Juvenile salmon movement related the tide cycle: a pilot study to inform tidal fish passage in Puget Sound

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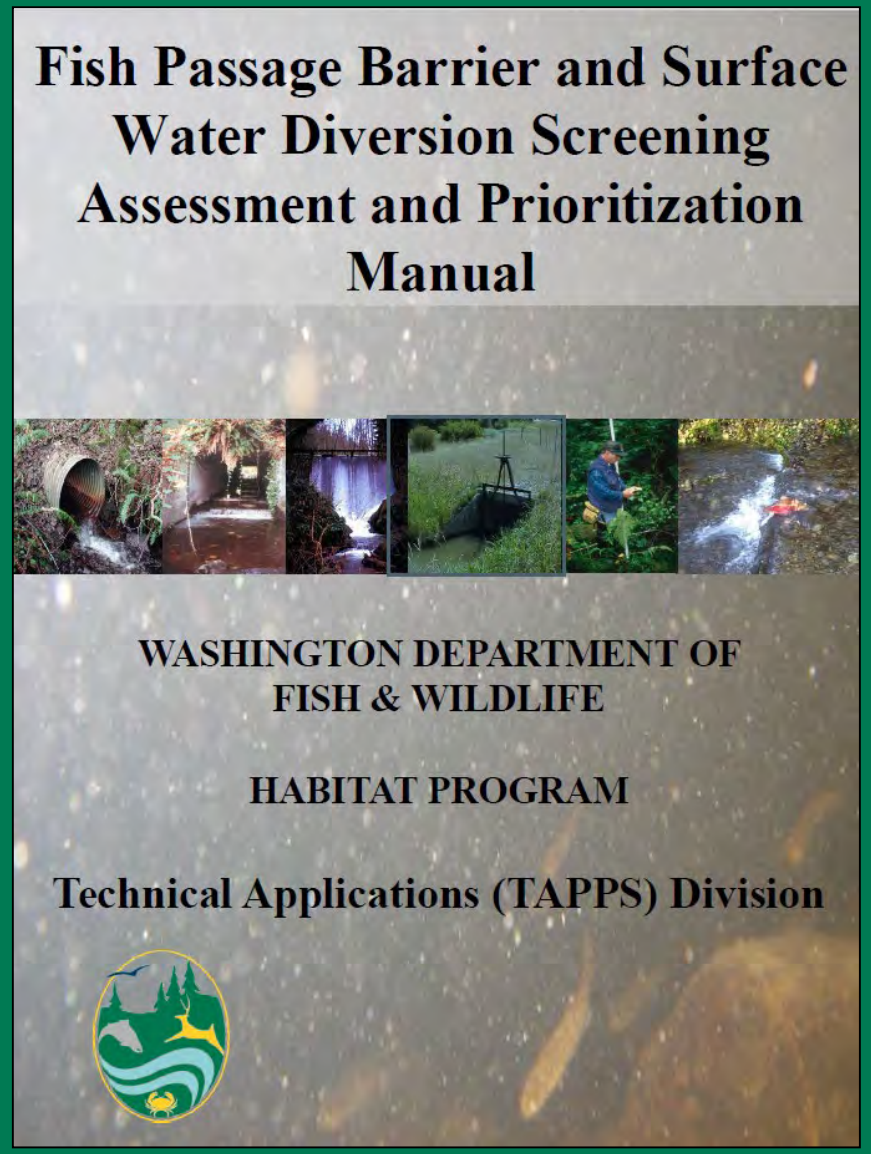
Salmon Recovery Conference
April 2019

Christopher Ellings
Sayre Hodgson

- **Lowest in the watershed**
- **High potential to impact fish use and habitat**
- **Fish passage remediation is happening *now***
  - ***Legal***
  - ***Failing infrastructure***
  - ***Restoration***
- **Future conditions**

→ ***Improved technical guidance for assessment and design***

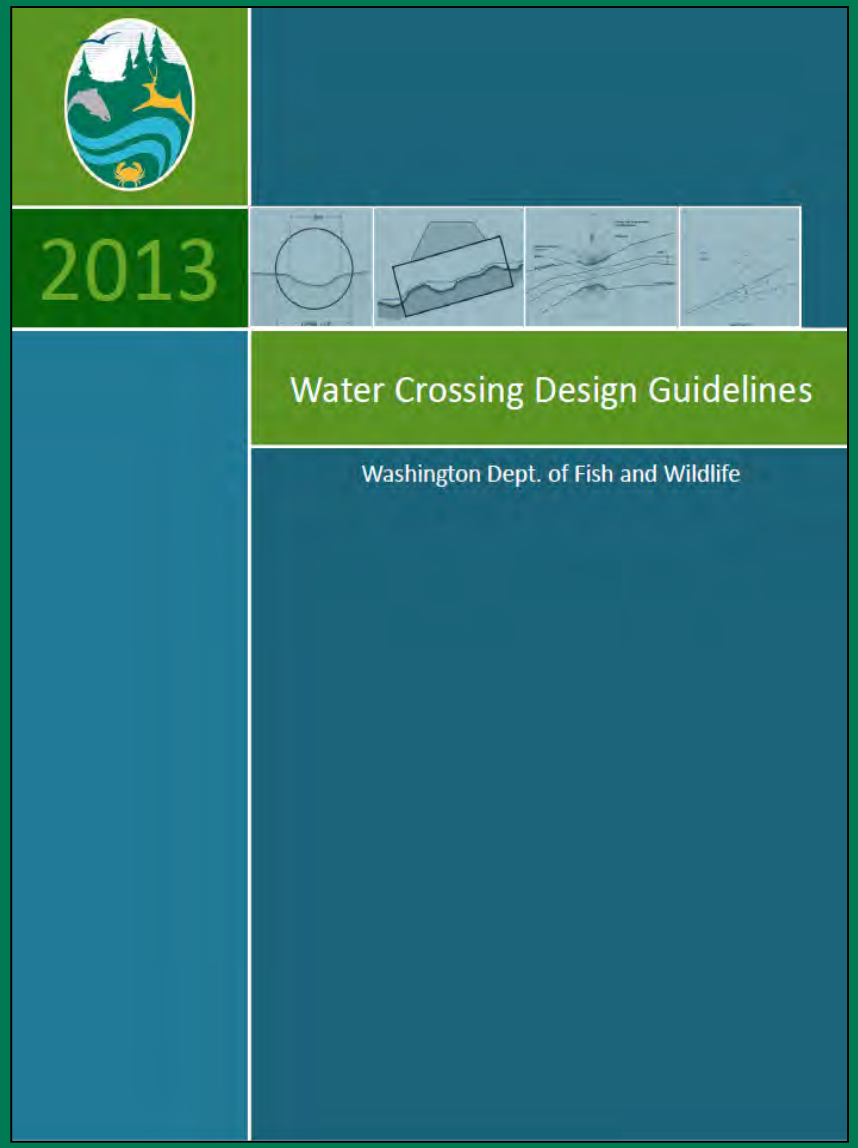


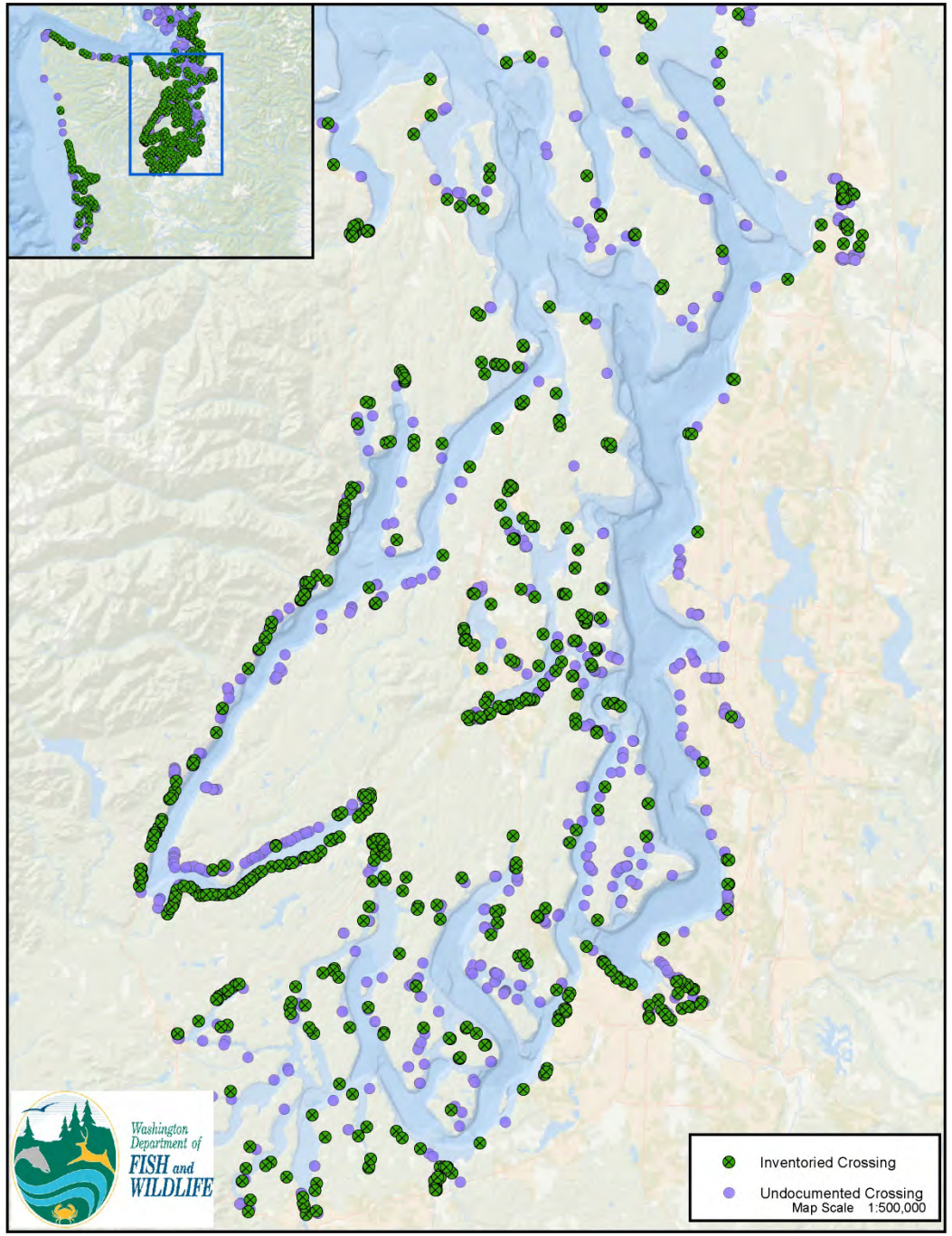
Barrier Assessment Criteria

- Developed for riverine systems
- Based on adult salmonids
- No specific provisions for intertidal systems

