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Biology, Exploitation and Escapement of Atlantic Salmon (Salmo salar), Liscomb River, N.S.

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BIOLOGY, EXPLOITATION AND ESCAPEMENT OF ATLANTIC SALMON (Salmo salar), LISCOMB RIVER, N.S.

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CONTENTS

LIST OF TABLES iv

LIST OF ILLUSTRATIONS vi

ABSTRACT vii

INTRODUCTION 1

METHODS AND MATERIALS 1

RESULTS AND DISCUSSION 4
RUN DEVELOPMENT, SIZE AND TIMING 4
ADULT SIZE, AGE, AND SEX COMPOSITION 6
MARINE MIGRATION AND COMMERCIAL EXPLOITATION 8
RIVER ESCAPEMENT AND ANGLING EXPLOITATION 8
EGG DEPOSITIONS AND SPAWNING ESCAPEMENTS - REQUIRED, ACTUAL, AND FORECAST 9

SUMMARY AND CONCLUSIONS 12

REFERENCES 14

LIST OF TABLES

TABLE 1. Trap operation and scale sampling protocol for Atlantic salmon at Liscomb Falls fishway, 1979-86. 16

TABLE 2. Hatchery releases of juvenile Atlantic salmon in Liscomb River above Liscomb Falls, 1977-86. 17

TABLE 3. Counts of grilse and large Atlantic salmon of hatchery and wild origin returning to the Liscomb Falls fishway, 1979-86. 18

TABLE 4. Proportion of Atlantic salmon with fork lengths <63.4 cm that were MSW fish and of salmon >63 cm that were 1SW fish based on aged salmon collected at Liscomb Falls fishway, 1979-85. 19

TABLE 5. Returns of grilse, adjusted for misclassification, and large Atlantic salmon of wild and hatchery origin to the Liscomb Falls fishway, 1979-86. 20

TABLE 6. Adjusted numbers of wild and hatchery-origin grilse and large Atlantic salmon returning to Liscomb Falls fishway, 1979-86. 21

TABLE 7. Proportions of 1SW and MSW salmon amongst wild and hatchery-origin returns at Liscomb Falls fishway, 1979-86. 22

TABLE 8. Numbers and proportions of Atlantic salmon maturing as 1SW, 2SW, and older based on the release of tagged hatchery smolts, Liscomb River, 1977-83 23

TABLE 9. Semi-monthly, unadjusted counts of grilse and salmon Liscomb Falls fishway trap, 1979-86. 24

TABLE 10. Fork lengths in relation to age and stock origin of Atlantic salmon at the Liscomb Falls fishway, 1979-85. 25

TABLE 11. Mean fork lengths of 1SW and MSW wild and hatchery-origin Atlantic salmon sampled at Liscomb Falls fishway, 1979-85. 27

TABLE 12. Freshwater and saltwater age composition of virgin, wild and hatchery-origin, Atlantic salmon Liscomb Falls fishway, 1979-85. 28

TABLE 13. Freshwater and saltwater age composition of combined samples (virgin and previous spawners) of wild and hatchery-origin Atlantic salmon Liscomb Falls fishway, 1979-85. 29

TABLE 14. Sea age composition and previous spawning history of wild and hatchery-return MSW Atlantic salmon, Liscomb Falls fishway, 1979-85 30

TABLE 15. Percentage of females among 1SW and MSW Atlantic salmon captured in Liscomb Falls fishway during September-November, 1979-86. 31

TABLE 16. Recapture location of adult Atlantic salmon from 71,294 tagged, hatchery-reared smolts released above Liscomb Falls, 1977-83. 32

TABLE 17. Angling exploitation rates and river escapements of 1SW salmon, based on tag recaptures in the angling fishery and Liscomb fishway, from hatchery smolt released above Liscomb Falls, 1979-86. 33

TABLE 18. Estimated egg depositions from wild and hatchery-return Atlantic salmon at Liscomb Falls fishway before and after adjustment for broodstock removal, 1979-86. 34

TABLE 19. Egg depositions from wild and hatchery-return Atlantic salmon above Liscomb Falls and resultant numbers and proportions of wild 1SW and MSW salmon at Liscomb Falls fishway trap in subsequent years. 35

TABLE 20. Estimated smolt output from hatchery-origin juvenile salmon releases above Liscomb Falls, finally adjusted numbers of adult hatchery returns and calculated return rates based on sea age-class adjusted counts of adults, 1977-1986. 36

LIST OF ILLUSTRATIONS

FIG. 1. Geographic location of Liscomb River and the Liscomb Falls fishway. 38

FIG. 2. Mean daily water temperatures and percentage of the total runs of grilse and salmon enumerated at Liscomb Falls fishway, arranged by semi-monthly period. Data were pooled for all years, 1979-86. 39

FIG. 3. Location of adult tag recaptures from hatchery-reared Atlantic salmon smolts released above Liscomb Falls, 1977-83. 40

ABSTRACT

Semple, J.R., and J.D. Cameron. 1990. Biology, exploitation and escapement of Atlantic salmon, (Salmo salar), Liscomb River, N.S. Can. MS Rep. Fish. Aquat. Sci. 2077: 40 p.

Nearly 447,000 hatchery-reared juvenile Atlantic salmon were released above Liscomb Falls Fishway between 1977 and 1986. Returning adult salmon have been enumerated at the fishway trap since 1979. Biological characteristics of the ensuing runs are presented including - run size, composition and timing; size (fork length), freshwater age (smolt age), saltwater age, spawning history, and sex ratios of adult returns.

Estimated angling exploitation rates on grilse revealed discrepancies between total river escapements and spawning escapements of grilse at Liscomb Falls for the years 1984-86.

Migration routes as determined from tag recoveries in all fisheries and spawning escapements are presented along with estimates of minimum relative exploitation rates in local and distant commercial fisheries.

The required and actual numbers of wild spawners and eggs for both the lower and upper Liscomb River are calculated. Run forecasts for 1987 are estimated. Underescapements in terms of numbers of wild grilse and salmon are predicted for 1987 in both river reaches. Where estimates of previous escapement levels of wild spawners were possible, underescapements were found for MSW salmon in all years, 1979-86, in both river reaches and for grilse excepting the lower Liscomb River in 1979, 1980 and 1983.

RÉSUMÉ

Semple, J.R., and J.D. Cameron. 1990. Biology, exploitation and escapement of Atlantic salmon, (Salmo salar), Liscomb River, N.S. Can. MS Rep. Fish. Aquat. Sci. 2077: 40 p.

On a relâché près de 447 000 jeunes saumons de l'Atlantique d'élevage en amont de la passe migratoire des chutes Liscomb de 1977 à 1986, et recensé les remontées de saumon adulte au piège de la passe migratoire depuis 1979. On présente ici les caractéristiques biologiques des montaisons : grosseur, composition et période où elles se produisent, données sur la taille (longueur à la fourche), sur l'âge en eau douce (âge à l'état de saumonneau), sur l'âge en eau salée ainsi que sur les antécédents de reproduction des saumons et proportions respectives des saumons des deux sexes.

Les estimations de taux d'exploitation des madeleineaux par les pêcheurs à la ligne révèlent des écarts entre les échappées totales dans la rivière et les échappées de madeleineaux reproducteurs aux chutes Liscomb pour les années 1984-1986.

On présente les routes de migration, établies dans toutes les pêches selon les étiquettes récupérées et les estimations des taux relatifs d'exploitation minimale dans les pêches locales et dans les pêches commerciales éloignées.

Le lecteur trouvera par ailleurs le calcul des besoins et des nombres réels de reproducteurs sauvages et d'oeufs pour l'amont et l'aval de la rivière Liscomb, ainsi que les prévisions de montaison pour 1987 dans les deux tronçons de la rivière. Dans les cas où il a été possible d'estimer les échappées antérieures de reproducteurs sauvages, on a établi qu'elles étaient chaque année insuffisante pour le saumon redibermarin de 1979 à 1986 dans les deux tronçons de la rivière; il en était également ainsi pour les madeleineaux, sauf dans l'aval de la rivière Liscomb en 1979, 1980 et 1983.

INTRODUCTION

In 1977, an Atlantic salmon development project was initiated in the upper Liscomb River involving both hatchery stocking and, since 1979, annual monitoring of the salmon runs in the fishway at Liscomb Falls, about 3.2 km from tidewater. Before construction of the pool-and-weir fishway in 1978, a small angling fishery exploited the population of native salmon existing below the falls.

