Bioenergetics Models as a Means to Evaluate Channel Habitat Availability

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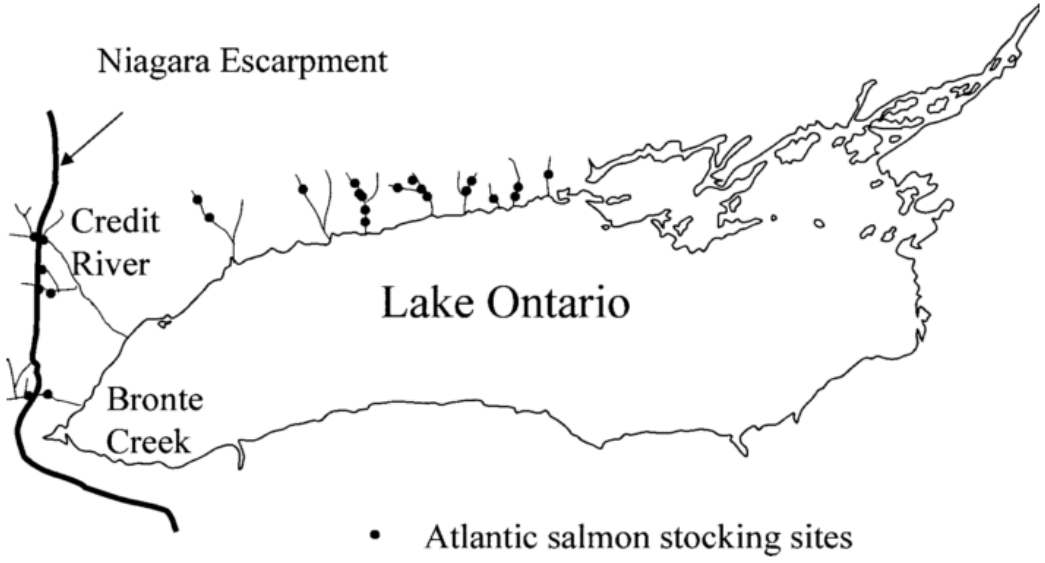
Background

- Effort to restore a breeding Atlantic Salmon population in the Credit River watershed
  - Population losses of introduced stock
- History of channel modification within the watershed
- Channel restoration
  - Increases salmonid abundance
  - In-stream structures (weirs, deflectors, LWD, boulders)
  - Lack of long-term monitoring



(Ketola et al., 1998; Stanfeild et al., 2003; Whiteway et al., 2010)

Objectives

- Develop (script) and apply a spatially explicit drift-foraging bioenergetics habitat model to two Credit River reaches
- Determine specific channel characteristics and features that provide energetically favourable habitat for juvenile salmonids
- Compare model outputs to observed fish distributions to assess validity and reveal aspects to improve

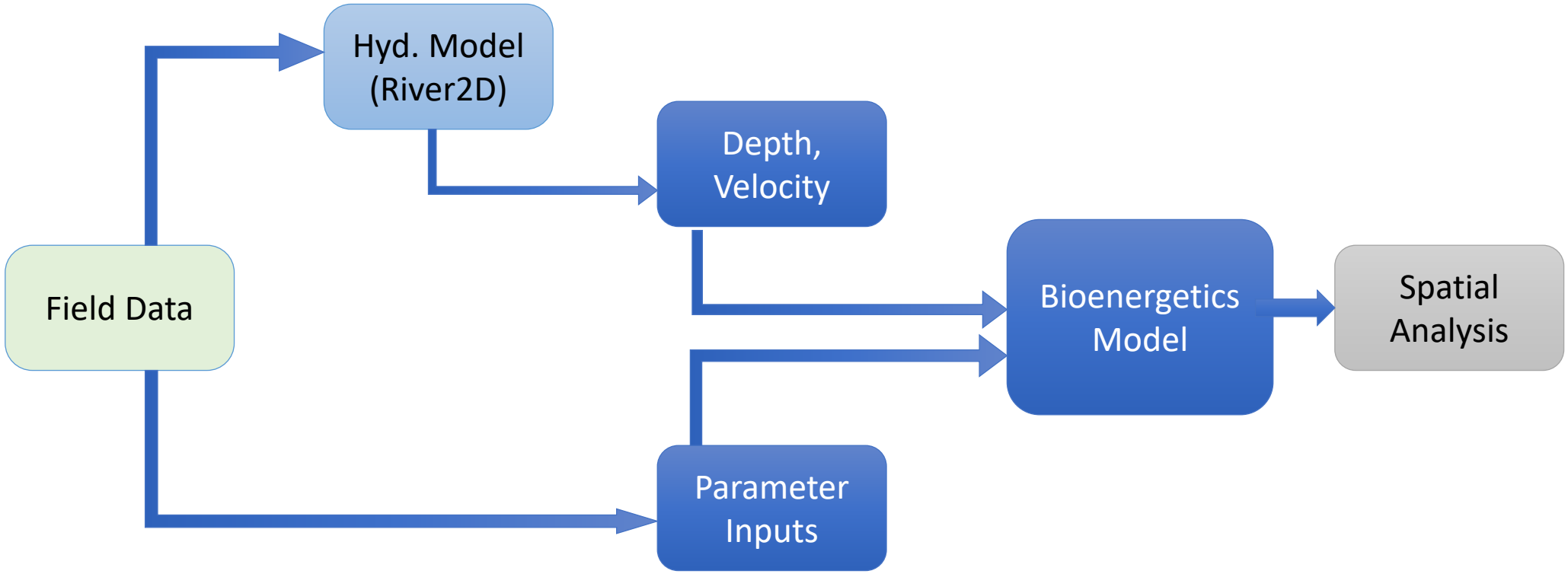
Lower Credit

West Credit

Methods Overview

- Field Data Collection
  - Topographic surveys
  - Velocity/discharge measurements
  - Benthic prey survey
  - Fish Community Surveillance
- Hydraulic Modelling
- Bioenergetics Modelling

Workflow


Hyd. Model
(River2D)
Depth,
Velocity
Field Data
Bioenergetics
Model
Spatial
Analysis
Parameter
Inputs

Field Data Collection

- Topographic channel surveys with SOKKIA Total Station
- Detailed representation of channel bed morphology
- Included every boulder with a b-axis >25 cm in length
  - ‘Tent pole & pegs’ survey method
- Large woody debris outlined

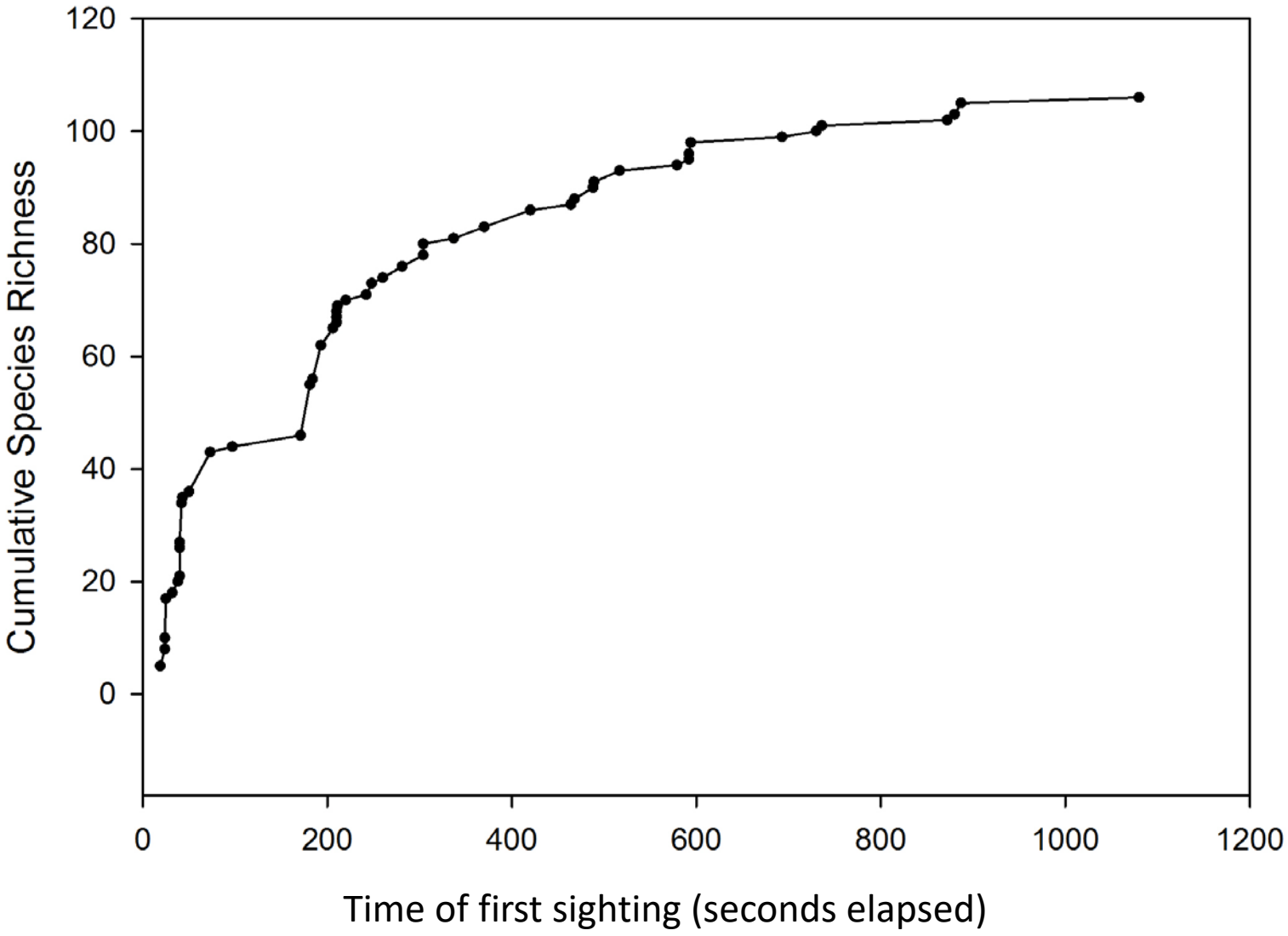
Field Data Collection

- Drifting invertebrate samples
  - Stationary drift nets placed in channel for ~24hr
  - Prey concentration = Q_{total} / # of invertebrates
- Turbidity sampling
  - YSI Optical Monitoring Sonde
- Water temp. and level monitoring

