Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

2018 Annual Performance Reports
F-61-R-21
Grant Number: F14AF00182

Jobs 1-14
Note: Jobs 5 and 7 have been completed

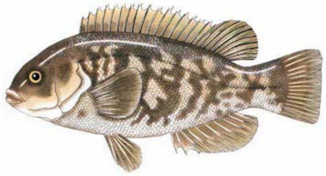
PERIOD: **January 1, 2018 – December 31, 2018**

Rhode Island Department of Environmental Management, Division of Marine Fisheries

ASSESSMENT OF RECREATIONALLY IMPORTANT FINFISH STOCKS IN RHODE ISLAND WATERS

COASTAL FISHERY RESOURCE ASSESSMENT
TRAWL SURVEY
2018

PERFORMANCE REPORT
F-61-R SEGMENT 21
JOBS 1 AND 2



Christopher Parkins
Principal Marine Biologist
Scott D. Olszewski
Deputy Chief

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

March 2019

Annual Performance Report

STATE: Rhode Island

PROJECT NUMBER: F-61-R-21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

JOB NUMBER: 1

TITLE: Narragansett Bay Monthly Fishery Resource Assessment

JOB OBJECTIVE: To collect, summarize and analyze bottom trawl data for biological and fisheries management purposes.

PERIOD COVERED: January 1, 2018 – December 31, 2018.

PROJECT SUMMARY: Job 1, summary accomplished:

A: 144 twenty-minute bottom trawl were successfully completed.

B: Data on weight, length, sex and numbers were gathered on 61 species. Hydrographic data were gathered as well. Additionally, anecdotal notations were made on other plant and animal species. Although not previously discussed, these notations are in keeping with past practice.

TARGET DATE: December 2018

SCHEDULE OF PROGRESS: On schedule.

SIGNIFICANT DEVIATIONS: During the month of August only 2 of the 13 monthly tows were completed due to mechanical issues with the survey vessel engine. To fix the vessel and not delay the start of the seasonal survey in September we did not fully sample our August monthly stations.

JOB NUMBER: 2

TITLE: Seasonal Fishery Resource Assessment of Narragansett Bay, Rhode Island Sound and Block Island Sound

JOB OBJECTIVE: To collect, summarize and analyze bottom trawl data for biological and fisheries management purposes.

PERIOD COVERED: Spring (April – May)/ Fall (September – October) 2018

PROJECT SUMMARY: Job 2, summary accomplished:

A: 44, twenty-minute tows were successfully completed during the Spring 2018 survey (26 NB. – 6 RIS – 12 BIS).
B: 44, twenty-minute tow were successfully completed during the Fall 2018 survey (26 NB. – 6 RIS – 12 BIS)
C: Data on weight, length, sex and numbers were gathered on 69 species. Hydrographic data were gathered as well. Additionally, anecdotal notations were made on other plant and animal species. Although not previously discussed, these notations are in keeping with past practice.

TARGET DATE: DECEMBER 2018.

SCHEDULE OF PROGRESS: On schedule.

SIGNIFICANT DEVIATIONS: None

JOBS 1 & 2

RECOMMENDATIONS: Continuation of both the Monthly and Seasonal Trawl surveys into 2019, Data provided by these surveys is used extensively in the Atlantic States Marine Fisheries Commission Fishery Management process and Fishery Management Plans.

RESULTS AND DISCUSSION: 144 tows were completed during 2018 Job 1 (Monthly survey). 69 species accounted for a combined weight of 6876.93 kgs. and 320,669 length measurements being added to the existing Narragansett Bay monthly trawl data set
By contrast, 88 tows were completed during 2018 Job 2 (Seasonal survey) 69 species accounted for a combined weight of 4033.18 kgs. and 338,662 length measurements added to the existing seasonal data set.

With the completion of the 2018 surveys, combined survey(s) Jobs (1&2) data now reflects the completion of 6,922 tows with data collected on 148 species.

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PREPARED BY: ________________________ ________________________
Christopher J. Parkins Date
Principal Marine Biologist
Principal Investigator

APPROVED BY: ________________________ ________________________
Jason McNamee Date
Chief, Marine Resources
RIDEM – Division of Marine Fisheries

Coastal Fishery Resource Assessment – Trawl Survey

Introduction:

The Rhode Island Division of Fish and Wildlife - Marine Fisheries Section, began monitoring finfish populations in Narragansett Bay in 1968, continuing through 1977. These data provided monthly identification of finfish and crustacean assemblages. As management strategies changed and focus turned to the near inshore waters, outside of Narragansett Bay, a comprehensive fishery resource assessment program was instituted in 1979. (Lynch T. R. Coastal Fishery Resource Assessment, 2007)

Since the inception of the Rhode Island Seasonal Trawl Survey (April 1979) and the Narragansett Bay Monthly Trawl Survey (January 1990), 6,922 tows have been conducted within Rhode Island territorial waters with data collected on 148 species. This performance report reflects the efforts of the 2018 survey year as it relates to the past 40 years. (Lynch T. R. Coastal Fishery Resource Assessment, 2007), (Olszewski S.D. Coastal Fishery Resource Assessment 2014)

Methods:

The methodology used in the allocation of sampling stations employs both random and fixed station allocation. Fixed station allocation began in 1988 in Rhode Island Sound and Block Island Sound. This was based on the frequency of replicate stations selected by depth stratum since 1979. With the addition of the Narragansett Bay monthly portion of the survey in 1990, an allocation system of fixed and randomly selected stations has been employed depending on the segment (Monthly vs. Seasonal) of the annual surveys.

Sampling stations were established by dividing Narragansett Bay into a grid of cells. The seasonal trawl survey is conducted in the spring and fall of each year. Usually 44 stations are sampled each season; however, this number has ranged from 26 to 72 over the survey time series due to mechanical and weather conditions. The stations sampled in Narragansett Bay are a combination of fixed and random sites. 13 fixed during the monthly portion and 26, (14 of which are randomly selected) during the seasonal portion. The random sites are randomly selected from a predefined grid. All stations sampled in Rhode Island and Block Island Sounds are fixed.

Depth Stratum Identification

Area	**Stratum**	**Area nm^2**	**Depth Range (m)**
Narragansett Bay	1	15.50	<=6.09
	2	51.00	>=6.09
Rhode Island Sound	3	0.25	<=9.14
	4	2.25	9.14 – 18.28
	5	13.5	18.28 – 27.43
	6	9.75	>=27.43
Block Island Sound	7	3.50	<=9.14
	8	10.50	9.14 – 18.28
	9	11.50	18.28 – 27.43
	10	12.25	27.43 – 36.57
	11	4.00	>=36.57

At each station, an otter trawl equipped with a ¼ mesh inch liner is towed for twenty minutes. The Coastal Trawl survey net is 210 x 4.5”, 2 seam (40’ / 55’), the mesh size is 4.5” and the sweep is 5/16” chain, hung 12” spacing, 13 links per space. Figure 1 depicts the RI Coastal Trawl survey net plan.

The research vessel used in the Coastal Trawl Survey is the R/V John H. Chafee. Built in 2002, the Research Vessel is a 50’ Wesmac hull, powered by a 3406 Caterpillar engine generating 700 hp.

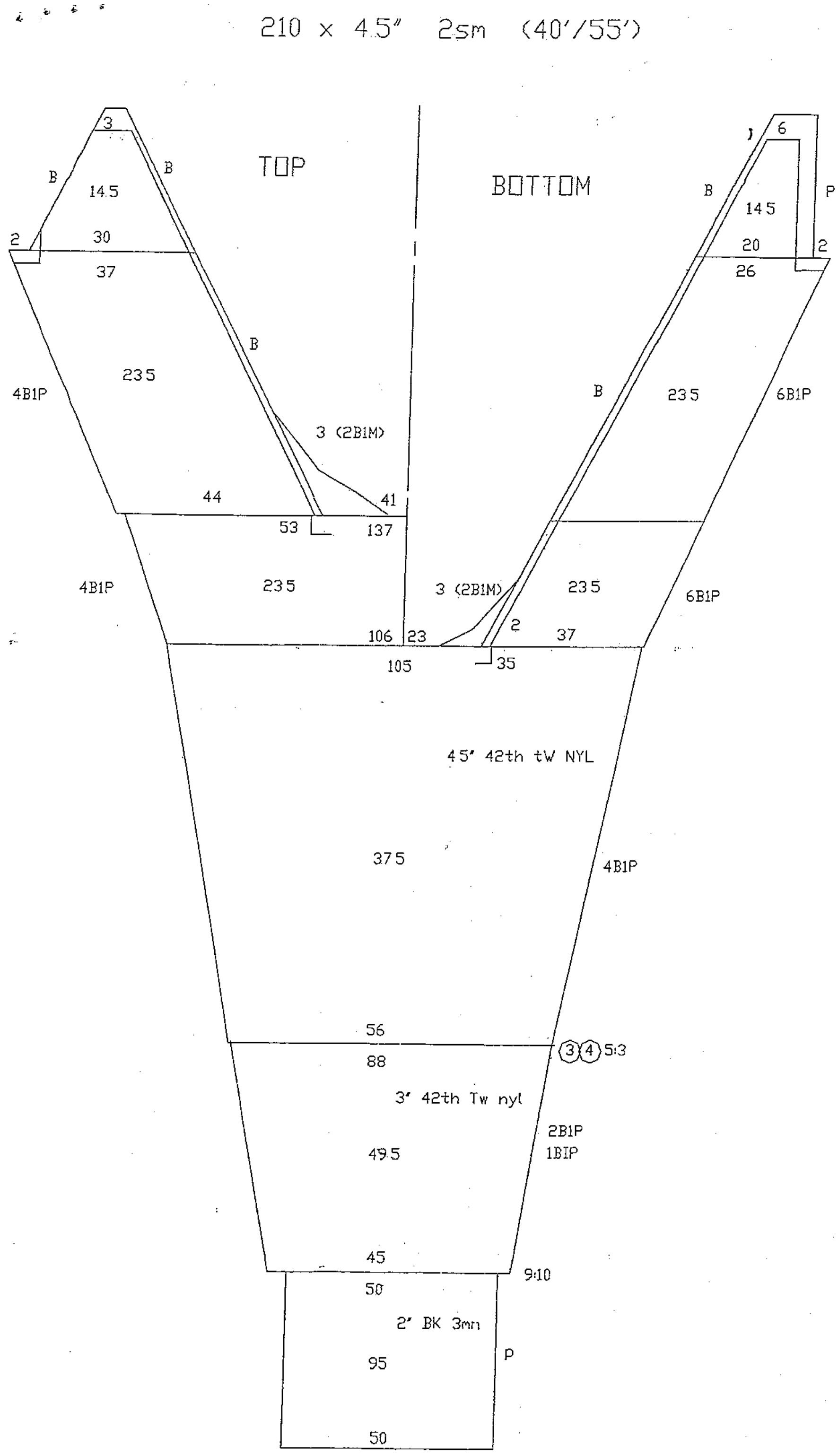
Data on wind direction and speed, sea condition, air temperature and cloud cover as well as surface and bottom water temperatures, are recorded at each station. Catch is sorted by species. Length (cm/mm) is recorded for all finfish, skates, squid, scallops, Whelk lobster, blue crabs and horseshoe crabs. Similarly, weights (g/kg) and number are recorded as well. Anecdotal information is also recorded for incidental plant and animal species.

Survey changes- Beginning January 2012 the Rhode Island Coastal Trawl Survey began using an updated set of trawl doors. Throughout 2012, a comparative gear calibration study was completed to determine if a significant change to the survey catch data is exists. The analysis of this calibration study was completed in 2013 and is available upon request.

RIDEM R/V John H. Chafee

Acknowledgements:
Special thanks are again extended to Captain Richard Mello (retired Feb 2018), Captain Patrick Brown and Assistant Captain Sean Fitzgerald, and the entire seasonal staff and volunteers. The support given over the years has been greatly appreciated.

Figure 1


210 x 4.5" 2sm (40'/55')
TOP
BOTTOM
3
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2
30
37
B
235
4B1P
3 (2B1M)
44
41
53
137
4B1P
235
106
23
105
6
B
P
145
20
2
26
B
235
6B1P
3 (2B1M)
235
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37
35
45' 42th tW NYL
375
4B1P
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3' 42th Tw nyl
2B1P
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495
45
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50
2' BK 3mm
P
95
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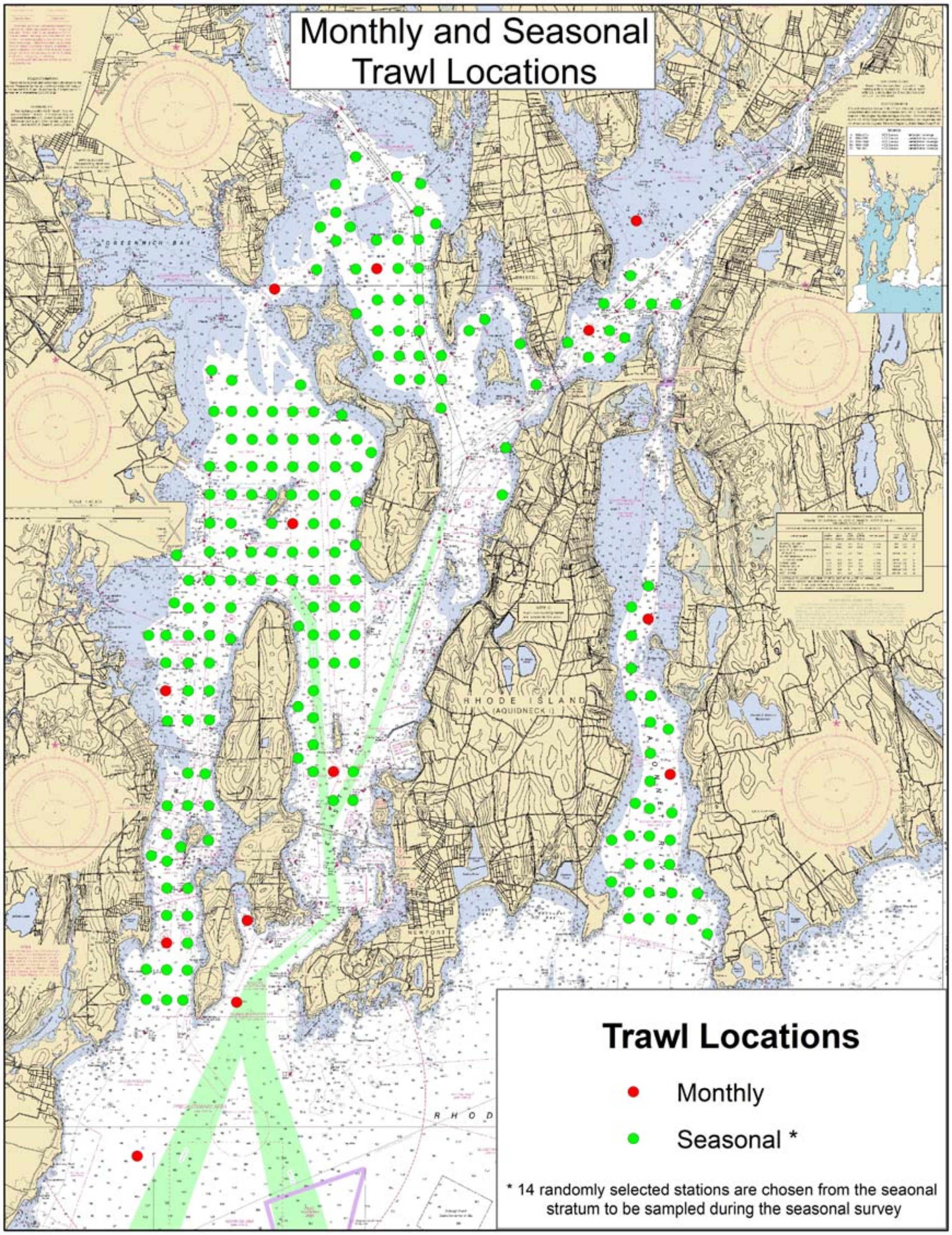
Map 1: Monthly (fixed) and Seasonal (grid) Stations in Narragansett Bay



Results: Job 1. Monthly Coastal Trawl Survey; 12 fixed stations in Narragansett Bay and 1 in Rhode Island Sound.

A total of 69 species were observed and recorded during the 2018 Narragansett Bay Monthly Trawl Survey totaling 320,669 individuals or 2226.9 fish per tow. In weight, the catch accounted for 6876.9 kg. or 47.7 kg. per tow. (Figures 2 and 3) The top ten species by number and catch are represented in figures 4 and 5. The catch between demersal and pelagic species is represented in figures 6 and 7and shows a clear shift from demersal species to a more pelagic or multi-habitat species.

Figure 2 (Total Catch in Number)

Scientific Name	Common Name	Total #
BREVOORTIA TYRANNUS	Atlantic Menhaden	117383
STENOTOMUS CHRYSOPS	Scup	78165
LOLIGO PEALEI	Longfin Squid	32770
MENIDIA MENIDIA	Atlantic Silverside	26620
ANCHOA MITCHILLI	Bay Anchovy	25380
CLUPEA HARENGUS	Atlantic Herring	14296
PEPRILUS TRIACANTHUS	Butterfish	10525
ALOSA PSEUDOHARENGUS	Alewife	5883
MERLUCCIUS BILINEARIS	Silver Hake	2706
SELENE SETAPINNIS	Atlantic Moonfish	1023
PRIONOTUS CAROLINUS	Northern Sea Robin	793
LEUCORAJA ERINACEA	Little Skate	662
CYNOSCION REGALIS	Weakfish	596
ALOSA AESTIVALIS	Blueback Herring	468
CENTROPRISTIS STRIATA	Black Sea Bass	436
CANCER IRRORATUS	Rock Crab	357
PRIONOTUS EVOLANS	Striped Sea Robin	297
UROPHYCIS REGIA	Spotted Hake	273
PLEURONECTES AMERICANUS	Winter Flounder	263
PARALICHTHYS DENTATUS	Summer Flounder	222
HOMARUS AMERICANUS	American Lobster	218
GADUS MORHUA	Atlantic Cod	186
UROPHYCIS CHUSS	Red Hake	173
TAUTOGA ONITIS	Tautog	159
PARALICHTHYS OBLONGUS	Fourspot Flounder	117
MUSTELUS CANIS	Smooth Dogfish	104
SCOPHTHALMUS AQUOSUS	Windowpane Flounder	70
ALOSA SAPIDISSIMA	American Shad	45
MENTICIRRHUS SAXATILIS	Northern Kingfish	40
RAJA EGLANTERIA	Clearnose Skate	38
TRACHURUS LATHAMI	Rough Scad	37

SQUILLA EMPUSA	Mantis Shrimp	36
POMATOMUS SALTATRIX	Bluefish	33
BUSYCOTYPUS CANALICULATUS	Channeled Whelk	33
ETROPUS MICROSTOMUS	Smallmouth Flounder	33
CALLINECTES SAPIDUS	Blue Crab	24
LIMULUS POLYPHEMUS	Horseshoe Crab	22
AMMODYTES AMERICANUS	Sand Lance	21
MORONE AMERICANA	White Perch	19
SYNODUS FOETENS	Inshore Lizardfish	16
MORONE SAXATILIS	Striped Bass	15
BUSYCON CARICA	Knobbed Whelk	15
TRINECTES MACULATUS	Hogchoker	9
DOROSOMA CEPEDIANUM	Gizzard Shad	9
ANCHOA HEPSETUS	Striped Anchovy	9
MYOXOCEPHALUS OCTODECEMSPINOS	Longhorn Sculpin	8
CANCER BOREALIS	Jonah Crab	7
ILLEX ILLECEBROSUS	Shortfin Squid	7
MICROGADUS TOMCOD	Atlantic Tomcod	7
TAUTOGOLABRUS ADSPERSUS	Cunner	6
LEUCORAJA OCELLATA	Winter Skate	5
MYOXOCEPHALUS AENAEUS	Grubby	5
SPHOEROIDES MACULATUS	Northern Puffer	4
ARGOPECTEN IRRADIANS	Bay Scallop	2
LEIOSTOMUS XANTHURUS	Spot	2
ALECTIS CILIARIS	African Pompano	2
OPHIDION MARGINATUM	Striped Cusk-Eel	2
SYNGNATHUS FUSCUS	Northern Pipefish	2
SCOMBER SCOMBRUS	Atlantic Mackerel	1
OPSANUS TAU	Oyster Toadfish	1
SPHYRAENA BOREALIS	Northern Sennet	1
CONGER OCEANICUS	Conger Eel	1
SQUALUS ACANTHIAS	Spiny Dogfish	1
MELANOGRAMMUS AEGLEFINUS	Haddock	1
EPINEPHELUS NIVEATUS	Snowy Grouper	1
ROSSIA MOELLERI	Bobtail Squid	1
DECAPTERUS PUNCTATUS	Round Scad	1
GOBIIDAE	Gobies	1
PHOLIS GUNNELLUS	Rock Gunnel	1

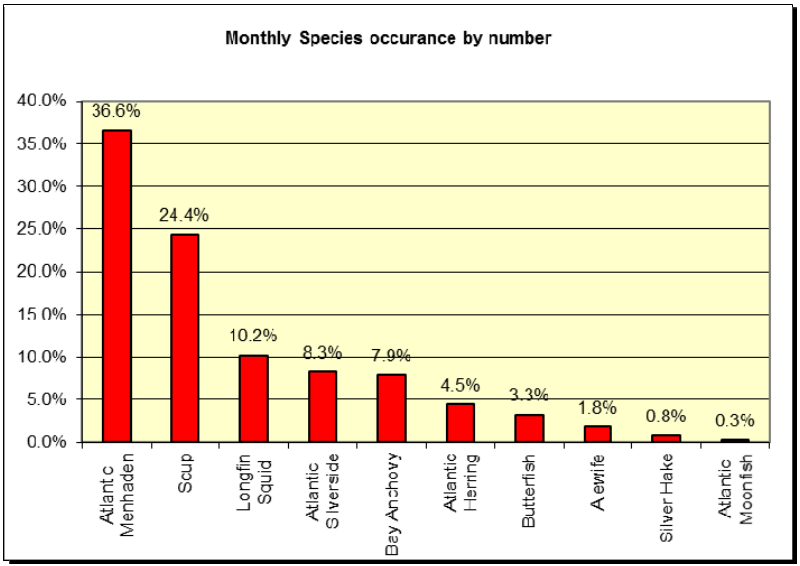
Figure 3 (Total Catch in Kilograms)

Scientific Name	Common Name	Total Weight (kg)
STENOTOMUS CHRYSOPS	Scup	4017.617
PEPRILUS TRIACANTHUS	Butterfish	389.434
LEUCORAJA ERINACEA	Little Skate	379.289
LOLIGO PEALEI	Longfin Squid	327.724
TAUTOGA ONITIS	Tautog	175.007
MERLUCCIUS BILINEARIS	Silver Hake	163.694
BREVOORTIA TYRANNUS	Atlantic Menhaden	147.181
PARALICHTHYS DENTATUS	Summer Flounder	127.963
PRIONOTUS CAROLINUS	Northern Sea Robin	127.634
ALOSA PSEUDOHARENGUS	Alewife	124.307
MUSTELUS CANIS	Smooth Dogfish	105.377
PRIONOTUS EVOLANS	Striped Sea Robin	104.394
CENTROPRISTIS STRIATA	Black Sea Bass	85.494
HOMARUS AMERICANUS	American Lobster	70.952
RAJA EGLANTERIA	Clearnose Skate	64.745
MENIDIA MENIDIA	Atlantic Silverside	60.633
LIMULUS POLYPHEMUS	Horseshoe Crab	53.930
CLUPEA HARENGUS	Atlantic Herring	48.721
CANCER IRRORATUS	Rock Crab	46.543
PLEURONECTES AMERICANUS	Winter Flounder	42.398
PARALICHTHYS OBLONGUS	Fourspot Flounder	28.305
UROPHYCIS REGIA	Spotted Hake	25.754
CYNOSCION REGALIS	Weakfish	25.142
MORONE SAXATILIS	Striped Bass	24.045
ANCHOA MITCHILLI	Bay Anchovy	23.913
SCOPHTHALMUS AQUOSUS	Windowpane Flounder	14.636
UROPHYCIS CHUSS	Red Hake	11.165
LEUCORAJA OCELLATA	Winter Skate	11.035
POMATOMUS SALTATRIX	Bluefish	10.519
CALLINECTES SAPIDUS	Blue Crab	5.487
SELENE SETAPINNIS	Atlantic Moonfish	5.373
BUSYCOTYPUS CANALICULATUS	Channeled Whelk	4.623
MENTICIRRHUS SAXATILIS	Northern Kingfish	4.239
BUSYCON CARICA	Knobbed Whelk	2.789
MYOXOCEPHALUS OCTODECEMSPINOS	Longhorn Sculpin	2.688
TRACHURUS LATHAMI	Rough Scad	2.595
ALOSA SAPIDISSIMA	American Shad	1.914
CANCER BOREALIS	Jonah Crab	1.816
ALOSA AESTIVALIS	Blueback Herring	1.345
SYNODUS FOETENS	Inshore Lizardfish	1.171

SPHOEROIDES MACULATUS	Northern Puffer	1.067
TRINECTES MACULATUS	Hogchoker	0.750
SQUILLA EMPUSA	Mantis Shrimp	0.505
TAUTOGOLABRUS ADSPERSUS	Cunner	0.403
MORONE AMERICANA	White Perch	0.390
SCOMBER SCOMBRUS	Atlantic Mackerel	0.298
DOROSOMA CEPEDIANUM	Gizzard Shad	0.270
ETROPUS MICROSTOMUS	Smallmouth Flounder	0.264
ILLEX ILLECEBROSUS	Shortfin Squid	0.165
OPSANUS TAU	Oyster Toadfish	0.158
ARGOPECTEN IRRADIANS	Bay Scallop	0.153
LEIOSTOMUS XANTHURUS	Spot	0.140
GADUS MORHUA	Atlantic Cod	0.137
SPHYRAENA BOREALIS	Northern Sennet	0.124
CONGER OCEANICUS	Conger Eel	0.100
SQUALUS ACANTHIAS	Spiny Dogfish	0.080
ANCHOA HEPSETUS	Striped Anchovy	0.069
MELANOGRAMMUS AEGLEFINUS	Haddock	0.046
MYOXOCEPHALUS AENAEUS	Grubby	0.042
EPINEPHELUS NIVEATUS	Snowy Grouper	0.038
ALECTIS CILIARIS	African Pompano	0.035
AMMODYTES AMERICANUS	Sand Lance	0.028
OPHIDION MARGINATUM	Striped Cusk-Eel	0.022
SYNGNATHUS FUSCUS	Northern Pipefish	0.019
MICROGADUS TOMCOD	Atlantic Tomcod	0.010
ROSSIA MOELLERI	Bobtail Squid	0.010
DECAPTERUS PUNCTATUS	Round Scad	0.006
GOBIIDAE	Gobies	0.005
PHOLIS GUNNELLUS	Rock Gunnel	0.004

Figure 4 Monthly Survey Top Ten Species Catch in Number

Fish Name	Scientific Name	%
Atlantic Menhaden	BREVOORTIA TYRANNUS	36.6%
Scup	STENOTOMUS CHRYSOPS	24.4%
Longfin Squid	LOLIGO PEALEI	10.2%
Atlantic Silverside	MENIDIA MENIDIA	8.3%
Bay Anchovy	ANCHOA MITCHILLI	7.9%
Atlantic Herring	CLUPEA HARENGUS	4.5%
Butterfish	PEPRILUS TRIACANTHUS	3.3%
Alewife	ALOSA PSEUDOHARENGUS	1.8%
Silver Hake	MERLUCCIUS BILINEARIS	0.8%
Atlantic Moonfish	SELENE SETAPINNIS	0.3%



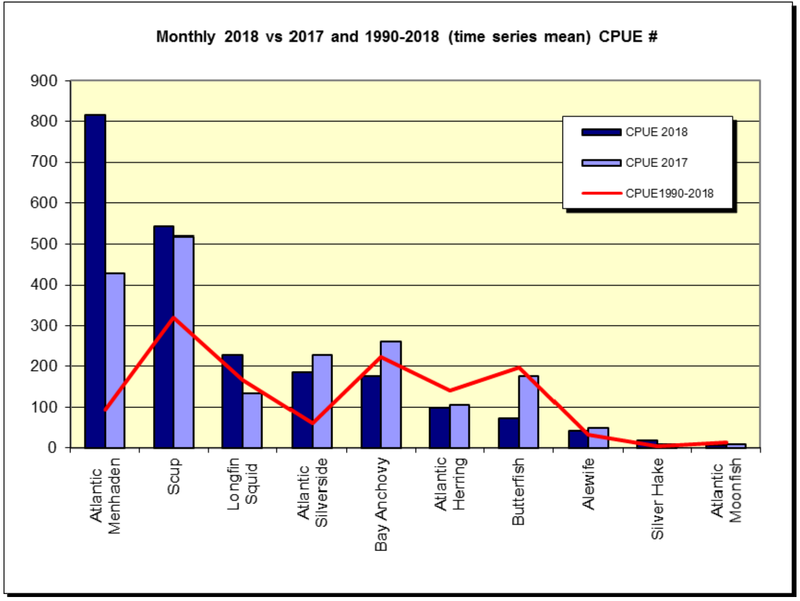
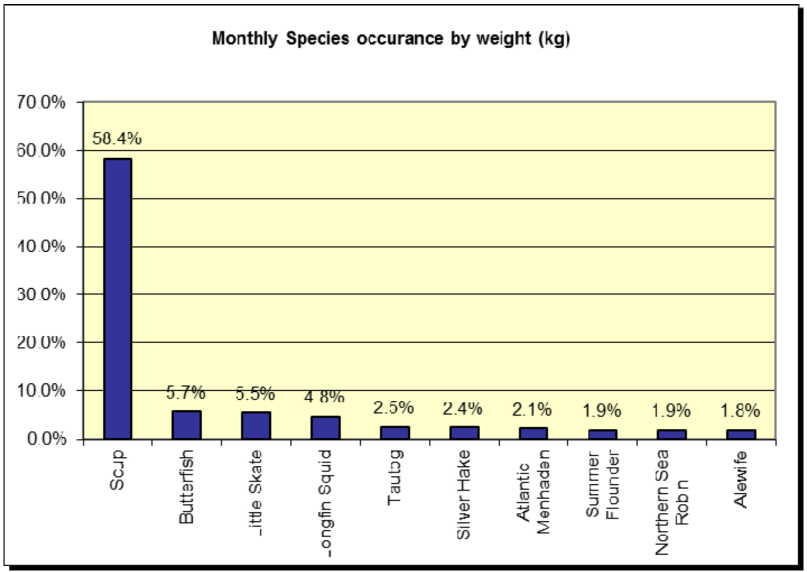


Figure 5 Top Ten Species Catch in Kilograms

Fish Name	Scientific Name	%
Scup	STENOTOMUS CHRYSOPS	58.4%
Butterfish	PEPRILUS TRIACANTHUS	5.7%
Little Skate	LEUCORAJA ERINACEA	5.5%
Longfin Squid	LOLIGO PEALEI	4.8%
Tautog	TAUTOGA ONITIS	2.5%
Silver Hake	MERLUCCIUS BILINEARIS	2.4%
Atlantic Menhaden	BREVOORTIA TYRANNUS	2.1%
Summer Flounder	PARALICHTHYS DENTATUS	1.9%
Northern Sea Robin	PRIONOTUS CAROLINUS	1.9%
Alewife	ALOSA PSEUDOHARENGUS	1.8%



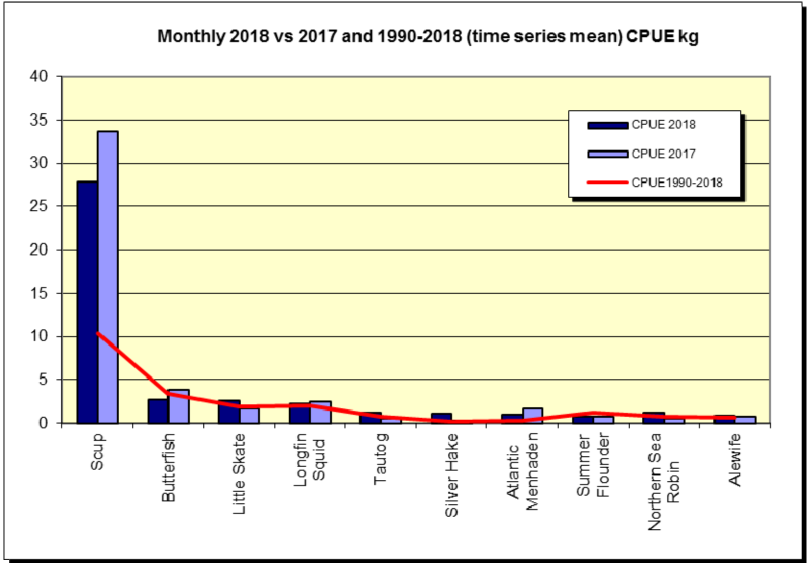
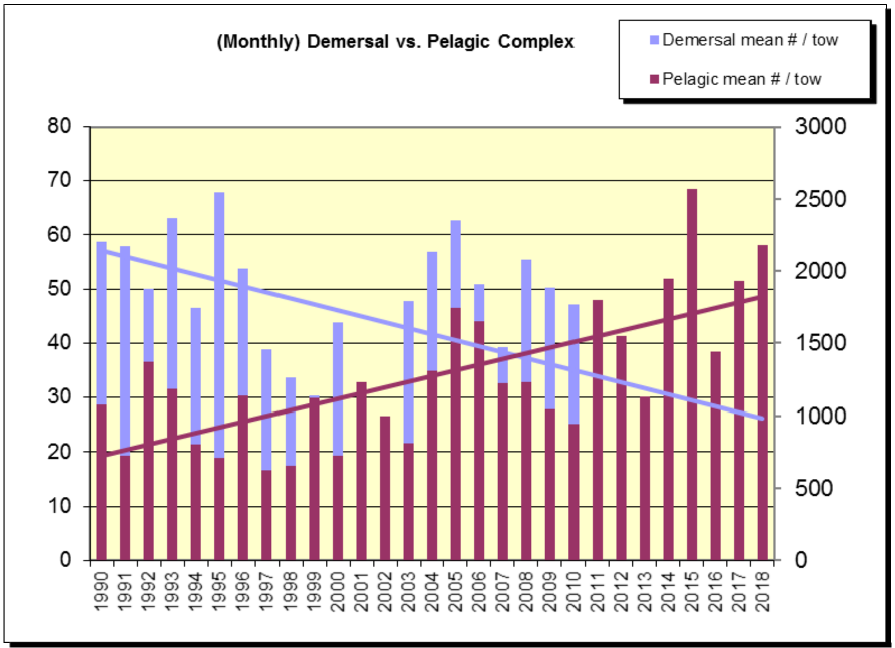
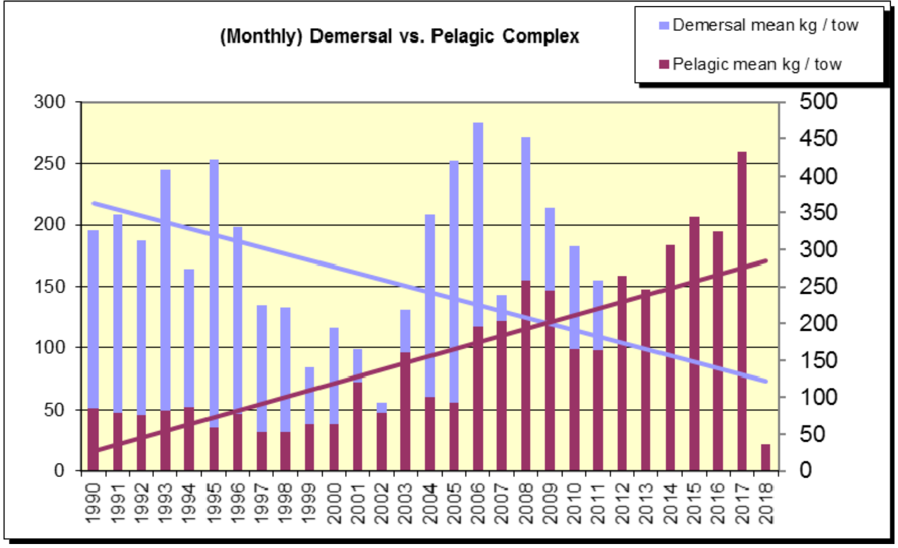


Figure 6 and 7: Demersal vs. Pelagic Species Complex

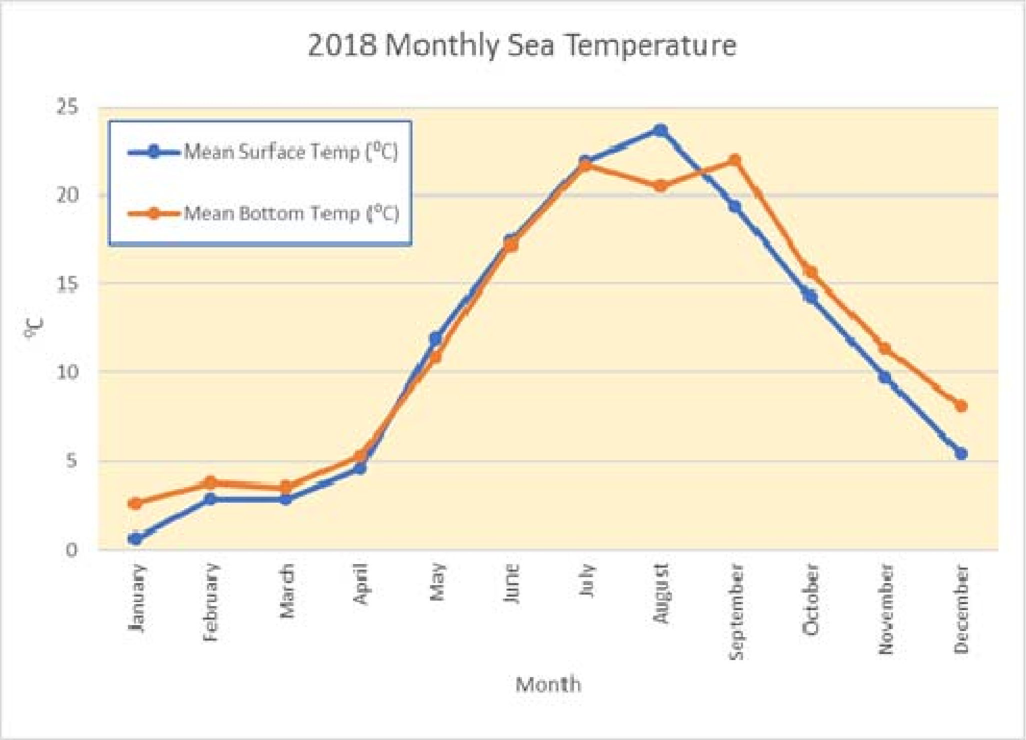
Demersal Species		Pelagic/Multi-Habitat Species	
Smooth Dogfish	Hogchoker	Atlantic Herring	Bluefish
Spiny Dogfish	Longhorn Sculpin	Alewife	Striped Bass
Skates	Sea Raven	Blueback Herring	Black Sea Bass
Silver Hake	Northern Searobin	Shad	Scup
Red Hake	Striped Searobin	Menhaden	Weakfish
Spotted Hake	Cunner	Bay Anchovy	Longfin Squid
Summer Flounder	Tautog	Rainbow Smelt	
4-Spot Flounder	Ocean Pout	Silverside	
Winter Flounder	Goosefish	Butterfish	
Windowpane Flounder	Lobster	Atlantic Moonfish	

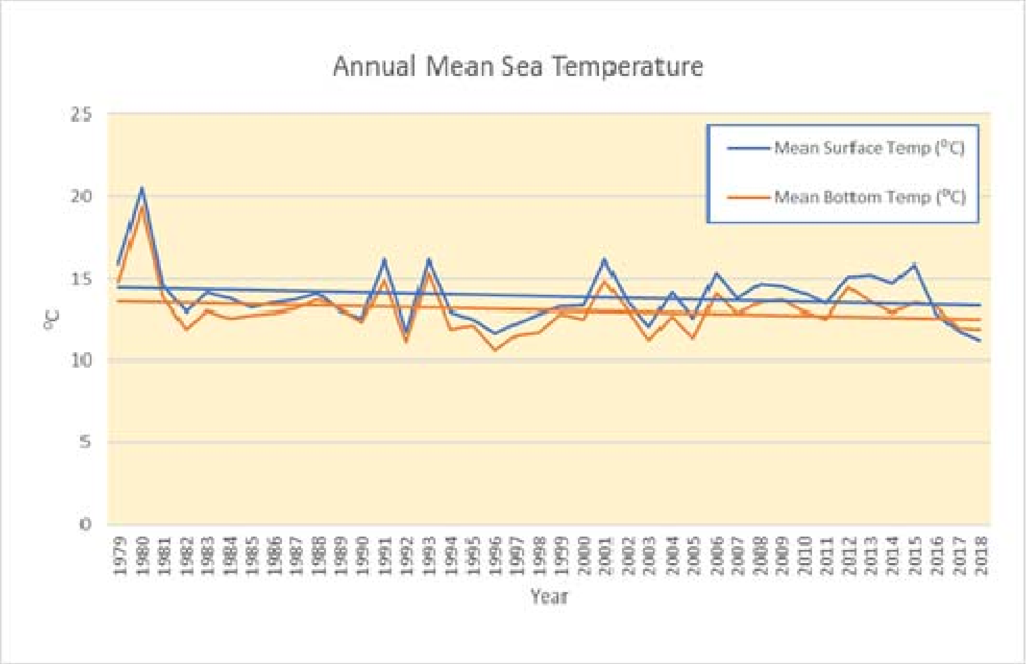




Monthly Survey Temperature Profile (Annual mean surface and bottom temperature)

Surface and bottom temperatures are collected at every station. The bottom temperature is collected by Niskin bottle at the average or maximum depth for each station.





Results: Job 2. The Seasonal Coastal Trawl Survey is defined by 12 fixed stations in Narragansett Bay, 14 random stations in Narragansett Bay, 6 fixed stations in Rhode Island Sound, 12 fixed stations in Block Island Sound.

61 species were observed and recorded during the 2017 Rhode Island Seasonal Trawl Survey, totaling 338,662 individuals or 3848.43 fish per tow. In weight, the catch accounted for 4033.2 kg. or 45.83 kg. per tow. (Figures 8 and 9) The top ten species by number and catch are represented in figures 10 and 11. The change between demersal and pelagic species is represented in figures 12 and 13 and shows a clear shift from demersal species to a more pelagic or multi-habitat species.

Figure 8 (Total Catch in Number)

Scientific Name	Common Name	Total #
BREVOORTIA TYRANNUS	Atlantic Menhaden	153547
STENOTOMUS CHRYSOPS	Scup	98728
ANCHOA MITCHILLI	Bay Anchovy	46754
PEPRILUS TRIACANTHUS	Butterfish	13919
LOLIGO PEALEI	Longfin Squid	12458
ALOSA PSEUDOHARENGUS	Alewife	2836
CYNOSCION REGALIS	Weakfish	2119
AMMODYTES AMERICANUS	Sand Lance	1409
SELENE SETAPINNIS	Atlantic Moonfish	1219
MENIDIA MENIDIA	Atlantic Silverside	1048
CLUPEA HARENGUS	Atlantic Herring	885
LEUCORAJA ERINACEA	Little Skate	694
GADUS MORHUA	Atlantic Cod	489
PLEURONECTES AMERICANUS	Winter Flounder	226
CENTROPRISTIS STRIATA	Black Sea Bass	221
PARALICHTHYS DENTATUS	Summer Flounder	205
PRIONOTUS CAROLINUS	Northern Sea Robin	188
MERLUCCIUS BILINEARIS	Silver Hake	175
POMATOMUS SALTATRIX	Bluefish	135
PRIONOTUS EVOLANS	Striped Sea Robin	135
ALOSA AESTIVALIS	Blueback Herring	118
UROPHYCIS REGIA	Spotted Hake	114
LEUCORAJA OCELLATA	Winter Skate	105
HOMARUS AMERICANUS	American Lobster	105
CANCER IRRORATUS	Rock Crab	95
SCOPHTHALMUS AQUOSUS	Windowpane Flounder	92
MENTICIRRHUS SAXATILIS	Northern Kingfish	91
MUSTELUS CANIS	Smooth Dogfish	86
RAJA EGLANTERIA	Clearnose Skate	67
UROPHYCIS CHUSS	Red Hake	63

LIMULUS POLYPHEMUS	Horseshoe Crab	33
ETROPUS MICROSTOMUS	Smallmouth Flounder	25
SPHOEROIDES MACULATUS	Northern Puffer	23
BUSYCOTYPUS CANALICULATUS	Channeled Whelk	22
TAUTOGA ONITIS	Tautog	21
ANCHOA HEPSETUS	Striped Anchovy	20
ALOSA SAPIDISSIMA	American Shad	19
CALLINECTES SAPIDUS	Blue Crab	18
SYNODUS FOETENS	Inshore Lizardfish	16
TAUTOGOLABRUS ADSPERSUS	Cunner	16
BUSYCON CARICA	Knobbed Whelk	15
PHOLIS GUNNELLUS	Rock Gunnel	14
SQUALUS ACANTHIAS	Spiny Dogfish	13
MYOXOCEPHALUS OCTODECEMSPINOS	Longhorn Sculpin	10
PARALICHTHYS OBLONGUS	Fourspot Flounder	9
LEIOSTOMUS XANTHURUS	Spot	8
SQUILLA EMPUSA	Mantis Shrimp	7
MORONE SAXATILIS	Striped Bass	5
TRACHURUS LATHAMI	Rough Scad	5
MACROZOARCES AMERICANUS	Ocean Pout	4
DECAPTERUS PUNCTATUS	Round Scad	4
CONGER OCEANICUS	Conger Eel	3
ETRUMEUS TERES	Round Herring	3
MYOXOCEPHALUS AENAEUS	Grubby	3
CANCER BOREALIS	Jonah Crab	2
LAGODON RHOMBOIDES	Pinfish	2
CARANX CRYSOS	Blue Runner	2
MONACANTHUS HISPIDUS	Planehead Filefish	2
PLACOPECTEN MAGELLANICUS	Sea Scallop	2
DASYATIS CENTROURA	Roughtail Stingray	1
MYLIOBATIS FREMINVILLII	Bullnose Ray	1
HEMITRIPTERUS AMERICANUS	Sea Raven	1
TRINECTES MACULATUS	Hogchoker	1
SCOMBER SCOMBRUS	Atlantic Mackerel	1
FISTULARIA TABACARIA	Cornetfish	1
SPHYRAENA BOREALIS	Northern Sennet	1
OPHIDION MARGINATUM	Striped Cusk-Eel	1
DOROSOMA CEPEDIANUM	Gizzard Shad	1
GOBIIDAE	Gobies	1

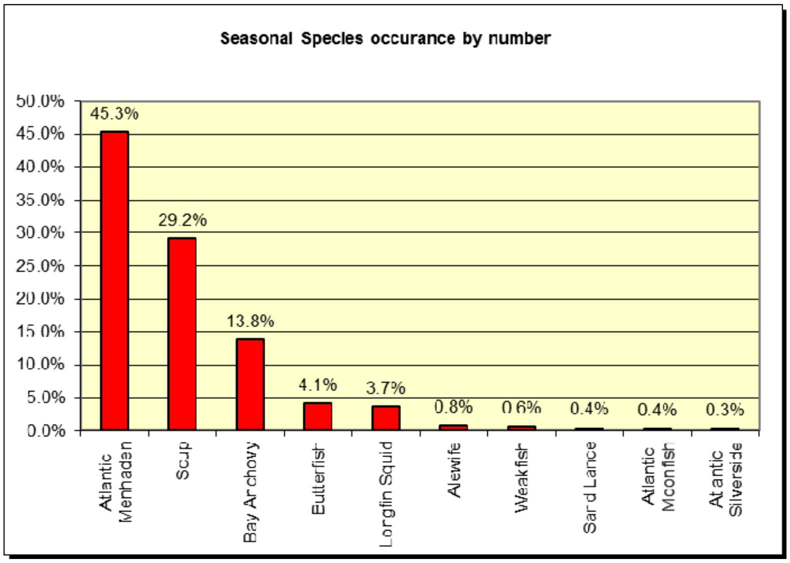
Figure 9 (Total Catch in Kilograms)

Scientific Name	Common Name	Total Weight (kg)
STENOTOMUS CHRYSOPS	Scup	1784.595
LEUCORAJA ERINACEA	Little Skate	388.619
PEPRILUS TRIACANTHUS	Butterfish	376.18
LOLIGO PEALEI	Longfin Squid	233.027
BREVOORTIA TYRANNUS	Atlantic Menhaden	169.52
PARALICHTHYS DENTATUS	Summer Flounder	113.297
RAJA EGLANTERIA	Clearnose Skate	109.746
MUSTELUS CANIS	Smooth Dogfish	94.155
LEUCORAJA OCELLATA	Winter Skate	91.98
CYNOSCION REGALIS	Weakfish	88.369
CENTROPRISTIS STRIATA	Black Sea Bass	72.174
LIMULUS POLYPHEMUS	Horseshoe Crab	70.074
PLEURONECTES AMERICANUS	Winter Flounder	58.805
POMATOMUS SALTATRIX	Bluefish	49.124
PRIONOTUS EVOLANS	Striped Sea Robin	43.293
ANCHOA MITCHILLI	Bay Anchovy	42.446
ALOSA PSEUDOHARENGUS	Alewife	35.64
HOMARUS AMERICANUS	American Lobster	31.901
PRIONOTUS CAROLINUS	Northern Sea Robin	26.818
SCOPHTHALMUS AQUOSUS	Windowpane Flounder	20.614
SQUALUS ACANTHIAS	Spiny Dogfish	19
CANCER IRRORATUS	Rock Crab	18.211
UROPHYCIS REGIA	Spotted Hake	10.162
AMMODYTES AMERICANUS	Sand Lance	9.265
MORONE SAXATILIS	Striped Bass	9.23
TAUTOGA ONITIS	Tautog	7.68
MENTICIRRHUS SAXATILIS	Northern Kingfish	7.402
MERLUCCIUS BILINEARIS	Silver Hake	6.791
SELENE SETAPINNIS	Atlantic Moonfish	6.089
MACROZOARCES AMERICANUS	Ocean Pout	4.318
MYOXOCEPHALUS OCTODECEMSPINOS	Longhorn Sculpin	3.875
MENIDIA MENIDIA	Atlantic Silverside	3.675
CALLINECTES SAPIDUS	Blue Crab	3.344
UROPHYCIS CHUSS	Red Hake	3.318
BUSYCOTYPUS CANALICULATUS	Channeled Whelk	2.585
CONGER OCEANICUS	Conger Eel	2.34
DASYATIS CENTROURA	Roughtail Stingray	2.17
BUSYCON CARICA	Knobbed Whelk	1.844
PARALICHTHYS OBLONGUS	Fourspot Flounder	1.723
ALOSA AESTIVALIS	Blueback Herring	1.538

SYNODUS FOETENS	Inshore Lizardfish	1.128
CLUPEA HARENGUS	Atlantic Herring	1.112
LEIOSTOMUS XANTHURUS	Spot	1
MYLIOBATIS FREMINVILLII	Bullnose Ray	0.765
SPHOEROIDES MACULATUS	Northern Puffer	0.542
ETROPUS MICROSTOMUS	Smallmouth Flounder	0.454
TRACHURUS LATHAMI	Rough Scad	0.385
ALOSA SAPIDISSIMA	American Shad	0.369
GADUS MORHUA	Atlantic Cod	0.338
HEMITRIPTERUS AMERICANUS	Sea Raven	0.32
CANCER BOREALIS	Jonah Crab	0.29
LAGODON RHOMBOIDES	Pinfish	0.26
DECAPTERUS PUNCTATUS	Round Scad	0.175
TRINECTES MACULATUS	Hogchoker	0.144
ANCHOA HEPSETUS	Striped Anchovy	0.138
SCOMBER SCOMBRUS	Atlantic Mackerel	0.12
CARANX CRYSOS	Blue Runner	0.119
FISTULARIA TABACARIA	Cornetfish	0.116
MONACANTHUS HISPIDUS	Planehead Filefish	0.095
ETRUMEUS TERES	Round Herring	0.08
SPHYRAENA BOREALIS	Northern Sennet	0.065
SQUILLA EMPUSA	Mantis Shrimp	0.063
PLACOPECTEN MAGELLANICUS	Sea Scallop	0.055
TAUTOGOLABRUS ADSPERSUS	Cunner	0.041
MYOXOCEPHALUS AENAEUS	Grubby	0.021
PHOLIS GUNNELLUS	Rock Gunnel	0.02
OPHIDION MARGINATUM	Striped Cusk-Eel	0.018
DOROSOMA CEPEDIANUM	Gizzard Shad	0.012
GOBIIDAE	Gobies	0.001

Figure 10 Top Ten Species Catch in Number

Fish Name	Scientific Name	%
Atlantic Menhaden	BREVOORTIA TYRANNUS	45.3%
Scup	STENOTOMUS CHRYSOPS	29.2%
Bay Anchovy	ANCHOA MITCHILLI	13.8%
Butterfish	PEPRILUS TRIACANTHUS	4.1%
Longfin Squid	LOLIGO PEALEI	3.7%
Alewife	ALOSA PSEUDOHARENGUS	0.8%
Weakfish	CYNOSCION REGALIS	0.6%
Sand Lance	AMMODYTES AMERICANUS	0.4%
Atlantic Moonfish	SELENE SETAPINNIS	0.4%
Atlantic Silverside	MENIDIA MENIDIA	0.3%



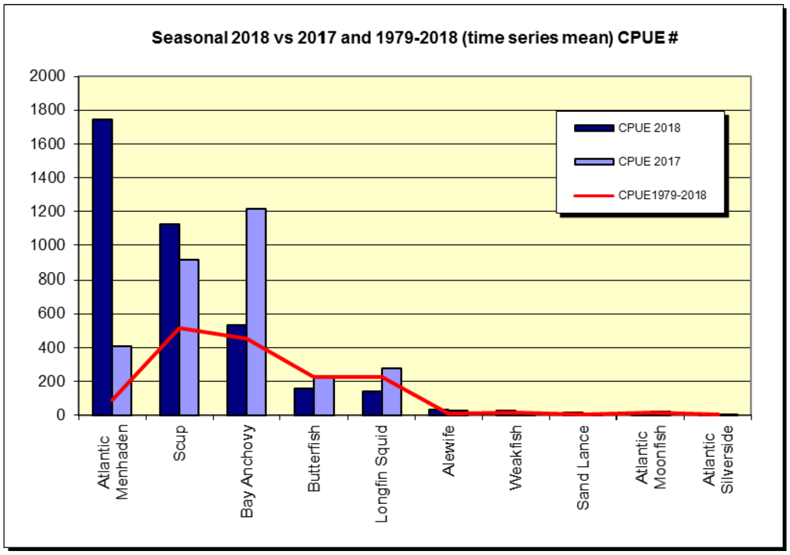
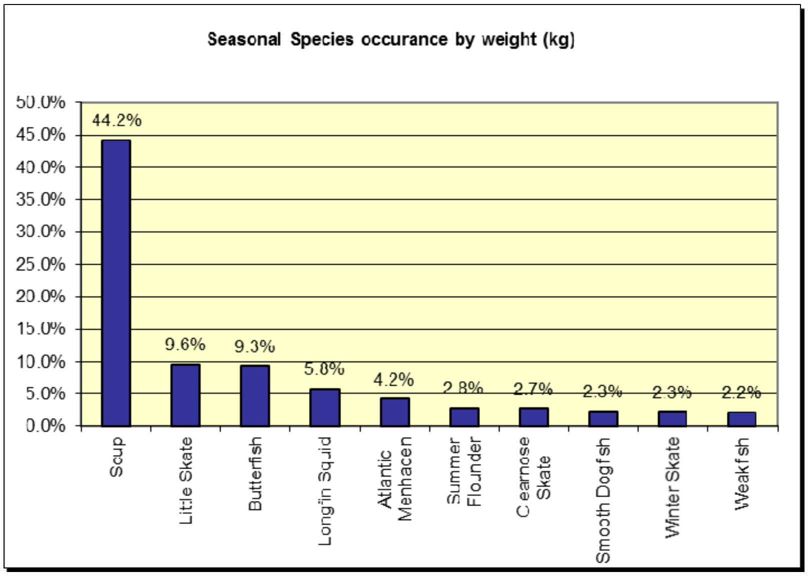


Figure 11 Top Ten Species Catch in Kilograms

Fish Name	Scientific Name	%
Scup	STENOTOMUS CHRYSOPS	44.2%
Little Skate	LEUCORAJA ERINACEA	9.6%
Butterfish	PEPRILUS TRIACANTHUS	9.3%
Longfin Squid	LOLIGO PEALEI	5.8%
Atlantic Menhaden	BREVOORTIA TYRANNUS	4.2%
Summer Flounder	PARALICHTHYS DENTATUS	2.8%
Clearnose Skate	RAJA EGLANTERIA	2.7%
Smooth Dogfish	MUSTELUS CANIS	2.3%
Winter Skate	LEUCORAJA OCELLATA	2.3%
Weakfish	CYNOSCION REGALIS	2.2%



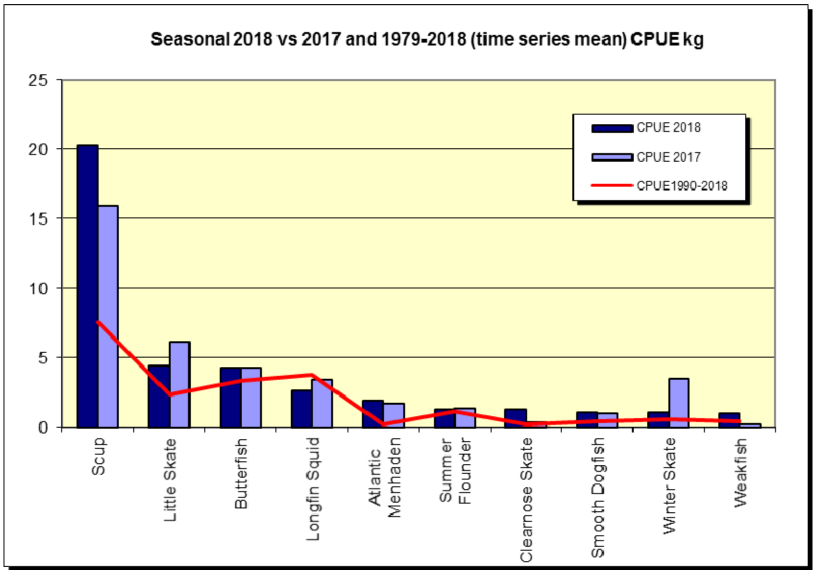
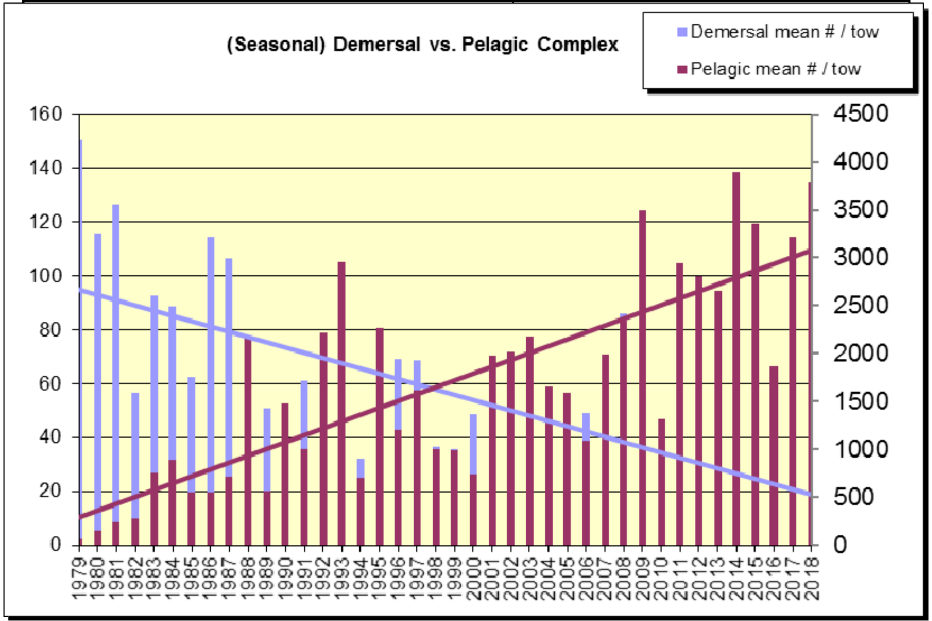
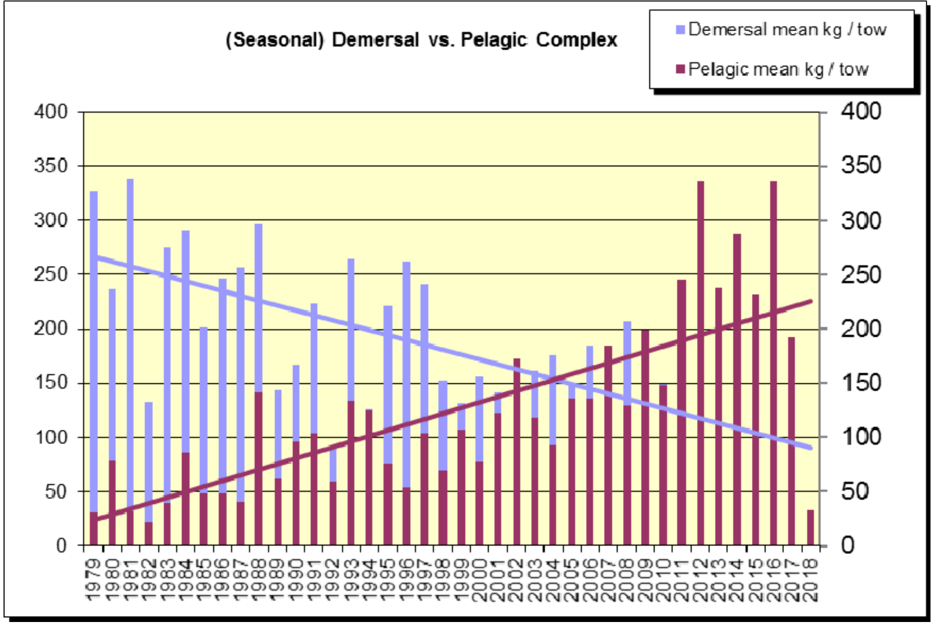


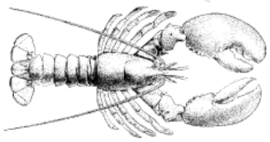
Figure 12 and 13: Demersal vs. Pelagic Species Complex

Demersal Species		Pelagic/Multi-Habitat Species	
Smooth Dogfish	Hogchoker	Atlantic Herring	Bluefish
Spiny Dogfish	Longhorn Sculpin	Alewife	Striped Bass
Skates	Sea Raven	Blueback Herring	Black Sea Bass
Silver Hake	Northern Searobin	Shad	Scup
Red Hake	Striped Searobin	Menhaden	Weakfish
Spotted Hake	Cunner	Bay Anchovy	Longfin Squid
Summer Flounder	Tautog	Rainbow Smelt	
4-Spot Flounder	Ocean Pout	Silverside	
Winter Flounder	Goosefish	Butterfish	
Windowpane Flounder	Lobster	Atlantic Moonfish	



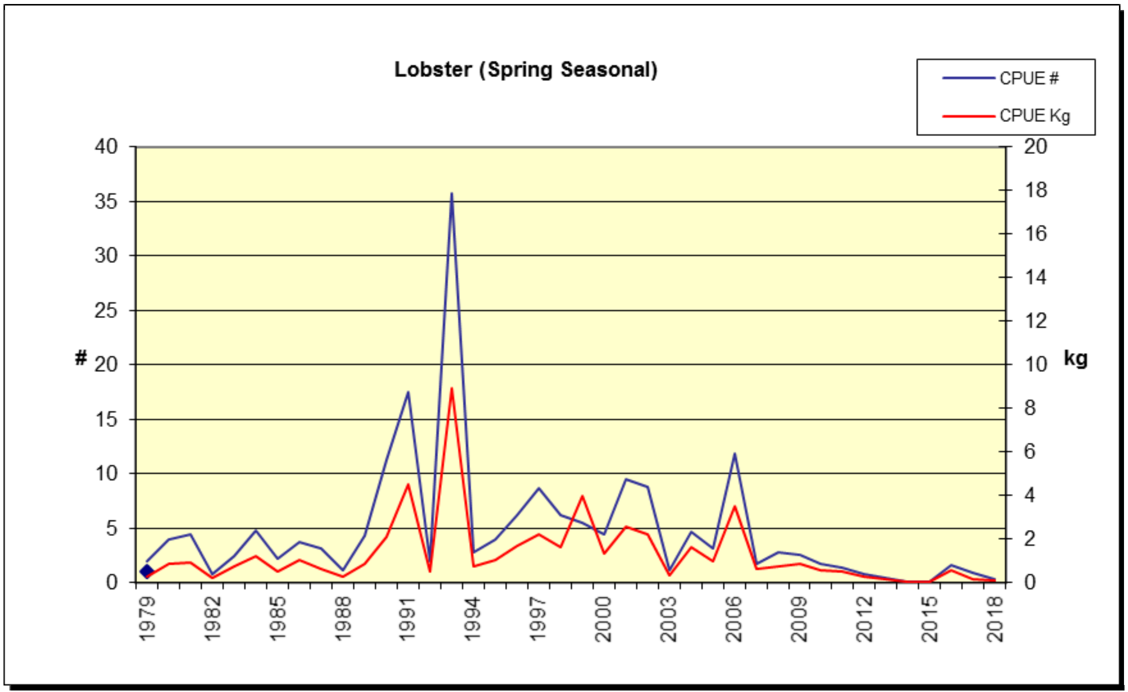


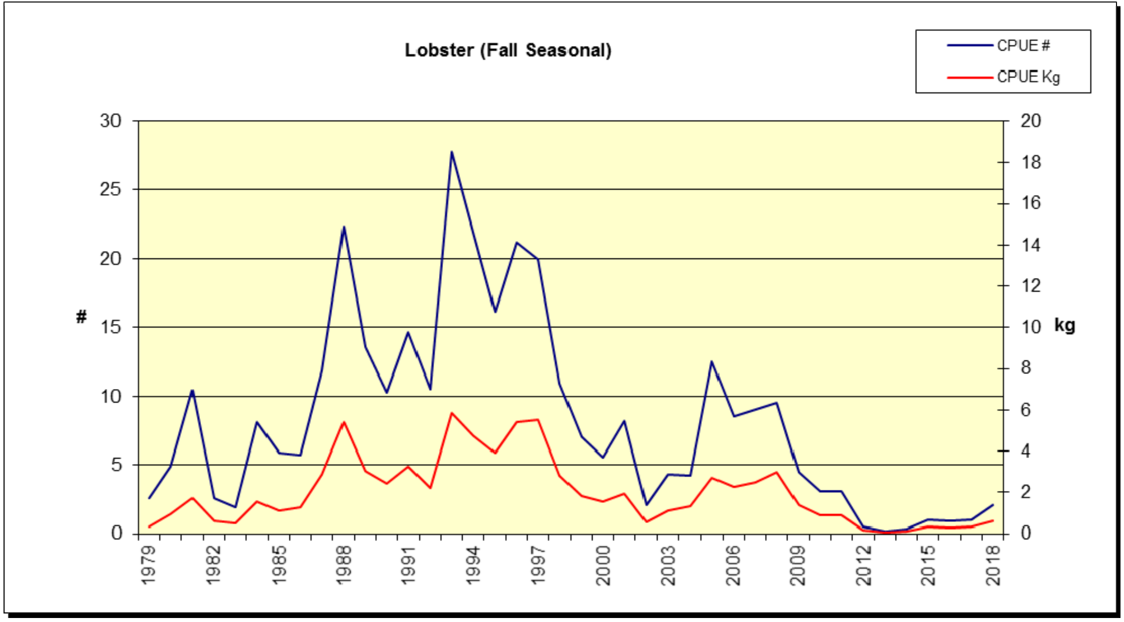
The following species represented are of high importance and are currently managed under fishery management plans through the Atlantic States Marine Fisheries Commission, New England Fishery Management Council, or the National Marine Fisheries Service. The seasonal portion of the Rhode Island Coastal Trawl Survey is an accurate indicator of relative abundance based on the biology and life history of a particular species. Values presented are expressed in either relative number or kilograms per tow. All data collected from both the Seasonal and Monthly Coastal Trawl Surveys are available upon request.



American Lobster ***Homarus americanus***

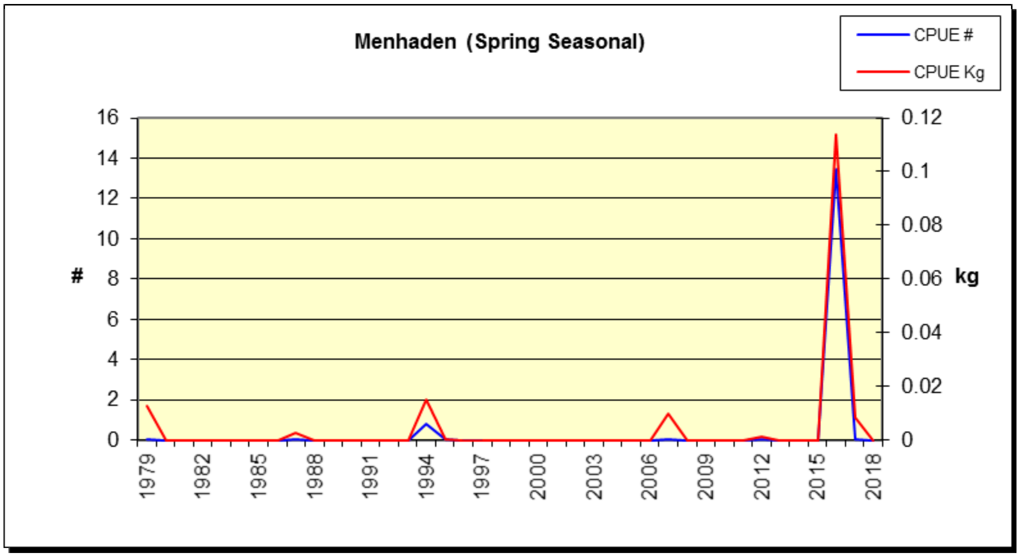
Stock Status: Southern New England Stock: overfished. Depleted Poor condition.
Management: ASMFC Amendment III, Addendum XXVI

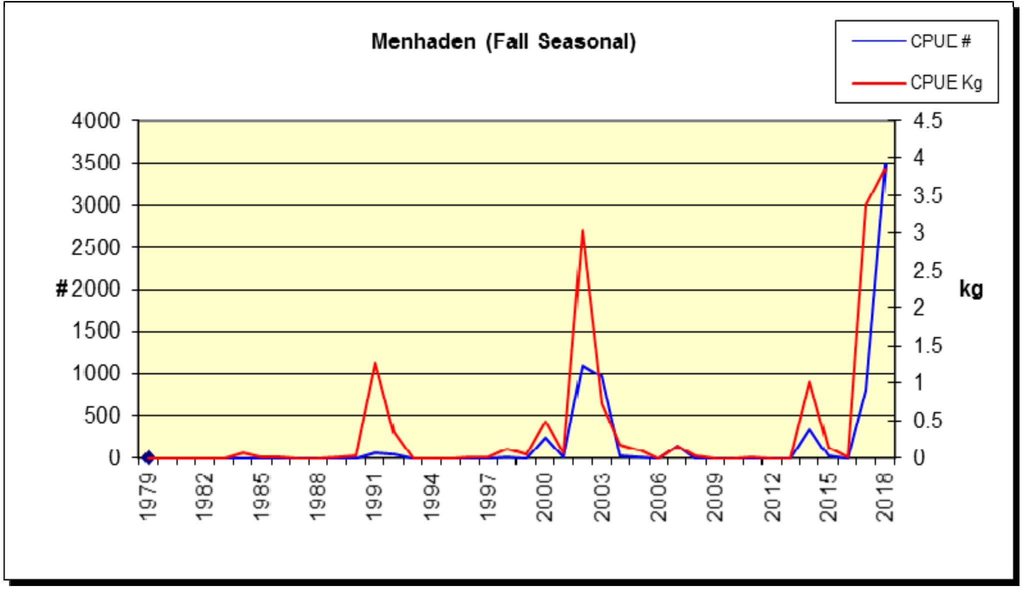




Atlantic Menhaden ***Brevoortia tyrannus***

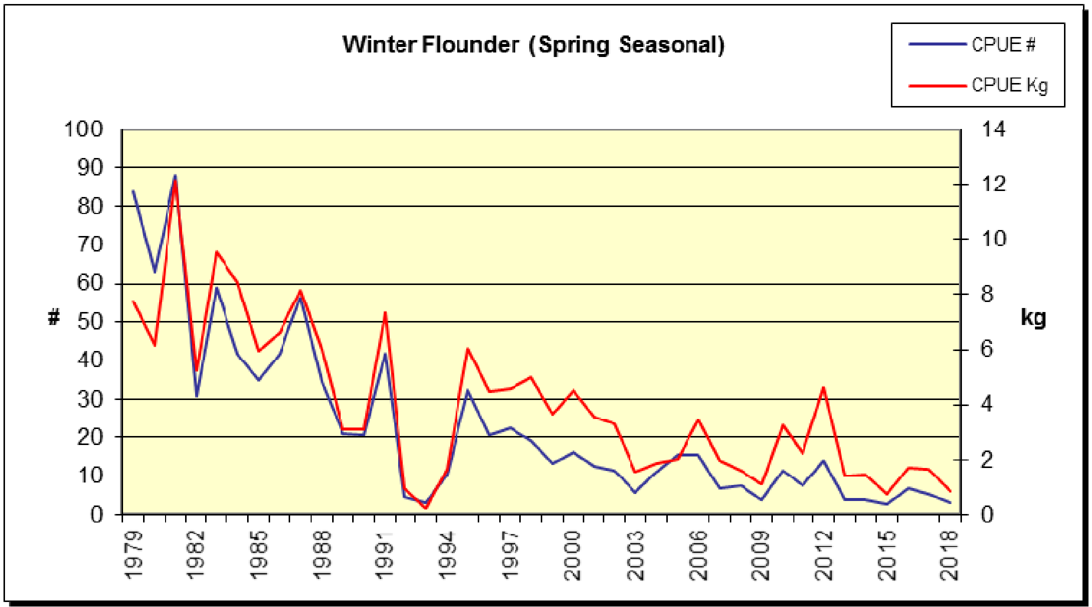
Stock Status: Not Overfished and overfishing is not occurring.
Management: ASMFC Amendment III, Addendum I

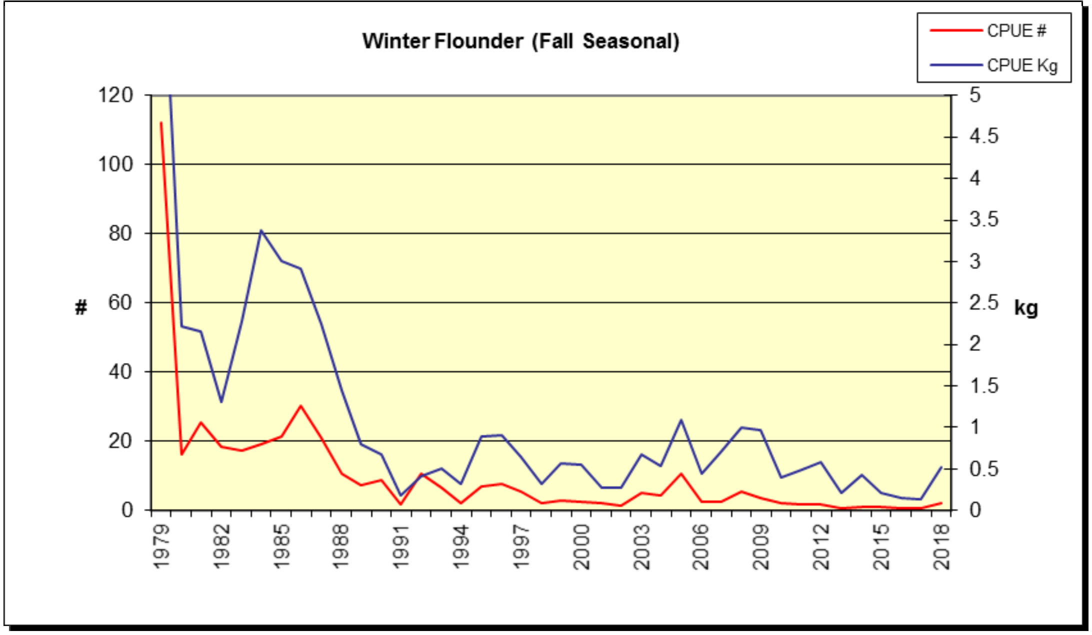




Winter Flounder ***Pleuronectes americanus***

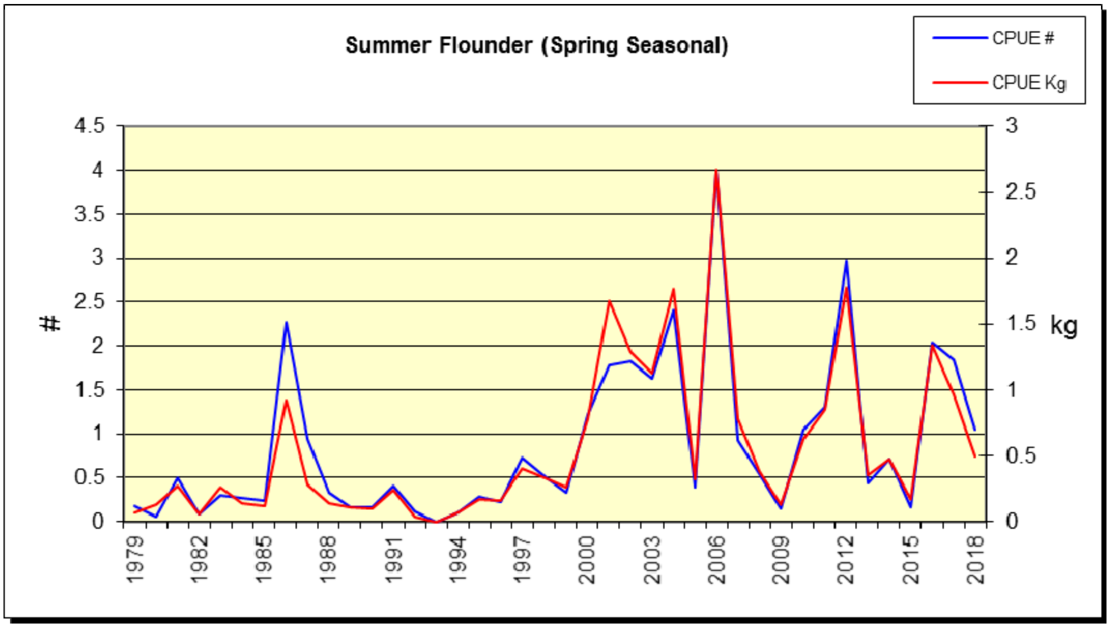
Stock Status: Overfished but overfishing is not occurring.
Management: ASMFC Amendment I, Addendum III

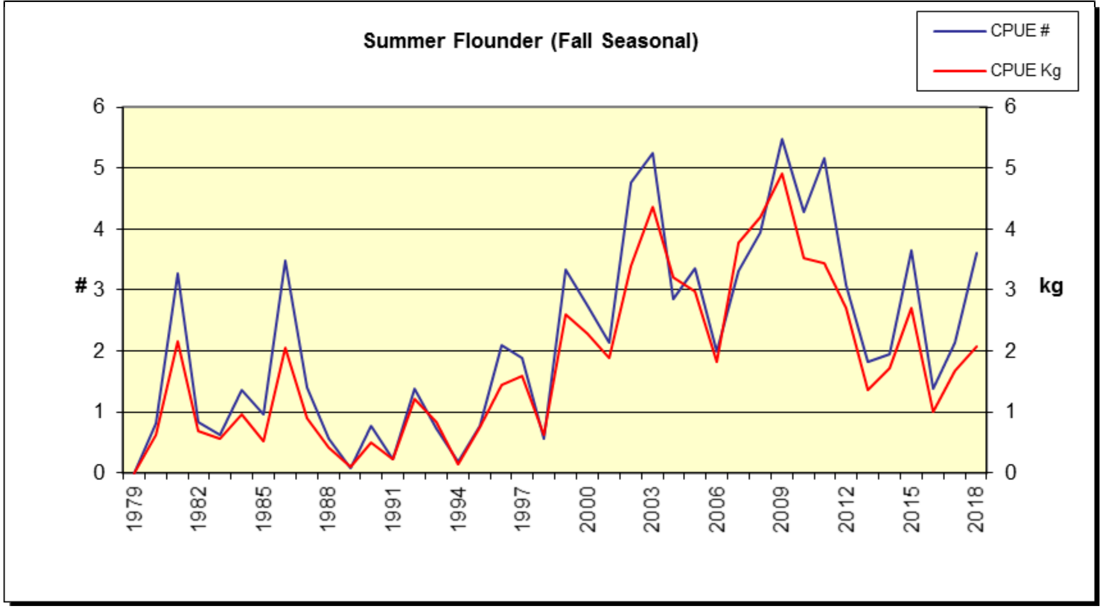




Summer Flounder ***Paralichthys dentatus***

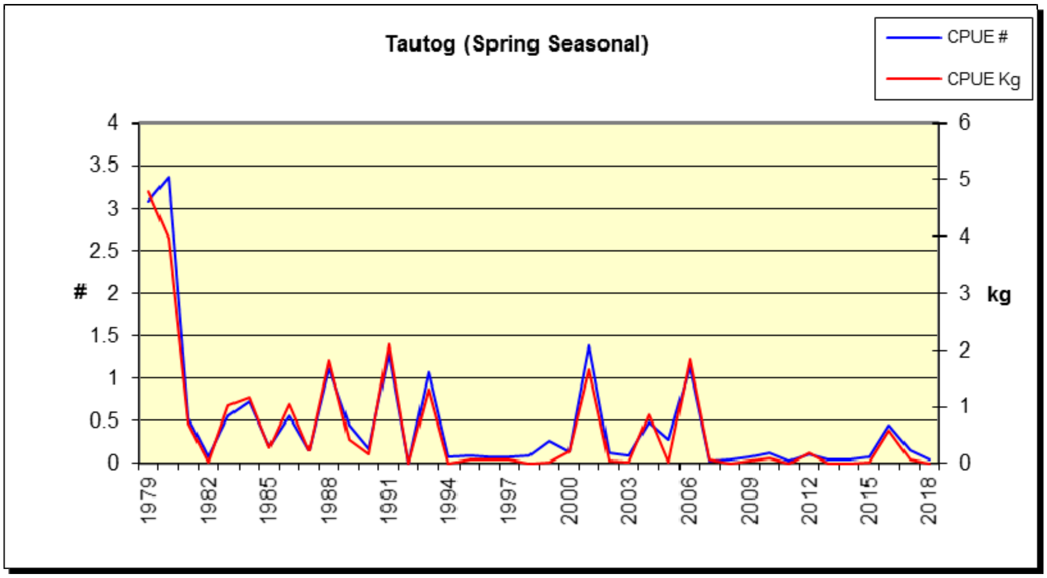
Stock Status: Not overfished and overfishing is occurring.
Management: ASMFC Amendment XIII Addendum XXXII

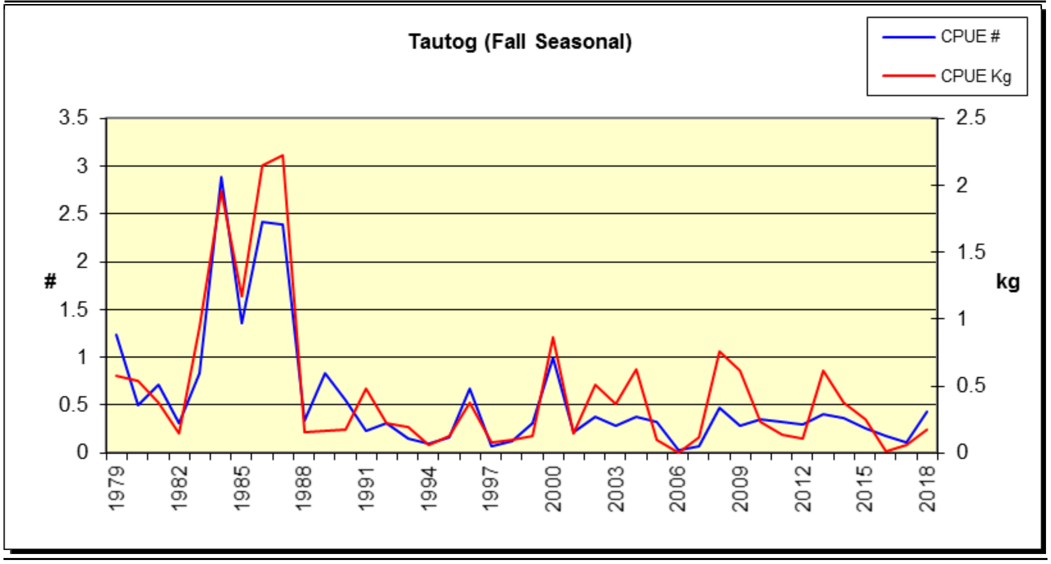


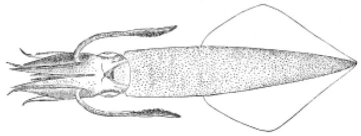


Tautog ***Tautoga onitis***

Stock Status: Not Overfished and Overfishing is not occurring based on Regional (Rhode Island and Massachusetts) Stock Assessment
Management: ASMFC Amendment I, Addendum VI

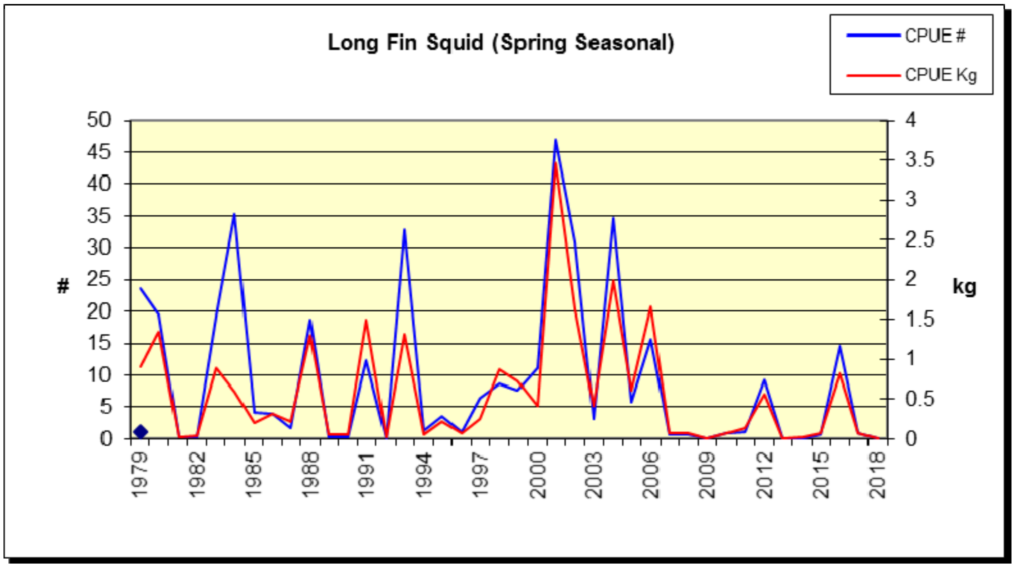


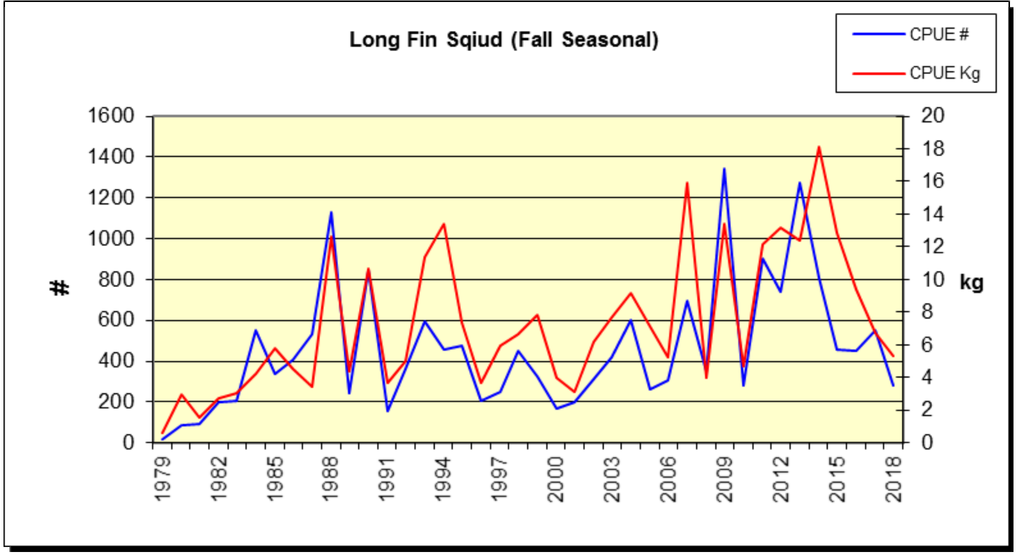




Longfin Squid ***Loligo pealei***

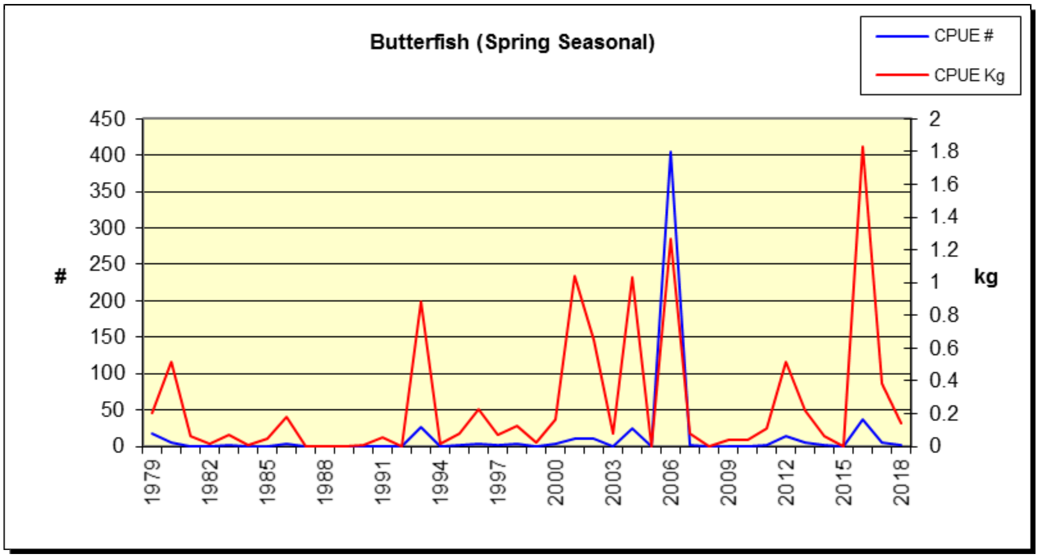
Stock Status: Overfishing undetermined not overfished
Management: NMFS, MAFMC, Atlantic Mackerel, Squid Butterfish FMP

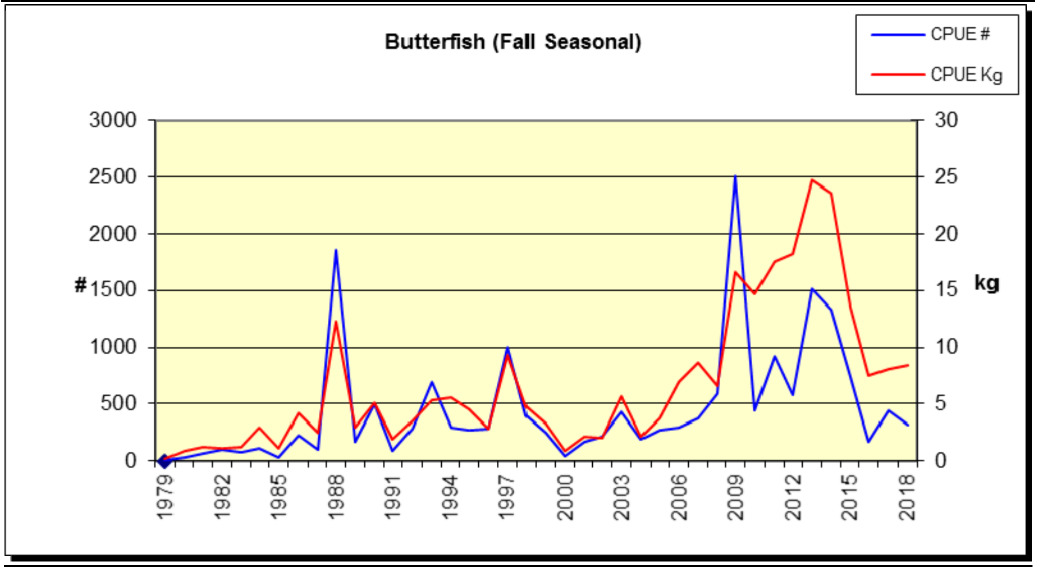




Butterfish **_Peprlilus triacanthus_**

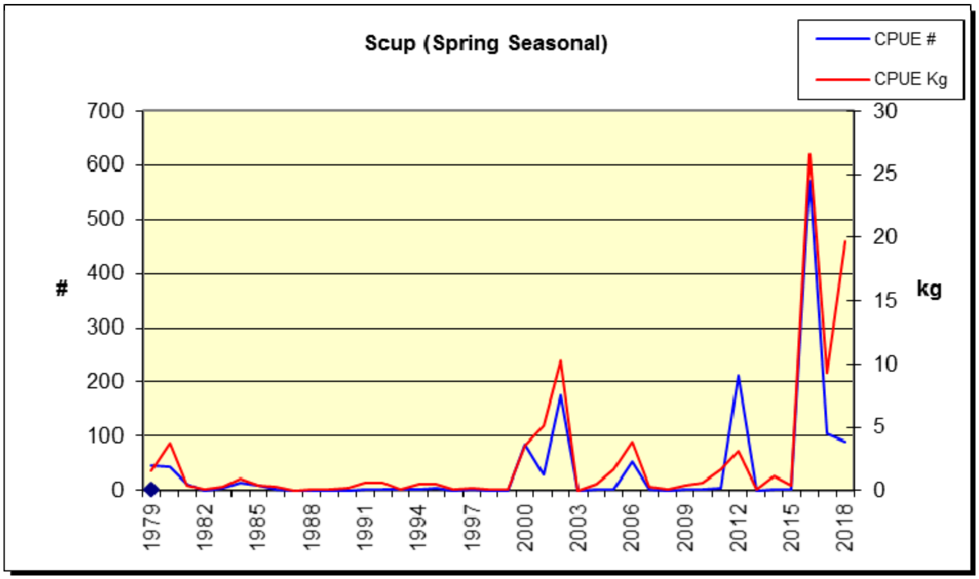
Stock Status: Variable / Uncertain
Management: Mid Atlantic Fishery Management Council, Atlantic Mackerel, Squid Butterfish FMP, ACL

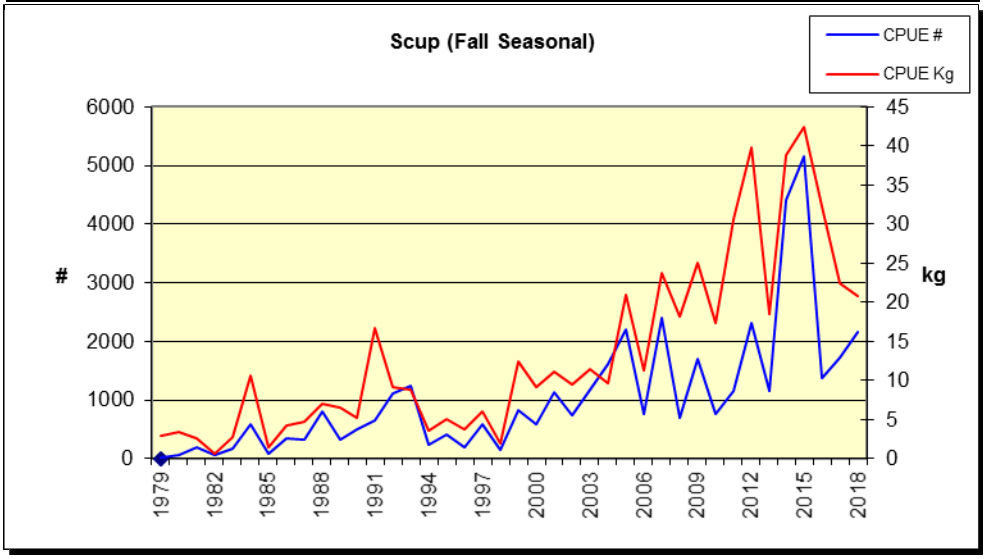


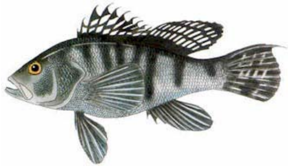


Scup **_Stenotomus chrysops_**

Stock Status: Rebuilt, not overfished and overfishing is not occurring
Management: ASMFC Amendment XIII, Addendum XXXI, Summer Flounder, Scup Black Sea Bass FMP

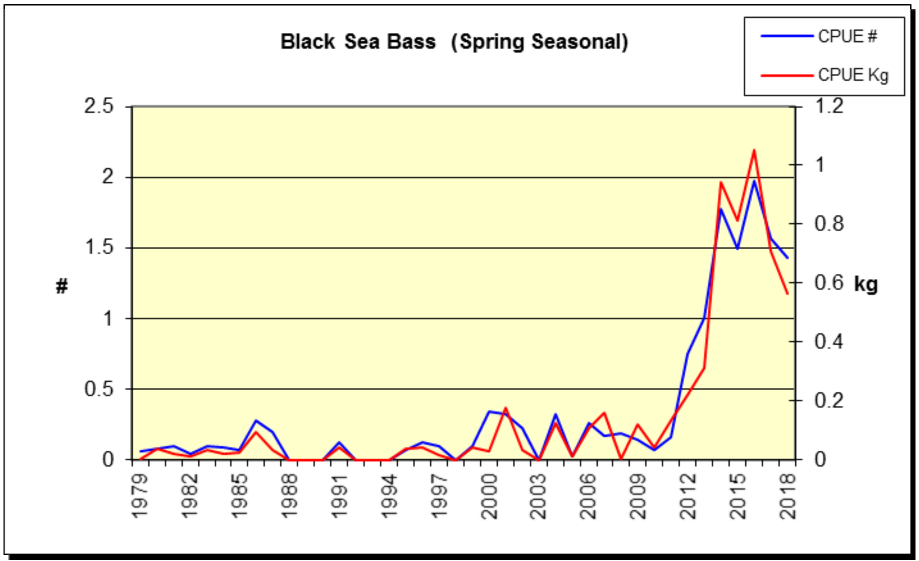


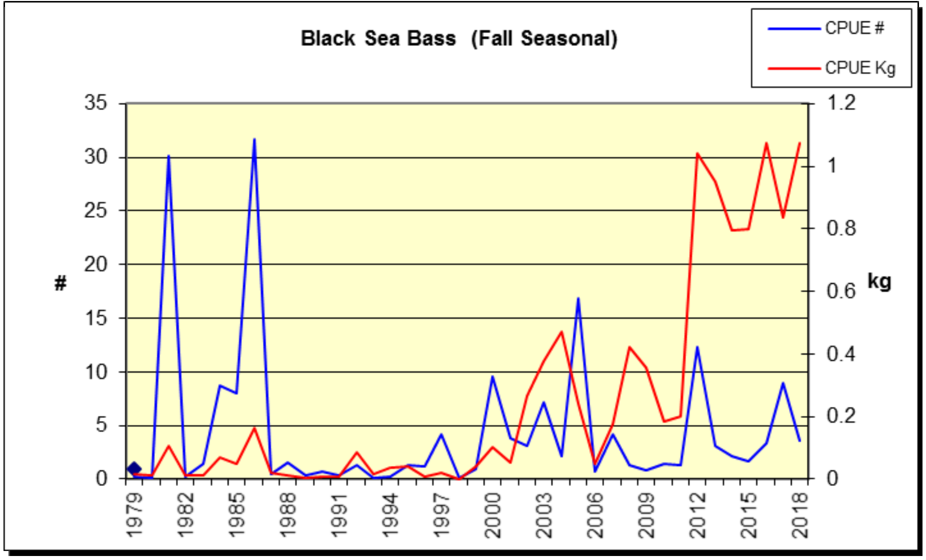




Black Sea Bass ***Centropristis striata***

Stock Status: Rebuilt, not overfished overfishing is not occurring
Management: ASMFC Amendment XIII, Addendum XXXI





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Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Ponds

Young of the Year Survey of Selected Rhode Island Coastal Ponds and Embayments

John Lake
Supervising Marine Biologist
john.lake@dem.ri.gov

Katie Rodrigue
Principal Marine Biologist
Katherine.rodrigue@dem.ri.gov

Rhode Island Department of Environmental Management
Division of Marine Fisheries
3 Fort Wetherill Road
Jamestown, RI 02835

Federal Aid in Sportfish Restoration
F-61-R

Performance Report – Job#3a Coastal Ponds in Washington County, RI
Job#3b Coastal Ponds in New Shoreham County, RI

March 2019

Performance Report

State: Rhode Island

Project Number: F-61-R
Segment Number: 21

Project Title: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters.

Period Covered: January 1, 2018 – December 31, 2018

Job Number & Title: Job 3 – Young of the Year Survey of Selected Rhode Island Coastal Ponds and Embayment's

Job Objectives: To collect, analyze, and summarize beach seine survey data from Rhode Island's coastal ponds and estuaries for the purpose of forecasting recruitment in relation to the spawning stock biomass of winter flounder and other recreationally important species.

Summary: In 2018, Investigators caught 50 species of finfish representing 36 families. This number is consistent with 2017, where 50 species from 35 families were collected. Additionally, the number of individuals caught in 2018 increased from the 2017 survey, with 47,024 collected in 2018 and 38,250 collected in 2017.

Target Date: 2019

Status of Project: On Schedule

Significant Deviations: There were no significant deviations in 2018.

Recommendations: Continue into the next segment with the project as currently designed; continue at each of the 24 sample stations.

Remarks:

During 2018, investigators successfully sampled all twenty-four traditional stations in eight coastal ponds from May through October: Winnapaug Pond, Quonochontaug Pond, Charlestown Pond, Point Judith Pond, Green Hill Pond, Potter Pond, Little Narragansett Bay and Narrow River (Figures 1-3). Beginning this year, the time series species indices for young of the year (YOY) winter flounder will include the data taken from the new stations added in 2011 (PP 1 and 2, GH 1 and 2, PR 1 through 3, PJ4). These stations were previously excluded due to potential unknown bias the new stations could introduce to the time series.

The abundance indices for winter flounder targets only YOY individuals. For the purpose of consistency, only individuals with a total length (TL) less than 12 cm are included in these analyses.

Materials and Methods:

As in previous years, investigators attempted to perform all seining on an outgoing tide. To collect animals, investigators used a seine 130 ft. long (39.62m), 5.5 ft deep (1.67m) with ¼” mesh (6.4mm). The seine has a bag at its midpoint, a weighted foot rope and floats on the head rope. Figure 4 describes the area covered by the seine net. The beach seine is set in a semi-circle away from the shoreline and back again using an outboard powered 16' Polarkraft aluminum boat. The net is then hauled toward the beach by hand and the bag is emptied into a large water-filled tote. All animals collected are identified to species, measured, enumerated, and sub-samples taken when appropriate. Water quality parameters including temperature, salinity and dissolved oxygen are measured at each station. Figure 1 shows the location of the subject coastal ponds and the Narrow River, while figures 2-3 indicate the location of the sampling stations within each pond.

Results and Discussion:

Winter Flounder (*Pseudopleuronectes americanus*)

Juvenile winter flounder were collected at all 24 stations over the course of the season. Winter flounder ranked seventh in overall species abundance (n=593) in 2018, with the highest mean abundance (fish/seine haul) occurring in July (Table 2, Total Pond Index=7.31). This is consistent with the usual expected pattern of highest index values occurring in July. This is later than in 2017 and 2016, when the peak abundance occurred in June. However, Charlestown Pond and Narrow River showed peak winter flounder abundance in June (3.0 and 23.0 respectively), Green Hill pond in May and June (2.0 for both months), Point Judith Pond and Winnapaug in August (6.75 and 9.0 respectively), and Potter Pond in October (0.5).

Winter flounder abundance was lower in 2018 than in any other year of the time series. A total of 593 winter flounder were collected, which was a 55% decrease from the total caught in 2017 (n=1317). The juvenile winter flounder abundance index (YOY WFL index) for the survey measured using the mean fish/seine haul decreased from 9.09 fish/seine haul in 2017 to 4.06 fish/seine haul in 2018. This is the lowest YOY abundance index value seen since the survey’s inception, and 46% less than the second lowest index in the time series (7.60 in 2013). Figure 5 displays the abundance indices by pond over the duration of the coastal pond survey. Table 2 and Figure 6 display the mean catch per seine haul (CPUE) of winter flounder for each month by pond during the 2018 survey. Figure 8 displays the annual winter flounder abundance index plotted over time, along with average recorded water temperature.

In all ponds, winter flounder abundance trended downward from 2017. Winnapaug Pond showed the largest decrease in abundance index value, going from 19.4 in 2017 to 4.9 in 2018. Green Hill Pond remained relatively consistent with last year’s abundance (decreasing only slightly from 0.83 to 0.67), although it is the second lowest abundance seen since this pond was added to the survey in 2011 (the lowest observed abundance was in 2015 when no winter flounder were caught). Overall, YOY winter flounder abundance peaked in the coastal ponds in July, although the most individuals were caught in June in Narrow River, with a CPUE of 23 fish/seine haul. No winter flounder were caught in Green Hill Pond after June, or in Pawcatuck River or Point Judith Pond after September. No winter flounder were caught in Potter Pond until October. Figure 17 is a map showing the total number of YOY winter flounder collected at each station.

With increasing seasonal temperatures, Rhode Island waters have seen an ecological shift from resident demersal species (including winter flounder) to a pelagic community dominated by more southern species (Collie et al. 2008, Oviatt 2004). Over the course of this survey, average water temperature of the coastal ponds has steadily increased, while winter flounder YOY CPUE has decreased (Figure 8). Average water temperature measured during the survey has not been below 20°C since 2006 (19.3°C). The highest average temperature was observed in 2016 at 22.5°C. These findings are consistent with the overall trend occurring in northeast region and the observed declines in winter flounder population.

In 2018, juvenile winter flounder ranged in size from 1.5 to 15.6 cm, representing age groups 0-1+ (Figure 7). The size range of animals collected is similar to those caught in previous years. Length-frequency distributions indicate that 98.5% of individuals collected during sampling season were group 0 fish (less than 12 cm total length). The size ranges of these fish agree with ranges for young-of-the-year winter flounder in the literature (Able & Fahay 1998; Berry 1959; Berry et al. 1965). Mean monthly lengths for winter flounder are presented in Table 3.

Two other RIDFW surveys target juvenile and adult winter flounder: the Narragansett Bay Spring Seasonal Trawl Survey (Spring Trawl) and the Narragansett Bay Juvenile Finfish Survey (NBS). A comparison of the Coastal Pond Survey (CPS) to these other projects reveals that despite some slight differences, they display similar trends (Figure 9). Similar to the CPS, the lowest abundance index of the time series was also observed in the NBS (1.55), down from 4.07 in 2017. The Spring Trawl Survey WFL index was also slightly down from 2017, decreasing from 5.25 fish/tow to 3.09 fish/tow. However, these low numbers are relatively consistent with the past few years (2013 to 2018). These low years may in part reflect regulations which changed ending the prohibition on possession of winter flounder in federal waters of Southern New England in 2012. Federal possession limits were either unlimited or set to 5,000 lbs per trip depending on the permit category of the vessel. It is believed that these high limits encourage a directed fishery for winter flounder in the spring. NOAA Fisheries has changed their procedures for administration of common pool possession limit, restricting it to lower values during the year than allowed (typically 2,000 lbs per day) in 2013. Possession limits remain 50 pounds in State waters.

The Narragansett Bay Seine Survey collects the most YOY WFL in June (McNamee Pers Comm). It should be noted that the Narragansett Bay Survey does not begin sampling until June and may miss those juvenile finfish which occur in May in the shallow coves. The Spring Trawl Survey collects the greatest number of winter flounder in April and May and is considered the best indicator for estimating local abundance, especially for post spawn adults (Olszewski Pers Comm).

The time series of the survey shows that the ponds exhibit fluctuations of WFL abundance over time. One exception is Point Judith pond, which has experienced a significant decline since 2000 and bottomed out at 1.29 fish/seine haul during 2010. Between 2011 and 2017, the overall YOY WFL index in Point Judith pond increased slightly from the low 2010 value and since then (with the exception of the low abundance of 2.9 fish/haul in 2018) has remained relatively level with index values averaging approximately 5 fish/haul. This trend in abundance might reflect the recent no possession rule in the pond as well as the former coast wide closure. Despite this, the pond's winter flounder population has not rebounded to historic levels. A winter fyke net survey (Adult Winter Flounder Tagging Survey) is also conducted targeting adult winter flounder that use the ponds to spawn. Currently, Point Judith and Potter Ponds are the only coastal ponds where both a juvenile survey and an adult winter flounder survey occur annually (winter fyke net stations do exist in Charlestown Pond and were sampled from 2012-2015 and will be continued in 2019). When relative abundance and number of WFL per seine haul of juvenile winter flounder are compared to the relative abundance and number of WFL per fyke net haul of the Adult Winter Flounder Tagging Survey, an overall declining trend in relative abundance of winter flounder is observed in both surveys (Figure 10). The index value observed in the adult spawner survey was the lowest ever recorded at 0.8 WFL per net haul in 2014, recovering slightly in 2016 (1.1 fish /haul) and 2017 (2.7 fish / haul). In 2018, an index value of 6.0 fish/haul was seen (Table 16). This is the highest abundance index in this survey since 2006, when 9.2 fish/haul were observed.

However, more than half of these fish were still immature (56%) and therefore would not have participated in spawning. A total of 5 mature, healthy females were tagged and released. Despite the higher number of adult WFL observed in 2018, a low number were captured during the summer juvenile survey, suggesting that there is poor recruitment or survival of YOY WFL in Point Judith Pond. The decline in adult spawner abundance and related decline in juvenile abundance does not support a fishery in the pond due to the lack of surplus production (Gibson, 2010). Given that winter flounder population shows an affinity for discrete spawning locations and the young of year tend to remain near the spawning location, the fish in this pond are in danger of depletion (Buckley et. al. 2008). A regulation was enacted on April 8, 2011 to close Point Judith Pond to both recreational and commercial fishing for winter flounder (RIMF Regulations Part 7 sec 8). Data from this survey and the Adult winter flounder spawning survey was the evidence used for justification of this regulation.

Bluefish *(Pomatomus saltatrix)*

A total of 13 bluefish were collected in 2018 (CPUE=0.09 fish/haul). The majority were caught in Narrow river in July, with small numbers in Potter's Pond in July, Pawcatuck River in August, and Quonochontaug Pond in September. This is a large decrease from the previous few years, with 49 fish caught in 2017 (CPUE=0.34 fish/haul), 55 caught in 2016 (CPUE=0.39 fish/haul), and 124 individuals captured during 2015 (0.86 fish/haul). Table 4 contains the abundance indices for the 2018 survey by month and pond. Bluefish ranged in size from 4 cm to 13 cm. No adult bluefish were caught in 2018. Figure 11 displays the annual abundance index of bluefish for all stations combined. Figure 18 is a map showing the total number of bluefish collected at each station.

Tautog (*Tautoga onitis*)

From May to October, 288 (CPUE= 2.0 fish/haul) tautog were collected in all ponds except Green Hill Pond. This is slightly down from the 351 tautog caught in 2017 (CPUE=2.4 fish/haul), but consistent with the 299 captured in 2016 (2.1 fish/haul). Table 5 contains the abundance indices for the survey by month and pond. The highest abundances in 2018 occurred in the Charlestown Pond in August. Tautog caught in 2018 ranged in size from 2.6 cm to 17.2 cm. Figure 12 displays the annual abundance index of tautog for all stations combined. Figure 19 is a map showing the total number of tautog collected at each station.

Black Sea Bass (*Centropristis striata*)

A total of 605 juvenile black sea bass were collected from August to October of 2018 from each of the ponds except Potter Pond and Pawcatuck River (CPUE=4.2 fish/haul). This is the highest abundance value of black sea bass recorded in the history of the survey. The second highest abundance was seen in 2012 at 403 fish (CPUE=2.8 fish/haul). 274 black sea bass were collected in 2017 (CPUE=1.9 fish/haul). The highest abundances in 2018 were seen in Narrow River in August (68.7 fish/haul) and again in September (50 fish/haul). The population in the ponds continues trending upwards (Figure 13). Table 6 contains the abundance indices for the survey by month and pond. Black sea bass caught in 2018 ranged in size from 3 cm to 10 cm. Figure 20 is a map showing the total number of black sea bass collected at each station.

Scup *(Stenotomus chrysops)*

In 2018, 393 scup were collected in August and September in all ponds except Green Hill Pond and Potter Pond (CPUE=2.7 fish/haul). This is down from the 558 collected in 2017 (3.9 fish/haul), which was the highest number caught since the inception of the survey. Both 2017 and 2018 saw the most scup in the time series of the survey, and much more than in 2016 (22 individuals, CPUE=0.16). Table 7 contains the abundance indices for the survey by month and pond. Figure 14 displays the annual abundance index of scup for all stations combined. Scup caught in 2018 ranged in size from 3 cm to 11 cm. Figure 21 is a map showing the total number of scup collected at each station.

Clupeids:

In 2018, five species of clupeids were caught in the coastal pond survey: Atlantic menhaden (*Brevoortia tyrannus*), Atlantic herring (*Alosa harengus*), Blueback Herring (*Alosa Aestivalis),* Alewife (*Alosa pseudoharengus*), and Bay Anchovy (*Anchoa mitchilli)*. The most prevalent clupeid caught in 2018 was by far Atlantic Menhaden, with 25,341 individuals captured from August to October in all ponds (CPUE=176.0 fish/haul). This is more than double the 10,789 menhaden caught in 2017. In multiple instances, high numbers of YOY menhaden were caught in a single seine haul, likely because a school was present at a given station upon sampling. The most caught in a single haul was 15,382 at the third station in Narrow River in August. There were five other instances in which over 1,000 individuals were caught in a single haul. The second most abundant clupeid observed in 2018 was Alewife (also the most frequently caught river herring in 2018). A total of 207 were captured from June to October in all ponds except Quonochontaug and Winnapaug (CPUE=1.4). This is down from the 347 caught in 2017. However, a slight increase in the number of Blueback Herring was seen. A total of 97 were collected in June, July, and October in four ponds (Point Judith, Potter, Charlestown, and Pawcatuck River; CPUE=0.67) compared to only 14 captured in 2017. Figure 22 is a map showing the total number of river herring collected at each station. From May to June, 36 Atlantic herring were captured in five out of eight ponds (Point Judith, Quonochontaug, Winnapaug, Narrow River, and Potter Pond; CPUE=0.25), up from only 2 individuals caught in 2017. This is the most Atlantic Herring caught in this survey since 2010 (320 individuals, CPUE=2.8). Finally, only 32 Bay Anchovies were caught in 2018 (CPUE=0.22) compared to 1,373 in 2017 (CPUE=9.5). However, the majority of these fish were caught in a single station in Narrow River in October 2018, indicating that a school happened to be present at this station at the time of sampling. No large schools of Bay Anchovies were encountered in 2018. Table 8 contains the abundance indices for clupeids by month pooled across all 8 ponds. Figure 15 displays the annual abundance indices of clupeids for all stations combined. Menhaden are plotted on a separate axis due to scale issues.

Baitfish Species:

Silversides *(Menidia sp.)*

Silversides had the second highest abundance of all species, with 11,147 caught during the 2017 survey (CPUE=77.4 fish/haul). This is down from the 13,423 caught in 2017, but up from the 7,443 silversides collected in 2016. Silversides were collected in each of the ponds throughout the time period of the survey (May-October). The highest abundances were observed in Charlestown Pond. August saw the highest numbers of silversides across the ponds. The total survey abundance index was 77.4 fish/seine haul. Table 9 contains the abundance indices for the survey by month and pond. Atlantic silversides caught in 2018 ranged in size from 2 cm to 14 cm.

Striped Killifish *(Fundulus majalis)*

Striped killifish ranked third in species abundance with 2,942 fish caught during 2018 (CPUE=17.1). This is slightly less than the 3,989 fish caught during 2017. They occurred in each of the ponds and were caught each month during the survey. Winnapaug Pond had the highest abundance of striped killifish, and overall, they were more prevalent in August. Table 10 contains the abundance indices for the survey by month and pond. Striped killifish caught in 2017 ranged in size from 2 cm to 13 cm.

Common Mummichog *(Fundulus heteroclitus)*

The mummichog was fourth in overall abundance in 2018 with 2,251 individuals collected (CPUE=15.6), up from the 1,963 caught in 2017. Mummichogs occurred in each of the ponds and were caught each month during the survey. Winnapaug Pond had the highest abundances of Mummichogs. This value continues the rebound from the lowest mummichog abundance on record of 2.09 fish/seine haul in 2013. Table 11 contains the abundance indices for the survey by month and pond. Mummichogs caught in 2018 ranged in size from 2 cm to 10 cm.

Sheepshead Minnow *(Cyprinodon variegatus)*

The Sheepshead minnow ranked eighth in overall abundance with 455 individuals collected (CPUE=3.16). This is a decrease from the 1,209 fish caught in 2017. Sheepshead minnow occurred in each of the ponds and were caught between May and October, with the exception of June. Overall, the highest abundances were seen in October. Potter Pond had the highest abundances of Sheepshead minnows. Table 12 contains the abundance indices for the survey by month and pond. Sheepshead minnow caught in 2017 ranged in size from 2 cm to 5 cm.

Figure 16 displays the annual abundance index of the baitfish species for all stations combined.

Physical and Chemical Data:

Physical and Chemical data for the 2018 Coastal Pond Survey is summarized in tables 13-15 and Figure 23. Water temperature in 2018 averaged 20.7 ºC, with the lowest observed value of 11.07 ºC in October in Pawcatuck River and the highest at 27.15 ºC in Green Hill Pond in July. Water temperature continues on an annual upward trend. Salinity ranged from 12.64 ppt to 28.90 ppt, and averaged 25.82 ppt. Dissolved oxygen ranged from 5.87 mg/l to 11.68 mg/l with an average of 8.20 mg/l.

New Station Preliminary Data

This year was the eighth year of sampling stations in the three additional ponds. On a whole, the samples were consistent with 2011-2017. Beginning this year, data from these additional stations has been included in the abundance indices for all species, including YOY winter flounder. A brief description of each pond follows.

Green Hill Pond: Green Hill Pond is a small coastal pond located east of Charlestown Pond. It does not open directly to the ocean, but instead its only inlet is via Charlestown Pond and is thus not well flushed. Green Hill pond has water quality issues including high summer temperatures, high nutrient load, and a permanent shellfish closure. GH-1 is in the northeastern quadrant of the pond on a small island. The bottom substrate is mud with shell hash. GH-2 is in the southeastern quadrant of the pond on a sand bar. The bottom substrate is fine, muddy sand. WFL YOY have been caught in relatively high abundance in May, suggesting spawning activity within the pond. The WFL YOY decrease in abundance at the stations in July and August when the water is warm and are not caught frequently after it cools in the fall. Other species frequently present in the pond are the baitfish species, naked goby, and blue crabs.

Potter Pond: Potter Pond is a small coastal pond located west of Point Judith Pond. Similarly to Green Hill Pond, it does not open directly to the ocean. Instead, its only inlet is via Point Judith Pond. However, the local geography is such that more tidal flushing occurs than in Green Hill Pond. The inlet to Potter Pond is closer to the inlet to Point Judith Pond, and its inlet is shorter. PP-1 is in the southwestern quadrant of the pond in a shallow cove. The bottom substrate is mud. PP-2 is in the northwestern quadrant of the pond adjacent to a deep (~25') glacial kettle hole. The bottom substrate is fine sand with some cobble. WFL YOY have been caught at both stations but only PP-1 with high frequency. Also similar to Green Hill Pond, WFL YOY are highest in abundance in May and decrease in abundance as the season progresses. The water temperature in Potter Pond does not get as warm as Green Hill Pond, but still may be a factor at station PP-1. The geography of this station does not facilitate flushing and water quality may explain the lack of WFL YOY in mid-summer. Interestingly, all eight years had small catches of 1-year old flounder at station PP-1 during the late summer and early fall. Water temperatures are generally higher than the pond proper, while dissolved oxygen near this station is lower. The rest of the pond does not have the same water quality issues. Other species frequently caught in the pond include the baitfish species, American eel, oyster toad fish, naked goby, tautog, and blue crabs.

Lower Pawcatuck River: The lower Pawcatuck River (also known as Little Narragansett Bay) is the mouth of a coastal estuary formed by the Pawcatuck River. It is different form the other stations on the survey in that it does not have a traditional barrier beach pierced by an inlet. Instead, it is relatively open to Block Island Sound. PR-1 is a small protected beach in a small cove surrounded by large boulders. The bottom substrate is fine sand. This station typically has the most consistent catch of WFL YOY which are present during all months of the survey. However, in 2018, WFL were only captured June-August. PR-2 is located on a sand bar island in the middle of Little Narragansett Bay on the protected (inland) side. This sand bar is all that is left of a larger barrier beach which existed prior to the 1938 hurricane. The bottom substrate is coarse sand. This station catches WFL YOY, but usually at lower frequencies than PR-1. PR-3 was originally located in the southern part of Little Narragansett Bay on the protected side of Napatree Beach. After it was initially sampled in May 2011, the station was relocated because it was extremely shallow and a high wave energy area. PR-3 is now located in the northern section of Little Narragansett Bay at the mouth of the river near G. Willie Cove. The station is on a *Spartina spp*. covered bank at the head of G. Willie Cove. The bottom substrate is cobble. This station was selected to best characterize the species assemblage in the Lower Pawcatuck River as the majority of the shoreline consists of marsh grass covered banks. The station has been sampled in all 6 months since 2012. WFL YOY are not present in high frequencies at the station which is not unexpected due to the bottom substrate. Other species frequently caught in the river include juvenile tautog, the baitfish species, alewife, tomcod, menhaden, and bluefish.

Point Judith Pond: The new station PJ-4 is located in the eastern section of the pond on Ram Island. The bottom substrate is silty sand with some large cobble. The station was selected because of its proximity to three fyke net stations sampled during the Adult Winter Flounder Spawner Survey. The station was added to better classify the species in the pond and to better document the decline of WFL YOY in the pond. The station has higher catch frequencies of WFL YOY than the other stations in the pond, but still is low in comparison to the other ponds.

The first six years of sampling the new stations successfully collected target species, notably WFL YOY. It is recommended that these stations be sampled into the future so as to continue to provide species assemblage information from these coastal ponds. The additional catch frequencies and distributions of WFL YOY will provide a better understanding of the population, notably in areas where the fish only occur in the spring/early summer. Moving forward, this data will be included in the time series abundance indices.

Summary

In 2018, Investigators caught 50 species of finfish representing 36 families. This number is consistent with 2017, where 50 species from 35 families were collected. Additionally, the number of individuals caught in 2018 increased from the 2017 survey, with 47,024 collected in 2018 compared to 38,250 collected in 2017. Appendix 1 displays the frequency of all species caught by station during the 2018 Coastal Pond Survey. Additional data is available by request.

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Table 1: 2018 Coastal Pond Survey Winter Flounder Frequency by Station and Month

Station	May	June	July	August	September	October	Totals	Mean	STD
CP1	7	8	3	2	1	0	**21**	**3.50**	**3.27**
CP2	0	2	0	0	0	1	**3**	**0.50**	**0.84**
CP3	0	1	3	2	0	1	**7**	**1.17**	**1.17**
CP4	0	2	0	0	0	0	**2**	**0.33**	**0.82**
GH1	3	4	0	0	0	0	**7**	**1.17**	**1.83**
GH2	1	0	0	0	0	0	**1**	**0.17**	**0.41**
NR1	1	17	0	0	0	0	**18**	**3.00**	**6.87**
NR2	9	46	25	37	5	3	**125**	**20.83**	**18.00**
NR3	2	6	8	3	1	2	**22**	**3.67**	**2.73**
PJ1	2	0	2	1	0	0	**5**	**0.83**	**0.98**
PJ2	4	6	1	10	0	0	**21**	**3.50**	**3.99**
PJ3	1	0	3	1	4	0	**9**	**1.50**	**1.64**
PJ4	6	5	12	16	0	0	**39**	**6.50**	**6.44**
PP1	0	0	0	0	0	1	**1**	**0.17**	**0.41**
PP2	0	1	0	0	0	0	**1**	**0.17**	**0.41**
PR1	0	16	40	6	0	0	**62**	**10.33**	**15.82**
PR2	0	0	0	0	2	0	**2**	**0.33**	**0.82**
PR3	0	5	2	0	2	0	**9**	**1.50**	**1.97**
QP1	5	13	2	4	3	2	**29**	**4.83**	**4.17**
QP2	0	2	34	30	5	3	**74**	**12.33**	**15.37**
QP3	3	9	22	6	3	1	**44**	**7.33**	**7.71**
WP1	1	2	19	10	3	5	**40**	**6.67**	**6.83**
WP2	1	12	5	10	4	1	**33**	**5.50**	**4.59**
WP3	0	5	2	7	3	1	**18**	**3.00**	**2.61**
Totals	**46**	**162**	**183**	**145**	**36**	**21**	**593**		
Mean	**1.92**	**6.75**	**7.63**	**6.04**	**1.50**	**0.88**	**24.71**		
STD	**2.55**	**9.79**	**11.62**	**9.57**	**1.79**	**1.30**	**29.19**		

Table 2: 2018 Coastal Pond Survey winter flounder abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	Aug	Sept	Oct
Charlestown Pond	1.75	3.00	1.50	1.00	0.25	0.50
Green Hill Pond	2.00	2.00	0.00	0.00	0.00	0.00
Narrow River	4.00	23.00	11.00	13.33	2.00	1.67
Pawcatuck River	0.00	7.00	14.00	2.00	1.33	0.00
Point Judith Pond	3.25	2.50	4.00	6.75	1.00	0.00
Potter Pond	0.00	0.00	0.00	0.00	0.00	0.50
Quonochontaug Pond	2.67	8.00	19.33	13.33	3.67	2.00
Winnapaug Pond	0.67	6.00	8.67	9.00	3.33	2.33
Total Pond Index	**1.79**	**6.44**	**7.31**	**5.68**	**1.45**	**0.88**

Table 3: 2018 Coastal Pond Survey average lengths (cm) of juvenile winter flounder by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	2.93	5.88	6.20	6.33	6.00	9.25
Greenhill Pond	4.30	6.45	0.00	0.00	0.00	0.00
Narrow River	3.64	5.64	6.39	6.40	8.02	8.22
Point Judith Pond	5.22	6.07	7.44	6.33	8.03	0.00
Potter Pond	0.00	15.60	0.00	0.00	0.00	9.10
Pawcatuck River	0.00	4.13	5.55	6.30	5.58	0.00
Quonochontaug Pond	4.43	5.10	5.48	5.75	7.35	8.57
Winnapaug Pond	12.00	4.82	5.38	5.84	6.89	6.74
Overall	**4.06**	**6.71**	**4.55**	**4.62**	**5.23**	**5.23**

Table 4: 2018 Coastal Pond Survey bluefish abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	0.00	0.00	0.00	0.00	0.00	0.00
Green Hill Pond	0.00	0.00	0.00	0.00	0.00	0.00
Narrow River	0.00	0.00	2.67	0.00	0.00	0.00
Point Judith Pond	0.00	0.00	0.00	0.00	0.00	0.00
Potter Pond	0.00	0.00	0.50	0.00	0.00	0.00
Pawcatuck River	0.00	0.00	0.00	0.67	0.00	0.00
Quonochontaug Pond	0.00	0.00	0.00	0.00	0.67	0.00
Winnapaug Pond	0.00	0.00	0.00	0.00	0.00	0.00
Total Pond Index	**0.00**	**0.00**	**0.40**	**0.08**	**0.08**	**0.00**

Table 5: 2018 Coastal Pond Survey tautog abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	0.50	0.50	0.00	20.00	11.75	1.00
Green Hill Pond	0.00	0.00	0.00	0.00	0.00	0.00
Narrow River	0.00	0.00	0.00	6.33	8.33	1.33
Point Judith Pond	0.00	0.00	0.00	2.75	0.00	0.00
Potter Pond	0.00	0.00	0.00	0.50	0.50	0.00
Pawcatuck River	0.33	0.00	0.33	7.00	3.33	0.33
Quonochontaug Pond	0.33	0.33	0.00	8.67	5.33	1.33
Winnapaug Pond	0.00	0.00	0.00	0.33	3.00	0.00
Total Pond Index	**0.15**	**0.10**	**0.04**	**5.70**	**4.03**	**0.50**

Table 6: 2018 Coastal Pond Survey black sea bass abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	0.00	0.00	0.00	8.75	14.75	5.50
Green Hill Pond	0.00	0.00	0.00	0.00	0.00	1.00
Narrow River	0.00	0.00	0.00	68.67	50.00	3.33
Point Judith Pond	0.00	0.00	0.00	9.25	0.50	0.25
Potter Pond	0.00	0.00	0.00	0.00	0.00	0.00
Pawcatuck River	0.00	0.00	0.00	0.00	0.00	0.00
Quonochontaug Pond	0.00	0.00	0.00	8.00	8.67	0.67
Winnapaug Pond	0.00	0.00	0.00	6.00	3.67	0.00
Total Pond Index	**0.00**	**0.00**	**0.00**	**12.58**	**9.70**	**1.34**

Table 7: 2018 Coastal Pond Survey Scup abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	0.00	0.00	0.00	43.75	20.33	0.00
Green Hill Pond	0.00	0.00	0.00	0.00	0.00	0.00
Narrow River	0.00	0.00	0.00	28.00	1.67	0.00
Point Judith Pond	0.00	0.00	0.00	0.25	0.50	0.00
Potter Pond	0.00	0.00	0.00	0.00	0.00	0.00
Pawcatuck River	0.00	0.00	0.00	4.67	1.00	0.00
Quonochontaug Pond	0.00	0.00	0.00	10.00	0.67	0.00
Winnapaug Pond	0.00	0.00	0.00	3.00	2.33	0.00
Total Pond Index	**0.00**	**0.00**	**0.00**	**11.21**	**3.31**	**0.00**

Table 8: 2018 Coastal Pond Survey Clupeid abundance indices (fish/seine haul) by month

Species	May	June	July	August	September	October
Alewife	0.00	3.88	1.83	1.38	0.04	1.50
Bay Anchovy	0.04	0.00	0.00	0.00	0.88	0.42
Atlantic Herring	1.04	0.46	0.00	0.00	0.00	0.00
Blueback herring	0.00	0.08	3.92	0.00	0.00	0.04
Atlantic Menhaden	0.00	0.00	0.00	873.38	83.83	98.67

Table 9: 2018 Coastal Pond Survey Silverside abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	9.25	33.00	73.50	412.25	356.25	279.00
Green Hill Pond	4.00	7.00	3.00	34.00	33.00	41.50
Narrow River	116.00	19.00	3.00	153.00	45.67	46.67
Point Judith Pond	20.75	24.25	76.25	42.50	78.50	31.25
Potter Pond	67.50	19.00	6.50	120.00	68.00	90.00
Pawcatuck River	24.00	48.67	47.33	161.67	90.33	1.33
Quonochontaug Pond	12.33	34.67	54.00	172.33	45.00	22.67
Winnapaug Pond	7.00	13.67	52.67	132.00	127.67	40.33
Total Pond Index	**32.60**	**24.91**	**39.53**	**153.47**	**105.55**	**69.09**

Table 10: 2018 Coastal Pond Survey Striped Killifish abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	0.50	23.50	27.00	16.25	39.00	17.25
Green Hill Pond	0.00	0.00	0.00	1.00	0.00	0.00
Narrow River	0.00	0.00	0.00	54.33	5.33	42.00
Point Judith Pond	0.00	6.25	0.50	25.75	16.00	99.50
Potter Pond	0.00	0.00	0.50	8.50	3.00	51.50
Pawcatuck River	8.00	0.00	16.00	8.67	3.67	2.67
Quonochontaug Pond	0.00	0.00	14.67	34.33	28.33	1.67
Winnapaug Pond	0.00	0.33	28.67	173.33	127.33	20.33
Total Pond Index	**1.06**	**3.76**	**10.92**	**40.27**	**27.83**	**29.36**

Table 11: 2018 Coastal Pond Survey Mummichog abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	5.00	2.75	19.50	56.75	3.25	27.50
Green Hill Pond	0.00	1.00	18.50	14.00	1.50	2.50
Narrow River	0.33	6.00	2.33	40.33	31.00	6.33
Point Judith Pond	2.50	57.5	0	43	7.5	2.75
Potter Pond	4.00	3.50	9.00	27.00	0.50	18.00
Pawcatuck River	0.00	2.75	0.00	13.25	0.75	0.25
Quonochontaug Pond	0.00	0.33	5.67	15.00	0.33	2.00
Winnapaug Pond	1.00	0.33	0.67	173.67	71.67	0.33
Total Pond Index	**1.60**	**9.27**	**6.96**	**47.88**	**14.56**	**7.46**

Table 12: 2018 Coastal Pond Survey Sheepshead Minnow abundance indices (fish/seine haul) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	5.00	2.75	19.50	56.75	3.25	27.50
Green Hill Pond	0.00	1.00	18.50	14.00	1.50	2.50
Narrow River	0.33	6.00	2.33	40.33	31.00	6.33
Point Judith Pond	2.50	57.5	0	43	7.5	2.75
Potter Pond	4.00	3.50	9.00	27.00	0.50	18.00
Pawcatuck River	0.00	2.75	0.00	13.25	0.75	0.25
Quonochontaug Pond	0.00	0.33	5.67	15.00	0.33	2.00
Winnapaug Pond	1.00	0.33	0.67	173.67	71.67	0.33
Total Pond Index	**1.60**	**9.27**	**6.96**	**47.88**	**14.56**	**7.46**

Table 13: 2018 Coastal Pond Survey average water temperature (°C) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	19.85	20.80	25.15	24.98	22.98	15.68
Green Hill Pond	21.25	21.95	27.15	25.70	24.30	15.85
Narrow River	14.67	18.30	23.47	25.50	24.43	15.33
Pawcatuck River	18.03	21.83	23.77	26.57	21.03	11.07
Point Judith Pond	17.23	19.38	23.30	24.35	22.28	16.25
Potter's Pond	17.95	21.70	26.75	24.30	21.40	16.35
Quonochontaug Pond	19.80	23.20	24.93	23.40	22.30	13.43
Winnapaug Pond	13.00	17.70	22.10	24.30	22.77	13.47
Average	**17.72**	**20.61**	**24.58**	**24.89**	**22.69**	**14.68**

Table 14: 2018 Coastal Pond Survey average salinity (ppt) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	26.44	25.77	28.59	28.03	27.08	25.48
Green Hill Pond	18.51	20.48	21.72	24.25	25.11	21.74
Narrow River	*	22.27	23.40	22.77	21.62	*
Pawcatuck River	17.47	27.00	25.32	25.25	27.17	12.64
Point Judith Pond	23.96	27.77	28.82	28.22	27.44	26.28
Potter’s Pond	25.88	24.99	26.58	27.22	25.37	26.25
Quonochontaug Pond	27.83	28.34	28.44	28.81	28.67	28.45
Winnapaug Pond	*	28.28	28.50	28.42	28.67	28.90
Average	**23.35**	**25.61**	**26.42**	**26.62**	**26.39**	**24.25**

*YSI unavailable

Table 15: 2018 Coastal Pond Survey average dissolved oxygen (mg/L) by pond and month

Waterbody	May	June	July	August	September	October
Charlestown Pond	9.11	8.91	9.09	8.05	6.03	8.57
Green Hill Pond	8.20	9.20	7.68	5.87	6.59	8.09
Narrow River	*	8.62	8.22	8.58	7.86	*
Pawcatuck River	11.67	9.64	8.69	7.44	6.60	8.76
Point Judith Pond	8.67	8.11	6.94	7.22	7.82	9.38
Potter's Pond	11.68	8.49	7.79	7.46	7.57	8.11
Quonochontaug Pond	9.73	7.57	8.28	7.57	7.84	8.94
Winnapaug Pond	*	9.20	7.29	6.10	7.43	7.95
Average	**9.84**	**8.72**	**8.00**	**7.28**	**7.22**	**8.54**

*YSI unavailable

Table 16: 2018 Adult Winter Flounder tagging Survey (Fyke Net Survey) summary

Total WFL Caught	Total CPUE (fish/net hauls)	Mature Males	Mature Females	Immature
36	6	5	11	20

Figure 1: Location of coastal ponds sampled by the Coastal Pond Juvenile Finfish Survey in Southern Rhode Island.

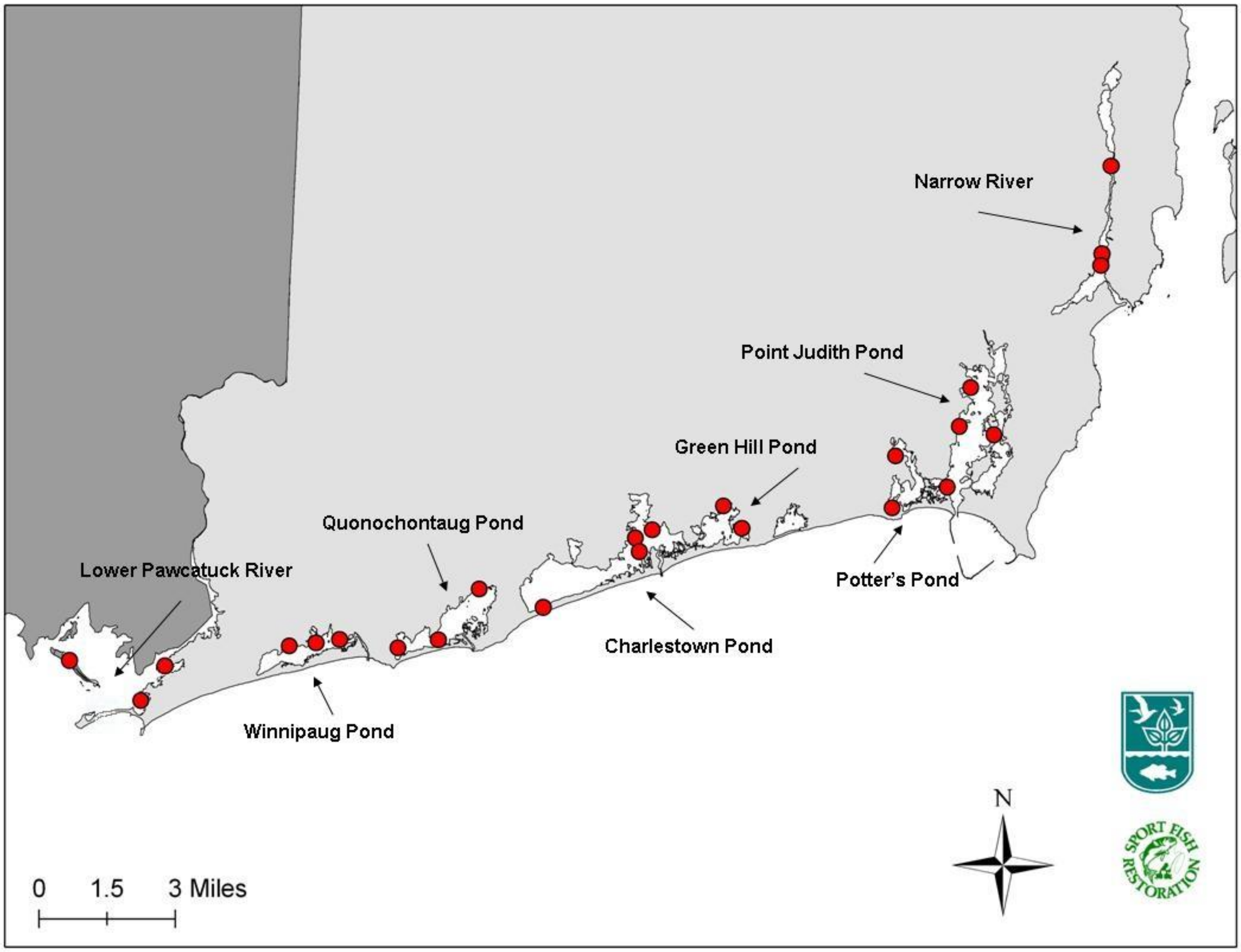


Figure 2: Coastal Pond Juvenile Finfish Survey station locations (western ponds).

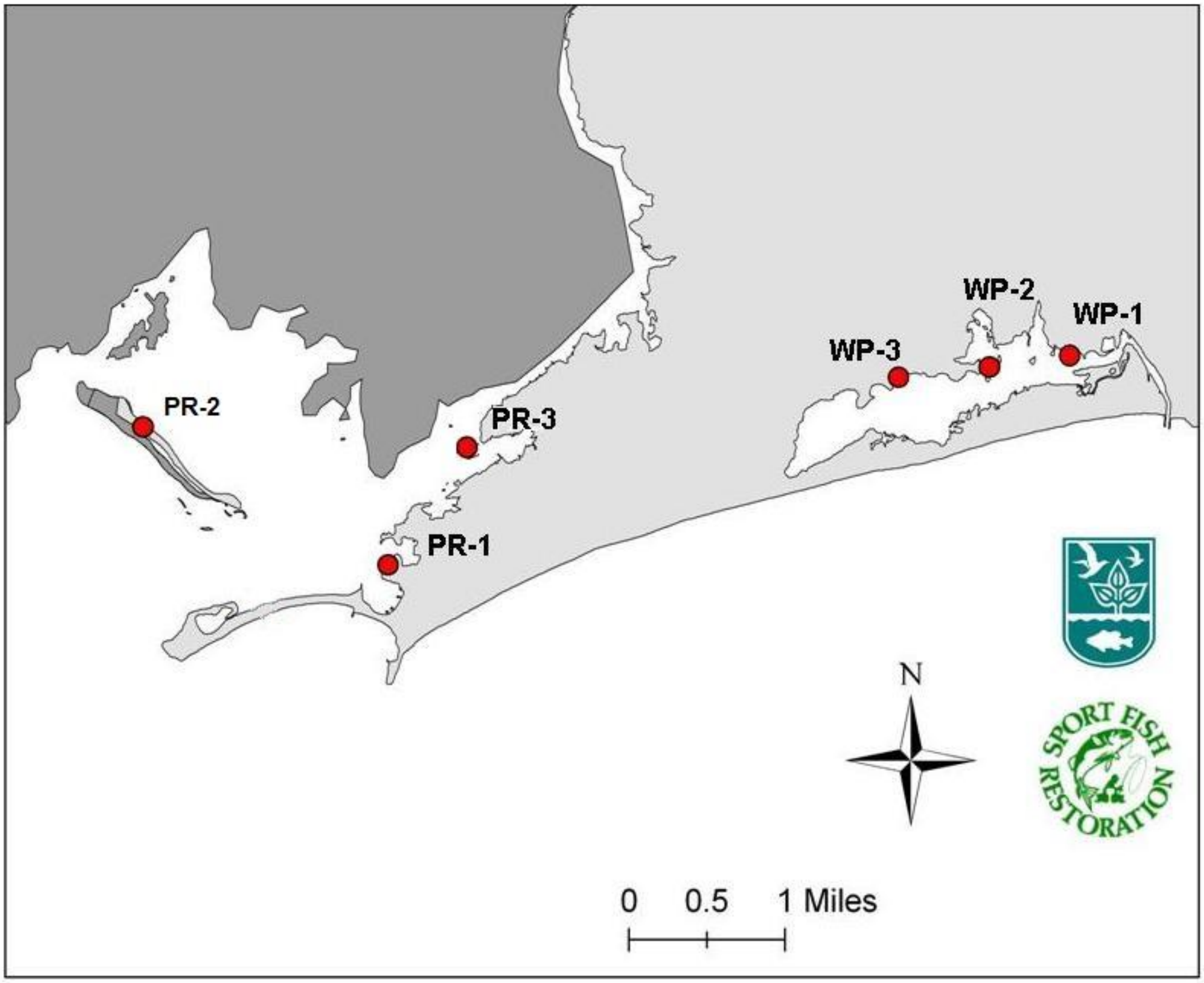


Figure 2 (cont): Coastal Pond Juvenile Finfish Survey station locations (western ponds).

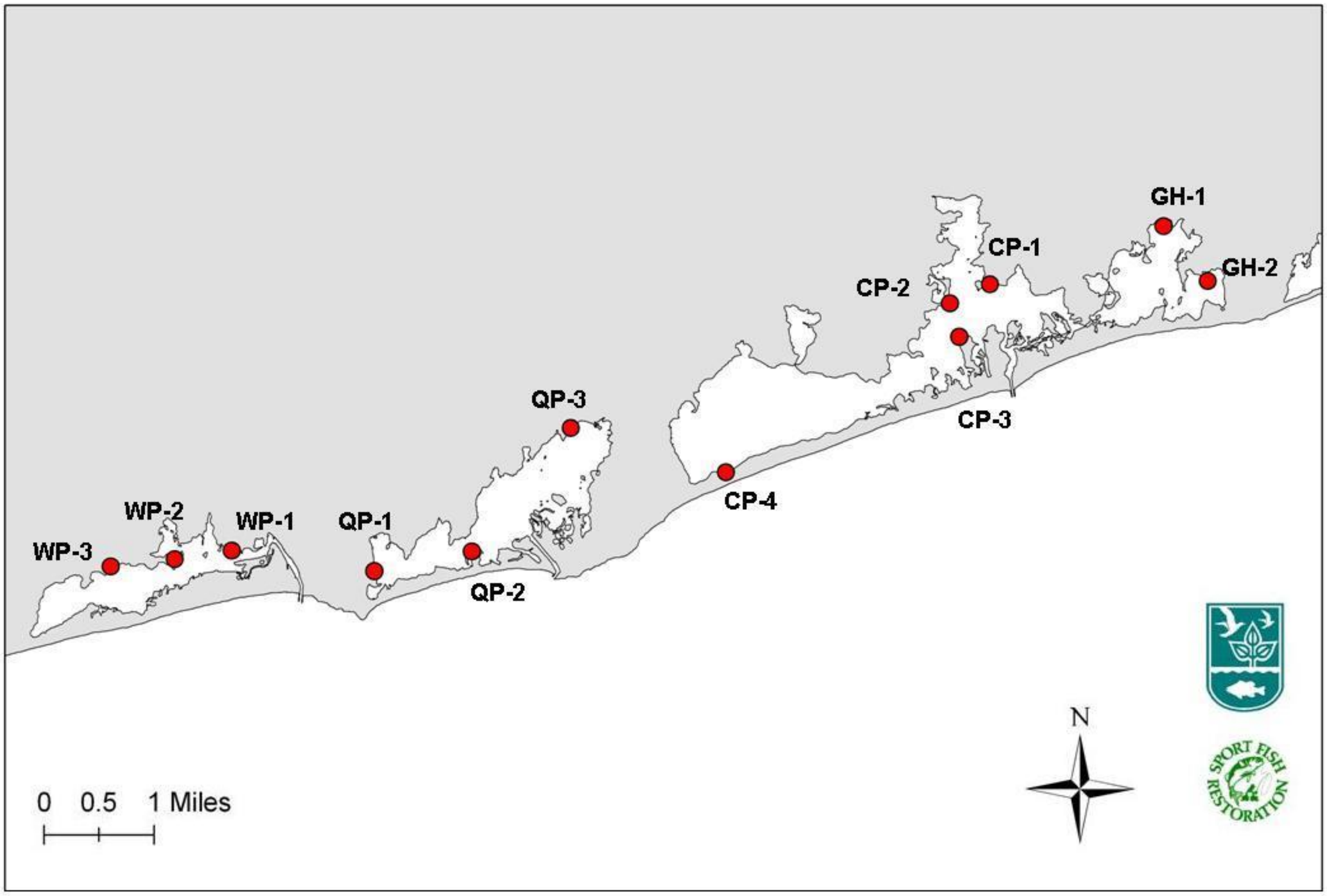


Figure 3: Coastal Pond Juvenile Finfish Survey station locations (eastern ponds).

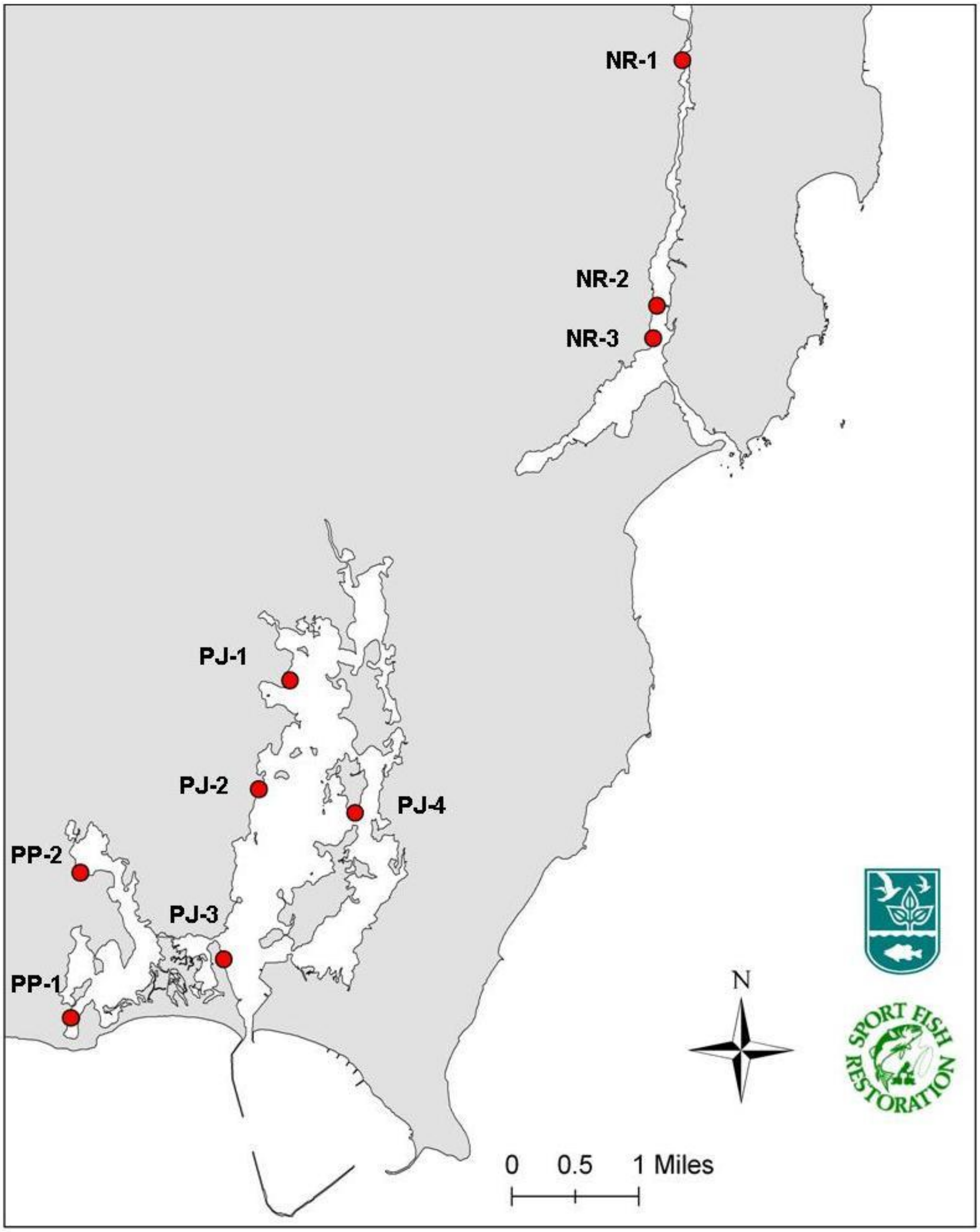
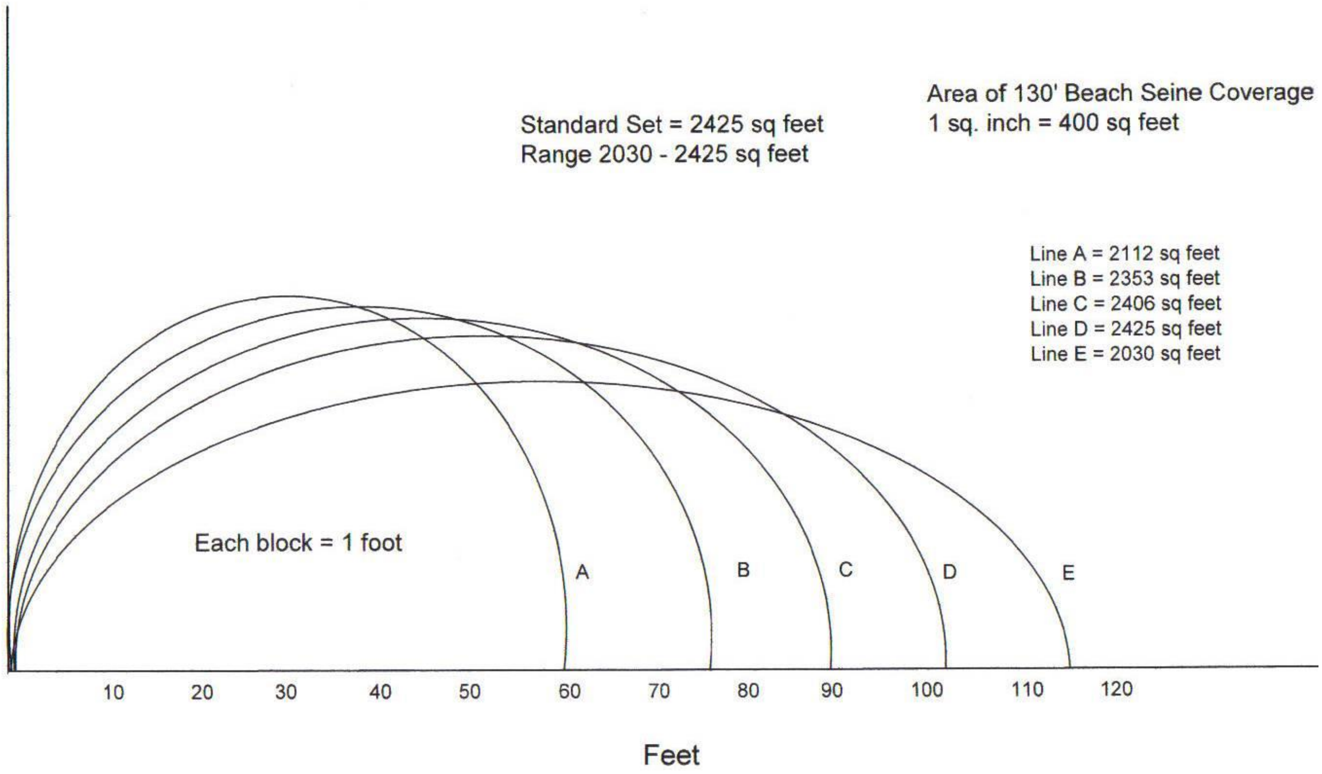


Figure 4
Coastal Pond Juvenile Finfish Survey



Area of 130' Beach Seine Coverage
1 sq. inch = 400 sq feet

Standard Set = 2425 sq feet
Range 2030 - 2425 sq feet

Line A = 2112 sq feet
Line B = 2353 sq feet
Line C = 2406 sq feet
Line D = 2425 sq feet
Line E = 2030 sq feet

Each block = 1 foot

Figure 5: Time series of abundance indices (fish/seine haul) for winter flounder YOY from all coastal ponds. Note: the vertical dashed line marks the addition of new stations in 2011.

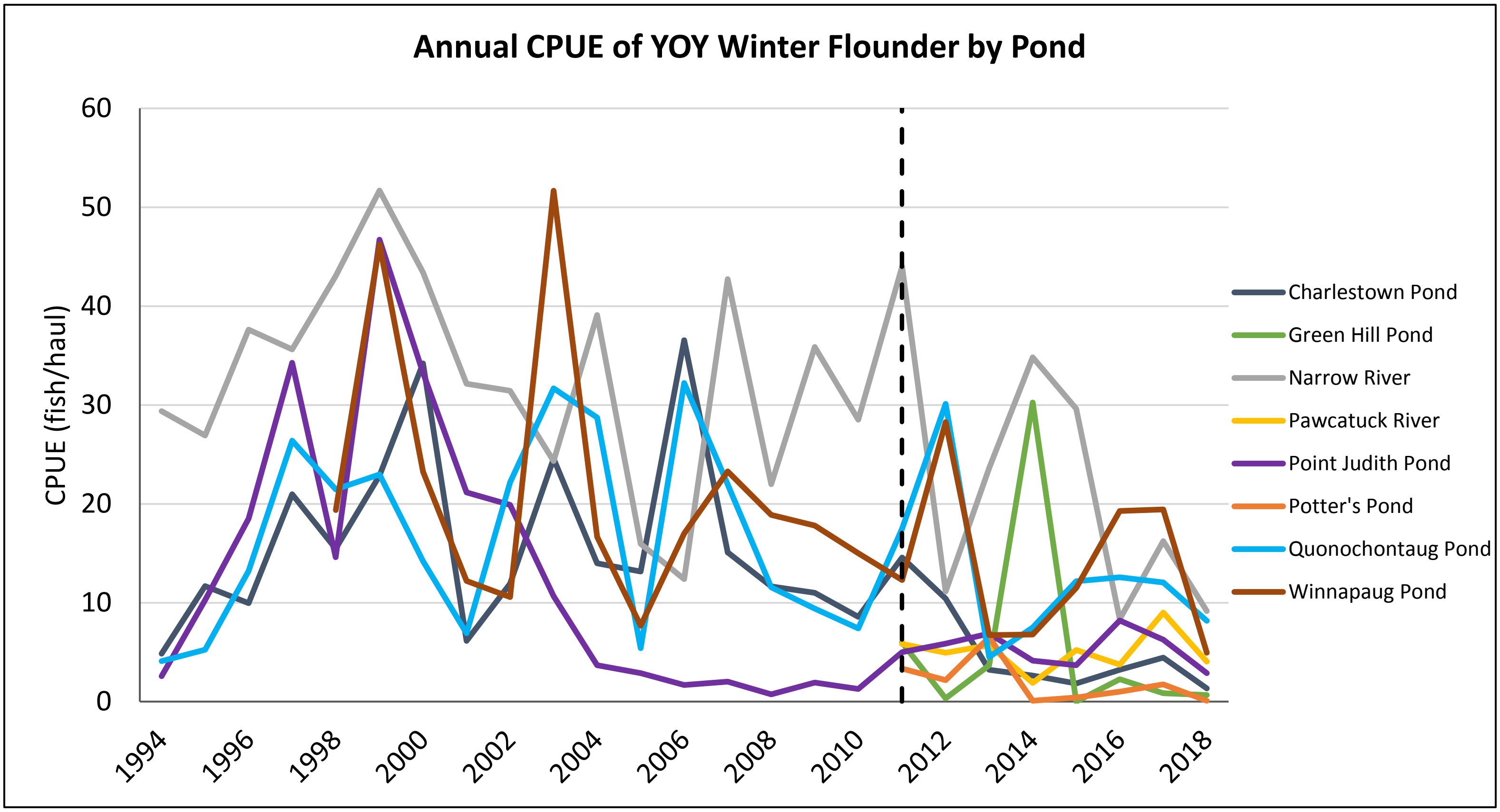


Figure 6: 2018 abundance indices (fish/seine haul) for YOY winter flounder for each pond by month.

