Juvenile salmon smolt migrations through the Salish Sea: routes and survival of sockeye and steelhead

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Acknowledgements

- Seymour Salmonid Society
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- Pacific Shelf Ocean Tracking Project
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- Marika Gale, Ken Jeffries, Matt Casselman, Andrew Lotto, Steve Cooke, Anthony Farrell

OCEAN TRACKING NETWORK

SALISH SEA MARINE SURVIVAL PROJECT

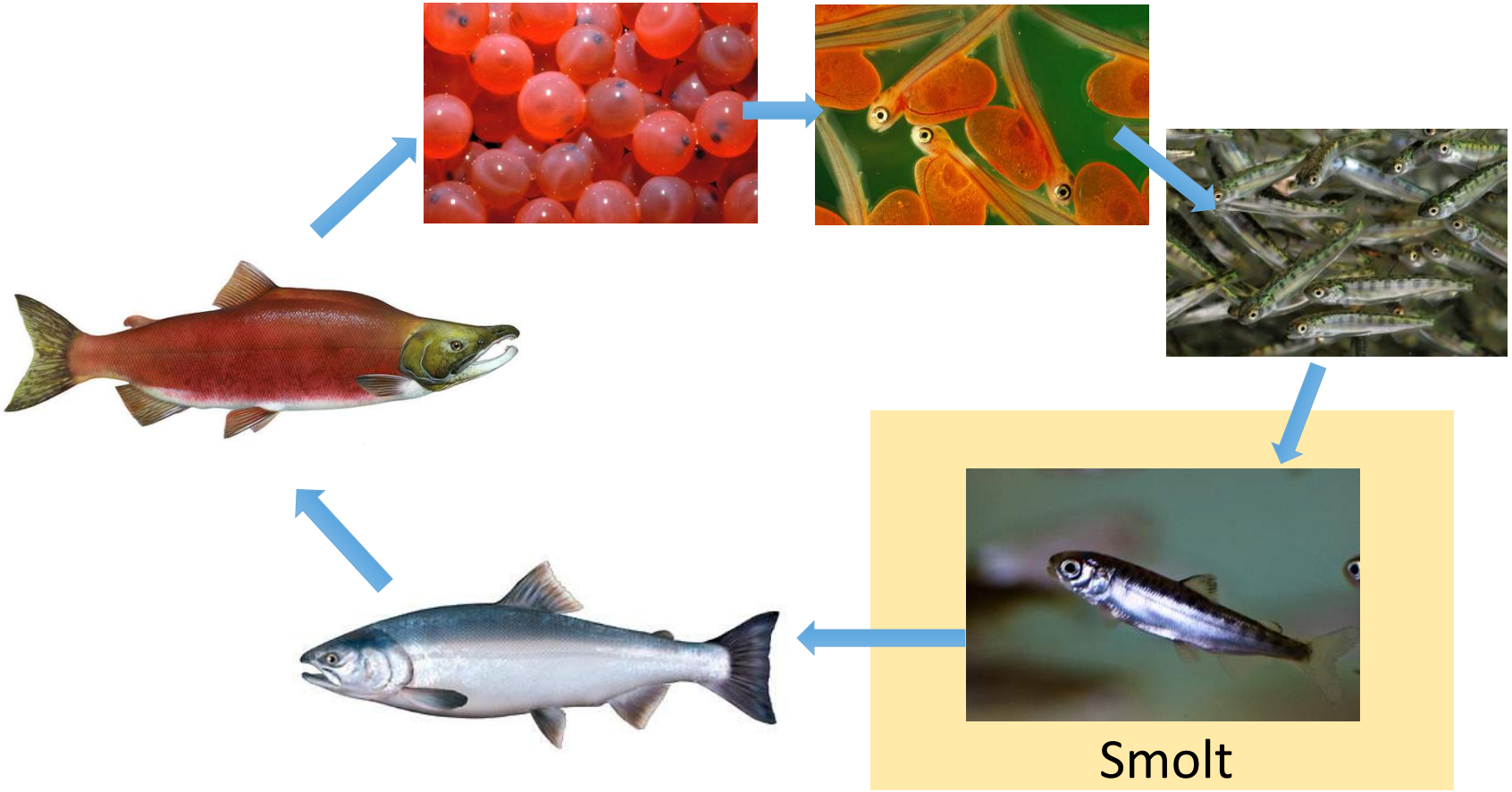
PACIFIC SALMON FOUNDATION

Fisheries and Oceans Canada

NSERC CRSNG

Mitacs Accelerate

Salmon life stages



Early marine behaviour and survival

- Little direct information on this life stage
- Thought to be important for productivity and poor returns of adults

Several large unknowns…..

- What are the specific migration routes?
- What is the role of currents or routes on survival?
- How do species differ?
- Are there mortality 'hotspots'?
- What is the role of pathogens and fish condition?

Review results of two studies

1) Multi-year acoustic tagging study:

Routes of sockeye and steelhead smolts at one locale in the Strait of Georgia (Salish Sea) and the ramifications to survival

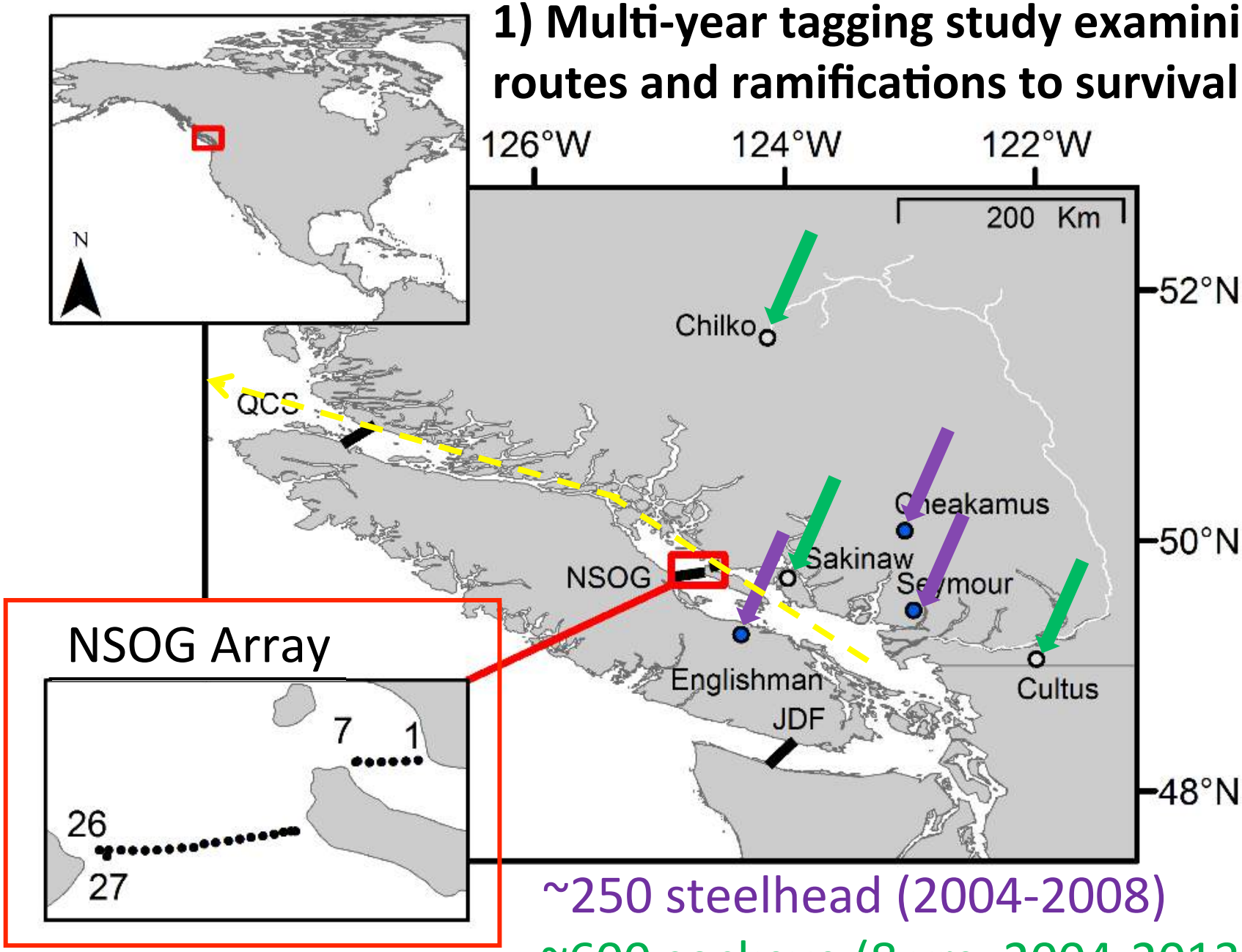
Nathan Furey

2) Single year acoustic tagging study:

Locale-specific survival of one population of steelhead smolts throughout the Salish Sea

Steve Healy

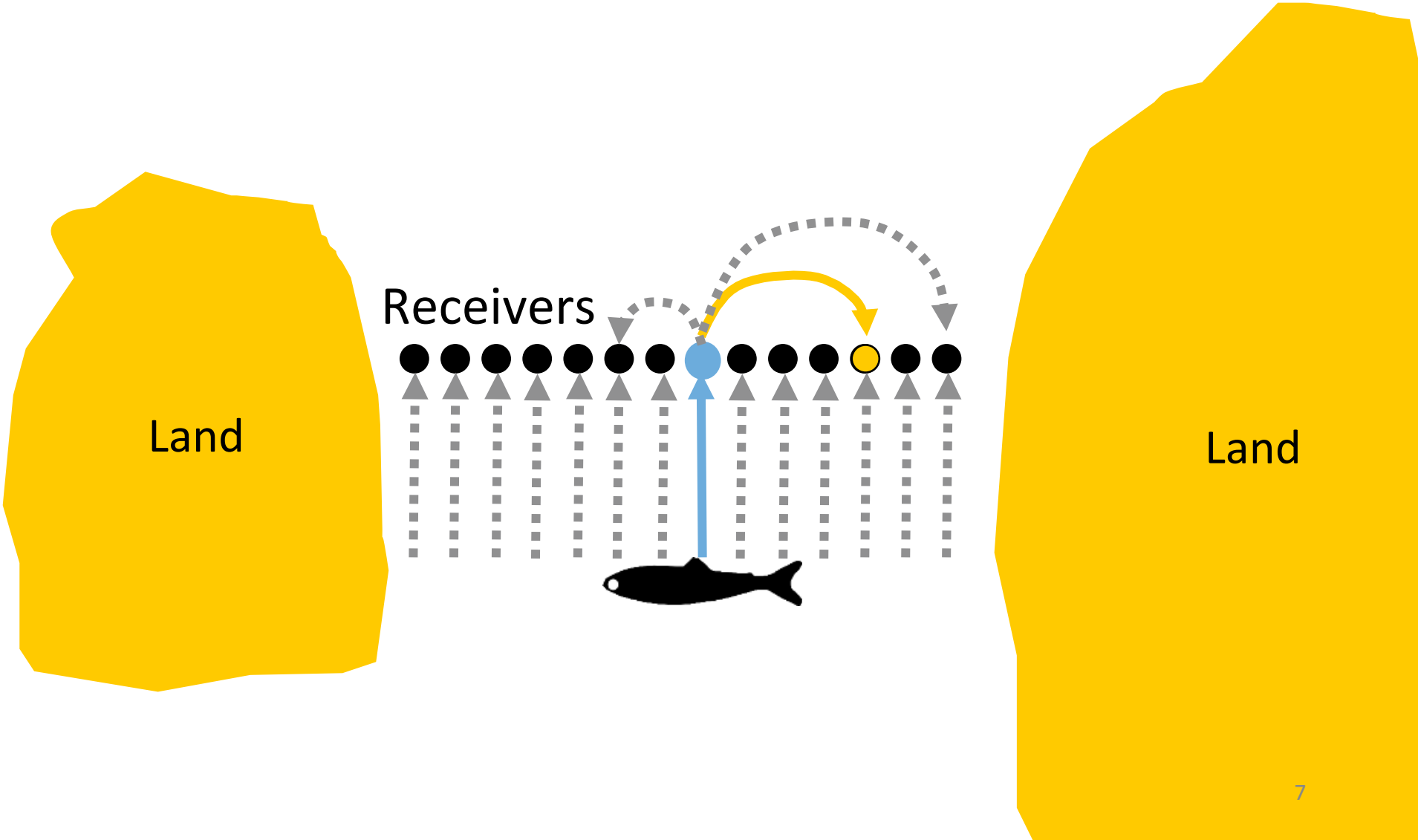
1) Multi-year tagging study examining routes and ramifications to survival



