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Smolt Migration of Wild and Hatchery-Raised Coho and Chinook Salmon in a Tributary of Northern Lake Michigan

Paul W. Seelbach

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SMOLT MIGRATION OF WILD AND HATCHERY-RAISED COHO AND CHINOOK SALMON IN A TRIBUTARY OF NORTHERN LAKE MICHIGAN[1]

Paul W. Seelbach

[1]Contribution from Dingell-Johnson Project F-35-R, Michigan.

Abstract

I examined the ages at migration and the timing of smolt migrations for both wild and hatchery-raised coho salmon, Oncorhynchus kisutch, and chinook salmon, Oncorhynchus tshawytscha, in a tributary of northern Lake Michigan. Smolt yield was measured for wild fish, and survival from planting to smolting was evaluated for hatchery-raised fish. Migrations were monitored using traps installed near the mouth of the river. The ages at migration and the timing of smolt migrations followed consistent patterns during the three study years. Most wild coho smolts migrated at age 1 in mid-May, although some age-0 smolts (age 8 months post-fertilization) were captured in June following one particularly mild winter. Wild chinook smolted primarily at age 0 in June, with a small proportion of the population holding over to smolt at age 1. Wild smolt yields were fairly low, averaging roughly 240 smolts per hectare for each of the two most common groups, age-1 coho and age-0 chinook. Hatchery-raised coho migrated at age 1 in a bimodal pattern, with one peak coming immediately after planting in late April, and the second coinciding with the movement of wild fish in mid-May. Hatchery-raised chinook migrated at age 0, immediately following planting in late May, and those grown at accelerated rates migrated immediately following planting in early April. Survival from planting to smolting ranged between 70–78%, and 68–100% for hatchery-raised coho and chinook, respectively. The timing of migration was most strongly influenced by photoperiod and fish size, however, the relationships between these factors and migration may differ with species.

Introduction

Great Lakes populations of fall-spawning coho salmon, Oncorhynchus kisutch, and chinook salmon, Oncorhynchus tshawytscha, are supported primarily by plantings of hatchery-raised fish in tributary streams, and supplemented by natural reproduction (Carl 1982; Patriarche 1980). Two factors have been shown to be critical relative to successful smolt migrations of the planted fish (1) fish size at a given age; and (2) time of planting (Wedemeyer et al. 1980). Fish size is important because fish must reach a certain minimum size at age if they are to smolt that season. Time of planting must be closely matched with the readiness to migrate. Early plantings result in mortality associated with river residence and in potential adverse impacts on resident communities (Ewing et al. 1984; Peck 1974). Late plantings result in the loss of smolt characteristics (Wedemeyer et al. 1980). The timing of migration of planted smolts is generally thought to mimic that of wild fish, however, factors which affect this timing (such as photoperiod, temperature, and growth rate) may differ among hatcheries, making it difficult to define exactly when a group of fish is ready to migrate (Ewing et al. 1984; Hasler and Scholz 1983; Wedemeyer et al. 1980). Knowledge of the smolt migrations of wild salmon, and of the performance of hatchery-raised salmon with respect to their wild counterparts, is therefore extremely valuable for the operation of effective planting programs; however, detailed information on these subjects is scarce for the Great Lakes region. In this paper I present the following information for salmon in a tributary of northern Lake Michigan (1) the ages at migration and the timing of migration for wild salmon smolts; (2) the yield of wild salmon smolts; (3) the ages at migration and the timing of migration for hatchery-raised salmon; and (4) the influence of environmental factors on the timing of salmon smolt migrations.

Methods

This study was conducted on the Little Manistee River, a cold-water trout stream which flows through gently rolling, forested areas of Michigan's northwestern lower peninsula before emptying into Lake Michigan near Manistee, Michigan (Fig. 1). The Little Manistee River is approximately 107 km long, with an average width of 13 m and an average depth of less than 1 m (although pools up to 2 m deep are common). Flow is fairly stable, averaging 5–6 cms, with peak flows reaching 12–14 cms. The primary bottom type is sand, although stretches of gravel and rubble exist. Spring seepage occurs along most of the main stream, maintaining water temperatures below 13 C throughout the year. The river provides excellent spawning, rearing, and adult residence habitat for abundant anadromous and resident salmonids, the most common of which are steelhead, Salmo gairdneri; resident brown trout, Salmo trutta; coho salmon; and chinook salmon. The Michigan Department of Natural Resources (MDNR) operates a fish weir 7 km upstream from the mouth of the river to collect anadromous salmonids for hatchery purposes.

