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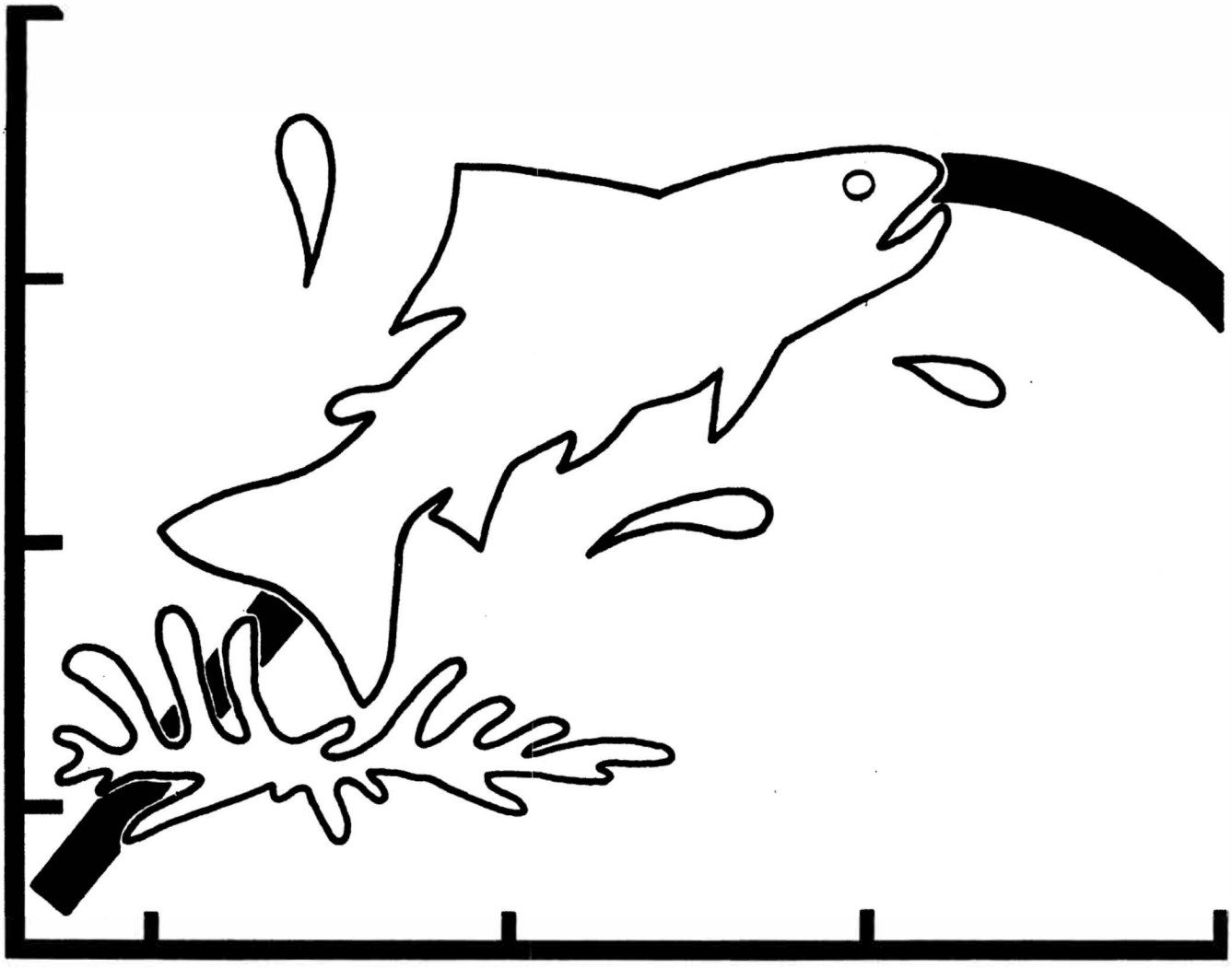

Michigan Department of
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Number 91 - 8
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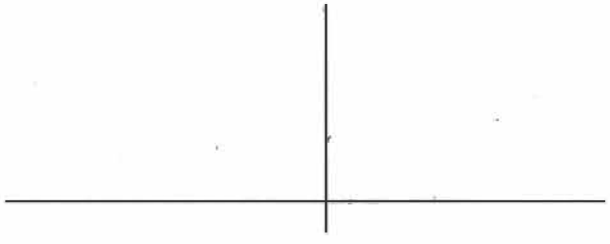

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

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GULL LAKE AS A BROODSTOCK SOURCE FOR LANDLOCKED ATLANTIC SALMON

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Gull Lake as a Broodstock Source for Landlocked Atlantic Salmon

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Abstract.—The use of Gull Lake as a broodstock source for landlocked Atlantic salmon (*Salmo salar*) began in 1986. Eggs from mature salmon were collected for the first time in the fall of 1988. A creel survey was conducted on Gull Lake during the summer of 1986 and the winter and summer of 1987. Results indicated a significant catch rate and harvest of salmon, especially in the winter. In order to obtain enough eggs for the hatchery program, fishing regulations for Gull Lake were changed twice to reduce salmon harvest. The current regulations are a 25.0-inch minimum size limit, one fish/day bag limit, with fishing permitted from the last Saturday in April through September 30. Protection of salmon, at least to time of first spawning, now appears adequate. Length of age of Gull Lake landlocked salmon far exceeded that of salmon populations in Maine. The length-weight relationship, spawning periodicity, and age at spawning were all similar to that of the Maine landlocked salmon. A stocking rate of approximately 12 spring yearlings/acre is recommended to meet the objectives of the program. With the appropriate stocking rate and regulations, Gull Lake can provide enough eggs to support Michigan's landlocked Atlantic salmon stocking program and enough catchable-size fish to support a substantial and unique sport fishery.

In 1873, one of the first official acts of the newly established Michigan Fish Commission was planting 21,250 ocean-strain Atlantic salmon (*Salmo salar*) into a number of lakes and streams throughout lower Michigan. Landlocked-strain Atlantic salmon from Sebec Lake, Maine were first planted into Dowagiac Creek, Cass County, in 1874 (Jerome 1875). A total of about 775,000 Atlantic salmon were planted in Michigan waters between 1873 and 1932, but no self-sustaining populations were established (Latta 1974). More recent attempts to introduce Atlantic salmon began in 1972, when the ocean-strain was planted in the Boyne and Au Sable rivers.

The State's modern landlocked Atlantic salmon program began in 1974, at Gull Lake, Kalamazoo County. This lake was chosen because of its excellent water quality, proximity to Wolf Lake State Fish Hatchery, and the presence of Michigan State University's Kellogg Biological Station on the lake. Gull Lake is now one of five Michigan lakes which contain landlocked-strain Atlantic salmon, hereafter, referred to simply as salmon.

Erratic stockings of salmon occurred in Gull Lake from 1974-78 (Table 1). Other Division responsibilities and a lack of hatchery space due to remodeling interrupted the stocking program in 1979.

During the 1980s, it was decided that a broodstock lake for salmon was needed. Gull Lake was selected because of its proven performance with salmon in the 1970s. Strong public support for the program also existed. This paper presents the results of the first 3 years of salmon broodstock collection efforts at Gull Lake and the results of a creel survey conducted in 1986 and 1987.

Study Site

Gull Lake is located in the southwestern Lower Peninsula of Michigan. The lake's 2,030 acres straddle the Barry and Kalamazoo county line. Classified by limnologists as mesotrophic (perhaps slightly oligotrophic), Gull Lake has provided an excellent two-story fishery for decades.

A healthy mix of bluegill (*Lepomis macrochirus)*, yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*), smallmouth bass (*Micropterus dolomieu*), and largemouth bass (*Micropterus salmoides*) can be found along with a well-accepted rainbow trout (*Oncorhynchus mykiss*) stocking program. Lake trout (*Salvelinus namaycush*) have also been stocked successfully in the past (Table 1).

The lake's deepest depression (110 feet) is located almost directly in the middle of the lake, and another depression (108 feet) is located at the north end. The shoal areas of Gull Lake comprise approximately 30% of the total surface area.

