Exploring how a range of management objectives could affect alewife population recovery

Betsy Barber[1*]
Alejandro Molina Moctezuma[1]
Jamie Gibson[2]
Andrew O'Malley[1]
Joseph Zydlewski[3,1]

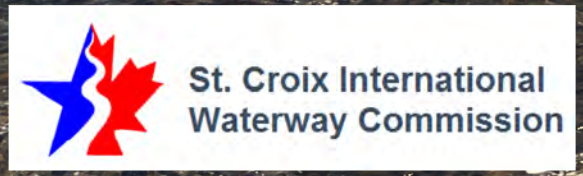
[1]*University of Maine, Department of Wildlife, Fisheries, and Conservation Biology, Orono, ME*

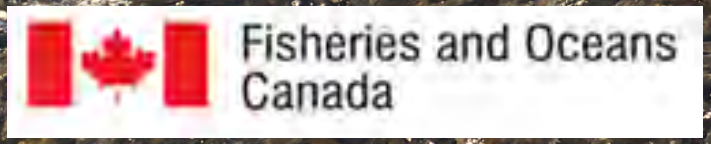
[2]*Fisheries and Oceans Canada, Dartmouth, NS, Canada*

[3]*U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono, ME*

**Primary contact: betsy.barber@maine.edu*

Funding and Support





Outline

- Alewife Population Modelling
  - Dam Passage
  - Nutrient Dynamics
- Online Application
  - DMAPP (Dynamic Modelling for Alewife Populations and Passage)

Question:

- What is the marine-derived nutrient potential in the St. Croix River associated with alewife population recovery?

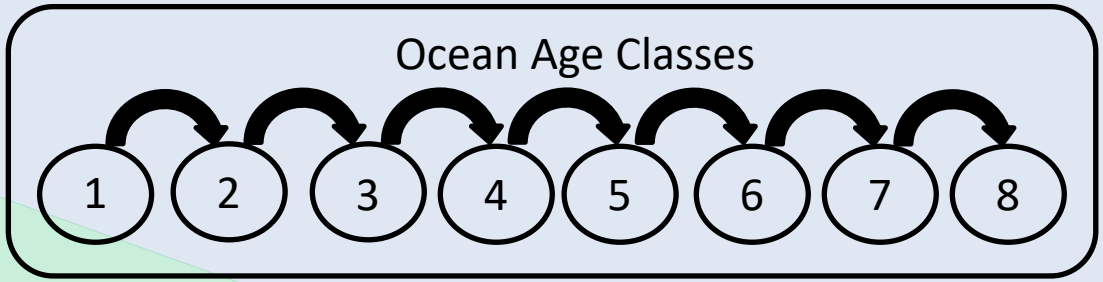
How to answer this?

- Modelling!

Approach

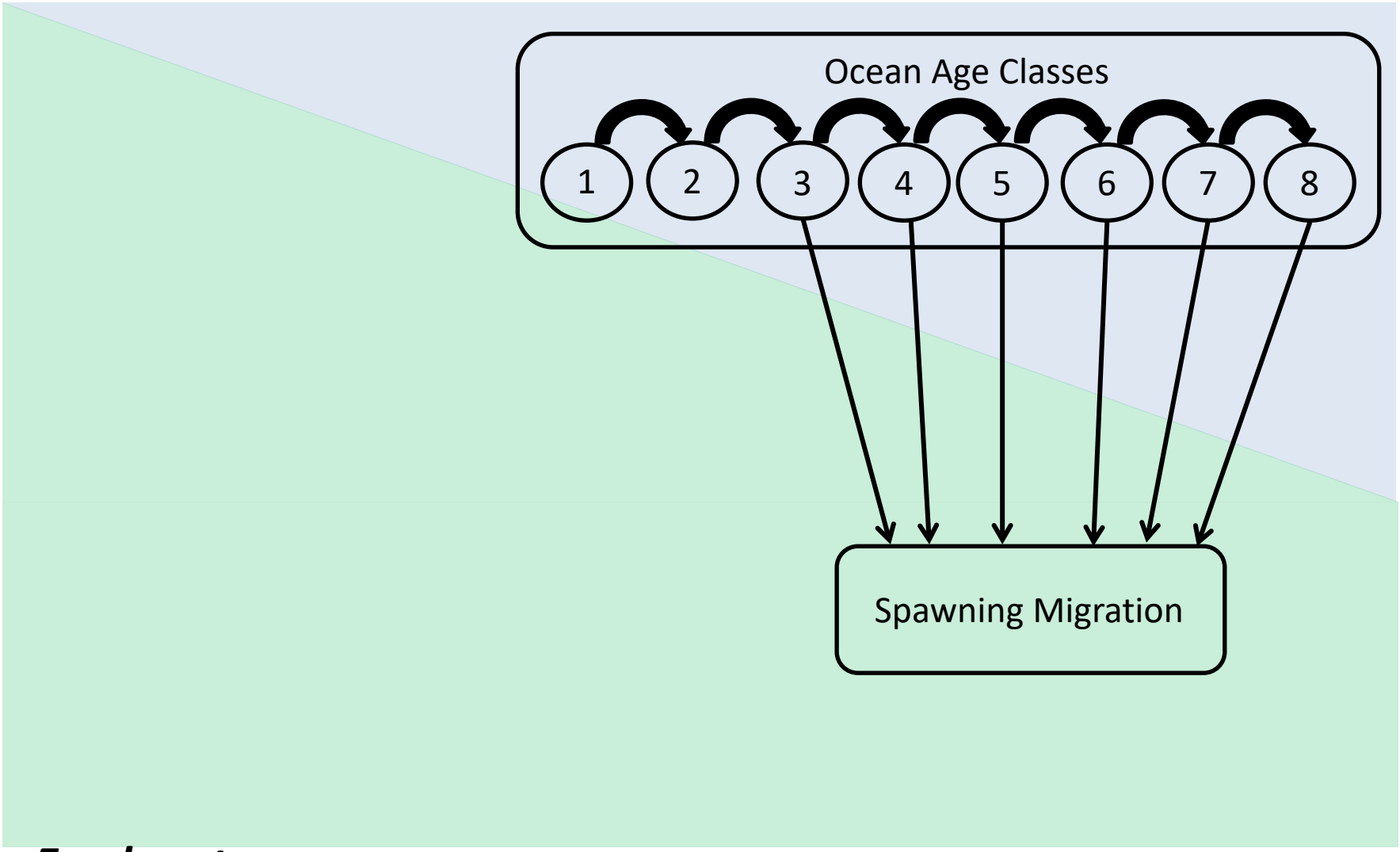
1. Develop deterministic population model
2. Link the estimation of population abundance to dam passage within the river
3. Estimation of net nutrient balance (N and P) for passage scenarios
4. Develop app to compare maximum theoretical spawner abundance between passage scenarios

