30 years ago, DEEP Fisheries Biologist Neal Hagstrom led an ambitious project; to survey the rivers and streams of Connecticut. Findings indicated wild Brook Trout were commonplace, but how are these wild populations doing now? See how a random sampling of these former sites provides an answer.

A Random Revisit of the Statewide Stream Survey Project

Focus on Wild Brook Trout

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Energy and Environmental Protection
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May 2020

Introduction:

The Department of Energy and Environmental Protection (DEEP) Fisheries Division conducted a statewide survey of Connecticut's rivers and streams between 1988 and 1994 (Hagstrom *et al*. 1996). The intent of this comprehensive project was to collect data on fish populations, physical habitat, macroinvertebrates, water chemistry, fishing effort, and socioeconomic value. The findings of the statewide stream survey project enabled the Fisheries Division to prepare a trout management plan, which could be sustained by Connecticut's stream resources and also meet the needs of Connecticut's anglers (Hyatt *et al.* 1999).

A key component of the statewide stream survey project (1988-1994) was the identification and quantification of wild trout populations in Connecticut's rivers and streams. From this research, it was determined wild trout were found in many streams and rivers, being the dominant fish in numerous

small cold brooks. Of the trout species, wild Brook Trout (*Salvelinus fontinalis*) were the most commonly occurring species (88% of total wild trout), followed by wild Brown Trout (*Salmo trutta*; 12% of total wild trout), with wild Rainbow Trout (*Oncorhynchus mykiss*) being rare (< 1% of total wild trout).

Connecticut's climate and landscape has changed over the approximately thirty-year period since the commencement of the statewide stream survey project (increased development, warming air temperatures, etc.) (UConn Clear 2015). In the years since, DEEP has identified water temperature and fish species as indicators of fish habitat. Specifically, cold water habitat is defined via the presence of wild Brook Trout, Slimy Sculpin (*Cottus cognatus*), or both and/or a mean summer water temperature (June, July, August) of no warmer than 18.29 ^{O}C (Beauchene *et al.* 2014).

The Fisheries Division continues to monitor and collect data on Connecticut's Fish Populations. This sampling provides data to support understanding change in distribution across the state, trends in abundance over time, and answer specific questions as they arise. In addition, the Water Quality monitoring program within DEEP's Bureau of Water Protection and Land Reuse (WPLR) collects fish community data to inform water quality assessments to support reporting requirements of the Federal Clean Water Act. Data on Connecticut's fish communities (1988-2017) are available online through a data viewer within Connecticut Environmental Conditions Online (CT ECO).

To determine the status of Connecticut's wild Brook Trout populations and to compare to historical statewide stream survey data, the Fisheries Division implemented a two-year resample of former statewide stream survey sample locations. The resampling was conducted by randomly selecting a set of former statewide stream survey sites that had wild Brook Trout present. The outcome of this finite, short-duration, probability-based sampling project enables the Fisheries Division to make statistically valid statements about wild Brook Trout on a statewide level.

Methods:

Site Selection: Former statewide stream survey sites containing at least one wild Brook Trout were randomly chosen (without replacement) for resampling; each site was assigned a number through random generation (N = 585). To ensure a final sample list of at least 100 locations (a 95% confidence interval and an error of 10% was determined to be appropriate), the first 116 were selected for potential sampling. Working in sequential order from site one to site 116, each site selected was evaluated for sampling potential through a combination of aerial photography review using Google Earth, prior knowledge regarding access, and when needed, site visits. If sampling access was no longer possible (private property and permission denied) or if the habitat was no longer appropriate (e.g., beaver impoundment), the site was dropped.

Sampling: One hundred and seven sites were sampled over the summers of 2018 and 2019. Each site was sampled using Smith Root electrofishing equipment (LR-24 backpacks or a 2.5 GPP Electrofisher in a tow behind unit). Voltage settings were adjusted to conductivity at each location to reach a targeted power output of 0.3 amps for backpack shockers (additional settings utilized were pulsed DC, a frequency of 60 Hz, and a duty cycle of 25%). For tow behind units, duty cycle and range (low or high) were adjusted until the desired voltage output was achieved; units were set to AC and 60 Hz for all samples. Sample location and length was replicated where possible as to what was previously surveyed during the early period (1988-1994). If unable to resample the exact location, an adjacent stream reach was selected for sampling. Additionally, sample length was increased or decreased based on the presence of a well-defined start or end (e.g. riffle or fall line). All fish were netted, identified, and measured to the nearest centimeter and then immediately released. All fish data were entered into a Microsoft Access relational database. Additionally, water chemistry data, sample site information (i.e. sample length and average width), and subjective information regarding stream habitat were recorded and entered into the same relational database.