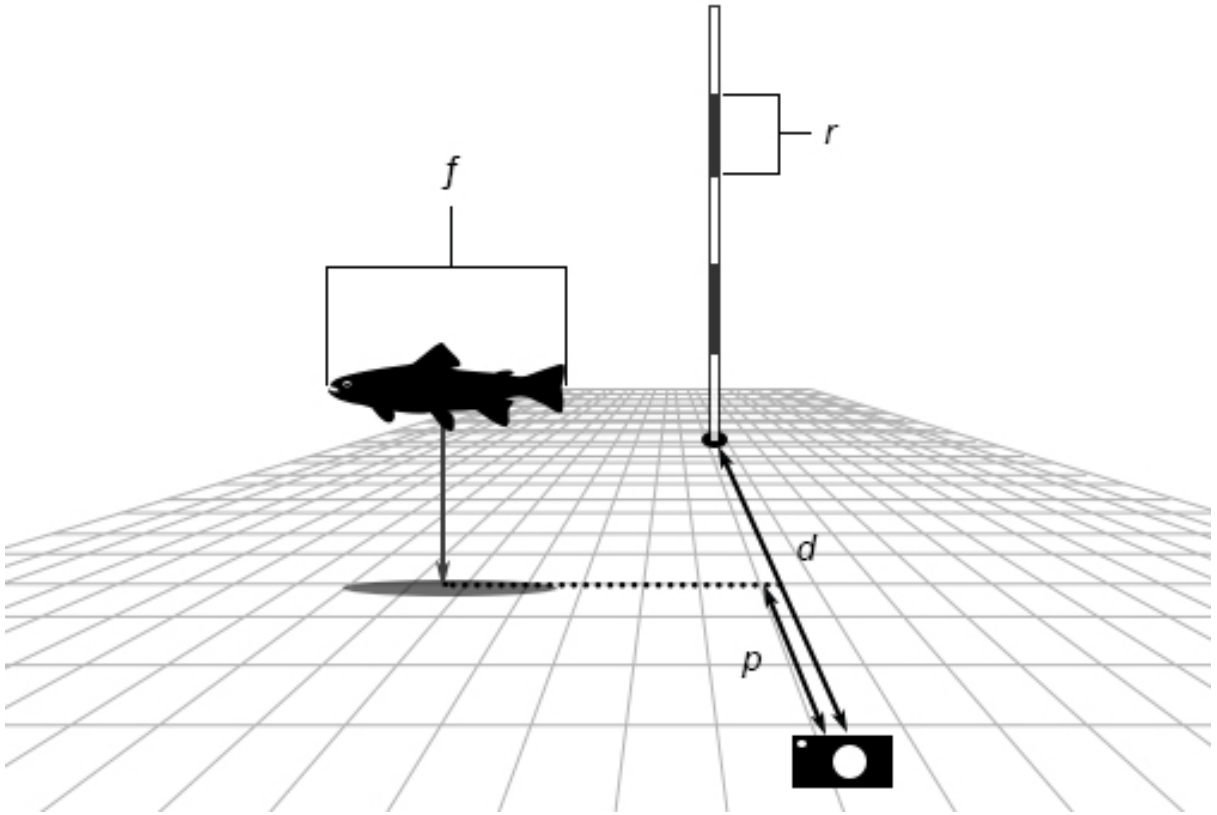
Fish Community Surveillance

- Monitored over summer with remote underwater video (RUV)
- Sony AS200V Action Camera
  - 60 fps, 1080p
- Species, MaxN, time of arrival, and fork-length estimates derived from resulting footage
- Locations of fish surveyed

- 20-25min filming periods to maximize replicates
  - Observing locations of station holding species
- Leveling curve indicates adequate filming times
  - Unlikely to see more fish if left in longer
  - 50% of fish seen within first 4 minutes

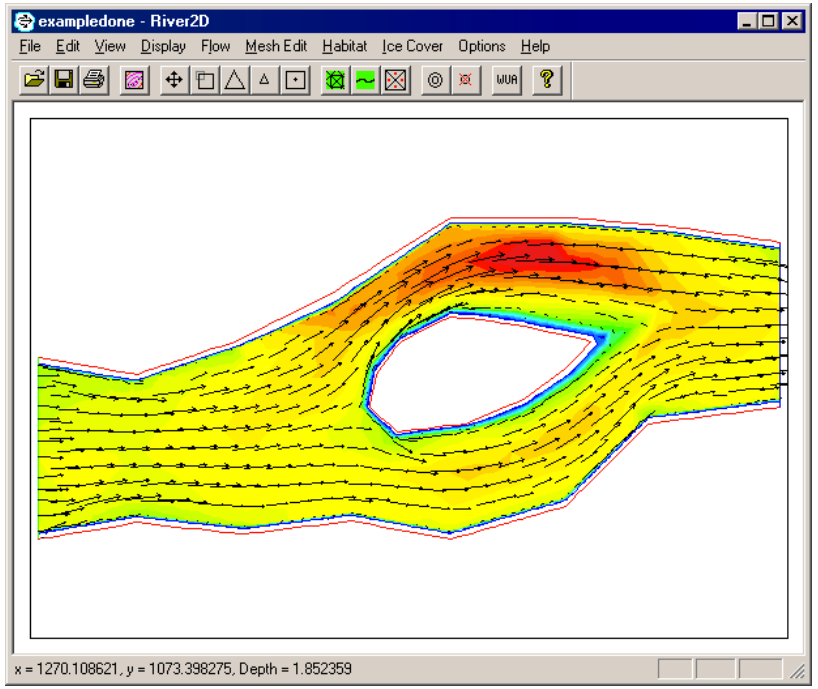


Fish Fork-Length Estimates



Hydraulic Model – River2D

- Inputs:
  - Topography
  - Bed roughness
  - Boundary conditions
    - Discharge & water surface elevation
- Outputs
  - Avg. water column velocity
  - Depth
- Calibrated with geo-referenced WSE and velocity point measurements



(Steffler & Blackburn, 2002)

Bioenergetics Model

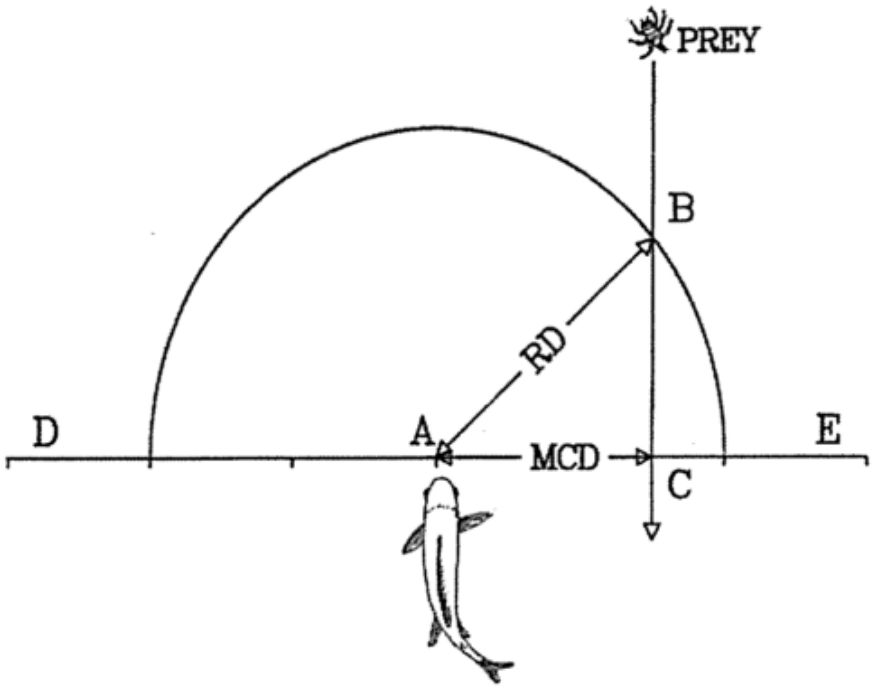
- Rosenfeld and Taylor (2009)
- Simulation of drift-foraging salmonid energy budget
  - Metabolic processes (-), feeding (+)
  - Net energy gain/loss determines growth rate
- Scripted using Python 2.7 within WhiteboxGAT

Bioenergetics Model

- Inputs
  - Initial fish length
  - Drifting invertebrate prey length & concentration
  - Water Temperature
  - Water velocity and depth
    - From River2D
  - Turbidity (NTU)
    - Addition
- Outputs
  - Growth rate potential (mm/day)

Bioenergetics Model – Feeding

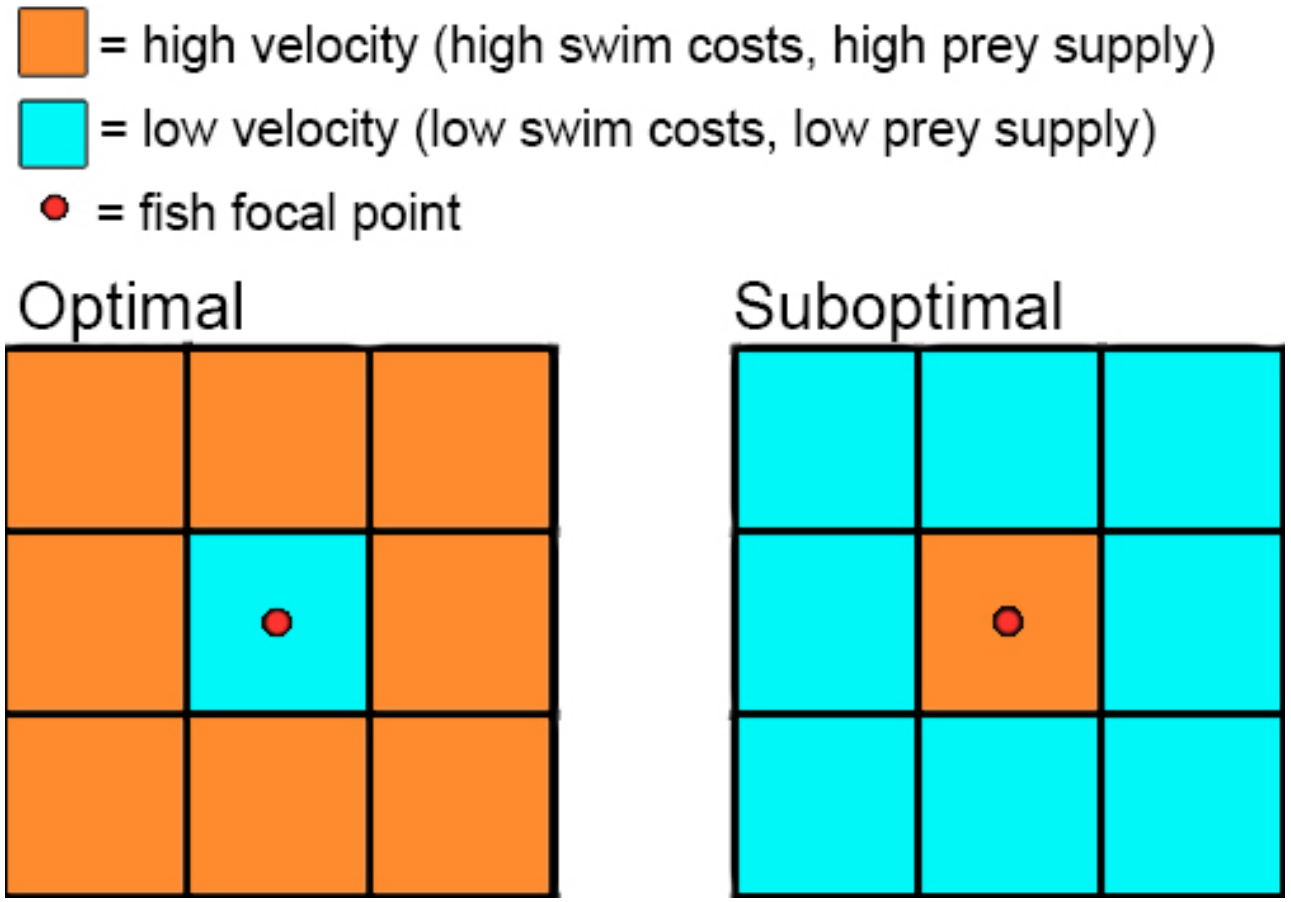
- Optimal foraging locations (Fausch, 1984)
  - Reside in low velocity area
    - Low swimming energy cost
  - Foray in adjacent high velocity area
    - Prey encounters increase
- Reactive Distance (RD)
  - Maximum distance a fish can detect its prey from
  - Decreases as turbidity increases