Marine

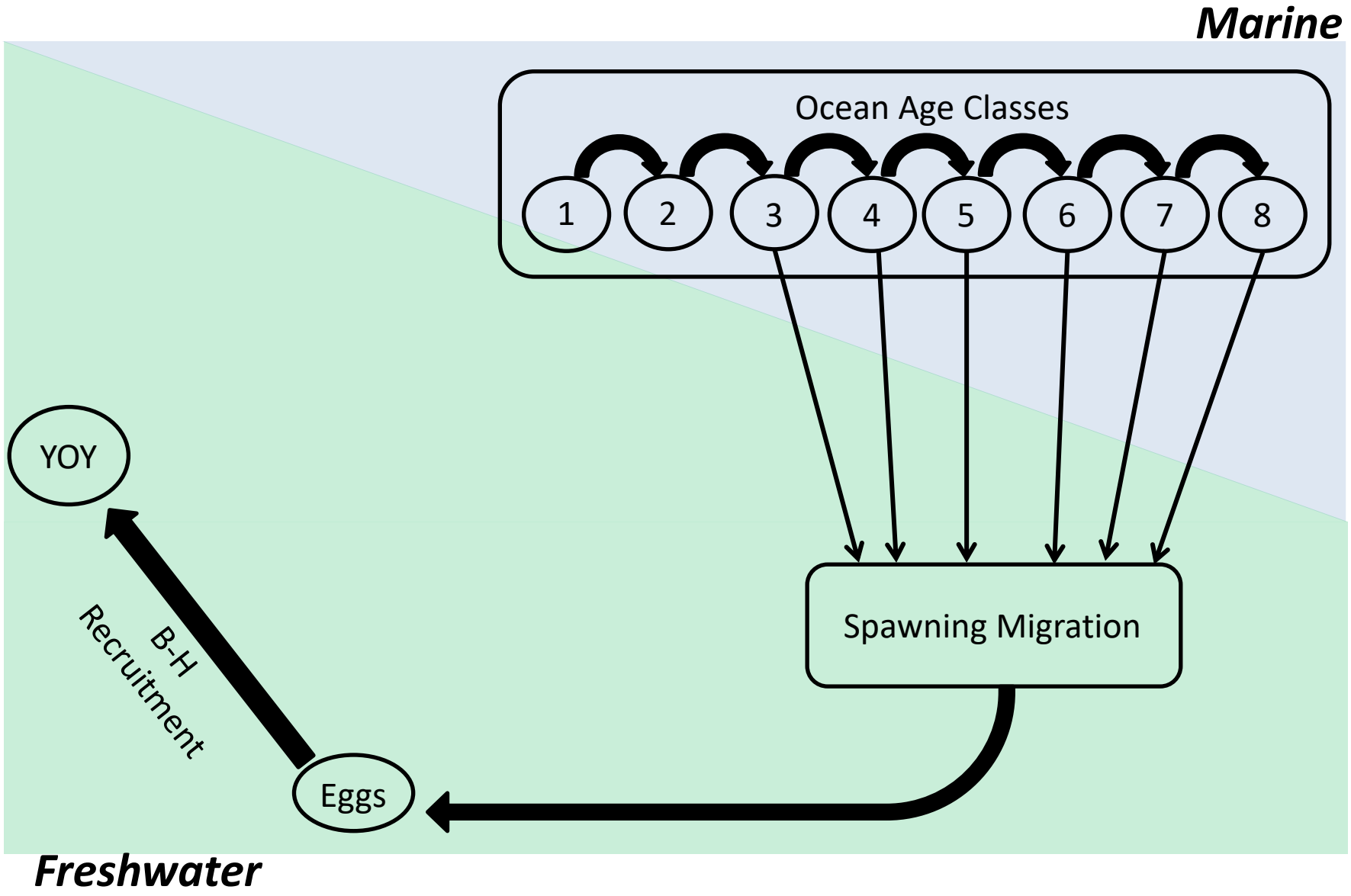


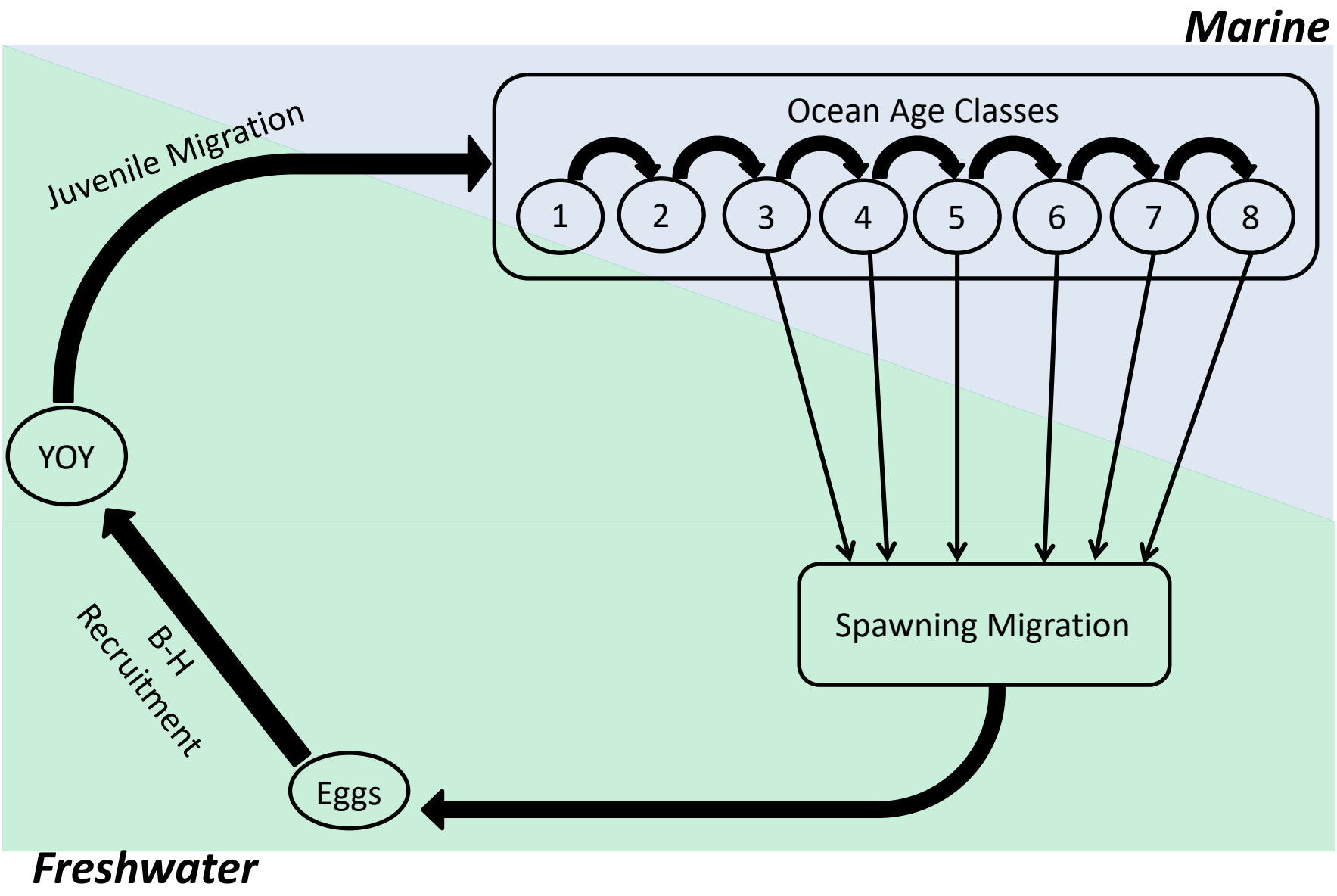
Freshwater

Marine



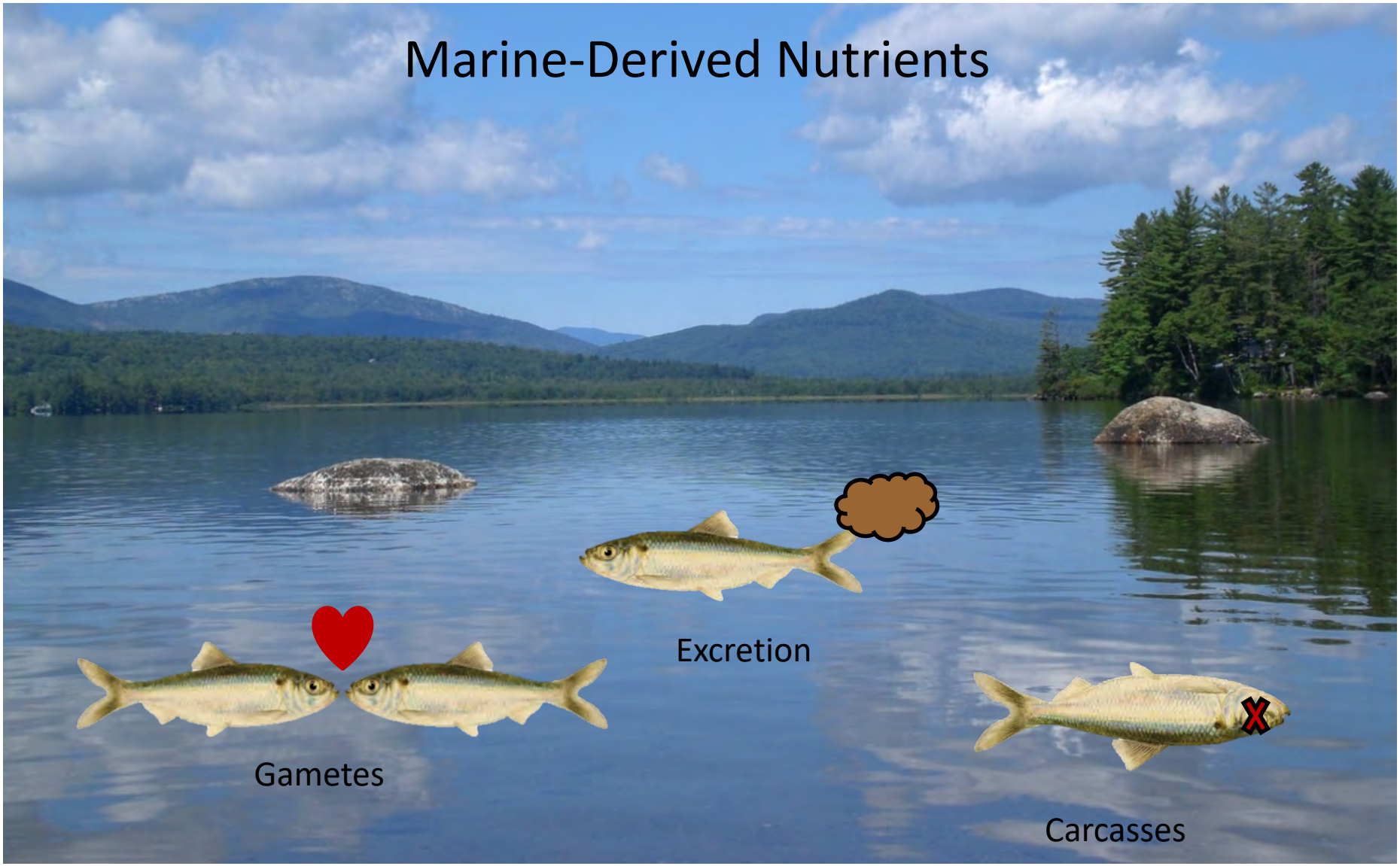
Freshwater


Marine
Ocean Age Classes
1
2
3
4
5
6
7
8
YOY
B-H Recruitment
Eggs
Spawning Migration
Freshwater

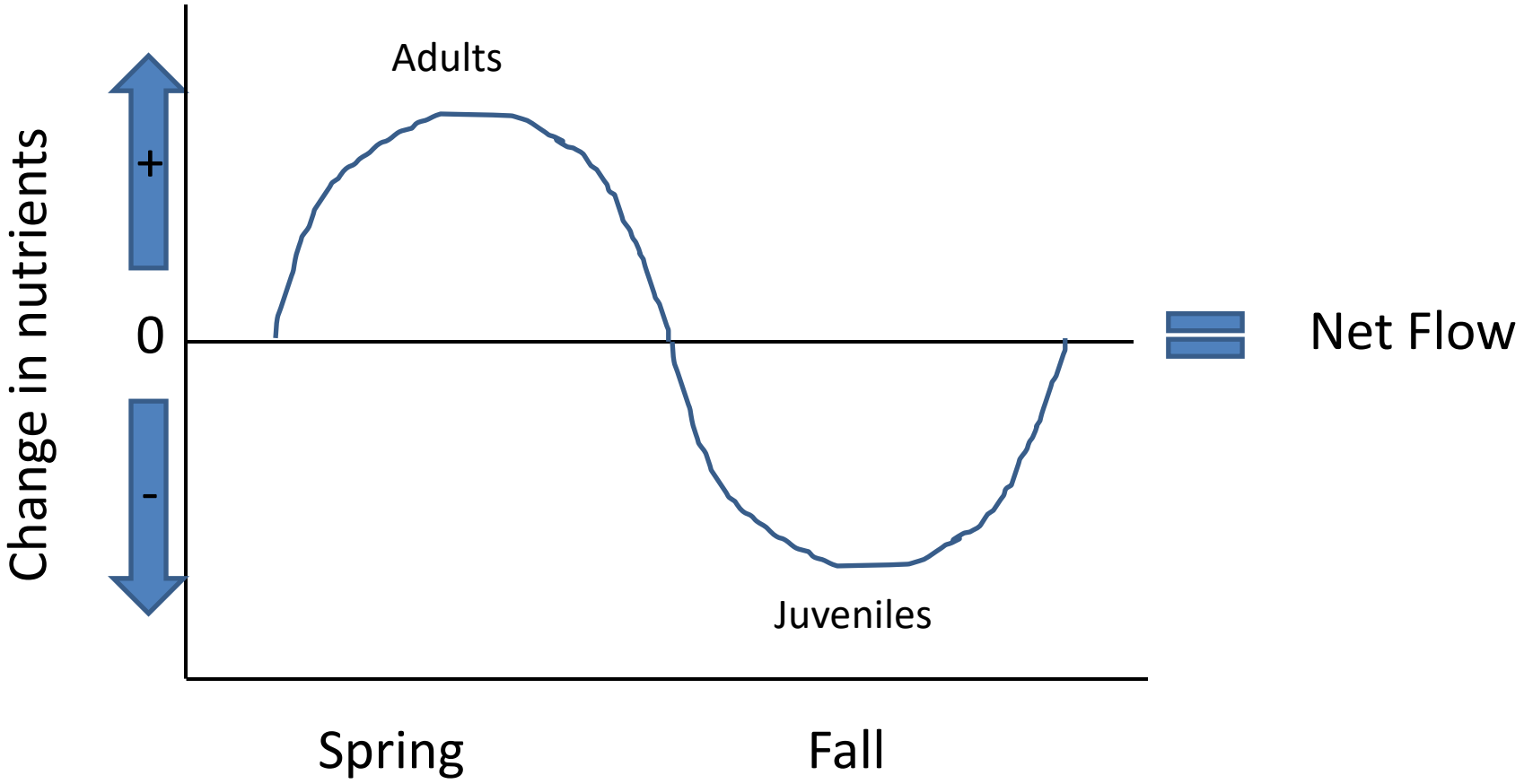

Marine
Ocean Age Classes
1
2
3
4
5
6
7
8
Juvenile Migration
YOY
B-H Recruitment
Eggs
Spawning Migration
Freshwater

Deterministic Model

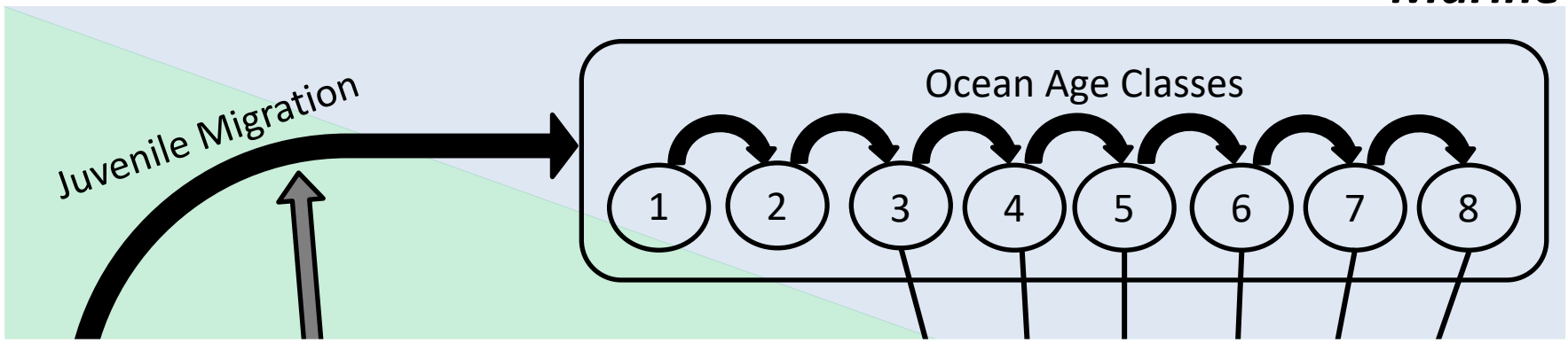
- Population demographics
  - St. Croix River 1981-2016
- Assumptions:
  - No environmental variability built into the model
    - Inputs are averages
  - Homogeneous habitat quality
  - Density-dependent mortality included in recruitment curve
  - In absence of dams, fish distribute throughout system according to habitat availability


Marine-Derived Nutrients
Excretion
Gametes
Carcasses

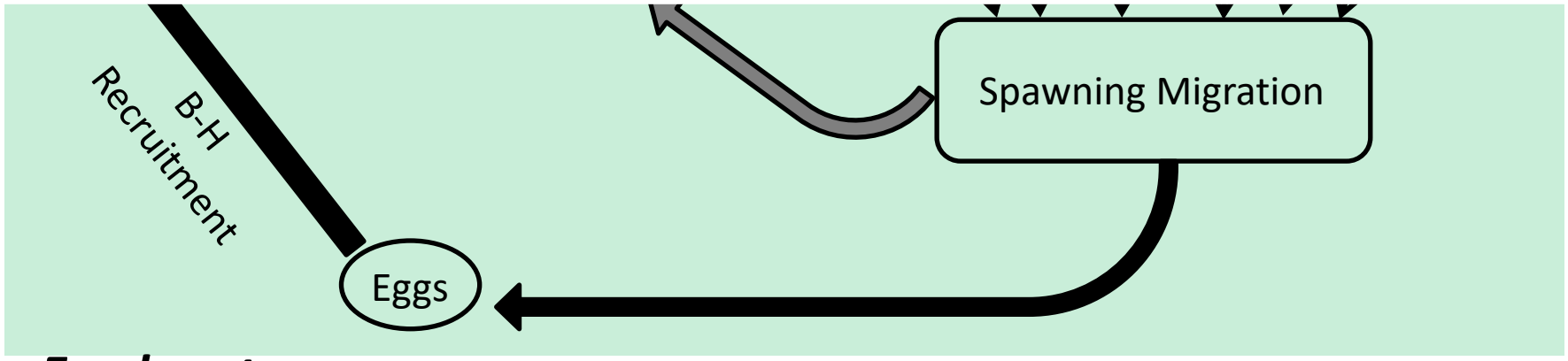
Time Factor


Adults
Change in nutrients
+
0
-
Juveniles
Net Flow
Spring
Fall

Marine



[1]Barber et al. 2018. Does what goes up also come down? Using a recruitment model to balance Alewife nutrient import and export. Marine and Coastal Fisheries. 10: 236-254.

