



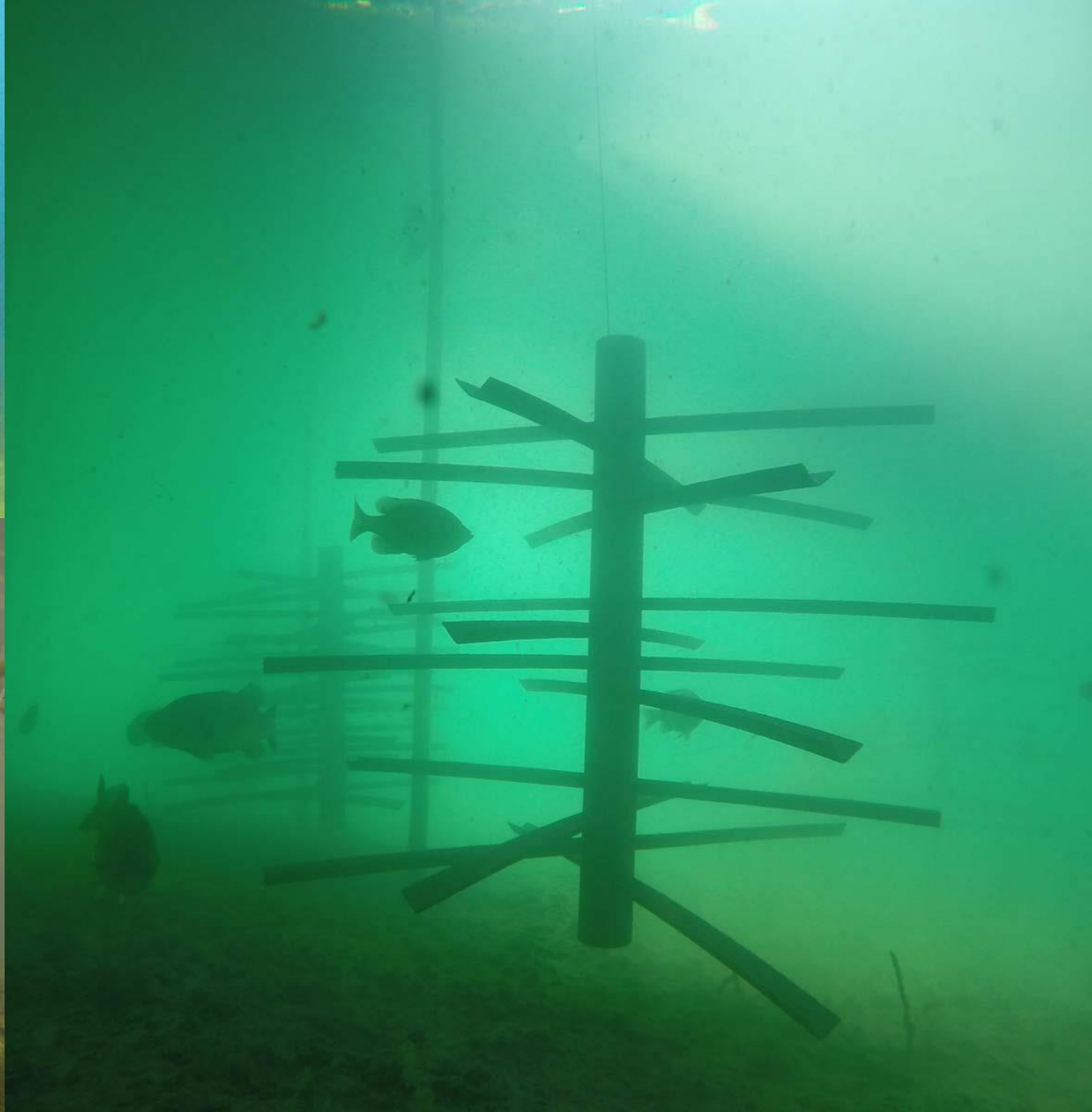
Fish and prey resources in reservoir coves with and without offshore artificial habitat structures

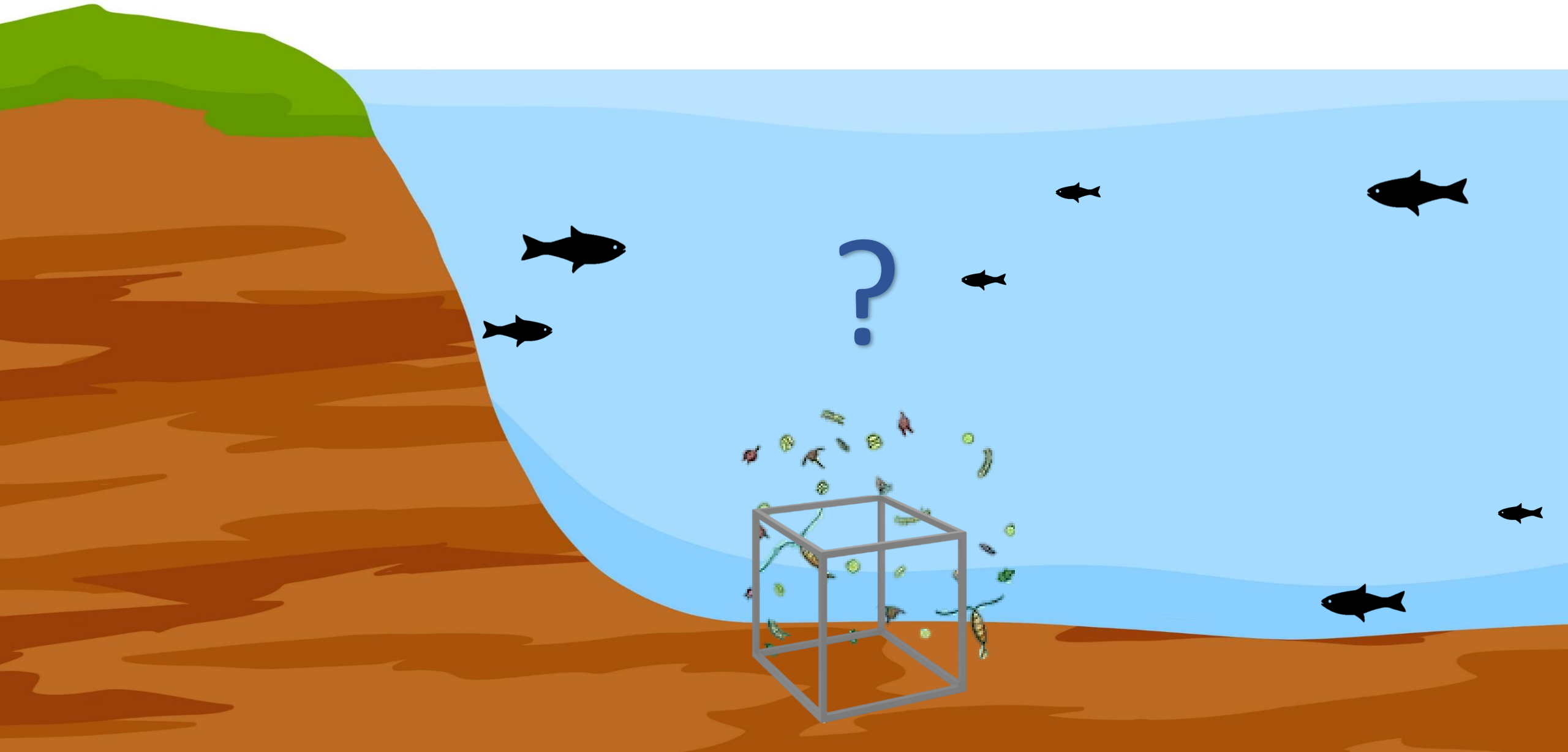
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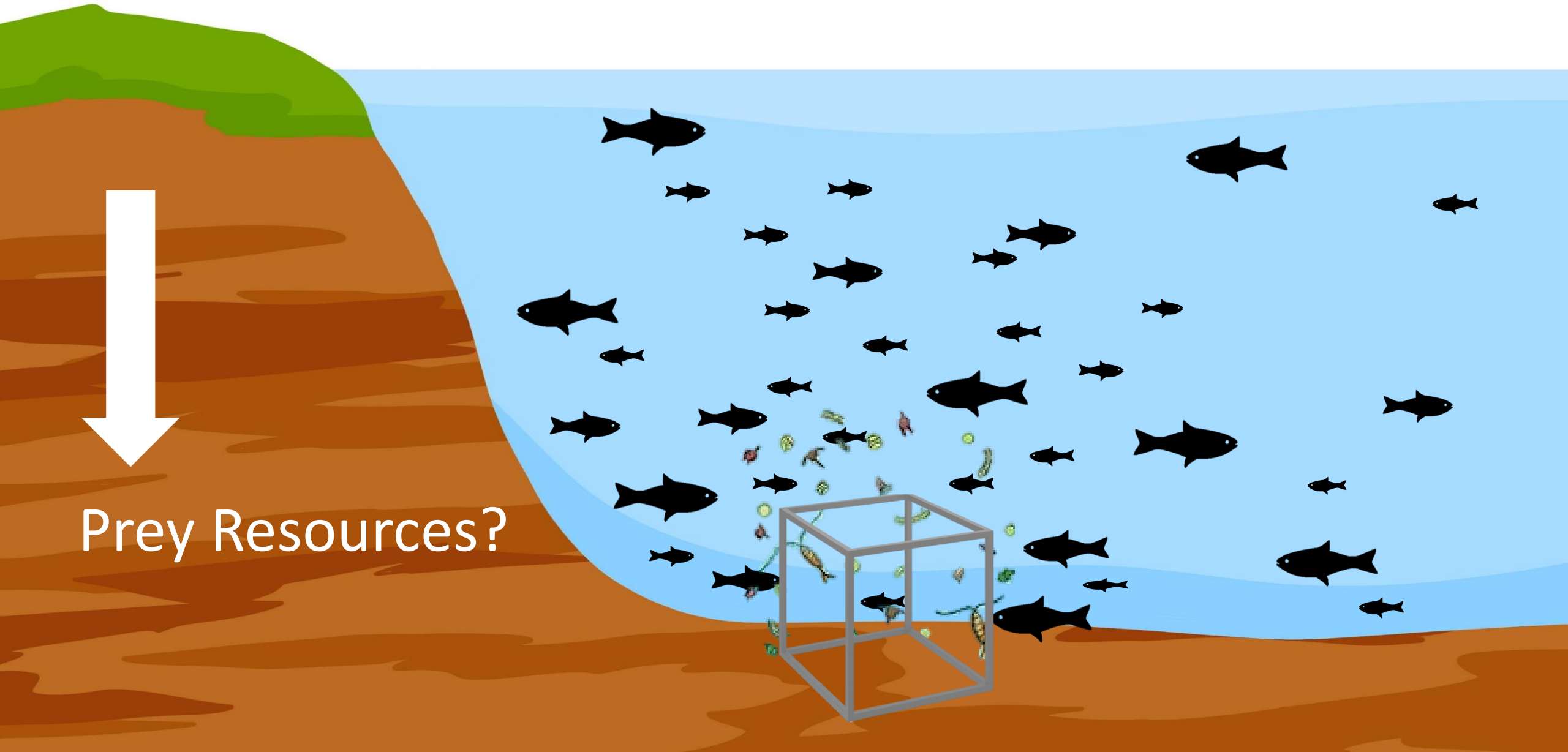




