= Finclip at trap (8 combinations)**
  R **= Release upstream & recapture at trap**
  U **= unmarked capture in trap**

  ****N-hat*** **is based marked: unmarked**



Trap avoidance and mortality

Installed upright antenna (16’ x 2.5’)

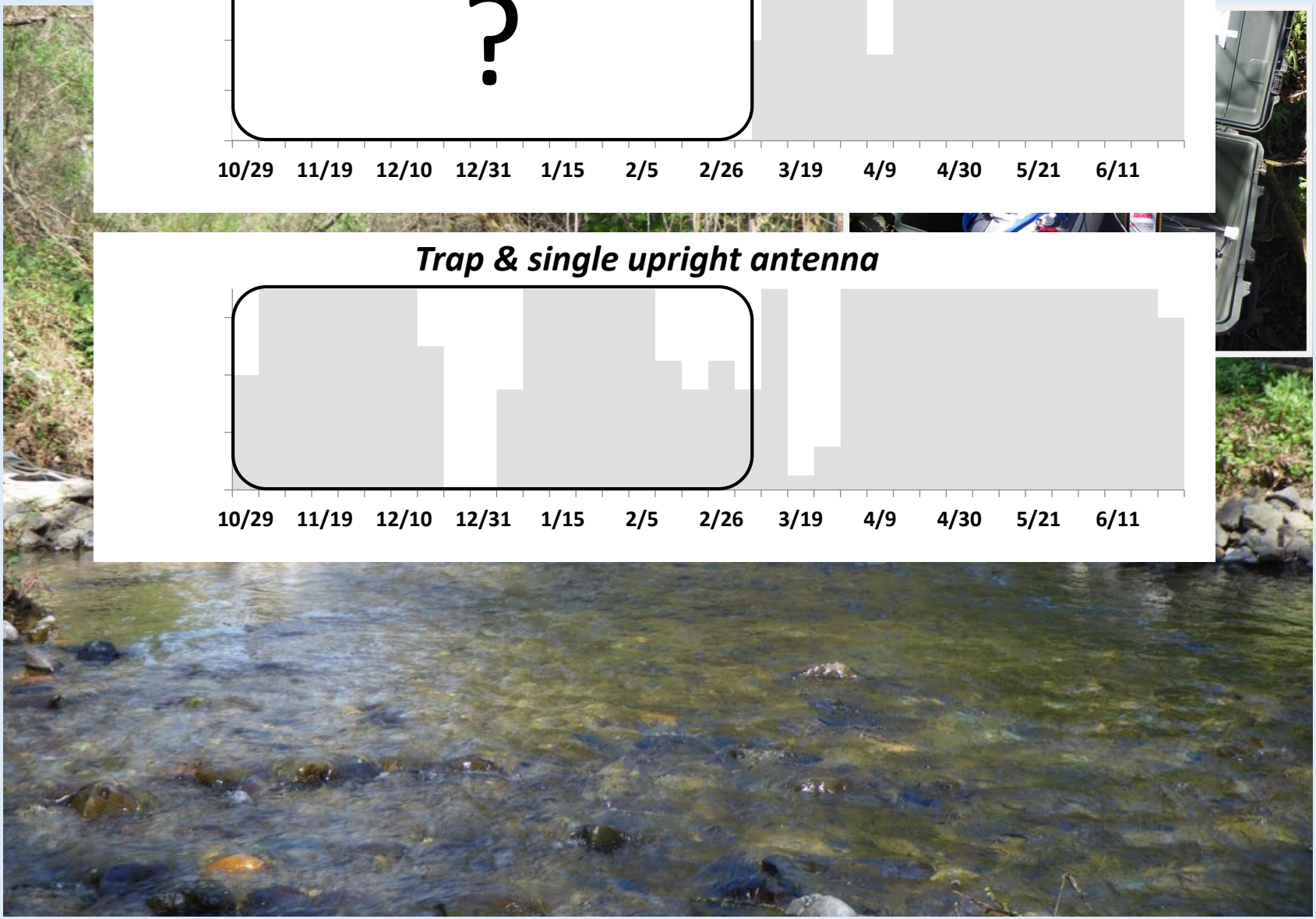


2-trap DARR (PIT & non-PIT)

- **Fish swim past antenna**

M **= PIT tags detected at antenna**
R **= PIT tags detected at antenna & trap**
U **= non-PIT & antenna only detected in trap**

N-hat **is based marked: unmarked**


Trap only
?
10/29
11/19
12/10
12/31
1/15
2/5
2/26
3/19
4/9
4/30
5/21
6/11
Trap & single upright antenna
10/29
11/19
12/10
12/31
1/15
2/5
2/26
3/19
4/9
4/30
5/21
6/11

Trap only

?

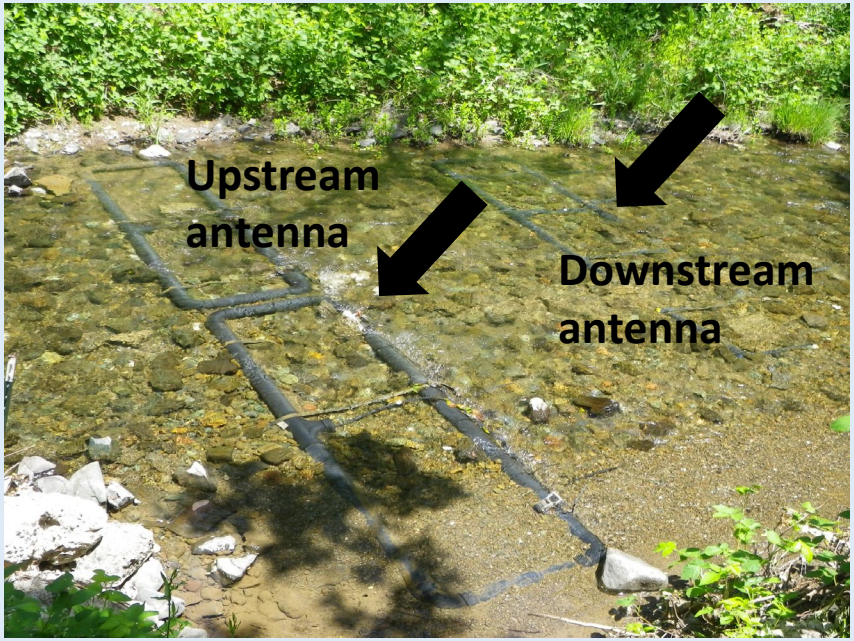
10/29 11/19 12/10 12/31 1/15 2/5 2/26 3/19 4/9 4/30 5/21 6/11

