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Comparative Abundance of Resident and Stocked Species of Fish in Harding Lake, Alaska, 1991

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Tim Viavant

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ABSTRACT

Fish populations of Harding Lake were sampled with fyke traps in the littoral zone, sinking gill nets in the benthic zone, and vertical gill nets in the pelagic zone during 1991 to evaluate enhancement efforts. Gill nets were fished in each of four sections of the benthic zone. Units of sampling gear were fished in each of four quadrants in each of these three limnological zones as well as in all four sections of the benthic zone. Catches of stocked species totalled 699 Arctic char *Salvelinus alpinus*, 30 rainbow trout *Oncorhynchus mykiss*, and 535 Arctic grayling *Thymallus arcticus*. Catches of resident species of fish were 34 northern pike *Esox lucius*, 38 burbot *Lota lota*, 10 lake trout *Salvelinus namaycush*, and 254 least cisco *Coregonus sardinella*. For all species combined, 594 fish were captured in the littoral zone, 526 fish were captured in the benthic zone, and 458 fish were captured in the pelagic zone. Growth of Arctic char was related to length at stocking, and ranged from 0.06 to 0.33 millimeters per day, depending on length at stocking and length of time fish were present in the lake.

KEY WORDS: Harding Lake, stocking evaluation, Arctic char, *Salvelinus alpinus*, rainbow trout, *Oncorhynchus mykiss*, Arctic grayling, *Thymallus arcticus*, northern pike, *Esox lucius*, burbot, *Lota lota*, least cisco, *Coregonus sardinella*, lake trout, *Salvelinus namaycush*, catch-per-effort, growth.

INTRODUCTION

Harding Lake is a large road accessible lake located about 100 km from Fairbanks. While Harding Lake is used extensively for outdoor recreation, it supports a much smaller sport fishery in terms of angler days than do other large, stocked, roadside lakes close to population centers in the Tanana Valley. It has long been the perception of fisheries managers that Harding Lake could support a much larger sport fishery than it currently does or has in the past, and increasing sport fishing effort at Harding Lake has been a goal of the Alaska Department of Fish and Game (ADF&G) for several years. In keeping with this goal, enhancement efforts aimed at improving sport fishing in Harding Lake have occurred for many years (Doxey 1991; Clark et al. 1991).

Recent enhancement efforts included rearing fish in floating net-pens at Harding Lake during 1990 and 1991. Net-pens were used to rear fish to a larger size prior to release because previous data available from Harding Lake have indicated that survival of fish stocked as fingerlings or fry has been negligible, and the production of larger fish from the state hatchery system was already fully utilized. Rearing fish in net-pens in Harding Lake has proved to be a cost effective method of increasing the number of available catchable sized fish for stocking into Harding Lake (Clark et al. 1991).

Most enhancement efforts at Harding Lake have resulted in limited success in terms of increases in harvest of the species stocked (Mills 1987 - 1991) or in terms of survival as documented by test netting and experimental hook and line fishing (Doxey 1989, 1991). However, recent introductions of catchable ($\geq$ 200 mm) sized Arctic char *Salvelinus alpinus* have been caught in increasing numbers in the sport fishery during 1989 and 1990 (Table 1) and have shown up in test netting and experimental hook and line fishing (Viavant and Clark in 1991a; Viavant and Clark 1991b). These recent introductions of Arctic char have also resulted in some catch and release angling (about two caught and released for every one harvested; Table 1). Because of the recent success of stocking catchable sized Arctic char, catchable ($\geq$ 200 mm) sized rainbow trout *Oncorhynchus mykiss* were stocked in 1990 and 1991 along with smaller rainbow trout.

Some assessment of the success of these stocking efforts began in 1986 with a program of test netting that was continued through 1991. Assessments to date have involved determining the relative index of abundance for sport fish species in Harding Lake; population estimates have not been attempted. These evaluation efforts have indicated that Arctic char have been the most successful species stocked into Harding Lake. This report will include the results of test netting in 1991 as well as evaluation of the stocking of Arctic char, rainbow trout, and Arctic grayling *Thymallus arcticus* in Harding Lake based on several sources of data. The objectives for 1991 were as follows:

1) estimate the median catch-per-net-night of stocked Arctic char in the benthic zone and stocked rainbow trout in the littoral zone of Harding Lake during September;

Table 1. Fishing effort and harvests of wild and stocked fish, Harding Lake, 1986 - 1990[a].

Fishing Effort of Harvests	Year				
	1986	1987	1988	1989	1990[b]
Number of Days Fished	2,064	5,125	3,256	4,935	3,895
Number of Anglers	1,590	3,371	2,599	2,976	2,650
Number of Fish Harvested:					
Arctic char	0	0	0	141	304
Arctic grayling	0	79	0	0	17
Burbot	0	53	73	10	17
Lake trout	24	0	55	119	51
Northern pike	673	1,886	2,092	1,764	591
Rainbow trout	0	118	73	456	354
Sheefish	0	0	73	0	0

[a] Data from Mills (1987, 1988, 1989, 1990, 1991).

[b] Catch in 1990 were as follows: Arctic char = 996; Arctic grayling = 84; burbot = 17; lake trout = 186; northern pike = 3,629; rainbow trout = 1,182; and, sheefish = 68.

2) estimate the proportion of age 1 and age 2 rainbow trout in Harding Lake; and,

3) estimate the proportion of all Arctic char caught in 1991 that were reared in the net-pens during 1990.

METHODS

Sampling of fish in Harding Lake took place in various limnological zones (Table 2). The littoral zone consisted of near-shore water less than 10 m deep. The benthic zone consisted of water within 2 m of the bottom at depths ranging from 10 to 36 m and the benthic zone was subdivided into four depth categories to spread sampling effort (Table 2). The pelagic zone consisted of the entire water column at depths of over 30 m. Sampling effort was dispersed among the four quadrants of each limnological zone and section of the lake (Figure 1).

Each quadrant of the littoral zone was fished for eight net-nights with fyke traps. The fyke traps had a 25 m center lead and 7.5 m wings. Each quadrant of each of the four depth categories within the benthic zone was fished for two net-nights with a 40 m x 2 m, variable mesh, monofilament, sinking gill-net. Each quadrant of the pelagic zone was fished for two net-nights with six vertical gill-nets. Each net was 3 m x 30 m, mono-filament or multi-filament, and had a different mesh size which ranged from 12.7 mm to 63.5 mm (bar measure). All sampling took place from September 16 to September 25, 1991. All netting locations were randomly chosen within each limnological zone, section, and quadrant. Each net-night consisted of fishing the gear for approximately 24 hours. Sample design in 1991 was similar to that of test netting conducted during 1989 and 1990 (Viavant and Clark 1991a). All captured fish were measured from tip-of-snout to fork-of-tail (FL) to the nearest millimeter and examined for the presence of fin clips and/or Floy tags.

In addition to test netting, other sources of data (Appendix A) included incidental captures during spring assessment of the northern pike *Esox lucius*, population (Skaugstad and Burkholder *In prep*), tag returns from anglers, data gathered during a winter creel survey at Harding Lake (Merritt et al. 1990), and data taken during experimental hook and line fishing at Harding Lake (Viavant and Clark 1991b). The recent stocking history is provided in Appendix B.

Relative Abundance

Relative abundance was defined as the median catch-per-net-night. The 95% confidence interval for the median catch-per-net-night was calculated as:

$$P(X_i \leq \text{median} \leq X_j) > 1 - \alpha, \qquad (1)$$

where: $i = C_{a(2),\, n+1}$;
$j = n - C_{a(2),n}$; and,

Table 2. Zones, depths, and sampling gear types used to sample fish in Harding Lake during September 1991.