~250 steelhead (2004-2008)

~600 sockeye (8 yrs; 2004-2013)

Detections grouped into "sequences" to represent distinct presences at the array



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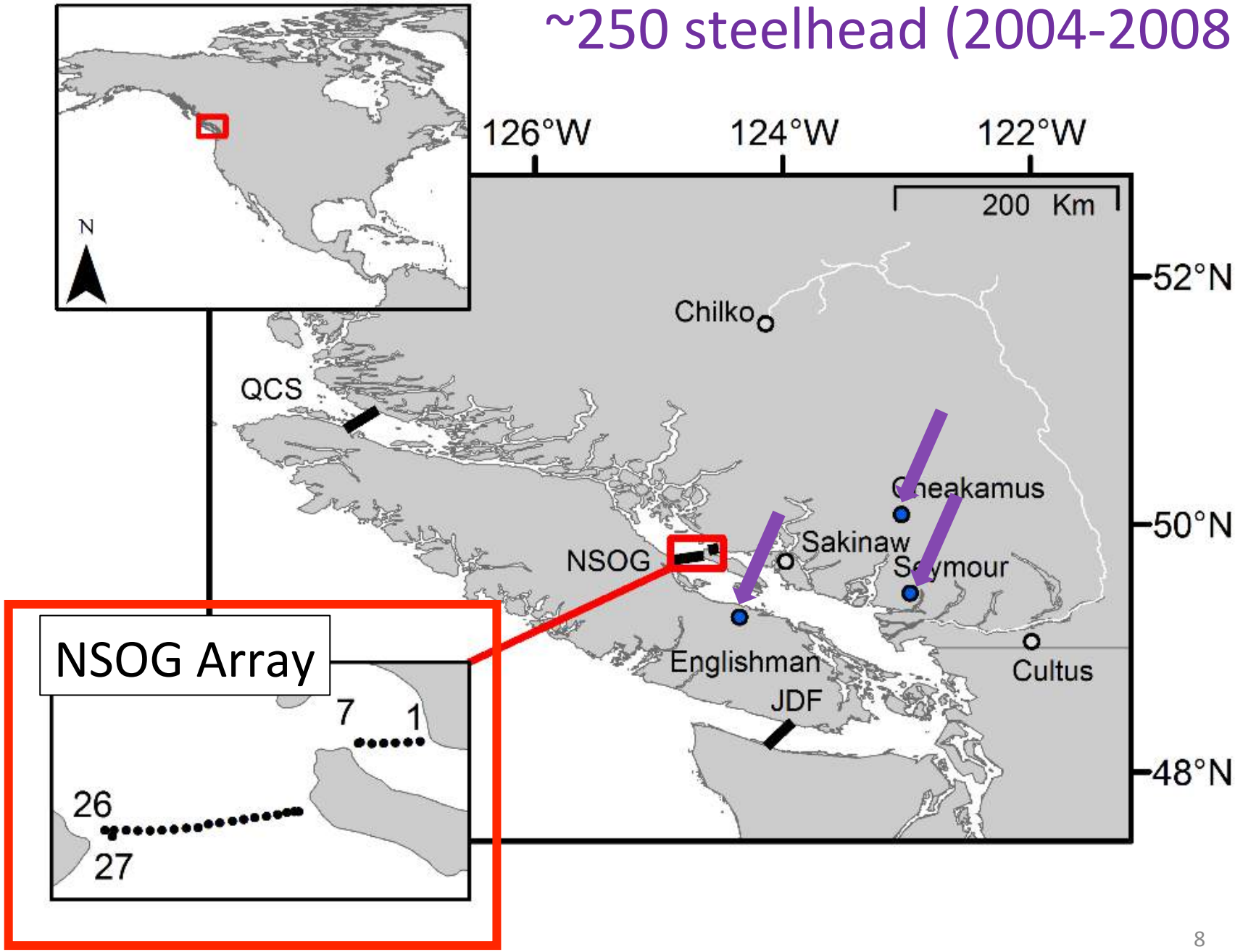
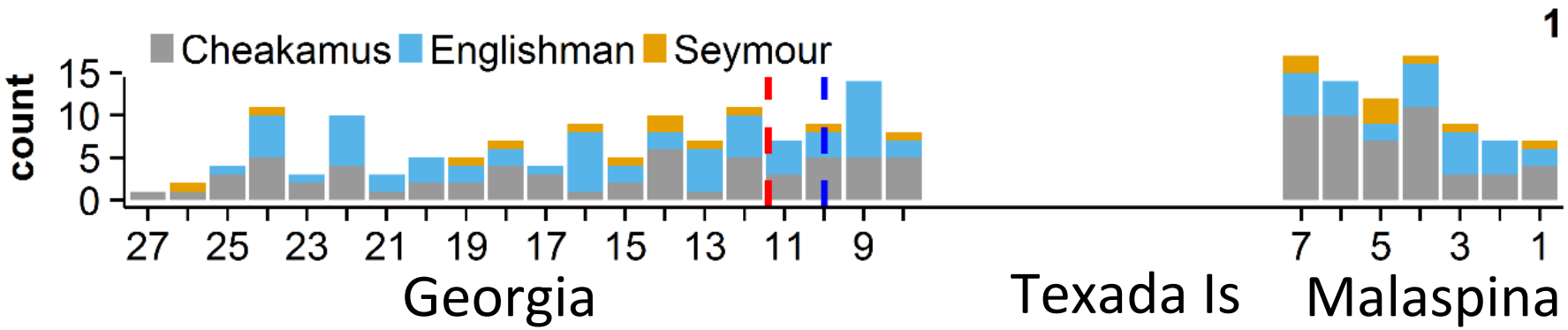
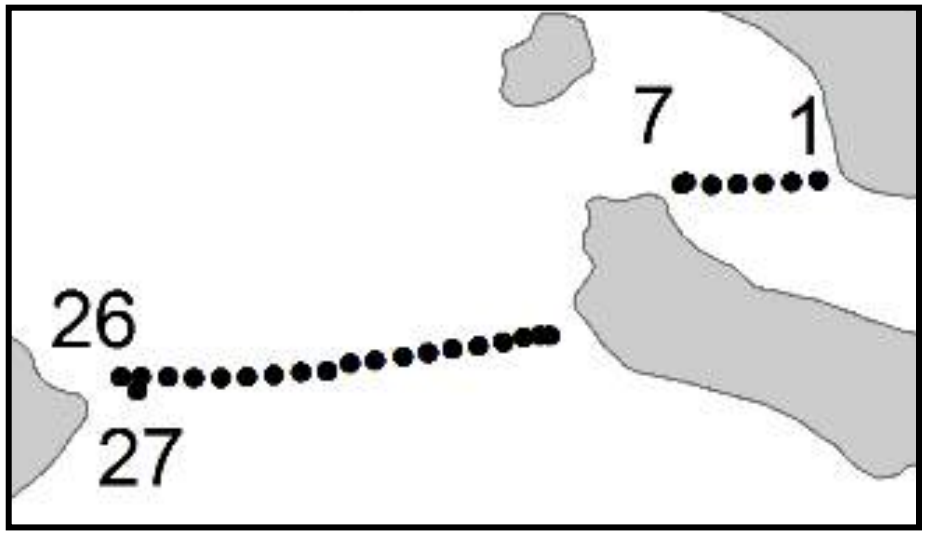


Lateral Distributions of Steelhead

Detection Sequence #



- 45-65% of steelhead move directly through the array



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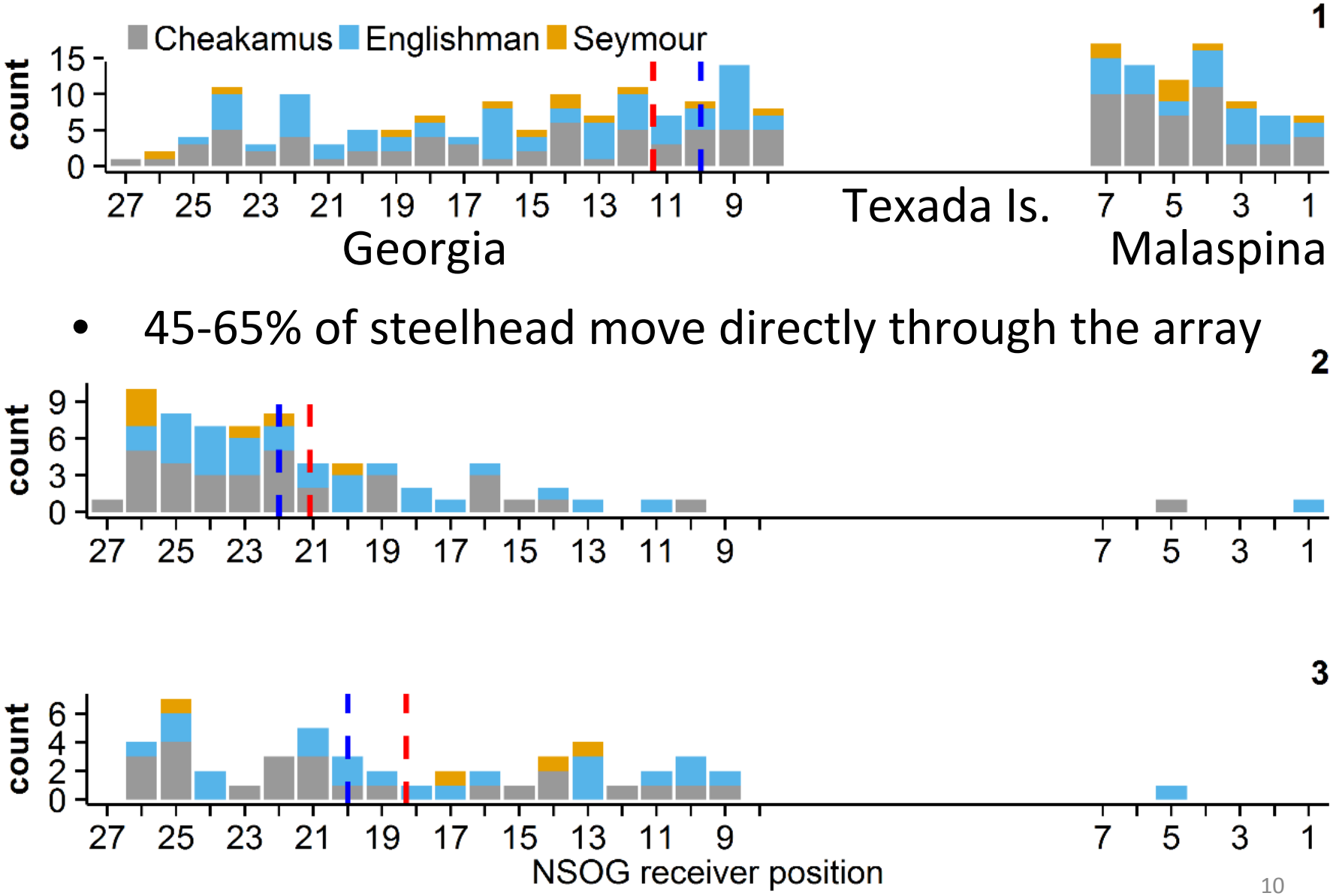