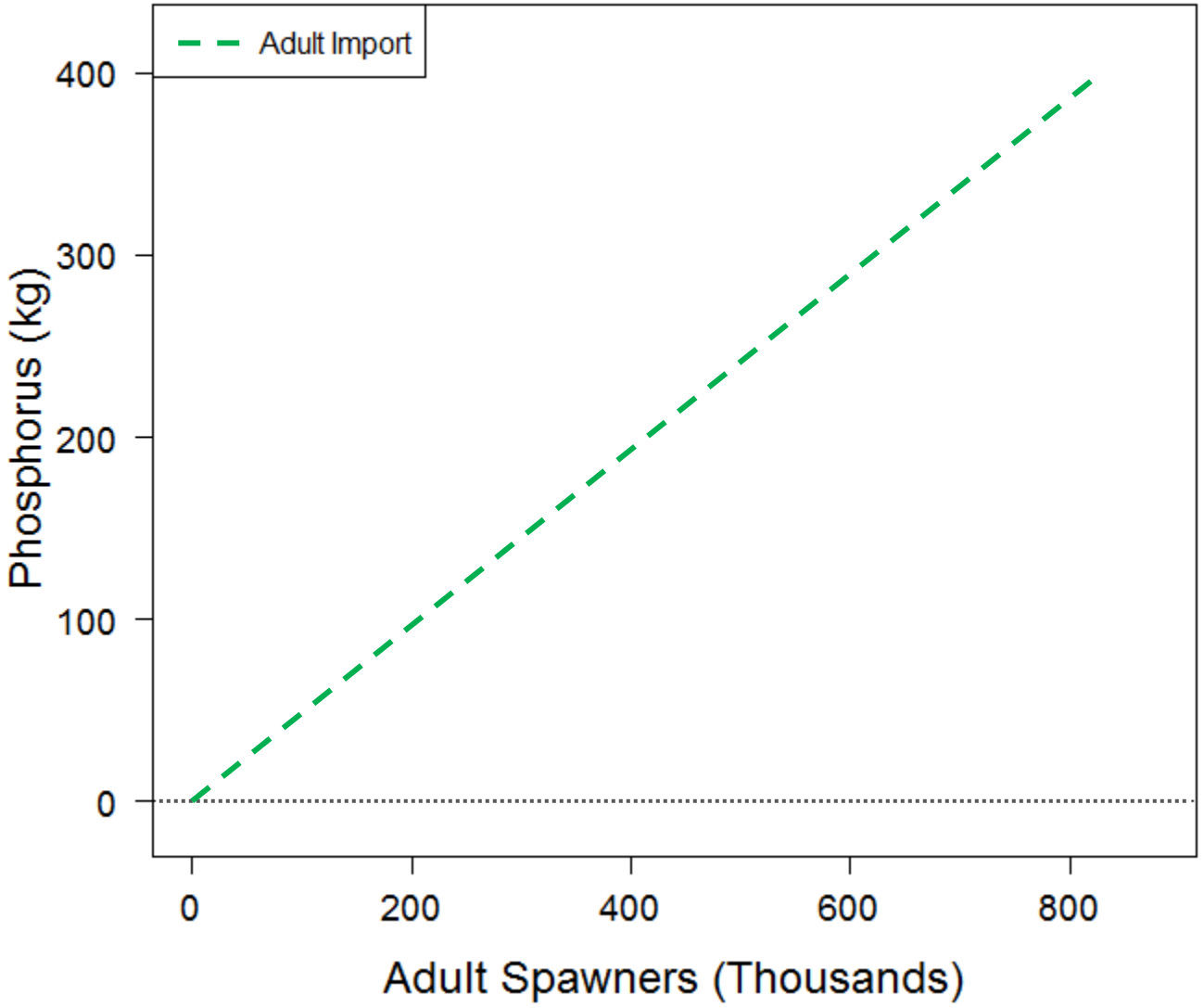


Freshwater

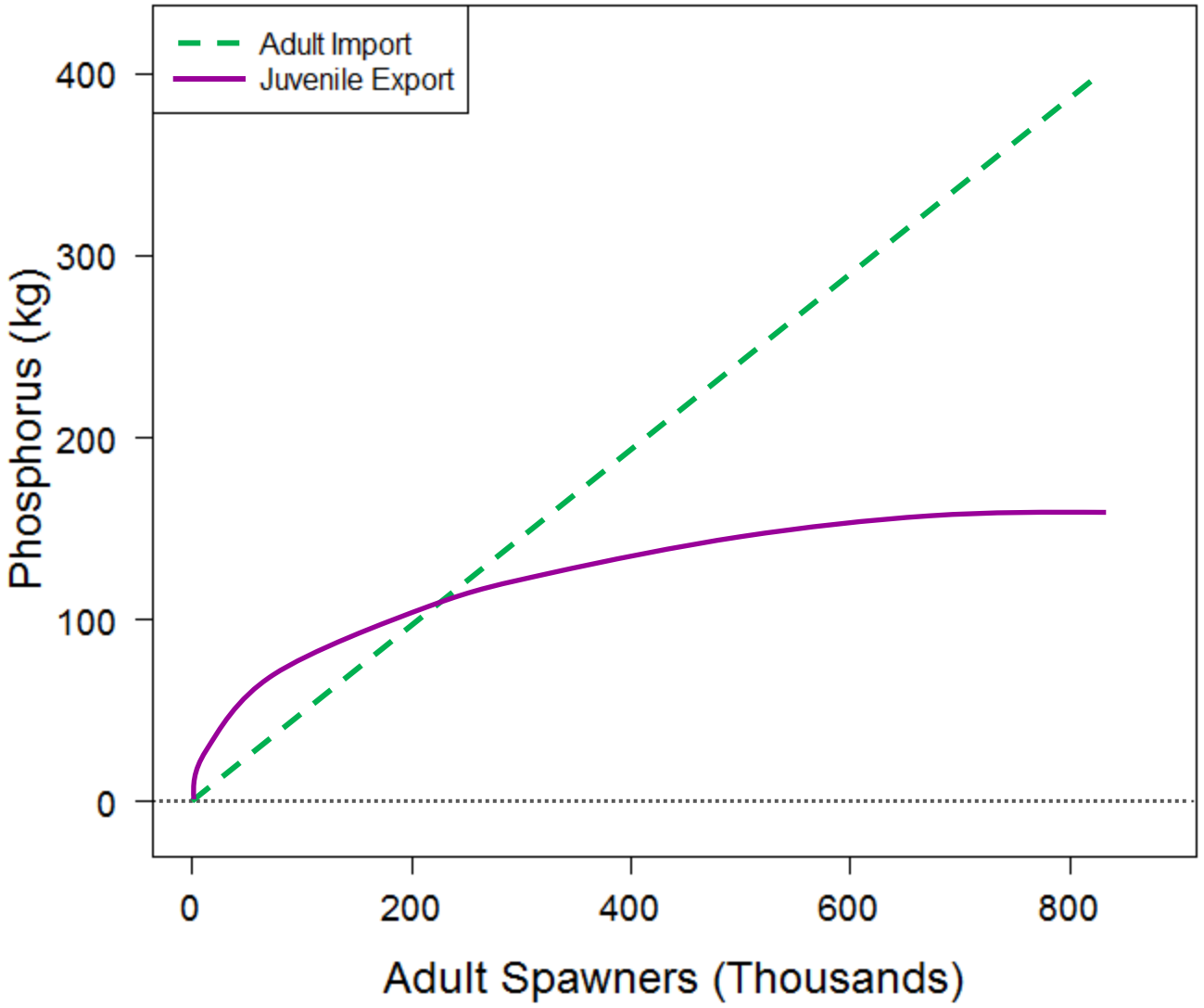
Simulations

- What are the nutrient trends for alewife?
  - No dams and all spawning habitat combined

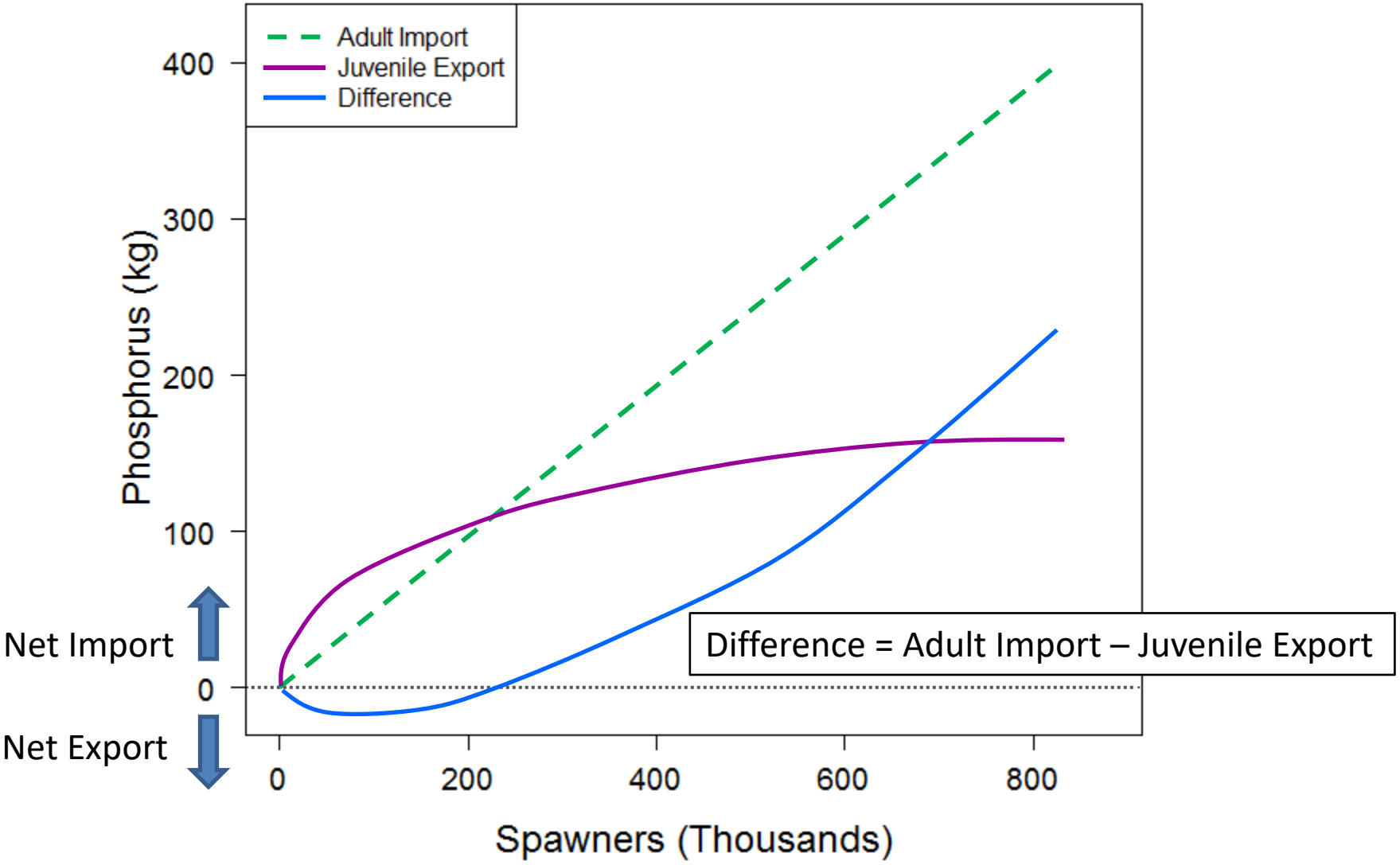
What are the nutrient trends for alewife?



What are the nutrient trends for alewife?



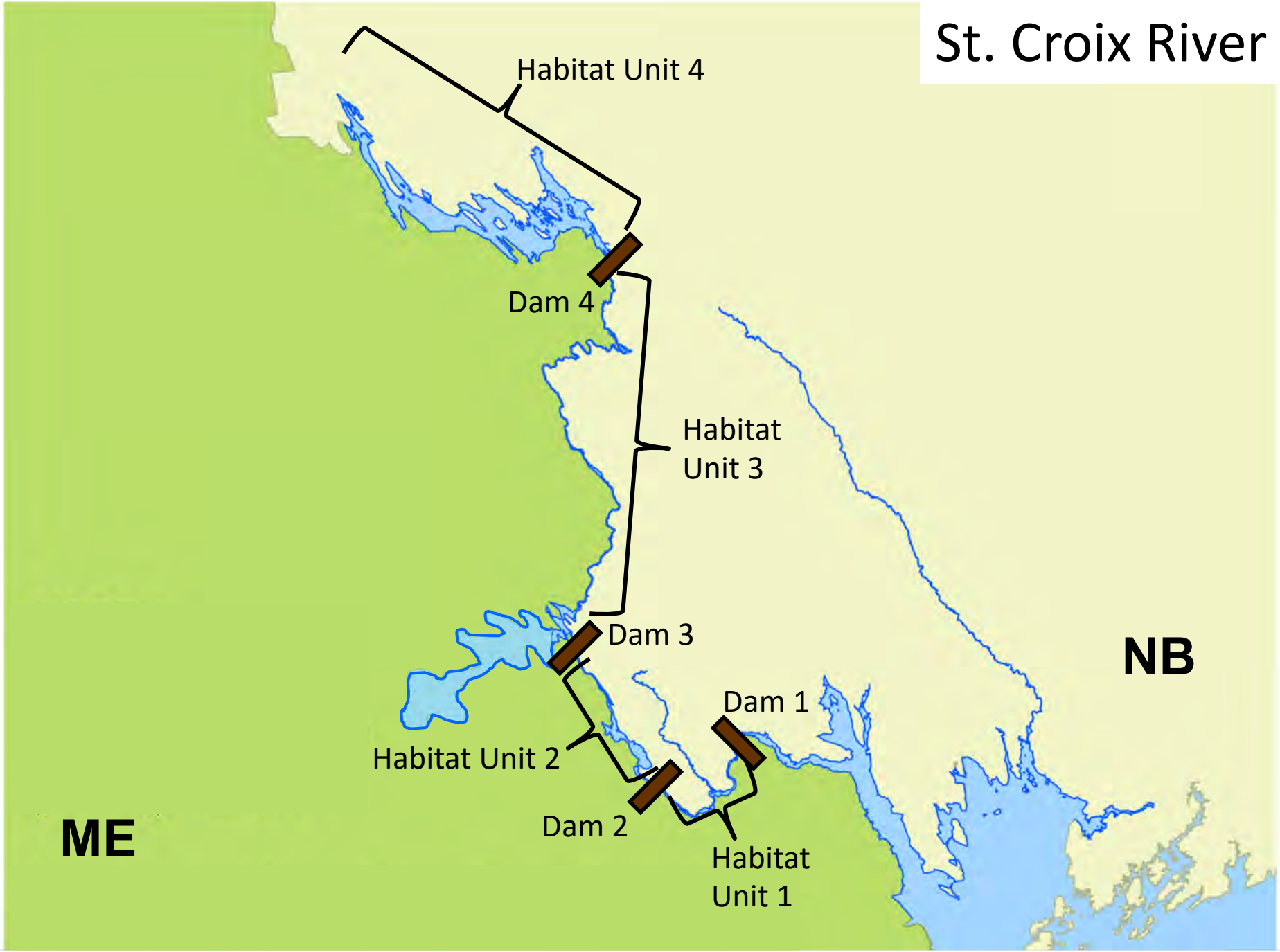
What are the nutrient trends for alewife?

