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Standing Crops of Brook Trout in Adirondack Waters before and after Removal of Non-trout Species

William A. Flick[1] and Dwight A. Webster[2]

Department of Natural Resources, Fernow Hall, Cornell University Ithaca, New York 14853-3001, USA

Abstract.—Ponds and lakes in the Adirondack Mountain region of New York State that contain brook trout *Salvelinus fontinalis* are generally infertile and trout production is low when brook trout have to compete with non-trout species. Standing crop estimates for seven waters with mixed-species associations ranged from 50 to 100 lb/acre; suckers *Catostomus* spp. were a major component of each assemblage. Brook trout standing crops were under 1 lb/acre in all but one water and were particularly low where yellow perch *Perca flavescens* were present. Following reclamation, during which major competing species were removed, brook trout were restocked. Subsequent estimates of brook trout standing crops ranged from 5 to 16 lb/acre, and good trout fishing prevailed where previously there had been little or none.

Competition from non-trout species frequently severely limits biomass of brook trout *Salvelinus fontinalis* in Adirondack lakes and ponds. A common management approach to release competitive constraints is to eradicate the fish population with rotenone (called reclamation) and then to stock the desired species. There is little information, however, on the actual biomass of either trout or non-trout in waters with mixed-species associations or on the change in trout biomass following reclamation and restocking. Such data are important for fish managers if they are to justify reclamation programs. We selected seven Adirondack lakes with mixed-species associations with which to evaluate reclamation practices. We measured fish biomasses before rotenone treatment and again after brook trout had been restocked in reclaimed lakes. Thus we obtained measures of productivity in the same bodies of water under contrasting conditions of population structure.

Study Area

The seven waters studied are in the central and northern Adirondack Mountains in New York State at elevations of about 1,600 ft. They all have outlet barrier dams, and they are relatively infertile and mesotrophic in character, except Cat Pond which is oligotrophic. The waters are on private property; fishing pressure is light and detailed angling records are maintained for four of the seven waters. Descriptive statistics for the ponds are shown in Table 1, and species assemblages found during pond reclamations are listed in Table 2.

Bay Pond.—Yellow perch became established in Bay Pond in the early 1900s, and brook trout fishing declined shortly thereafter. Rainbow smelt stocked in 1926 and in 1938 became self-reproducing. During the late 1930s yellow perch population control was attempted by direct removal with fyke nets and by drawdown during spawning to destroy eggs. These practices were unsuccessful in restoring brook trout fishing, and the trout population was negligible at reclamation in 1968.

Follensby Jr. Pond.—Before yellow perch became established in 1935, Follensby Jr. Pond was considered among the better regional trout waters. Rainbow smelt were stocked in 1935 and became established. A very small population of longnose suckers occurred in Follensby Jr., but only a few were taken during netting or reclamation, and they are included with white suckers.

A dam was constructed in 1939 at the outlet to regulate water levels for yellow perch control. This measure and the use of fyke nets were unsuccessful in controlling yellow perch or restoring brook trout angling; both practices were discontinued in the late 1940s. An intensive control program for non-trout species with Oneida Lake-type trap nets began in 1954 and continued until reclamation in 1966. During this program, the catch dropped from 94 to 34 lb/net-day; concurrently, numbers of brook trout increased and angling improved. Follensby Jr. is the only water where a prior control program influenced the standing crop at the time of reclamation.

Arbutus Lake.—Arbutus Lake had good brook trout fishing prior to establishment of yellow perch in the mid-1930s. Smallmouth bass were intro-

[1] Retired. Address correspondence to William D. Youngs, Department of Natural Resources, Fernow Hall, Cornell University, Ithaca, New York 14853-3001, USA.

[2] Deceased.

TABLE 1.—Descriptive statistics for seven Adirondacks waters. Water chemistry data are based on midsummer samples.

Item	Bay Pond	Follensby Jr. Pond	Arbutus Lake	Cat Pond	Cranberry Pond	Second Anthony Pond	Third Anthony Pond
Area (acres)	212	146	120	48	43	35	35
Maximum depth (ft)	50	29	26	45	6	20	12
Average depth (ft)	17	13	10	18	4.5	10	8
Transparency, Secchi (ft)	8	8	15	20	6[a]	12	11
Thermally stratified	Yes	Yes	Yes	Yes	No	No	No
Oxygen deficit (bottom)	Yes	Yes	Yes	Yes	No	No	No
Alkalinity (ppm)	300	250	60	95	210	136	159
pH	6.0	6.8	6.8	6.1	7.6	7.0	6.8
Date reclaimed	Aug 23, 1968	Aug 20, 1966	Sep 5, 1973	Aug 26, 1966	Aug 28, 1967	Sep 20, 1970	Sep 19, 1970

[a] Bottom depth.

duced about 1965 and provided some angling under light fishing pressure prior to reclamation.

Cat Pond.—Lake trout *Salvelinus namaycush* and brook trout were common in Cat Pond before yellow perch became established around 1930. Lake trout were stocked in 1937 and brook trout were stocked on several occasions. Rainbow smelt were stocked and became established in 1938. A few brook trout, but no lake trout, were observed at the time of reclamation in 1966.

Cranberry Pond.—No historic information exists for shallow Cranberry Pond as a trout water. Since brook trout were established following reclamation in 1967, several partial fish kills have been observed during periods of unusually warm weather.

Second Anthony and Third Anthony ponds.—Second and Third Anthony ponds are relatively shallow and similar in water chemistry. They were the only two waters not containing yellow perch, and they reportedly provided some trout angling. Test netting in 1955 and 1970 indicated high sucker populations, which were believed to limit trout production in both ponds.

Species compositions.—Fourteen species of fish were found in the various waters at reclamation (Table 2); of these, yellow perch, smallmouth bass, and rainbow smelt were not endemic. Rainbow smelt were present in three waters, but they were not taken by trapnetting and reclamation samples suggest they were not important parts of the pond biomasses. Bay and Follensby Jr. ponds contained longnose suckers, but in only Bay Pond were they an important segment of the fish community.