The Liscomb River drains an area of 400 km^2 and empties into the Atlantic Ocean about 185 km northeast of Halifax, Nova Scotia (Fig. 1). Its water is moderately acidic (pH = 4.8-5.3), extremely soft (total hardness as $CaCO_3$ = 4.2-5.4 $mg.l^{-1}$) and practically unbuffered (total hardness as $CaCO_3$ = less than 0.5 $mg.l^{-1}$) (Farmer et al. 1980) as a consequence of a predominantly greywacke (Goldenville Formation) bedrock geology, accompanied by bands of slate (Halifax Formation) in the midreaches and granites in the headwaters and upper reaches. Forest harvesting is the main economic activity in the sparsely settled watershed. Gray (1976) summarized the distribution and abundance of salmon spawning and rearing area as well as other physical and biological characteristics of the Liscomb River system.

This report describes the development, biological characteristics, and exploitation of the Atlantic salmon run above Liscomb Falls. It also compares estimates of the required number of spawners and egg deposition levels above and below Liscomb Falls with actual (1985, 86) and predicted levels for 1987.

METHODS AND MATERIALS

All salmon (MSW) and grilse (1SW) were counted annually at a trap at the outlet of the Liscomb Falls fishway (1979-86). Maximum and minimum water temperatures were recorded daily. An electrically operated hoist raised the trap during inspections, during which salmon were dipped and placed in a container of fresh water. Fish were placed in a calibrated wooden trough and fork lengths were recorded to the nearest mm. Fish longer than 63 cm were classed as salmon (MSW fish); smaller fish were grilse (1SW). Fish bearing tags or finclips were classed as hatchery returns, those without as wild returns. Numbers of salmon in each sea age-class (1SW, MSW) were adjusted by scale-based age composition. All MSW fish exceeded 63 cm FL but a proportion of the smaller fish were actually MSW salmon. This proportion was multiplied by the numbers of fish classed as grilse; the resultant adjustment factor was annually subtracted from the grilse count and added to the MSW count for wild and hatchery fish separately. Sea age-class adjusted counts were further adjusted for stock origin (hatchery, wild) because not all juvenile, hatchery-reared salmon released above Liscomb Falls were marked or tagged.

Final adjustments were made by calculating the yearly outputs of marked and unmarked hatchery smolts in year t and the proportion of the marked smolts returning to Liscomb Falls in year t+1 as grilse and in year t+2 as MSW salmon. These proportions were then multiplied by the total output of marked and unmarked smolts in year t to estimate the total numbers of marked and unmarked hatchery grilse and MSW salmon returning in years t+1 and t+2, respectively. The finally adjusted counts of 1SW and MSW wild returns were obtained by subtracting the finally adjusted counts of 1SW and MSW hatchery returns from the total (hatchery + wild) sea age-class adjusted counts.

A second method of estimating wild MSW returns to Liscomb Falls employed the significant correlation between the finally adjusted counts of wild 1SW salmon at Liscomb Falls in year t and MSW counts in year t+1 ($Y_{MSW(W)} = -10.26 + 0.24X_{1SW(W)}$; $P<0.005$, $r=0.91$, 1979-85). The relationship between the finally adjusted counts of 1SW hatchery returns in year t and MSW hatchery returns in year t+1 was not significant ($P>0.04$).

Yearly outputs of hatchery smolts from above Liscomb Falls were calculated on the assumption that: (1) all age 2+ smolts leave the river in the year of release, (2) about 5% of the age 1+ smolts revert parr (stage determined from tag returns and scale reading for Liscomb Falls hatchery fish) and stay in the river another year before becoming smolts, (3) survival in fresh water from age 1+ parr to age 2+ smolts is 40% (Elson 1962), (4) all stocked age 0+ parr and unfed fry smoltify at age 2+, (5) survival of stocked unfed fry and 0+ parr to age 2+ smolts is 9.6% and 16%, respectively (Elson 1962).

Annual variation in the size and composition of the salmon run at Liscomb Falls fishway required changes in sampling protocol (Table 1). Scale samples were removed from the left side of the fish midway between the dorsal fin and lateral line. Scales were magnified 40x for ageing purposes. Age designations included fresh water age (age at smoltification), total sea age (winters) and sea ages(s) at previous spawning. For example, a sample aged 2.4 (1,3) is a fish that smoltified after two years in fresh water, spent four years (winters) at sea and spawned twice previously at one seawinter (1SW) and 3SW.

Sex of grilse and salmon was determined by external examination. Salmon captured from September 1 to the end of the salmon run in October/November can be reliably sexed in this manner and were the only fish to be sexed. Because few salmon were captured during this period, grilse of hatchery and wild origin were pooled, as were salmon. In some years, the pooled totals had fewer than 30 fish. In such cases the weighted average (1979-86) proportions of

female grilse and salmon were used in estimating required and actual egg depositions above Liscomb Falls.

Most hatchery releases of juvenile Atlantic salmon above Liscomb Falls were marked adipose or ventral (right or left) fin clips or by a small Carlin tag (to smolts only). Fish were anaesthetized with MS222 prior to applying tags at the anterior insertion of the dorsal fin (Saunders 1968). Tag returns provided a method for determining angling and commercial exploitation rates, and migration routes. No adjustments were made for tag loss or tag non-reporting in estimating relative exploitation rates in various commercial fisheries.

Angling exploitation rates were calculated by adjusting the actual numbers of tag recoveries from the Liscomb sport fishery upwards 30% for non-reporting (Cutting and Gray MS 1984). Angling exploitation rate equals the adjusted numbers of tag recoveries from the sport fishery divided by the sum of the tags recovered at Liscomb Falls fishway trap and the adjusted numbers of tags taken in the angling fishery. Angling exploitation rates for MSW salmon could not be calculated, because no tags from MSW salmon were reported from the Liscomb angling fishery.

River escapement of grilse equals the total grilse (hatchery and wild) angled (Redbooks) divided by the angling exploitation rate of grilse, assuming that both hatchery and wild grilse are angled at the same rate.

Required egg depositions in various parts of the Liscomb River are the product of rearing area estimates (Gray 1976) and the eggs required per unit area, which is assumed to be 2.4 eggs m^{-2} (Elson 1974). Rearing area is estimated as: 147,100 m^2 below Liscomb Falls and 1,538,500 m^2 above Liscomb Falls (324,400 m^2 Little Liscomb River tributary plus 1,214,100 m^2 in the West Liscomb River and mainstem).

Annual egg depositions above Liscomb Falls were calculated, with and without adjustment for broodstock removal, as the sum of the eggs contributed by each run component (H1SW, W1SW, HMSW, WMSW). Eggs contributed by each component is the product of the finally adjusted count of the respective stock components at Liscomb Falls times the proportion female (see qualifications discussed under sex ratios) times the fecundity of female salmon of mean fork length. Fecundities were calculated from the fecundity - length relationship for LaHave/Medway stock; $Y=6.15066 + 0.3525X$, where Y = number of eggs and X = fork length (cm) (Cutting and Jefferson MS 1986). This method was considered appropriate because LaHave River stock provided hatchery-reared juvenile salmon for release above Liscomb Falls during the early part of the development.

Required spawning escapements of wild 1SW and MSW salmon above Liscomb Falls were calculated from the total egg deposition per fish, rearing area estimates (Gray 1976). Estimates of spawning escapements to the lower Liscomb River in later years (1985-86) were estimated by extrapolating spawning escapements per unit rearing area above Liscomb Falls to rearing area below the Falls.

The 1987 forecast of spawning escapement for wild grilse above Liscomb Falls was based on the mean proportions of eggs deposited above the Falls (adjusted from broodstock removal) in years t and t+1 that yielded 1SW salmon there in year t+5. For wild MSW salmon, the mean proportion of eggs deposited above the falls in years t-1 and t that yielded MSW wild returns at Liscomb Falls in year t+5 was used in forecasting returns of MSW salmon in 1987.

RESULTS AND DISCUSSION

RUN DEVELOPMENT, SIZE AND TIMING

The pool-and-weir fishway which provides passage for Atlantic salmon upstream of Liscomb Falls and an abandoned hydroelectric facility is cut through solid rock, the 15 pools of which are separated by concrete weirs. A head difference of approximately 61 cm exists between each pool. Prior to completion of the fishway, salmon broodstock were collected from the St. Mary's River in 1974 and the LaHave River in 1975, which provided the initial stocking with hatchery-reared smolt and parr in 1977. In subsequent years, broodstock were collected from Liscomb River and East River Sheet Harbour.