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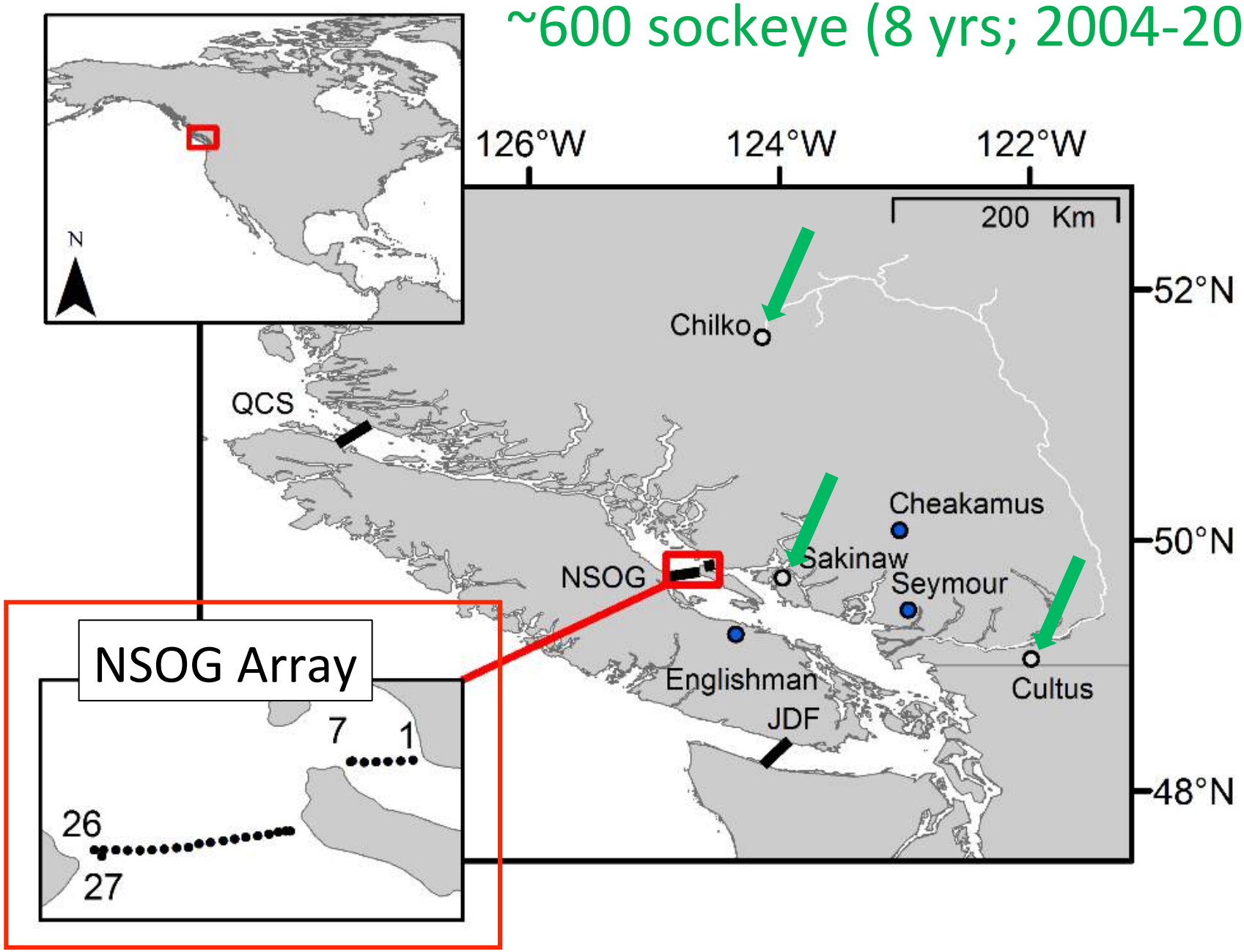
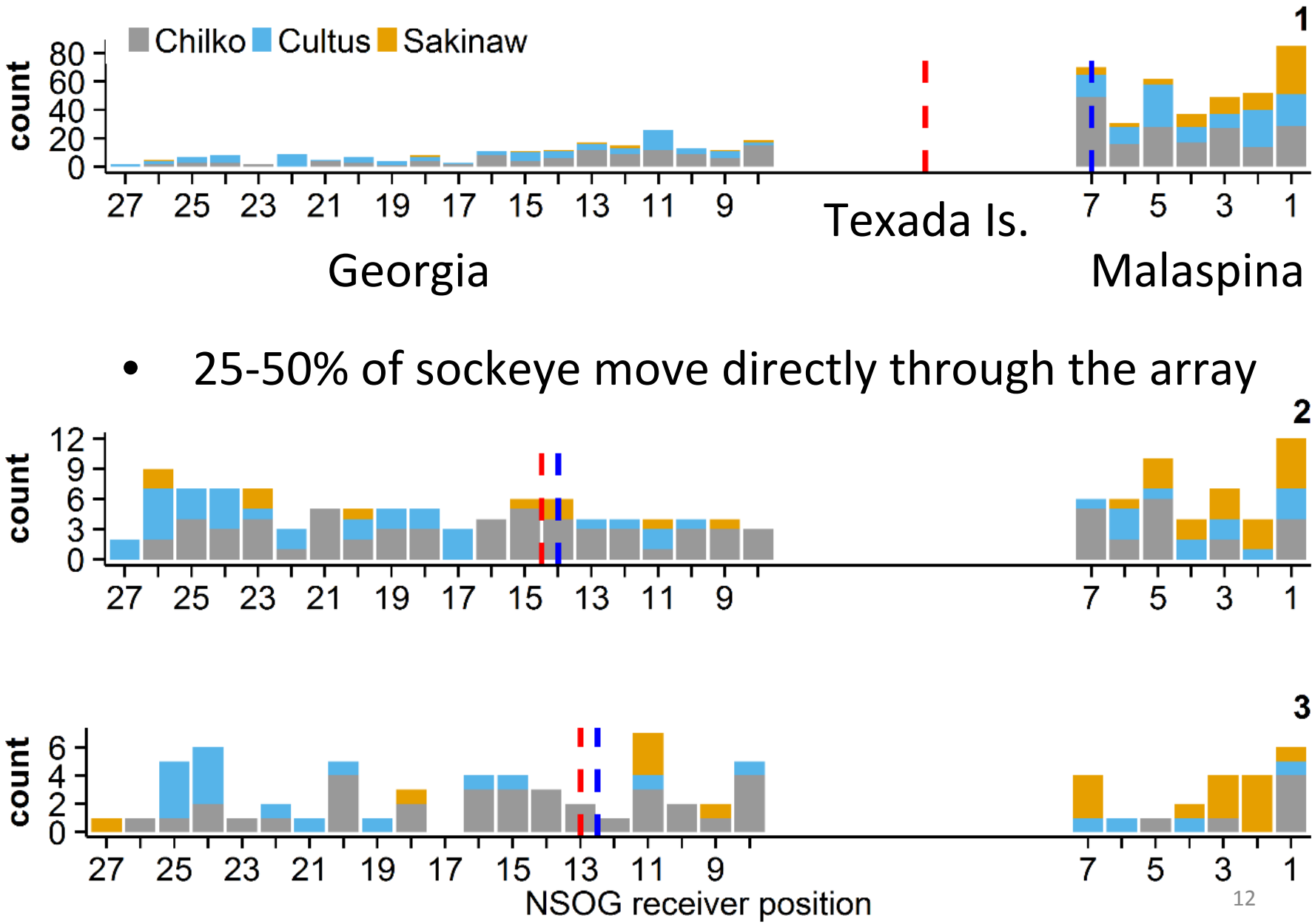