Methods

Biomass Estimation

Biomass at reclamation was estimated with standard or modified mark-and-recapture methods in which the marked component was secured

TABLE 2.—Checklist of fish species collected at reclamation in seven Adirondack ponds: + denotes presence, − denotes absence.

Species	Bay Pond	Follensby Jr. Pond	Arbutus Lake	Cat Pond	Cranberry Pond	Second Anthony Pond	Third Anthony Pond
Brook trout *Salvelinus fontinalis*	+	+	+	+	+	+	+
Rainbow smelt *Osmerus mordax*	+	+	−	+	−	−	−
Northern redbelly dace *Phoxinus eos*	+	+	−	−	−	+	+
Golden shiner *Notemigonus crysoleucas*	+	+	−	+	+	−	−
Common shiner *Luxilus cornutus*	+	+	+	+	+	+	+
Blacknose dace *Rhinichthys atratulus*	−	−	−	+	−	+	+
Creek chub *Semotilus atromaculatus*	+	+	+	+	+	+	+
Pearl dace *Margariscus margarita*	−	−	+	+	−	+	+
Longnose sucker *Catostomus catostomus*	+	+	−	−	−	−	−
White sucker *Catostomus commersoni*	+	+	+	+	+	+	+
Brown bullhead *Ameiurus nebulosus*	+	+	+	+	+	+	+
Pumpkinseed *Lepomis gibbosus*	+	+	+	+	+	−	−
Smallmouth bass *Micropterus dolomieu*	−	−	+	−	−	−	−
Yellow perch *Perca flavescens*	+	+	+	+	+	−	−

TABLE 3.—Movement of fish marked and recaptured during trapnetting in four sections of Follensby Jr. Pond, 1966. Percentages of total recovery are in parentheses.

Species	Number marked, Jul 26–28	Number recovered, Jul 29		Number marked, Jul 26–Aug 1	Number recovered, Aug 2[a]	
		Marking area	Other		Marking area	Other
White sucker	389	5 (50)	5 (50)	713	10 (59)	7 (41)
Yellow perch	152	10 (100)	0 (0)	276	7 (54)	6 (46)
Brown bullhead	966	99 (41)	142 (59)	1,490	73 (53)	65 (47)
Pumpkinseed	894	51 (77)	15 (23)	1,960	79 (77)	24 (23)
Brook trout	99	1 (50)	1 (50)	404	9 (64)	5 (36)

[a] Based on three of four sections.

by trapnetting and recovered in the rotenone sample 2–3 weeks later. Most postreclamation estimates of brook trout biomass were obtained 3 or more years after initial stocking to allow time for populations to reach maximum levels and stabilize. Our Oneida Lake-type trap nets of 0.5-in mesh took fish starting at lengths of approximately 3.0 in. Non-trout species were marked by removal of a fin or part of a fin. Brook trout were marked by partial fin clips or jaw tags. The larger minnow species—common shiner, creek chub, and golden shiner—were marked, but rarely in sufficient numbers to provide population estimates; they have been combined under the heading "minnows" in this paper.

Waters were reclaimed with ProNoxfish (2.5% rotenone; S. B. Penick Corp.) at concentrations of 0.6–0.7 ppm. Applied to the surface by boat, this product successfully penetrated the thermocline without deep pumping. Prior reclamation experience had shown that fish attempt to avoid rotenone, and for this reason deep-water areas were treated first. This drove fish into the shallows, thereby maximizing both mixing of populations and recovery of fish. Tributaries were treated from their sources to each pond.

Recapture samples of brook trout and other species were collected during and following reclamation. Dead or moribund fish over 3 in were picked up by boat and from shore. At the concentrations used, rotenone is not size selective and samples were considered representative of the population. In several instances marking and recapture samples were too small for population estimates, and the number of fish marked plus the number of unmarked fish recovered was used as the estimate of minimum population size. In Follensby Jr. Pond, seining "spring hole" concentrations of brook trout prior to reclamation provided additional data for this species.

Postreclamation brook trout populations.—After reclamation, all waters were stocked with fin-clipped, fall fingerling brook trout at rates of 30–50 fish per surface acre. Three or more years later, trout were trapnetted for mark–recapture population estimates. The 2–3 weeks between samples was considered sufficient to allow dispersal of trout yet minimize recruitment. When longer intervals occurred between marking and recapture, modifications of standard Peterson techniques were used for estimation, as described by Flick and Webster (1976).

Statistical Considerations

Dispersal of marked fish.—An assumption behind population estimates based on mark–recapture data is that marked fish are randomly distributed within the population at the time of resampling or that the recapture sample is random. Information on movement of marked fish is available from Follensby Jr. and Bay ponds to test the dispersal assumption.

Follensby Jr. was divided into four sections, each approximately half a mile long. During trapnetting, fish from each section were given a distinctive temporary fin clip. Recoveries of marked fish 3–7 d later indicated movements of all species among the four sections (Table 3). Brown bullheads showed the greatest movements; many covered the entire 2-mi length of the pond between samples.

Similar evidence on movement is available from Bay Pond, where fish from the two basins were given distinctive fin clips. Movement was particularly heavy from the deeper north basin into the shallower south basin (Table 4). A screen divided the two basins at the time of reclamation to prevent mixing of populations due to the influence of rotenone.