Results:

Wild Brook Trout occurrence differed between the two sample periods. Of the 107 locations resampled during 2018-2019, the overall majority (68) retained at least one wild Brook Trout (Figure 1). Wild Brook Trout went undetected at the other 39 locations. The majority of locations where wild Brook Trout went

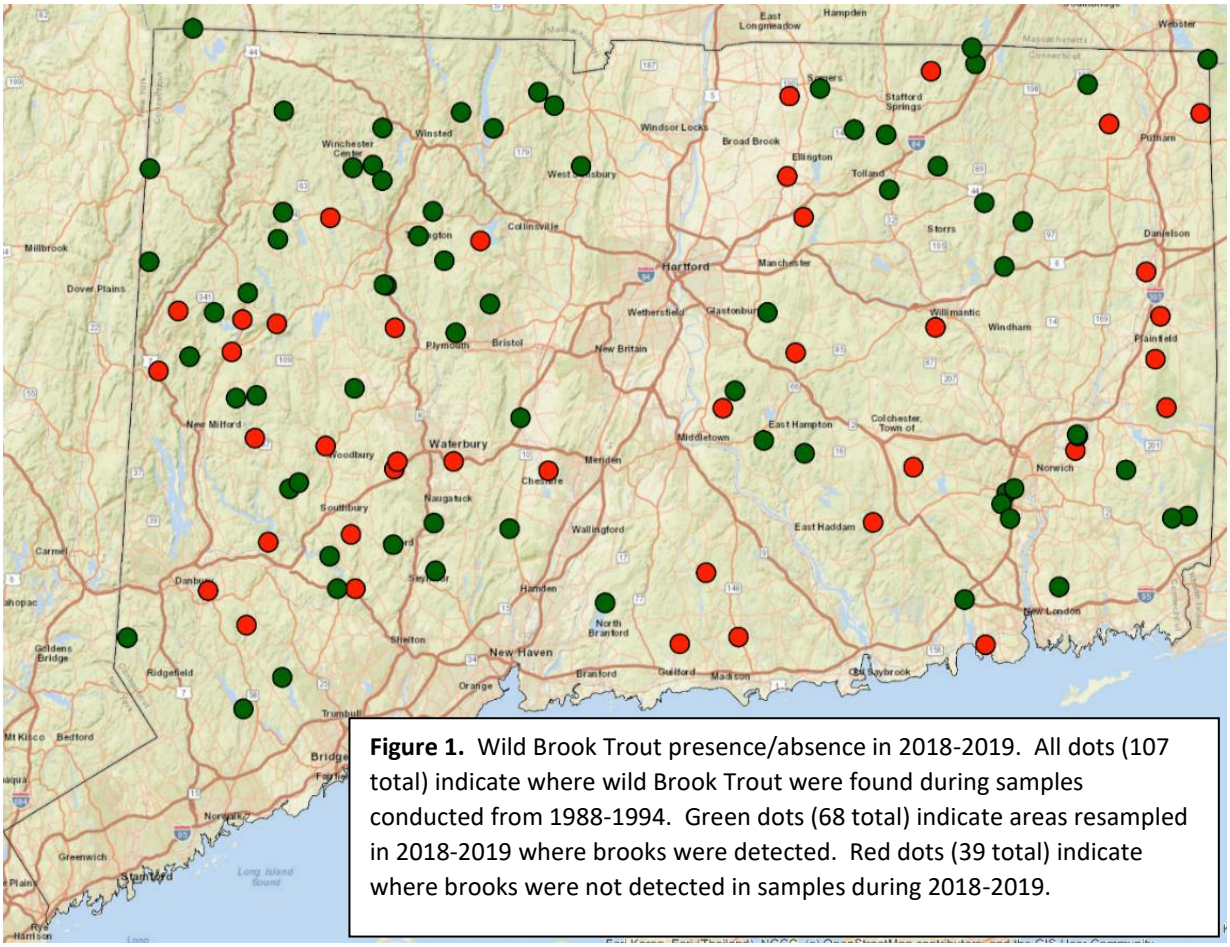

Figure 1. Wild Brook Trout presence/absence in 2018-2019. All dots (107 total) indicate where wild Brook Trout were found during samples conducted from 1988-1994. Green dots (68 total) indicate areas resampled in 2018-2019 where brooks were detected. Red dots (39 total) indicate where brooks were not detected in samples during 2018-2019.

