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HABITAT VARIABLES INFLUENCING THE RETURN OF HATCHERY-REARED FALL-YEARLING BROOK TROUT IN MAINE WATERS

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FINAL REPORT

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ABSTRACT

The Maine Department of Inland Fisheries and Wildlife (MDIFW) stocks over one million brook trout (*Salvelinus fontinalis*) statewide annually at a substantial cost to the State of Maine. Considerable hatchery production is dedicated to the rearing of larger fall-yearling brook trout (FY BKT), which are stocked in the fall (age I+) and primarily into marginal waters with limited summer holdover potential. However, most of these waters are suitable for fall to spring survival, and thus provide popular fishing opportunities for Maine ice anglers. Given the financial investment put forth by MDIFW in providing a FY BKT program, waters should be selected based on a specific suite of habitat criteria that promote higher angler returns. The goal of this study was to investigate those habitat variables that contribute most to the "catchability" of stocked FY BKT.

Twenty-eight (28) waters from fishery management regions A, B, and D were selected for analyses for this study. Study waters ranged in size from 6 to 5,515 acres (

INTRODUCTION

The Maine Department of Inland Fisheries and Wildlife (MDIFW) stocks well over one million salmonines statewide annually and at a substantial cost to the State of Maine (Table 1). Of all fishes, brook trout (*Salvelinus fontinalis*) comprise the greatest expenditure to Maine hatcheries (Tables 1 and 2). Brook trout are stocked at various age groups, but most hatchery production is dedicated to the rearing of larger spring (age I) and fall-yearlings (age I+) (Table 2). Most fall-yearlings are used to create stand-alone put-and-take fisheries, or to augment put-grow-and-take fisheries with other stocked salmonines such as brown trout (*Salmo trutta*) or landlocked salmon (*Salmo salar*). Fall-yearling brook trout (FY BKT) are stocked in the fall and primarily into marginal waters with limited summer holdover potential. Most of these waters are suitable for fall to spring survival, and thus provide popular (and potentially high-return) fishing opportunities for Maine ice anglers (Havey and Locke 1980). Historically, high catch rates on FY BKT waters were not always realized, as some waters provided better returns than others.

FY BKT are an increasingly popular catch among Maine anglers, and the MDIFW hatchery system is at or beyond capacity to meet this demand. Given the financial investment put forth by MDIFW in providing a FY BKT program, waters destined for stocking should be selected based on a specific suite of habitat criteria that promote higher angler returns and overall program success. Therefore, the goal of this study was to investigate those physical and biotic variables that contribute most to the "catchability" of stocked FY BKT in order to assist fisheries biologists in distinguishing between those waters that should provide high returns to Maine anglers and those that will not.

METHODS

Study sites:

Twenty-eight (28) FY BKT waters from fishery management Regions A, B, and D were selected for analyses for this catchable brook trout study (Figure 1). The waters were selected along a gradient of habitat quality and features. Biotic and physical habitat variables were selected based on both *a priori* and professional insight as to their importance in relation to angler returns of stocked salmonines (Johnson et al. 1992; Miko et al. 1995; Wurtsbaugh et al. 1996; Beckmann et al. 2006; Flinders and Bonar 2008; Christensen and Moore 2010; Post and Parkinson 2012). Site-specific values of water size (ac), mean depth (ft), maximum depth (ft), species richness (# of fish species/water body), adult common loon (*Gavia immer*) density (# of adult loons/ac), urban proximity (# of mi from urban center of population ≥ 5,000), and initial FY BKT stocking density (# of stocked FY BKT/ac) were calculated and used in subsequent analyses. Water quality variables were removed from these analyses, as we did not anticipate water quality issues (e.g. with dissolved oxygen and temperature) affecting the catchability of FY BKT during the winter months.

Angler returns (i.e. % FY BKT caught post-stocking) were determined based on random, stratified creel clerk survey data that were conducted during the first full month of ice fishing from one or more years of data collection (2008-2013) and with comparable effort. Angler return calculations incorporated only raw field data, and were not estimated based on projections or extrapolations.