Reclamation population estimates.—Extrapolation of biomass estimates from the reclamation samples to the original populations requires an assumption that the size distributions and average weights of fish collected at reclamation fairly rep-

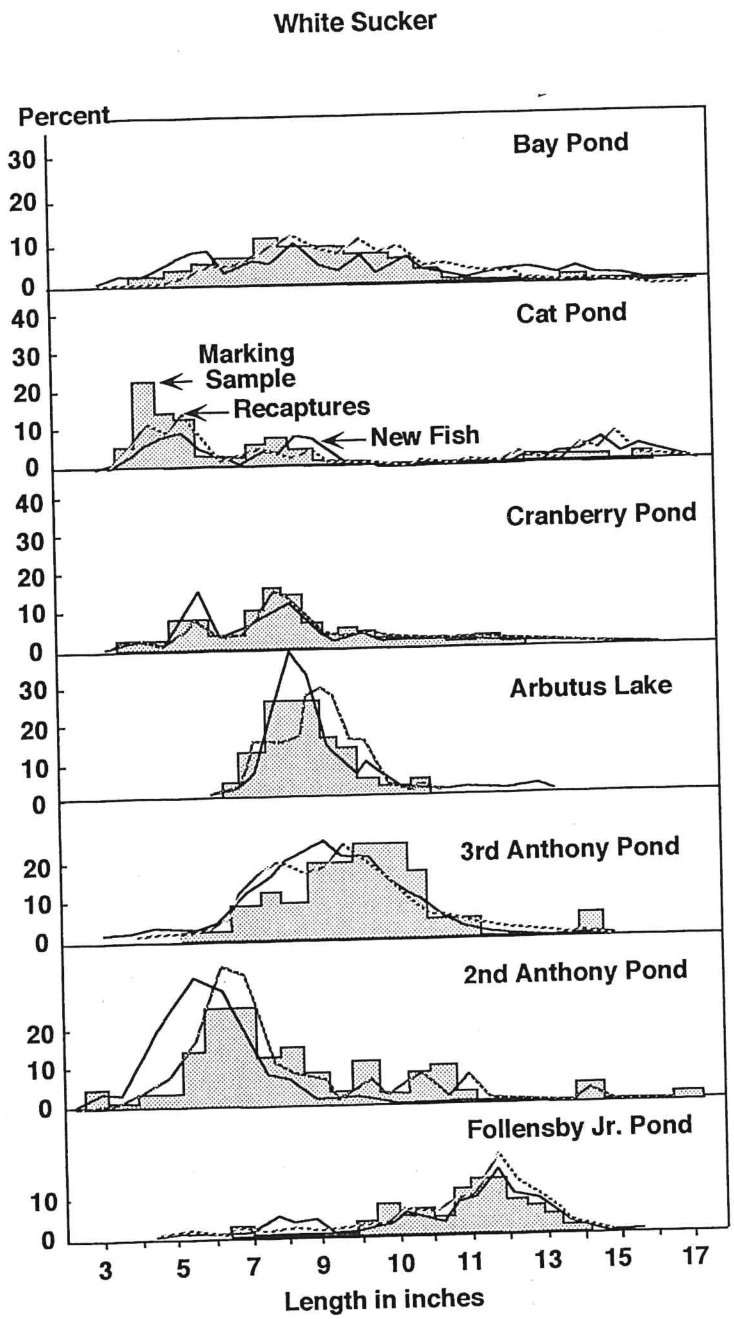
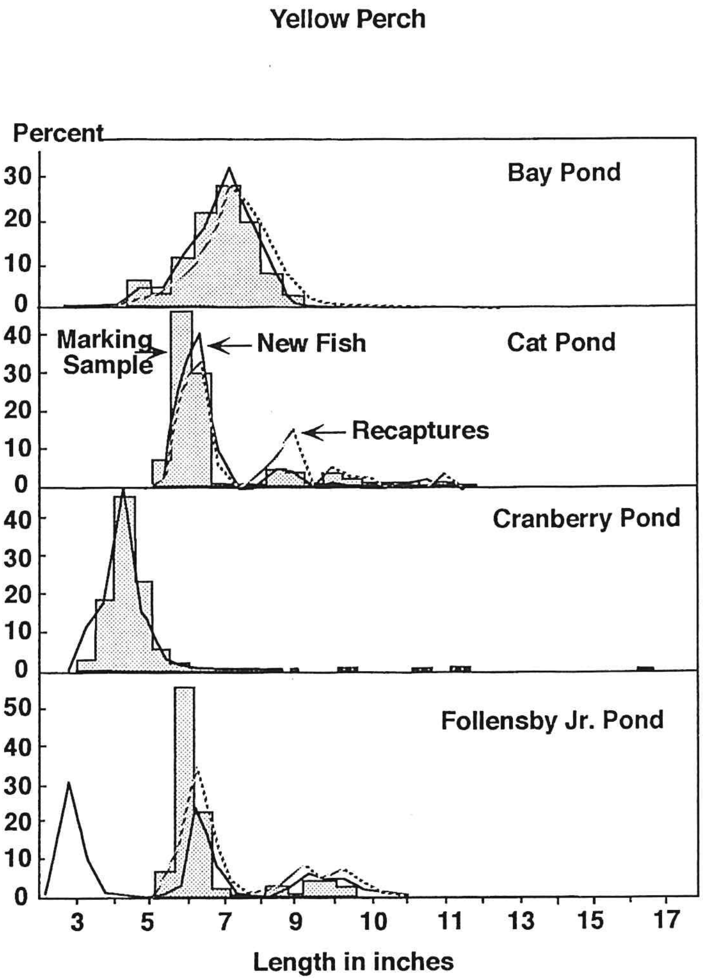


FIGURE 1.—Size distributions of four non-trout species—white sucker, yellow perch, brown bullhead, and pumpkinseed (sunfish)—taken by trap net for marking and at reclamation with rotenone in Adirondack ponds. "Recaptures" are marked fish recovered during reclamation; "new fish" are unmarked fish in the rotenone samples.

resented those of the actual populations. As noted previously, we believe that the rotenone samples met this criterion. We also assumed, without direct evidence, that natural mortality of marked and unmarked components was similar and that recruitment was negligible in the 1–3 weeks between marking and reclamation. We did not investigate the influences of fish size and water depth on recovery efficiency after rotenone application, although visual inspection suggested that size dis-



tributions of marked and recaptured fish were similar.