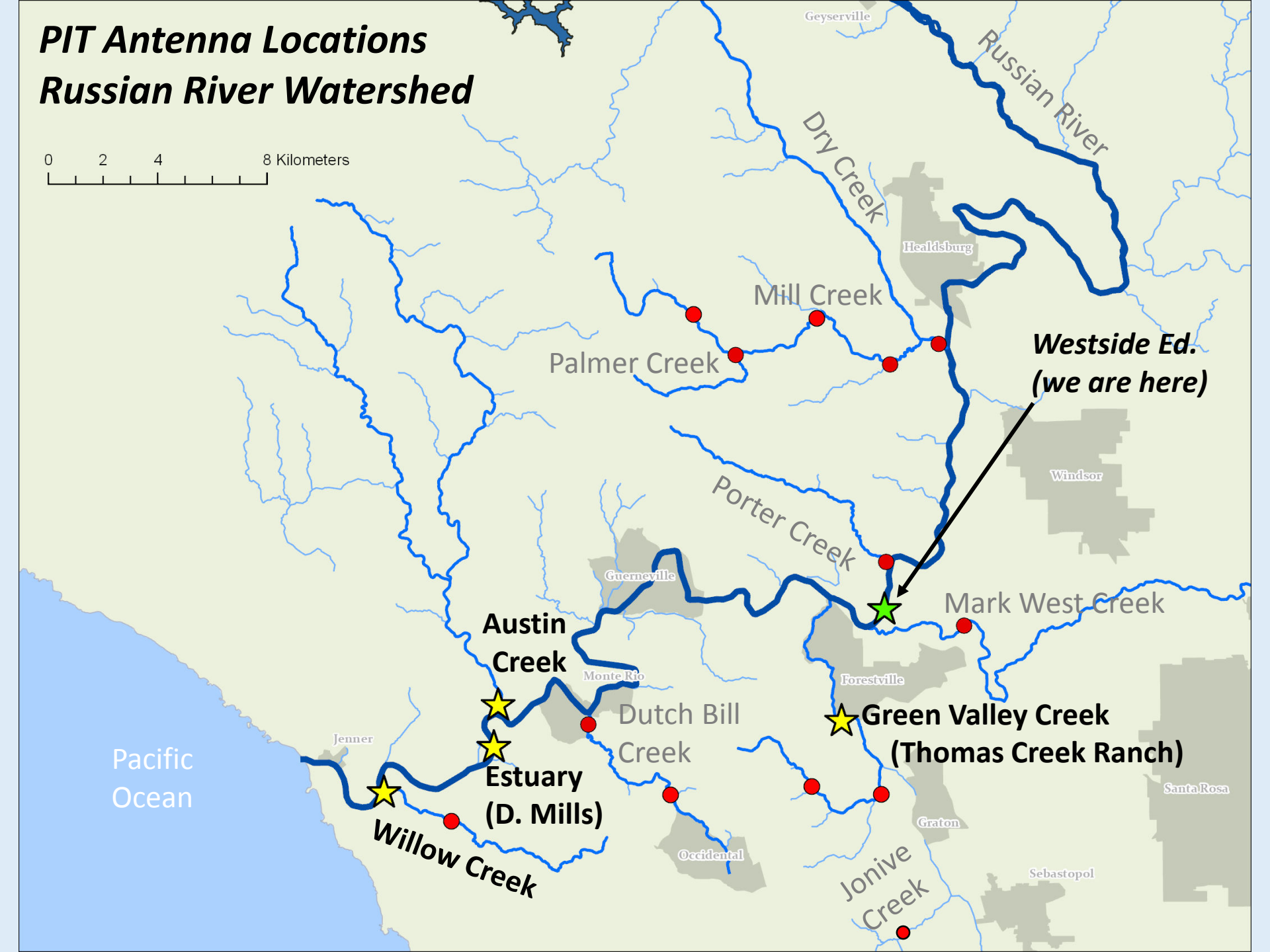
Trap & single upright antenna

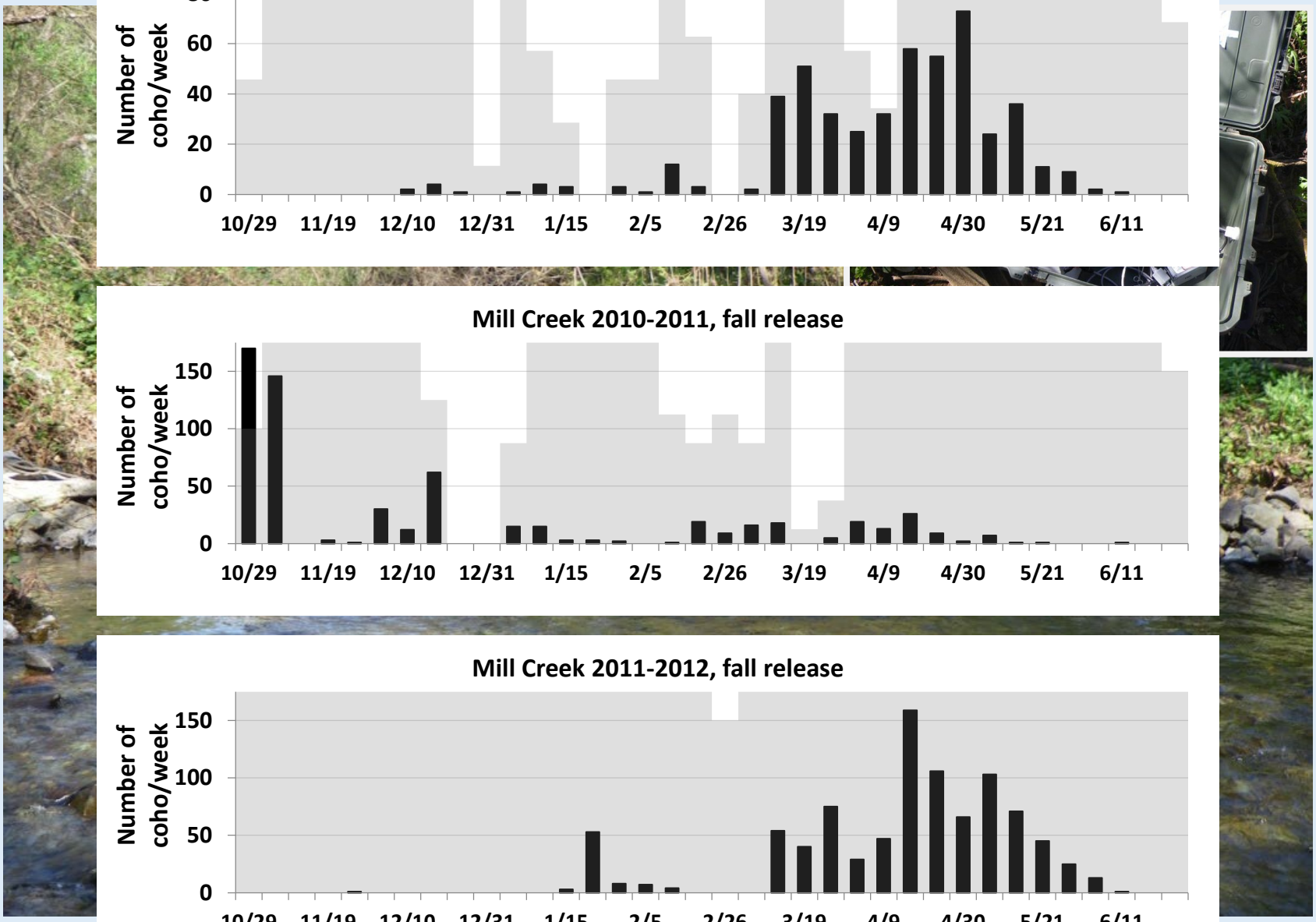
10/29 11/19 12/10 12/31 1/15 2/5 2/26 3/19 4/9 4/30 5/21 6/11

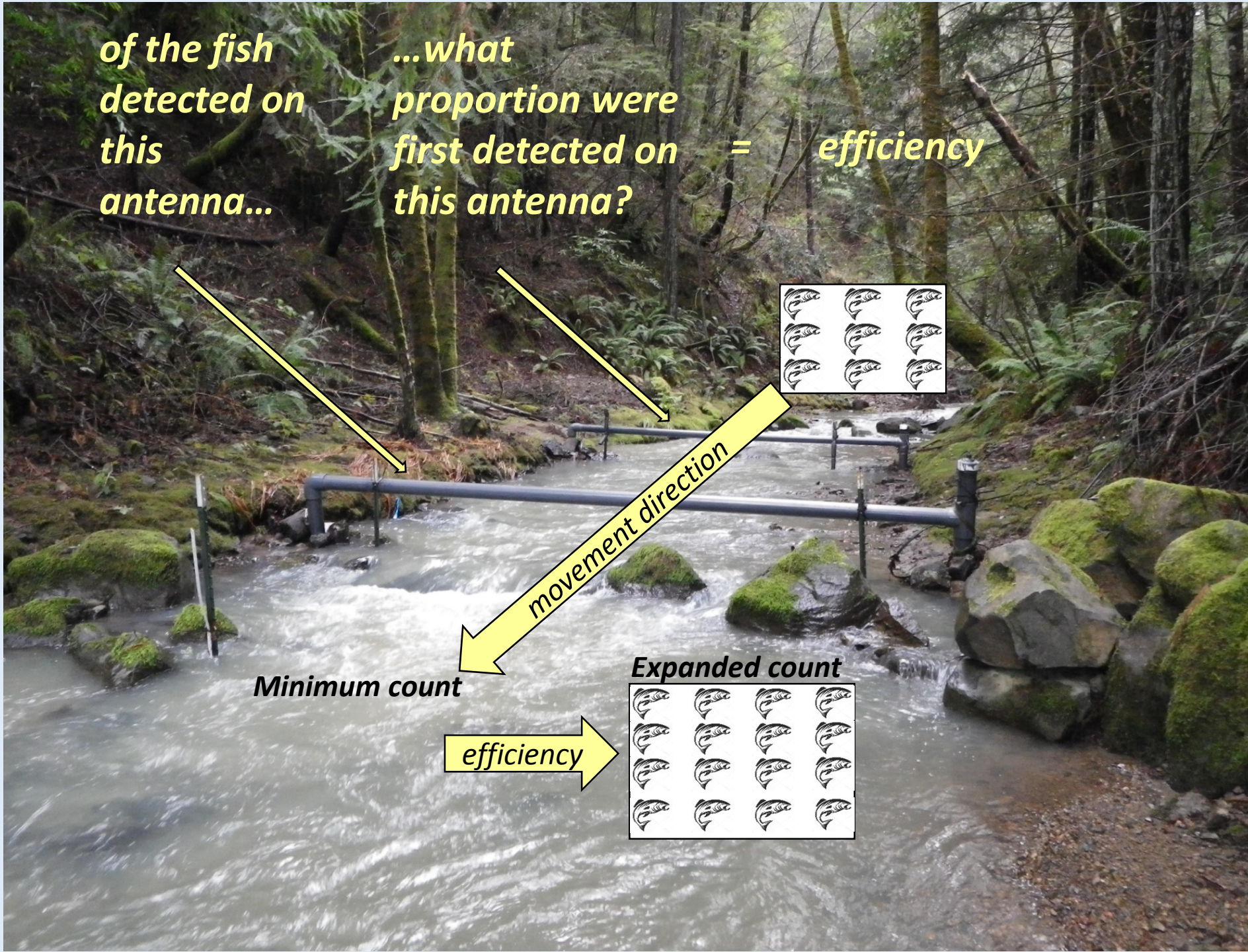
Trap & multiple flat plate (pass by) antennas