Hatchery stocking above Liscomb Falls is summarized in Table 2. Between 1977 and 1986, a total of 447,283 juvenile salmon were released. Of this total, 15.2% were age 1+ smolts and 68.2% were age 2+ smolts. Nearly 98% of the total fish released were marked and/or tagged. Table 2 excludes 4,395 age 1+ tagged and marked (adipose fin clip) smolts that were released below Liscomb Falls in 1986.

The salmon counts in Liscomb Falls fishway trap represent the spawning escapement to the upper Liscomb River. Salmon angling has not been permitted above Liscomb Falls since the fishway was opened in 1978 and poaching there is assumed to be negligible.

Unadjusted annual counts of salmon and grilse of wild and hatchery origin are summarized in Table 3 for years 1979-86. Because some of the fish recorded as grilse (1SW salmon) were actually MSW fish, the annual totals of salmon and grilse in Table 3 were adjusted by the length-at-age results of Table 4. All salmon > 63 cm fork length were correctly classified as MSW fish. The adjusted compositions are summarized in Table 5. A further adjustment to the

sea age-class adjusted results of Table 5 accounts for returns of unmarked/untagged hatchery juveniles released in previous years (Table 6). Wild grilse returns gradually increased from 60 fish in 1979 to an all time high of 704 in 1986 and wild MSW salmon increased from zero to 149 fish. Escapements in 1985-86 increased in response to prohibition of the angling of large salmon (>63 cm FL) and a ban on commercial salmon fishing. The angling ban was supposed to take effect in 1984, but did not do so until the end of that angling season. Hatchery-origin returns in 1979-86 varied from 175 to 977 grilse and from 2 to 186 large salmon (Table 6). Hatchery-origin returns have been influenced by the numbers of hatchery juveniles released above Liscomb Falls in previous years (Table 2) and by restrictions on angling and commercial fisheries.

Grilse:salmon ratios for the finally adjusted counts at Liscomb Falls (Table 6) are summarized in Table 7. Between 1979 and 1986, the proportion of wild MSW salmon ranged from zero to 0.197 (weighted mean = 0.128) while hatchery-origin proportions ranged from 0.004 to 0.279 (weighted mean - 0.123). Annual proportions of MSW salmon returning to Liscomb Falls were more erratic in hatchery than wild components, probably due to annual broodstock selection criteria and to different marine harvesting regimes between years. Also, varying numbers of age 1+ and 2+ hatchery smolts were released above Liscomb Falls in different years and age 1+ smolts contribute a higher proportion of 2SW salmon than age 2+ smolts (Gray 1973; Ritter 1974).

The proportions of Liscomb salmon maturing as 1SW and MSW fish are summarized in Table 8. Of 71,294 tagged hatchery smolts released above the falls in 1977-83, 101 MSW salmon or 25.1% of the total tag recaptures from salmon of known sea age-class were reported from various fisheries and escapements. The figures represent minimum values as a portion of the 1SW salmon captured in Newfoundland that would have returned as MSW salmon. Results of the smolt tagging suggest a lower return (8.8%; Table 8) of hatchery-origin MSW returns to Liscomb Falls than was actually observed in the spawning escapement (12.3%; Table 7).

Salmon runs in Liscomb River start during the first two weeks in June and end in late October. The counts of grilse and salmon at Liscomb Falls peaked between July 1-15 in 5 of 8 years, with over 28% of the total return counted (Table 9; Fig. 2).

Returns (pooled data) of grilse and salmon increase with increasing mean daily water temperature until it rises above 20°C in late July, after which water temperature has little influence on daily count. The activity of migrating adult Atlantic salmon can be severely reduced at temperatures above 20°C (DeCola 1970), while freshets may increase the numbers of Atlantic salmon migrating upstream during a given period (Huntsman 1948; Hayes 1953; Banks 1968).

ADULT SIZE, AGE, AND SEX COMPOSITION

Mean fork lengths of wild 1SW returns captured in Liscomb Falls fishway between 1979-85 ranged from 52.1-54.2 cm (weighted mean = 52.8 cm) and from 51.0-53.4 cm (weighted mean - 52.2 cm) for hatchery returns (Table 10). The weighted and unweighted mean lengths for the pooled data of all years were essentially similar (Table 11). Mean lengths of wild MSW salmon varied from 61.3-78.4 cm (weighted mean = 70.4 cm) and for hatchery returns the range was 64.6-78.4 cm (weighted mean = 69.2 cm) (Tables 10 and 11). Mean lengths of Liscomb River 1SW returns are similar to those from other Maritime rivers: LaHave (Gray 1986), Restigouche (Randall MS 1984), Big Salmon (Jessop 1986) and Stewiacke (Amiro and McNeil MS 1986). MSW salmon in Liscomb River are comparable in size to Stewiacke and Big Salmon river stocks but smaller than those of Restigouche and LaHave stocks.

Virgin, wild salmon sampled at Liscomb Falls from 1979-85 consisted of 89.4% 1SW, 10.4% 2SW, and 0.2% 3SW fish. In 1979-80, all virgin wild salmon were 1SW returns, in later years the proportions of salmon older than 1SW increased gradually from 0.0%-27.1% (Table 12). During the (1979-85) period, maiden hatchery salmon consisted of 91.9% 1SW, 7.2% 2SW, and 0.8% 3SW returns. The lower proportion of 2SW salmon in the hatchery stock component was unexpected because nearly 18% (Table 2) of the hatchery smolts released (1977-86) above Liscomb Falls were age 1+ smolts and may contribute a higher proportion of maiden 2SW salmon (Gray 1973; Ritter 1974). Moreover, the commercial ban on salmon harvesting and the angling ban on large salmon (> 63 cm FL) in 1985-86 also should have influenced the age composition of the salmon run at Liscomb Falls.

The sea age composition of the combined virgin and previous spawning salmon of wild and hatchery origin is summarized in Table 13. Pooling (virgin and previous spawners) reduced the contribution of maiden 1SW salmon from 89.4% to 78.9% for wild returns and from 91.9% to 82.1% for hatchery returns. From 1979-85, a total of 60 wild and 71 hatchery-return previous spawners was sampled at Liscomb Falls (Table 13), representing 11.7% and 10.7% of the 15 total respective stocks. The MSW wild run component consisted of 44.4% maiden fish, 36.1% consecutive-year previous spawners, and 19.4% alternate-year previous spawners (Table 14). In comparison, hatchery-return MSW fish during the same period consisted of 40.3% virgin salmon, 44.5% consecutive-year previous spawners, and 15.1% alternate-year previous spawners. Previous spawners predominated amongst MSW fish of both hatchery and wild origin. Amongst fish that had spawned before, consecutive-year spawning was most prevalent.

A different distribution of maiden and previous spawning MSW fish occurred at Morgan Falls, LaHave River (1974-83).

(Cutting an Gray MS 1984), viz-

Run component	Virgin	Consecutive-year previous spawners	Alternate-year previous spawners	Total MSW salmon
HMSW	79.9%	6.7%	13.4%	418
WMSW	64.2%	10.1%	25.6%	464

Amongst MSW LaHave stock, maiden fish predominated; alternate-year spawners were more prevalent amongst previous spawners.

Differential harvest rates on stock components in various fisheries and varying escapements due to weather conditions and harvest restrictions; combined with different broodstock selection criteria and the age of hatchery smolts released in Liscomb River, are all likely contributors to the annual fluctuation in the proportion of maiden and previous spawning MSW salmon (Table 14).

Returns of virgin, wild salmon and grilse at Liscomb Falls originate from age 2+ and 3+ smolts (Table 12). Proportions of age 2+ smolts during 1979-85 ranged from 78.9%-96.2% and averaged (weighted) 92.1%. Smolt composition of the combined samples (1979-85) of maiden and previous spawning, wild adult returns was similar to that of maiden fish alone (92.0% age 2+ and 8.0% age 3+; Table 13), and were similar to those found in upper LaHave system (Gray 1986). Stocks in both rivers were developed through hatchery stocking and the provision of fish passage facilities. Density-dependent growth particularly in the early development years may be promoting a larger contribution of younger age 2+ smolts than in natural systems with a more developed salmon resource such as Big Salmon River where age 2+ and 3+ smolts contributions are nearly equal (Jessop 1975).

Returns of maiden, hatchery salmon and grilse originated from age 1+ and 2+ smolts (Table 12). The contributions of age 2+ smolts in this component varied yearly (1979-85) between 84.5% and 98.0% and averaged (weighted) 89.7%. These results were likely influenced by the numbers of age 1+ and 2+ hatchery smolts released above Liscomb Falls in previous years (Table 2).