Current Design Guidelines: Appendix D

- Current riverine criteria may not be appropriate for intertidal sites
- Recommends biggest opening possible within the constraints of the project including budget
- Both the regulatory and design community would benefit from more prescriptive guidance





- Magnitude of potential tidal crossings
- Most tidal sites are categorized as “unknown” passability
- Projects are reviewed and designed on a case by case basis

Fish Passage Barrier Identification (FW)

Established for rivers and streams to move fish upstream during the time that fish are moving

Guidelines:

- 6” trout
- 10% exceedance design flow

Velocity

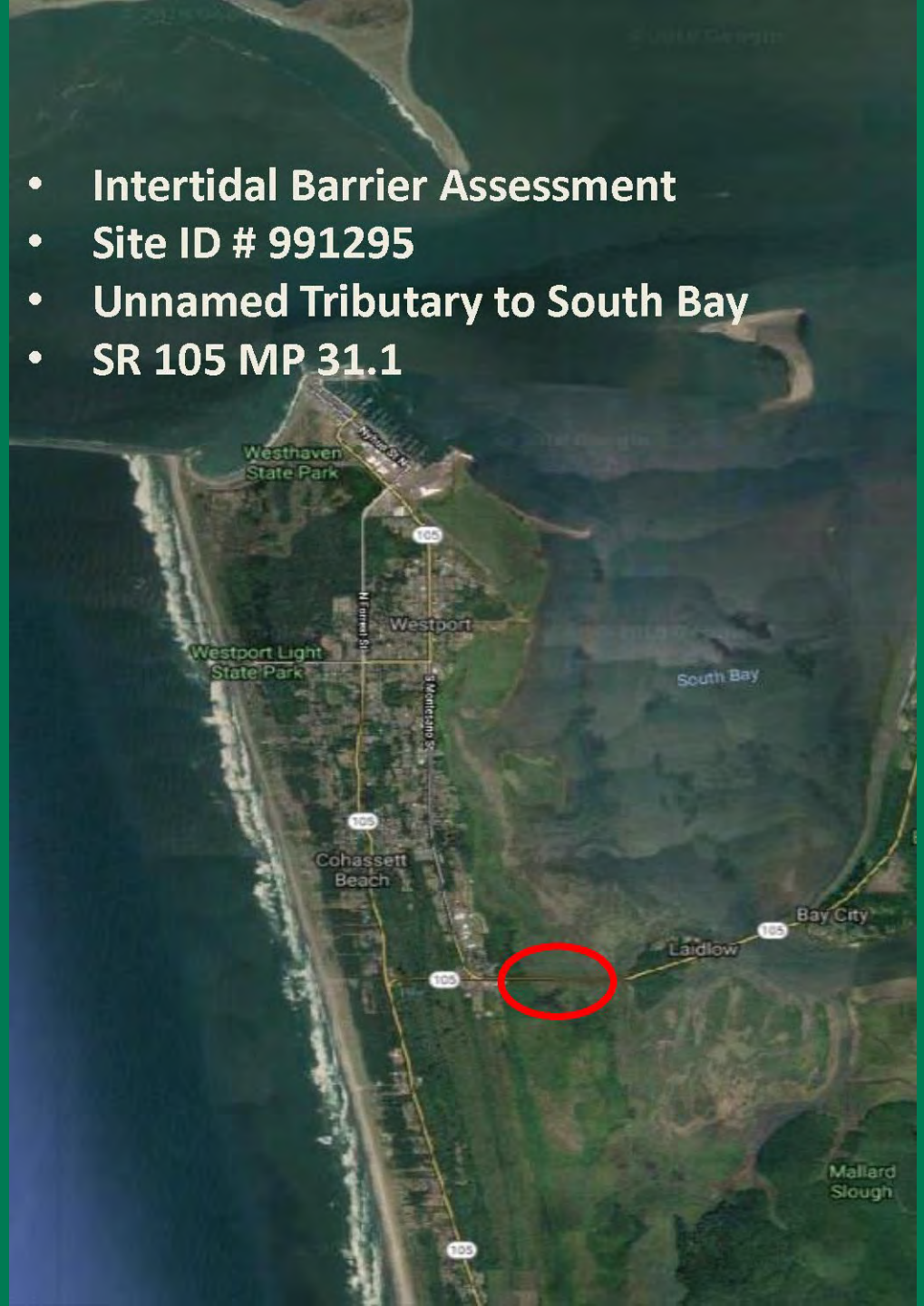
Vertical Drop

Water Depth

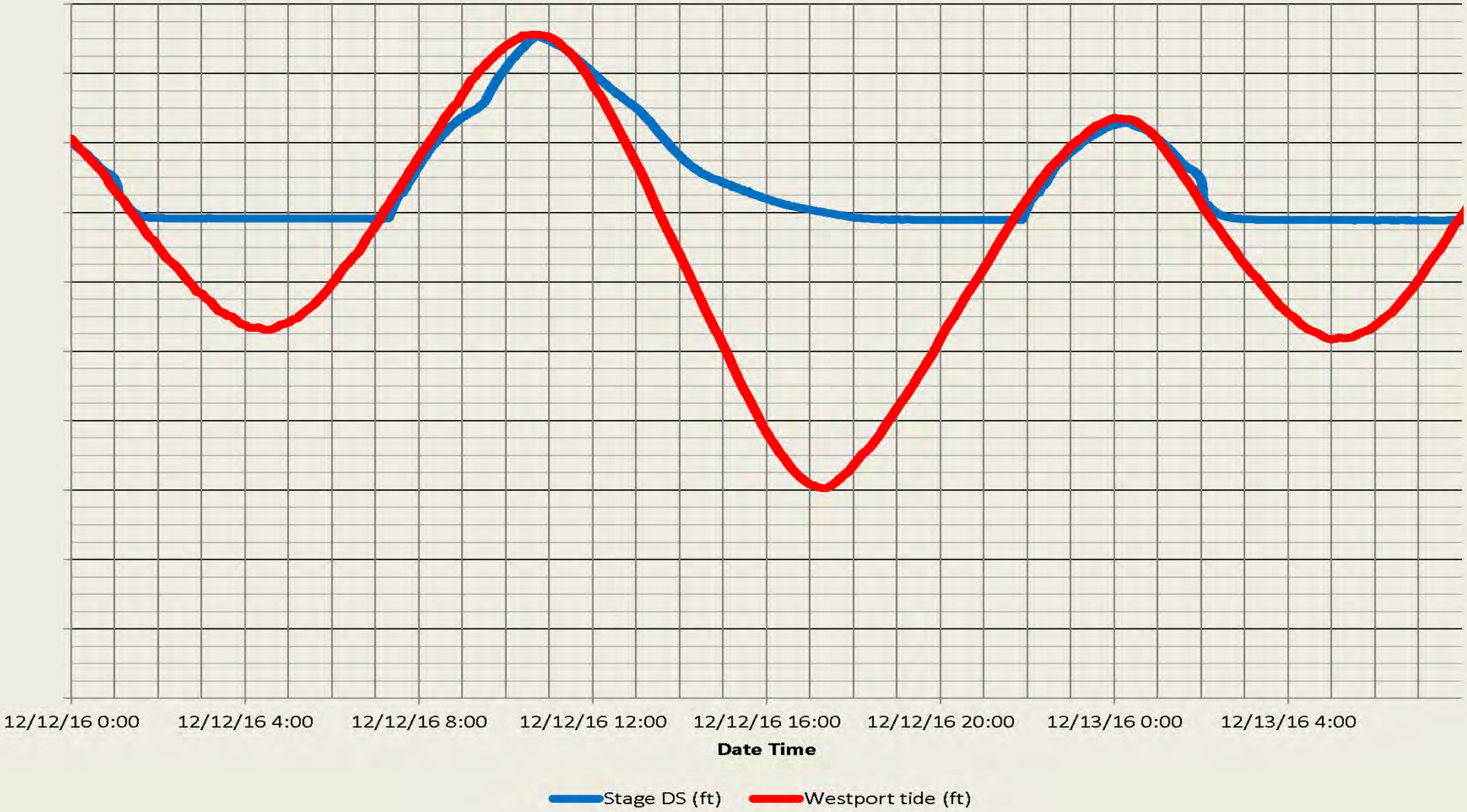
What is a fish passage barrier in the intertidal?

- Bi-directional tidal flow + riverine flows
- Drop, depth & velocity vary throughout tide cycle

- Intertidal Barrier Assessment
- Site ID # 991295
- Unnamed Tributary to South Bay
- SR 105 MP 31.1