Hatchery-raised salmon were obtained from MDNR fish hatcheries. These fish were first-generation offspring of adults captured in either the Little Manistee River (chinook) or the Platt River (coho). The three planting groups were (1) coho salmon (age 18 months post-fertilization), the most common age and size group of coho planted in Michigan; (2) chinook salmon (age 7 months post-fertilization), the most common age and size group of chinook planted in Michigan; and (3) accelerated-growth chinook salmon (age 5 months post-fertilization), a less common group which has been planted in recent years. Fish were planted 10–20 km upstream from the mouth of the river, typical of MDNR salmon plants in rivers (Fig. 1).

Smolting was monitored using two traps installed at the MDNR fish weir. Modified inclined-screen traps (Seelbach et al. 1985) were used in April-July 1982, March-June 1983, and April-June 1984. Traps were checked daily, with the total number captured being recorded for each species, origin, and age group. Origin (wild or hatchery-raised) was determined for all salmon based on external appearance (body shape, coloration, and fin condition), total length, and date of capture relative to planting dates. Age was determined using length-frequency analysis. For days when data were missed (due to debris-laden traps, vandalism, or sampling limitations), the missing data were estimated using catch data from a period of several days before and after the period of missing data (the percentage of the total salmon catch which was estimated averaged 21% per year for the three study years). The total number of smolts trapped from each group was calculated by summing the daily catch totals. The total number of smolts produced by each group was calculated by dividing the total number trapped from each group by the estimated trapping efficiencies (Table 1). Trapping efficiency was tested by returning captured smolts upstream. Fish were marked with a fin clip and released 100 m upstream of the traps. The recapture proportions were considered to be an estimate of the efficiency of the trapping system to capture all migrating smolts. Confidence limits (95%) were calculated using the variance of the binomial distribution (Remington and Schork 1970). The number of smolts per hectare of river was determined by dividing the total number of smolts by the area of river from the MDNR fish weir to Luther (see Fig. 1). This area was determined using measurements from aerial photographs combined with on-site measurements.

A weighted mean migration date was calculated for each group (weighted by the number of smolts captured each day). Smolt migration patterns were similar to a normal curve (the exception being hatchery-raised coho), and the mean plus the confidence band (± 2 standard deviations) were good descriptors of the peak migration date and of the period in which 95% of the smolts migrated (Brown and Hollander 1977).

Percent survival from planting to smolting was calculated for each group by dividing the total number of smolts by the number of fish planted.

Daily minimum and maximum water temperatures were measured using either a thermograph or a minimum-maximum thermometer. Water levels were read from a staff gauge located approximately 1 km downstream from the traps in 1982. These data were calibrated to a discontinued United States Geological Survey (USGS) flow gauging station located 3 km upstream. Day length (minutes of daylight) data were obtained from the Michigan Department of Agriculture (Anonymous, MDA, Climatology Program, East Lansing, Michigan, personal communication 1984). Data on lunar periods were obtained from the U. S. Government Printing Office (1982–84).

Several assumptions were involved with this study. I assumed that I could distinguish wild from hatchery-raised salmon by (1) differences in appearance and size, and (2) timing of migration relative to time of planting. I also assumed that I could age fish based on (1) length (two distinct size groups were present, representing age-0 and age-1 fish), and (2) timing of migration (the distinct size groups also migrated at distinct times). The criteria used in the identification of age-0 coho smolts were as follows (1) these fish were silver with black-tipped caudal fins; (2) these fish were 70–80 mm in length in June, while fry were typically 30–40 mm and yearlings were 120–140 mm in May (see Carl 1983 and Johnson 1980 for coho growth in Great Lakes tributaries); and (3) these fish migrated in a group distinct from other coho, at a time identical to the migration time of age-0 chinook (also 70–90 mm in length).

Trapping efficiency estimates were based on three assumptions (1) that no handling mortality occurred; (2) that handled smolts did not avoid the traps on their second migration; and (3) that handled smolts resume migration. I found assumptions (1) and (2) valid for steelhead smolts (unpublished data); assumption (3) remains untested.

Results

The ages and timing of wild smolt migrations followed consistent patterns during the three study years. Most wild coho smolted at age 1, although some age-0 smolts were found in 1983. Wild chinook smolted primarily at age 0, with a small proportion of the population holding over to smolt at age 1. Age-1 salmon smolts consistently migrated during mid-May, and age-0 smolts during June, with patterns roughly following normal curves. Mean migration dates were May 15, 16, and 21 during the study years for age-1 coho (Fig. 2). For the age-0 coho smolts, the mean migration date was June 24 $\pm$ 16 days. Mean migration dates were June 13, 19, and 20 for age-0 chinook (Fig. 3), and May 6, 7, and 9 for age-1 chinook.

The yield of wild smolts was fairly consistent throughout the study, although some changes occurred in 1984 (Table 3). The yield of the two most common groups, age-1 coho and age-0 chinook, averaged 253 and 232 smolts per hectare, respectively, in 1982 and 1983. In

1984, age-1 coho yield fell to 76 smolts per hectare, while age-0 chinook rose to 992 smolts per hectare. Age-1 chinook yield averaged 26 smolts per hectare during the study years, and age-0 coho yield was limited to 6 smolts per hectare in 1983.