Lateral Distributions of Sockeye

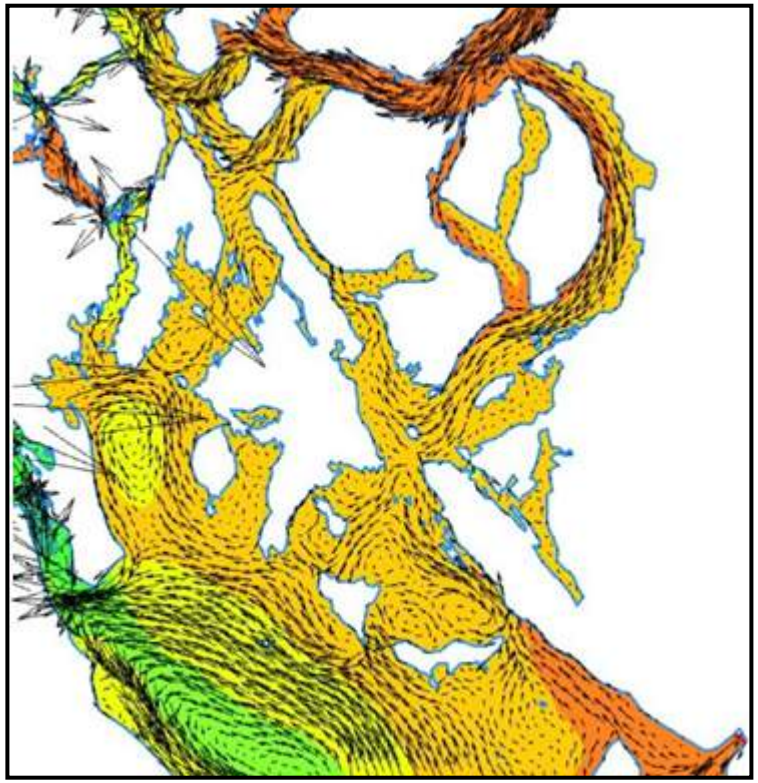
Detection Sequence #



- 25-50% of sockeye move directly through the array

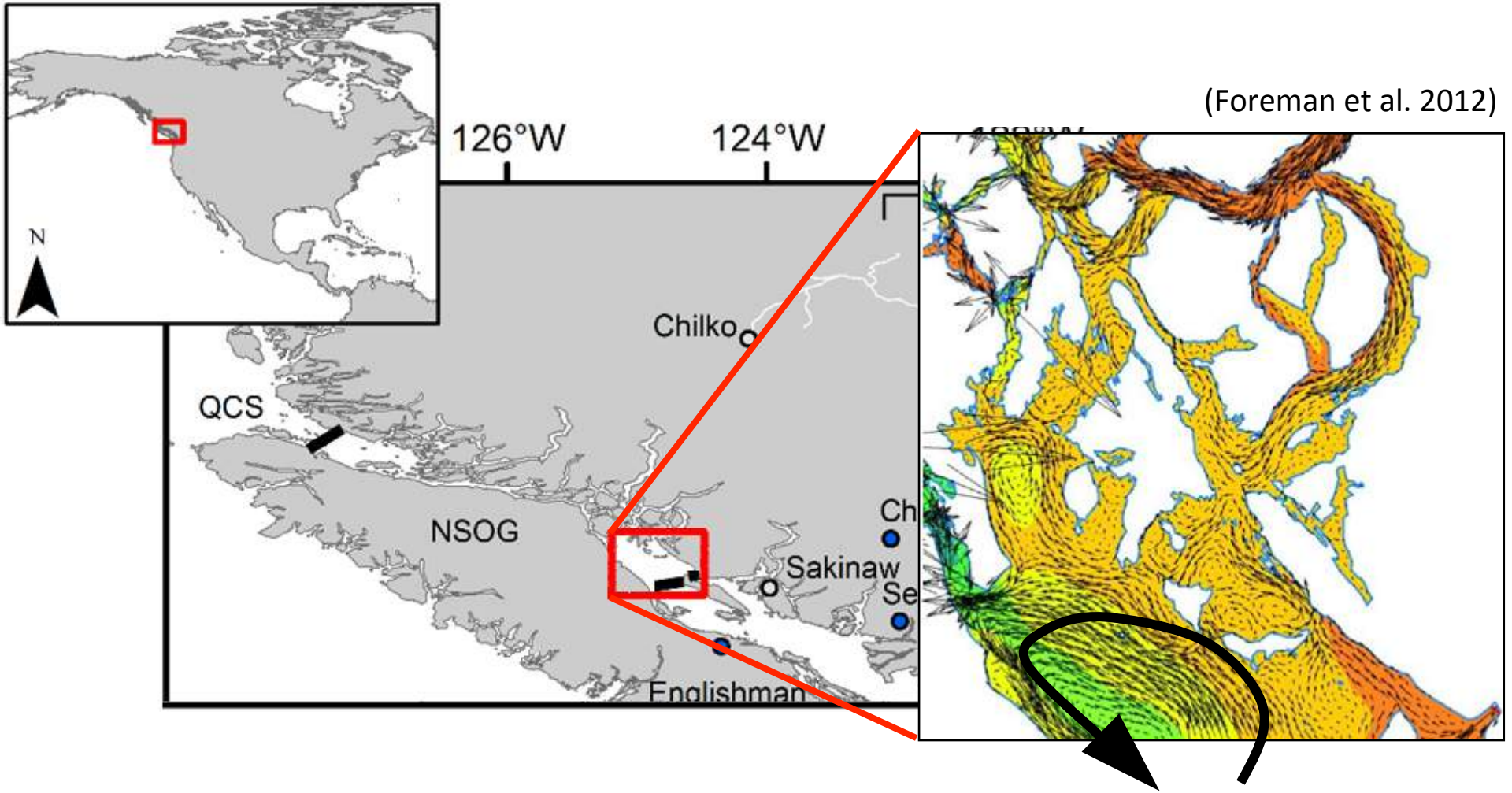
Smolts possibly influenced by counterclockwise circulation patterns

(Foreman et al. 2012)

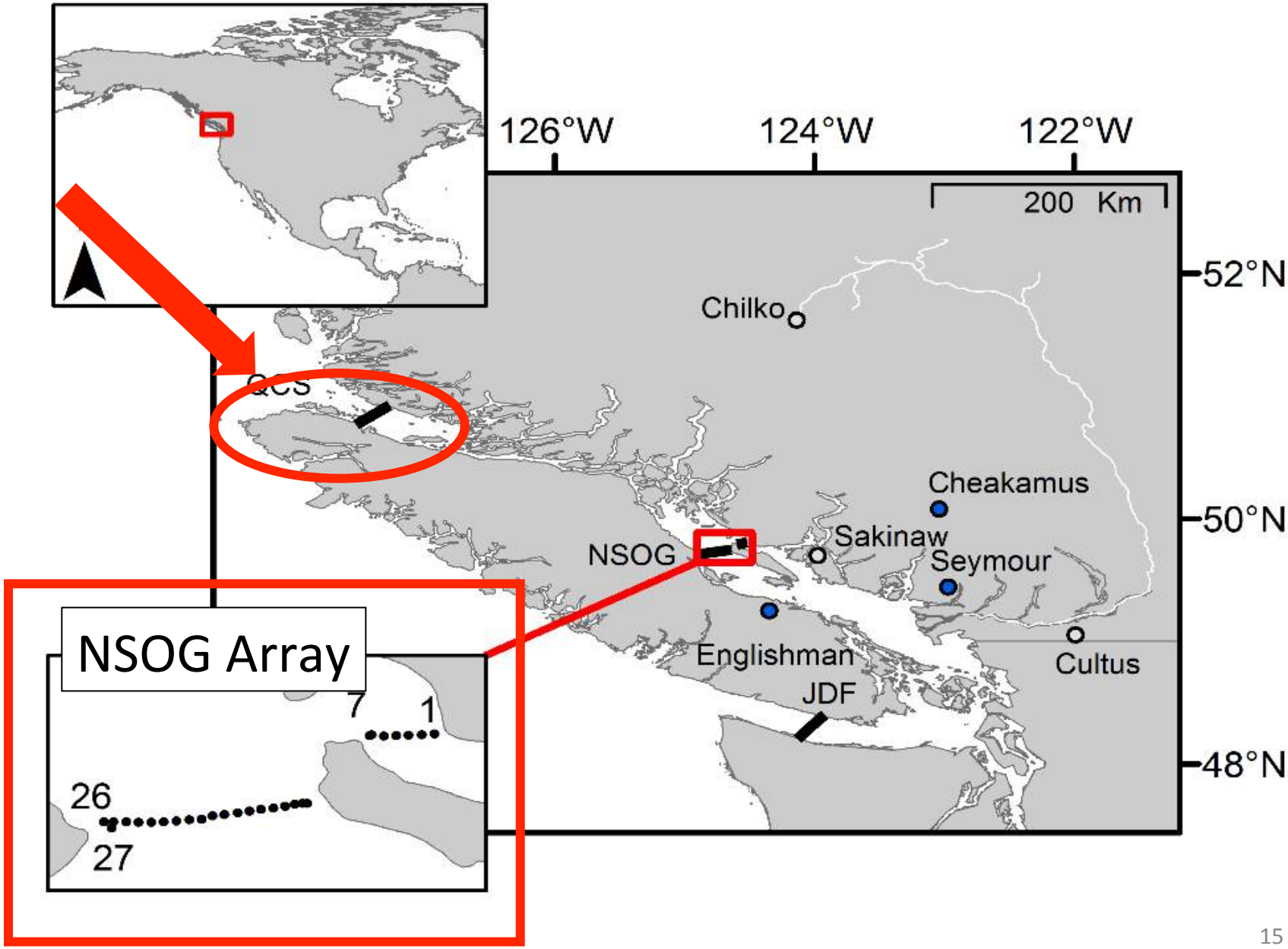


- Steelhead smolts show much more counterclockwise behavior
- More surface oriented than sockeye
- Due to wind-driven currents?

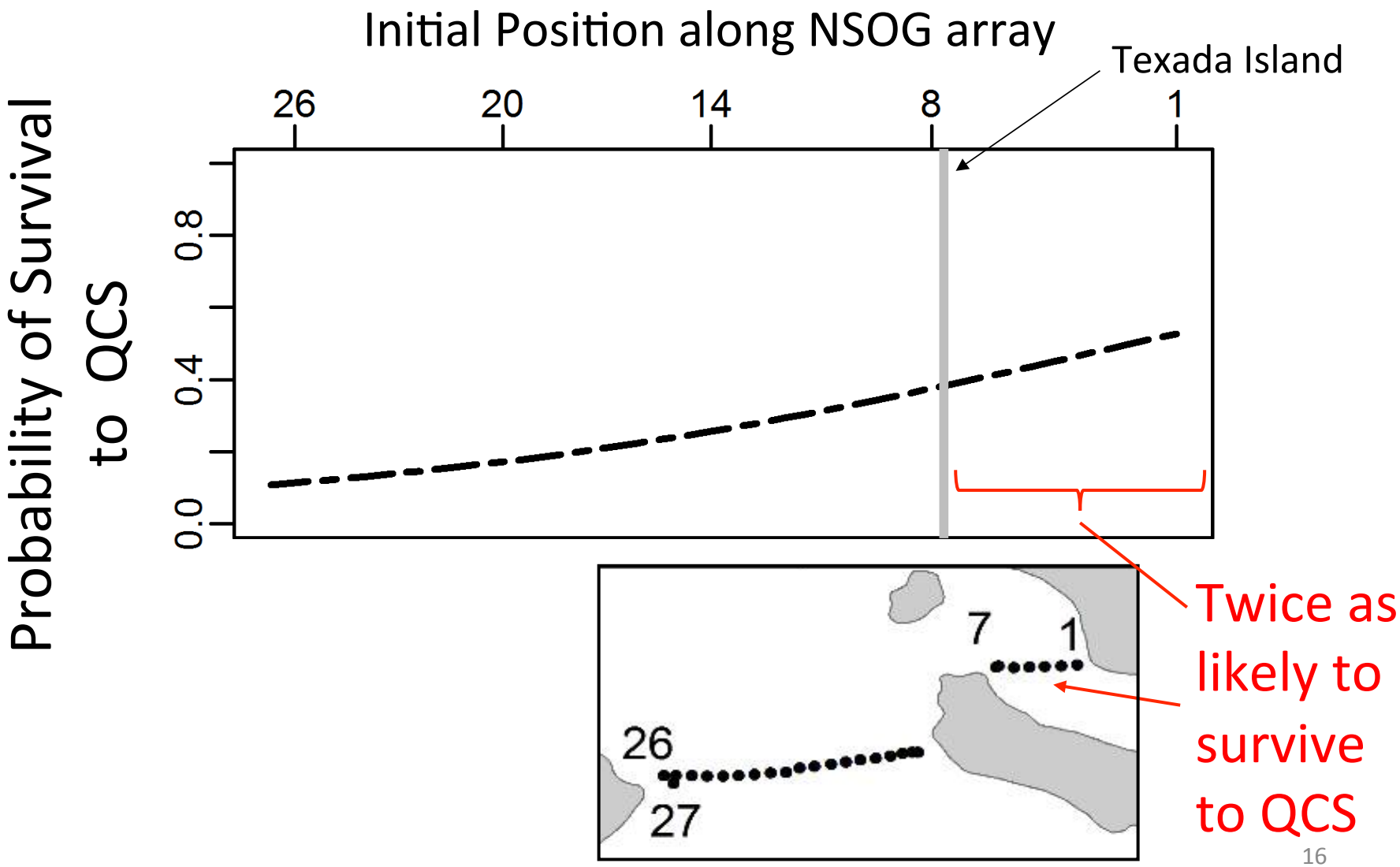
Smolts possibly influenced by counterclockwise circulation patterns



What is the role of route on subsequent survival?