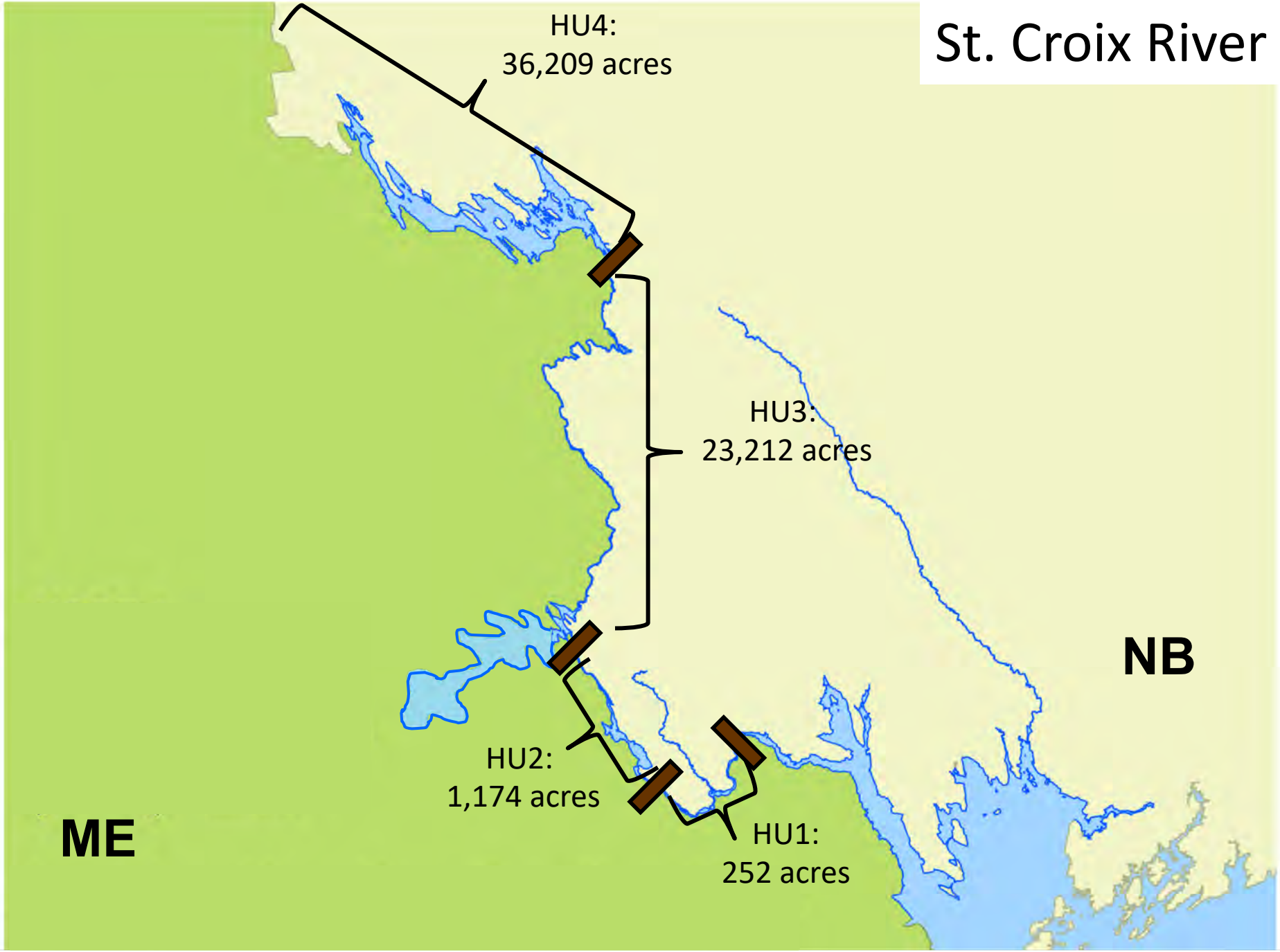


Distribution and Dam Passage

Distribution with No Dams

- Spawners distribute according to the proportion of spawning habitat available:
  - Between each set of dams
  - Upstream of the last dam on the system

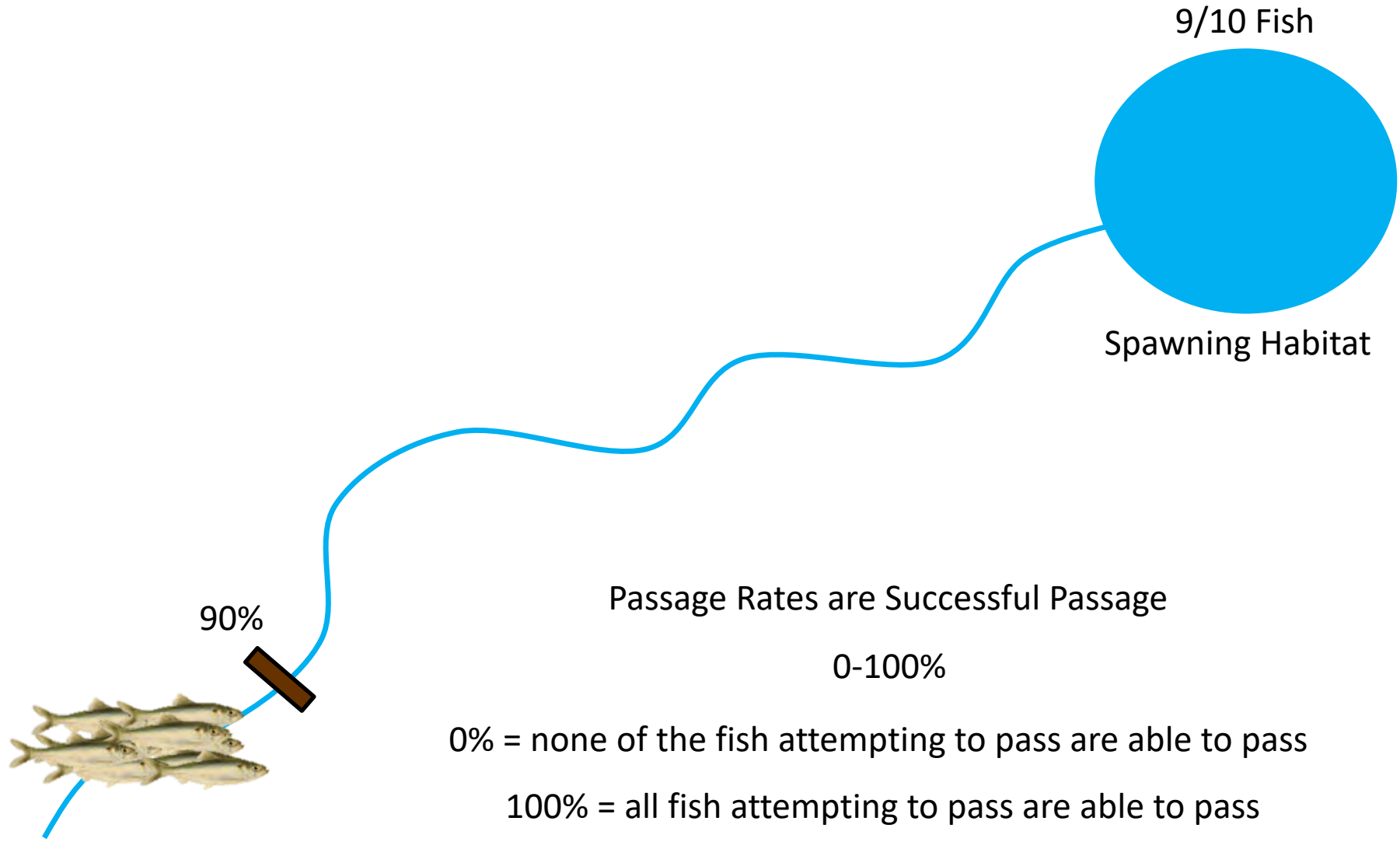

St. Croix River
Habitat Unit 4
Dam 4
Habitat
Unit 3
Dam 3
Dam 1
Habitat Unit 2
Dam 2
Habitat
Unit 1
NB
ME


St. Croix River
HU4:
36,209 acres
HU3:
23,212 acres
HU2:
1,174 acres
HU1:
252 acres
ME
NB

Dam Passage

- Fish distribute according to habitat availability
- But…. Specified passage rates only allow so many fish to pass
- The bottom line:
  - Fish can try to move upstream, but only a certain percentage will do so successfully

Dam Passage



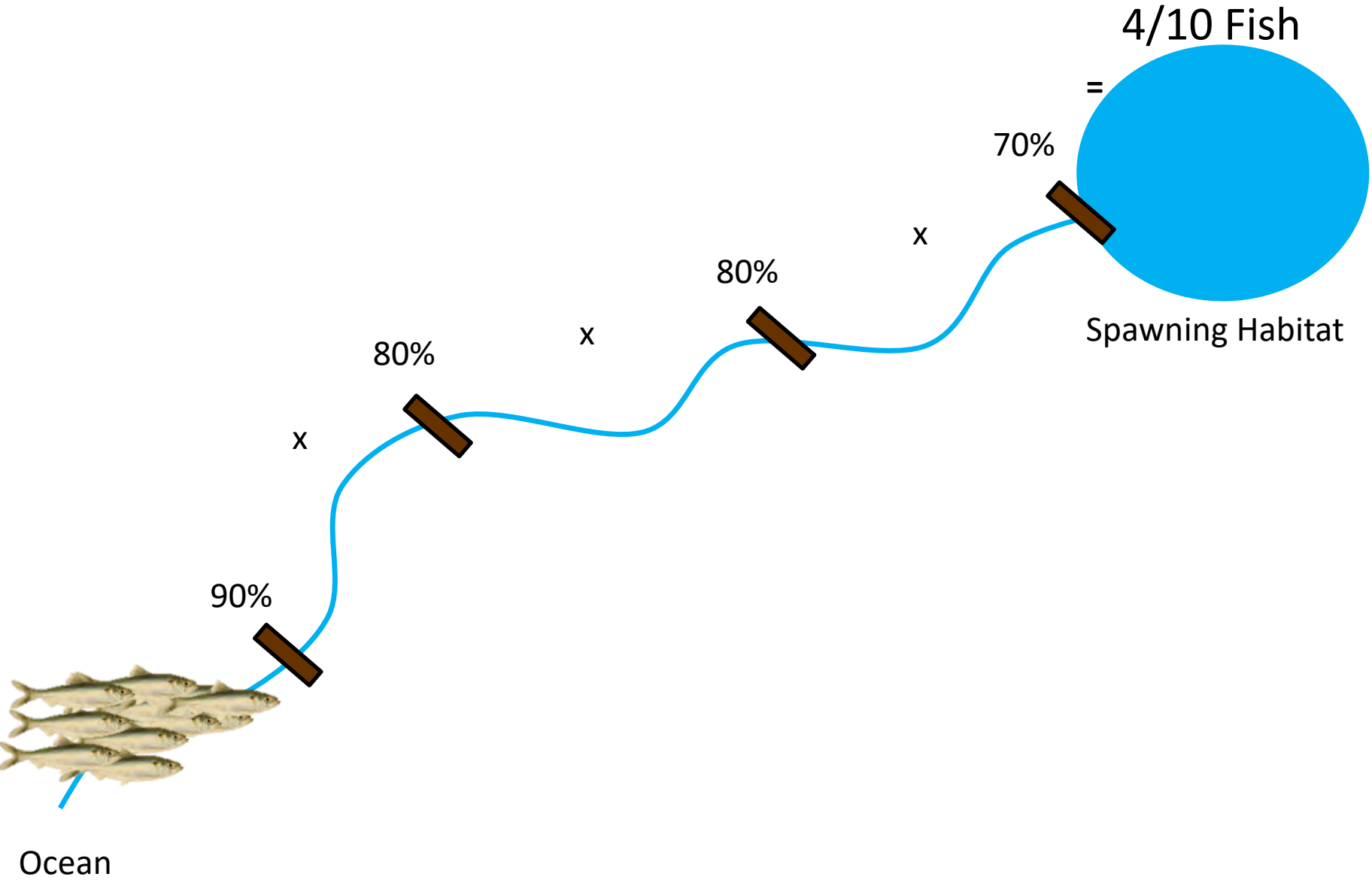
Passage Rates are Successful Passage

0-100%

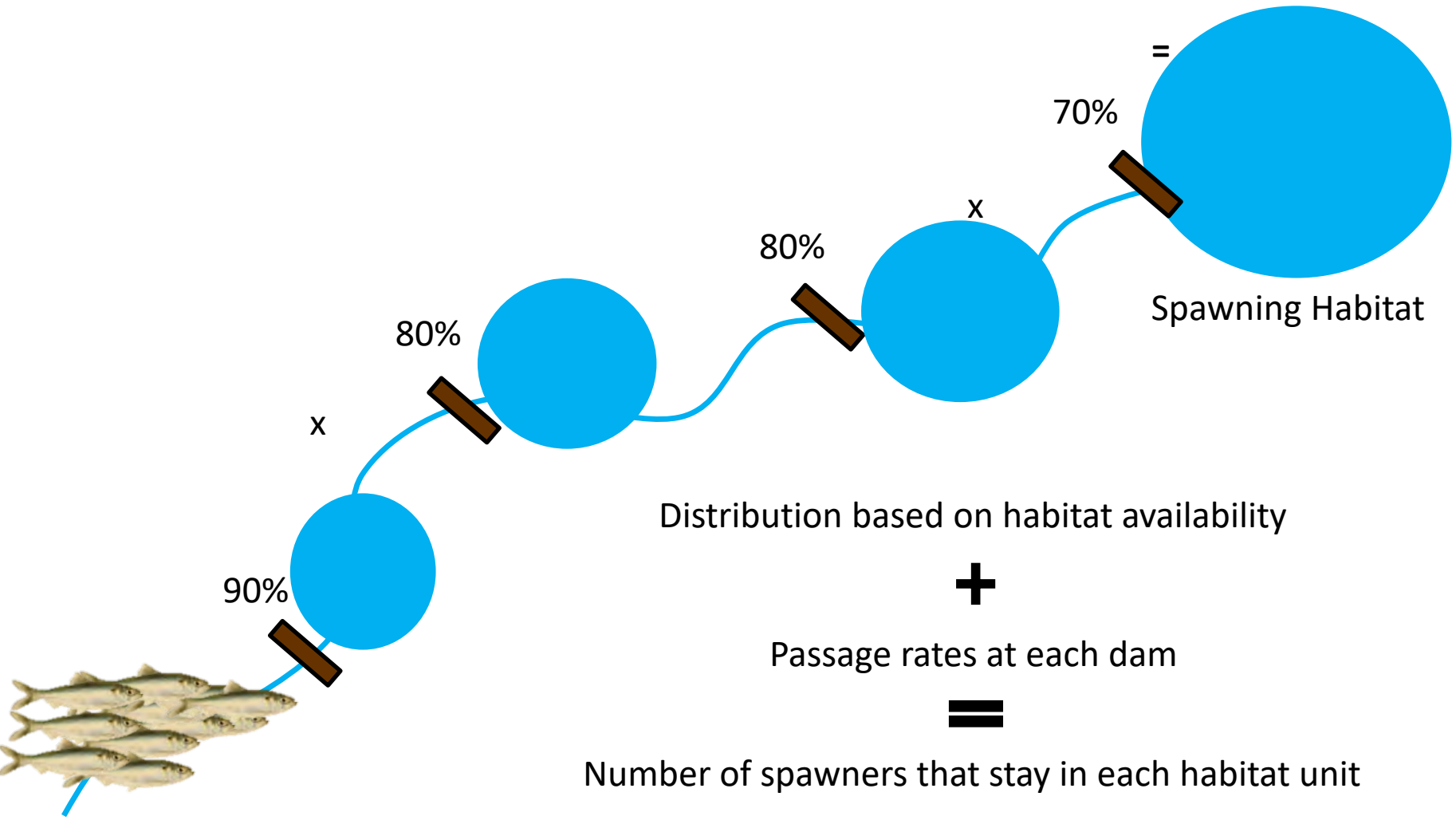
0% = none of the fish attempting to pass are able to pass