The water quality of Gull Lake is excellent. Secchi disc readings in May of 1989 were as deep as 40 feet. In August of 1989, the thermocline was between 29 to 37 feet and dissolved oxygen levels remained above 5 ppm down to 65 feet. Water temperatures ranged from 74°F at the surface to 46°F at the bottom. Alkalinities ranged from 116-145 ppm (moderately hard), while pH readings were alkaline (8.6-8.8). Water quality parameters have changed little over the years, except for increased dissolved oxygen and greater water clarity. These two parameters have improved because of improved wastewater treatment. A wastewater treatment plant was built and began operating in the early 1980s.

Several tributaries flow into Gull Lake, although all are quite small. The largest is Prairieville Creek, located at the north end of the lake. This designated trout stream flows at about 5-10 ft^3/s and is the main tributary that spawning salmon utilize for their fall run.

Methods

To develop Gull Lake as a broodstock source, spring yearling salmon were planted in Prairieville Creek or at its mouth annually since 1986 (Table 1). Most of these fish were marked with an identifying fin clip (Table 2). The stocking rate goal has been 12 spring yearlings per surface acre.

Spawning salmon were collected in late October through mid-November by deploying a removable weir in Prairieville Creek (1988) and setting trap nets near the mouth of Prairieville Creek (1988, 1989, and 1990). Collection methods were modified as more was learned about the characteristics of the run.

In 1989 and 1990, lengths, weights, and scale samples were collected from all salmon. Only total lengths were recorded in 1988. All salmon captured and returned to the lake received a clip on the top caudal fin to identify recaptures. Ages of salmon were determined by fin clips applied before stocking (Table 2). Scales were examined for spawning checks to assess the amount of repeated spawning.

A creel survey was conducted during June, July, and August of 1986, January and February of 1987, and April through August of 1987. A randomized schedule was developed for both interviews and counts according to methods of Ryckman and Lockwood (1985). Anglers were interviewed only at the end of their trip, where upon the survey clerk recorded the size and number of species caught, the number of salmon caught and released in winter, and the number of bass caught and released in the summer (1986). Lengths, weights, scale samples, and a few stomach samples of major game fishes

were also obtained for analysis. Data were analyzed using a computer program developed by Rick Clark and Jim Ryckman at the Institute for Fisheries Research in Ann Arbor.

Results

Broodstock Collections - 1988

Salmon were first discovered ascending Prairieville Creek in 1988, on November 7, when 18 salmon and 15 redds were identified. On November 9, a weir was installed to collect adult salmon. A 3-inch rainfall that night washed the weir out. It was reinstalled on November 10, and reinforced with sandbags. The weir was operated on a 24-hour basis until November 21. At that time, three standard trap nets (6 ft x 3 ft, 1½-inch mesh) were set near the creek mouth in an attempt to collect adults that had not yet entered the creek. These nets were fished two nights only.

One hundred thirty mature salmon, ranging in size from 18.3 to 26.3 inches were collected and sent to Wolf Lake State Fish Hatchery for spawning (Figure 1). Males averaged over 1 inch larger than females (Tables 3 and 4). An additional 90 salmon both immature and spent, were handled. No biological data was collected from these additional fish except for sex ratio (1:1, male:female). The observed sex ratio of all individual fish handled was 1:2.

Salmon collected at the weir exhibited two major peaks in abundance over time (November 12 and November 17) before declining sharply (Figure 2). We removed the weir on November 22 after failing to capture any mature females for three consecutive days.

Ninety-seven of the salmon sent to the hatchery were ripe females. Ninety-two females were spawned at the hatchery on November 18, producing a total of 235,913 eggs (2,564 eggs/female). Two females died before spawning, two were spent, and one was immature.

Two-year-old salmon made up 11.8% of the fish collected, while 3 year olds accounted for 88.2% (Table 5). The return of age-2 salmon represented 0.12% of the 1987 salmon plant, whereas 0.83% of the 1986 plant returned as age 3.

Three fin-clip combinations were recorded in the catch, adipose (AD), right ventral+adipose (RV+AD), and left ventral (LV). These fish were spring fingerlings stocked in Prairieville Creek below Mud Lake, a small natural lake about 0.75-mile upstream from Gull Lake. The stocking rates and years were 21,356 AD in 1986, 11,966 RV+AD in 1987, and 11,966 LV in 1987 (Table 2). No salmon were recorded from an experimental plant of 2,000 9-inch spring yearlings (right pectoral clip-RP) made in Prairieville Creek upstream of Mud Lake on April 14, 1986. No salmon were recorded from a plant of 2,000 spring fingerlings (right ventral clip-RV) made in a small tributary to Mud Lake on June 20, 1986.

In 1988, movement out of the lake through the Gull Lake outlet accounted for 11.3% of the entire run. No attempt was made to collect salmon in the Gull Lake outlet.

Broodstock Collections - 1989

One hundred eighty-five salmon were collected in trap nets in the fall of 1989. They ranged in size from 10.5-32.0 inches (Figure 3). As in 1988, mature males averaged about 1 inch larger than mature females of the same age (Tables 3 and 4). Immature salmon of all ages were considerably smaller than mature salmon. The sex ratio was 1:2.1 (male: female).

Trap netting occurred from October 18 through November 9, 1989. The highest catch of mature adults (34) occurred on October 18 (Figure 4). The highest total catch, including recaptured males and immature fish, occurred on October 22. Only one mature adult was collected after October 30. Movement down the outlet of Gull Lake was minimal (five fish), and no fish were observed in Prairieville Creek upstream of nets.

Sixty-eight mature females and 32 mature males were sent to Wolf Lake State Fish Hatchery for spawning. Only 17 females and 9 males survived to egg-take. The other

salmon developed severe fungal infections and died before spawning. Surviving females were ripe by November 12 and produced 44,393 eggs. They averaged 2,611 eggs/female compared to 2,564 eggs/female in 1988.

The 1989 run was mostly 3-year-old salmon (68%) as it was in 1988. One-year-old males accounted for 6.5% of the total run of mature salmon (Table 5). The return of age-2 salmon represented 0.02% of the 1988 salmon plant, whereas 0.30% of the 1987 plant returned as age 3. Age-4 salmon accounted for a 0.13% return on the 1986 plant.

The 1989 stocking was approximately 50% RP clipped, and 50% without a clip (Table 2). This occurred because fish were subjected to excessive stress due to a problem with furunculosis. The clipped half of the 1989 plant were stocked in Prairieville Creek just below Mud Lake. The unclipped half were stocked in Gull Lake proper. Eighty-seven percent of this 1989 plant returning to spawn were unclipped.

Spawning checks on scales revealed much variability in spawning and maturation schedules (Table 6). Nine salmon had spawned once and then remained immature for 1 or 2 years. Six salmon spawned at least two consecutive years, while three salmon matured every other year. One salmon spawned at ages 2 and 3, and did not spawn at age 4. Just over 75% of the 3-year-old salmon we handled were spawning for the first time. Almost 50% of the 4-year-old salmon were also on their maiden spawning run. Eleven percent of age-3 salmon had spawned at least once, and 35% of age-4 salmon had spawned at least once (Table 6). One fish was spawning for its third time. Most repeat spawners were males.

Broodstock Collections - 1990

Mature male salmon were observed ascending Prairieville Creek on November 1. Six trap nets were set on November 7 in the same locations as in 1989. Netting occurred later because the hatchery did not want to receive and hold brood salmon any longer than necessary. Three hundred fourteen salmon were collected during trap-netting operations from November 8 through November 13. They ranged in size from 11.8 to 25.9 inches (Figure 5). Two-year-old mature males averaged 1 inch larger than 2-year-old females (Tables 3 and 4). Unlike 1989, immature salmon were either larger or the same size on average as mature salmon in 1990. Two year olds comprised 91% of the 1990 run. Eighty four percent of these originated from the lake stocking in 1989. As in 1989, 1 year olds accounted for 6.5% of the run (Table 5). The return of age-2 salmon represented 1.08% of the 1989 plant, whereas all older salmon returns were less than 0.01%.

The highest total catch of mature adults occurred on November 8 (Figure 6). The catch rate of "new" salmon declined very quickly. The nets were removed on November 13. During the last 3 days of netting only four mature 2-year-old females were collected.