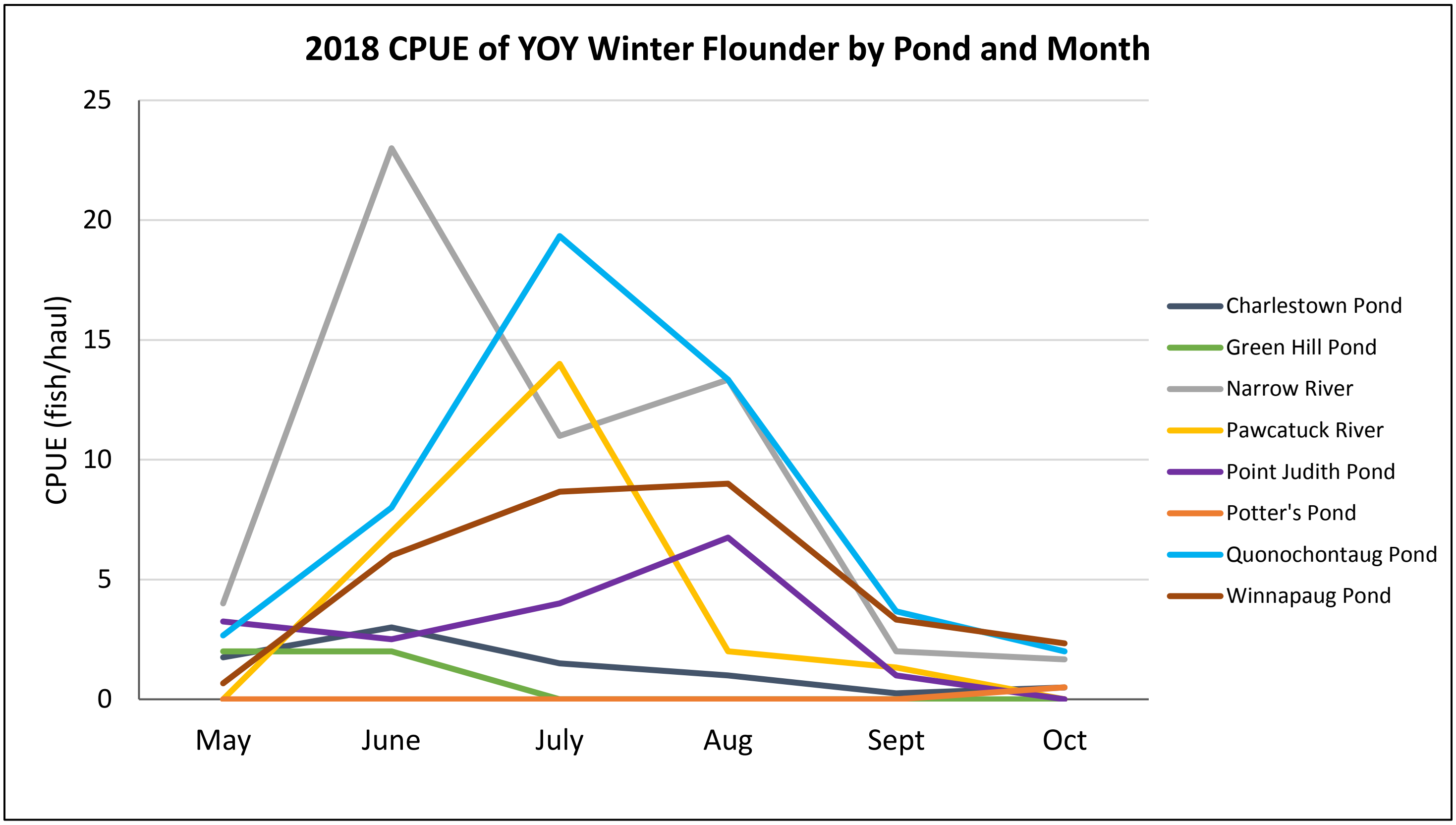


Figure 7: Length frequency of all winter flounder caught in Coastal Pond Survey during 2018. Note: YOY are to the left of the dashed line (<12cm TL)

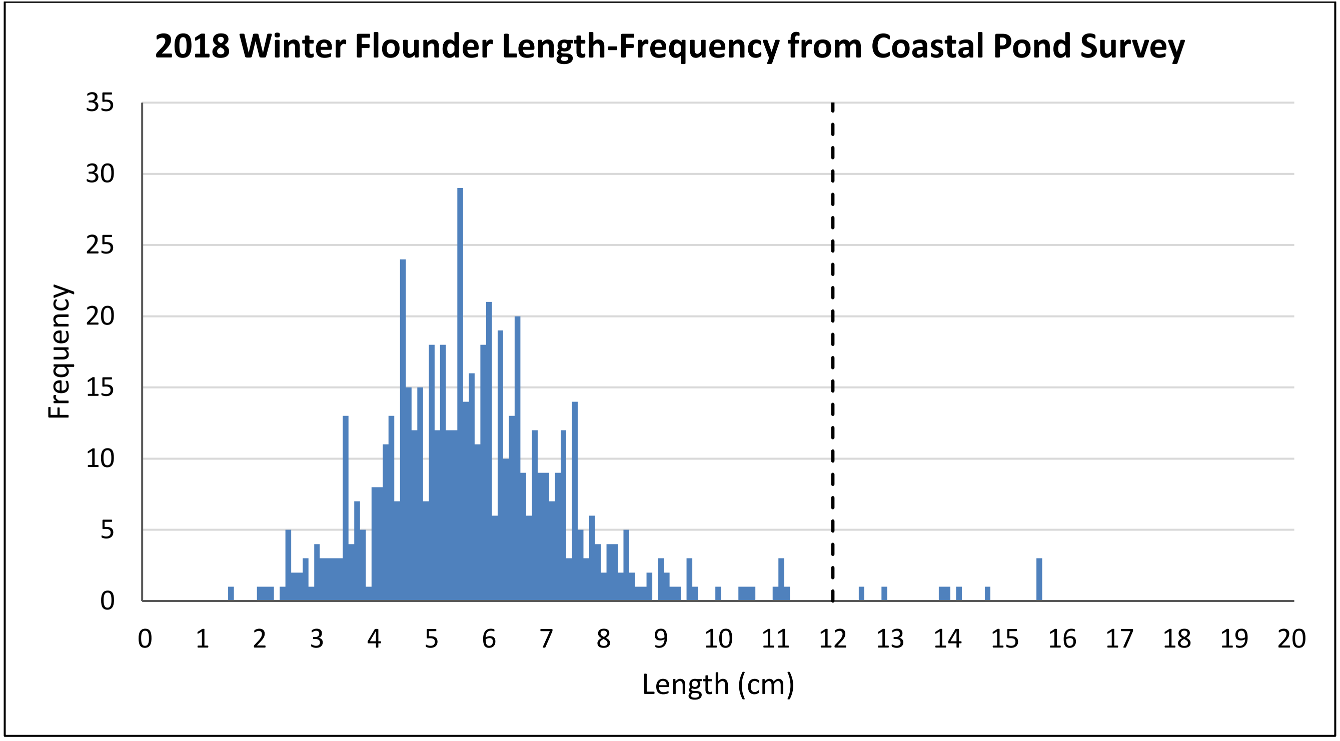


Figure 8: Time series of annual abundance indices for winter flounder YOY from the coastal pond survey. Note: the vertical dashed line marks the addition of new stations in 2011.

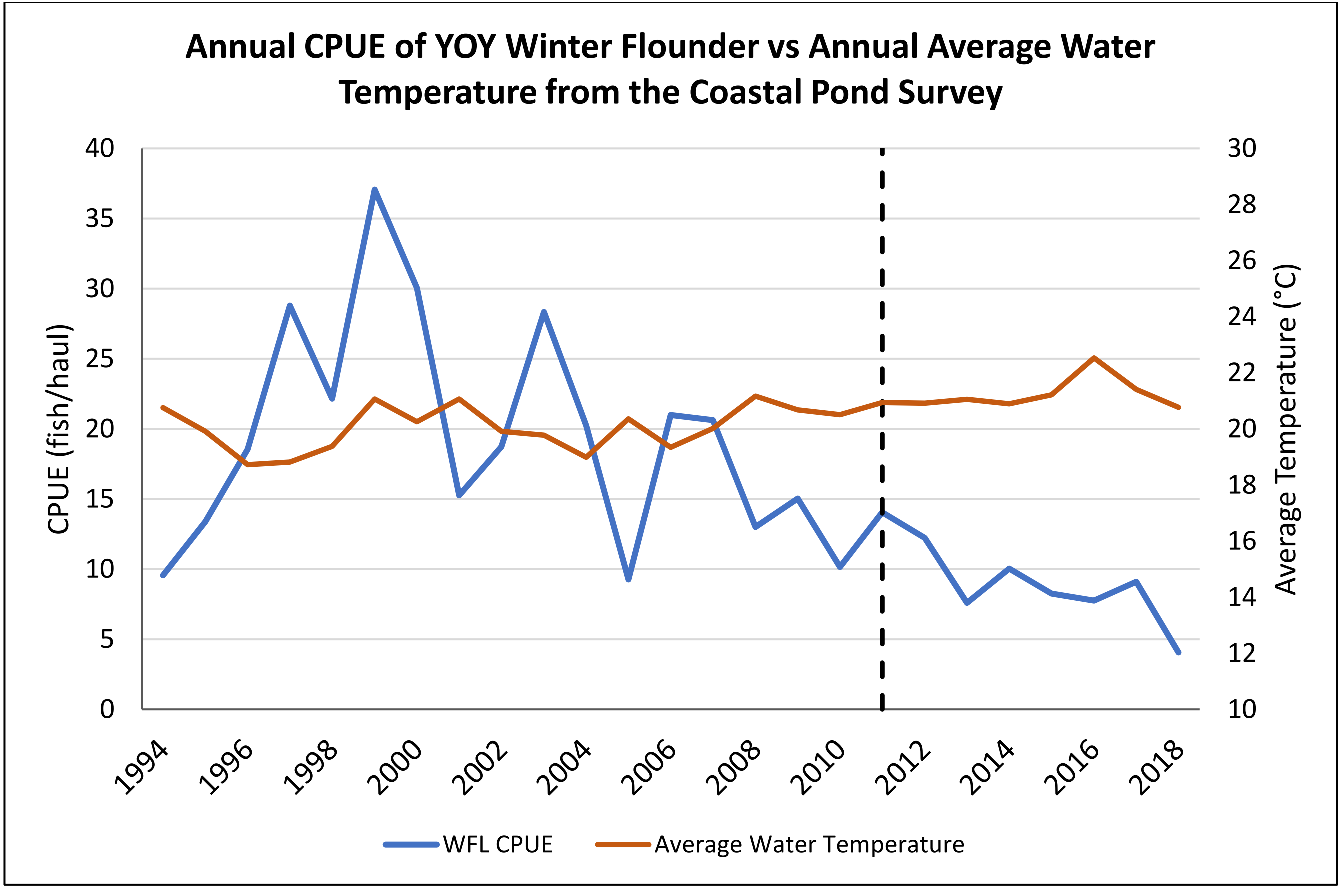


Figure 9: Abundance indices (fish/haul) from the RIDMF Coastal Pond Survey, Narragansett Bay Seine Survey, and Spring Trawl Survey for winter flounder.

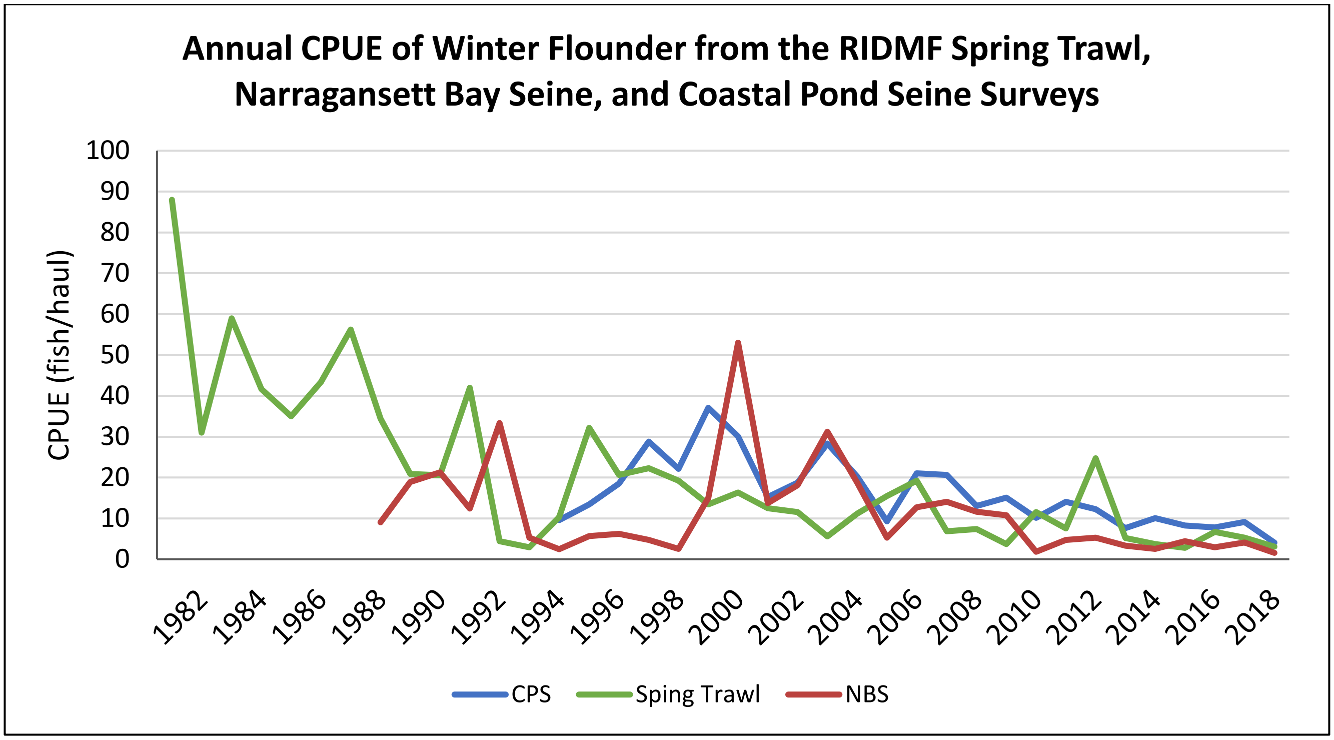


Figure 10: Abundance indices (fish/haul) from the Coastal Pond Survey and the Adult Winter Flounder Tagging Survey for winter flounder.

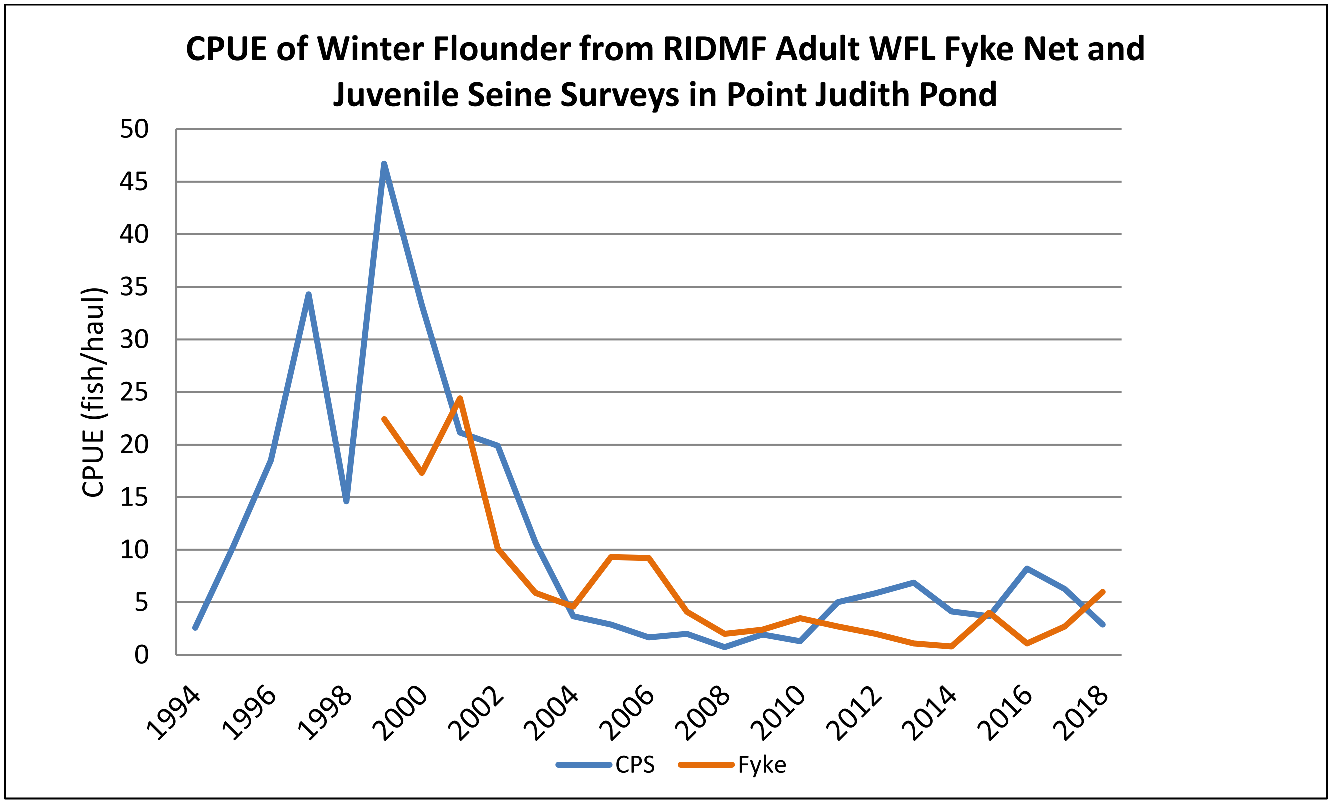


Figure 11. Time series of annual abundance indices for bluefish from the coastal pond survey.

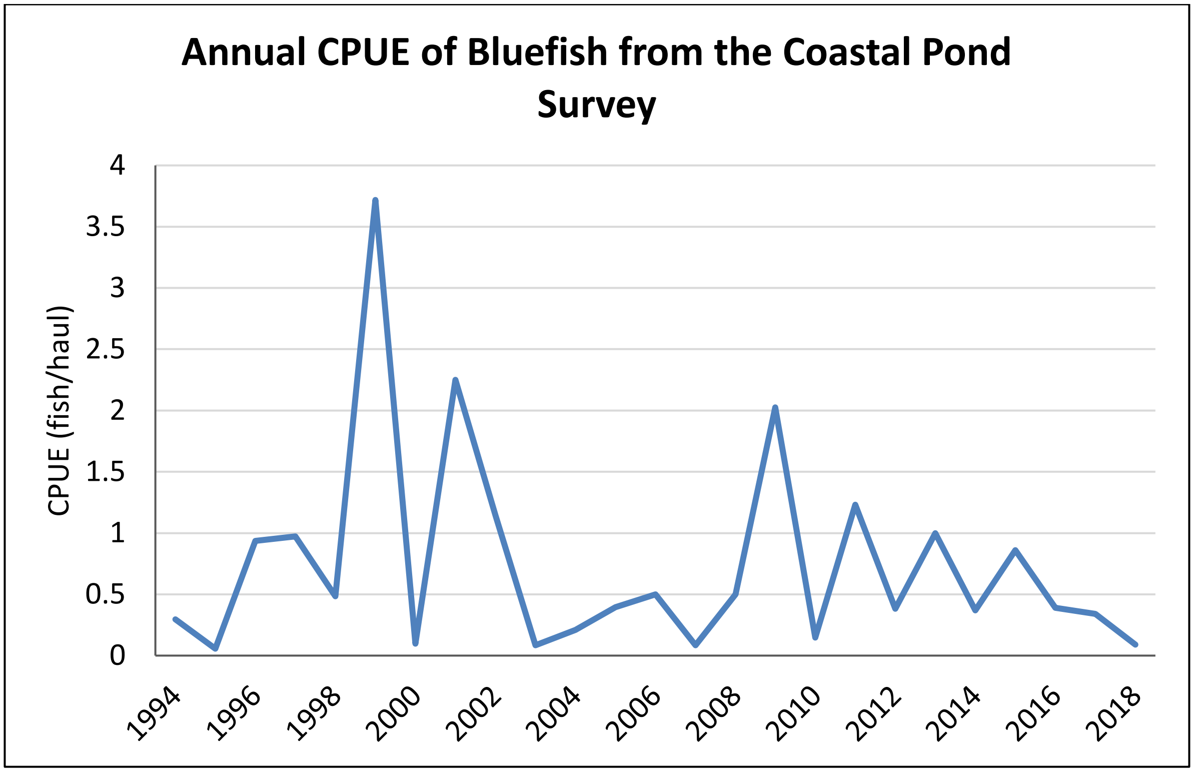


Figure 12. Time series of annual abundance indices for Tautog from the coastal pond survey.

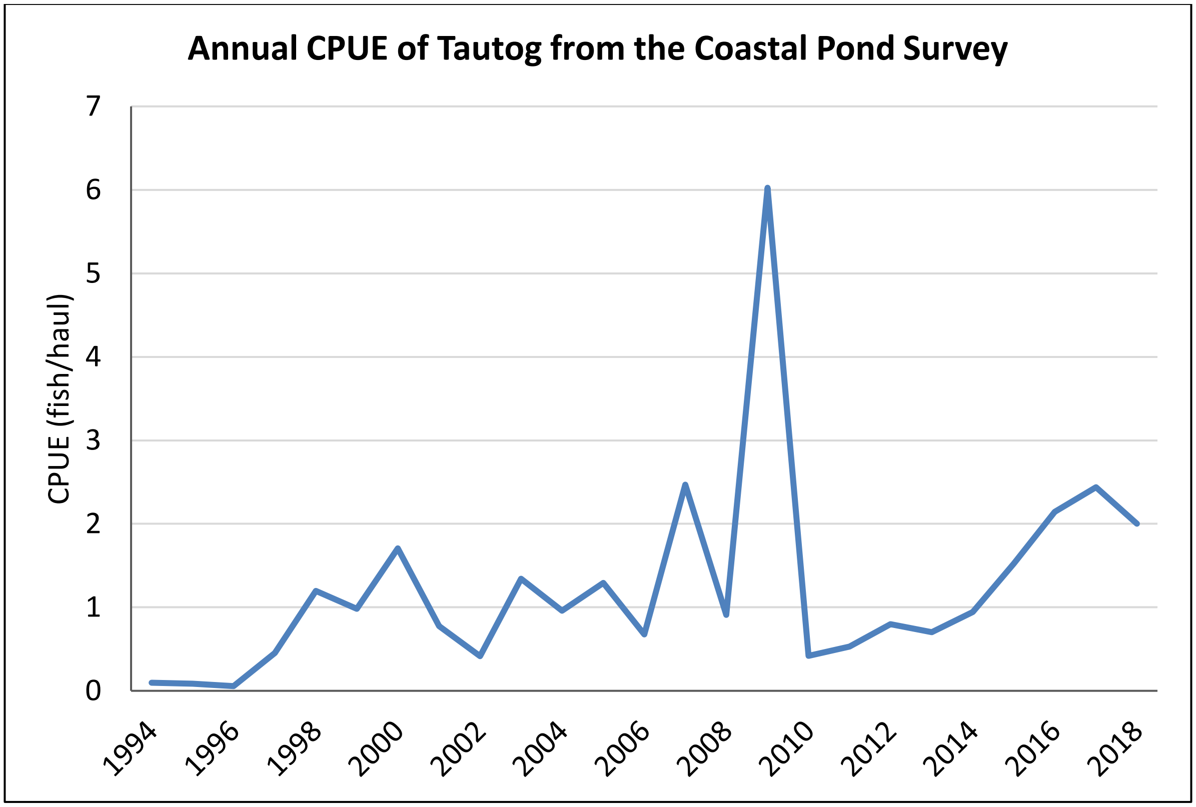


Figure 13. Time series of annual abundance indices for Black Sea Bass from the coastal pond survey.

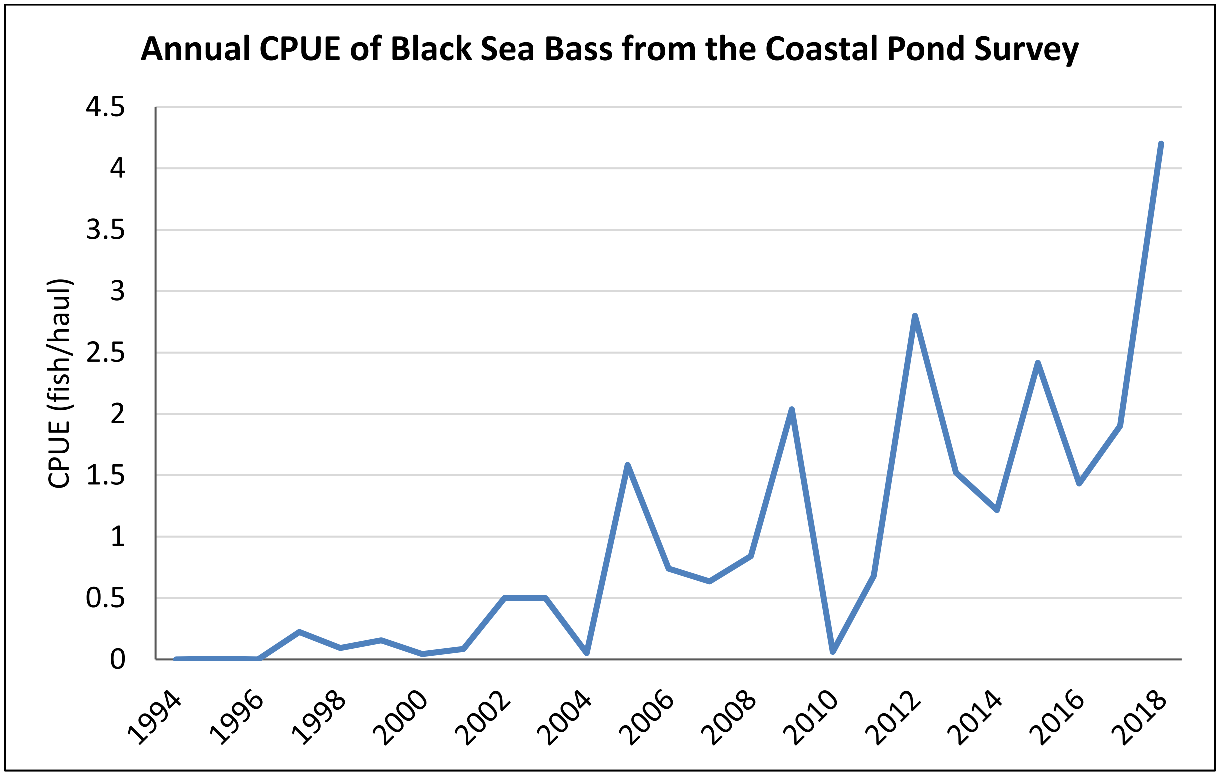


Figure 14. Time series of annual abundance indices for Scup from the coastal pond survey.

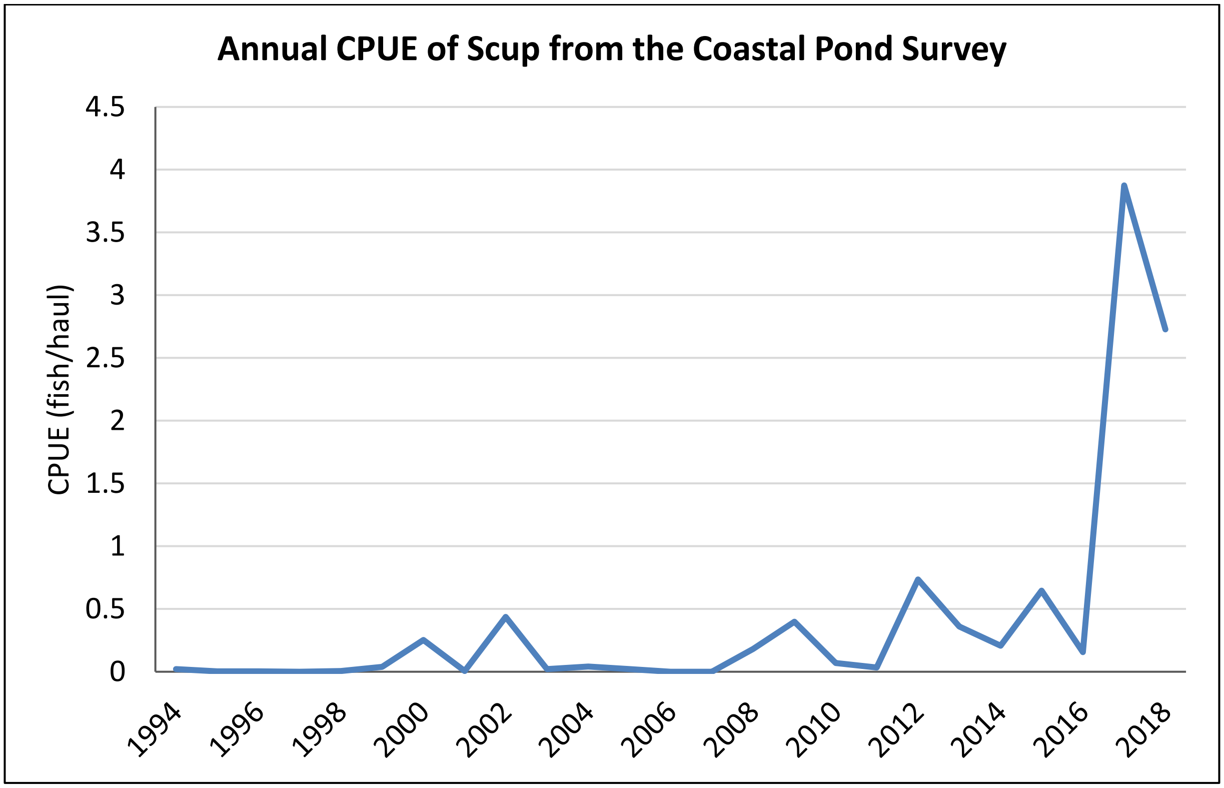


Figure 15. Time series of annual abundance indices for Clupeids from the coastal pond survey (Atlantic Menhaden on left y-axis, all other species on right y-axis)

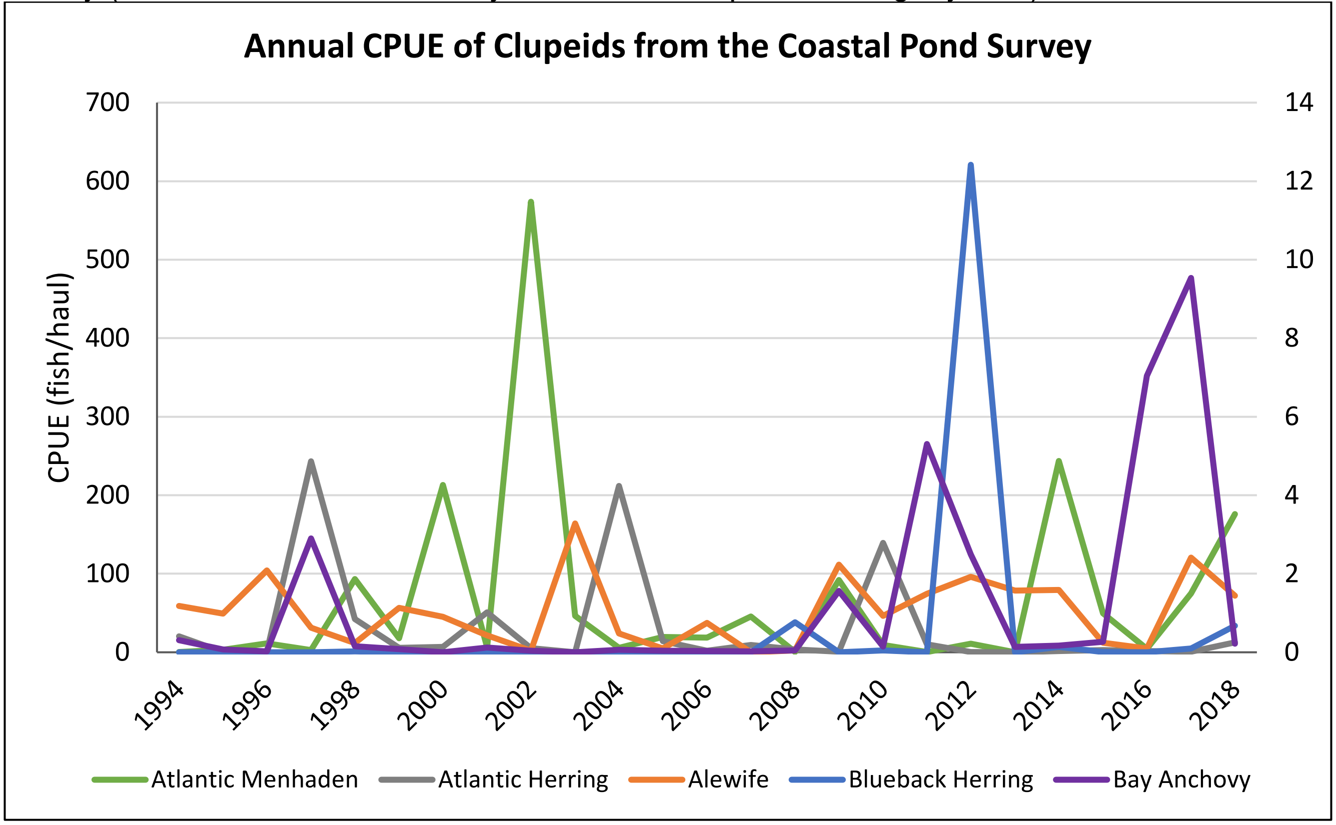


Figure 16. Time series of annual abundance indices for Baitfish from the coastal pond survey (Atlantic Silversides on left y-axis, all other species on right y-axis).

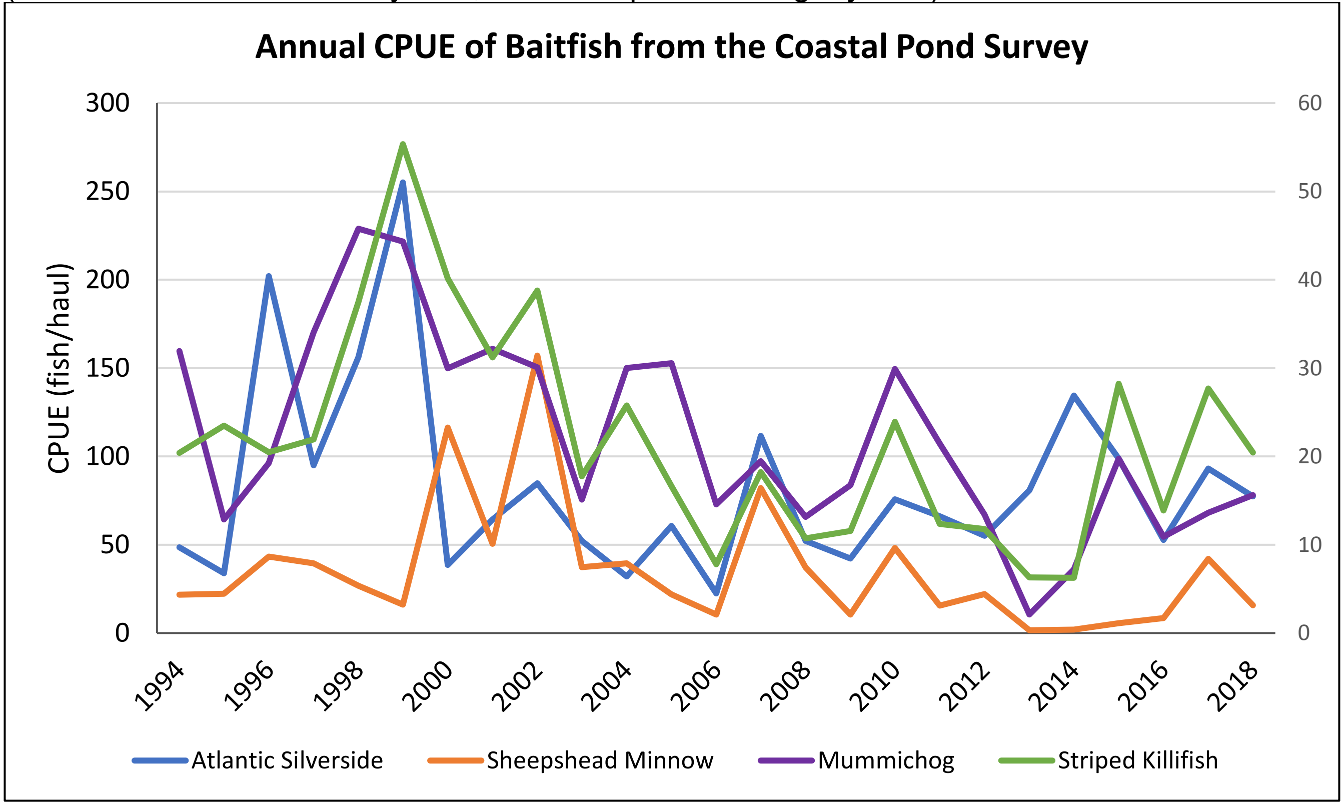


Figure 17: Map of total YOY WFL collected at each station in 2018.

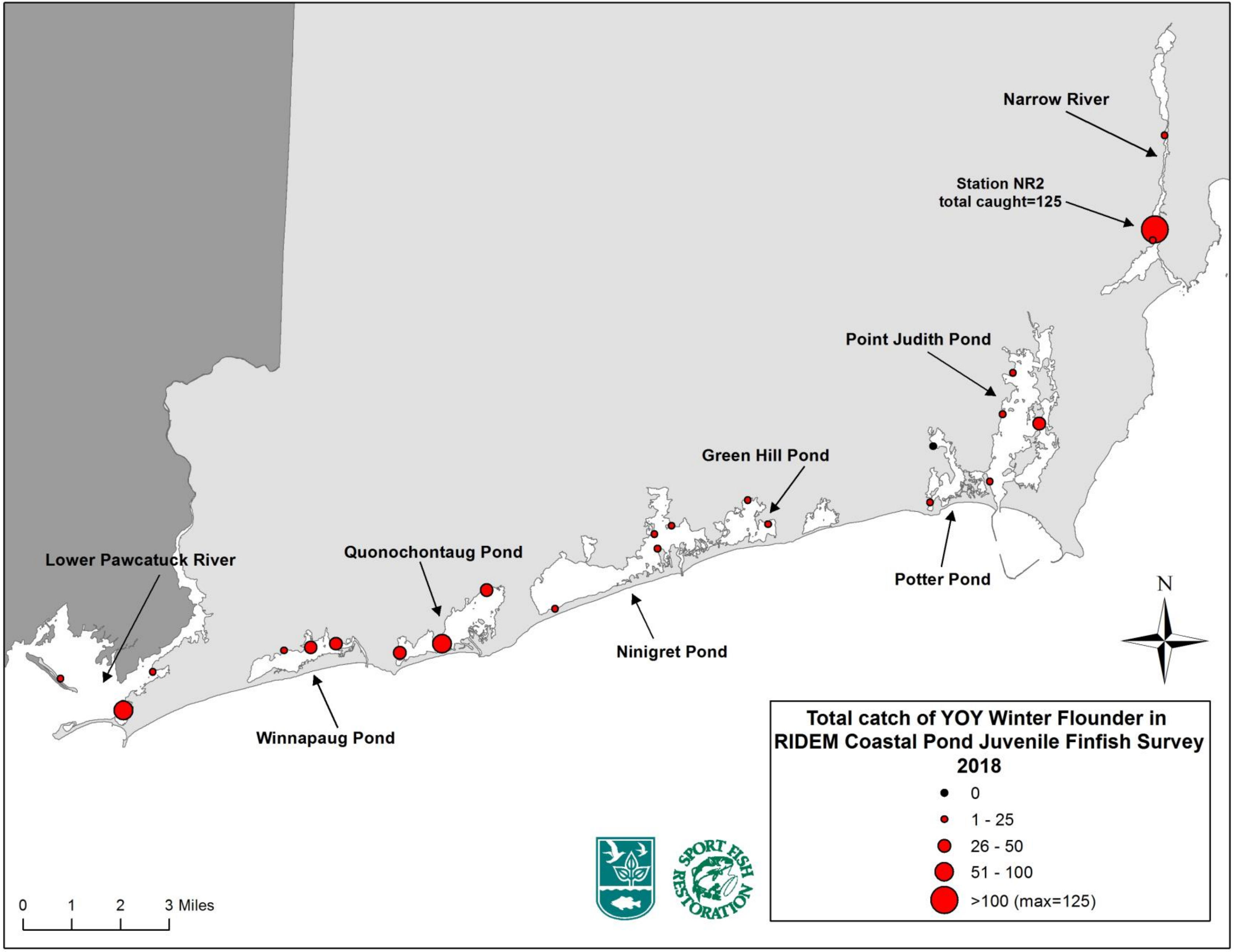


Figure 18: Map of total Bluefish collected at each station in 2018

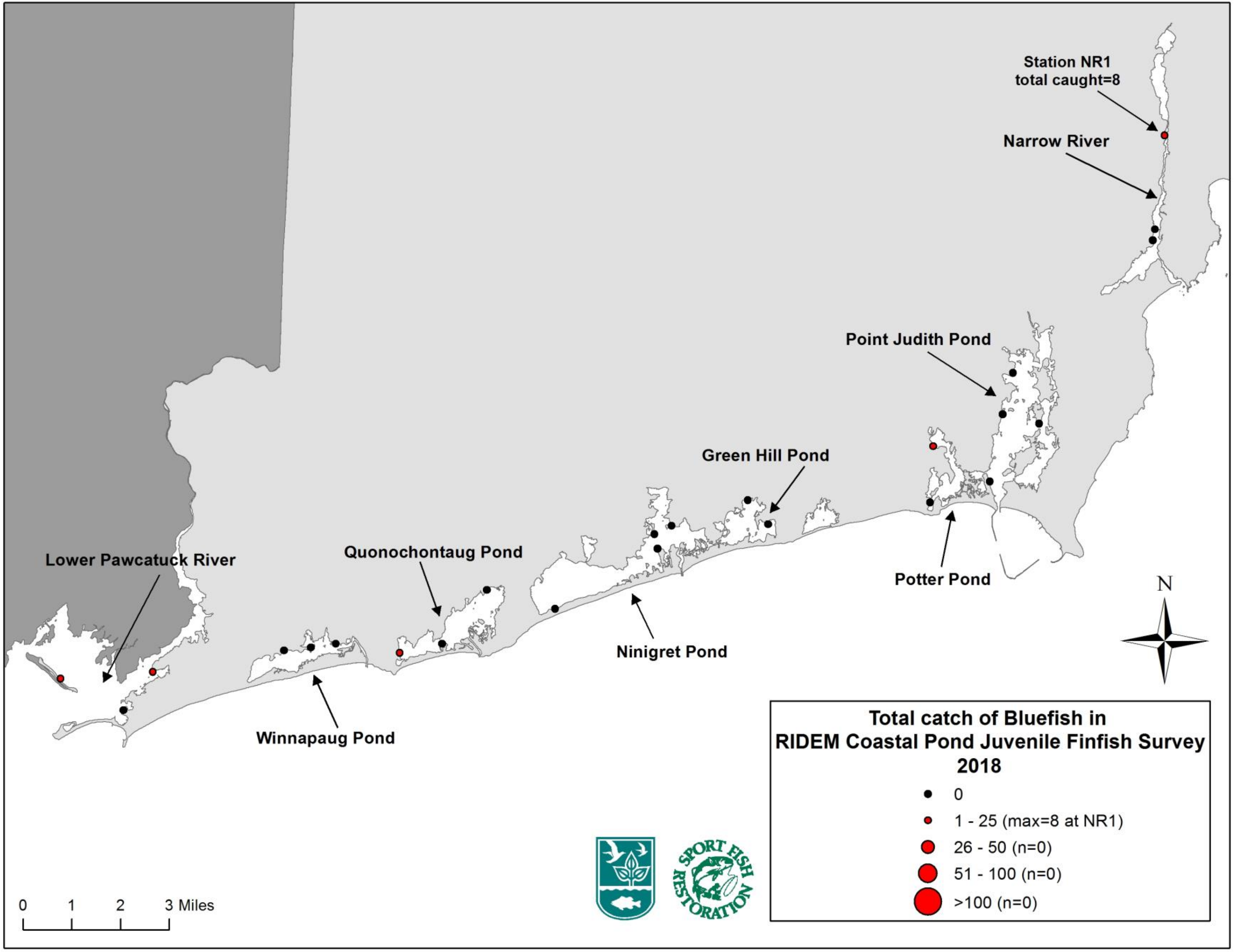


Figure 19: Map of total Tautog collected at each station in 2018

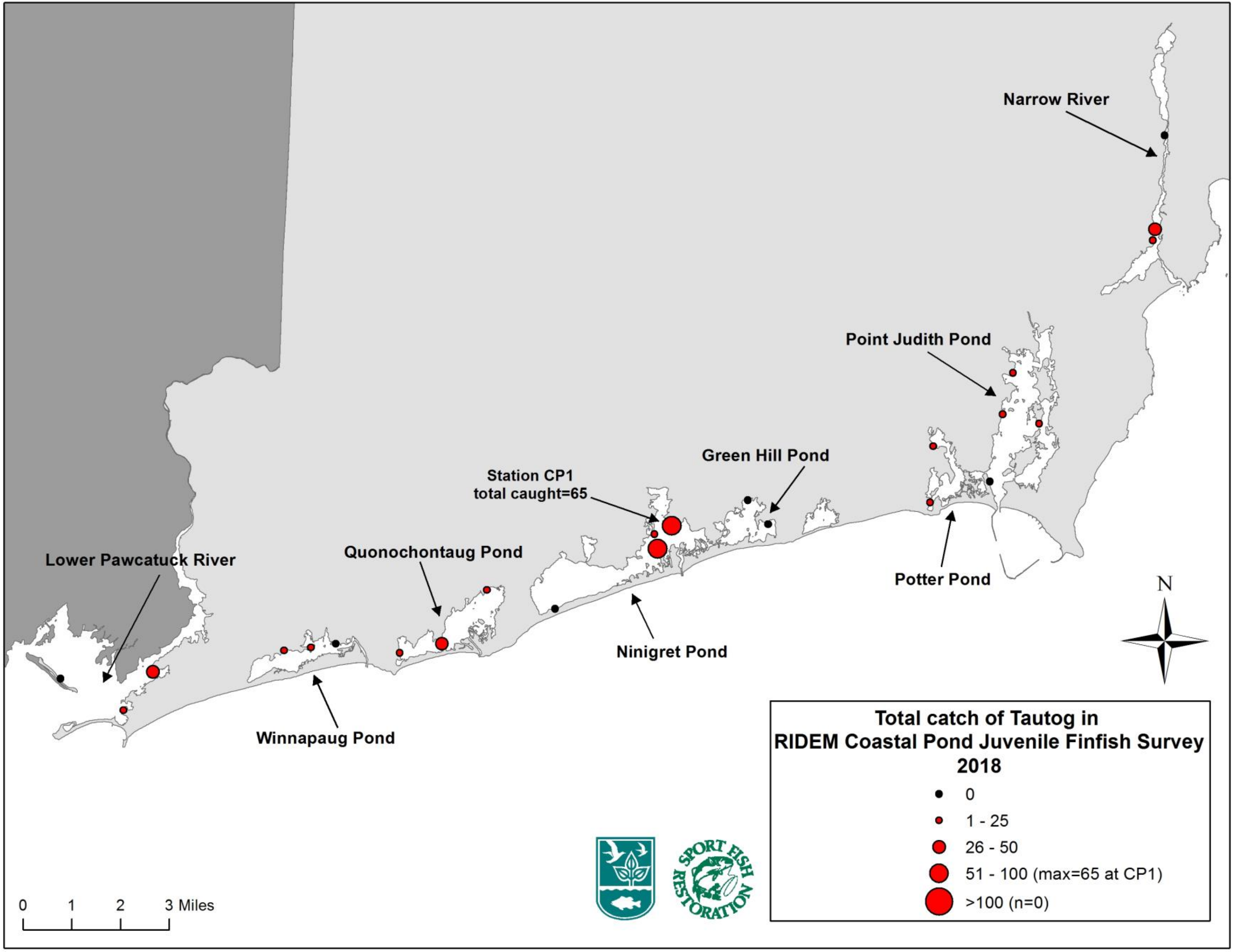


Figure 20: Map of total Black Sea Bass collected at each station in 2018

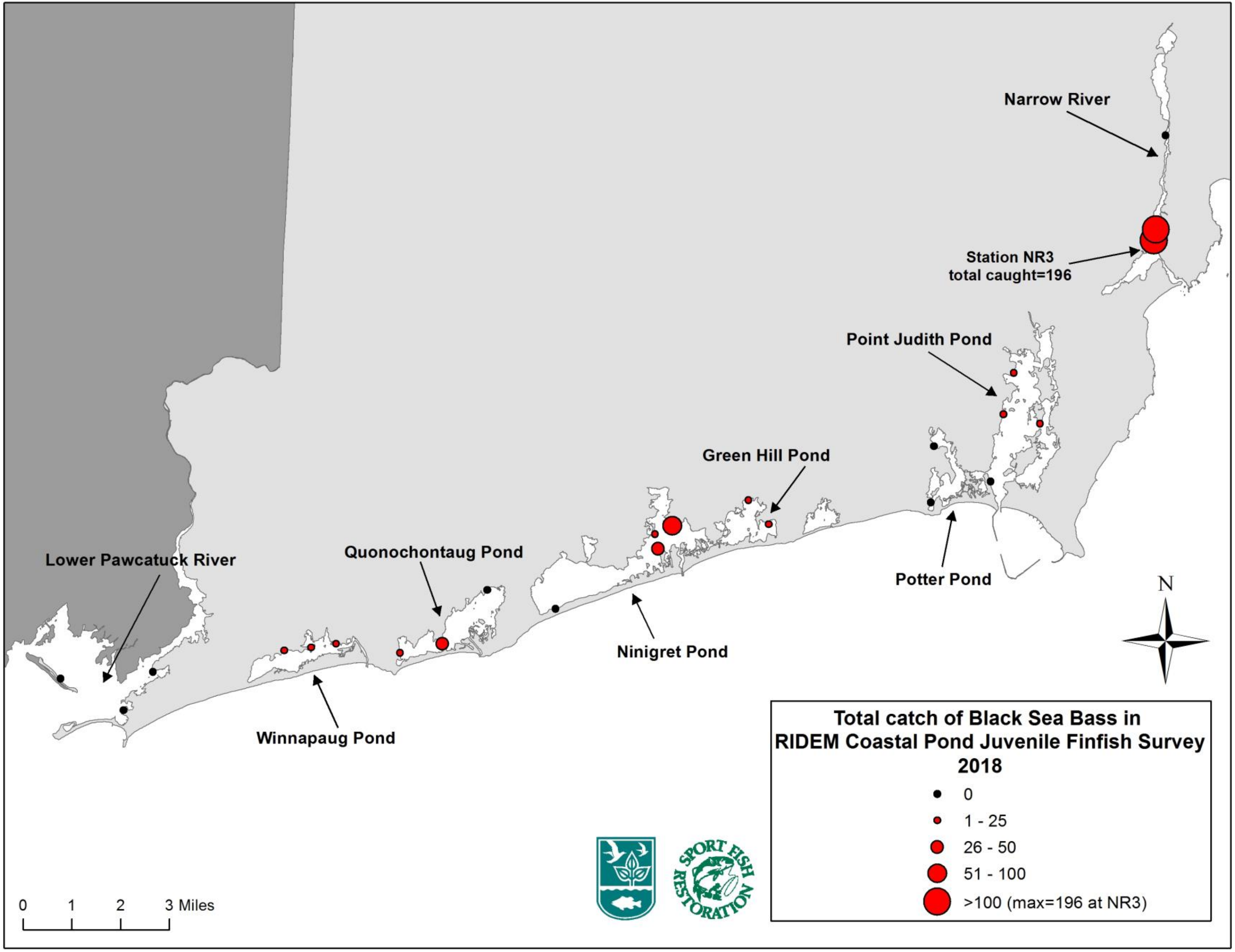


Figure 21: Map of total Scup collected at each station in 2018

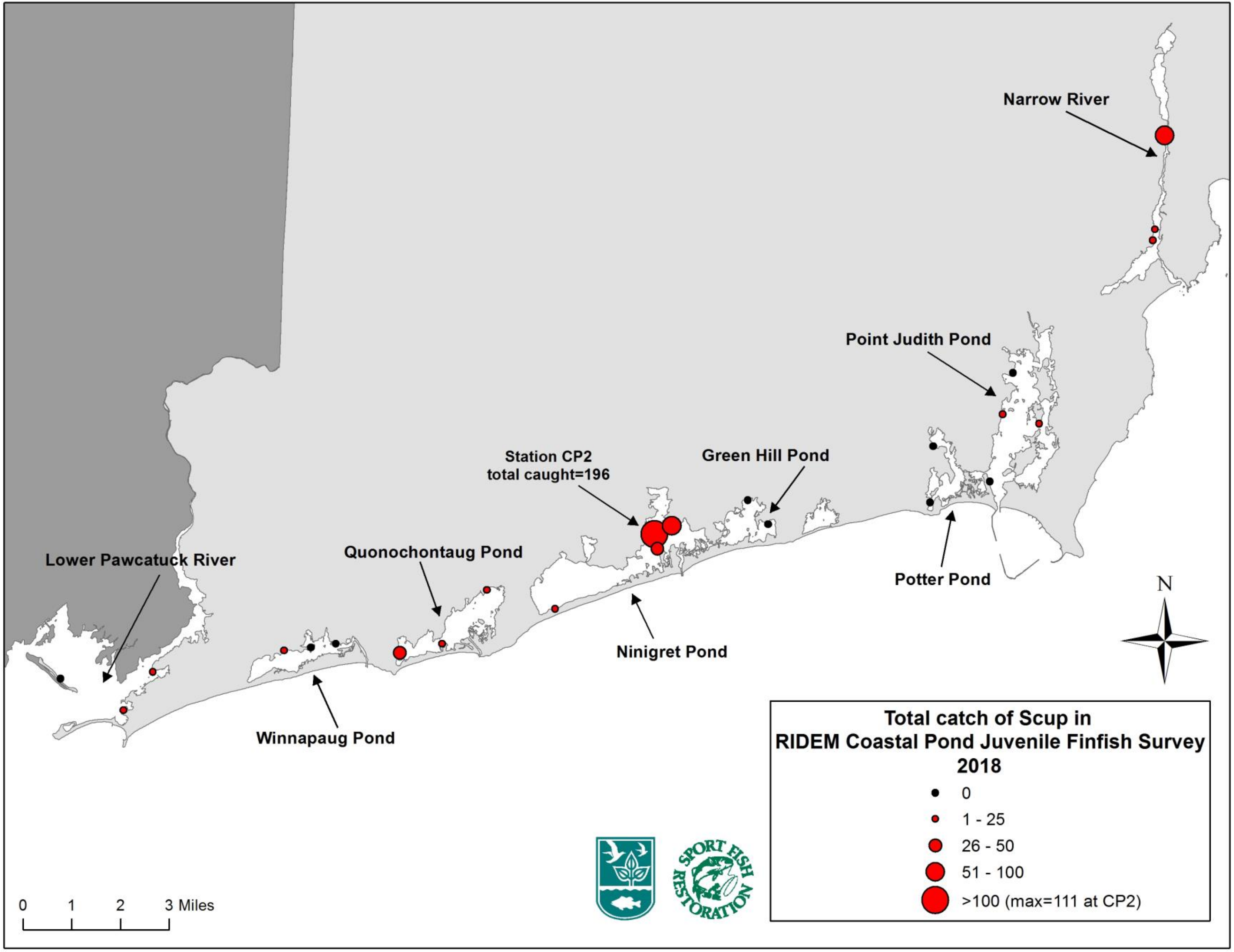


Figure 22: Map of total River Herring collected at each station in 2018

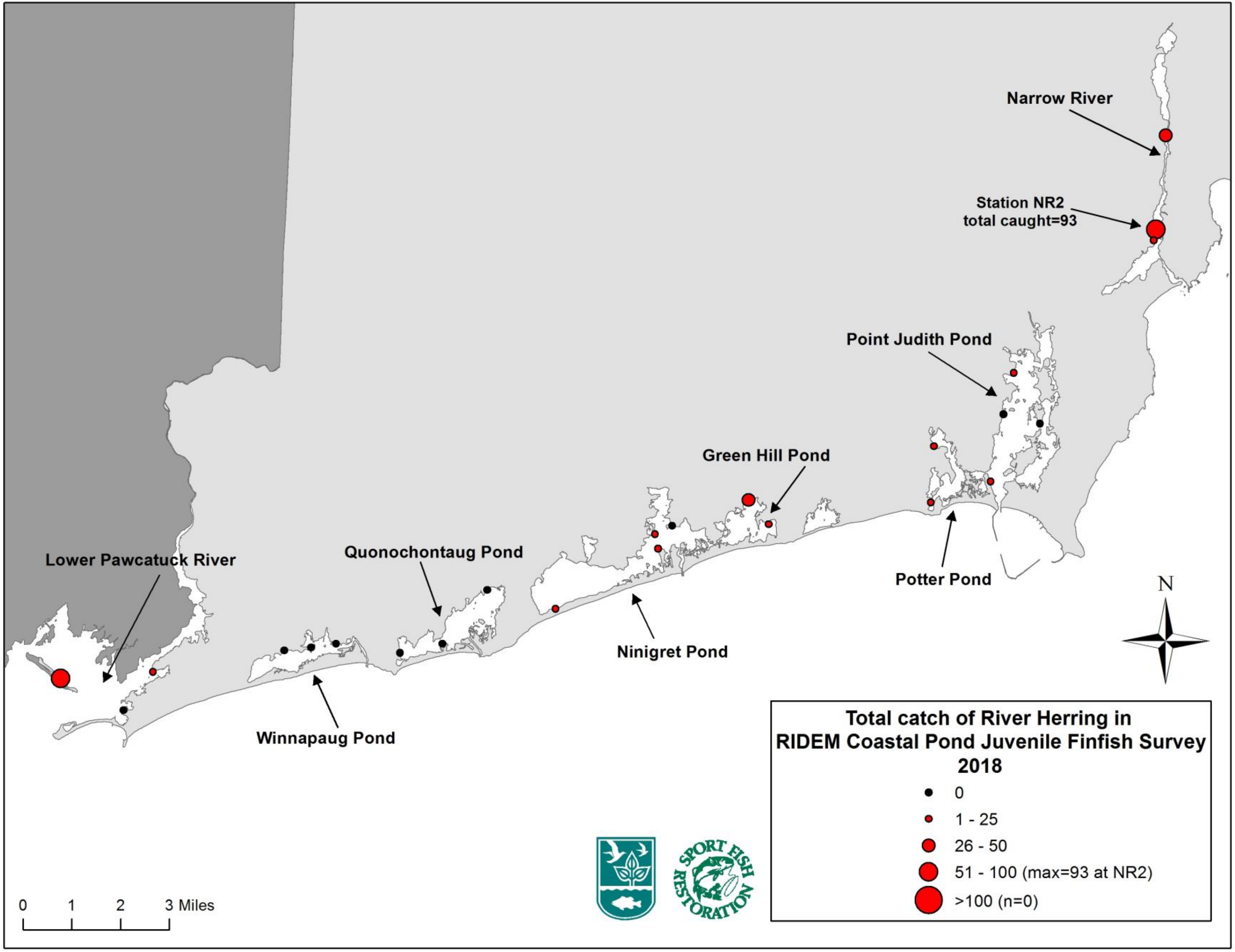
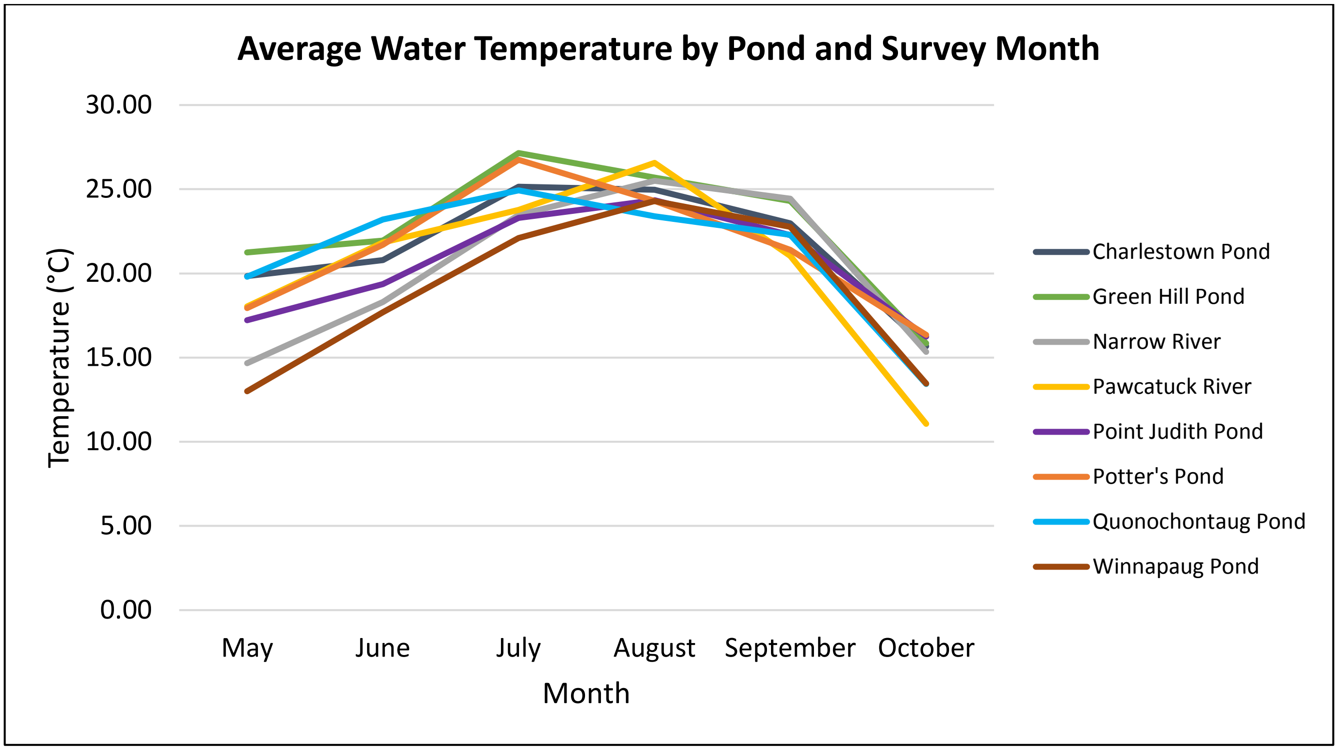


Figure 23. Average recorded water temperature in the coastal ponds by month for 2018.



Appendix 1: Catch frequency of all species by station for 2018 Coastal Pond Survey.

Species	CP1	CP2	CP3	CP4	GH1	GH2	NR1	NR2	NR3	PJ1	PJ2	PJ3	PJ4	PP1	PP2	PR1	PR2	PR3	QP1	QP2	QP3	WP1	WP2	WP3
ALEWIFE (ALOSA PSEUDOHARENGUS)		1	1	2	47	2	27	93	3			20		1	1		2	7						
ANCHOVY BAY (ANCHOA MITCHILLI)			7		1									13	1	1			9					
BAY SCALLOP (ARGOPECTEN IRRADIANS)	1		1																2					
BLUE CRAB (CALLINECTES SAPIDIUS)			1				13		1	1	1		2	1			1				1			1
BLUE CRAB FEMALE (CALINECTES SAPIDIUS)	4	4		6	1		29	48	3	6	1	2	5	5	4			5	3		2		3	7
BLUE CRAB MALE (CALINECTES SAPIDIUS)	6	14	1	18	4	1	68	45	4	12	2	4	17	14	9	1		1	6	3	2		1	20
BLUEFISH (POMATOMUS SALTATRIX)							8								1		1	1	2					
CORNETFISH BLUESPOTTED (FISTULARIA TABACARIA)			1								1													
CUNNER (TAUTOGOLABRUS ADSPERSUS)	1		7																	2	1			
EEL AMERICAN (ANGUILLA ROSTRATA)		3	10		1	1			1					3	1								1	1
FLOUNDER SMALLMOUTH (ETROPUS MICROSTOMUS)				1							3		1											18
FLOUNDER SUMMER (PARALICHTHYS DENTATUS)		1	2		1	1	2		3	2	1		7	3	1		1		1		1		1	4
FLOUNDER WINTER (PSEUDOPLEURONECTES AMERICANUS)	21	3	7	2	7	1	18	125	22	5	21	9	39	1	1	62	2	9	29	74	44	40	33	18
GOBY NAKED (GOBIOSOMA BOSC)	2				1		1			5			15	26	21			2	4		1			
GRUBBY (MYOXOCEPHALUS AENAEUS)	2		1					14	14		3	2	7			12	9	3	2	20	2	32	8	4
GUNNEL ROCK (PHOLIS GUNNELLUS)																2								
HERRING ATLANTIC (CLUPEA HARENGUS)							2	2		8					21					1		1		1
HERRING BLUEBACK (ALOSA AESTIVALIS)			1							2		4			1		89							
HORSESHOE CRAB (LIMULUS POLYPHEMUS)																			1					
HORSESHOE CRAB FEMALE (LIMULUS POLYPHEMUS)	2					1										1	1		1	1	1			
HORSESHOE CRAB MALE (LIMULUS POLYPHEMUS)	2					1		1								1					1			1
JACK CREVALLE (CARANX HIPPOS)							7								1				9					
JACKS (CARANGIDAE)		1					1														1			
KILLIFISH STRIPED (FUNDULUS MAJALIS)	76	25	282	129		2	6	299		61	60	444	27	67	60	11	96	10	102	86	49	856	15	179
KINGFISH NORTHERN (MENTICIRRHUS SAXATILIS)								2	3					1		8			1					1
LIZARDFISH INSHORE (SYNODUS FOETENS)	2							1			7		3	1		23			1	2	4	2	3	
MACKEREL ATLANTIC (SCOMBER SCOMBRUS)												1												
MANTIS SHRIMP (SQUILLA MANTIS)													2											
MENHADEN ATLANTIC (BREVOORTIA TYRANNUS)		1			1006	1		33	15382		1	1	1	1340	16	1	1	3561	177		4	3645	163	7
MINNOW SHEEPSHEAD (CYPRINODON VARIEGATUS)	5	5	26	8	4	3	9	39	1	12		40		89	119	1		1	3	5	15	28	7	35
MOJARRA SPOTFIN (EUCINOSTOMUS ARGENTEUS)							2	20														1		
MULLET WHITE (MUGIL CUREMA)				2			9	4							2									21
MUMMICHOG (FUNDULUS HETEROCLITUS)	61	196	199	3	50	25	42	201	16	420	3	3	27	80	44	3		65	24	40	6	489	248	6
NEEDLEFISH ATLANTIC (STRONGYLURA MARINA)		3	2	3							1		1		6					6				4
PERCH WHITE (MORONE AMERICANA)							61	29							1									
PERMIT (TRACHINOTUS FALCATUS)		3		1																				

Species	CP1	CP2	CP3	CP4	GH1	GH2	NR1	NR2	NR3	PJ1	PJ2	PJ3	PJ4	PP1	PP2	PR1	PR2	PR3	QP1	QP2	QP3	WP1	WP2	WP3
PIPEFISH NORTHERN (SYNGNATHUS FUSCUS)	6	5	7		4	4	1	13		1	4		5	1	19	1	5	2	5	3	3	1	2	2
PUFFER NORTHERN (SPHOEROIDES MACULATUS)							1		5		1		3			18			7	3	4		1	1
RAINWATER KILLIFISH (LUCANIA PARVA)	8	88	131	4	21	39	1		5	6	2		26	9	21			22	1			2	6	5
SCUP (STENOTOMUS CHRYSOPS)	95	111	29	1			83	2	4		2		1			14		3	29	1	2			16
SEA BASS BLACK (CENTROPRISTIS STRIATA)	67	9	40		1	1		170	196	1	22		17						3	49		2	18	9
SEAHORSE LINED (HIPPOCAMPUS ERECTUS)	1																			3				
SEAROBIN NORTHERN (PRIONOTUS CAROLINUS)			1					2								2			1				1	
SEAROBIN STRIPED (PRIONOTUS EVOLANS)	1						1	5	6		3	1	1						2	5	19		1	4
SILVERSIDE ATLANTIC (MENIDIA MENIDIA)	576	377	524	3176	143	102	234	662	254	227	146	446	275	519	223	91	407	622	635	170	218	246	237	637
SNAPPER GRAY (LUTJANUS GRISEUS)			1																					
SPOT (LEIOSTOMUS XANTHURUS)										1													1	
SQUID LONGFIN (LOLIGO PEALEI)																			45			1		
STICKLEBACK FOURSPINE (APELTES QUADRACUS)	4	157	503	2	15	76		1	9	8				22	9	3	3	25	18		4	5		15
STICKLEBACK THREESPINE (GASTEROSTEUS ACULEATUS)		1				1									2							5	1	1
TAUTOG (TAUTOGA ONITIS)	65	6	64					31	17	4	5		2	1	1	8		26	20	27	1		1	9
TOADFISH OYSTER (OPSANUS TAU)	1					3		1	1				1	9	4			4	4					3
TOMCOD ATLANTIC (MICROGADUS TOMCOD)		11	2					1	1						1	5	2	2	1			8	11	
WINDOWPANE (SCOPHTHALMUS AQUOSUS)	1							3			1													

STATE OF RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
DIVISION OF MARINE FISHERIES

and

THE RHODE ISLAND CHAPTER OF THE NATURE CONSERVANCY

COOPERATIVE AGREEMENT AWARD 3425240

2018 Performance Report – Job III, Part B

Prepared by Diandra Verbeyst
Conservation Practitioner III
The Nature Conservancy in Rhode Island

Approved by Scott Comings
Associate State Director
The Nature Conservancy in Rhode Island

Project Title: "Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters"

Project Report Period: January 1, 2018 – December 31, 2018

Approach:

"Under the cooperative agreement with The Nature Conservancy, the Department of Environmental Management, Division of Fish and Wildlife will execute a Blanket Purchase Agreement with The Nature Conservancy to provide special scientific and field survey services to the Division of Fish and Wildlife.

Under the Purchase Agreement, The Nature Conservancy will collect, analyze, and summarize beach seine survey data from Great Salt Pond and Old Harbor, Block Island. The Nature Conservancy is obligated to perform the work as part of a grant awarded to the Division of Fish and Wildlife under the federal Aid to Sportfish Restoration Program".

Schedule and Work Tasks:

"Under the cooperative agreement the work will continue for a period of four years starting in May 2015 and ending in December of 2018. The work will be organized in the following tasks".

<u>Task I. Methodology, Schedule, and Location of Sampling Stations</u>

"All methodology and sampling gear will be consistent with the current Division of Fish and Wildlife survey entitled "Young of the Year Survey of Selected Rhode Island Coastal Ponds and Embayments". The Nature Conservancy will sample a total of eight stations which will be located in Great Salt Pond and three stations which will be located in Old Harbor, Block Island. A single haul will be performed at each station with a beach seine net during daylight, with monthly frequency, from May to October. Consistent with the seine net that has been standardized and used in the current Division of Fish and

Wildlife survey, The Nature Conservancy will use a 130’ knotless heavy delta ¼ mesh, 6’ deep with a 6’/6’/6’/ bag, with a weighted footrope and floats on the head rope. The beach seine will be deployed from a 23 ft., outboard powered boat in 40 ft. radius semi-circle, leaving one end resting on the shoreline. The net will be hauled in manually from the shore where it will be emptied into a bucket of sea water. Species will be identified and total length (TL) will be measured. With the exception of winter flounder, a sub-sample of 20 individuals of each species will be measured when the catch is plentiful. The Division of Fish and Wildlife will select one of the monthly sampling dates per year to join The Nature Conservancy staff on Block Island to provide oversight and assistance to The Nature Conservancy’s sampling program, in order to ensure that the sampling techniques in Great Salt Pond and Old Harbor, Block Island, are standardized and consistent with the current Division of Fish and Wildlife survey”.

Task II. Data Analysis

“All data collected in the field will be recorded and entered into the standard spreadsheet currently in use by the Division of Fish and Wildlife. A catch frequency table of all species by station in Great Salt Pond and Old Harbor, for each year sampled, will be presented. Monthly and yearly relative abundance indices will be calculated for each species recorded and compared to the data available from previous season in the mainland coastal ponds as well as the developing time series on Block Island. Length frequency data for winter flounder will be prepared and presented. Monthly water temperature, salinity, and oxygen levels will be presented”.

Task III. Reporting

“Annual reports containing all sampling data and analysis will be submitted at the end of each sampling season. In addition to the report narrative, The Nature Conservancy will provide the Division of Fish and Wildlife with the raw sample data in Microsoft Access format. The Division of Fish and Wildlife and The Nature Conservancy will have shared use of the data and the data products. Joint authorship on peer-reviewed, non-pier reviewed, and professional presentations will be recognized”.

Assessment of Recreationally Important Finfish
Stocks in Rhode Island Coastal Waters

2018 Annual Performance Report for Job III, Part B:

Young of the Year Survey of Selected Rhode Island Coastal Ponds and Embayments

Monitoring Stocks of Juvenile Finfish in Great Salt Pond and Old Harbor, Block Island, Rhode Island

Prepared by:
Diandra Verbeyst
Conservation Practitioner III
diandra.verbeyst@tnc.org
401.466.2129

The Nature Conservancy Rhode Island Chapter
Block Island Office
352 High Street
New Shoreham, RI 02807

Federal Aid in Sportfish Restoration
F-61-R

2018 Performance Report – Job III, Part B March 2019

PERFORMANCE REPORT

STATE: Rhode Island

PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters

PERIOD COVERED: January 1, 2018 – December 31, 2018

JOB NUMBER AND TITLE: Job 3 – Young of the Year Survey of Selected Rhode Island Coastal Ponds and Embayments

STAFF: John Lake (RI DEM Division of Marine Fisheries, Supervising Biologist, Marine)
Katherine Rodrigue (RI DEM Division of Marine Fisheries, Principal Biologist)
Diandra Verbeyst (TNC RI Chapter, Conservation Practitioner III)

JOB OBJECTIVES: The goal of this project is to collect, analyze, and review beach seine survey data from Block Island's (BI) coastal salt pond, the Great Salt Pond (GSP), and Old Harbor (OH), to better understand recruitment relative to spawning stock biomass of winter flounder and other important finfish species. We obtain this goal by addressing the following objectives:

(1) Follow standardized sampling schedules and procedures as termed in the cooperative agreement to sustain time series information collected for fishery managers.

(2) Provide a comprehensive review of stock assessment data using time series juvenile indices to support best management projects targeting declining fishery resources.

SUMMARY: This report summarizes all work conducted for this project between January 1 and December 31, 2018. During this period, we focused on aspects related to the objectives mentioned above.

To address Objective 1, we continued surveying the 8 stations in the GSP and the 2 stations in OH. To address Objective 2, TNC and DEM follow the terms of reference (TORS) established at the inception of the time series to successfully complete project tasks and criteria for analyses.

In 2018, a total of 48 seines were hauled across 8 sites in GSP resulting in the identification of 42 distinct species representing 30 families (see Appendix 1 for time series catch by species). A total of 12 seines were also hauled during this time across 2 sites in OH. Investigators identified 25 distinct species representing 16 families in OH (see Appendix 7 for time series catch by species). Winter flounder, the survey's target species, were caught in the seine at all 8 stations each with varying catches and size structures. Additional species of interest identified for this survey were collected across these stations: scup, tautog, black sea bass, pollock (see Appendix 8a for additional species of interest by functional group). YSI ProDSS handheld multiparameter meter recorded point measurements for water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) per seine and station. The location for the seine sites were determined prior to sampling. The fixed stations stretch around the perimeter of the GSP and have relatively homogenous substrates and habitat features. The fixed sites in OH extend across an existing eelgrass bed within the break wall of the harbor.

TARGET DATE: March 30, 2019

STATUS OF PROJECT: On schedule.

DEVIATIONS: There were no significant deviations from the timeline projected in the current grant.

To address Objective 1 of Job III, Part B, in the context of OH, 2016 investigators eliminated station OH 3 due to issues with access and safety. Exposed marine debris and heavy boat traffic prevented investigators from successfully following protocol. We concluded the sites were not conducive for sustainable monitoring; and thereby, not included in the time series.

RECOMMENDATIONS: We recommend continued seine sampling in the GSP and OH. We also recommend continuing to work closely with RI DEM in view of our long-term commitment to monitoring fish populations, habitat, and environmental conditions in RI waters. We will be planning with our partners for how to proceed with the standardized project as defined in the cooperative agreement.

We also recommend investigating whether the current sampling method is adequately capturing the abundance of winter flounder. If not, we suggest additional sampling techniques be considered.

We also recommend continued collaboration efforts with Dr. Hannes Baumann, Marine Science Professor at the University of Connecticut. Dr. Baumann studies how fish populations are adapted to the natural variability in their environment and how they therefore react to unfolding anthropogenic changes in our oceans and coastal waters. He pursues these questions by employing a healthy mix of experimental, field, and modeling approaches with tools ranging widely from otolith microstructure and microchemistry, fish physiology, to population dynamics and evolutionary genetics.

Specific to our collaboration with Dr. Baumann's lab, the current focus is understanding local and regional adaptation and vulnerability in coastal fish. Silversides spp. are the target species for Baumann's supplemental study of the GSP. TNC investigators collect any individual with TL greater than 14cm. These individuals are recorded, preserved, and shipped to Baumann's lab at the close of the sampling season.

REMARKS: Investigators successfully sampled all stations for each sampling event from May to October. The index value time series targets young of the year (YOY) winter flounder (TL>120mm). Data does not include sizes outside of this cohort (>120mm) for consistent analyses.

Specific to the 2014 seine survey, investigators used a seine net with no pocket at the mid-point. TNC obtained a seine net with mid-point pocket in 2015. All other features of the net (mesh size, total net length and width) were the same throughout the time series. We acknowledge the difference in nets as they may be a factor in number of fishes caught in 2014 compared to number of fishes caught between 2015 and 2018.

Specific to species identification, New World Order Silversides (Atlantic and inland silversides) are classified to the family *Atherinopsidae spp*. In 2016, investigators differentiated Atlantic and inland silversides. To avoid misidentification in the field all individuals are referred to as silversides spp. The time series dataset was modified to clarify this matter.

INTRODUCTION

Stock assessments of early juvenile (age 0) fishes help fisheries managers determine status of populations and potential management actions in view of forecasting future conditions (Hayes 1983). Relative abundance estimates provide a reliable and early indicator of year-class strength (Tuckey and Fabrizio 2013). Site specific baseline information detailing the condition of habitat (e.g., water parameters, water column conditions) is required for fishery management tasks, particularly in assessing changes over time (Hart 1992).

In RI, the Division of Marine Fisheries Section prepares annual reports on conservation and management of marine fisheries resources for the General Assembly and the citizens of the State. Information collected by these projects establishes priorities for future work. This plan is vital when establishing goals and objectives of cooperative projects, especially when seeking funds in competitive grant processes.

Data presented reflect the most currently available at the time the report was written. The current report provides data collected between 2014 and 2018 in the GSP. TNC is committed to long-term monitoring in the GSP and OH to assess ecological function of this system as a critical nursey habitat. We plan to continue the standardized protocol and collaboration with RI DEM.

APPROACH

The approach for each objective is described separately below.

Objective 1 – Overview

> Follow standardized sampling schedules and procedures as termed in the cooperative agreement to sustain time series information collected for fishery managers.

The purpose and scope of this objective is to focus on the established statewide and regional approach to monitoring YOY finfish populations for stock assessments of commercially and recreationally important species. This work is conducted under the multi-year cooperative agreement with RI DEM, Division of Marine Fisheries (DMF). TNC and DMF's ability to monitor fishery resources is largely dependent upon the quality and extent of data available. Therefore, the team strictly adheres to established protocols to strengthen high quality, quantitative information collected for the time series.

Objective 2 – Overview

> Provide a comprehensive review of stock assessment data using time series juvenile indices to support best management projects targeting declining fishery resources.

To address Objective 2, TNC and DMF provide a complete review of time series indices standardized in the project. The creation of juvenile indices helps fishery managers identify year of below-average recruitment. If persistent, examined trends serve as an early warning to managers of potential declines in the species of interest standing stock biomass. The time series dataset becomes more valuable with time as it increases the knowledge base for juvenile stock assessments. This approach allows us to provide reliable information about species assemblage in our efforts to fill informational gaps encountered in fisheries science.

STUDY AREA

Great Salt Pond

The GSP is a diverse body of water in the center of BI (see inset map in Appendix 9a). It is characterized as an estuarine habitat, or coastal salt pond – a body of salt water surrounded by salt water (Hale 2000). The GSP's low flushing rate, absence of major freshwater aquifers, and relatively small size creates a diverse mix of species and physical properties (Ketchum 1983; Shumway 2008). Rain falling on upland parts of the watershed also creates a salinity gradient combined with fresh water input from inner pond locations (Harbor and Trims Pond; see site map with labels in Figure 2) (Shumway 2008).

The permanent breach way in GSP was constructed in 1895 (TNS Harbor Management Plan 2018). This change had broad-reaching effects on the ecosystem (Lee 1980; Katz 2000). The channel is dredged every two years for navigational purposes.

Total acreage of the GSP is approximately 800 acres at mean low water (MLW). Close to 50-percent of the area is less than 4m at MLW. Maximum depth in the center of the pond reaches 17m (reference NOAA chart 13205).

Old Harbor

OH is a coastal harbor on the east shore of BI (see inset map in Appendix 9b). This pelagic system comprises a matrix of submerged aquatic vegetation (SAV), sand, mud, and rocks, with depths ranging between .5m and 6m at MLW. Total acreage of OH is approximately 25 acres, breakwater to breakwater.

In 1870, the breakwaters were constructed to form the harbor (TNS Harbor Management Plan 2018). OH is a commercial ferry landing with limited anchorage space inside the west breakwater. Municipal facilities are located around the inner basin within the southeast corner of the harbor, including commercial and charter fishing slips and temporary tie-ups of transient recreational craft. The central portion of the harbor is occupied by a private company providing year-round ferry service for passengers and cargo to the mainland. The northwestern section allows limited anchorage and 10 private moorings. The channel is dredged annually for navigational purposes.

METHODS

All sites in GSP (8 stations) and OH (2 stations) were sampled at monthly intervals from May through October (see site maps for sampling locations in Figures 1-2 (GSP) and Figure 15 (OH)). At each site a 130' long, 5.5' deep, ¼ inch diamond mesh beach seine net was used for sampling. The net was also outfitted with midpoint pocket and with a weighted footrope and floated headrope to ensure efficient catches of fish. The seine net was consistent with schematics outlined in F-61-R-23, Job 3.

In GSP, the net was deployed using an outboard vessel. OH stations required investigators to haul the net without the vessel due to access limitations. One investigator was dropped onshore and held one end of the net while the boat reversed in a round haul fashion to create semicircle for swept area. Once boat was close to shore, another team member hauled the net toward the beach and met team members to tow in by hand. Species caught in net were transferred into a water-filled tote.
All collected fishes were identified to genus or species and measured to the nearest centimeter for TL.

When appropriate, species were subsampled by measuring the first 20 individuals identified. The remaining individuals were enumerated. Winter flounder were the exception: all individuals were measured to the nearest millimeter TL. All specimens were released back into the water at the collection site.

Water parameters — water temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) — were recorded per sampling site using a Professional Plus handheld YSI multiparameter meter. Water transparency and depth were also recorded at each site using a Secchi disk.

METRICS AND RATIONALE

Species of Interest

Winter flounder were defined as species of interest for the survey. The following species were targeted as species to quantify for discussion of recreationally important species: striped bass (pelagic, multi-habitat), black sea bass (pelagic, multi-habitat), winter flounder (demersal), tautog (demersal), and scup (pelagic, multi-habitat) (see Appendix 8a for additional species of interest identified by functional group).

Juvenile cutoff sizes for species of interest were defined to compare species growth parameters. The following accepted values for YOY cutoff ranges were derived from Bigelow and Schroeder (1953c). YOY winter flounder TL<120mm. YOY black sea bass TL<13cm. YOY scup TL<10cm. YOY tautog TL<12cm.

Analysis

Mean Shannon diversity and species richness were both compared by 1-way ANOVAs (Shannon Diversity ~ Site; Richness ~ Site). Diversity was calculated using the "Shannon Index" (Shannon 1948), and richness was defined as the total number species caught. Diversity and richness were calculated for each haul and the mean values per haul were determined for each site sampled during the 2018 season.

Catch per haul was calculated for each species of interest. Comparisons of catch per haul for all species caught were demonstrated though generalized models and clustered bar graphs, inputting site, month, and year. Size frequency distributions were demonstrated through histograms for YOY winter flounder. JMP software was used for statistical computing.

RESULTS

In 2018, a total of 48 seines were hauled across the fixed stations in the GSP (GSP 1-8; Table 1), and a total of 12 seines were hauled in OH (OH 1-2; Table 15). Block nets were calculated at the start of the first survey in 2014 to demonstrate enclosed ranges for swept area (Figure 3). A standard set ranged 2030-2425 ft^2. Sampling occurred in the rocky intertidal zone at depths shallower than 2m (Table 2 (GSP); Table 16 (OH)). Sampling dates were selected for tides between 1.2m and 0.6m.

Water parameters were recorded at each station during time of seine as point measurements using handheld YSI meter. Water temperature, salinity, and dissolved oxygen data points were summarized in Table 3 (GSP) and Table 17 (OH). Measurements were taken about 1m below surface water, or at midpoint of water column at given time.

In GSP, water temperature ranged from 12.7°C recorded in May, and 23.8°C recorded in July. Salinity ranged between 31.13 ppt recorded in August, and 34.61 ppt recorded in September. Dissolved oxygen ranged from 6.12 mg/L recorded in August, and 8.96 mg/L recorded in May. Figures 4-6 display data points for each parameter taken according to month and station in GSP.

In OH, water temperature ranged 12.2°C recorded in May and 23.5°C recorded in August. Salinity ranged between 31.51 ppt in May and 34.99 ppt in August. Dissolved oxygen ranged from 7.03 mg/L recorded in September and 9.23 mg/L recorded in May. Figures 16-18 summarize water parameters according to month and station in OH.

All figures and analyses only include finfish. All invertebrates were removed from list of species to focus on fish assemblage.

Great Salt Pond

20,855 finfish were identified and enumerated in 2018 (see Table 6 for catch data summary). Catch data is presented as mean catch per haul ± the standard error (SE). A total of 41 species from 20 different families were caught this season (Table 4).

Based on the mean catch per haul, the most abundant fish in descending rank order were: 1) silversides spp., 2) Atlantic menhaden, 3) striped killifish, 4) American sand lance, 5) mummichog, and 6) winter flounder. Forage fish comprised 94.98% of total catch.

Atlantic menhaden, silversides spp., tautog, and winter flounder were caught at all stations (see Table 5 for species presence and absence). 16 out of 41 species were rarely encountered and occurred at a single station. Species in this category included: American sand lance, bluespotted cornetfish, butterfish, crevalle jack, grubby, grunt spp., horse-eye jack, lined seahorse, lookdown, pigfish, pollock, rainwater killifish, sand diver, shortfin squid, striped cusk-eel, and windowpane (Table 6). See tables in Appendix 1 for comprehensive list of species presence and absence since 2014.

Results of the 1-way ANOVA testing the effect of site on species diversity was partially significant (p-value <0.1), suggesting diversity may vary by site despite a stable Shannon diversity index (1-way ANOVAs; Diversity ~ Site: p=0.573; Richness ~ Site: p=0.0867). Results of the 1-way ANOVA testing for the effect of site on species richness was not significant. Species richness was log-transformed to satisfy assumptions of the ANOVA.

On average, 434.48 ± 61.59 finfish were caught per haul. GSP 5 was the most abundant site for catch per haul with 584.67 ± 197.14 finfish while GSP 7 was the least abundant site for catch per haul with 280.83 ± 161.17 finfish (Figure 8). These results may be confounded by large abundances of silversides spp. and juvenile Atlantic menhaden at the close of the sampling season. The highest catch per haul was in September at 1065.38 ± 134.87, while the lowest was in July at 107.63 ± 40.11 (Figure 7).

Silversides were caught during each month of the 2018 survey with consecutive large catches in August through October (Table 8). A total of 14,044 individuals were measured and counted in 2018. Atlantic menhaden were caught in the seines in September (n=1,076) and October (n=1,258) for a combined total of 2,334 individuals measured and enumerated in 2018 (Table 9). Striped killifish were also caught across all stations between June and October with a total catch of 1,805 (Table 10). A total of 409 mummichogs were caught at all stations and months except for GSP 3 and 7, and May and

October, respectively (Table 11).

All five species of interest identified in this survey were caught in the GSP seines (Figure 9). Winter flounder were the most abundant species of interest caught across all seine sites at a catch per haul of 6.10 ± 1.57. Tautog were also abundant across the seine sites with a catch per haul of 3.88 ± 1.34.

Of the 293 winter flounder caught in 2018 seines, 286 were YOY. The length frequency distribution for 2018 indicated most individuals were age 0 (TL<120mm) (Figure 13). Figure 14 displays a series of histograms to depict monthly length frequencies for 2018. Year-0 individuals were measured between 30mm and 120mm. Year-1 individuals measured between 130mm and 185mm. The individuals caught in May were measured at 130mm and 159mm at stations GSP 3 and 2, respectively; further suggesting recruitment the year prior based on age at length studies for southern New England (Packer et all. 1999; Meng et al. 2000). Additional individuals caught in the size range were caught at GSP 2 and 8: two in June, one in August, and two in October. Table 14 outlines mean length per station and month for 2018.

Winter flounder were caught at all 8 stations. The most abundant site for winter flounder was GSP 5 at a catch per haul of 22.67 ± 8.91 (Figure 11). The most abundant month for winter flounder was September at a catch per haul of 11.50 ± 5.49 (Figure 10). Figure 12 illustrates mean abundance for winter flounder by station and month.

A total of 186 tautog were caught in 2018 beach seines ranging in size from 3cm to 16cm. Tautog were caught at all sites, with one occurrence at stations GSP 2, 3, and 8. Higher catches occurred at GSP 1 and 6, particularly in September. Tautog were most abundant at GSP 6 at a catch per haul of 11.17 ± 4.79. The most individuals were caught in September (n=121) at a catch per haul of 15.13 ± 6.05 (Table 12).

Old Harbor

7,284 finfish were identified and enumerated in 2018 (see Table 20 for catch data summary). Catch data is presented as mean catch per haul ± the standard error (SE). A total of 25 species of finfish representing 16 families were caught at the 2 sampling sites (Table 18).

Based on the mean catch per haul, the most abundance finfish in descending rank order were: 1) silversides spp., 2) Atlantic menhaden, 3) pollock, 4) tautog, and 5) winter flounder. Forage fish accounted for 79.08% of total catch.

Atlantic menhaden, black sea bass, pollock, scup, silversides spp., tautog, and winter flounder were caught at all stations (see Table 19 for species presence and absence). 7 out of 25 species were rarely encountered and occurred at a single station. Species in this category included: Atlantic needlefish, Atlantic tomcod, bighead sea robin, naked goby, smooth trunkfish, spotted trunkfish, and striped sea robin (Table 20).

Results of the 1-way ANOVA testing the effect of site on species diversity was not significant (p-value >0.1; Diversity ~ Site: p=0.256). Results of the 1-way ANOVA testing for the effect of site on species richness was also not significant (p-value >0.1; Richness ~ Site: p=0.437). Species richness was log-transformed to satisfy assumptions of the ANOVA.

On average, 607.00 ± 182.07 finfish were caught per haul. Catch per haul was slightly greater at OH 1, with a catch per haul 706.17 ± 307.94 while catch per haul for OH 2 was 507.83 ± 217.02 finfish (Figure 20). The highest catch per haul was in October at 1600.00 ± 194.00, while the lowest was in July at 544.50 ± 31.50 (Figure 19).

Silversides were caught during each month of the 2018 survey with consecutive large catches in September and October (Table 22). A total of 2,994 individuals were measured and counted in 2018. Atlantic menhaden were caught in the seines between August and October for a combined total of 2,334 individuals measured in enumerated in 2018 (Table 22). Pollock was also caught at both stations with most of the catches happening in May (Table 24). A total of 541 individuals were measured and counted in 2018. Black sea bass were caught only caught in August at both stations for a combined total of 148 individuals recorded in 2018 (Table 26).

Of the five species of interest in this study, four were caught in the seines: black sea bass, scup, tautog, and winter flounder (Figure 21). Tautog and winter flounder were the most abundant species of interest across OH sites at a catch per haul of 24.58 ± 11.03 and 18.25 ± 5.10, respectively. Black sea bass and scup were caught at a catch per haul of 12.33 ± 12.06 and 8.08 ± 5.48, respectively.

Of the total 219 winter flounder caught in 2018 seines, 216 were YOY. The length frequency distribution for 2018 indicated most individuals were age 0 (TL<120mm) (Figure 25). Length frequency distribution for YOY caught at OH 1 is demonstrated in Figure 26 while length frequency distribution for YOY caught at OH 2 is shown in Figure 27. Figure 28 displays a series of histograms to depict length frequencies of winter flounder according to month. Year-0 individuals were measured between 25mm and 120mm. Year-1 individuals measured 121mm, 123mm, and 131mm, and were caught in September and October, suggesting recruitment from the year prior based on previous age at length studies (Berry et al. 1965; Pentilla et al. 1989). Table 27 outlines mean length per station and month for 2018.

Winter flounder were caught at both stations. Catch frequencies were consistent between sites. OH 1 was slightly more abundant than OH 2 at a catch per haul of 20.00 ± 7.12 (Table 21; Figure 23). The most abundant month for winter flounder was August at a catch per haul of 42.50 ± 5.50 (Figure 22). Figure 24 demonstrates mean abundance per month and station to suggest YOY preference for eelgrass habitat found at OH 1.

A total of 295 tautog were caught in 2018 beach seines ranging in size from 1cm to 17cm. Tautog were caught at both OH stations. Tautog were most abundant at OH 1 at a catch per haul of 34.67 ± 19.24 (Figure 21). The most abundant individuals were caught in August, totaling 113 individuals with much of the catch occurring at OH 1 at a catch per haul of 56.50 ± 54.50 (Table 25).

DISCUSSION

The Shannon diversity showed partial diversity amongst sites. Mean finfish abundance varied across sites and sampling months. GSP and OH data may be confounded by large abundances of Atlantic menhaden caught at all stations in September and October (Table 9 for GSP; Table 23 for OH). Since this species is not a species of interest, we suggest the discussion of whether to omit Atlantic menhaden for future abundance and diversity analyses.

Though all five species of interest were caught in both the GSP and OH (except for striped bass in OH) in 2018, catch numbers were minimal. Investigators should determine whether the beach seine efficiently captures YOY populations of the target species. Additional sampling methods and gear types should be considered to better sample these species.

All sites in GSP and OH supported presence of winter flounder. Abundance varied by site. In GSP, winter flounder were predominately caught in August and September at GSP 5. In OH, winter flounder were most abundant in August at OH 1. Habitat preferences for juvenile winter flounder may vary according to waterbody features and local conditions (Bigelow and Schroeder 2002). YOY populations found within southern New England estuaries are generally associated with sand and mud matrices (Neumann 1993; Howell et al. 1999). Stations GSP 5 and OH 1 represent these habitat conditions. While these sites provide qualitative reasoning to help explain some disparity across sampling sites, additional benthic monitoring is recommended. To make better distinctions between presence of year 0-1 individuals and habitat types, it may also be beneficial for investigators to establish categorical parameters to describe the habitat setting to complement data collected per site and survey area. Future analysis is expected to combine water quality, benthic substrate, and fish assemblage to explicate variability in species of interest abundances.

CONCLUSION

In 2018, TNC and DMF successfully completed field and analytical work related to Objectives 1 and 2. This information is a critical characteristic of the juvenile indices used for stock assessments. Relative to years prior, the team completed all seine work and made substantial gains with other monitoring surveys related to fisheries science. TNC and DMF will continue to improve data collection and engage in planning processes to asses fishery resources in RI waters.

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TABLES, GREAT SALT POND

Table 1. Summary of sampling effort for GSP survey, 2018.

Sampling dates	Number of sets
29-May	8
13-June	8
12-July	8
10-August	8
10-September	8
9-October	8
Total	**48**

Table 2. Water depth and transparency ranges, 2018.

Depth of area seined	
Maximum	2 meters
Minimum	0.3 meters
Average and (1 standard deviation)	1.04 (0.43) meters

Depth of water transparency (Secchi disc)	
Maximum	2 meters
Minimum	0.3 meters
Average and (1 standard deviation)	1.04 (0.43) meters

Table 3. Summary of water quality parameters recorded during 2018 sampling season.

2018 YSI Data									
Station	Month	Temp. (°C)	Sal. (ppt)	DO (mg/L)	Station	Month	Temp. (°C)	Sal. (ppt)	DO (mg/L)
GSP 1	May	14.7	32.17	8.60	GSP 5	May	13.2	32.17	8.39
	Jun	16.2	32.31	7.96		Jun	15.3	32.55	8.86
	Jul	22.7	33.58	6.85		Jul	21.8	33.58	6.79
	Aug	22.2	33.97	6.62		Aug	22.4	33.99	6.39
	Sep	23.5	34.35	6.99		Sep	22.9	33.97	7.81
	Oct	19.2	32.72	7.05		Oct	19.9	32.61	7.60
GSP 2	May	13.9	31.89	8.49	GSP 6	May	13.4	32.02	8.27
	Jun	15.8	32.29	7.88		Jun	15.3	32.37	8.87
	Jul	22.6	33.46	7.42		Jul	22.2	33.85	6.74
	Aug	23.2	34.02	6.99		Aug	22.6	33.12	6.83
	Sep	23.6	34.20	6.90		Sep	23.0	34.20	7.34
	Oct	19.5	32.88	7.29		Oct	19.2	32.72	7.05
GSP 3	May	12.7	32.12	8.89	GSP 7	May	13.9	32.14	8.96
	Jun	15.7	32.35	8.85		Jun	15.4	32.61	8.95
	Jul	22.5	33.61	6.71		Jul	22.5	33.52	6.15
	Aug	22.8	34.24	6.98		Aug	22.6	33.26	6.12
	Sep	23.3	34.50	7.05		Sep	23.1	34.61	7.28
	Oct	19.1	33.44	7.13		Oct	19.7	32.53	7.83
GSP 4	May	13.1	32.25	8.10	GSP 8	May	15.8	31.79	8.94
	Jun	15.2	32.37	8.42		Jun	15.6	32.43	8.12
	Jul	22.7	33.69	7.23		Jul	23.8	31.64	7.57
	Aug	22.7	34.12	6.87		Aug	22.4	31.13	6.18
	Sep	23.2	34.51	7.14		Sep	23.3	33.11	7.92
	Oct	19.8	33.61	7.85		Oct	20.1	32.27	6.64

Table 4. Catalogue of species, 2018. Bolded names were identified as Rhode Island Species of Greatest Conservation Need (SGCN) in 2015 Wildlife Action Plan (RI Team Taxa 2014).

2018		
Common Name	Scientific Name	Family
American Sand Lance	***Ammodytes americanus***	**Ammodytidae**
Atlantic Herring	***Clupea harengus***	**Clupeidae**
Atlantic Menhaden	***Brevoortia tyrannus***	**Clupeidae**
Atlantic Needlefish	*Strongylura marina*	Belonidae
Black Sea Bass	***Centropristis striata***	**Serranidae**
Bluespotted Cornetfish	*Fistularia tabacaria*	Fistulariidae
Butterfish	***Peprilus triacanthus***	**Stromateidae**
Chain Pipefish	*Syngnathus louisianae*	Syngnathidae
Crevalle Jack	*Caranx hippos*	Carangidae
Cunner	*Tautogolabrus adspersus*	Labridae
Grubby	***Myoxocephalus aenaeus***	**Cottidae**
Grunt spp.	*Haemulon spp.*	Haemulidae
Horse-eye Jack	*Caranx latus*	Carangidae
Lined Seahorse	***Hippocampus erectus***	**Syngnathidae**
Longfin Squid	*Loligo pealeii*	Loliginidae
Lookdown	*Selene vomer*	Carangidae
Mummichog	***Fundulus heteroclitus***	**Cyprinodontidae**
Naked Goby	*Gobiosoma bosc*	Gobiidae
Ninespine Stickleback	***Pungitius pungitius***	**Gasterosteidae**
Northern Pipefish	*Syngnathus fuscus*	Syngnathidae
Northern Puffer	*Sphoeroides maculatus*	Tetraodontidae
Northern Sea Robin	***Prionotus carolinus***	**Triglidae**
Northern Sennet	*Sphyraena borealis*	Shyraenidae
Oyster Toadfish	***Opsansus tau***	**Batrachoididae**
Pigfish	*Orthopristis chrysoptera*	Haemulidae
Pinfish	*Lagodon rhomboides*	Sparidae
Pollock	***Pollachius virens***	**Gadidae**
Rainwater Killifish	***Lacania parva***	**Cyprinodontidae**
Sand Diver	*Synodus intermedius*	Synodontidae
Scup	*Stenotomus chrysops*	Sparidae
Sheepshead Minnow	***Cyprinodon variegatus***	**Cyprinodontidae**
Shortfin Squid	*Illex illecebrosus*	Ommastrephidae
Silversides spp.	***Atherinopsidae spp.***	**Atherinopsidae**
Snakefish	*Trachinocephalus myops*	Synodontidae
Striped Bass	*Morone saxatilis*	Moronidae
Striped Cusk-eel	*Ophidion marginatum*	Ophidiidae
Striped Killifish	***Fundulus majalis***	**Cyprinodontidae**
Summer Flounder	*Paralichthys dentatus*	Paralichthyidae
Tautog	***Tautoga onitis***	**Labridae**
Windowpane	***Scophthalmus aquosus***	**Scophthalmidae**
Winter Flounder	***Pseudopleuronectes americanus***	**Pleuronectidae**

Table 5. Summary of species presence/absence for 2018. “1” represents present and blank slots represent absent.

2018		Station							
Common Name	Scientific Name	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8
American Sand Lance	***Ammodytes americanus***					1			
Atlantic Herring	***Clupea harengus***	1							1
Atlantic Menhaden	***Brevoortia tyrannus***	1	1	1	1	1	1	1	1
Atlantic Needlefish	*Strongylura marina*		1						
Black Sea Bass	***Centropristis striata***		1	1	1	1	1	1	
Bluespotted Cornetfish	*Fistularia tabacaria*						1		
Butterfish	***Peprilus triacanthus***					1			
Chain Pipefish	*Syngnathus louisianae*			1			1		
Crevalle Jack	*Caranx hippos*			1					
Cunner	*Tautogolabrus adspersus*	1					1	1	1
Grubby	***Myoxocephalus aenaeus***							1	
Grunt spp.	*Haemulon spp.*						1		
Horse-eye Jack	*Caranx latus*			1					
Lined Seahorse	***Hippocampus erectus***			1					
Longfin Squid	*Loligo pealeii*					1	1	1	
Lookdown	*Selene vomer*		1						
Mummichog	***Fundulus heteroclitus***	1	1		1	1	1	1	
Naked Goby	*Gobiosoma bosc*							1	1
Ninespine Stickleback	***Pungitius pungitius***							1	1
Northern Pipefish	*Syngnathus fuscus*	1	1		1		1	1	
Northern Puffer	*Sphoeroides maculatus*		1				1		
Northern Sea Robin	***Prionotus carolinus***						1	1	
Northern Sennet	*Sphyraena borealis*				1	1			
Oyster Toadfish	***Opsansus tau***								1
Pigfish	*Orthopristis chrysoptera*			1					
Pinfish	*Lagodon rhomboides*	1			1		1		1
Pollock	***Pollachius virens***			1					
Rainwater Killifish	***Lacania parva***		1						
Sand Diver	*Synodus intermedius*				1				
Scup	*Stenotomus chrysops*	1			1		1		
Sheepshead Minnow	***Cyprinodon variegatus***	1	1						
Shortfin Squid	*Illex illecebrosus*						1		
Silversides spp.	***Atherinopsidae spp.***	1	1	1	1	1	1	1	1
Snakefish	*Trachinocephalus myops*		1				1		1
Striped Bass	*Morone saxatilis*					1			1
Striped Cusk-eel	*Ophidion marginatum*								1
Striped Killifish	***Fundulus majalis***	1	1	1	1	1	1	1	1
Summer Flounder	*Paralichthys dentatus*						1		
Tautog	***Tautoga onitis***	1	1	1	1	1	1	1	1
Windowpane	***Scophthalmus aquosus***						1		
Winter Flounder	***Pseudopleuronectes americanus***	1	1	1	1	1	1	1	1

Table 6. Breakdown of species measured and enumerated according to station, 2018. Total fish and number of different species identified per station is included in the summary table.

2018		Station								
Common Name	Scientific Name	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	Total
American Sand Lance	***Ammodytes americanus***					1200				1200
Atlantic Herring	***Clupea harengus***	5							7	12
Atlantic Menhaden	***Brevoortia tyrannus***	541	198	92	270	14	242	241	736	2334
Atlantic Needlefish	*Strongylura marina*		2							2
Black Sea Bass	***Centropristis striata***		1	1	26	11	42	35		116
Bluespotted Cornetfish	*Fistularia tabacaria*						1			1
Butterfish	***Peprilus triacanthus***					1				1
Chain Pipefish	*Syngnathus louisianae*			1			2			3
Crevalle Jack	*Caranx hippos*			2						2
Cunner	*Tautogolabrus adspersus*	2					2	2	2	8
Grubby	***Myoxocephalus aenaeus***							3		3
Grunt spp.	*Haemulon spp.*						3			3
Horse-eye Jack	*Caranx latus*			1						1
Lined Seahorse	***Hippocampus erectus***			1						1
Longfin Squid	*Loligo pealeii*					1	2	1		4
Lookdown	*Selene vomer*		1							1
Mummichog	***Fundulus heteroclitus***	3	13		146	51	164	32		409
Naked Goby	*Gobiosoma bosc*							10	3	13
Ninespine Stickleback	***Pungitius pungitius***							1	1	2
Northern Pipefish	*Syngnathus fuscus*	3	5		9		2	1		20
Northern Puffer	*Sphoeroides maculatus*		2				17			19
Northern Sea Robin	***Prionotus carolinus***						1	2		3
Northern Sennet	*Sphyraena borealis*				147	10				157
Oyster Toadfish	***Opsansus tau***								23	23
Pigfish	*Orthopristis chrysoptera*			1						1
Pinfish	*Lagodon rhomboides*	4			1		1		1	7
Pollock	***Pollachius virens***			2						2
Rainwater Killifish	***Lacania parva***		5							5
Sand Diver	*Synodus intermedius*				1					1
Scup	*Stenotomus chrysops*	16			4		88			108
Sheepshead Minnow	***Cyprinodon variegatus***	33	16							49
Shortfin Squid	*Illex illecebrosus*						1			1
Silversides spp.	***Atherinopsidae spp.***	1791	2640	1663	1328	1705	1613	1148	2156	14044
Snakefish	*Trachinocephalus myops*		3				5		1	9
Striped Bass	*Morone saxatilis*					1			2	3
Striped Cusk-eel	*Ophidion marginatum*								1	1
Striped Killifish	***Fundulus majalis***	61	208	28	415	366	122	167	438	1805
Summer Flounder	*Paralichthys dentatus*						1			1
Tautog	***Tautoga onitis***	44	1	1	11	23	67	38	1	186
Windowpane	***Scophthalmus aquosus***						1			1
Winter Flounder	***Pseudopleuronectes americanus***	11	82	3	11	125	42	4	15	293
	Total fish per station	2514	3177	1796	2369	3508	2419	1685	3387	**Total Fish**
	Number of species	12	14	12	12	12	21	14	14	**20855**

Table 7. Winter flounder frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
Winter Flounder	GSP 1	2	0	0	0	7	0	9	1.50	1.15	2.81
	GSP 2	1	15	18	13	13	14	74	12.33	2.39	5.85
	GSP 3	1	0	0	1	0	0	2	0.33	0.21	0.52
	GSP 4	0	1	1	1	8	0	11	1.83	1.25	3.06
	GSP 5	1	3	18	51	48	15	136	22.67	8.91	21.82
	GSP 6	0	0	1	17	12	12	42	7.00	3.08	7.54
	GSP 7	0	0	2	0	0	2	4	0.67	0.42	1.03
	GSP 8	0	0	2	5	4	4	15	2.50	0.89	2.17
	Total	5	19	42	88	92	47				
	Mean	0.63	2.38	5.25	11.00	11.50	5.88		**Total Fish**		
	SE±	0.26	1.84	2.80	6.15	5.49	2.35		**293**		
	SD	0.74	5.21	7.91	17.39	15.53	6.64				

Table 8. Silversides spp. frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
Silversides spp.	GSP 1	150	207	125	360	667	282	1791	298.50	81.73	200.19
	GSP 2	174	377	348	512	598	631	2640	440.00	70.67	173.10
	GSP 3	65	22	32	124	552	868	1663	277.17	143.56	351.66
	GSP 4	32	0	0	356	778	162	1328	221.33	124.55	305.08
	GSP 5	128	111	214	275	457	520	1705	284.17	69.49	170.22
	GSP 6	27	0	5	114	1336	131	1613	268.83	214.65	525.77
	GSP 7	203	0	35	212	616	82	1148	191.33	92.00	225.35
	GSP 8	645	105	43	164	902	297	2156	359.33	139.39	341.43
	Total	1424	822	802	2117	5906	2973				
	Mean	178.00	102.75	100.25	264.63	738.25	371.63		**Total Fish**		
	SE±	70.57	47.12	43.56	48.94	98.12	97.74		**14044**		
	SD	199.61	133.28	123.20	138.41	277.54	276.46				

Table 9. Atlantic menhaden frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
Atlantic Menhaden	GSP 1	0	0	0	0	199	342	541	90.17	59.94	146.82
	GSP 2	0	0	0	0	0	198	198	33.00	33.00	80.83
	GSP 3	0	0	0	0	82	10	92	15.33	13.43	32.90
	GSP 4	0	0	0	0	13	257	270	45.00	42.45	103.99
	GSP 5	0	0	0	0	0	14	14	2.33	2.33	5.72
	GSP 6	0	0	0	0	242	0	242	40.33	40.33	98.80
	GSP 7	0	0	0	0	214	27	241	40.17	35.05	85.84
	GSP 8	0	0	0	0	326	410	736	122.67	78.34	191.88
	Total	0	0	0	0	1076	1258				
	Mean	0.00	0.00	0.00	0.00	134.50	157.25		**Total Fish**		
	SE±	0.00	0.00	0.00	0.00	44.80	58.79		**2334**		
	SD	0.00	0.00	0.00	0.00	126.72	166.27				

Table 10. Striped killifish frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	Total	Mean	SE±	SD
Striped Killifish	GSP 1	0	0	0	0	0	61	61	10.17	10.17	24.90
	GSP 2	0	8	16	20	118	46	208	34.67	17.84	43.70
	GSP 3	0	0	0	0	0	28	28	4.67	4.67	11.43
	GSP 4	0	0	0	288	103	24	415	69.17	46.70	114.39
	GSP 5	0	0	0	275	91	0	366	61.00	45.31	110.98
	GSP 6	0	0	0	122	0	0	122	20.33	20.33	49.81
	GSP 7	0	0	0	0	167	0	167	27.83	27.83	68.18
	GSP 8	0	0	1	156	248	33	438	73.00	42.80	104.84
	Total	0	8	17	861	727	192				
	Mean	0.00	1.00	2.13	107.63	90.88	24.00		**Total Fish**		
	SE±	0.00	1.00	1.99	43.41	31.66	8.10		**1805**		
	SD	0.00	2.83	5.62	122.78	89.56	22.92				

Table 11. Mummichog frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	Total	Mean	SE±	SD
Mummichog	GSP 1	0	0	0	0	3	0	3	0.50	0.50	1.22
	GSP 2	0	9	4	0	0	0	13	2.17	1.51	3.71
	GSP 3	0	0	0	0	0	0	0	0.00	0.00	0.00
	GSP 4	0	0	1	145	0	0	146	24.33	24.13	59.12
	GSP 5	0	0	0	1	50	0	51	8.50	8.30	20.33
	GSP 6	0	0	0	160	4	0	164	27.33	26.54	65.01
	GSP 7	0	0	0	0	32	0	32	5.33	5.33	13.06
	GSP 8	0	0	0	0	0	0	0	0.00	0.00	0.00
	Total	0	9	5	306	89	0				
	Mean	0.00	1.13	0.63	38.25	11.13	0.00		**Total Fish**		
	SE±	0.00	1.13	0.50	24.97	6.76	0.00		**409**		
	SD	0.00	3.18	1.41	70.63	19.12	0.00				

Table 12. Tautog frequency by month and station, 2018.

	2018	Month									
	Station	May	Jun	Jul	Aug	Sep	Oct	Total	Mean	SE±	SD
Tautog	GSP 1	0	0	0	0	44	0	44	7.33	7.33	17.96
	GSP 2	0	0	0	0	1	0	1	0.17	0.17	0.41
	GSP 3	0	0	0	1	0	0	1	0.17	0.17	0.41
	GSP 4	0	0	0	0	11	0	11	1.83	1.83	4.49
	GSP 5	0	0	2	15	4	2	23	3.83	2.32	5.67
	GSP 6	0	0	4	18	29	16	67	11.17	4.79	11.74
	GSP 7	0	0	1	6	31	0	38	6.33	5.02	12.31
	GSP 8	0	0	0	0	1	0	1	0.17	0.17	0.41
	Total	0	0	7	40	121	18				
	Mean	0.00	0.00	0.88	5.00	15.13	2.25		**Total Fish**		
	SE±	0.00	0.00	0.52	2.63	6.05	1.98		**186**		
	SD	0.00	0.00	1.46	7.43	17.10	5.60				

Table 13. Black sea bass frequency by month and station, 2018.

Black Sea Bass

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
GSP 1	0	0	0	0	0	0	0	0.00	0.00	0.00
GSP 2	0	0	0	1	0	0	1	0.17	0.17	0.41
GSP 3	0	0	0	1	0	0	1	0.17	0.17	0.41
GSP 4	0	0	0	26	0	0	26	4.33	4.33	10.61
GSP 5	0	0	0	11	0	0	11	1.83	1.83	4.49
GSP 6	0	0	0	7	23	12	42	7.00	3.78	9.25
GSP 7	0	0	0	19	16	0	35	5.83	3.71	9.09
GSP 8	0	0	0	0	0	0	0	0.00	0.00	0.00
Total	0	0	0	65	39	12				
Mean	0.00	0.00	0.00	8.13	4.88	1.50				
SE±	0.00	0.00	0.00	3.49	3.26	1.50				
SD	0.00	0.00	0.00	9.86	9.22	4.24				

Total Fish

116

Table 14. Winter flounder mean length (mm) per station and month, 2018.

Winter Flounder

2018	May	Jun	Jul	Aug	Sep	Oct
GSP 1	100.00	0.00	0.00	0.00	78.50	0.00
GSP 2	159.00	62.07	57.22	65.77	78.92	63.95
GSP 3	130.00	0.00	0.00	51.00	0.00	0.00
GSP 4	0.00	114.00	46.00	66.00	71.63	0.00
GSP 5	112.00	51.67	54.67	82.51	84.42	69.93
GSP 6	0.00	0.00	55.00	67.06	68.58	55.42
GSP 7	0.00	0.00	58.00	0.00	0.00	58.00
GSP 8	0.00	0.00	84.00	98.80	102.00	116.00

TABLES, OLD HARBOR

Table 15. Summary of sampling effort for OH survey, 2018.

Sampling dates	Number of sets
30-May	2
28-June	2
27-July	2
30-August	2
24-September	2
25-October	2
Total	**12**

Table 16. Water depth and transparency ranges, 2018.

Depth of area seined	
Maximum	2.43 meters
Minimum	0.26 meters
Average and (1 standard deviation)	1.19 (0.54) meters

Depth of water transparency (Secchi disc)	
Maximum	2.43 meters
Minimum	0.26 meters
Average and (1 standard deviation)	1.19 (0.54) meters

Table 17. Summary of water quality parameters recorded during 2018 sampling season.

2018 YSI Data				
Station	Month	Temp. (°C)	Sal. (ppt)	DO (mg/L)
OH 1	May	12.2	31.51	9.23
	Jun	17.1	32.89	8.63
	Jul	22.1	34.92	7.15
	Aug	23.2	34.99	7.25
	Sep	21.2	34.01	7.03
	Oct	17.1	33.66	8.99
OH 2	May	12.2	32.24	9.13
	Jun	17.1	32.89	8.63
	Jul	22.1	34.92	7.15
	Aug	23.5	34.99	7.87
	Sep	21.2	34.01	7.03
	Oct	17.2	33.72	9.02

Table 18. Catalogue of species, 2018. Bolded names are classified as RI SGCN (RI Team Taxa 2014).

2018		
Common Name	Scientific Name	Family
Alewife	***Alosa pseudoharengus***	**Clupeidae**
Atlantic Cod	***Gadus moruha***	**Gadidae**
Atlantic Menhaden	***Brevoortia tyrannus***	**Clupeidae**
Atlantic Needlefish	*Strongylura marina*	Belonidae
Atlantic Tomcod	***Microgadus tomcod***	**Gadidae**
Bighead Sea Robin	*Prionotus tribulus*	Triglidae
Black Sea Bass	***Centropristis striata***	**Serranidae**
Bluefish	***Pomatomus saltatrix***	**Pomatomidae**
Buffalo Trunkfish	*Lactophrys trigonus*	Ostraciidae
Cunner	*Tautogolabrus adspersus*	Labridae
Grubby	***Myoxocephalus aenaeus***	**Cottidae**
Naked Goby	*Gobiosoma bosc*	Gobiidae
Northern Pipefish	*Syngnathus fuscus*	Syngnathidae
Northern Puffer	*Sphoeroides maculatus*	Tetraodontidae
Northern Sea Robin	***Prionotus carolinus***	**Triglidae**
Pinfish	*Lagodon rhomboides*	Sparidae
Pollock	***Pollachius virens***	**Gadidae**
Scup	*Stenotomus chrysops*	Sparidae
Silversides spp.	***Atherinopsidae spp.***	**Atherinopsidae**
Smooth Trunkfish	*Lactophrys triqueter*	Ostraciidae
Spotted Trunkfish	*Rhinesomus triqueter*	Ostraciidae
Striped Killifish	***Fundulus majalis***	**Cyprinodontidae**
Striped Sea Robin	*Prionotus evolans*	Triglidae
Tautog	***Tautoga onitis***	**Labridae**
Winter Flounder	***Pseudopleuronectes americanus***	**Pleuronectidae**

Table 19. Summary of species presence/absence for 2018. "1" represents present and blank slots represent absent.

2018		Stations	
Common Name	Scientific Name	OH 1	OH 2
Alewife	***Alosa pseudoharengus***	1	
Atlantic Cod	***Gadus moruha***	1	1
Atlantic Menhaden	***Brevoortia tyrannus***	1	1
Atlantic Needlefish	*Strongylura marina*		1
Atlantic Tomcod	***Microgadus tomcod***	1	
Bighead Sea Robin	*Prionotus tribulus*		1
Black Sea Bass	***Centropristis striata***	1	1
Bluefish	***Pomatomus saltatrix***	1	
Buffalo Trunkfish	*Lactophrys trigonus*	1	1
Cunner	*Tautogolabrus adspersus*	1	
Grubby	***Myoxocephalus aenaeus***	1	1
Naked Goby	*Gobiosoma bosc*	1	
Northern Pipefish	*Syngnathus fuscus*	1	1
Northern Puffer	*Sphoeroides maculatus*	1	1
Northern Sea Robin	***Prionotus carolinus***	1	1
Pinfish	*Lagodon rhomboides*	1	
Pollock	***Pollachius virens***	1	1
Scup	*Stenotomus chrysops*	1	1
Silversides spp.	***Atherinopsidae spp.***	1	1
Smooth Trunkfish	*Lactophrys triqueter*	1	
Spotted Trunkfish	*Rhinesomus triqueter*	1	
Striped Killifish	***Fundulus majalis***	1	1
Striped Sea Robin	*Prionotus evolans*		1
Tautog	***Tautoga onitis***	1	1
Winter Flounder	***Pseudopleuronectes americanus***	1	1

Table 20. Breakdown of species measured and enumerated according to stations, 2018. Total fish and number of different species identified per station is included in the summary table.

2018		Stations		
Common Name	Scientific Name	OH 1	OH 2	Total
Alewife	***Alosa pseudoharengus***	165		165
Atlantic Cod	***Gadus moruha***	24	9	33
Atlantic Menhaden	***Brevoortia tyrannus***	1743	819	2562
Atlantic Needlefish	*Strongylura marina*		2	2
Atlantic Tomcod	***Microgadus tomcod***	2		2
Bighead Sea Robin	*Prionotus tribulus*		1	1
Black Sea Bass	***Centropristis striata***	145	3	148
Bluefish	***Pomatomus saltatrix***	6		6
Buffalo Trunkfish	*Lactophrys trigonus*	3	1	4
Cunner	*Tautogolabrus adspersus*	72		72
Grubby	***Myoxocephalus aenaeus***	25	11	36
Naked Goby	*Gobiosoma bosc*	2		2
Northern Pipefish	*Syngnathus fuscus*	23	11	34
Northern Puffer	*Sphoeroides maculatus*	7	8	15
Northern Sea Robin	***Prionotus carolinus***	5	2	7
Pinfish	*Lagodon rhomboides*	7		7
Pollock	***Pollachius virens***	340	201	541
Scup	*Stenotomus chrysops*	72	25	97
Silversides spp.	***Atherinopsidae spp.***	1246	1748	2994
Smooth Trunkfish	*Lactophrys triqueter*	1		1
Spotted Trunkfish	*Rhinesomus triqueter*	1		1
Striped Killifish	***Fundulus majalis***	20	19	39
Striped Sea Robin	*Prionotus evolans*		1	1
Tautog	***Tautoga onitis***	208	87	295
Winter Flounder	***Pseudopleuronectes americanus***	120	99	219
	Total	4237	3047	**Total Fish**
	Number of species	22	17	**7284**

Table 21. Winter flounder frequency by month and station, 2018.

Winter Flounder

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	7	2	4	37	39	31	120	20.00	7.12	17.44
OH 2	1	32	13	48	3	2	99	16.50	7.91	19.38
Total	8	34	17	85	42	33				
Mean	4.00	17.00	8.50	42.50	21.00	16.50		**Total Fish**		
SE±	3.00	15.00	4.50	5.50	18.00	14.50		**219**		
SD	4.24	21.21	6.36	7.78	25.46	20.51				

Table 22. Silversides spp. frequency by month and station, 2018.

Silversides spp.

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	0	7	5	61	539	634	1246	207.67	120.76	295.81
OH 2	0	12	22	390	481	843	1748	291.33	139.70	342.20
Total	0	19	27	451	1020	1477				
Mean	0.00	9.50	13.50	225.50	510.00	738.50		**Total Fish**		
SE±	0.00	2.50	8.50	164.50	29.00	104.50		**2994**		
SD	0.00	3.54	12.02	232.64	41.01	147.79				

Table 23. Atlantic menhaden frequency by month and station, 2018.

Atlantic Menhaden

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	0	0	0	0	718	1025	1743	290.50	187.95	460.39
OH 2	0	0	0	59	279	481	819	136.50	81.83	200.44
Total	0	0	0	59	997	1506				
Mean	0.00	0.00	0.00	29.50	498.50	753.00		**Total Fish**		
SE±	0.00	0.00	0.00	29.50	219.50	272.00		**2562**		
SD	0.00	0.00	0.00	41.72	310.42	384.67				

Table 24. Pollock frequency by month and station, 2018.

Pollock

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	254	9	1	0	0	76	340	56.67	41.27	101.10
OH 2	196	0	0	0	5	0	201	33.50	32.51	79.63
Total	450	9	1	0	5	76				
Mean	225.00	4.50	0.50	0.00	2.50	38.00		**Total Fish**		
SE±	29.00	4.50	0.50	0.00	2.50	38.00		**541**		
SD	41.01	6.36	0.71	0.00	3.54	53.74				

Table 25. Tautog frequency by month and station, 2018.

Tautog

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	0	3	75	111	0	19	208	34.67	19.24	47.13
OH 2	0	0	1	2	15	69	87	14.50	11.15	27.31
Total	0	3	76	113	15	88				
Mean	0.00	1.50	38.00	56.50	7.50	44.00		**Total Fish**		
SE±	0.00	1.50	37.00	54.50	7.50	25.00		**295**		
SD	0.00	2.12	52.33	77.07	10.61	35.36				

Table 26. Black sea bass frequency by month and station, 2018.

Black Sea Bass

2018	Month									
Station	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**	**SE±**	**SD**
OH 1	0	0	0	145	0	0	145	24.17	24.17	59.20
OH 2	0	0	0	3	0	0	3	0.50	0.50	1.22
Total	0	0	0	148	0	0				
Mean	0.00	0.00	0.00	74.00	0.00	0.00		**Total Fish**		
SE±	0.00	0.00	0.00	71.00	0.00	0.00		**148**		
SD	0.00	0.00	0.00	100.41	0.00	0.00				

Table 27. Winter flounder mean length (mm) per station and month, 2018.

Winter Flounder

2018	May	Jun	Jul	Aug	Sep	Oct
OH 1	67.57	29.00	51.40	77.19	78.10	68.52
OH 2	36.00	37.47	49.62	73.71	101.00	113.50

FIGURES, GREAT SALT POND

Study Area

Figure 1. Map extent to show sampling site locations in the GSP and OH. Green dots represent stations GSP 1-8. Red dots represent OH 1-2 (ArcGIS Pro 2018).

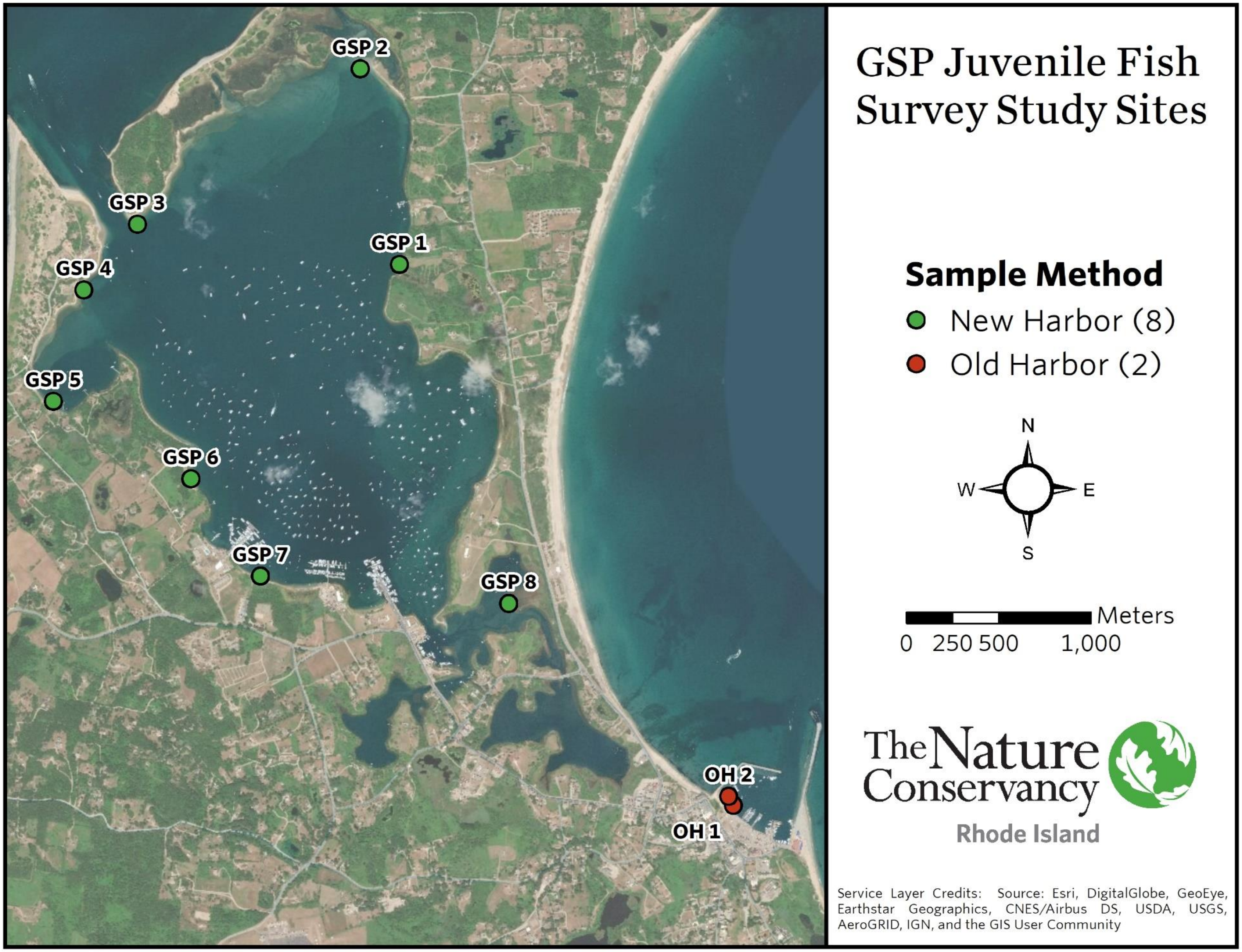
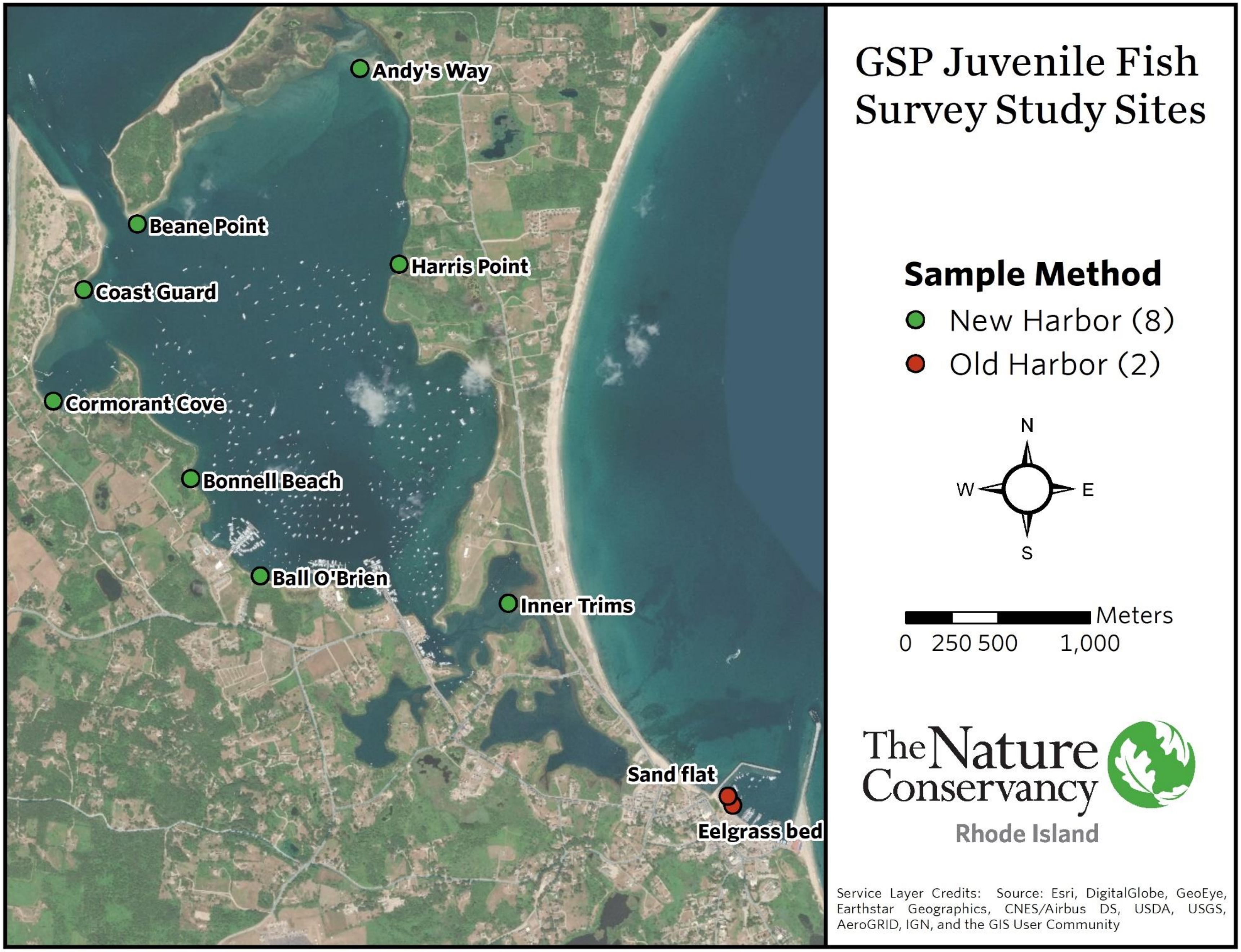


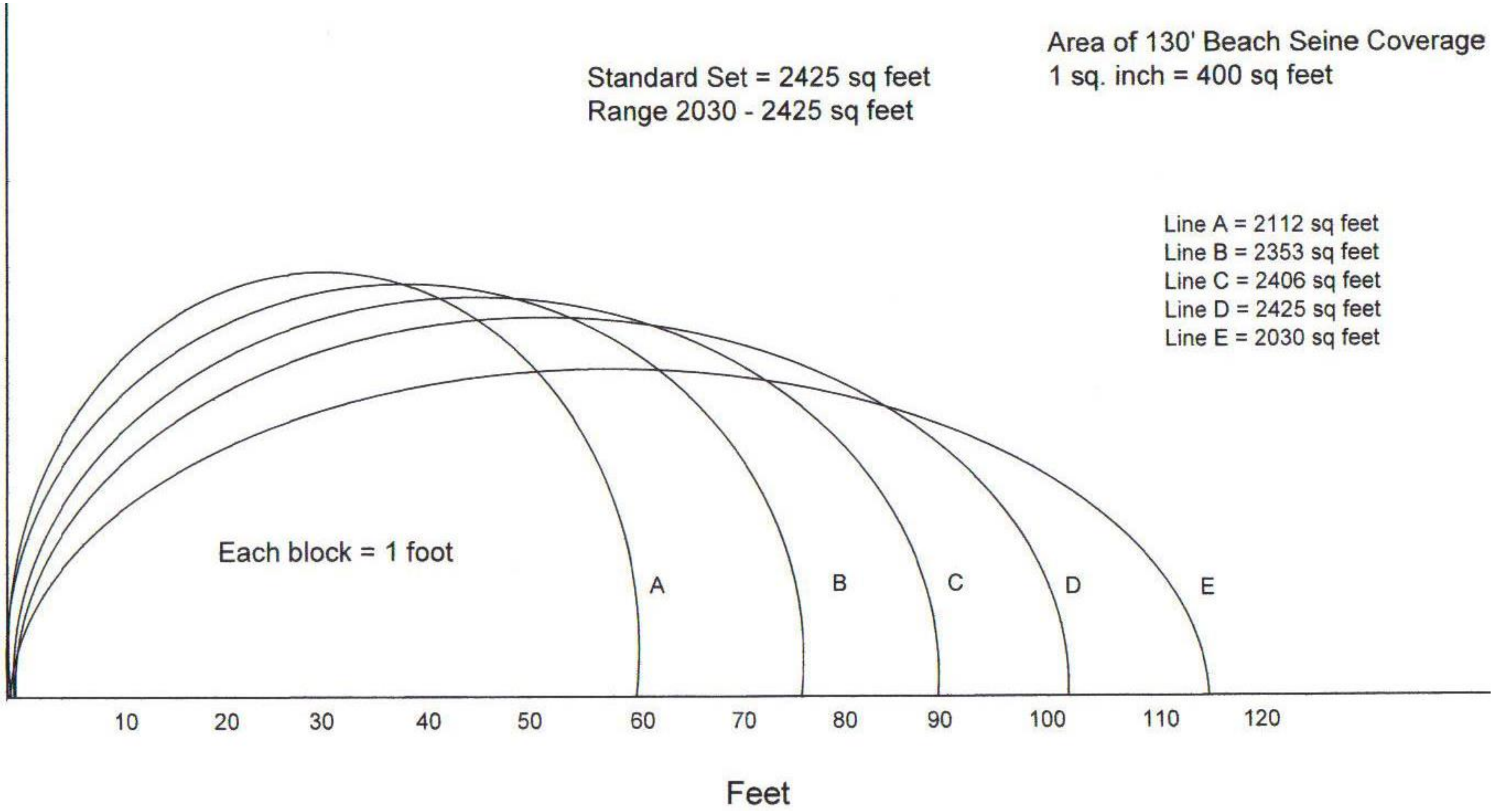
Figure 2. Map to depict colloquial names for sampling site locations in the GSP and OH (ArcGIS Pro 2018).



Sampling Overview

Beach Seine Effort

Figure 3. Area covered by 130-ft seine net.



Physical and Chemical Data

Water Chemistry, 2018

Figure 4. Water temperature measurements taken at each station in 2018.

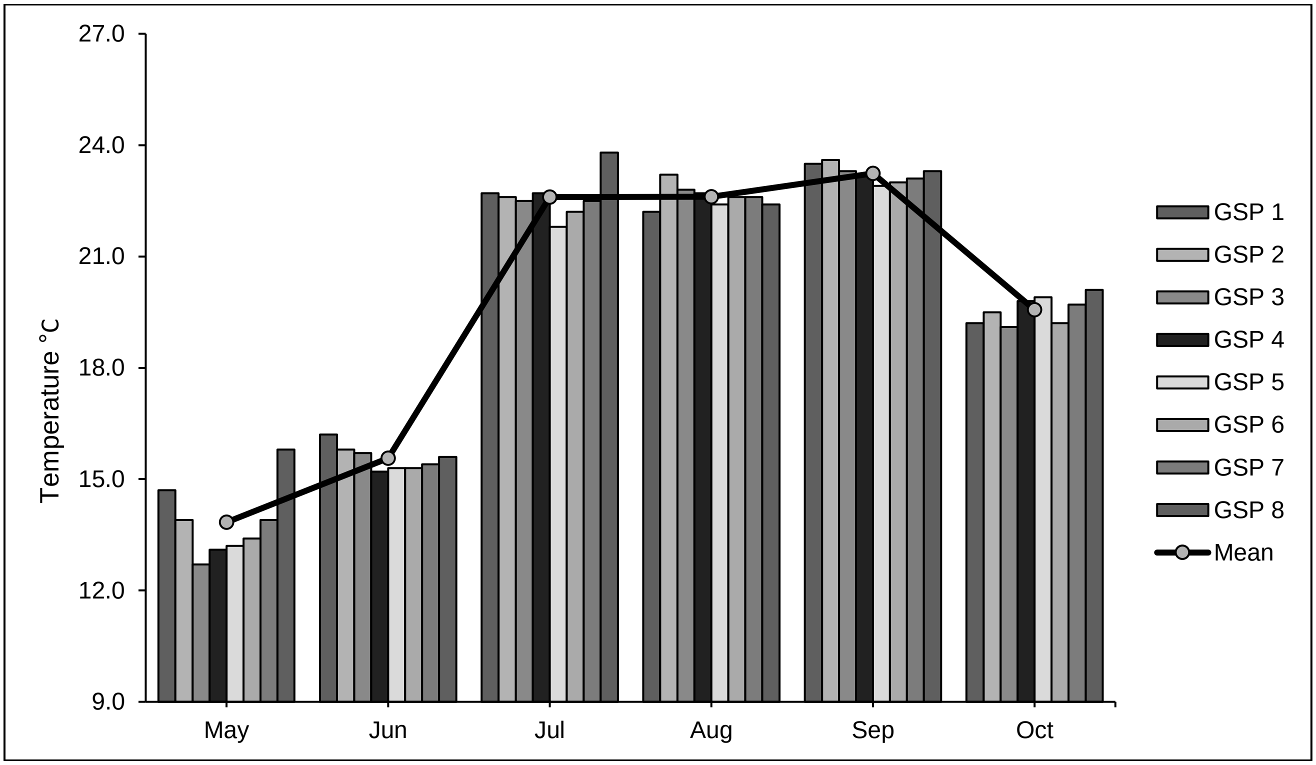


Figure 5. Salinity measurements taken at each station in 2018.

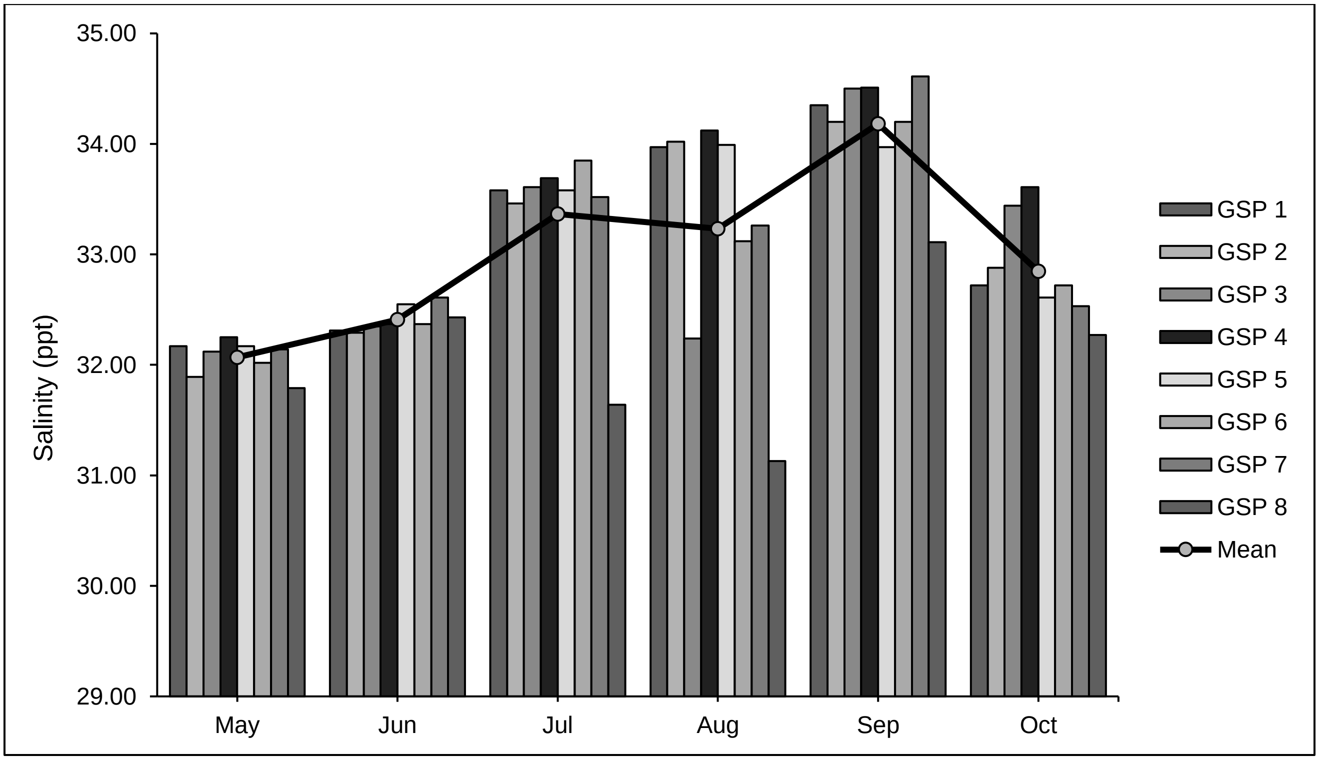
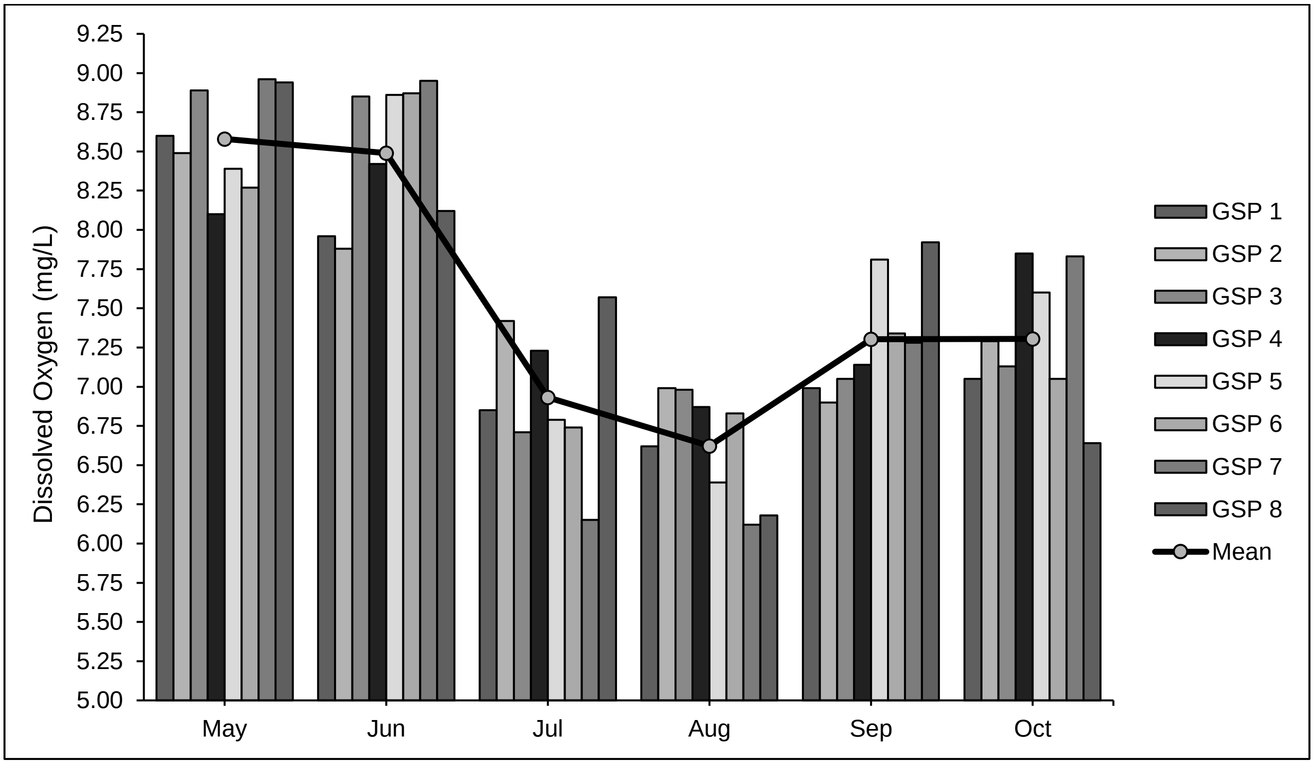


Figure 6. Dissolved oxygen measurements taken at each station in 2018.



Biological Data

Abundance Indices, All Species, 2018

Figure 7. Mean abundance (± SE) of finfish caught each month in 2018.

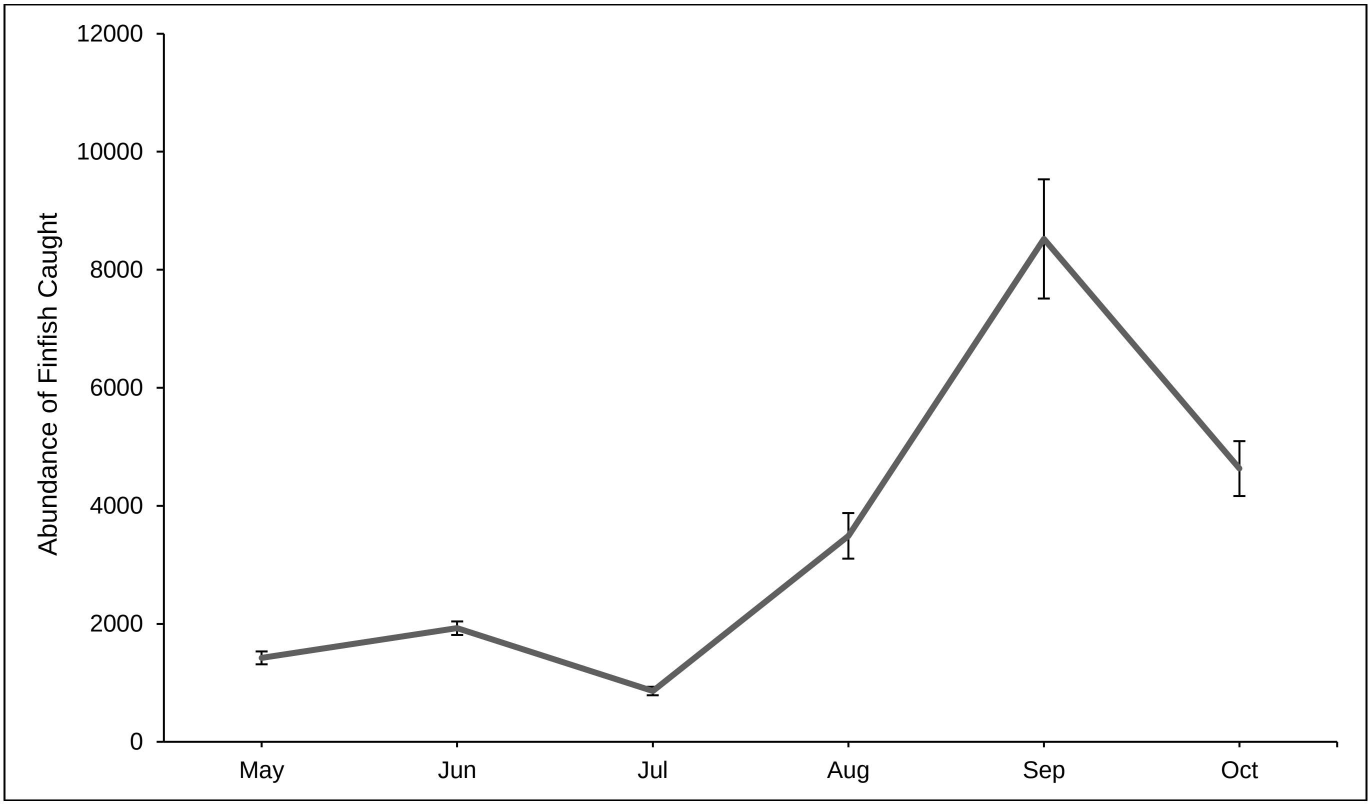
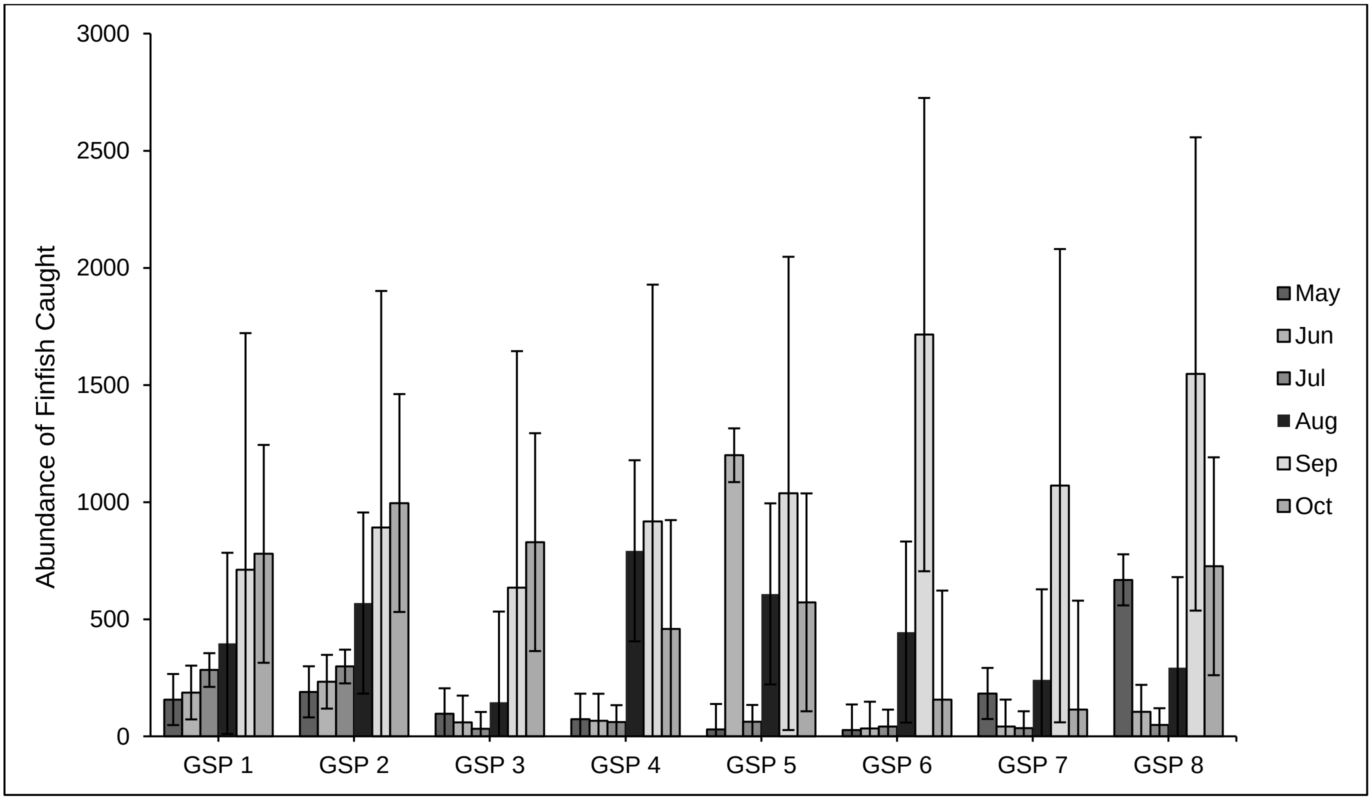
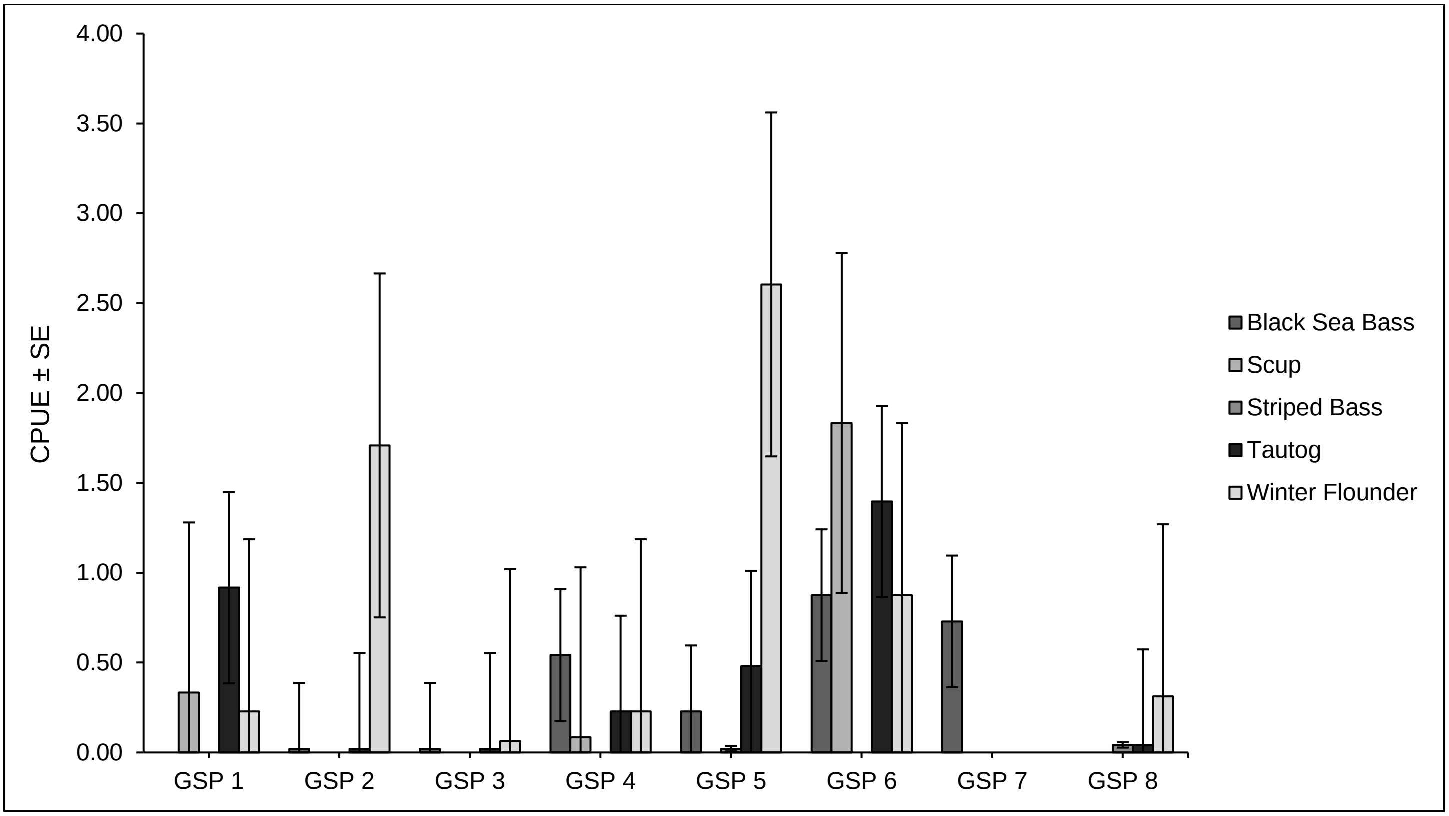


Figure 8. Mean abundance (± SE) of all finfish caught across sites in 2018.



Abundance Indices, Species of Interest, 2018

Figure 9. Mean abundance (± SE) of species of interest caught across GSP sites in 2018.



Catch by Target Species, Winter Flounder, 2018

Figure 10. Mean abundance ± SE (fish/seine haul) by month for winter flounder, 2018.