Length-frequency distributions of marked and unmarked fish in the reclamation samples indicated that trap nets were size selective in several instances, allowing smaller fish to escape (Figure 1). Such bias would give disproportionately high values of biomass in Peterson estimates. Use of the culling technique described by Robson and Flick (1961) to separate biased and unbiased data segments was investigated but found impractical for the purpose of this study. Visual examination

TABLE 4.—Numbers of fish moving between north and south basins of Bay Pond between marking during trapnetting August 6–14, 1968, and recovery during reclamation, August 20, 1968. Percentages of total recovery are in parentheses.

	South basin marking			North basin marking		
		Number recovered			Number recovered	
Species	Number marked	South	North	Number marked	South	North
White sucker	305	14 (33)	28 (67)	2,819	272 (93)	21 (7)
Yellow perch	1,059	88 (55)	72 (45)	2,522	254 (83)	52 (17)
Brown bullhead	85	11 (55)	9 (45)	107	40 (95)	2 (5)
Pumpkinseed	285	8 (22)	29 (78)	771	74 (96)	3 (4)

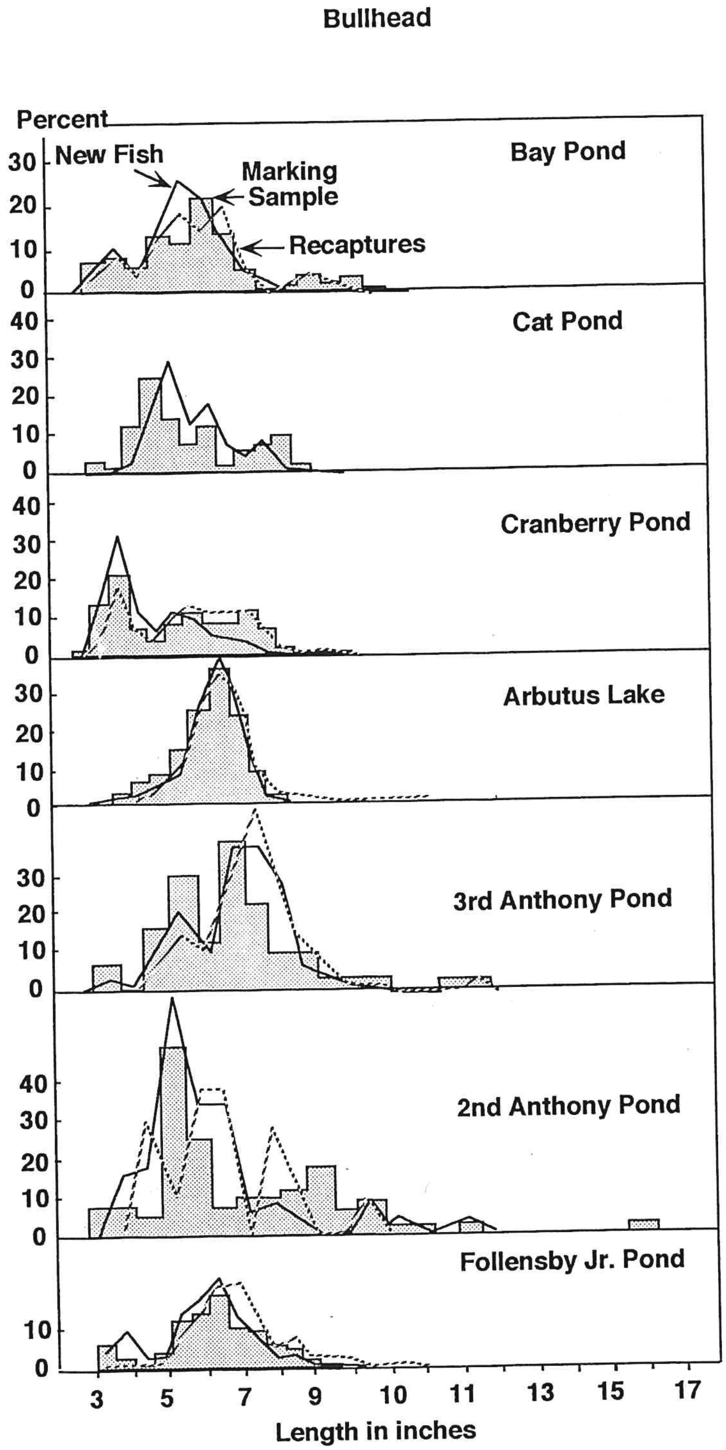


FIGURE 1.—Continued.