Annual sex ratios (% female) for 1SW and MSW salmon captured at Liscomb Falls during September-November 1979-86 are summarized in Table 15. Hatchery and wild returns were pooled (all years) because sample sizes were small. The weighted average percent female among grilse was 52%, compared with 67% for large salmon. Except for MSW salmon returns in 1981, the numbers of sexed MSW salmon were low (<30 fish); hence, the reliability of the proportions of females amongst MSW salmon in other years is uncertain.

The proportion of females among 1SW Liscomb salmon is higher than in many Maritime rivers, including the LaHave (Gray 1986), Restigouche (Randall MS 1984) and Saint John (Penny and Marshall MS 1984). The Stewiacke River is an exception (Amiro and McNeill MS 1986). The Liscomb stock has a MSW female salmon proportion comparable to the Restigouche but lower than found in LaHave, Saint John, and Stewiacke stocks.

MARINE MIGRATION AND COMMERCIAL EXPLOITATION

Tag recaptures from 72,294 age 1+ and 2+ hatchery smolts released upriver of Liscomb Falls (1977-83) are summarized in Table 16 and Figure 3. A total of 407 recaptures or 0.6% of the total tags released was made in various fisheries or escapement stretching from the upper Bay of Fundy to western Greenland (NAFO area 1A). In the intervening area, tags were recovered along the eastern Nova Scotia coast and in northern, eastern, and southern Newfoundland. Few tagged fish were recovered in Labrador (1 fish), Québec (2 fish), southwestern Nova Scotia (10 fish) and the upper Bay of Fundy (1 fish) compared with those captured in commercial fisheries (124 fish) north of the Eastern Shore Salmon Management Zone where Liscomb River is located.

Total exploitation in all commercial fisheries was 40.8% (166 fish) distributed as follows, in relation to the total tag recoveries: Nova Scotia (14.3%), Québec (0.5%), Newfoundland and Labrador (13.5%), Greenland (11.5%), other (1.0%). These are minimum values because no adjustments have been made for tag-nonreporting, variability in tag-nonreporting between the various commercial fisheries, tag loss, or natural mortality.

RIVER ESCAPEMENT AND ANGLING EXPLOITATION

No tags from MSW salmon were recovered by the Liscomb sportfishery, 1979-84. Moreover, there was an angling ban on the retention of large (MSW) salmon >63 cm fork length in 1985-86. Thus, yearly sport fishing exploitation rates and total escapements of MSW salmon could not be determined.

Tag recoveries from 1SW fish in both the Liscomb sportfishery and the fishway trap at Liscomb Falls are summarized in Table 17. Adjusted, yearly exploitation rates in the angling fishery ranged from 0.04 to 0.32 in years 1979-86. The numbers of tagged 1SW fish reported from the sport catch were adjusted upward by an assumed tag nonreporting rate of 30%.

Estimates of total river escapements of grilse based on numbers angled (Redbooks) and angling exploitation rates in four years (years 1981, 1984-86) gave fewer grilse than actually ascended the fishway

at Liscomb Falls. This inconsistency is clearly impossible because the total count of grilse at Liscomb Falls cannot exceed the total river escapement since grilse counted at Liscomb Falls are only part of the total. Either the angling exploitation rates in these years (1981, 1984-86) are too high and/or the estimated sport catches (Redbooks) are lower than were actually harvested. In three years (1979, 1980 and 1983) estimated total river escapements of grilse exceeded the numbers counted at Liscomb Falls fishway and hence, were deemed plausible (Table 17).

Hatchery grilse originating from juveniles released above Liscomb Falls and wild grilse originating from natural spawning there are assumed to migrate upstream beyond the falls, leaving only wild grilse in the lower Liscomb River. All hatchery stocking 1977-85 was above the falls, so it is possible to estimate the total escapement and spawning escapement of wild grilse in lower Liscomb River in 1979, 1980, and 1983 (Table 17). Total estimated lower river escapements of wild grilse ranged from 452-456 fish; spawning escapements ranged from 309-400 fish and were in excess of estimated spawning requirements (167 wild grilse). These escapement levels seem high in relation to the available spawning (800 m^2) and rearing area (147,100 m^2) below Liscomb Falls.

EGG DEPOSITIONS AND SPAWNING ESCAPEMENTS - REQUIRED, ACTUAL, AND FORECAST

The required egg depositions for various parts of the Liscomb River system are based on rearing area estimates (Gray 1976) and eggs required per unit area (Elson 1974) (see Materials and Methods Section). Egg requirements below Liscomb Falls are estimated at 353,000 with 3,692,000 required above the falls. The above-falls estimate can be subdivided into that required for Little Liscomb River tributary (778,600 eggs) and for the West Liscomb River plus mainstem (2,913,800 eggs).

Annual egg depositions in the upper Liscomb River from both wild and hatchery fish returning to Liscomb Falls before adjustment for broodstock removal are summarized in Table 18. Egg depositions were below requirements (3,692,000 eggs) in all years, 1979-86 (Table 18). The 1986 egg deposition from wild returns at Liscomb Falls, the highest on record, was only 47% of the required number of eggs.

Required average spawning escapement for various parts of the Liscomb River system was determined from egg deposition per fish, rearing area estimates (Gray 1976) and an assumed egg deposition requirement of 2.4 $eggs.m^{-2}$ (Elson 1974). Egg deposition per fish was calculated as follows:

Eggs per wild female of mean fork length		Proportion wild female (Table 15)		Proportion in runs (Table 7)		Egg deposition per fish
MSW:5,611	x	0.67	x	0.128	=	481
1SW:3,017	x	0.52	x	0.872	=	1,368
		Egg deposition per fish			=	1,849

Spawning escapement needed to meet the egg deposition requirements was estimated from the required egg deposition rate times rearing area (m2) divided by the egg deposition per fish, as follows:

River Section	Required egg deposition per unit (m^2) rearing area		Rearing area (m^2)		Total egg deposition per fish		Total	1SW	MSW
Below Liscomb Falls	2.4	x	(147,100	- 1,849)	=		191	167	24
Above Liscomb Falls									
Little Liscomb R.	2.4	x	(324,400	- 1,849)	=		421	367	54
West Liscomb R. + main river	2.4	x	(1,214,100	- 1,849)	=		1,576	1,374	202
Total							2,188	1,908	280

A total of 2,188 wild fish (1,908 grilse and 280 salmon) is required on average for spawning in the Liscomb River system. Of these, 1997 fish (1,741 grilse + 256 salmon) are needed for the upper Liscomb River and 191 (167 grilse + 24 salmon) for the Liscomb River below the falls. The observed spawning escapements of wild fish to the upper Liscomb River in years 1979-86 (Table 6) indicate that annual escapements have not yet reached the required level. In 1986 only 58% of the wild salmon and 40% of the wild grilse requirements were achieved.

Assuming that wild spawning escapement in the lower Liscomb River in the later years (1985, 1986) is proportional to rearing area above and below the falls and to spawning escapement above (Table 6), they can be calculated as follows:

$$\text{Wild 1SW spawning escapement} = \frac{\text{Rearing area below falls} \times \text{Wild 1SW spawning escapement above falls}}{\text{Rearing area above falls}}$$

Spawning escapement of wild MSW salmon below Liscomb Falls is calculated in a similar manner. It may thus be estimated that 57 wild fish (46 grilse + 11 salmon) spawned in the lower Liscomb River in 1985 and 81 fish (67 grilse + 14 salmon) in 1986. These spawning escapement levels indicate there was an underescapement of wild grilse and salmon in both of these years (target was 167 grilse and 26 salmon).

Forecasts of wild 1SW and MSW returns to Liscomb Falls in 1987 were determined by two methods. Method 1 predicts age-adjusted

return of 1SW salmon based on the average return rate (0.000253) in years 1985 and 1986 (year t+5) (comparable fisheries to those expected in 1987) from eggs deposited above Liscomb Falls in 1980-81 and 1981-82 (years t and t+1), respectively, applied to the egg deposition in 1982-83 (Table 19). On this basis, 931 wild grilse are predicted for Liscomb Falls in 1987 (1,160 actually returned). The forecast of wild MSW returns is based on the average return rate (0.000054) of wild salmon at Liscomb Falls in years 1985 and 1986 (year t+5) from eggs deposited above the falls in 1979-80 and 1980-81 (year t-1 and t), respectively (Table 19), applied to the egg deposition there in 1981-82. A total of 123 wild MSW salmon is predicted to return to the upper Liscomb River in 1987 (93 actually returned). Method 2 used the significant correlation between wild 1SW counts at Liscomb Falls in year t and wild MSW returns in year t+1 (Table 6). The regression $Y_{MSW(W)} = -10.26 + 0.24X_{1SW(W)}$ ($P>0.005$, $r=0.91$, 1979-85) estimates a 1987 spawning escapement of 159 (98-220, 95% confidence intervals) wild MSW salmon at Liscomb Falls from 704 wild grilse in 1986.