Forty mature females and 23 mature males were sent to Wolf Lake State Fish Hatchery for spawning. For the first time more mature males were captured than were needed. At time of capture, 40% of the mature females were running eggs. The first eggs were spawned on November 15, when 88% (35) of the females were ready. The remaining five females were spawned on November 17. The total number of eggs collected was 69,150. Eggs per female was 1,725 which was significantly lower than 1988 and 1989. However, females were primarily 3 year olds in 1988 and 1989, while 98% were 2-year-old females, in 1990.

Growth and Maturity

Salmon in Gull Lake grow quite rapidly, with most fish exceeding 21 inches in length by their third year (Table 7). The average length at age in the fall spawning run exhibited by Gull Lake salmon was above the average lengths reported in Maine (although there is about a 6 months difference in each age group), as Maine data are back calculated on spring lengths. The relationship between length and weight of Gull Lake salmon was calculated based on a sample of 481 fish

collected in 1989 and 1990 (pooled). A least squared regression gave the following equation.

$$Log_{10}(W) = -3.220 + 2.781\ Log_{10}(L),$$

where W was weight in pounds and L was length in inches. No comparable data in this format could be found in the literature. However, using a graph of data collected from Maine (Warner and Havey 1985), I was able to compare our data (length versus weight) to theirs (Figure 7). The relationships were very similar except at larger sizes Gull Lake salmon were slightly lighter than Maine salmon.

In Gull Lake, most males were sexually mature by age 2 (Table 8). Some males also spawned as precocious 1 year olds. No females matured at age 1, but most were mature by age 3 (Table 9). Mature salmon in Gull Lake did not necessarily spawn every year. Both sexes were observed skipping spawning after spawning the previous year. This same phenomenon also has been reported in Maine (Warner and Havey 1985). Unfortunately, the low number of salmon stocked in 1988 severely limited the information that could be gained, concerning repeat spawning. This year class virtually disappeared by 1989, and has produced a significant gap in the data collected.

Creel Survey

During 1986, a creel survey was conducted from June through August. An estimated 20,065 (±3,356) hours of effort (9.9 h/acre) was expended for all species (Appendix 1). Angler trips numbered 4,402 (±660) for the same period. Although salmon had only been in the lake since April, anglers still experienced fairly good catches. Catch per hour (CPH) was estimated at 0.04 (±0.02) salmon. A total of 855 (±310) salmon were estimated to have been harvested. Thus salmon accounted for 4% of the total catch by number of all species at Gull Lake for the period. Rock bass, bluegill, largemouth bass, and yellow perch accounted for almost 90% of the rest of the harvest. These estimates were for boat fishing activity only. Shore fishing activity was negligible.

Fishing regulations were changed on September 15, 1986 to give more protection to salmon. Under the old regulations, anglers were allowed five salmon/day, with a 10-inch minimum size. This was changed to two salmon/day, with an 18-inch minimum size limit. The season remained the same; the last Saturday in April through September 30.

A creel survey was conducted in January and February of 1987. A total of 5,458 (±2,075) fish (all species) were harvested by ice anglers, including 1,150 (±580) illegally kept (out of season) salmon (Appendix 2). Another 13,583 (±7,284) salmon were estimated to have been caught and released. Salmon comprised 21% of the total harvest. Yellow perch, bluegill, rainbow trout, and northern pike (*Esox lucius*) contributed to the remainder of the harvest. A total of 12,073 h (±3,348) of angling was generated during these 2 months (5.9 h/acre). Anglers completed 2,966 (±860) trips. CPH for caught-and-released salmon was 1.1251 (±0.6792).

A creel survey conducted during spring and summer of 1987 estimated a total of 52,414 (±3,484) anglers hours (boat and shore) expended for all species (25.8/acre). A total of 2,222 (±1,792) salmon was harvested for a CPH of 0.04 (±0.01). Anglers generated 10,809 (±770) fishing trips. As in 1986, rock bass, bluegill, largemouth bass, and yellow perch accounted for just over 90% of the total harvest (Appendix 3).

Discussion

Stockings, Returns, and Regulations

Fall returns of salmon from Gull Lake to Prairieville Creek have been variable over the past 3 years. Stocking rates at Gull Lake are quite high when compared to salmon lakes in the East Coast region. When this program was started, it was believed that the rate of 12 salmon/acre would be sufficient to provide both broodstocks and fishery needs. Maine typically stocks its salmon lakes with the same

size and age (spring yearlings) fish as Michigan does, but only up to two fish/acre (Warner and Havey 1985). These are considered maintenance stockings in Maine, and this rate is used even when predation and/or competition is considered intense. New York's major broodstock lake (Little Clear Pond) is stocked with three spring yearlings/acre. (P. Hulbert, New York State Department of Environmental Conservation, personal communication). New Hampshire lakes are also routinely stocked with spring yearlings at the rate of about two/acre (Seamans and Newell 1973). It should be mentioned that East Coast broodstock lakes usually have very restrictive fishing regulations or no fishing at all.

The first 3 years of salmon stocking occurred in Prairieville Creek. During 1989, furunculosis problems prompted stocking directly into the lake. Returns of salmon from lake stocking appeared greater than those from stream stocking. East Coast states also stock salmon directly into the lake and receive good returns. It appears that these fish do not need to be imprinted to the "natal" stream. Subsequent plants will be made directly into Gull Lake.

Salmon growth and survival in Gull Lake was good despite the absence of one of their more traditional food items, rainbow smelt (*Osmerus mordax*). Very limited stomach analysis conducted through the creel survey on Gull Lake indicated salmon ate mayfly nymphs, small bluegills, yellow perch, and minnows. By contrast, Havey (1980) found that growth and yield of salmon in a Maine pond was dependent on abundance of rainbow smelt. Stocking rates in excess of three salmon per acre led to reductions in smelt populations and salmon growth in the pond. Perhaps, salmon in Gull Lake would grow and survive better if smelt were present, but they have displayed adequate growth and survival on the more diversified diet.

The 1987 creel survey showed that salmon were becoming highly vulnerable to fishing. Local fishing techniques were quite effective, and more people were targeting salmon than previously. Winter catch rates at Gull Lake were high, as was shown in the winter creel survey of 1987. Angler catches of salmon through the ice were 16.7 times greater than the best Maine ice fishing catches (Warner and Havey 1985). Maine biologists concluded that ice fishing catch per hour was less than half the statewide average catch per hour for open-water fishing. Based on this, they believed that ice fishing (where permitted) would not be detrimental to the salmon population. Gull Lake data shows this would not be true in Michigan. However, summer CPH in Gull Lake (0.04 salmon/h harvested) was similar to Maine's fishery, which averaged 0.059 salmon/h harvested for 10 lakes, (Warner and Havey 1985).

Gull Lake also received considerably more fishing pressure than Maine salmon lakes. Havey and Andrews (1973) found an average angler pressure of 3.7 h/acre in Schoodic Lake for a 7-year period. Warner and Havey (1985) concluded that a typical large Maine lake receives 2 to 4 angler h/acre per year. I found 9.9 to 25.8 h/acre in Gull Lake.

Considering the increasing vulnerability of salmon and the high fishing effort found at Gull Lake, I believe the more restrictive fishing regulations (two salmon/day bag limit and 18-inch minimum size limit) imposed in 1986 were justified. Furthermore, because the average salmon in Gull Lake was not mature until obtaining a length of over 22 inches, even more restrictive regulations were recommended and adopted in 1991. These new regulations allow harvest of one salmon/day with a 25-inch minimum size limit. The season length was not changed. I believe regulations are now adequate to protect the broodstock program. They also promote salmon as a trophy fish and allow a reduction in stocking rate, as more fish should survive to maturity. The stocking rate was scheduled to decreased to nine spring yearlings per acre in 1991, but was changed to 13 fall/fingerlings per acre due to continuing furunculosis problems at the hatchery.

Spawning Run Composition

Unlike Pacific salmon, Atlantic salmon can spawn more than once. Techniques have been developed to determine from scales the years in which fish participate in spawning (Myers and Hutchins 1987; Seelbach and Whelan 1988). This provides important information for the manager who needs to be able to estimate the size of the spawning run and strike a balance between stocking rates and mortality (fishing and natural).