undetected had low (0.1 – 30 fish/km) to moderate (30.1 to 180 fish/km) densities in the original samples, but a few had high (180.1 to 570 fish/km) to very high (> 570.1 fish/km) initial densities. Density rankings were based on quartile statistics generated from samples conducted 1988-1994.

In addition to the decrease in number of sites between both sample periods, density of wild Brook Trout, when present, also decreased (Appendix 1). A paired T-Test of wild Brook Trout density (square-root transformation) showed a highly significant difference (<0.001) between samples from both periods. Mean density also decreased between the two sample periods (391 fish/km vs. 138 fish/km; early and late periods, respectively). Overall, a large decrease in the number of high density wild Brook Trout populations was observed, but the number of low to high density populations remained similar (Figure 2).

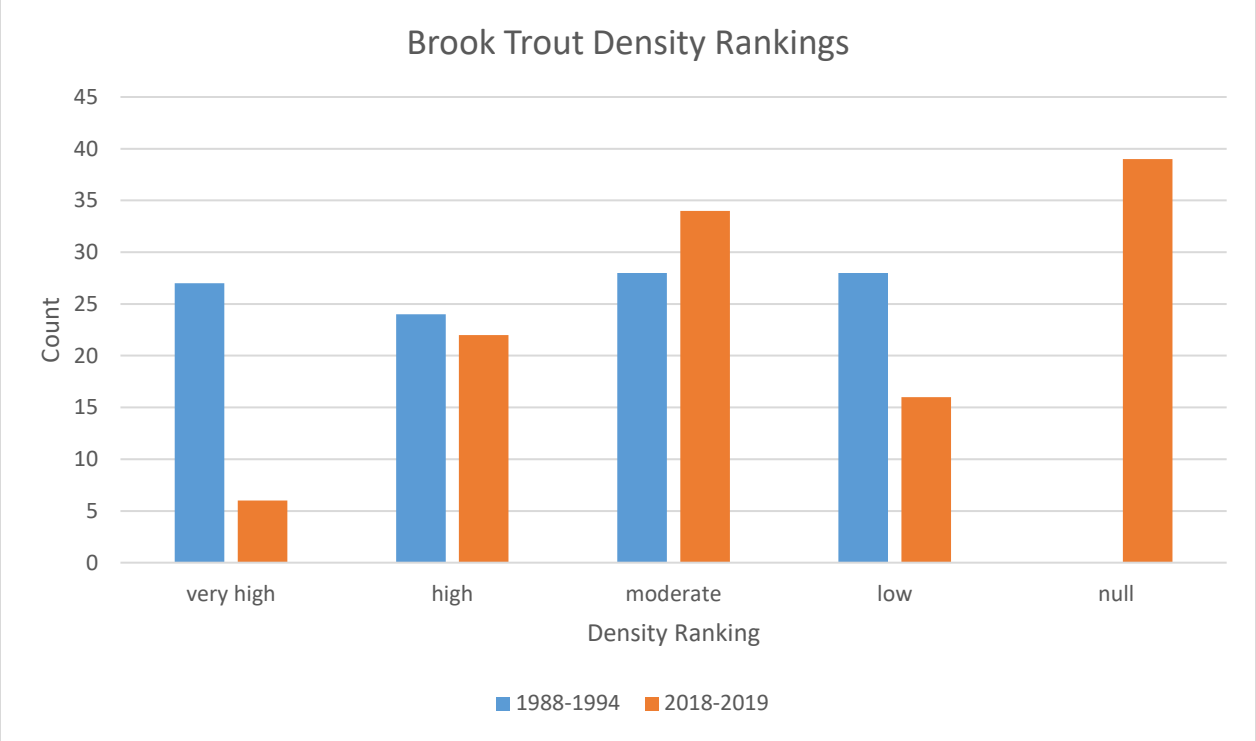

Figure 2. Count of density rankings between the two sample periods. A null ranking means wild Brook Trout were not detected.