Food Resources

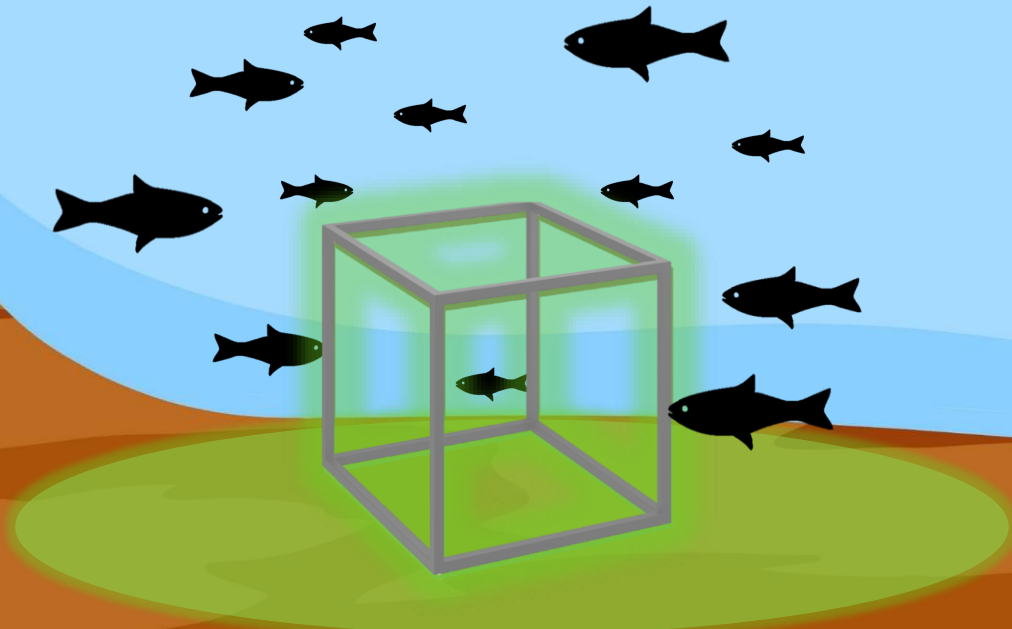


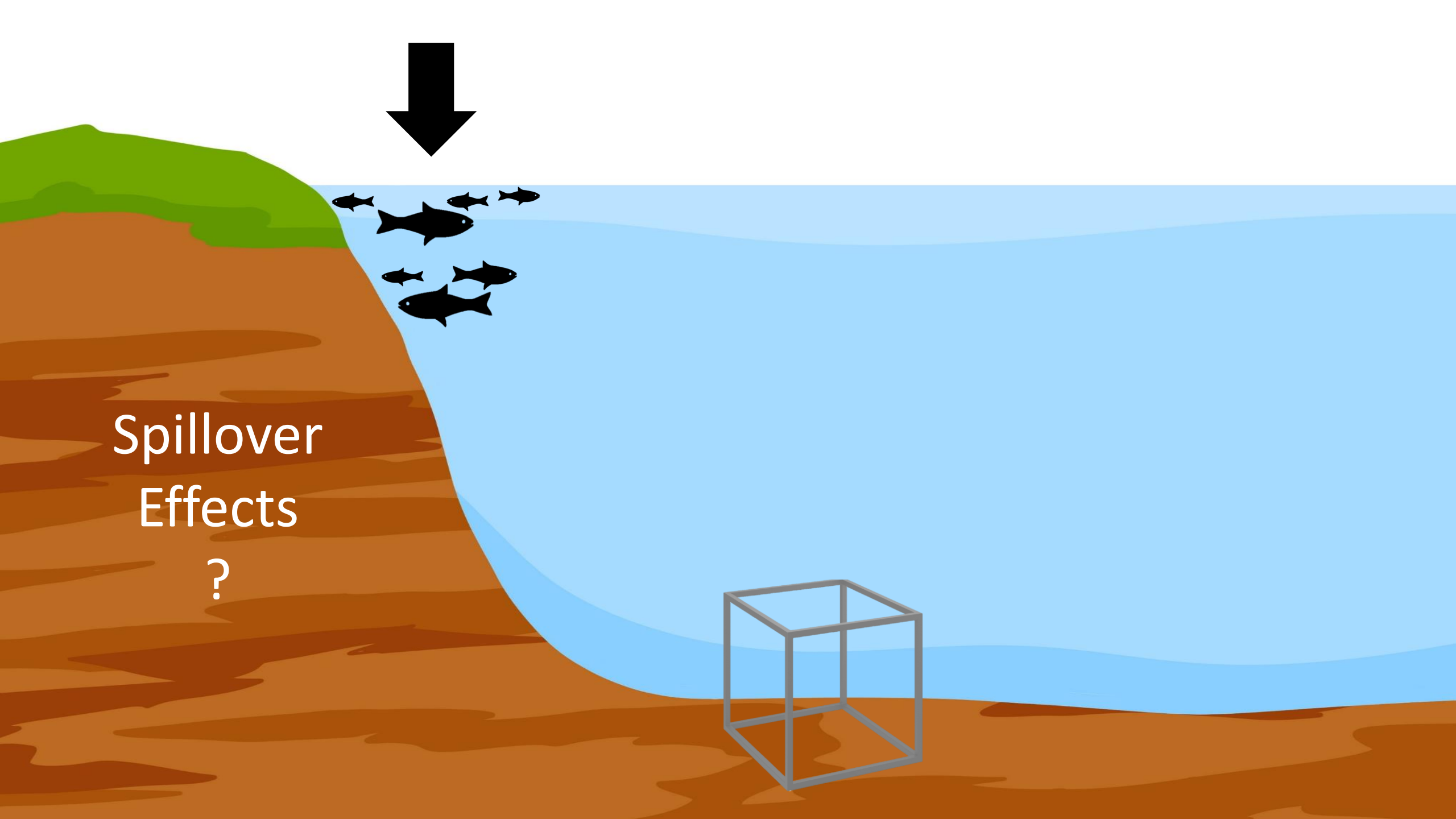
Food Resources



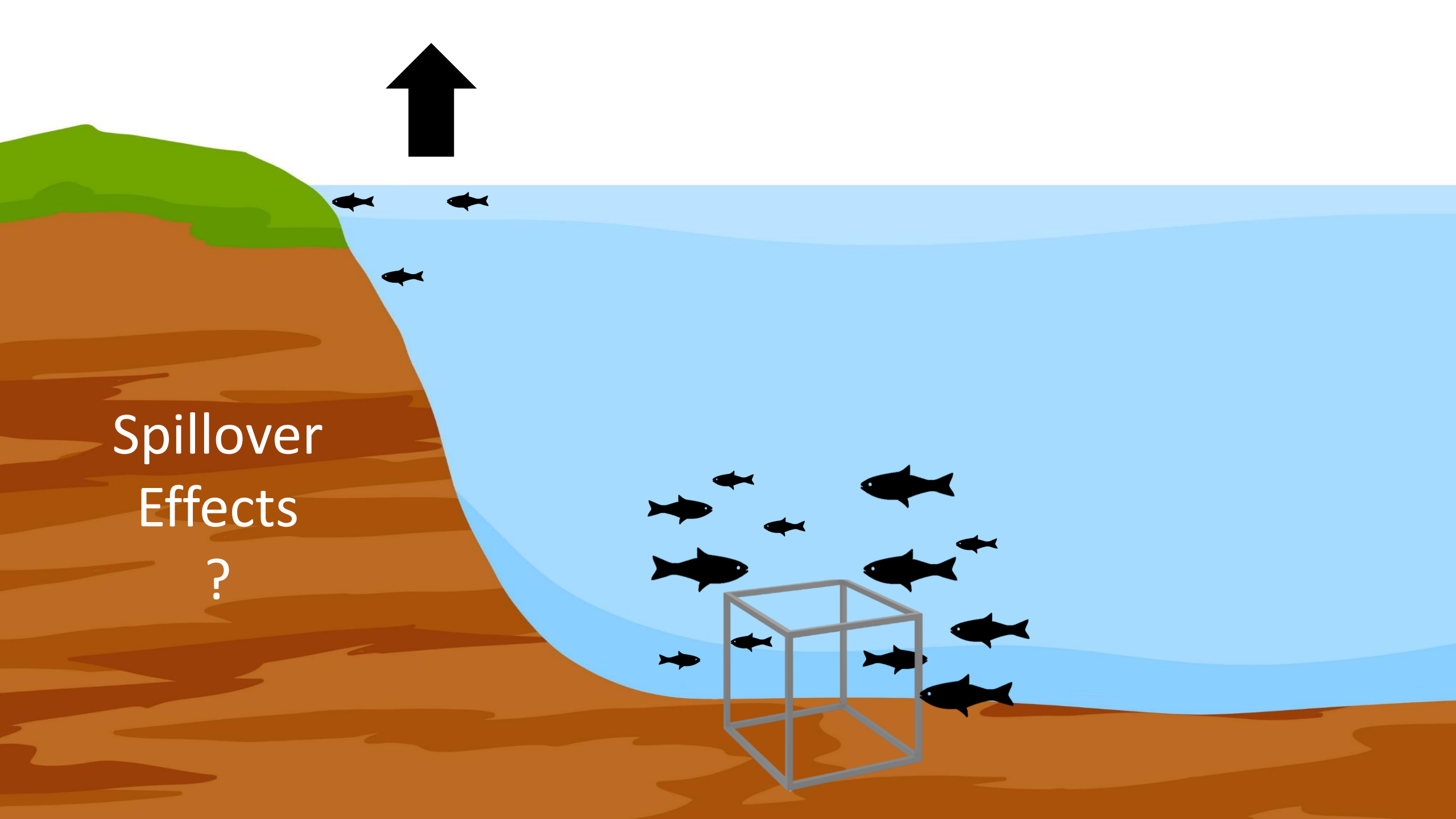
Prey Resources?

Prey Resources?





Spillover
Effects
?



Spillover
Effects
?

Objectives:



Fish



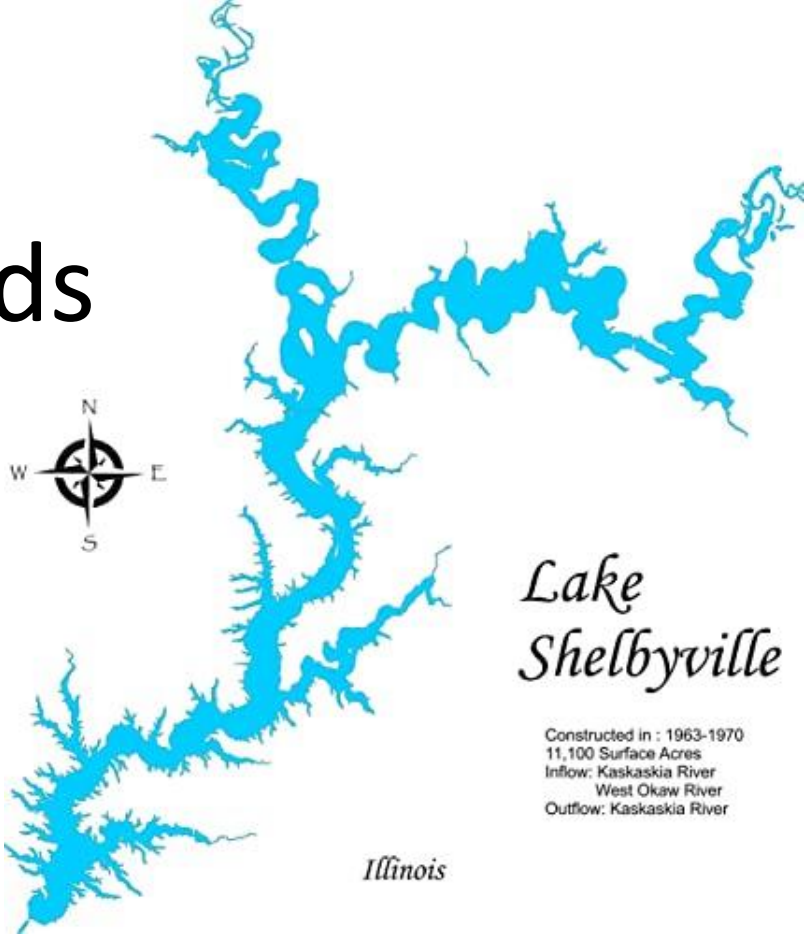
Benthic macroinvertebrates



Zooplankton

- 1) Compare relative abundance and assemblage structures of **fish and prey** at offshore sites with and without artificial structures.
- 2) Compare littoral (inshore) **fish** relative abundance and assemblage structures in coves with and without artificial structures.

Methods



*Lake
Shelbyville*

Constructed in : 1963-1970
11,100 Surface Acres
Inflow: Kaskaskia River
West Okaw River
Outflow: Kaskaskia River