(Fausch, 1984; Hughes and Dill, 1990; Taylor et al. 2011)

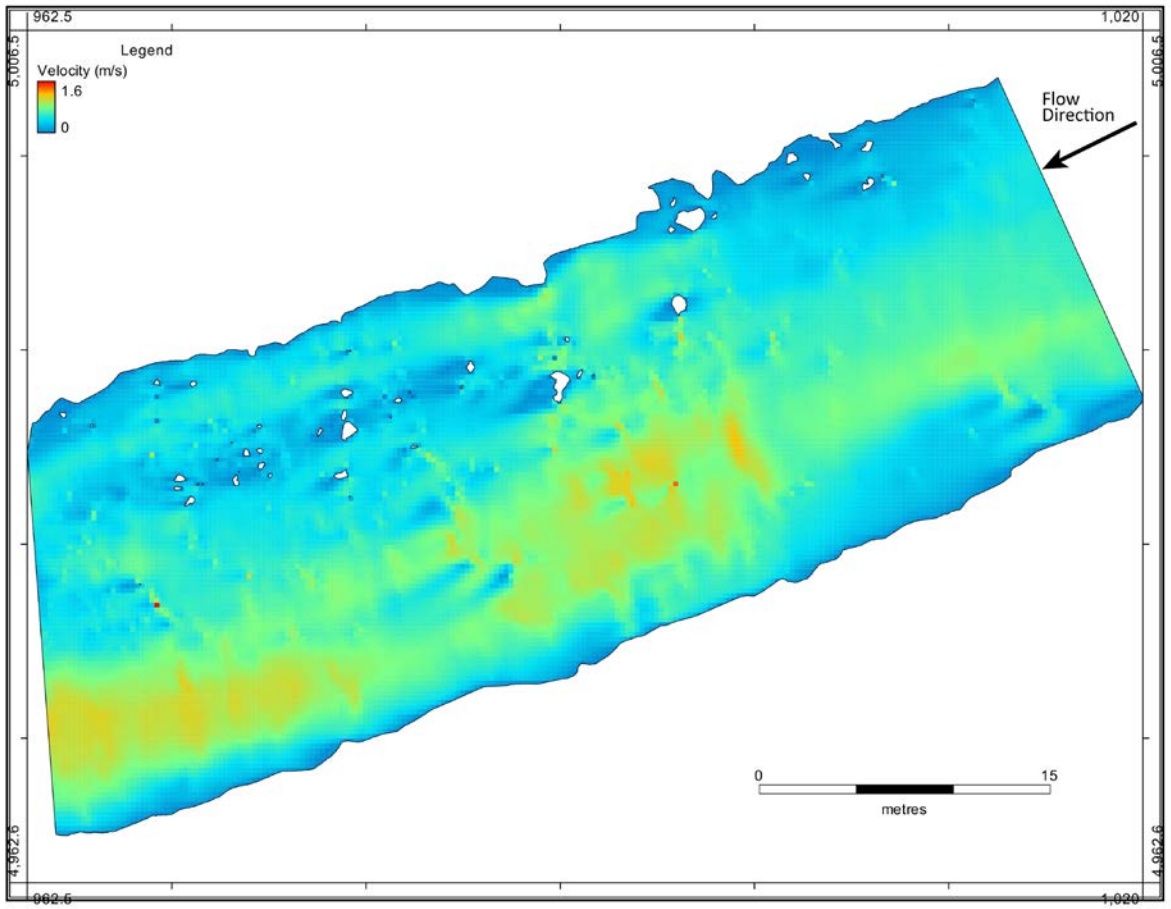
Bioenergetics Model – Feeding

- Focal point velocity determines swimming energy losses
- Adjacent column velocity determines prey encounter and feeding rates