Dec 12 2016 SR 105 991295



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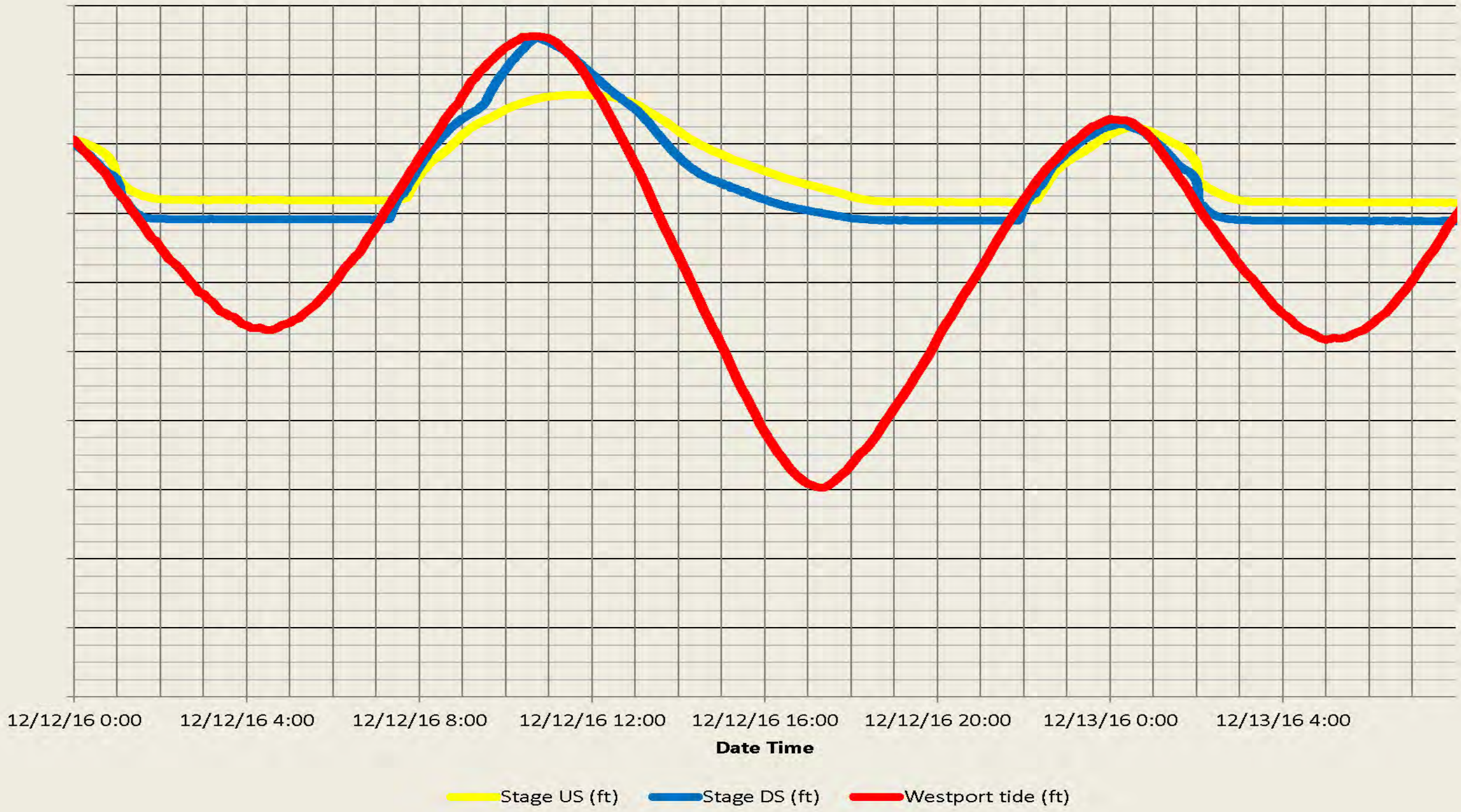

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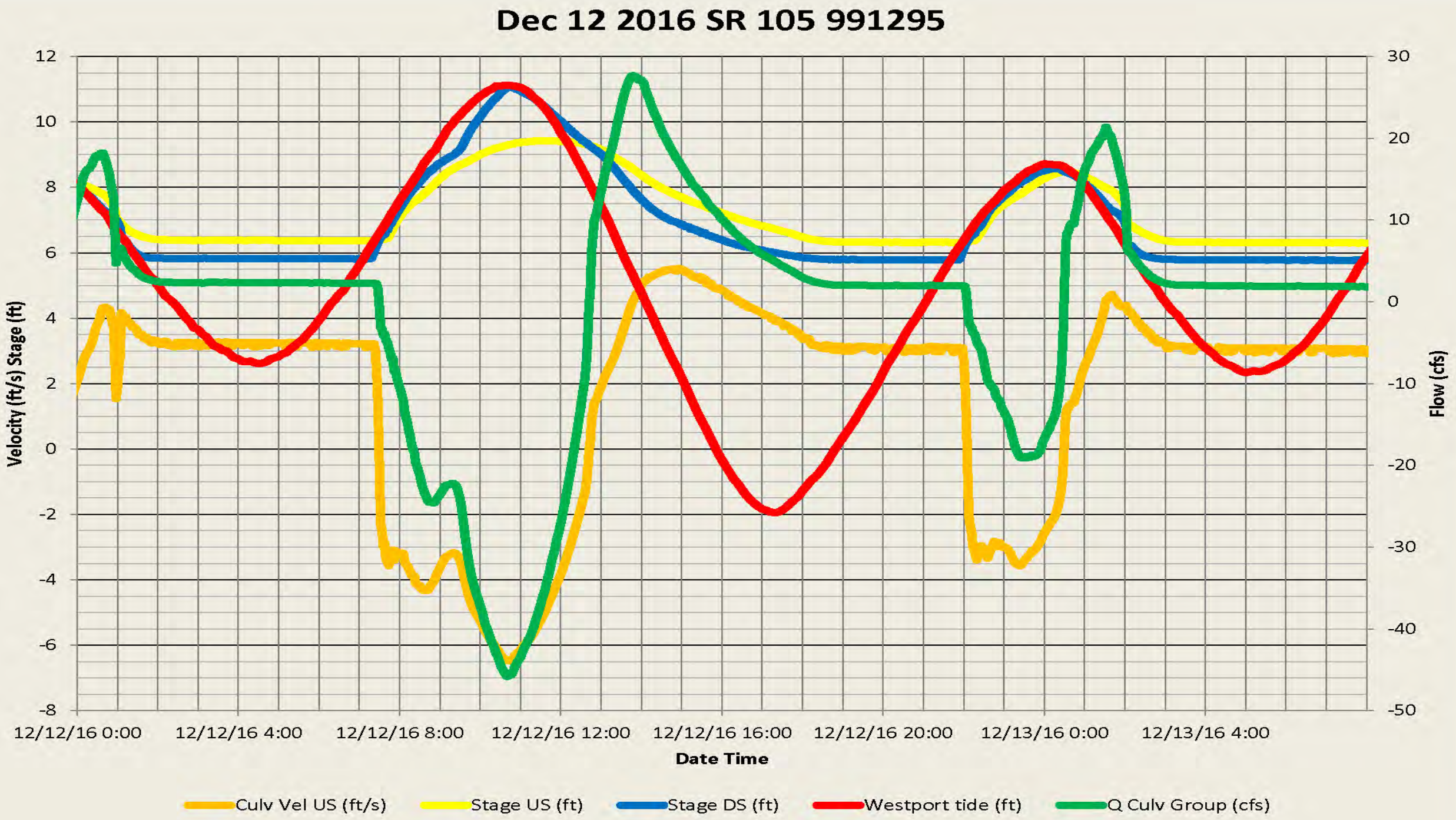
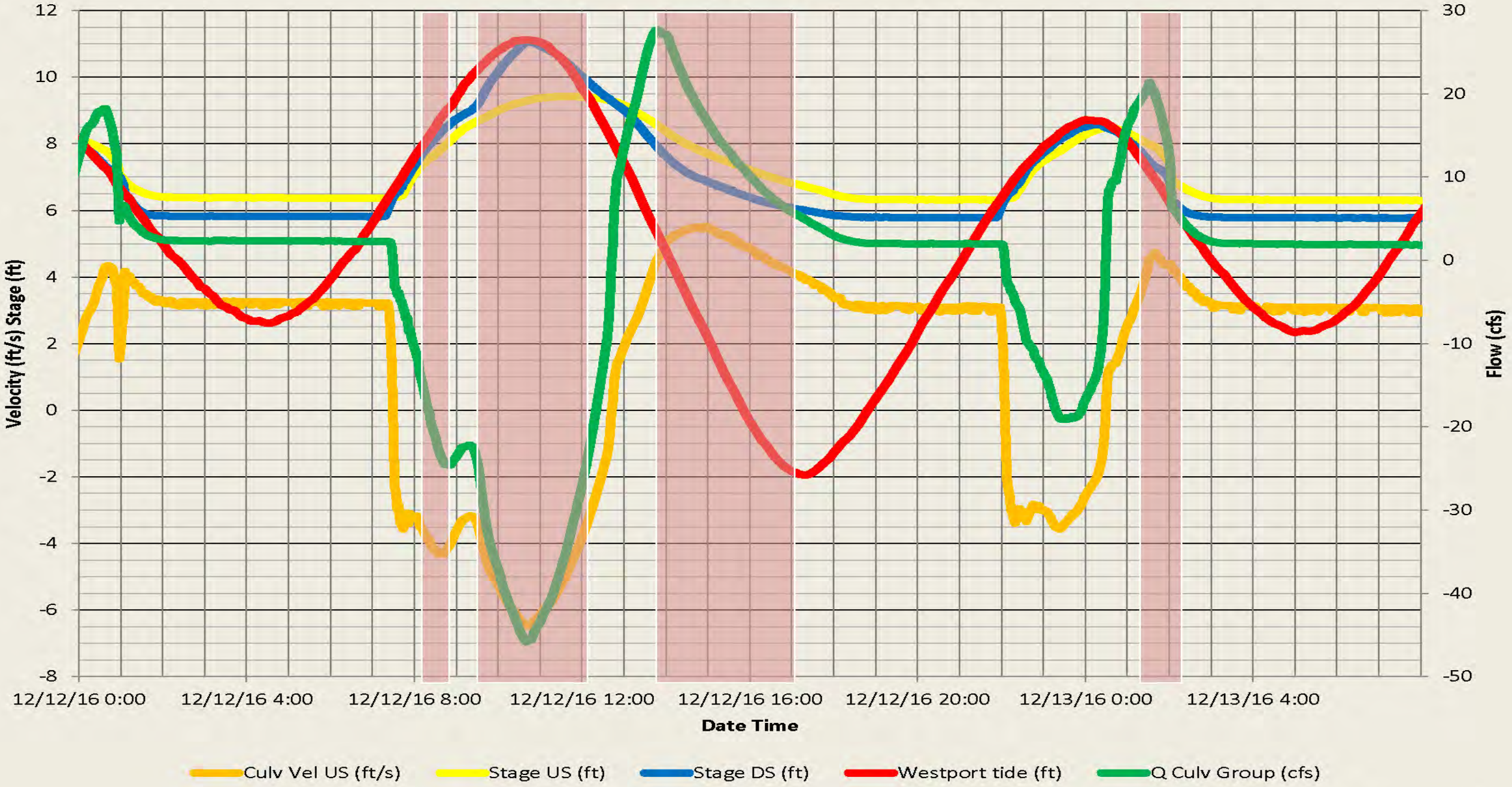

Dec 12 2016 SR 105 991295
Velocity (ft/s) Stage (ft)
Flow (cfs)
12
10
8
6
4
2
0
-2
-4
-6
-8
30
20
10
0
-10
-20
-30
-40
-50
12/12/16 0:00
12/12/16 4:00
12/12/16 8:00
12/12/16 12:00
12/12/16 16:00
12/12/16 20:00
12/13/16 0:00
12/13/16 4:00
Date Time
Culv Vel US (ft/s)
Stage US (ft)
Stage DS (ft)
Westport tide (ft)
Q Culv Group (cfs)

Dec 12 2016 SR 105 991295



What is a fish passage barrier in the intertidal?