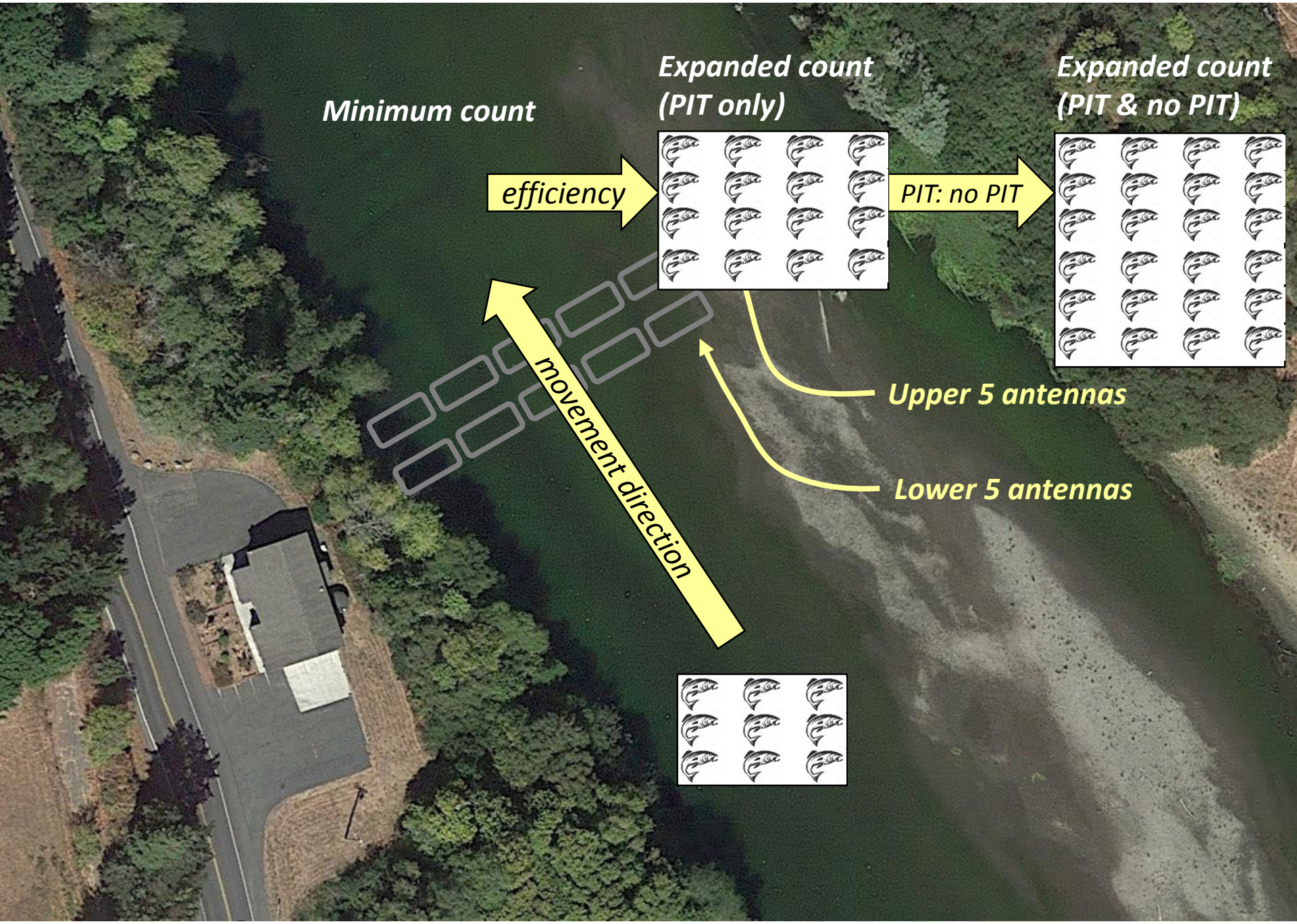
10/29 11/19 12/10 12/31 1/15 2/5 2/26 3/19 4/9 4/30 5/21 6/11

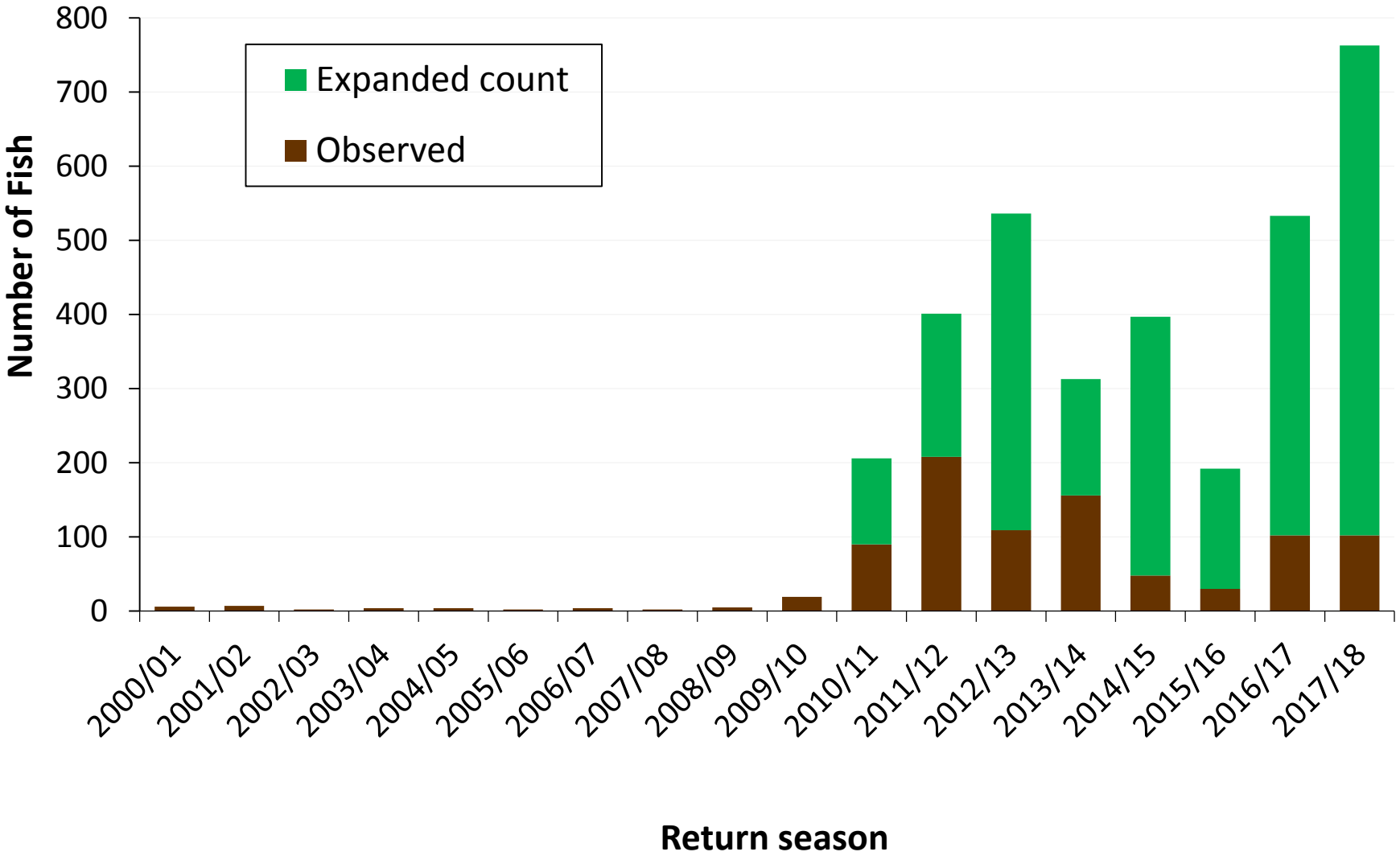

Upstream antenna
Downstream antenna

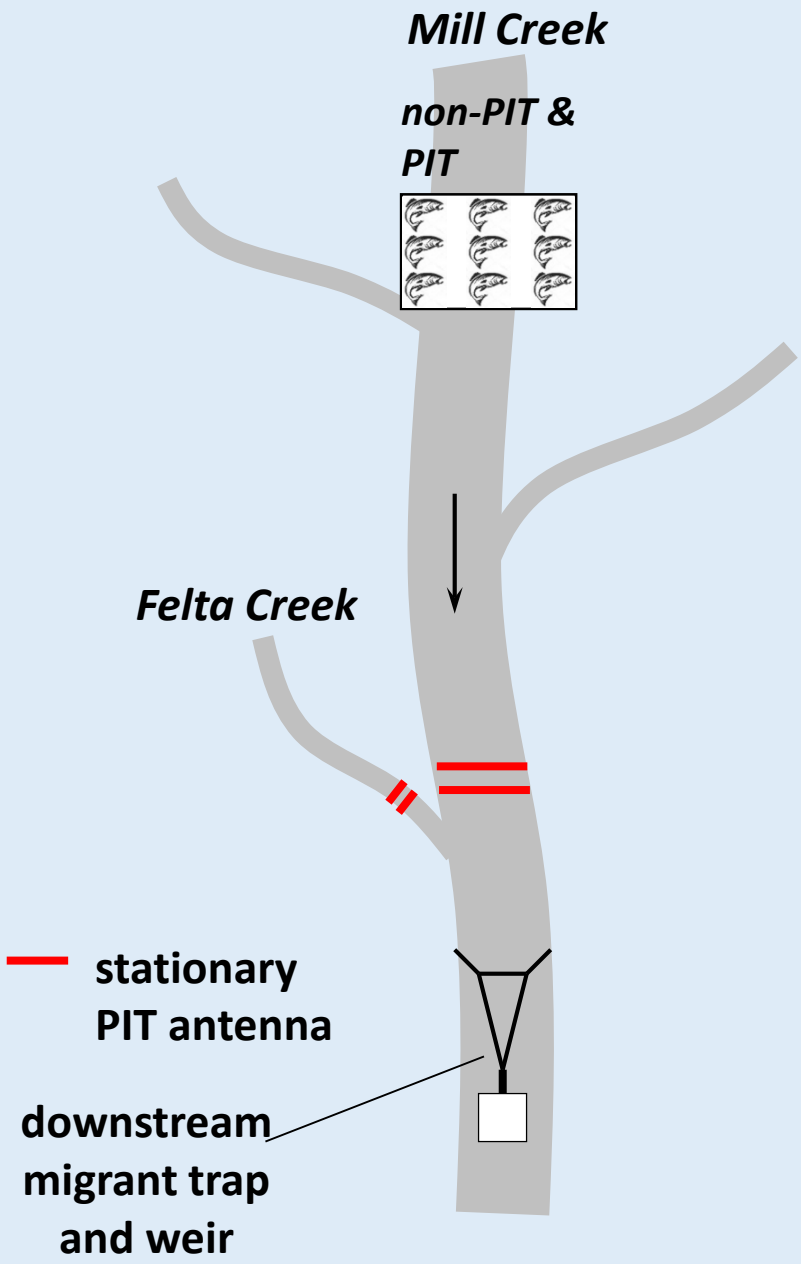

PIT Antenna Locations
Russian River Watershed
0 2 4 8 Kilometers
Geyserville
Russian River
Dry Creek
Healdsburg
Mill Creek
Palmer Creek
Westside Ed.
(we are here)
Windsor
Porter Creek
Guerneville
Mark West Creek
Austin
Creek
Monte Rio
Forestville
Dutch Bill
Creek
Green Valley Creek
(Thomas Creek Ranch)
Jenner
Pacific
Ocean
Estuary
(D. Mills)
Willow Creek
Graton
Santa Rosa
Occidental
Jonive
Creek
Sebastopol