Limnological Zone	Water Depth (m)	Gear Type	Number of Net-Nights Fished[a]
Littoral	0 - 9	Fyke trap	32
Benthic	10 - 15	Sinking Gill-net	8
Benthic	15 - 21	Sinking Gill-net	8
Benthic	21 - 27	Sinking Gill-net	8
Benthic	27 - 36	Sinking Gill-net	8
Pelagic	0 - 36	Vertical Gill-net	48

[a] A net-night is defined as 24 hours.

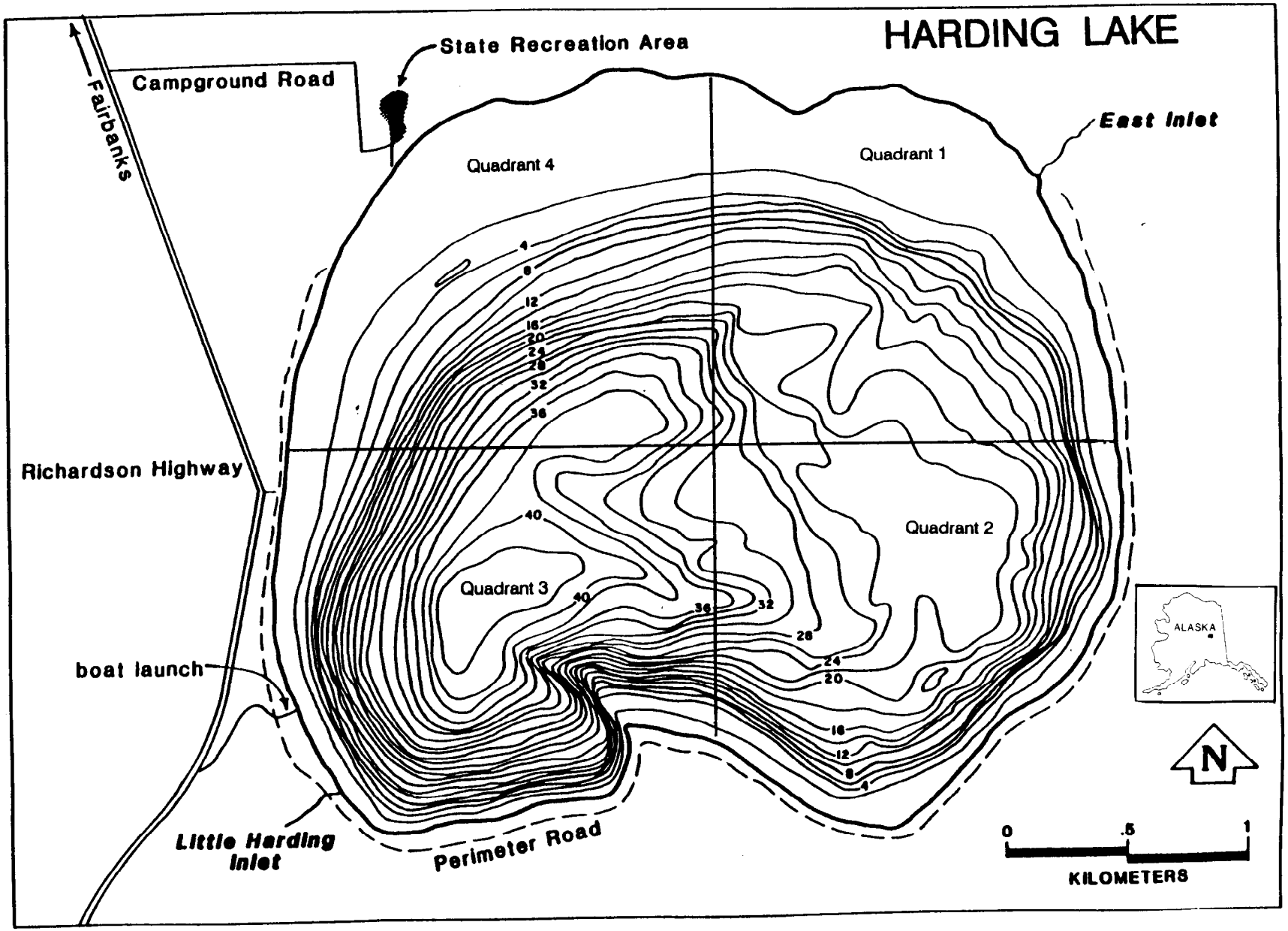

Figure 1. Map of Harding Lake, Alaska, showing quadrants used to disperse sampling effort.

$C_{a(2)}$ = critical values of the binomial distribution with p = 0.5 and X_i and X_j being the ith and jth ranked observations (Zar 1984).

The median catch-per-net-night of a species in a zone was classified as abundant, moderately abundant, or sparse, based on the numerical criteria for each species as provided in Appendix C. These abundance criteria were arrived at by polling biologists regarding their opinions of what catch levels they would categorize as abundant, moderately abundant, or sparse for each species for a net-night, and averaging the results (see Viavant and Clark 1991a). These abundance criteria were used only as a consistent basis for categorizing relative catch levels.

Proportion of Stocked Fish in Test Net Catches

The proportion of fish sampled that had been reared in net-pens was estimated as follows:

$$\hat{p} = \frac{\frac{n_i}{n}}{f} \tag{2}$$

$$\hat{V}[p] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1} * \left[\frac{1}{f}\right]^2 \tag{3}$$

where:

n_i = number of marked fish in the sample that were known to have been raised in net-pens;

n = sample size; and,

f = proportion of pen reared fish that received a mark.

Growth of Arctic Char

Data were available for 91 Arctic char that were measured and tagged at Clear Hatchery just prior to stocking and later recaptured. Five of these fish were measured as shorter at recapture than at stocking. These five fish were excluded from analysis along with two fish that were recaptured less than ten days after stocking, leaving growth data for 84 fish. These 84 fish resided in Harding Lake for 100 to 875 days between marking and recapture events. Because growth rates of Arctic char were shown to be dependent on the length of the fish at marking (Buklis 1978), growth data were grouped into 25 mm

length categories based on fork-length at time of marking. Growth was subsequently estimated as follows:

$$G_{ij} = \frac{L(t_{rij}) - L(t_{mij})}{(t_{rij} - t_{mij})} \quad (4)$$

where: G_{ij} = growth in mm/day of the ith fish in the jth length category;
$L(t_{rij})$ = fork length at time of recapture;
$L(t_{mij})$ = fork length at time of marking;
t_{mij} = time of marking in days, and;
t_{rij} = time of recapture in days.

RESULTS

Catch Statistics and Relative Abundance

Catches of stocked species in 1991 totaled 699 Arctic char, 30 rainbow trout, and 535 Arctic grayling (Table 3; Figure 2). Catches of naturally reproducing species totaled 34 northern pike *Esox lucius*, 38 burbot *Lota lota*, 10 lake trout *Salvelinus namaycush*, and 254 least cisco *Coregonus sardinella*. Fishing effort totaled 32 net-nights with fyke nets in the littoral zone, 32 net-nights with gill nets in the benthic zone, and 48 net-nights with gill nets in the pelagic zone (Table 2). For stocked and resident species combined, 594 fish were captured in the littoral zone, 526 fish were captured in the benthic zone, and 458 fish were captured in the pelagic zone.

Arctic Char:

Two Arctic char were captured in the littoral zone, 360 were caught in the benthic zone, and 337 were caught in the pelagic zone (Table 3). Catches of Arctic char generally increased with depth in the benthic zone. The median catch per net-night (and range) for: (1) the littoral zone was 0 Arctic char (0 to two fish); (2) the benthic zone was 5.0 Arctic char (0 to 80 fish); and, (3) the pelagic zone was 2.0 Arctic char (0 to 86 fish; Table 4). Relative abundance in the littoral, benthic, and pelagic zones were rated sparse, moderate, and moderate, respectively (Table 4).