Forecasts of 1SW and MSW hatchery returns to the upper Liscomb River are based on the estimated hatchery outputs of smolts from juveniles released above Liscomb Falls in year t and the proportion returning in year t+1 as 1SW salmon and in year t+2 as MSW salmon (Table 20). Because the salmon runs of 1985 and 1986 but not earlier years were subject to commercial fishing bans and to angling removal of large salmon (>63 cm FL) only the mean proportions of hatchery 1SW and MSW salmon returning to Liscomb Falls in these two years, from smolt outputs in 1984 + 85 (1.07%) and 1983 + 84 (0.22%) respectively, were applied to smolt outputs in years 1986 and 1985 to forecast returns of hatchery 1SW and MSW salmon in 1987. On this basis, it was predicted that 220 hatchery grilse and 94 salmon would escape to the upper Liscomb River in 1987. Actual escapements were 523 grilse and 54 salmon.

Predictions of wild spawning escapement of 1SW and MSW salmon below Liscomb Falls in 1987 are based on forecast of wild 1SW and MSW returns above the falls in 1987 (by Methods 1 and 2) and on the ratio of rearing area above and below the falls. On this basis 89 wild 1SW and 12 wild MSW returns are predicted for 1987. Applying the 1987 forecast of wild MSW salmon for the upper Liscomb River derived by Method 2 of the ratio of rearing area above and below the falls gives a spawning escapement prediction of 15 (9-21) wild MSW to the lower Liscomb River in 1987.

All hatchery releases of juvenile salmon, except in 1986, were made above Liscomb Falls (Table 2), so it is assumed that all adults returning from these stockings will ascend past the falls leaving only wild fish to spawn below. However, in 1986, 4,395 age-1+ hatchery smolts were released in the lower Liscomb River. Assuming that 95% of these fish leave the river as 1+ smolts, and applying the

mean return rate of 1SW salmon from smolt outputs in years 1984 and 1985 (1.07%) (Table 20) gives a prediction of 45 hatchery grilse in the spawning escapement below Liscomb Falls in 1987.

The 1987 forecasts of wild 1SW and MSW spawning escapements are below requirements for both the upper (1,741 wild grilse + 256 wild salmon) and lower (167 wild grilse + 24 wild salmon) Liscomb River sections.

SUMMARY AND CONCLUSIONS

1. A fishway was opened for fish passage at Liscomb Falls in 1978 and 447,283 hatchery-reared juvenile Atlantic salmon were released above the falls between 1977-86 to develop a natural spawning stock for the upper Liscomb River.

2. The salmon run to the upper Liscomb River reach an all-time high of 1,727 fish in 1986.

3. Grilse:salmon ratios at Liscomb Falls fishway trap have averaged 0.877:0.123 for the hatchery component and 0.872:0.128 for the wild run component.

4. Salmon movements at Liscomb Falls begin in early June, reach a peak during a period of rising water temperature in early July, decline when water temperatures rise above 20°C in late July and August, and end in late October.

5. Mean fork lengths of aged 1SW wild and hatchery-return salmon were 52.8 cm and 52.2 cm, respectively; MSW wild and hatchery-return salmon averaged 70.4 cm and 69.2 cm, respectively.

6. Maiden fish of wild origin consisted of 89.4% 1SW, 10.4% 2SW, and 0.2% 3SW; maiden hatchery-returns consisted of 91.9% 1SW, 7.2% 2SW, and 0.8% 3SW salmon.

7. Of the total wild aged sample, 11.7% were previous spawners compared with 10.7% in the hatchery-return component.

8. For MSW wild returns, 44.4% of the total were maiden fish, 36.1% were consecutive-year previous spawners and 19.4% were alternate year previous spawners. Among the MSW hatchery-returns, 40.3% were maiden fish, 44.5% were consecutive-year previous spawners and 15.1% were alternate-year previous spawners.

9. Among maiden wild adult returns, only the 2+ and 3+ smolt age-classes were represented; 2+ smolts contributed to 92.1% of the

return. Maiden hatchery returns, originate from age-1+ and 2+ smolts, were derived 89.7% from age-2+ smolts.

10. Grilse and salmon (wild and hatchery origin combined) averaged 52% and 67% female, respectively.

11. Migration routes of adult salmon, as determined from tag recaptures, extended from NAFO area 1A in West Greenland to the northern, eastern, and southern coasts of Newfoundland, and thence to the eastern Nova Scotia coast as far as the upper Bay of Fundy and west to Québec.

12. Relative exploitation in commercial fisheries based on tag returns in fisheries and escapements was 40.8%, distributed as follows: Nova Scotia (14.3%), Québec (0.5%), Newfoundland/Labrador (13.5%), Greenland (11.5%), and other (1.0%).

13. Angling exploitation rates based on tag recoveries could not be determined for MSW salmon; exploitation rates on 1SW fish ranged from 0.040 to 0.316, but these were of limited applicability in calculating total annual river escapements of 1SW fish owing to the incompatibility of the sport catches, fishway counts, and/or angling exploitation rates in some years.

14. Required egg depositions in the lower and upper Liscomb River are estimated at 353,000 and 3,692,000, respectively. Achieved egg depositions in both reaches of the river by wild salmon alone or the combined wild and hatchery-returns were below requirements in all years, 1979-86.

15. Average spawning requirements of wild fish are estimated as 191 (167 1SW and 23 MSW) in the lower and 1,997 (1,741 1SW and 256 MSW) in the upper Liscomb River.

16. The Method 1 forecast for 1987 of spawning escapement to the upper Liscomb River is 220 hatchery-origin and 931 wild grilse and 94 hatchery-origin and 123 wild large salmon; to the lower Liscomb River it is 45 and 89 grilse of hatchery and wild origin, respectively, and 0 and 12 large salmon.

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TABLE 1. Trap operation and scale sampling protocol for Atlantic salmon at Liscomb Falls Fishway, 1979-86.

Year	Trapping date		Scale sampling protocol	
	From	To	Grilse	Salmon
1979	June 24	Oct. 10	1:4	1:2
1980	June 13	Oct. 22	1:7	1:4
1981	June 9	Oct. 28	1:7	1:4
1982	May 25	Nov. 2	1:9	1:3
1983	May 16	Nov. 4	1:5	1:2
1984	May 8	Nov. 2	1:6	1:6
1985	June 24	Oct. 23	1:4	1:2
1986	June 2	Oct. 23	1:3	1:2

TABLE 2. Hatchery releases of juvenile Atlantic salmon in Liscomb River above Liscomb Falls, 1977-86.

Year	Age 0+		Age 1+ smolt			Age 2+ smolt		Total
	Unfed fry	Parr	Age 1+ parr	Total released	Number marked and/or tagged	Total released	Number marked and or tagged	released (all stages)
1977				3,968	3,968	4,010	4,010	7,978
1978			1,424	9,140	9,140	38,219	38,219	48,783
1979				7,416[2]	4,414	50,329	50,329	57,745
1980				4,795	4,795	22,112	22,112	26,907
1981	2,076[1]			3,001	3,001	39,393[3]	36,907	44,470
1982				3,019	3,019	40,241	40,241	43,260
1983		37,736		17,269	17,269	43,692	43,692	98,697
1984			11,972			40,119	40,119	52,091
1985	600[1]	16,311		4,877	4,877	27,043	27,043	48,831
1986[4]			3,885	14,636	14,636			18,521
TOTAL	2,676	54,047	17,281	68,121	65,119	305,158	302,672	447,283

1. All of these fish were neither marked nor tagged.
2. 3,002 of these fish were not marked or tagged.
3. 2,486 of these fish were not marked or tagged.
4. A total of 4,395 tagged and marked (adipose fin clip) age 1+ smolts was released below Liscomb Falls in 1986 (none in other years) and are not included in the table.

TABLE 3. Counts of grilse and large Atlantic salmon of hatchery and wild origin returning to the Liscomb Falls fishway, 1979-86.