Hatchery-raised salmon smolts migrated at ages and times similar to, or slightly earlier than, those for comparable wild salmon, with mean migration dates of May 8 and 11 for age-1 coho (Fig. 2) and May 30 for age-0 chinook (Fig. 3). The exception was accelerated-growth chinook, which migrated nearly 2 months ahead of the wild fish, with a mean migration date of April 7 (Fig. 3). Coho exhibited a bimodal migration pattern in 1984 and a similar pattern was assumed for 1982 (based on similarities in size and timing of observed peaks). The initial peak came immediately following planting, with the second peak being concurrent with wild fish migrations (Fig. 2). In both groups of chinook, nearly all of the fish smolted within the first few days of planting (Fig. 3).

Survival from planting to smolting was fairly high for all hatchery-raised groups, ranging between 70–78% for coho, and between 68–100% for chinook (with the accelerated-growth group apparently showing higher survival)(Table 2).

Of four environmental factors examined, only day length seemed to be consistently related to peak smolt migration dates. Peak smolting dates consistently occurred as day length reached specific levels (for example, 870–890 minutes for wild age-1 coho)(Fig. 4). Migrations generally occurred after daily mean water temperatures had warmed to 7 C or higher, but fluctuations were erratic and no direct relationship between temperature patterns and migration was evident (Fig. 5). Water flow slowly decreased during the spring months and peak migration dates did not seem related to any noticeable fluctuations in flow (Fig. 4). Although only 1 year's data are available, flow patterns were similar during the other 2 years, with the exception that flow increased dramatically in late June 1984. Lunar periods (new moon and full moon) differed from year to year (Fig. 4) and were not related to migration dates in any consistent manner.

Discussion

The ages and timing of wild salmon smolt migrations in the Little Manistee River were quite similar to those reported in river systems throughout North America. In Pacific Coast systems (at latitudes comparable to Michigan), coho typically smolt at age 1 during May (Crone and Bond 1976; Hasler and Scholz 1983) and fall chinook smolt primarily at age 0 during June, with some smolting at age 1 the following May (Ewing et al. 1980; Healey 1980; Reimers 1973). In the Great Lakes region, coho salmon have been reported as smolting at age 1 in April (Avery 1974; Carl 1982) and Carl (1982) found chinook salmon smolting at age 0 in June.

Smolt migrations were most strongly influenced by photoperiod. The environmental factors which affect the timing of smolt migrations have been examined by several authors, and these have consistently pointed to photoperiod as the primary influence (Ewing et al. 1980; Ewing et al. 1984; Hasler and Scholz 1983; Wedemeyer et al. 1980). Other factors can play a role in specific cases, for example, temperature generally needs to be at least 10 C and large freshets can affect daily movements, especially of subyearling fish. There is no evidence that lunar cycles affect salmon smolt migrations (McDowall 1969), although Mason (1975) did find a lunar periodicity in the downstream movements of coho fry.

The observation of wild age-0 coho smolts in 1983 is, to my knowledge, unique. Wild coho salmon are considered to be fairly plastic in terms of life history strategy (G. F. Hartman, Pacific Biological Station, Nanaimo, British Columbia, Canada, personal communication, December 1984), and have been observed to follow a number of subyearling downstream migrational patterns, but never actual smolting migrations. Subyearling migrations generally involve the emigration of fry (Chapman 1962), which may or may not result in a period of estuarine or riverine (springs or ponds) rearing. These fish possibly undergo subsequent fall or winter migrations to sea (C. J. Cedarholm, Washington Department of Natural Resources, Forks, Washington; and G. F. Hartman, Pacific Biological Station, Nanaimo, British Columbia, Canada, personal communications, December 1984). The age-0 smolts which I observed developed during an extremely warm winter (the period November-April 1982–83 was 724 heating degree days lower (warmer) than the average for the period 1974–84 (U. S. Department of Commerce 1974–84), and apparently reached the minimum smolting size (70–80 mm for coho) by June (age 8 months post-fertilization). Several investigators have shown that coho grown under hatchery conditions at accelerated rates can reach minimum smolting size by their first June (Bilton and Jenkinson 1980; Clarke and Shelbourne 1980; Donaldson and Brannon 1976; Garrison 1965; Saxton et al. 1983). In these cases, the accelerated smolts were only a portion of the cohort, presumably the faster-growing members; similarly, the wild age-0 smolts were only a portion of the 1982-spawned cohort, as evidenced by the migration of numerous age-1 coho smolts in May 1984.