Mill Creek 2009-2010, fall release
Number of coho/week
80
60
40
20
0
10/29
11/19
12/10
12/31
1/15
2/5
2/26
3/19
4/9
4/30
5/21
6/11
Mill Creek 2010-2011, fall release
Number of coho/week
150
100
50
0
10/29
11/19
12/10
12/31
1/15
2/5
2/26
3/19
4/9
4/30
5/21
6/11
Mill Creek 2011-2012, fall release
Number of coho/week
150
100
50
0
10/29
11/19
12/10
12/31
1/15
2/5
2/26
3/19
4/9
4/30
5/21
6/11


of the fish detected on this antenna…
…what proportion were first detected on this antenna?
=
efficiency
movement direction
Minimum count
Expanded count
efficiency

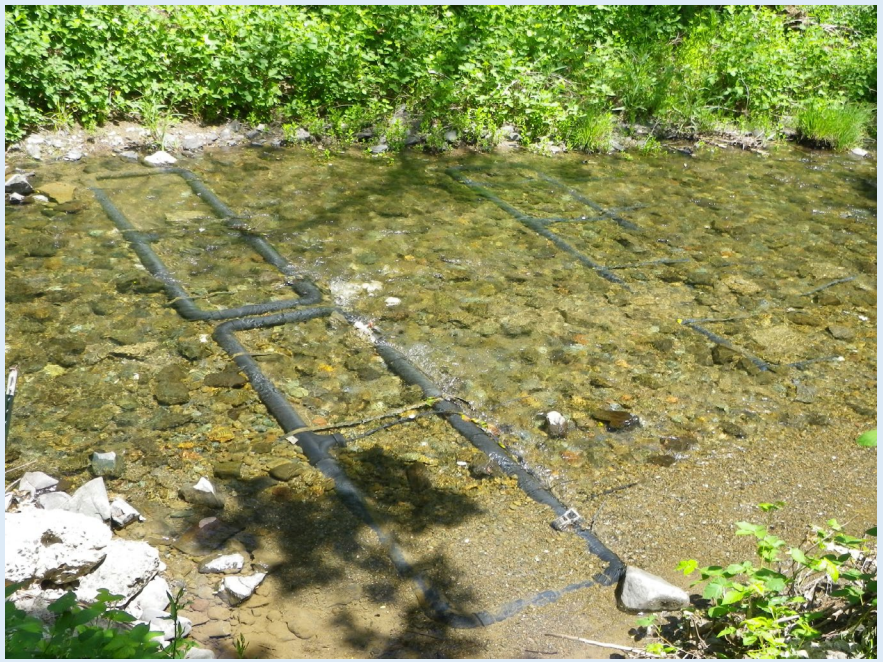

Minimum count
Expanded count
(PIT only)
Expanded count
(PIT & no PIT)
efficiency
PIT: no PIT
movement direction
Upper 5 antennas
Lower 5 antennas


Adult Coho Salmon Returns to the Russian River
Expanded count
Observed
Number of Fish
800
700
600
500
400
300
200
100
0
2000/01
2001/02
2002/03
2003/04
2004/05
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
Return season

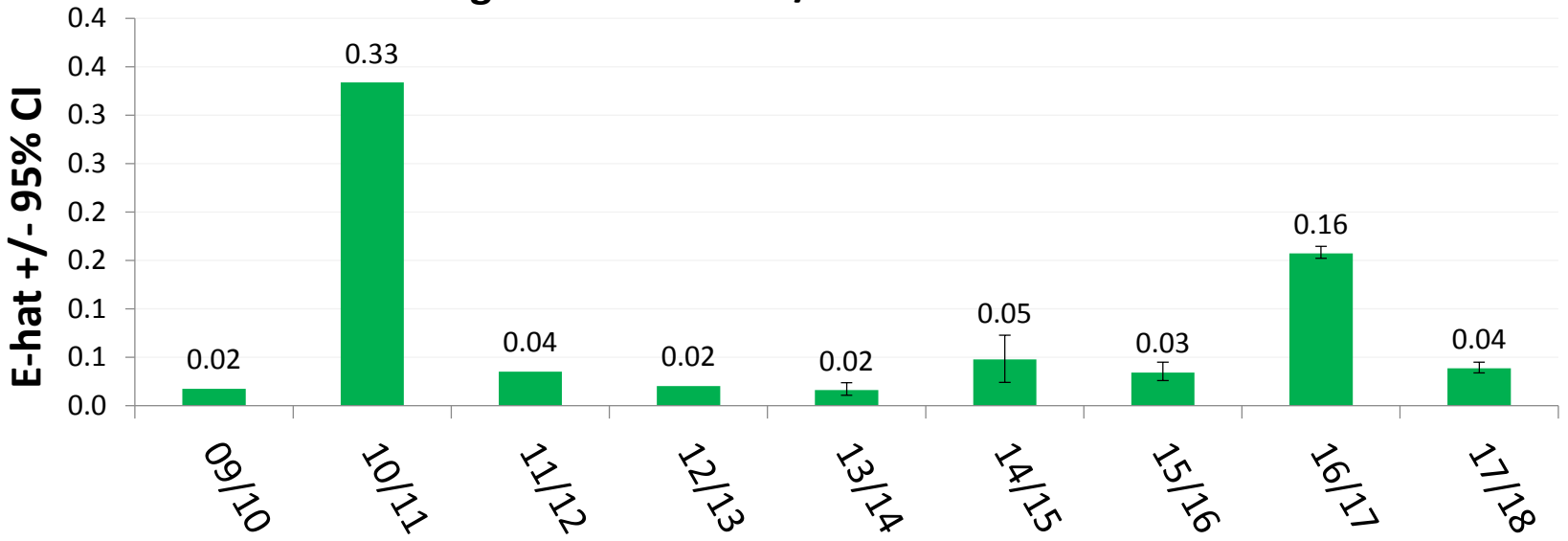


Multistate Emigration Model

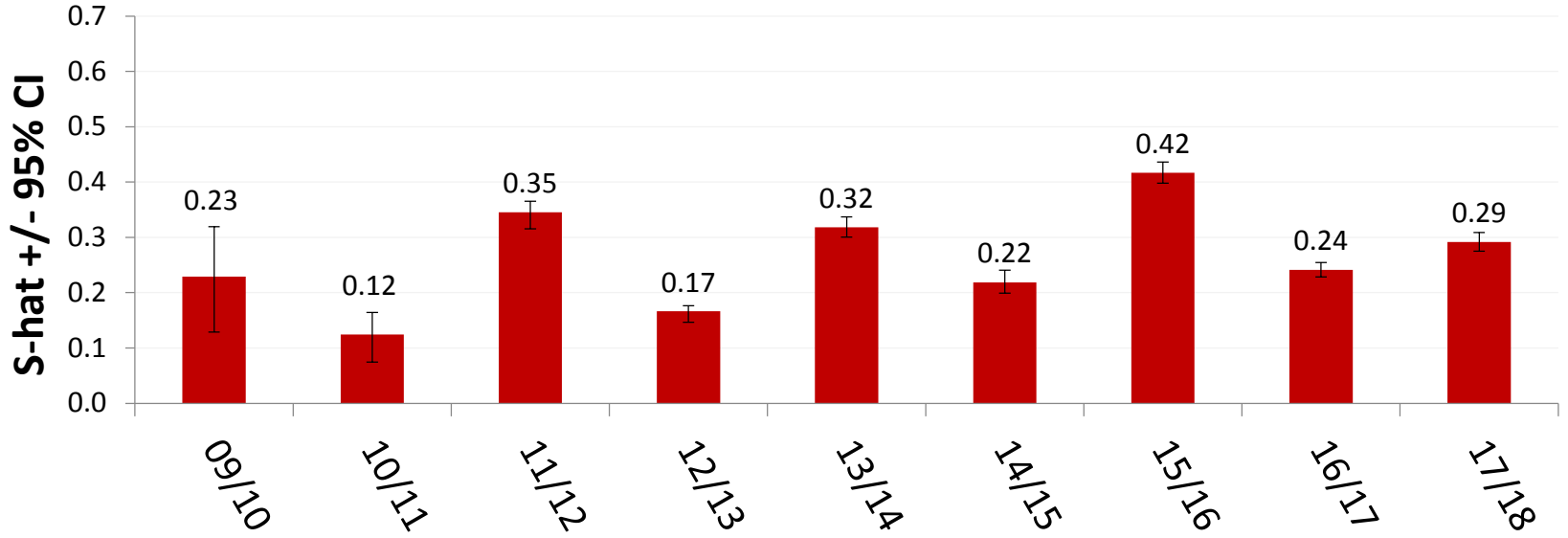
- use PIT tag detections at year-round paired antennas to estimate true *S*, *p*, & emigration for PIT tagged fish
- derived estimates of *N* for PIT-tagged fish
- estimates of *N* for all fish by using ratio of PIT to non-PIT