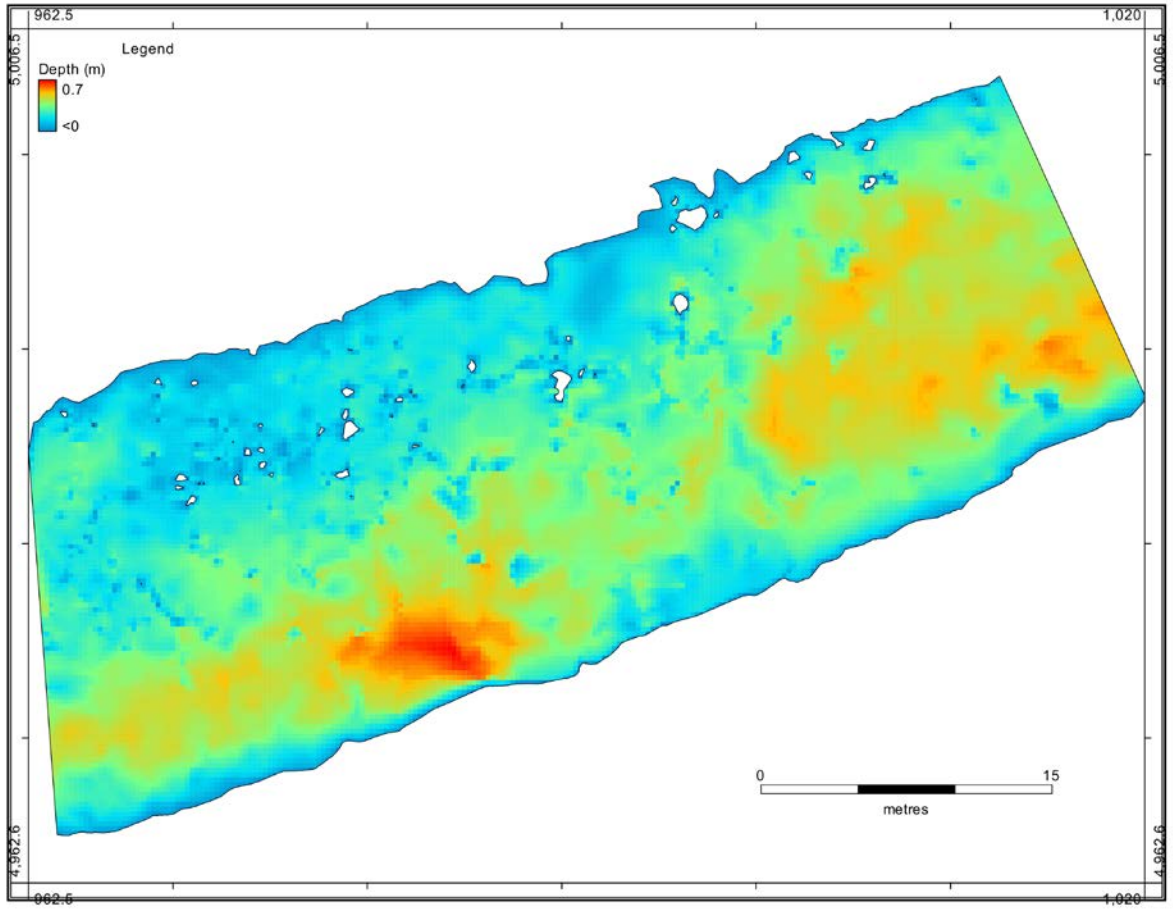


Results and Discussion

Lower Credit

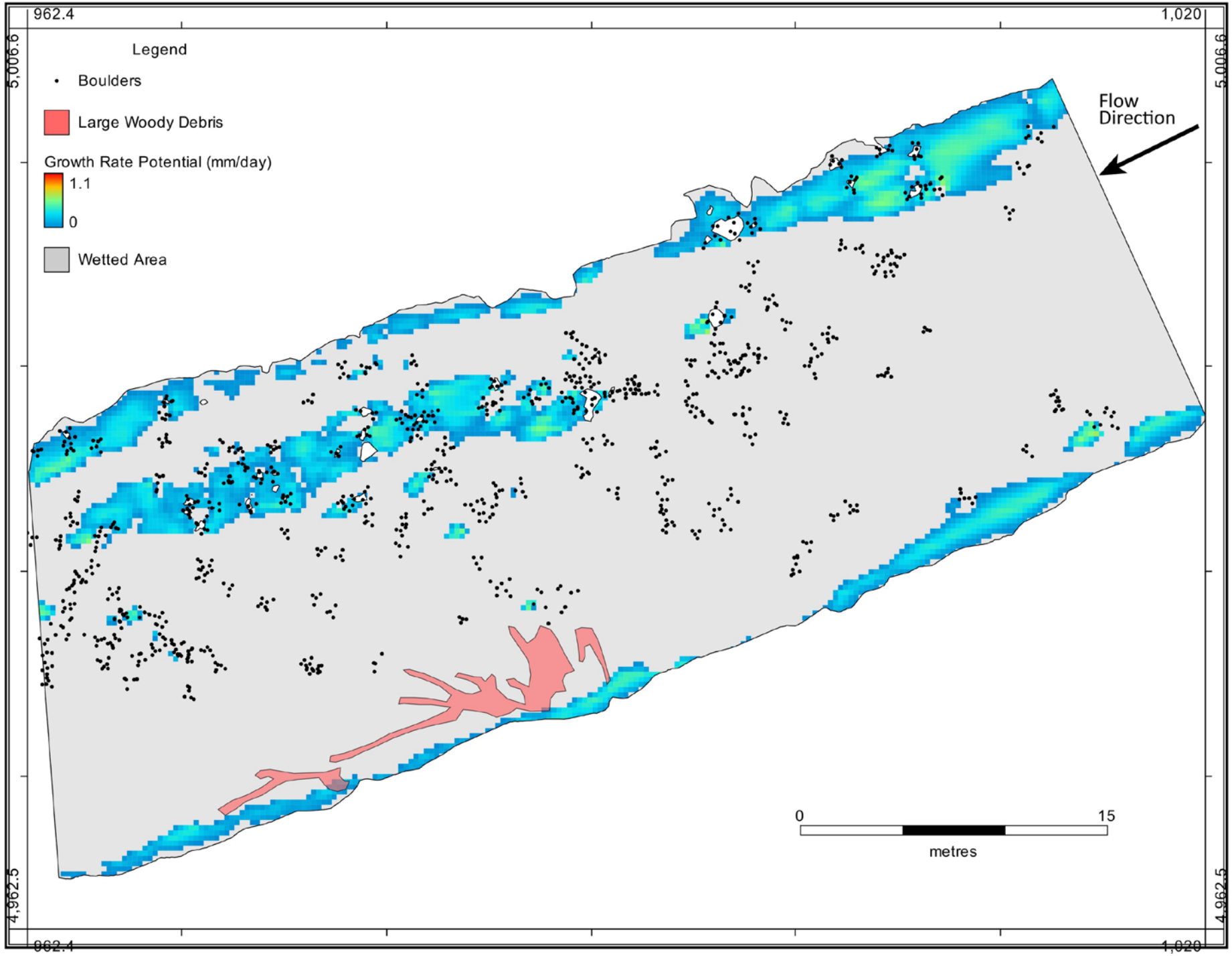


Velocity



Depth

Lower Credit



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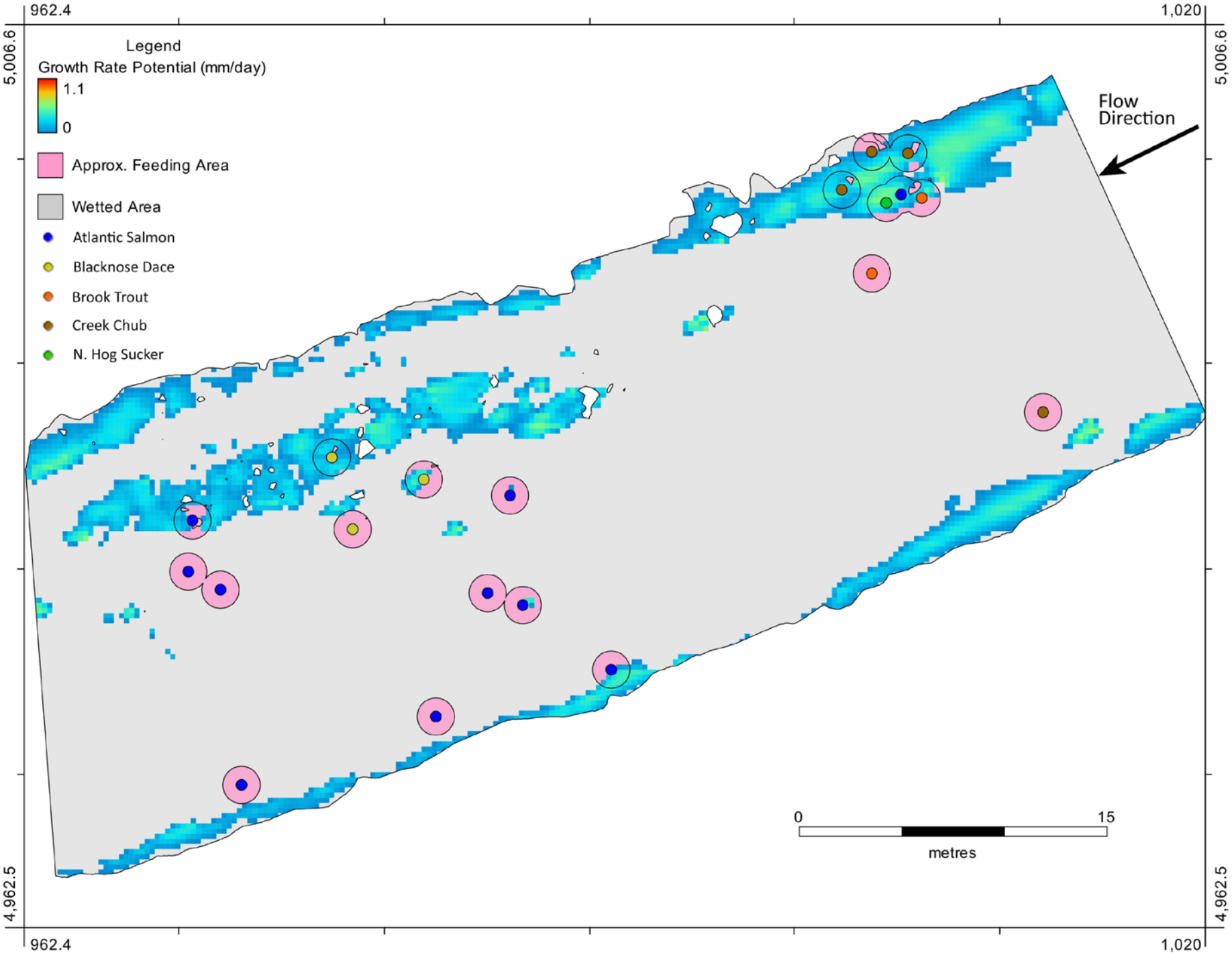