100% = all fish attempting to pass are able to pass

Effect of Multiple Dams



Distribution and Multiple Dams



Distribution based on habitat availability

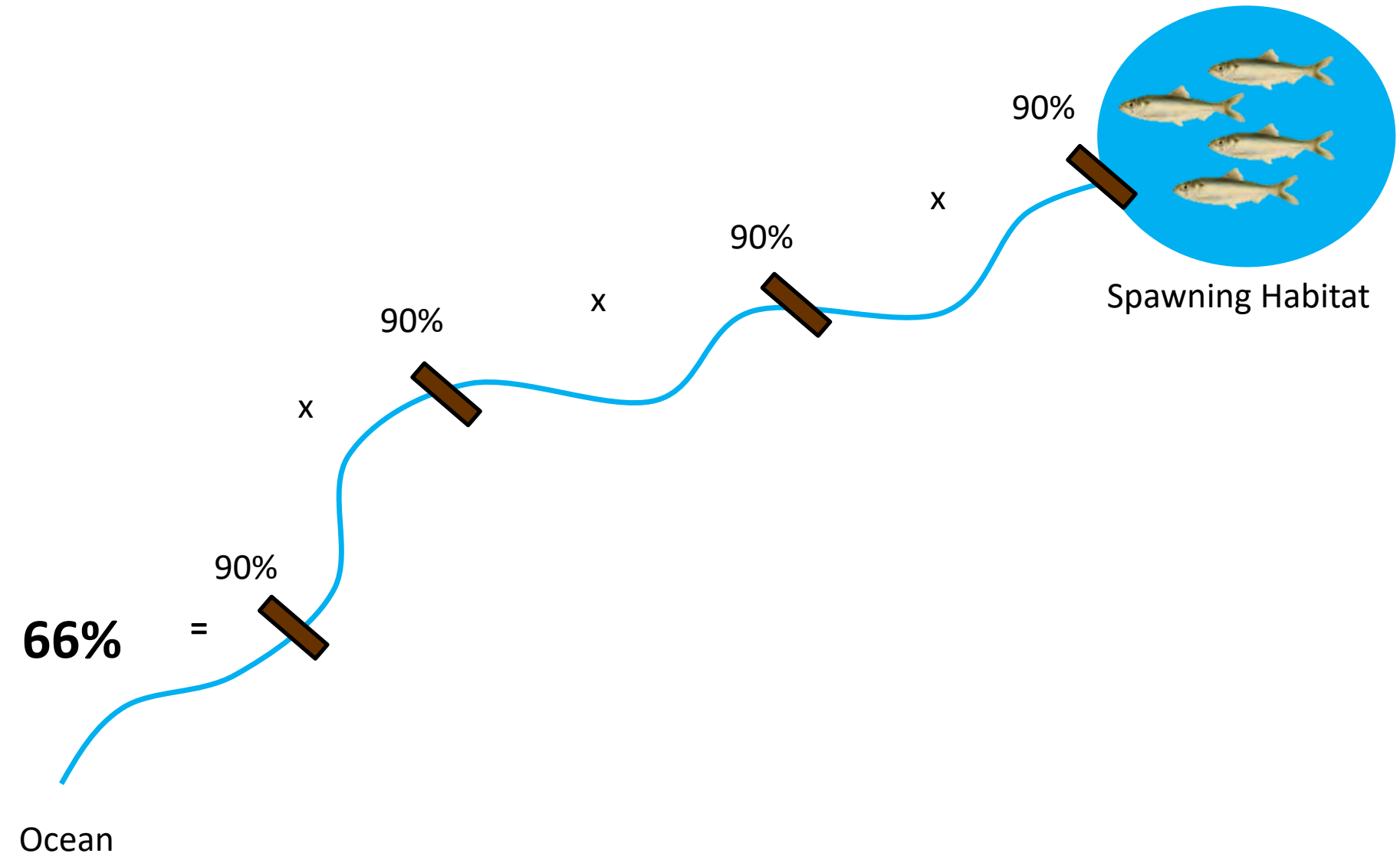
+

Passage rates at each dam

=

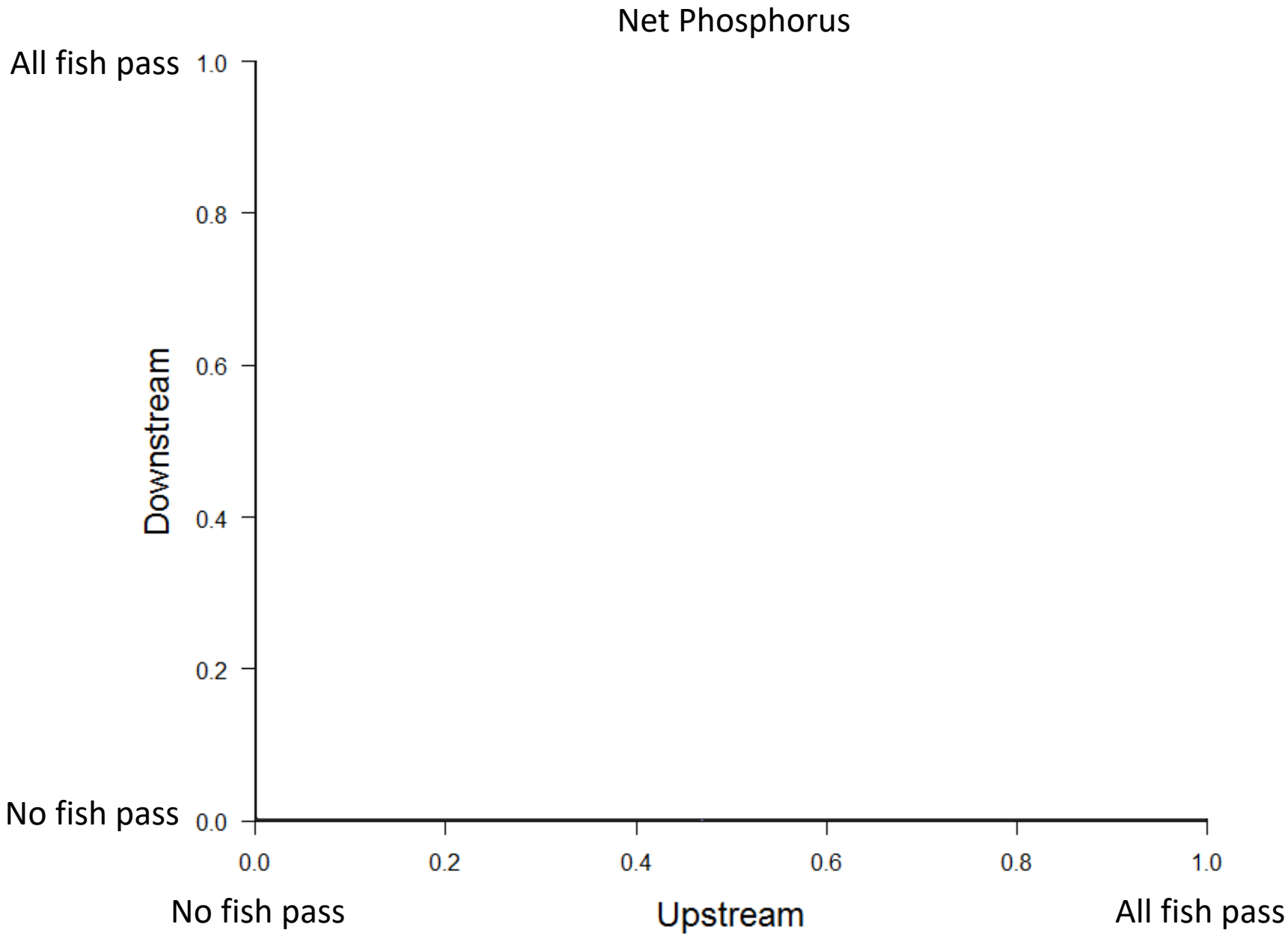
Number of spawners that stay in each habitat unit