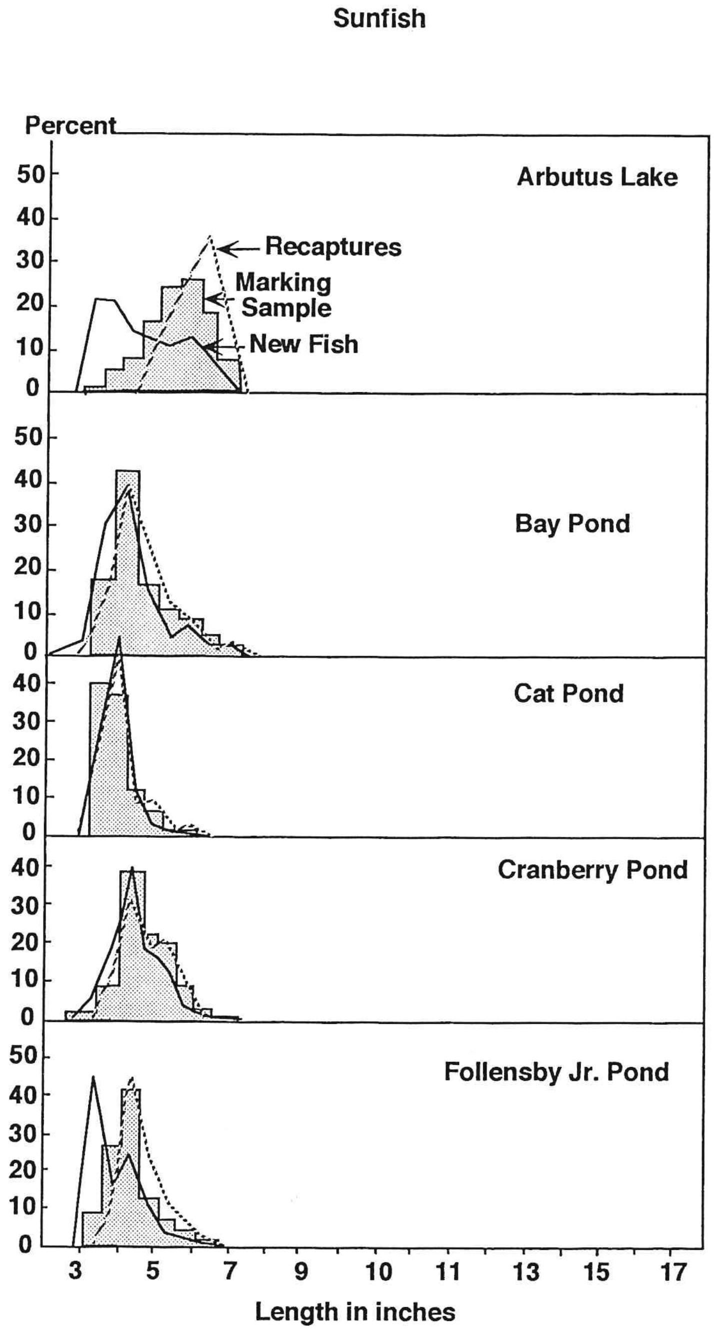


FIGURE 1.—Continued.

of size distributions allowed us to judge separations of obviously biased segments of the data. Although this could have resulted in some error, we did not consider the errors important in comparison with the total biomass, given the objectives of this paper. When we detected trap-net bias, we made a ratio estimate of the unmarked fish at reclamation and then added the known number of marked fish. The ratio estimate was described in detail by Cochran (1963) and is briefly discussed here.

Within the unbiased segment of the mark–re-

TABLE 5.—Estimated fish population sizes and standing crops in seven Adirondack waters at reclamation. Population values with standard errors [in square brackets] are based on unadjusted reclamation samples. Values with neither SEs nor parentheses are based on unbiased segments of trap-net (marking) data. Values in parentheses are unexpanded counts of fish handled. NA means data not available.

Species	Number marked	Reclamation sample		Unbiased data segment			Population data		
		Marked	Unmarked	Size (inches)	Number marked	Number recaptured	Estimated population	Average weight (lb)	Pounds per acre
Bay Pond									
White sucker (all)	3,102	334	2,026	3.5–17.4	3,102	334	21,918 [1,050]	0.40	41.4
White sucker (7.0–17.4 in)	2,414	278	1,547	7.0–17.4	2,414	278	15,847 [823]	NA	NA
Longnose sucker	0	0	425	7.0–17.4	0	425	3,690	1.03	17.9
Yellow perch	3,532	446	12,119	3.0–12.4	3,532	466	95,387 [4,040]	0.094	42.3
Brown bullhead	192	62	364	3.0–10.4	192	62	1,319 [127]	0.092	0.6
Pumpkinseed	1,055	113	1,204	3.0–6.9	1,055	113	12,296 [1,045]	0.052	3.0
Minnows	590	6	524	3.0–6.9			(1,114)	0.040	0.2
Brook trout	4	0	70				(74)	0.31	0.1
Rainbow smelt	0	0	998				998	0.031	0.2
Total									105.7
Follensby Jr. Pond									
White sucker	970	148	1,180	4.5–18.8	970	148	8,704 [621]	0.83	49.5
Yellow perch	358	70	397	5.5–12.4	356	70	2,377	0.23	3.7
Brown bullhead	1,593	266	299	4.5–11.2	1,416	265	3,191	0.14	3.1
Pumpkinseed	2,130	311	819	4.0–6.9	1,394	276	6,267	0.050	2.1
Minnows	551	28	1,768	3.0–8.2			(2,319)	0.066	1.1
Brook trout	490	239	791	6.0–17.7	422	228	1,954	0.29	3.9
Total									63.4
Arbutus Lake									
White sucker	436	9	155	6.5–16.2	436	9	7,945 [2,548]	0.24	15.9
Yellow perch	44	5	1,197				(1,241)	0.031	0.3
Brown bullhead	2,288	267	1,727	3.5–12.6	2,288	267	17,087 [915]	0.41	19.9
Pumpkinseed	566	29	761	4.5–12.7	488	29	12,805	0.058	6.2
Smallmouth bass	169	27	139	6.0–16.7	161	27	998	0.66	5.5
Minnows	0		7				(7)	0.059	<1.0
Brook trout	0		1				(1)	0.10	<1.0
Total									47.8
Cat Pond									
White sucker	431	86	864	3.4–20.3	431	86	4,761 [438]	0.58	57.5
Yellow perch	239	40	120	5.0–13.2	239	40	956 [120]	0.13	2.6
Brown bullhead	72	17	90	3.0–9.2	72	17	453 [88]	0.11	1.0
Pumpkinseed	491	95	211	3.0–5.9	491	95	1,582 [121]	0.028	1.0
Minnows	1,017	6	573				(1,590)	0.037	1.2
Brook trout	4	0	93				(97)	0.11	0.2
Total									63.5
Cranberry Pond									
White sucker	1,081	124	754	3.0–17.6	1,081	124	7,654 [599]	0.30	53.4
Yellow perch	271	2	1,822				(6,793)[a]	0.031	4.9
Brown bullhead	625	210	674	3.0–9.8	625	210	2,631 [129]	0.066	4.0
Pumpkinseed	315	81	826	3.0–6.5	315	81	3,527 [322]	0.069	5.7
Minnows	233	9	384				(617)	0.049	0.7
Brook trout	4	1	3				(7)	0.21	<1.0
Total									68.7
Second Anthony Pond									
White sucker	1,690[b]	117	796	3.5–13.8	1,690	117	13,188 [1,098]	0.22	82.9
Brown bullhead	151	17	52	3.2–10.8	151	17	613 [122]	0.13	2.3
Minnows	395	33	284	4.0–6.6	378	33	3,648	0.041	4.3
Brook trout	10	3	7	7.5–13.4	10	3	33 [14]	0.35	0.3
Total									89.8

TABLE 5.—Continued.