During 1991, 153 marked fish from five of six marked cohorts of stocked Arctic char were captured during this and other studies of the fish in Harding Lake (Figure 3, Appendix A). Nine Arctic char were from the cohort stocked in October 1988, four were from February 1989, 11 were from the cohort stocked in May 1989, one was from the cohort stocked in March 1990, and 128 were from the cohort stocked in May 1991. No Arctic char released from the net-pens during August 1990 were caught in these 1991 sampling efforts. During similar studies in 1990, three Arctic char were from the cohort stocked in October 1988, 13 were from the cohort stocked in February 1989, 15 were from the

Table 3. Total catch by species, size, and zone while test netting Harding Lake during September 1991.

Species	Fork Length (mm)	Number of Fish Caught						
		Zone[a]						
			Benthic					
		Littoral	10 m	15 m	21 m	27 m	Pelagic	Total
Arctic char	< 200	2	23	34	63	151	327	600
	≥ 200	0	17	18	32	22	10	99
Arctic grayling	< 200	534	0	0	0	0	0	534
	≥ 200	1	0	0	0	0	0	1
Lake trout	< 300	1	0	0	0	0	0	1
	≥ 300	0	1	6	2	0	1	9
Least cisco	All	0	4	15	68	70	97	254
Northern pike	< 300	15	0	0	0	0	0	15
	≥ 300	11	4	1	0	0	3	19
Rainbow trout	< 200	0	0	0	0	0	0	0
	≥ 200	29	0	1	0	0	0	30
Burbot	< 300	1	0	0	0	0	0	1
	≥ 300	0	3	9	4	1	20	37
Zone Total		594	53	84	151	238	458	1,578
Number of net-nights		32	8	8	8	8	48	112

[a] The littoral zone consisted of near-shore water less than 10 m deep and fishing gear was fyke traps; the benthic zone consisted of water just off the bottom at depths listed and fishing gear was 40 m by 2 m, variable mesh, sinking gill-nets; and, the pelagic zone consisted of the entire water column at depths over 30 m and fishing gear was six vertical gill-nets composed of 3 m by 30 m panels, each of a different mesh size.

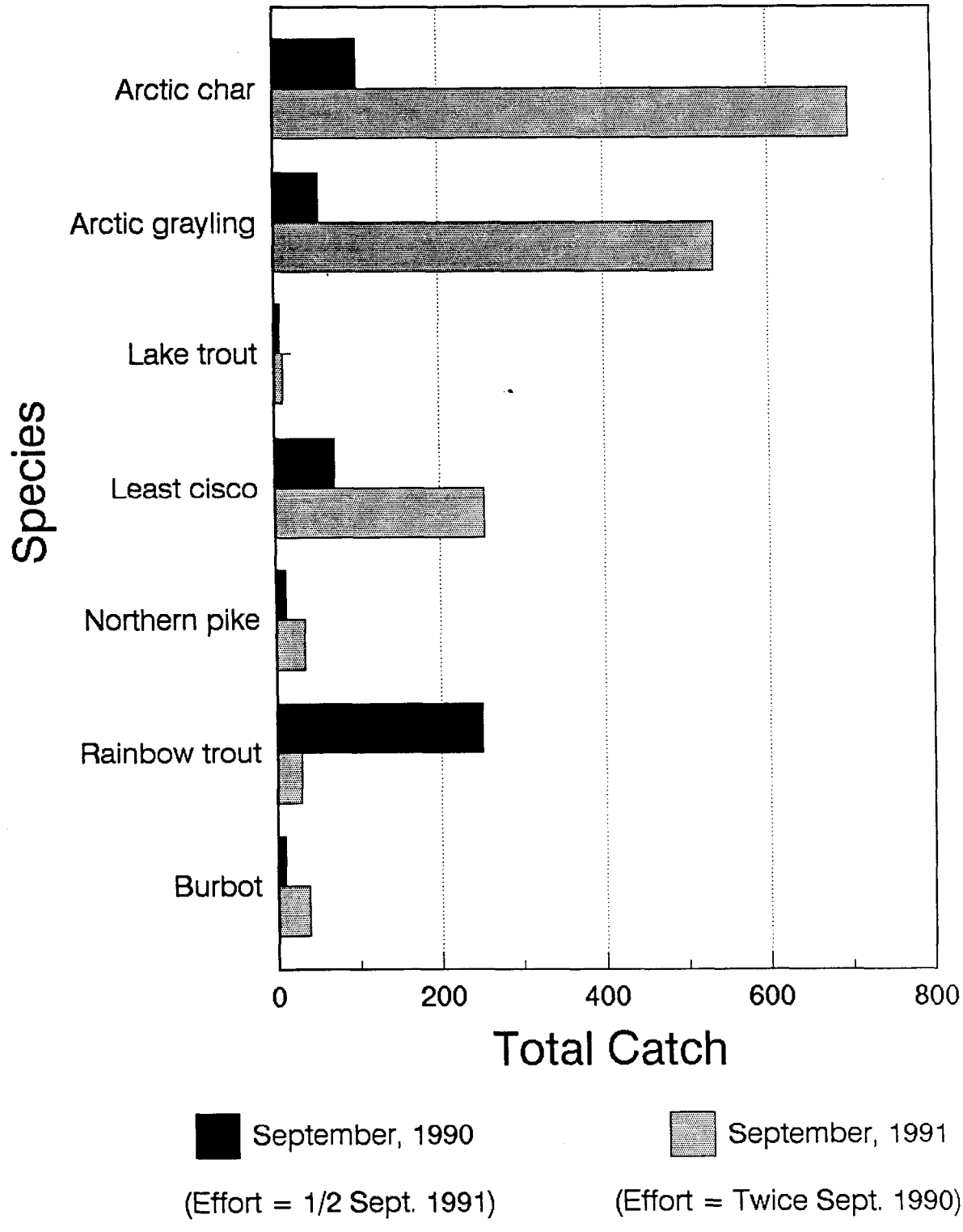

Figure 2. Total catches from all zones and gear types for each species caught while test netting Harding Lake during September 1990 and September 1991 (zones, gear types, and methods were identical for both years, except that fishing effort during 1991 was twice that during 1990).

Table 4. Minimum, maximum, and median, catches of fish per net-night by zone and designated level of abundance, Harding Lake, September 1991.

Species	Zone[a]	Catch per net-night				Designated Abundance[b]
		Minimum	Maximum	Median	95% C.I.	
Arctic char	Littoral	0	2	0.0	0 - 2	Sparse
	Benthic	0	80	5.0	2 - 8	Moderate
	Pelagic	0	86	2.0	0 - 7	Moderate
Arctic grayling	Littoral	0	232	3.5	0 - 6	Sparse
	Benthic	0	0	0.0	0 - 0	Sparse
	Pelagic	0	0	0.0	0 - 0	Sparse
Lake trout	Littoral	0	1	0.0	0 - 0	Sparse
	Benthic	0	2	0.0	0 - 2	Sparse
	Pelagic	0	1	0.0	0 - 1	Sparse
Least cisco	Littoral	0	0	0.0	0 - 0	Sparse
	Benthic	0	30	2.5	0 - 7	Sparse
	Pelagic	0	9	0.0	0 - 9	Sparse
Northern Pike	Littoral	0	4	0.0	0 - 1	Sparse
	Benthic	0	2	0.0	0 - 2	Sparse
	Pelagic	0	2	0.0	0 - 2	Sparse
Rainbow trout	Littoral	0	5	0.0	0 - 1	Sparse
	Benthic	0	1	0.0	0 - 1	Sparse
	Pelagic	0	0	0.0	0 - 0	Sparse
Burbot	Littoral	0	1	0.0	0 - 0	Sparse
	Benthic	0	4	0.0	0 - 0	Sparse
	Pelagic	0	4	0.0	0 - 0	Sparse

[a] The littoral zone consisted of near-shore water less than 10 m deep and fishing gear was fyke traps; the benthic zone consisted of water just off the bottom at depths listed and fishing gear was 40 m by 2 m, variable mesh, sinking gill-nets; and, the pelagic zone consisted of the entire water column at depths over 30 m and fishing gear was six vertical gill-nets composed of 3 m by 30 m panels, each of a different mesh size.