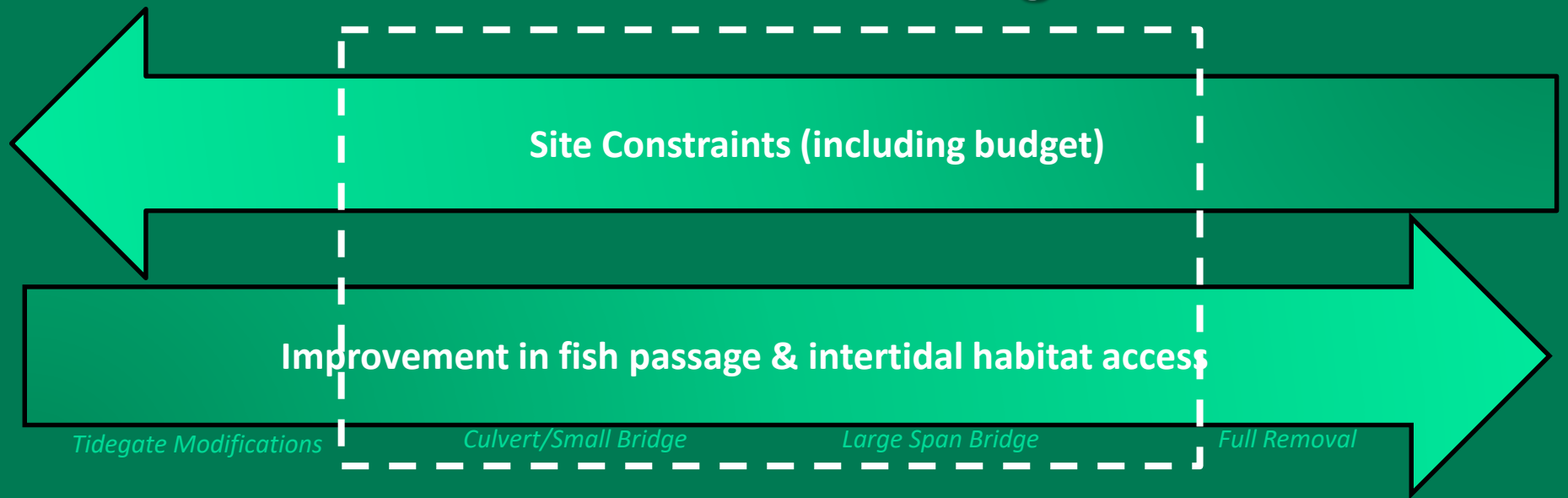
- Adult fish passage to spawning grounds
- Access to intertidal rearing habitat

Small fish with weak swimming abilities

Key Questions – Fish Movement

- *When are fish moving during the tide cycle?*
- *Do fish move with or against the tide?*
- *Are fish moving volitionally at all tidal stages? Does it matter if they are not?*
- *Are fish behaviorally affected by physical changes in hydrology at crossing structures?*
- *What are the consequences of blockage or delay?*

How much is enough?



"Effects of Intertidal Water Crossing Structures on Estuarine Fish and Their Habitat: A literature review and synthesis"

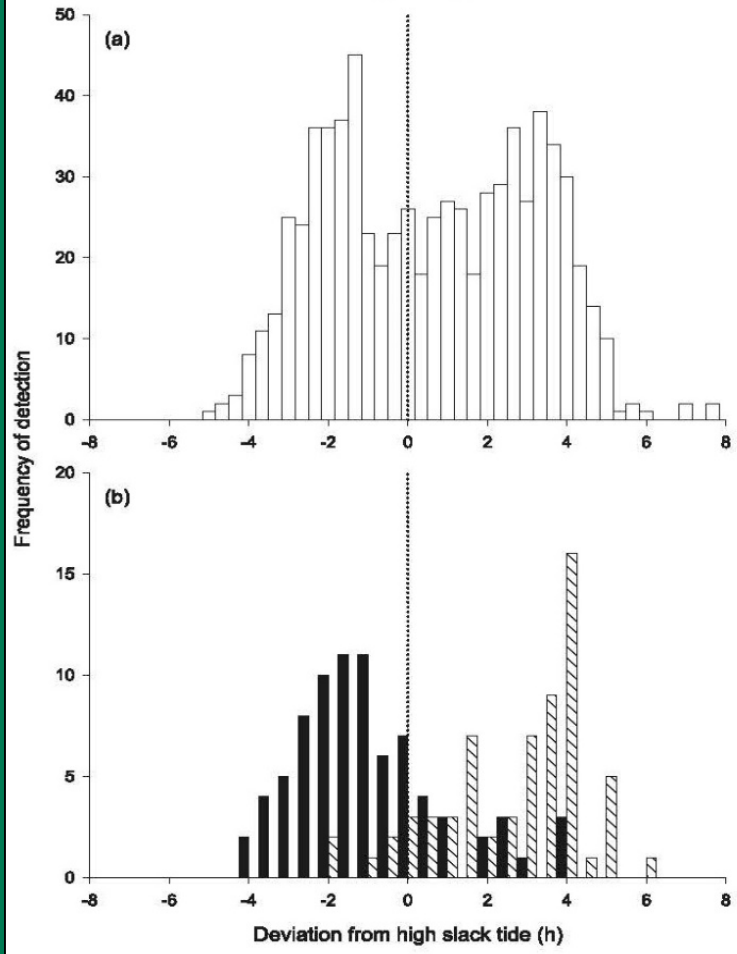
Correigh Greene. NOAA Fisheries NWFSC
Jason Hall, Cramer Fish Sciences
Doris Small & Pad Smith, Washington Dept Fish & Wildlife
Oct 2017

- *Tidal fish movement studies lacking*
- *Estuarine fish use by juvenile salmonids for rearing*
- *Natal and non-natal estuaries used for rearing*
- *Structures impact fish passage and habitat quality/quantity*
- *Climate change*
- *Data gaps*

Tidal movements and residency of subyearling Chinook salmon (*Oncorhynchus tshawytscha*) in an Oregon salt marsh channel

David K. Hering, Daniel L. Bottom, Earl F. Prentice, Kim K. Jones and Ian A. Fleming

Fig. 5. (*a*) Frequency of all PIT tag detections at antenna 1, and (*b*) frequency of fish movements into (solid bars) and out of (hatched bars) the study channel in 2005, relative to the tidal cycle. Vertical dotted lines indicate timing of high slack tide.



Juvenile Salmonid Movement Studies

Culverts & Bridges

- Small stream outlets
- Embayments

Not focused on tidegates
(see Greene et al. 2012)

Which fish species and sizes are most impacted at these sites?

- *Chinook <60 mm FL*
  60-120 mm FL
- *Chum <60 mm FL*
- *Coho subyearlings <60 mm FL*

Thorndyke Bay, Hood Canal

Project partner:
Port Gamble/S'Klallam Tribe

Landowner: Olympic Property Management

Target fish: Chum (<60mm)

- **Blue-View imaging sonar**
- **Underwater camera array**

Skagit Delta, North Puget Sound

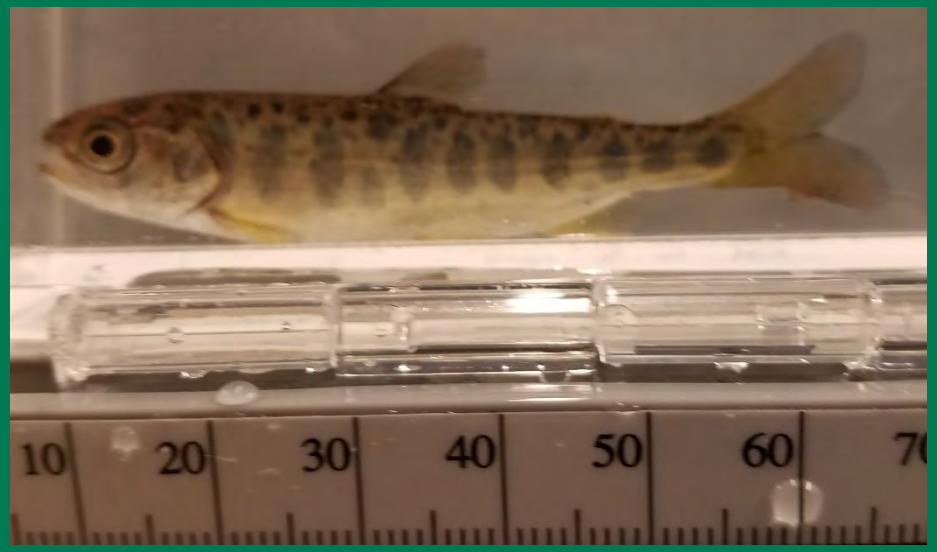
Project partner:
Skagit River System Cooperative

Target fish: < 60 mm Chinook & Chum

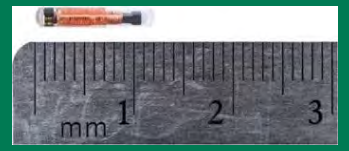
- **Beach seines**
- **Underwater camera**

Double beach seine

Passive Integrated Transponder (PIT)



Target fish: Hatchery Chinook
(65 – 100 mm FL)
12 mm tag



- Can monitor individual fish
- Larger salmonids (>65 mm) estuarine residence
- Conductivity in saltwater
  - *Detection range is limited*
  - *Smaller antenna (10’ x 3’)*
  - *Antenna higher in watershed*

One PIT tag antenna to share between two sites

Nisqually River Estuary, South Puget Sound

Project partner:
Nisqually Indian Tribe

Target fish: Hatchery Chinook (>65mm)
Timing: mid-May to mid-June

Skokomish River Estuary, Hood Canal

Project partner:
Skokomish Indian Tribe

Target fish: PIT tagged coho & sockeye released from Cushman juvenile collector trials
Timing: Mid-June to July