Discussion and next steps:

Connecticut's landscape and climate has changed over the past three decades. These changes are predicted to continue and most likely have a negative impact on cold water obligate fish species such as Brook Trout.

The Brook Trout is Connecticut's only native non-migratory salmonid species. As a species with specific cold water requirements, the future of wild Brook Trout in Connecticut in the context of climate change and increased development is uncertain and potentially in jeopardy. The primary intent of this two-year project was to compare wild Brook Trout populations to those documented 30 years ago. As the approach was random (sites chosen randomly without replacement from a finite population), the results can be used to support statements about wild Brook Trout populations in Connecticut. Going forward

we recommend re-drawing a new list of randomly selected sites every 5-years in order to compile a series of statewide estimates of wild Brook Trout distribution and population density values.

Starting now, additional work using the universe of locations where wild Brook Trout were not observed is warranted. This work should seek to identify key variables responsible or related to the absence of wild Brook Trout and determine their magnitude of change. Some categories of variables, which may have changed from the initial sampling over 30 years ago include land cover, out of stream diversion of water (including groundwater), and recreational fisheries management (stocking of adult domestic trout (brooks, browns, rainbows, and tigers) in the same reach containing wild populations, stocking of Atlantic Salmon and Brown Trout fry, harvest limits, size limits, etc.).

The creation of a wild trout management plan has been identified in the Statewide Salmonid Action Plan (CT DEEP in draft) as an important next step to ensure this natural resource remains viable and sustainable. Several potential actions to be addressed in this plan are included as Appendix 2.

Citations:

Beauchene, M., M. Becker, C. J. Bellucci, N. Hagstrom & Y. Kanno (2014) Summer Thermal Thresholds of Fish Community Transitions in Connecticut Streams, North American Journal of Fisheries Management, 34:1, 119-131, DOI: 10.1080/02755947.2013.855280

Hagstrom, N. T., M. Humphreys, W.A. Hyatt, and W.B. Gerrish. 1996. A survey of Connecticut streams and rivers. Connecticut Department of Environmental Protection, Final Report, F-66-R.

Hyatt, W. A., M. Humphreys, N. T. Hagstrom. 1999. A trout management plan for Connecticut's rivers and streams. Final Report F-66-R. Job 4.

UConn CLEAR. 2015. E. Wilson.
http://clear.uconn.edu/projects/landscape/CT/stats/change19852015.htm#top

Appendices:

Appendix 1. Waterbodies, sorted alphabetically, resampled during 2019-2019 along with wild Brook Trout densities from both sample periods. Station ID refers to the unique sample location.

STATION NAME	STATION ID	MUNICIPALITY	1988-1994 NUMBER/KM	2018-2019 NUMBER/KM
ABBEY BROOK	16467	SOMERS	280	0
ABORN BROOK	16469	ELLINGTON	1580	160
ASPETUCK RIVER	16478	NEWTOWN	130	0
BEACON HILL BROOK	18126	BEACON FALLS	40	7
BEAVER BROOK	15680	BARKHAMSTED	440	333
BEAVER POND BROOK	14130	WATERBURY	9	0
BEBBINGTON BROOK	15988	ASHFORD	10	10
BIGELOW BROOK	16506	EAST HAMPTON	200	17
BLACKLEDGE RIVER	16517	MARLBOROUGH	8	0
BLACKMORE BROOK	16450	THOMPSON	20	0
BONEMILL BROOK	14141	TOLLAND	1360	346
BROWNS BROOK, TRIBUTARY TO	16533	UNION	740	540
BUCK BROOK	16535	PORTLAND	960	600
BUTTONBALL BROOK	16548	CHAPLIN	170	120
CARR BROOK	16556	PORTLAND	13	0
CAVANAUGH BROOK	16560	NEWTOWN	20	0
CHOATE BROOK	16572	PRESTON	7	0
COBBLE BROOK, TRIBUTARY TO	17141	KENT	330	0
CROOKED BROOK	16597	NORTH BRANFORD	950	220
CURTIS BROOK	16601	WILLINGTON	400	78
DEEP RIVER	16607	COLCHESTER	580	0
DENMAN BROOK	16610	NEW MILFORD	280	20
EAST ASPETUCK RIVER, TRIBUTARY TO	17142	WASHINGTON	60	0
EAST BR. NAUGATUCK RIVER, TRIBUTARY TO	17145	TORRINGTON	1220	109
EAST BRANCH LEADMINE BROOK	16623	NEW HARTFORD	620	118
EAST BRANCH SHEPAUG RIVER	16630	GOSHEN	440	679
EAST SWAMP BROOK	14184	BETHEL	140	0
EIGHTMILE BROOK	14186	OXFORD	7	0
EIGHTMILE RIVER	14605	SOUTHINGTON	20	22
EIGHTMILE RIVER	15179	EAST HADDAM	7	0
EKONK BROOK	14888	PLAINFIELD	20	0
FENN BROOK	16656	ROXBURY	100	0
FORD BROOK	16668	NORWICH	180	32
FOX BROOK	16674	WINCHESTER	90	24
GOODWIN BROOK	16697	CHAPLIN	1278	258
GRAVELLY BROOK	16699	WOODSTOCK	680	13
GREAT BROOK	16702	GROTON	22	44