Species	Number marked	Reclamation sample		Unbiased data segment			Population data		
		Marked	Unmarked	Size (inches)	Number marked	Number recaptured	Estimated population	Average weight (lb)	Pounds per acre
Third Anthony Pond									
White sucker	1,952[b]	199	861	4.5–14.4	1,952	199	10,398 [630]	0.27	80.2
Brown bullhead	870[b]	116	355	3.0–10.7	870	116	3,533 [265]	0.11	11.1
Minnows	95	42	197	4.5–8.2	91	42	522	0.075	1.1
Brook trout	13	4	3	8.0–12.9	13	4	23 [6]	0.46	0.3
Total									92.7

[a] Includes 4,700 fish counted but not checked for fin clips.
[b] Only 100 fish were measured at marking.

capture data, the recovery of marked fish at reclamation represented a fraction of the number originally marked. The reciprocal of this fraction was applied to the total number of unmarked fish of all sizes in the reclamation sample to calculate the population of unmarked fish in the lake. The number of fish originally marked then was added to the extrapolated number of unmarked fish to obtain an estimate of the total population. For example, from Figure 1 we decided that the size distributions of marked and unmarked yellow perch 5.5 in and larger in the Follensby Jr. reclamation sample were in reasonable agreement. The marked yellow perch recaptured represent a fraction 70/356 of the original marked sample of this size range (Table 5). The reclamation sample from Follensby Jr. Pond contained 397 unmarked yellow perch of all sizes (3.0 in and larger), so the population of unmarked fish was 397 × 356/70 or 2,019 yellow perch. The number of yellow perch originally marked (358) was then added to obtain an estimate of the total population, from which the biomass was calculated.

Longnose suckers in Bay Pond occurred only in the deep basin; none were taken in the trap-net marking sample. The population estimate for this species was based on the assumption that white suckers and longnose suckers were recovered at reclamation in proportion to their actual abundances. Although it was not possible to test the validity of this assumption, we believe that treating the deep water with rotenone before the shallow water caused the populations of white and longnose suckers to mix. The technique used to obtain an estimate of longnose suckers in Bay Pond was as follows.

A Peterson estimate of 15,847 white suckers was obtained for fish of the same size range as longnose suckers (7.0–17.4 in). The reclamation sample of white suckers contained 278 marked fish and 1,547 unmarked fish in this size interval, giving a ratio to the total of 1,825/15,837 (Table 5). The reciprocal fraction then was applied to the 425 longnose suckers recovered to estimate the population of longnose suckers as 425 × 15,847/1,825 = 3,690.

Postreclamation population estimates.—Marking and recapture samples of brook trout stocked after reclamation generally were obtained by trap-netting; however, in some cases the recapture sample occurred several months after the marking period. This posed no problem for a population estimate of stocked, fin-clipped trout, but the possibility of recruitment from natural reproduction precluded use of a Peterson estimate. In these instances a population estimate for stocked fish of sizes comparable to those of fish from natural reproduction (which were progenies of the stocked strain) was used as a basis for estimating fish from natural reproduction. The assumption was made that naturally reproduced and stocked trout of the same size were similarly vulnerable to trap nets. The procedure was as follows.

The number of brook trout marked during the original marking sample represented a fraction of the total number of the fish present in a pond. The reciprocal fraction was applied to the number of naturally reproduced trout in the original marking sample to obtain a population estimate for this group. In Arbutus Lake, for example, the 1977 year-class of stocked brook trout (in spring 1979) had approximately the same average size as fish from natural reproduction. The population estimate for the 1977 year-class of stocked trout, based on a marking of 351 stocked fish, was 971 (Table 7). Forty-four naturally produced brook trout were in the marking sample. Thus, the estimated population of naturally produced brook trout was 44 × 971/351 = 136.

TABLE 6.—Standing crop percentages of major fish species in seven Adirondack waters at reclamation. Values in parentheses are minimum percentages based on pickup only.

Pond	Standing crop (lb/acre)	Species (%)						
		Suckers	Yellow perch	Brown bullhead	Pumpkinseed	Minnows	Smallmouth bass	Brook trout
Bay	106	56	40	<1	3	(<1)		(<1)
Follensby Jr.	63	78	6	5	3	(2)		6
Arbutus	48	33	(<1)	42	13	(<1)	11	(<1)
Cat	64	91	4	2	2	(2)		(<1)
Cranberry	69	78	(7)	6	8	(1)		(<1)
Second Anthony	90	92		3		5		<1
Third Anthony	93	87		12		1		<1

Results

Standing Crops

The total standing crops (biomass divided by surface water area) of non-trout species in the seven study waters ranged from 48 to 106 lb/acre (Tables 5, 6). The two waters with similar morphology, species composition, and water chemistry (Anthony ponds) had nearly identical standing crops, approximately 90 lb/acre. In most cases the standing crop of minnows could not be estimated but we do not believe these species would have added substantially to the total; estimates of minnow standing crops in the Anthony ponds were only 1–4 lb/acre, and observations and collections from the other waters did not indicate greater densities. The only water with a major piscivore—Abutus Lake with smallmouth bass—had the lowest total standing crop: 48 lb/acre. Follensby Jr. Pond sustained a program of population control by netting for 13 years prior to reclamation and, as a result of the annual removal of non-trout, had a standing crop of only 64 lb/acre.

Suckers.—Suckers are abundant in most Adirondack waters and it was usually possible to obtain large samples for population estimates (Table 5). The size distributions of marking and recapture samples agreed well for white suckers, and only in Second Anthony Pond was it necessary to adjust for selective sampling (Figure 1). White and longnose suckers combined made up 56–92% of the total standing crop in six of the seven waters studied (Table 6); only in Arbutus Lake, where smallmouth bass were also present, were suckers less than 50% of the total.