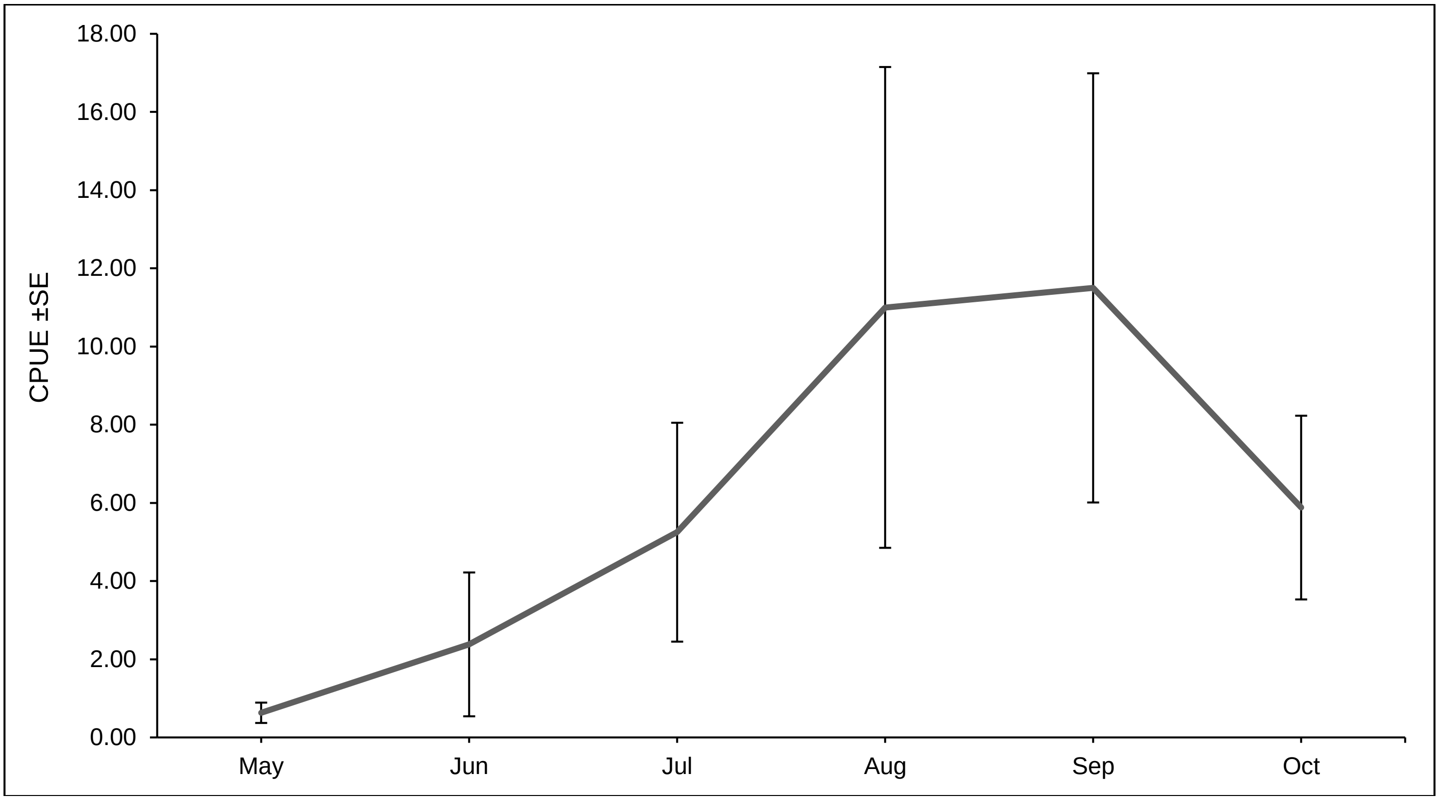


Figure 11. Mean abundance ± SE (fish/seine haul) by station for winter flounder, 2018.

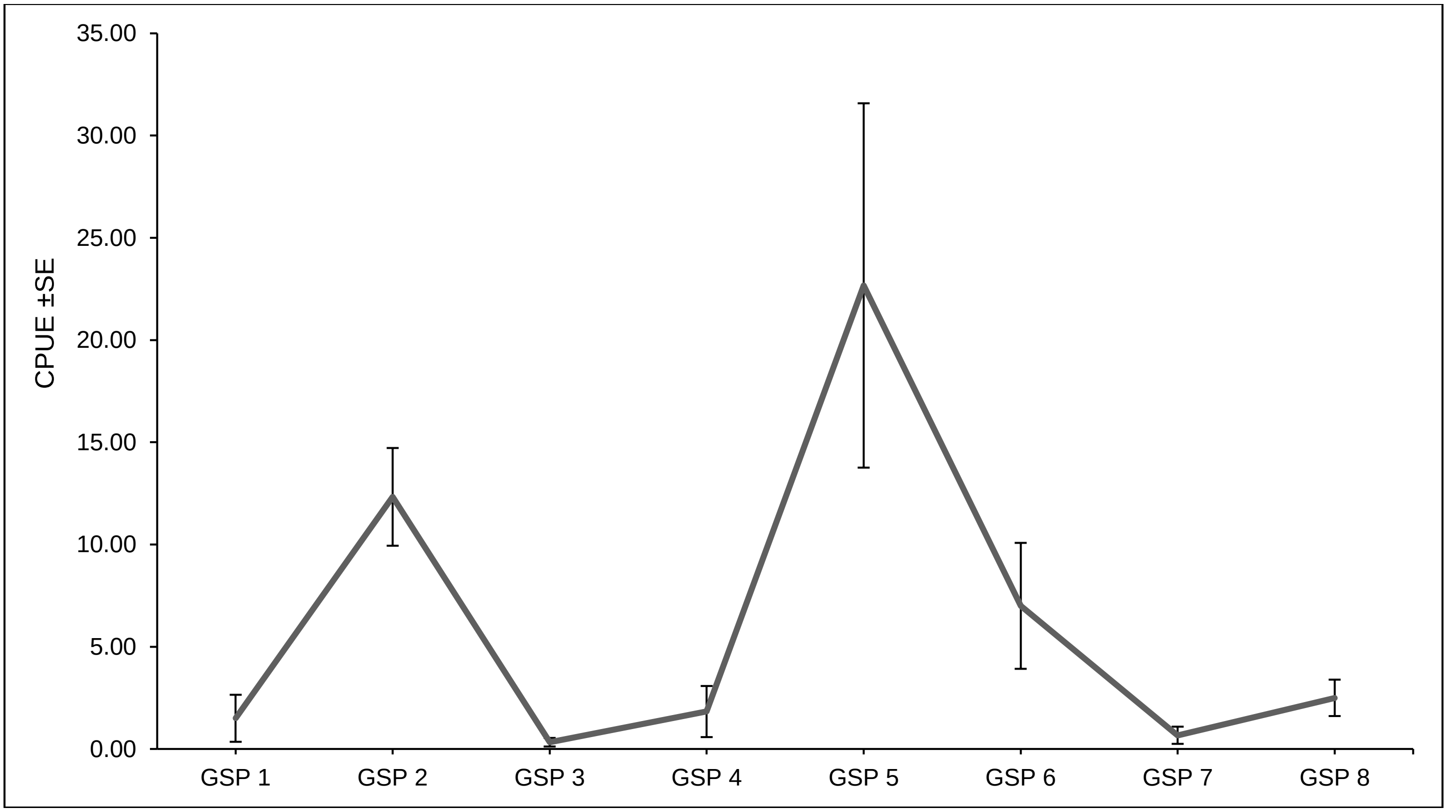


Figure 12. Mean abundance ± SE (fish/seine haul) by station and month for winter flounder, 2018.

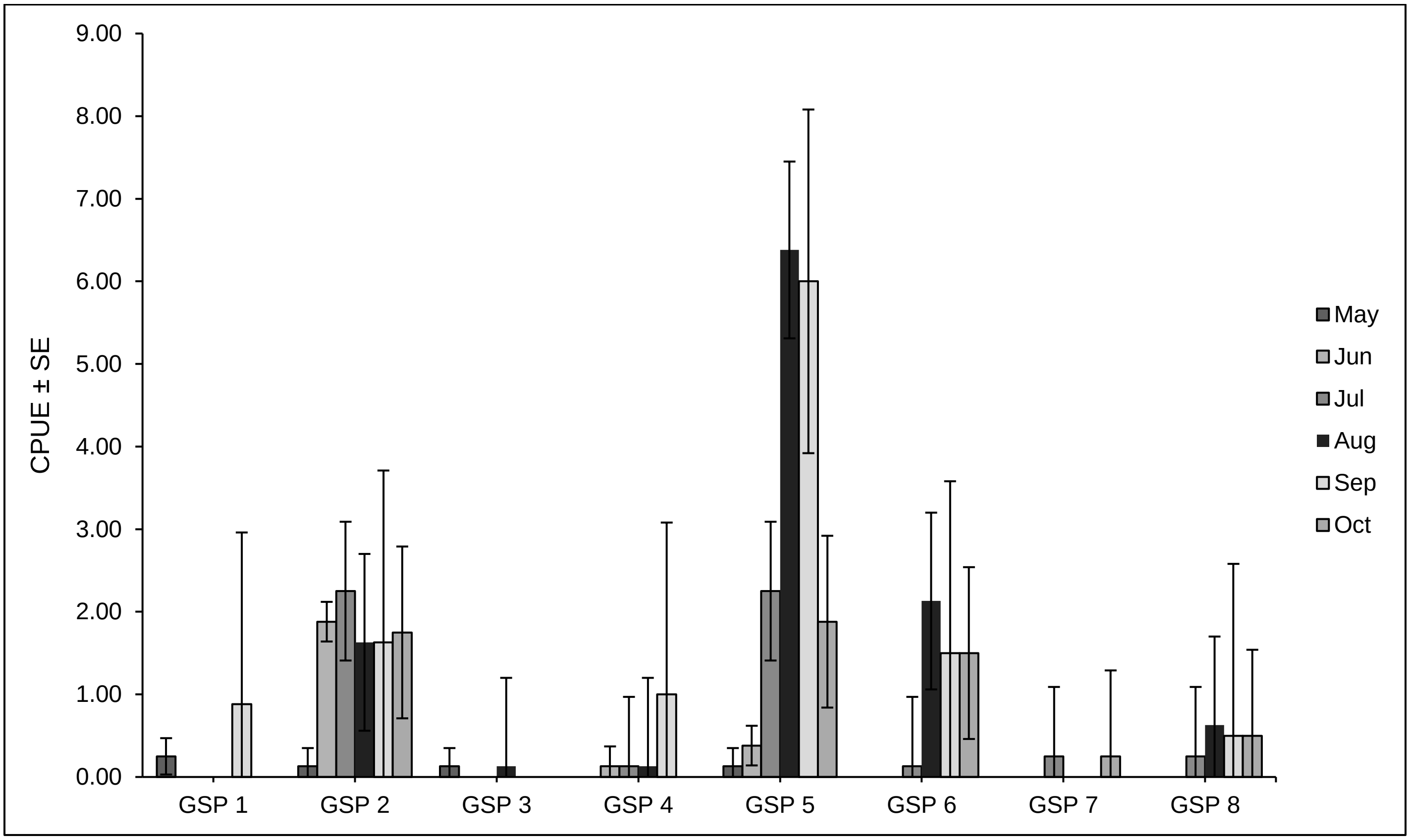


Figure 13. Length frequency distribution for all winter flounder caught in 2018. YOY cutoff left of dotted line (TL<120 mm).

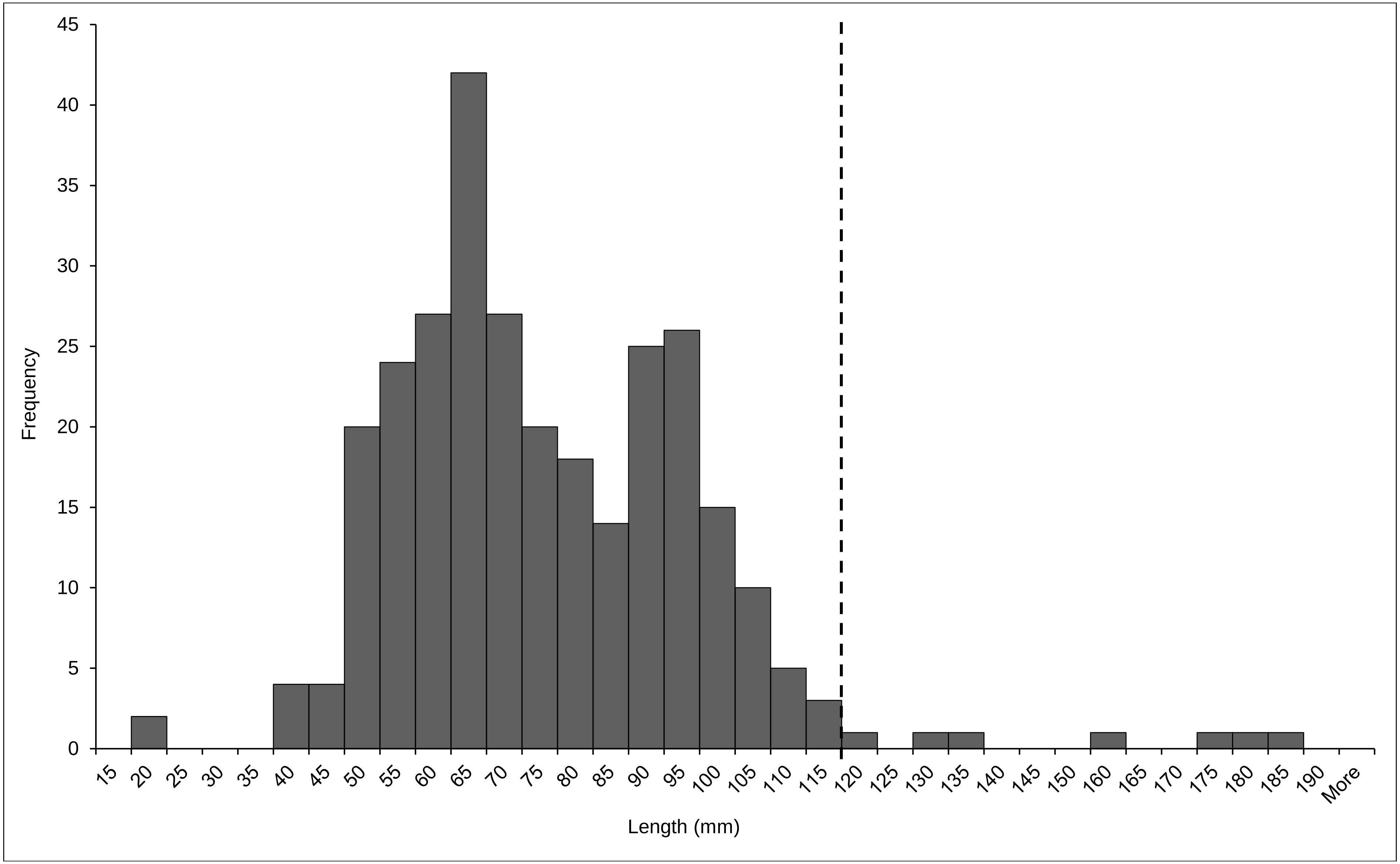
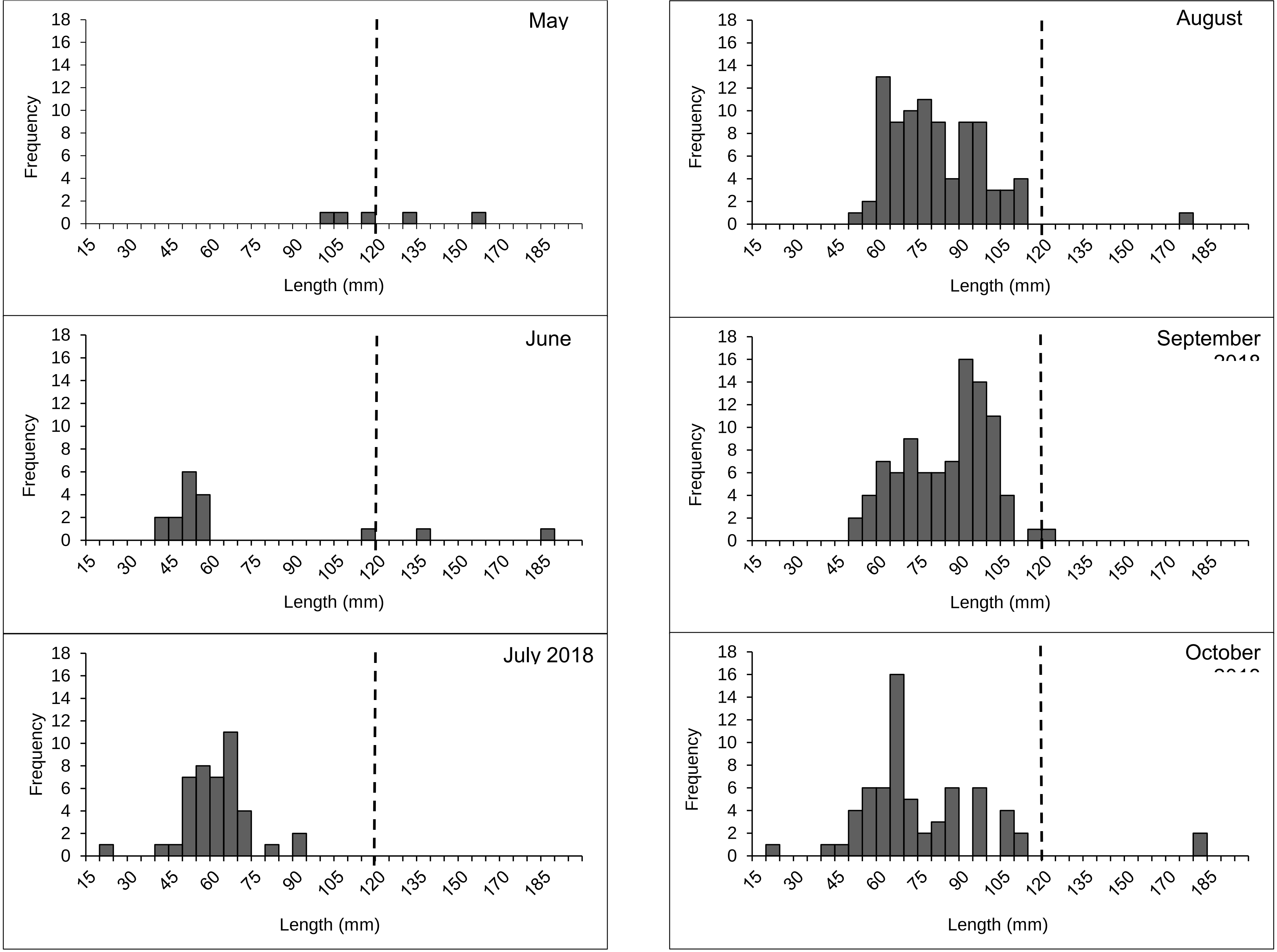


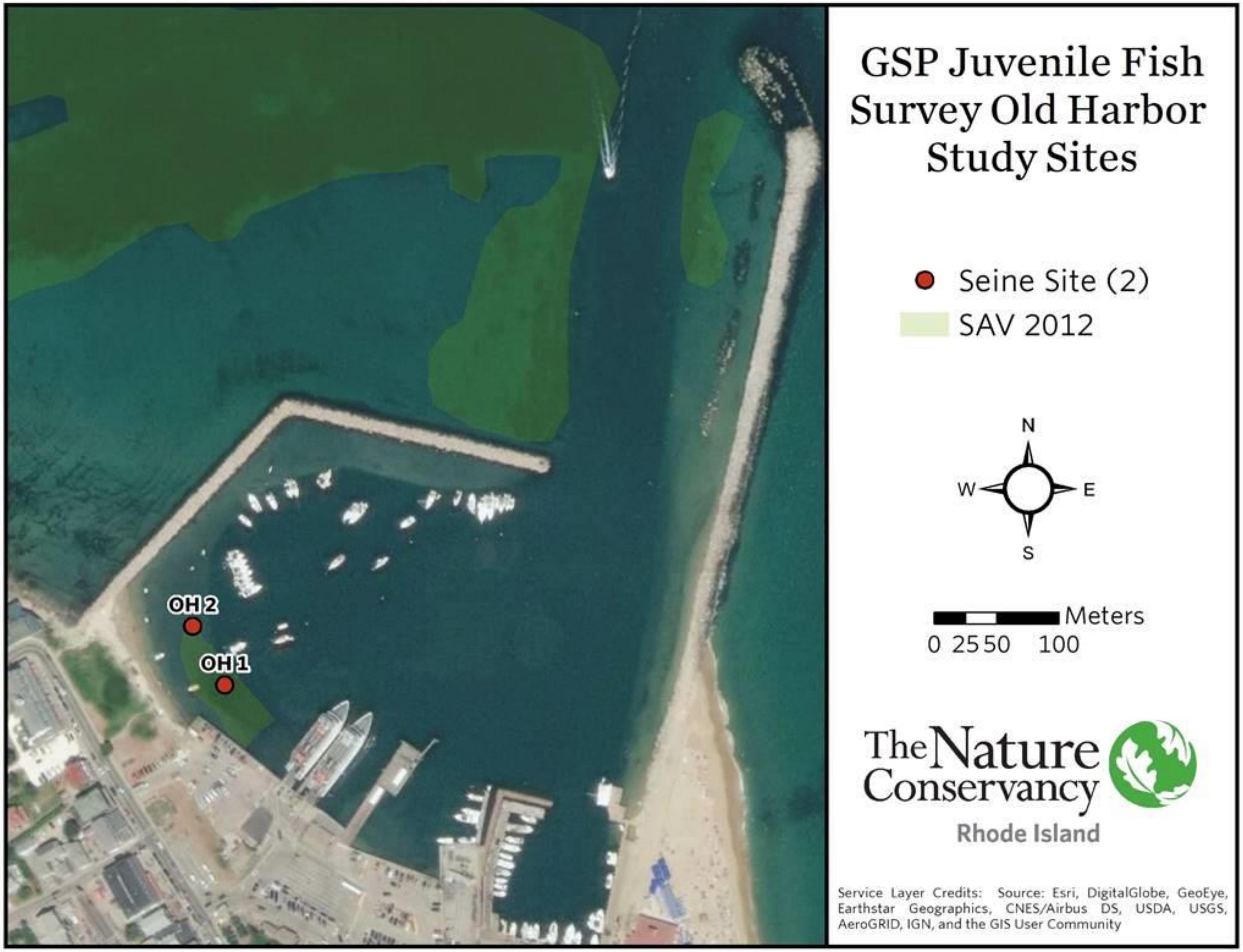
Figure 14. The histograms below depict month length frequencies of winter flounder from the GSP, 2018. YOY cutoff left of dotted line <120mm (TL).



FIGURES, OLD HARBOR

Study Area

Figure 15. Site map depicting fixed stations for OH survey. Red dots indicate fixed stations. Shaded green areas show submerged vegetation data from 2012 (ArcGIS 2018).



Physical and Chemical Data

Water Chemistry, 2018

Figure 16. Water temperature measurements taken at each station in 2018.

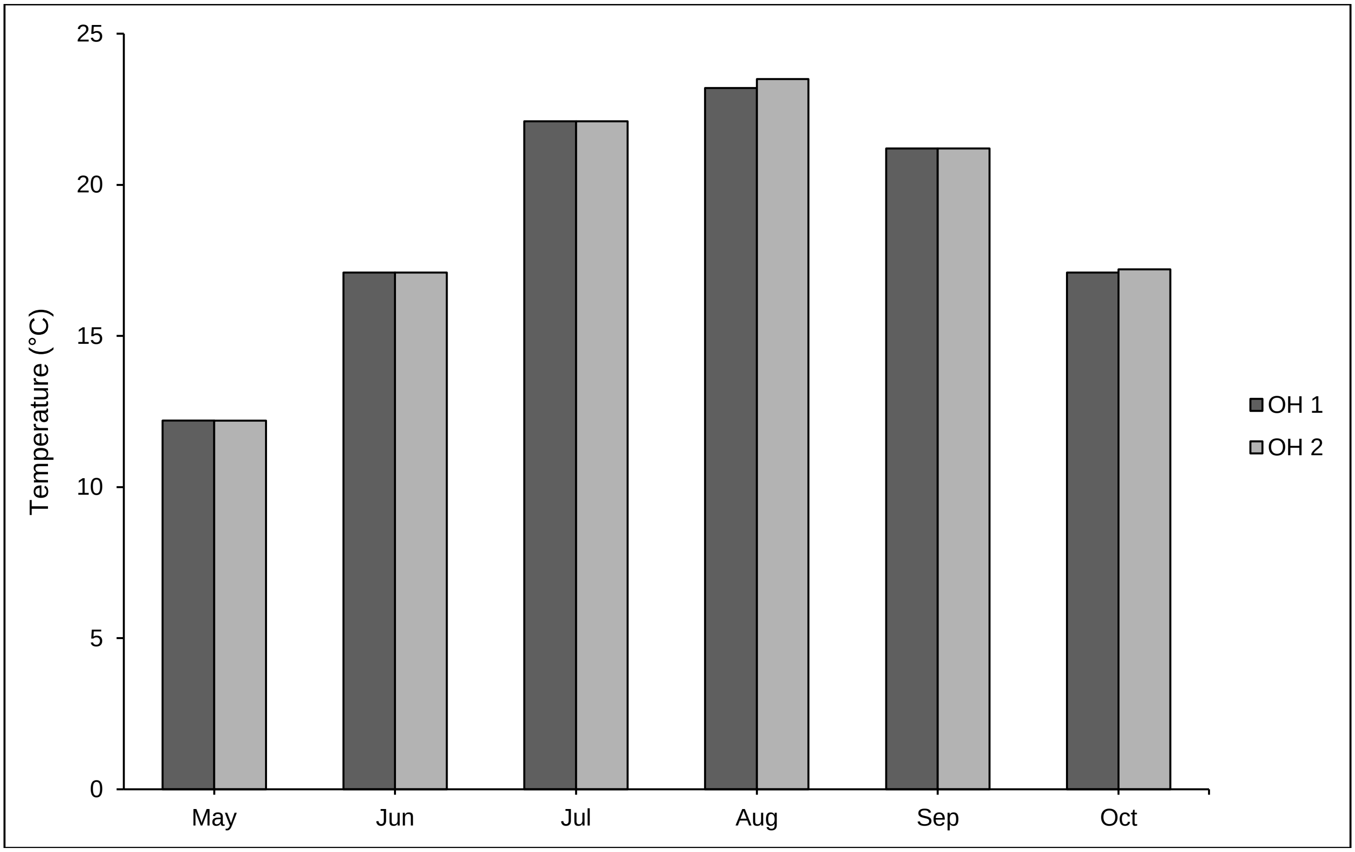


Figure 17. Salinity measurements taken at each station in 2018.

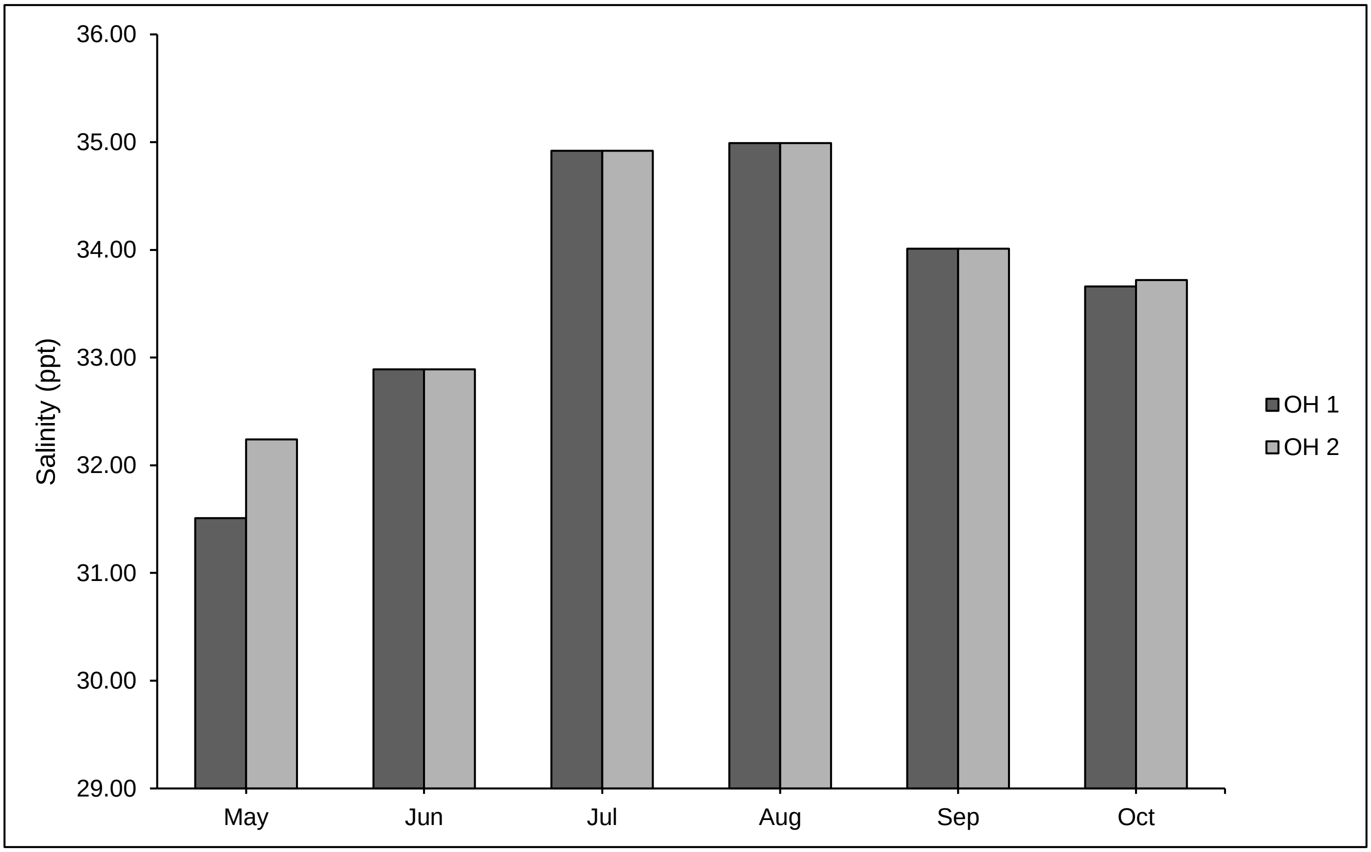
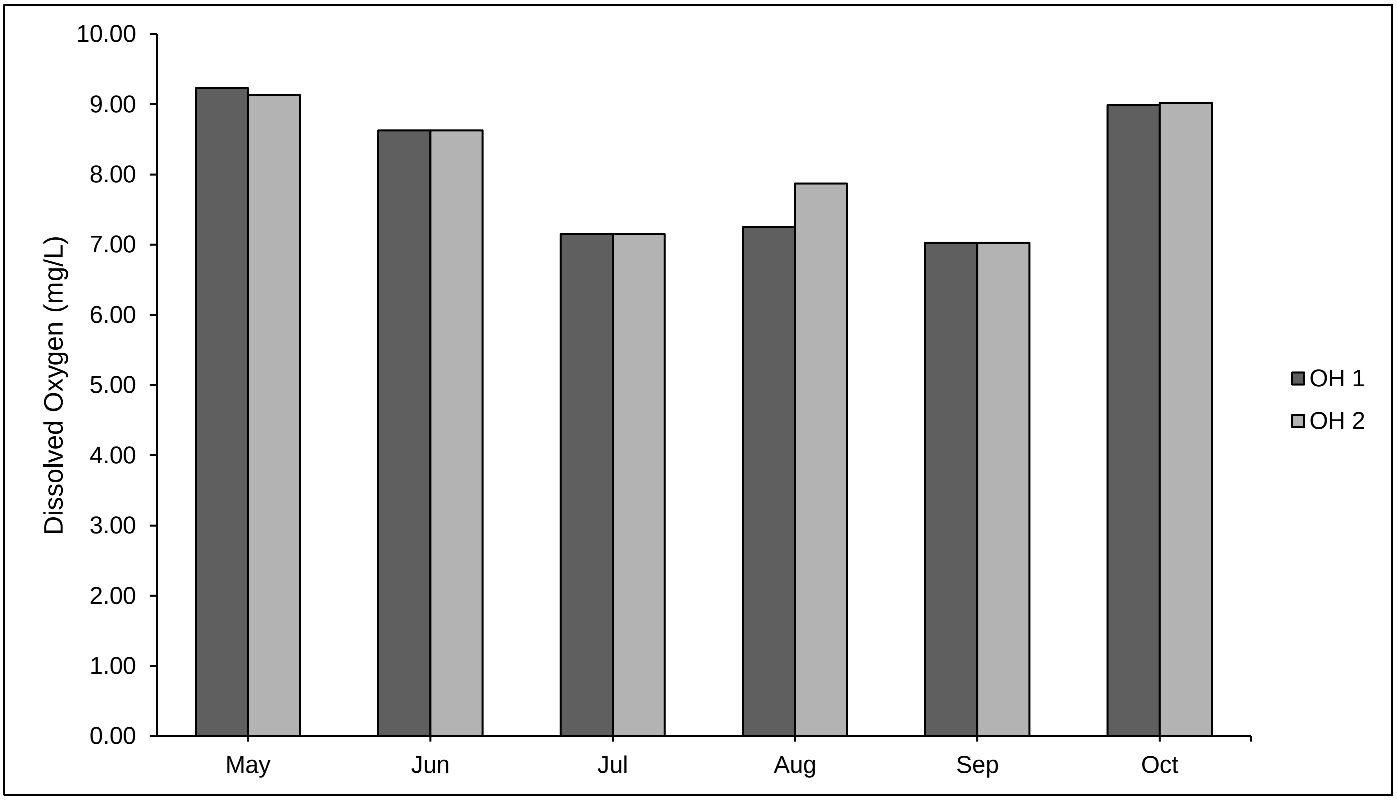


Figure 18. Dissolved oxygen measurements taken at each station in 2018.



Biological Data

Abundance Indices, All Species, 2018

Figure 19. Mean abundance (± SE) all finfish caught each month in OH, 2018.

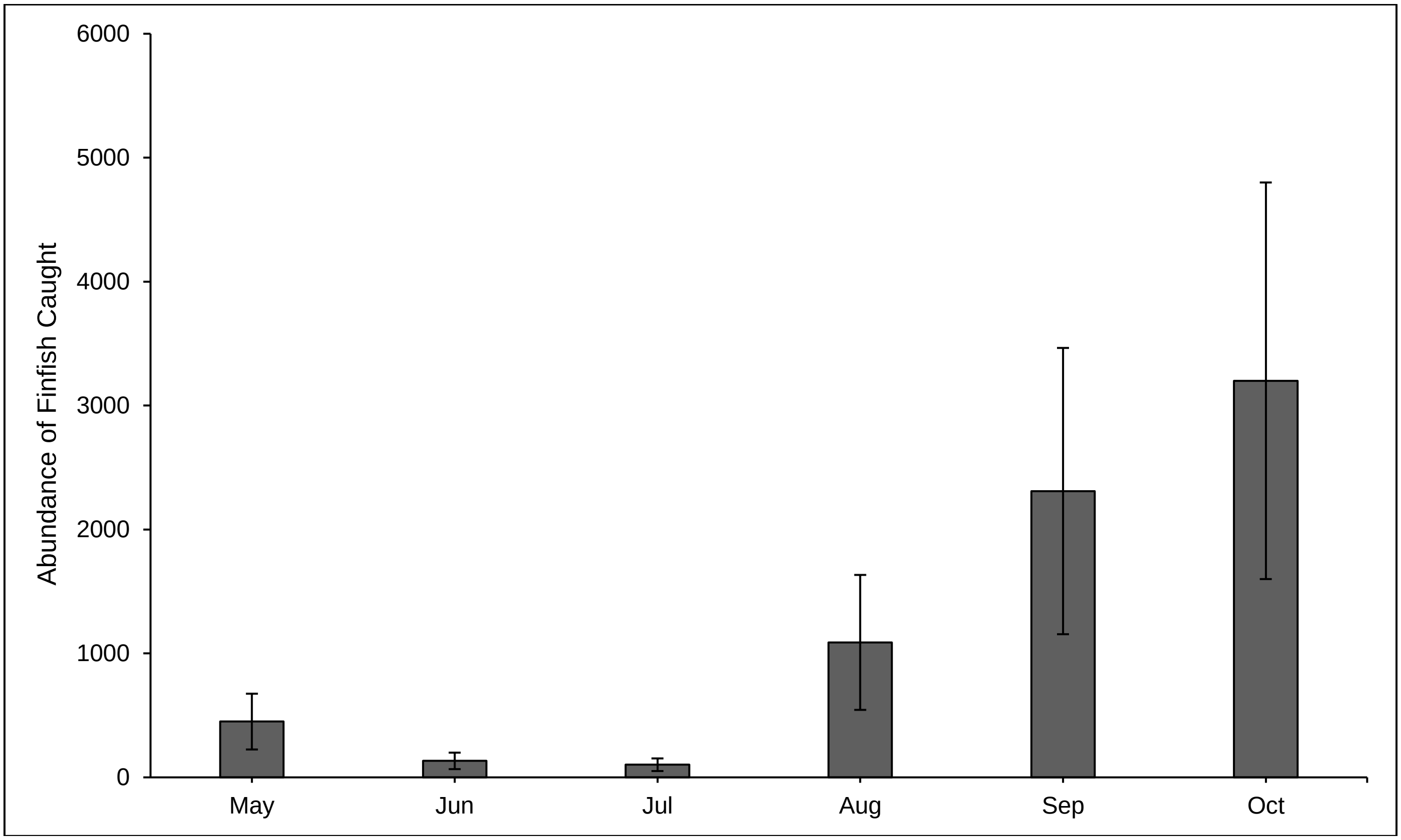
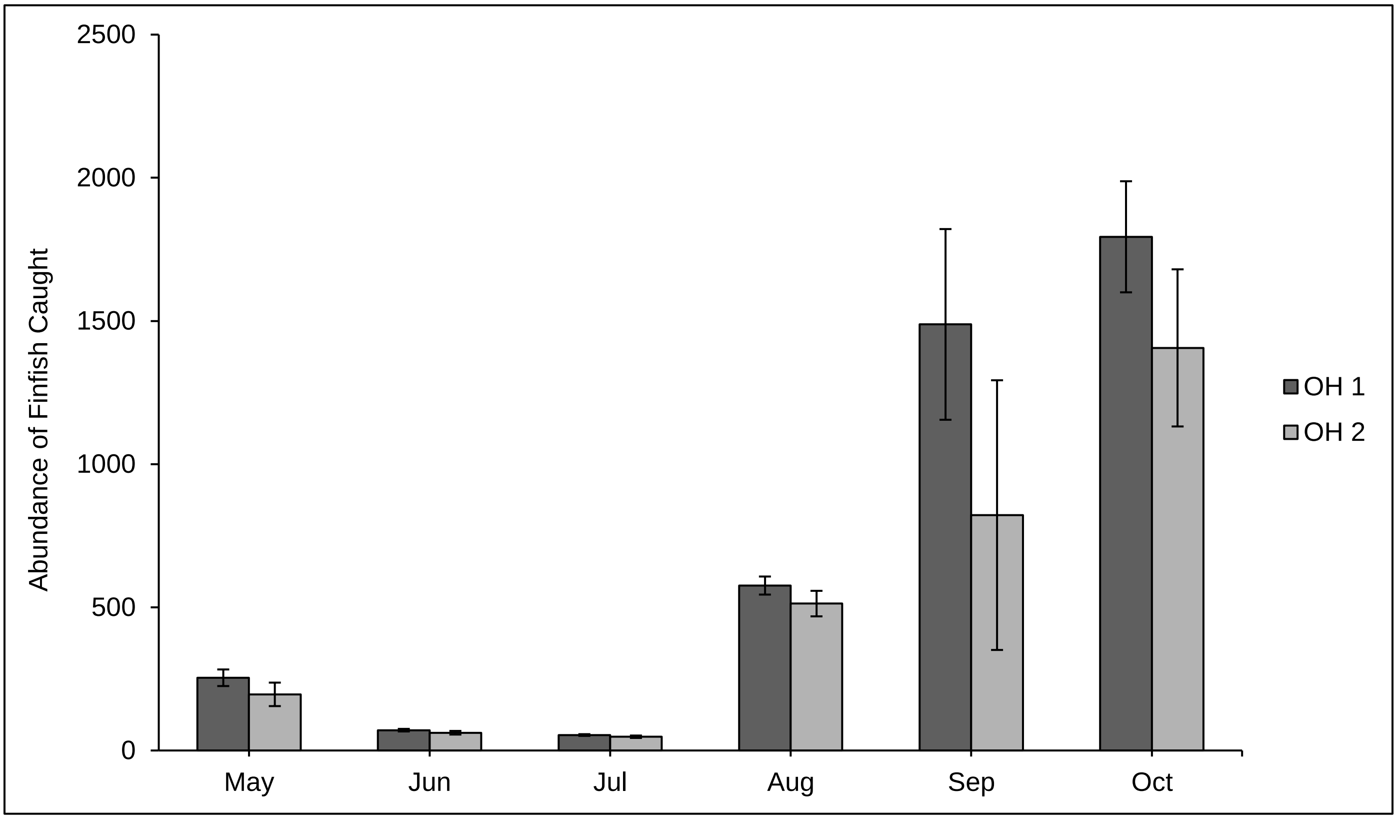
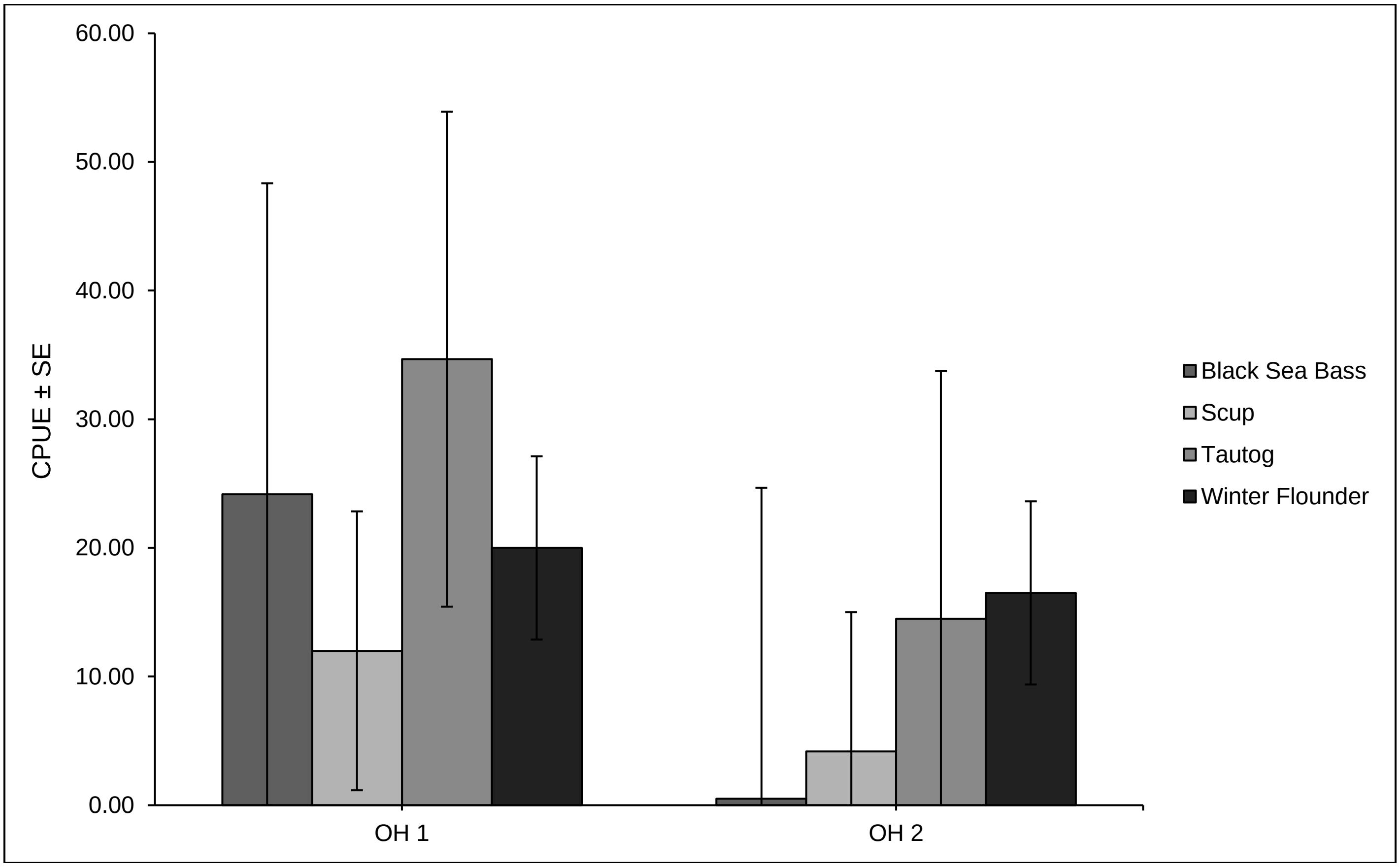


Figure 20. Mean abundance (± SE) all finfish caught across OH sites in 2018.



Abundance Indices, Species of Interest, 2018

Figure 21. Mean abundance (± SE) species of interest caught across sites in 2018.



Catch by Target Species, Winter Flounder, 2018

Figure 22. Mean abundance ± SE (fish/seine haul) by month for winter flounder, 2018.

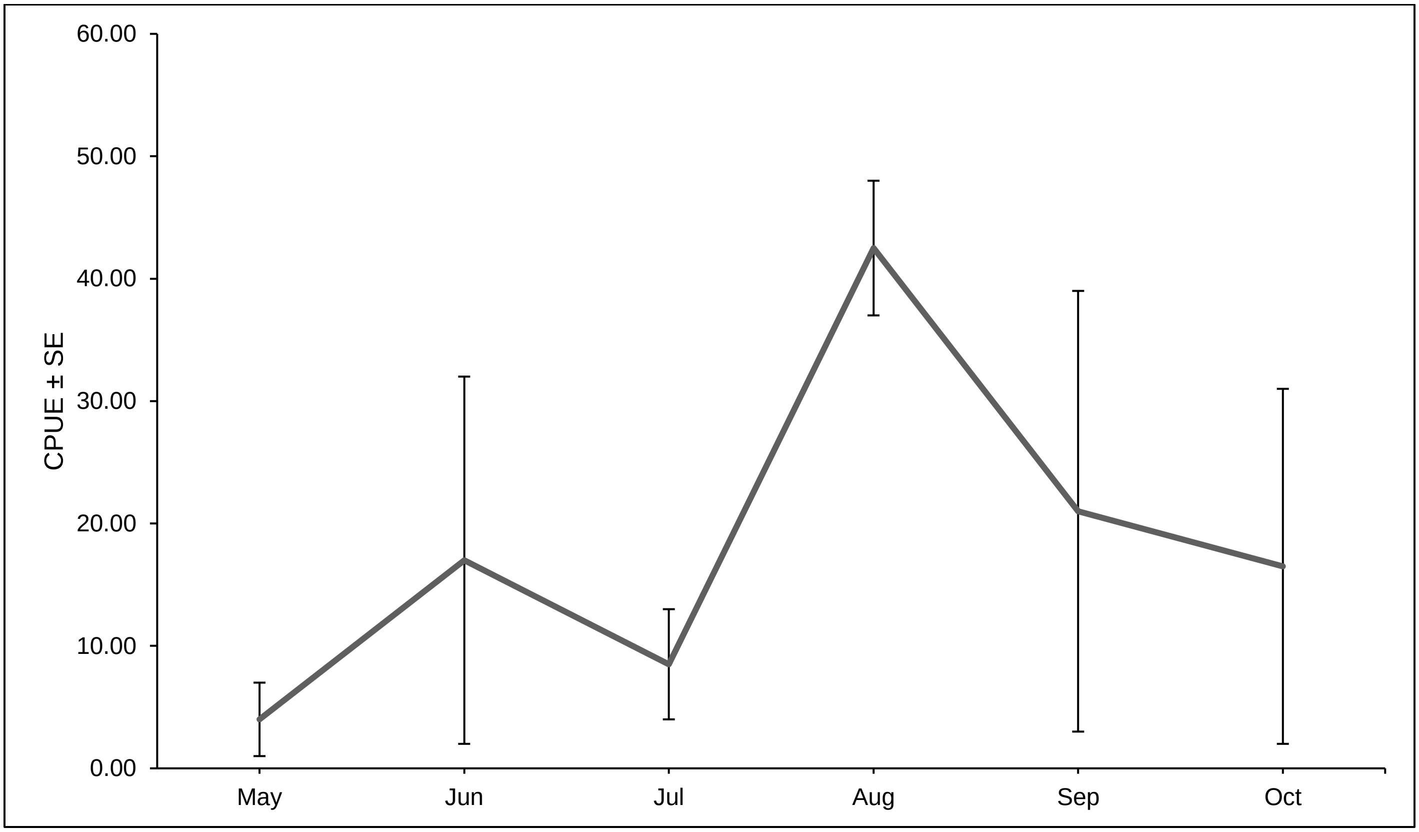


Figure 23. Mean abundance ± SE (fish/seine haul) by station for winter flounder, 2018.

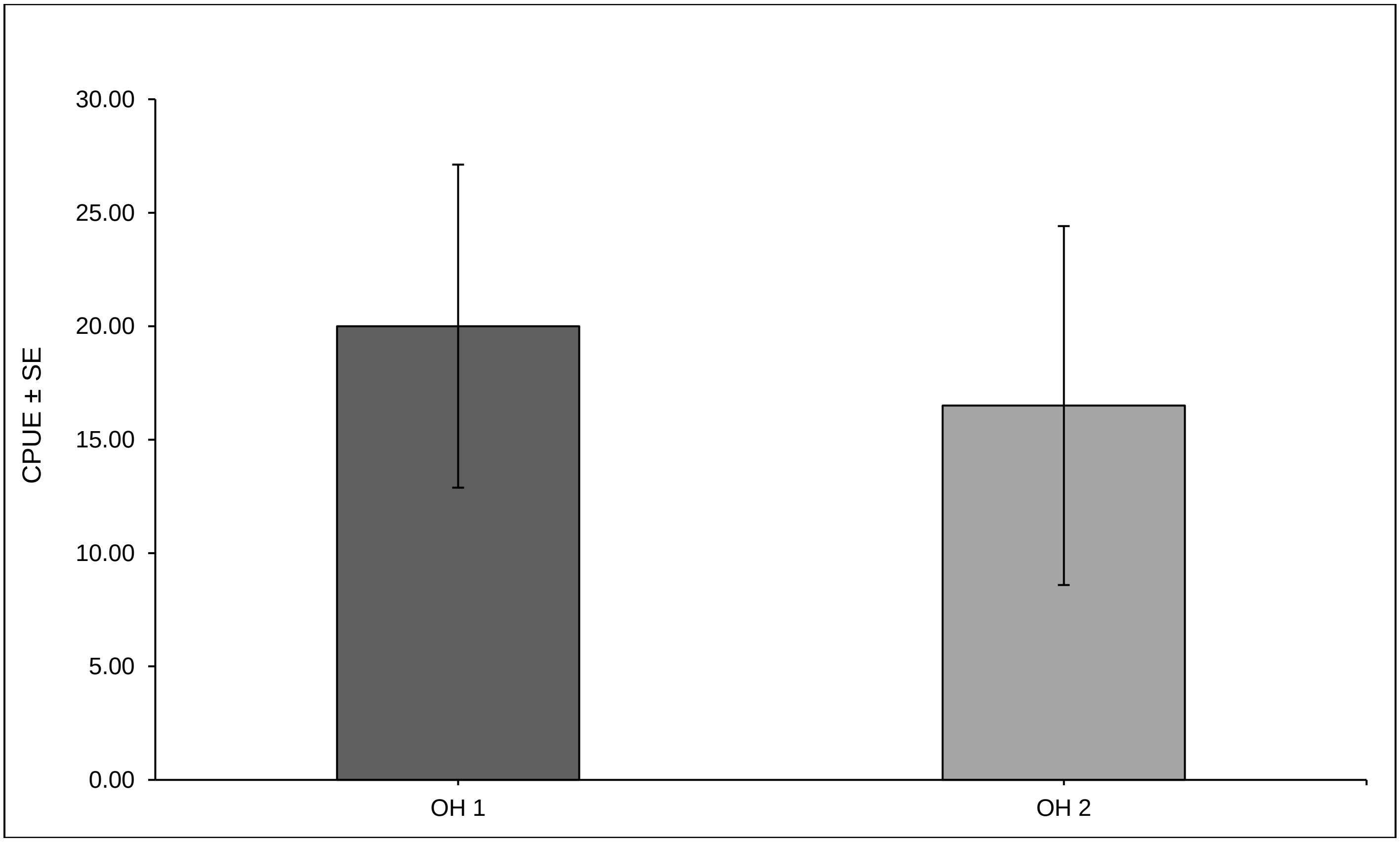


Figure 24. Mean abundance ± SE (fish/seine haul) by month and station for winter flounder, 2018.

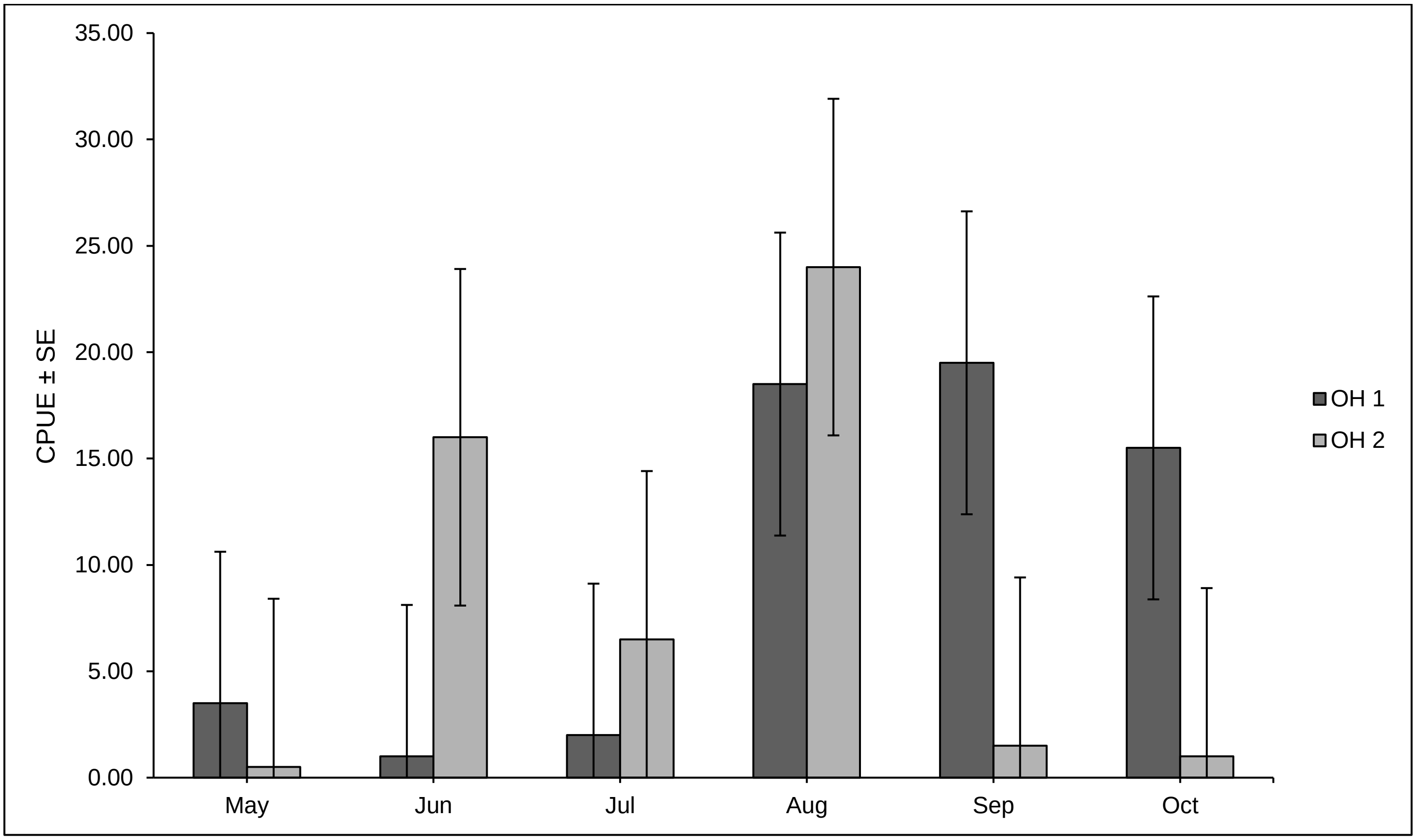


Figure 25. Length frequency distribution for all winter flounder caught in OH, 2018. YOY cutoff left of dotted line (TL<120 mm).

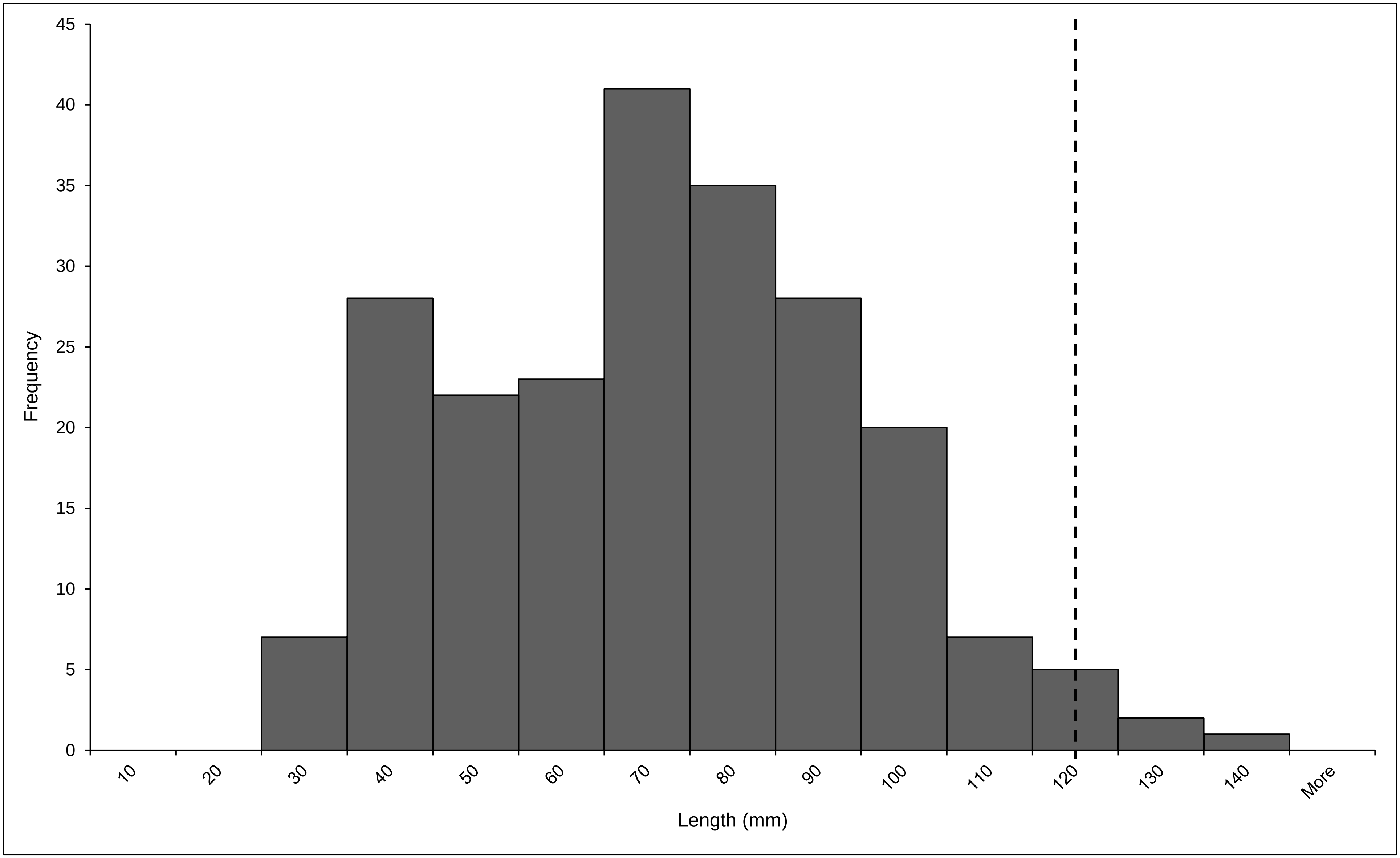


Figure 26. The histogram below shows length frequency distribution for YOY winter flounder caught at OH 1 station in 2018. YOY cutoff left of dotted line.

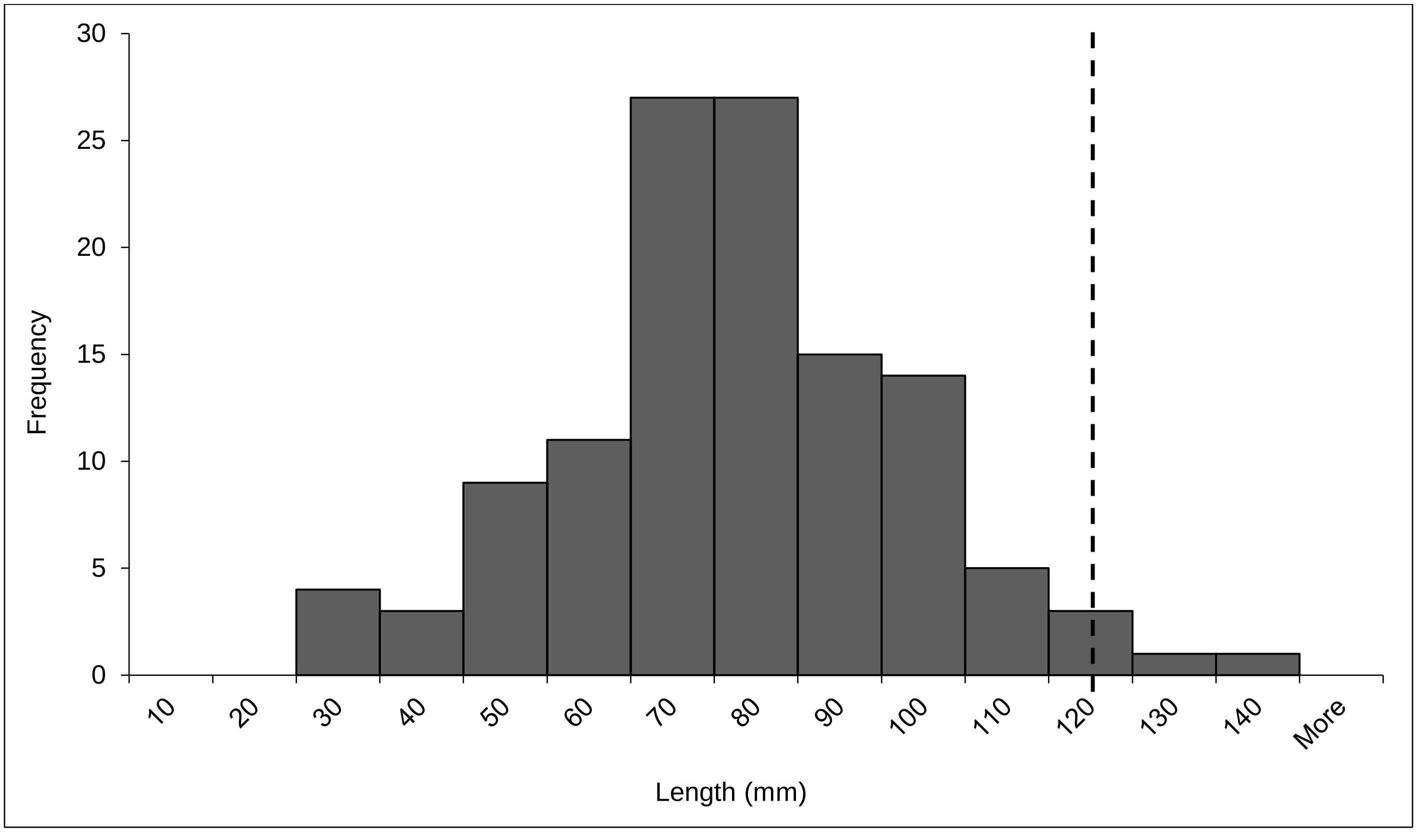


Figure 27. The histogram below shows length frequency distribution for YOY winter flounder caught at OH 2 station in 2018. YOY cutoff left of dotted line.

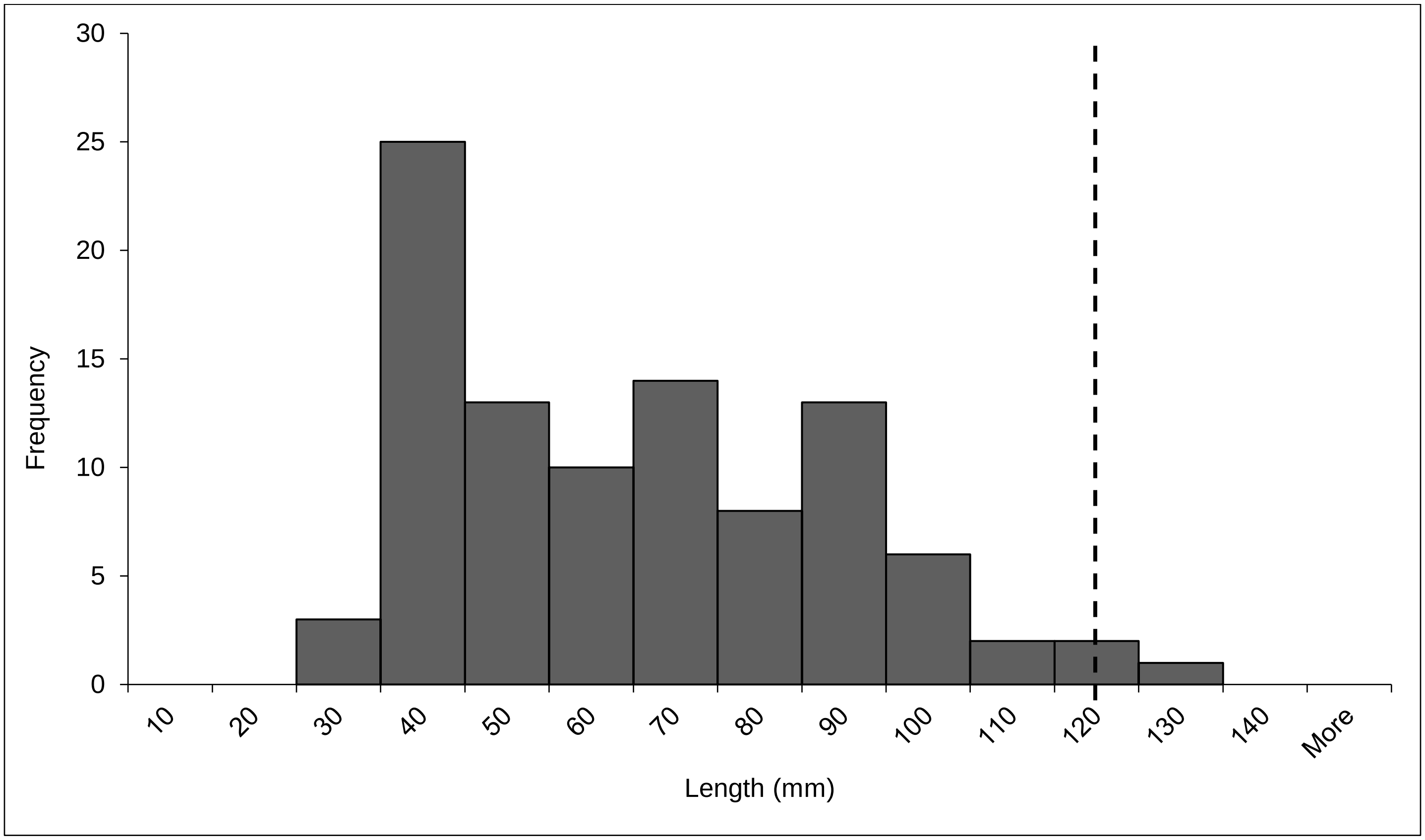
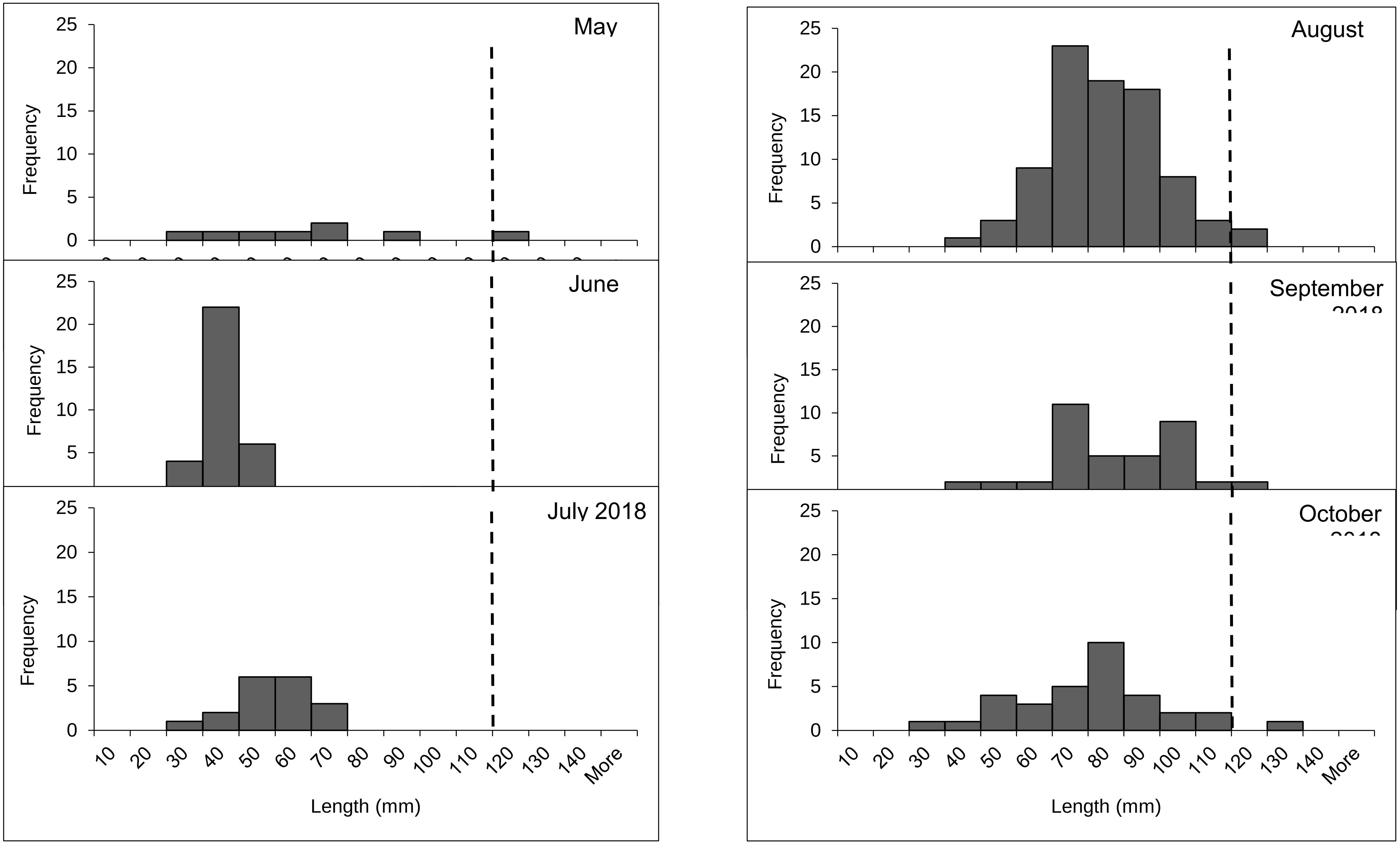


Figure 28. The series of histograms below depict length frequencies of winter flounder according to month in 2018. YOY cutoff is left of dotted line.



APPENDICES

Appendix 1: Time Series Presence/Absence, All Species, Great Salt Pond

Appendix 1a. Presence/absence of species catalogued for each survey year, 2014-2018. “1” represents present while blank slots represent absent. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

Presence/Absence		Time Series				
Common Name	Scientific Name	2014	2015	2016	2017	2018
Alewife	***Alosa pseudoharengus***	1	1			
American Sand Lance	***Ammodytes americanus***		1	1	1	1
Atlantic Cod	***Gadus morhua***		1	1		
Atlantic Croaker	*Micropogonias undulatus*	1	1	1	1	
Atlantic Herring	***Clupea harengus***	1		1	1	1
Atlantic Lizardfish	*Synodus saurus*	1				
Atlantic Menhaden	***Brevoortia tyrannus***		1	1	1	1
Atlantic Needlefish	*Strongylura marina*					1
Bay Anchovy	***Anchoa mitchilli***		1			
Bighead Sea Robin	*Prionotus tribulus*		1	1	1	
Black Sea Bass	***Centropristis striata***	1	1	1	1	1
Blueback Herring	***Alosa aestivalis***		1			
Bluefish	***Pomatomus saltatrix***	1		1	1	
Bluespotted Cornetfish	*Fistularia tabacaria*		1	1	1	1
Bonefish	*Albula vulpes*		1			
Butterfish	***Peprilus triacanthus***			1		1
Chain Pipefish	*Syngnathus louisianae*					1
Crevalle Jack	*Caranx hippos*		1	1		1
Cunner	*Tautogolabrus adspersus*		1	1	1	1
Dwarf Goatfish	*Upeneus parvus*		1		1	
Fourspine Stickleback	*Apeltes quadracus*		1			
Fourspot Flounder	*Paralichthys oblongus*		1			
Grubby	***Myoxocephalus aenaeus***		1	1	1	1
Grunt spp.	*Haemulon spp.*	1				1
Horse-eye Jack	*Caranx latus*					1
Inshore Lizardfish	*Synodus foetens*			1	1	
Leopard Sea Robin	*Prionotus scitulus*		1			
Lined Seahorse	***Hippocampus erectus***	1				1
Lizardfish spp.	*Synodontidae app.*	1				
Longfin Squid	*Loligo pealeii*		1			1
Longhorn Cowfish	*Lactoria cornuta*	1				
Longhorn Sculpin	*Myoxocephalus octodecimspinosus*		1			
Lookdown	*Selene vomer*					1
Mojarras spp.	*Gerreidae spp.*			1		
Mummichog	***Fundulus heteroclitus***	1	1	1	1	1
Naked Goby	*Gobiosoma bosc*		1		1	1
Ninespine Stickleback	***Pungitius pungitius***		1	1		1
Northern Kingfish	*Menticirrhus saxatilis*		1	1	1	
Northern Pipefish	*Syngnathus fuscus*	1	1	1	1	1
Northern Puffer	*Sphoeroides maculatus*	1	1	1	1	1
Northern Sea Robin	***Prionotus carolinus***	1	1	1	1	1
Northern Sennet	*Sphyraena borealis*		1	1	1	1

Appendix 1b. Continued table for time series presence/absence. 72 different species identified in the GSP survey between 2014 and 2018.

Presence/Absence		Time Series				
Common Name	Scientific Name	2014	2015	2016	2017	2018
Orange Filefish	*Aluterus shoepfi*		1			
Oyster Toadfish	***Opsansus tau***					1
Pigfish	*Orthopristis chrysoptera*					1
Pinfish	*Lagodon rhomboides*	1	1		1	7
Pollock	***Pollachius virens***			1		1
Pompano spp.	*Trachinotus spp.*	1				
Rainwater Killifish	***Lacania parva***	1	1	1		1
Round Herring	*Etrumeus sadina*				1	
Sand Diver	*Synodus intermedius*			1	1	1
Sculpin spp.	***Myoxocephalus spp.***	1				
Scup	*Stenotomus chrysops*		1	1	1	1
Sheepshead Minnow	***Cyprinodon variegatus***	1	1	1	1	1
Shortfin Squid	*Illex illecebrosus*		1			1
Shorthorn Sculpin	*Myoxocephalus scorpius*		1			
Silversides spp.	***Atherinopsidae spp.***	1	1	1	1	1
Smooth Trunkfish	*Rhinesomus triqueter*		1			
Snakefish	*Trachinocephalus myops*		1	1	1	1
Spot	*Leiostomus xanthurus*	1	1			
Spotfin Mojarra	*Eucinostomus argenteus*		1			
Spotted Hake	*Urophycis regia*				1	
Spotted Whiff	*Citharichthys macrops*		1			
Striped Bass	*Morone saxatilis*	1		1	1	1
Striped Cusk-eel	*Ophidion marginatum*					1
Striped Killifish	***Fundulus majalis***	1	1	1	1	1
Striped Sea Robin	*Prionotus evolans*		1	1		
Summer Flounder	*Paralichthys dentatus*		1	1		1
Tautog	***Tautoga onitis***	1	1	1	1	1
Threespine Stickleback	***Gasterosteus aculeatus***		1	1		
Windowpane	***Scophthalmus aquosus***		1	1		1
Winter Flounder	***Pseudopleuronectes americanus***	1	1	1	1	1

Appendix 1c. Catch frequency of all species collected for the time series survey, 2014-2018. The summary table shows total fish and number of species per year.

Presence/Absence		Time Series					
Common Name	Scientific Name	2014	2015	2016	2017	2018	Total
Alewife	***Alosa pseudoharengus***	1	12				13
American Sand Lance	***Ammodytes americanus***		1221	21	11	1200	2453
Atlantic Cod	***Gadus morhua***		1	3			4
Atlantic Croaker	*Micropogonias undulatus*	1	53	56	30		140
Atlantic Herring	***Clupea harengus***	2		1	1	12	16
Atlantic Lizardfish	*Synodus saurus*	1					1
Atlantic Menhaden	***Brevoortia tyrannus***		20	5	114	2334	2473
Atlantic Needlefish	*Strongylura marina*					2	2
Bay Anchovy	***Anchoa mitchilli***		1				1
Bighead Sea Robin	*Prionotus tribulus*		9	13	51		73
Black Sea Bass	***Centropristis striata***	25	898	361	19	116	1419
Blueback Herring	***Alosa aestivalis***		1				1
Bluefish	***Pomatomus saltatrix***	1		1	63		65
Bluespotted Cornetfish	*Fistularia tabacaria*		1	1	2	1	5
Bonefish	*Albula vulpes*		3				3
Butterfish	***Peprilus triacanthus***			2		1	3
Chain Pipefish	*Syngnathus louisianae*					3	3
Crevalle Jack	*Caranx hippos*		2	3		2	7
Cunner	*Tautogolabrus adspersus*		57	3	6	8	74
Dwarf Goatfish	*Upeneus parvus*		1		1		2
Fourspine Stickleback	*Apeltes quadracus*		1				1
Fourspot Flounder	*Paralichthys oblongus*		2				2
Grubby	***Myoxocephalus aenaeus***		11	1	5	3	20
Grunt spp.	*Haemulon spp.*	1				3	4
Horse-eye Jack	*Caranx latus*					1	1
Inshore Lizardfish	*Synodus foetens*			1	2		3
Leopard Sea Robin	*Prionotus scitulus*		9				9
Lined Seahorse	***Hippocampus erectus***	1				1	2
Lizardfish spp.	*Synodontidae app.*	1					1
Longfin Squid	*Loligo pealeii*		1			4	5
Longhorn Cowfish	*Lactoria cornuta*	1					1
Longhorn Sculpin	*Myoxocephalus octodecimspinosus*		9				9
Lookdown	*Selene vomer*					1	1
Mojarras spp.	*Gerreidae spp.*			13			13
Mummichog	***Fundulus heteroclitus***	22	199	253	133	409	1016
Naked Goby	*Gobiosoma bosc*		2		5	13	20
Ninespine Stickleback	***Pungitius pungitius***		1	3		2	6
Northern Kingfish	*Menticirrhus saxatilis*		6	2	12		20
Northern Pipefish	*Syngnathus fuscus*	3	12	6	13	20	54
Northern Puffer	*Sphoeroides maculatus*	2	3	5	15	19	44
Northern Sea Robin	***Prionotus carolinus***	3	1	2	8	3	17
Northern Sennet	*Sphyraena borealis*		1	4	17	157	179

Appendix 1d. Continued table for time series catch frequency. A total of 82,581 individuals were collected between 2014 and 2018.

Presence/Absence		Time Series					
Common Name	Scientific Name	2014	2015	2016	2017	2018	Total
Orange Filefish	*Aluterus shoepfi*		1				1
Oyster Toadfish	***Opsansus tau***					23	23
Pigfish	*Orthopristis chrysoptera*					1	1
Pinfish	*Lagodon rhomboides*	1	18		33	7	59
Pollock	***Pollachius virens***			6		2	8
Pompano spp.	*Trachinotus spp.*	5					5
Rainwater Killifish	***Lacania parva***	170	57	55		5	287
Round Herring	*Etrumeus sadina*				32		32
Sand Diver	*Synodus intermedius*			3	5	1	9
Sculpin spp.	***Myoxocephalus spp.***	7					7
Scup	*Stenotomus chrysops*		46	18	156	108	328
Sheepshead Minnow	***Cyprinodon variegatus***	2	20	35	17	49	123
Shortfin Squid	*Illex illecebrosus*		1			1	2
Shorthorn Sculpin	*Myoxocephalus scorpius*		4				4
Silversides spp.	***Atherinopsidae spp.***	3649	15112	11966	16021	14044	60792
Smooth Trunkfish	*Rhinesomus triqueter*		1				1
Snakefish	*Trachinocephalus myops*		1	1	2	9	13
Spot	*Leiostomus xanthurus*	1	6				7
Spotfin Mojarra	*Eucinostomus argenteus*		20				20
Spotted Hake	*Urophycis regia*				1		1
Spotted Whiff	*Citharichthys macrops*		3				3
Striped Bass	*Morone saxatilis*	2		1	1	3	7
Striped Cusk-eel	*Ophidion marginatum*					1	1
Striped Killifish	***Fundulus majalis***	2441	2482	1606	2765	1805	11099
Striped Sea Robin	*Prionotus evolans*		1	2			3
Summer Flounder	*Paralichthys dentatus*		1	7		1	9
Tautog	***Tautoga onitis***	23	201	30	142	186	582
Threespine Stickleback	***Gasterosteus aculeatus***		4	8			12
Windowpane	***Scophthalmus aquosus***		9	13		1	23
Winter Flounder	***Pseudopleuronectes americanus***	101	188	192	159	293	933
	Total individuals	6467	20714	14703	19842	20855	**Total Fish**
	Number of species	25	48	37	31	41	**82581**

Appendix 2: Time Series Catch Frequency Tables & Figures, All Species, Great Salt Pond

Appendix 2a. Catch frequency of species collected per station in 2017. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

2017		Station								
Common Name	**Scientific Name**	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	Total
American Sand Lance	***Ammodytes americanus***								11	11
Atlantic Croaker	*Micropogonias undulatus*		10				4		16	30
Atlantic Herring	***Clupea harengus***			1						1
Atlantic Menhaden	***Brevoortia tyrannus***			18	27	9		14	46	114
Bighead Sea Robin	*Prionotus tribulus*		12			4	18	13	4	51
Black Sea Bass	***Centropristis striata***		4	1	6	2	6			19
Bluefish	***Pomatomus saltatrix***	1	20	17	22			2	1	63
Bluespotted Cornetfish	*Fistularia tabacaria*						2			2
Cunner	*Tautogolabrus adspersus*	3			2		1			6
Dwarf Goatfish	*Upeneus parvus*	1								1
Grubby Sculpin	***Myoxocephalus aeneus***	1	1		1		2			5
Inshore Lizardfish	*Synodus foetens*			2						2
Mummichog	***Fundulus heteroclitus***	31	13	18	2	19	28	6	16	133
Naked Goby	*Gobiosoma bosc*		5							5
Northern Kingfish	*Menticirrhus saxatilis*		2	1			1	5	3	12
Northern Pipefish	*Syngnathus fuscus*	1	3			2	7			13
Northern Puffer	*Sphoeroides maculatus*				3	8	4			15
Northern Sea Robin	***Prionotus carolinus***			2		3	2	1		8
Northern Sennet	*Sphyraena borealis*		7	10						17
Pinfish	*Lagodon rhomboides*	17	10	3	2	1				33
Round Herring	*Etrumeus sadina*		12				16		4	32
Sand Diver	*Synodus intermedius*			5						5
Scup	*Stenotomus chrysops*	1	27	49	8	44	11	16		156
Sheepshead Minnow	***Cyprinodon variegatus***		1		1	11	1		3	17
Silversides spp.	***Atherinopsidae spp.***	850	2927	6106	1727	876	1803	741	991	16021
Snakefish	*Trachinocephalus myops*			1			1			2
Spotted Hake	*Urophycis regia*							1		1
Striped Bass	*Morone saxatilis*	1								1
Striped Killifish	***Fundulus majalis***	247	567	224	264	662	307	151	343	2765
Tautog	***Tautoga onitis***	32	48	11	1		2	15	33	142
Winter Flounder	***Pseudopleuronectes americanus***	14	11	15	12	70	22	2	13	159
	Total individuals	1200	3680	6484	2078	1711	2238	967	1484	**Total Fish**
	Number of species	13	18	17	14	13	19	12	13	**19842**

Appendix 2b. Catch frequency of species collected per station in 2016. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

2016		**Station**								
Common Name	**Scientific Name**	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	Total
American Sand Lance	***Ammodytes americanus***				20	1				21
Atlantic Cod	***Gadus morhua***				2	1				3
Atlantic Croaker	*Micropogonias undulatus*	3	5			40	6	2		56
Atlantic Herring	***Clupea harengus***					1				1
Atlantic Menhaden	***Brevoortia tyrannus***			4					1	5
Bighead Sea Robin	*Prionotus tribulus*		4		1	2	3	1	2	13
Black Sea Bass	***Centropristis striata***	16	12	130	4	165	28	6		361
Bluefish	***Pomatomus saltatrix***								1	1
Bluespotted Cornetfish	*Fistularia tabacaria*						1			1
Butterfish	***Peprilus triacanthus***			2						2
Crevalle Jack	*Caranx hippos*	1	2							3
Cunner	*Tautogolabrus adspersus*	2	1							3
Grubby Sculpin	***Myoxocephalus aenaeus***							1		1
Inshore Lizardfish	*Synodus foetens*			1						1
Mojarras spp.	*Gerreidae spp.*					13				13
Mummichog	***Fundulus heteroclitus***	43				1		1	208	253
Ninespine Stickleback	***Pungitius pungitius***							2	1	3
Northern Kingfish	*Menticirrhus saxatilis*		1	1						2
Northern Pipefish	*Syngnathus fuscus*		3			1		2		6
Northern Puffer	*Sphoeroides maculatus*			1	2	1	1			5
Northern Sea Robin	***Prionotus carolinus***						2			2
Northern Sennet	*Sphyraena borealis*				1	3				4
Pollock	***Pollachius virens***	2		2	0			2		6
Rainwater Killifish	***Lacania parva***		2	1	16	5	10	21		55
Sand Diver	*Synodus intermedius*			3						3
Scup	*Stenotomus chrysops*				4	3	11			18
Sheepshead Minnow	***Archosargus probatocephalus***		35							35
Silversides spp.	***Atherinopsidae spp.***	961	2552	2454	371	304	654	2209	2461	11966
Snakefish	*Trachinocephalus myops*			1						1
Striped Bass	*Morone saxatilis*					1				1
Striped Killifish	***Fundulus majalis***	21	660	143	34	614	57	27	50	1606
Striped Sea Robin	*Prionotus evolans*					2				2
Summer Flounder	*Paralichthys dentatus*	1	3		1				2	7
Tautog	***Tautoga onitis***	4	2	3	5	6	4	5	1	30
Threespine Stickleback	***Gasterosteus aculeatus***	2							6	8
Windowpane	***Scophthalmus aquosus***			5	2	4	1	1		13
Winter Flounder	***Pseudopleuronectes americanus***	13	45	32	21	17	24	9	31	192
	Total individuals	1069	3327	2783	484	1185	802	2289	2764	**Total Fish**
	Number of species	12	14	15	15	20	13	14	11	**14703**

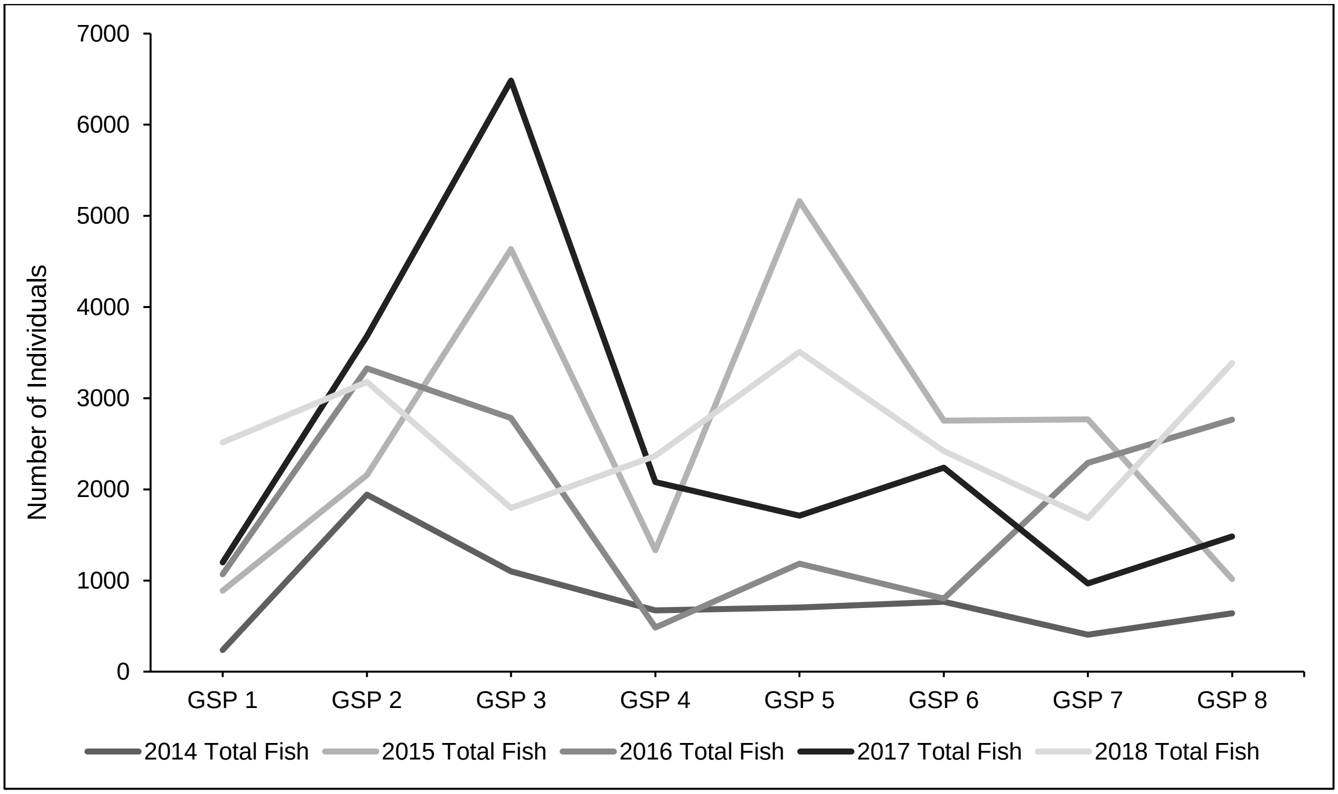
Appendix 2c. Catch frequency of species collected per station in 2015. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

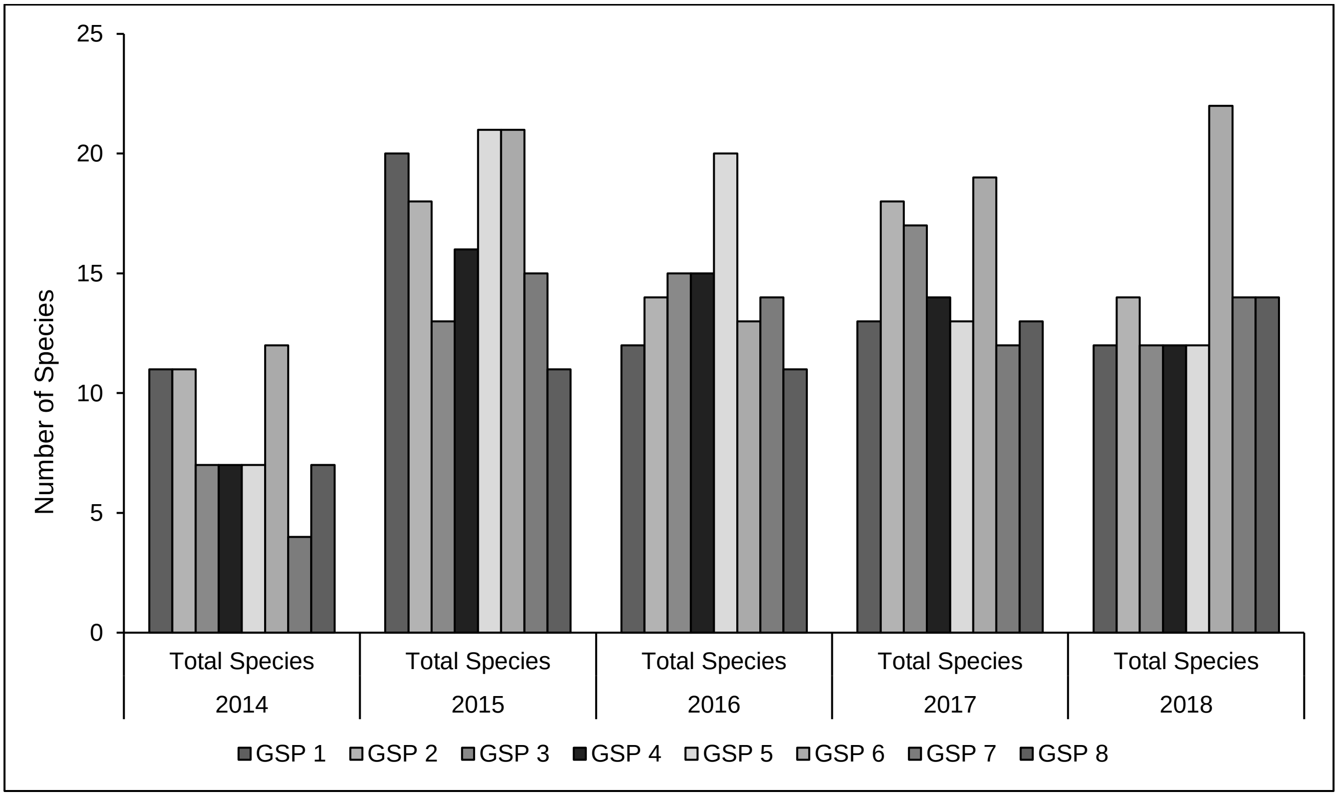
2015		Station								
Common Name	**Scientific Name**	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	Total
Alewife	***Alosa pseudoharengus***		1	2		7	2			12
American Sand Lance	***Ammodytes americanus***				1	1200	20			1221
Atlantic Cod	***Gadus morhua***				1					1
Atlantic Croaker	*Micropogonias undulatus*	4	3			33	13			53
Atlantic Menhaden	***Brevoortia tyrannus***	20								20
Bay Anchovy	***Anchoa mitchilli***					1				1
Bighead Sea Robin	*Prionotus tribulus*		2			2	1	3	1	9
Black Sea Bass	***Centropristis striata***	21	7	23	112	453	218	64		898
Blueback Herring	***Alosa aestivalis***								1	1
Bluespotted Cornetfish	*Fistularia commersonii*						1			1
Bonefish	*Albula vulpes*		3							3
Crevalle Jack	*Caranx hippos*		2							2
Cunner	*Tautogolabrus adspersus*	22		3	2	4	5	21		57
Dwarf Goatfish	*Upeneus parvus*	1								1
Fourspine Stickleback	*Apeltes quadracus*	1								1
Fourspot Flounder	*Paralichthys oblongus*		2							2
Grubby Sculpin	***Myoxocephalus aenaeus***				3	1	6	1		11
Leopard Sea Robin	*Prionotus scitulus*					9				9
Longfin Squid	*Loligo pealeii*					1				1
Longhorn Sculpin	*Myoxocephalus octodecimspinosus*	2	3		2			2		9
Mummichog	***Fundulus heteroclitus***	38	12	32	6	27	9	29	46	199
Naked Goby	*Gobiosoma bosc*						2			2
Ninespine Stickleback	***Pungitius pungitius***								1	1
Northern Kingfish	*Menticirrhus saxatilis*		2					1	3	6
Northern Pipefish	*Syngnathus fuscus*	5			1	1	4	1		12
Northern Puffer	*Sphoeroides maculatus*				1	2				3
Northern Sea Robin	***Prionotus carolinus***						1			1
Northern Sennet	*Sphyraena borealis*		1							1
Orange Filefish	*Aluterus shoepfi*				1					1
Pinfish	*Lagodon rhomboides*	5	2				1	5	5	18
Rainwater Killifish	***Lacania parva***	18	1	6	6	14	5	7		57
Scup	*Stenotomus chrysops*	1				41		4		46
Sheepshead Minnow	***Cyprinodon variegatus***		20							20
Shortfin Squid	*Illex illecebrosus*	1								1
Shorthorn Sculpin	*Myoxocephalus scorpius*						4			4
Silversides spp.	***Atherinopsidae spp.***	621	948	4416	906	2804	2381	2562	474	15112
Smooth Trunkfish	*Rhinesomus triqueter*	1								1
Snakefish	*Trachinocephalus myops*			1						1
Spot	*Leiostomus xanthurus*			6						6
Spotfin Mojarra	*Eucinostomus argenteus*					20				20
Spotted Whiff	*Citharichthys macrops*	1				2				3
Striped Killifish	***Fundulus majalis***	8	1102	118	248	470	57	29	450	2482
Striped Sea Robin	*Prionotus evolans*						1			1
Summer Flounder	*Paralichthys dentatus*			1						1
Tautog	***Tautoga onitis***	105	8	5	20	6	21	35	1	201
Threespine Stickleback	***Gasterosteus aculeatus***	1							3	4
Windowpane	***Scophthalmus aquosus***			4	1	3	1			9
Winter Flounder	***Pseudopleuronectes americanus***	12	38	18	21	61	2	5	31	188
	Total individuals	888	2157	4635	1332	5162	2755	2769	1016	**Total Fish**
	Number of species	20	18	13	16	21	21	15	11	**20714**

Appendix 2d. Catch frequency of species collected per station in 2014. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

2014		**Station**								
Common Name	**Scientific Name**	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	Total
Alewife	***Alosa pseudoharengus***		1							1
Atlantic Croaker	*Micropogonias undulatus*		1							1
Atlantic Herring	***Clupea harengus***		2							2
Atantic Silverside	***Menidia menidia***	107	585	441	605	511	474	351	575	3649
Black Sea bass	***Centropristis striata***		4	4		4	12		1	25
Bluefish	***Pomatomus saltatrix***			1						1
Grunt	*Haemulon spp*	1								1
Atlantic Lizardfish	*Synodus saurus*			1						1
Longhorn Cowfish	*Lactoria cornuta*	1								1
Mummichog	***Fundulus heteroclitus***	11	2				7	2		22
Pinfish	*Lagodon rhomboides*		1							1
Pipefish	*Syngnathus fuscus*				1	1	1			3
Pompano spp.	*Trachinotus spp.*				1					1
Northern Pufferfish	*Sphoeroides maculatus*	1					1			2
Rainwater Killifsh	***Lucania parva***	32	1	2	25	23	52	30	5	170
Sculpin spp.	***Myoxocephalus spp***	3					4			7
Northern Sea Robin	***Prionotus carolinus***						3			3
Lined Seahorse	***Hippocampus erectus***						1			1
Sheapshead minnow	***Cyprinodon variegatus***	1			1					2
Spot	*Leiostomus xanthurus*								1	1
Striped Bass	*Morone saxatilis*					2				2
Striped Killifish	***Fundulus majalis***	61	1319	642	34	132	196	21	36	2441
Tautog	***Tautoga onitis***	13	9						1	23
Windowpane	***Scophthalmus aquosus***						2			2
Winter Flounder	***Pseudopleuronectes americanus***	6	17	9	6	29	14		20	101
	Total individuals	237	1942	1100	673	702	767	404	639	**Total Fish**
	Number of species	11	11	7	7	7	12	4	7	**6464**

Appendix 2e. Time series counts for total individuals recorded as well as species frequency per station and survey year, 2014-2018.





Appendix 3: Time Series Tables, Winter Flounder, Great Salt Pond

Appendix 3a. Time series data for winter flounder frequency, 2014-2018.

	Time Series		Station											
		Month	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8	**Total**	**Mean**	**SD**	**SE±**
Winter Flounder	2014	May	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
		Jun	2	2	0	0	0	0	0	5	9	1.13	1.81	0.64
		Jul	0	7	0	4	4	0	1	7	23	2.88	3.04	1.08
		Aug	1	0	0	2	0	2	0	0	5	0.63	0.92	0.32
		Sep	2	8	9	0	19	4	0	2	44	5.50	6.41	2.27
		Oct	0	0	0	0	6	8	0	6	20	2.50	3.51	1.24
		Total	5	17	9	6	29	14	1	20				
		Mean	0.83	2.83	1.50	1.00	4.83	2.33	0.17	3.33		**Total Fish**		
		SD	0.98	3.71	3.67	1.67	7.39	3.20	0.41	3.08		**101**		
		SE±	0.40	1.51	1.50	0.68	3.02	1.31	0.17	1.26				
	2015	May	0	0	0	0	3	0	0	0	3	0.38	1.06	0.38
		Jun	0	5	0	3	3	0	0	20	31	3.88	6.79	2.40
		Jul	3	3	1	0	3	1	0	1	12	1.50	1.31	0.46
		Aug	2	20	4	1	0	0	0	8	35	4.38	6.89	2.43
		Sep	6	10	12	17	25	1	4	0	75	9.38	8.52	3.01
		Oct	1	0	1	0	27	0	1	2	32	4.00	9.32	3.30
		Total	12	38	18	21	61	2	5	31				
		Mean	2.00	6.33	3.00	3.50	10.17	0.33	0.83	5.17		**Total Fish**		
		SD	2.28	7.66	4.65	6.72	12.34	0.52	1.60	7.86		**188**		
		SE±	0.93	3.13	1.90	2.74	5.04	0.21	0.65	3.21				
	2016	May	0	3	0	1	1	0	0	13	18	2.25	4.46	1.58
		Jun	1	1	1	2	6	0	0	4	15	1.88	2.10	0.74
		Jul	3	9	2	7	0	5	0	1	27	3.38	3.34	1.18
		Aug	3	14	11	6	0	7	0	0	41	5.13	5.36	1.89
		Sep	5	17	16	3	4	12	5	8	70	8.75	5.55	1.96
		Oct	1	1	2	2	6	0	4	5	21	2.63	2.13	0.75
		Total	13	45	32	21	17	24	9	31				
		Mean	2.17	7.50	5.33	3.50	2.83	4.00	1.50	5.17		**Total Fish**		
		SD	1.83	6.92	6.56	2.43	2.86	4.94	2.35	4.79		**192**		
		SE±	0.75	2.83	2.68	0.99	1.17	2.02	0.96	1.96				
	2017	May	0	2	0	2	2	0	0	0	6	0.75	1.04	0.37
		Jun	2	3	11	1	18	1	2	2	40	5.00	6.19	2.19
		Jul	8	3	1	1	2	3	0	0	18	2.25	2.60	0.92
		Aug	0	0	0	7	9	3	0	0	19	2.38	3.66	1.29
		Sep	2	0	0	1	36	15	0	0	54	6.75	12.88	4.55
		Oct	2	3	3	0	3	0	0	11	22	2.75	3.62	1.28
		Total	14	11	15	12	70	22	2	13				
		Mean	2.33	1.83	2.50	2.00	11.67	3.67	0.33	2.17		**Total Fish**		
		SD	2.94	1.47	4.32	2.53	13.43	5.72	0.82	4.40		**159**		
		SE±	1.20	0.60	1.77	1.03	5.48	2.33	0.33	1.80				
	2018	May	2	1	1	0	1	0	0	0	5	0.63	0.74	0.26
		Jun	0	15	0	1	3	0	0	0	19	2.38	5.21	1.84
		Jul	0	18	0	1	18	1	2	2	42	5.25	7.91	2.80
		Aug	0	13	1	1	51	17	0	5	88	11.00	17.39	6.15
		Sep	7	13	0	8	48	12	0	4	92	11.50	15.53	5.49
		Oct	0	14	0	0	15	12	2	4	47	5.88	6.64	2.35
		Total	9	74	2	11	136	42	4	15				
		Mean	1.50	12.33	0.33	1.83	22.67	7.00	0.67	2.50		**Total Fish**		
		SD	2.81	5.85	0.52	3.06	21.82	7.54	1.03	2.17		**293**		
		SE±	1.15	2.39	0.21	1.25	8.91	3.08	0.42	0.89				

Appendix 3b. Summary table for time series data regarding winter flounder CPUE (fish/seine haul) per month and station, 2014-2018.

Winter Flounder CPUE

Time Series		Station							
	Month	GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8
2014	May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Jun	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.63
	Jul	0.00	0.88	0.00	0.50	0.50	0.00	0.13	0.88
	Aug	0.13	0.00	0.00	0.25	0.00	0.25	0.00	0.00
	Sep	0.25	1.00	1.13	0.00	2.38	0.50	0.00	0.25
	Oct	0.00	0.00	0.00	0.00	0.75	1.00	0.00	0.75
2015	May	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00
	Jun	0.00	0.63	0.00	0.38	0.38	0.00	0.00	2.50
	Jul	0.38	0.38	0.13	0.00	0.38	0.13	0.00	0.13
	Aug	0.25	2.50	0.50	0.13	0.00	0.00	0.00	1.00
	Sep	0.75	1.25	1.50	2.13	3.13	0.13	0.50	0.00
	Oct	0.13	0.00	0.13	0.00	3.38	0.00	0.13	0.25
2016	May	0.00	0.38	0.00	0.13	0.13	0.00	0.00	1.63
	Jun	0.13	0.13	0.13	0.25	0.75	0.00	0.00	0.50
	Jul	0.38	1.13	0.25	0.88	0.00	0.63	0.00	0.13
	Aug	0.38	1.75	1.38	0.75	0.00	0.88	0.00	0.00
	Sep	0.63	2.13	2.00	0.38	0.50	1.50	0.63	1.00
	Oct	0.13	0.13	0.25	0.25	0.75	0.00	0.50	0.63
2017	May	0.00	0.25	0.00	0.25	0.25	0.00	0.00	0.00
	Jun	0.25	0.38	1.38	0.13	2.25	0.13	0.25	0.25
	Jul	4.00	0.38	0.13	0.13	0.25	0.38	0.00	0.00
	Aug	0.00	0.00	0.00	0.88	1.13	0.38	0.00	0.00
	Sep	0.25	0.00	0.00	0.13	4.75	1.88	0.00	0.00
	Oct	0.25	0.38	0.38	0.00	0.38	0.00	0.00	1.38
2018	May	0.25	0.13	0.13	0.00	0.13	0.00	0.00	0.00
	Jun	0.00	1.88	0.00	0.13	0.38	0.00	0.00	0.00
	Jul	0.00	2.25	0.00	0.13	2.25	0.13	0.25	0.25
	Aug	0.00	1.63	0.13	0.13	6.38	2.13	0.00	0.63
	Sep	0.88	1.63	0.00	1.00	6.00	1.50	0.00	0.50
	Oct	0.00	1.75	0.00	0.00	1.88	1.50	0.25	0.50

Appendix 3c. The table below outlines the time series information regarding mean abundance ± SE (fish/seine haul) for winter flounder, 2014-2018. The total number of individuals recorded for each month were divided by the total number of hauls for each sampling season (8 hauls=8 stations).

Winter Flounder

Time Series	Month					
	May	Jun	Jul	Aug	Sep	Oct
Pond Index 2014	0.00	1.13	2.75	0.63	5.50	2.50
Pond Index 2015	0.63	14.50	9.25	10.00	10.13	4.75
Pond Index 2016	2.25	1.88	3.38	5.13	8.75	2.63
Pond Index 2017	0.75	5.00	2.25	2.38	6.75	2.75
Pond Index 2018	0.63	2.38	5.25	11.00	11.50	5.88

Appendix 4: Mean Average Length (mm), Winter Flounder, Great Salt Pond

Appendix 4a. Winter flounder mean average length (mm) per station and month, 2014-2018.

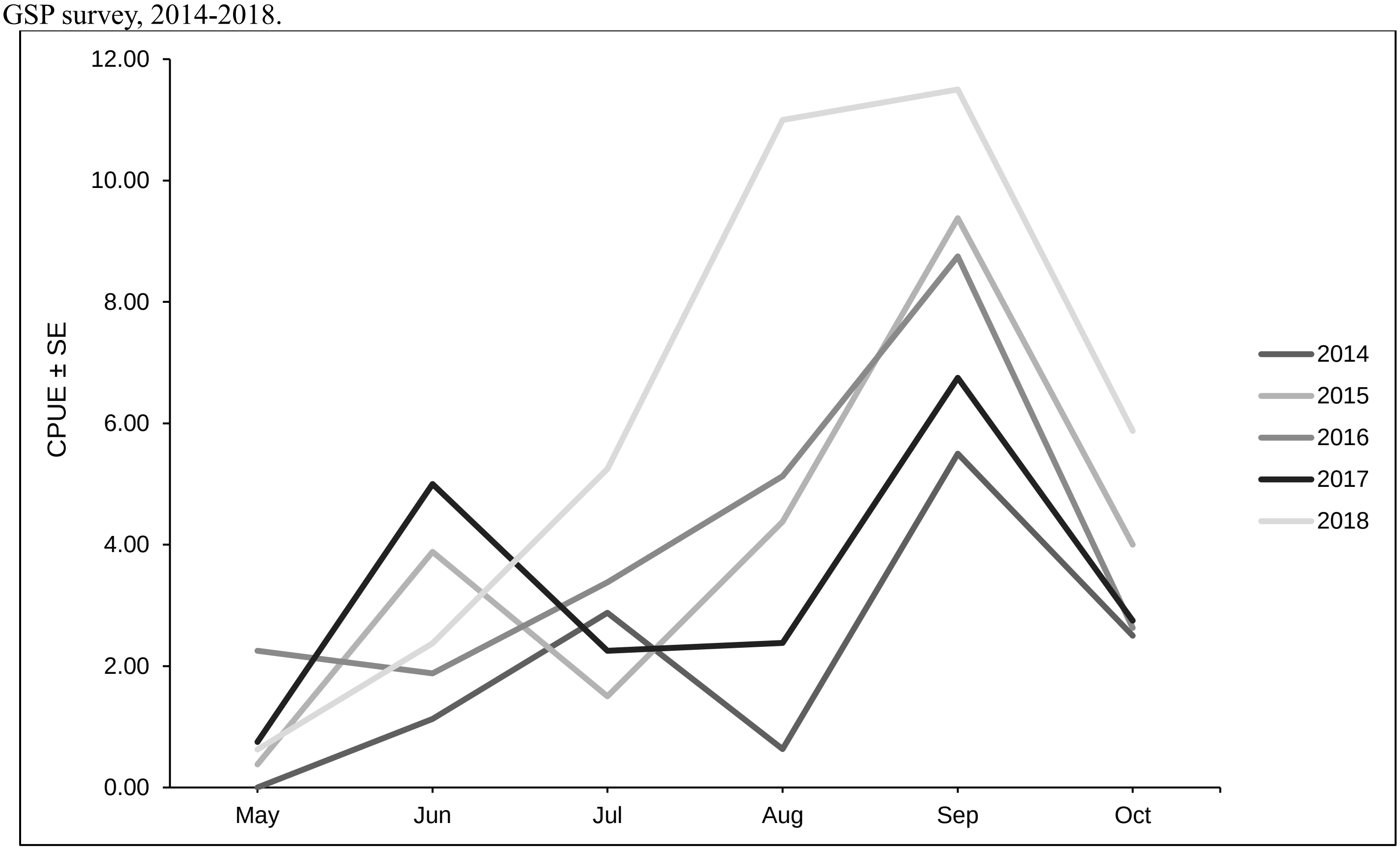
	Time Series		May	Jun	Jul	Aug	Sep	Oct
Winter Flounder	2014	GSP 1	0.00	37.00	0.00	50.00	55.00	0.00
		GSP 2	0.00	121.00	69.43	0.00	72.00	0.00
		GSP 3	0.00	0.00	0.00	0.00	72.00	0.00
		GSP 4	0.00	0.00	69.25	64.50	0.00	0.00
		GSP 5	0.00	0.00	95.00	0.00	66.36	85.00
		GSP 6	0.00	0.00	0.00	44.50	66.75	76.25
		GSP 7	0.00	0.00	0.00	0.00	0.00	0.00
		GSP 8	0.00	44.80	55.00	0.00	69.50	77.17
	2015	GSP 1	0.00	0.00	59.33	97.00	60.33	59.00
		GSP 2	0.00	84.00	56.00	59.10	68.64	0.00
		GSP 3	0.00	0.00	41.00	63.50	90.67	68.00
		GSP 4	0.00	117.67	0.00	63.00	68.59	0.00
		GSP 5	88.00	42.33	50.67	0.00	69.72	72.96
		GSP 6	0.00	0.00	55.00	0.00	50.00	0.00
		GSP 7	0.00	0.00	0.00	0.00	129.50	142.00
		GSP 8	0.00	78.84	171.00	59.75	0.00	77.50
	2016	GSP 1	0.00	97.00	161.50	0.00	143.00	0.00
		GSP 2	106.75	104.75	134.00	0.00	0.00	0.00
		GSP 3	105.69	192.00	0.00	0.00	94.00	0.00
		GSP 4	0.00	0.00	0.00	65.40	0.00	71.00
		GSP 5	90.00	64.40	0.00	80.63	0.00	80.80
		GSP 6	119.00	45.00	0.00	0.00	73.50	0.00
		GSP 7	0.00	0.00	0.00	0.00	0.00	0.00
		GSP 8	120.00	56.00	0.00	0.00	0.00	87.00
	2017	GSP 1	0.00	41.00	51.29	0.00	81.50	60.50
		GSP 2	118.50	81.33	47.67	0.00	0.00	76.00
		GSP 3	0.00	45.91	148.00	0.00	0.00	80.00
		GSP 4	113.50	36.00	49.00	58.67	88.00	0.00
		GSP 5	122.50	45.27	54.00	66.75	72.40	72.67
		GSP 6	0.00	37.00	41.00	66.00	62.18	0.00
		GSP 7	0.00	0.00	50.00	0.00	0.00	0.00
		GSP 8	0.00	38.50	0.00	0.00	0.00	89.75
	2018	GSP 1	100.00	0.00	0.00	0.00	78.50	0.00
		GSP 2	159.00	62.07	57.22	65.77	78.92	63.95
		GSP 3	130.00	0.00	0.00	51.00	0.00	0.00
		GSP 4	0.00	114.00	46.00	66.00	71.63	0.00
		GSP 5	112.00	51.67	54.67	82.51	84.42	69.93
		GSP 6	0.00	0.00	55.00	67.06	68.58	55.42
		GSP 7	0.00	0.00	58.00	0.00	0.00	58.00
		GSP 8	0.00	0.00	84.00	98.80	102.00	116.00

Appendix 4b. Summary table to show mean average lengths for winter flounder (including individuals >120mm) per month, station and survey year, 2014-2018.

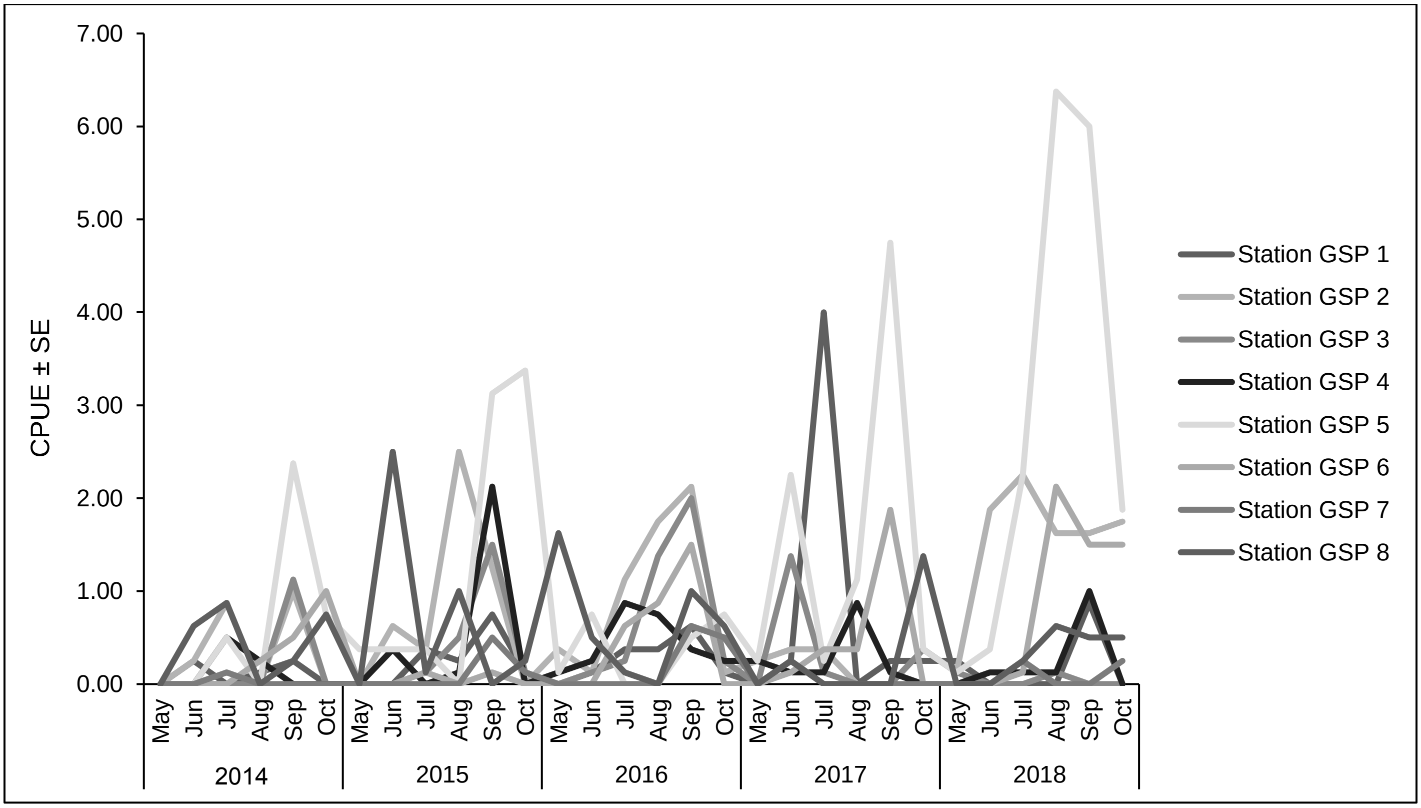
Time Series		GSP 1	GSP 2	GSP 3	GSP 4	GSP 5	GSP 6	GSP 7	GSP 8
2014	May	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Jun	37.00	121.00	0.00	0.00	0.00	0.00	0.00	44.80
	Jul	0.00	69.42	0.00	69.25	95.00	0.00	0.00	55.00
	Aug	50.00	0.00	0.00	64.50	0.00	44.50	0.00	0.00
	Sep	55.00	72.00	72.00	0.00	66.41	66.75	0.00	69.50
	Oct	0.00	0.00	0.00	0.00	85.00	76.25	0.00	77.20
2015	May	0.00	0.00	0.00	0.00	88.00	0.00	0.00	0.00
	Jun	0.00	84.00	0.00	117.67	42.33	0.00	0.00	78.84
	Jul	59.33	56.00	41.00	0.00	50.67	55.00	0.00	171.00
	Aug	97.00	59.10	63.50	63.00	0.00	0.00	0.00	59.75
	Sep	60.33	68.64	90.97	68.59	69.72	50.00	129.50	0.00
	Oct	59.00	0.00	68.00	0.00	72.96	0.00	142.00	77.50
2016	May	0.00	106.75	105.69	0.00	90.00	119.00	0.00	120.00
	Jun	97.00	104.75	192.00	0.00	64.40	45.00	0.00	56.00
	Jul	161.50	134.00	0.00	0.00	0.00	0.00	0.00	0.00
	Aug	0.00	0.00	0.00	65.40	80.63	0.00	0.00	0.00
	Sep	143.00	0.00	94.00	0.00	0.00	73.50	0.00	0.00
	Oct	0.00	0.00	0.00	71.00	80.80	0.00	0.00	87.00
2017	May	0.00	118.50	0.00	113.50	112.50	0.00	0.00	0.00
	Jun	41.00	81.33	45.91	36.00	45.27	37.00	0.00	38.50
	Jul	51.29	47.67	148.00	49.00	54.00	41.00	50.00	0.00
	Aug	0.00	0.00	0.00	58.67	66.75	66.00	0.00	0.00
	Sep	81.50	0.00	0.00	88.00	72.40	62.18	0.00	0.00
	Oct	60.50	76.00	80.00	0.00	72.67	0.00	0.00	89.75
2018	May	100.00	159.00	130.00	0.00	112.00	0.00	0.00	0.00
	Jun	0.00	62.07	0.00	114.00	51.67	0.00	0.00	0.00
	Jul	0.00	57.22	0.00	46.00	54.67	55.00	58.00	84.00
	Aug	0.00	65.77	51.00	66.00	82.51	67.06	0.00	98.80
	Sep	78.50	78.92	0.00	71.63	84.42	68.58	0.00	102.00
	Oct	0.00	63.95	0.00	0.00	69.93	55.42	58.00	116.00

Appendix 5: Time Series Figures, Winter Flounder, Great Salt Pond

Appendix 5a. Time series abundance indices CPUE ± SE (fish/seine haul) for YOY winter flounder for each month of the GSP survey, 2014-2018.

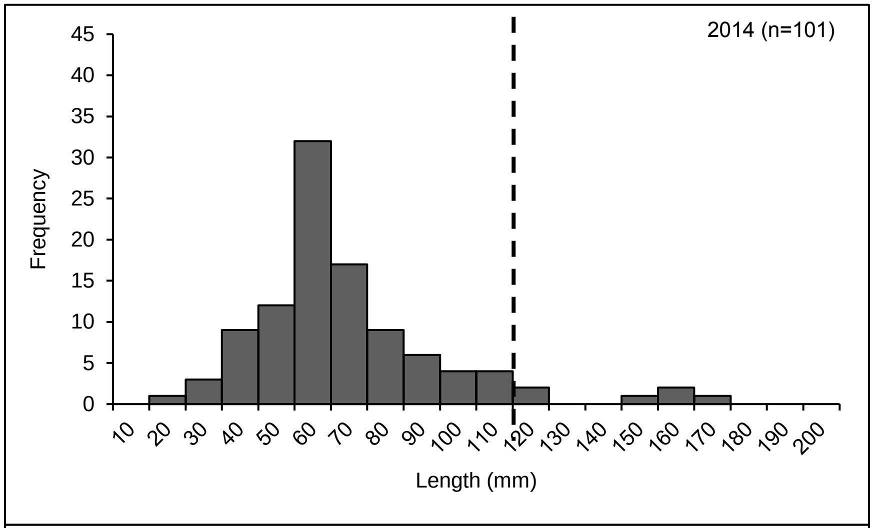


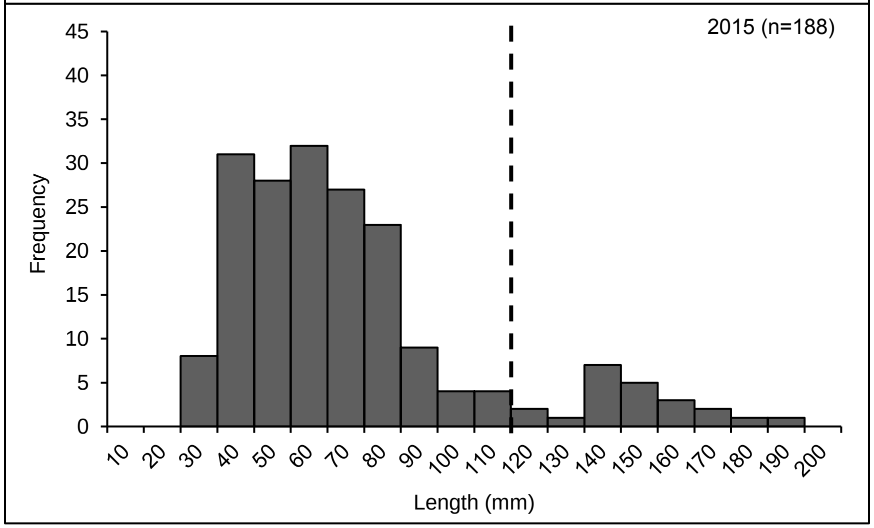
Appendix 5b. Time series abundance indices CPUE ± SE (fish/seine haul) for YOY winter flounder by month and station, 2014-2018.

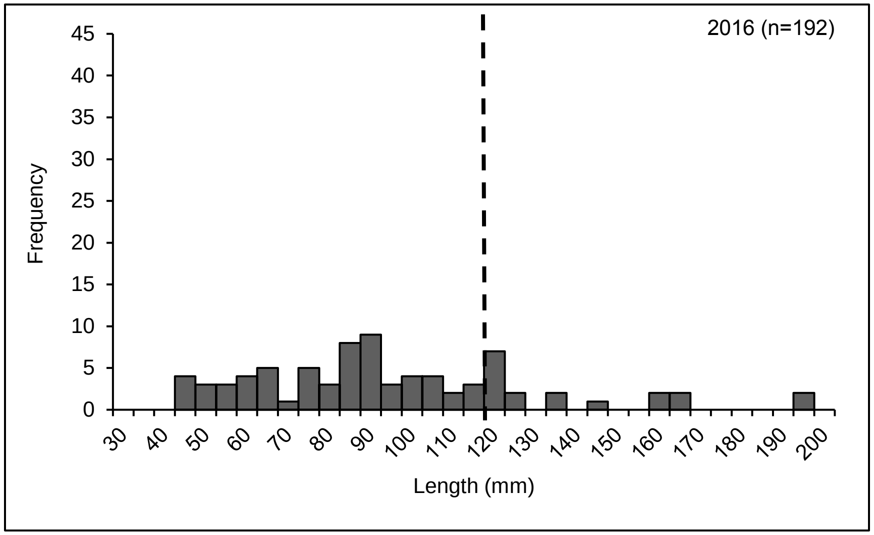


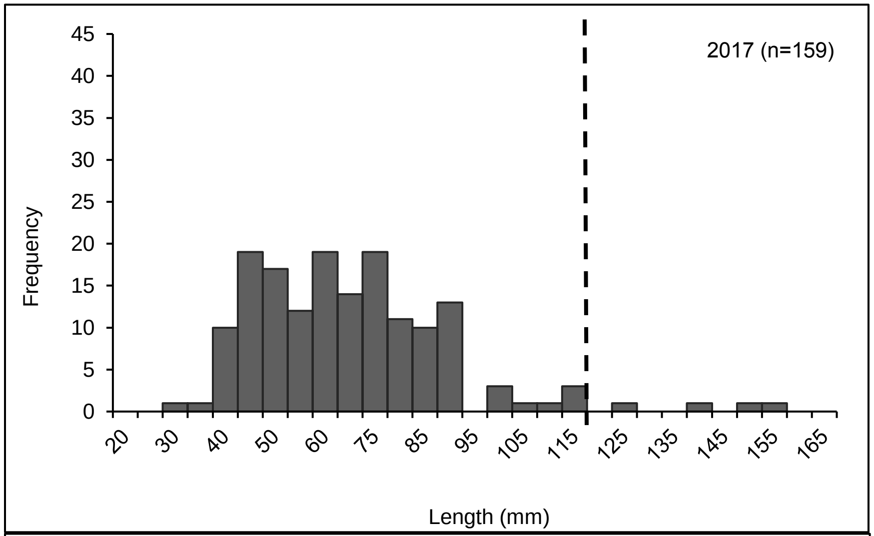
Appendix 6: Length Frequency Distributions, Winter Flounder, Great Salt Pond

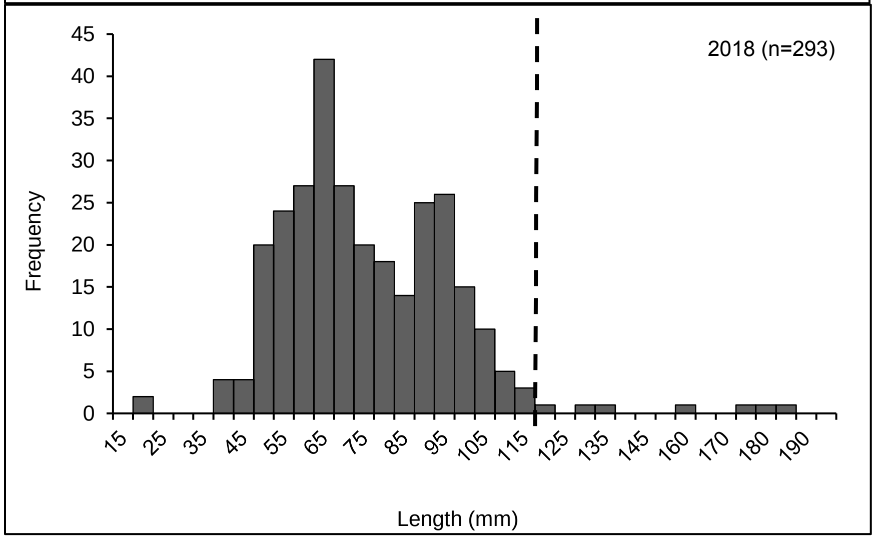
Appendix 6a. Length frequency distributions for winter flounder caught in time series survey, 2014-2018. The total number of YOY individuals were included in dataset per survey season.











Appendix 7: Time Series Presence/Absence, All Species, Old Harbor

Appendix 7a. Presence/absence of species catalogued for each survey year, 2014-2018. “1” represents present while blank slots represent absent. Bolded names represent SGCN identified by the RI Taxa Team in 2014.

Presence/Absence		Time Series				
Common Name	Scientific Name	2014	2015	2016	2017	2018
Alewife	***Alosa pseudoharengus***		1	1		1
Atlantic Cod	***Gadus moruha***					1
Atlantic Croaker	*Micropogonias undulatus*	1				
Atlantic Menhaden	***Brevoortia tyrannus***		1		1	1
Atlantic Needlefish	*Strongylura marina*				1	1
Atlantic Tomcod	***Microgadus tomcod***				1	1
Bighead Sea Robin	*Prionotus tribulus*		1			1
Black Sea Bass	***Centropristis striata***	1	1	1	1	1
Blueback Herring	***Alosa aestivalis***	1	1			
Bluefish	***Pomatomus saltatrix***			1		1
Bluespotted Cornetfish	*Fistularia tabacaria*				1	
Buffalo Trunkfish	*Lactophrys trigonus*					1
Crevalle Jack	*Caranx hippos*	1		1		
Cunner	*Tautogolabrus adspersus*	1	1	1	1	1
Damselfish spp.	*Pomacentridae*	1				
Dwarf Goatfish	*Upeneus parvus*		1			
Fourspine Stickleback	***Apeltes quadracus***		1			
Fourspot Flounder	*Paralichthys oblongus*		1			
Grubby	***Myoxocephalus aenaeus***		1	1		1
Hickory Shad	*Alosa mediocris*			1		
Lizardfish spp.	*Synodontidae spp.*	1				
Longhorn Sculpin	*Myoxocephalus octodecemspinos*		1			
Mojarras spp.	*Gerreidae spp.*			1		
Mummichog	***Fundulus heteroclitus***		1		1	
Naked Goby	*Gobiosoma bosc*					1

Appendix 7b. Continued table for time series presence/absence. 72 different species identified in the OH survey between 2014 and 2018.

Presence/Absence		Time Series				
Common Name	Scientific Name	2014	2015	2016	2017	2018
Ninespine Stickleback	***Pungitius pungitius***		1			
Northern Kingfish	*Menticirrhus saxatilis*			1		
Northern Pipefish	*Syngnathus fuscus*	1	1	1	1	1
Northern Puffer	*Sphoeroides maculatus*		1	1		1
Northern Sea Robin	***Prionotus carolinus***	1			1	1
Northern Sennet	*Sphyraena borealis*		1	1		
Pinfish	*Lagodon rhomboides*	1	1	1	1	1
Pollock	***Pollachius virens***			1		1
Rainwater Killifish	***Lacania parva***	1				
Sculpin spp.	*Cottidae spp.*	1			1	
Scup	*Stenotomus chrysops*			1	1	1
Sea Robin spp.	*Triglidae spp.*	1				
Sheepshead Minnow	***Cyprinodon variegatus***	1	1	1		
Shorthorn Sculpin	*Myoxocephalus scorpius*		1			
Silversides spp.	***Atherinopsidae spp.***	1	1	1	1	1
Smooth Trunkfish	*Lactophrys triqueter*					1
Spotfin Mojarra	*Eucinostomus argenteus*		1			
Spotted Trunkfish	*Rhinesomus triqueter*					1
Striped Killifish	***Fundulus majalis***	1	1	1	1	1
Striped Sea Robin	*Prionotus evolans*			1		1
Tautog	***Tautoga onitis***	1	1	1	1	1
Threespine Stickleback	***Gasterosteus aculeatus***		1			
White Mullet	*Mugil curema*			1		
Windowpane	***Scophthalmus aquosus***		1			
Winter Flounder	***Pseudopleuronectes americanus***	1	1	1	1	1
Yellow Jack	*Caranx bartholomaei*	1				

Appendix 7c. Catch frequency of all species collected for the time series survey, 2014-2018. The summary table shows total fish and number of species per year. A total of 18,378 individuals were collected between 2014 and 2018.

Presence/Absence		Time Series					
Common Name	Scientific Name	2014	2015	2016	2017	2018	Total
Alewife	***Alosa pseudoharengus***		15	18		165	198
Atlantic Cod	***Gadus moruha***					33	33
Atlantic Croaker	*Micropogonias undulatus*	1					1
Atlantic Menhaden	***Brevoortia tyrannus***		234		803	2562	3599
Atlantic Needlefish	*Strongylura marina*				10	2	12
Atlantic Tomcod	***Microgadus tomcod***				3	2	5
Bighead Sea Robin	*Prionotus tribulus*		8			1	9
Black Sea Bass	***Centropristis striata***	27	1	2	2	148	180
Blueback Herring	***Alosa aestivalis***	62	1				63
Bluefish	***Pomatomus saltatrix***			68		6	74
Bluespotted Cornetfish	*Fistularia tabacaria*				2		2
Buffalo Trunkfish	*Lactophrys trigonus*					4	4
Crevalle Jack	*Caranx hippos*	1		3			4
Cunner	*Tautogolabrus adspersus*	1	24	14	2	72	113
Damselfish spp.	*Pomacentridae*	1					1
Dwarf Goatfish	Mullidae		1				1
Fourspine Stickleback	***Apeltes quadracus***		1				1
Fourspot Flounder	*Paralichthys oblongus*		1				1
Grubby	***Myoxocephalus aenaeus***		1	4		36	41
Hickory Shad	*Alosa mediocris*			4			4
Lizardfish spp.	*Synodontidae spp.*	2					2
Longhorn Sculpin	*Myoxocephalus octodecemspinos*		10				10
Mojarras spp.	*Gerreidae spp.*			2			2
Mummichog	***Fundulus heteroclitus***		12		17		29
Naked Goby	*Gobiosoma bosc*					2	2
Ninespine Stickleback	***Pungitius pungitius***		3				3
Northern Kingfish	*Menticirrhus saxatilis*			4			4
Northern Pipefish	*Syngnathus fuscus*	2	1	5	4	34	46
Northern Puffer	*Sphoeroides maculatus*		1	1		15	17
Northern Sea Robin	***Prionotus carolinus***	3			7	7	17
Northern Sennet	*Sphyraena borealis*		1	6			7
Pinfish	*Lagodon rhomboides*	3	13	6	150	7	179
Pollock	***Pollachius virens***			206		541	747
Rainwater Killifish	***Lacania parva***	1					1
Sculpin spp.	*Cottidae spp.*	1			3		4
Scup	*Stenotomus chrysops*			1	16	97	114
Sea Robin spp.	*Triglidae spp.*	6					6
Sheepshead Minnow	***Cyprinodon variegatus***	78	3	2			83
Shorthorn Sculpin	*Myoxocephalus scorpius*		6				6
Silversides spp.	***Atherinopsidae spp.***	683	2096	1903	3056	2994	10732
Smooth Trunkfish	*Lactophrys triqueter*					1	1
Spotfin Mojarra	*Eucinostomus argenteus*		9				9
Spotted Trunkfish	*Rhinesomus triqueter*					1	1
Striped Killifish	***Fundulus majalis***	16	6	4	105	39	170
Striped Sea Robin	*Prionotus evolans*			1		1	2
Tautog	***Tautoga onitis***	2	26	19	26	295	368
Threespine Stickleback	***Gasterosteus aculeatus***		2				2
White Mullet	*Mugil curema*			4			4
Windowpane	***Scophthalmus aquosus***		2				2
Winter Flounder	***Pseudopleuronectes americanus***	68	209	592	373	219	1461
Yellow Jack	*Caranx bartholomaei*	1					1
	Total individuals	959	2687	2869	4579	7284	**Total Fish**
	Number of species	19	26	22	16	25	**18378**

Appendix 8: Metrics and Rationale

Appendix 8a. Additional Species of Interest by Functional Group.

Bait: Killifish (Rainwater, Striped, Silversides, Mummichog).

Pelagic (multi-habitat): Menhaden, Spot, Herring (River Herring, Alewife, Bluefish, Pinfish, Mullet (White, Striped), Needlefish, Northern Sennet, Butterfish, Northern Kingfish, White Perch, Weakfish, Sand Tiger Shark, American Amberjack, Atlantic Croaker, Banded Rudderfish.

Demersal: Oyster Toadfish, Cunner, Striped Sea Robin, Sticklebacks (Threespine, Fourspine), American Eel (mostly demersal), Naked Goby, Northern Pipefish, Sculpins, Summer Flounder, Smooth Dogfish, Hogchoker.

Crustaceans (mobile invertebrates, shrimp): Sand Shrimp, Grass Shrimp, Spider Crab, Blue Crab, Green Crab, Mud Crab, Lady Crab, Rock Crab, Mantis Shrimp.

Appendix 8b. Summary information for species collected in GSP and OH seines for 2018 survey.

Great Salt Pond

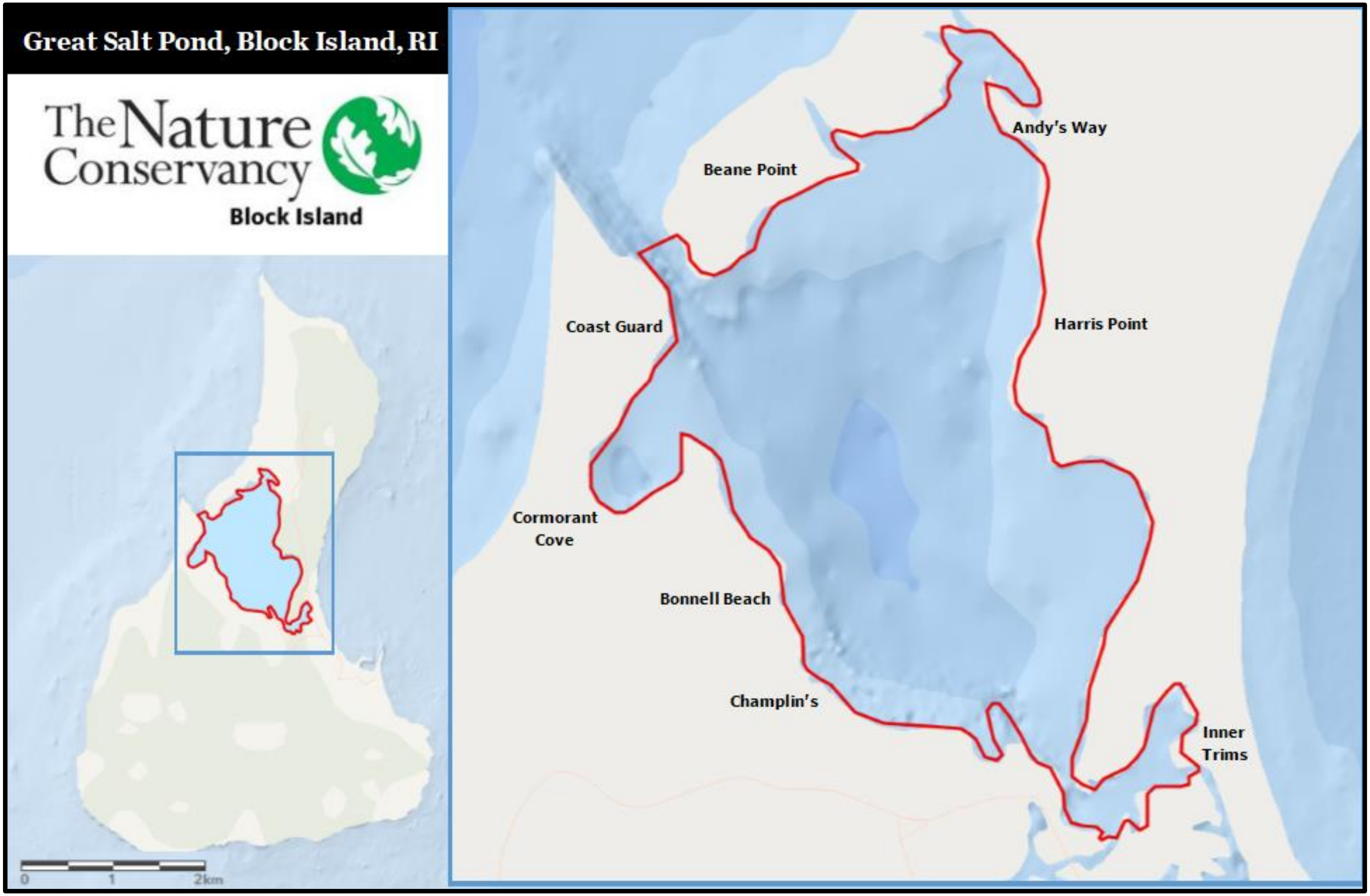
2018 investigators recorded 20,855 fish representing 41 different species from 20 families in 2018 (see Table 6 for catch data summary). The total number of fishes marked the highest overall count for the time series: 2014 (totnum=6,467); 2015 (totnum=20,714); 2016 (totnum=14,703); 2017 (totnum=19,842) (see catch frequency table in Appendix 1b for complete breakdown of all species catalogued from 2014 through 2018). Based on the geometric mean catch per haul, the most abundant fish in descending rank order for 2018 were 1) silversides spp., 2) Atlantic menhaden, 3) striped killifish, 4) American sand lance, 5) mummichog, and 6) winter flounder.

Old Harbor

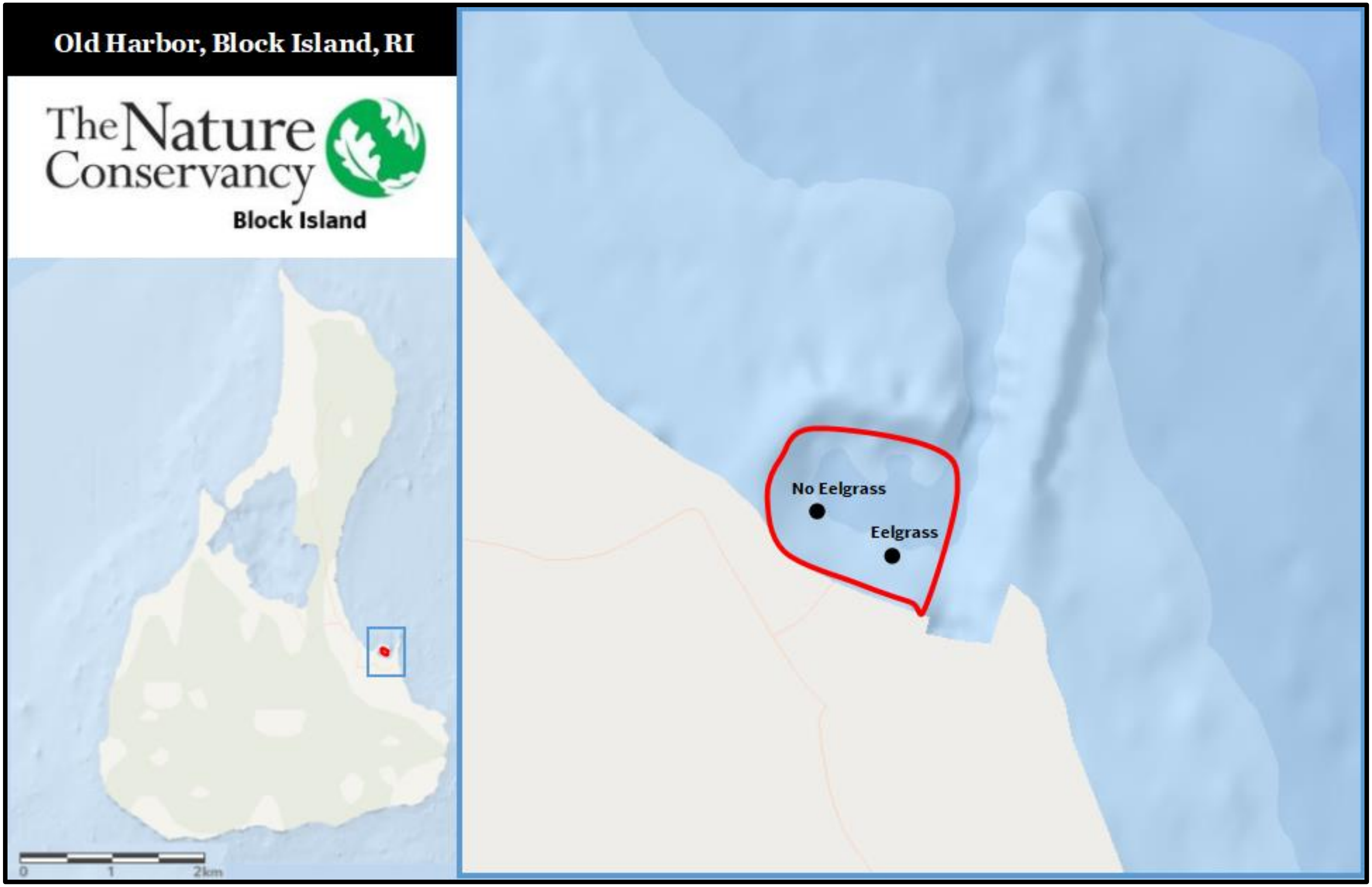
In 2018, TNC investigators caught 25 species of finfish representing 16 families in OH (see Table 18 for catch data summary). The total number of individuals collected during 2018 survey was second to the overall highest for time series record (totnum: 7,284). The species of highest frequency for 2018 ranked in descending order were: 1) silversides spp. (n=2,994), 2) Atlantic menhaden (n=2,562), 3) pollock (n=541), 4) tautog (n=295), 5) winter flounder (n=219). High frequencies of silversides and Atlantic menhaden may be reflective of large catches recorded during September and October sampling events. Catches of juvenile pollock occurred at both stations during May and October seine sessions.

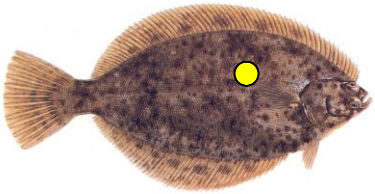
Appendix 9: Inset Maps, Study Areas

Appendix 9a. Inset map for the Great Salt Pond (ESRI 2017).



Appendix 9b. Inset map for Old Harbor (ESRI 2017).





Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters

Winter Flounder Spawning Stock Biomass Survey in Pt. Judith Pond, RI

Scott D. Olszewski
Deputy Chief
Scott.Olszewski@dem.ri.gov

John Lake
Supervising Marine Biologist
John.Lake@dem.ri.gov

Katie Rodrigue
Principal Marine Biologist
Katherine.Rodrigue@dem.ri.gov

Rhode Island Department of Environmental Management
Division Marine Fisheries
3 Fort Wetherill Road
Jamestown, RI 02835

Federal Aid in Sportfish Restoration
F-61-21

Performance Report March 2019

State: Rhode Island Project Number: F-61-R-21

Project Title: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

Period Covered: January 1, 2018 – December 31, 2018

Job Number and Title: Job III - Spawning Stock Biomass (SSB) in Rhode Island Coastal Ponds.

Job Objective: To support a seasonal Young of the Year Winter flounder survey by providing data on the dynamics and abundance of the spawning population of winter flounder in Rhode Island coastal ponds.

Significant Deviations: Staff limitations are leading to a shortened sampling period. The addition of staff should allow more robust sampling in 2019.

Summary:

In 1999, the Rhode Island Coastal Ponds Project was expanded to support an adult winter flounder monitoring and tagging project. This winter phase of the seasonal coastal pond juvenile flounder work was an opportunity to collect data on the adult spawning populations of winter flounder in the south shore coastal ponds. An experimental winter flounder tagging study and monitoring project could be conducted with little additional funding or manpower. A commercial fisherman who had historically fished for winter flounder in the coastal ponds agreed to assist the RI Marine Fisheries staff and get the survey off the ground.

The research project runs from January through May annually. Fishing gear is deployed depending on ice cover in the ponds and the gear is generally hauled on three to seven-night sets. There is a total of ten stations where data exists, with eight found in the Pt. Judith Pond system (including Potter Pond) and two in Charlestown/Ninigret Pond (NOAA Nautical Charts 13219 and 13215). Point Judith and Potter Ponds use the same breach to connect to the Block Island and Rhode Island Sounds.

Additional Research:

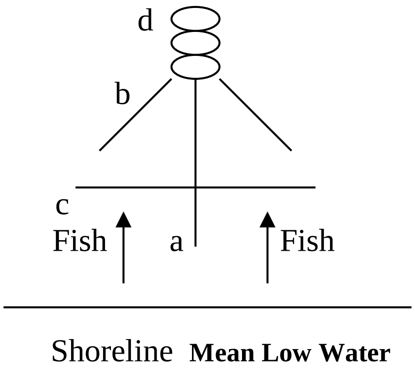
In 2012, an additional coastal pond system was added to the survey. As adult winter flounder abundance in the Point Judith system declined to all-time lows, the adjacent Charlestown Pond (also known as Ninigret Pond (NOAA Nautical Chart 13215)) was surveyed during the same time period and continued during the 2015 sampling year. During this period, Rhode Island Coastal Trawl Survey data (Spring Survey) showed a sharp increase in relative abundance in the Block Island Sound area. This appeared to be similar to the trend seen in the Charlestown Pond system. However, in more recent years, winter flounder captured in the Spring Trawl Survey has declined and shown an overall downward trend throughout the time series. Charlestown Pond has not been sampled since 2015 but will be surveyed again beginning in 2019. If, through this continuation of the multiple sampling areas, Point Judith continues to experience low abundance and recruitment while other area surveys show a diverging trend, then the assumption would be that the Point Judith system is having localized winter flounder depletion from sources other than fishing mortality. Commercial fishing activity in Block Island Sound is also returning valuable tag recapture information from the Charlestown Pond sampling, that which is now missing from the Point Judith Pond survey due to the inability to catch enough fish to tag. The Environmental Protection Agency partnered in this project on Charlestown Pond and currently has collected data during three winter survey seasons. In the future, this data set will be added to the current Adult Winter Flounder time series which was existed since 1999.

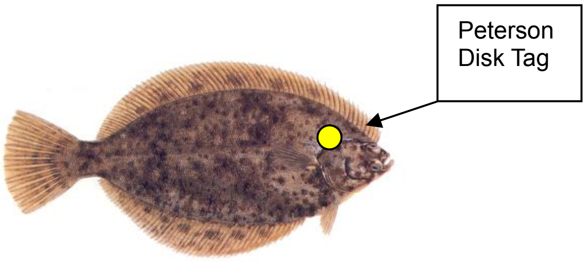
Methods and Materials:

Fyke Nets are a passive fixed fishing gear, attached perpendicular to the shoreline at mean low water. A vertical section of net wall or leader directs fish toward the body of the net where the catch is funneled through a series of parlors, eventually being retained in the terminal parlor. The wings of the net accomplish further direction of the catch. Adult winter flounder are tagged using Peterson Disk Tags.

Net dimensions:
a. Leader - 100'
b. Wings - 25'
c. Spreader Bar - 15'
d. Net parlors – 2.5'
Mesh size - 2.5" throughout

Station water profile:
Depth / turbidity - feet
Dissolved oxygen - mg/l
Salinity - ppt
Temperature - degree C





Fieldwork:

Three fyke nets were set at three fixed stations in Pt. Judith and Potter Ponds during January and April in 1999-2001, and two nets are typically set at five fixed stations from 2002 to present. However, due to staffing limitations and ice and snow obstructing access to the ponds in February 2018, nets were set at two fixed stations in the Point Judith/Potter Pond system and sampled three times during the season. The nets are fixed at mean low water and set perpendicular to the shoreline. Fyke nets are a passive fishing gear and allow the catch to be retained alive for a short period of time. Nets are tended from two to seven days depending on the size of the catch and weather conditions. Higher catches increase density inside the net and attract predators such as cormorants, seals, and otters thus increasing survey-induced mortality.

All fish captured are measured, sexed, enumerated and categorized to describe spawning stage. Spawning stage is defined as ripe (pre-spawn), ripe/running (active spawn), spent (post-spawn), resting (non-active spawn) and immature. These data illustrate how the spawning activity of flounder advances throughout the duration of the survey season. This is useful in determining the potential impacts of coastal zone activities such as harbor and breach way dredging and pier construction.

Fish of legal size (30.48 cm) or recruits to the fishery are tagged and released away from the capture area. Tagging and recapture data is presented in Tables 1-4.

Fisheries:

Winter Flounder (***Pseudopleuronectes americanus***) are both a commercially and recreationally important species to the State of Rhode Island. From 1999-2018, commercial landings of winter flounder in Rhode Island averaged over 300 metric tons and an average value of one million dollars annually (Table 4, Figure 1). Throughout the time series, landings have shown an overall downward trend. Recreational harvest has declined rapidly throughout the period and remains low through 2018 (Figure 2) (NMFS 2018 commercial landings query and MRIP database). Note that due to the rarity of the MRIP Access Point Angler Intercept Survey encountering anglers who have captured winter flounder, the percent standard error (PSE) for these data points is commonly very high (Table 5).

Spawning Behavior: Pt Judith / Potters Pond System

Winter Flounder enter the south shore coastal pond systems in Rhode Island to spawn in the early part of winter (typically in November) and engage in spawning activity from January through May annually. Spawning and egg deposition takes place on sandy bottoms and algal accumulations. Winter Flounder eggs are non-buoyant and clump together on these substrates. Survey data indicate that peak-spawning activity takes place during the month of February, however this appears to vary annually in relation to average water temperatures. Figure 3 displays the ratios of spawning stages of winter flounder captured from 1999-2018 by month. Approximately 55% of fish captured in 2018 were sexually immature and therefore would not have contributed to spawning.

Spawning occurs in inshore waters at close to seasonal minimal water temperatures of 0 - 1.7 degrees C and in estuarine salinities as low as 11.4 ppt. (Bigelow and Schroeder 2002). With the shortened sampling period in 2017, temperature and salinity data were not available. Sampling was again limited in 2018 due to staffing limitations and a high number of days with ice and snow obstructing pond access in February, and only temperature data was recorded (Figure 4). Due to a limited number of sampling days, data was only recorded on three days in March, with two readings for both 3/19/2018 and 3/28/2018.

Sex ratios throughout the time series tend to favor females. Similar observations were made in Green Hill Pond, a neighboring coastal pond (Saila 1961), and in Narragansett Bay (Saila 1962). Sex ratios for winter flounder captured from 1999-2018 are shown in Figure 5.

Note that here immature fish refers to those individuals that were too young to sex, and not the spawning stage. Therefore, some of these male and female fish were still immature in terms of spawning stage. Refer to Figure 3 for spawning stage composition by month over the time series.

Size Distribution: Pt Judith/Potter Pond System

The total number of winter flounder sampled during the 2018 survey was 36. This was a 350% increase from the 2017 survey. This may be due in part to the slightly decreased sampling effort in 2018 compared to 2017 which would add a high degree of variability. The Catch per Unit Effort was greater in 2018 (6.0 fish/net haul versus 2.0 fish/net haul). Sizes ranged from 14cm to 38cm (Figure 6). The mean size sampled was 20.6 cm.

Results:

2018 Adult winter flounder CPUE in Pt Judith Pond increased to 6.0 fish per net haul (Figure 7). This is an increase of 4 fish/haul from 2017. However, this value is still well below the time series high of 24.4 in 2001. The catch rates have shown a downward trend throughout the time series with the 2014 CPUE being the lowest data point ever recorded. CPUE for sampling in Charlestown Pond from 2012-2015 is shown in Figure 8. In 2018, a total of 5 mature fish were tagged in the Point Judith Pond system. No recaptured fish were reported.

Additional Species captured throughout survey time series:

Summer Flounder	***Paralicthes detatus***
Striped Bass	***Morone saxatilis***
White Perch	***Morone americana***
Atlantic Tomcod	***Microgadus tomcod***
Tautog	***Tautoga onitis***
Alewife	***Alosa pseudoharengus***
Atlantic Menhaden	***Brevortia tyrannus***
American Eel	***Anguilla rostrata***
Horseshoe Crab	***Limulus polyphemus***
American Lobster	***Homarus americanis***
Green Crab	***Carcinus maenas***
Atlantic Rock Crab	***Cancer irroratus***
Blue Crab	***Callinectes sapidus***
Longnose Spider Crab	***Libinia dubia***
Portly Spider Crab	***Libinia emarginata***

Discussion:

Much lower catch rates are being observed in the later years of the adult coastal pond survey. For some time, the data indicated that the problems found in nearby Narragansett Bay were not as obvious in the south shore coastal ponds and that possibly, there were lower fishing mortality rates exhibited on the stocks that inhabit theses ponds and Block Island Sound. Continued sampling in the Point Judith Pond system as well as the Charlestown Pond system is necessary to monitor these trends.

Tagging/recapture data gives accurate estimations on population size and year class structure. These estimations depend on additional years and recapture data and therefore show the need for a more long-term approach to adult winter flounder assessments in Rhode Island south shore coastal ponds. Total tag return rates over the survey time series are between 9.2% and 12.4% for Point Judith Pond and 11.3% for Charlestown Pond (Tables 2, 3, and 5). In past years, almost the entire set of tag returns came from the recreational fishery, which has been closed since 2012. The offshore trawl fleet has been the source of tag returns in the more recent years (along with survey recaptures) indicating the increased willingness of the offshore commercial trawler fleet to supply information on flounder movements and mortality rates. Tagging and recapture data is presented in Tables 1-5.

Recommendations:

Continuation of all adult winter flounder work statewide in order to make accurate connections between coastal ponds, Narragansett Bay, and Rhode Island/Block Island Sound winter flounder stocks is necessary. In addition, the survey in the Charlestown Pond System will be continued in 2019 in order to track local adult winter flounder abundance and use the catch as a source of taggable animals to gain information on population size, mortality and year class structure. Although sampling in this pond in 2019 will be completed at a lesser scale than in the past due to the staffing and gear limitations, it is expected to be resumed at a greater extent in 2020 and beyond. The importance of returning tag data from the commercial trawl fleet in Rhode Island Sound and Block Island Sound should be stressed in order to facilitate continued reporting of recaptured fish. The addition of dedicated staff should be investigated, as current staffing limitations are part of the reason for shortened sampling season. With the addition of staff in 2019, this constraint should be alleviated.

References:

Collette B. and Klein-MacPhee G. 2002   Bigelow and Schroeder's Fishes of the Gulf of Maine. 3rd edition

Saila, S. B. 1961. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf Carib. Fish. Inst.