GREEN BROOK	16705	TOLLAND	140	302
GULF STREAM	16713	SOMERS	267	792
HALFWAY RIVER	16718	MONROE	12	30
HALL MEADOW BROOK	16126	NORFOLK	6	345
HAWLEYS BROOK	16731	WESTON	1950	520
HOCKANUM RIVER	14238	ELLINGTON	2	0
HOP BROOK	16748	MIDDLEBURY	129	0
HOPP BROOK	16750	BETHANY	1486	757
HUMISTON BROOK	16762	LITCHFIELD	30	0
INDIAN RIVER	16772	KILLINGWORTH	20	0
IVY MOUNTAIN BROOK	16778	GOSHEN	30	0
JEFFERSON HILL BROOK	15062	LITCHFIELD	360	188
JEREMY BROOK	16783	SOUTHBURY	10	0
KETTLE BROOK	16116	BARKHAMSTED	1610	200
KETTLETOWN BROOK	15577	SOUTHBURY	320	50
KIRBY BROOK	15128	WASHINGTON	110	286
LAKE WARAMAUG BROOK ("SUCKER BROOK")	16795	WARREN	7	0
LAKE WARAMAUG BROOK, TRIBUTARY TO	17151	WARREN	571	267
LATHROP BROOK,TRIBUTARY TO	16797	PLAINFIELD	33	0
LISBON BROOK	16807	PRESTON	405	211
LISBON BROOK,TRIBUTARY TO	16808	PRESTON	333	421
LONG SWAMP BROOK	16817	MIDDLEBURY	180	0
MACEDONIA BROOK	16821	KENT	100	81
MAY BROOK	16831	UNION	1440	76
MILL BROOK	16451	WOODSTOCK	10	0
MILLER BROOK	16852	PRESTON	222	76
MILLSTONE BROOK	16816	WATERFORD	10	0
MOHAWK POND OUTFLOW	16857	GOSHEN	190	10
MOOSEHORN BROOK	16861	GRANBY	740	418
MOUNT MISERY BROOK	14718	VOLUNTOWN	108	0
MUDDY GUTTER BROOK	16879	EAST HAMPTON	160	177
NECK RIVER	16897	GUILFORD	40	0
NEGRO HILL BROOK	16898	BURLINGTON	1160	770
NEW CITY BROOK	16900	STAFFORD	20	0
NO NAME	16909	KILLINGWORTH	160	0
NONEWAUG RIVER	14355	WOODBURY	80	0
NONEWAUG RIVER, TRIBUTARY TO	16916	BETHLEHEM	100	27
OIL MILL BROOK	16930	WATERFORD	200	17
OWENS BROOK	16933	SIMSBURY	920	89
PENDLETON HILL BROOK	15796	NORTH STONINGTON	312	61
PHELPS BROOK	16962	BURLINGTON	20	0
POLAND RIVER	14402	PLYMOUTH	54	13