	Hatchery		Wild		Total		
Year	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Total
1979	485	2	60	2	545	4	549
1980	931	51	111	0	1,042	51	1,093
1981	241	49	76	6	317	55	372
1982	827	41	252	10	1,079	51	1,130
1983	594	63	520	15	1,114	78	1,192
1984	331	42	606	48	937	90	1,027
1985	175	49	507	87	682	136	818
1986	766	108	736	117	1,502	225	1,727

1. Based on fork lengths $<$ 63 cm for grilse and $\geq$ 63 cm for salmon and on returns of marked or tagged fish.

TABLE 4. Proportion of Atlantic salmon with fork lengths < 63 cm that were MSW fish and of salmon ≥ 63 cm that were 1SW fish based on aged salmon collected at Liscomb Falls fishway traps, 1979-85.

	Fork length < 63 cm				Fork length ≥ 63 cm			
	Wild returns		Hatchery returns		Wild returns		Hatchery returns	
Year	Sample size	Proportion MSW	Sample size	Proportion MSW	Sample size	Proportion 1SW	Sample size	Proportion 1SW
1979	19	0.000	109	0.000	1	nil	1	nil
1980	18	0.000	137	0.000			14	nil
1981	15	0.000	40	0.100	1	nil	12	nil
1982	38	0.000	81	0.000	1	nil	18	nil
1983	112	0.062	121	0.190	3	nil	32	nil
1984	104	0.038	49	0.020	12	nil	3	nil
1985	117	0.060	37	0.000	73	nil	11	nil
All years	423	0.043	574	0.049	91	nil	91	nil

TABLE 5. Returns of grilse, adjusted for misclassification[1], and large Atlantic salmon of wild and hatchery origin to the Liscomb Falls fishway 1979-86,

	Hatchery		Wild		Total		
Year	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Total
1979	485	2	60	2	545	4	549
1980	931	51	111	0	1,042	51	1,093
1981	217	73	76	6	293	79	372
1982	827	41	252	10	1,079	51	1,130
1983	481	176	488	47	969	223	1,192
1984	324	49	583	71	907	120	1,027
1985	175	49	477	117	652	166	818
1986	728	146	704	149	1,432	295	1,727

1. Derived from mean (weighted) proportions of length-misclassified 1SW wild and hatchery-returns for 1979-85 (Table 4) applied to the unadjusted counts for 1986 in Table 3.

TABLE 6. Adjusted numbers of wild and hatchery-origin grilse and large Atlantic salmon returning to Liscomb Falls fishway, 1979-86.

Year	Hatchery[1]		Wild[2]		Total		
	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Total
1979	485	2	60	2	545	4	549
1980	977	51	65	0	1,042	51	1,093
1981	217	76	76	3	293	79	372
1982	881	41	198	10	1,079	51	1,130
1983	481	186	488	37	969	223	1,192
1984	326	49	581	71	907	120	1,027
1985	175	49	477	117	652	166	818
1986	728	146	704	149	1,432	295	1,727

1. Adjusted hatchery returns based on the proportions of marked 1SW and MSW salmon returning to Liscomb Falls in year t+1 (1SW) and year t+2 (MSW) (Table 5) from the estimated output of marked smolts in year t (Table 19) applied to the total output of marked and unmarked smolts in year t.

2. Adjusted 1SW wild returns equal the difference between the adjusted numbers of 1SW hatchery returns in the above table and total grilse (hatchery + wild) in Table 5; adjusted MSW wild returns equal the difference between the adjusted numbers of MSW hatchery returns in the above table and total MSW salmon (hatchery and wild) in Table 5.

TABLE 7. Proportions of 1SW and MSW Atlantic salmon amongst wild and hatchery-origin returns to Liscomb Falls Fishway, 1979-86.[1]

Year	Hatchery returns		Wild returns	
	1SW	MSW	1SW	MSW
1979	0.996	0.004	0.968	0.032
1980	0.950	0.050	1.000	0.000
1981	0.741	0.259	0.962	0.038
1982	0.956	0.044	0.952	0.048
1983	0.721	0.279	0.930	0.070
1984	0.869	0.131	0.891	0.109
1985	0.781	0.219	0.803	0.197
1986	0.833	0.167	0.825	0.175
Weighted mean	0.877	0.123	0.872	0.128

1. Derived from salmon counts at Liscomb Falls fishway trap, adjusted for sea age-class and origin (Table 6).

TABLE 8. Numbers and proportions of Atlantic salmon maturing as 1SW, 2SW, and older, based on the release of tagged hatchery smolts, Liscomb River, 1977-83[1].

Recapture location	Age at maturity[2] 1SW	2SW and older	Unknown
Spawning escapement[3]			
Liscomb River	187(0.464)	18(0.045)	
LaHave River	1(0.002)		
Subtotal	188(0.466)	18(0.045)	
Commercial			
Nova Scotia	34(0.084)	24(0.060)	
Newfoundland/Labrador	45(0.112)	10(0.025)	
Greenland		44(0.109)	3
Quebec	2(0.005)		
Other	1(0.002)	3(0.007)	
Subtotal	82(0.203)	81(0.201)	
Angling			
Liscomb River	19(0.047)		
Other N.S. Rivers	12(0.030)	2(0.005)	1
Newfoundland	1(0.002)		
Subtotal	32(0.079)	2(0.005)	
TOTAL	302(0.749)	101(0.251)	4

1. Tag recoveries to December 31, 1984.
2. Proportions of the total tagged fish recovered, excluding unknowns, are given in parentheses.
3. Determined from fishway traps at Liscomb Falls and Morgan Falls (LaHave River).

Table 9. Semi-monthly unadjusted counts of grilse and salmon at Liscomb Falls fishway, 1979-86.

Period	1979		1980		1981		1982		1983		1984		1985		1986		All years combined[1]	
	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse	Salmon
Jun 01-15							1	1	1	3	1	4			5	16	8(0.1)	24(1.9)
16-30	47			3	7		53	15	34	2	60	26	7		179	55	387(5.8)	101(8.2)
Jul 01-15	255	2	189	24	45	3	137	14	720	44	442	29	63	170	568	62	2419(36.3)	348(28.2)
16-31	100		411	14	39	2	269	8	186	14	151	16	34	245	319	23	1509(22.6)	322(26.1)
Aug 01-15	3		134		28	3	311	7	111	9	76	3	15	111	140	17	818(12.3)	150(12.1)
16-31	104	1	100		92	11	214	4	40	4	135	8	7	99	204	26	896(13.4)	153(12.4)
Sep 01-15	19	1	10	8	102	34	53		7	2	23		7	49	31	5	252(3.8)	99(8.0)
16-30	12		153		4	2	23	1	10		15	1	1	3	26	8	244(3.7)	15(1.2)
Oct 01-15	3		45	2			9		4		18	2	2		14	10	95(1.4)	14(1.1)
16-31							9	1	1		16	1		5	16	3	42(0.6)	10(0.8)
Total	543	4	1,042	51	317	55	1,079	51	1,114	78	937	90	136	682	1,502	225	6670(100.)	1236(100.)

[1] Percent of totals shown in parentheses.

TABLE 10. Fork lengths, in relation to age and stock origin, of Atlantic salmon at the Liscomb Falls fishway, 1979-85.