Saila, S. B. 1962. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. Trans. American Fisheries Society

Table 1 - WFL Tagging/Recapture totals in PJ Pond by year

Year	Number caught	Number tagged	Number recaptured
1999	1301	332	31
2000	417	208	31
2001	538	358	70
2002	265	182	18
2003	160	87	6
2004	102	64	14
2005	252	115	7
2006	416	91	9
2007	120	35	6
2008	42	14	2
2009	63	0	0
2010	85	19	0
2011	68	11	0
2012	41	15	0
2013	22	5	0
2014	14	3	0
2015	56	14	0
2016	14	2	0
2017	8	2	0
2018	36	5	0
Total	4020	1562	194

Table 2 - Tagging/Recapture Data by Year in PJ Pond (recaptured by survey and commercial/recreational fishing activity)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**Total**	% recap by year
1999	31	8	10	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	15.36144578
2000		23	17	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	22.11538462
2001			43	11	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	15.92178771
2002				1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2.747252747
2003					1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4.597701149
2004						9	1	2	0	0	0	0	0	0	0	0	0	0	0	0	12	18.75
2005							4	4	2	1	0	0	0	0	0	0	0	0	0	0	11	9.565217391
2006								3	2	0	0	0	0	0	0	0	0	0	0	0	5	5.494505495
2007									2	1	0	0	0	0	0	0	0	0	0	0	3	8.571428571
2008										0	0	0	0	0	0	0	0	0	0	0	0	0
2009											0	0	0	0	0	0	0	0	0	0	0	0
2010												0	0	0	0	0	0	0	0	0	0	0
2011													0	0	0	0	0	0	0	0	0	0
2012														0	0	0	0	0	0	0	0	0
2013															0	0	0	0	0	0	0	0
2014																0	0	0	0	0	0	0
2015																	0	0	0	0	0	0
2016																		0	0	0	0	0
2017																			0	0	0	0
2018																				0	0	0
																						Total % recap over time series
Total	**31**	**31**	**70**	**18**	**6**	**14**	**7**	**9**	**6**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**194**	**12.41997439**

Table 3 - Tagging/Recapture Data by Year in PJ Pond (recaptured by commercial/recreational fishing activity only)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	% recap by year
1999	26	6	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	11.74698795
2000		18	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	13.46153846
2001			39	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	12.29050279
2002				1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2.747252747
2003					1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4.597701149
2004						9	1	2	0	0	0	0	0	0	0	0	0	0	0	0	12	18.75
2005							1	3	2	1	0	0	0	0	0	0	0	0	0	0	7	6.086956522
2006								1	1	0	0	0	0	0	0	0	0	0	0	0	2	2.197802198
2007									2	1	0	0	0	0	0	0	0	0	0	0	3	8.571428571
2008										0	0	0	0	0	0	0	0	0	0	0	0	0
2009											0	0	0	0	0	0	0	0	0	0	0	0
2010												0	0	0	0	0	0	0	0	0	0	0
2011													0	0	0	0	0	0	0	0	0	0
2012														0	0	0	0	0	0	0	0	0
2013															0	0	0	0	0	0	0	0
2014															0	0	0	0	0	0	0	0
2015																	0	0	0	0	0	0
2016																		0	0	0	0	0
2017																			0	0	0	0
2018																				0	0	0
																						Total % recap over time series
Total	**26**	**24**	**54**	**3**	**6**	**14**	**4**	**6**	**5**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**144**	**9.218950064**

Table 4 - WFL Tagging/Recapture totals in Charlestown Pond by year

Year	Number caught	Number tagged	Number recaptured
2012	113	98	11
2013	147	128	12
2014	33	33	3
2015	140	67	11
2016	0	0	0
Total	**433**	**326**	**37**

Table 5 - Tagging/Recapture Data by Year in Charlestown Pond (recaptured by survey and commercial/recreational fishing activity)

	2012	2013	2014	2015	2016	Total	% recap by year
2012	10	0	1	0		11	11.2244898
2013		11	1	0		12	9.375
2014			2	1	1	4	12.12121212
2015				10		10	14.92537313
2016					0	0	
							Total % recap over time series
Total	**10**	**11**	**4**	**11**	**0**	**37**	**11.34969325**

Table 6 - Commercial Landings and Value of WFL in Rhode Island

Year	Landings (metric tons)	Value (millions of dollars)
1999	525	1.4
2000	813.1	1.8
2001	658.5	1.4
2002	602	1.5
2003	470.6	1.2
2004	394.5	1
2005	306.4	0.97
2006	586.4	2.5
2007	530.1	2.4
2008	289.3	1.3
2009	140.2	0.49
2010	34.1	0.15
2011	37.9	0.13
2012	20.1	0.09
2013	181.7	0.6
2014	206.2	0.94
2015	167.4	0.74
2016	135.7	0.82
2017	135.8	0.9
2018	86.7	0.574
Average	316.0844833	1.0452

Table 2 - MRIP Estimated Recreational Harvest for WFL in Rhode Island

Estimate Status	Year	Total Harvest (A+B1)	Percent Standard Error
FINAL	1999	134,519	23.7
FINAL	2000	68,191	29.9
FINAL	2001	96,166	31.9
FINAL	2002	31,266	28.5
FINAL	2003	24,619	48.3
FINAL	2004	17,675	48.9
FINAL	2005	60	65.8
FINAL	2006	27	72.1
FINAL	2007	999	99.1
FINAL	2008	4,246	105.8
FINAL	2009	20,600	79.2
FINAL	2010	5,082	106.3
FINAL	2011	0	.
FINAL	2012	0	.
FINAL	2014	624	97.4
FINAL	2015	44	102.5
FINAL	2016	2,422	97.5
FINAL	2017	8,331	108.3
PRELIMINARY	2018	325	71.5

Figure 1 - WFL Commercial Landings - 1999-2018

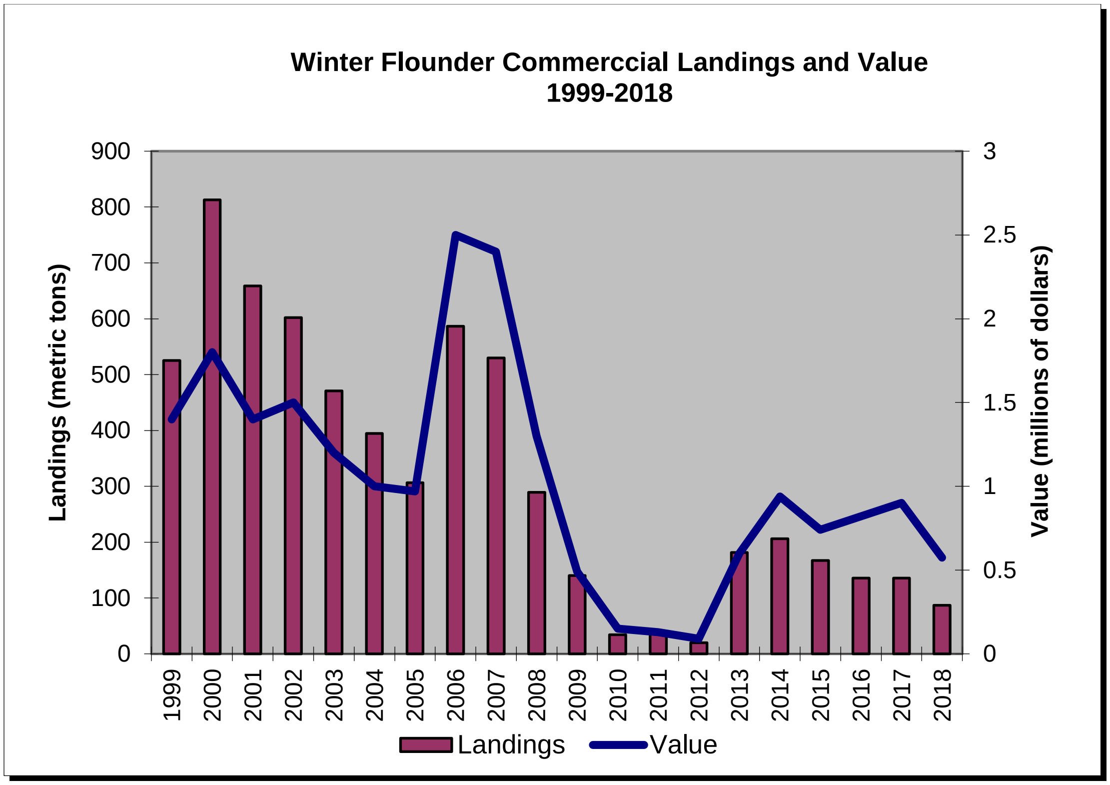


Figure 2 - WFL Recreational Harvest - 1999-2018

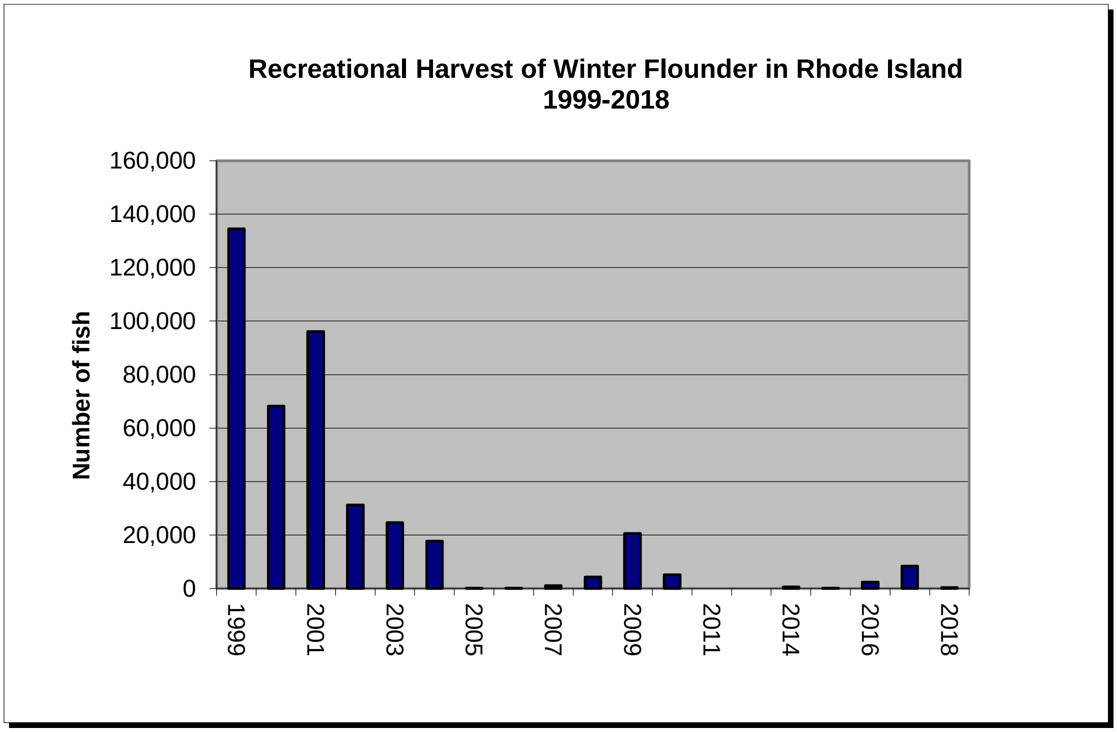


Figure 3 - WFL Spawning Stages 1999-2018

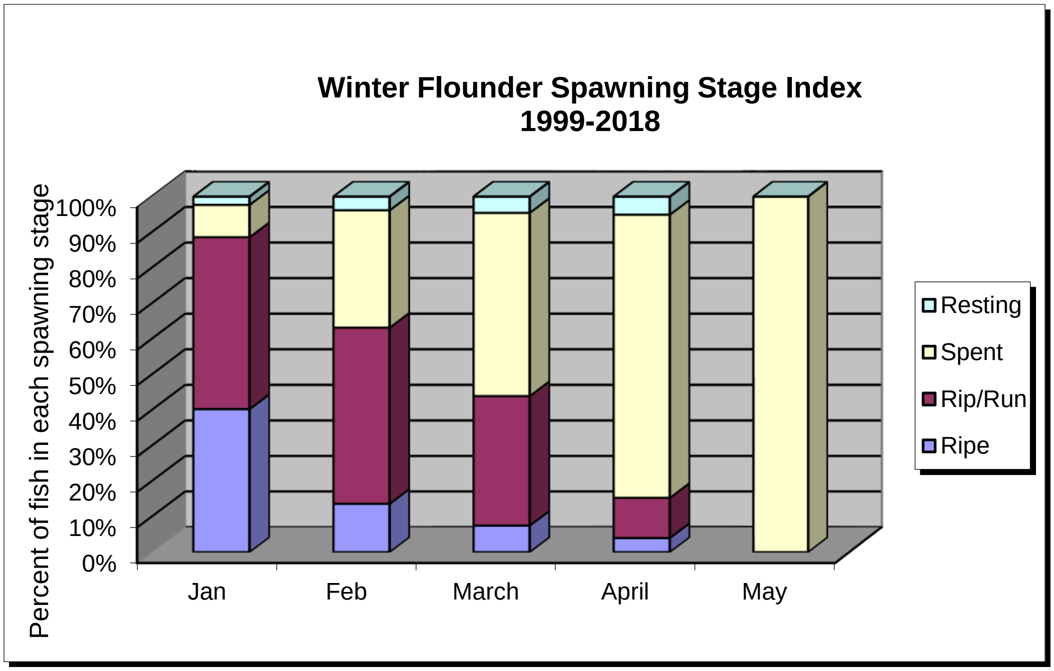


Figure 4 - 2018 recorded water temperature

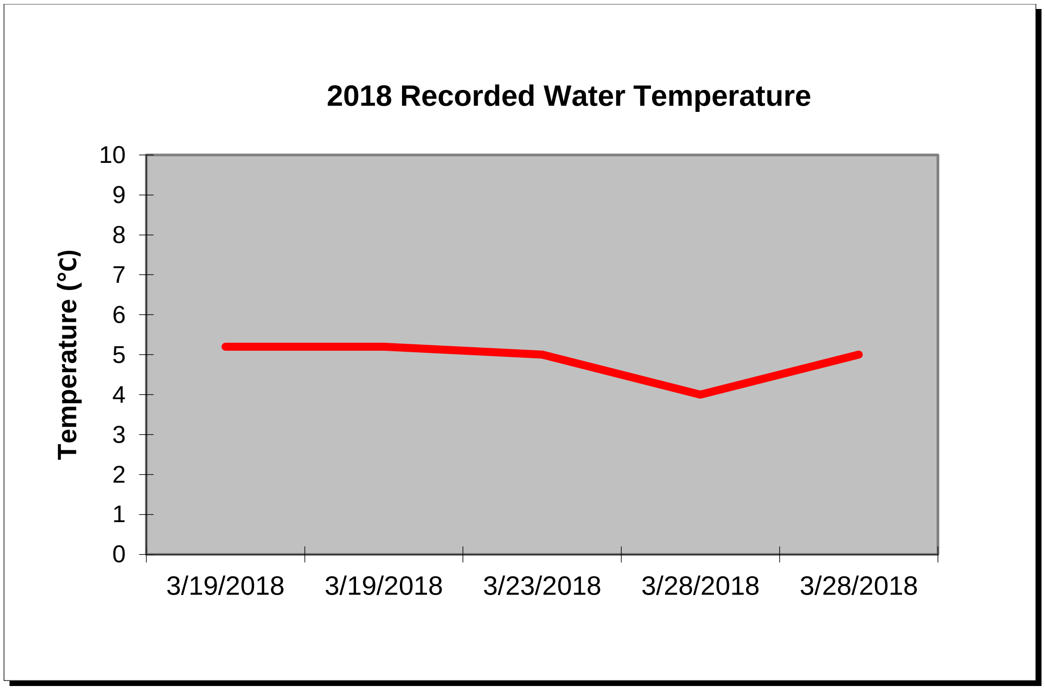


Figure 5 - WFL Male to Female ratio 1999-2018

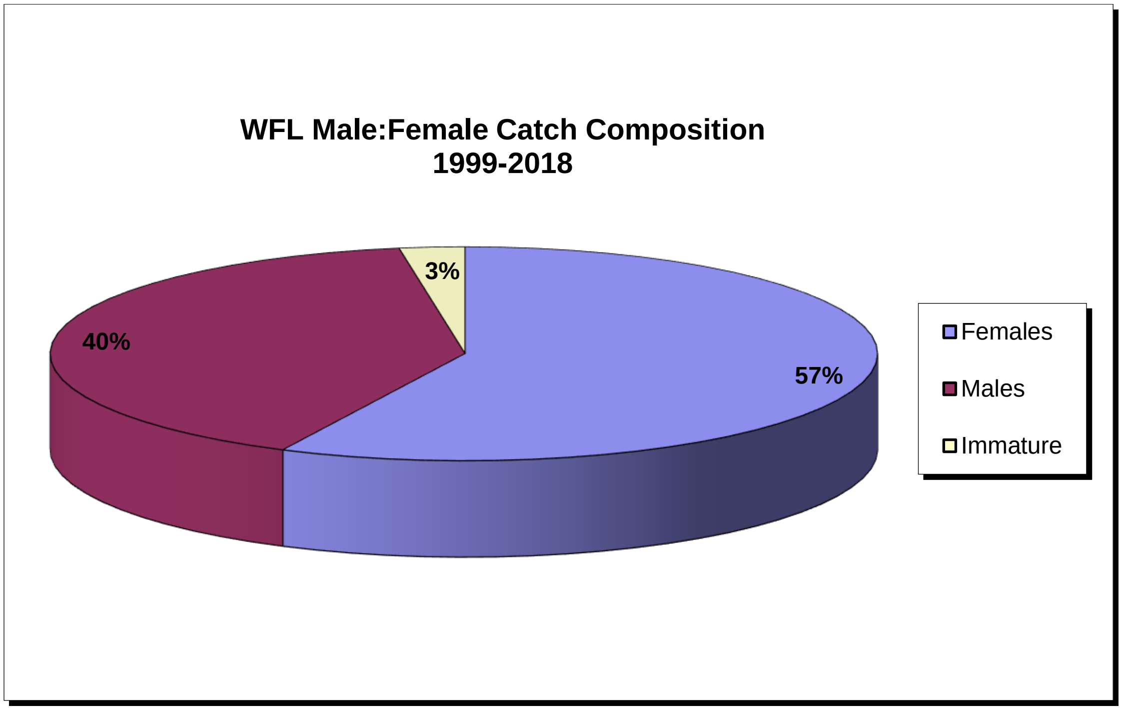


Figure 6 - WFL Length-Frequency for 2018 survey

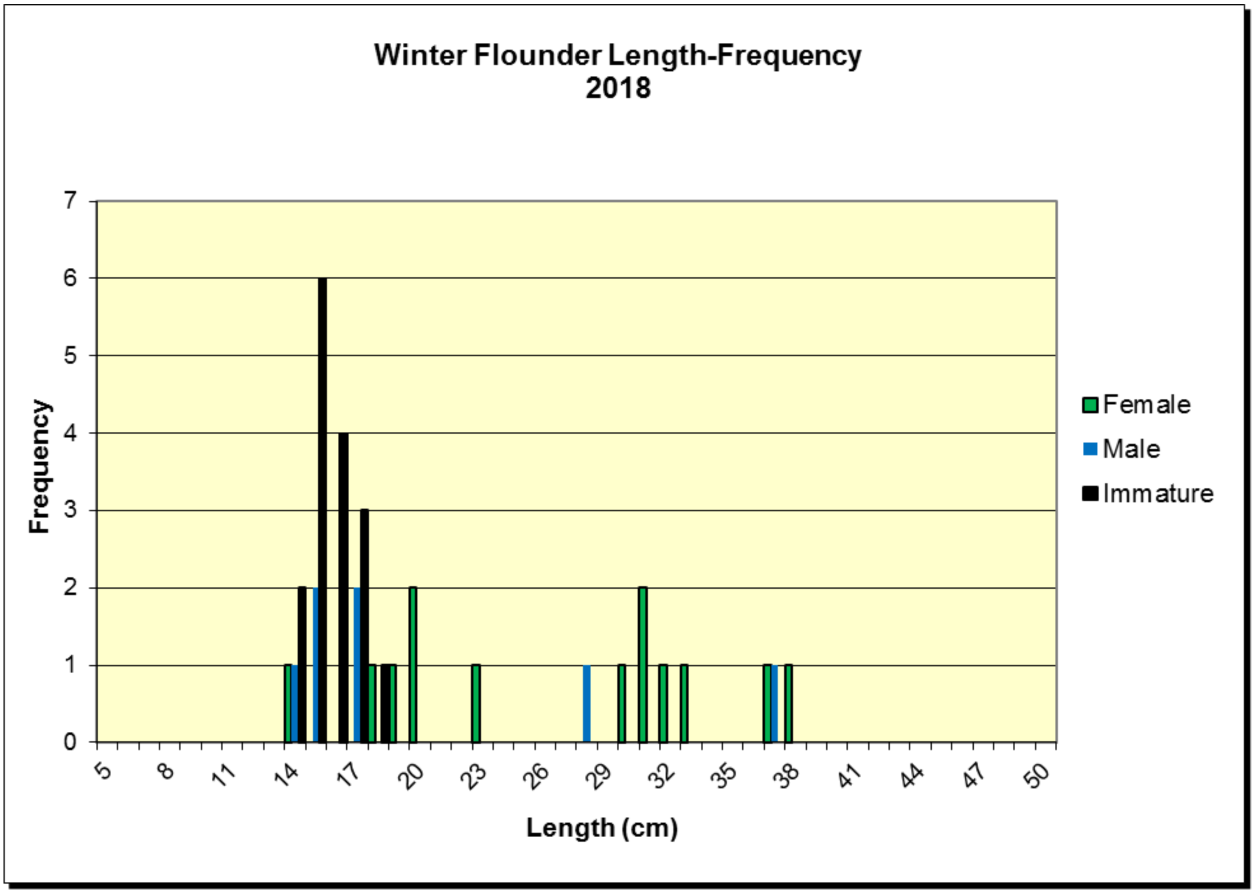


Figure 7 - WFL CPUE in Point Judith/Potter Pond - 1999-2018

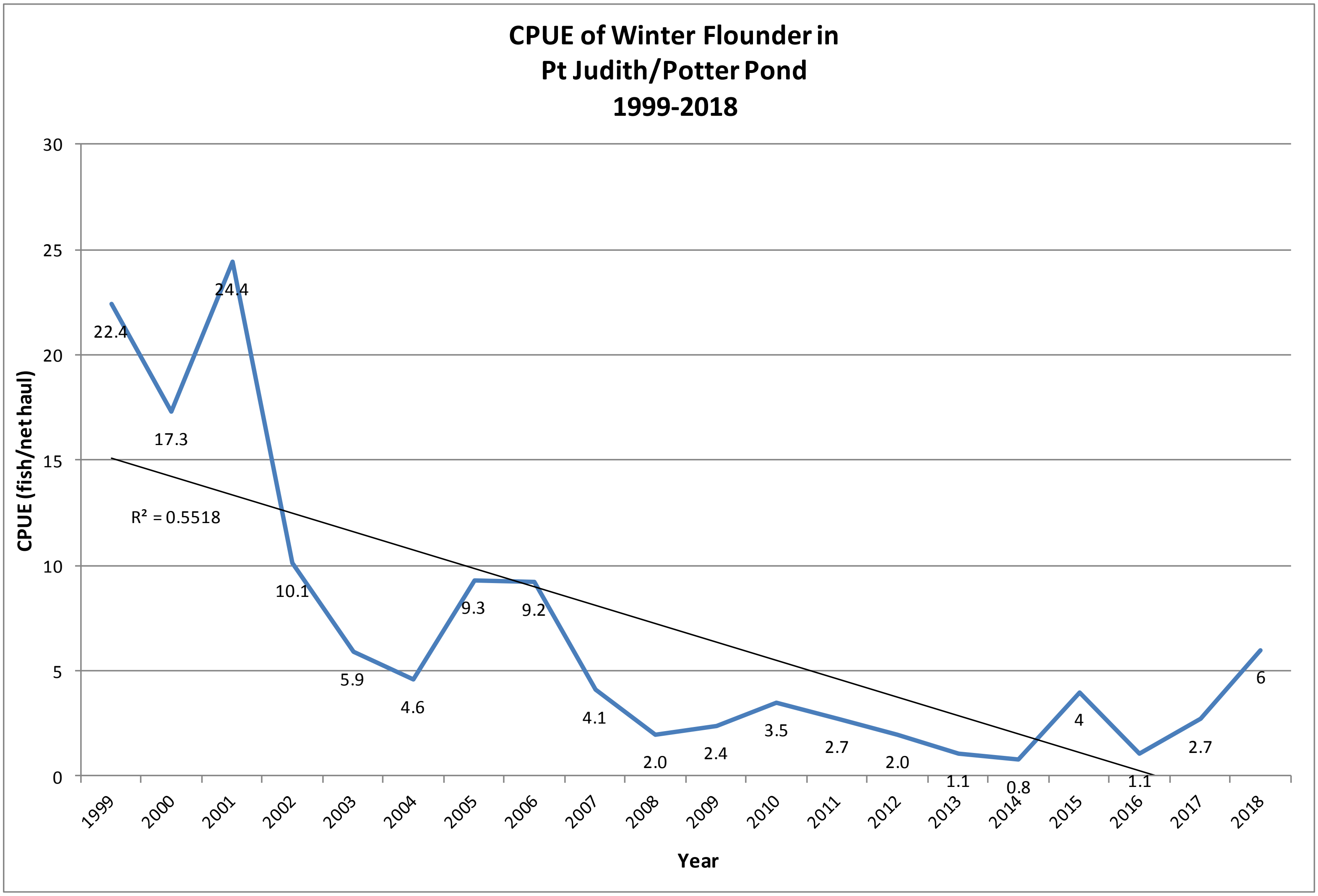
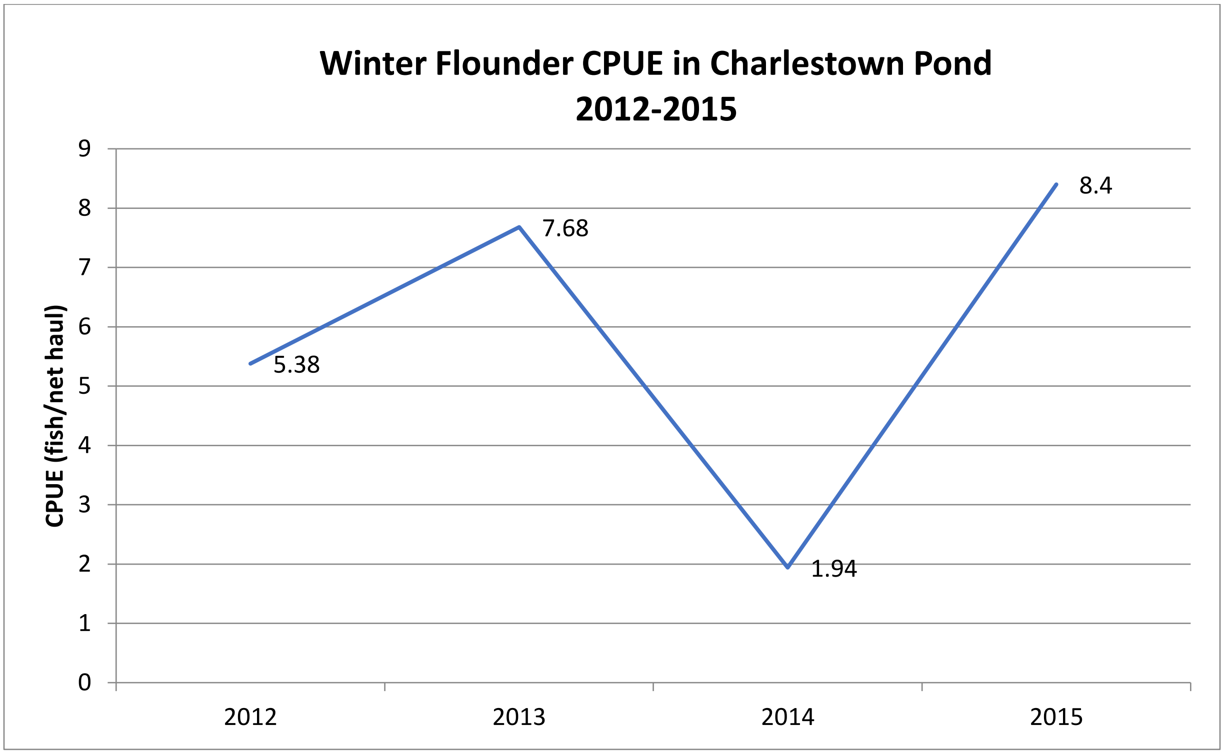


Figure 8 - WFL CPUE in Charlestown Pond - 2012-2015



ASSESSMENT OF RECREATIONALLY IMPORTANT FINFISH STOCKS IN RHODE ISLAND WATERS

NARRAGANSETT BAY JUVENILE FINFISH SURVEY

Jason McNamee
Chief Marine Resource Management

Anna Gerber-Williams
Principal Marine Fisheries Biologist

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

2018

PERFORMANCE REPORT

STATE: Rhode Island

PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters.

PERIOD COVERED: 1 January 2018 - 31 December 2018

JOB NUMBER AND TITLE: IV - Juvenile Marine Finfish Survey

JOB OBJECTIVE: To monitor the relative abundance and distribution of the juvenile life history stage of winter flounder (*Pseudopleuronectes americanus*), tautog (*Tautoga onitis*), bluefish (*Pomatomus saltatrix*), scup (*Stenotomus crysops*), weakfish (*Cynocion regalis*), black sea bass (*Centropristis striata*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic herring (*Clupea harengus)*, striped bass (*Morone saxatilis*), and other selected species of commercial and recreational importance in Narragansett Bay. To use these data to evaluate short and long term annual changes in juvenile population dynamics, to provide data for stock assessments, and for the development of Fishery Management Plans. To collect fish community data that is used to continue to identify, characterize, and map essential juvenile finfish habitat in Narragansett Bay.

SUMMARY: Eighteen fixed stations (Figure 1) around Narragansett Bay were sampled once a month from June through October 2018 with the standard 61 x 3.05 m beach seine. However, due to weather delays during September, stations 4 and 6-9 were sampled in early October (10/2/2018 and 10/4/2018) and stations 3, 4, 7 and 18 were sampled November 1st, 2018 for the October survey. Adults and juveniles of forty-three species were collected during the 2018 survey. For comparison eighty species were collected in 2015, the highest number of species and families collected since the survey began. For the entire survey time series (1988 – 2018), all individuals of the target species: winter flounder, tautog, bluefish, weakfish, black sea bass, scup, river herring, sea herring, and menhaden were enumerated and measured. With few exceptions (noted) all individuals of these species that were collected in the survey were juveniles. Adult and juveniles of other species collected were not differentiated for data analysis or descriptive purposes prior to 2009. Presence and relative abundance (few, many, abundant) of three forage species: Atlantic silversides (*Menidia menidia*), common mummichog (*Fundulus heteroclitus*) and striped killifish (*Fundulus majalis*) had been noted until 2009. Since 2009 all finfish species caught were enumerated and measured. Invertebrate species were noted and enumerated using the relative abundance scale as noted above. Data on weather, water temperature, salinity, and dissolved oxygen were recorded at each station.

TARGET DATE: December 2018

SIGNIFICANT DEVIATIONS: There were no significant deviations to methodology in 2018.

RECOMMENDATIONS: Continue standard seine survey at all eighteen stations. Continue to provide comments and recommendations to other resource management and regulatory agencies regarding potential anthropogenic impacts to fisheries resources and habitat. Continue to analyze and provide data for use in fisheries stock assessments. A reassessment and characterization of the habitat at each station should be undertaken to see if any major changes have occurred since the original evaluation.

REMARKS: Abundance trends derived from adult data collected from the RIDFW seasonal trawl survey since 1979 indicate a declining abundance of demersal species and an increasing abundance for pelagic species in Rhode Island waters. It should be noted that the trawl survey samples both adult and juvenile fish and invertebrates. This trend has also been observed in other estuaries along the Atlantic coast. Reasons for these shifts are attributed to a number of factors but may not be limited to these factors. These include the effects of climate change, warming coastal waters, water quality, habitat degradation and loss, overexploitation of some species leading to niche replacement by other species, and trophic level changes and shifts associated with all of these factors. Anthropogenic affects and the synergy between factors have no doubt led to changes in fish communities along the coast (Kennish, 1992).

A non-parametric Mann-Kendall test for trend significance can be used to show annual abundance trends for species collected during this juvenile survey. Two iterations of this test were run on for a set of target species. The first iteration analyzed the entire dataset and then a second iteration of this non- parametric trend analysis was done using a shortened time period of 10 years. While most of the target species do not have any significant long-term trend, bluefish is showing a decreasing trend (p = 0.025, Table 1a). However, Menhaden (p = 0.02), River Herring (p = 0.002), and Tautog (p = 0.002) show a positive increasing trend in the shortened 10-year analysis (Table 1b). Other species, such as winter flounder and striped bass, show no abundance trend for either the full dataset or the past ten years (Table 1a, b).

Reductions and annual fluctuations in abundance of many species may be attributed to a number of factors outlined above. Any one or more of these factors and/or the synergy between them may be responsible for inhibiting populations of some species from returning to historic or in some cases sustainable levels. Continued monitoring of juvenile fish populations is necessary to document the abundance and distribution of important species as well as the interactions between species. Further, this data can be analyzed to evaluate the effectiveness of management actions, an example being a spawning closure enacted for tautog in 2006 and then lengthened in 2010. This spawning closure was in part supported by the data derived from this survey. Trends in abundance and shifts in fish community composition can also be evaluated with these data.

While the primary purpose for conducting this survey is to provide data for making informed fisheries management decisions, these data are also used when evaluating the adverse impacts of dredging and water dependent development projects.

METHODS, RESULTS & DISCUSSION: A 61m x 3.05m beach seine, deployed from a 22’ boat, was used to sample the juvenile life stage of selected fish species in Narragansett Bay. Monthly seine collections were completed at the eighteen standard survey stations (Figure 1) from June through October 2018 (October sampling was extended into early November due to weather delays).

Number of individuals and lengths were recorded for all finfish species. While both juveniles and adults were represented in the collections for many species, individuals collected for the target species were predominately young-of-the-year juveniles (YOY). Species and number of individuals (both juveniles and adults) of invertebrate species collected were also recorded with the use of a relative index of abundance (abundant, many, few). Tables 3 - 7 show the species occurrence and number caught at each station for June through October. Table 8 is a summary table for all stations and species collected during the 2018 survey. Tables 9-13 provide the number of fish/seine haul for each station along with the station mean, monthly mean, and annual abundance index for each target species. Figures 2 – 10 show the annual abundance index trends for a number of important species for both the original and standardized indices. It should be noted when interpreting these data, that the survey began in 1986 with fifteen stations. The data represented in the graphs begins in 1988 as the period of time when the survey began using consistent methodology with the 15 stations. Station 16 (Dyer Is.) was added in June 1990, station 17 (Warren R.) was added in July of 1993, and station 18 (Wickford) was added in July of 1995. The addition of the stations is standardized in the analysis, see appendix A.

Table 15 provides bottom temperature, salinity, and dissolved oxygen data for each station by month.

Winter flounder

Juvenile winter flounder (*Pseudopleuronectes americanus*) were present in thirty-two percent of the seine hauls for 2018. This is a decrease from 2017 when they were present in fifty-seven percent of the hauls. A total of 129 fish were collected in 2018 (six of the fish collected in 2018 would not be considered young-of-the-year (YOY) according to Table 2 winter flounder maximum size by month). This was a decrease from the 366 individuals collected during the 2017 survey. They were present at all but four stations (no presence at stations 7, 10, 14, and 16), and were collected in all months (Table 9).

The 2018 juvenile winter flounder standardized abundance index was 1.55 ± 0.45 fish/seine haul; this is less than the 2017 index of 4.07 ± 1.37 S.E. fish/seine haul. Figure 2 shows the standardized annual abundance indices since 1988. The Mann-Kendall test showed no significant abundance trend for this species for the full dataset, or in the last 10 years (Table 1a, b).

June had the highest mean monthly abundance of 4.71 ± 1.40 S.E. fish/seine haul. Spectacle Cove (Sta. 13) and Chepiwonoxet Pt (Sta. 3) had the highest mean station abundance of 7.25 ± 2.81 and 6.60 ± 4.12 S.E. respectively. Overall upper and mid bay stations continue to have higher abundances than lower bay stations. This is expected since the primary spawning area for this species is believed to be in the Providence River followed by a secondary spawning area in Greenwich Bay where Station 3 is located.

Winter flounder length frequency data from the 2018 survey indicate that all except six of the winter flounder collected were young-of-the-year (YOY). The maximum lengths by month for YOY winter flounder used for this report are supported by growth rates in Rhode Island waters as reported in the literature (Delong et al, 2001; Meng et al, 2000; Meng et al, 2001; Meng et al, 2008). See Table 2 for maximum YOY lengths by month.

Figure 2 shows the 2018 abundance index continues to be lower than most years since 2000, the survey high. The Division of Fish and Wildlife's trawl survey data (sampling both adults and juveniles) saw a small increase in winter flounder from 2017 to 2018. Over the course of the Narragansett Bay Juvenile Finfish Seine Survey the abundance index rose between 1995 and 2000, but then decreased with variability to 2018. The Mann-Kendall trend analysis shows no trend in the abundance of juvenile winter flounder in Narragansett Bay over the entire time series, and the declining trend indicated for the shortened 10-year time series in the terminal year of 2012 has dissipated, now showing no trend as we move away from the peak years of the early 2000's. The dramatic abundance fluctuations over the past ten years shown in Figure 2 and the declining trend over the last decade continue to be a concern to resource managers.

Tautog

During the 2018 survey 902 juvenile tautog (*Tautoga onitis*) were collected. This is an increase from the 2017 survey when 773 juveniles were collected. The 2018 abundance index was 10.87 ± 3.11 S.E. fish/seine haul, an increase from the 2017 index 8.59 ± 3.93 S.E. (Figure 3). As indicated in the introduction, based on this survey data, it can be concluded that the spawning closure enacted in 2006 and then extended in 2010 may be having an impact on the number of juveniles produced during the spring as there appears to be an increasing trend since this time period. It may take some time for a slow growing species such as tautog to recoup its spawning stock biomass to levels that will have significant impacts and major increases in biomass; therefore, we will continue to monitor this species closely in the coming years.

Juvenile tautog were collected in fifty-five percent of the seine hauls in 2018 (Table 10). This is a decrease from 2017 when they were present in sixty-five percent of the seine hauls. September and August had the highest mean monthly abundances of 26.64 ± 12.17 S.E. and 25.72 ± 17.19 S.E. fish per seine haul, which corresponds to the majority of the survey time series data which indicates August as being the month with the highest abundance. Patience Island (Sta. 5) had the highest mean station abundance of 102.60 ± 58.39 S.E. which was driven by high sampling numbers in September (147 fish) and August (313 fish). Hog Island (Sta. 9) and Spectacle Cove (Sta. 13) had the next highest abundances with a mean station abundance of 32.40 ± 20.68 S.E. and 13.25 ± 7.41 S.E. fish/seine haul respectively. The Mann-Kendall test showed no long-term trend in juvenile abundance, but a short term increasing abundance trend for juvenile tautog is present for the 10-year series (Table 1a, b). It is plausible that the spawning closure is positively impacting the juvenile tautog population, and the increasing trend in the Mann-Kendall test supports this. It should be noted that this survey data was used as a young of the year index for the benchmark stock assessment for tautog by the Atlantic States Marine Fisheries Commission (ASMFC 2016).

Our Narragansett Bay trawl survey had an increase in abundance for tautog from 2017 to 2018. There would be a lag in time between when juveniles are caught in the seine survey and when the cohort shows up in the trawl survey, but the trends are worth monitoring.

Bluefish

During the 2018 survey 112 juvenile bluefish (*Pomatomus saltatrix*) were collected. This is a decrease from the 165 juveniles collected in 2017. Juveniles were present in sixteen percent of the seine hauls and were collected at eleven of the eighteen stations (Table 11). They were present in all months except for October, with the highest abundance occurring in July. October 2018 had no juvenile bluefish collected during the survey, which is most likely due to the colder water temperatures (11.1 – 20.2° C), with most sampling days occurring later in the month when temperatures fell below 16° C. Since this survey began and prior to 2016, only one hundred forty-one juvenile bluefish have been collected in October, in seven different years (1990, 1997, 1999, 2005, 2011, 2012, and 2015), and only when water temperatures were 16 – 21° C.

The abundance index for 2018 was 1.35 ± 0.85 S.E. fish/seine haul. This is less than the 2017 abundance index of 1.83 ± 0.98 S.E. fish/seine haul (Figure 4). The Mann-Kendall test showed a significant decrease in long-term abundance, however there is no 10-year abundance trend for this species (Table 1a, b).

July had the highest mean monthly abundance of 5.78 ± 1.84 S.E. fish/seine haul (Table 11). July and August are typically the months of highest juvenile abundance for this species. The only exception to this was in 2005 when September had the highest mean monthly abundance. This was probably due to the higher than normal water temperatures during September 2005.

In 2018, Pojac Point (Sta. 4) had the highest mean station abundances of 7.67 ± 5.94 S.E. (Table 11). This is driven by a large catch in July, the only month the station caught bluefish.

Length frequency data for 2018 indicates that all juveniles collected were young-of-the-year individuals.

The spatial distribution and abundance of juvenile bluefish in Narragansett Bay is highly variable and is dependent on a number of factors: natural mortality, fishing mortality, size of offshore spawning stocks, spawning success, number of cohorts, success of juvenile immigration into the estuaries, and the availability of appropriate size prey species like Atlantic silversides (*Menidia menidia*) when juveniles enter the bay. The annual abundance indices since 1988 show dramatic fluctuations supporting a synergy of these factors affecting recruitment of this species to Narragansett Bay (Figure 4).

Striped Bass

During the 2018 survey 14 striped bass (*Morone saxatalis*) were collected. This is the same as was collected in 2016. Striped bass were present in nine percent of the seine hauls and were collected at seven of the eighteen stations (Table 14). They were present in June, July, and September.

The abundance index for 2018 was 0.17 ± 0.08 S.E. fish/seine haul. This is slightly higher than in 2017, which had an abundance index of 0.16 ± 0.10 S.E. fish/seine haul (Figure 8). The Mann-Kendall test showed no abundance trend for this species for the entire dataset or for the shortened 10-year series (Table 1a, b).

July had the highest mean monthly abundance of 0.33 ± 0.28 S.E. fish/seine haul (Table 12). June had the second highest mean monthly abundance at 0.28 ± 0.14 fish/seine haul. September and October are usually the months with the highest abundance for the entire time series.

In 2018, striped bass were only present at 7 stations, Gaspee Point (Sta. 1), Conimicut Point (Sta. 2), Sand Point (Sta. 6), Potters Cove (Sta. 8), Hog Island (Sta. 9), Spar Island (Sta. 12), and Dyer Island (Sta. 16). The highest abundance was found at Dyer Island with 1.20 ± 0.97 fish/seine haul, which was driven by a single catch of 5 fish in July and 1 in June. The station with the highest abundance each year is variable, though it does tend to be the lower bay stations in general for the entire time series.

Length frequency data for 2018 indicates that a mix of juveniles and adults were collected. This is normal for the seine survey. The spatial distribution and abundance of striped bass in Narragansett Bay is highly variable and is most likely highly dependent on the availability of appropriate size prey species like Atlantic silversides (*Menidia menidia*) and juvenile menhaden (*Brevoortia tyrannus*) when fish enter the bay. The annual abundance indices since 1988 show fluctuations in abundance from year to year (Figure 8), but generally appears to have had an increasing trend during the late 90s to early 2000s, but now appears to be on a downward trajectory since 2008, although in recent years there seems to be a very slight upward trend. The standardized index, which accounts for some of these factors, follows a similar trend year to year as the straight catch per unit effort (CPUE) index.

Clupeidae

Four species of clupeids are routinely collected during the survey. Alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*), collectively referred to as river herring, and Atlantic menhaden (*Brevoortia tyrannus*) are most common. Atlantic herring (*Clupea harengus*) have also been collected during the surveys time series but in very small numbers.

River Herring

Due to the large numbers of anadromous herring collected, and the difficulty of separating juvenile alewives from juvenile blueback herring without sacrificing them, both species are combined under the single category of river herring. Data collected from this survey and the Division of Fish and Wildlife’s Anadromous Fish Restoration Project show alewives to be the predominate river herring species collected, although both species are present and have been stocked as part of the Division’s restoration efforts.

River herring were present in thirty-two percent of the seine hauls and were collected at fifteen of the eighteen stations during 2018, and were present in all months. A total of 1,364 juveniles were collected in 2018, a decrease from the number collected in 2017 (3,593 fish).

The highest mean monthly abundance for 2018 occurred during July and was 61.94 ± 25.75 S.E. fish/seine haul. The Warren River (Sta 17) and Spectacle Cove (Sta. 13) had the highest mean station abundance of 109.50 ± 97.34 S.E. and 46.25 ± 40.48 S.E., respectively (Table 13). The Warren River experienced a single large catch in July (436 fish), and Spectacle Cove experienced a single large catch in July (182 fish) which drove their mean station abundances.

Single large catches of these species are due to their schooling behavior and is the reason for the high standard error associated with the indices.

The standardized abundance index for 2018 was 16.24 ± 12.54 S.E. fish/seine haul (Figure 5). The annual abundance indices since 1988 show dramatic fluctuations as is a common occurrence with schooling clupeid species. Due to these fluctuations, there was no significant trend in the 10-year Mann-Kendall (Table 1b), and no long-term abundance trend for river herring (Table 1a).

Figure 6 shows the estimated spawning stock size of river herring as monitored by our Anadromous Fish Restoration Program at two fishways in Rhode Island. There may be some correlation between increasing numbers of returning adult fish (Figure 6) and the abundance index generated by this survey (Figure 5) as the recent small increases in juvenile abundance in the data corresponds to an increase in returning adults, and vise versa. Due to an extended period of low abundance of river herring in Rhode Island, the taking of either species of river herring is currently prohibited in all state waters.

Menhaden

Thirty-seven thousand two-hundred and twenty-nine Atlantic menhaden (*Brevoortia tyrannus*) were collected during the 2018 survey, a decrease from 2017 when 148,598 fish were caught. The 2018 abundance is one of the highest in recent years; the last high abundance was 2007, when eight thousand two hundred fifty-three juveniles were collected. They were present in twenty-nine percent of the seine hauls and were collected at fourteen of the eighteen stations (Table 12).

The highest mean monthly abundance for 2018 occurred during August and was 1083.94 ± 523.96 S.E. fish/seine haul. Potters Cove (Sta. 8) had the highest mean station abundance of 2298.20 ± 1676.25 S.E. (Table 14) which was driven by a single large catch in August of 2,866 fish. Single large catches of these species are due to their schooling behavior and is the reason for the high standard error associated with the indices.

The standardized abundance index for 2018 was 1562.20 ± 1507.86 S.E. fish/seine haul. This is less than 2017 (1562.20 ± 1507.86 S.E. fish/seine haul, Figure 7), however, the Mann-Kendall test shows that there is a significant increasing trend in the abundance data for the prior ten years (Figure 1b). The standardized index indicates an increased abundance during the 2000s followed by lower numbers through the 2010s. In the most recent years an increasing abundance is evident. Our Narragansett Bay trawl survey showed an increase in menhaden abundance from 2017 to 2018. The trawl survey catches juveniles as well as some age one fish. The Mann-Kendall test showed no long-term abundance trend for this species (Table 1a).

Similar to river herring, juvenile menhaden were also observed in very large schools around Narragansett Bay and as discussed earlier, this behavior often results in single large catches resulting in a high abundance index and large standard error. This schooling behavior also contributes to the variability of their spatial and temporal abundance from year to year. Because of these characteristics it is difficult to develop an abundance index that will accurately reflect the number of juveniles observed in the field rather than the number represented in the samples.

The standardization techniques used for analysis this year are an effort to take in to account this variability and high percentage of zero catches through the use of a delta lognormal model (Appendix A).

Weakfish

There were zero weakfish, *Cynocion regalis,* collected during the 2018 survey. Station 3 in Greenwich Bay and Station 4 at the mouth of the Potowomut River, immediately south of Greenwich Bay, are the stations where this species is typically collected most frequently.

The abundance trend over the past several years indicate the juvenile population of this species in Narragansett Bay fluctuates dramatically, a trend also reflected in our trawl survey. There, have been 11 years since 1988 where no fish have been caught. Seven of the 11 total zero catch years occur after 2004. Possible reasons for this high variability in abundance, other than fishing pressure, may be environmental and anthropogenic factors that affect spawning and nursery habitat. Survival rate at each life history stage may also be influenced by these factors. The literature indicates this species spawns in calm coves within the estuary and juveniles move up the estuary to nursery areas of lower salinity. These are the same areas of the bay where anthropogenic impacts are high, often resulting in hypoxic and/or anoxic events that may increase mortality of the early life history stages of this species.

With the limited and sporadic juvenile data generated by this survey a juvenile population trend analysis is difficult. A nominal index was developed, but due to the sparse nature of the data, the index generated should be viewed with caution.

Black Sea Bass

Fifty-four black sea bass (*Centropristis striata*) were caught in 2018, a small decrease from the 59 fish that were collected in 2017. The number of black sea bass has been highly variable from year to year during the time series of this survey, but the high abundance during 2012 and 2015 (Figure 10) stand out as unique. Black sea bass were caught in fourteen percent of the seine hauls in 2018.

The highest mean monthly abundances for 2018 occurred during August and September at 20.00 ± 0.46 S.E. fish/seine haul and 33.00 ± 2.04 fish/seine haul, respectively. Black sea bass were caught at 10 of the 18 stations; Patience Island (Sta. 5) and Sand Point (Sta. 6) had the highest mean station abundances of 5.80 ± 5.80 S.E. and 1.20 ± 0.80 fish/seine haul, respectively (Table 15).

The abundance index for 2018 was 0.65 ± 0.36 S.E. fish/seine haul. This was similar to the 2017 index 0.66 ± 0.28 S.E. (Figure 10). Our Narragansett Bay trawl survey had a small decrease in the abundance of black sea bass from 2017 to 2018 in the spring seasonal survey. However, the abundance was still much greater than it has been since the survey began in 1979. The fall index dropped down from the high values in 2012 and 2013, but did show a small increase in abundance from 2016 to 2018. This recruitment signal in recent years was seen not only in RI waters, but all along the Northern Atlantic coast.

Both the trawl survey and the coastal pond survey seem to be better indicators for local abundances of black sea bass. The Narragansett Bay seine survey does not catch them in any consistent manner leading one to believe that they may be using deeper water and or the coastal ponds as their preferred nursery areas. There are no indications that there are any problems with the local abundance of black sea bass, information that is also corroborated by the coastwide stock assessment for black sea bass, which indicates no overfishing and a rebuilt stock (NEFSC 2016).

Other important species

Juveniles of other commercial or recreationally important species were also collected during the 2018 survey. These juveniles included scup (*Stenotomus chrysops*), and Northern kingfish (*Menticirrhus saxatilis*).

One hundred and sixty-two juvenile scup were collected in 2018 during June, July, August, September and October, a decrease from 2018 when 333 scup were collected but an increase from 2016 when 66 scup were collected. One hundred and thirty-nine Northern kingfish were collected in 2018, and were present in the greatest numbers during July and August. This is a decrease from 2017 when 599 Northern kingfish were caught. Five summer flounder were collected in 2018 in June and July. Six smallmouth flounder were caught in 2018. Relative to the sixty-eight smallmouth flounder that were caught in 2011, and the thirty-three that were caught in 2010, the decrease in abundance continued in 2018. This species will have to be monitored in future years to see if, due to changing habitat conditions or possible vacant niches, it is increasing its residency in the Bay. No juvenile Haddock were caught in 2018, unlike June 2016 when 44 juvenile haddock were caught, or June 2015 when 27 were caught. They were caught primarily in the lower portion of the bay. 2015 was the first recorded observance of juvenile Haddock in the history of the survey, this species will continue to be monitored in future years to see if there is an increasing abundance over time in Narragansett Bay. See Tables 3-8 for additional survey data on these species.

Physical & Chemical Data

Previous to 2010 a YSI 85 was used to collect water temperature, salinity and dissolved oxygen data from the bottom water at all stations on each sampling date. This meter was upgraded in 2010 to a YSI Professional Plus Multiparameter instrument 6050000. The instrument collects the same suite of information as the YSI 85, but is an improved meter with better functionality. The water quality data collected are shown in Table 15.

Water temperatures during the 2018 survey ranged from a low of 11.1°C at Kickemuit River (Sta. 11) in October to a high of 28.1°C at Chepiwanoxset (Sta. 3) in August.

Salinities ranged from 16.7 *ppt* at Gaspee Point (Sta. 1) in July to 29.2 *ppt* at Rose Island (Sta. 10) in June.

Dissolved oxygen ranged from 5.04 *ppm* at Kickemuit River (Sta. 11) in Auguest to a high of 12.75 *ppm* at Conimicut Point in October.

<u>SUMMARY</u>: In summary, data from the 2018 Juvenile Finfish Survey continue to show that a number of commercial and recreationally important species utilize Narragansett Bay as an important nursery area. Using the Mann Kendall test, winter flounder, tautog, river herring, menhaden and striped bass, showed no long-term abundance trends but indicated a significant long-term decrease in bluefish abundance. There are some species abundance trends from this survey that agree with those from our coastal pond survey and/or trawl survey, however, in some instances they do not relate. This outcome is probably influenced by the species-specific use of habitat and looking at appropriate data lags between the juvenile life stages and the adult stages. Hopefully, juvenile survey abundance indices will be reflected later in the abundance of adults in the trawl survey, but this is not always the case.

Forty-three species, both vertebrates and invertebrates, were collected in 2018. This is slightly lower than the survey mean for the past twenty-five years of sixty species. An initial audit of the earlier time series and information contained on the field logs was undertaken to determine if some of the species diversity was missing from the earlier time series. Some issues were resolved from this analysis, however there are still some unresolved issues contained in the historical field logs. These final issues will be addressed over the coming year.

During 2018 one tropical species (*Mugil curema*) was collected during the survey. While tropical and subtropical species are collected during this survey every year, the number of species and individuals is dependent upon the course of the Gulf Stream, the number of streamers and warm core rings it generates, and the proximity of these features to southern New England.

The survival and recruitment of juvenile finfish to the Rhode Island fishery is controlled by many factors: over-fishing of adult stocks, spawning and nursery habitat degradation and loss, water quality changes, and ecosystem changes that effect fish community structure. Any one of these factors, or a combination of them, may adversely impact juvenile survival and/or recruitment in any given year.

An ongoing effort to increase populations of important species must embrace a comprehensive approach that takes into account the above factors, their synergy and the changing fish community in the Bay. A continued effort to identify and protect essential fish habitat (EFH) and improve water quality is essential to this effort. The Division through our permit review program does represent the interests of fish and habitat preservation and protection. As well, properly informed management decisions are tantamount to preserving spawning stock biomass in order to create and maintain sustainable populations. This survey’s dataset is used to inform the statistical catch at age models for both a regional tautog assessment as well as the coastwide menhaden assessment. In addition to the direct usage of the data in fisheries models, the other information collected by the survey helps to identify ancillary information such as abundances of forage species and habitat parameters, all important information for making good informed management decisions. These activities will all continue to be an important component of this project.

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FIGURES

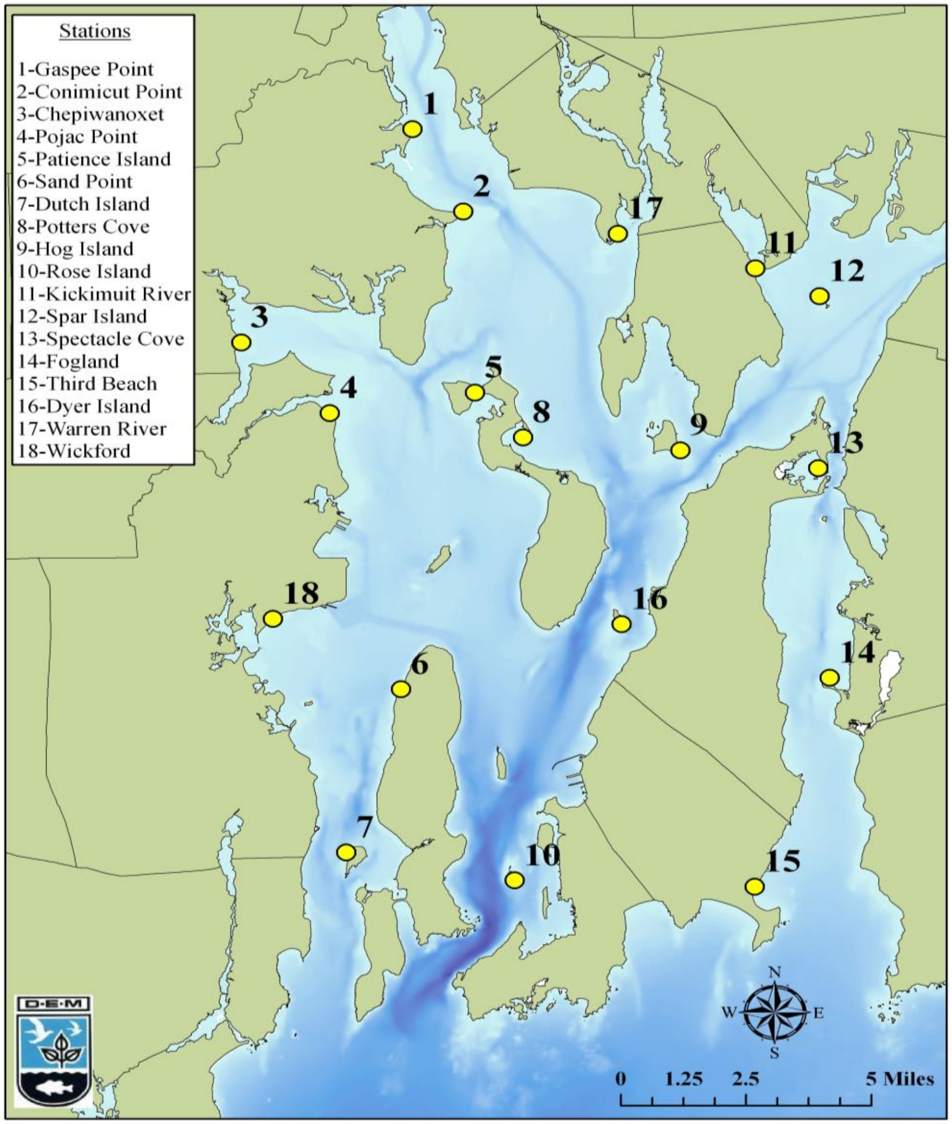


Figure 1. Survey station location map.

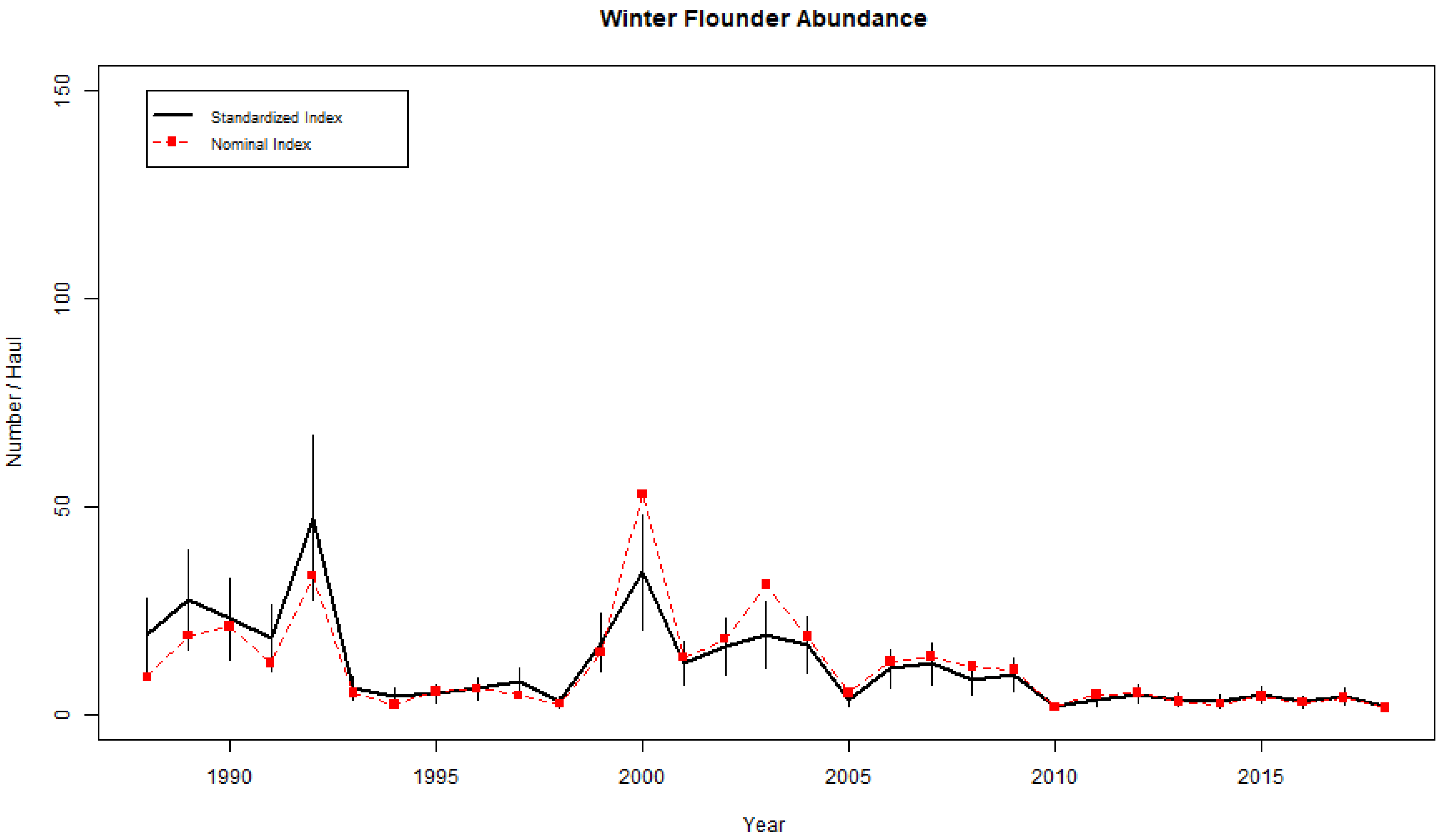


Figure 2. Juvenile winter flounder standardized abundance index 1988 – 2018 (see appendix A for standardization methodology).

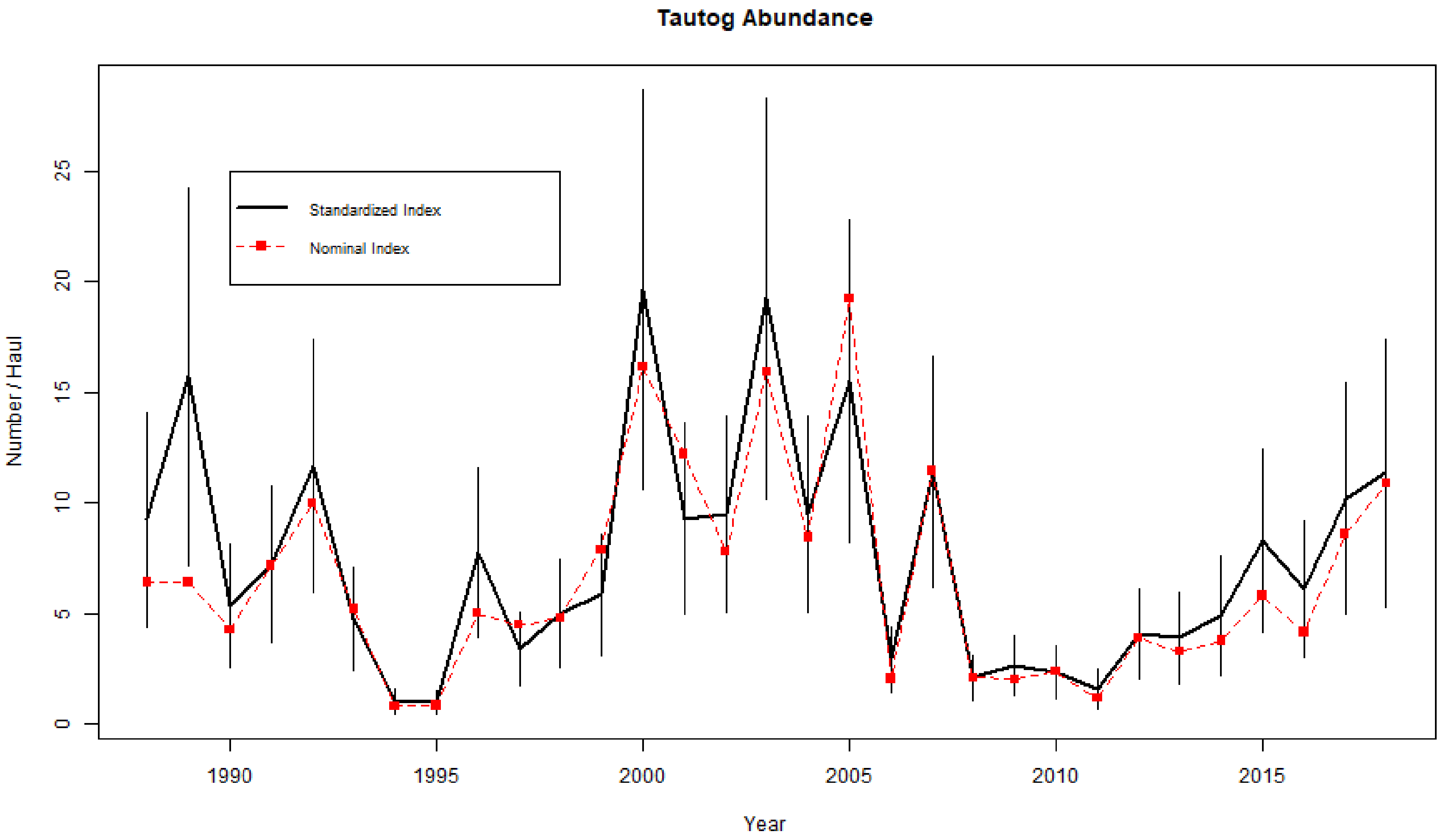


Figure 3. Juvenile tautog standardized annual abundance index 1988 – 2018 (see appendix A for standardization methodology).

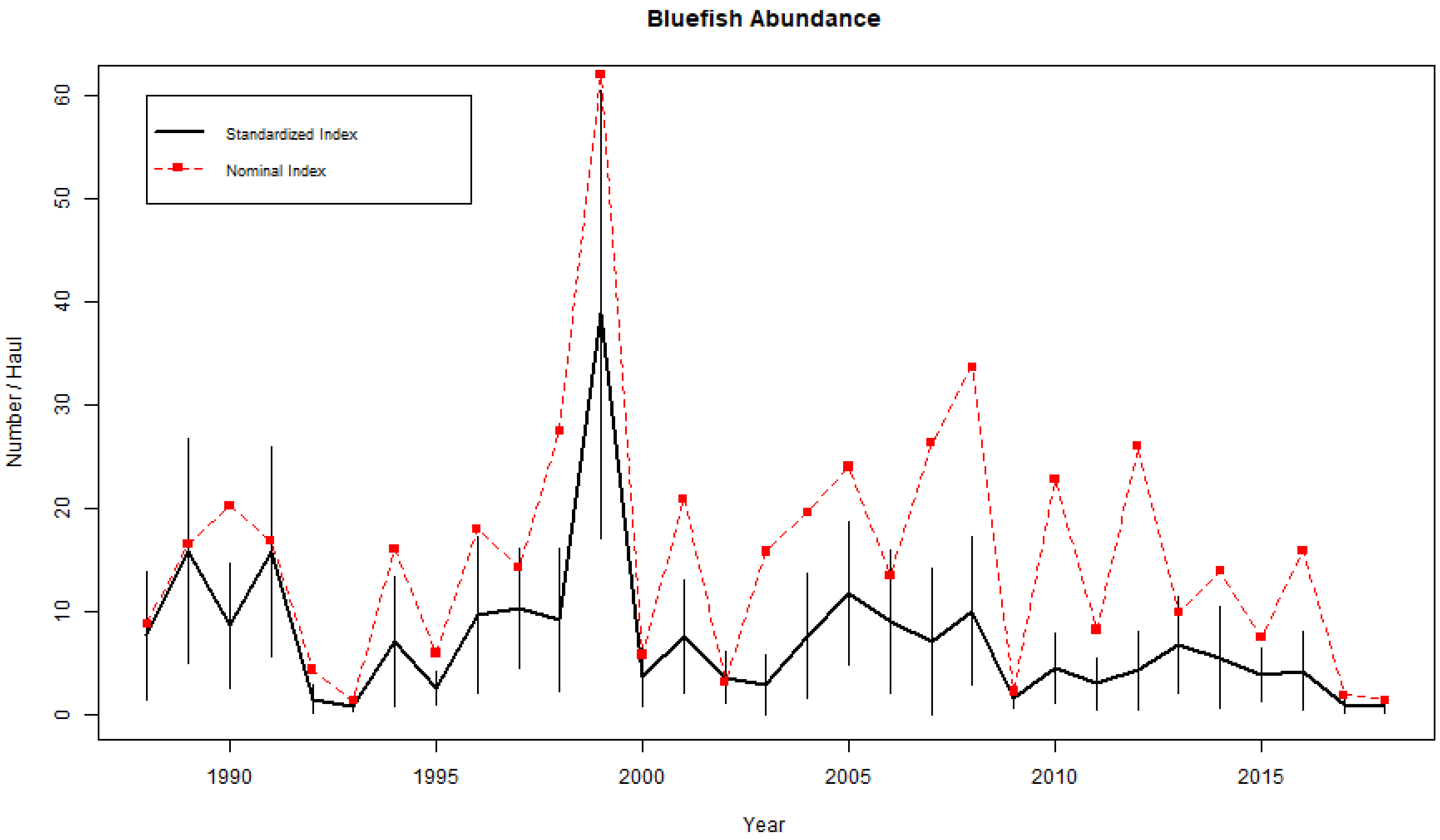


Figure 4. Juvenile bluefish standardized annual abundance index 1988 – 2018 (see appendix A for standardization methodology).

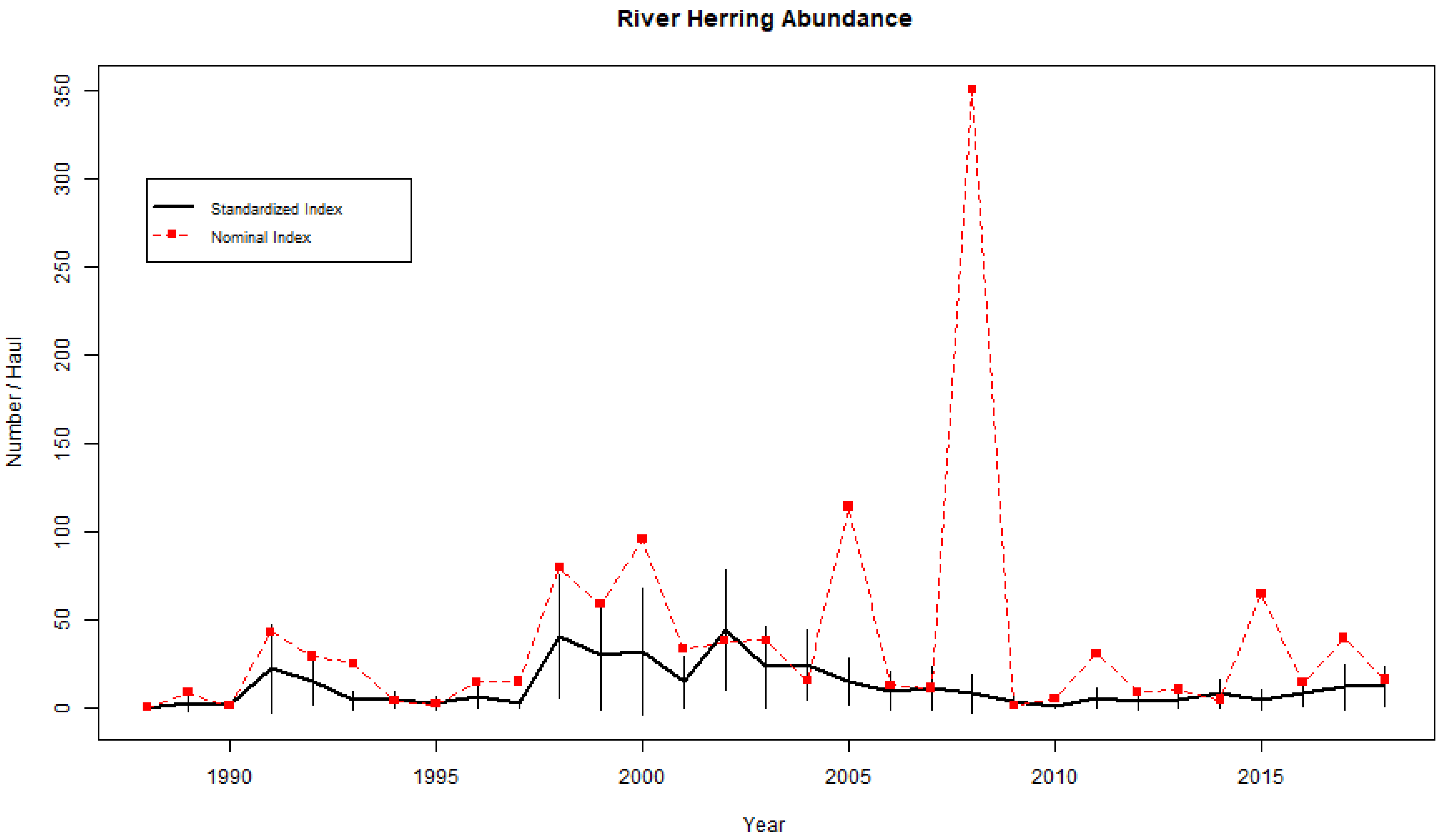
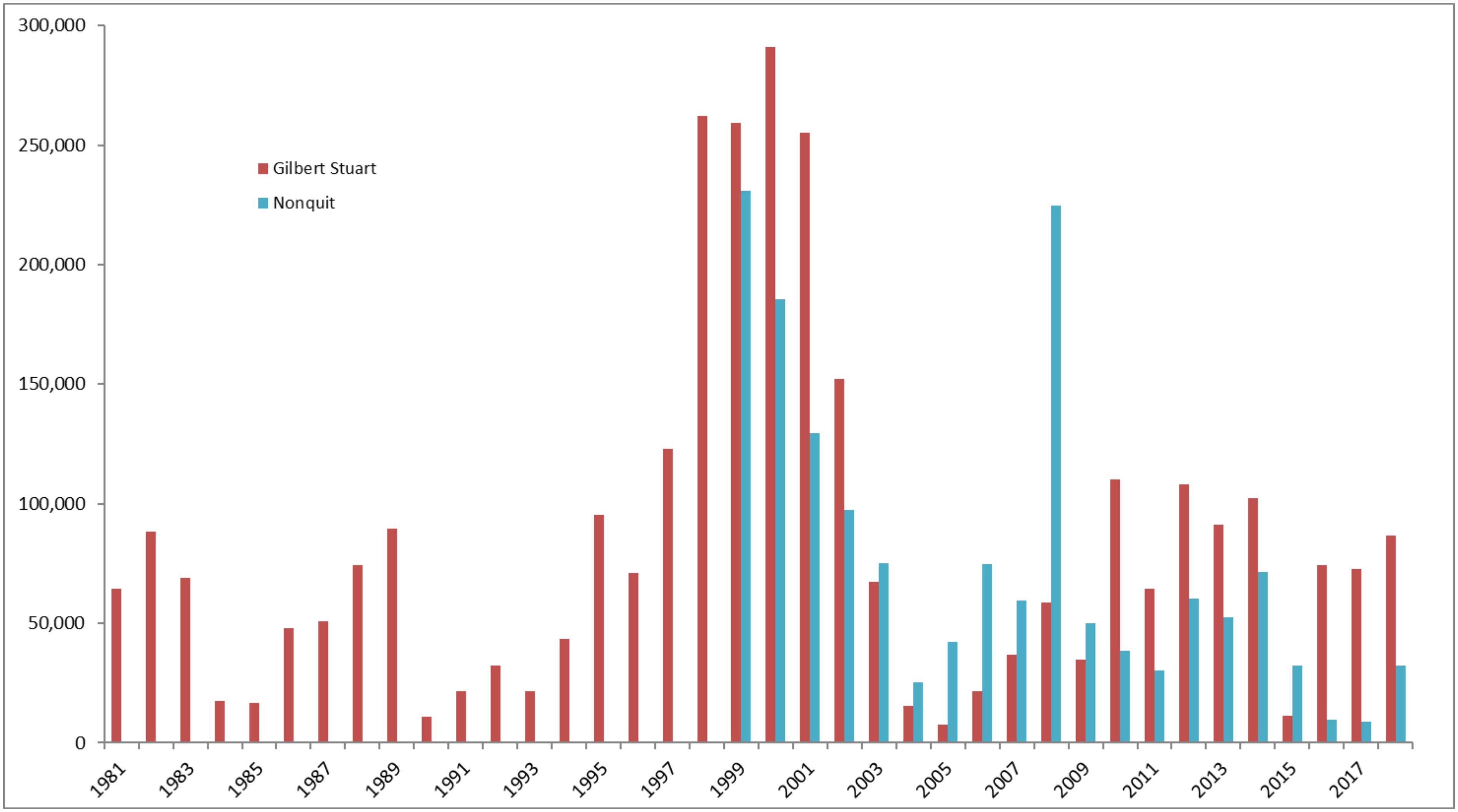


Figure 5. Juvenile river herring standardized annual abundance index 1988 – 2018 (see appendix A for standardization methodology).



Courtesy - Phil Edwards, RIF&W Anadromous Fish Restoration Program

Figure 6. River herring spawning stock size from monitoring at two locations 1999 – 2018.

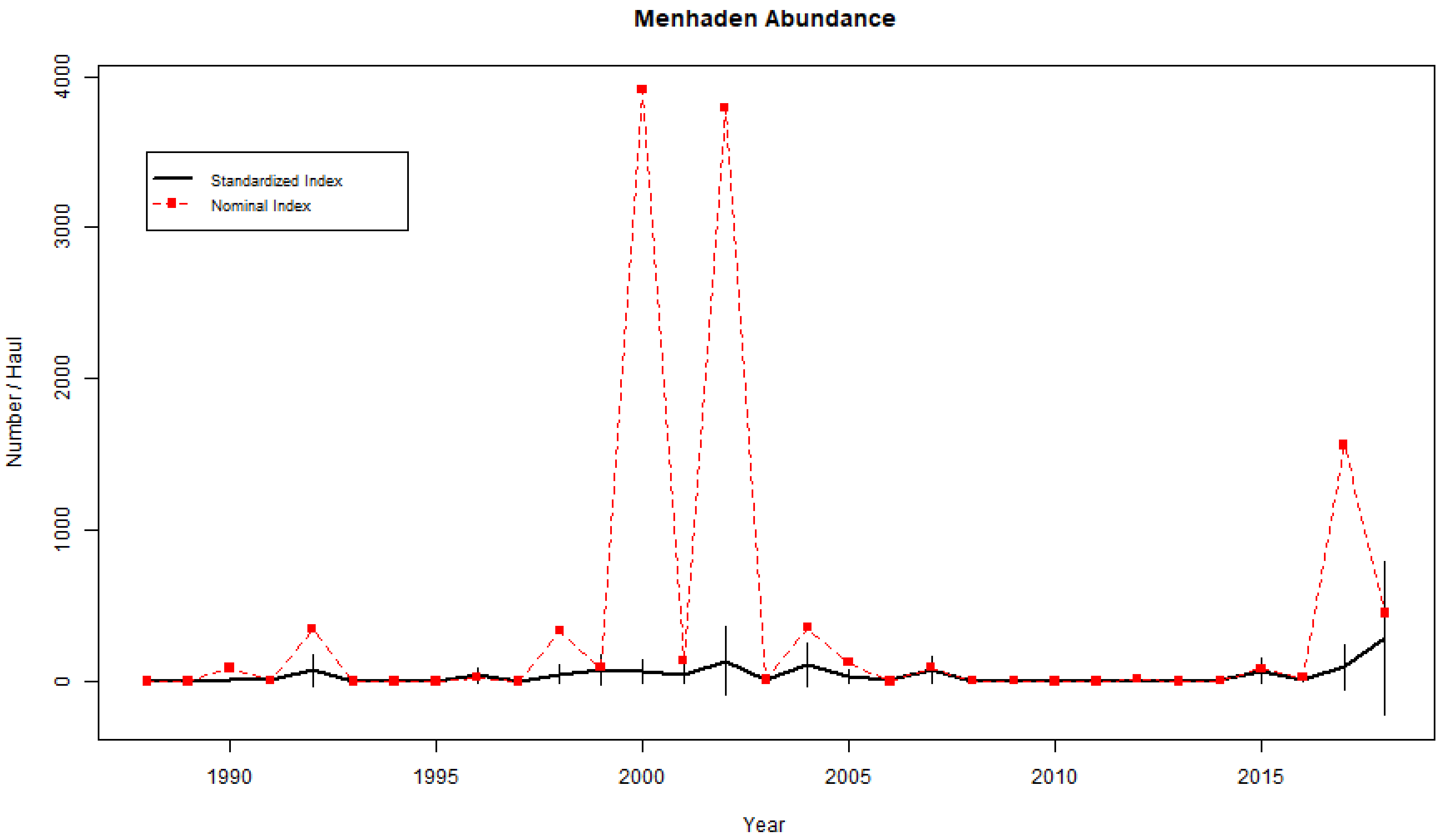


Figure 7. Juvenile menhaden standardized annual abundance index 1988 – 2018 (see appendix A for standardization methodology).

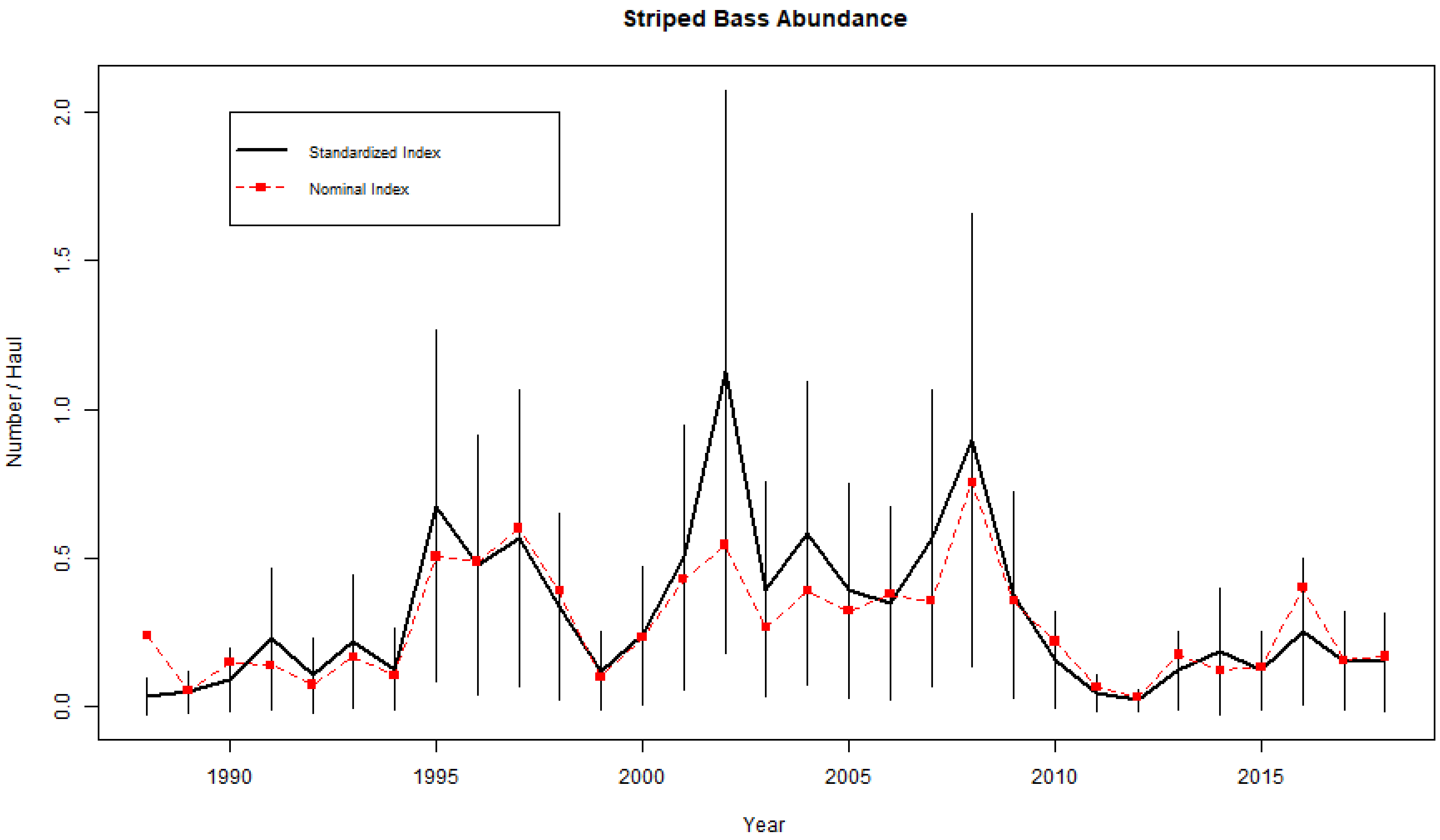


Figure 8. Striped bass standardized annual abundance index 1988 – 2018 (see appendix A for standardization methodology).

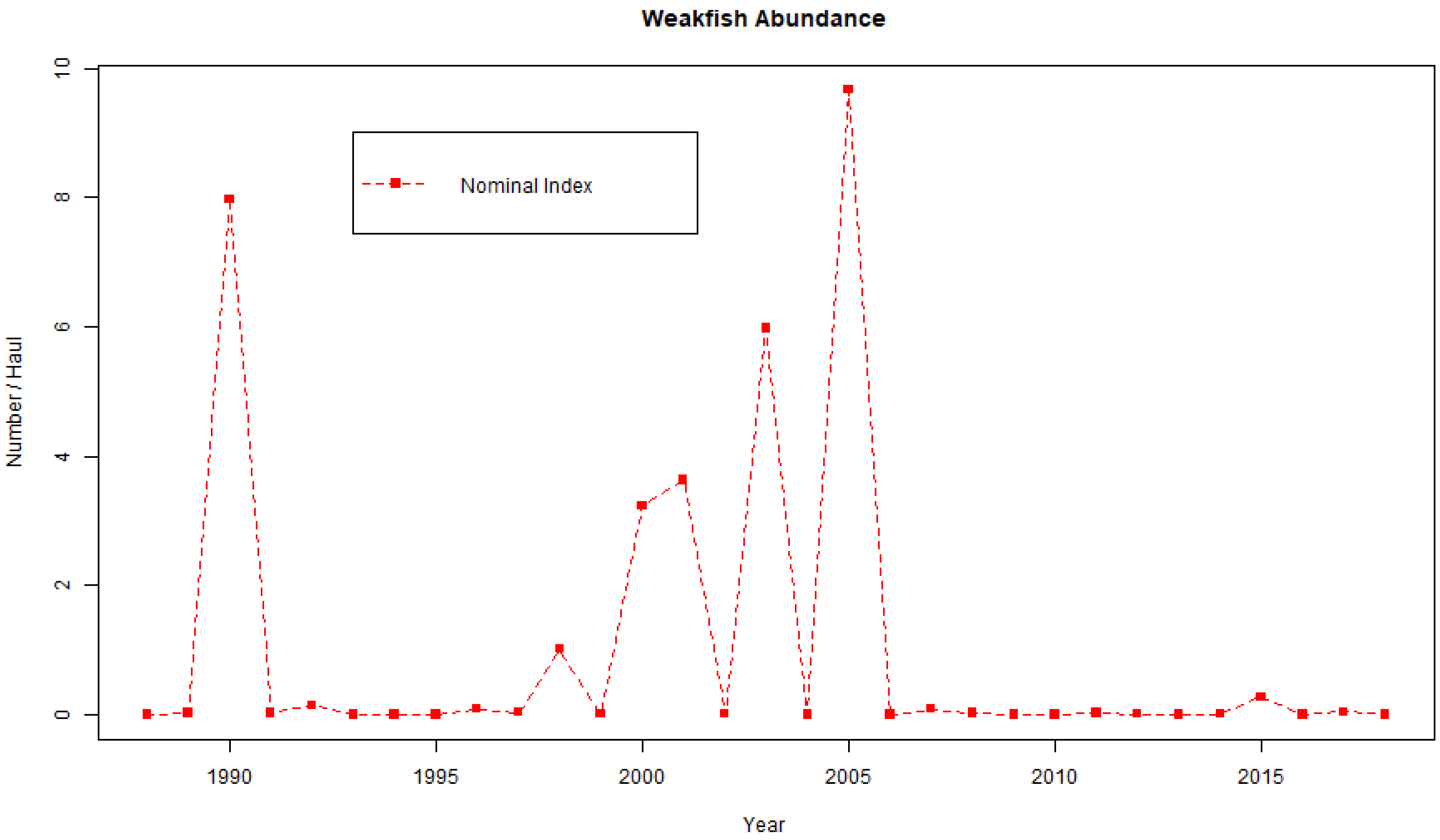


Figure 9. Weakfish annual abundance index 1988 – 2018.

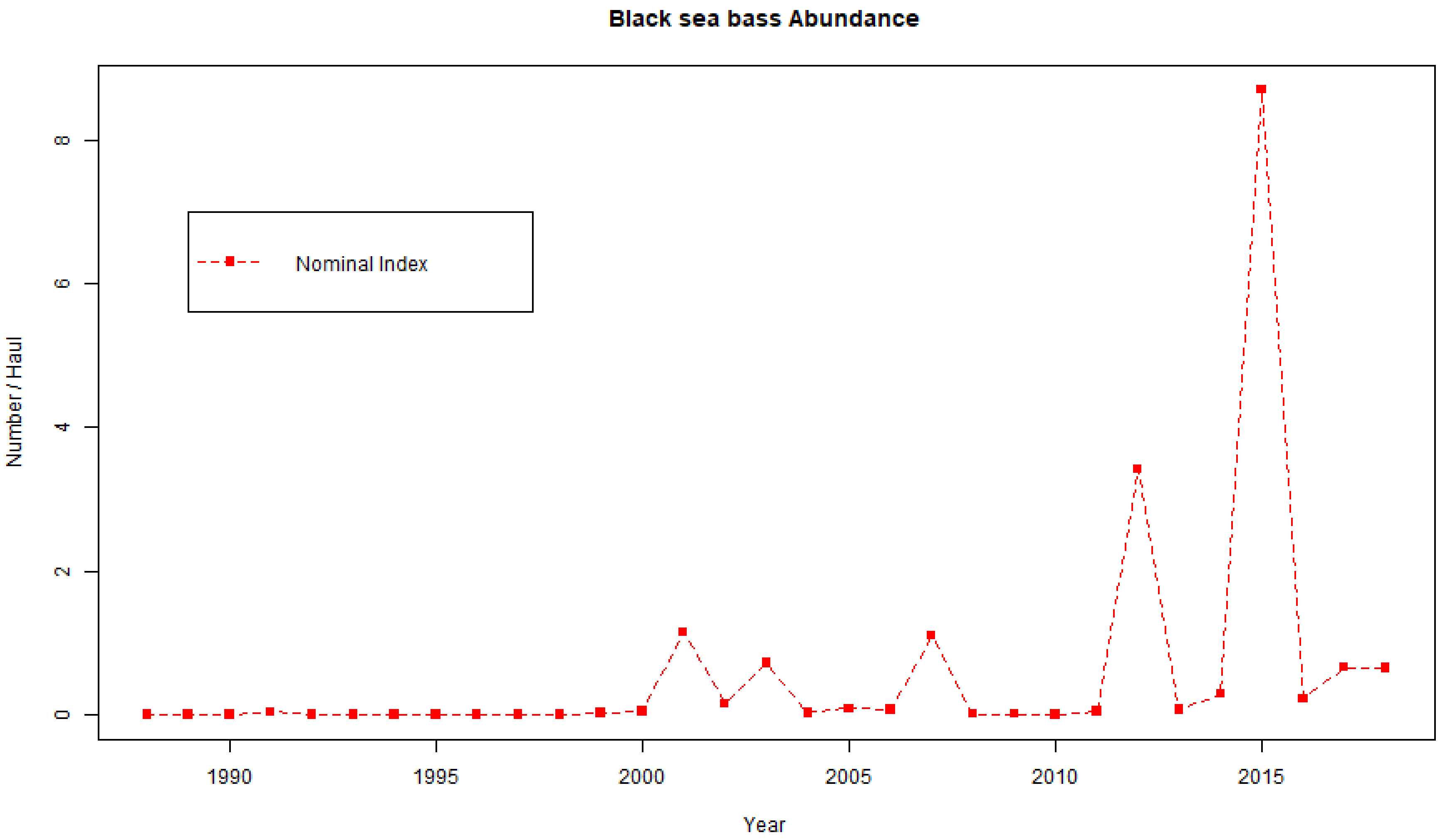


Figure 10. Black sea bass annual abundance index 1988 – 2018.

TABLES

Table 1a. Mann-Kendall test for target species abundance trend analysis (Full dataset; 1988 - 2018).

Mann-Kendall test	Winter Flounder	Tautog	Bluefish	River Herring	Menhaden	Striped Bass
S	-13	-13	-133	23	73	13
n Observations	31	31	31	31	31	31
Variance	3462	3462	3462	3462	3462	3462
Tau	-0.028	-0.028	-0.286	0.0495	0.157	0.028
2-sided p value	0.838	0.838	0.025	0.708	0.221	0.838
α	0.05	0.05	0.05	0.05	0.05	0.05
Significant Trend	No	No	Yes ↓	No	No	No

Table 1b. Mann-Kendall test for target species abundance trend analysis (2009 - 2018).

Mann-Kendall test	Winter Flounder	Tautog	Bluefish	River Herring	Menhaden	Striped Bass
S	-9	35	-11	35	27	1
n Observations	10	10	10	10	10	10
Variance	125	125	125	125	125	125
Tau	-0.2	0.778	-0.244	0.778	0.6	0.022
2-sided p value	0.47427	0.002	0.371	0.002	0.02	1
α	0.05	0.05	0.05	0.05	0.05	0.05
Significant Trend	No	Yes ↑	No	Yes ↑?	Yes ↓	No

Table 2. Young-of-the-Year (YOY) winter flounder - maximum total length for each month. *

Month	July	August	September	October
Max. YOY length (TL)	100 mm	107 mm	109 mm	115 mm

* data provided by L. Buckley, National Marine Fisheries Service, Narragansett Laboratory, Narragansett, R.I.

Table 3. Species presence by station for June 2018.

JUNE	**Station**																		
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus	106	85		1								15	3						210
Anchoa mitchilli			2	1															3
Anguilla rostrata			2																2
Calinectes sapidus		1	2														3		6
Clupea harengus			1											1					2
Etropus microstomus																		3	3
Fundulus heteroclitus			110			1							102						213
Fundulus majalis	5				21								31				1		58
Gobiosoma bosc		1			1						1								3
Limulus polyphemus			1					1											2
Menidia menidia	45	119	2	138		1516			17		1	9	333	23	7		147	90	2447
Microgadus tomcod					13					4	1		1	1		2			22
Morone saxatilis								1	2			1				1			5
Myoxocephalus aenaeus	1		13		3				1	2	13	1	10	2		1	1		48
Paralichthys dentatus				1							1				2				4
Pollachius virens					1														1
Pomatomus saltatrix			1																1
Prionotus carolinus																		1	1
Prionotus evolans																1			1
Pseudopleuronectes americanus	8	3	19	7	1	1					15	2	13		6		5		80
Sphoeroides maculatus					1														1
Stenotomus chrysops												5					2		7
Syngnathus fuscus			7		1								3	1					12
Tautoga onitis		1			18	2				2	1	8					6		38
Tautogolabrus adspersus					1					3		1					2		7

Table 4. Species presence by station for July 2018.

JULY	**Station**																		
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus	91	24		1	1	15	158	19	53		13	7	182	106		9	436		1115
Anchoa mitchilli		2		1				14											17
Anguilla rostrata					2														2
Brevoortia tyrannus		2															1		3
Calinectes sapidus			8		1														9
Caranx hippos			1																1
Centropristus striata															1				1
Clupea harengus							279												279
Cyprinodon variegatus																1			1
Etropus microstomus															3				3
Fundulus heteroclitus	1		359		1				2		33		7						403
Fundulus majalis	69	3	140		6	3		28	2		14		9	4		1	2	1	282
Gasterosteus aculeatus																		1	1
Gobiosoma bosc	1	1																1	3
Limulus polyphemus																1			1
Menidia menidia	119	7	144	298	618	705	236	93	41		573	568	34	779	219	335	1089	192	6050
Menticirrhus saxatilis	2	4										4					1	35	46
Microgadus tomcod														2					2
Morone saxatilis	1															5			6
Myoxocephalus aenaeus								1		2	1		2	1					7
Paralichthys dentatus		1																	1
Peprilus triacanthus															135				135
Pomatomus saltatrix	13	12	3	23	5		1	4	24					7	1		11		104
Prionotus carolinus	2												1						3
Prionotus evolans																1		1	2
Pseudopleuronectes americanus	1		14								1		12					1	29
Scophthalmus aquosus															1				1
Sphoeroides maculatus	2	3		2	1	1											1	16	26
Stenotomus chrysops							1	3					6	9	3		7		29
Strongylura marina																	1	1	2
Syngnathus fuscus					9								6						15
Tautoga onitis	1	1			30	3				1		1	15	1			9		62
Tautogolabrus adspersus	1	1			1		1				1								5
Trachinotus carolinus																		1	1
Trachinotus falcatus															5				5

Table 5. Species presence by station for August 2018.

AUGUST	**Station**																		
Row Labels	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus		5						1	4								2		12
Apeltes quadracus	1	1															1		3
Brevoortia tyrannus	1		8531		2103	2	1668	2866				1	4112			227			19511
Calinectes sapidus	3		2										1				2		8
Centropristus striata		3				7			4				1		1		3	1	20
Cyprinodon variegatus									1								1		2
Fundulus heteroclitus	76	4			3	79		55			25		3	435		11	405	1	1097
Fundulus majalis	480	90	90	68	38	95	1	316	110		8		5	260		791	232	14	2598
Gobiosoma bosc																	1		1
Limulus polyphemus																	1		1
Lutjanus griseus													1						1
Menidia menidia	78	175	50	12	146	47	3633	517	223	1025	126	953	166	145	12	1093	930	115	9446
Menticirrhus saxatilis	3	27										18	1		6	1		32	88
Mugil curema													1					1	2
Myoxocephalus aenaeus																1			1
Opsanus tau									1										1
Pomatomus saltatrix															1				1
Prionotus carolinus															1				1
Prionotus evolans	1	2																75	78
Pseudopleuronectes americanus	1							1	1			1	4						8
Sphoeroides maculatus	3	2				1												3	9
Stenotomus chrysops	3	7		1	1		12	7	5			1	2	8	2		4	56	109
Strongylura marina	1	3				1												3	8
Syngnathus fuscus	5	2			1					2							4	1	15
Synodus foetens	9																2	15	26
Tautoga onitis		2	1		313	34	5		27	1	2		36	6			34	2	463
Tautogolabrus adspersus					6	12	2		1	3							1		25
Trachinotus carolinus															1			1	2

Table 6. Species presence by station for September 2018.

SEPTEMBER	**Station**																		
Row Labels	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus			2					6											8
Brevoortia tyrannus	4	39	667		1	32			1	14						1			759
Calinectes sapidus			1																1
Centropristus striata					29			1	2	1									33
Cyprinodon variegatus			2						1										3
Fundulus heteroclitus	126	24																	150
Fundulus majalis	251	314	997	16	20	59	1	17	39	1						645			2360
Gobiosoma bosc			1						1										2
Loligo pealei								1											1
Menidia menidia	179	874	700	87	450	1586	1247	2657	1197	741						2366			12084
Menticirrhus saxatilis	2	2		1		2													7
Morone saxatilis		1																	1
Mugil curema			43																43
Opsanus tau					1														1
Pomatomus saltatrix		6																	6
Prionotus carolinus				1					1										2
Pseudopleuronectes americanus				1	2				2										5
Stenotomus chrysops			4		6		2			3						1			16
Syngnathus fuscus					5														5
Tautoga onitis					147	11	5	1	112	11						6			293
Tautogolabrus adspersus					6	2			19	8						1			36
Trachinotus carolinus			5																5

Table 7. Species presence by station for October 2018.

OCTOBER	Station																		
Row Labels	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus								19											19
Brevoortia tyrannus			212					8625	8106				12					1	16956
Calinectes sapidus			3															1	4
Cancer irroratus																		1	1
Cyprinodon variegatus	1					1										3		1	6
Fundulus heteroclitus	13		5				1	16	5				1						41
Fundulus majalis	41	7	6	5	7	148		27	148			1	3	1	4	9	1	41	449
Gobiosoma bosc					1		1												2
Menidia menidia	20	38	103	69	35	1327	122	79	45		49	85	39	5	215	323	21	59	2634
Myoxocephalus aenaeus							1												1
Opsanus tau											1								1
Pseudopleuronectes americanus									1						4			2	7
Stenotomus chrysops								1											1
Syngnathus fuscus				2									1						3
Tautoga onitis		2			5	1	1		23	1			2	5	1			1	42
Tautogolabrus adspersus					2		3		5										10

Table 8. Summary of species occurrence by station in 2018.

ALL MONTHS	**Station**																		
Row Labels	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Grand Total**
Alosa aestivalis &/or pseudoharengus	197	114	2	2	1	15	158	45	57		13	22	185	106		9	438		1364
Anchoa mitchilli		2	2	2				14											20
Anguilla rostrata			2		2														4
Apeltes quadracus	1	1															1		3
Brevoortia tyrannus	5	41	9410		2104	34	1668	11491	8107	14		1	4124			228	1	1	37229
Calinectes sapidus	3	1	16		1								1				5	1	28
Cancer irroratus																		1	1
Caranx hippos			1																1
Centropristus striata		3			29	7		1	6	1			1		2		3	1	54
Clupea harengus			1				279							1					281
Cyprinodon variegatus	1		2			1			2							4	1	1	12
Etropus microstomus															3			3	6
Fundulus heteroclitus	216	28	474	1	4	107	1	73	7		58		113	435		28	405	1	1951
Fundulus majalis	846	414	1233	89	92	305	2	388	299	1	22	1	48	265	4	1446	236	55	5746
Gasterosteus aculeatus																		1	1
Gobiosoma bosc	1	2	1		2		1		1		1						1	1	11
Limulus polyphemus			1					1								1	1		4
Loligo pealei								1											1
Lutjanus griseus													1						1
Menidia menidia	441	1213	999	604	1249	5181	5238	3346	1523	1766	749	1615	572	952	453	4117	2187	456	32661
Menticirrhus saxatilis	7	33		1								22	1		6	1	1	67	139
Microgadus tomcod					13					4	1		1	3		2			24
Morone saxatilis	1	1				2		1	2			1				6			14
Mugil curema			43										1					1	45
Myoxocephalus aenaeus	1		13		3		1	1	1	4	14	1	12	3		2	1		57
Opsanus tau					1				1		1								3
Paralichthys dentatus		1		1							1				2				5
Peprilus triacanthus															135				135
Pollachius virens					1														1
Pomatomus saltatrix	13	18	4	23	5		1	4	24					7	2		11		112
Prionotus carolinus	2			1					1				1		1			1	7
Prionotus evolans	1	3														2		76	82
Pseudopleuronectes americanus	10	3	33	8	3	1		1	4		16	3	29		10		5	3	129
Scophthalmus aquosus															1				1
Sphoeroides maculatus	5	5		2	2	2											1	19	36
Stenotomus chrysops	3	7	4	1	7		15	11	5	3		6	8	17	5	1	13	56	162
Strongylura marina	1	3				1											1	4	10
Syngnathus fuscus	5	2	7	2	16					2			10	1			4	1	50
Synodus foetens	9																2	15	26
Tautoga onitis	1	6	1	4	513	51	11	1	162	16	3	9	53	7		11	50	3	902
Tautogolabrus adspersus	1	1			16	14	6		25	14	1	1				1	3		83
Trachinotus carolinus			5												1			2	8
Trachinotus falcatus															5				5

* The units are number of times present at each station (maximum would be 18 times present for a species at all stations for the year).

Table 9. Numbers of juvenile winter flounder per seine haul in 2018.

	Station																			
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	8	3	19	7	1	1	0		0	0	15	2	13	0	6	0	5	0	4.71	5.96	1.40
JUL	1	0	14	0	0	0	0	0	0	0	1	0	12	0	0	0	0	1	1.61	4.17	0.98
AUG	1	0	0	0	0	0	0	1	1	0	0	1	4	0	0	0	0	0	0.44	0.98	0.23
SEP	0	0	0	1	2	0	0	0	2	0	ns	ns	ns	ns	ns	0	ns	ns	0.45	0.82	0.19
OCT	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	2	0.39	1.04	0.24
Mean	2.00	0.60	6.60	1.60	0.60	0.20	0.00	0.25	0.80	0.00	4.00	0.75	7.25	0.00	2.50	0.00	1.25	0.75			
St Dev	3.39	1.34	9.21	3.05	0.89	0.45	0.00	0.50	0.84	0.00	7.35	0.96	6.29	0.00	3.00	0.00	2.50	0.96		Total Fish	
SE	1.52	0.60	4.12	1.36	0.40	0.20	0.00	0.22	0.37	0.00	3.29	0.43	2.81	0.00	1.34	0.00	1.12	0.43		129	
Number	10	3	33	8	3	1	0	1	4	0	16	3	29	0	10	0	5	3			

*ns indicates that there was no sample collected

Table 10. Numbers of juvenile tautog per seine haul in 2018.

	Station																			
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	0	1	0	0	18	2	0	0	0	2	1	8	0	0	0	0	6	0	2.11	4.56	1.08
JUL	1	1	0	0	30	3	0	0	0	1	0	1	15	1	0	0	9	0	3.44	7.69	1.81
AUG	0	2	1	0	313	34	5	0	27	1	2	0	36	6	0	0	34	2	25.72	72.95	17.19
SEP	0	0	0	0	147	11	5	1	112	11	ns	ns	ns	ns	ns	6	ns	ns	26.64	51.63	12.17
OCT	0	2	0	4	5	1	1	0	23	1	0	0	2	0	0	5	1	1	2.56	5.37	1.27
Mean	0.20	1.20	0.20	0.80	102.60	10.20	2.20	0.20	32.40	3.20	0.75	2.25	13.25	1.75	0.00	2.20	12.50	0.75			
St Dev	0.45	0.84	0.45	1.79	130.57	13.88	2.59	0.45	46.24	4.38	0.96	3.86	16.56	2.87	0.00	3.03	14.71	0.96		Total Fish	
SE	0.20	0.37	0.20	0.80	58.39	6.21	1.16	0.20	20.68	1.96	0.43	1.73	7.41	1.28	0.00	1.36	6.58	0.43		902	
Number	1	6	1	4	513	51	11	1	162	16	3	9	53	7	0	11	50	3			

*ns indicates that there was no sample collected

Table 11. Numbers of juvenile bluefish per seine haul in 2018.

	Station																			
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	0	0	1	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0.06	0.24	0.06
JUL	13	12	3	23	5	0	1	4	24	0	0	0	0	7	1	0	11	0	5.78	7.82	1.84
AUG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.06	0.24	0.06
SEP	0	6	0	0	0	0	0	0	0	0	ns	ns	ns	ns	ns	0	ns	ns	0.55	1.81	0.43
OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Mean	4.16	4.32	1.00	5.75	1.00	0.00	0.25	1.00	6.00	0.00	0.00	0.00	0.00	2.33	0.67	0.00	3.67	0.00			
St Dev	5.81	5.37	1.41	11.50	2.24	0.00	0.50	2.00	12.00	0.00	0.00	0.00	0.00	4.04	0.58	0.00	6.35	0.00		Total Fish	
SE	2.60	2.40	0.63	5.14	1.00	0.00	0.22	0.89	5.37	0.00	0.00	0.00	0.00	1.81	0.26	0.00	2.84	0.00		112	
Number	13	18	4	23	5	0	1	4	24	0	0	0	0	7	2	0	11	0			

*ns indicates that there was no sample collected

Table 12. Numbers of striped bass per seine haul in 2018.

	Station																				
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	0	0	0	0	0	0	0	1	2	0	0	1	0	0	0	1	0	0	0.28	0.57	0.14
JUL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0.33	1.19	0.28
AUG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
SEP	0	1	0	0	0	2	0	0	0	0	ns	ns	ns	ns	ns	0	ns	ns	0.27	0.65	0.15
OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Mean	0.20	0.20	0.00	0.00	0.00	0.40	0.00	0.20	0.40	0.00	0.00	0.25	0.00	0.00	0.00	1.20	0.00	0.00			
St Dev	0.45	0.45	0.00	0.00	0.00	0.89	0.00	0.45	0.89	0.00	0.00	0.50	0.00	0.00	0.00	2.17	0.00	0.00		Total Fish	
SE	0.20	0.20	0.00	0.00	0.00	0.40	0.00	0.20	0.40	0.00	0.00	0.22	0.00	0.00	0.00	0.97	0.00	0.00		14	
Number	1	1	0	0	0	2	0	1	2	0	0	1	0	0	0	6	0	0			

*ns indicates that there was no sample collected

Table 13. Numbers of juvenile river herring per seine haul in 2018.

	Station																				
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	106	85	0	1	0	0	0	0	0	0	0	15	3	0	0	0	0	0	11.67	30.91	7.29
JUL	91	24	0	1	1	15	158	19	53	0	13	7	182	106	0	9	436	0	61.94	109.25	25.75
AUG	0	5	0	0	0	0	0	1	4	0	0	0	0	0	0	0	2	0	0.67	1.50	0.35
SEP	0	0	2	0	0	0	0	6	0	0	ns	ns	ns	ns	ns	0	ns	ns	0.73	1.85	0.44
OCT	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	1.06	4.48	1.06
Mean	39.40	22.80	0.40	0.40	0.20	3.00	31.60	9.00	11.40	0.00	3.25	5.50	46.25	26.50	0.00	1.80	109.50	0.00			
St Dev	54.21	36.15	0.89	0.55	0.45	6.71	70.66	9.41	23.32	0.00	6.50	7.14	90.51	53.00	0.00	4.02	217.67	0.00		Total Fish	
SE	24.24	16.17	0.40	0.24	0.20	3.00	31.60	4.21	10.43	0.00	2.91	3.19	40.48	23.70	0.00	1.80	97.34	0.00		1364	
Number	197	114	2	2	1	15	158	45	57	0	13	22	185	106	0	9	438	0			

*ns indicates that there was no sample collected

Table 14. Numbers of juvenile menhaden per seine haul in 2018.

	Station																				
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
JUL	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.17	0.51	0.12
AUG	1	0	8531	0	2103	2	1668	2866	0	0	0	1	4112	0	0	227	0	0	1083.94	2222.98	523.96
SEP	4	39	667	0	1	32	0	0	1	14	ns	ns	ns	ns	ns	1	ns	ns	69.00	198.82	46.86
OCT	0	0	212	0	0	0	0	8625	8106	0	0	0	12	0	0	0	0	1	942.00	2702.62	637.01
Mean	1.00	8.20	1882.00	0.00	420.80	6.80	333.60	2298.20	1621.40	2.80	0.00	0.25	1031.00	0.00	0.00	45.60	0.25	0.25			
St Dev	1.73	17.24	3726.87	0.00	940.38	14.11	745.95	3748.20	3625.00	6.26	0.00	0.50	2054.01	0.00	0.00	101.41	0.50	0.50		Total Fish	
SE	0.77	7.71	1666.71	0.00	420.55	6.31	333.60	1676.25	1621.15	2.80	0.00	0.22	918.58	0.00	0.00	45.35	0.22	0.22		37,229	
Number	5	41	9410	0	2104	34	1668	11491	8107	14	0	1	4124	0	0	228	1	1			

*ns indicates that there was no sample collected

Table 15. Numbers of juvenile black sea bass per seine haul in 2018.

	Station																				
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	Mean	St Dev	SE
JUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1.00	0.24	0.06
AUG	0	3	0	0	0	7	0	0	4	0	0	0	1	0	1	0	3	1	20.00	1.94	0.46
SEP	0	0	0	0	29	0	0	1	2	1	ns	ns	ns	ns	ns	0	ns	ns	33.00	8.65	2.04
OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Mean	0.00	0.60	0.00	0.00	5.80	1.40	0.00	0.20	1.20	0.20	0.00	0.00	0.25	0.00	0.50	0.00	0.75	0.25			
St Dev	0.00	1.34	0.00	0.00	12.97	3.13	0.00	0.45	1.79	0.45	0.00	0.00	0.50	0.00	0.58	0.00	1.50	0.50		Total Fish	
SE	0.00	0.60	0.00	0.00	5.80	1.40	0.00	0.20	0.80	0.20	0.00	0.00	0.22	0.00	0.26	0.00	0.67	0.22		54	
Number	0	3	0	0	29	7	0	1	6	1	0	0	1	0	2	0	3	1			

*ns indicates that there was no sample collected

Table 15. Temperature, salinity, and dissolved oxygen by station and month – 2018 (NA indicates a day where batteries failed on YSI).

		Month					
Station		**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**Total Average**
1	Temperature (C)	21.7	25.4	25.2	21.4	14.8	21.70
	Salinity	23.2	16.7	21.2	18.8	23.4	20.66
	Dissolved Oxygen	7.44	7.4	5.72	6.2	7.67	6.89
2	Temperature (C)	22.4	25	25.7	21.2	13.1	21.48
	Salinity	24.1	17	23.1	22.2	22.6	21.80
	Dissolved Oxygen	7.22	8	6.12	6.98	12.75	8.21
3	Temperature (C)	24.5	27.5	28.1	21.9	12.8	22.96
	Salinity	18.6	26.6	26	19.9	24.4	23.10
	Dissolved Oxygen	8.7	8.75	7.2	6.12	9.3	8.01
4	Temperature (C)	20.5	24.8	26.2	19.8	12.8	20.82
	Salinity	27	27.6	26.7	27.7	25.6	26.92
	Dissolved Oxygen	7.71	6.2	8.95	9.27	10.47	8.52
5	Temperature (C)	18.9	24.2	24.9	21.3	13.5	20.56
	Salinity	26.9	27.3	27.6	27.3	25.4	26.90
	Dissolved Oxygen	7.82	7.48	5.85	5.17	8.7	7.00
6	Temperature (C)	17.1	23.1	26	18.7	14.1	19.80
	Salinity	27.8	28.3	27.5	26.3	27.4	27.46
	Dissolved Oxygen	8.1	7.26	9.79	7.49	8.46	8.22
7	Temperature (C)	17.9	21.5	25.5	19.2	12.8	19.38
	Salinity	28.5	28.7	28	27.4	28	28.12
	Dissolved Oxygen	9.49	6.1	10.2	7.17	9.61	8.51
8	Temperature (C)	18.1	24.5	25.5	19	20.3	21.48
	Salinity	26.2	26.9	26.6	24	25.3	25.80
	Dissolved Oxygen	7.61	7.93	5.2	7.97	8.6	7.46
9	Temperature (C)	17.7	22.7	23.8	19.4	20.2	20.76
	Salinity	26.8	27.5	27.6	23	26.3	26.24
	Dissolved Oxygen	7.7	5.74	5.06	6.77	7.95	6.64
10	Temperature (C)	16.4	19.2	22	19.7	19.3	19.32
	Salinity	29.2	19.7	28.9	0	28.8	21.32
	Dissolved Oxygen	9.85	8.06	7.18	0	7.46	6.51
11	Temperature (C)	21.9	25.3	23.7		11.1	20.50
	Salinity	17.8	26.9	26.4		20.4	22.88
	Dissolved Oxygen	5.82	5.13	5.04		9.69	6.42
12	Temperature (C)	21	25	23.5		11.6	20.28
	Salinity	18.4	27.1	26.6		20.3	23.10
	Dissolved Oxygen	8.79	8.32	7.53		8.7	8.34
13	Temperature (C)	22.9	25.5	27.2		12.2	21.95
	Salinity	18.7	27.4	27.7		25.9	24.93
	Dissolved Oxygen	8.64	7.27	7.6		9.62	8.28
14	Temperature (C)	21.8	25.5	26.5		14	21.95
	Salinity	19.1	28.5	17.4		25.3	22.58
	Dissolved Oxygen	8.74	9.32	9.64		9.86	9.39
15	Temperature (C)	20.6	22.6	25.4		11.8	20.10
	Salinity	20.6	29	17.8		28	23.85
	Dissolved Oxygen	8.1	7.25	7.69		9.47	8.13
16	Temperature (C)	16.5	21.3	23	19.7	19.4	19.98
	Salinity	27.7	18.9	27.9	0	27.3	20.36
	Dissolved Oxygen	7.57	7.33	6.33	0	7.28	5.70
17	Temperature (C)	17.8	26.4	24.2		12.1	20.13
	Salinity	26.5	28.8	26.5		23.7	26.38
	Dissolved Oxygen	6.08	6.43	6.86		9.36	7.18
18	Temperature (C)	22	24.1	27.2		13	21.58
	Salinity	18.6	28.2	27.6		27	25.35
	Dissolved Oxygen	7.87	7.21	8.95		9.32	8.34

APPENDIX A

Standardized Index Development – Delta Lognormal

Menhaden, Bluefish, River Herring

The standardized indices for 3 of the main target species of the survey considered five factors as possible influences on the indices of abundance, which are summarized below:

Factor	**Levels**	**Value**
Year	31	1988-2018
Month	5	June - October
Temperature (°C)	Continuous	
Salinity (ppt)	Continuous	
Station	18	18 fixed stations throughout bay

The delta lognormal model approach (Lo et al., 1992) was used to develop standardized indices of abundance for the seine survey data. This method combines separate generalized linear model (GLM) analyses of the proportion of successful hauls (i.e. hauls that caught winter flounder) and the catch rates on successful hauls to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure in the R statistical software package (dglm function see: http://www.sefsc.noaa.gov/sedar/download/SEDAR17-RD16%20User%20Guide%20Delta-GLM%20function%20for%20R%20languageenvironment%20(Ver.%201.7.2,%2007-06-2006).pdf?id=DOCUMENT).

For each GLM procedure of proportion positive trips, a binomial error distribution was assumed, and the logit link was selected. The response variable was proportion successful trips. During the analysis of catch rates on successful trips, a model assuming lognormal error distribution was examined.

The final models for the analysis of catch rates on successful trips, in all cases were:

Ln(catch) = Year + Month + Station + Temperature + Salinity

The final models for the analysis of the proportion of successful hauls, in all cases including menhaden, were:

Success = Year + Month + Station + Temperature + Salinity

Standardized Index Development – Negative Binomial Generalized Linear Model

Winter Flounder, Tautog, Striped Bass

The standardized indices for 3 of the main target species of the survey considered up to six factors as possible influences on the indices of abundance, which are summarized below:

Species	**Factor**	**Levels**	**Value**
Winter Flounder	Year	31	1988-2018
	Station Periods	4	Stations were added to the survey on 3 separate occasions (station 16 added June 1990, station 17 added July 1993, station 18 added July 1995)
	Temperature (°C)	Continuous	
	Salinity (ppt)	Continuous	
	Station	18	18 fixed stations throughout bay
Tautog	Year	31	1988-2018
	Station Periods	4	Stations were added to the survey on 3 separate occasions (station 16 added June 1990, station 17 added July 1993, station 18 added July 1995)
	Station	18	18 fixed stations throughout bay
Striped Bass	Year	31	1988-2018
	Station Periods	4	Stations were added to the survey on 3 separate occasions (station 16 added June 1990, station 17 added July 1993, station 18 added July 1995)
	Temperature (°C)	Continuous	
	Salinity (ppt)	Continuous	
	Station	18	18 fixed stations throughout bay
	Month	6	June - November

The negative binomial generalized linear model approach was used to develop standardized indices of abundance for the seine survey data. This method produces a generalized linear model (GLM) for the catch rates on all hauls to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure in the R statistical software package, the code of which was modified from Nelson and Coreia of the Northeast Fishery Science Center (personal communication).

During the analysis of catch rates on hauls, a model assuming a negative binomial error distribution was examined. The linking function selected was “log”, and the response variable was abundance (count) for each individual haul where one of the three species was caught.

A stepwise approach was used to quantify the relative importance of the factors. First a GLM model was fit on year. These results reflect the distribution of the nominal data. Next, each potential factor was added to the null model sequentially and the resulting reduction in deviance per degree of freedom was examined. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$). This model then became the base model, and the process was repeated, adding factors individually until no factor met the criteria for incorporation into the final model.

The final models for the analysis of catch rates were:

Winter Flounder: Abundance = Year + Temperature + Station + Station Periods
Tautog: Abundance = Year + Temperature + Station + Salinity
Striped Bass: Abundance = Year + Station

Assessment of Recreationally Important Finfish
Stocks in Rhode Island Coastal Waters

2018 Annual Performance Report for Job VI, Part A:

Assessment, Protection, and Enhancement of Fish Habitat to Sustain Coastal and Marine Ecosystems and Healthy Stocks of Recreationally Important Finfish:

Assessing, Monitoring, and Minimizing Impacts to Marine Habitat

Prepared by: Eric G. Schneider, Julia Livermore, Katie Rodrigue, and Conor McManus (Rhode Island DEM, Div. of Marine Fisheries), and William Helt and Heather Kinney (TNC RI Chapter)

Rhode Island Department of Environmental Management
Division of Fish and Wildlife, Marine Fisheries
Fort Wetherill Marine Fisheries Laboratory
3 Fort Wetherill Road
Jamestown, RI 02835

Federal Aid in Sportfish Restoration
F-61-R

2018 Performance Report for Job VI, Part A March 8, 2019

PERFORMANCE REPORT

STATE: Rhode Island

PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 21

PROJECT TITLE: Assessing, Monitoring, and Minimizing Impacts to Marine Habitat

PERIOD COVERED: January 1, 2018 - December 31, 2018

JOB NUMBER AND TITLE: VI, Part A: Assessment, Protection, and Enhancement of Fish Habitat to Sustain Coastal and Marine Ecosystems and Healthy Stocks of Recreationally Important Finfish: initial project area Providence-Seekonk Tidal Estuaries (head of Narragansett Bay)

STAFF: Eric G. Schneider, Julia Livermore, Katie Rodrigue, and Conor McManus (Rhode Island DEM, Div. of Marine Fisheries), and William Helt and Heather Kinney (TNC RI Chapter)

JOB OBJECTIVES: The goal of this project is to assess, protect, enhance, and restore important marine habitat to support healthy marine ecosystems and stocks of recreationally important finfish. We will obtain this goal by addressing the following objectives:

(1) Identify, assess, and monitor sensitive and important marine habitat in Rhode Island (RI) waters in concert with developing a RI Marine Habitat Management and Restoration Plan through a regional approach, starting at the Head of Narragansett Bay.
(2) Provide a comprehensive review of permit applications for projects that occur in RI waters and may directly or indirectly impact coastal and marine resources and their habitat, including economic development projects, such as energy, infrastructure, dredging, and dredge spoil disposal projects, as well as aquaculture and habitat restoration projects.
(3) Respond to major fish kills and assess habitat conditions, and in the event of a significant environmental incident, coordinate hazard mitigation, assessment of natural resource damages, and resulting habitat restoration.

SUMMARY:

Objective 1: During the 2018 season, a total of 72 seines were hauled at 12 sites resulting in the identification of 46 distinct species (see Table 1). All five target species (black sea bass, scup, summer flounder, tautog, and winter flounder) were captured.

A total of 25 successful video transects were completed. A quantitative analysis using the Coastal and Marine Ecological Classification Standard (CMECS) (FGDC 2012) was used to evaluate the video footage from 2017 and 2018. HOBO Salt Water Conductivity/Salinity and Dissolved Oxygen Data Loggers collected data at 11 of 12 sites. A total of 154,997 instances were recorded, containing temperature (°C), salinity (ppt), and dissolved oxygen (mg/L).

A total of 15 sites were sampled with fish traps in the 2018 season. The Seekonk sites (Pawtucket Ramp, Bishop Point, Butler, and Omega Pond) were discontinued by July because of two northern diamondback terrapin (*Malaclemys terrapin*) interactions. Two terrapin captures in the survey gear were reported to the RI Natural History Survey, as well as Dr. Malia Schwartz, URI FAVS professor, and Dr. Scott Buchanan, RIDEM herpetologist. To replace the discontinued sites, three additional fish trap locations (Watchemocket Cove, Sabin Pier, Rocky Point) were added in August and sampled through October (Table 2; Table 3). In all, a total of 64 deployments were completed from May-October catching eleven species including 280 finfish and 687 crustaceans (Table 4).

An artificial reef project was designed, and permits were submitted, to evaluate the application of reef balls to enhance fish habitat. Pending acquisition of permits, site monitoring will begin in summer 2019, and construction will begin in fall 2019.

Objective 2: This past year, DMF reviewed 95 projects and applications as part of its Environmental Review program, excluding aquaculture application reviews, which are reported separately. Verbal and/or written comments were provided on all general permit reviews through the monthly general permit meeting with the RI Coastal Resource Management Council (CRMC), RI DEM Office of Water Resources (OWR), U.S. Environmental Protection Agency (EPA), and U.S. Army Corps of Engineers (USACE). As part of these reviews, the DMF reviewed and provided comments, including time of year work windows for all dredge-related all projects. Table 1 contains a summary of the activities and/or potential impacts identified during the permit review process.

This past year, the DMF participated in and formulated responses for 6 preliminary determination meetings with aquaculture applicants. DMF also created site maps for 4 prospective applicants by meeting with them prior to their preliminary determination submissions; this practice serves to mitigate habitat and fisheries concerns by eliminating important biological areas from consideration. We also provided formal, written responses for over 12 public noticed lease applications, and held RI Marine Fishery Council (RIMFC) Advisory Panel meetings to gain input from industry on aquaculture sites and to provide scientific opinion to the RIMFC regarding the sites. We coordinated all responses with RI DEM Fish and Wildlife Program for waterfowl habitat and hunting concerns, and drafted DMF official response letters related to fish habitat impacts that were identified through a detailed review of applications for new and modifications to aquaculture leases starting in January 2018.

As a result of frequent concerns with protecting fish habitat, the DMF developed the state's first spatial database of all active and proposed aquaculture sites in state waters in 2017. This database is used, along with other spatial use layers, by the DMF to better understand potential habitat and public use conflicts with newly proposed aquaculture locations. The Division has made the active sites layer public via an interactive map on the Department's website: http://ridemgis.maps.arcgis.com/apps/webappviewer/index.html?id=8beb98d758f14265a84d69758d96742f. This interactive map features mapping tools for future applicants to aid in the site selection process and help them avoid areas of public use or historic eelgrass habitat. The aquaculture layer provided is updated bi-annually and was therefore updated twice in 2018.

Objective 3: DMF staff participated in a joint full-scale oil spill response exercise led by the US Coast Guard and RI DEM, with assistance from local responders in Westerly. The exercise illustrated the need for planning and the utility of Geographic Response Plans (GRP). In addition, RI DMF received a total of 11 reports of fish kill events. Eight of these reports required RI DMF to respond to and assess the scene.

TARGET DATE: December 31, 2018

DEVIATIONS:

Deviations for work related to Objective No. 1 are: Fish trap locations were altered due to the interactions with norther diamondback terrapin at the Seekonk sites. The discontinuation of these sites led to three new stations being added. Two were sampled from August - October, and the third was sampled July - October. Water quality data was only taken during June benthic video sampling due to problems with the Eureka Sonde.

No deviations occurred for work related to Objective No. 2 and 3.

RECOMMENDATIONS:

Recommendations for work related to Objective 1 include continued sampling of beach seines, fish traps, and water quality data loggers at the 12 designated sites. Specific to the Benthic Video Survey, although QWVR is a time-consuming process, it is an important contribution to the overall site analysis. It may also make it easier to highlight important qualitative differences between sites or the upper and lower reaches of the Providence River Estuary. The QWVR also provides the potential to identify faster-moving animals and rare items that may not be caught in the CMECS snapshots but could include important insight on site suitability and possible restoration methods.

Recommendations for work related to Objective 2 include: To protect the important recreational fishery resources of the state, DMF will continue to improve data collection, assessment, and engage in planning and permit review processes.

Recommendations for work related to Objective 3 include: To maintain efficient response and assessment of environmental impact incidents, RI DMF staff will continue participation in emergency response training programs and understanding the spatio-temporal dynamics of critical habitats and their residents. In 2019, staff will participate in several training courses through FEMA’s National Incident Management System Training Program.

REMARKS

A summary of work conducted under Objective 1 was prepared by The Nature Conservancy (TNC), Rhode Island Chapter (see attached). In an attempt to improve clarity in reporting, work related to Objective No. 2 and 3 are summarized in separate subsections below.

OBJECTIVE No. 1

See Attached Report

OBJECTIVE No. 2

Approach - Objective 2

To address Objective 2, the Division provides a comprehensive review of any project or activity, including economic development projects (e.g. energy and infrastructure), dredging and dredge spoil disposal projects, as well as other activities (e.g. recreational and commercial fishing, aquaculture, habitat restoration, etc.) that are proposed for Rhode Island waters and could pose potential direct or indirect impacts to coastal and marine resources and their habitat. Reviews include all available data and provided important information to permitting agencies to allow for more informed permitting decisions.

As part of this effort, the DMF attends a monthly meeting of upcoming General Permit activities with staff representing the RI Coastal Resource Management Council (CRMC), RI DEM Office of Water Resources (OWR), U.S. Environmental Protection Agency (EPA), and U.S. Army Corps of Engineers (USACE)on the first Thursday of the month. During that meeting, applications for pier expansions, new piers, dredging projects, as well as any other projects that may present concerns over natural resource impacts were discussed by the agencies. Depending on the size, scope, and location of the proposed project or activity, the review process sometimes involves determining the living and non-living resources present at or near the project site and evaluating the potential direct and indirect adverse effects of the proposed project or activity on fishery resources and marine habitat. More specifically, this process often requires a site visit and a review of fishery resource data and marine habitat data, including EFH, that were collected at or near the project site or in similar habitat conditions. These data may include data collected by RI DMF finfish surveys funded by the USFWS Sport Fish Restoration Program (e.g. Narragansett Bay Monthly and Seasonal Fishery Resource Assessment, Winter Flounder Spawning Stock Biomass Survey, Young of the Year Survey of Selected RI Coastal Ponds and Embayments, and the Juvenile Marine Finfish Survey) and surveys related to finfish, shellfish, and ichthyoplankton conducted by RI DMF pursuant to other funding sources or other originations and institutions (e.g. MA DMF, NEMAP, NEFSC, URI GSO, etc.). Habitat data, including EFH data, may require leveraging data collected previously by RI DMF or other organizations and institutions.

In cases where site-specific habitat and marine resource data is limited, dated, or absent new data may be collected, analyzed, and summarized. When possible, this work takes advantage of collaborative efforts with other agencies. Data is assimilated and analyzed using statistical software, databases, imaging processing software, and GIS mapping and processing technologies where applicable. When necessary, DMF staff testify at CRMC hearings for permits where there is a significant objection by the Division.

As the aquaculture industry continues to expand, there is an increasing concern about additional user conflicts arising from the leasing of marine waters for aquaculture, which may limit certain public uses (e.g., fishing & waterfowl hunting). The DMF has been active in reviewing aquaculture permits to ensure prospective sites do not pose a threat to marine fish and their habitats. The most frequent concern with aquaculture applications is the spatial overlap with recent (e.g., last 3-4 years) or historic presence of eelgrass within the footprint of the proposed lease site. Additional fish habitat concerns include certain bottom substrates that impact foraging or spawning activities, or those located in areas of high recreational fishing activity.

Objective 2 – Results and Discussion

As part of its environmental review program the DMF reviewed 95 permits applications that contained approximately 163 separate activities and potential impacts and/or concerns that may affect marine resources (Table 1). Verbal and/or written comments were provided on all general permit reviews through the monthly general permit meeting with CRMC, RI DEM OWR, U.S. EPA, and USACE. As part of these reviews, RI DMF reviewed and provided comments and time of year work windows for all dredge-related all projects. Although the number of applications for modifications to residential docks remained unchanged at 39, there were 29 applications for new residential docks, of which there were no such applications during 2017. Several applications for new docks and piers were within or adjacent to eelgrass requiring further assessment and permit modifications to minimize impacts.

The DMF continued to participate in the Manchester Street Power Station 316(b) review process, as well several additional large-scale (potential) projects. For example, the DMF reviewed, commented on, and worked closely with stakeholders and applicants to revise large-scale restoration projects focused on maintenance dredging for the purpose of saltmarsh and eelgrass restoration, beach nourishment, and navigation channel maintenance. We also worked closely with applicants to redesign a large-scale maintenance dredging project to ensure impacts to saltmarshes, subtidal cobble/shell bottom, and other sensitive habitats were avoided.

This past year, the DMF participated in and formulated responses for 6 preliminary determination meetings with aquaculture applicants. DMF also created site maps for 4 prospective applicants by meeting with them prior to their preliminary determination submissions; this practice serves to mitigate habitat and fisheries concerns by eliminating important biological areas from consideration. The meetings are designed to allow participants to voice any concerns, including those related to fish and fish habitat. We also provided formal, written responses for over 12 public noticed lease applications, and held RI Marine Fishery Council (RIMFC) Advisory Panel meetings to gain input from industry on aquaculture sites for and to provide scientific opinion to the RIMFC regarding the sites. We coordinated all responses with RI DEM Fish and Wildlife Program for waterfowl habitat and hunting concerns, and drafted DMF official response letters related to fish habitat impacts that were identified through a detailed review of applications for new and modifications to aquaculture leases starting in Jan 2018.

As a result of frequent concerns with protecting fish habitat, the DMF developed the state's first spatial database of all active and proposed aquaculture sites in state waters in 2017. This database is used, along with other spatial use layers, by the DMF to better understand potential habitat and public use conflicts with newly proposed aquaculture locations. The Division has made the active sites layer public via an interactive map on the Department's website: http://ridemgis.maps.arcgis.com/apps/webappviewer/index.html?id=8beb98d758f14265a84d69758d96742f. This interactive map features mapping tools for future applicants to aid in the site selection process and help them avoid areas of public use or historic eelgrass habitat. The aquaculture layer provided is updated bi-annually and was therefore updated twice in 2018.

OBJECTIVE No. 3

Objective 3 - Approach

The Division has the duty to provide available scientific information on sudden mass-die-off events such as fish kills in marine waters and identify important recreational fish habitat and pre-impact conditions in the event of a significant environmental incident classified as a Category 3 major environmental disaster incident (e.g., > 10,000-gal oil spill or wide coastal environmental impact likely). In addition, the DMF provides a staff member with recreational fishery habitat expertise for coordination of DMF responses related to assisting the Office of Emergency Response Incident Command in assessing any significant environmental impacts of a major oil spill or incident on recreational habitat and biota in Rhode Island marine waters. For moderate incidents such as fish kills, the staff will follow the "Bay Response Team" (BART) protocols. We have been responding to all moderate and large kills and investigating habitat conditions to ascertain the role of severe hypoxia/anoxia in fish kills (the typical cause in summer months) in RI marine habitats.

Objective 3 – Results and Discussion

RI DMF received a total of 11 reports of fish kill events. Eight of these reports required RI DMF to respond to the scene. It was determined that most of these kills were due to natural causes (hypoxic conditions, high water temperatures, driven into shallow waters by predators, or a combination of these factors) with one reported kill of scup due to commercial fishing bycatch. The most commonly affected species was juvenile Atlantic menhaden. Other species include blue mussels, alewife, horseshoe crabs, and juvenile weakfish. See Table 2 for a summary of all fish kills reported in 2018.

In the event of an incident that causes significant environmental impact, it is imperative for RI DMF to be able to respond quickly and efficiently to assess the effects on fish habitat in Rhode Island waters. Coordination with other state agencies (including RI DEM Office of Emergency Response, OWR, and Office of Law Enforcement) has proven fundamental to this fast response time and impact assessment. A relatively high number of fish kill events were reported in 2018 (i.e., 11 reported events), and due to the diligence of staff throughout RI DEM, all events requiring action were responded to in a timely manner. The continuation of this coordinated effort is necessary to ensure that a fast and efficient response is maintained. Also, continued emergency response training will allow further improved response to these incidents.

Table 1. Activities and potential impacts identified during the permit review process performed in 2018 by RI DMF for 95 separate projects. Aquaculture and off-shore wind related reviews are excluded from this table.

Activities & Potential Impacts - 2018	Total
Potential Impacts to SAV or Benthic Habitat	11
Saltmarsh Restoration	6
Eelgrass Restoration	4
Artificial Reef	1
Maintenance Dredging	6
New Dredging	2
New Marina	2
Marina Expansion or Reconfiguration	2
Restoration of Tidal Flow to Coastal Pond	5
Residential Docks (new)	29
Residential Docks (modification)	39
Commercial/Municipal Piers or Docks	5
Commercial/Municipal Mooring expansion	0
Salt Marsh or Coastal Wetland Impacts	14
Beach Nourishment or Coastal Feature Restoration	4
Waterfront Bulkhead/Riprap	6
Waterfront Development	1
Public Works or Utility	6
Fish Passage	0
Potential Shellfish Impacts	4
Channel Maintenance	1
Boat Ramp (New or Repair)	1
Oyster Restoration	4
Recreational Use (Improve/Impacts)	7
Impacts from Discharge	3
Total	163

Table 2 Summary of fish kill events in 2018.

Date Reported	Water Body	Persons/Agencies Notified	Response	Date of Response	Species Affected	Approximate number affected/dead	Water Quality Measured	Samples Taken	Photos	Cause
6/29/2018	Sakonnet River	DEM OER, DEM DMF	DEM DMF responded to the scene	7/3/2018	Unknown baitfish species (reported as "minnows")	Minor (<100, none seen during investigation)	N	N	N	Unknown - likely natural
7/11/2018	Providence River	DEM OER, DEM DMF, DEM OWR	DEM DMF responded to the scene	7/12/2018	Blue mussel *Mytilus edulis*	Major (tens of thousands)	Y	N	Y	Natural - mortality likely due to high water temps
7/31/2018	West Passage	DEM DMF	DEM DMF followed up with reporter to get specific details. Determined that investigation was not necessary.	8/8/2018	Scup *Stenotomus chrysops*	Minor (~100)	N	N	N	Fishing bycatch from a trawling vessel. No further action needed.
8/10/2018	Greenwich Bay	DEM OER, DEM DMF, DEM OWR, DEM Director's Office (Mike Healy, Chief Public Affairs Officer)	DEM DMF responded to the scene	Apponaug Cove: 8/10/2018 Greenwich Bay Proper: 8/12/2018 Greenwich Cove: 8/14/2018	juvenile Atlantic menhaden *Brevoortia tyrannus* Alewife *Alosa pseudoharengus* juvenile weakfish *Cynoscion regalis* Horseshoe crab *Limulus polyphemus*	~1000 dead fish reported in Apponaug Cove, 75-100 observed during investigation on 8/10/18 (majority being menhaden). 5 dead horseshoe crabs observed in Greenwich Bay Proper on 8/12/2018. No dead organisms seen in Greenwich Cove on 8/14/2018.	Y	N	Y	Natural - hypoxic conditions. Brown murkey water caused by *Cochlodinium polykrikoides* phytoplankton bloom.
8/24/2018	Point Judith Pond	DEM OER, DEM DMF, DEM OWR	DEM DMF responded to the scene	8/24/2018	None observed	None observed	Y	Y (plankton)	Y	Natural - "rust tide" caused by *Cochlodinium polykrikoides* bloom
8/29/2018	West Passage	DEM OER, DEM DMF, DEM OWR	DEM DMF responded to the scene	8/29/2018	None observed	None observed	N	Y (plankton)	N	Natural - "rust tide" caused by *Cochlodinium polykrikoides* bloom
9/1/2018	Greenwich Bay	DEM DMF, DEM OER, DEM Enforcement	Response not deemed necessary	NA	juvenile Atlantic menhaden *Brevoortia tyrannus*	Moderate - small numbers dying as part of ongoing trend	N	N	N	Natural - ongoing hypoxic conditions

Date Reported	Water Body	Persons/Agencies Notified	Response	Date of Response	Species Affected	Approximate number affected/dead	Water Quality Measured	Samples Taken	Photos	Cause
9/7/2018	Seekonk River	DEM DMF	DEM DMF responded to the scene	9/7/2018	Atlantic menhaden *Brevoortia tyrannus* Horseshoe crab *Limulus polyphemus*	Thousands of dead menhaden and 3-4 dead horseshoe crabs reported along beach and in water of Seekonk River. Only some menhaden observed during DEM DMF investigation.	N	N	Y	Natural - likely due to hypoxic conditions.
9/18/2018	Little Narragansett Bay	DEM DMF	Response not deemed necessary	NA	Atlantic menhaden *Brevoortia tyrannus*	1000+	N	N	Y (provided by reporter)	Natural - likely driven into lagoon by predators and killed at night when DO dropped from rotting algae
9/30/2018	Seekonk River	DEM DMF	Response not deemed necessary	NA	Atlantic menhaden *Brevoortia tyrannus*	~50	Y (by reporter)	N	N	Natural - likely part of ongoing trend in hypoxic conditions in the area
11/15/2018	Mt. Hope Bay	DEM DMF	DEM DMF responded to the scene	11/15/2018	None observed	None observed	N	N	Y	No evidence of a kill

The Rhode Island Chapter of The Nature Conservancy
Annual Progress Report

Submitted to

The Rhode Island Department of Environmental Management
Division of Fish and Wildlife

Title: Identify, assess, and monitor sensitive and important marine habitat in Rhode Island (RI) waters in concert with developing an RI Marine Habitat Management and Restoration Plan through a regional approach, starting at the Head of Narragansett Bay.

Cooperative Agreement Award Number: 3439577

Award Term: 10/5/2015 to 12/31/2019

Reporting Period: 1/1/2018 to 12/31/2018

Prepared By

William Helt (Coastal Restoration Scientist) and
Heather Kinney (Coastal Restoration Science Technician)

Approved By

Scott Comings, Associate State Director

The Nature Conservancy Rhode Island Chapter
159 Waterman Street
Providence, RI 02906

SUMMARY

During the 2018 season, a total of 72 seines were hauled at 12 sites resulting in the identification of 46 distinct species (see Table 1). All five-target species (black sea bass, scup, summer flounder, tautog, and winter flounder) were captured. A total of 25 successful video transects were completed. A quantitative analysis using the Coastal and Marine Ecological Classification Standard (CMECS) (FGDC 2012) was used to evaluate the video footage from 2017 and 2018.

HOBO Salt Water Conductivity/Salinity and Dissolved Oxygen Data Loggers collected data at 11 of 12 sites. A total of 154,997 instances were recorded, containing temperature (°C), salinity (ppt), and dissolved oxygen (mg/L).

A total of 15 sites were sampled with fish traps in the 2018 season. The Seekonk sites (Pawtucket Ramp, Bishop Point, Butler, and Omega Pond) were discontinued by July because of two northern diamondback terrapin (*Malaclemys terrapin*) interactions. Two terrapin captures in the survey gear were reported to the RI Natural History Survey, as well as Dr. Malia Schwartz, URI FAVS professor, and Dr. Scott Buchanan, RIDEM herpetologist. To replace those sites, three additional fish trap locations (Watchemocket Cove, Sabin Pier, Rocky Point) were added in August and were sampled through October (Table 2; Table 3). In all, a total of 64 deployments were completed throughout May-October catching eleven species including 280 finfish and 687 crustaceans (Table 4).

An artificial reef project was designed, and permits were submitted, for to evaluate the application of reef balls to enhance fish habitat. Pending acquisition of permits, site monitoring will begin in summer 2019, and construction will begin in fall 2019.

TARGET DATE:

December 31, 2018

DEVIATIONS

Fish trap locations were altered due to interactions with northern diamondback terrapin, which are state-listed as endangered in RI, at the Seekonk sites. Three new locations were added. Two were sampled from August - October, and the third was sampled July–October. Water quality data was only taken during June benthic video sampling due to problems with the Eureka Sonde.

REMARKS

Objective 1 of Job VI, Part A is being included as a separate report to allow investigators to disseminate the document separately from Objectives 2 & 3.

RECOMMENDATIONS

We recommend continued sampling of beach seines, fish traps, and water quality data loggers at the 12 designated sites.

Specific to the Benthic Video Survey, although QWVR is a time-consuming process, it is an important contribution to the overall site analysis. It may also make it easier to highlight important qualitative differences between sites or the upper and lower reaches of the Providence River Estuary. The QWVR also provides the potential to identify faster-moving animals and rare items that may not be caught in the CMECS snapshots but could include important insight on site suitability and possible restoration methods.

NEXT STEPS

As a result of the work conducted in Job VI, Part A, the following project has been initiated:

Sabin Point Reef Ball

The team intends to construct an experimental artificial reef array at the Sabin Point sampling site about 75-100 feet from the end of the fishing pier (See Appendix A for the full Coastal Resources Management Council Assent application). This array will be monitored to evaluate whether artificial reef balls are a viable fish habitat enhancement practice in southern New England. At the time of reporting, the project team is awaiting CRMC Council approval of the proposed plans and intends to begin monitoring in summer 2019 and construction in fall 2019.

Revised study area maps

In an effort to incorporate the project's data into study area maps, the team is in the process of revising maps that will aid in investigating future habitat enhancement sites. Modifications will include the new fish trap sampling sites, CMECS biotic and abiotic site descriptors, a summary of seine and fish trap finfish catch by site and month, oblique images of the sample sites, and additional upland topography. These maps will be completed in April 2019 and will be available upon request (sample in Appendix B).

INTRODUCTION

Healthy and resilient coastal and marine ecosystems depend on the careful stewardship of both the living marine resources and the habitats upon which they depend. The importance of fish habitat to the sustainability of healthy fisheries was formally recognized with the advent of the Essential Fish Habitat (EFH) component of the Sustainable Fisheries Act (1996). Site specific baseline information detailing the condition of the habitat (e.g. water column conditions for salinity, temperature, dissolved oxygen (D.O.), and chlorophyll (Chl *a*), submerged aquatic vegetation (SAV), and the benthic structural habitat and epifauna) is required for several important fishery management tasks, including identifying areas of important habitat that should be protected, documenting the spatial distribution and condition of habitat in case of an environmental disaster, assessing changes over time due to impacts from climate change or other anthropogenic factors, as well as minimizing impacts from development activities.

In Rhode Island, most of the habitat-related survey work is conducted via collaborative projects often coordinated by non-regulatory partners and do not have consistent funding sources. Although the information collected by these projects is usually beneficial to managers, there is not an overarching plan or vision regarding how RI's marine habitat should be assessed, monitored, and managed. Thus, there is a clear need for a Marine Habitat Management and Restoration Plan that provides guidance for current (on-going) projects and establishes priorities for future work. This type of plan would also be a vital resource when establishing goals and objectives of cooperative projects, and when seeking funds via a competitive grant process. Because such a plan requires extensive filling of data gaps, we will be taking a regional approach to developing a statewide habitat plan, starting with the Providence-Seekonk tidal rivers (Head of Narragansett Bay).

APPROACH

The purpose and scope of this objective is to focus on a regional approach to developing a Habitat Management and Restoration Plan by filling serious habitat data gaps for critical marine areas where very little recent habitat data are available. This approach will allow us to evaluate and develop recommendations for restoration and enhancement techniques that can be rapidly deployed as part of a state-wide plan. It will also allow us to make positive improvements to fishery habitat and resources more quickly, while increasing the knowledge base for the state-wide plan. For the next 1-2 years we will continue to concentrate on the urban marine waters at the Head of the Bay where substantial water quality improvements have been recorded.

This work is being conducted under a multi-year cooperative agreement with The Nature Conservancy (TNC) and Rhode Island Department of Environmental Management (DEM) Division of Marine Fisheries (DMF). The agreement addresses the following tasks:

> Task I. Identify and study locations of degraded coastal habitat in Rhode Island estuaries that have the greatest potential to benefit from shoreline and sub-tidal restoration techniques and improved fish production.
>
> Task II. Identify relevant and cost-effective coastal fishery habitat enhancement practices that have the potential to make the greatest improvements to the degraded fish habitat sites selected for the study.
>
> Task III. Design pilot studies and obtain permitting necessary to begin evaluating fish habitat restoration techniques

Overall, fish populations and habitats in these urban areas have been rarely investigated, but the few research studies available suggest that these populations may be significant for important recreational species like juvenile winter flounder due to the high primary production found here. In 2019, we will continue efforts to assess the fish assemblages and present fish habitat and water column conditions at the Head of Narragansett Bay. We will continue the work begun in 2016 that focuses on gathering information on present fish habitat using seasonal video transects, as well as characterizing the fish assemblages at 12 sites (8 in Providence tidal River and 4 in the Seekonk tidal River) using beach seines and fish traps on a monthly basis. Results of this work will lead to the development of a fish habitat restoration and enhancement action plan (2020) for this area. Future grant years will entail implementing components of the plan that are feasible with the funds available, as well as applying for additional funds through grant opportunities pertinent to fish habitat restoration.

METHODS

Beach Seine

All 12 sites were sampled at monthly intervals from May through October. At each site a 130' long, 5.5'deep, ¼" mesh net beach seine was used. This net was also outfitted with a bag at its midpoint for fish collection, a weighted footrope, and a floated headrope, all consistent with the net used in the Young of the Year Survey of Selected RI Coastal Ponds and Embayments (conducted as part of F-61-R-23, Job #3). For sampling, the net was deployed along the shoreline in a semicircle by boat. The net was then hauled onto shore from both ends toward the beach by hand. Animals caught were then emptied from the bag and transferred into a water-filled tote. All collected animals were then identified to genus or species and measured to the nearest centimeter (except winter flounder which were measured to the nearest millimeter). When appropriate, species were subsampled by measuring the first 30 individuals identified then enumerating the remainder. Upon completion, all animals were discarded back into the water at the collection site. While at the sampling site, temperature (°C), salinity (ppt), and dissolved oxygen (mg/L) were recorded with a Professional Plus series handheld YSI multiparameter meter.

To preliminarily evaluate difference in total catch across the sites, a 2-way ANOVA (Total Catch ~ Site * Year) was performed. Only finfish were included in the analysis, and Atlantic menhaden were removed. Analysis was performed in R (version 3.5.2).

It was determined that the current, 2-year dataset does not cover enough sampling years to draw conclusions from the effort thus far. Future reports will include more robust data analysis after an additional sampling season at the selected sites. Mean catch per haul for target species has been compared across Providence River seine sites, and future reports will incorporate the Young of the Year Survey of Selected RI Coastal Ponds and Embayments beach seine results to compare across other water bodies. We expect to make future comparisons of catch per haul using a generalized linear model, inputting site, month, temperature, salinity, dissolved oxygen, and tidal stage after additional time- sampled. We also plan to evaluate the difference in finfish communities across sites through a non-metric multidimensional scaling approach.

Benthic Video Survey

During the 2018 field season, video transects were collected at the 12 sites with the same PVC benthic sled used in previous years. The sled included a HD digital video camera (SeaViewer), two green laser lights separated by ~15cm (14.85cm) for measuring fauna during video analysis (Figure 2), and two LED lights to increase visibility at deeper transects or overcast days. In addition, the Eureka Manta 2 WQ Sonde was attached to the rear crossbar for measuring salinity (ppt), temperature (°C), D.O. (mg/L) and Chl. a (µg/L) (Figure 1).

Before each video transect, the lasers were calibrated to a 15cm ruler on the datasheet. The sled was then lowered to the bottom and pulled ~15 meters behind the boat at ~1knot. Where possible, transects were recorded perpendicular to the shore. At the two northernmost sites (Pawtucket Boat Ramp and Bishop Point) tracks were taken parallel to the shore due to the narrow river width. In 2018, the other two Seekonk sites (Omega Pond and Butler) were combined into one transect which was split down the middle during analysis. The sled tracks were recorded from the stern of the boat with a handheld Garmin GPS to estimate transect locations.

The open-source media player VLC was used along with Windows Photo Viewer to analyze the benthic videos and video snapshots taken for analysis. The brightness, contrast, and saturation were altered when necessary to gain the clearest image of the seafloor. Snapshots were taken every 60 seconds starting from the beginning of the transect.

There were two analysis methods used to evaluate the video: a qualitative whole-video review (QWVR) and a quantitative analysis using the Coastal and Marine Ecological Classification Standard (CMECS) (FGDC 2012). Video quality was also documented, as recommended by a Narragansett Bay Commission scientist, on a range on 1-5 where 1 represented very poor visibility and 5 represented excellent visibility (Moore pers. comm.; Figure 3; Table 5). These ranges were later used during analysis to determine the level at which the CMECS framework could be documented accurately.

Qualitative Whole-Video Review (QWVR)

During QWVR each video transect was viewed from start to finish, and any rare occurrences (presence of nekton, large epifauna, anthropogenic materials, etc.) were noted, and corresponding timestamps were recorded. Videos were viewed at half-speed to properly analyze the data.

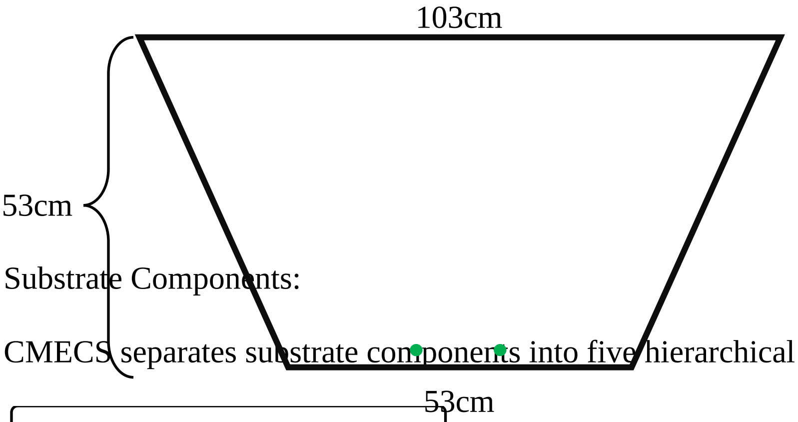
Quantitative analysis using CMECS

This report considered two of the four CMECS components: Substrate and Biotic. Together, this information will be utilized to identify biotopes within the Providence River Estuary based on guidelines set up in the CMECS framework. These biotopes, along with the beach seine, data-logger, and fish trap data, will help determine locations of future restoration work that will have the greatest impact on selected degraded areas. In addition, the CMECS framework will allow the results to be more comparable with other studies, in this area and throughout the rest of

Narragansett Bay, that have used the same framework for previous biotope evaluation (Shumchenia, Guarinello, and King 2016).

The angle of the camera created a slightly skewed field of view (shown below) which was taken into consideration during the analysis (CMECS is a spatially based classification system so the field of view impacts the percent-cover analysis).

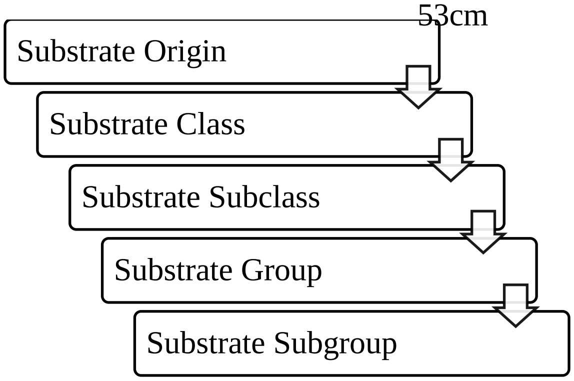
Field of view:



*Note: green laser lights not to scale

Substrate Components:

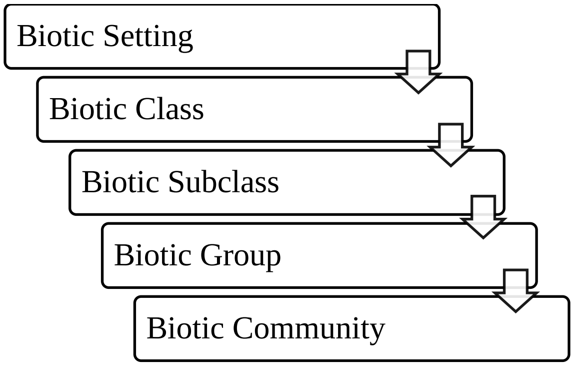
CMECS separates substrate components into five hierarchical levels:



Substrate components were analyzed to the most specific level possible without sacrificing the integrity of the data. Video samples, regardless of rating, were analyzed to the Substrate Class and video samples with ratings ≥3 were analyzed down to the Substrate Group level (Figure 4). Co-occurring elements were also used to identify non-dominant substrate types and were expressed using the Percent Cover Modifier: Coarse Percent Cover Values from CMECS (Table 6). A few modifications were made to the Coarse Percent Cover Values to better represent the data. These modifications change the trace and sparse values to <10% and 10-<30% respectively, and the moderate value to two separate values: moderate low (30-<50%) and moderate high (50-<70%) (Table 6). These changes were based on a recommendation from the Narragansett Bay Commission scientists working on similar research (Moore pers. comm.).

Biotic Components:

CMECS separates biotic components into five hierarchical levels:



Biotic components were analyzed down to the most specific level possible without sacrificing the integrity of the data. Video samples, regardless of rating, were analyzed to the Biotic Class, and video samples with ratings ≥3 were analyzed down to the Biotic Group, and to the Biotic Community when possible (Figure 5). Non-dominant biota, associated taxa, and community successional stage were also noted. Associated taxa represent biota that do not fall into a CMECS classification unit, and community successional stage was determined based off the CMECS modifier on videos with quality grades ≥3 (FGDC 2012).

Water Quality Data Loggers

HOBO Salt Water Conductivity/Salinity Data Loggers (Part # U24-002-C) and Dissolved Oxygen Data Loggers (Part # U25-001) were placed at all 12 sites during the 2018 sampling season from 6/4/18 to 10/31/18. The data loggers were housed within specially-designed PVC enclosures for protection while still allowing water flow. They were then attached ~ 1m from the bottom when there was sufficient depth to up and down lines anchored within each site. The data loggers recorded temperature (°F), conductivity (uS/cm), and dissolved oxygen (mg/L) every 30 minutes. Data from the data loggers were uploaded monthly by hauling them to the surface, connecting to a HOBO Waterproof Shuttle (Part # U-DTW-1) to upload information, and resyncing the internal clock. Any fouling to the housing was scrubbed with a brush, then redeployed.

Fish Traps

Fish traps were deployed at 15 sites throughout the season. The original eight sites located in the Providence River were consistently sampled monthly from May-October, while other site location additions (as previously stated) were made (Table 3). Black Sea Bass traps, with dimensions 43.5” length, 23” width, 16” height, and 1.5”x1.5” coated wire mesh, were used. The traps also contained a single mesh entry head and single mesh inverted parlor nozzle consistent with the Black Sea Bass Traps used in the Narragansett Bay Ventless Pot, Multispecies Monitoring and Assessment Program (conducted as part of F-61-R-23, Job #12). Two fish traps were deployed by boat approximately 20 meters apart at each site and left to soak for ~96 hours, unbaited. The traps were then hauled, all animals were identified to genus or species, measured to the nearest centimeter by fork length, enumerated, then discarded back into the water.

Catch rate per site was calculated using the following equation:

$$CPUE = \frac{Total\ catch\ at\ site}{Number\ of\ soak\ days\ \times\ Total\ samples\ by\ site}$$

Number of soak days = 4
Total samples by site = Refer to Table 2
Total catch at site = Refer to Table 4

Catch rate and presence/absence of fish and invertebrate species were compared by site and month (Figure 6-7, see Appendix B for presence/absence tables. Percent of species of interest (black sea bass, scup, tautog, and blue crab) within total catch by sites was compared, as well as their length frequency by month and site (Figure 8, see Appendix B for length frequency data).

RESULTS

Beach Seine

For the 2018 field sampling season, a total of 72 seines were hauled across the selected sites. 349,217 individuals were identified and enumerated, and 4,945 of those were measured. A total of 46 species were caught in the beach seines this season (Table 1). Aside from the list of species caught, all figures and analyses include only finfish. Additionally, Atlantic menhaden were removed from figures and analyses, given their overwhelming numbers and the seemingly random chance that a school will be caught in a haul. All invertebrates were removed to focus on the fish assemblage alone.