Principal components analysis and multiple regression models:

Logarithmic transformations were applied to select habitat variables (i.e. mean depth, max depth, water size, and FY BKT stocking density), while square root transformations were applied to adult loon density and urban proximity. The transformations were applied prior to analyses to promote normality and eliminate heteroscedasticty (Zar 1974). We used principal components analysis (PCA) to distill the data set into a few important factors that captured most of the environmental variability across all study sites (Manly 2005). Based on scree plot inspection and the broken-stick model, we retained only those principal component scores with nontrivial eigenvalues (Jackson 1993; Peres-Neto et al. 2003). We then used stepwise multiple regressions to select the most parsimonious combination of habitat principal component scores successful in predicting the % of FY BKT caught (Kutner et al. 2005; Coghlan et al. 2007). The best model was identified using adjusted R^2 values and Akaike's Information Criterion (AIC) (Shaw 2003).

Response variable thresholds and Welch's t-test analyses:

We calculated running averages on the response variable (in relation to those ranked habitat variables identified by the principal component multiple regression models as being important) to detect threshold values that marked precipitous changes in angler returns. These threshold values were used in splitting the data into two distinct subsets. Welch's t-tests were performed to compare differences between mean values for each subset of % FY BKT caught.

RESULTS

Study sites:

Study water size ranged from 6 to 5,515 acres (

stocking densities to larger study waters with a greater species assemblage and low FY BKT stocking densities. PC2 was correlated strongly and negatively with urban proximity, and thus implied a transition from study waters that were located greater distances to urban areas to waters that were in close proximity to population centers. PC3 was correlated strongly and positively with loon density and correlated strongly and negatively with maximum water depth. Thus, PC3 implied a gradient in increased adult loon presence, and a transition from deeper to shallower water depths.

The best multiple regression model for the % of FY BKT caught incorporated the first and third principal components ($P < 0.0001$) (Table 5).

Response variable thresholds and Welch's t-test analyses:

Threshold values on select habitat variables were identified and the corresponding sample sizes and mean values (± two standard errors) were calculated for the % of FY BKT caught (Table 6). Welch's t-tests determined that the mean value for each subset of the % of FY BKT caught varied significantly for all habitat variables (Table 6).

DISCUSSION

PC regression models & response variable thresholds:

According to the principal component regression models, water size, initial stocking density, and fish species richness were the most important variables influencing FY BKT returns. In particular, water size was most influential in determining FY BKT returns, and smaller waters (< 100 ac) provided significantly higher returns than larger waters (≥ 100 ac). Unlike larger waters, smaller lakes and ponds offer habitat more conducive to brook trout and are more amenable to managerial control (i.e. manipulation of stocking density). The initial FY BKT stocking density was also important to angler returns, and those waters stocked at densities < 4.5 FY BKT/ac resulted in significantly lower returns than those stocked at higher densities (≥ 4.5 FY BKT/ac) (Miko et al. 1995). Fish species richness also contributed to FY BKT returns, as those waters with fewer species (< 15) had fewer competing and predatory influences (i.e. northern pike (*Esox lucius*) and largemouth bass (*Micropterus salmoides*)), and thus provided Maine anglers with higher returns than in those waters with more fish species (≥ 15) (Flinders and Bonar 2008; Christensen and Moore 2010). Fisheries biologists should give special consideration to the presence of invasive northern pike in fall-yearling brook trout waters. We have observed considerable habitat overlap between brook trout and northern pike during winter, and high rates of predation are inevitable. Therefore, the presence of northern pike in a given watershed may preclude the stocking of brook trout altogether.

Maximum water depth and adult loon density were also major determinants of the % of FY BKT caught. Those waters with maximum depths less than 42 ft offered habitat that was more amenable for feeding and growth during the winter months (Johnson et al. 1992), and made fall-yearlings more susceptible to angling pressure in shallower waters. In addition, waters with greater densities of adult common loons (≥ 0.0037) contributed to lower FY BKT returns than those waters with lower loon densities. Adult loons are voracious piscivorous predators, and likely contributed to increased brook trout mortality during late fall/early winter and reduced FY BKT returns (Beckmann et al. 2006).

We acknowledge that there are correlative relations among many of the physical and biotic variables used in these analyses. For instance, larger water size is correlated with deeper water, a greater fish species assemblage, and higher adult loon densities. However, these correlations are unavoidable, since the plausible environmental factors influencing FY BKT returns are seemingly limited. That being said, we recognize one physical habitat variable not included in this research that could potentially influence angler return on FY BKT. In central and southern Maine, we have documented several instances of fecund, FY BKT moving from lentic habitat to lotic habitat immediately following stocking in an attempt to spawn or seek out refuge from lacustrine predators. This migration into inlet and outlet streams could potentially reduce FY BKT numbers and decrease angler returns on stocked waters (Josephson et al. 2001).