1.22 m
x 1.22 m
x 1.52 m

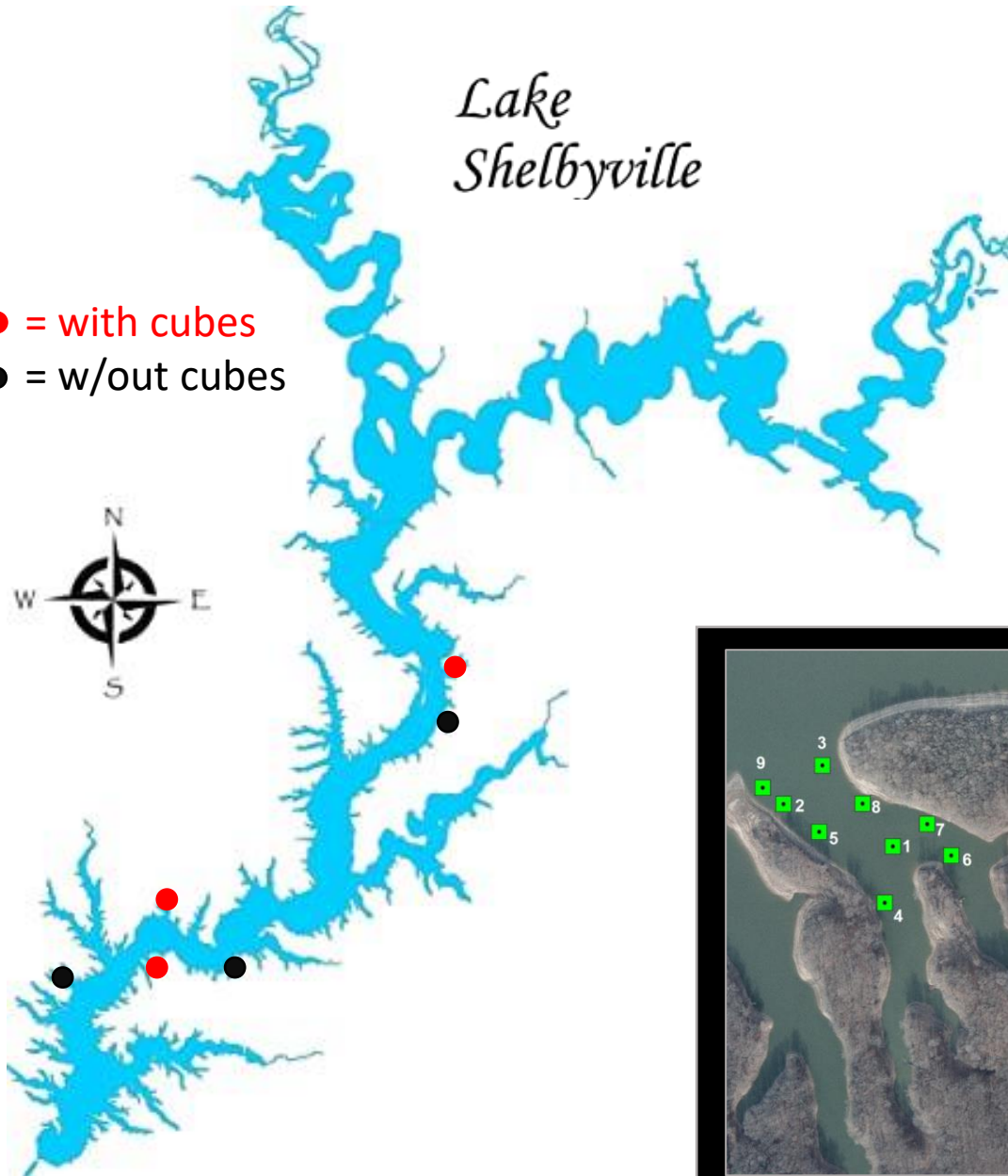


Artificial
structures
added
Oct. 2017

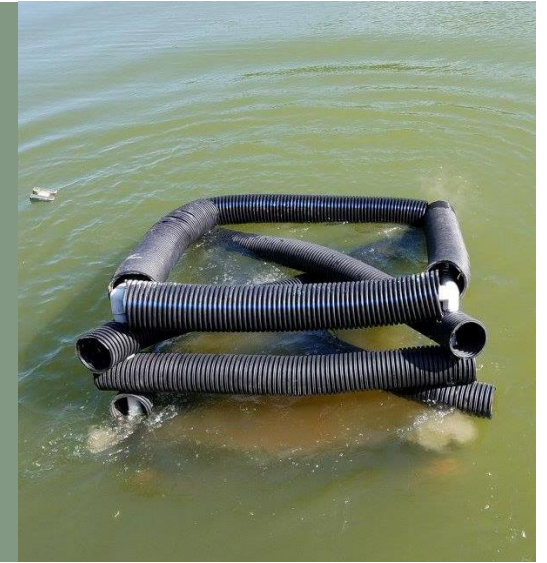


Lake Shelbyville

- = with cubes
- = w/out cubes



- Placed cubes as pairs
- Approx. 2 structures per surface acre
- Depth 4-5 m



Offshore Fish



Inshore Fish



Benthic Macroinvertebrates



Zooplankton



Fall 2017



Spring 2018



Fall 2018



Spring 2019



Fall 2019



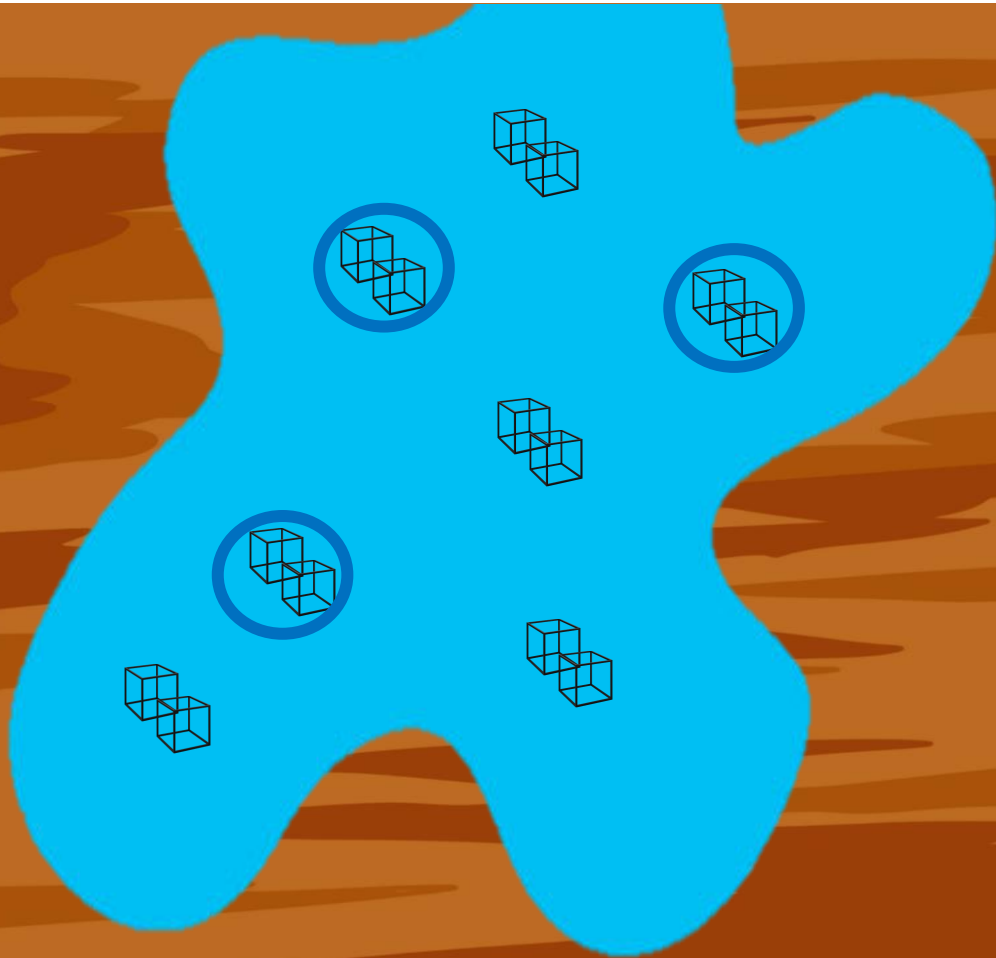
Spring 2020

No sampling due to COVID-19 restrictions

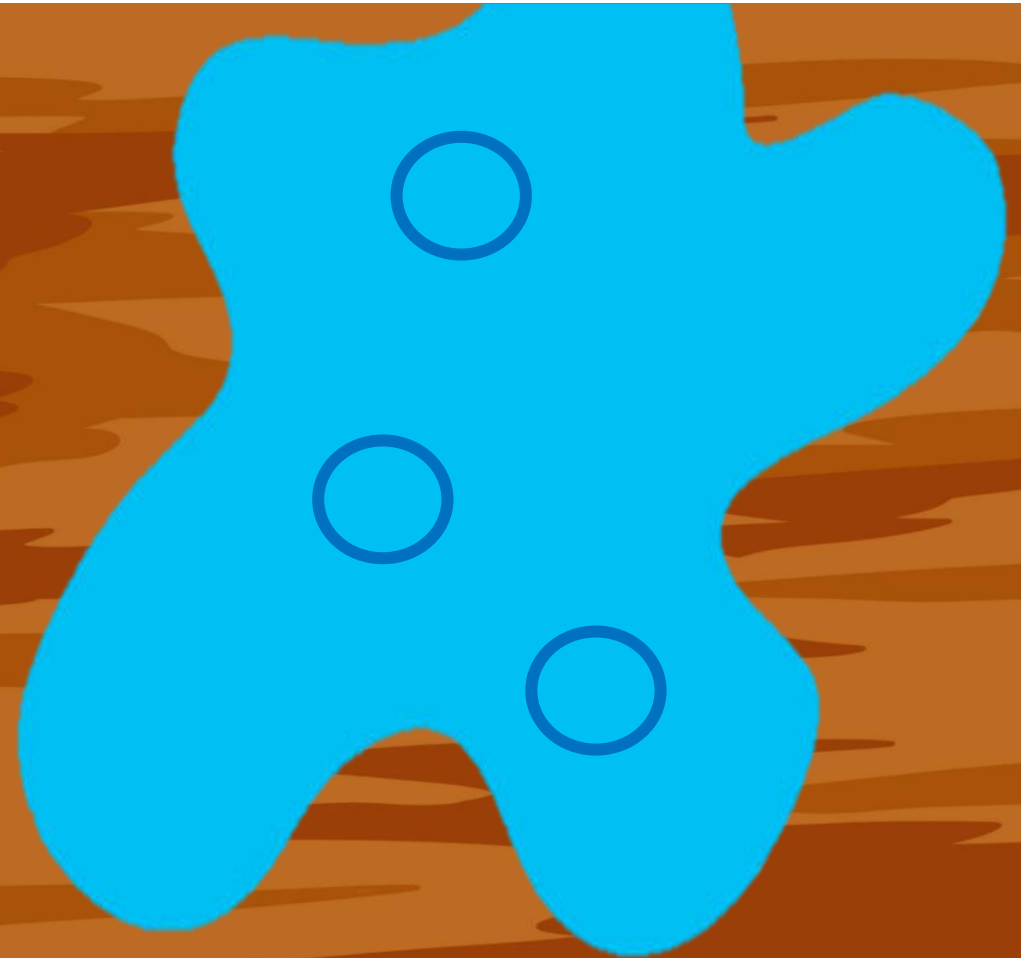
Fall 2020



3 coves WITH CUBES



3 coves WITHOUT CUBES



Offshore Fish



Fall 2017



Spring 2018



Fall 2018



Spring 2019



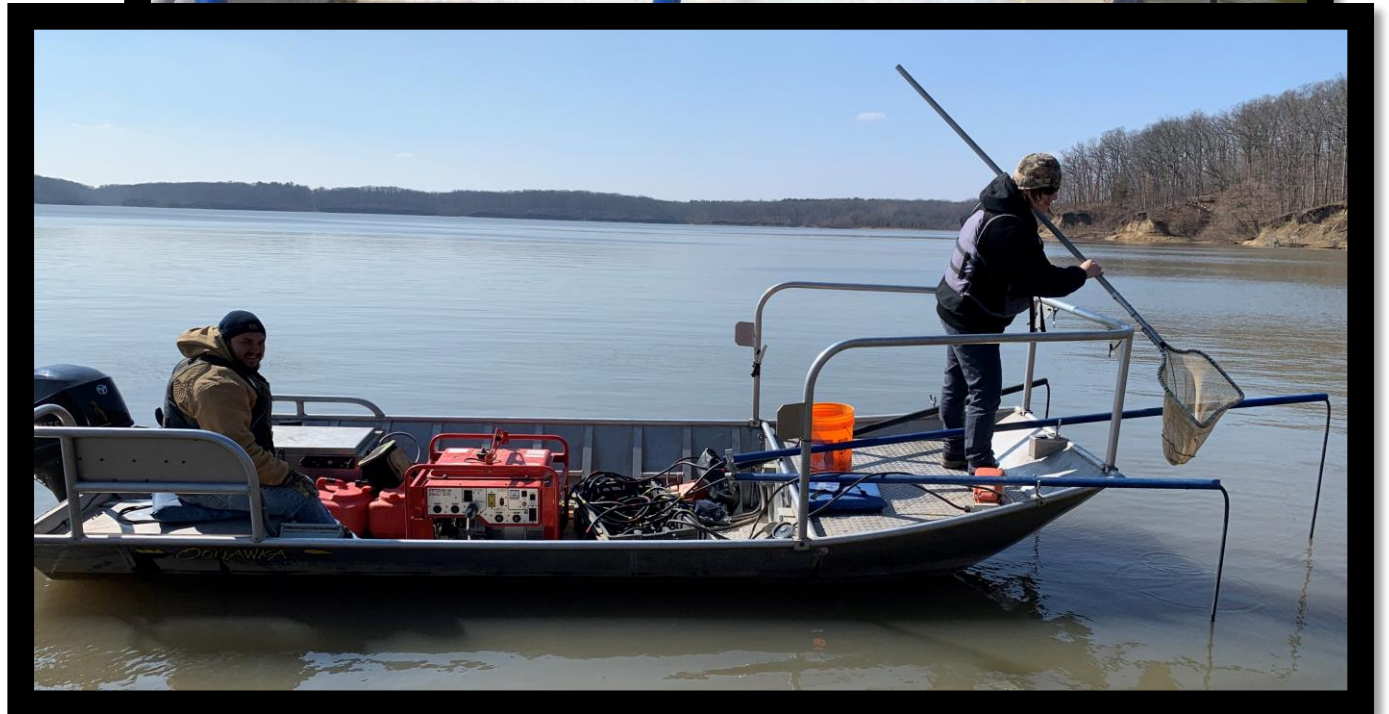
Fall 2019



Spring 2020



Fall 2020



Offshore Fish



Fall 2017



Spring 2018



Fall 2018



Spring 2019

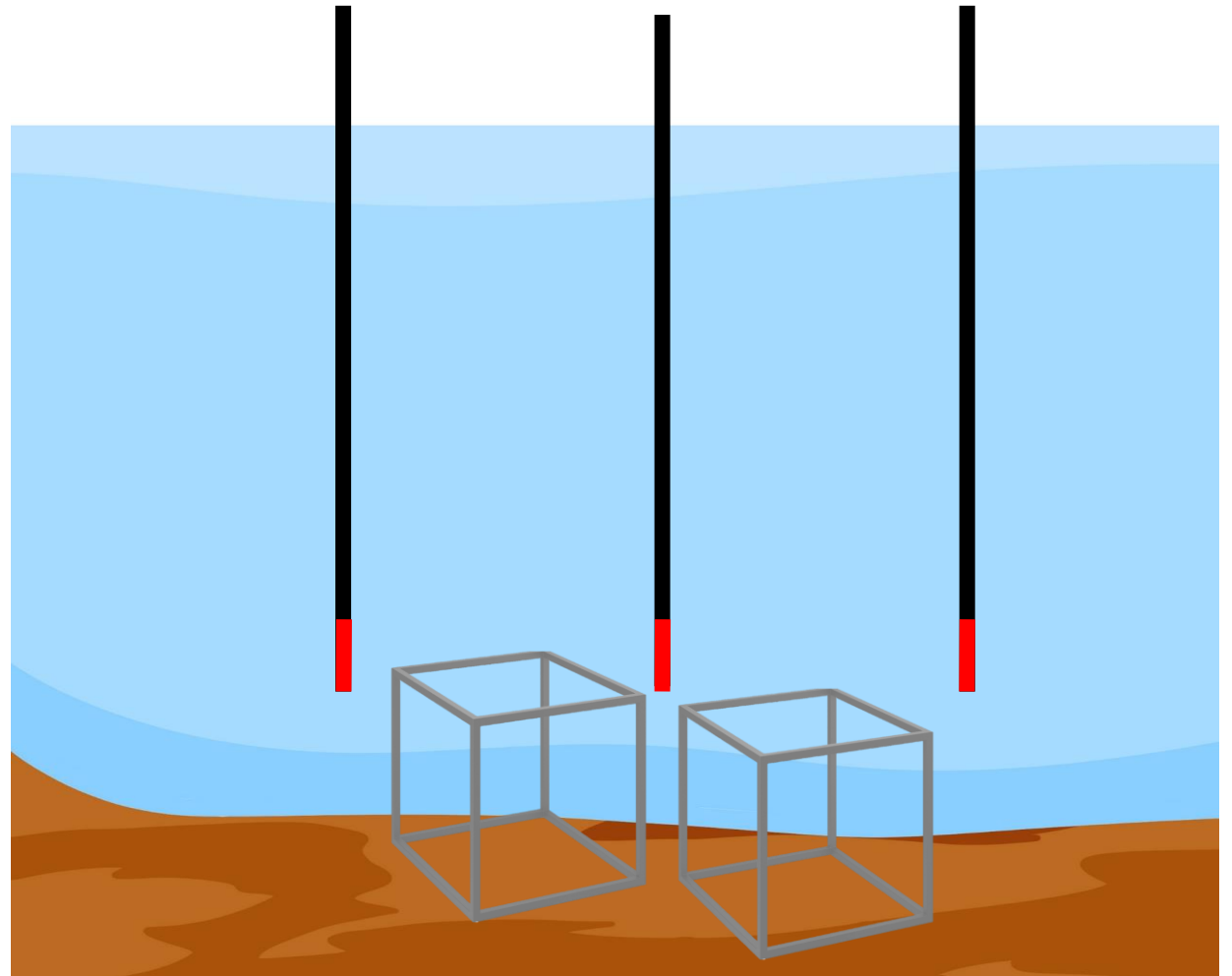