Nisqually River Estuary – Pilot work in 2018

Tagged 496 hatchery Chinook (75 – 110 mm FL)

Released over 3 days at 3 locations

Nisqually Pilot 2018

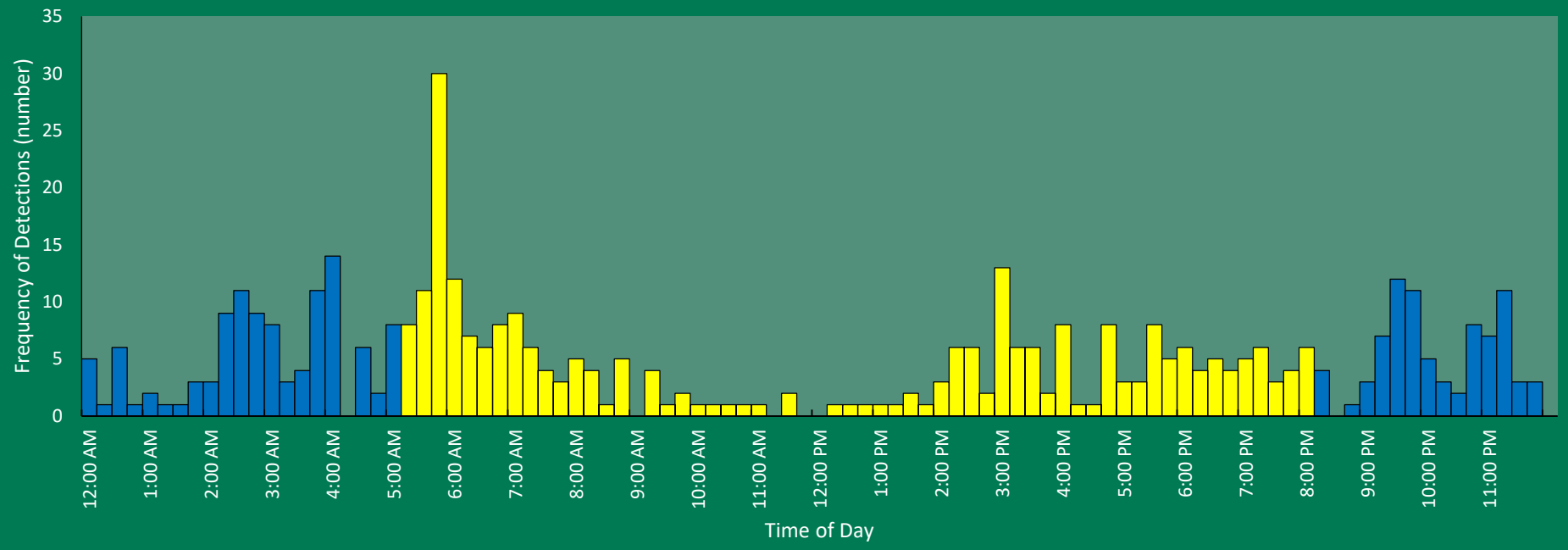
Tagged Fish	Hatchery Chinook 70 – 109 mm FL	
Total tags	496 tagged fish	
	Detections	
Total	**60 fish**	**453 hits**
5/21	6	197
5/22	12	217
5/23	42	82
Cattle Bridge	6	26
Antenna	54	427
Tagging Site	0	0
Dates	5/23 – 6/7	16 of 19 days
Tag Hits	1 hit	23 (38%)
	<10 hits	85%
Tide cycle	1 tide	75%
	>1 tide	25% (range 1 - 19)

Fish Movement

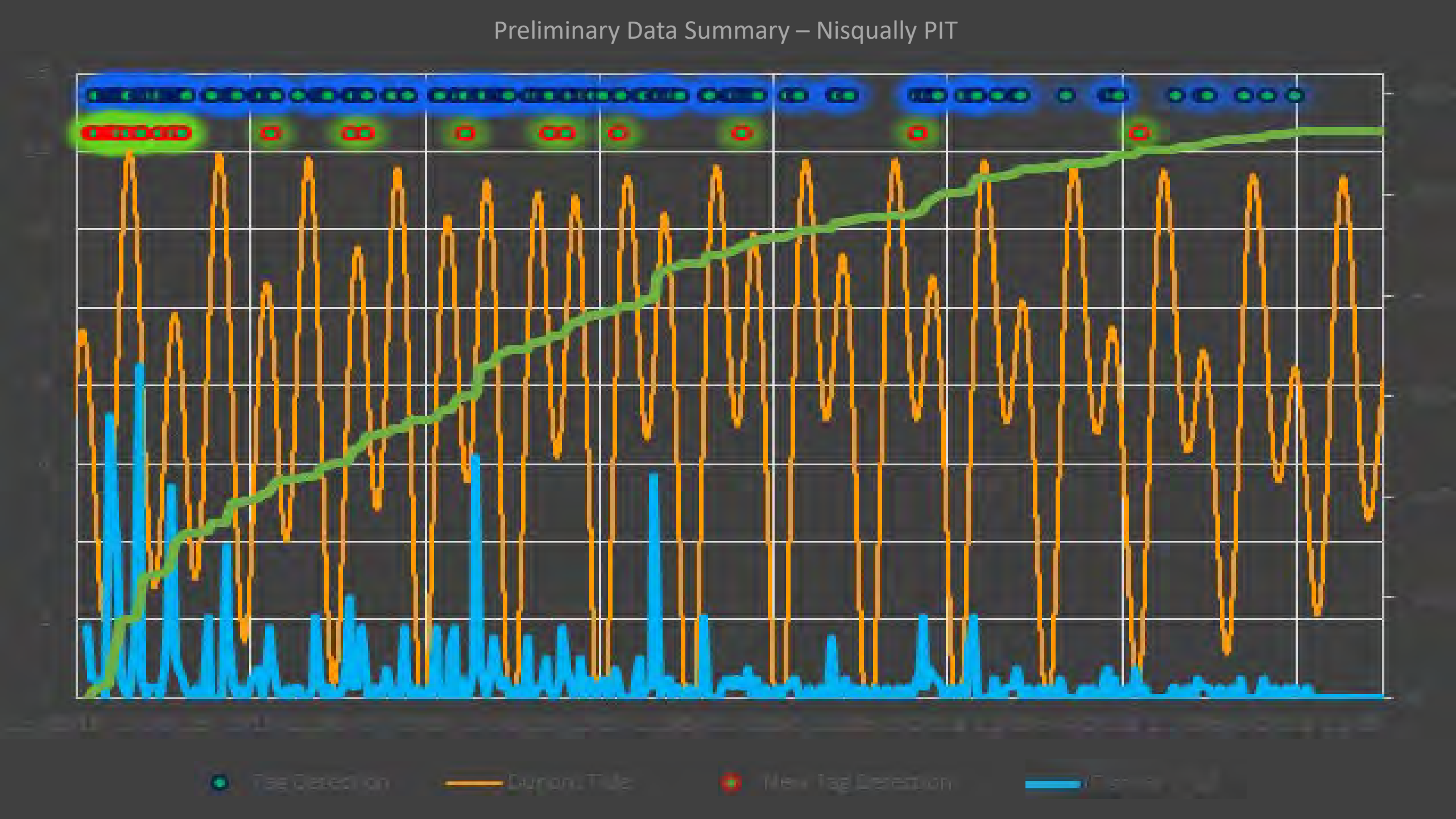
Tide cycle

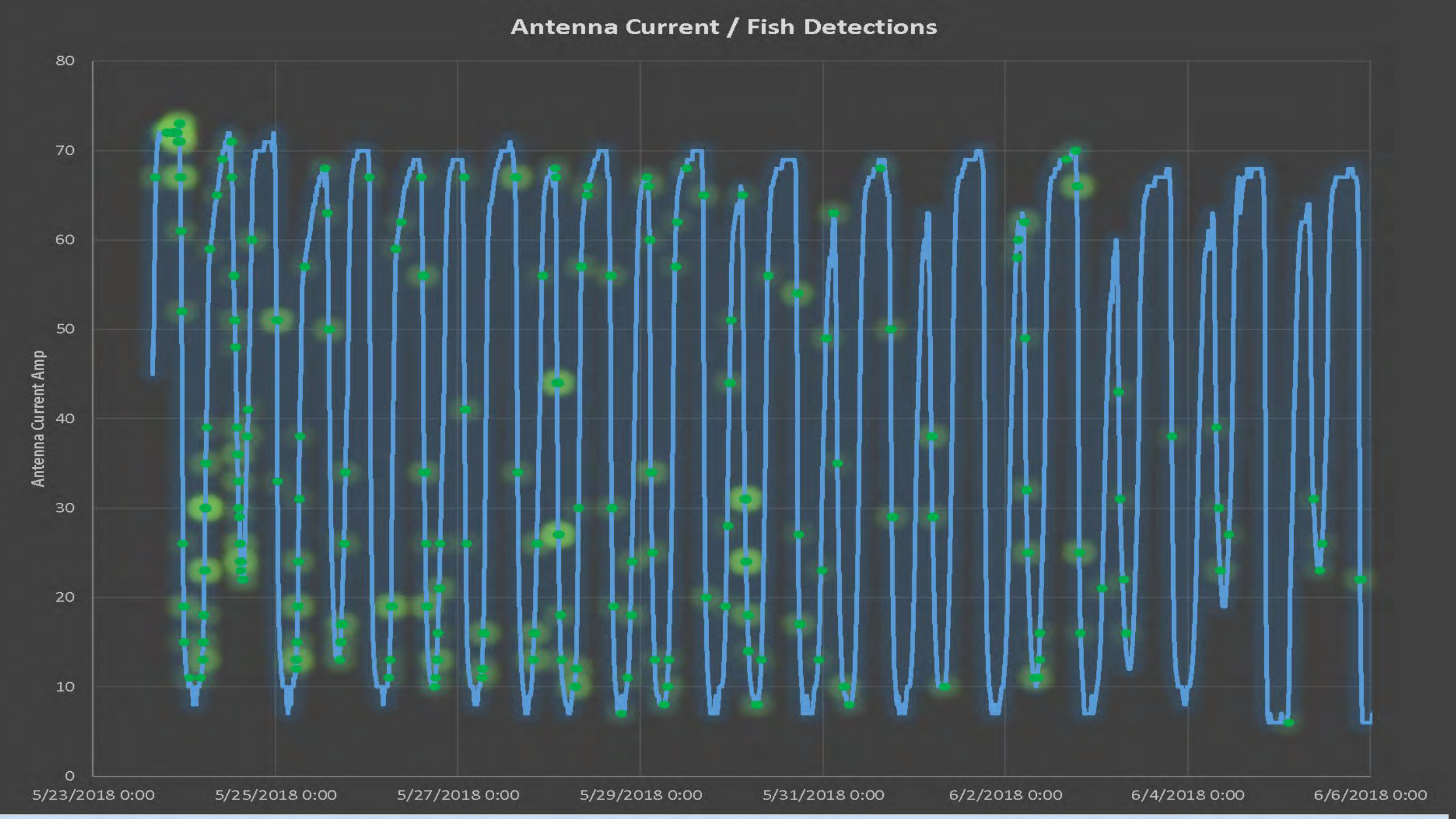
- Time of day
- Temperature, Salinity, DO
- Depth of water in channel
- Velocity
- Water column position