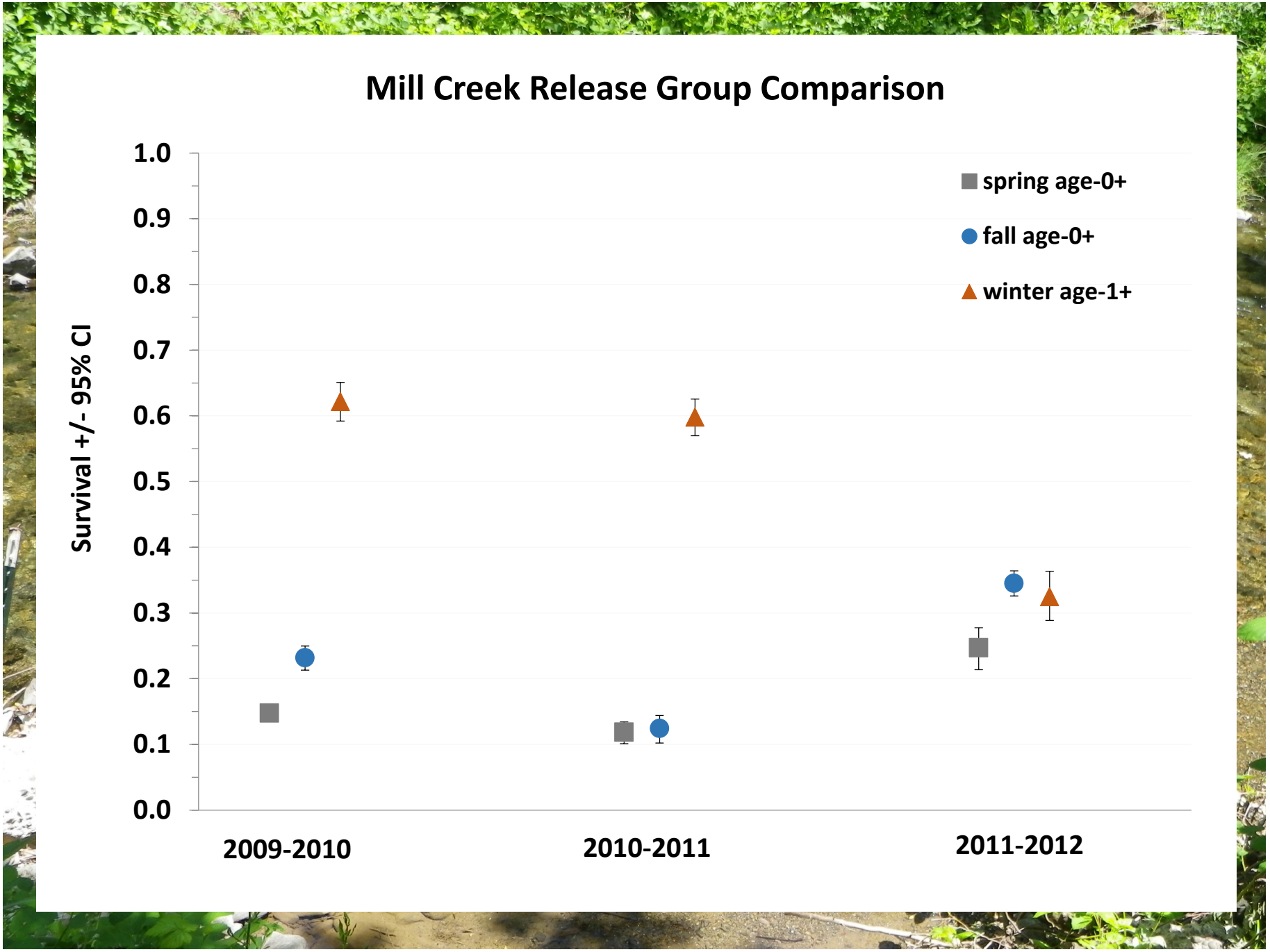


Emigration Prior to 3/1: Mill Creek Fall Release

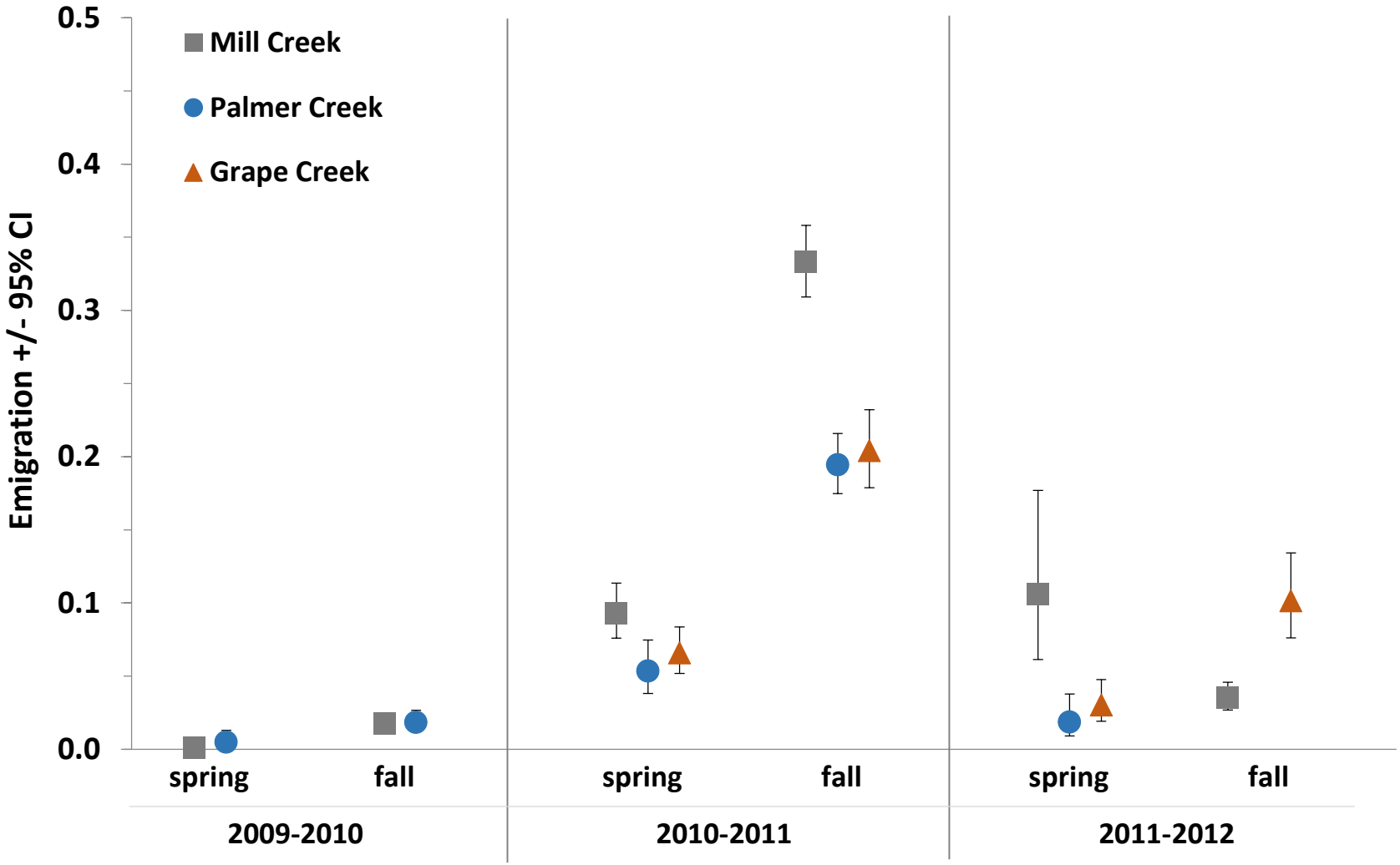


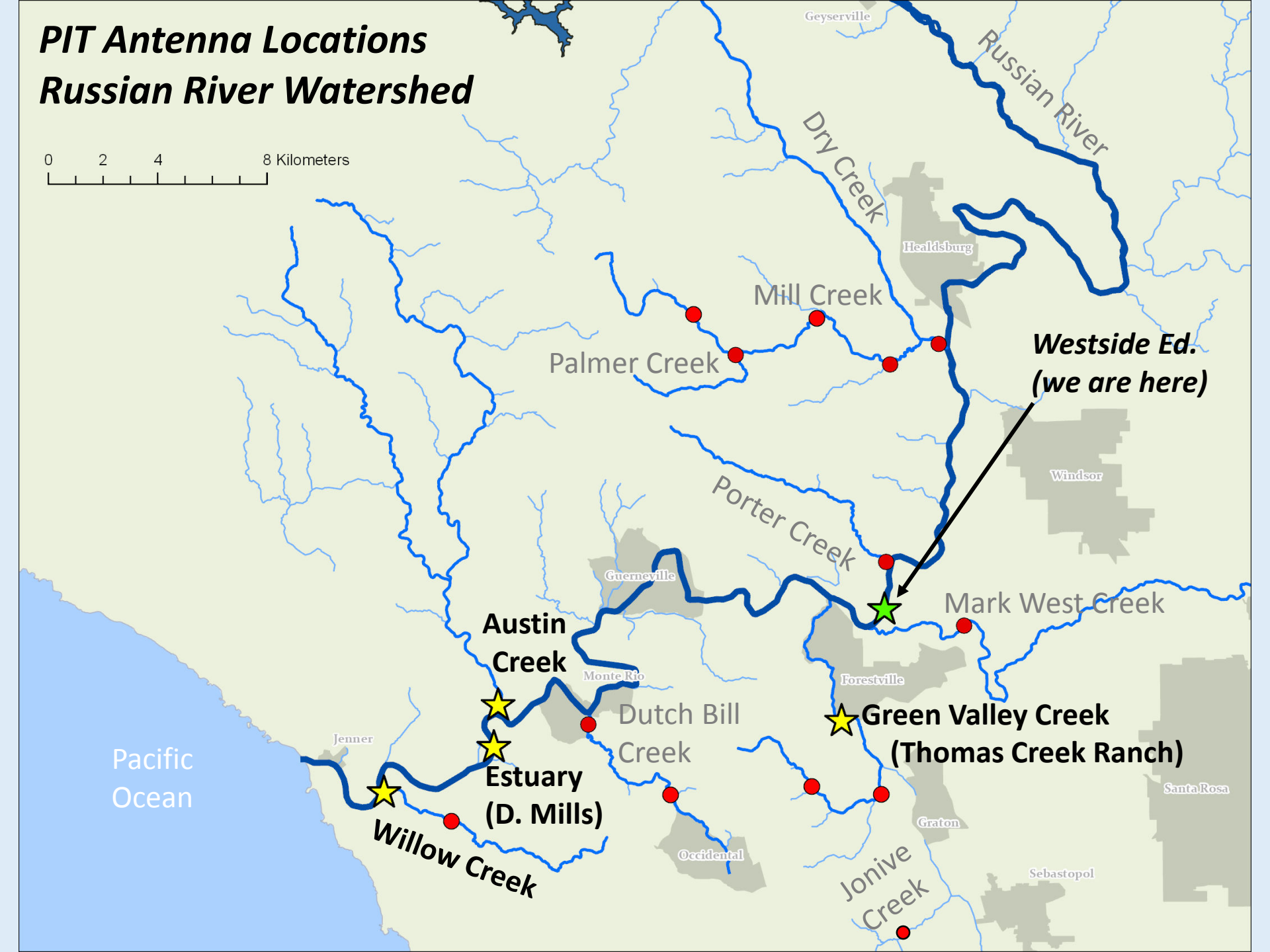
Overwinter Survival: Mill Creek Fall Release