The yield of salmon smolts was quite low, averaging 240 smolts per hectare for the most common age group in each species. Carl (1983) and Johnson (1980) found late fall densities for subyearling coho of 1700–2000 fish per hectare in Great Lakes tributaries; presumably smolt yield was well over 1000 per hectare in these cases. Crone (1981) reported yields for coho between 970–4200 smolts per hectare for streams in Oregon, British Columbia, and Alaska. Using Carl's (1980) surveys, I calculated that Michigan's best chinook-producing rivers yielded between 1000–2000 smolts per hectare. Similarly, using information provided by Lister and Walker (1966), I calculated that at least 2000 smolts per hectare were produced in one British Columbia stream. Salmon spawner escapement in the Little Manistee River is purposely limited by MDNR harvest practices, and the yields reported here probably represent minimal values for this river. Supporting this idea, the increase in chinook smolt yield in 1984 coincided with what appeared to be a larger-than-normal spawner escapement in fall 1983 (a larger-than-normal escapement was reported by local fishermen and riparian landowners, however, no data on the magnitude of escapements are available), indicating that smolt yield is spawner limited. Information on the escapement of coho spawners is unavailable, and the 1984 decrease in smolt yield is unexplained.

Planted hatchery-raised salmon are generally thought to migrate at times similar to wild fish (Wedemeyer et al. 1980). My results supported this idea, however, accelerated growth affected migration timing in at least one group of chinook, and a similar effect is suggested by the bimodal pattern of coho. The effect of growth has long been recognized (Bilton et al. 1982; Hasler and Scholz 1983; Wedemeyer et al. 1980), however, the extent to which it may vary among species, or in concert with the effects of additional factors, is incompletely understood.

The results of other studies of planted salmon are similar to mine. In Michigan, coho have been observed to begin migrating shortly after planting in late April-early May (Miller 1968, 1969; Peck 1974) and to still be migrating in mid-May (Miller 1969). In Wisconsin, coho smolts migrated from holding ponds in mid-May (Hasler and Scholz 1983). Fish planted in southern streams (in Indiana or Ohio) migrated by mid-April (W. P. Hillman, Ohio Department of Natural Resources, Akron, Ohio; and R. A. Koch, Indiana Department of Natural Resources, Michigan City, Indiana, personal communications, January 1985); it is possible that they were forced out by rising water temperatures. Chinook have been observed to migrate rapidly following planting in mid-May in Michigan (Miller 1969). On the Pacific Coast, Salo and Bayliff (1958) found that coho migrated at times similar to wild fish (in May), no matter how early they were planted. Ewing et al. (1984) found that chinook planted at various times from February-May all migrated in late May, while fish released in late May or June migrated soon after planting.

In this study, survival from planting to smolting was quite high. In comparable studies, Salo and Bayliff (1958) found survival from planting to smolting of 87% for planted coho. Ewing et al. (1984) reported values between 80–90% for chinook, and Bjornn et al. (1978) found values of 32–54% for planted steelhead. Planted fish are subjected to a number of potential causes of mortality, such as handling stress, crowding stress, temperature change, concentrated predation, and changed feeding conditions and survival from planting to smolting of over 70% is excellent. The accelerated-growth chinook appeared to have the best survival, however, their value as a management tool is questionable, as, often a high percentage of accelerated-growth smolts return as jacks, lowering the biomass returns to the fishery (Bilton and Jenkinson 1980; Hagar and Noble 1976).

The age, size, and time at which coho and chinook salmon are planted in Michigan appear to be appropriate, however, more research is needed concerning the value of accelerated-growth smolts. In addition, the MDNR salmon harvest weir on the Little Manistee River appears to be successfully keeping wild smolt yields to minimal levels.

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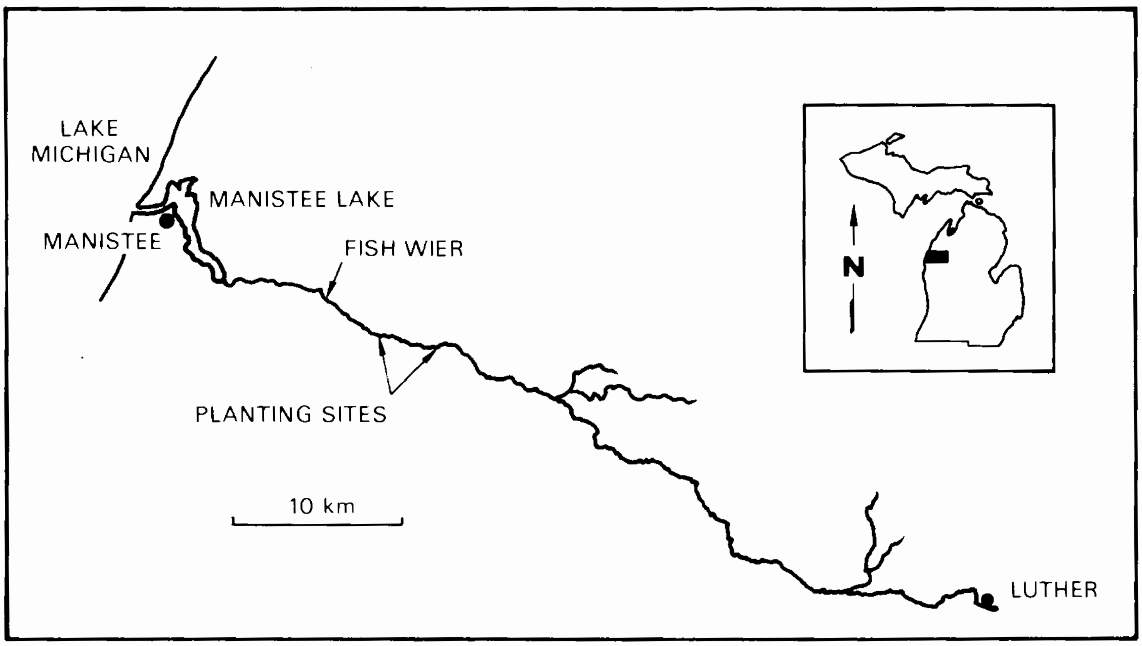