Year/Age · age	Wild returns n	Mean	SD	Range	Hatchery returns n	Mean	SD	Range
1979								
1·1					17	51.6	2.6	46.0-55.0
2·1	15	53.5	2.0	51.0-58.0	92	52.1	3.3	42.0-59.5
3·1	4	52.7	3.9	48.5-58.0				
2·2					1	76.5	-	-
2·2(1)	1	58.0	-	-				
1980								
1·1					12	52.4	2.3	47.5-55.5
2·1	15	54.2	2.2	49.5-58.0	125	53.0	2.2	47.0-59.0
3·1	3	54.1	0.6	53.5-54.5				
1·2					1	74.5	-	-
2·2					12	72.1	4.9	67.0-82.0
2·3(1)					1	65.0	-	-
1981								
1·1					13	52.5	3.1	46.5-56.5
2·1	13	52.6	2.2	48.5-56.5	23	51.7	3.6	44.0-60.5
3·1	2	49.3	3.9	46.5-52.0				
1·2					1	72.0	-	-
2·2					6	72.9	4.5	67.5-78.5
1·3					1	90.5	-	-
2·3					1	84.5	-	-
2·2(1)					6	62.3	6.1	55.0-69.5
2·3(1)					1	81.5	-	-
1982								
1·1					9	52.7	2.2	49.0-56.0
2·1	32	52.3	3.3	49.5-62.0	72	52.1	2.6	48.0-58.0
3·1	6	51.2	1.8	49.0-54.0				
2·2	1	70.1	-	-	8	71.0	3.6	65.0-77.5
2·3					3	94.5	3.0	92.5-98.0
2·3(1)					4	77.3	3.2	74.5-82.0
2·3(2)					1	78.0	-	-
2·4(2)					1	90.0	-	-
2·4(1)					1	91.0	-	-

TABLE 10. (Cont'd)

Year/Age • age	Wild returns n	Mean	SD	Range	Hatchery returns n	Mean	SD	Range
1983								
1•1					4	51.0	2.0	50.0-54.0
2•1	98	52.1	2.7	45.0-58.0	94	51.0	2.0	46.0-57.0
3•1	7	53.1	2.7	49.0-57.0				
2•2	2	69.0	0.0	69.0-69.0	11	72.3	3.2	69.0-78.0
2•2(1)	6	60.3	1.8	58.0-61.0	39	62.1	2.7	49.0-60.0
3•2(1)	2	56.5	9.2	50.0-63.0				
2•3(1)					2	73.0	4.2	70.0-76.0
2•3(1,2)					2	72.0	1.4	71.0-73.0
2•4(1,3)					1	88.5	-	
1984								
1•1					1	50.0	-	-
2•1	96	53.0	2.0	48.0-57.0	47	52.5	2.5	52.0-56.0
3•1	4	54.5	1.9	52.0-56.0				
2•2	4	69.5	4.0	66.0-75.0	1	74.0	-	-
2•2(1)	8	63.1	3.9	56.0-67.0	1	55.5	-	-
2•3(1)	2	74.0	0.0	74.0-74.0				
2•3(1,2)	2	65.5	0.7	65.0-67.0	2	65.5	0.7	65.0-67.0
1985								
2•1	100	53.0	2.4	47.0-58.0	37	53.4	3.4	46.5-59.0
3•1	10	54.2	1.9	51.0-58.0				
1•2					2	70.5	0.7	70.0-71.0
2•2	40	69.5	3.1	65.0-78.0				
2•3	1	86.0	-	-				
2•2(1)	6	60.6	3.1	55.0-64.0				
3•2(1)	3	55.7	8.1	51.0-65.0				
2•3(1)	13	74.0	2.5	69.0-78.0	6	72.8	2.9	68.5-77.0
2•3(2)	5	70.7	3.3	69.0-76.5				
2•3(1,2)	5	68.2	2.6	65.0-72.0				
1•4(1,2,3)					1	82.5	-	-
2•4(2)	4	77.8	2.1	75.0-80.0	1	77.0		
2•5(1,3)	1	82.0	-	-				
2•5(2,4)	1	83.0	-	-				
2•4(1,2)	1	82.0	-	-				

TABLE 11. Mean fork lengths of 1SW and MSW wild and hatchery-return Atlantic salmon sampled at Liscomb Falls fishway, 1979-85[1]

Year	Wild		Hatchery	
	1SW	MSW	1SW	MSW
1979	53.3(19)	67.2(2)[2]	52.0(109)	67.2(2)[2]
1980	54.2(18)	71.8(14)[2]	53.0(137)	71.8(14)[2]
1981	52.2(15)	70.8(17)[2]	52.0(36)	70.8(17)
1982	52.1(38)	78.4(19)[2]	52.2(81)	78.4(19)
1983	52.2(105)	61.3(10)	51.0(98)	64.6(55)
1984	53.1(100)	66.4(16)	52.4(48)	65.1(4)
1985	53.1(110)	70.1(80)	53.4(37)	72.2(11)
Mean Weighted	52.8±0.5	70.4±3.0	52.2±0.7	69.2±5.0
Unweighted	52.9±0.8S	69.4±5.3S	52.3±0.8S	70.0±4.8

1. Figures in parentheses are numbers of fish measured and aged; following ± is standard deviation of mean.
2. Means derived from pooled MSW hatchery and wild fish in these years as few if any of one component were represented in the sample.

TABLE 12. Freshwater and saltwater age composition of virgin, wild and hatchery-origin, Atlantic salmon Liscomb Falls fishway, 1979-85[1]. (Numbers in parentheses are percentages of the total numbers of salmon sampled by stock origin each year).

Origin/ year	n	Freshwater age			Saltwater age (sea winters)		
		1	2	3	1	2	3
Wild							
1979	19		15(78.9)	4(21.1)	19(100.0)		
1980	18		15(83.3)	3(16.7)	18(100.0)		
1981	15		13(86.7)	2(13.3)	15(100.0)		
1982	39		33(84.6)	6(15.4)	38(97.4)	1(2.6)	
1983	107		100(93.5)	7(6.5)	105(98.1)	2(1.9)	
1984	104		100(96.2)	4(3.8)	100(96.2)	4(3.8)	
1985	151		141(93.4)	10(6.6)	110(72.8)	40(26.5)	1(0.6)
All years	453		417(92.1)	36(7.9)	405(89.4)	47(10.4)	1(0.2)
Hatchery							
1979	110	17(15.5)	93(84.5)		109(99.1)	1(0.9)	
1980	150	13(8.7)	137(91.3)		137(91.3)	13(8.7)	
1981	45	15(33.3)	30(66.7)		36(80.0)	7(15.6)	2(4.4)
1982	92	9(9.8)	83(90.2)		81(88.0)	8(8.7)	3(3.3)
1983	109	4(3.7)	105(96.3)		98(89.9)	11(10.1)	
1984	49	1(2.0)	48(98.0)		48(98.0)	1(2.0)	
1985	39	2(5.1)	37(94.9)		37(94.9)	2(5.1)	
All years	594	61(10.3)	533(89.7)		546 (91.9)	43(7.2)	5(0.8)

[1] Numbers etc.

TABLE 13. Freshwater and saltwater age composition of combined samples (virgin and previous spawners) of wild and hatchery, origin Atlantic salmon, Liscomb Falls fishway, 1979-85.[1]

Fish origin and year	n	Freshwater age			Saltwater age (sea-winters)				
		1	2	3	1	2	3	4	5
Wild returns									
1979	20		16(80.0)	4(20.0)	19(95.0)	1(5.0)			
1980	18		15(83.3)	3(16.7)	18(100.0)				
1981	15		13(86.7)	2(13.3)	15(100.0)				
1982	39		33(84.6)	6(15.4)	38(97.4)	1(2.6)			
1983	115		106(92.2)	9(7.8)	105(91.3)	10(8.7)			
1984	116		112(96.6)	4(3.4)	100(86.2)	12(10.4)	4(3.4)		
1985	190		177(93.2)	13(6.8)	110(57.9)	49(25.8)	24(12.6)	5(2.6)	2(1.1)
All years	513		472(92.0)	41(8.0)	405(78.9)	73(14.2)	28(5.5)	5(1.0)	2(0.4)
Hatchery returns									
1979	110	17(15.5)	93(84.5)		109(99.1)	1(0.9)			
1980	151	13(8.6)	138(91.4)		137(90.7)	14(9.3)			
1981	52	15(28.8)	37(71.2)		36(69.2)	13(25.0)	3(5.8)		
1982	99	9(9.1)	90(90.9)		81(81.8)	8(8.1)	8(8.1)	2(2.0)	
1983	153	4(2.6)	149(97.4)		98(64.0)	50(32.7)	4(2.6)	1(0.7)	
1984	52	1(1.9)	51(98.1)		48(92.3)	2(3.8)	2(3.8)		
1985	48	3(6.2)	45(93.8)		37(77.1)	2(4.2)	6(12.5)	3(6.2)	
All years	665	62(9.3)	603(90.7)		546(82.1)	90(13.5)	23(3.5)	6(0.9)	

1. Figures in parentheses are percentages of the total numbers sampled each year.

TABLE 14. Sea age composition and previous spawning history of wild and hatchery origin MSW Atlantic salmon, Liscomb Falls fishway trap, 1979-85[1].