Mill Creek Release Group Comparison
Survival +/- 95% CI
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
spring age-0+
fall age-0+
winter age-1+
2009-2010
2010-2011
2011-2012

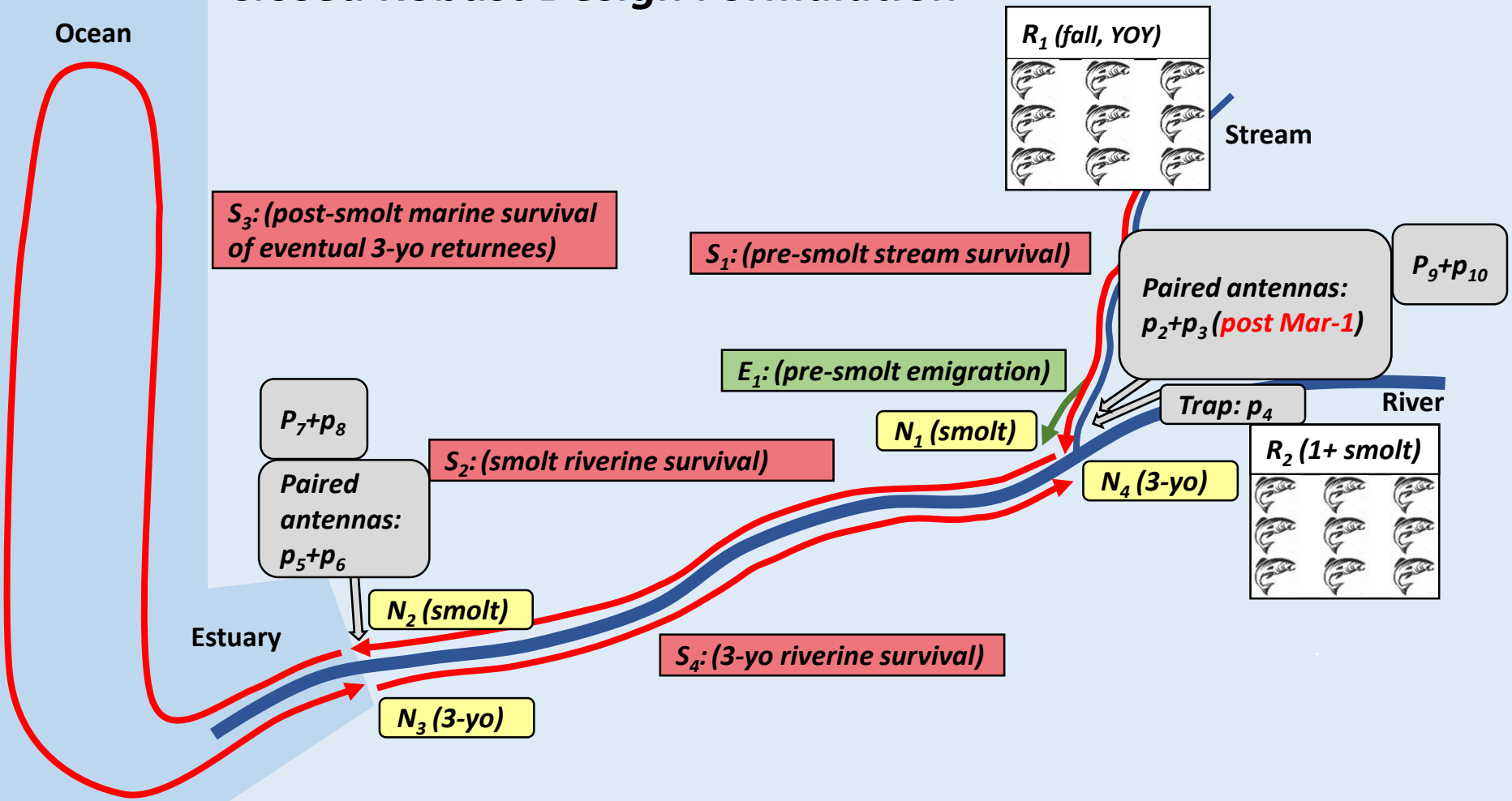
Comparison of emigration among streams and years



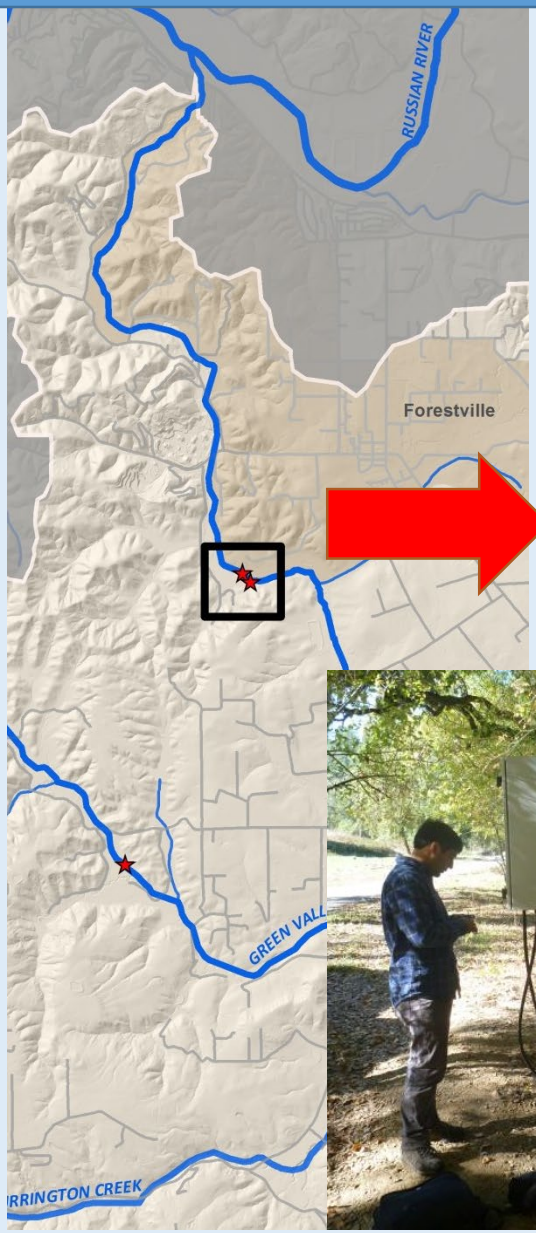

PIT Antenna Locations
Russian River Watershed
0 2 4 8 Kilometers
Geyserville
Russian River
Dry Creek
Healdsburg
Mill Creek
Palmer Creek
Westside Ed.
(we are here)
Windsor
Porter Creek
Guerneville
Mark West Creek
Austin
Creek
Monte Rio
Forestville
Dutch Bill
Creek
Green Valley Creek
(Thomas Creek Ranch)
Jenner
Pacific
Ocean
Estuary
(D. Mills)
Willow Creek
Graton
Santa Rosa
Occidental
Jonive
Creek
Sebastopol