On average, 235 finfish were caught per haul. Catch per haul was greatest at Pawtuxet Cove (516.17 ± 208.49 SE) while finfish were least abundant at Pawtucket Boat Ramp (33.33 ± 11.84 SE; Figure 9). The highest catch per haul was in July at 325.83 ± 136.33 SE, while the lowest was in October at 164.50 ± 60.62 SE (Figure 10).

All five-target species in this study were caught in the seines: black sea bass, scup, summer flounder, tautog, and winter flounder (Figure 11). Winter flounder were the most abundant target finfish caught across all seine sites at a catch per haul of 2.32. Black sea bass were the least abundant caught at a catch per haul of 0.26.

Of the total 167 winter flounder caught in 2018 seines, all were young of the year (max length = 73mm; Able and Fahay 1998; Berry et al. 1965). Winter flounder were caught at 9 of the 12 sites; they were not caught at Stillhouse Cove, Mussachuck Creek, and Gaspee Point. The most abundant site for winter flounder was Omega Pond at a catch per haul of 10.67 ± 6.82 SE. The most abundant month for winter flounder was June at a catch per haul of 9.25 ± 3.40 SE (Figure 11).

A total of 128 tautog were caught in 2018 beach seines ranging in size from 2cm to 13cm. Tautog were caught at 6 of the 12 sites: Conimicut Point, Fields Point, Gaspee Point, Mussachuck Creek, Narragansett Terrace, and Stillhouse Cove. Of the six sites they were caught, tautog were most abundant at Fields Point, a catch per haul of 9.50 ± 2.73. The most individuals were caught in October at a catch per haul of 3.67 ± 1.46 SE (Figure 11).

A total of 84 summer flounder were caught in 2018 beach seines ranging in size from 10mm to 110mm. Summer flounder were caught at 6 of the 12 sites: Bishop Point, Butler, Omega Pond, Pawtucket State Pier, Pawtuxet Cove, and Stillhouse Cove. Summer flounder were most abundant at Pawtucket State Pier, at a catch per haul of 8.50 ± 7.50 SE. Most individuals were caught in June at a catch per haul of 9.25 ± 3.40 SE (Figure 11).

Results of the 2-way ANOVA testing the effect of site and year on total catch suggest that catch was significantly different between sampling years and sites (Total Catch ~ Site: p = 0.00387; Total Catch ~ Year = p = 0.0354). Furthermore, there was no significant interaction between site and year (p = 0.72). Total catch was log-transformed to satisfy assumptions of the ANOVA (Levene’s and Shapiro Wilks, p-value>0.05?). A post-hoc Tukey’s test showed that catch at Pawtucket State Pier was significantly different from Pawtuxet Cove, Mussachuck Creek, and Fields Point.

Benthic Video Survey

A total of 45 videos (20 from 2017) have been analyzed for substrate and biotic components (see Tables 7 and 8 for sampling frequency). In 2018, the average transect length was 0.45 km and the average video length was ~19 minutes. Video quality varied significantly between transects and was dependent on water turbidity, boat speed, and video settings (720p vs 1080p). The average video quality rating among analyzed video across all transects was three (Table 7-8).

Qualitative Whole-Video Review (QWVR)

Rare occurrences identified through video analysis were grouped into seven categories: large invertebrates, faunal aggregations, dead fauna, anthropogenic material, air bubbles, presence of fish, and other (Table 9).

Anthropogenic Material was found in different quantities at Bishop Point, Omega Dam, Butler, Sabin Point, Fields Point, and Stillhouse Cove and ranged from large items such as tires, to small pieces of plastic wrappers and bottles.

Blue crabs, horseshoe crabs, and spider crabs were among the most common crustaceans found along the transects. The presence of blue crabs was common in the Seekonk sites. Horseshoe crabs were identified at Pawtuxet Cove, Narragansett Terrace, Mussachuck Creek, Butler, and Omega Pond. Sea stars (2 ind.) were documented at Sabin Point in 2018 and were not found on transects at any other site.

A large aggregation of Nassariidae (most likely *Ilyanassa obseleta;* estimated N >800 animals in one snapshot) were found at Omega Dam in 2017. Also, in 2017 a concentration of lugworm eggs was identified at Stillhouse Cove. This aggregation was not found within the transects in 2018.

A few occurrences of air bubbles were recorded being released from the sediment at Bishop Point during both years of sampling. Often in conjunction with the air bubbles were dead menhaden and blue crab carcasses spread out along the Bishop Point transects. Water quality data assessed in CMECS identified a hypoxic zone along this same transects during the summer months. A more severe hypoxic event was documented in 2018 at Omega Pond and Butler through a mass mortality event of a softshell clam bed (*Mya arenaria*). Throughout the season, video captured a healthy population of softshells in June, stressed siphon-extended animals in August, and a mass die-off of the population by early October (Figure 12).

In terms of fish species, small schools of juvenile menhaden (~ 4-6cm) were often seen swimming with the sled at Sabin Point, Omega Dam, Butler, and early in the Bishop Point video (before the hypoxic zone). In 2018, juvenile black sea bass and scup were identified along transects at Mussachuck Creek and Conimicut Point

Quantitative analysis using CMECS

Four of 13 distinct substrate classes were identified throughout the 12 sites: anthropogenic wood, shell substrate, trash, and unconsolidated mineral substrate (Figure 13). Samples with video quality too poor to positively categorize were placed in the 'undetermined' category.

Unconsolidated mineral substrate was the dominant substrate class at most sites except Pawtuxet, which had a greater number of samples with shell substrate as the dominant class (as well as the site with the highest number of 'undetermined' samples). Conimicut Point was close to a 50/50 split between shell and unconsolidated mineral substrate. The anthropogenic wood was dominant in only one snapshot at Bishop Point, and trash was the dominant substrate in only one snapshot at Fields Point. The unconsolidated mineral substrate and shell substrate were also broken down into their more specific Substrate Groups for further analysis (Figure 4).

There were seven distinct unconsolidated substrate groups (out of eight) identified throughout all the sites: mud, muddy-sand, sand, slightly gravelly, gravelly, gravel mixes, and gravel. Most sites had the highest number of snapshots identified as mud or muddy sand. Mussachuck Creek was the only site analyzed so far that had no snapshots identified as mud and both Mussachuck and Gaspee had the most diverse substrate. Although Fields Point was less diverse, it had a higher percentage of total snapshots with the larger grain sizes indicating that parts of the transect was composed of larger rock features (Figure 14).

The shell substrate was also broken down into distinct groups. Omega Pond, Sabin Point, Pawtuxet Cove, Gaspee Point, Narragansett Terrace and Conimicut Point had snapshots with shell substrate as the dominant component. Conimicut Point had the largest number of snapshots with shell (*Crepidula* reef) as the dominant substrate by far. The remaining sites had varying types of clam shell (hash, rubble, and reef) in addition to some *Crepidula* dominating the snapshots (Figure 15). In many cases the specific species of clams could not be determined especially for the broken and smaller pieces.

Four of eight distinct Biotic Classes were identified throughout the twelve sites: Reef Biota, Faunal Bed, Aquatic Vegetation Bed, Microbial Communities (Figure 16). Samples with video quality too poor to positively categorize were placed in the 'undetermined' category.

Reef Biota were dominant in small percentages (1-2%) at Stillhouse Cove, Sabin Point, and Gaspee Point and as the largest percentage at Conimicut Point (28%). The Reef Biota were more specifically identified as Crepidula Reef (level: Biotic Community). These values correspond to the number of dominant shell substrate snapshots at some of the sites.

Snapshots identifying Aquatic Vegetation Bed as the dominant biota were at every site except Pawtucket Ramp, and tended to have a stronger presence at the more southern sites. In all cases the vegetation was composed of filamentous or sheet benthic macroalgae. Common species identified include *Ulva sp.*, *Petalonia sp.*, *Porphyra sp.*, and *Agardhiella subulata*. Often during the warmer months *Ulva* rafts would dominate large sections of the transect areas at Pawtuxet Cove, Sabin Point, and Gaspee Point.

The Microbial Communities identified in the northern versus southern sites were distinctly different. The Seekonk sites (Pawtucket Ramp, Bishop Point, Butler, and Omega Pond) have the greatest percentage of snapshots with Microbial Communities identified as the dominant biota. These Microbial Communities were more specifically identified as *Beggiatoa* Communities, while the southern communities were identified as diatom felt.

Faunal Beds were made up of Soft Sediment Fauna (e.g. Nassariid Beds, Small Surface-Burrowing Fauna (e.g. polychaetes), Larger Deep Burrowing Fauna (e.g. softshell clam beds), Tunneling Megafauna (e.g. Squilla Beds) and Inferred Fauna (e.g. Gastropod Trails; see Figure 5 for a complete list). Faunal Beds were the most dominant snapshot at Stillhouse, Narragansett Terrace, Mussachuck, Butler and Omega Pond. At the northern sites the faunal beds were composed mostly of softshell clam beds. In the southern locations *Chaetoptera, Squilla sp., Ampellisca sp.*, and *Terrabellids* were identified as well as unidentified infauna.

Water Quality Data Loggers

A total of 154,997 instances were recorded across 11 sites (all except Stillhouse Cove due to known datalogger failure) containing temperature, salinity, and DO for the 2018 sampling season, from 6/4 to 10/31. Unfortunately, given that these loggers are a complex technology being applied in the marine environment, precursory analysis of the results showed some loggers recorded unreliable data. Visual inspection of the loggers during monthly checks revealed that the loggers became heavily fouled by colonizing organisms, especially during the summer months and at sites in the Providence River. For this report, investigators only summarized data that appeared to fall within expected values comparable to water quality information taken from the handheld YSI during other sampling.

Temperature ranges were fairly consistent across sites (Figure 17). Mean temperature values by site ranged from 22.11°C at Pawtuxet Cove to 22.78°C at Sabin Point during the sampled time period. Mean temperature across sites was highest in August at 26.23°C and lowest in October at 16.32°C (Figure 18).

Salinity data appeared to be the least accurately recorded parameter, and only two sites recorded salinity within the expected range for the duration of the season: Butler and Pawtucket Boat Ramp (Figure 19). The other sites recorded expected values until July or August, then recorded values close to 0ppt (See Figure 20 for example). Researchers found that Pawtucket Boat Ramp, Bishop Point, Butler, Omega, and Pawtucket Cove recorded greatly fluctuating daily salinities. Investigators then compared the salinity data points with tide height data from a nearby NOAA weather buoy (Figure 21). Visual inspection showed that the fluctuation of salinity generally coincided with tide height. For example, Pawtuxet Cove can experience salinity ranging from 7ppt to 23ppt within a 12 hour period.

DO results appeared to be inconsistent with YSI recorded values, generally recording lower values than the handheld. All sites except Mussachuck Creek, Gaspee Pt., and Omega Pond recorded data the entire field season (Figures 22 & 23). Analysis of three sites in the Seekonk River and three in the Providence River showed that all six sites were subject DO values less than 2 mg/L, suggesting hypoxia. DO values across all sites recorded the more frequent and intense hypoxia during July, August, and September. Percentage of hypoxic instances (<2mg/L) by site ranged from 8.68% at Conimicut Point to 71% at Sabin Point. Percentage of hypoxic instances by month ranged from 4.87% in June to 63.11% in August.

Fish Traps

Coordinates were maintained for the Providence River sites and three new sites were added based on depth, ease of access, location of channel, and presence of fishing piers (Table 3). A total of eleven species were caught in 2018, including 280 finfish and 687 crustaceans (Table 10 and Table 4). Mussachuck had the highest overall catch rate (~12 individuals/sampling effort), while Conimicut had the highest finfish catch rate (~4 fish/sampling effort). Spider crabs were the most abundant species caught (588 ind.) and Scup were second most abundant (204 ind.). Fish catch rate was highest in June and was mainly composed of Scup.

Black sea bass made up a higher percentage of the total catch at the southern sites than those in the upper Providence river. Scup made up more than 50% of the total catch in the nine southernmost sites (except for Mussachuck which had a higher percentage of black sea bass caught).

DISCUSSION:

Beach Seine

Results from the comparison across sites and years reveals that some sites support different amounts of finfish during the season. Investigators are cautious to draw conclusions about the lower catch at Pawtucket State Pier compared to some other sites, because it is a challenging site to sample, which may lead to reduced sampling efficiency. Though extrapolating trends over such a short time series should be tempered, researchers noted other interesting comparisons between sampling years. Catch across all sites varied between years during the months of June and July. In fact, catch in May 2017 was over four times as high as catch in June and July of 2017. Catch during these months in 2018 was also over three times as high as in 2017. This trend through sampling months in 2017 could be an anomaly, and future seine sampling years will ideally inform the study.

11 of 12 sites appear to support winter flounder, and abundance varied by site. Winter flounder were predominantly caught in June, July, and August, consistent with other beach seine surveys in this region (Young of the Year Survey of Selected RI Coastal Ponds and Embayments & Narragansett Bay Juvenile Fish Survey). If winter flounder are targeted in habitat restoration projects within this study area, investigators should consider suitable habitat connectivity, allowing for migration of these recruits into more suitable waters as the season progresses (Neumann 1993). Tautog were caught in all sampling months except May, predominantly at Fields Point. Additionally, scup and black sea bass were primarily found at Fields Point and Narragansett Terrace in August through October. These temporal findings are consistent with known life histories of these species. For example, both scup and black sea bass are known to migrate into high-salinity estuarine areas in August and September within this region (Lux and Nichy 1971). Summer flounder were found almost exclusively in the Seekonk River and were most abundant at Pawtucket State Pier. Their abundance was highest in June and were not found in significant numbers the rest of the sampling season. We may be able to explain the high catch at Pawtucket State Pier in June by comparing pulses of high salinity during the month, because they are known to remain in estuaries until the winter season but prefer salinities higher than 12ppt (Powell and Schwartz 1977; Collette and Klein-MacPhee 2002). Perhaps the animals followed the higher salinity on an incoming tide that happened to coincide with the seine sample. Summer flounder, like winter flounder, are susceptible to hypoxic conditions, so the known prolonged hypoxic events in the Seekonk River may induce emigration or mortality. This catch suggests that summer flounder are present in the study area, at least in early summer, but may not be fully represented by the current sampling sites and methods. If summer flounder habitat enhancement becomes a priority, we recommend evaluating whether the current sampling design accurately reflects their population.

It is expected that future analysis combining water quality, benthic substrate, and fish assemblage will explain some variability in target species abundances. For example, juvenile winter flounder and tautog habitat preferences are well known and qualitatively explain some disparity across sampling sites. Juvenile tautog prefer rocky habitat and algal mats provided at Field’s Point (Dorf and Powell 1997). Though juvenile winter flounder habitat preferences appear to vary by waterbody, they can generally be found in sandy/muddy habitats within estuaries (Neumann 1993). In addition to the benthic substrate monitoring, it is recommended that categorical parameters describing the habitat setting be added to complement current descriptors, for example adjacent aquatic and intertidal/upland habitat types.

Benthic Video Survey

This analysis utilized data from 2017 and 2018 only. More uniform transect lengths were taken in 2018 than 2017 and the average length was much closer to the desired 0.5 km. This was helped by conducting Omega and Butler as one transect in the field then analyzing them separately. The video quality was also lower than the desired average of at least four impacting the CMECS analysis. Although a higher resolution was used in 2018, water turbidity, loose substrate, and macroalgae getting stuck on the sled camera still had a negative impact on the clarity of the video clips.

Qualitative Whole-Video Review (QWVR)

It is clear through the video review that the Upper Seekonk remains highly impacted by hypoxia. While water quality monitoring devices can provide quantitative data of D.O. levels and how concentration changes over time, the video surveys provide important qualitative information about how these events impact the system (both directly and indirectly, i.e. species composition, animal behavior and trophic interactions). For example, the benthos at the two northernmost sights have extensive visible *Beggiatoa* spp. communities, which are not only tolerant to hypoxic conditions due to their ability to survive anaerobically but tend to reside at the interface between gradients of oxygen and sulfide (Megonigal, Hines and Visscher 2003, Canfield, Kristensen, Thamdrup 2005). MuBmann et al. (2003) have shown that species of *Beggiatoa* are critical for sulfur cycling and balancing of nitrogen in coastal environments and their use as a nitrogen sink is often used in the finfish aquaculture industry as an indicator of benthic health (Hamoutene 2014). In addition, Rosenberg and Diaz (1993) have used *Beggiatoa* as an indicator of benthos that sustains long periods of hypoxic/anoxic conditions.

In addition to the microbial communities, the infauna presence and health indicate acute hypoxic events. This is represented by the *Mya arenaria* mortality event that was documented at Omega Pond and Butler in August 2018. The size range of the softshell clams sampled (10-30mm) indicate that they were not all young of year (Appeldoorn 1982, Filippenko and Naumenko 2014) especially considering the high levels of silty mud, which have been shown to reduce growth rate (Swan 1952, Dow and Wallace 1961). This supports the water quality data that show the severity of the hypoxic event in 2018 (Figure 22 of DO data). It also demonstrates that the clam population was able to withstand the 2017 event suggesting that it was the duration of the event in 2018 rather than the level of DO that ultimately caused the mass die-off. The softshell clam behavior during the transects at Omega and Butler in August also indicates hypoxic conditions. In a study conducted by Taylor and Eggleston (2000) *Mya arenaria* were shown to exhibit exaggerated siphon extension during instances of low dissolved oxygen (≤1.5 mg/L) (this stressed behavior can be seen in Figure 12B). The same study showed that large and relatively abrupt changes in DO concentrations can impact the trophic dynamics between blue crab predation on softshell clams. The results indicate that while lower DO levels provide some refuge for clams, blue crabs' ability to migrate allow them to take advantage of a stressed *Mya* bed once oxygen levels return to tolerable levels. Blue crabs were commonly found at the Seekonk sites and therefore may have contributed to the severity of the clam mortality event.

Another rare occurrence that was documented in the Seekonk was the large aggregation of *Nassaridae*. The morphology and behavior of the snails in this area suggest they are most likely Eastern mud snails (*Ilyanassa obseleta*). This species is omnivorous and is known to scavenge on dead and decaying organisms and reside in large aggregations (Wilson 1988, Curtis 2005, Connor and Edgar 1982). The acute hypoxic events that occur in the Seekonk during the summer months causes fish kills resulting in an accumulation of dead menhaden and river herring. Through video analysis the large aggregations of mud snails could be seen feeding on these dead fish. This information could be valuable considering these snails are extensive parasite hosts impacting waterfowl and estuarine reptiles like the endangered northern diamondback terrapin (*Malaclemys terrapin*) that feed on the snails (Coen and Bishop 2015). During the fish trap survey, these terrapin were identified at nearby Seekonk sites. It is possible that the low dissolved oxygen's effect on the amount of decaying fish in the area promote these large populations/aggregations of the Eastern mud snails, which may have indirect impacts on the terrapin species.

Other rare occurrences, like the synchronous epidemic spawning of lugworms at Stillhouse Cove in 2017, may have gone unnoticed without benthic monitoring, which captured the presence of the egg sacs along the transect. Lugworms (*Arenicola marina*) are known ecological engineers that have significant positive impacts on substrate bioturbation, oxygen exchange, and nitrogen sequestration (Volkenborn et al 2007, Dornhoffer, Waldbusser, and Meile 2015). As deep burrowers, the limitations of video monitoring prevent direct confirmation of their presence in subtidal areas. However, the discovery of their egg sacs show they have been present in the Stillhouse Cove area for at least a year (they do not become sexually mature until they are over one year old (Vooys 1975)). Knowledge of their presence here can help describe any changes in species composition over time, and the transect data could be used to get a rough idea of *A.marina* density in the sampled area.

The video clip selection method used in the CMECS analysis did not provide clips showing the dead menhaden or gas bubbles at Omega Pond as well as other occurrences of associated taxa (sea stars at Sabin Point, a sea robin at Conimicut Point, blue crabs at varying sites etc.). This supports the need to continue with QWVR in conjunction with CMECS as each provides important data for habitat quality evaluation.

Another interesting occurrence was the presence of juvenile menhaden that could be seen swimming along with the sled. A potential explanation is that the lights and/or lasers attached to the sled that may have attracted them. This is important to note for future tows and something to take into consideration during data analysis.

The presence of anthropogenic material was not surprising in any of these areas. In the future, items like tires and large pieces of debris may be separated into their own category as they provide some level of structure to certain species like blue crabs and other invertebrates commonly found in the area. For example, some tires were seen with blue crabs foraging off them. It will also be important to take note of areas that have higher volumes of garbage found along the transect as this could be an indicator of lower site suitability.

Quantitative analysis using CMECS

The high percentage of unconsolidated mineral substrate is not surprising across all sites and is relatively consistent with a similar ongoing study conducted by the Narragansett Bay Commission (Moore pers. comm.). Sites that contain a high percentage of snapshots (>75%)

identified as mud (Pawtucket Ramp, Butler, Omega Pond, Fields Point, and Pawtuxet Cove) also exhibit organisms that thrive in these areas including Nassariidae, *Beggiatoa*, and *Mya arenaria*. At Sabin Point and Conimicut Point, both the Substrate and Biotic Groups identify the presence of *Crepidula*. Interestingly, the Biotic Groups identified at Pawtuxet Cove did not include presence of clam reefs, even though the substrate component was dominantly clam shell. It is possible that the lack of snapshots of clam reefs identified as a dominant Biotic Group was due to the high volume of aquatic vegetation, (which often impedes the view of other biota) rather than an absence of the live biota altogether. This may be important as existence of a high density of shell substrate with the absence of live organisms could indicate reduced water quality, and/or an unsuitable habitat for that species at that site similar to what was found at Omega Pond. The issue of aquatic vegetation (especially sheet algal species like *Ulva*) is currently unavoidable using this CMECS strategy, however, an increased number of transects at varying times during the season may be able to provide a more comprehensive picture of the biotic communities.

Within the upper Seekonk transects, higher percentages of *Beggiatoa* communities were identified in the snapshots. This presence is consistent with the previous reports. In the future, it will be interesting to evaluate potential changes in the microbial community's scope over time by comparing the results to Shumchenia, Guarinello, and King's (2010) study describing it presence in 2008 and 1988.

Overall, it can be hypothesized that Butler and Omega Dam have similar substrate compositions because of their relative proximity to one another. However, Omega Dam does have a direct input of freshwater coming into the area potentially impacting the epifauna and aquatic vegetation composition. Other sites that have known freshwater inputs are Pawtucket Ramp, Pawtuxet Cove, and Mussachuck Creek. More research on these freshwater inputs and their impacts on different species is needed. It will also be interesting to compare the difference in biotic composition of the areas with inconsistent salinity regimes.

Continued analysis of existing transects, and those to be completed in 2016 and beyond will be used to create CMECS biotopes, evaluate the identified site's suitability for different restoration methods, and add to quantitative and standardized classification of the Providence River Estuary. Pairing the benthic video with actual substrate samples would be beneficial and could allow for greater species level identification where video is limited and could provide useful insight to the CMECS community.

Water Quality Data Loggers

While mean temperatures were similar across sites, it is important to examine the maximum temperatures during the summer sampling period where warmest temperature ranged from 28.95°C at Conimicut Point to 32.12°C at Pawtucket State Pier. Warm summer temperatures are known to negatively impact certain fishes. For example, Nichols observed a massive die-off of winter flounder that were trapped in shallow enclosed bays when temperatures rose to about 30°C (Nichols 1918). Furthermore, observations made in Great South Bay, Long Island reported that winter flounder became inactive at 23°C (Olla et al. 1969). Though individuals of this species have been known to bury themselves to avoid heat, that technique may only offset a few degrees of temperature. Given that winter flounder were caught in relative abundance at sites prior to temperatures that exceeded their tolerance threshold and very few were caught in the months following, maximum water temperatures should be considered in future restoration sites. Investigators should also consider suitable adjacent habitats that allow for emigration of individuals from a site that may become unsuitable during warmer months.

Mean salinities appeared to vary greatly by site. The two driving factors in salinity at these sites are tidal flow and precipitation, which appear to affect our sites at different magnitudes. Salinity at the four sites in the Seekonk River (Pawtucket Boat Ramp, Bishop Point, Butler, and Omega Dam) as well as Pawtuxet Cove varied greatly with tidal stage, while the remaining sites showed little correlation with tide. This finding is important, because juvenile finfish residing at the sites where salinity varies with tide will experience significant fluctuations in salinity depending on whether the tide is incoming or outgoing. Species must be able to endure frequent and rapid salinity changes or migrate to a more suitable habitat. At times, water was fresh enough at these sites to record freshwater species (e.g. bluegill). We recommend that investigators consider whether target species can endure these variable and at times low saline habitats. Alternatively, ensuring passage to other suitable habitats along the salinity gradient could be considered.

To address the effect of precipitation on salinity at these sites, we recommend that investigators identify the major freshwater inputs into the study area and contributing watersheds. Combining salinity data with precipitation data in this area should explain variations in salinity, especially at sites where salinity does not depend on tidal flow.

Though dissolved oxygen readings below 2 mg/L were measured at all sampled sites, the frequency and intensity of these hypoxic recordings varied. Interestingly, Sabin Point appeared to have the most frequent and intense hypoxic readings, likely resulting from the dense mats of algae found at this site. Given that demersal species such as winter flounder, by nature of being restricted to the bottom surface, can be most impacted by hypoxic events, a site’s dissolved oxygen levels should be considered when selecting a restoration site. Previous studies have caught winter flounder in significantly lower numbers when D.O. concentration was 2.0-2.2 mg/L and showed reduced lengths at concentrations higher than 2.0 mg/L (Howell and Simpson 1994). Supporting these findings Bejda et al. performed mesocosm experiments determining that growth rates of YOY winter flounder were significantly lower in constant low (2.2 mg/L) dissolved oxygen levels than diurnally fluctuating (2.5-6.5 mg/L), which were then significantly lower than those in constant high dissolved oxygen levels (Bejda et al. 1992). This research highlights the impact of dissolved oxygen on winter flounder growth and survival. We recommend that investigators research and consider the effects of low dissolved oxygen concentrations on individual target species by frequency, magnitude, and duration to inform restoration practices. Investigators should also consider the availability of adjacent suitable habitat when conditions do become unsuitable for these species. The initial findings from these dissolved oxygen dataloggers highlight the need for continued monitoring of these sites, as these hypoxic events are rarely recorded by YSI instruments at the time of seine.

Both the salinity and DO dataloggers faced issues with fouling and maintaining accuracy. We advise that these loggers be inspected more often in future sampling. Loggers placed in the Seekonk River appeared less fouled than the others, which coincides with our results. Additionally, the companion HOBOware software allows for post-sample recalibration by inputting known salinity values to account for drift in datalogger readings. We suggest taking consistent YSI measurements near the dataloggers, not only for comparison, but also for calibration. Measurements near the dataloggers will also negate the effects of stratification and proximity to freshwater sources that may be causing out datalogger results to be inconsistent with YSI measurements.

Fish Traps

The depth at the fish trap locations varies by site, especially in the upper estuary. This is simply due to limited depth in the Seekonk River. Traps were placed within ~0.25 km of the beach seine locations where possible to remain consistent with the original site selection. In the Seekonk, traps were placed closer to the channel to provide enough water for the trap to be submerged at mean low tide. As previously stated, the sites in the Seekonk were removed and three new sites were added. The selection of the new sites was based on proximity to potential recreational fishing locations (either currently functional fish piers, or locations where a fish pier may be constructed in the future). In order to create a feasible study some locations were adjusted to improve ease of access, and to limit impacts to other users of the area. For example, the original fish trap location was adjusted at the Pawtuxet Cove site to avoid the channel and main marina access.

Target species were caught in the traps (tautog, black sea bass, and scup). Black sea bass are a structure seeking species, so it is interesting that certain sites with available structure did not exhibit a strong (or any presence of black sea bass) like Fields Point and Pawtuxet Cove. Blue crabs also exhibited a trend of abundance that decreased by latitude across the sites. In future sampling a record of male/female ration will be kept to evaluate the sex ratios of the crabs that utilize the fish traps. Results from continued implementation of the fish trap survey may also be compared with the previously mentioned F-61-R-23, Job #12 ongoing study of the Narragansett Bay.

The intention of adding fish traps to the sampling regime was to sample presence of fish life stages that were not captured in the beach seines. Visual inspection of histograms comparing frequency at length between gear types of the four-target species caught in both gear types shows that, aside from a few exceptions, each gear type samples a differing size class for all comparable species (Figure 24). Though these results support our expectations, continued comparisons of gear size selection should be made to confirm the results across multiple sampling years.

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patterns and processes. Ophelia 29, 227–245.

FIGURES

Figure 1. Photo depicting benthic sled configuration. A) Eureka Manta 2; B) SeaView Camera; C) Lasers; D) LED lights.

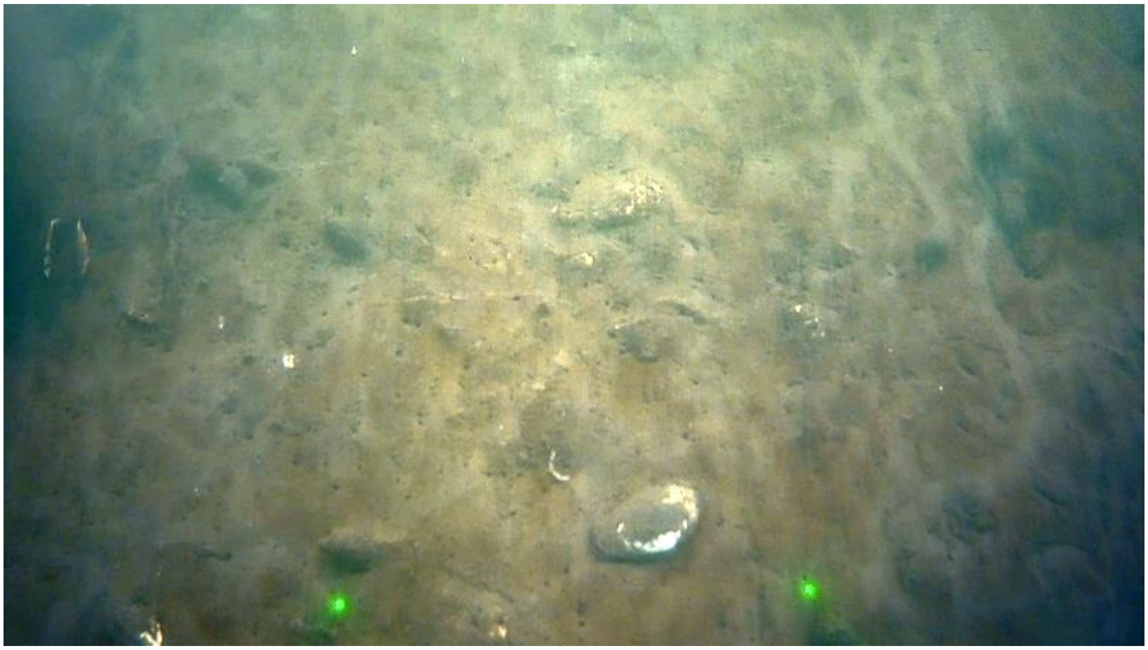

Figure 2. Benthic video snapshot #4 from Butler depicting green laser lights calibrated ~15cm apart in field of view. Video quality: 5, Substrate Class: Unconsolidated Mineral Substrate, Substrate Group: Mud. Biotic Class: Faunal Bed, Biotic Group: Small Surface-Burrowing Fauna, Co-occurring Elements: Tracks and Trails (Sparse), Bacterial Mat/Film (Moderately Low), Nassariid Bed (Trace).

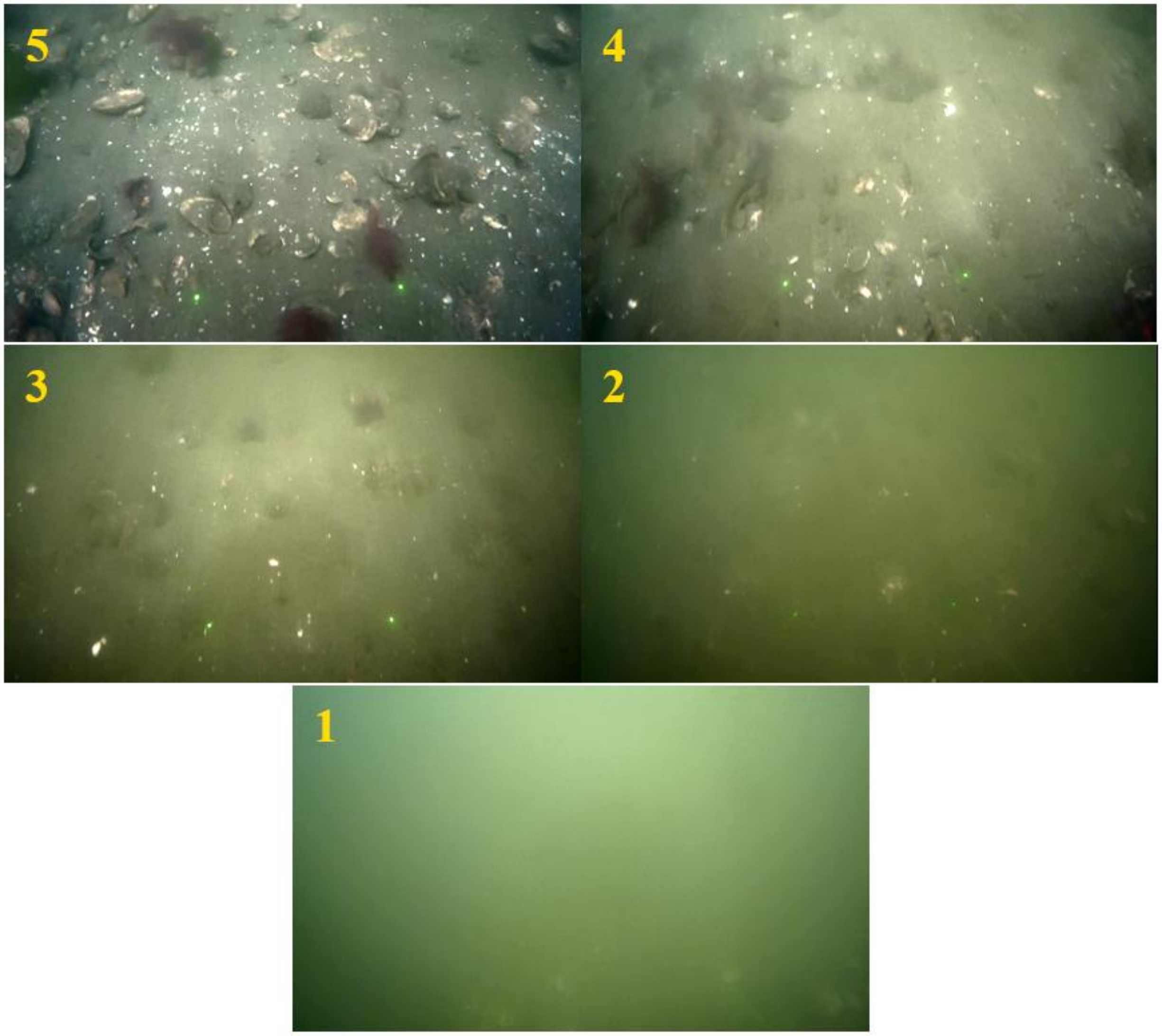

Figure 3. Video quality scale. Video snapshots taken from Gaspee Point. A video snapshot with grade ≥3 was used to identify Substrate and Biotic Components down to the Group level, when possible. See Table 1 for more detailed description of video quality determination.

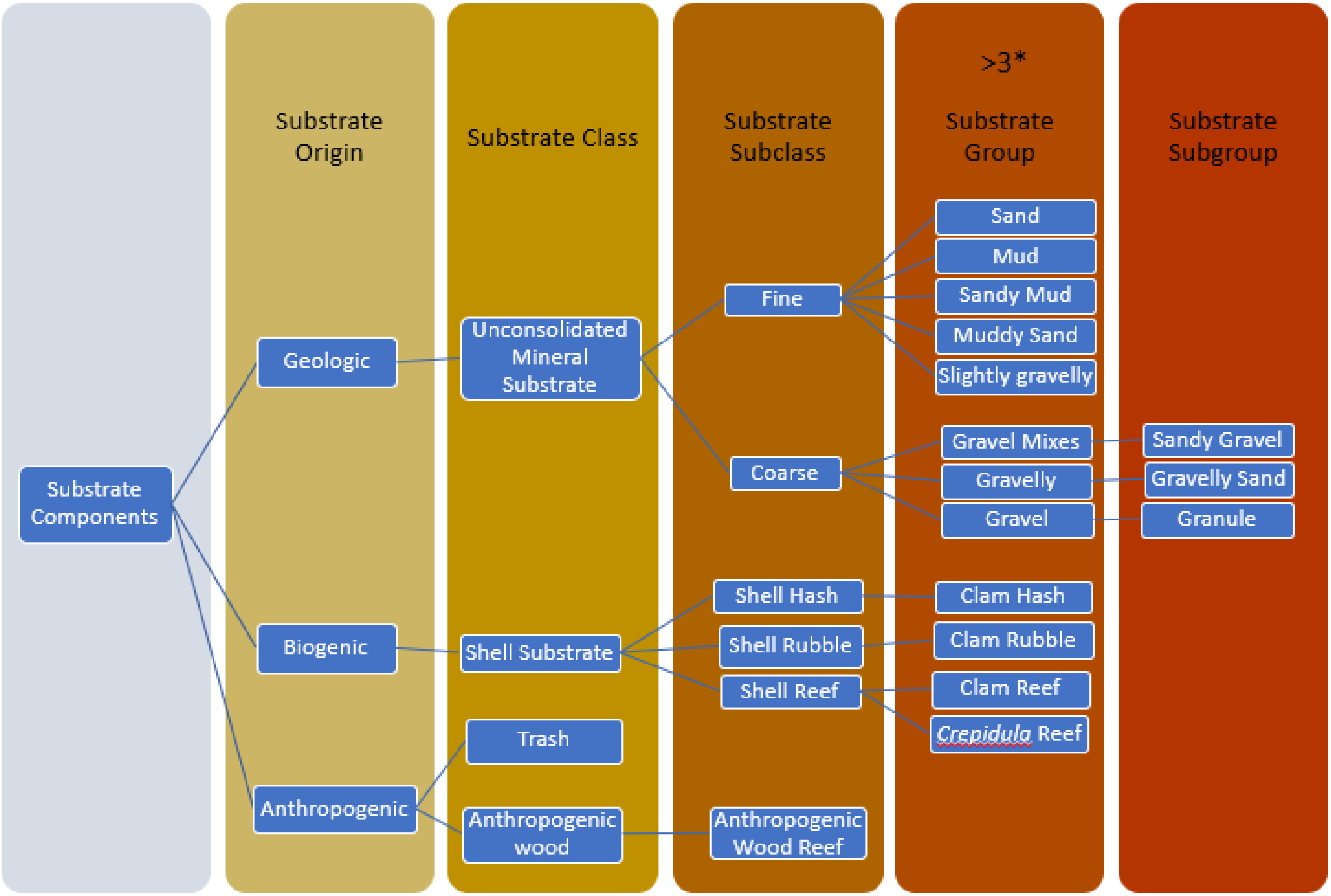

Figure 4. Flowchart of CMECS substrate components used in video analysis.

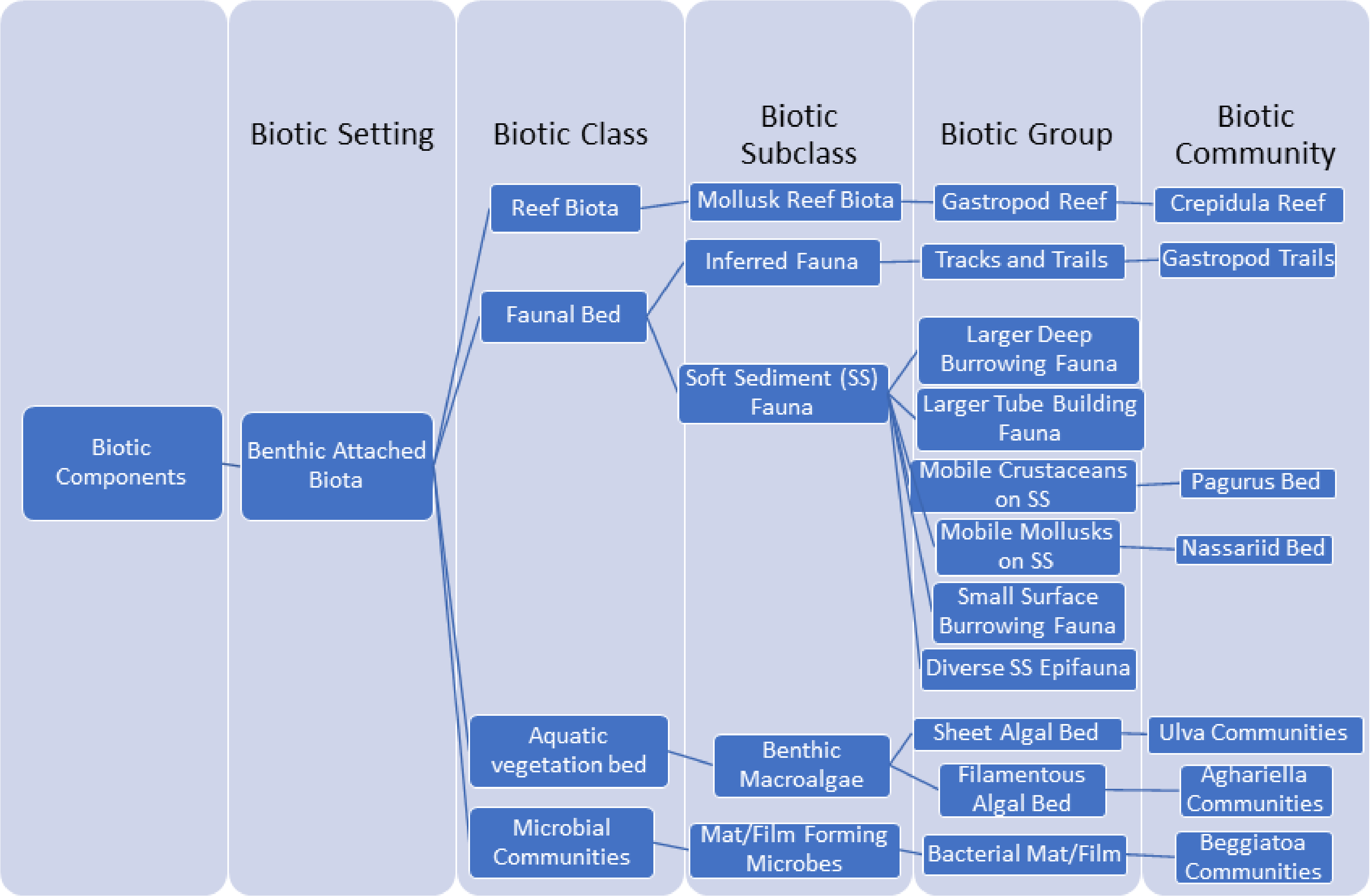

Figure 5. Flowchart of CMECS biotic components used in video analysis thus far.

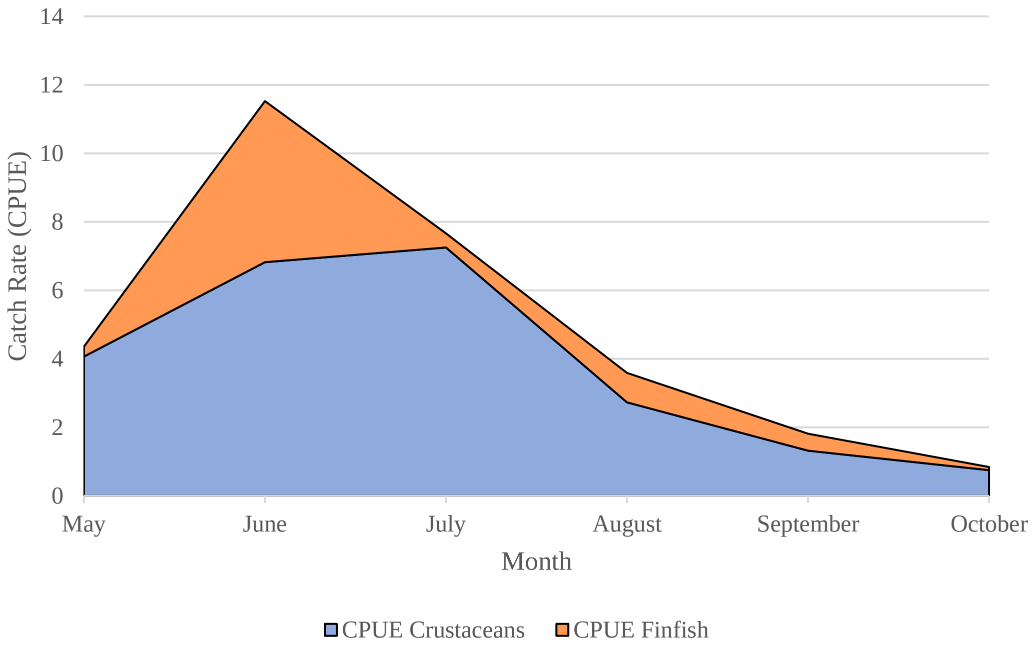

Figure 6. Total catch rate by month in 2018 (stacked). CPUE = Total fish caught/(Number of hauls*Number of soak days). All hauls were based on two black sea bass traps per haul.

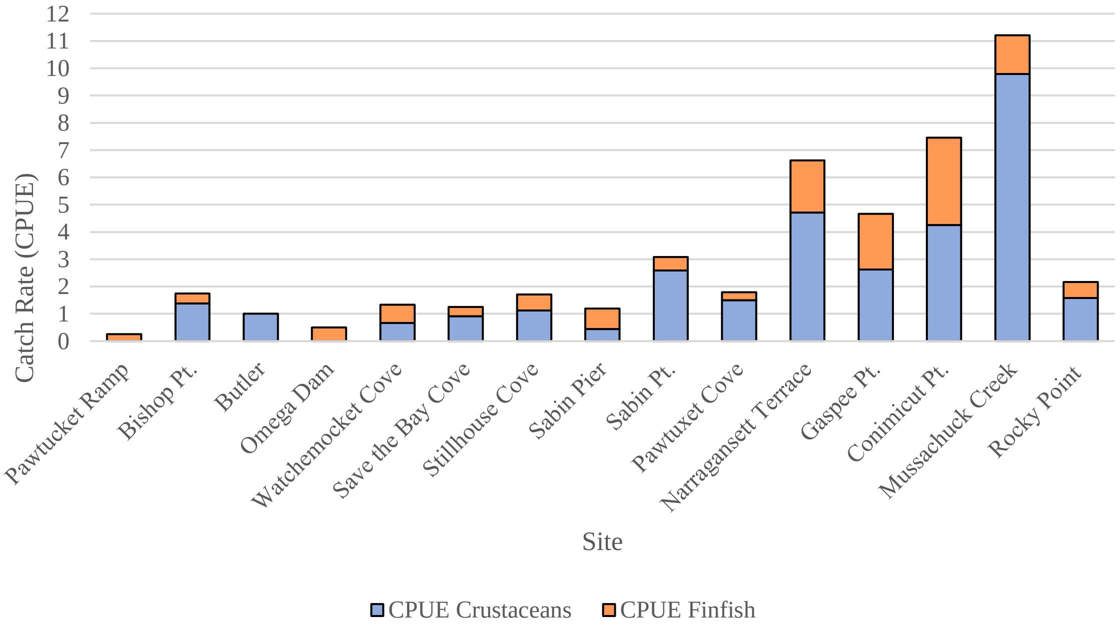

Figure 7. Total catch rate by site (stacked). Sites are shown from northern to southernmost extent of sampling area. CPUE = Total fish caught/(Number of hauls*Number of soak days). All hauls were based on two black sea bass traps per haul.

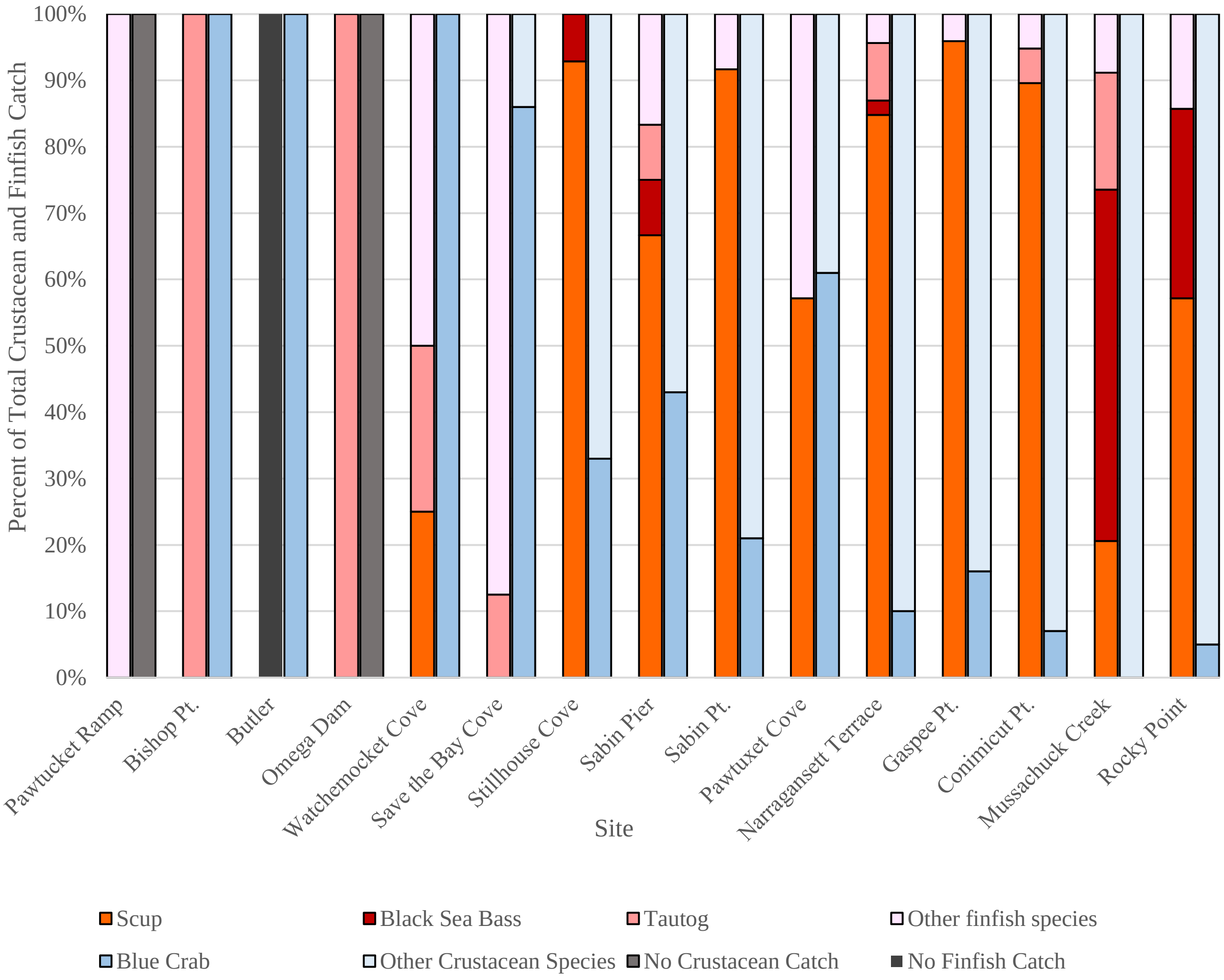

Figure 8. Percent of finfish and crustacean species caught at each site in the 2018 season (stacked). Sites are shown from northern to southernmost extent of sampling area.

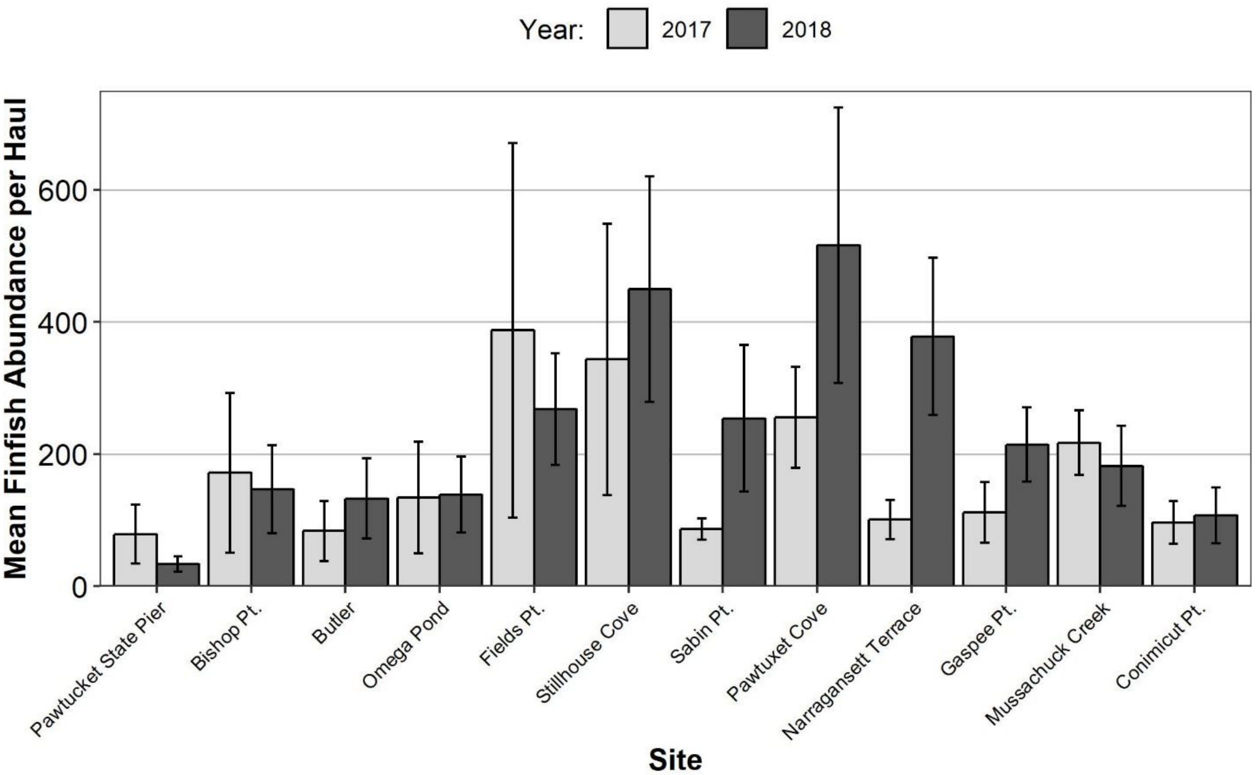

Figure 9. Mean abundance of finfish across sites in 2017 and 2018 beach seines.

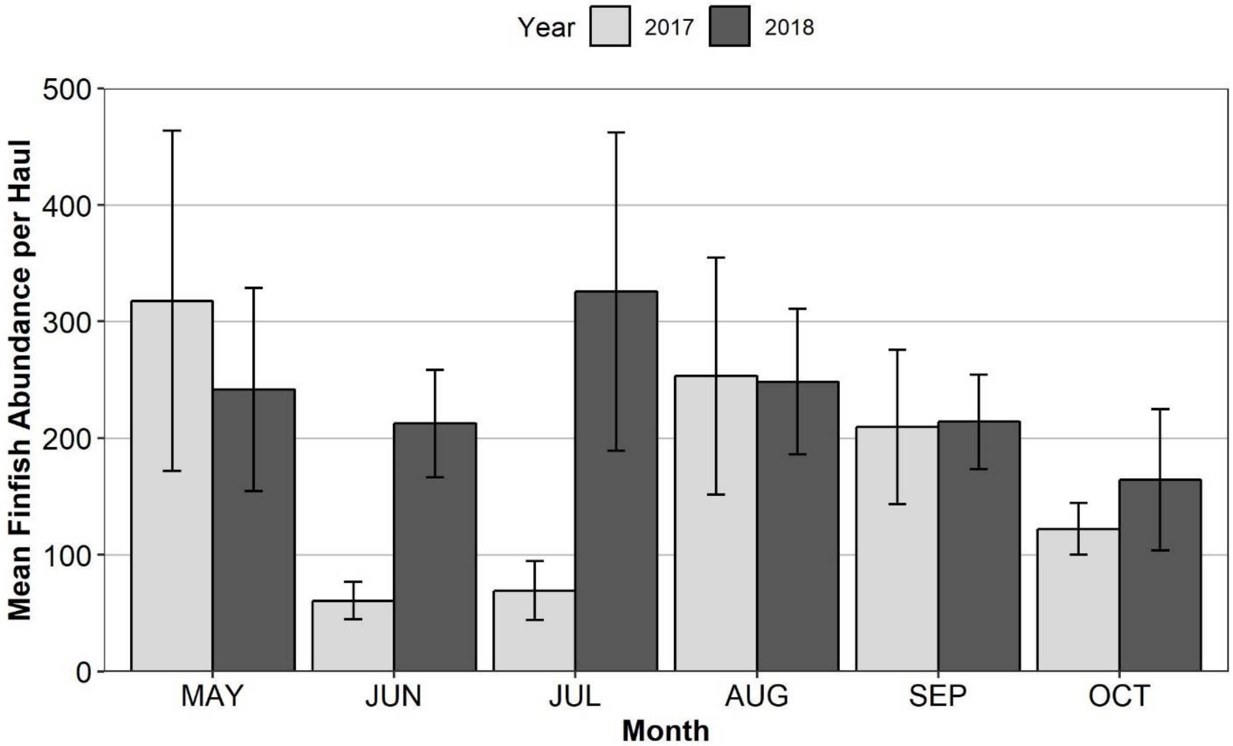

Figure 10. Mean abundance finfish caught each month in 2017 and 2018 beach seines.

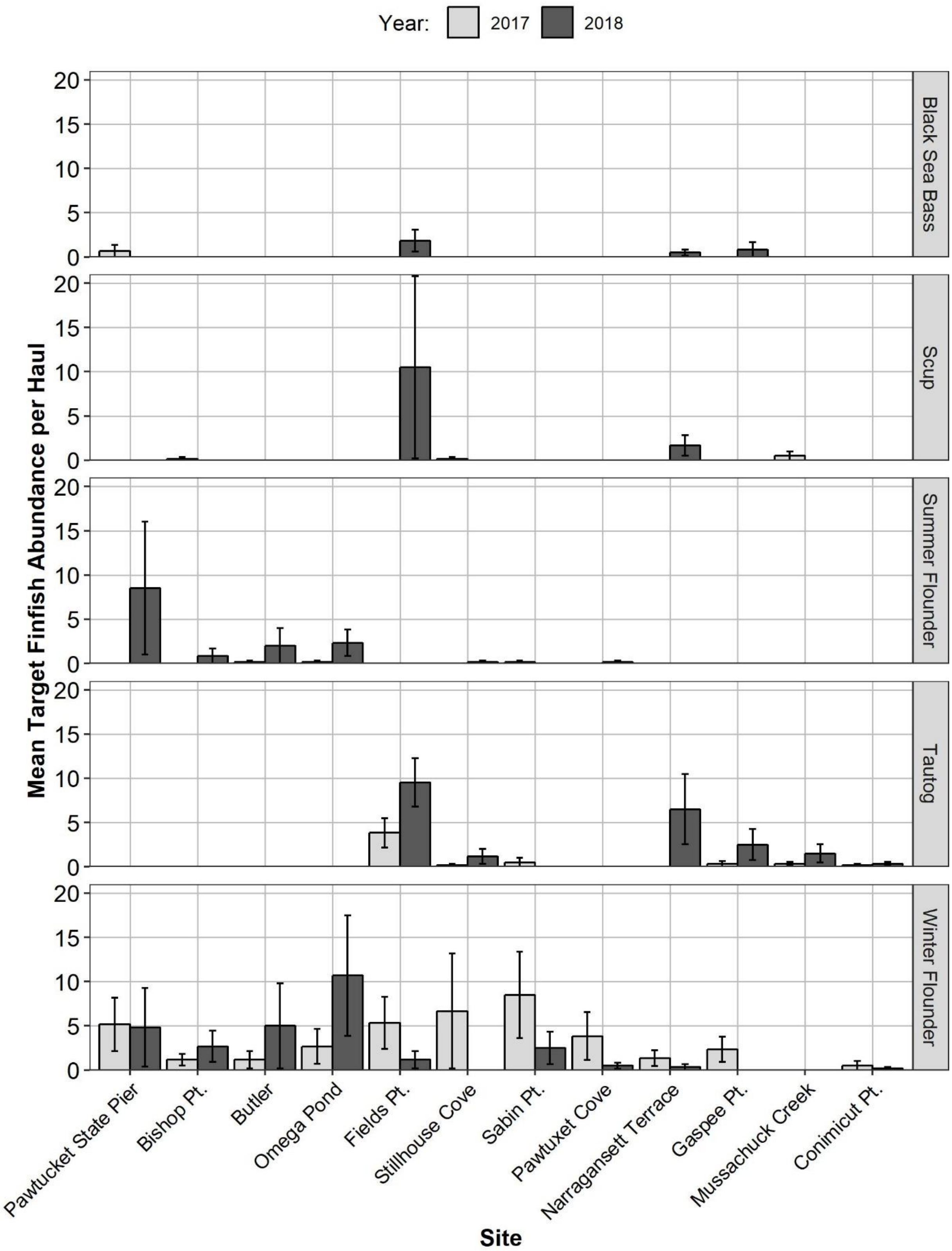

Figure 11a. Mean abundance of target finfish caught by site in 2017 and 2018 beach seines.

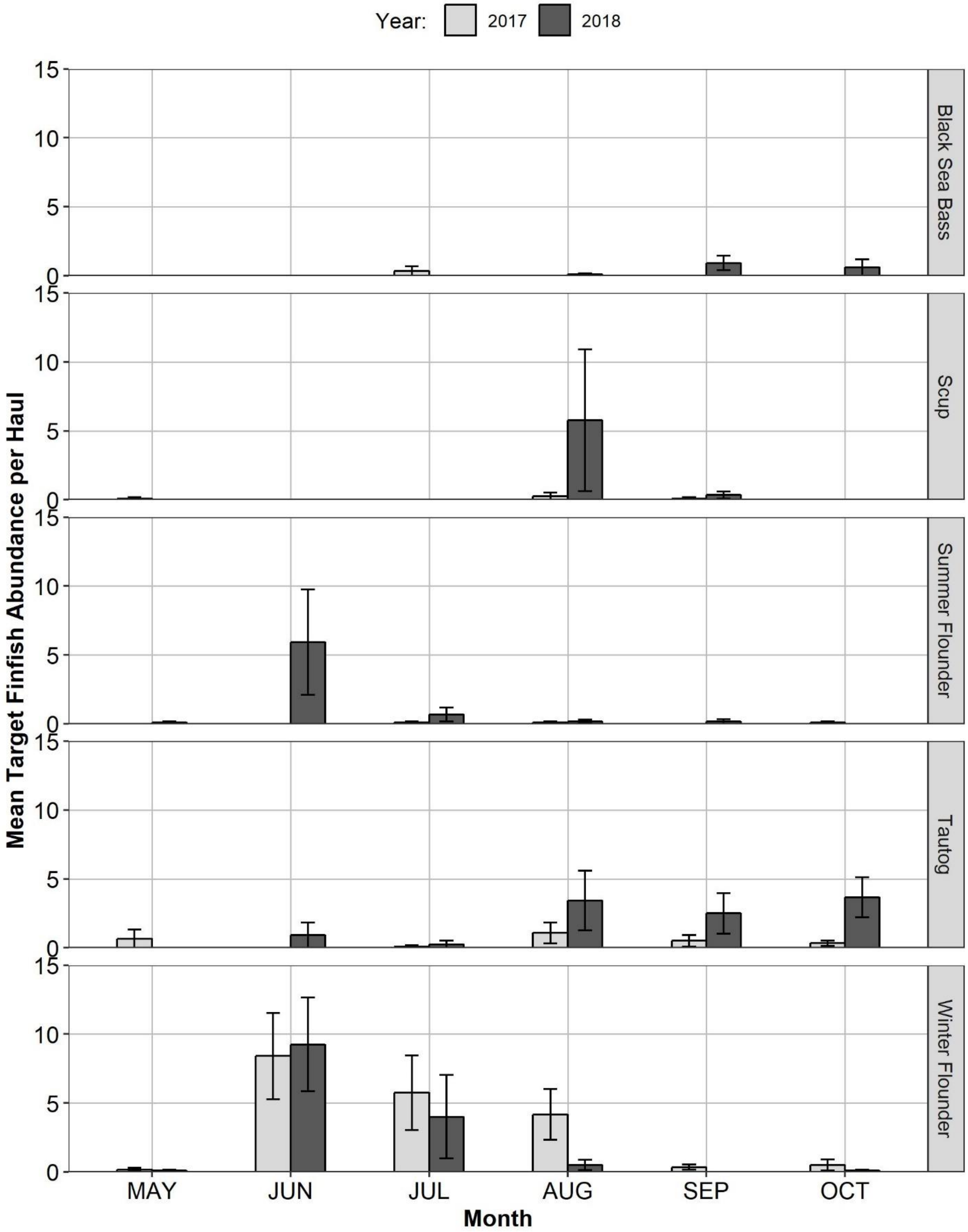

Figure 11b. Mean target finfish per seine haul (± SE) plotted for each month sampled during the 2017 and 2018 field seasons.

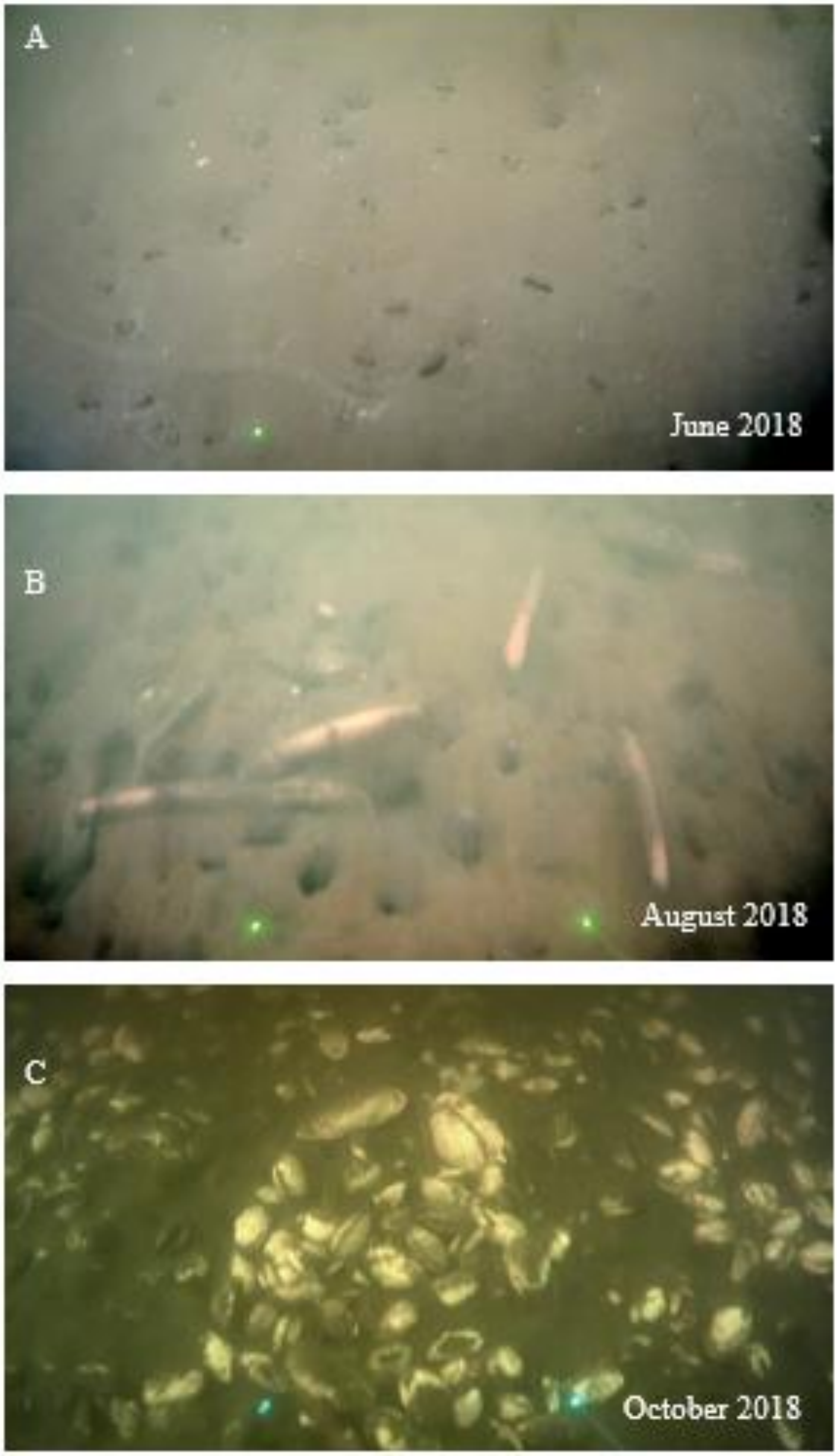

Figure 12. Selected clips from Omega Pond over the course of the field season in 2018. A) *Mya arenaria* siphons can be seen at the substrate surface in June 2018. Bottom dissolved oxygen was recorded at ~9mg/L. B) *M. arenaria* in stressed position with siphons extended in August 2018. Bottom dissolved oxygen was recorded at ~2 mg/L. C) *M.arenaria* shells at surface with high

mortality by October 2018. Ponar grabs from site showed mostly empty shells with remaining tissue in <20% of cases. Length ranges of sampled shells ranged from ~10-30mm).

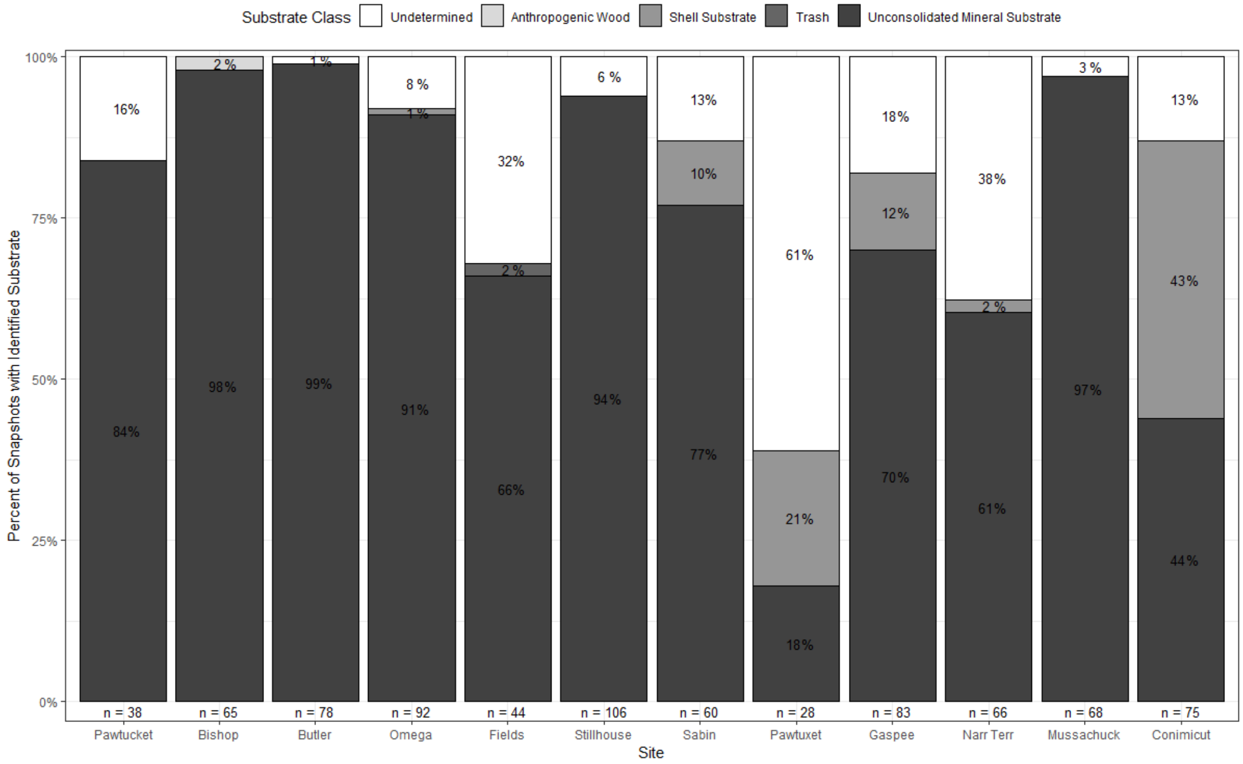

Figure 13. Identified Substrate Class across analyzed sites in 2017 and 2018 (Figure 4). Percent values indicate the number of snapshots identified as that substrate. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column (e.g. the Bishop transect contained 65 total snapshots). Sites are listed by latitude starting from the northernmost to the southernmost site.

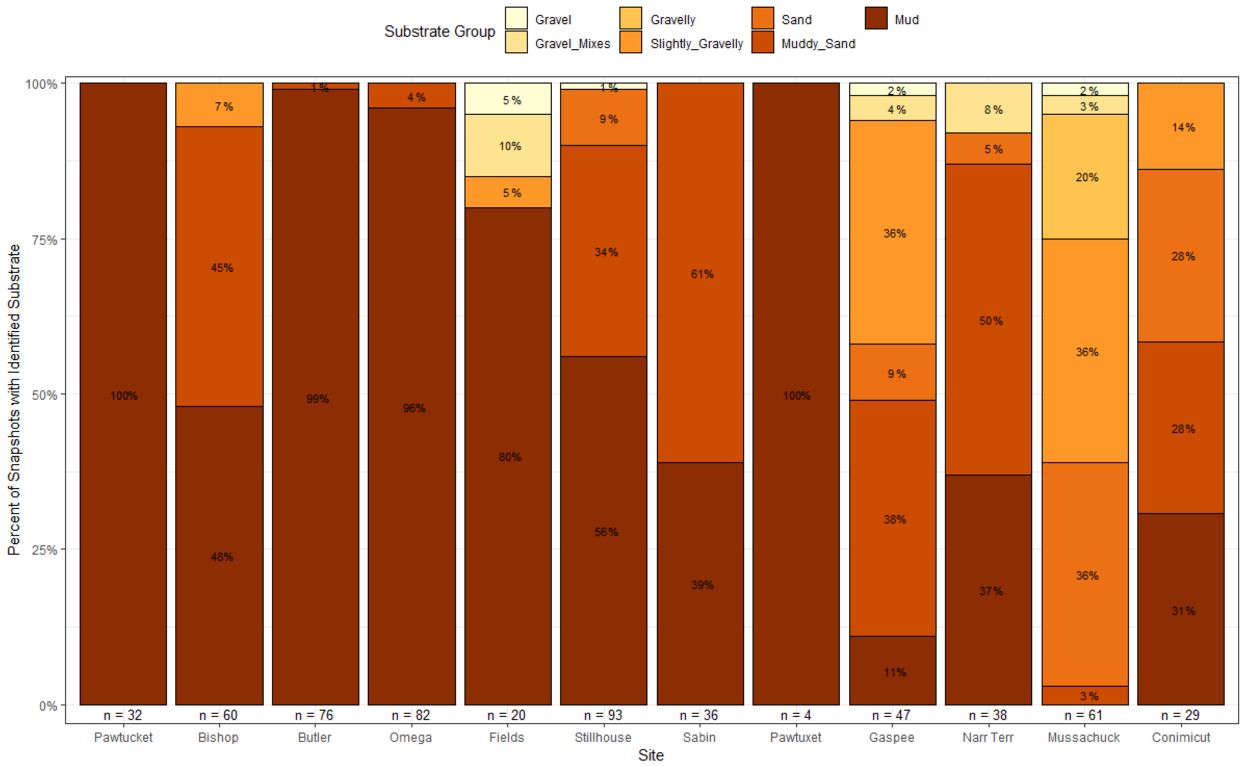

Figure 14. Unconsolidated Mineral Substrate broken down into Substrate Group with video quality ≥3 across analyzed sites in 2017 and 2018 (Figure 4). Percent values indicate the number of snapshots identified as that substrate. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column. Sites are listed by latitude starting from the northernmost to the southernmost site.

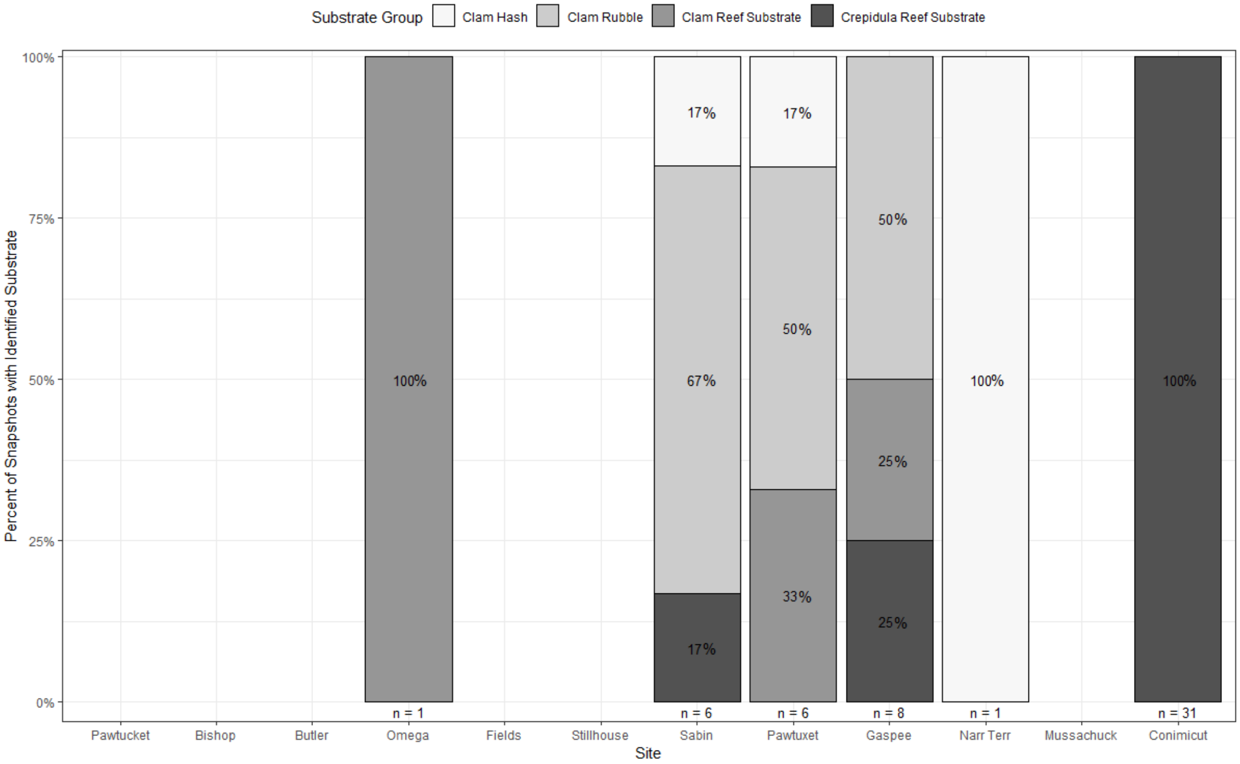

Figure 15. Shell Substrate broken down into Substrate Group with video quality ≥3 across analyzed sites in 2017 and 2018 (Figure 4). Percent values indicate the number of snapshots identified as that substrate. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column. Sites are listed by latitude starting from the northernmost to the southernmost site.

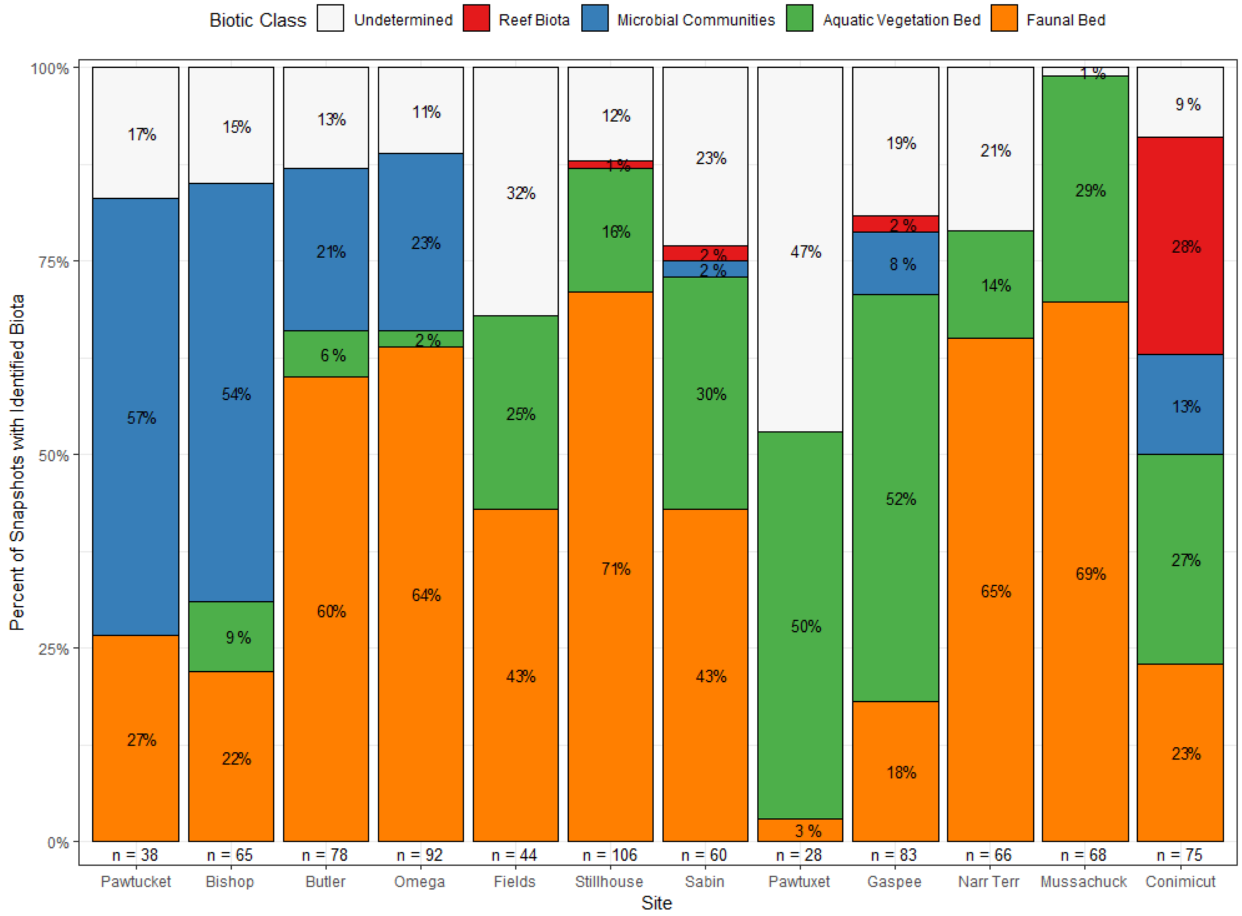

Figure 16. Identified Biotic Class across analyzed sites in 2017 (Figure 5). Percent values indicate the number of snapshots identified as that substrate. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column. Sites are listed by latitude starting from the northernmost to the southernmost site.

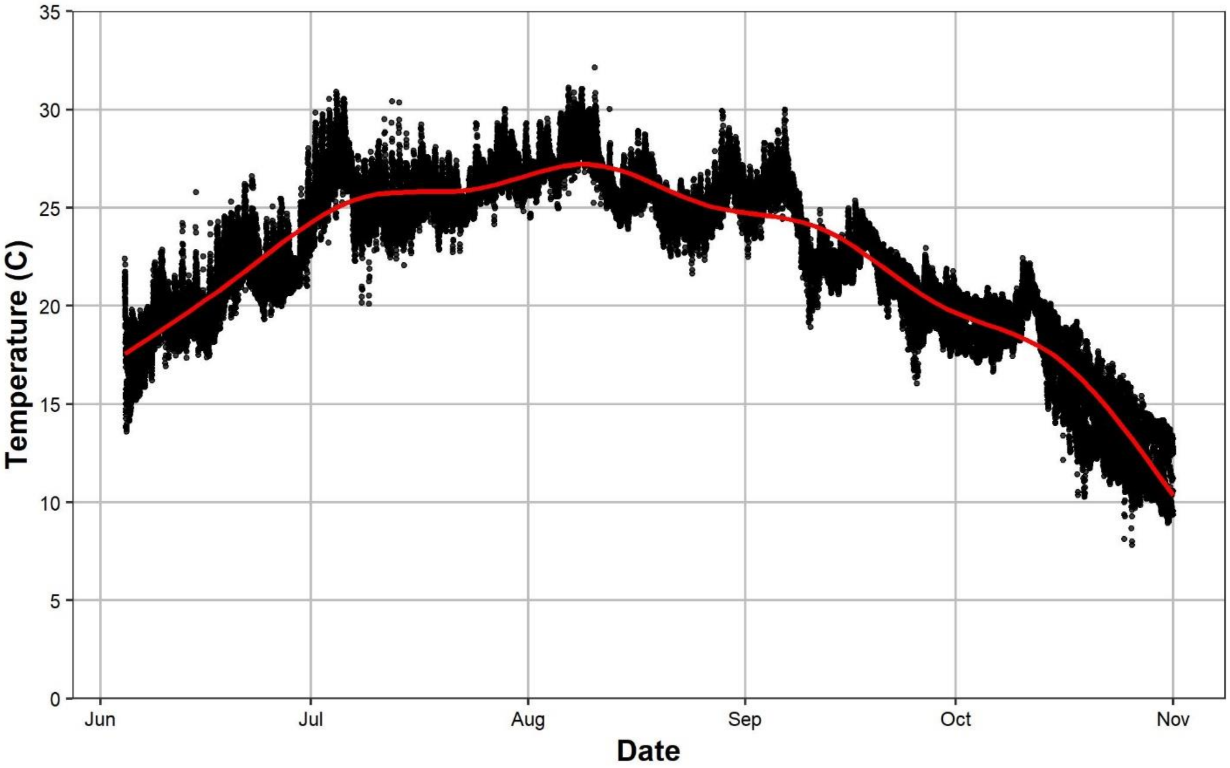

Figure 17. Plot of all temperature recordings during the 2018 sampling season. The red line represents Loess smoothing line.

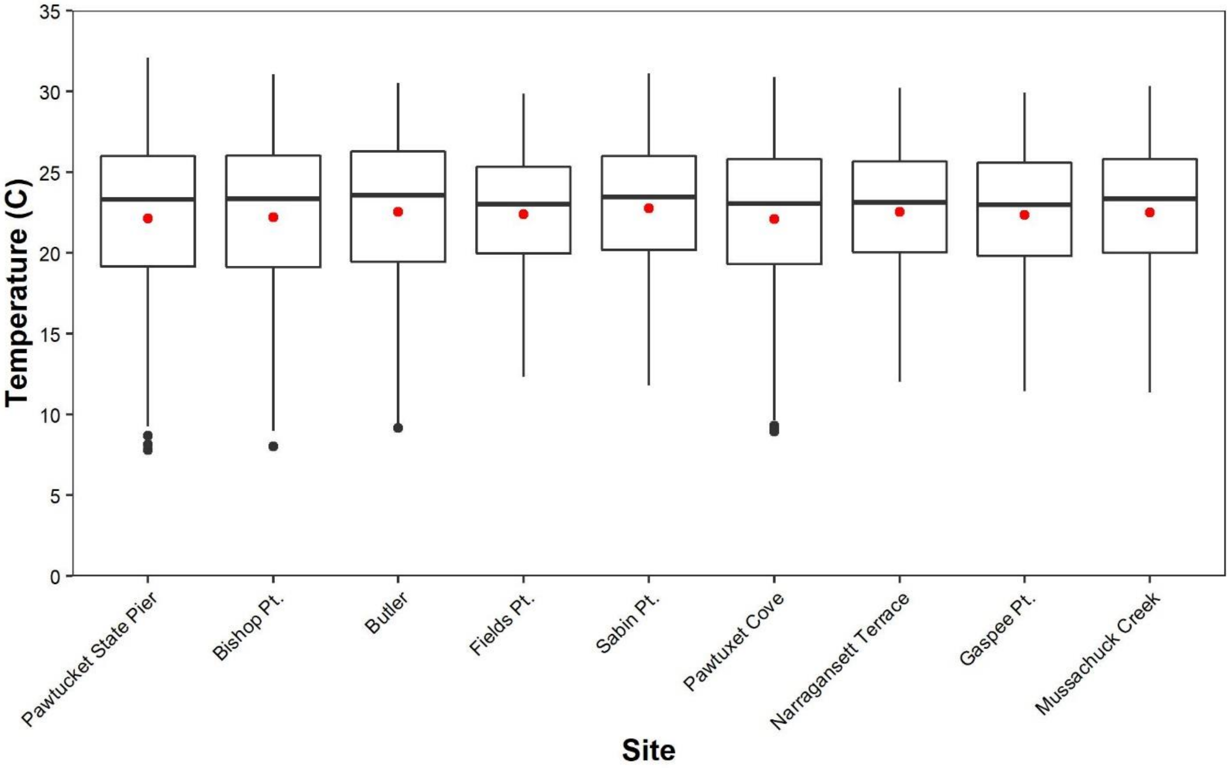

Figure 18. Boxplots of temperature (°C) at sites during 6/4/18 – 10/31/18 with center points representing mean values.

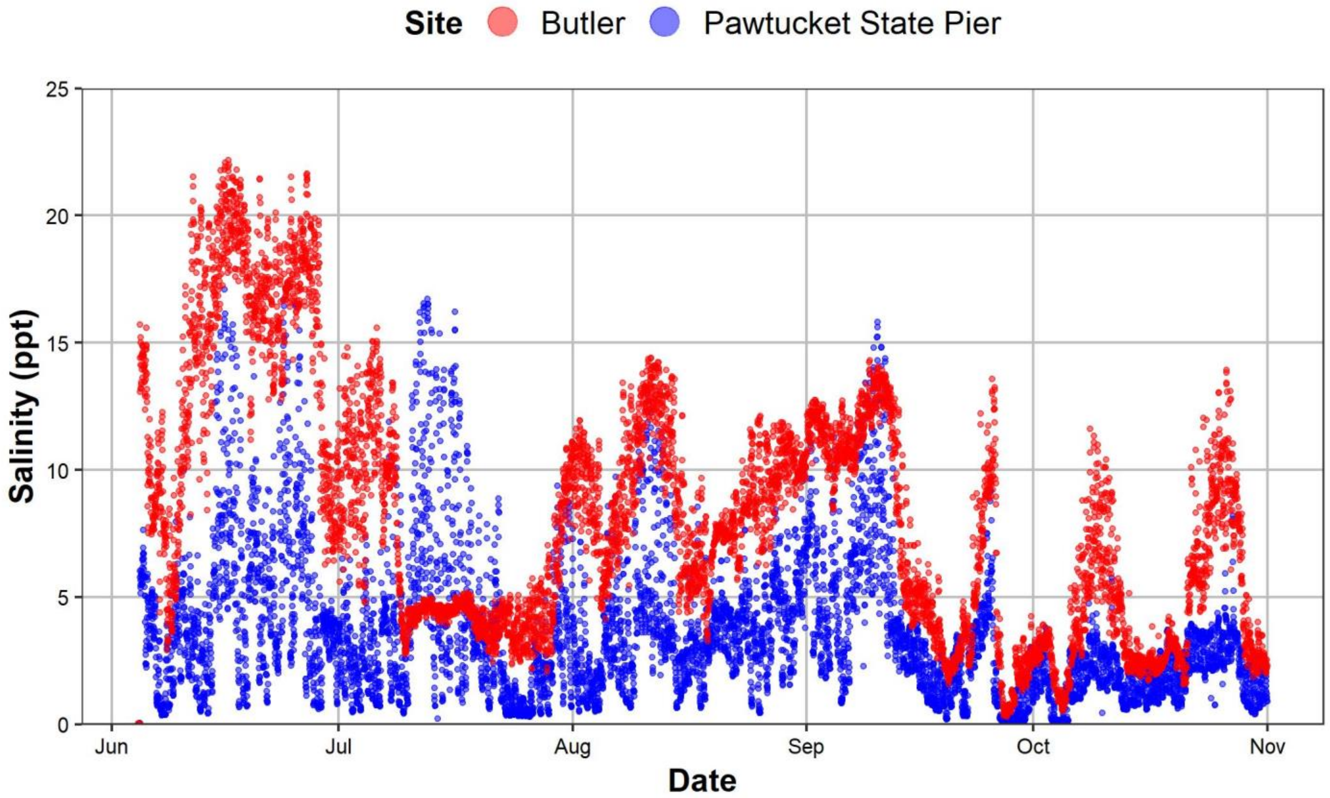

Figure 19. Plot of salinity (ppt) at Butler and Pawtucket State Pier during the 2018 sampling season.

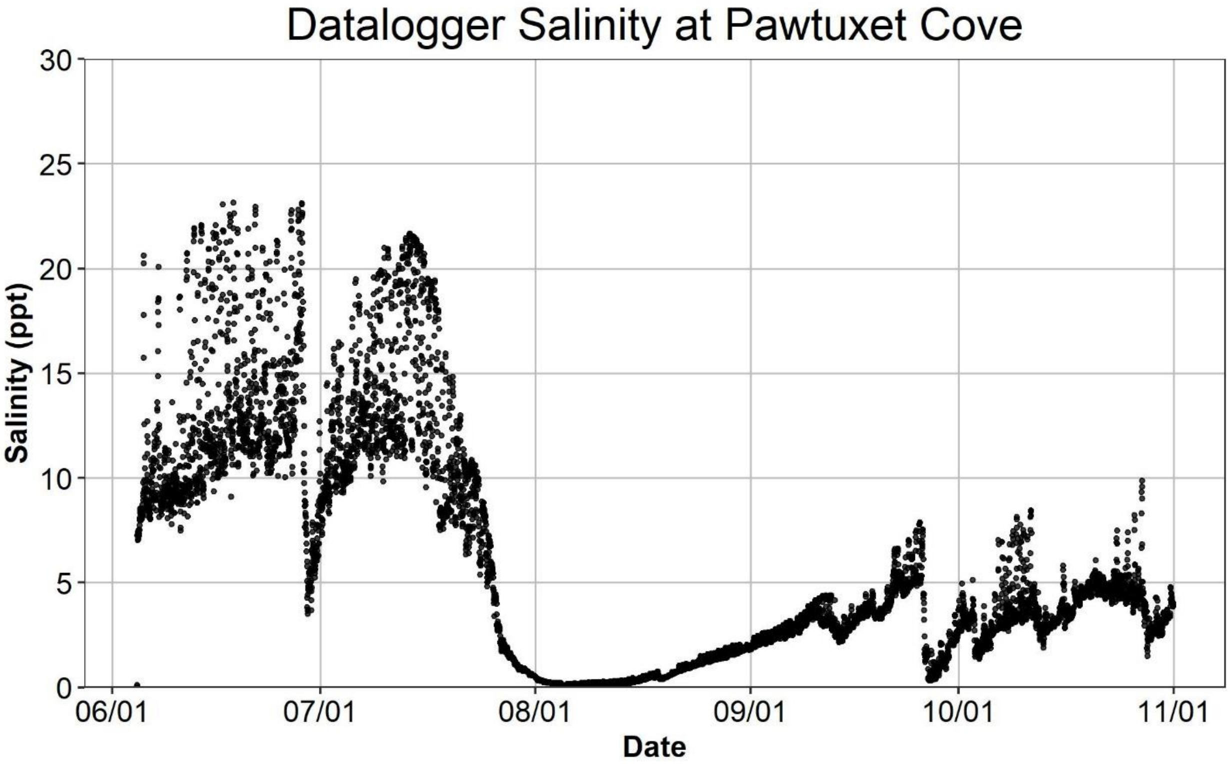

Figure 20. Plot showing salinity from Pawtuxet Cove during the 2018 sampling season.

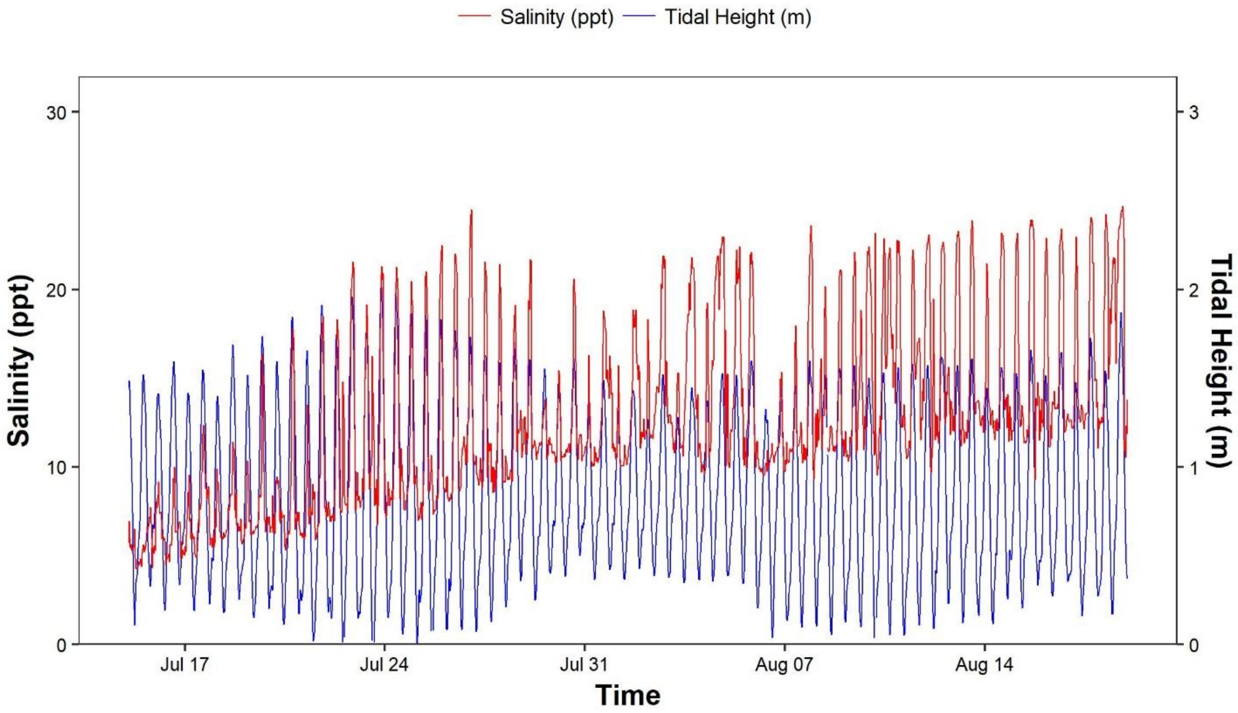

Figure 21. Line graph showing salinity from the Pawtuxet Cove water quality datalogger and tidal height from the NOAA Pawtuxet Cove site during 7/15/17 – 8/18/17.

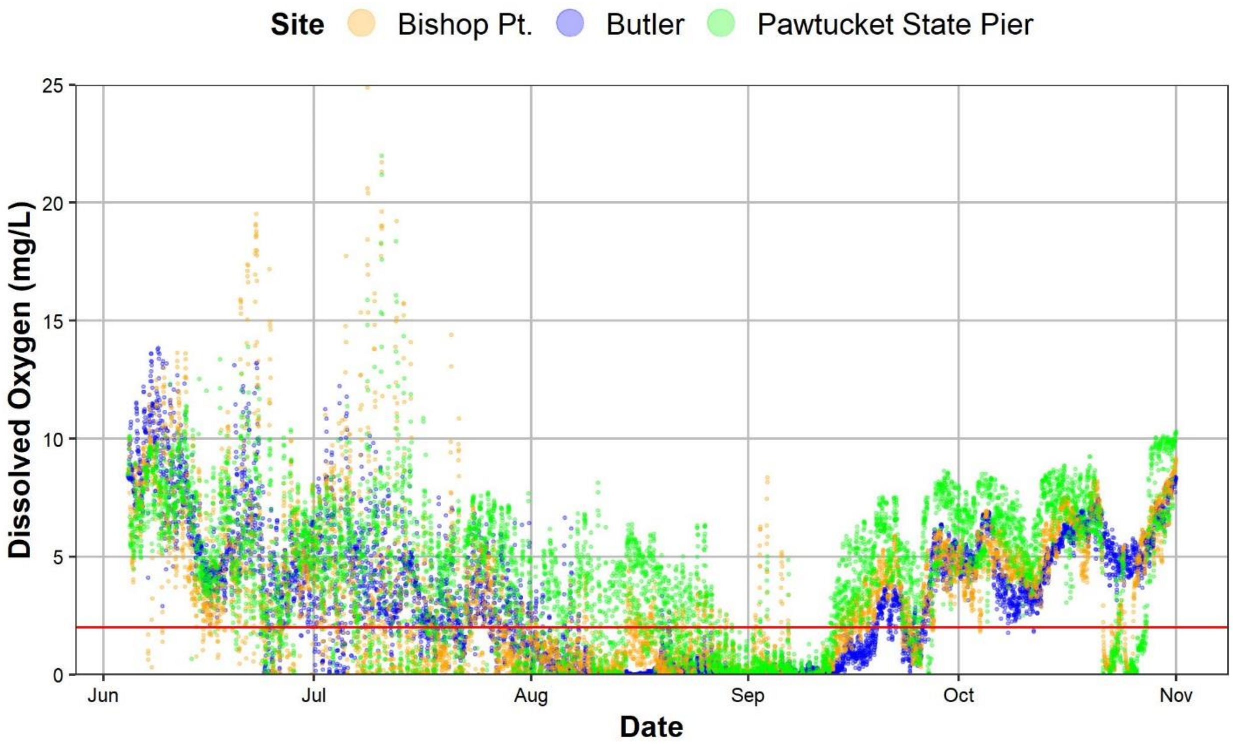

Figure 22. Plot of DO concentrations at 3 sites in the Seekonk River during the 2018 sampling season. The red line represents hypoxia threshold (2 mg/L)

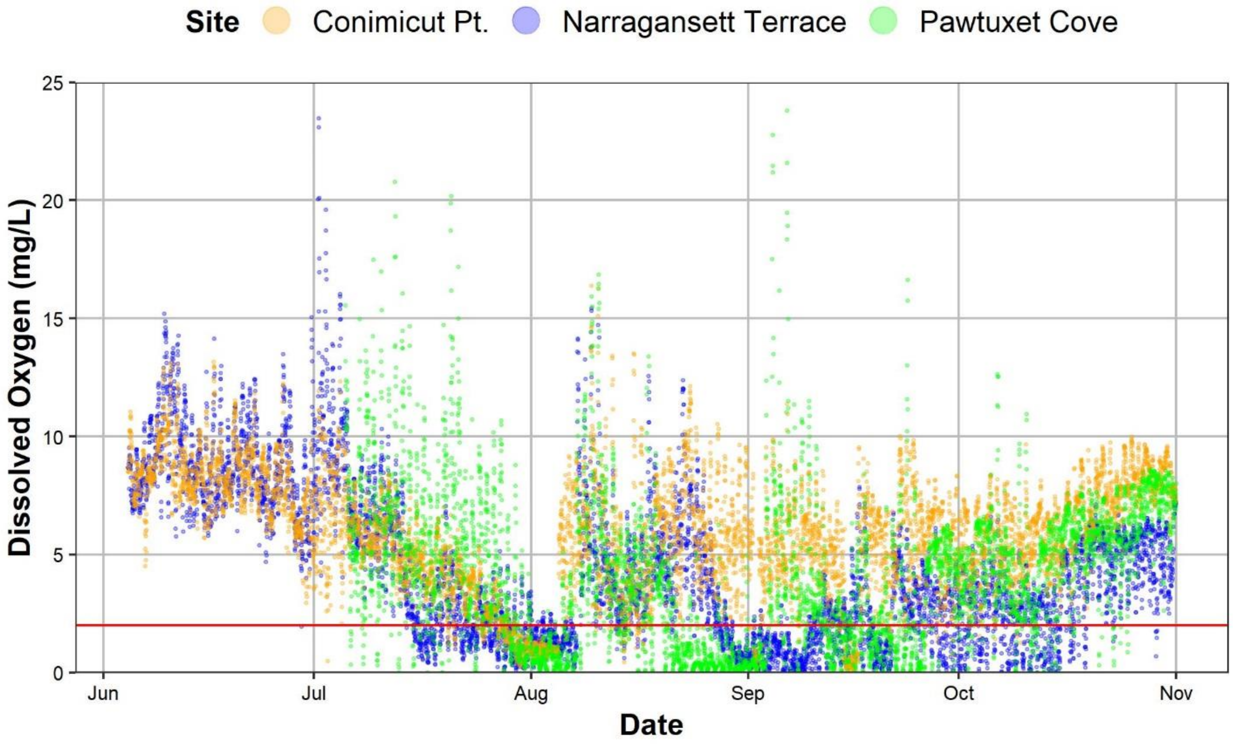

Figure 23. Plot of DO concentrations at 3 sites in the Providence River during the 2018 sampling season. The red line represents hypoxia threshold (2 mg/L)

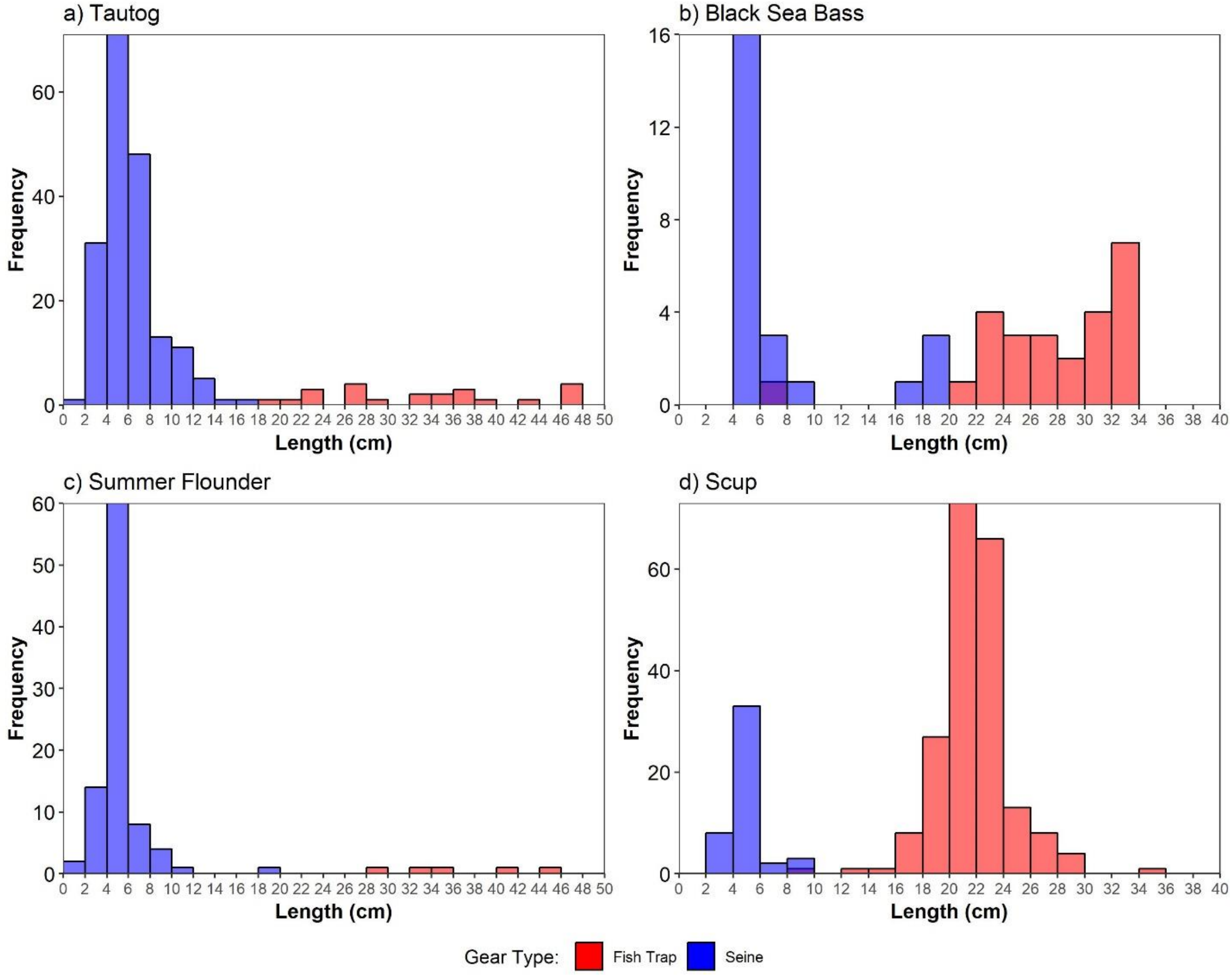

Figure 24. Histograms showing the size frequency at length of target species caught in fish traps and seines (a = tautog, b = black sea bass, c = summer flounder, d = scup).

TABLES:

Table 1. Common, scientific names, and total abundance of all species collected in beach seines during 2018.

Common Name	Scientific Name	Abundance
Atlantic Menhaden	*Brevoortia tyrannus*	332,511
Silverside	*Menidia spp.*	9,070
Striped Killifish	*Fundulus majalis*	2,769
River Herring	*Alosa spp.*	2,500
Common Mummichog	*Fundulus heteroclitus*	934
Gizzard Shad	*Dorosoma cepedianum*	364
Winter Flounder	*Pseudopleuronectes americanus*	167
Tautog	*Tautoga onitis*	129
Bluefish	*Pomatomus saltatrix*	123
Summer Flounder	*Paralichthys dentatus*	84
Northern Kingfish	*Menticirrhus saxatilis*	76
Scup	*Stenotomus chrysops*	73
White Perch	*Morone americana*	67
Hogchoker	*Trinectes maculatus*	47
Clupeids	Clupeidae family	40
Atlantic Tomcod	*Microgadus tomcod*	39
American Eel	*Anguilla rostrata*	32
Blue Crab	*Calinectes sapidus*	22
Black Sea Bass	*Centropristus striata*	19
Weakfish	*Cynoscion regalis*	16
Northern Pipefish	*Syngnathus fuscus*	16
Striped Searobin	*Prionotus evolans*	13
Green Crab	*Carcinus maenus*	10
Banded Killifish	*Fundulus diaphanus*	10
Spot	*Leiostomus xanthurus*	10
Oyster Toadfish	*Opsanus tau*	9
Striped Bass	*Morone saxatilis*	8
Northern Puffer	*Sphoeroides maculatus*	7
4-Spine Stickleback	*Apeltes quadracus*	6
Golden Shiner	*Notemigonus crysoleucas*	6
Cunner	*Tautogolabrus adspersus*	6
Sheepshead Minnow	*Cyprinodon variegatus*	4
Bluegill	*Lepomis macrochirus*	4
Crevalle Jack	*Caranx hippos*	3
Lady Crab	*Ovalipes ocellatus*	3
Northern Searobin	*Prionotus carolinus*	3
Atlantic Needlefish	*Strongylura marina*	3
3-Spine Stickleback	*Gasterosteus aculeatus*	2
Largemouth Bass	*Micropterus salmoides*	2
Searobins	Prionotus genus	2
Inshore Lizardfish	*Synodus foetens*	2
Naked Goby	*Gobiosoma bosc*	1
Spider Crab	*Libinia emarginata*	1
Longhorn Sculpin	*Myoxocephalus octodecemspinos*	1
Yellow Perch	*Perca flavescens*	1
Windowpane Flounder	*Scophthalmus aquosus*	1
Permit	*Trachinotus falcatus*	1

Table 2. Sampling frequency of black sea bass traps in 2018.

	May	**June**	**July**	**August**	**September**	**October**	**Total samples by site**
Pawtucket Ramp	X						1
Bishop	X						1
Omega	X	X					2
Butler	X	X					2
Watchemocket				X	X	X	3
Save the Bay	X	X	X	X	X	X	6
Stillhouse	X	X	X	X	X	X	6
Sabin Point	X	X	X	X	X	X	6
Sabin Pier			X	X	X	X	4
Pawtuxet	X	X	X	X	X	X	6
Narragansett Terrace	X	X	X	X	X	X	6
Gaspee	X	X	X	X	X	X	6
Conimicut	X	X	X	X	X	X	6
Mussachuck	X	X	X	X	X	X	6
Rocky Point				X	X	X	3
Total samples per month	12	10	9	11	11	11	64

Table 3. Geographic coordinates for black sea bass trap placement.

Fish Trap Locations 2018		
Site	Latitude	Longitude
Conimicut Pt.	41.722890	-71.362221
Mussachuck Crk.	41.727808	-71.343107
Gaspee Pt.	41.747028	-71.374000
Narragansett Terrace	41.752252	-71.365404
Sabin Pt.	41.763186	-71.366948
Pawtuxet Cove	41.759085	-71.385439
Stillhouse Cove	41.772970	-71.385511
Fields Pt.	41.786896	-71.379877
Omega Pond	41.836868	-71.372217
Butler	41.839410	-71.377830
Bishop Pt.	41.862270	-71.378670
Pawtucket Pier	41.869740	-71.380800
Watchemocket Cove	41.79782	-71.38161
Rocky Point	41.68857	-71.36388
Sabin Pier	41.76362	-71.36858

Table 4. Total number caught by site with calculated total catch rate and finfish catch rate by site.

Species	Pawtucket Ramp	Bishop	Butler	Omega	Watchemocket	Save the Bay	Stillhouse	Sabin Pier	Sabin Point	Pawtuxet	Narragansett Terrace	Gaspee	Conimicut	Mussachuck	Rocky Point	**Total**
American Eel						1										**1**
Black Sea Bass							1	1			1			18	2	**23**
Blue Crab		11	8		8	19	9	3	13	22	11	10	7	1	1	**123**
Green Crab														1		**1**
Oyster Toadfish					3	4		2		2	2	2	4		1	**20**
Rock Crab														1		**1**
Scup					2		13	8	11	4	39	47	69	7	4	**204**
Spider Crab						3	18	4	49	14	102	53	95	232	18	**588**
Striped Bass						1										**1**
Summer Flounder					1				1					3		**5**
Tautog		3		2	2	1		1			4		4	6		**23**
White Perch	1					1				1						**3**
Total	**1**	**14**	**8**	**2**	**16**	**30**	**41**	**19**	**74**	**43**	**159**	**112**	**179**	**269**	**26**	**967**
Catch Rate	**0.25**	**1.75**	**1.00**	**0.50**	**1.33**	**2.50**	**1.71**	**1.19**	**3.08**	**1.79**	**6.63**	**4.67**	**7.46**	**11.21**	**2.17**	
Finfish Catch Rate	0.25	0.38	0.00	0.50	0.67	0.33	0.58	0.75	0.50	0.29	1.92	2.04	3.21	1.42	0.58	

Table 5. Description of video quality determination with associated rating and grade.

Video Quality Grade	**Rating**	**Description**
5	Excellent	Video exhibits perfect to almost perfect visibility. Image snapshot able to be identified down to Substrate and Biotic Group without help from video. Fauna >2mm can be quantified.
4	Great	Video exhibits great to very good visibility. Image snapshot able to be identified down to Substrate and Biotic Group with some help from video. Fauna >5mm can be quantified.
3	Good	Video exhibits good visibility. Image snapshot able to be identified down to Substrate and Biotic Group with much help from video. Fauna >1cm can be quantified.
2	Poor	Video exhibits poor visibility. Image snapshot able to be identified down to only Substrate Class, and Biotic Class where possible with help from video. Fauna >2cm can be quantified.
1	Very Poor	Video exhibits very poor to no visibility. Image snapshot able to be identified down to only Substrate and Biotic Class with much help from video, and in some cases not at all. Fauna are not able to be quantified.

Table 6. Adapted CMECS percent cover modifier.

Coarse Percent Cover Values	**Percent Cover Range (%)**
Trace	0 – 9
Sparse	10 – 29
Moderate Low	30 – 49
Moderate High	50 – 69
Dense	70 – 89
Complete	90 - 100

Table 7. Overview of sampling frequency from 2017. * = incomplete GPS transect data; this value was not included in calculating the average transect length.

Site	Month	Transect length (km)	Total Video Time (min)	Average video quality
Pawtucket Ramp	6	-	3:24	-
Bishop Point	6	-	14:08	-
Butler	6	-	21:08	-
Omega Pond	6	-	16:12	-
Stillhouse Cove	6	-	16:16	-
Pawtuxet Cove	6	-	7:37	-
Gaspee Point	6	-	22:05	-
Conimicut Point	6	0.75	21:18	-
Mussachuck Creek	6	0.44	20:01	-
Field Point	8	0.66	1:04	3
Sabin Point	8	-	10:16	2
Narragansett Terrace	8	0.41	24:10	2
Gaspee Point	8	0.58	15:35	3
Conimicut Point	8	0.59	15:28	3
Mussachuck Creek	8	0.86	7:02	3
Bishop Point	9	1.29	30:52	2
Butler	9	0.96	19:58	3
Omega Pond	9	1.47	25:59	3
Stillhouse Cove	9	0.7	16:48	2
Pawtuxet Cove	9	*0.07	11:00	4

Table 8. Overview of sampling frequency from 2018

Site	Month	Transect length	Total Video Time	Average video quality
Stillhouse	6	0.46	23:53	3
Sabin	6	0.44	27:32	3
Pawtuxet	6	0.12	8:36	2
Pawtucket	6	-	4:16	1
Omega	6	0.39	13:04	2
Butler	6	0.39	12:09	2
Narragansett Terrace	6	0.58	20:31	2
Mussachuck	6	0.5	23:00	3
Gaspee	6	0.53	22:44	2
Fields	6	0.47	18:52	2
Conimicut	6	0.4	18:15	3
Stillhouse	8	0.49	15:30	2
Sabin	8	0.63	20:13	3
Pawtuxet	8	0.19	7:15	2
Pawtucket	8	0.51	20:39	3
Narragansett Terrace	8	0.48	19:04	3
Mussachuck	8	0.56	14:05	3
Gaspee	8	0.48	24:45	3
Save the Bay	8	0.72	22:41	3
Conimicut	8	0.4	18:24	3
Omega	8	0.37	15:53	3
Butler	8	0.37	22:07	3
Bishop	8	0.48	17:11	3
Stillhouse	10	0.47	31:17	4
Omega	10	0.4	18:41	3

Table 9. Description of rare occurrences by category. NOTE: Categories are still being developed as more video is analyzed, and therefore are not limited to this list in the future.

Category	Specific Description of Occurrences
Large Crustaceans	blue crabs, spider crabs, and horseshoe crabs
Faunal Aggregations	Abnormal aggregation of fauna (mud snails, softshell clams)
Dead Fauna	dead adult menhaden
Anthropogenic Material	plastic, aluminum cans, glass bottles, rubber gloves, tires, other
Air Bubbles	air bubbles released from substrate
Fish	juvenile menhaden, sea robin, juvenile black sea bass, juvenile scup
Other	Lugworm egg sacs

Table 10. Common and scientific names of all species collected in black sea bass traps during 2018 sampling season.

Common Name	Scientific Name
American Eel	*Anguilla rostrata*
Black Sea Bass	*Centropristis striata*
Blue Crab	*Callinectes sapidus*
Green Crab	*Carcinus maenas*
Oyster Toadfish	*Opsanus Tau*
Rock Crab	*Cancer irroratus*
Scup	*Stinotomus chrysops*
Spider Crab	*Libinia sp.*
Summer Flounder	*Paralichthys dentatus*
Tautog	*Tautoga onitis*
White Perch	*Morone americana*

APPENDIX A

PERMIT APPLICATION
REQUEST 2019

Project Title: Sabin Point Artificial Reef Pilot Project: Enhancing Habitat and Fishing Opportunities in the Providence River

Project Category: Research

Lat/Lon of Site: **Site 1 41.76435, -71.36905**
corner points provided in **Figure 1*

Permit Area: <1 acre (~0.91 acres)

Reef Area: <0.25 acres (~0.14 acres)

Applicant(s):

Will Helt
The Nature Conservancy, Rhode Island Chapter
159 Waterman Street
Providence, RI 02906
Email: william.helt@tnc.org
Phone: 401-214-4528

Patrick Barrett
Rhode Island Department of Environmental Management
Division of Marine Fisheries
Fort Wetherill Marine Laboratory, 3 Fort Wetherill Road
Jamestown, Rhode Island 02835
Email: patrick.barrett@dem.ri.gov
Phone: 401-423-1947

Date Submitted: ____________________

APPENDIX A

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APPENDIX A

TABLE OF CONTENTS

APPENDIX A

PERMIT APPLICATION
REQUEST 2019

1. PERMIT REQUEST

The Nature Conservancy (TNC), in partnership with the Rhode Island Department of Environmental Management (RI DEM) Division of Marine Fisheries (DMF), is requesting an Army Corps of Engineers (ACOE) Individual Permit, Rhode Island Department of Environmental Management (DEM) Water Quality Certificate, and a Rhode Island Coastal Resources Management Council (CRMC) Category B Assent for habitat restoration projects undertaken by public entities. This project seeks to enhance habitat and fishing opportunities in the Providence River. Pre- and post-enhancement monitoring will allow us to evaluate the effectiveness of artificial reefs as an enhancement tool in Rhode Island waters. We expect this project will serve as a model for artificial reef projects in Rhode Island state waters by improving habitat, increasing local abundance of fish, and providing societal benefits through increased fishing opportunities.

2. PROJECT NEED

The main ***objective*** of our study is to determine how artificial reefs can be used as a fisheries resource and fish habitat enhancement tool in degraded areas of the upper Narragansett Bay and Providence River estuary. Since 2016, TNC and DMF (hereafter the applicants) have conducted benthic video monitoring and finfish surveys at selected sites to assess their suitability for various enhancement techniques. These assessments have provided the applicants insight into the current habitat condition and fish assemblage in these areas, and the ability to prioritize locations of where such fish habitat enhancement work would be most successful.

Through this assessment, artificial reefs (ARs) set at Sabin Point were identified as the best viable option for fish habitat in the Providence River estuary. Alternate sites were evaluated, including upland alternatives as required by the ACOE Individual Permit. Constructing an AR using a three-dimensional Reef Ball™ module array at Sabin Point Park will help enhance fish habitat by providing structure for fish – a habitat that is currently not present at this site. In addition to the actual structures, the resulting epifaunal colonization (e.g., algae, barnacles, bivalves, sponges, and anemone species) on the AR will provide food and enhanced habitat for fish species. The increase in fish abundance created by the reef system will help improve the recreational fishing experience at the park's pier. Finally, this array will help advance research on the impact of ARs in Rhode Island waters and provide the first AR Reef Ball™ research site in Narragansett Bay, which may serve as a model in future AR initiatives.

Using a variety of research techniques, we will seek to answer the following questions:

1) How do reef balls affect the area's fish assemblage and abundance?

2) What colonizing organisms will inhabit the reef over time?

3) How do fishes utilize the added structure?

4) How has recreational use of the pier changed post reef installation? (Pending Funding)

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We propose the construction of a ***0.14-acre artificial reef*** using up to 100 pre-fabricated reef modules, with a maximum combined fill volume of ~2,847 ft^3. The AR footprint will be a 200 ft^2 area beginning 50 feet away from the end of the pier (Figure 1). Our current design includes 91 reef modules consisting of 58 Pallet Balls and 33 Bay Balls at a combined fill volume of ~2,016 ft^3 and will begin 75-100 feet from the end of the pier (Figure 9).

The Artificial Reef Team consists of individuals with backgrounds in fisheries management, restoration science, and GIS:

- William Helt (Co-Principal Investigator, Coastal Restoration Scientist - TNC)
- Patrick Barrett (Co-Principal Investigator, Fisheries Specialist – DEM)
- Eric Schneider (Collaborator, Principal Biologist- DEM)
- Conor McManus (Collaborator, Deputy Chief - DEM)
- Heather Kinney (Collaborator, Coastal Restoration Science Tech – TNC)
- Kevin Ruddock (Collaborator, GIS Manager- TNC)
- John O'Brien (Collaborator, Partner Specialist – TNC)

3. SITE SELECTION

Our intended goal is to enhance a site that currently provides fishing access but supports low fish abundance due to the unproductive benthic habitat. The project site has been carefully chosen to balance the goals and objectives of the project while taking into consideration the environmental constraints, logistics of implementation, and competing uses.

We used geospatial, benthic video monitoring, and scientific fisheries data to ensure that our enhancement work was conducted in a suitable location. Data collected and evaluated for the assessment included bathymetry, slope, marine shipping channel use, sediment type, dissolved oxygen, benthic habitat, seagrass distribution, and demersal fish abundance. Data sources and maps can be provided upon request.

Based on our pre-enhancement monitoring and site assessment of 12 locations in the upper Narragansett Bay and Providence River estuary, we identified Sabin Point as an ideal location for AR fish habitat enhancement. This area was selected based on the following attributes:

(1) Available infrastructure near project site for fishing access
(2) Relatively low quantity and quality of fish habitat structure currently in the surrounding subtidal
(3) Suitable physical and biological attributes to support fish abundance
(4) Background knowledge on recreational and commercial uses of the site

(1) Available infrastructure for fishing access

On the southwest end of Sabin Point Park, a public access fishing pier was constructed to improve the recreational fishing opportunity (Figure 1). Of the eleven alternative sites that are suitable for AR enhancement work, Sabin Point is the only location that has a fishing pier in place at this time.

	LATITUDE	LONGITUDE
A	41.7646	-71.3694
B	41.7646	-71.3687
C	41.7641	-71.3694
D	41.7641	-71.3687

Figure 1. Sabin Point Park Fishing Pier, Sabin Point artificial reef area (teal line).

(2) *Presence of structure in surrounding subtidal*

Benthic habitat condition from 2016 to 2018 at all sites was evaluated with an underwater video sled, along with water quality parameters including salinity (ppt), temperature (°C), dissolved oxygen (mg/L), and chlorophyll a (µg/L). A quantitative analysis using the Coastal and Marine Ecological Classification Standard (CMECS) was used to analyze the data. During the analysis, two of the four CMECS components (substrate and biota) were used to describe the benthic habitat.

In 2017, a 0.5km video transect was taken in the Sabin Point cove area. During the analysis, eight of the ten randomly selected video snapshots were defined as unconsolidated mineral substrate and had a predominantly dense composition (70-<90%) of muddy sand with sparse amounts (10-<30%) of shell hash/rubble (Figure 2). One of the snapshots was classified as unidentifiable due to poor video quality, and another was defined as shell substrate and composed of a moderately high density (50-<70%) of *Crepidula fornicata* and moderately low amounts (30-<50%) of shell hash/rubble. Areas closer to the shoreline and sandspit tend to have a higher density of shell rubble (mostly clam and slippershell) mixed with the muddy sand. This can be seen in the snapshots taken within the proposed site from the 2018 video transect (Figures 3 and 4). The video also shows that area is devoid of complex structure for fish (aside from the fishing pier).

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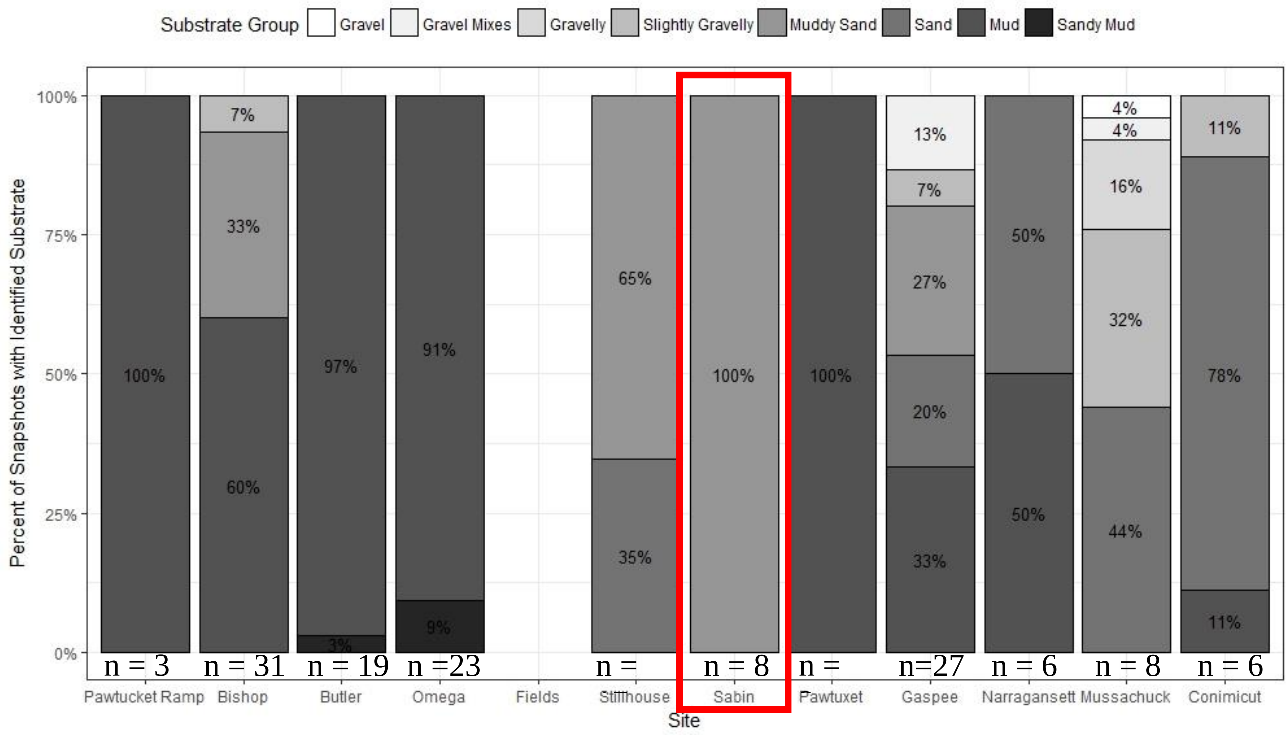

Figure 2. Unconsolidated Mineral Substrate broken down into Substrate Group for samples with sufficient video quality at the 12 potential locations in the upper Narragansett Bay and Providence River estuary analyzed in 2017. Percent values indicate the proportion of snapshots identified as the dominant substrate. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column. Sites are listed by latitude starting from the northernmost to the southernmost site.

An extensive survey of the project location was completed on October 24, 2018. A Ponar grab (0.06 m^2) was used to sample sediments and benthic macrofauna to ground truth the results from the CMECS video analysis. Upon retrieval, grab samples were sieved, and individual organisms were identified to the lowest possible taxonomic level. Sediment grain size was analyzed in the field using texturing techniques to determine general soil description and relative grain size proportions. A YSI Pro-Plus® probe was suspended about one meter above the sediment surface at each sample location to measure water temperature, salinity, and dissolved oxygen. Water depth and location were recorded using on-ship navigational tools (Garmin GPSMAP® 7607xsv).

Results from the grain size analysis indicated that sediments are composed almost entirely of coarse to fine sands, with only minor percentages of silt. The samples taken from within the proposed permit area have coarse sand contents indicating that the material is well-sorted and located in a medium-high energy environment. Low benthic habitat quality was evident from video as well as benthic grab samples. Bottom habitat features included shell hash of *Mya arenaria* and *Crepidula* spp. The video and Ponar grab data suggest that the area has the appropriate bottom type to support the proposed reef and that this location could benefit from this type of structural enhancement.

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(3) Physical and Biological Attributes

Onset HOBO data loggers (Dissolved Oxygen-U26-001 and Conductivity-U24-002-C) were deployed at each of the 12 potential locations in the upper Narragansett Bay and Providence River estuary monitored during pre-enhancement finfish seine and fish trap surveys conducted by the applicants. Temperature, salinity, and dissolved oxygen (DO) data were collected to determine how sites differed and if any differences in catch per unit effort covaried with any of these parameters. As expected, several locations in the Providence River estuary experienced temporary periods of hypoxic conditions (< 2.0 mg/l) in the late summer and early fall. In 2017, Sabin Point experienced temporary hypoxia from mid-September to the beginning of October (Figure 5). Mats of *Ulva* spp. get blown into the cove formed behind the sandspit and settle in the shallows south of Sabin Point park, contributing to the observed hypoxic days. We do not anticipate these events having a significant impact on the success of the artificial reef in this location and provides additional reasoning why we believe that Sabin Point could benefit from habitat enhancement. Added structure and improved rugosity to benthic habitats have been shown to improve turbulent flow of an area, which could help alleviate the severity and length at which these events occur as well as provide important water column mixing for active suspension feeders that will colonize the reef (Lenihan 1996, Lenihan 1998, Lenihan 1999, Lenihan 2001). Turbulent flow also increases shear stress that thins the diffusive boundary layer that regulates mass transfer, allowing for greater mass flux of molecules, such as oxygen, across the sediment-water interface (Patterson 1991a, 1991b, Reidenbach 2010). These physical processes are especially important for sessile organisms (e.g., corals, oysters) during times of stress as they can increase the transfer of oxygen molecules (Finelli et al. 2006). Despite these periodic low DO events, this location still possesses a dense quahog population according to DEM’s dredge survey data, and the Providence River surveys record that demersal finfish utilize this location both before and after events, suggesting that the low DO conditions should not negatively impact the potential benefits of the artificial reef and should improve once the reef is constructed.

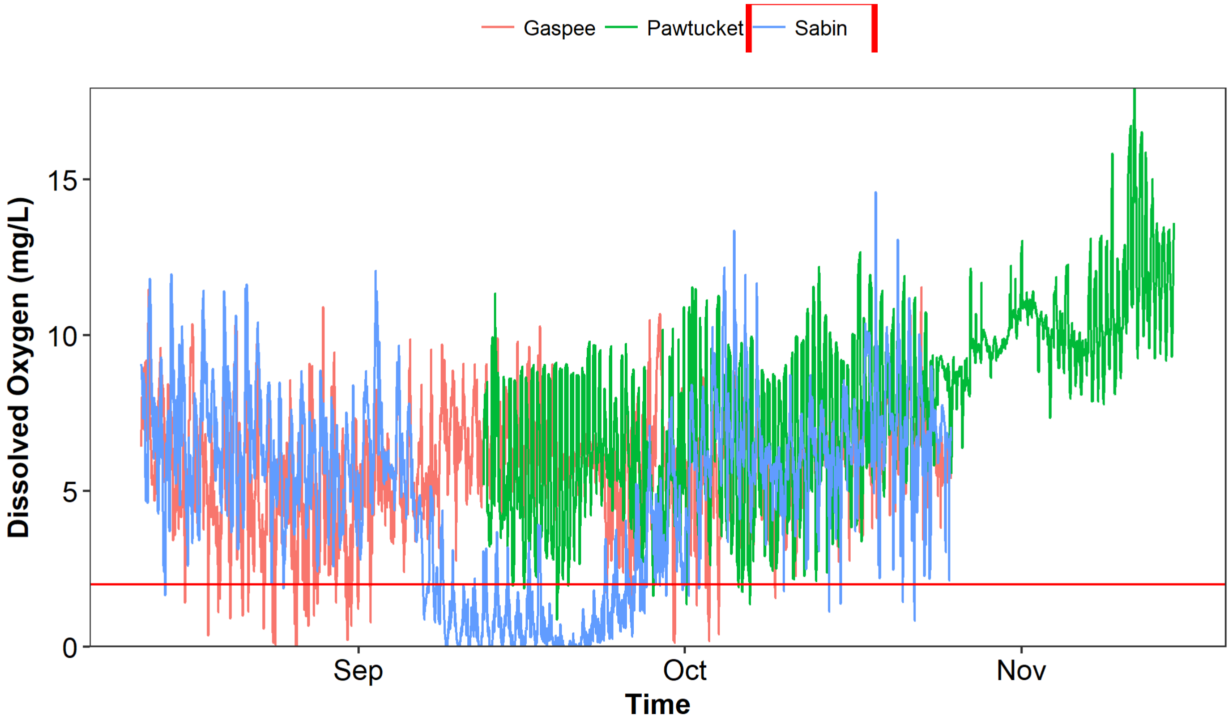

Figure 5. Timeseries displaying Dissolved Oxygen (DO) values at Sabin Point from 9/12/17 – 10/25/17. Red horizontal line represents hypoxia threshold (DO < 2 mg/L)

During the October 2018 survey, the Ponar grabs suggested that benthic infaunal diversity and abundance was low and comprised mostly of small crustacea and amphipods. Hard clam density ranged from 0 to 1 individuals per grab. In addition, the DMF dredge survey at the site most representative of the proposed site has an average quahog density of ~11.49 (ind./m^2). Prior to deploying the reef modules, we will survey the shellfish density of the proposed area. If deemed necessary by the RI DEM DMF, shellfish from the reef footprint area will be relocated prior to construction in accordance with process described in the RI DEM DMF "Guidance for Conducting Shellfish Surveys for Dredging Projects" document, updated August 2018.

Video analysis of the biotic components showed three of the five video snapshots defined as aquatic vegetation bed, one as reef biota, and one as faunal bed. Snapshots defined as aquatic vegetation had a sparse composition (10-<30%) of sheet algal species (mainly *Ulva* sp.) with trace amounts (<10%) of mud snails and sparse amounts of small surface burrowing fauna (2-<5mm burrow width). The snapshot defined as reef biota had a moderately low density of *Crepidula* with trace amounts of filamentous algae (*Aghardiella* sp.) and mud snails, and sparse amounts of sheet algae. Examples of benthic substrate snapshots from the benthic monitoring tows at Sabin Point, with GPS tacks, are included in the Figures 2 and 4.

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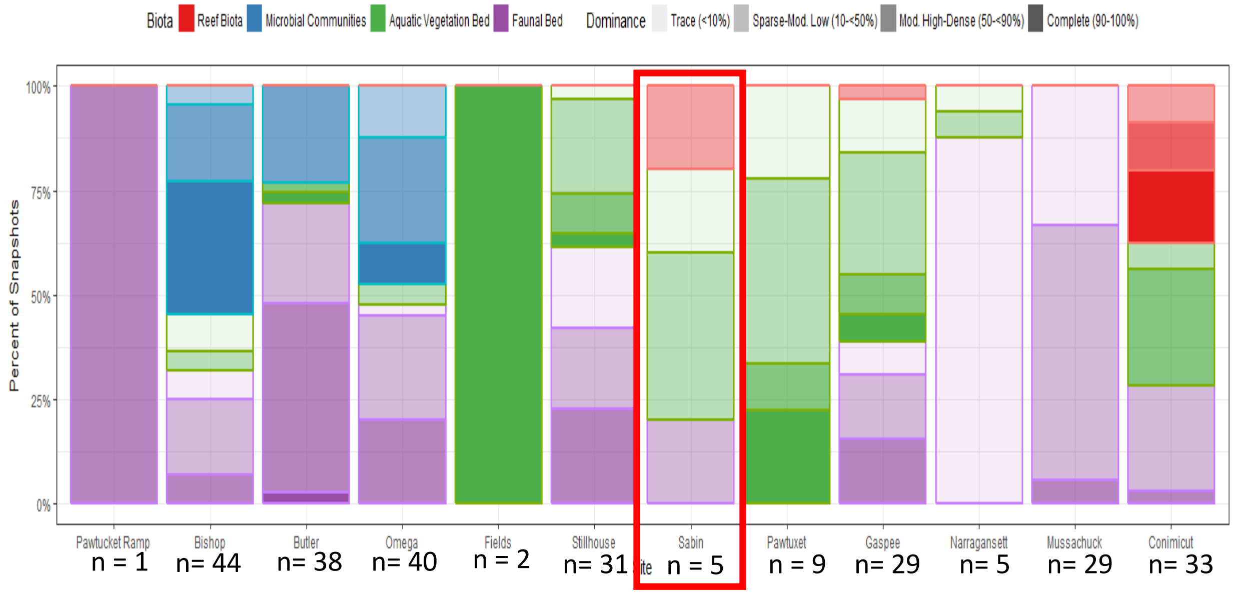

Figure 6. Biotic components broken down into Biotic Class with video quality ≥3 across the 12 potential locations in the upper Narragansett Bay and Providence River estuary analyzed in 2017. Percent values indicate the number of snapshots identified as the dominant substrate with levels of dominance depicted by increasing color saturation. Sites contain varying numbers of total snapshots analyzed and are indicated by the number within the column. Sites are listed by latitude starting from the northernmost to the southernmost site.

Baseline seine and fish trap data from 2016 to 2017 show that Sabin Point supports has the highest number of juvenile winter flounder of the 12 sites (Figure 7). However, the beach seine conducted at Sabin Point is approximately 250 meters away from the proposed AR on a sand substrate, which is more suitable for winter flounder settlement (Pereira, 1999). Given the small scale, non-preferential sediment type for settlement, and time of the year we plan to build (October 15th, pre-spawning), the artificial reef at Sabin Point should not impact the Winter Flounder spawning potential of the nearby sandy locations. The fish trap data also suggest that the area supports recreationally important finfish such as scup, tautog and black sea bass (Figure 8). Analyzing the length frequencies of fish caught shows that although there is a low abundance of fish per haul, at Sabin Point, legal recreationally-sized scup are present, along with tautog that are within one inch of the legal possession limit (Figure 9).

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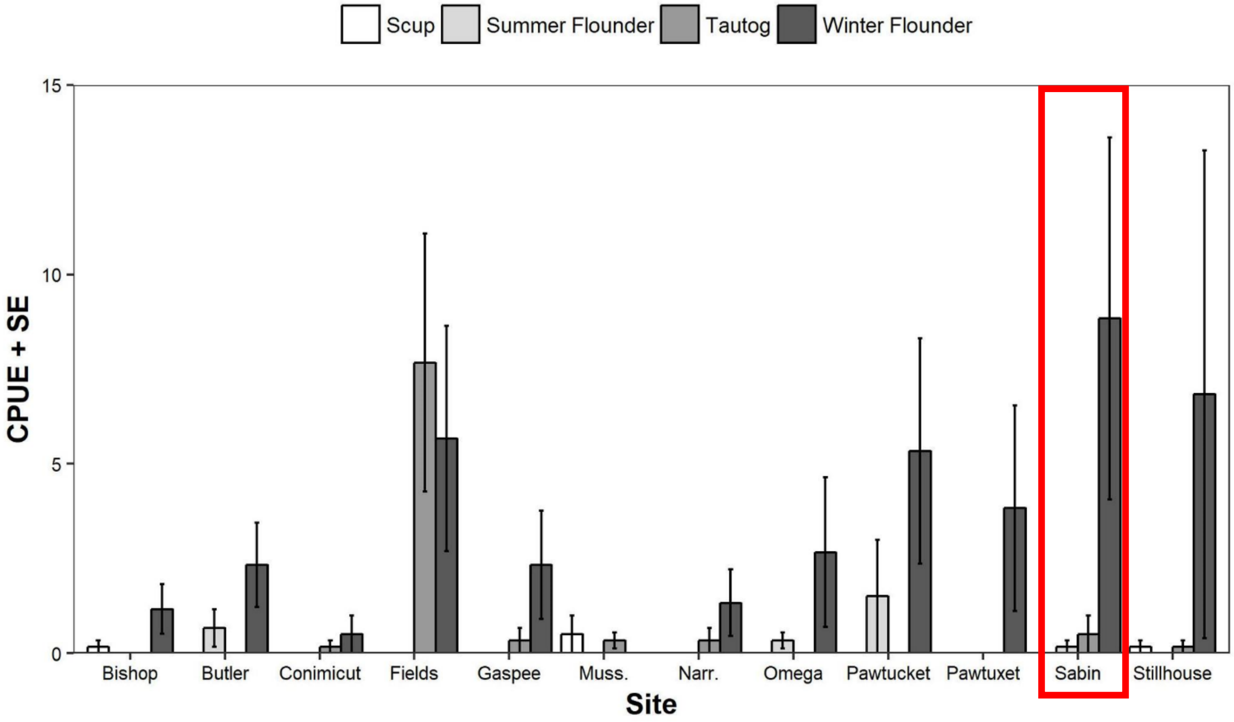

Figure 7. Catch per unit effort of scup, summer flounder, tautog, and winter flounder during seine sampling (2016-2018) at the 12 study sites.

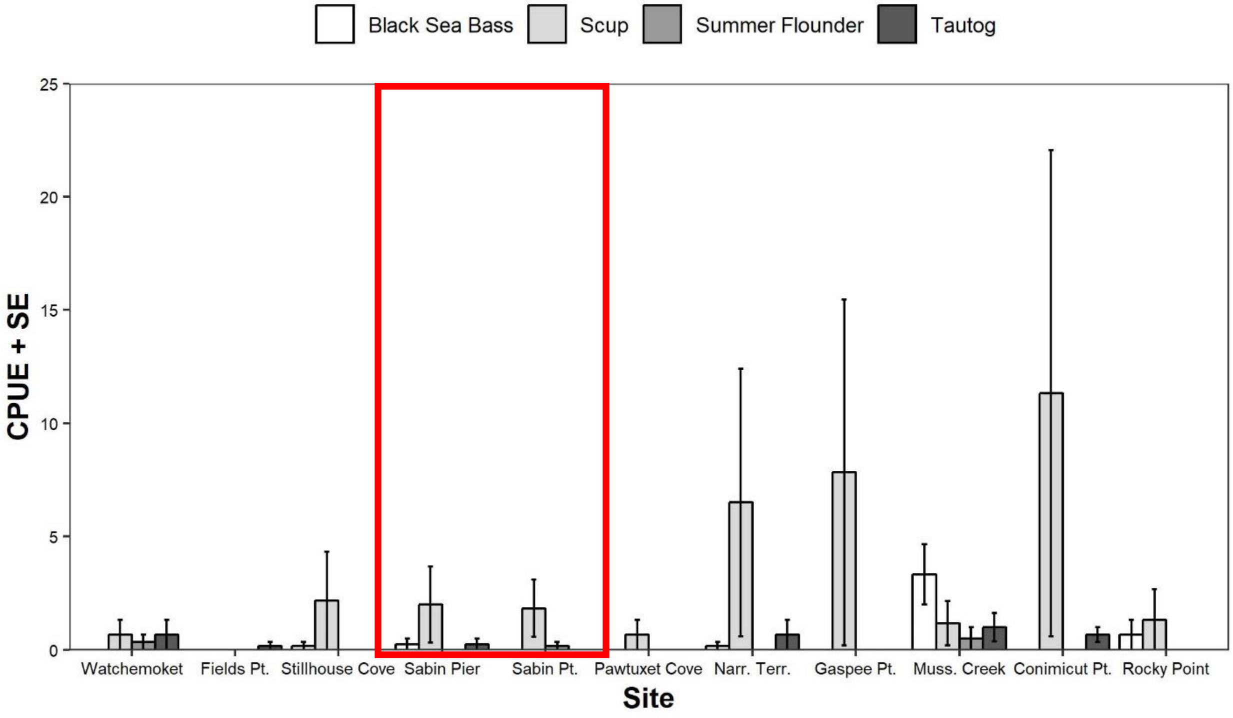

Figure 8. Catch per unit effort of black sea bass, scup, summer flounder, and tautog during fish trap sampling (2017-2018) at the 12 study sites.

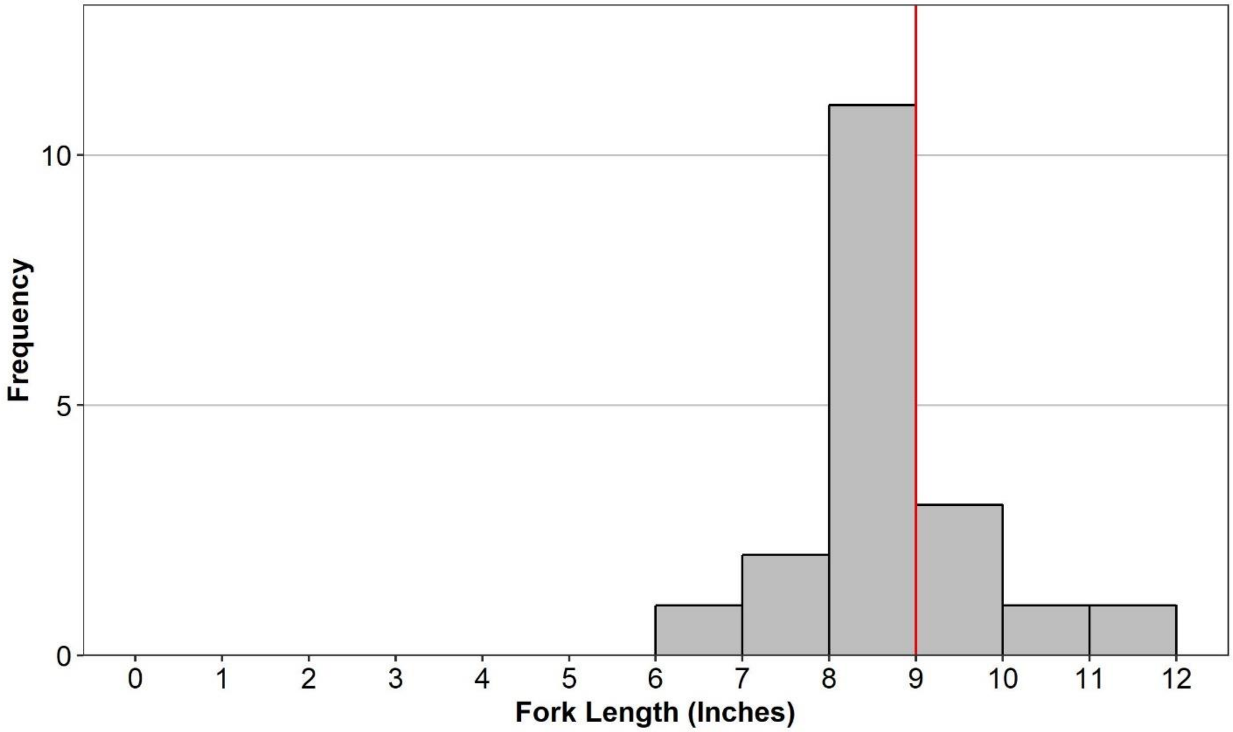

Figure 9. Histogram of scup caught in the Sabin Point fish traps. Scup were measured by fork length. The red line represents the recreational legal limit (9 inches by Total Length).

(4) Background Knowledge: Recreational and Commercial Use

Historically, Sabin Point was a significant winter flounder fishing spot (pers. comm. Michael Bucko, DMF Lead APAIS Biologist). However, the decline of the winter flounder population has reduced the popularity of the park and fishing pier for recreational anglers. Angler survey data gathered from the APAIS MRIP program, as well as communications with the Rhode Island Saltwater Anglers Association (RISAA), have confirmed that Sabin Point is an unpopular recreational fishing spot for demersal finfish, with occasional recreational fishing for pelagic or multi-habitat associated fish (NOAA, MRIP Rhode Island Public Access Fishing Site Register). This information supports the low abundance of demersal finfish observed in our surveys at this location. Since this area is not heavily utilized, the applicants believe additional structure provided by reef balls can help enhance scup, tautog, and black sea bass fishing opportunities at this location, increasing utilization of the park and enhancing fishing opportunities in the upper bay.

The 0.91-acre project site (Figure 1) is highly suitable for artificial reef construction based on data collected during our field survey and information collected from meetings and communications with stakeholders (City of East Providence, RISAA, Commercial Whelk and Quahog Fisheries, DEM Enforcement, USACE, and CRMC; see Section 8: Public Support and

Communications). Through this assessment, artificial reefs (ARs) were highlighted as the best viable option for fish habitat enhancement work at Sabin Point.

In summary, Sabin Point was selected because of the available infrastructure near project site for fishing access, the relatively low quantity and quality of fish habitat structure in the surrounding subtidal, the suitable physical and biological attributes for supporting fish, the low impact to competing uses of the selected area.

4. ALTERNATIVE SITES

Alternative sites for fish habitat enhancement are located within the same geographic area as the chosen Sabin Point Park location (Figure 10). The purpose of this project is to improve fish habitat and increase fishing opportunities in the Providence River estuary. This project is water-dependent, and an upland alternative would not be applicable given the goals of this project.

The four northern sites (Pawtucket State Pier, Bishop Point, Butler, and Omega Pond) are not deep enough (1ft MLW) to support this type of AR work. In addition, instances of hypoxia and fish kills in these areas make them less suitable locations for fish habitat enhancement. The remaining sites generally maintain more suitable water quality conditions for finfish than those in the Seekonk River. Fields Point was not selected because it is relatively shallow (3ft MLW) and already has a large amount of underwater structure from the riprap along the shore. Enhancement from additional structure in this area would not have as much added benefit than at other sites. The remaining sites were either too shallow (Stillhouse, Pawtuxet Cove, Gaspee), too close to the shipping channel, had more competing uses than Sabin (Conimicut, and Mussachuck), were more heavily trafficked by boaters (Mussachuck, Conimicut, Narragansett Terrace, and Pawtuxet Cove), were closer to surrounding residential waterfront property (Narragansett Terrace, Conimicut, Pawtuxet Cove) among other logistical reasons relating to ease of reef construction. Ultimately, Sabin Point was determined to be the most ideal location for AR fish habitat enhancement work at this time.

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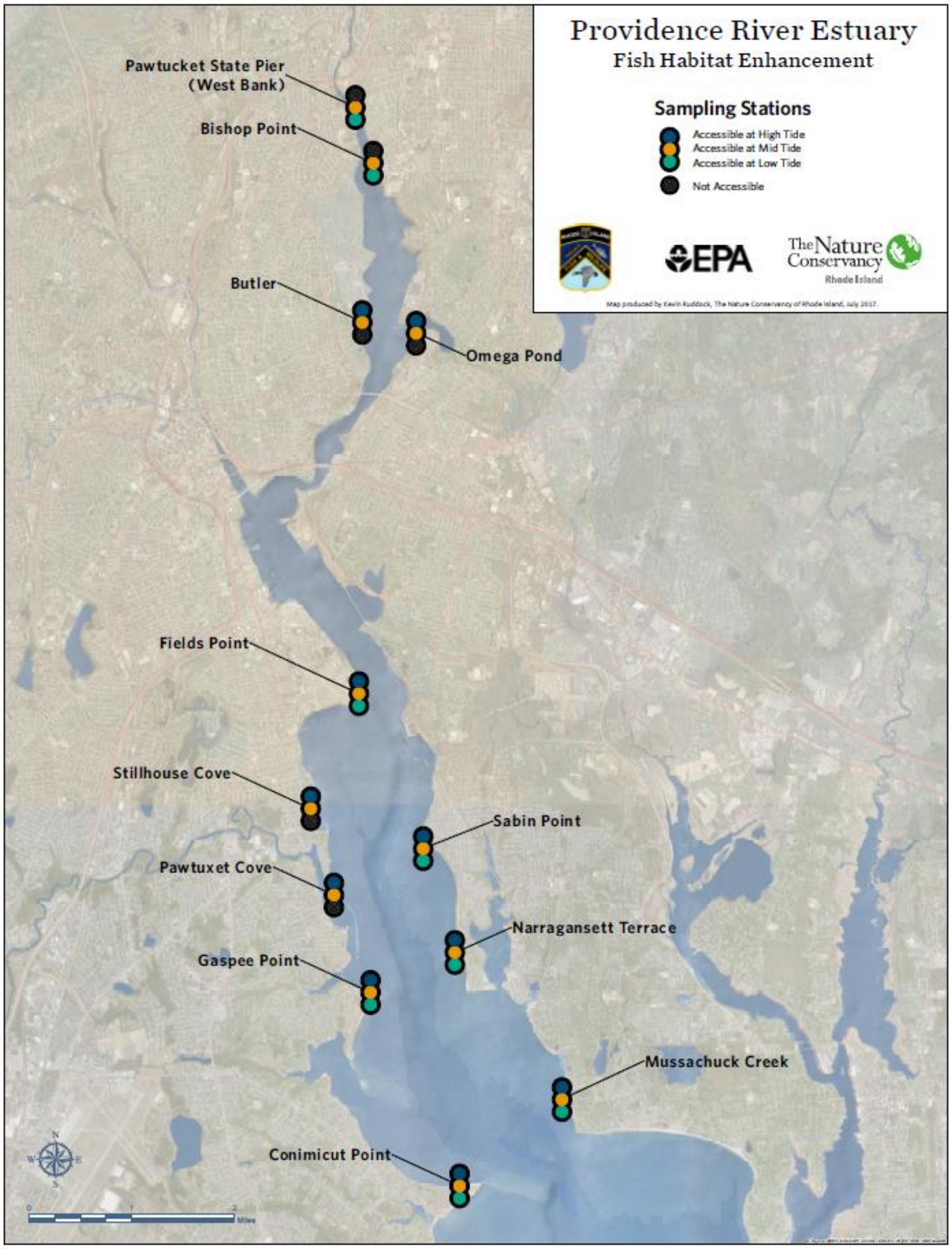

Figure 10. Site map and for habit assessment conducted in the Providence River and upper Narragansett Bay tidal estuaries.

5. REEF DESIGN AND CONSTRUCTION

We chose Reef Balls^{TM} to design our fish habitat enhancement work at Sabin Point because of their documented success in estuarine environments in the Southeastern Atlantic and West Coast of the United States. Studies show that artificial reefs balls promote aggregations of demersal finfish (Bohnsack 1990, Bohnsack 1991, Ambrose 1989), which is one of the primary objectives of our project. Several AR experiments have shown that habitat enhancement with Reef Balls^{TM} can increase abundance, diversity, and production when compared to natural reefs and sandy substrate controls (Folpp 2013, Hackradt 2011, Powers 2003). Upon review of these publications, we have decided to maximize the number and limit the spacing between modules in order to increase the potential benefit of the Sabin Point Artificial Reef Project (Bohnsack 1994, Sherman 2002). ARs have also shown greater attraction of planktivores (i.e., menhaden, herring, and juvenile grunts) as well as benthic feeding fish compared to natural reefs and sand bottom (Bohnsack 1994). In addition to the biological benefits observed, a new research project in Maryland is attempts to utilize Reef Balls^{TM} to alleviate hypoxic zones in the Severn River in an effort to restore this habitat for oyster and associated reef fish colonization (Wheeler 2018).

A contracted professional (Reef Innovations) will oversee the fabrication and deployment of the reef modules to maintain quality assurance and control. The contractor has over 15 years of experience in reef construction and is licensed to construct and deploy Reef Balls™. We will use Reef Balls™ made from a mixture of cement (limestone), silica and water. Cement types II or greater will be used, as these cement grades are resistant to sulfates and other chemicals in sea water which can break down lower grade concrete. Pozzalanic materials such as micro-silica, and/or crushed shell will be used to help neutralize the pH of the cement to that of seawater (pH of 8.3). An adequate water to cement ratio will be used in the manufacturing process to ensure structural integrity and durability. Reef Balls™ are chemically engineered to be long-lasting (500-yr lifespan) in seawater and enhance epifaunal growth. Reef Balls™ are physically designed to resist being overturned by waves in shallow subtidal and subtidal locations. A certified pre-cast company will be hired to fabricate reef modules and ship them to Rhode Island. We intend to use two sizes of Reef Balls™ to maximize topographic heterogeneity and mimic natural reefs, while keeping logistics simple for this pilot project (Table 1).

Table 1. Type and number of Reef Balls™ that will be used per location based on the current array. Data was provided by Reef Innovations Inc. The ratio or Pallet to Bay bays may change based on logistics but the number will not exceed a total of 100 Reef Balls™.

Unit Type	#	Width (ft.)	Height (ft.)	Surface Area (ft^2)	Volume (ft^3)	Weight (lbs)
Pallet Ball	58	4	2.9	75	28.47	1,300
Bay Ball	33	3	2	40	11.043	500

Prior to construction, the boundaries of project sites will be georeferenced using d-GPS and marked with surface floats. Boundary markers will be maintained throughout the duration of our study. We are applying for a 200’x 200’ permit area, within which we will be constructing the artificial reef array. Our current reef design is currently scoped to have a 95.4 by 62.9 foot reef area (0.14 acres) but will not exceed the 200 by 200 permit area if spacing between, or the number of, Reef Balls^{TM} needs to be adjusted. 91 Reef Balls^{TM} will be evenly distributed in a 7x13 grid parallel to shore. Each row will curve, starting ~75 to 100 feet from the end of the pier, so that within each row the modules are the same distance from the pier. (Figure 11).