Fall 2019



Spring 2020

Fall 2020



Offshore Fish



Fall 2017



Spring 2018



Fall 2018



Spring 2019



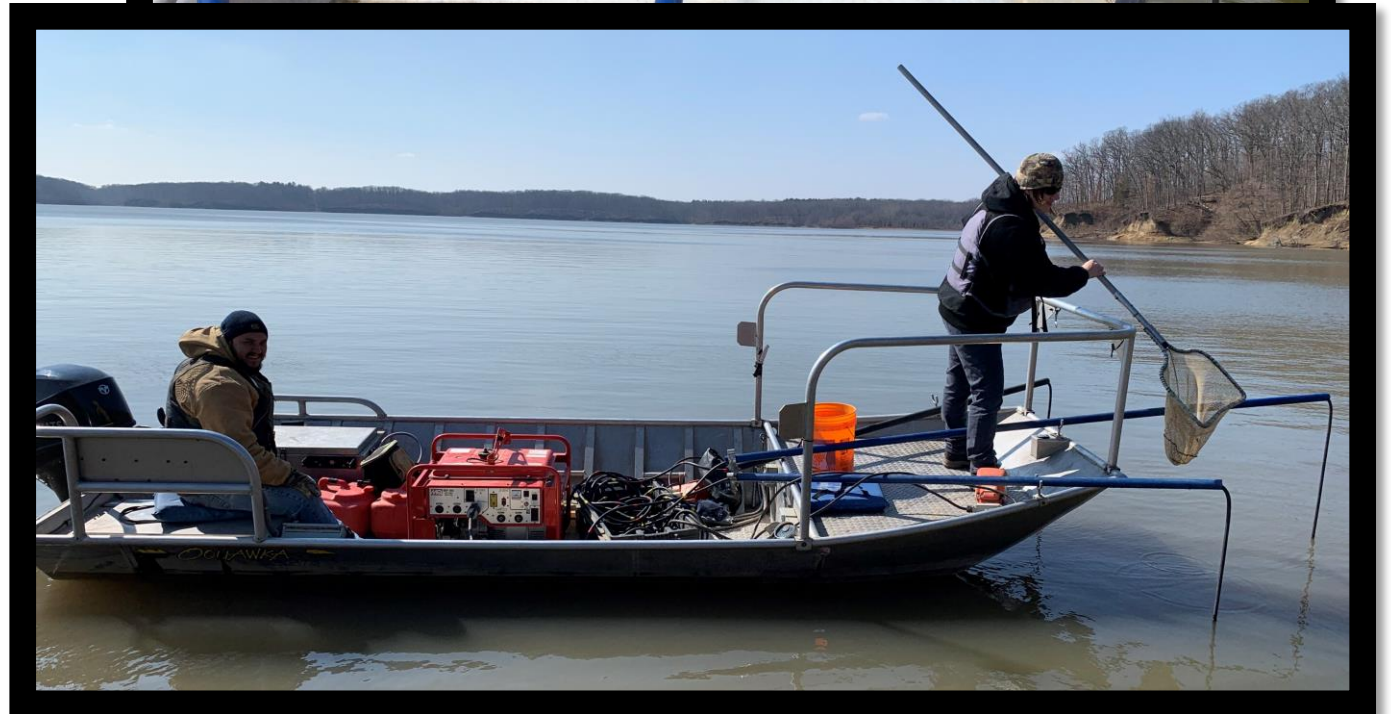
Fall 2019



Spring 2020



Fall 2020



Inshore Fish



Fall 2017



Spring 2018



Fall 2018



Spring 2019

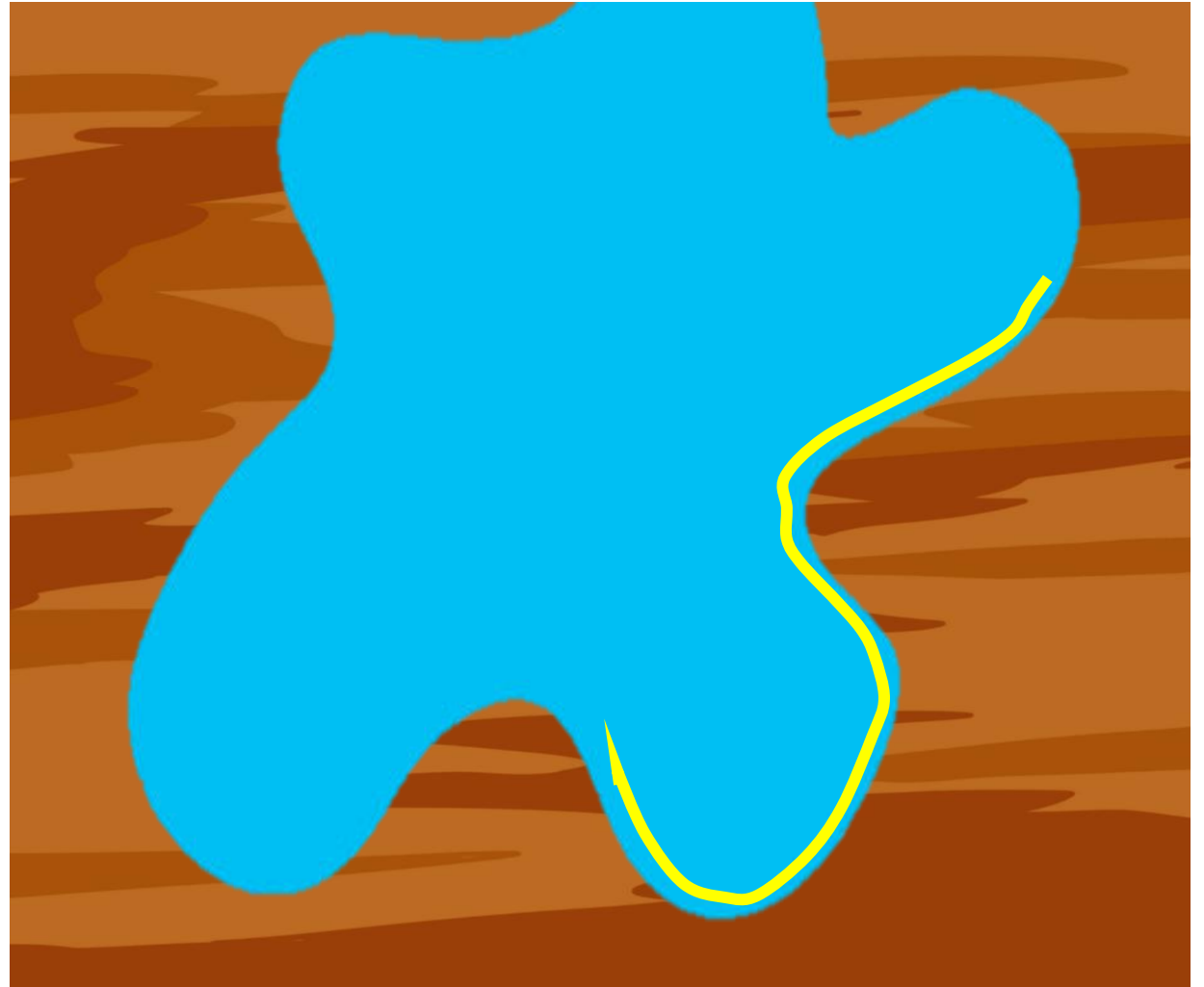


Fall 2019



Spring 2020

Fall 2020



Benthic
Macroinvertebrates



Fall 2017



Spring 2018



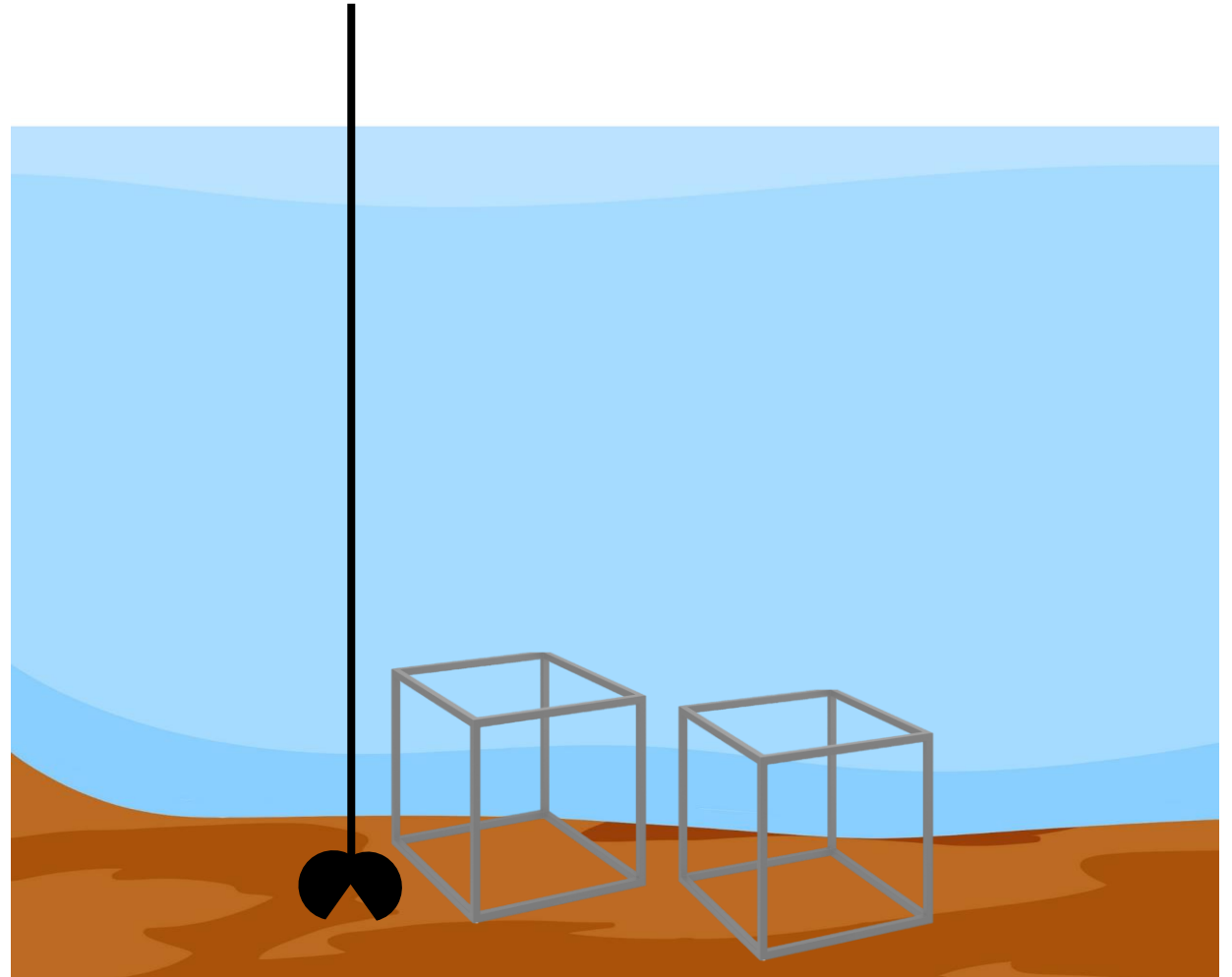
Fall 2018



Spring 2019



Fall 2019



Zooplankton



Fall 2017



Spring 2018



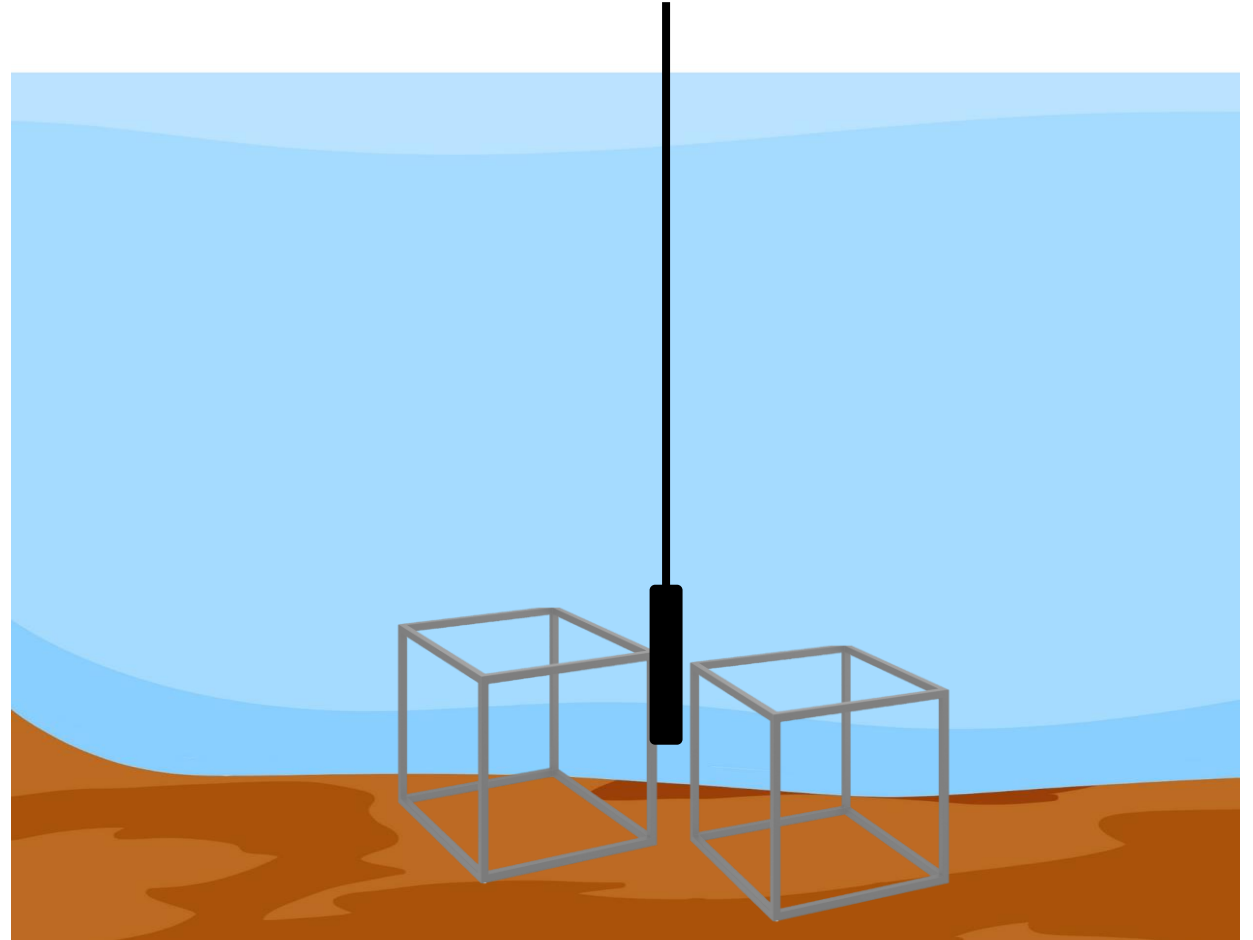
Fall 2018



Spring 2019



Fall 2019





RESULTS

Comparison of Coves

Benthic
Macroinvertebrates



With
Structures

Without

Difference in
density? (n/m²)

Fall

2502.5 (493.1)

P = 0.296

3290.8 (505.0)

Wilcoxon
signed rank tests

Spring

3216.5 (725.1)

P = 0.579

3484.4 (730.0)

Difference in
taxa assemblage
structure?