Longnose suckers were abundant in Bay Pond (17.9 lb/acre) and made up approximately one-third of the sucker standing crop. They were also large, averaging 1.03 lb compared with an average of 0.40 lb for white suckers (Table 5).

Yellow perch.—Yellow perch were important by weight in only Bay Pond, where they represented 40% of the standing crop (41 lb/acre). Elsewhere their standing crops were low (<5 lb/acre), although only minimum estimates were possible in two waters due to sampling bias (Table 5). In Follensby Jr. Pond a netting control program had decreased the yellow perch population, and 3.7 lb/acre were present at reclamation.

Brown bullhead.—Most Adirondack waters contain brown bullheads, and at times this species is abundant. All of the study waters contained brown bullheads, and the mark–recapture data were apparently unbiased, permitting population estimates without adjustments except in Follensby Jr. Pond (Figure 1). Brown bullheads were very abundant in Arbutus Lake—19.9 lb/acre, or 40% of the total biomass (Table 6). The standing crops in the remaining waters ranged from 1 to 11 lb/acre (Table 5).

Pumpkinseed.—Although pumpkinseeds were small, sufficient numbers were taken by trapnetting in five waters to allow population estimates for at least part of the size distribution (Figure 1). In two waters pumpkinseeds made up at least 8% of the total standing crop (approximately 6 lb/acre), but they constituted 3% or less in the other three waters containing this species (Tables 5, 6).

Minnows.—Except in the Anthony ponds, mark–recapture samples were inadequate for population estimates of minnows. In these two waters standing crops were estimated at 1–4 lb/acre (Table 5). Observations at reclamation indicated that minnows were not a major component of the standing crop in any study water.

Smallmouth bass.—Arbutus Lake was the only study water that contained smallmouth bass. The population estimate for this species is based on fish 6.0 in and larger. The size distributions of marked and recaptured fish suggest there may have been some selective sampling, but observations during reclamation indicated that the standing crop estimate of 5.5 lb/acre was reasonable. The smallmouth bass population consisted of a substantial number of fish longer than 10.0 in and this species made up 11% of the total biomass in Arbutus Lake (Table 6).

Brook trout.—Brook trout were present in all study waters at reclamation, but made up a substantial population only in Follensby Jr. Pond. Even there, the standing crop was low compared to those of non-trout species: large marking and recapture samples were obtained, and the trout population was estimated at 3.9 lb/acre (Table 5). In four other waters with yellow perch populations, insufficient brook trout were obtained for population estimates. The two Anthony ponds did not have yellow perch, but even in these waters the trout population was less than 1 lb/acre and made up less than 1% of the total standing crop (Table 6).

Postreclamation Non-trout Species

Reclamation successfully eliminated the major target species—suckers and yellow perch—from all waters, as well as the less abundant pumpkinseed and rainbow smelt. Brown bullheads, one of the more difficult species to eradicate, were eliminated from four of the seven waters; where they were not killed off, they made up only a small part of the trap-net catch at the time of later brook trout population estimates. Although no quantitative data are available on brown bullhead abundance at the time of these estimates, there was no indication that the species formed an important segment of the total biomass. Subsequently, however, brown bullheads have become very abundant in Arbutus Lake and may be a factor in the reported depression of the trout population. In the other two waters (Anthony ponds) where bullheads were ot eliminated, the brook trout population is still considered normal for reclaimed waters and brown bullhead catches during trapnetting have been low.

Postreclamation Trout Populations

Following reclamation all waters were stocked with one or more wild strains of brook trout. Natural reproduction has been widely successful. Only Arbutus Lake has needed supplemental stocking to maintain trout populations at satisfactory levels for angling. In Follensby Jr., Bay, and Cat ponds natural reproduction is so successful that population control measures have been necessary to prevent stunting.

Standing crops.—Population estimates for brook trout are available up to 17 years following reclamation, ample time for maximum biomasses to develop. During the first few years after reclamation, the major part of the biomasses was stocked fish that had been fin-clipped when released as fall fingerlings. Once these fish reached sexual maturity, natural reproduction occurred in six waters and complicated population estimates. The standing crops of brook trout in the various waters ranged from 5 to 16 lb/acre (Table 7). Four of the seven waters yielded estimates greater than 10 lb/acre; the highest—15.7 lb/acre—was in Follensby Jr. Pond. Cat Pond, the one oligotrophic lake, had a maximum standing crop estimate of 6.8 lb/acre, but this is a minimum figure based on the number of fish actually handled, not a population estimate.

Total harvest.—Natural reproduction by brook trout has been so successful that brook trout have been removed from three waters by netting, as well as by angling, to prevent stunting. Follensby Jr. Pond supported the highest annual harvests: 13.2 lb/acre in 1984 and 10.6 lb/acre in 1985; no population estimates are available for this period, however. The 1984 harvest from Follensby Jr.—1,927 lb—is particularly notable in comparison with the total biomass of brook trout—467 lb—estimated when the pond was reclaimed in 1966; by 1966, the pond had been under an intensive netting control program for non-trout species for 13 years. Harvests from the other waters are not particularly meaningful because angling pressure has been light and annual netting removal of brook trout has been carried out only in Follensby Jr. in recent years.

Discussion

Fishery managers have long recognized the inability of brook trout to compete successfully with many non-trout species, particularly yellow perch, in ponds and lakes. Eschmyer (1938) noted that in Michigan lakes, brook trout survived poorly in waters with yellow perch but often survived and grew well when yellow perch were absent. Similar conclusions with respect to yellow perch as a competitor were drawn by Fraser (1978), who noted that angling yielded approximately 3 lb of brook trout per pound stocked in the absence of perch but only 0.4 lb/lb after yellow perch became established. In the Adirondacks as well, there has been a history of loss of brook trout populations once yellow perch became established. The small size attained by yellow perch in the Adirondacks

TABLE 7.—Population and standing crop estimates for brook trout established in seven reclaimed Adirondack waters. Standard errors are in square brackets. Year-class dates indicate fin-clipped fish recognizable from postreclamation stockings; NR denotes fish naturally reproduced from stocked strains.