Myers and Hutchins (1987) used these techniques to determine that a large percentage of Newfoundland salmon had been incorrectly aged. In this instance, years were being added to the fish's age when in reality spawning checks on scales were mistaken for annuli. Spawning checks resemble annuli on scales and are formed because the energy demand of spawning reduces the growth of a salmon. Spawning checks have been identified by others, such as Warner (1971) with salmon and Seelbach and Whelan (1988) with steelhead.

The numbers of maiden and repeat spawners in Gull Lake were very consistent with the corresponding numbers in Maine. In the Fish River lakes of Maine, maiden fish comprised 70.5%, 70.9%, and 73.1% of the spawning runs in 1953, 1954, and 1955, respectively (Warner 1962). Maiden salmon have comprised up to 87% of the West Grand Lake run in Maine. Warner (1971) concluded that females spawn first at ages 3-4, while males spawned first at ages 1-5.

Warner (1962) also found that many salmon returned to spawn a second time. Of 174 tagged salmon returning to spawn over a 4-year period, 90% were spawning a second time, and 10% were spawning for a third time. About 27% were spawning for the second consecutive year, while only 5% were spawning a third consecutive year. Warner's (1962) data indicates that some salmon spawn twice, skip a year, then spawn again. A few salmon have also been known to skip 2 or 3 years between spawnings.

Sex ratios of salmon in Gull Lake were similar to those in Maine. In the Fish River lakes, salmon were present in approximately 1:1 sex ratios. Sex ratios for a 55-year period at West Grand Lake averaged 1:1.27. Sebago River salmon for a 17-year period were similar (Warner and Havey 1985). They also indicated that the sex ratio differed among age groups in the spawning run. This was consistent with my findings at Gull Lake.

Age composition of runs in Gull Lake and Maine lakes were similar. Most spawning runs in Maine were comprised of ages 2-6. Salmon that live past the age of 6 in Maine (and spawn) are mostly females. Warner and Havey (1985) suggest that the life span of males may be shortened by earlier maturity and extended lingering on the spawning grounds. Data from studies across Maine strongly indicate that salmon stocked as spring yearlings (especially males) mature earlier than those stocked as fall yearlings or spring 2 year olds.

Mature Gull Lake males consistently averaged about 1 inch larger in size than mature females of the same age. Sebago Lake salmon in Maine have a similar growth pattern (Warner and Havey 1985).

Salmon grow faster in Gull Lake than in Maine. Under a 14-inch size limit, Maine salmon commonly enter the fishery in the third or fourth year of life. At Gull Lake, salmon average over 17 inches at the end of their second year. This rapid growth in Gull Lake presents a problem for managers, because 12- to 20-inch salmon are not sexually mature but are highly vulnerable to anglers. As discussed earlier, a 25-inch size limit was employed to protect salmon to maturity in Gull Lake. The largest salmon captured in Gull Lake during our broodstock collections was a 4-year-old female weighing over 12 pounds and measuring 32.0 inches. Only two age-5 fish (both females) have been captured.

Hatchery Procedures

At Wolf Lake State Fish Hatchery, rearing typically occurs in one linear raceway at very high densities. Usually these densities are much higher than those employed at East Coast hatcheries (Hosmer et al. 1979). This could be one reason why various infections

and diseases spread rapidly in salmon at Wolf Lake Hatchery. Most salmon raised at Wolf Lake have had to be treated for furunculosis, bacterial gill disease, or a fungal infection. Furunculosis has been particularly troublesome. The effect of hatchery diseases on the return of stocked fish is unknown. Appendix 4 lists the hatchery lots of salmon raised to date, along with diagnosed infections and treatments.

Movements Out of Gull Lake

During our first year of egg collections at Gull Lake, we were concerned about the amount of salmon escaping downstream. In 1988 fish leaving the lake through the outlet accounted for approximately 11% of the entire spawning run. The number moving downstream decreased in subsequent years, and now does not appear to be a problem. Other Maine studies found little movement of salmon through lake outlets. Havey (1960) found that less than 0.5% of 9,271 fall yearlings stocked in Long Pond, Maine, moved through the outlet during their life. Warner and Havey (1985) found some downstream movement, but mostly from juveniles shortly after stocking.

Management Implications

The salmon program at Gull Lake has been a successful one. The salmon can support a substantial and valuable fishery and serve as a productive source of broodstock. Consistent stocking rates are important to meeting both goals. Stocking rates of nine spring yearlings per acre appear to be adequate at this time.

The timing of spawning runs have been very consistent each year, peaking (according to egg ripeness) around November 15. The composition of the run has been fairly predictable based on the age at maturity of each sex using Maine data. Gull Lake salmon have been shown to behave and exhibit maturation cycles virtually the same as Maine salmon.

Fishing regulations, while inadequate at first, were adjusted to better protect the spawning stock from being depleted by fishing. The current regulations (25-inch minimum size limit, one fish/day bag limit, and April-September season) should allow enough protection to produce broodstock. By monitoring the fishery and the spawning run, adjustments to the stocking schedule and regulations can be made in the future if problems develop.

Because of problems experienced in raising salmon at Wolf Lake Hatchery, modifications of rearing techniques and stocking rates should be considered. Disease problems could possibly be reduced at lower rearing densities or higher water volumes.

Acknowledgments

Paul Seelbach helped me understand interpretation of spawning checks. Joan Duffy provided the creel survey information, and computer guidance with the use of SPSS. Tom Cole and Gaye Blind provided the hatchery information contained in Appendix 4. Joan Duffy and Dave Johnson reviewed the first drafts. My secretary Joyce Grant suffered with a smile with the many revisions.

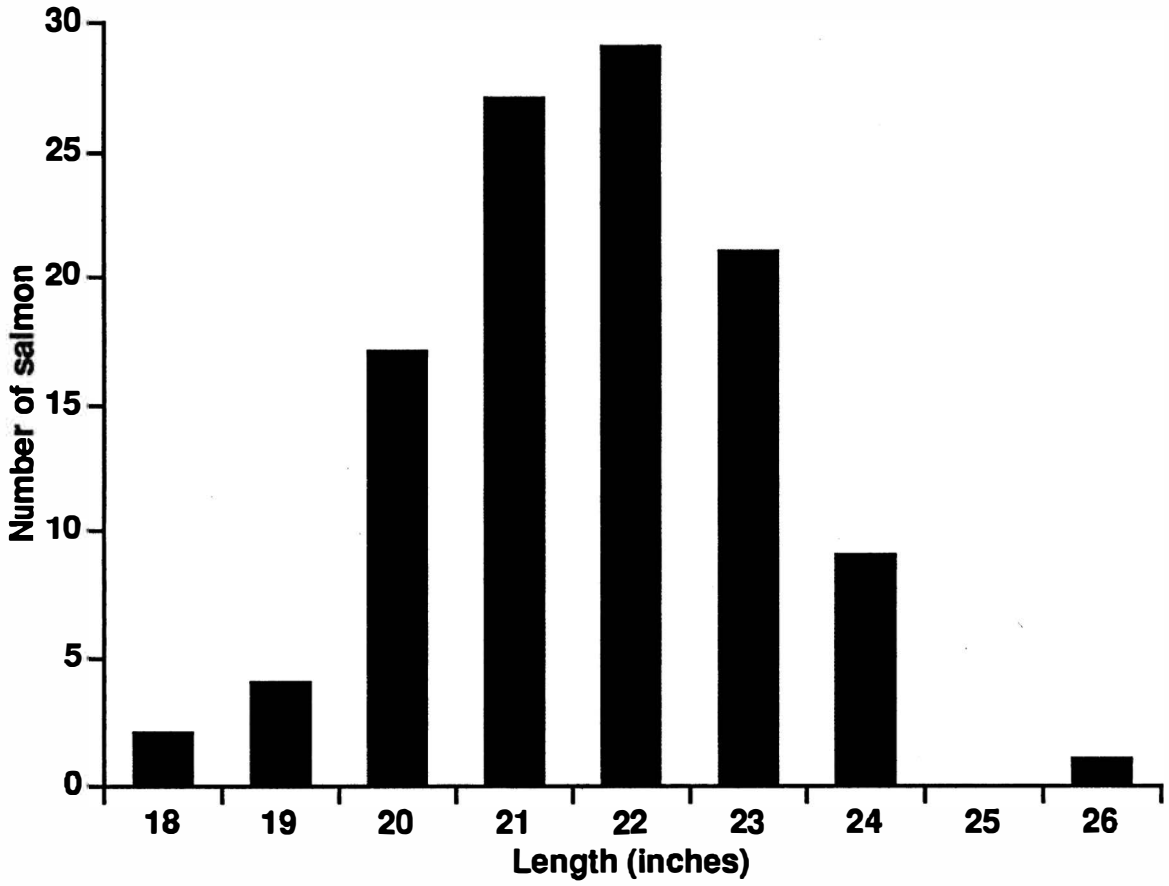

Figure 1.—Length frequency of mature salmon collected at the weir from Gull Lake during the fall in 1988.