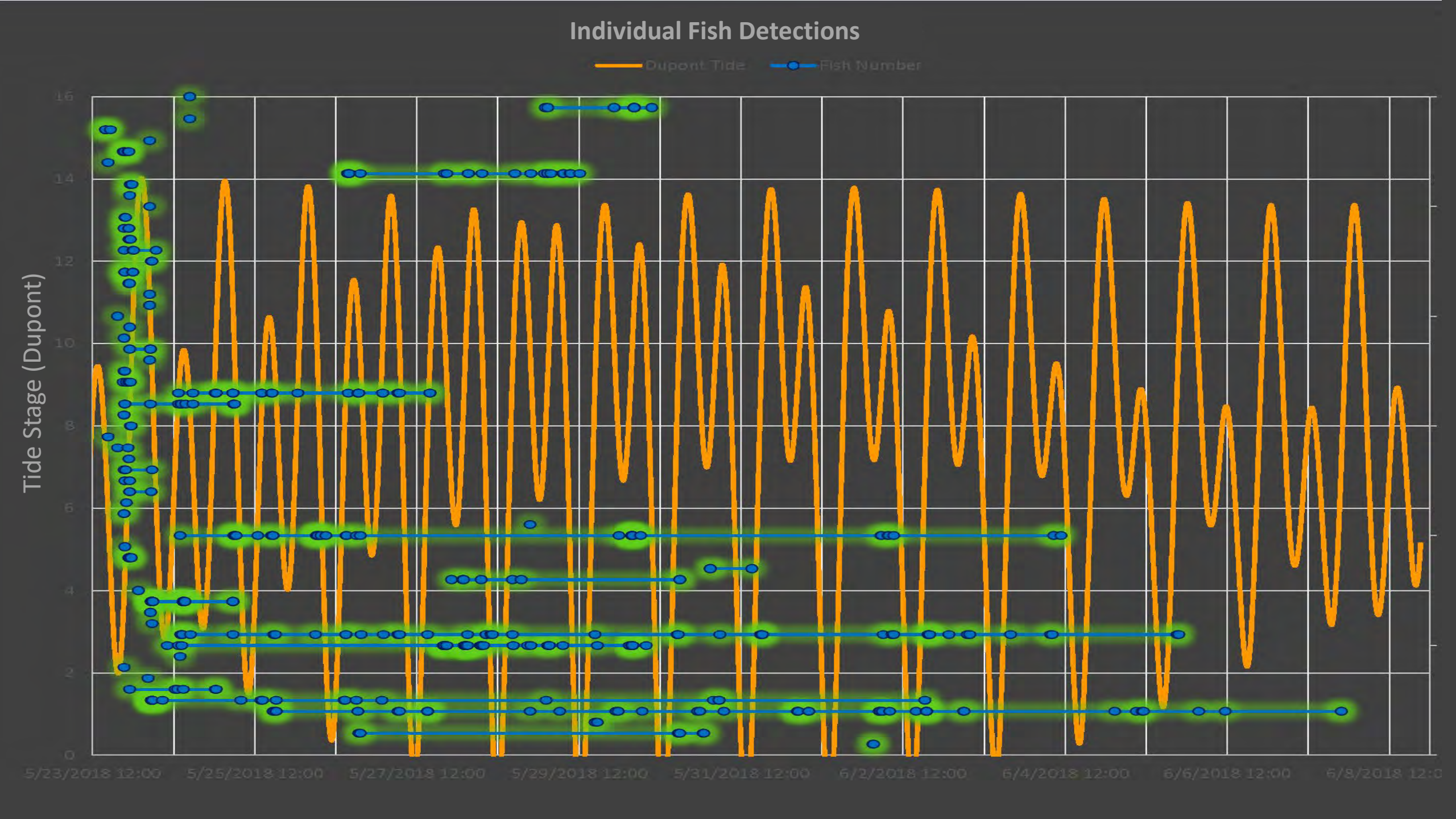
Behavior (predation, competition, food, etc.)



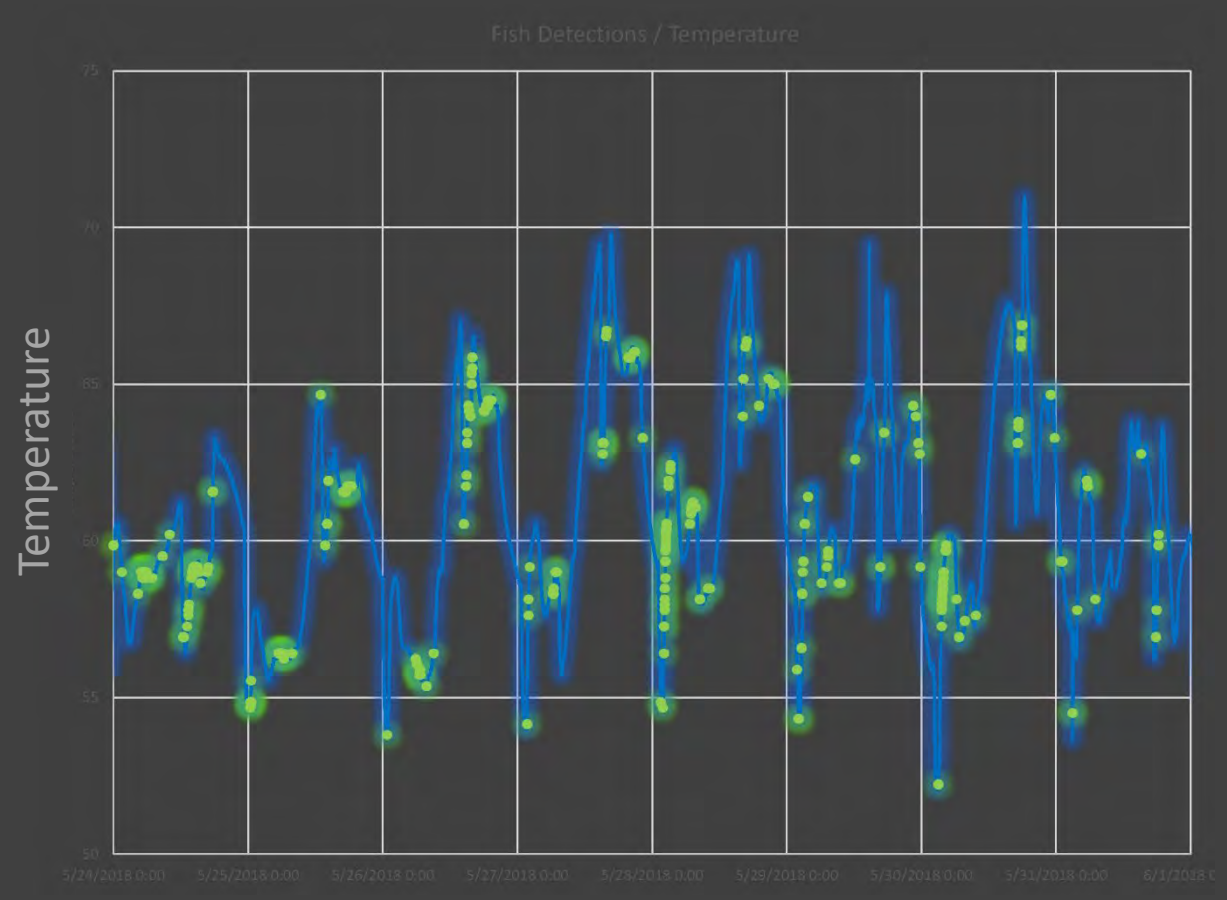
Preliminary Data Summary – Nisqually PIT