[b] Criteria used to develop these abundance designations appear in Appendix C.

Sampling Event

Marked Cohort	1989 Summer Netting	1989 Hook and Line	1990 Winter Creel	1990 Summer Netting	1990 Hook and Line	1991 Spring Netting	1991 Summer Netting	1991 Hook and Line
11/1/88 165 mm 10,799 AD Clip	3 N/A	2 256 mm	0	3 327 mm	0	2 360 mm	7 382 mm	0
2/8/89 210 mm 8,391 RV Clip	14 253 mm	14 266 mm	8 286 mm	4 350 mm	1 375 mm	1 392 mm	3 402 mm	0
5/22/89 322 mm 1,909 Green Tag	16 352 mm	44 363 mm	0	10 395 mm	5 392 mm	1 452 mm	3 473 mm	7 466 mm
3/22/90 339 mm 1,304 Blue Tag			0	8 382 mm	2 422 mm	0	1 374 mm	0
8/23/90 121 mm 7,500/50,000 AD Clip			0	2 119 mm	2 146 mm	0	0	0
5/30/91 369 mm 1,556 Blue Tag						1 350 mm	27 383 mm	100 N/A

KEY

	Year and Type of Sampling
Stocking Date Average Length Number Stocked Mark	Number Caught Average Length

Figure 3. Summary of recaptured fish from each marked cohort of Arctic char stocked into Harding Lake, 1988-1991 (sampling events listed as hook and line include both tag returns from the public as well as data gathered during experimental hook and line sampling).

cohort stocked in May 1989, 10 were from the cohort stocked in March 1990, and four were from the cohort stocked in August 1990 (reared in net-pens). In 1989, five Arctic char were from the cohort stocked in October 1988, 28 were from the cohort stocked in February 1989, and 60 were from the cohort stocked in May 1989.

Rainbow Trout:

Twenty-nine rainbow trout were captured in the littoral zone, one was captured in the benthic zone and none were captured in pelagic zone (Table 3). The median catch of rainbow trout per net-night (and range) in the littoral zone was 0 (0 to 5 fish) and the median catch per net-night (and range) in the benthic zone was 0 (0 to 1 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

During 1991, 15 marked rainbow trout were captured during this and other studies of fish in Harding Lake (Appendix A). One rainbow trout was from the two cohorts of large fish (125 and 177 g) stocked in August 1990. Five rainbow trout had adipose fin clips but had no tags. These fish were also from the two cohorts of large fish stocked in 1990 because no other cohort of rainbow trout received adipose fin clips by spring 1991. One additional marked fish from these two cohorts was caught by an angler. Ten rainbow trout were from the cohort stocked in August 1991. No marked rainbow trout were captured from the two cohorts of small fish (3.2 and 6.9 g) stocked in August 1990. In 1990, 64 marked rainbow trout were captured from the two cohorts of large fish stocked in August 1990.

Arctic Grayling:

Two-hundred-thirty-two Arctic grayling were captured in the littoral zone but none were captured in the benthic or pelagic zones (Table 3). The median catch per net-night (and range) for the littoral zone was 3.5 (0 to 232 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

During 1991, one marked Arctic grayling was captured while sampling fish in Harding Lake (Appendix A). This fish was from the cohort of large Arctic grayling (100 g) stocked in August 1991.

Northern Pike:

Twenty-six northern pike were captured in the littoral zone, five were captured in the benthic zone, and three were captured in the pelagic zone (Table 3). The median catch per net-night (and range) in: (1) the littoral zone was 0 (0 to 4 fish); (2) the benthic zone was 0 (0 to 2 fish); and, (3) the pelagic zone was 0 (0 to 2 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

Burbot:

One burbot was captured in the littoral zone, 17 were captured in the benthic zone, and 20 were captured in the pelagic zone (Table 3). The median catch per net-night (and range) in: (1) the littoral zone was 0 (0 to 1 fish);

(2) the benthic zone was 0 (0 to 4 fish); and, (3) the pelagic zone was 0 (0 to 4 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

Lake Trout:

One lake trout was captured in the littoral zone, nine were captured in the benthic zone, and none were captured in the pelagic zone (Table 3). The median catch per net-night (and range) in: (1) the littoral zone was 0 (0 to 1 fish); and, (2) the benthic zone was 0 (0 to 2 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

Least Cisco:

No least cisco were captured in the littoral zone, 157 were captured in the benthic zone, and 97 were captured in the pelagic zone (Table 3). Catches generally increased with depth in the benthic zone. The median catch per net-night (and range) in: (1) the benthic zone was 2.5 (0 to 30 fish); and, (2) the pelagic zone was 0 (0 to 9 fish; Table 4). Relative abundance was rated sparse in all zones (Table 4).

Proportion of Arctic Char from 1990 Net-Pens

Of 699 Arctic char captured in test nets in September 1991, none were marked fish released from the net-pens in 1990 (Appendix A). Length frequency analysis could not be used to separate the cohort of unmarked fish released from the net-pens from other stocked cohorts (Figure 4). Arctic char released from the net-pens in 1990 and Arctic char stocked from the hatchery in 1990 and 1991 had similar length in September 1991.

Proportion of Age 1 and Age 2 Rainbow Trout in the Population

The proportions of marked rainbow trout that were released from the net-pens in 1990 and 1991 were 0.46 (5,000 of 10,970) and 0.47 (4,406 of 9,406). Of 30 rainbow trout captured in September 1991, 10 (0.33) were marked as being released from the net-pens in 1991 (Age 1). No marked fish were captured that had been released from the net-pens in 1990 (Age 2). The proportion of Age 1 rainbow trout from the 1991 net-pens in the population was 0.71 (SE = 0.18).

Arctic Char Growth

The length frequency distribution of Arctic char captured at Harding Lake during September 1991 showed the population strongly weighted towards fish ranging in size from 151 to 225 mm (Figure 4). There was a second smaller peak around 400 mm.

Lengths of 84 recaptured Arctic char were used to estimate growth rate. Of these, 69 had resided in the lake less than 250 days when recaptured and 15 had resided in the lake for over 450 days when captured (Figure 5). The average gain in length for Arctic char that had resided in the lake for less than 250 days was 0.21 mm-per-day (range was 0.11 to 0.33 mm-per-day; Figure 6). The initial length of these fish ranged from 275 to 450 mm. The