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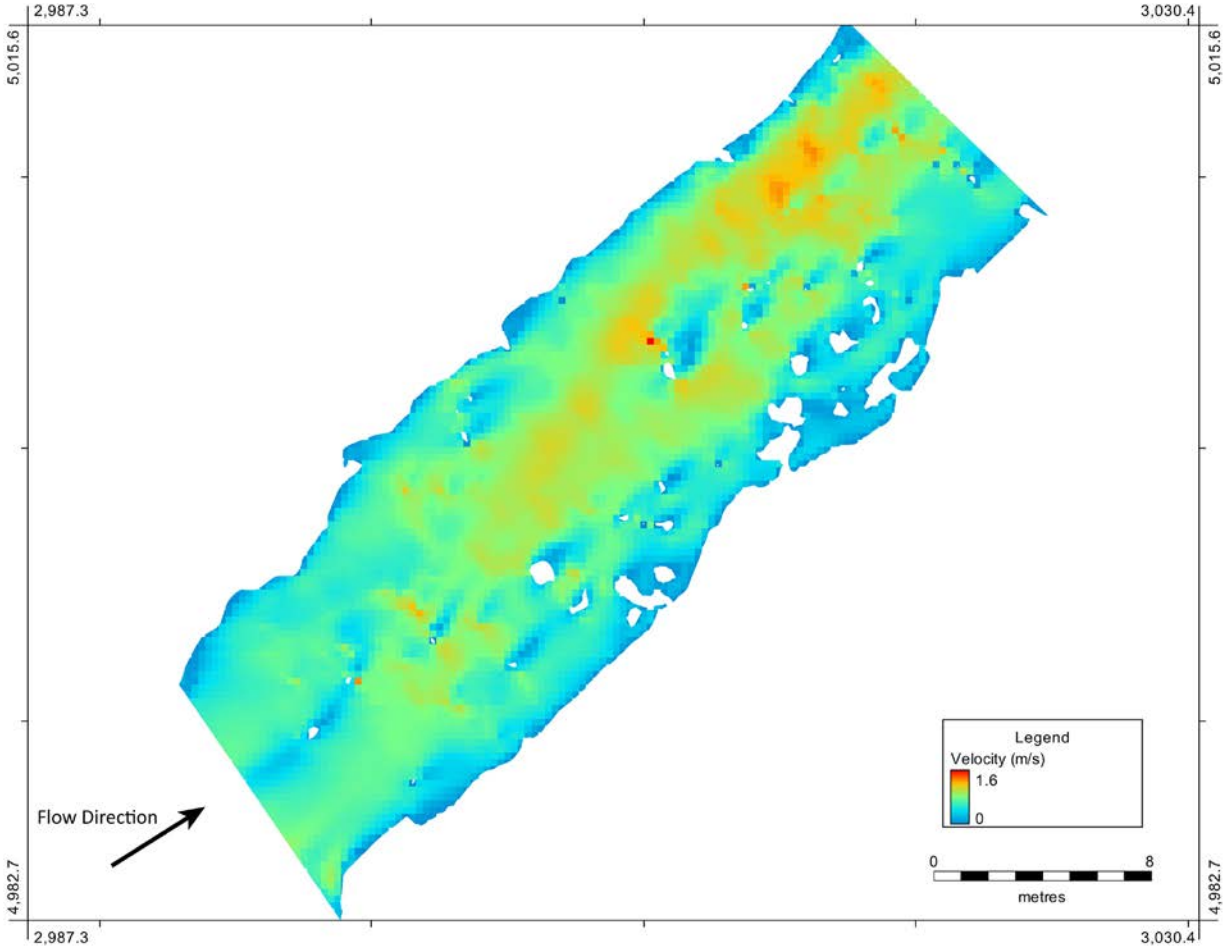
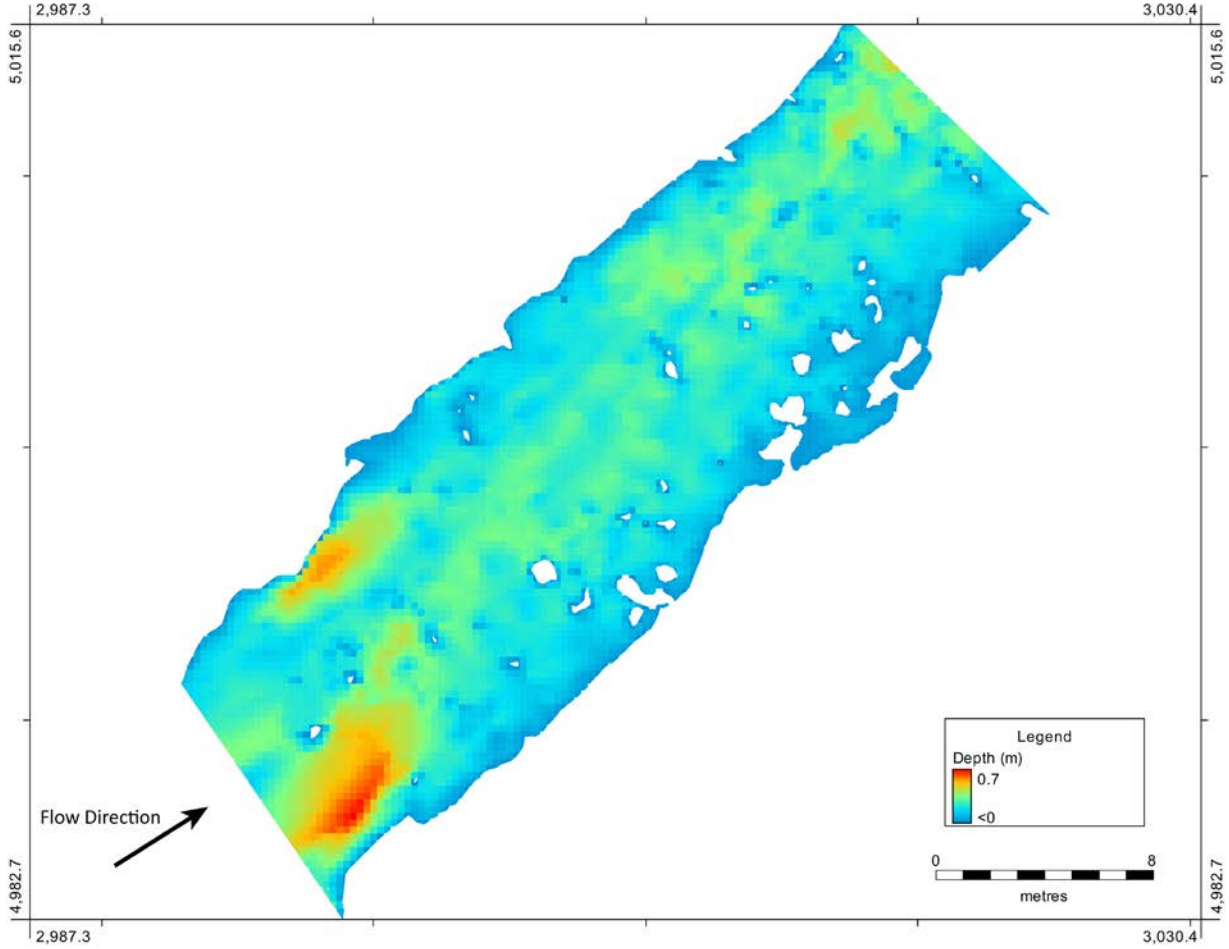
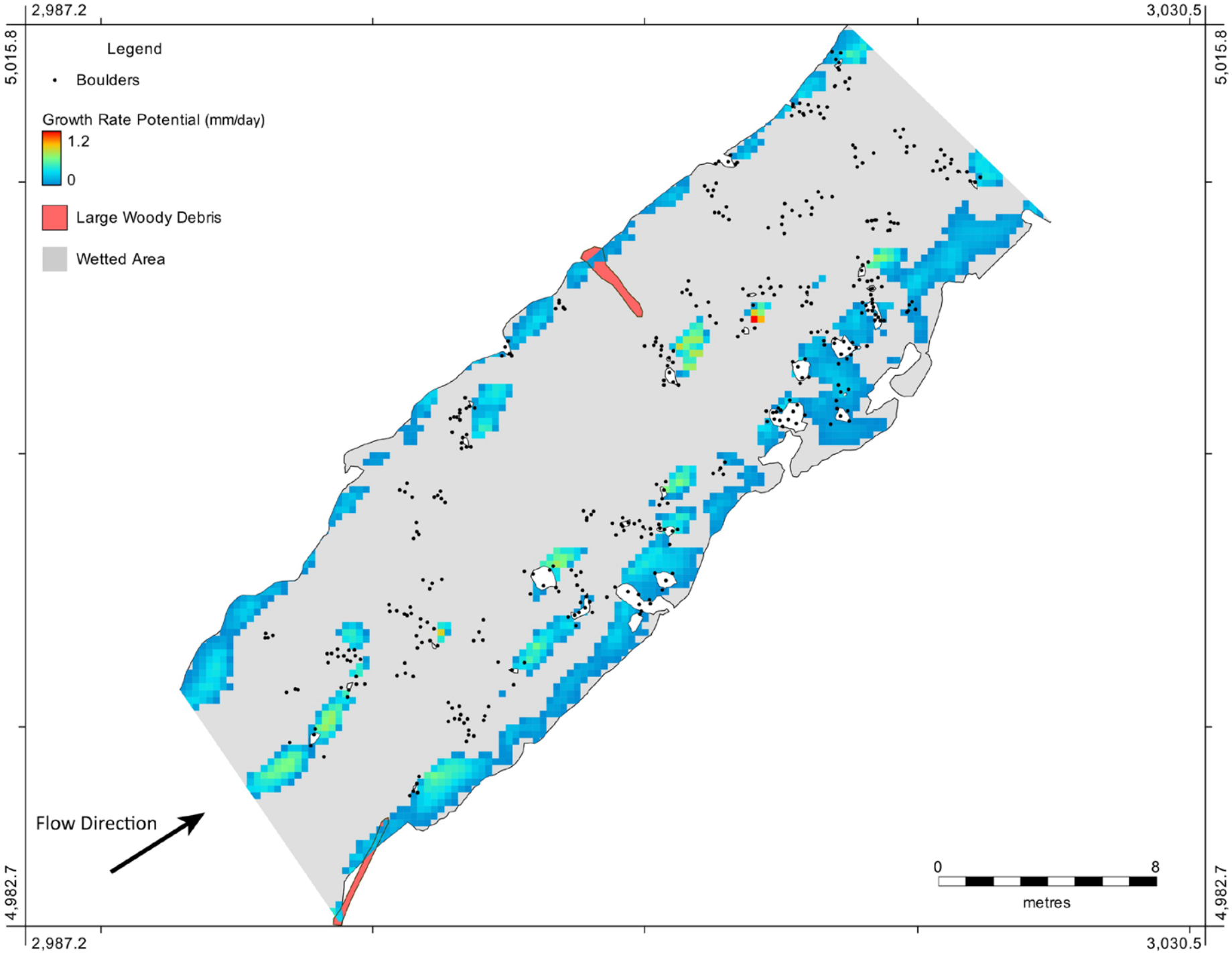