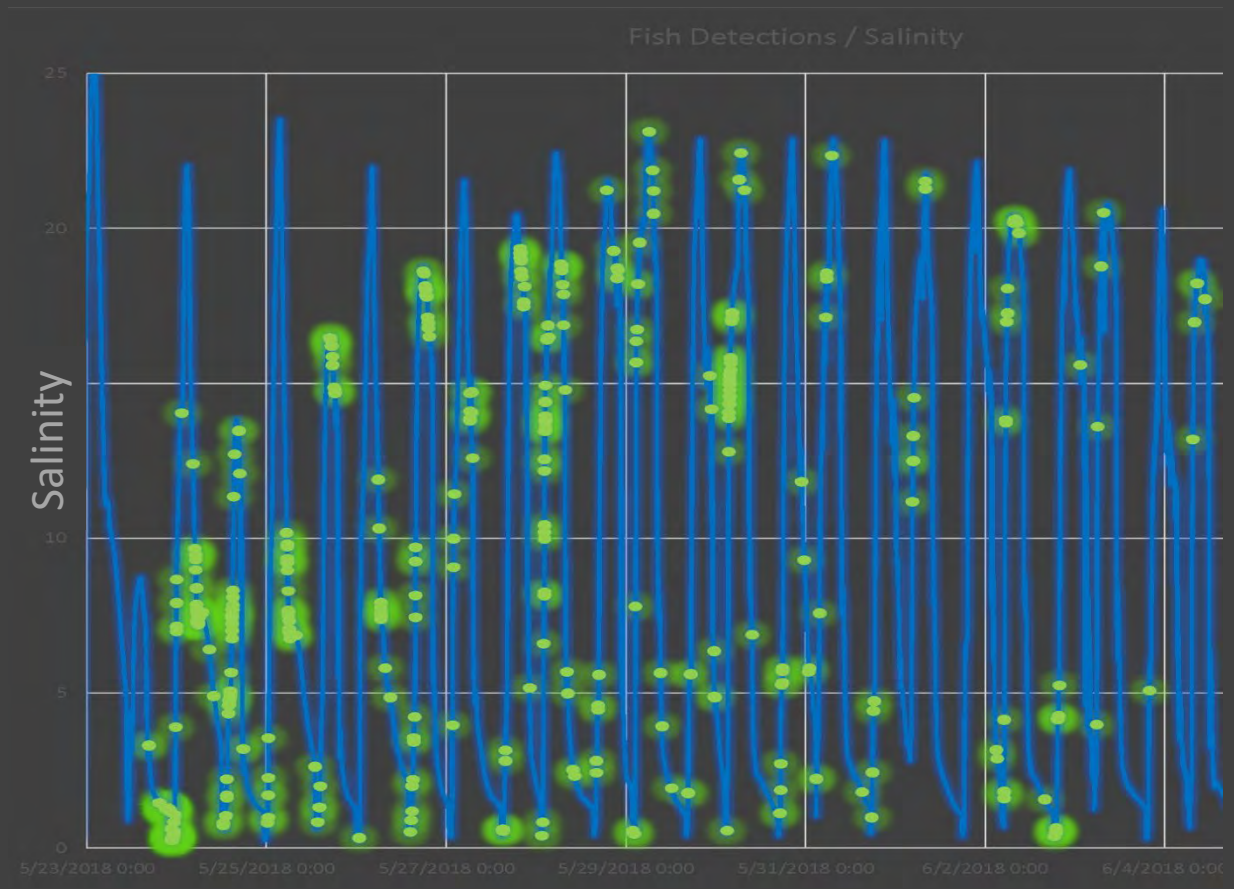


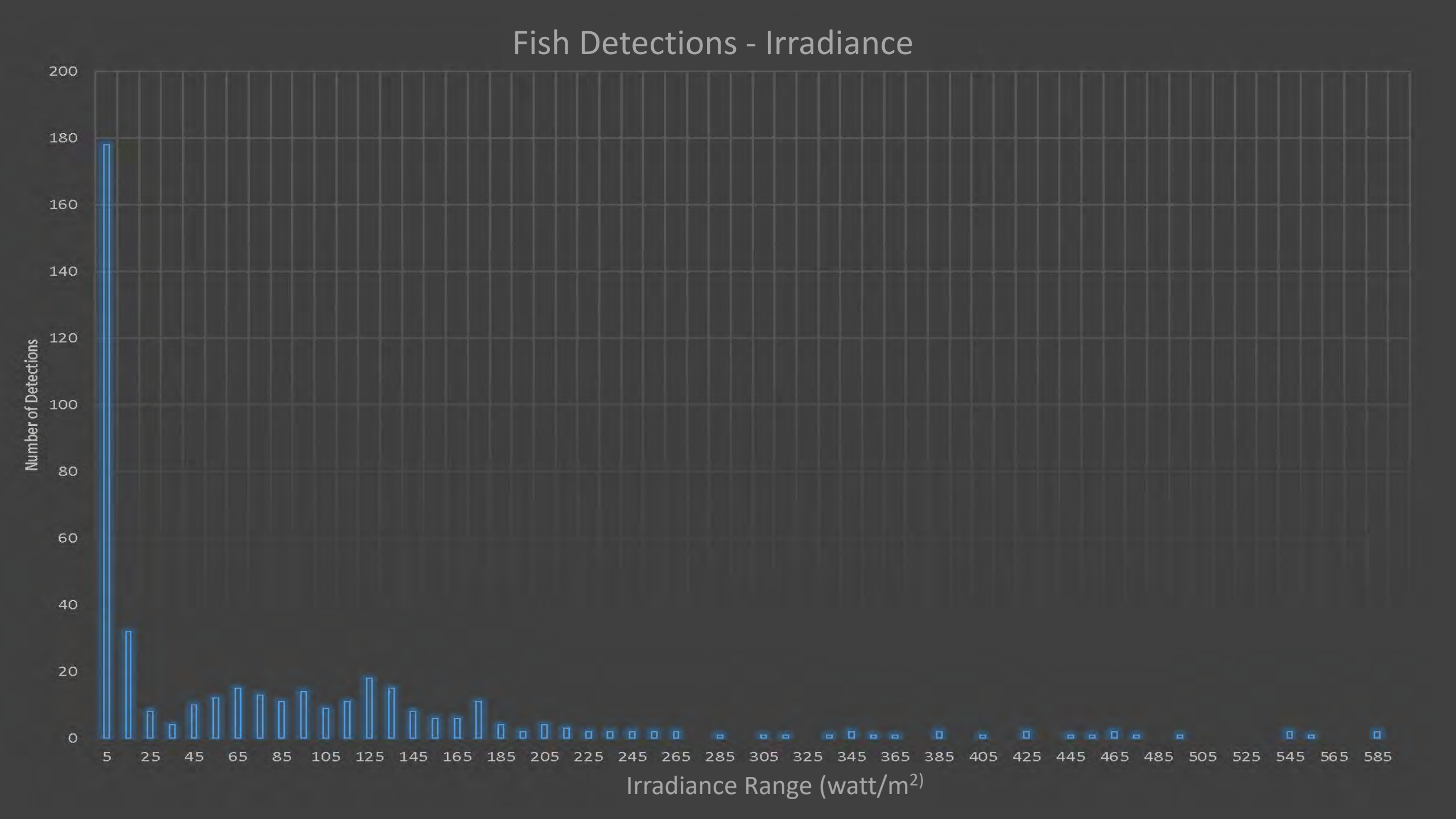

Antenna Current / Fish Detections
Antenna Current Amp
80
70
60
50
40
30
20
10
0
5/23/2018 0:00
5/25/2018 0:00
5/27/2018 0:00
5/29/2018 0:00
5/31/2018 0:00
6/2/2018 0:00
6/4/2018 0:00
6/6/2018 0:00


Individual Fish Detections
Dupont Tide
Fish Number
Tide Stage (Dupont)
16
14
12
10
8
6
4
2
0
5/23/2018 12:00
5/25/2018 12:00
5/27/2018 12:00
5/29/2018 12:00
5/31/2018 12:00
6/2/2018 12:00
6/4/2018 12:00
6/6/2018 12:00
6/8/2018 12:0

Fish Detections - Temperature & Salinity

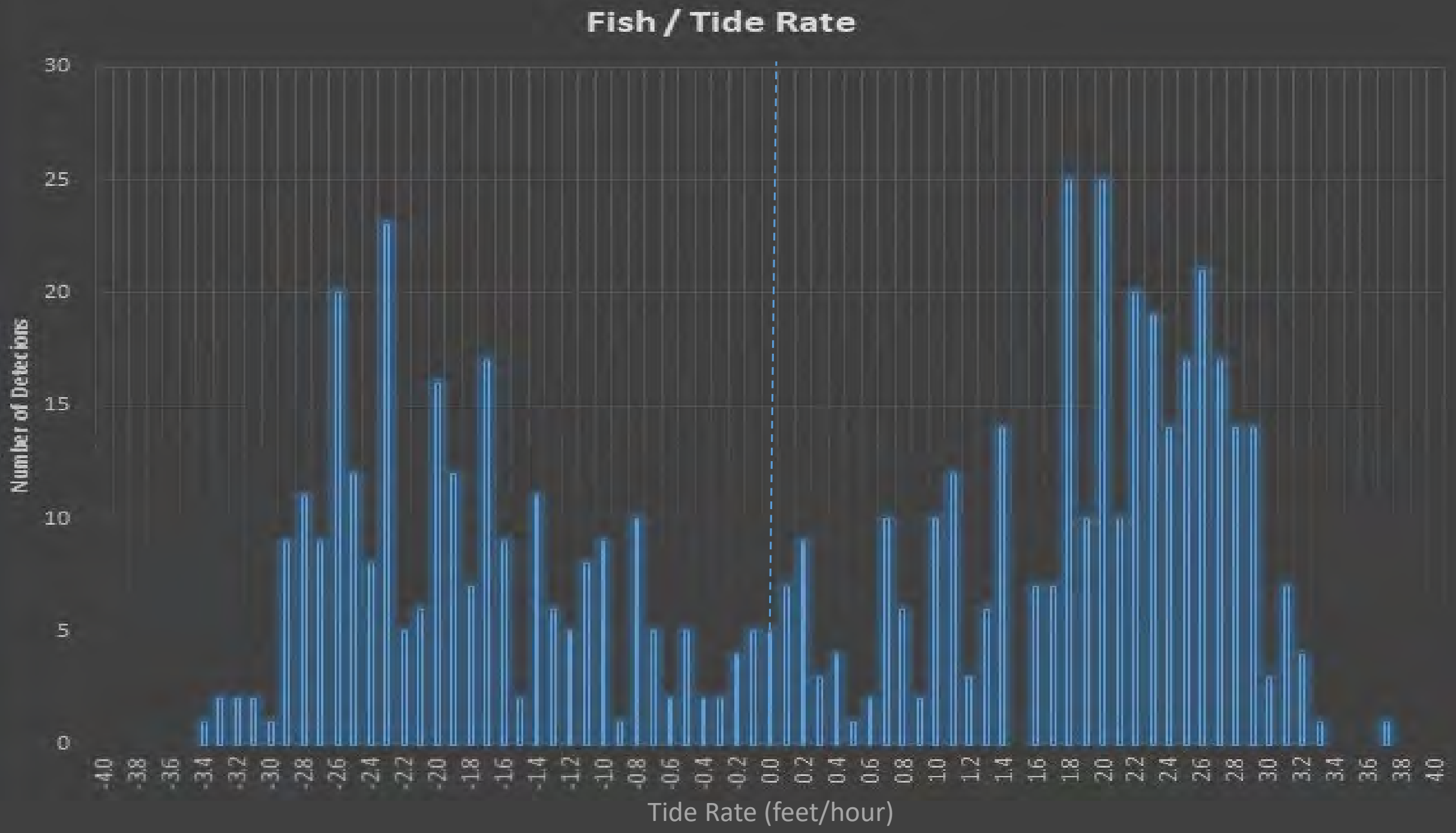





Fish Detections - Irradiance
Number of Detections
200
180
160
140
120
100
80
60
40
20
0
5
25
45
65
85
105
125
145
165
185
205
225
245
265
285
305
325
345
365
385
405
425
445
465
485
505
525
545
565
585
Irradiance Range (watt/m2)