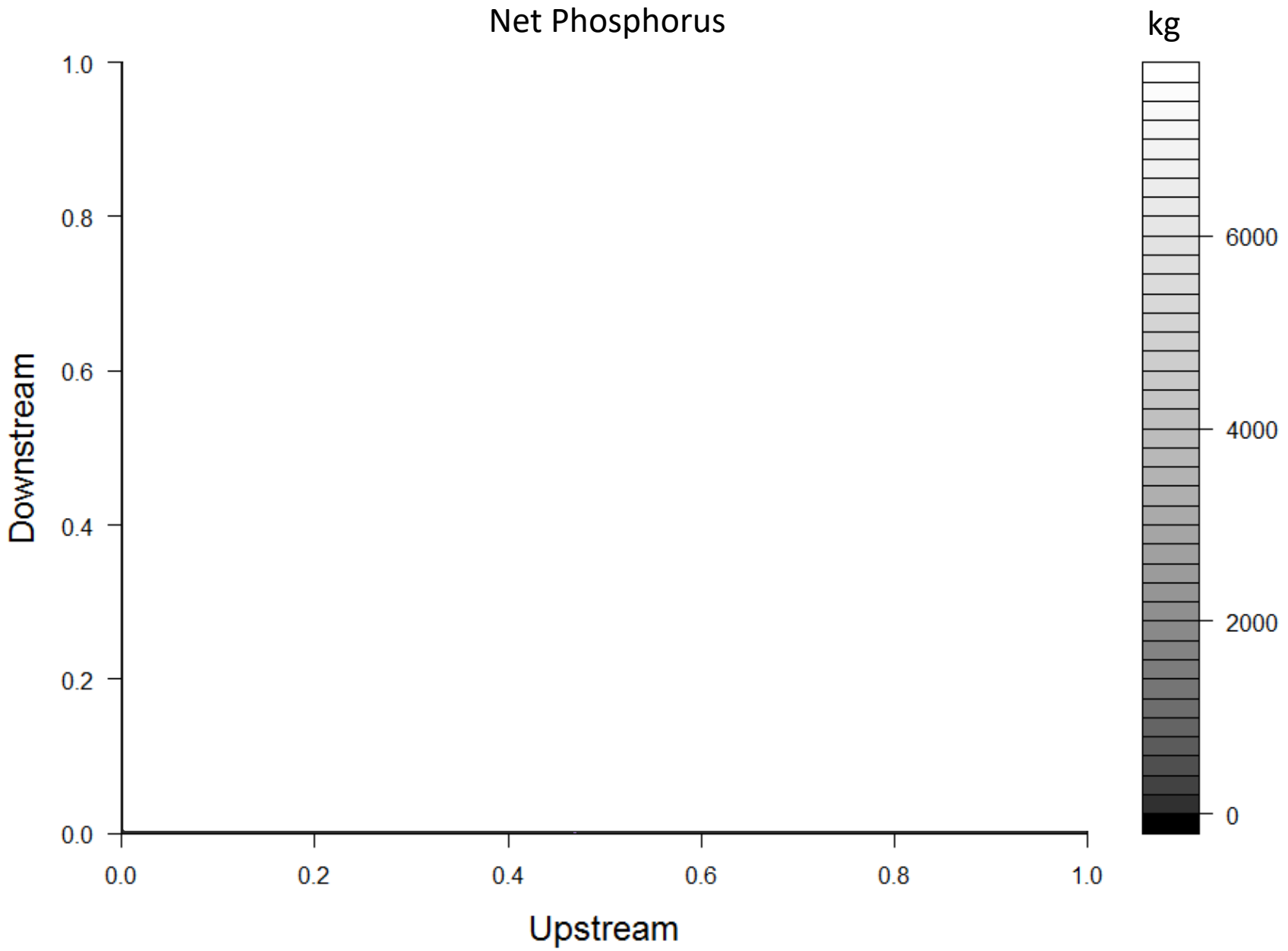
Adult and Juvenile Downstream Passage

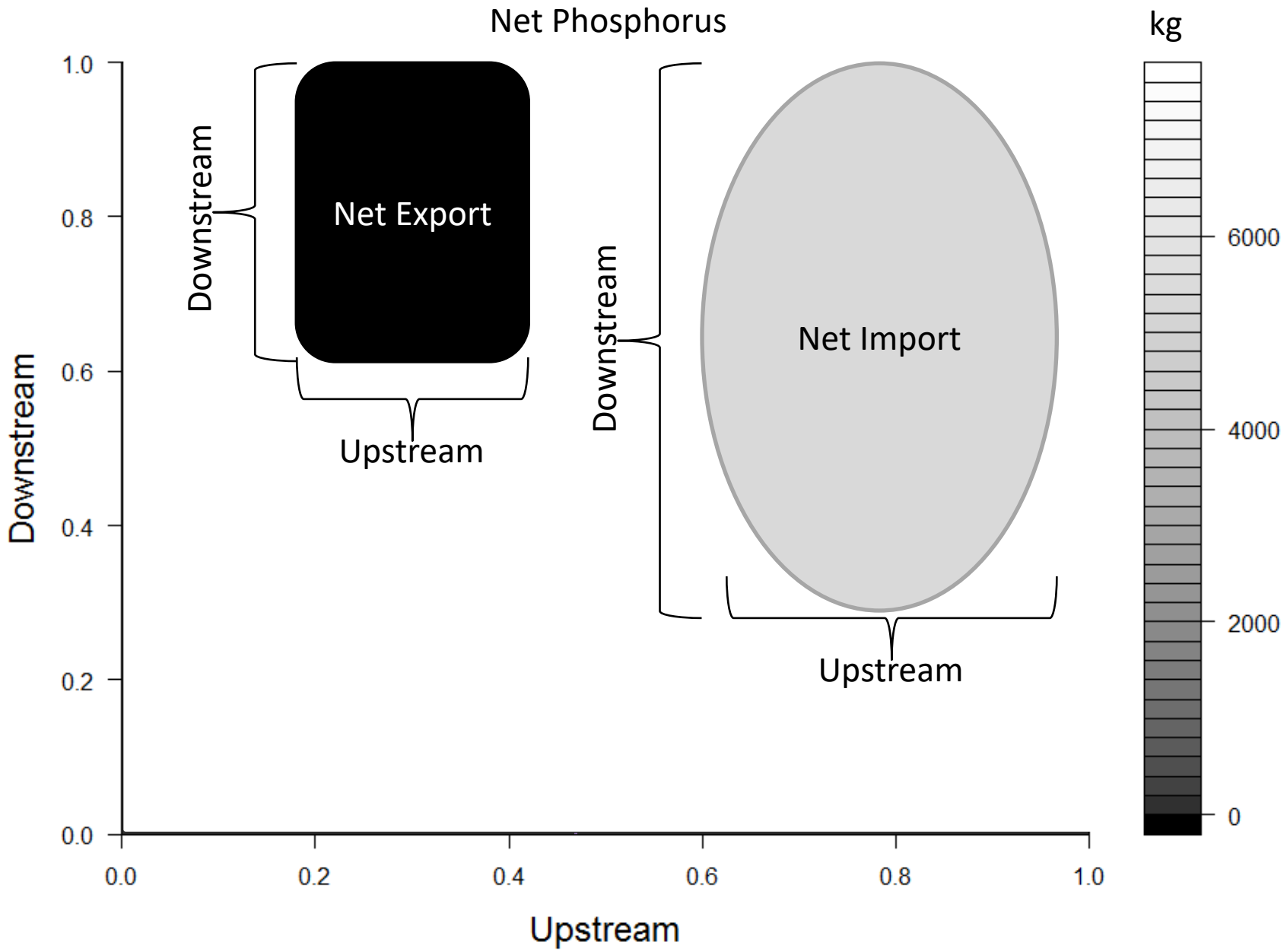


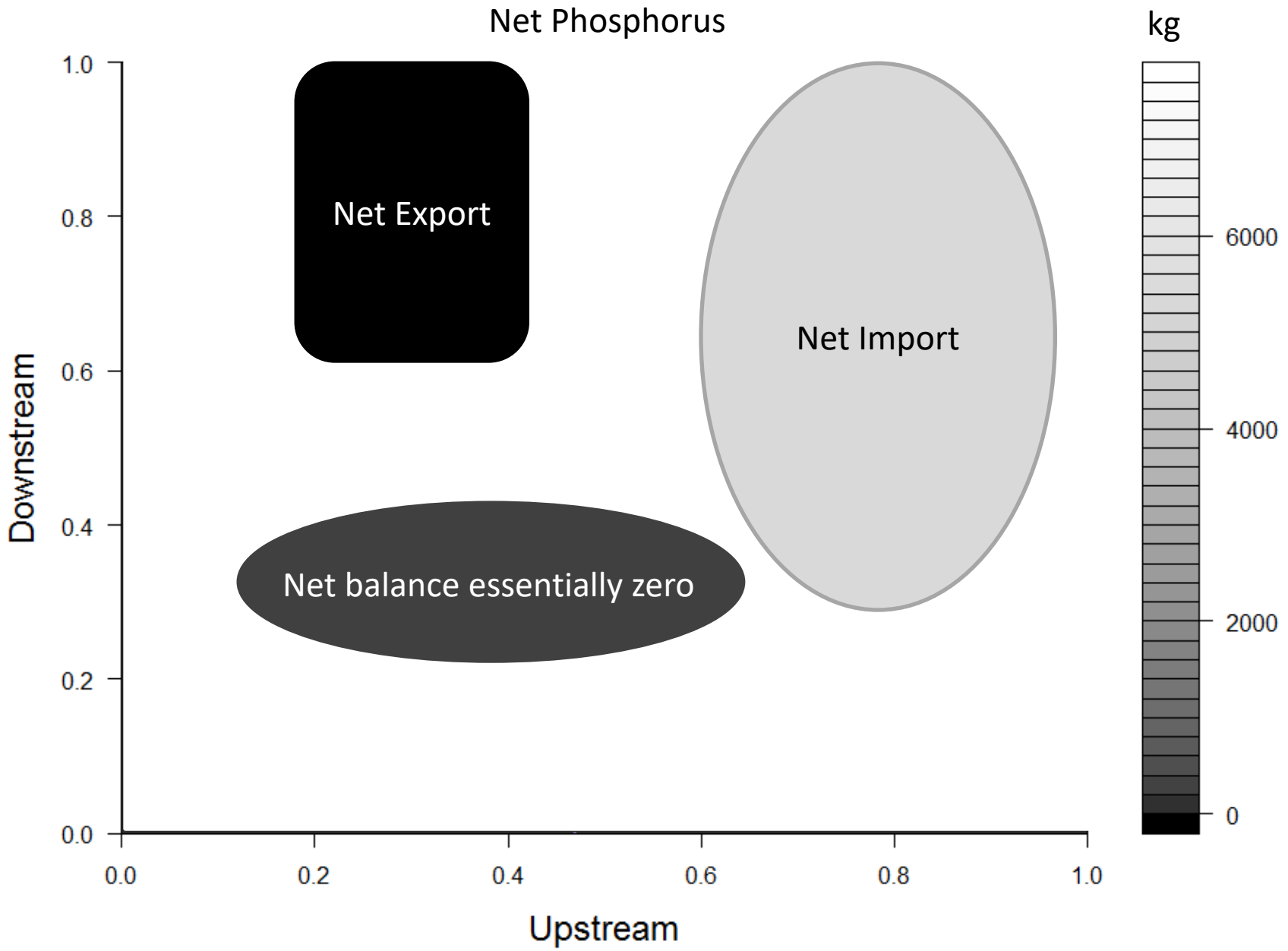
Nutrient Dynamics

- Phosphorus balance associated with a range of upstream and downstream passage rates
- St. Croix River

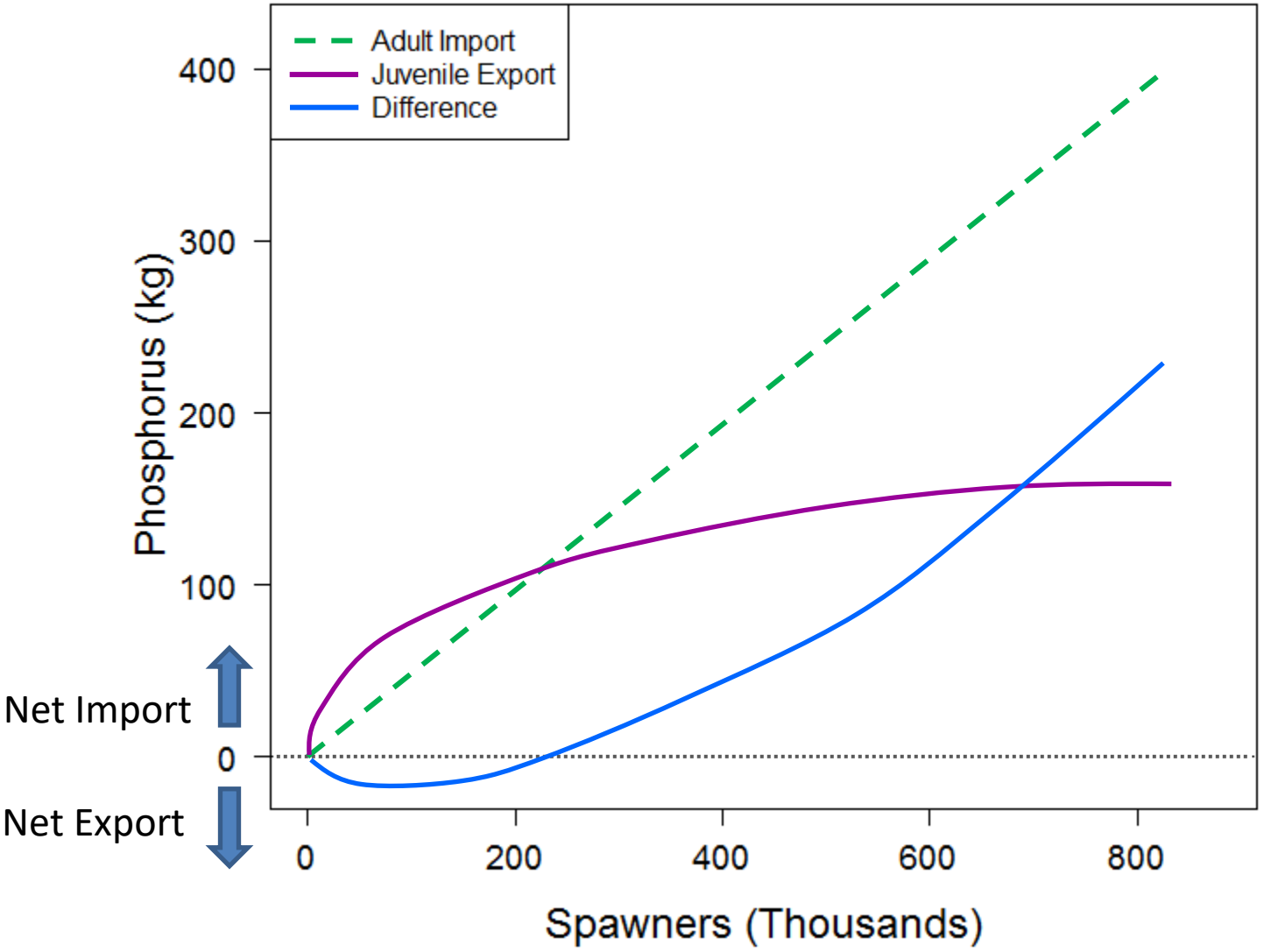

Net Phosphorus
All fish pass
No fish pass
Downstream
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
No fish pass
Upstream
All fish pass

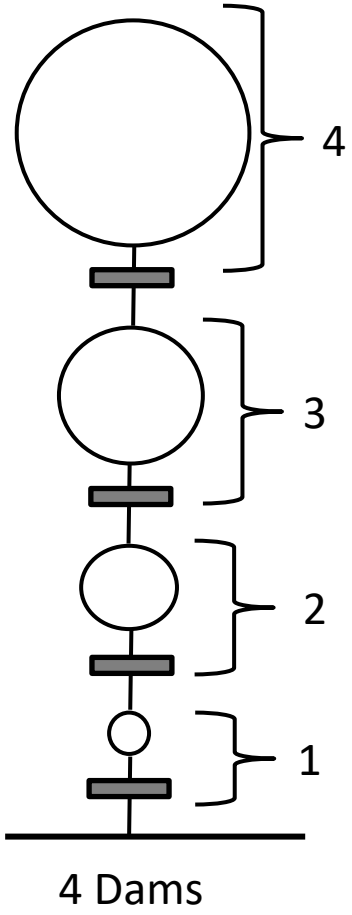

Net Phosphorus
kg
6000
4000
2000
0
Downstream
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Upstream

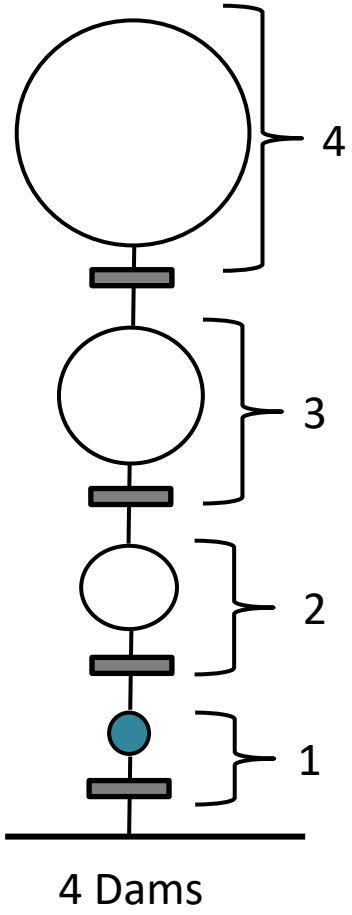

Net Phosphorus
kg
Net Export
Net Import
Downstream
Upstream
Downstream
Upstream
Downstream
Upstream
0.0
0.2
0.4
0.6
0.8
1.0
0
2000
4000
6000

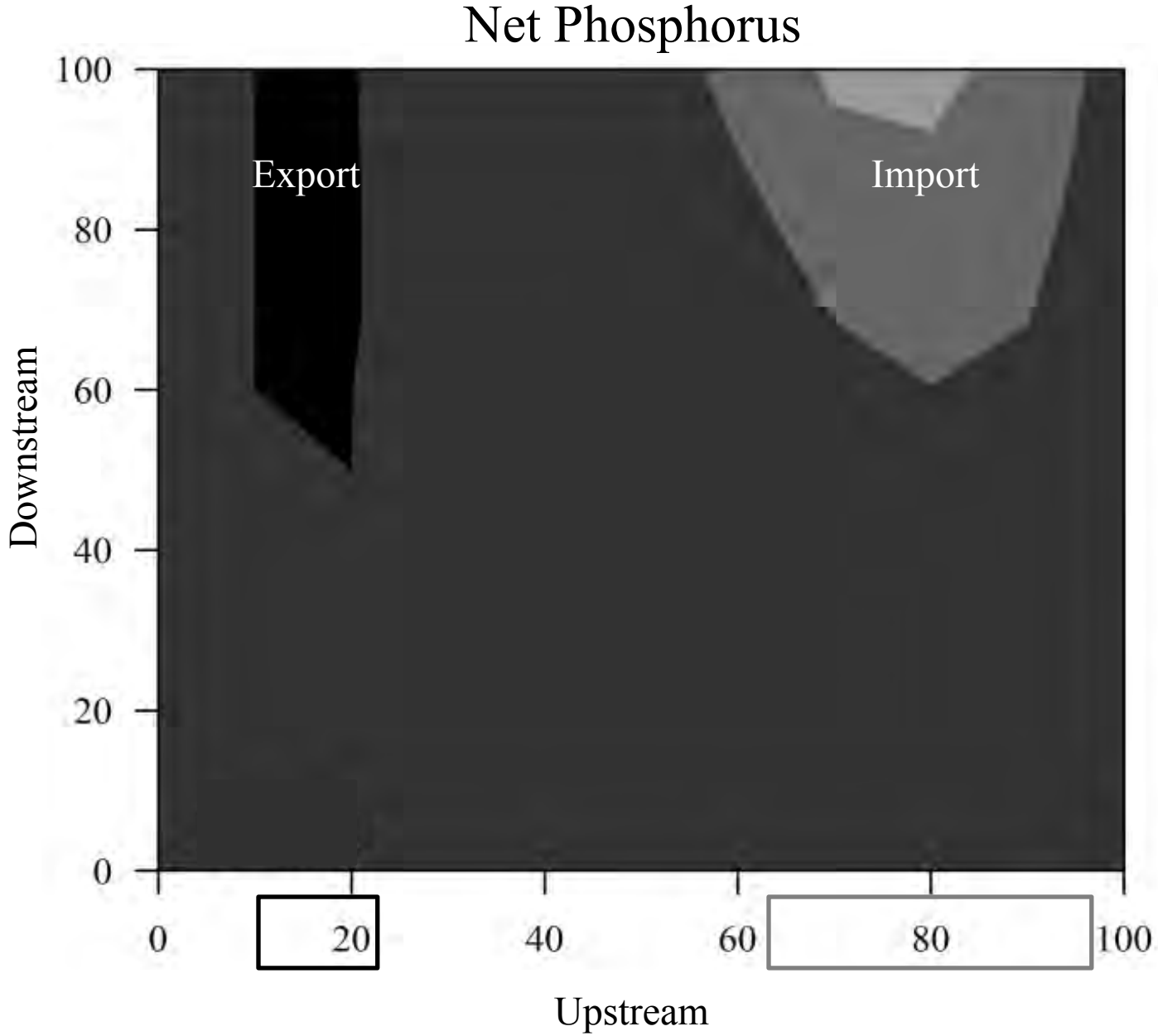

Net Phosphorus
kg
Net Export
Net Import
Net balance essentially zero
Downstream
Upstream
0.0
0.2
0.4
0.6
0.8
1.0
6000
4000
2000
0

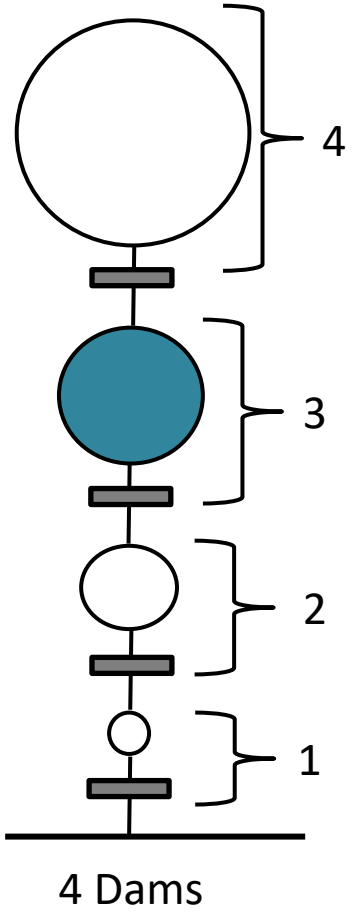
What are the nutrient trends for alewife?