Migration route important for steelhead



Migration route less important for sockeye

- Sockeye survival to QCS more affected by timing
  - Chilko sockeye that arrived later to NSOG survived better to QCS
- The longer time spent milling near NSOG the poorer the survival
- Steelhead did not show these patterns

2) Single year tagging study examining locale specific survival in steelhead smolts through the Salish Sea

Acoustic Tagging (May, 2015)

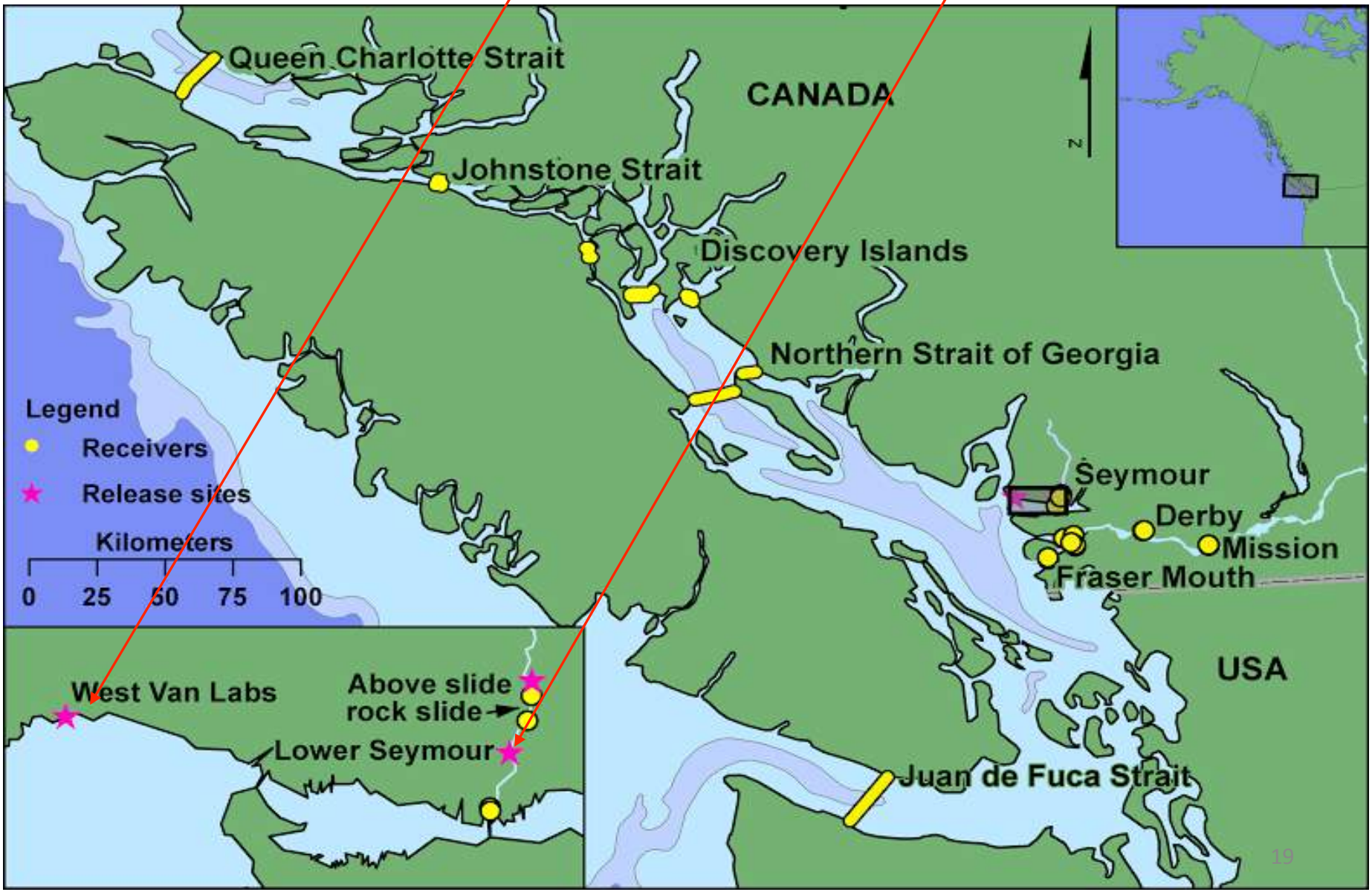
- Seymour River Hatchery
- Steelhead smolts (n=274)
- Gill biopsies taken for genomic analysis (n=164)


Photo: Etovre Vese

Releases

West Vancouver (n=160)

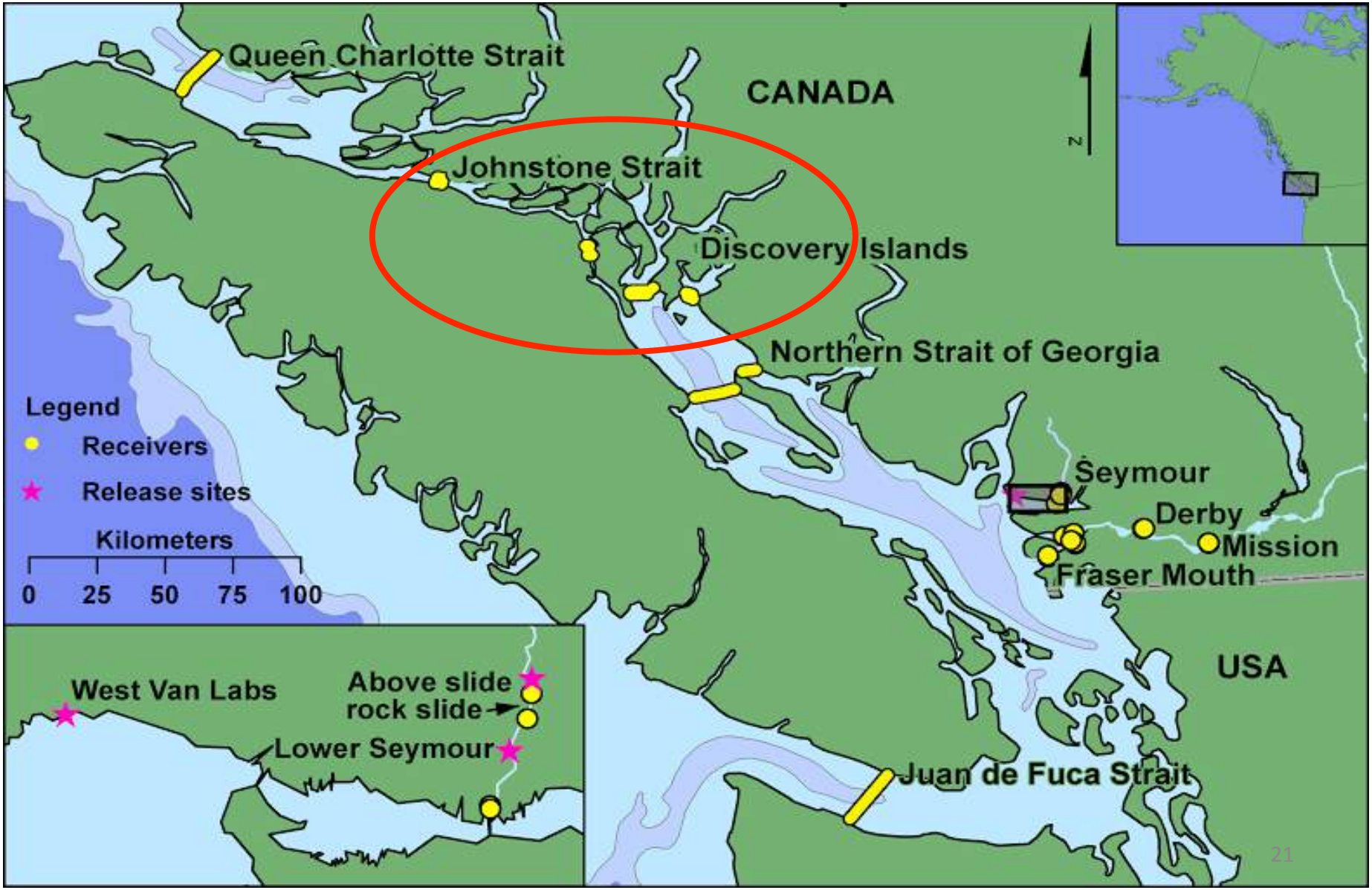
Seymour River (n=83)