Our proposed artificial reef array currently consists of 58 Pallet Balls and 33 Bay Balls (91 total modules). Reef modules will be transported to the project site by barge and lowered to the seafloor by crane. A single reef module will be lowered to the seafloor using a spray bar and a crane. Once in contact with the bottom, tension hooks (Pelican Hook) will release the reef modules from its strap in a fixed position. Divers may be used to ensure proper placement. This methodology will ensure accuracy and proper placement of the reef modules. We anticipate reef construction to take no more than one week and will begin after October 15th. We expect the construction window will have little to no impact on commercial and recreational use of the surrounding waters as well as the temporal winter flounder essential fish habitat (EFH) window.

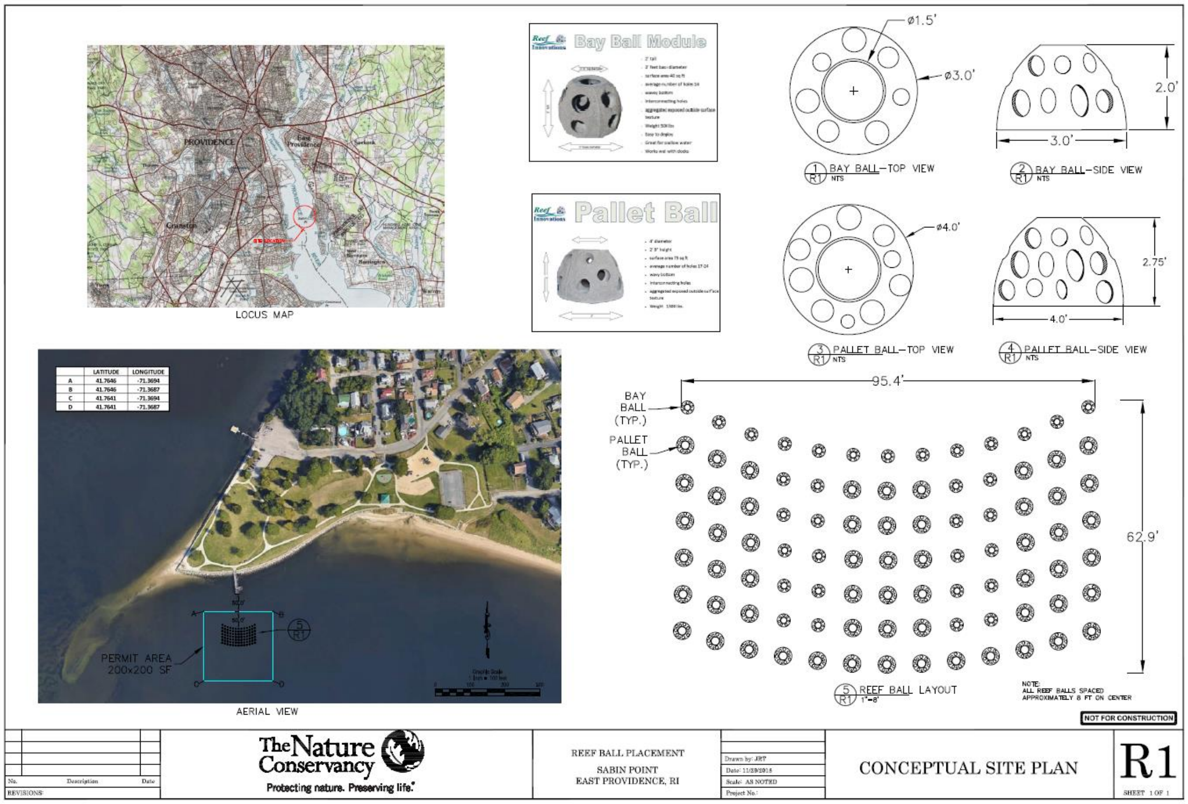

Figure 11. proposed reef layout showing the intended array of reef modules consisting of Pallet Balls and Bay Balls.

6. REEF MONITORING

The applicants will monitor the reef sites with video observations following the deployment of the Reef Balls™. Survey data will provide a baseline to evaluate potential movement or burial of reef materials.

The applicants will monitor changes in fish and macroinvertebrate communities due to the artificial reef habitat. Prior to installing AR modules, the applicants will finalize an appropriate monitoring design using techniques such as underwater video, fish traps, and dive surveys to monitor fish populations. Baseline beach seine and fish trap survey data have been collected monthly (May-October) at Sabin Point over the last two years (2017 and 2018) and will continue after installation of the artificial reefs, assisting with the evaluation of differences in fish abundance before and after reef construction.

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To determine the relative habitat value produced by creating an AR at Sabin Point, the applicants intend to utilize a modified version of the Kelp Ecosystem Ecology Network (KEEN) monitoring protocol. This approach will allow the applicants to compare AR habitat to those such as kelp, eelgrass, and oyster reefs. The applicants expect to conduct monitoring up to three years after construction. Examples of KEEN monitoring techniques include: quadrat, uniform point count, swath, cube, and hand core surveys. These surveys are designed to sample common algae, invertebrates, and fish species associated with artificial reefs. Additionally, temperature, salinity, and dissolved oxygen measurements will be collected at the site.

7. TIMELINE OF ACTIVITIES

Table 2 provides an expected timeline of project activities. We do not anticipate any changes in proposed timeline, but notifications will be provided to partners if changes occur. Reef construction will between 10/15/19 and 11/30/19. Post-construction monitoring will begin following reef construction. Biological monitoring of fish populations will start in Spring 2019.

Table 2: Timeline of project activities and completion dates.

Project Component	Activity	Projected Date
I. Location, design & permits	Identify project sites and control sites	Aug 2018
	Facilitate partner and stakeholder meetings	Fall 2018
	Baseline survey of sites (use intensity, bottom video, sediments)	May 2017-Oct 2018
	Submit permit applications	Dec 2018
	Public Hearing	Spring 2019
II. Reef Construction	Secure contracts for modules	April/May 2019
	Delineate and survey reef sites	May 2019
	Deploy modules and monitor	On or after Oct 15th, 2019
III. Post-Construction Monitoring	Bottom survey of reefs (side-scan, video transects)	2019-22
	Evaluate reef habitat succession	2019-22
	Evaluate habitat use by juvenile finfish	2019-22

	Data synthesis and analysis	2019-22

8. PUBLIC SUPPORT AND COMMUNICATIONS

Over the last six months, the project team has facilitated meetings and provided background on the project to foster awareness and gain feedback from user groups. Before the project was presented at the Rhode Island Marine Fisheries Council public hearing, several in-person and phone meetings were held with prospective stakeholders including: RISAA, the City of East Providence Planning department and Harbor Master, ACOE, CRMC, RIDEM Enforcement, and fishermen that represent whelk and quahog industries in the vicinity of our project area. Quahogging is prohibited at Sabin Point, as it is north of the shellfishing closure line. Our reef design was created by Jillian Thompson (TNC Conservation Engineer) and was reviewed by the contacted stakeholder groups to ensure they were well briefed on the scope and goals of the proposed work. Expert advice and support on earlier drafts of the project proposal, particularly on reef construction and design, experimental design, and sampling methodology presented in our permit application (Personal Communication, Mark Russo (MA Division of Marine Fisheries Climate and Artificial Reef Specialist) and Jordan Byrum (NC Department of Environmental Quality Artificial Reef Coordinator).

On November 14th, Steve Medieros (RISAA President), was contacted and briefed on the goals and scope of the Artificial Reef Project at Sabin Point. Site plans and aerial maps of the project location were reviewed by the board of directors on two separate occasions, November 20th and December 11th. Overall, RISAA supports our study and will provide a letter of support during the public notice period.

On December 3rd, 2018, TNC and DEM met with the city of East Providence planning department to provide background and details regarding the Sabin Point Artificial Reef Project. We have received positive feedback from the department who do not foresee any negative impacts to the existing infrastructure or navigable waterways.

On December 6th, 2018, DEM met with ACOE and CRMC for a pre-application meeting to discuss the project, permitting, and any concerns they have with the proposal. Artificial reefs are considered fill by the ACOE and require an Individual Permit in which we have compared alternative locations as well as upland alternatives, to our chosen work site. Comments regarding the distance from the pier and the depth at mean low tide (~5 ft) were discussed and helped improve the siting for our artificial reef for maximum benefit to those fishing off the pier.

We have reached out to Katie Eagan, who in turn reach out to other members of the commercial whelk and quahog community regarding the suitability of the proposed project site. We have identified that the area south of Sabin Point maintains little commercial whelk activity, but given the limited footprint of our Artificial Reef, those who fish that area were not concerned that the project would not interfere with their whelk fishing efforts. Sabin Point is located north of the shellfish closure line, and thus should not interfere with the commercial Quahog community.

On December 20th we met with Chief Dean Hoxie from RIDEM Law Enforcement as well as some members of the RIDEM Public Access Committee to brief them on the project. The project was received well, and they did not foresee any issues providing the reef footprint is clearly marked. There is no dockage on the fishing pier and the shoal to the west prevents major boating traffic lowering the reefs risk as navigational hazard. Given the prevailing SW wind during the summer, it was suggested to move the landward edge of the array as close as 75 feet from the pier so that fishers will have the opportunity to reach the reef from the pier.

While developing our permit application we have taken into consideration the thoughts and comments made by the different stakeholder groups we've met with and have adjusted the project site and construction window accordingly in order to minimize potential user-conflicts, provide maximum benefit to existing resources and users, and to avoid areas and timeframes associated with Essential Fish Habitat designations for Winter Flounder (Pereira, 1999). To our knowledge and based on response to with stakeholder groups, the proposed project will not displace or impact current users or biological communities.

9. POTENTIAL ADVERSE IMPACTS

We do not anticipate negative ecological or social impacts resulting from the proposed research project. Reef locations were surveyed using underwater video and Ponar grabs on October 24, 2018. In addition to our review of existing literature and spatial data, we do not expect displacement or loss of existing bottom habitat features. The project site is in an area of sandy sediment and shell hash. Social impacts may include the displacement of commercial fishing; however, we have consulted with representatives of fishing industry to identify potential user conflicts and concerns. Due to the small footprint and shellfish harvest closure in the Providence River, there will be negligible to no impact to these stakeholder groups. Additionally, this artificial reef will be open to both recreational and commercial fishing industries. The proposed reef construction plan will impact boat navigation in the specific 0.25-acre reef footprint but is not located in a frequented boating location and is greater than 1,000 feet from the navigation lane, thus does not pose a significant navigation hazard. The corners of the artificial reef will be marked for the duration of the study to provide awareness of potential boating hazards. At no time will reef modules extend greater than 3-feet from the sea floor. Boats will be able to navigate around and inside at their own risk and may anchor within and around project sites. Notifications of work and work dates will be provided to local Harbor Masters, RI DEM, RI CRMC, USCG, and ACOE. Annual progress reports will be provided to RI CRMC, RI DEM, and ACOE in January of each year. TNC staff will monitor reef sites over a minimum of 3-years for reef movement, subsidence, and scouring, in addition to the biological surveys planned for the project. Given the small footprint, the artificial reef will not significantly impact the viable winter flounder habitat (flat, sandy silt environment).

10. LIMITATIONS ON SUCCESS

The performance of our artificial reefs may vary based on site-dependent attributes such as localized water circulation patterns, sediment firmness and grain size, water quality and nutrient loads, and fish and invertebrate larval supply. We anticipate minor sediment burial and scouring of reefs. The water depth at Sabin Point is on the shallower end of the depth range than other fish habitat enhancement work. This may limit the amount of legal size fish that could be attracted to the area even after the reef is created. The speed of colonization of sessile organisms on the reefs could also alter the impact the added structure has on fish abundance.

11. BENEFITS AND EXPECTED RESULTS

Constructing an AR using a three-dimensional Reef Ball™ module array at Sabin Point Park will help enhance fish habitat by providing structure for fish in an area devoid of such habitat. Added structure will increase rugosity and provide a surface area for colonization that will result in a more complex benthic environment. Added structure is expected to increase turbulent flow experienced on the sea floor (Reidenbach 2010), increasing mixing of the water column and sediment transport, which will help alleviate the stress of periodic hypoxic events allowing the colonization of a more robust benthic invert and epifaunal communities, further promoting the quality of the habitat near the Sabin Point Pier. Our assessment will allow us to determine how Artificial Reefs can enhance fishing opportunities in Rhode Island. In addition, the resulting colonization of epifauna on the reef will provide food and enhanced habitat for fish species. We expect the artificial Reef Ball^{TM} array will increase the aggregation demersal finfish that associate with bottom structure (i.e., Scup, Tautog, and Black Seabass) (Folpp 2013, Sherman 2002, Powers 2003, Lenihan 1998, Hackradt 2011). Ultimately, we anticipate that the creation of the artificial reef at Sabin Point will improve the quality of the fishing experience at the park as a result of improved habitat, and aggregations of finfish likely to follow.

By working with resource management agencies, environmental non-profits, academics, recreational sport fishing organizations, and commercial fisheries, we will facilitate a dialog on establishing scientifically and socially-sound fish habitat enhancement practices in the Bay. Limited information exists on the benefits of artificial reef enhancement in Rhode Island let alone New England. This array will help advance research on the impact of ARs in Rhode Island and provide the first long-term AR Reef Ball^{TM} research site in Narragansett Bay. As a pilot project, this work will help guide future fish habitat enhancement work in Narragansett Bay.

APPENDIX A

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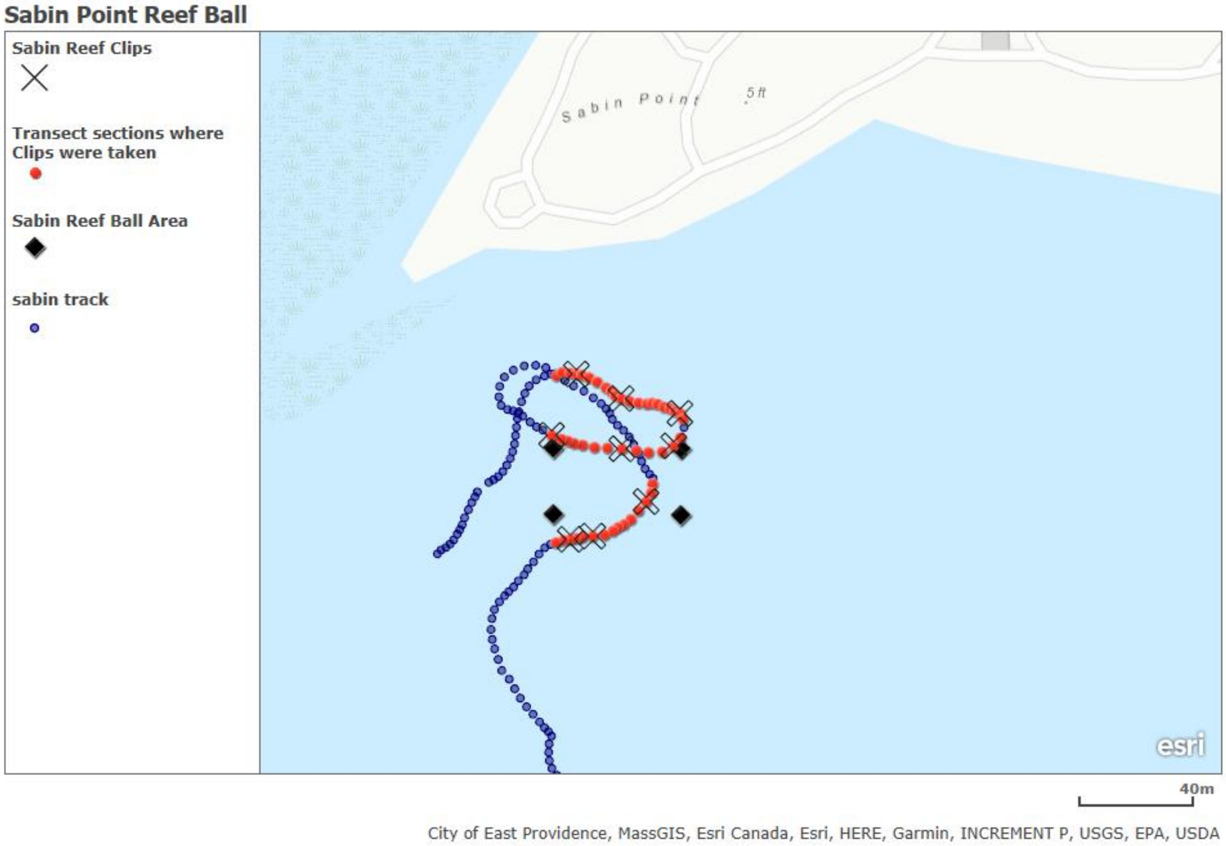


City of East Providence, MassGIS, Esri Canada, Esri, HERE, Garmin, INCREMENT P, USGS, EPA, USDA

Figure 3. Benthic Monitoring Tows at Sabin Point, with Photo Snapshot location (X's) and GPS tacks.

APPENDIX A

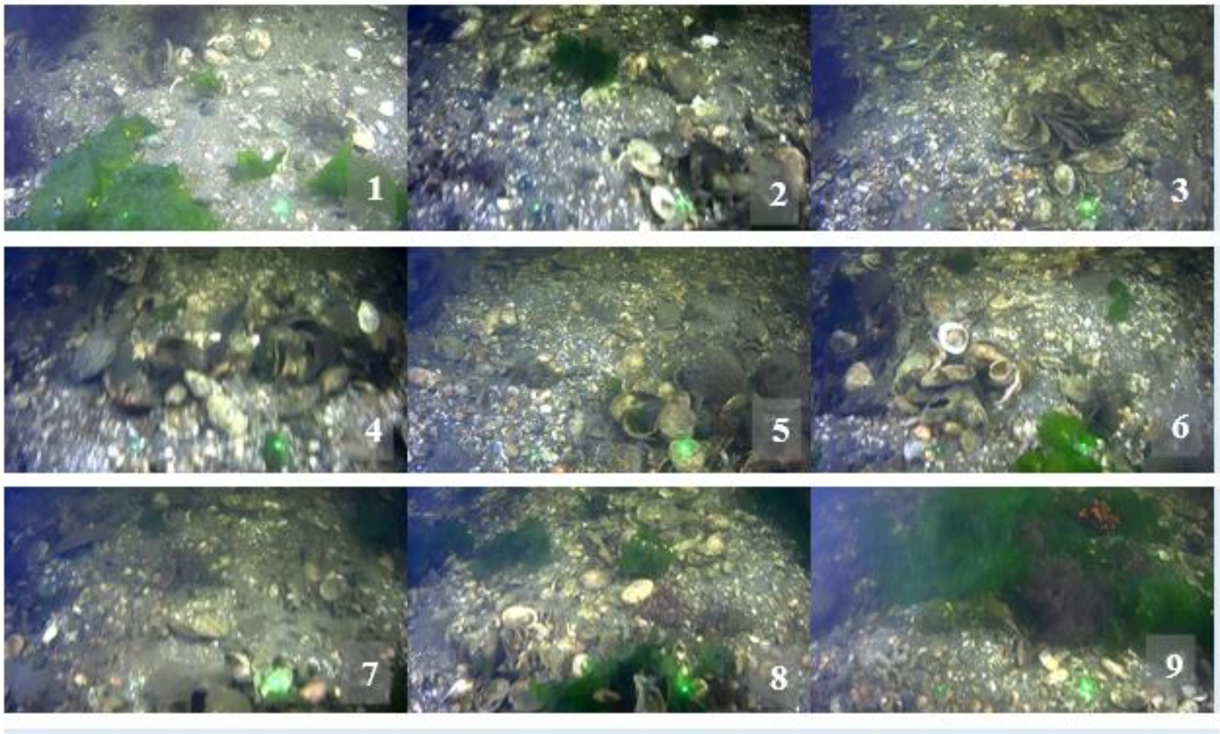
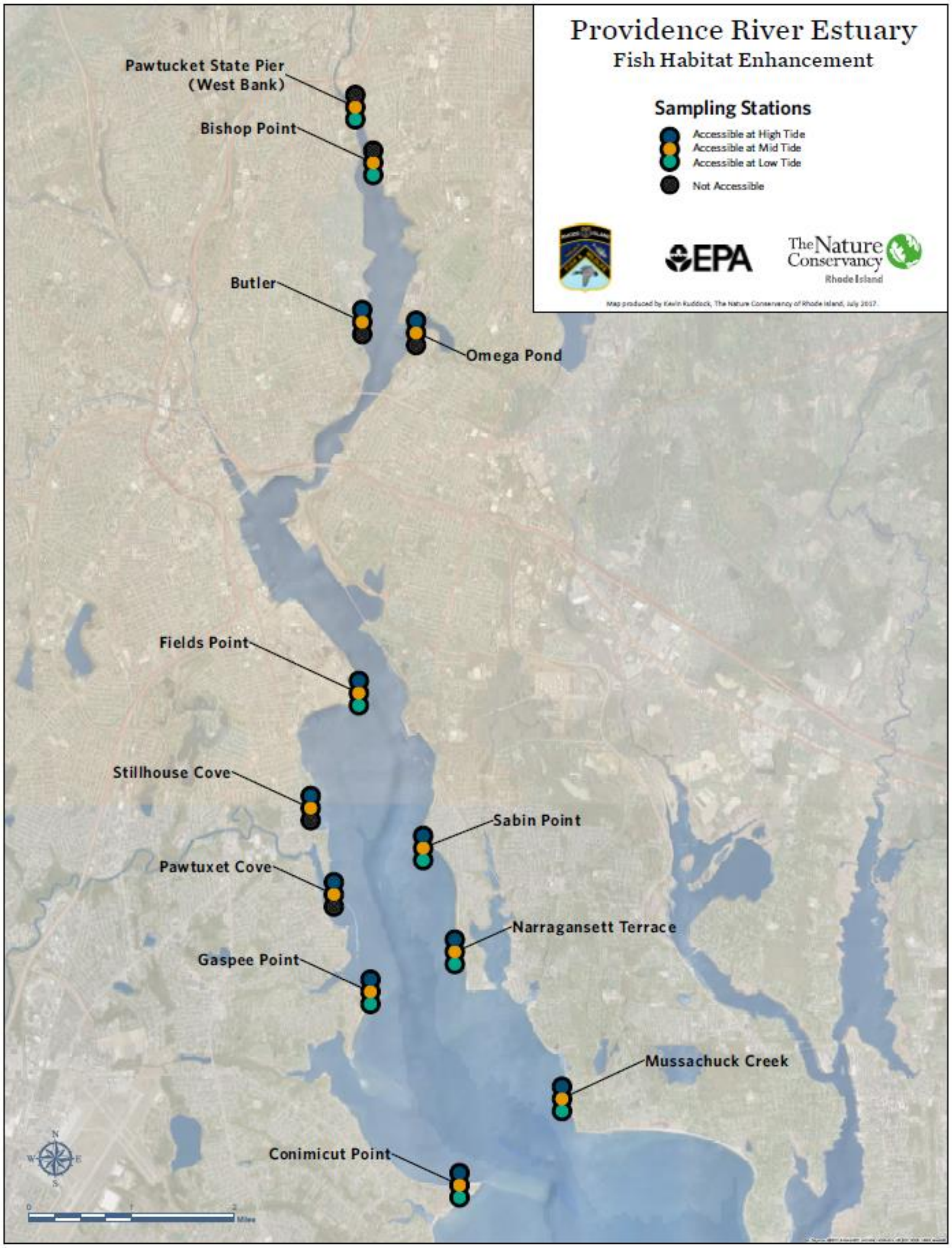


Figure 4. Snapshots taken from the Benthic Video Monitoring.

APPENDIX B

APPENDIX B – Sample of Revised DRAFT Maps and Data to Aid in Investigating Future Habitat Enhancement Sites

Map depicting sampling site locations within the Providence River Estuary.



Map produced by Kevin Ruddock, The Nature Conservancy of Rhode Island, July 2017.

APPENDIX B

Species presence by site for May 2018 beach seines.

MAY	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
3-Spine Stickleback						1							**1**
Atlantic Silverside	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Atlantic Tomcod	1	1		1	1								**4**
Banded Killifish								1					**1**
Clupeids									1				**1**
Common Mummichog		1				1		1					**3**
Cunner							1						**1**
Hogchoker	1												**1**
River Herring	1	1			1		1						**4**
Striped Killifish	1				1	1		1	1	1	1		**7**
Summer Flounder	1												**1**
White Perch	1			1									**2**
Windowpane Flounder											1	1	**2**
Winter Flounder			1										**1**

Species presence by site for June 2018 beach seines.

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JUNE	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
3-Spine Stickleback							1						**1**
4-Spine Stickleback				1	1								**2**
American Eel		1		1									**2**
Atlantic Menhaden				1		1							**2**
Atlantic Silverside			1		1	1	1	1	1	1	1	1	**9**
Atlantic Tomcod	1	1	1		1	1							**5**
Clupeids		1											**1**
Common Mummichog	1	1		1		1							**4**
Hogchoker	1		1	1									**3**
Northern Pipefish					1		1						**2**
River Herring				1		1	1		1		1	1	**6**
Spot				1									**1**
Striped Bass								1					**1**
Striped Killifish						1	1	1				1	**4**
Summer Flounder	1	1	1	1									**4**
Tautog					1								**1**
White Perch				1									**1**
Winter Flounder	1	1	1	1	1		1	1	1				**8**

Species presence by site for July 2018 beach seines.

APPENDIX B

JULY	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
American Eel						1							**1**
Atlantic Menhaden	1		1	1		1		1					**5**
Atlantic Silverside		1	1	1	1	1	1	1	1	1	1	1	**11**
Atlantic Tomcod		1											**1**
Bluefish			1			1		1	1	1		1	**6**
Common Mummichog		1	1	1						1			**4**
Crevalle Jack		1											**1**
Hogchoker				1									**1**
Longhorn Sculpin							1						**1**
Naked Goby												1	**1**
Northern Kingfish						1	1						**2**
Northern Pipefish					1	1							**2**
Northern Puffer							1						**1**
River Herring		1	1	1	1	1		1	1	1	1	1	**10**
Searobins								1					**1**
Spot						1		1					**2**
Striped Killifish				1	1	1		1	1	1			**6**
Summer Flounder	1			1		1							**3**
Tautog					1								**1**
White Perch		1	1	1									**3**
Winter Flounder		1		1	1			1					**4**

APPENDIX B

Species presence by site for August 2018 beach seines.

AUGUST	Site												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
4-Spine Stickleback										1			**1**
American Eel										1			**1**
Atlantic Menhaden		1	1										**2**
Atlantic Silverside	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Black Sea Bass									1				**1**
Bluefish												1	**1**
Common Mummichog						1	1	1	1	1	1		**6**
Cunner									1				**1**
Inshore Lizardfish								1					**1**
Northern Kingfish					1	1	1		1	1	1	1	**7**
Northern Pipefish				1					1	1			**3**
Northern Puffer					1					1			**2**
Northern Searobin										1			**1**
Permit							1						**1**
River Herring	1	1	1		1	1	1		1				**7**
Scup					1				1				**2**
Searobins							1						**1**
Striped Bass						1							**1**
Striped Killifish			1		1	1	1	1	1	1	1	1	**9**
Striped Searobin					1				1				**2**
Summer Flounder	1							1					**2**
Tautog					1				1	1	1		**4**
Weakfish				1	1								**2**
White Perch	1				1				1		1		**4**
Winter Flounder	1						1						**2**

APPENDIX B

Species presence by site for September 2018 beach seines.

SEPTEMBER	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
4-Spine Stickleback								1					**1**
Atlantic Menhaden	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Atlantic Needlefish										1	1	1	**3**
Atlantic Silverside	1	1	1	1	1	1		1	1	1	1	1	**11**
Black Sea Bass					1				1	1			**3**
Bluefish			1		1				1			1	**4**
Common Mummichog		1	1	1	1			1	1	1	1	1	**9**
Crevalle Jack			1					1					**2**
Gizzard Shad	1	1	1	1									**4**
Hogchoker	1		1	1									**3**
Inshore Lizardfish									1				**1**
Northern Kingfish			1						1				**2**
Northern Pipefish									1	1	1		**3**
Northern Searobin										1			**1**
Oyster Toadfish					1								**1**
River Herring		1									1		**2**
Scup					1				1				**2**
Sheepshead Minnow					1			1					**2**
Striped Killifish		1	1	1	1	1		1	1	1	1	1	**10**
Striped Searobin					1					1			**2**
Summer Flounder	1												**1**
Tautog					1	1			1	1		1	**5**
White Perch				1	1								**2**

APPENDIX B

Species presence by site for October 2018 beach seines.

OCTOBER	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Total**
4-Spine Stickleback								1					**1**
Atlantic Menhaden		1				1	1	1	1	1	1	1	**8**
Atlantic Silverside	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Black Sea Bass					1								**1**
Bluefish							1						**1**
Bluegill	1			1	1					1			**4**
Common Mummichog					1	1	1	1	1	1	1	1	**8**
Cunner						1							**1**
Gizzard Shad											1		**1**
Golden Shiner	1												**1**
Hogchoker	1	1											**2**
Largemouth Bass	1	1											**2**
Northern Kingfish							1						**1**
Northern Pipefish											1		**1**
Oyster Toadfish					1								**1**
River Herring	1	1						1	1	1	1		**6**
Striped Killifish	1		1	1	1	1	1	1	1	1		1	**10**
Tautog					1	1			1	1	1	1	**6**
Winter Flounder												1	**1**
Yellow Perch	1												**1**

APPENDIX B

Abundances of summer flounder in 2018 beach seines.

Summer Flounder

	Site														
Month	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Mean**	**SD**	**SE**
May	1	0	0	0	0	0	0	0	0	0	0	0	0.08	0.29	0.08
June	46	5	12	8	0	0	0	0	0	0	0	0	5.92	13.24	3.82
July	1	0	0	6	0	1	0	0	0	0	0	0	0.67	1.72	0.50
August	1	0	0	0	0	0	0	1	0	0	0	0	0.17	0.39	0.11
September	2	0	0	0	0	0	0	0	0	0	0	0	0.17	0.58	0.17
October	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
Mean	8.50	0.83	2.00	2.33	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00			
SD	16.78	1.86	4.47	3.35	0.00	0.37	0.00	0.37	0.00	0.00	0.00	0.00		Total Fish	
SE	6.85	0.76	1.83	1.37	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00		84	
Total	51	5	12	14	0	1	0	1	0	0	0	0			

APPENDIX B

Abundances of winter flounder in 2018 beach seines.

Winter Flounder

	Site													
Month	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	Mean	SD	SE
May	0	0	1	0	0	0	0	0	0	0	0	0	0.08	0.29	0.08
June	27	6	29	28	6	0	11	2	2	0	0	0	9.25	11.79	3.40
July	0	10	0	36	1	0	0	1	0	0	0	0	4.00	10.47	3.02
August	2	0	0	0	0	0	4	0	0	0	0	0	0.50	1.24	0.36
September	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
October	0	0	0	0	0	0	0	0	0	0	0	1	0.08	0.29	0.08
Mean	4.83	2.67	5.00	10.67	1.17	0.00	2.50	0.50	0.33	0.00	0.00	0.17			
SD	9.94	3.94	10.74	15.26	2.19	0.00	4.07	0.76	0.75	0.00	0.00	0.37		Total Fish	
SE	4.06	1.61	4.38	6.23	0.89	0.00	1.66	0.31	0.30	0.00	0.00	0.15		167	
Total	29	16	30	64	7	0	15	3	2	0	0	1			

APPENDIX B

Abundances of black sea bass 2018 beach seines.

		Site														
	Month	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Mean**	**SD**	**SE**
Black Sea Bass	**May**	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	June	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	July	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	August	0	0	0	0	0	0	0	0	1	0	0	0	0.08	0.29	0.08
	September	0	0	0	0	4	0	0	0	2	5	0	0	0.92	1.78	0.51
	October	0	0	0	0	7	0	0	0	0	0	0	0	0.58	2.02	0.58
	Mean	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00	0.50	0.83	0.00	0.00			
	SD	0.00	0.00	0.00	0.00	2.73	0.00	0.00	0.00	0.76	1.86	0.00	0.00		Total Fish	
	SE	0.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.31	0.76	0.00	0.00		19	
	Total	0	0	0	0	11	0	0	0	3	5	0	0			

APPENDIX B

Abundances of scup in 2018 beach seines.

		Site														
	Month	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Mean**	**SD**	**SE**
Scup	**May**	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	June	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	July	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	August	0	0	0	0	62	0	0	0	7	0	0	0	5.75	17.83	5.15
	September	0	0	0	0	1	0	0	0	3	0	0	0	0.33	0.89	0.26
	October	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
	Mean	0.00	0.00	0.00	0.00	10.50	0.00	0.00	0.00	1.67	0.00	0.00	0.00			
	SD	0.00	0.00	0.00	0.00	23.03	0.00	0.00	0.00	2.62	0.00	0.00	0.00		Total Fish	
	SE	0.00	0.00	0.00	0.00	9.40	0.00	0.00	0.00	1.07	0.00	0.00	0.00		73	
	Total	0	0	0	0	63	0	0	0	10	0	0	0			

APPENDIX B

Abundances of tautog in 2018 beach seines.

Tautog

	Site														
Month	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Mussachuck Creek	Conimicut Pt.	**Mean**	**SD**	**SE**
May	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00
June	0	0	0	0	11	0	0	0	0	0	0	0	0.92	3.18	0.92
July	0	0	0	0	3	0	0	0	0	0	0	0	0.25	0.87	0.25
August	0	0	0	0	11	0	0	0	25	2	3	0	3.42	7.50	2.17
September	0	0	0	0	17	2	0	0	8	2	0	1	2.50	5.11	1.47
October	0	0	0	0	15	5	0	0	6	11	6	1	3.67	5.07	1.46
Mean	0.00	0.00	0.00	0.00	9.50	1.17	0.00	0.00	6.50	2.50	1.50	0.33			
SD	0.00	0.00	0.00	0.00	6.10	1.86	0.00	0.00	8.86	3.91	2.29	0.47		Total Fish	
SE	0.00	0.00	0.00	0.00	2.49	0.76	0.00	0.00	3.62	1.59	0.94	0.19		129	
Total	0	0	0	0	57	7	0	0	39	15	9	2			

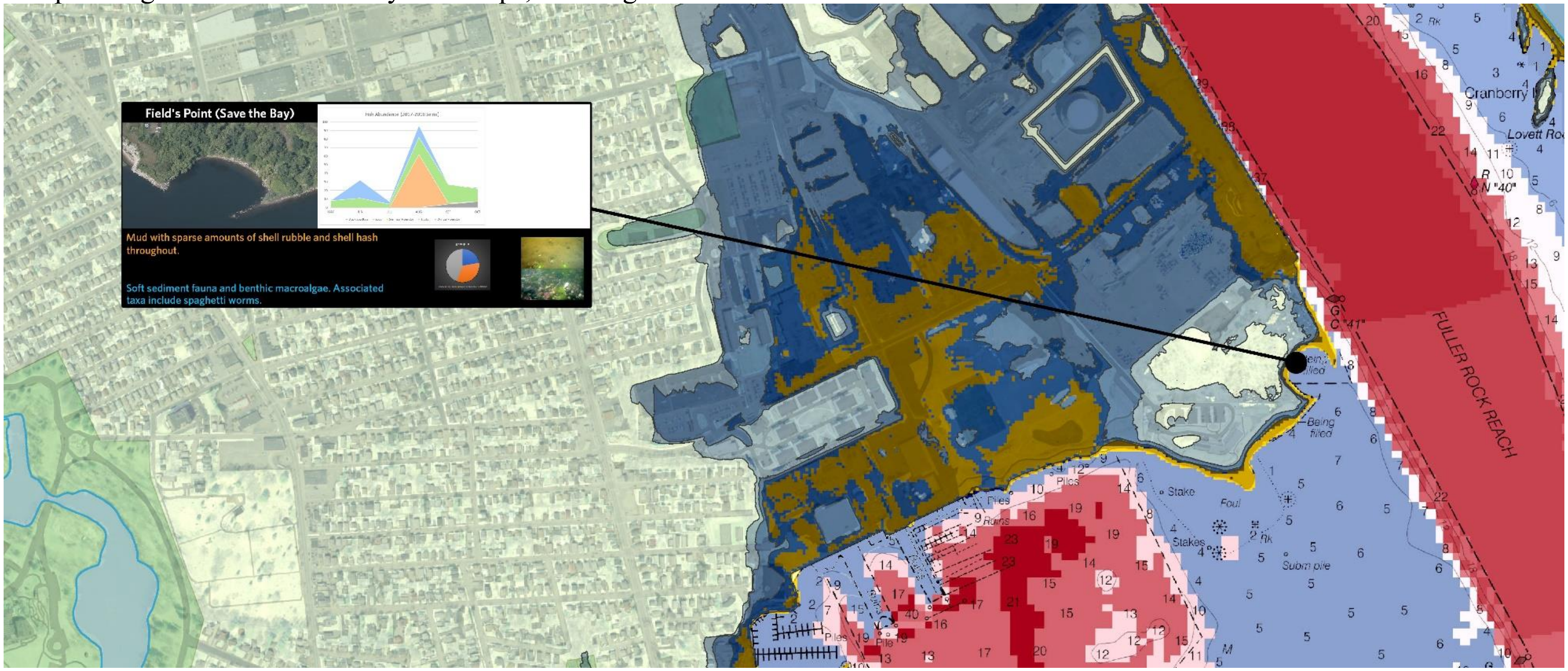
APPENDIX B

Temperature, salinity, and dissolved oxygen by site and month during 2018 beach seines (NA indicates when YSI device was not functional or available).

Site	Month	Temp (°C)	Sal. (ppt)	DO (mg/L)	Site	Month	Temp (°C)	Sal. (ppt)	DO (mg/L)
Pawtucket State Pier	May	NA	2.0	NA	Sabin Pt.	May	NA	22.0	NA
	Jun	18.3	2.8	7.39		Jun	16.5	24.1	7.61
	Jul	27.9	4.8	9.70		Jul	23.9	24.6	6.50
	Aug	26.6	26.7	6.92		Aug	25.0	25.3	6.78
	Sep	24.7	23.7	0.67		Sep	NA	NA	NA
	Oct	16.6	0.1	10.58		Oct	18.1	15.2	7.44
Bishop Pt.	May	NA	2.0	NA	Pawtuxet Cove	May	NA	6.0	NA
	Jun	19.0	2.8	6.67		Jun	20.0	11.5	6.51
	Jul	25.4	4.9	6.84		Jul	24.3	7.5	11.64
	Aug	26.3	2.8	8.33		Aug	29.0	9.1	8.55
	Sep	26.2	9.0	5.47		Sep	25.1	26.8	6.25
	Oct	16.6	0.1	14.42		Oct	17.1	3.9	8.21
Butler	May	NA	7.0	NA	Narragansett Terrace	May	NA	NA	NA
	Jun	19.8	4.3	8.01		Jun	16.4	24.8	8.86
	Jul	24.6	15.3	6.78		Jul	23.9	23.4	6.79
	Aug	27.3	14.4	8.39		Aug	29.0	20.8	13.09
	Sep	26.8	17.5	6.75		Sep	25.7	26.6	8.66
	Oct	10.2	1.8	11.50		Oct	18.4	12.7	7.32
Omega Pond	May	NA	13.0	NA	Gaspee Pt.	May	NA	23.0	NA
	Jun	19.3	5.7	7.66		Jun	16.7	26.2	9.56
	Jul	24.3	18.8	4.99		Jul	24.1	25.3	5.40
	Aug	26.8	17.5	2.97		Aug	25.5	25.9	5.44
	Sep	26.7	17.7	7.89		Sep	25.6	28.0	5.01
	Oct	10.4	1.5	11.44		Oct	19.1	17.4	6.94
Fields Pt.	May	NA	20.0	NA	Mussachuck Creek	May	NA	23.0	NA
	Jun	17.0	21.9	7.29		Jun	17.0	26.9	7.27
	Jul	24.5	22.3	6.72		Jul	21.5	27.2	6.09
	Aug	27.9	22.4	9.90		Aug	28.7	25.0	11.57
	Sep	25.7	26.4	7.06		Sep	24.9	28.8	6.24
	Oct	19.1	19.0	6.28		Oct	18.9	21.4	6.71
Stillhouse Cove	May	NA	17.0	NA	Conimicut Pt.	May	NA	25.0	NA
	Jun	19.5	22.4	9.57		Jun	16.3	27.1	6.69
	Jul	NA	NA	NA		Jul	25.0	25.4	6.64
	Aug	25.3	24.2	7.47		Aug	25.4	27.9	5.55
	Sep	28.1	27.0	7.46		Sep	24.8	27.5	5.88
	Oct	19.0	17.8	6.74		Oct	19.5	20.3	7.85

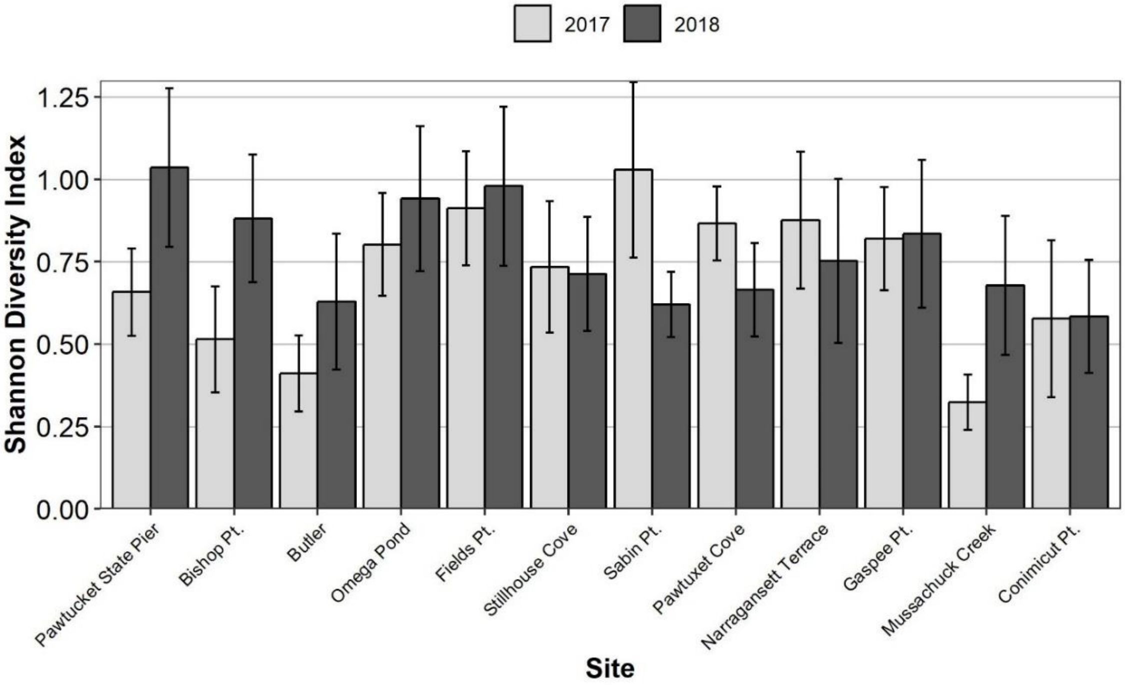
APPENDIX B

Sample image of the revised study area maps, showing the Field's Point site.

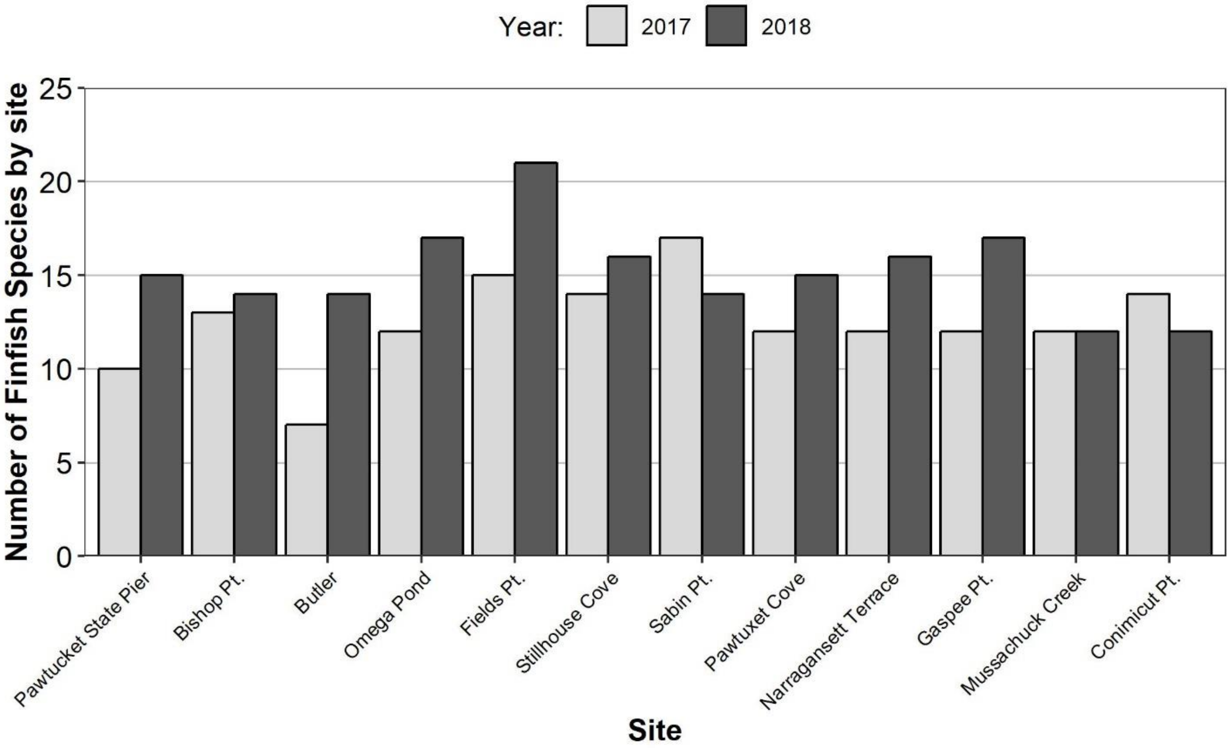


APPENDIX B

Mean Shannon diversity across sites in 2017 & 2018 beach seines.



Cumulative number of finfish species by site in 2017 and 2018 beach seines.



APPENDIX B

Mean, minimum, and maximum temperature (°F) at sites during 7/19/17 - 7/27/17.

Site	Mean	SE	Min	Max
Bishop	73.62	0.17	68.43	79.52
Butler	73.56	0.22	65.79	84.29
Conimicut	73.81	0.25	67.62	83.35
Fields	73.26	0.18	68.20	79.95
Gaspee	73.88	0.24	67.10	82.99
Mussachuck	74.41	0.26	68.14	84.47
Narr. Terr.	74.66	0.25	67.62	83.64
Omega	73.80	0.23	65.70	85.95
Pawtucket	73.96	0.18	68.38	79.45
Pawtuxet	74.58	0.28	66.13	82.78
Sabin	74.02	0.22	67.96	83.98
Stillhouse	73.64	0.19	67.77	79.30

Mean, minimum, and maximum salinity (ppt) at sites during 7/19/17 - 7/27/17.

Site	Mean	SE	Min	Max
Bishop	13.99	0.32	2.31	21.55
Butler	17.02	0.32	2.27	24.85
Conimicut	21.85	0.10	17.99	24.64
Fields	19.15	0.09	15.85	21.43
Gaspee	20.62	0.11	16.94	24.04
Mussachuck	23.93	0.11	20.08	26.31
Narr. Terr.	19.48	0.09	15.64	21.54
Omega	15.75	0.30	1.31	22.62
Pawtucket	12.58	0.32	1.48	20.51
Pawtuxet	11.68	0.29	5.64	24.49
Sabin	21.28	0.11	15.89	23.84
Stillhouse	17.56	0.19	8.93	20.69

APPENDIX B

Presence of finfish and crustaceans by month captured by the fish traps in 2018.

MAY	**Site**												
Species	Pawtucket State Pier	Bishop Pt.	Butler	Omega Pond	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	**Total out of 12**
Blue Crab						1							**1**
Scup											1		**1**
Spider Crab						1	1	1	1	1	1	1	**7**
Tautog		1		1	1						1	1	**5**
White Perch	1												**1**

JUNE	**Site**										
Species	Bishop Pt.	Butler	Fields Pt.	Stillhouse Cove	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	**Total out of 10**
Black Sea Bass				1						1	**2**
Blue Crab	1	1	1	1	1	1					**6**
Oyster Toadfish			1				1	1	1		**4**
Scup				1		1	1	1	1	1	**6**
Spider Crab			1	1	1		1	1	1	1	**7**
Striped Bass			1								**1**
Summer Flounder					1						**1**
Tautog							1		1	1	**3**

JULY	**Site**									
Species	Fields Pt.	Stillhouse Cove	Sabin Pier	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	**Total out of 9**
Black Sea Bass									1	**1**
Blue Crab	1	1	1		1	1	1	1		**7**
Oyster Toadfish								1		**1**
Scup				1				1		**2**
Spider Crab		1	1	1		1	1	1	1	**7**
Summer Flounder									1	**1**
Tautog			1					1		**2**

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AUGUST	**Site**											
Species	Watchemocket Cove	Fields Pt.	Stillhouse Cove	Sabin Pier	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	Rocky Point	**Total out of 11**
Black Sea Bass							1			1	1	**3**
Blue Crab	1	1	1		1	1	1	1	1	1		**9**
Oyster Toadfish	1	1				1		1				**4**
Scup	1			1	1		1	1			1	**6**
Spider Crab				1			1	1	1	1	1	**6**
Summer Flounder	1											**1**
Tautog	1									1		**2**

SEPTEMBER	**Site**											
Species	Watchemocket Cove	Fields Pt.	Stillhouse Cove	Sabin Pier	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	Rocky Point	**Total out of 11**
American Eel		1										**1**
Black Sea Bass				1						1		**2**
Blue Crab		1	1		1	1	1				1	**6**
Oyster Toadfish				1							1	**2**
Scup				1	1		1			1		**4**
Spider Crab				1	1		1		1	1	1	**6**
White Perch		1				1						**2**

OCTOBER	**Site**											
Species	Watchemocket Cove	Fields Pt.	Stillhouse Cove	Sabin Pier	Sabin Pt.	Pawtuxet Cove	Narragansett Terrace	Gaspee Pt.	Conimicut Pt.	Mussachuck Creek	Rocky Point	**Total out of 11**
Black Sea Bass										1		**1**
Blue Crab		1			1	1						**3**
Green Crab										1		**1**
Oyster Toadfish	1	1										**2**
Rock Crab										1		**1**
Spider Crab			1		1		1	1	1	1	1	**7**

Assessment of Recreationally Important Finfish
Stocks in Rhode Island Coastal Waters

2018 Annual Performance Report for Job VI, Part B:

Assessment, Protection, and Enhancement of Fish Habitat to Sustain Coastal and Marine Ecosystems and Healthy Stocks of Recreationally Important Finfish:

Investigating techniques to enhance degraded marine habitats to improve recreational fisheries

Prepared By

Pat Barrett and Eric Schneider
Rhode Island Department of Environmental Management
Division of Marine Fisheries
Fort Wetherill Marine Fisheries Laboratory
3 Fort Wetherill Road
Jamestown, RI 02835

Federal Aid in Sportfish Restoration
F-61-R

PERFORMANCE REPORT

STATE: Rhode Island

PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 21

PROJECT TITLE: Investigating techniques to enhance degraded marine habitats to improve recreational fisheries

PERIOD COVERED: January 1, 2018 - December 31, 2018

JOB NUMBER AND TITLE: VI, Part B: Assessment, Protection, and Enhancement of Fish Habitat to Sustain Coastal and Marine Ecosystems and Healthy Stocks of Recreationally Important Finfish

STAFF: Eric Schneider (Principal Marine Fisheries Biologist) and Pat Barrett (Fisheries Specialist), RI DEM, Div. of Marine Fisheries, and William Helt (Coastal Restoration Scientist), The Nature Conservancy Rhode Island Chapter

JOB OBJECTIVE: This project aims to positively affect local fish populations by improving degraded marine habitat. Specifically, the goal is to determine if oyster reef construction can be used to improve productivity of young of the year to juvenile stages of recreationally important fishes such as black sea bass (*Centropristis striata*), tautog (*Tautoga onitis*), scup (*Stenotomus chrysops)*, summer flounder (*Paralichthys dentatus*), and winter flounder (*Pseudopleuronectes americanus*).

This goal will be addressed with the following objectives:
(1) Determine the appropriate location for reef establishment, considering oyster suitability modeling, present habitat quality and value, and connectivity to adjacent fish habitat;
(2) Create and establish oyster reefs in selected coastal ponds; and
(3) Conduct pre- and post-enhancement evaluation of study sites and controls to establish baselines and determine if there are changes in fish productivity, such as changes in recruitment and survival of early life stages of recreationally important fish.

SUMMARY: This report summarizes all work conducted for this project between January 1 and December 31, 2018. During this period, we: (1) identified potential FHE locations, conducted pre-enhancement monitoring, and submitted permit applications for FHE work in Pt. Judith Pond. Through a public review process for the permits required to create FHE reefs, we determined that due to increasing user conflicts in the Pond there are not locations in Pt Judith Pond that will support the FHE work as designed, (2) conducted Year-3 of post-enhancement fish and reef monitoring of FHE reef sites in Ninigret Pond as well as Year-2 of post-enhancement fish and reef monitoring of FHE reef sites in Quonochontaug Pond, (3) evaluated the performance (survival, growth, decay, and disease prevalence) of oysters in both ponds, and (4) determined the influence our FHE oyster reefs had on the community assemblages in each pond and the relative abundance of juvenile finfish expected to colonize them.

We continued to conduct post-enhancement fish monitoring in both Ninigret and Quonochontaug Pond. To date under this project, four years of monitoring has been conducted consisting of 581 and 462 hauls of fish sampling gear in Ninigret and Quonochontaug Ponds, respectively. In 2018 the most frequently captured finfish species in traps in Ninigret Pond and Quonochontaug Pond were oyster toadfish, black sea bass, tautog, and cunner (Table 2a), and black sea bass, winter flounder, scup, and cunner (Table 2b), respectively. The most frequently captured finfish species in gillnets in Ninigret Pond and Quonochontaug Pond were striped bass, menhaden, and bluefish (Table 3a), and striped bass, menhaden, and river herring (Table 3b), respectively.

Overall, our analyses suggest more fish were observed at FHE sites during the post-enhancement monitoring (i.e. after reef construction) compared with the pre-enhancement baseline and specific reef-dwelling species, such as tautog and black sea bass, were observed more frequently at FHE reefs sites compared to unseeded reefs and bare plot controls (Tables 1a and 1b). Reef habitat monitoring showed that oyster density on the reefs stabilized after 6 months post construction and that oyster growth and mortality varied by location and oyster lineage used to construct the reef.

We expect to enhance the fishery performance of the FHE reefs created in Ninigret in 2015 by reseeding these reefs to increase oyster density. We anticipate obtaining agreements for spawning and rearing oysters to reseed the FHE reefs created in Ninigret, with reseeding expected to occur in October 2019. In addition to the current fish monitoring survey work, we will also investigate whether additional monitoring should be implemented, such as utilizing habitat trays to collect biomass, and video monitoring for fish habitat utilization.

TARGET DATE: December 2018

SIGNIFICANT DEVIATIONS: Due to unforeseen challenges with obtaining the required permits for fish habitat enhancement (FHE) reef construction in Pt. Judith Pond, the construction of the FHE reefs has been postponed indefinitely. Based on feedback obtained during a public meetings as part of the review process, we determined that we would not construct FHE reefs in Pt Judith Pond as part of this project. We instead plan to focus our efforts on monitoring the current FHE reefs in Ninigret and Quonochontaug Ponds, including new survey techniques to increase our ability to evaluate this practice. We also expect to enhance the fishery performance of the FHE reefs created in Ninigret in 2015 by reseeding these reefs to increase oyster density.

RECOMMENDATIONS: Given that we were unable to obtain the required permits for the work proposed in Pt Judith Pond, we have dedicated time to creating more robust analysis of the data we have collected from Ninigret and Quonochontaug Ponds in order to focus on publications on our work. Given some of the complaints and concerns from pond users, we want to ensure that our monitoring programs and enhancement practices are based on the most up to date and site-specific data available.

Additional assistance from a DMF contract employee, as well as DMF and TNC seasonal staff was crucial in completing all necessary reef construction and monitoring in 2018. We have determined that this increased level of staffing will be required to complete fish habitat monitoring in 2019. These aspects will be assessed during 2019 and revisions to the grant will be requested, if necessary.

INTRODUCTION

Alteration and loss of coastal habitats, such as saltmarshes, eelgrass, and oyster reefs, is believed to be one of the most important factors contributing to declines in populations of marine finfish (Deegan and Bucshbaum 2005). For example, more than 70% of Rhode Island’s recreationally and commercially important finfish spend part of their lives in coastal waters, usually when they are young (Meng and Powell, 1999). The shallow water, salt marshes, sea grasses, and oyster reefs provide excellent foraging and feeding areas as well as protection from larger, open-water predators. Juvenile finfish show a high degree of site fidelity, rarely moving far from shallow-water nursery habitats until either water cools in the late fall or resources are insufficient (Saucerman and Deegan 1991). Habitats known to be important to early life stages of finfish include unvegetated soft sediments or tidal flats, submerged aquatic vegetation, and complex shellfish and oyster reefs (ASMFC 2007). It is broadly accepted that habitat restoration and enhancement improves coastal ecosystems; however, it remains unclear if coastal habitat restoration practices conducted here in RI would benefit the survival and growth of early life stages of finfish as in the mid-Atlantic.

In Rhode Island, complex shellfish reefs formed by oysters (*Crassostrea virginica*) and ribbed mussels (*Geukensia demissa*) are found in intertidal and shallow subtidal waters of coastal ponds and bays. Recent decades have witnessed declines in this habitat. For example, Beck *et al.* (2011) estimated that shellfish reefs are at less than 10% of their prior abundance and that ~85% of reefs have been lost globally. The decrease in oyster reef extent and condition has coincided with decreases in water quality and clarity, and loss of important nursery habitat for finfish and crustaceans (zu Ermgassen et al. 2013).

Numerous studies completed in the mid-Atlantic have identified shellfish reefs as essential fish habitat (EFH) for resident and transient finfish (Breitburg 1999, Coen et al. 1999). Similarly, Wells (1961) collected 303 different species of marine life that utilized oyster reef habitat. Reef-dwelling organisms are then consumed by transient finfish of recreational and commercial importance (Grabowski *et al.* 2005; Grabowski and Peterson, 2007). Harding and Mann (2001) suggested that oyster reefs may provide a higher diversity and availability of food or a greater amount of higher quality food compared to other marine habitats. Grabowski et al. (2005) found that oyster reefs constructed in soft sediments increased the abundance of juvenile fish such as the black sea bass *Centropristis striata*. Studies in the Mid-Atlantic and Gulf of Mexico have also shown that oyster reefs can increase the growth and survival of juvenile finfish (e.g., Peterson et al. 2003, zu Emgassen et al. 2016), as well as fish and invertebrate biomass (e.g., Humphries and La Peyre 2015) compared to unenhanced habitats. Despite these successes, this approach has not yet been evaluated in the New England region.

The growing recognition of the ecological and economic importance of complex benthic habitat has led to an increase in the efforts to construct oyster reefs (Coen and Luckenback 2000, Brumbaugh et al. 2006, Scyphers et al. 2011). In North Carolina, recreational fisherman value constructed oyster reefs as a place to find a large number and variety of fish. Grabowski and

Peterson (2007) estimated that an acre of oyster reef sanctuary will result in ~$40,000 in additional value of commercial finfish and crustacean fisheries. Note that Grabowski and Peterson (2007) suggested that the recreational sector, like the commercial sector, would be positively affected by an oyster reef sanctuary; however, there was not a clear and convenient value metric for the recreational sector for assessment (i.e., value of landings for commercial species was used to assess commercial value).

APPROACH

Under a cooperative agreement between the Division of Marine Fisheries (DMF) and The Nature Conservancy (TNC), we will collaborate to examine the practice of establishing oyster reefs in shallow coastal waters as a tool to improve populations of recreationally important fishes. The project is broken into four components. In general, we aim to construct up to 4 acres of oyster reef habitat (up to 1 acre per pond per year starting in 2015) to evaluate reef habitat function and services related to local fish populations. The project will be completed in four stages: (1) identify optimal project locations, and if not already in place promulgate regulatory protections for the “to be created resource”, and submit permit applications; (2) construct oyster reefs; (3) monitor reefs and evaluate fish use and productivity; and (4) develop public outreach materials and reports.

This project will be completed in the coastal ponds of South County, Rhode Island (Figure 1). The coastal pond ecosystems provide refuge and spawning areas for numerous estuarine and marine finfish and are popular fishing areas for recreational anglers. A thorough analysis of oyster and finfish habitat suitability will be completed prior to reef construction. This will be done at the pond and site-level scale to identify areas with appropriate physical and biological characteristics. We will use TNC’s oyster restoration suitability model along with DEM’s juvenile fisheries data to evaluate not only suitability but the likelihood of recruitment of juvenile fishes. Geospatial data developed in our suitability analysis will greatly inform this project and future fish habitat restoration projects in coastal pond ecosystems.

Reef construction will take place in state-designated Shellfish Management Areas, within which the DMF has authority to conserve and enhance shellfish resources with appropriate management strategies including transplanting, area closures, establishment of spawner sanctuaries, and daily possession limits. If needed, the DMF will promulgate regulations to protect the “to be created” resource prior to placing shell in the water for reef creation. These rules and regulations are promulgated pursuant to Chapter 42-17.1, §20-1-4, §§20-2.1 and Public Laws Chapter 02-047, in accordance with §42-35 of the Rhode Island General Laws of 1956, as amended.

ACTIVITIES

This report summarizes all work conducted for this project between January 1 and December 31, 2018. During this period, (1) identified potential FHE locations, conducted pre-enhancement monitoring, and submitted permit applications for FHE work in Pt. Judith Pond, (2) conducted Year-3 of post-enhancement fish and reef monitoring of FHE reef sites in Ninigret Pond as well as Year-2 of post-enhancement fish and reef monitoring of FHE reef sites in Quonochontaug Pond, (3) evaluated the performance (survival, growth, decay, and disease prevalence) of oysters in both Ponds, and (4) determined the influence reef enhancement practices have had on the community assemblages in each pond and the relative abundance of juvenile finfish expected to colonize the reefs.

Pt Judith FHE Permitting

Consistent with the original grant proposal, which stated, "…construct up to 4 acres of oyster reef habitat (up to 1 acre per pond per year starting in 2015) to evaluate reef habitat function and services related to local fish populations", we conducted work to establish 3 FHE sites in Pt. Judith Pond. Specifically, we conducted field and desktop analyses to identify 3 potential FHE sites in Pt Judith Pond (Figure 1 in Appendix A), initiated pre-enhancement monitoring, drafted and submitted permit applications, and participated in the permit review process. Based on feedback from stakeholders and members of the public during the permit review process, we proposed 3 additional sites and submitted new permit applications, allowing for feedback on 6 potential sites in total (Figure 1 in Appendix A). An example of one of the permits can be found in Appendix A.

Material and Design

In an attempt to create oyster reefs that will provide quality habitat for fish, we are collaborating with Drs. Jon Grabowski and Randall Hughes of Northeastern University to implement and test the performance of oyster restoration reefs using two different, but similar, experimental designs in the coastal ponds of Rhode Island (Figure 1). In Ninigret Pond we have created four replicates (Figures 2 and 3) of three distinct treatments that include a cultch only reef, a seeded reef, and bare plot control, to test the influence of not only enhanced structure (cultch only reefs), but enhanced biomass (seeded reefs), have on the abundance of juvenile finfish that utilize these reef habitats. In Quonochontaug Pond, the goal is to identify whether specific genetic lines (lineage) of oysters contain desirable traits for both fish habitat and reef longevity. To evaluate this effect, we used two 'wild' linages of oysters, spawned from adults collected from existing populations that will be compared against a commercial strain of oysters (eyed larvae purchased from Aquaculture Research Corporation in Dennis, Massachusetts) commonly used in oyster reef restoration and enhanced projects in RI. The commercial hatchery lineage in Quonochontaug Pond was the same used for all the 2015 Ninigret Pond FHE seeded reefs. The experimental design in Quonochontaug included creating three reefs, each seeded with one oyster linage, and a bare control plot at three different sites (replicates) (Figures 3 and 4). In total, there are a 12 experimental reef plots, which is consistent with Ninigret Pond; however, the number of replicates from four to three.

Oyster reef monitoring

Oysters are monitored twice a season (May and October) using the Rhode Island Oyster Restoration Minimum Monitoring Metrics and Assessment Protocols (Griffin et al. 2012). At each reef, a 0.25m^2 quadrat was haphazardly placed six times. Using standard cover practices, the percent cover of macroalgae was estimated, then all algae was brushed away to allow for percent cover estimation of benthic substrate. Relief, quadrat height relative to the bottom, was measured by finding the difference between the water depth at the reef edge and the depth from the center of the quadrat. All oysters and dead shell were then excavated from the quadrat. All live oysters and dead oysters per quadrat were counted as well as the presence of boring sponge. Density was calculated for both living and recently dead oysters by multiplying abundance per quarter meter quadrat by 4. All material was then returned to the sampling location so as not to disturb the reef. An additional 30 oysters from each reef are collected for disease and pathological work conducted by the Hughes Lab at Northeastern.

In addition to the standard oyster sampling, mean spat length and density at the time of seeding were collected by averaging a sub sampled of seeded cultch bags provided by the oyster growers during reef construction. This average length and density per bag was then multiplied by the total number of bags deployed per reef, and divided by the total area (m^2) of the reef to calculate initial seed length and density. These initial seeding density and length measurements are only used during the creation of the oyster growth and mortality curves discussed below.

Density and Length

Prior to analysis, all oyster data were tested for homogeneity of variance and conformance to a normal distribution using a Levene's test and Shapiro Wilks, respectively (Levene's $p > 0.05$, Shapiro Wilks $p > 0.05$). Oyster quadrat data that did not meet the assumptions was log transformed prior to analysis. After log transformation, mean density, mean length, proportion living, and proportion with boring sponge data met assumption of homogeneity of variance and normality in all but 1 case. Considering that ANOVAs are a robust test against the normality assumption (Zar 1999) and capable of overcoming small violations in normality that are typical to quadrat sampling data (Underwood 1981), we decided to continue with the parametric ANOVA despite this small normality infraction. Precedent has been set to continue with parametric ANOVAs in cases specific to oyster quadrat sampling (e.g., density of living oysters per quadrat in Scyphers et al. 2011).

We present values as mean ± one standard error and set level of significance for all tests at $p <0.05$, unless stated otherwise. All significant differences between the ANOVA factors were denoted using letters derived from Tukey's post hoc tests on the ANOVA models.
Oyster density (ind./m^2), and mean length (mm), per quadrat were used to calculate a mean oyster density and length value for each reef. To evaluate if oyster density and length differed by treatment, between ponds, or over time we used a two-way ANOVAs testing the effect of factors such as Time (monitoring event) and Site (pond location; includes one of each reef treatment type), or Site and Seed (Treatment; Control, Unseeded, ARC, Green Hill Pond, Narrow River).

Oyster Growth and Mortality

In order to calculate the growth and natural mortality rates on the FHE reefs, all oysters below 30 mm recorded during monitoring events that took place after the first-year post construction, were deemed new recruits and removed from mean density and length calculations. The 30 mm threshold was chosen as the cutoff size for the maximum mean spat length per shell at the time of deployment (6-12 months post settlement) in Ninigret and Quonochontaug Ponds was ~28.06 mm and ~23.53 mm, respectively. Rounding up to 30 conservatively accounts for some natural yearly variation in the growth of newly settled recruits.

Oyster growth curves were developed for each reef using the von Bertlanffy growth equation:

$$Lt = L_{\infty} * (1 - e^{(-K\ (t - t0))}) \qquad \text{(von Bertlanffy)}$$

Where Lt is the length at time t (age in years) and t0 age at time 0 (Set to 0). Mean oyster length per quadrat (n= 3-6) for each reef replicate were used as observed values to generate predicted initial values through the vbStarts "r package" (Ogle, 2016). The asymptotic length (L_{∞}) and growth constant (K) growth parameters were also estimated for each reef using maximum likelihood estimation.

The FHE reefs have been cited shellfish prohibited areas of the coastal ponds thus, all calculations of Total Mortality (Z) are assumed to reflect Natural Mortality (M). Total Mortality (Z) estimates were derived by fitting mean oyster density data from each monitoring event to the exponential decay equation:

$$Dt = Do * e^{(-Z*(t-t0))} \qquad \text{(Exponential Decay)}$$

Where Dt is the density at time t (age in years) and t0 is the time at reef construction. Initial mortality parameter values for Do and Z were determined via Generalized Linear Models (GLMs) of Density ~ Oyster Monitoring Event (Years). The GLMs assumed a Gamma distribution and used an inverse link function to mimic a theoretical exponential decay model. The predicted values from the GLMs were used to estimate the intercept (Do) and slope (Z) of the curve, $\ln (Dt)/\Delta t$, for each reef. Mortality parameters were then optimized using maximum likelihood estimation.

Using the optimized growth and mortality parameters developed for each reef we are able to generate an estimated oyster density (EOD) and length (EOL) by plotting these newly fitted curves over time (days since creation). This information allowed us to incorporate quantitative values of reef condition during sampling events where we fished but did not collect oyster measurements (June-September). EOL and EOD for each reef are included in the Generalized Additive Models (GAMs) that were created for each finfish species of interest to evaluate how certain reef habitat characteristics, such as EOL and EOD, are influencing the catch per unit effort (CPUE) of young of the year finfish, in addition to other abiotic factors, at our FHE reef sites (See CPUE calculation and After Impact YOY GAMs below).

Pre- and Post-enhancement finfish monitoring

We continued the Year-3 of post-enhancement fish monitoring at the FHE reef sites in Ninigret and began Year-2 of post-enhancement monitoring in Quonochontaug Pond. Each month, we conducted a multi-gear finfish survey work using eel pots, minnow traps, and gillnets in both ponds. Fish pot sampling consisted of setting 2 eel pots and 3 minnow pots connected on a trot line at each site twice per month. The pots were soaked (i.e., fished) for 6 and 24 hours before hauling. At each site gillnets were set seasonally (May, July, and September) and typically set between 18:00 or 19:00 and soaked for 12 hours. Gillnets consisted of two 15' long by 4' tall panels, with one panel made of 3.8cm (1.5") (Small Mesh) and the other panel made of 7.6cm

(3”) (Large Mesh) stretch mesh (monofilament). Fish captured with the aforementioned gears were identified, measured to the nearest millimeter, counted, and released alive whenever possible.

Environmental data such as temperature, salinity, and dissolved oxygen are collected using YSI Professional Plus Multiparameter instrument during every oyster monitoring session, as well as at least once a month at each sampling station during either the gillnet or eel pot hauls, and sometimes both. Mean temperature (Cº), salinity (ppt), and dissolved oxygen (mg/L) per month. This data is incorporated into the generalized additive models discussed below.

BACI and CPUE calculation

A Before-After-Control-Impact (BACI) approach was used to determine how reef construction can impact the fish assemblage, relative species abundance, and juvenile length distributions in the coastal ponds. We specifically assessed how relative species abundance and community assemblages have changed over time between our baseline surveys and up to 3 years post reef construction. For the BACI analysis we derived mean catch per haul by aggregating the number of fish caught per minnow trap + eel pot haul, or gillnet haul, (herein after, CPUE) and then finding the average CPUE for each month by habitat treatment (Control, Unseeded, Seed lineage (i.e, Ninigret = ARC; Quonochontaug = ARC, Green Hill, and Narrow River)).

For each recreational species of interest we created a mean CPUE BACI figure from the aforementioned CPUE data, and analysis of augmented YOY abundance when data permitted. Ninigret and Quonochontaug Ponds were analyzed separately for each species. Additionally, analysis for Ninigret winter flounder (*n* = 3) and summer flounder (*n* = 7, both ponds combined) were not tested in due to insufficient catch.

After Impact YOY GAMs

To understand how the impact reef creation may have had on increasing secondary production, only YOY fish where included in the generalized additive models (GAMs). Comparing the length frequencies graphs to known regional values we implemented a maximum length cutoff (mm) per month as follows:

Species	June	July	Aug	Sept	Oct	Nov
Black sea bass[1]	*NA*	*NA*	*NA*	*NA*	*NA*	130
Scup[2]	50	*NA*	*NA*	*NA*	*NA*	100
Tautog[3]	100	107	109	115	*NA*	*NA*
Winter flounder[4]	*NA*	*NA*	*NA*	*NA*	*NA*	120

1 J. E. McNamee, personal communication (2018).
2 O'Brien, Loretta, Jay Burnett, and Ralph K. Mayo. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990.US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, (1993).
3 data provided by L. Buckley, National Marine Fisheries Service, Narragansett Laboratory, Narragansett, R.
4 Bigelow, A., and Shroeder, W. 2002. Bigelow and Shroeder’s Fishes of the Gulf of Maine (3rdEd.).

Length frequency distributions and kernel density estimations were generated using the total catch of each species by gear type in order to visualize the size distributions of the fish caught between the different reef treatments and fishing gear. Both length frequency bins and kernel density bandwidths were set to 5mm. YOY max cutoff lines were added to both plots in order to clarify size class specific trends in YOY vs Year 1+ aggregations among the different seeded treatments and control plots in each pond.

After removing all non-YOY sized fish, Kruskal-wallis test for non-parametric comparison of means were used to identify any preexisting differences between sites during our pre-enhancement monitoring. All data collected post-enhancement were compared relative to the abundance of fish caught at the control plot within each site. Factors included in the GAM analysis include both categorical (i.e., Year, Site, Seed) and continuous (Temp, Salinity, Dissolved Oxygen, Estimated Oyster Density and or Estimated Oyster Length) variables. All catch per haul data, post enhancement, were used in GAM analysis and all models included an offset function of log(hours fished) to account for soak time differences. All factors were initially added to the model and removed in a step-wise fashion in order of least significant, until all remaining parameters were significant. Once the factors were set, models with Poisson, Zero-Inflated Poisson, Negative Binomial, and Zero-Inflated Negative Binomial error distributions were compared amongst one another to determine the best fit. Histograms of catch per haul in addition to comparisons between adjusted-r^2, AIC, and BIC were used to identify best fits for the final model for each species.

RESULTS

Pt Judith FHE Permitting and Baseline Survey Work

During the public notice periods for the 6 applications (see Appendix A for example), we obtained feedback from stakeholders, abutting landholders, and the general public during public meetings and via written comments submitted as part of the review process. Although many participants appreciated the proposed work and supported the scientific merit, they had concerns that the proposed work would interfere with current uses including navigation, fishing, anchoring, and swimming, and may open the door for non-FHE practices, such as aquaculture, to progress into new areas of the pond. Although, DMF/TNC believed that most of these concerns and objections were misguided, we needed to establish 3 FHE sites to satisfy the experimental design of this work. Since we were not able to gain support for 3 sites, we determined that we would not construct FHE reefs in Pt Judith Pond as part of this project. We instead plan to focus our efforts on monitoring the current FHE reefs in Ninigret and Quonochontaug Ponds, including new survey techniques to increase our ability to evaluate this practice. We also expect to enhance the fishery performance of the FHE reefs created in Ninigret in 2015 by reseeding these reefs to increase oyster density.

As part of the pre-enhance survey work, we collected fisheries data at all 6 potential FHE sites. This catch data is summarized in Table 1 and will be valuable for assessing the potential for other future habitat enhancement practices.

Oyster Reef Monitoring

Oyster Density

In each pond we tested for difference between oyster density amongst our seeded reef treatments. In Ninigret Pond, oyster density differed by year. During this time mean oyster density dropped from 409 ± 129 oysters/m^2 at time 1 (spring 2016), down to 126 ± 46 oysters/m^2 over the next five monitoring events (Figure 7). Only the initial decrease from time 1 and time 2 were different, suggest mortality was highest during the first six months after seeding the reefs and then leveled off from there on out (Table 4a).

In Quonochontaug Pond, Oyster monitoring event had a significant effect on density where similar to Ninigret Pond, oyster density had a significant decline within the first 6 months, but leveled off afterwards. Interestingly, Fall of 2018 was partially distinct from both, potentially due to a small recruitment event to the reefs this past summer (Figure 8A). In addition to time post construction, oyster lineage had a significant effect on the density of oysters over the 18 months prior to reef construction, with the wild Green Hill Pond (472 ± 68 ind./m^2) and Narrow River (343 ± 58 ind./m^2) lineages being 69.7% and 40.3% more dense than the commercial ARC lineage (228 ± 32 ind./m^2) (Figure 8B). These results suggest that the Green Hill Pond lineage had higher densities compared to the ARC commercial lineage, 18 months post reef creation (Table 4c).

Oyster Length

Oyster length was used to measure oyster growth over time, as well as site and seed lineage specific trends. In Ninigret Pond the ANOVA on mean oyster length per quadrat revealed that time and site had independent effects on mean oyster length (mm) per quadrat, where each time was greater than the next (Table 4b). These results show that oysters on the reefs all started at the same length and maintained steady growth between monitoring events; growing as much as 24.8 mm during the first summer period and almost 80 mm during the first two years (Figure 9).

Growth and Mortality

Before calculating growth and mortality coefficients all juveniles were identified and removed from mean density and lengths .. Almost no recruitment (< 1 ind./m^2) has been observed since the creation of the FHE reefs in Ninigret and only minimally during the 2018 season localized to the eastern reef sites in Quonochontaug Pond (~40 individuals total).

Oyster growth and mortality were found to vary by reef location in Ninigret Pond. Growth rates (k) were greater at the two southern reefs (Figure 10a-b, Table 5a) (Sites 3: k = 0.14 and Site 4: k= 0.13). Whereas mortality was highest at the eastward reefs (Figure 11a-b, Table 5b) (Sites 2: Z = 1.36 and Site 4: Z = 1.38). Total Mortality (Z) from all the Ninigret FHE reefs combined was 1.175. In Quonochontaug Pond, oyster growth and mortality varied oyster lineage. Green Hill Pond showed to have the both the fastest growth rate and the lowest mortality rate (Table 5c and 5d, k = 0.12, and Z =1.65). Parameter coefficient standard errors overlapped between Green Hill Pond lineages and the ARC lineage, however, Green Hill Pond was distinctly different from the Narrow River lineage (Figures 12a-b and 13a-b).

Fish Monitoring – BACI Catch per Haul and Young of the Year GAMs

Ninigret Pond – Unseeded vs. Seeded Treatments

Black Sea Bass (YOY)

In Ninigret Pond, young of the year black sea bass were most abundant in 2016 across all treatments (0.72 ± 0.35 per haul), during the first tear post reef enhancement (Figure 14a). In all year post impact, reef creation, young of the year black sea bass catch was greatest at seeded enhancement treatment reefs, black sea bass caught per seeded reef (1.45 ±1.02) was 2.48 and 7.58 times greater than the catch at the unseeded and control sites, respectively (Figure 14).

The YOY Black Sea Bass GAM was fit with a zero-inflated poisson model and explained 62.4% of the deviance (Table 6, model 1). The results from the Ninigret analysis confirmed the observed trends from the BACI CPUEs, in that abundance was highly influenced by yearly trends in the overall sea bass population (Table 6b, 2017: -5.796, 2018: -1.7116) with 2016 being a significantly greater year class than 17' or 18' at our FHE reefs (Figure 14b top right panel). Both the unseeded and seeded reef treatments positively enhanced black sea bass abundance relative to the control sites (Figure 14b, bottom left) with the seeded treatments (Table 14b, 1.879x greater than control, p-value <0.001) more significantly enhancing abundance relative to the control compared to the unseeded reef treatments (Table 6b, 1.0648x greater than control, p-value <0.01). Additionally, Temperature also had a strong effect on the abundance of YOY black sea bass, with abundance positively enhanced at temperatures greater than 17°C, and highest at approximately 23°C (Figure 14b, top left panel).

Tautog (YOY)

In Ninigret Pond, Tautog CPUE was greatest at both the unseeded and seeded enhancement treatments relative to the control sites for all years post reef construction (Figure 15a). Similarly, to Black Sea Bass, YOY of Tautog also seemed to be enhanced more significantly at seeded reefs (5.59x greater than control, p-value <0.001) than the unseeded treatments (2.41x greater than control, p-value <0.01) (Figure 15b, Table 6). The tautog model was fit with a Poisson distribution, and explained 15.3% of the deviance (model 3, Table 6)

<u>Quonochontaug Pond – Habitat Parameters</u>

Black Sea Bass (YOY)

In 2018, Quonochontaug Pond young of the year black sea bass were observed to be caught in greater abundances at the reef enhancement treatments ARC: (2.3 ± 0.32) and Green Hill Pond 2.34 ± 0.32) relative to the controls (2.09 ± 0.34) (Figure 16a). The best fit for the Quonochontaug Black sea Bass model was a negative binomial distrusted model and explained 39.5% of the deviance (model 2, Table 6). In Quonochontaug pond the interaction between EOD and EOL significantly impacted the YOY abundance at our FHE sites, where sea bass were more positively enhanced with increasing oyster length than increasing oyster density (Figure 16b, bottom left panel). Similar to Ninigret Pond, Black Sea Bass were also influenced by temperature, with catch increasing as temperature rises above ~20°C (Figure16b, top left panel). In Quonochontaug Pond, Black Sea bass were also found to have greater relative abundance at the eastern basin sites (Sites 2 and 3) compared to the western basin (Site 1) (Figure 16b, bottom right).

Tautog (YOY)

In each year post reef construction, tautog abundance was greatest on the reef enhancement treatments relative to the controls (Table 3a) (Figure 17a). The Quonochontaug Tautog GAM was fit with negative binomial distribution and explained 28.1% of the deviance (Table 6). Results of the YOY GAM suggest that tautog abundance is positively enhanced with increasing oyster density (Figure 17b, bottom left). Young of the year tautog were also influenced by temperature, where abundance was positively enhanced at temperatures less than 24°C and greater than 15°C, with max abundance at approximately 20°C (Figure 17b, top left). Contrasting to Black Sea Bass, Tautog abundance was greatest in the western basin (Site 1) relative to the eastern basin (Sites 2 and 3), where sites 2 and 3 were 2.18x and 1.048x less than CPUE at site 1 respectively (Table 6).

Winter Flounder (YOY)

In Ninigret Pond, mean CPUE for Winter Flounder was quite low, 0.18 ± 0.13 at its greatest. However, all observations were found to be at either an unseeded or seeded enhancement treatment (Table 2a). In Quonochontaug pond, mean CPUE ranges from 0.87 ± 0.26 to 1.75 ± 0.33 which is dramatically different than in Ninigret Pond (Table 3a). BACI analysis of mean CPUE shows that mean CPUE has increased post enhancement, but that abundance of winter flounder was greatest on the control sites than on the reef enhancement treatments (Figure 18a). The YOY GAM was fit using a zero-inflated poisson distribution, and was found to explain 68% of the deviance (Table 6). Despite having slightly lower abundances on the reefs compared to controls, the model results showed that compared relative to one another, winter flounder catch increased with both increasing oyster density and length (Figure 18b, bottom left panel). Like Black Sea Bass, sites 2 and 3 in eastern basin more positively enhanced winter flounder abundance relative to site 1 in the western basin (2.44x and 2.53x greater respectively, Table 6b; Figure 19b, bottom right).

All Ponds – Gillnets CPUEs

Scup (YOY)

Gillnets were the most successful gear type for catching scup (Figure 19a). In Ninigret Pond, Scup CPUE has steadily increased each since the creation of the FHE reefs in Ninigret Pond; however, there has been no significant differences between the different habitat enhancement treatments (Figure 19b). Similarly, in Quonochontaug Pond, a total increase has been observed, but no differences existed between the different reef treatments (Figure 20b). Results from the YOY GAMs suggested that abiotic factors such as Salinity and Dissolved oxygen may be stronger influencing factors on abundance than oyster density in the coastal ponds (Table 6).

CPUE by gear type and length frequencies were specifically generated for Scup as it was the only species of interest that was caught regularly in all three gear types (Minnow Traps, Eel Pots, and Gillnets). By comparing the YOY cutoff length to the distributions of each gear type, we determined that YOY Scup were found in all gears except for the large mesh panel of the gillnets which were typically 1+ size class (Figure 20a).

Striped Bass

Stripe Bass CPUE increased from 0 to 4.02 ± 0.85 at control sites in Ninigret Pond between the pre-enhancement and post enhancement monitoring events. However, no differences were observed between the controls and enhancement treatments (Figure 21). In fact, abundance at the reef sites were always lower than relative to the controls (Table 2b). The same was true for Quonochontaug Pond were no differences were found between enhancement treatments and the controls (Figure 22, Table 3b).

DISCUSSION

Reef Habitat

Before we could evaluate whether oyster reef construction can be used to improve productivity of young of the year and juvenile stages of recreationally important finfish, we first needed to create functional oyster reef habitat. Results from oyster reef monitoring suggest our reef establishment approaches have thus far been successful in both Ninigret and Quonochontaug Ponds. In Ninigret Pond where there was only a single lineage of oysters seeded (e.g., commercial ARC) oyster density decreased over the first 6-months but has since stabilized. In Quonochontaug Pond, the density of oysters 6 months after construction differed by oyster lineage, where the wild Green Hill Pond and Narrow River lineages were 75.8% and 69.1% more dense than the commercial ARC. Overall, the level of survival and general stability in density is promising and allows these reefs to function and provide habitat for fish, as well as some level of associated ecosystem services.

We were also pleased that reefs in both ponds continue to exhibit increased growth between successive monitoring events. In Quonochontaug Pond, the ARC lineage was the smallest of all the three linages at the time of reef establishment; however, after one growing season, all lineages were equal in mean length, suggesting the ARC line grows more quickly during the first 6 months on the reefs. Additional oyster pathology monitoring and future survival analysis, combined with fish monitoring at these sites, will help determine which lineages present a better option for FHE reef establishment and long-term FHE functions.

Growth and Mortality estimates for the two ponds and three lineages have allowed us to evaluate the success of these reefs as well as the factors that may influence successful reefs in a more robust way. Site selection for FHE reefs should be taken seriously when planning enhancement efforts. Since all reefs in Ninigret were seeded with the same Hatchery lineage, we were able to determine that reef site influenced growth and mortality differently. Additionally, in Quonochontaug Pond, the different growth and mortality rates between these the different wild lineages was interesting. Choosing wild oyster broodstock that have traits conditioned for two fairly different environments is may be contributing tothe higher mortality and lower growth rates observed by the Narrow River lineage compared to Green Hill lineage at the FHE reefs built in Quonochontaug Pond. Green Hill Pond has a higher mean salinity and is more similar to Quonochontaug Pond, than the brackish upper section of the Narrow River were the wild stock resides. These findings provide a potential reason why they outperformed the Narrow River lineage thus far but warrant further investigation.

Fish Abundance and Influencing Abiotic and Benthic Habitat Parameters

Providing the health of these reefs are maintained, the quality of habitat provided should increase over time in response to successional changes on these reefs. That said, it’s generally agreed that oyster reefs provide some level of enhancement to fish habitat beginning at time of reef creation. Consistent with this expectation, we observed that abundance of fish increased across sites after reef creation, in comparison to preconstruction baseline monitoring. We also observed an increase in targeted species, such as black sea bass, tautog, and winter flounder.

Preliminary quantitative analysis of the mean catch per haul and length frequency distributions are showing promise and providing information on how juvenile fish such as black sea bass, scup, tautog, and winter flounder are utilizing enhanced reef. Consistent with studies conducted in the mid-Atlantic (i.e, zu Ermgassen 2016; Grabowski, 2005), results to date for this work suggest that black sea bass are utilizing oyster reef sites post enhancement. For example, in Ninigret Pond YOY black sea bass were observed more often on seeded reefs compared to unseeded reefs and control mud flat plots in all year post enhancement. Although this result is not shocking, due in part to black sea bass's affinity for structure, we were surprised to see that in some years YOY black sea bass almost exclusively utilized reef habitat, whereas older fish more likely to use both reef and fringe habitat.

Tautog saw an increase in YOY abundance on reefs that most likely related to increased enhancement, which like black sea bass was anticipated for structure-oriented species like tautog. Young-of-year sized tautog were observed most often during our 2017 monitoring season. This represented Ninigret Pond 2nd and Quonochontaug 1st year post reef enhancement. In 2018, Tautog exhibited abundance at our enhancement treatments than the controls and showed a strong response to increasing oyster density in both Ponds.

Winter Flounder were more abundant post reef enhancement in Quonochontaug Pond; however, great ambulances were observed off reefs at adjacent control sites compared to the reefs themselves. Although this could be a year-class effect, it may also suggest that winter flounder are benefiting from reef enhancement as a secondary or fringe habitat. Previous work has shown that other flounder species benefited from reef habitat that was adjacent to their more preferred seagrass or mud flat nursery habitats (e.g., Grabowski et al. 2005). Furthermore, the preliminary results from our GAM analysis show that abundance of winter flounder observed at our FHE sites increased at all sites as the reefs mature.

In Quonochontaug Pond, Black Sea Bass, Tautog, and Winter Flounder all showed that enhancement potential can be limited by adjacent or pre-existing habitat conditions. Black Sea Bass and Winter Flounder were more positively influenced at the eastern basin that has a sandier and more rugose substrate, whereas Tautog were more positively increased at the western basin that is relatively flat and muddy between the reefs compared to the eastern sites. This is not to suggest that tautog prefer a muddier substrate but that the potential for enhancement may have been higher seeing how the baseline value of that habitat may have been lower. Our findings also provide some insight into potential bottlenecks that could be limiting young of the year tautog colonization in the coastal ponds. Suggesting tautog may be more limited by the lack of suitable habitat than the lack of recruitment. Similar reef-oriented fish habitat enhancement projects have been used to identify potential bottlenecks that exist in species that have spatially stage-structured life histories, where juveniles require the presence of a habitat to increase survival and production (e.g. juvenile gag grouper) (Lindberg, 2013). It is also worth considering that there could be some negative competitive influence of young of year black sea bass on young of the year tautog at these small-scale reef habitats.

Scup and Stripe Bass have yet to show any strong trends at our FHE sites, which is similar to work in the Mid-Atlantic (Peterson 2003) where Striped Bass do not show any augmented production from the enhancement of oyster habitat. It's possible that the methodology used to determine the CPUE on and off reefs was not sufficient to document the relative use for these different FHE treatments by striped bass, scup, and other pelagics (e.g., bluefish, menhaden).

Other methodologies, such as a conventional or acoustic, should be considered to properly document the preferential habitat use for striped bass.

Aspects of work for 2018 and thereafter

Permit applications for reef construction in Pt. Judith Pond have been postpone indefinitely. In 2019 we plan to conduct Year-4 and Year-3 of post-enhancement monthly fish monitoring and seasonal oyster monitoring on the FHE reefs in Ninigret and Quonochontaug Ponds, respectively. At the end of the monitoring season we also plan to reseed the Ninigret Pond FHE Reefs. We will also investigate whether additional monitoring should be implemented, such as video, snorkel transect surveys, utilizing habitat trays which will allow us to estimate density and productivity of prey species that live in and around the reefs.

CONCLUSION

With exception for the setbacks in Pt. Judith pond reef construction, all other tasks were completed as expected. We completed the Year-3 post-enhancement fish and habitat (reef) monitoring of FHE reefs sites in Ninigret Pond, conducted Year-2 post-enhancement fish and habitat (reef) monitoring of FHE sites in Quonochontaug, and began planning for the 2019 season including discussions regarding the inclusion of additional sampling techniques.

Overall, a qualitative assessment appears to show more fish species were observed at FHE reefs during the post-enhancement monitoring (i.e. after reef construction) compared with the pre-enhancement baseline. However, one more year of additional data will be needed to properly evaluate the success of these FHE reefs over time. Reef habitat monitoring showed the overall health of the FHE reefs in both Ninigret Pond and Quonochontaug Pond was good, with higher densities and more potential for self-sustaining recruitment on the Quonochontaug Pond at the Ninigret reefs.

We believe conducting video work, in addition to the current fish monitoring survey work, will confirm that the targeted fish species utilizing the FHE sites are being captured by our sampling gear, as well as provide insight into fish behavior, such as residence time and reef utilization. We will also investigate whether additional monitoring should be implemented and or current monitoring techniques should be removed (i.e, Gillnets).

The additional assistance from the DMF contract employee, as well as DMF and TNC seasonal staff was crucial in completing all necessary reef construction and monitoring in 2018. We have determined that this additional staffing will be required once again to complete fish habitat monitoring in 2019.

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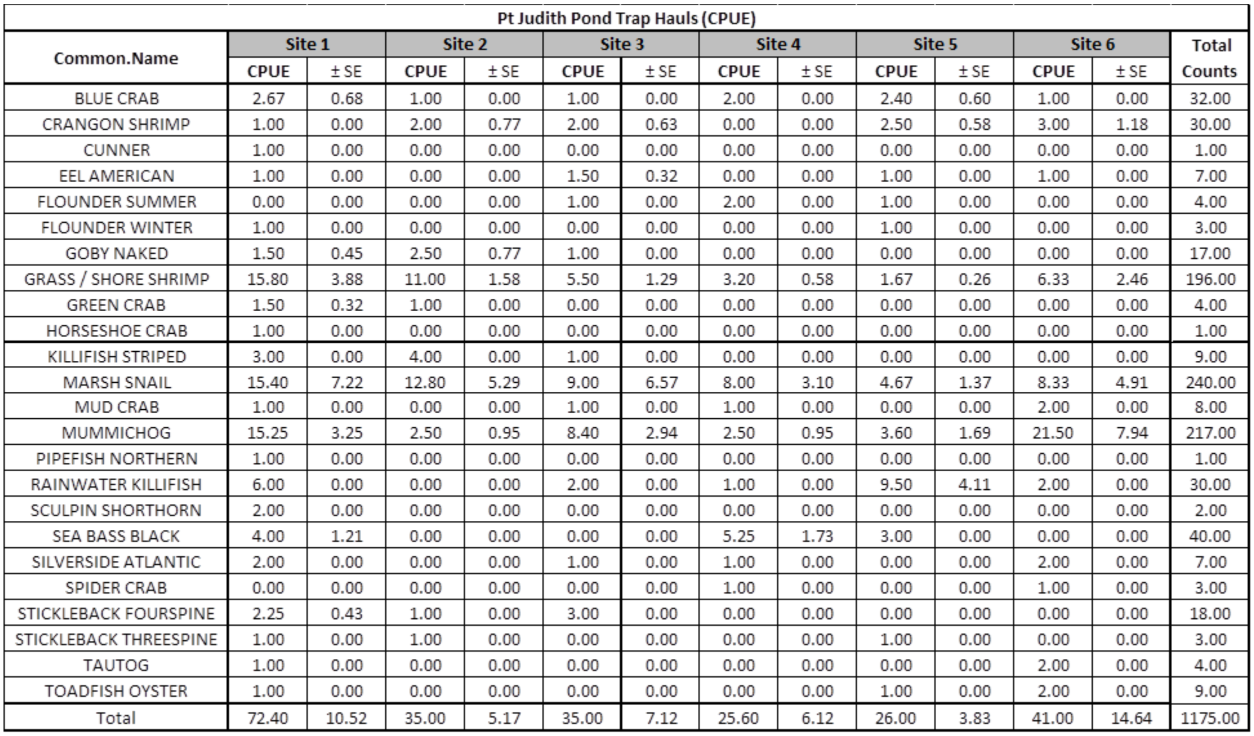


Pt Judith Pond Trap Hauls (CPUE)

Common.Name	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6		Total Counts
	CPUE	± SE	CPUE	± SE	CPUE	± SE	CPUE	± SE	CPUE	± SE	CPUE	± SE	
BLUE CRAB	2.67	0.68	1.00	0.00	1.00	0.00	2.00	0.00	2.40	0.60	1.00	0.00	32.00
CRANGON SHRIMP	1.00	0.00	2.00	0.77	2.00	0.63	0.00	0.00	2.50	0.58	3.00	1.18	30.00
CUNNER	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
EEL AMERICAN	1.00	0.00	0.00	0.00	1.50	0.32	0.00	0.00	1.00	0.00	1.00	0.00	7.00
FLOUNDER SUMMER	0.00	0.00	0.00	0.00	1.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00	4.00
FLOUNDER WINTER	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00
GOBY NAKED	1.50	0.45	2.50	0.77	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00
GRASS / SHORE SHRIMP	15.80	3.88	11.00	1.58	5.50	1.29	3.20	0.58	1.67	0.26	6.33	2.46	196.00
GREEN CRAB	1.50	0.32	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
HORSESHOE CRAB	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
KILLIFISH STRIPED	3.00	0.00	4.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00
MARSH SNAIL	15.40	7.22	12.80	5.29	9.00	6.57	8.00	3.10	4.67	1.37	8.33	4.91	240.00
MUD CRAB	1.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	2.00	0.00	8.00
MUMMICHOG	15.25	3.25	2.50	0.95	8.40	2.94	2.50	0.95	3.60	1.69	21.50	7.94	217.00
PIPEFISH NORTHERN	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
RAINWATER KILLIFISH	6.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	9.50	4.11	2.00	0.00	30.00
SCULPIN SHORTHORN	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
SEA BASS BLACK	4.00	1.21	0.00	0.00	0.00	0.00	5.25	1.73	3.00	0.00	0.00	0.00	40.00
SILVERSIDE ATLANTIC	2.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	2.00	0.00	7.00
SPIDER CRAB	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	3.00
STICKLEBACK FOURSPINE	2.25	0.43	1.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00
STICKLEBACK THREESPINE	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00
TAUTOG	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	4.00
TOADFISH OYSTER	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	2.00	0.00	9.00
Total	72.40	10.52	35.00	5.17	35.00	7.12	25.60	6.12	26.00	3.83	41.00	14.64	1175.00

Table 1. Summary of species caught in Pt Judith Pond during the 2018 pre-enhancement baseline survey for all Eel Pot and Minnow Trap hauls.

Common Name	Ninigret Pond Traps (CPUE)											
	2015 (Pre Enhancement)			2016			2017			2018		
	Control	Unseeded	ARC	Control	Unseeded	ARC	Control	Unseeded	ARC	Control	Unseeded	ARC
ALEWIFE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
AMBERJACK GREATER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BASS STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BLUE CRAB	0 ± 0	0.48 ± 0.33	0 ± 0	0.24 ± 0.17	**0.37 ± 0.18**	**0 ± 0**	0.45 ± 0.16	**0.55 ± 0.19**	**0.37 ± 0.15**	0 ± 0	**0.24 ± 0.12**	**0.48 ± 0.2**
BLUEFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BUTTERFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CRANGON SHRIMP	0 ± 0	0 ± 0	0 ± 0	0.34 ± 0.17	**0.17 ± 0.12**	**0.17 ± 0.12**	3.51 ± 0.35	**4.22 ± 0.33**	**4.1 ± 0.35**	3.11 ± 0.33	**2.03 ± 0.33**	**2.33 ± 0.36**
CROAKER ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CUNNER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.46 ± 0.23**	**0.17 ± 0.12**	0 ± 0	**0.45 ± 0.16**	**0.64 ± 0.2**	0.21 ± 0.1	**0.67 ± 0.23**	**0.83 ± 0.21**
EEL AMERICAN	0.58 ± 0.4	0.48 ± 0.33	0.69 ± 0.37	0 ± 0	0 ± 0	0 ± 0	0.26 ± 0.13	**0 ± 0**	**0.38 ± 0.15**	0.53 ± 0.22	**0.65 ± 0.23**	**0.21 ± 0.15**
FLOUNDER SUMMER	0 ± 0	0 ± 0	0 ± 0	0.17 ± 0.12	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
FLOUNDER WINTER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.15 ± 0.1**	**0.13 ± 0.09**	0 ± 0	0 ± 0	**0.18 ± 0.13**
GOBY NAKED	0 ± 0	0 ± 0	0 ± 0	0.29 ± 0.2	**0.51 ± 0.25**	0.29 ± 0.2	0.39 ± 0.19	**0.17 ± 0.12**	**0.53 ± 0.21**	0.31 ± 0.12	**0 ± 0**	**0.11 ± 0.08**
GREEN CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HERRING ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HOGCHOKER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HORSESHOE CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
KILLIFISH STRIPED	0 ± 0	0 ± 0	0.62 ± 0.42	0.43 ± 0.21	**0 ± 0**	**0 ± 0**	0.18 ± 0.13	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0
KINGFISH NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
LADY CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MACKEREL ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MANTIS SHRIMP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MENHADEN ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MUD CRAB	0 ± 0	0 ± 0	0 ± 0	0.17 ± 0.12	**0.83 ± 0.32**	**1.36 ± 0.36**	0.61 ± 0.22	**0.68 ± 0.21**	**1.04 ± 0.27**	1.03 ± 0.27	**2.52 ± 0.33**	**2.68 ± 0.36**
MULLET STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MULLET WHITE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MUMMICHOG	0 ± 0	0 ± 0	0.68 ± 0.47	2.07 ± 0.38	**1.59 ± 0.37**	**0.86 ± 0.29**	0.18 ± 0.13	**0.29 ± 0.14**	**0.25 ± 0.12**	0.21 ± 0.15	**0.21 ± 0.15**	**0.39 ± 0.19**
NEEDLEFISH ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PERCH WHITE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PINFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.13 ± 0.09	**0.25 ± 0.12**	**0.3 ± 0.15**	0 ± 0	0 ± 0	0 ± 0
PIPEFISH NORTHERN	0 ± 0	0.53 ± 0.37	0 ± 0	0 ± 0	**0.17 ± 0.12**	**0.17 ± 0.12**	0 ± 0	**0.44 ± 0.17**	**0.18 ± 0.13**	0.25 ± 0.12	**0.23 ± 0.13**	**0.21 ± 0.1**
POLLOCK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RAINWATER KILLIFISH	0.59 ± 0.41	1.8 ± 0.64	0.58 ± 0.4	3.22 ± 0.38	**2.26 ± 0.37**	**2.14 ± 0.35**	1.01 ± 0.28	**0.84 ± 0.23**	**0.6 ± 0.18**	0.61 ± 0.22	**0.4 ± 0.16**	**0.55 ± 0.22**
RIVER HERRING	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
ROCK CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUDDERFISH BANDED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUNNER BLUE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SAND TIGER SHARK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPIN SHORTHORN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPINS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.15 ± 0.1**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCUP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.12 ± 0.08	**0.38 ± 0.15**	**0.4 ± 0.16**	0.44 ± 0.17	**0.1 ± 0.1**	**0.11 ± 0.08**
SEA BASS BLACK	0 ± 0	0 ± 0	0 ± 0	0.88 ± 0.29	**0.84 ± 0.28**	**1.28 ± 0.33**	0.33 ± 0.16	**0.52 ± 0.18**	**0.68 ± 0.21**	0.6 ± 0.18	**1.7 ± 0.33**	**1.12 ± 0.29**
SEAROBIN STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SENNET NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SILVERSIDE ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.65 ± 0.21	**0.8 ± 0.22**	**0.41 ± 0.16**	0.52 ± 0.19	**0.06 ± 0.05**	**0.86 ± 0.27**
SMOOTH DOGFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SNAPPER GRAY	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.12 ± 0.09**
SPIDER CRAB	0 ± 0	0 ± 0	0.53 ± 0.37	0.29 ± 0.2	**0.72 ± 0.28**	**0 ± 0**	0 ± 0	**0.11 ± 0.08**	0 ± 0	0 ± 0	**0.19 ± 0.1**	0 ± 0
SPOT	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.1 ± 0.07	**0.24 ± 0.12**	**0.13 ± 0.09**	0 ± 0	0 ± 0	0 ± 0
STICKLEBACK FOURSPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.14 ± 0.1	**0.43 ± 0.17**	**0.13 ± 0.09**	0 ± 0	**0.06 ± 0.05**	**0.15 ± 0.11**
STICKLEBACK THREESPINE	1.24 ± 0.57	0.58 ± 0.4	1.12 ± 0.52	0.99 ± 0.33	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.08 ± 0.06**	**0.07 ± 0.05**
TAUTOG	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.29 ± 0.2**	0 ± 0	**0.79 ± 0.24**	**0.45 ± 0.18**	0.37 ± 0.15	**0.59 ± 0.19**	**0.81 ± 0.22**
TOADFISH OYSTER	0.75 ± 0.38	0.48 ± 0.33	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.45 ± 0.18	**0.72 ± 0.2**	**0.4 ± 0.16**	0.55 ± 0.2	**1.57 ± 0.29**	**1.63 ± 0.32**
TOMCOD ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.17 ± 0.12	**0.29 ± 0.14**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0
WEAKFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 2a. Summary of species caught by year and enhancement treatment for all Eel Pot and Minnow Trap hauls from Ninigret Pond, summed across sites by month. Species of interest are highlighted in yellow. Mean CPUEs for enhancement treatments are colored relative to the control sites for each year. Red < Control, Blue > Control.

Common Name	Ninigret Pond Gillnets (CPUE)											
	2015 (Pre Enhancement)			2016			2017			2018		
	Control	Unseeded	ARC	Control	Unseeded	ARC	Control	Unseeded	ARC	Control	Unseeded	ARC
ALEWIFE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.35 ± 0.35	0 ± 0	0 ± 0	0.38 ± 0.38	0.38 ± 0.38
AMBERJACK GREATER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.34 ± 0.34	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BASS STRIPED	0 ± 0	0 ± 0	0 ± 0	4.02 ± 0.85	3.49 ± 0.87	2.45 ± 0.8	4.4 ± 0.85	3.08 ± 0.83	3.86 ± 0.89	3.07 ± 0.81	1.66 ± 0.7	2.6 ± 0.79
BLUE CRAB	2.83 ± 1.38	0.91 ± 0.91	2.83 ± 1.38	5.8 ± 0.8	5.11 ± 0.84	2.67 ± 0.79	3.07 ± 0.83	3.44 ± 0.85	3.78 ± 0.86	1.98 ± 0.67	1.81 ± 0.68	1.4 ± 0.66
BLUEFISH	1.92 ± 1.26	0.96 ± 0.96	1.92 ± 1.26	0.92 ± 0.51	1.23 ± 0.57	1.58 ± 0.64	1.69 ± 0.69	2.31 ± 0.75	0.37 ± 0.37	1.73 ± 0.65	2.32 ± 0.73	1.34 ± 0.57
BUTTERFISH	0 ± 0	0 ± 0	0 ± 0	0.38 ± 0.38	0.79 ± 0.56	0 ± 0	0.69 ± 0.48	0.32 ± 0.32	0 ± 0	0.22 ± 0.22	0 ± 0	0 ± 0
CRANGON SHRIMP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CROAKER ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CUNNER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
EEL AMERICAN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
FLOUNDER SUMMER	0 ± 0	0 ± 0	0 ± 0	0.31 ± 0.31	0 ± 0	0 ± 0	0.37 ± 0.37	0 ± 0	0 ± 0	0.43 ± 0.3	0.22 ± 0.22	0.36 ± 0.36
FLOUNDER WINTER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.37 ± 0.37	0 ± 0	0 ± 0	0 ± 0
GOBY NAKED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GREEN CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HERRING ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.34 ± 0.34	0 ± 0	0.2 ± 0.2	0 ± 0
HOGCHOKER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.35 ± 0.35	0 ± 0	0 ± 0	0 ± 0
HORSESHOE CRAB	0 ± 0	0 ± 0	0 ± 0	0.34 ± 0.34	0 ± 0	0.35 ± 0.35	0.37 ± 0.37	0 ± 0	0.36 ± 0.36	0 ± 0	0 ± 0	0 ± 0
KILLIFISH STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
KINGFISH NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.37 ± 0.37	0 ± 0	0 ± 0	0.42 ± 0.42	0 ± 0	0.2 ± 0.2
LADY CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.33 ± 0.33	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MACKEREL ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MANTIS SHRIMP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MENHADEN ATLANTIC	2.83 ± 1.38	1.92 ± 1.26	3.39 ± 1.33	3.25 ± 0.9	3.78 ± 0.89	4.18 ± 0.9	2.64 ± 0.78	3.04 ± 0.82	2.98 ± 0.81	2.65 ± 0.68	2.1 ± 0.66	2.6 ± 0.74
MUD CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MULLET STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MULLET WHITE	0 ± 0	0 ± 0	0 ± 0	0.7 ± 0.49	0.35 ± 0.35	1.18 ± 0.66	0 ± 0	0 ± 0	0 ± 0	0.22 ± 0.22	0 ± 0	0.22 ± 0.22
MUMMICHOG	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
NEEDLEFISH ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0.74 ± 0.51	0.36 ± 0.36	0.34 ± 0.34	0.66 ± 0.46	1.06 ± 0.59	1.04 ± 0.58	0.73 ± 0.51	0.49 ± 0.34	0.26 ± 0.26
PERCH WHITE	0 ± 0	0 ± 0	0 ± 0	0.31 ± 0.31	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PINFISH	0 ± 0	0 ± 0	0.96 ± 0.96	0 ± 0	0 ± 0	0 ± 0	0.68 ± 0.47	0.3 ± 0.3	1.28 ± 0.6	0 ± 0	0 ± 0	0.22 ± 0.22
PIPEFISH NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.36 ± 0.36	0 ± 0
POLLOCK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RAINWATER KILLIFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RIVER HERRING	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	4.7 ± 0.83	4.37 ± 0.84	4.86 ± 0.88	0.72 ± 0.5	0.81 ± 0.47	0.54 ± 0.4
ROCK CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUDDERFISH BANDED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUNNER BLUE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SAND TIGER SHARK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPIN SHORTHORN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPINS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCUP	0 ± 0	0 ± 0	0 ± 0	1.33 ± 0.74	1.68 ± 0.79	1.72 ± 0.81	0.37 ± 0.37	0.37 ± 0.37	0.37 ± 0.37	1.4 ± 0.51	0.87 ± 0.4	1.65 ± 0.54
SEA BASS BLACK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.75 ± 0.54	0 ± 0	0 ± 0	0.32 ± 0.32	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SEAROBIN STRIPED	0.91 ± 0.91	0.91 ± 0.91	0.91 ± 0.91	1.64 ± 0.78	1.3 ± 0.73	0.95 ± 0.66	0.37 ± 0.37	0 ± 0	0.37 ± 0.37	0 ± 0	0.22 ± 0.22	0.43 ± 0.3
SENNET NORTHERN	0 ± 0	0 ± 0	0 ± 0	0.75 ± 0.52	0 ± 0	0 ± 0	0.68 ± 0.47	0 ± 0	0 ± 0	0.3 ± 0.3	0 ± 0	0 ± 0
SILVERSIDE ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SMOOTH DOGFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.33 ± 0.33	0 ± 0	0 ± 0	0 ± 0
SNAPPER GRAY	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SPIDER CRAB	0.96 ± 0.96	0.96 ± 0.96	0 ± 0	3 ± 0.89	2.44 ± 0.8	1.04 ± 0.58	2.39 ± 0.78	2.46 ± 0.8	2.44 ± 0.79	1.6 ± 0.68	1.12 ± 0.54	1.22 ± 0.58
SPOT	0 ± 0	0 ± 0	0 ± 0	0.31 ± 0.31	0 ± 0	0 ± 0	0.64 ± 0.45	0.64 ± 0.45	1.01 ± 0.56	0 ± 0	0.42 ± 0.42	0 ± 0
STICKLEBACK FOURSPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
STICKLEBACK THREESPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TAUTOG	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.31 ± 0.31	0.68 ± 0.47	0.5 ± 0.5	0 ± 0	0 ± 0	0.42 ± 0.42
TOADFISH OYSTER	0 ± 0	0 ± 0	0 ± 0	0.35 ± 0.35	0.66 ± 0.46	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0
TOMCOD ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.34 ± 0.34	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
WEAKFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 2b. Summary of species caught by year and enhancement treatment for all Gillnets hauls from Ninigret Pond, summed across sites by month. Species of interest are highlighted in yellow. Mean CPUEs for enhancement treatments are colored relative to the control sites for each year. Red < Control, Blue > Control.

Common Name	Quonochontaug Pond Traps (CPUE)											
	2016 (Pre Enhancement)				2017				2018			
	Control	ARC	Narrow River	Green Hiill Pond	Control	ARC	Narrow River	Green Hiill Pond	Control	ARC	Narrow River	Green Hiill Pond
ALEWIFE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
AMBERJACK GREATER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BASS STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BLUE CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.56 ± 0.22	**0.13 ± 0.1**	**0.13 ± 0.1**	**0.37 ± 0.18**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BLUEFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BUTTERFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CRANGON SHRIMP	0 ± 0	0 ± 0	0.18 ± 0.13	0 ± 0	3.11 ± 0.41	**3.23 ± 0.4**	**2.76 ± 0.42**	**2.71 ± 0.44**	0.54 ± 0.2	**0.97 ± 0.31**	**0.74 ± 0.25**	**0.21 ± 0.11**
CROAKER ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CUNNER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.02 ± 0.35	**0.89 ± 0.3**	**0.8 ± 0.28**	**0.19 ± 0.13**	1.01 ± 0.28	**0.86 ± 0.29**	**1.05 ± 0.3**	**1.08 ± 0.27**
EEL AMERICAN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.23 ± 0.33	**0.18 ± 0.12**	**0.32 ± 0.22**	**0.56 ± 0.23**	0.21 ± 0.1	**0.41 ± 0.2**	**0.8 ± 0.27**	**0.59 ± 0.23**
FLOUNDER SUMMER	0 ± 0	0.41 ± 0.29	0 ± 0	0 ± 0	0.24 ± 0.17	**0 ± 0**	**0 ± 0**	**0.25 ± 0.18**	0.32 ± 0.16	**0.24 ± 0.17**	**0 ± 0**	**0 ± 0**
FLOUNDER WINTER	0 ± 0	0 ± 0	0.78 ± 0.37	1.5 ± 0.48	1.55 ± 0.31	**1.75 ± 0.33**	**0.87 ± 0.26**	**1.05 ± 0.31**	1.81 ± 0.37	**1.51 ± 0.36**	**1.3 ± 0.33**	**0.86 ± 0.29**
GOBY NAKED	0.51 ± 0.35	0.34 ± 0.24	0.41 ± 0.29	0 ± 0	0.13 ± 0.1	**0 ± 0**	0.13 ± 0.1	**0.43 ± 0.21**	0.19 ± 0.11	**0.39 ± 0.19**	**0.39 ± 0.19**	**0.2 ± 0.14**
GREEN CRAB	0.85 ± 0.41	0.41 ± 0.28	0.72 ± 0.35	0.68 ± 0.32	0.88 ± 0.3	**0.54 ± 0.21**	**0.71 ± 0.24**	**3.12 ± 0.48**	1.16 ± 0.29	**0.69 ± 0.24**	**1.3 ± 0.35**	**1.27 ± 0.33**
HERRING ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HOGCHOKER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HORSESHOE CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
KILLIFISH STRIPED	0 ± 0	0 ± 0	0 ± 0	0.45 ± 0.31	0 ± 0	0 ± 0	**0.33 ± 0.16**	0 ± 0	0.42 ± 0.22	**0.23 ± 0.16**	**0.23 ± 0.16**	**0 ± 0**
KINGFISH NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.29 ± 0.2**	0 ± 0	0 ± 0
LADY CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MACKEREL ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MANTIS SHRIMP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MENHADEN ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.24 ± 0.17	**0 ± 0**	**0.31 ± 0.15**	**0 ± 0**
MUD CRAB	0.45 ± 0.31	0.34 ± 0.24	0.67 ± 0.34	0.67 ± 0.34	0.23 ± 0.16	**1.17 ± 0.36**	**1.73 ± 0.43**	**0 ± 0**	1.73 ± 0.3	**2.03 ± 0.34**	**2.36 ± 0.35**	**2.51 ± 0.32**
MULLET STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MULLET WHITE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MUMMICHOG	0 ± 0	0.79 ± 0.38	1.55 ± 0.49	0.22 ± 0.16	0 ± 0	0 ± 0	**0.63 ± 0.27**	0 ± 0	0.45 ± 0.18	**0.19 ± 0.13**	**0.48 ± 0.24**	**0.17 ± 0.12**
NEEDLEFISH ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PERCH WHITE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PINFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.82 ± 0.24	**0 ± 0**	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PIPEFISH NORTHERN	0 ± 0	0.22 ± 0.16	0.89 ± 0.34	0 ± 0	0.36 ± 0.18	**0.31 ± 0.15**	**0 ± 0**	**0 ± 0**	0.64 ± 0.25	**0.23 ± 0.16**	0.64 ± 0.25	**0.4 ± 0.2**
POLLOCK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.14 ± 0.1**	0 ± 0	**0.3 ± 0.15**
RAINWATER KILLIFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.18 ± 0.13	**0.57 ± 0.23**	**0.46 ± 0.18**	**0.73 ± 0.25**	0.19 ± 0.11	**0.23 ± 0.16**	**0 ± 0**	**0 ± 0**
RIVER HERRING	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.23 ± 0.16	**0.27 ± 0.19**	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	**0.14 ± 0.1**	0 ± 0
ROCK CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.24 ± 0.17**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUDDERFISH BANDED	0.27 ± 0.19	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUNNER BLUE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SAND TIGER SHARK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPIN SHORTHORN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.17 ± 0.12	**0 ± 0**	**0.16 ± 0.11**	**0.16 ± 0.12**	0.45 ± 0.22	**0.24 ± 0.17**	**0 ± 0**	**0 ± 0**
SCULPINS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.5 ± 0.25	**0.32 ± 0.22**	**0 ± 0**	**0.27 ± 0.19**	0.24 ± 0.13	**0.51 ± 0.22**	**0.09 ± 0.07**	**0.57 ± 0.23**
SCUP	0 ± 0	0 ± 0	0.5 ± 0.24	0 ± 0	0.27 ± 0.19	**0.15 ± 0.1**	**0 ± 0**	**0 ± 0**	1.47 ± 0.31	**0.46 ± 0.18**	**1.17 ± 0.29**	**0.95 ± 0.26**
SEA BASS BLACK	1.6 ± 0.39	1.39 ± 0.34	1.7 ± 0.37	1.55 ± 0.39	3.01 ± 0.41	**1.38 ± 0.33**	**2.64 ± 0.42**	**2.02 ± 0.42**	2.09 ± 0.34	**2.3 ± 0.32**	**1.99 ± 0.31**	**2.34 ± 0.32**
SEAROBIN STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SENNET NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SILVERSIDE ATLANTIC	0.77 ± 0.29	0.72 ± 0.27	0.27 ± 0.19	0.84 ± 0.32	1.19 ± 0.35	**1.37 ± 0.37**	**0.74 ± 0.25**	**0.66 ± 0.26**	0.54 ± 0.21	**0.18 ± 0.13**	**0.28 ± 0.14**	**0.23 ± 0.16**
SMOOTH DOGFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SNAPPER GRAY	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SPIDER CRAB	0 ± 0	0 ± 0	0.41 ± 0.28	0 ± 0	0.51 ± 0.25	**0 ± 0**	**0.19 ± 0.14**	**0 ± 0**	0.34 ± 0.18	**0 ± 0**	**0.59 ± 0.23**	**0 ± 0**
SPOT	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.19 ± 0.14	**0 ± 0**	**0 ± 0**	**0 ± 0**	0.04 ± 0.03	**0.07 ± 0.05**	**0 ± 0**	**0 ± 0**
STICKLEBACK FOURSPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.67 ± 0.27**	0 ± 0	**0.23 ± 0.16**	0.48 ± 0.2	**0.08 ± 0.06**	**0.32 ± 0.18**	**0.29 ± 0.15**
STICKLEBACK THREESPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.13 ± 0.1	**0 ± 0**	**0 ± 0**	**0 ± 0**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TAUTOG	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.94 ± 0.32	**1.24 ± 0.33**	**1.57 ± 0.38**	**1.14 ± 0.28**	0 ± 0	**0.39 ± 0.2**	**0.34 ± 0.16**	**0.97 ± 0.22**
TOADFISH OYSTER	0 ± 0	0 ± 0	0.37 ± 0.26	0 ± 0	0.59 ± 0.23	**1.02 ± 0.31**	**0.7 ± 0.29**	**1.47 ± 0.36**	1.03 ± 0.28	**1 ± 0.27**	**1.13 ± 0.28**	**1.13 ± 0.28**
TOMCOD ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.31 ± 0.22	**0 ± 0**	**0 ± 0**	**0.19 ± 0.13**	0.24 ± 0.17	**0.26 ± 0.13**	**0 ± 0**	**0.08 ± 0.06**
WEAKFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0

Table 3a. Summary of species caught by year and enhancement treatment for all Eel Pot and Minnow Trap hauls from Quonochontaug Pond, summed across sites by month. Species of interest are highlighted in yellow. Mean CPUEs for enhancement treatments are colored relative to the control sites for each year. Red < Control, Blue > Control.

Common Name	Quonochontaug Pond Gillnets (CPUE)											
	2016 (Pre Enhancement)				2017				2018			
	Control	ARC	Narrow River	Green Hiill Pond	Control	ARC	Narrow River	Green Hiill Pond	Control	ARC	Narrow River	Green Hiill Pond
ALEWIFE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.49 ± 0.49	**0.33 ± 0.33**	0.49 ± 0.49	**0.24 ± 0.24**
AMBERJACK GREATER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
BASS STRIPED	4.42 ± 0.94	4.28 ± 0.92	5.24 ± 0.96	4.01 ± 0.92	6.69 ± 0.74	**6.23 ± 0.86**	**5.08 ± 0.98**	**6.44 ± 0.88**	5.11 ± 0.72	**3.21 ± 0.79**	**5.29 ± 0.73**	**3.7 ± 0.84**
BLUE CRAB	2.37 ± 0.89	2.53 ± 0.94	2.24 ± 0.83	1.85 ± 0.81	1.52 ± 0.83	**1.54 ± 0.84**	**0.41 ± 0.41**	**1.53 ± 0.83**	1.43 ± 0.68	**1.19 ± 0.66**	**2.36 ± 0.84**	**0.99 ± 0.56**
BLUEFISH	2.62 ± 0.84	3.06 ± 0.97	2.82 ± 0.92	3.11 ± 0.99	1.88 ± 0.84	**1.99 ± 0.88**	**2.02 ± 0.89**	**1.84 ± 0.82**	1.52 ± 0.69	**0.65 ± 0.45**	**1.44 ± 0.66**	**1.65 ± 0.75**
BUTTERFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.45 ± 0.45**
CRANGON SHRIMP	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CROAKER ATLANTIC	0 ± 0	0.51 ± 0.51	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
CUNNER	0 ± 0	0 ± 0	0.66 ± 0.66	0.59 ± 0.59	0 ± 0	**0.89 ± 0.61**	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.83 ± 0.58**
EEL AMERICAN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
FLOUNDER SUMMER	0 ± 0	0.61 ± 0.61	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.45 ± 0.45**
FLOUNDER WINTER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GOBY NAKED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GREEN CRAB	1.13 ± 0.78	1.11 ± 0.76	0.66 ± 0.66	0.94 ± 0.64	0.52 ± 0.52	**0.61 ± 0.61**	**0.44 ± 0.44**	**1.12 ± 0.77**	0 ± 0	**0.44 ± 0.44**	**0.74 ± 0.51**	**0.28 ± 0.28**
HERRING ATLANTIC	0.54 ± 0.54	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.35 ± 0.35**	0 ± 0	0 ± 0
HOGCHOKER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
HORSESHOE CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.45 ± 0.77	**0.57 ± 0.57**	**0 ± 0**	**0 ± 0**	0.88 ± 0.61	**1.09 ± 0.61**	**0.39 ± 0.39**	**0.39 ± 0.39**
KILLIFISH STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
KINGFISH NORTHERN	0.42 ± 0.42	0 ± 0	0 ± 0	0.99 ± 0.68	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.26 ± 0.26	0.26 ± 0.26	**0.77 ± 0.53**	**0 ± 0**
LADY CRAB	2.02 ± 0.9	1.56 ± 0.83	2.46 ± 0.94	1.09 ± 0.74	1.45 ± 0.77	**0.61 ± 0.61**	**0.96 ± 0.66**	**0.6 ± 0.6**	1.14 ± 0.62	**0.75 ± 0.52**	**0.35 ± 0.35**	**0.28 ± 0.28**
MACKEREL ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.35 ± 0.35**	0 ± 0	**0.41 ± 0.41**
MANTIS SHRIMP	0 ± 0	0.99 ± 0.68	0.54 ± 0.54	0.59 ± 0.59	0 ± 0	0 ± 0	0 ± 0	**0.51 ± 0.51**	0.75 ± 0.52	**0 ± 0**	**0 ± 0**	**0 ± 0**
MENHADEN ATLANTIC	4.51 ± 0.81	2.53 ± 0.94	4.11 ± 0.87	3.98 ± 0.93	0.41 ± 0.41	**0.97 ± 0.66**	**0.48 ± 0.48**	**2.49 ± 0.95**	1.24 ± 0.68	**1.42 ± 0.65**	**1.41 ± 0.65**	**1.75 ± 0.69**
MUD CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.41 ± 0.41**	0 ± 0
MULLET STRIPED	0.66 ± 0.66	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
MULLET WHITE	1.09 ± 0.74	1.44 ± 0.77	0.37 ± 0.37	1.17 ± 0.79	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.41 ± 0.41**	0 ± 0	0 ± 0
MUMMICHOG	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
NEEDLEFISH ATLANTIC	0 ± 0	0 ± 0	0.37 ± 0.37	0.4 ± 0.4	0.41 ± 0.41	**0 ± 0**	**0 ± 0**	**0 ± 0**	0.36 ± 0.36	**0 ± 0**	**0.4 ± 0.4**	**0.38 ± 0.38**
PERCH WHITE	0 ± 0	0 ± 0	0.37 ± 0.37	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
PINFISH	0 ± 0	0 ± 0	0 ± 0	0.45 ± 0.45	0.48 ± 0.48	**1.21 ± 0.83**	**1.58 ± 0.85**	**0.6 ± 0.6**	0.35 ± 0.35	**0 ± 0**	**0 ± 0**	**0 ± 0**
PIPEFISH NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.52 ± 0.52**	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
POLLOCK	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RAINWATER KILLIFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RIVER HERRING	1.96 ± 0.87	1.63 ± 0.87	2.6 ± 0.98	1.61 ± 0.86	4.23 ± 1.07	**3 ± 1**	**3.7 ± 1.07**	**3.6 ± 1.04**	1.52 ± 0.69	**1.87 ± 0.74**	**1.18 ± 0.64**	**1.63 ± 0.74**
ROCK CRAB	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1.02 ± 0.7	**0.57 ± 0.57**	**0 ± 0**	**0.57 ± 0.57**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUDDERFISH BANDED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
RUNNER BLUE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.41 ± 0.41	**0 ± 0**	**0 ± 0**	**0 ± 0**
SAND TIGER SHARK	0 ± 0	0 ± 0	0.47 ± 0.47	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPIN SHORTHORN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCULPINS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SCUP	0.54 ± 0.54	1.17 ± 0.79	0.54 ± 0.54	1.17 ± 0.79	0 ± 0	0 ± 0	0 ± 0	**0.98 ± 0.67**	1.05 ± 0.58	**0.76 ± 0.52**	**1.53 ± 0.7**	**1.24 ± 0.68**
SEA BASS BLACK	0 ± 0	0.59 ± 0.59	0.47 ± 0.47	0.59 ± 0.59	1 ± 0.68	**0.5 ± 0.5**	**0 ± 0**	**0.52 ± 0.52**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SEAROBIN STRIPED	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.41 ± 0.41	**0 ± 0**	**0 ± 0**	**0 ± 0**	1.84 ± 0.73	**0.28 ± 0.28**	**1.21 ± 0.66**	**0.84 ± 0.58**
SENNET NORTHERN	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.44 ± 0.44**	0 ± 0
SILVERSIDE ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SMOOTH DOGFISH	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	**0.48 ± 0.48**	**1 ± 0.68**	0 ± 0	0 ± 0	0 ± 0	**0.44 ± 0.44**	0 ± 0
SNAPPER GRAY	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
SPIDER CRAB	3.02 ± 0.99	3.93 ± 1.07	3.43 ± 1.11	2.7 ± 1	3.03 ± 1.01	**2.69 ± 1.02**	**1.04 ± 0.72**	**1.68 ± 0.9**	3.39 ± 0.78	**2.18 ± 0.76**	**2.88 ± 0.88**	**0.78 ± 0.53**
SPOT	0.94 ± 0.64	1.52 ± 0.8	0.94 ± 0.64	1.01 ± 0.69	2.48 ± 0.94	**2.98 ± 0.98**	**2.47 ± 0.93**	**2.94 ± 0.97**	0.73 ± 0.5	**0.38 ± 0.38**	**0.84 ± 0.59**	**0 ± 0**
STICKLEBACK FOURSPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
STICKLEBACK THREESPINE	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TAUTOG	0 ± 0	0 ± 0	0 ± 0	1.21 ± 0.83	1.01 ± 0.69	**0.44 ± 0.44**	**0 ± 0**	**0.52 ± 0.52**	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TOADFISH OYSTER	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TOMCOD ATLANTIC	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
WEAKFISH	0 ± 0	0.51 ± 0.51	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	**0.63 ± 0.44**	**0 ± 0**	**0 ± 0**

Table 3b. Summary of species caught by year and enhancement treatment for all Gillnets hauls from Quonochontaug Pond, summed across sites by month. Species of recreational interest are highlighted in yellow. Mean CPUEs for enhancement treatments are colored relative to the control sites for each year. Red < Control, Blue > Control.

Ninigret Pond Mean Oyster Density								
Age	**Site 1**	± SE	**Site 2**	± SE	**Site 3**	± SE	**Site 4**	± SE
1	854.6667	256.64848	834.4	483.8324	585.3333	381.72474	331	110.87981
1.5	322.6667	59.73869	112	32.86335	147.3333	38.40023	100.5	52.83634
2	250.8571	62.31541	106.8571	34.27301	249.6	140.80682	56.66667	33.88477
2.5	317.3333	95.89809	178	29.23468	325	148.18344	54.66667	31.01254
3	184.8	52.93619	88.8	33.1397	139.2	76.41361	94.4	25.44327
3.5	137.3333	44.20156	40	8.262364	92	35.80689	55.2	15.96997

Table 4a Ninigret Mean Oyster Density.

Ninigret Pond Mean Oyster Length								
Age	**Site 1**	± SE	**Site 2**	± SE	**Site 3**	± SE	**Site 4**	± SE
1	26.84177	1.2584202	29.69115	0.908372	29.73779	0.4259706	28.68507	0.5202961
1.5	50.97806	1.0297008	43.55382	3.652875	58.85677	1.0095301	56.84039	2.7303593
2	58.70952	1.9491527	61.62526	2.816227	73.83894	3.3865256	63.45377	5.3699973
2.5	70.82503	5.0441856	79.12476	2.224702	82.56648	3.9675677	83.24856	13.968188
3	78.42559	4.3891266	93.68073	3.369558	92.8074	6.4136683	88.72768	3.3950965
3.5	77.94617	0.6763464	87.31613	4.637778	99.021	2.3190016	103.87582	8.2418391

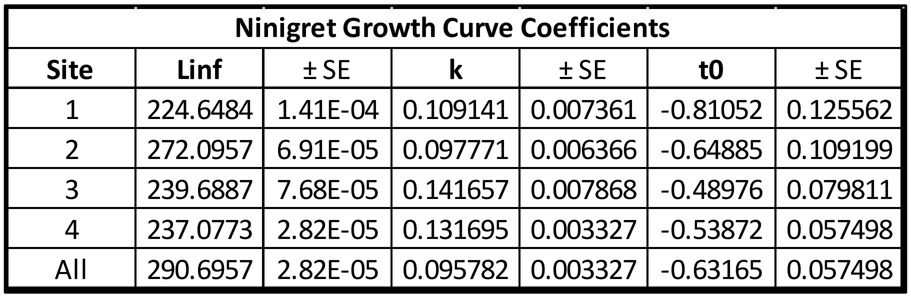
Table 4b Ninigret Mean Oyster Length.

Quonochontaug Mean Oyster Density by Age (A) and Seed (B)							
Panel A	**Age**	**1**	± SE	**1.5**	± SE	**2**	± SE
	Density	496.9524	85.40551	247.7209	37.7029	313.1667	34.43175
Panel B	**Seed**	**ARC**	± SE	**NR**	± SE	**GHP**	± SE
	Density	228.2791	31.77228	343.7333	58.33825	472.7111	68.7037

Table 4c. Mean Oyster Density by A) Age and B) Seed for Quonochontaug Pond.

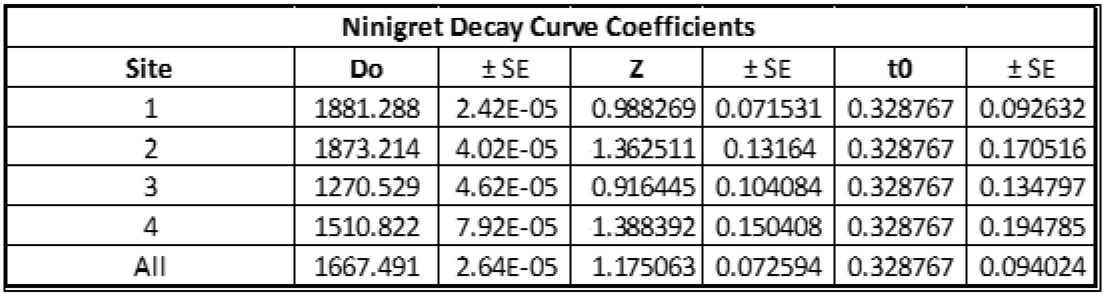
Quonochontaug Mean Oyster Length						
Site	***ARC (at X Year(s))***					
	1	± SE	**1.5**	± SE	**2**	± SE
1	41.59524	3.2480591	47.19048	2.784923	87.06481	5.139333
2	36.94	0.9295221	39.8866	1.592301	64.61191	2.907598
3	*45.19251*	1.679845	55.75717	3.862359	72.88	4.559442
Site	**Narrow River (at X Year(s))**					
	1	± SE	**1.5**	± SE	**2**	± SE
1	42.3	3.606969	57.23854	5.645088	*66.88235*	3.190253
2	36.65501	3.482623	40.6565	1.36721	58.83871	4.025258
3	35.85471	4.776185	53	2.960394	62.76471	4.991429
Site	**Green Hill Pond (at X Year(s))**					
	1	± SE	**1.5**	± SE	**2**	± SE
1	35	2.520608	41.08333	4.050955	55.97938	1.600211
2	27.86158	1.612654	34.80315	2.553719	52.95652	4.63568
3	37.6764	2.344958	44.81982	1.308828	55.11765	1.706675

Table 4d. Mean Oyster Length by site, seed, and age for Quonochontaug Pond.



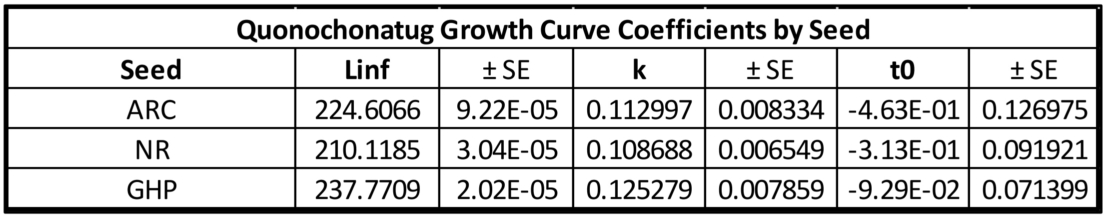
Ninigret Growth Curve Coefficients						
Site	**Linf**	± SE	**k**	± SE	**t0**	± SE
1	224.6484	1.41E-04	0.109141	0.007361	-0.81052	0.125562
2	272.0957	6.91E-05	0.097771	0.006366	-0.64885	0.109199
3	239.6887	7.68E-05	0.141657	0.007868	-0.48976	0.079811
4	237.0773	2.82E-05	0.131695	0.003327	-0.53872	0.057498
All	290.6957	2.82E-05	0.095782	0.003327	-0.63165	0.057498

Table 5a. Ninigret Growth Parameter Estimates by Site.



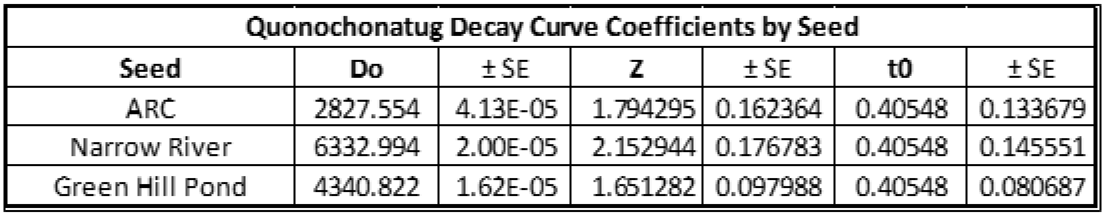
Ninigret Decay Curve Coefficients						
Site	**Do**	± SE	**Z**	± SE	**t0**	± SE
1	1881.288	2.42E-05	0.988269	0.071531	0.328767	0.092632
2	1873.214	4.02E-05	1.362511	0.13164	0.328767	0.170516
3	1270.529	4.62E-05	0.916445	0.104084	0.328767	0.134797
4	1510.822	7.92E-05	1.388392	0.150408	0.328767	0.194785
All	1667.491	2.64E-05	1.175063	0.072594	0.328767	0.094024

Table 5b. Ninigret Mortality Parameter Estimates by Site.



Quonochonatug Growth Curve Coefficients by Seed						
Seed	**Linf**	± SE	**k**	± SE	**t0**	± SE
ARC	224.6066	9.22E-05	0.112997	0.008334	-4.63E-01	0.126975
NR	210.1185	3.04E-05	0.108688	0.006549	-3.13E-01	0.091921
GHP	237.7709	2.02E-05	0.125279	0.007859	-9.29E-02	0.071399

Table 5c. Quonochontaug Growth Parameter Estimates by Seed.



Quonochonatug Decay Curve Coefficients by Seed						
Seed	**Do**	± SE	**Z**	± SE	**t0**	± SE
ARC	2827.554	4.13E-05	1.794295	0.162364	0.40548	0.133679
Narrow River	6332.994	2.00E-05	2.152944	0.176783	0.40548	0.145551
Green Hill Pond	4340.822	1.62E-05	1.651282	0.097988	0.40548	0.080687

Table 5d. Quonochontaug Mortality Parameter Estimates by Seed.

6a)

YOY Generalized Addative Models - Approximate signficinte of smooth terms (edf, p-value)							
Species	**Pond**	**Temp (°C)**	**Salinity (ppt)**	**DO (mg/L)**	**EOD (ind/m2)**	**EOL (mm)**	**te(EOD,EOL)**
Sea Bass Black$_{1,2}$	Ninigret	1.972 ***	1.001 ***	X	X	X	-
	Quonochontaug	1.971 ***	1.884 *	X	X	X	3.992 ***
Tautog$_{3,4}$	Ninigret	X	X	X	X	1 .	-
	Quonochontaug	1.84 *	1	X	1.27 **	X	X
Scup$_{5,6}$	Ninigret	X	1.926 **	1 ***	X	X	-
	Quonochontaug	1.958 ***	1.918 **	X	X	X	4.591 *
Winter Flounder$_{7}$	Quonochontaug	1 ***	1.92 **	X	X	X	3 *

6b)

YOY Generalized Addative Models - Parametric Coefficients (estimate, Pr(>|z|))								
Species	**Pond**	**Year**		**Site**			**Treatment**	
		2017	**2018**	**Site 2**	**Site 3**	**Site 4**	**Unseeded**	**Seeded**
Sea Bass Black$_{1,2}$	Ninigret	- 5.7967 ***	-1.7116 ***	0.5950 .	0.8019 *	0.7510 *	1.0648 **	1.8791 ***
	Quonochontaug	X	X	0.9412 *	1.5019 ***	-	-	-
Tautog$_{3,4}$	Ninigret	X	X	X	X	1.4210 *	2.4014 *	5.5939 **
	Quonochontaug	X	X	-2.1897 ***	-1.0482 *	-	-	-
Scup$_{5,6}$	Ninigret	X	X	X	X	X	X	X
	Quonochontaug	X	X	X	X	-	-	-
Winter Flounder$_{7}$	Quonochontaug	X	X	2.4452 ***	2.5335 ***	-	-	-

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Notes:

"X" : Not significant, "-" :Not applicable

1. Zero Inflated Poisson model, deviance explained = 62.4%, AIC: 311.2632
2. Negative Binomial model, devaince explained = 39.5%, adjusted-r^2 = 0.16 , AIC: 632.9118
3. Poisson model, deviance explained = 15.3%, adjusted-r^2 = 0.0386, AIC: 163.237
4. Negative Binomial model, deviance explained = 28.1%, adjusted-r^2 = 0.089, AIC:238.634
5. Negative Binomial model, deviance explained = 62.4%, adjsuted-r^2 =0.232, AIC: 120.1836
6. Zero Inflated Poisson model, deviance explained = 49%, AIC: 407.2852
7. Zero Inflated Poisson model, deviance explained = 68%, AIC: 365.5742

Tables 6a-b YOY GAM outputs. A) Significance of smooth terms (abiotic) and B) significance of parametric terms included in the GAM model.

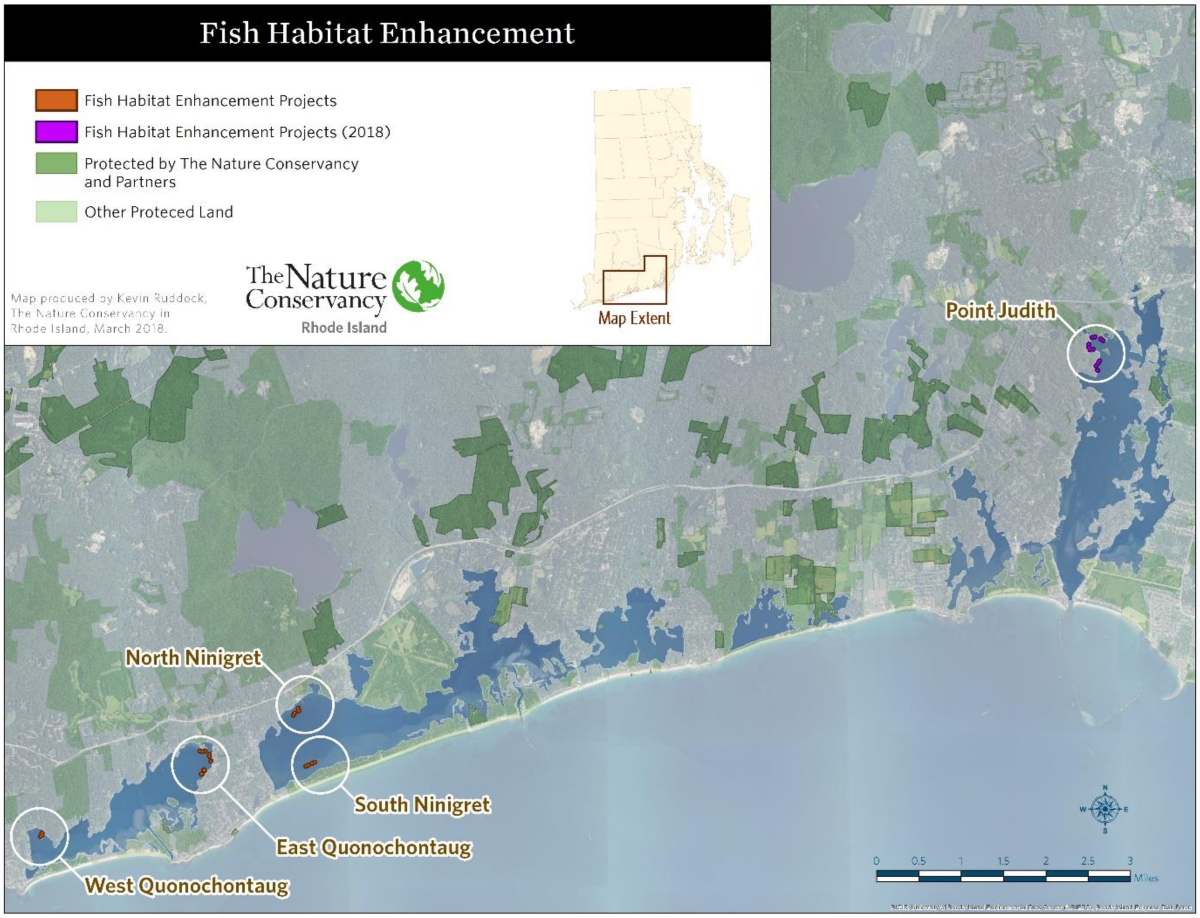
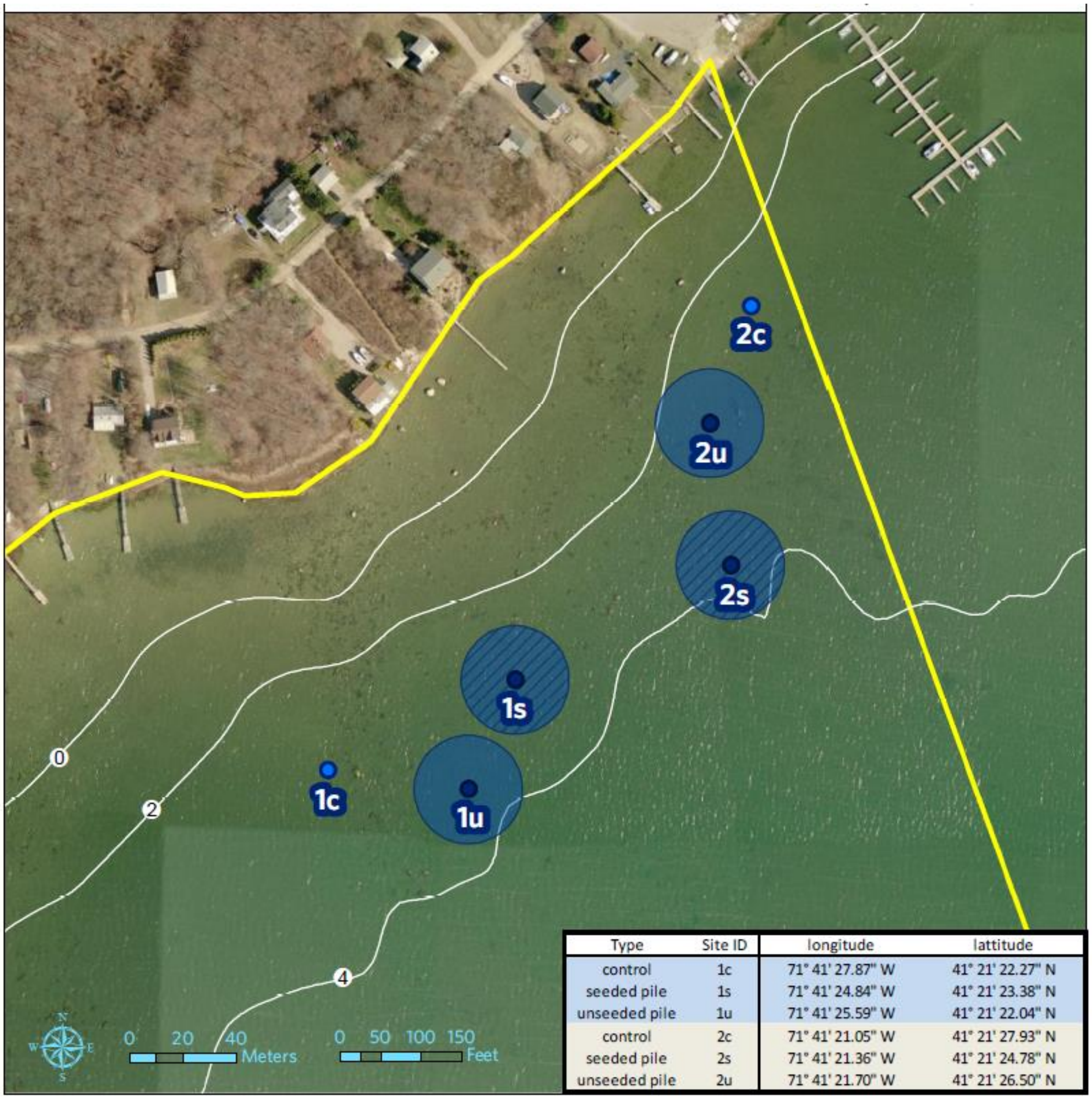
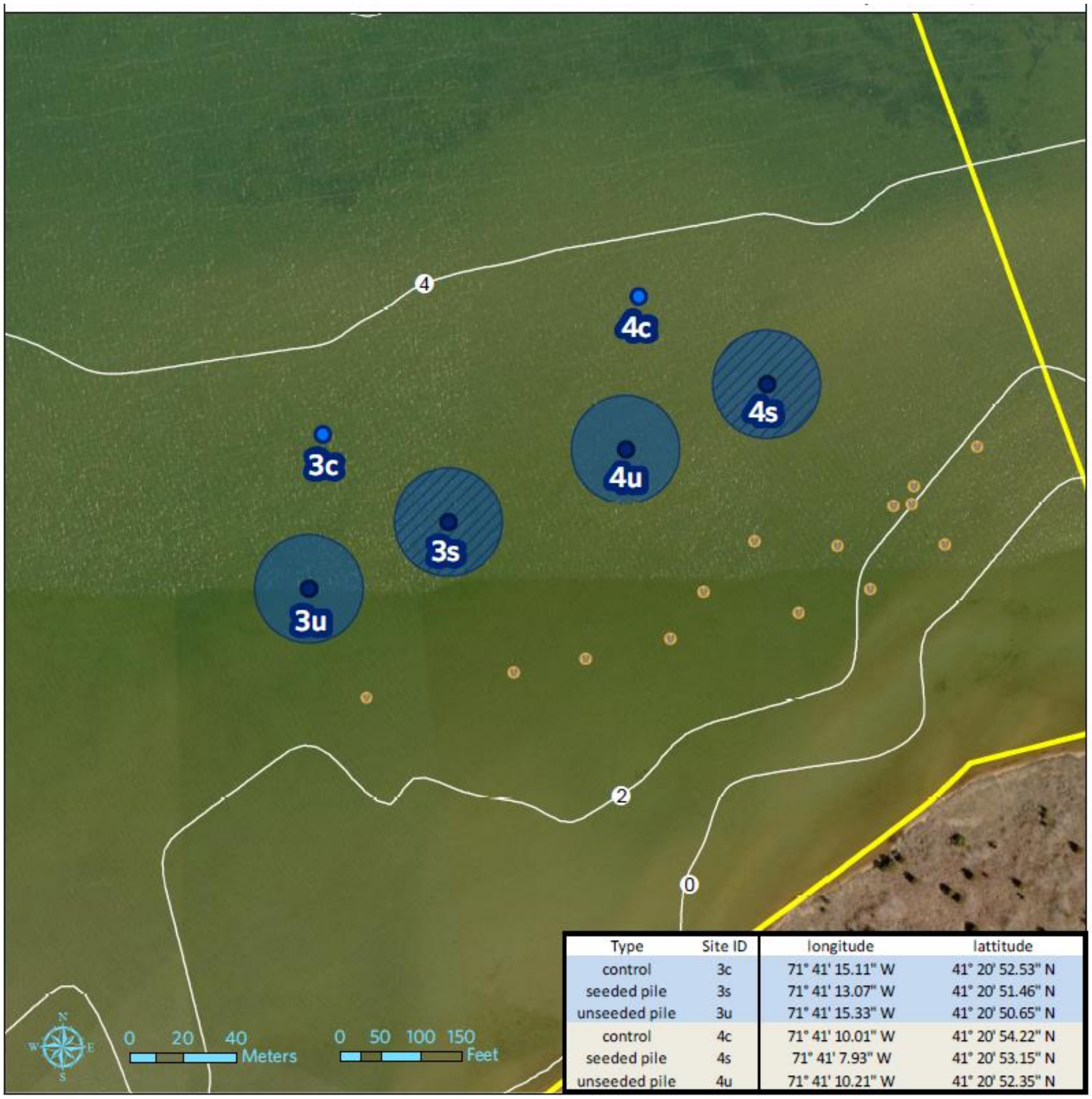


Figure 1. Coastal ponds located in Southern Rhode Island including constructed and formerly proposed (Pt Judith Pond) Fish Habitat Enhancement sites.



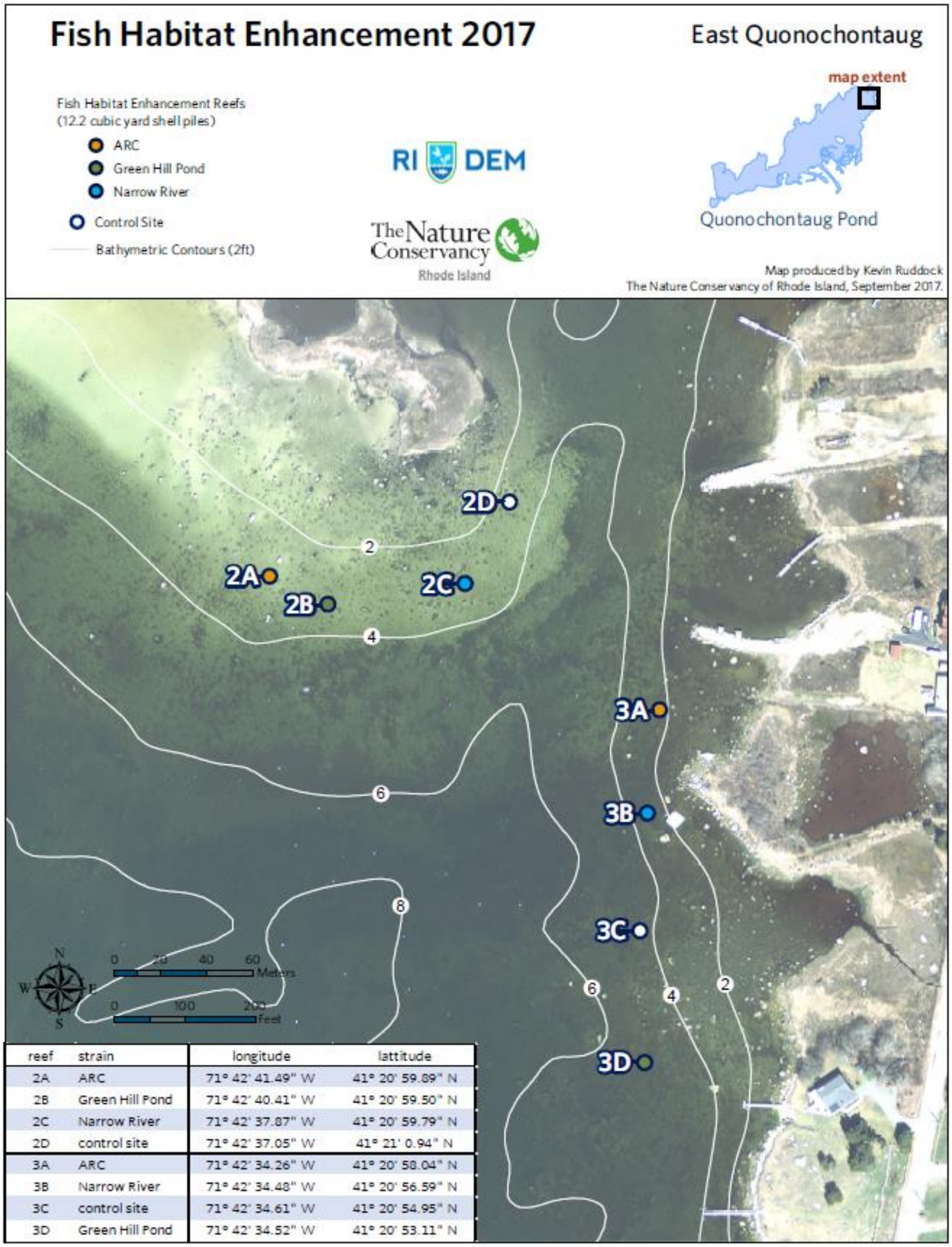
Type	Site ID	longitude	lattitude
control	1c	71° 41' 27.87" W	41° 21' 22.27" N
seeded pile	1s	71° 41' 24.84" W	41° 21' 23.38" N
unseeded pile	1u	71° 41' 25.59" W	41° 21' 22.04" N
control	2c	71° 41' 21.05" W	41° 21' 27.93" N
seeded pile	2s	71° 41' 21.36" W	41° 21' 24.78" N
unseeded pile	2u	71° 41' 21.70" W	41° 21' 26.50" N

Figure 2. Fish Habitat Enhancement sites in the northern portion of Ninigret Pond. The RI DMF management closure (i.e., Shellfish Spawner Sanctuary) is depicted by the yellow outline. Map produced by Kevin Ruddock (TNC).



Type	Site ID	longitude	lattitude
control	3c	71° 41' 15.11" W	41° 20' 52.53" N
seeded pile	3s	71° 41' 13.07" W	41° 20' 51.46" N
unseeded pile	3u	71° 41' 15.33" W	41° 20' 50.65" N
control	4c	71° 41' 10.01" W	41° 20' 54.22" N
seeded pile	4s	71° 41' 7.93" W	41° 20' 53.15" N
unseeded pile	4u	71° 41' 10.21" W	41° 20' 52.35" N

Figure 3. Fish Habitat Enhancement sites in the southern portion of Ninigret Pond. The RI DMF management closure (i.e., Shellfish Spawner Sanctuary) is depicted by the yellow outline. Points marked to the south of our reefs are restored oyster reefs created by the NRCS EQIP Program between 2008 and 2010. Map produced by Kevin Ruddock (TNC).



reef	strain	longitude	lattitude
2A	ARC	71° 42' 41.49" W	41° 20' 59.89" N
2B	Green Hill Pond	71° 42' 40.41" W	41° 20' 59.50" N
2C	Narrow River	71° 42' 37.87" W	41° 20' 59.79" N
2D	control site	71° 42' 37.05" W	41° 21' 0.94" N
3A	ARC	71° 42' 34.26" W	41° 20' 58.04" N
3B	Narrow River	71° 42' 34.48" W	41° 20' 56.59" N
3C	control site	71° 42' 34.61" W	41° 20' 54.95" N
3D	Green Hill Pond	71° 42' 34.52" W	41° 20' 53.11" N

Figure 4. Configuration for Fish Habitat Enhancement sites (i.e., research plot #2 and #3) located in the eastern end of Quonochontaug Pond, Charlestown, RI. Each research plot contains 3 experimental reefs and 1 control. Map produced by Kevin Ruddock (TNC).

reef	strain	longitude	lattitude
1A	control site	71° 44' 51.89" W	41° 20' 9.93" N
1B	ARC	71° 44' 51.68" W	41° 20' 8.65" N
1C	Narrow River	71° 44' 52.40" W	41° 20' 7.62" N
1D	Green Hill Pond	71° 44' 52.89" W	41° 20' 6.37" N

Figure 5. Configuration for Fish Habitat Enhancement sites (i.e., research plot #1) located in the western end of Quonochontaug Pond, Westerly, RI. Each research plot contains 3 experimental reefs and 1 control. Map produced by Kevin Ruddock (TNC).