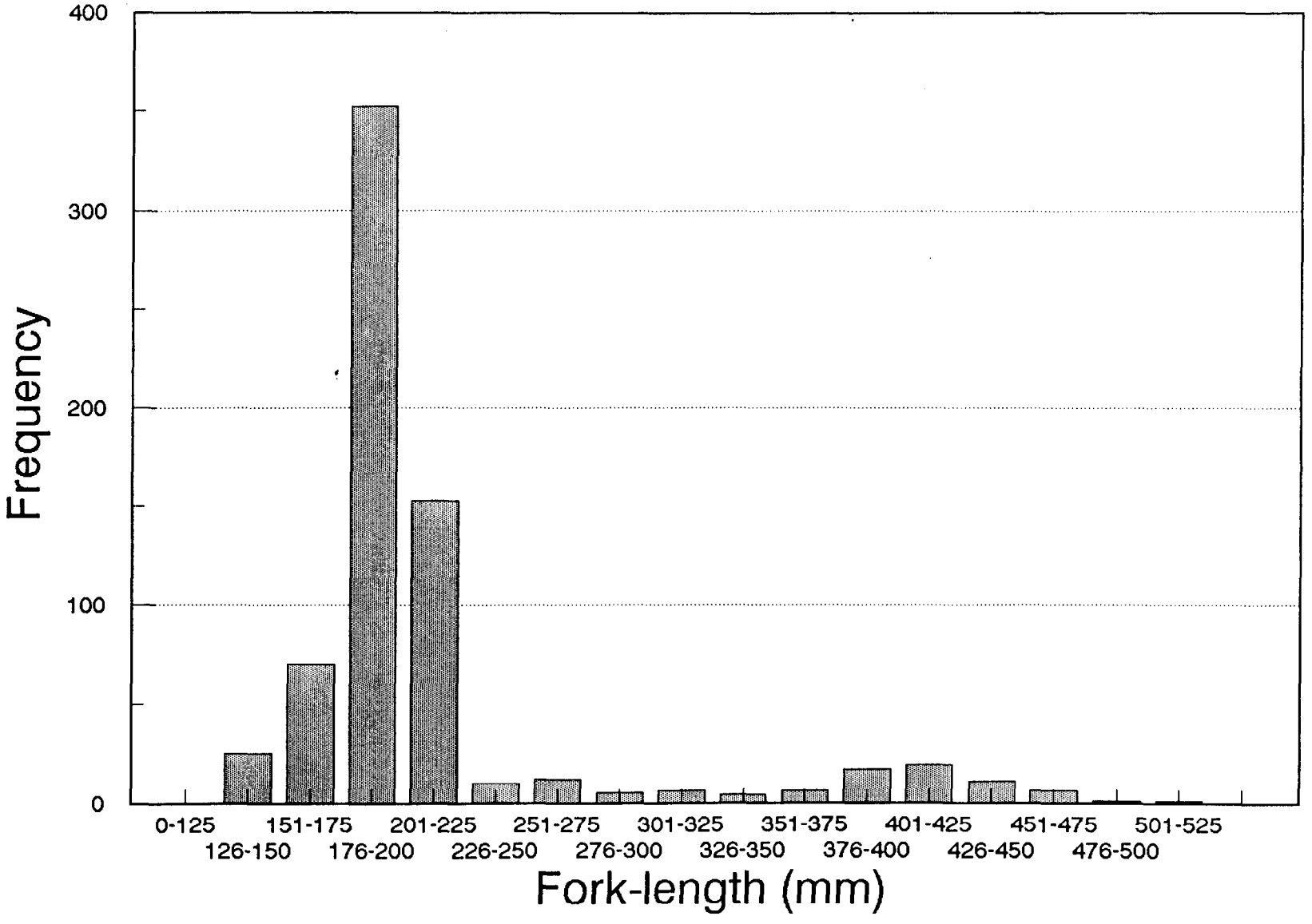

Figure 4. Length frequency distribution of Arctic char captured during test netting at Harding Lake, September 1991.

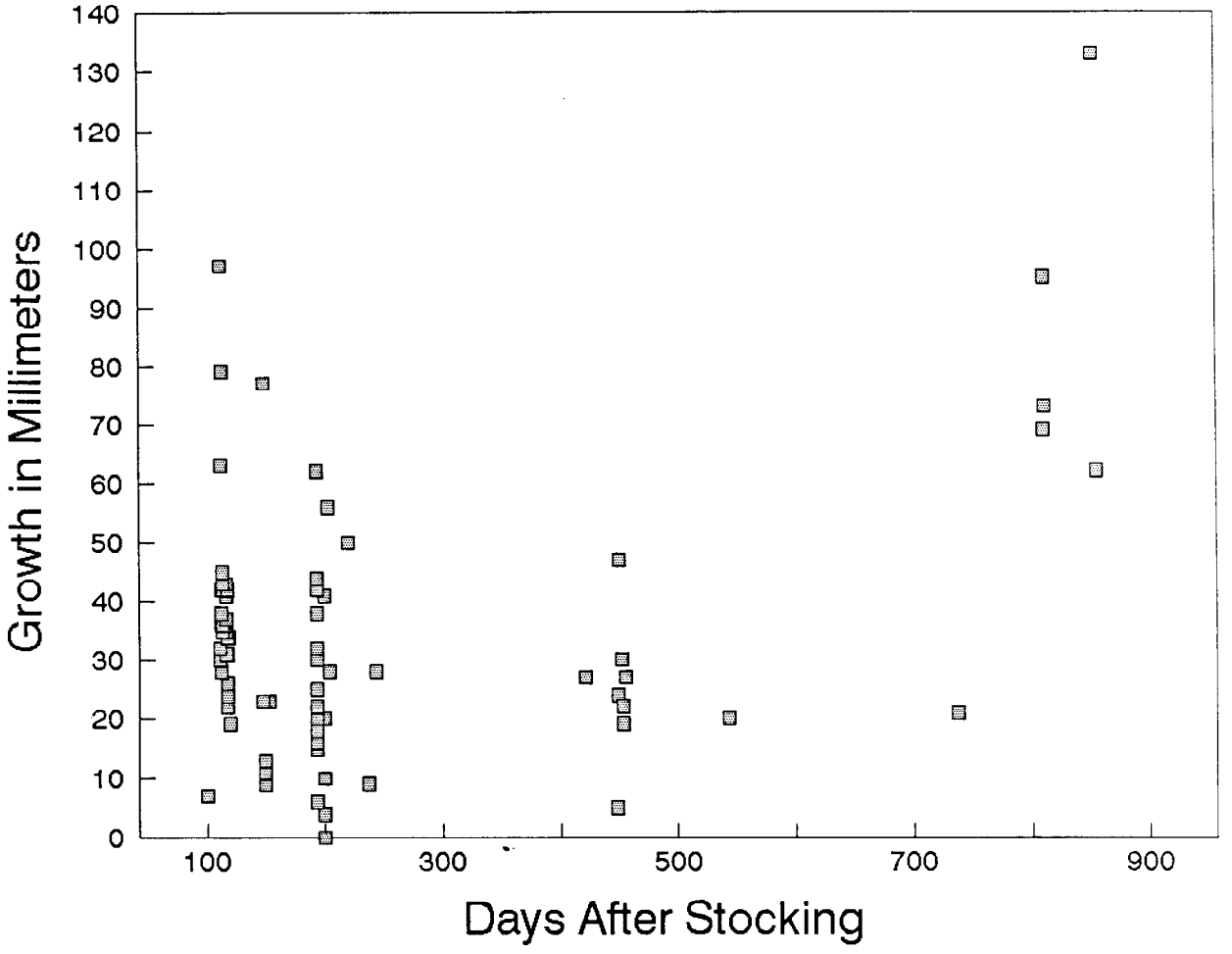

Figure 5. Growth in mm for tagged Arctic char stocked into Harding Lake and recaptured between 95 and 875 days after stocking.

average gain in length for Arctic char that had resided in the lake for over 450 days was 0.07 mm-per-day (range was 0.06 to 0.08 mm-per-day; Figure 7). The initial length of these fish ranged from 275 to 450 mm. When growth was compared to the size of the fish when stocked, Arctic char stocked at 350 mm or larger grew less per day on average than fish stocked at less than 350 mm ($t = 3.90$, $p < 0.01$, $a = 0.05$).

DISCUSSION

Catches of each stocked and naturally reproducing species of fish were usually highest in one or two of the limnological zones probably because of species - specific habitat preferences. Arctic char, burbot, and least cisco were captured in greatest numbers in the pelagic and benthic zones; rainbow trout, Arctic grayling, and northern pike were captured most often in the littoral zone; most lake trout were captured in the benthic zone.