Management implications:

Historically, the selection of FY BKT waters has been at the discretion of the regional fisheries biologists without a defined set of habitat criteria by which to select lakes and ponds with higher returns. This research identifies a suite of habitat variables and pinpoints discrete threshold values (breakpoints) by which FY BKT waters can be selected based on the probability of higher angler returns. We recommend that MDIFW fisheries biologists adopt a tiered, decision tree selection process by which regional waters proposed for FY BKT stockings be evaluated and chosen based on three habitat variables; water size, fish species richness, and maximum depth (Figure 2). These criteria will provide fisheries managers with the ability to determine the potential success of FY BKT stocking programs on given waters prior to their inception.

Of these habitat features, water size is the most important and the first tier in the decision tree. Lakes and ponds less than 100 acres in total size provided higher returns on FY BKT than larger waters. The second tier in the decision tree is based on total fish species richness. Waters with less than 15 fish species provided higher returns on FY BKT than waters with more complex fish assemblages. The final tier in the decision tree is in selecting waters by maximum depth. Lakes and ponds with maximum water depths less than 42 feet provided higher FY BKT returns. Waters that favorably meet as many of the habitat thresholds set forth above should provide Maine anglers with higher FY BKT returns (Figure 2).

Adult loon density was omitted from the decision-tree as loon densities fluctuate from year-to-year and cannot reliably be used by fisheries biologists in the selection of FY BKT waters. FY BKT stocking density was also omitted from the decision-tree selection process as it is controlled by fisheries biologists and is not a habitat variable dictated solely by the physical or biotic environment.

Although stocking density was omitted from the decision-tree it should still be considered as important to FY BKT returns as water size, species richness, and water depth. At a threshold stocking density of 4.5 FY BKT/ac, angler return was significantly higher than for those waters stocked below this threshold. We did find that catch rates increased as stocking densities approached this threshold; however, our results indicated only marginally higher returns at densities greater than 4.5 FY BKT/ac. Currently, many waters are stocked at densities greater than 4.5, and this may not be necessary as stocking additional FY BKT above this threshold does not always equate to increased angler returns during the winter months. This information also illustrates the difficulty in creating successful put-and-take brook trout fisheries in larger lakes and ponds. In order to approach the threshold stocking density that equates to acceptable angler returns, larger waters would require several thousand stocked FY BKT annually. Stocking at these high numbers is not feasible due to fiscal and hatchery space constraints.

The success of the stocked FY BKT program is determined through angler returns, particularly during early winter and the first weeks of ice fishing season. In this research, we identified those lentic habitat variables (i.e. water size, stocking density, species richness, and maximum water depth) and pinpointed threshold values that contributed most to FY BKT returns in marginal, put-and-take waters in central and southern Maine. We believe that by incorporating this research into the selection process by which fisheries biologists identify waters destined for stockings, the FY BKT program will allocate limited hatchery resources more efficiently. The results of this study should serve as a tool for Department fisheries staff in making sound decisions regarding the distribution of FY BKT. Ultimately, both fisheries biologists and the angling public will benefit by a more focused approach to FY BKT stockings.

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Table 1. Species-specific salmonine stocking numbers and total associated hatchery expenditures by the Maine Department of Inland Fisheries and Wildlife (2010-12).

Species	2012	2011	2010
Brook Trout	1,168,972	1,030,423	1,074,507
Brown Trout	139,426	157,237	196,300
Lake Trout	12,450	8,250	10,450
Landlocked Salmon	101,695	105,604	99,983
Lake Whitefish	0	0	10,680
Rainbow Trout	19,900	24,800	27,668
Splake	30,455	31,754	34,691
Total Quantity	1,472,898	1,358,068	1,454,279
Total Expenditures	$2,967,577	$3,109,218	$2,983,881

Table 2. Total brook trout expenditures incurred by the Maine Department of Inland Fisheries & Wildlife by region and age group in 2012 (FF = fall-fingerling, AFF = advanced fall-fingerling, SY = spring-yearling, FY = fall-yearling, AY = advanced yearling, AD = adult).