Figure 1. The Little Manistee River, showing the fish weir.

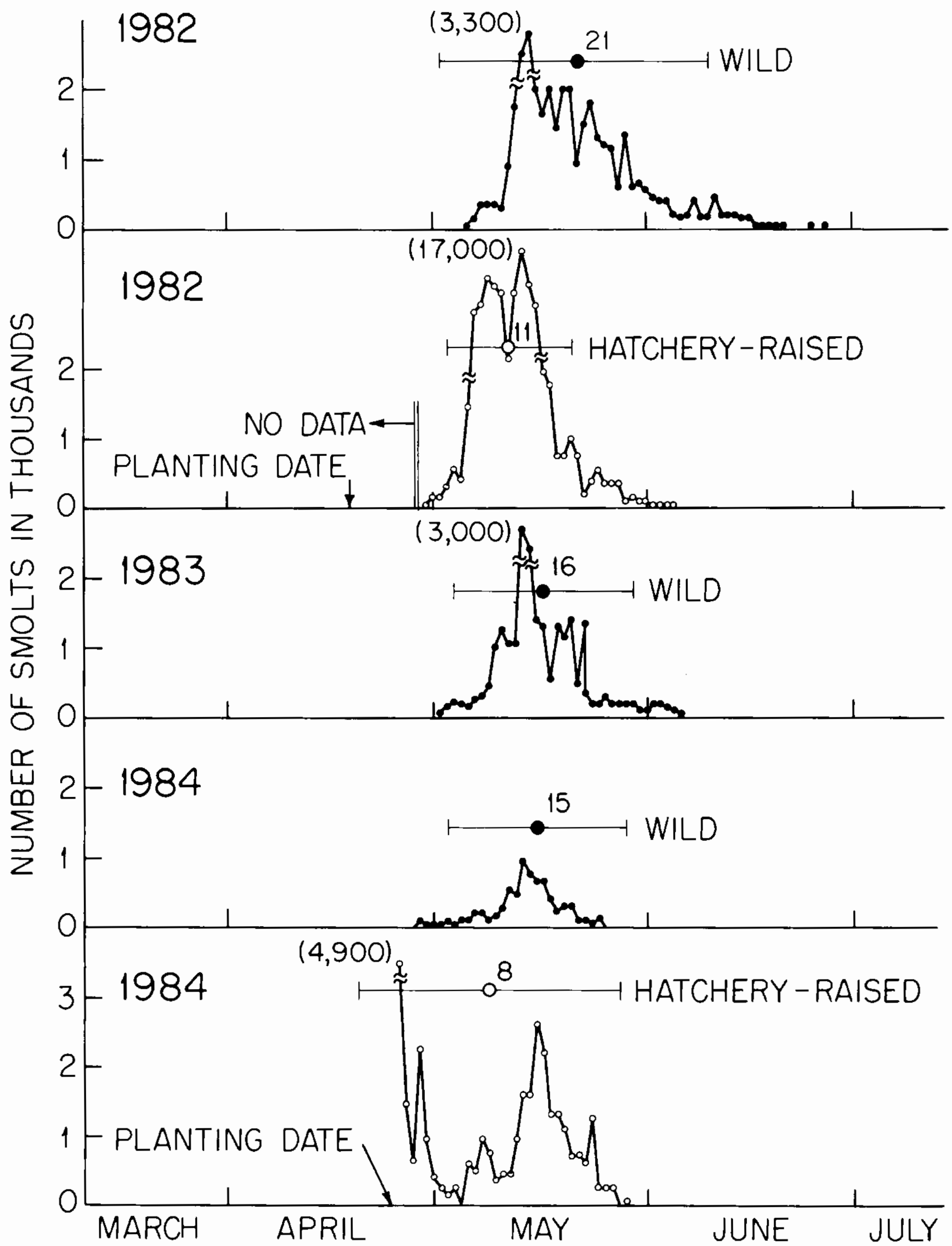

Figure 2. Numbers of wild and hatchery-raised age-1 coho salmon smolts emigrating each day from the Little Manistee River, 1982–84. The mean migration date is plotted and the date added as a superscript. The error bars on the mean represent 95% of the migration period.