When adjusted for differential fishing effort, catches in 1991 as compared to catches in 1990 increased for Arctic char, Arctic grayling, burbot, and least cisco; catches decreased for rainbow trout; and, there was not much change for northern pike or lake trout. Catches of Arctic char, rainbow trout, and Arctic grayling were probably influenced by the size of the fish when stocked and the elapsed time from when fish were stocked and when test netting occurred. Most of the catch of Arctic char and Arctic grayling in 1991 was comprised of small unmarked fish. These fish were most likely from the 170,000 Arctic char (38 g) and roughly 300,000 Arctic grayling (2.6 to 3.9 g) that were stocked in Harding Lake about three weeks prior to test netting. Because of their size, it is unlikely that these fish were from the cohorts of unmarked fish that were stocked in previous years.

No small rainbow trout were captured in 1991 but small rainbow trout were captured in 1990 (36 of 245; Viavant and Clark 1991a). This also may be a result of size at stocking and the time from when fish were stocked and when test netting occurred. In 1991, rainbow trout (1.8 and 90.6 g) were released seven weeks before the start of test netting. All captured rainbow trout in 1991 were probably from releases of large fish (< 80 g) in 1990 and 1991. In 1990, on the other hand, large (90.0 to 177.0 g) and small (3.2 to 6.9 g) rainbow trout were released three to six weeks prior to test netting. Although small rainbow trout were captured in 1990 (36 of 245) most of the catch in 1990 was comprised of large fish.

These results indicate that large numbers of small fish were captured when stocking occurred just prior to test netting but catches of these fish rapidly decreased as the elapsed time between stocking and test netting increased. This study provides evidence that rainbow trout do not make a significant contribution to the population one year after stocking when the fish were stocked at less than 7 g. The same evidence exists for Arctic grayling stocked at less than 6 g. The absence of fish one year after they were stocked at a small size may be due to low rates of survival or methods used to sample the populations. As these small fish grew, they may have sought habitats that were not effectively sampled by the gear used in these habitats.

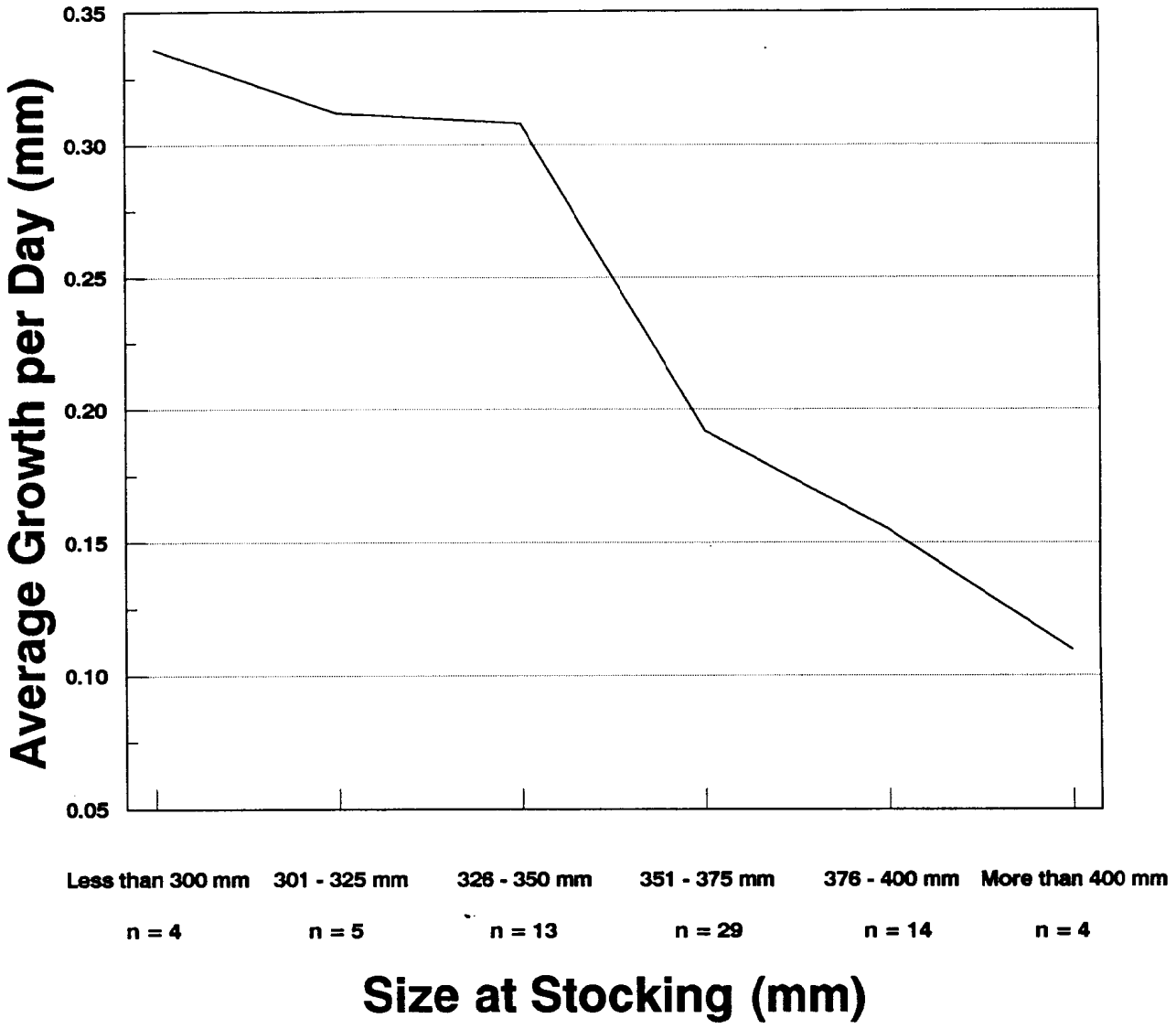

Figure 6. Average growth expressed as mm-per-day for various length classes of tagged Arctic char stocked into Harding Lake and recaptured between 95 and 250 days after stocking.