PERMANOVA

Benthic
Macroinvertebrates



Difference in
density? (n/m²)

Wilcoxon
signed rank tests

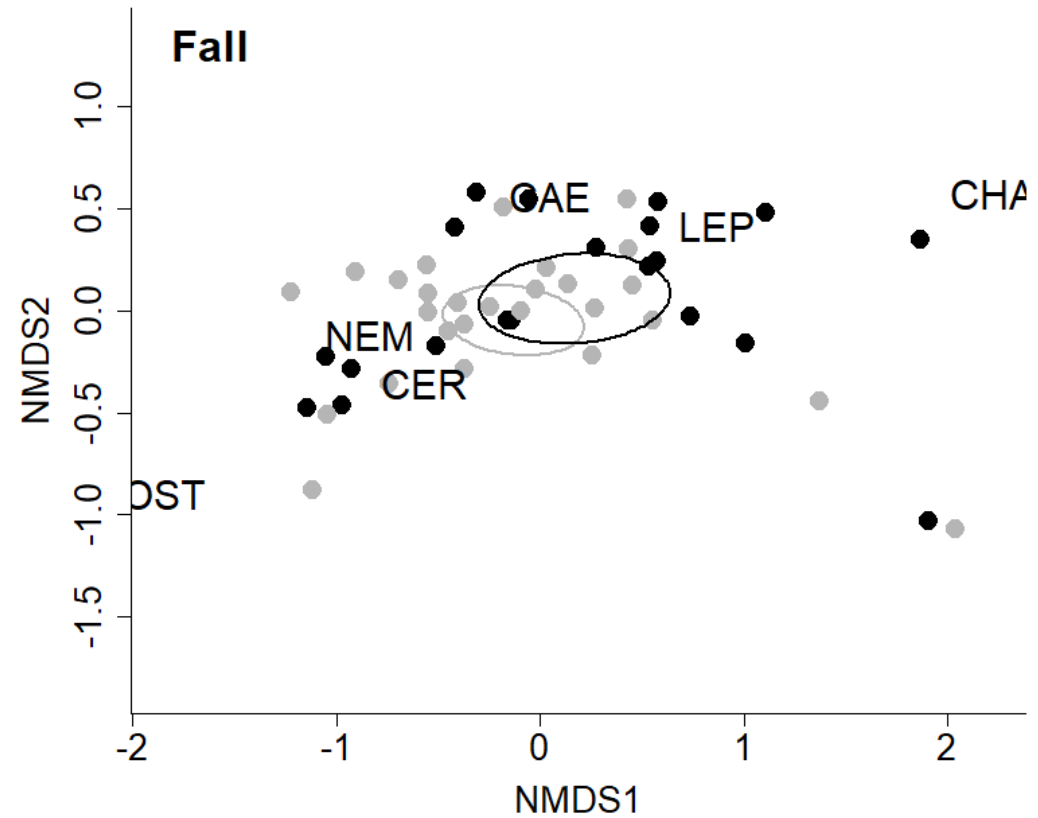
Fall

Spring

Difference in
taxa assemblage
structure?

PERMANOVA

Fall



Pseudo-F_{1,5.34} = 0.73

P = 0.715

Benthic
Macroinvertebrates



Difference in
density? (n/m²)

Wilcoxon
signed rank tests

Fall

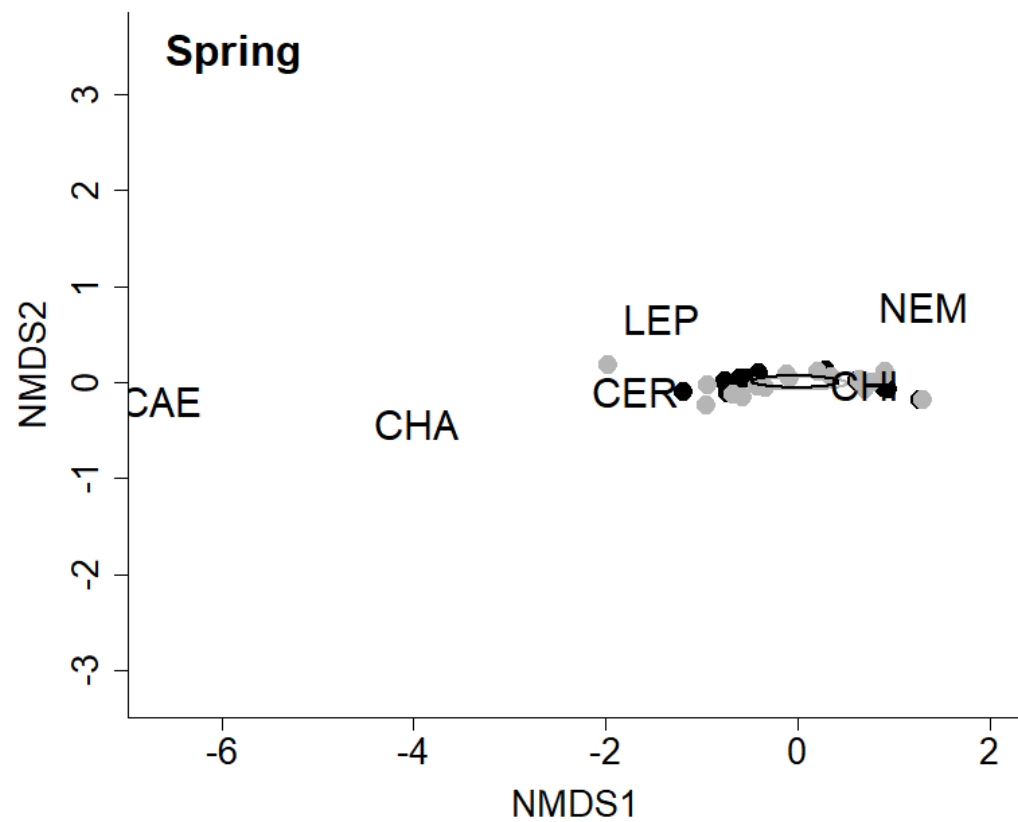
Spring

Difference in
taxa assemblage
structure?

PERMANOVA

Fall

Spring



Pseudo-F_{1,5.34} = 0.73

P = 0.715

Pseudo-F_{1,4.07} = 2.62

P = 0.158

Zooplankton



Comparison of Coves



With
Structures

Without

**Difference in
density? (n/L)**

Fall

218.8 (15.3)

P = 0.829

217.8 (16.8)

Wilcoxon
signed rank tests

Spring

524.4 (112.0)

P = 0.163

439.1 (88.9)

**Difference in
taxa assemblage
structure?**

PERMANOVA

Zooplankton



Difference in
density? (n/L)

Wilcoxon
signed rank tests

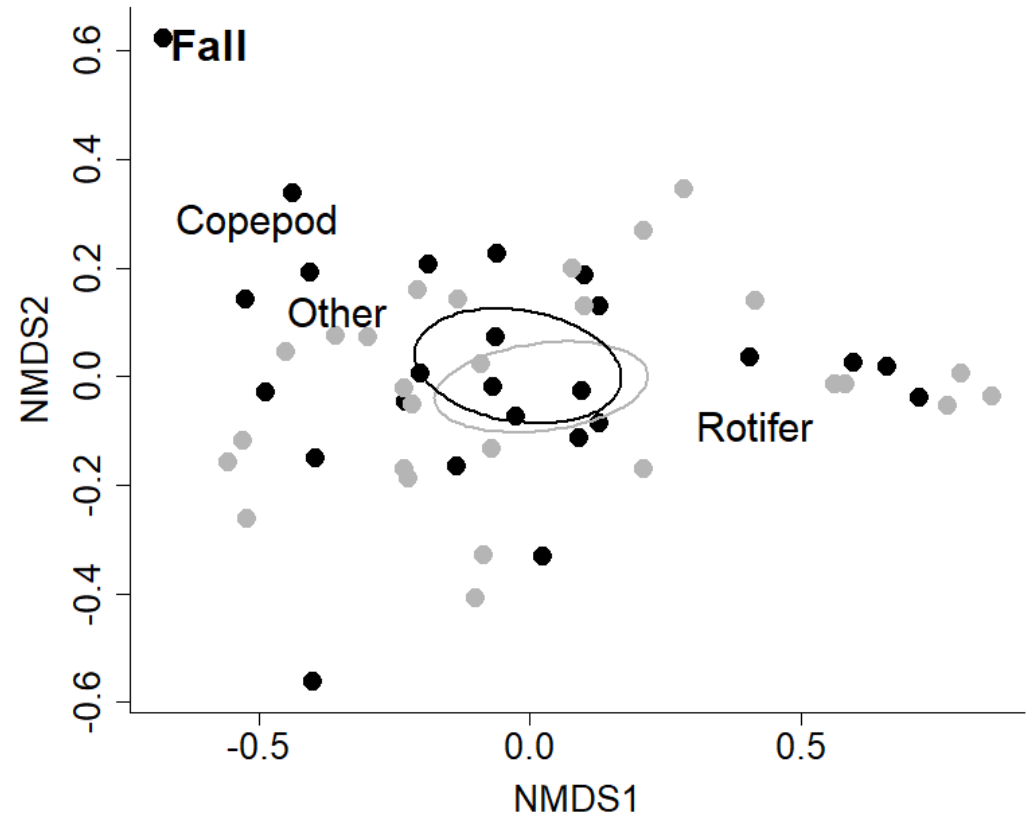
Fall

Spring

Difference in
taxa assemblage
structure?

PERMANOVA

Fall



Pseudo- $F_{1,4.01} = 0.27$

$P = 0.801$

Zooplankton



Difference in
density? (n/L)

Wilcoxon
signed rank tests

Fall

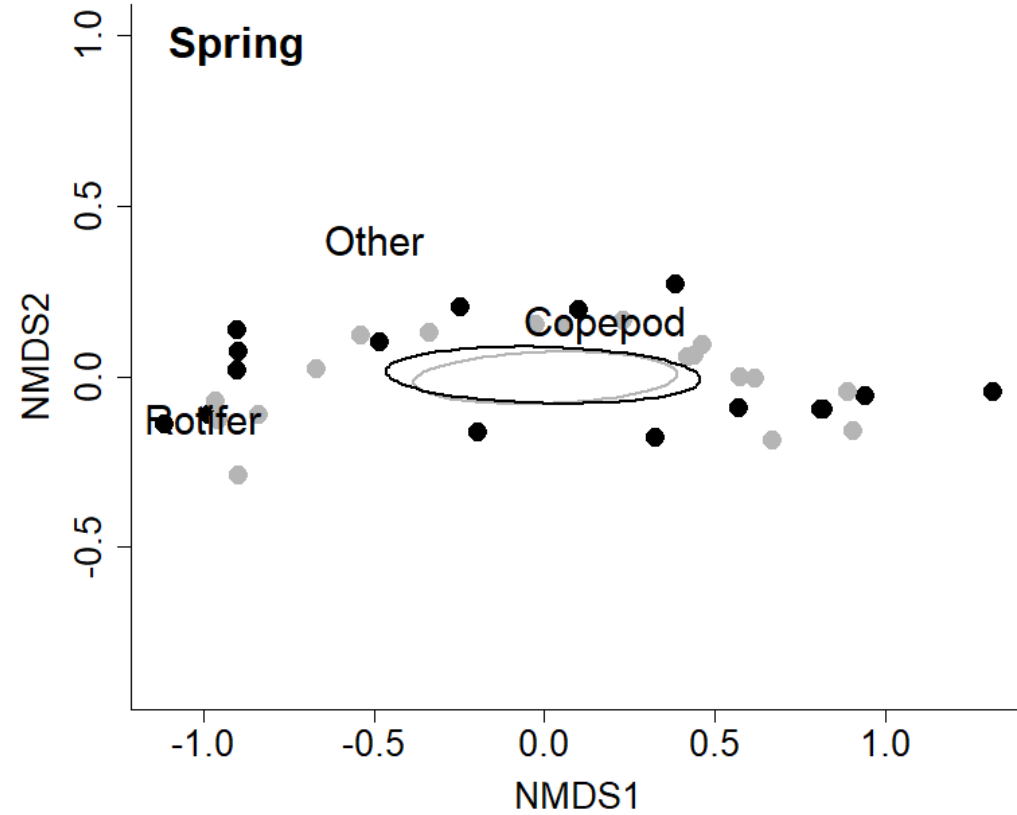
Spring

Difference in
taxa assemblage
structure?

PERMANOVA

Fall

Spring



Pseudo- $F_{1,4.01} = 0.27$

P = 0.801

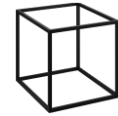
Pseudo- $F_{1,4.07} = 0.31$

P = 0.824

Inshore Fish



Comparison of Coves



With
Structures

Without

Difference in
CPUE? (n/15min)

Fall

163.1 (25.2)

P = 0.023

199.1 (31.9)

Wilcoxon
signed rank tests

Spring

137.8 (19.8)

P = 0.063

88.8 (5.3)

Inshore Fish



Comparison of Coves

With
Structures

Without

**Difference in
CPUE? (n/15min)**

Wilcoxon
signed rank tests

Fall

163.1 (25.2)

P = 0.023

199.1 (31.9)

Without Gizzard Shad

81.5 (7.5)

P = 0.424

83.3 (18.6)

Spring

137.8 (19.8)

P = 0.063

88.8 (5.3)

**Difference in
taxa assemblage
structure?**

PERMANOVA

Inshore Fish



Difference in CPUE? (n/15min)

Wilcoxon signed rank tests

Fall

Spring

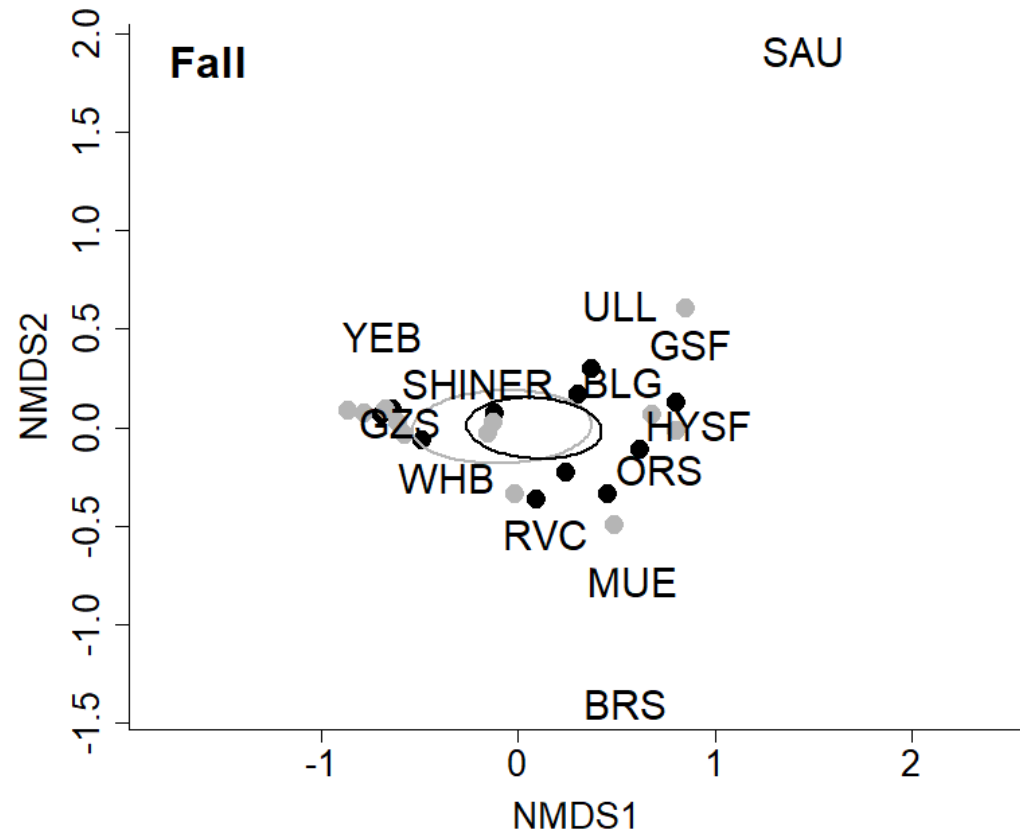
Difference in taxa assemblage structure?