	Brook trout age group							
Region	**FRY**	**FF**	**AFF**	**SY**	**FY**	**AY**	**AD**	**Total Expense by Region**
A	$542	$3,617	$21,735	$167,035	$101,884	$18,271	$9,963	**$323,047**
B	$3,227	$12,569	$0	$167,223	$166,468	$4,343	$13,385	**$367,215**
C	$0	$71,423	$461	$18,707	$38,390	$0	$7,552	**$136,533**
D	$4,947	$99,703	$0	$138,280	$159,057	$0	$8,492	**$410,479**
E	$0	$63,667	$0	$175,261	$85,781	$0	$5,567	**$330,276**
F	$5,421	$24,210	$0	$63,924	$89,630	$0	$8,174	**$191,359**
G	$7	$34,036	$0	$26,087	$42,073	$0	$7,581	**$109,784**
Total Expense by Age Group	**$14,144**	**$309,225**	**$22,196**	**$756,517**	**$683,283**	**$22,614**	**$60,714**	**$1,868,693**

Figure 1. Fisheries Management Regions – Maine Department of Inland Fisheries and Wildlife.

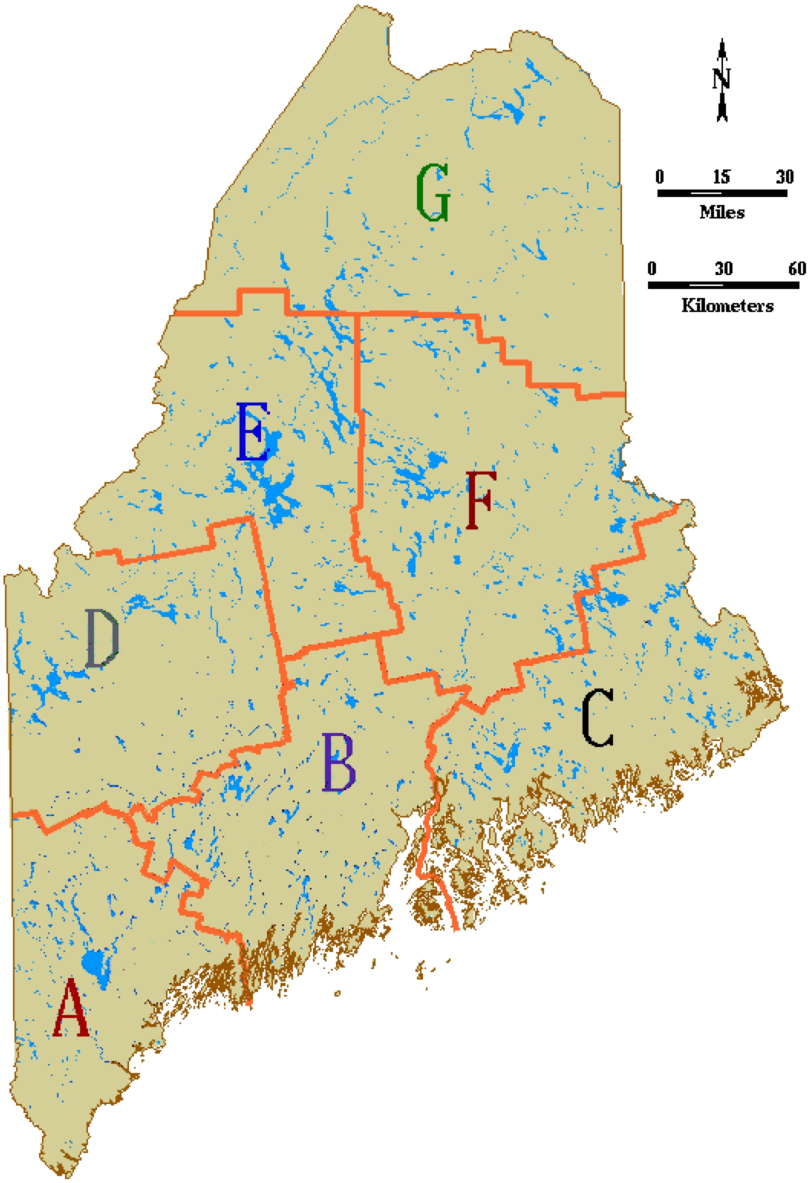

Table 3. Physical and biotic habitat variables and corresponding % of FY BKT caught by study water.