QUANDOCK BROOK	16985	KILLINGLY	78	0
QUINNIPIAC RIVER	14413	MERIDEN	5	0
RAILROAD BROOK	16995	VERNON	80	0
ROARING BROOK	17006	GLASTONBURY	53	75
ROCK BROOK, TRIBUTARY TO	17157	HARWINTON	500	92
ROCKY BROOK	14863	THOMPSON	840	495
RUGG BROOK	16114	WINCHESTER	1640	46
SAGES RAVINE BROOK	15505	SALISBURY	314	1450
SHEPAUG RIVER	15887	WASHINGTON	13	0
SPRUCE BROOK	15035	LITCHFIELD	347	73
STONY BROOK	16297	MONTVILLE	402	215
STONY BROOK	16298	MONTVILLE	180	133
TATETUCK BROOK	17105	EASTON	644	483
TENMILE RIVER, TRIBUTARY TO	17112	LEBANON	1280	0
TITICUS RIVER	15016	RIDGEFIELD	8	6
TORRINGFORD BROOK	17121	NEW HARTFORD	1160	155
TOWANTIC BROOK	17122	OXFORD	770	333
TRADING COVE BROOK	14731	MONTVILLE	382	283
TRANSYLVANIA BROOK, TRIBUTARY TO	17133	ROXBURY	600	264
TRANSYLVANIA BROOK, TRIBUTARY TO	17134	SOUTHBURY	1920	59
WALKER BROOK, TRIBUTARY TO	17135	NEW MILFORD	340	20
WANGUM LAKE BROOK	17172	CANAAN	184	92
WEBETUCK CREEK	14627	SHARON	25	11
WEST ASPETUCK RIVER, TRIBUTARY TO	17162	KENT	1900	444
WEST BRANCH SALMON BROOK	15703	GRANBY	71	6
WILLOW BROOK (HAMDEN)	15818	HAMDEN	173	108
WOMENSHENUCK BROOK	17206	NEW MILFORD	47	0
WYASSUP BROOK	17210	NORTH STONINGTON	453	27

Appendix 2. A partial listing of actions for preservation and conservation of Connecticut's wild Brook Trout for inclusion in a management plan for Connecticut's wild trout populations.

Monitoring:

- Conduct additional sampling at specific sites to acquire fine-scale assessment in waters where wild Brook Trout were not observed (sample additional reaches and nearby tributaries to see if still present but at smaller extent)
- Evaluate the potential for use of e-DNA techniques to complement electrofishing efforts in order to determine the presence of wild Brook Trout, especially where population numbers are low or to identify presence in upstream reaches that have not been electrofished.

Restoration:

- When wild Brook Trout are determined to be extirpated
    - Evaluate changes in land use, water diversions, and water temperature
    - Evaluate recreational fisheries management (stocking adult trout, stocking early life stage Atlantic Salmon and Brown Trout, harvest limits, size limits, etc.)
    - Produce Standard Operating Procedures to implement restoration of wild Brook Trout if prevailing waterbody conditions are deemed appropriate for supporting wild populations.

Education and Outreach:

- Produce a statewide interactive map showing areas of wild Brook Trout population status
    - Identify areas of
        - Robust populations
        - Stable populations (may not be robust, but remain steady)
        - Populations in peril
        - Areas for restoration (extirpated from adequate habitat)
        - Areas where extirpated (restoration not likely)
- Increase public awareness of wild Brook Trout amongst fishing and, maybe more importantly, the non-fishing members of the public
    - Hold advertised public meetings throughout the state
    - Create educational products such as ArcGIS StoryMaps
    - Create and increase social media opportunities

Conservation:

- When wild Brook Trout population densities are deemed to be unnaturally low or if populations are determined to be disconnected from all other wild Brook Trout populations
    - Determine if transplanting fish from other populations are needed when habitat conditions are appropriate.
    - Determine if habitat restoration efforts are needed (i.e. instream restoration efforts, dam removals, culvert replacements, water temperature management)
    - Determine if fish management regulations are appropriate.
- Collaborate with partners and municipalities

- Northeast Fisheries Administrators Association's River and Stream Technical Committee, Wild Trout Subgroup
- Eastern Brook Trout Joint Venture (EBTJV) with monitoring wild Brook Trout distribution at a regional level
- Local and statewide Trout Unlimited
- Town Conservation Commissions, Town Planners, Wetland Commissions
- Other DEEP programs (permitting, WPLR)
- Other Fisheries Division Programs (Habitat, Conservation and Enhancement Program)
- Connecticut Department of Transportation