PERMANOVA

Fall

Pseudo- $F_{1,4} = 0.55$

$P = 0.721$



Inshore Fish



Difference in CPUE? (n/15min)

Wilcoxon signed rank tests

Fall

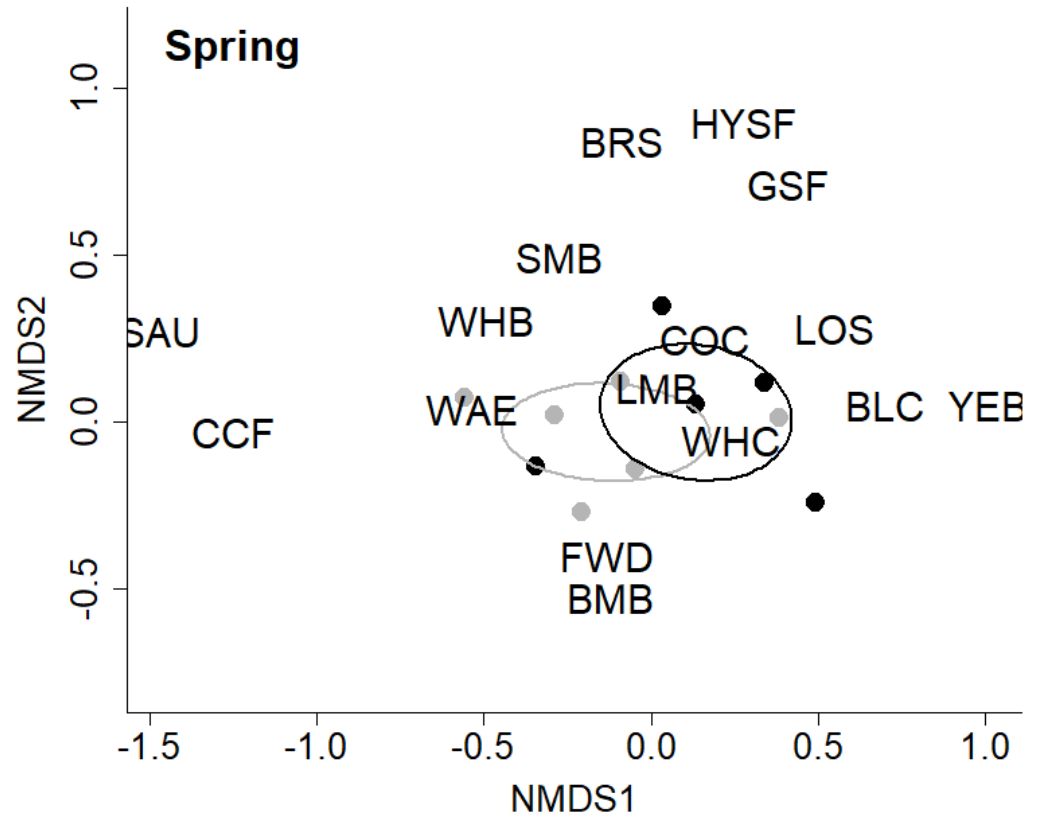
Spring

Difference in taxa assemblage structure?

PERMANOVA

Fall

Spring



Pseudo- $F_{1,4} = 0.55$

$P = 0.721$

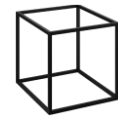
Pseudo- $F_{1,4} = 1.51$

$P = 0.207$

Offshore Fish



Comparison of Coves



With
Structures

Without

**Difference in
CPUE? (n/10min)**

Fall

8.0 (1.1)

P < 0.001

2.6 (0.6)

Wilcoxon
signed rank tests

Spring

3.5 (0.7)

P = 0.005

1.2 (0.2)

**Difference in
taxa assemblage
structure?**

PERMANOVA

Offshore Fish



Difference in CPUE? (n/10min)

Wilcoxon signed rank tests

Fall

Spring

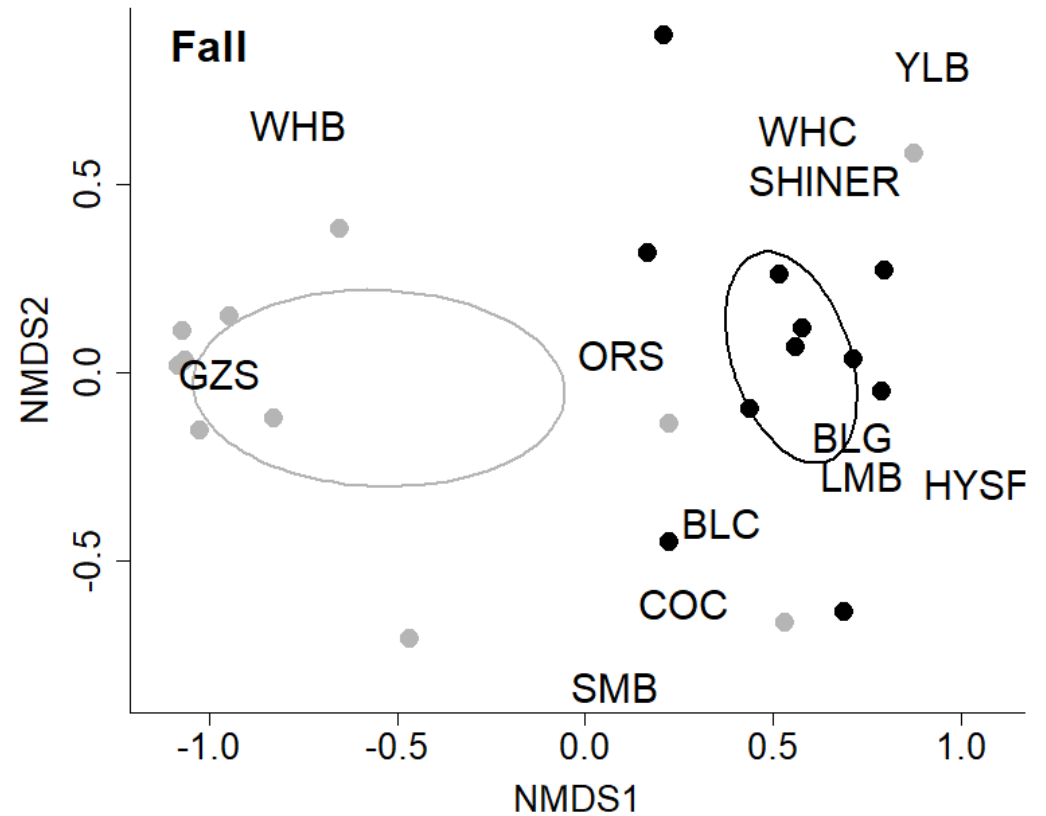
Difference in taxa assemblage structure?

PERMANOVA

Fall

Pseudo- $F_{1,6.66} = 9.84$

$P = 0.001$



Offshore Fish



Difference in CPUE? (n/10min)

Wilcoxon signed rank tests

Fall

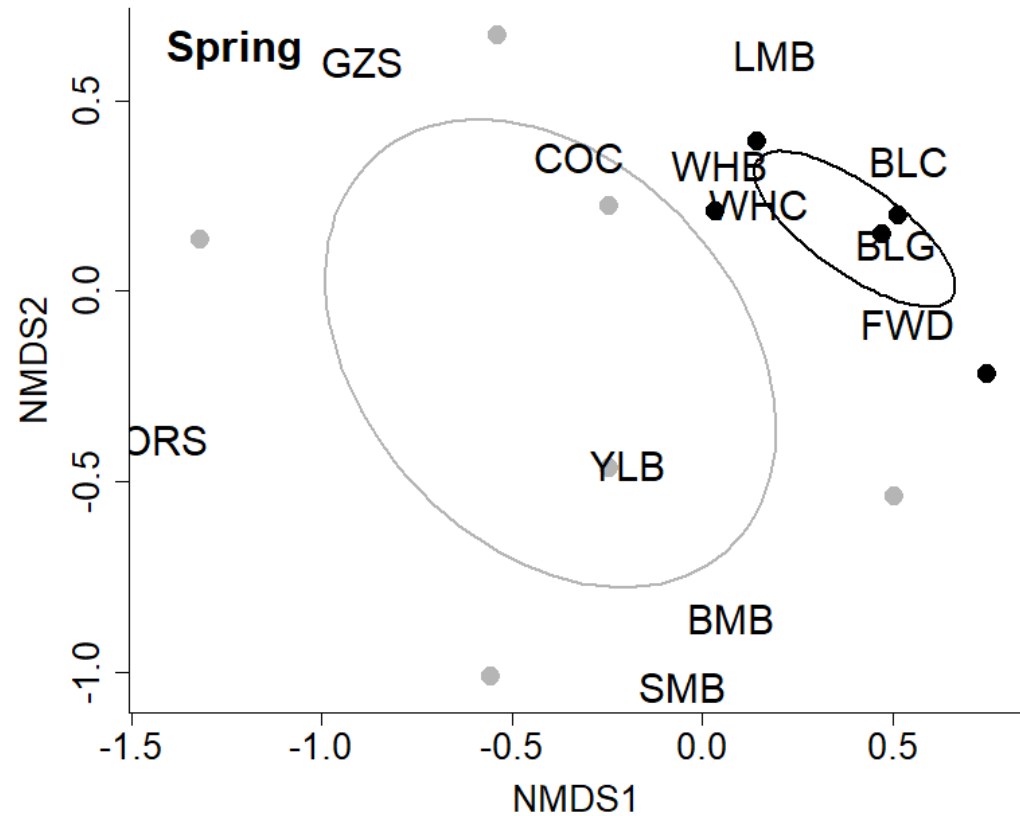
Spring

Difference in taxa assemblage structure?

PERMANOVA

Fall

Spring



Pseudo-F_{1,6.66} = 9.84

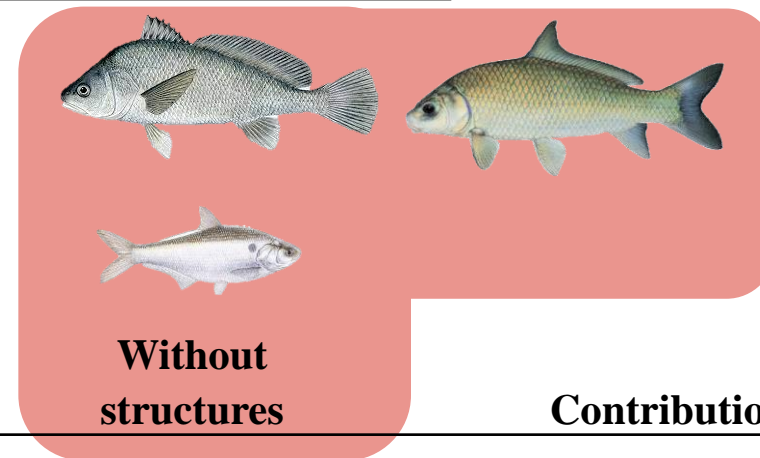
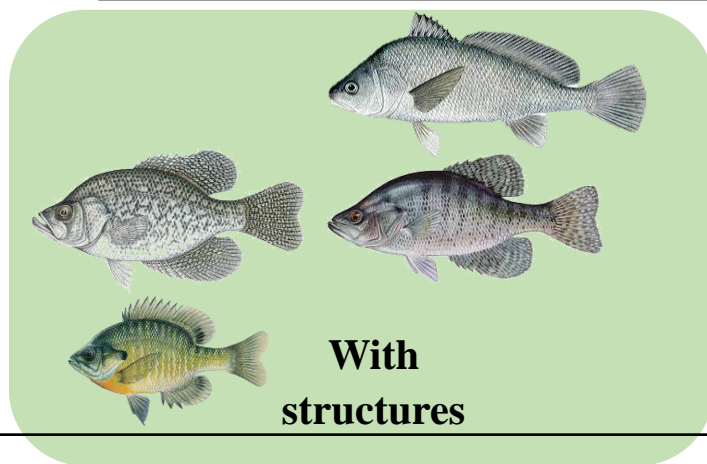
P = 0.001

Pseudo-F_{1,5.28} = 2.88

P = 0.044

Offshore Fish

CPUE (fish per 10-min sample)



Contribution (%)

Fall

Bluegill	3.22 (0.62)	0.52 (0.33)	23.05
Gizzard Shad	0.52 (0.15)	0.72 (0.17)	21.88
Freshwater Drum	0.33 (0.16)	0.64 (0.17)	14.74
White Crappie	1.81 (0.37)	0.08 (0.05)	12.22
Black Crappie	0.64 (0.17)	0.06 (0.04)	6.55


Spring

Bluegill	1.06 (0.42)	0.11 (0.08)	17.76
White Crappie	1.11 (0.30)	0.22 (0.13)	16.21
Gizzard Shad	0.17 (0.12)	0.28 (0.18)	15.72
Freshwater Drum	0.39 (0.12)	0.11 (0.08)	10.69
Smallmouth Buffalo	0.00 (0.00)	0.17 (0.09)	9.71

Comparison of Coves

Offshore Fish



 With Structures

CPUE (n/10min)

Fall

More young/small prey fish
Thermal refuge

8.0 (1.1)



Spring

Littoral spawning

3.5 (0.7)

**Coves with v. coves
without added
habitat:**

Benthic
Macroinvertebrates



Zooplankton



Difference in
CPUE/density?