Fish Detection / Tide
Tide Stage (Dupont)
14
12
10
8
6
4
2
0
-2
5/23/2018 0:00
5/25/2018 0:00
5/27/2018 0:00
5/29/2018 0:00
5/31/2018 0:00
6/2/2018 0:00
6/4/2018 0:00
6/6/2018 0:00
Creek mode

Fish / Tide Range
Detections
100
90
80
70
60
50
40
30
20
10
0
Creek mode
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
Tide Stage (Dupont)


Fish / Tide Rate
Number of Detections
30
25
20
15
10
5
0
-.40
-.38
-.36
-.34
-.32
-.30
-.28
-.26
-.24
-.22
-.20
-.18
-.16
-.14
-.12
-.10
-.08
-.06
-.04
-.02
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
Tide Rate (feet/hour)

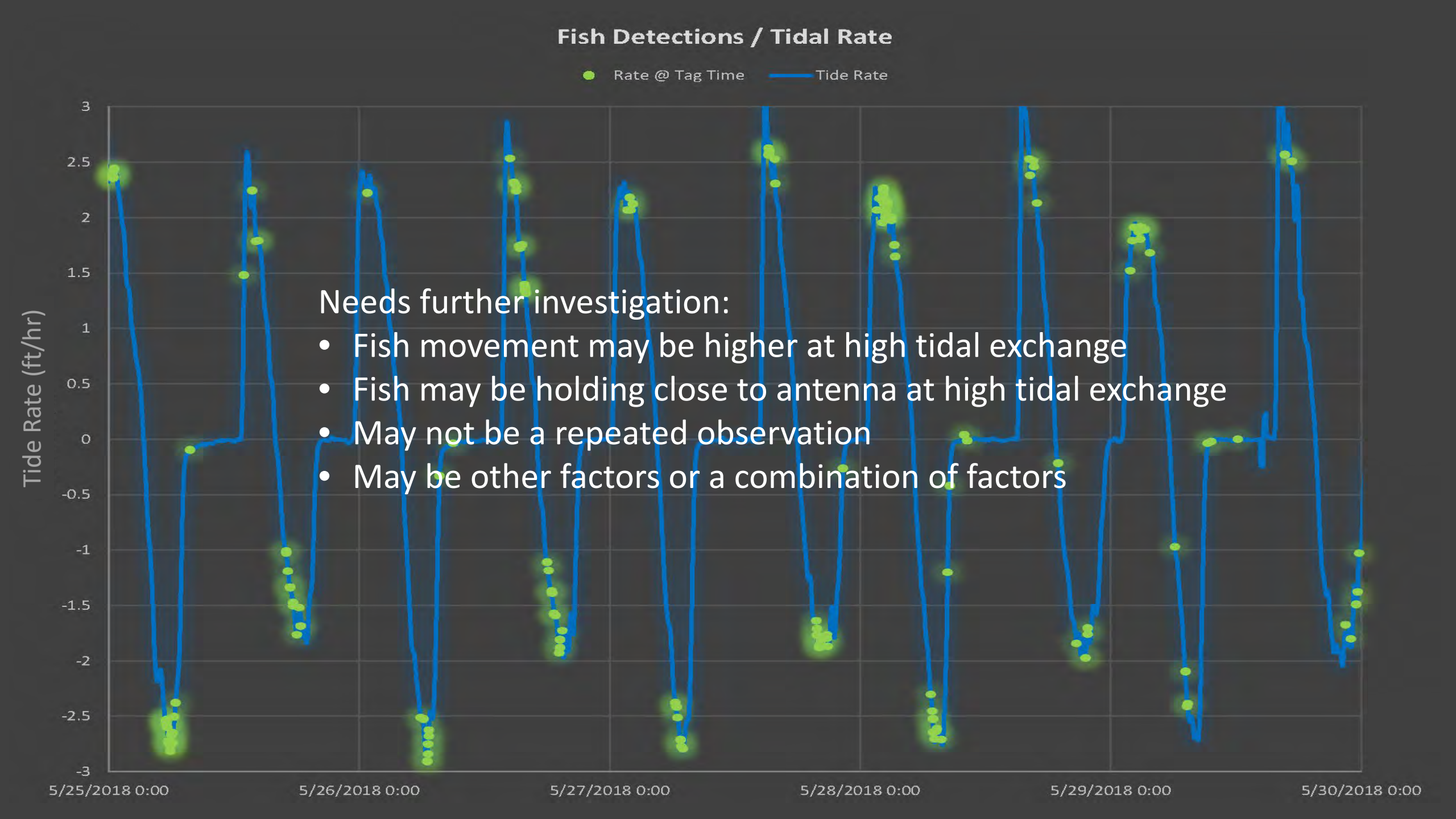

Fish Detections / Tidal Rate
Rate @ Tag Time
Tide Rate
Tide Rate (ft/hr)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
5/25/2018 0:00
5/26/2018 0:00
5/27/2018 0:00
5/28/2018 0:00
5/29/2018 0:00
5/30/2018 0:00
Needs further investigation:
• Fish movement may be higher at high tidal exchange
• Fish may be holding close to antenna at high tidal exchange
• May not be a repeated observation
• May be other factors or a combination of factors

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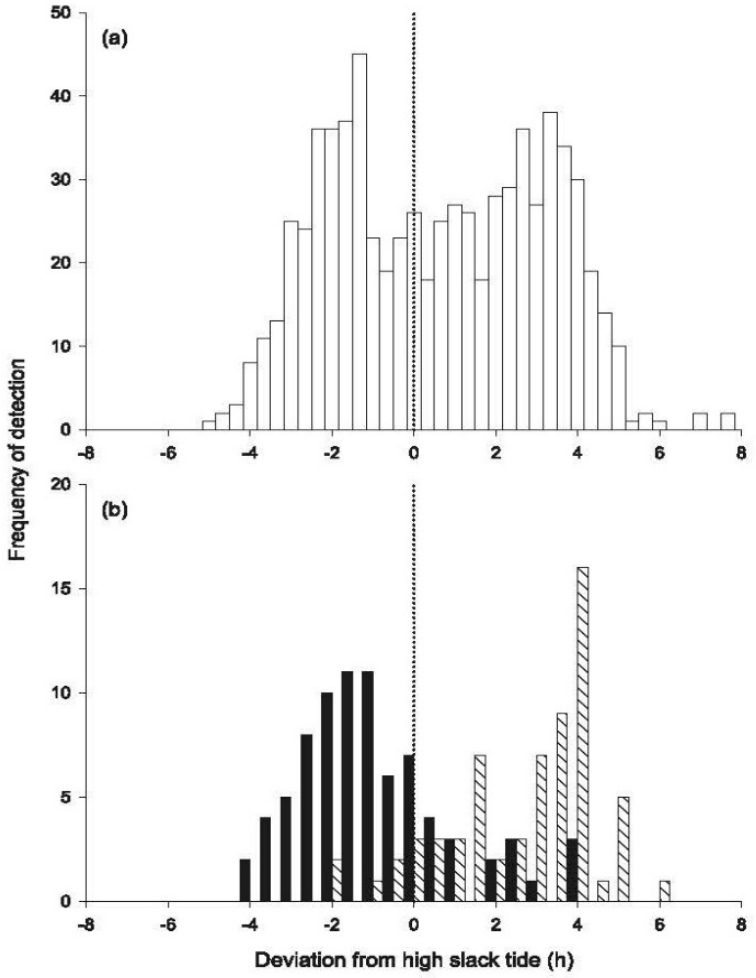
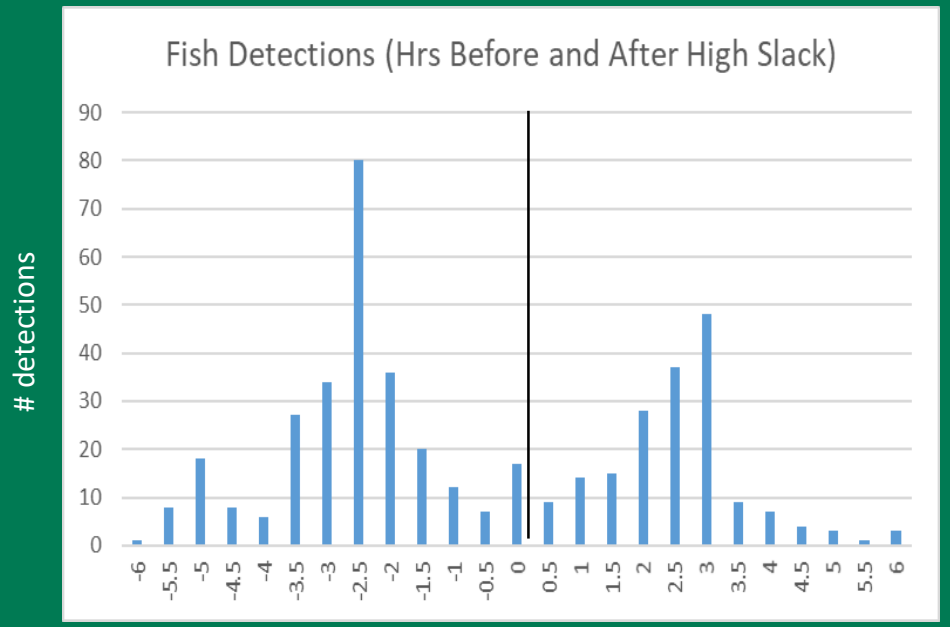
Fig. 5. (*a*) Frequency of all PIT tag detections at antenna 1, and (*b*) frequency of fish movements into (solid bars) and out of (hatched bars) the study channel in 2005, relative to the tidal cycle. Vertical dotted lines indicate timing of high slack tide.





Directional antenna deployment - planned for 2019

Key Points

- Tidal fish passage emerging topic of interest
- Access to intertidal rearing habitat is as important as adult fish migration
- Fine-scale fish movement is a data gap to inform assessment & design tech guidance development
- Pilot work in 2018

Upcoming work in 2019

- Fish studies
  - PIT tags – directional deployment!
  - Underwater cameras
- Case studies & physical factors

Thank you to our collaborators!

Nisqually Indian Tribe: Chris Ellings, Sayre Hodgson
Skokomish Tribe: Joseph Pavel, Lisa Belleveau, Anthony Battista, Alex Gouley
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