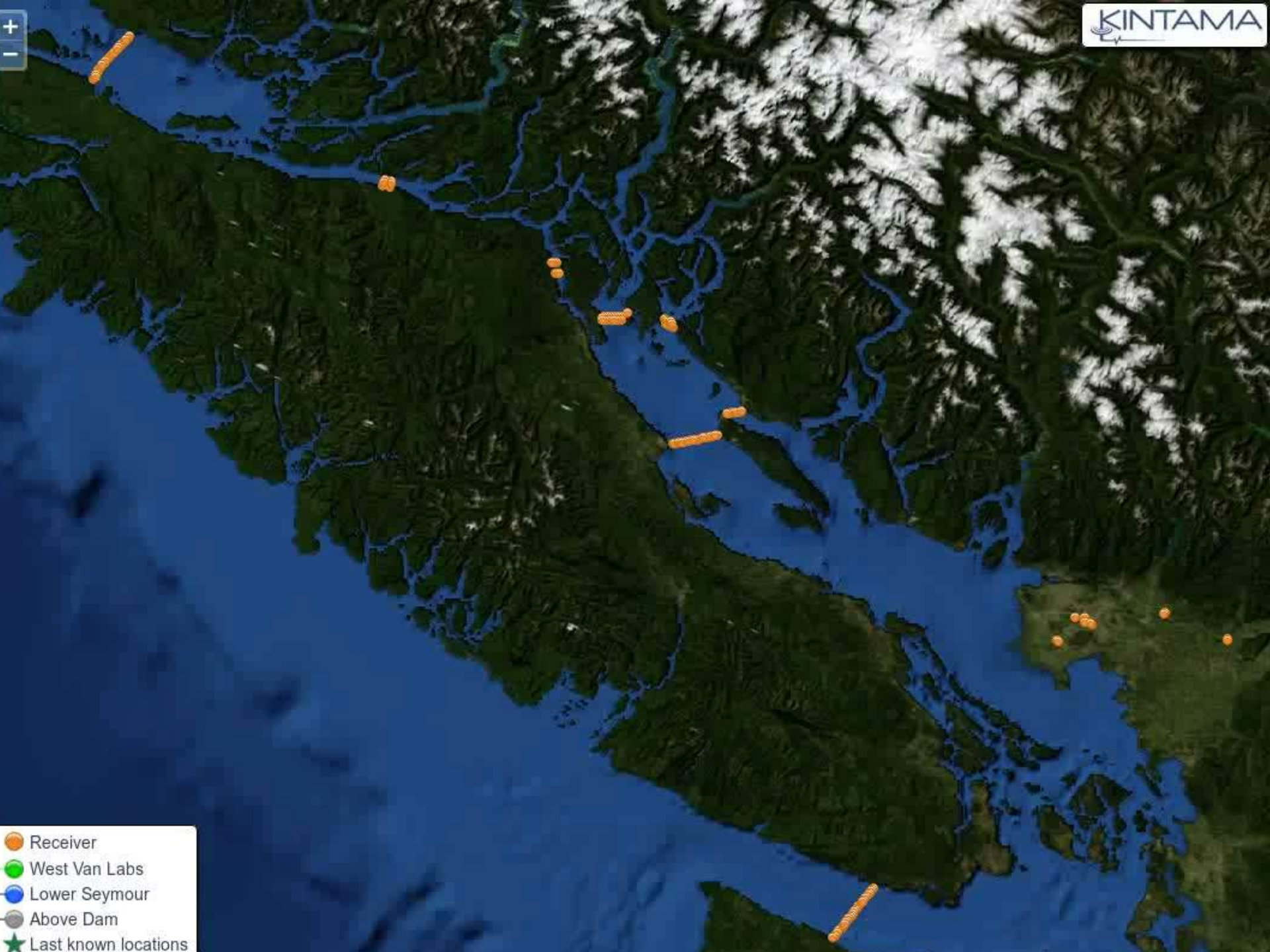


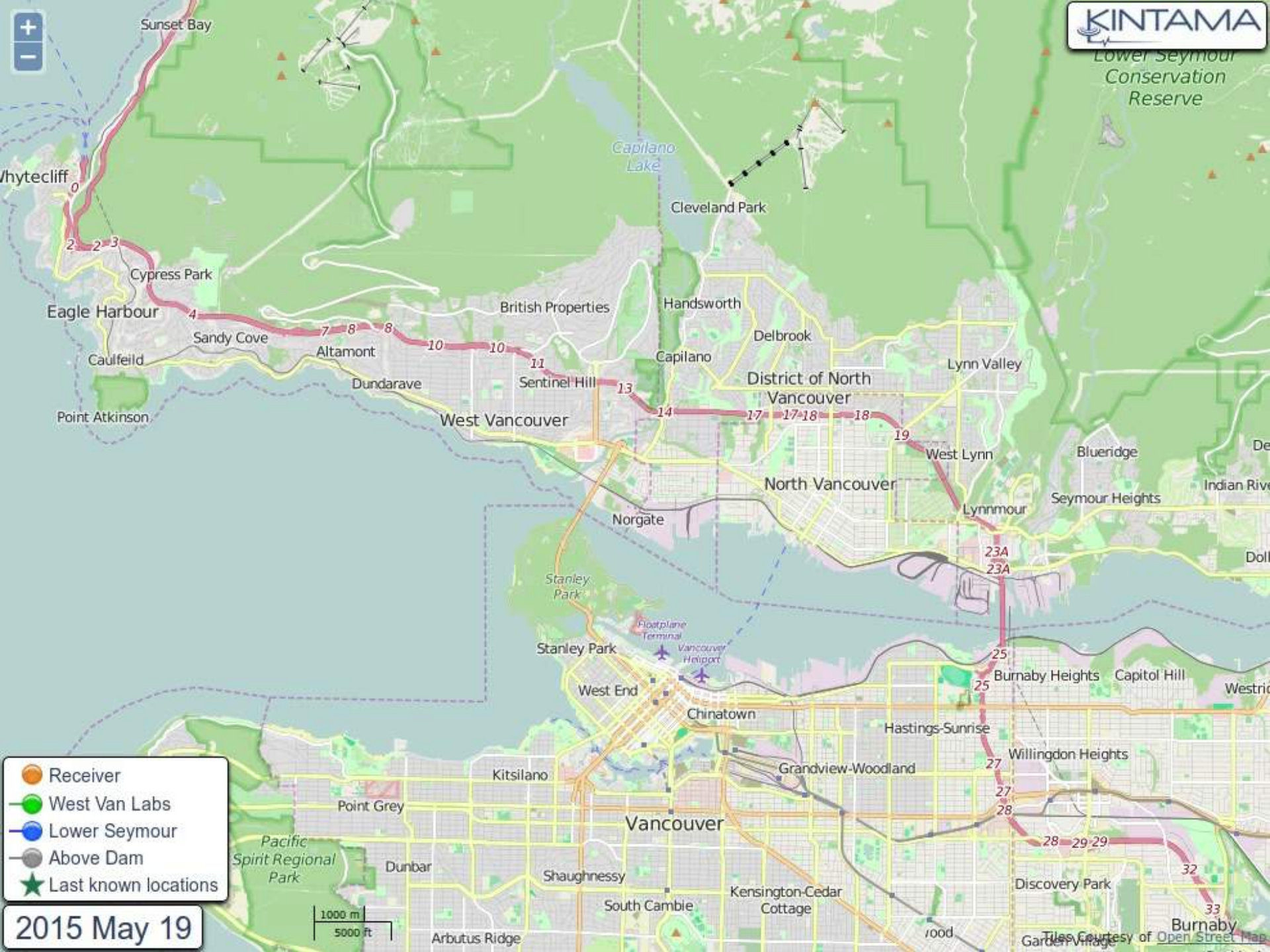
Releases

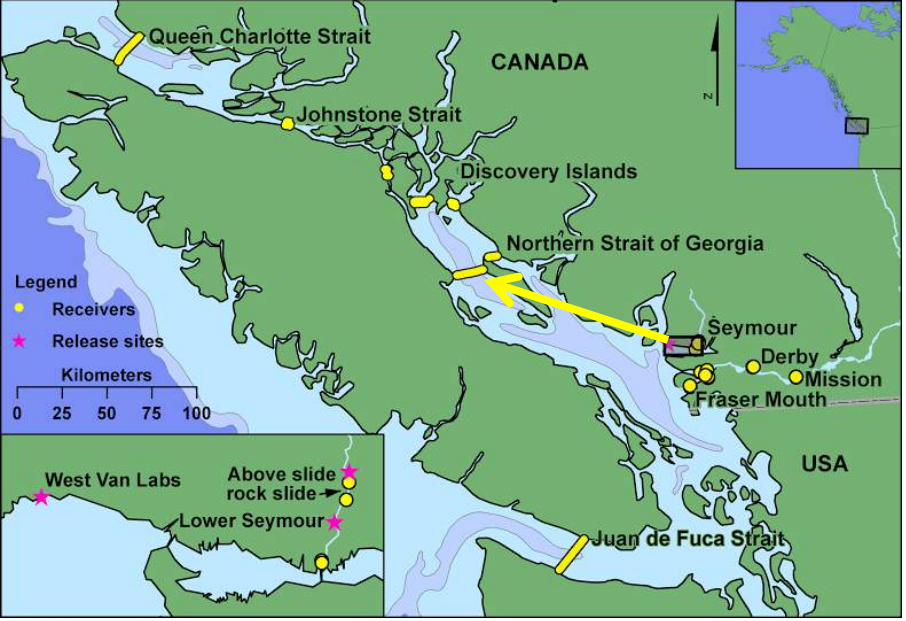

Legend
Receivers
Release site
Kilometers
0
25
50
West Van Labs
Above slide
rock slide
Lower Seymour
USA
Juan de Fuca Strait

Releases

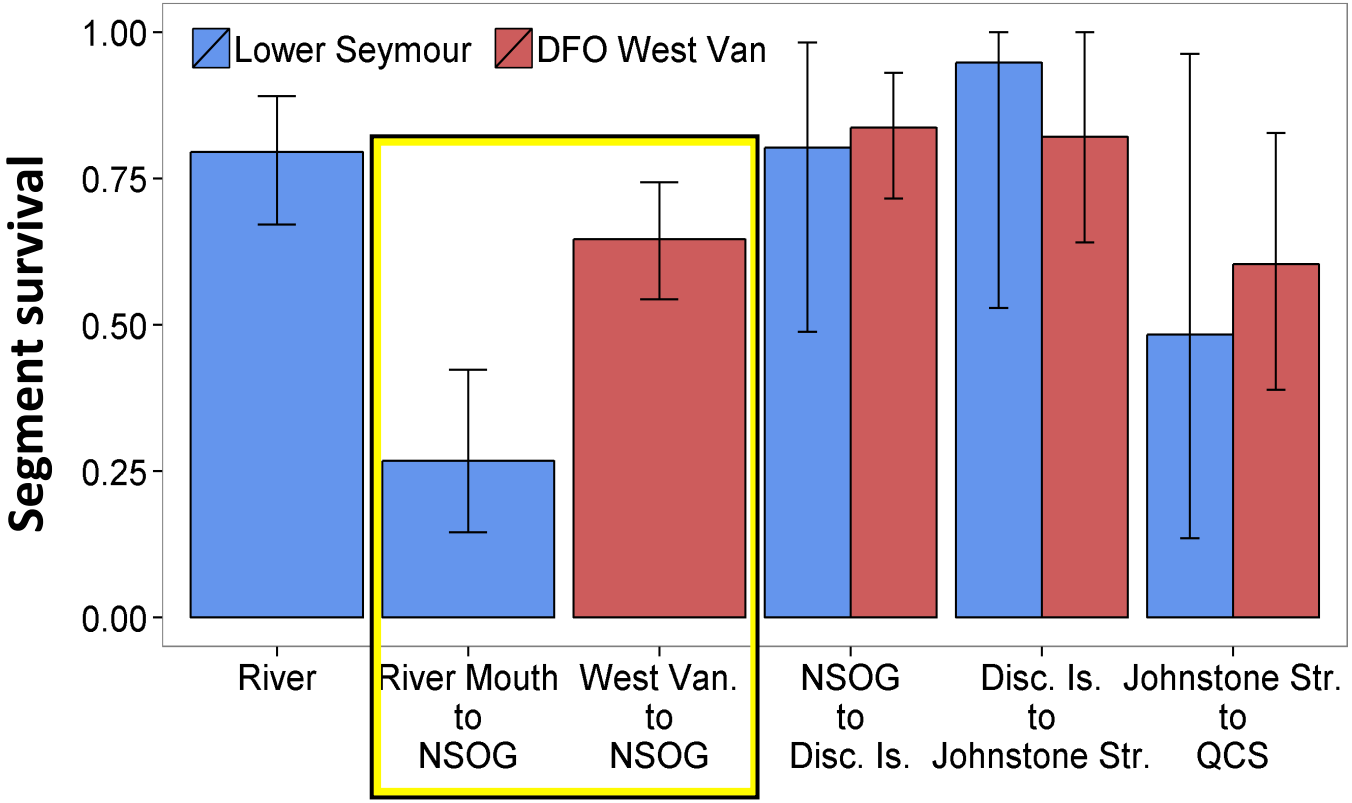

Queen Charlotte Strait
CANADA
N
Johnstone Strait
Discovery Islands
Northern Strait of Georgia
Legend
Receivers
Release sites
Kilometers
0 25 50 75 100
Seymour
Derby
Mission
Fraser Mouth
USA
West Van Labs
Above slide
rock slide
Lower Seymour
Juan de Fuca Strait