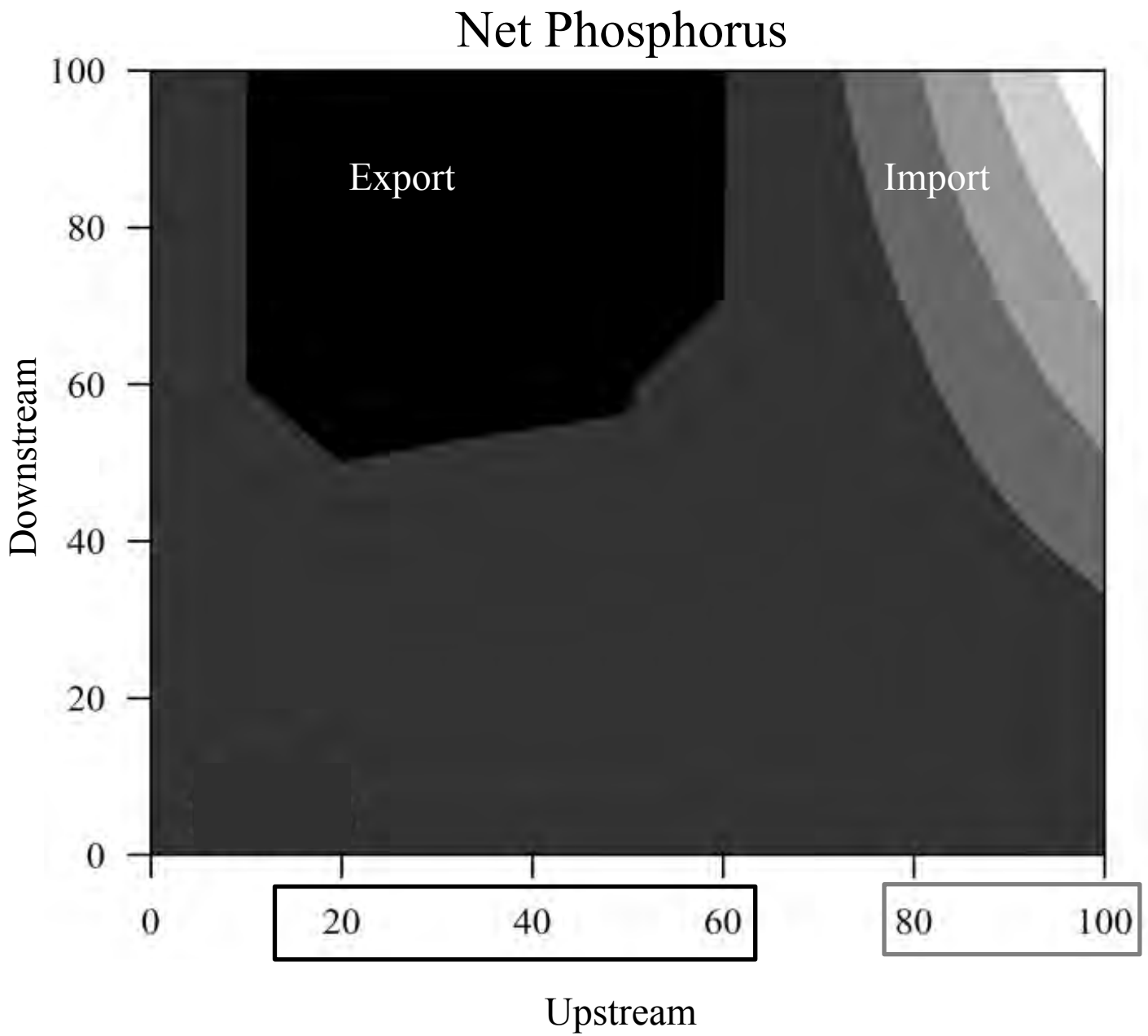



4
3
2
1
4 Dams


4
3
2
1
4 Dams


Net Phosphorus
Export
Import
Downstream
Upstream
100
80
60
40
20
0
0
20
40
60
80
100

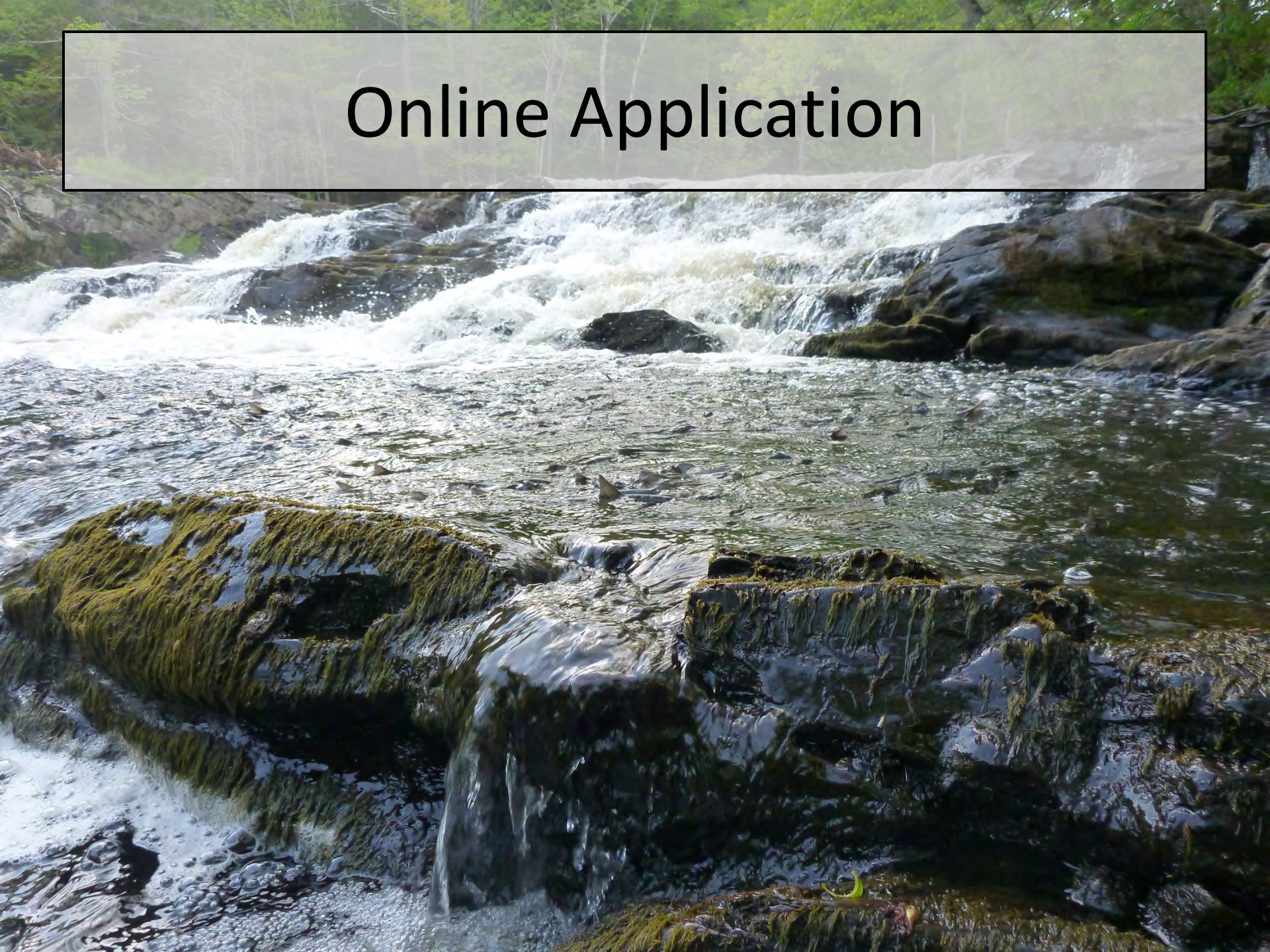

4
3
2
1
4 Dams


Net Phosphorus
Export
Import
Downstream
100
80
60
40
20
0
0
20
40
60
80
100
Upstream

Management Implications

- Low population levels could maintain P balance at net export
  - Will depend on location of passage bottlenecks in relation to spawning habitat
- Magnitude of net export by juveniles is relatively small
- Alewife input of N and P could also be small compared to watershed contributions

Online Application



Dynamic **M**odelling for **A**lewife **P**opulations and **P**assage

- Connect population model to a user interface
  - Using the R package shiny
- This allows us to access the application and run simulations online
- "Reactive"
  - Application "reacts" to the inputs specified by the user

- **Not meant to make forecasts, but rather to look at general trends and how things change given a new set of values!**

Example Question:

How dam removal might affect population abundance in the St. Croix River

Step 1: Create your River

Choose your system

Create your own system

Choose number of dams

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

Name of dam #1

Dam 1

Name of dam #2

Dam 2

Name of dam #3

Dam 3

Available habitat (acres) dam #1

200

Available habitat (acres) dam #2

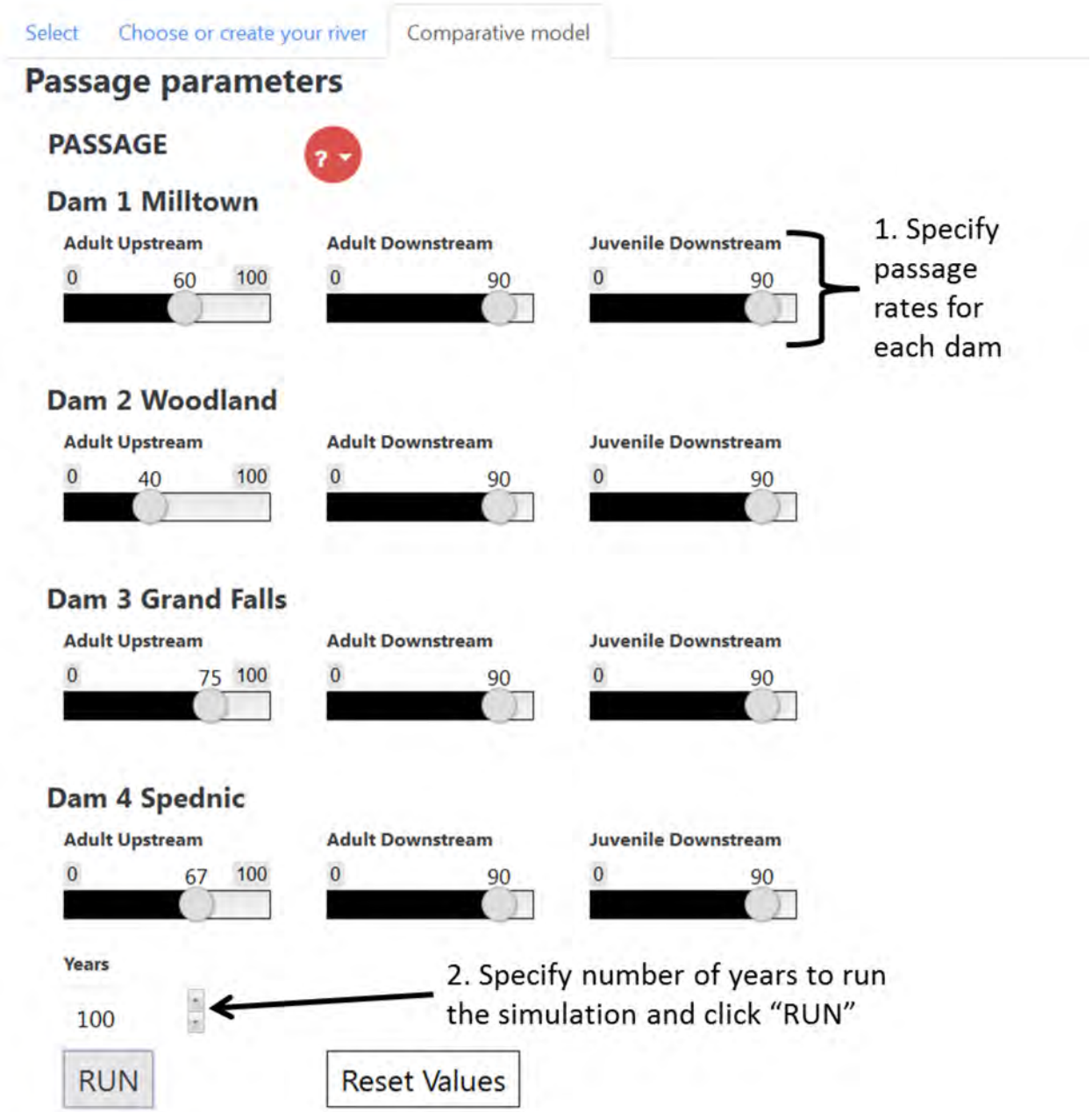
200

Available habitat (acres) dam #3

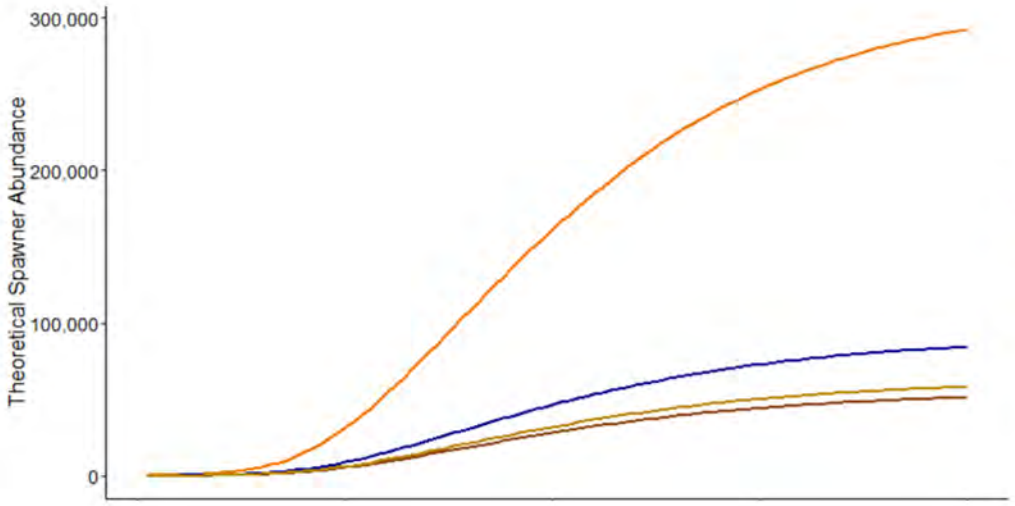
200

Press button to load river

Load


Select
Choose or create your river
Comparative model
Passage parameters
PASSAGE
Dam 1 Milltown
Adult Upstream
0 60 100
Adult Downstream
0 90
Juvenile Downstream
0 90
1. Specify passage rates for each dam
Dam 2 Woodland
Adult Upstream
0 40 100
Adult Downstream
0 90
Juvenile Downstream
0 90
Dam 3 Grand Falls
Adult Upstream
0 75 100
Adult Downstream
0 90
Juvenile Downstream
0 90
Dam 4 Spednic
Adult Upstream
0 67 100
Adult Downstream
0 90
Juvenile Downstream
0 90
Years
100
2. Specify number of years to run the simulation and click "RUN"
RUN
Reset Values

Results



Results for the habitat unit associated with each dam

Save for comparison

Click button to save totals for comparison between simulations

Juveniles | Ocean | Spawning

Click to download data as csv files

juveniles | ocean | Spawning

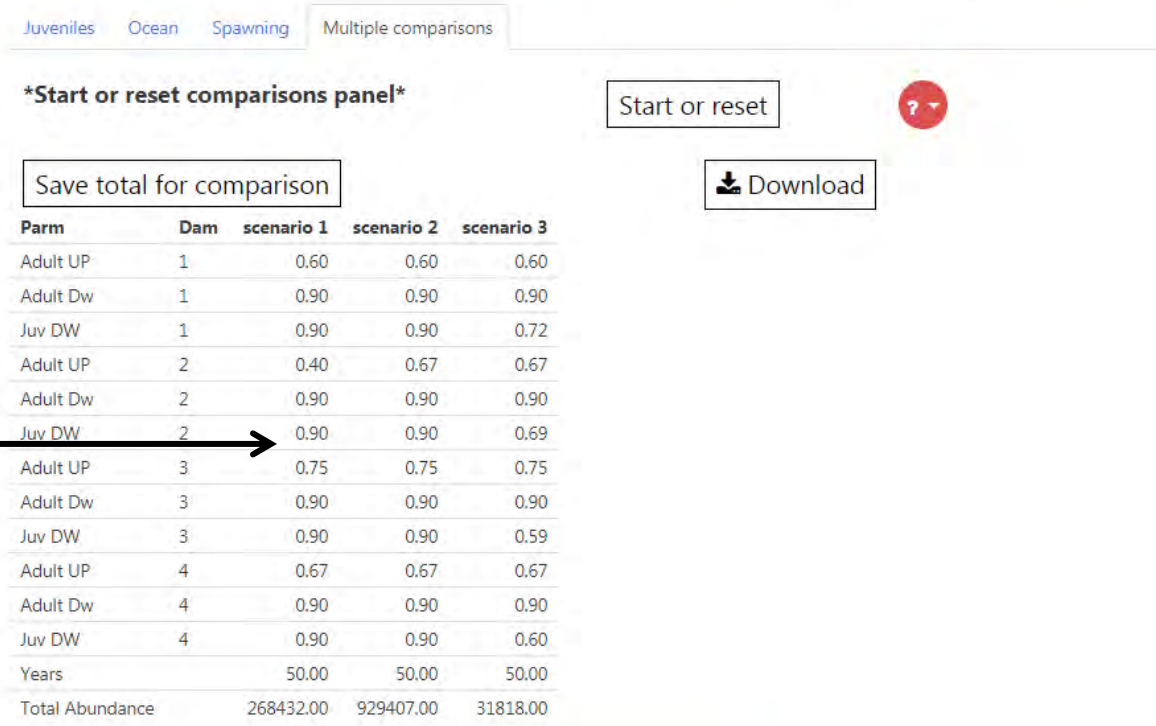
Year	JuvenilesHU1	JuvenilesHU2	JuvenilesHU3	JuvenilesHU4	SurvivingJuvenilesHU1	Survivin
1	18617.00	3628.00	5293.00	3152.00	16755.00	
2	14573.00	2732.00	4062.00	2631.00	13115.00	
3	16487.00	2978.00	4845.00	2921.00	14838.00	
4	23603.00	4354.00	6883.00	4466.00	21242.00	

Results displayed as table

Making Comparisons

1. Run multiple simulations

2. Save the passage rates specified for each



Parm	Dam	scenario 1	scenario 2	scenario 3
Adult UP	1	0.60	0.60	0.60
Adult Dw	1	0.90	0.90	0.90
Juv DW	1	0.90	0.90	0.72
Adult UP	2	0.40	0.67	0.67
Adult Dw	2	0.90	0.90	0.90
Juv DW	2	0.90	0.90	0.69
Adult UP	3	0.75	0.75	0.75
Adult Dw	3	0.90	0.90	0.90
Juv DW	3	0.90	0.90	0.59
Adult UP	4	0.67	0.67	0.67
Adult Dw	4	0.90	0.90	0.90
Juv DW	4	0.90	0.90	0.60
Years		50.00	50.00	50.00
Total Abundance		268432.00	929407.00	31818.00

Making Comparisons

Save total for comparison

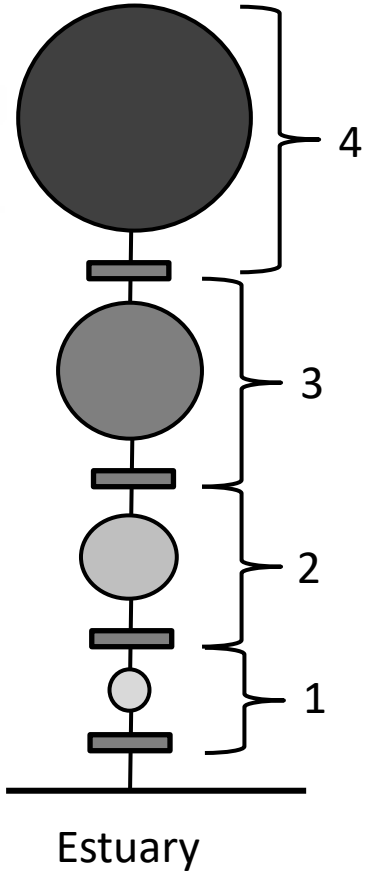
Download

Parm	Dam	scenario 1	scenario 2	scenario 3
Adult UP	1	0.60	0.60	0.60
Adult Dw	1	0.90	0.90	0.90
Juv DW	1	0.90	0.90	0.72
Adult UP	2	0.40	0.67	0.67
Adult Dw	2	0.90	0.90	0.90
Juv DW	2	0.90	0.90	0.69
Adult UP	3	0.75	0.75	0.75
Adult Dw	3	0.90	0.90	0.90
Juv DW	3	0.90	0.90	0.59
Adult UP	4	0.67	0.67	0.67
Adult Dw	4	0.90	0.90	0.90
Juv DW	4	0.90	0.90	0.60
Years		50.00	50.00	50.00
Total Abundance		268432.00	929407.00	31818.00

3. Calculate and graph total spawner abundance in the river for each simulation

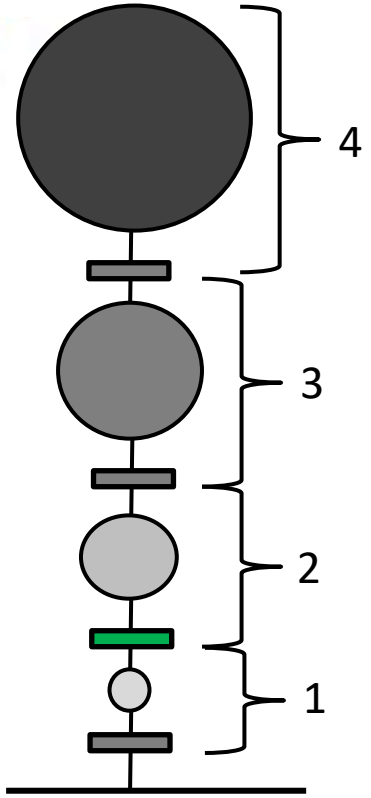
Save total for comparison

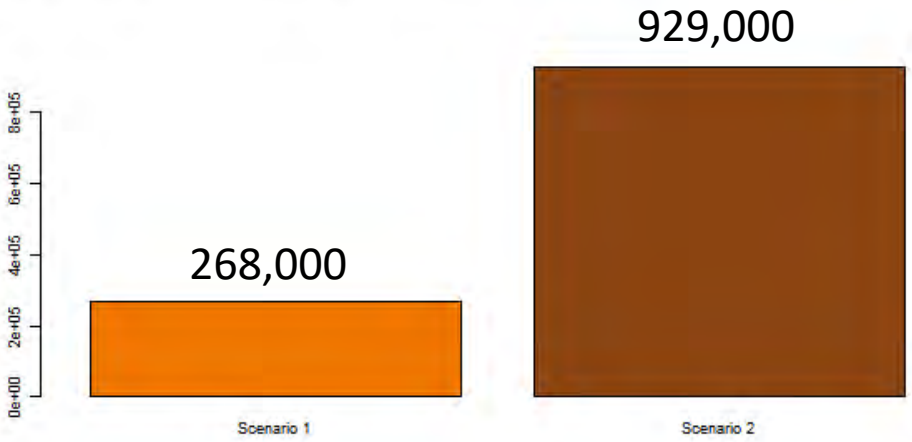
Parm	Dam	scenario 1
Adult UP	1	0.60
Adult Dw	1	0.90
Juv DW	1	0.90
Adult UP	2	0.40
Adult Dw	2	0.90
Juv DW	2	0.90
Adult UP	3	0.75
Adult Dw	3	0.90
Juv DW	3	0.90
Adult UP	4	0.67
Adult Dw	4	0.90
Juv DW	4	0.90
Years		50.00
Total Abundance		268432.00



Save total for comparison

Parm	Dam	scenario 1	scenario 2
Adult UP	1	0.60	0.60
Adult Dw	1	0.90	0.90
Juv DW	1	0.90	0.90
Adult UP	2	0.40	0.67
Adult Dw	2	0.90	0.90
Juv DW	2	0.90	0.90
Adult UP	3	0.75	0.75
Adult Dw	3	0.90	0.90
Juv DW	3	0.90	0.90
Adult UP	4	0.67	0.67
Adult Dw	4	0.90	0.90
Juv DW	4	0.90	0.90
Years		50.00	50.00
Total Abundance		268432.00	929407.00





Dam 2: 40%

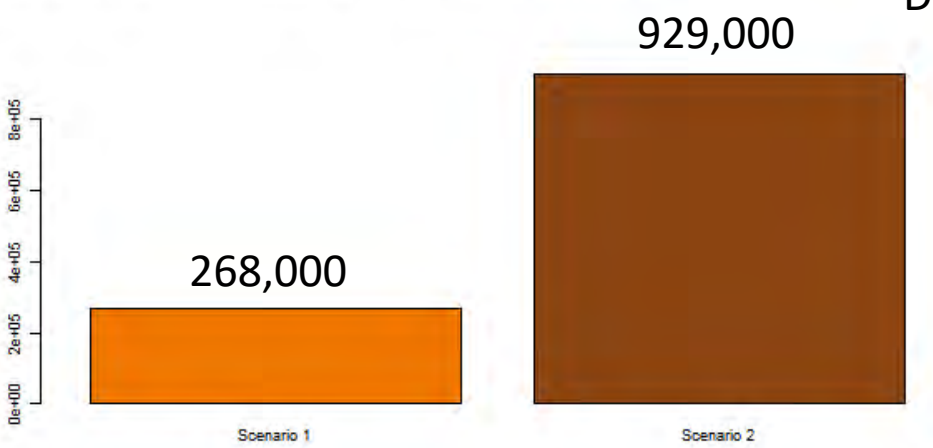
Dam 2: 67%

Save total for comparison

Download

Parm	Dam	scenario 1	scenario 2	scenario 3
Adult UP	1	0.60	0.60	0.60
Adult Dw	1	0.90	0.90	0.90
Juv DW	1	0.90	0.90	0.72
Adult UP	2	0.40	0.67	0.67
Adult Dw	2	0.90	0.90	0.90
Juv DW	2	0.90	0.90	0.69
Adult UP	3	0.75	0.75	0.75
Adult Dw	3	0.90	0.90	0.90
Juv DW	3	0.90	0.90	0.59
Adult UP	4	0.67	0.67	0.67
Adult Dw	4	0.90	0.90	0.90
Juv DW	4	0.90	0.90	0.60
Years		50.00	50.00	50.00
Total Abundance		268432.00	929407.00	31818.00

Dam 2: 67%, reduced juvenile DS



Dam 2: 40%

Dam 2: 67%

Summary

- **Nutrients:** modelling work indicates P removal at low spawner abundances
  - But is a relatively low magnitude
- **Passage:** Downstream passage is a strong driver of population dynamics
  - Another important factor is where spawning habitat is located in relation to bottlenecks to passage

- DMAPP is available to test scenarios!


Questions?