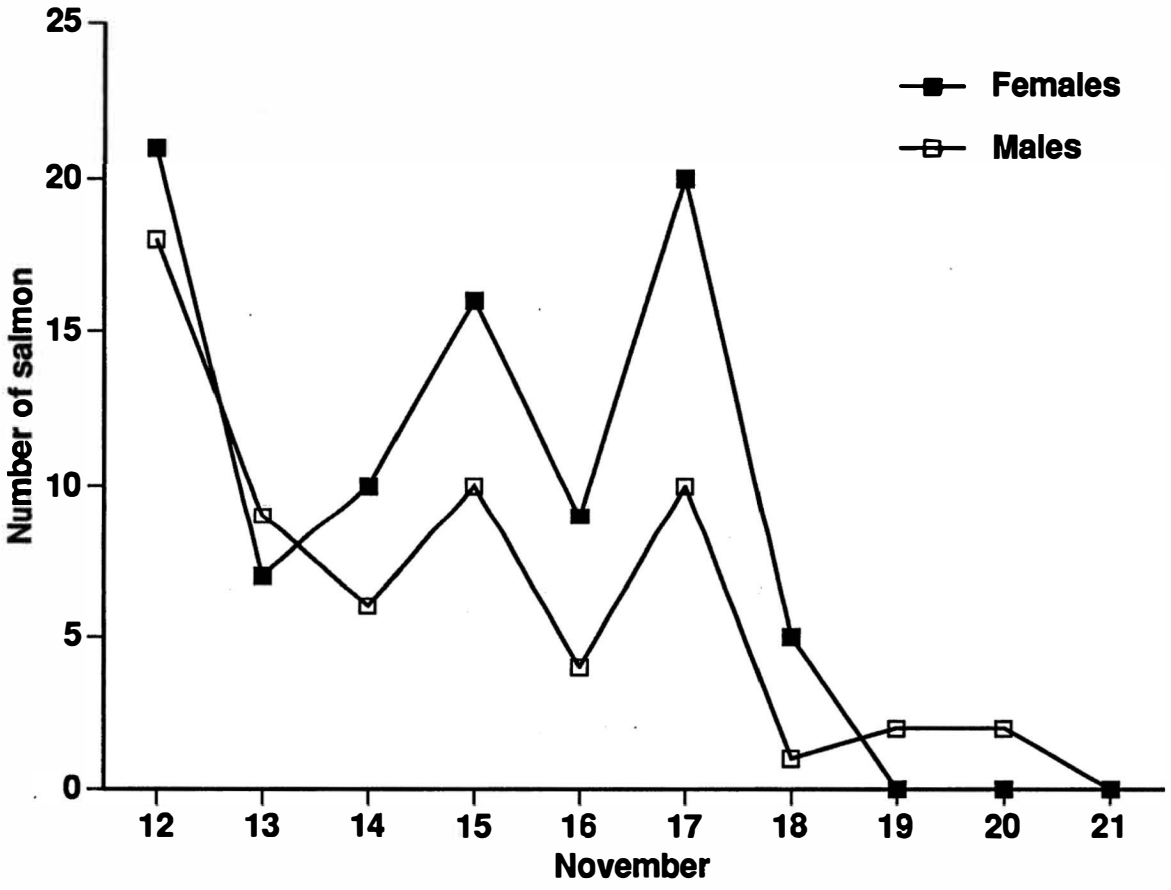

Figure 2.—Number of mature male and female salmon collected from the weir by date at Gull Lake in 1988.

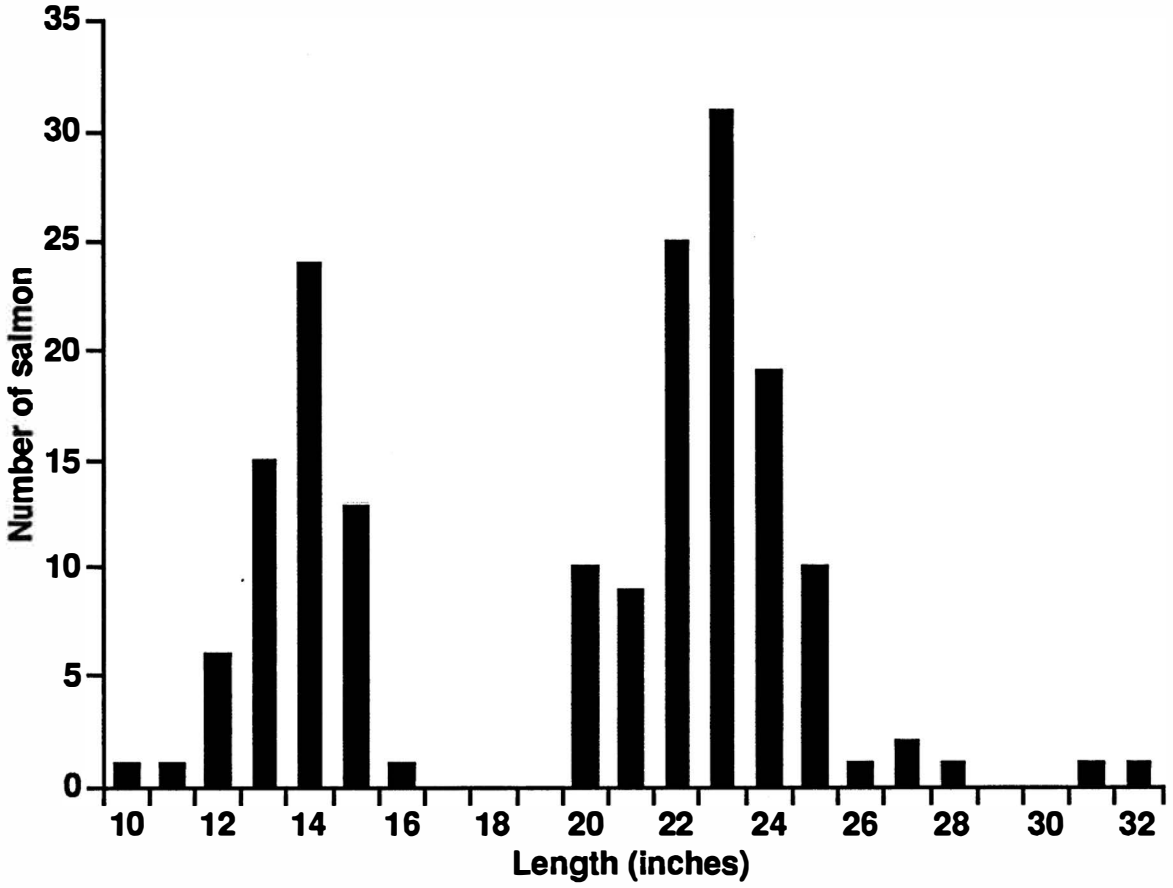

Figure 3.—Length frequency of all salmon captured during fall netting at Gull Lake in 1989.