Estimation period	Year-class	Number marked	Recapture sample: Marked	Recapture sample: Unmarked	Population estimate	Average weight (lb)	Pounds per acre	Years following reclamation
				Bay Pond				
Spring 1975	NR	993	140	696	5,930 [424]	0.53	14.8	7
Spring 1976	NR	854	394	584	2,120 [61]	0.60	6.0	8
Spring 1977	NR	530	66	292	2,875 [299]	0.41	5.6	9
				Follensby Jr. Pond				
Spring 1972	NR	1,049	152	328	3,313 [205]	0.69	15.7	6
Spring 1973	NR	946	64	293	5,277 [577]	0.42	15.2	7
Spring 1982	NR	750	198	685	3,345 [180]	0.39	8.9[a]	17
				Arbutus Lake				
Fall 1978	1977	333	73	286	1,638 [151]	0.28		
	NR	67			330	0.38		
Total					1,968		4.9	5
Spring 1979	1977	315	37	77	971 [123]	0.55		
	1978	80	13	404	2,566 [641]	0.13		
	NR	44			136	0.56		
Total							7.9	6
				Cat Pond				
Fall 1969	1966	69	23	10	99 [9]	1.38		
	1968	115	32	52	301 [36]	0.39		
	NR	35			92	0.28		
Total					492		5.9	3
Fall 1974	NR	606			606	0.54	6.8[b]	8
				Cranberry Pond				
Fall 1970	1968	91	44	51	197 [16]	1.80		
	NR	28			61	0.66		
Total							9.2	3
Spring 1972	1968	29	22	21	57 [4]	2.24		
	1970	30	18	22	67 [7]	1.18		
	1971	26	5	21	135 [49]	0.26		
	NR	149	45	96	467 [48]	0.54		
Total							11.7	5
				Second Anthony Pond				
Fall 1972	1971	100	25	83	432 [66]	0.64	7.9	2
Spring 1977	NR	140	32	197	1,002 [144]	0.37	10.6	7
				Third Anthony Pond				
Spring 1974	1971	45	22	29	104 [12]	1.46		
	1973	40	19	101	253 [39]	0.20		
	NR	17			108	0.24		
Total					465		6.5	4
Fall 1974	1971	40	11	11	80 [15]	1.42		
	1973	94	20	26	216 [32]	0.42		
	NR	65			119	0.51		
Total							7.5	4

[a] 8.2 lb/acre were harvested in 1981.
[b] Minimum estimate.

has kept this species from becoming a popular angling target and, except for bullheads, other native non-trout species are likewise of little interest to anglers. Although bullheads are popular, they are available in numerous waters of the region. Thus, elimination of fish that compete with trout in the Adirondack region has little or no effect on the angling fraternity, even though the standing crop of these species may be considerably higher than that of brook trout alone.

The standing crop of fish is normally highest when the number of species increases, because the various ecological niches are exploited more effectively. Prior to reclamation of the study waters, when several fish species were present, standing crops ranged from 50 to 100 lb/acre, and they dropped to 5–16 lb/acre following reclamation. The prereclamation data are similar to those from some small lakes in Maine, where Rupp and DeRoche (1965) obtained biomass estimates of approximately 100 lb/acre in waters containing suckers and smallmouth bass. In contrast, Carlander (1955) reported standing crops exceeding 400 lb/acre in small lakes in the Midwest. Adirondack lakes have low productivity, which should be taken into consideration when mixed-species biomasses and trout production data are compared between regions.

Prior to reclamation, suckers made up the major part of the total biomass in five of the seven study waters and were a major component of fish assemblages in all waters. Suckers can utilize primary food supplies such as organisms contained in detritus, which contributes to their success in infertile Adirondack waters and similar regions of the Northeast. The ecological relationship between suckers and brook trout is not well understood. The species associations in the Anthony ponds were not confounded by the presence of yellow perch, but the standing crop of brook trout increased from 0.3 lb/acre before suckers were eliminated to approximately 8–10 lb/acre after reclamation. This indicates that suckers can be serious competitors, although brook trout can sustain populations high enough for some angling when in competition with these species. It has generally been found over the past 30 years, however, that elimination of competition from suckers improves brook trout survival and growth in Adirondack waters.

The inability of brook trout to maintain high levels of survival and growth when in competition with yellow perch and other non-trout species is well documented by the data from this study. Only in Follensby Jr. Pond, which had a population control program in effect for 13 years, was there a measureable trout population at the time of reclamation. Following removal of yellow perch and most other competing species, viable brook trout populations were established in all waters. Although yellow perch are severe competitors of brook trout, the data from this study indicate that yellow perch may not always make up a major part of the total biomass; in four of the five waters containing the species, yellow perch constituted less than 5% of the total biomass.

Following reclamation and removal of competing species, all waters supported good survival and growth of brook trout. Postreclamation standing crops of brook trout ranged from 5 to 16 lb/acre, whereas several of the waters did not have measureable populations before reclamation. Hatch and Webster (1961) found similar standing crops (6–12 lb/acre) in four reclaimed waters in the western Adirondack Mountain area. Although these total standing crops are low compared with values for mixed-species associations, they are sufficient to provide good brook trout fishing where previously there had been little or none. Angling catch records are available for four of the seven waters: postreclamation catch rates averaged approximately 2 brook trout/h except in Follensby Jr., which has sustained catch rates of 4–8 trout/h for over 20 years. Average size of brook trout retained has generally been 0.75–1.0 lb; however, all waters are on private property with light fishing pressure (one or two trips per surface acre annually).

Given the favorable cost–benefit ratio and the long history of reclamation as a safe management tool, it is unfortunate that fish managers now often find strong opposition to such programs from uninformed environmental groups.

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