Velocity

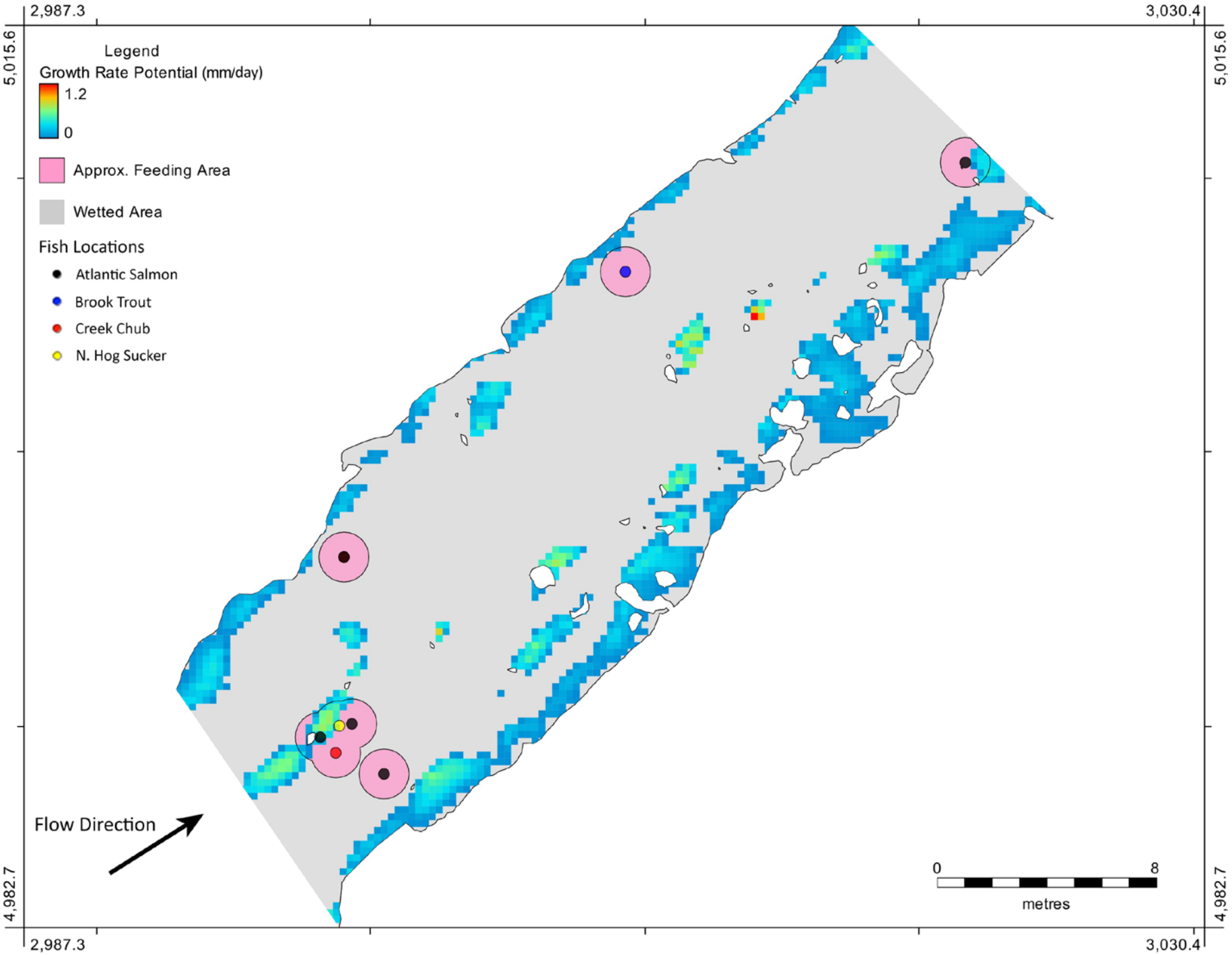


Depth

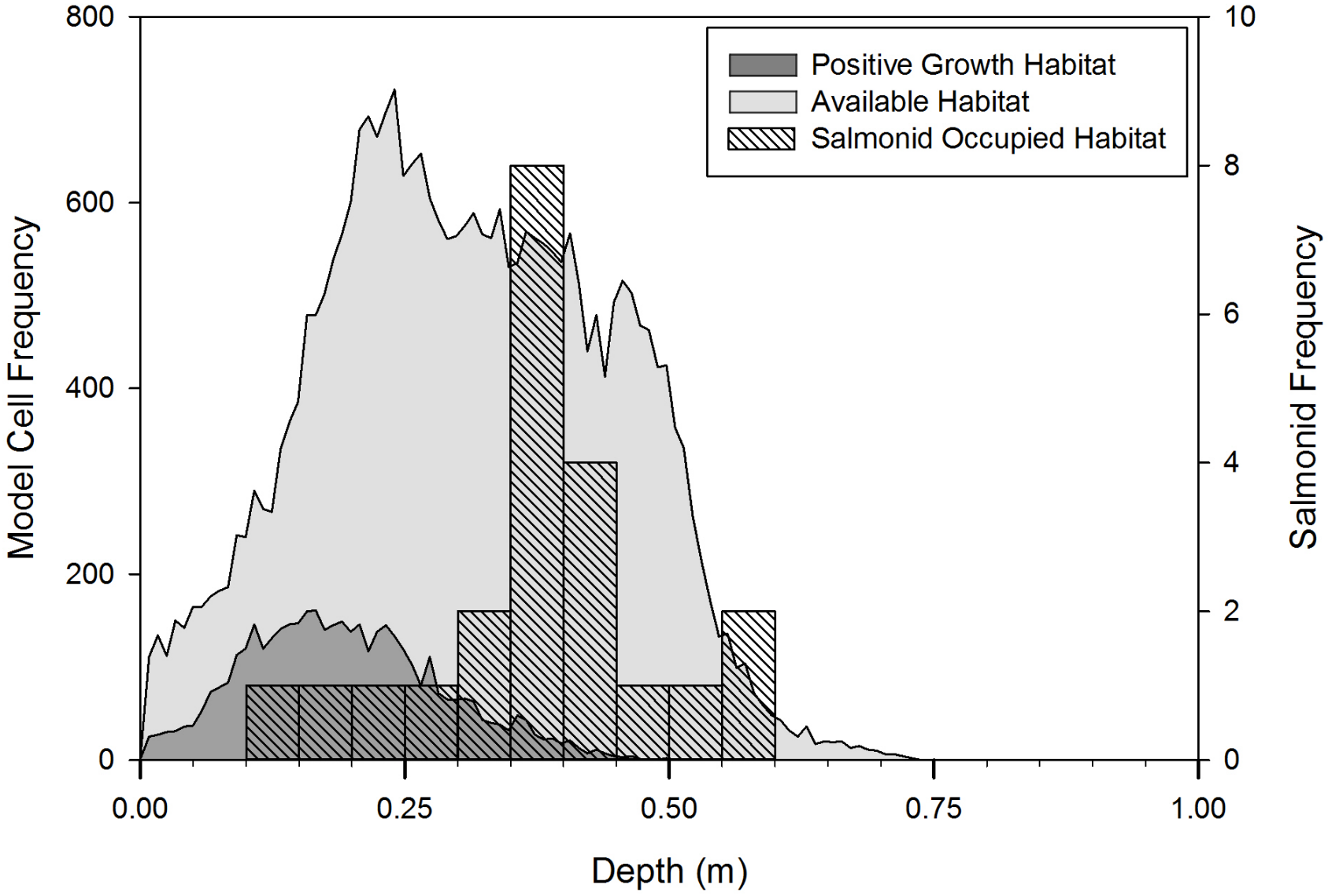
West Credit


2,987.2
3,030.5
5,015.8
4,982.7
Legend
Boulders
Growth Rate Potential (mm/day)
1.2
0
Large Woody Debris
Wetted Area
Flow Direction
0
8
metres

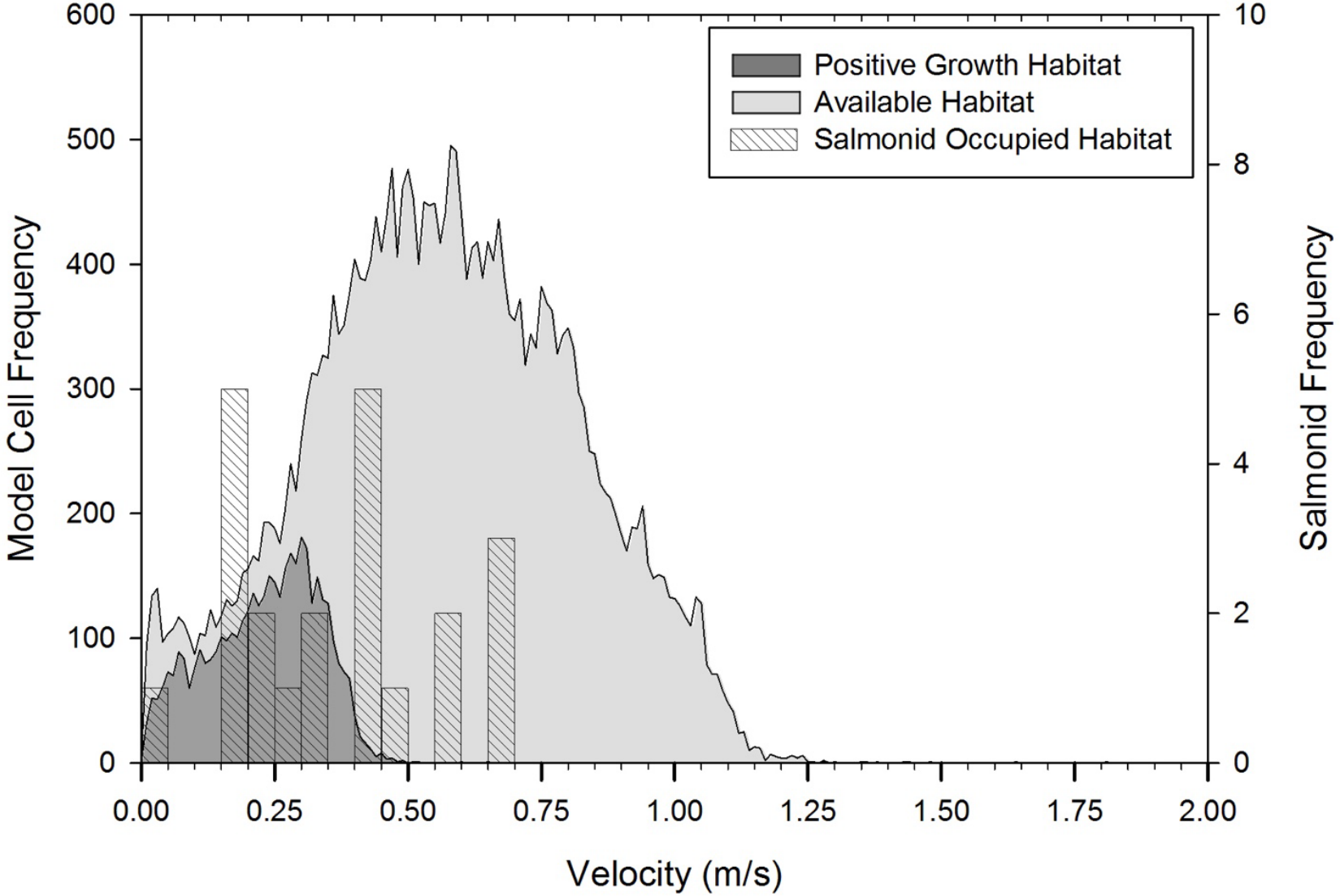
West Credit


2,987.3
3,030.4
5,015.6
4,982.7
Legend
Growth Rate Potential (mm/day)
1.2
0
Approx. Feeding Area
Wetted Area
Fish Locations
Atlantic Salmon
Brook Trout
Creek Chub
N. Hog Sucker
Flow Direction
0
8
metres