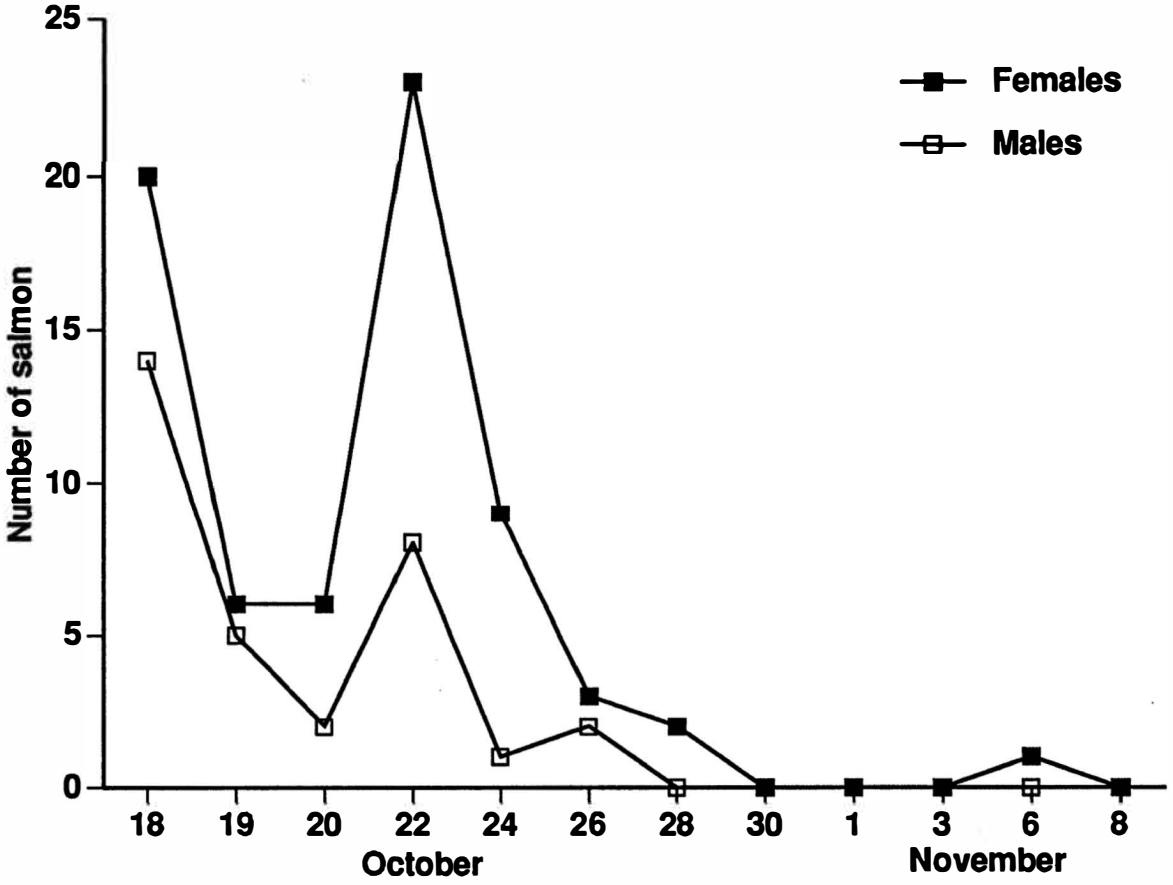

Figure 4.—Total number of mature male and female salmon collected by date, during fall trap netting at Gull Lake in 1989.

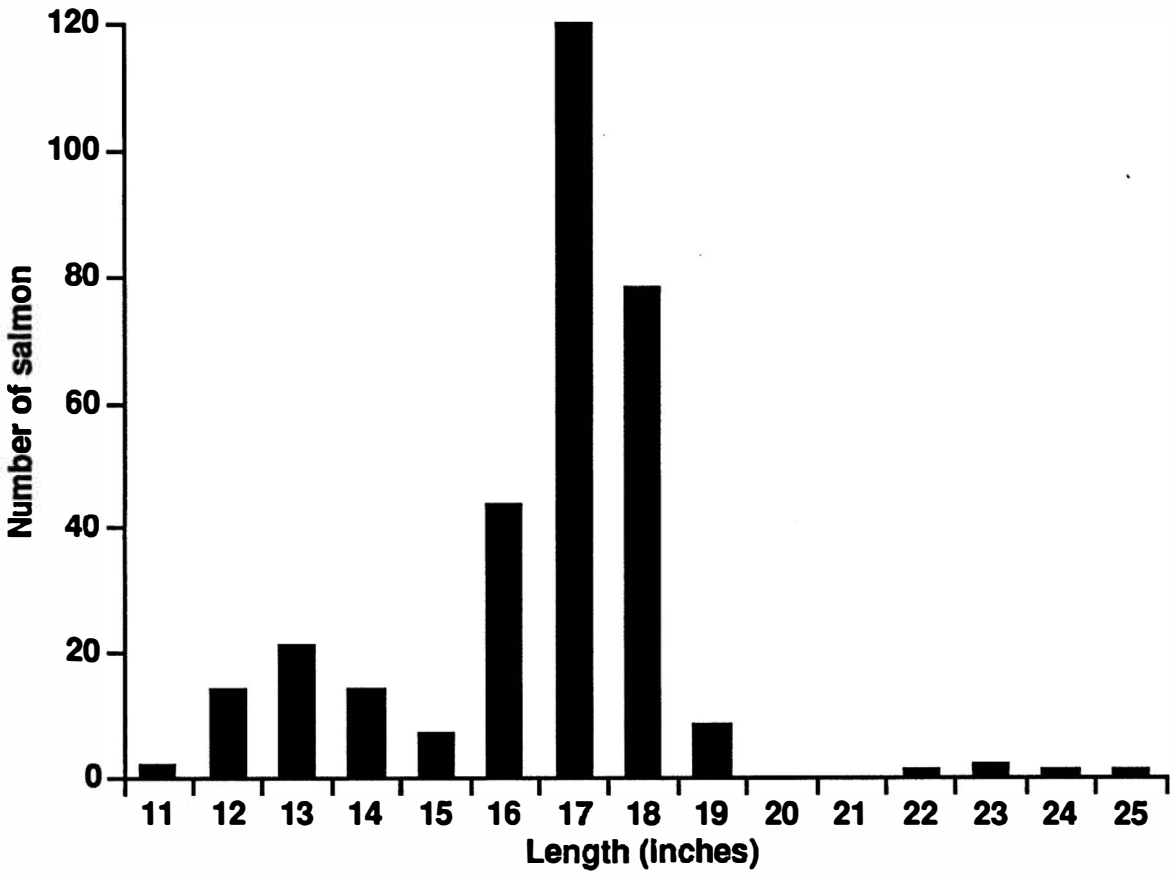

Figure 5.—Length frequency of all salmon captured during fall netting at Gull Lake in 1990.