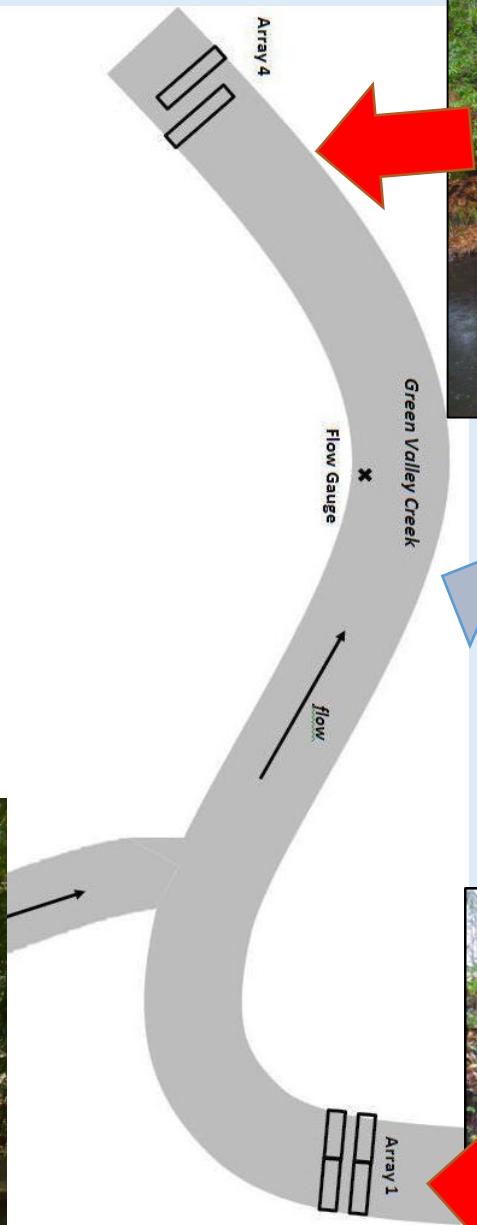
Multi-state Emigration Model

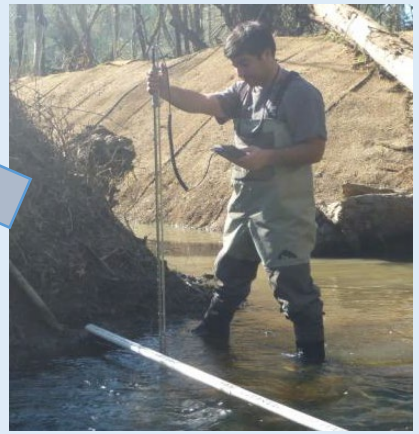
Closed Robust Design Formulation



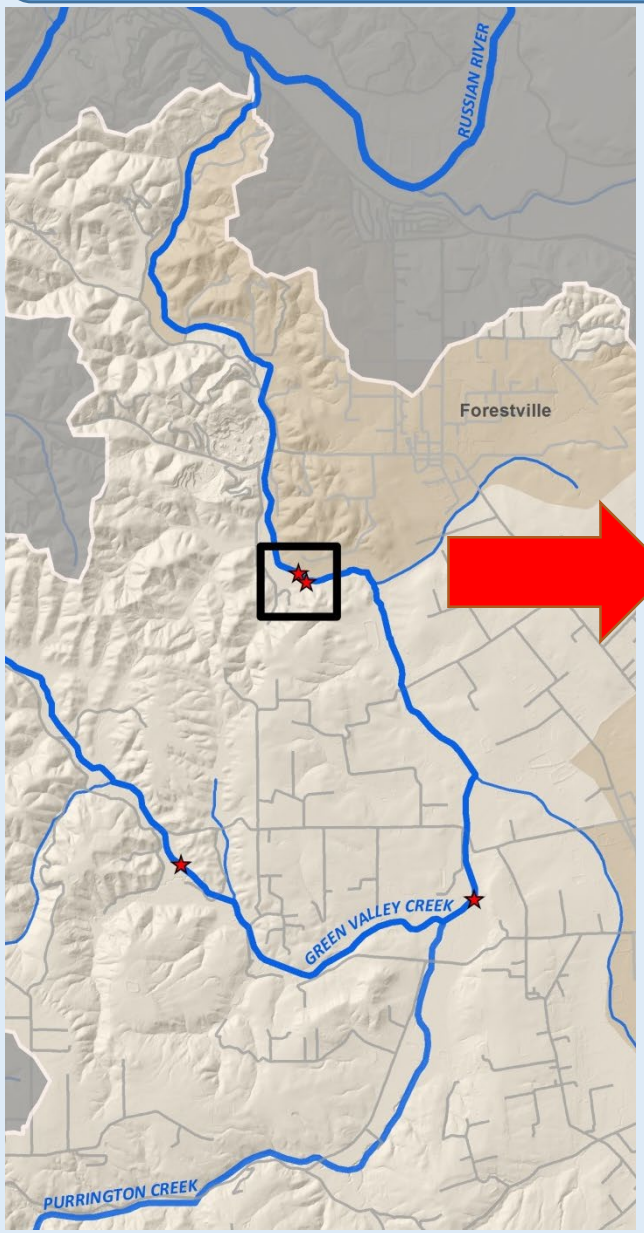
Pre-restoration

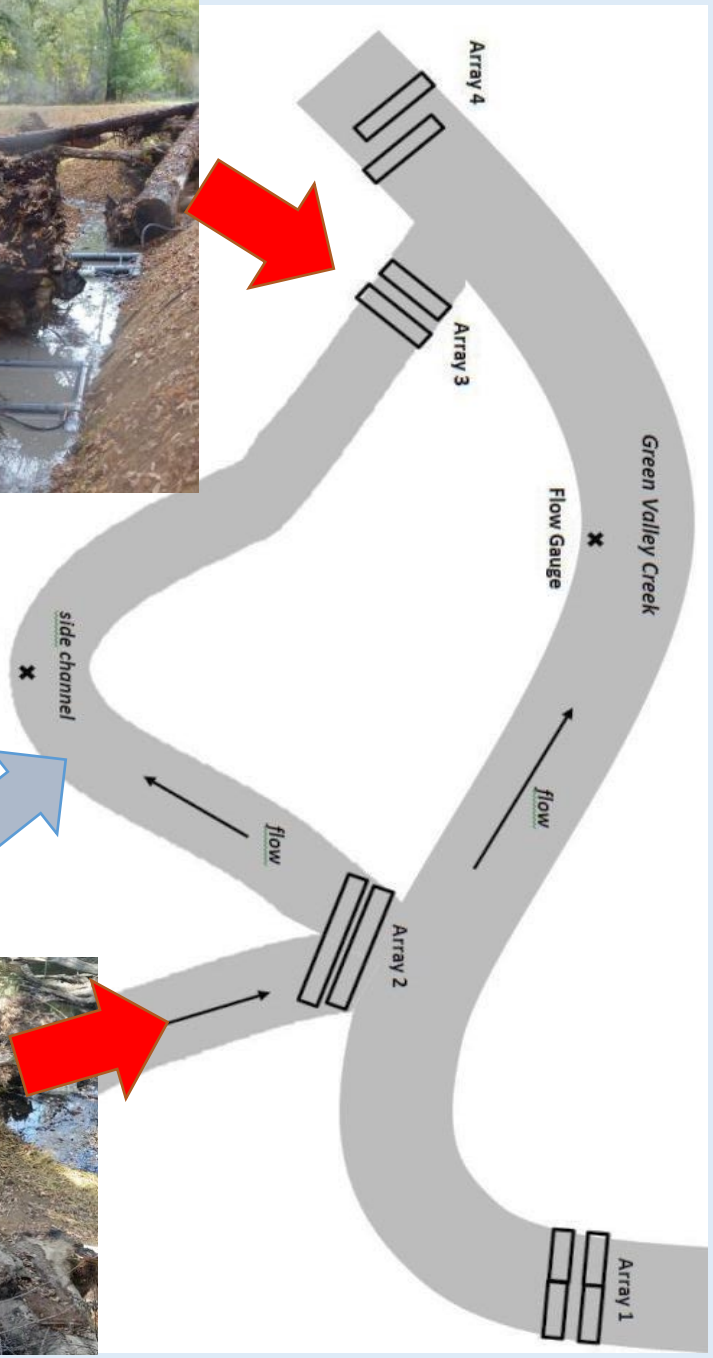






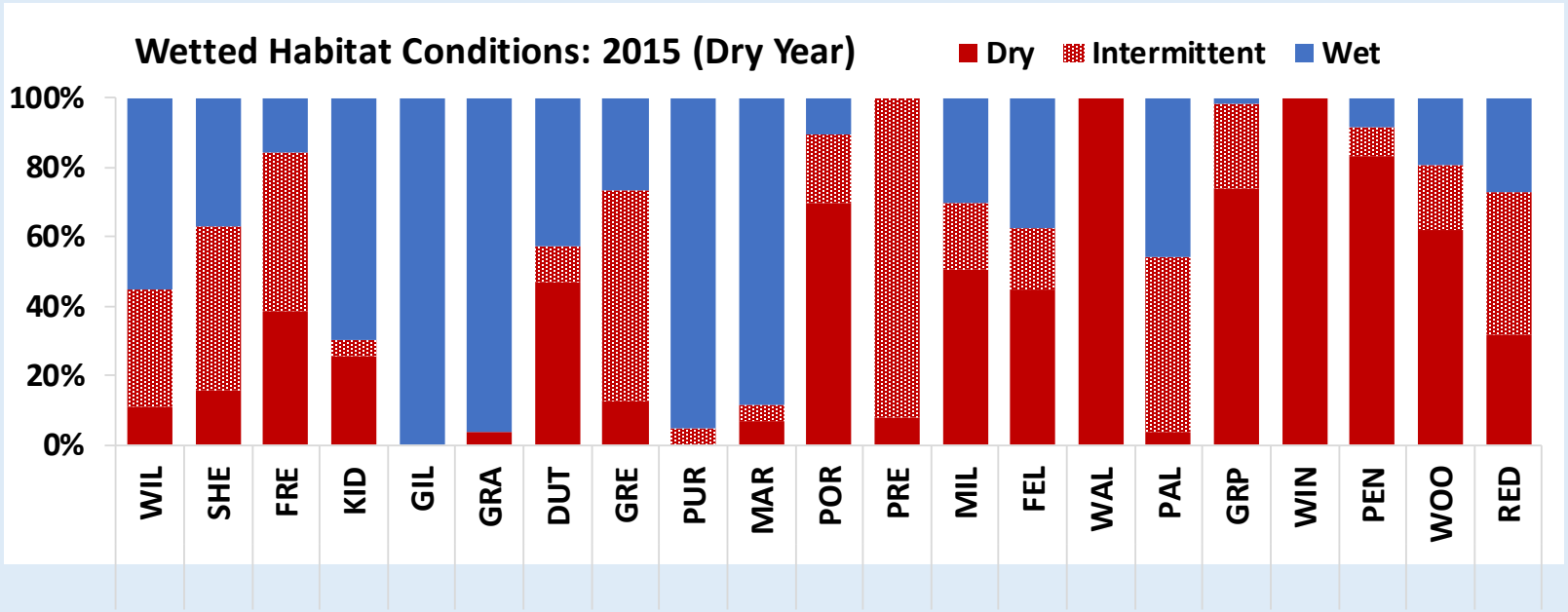
Post-restoration



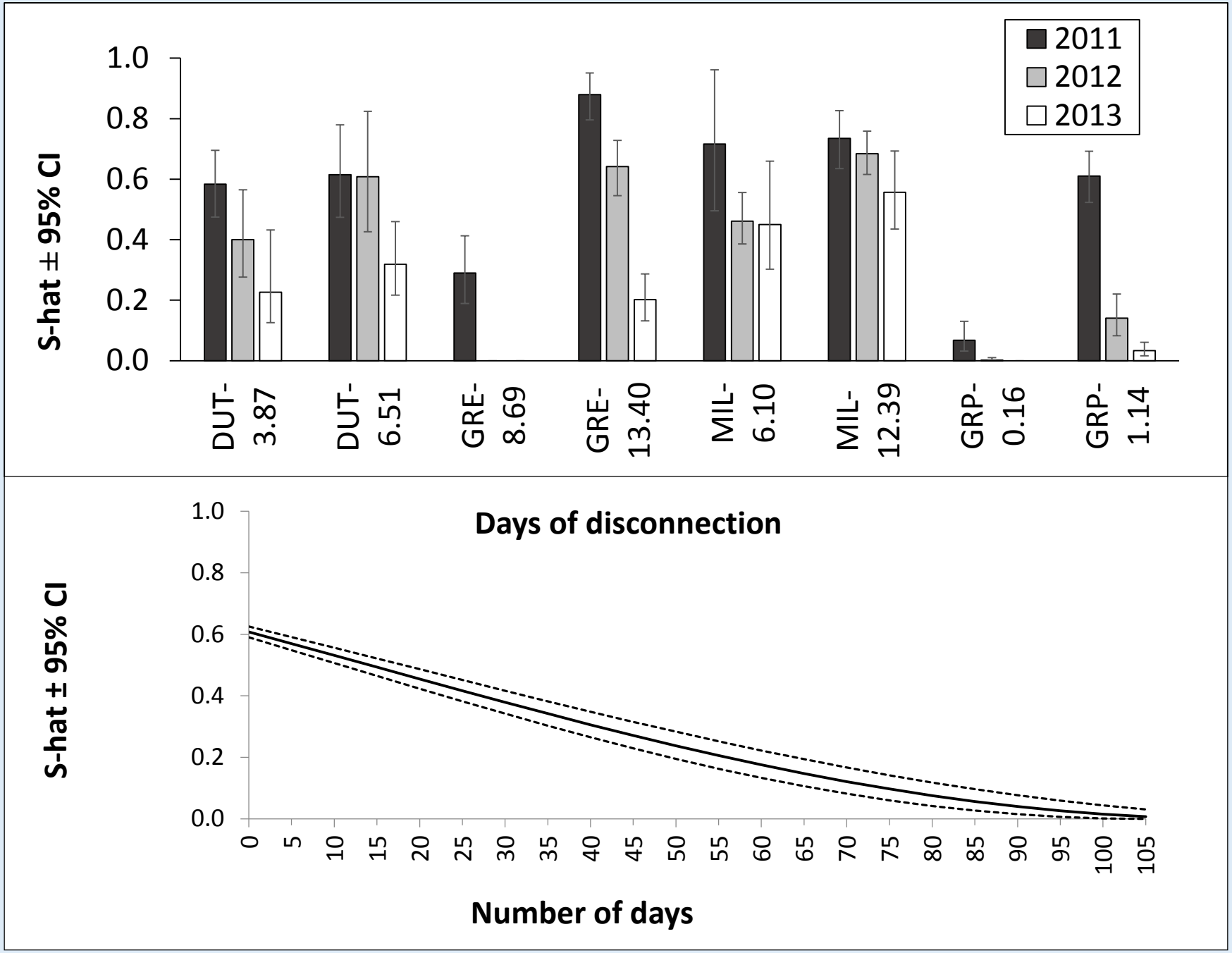







Wetted Habitat Conditions: 2015 (Dry Year)
Dry
Intermittent
Wet
100%
80%
60%
40%
20%
0%
WIL
SHE
FRE
KID
GIL
GRA
DUT
GRE
PUR
MAR
POR
PRE
MIL
FEL
WAL
PAL
GRP
WIN
PEN
WOO
RED


MENU
ESCAPE


S-hat ± 95% CI
1.0
0.8
0.6
0.4
0.2
0.0
2011
2012
2013
DUT-3.87
DUT-6.51
GRE-8.69
GRE-13.40
MIL-6.10
MIL-12.39
GRP-0.16
GRP-1.14
S-hat ± 95% CI
Days of disconnection
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Number of days

Estimation Parameters and Approaches (expanded count & abundance)

Parameter	Field method	Estimation method	Population segment	Ancillary information
Abundance-with CI (smolts-LCM)	Antenna array and trap	1-trap DARR	All	None – (marked: unmarked in trap)
Expanded count-no CI (adults, smolts-LCM)	Multiple antennas within array	Adjust for efficiency	PIT only	Known or estimated ratio of PIT to non-PIT
Abundance-with CI (adults, smolts-LCM)	Multiple antennas within array & multiple arrays	Multistate emigration model	PIT only	Known or estimated ratio of PIT to non-PIT

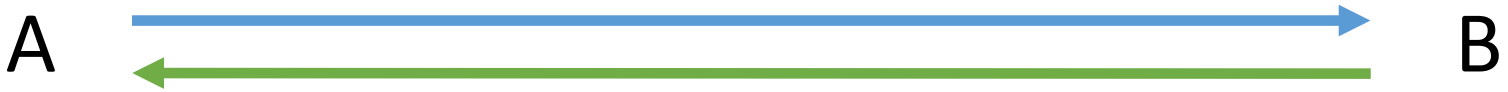
Estimation Parameters and Approaches (expanded count & abundance, true survival & emigration)

Parameter	Field method	Estimation method	Population segment	Ancillary information
Abundance-with CI (smolts-LCM)	Antenna array and trap	1-trap DARR	All	None – (marked: unmarked in trap)
Expanded count-no CI (adults, smolts-LCM)	Multiple antennas within array	Adjust for efficiency	PIT only	Known or estimated ratio of PIT to non-PIT
Abundance-with CI (adults, smolts-LCM)	Multiple antennas within array & multiple arrays	Multistate emigration model	PIT only	Known or estimated ratio of PIT to non-PIT
Emigration timing/ habitat use	Single PIT antenna	Summary stats, graphical	PIT only	None – inference to non-PIT
True survival & emigration	Multiple antennas within array & multiple arrays	Multistate emigration model	PIT only	None – inference to non-PIT

Simplex

- One-way messaging, no back and forth
- Example: TV remote

Half-Duplex (HDX)



- Data can be sent in two directions but only in one direction at a time
- Transmits then receives
- Example: two-way radio

Full-Duplex (FDX)

- Data can be sent in two directions at the same time
- Example: telephone

Half-Duplex (HDX) Arrays

- HDX PIT tags have internal capacitors
- HDX readers generate short interval magnetic pulses.