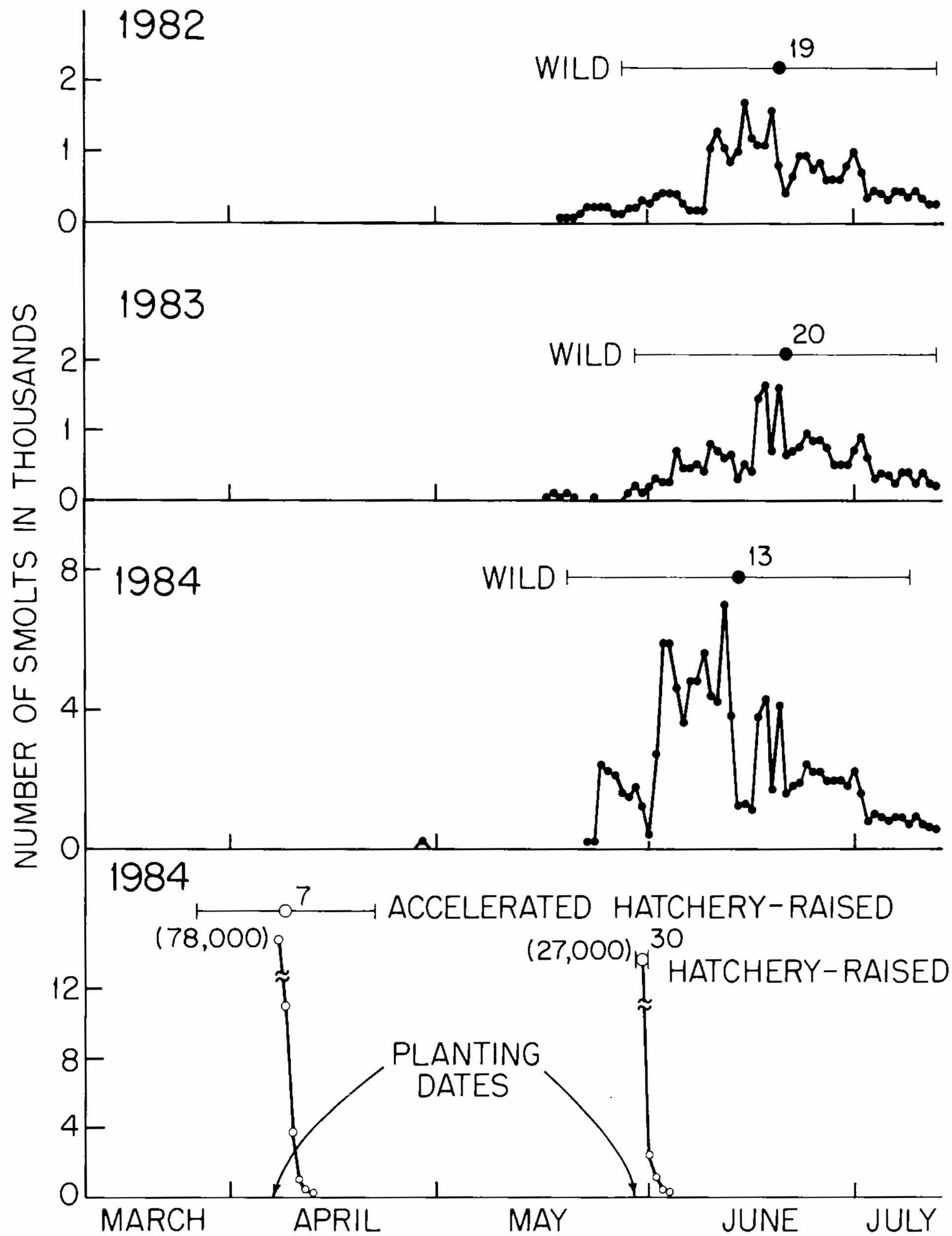

Figure 3. Numbers of wild and hatchery-raised age-0 chinook salmon smolts emigrating each day from the Little Manistee River, 1982–84. The mean migration date is plotted and the date added as a superscript. The error bars on the mean date represent 95% of the migration period.