		Habitat Variables							FY BKT Response
Waterbody	Watcode	Size (acres)	Mean Depth (ft)	Max Depth (ft)	Species Richness	Loon Density (#/acre)	Urban Proximity (mi)	Stocking Density (#/acre)	% Caught
Hosmer	4808	53	9	16	14	0.038	2	5.2	10.9
Messalonskee	5280	3691	33	113	23	0.008	0	0.2	0.3
Echo	5814	1109	21	117	20	0.014	13	0.3	10.7
Levenseller	4836	34	6	10	9	0	11	10.3	16.9
Dutton	4872	41	15	22	12	0	15	6.1	57.6
Wassookeag	0227	1152	27	86	19	0.005	1	0.4	2.4
Minnehonk	5812	85	32	73	18	0.024	16	4.1	4.0
Cobbossee	5236	5516	37	100	25	0.012	3	0.3	0.1
Cochnewagon	3814	394	22	28	14	0.008	6	1.3	16.8
Wilson	3832	588	23	42	15	0.009	6	1.5	2.7
Alford	4798	585	31	78	16	0.015	7	1.3	6.7
Flying	5182	403	27	80	20	0.015	19	1.2	5.6
Nequasset	5222	465	30	63	20	0.002	1	1.3	7.8
McGrath	5348	467	16	27	15	0.013	3	1.7	3.0
Salmon	5352	695	23	57	17	0.007	5	1.3	6.2
Biscay	5710	382	39	61	15	0.008	18	1.6	6.5
Crystal	3708	185	25	59	19	0	1	4.8	33.5
Round	5038	6	14	36	5	0	7	8.3	30.0
Sabbathday	3700	342	24	68	17	0.007	9	4.5	22.0
Worthley	3764	54	14	46	10	0	13	5.6	14.7
Keoka	3416	460	25	42	14	0.004	31	4.5	15.2
Keewaydin	3272	263	17	52	17	0.009	36	5.2	6.2
Otter #2	3404	12	11	39	11	0	4	18.8	59.6
Otter #4	9689	6	9	21	11	0	4	24.8	24.2
Roxbury	3504	919	10	43	11	0.004	15	1.1	3.4
Embden	0078	1542	62	180	18	0.004	18	0.6	0.0
Clearwater	5190	796	60	129	19	0.008	6	1.2	2.2
Webb	3672	2194	24	42	20	0.008	22	0.9	11.7

Table 4. Principal component loadings (PC1 - PC3) for physical and biotic variables and the associated proportional variance for each. PC loadings ≥ 0.43 and ≤ -0.43 are shown in bold italics.

	PC loadings		
Habitat variables	**PC1**	**PC2**	**PC3**
Water size (acres)	***0.444***	-0.039	0.112
Max depth (ft.)	0.408	-0.086	***-0.452***
Mean depth (ft.)	0.411	-0.125	-0.390
Species richness	***0.438***	0.116	0.059
FY BKT stocking density (#/acre)	***-0.439***	-0.113	-0.102
Loon density (#/acre)	0.284	-0.153	***0.785***
Urban proximity (mi)	-0.049	***-0.962***	-0.020
Proportion of variance	0.604	0.150	0.122
Cumulative proportion of variance	***0.604***	***0.754***	***0.876***

Table 5. Adjusted R^2 and AIC values for all combinations of principal component multiple regression models for the % of FY BKT caught. The best model is shown in bold italics.

Principal components	**Response variable**	**Adjusted R^2**	**AIC**
PC1 + PC2 + PC3	% of FY BKT caught	0.491	219.7
PC1 + PC2		0.401	223.4
PC1 + PC3		***0.500***	***218.3***
PC2 + PC3		0.042	236.5
PC1		0.413	221.9
PC2		-0.027	237.6
PC3		0.097	234.8

Table 6. Sample size, mean, and 2 SE for subsetted response variable based on threshold values for select habitat variables. P-values are based on comparison of subsetted response variable (i.e. % FY BKT caught) using Welch's two sample t-test ($\alpha = 0.05$).

	% of FY BKT caught			
Habitat Variable Thresholds	**n**	**Mean**	**2 SE**	**P-value**
Water size				
< 100 acres	8	27.2	14.8	***0.037***
>= 100 acres	20	8.2	3.8	
Stocking density				
< 4.5 FY BKT/acre	18	6.2	2.8	***0.007***
>= 4.5 FY BKT/acre	10	26.9	11.8	
Species richness				
< 15 fish spp.	10	24.9	12.1	***0.018***
>= 15 fish spp.	17	7.3	4.0	
Loon density				
< 0.0037 loons/acre	9	28.8	12.4	***0.007***
>= 0.0037 loons/acre	19	6.4	2.7	
Maximum Water Depth				
<= 42 feet	11	22.6	11.8	***0.034***
> 42 feet	17	7.8	4.2	

Figure 2. Decision-Tree Diagram – a tiered, decision-tree exploring all possible outcomes of habitat threshold values for water size, species richness, and maximum depth in relation to the expected gradient of FY BKT returns to Maine anglers.