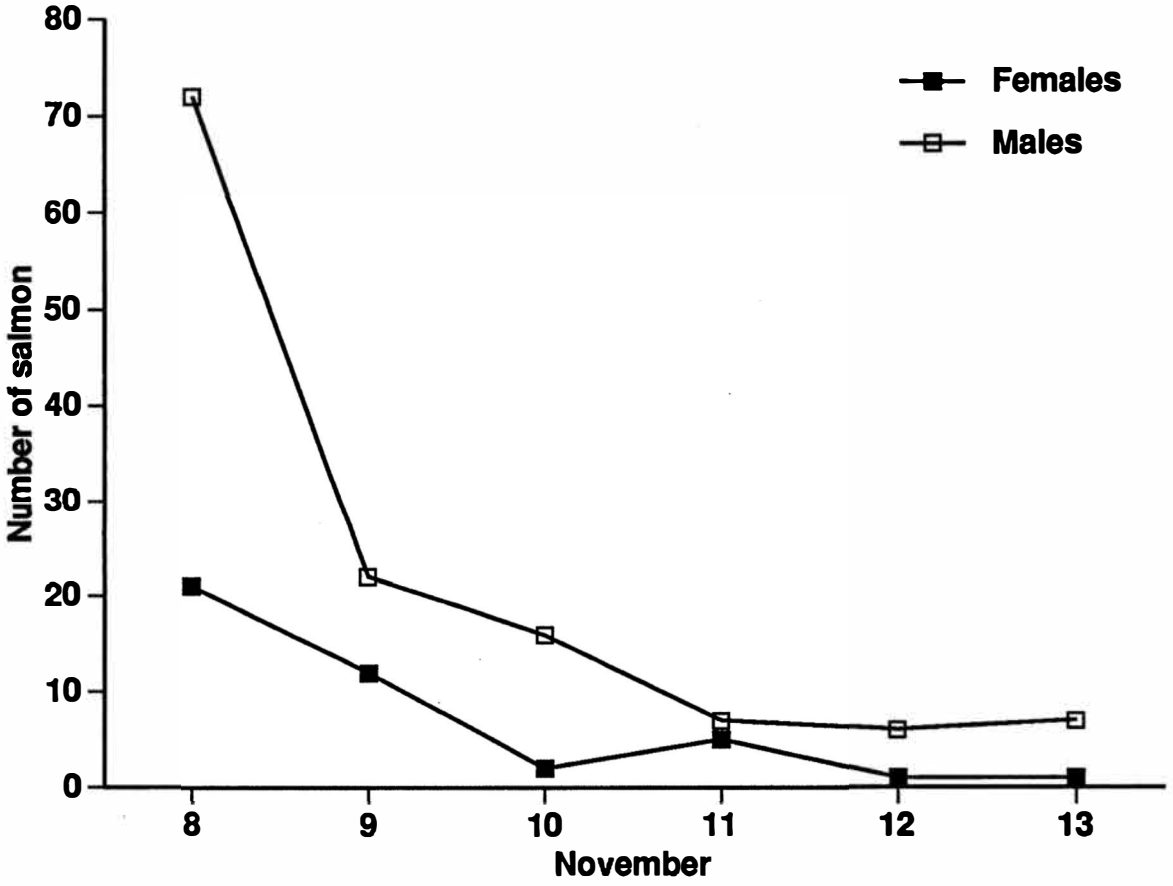

Figure 6.—Total number of mature male and female salmon collected during fall trap netting at Gull Lake in 1990.

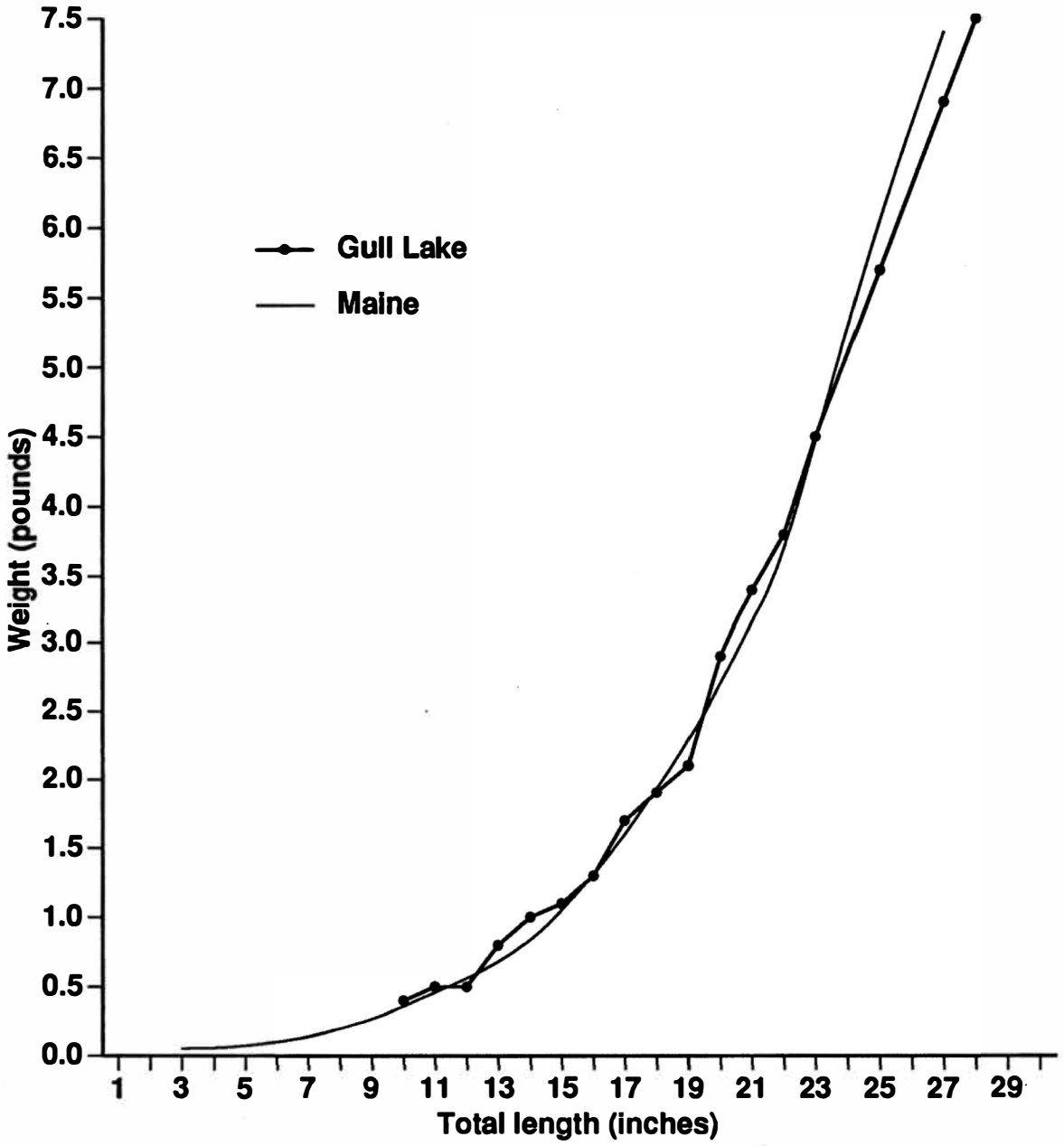

Figure 7.—Relationship between total length (inches) and weight (pounds) for (Maine and Gull Lake salmon).

Table 1.—Stocking history of trout and salmon in Gull Lake from 1965 to present. The letter codes represent the size/age of fish stocked. Fall fingerlings are ff. Spring yearlings are sy. Adults are A.

Year	Species		
	Lake trout	Rainbow trout	Atlantic salmon
1965	—	15,000 ff	—
1966	157 A	4,000 ff	—
1967	—	—	—
1968	—	8,000 sy	—
1969	—	8,000 ff	—
1970	8,100 sy	8,000 ff	—
1971	—	12,000 sy	—
1972	4,525 sy	10,070 sy	—
1973	—	14,000 sy	—
1974	10,000 sy	14,000 sy	2,558 sy, 37A
1975	10,000 sy	—	11,366 sy
1976	10,000 sy	—	29,905 sy
1977	10,000 sy	—	280 A
1978	10,000 sy	22,023 sy	324 A
1979	13,700 sy	30,000 sy	—
1980	15,000 sy	30,000 sy	—
1981	—	22,000 sy	—
1982	10,000 sy	25,000 sy	—
1983		30,000 sy	—
1984	194 A	19,000 sy	—
1985	—	29,900 sy	—
1986	—	—	25,356 sy
1987	—	—	23,632 sy
1988	—	6,018 sy	11,956 sy
1989	—	5,300 s.y	23,688 sy
1989	—	+25,000 ff	—
1990	—	6,000 sy	25,103 sy
1990	—	—	29,899 ff

Table 2.—Fin-clip combinations for salmon stocked in Gull Lake, 1986-91. Adipose clip is AD, right pectoral is RP, right ventral is RV, left pectoral is LP, and left ventral is LV.

Year	Number stocked	Fin clip
1986	21,356	AD
	2,000	RP
	2,000	RV
1987	11,966	RV + AD
	11,966	LV
1988	11,956	RV
1989	12,438	RP
	11,250	None
1990	25,103	None
1991	29,899	LP

Table 3.—Average lengths and weights of male salmon collected in Gull Lake in the fall 1988, 1989, and 1990.

Year and age	Mature			Immature		
	Number	Mean length (inches)	Mean weight (pounds)	Number	Mean length (inches)	Mean weight (pounds)
1988						
2	2	21.1	—	—	—	—
3	9	23.7	—	—	—	—
1989						
1	6	11.9	0.9	9	14.1	0.9
3	20	24.0	4.4	8	22.7	2.9
4	5	25.0	5.8	1	20.9	2.5
1990						
1	12	13.6	1.0	5	14.1	0.9
2	126	17.8	1.8	8	17.8	1.6
4	3	23.7	3.4	—	—	—

Table 4.—Average lengths and weights of female salmon collected in Gull Lake in the fall 1988, 1989, and 1990.