- Magnetic pulses charge capacitors inside tags within range, which then use stored energy to send the tag info back to the reader

HDX swim through PIT antenna on the San Joaquin River (image: Bureau of Reclamation)

Pros

- Simple antenna design
- Multiple tags can be within antenna field without signal interference
- Antennas can be larger (up to 190’), water separation not needed
- Uses less power than FDX since field is pulsed; longer battery life

Cons

- Internal capacitors limit tag size (12mm now available)
- Slower detection rate than FDX (14 detections/second)
- Single antenna setups are more vulnerable to system failure

Full-Duplex (FDX) Arrays

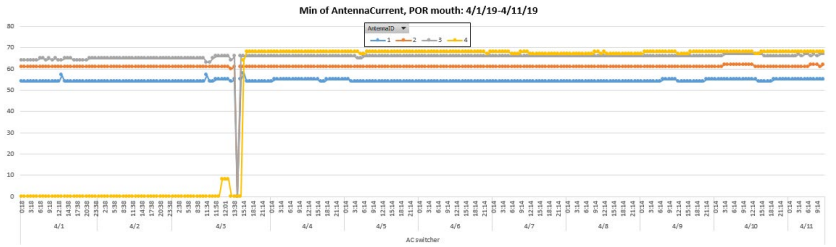
- FDX PIT tags lack internal capacitors
- FDX readers continuously emit magnetic charges as opposed to HDX that send pulse charges

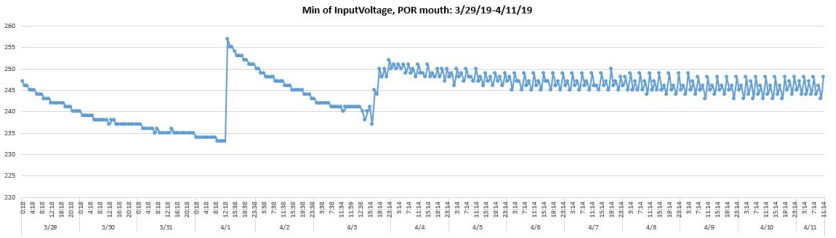
Pros

- Smaller tag sizes than HDX (8-32mm)
- Higher detection rate (30 detections/second)
- Ongoing R&D
- Variety in antenna designs (pass-by, floating, disc, cord, wand, etc.)
- User friendly software
- Status reporting
- Tag sensors

Cons

- When a tag is within FDX reader field, creates signal interference.
- Smaller antenna size (20’ max)
- Susceptible to external sources of noise (pumps, ferrous metal, salt, Navy testing)





Selecting a tag

- Both HDX and FDX tags can read at same frequency (134.2kHz)
- Many venders (Biomark, Oregon RFID, AVID, BTS-ID, UID, etc.)
- HDX tag detection can be enabled on Biomark FDX readers

Tag	Tag type	Length (mm)	Diameter (mm)
Oregon RFID FDX-B "skinny"	FDX	8	1.4
Biomark Mini HPT8	FDX	8.4	1.4
UID FDX	FDX	8.5	1.4
Biomark HPT9	FDX	9	2.1
Biomark HPT10	FDX	10	1.4
Biomark HDX12	HDX	12	2.1
Oregon RFID FDX-B XL	FDX	12	2.15
Oregon RFID HDX+ tag	HDX	12	2.12
UID FDX	FDX	12	2.1
Biomark HPT12	FDX	12.5	2.1
Biomark HPT23	FDX	23	2.1
Oregon RFID HDX+ tag	HDX	23	3.65
Oregon RFID HDX+ tag	HDX	32	3.65

- 50-59mm fork length → 8mm tag
- 60-130mm fork length → 12mm tag
- 131mm+ fork length → 23mm tag

Powering your array

AC

- Reliable power source however, power outages tend to occur during high value fish movement windows
- Requires outlet in close proximity to array (<100’)
- Must have switcher to avoid noise interference
- Monthly cost

Solar

- Site selection very important
- Predictable lulls in power input
- Upfront cost

Batteries

- Most reliable power source
- Requires frequent battery swaps
- Lugging batteries

Other alternative power sources: propane and wind

Biomark®

SPECIALISTS IN IDENTIFICATION SOLUTIONS

Oregon RFID

Avid™

The MicroChip Company

Sea Grant

California

Sonoma Water