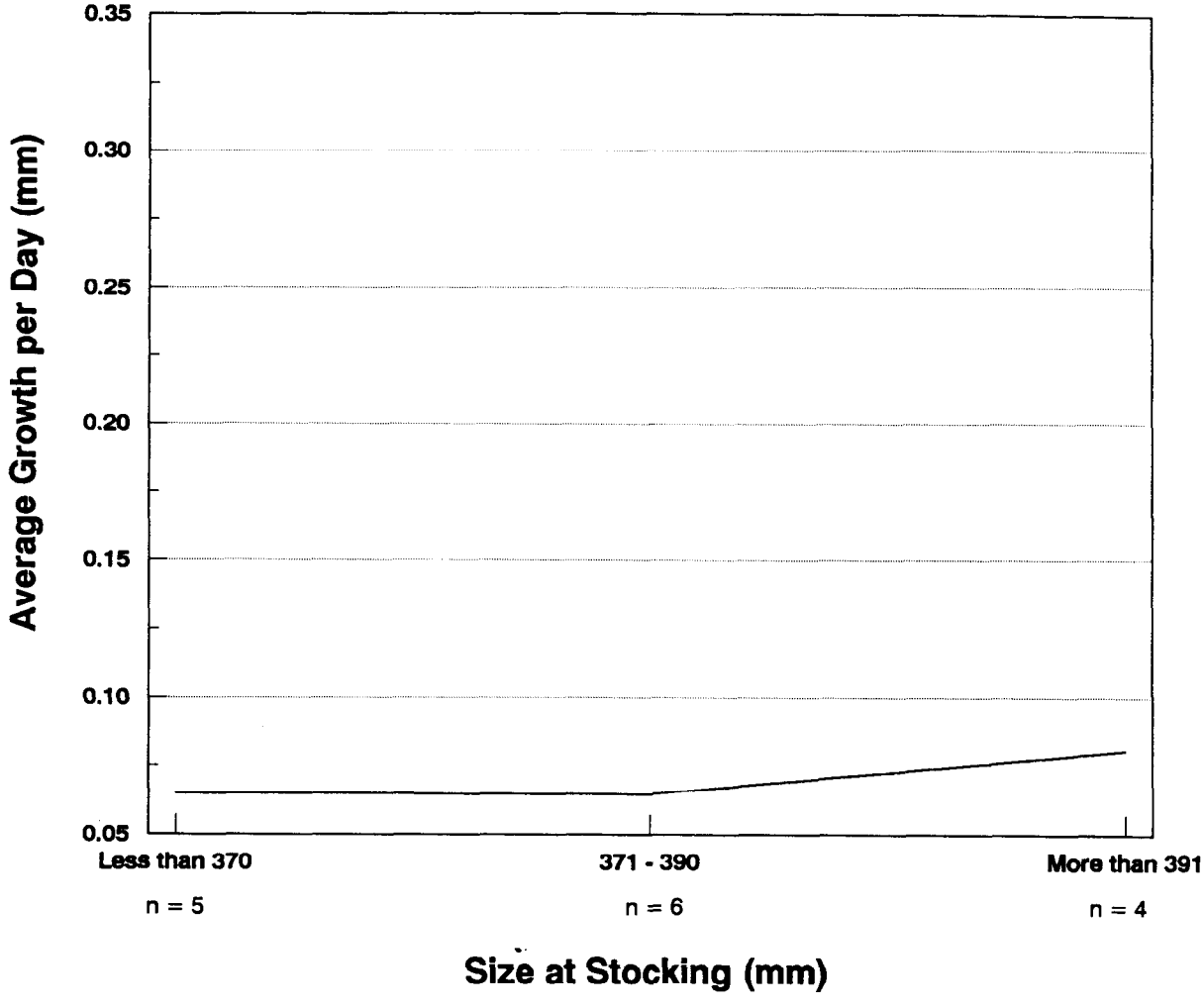

Figure 7. Average growth expressed as mm-per-day for various length classes of tagged Arctic char stocked into Harding Lake and recaptured between 450 and 875 days after stocking.

The size at stocking of rainbow trout (< 7 g or > 80 g) and Arctic grayling (< 6 g or 100 g) used in this study was constrained by sizes available for stocking from the hatchery and pen-rearing programs. As a result, the potential effectiveness of stocking intermediate sized fish is not known.

Since 1988, average size at stocking of various cohorts of Arctic char ranged from 11 to 761 g. Cohorts of marked Arctic char weighing 53 g or larger when stocked have been captured one to two years later. Marked Arctic char stocked at 20 g in 1990 were captured in 1990 but not in 1991. These results indicate that Arctic char stocked at 20 g and smaller did not contribute to the population. Cohorts of Arctic char stocked at about 35 and 50 g were not marked and could not be separated from other unmarked cohorts through length frequency analysis of catches during 1991. In another study, Arctic char were captured during the winter of 1990-1991 that were probably from these two stocking cohorts (Viavant and Clark 1991b)

Proportion of Arctic Char from 1990 Net-Pens

In 1991, 15% of the Arctic char (7,500 of 50,000) released from the net-pens were marked with an adipose fin clip. About 51,300 unmarked Arctic char of a similar size from Clear Hatchery were stocked. This resulted in about 7.4% of the fish of this size being marked. In 1991, 600 Arctic char smaller than 200 mm were captured. Based upon this proportion, 44 of these fish should have been marked had post-release survival been equal. These results indicate that survival was low when Arctic char were stocked at 20 g from the 1990 net-pens.

Proportion of Age 1 and Age 2 Rainbow Trout in the Population

Based on the marked to unmarked ratio of rainbow trout stocked in 1991, 21 of the 30 fish captured (10 ÷ 0.47) were released from the net-pens in 1991 (Age 1) and the other nine were either released from the net-pens in 1990 or were from another stocking (Age 2 or older). If these nine fish were from the net-pens in 1990 then four (0.46 X 9) should have been marked. It is likely that these fish were survivors from the stockings of small (< 2 g) rainbow trout in 1988 or 1989.

Arctic Char Growth

The majority of Arctic char captured in the test nets were probably from the introduction of 171,376 sub-catchable (38 g) Arctic char stocked in late August 1991. The other small peak in the distribution at around 400 mm was probably due mostly to introductions of catchable Arctic char in 1989, 1990, and 1991. The middle section of the distribution probably represents survivors of previous introductions of sub-catchable fish.

Growth of tagged Arctic char was inversely related to size at stocking for fish present in the lake for less than 250 days. Baker (1988) and Buklis (1978) reported similar growth (based on initial size) for Arctic char in Aleknagik Lake. The Arctic char stocked into Harding Lake were derived from Lake Aleknagik brood stock. Average growth of Arctic char from various Lake Aleknagik stocks ranged from 0.07 to 0.23 mm for fish initially measured at

between 300 and 450 mm (Baker 1988). These data indicate that growth of Arctic char is similar in Harding Lake and Lake Aleknagik.

The pattern of decreased growth of larger sized fish was not apparent for Arctic char that had been in the lake for 450 days or more. This could be due to the small sample size (15), or the smaller range of sizes at stocking for these groups of fish.

CONCLUSIONS AND RECOMMENDATIONS

The stocking program at Harding Lake has led to increased harvest of both Arctic char and rainbow trout, and while catch versus harvest data are not available for years prior to 1990, the 1990 data show that for every Arctic char or rainbow trout harvested in 1990, two and three more fish respectively, were caught and released. Fishing effort since 1986 has varied without showing a discernable trend.

Capture histories of marked fish indicated that relative survival and growth of Arctic char in Harding Lake stocked at 56 g or larger was acceptable, but relative survival of Arctic char stocked into Harding Lake at 20 g or less was low.

It is likely that the low test netting catch rates of rainbow trout in Harding Lake were due to low stocking densities, and not due to low survival of rainbow trout. The average catch of catchable sized rainbow trout in Harding Lake in fyke traps during September of 1990 was 13.1 fish per net-night. This is higher, but in the same range as the average catch of 7.8 catchable sized rainbow trout caught per net-night in fyke traps fished at Big Lake in October of 1988 (Havens and Alexandersdottir 1990).

There were limited numbers of marked Arctic grayling stocked into Harding Lake. However, absence of unmarked Arctic grayling stocked as fingerlings in 1990 and caught in 1991 indicated that survival of Arctic grayling stocked into Harding Lake at less than 40 g was low.

Based on growth data and on survival information as indicated by catch rates and recapture histories, Arctic char appear to be best suited for the stocking of Harding Lake. While it is unclear what the optimal size of Arctic char is for the stocking of Harding Lake, capture histories of previously stocked cohorts indicate that the size is probably at least 56 g. To more accurately determine the optimal size of Arctic char for the stocking of Harding Lake (based on costs versus benefits), it will be necessary to estimate the relative survival of future stocking cohorts. Because of the small numbers of marked fish recaptured during subsequent netting, it is recommended that a higher proportion of fish be marked prior to stocking.

Because of the apparent lack of 1990 pen-reared rainbow trout in Harding Lake, it is recommended that some changes be made in the rearing of rainbow trout at the net-pens. Rainbow trout started at the net-pens as subcatchables should be placed in the net-pens as early in the season as possible in order to achieve as large a size as possible before release. Because of the low

catches of rainbow trout during test netting, it is recommended that future fishing effort in the littoral zone be at least doubled. Increased catches from such increased fishing effort should allow for better evaluation of the contribution of each stocking cohort.

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APPENDIX A

Appendix A. Number of Arctic char, rainbow trout and Arctic grayling caught, date and method of capture, and type of mark for fish captured at Harding Lake between 1989 and 1991.