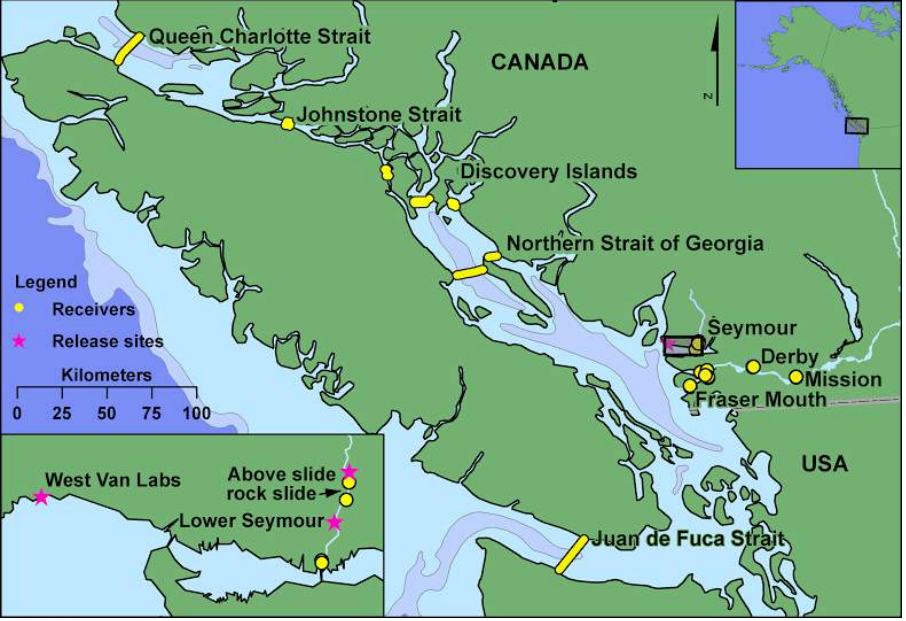

KINTAMA
Receiver
West Van Labs
Lower Seymour
Above Dam
Last known locations


KINTAMA
Sunset Bay
Whytecliff
Lower Seymour Conservation Reserve
Capilano Lake
Cleveland Park
Cypress Park
Eagle Harbour
Sandy Cove
Caulfeild
Point Atkinson
Altamont
Dundarave
British Properties
Handsworth
Delbrook
Capilano
Sentinel Hill
District of North Vancouver
Lynn Valley
West Vancouver
West Lynn
Blueridge
North Vancouver
Seymour Heights
Lynnmour
Norgate
Stanley Park
Floatplane Terminal
Vancouver Heliport
Burnaby Heights
Capitol Hill
West End
Chinatown
Hastings-Sunrise
Willingdon Heights
Grandview-Woodland
Kitsilano
Point Grey
Vancouver
Pacific Spirit Regional Park
Dunbar
Shaughnessy
Kensington-Cedar Cottage
South Cambie
Discovery Park
Arbutus Ridge
Burnaby
Tiles Courtesy of Open Street Map
Receiver
West Van Labs
Lower Seymour
Above Dam
Last known locations
2015 May 19
1000 m
5000 ft

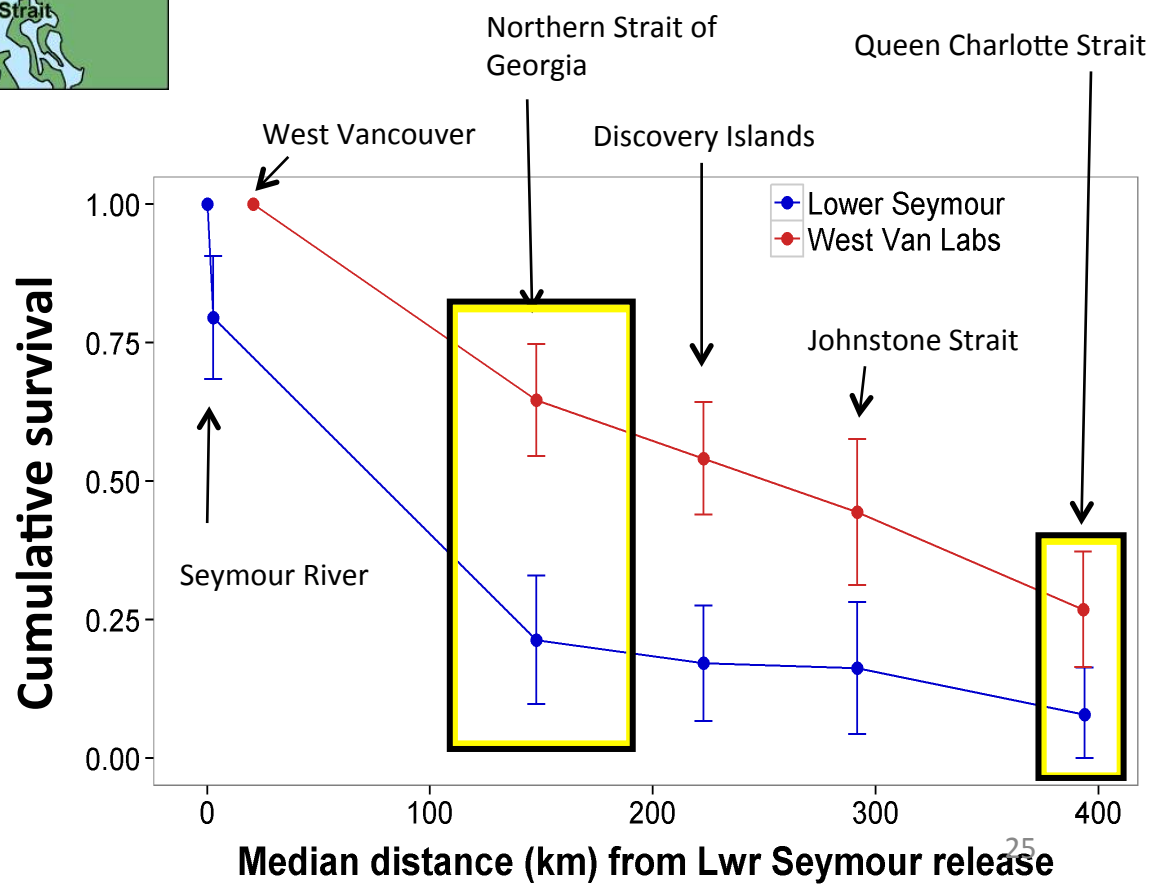


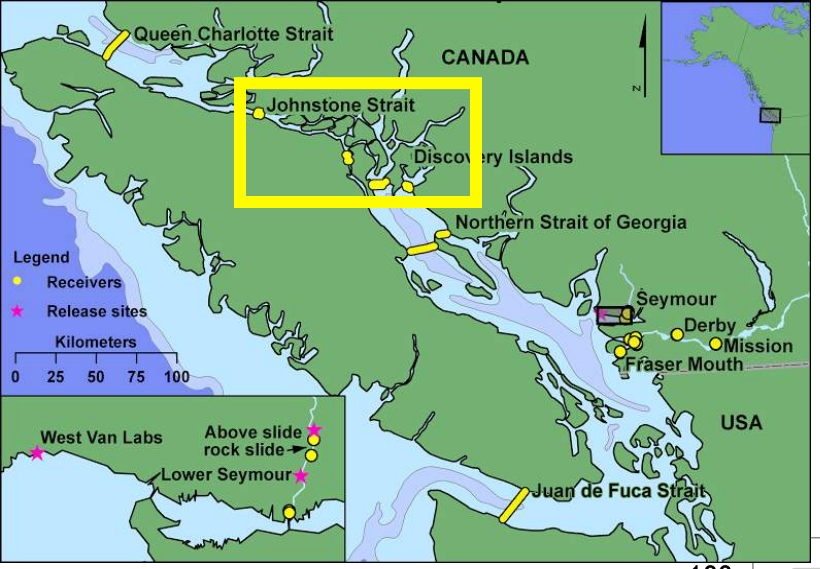
- **High mortality in Burrard Inlet**



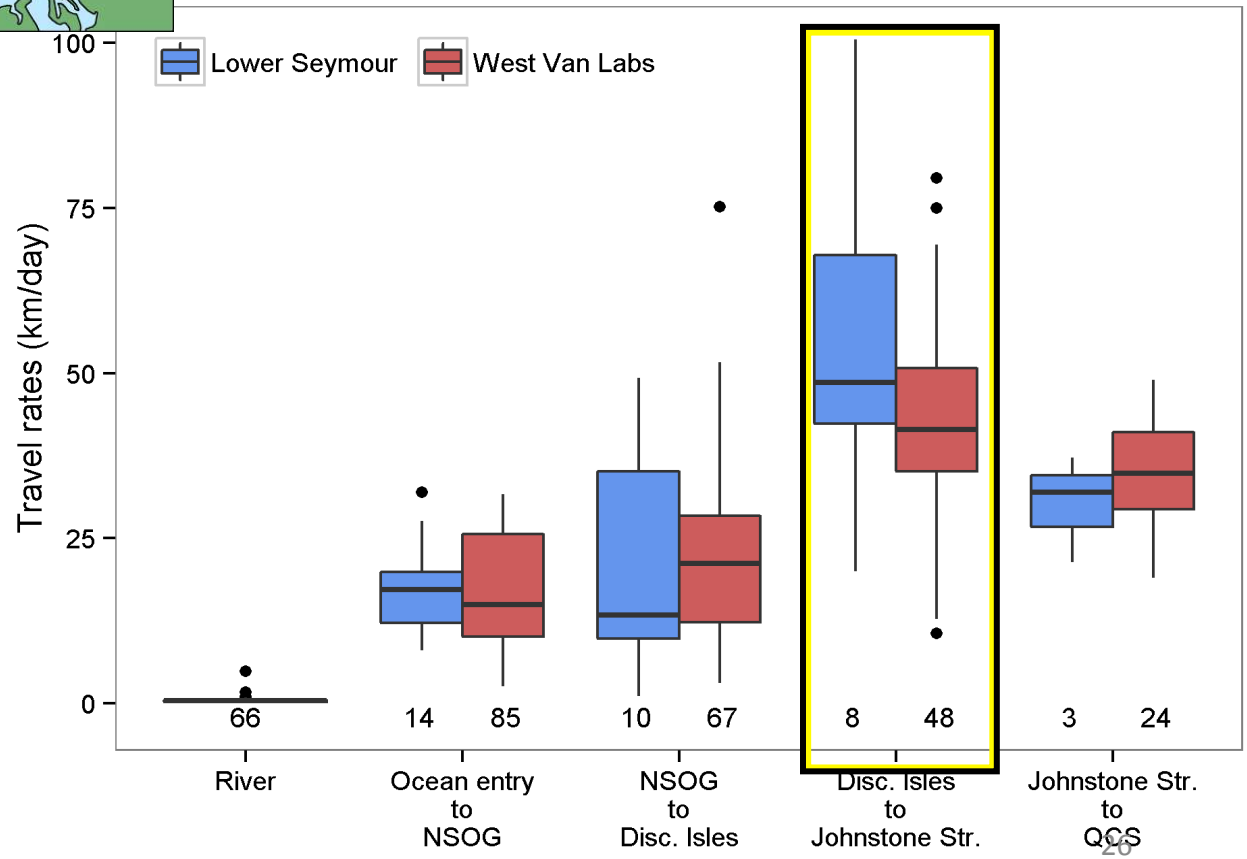


- **Cumulative survival between release groups becomes more similar by final receiver array**