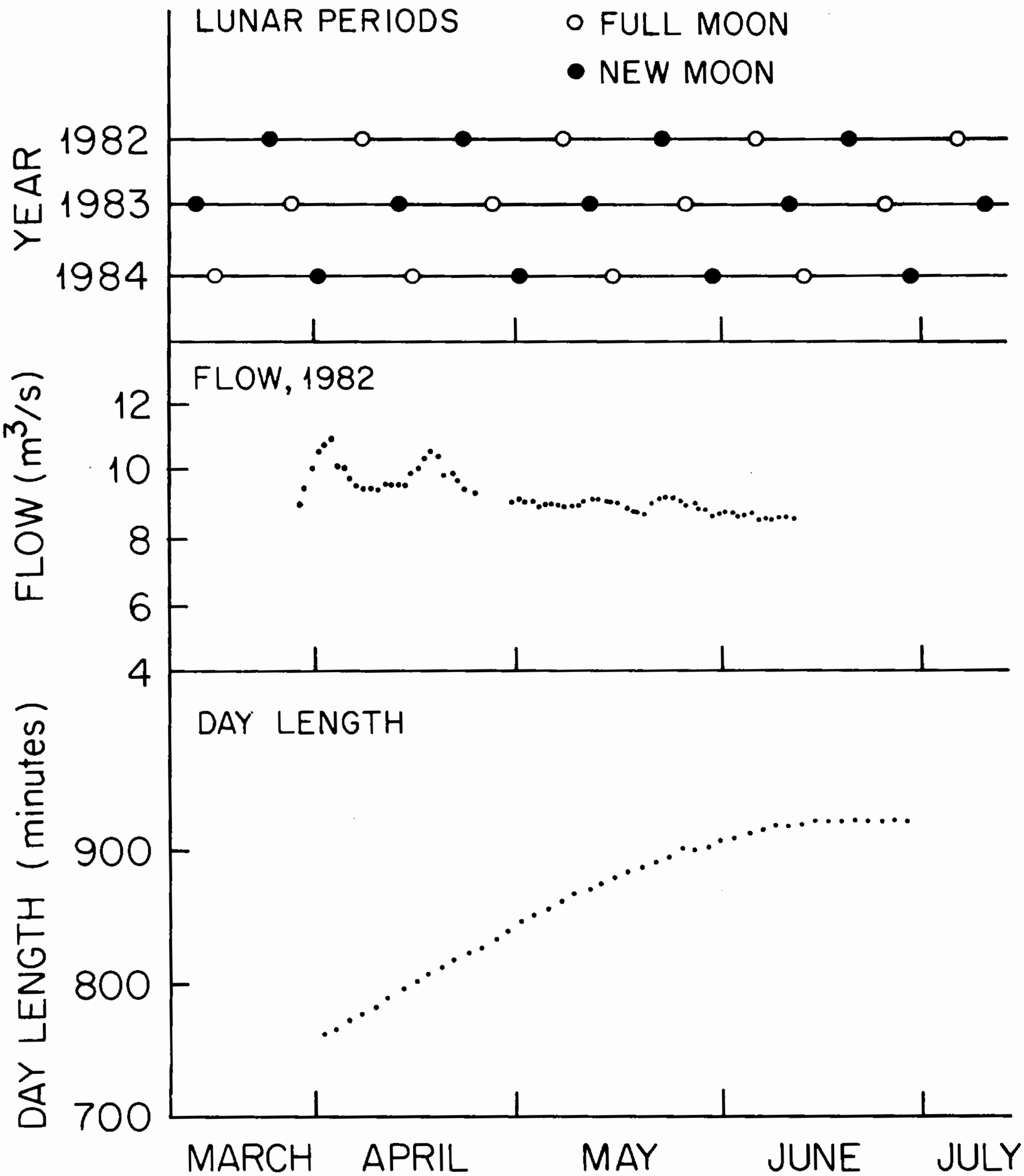

Figure 4. Lunar periods, flow, and day length for the Little Manistee River.