~~Fall~~

~~Fall~~

~~Spring~~

~~Spring~~

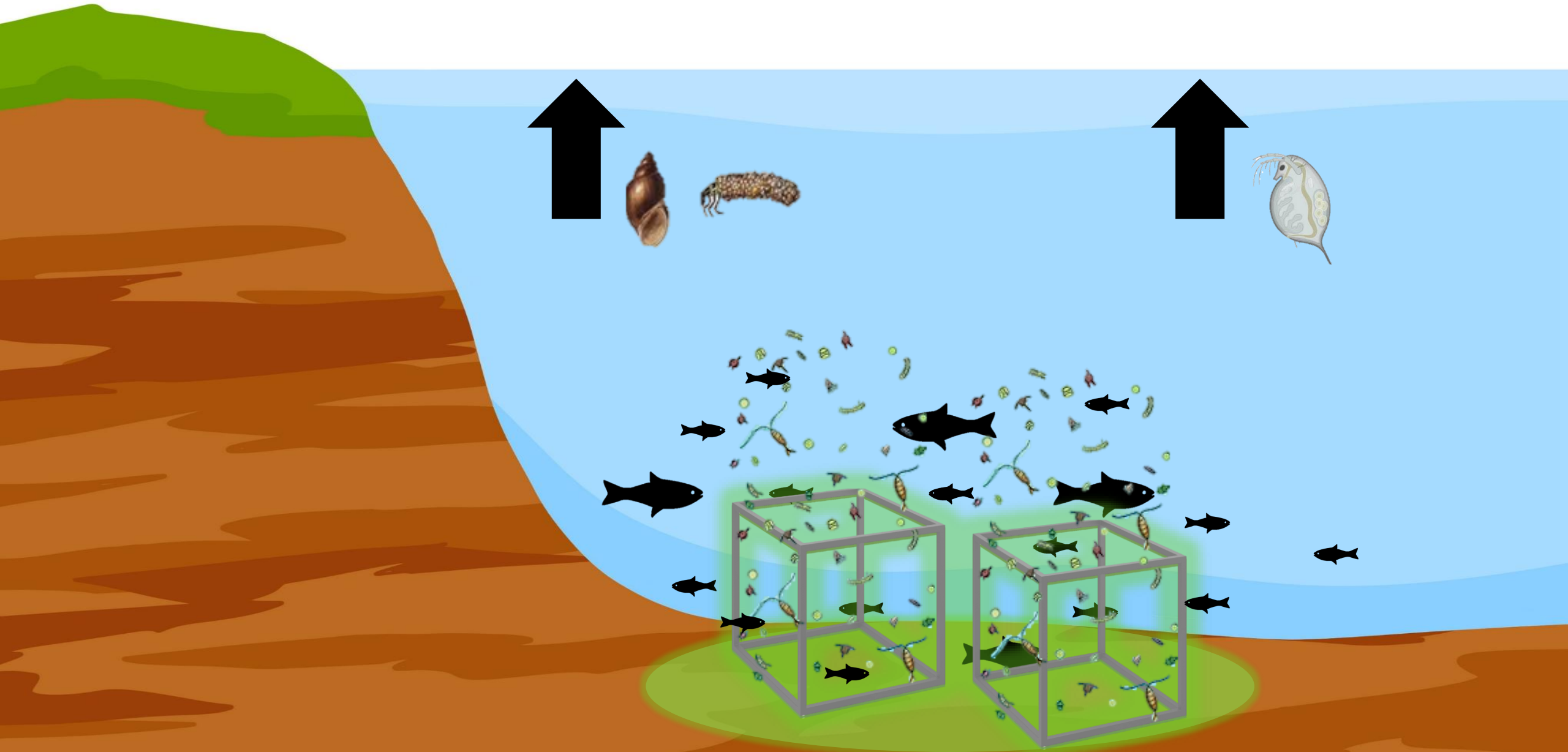
Difference in
taxa assemblage
structure?

~~Fall~~

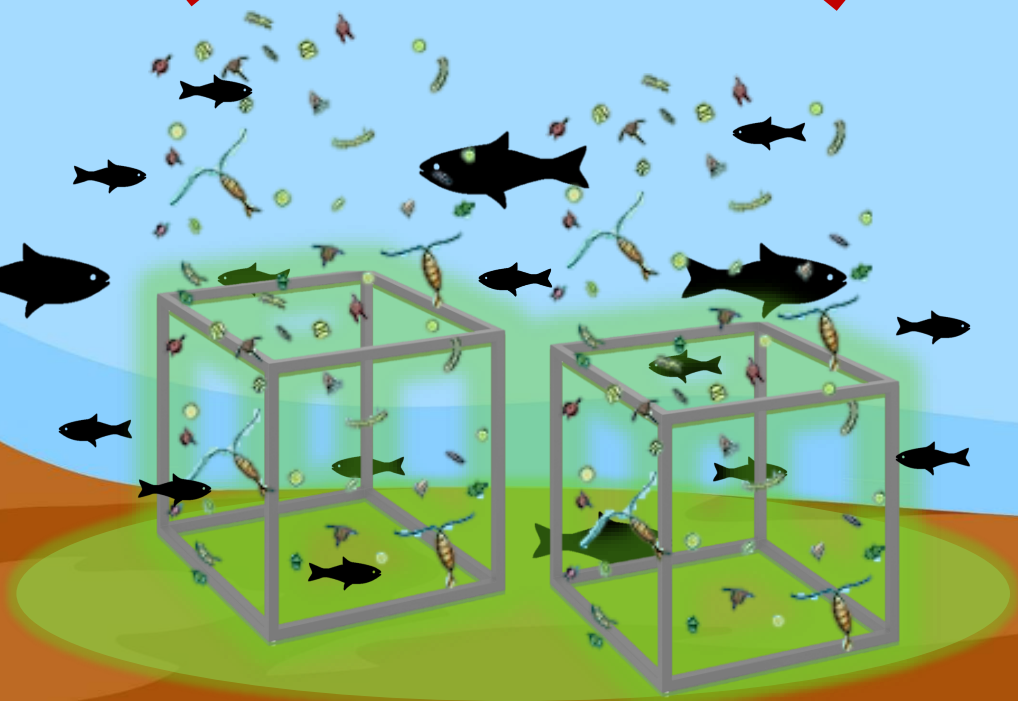
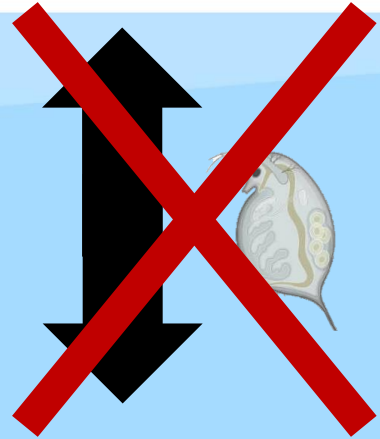
~~Fall~~

~~Spring~~

~~Spring~~



Fish Foraging?



**Coves with v. coves
without added
habitat:**

Offshore Fish



Inshore Fish



Difference in
CPUE/density?

Fall

~~Fall~~

Spring

~~Spring~~

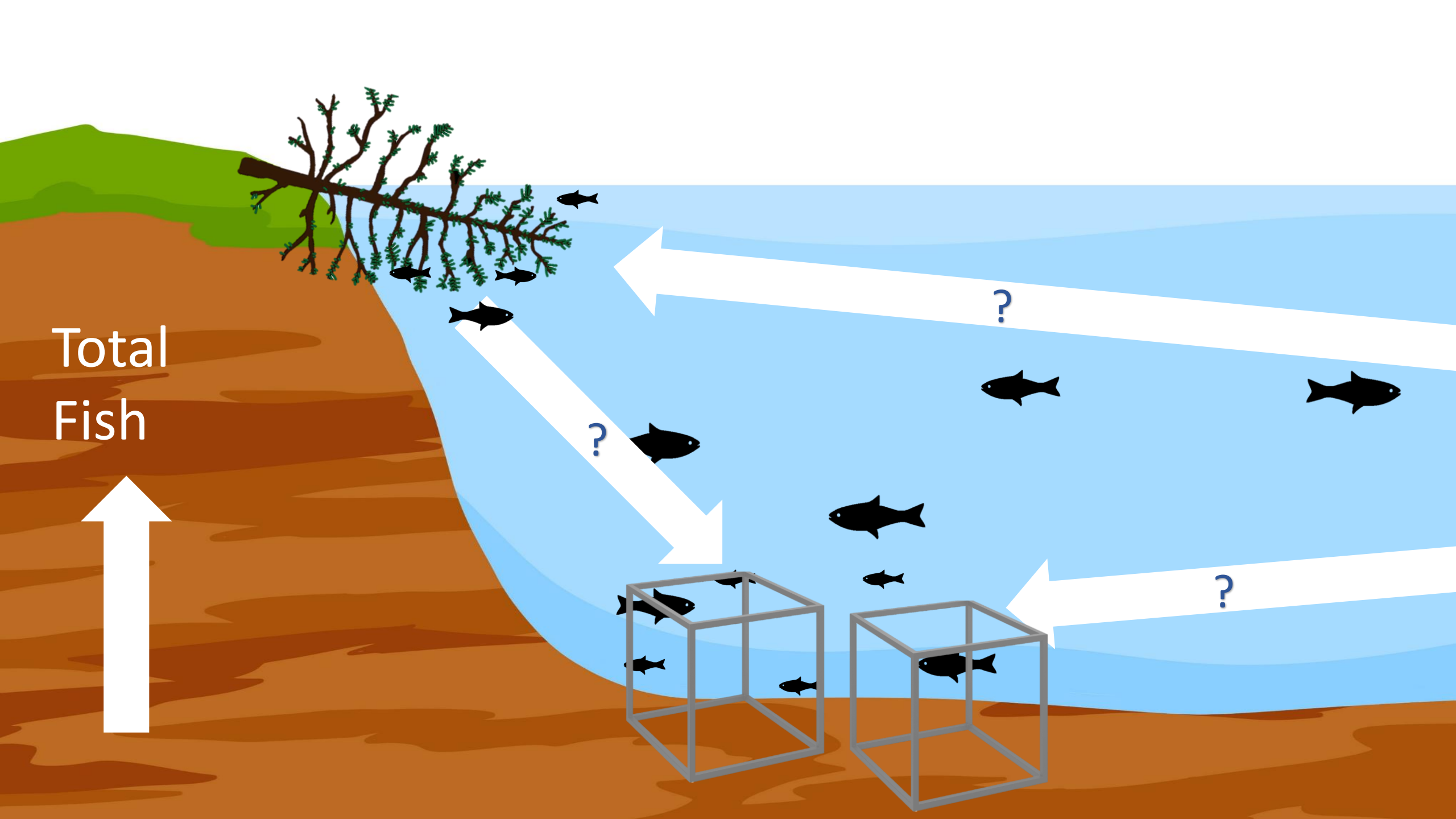
Difference in
taxa assemblage
structure?

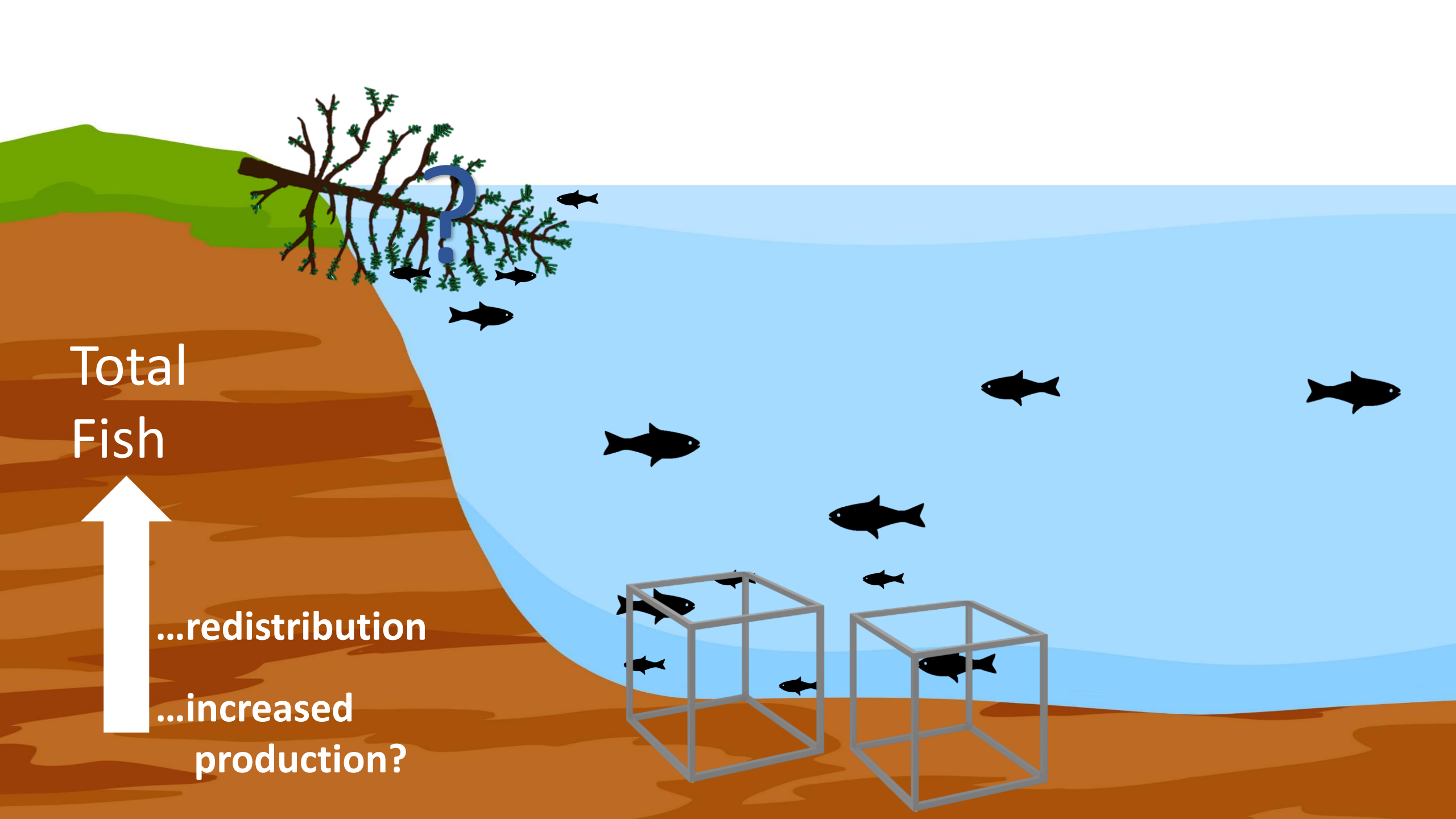
Fall

~~Fall~~

Spring

~~Spring~~





Total
Fish



...redistribution

...increased
production?



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Acknowledgements



Co-authors:

Anthony P. Porreca
Kyle J. Broadway
Thomas M. Detmer
Carly C. Fenstermacher
Joseph J. Parkos III

Field & laboratory work completed
by Kaskaskia Biological Station biologists,
technicians & students.