- **Travel rates twice as fast through Discovery Islands**
- **Possible influence of currents and tides**



SUMMARY

- **Migration route differs between species**
  - Northern Strait of Georgia: sockeye migrate more to the eastern side than steelhead
  - About half of smolts travel in counterclockwise loop here (particularly steelhead)
- **Migration route effects survival**
  - Steelhead that travelled on eastern side of NSOG had twice the survival rate to Queen Charlotte Strait (~250 km)
- **Burrard inlet appears to be a mortality hotspot**
  - 18 km of migratory area accounted for 50% of the loss in steelhead to NSOG

Next Steps

Influence of pathogens and fish condition:

- Non-lethal gill biopsies taken
  (Jeffries et al., 2014)
- Genomics to assess physiology and pathogen presence
- Relate to migration fate
- Steelhead (2015)
  Sockeye (2016) C. Stevenson Poster

contact: steve.healy2@gmail.com

MOLECULAR ECOLOGY
Molecular Ecology (2014) 23, 5803–5815 doi: 10.1111/mec.12980

Immune response genes and pathogen presence predict migration survival in wild salmon smolts

KEN M. JEFFRIES,* SCOTT G. HINCH,* MARIKA KIRSTIN GALE,* TIMOTHY D. CLARK,† ANDREW G. LOTTO,* MATTHEW T. CASSELMAN,* SHAORONG LI,‡ ERIN L. RECHISKY,§ ASWEA D. PORTER,§ DAVID W. WELCH§ and KRISTINA M. MILLER‡

Approach

- in 2012 half of our V7 tagged smolts had a small piece of gill removed prior to release

- gill tissue used for functional genomics assessment using high throughput qPCR

- no difference in survival between gill clipped and non-clipped fish

Results

- 15% of smolts that were never detected after release had gene expression profiles consistent with immune response to one or more viral pathogens

- the most commonly detected pathogen in the smolts was infectious haematopoietic necrosis virus (IHNV)

Next Steps

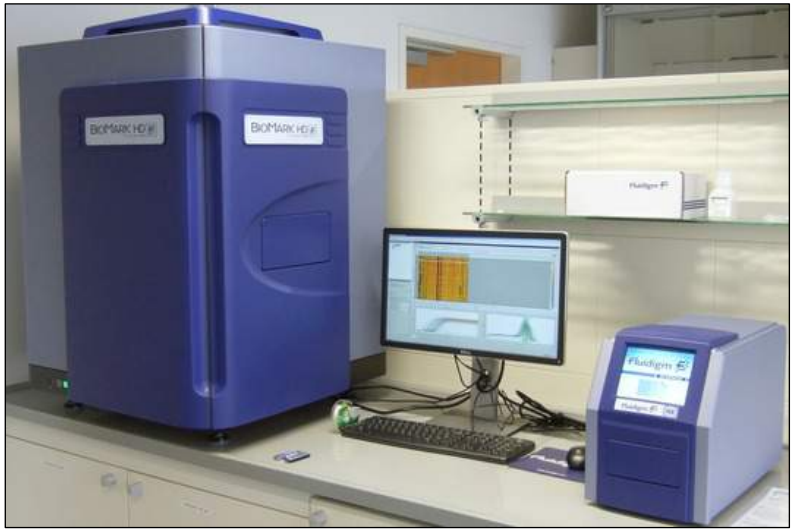
April 2016 – The return to Chilko lake:

(Clark et al. *Ecological Applications* accepted)

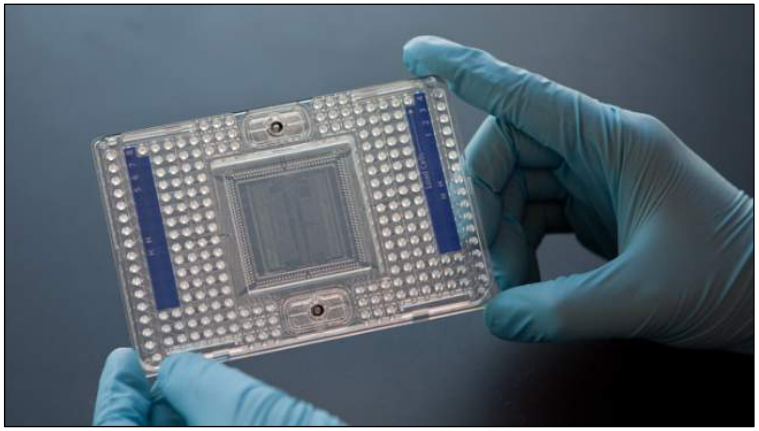
- Tracked over 1800s smolts for >1000 km (2010-2013)
- 63-90% survival over first ~14 km
- Upper Chilko = nocturnal movements
- Elsewhere = day and night movements
- Predation in the upper river?
- Data only from age-two smolts

Genomic Work

- qPCR using Biomark Fluidigm
- Assess up to 45 pathogens and 45 physiological biomarkers per sample
- Conducted on steelhead samples (2015) in March, 2016 at Pacific Biological Station (DFO) in Nanaimo, B.C.



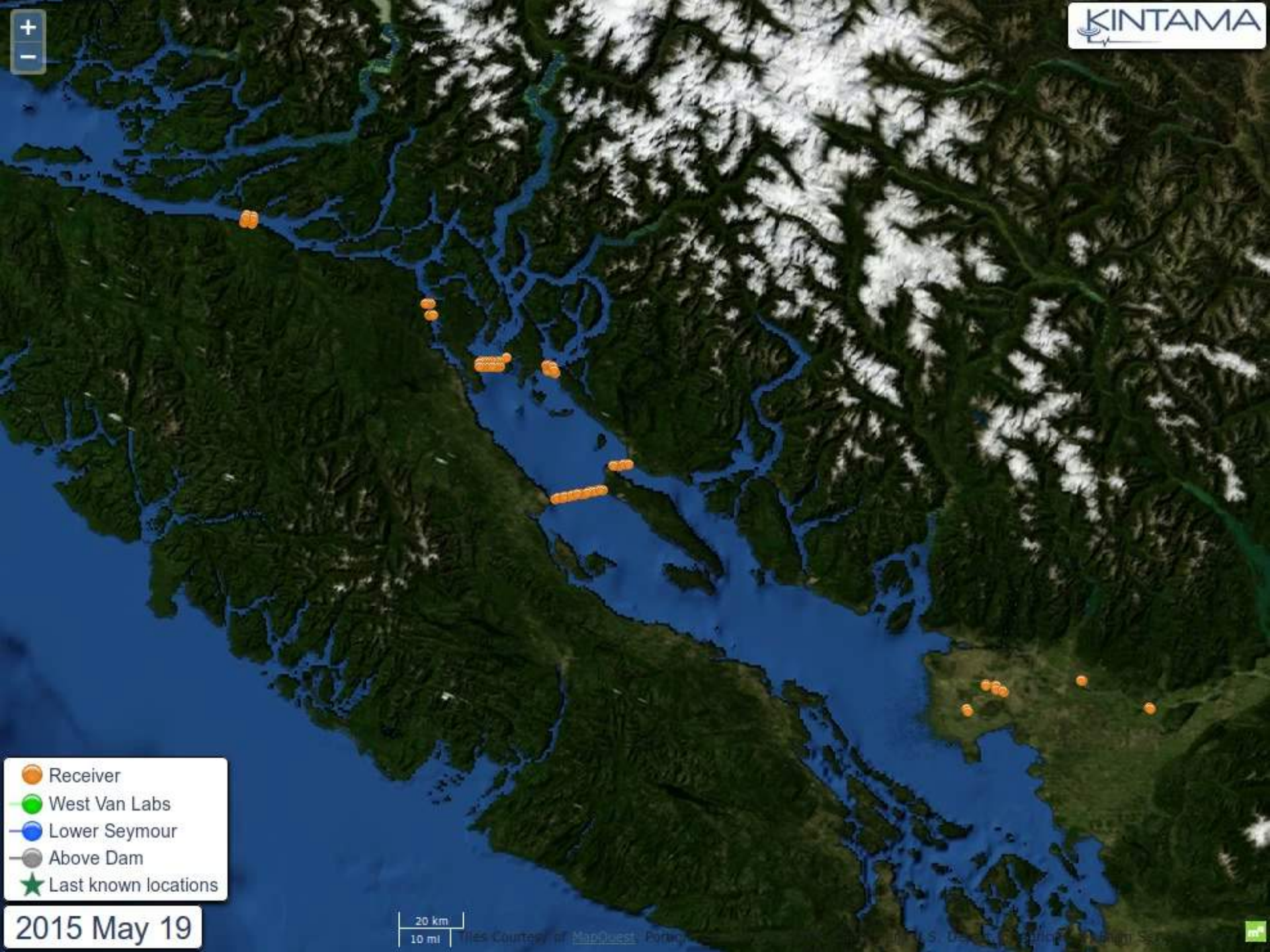
Humangenetik.com



systembiology.columbia.edu

Genomic Work – example biomarkers and pathogens

Name	Assay	Type or Function	Source
Renibacterium salmoninarum	Microbe	Pathogen	Balfry et al., 2011; Halpenny & Gross, 2008
Aeromonas salmonicida	Microbe	Pathogen	Balfry et al., 2011; Halpenny and Gross, 2008
Listonella anguillarum	Microbe	Pathogen	Balfry et al., 2011
Flavobacterium psychrophilum	Microbe	Pathogen	Balfry et al., 2011
Infectious hematopoietic necrosis virus	Microbe	Pathogen	Hostetter et al., 2011; Jeffries et al., 2014
Interferon-induced GTP-binding protein Mx	Biomarker	Immune	Jeffries et al., 2014
Signal transducer and activator of transcription 1-alpha/beta	Biomarker	Immune	Jeffries et al., 2014
Immunoglobulin M	Biomarker	Immune	Jeffries et al., 2014
Complement factor C3	Biomarker	Immune	Jeffries et al., 2014
Heat-shock protein 90-beta	Biomarker	Stress	Jeffries et al., 2014
Phospholemman	Biomarker	Stress	Jeffries et al., 2014
Sodium Potassium ATPase	Biomarker	Osmoregulation/Stress	Kennedy et al., 2007; Stich, et al., 2015
Cold inducile RNA binding protein	Biomarker	Osmoregulation/Stress	Pan et al., 2004
Insulin-like growth factor 1	Biomarker	Growth; salinity tolerance	Beckman et al., 1998


KINTAMA
Receiver
West Van Labs
Lower Seymour
Above Dam
Last known locations
2015 May 19
20 km
10 mi