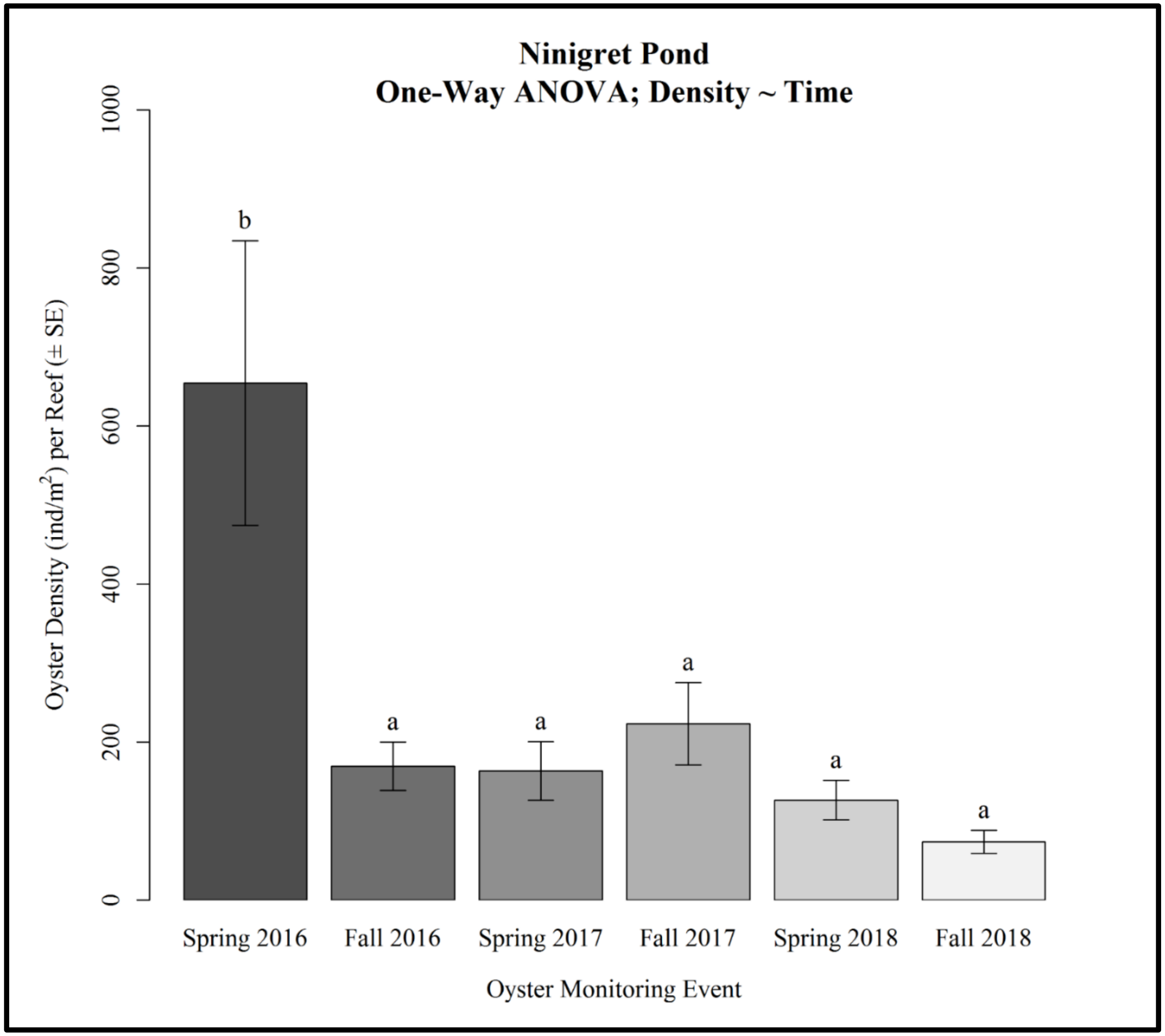


Figure 7. Two-way ANOVAs of Mean Density per Quadrat by Year and Site for Ninigret Pond letters denote significant differences (p-value <0.05) from Tukey's post hoc test.

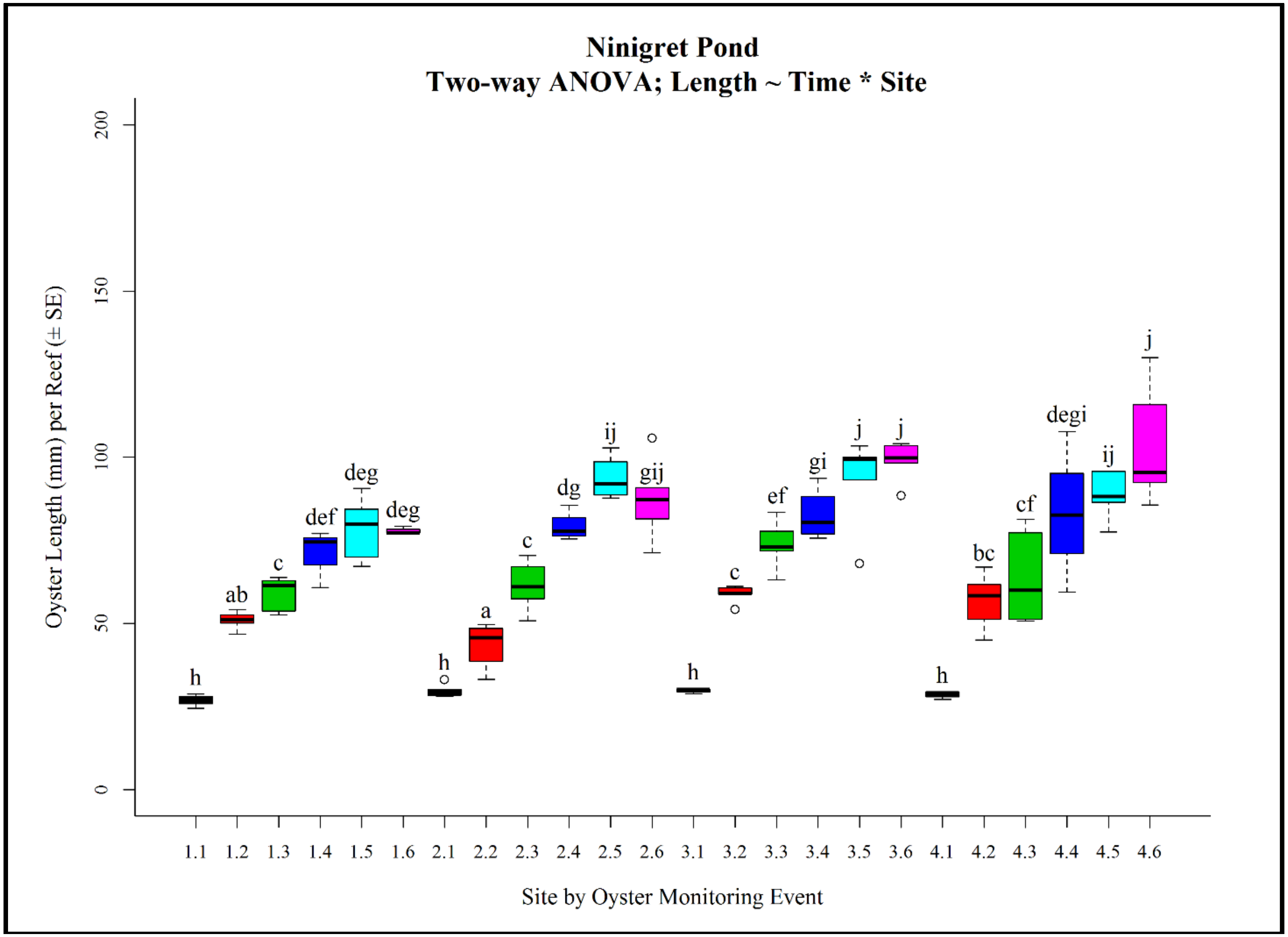


Figure 8. Two-way ANOVA of mean length per quadrat by site (Ninigret Pond, Sites 1-4) time (monitoring event, 1-6). Represented as a decimal on the x-axis as Site. Monitoring Event. Letters denote significant differences on the interactive effect between time and site (tukey's post-hoc test; p-value <0.05)

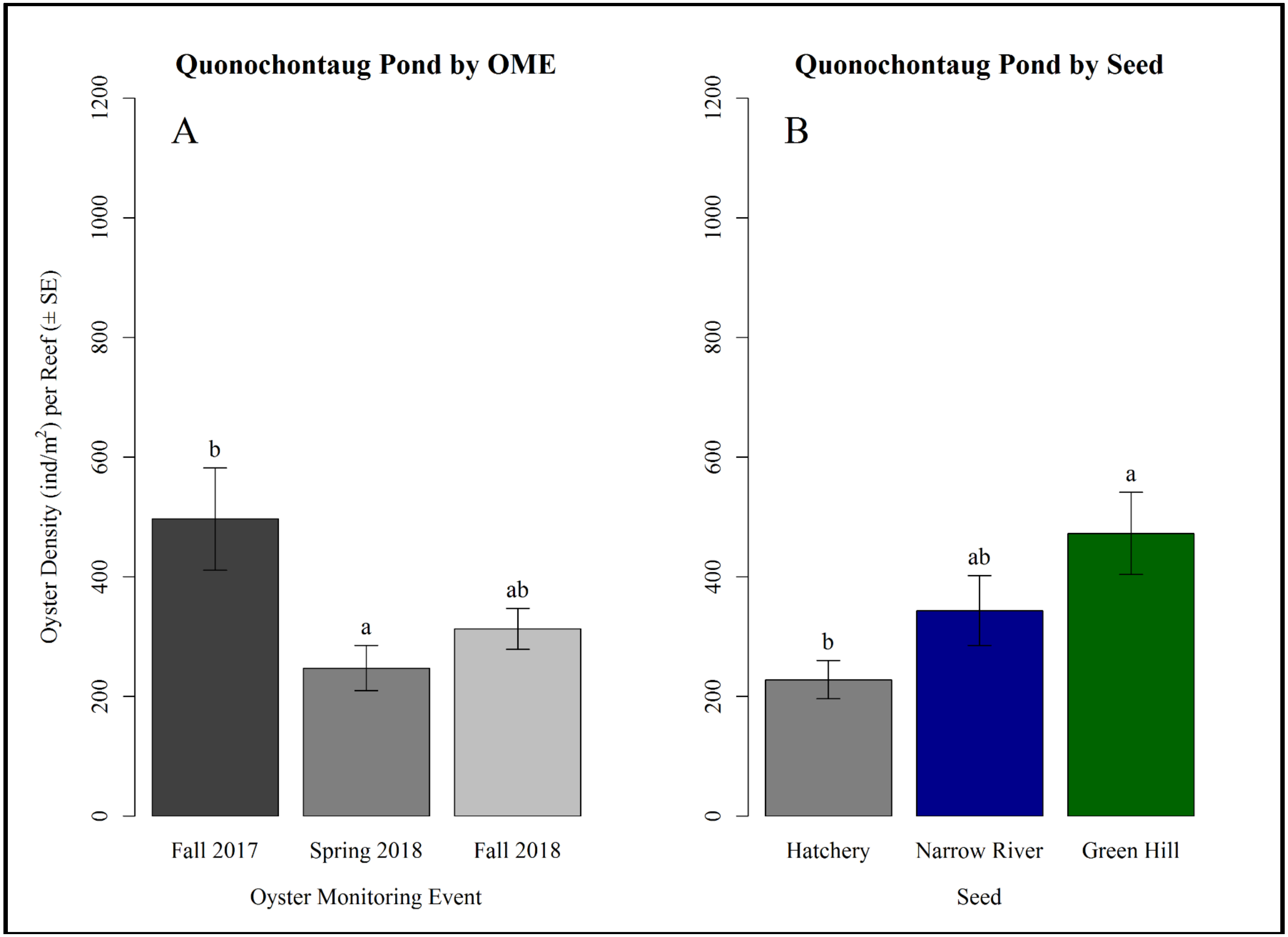


Figure 9. One-way ANOVAs of mean length by time (monitoring event) (A), and by oyster lineage (B) in Quonochontaug Pond. Letters denote significant differences on the independent and significant factors of time and oyster lineage (tukey's post-hoc test; p-value <0.05)

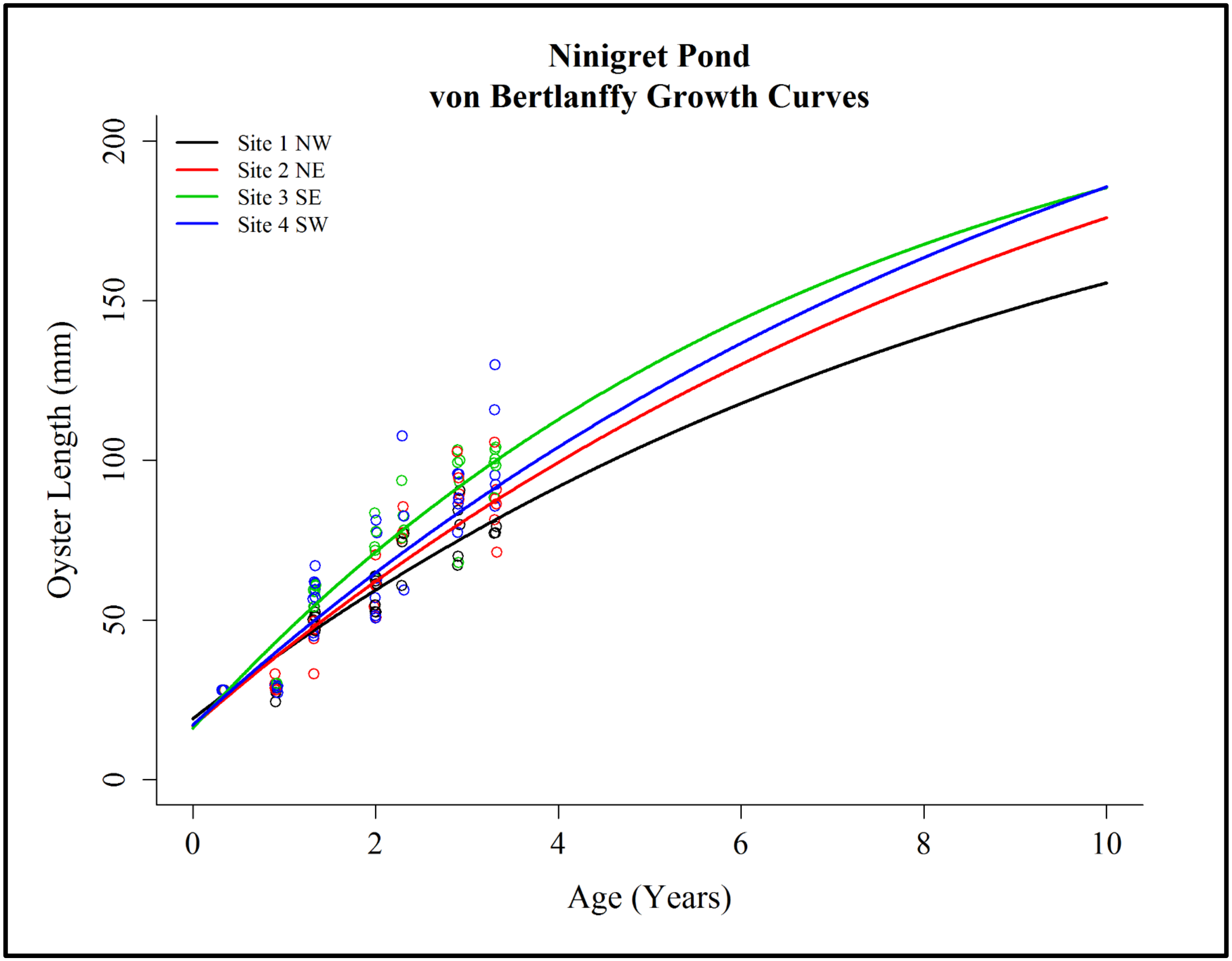


Figure 10a. Oyster growth curves by reef location (color) in Ninigret Pond. Mean oyster length per quadrat (circles) plotted over age in years.

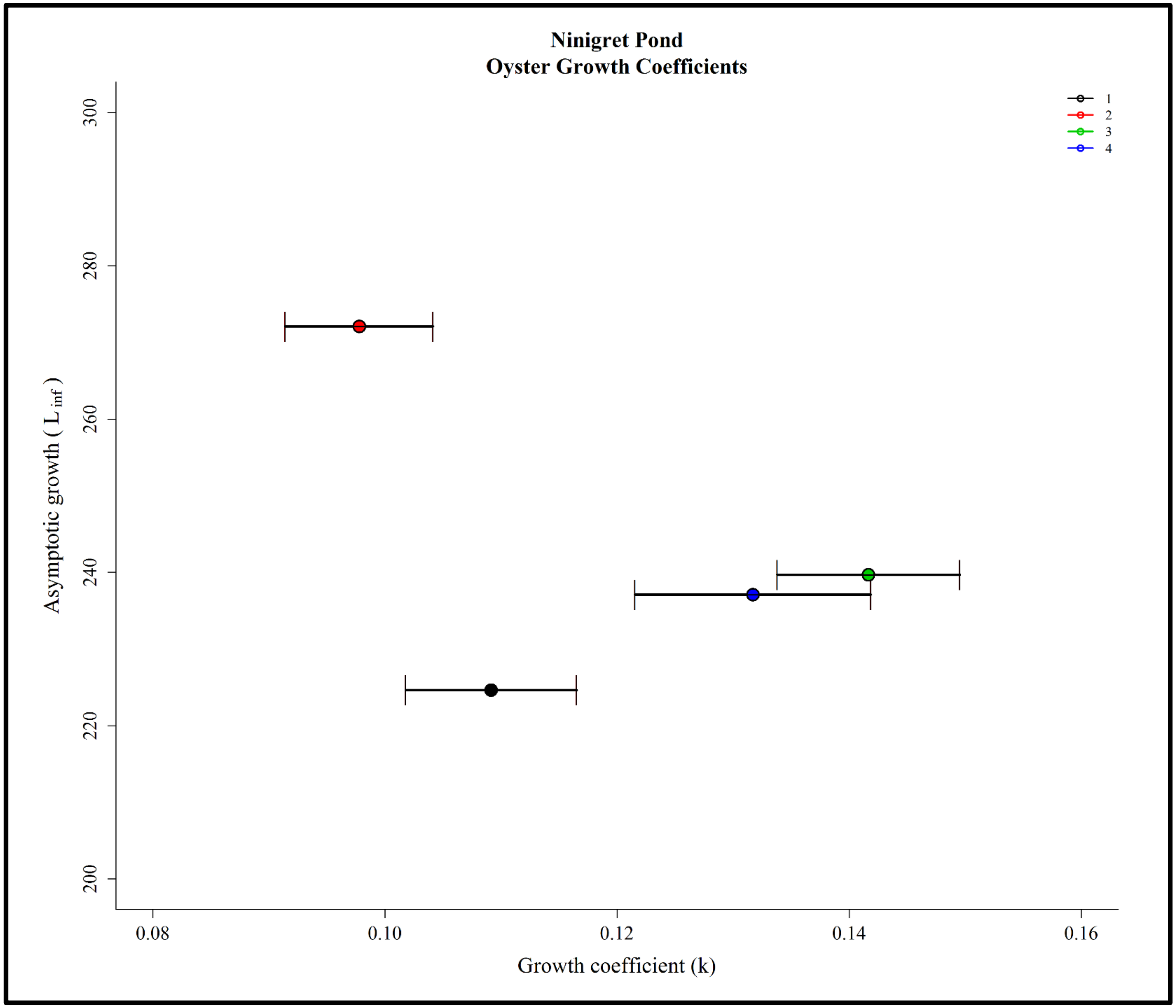


Figure 10b Oyster growth coefficients L_{inf} and k plotted together by reef location (color) in Ninigret Pond.

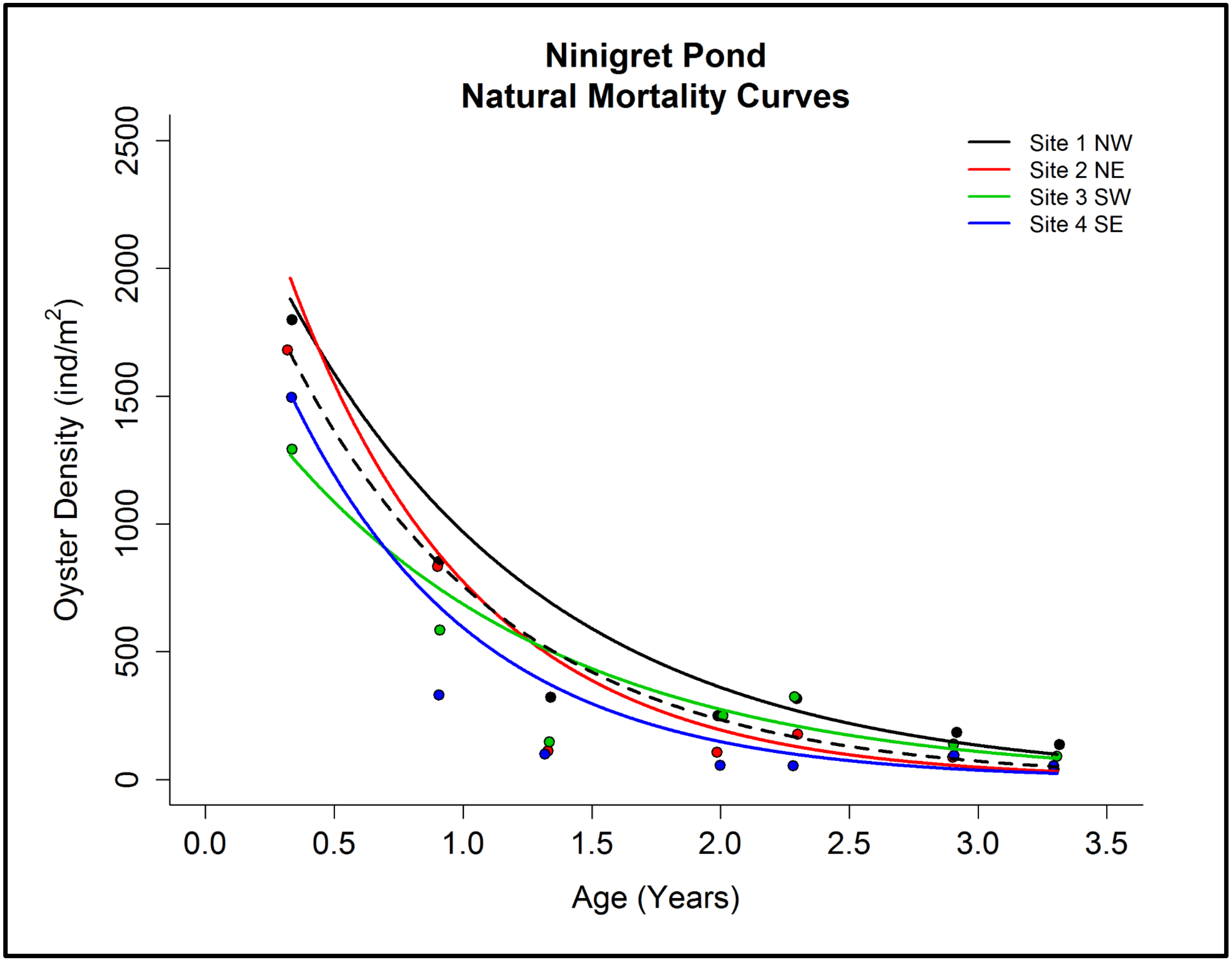


Figure 11a Oyster decay curves by reef location (color) in Ninigret Pond. Mean oyster density per monitoring event (circles) plotted over time by Age in years

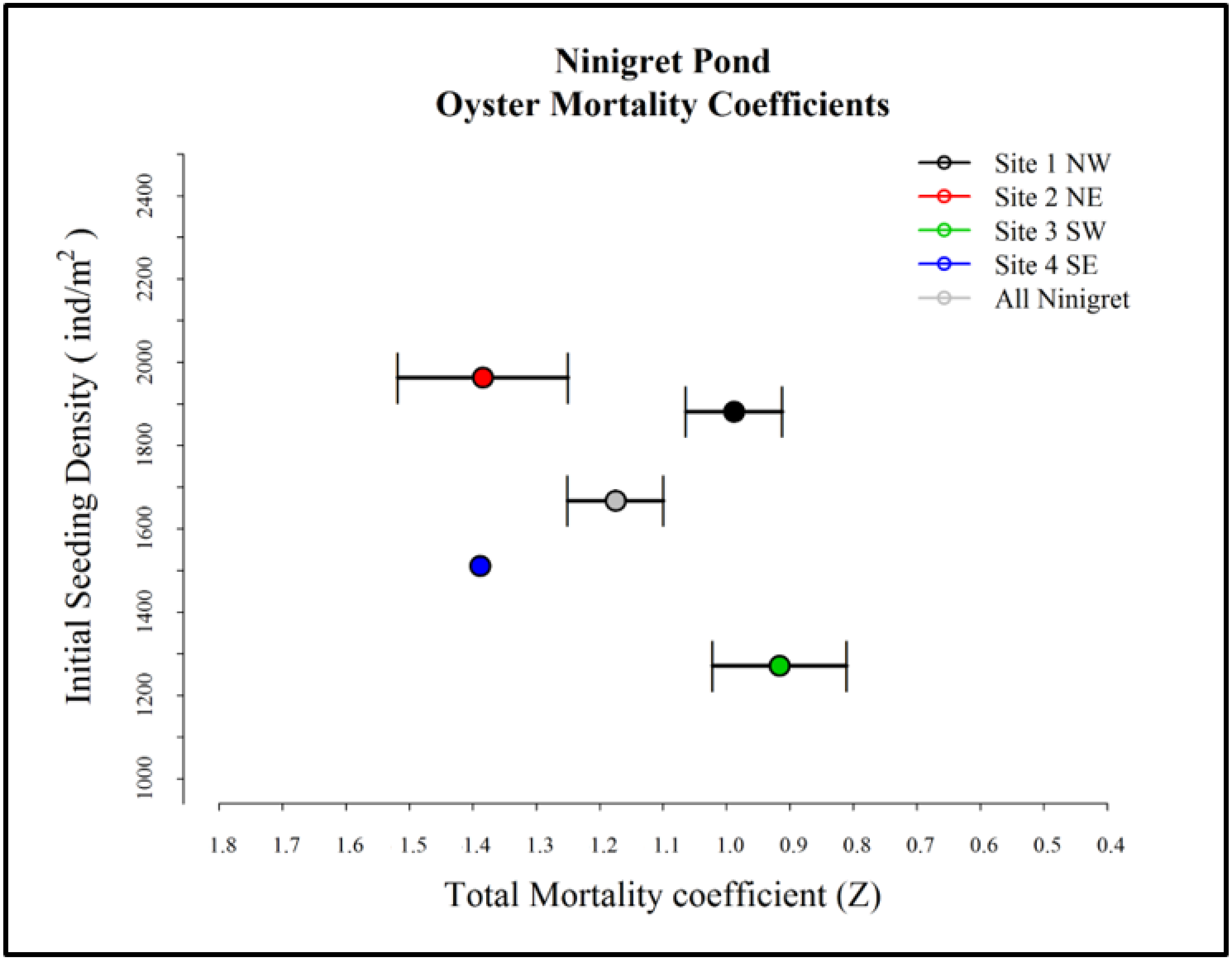


Figure 11b Oyster growth coefficients Do and Z plotted together by reef location (color) in Ninigret Pond.

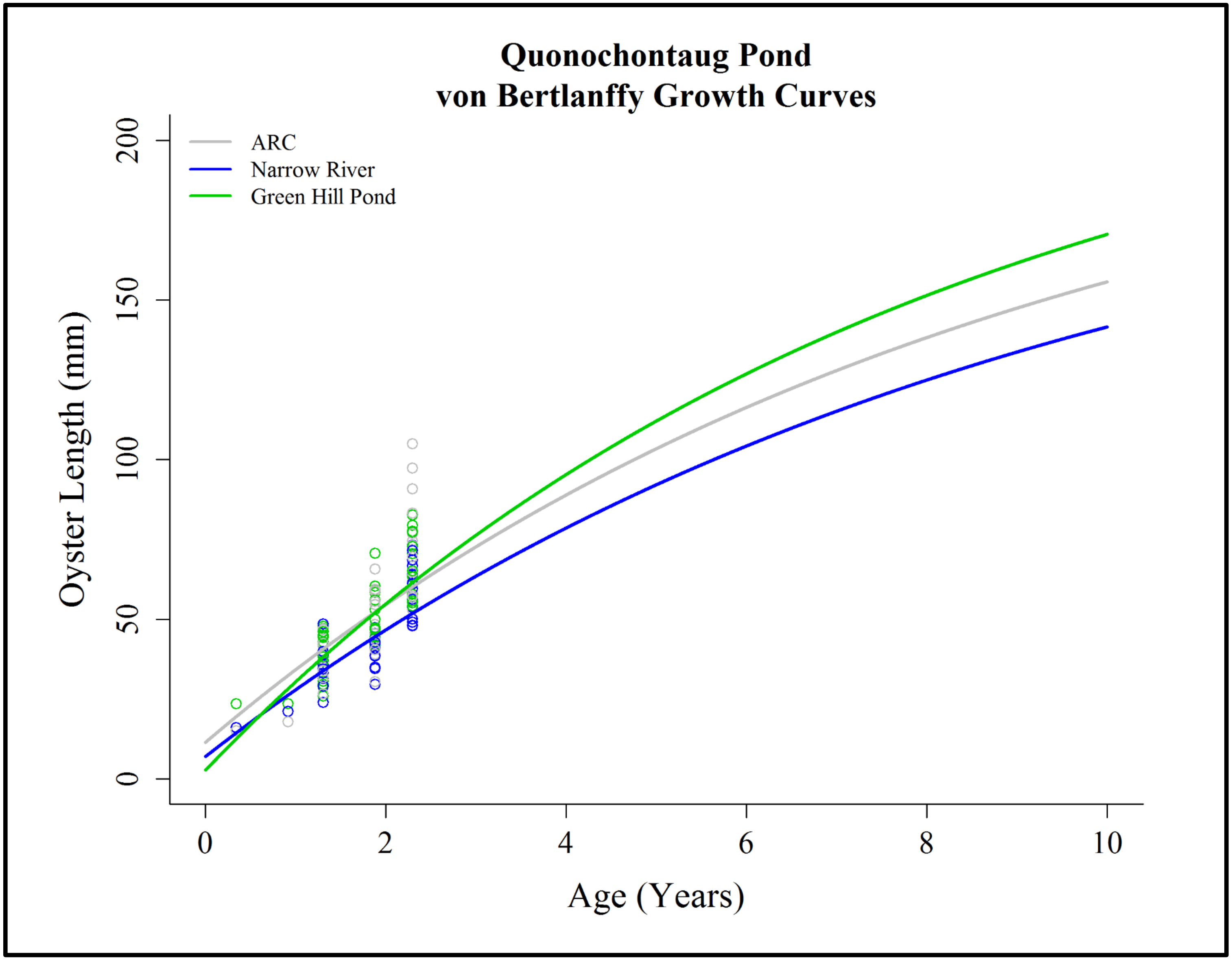


Figure 12a. Oyster growth curves by oyster lineage (color) in Quonochontaug Pond. Mean oyster length per quadrat (circles) plotted over age in years.

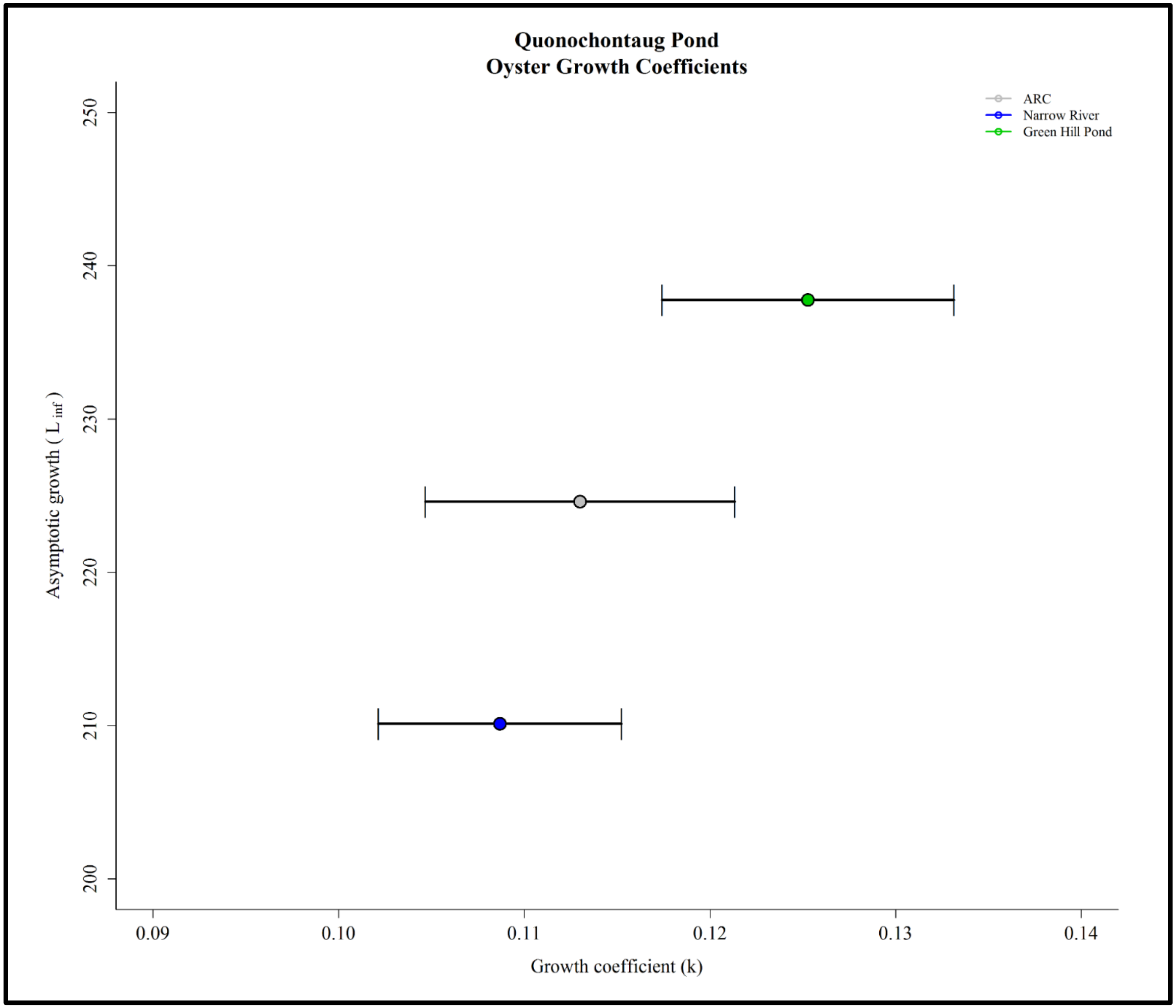


Figure 12b Oyster growth coefficients L_{inf} and k plotted together by oyster lineage (color) in Quonochontaug Pond.

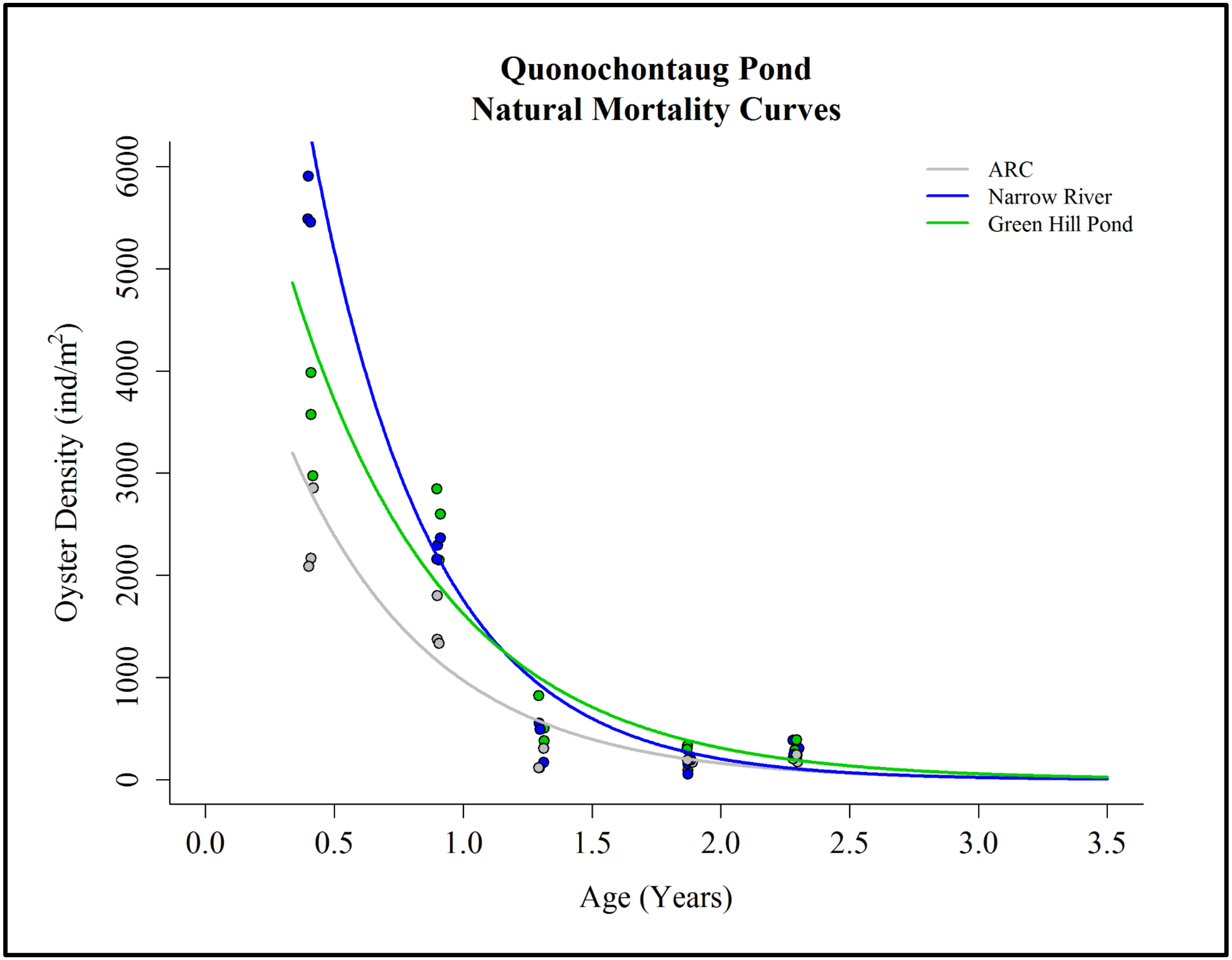


Figure 13a Oyster decay curves by oyster lineage (color) in Quonochontaug Pond. Mean oyster density per monitoring event (circles) plotted over time by Age in years.

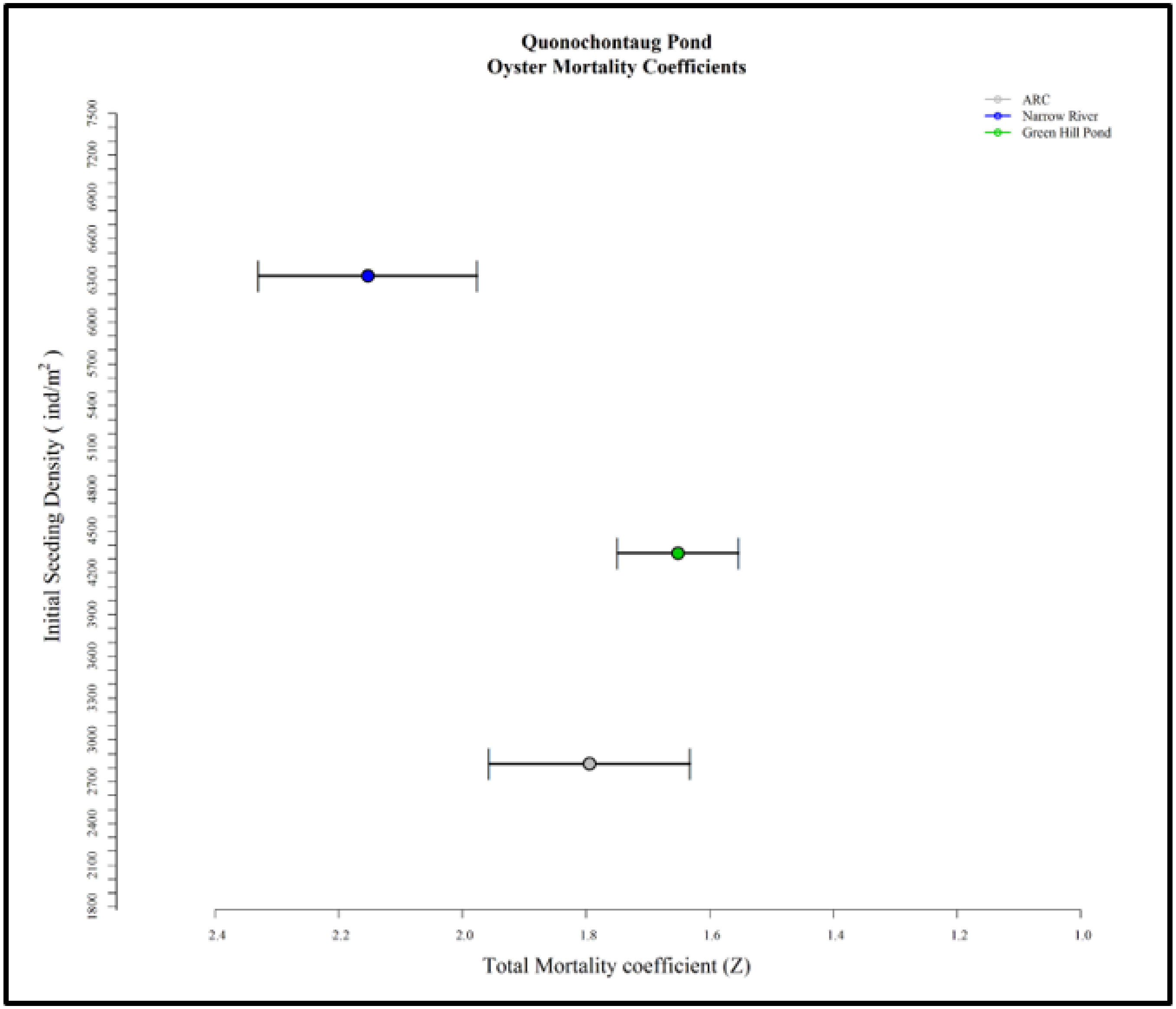


Figure 13b Oyster growth coefficients Do and Z plotted together by oyster lineage (color) in Quonochontaug Pond.

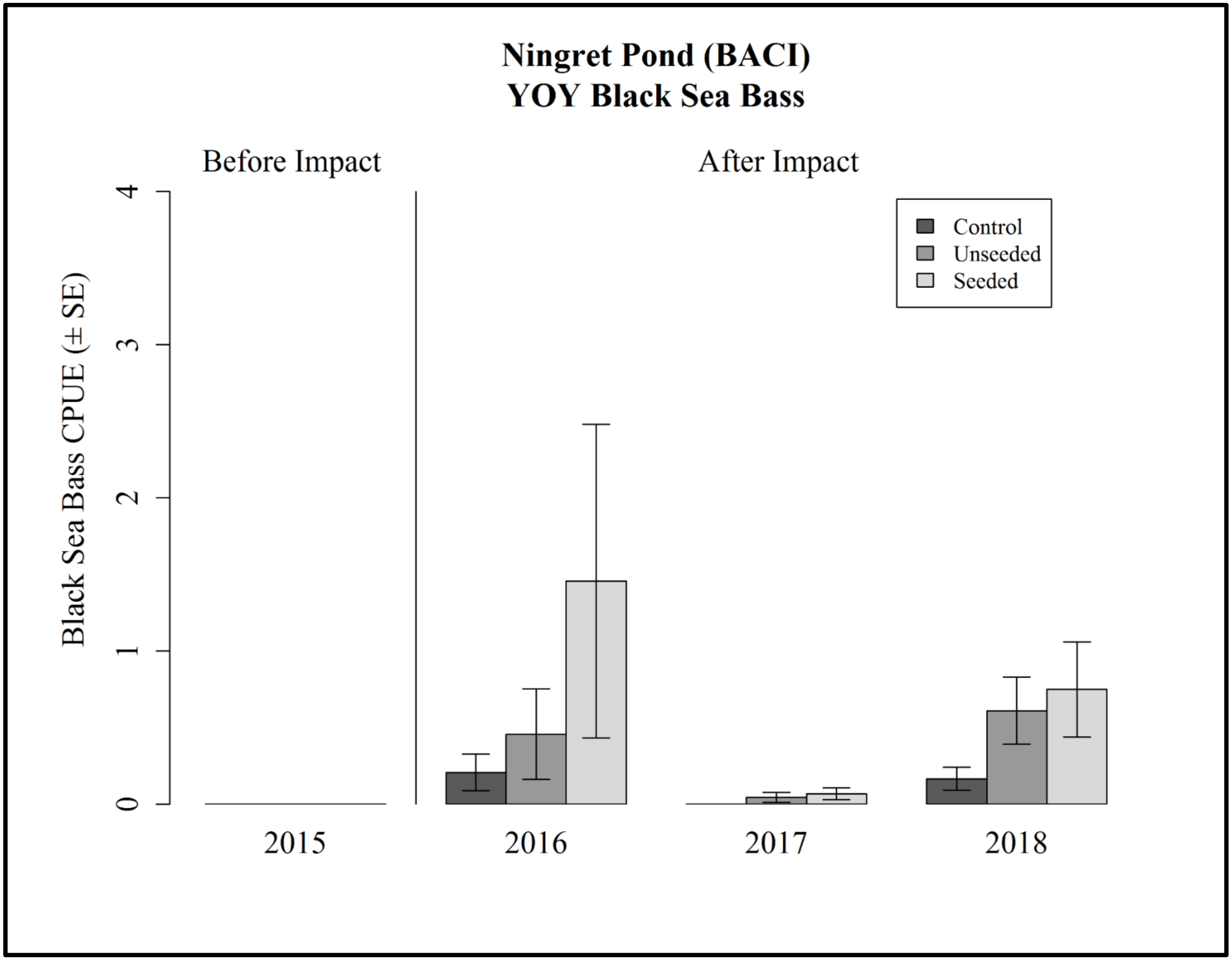


Figure 14a. Black Sea Bass BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Ninigret Pond. In 2015 no Young of Year the Black Sea Bass were caught.

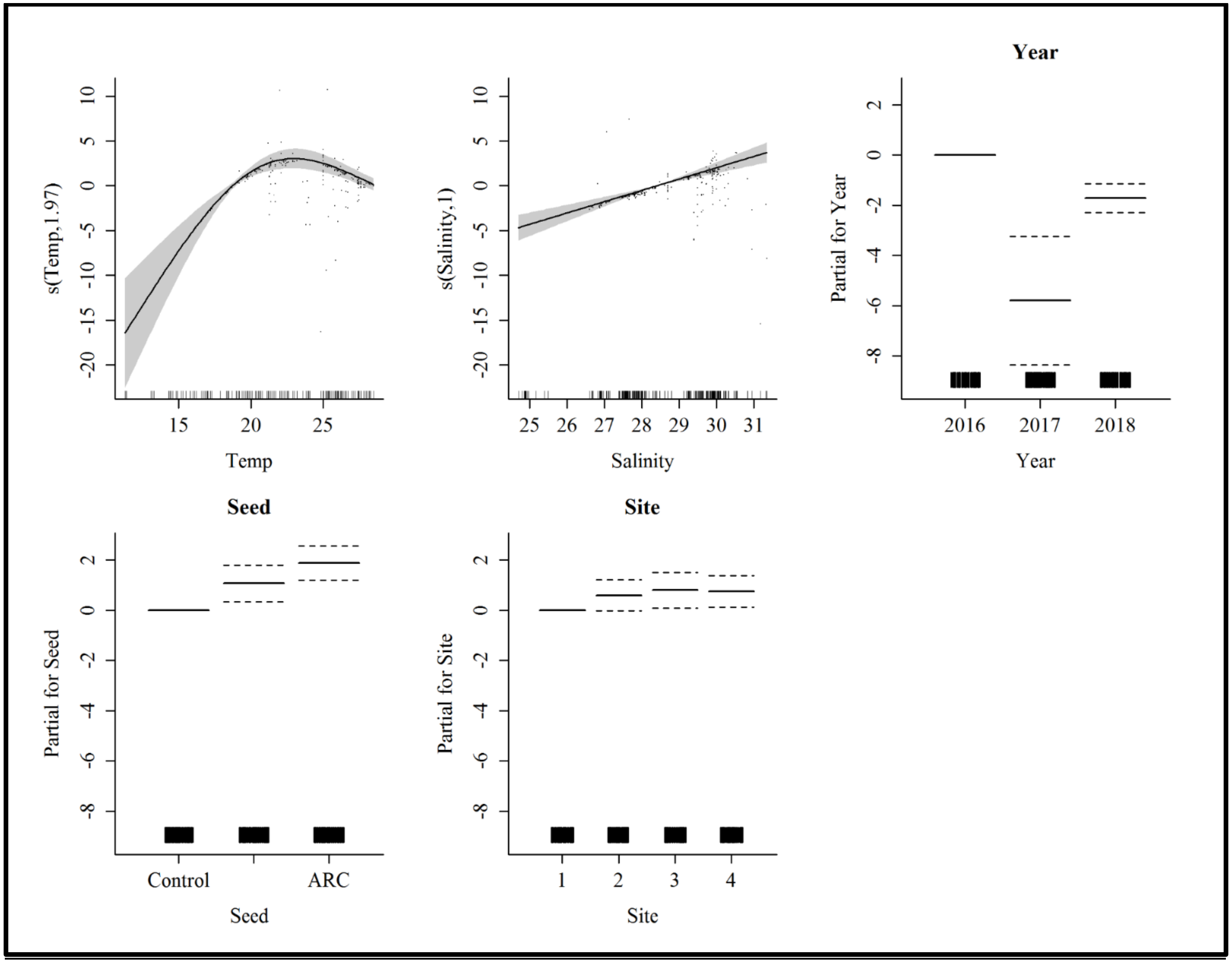


Figure 14b. Ninigret YOY Black Sea Bass GAM Analysis: Partial effects plots for significant factors Temperature (top left), Salinity (top middle), Year (top right), Seed (bottom left), and Site (bottom middle). All partial effect values great than 0 represent a positive enhancement for smoothed terms on CPUE. All parametric terms are relative to the first factor of that category (i.e., 2016, Control, and Site 1).

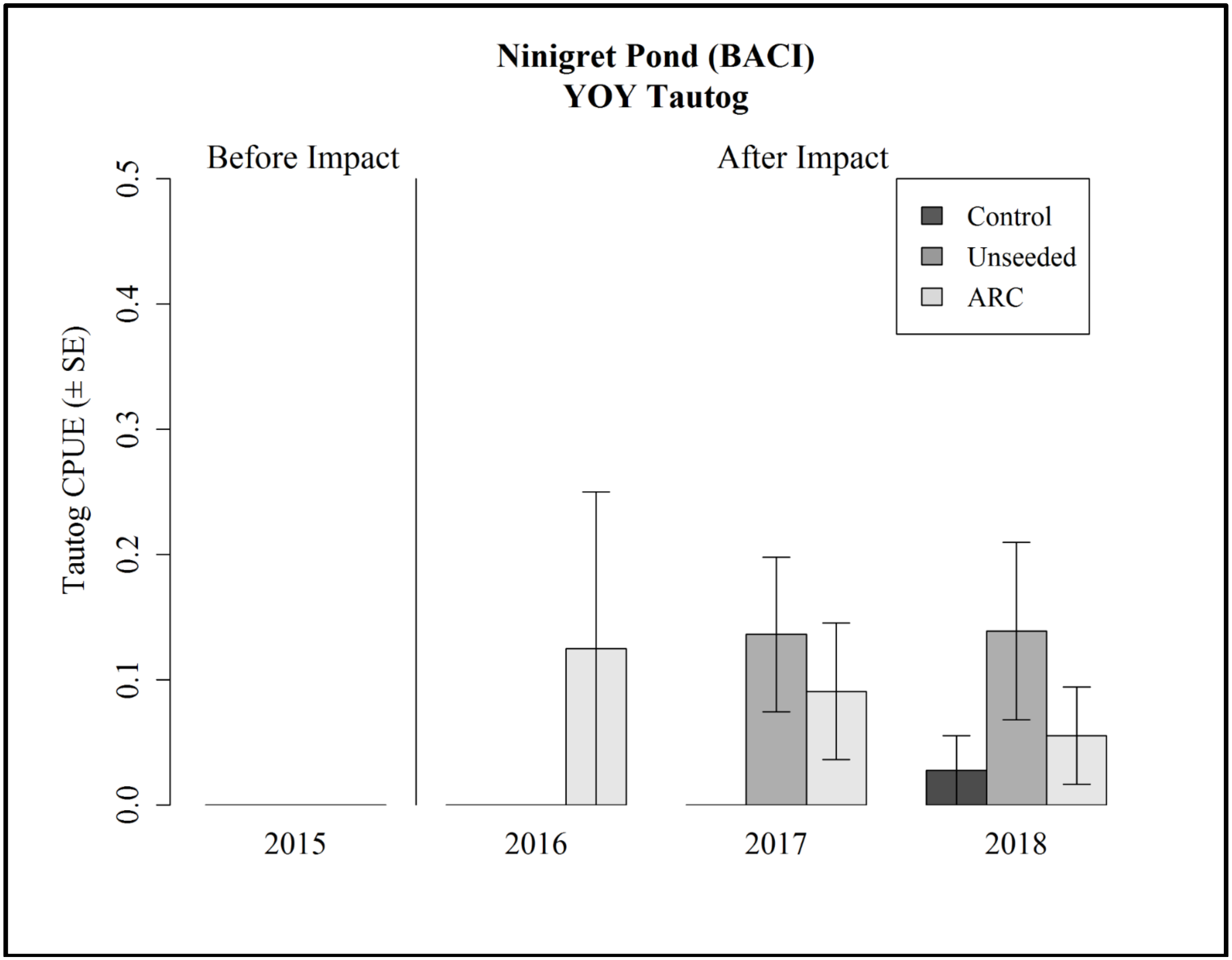


Figure 15a. Tautog BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Ninigret Pond. In 2015 no Young of Year the Tautog were caught.

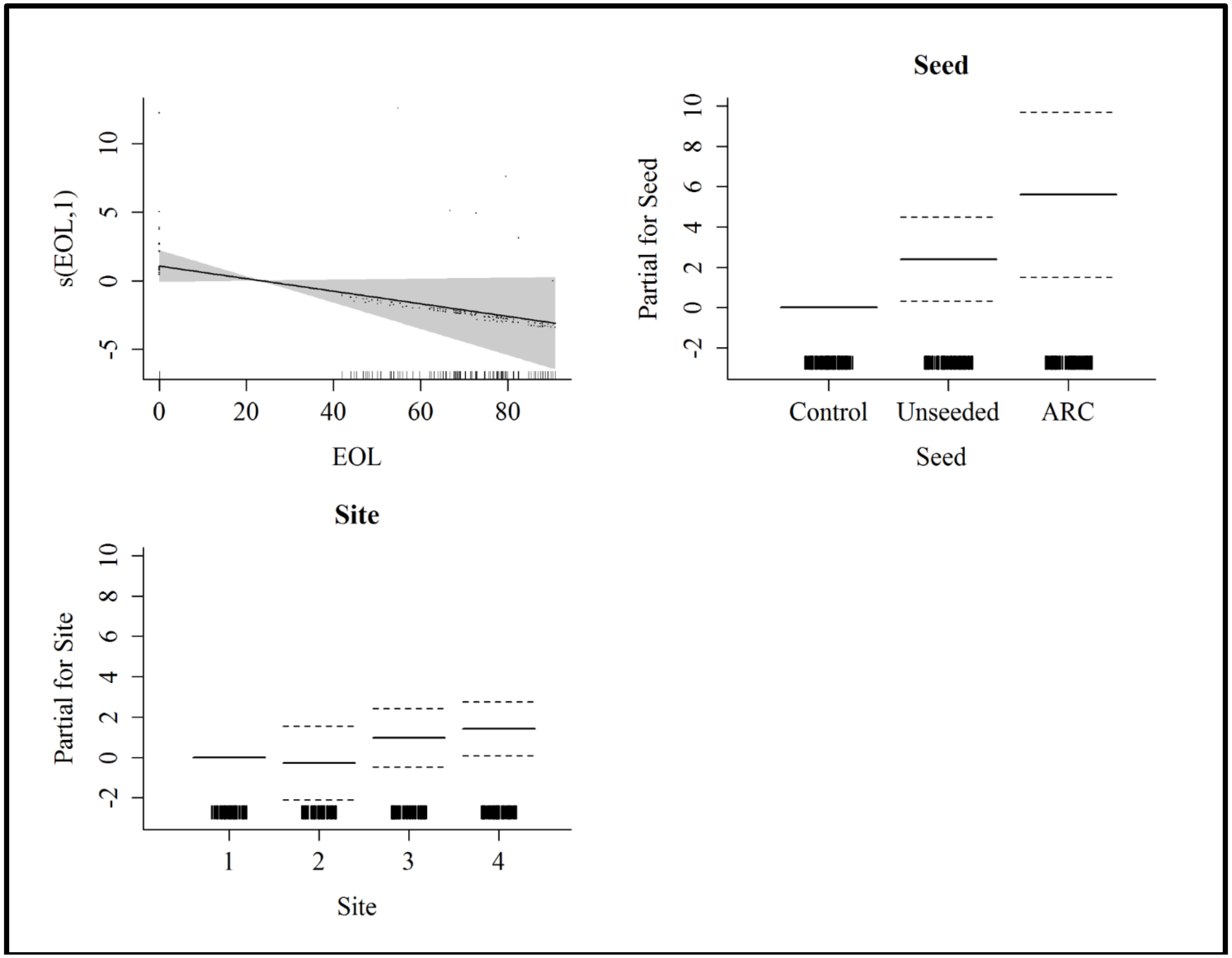


Figure 15b. Ninigret YOY Tautog GAM Analysis: Partial effects plots for significant factors EOL (top left), Seed (Top right), and Site (bottom left). All partial effect values great than 0 represent a positive enhancement for smoothed terms on CPUE. All parametric terms are relative to the first factor of that category (i.e., Control and Site 1).

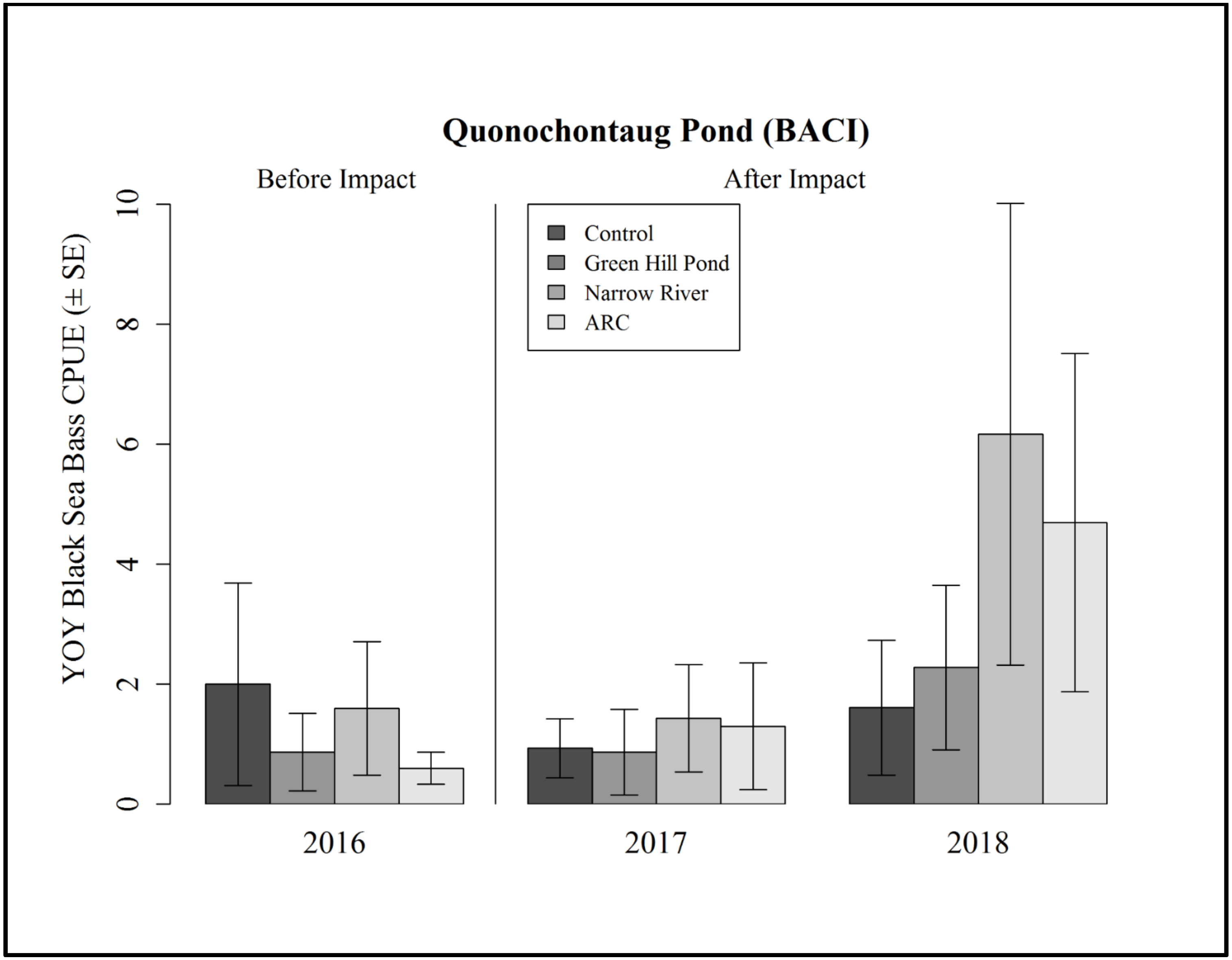


Figure 16a. Black Sea Bass BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Quonochontaug Pond.

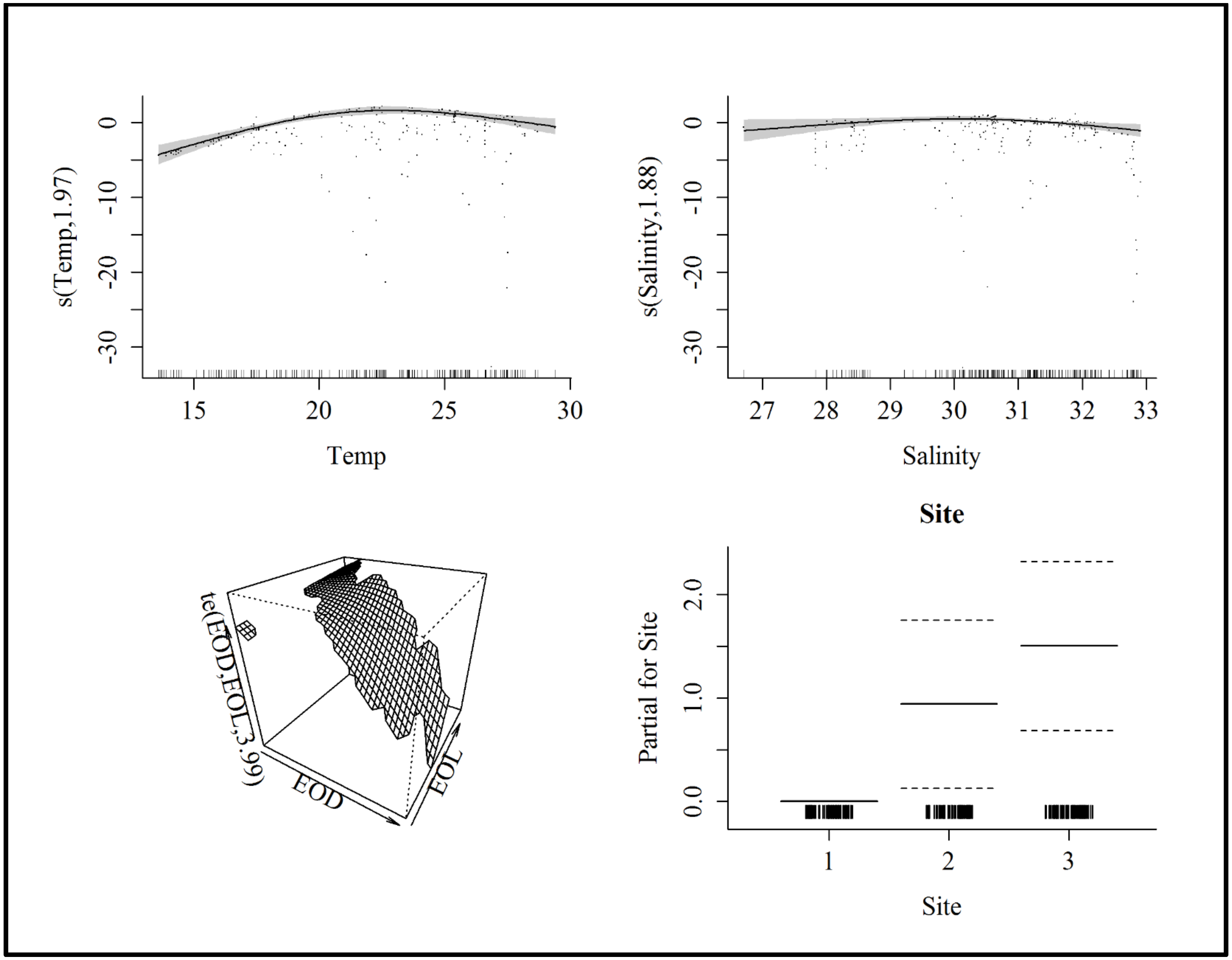


Figure 16b. Quonochontaug YOY Black Sea Bass GAM Analysis: Partial effects plots for significant factors Temperature (top left), Salinity (Top right), and Estimated Oyster Density and Estimated Oyster Length (Bottom left), and Site (bottom right). All partial effect values great than 0 represent a positive enhancement for smoothed terms on CPUE. All parametric terms are relative to the first factor of that category (i.e., Site 1).

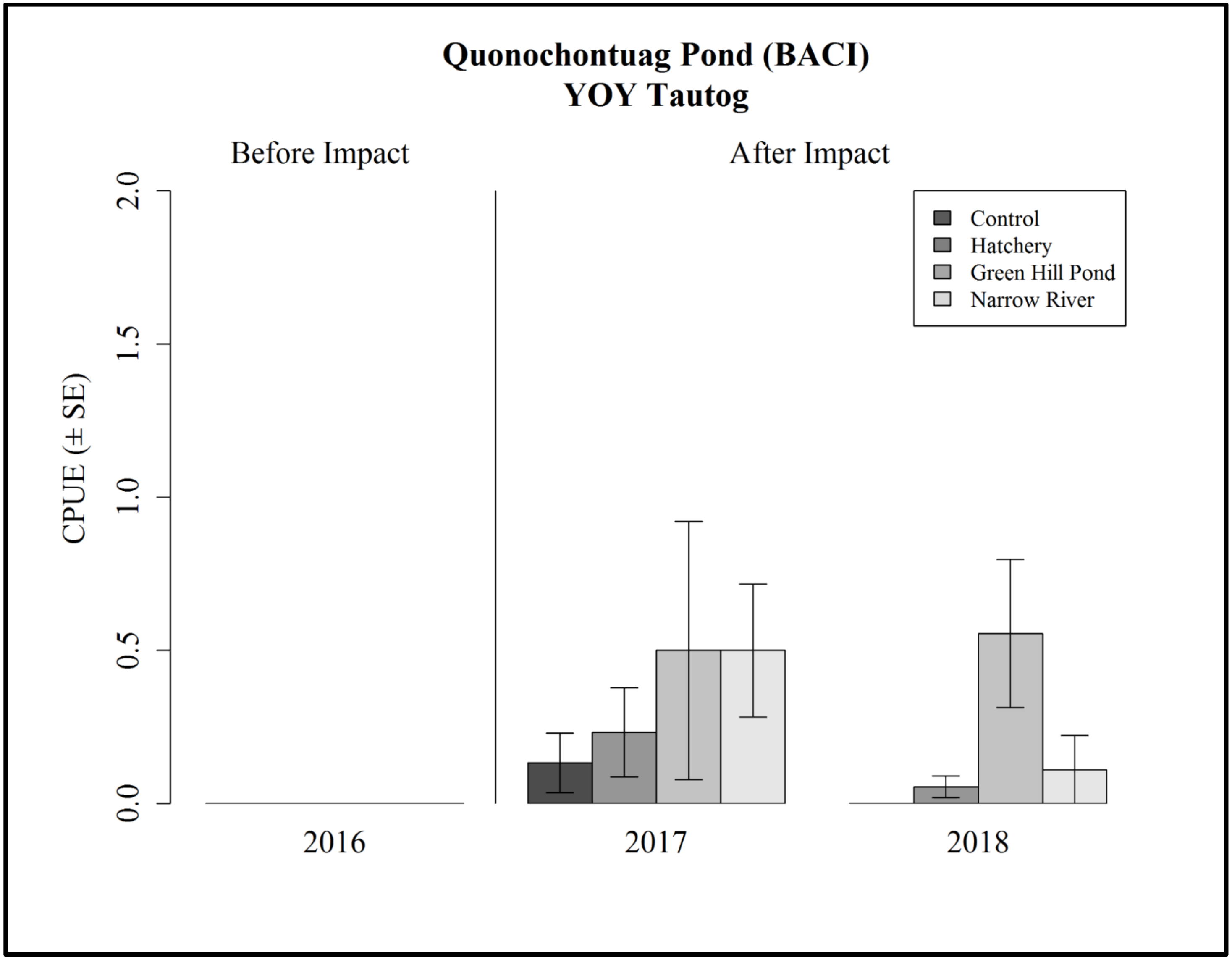


Figure 17a. Tautog BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Quonochontaug Pond. In 2016 no Young of Year the Tautog were caught.

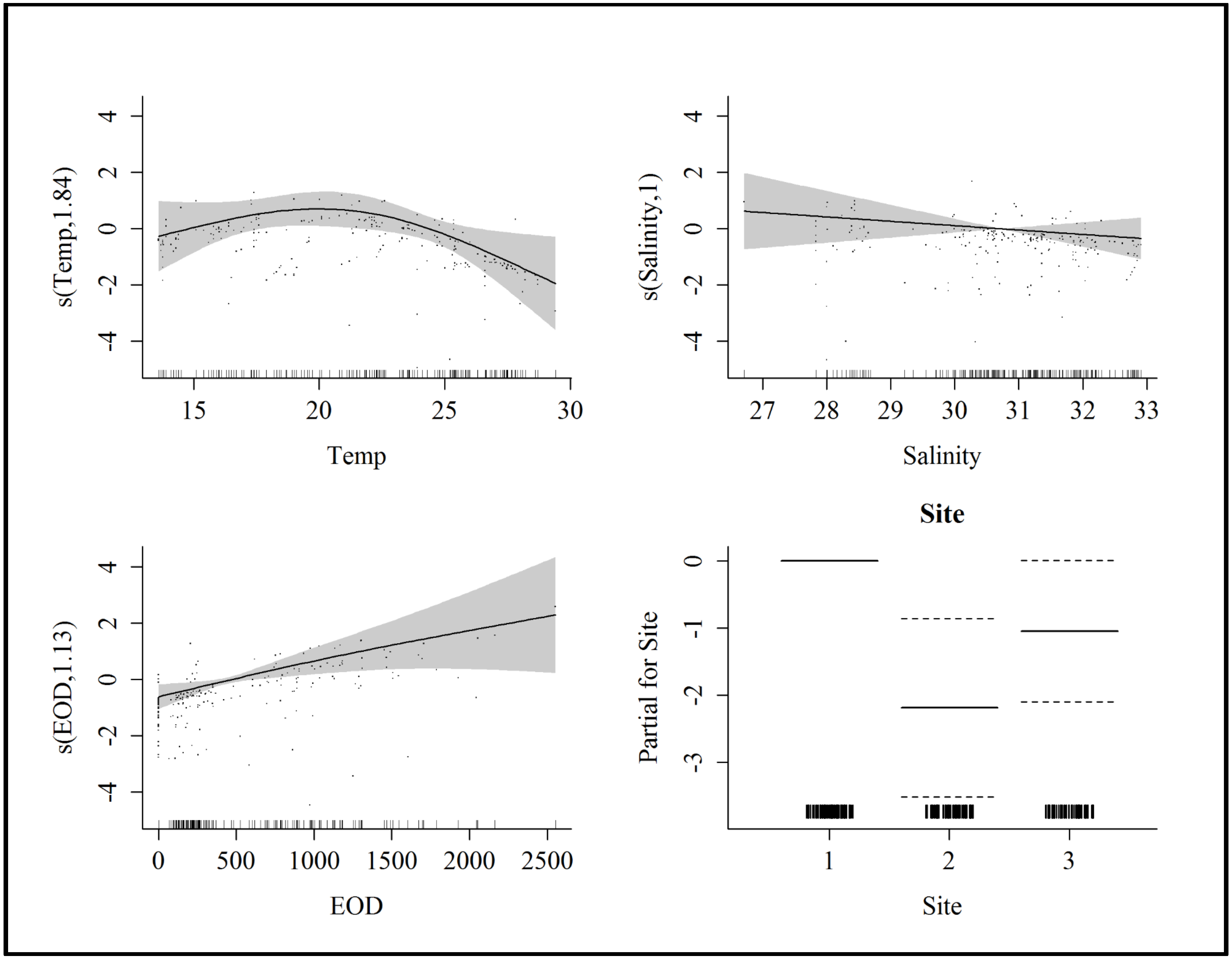


Figure 17b. Quonochontaug YOY Tautog GAM Analysis: Partial effects plots for significant factors Temperature (top left), Salinity (Top right), and EOD (Bottom left), and Site (bottom right). All partial effect values great than 0 represent a positive enhancement for smoothed terms on CPUE. All parametric terms are relative to the first factor of that category (i.e., Site 1).

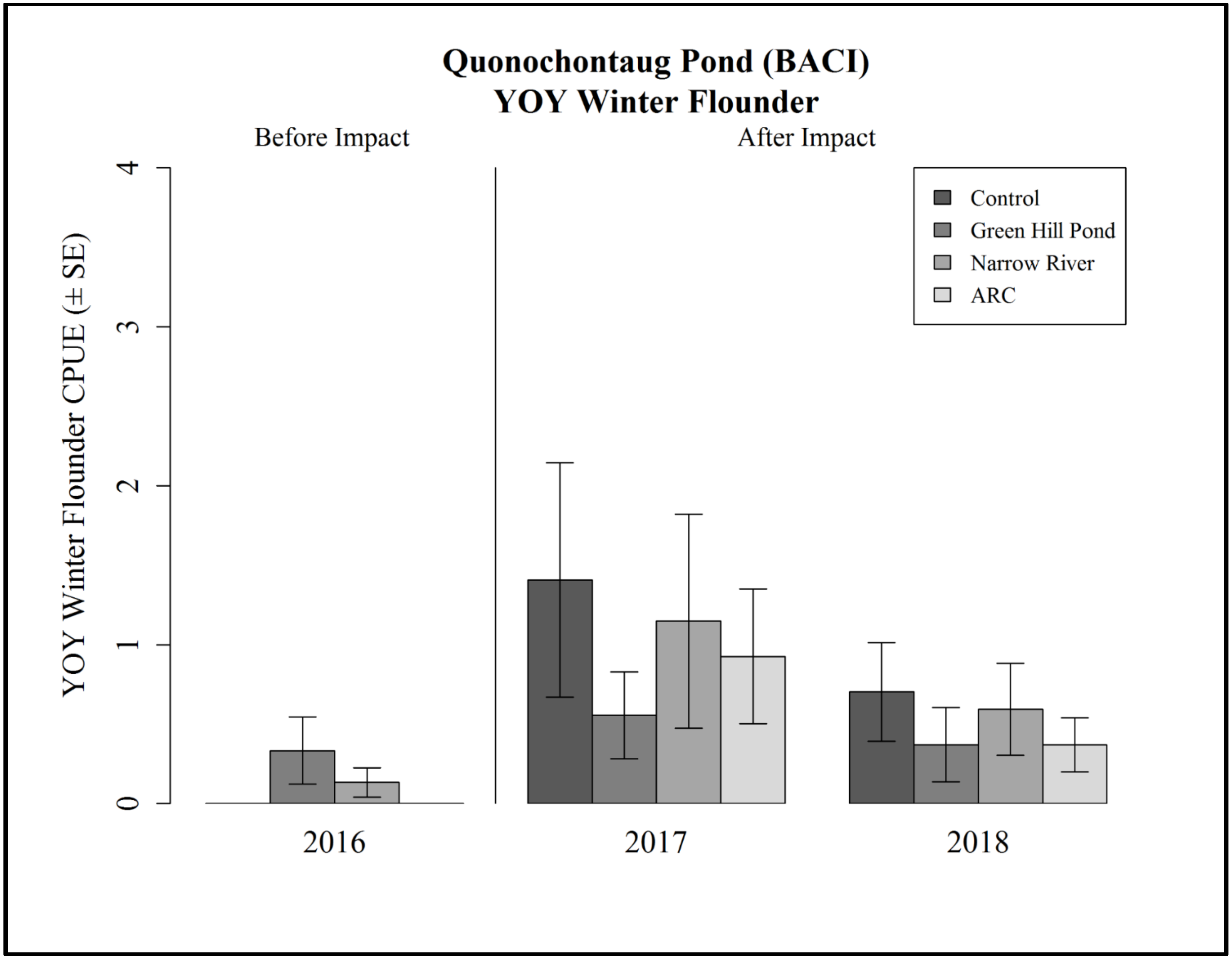


Figure 18a. Winter Flounder Bass BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Quonochontaug Pond.

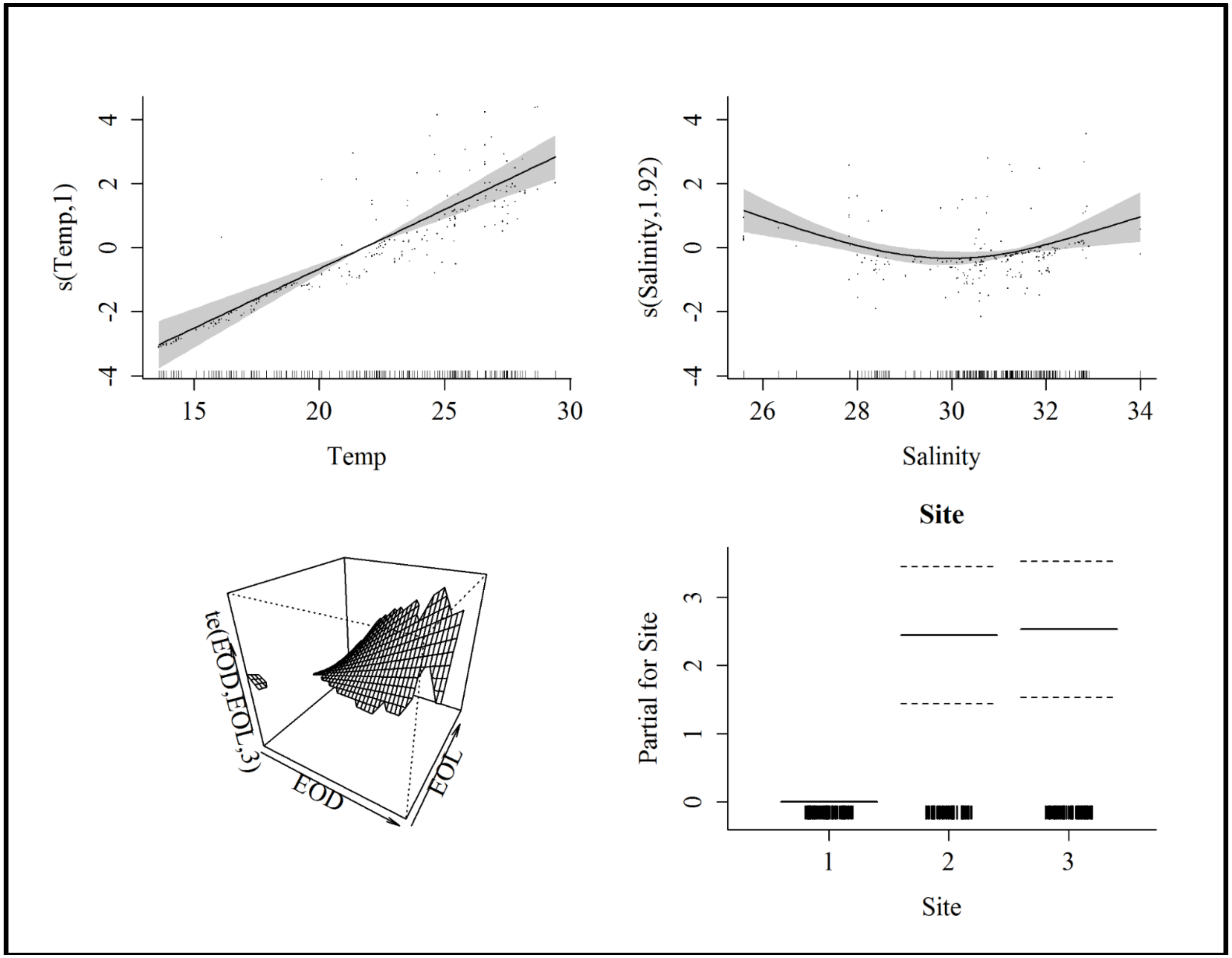


Figure 18b. Quonochontaug YOY Winter Flounder GAM Analysis: Partial effects plots for significant factors Temperature (top left), Salinity (Top right), and EOD x EOL (Bottom left), and Site (bottom right). All partial effect values great than 0 represent a positive enhancement for smoothed terms on CPUE. All parametric terms are relative to the first factor of that category (i.e., Site 1).

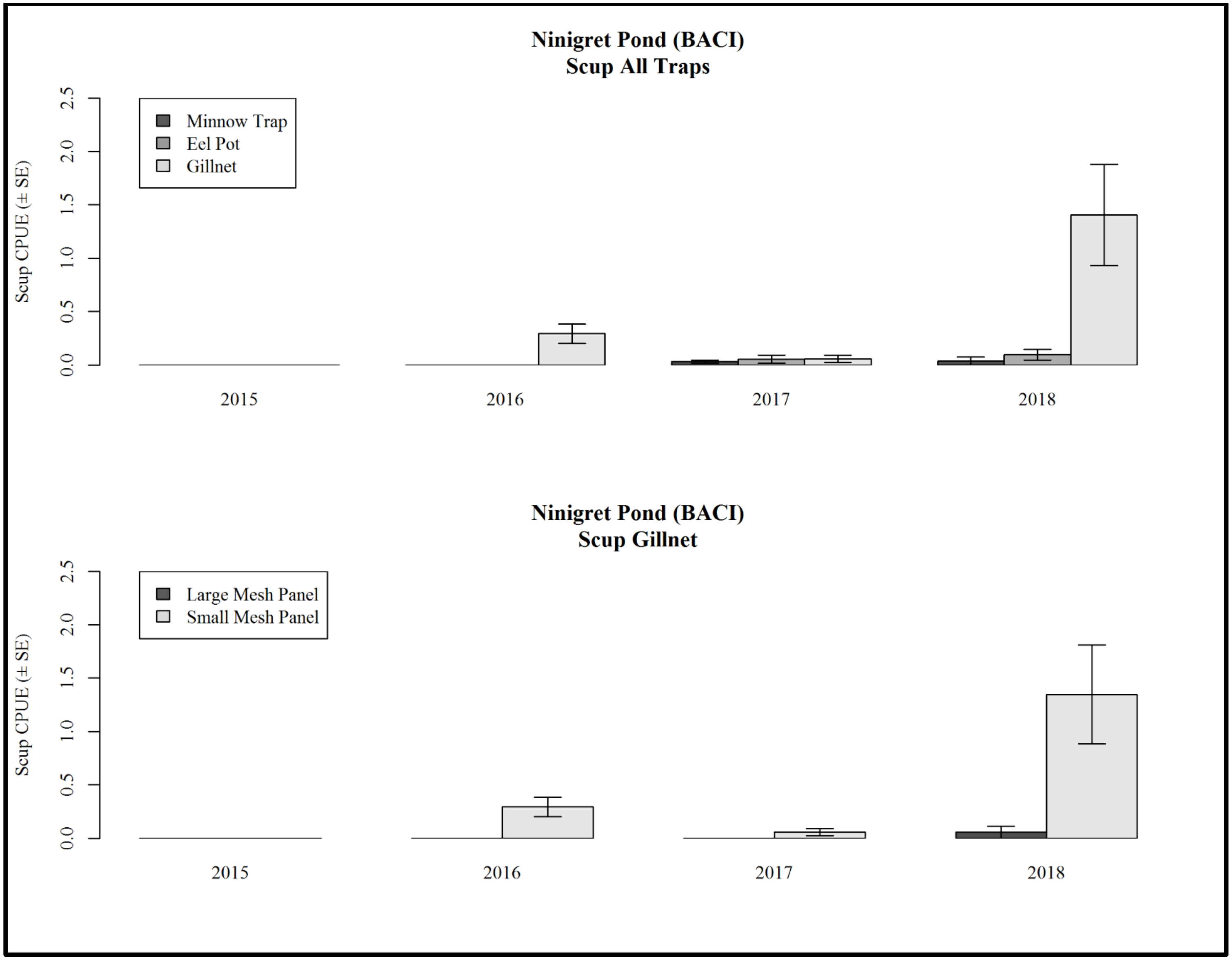


Figure 19a. Scup Bass BACI Analysis: Mean catch per haul (± SE) by year and gear type (top) and by year and mesh panel size in Ninigret Pond.

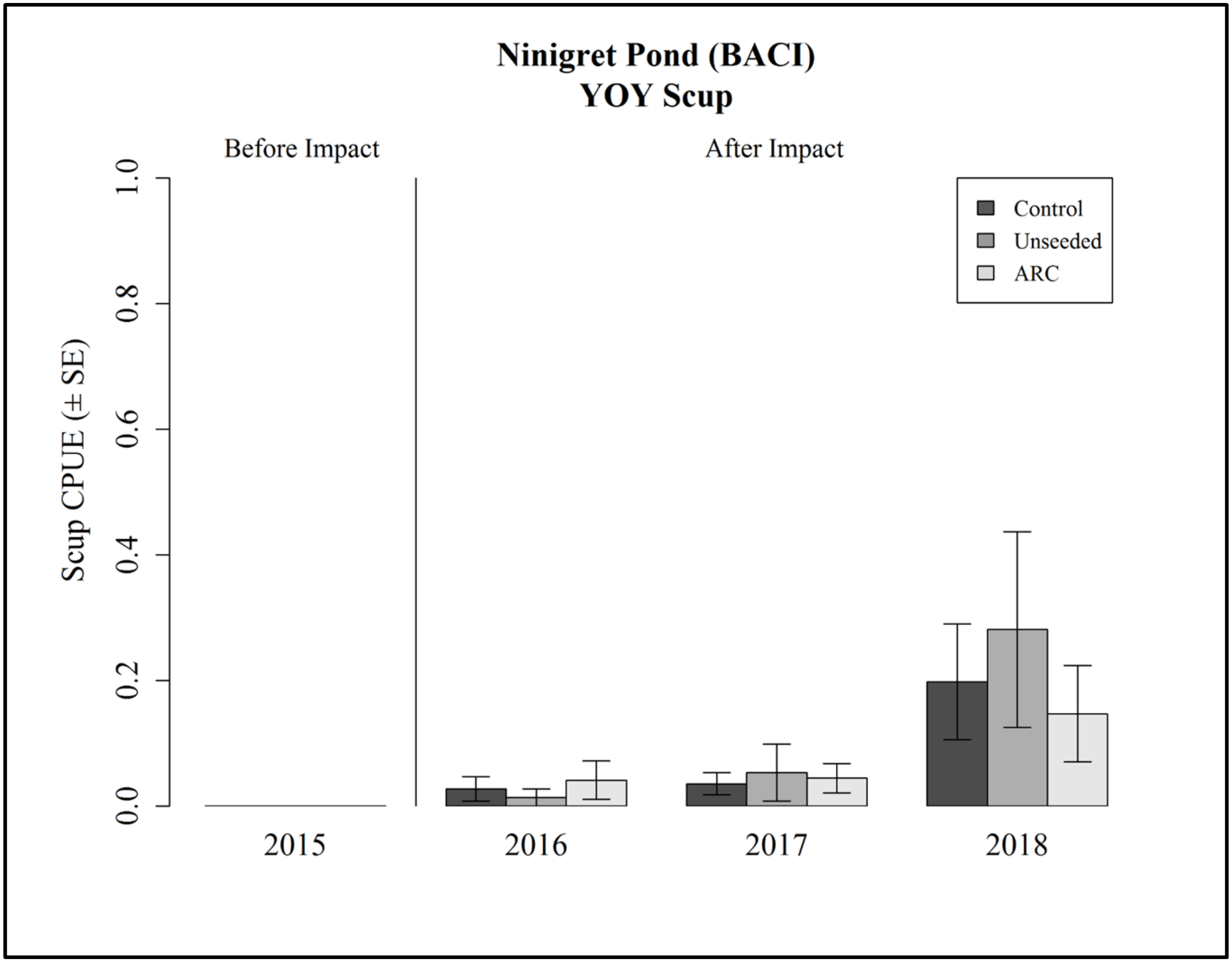


Figure 19b. Striped Bass BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Ninigret Pond.

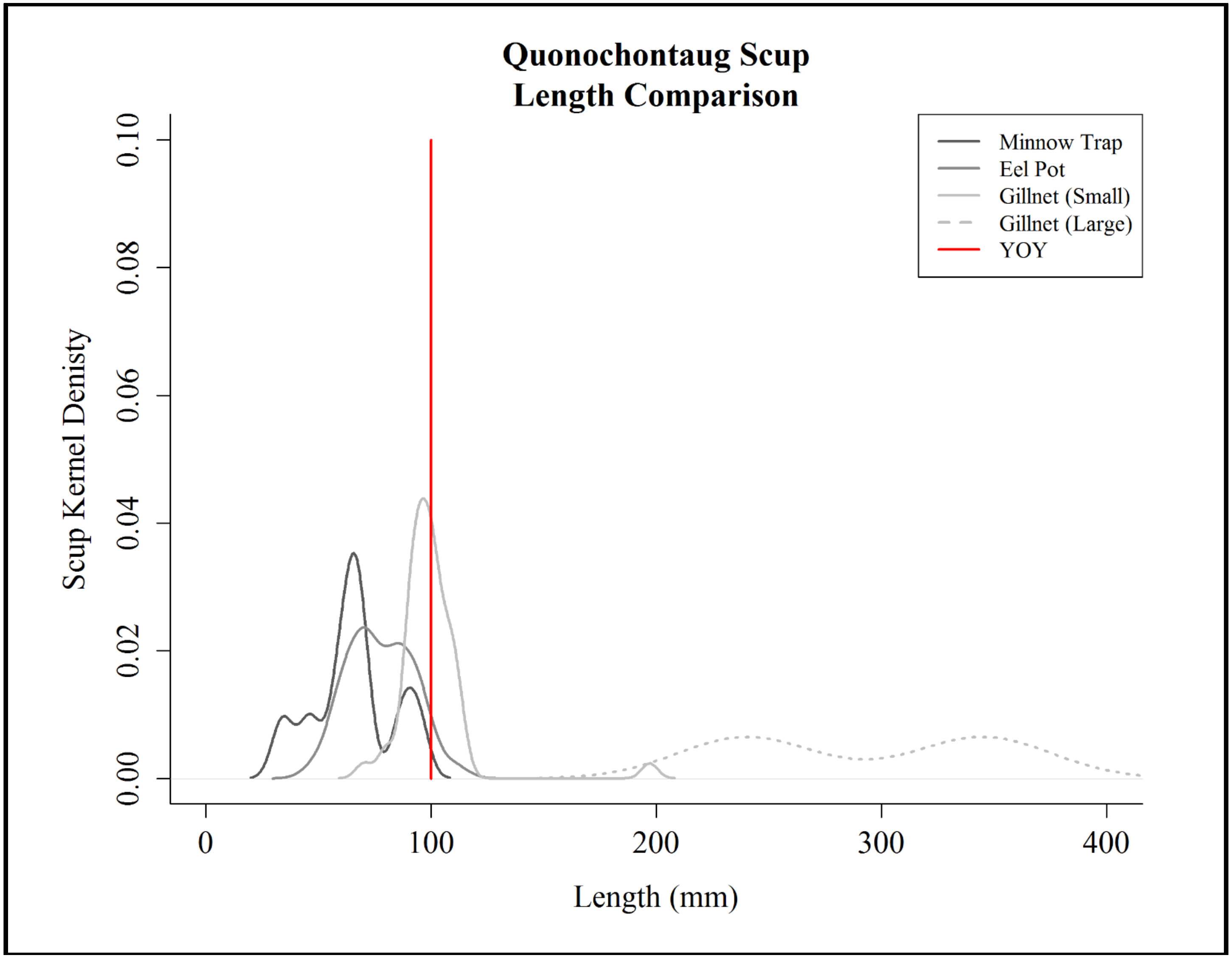


Figure 20a. Scup Length Frequency Analysis: Kernel density estimation of length separated by gear type (col and line type). Red line indicated YOY November cutoff length.

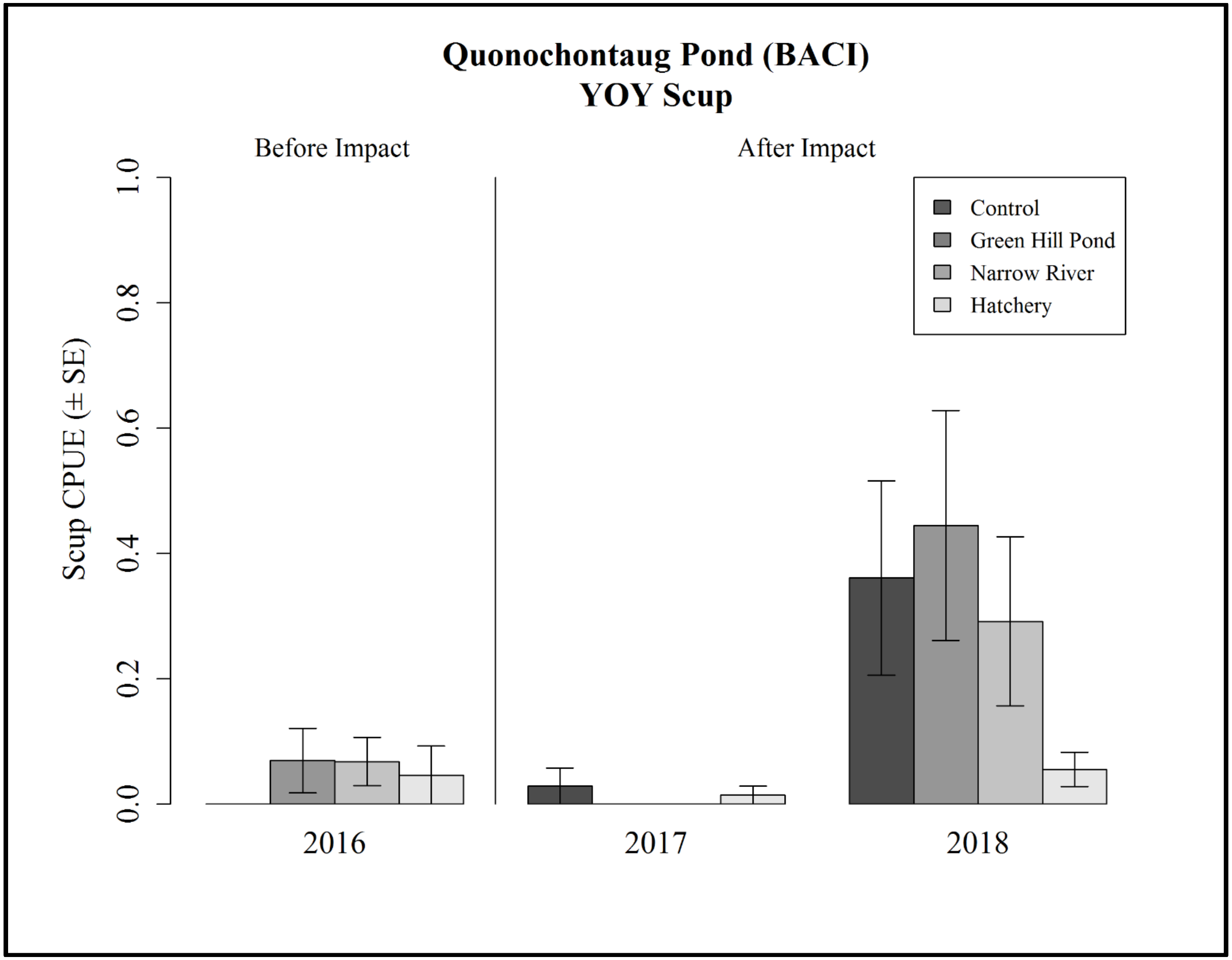


Figure 20b. Scup Bass BACI Analysis: Mean catch per haul (± SE) by year and enhancement treatment in Quonochontaug Pond.

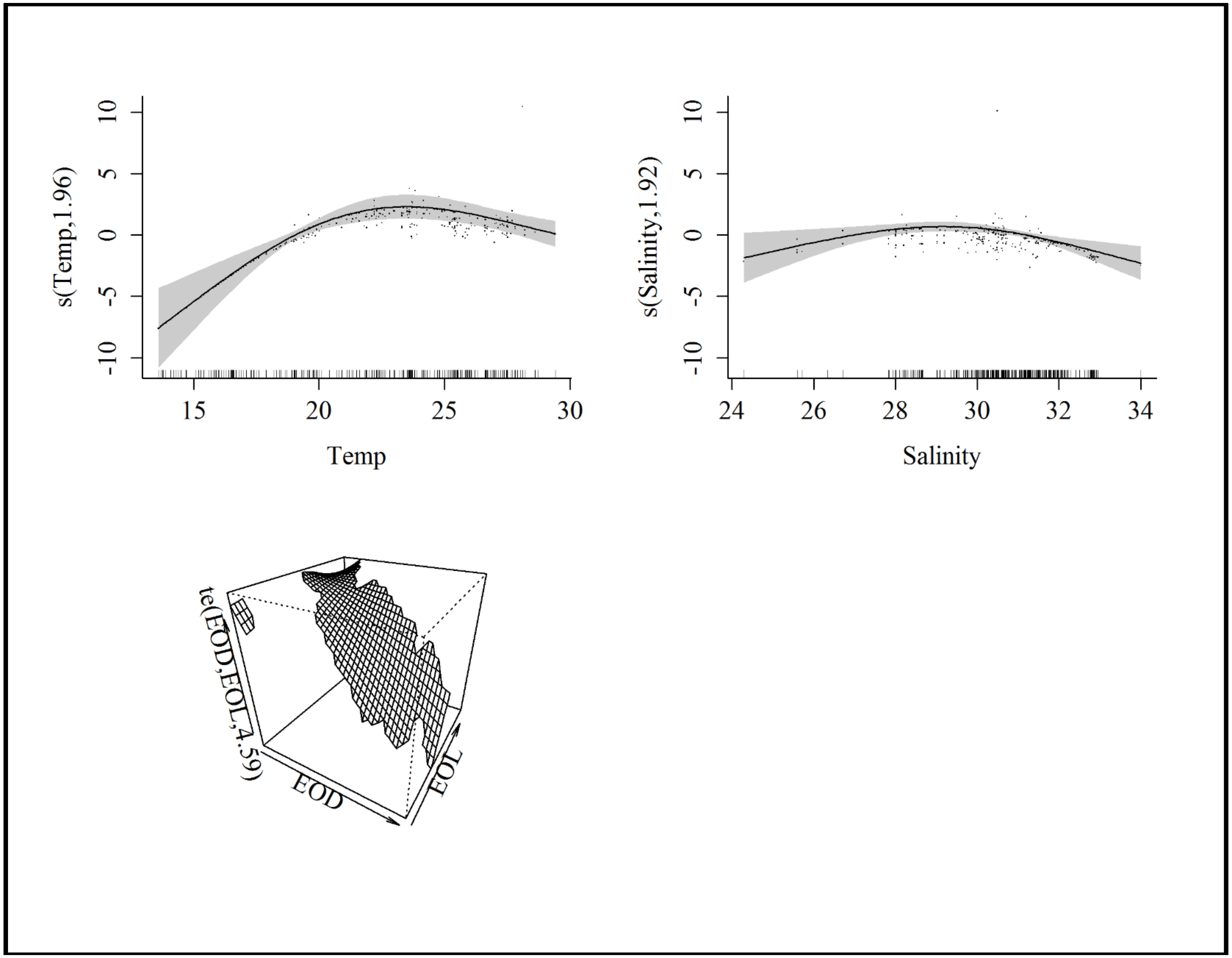


Figure 20c. Quonochontaug Scup YOY GAM Analysis: Partial effects plots for significant factors Temperature (top left), Salinity (Top right), and EOD x EOL (Bottom left). All partial effect values great than 0 represent a positive enhancement of CPUE.

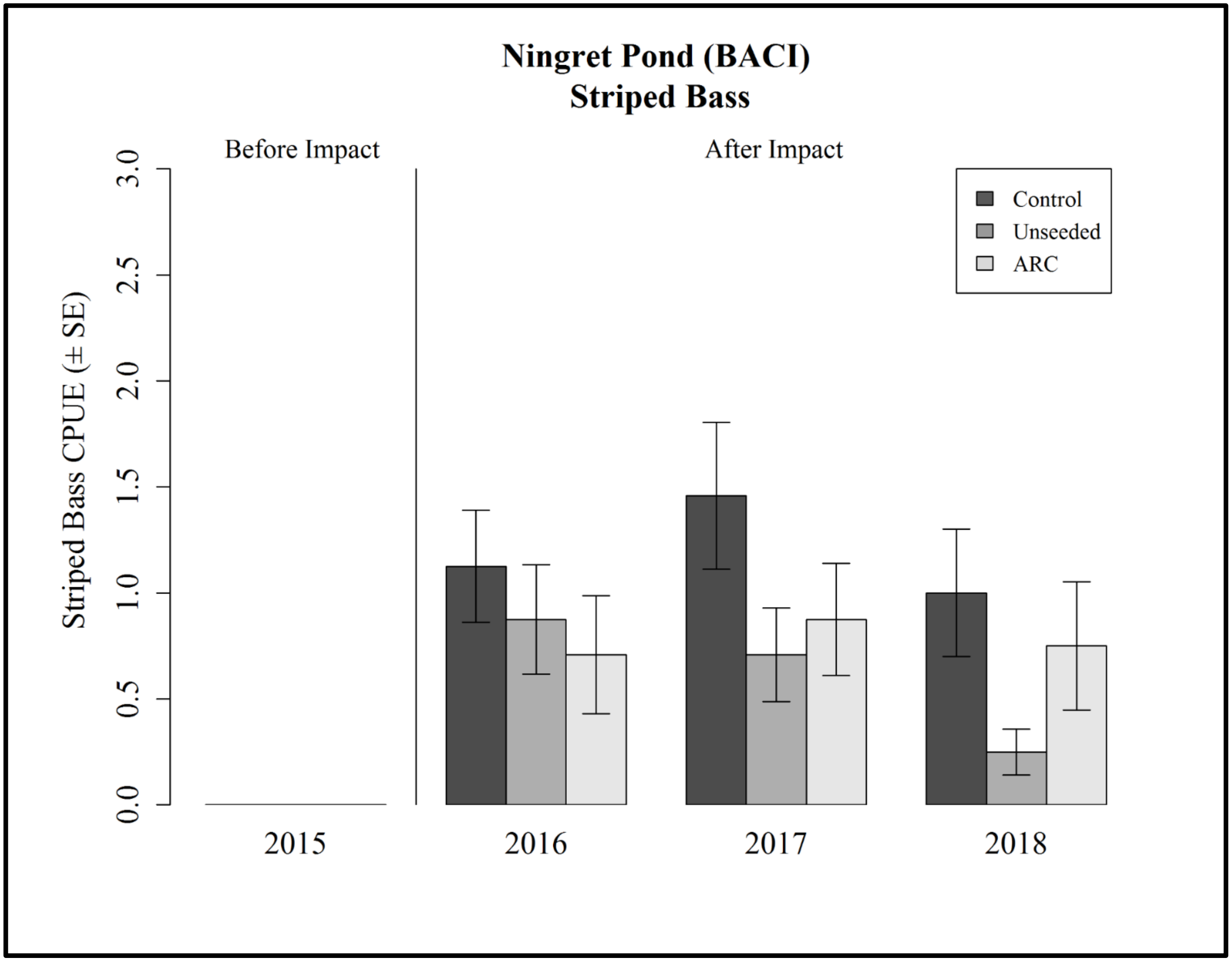


Figure 21. Striped Bass BACI Analysis: Mean catch per gillnet haul (± SE) by year and enhancement treatment in Ninigret Pond.

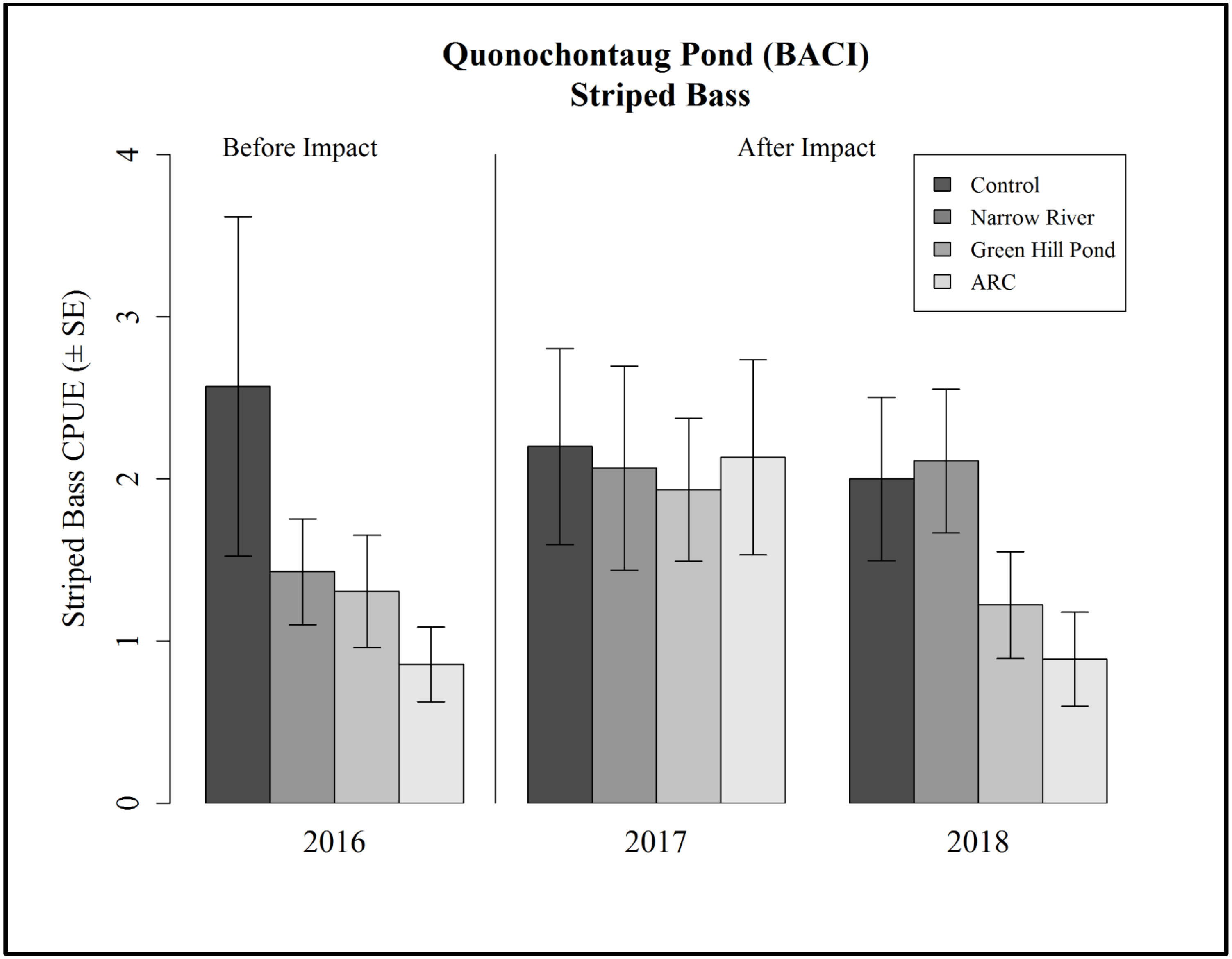


Figure 22. Striped Bass BACI Analysis: Mean catch per gillnet haul (± SE) by year and enhancement treatment in Quonochontaug Pond.

Figure 23. Photograph of DMF and TNC employees sampling gillnets for post-enhancement of reefs in Ninigret Pond.

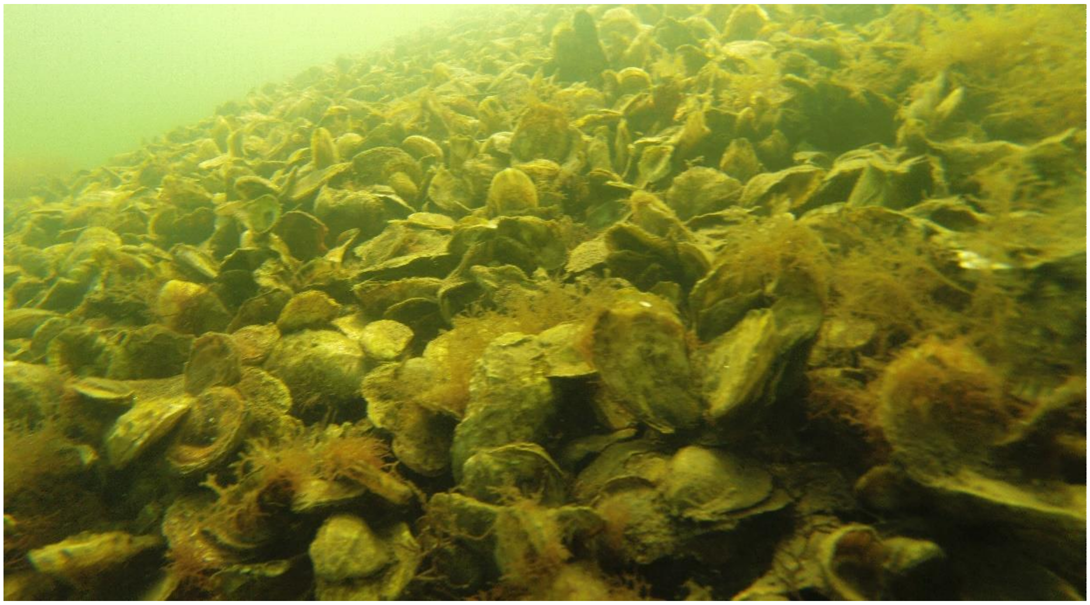


Figure 24. Photograph of a seeded FHE reef in Ninigret Pond taken during FHE habitat monitoring.

Figure 25. Photograph of black sea bass caught and measured in an eel pot during sampling.

Figure 26. Photograph of black sea bass being measured during sampling.

APPENDIX A
PERMIT APPLICATION REQUEST 2018

Proposed Work: Scientific research to assess if enhancing fish habitat, by creating oyster reefs, increases productivity of juvenile fish

Water Body Name: Point Judith Pond

City/State/ Zip: South Kingstown, Rhode Island

Site Location: Reefs will be created within a defined area (i.e., research sites) located in the northern portion of the current Shellfish Management Area of Point Judith Pond, South Kingstown, RI. The coordinates of the research sites and potential center points of the reef sites are presented in Table 1 and Figure 1.

This application is specific to Research Site 5 (Alternative).

Applicant(s):
Rhode Island Department of Environmental Management
Division of Marine Fisheries
Fort Wetherill Marine Laboratory, 3 Fort Wetherill Road
Jamestown, Rhode Island 02835

Principal Investigators: Jason McNamee (Chief of Marine Resource Management), and Eric Schneider (Principal Marine Fisheries Biologist)
Contact: Eric.Schneider@dem.ri.gov │ Phone: 401-423-1933

RI Chapter of The Nature Conservancy (TNC) *
159 Waterman Street
Providence, RI 02906
Co-Investigator: William Helt (Coastal Restoration Scientist)
*TNC is the co-applicant

PERMIT APPLICATION
REQUEST 2018

Summary

The Rhode Island Department of Environmental Management (RI DEM) Division of Marine Fisheries (DMF) in collaboration with The Nature Conservancy (TNC) is evaluating techniques to improve fisheries habitat in the coastal ponds along the south shore of RI. The scientific research outlined in this permit application is part of a multi-year, collaborative research program to determine if the practice of establishing oyster reefs in shallow coastal waters can be used as a tool to improve populations of recreationally important sportfish. Previous work in the mid-Atlantic has shown these techniques increased abundance of juvenile fish compared to unenhanced mudflat habitat (e.g. Grabowski et al. 2005); however, these techniques have not yet been evaluated in a temperate region of the Atlantic.

Specific to this permit application is scientific research to determine if construction of oyster reefs (using oyster and surf clam shell) can be used to enhance productivity of early-life stages of recreationally important fishes, such as black sea bass, tautog, scup, summer flounder, and winter flounder. The experimental design is discussed in the Approach section below.

Based on feedback and recommendations received from stakeholders during the previous Public Notice (PN) on Research Sites (RS) sites 1, 2, 3 (see CRMC File # 201-05-063; 201-05-064; 201-05-065), we're submitting additional permit applications containing potential alternative locations (RS 4, 5, 6) for the two previously noticed RS in Congdon Cove (i.e., RS 2, 3). **Specifically, in this permit, we propose to designate RS-5 (Table 1), which is a preferred alternative location where oyster reef creation would occur.** Each RS will contain four reefs and a control plot. All of the proposed RS are located in the northern end of PT Judith Pond (see Figure 1), which is an established RI DEM Shellfish Management Area. Shellfish harvest is prohibited in the northern end of the pond, where the RS are proposed to be located, due to the water quality impairments. The probation of oyster harvest will protect the oyster reefs and the fish habitat they provide. The coordinates for RS-5 are provided to mark the area in which reefs will be constructed, but does not reflect the actual area that will be taken up by the reefs.

Each reef has a footprint of ~ 200ft^2 and is comprised of not more than 10 cubic yards (y^3) of steam-shucked surf clam and seasoned oyster shell (Figure 2). Thus, the total oyster reef footprint in RS-5 will be ~800 ft^2 (0.019 acres) and consist of a volume of shell estimated at not more than 40 y^3. Oyster seed-on-shell will be placed on these reefs according to the experimental design (See Approach; Figure 2). Fish and habitat surveys will be conducted at the 4 experimental reefs as well as at the control plot prior to reef creation to determine the baseline conditions. These sites will also be monitored for 3-years post reef creation to determine if there are changes in fish productivity, such as changes in abundance and species composition at these reefs compared to control plots, as well as the success of the oyster reef creation techniques.

Specifically, we are requesting a CRMC Letter of Authorization to place cultch in tidal waters. The proposed work is eligible under the "Self-verification" provision in the US Army Corps of Engineer (ACOE) Rhode Island General Permit (RI GP) No. 10, entitled "Aquatic habitat restoration, establishment and enhancement activities". Therefore, a permit application to ACOE is not required; however, we will forward documents and permit applications, as applicable, to ensure the ACOE is aware of the proposed work. Similarly, a RI DEM Water Quality Certification (WQC) is not required for this work; however, we will forward a copy of this application to the RI DEM Office of Water Resources. We highlight that we are only returning shell to marine waters and seeding this shell with live oysters. We emphasize that this work is proposed within a duly promulgated RI DEM Shellfish Management Area (RI General Law § 20-3-4) in PT Judith Pond (RI DEM Marine Fisheries Regulations, Part IV, Shellfish, 4.12.2(K)) and will occur within a defined RS. The probation of oyster harvest in these areas will protect the oyster reefs and the fish habitat they provide.

We also emphasize that this research is conducted by a public entity and serves a compelling public purpose by providing benefits to public trust resources (e.g., the PT Judith Pond ecosystem and local fish stocks). This work consists of only returning shell to waters of the state and placing oyster seed in areas that historically supported oysters and/or currently consists of sediment with no complex structure. We hypothesize that these unenhanced sites have a reduced habitat value compared to the to be created oyster reef habitat (e.g., see Grabowski et al. 2005, Grabowski and Peterson 2007, Harding and Mann 2001). We expect the impacts of this work will only be beneficial, with no negative effects to the biological community.

It is important to recognize that in addition to expertise provided by RI DMF and TNC, Drs. Jon Grabowski and Randall Hughes of Northeastern University are assisting with aspects including the experimental design monitoring design, and subsequent analyses of the data. We note that RI DMF and TNC have pooled their financial resources to help fund this work, with additional funding provided by a grant awarded to the RI DMF under the US FWS Sportfish Restoration Program.

Introduction

Alteration and loss of coastal habitats, such as saltmarshes, eelgrass, and oyster reefs, is believed to be one of the most important factors contributing to decline in populations of marine finfish (Deegan and Bucshbaum, 2005). For example, more than 70% of Rhode Island’s recreationally and commercially important finfish spend part of their lives in coastal waters, usually when they are young (Meng and Powell, 1999). The shallow water, salt marshes, sea grasses, and oyster reefs provide excellent foraging and feeding areas as well as protection from larger, open-water predators. Juvenile finfish show a high degree of site fidelity, rarely moving far from shallow-water nursery habitats until either water cools in the late fall or resources are insufficient (Saucerman and Deegan, 1991). Habitats known to be important to early life stages of finfish include unvegetated soft sediments or tidal flats, submerged aquatic vegetation, and complex shellfish and oyster reefs (ASMFC 2007).

In Rhode Island, complex shellfish reefs formed by oysters (*Crassostrea virginica*) and ribbed mussels (*Geukensia demissa*) are found in intertidal and shallow subtidal waters of coastal lagoons and bays. Recent decades have witnessed declines in this habitat. For example, Beck *et al.* (2011) estimated that shellfish reefs are at less than 10% of their prior abundance and that

~85% of reefs have been lost globally. The decrease in oyster reef extent and condition has coincided with decreases in water quality and clarity, and loss of important nursery habitat for finfish and crustaceans (zu Ermgassen et al. 2013). Numerous studies have identified shellfish reefs as critical and essential fish habitat (EFH) for resident and transient finfish (Breitburg, 1999; Coen et al., 1999, ASMFC 2007). For example, Wells (1961) collected 303 different species of marine life that utilized oyster reef habitat. Reef-dwelling organisms are then consumed by transient finfish of recreational and commercial importance (Grabowski *et al.*, 2005; Grabowski and Peterson, 2007). Harding and Mann (2001) suggested that oyster reefs may provide a higher diversity and availability of food or a greater amount of higher quality food compared to other marine habitats. Grabowski et al. (2005) found that oyster reefs constructed in soft sediments increased the growth and survival of juvenile fishes such as the black sea bass *Centropristis striata*.

The growing recognition of the ecological and economic importance of complex benthic habitat has caused an increase in the efforts to construct oyster reefs (Coen and Luckenback, 2000; Brumbaugh et al., 2006). Although broadly accepted that habitat restoration and enhancement improves coastal ecosystems, it remains unclear if coastal habitat enhancement practices conducted here in RI would benefit the survival and growth of early life stages of finfish as in the mid-Atlantic.

Objectives

Specifically, the goal of the proposed research is to determine if oyster reef construction can be used to improve productivity of early-life stages of recreationally important fishes such as black sea bass (*Centropristis striata*), tautog (*Tautoga onitis*), scup (*Stenotomus chrysops)*, summer flounder (*Paralichthys dentatus*), and winter flounder (*Pseudopleuronectes americanus*). We will obtain this goal by addressing the following objectives:

(1) Determine the appropriate location for reef establishment considering oyster suitability modeling, present habitat quality and value, and connectivity to adjacent fish habitat.

(2) Conduct pre-enhancement evaluation of the experimental and associated control plots to establish baselines

(3) Create and establish oyster reefs at the experimental sites, consistent with the experimental design; and

(4) Conduct post-enhancement evaluation of the experimental reefs and control plots to determine if there are changes in fish productivity, such as changes in abundance and species composition of early life stages of recreationally important fish, and the effectiveness of the oyster reef construction techniques.

Approach

Experimental Design

This work is part of a multiyear project, occurring in several coastal ponds (Ninigret, Quonochontaug, and PT Judith). We have completed baseline monitoring and reef constructions and continue with post-construction fish and oyster monitoring in Ninigret and Quonochontaug. PT Judith represents the third and final phase of this work. This research will occur within a duly promulgated Shellfish Management Area (RI General Law § 20-3-4) and within defined research sites (RS) located in waters that are unapproved to shellfishing due to water quality impairments.

The prohibition on shellfishing allows for oyster propagation and growth and protects the oyster reefs and the fish habitat they provide. The experimental design for this research consists of 3 research sites in Northern PT Judith Pond (Table1, Figure 1). **This permit application pertains to RS-5 only. Details regarding the other five potential RS (1, 2, 3, 4, and 6) are contained in separate applications (see CRMC's website for PNs).** Within each RS there will be 4 experimental reefs, seeded with oysters, and 1 control plot that will remain untouched with no shell or alterations (Figure 1). By having these plots (reefs and controls) with in the same geographical area, we can ensure that these sites experience similar environmental conditions.

Site Selection and Characteristics

The DMF and TNC completed an initial site suitability analysis using available geospatial and fisheries data, including TNC oyster restoration suitability modeling results, marine sediment data, fish habitat data, and DMF seine survey data combined with visual underwater inspections were used to determine potential suitable locations for establishing oyster reef habitat in PT Judith Pond. During the initial scoping process, we identified and assessed 45 potential experimental reef plots. Based on stakeholder feedback, we identified and assessed an additional 20 potential sites, for a total of 65 sites. During both the initial and secondary assessments, we used an exclusionary analysis to eliminate sites based on feedback from stakeholders, as well as qualitative and quantitative marine habitat data. Using this process, we eliminated 35 potential reefs plots, resulting in the previous 15 sites sent to PN (i.e., RS 1, 2, 3) and the current 15 alternative potential experimental reef plots (i.e., RS 4, 5, 6) that satisfy the scientific requirements of this research and minimize impacts to other known uses occurring in these coastal ponds.

The 4 experimental reef plots and control plot relevant to this permit application are grouped within RS-5 (Table 1, Figure 1), which is located in a near shore area south west of Billington Cove outside of the typical area used for navigation and devoid of moorings. This area is suitable habitat for oyster restoration and is uniquely located adjacent to habitat that could be high quality fish habitat. However, based on preliminary observations, this area appears to be underutilized by targeted fish species. The sediment at this site consists of Anguilla mucky sand (sandy and gravelly marine/estuarine deposits)

Reef Construction

Shell used in this project will consist of disarticulated oyster and surf clam shell that has been seasoned for at least six months following Busheck et al. (2004) or steam-sucked and thus, possessing no viable biological material. Shell will be inspected by CRMC staff for residual tissue prior to use. Reef construction will occur as follows: Shell will be loaded into fish totes and transported by pontoon boat to each reef site. Shell will be deposited, by hand, along transects established by RI DMF and TNC. Each transect will mark the exact locations where shell will be deposited and the experimental reef will be created. Each reef will be round and have a footprint of ~200 ft^2 and comprised not more than 10 cubic yards (y^3) of steam-shucked surf clam and seasoned oyster shell (Figure 2). The total oyster reef footprint pertinent to this application is ~800 ft^2 (0.019 acres) and volume of shell estimated at not more than 40 y^3 (Figure 2).

Research has shown that reef height, or vertical relief from the bottom, significantly affects oyster larval survival and after one growing season, larval densities can be an order of a magnitude greater on high versus low vertical relief reefs (Brown, DS. 2013). At our experimental reef plots we aim to achieve sufficient relief to reduce impacts from predators and microalgae by deploying not more than 10 cubic yards of shell to create a round reef with an initial reef height of at least 18 inches and not more than 30 inches from the bottom. This "built" height accounts for future reef subsidence (up to 6" at some sites), general compression, and wave scour that will likely reduce the final reef height by as much as 6-12 inches. We note that the volume of shell at a given site will be a function of desired final reef height and water depth at the site. We anticipate the top of each reef will be at minimum 12 inches below the surface of the water and typically 12-30 inches below mean low water depending on the site and given tide. This is generally consistent with the amount of water over oyster reefs at restoration sites located in Ninigret and Quonochontaug Ponds, where Fish Habitat Enhancement reefs were established in 2015 and 2017, respectively, as well as various other restoration projects conducted by DEM-NRCS and DEM-TNC (e.g., over 120 small-scale individual reefs since 2015).

Construction will occur during October or November 2018. Live oyster seed-on-shell at a density of at least 1,000 oysters/m^2 will placed on reefs during late November. These sites will be marked according to RI DMF and RI CRMC requirements.

Monitoring

Monitoring of fish habitat and assemblage will be conducted prior to reef construction at both experimental reefs and adjacent controls to establish baselines. Monitoring of fish habitat, fish assemblages, and oyster reefs will be conducted at both experimental reefs and adjacent controls (except controls will not have reefs, thus no reef monitoring) post-reef creation to determine if there are changes in abundance and species assemblage of recreationally important fish, and ultimately to determine the effectiveness of the oyster reef construction techniques. This monitoring will be conducted monthly (May, June, July, August, September, and October) over 4 years (1-year pre- and 3-years post-reef creation) across sites. Pre-reef construction monitoring (i.e. baseline) begins in 2018; post-construction monitoring will begin in 2019 and continue until at least 2011.

To assess fish assemblages we will use a combination of standard fisheries sampling techniques, including deploying minnow pots, modified eel pots, and gill nets at each study plot. Gillnets will be 10m long, consisting of two different mesh sizes. We will also evaluate the use of video sampling to target the resident fishes on the reefs. To determine the health of the oyster reefs and evaluate the success of reef creation techniques, each reef will be monitored using techniques consistent with those outlined in the "Essential Monitoring" requirements established by the Rhode Island Shellfish Technical Working Group and documented in the Monitoring Outline (pg 22) of the RI Oyster Restoration Minimum Monitoring Metric and Assessment Protocols (Griffin et al. 2012). We will assess whether recruitment monitoring using artificial spat collectors is needed based on other monitoring projects being conducted within the Shellfish Spawner Sanctuary.

It is important to recognize that in addition to expertise provided by RI DMF and TNC, Drs. Jon Grabowski and Randall Hughes of Northeastern University are assisting with aspects including the experimental design, monitoring design, and subsequent analyses of the data. We note that RI DMF and TNC have pooled their financial resources to help fund this work, with additional funding provided by a grant awarded to the RI DMF under the US FWS Sportfish Restoration Program.

Potential Impacts

We do not anticipate any negative impacts from the proposed restoration work. As part of the site selection process and baseline monitoring, the three RS locations were surveyed using underwater video, snorkel, and SCUBA to evaluate benthic habitat and eelgrass presence. Based on our findings, the proposed reef locations are not located on eelgrass or areas mapped as containing eelgrass and will not impact eelgrass or benthic habitat. We note that any shellfish located within the reef footprint will be relocated prior to reef construction, thus there will be no impacts to current shellfish stocks. We also consulted marine habitat specialists and benthic ecologists to obtain feedback on potential impacts to the spring cinder worm hatch from the proposed reef creations. Experts conveyed that, in their opinion, due to the depth and small size of the proposed reefs, there would not be an impact on worms spawning in the spring cinder worm hatch that fishers and striped bass are keying on in Pt. Judith Pond. They also noted that the creation of oyster reefs does not represent a true loss of habitat because, some Nereis species utilize oyster reefs as habitat.

We emphasize that this research is conducted by a public entity and serves a compelling public purpose by providing benefits to public trust resources (e.g. the PT Judith Pond ecosystem and local fish stocks). We also highlight that this work is proposed within a duly promulgated RI DEM Shellfish Management Area (RI General Law § 20-3-4) in PT Judith Pond (RI DEM Marine Fisheries Regulations, Part IV, Shellfish, 4.12.2(K)) and within the to be created RS. The current probation of shellfish harvest encompassing this RS will protect the oyster reefs and the fish habitat they provide. This work consists of only returning shell to waters of the state and placing oyster seed in areas that historically supported oysters and/or consists of sediment with no complex structure. We hypothesize that these unenhanced sites have a reduced habitat value compared to the to be created oyster reef habitat (e.g., see Grabowski et al. 2005, Grabowski and Peterson 2007, Harding and Mann 2001). We expect the impacts of this work will only be beneficial, with no negative effects.

Potential Limitations on Success

Challenges to the establishment of these oyster reefs and the associated enhanced habitat they provide of recreationally important fish species include natural variation in oyster larval supply and recruitment success, predation, and physical disturbance, including sediment burial, wave impact, and scouring. Unlike most research and habitat enhancement projects, we are able to assess the success of these reefs and conduct maintenance seeding in future years if deemed necessary and appropriate.

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Table 1. Coordinates for the corner points of RS-5.

Site 5 - Billington Cove

Reef	longitude	latitude
5A	71° 30' 17.21"" W	41° 25' 13.91"" N
5B	71° 30' 15.67"" W	41° 25' 12.49"" N
5C	71° 30' 13.64"" W	41° 25' 11.50"" N
5D	71° 30' 11.32"" W	41° 25' 12.43"" N
5E	71° 30' 10.64"" W	41° 25' 14.17"" N
Habitat Enhancement Area 5 (2.0 acres)	71° 30' 12.03"" W	41° 25' 14.59"" N
	71° 30' 9.89"" W	41° 25' 14.64"" N
	71° 30' 10.35"" W	41° 25' 12.36"" N
	71° 30' 14.41"" W	41° 25' 10.99"" N
	71° 30' 16.18"" W	41° 25' 12.09"" N
	71° 30' 17.89"" W	41° 25' 13.97"" N
	71° 30' 16.99"" W	41° 25' 14.47"" N
	71° 30' 14.65"" W	41° 25' 12.45"" N
	follow shore to close area	

Figure 1. Proposed configuration of fish habitat enhancement research sites (RS) 1-6, each of which would contain 4 small scale reefs and 1 control (undisturbed) in the northern end of Pt Judith Pond, RI. The experimental design of this research project requires a total of three (3) RS. Note that RS sites 1, 2, 3 were originally sent to CRMC public notice (PN) (see CRMC File # 201-05-063; 201-05-064; 201-05-065). Current applications for alternative locations RS 4, 5, 6 are in response to stakeholder feedback on previous locations, including RS 2, 3 in Congdon Cove.

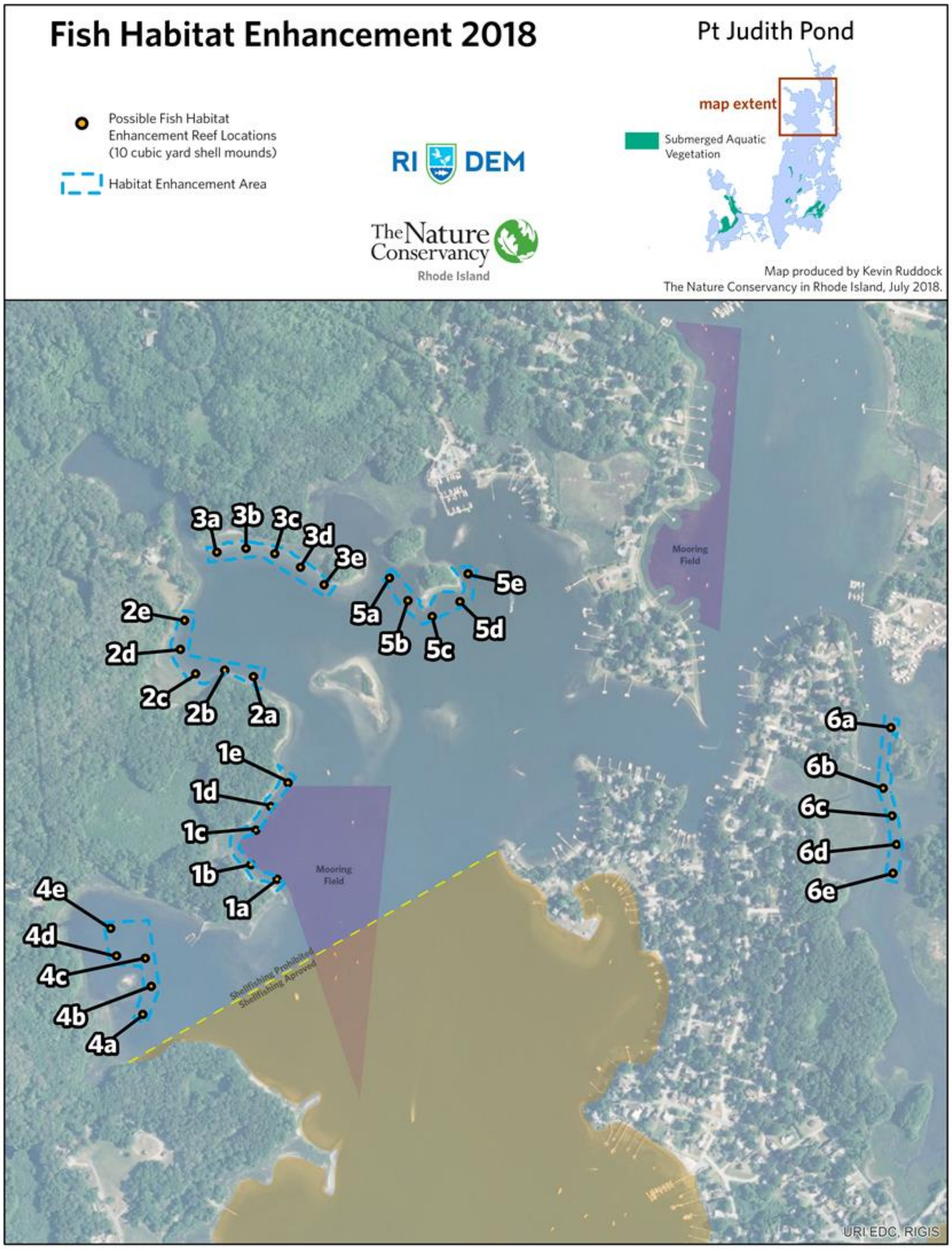
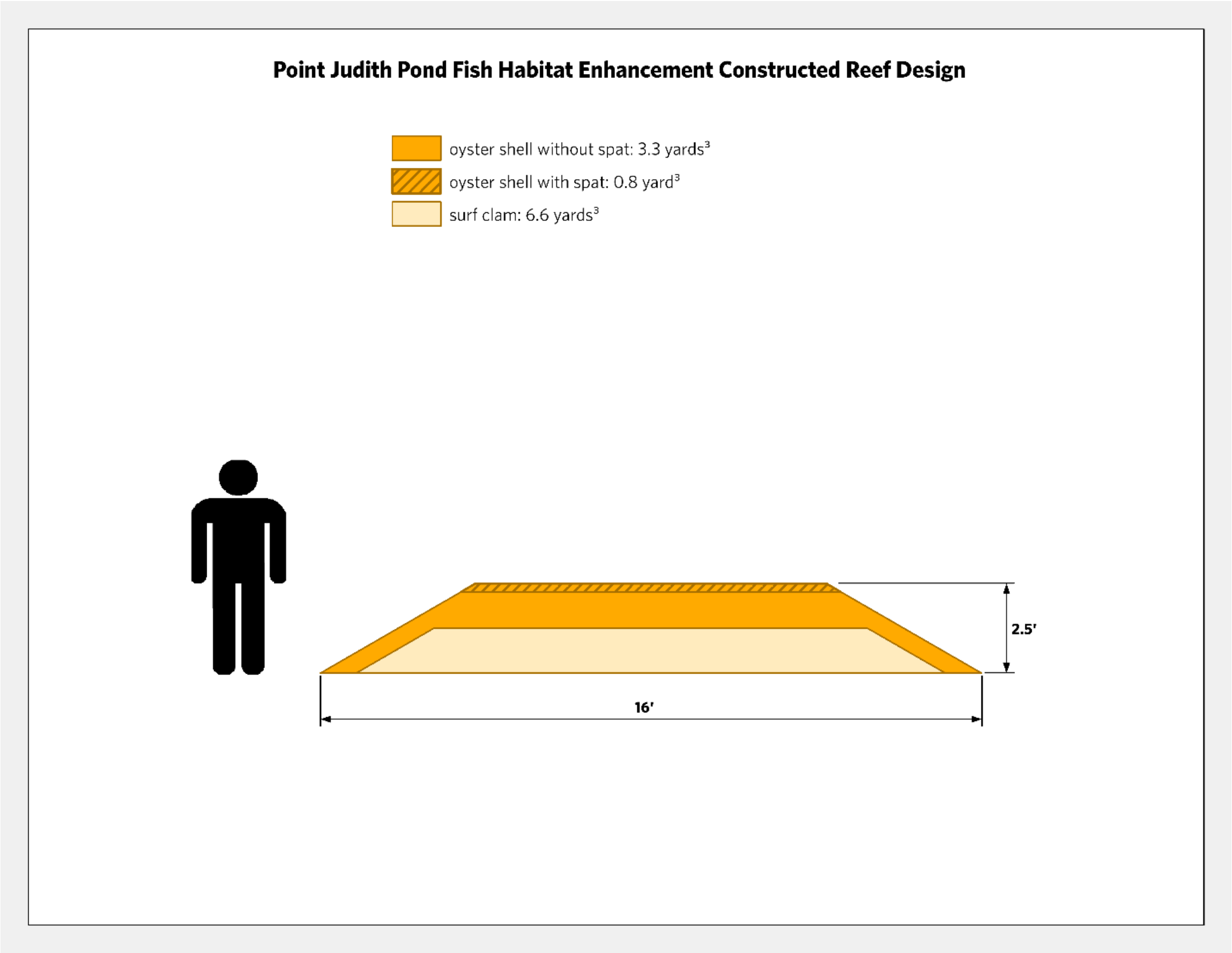


Figure 2. Side profile of an experimental reef showing the maximum "built" height immediately following reef creation. We note that the volume of shell at a given site will be a function of desired final reef height and water depth at the site, as well as expected effects from reef subsidence. Each reef will be round extending 8 feet from the center, have a total footprint of ~ 200 ft^2, and comprised not more than 10 cubic yards (y^3) of steam-shucked surf clam and seasoned oyster shell. We anticipate the top of each reef will be typically 12-30 inches below mean low water depending on the site and given tide.



--- End of Permit Application ---

- End of Report –

Sportfish Assessment and Management in Rhode Island Waters

Jason McNamee
Eric Schneider
Nicole Costa
Conor McManus
Nichole Ares
Julia Livermore
Corinne Truesdale

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

STATE: Rhode Island

PROJECT NUMBER: F-61-R

SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

PERIOD COVERED: January 1, 2018 – December 31, 2018

JOB NUMBER 8 TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

During this segment, two fish stock assessments were completed that included a benchmark assessment for summer flounder and a benchmark assessment for striped bass. In addition to completed stock assessments, there are five other stock assessments that RI staff participate in that have been initiated and are in progress including assessments for bluefish (enhanced update), menhaden (benchmark), multispecies (benchmark), black sea bass (enhanced update), and scup (enhanced update). One final exercise that is in process is a management strategy evaluation for recreational summer flounder. RI also contributes local small-scale stock assessments to help inform local management decisions, and these often rely on survey information that is derived from surveys funded by the sportfish restoration grant. Scientific advice to fisheries managers emerged from these assessments, particularly during the deliberations of the state's licensing provisions for 2018, which has impacts to recreational fisheries, as well as in the process for setting the recreational management plans for 2019. The project leaders participated at the Atlantic States Marine Fisheries Commission's (ASMFC) meetings relative to the management of recreationally important coastal stocks. They also participated in the National Oceanographic and Atmospheric Administration (NOAA) stock assessment meetings for species under their jurisdiction, including the peer review for striped bass and summer flounder referred to as the SAW/SARC review process. Other project staff participated at fish stock assessment trainings conducted through the ASMFC and NOAA. The status of the most important recreationally caught species in Rhode Island were presented in the finfish sector management plan which was submitted for public review and input for establishing management strategies for 2019 (Finfish Sector Management Plan 2017, see: http://www.dem.ri.gov/pubs/regs/regs/fishwild/mpfinfsh.pdf). The following is a summary of the activities that took place in 2018.

1. SUMMER FLOUNDER

A full benchmark assessment was performed and was peer reviewed at the SAW/SARC 66 meeting (https://www.nefsc.noaa.gov/publications/crd/crd1901/). This assessment passed peer review and is being used for management in 2019. This assessment process included multiple modeling frameworks such as sex specific and state-space models. The main tasks performed by staff were to gather both catch and fishery independent information from previous years and stratify that information by age based on aging information from the NOAA trawl survey. RI contributes its Division of Marine Fisheries trawl survey data (see job number 2 from this grant) and the University of Rhode Island Trawl Survey information (see job number 14 from this grant) to the assessment. Staff were active members of the benchmark stock assessment working group and participated in meetings where the assessment information was released. Additionally, the RI participant on this working group developed unique ways for combining survey indices, and ran multiple alternative assessment runs with this combined survey information.

The 2018 benchmark summer flounder stock assessment used recreational catch estimates from 1982 – 2017 as a source of removals in a combined sex statistical catch-at-age (SCA) model, like the previously approved assessment structure. Catch estimates included both direct harvest and live releases, but only a portion of the live releases are considered removals (dead). One big change from previous assessments for summer flounder was the use of the newly calibrated Marine Recreational Information Program (MRIP) data. The assessment compared uncalibrated and calibrated harvest and dead release estimates. These comparisons indicated that calibrated MRIP estimates were significantly higher than non-calibrated MRIP estimates. Calibrated harvest estimates increased total harvest by an average of 29% over the time period analyzed. The differences generally scaled the biomass of the population up, but the trends through time were similar to the old estimates.

The impact of the newly calibrated data on the summer flounder assessment was that it increased the population size to support the additional removals. For the case of summer flounder, stock status (relative to current reference points) and model diagnostics improved with the new data. Things generally improved with the new assessment, but the challenge will be how to contend with the resource allocation between the recreational and commercial fisheries. As a case in point, the commercial quota will increase significantly in 2019, but recreational regulations will stay close to what they are now due to the fact that the recreational harvest was higher than earlier projections anticipated due to the calibration, while the commercial fishery was constrained to the quota. Deciding how to handle this effect of the recalibration will likely keep fishery managers busy over the coming couple of years.

Beginning in 2018, a Management Strategy Evaluation (MSE) framework to test the performance of the current and potential alternative F-based management approaches for the recreational summer flounder fishery was developed. The intent with this project is to show the relative value of both current and potential management actions for satisfying management objectives. F-based management alternatives were constructed in the context of application to the existing specification setting process for summer flounder. An age-structured operating model of summer flounder population and fishery dynamics was constructed that explicitly included implementation uncertainty associated with application of management measures in the recreational fishery. Available data on the responses of recreational fishers to summer flounder management measures was synthesized to construct a set of plausible alternatives for these fleet dynamics and their associated uncertainty. Additionally, historical effects of various management measures

on harvest and catch at various levels of refinement (e.g. state, wave, mode) based on MRIP data were used to quantify the most appropriate levels of effect and uncertainty to associate with the management choices made in the MSE analysis.
The management approaches tested within the MSE seek to replicate the steps associated with data collection, interpretation, and decisions about whether and how to adjust recreational fishing measures. The simulations consider several broad sets of alternative management approaches including: 1) Status quo, where recreational harvest limits are compared to estimates of current recreational harvest based on the MRIP statistical sampling program, with adjustment measures to include: season length, minimum size, bag limits, and combinations thereof; 2) Risk-based status quo, where a percentile of the estimated uncertainty is used rather than point estimates of recreational harvest; 3) F-based management, where the stock assessment estimate of the current fishing mortality is compared to the target F, with one or more of the management measures described above being adjusted accordingly. Alternatives within this approach will include incremental adjustments to encourage stability in advice and overfishing threshold projections based on expected probabilities of overfishing given different management measures; 4) Risk-based F-based management where similar approaches as for 3. are applied but percentiles of uncertainty estimates are used to determine appropriate adjustments instead of point estimates. The performance of the various management options will be evaluated by comparing the projections of recreational harvest to prescribed limits (for options that retain RHLs), as well as projected stock biomass and fishing mortality rates relative to reference points and risk tolerances. The relative performance of these measures will be presented to the ASMFC and the Mid Atlantic Fishery Management Council, and a RI staff member is one of the principal investigators on this project.

2. STRIPED BASS

A full benchmark assessment was performed and was peer reviewed at the SAW/SARC 66 meeting (https://www.nefsc.noaa.gov/publications/crd/crd1901/). This assessment passed peer review and will likely be used for the management process that will unfold in 2019. This assessment process included multiple modeling frameworks such as area specific modeling approaches. The main tasks performed by staff were to gather both catch and fishery independent information from previous years. RI contributed its survey information to the assessment, however none of those surveys were incorporated in to the final assessment. Staff were active members of the benchmark stock assessment working group and participated in meetings where the assessment information was released.

The 2018 benchmark striped bass stock assessment used recreational catch estimates from 1982 – 2017 as a source of removals in a statistical catch-at-age (SCA) model. Catch estimates included both direct harvest and live releases. Newly calibrated recreational data were used as noted in the summer flounder section. Calibrated harvest estimates were on average 140% higher while calibrated live releases were on average 160% higher. Despite these differences in removals, both the calibrated and non-calibrated estimates showed similar trends in spawning stock biomass (SSB) over time.

The impact of these data on the assessment findings was significant. In order for the striped bass population to be able to support the larger recreational removals indicated by the newly calibrated MRIP estimates, the model estimated that there was a higher level of SSB than previously indicated. Although the 2018 SCA model shows a similar declining trend in female SSB to that of the 2013 SCA model (the last benchmark assessment for striped bass), the decline since 2012 became much sharper. The striped bass population is defined as overfished when the female SSB is below the estimate of female SSB in 1995, the year the striped bass population was declared restored. Female SSB in 2017 was estimated at 68,476 mt, a value below the SSB threshold of 91,436 mt, indicating the striped bass stock is overfished.

The fishing mortality rate (F) that will maintain the striped stock at the SSB threshold is the defined as the F threshold. In the 2018 SCA model the F threshold was estimated to be 0.240 and F in 2017 was estimated to be 0.307, indicating the stock is experiencing overfishing.

While the newly calibrated MRIP estimates are thought to be a major factor contributing to the finding that the striped bass stock is overfished and overfishing is occurring, other contributing factors include the reduced bag limits from previous management actions and sizeable year classes that have not yet fully recruited to the fishery that are increasing discards in the Chesapeake Bay and along the coast. Finding ways to improve the stock status of striped bass will be the challenge for managers in 2019.

3. ATLANTIC MENHADEN AND MULTISPECIES MODELS

The ASMFC began a benchmark assessment in 2018 for the coastwide stock for Atlantic menhaden. The Atlantic menhaden stock is assessed with a statistical catch at age model called BAM (Beaufort Assessment Model). This will be a full benchmark assessment, therefore it is more time consuming than an update assessment, so while it began in 2018, it will conclude in late fall of 2019. The main tasks are to gather both catch and fishery independent information from previous years and stratify that information by age based on aging information from the NOAA menhaden sampling program, which RI contributed locally caught samples to. RI contributes its Division of Marine Fisheries seine survey data (see job number 4 from this grant) and its trawl survey data (jobs 1 and 2 from this report) to the assessment. Staff collects the information and processes it for the assessment. Staff also participate in meetings where the assessment information is reviewed and are active members of the stock assessment sub-committee.

In addition to the single-species menhaden assessment, a series of multispecies models will be produced for the same peer review as the menhaden single-species assessment. These models will include an Ecopath with Ecosim model, a Steele-Henderson multispecies surplus production model, a Bayesian time-varying surplus production model, and RI staff have created a multispecies statistical catch-at-age model (MSSCAA). The MSSCAA model features menhaden, striped bass, bluefish, weakfish, and scup as the modeled species, all recreationally important species. The goal for these models is to incorporate more ecosystem and trophic interaction information in to the assessment process, and to create ecological reference points. The tasks associated with the preparation of these multispecies assessments is similar to that of the single-species assessments as mentioned in the other sections of this report. These models will also be reviewed in late fall 2019, with RI staff being required to present the MSSCAA model as the lead assessment scientist.

3. BLACK SEA BASS

NOAA began an update assessment in 2019 for the black sea bass stock. The black sea bass stock had been assessed with a spatial statistical stock assessment model. This spatial benchmark assessment was approved in 2016 and will be used for the update assessment in 2019. This is another species that will incorporate the newly recalibrated MRIP data for the recreational harvest component. The main tasks are to gather both catch and fishery independent information from previous years and stratify that information by age based on aging information that is collected in each state and by NOAA. RI contributes its Division of Marine Fisheries trawl survey data (see jobs 1 and 2 from this document) and hopes to contribute the new ventless pot survey information in the future to the assessment. Staff collects the information and processes it for the assessment. Staff will also participate in meetings where the assessment information will be reviewed and will also be active members of the stock assessment sub-committee, with responsibilities for developing management analyses after the assessment is complete.

5. SCUP

NOAA began an update assessment in 2019 for the scup stock. The scup stock had been assessed with a statistical catch-at-age assessment model. This benchmark assessment was approved in 2015 and will be used for the update assessment in 2019. This is another species that will incorporate the newly recalibrated MRIP data for the recreational harvest component. The main tasks are to gather both catch and fishery independent information from previous years and stratify that information by age based on aging information that is collected by NOAA. RI contributes its Division of Marine Fisheries trawl survey data (see jobs 1 and 2 from this document) and the University of Rhode Island Trawl Survey information (see job number 14 from this grant) and hopes to contribute the new ventless pot survey info in the future to the assessment. Staff collects the information and processes it for the assessment. Staff will also participate in several meetings where the assessment information will be reviewed and will also be active members of the stock assessment sub-committee, with responsibilities for developing management analyses after the assessment is complete.

6. BLUEFISH

NOAA began an update assessment in 2019 for the bluefish stock. The bluefish stock had been assessed with a statistical catch-at-age assessment model. This benchmark assessment was approved in 2015 and will be used for the update assessment in 2019. This is another species that will incorporate the newly recalibrated MRIP data for the recreational harvest component. Importantly, recreational harvest represents the vast majority of the harvest in this fishery, much higher than the commercial component, therefore the calibrated data will likely have an important effect on this assessment. The main tasks are to gather both catch and fishery independent information from previous years and stratify that information by age based on aging information that is collected by NOAA. RI contributes its Division of Marine Fisheries trawl survey data (see jobs 1 and 2 from this document), the University of Rhode Island Trawl Survey information (see job number 14 from this grant), and seine survey data (see job number 4 from this grant). Staff collects the information and processes it for the assessment. Staff will also participate in several meetings where the assessment information will be reviewed and will also be active members of the stock assessment sub-committee, with responsibilities for developing management analyses after the assessment is complete.

ASSESSMENT OF RECREATIONALLY IMPORTANT FINFISH STOCKS IN RHODE ISLAND COASTAL WATERS

Age and Growth Study

Nicole Lengyel Costa
Thomas Angell
Christine Denisevich

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

March 2019

PERFORMANCE REPORT

STATE: Rhode Island **PROJECT NUMBER:** F-61-R

SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters

PERIOD COVERED: January 1, 2018 – December 31, 2018

JOB NUMBER AND TITLE: 9, Age and Growth Study

JOB OBJECTIVE: To collect age, growth, diet composition, and maturity data on recreationally and ecologically important finfish in Narragansett Bay for management purposes. Data collected in this study will be used in state, regional and coast-wide stock assessments and fisheries management.

SUMMARY: Investigators collected lengths, weights, and age structures from target species of recreationally important finfish. The type of age structure collected, and the number of samples collected varied by species. Investigators were able to collect, or exceed, the target sample numbers for black sea bass, bluefish, scup, striped bass, summer flounder, and tautog, and weakfish, however fell short on target sample numbers for menhaden (56/100). Ageing structures were also collected for spiny dogfish and winter flounder although they are not target species for ageing. Investigators had difficulty in obtaining samples for certain species, particularly weakfish and menhaden, due to the dynamics of the fisheries and the availability of fish. Work to age the primary ageing structures collected in 2018 is complete.

In addition to age and growth data collected in 2018, investigators continued the collection of stomach content, sex, and maturity stage data from target species in 2018. This data was collected through collaboration with investigators on the RIDMF monthly and seasonal trawl survey (Jobs 1 and 2), commercial floating fish trap operations, commercial gillnetters, and fish donated by recreational hook and line fishers.

TARGET DATE: Ongoing

STATUS OF PROJECT: On schedule

SIGNIFICANT DEVIATIONS: No significant deviations occurred in 2018. Investigators achieved, or exceeded, sampling targets for seven species (black sea bass, bluefish, scup, striped bass, summer flounder, and tautog, and weakfish), and fell short on the sampling targets for one species (menhaden). This was due to the dynamics of the fishery as well as the availability of fish.

RECOMMENDATIONS: Move into the next grant award period and project segment and continue data collection in 2019.

REMARKS: In the future and to better describe the natural diet, stomach content analysis will not utilize fish caught in baited fish pots (i.e. scup pots). Through the Atlantic States Marine Fisheries Commission (ASMFC), a full-time contracted Fisheries Specialist I was hired in 2017 that will assist on this project to ensure that all sampling targets are met.

INTRODUCTION

Age and growth information is essential in estimating the age-structure of a fish population. Understanding the age-structure of a population allows scientists to make informed management decisions regarding acceptable harvest levels for a species. In recent years, diet composition of finfish has become increasingly important in understanding the age and growth of a population. Diet composition of a species may help to inform managers on whether an observed change in a population may be due to prey availability. Understanding predator-prey dynamics can also allow managers to utilize a multi-species modeling approach by which they can better understand not only the population dynamics of one particular target species, but other choke or prey species that may be associated with the target species. Work is currently underway at ASMFC through the Biological Ecological Reference Points (BERP) working group, to develop an ecosystem-based approach for assessing Atlantic menhaden. The data collected in this study will help contribute to the aforementioned efforts.

This study is aimed to characterize the age-structure and diet composition of stocks whose ranges extend into Narragansett Bay and will supplement data collected in the Northeast Fisheries Science Center (NEFSC) spring and fall surveys as well as the NorthEast Area Monitoring and Assessment Program (NEAMAP), which do not sample within Narragansett Bay. Data collected in this study is already used in several stock assessments and we expect that number to increase each year as benchmark stock assessments are conducted and ecosystem-based modeling approaches are further developed. Additionally, this study satisfies the requirements of ASMFC Fishery Management Plans (FMP's) for tautog, bluefish, menhaden and weakfish which require the state of Rhode Island to collect a minimum number of age and growth samples annually for stock assessment purposes. This study has also been designed to use other jobs in this grant as a platform for obtaining biological samples.

Collection of stomach content, sex, and maturity stage data for the species listed above was initiated in 2014. This task also included collection of both scale and otolith samples for ageing from most species, except for weakfish and bluefish for which only otolith samples were taken. For tautog, opercula and otoliths were collected (no scales). Additionally, and beginning in 2017, the first anal spine of tautog, the dorsal spine array (nine spines) of striped bass, and both dorsal spines (2) and section of 3-4 vertebrae of spiny dogfish were collected for use in future ageing. For tautog in 2018, the first pelvic fin was also collected, as should have originally been done in 2017.

METHODS, RESULTS & DISCUSSION

Seasonal port sampling of nine species of finfish considered to be extremely important to the recreational fishing community was conducted primarily from May through December of 2018. Data collected included lengths, weights and the appropriate age structure for the specific species (i.e. scale, otolith, operculum, anal or dorsal spines, vertebrae). The number of samples and age structures collected varied depending on the species (Table 1). Investigators focused on obtaining samples from various locations throughout the state from various finfish dealers, recreational anglers, commercial floating fish trap companies, commercial gillnetters, and Rhode Island Division of Marine Fisheries (RIDMF) surveys (otter trawl) (Table 2).

Diet composition data was collected for high priority species by excising fish stomachs from fish collected during the RIDMF seasonal and monthly bottom trawl surveys, or from fish racks and whole fish collected during port sampling, purchased from dealers, or which were donated. For each species, the target number of stomachs to be examined is 40 (Table 3). Additional data collected from these samples included length, weight (if whole fish available), sex, maturity, and age structures. Once stomachs were removed, they were analyzed in the laboratory by sorting and identifying prey to the lowest taxonomic level possible and recording the wet mass for each taxon. All collected data were entered and stored in a Microsoft Access database.

Black sea bass

A total of 233 black sea bass age samples were collected from multiple sources including hook and line, RIDMF otter trawl, commercial fish pots, commercial gill nets, and recreational spear in 2018. In 2018, RIDMF collaborated again with the Commercial Fisheries Research Foundation (CFRF) on a project that would allow RIDMF to collect our required samples and provide additional data for stock assessment purposes. This resulted in our target number of samples (100) being exceeded in 2018.

Currently the use of scales is an acceptable ageing technique for black sea bass, however otoliths remain the preferred method when they are available for extraction. While scales are the primary age structure collected by project staff, when available, otoliths are collected as well. Black sea bass samples collected ranged in size from 9.3-21.3 inches (22.1-56.3 cm) total length. Age samples have been sent to the Virginia Institute of Marine Science (VIMS) and Massachusetts Division of Marine Fisheries (MADMF) for processing and ageing. This was primarily due to the fact that VIMS and MADMF will be collecting additional information as part of other ongoing research projects. Stomach content and maturity stage data was collected from 233 black sea bass. Stomach contents included prey items from 12 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Black sea bass stomach contents were dominated by crustaceans (38%), bivalve molluscs (16%), and finfish (13%), with minor contributions from cephalopod molluscs (5%) and gastropod molluscs (1%); “unidentifiable” contents accounted for 25%. Removal of “unidentifiable” contents from the analysis resulted in crustaceans accounting for 51%, bivalve molluscs (21%), and finfish for 17%, with minor contributions from cephalopod molluscs (7%) and gastropod molluscs (2%) (Figure 9, Table 5). Combined 2014-2018 data (“unidentifiable” and “bait” (ocean quahog) contents removed) shows stomach contents dominated by crustaceans (43%), cephalopod molluscs (26%), followed by finfish (14%) and bivalve molluscs (13%); minor contributions came from gastropod molluscs (1.4%), with all other identifiable contents accounting for less than 2.4% (Figure 10, Table 6).

Bluefish

The ASMFC requires that a minimum of 100 bluefish age samples be collected annually by the state of Rhode Island. Due to the assistance of commercial gillnetters, recreational hook and line fishers, and the RIDMF otter trawl, staff successfully collected 105 bluefish otolith samples in 2018. Bluefish samples ranged in fork length from 13.4-31.5 inches (34.1-80.1 cm) and 1-6 years old (Figure 1). Stomach content and maturity stage data was collected from 63 and 104 bluefish, respectively. Stomach contents included prey items from 1 taxonomic group (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Of the bluefish stomachs examined in 2018, the only identifiable stomach contents encountered were all finfish (77%); “unidentifiable” contents accounted for 23%. Removal of “unidentifiable” contents from the analysis resulted in stomach contents being made up completely of finfish (100%) (Figure 9, Table 5). Combined 2014-2018 data (“unidentifiable” and “bait” (ocean quahog) contents removed) shows stomach contents dominated by finfish (88%) and cephalopod molluscs (12%) (Figure 10, Table 6).