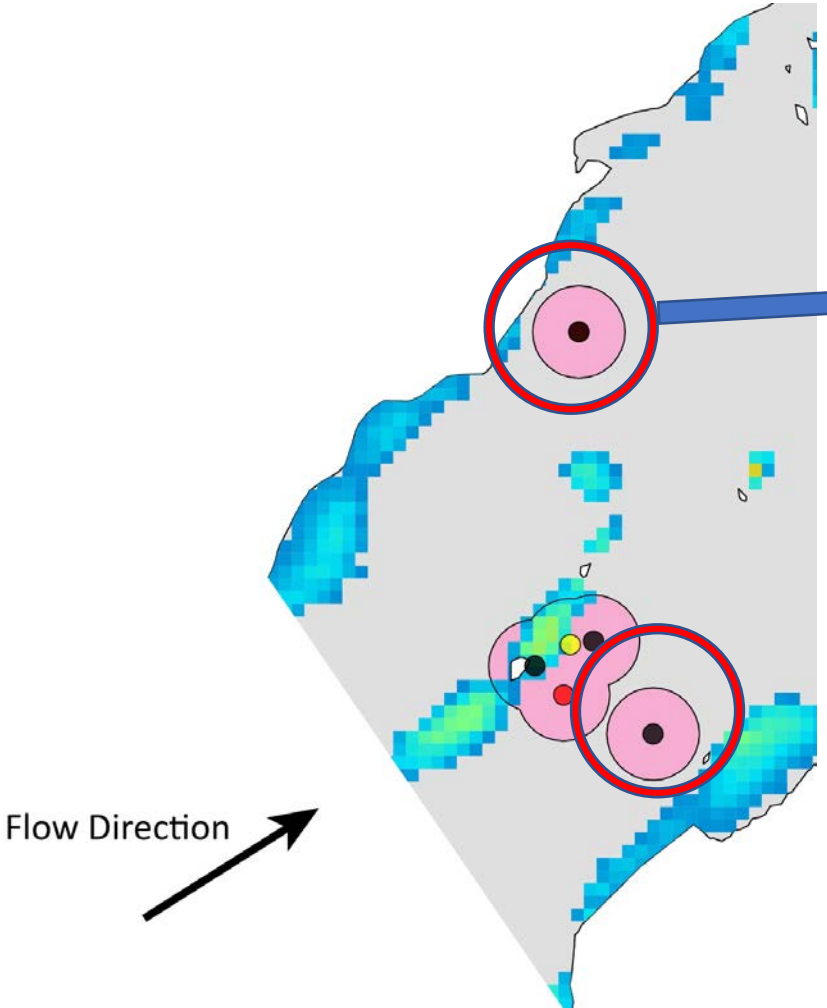
Depth

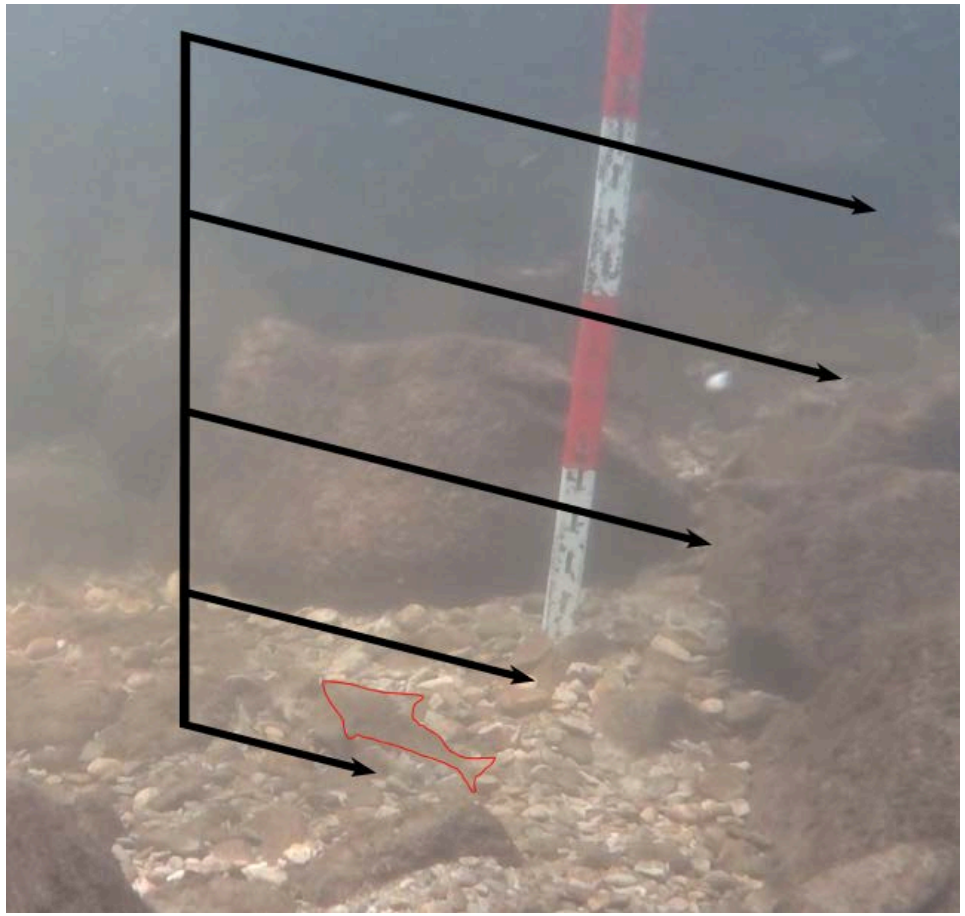

Positive Growth Habitat
Available Habitat
Salmonid Occupied Habitat
Model Cell Frequency
Salmonid Frequency
Depth (m)
0
200
400
600
800
0
2
4
6
8
10
0.00
0.25
0.50
0.75
1.00

Velocity

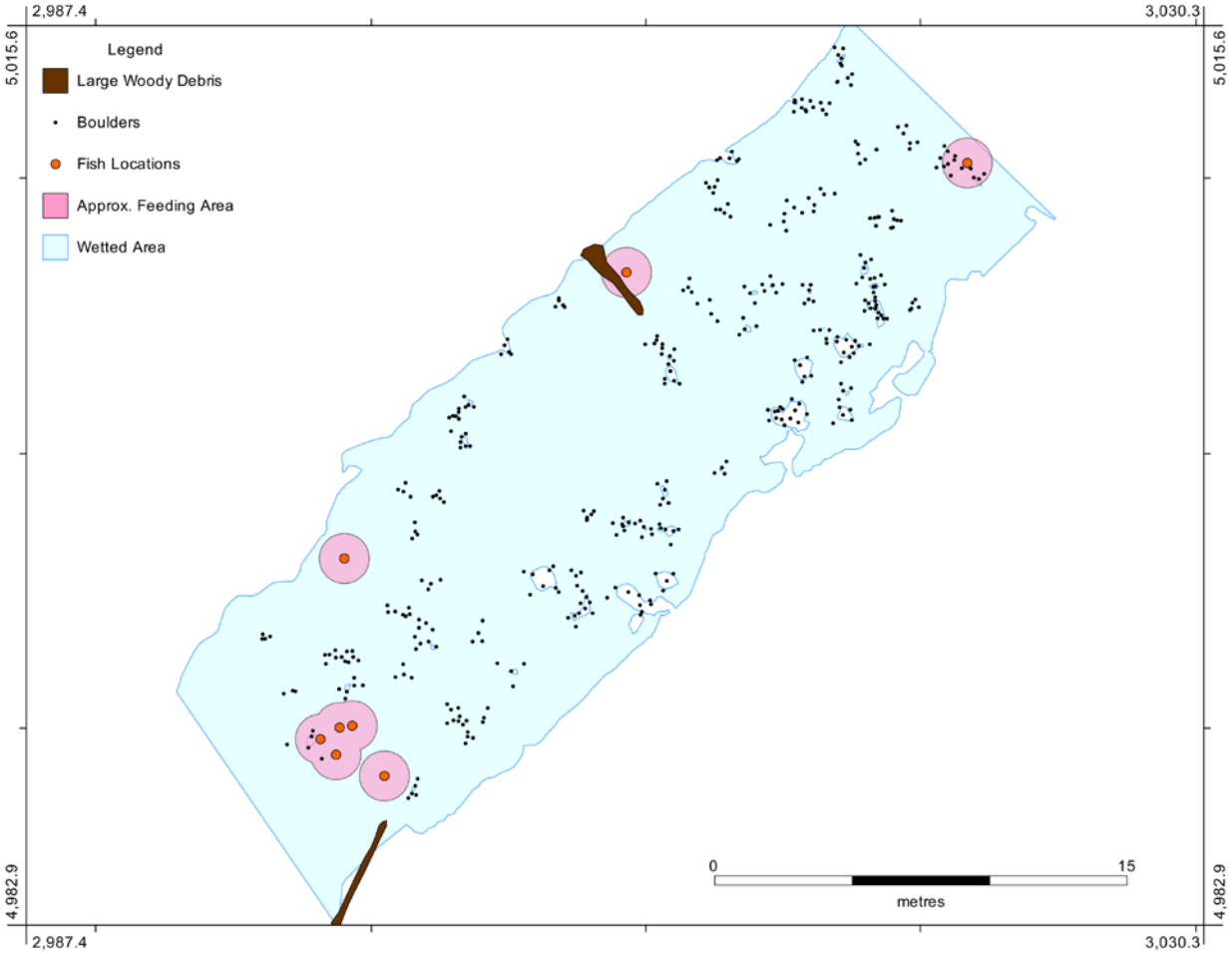

Positive Growth Habitat
Available Habitat
Salmonid Occupied Habitat
Model Cell Frequency
Salmonid Frequency
Velocity (m/s)
0
100
200
300
400
500
600
0
2
4
6
8
10
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

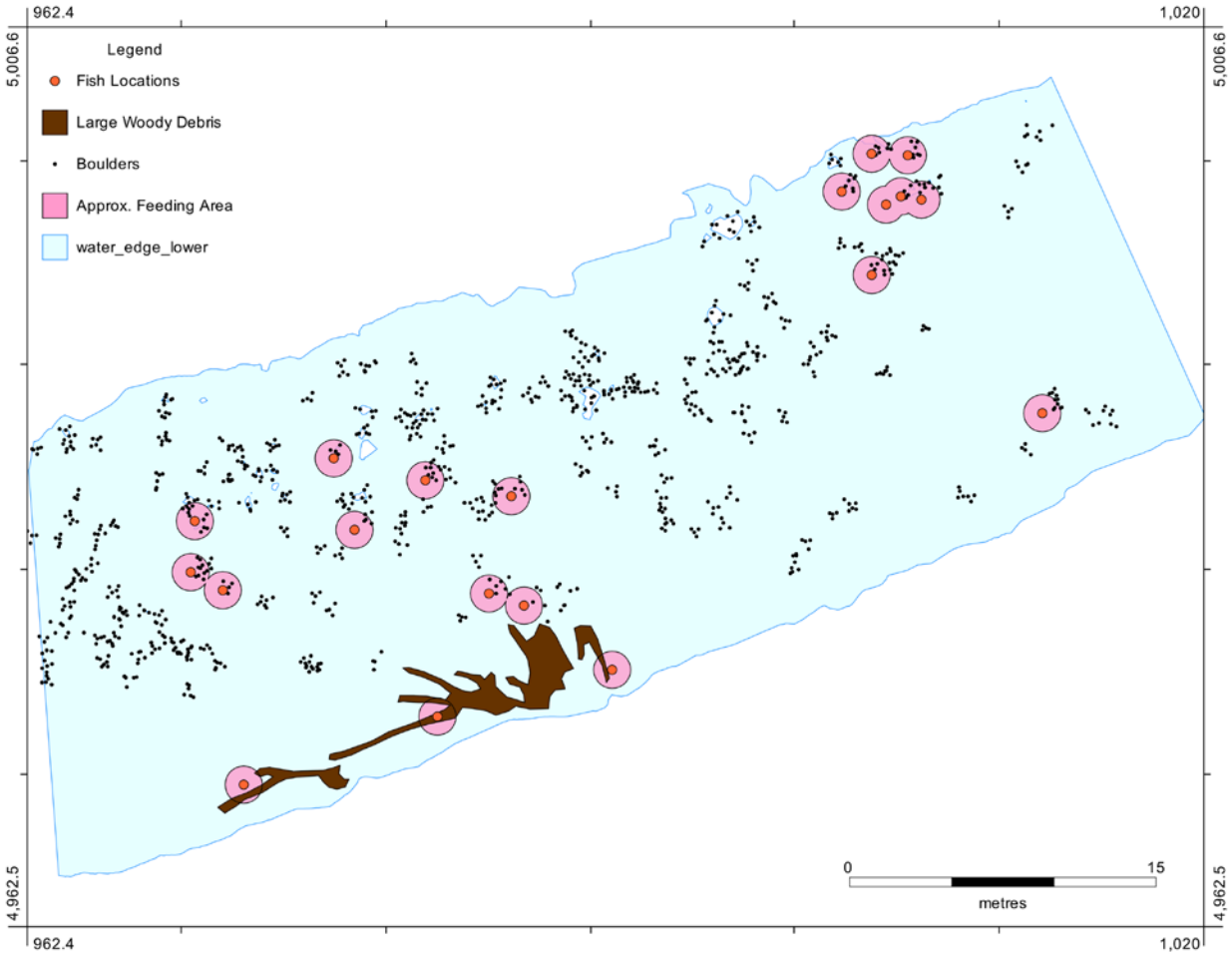
- Depth-averaged velocity issues
  - No feeding upwards from substrate refuge
  - Vertical velocity gradient ignored