Species	Date of Capture	Capture Method[a]	Number Caught	Type of Mark[b]	Size Cohort When Captured
Arctic char	6/89	TR	1	GT	
Arctic char	7/89	TN	97	N	
Arctic char	7/89	TN	14	RV	
Arctic char	7/89	TN	3	AD	
Arctic char	7/89	TN	16	GT	
Arctic char	11/89	TR	29	GT	
Arctic char	12/89	HL	141	N	
Arctic char	12/89	HL	14	RV	
Arctic char	12/89	HL	2	AD	
Arctic char	12/89	HL	1	GT/AD	
Arctic char	12/89	HL	3	GT/LV	
Arctic char	12/89	HL	5	GT/LP	
Arctic char	12/89	HL	1	GT/UC	
Arctic char	12/89	HL	4	GT/NC	
Arctic char	1-2/90	CC	23	N	
Arctic char	1-2/90	CC	8	RV	
Arctic char	6-9/90	TN	14	N	> 299 mm
Arctic char	6-9/90	TN	57	N	200 to 299 mm
Arctic char	6-9/90	TN	104	N	< 200 mm
Arctic char	6-9/90	TN	4	RV	
Arctic char	6-9/90	TN	3	AD	> 300 mm
Arctic char	6-9/90	TN	2	AD	< 200 mm

-continued-

Appendix A. (Page 2 of 3).

Species	Date of Capture	Capture Method[a]	Number Caught	Type of Mark[b]	Size Cohort When Captured
Arctic char	6-9/90	TN	3	GT/AD	
Arctic char	6-9/90	TN	3	GT/NC	
Arctic char	6-9/90	TN	1	GT/RV	
Arctic char	6-9/90	TN	2	GT/LV	
Arctic char	6-9/90	TN	1	GT/UC	
Arctic char	6-9/90	TN	8	BT/AD	
Arctic char	11/90	TR	4	GT	
Arctic char	12/90	HL	41	N	
Arctic char	12/90	HL	1	GT	
Arctic char	12/90	HL	1	RV	
Arctic char	12/90	HL	2	AD	< 200 mm
Arctic char	5/91	TN	2	N	
Arctic char	5/91	TN	1	RV	
Arctic char	5/91	TN	1	AD	
Arctic char	5/91	TN	1	GT/LP	
Arctic char	5/91	TN	1	BT/AD	
Arctic char	6-8/91	TR	100	BT	
Arctic char	6-8/91	TR	7	GT	
Arctic char	9/91	TN	25	N	≥ 300 mm
Arctic char	9/91	TN	634	N	< 300 mm
Arctic char	9/91	TN	3	RV	
Arctic char	9/91	TN	7	AD	≥ 300 mm
Arctic char	9/91	TN	3	GT/NC	

-continued-

Appendix A. (Page 3 of 3).

Species	Date of Capture	Capture Method[a]	Number Caught	Type of Mark[b]	Size Cohort When Captured
Arctic char	9/91	TN	28	BT/AD	
Rainbow trout	6-9/90	TN	64	BT/AD	
Rainbow trout	6-9/90	TN	177	N	≥ 150 mm
Rainbow trout	6-9/90	TN	12	N	< 150 mm
Rainbow trout	5/91	TN	9	N	
Rainbow trout	5/91	TN	5	AD	
Rainbow trout	5/91	TN	1	BT/AD	
Rainbow trout	6-8/91	TR	1	BT/AD	
Rainbow trout	9/91	TN	10	RV	
Rainbow trout	9/91	TN	20	N	
Arctic grayling	6-9/90	TN	55	N	< 150 mm
Arctic grayling	9/91	TN	1	GT	
Arctic grayling	9/91	TN	534	N	< 150 mm

[a] TN = test netting, HL = experimental hook and line sampling, TR = tag return (from anglers), CC = creel census sampling

[b] N = no mark, AD = adipose clip, RV = right ventral clip, LV = left ventral clip, LP = left pectoral clip, TC = top caudal clip, BT/__ = blue tag with fin clip, GT/__ = green tag with fin clip, GT/NC = green tag with no fin clip, GT = Green tag with unknown clip.

APPENDIX B

Appendix B. Number of Arctic char, rainbow trout and Arctic grayling stocked, size at stocking, type of mark, and number marked, Harding Lake, 1988 - 1991.

Species	Stocking Date	Number Stocked	Size at Stocking (g)	Number Marked	Type of Mark[a]	Pen Reared
Arctic char	10/1/88	20,021	50.0	0		No
Arctic char	11/1/88	10,799	53.0	All	AD	No
Arctic char	2/8/89	8,391	122.0	All	RV	No
Arctic char	5/22/89	380	739.0	All	GT/AD	No
Arctic char	5/22/89	389	739.0	All	GT/LV	No
Arctic char	5/22/89	389	739.0	All	GT/LP	No
Arctic char	5/22/89	389	739.0	All	GT/TC	No
Arctic char	5/22/89	362	739.0	All	GT/NC	No
Arctic char	7/18/89	12,365	20.0	0		No
Arctic char	10/17/89	38,696	108.0	0		No
Arctic char	3/22/90	1,304	654.0	All	BT/AD	No
Arctic char	8/23/90	50,000	20.0	7,500	AD	Yes
Arctic char	8/30/90	32,733	35.5	0		No
Arctic char	9/14/90	18,561	54.0	0		No
Arctic char	5/30/91	1,556	761.0	ALL	BT/AD	No
Arctic char	7/19/91	106,050	11.0	0		No
Arctic char	8/30/91	171,376	37.7	0		No
Rainbow trout	8/20/88	248,658	1.3	0		No
Rainbow trout	8/2/89	148,836	1.4	0		No
Rainbow trout	8/14/89	44,921	1.0	0		No
Rainbow trout	7/19/90	1,019	110.0	0		No
Rainbow trout	7/24/90	100,000	1.7	0		No

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Appendix B. (Page 2 of 2).

Species	Stocking Date	Number Stocked	Size at Stocking (g)	Number Marked	Type of Mark[a]	Pen Reared
Rainbow trout	8/26/90	9,970	125.5	4,000	BT/AD	Yes
Rainbow trout	8/26/90	49,912	3.2	12,500	LV	Yes
Rainbow trout	8/28/90	99,907	6.9	25,000	LV	Yes
Rainbow trout	8/28/90	1,000	177.0	All	BT/AD	Yes
Rainbow trout	7/24/91	173,800	1.8	0		No
Rainbow trout	8/1/91	9,406	90.6	4,406	RV	Yes
Arctic grayling	6/17/88	1,169,806	0.02	0		No
Arctic grayling	6/7/90	54,200	0.02	0		No
Arctic grayling	8/28/90	2,400	3.9	0		Yes
Arctic grayling	8/29/90	29,972	5.2	0		Yes
Arctic grayling	6/8/91	697,178	0.02	0		No
Arctic grayling	8/25/91	71	100.0	All	GT	Yes
Arctic grayling	8/27/91	186,800	3.9	0		Yes
Arctic grayling	8/28/91	150,200	2.6	0		Yes
Arctic grayling	9/20/91	43,397	5.3	0		No

[a] N = no mark, AD = adipose clip, RV = right ventral clip, LV = left ventral clip, LP = left pectoral clip, TC = top caudal clip, BT/AD = blue tag with adipose fin clip, GT/__ = green tag with fin clip (AD, LV, LP, TC), GT/NC = green tag with no fin clip.

APPENDIX C

Appendix C. Abundance criteria by species as applied to catch-per-net-night statistics for Harding Lake.

Species	Abundance Criteria for Average Catch Per Net-Night Data[a]		
	Sparse	Moderate	Abundant
Arctic char	0 to 1	2 to 6	more than 6
Arctic grayling	0 to 5	5 to 20	more than 20
Burbot	0 to 1	2 to 6	more than 6
Lake trout	0 to 1	2 to 6	more than 6
Least cisco	0 to 6	7 to 30	more than 30
Northern Pike	0 to 4	5 to 10	more than 10
Rainbow trout	0 to 5	6 to 20	more than 20

[a] These criteria represent the arithmetic average of values given by regional sport fish biologists for catches from a standard experimental gill-net.