**US Army Corps
of Engineers®**



Coves with Cubes - Offshore Fish Size Distribution

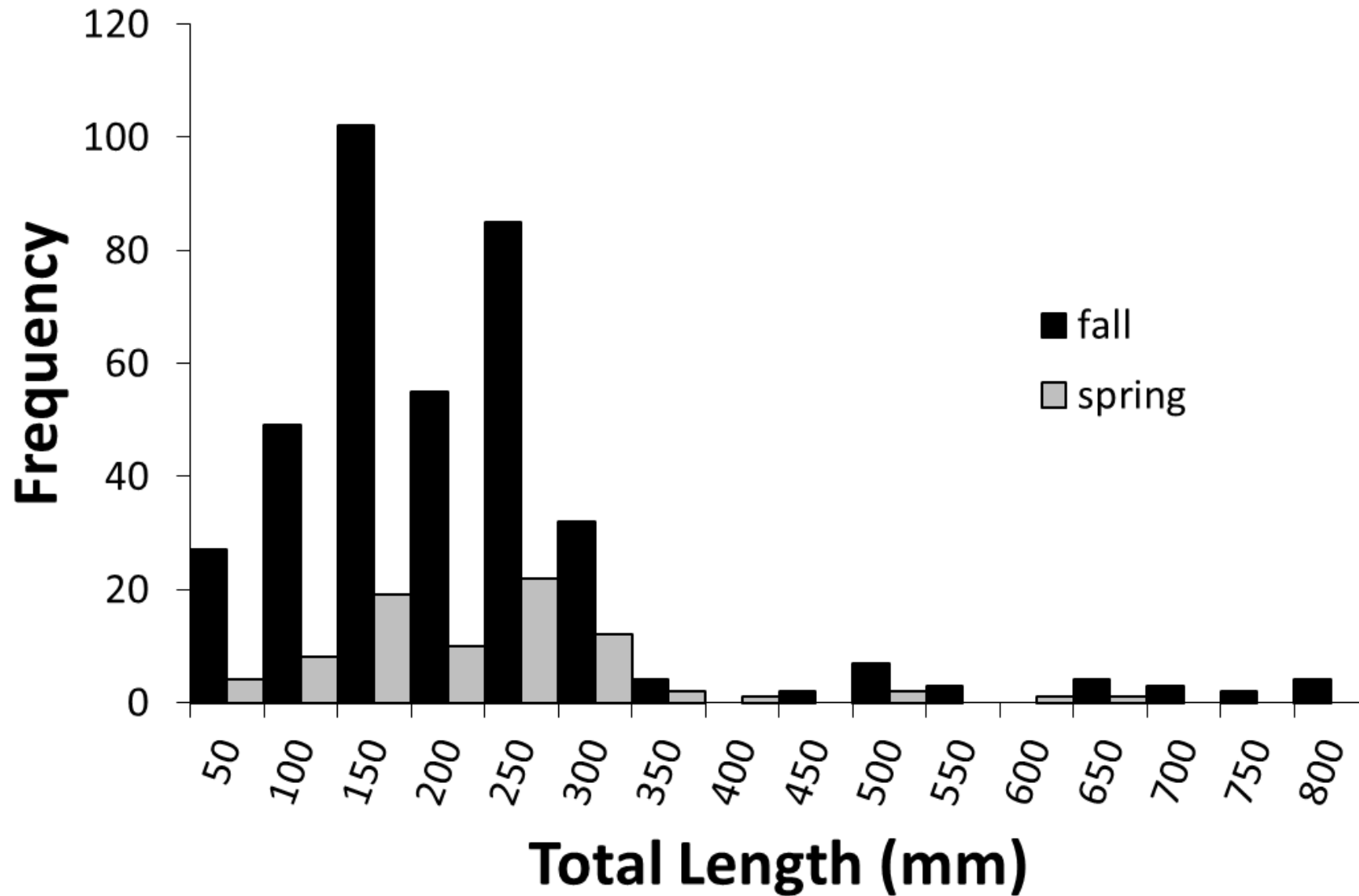


Table S1. Mean density by season of zooplankton (organisms/liter \pm SE) and macroinvertebrate (organisms/m² \pm SE) prey collected from offshore sites in reservoir coves with offshore structures and without offshore structures.

Prey taxa	Without structures		With structures	
	Fall	Spring	Fall	Spring
Zooplankton				
Cladocera	4.62 (0.76)	19.17 (0.75)	4.67 (0.79)	20.57 (4.47)
Copepod	64.34 (5.25)	157.88 (5.25)	71.03 (5.68)	185.90 (32.02)
Rotifer	149.70 (90.18)	303.17 (17.36)	143.05 (17.13)	317.72 (79.64)
Macroinvertebrates				
Caenidae	434.99 (936.20)	4.73 (3.24)	263.42 (101.37)	12.52 (4.85)
Ceratopogonidae	197.01 (77.96)	80.38 (19.12)	83.08 (33.93)	42.55 (18.24)
Chaoboridae	3.15 (3.15)	9.46 (4.29)	24.32 (13.95)	17.52 (12.13)
Chironomidae	2097.71 (306.73)	3212.77 (664.80)	1558.26 (311.05)	3043.80 (705.81)
Hydrachnidia	192.28 (104.37)	16.55 (11.99)	48.63 (19.32)	2.50 (2.50)
Leptoceridae	29.94 (11.08)	7.09 (5.16)	18.24 (6.93)	5.01 (3.43)
Nematoda	20.49 (17.35)	49.65 (29.64)	62.82 (34.82)	40.05 (27.18)
Ostracoda	348.31 (222.16)	0.0 (0.0)	372.85 (193.94)	0.0 (0.0)

Table S2. Littoral fishes (all species; percent of catch) collected using pulsed-DC boat electrofishing in reservoir coves without added structures.

Family	Species	Common name	Fall 2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Fall 2020
Atherinopsidae	<i>Labidesthes sicculus</i>	Brook Silverside	0.0	0.0	0.0	0.0	0.2	0.2
Catostomidae	<i>Carpoides carpio</i>	River Carpsucker	0.7	0.0	0.0	0.0	2.7	0.0
	<i>Carpoides cyprinus</i>	Quillback	1.8	0.8	0.7	1.4	0.0	0.0
Centrarchidae	<i>Ictiobus bubalus</i>	Smallmouth Buffalo	0.4	0.8	0.0	0.0	0.2	2.4
	<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo	0.6	0.0	0.1	0.7	0.2	0.2
	<i>Lepomis cyanellus</i>	Green Sunfish	1.1	0.0	0.0	0.0	0.0	0.2
	<i>Lepomis humilis</i>	Orangespotted Sunfish	0.0	0.0	0.1	0.0	0.2	0.0
	<i>Lepomis macrochirus</i>	Bluegill	36.3	14.5	12.3	5.4	8.2	29.2
	<i>Lepomis megalotis</i>	Longear Sunfish	3.7	0.0	0.1	2.2	0.5	2.8
	<i>Leopomis spp.</i>	Hybrid Sunfish	0.0	0.0	0.1	0.0	0.2	0.2
	<i>Micropterus salmoides</i>	Largemouth Bass	6.2	7.3	2.7	9.4	3.4	9.0
	<i>Pomoxis annularis</i>	White Crappie	1.1	25.4	1.0	39.1	2.3	10.6
	<i>Pomoxis nigromaculatus</i>	Black Crappie	5.9	1.6	6.3	3.6	3.7	10.6
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard Shad	37.6	45.6	72.8	29.7	74.1	26.4
Cyprinidae	<i>Cyprinus carpio</i>	Common Carp	0.0	0.0	0.4	0.0	0.0	1.2
	<i>Notropis spp.</i>	Shiner Spp.	0.0	0.0	0.0	0.0	0.0	0.0
Esocidae	<i>Esox masquinongy</i>	Muskellunge	0.0	0.0	0.0	0.0	0.0	0.2
Ictaluridae	<i>Ameiurus natalis</i>	Yellow Bullhead	0.0	0.0	0.7	0.0	0.0	0.0
	<i>Ictalurus punctatus</i>	Channel Catfish	0.0	0.4	0.1	0.0	0.0	0.2
Moronidae	<i>Morone chrysops</i>	White Bass	1.3	0.8	0.7	0.0	0.7	1.9
	<i>Morone mississippiensis</i>	Yellow Bass	2.2	2.0	0.0	6.9	2.1	3.1
Percidae	<i>Sander canadensis</i>	Sauger	0.2	0.4	0.0	0.0	0.0	0.0
	<i>Sander vitreus</i>	Walleye	0.7	0.4	0.8	0.0	0.7	0.2
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater Drum	0.2	0.0	0.8	1.4	0.7	1.2

Table S3. Littoral fishes (all species; percent of catch) collected using pulsed-DC boat electrofishing in reservoir coves with added structures.

Family	Species	Common name	Fall 2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Fall 2020
Atherinopsidae	<i>Labidesthes sicculus</i>	Brook Silverside	0.0	0.0	0.0	0.0	0.0	0.0
Catostomidae	<i>Carpoides carpio</i>	River Carpsucker	0.3	0.0	0.2	0.0	1.2	0.0
	<i>Carpoides cyprinus</i>	Quillback	2.1	1.0	0.5	0.4	0.0	0.0
	<i>Ictiobus bubalus</i>	Smallmouth Buffalo	3.1	1.3	0.2	0.0	2.1	9.3
	<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo	1.7	0.0	0.2	0.0	0.2	0.6
Centrarchidae	<i>Lepomis cyanellus</i>	Green Sunfish	0.0	0.0	0.5	0.2	0.4	0.3
	<i>Lepomis humilis</i>	Orangespotted Sunfish	0.0	0.0	0.2	0.0	0.8	0.0
	<i>Lepomis macrochirus</i>	Bluegill	28.7	16.4	25.6	7.2	18.6	22.0
	<i>Lepomis megalotis</i>	Longear Sunfish	4.5	0.0	4.3	3.5	4.6	0.6
	<i>Leopomis spp.</i>	Hybrid Sunfish	2.1	0.0	0.0	0.2	0.8	0.0
	<i>Micropterus salmoides</i>	Largemouth Bass	13.1	9.6	3.2	5.3	5.2	9.3
	<i>Pomoxis annularis</i>	White Crappie	2.8	40.2	2.6	38.0	3.9	12.7
	<i>Pomoxis nigromaculatus</i>	Black Crappie	8.7	0.6	3.4	13.1	7.2	10.2
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard Shad	26.0	24.4	57.0	21.1	49.9	27.9
Cyprinidae	<i>Cyprinus carpio</i>	Common Carp	1.4	2.3	0.2	0.6	0.0	0.9
	<i>Notropis spp.</i>	Shiner Spp.	0.0	0.0	0.0	0.0	0.2	0.0
Esocidae	<i>Esox masquinongy</i>	Muskellunge	0.0	0.0	0.0	0.0	0.0	0.3
Ictaluridae	<i>Ameiurus natalis</i>	Yellow Bullhead	0.0	0.0	0.3	0.0	0.0	0.0
	<i>Ictalurus punctatus</i>	Channel Catfish	0.3	0.0	0.0	0.2	0.0	0.3
Moronidae	<i>Morone chrysops</i>	White Bass	3.5	0.3	1.4	0.0	2.5	3.1
	<i>Morone mississippiensis</i>	Yellow Bass	0.7	3.2	0.0	9.6	2.1	1.5
Percidae	<i>Sander canadensis</i>	Sauger	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Sander vitreus</i>	Walleye	0.7	0.0	0.5	0.2	0.0	0.0
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater Drum	0.3	0.6	0.2	0.4	0.2	0.9

Table S4. Offshore fishes (all species; percent of catch) collected using deep-water AC electrofishing at sites in reservoir coves without added structures.

Family	Species	Common name	Fall					
			2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Fall 2020
Catostomidae	<i>Ictiobus bubalus</i>	Smallmouth Buffalo	0.0	7.7	8.0	22.2	0.0	4.3
	<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo	0.0	0.0	12.0	11.1	0.0	0.0
Centrarchidae	<i>Lepomis cyanellus</i>	Green Sunfish	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Lepomis humilis</i>	Orangespotted Sunfish	15.0	0.0	0.0	22.2	4.2	0.0
	<i>Lepomis macrochirus</i>	Bluegill	40.0	7.7	44.0	11.1	0.0	0.0
	<i>Lepomis megalotis</i>	Longear Sunfish	0.0	0.0	0.0	0.0	4.2	0.0
	<i>Leopomis spp.</i>	Hybrid Sunfish	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Micropterus salmoides</i>	Largemouth Bass	5.0	0.0	0.0	0.0	0.0	0.0
	<i>Pomoxis annularis</i>	White Crappie	5.0	30.8	0.0	0.0	0.0	8.7
	<i>Pomoxis nigromaculatus</i>	Black Crappie	0.0	0.0	8.0	0.0	0.0	0.0
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard Shad	25.0	30.8	8.0	11.1	45.8	34.8
Cyprinidae	<i>Cyprinus carpio</i>	Common Carp	0.0	7.7	4.0	0.0	0.0	0.0
	<i>Notropis spp.</i>	Shiner Spp.	0.0	0.0	0.0	0.0	0.0	0.0
Moronidae	<i>Morone chrysops</i>	White Bass	0.0	0.0	0.0	0.0	4.2	13.0
	<i>Morone mississippiensis</i>	Yellow Bass	10.0	7.7	0.0	11.1	0.0	0.0
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater Drum	0.0	7.7	16.0	11.1	41.7	39.1

Table S5. Offshore fishes (all species; percent of catch) collected using deep-water AC electrofishing in reservoir coves with added structures.

Family	Species	Common name	Fall 2017	Spring 2018	Fall 2018	Spring 2019	Fall 2019	Fall 2020
Catostomidae	<i>Ictiobus bubalus</i>	Smallmouth Buffalo	6.1	0.0	3.4	0.0	1.7	1.1
	<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo	4.1	0.0	6.9	5.6	0.0	3.3
Centrarchidae	<i>Lepomis cyanellus</i>	Green Sunfish	0.0	0.0	0.0	0.0	5.1	0.0
	<i>Lepomis humilis</i>	Orangespotted Sunfish	6.1	0.0	0.0	0.0	0.0	4.4
	<i>Lepomis macrochirus</i>	Bluegill	38.8	26.2	51.7	38.9	45.8	30.8
	<i>Lepomis megalotis</i>	Longear Sunfish	0.0	0.0	0.0	0.0	9.3	0.0
	<i>Leopomis spp.</i>	Hybrid Sunfish	0.0	0.0	6.9	0.0	0.0	0.0
	<i>Micropterus salmoides</i>	Largemouth Bass	0.0	2.4	3.4	0.0	0.8	0.0
	<i>Pomoxis annularis</i>	White Crappie	16.3	35.7	10.3	27.8	20.3	31.9
	<i>P. nigromaculatus</i>	Black Crappie	18.4	7.1	13.8	5.6	5.9	3.3
Clupeidae	<i>Dorosoma cepedianum</i>	Gizzard Shad	4.1	7.1	0.0	0.0	8.5	7.7
Cyprinidae	<i>Cyprinus carpio</i>	Common Carp	2.0	0.0	3.4	0.0	0.0	1.1
	<i>Notropis spp.</i>	Shiner Spp.	0.0	0.0	0.0	0.0	0.0	1.1
Moronidae	<i>Morone chrysops</i>	White Bass	0.0	2.4	0.0	0.0	0.0	4.4
	<i>M. mississippiensis</i>	Yellow Bass	2.0	11.9	0.0	0.0	0.0	2.2
Sciaenidae	<i>Aplodinotus grunniens</i>	Freshwater Drum	2.0	7.1	0.0	22.2	2.5	8.8

**Coves with v. coves
without added
habitat:**

Offshore Fish



Inshore Fish



Benthic
Macroinvertebrates



Zooplankton



Difference in
CPUE/density?

Fall

~~Fall~~

~~Fall~~

~~Fall~~

Spring

~~Spring~~

~~Spring~~

~~Spring~~

Difference in
taxa assemblage
structure?

Fall

~~Fall~~

~~Fall~~

~~Fall~~

Spring

~~Spring~~

~~Spring~~

~~Spring~~