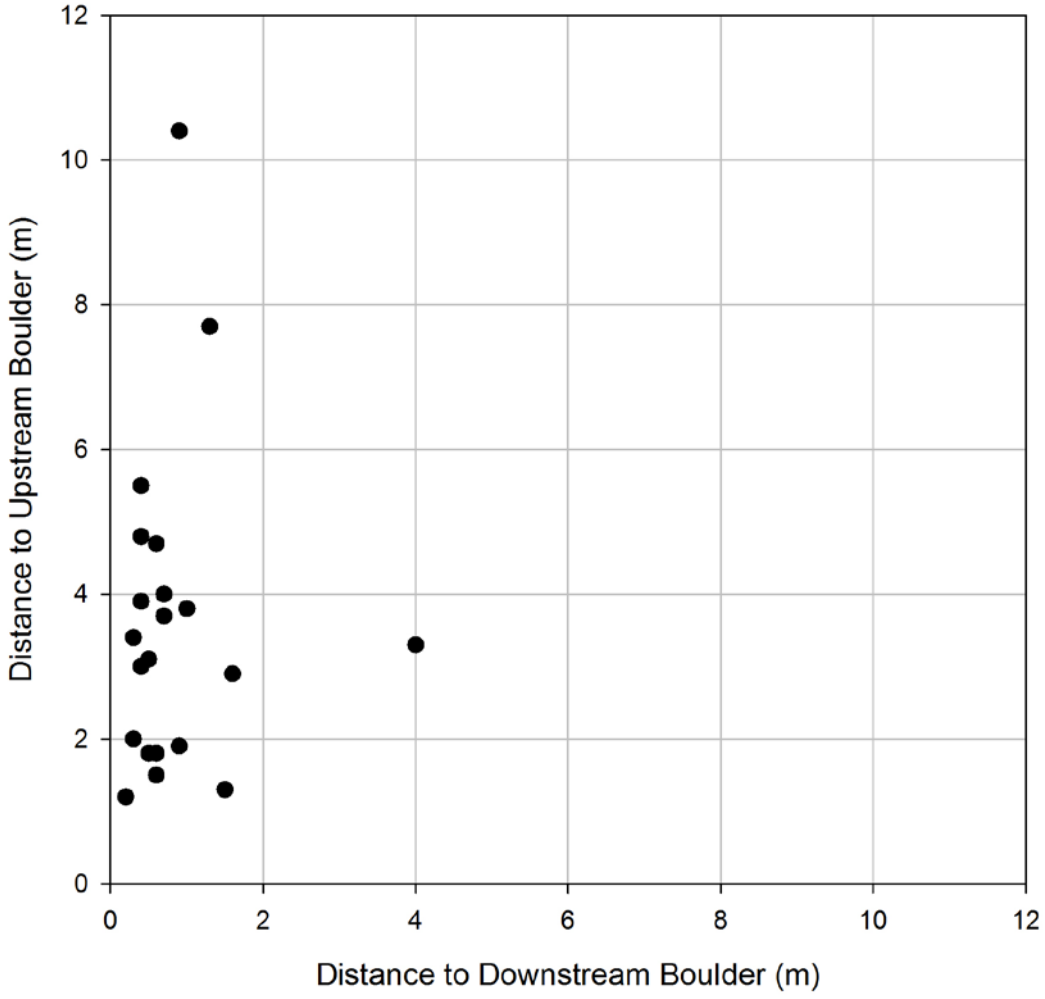


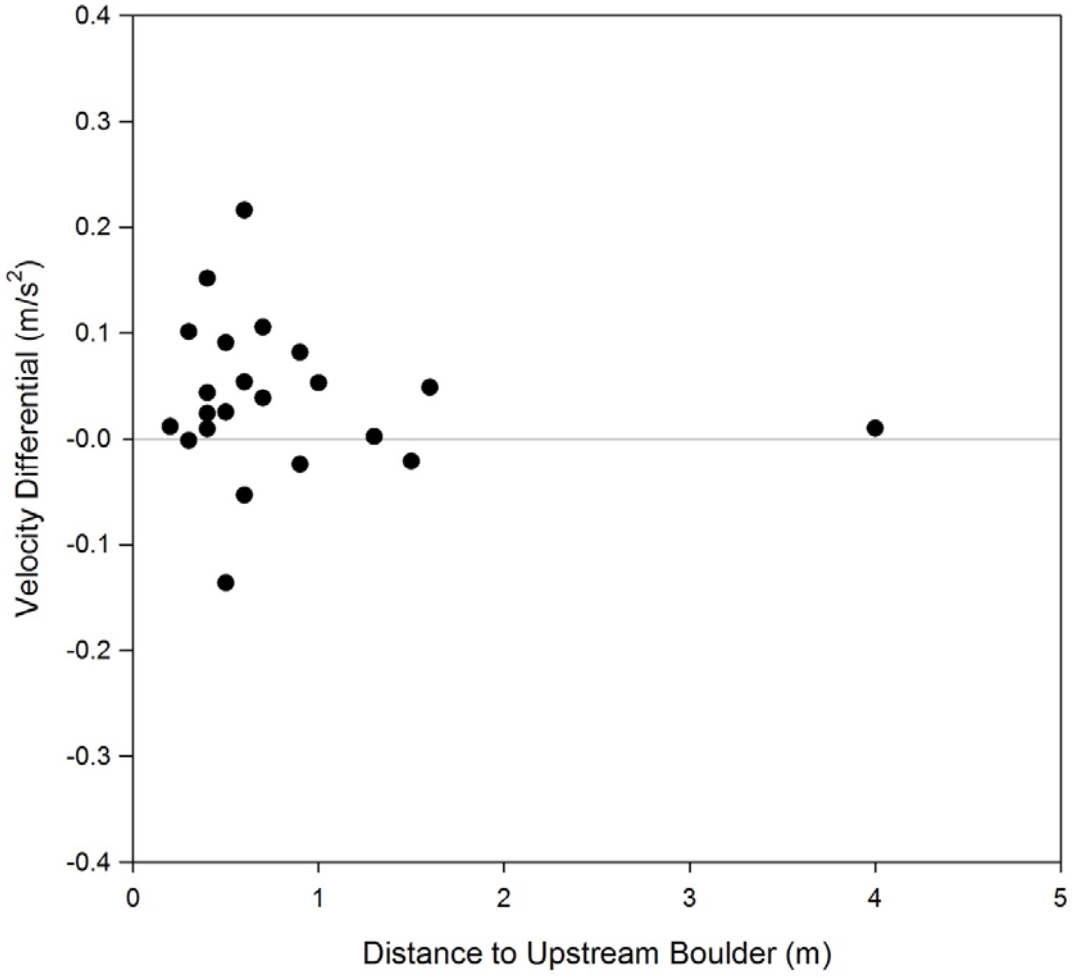
- Association between mid-channel boulders and +ve GRP habitat
  - Alters flow patterns creating positive velocity gradients in deeper areas
- Fish almost always utilizing channel features/refuge



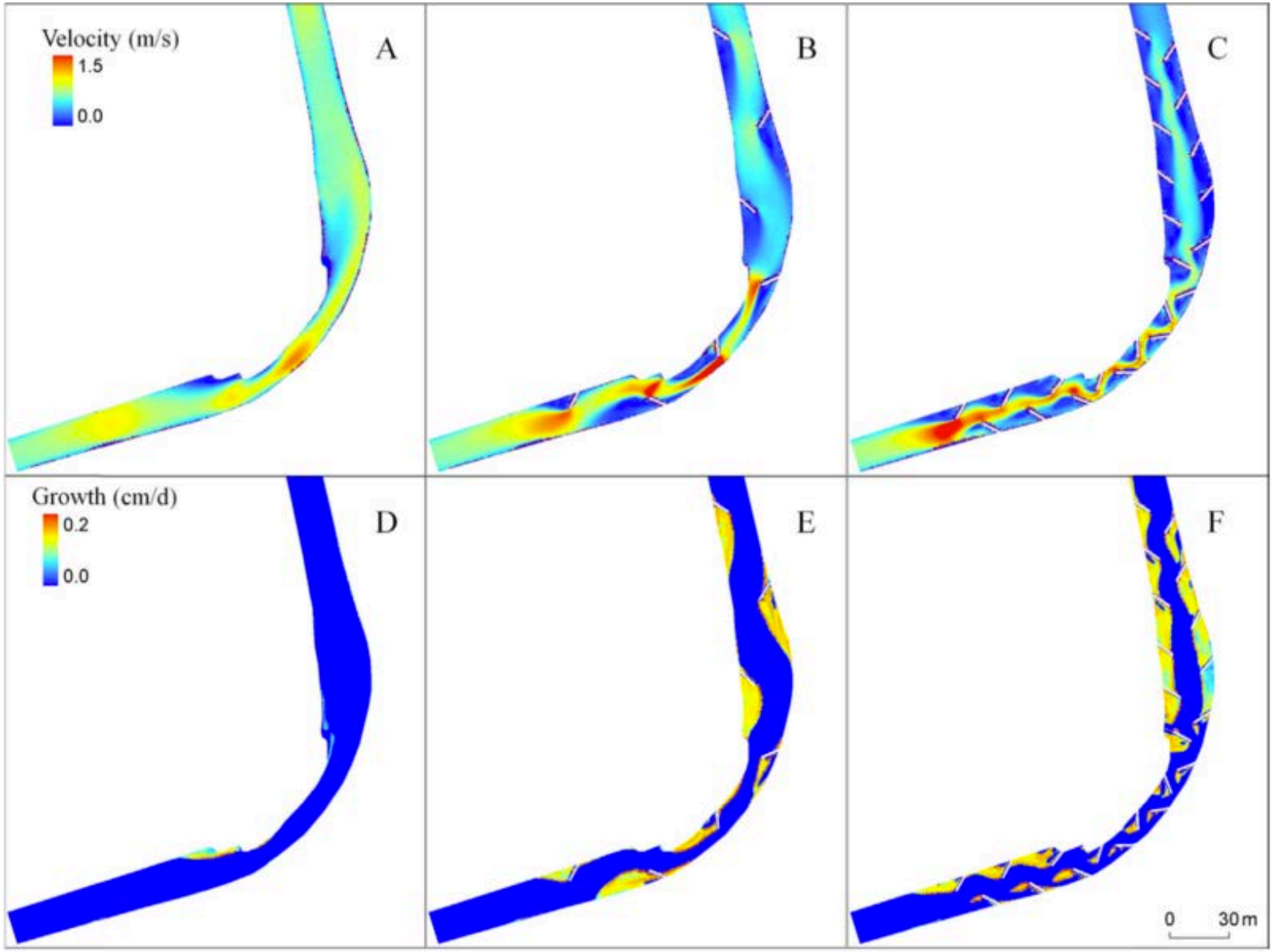


- Boulder wakes popular with fish
- Wakes generally yield velocity refuge and positive velocity gradients





- Lack of similar PGH association for LWD
  - Issues incorporating within hydraulic model
- LWD still utilized by fish
  - Potential predatory cover in marginal zones
  - PGH often in marginal zones regardless of LWD
- Heterogeneous flow patterns imperative for salmonid growth



Hafs et al., 2014

Concluding Remarks

- Highlights potential of interdisciplinary approaches for habitat suitability analysis
  - Mechanistic link between fish growth and channel flow
  - Inform, evaluate, and explore restoration/channel design options
  - Extensive data requirements, more validation needed

- RUV as a framework for long-term restoration success monitoring
  - Best suited for unit/feature scale, some implications at reach scale
  - Monitor growth, behaviour, species distribution with less disturbance
  - Archive data, public outreach

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- End
  - Thank You
    - Questions?