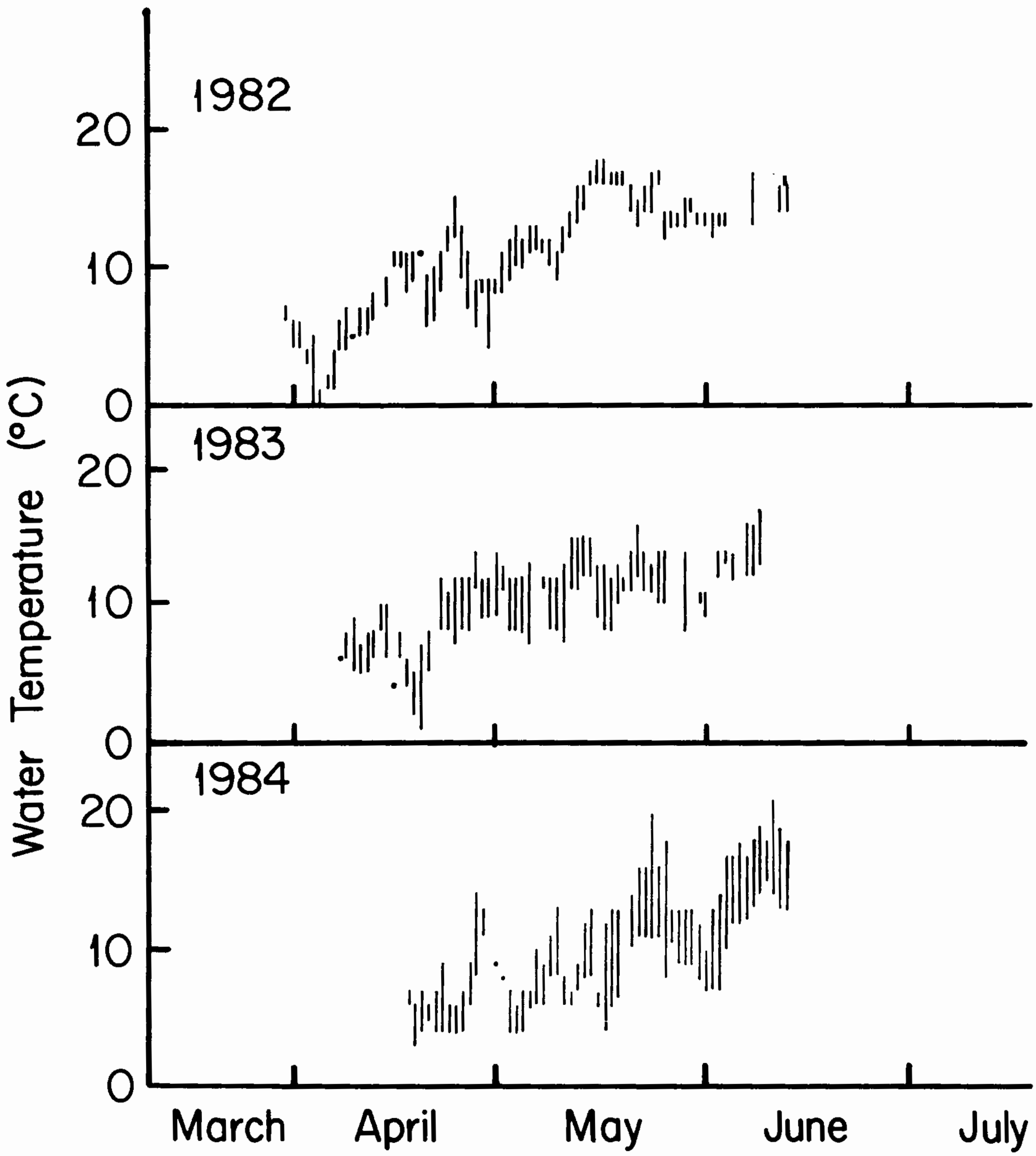

Figure 5. Daily minimum and maximum water temperatures for the Little Manistee River, 1982–84.

Table 1. Percent efficiency of smolt traps with 95% confidence limits.

Species	Year	Number marked and released	Number recaptured	Percent trapping efficiency
Coho	1982	67	15	22.4±10.2
Coho	1984	1,050	192	18.3± 2.0
Chinook	1984	871	126	14.5± 2.0
Chinook	1984	444	55	12.4± 3.0

Table 2. Percent survival from planting to smolting for hatchery-raised coho and chinook salmon planted in the Little Manistee River, 1982–84.

Year (planting date)	Number planted	Size (fish/kg)	Number smolting	Percent survival
<u>Coho</u>				
1982 (4/18)	200,000	29	139,920±63,714	70.0±31.9
1984 (4/24)	50,000	44	39,000± 4,333	78.0± 8.7
<u>Chinook</u>				
1984 (4/6)	50,000	213	92,543±13,220	185.1±26.4
1984 (5/29)	50,000	209	33,975± 4,854	68.0± 9.7

Table 3. Total numbers of wild coho and chinook salmon smolts emigrating from the Little Manistee River, 1982–84. Smolt yield is shown in parentheses as number per hectare.

Species and age	1982	1983	1984
Coho Age 1	37,192 ± 16,936 (307 ± 139)	24,049 ± 10,951 (198 ± 90)	9,272 ± 1,030 (76 ± 17)
Coho Age 0	— —	668 ± 118 (6 ± 0)	— —
Chinook Age 1	2,174 ± 495 (18 ± 4)	6,210 ± 2,828 (51 ± 23)	908 ± 140 (8 ± 0)
Chinook Age 0	30,235 ± 5,318 (249 ± 44)	25,980 ± 4,570 (214 ± 38)	120,331 ± 18,512 (992 ± 153)

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