Year and age	Mature			Immature		
	Number	Mean length (inches)	Mean weight (pounds)	Number	Mean length (inches)	Mean weight (pounds)
1988						
2	11	20.3	—	—	—	—
3	88	22.2	—	—	—	—
1989						
1	—	—	—	24	14.6	1.0
2	1	21.0	3.1	—	—	—
3	44	22.8	4.1	5	22.8	3.4
4	17	24.6	6.0	10	23.0	3.6
1990						
1	—	—	—	32	13.3	0.8
2	42	16.8	1.8	77	17.4	1.5
5	2	24.6	3.4	—	—	—

Table 5.—Percent age composition of mature salmon collected from Gull Lake during 1988, 1989, and 1990.

Age	Year		
	1988	1989	1990
1	—	6.5	6.5
2	11.8	1.1	90.8
3	88.2	68.8	—
4	—	23.6	1.6
5	—	—	1.1

Table 6.—Percent of salmon in Gull Lake collected in 1989 that had previously spawned. Number in parentheses indicates the percentage of the sample that were males.

Age	Sample size	Percent having number of previous spawnings		
		1	2	3
3	72	2.7	8.3	—
		(100)	(83)	—
4	31	22.5	9.7	3.2
		(29)	(100)	(100)

Table 7.—Average (fall) length at age for salmon in Gull Lake. Maine average is from 18 lakes. Sebago Lake average is from salmon collected since 1970 (Warner and Havey 1985). The latter two are either back-calculated lengths or spring lengths.

Water body	Age				
	1	2	3	4	5
Gull Lake	13.8	17.7	22.7	24.0	24.6
Sebago Lake	—	—	16.1	18.5	20.0
Maine average	—	—	13.6	15.8	20.0

Table 8.—Percent maturity by age for male salmon collected during egg-take operations at Gull Lake in 1989 and 1990. Number in parentheses indicates the total number of males collected.

Year	Percent mature at age				
	1	2	3	4	5
1989	40	—	71	83	—
	(15)	—	(28)	(6)	—
1990	71	94	—	100	—
	(17)	(134)	—	(3)	—

Table 9.—Percent maturity by age for female salmon collected during egg-take operations at Gull Lake in 1989 and 1990. Number in parentheses indicates the total number of females collected.

Year	Percent mature at age				
	1	2	3	4	5
1989	0	100	89	63	—
	(24)	(1)	(47)	(27)	—
1990	0	35	—	—	100
	(36)	(119)	—	—	(2)

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Appendix 1.—Results of creel survey on Gull Lake in summer 1986 (two standard errors in parentheses).

Species	Total catch per hour	Estimated boat catches for: Jun	Jul	Aug	Season
Rainbow trout	0.0104 (0.0067)	10 (13)	60 (59)	140 (115)	210 (130)
Lake trout	0.0013 (0.0020)	6 (13)	19 (38)	0 (0)	25 (40)
Atlantic salmon	0.0426 (0.0170)	339 (201)	178 (136)	338 (193)	855 (310)
Northern pike	0.0008 (0.0008)	13 (15)	4 (7)	0 (0)	17 (16)
Yellow perch	0.1191 (0.0491)	719 (467)	760 (489)	912 (594)	2,391 (900)
Smallmouth bass	0.0316 (0.0129)	323 (155)	134 (94)	177 (151)	634 (236)
Largemouth bass	0.1205 (0.0467)	1,761 (810)	398 (203)	259 (130)	2,418 (845)
Bluegill	0.2973 (0.0969)	3,125 (1,372)	2,042 (787)	797 (533)	5,964 (1,669)
Rock bass	0.3887 (0.1507)	6,450 (2,664)	970 (545)	378 (223)	7,798 (2,728)
Sunfish	0.0099 (0.0082)	108 (120)	34 (68)	57 (83)	199 (161)
Bowfin	0.0016 (0.0016)	18 (26)	13 (19)	0 (0)	31 (32)
Caught-and-released smallmouth bass	0.0017 (0.0013)	0 (0)	0 (0)	34 (25)	34 (25)
Caught-and-released largemouth bass	0.0039 (0.0025)	12 (25)	0 (0)	65 (42)	77 (49)
Bullhead	0.0003 (0.0006)	6 (11)	0 (0)	0 (0)	6 (11)
Gar	0.0005 (0.0010)	0 (0)	0 (0)	10 (19)	10 (19)
Total		12,890 (3,151)	4,612 (1,110)	3,167 (886)	20,669 (3,457)
Angler hours		7,305 (3,112)	6,179 (851)	6,581 (925)	20,065 (3,356)
Angler trips		1,522 (582)	1,414 (205)	1,465 (233)	4,402 (660)

Appendix 2.—Results of ice fishing creel survey on Gull Lake in winter 1987 (two standard errors for estimates are in parentheses).

Species	Total catch per hour	Estimated open-ice catches for: Jan	Feb	Season
Rainbow trout	0.0232 (0.0149)	139 (120)	141 (109)	280 (162)
Atlantic salmon	0.0953 (0.0548)	172[1] (116)	978[1] (568)	1,150[1] (580)
Northern pike	0.0144 (0.0172)	20 (23)	154 (200)	174 (202)
Yellow perch	0.1686 (0.1205)	150 (148)	1,885 (1,334)	2,035 (1,341)
Bluegill	0.1507 (0.1272)	0 (0)	1,819 (1,451)	1,819 (1,451)
Caught-and-released Atlantic salmon	1.1251 (0.6792)	661 (591)	12,922 (7,260)	13,583 (7,284)
Total harvest		481 (224)	4,977 (2,064)	5,458 (2,075)
Angler hours		2,902 (868)	9,171 (3,233)	12,073 (3,348)
Angler trips		642 (210)	2,324 (834)	2,966 (860)

[1]Illegal harvest.

Appendix 3.—Results of creel survey on Gull Lake in spring and summer 1987 (two standard errors in parentheses).

Species	Total catch per hour	Estimated boat and shore fishing for: Mar 28-Apr	May	Jun	Jul	Aug-Sep 7	Season
Rainbow trout	0.0013	21	0	0	32	13	66
	(0.0015)	(23)	(0)	(0)	(65)	(27)	(74)
Atlantic salmon	0.0424	150	265	249	700	858	2,222
	(0.0154)	(181)	(424)	(164)	(519)	(345)	(792)
Northern pike	0.0050	7	110	23	90	32	262
	(0.0044)	(14)	(199)	(34)	(100)	(40)	(229)
Yellow bullhead	0.0011	0	0	0	0	57	57
	(0.0017)	(0)	(0)	(0)	(0)	(87)	(87)
Rock bass	0.2003	0	1,155	3,411	4,650	1,280	10,496
	(0.0574)	(0)	(987)	(1,243)	(2,337)	(755)	(2,924)
Green sunfish	0.0001	0	0	6	0	0	6
	(0.0002)	(0)	(0)	(12)	(0)	(0)	(12)
Bluegill	0.4915	47	1,577	8,341	10,562	5,234	25,761
	(0.1253)	(66)	(1,525)	(2,683)	(4,772)	(2,814)	(6,342)
Smallmouth bass	0.0253	0	188	264	248	626	1,326
	(0.0087)	(0)	(163)	(181)	(208)	(314)	(449)
Largemouth bass	0.0805	0	479	902	1,497	1,343	4,221
	(0.0204)	(0)	(350)	(337)	(723)	(549)	(1,030)
Black crappie	0.0004	20	0	0	0	0	20
	(0.0008)	(40)	(0)	(0)	(0)	(0)	(40)
Yellow perch	0.1284	1,077	473	849	2,188	2,144	6,731
	(0.0486)	(678)	(495)	(496)	(1,776)	(1,474)	(2,506)
Other	0.0010	0	0	0	32	20	52
	(0.0015)	(0)	(0)	(0)	(65)	(41)	(77)
Total		1,322	4,247	14,045	19,999	11,607	51,220
		(706)	(1,978)	(3,027)	(5,678)	(3,345)	(7,550)
Angler hours		4,097	9,804	11,876	14,182	13,455	52,414
		(757)	(1,531)	(1,189)	(2,360)	(1,496)	(3,484)
Angler trips		917	1,830	2,392	2,740	2,930	10,809
		(206)	(364)	(271)	(479)	(339)	(770)
Angler days		917	1,830	2,392	2,740	2,930	10,809
		(206)	(364)	(271)	(479)	(339)	(770)