Menhaden

A total of 56 Atlantic menhaden age samples (56 scales and 13/56 including otoliths) were collected in 2018 from 2 commercial floating fish trap operations, and the RIDMF and URIGSO otter trawl surveys. Typically, additional samples are collected from commercial purse seine operations when the Narragansett Bay menhaden management area is open to commercial fishing. In 2018, the menhaden management area remained closed for the entire year and therefore no samples were collected form the purse seine fishery. Menhaden samples ranged in fork length from 9.9-12.2 inches (25.1-31.0 cm). Age samples will be sent to the NOAA Fisheries Beaufort Laboratory for processing and ageing. A joint conference call among the ASMFC menhaden technical committee and ageing staff from each state along the Atlantic coast in January 2018 took place to discuss menhaden ageing practices among the Atlantic coast states. It was determined that a menhaden ageing workshop was needed and that until that workshop occurred, all age samples should be sent to the Beaufort laboratory for ageing. Maturity stage data was collected from 13/56 fish. Due to the fact that menhaden are filter feeders, all stomach contents encountered in previous years of this study were liquefied, with prey item(s) unable to be identified and classified. Due to this, no menhaden stomachs were examined in 2018. Generally, menhaden stomach contents should reflect the dominant planktonic species present at the time of sample collection.

Scup

Scup age samples were collected in 2018 from multiple sources including 2 commercial floating fish trap operations, and the RIDMF and URIGSO otter trawl surveys. Investigators successfully collected scales from 173 scup and otoliths from 98/173 fish. Scup samples ranged in fork length from 4.3-13.8 inches (11-35 cm) and age from 1-11 years old (Figure 2). Stomach content and maturity stage data was collected from 47 and 98 scup, respectively. Stomach contents included prey items from 8 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Identifiable stomach contents were dominated by bivalve molluscs (21%), finfish (13%), cephalopod molluscs (12%) and polychaetes (11%), with a small quantity of crustaceans (4%), sipunculids (1%), and gastropod molluscs (1%); "unidentifiable" contents accounted for 36%. Removal of "unidentifiable" data from the analysis resulted in stomach contents being dominated by bivalve molluscs (33%), finfish (21%), cephalopod molluscs (18%) and polychaetes (18%), with minor amounts of crustaceans (7%), sipunculids (2%), and gastropod molluscs (2%) (Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated equally by crustaceans (24%), bivalve molluscs (24%), and polychaetes (25%), followed by finfish (11%) and cephalopod molluscs (10%), with minor contributions from gastropod molluscs (3%), algae (1%) and sipunculids (1%) (Figure 10, Table 6).

Spiny Dogfish

For 2018, a total of 12 spiny dogfish were obtained from the RIDMF otter trawl survey. Ageing structures collected included a section of several vertebrae and both dorsal spines. Spiny dogfish sampled ranged in fork length from 23.4-29.0 inches (59.5-73.6 cm) and have not been aged yet as staff must learn this new protocol for spines and vertebrae. Stomach content and maturity stage data was collected from all 12 spiny dogfish samples. Identifiable stomach contents were composed of finfish (4%) and crustaceans (<1%); "unidentifiable" contents accounted for 96%. Removal of "unidentifiable" data from the analysis resulted in stomach contents being dominated by finfish (98%) with a minor contribution from crustaceans (2%). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by finfish (69%) and cephalopod molluscs (30%), with a minor contribution from crustaceans (1%) (Figure 10, Table 6).

Striped Bass

A total of 332 striped bass scale, 40 otolith, and 40 sets of dorsal spine arrays (9 spines per array) samples were collected in 2018. Each year investigators set a sampling target of 150 samples from floating fish traps and 150 samples from the general category fishery. Floating fish traps have a minimum size of 26" while the commercial general category fishery has a minimum size of 34". Sampling from both of these operations allows us to sample a wider size range of striped bass. In 2018 there were a very limited number of floating fish traps fishing for striped bass making obtaining samples from this fishery difficult. A total of 200 samples were obtained from floating fish traps and 91 samples were obtained from the general category fisheries, for a total of 291 samples. Staff supplemented traditional sampling by collecting 45 striped bass age samples from the RIDMF Narragansett Bay Juvenile Finfish (Beach seine) survey, RIDMF and URIGSO otter trawl surveys, and recreational hook and line. These samples were generally below legal minimum size(s) but helped to expand the length frequency distribution sampled. Striped bass sampled ranged from 12.6-48.0 inches fork length (32.1-122.0 cm) and 3-19 years old (Figure 3). Stomach content and maturity stage data was collected from 40 striped bass. Stomach contents included prey items from 8 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Identifiable stomach contents were dominated by finfish (74%), with a small quantity of crustaceans (3%) and cephalopod molluscs (1%) also encountered; "unidentifiable" contents accounted for 20%. Removal of "unidentifiable" contents from the analysis resulted in stomach contents being dominated by finfish (93%), with small amounts of crustaceans (4%) and cephalopod molluscs (1%) (Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by finfish (88%), followed by cephalopod molluscs (5%) and crustaceans (5%). Algae, aquatic plants, bivalve and gastropod molluscs, and polychaetes made up the remaining 2% of identifiable stomach contents (Figure 10, Table 6).

Summer Flounder

A total of 125 summer flounder scale and 125 otolith samples were collected in 2018. All of these samples were collected by RIDMF staff on board our RIDMF otter trawl (Jobs 1, 2) survey. Summer flounder samples collected varied in size from 9.7-24.6 inches (24.6-62.6 cm) total length and 1-8 years old (Figure 4). Stomach content and maturity stage data was collected from 48 and 109 summer flounder, respectively. Stomach contents included prey items from 5 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Identifiable stomach contents were dominated by finfish (36%), followed by crustaceans (6%); "unidentifiable" contents accounted for 57%. Removal of "unidentifiable" contents from the analysis resulted in stomach contents being dominated by finfish (83%), followed by crustaceans (15%), with small quantities of cephalopod and gastropod molluscs (2%) and nematodes (<0.5%) (Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by finfish (48%), cephalopod molluscs (32%), and crustaceans (20%), with small amounts of bivalve molluscs and nematodes (<0.5%) (Figure 10, Table 6).

Tautog

A total of 219 pair of tautog opercula, 219 otoliths, 214 anal spines, and 79 pelvic spines were collected in 2018 from the recreational hook and line fishery (n=169), RIDMF Narragansett Bay Juvenile Finfish (Beach seine) survey (n=2), RIDMF otter trawl survey (n=39), and recreational spear fishery (n=9). Tautog samples are typically collected in the fall months when the party and charter boat vessels are targeting them. The ability to obtain samples during this period of time can be quite variable due to weather conditions such as strong winds and high seas. Tautog samples collected ranged from 10.9-26.8 inches (27.6-68.1 cm) total length and 2-21 years old (Figure 5). Stomach content and maturity stage data was collected from 44 and 214 tautog, respectively. Stomach contents included prey items from 8 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Identifiable tautog diet was primarily comprised of crustaceans (41%) and bivalve molluscs (24%), with smaller quantities of gastropod molluscs (4%), and maxillopods (3%) also observed; "unidentifiable" contents accounted for 26%. Removal of "unidentifiable" contents from the analysis resulted in stomach contents being dominated by crustaceans (56%) and bivalve molluscs (33%), with minor contributions from gastropod molluscs (5%) and maxillopods (4%) (Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by crustaceans (63%), followed by bivalve molluscs (21%) and gastropod molluscs (11%), with minor contributions from maxillopods (3%), algae (2%) and echinoderms (1%) (Figure 10, Table 6).

In 2017 staff began to explore a new, non-lethal ageing technique for tautog. This new technique uses a cross-section of the first anal spine for age determination. Staff received training at a workshop held in April 2017 and are in the process of planning additional training workshops, so they will be able to utilize this new method which will aid in achieving our sampling targets in 2019, as samples can now be collected from live fish. In 2018, staff also collected the first pelvic spine from a subset of sampled fish (n=79); age determinations from both structures will be compared and assessed for level of accuracy.

Weakfish

Rhode Island is required by the ASMFC to collect three age structures and 6 lengths per metric ton of weakfish landed commercially in the state. In 2018, this would have resulted in a sampling target of 47 fish lengths and 24 ages. The weakfish stock assessment sub-committee and management board have requested that length samples come from the commercial fishery as these data are used in developing the commercial age-length keys. In recent years, weakfish have become scarce in RI, which has resulted in extreme difficulty in obtaining samples. Investigators now purchase fish directly from seafood dealers at market value to ensure that they can obtain samples, however strong market demand and limited supply during 2018 prevented the availability of this species for sampling. In 2018, a total of 93 weakfish length and otolith samples were collected, with 38 samples collected from legal-sized commercial fish. Weakfish collected by the RIDMF otter trawl (n=55) were entirely sub-legal sized fish. Weakfish sampled ranged from 2.7-18.0 inches (6.8-44.6 cm) total length and were 0-2 years old (Figure 6). Stomach content and maturity stage data was collected from 50 and 82 weakfish, respectively. Stomach contents included prey items from 4 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Of the weakfish stomachs examined in 2018, stomach contents were dominated by finfish (83%), with a small amount of cephalopod molluscs (3%) and minor contributions from crustaceans (<0.5%) and algae (<0.1%) comprising identifiable stomach contents encountered; "unidentifiable" contents accounted for 14%. Removal of "unidentifiable" contents from the analysis resulted in stomach contents being made up nearly completely of finfish (97%), with minor contributions from cephalopod molluscs (3%), crustaceans (<0.5%), and algae (<0.1%)

(Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by finfish (91%), followed by cephalopod molluscs (7%) and minor contributions from crustaceans (2%) and algae (<0.1%) (Figure 10, Table 6).

In 2019, staff will continue to collect more weakfish samples from the RIDMF trawl survey to ensure our sampling targets are met, although these are usually small YOY and age 1 fish.

Winter Flounder

A total of 40 winter flounder scale and otolith samples were collected in 2018. These samples were collected entirely by RIDMF staff on board our RIDMF otter trawl survey (Jobs 1 and 2). Winter flounder samples collected varied in size from 8.3-17.2 inches (21.1-43.7 cm) total length and 1-8 years old (Figure 7). Stomach content and maturity stage data was collected from 40 winter flounder. Stomach contents included prey items from 6 taxonomic groups (Tables 3 and 4). The proportional contribution of all stomach contents encountered in 2018 is shown in Figure 8 and summarized in Table 4. Of the winter flounder stomachs examined in 2018, stomach contents were dominated by polychaetes (34%) and cnidarians (20%), with small amounts of crustaceans (5%) and algae (5%), and minor contributions from bryozoa (1%) and bivalve molluscs (<1%) comprising identifiable stomach contents encountered; "unidentifiable" contents accounted for 34%. Removal of "unidentifiable" contents from the analysis resulted in stomach contents being dominated by polychaetes (51%) and cnidarians (30%), with small amounts of crustaceans (8%) and algae (8%) and minor contributions from bryozoa (2%) and bivalve molluscs (1%) (Figure 10, Table 5). Combined 2014-2018 data ("unidentifiable" and "bait" (ocean quahog) contents removed) shows stomach contents dominated by polychaetes (45%) and cnidarians (37%), with small amounts of crustaceans (8%) and algae (4%), and minor contributions from nemerteans (2%), bivalve molluscs (2%), bryozoan (,1%), sipunculids (<0.5%), gastropod molluscs (<0.5%), and cephalopod molluscs (<0.01%) (Figure 10, Table 6).

SUMMARY

In 2018 investigators were able to collect, or exceed, the target sample numbers for most species, while under-achieving target sample numbers for menhaden (56/100). Although our sample target for menhaden was not met, the ASMFC FMP sampling requirement of one 10-fish sample per 300 metric tons landed was satisfied. In the cases where the sample targets were not achieved, this was due to dynamics of the fisheries, inclement weather, and availability of fish. Processing and ageing of all hard parts is complete for 2018 and staff completed an ageing precision exercise. The ageing precision exercise involved staff reading samples collected in 2017 to double check their ageing precision. A minimum of 10% of samples went through a second reading and all precision estimates had a level of agreement of 90% or greater. In 2019, staff will continue reaching out to additional seafood dealers and the recreational community to ensure that the target number of samples is met for each species. Additionally, staff have been working on the

ASMFC ageing sub-committee to help draft a Gulf and Atlantic coasts ageing manual. Staff will continue to participate in ASMFC ageing workshops as they occur in 2019.

FIGURES

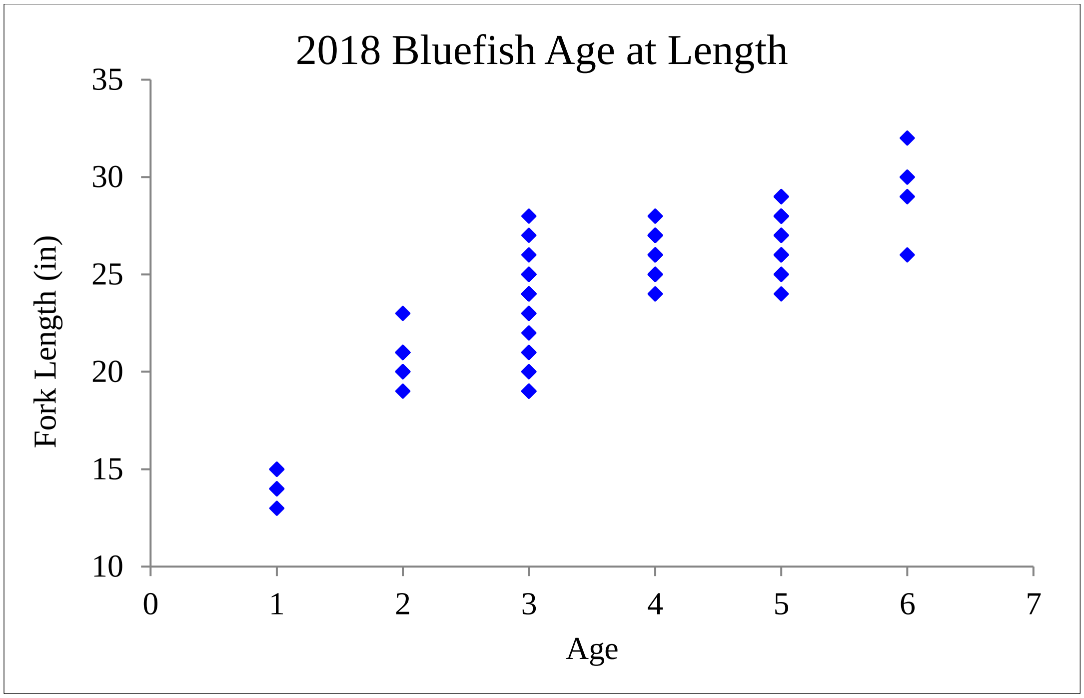


Figure 1. Bluefish age at length.

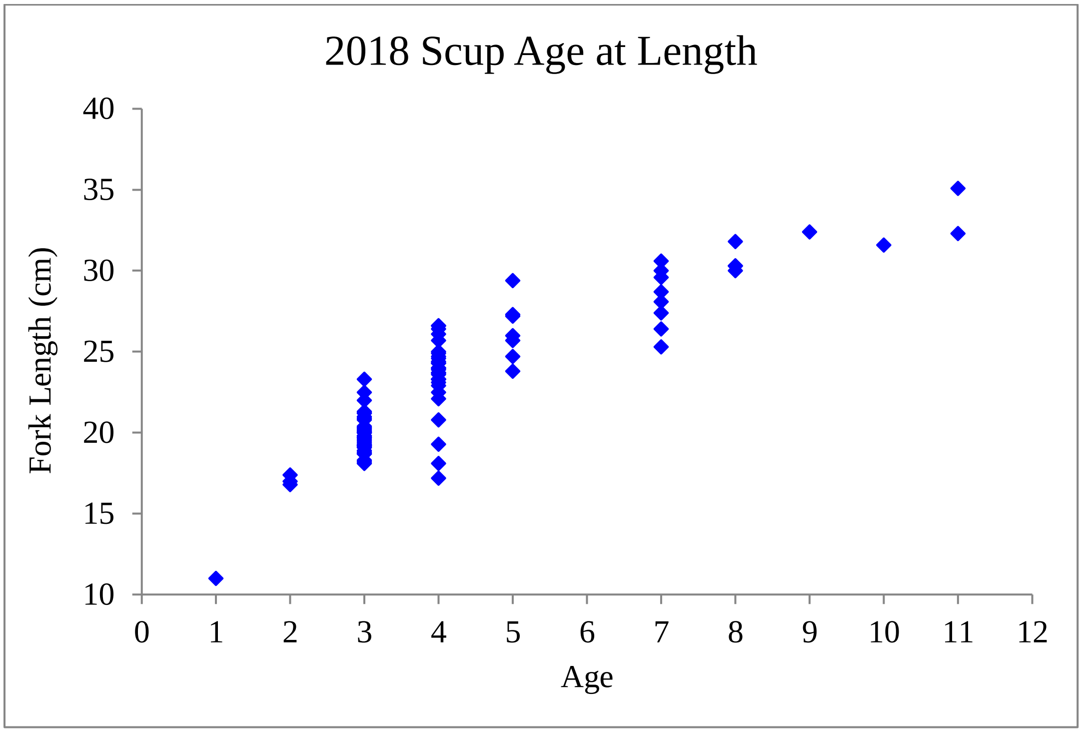


Figure 2. Scup age at length.

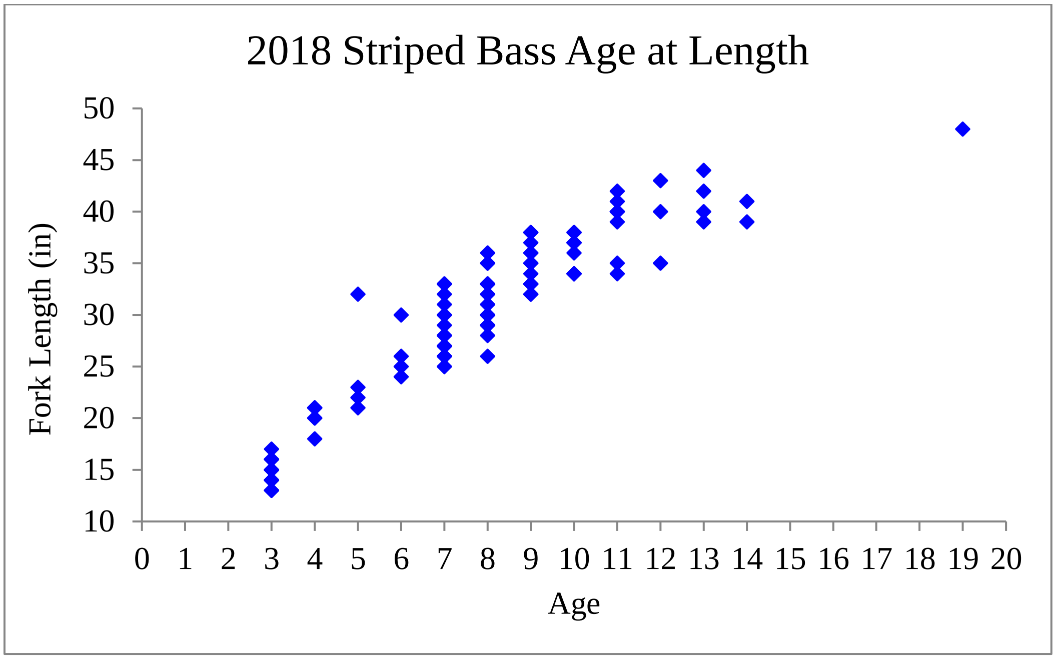


Figure 3. Striped bass age at length.

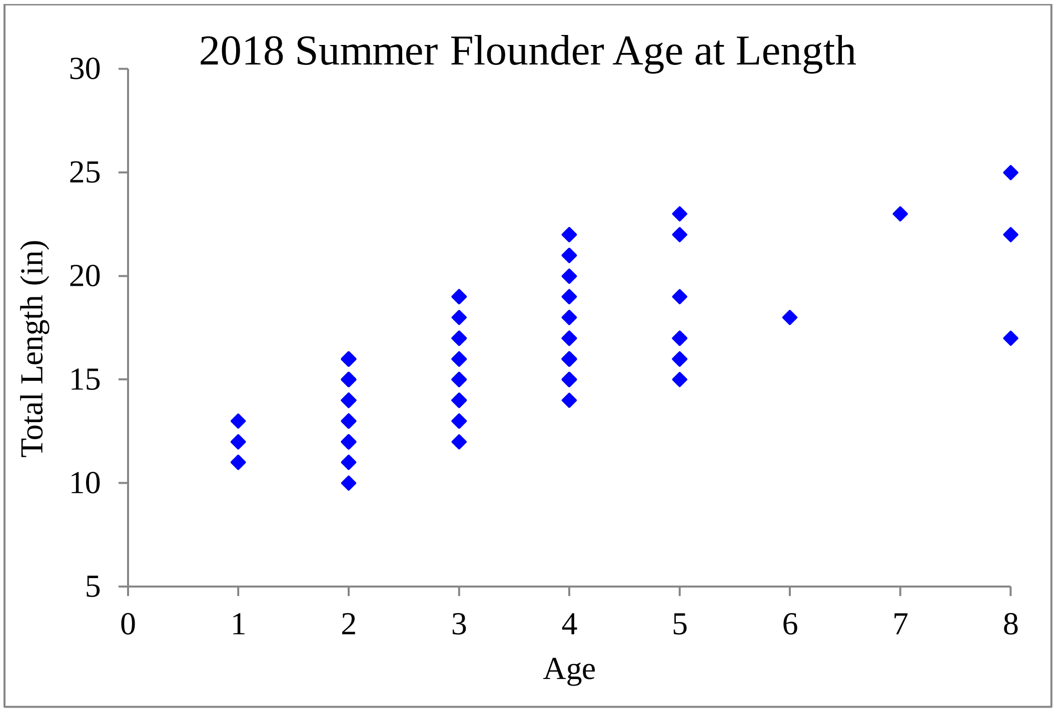


Figure 4. Summer flounder age at length.

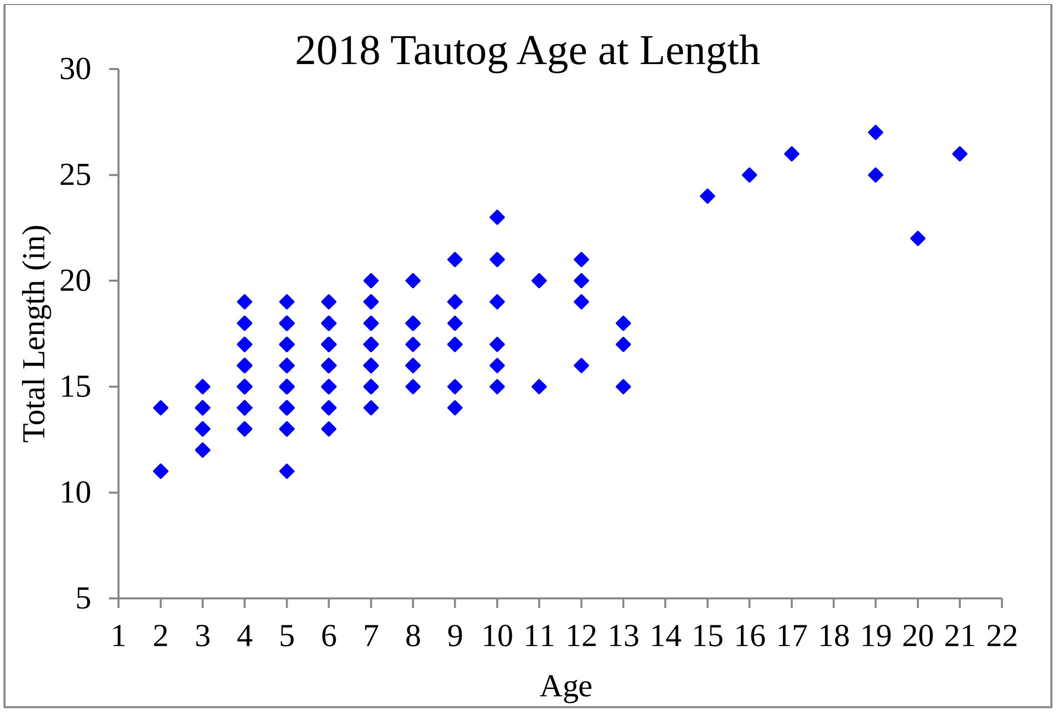


Figure 5. Tautog age at length.

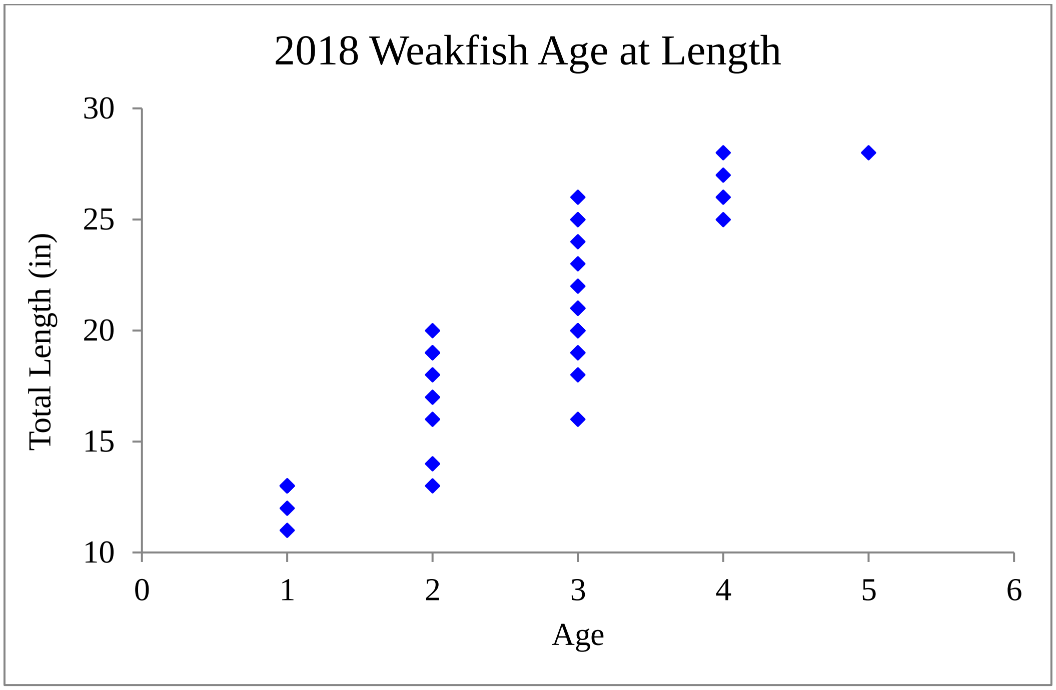


Figure 6. Weakfish age at length.

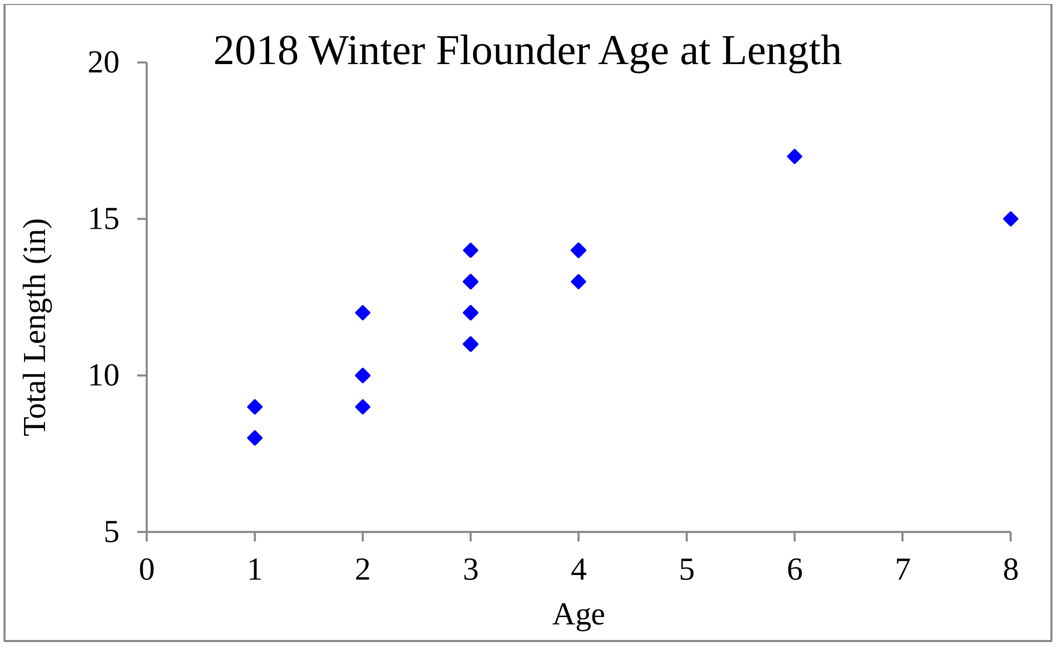


Figure 7. Winter flounder age at length.

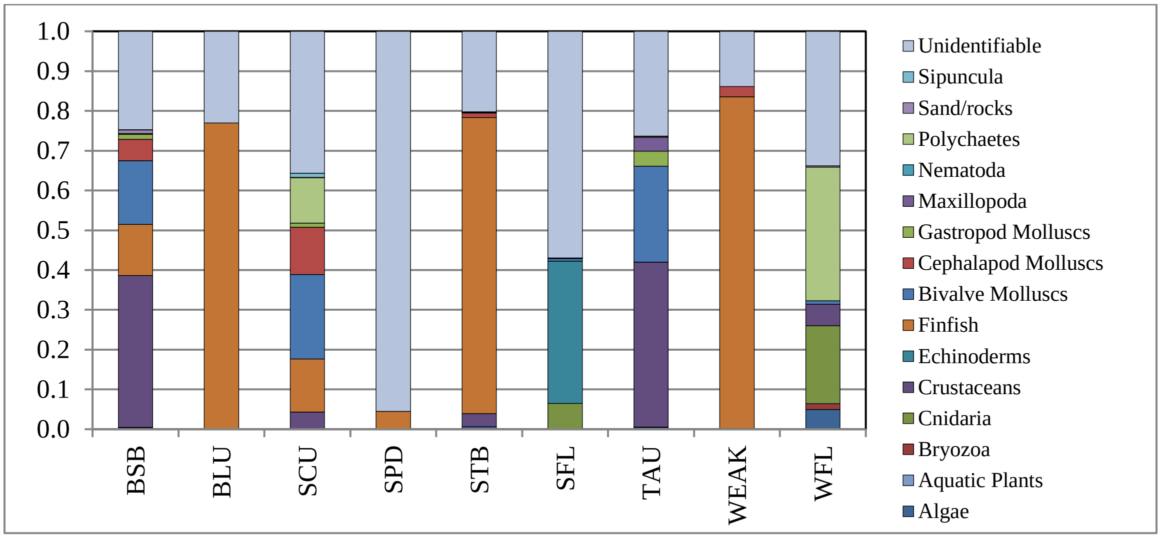


Figure 8. 2018 Proportional contribution of **all** stomach content types by species.

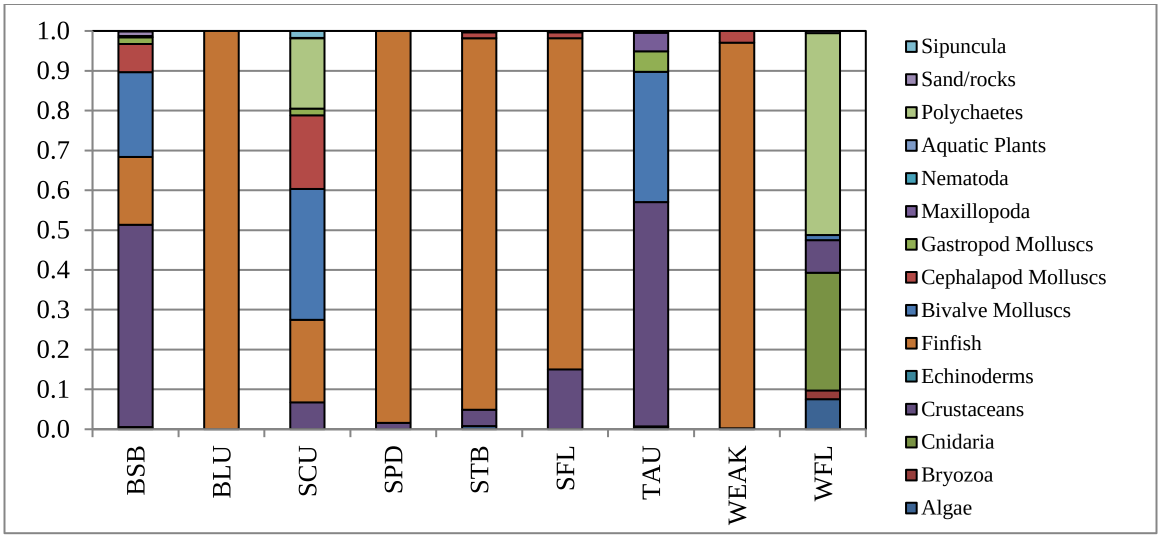


Figure 9. 2018 Proportional contribution of stomach content types by species; "unidentifiable" contents not included.

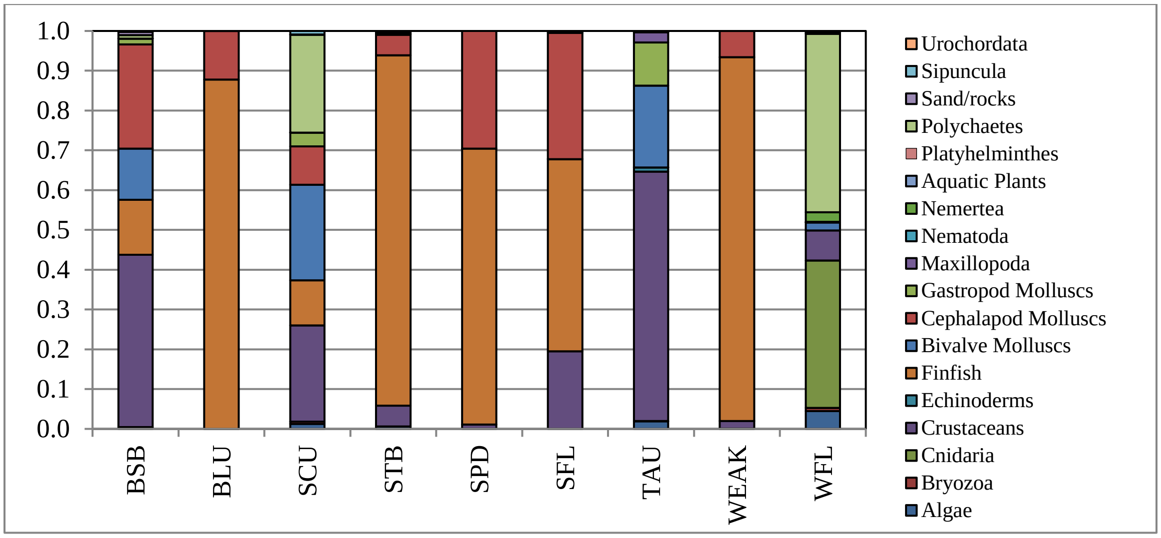


Figure 10. 2014-2018 Proportional contribution of stomach content types by species; "unidentifiable" and bait (Ocean quahog) contents not included.

TABLES

Table 1. Species, ageing structures collected, and numbers of fish sampled in 2018.

Common name	**Ageing structure(s)**	**Target number of ageing structures**	**Number of ageing structures collected**
Black sea bass	Scale, Otolith	100	233 scale, 233 otolith
Bluefish***	Otolith	100	105 otolith
Menhaden***	Scale, Otolith	100	56 scale, 13 otolith
Scup	Scale, Otolith	100	173 scale, 47 otolith
Spiny Dogfish	Vertebrae, Dorsal spines	NA	12 vertebrae arrays, 12 dorsal spine arrays
Striped bass	Scale, Otolith, Dorsal spines	150 fish/gear type**	332 scale, 40 otolith, 40 dorsal spine arrays
Summer Flounder	Scale, Otolith	100	125 scale, 125 otolith
Tautog***	Operculum, Otolith, 1st anal & pelvic spines	200	219 operculum, 219 otolith, 219 anal spines, 79 pelvic spines
Weakfish***	Otolith	3 fish aged per metric ton landed*	82
Winter Flounder	Scale, Otolith	NA	40 scale, 40 otolith

*Per ASMFC FMP requirements, 23 ages required for 2017

**Gear types include floating fish trap and general category

***Required by ASMFC

Table 2. Gear type sampled for each species collected in 2018 (FFT=Floating Fish trap).

Common name	**Gear Type**
Black sea bass	Hook and Line, Otter Trawl, Lobster Pot
Bluefish	Gillnet, Hook and Line, Otter Trawl
Menhaden	FFT, Otter Trawl
Scup	FFT, Otter Trawl
Spiny Dogfish	Otter Trawl
Striped bass	FFT, Hook and Line, Otter Trawl, Beach Seine
Summer Flounder	Otter Trawl
Tautog	Hook and Line, Otter Trawl, Beach Seine, Spear
Weakfish	FFT, Gillnet, Otter Trawl
Winter Flounder	Otter Trawl

Table 3. 2018 Summary of stomach content sampling by species (* **Sand/rocks and “unidentifiable” stomach contents not included in number of prey taxa**).

SPECIES	Target # Stomachs	# Stomachs sampled	# PREY TAXA*****
Black Sea Bass	40	233	12
Bluefish	40	63	1
Scup	40	47	8
Spiny Dogfish	40	12	2
Striped Bass	40	40	8

Summer Flounder	40	48	5
Tautog	40	44	8
Weakfish	40	50	4
Winter Flounder	40	40	6

Table 4. 2018 Proportional contribution of **all** stomach content types by species (see Figure 9).

	BSB	BLU	SCU	STB	SPD	SFL	TAU	WEAK	WFL
Algae	0.0036	0	0	0.0061	0	0	0.0043	0.0002	0.0501
Aquatic Plants	0.0001	0	0	0	0	0	0	0	0
Bryozoa	0	0	0	0	0	0	0.0010	0	0.0143
Cnidaria	0.0008	0	0	0	0	0	0	0	0.1956
Crustaceans	0.3819	0	0.0434	0.0329	0.0007	0.0647	0.4147	0.0016	0.0539
Echinoderms	0	0	0	0	0	0	0.0004	0	0
Finfish	0.1283	0.7696	0.1333	0.7440	0.0440	0.3581	0	0.8339	0
Bivalve Mollusc	0.1605	0	0.2118	0.00001	0	0	0.2407	0	0.0089
Cephalopod Mollusc	0.0534	0	0.1190	0.0119	0	0.0061	0	0.2524	0
Gastropod Mollusc	0.0126	0	0.0105	0.0003	0	0.0006	0.0378	0	0
Maxillopoda	0	0	0	0	0	0	0.0346	0	0
Nematoda	0.000001	0	0.0001	0.0001	0	0.00006	0	0	0
Nemertea	0	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0	0
Polychaetes	0.0020	0	0.1140	0.0007	0	0	0.0025	0	0.3356
Sand/rocks *****	0.0090	0	0.0006	0.0018	0	0.0011	0.0007	0	0.0034
Sipuncula	0.0008	0	0.0110	0	0	0	0	0	0
Urochordata	0	0	0	0	0	0	0	0	0
Unidentifiable *****	0.2470	0.2304	0.3564	0.2022	0.9553	0.5693	0.2633	0.1391	0.3383

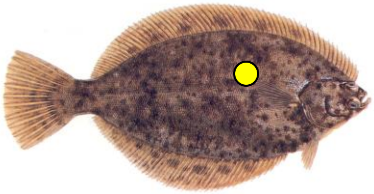
Table 5. 2018 Proportional contribution of stomach content types by species; "unidentifiable" stomach contents not included (see Figure 9).

	BSB	BLU	SCU	STB	SPD	SFL	TAU	WEAK	WFL
Algae	0.0048	0	0	0.0076	0	0	0.0059	0.0003	0.0757
Aquatic Plants	0.0001	0	0	0	0	0	0	0	0
Bryozoa	0	0	0	0	0	0	0.0013	0	0.0216
Cnidaria	0.0010	0	0	0	0	0	0	0	0.2957
Crustaceans	0.5071	0	0.0674	0.0413	0.0161	0.1503	0.5630	0.0018	0.0814
Echinoderms	0	0	0	0	0	0	0.0006	0	0
Finfish	0.1703	1.0000	0.2071	0.9325	0.9839	0.8316	0	0.9686	0
Bivalve Mollusc	0.2131	0	0.3291	0.00002	0	0	0.3268	0	0.0135
Cephalopod Mollusc	0.0709	0	0.1848	0.0149	0	0.0142	0	0.0293	0
Gastropod Mollusc	0.0168	0	0.0163	0.0004	0	0.0013	0.0513	0	0
Maxillopoda	0	0	0	0	0	0	0.0470	0	0
Nematoda	0.000001	0	0.0002	0.0002	0	0.0001	0	0	0
Nemertea	0	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0	0
Polychaetes	0.0027	0	0.1771	0.0009	0	0	0.0034	0	0.5071
Sand/rocks *****	0.0120	0	0.0009	0.0023	0	0.0026	0.0009	0	0.0051

Sipuncula	0.0011	0	0.0171	0	0	0	0	0	0
Urochordata	0	0	0	0	0	0	0	0	0

Table 6. 2014-2018 Proportional contribution of stomach content type by species; "unidentifiable" stomach contents not included (see Figure 10).

	BSB	BLU	SCU	STB	SPD	SFL	TAU	WEAK	WFL
Algae	0.0014	0.00003	0.0125	0.0062	0	0	0.0191	0.0009	0.0449
Aquatic Plants	0.00006	0.00004	0	0.0019	0	0	0	0	0
Bryozoa	0	0	0.0054	0	0	0	0.0007	0	0.0080
Cnidaria	0.0030	0	0	0	0	0	0	0	0.3705
Crustaceans	0.4335	0	0.2422	0.0520	0.0114	0.1951	0.6264	0.0193	0.0756
Echinoderms	0	0	0	0	0	0	0.0104	0	0
Finfish	0.1380	0.8782	0.1135	0.8810	0.6932	0.4827	0.0001	0.9140	0
Bivalve Mollusc	0.1282	0	0.2398	0.0001	0	0.0001	0.2060	0	0.0196
Cephalopod Mollusc	0.2621	0.1216	0.0965	0.0511	0.2955	0.3172	0	0.0657	0.0001
Gastropod Mollusc	0.0142	0	0.0344	0.0019	0	0.0040	0.1080	0	0.0019
Maxillopoda	0	0	0	0	0	0	0.0259	0	0
Nematoda	0.00003	0	0.0001	0	0	0.0002	0	0	0
Nemertea	0	0	0	0	0	0	0	0	0.0243
Platyhelminthes	0.00006	0	0	0	0	0	0	0	0
Polychaetes	0.0090	0	0.2462	0.0053	0	0	0.0009	0.0001	0.4479
Sand/rocks	0.0080	0.0001	0.0004	0.0006	0	0.0006	0.0023	0	0.0026
Sipuncula	0.0023	0	0.0089	0	0	0	0	0	0.0047
Urochordata	0.00014	0	0	0	0	0	0	0	0



Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters

Winter Flounder Spawning Stock Biomass Survey in Pt. Judith Pond, RI

Scott D. Olszewski
Deputy Chief
Scott.Olszewski@dem.ri.gov

John Lake
Supervising Marine Biologist
John.Lake@dem.ri.gov

Katie Rodrigue
Principal Marine Biologist
Katherine.Rodrigue@dem.ri.gov

Rhode Island Department of Environmental Management
Division Marine Fisheries
3 Fort Wetherill Road
Jamestown, RI 02835

Federal Aid in Sportfish Restoration
F-61-21

Performance Report March 2019

State: Rhode Island Project Number: F-61-R-21

Project Title: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

Period Covered: January 1, 2018 – December 31, 2018

Job Number and Title: Job III - Spawning Stock Biomass (SSB) in Rhode Island Coastal Ponds.

Job Objective: To support a seasonal Young of the Year Winter flounder survey by providing data on the dynamics and abundance of the spawning population of winter flounder in Rhode Island coastal ponds.

Significant Deviations: Staff limitations are leading to a shortened sampling period. The addition of staff should allow more robust sampling in 2019.

Summary:

In 1999, the Rhode Island Coastal Ponds Project was expanded to support an adult winter flounder monitoring and tagging project. This winter phase of the seasonal coastal pond juvenile flounder work was an opportunity to collect data on the adult spawning populations of winter flounder in the south shore coastal ponds. An experimental winter flounder tagging study and monitoring project could be conducted with little additional funding or manpower. A commercial fisherman who had historically fished for winter flounder in the coastal ponds agreed to assist the RI Marine Fisheries staff and get the survey off the ground.

The research project runs from January through May annually. Fishing gear is deployed depending on ice cover in the ponds and the gear is generally hauled on three to seven-night sets. There is a total of ten stations where data exists, with eight found in the Pt. Judith Pond system (including Potter Pond) and two in Charlestown/Ninigret Pond (NOAA Nautical Charts 13219 and 13215). Point Judith and Potter Ponds use the same breach to connect to the Block Island and Rhode Island Sounds.

Additional Research:

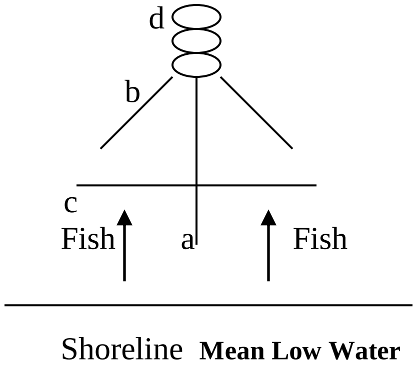
In 2012, an additional coastal pond system was added to the survey. As adult winter flounder abundance in the Point Judith system declined to all-time lows, the adjacent Charlestown Pond (also known as Ninigret Pond (NOAA Nautical Chart 13215)) was surveyed during the same time period and continued during the 2015 sampling year. During this period, Rhode Island Coastal Trawl Survey data (Spring Survey) showed a sharp increase in relative abundance in the Block Island Sound area. This appeared to be similar to the trend seen in the Charlestown Pond system. However, in more recent years, winter flounder captured in the Spring Trawl Survey has declined and shown an overall downward trend throughout the time series. Charlestown Pond has not been sampled since 2015 but will be surveyed again beginning in 2019. If, through this continuation of the multiple sampling areas, Point Judith continues to experience low abundance and recruitment while other area surveys show a diverging trend, then the assumption would be that the Point Judith system is having localized winter flounder depletion from sources other than fishing mortality. Commercial fishing activity in Block Island Sound is also returning valuable tag recapture information from the Charlestown Pond sampling, that which is now missing from the Point Judith Pond survey due to the inability to catch enough fish to tag. The Environmental Protection Agency partnered in this project on Charlestown Pond and currently has collected data during three winter survey seasons. In the future, this data set will be added to the current Adult Winter Flounder time series which was existed since 1999.

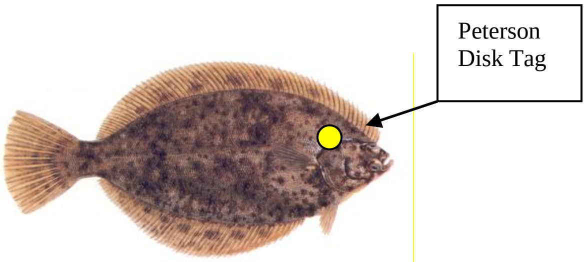
Methods and Materials:

Fyke Nets are a passive fixed fishing gear, attached perpendicular to the shoreline at mean low water. A vertical section of net wall or leader directs fish toward the body of the net where the catch is funneled through a series of parlors, eventually being retained in the terminal parlor. The wings of the net accomplish further direction of the catch. Adult winter flounder are tagged using Peterson Disk Tags.

Net dimensions:
a. Leader - 100'
b. Wings - 25'
c. Spreader Bar - 15'
d. Net parlors – 2.5’
Mesh size - 2.5" throughout

Station water profile:
Depth / turbidity - feet
Dissolved oxygen - mg/l
Salinity - ppt
Temperature - degree C





Fieldwork:

Three fyke nets were set at three fixed stations in Pt. Judith and Potter Ponds during January and April in 1999-2001, and two nets are typically set at five fixed stations from 2002 to present. However, due to staffing limitations and ice and snow obstructing access to the ponds in February 2018, nets were set at two fixed stations in the Point Judith/Potter Pond system and sampled three times during the season. The nets are fixed at mean low water and set perpendicular to the shoreline. Fyke nets are a passive fishing gear and allow the catch to be retained alive for a short period of time. Nets are tended from two to seven days depending on the size of the catch and weather conditions. Higher catches increase density inside the net and attract predators such as cormorants, seals, and otters thus increasing survey-induced mortality.

All fish captured are measured, sexed, enumerated and categorized to describe spawning stage. Spawning stage is defined as ripe (pre-spawn), ripe/running (active spawn), spent (post-spawn), resting (non-active spawn) and immature. These data illustrate how the spawning activity of flounder advances throughout the duration of the survey season. This is useful in determining the potential impacts of coastal zone activities such as harbor and breach way dredging and pier construction.

Fish of legal size (30.48 cm) or recruits to the fishery are tagged and released away from the capture area. Tagging and recapture data is presented in Tables 1-4.

Fisheries:

Winter Flounder (***Pseudopleuronectes americanus***) are both a commercially and recreationally important species to the State of Rhode Island. From 1999-2018, commercial landings of winter flounder in Rhode Island averaged over 300 metric tons and an average value of one million dollars annually (Table 4, Figure 1). Throughout the time series, landings have shown an overall downward trend. Recreational harvest has declined rapidly throughout the period and remains low through 2018 (Figure 2) (NMFS 2018 commercial landings query and MRIP database). Note that due to the rarity of the MRIP Access Point Angler Intercept Survey encountering anglers who have captured winter flounder, the percent standard error (PSE) for these data points is commonly very high (Table 5).

Spawning Behavior: Pt Judith / Potters Pond System

Winter Flounder enter the south shore coastal pond systems in Rhode Island to spawn in the early part of winter (typically in November) and engage in spawning activity from January through May annually. Spawning and egg deposition takes place on sandy bottoms and algal accumulations. Winter Flounder eggs are non-buoyant and clump together on these substrates. Survey data indicate that peak-spawning activity takes place during the month of February, however this appears to vary annually in relation to average water temperatures. Figure 3 displays the ratios of spawning stages of winter flounder captured from 1999-2018 by month. Approximately 55% of fish captured in 2018 were sexually immature and therefore would not have contributed to spawning.

Spawning occurs in inshore waters at close to seasonal minimal water temperatures of 0 - 1.7 degrees C and in estuarine salinities as low as 11.4 ppt. (Bigelow and Schroeder 2002). With the shortened sampling period in 2017, temperature and salinity data were not available. Sampling was again limited in 2018 due to staffing limitations and a high number of days with ice and snow obstructing pond access in February, and only temperature data was recorded (Figure 4). Due to a limited number of sampling days, data was only recorded on three days in March, with two readings for both 3/19/2018 and 3/28/2018.

Sex ratios throughout the time series tend to favor females. Similar observations were made in Green Hill Pond, a neighboring coastal pond (Saila 1961), and in Narragansett Bay (Saila 1962). Sex ratios for winter flounder captured from 1999-2018 are shown in Figure 5.

Note that here immature fish refers to those individuals that were too young to sex, and not the spawning stage. Therefore, some of these male and female fish were still immature in terms of spawning stage. Refer to Figure 3 for spawning stage composition by month over the time series.

Size Distribution: Pt Judith/Potter Pond System

The total number of winter flounder sampled during the 2018 survey was 36. This was a 350% increase from the 2017 survey. This may be due in part to the slightly decreased sampling effort in 2018 compared to 2017 which would add a high degree of variability. The Catch per Unit Effort was greater in 2018 (6.0 fish/net haul versus 2.0 fish/net haul). Sizes ranged from 14cm to 38cm (Figure 6). The mean size sampled was 20.6 cm.

Results:

2018 Adult winter flounder CPUE in Pt Judith Pond increased to 6.0 fish per net haul (Figure 7). This is an increase of 4 fish/haul from 2017. However, this value is still well below the time series high of 24.4 in 2001. The catch rates have shown a downward trend throughout the time series with the 2014 CPUE being the lowest data point ever recorded. CPUE for sampling in Charlestown Pond from 2012-2015 is shown in Figure 8. In 2018, a total of 5 mature fish were tagged in the Point Judith Pond system. No recaptured fish were reported.

Additional Species captured throughout survey time series:

Summer Flounder	***Paralicthes detatus***
Striped Bass	***Morone saxatilis***
White Perch	***Morone americana***
Atlantic Tomcod	***Microgadus tomcod***
Tautog	***Tautoga onitis***
Alewife	***Alosa pseudoharengus***
Atlantic Menhaden	***Brevortia tyrannus***
American Eel	***Anguilla rostrata***
Horseshoe Crab	***Limulus polyphemus***
American Lobster	***Homarus americanis***
Green Crab	***Carcinus maenas***
Atlantic Rock Crab	***Cancer irroratus***
Blue Crab	***Callinectes sapidus***
Longnose Spider Crab	***Libinia dubia***
Portly Spider Crab	***Libinia emarginata***

Discussion:

Much lower catch rates are being observed in the later years of the adult coastal pond survey. For some time, the data indicated that the problems found in nearby Narragansett Bay were not as obvious in the south shore coastal ponds and that possibly, there were lower fishing mortality rates exhibited on the stocks that inhabit theses ponds and Block Island Sound. Continued sampling in the Point Judith Pond system as well as the Charlestown Pond system is necessary to monitor these trends.

Tagging/recapture data gives accurate estimations on population size and year class structure. These estimations depend on additional years and recapture data and therefore show the need for a more long-term approach to adult winter flounder assessments in Rhode Island south shore coastal ponds. Total tag return rates over the survey time series are between 9.2% and 12.4% for Point Judith Pond and 11.3% for Charlestown Pond (Tables 2, 3, and 5). In past years, almost the entire set of tag returns came from the recreational fishery, which has been closed since 2012. The offshore trawl fleet has been the source of tag returns in the more recent years (along with survey recaptures) indicating the increased willingness of the offshore commercial trawler fleet to supply information on flounder movements and mortality rates. Tagging and recapture data is presented in Tables 1-5.

Recommendations:

Continuation of all adult winter flounder work statewide in order to make accurate connections between coastal ponds, Narragansett Bay, and Rhode Island/Block Island Sound winter flounder stocks is necessary. In addition, the survey in the Charlestown Pond System will be continued in 2019 in order to track local adult winter flounder abundance and use the catch as a source of taggable animals to gain information on population size, mortality and year class structure. Although sampling in this pond in 2019 will be completed at a lesser scale than in the past due to the staffing and gear limitations, it is expected to be resumed at a greater extent in 2020 and beyond. The importance of returning tag data from the commercial trawl fleet in Rhode Island Sound and Block Island Sound should be stressed in order to facilitate continued reporting of recaptured fish. The addition of dedicated staff should be investigated, as current staffing limitations are part of the reason for shortened sampling season. With the addition of staff in 2019, this constraint should be alleviated.

References:

Collette B. and Klein-MacPhee G. 2002 Bigelow and Schroeder's Fishes of the Gulf of Maine. 3rd edition

Saila, S. B. 1961. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf Carib. Fish. Inst.

Saila, S. B. 1962. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. Trans. American Fisheries Society

Prepared by:____________________	Approved by:___________________
Katie Rodrigue	Jason McNamee
Principal Marine Biologist	Chief, Marine Resources

Table 1 - WFL Tagging/Recapture totals in PJ Pond by year

Year	Number caught	Number tagged	Number recaptured
1999	1301	332	31
2000	417	208	31
2001	538	358	70
2002	265	182	18
2003	160	87	6
2004	102	64	14
2005	252	115	7
2006	416	91	9
2007	120	35	6
2008	42	14	2
2009	63	0	0
2010	85	19	0
2011	68	11	0
2012	41	15	0
2013	22	5	0
2014	14	3	0
2015	56	14	0
2016	14	2	0
2017	8	2	0
2018	36	5	0
Total	4020	1562	194

Table 2 - Tagging/Recapture Data by Year in PJ Pond (recaptured by survey and commercial/recreational fishing activity)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**Total**	% recap by year
1999	31	8	10	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	15.36144578
2000		23	17	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	22.11538462
2001			43	11	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	15.92178771
2002				1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2.747252747
2003					1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4.597701149
2004						9	1	2	0	0	0	0	0	0	0	0	0	0	0	0	12	18.75
2005							4	4	2	1	0	0	0	0	0	0	0	0	0	0	11	9.565217391
2006								3	2	0	0	0	0	0	0	0	0	0	0	0	5	5.494505495
2007									2	1	0	0	0	0	0	0	0	0	0	0	3	8.571428571
2008										0	0	0	0	0	0	0	0	0	0	0	0	0
2009											0	0	0	0	0	0	0	0	0	0	0	0
2010												0	0	0	0	0	0	0	0	0	0	0
2011													0	0	0	0	0	0	0	0	0	0
2012														0	0	0	0	0	0	0	0	0
2013															0	0	0	0	0	0	0	0
2014																0	0	0	0	0	0	0
2015																	0	0	0	0	0	0
2016																		0	0	0	0	0
2017																			0	0	0	0
2018																				0	0	0
																						Total % recap over time series
Total	**31**	**31**	**70**	**18**	**6**	**14**	**7**	**9**	**6**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**194**	**12.41997439**

Table 3 - Tagging/Recapture Data by Year in PJ Pond (recaptured by commercial/recreational fishing activity only)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	% recap by year
1999	26	6	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	11.74698795
2000		18	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	13.46153846
2001			39	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	12.29050279
2002				1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2.747252747
2003					1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4.597701149
2004						9	1	2	0	0	0	0	0	0	0	0	0	0	0	0	12	18.75
2005							1	3	2	1	0	0	0	0	0	0	0	0	0	0	7	6.086956522
2006								1	1	0	0	0	0	0	0	0	0	0	0	0	2	2.197802198
2007									2	1	0	0	0	0	0	0	0	0	0	0	3	8.571428571
2008										0	0	0	0	0	0	0	0	0	0	0	0	0
2009											0	0	0	0	0	0	0	0	0	0	0	0
2010												0	0	0	0	0	0	0	0	0	0	0
2011													0	0	0	0	0	0	0	0	0	0
2012														0	0	0	0	0	0	0	0	0
2013															0	0	0	0	0	0	0	0
2014															0	0	0	0	0	0	0	0
2015																	0	0	0	0	0	0
2016																		0	0	0	0	0
2017																			0	0	0	0
2018																				0	0	0
																						Total % recap over time series
Total	**26**	**24**	**54**	**3**	**6**	**14**	**4**	**6**	**5**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**144**	**9.218950064**

Table 4 - WFL Tagging/Recapture totals in Charlestown Pond by year

Year	Number caught	Number tagged	Number recaptured
2012	113	98	11
2013	147	128	12
2014	33	33	3
2015	140	67	11
2016	0	0	0
Total	**433**	**326**	**37**

Table 5 - Tagging/Recapture Data by Year in Charlestown Pond (recaptured by survey and commercial/recreational fishing activity)

	2012	2013	2014	2015	2016	Total	% recap by year
2012	10	0	1	0		11	11.2244898
2013		11	1	0		12	9.375
2014			2	1	1	4	12.12121212
2015				10		10	14.92537313
2016					0	0	
							Total % recap over time series
Total	**10**	**11**	**4**	**11**	**0**	**37**	**11.34969325**

Table 6 - Commercial Landings and Value of WFL in Rhode Island

Year	Landings (metric tons)	Value (millions of dollars)
1999	525	1.4
2000	813.1	1.8
2001	658.5	1.4
2002	602	1.5
2003	470.6	1.2
2004	394.5	1
2005	306.4	0.97
2006	586.4	2.5
2007	530.1	2.4
2008	289.3	1.3
2009	140.2	0.49
2010	34.1	0.15
2011	37.9	0.13
2012	20.1	0.09
2013	181.7	0.6
2014	206.2	0.94
2015	167.4	0.74
2016	135.7	0.82
2017	135.8	0.9
2018	86.7	0.574
Average	316.0844833	1.0452

Table 2 - MRIP Estimated Recreational Harvest for WFL in Rhode Island

Estimate Status	Year	Total Harvest (A+B1)	Percent Standard Error
FINAL	1999	134,519	23.7
FINAL	2000	68,191	29.9
FINAL	2001	96,166	31.9
FINAL	2002	31,266	28.5
FINAL	2003	24,619	48.3
FINAL	2004	17,675	48.9
FINAL	2005	60	65.8
FINAL	2006	27	72.1
FINAL	2007	999	99.1
FINAL	2008	4,246	105.8
FINAL	2009	20,600	79.2
FINAL	2010	5,082	106.3
FINAL	2011	0	.
FINAL	2012	0	.
FINAL	2014	624	97.4
FINAL	2015	44	102.5
FINAL	2016	2,422	97.5
FINAL	2017	8,331	108.3
PRELIMINARY	2018	325	71.5

Figure 1 - WFL Commercial Landings - 1999-2018

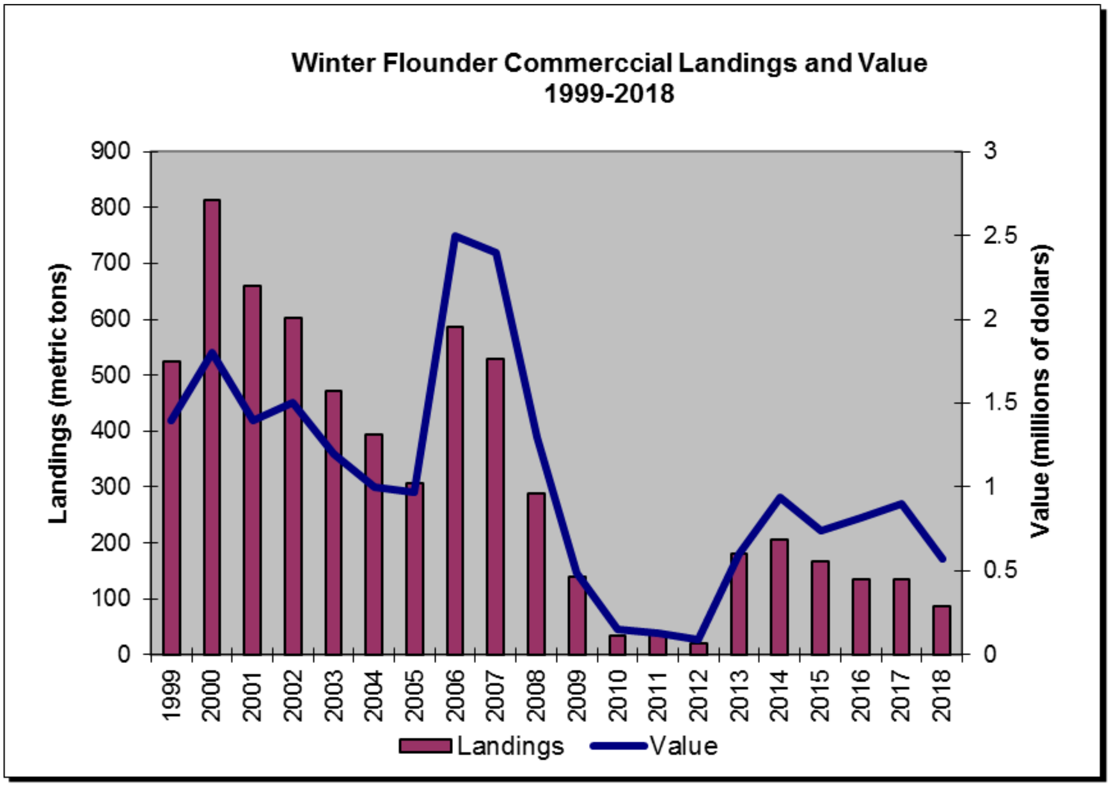


Figure 2 - WFL Recreational Harvest - 1999-2018

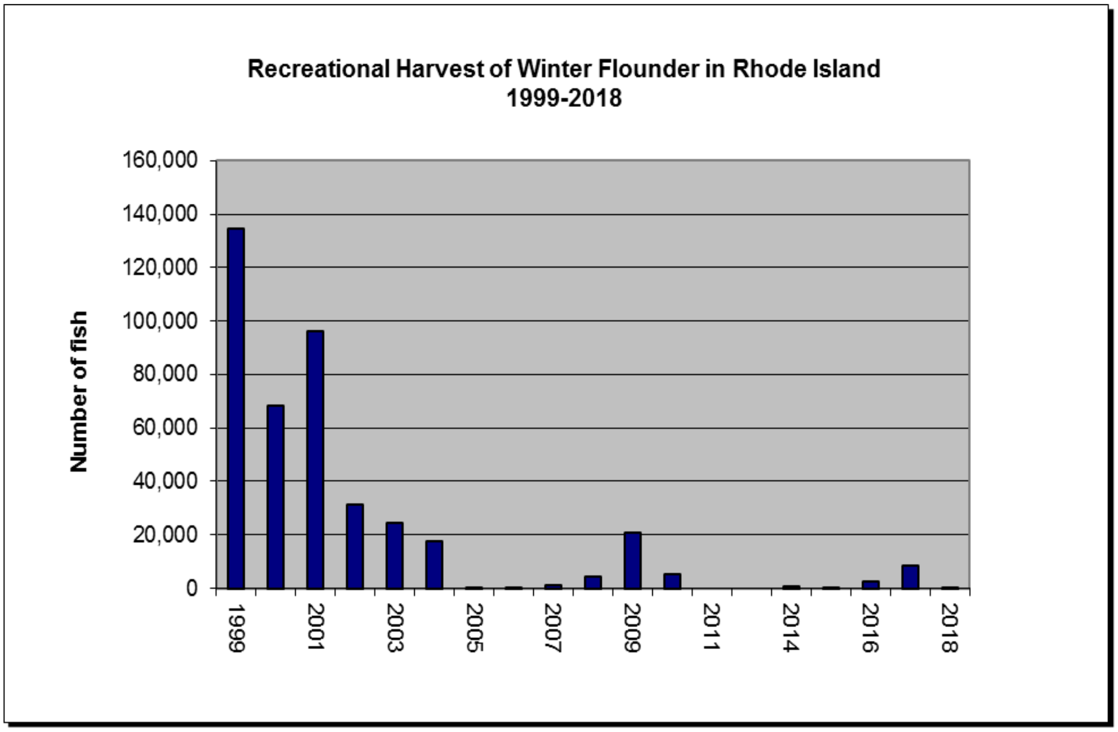


Figure 3 - WFL Spawning Stages 1999-2018

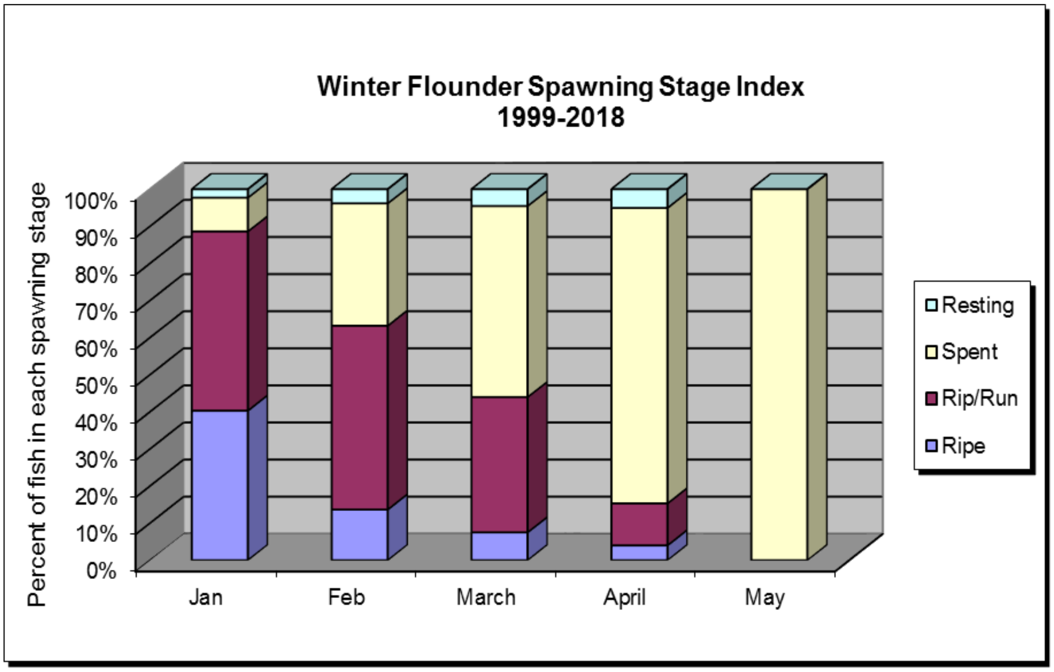


Figure 4 - 2018 recorded water temperature

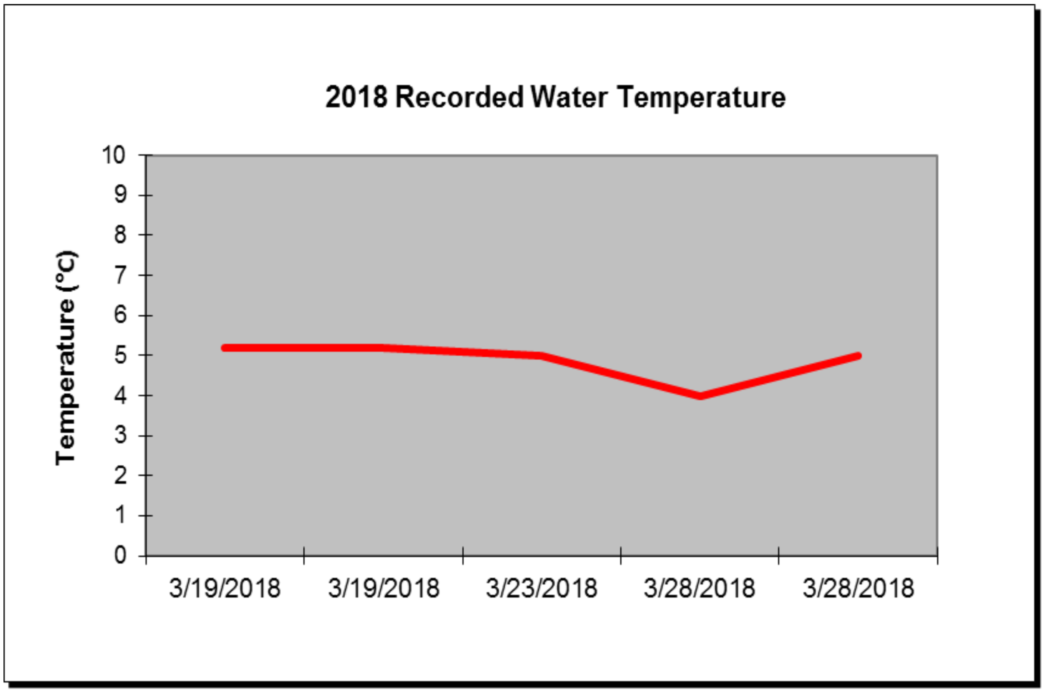


Figure 5 - WFL Male to Female ratio 1999-2018

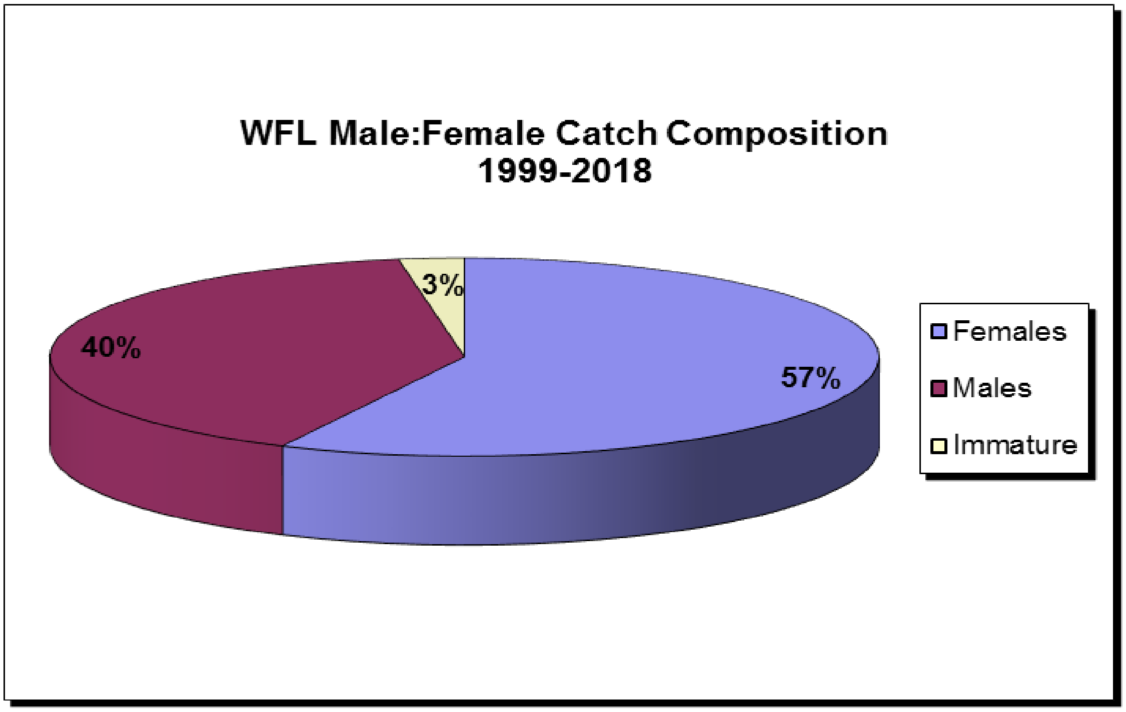


Figure 6 - WFL Length-Frequency for 2018 survey

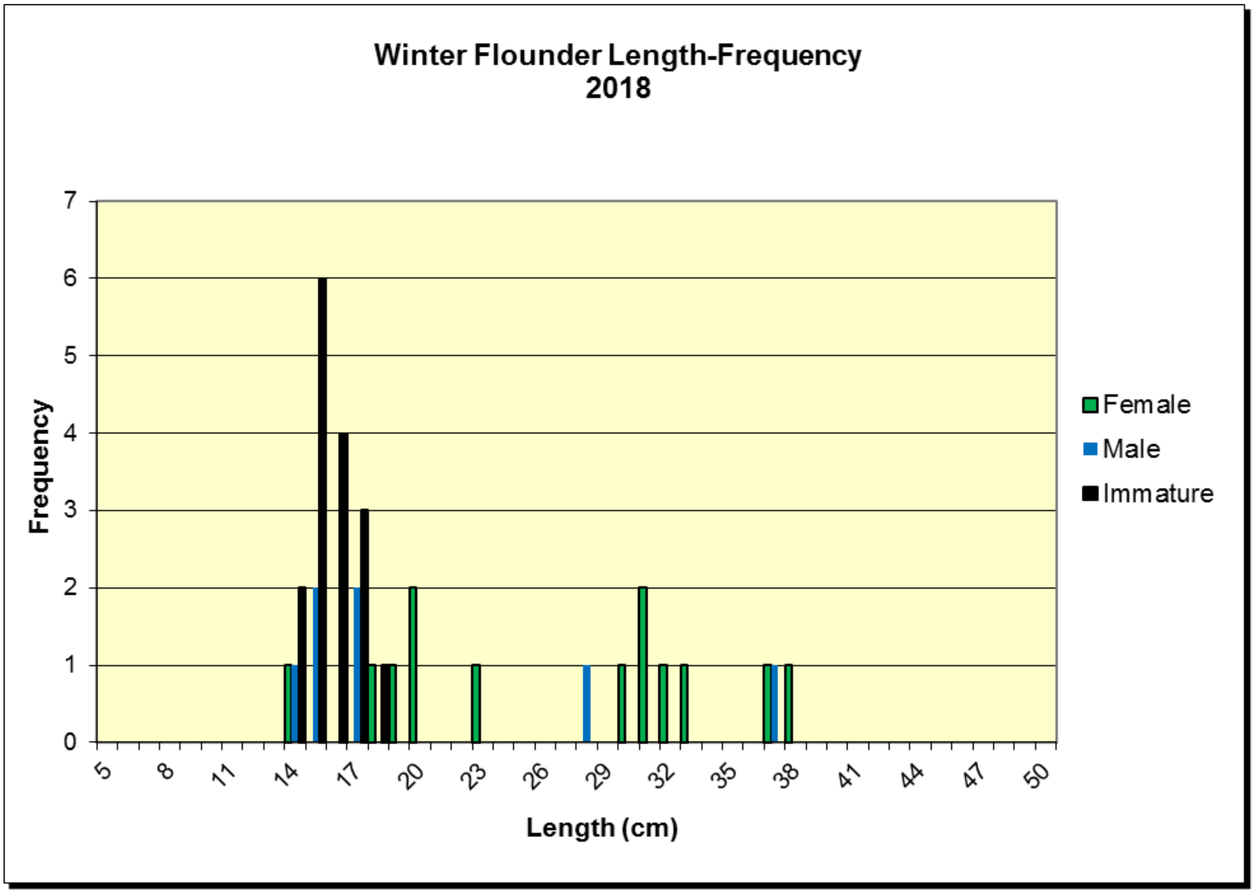


Figure 7 - WFL CPUE in Point Judith/Potter Pond - 1999-2018

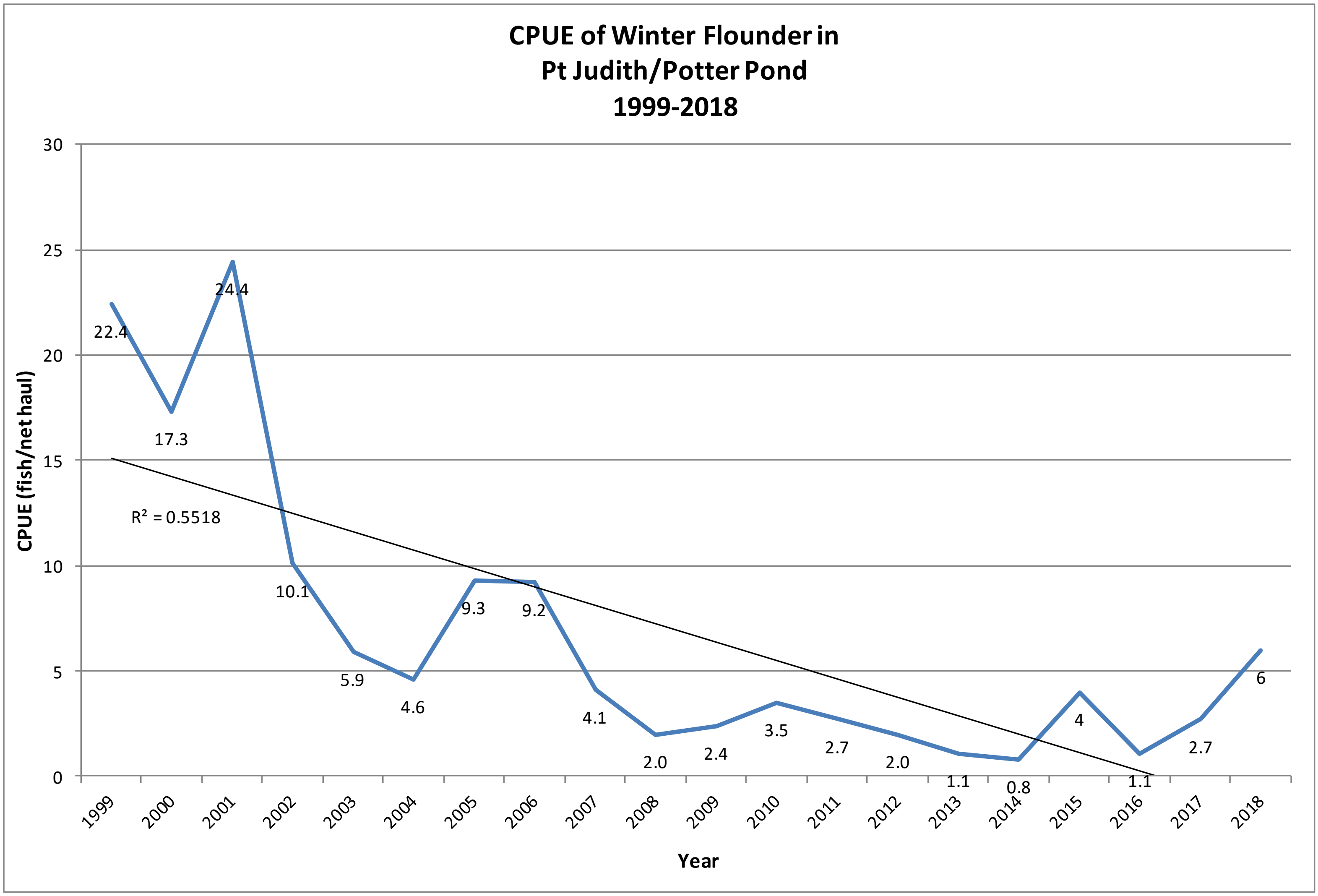
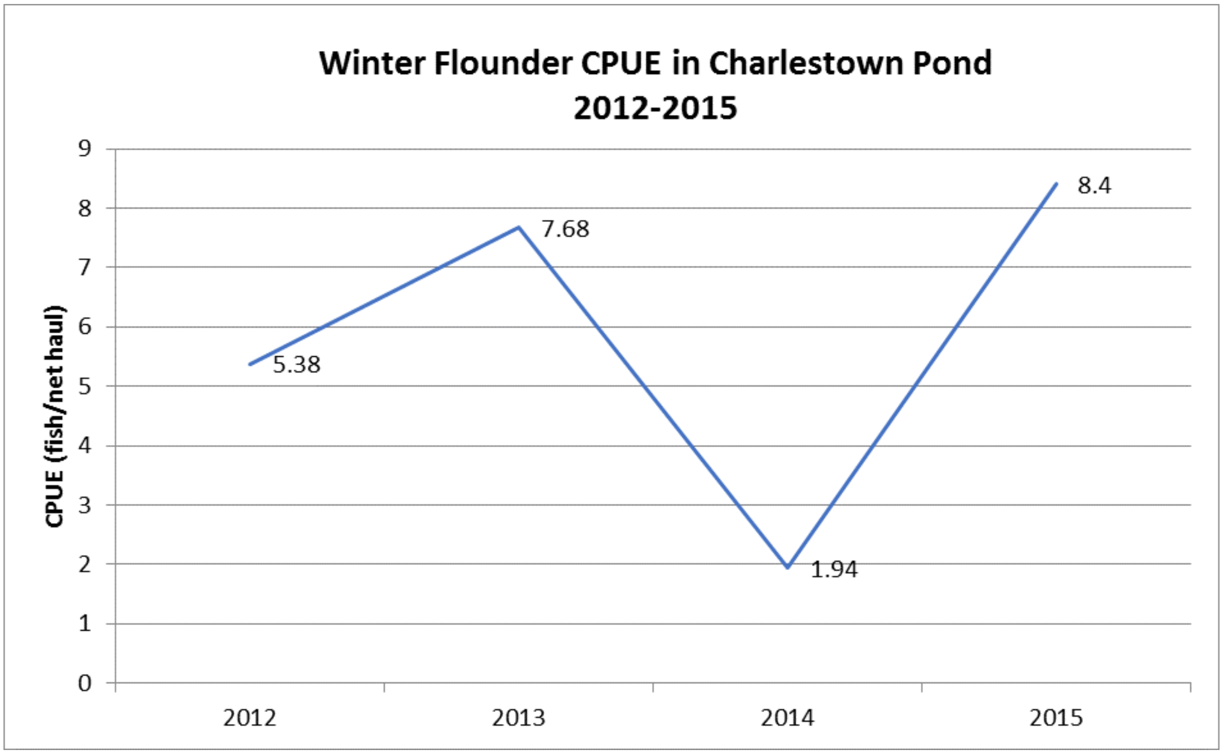


Figure 8 - WFL CPUE in Charlestown Pond - 2012-2015



Narragansett Bay Atlantic Menhaden Monitoring Program

Dr. Jason McNamee
Nicole Lengyel Costa

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

STATE: Rhode Island

PROJECT NUMBER: F-61-R

SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

PERIOD COVERED: January 1, 2018 – December 31, 2018

JOB NUMBER 11 TITLE: Narragansett Bay Atlantic Menhaden Monitoring Program

JOB OBJECTIVE: Continue administering an Atlantic menhaden monitoring program in Narragansett Bay that uses sentinel fishery observations (information of landings from floating fish traps), abundance information from spotter flights (with a trained spotter pilot), removal information by tracking fishery landings, and a mathematical model (Depletion Model for Open Systems; see Gibson, 2007) to monitor the abundance of menhaden in Narragansett Bay in close to real-time and adjust access to the fishery as necessary through a dynamic regulatory framework.

SUMMARY: Atlantic menhaden (menhaden) undergo large coastwide migrations each year. After aggregating in the offshore waters of the Mid-Atlantic region during the winter, menhaden migrate west and north stratifying by size and age the further north they migrate (Arenholz, 1991). Menhaden arrive in RI coastal waters beginning in the early spring, and in some years, enter Narragansett Bay in large numbers, where they can reside for varying amounts of time until they begin their southward migration in the fall. During the period when they reside in Narragansett Bay, a number of user groups compete for the resource. Commercial bait companies begin to fish on the schools of menhaden and provide bait for both recreational fishing interests and for the lobster fishery. As well, recreational fishermen access the schools of menhaden directly and use the resource as bait for catching larger sport fish such as striped bass and bluefish. Large numbers of sport fishermen can be seen in their boats surrounding large schools of menhaden throughout the spring and summer using various methods to harvest them (snagging lures, cast nets, dip nets). The migration of menhaden to the north is also one factor which brings these larger sport fish to northern areas, as they are an important food resource for these species (Arenholz, 1991; ASMFC, 2017). During the period when the menhaden resource is within Narragansett Bay and multiple user groups are accessing it, user group conflicts are an inevitable outcome. These conflicts were further exacerbated in 2013 with the implementation of Technical Addendum I and Amendment 2 to the Interstate Fishery Management Plan for Atlantic menhaden. Amendment 2 established coast-wide state quotas for Atlantic menhaden while Technical Addendum I established an Episodic Event Set Aside program. Both of these management measures resulted in increased resource conflicts due to a very low quota allocated to the state. In November of 2017, Amendment 3 to the Interstate Fishery Management Plan for Atlantic menhaden was approved by the Atlantic menhaden management board and was implemented in 2018. Amendment 3 maintained many of the measures from Amendment 2 but additionally gave Rhode Island a significant increase in our state quota allocation. It is anticipated that with the increased quota and high availability of fish in the spring in summer in Narragansett Bay, user conflicts will persist and may worsen. This makes

it important now more than ever for RI to accurately monitor the Atlantic menhaden resource in Narragansett Bay.

To help assuage some of these conflicts, to allow for an amount of the menhaden resource to remain unharvested by commercial interests for use by the recreational community, and to allow a portion of the menhaden resource to remain in Narragansett Bay to provide ecological services, the RI Department of Environmental Management Division of Marine Fisheries (Division) administers a menhaden monitoring program in Narragansett Bay. The program collectively uses sentinel fishery observations (floating fish trap data), spotter flight information with a trained spotter pilot, fishery landings information, computer modeling, and biological sampling information to open, keep track of, and close the fisheries on menhaden as conditions dictate.

TARGET DATE: December 2018

SIGNIFICANT DEVIATIONS: In 2018, Division staff were still not able to utilize the state helicopter as a resource for this monitoring program to conduct independent school counts due to changes that occurred at the RI Airport Corporation. Investigators will continue to request use of the state helicopter in the future or will attempt to contract a helicopter for future use if funds are available.

RECOMMENDATIONS: Continue spotter flights and data collection to create the estimate of Narragansett Bay Atlantic menhaden biomass. Continue to analyze and provide data for use in the RI menhaden fishery management program. Continue development of the assessment model and continue to move from a Microsoft excel framework in to a more advanced statistical program such as ADMB.

REMARKS: Abundance estimates derived from the menhaden monitoring program have been used to open and close the Narragansett Bay menhaden fishery. The management is performed to accommodate the recreational sportfish fishery that depends on menhaden as a source of bait for striped bass, bluefish, and weakfish, popular sportfish species in Narragansett Bay. In addition, the maintenance of a standing stock of menhaden biomass in Narragansett Bay meets other ecological services that this species performs.

The management structure maintains a biomass threshold of 1.5 million pounds in the Bay, which provides forage for the predatory species of striped bass and bluefish. Prior to the commencement of commercial fishing, the biomass needs to reach 2 million pounds to provide a body of fish for the fishery to remove without dropping below the 1.5 million pound threshold. Once fishing is authorized, the commercial fishery is allowed to remove 50% of the biomass above the 1.5 million pound threshold, leaving the rest for ecological services and for use as bait by recreational fishermen. If the biomass estimates based on the spotter flights drop below the 1.5 million pound threshold, the fishery will close. In addition, if landings by the commercial fishery reach the 50% cap, the fishery closes. Beginning in 2015, DEM adopted a regulation that opens the fishery annually on September 1st in the lower portion of Narragansett Bay at a reduced possession limit, despite the level of biomass present in the Bay. This opening is contingent upon the state having unharvested state quota remaining or having opted into the Episodic Event Set Aside program through ASMFC.

METHODS, RESULTS & DISCUSSION: The program in 2018 consisted of three main elements: collection of fishery landing information through call in requirements, computer modeling work, and field work (spotter flights and biological sampling). DEM regulations require that purse seine vessels fishing for menhaden in Narragansett Bay report their catches to Division staff. The commercial fishery interests also agree to carry a Division observer on the fishing vessel upon request or allow a port sample to occur while the catch is being offloaded.

In 2018, the estimated biomass of menhaden in Narragansett Bay never reached the minimum 2 million pound threshold and consequently the menhaden management area remained closed for the duration of 2018.

Port samples were collected from floating fish traps that operate in state waters outside of the menhaden management area as well as from the Divisions trawl survey (Jobs 1 and 2 of this grant). Sampling includes length frequencies, body weights, and collecting scales and otoliths for age determination (see Age and Growth Study, Job 9 of this F-61R grant progress report). The Division staff also contracted a trained spotter pilot to make abundance estimates of menhaden in Narragansett Bay. When in the air, the pilot records counts of menhaden schools observed, the estimated weight within the schools, and the location of the schools. All RI licensed commercial harvesters, including floating fish trap and purse seine operators, were required to file logbook reports monthly with the Division that detailed daily fishing activities. The fixed gear floating fish trap fishery is useful as sentinels, documenting the arrival and movements of menhaden in state waters. Other information on menhaden abundance and movements were obtained from scientific staff on Division research cruises and a network of fishers working in Narragansett Bay. Collectively, these sources of information were analyzed using the theory of depletion estimation as applied to open populations. All of the aforementioned information was centrally collected and used in a computer modeling approach that allows the Division to monitor the abundance of menhaden in Narragansett Bay. The existing regulatory framework governing state waters allows the Division to use the output from the mathematical modeling approach to set a number of fishing activity parameters including a static amount of fish that need to be present to allow commercial fishing to commence, thus protecting recreational and ecological interests if only a small population enters the Bay, allows for only half of the standing population present in Narragansett Bay above the initial threshold amount to be harvested, thus maintaining an amount of unharvested fish even when commercial fishing has commenced, and subsequently allows the Division to close the fishery when the standing population of menhaden in Narragansett Bay drops back below the threshold level of fish, again maintaining a portion of the population for recreational fishermen and ecological services. This program also allows the Division to accurately track the newly implemented state quota and provides justification for Rhode Island to participate in the Episodic Event Set Aside Program.

2018 Fishery Data

In 2018, the menhaden management area was never opened as the result of low biomass estimates that persisted throughout the year (Figure 1). All state landings of menhaden occurred outside of the management area. As a result of the management area not opening and reduced fishing effort in 2018, RI drastically under-harvested its commercial menhaden quota in 2018 (Table 1).

SUMMARY: The menhaden monitoring program in Narragansett Bay did not open in 2018. Biomass remained below the 2 million pound threshold throughout the year. All state landings occurred outside of the menhaden management area and Ri under-harvested its quota in 2018.

Table 1.

Quota	Total Landings	Quota Remaining
2,366,618 lbs	722,388 lbs	1,644,230 lbs

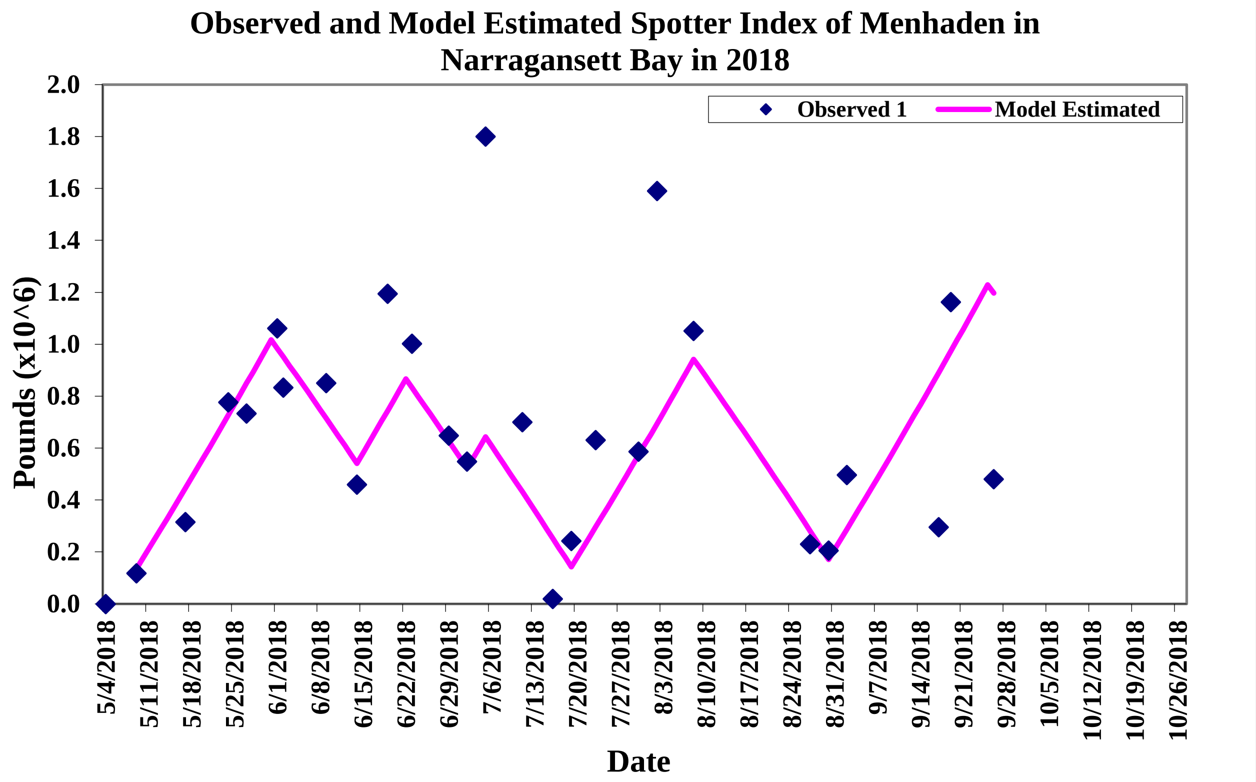


Figure 1. Predicted spotter pilot estimates and observed biomass in Narragansett Bay in 2018.

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Gibson, M. 2007. Estimating Seasonal Menhaden Abundance in Narragansett Bay from Purse Seine Catches, Spotter Pilot Data, and Sentinel Fishery Observations. http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/menabnnb.pdf

Narragansett Bay Ventless Pot, Multi-species Monitoring and Assessment Program

By
Scott Olszewski
Deputy Chief Marine Fisheries
scott.olszewski@dem.ri.gov

Rhode Island Department of Environmental Management
Division of Marine Fisheries
Ft. Wetherill Marine Laboratory
3 Ft. Wetherill Road
Jamestown, Rhode Island 02835

Performance Report - Job - 12 - 21 March 2019

PERFORMANCE REPORT

State: Rhode Island Project Number: F-61-R

Project Type: Resource Monitoring

Project Title: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

Period Covered: January 1, 2018 to December 31, 2018

Job Number & Title: 12- 21 Narragansett Bay Ventless Pot, Multi-species Monitoring and Assessment Program

Job Objective: The goal of this project is to assess and standardize a time series of relative abundance for structure-oriented finfish (particularly scup, black sea bass, and tautog) in Narragansett Bay. Investigators will also collect age, weight, and length data for these species, as well as collect data on other biological characteristics while they're in RI state waters. Abundance data will be integrated into both local and coast wide stock assessments for the target species.

Summary: Vessel service needs in spring 2017 delayed the vessels operation until June. Additionally, due to continuing vessel issues, we were forced to curtail sampling after several weeks in 2017. The vessel was put back into service for the 2018 sampling season but due to staff limitations and vessel reliability the survey was suspended for the 2018 sampling season. Investigators are confident that this project is working properly as designed and the Division is in the process of having a new vessel built which will accommodate the survey for the future.

Target Date: 2019

Status of Project: Behind Schedule

Significant Deviations: Investigators were unable to complete sampling during the entire sampling season due to vessel problems and limited project staff.

Recommendations: Continue into the next segment.

Remarks: In 2018 the decision was made to birth the existing survey vessel in the water and prepare it for some level of survey to be done. The vessel used in the survey has reached its life span and various components that are essential for both the boat and survey specifically need to be repaired or replaced. Along with staff limitations due to employee attrition, it was decided by the Division management staff to suspend the survey for the 2018 sampling season. The Division is now in the process of building a new research vessel which will be dedicated to the ventless fish pot survey. This vessel will have a larger carrying capacity for the sampling gear, will be outfitted to conduct the survey efficiently, and a new principal investigator has been obtained to help progress this survey into the future. The new vessel is currently in the building stage and will be the primary vessel for this survey into the future.

In 2017, the Division utilized the King side scan maps, PDF's and computer images of Narragansett Bay for selection of stations as they refer to structure, non-structure. As more data is gathered, Investigators will perform data analysis on the efficacy of the changes to be implemented in 2019 and as the survey moves forward.

Personnel work with staff from our age and growth project to obtain scales, otoliths, and weights from fishes.

Introduction: Working groups such as the Northeast Data Poor Stocks Working Group (2008), have reported that size classes of many species may be under represented in their assessments, particularly scup, black sea bass, and tautog. All three of these species tend to associate with bottom structure for a major portion of the year and as a result tend to be unavailable to traditional trawl surveys. This survey is an attempt to employ an alternative survey gear type for these species, e.g. fish traps, as recommended by Shepherd (2008) and Terceiro (2008) to construct indices of abundance for structured-oriented fish and be of use in formal stock assessments of said species.

Methods: Narragansett Bay is divided into five sampling areas: The Providence/lower Seekonk River including portions of the Upper Bay/Greenwich Bay, West Passage, East Passage, Mount Hope Bay including portions of the Upper Bay, and the Sakonnet River including the area from Land’s End to Sakonnet Point (Figure 1). Each area was subdivided into 0.5 deg. of latitude and longitude squares and numbered. These numbered boxes were referred to as stations. Investigators then located areas of hard bottom, shipwreck, major bridge abutments, or pilings, etc., in each station. The areas of structure were noted in the stations containing structural elements and the goal for each month was to randomly sample half of the replicates in areas of known structure and half in areas without known structure.

All sampling stations are selected randomly. In order to maintain a consistent methodology with the other sampling efforts in Rhode Island waters, investigators adopted the following sampling schedule.

A monthly survey is conducted in the Narragansett Bay from May through October. The unvented scup pots (2'x2'x2') are constructed of 1.5” x 1.5” coated wire mesh. The unvented Black Sea Bass Pots (43.5” L, 23” W, and 16” H) are also constructed of 1.5” x 1.5” coated wire mesh, single mesh entry head, and single mesh inverted parlor nozzle.

Investigators set black sea bass pots in five (5) pot trawls at two (2) randomly selected stations in two separate sampling areas. One trawl is set on structured bottom and one on bottom without structure. These traps are unbaited and allowed to fish for 96+/- 1 hr. After the four day soak, the traps are hauled, the catch is processed, and the trawls held for 24 hours are then moved to a new areas and allowed reset. This is repeated until there are ten set in total for Narragansett Bay.

In the intervening time, Investigators set scup pots at ten (10) randomly selected stations, five on structured bottom and five on bottom without structure, in one of the five sampling areas and left to soak for 24+/-1 hr. All pots are baited with sea clams. After 24 hrs the pots set are hauled, the catch is processed, and gear is either reset or removed from the water, so investigators could tend to additional sampling gear. This continues until 50 sets have been made throughout Narragansett Bay.

Upon hauling all gear types, the catch is sorted by species, finfish are measured to the nearest centimeter, fork length (FL) or total length (TL). Invertebrates are measured using a species-specific appropriate metric or counted. Personnel from the age and growth project have accompanied on the survey to obtain scale samples and fish specimens from which to obtain stomach samples, otoliths and/or opercula. These instances have indicated that this could become a normal part of this project. Project personnel collect data on water temperatures, salinities, dissolved oxygen, air temperature at each sampling station using a Eureka Systems Manta 2 Multiprobe.

Results/Discussion: Due to vessel failure and staff limitations due to employee attrition, there was no survey work done for this job in 2018. A new research vessel is being built that will be enable the Division to conduct this work in the future. This vessel will have a larger carrying capacity for the sampling gear and will allow the principal investigator to focus on the biological aspects of the survey and add efficiency to the job.

Prepared by: ________________
Scott Olszewski
Deputy Chief, Marine Fisheries

Approved by: ____________________
Jason McNamee
Chief, Marine Fisheries

References:

Shepherd, G. 2008. Black Sea Bass. Northeast Data Poor Stocks Working Group Meeting. Dec 8-12. National Marine Fisheries Service. Northeast Fisheries Science Center. 166 Water St., Woods Hole, MA 02543

Terceiro, M. 2008. Scup: Stock Assessment and Biological Reference Points for 2008. Northeast Data Poor Stocks Working Group Meeting. Dec. 8-12. Northeast Fisheries Science Center, 166 Water St. Woods Hole, MA 02543.

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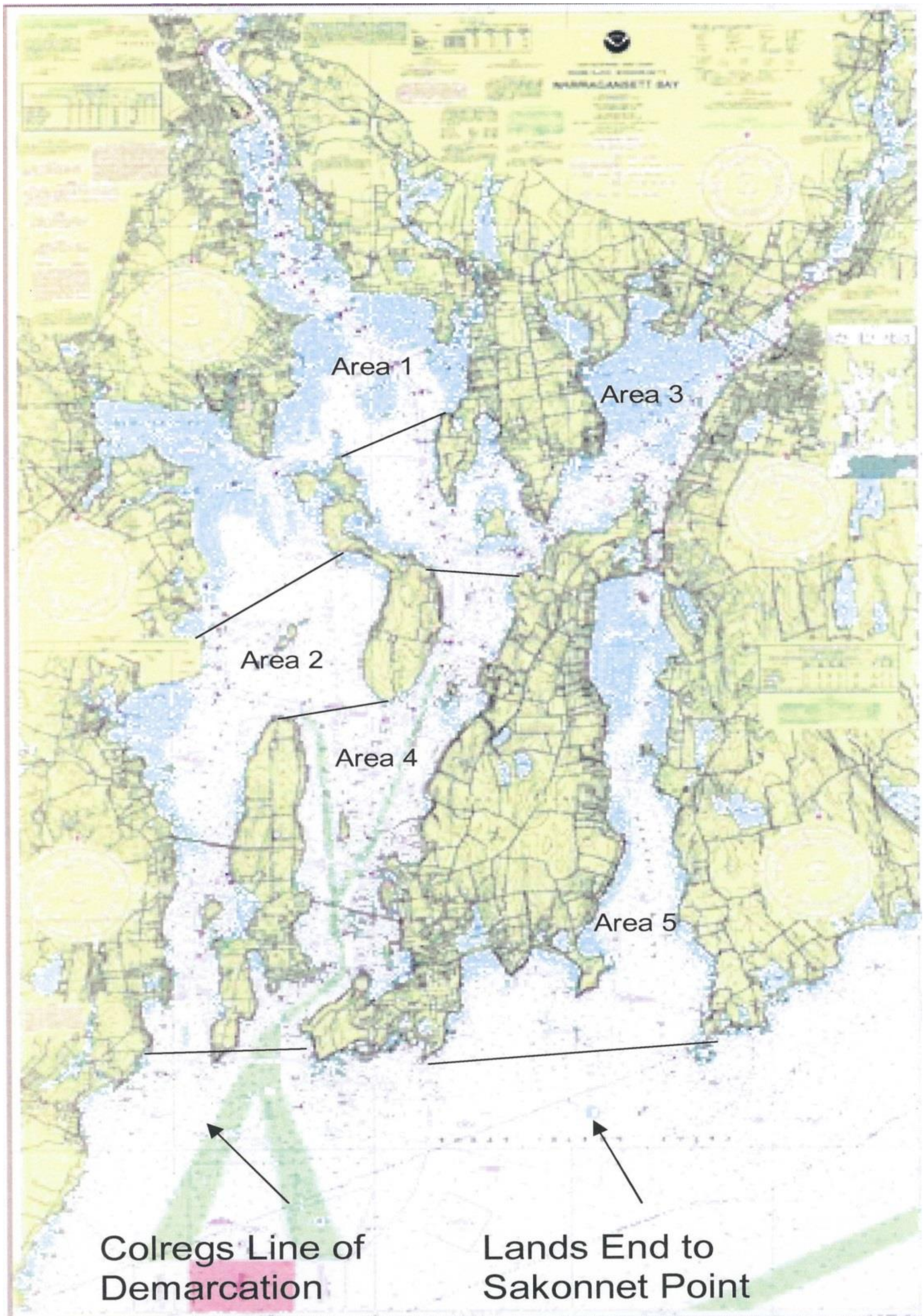


Figure 1. – Chart of Narragansett Bay with Colregs line of demarcation and Location of Five Sampling Areas.

ASSESSMENT OF RECREATIONALLY IMPORTANT FINFISH STOCKS IN RHODE ISLAND COASTAL WATERS

2018 ANNUAL PERFORMANCE REPORT

Federal Aid in Sportfish Restoration
F-61-R
SEGMENT 21, JOB 13

MARINE FISHES OF RHODE ISLAND

Prepared by
Thomas E. Angell
Principal Marine Fisheries Biologist
thomas.angell@dem.ri.gov

Rhode Island Department of Environmental Management
Division of Marine Fisheries
3 Fort Wetherill Road
Jamestown, RI 02835

March 2019

STATE: Rhode Island
PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 21

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Coastal Waters

JOB NUMBER: 13

JOB TITLE: Marine Fishes of Rhode Island

PERIOD COVERED: January 1, 2018 – December 31, 2018

JOB OBJECTIVE:

The goal of this project is to produce a manuscript which will act as a reference for recreational fishermen, commercial fishermen, and fisheries scientists alike. The finished product will summarize existing knowledge on the occurrence and distribution of fish species observed within Rhode Island marine waters, based on information collected through several field surveys conducted by RIDMF. The information will be presented systematically and the manuscript will include scientific illustrations of fish species encountered occasionally to commonly in RIDMF surveys; rare species will not be illustrated. This work is designed to be a stand-alone manuscript, but also to be compatible with and be a companion volume to the Fresh Water Fishes of Rhode Island book produced in 2013.

SUMMARY:

The basic format and foundation of the book was laid out in 2017 and included the following sections: cover page, table of contents, acknowledgements, dedication, glossary, introduction, description of the data sources (field surveys) that collected the data with maps of survey sampling locations and survey activity photographs, lists of species observed in RIDMF surveys (all surveys combined and by individual survey) and species observed historically with life history classification and historic status, family description, species description (including scientific and common name(s), species identification characteristics, species distribution (general and in RI), current management in RI (where applicable)), current RI sportfish and all-tackle (worldwide) records (where applicable), references used, and an index.

There is a total of 282 species that will appear in the “Marine Fishes of Rhode Island” book. Of these 282 species, 187 species were observed in recent RIDMF surveys and 95 species have been observed by entities other than RIDMF, either recently or historically. Of the 187 species observed in recent RIDMF surveys, 83 species were rarely-observed. A total of 178 species (83+95) observed rarely, or not at all in recent RIDMF surveys, will not be illustrated in this book. There will be a total of 104 illustrated species in this book. A total of 53 illustrations (51 species; 2 species with both sexes illustrated) have been completed previously for the “Inland Fishes of Rhode Island” book authored by Alan Libby (2013) and will be utilized in this book, leaving 53 species illustrations (2 species with both sexes illustrated) to be completed for this book. If some of the rarely-observed species can be obtained, they may also be included for illustration, up to a maximum of 65 species illustrations.

A modest amount of progress was made on this job during 2018. To date, the following sections and portions of the book have been completed:

- cover page,
- acknowledgements,
- dedication page,
- table of contents,
- introduction,
- data source descriptions for 7 RIDFW / RIDMF field sampling surveys (including maps of sampling locations, tables of species (scientific and common name) caught in recent RIDMF surveys (all surveys combined and by individual survey) or observed by others historically and including life history classifications and relative abundance level (abundant, common, occasional, rare)
- scientific and common names, current RI sportfish records, and all-tackle worldwide records

The glossary, references, and index sections are near completion but will need occasional revision/updates as more text is added. To date, a total of 7 family descriptions have been prepared, including Acipenseridae, Albulidae, Clupeidae, Engraulidae, Serranidae, Sparidae, and Petromyzontidae, of which 2 were completed during this report period. To date, species descriptions for 15 species have been prepared (scientific and common name(s), species identification, species distribution, importance, and current management), including bonefish (*Albula vulpes*), blueback herring (*Alosa aestivalis*), hickory shad (*Alosa mediocris*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), rock sea bass (*Centropristis philadelphica*), black sea bass (*Centropristis striata*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic herring (*Clupea harengus*), Atlantic round herring (*Etrumeus teres*), Atlantic thread herring (*Opisthonema oglinum*), striped anchovy (Anchoa hepsetus), bay anchovy (*Anchoa mitchilli*), jolthead porgy (*Calamus bajonado*), pinfish (*Lagodon rhomboides*), and sea lamprey (*Petromyzon marinus*), of which 8 were completed during this report period.

Species distribution maps are in the process of being compiled from GPS sampling location data for each species by each RIDMF survey. To date, species distribution information has been compiled for 4 of the 7 RIDFW / RIDMF field sampling surveys being used for the book.

There has been 1 meeting (October 17, 2018) and 8 email correspondences with the illustrator (Robert Jon Golder) during this report period. At this latest meeting, a contract was signed that included a schedule for the illustrations to be completed over the next 2.5 - 3 years. Also, at this meeting, the illustrator received 10 frozen specimens of species requiring illustration and is currently in the process of preparing these illustrations; these species included American sand lance (*Ammodytes americanus*), striped anchovy (*Anchoa hepsetus*), oyster toadfish (*Opsanus tau*), rock gunnel (*Pholis gunnellus*), pollock (*Pollachius virens*), striped searobin (*Prionotus evolans*), clearnose skate (*Raja eglanteria*), tautog male and female (*Tautoga onitis*), and spotted skate (*Urophycis regia*). There are currently another 12 frozen specimens in queue, including Atlantic herring (*Clupea harengus*), smallmouth flounder (*Etropus microstomus*), little skate (*Leucoraja erinacea*), American goosefish (*Lophius americanus*), haddock (*Merluccius bilinearis*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), summer flounder (*Paralichthys dentatus*), Atlantic mackerel (*Scomber scombrus*), Atlantic spiny dogfish (*Squalus acanthias*), scup (*Stenotomus chrysops*), inshore lizardfish (*Synodus foetens*), and red hake (*Urophycis chuss*).

TARGET DATE: December 31, 2019 and continuing into the next grant cycle

SIGNIFICANT DEVIATIONS: None

RECOMMENDATIONS: Continue into the next grant cycle/segment

REMARKS:

While this job had fallen behind schedule, it is now close to being, if not, on schedule. It is the intent and goal of staff currently assigned to this job (Thomas Angell) to have this job completed prior to the end of the next grant cycle (i.e. within 5 years).

ASSESSMENT OF RECREATIONALLY IMPORTANT FINFISH STOCKS IN RHODE ISLAND WATERS

University of Rhode Island
Graduate School of Oceanography
Weekly Fish Trawl
2018

PERFORMANCE REPORT
F-61-R SEGMENT 21
JOB 14

Jeremy Collie, PhD
Professor of Oceanography
March 2019

Annual Performance Report

STATE: Rhode Island

PROJECT NUMBER: F-61-R
SEGMENT NUMBER: 22

PROJECT TITLE: Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters

JOB NUMBER: 14

TITLE: University of Rhode Island Graduate School of Oceanography Weekly Fish Trawl

JOB OBJECTIVE: To collect, summarize and analyze bottom trawl data for biological and fisheries management purposes.

PERIOD COVERED: January 1, 2018 – December 31, 2018.

TARGET DATE: December 2018

SCHEDULE OF PROGRESS: On schedule.

SIGNIFICANT DEVIATIONS: None

RECOMMENDATIONS: Continuation of the weekly trawl survey into 2019; data provided by the survey are used extensively in the Atlantic States Marine Fisheries Commission and NOAA Fisheries fish stock assessments and fishery management plans.

Introduction:

The University of Rhode Island, Graduate School of Oceanography, began monitoring finfish populations in Narragansett Bay in 1959, and has continued through 2018. These data provide weekly identification of finfish and crustacean assemblages. Since the inception of the weekly fish trawl, survey tows have been conducted within Rhode Island territorial waters at two stations, one representing habitat of Narragansett Bay and one representing more open-water type habitats, characteristic of Rhode Island Sound. The weekly time step of this survey and its long duration are two unique characteristics of this survey. The short duration time step (weekly) has enough definition to capture migration periods and patterns of important finfish species and the length of the time series allows for the characterization of these patterns back into periods of time that may represent different productivity or climate regimes for many of these species. This performance report reflects the efforts of the 2018 survey year as it relates to the past 59 years.

Methods:

A weekly trawl survey is conducted on the URI research vessel Cap'n Bert. Two stations are sampled each week: one off Wickford represents conditions in mid Narragansett Bay (Fox Island) and one at the mouth of Narragansett Bay represents conditions in Rhode Island Sound (Whale Rock). A hydrographic profile at each station measures temperature, salinity and dissolved oxygen. The same otter trawl net design has been used for the past 59 years. A half-hour tow is made at each station at a speed of 2 knots. All species are counted and weighed with an electronic balance. Winter flounder are routinely measured and sexed. When present on board, an undergraduate intern measures all other species with an electronic measuring board.

The following are the station locations for the survey:

Site	Location	Coordinates	Depth Range at Low Tide (North to South Along Tow Line)	Bottom Substrate
Fox Island	Adjacent to Quonset Point and Wickford	41°34.5' N, 71°24.3' W	20 feet (6.1 meters) to 26 feet (7.9 meters)	Soft mud and shell debris
Whale Rock	Mouth of West Passage	41°26.3' N, 71°25.4' W	65 feet (19.8 meters) to 85 feet (25.9 meters)	Coarse mud/fine sand

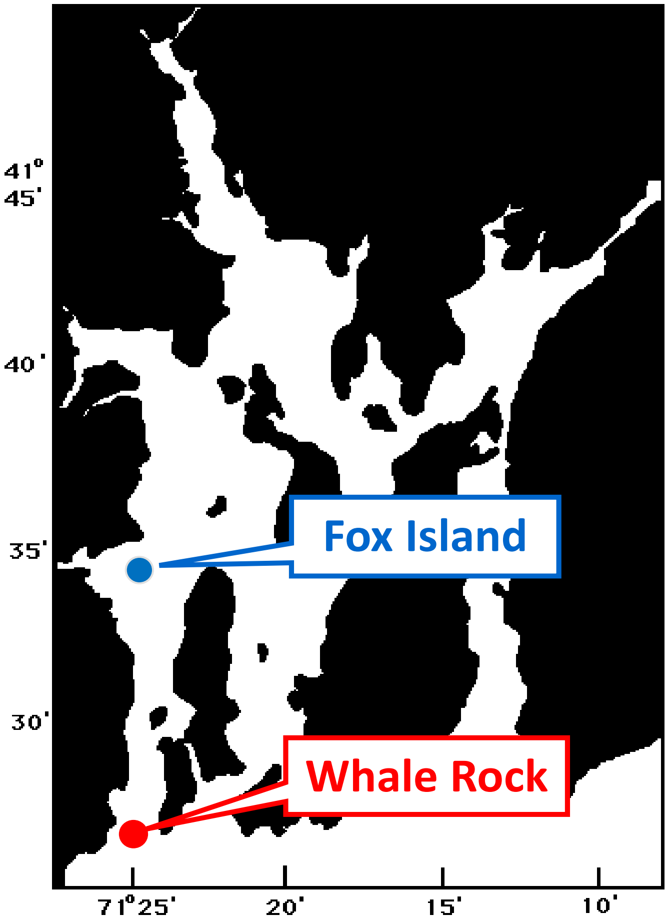


Figure 1. Location of trawl stations in Narragansett Bay.

The gear dimensions of the net are as follows:

Net type	2-seam with bag
Length of headrope	39 feet (11.9 meters)
Otter boards	steel, 24 inches tall, 48 inches long (61 centimeters by 1.24 meters)
Distance from otter boards to net	60 feet (18.3 meters)
Mesh size: net	3 inches (7.6 centimeters)
Mesh size: codend	2 inches (5.1 centimeters)
Distance between otter boards while fishing	52 feet (15.8 meters) at Fox Island 64.5 feet (19.7 meters) at Whale Rock

(For more information about the GSO fish trawl go https://web.uri.edu/fishtrawl/)

Results:

47 and 46 weekly tows were made at the bay (Fox Island) and sound (Whale Rock) stations respectively.

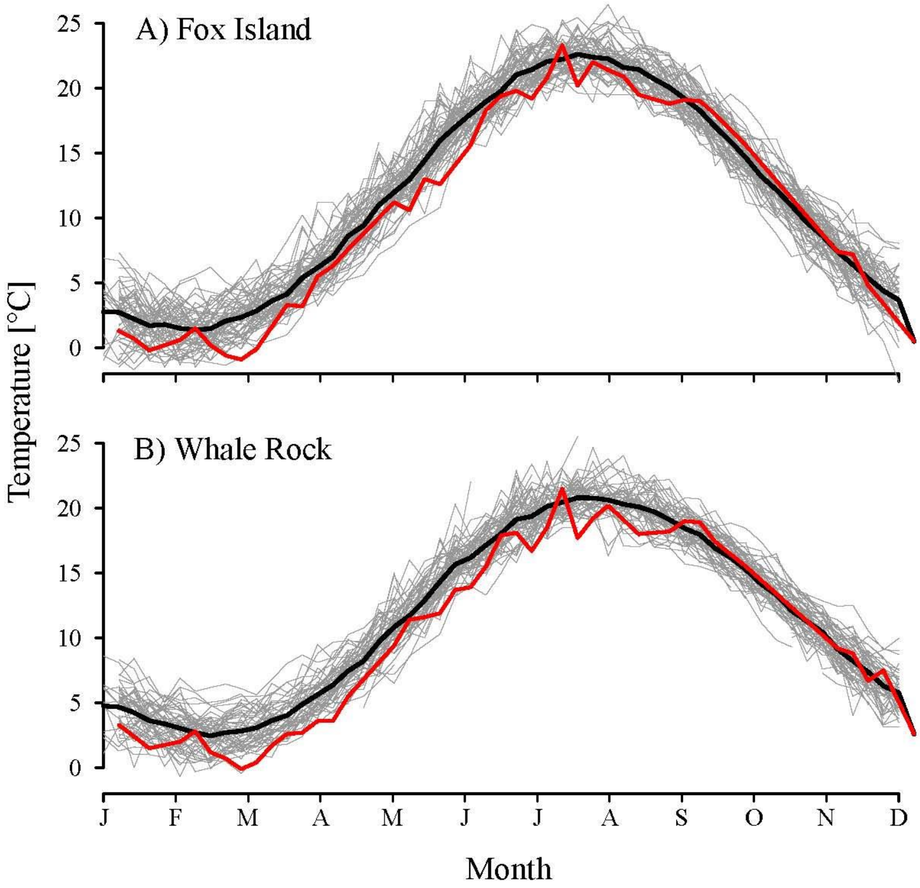


Figure 2. Weekly sea surface temperature of Narragansett Bay at each sampling station. The gray lines represent the seasonal temperature cycle for each previous year. The black line is the average temperature over all years. The most recent year, 2018, is labeled red.

Environmental conditions

Weekly water temperatures in 2018 began cooler than the historical average (Figure 2). Spring warming was delayed, and temperature remained below average until September, after which fall cooling was consistent with the historical average.

Summary catch statistics

Table 1. Total catch by species at Fox Island (FI) and Whale Rock (WR) for the top 25 species.

Species	**FI**	**WR**	**Total**
Scup (*Stenotomous chrysops*)	5254	3306	**8560**
Butterfish (*Peprilus triacanthus*)	232	1726	**1958**
Silver hake (*Merluccius bilinearis*)	3	1575	**1578**
Squid (*Doryteuthis pealii*)	299	1120	**1419**
Rock crab (*Cancer irroratus*)	25	1058	**1083**
Spider crab (*Libinia emarginata*)	335	265	**600**
Little skate (*Leaucoraja erinacea*)	30	484	**514**
Summer flounder (*Paralichthys dentatus*)	228	274	**502**
Northern searobin (*Prionotus carolinus*)	15	389	**404**
Winter flounder (*Pseudopleuronectes americanus*)	93	304	**397**
Hermit crabs	259	16	**275**
Striped searobin (*Prionotus evolans*)	91	155	**246**
Moonfish (*Selene setapinnis*)	196	35	**231**
Scallop (*Aequipecten irradians*)	231	0	**231**
Sand flounder (*Scophthalmus aquosus*)	8	216	**224**
Menhaden (*Brevootia tyrannus*)	211	11	**222**
Smallmouth flounder (*Etropus microstomus*)	13	205	**218**
Conch (*Busycon canaliculatum* & *B. carica*)	204	8	**212**
Fourspot flounder (*Paralichthys oblongus*)	1	196	**197**
Sponge (*Suberites* spp)	164	1	**165**
Spotted hake (*Urophycis regia*)	1	131	**132**
Black sea bass (*Centropristis striatus*)	9	123	**132**
Lobster (*Homarus americanus*)	0	104	**104**
Cockle	96	0	**96**
Smooth dogfish (*Mustelus canis*)	61	31	**92**
Total	**8059**	**11733**	**19792**

The top 10 species caught in 2018 (and the station where they were most numerous) were: Scup (FI), Butterfish (WR), Silver hake (WR), Squid (WR), Rock crab (WR), Spider crab (FI), Little skate (WR), Summer flounder (WR), Northern Searobin (WR), and Winter flounder (WR).

A number of species of recreational importance were collected during 2018 by the URI Fish trawl survey. Represented below are a number of important species and their abundance trends throughout the time series of this survey. On each graph, the species abundance at the two stations is represented separately for each station.

Winter flounder

Winter flounder are one of the target species for the survey. The population of winter flounder has declined dramatically since the mid 1980s with some of the lowest estimates on record for both stations occurring in the last decade (Figure 3). Winter flounder was historically more abundant at the Bay Station (Fox Island), but the abundance of this subpopulation has declined. A slight increase at Whale Rock was observed in 2018. The survey information is used during the stock assessment process for winter flounder.

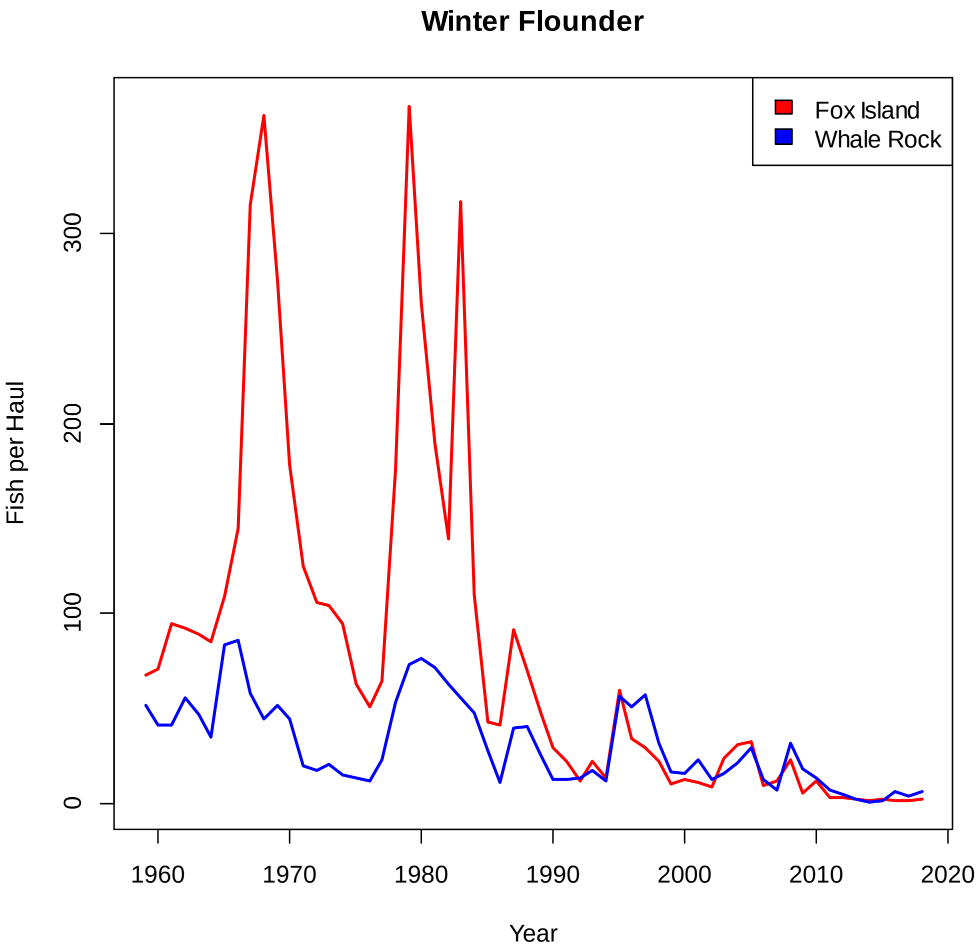


Figure 3 – Survey data for entire time series for winter flounder at both sampling stations (Fox Island and Whale Rock).

Tautog

Tautog are another important recreational species caught by the survey. The population of tautog was historically more abundant in Narragansett Bay before the mid 1980s. It declined dramatically during the time period of the survey, but does show some improvement in the most recent period of time (Figure 4). Despite the improvement, the population according to the survey has not rebounded to former levels. Tautog are mainly caught at the Fox Island station, with only random and infrequent catches occurring at Whale Rock. The survey information was reviewed during the stock assessment process for tautog.

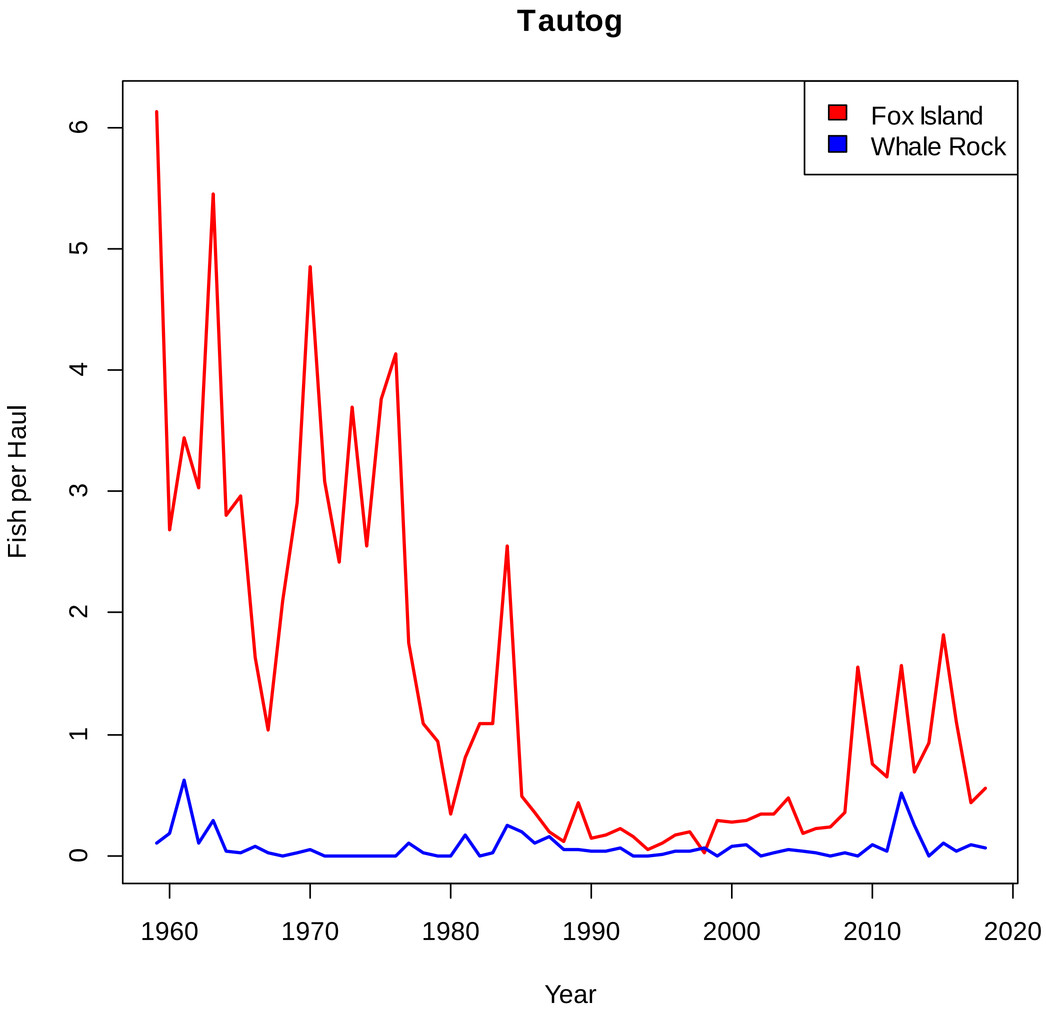


Figure 4 – Survey data for entire time series for tautog at both sampling stations (Fox Island and Whale Rock).

Summer Flounder

Summer flounder are another important recreational species caught by the survey. The population of summer flounder has increased dramatically during the time period of the survey, but does show a fair amount of variability in the most recent time period (Figure 5). Summer flounder are caught at both sampling stations pretty consistently, though abundance has increased at Whale Rock relative to Fox Island. Both stations are capturing the seasonal migration patterns of summer flounder. The survey information was reviewed during the stock assessment process for summer flounder, and the trends indicated by the survey are similar to those indicated by the overall population trends.

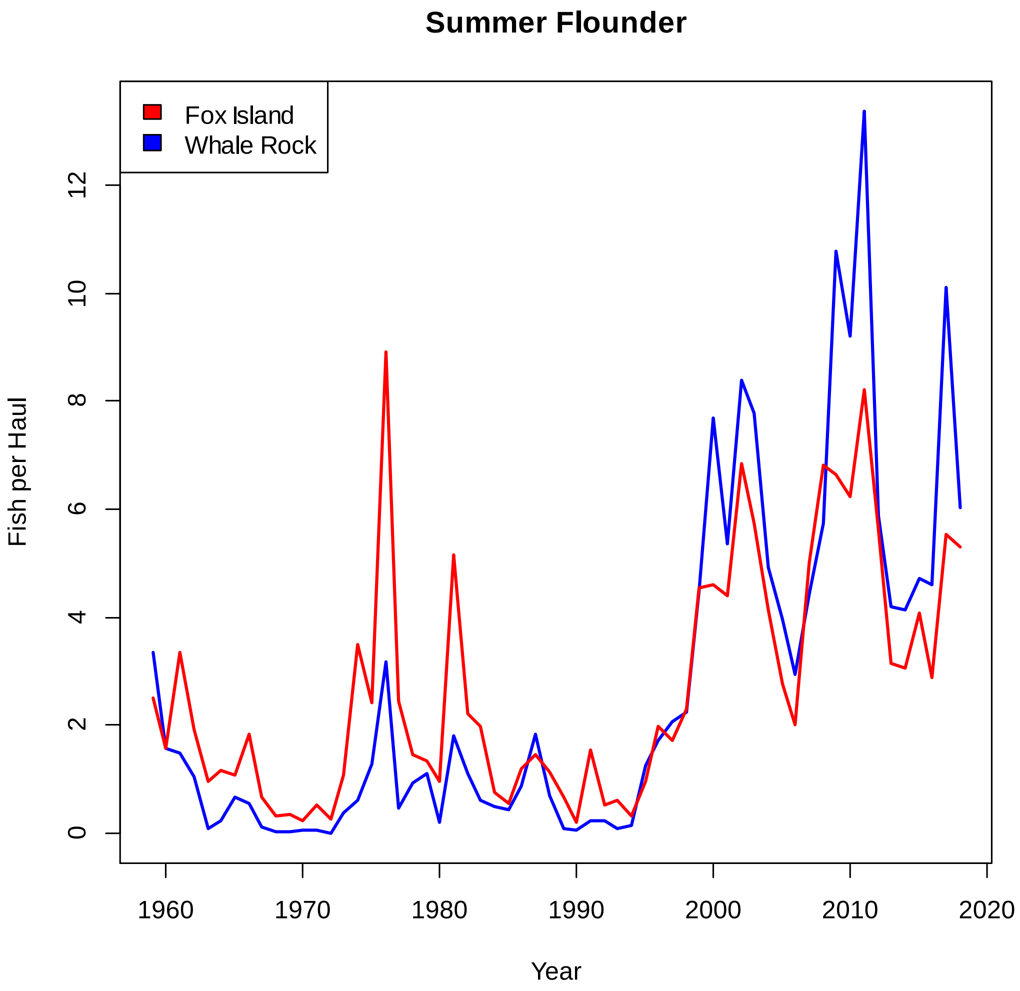
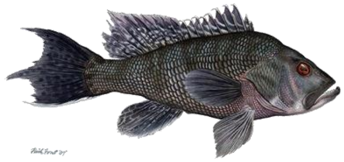


Figure 5 – Survey data for entire time series for summer flounder at both sampling stations (Fox Island and Whale Rock).



Black Sea Bass

Black sea bass are another important recreational species caught consistently by the survey. The population of black sea bass has increased dramatically since the mid 1990s, much like summer flounder, and also shows a fair amount of variability in the most recent time period (Figure 6). The 2018 survey year produced the highest catch per unit effort for Black sea Bass ever recorded in the survey. Black sea bass are caught at both sampling stations pretty consistently.

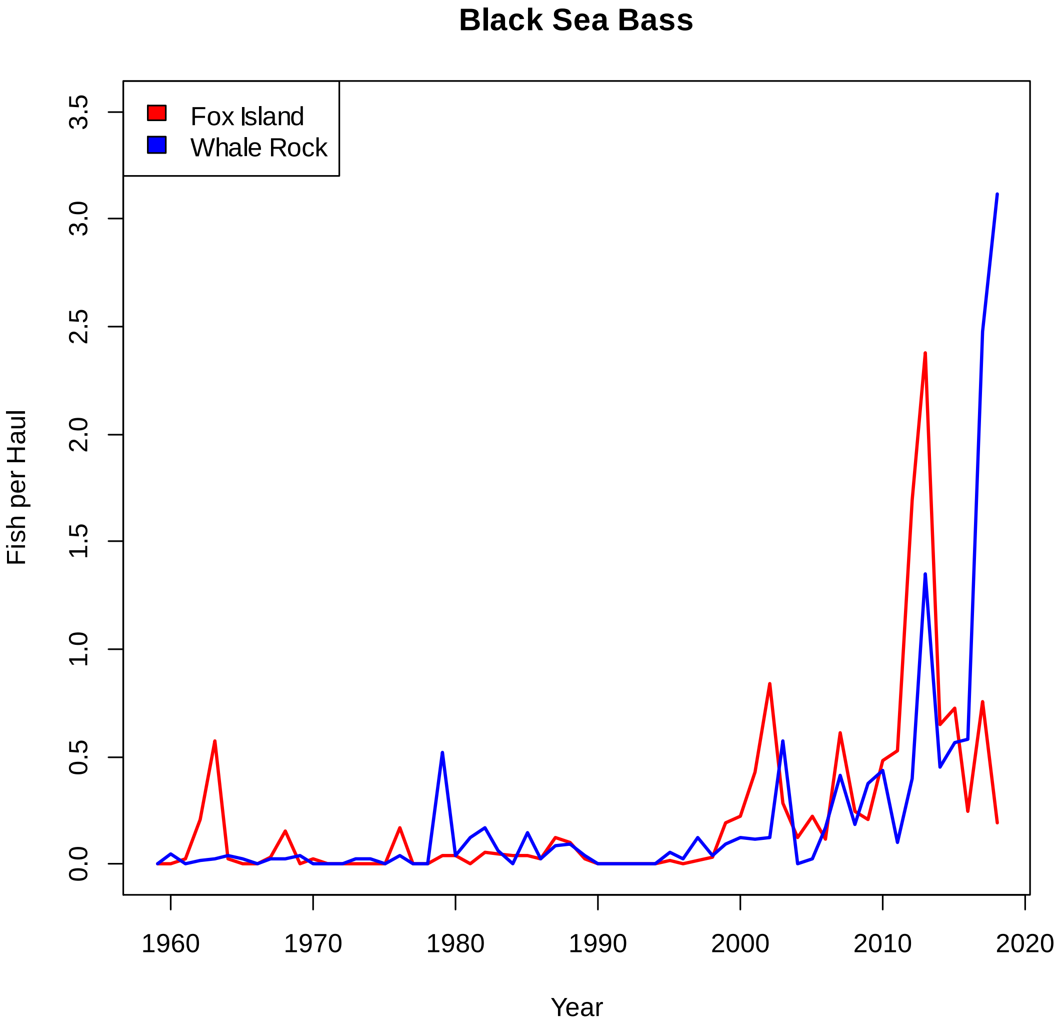
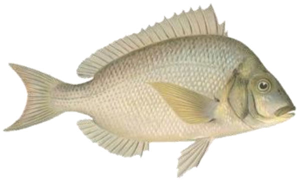


Figure 6 – Survey data for entire time series for black sea bass at both sampling stations (Fox Island and Whale Rock).



Scup

Scup is another of the Mid-Atlantic species caught consistently by the survey, along with summer flounder, black sea bass, bluefish, and menhaden. The population of scup has increased dramatically during the time period of the survey, much like summer flounder and black sea bass, but starting in the mid 1970s (Figure 7). Scup are caught at both sampling stations pretty consistently, though the Fox Island station catches a much higher magnitude than does the Whale Rock station. Though caught in large numbers, scup catches have a high degree of variability. Some of this variability and magnitude difference for scup is driven by high recruitment events, the young of the year recruits being susceptible to the trawl gear. The 2017 survey year produced the 2nd highest catch per unit effort for scup ever recorded in the survey, while the 2018 survey year produced the lowest catch per unit effort for scup since 2013. The survey information was reviewed during the stock assessment process for scup.

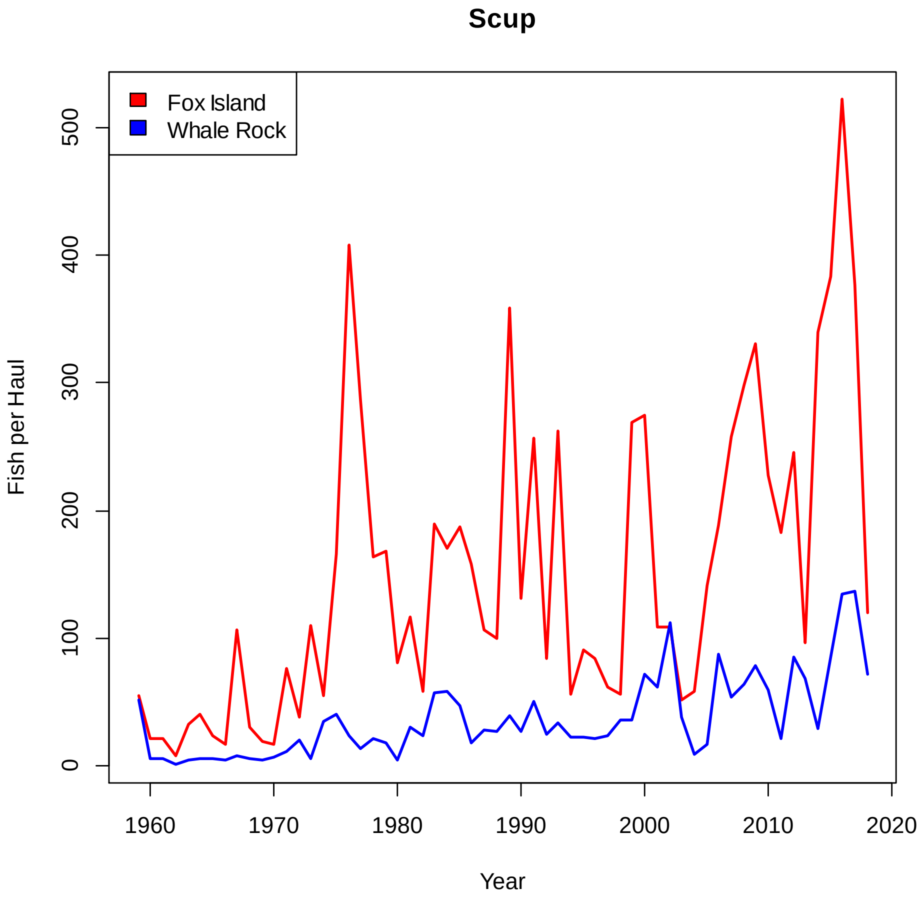


Figure 7 – Survey data for entire time series for scup at both sampling stations (Fox Island and Whale Rock).

Bluefish

Bluefish is another of the Mid-Atlantic species caught consistently by the survey. The population of bluefish peaked during the mid-1990s, but has since declined, with some potential improvement in recent years. There is high variability for this species in the survey data, again mainly due to catching young of the year bluefish as opposed to adults (Figure 8). Bluefish are caught at both sampling stations pretty consistently.

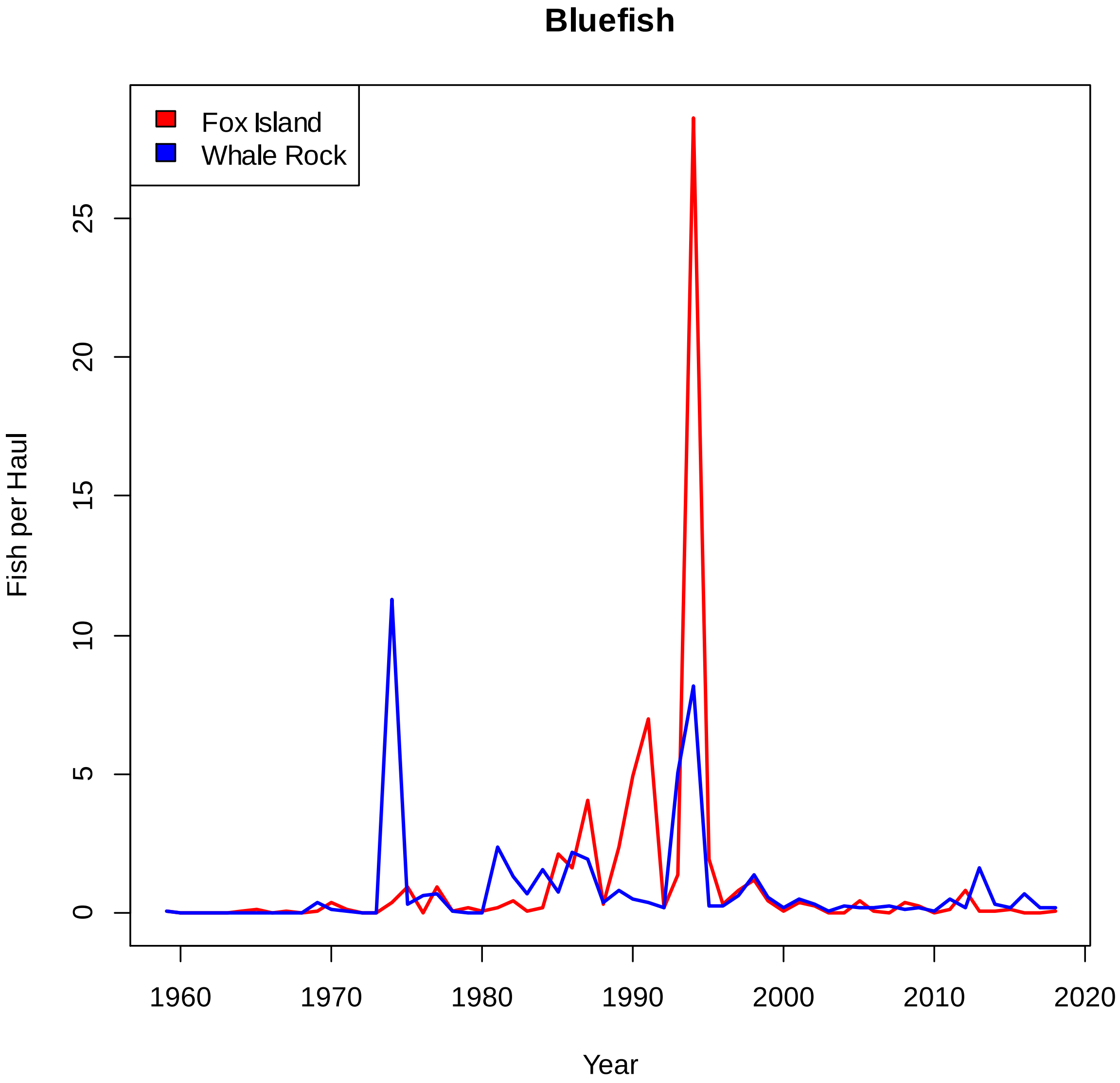
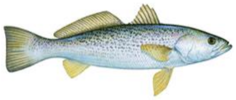


Figure 8 – Survey data for entire time series for bluefish at both sampling stations (Fox Island and Whale Rock).



Weakfish

Weakfish is another of the Mid-Atlantic species caught consistently by the survey, as weakfish use Narragansett Bay as a nursery habitat. The population of weakfish has been variable through the time period of the survey with periods of high abundance in the 1970s and 1990s and periods of very low abundance. There is high variability for this species in the survey data, again mainly due to catching young of the year weakfish as opposed to adults (Figure 9), so this survey is probably a better indicator of recruitment than adult population size. Weakfish are caught at both sampling stations pretty consistently.

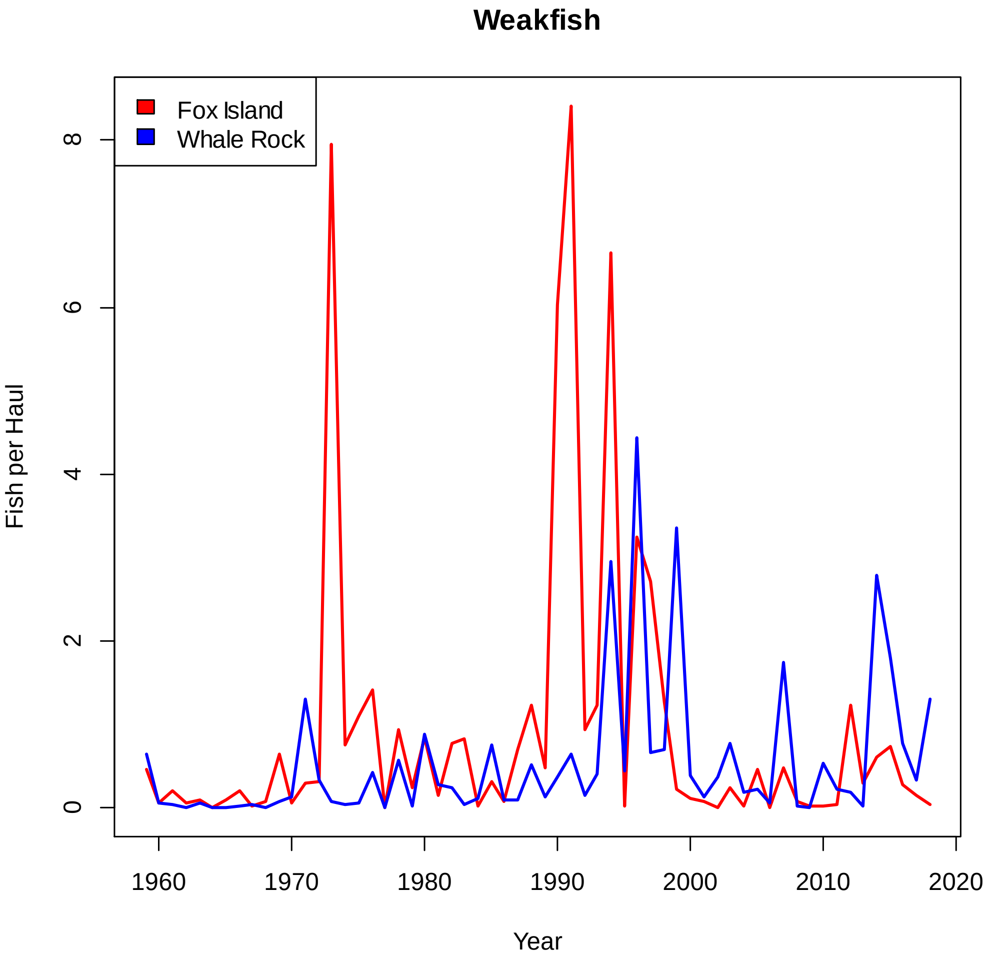


Figure 9 – Survey data for entire time series for weakfish at both sampling stations (Fox Island and Whale Rock).

Striped Bass

Striped bass is probably the premier recreational species caught by the survey. The catch of striped bass has been variable throughout the time period of the survey. Striped bass were rarely caught before 1990, especially during the period of low coast-wide abundance in the 1980s. Frequencies were higher 1990 and 2010. There is high variability for this species in the survey data, but the survey catches both juveniles and adults (Figure 10). Striped bass are generally caught in greater abundance and frequency at Fox Island than at Whale Rock. The 2018 survey year produced the highest striped bass catch per unit effort ever recorded in the survey at Fox Island, while Whale Rock experienced a decline.

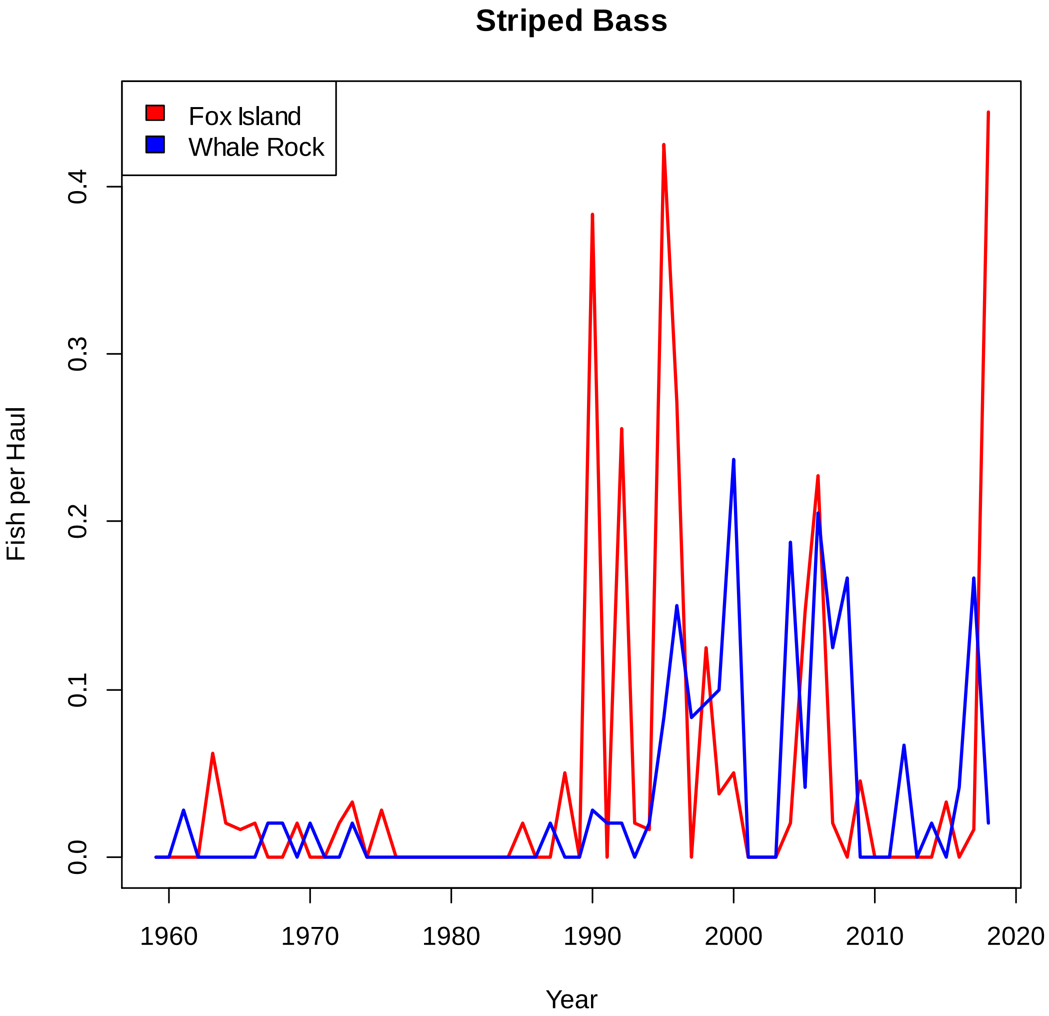


Figure 10 – Survey data for entire time series for striped bass at both sampling stations (Fox Island and Whale Rock).

Menhaden

Menhaden is another of the Mid-Atlantic species caught consistently by the survey. The catch of menhaden has been variable throughout the time period of the survey, mainly due to the schooling pelagic nature of this species. Menhaden were rarely caught prior to 1985 and have been caught in higher numbers since then. There is high variability for this species in the survey data, but the survey mainly catches juveniles (Figure 11). Menhaden are caught in greater abundance and frequency at Fox Island than at Whale Rock. The survey information was reviewed during the stock assessment process for menhaden.

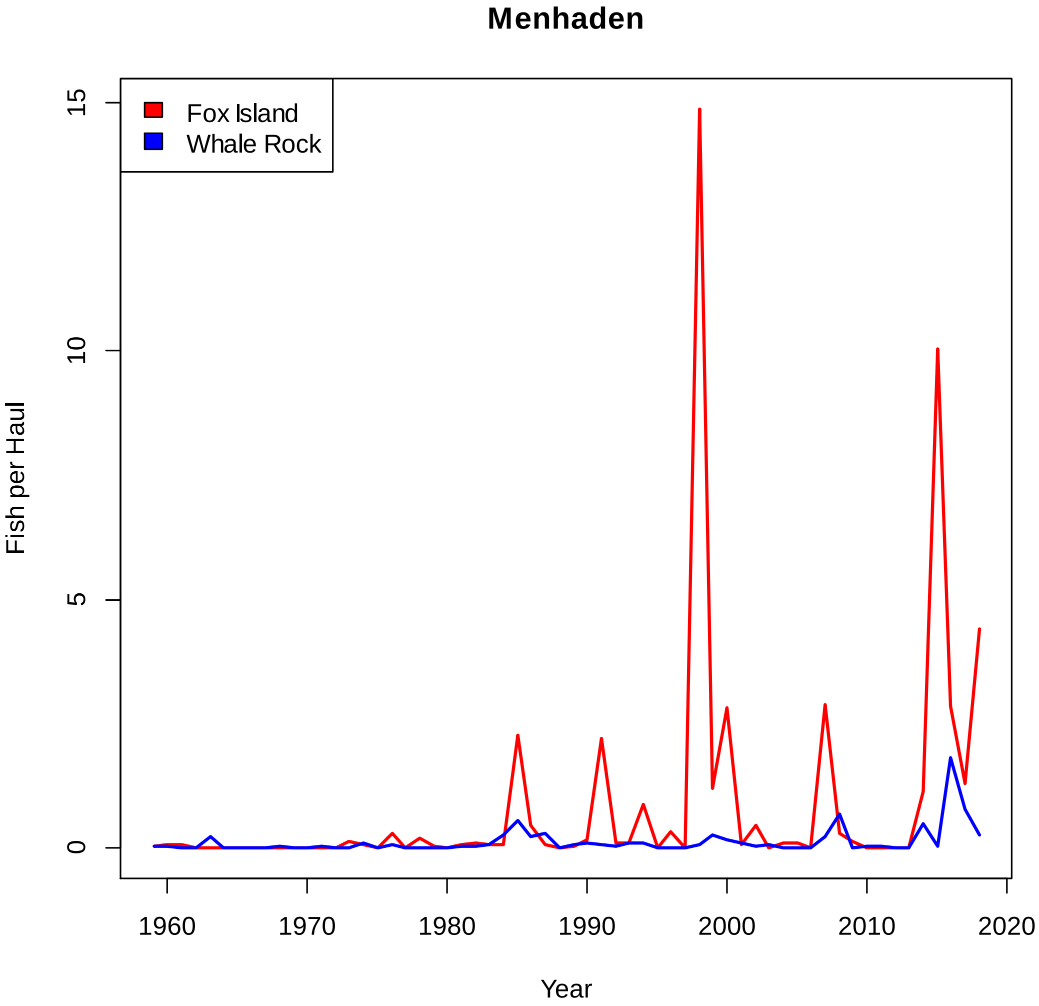


Figure 11 – Survey data for entire time series for menhaden at both sampling stations (Fox Island and Whale Rock)

In general, the abundance trends measured by the GSO/URI trawl survey are consistent with other coast-wide abundance trends for the same species. In addition to measuring the local abundance in Narragansett Bay, this survey contributes to the coast-wide assessment of migratory fish species. It not only extends the time series to almost 60 years, but also provides weekly time resolution.

Special Projects

Summer Flounder Research

A special project on summer flounder was started in 2016 by summer student Adena Schonfeld. Summer flounder collected by the fish trawl were analyzed for sex ratio and stomach contents. This sampling continued through 2017 and was augmented with summer flounder collected on the DEM trawl surveys. This work was presented at the 2016 Flatfish Symposium and the American Fisheries Society 2018 Annual Meeting. A paper based on this work has recently been published in Marine and Coastal Fisheries, https://doi.org/10.1002/mcf2.10065. Results from the project were used in the recent summer flounder benchmark assessment.

Evaluating Summer Flounder Spatial Sex Segragation in a Southern New England Estuary

Langan, JA, MC McManus, A Schonfeld, C Truesdale, & JS Collie

Marine fish species can exhibit sex-specific differences in their biological traits. Not accounting for these characteristics in the stock assessment or management of a species can lead to misunderstanding its population dynamics and result in ineffective regulatory strategies. Summer Flounder *Paralichthys dentatus*, a flatfish that supports significant commercial and recreational fisheries along the northeastern U.S. shelf, expresses variation in several traits between the sexes, including growth and habitat preference. To further understand these patterns, 1,302 Summer Flounder were collected and sexed in 2016 and 2017 from fisheries-independent surveys conducted in Rhode Island state waters. Female flounder were more prevalent in shallow waters (≤15 m) through all months, but males had a greater presence in deeper waters (>15 m) from May through September. The probability of a collected flounder being female was evaluated with generalized linear models and covariates representing depth, temperature, month, year, and TL. Summer Flounder were more likely to be female at larger sizes, in shallower waters, and late in the season. When compared with landings data in the recreational fishery over the sampling period, the results suggest that nearly all flounder harvested in the sector were female. This work provides further evidence for and characterization of Summer Flounder sex-segregation and highlights, for management purposes, the importance of considering fine-scale spatial dynamics in addition to broader distribution patterns. The fitted model represents an effective first step toward understanding the implications of an aggregated fishing effort for disproportionate removals of male or female flounder and for exploring resulting consequences for regional spawning stock biomass and stock resiliency.

Phenology of the Fish Community

The weekly trawl data are being used to investigate how the seasonal residence times (phenology) of fish in Narragansett Bay have changed in response to warming sea temperatures. This study is being prepared for publication.

<u>List of references that have used the GSO Fish Trawl Survey data</u>:

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