Age/spawning history	Year							
	1979	1980	1981	1982	1983	1984	1985	years
Wild origin								
Virgin salmon								
2				1(100.0)	2(20.0)	4(25.0)	40(50.0)	47(43.5)
3							1(1.2)	1(0.9)
Subtotal				1(100.0)	2(20.0)	4(25.0)	41(51.2)	48(44.4)
Consecutive-year previous spawners								
2(1)	1(100.0)				8(80.0)	8(50.0)	9(11.2)	26(24.1)
3(2)							5(6.2)	5(4.6)
3(1,2)						2(12.5)	5(6.2)	7(6.5)
5(2,4)							1(1.2)	1(0.9)
Subtotal	1(100.0)				8(80.0)	10(62.5)	20(25.0)	39(36.1)
Alternate-year previous spawners								
3(1)						2(12.5)	13(16.2)	15(13.9)
4(2)							4(5.0)	4(3.7)
4(1,2)							1(1.2)	1(0.9)
5(1,3)							1(1.2)	1(0.9)
Subtotal						2(12.5)	19(23.7)	21(19.4)
Hatchery Origin								
Virgin salmon								
2	1(100.0)	13(92.9)	7(43.8)	8(44.4)	11(20.0)	1(25.0)	2(18.2)	43(36.1)
3			2(12.5)	3(16.7)				5(4.2)
Subtotal	1(100.0)	13(92.9)	9(56.3)	11(20.0)	11(20.0)	1(25.0)	2(18.2)	48(40.3)
Consecutive-year previous spawners								
2(1)			6(37.5)		39(70.9)	1(25.0)		46(38.7)
3(2)				1(5.6)				1(0.8)
3(1,2)					2(3.6)	2(50.0)		4(3.4)
4(1,3)					1(1.8)			1(0.8)
4(1,2,3)							1(9.0)	1(0.8)
Subtotal			6(37.5)	1(5.6)	42(76.4)		1(9.0)	53(44.5)
Alternate-year previous spawners								
3(1)		1(7.1)	1(6.2)	4(22.2)	2(3.6)		6(54.5)	14(11.8)
4(1)				1(5.6)				1(0.8)
4(2)				1(5.6)			2(18.2)	3(2.5)
Subtotal		1(7.1)	1(6.2)	6(33.3)	2(3.6)		8(72.7)	18(15.1)

1 Numbers in parentheses are percentages (by stock origin) of the annual total of MSW fish.

TABLE 15. Percentage of females among 1SW and MSW Atlantic salmon captured at Liscomb Falls fishway during September-November, 1979-86[1].

	1SW		MSW	
Year	Number of fish	% female	Number of fish	% female
1979	37	48	1	100
1980	208	55	10	60
1981	106	51	36	78
1982	94	47	2	50
1983	21	73	2	50
1984	70	43	4	25
1985	56	52	16	50
1986	88	56	29	72
Weighted average		52		67

[1] Hatchery and wild returns were pooled because of low numbers of fish in either or both of the run components (hatchery, wild)

TABLE 16. Recapture location of adult Atlantic salmon from 71,294 tagged, hatchery-reared smolts released above Liscomb Falls, 1977-83.[1]

	Spawning escapement		Sport fisheries			Commercial fisheries[3]											
						Nova Scotia (S.M.Z)[2]											
						South-											
Sea age at recapture	Liscomb Falls	Morgan Falls	Liscomb River	Other N.S. rivers	Newfound-land	Cape Breton East	Eastern Shore	Western N.S.	Upper Bay of Fundy	Unknown	Quebec	Newfoundland Labrador	Newfoundland A-F	Newfoundland G-K	Green-land	Other	Total re-captures
1SW	187	1	19	12	1	15	12	5	1	1	2	1	41	3	42	1	344
2SW	12	0	0	2	0	5	15	4	0	0	0	0	7	2	1	2	50
Older	6	0	0	1	0	0	0	0	0	0	0	0	0	1	1+3	1	13
Total	205	1	19	15	1	20	27	9	1	1	2	1	48	6	47	4	407

1. Recaptures to December 31, 1984.

2. Salmon Management Zone (Statistical districts)
   Zone 5 - Cape Breton East (Dist. 1,4,6-9)
   Zone 7 - Eastern Shore (Dist. 14-21)
   Zone 8 - Upper Bay of Fundy (Dist. 24, 35, 39-44)
   Zone 9 - Southwestern Nova Scotia (Dist. 22-23, 25-28, 30-34, 36-38)

3. See Figure 3.

TABLE 17. Angling exploitation rates and river escapements of 1SW salmon, based on tag recaptures in the angling fishery and Liscomb fishway from tagged hatchery smolts released above Liscomb Falls, 1979-86.

Year	Numbers of tagged grilse recovered				Angling exploitation rate (5) Col.2÷Col.4	Total angling[2] harvest of grilse (w+h) (6)	Total escapement of grilse (h+w) (7) Col.6÷Col.5	Total count[3] of grilse (h+w) at Liscomb trap (8)	Below Liscomb Falls[4]	
	Observed (1)	Adjusted[1] (2)	Liscomb Fishway trap (3)	Adjusted total (4)					Total grilse escapement(w) (9) Col.7-Col.8	Spawning escapement(w) (10) Col.9-(Col.6-Col.2)
1979	3	4	43	47	0.085	85	1,000	545	455	374
1980	10	14	76	90	0.156	233	1,494	1,042	452	309
1981	4	4	13	17	0.316	46	146	293	Not plausible[5]	
1982	0	0	27	27	N/A	79	N/A	1,079	N/A	
1983	1	1	24	25	0.040	57	1,425	969	456	400
1984	1	1	4	5	0.200	61	305	907	Not plausible[5]	
1985	1	1	7	8	0.125	64	512	652	Not plausible[5]	
1986	3	4	20	24	0.167	95	569	1,432	Not plausible[5]	

1. Adjusted upward for an assumed tag nonreporting rate of 30% in the angling fishery.
2. From angling statistics given in "Redbooks" by O'Neil and Swetnam (1984), O'Neil et al. (1985), O'Neil et al. (1986), O'Neil pers. comm. (1986 angling figures).
3. From adjusted trap counts at Liscomb Falls (Table 6).
4. All hatchery releases of juvenile salmon were made above Liscomb Falls, except in 1986; hence, it was assumed that all hatchery fish would return above Liscomb Falls leaving only the wild component for escapement in the lower Liscomb River.
5. Total counts of grilse at Liscomb Falls can not exceed total river escapement of grilse because grilse counted at Liscomb Falls are only part of the total river escapement of that component.

TABLE 18. Estimated egg depositions[1] from wild and hatchery-return Atlantic salmon at Liscomb Falls fishway before and after adjustment for broodstock removal, 1979-86.

Year	Not adjusted for broodstock removal			Adjusted for broodstock removal		
	Hatchery returns	Wild returns	Total returns	Hatchery returns	Wild returns	Total returns
1979	689,518(88)	95,132(12)	784,650	555,774(87)	81,459(13)	637,233
1980	1,833,867(94)	113,292(6)	1,947,159	1,695,648(94)	104,577(16)	1,800,225
1981	661,898(84)	127,812(16)	789,710	567,200(89)	69,301(11)	636,501
1982	1,427,485(82)	323,711(18)	1,751,196	1,355,684(83)	288,016(17)	1,643,700
1983	1,277,977(60)	850,527(40)	2,128,504	1,242,048(61)	801,746(39)	2,043,794
1984	569,827(36)	993,541(64)	1,563,368	531,689(36)	938,011(64)	1,469,700
1985	476,629(29)	1,191,417(71)	1,668,046	442,184(28)	1,143,068(72)	1,585,252
1986	1,730,363(50)	1,749,568(50)	3,479,931	1,659,182(50)	1,688,489(50)	3,347,671

1. Percentage contributions of the total estimated egg depositions by fish of hatchery and wild origin are given in parentheses. LaHave fecundity relationship was used.

TABLE 19. Egg depositions from wild and hatchery-return Atlantic salmon above Liscomb Falls and resultant numbers and proportions of wild 1SW and MSW salmon at Liscomb Falls fishway in subsequent years. (Egg depositions were adjusted for broodstock removal.)

Egg deposition		Total 1SW (W)			Egg deposition		Total MSW (W)		
Years to and (t+1) from	Numbers of eggs[1]	Year t+5[2]	Number of fish	Proportion returning from eggs deposited	Years (t-1) and t	Number of eggs[1]	Year t+5	Number of fish	Proportion returning eggs deposited
1978-79	NA[3]	1983	488		1977-78	NA[3]	1983	37	----
1979-80	2,437,458	1984	581	0.000238	1978-79	NA[3]	1984	71	----
1980-81	2,436,726	1985	477	0.000196	1979-80	2,437,458	1985	117	0.000048
1981-82	2,274,201	1986	704	0.000310	1980-81	2,436,726	1986	149	0.000061
1982-83	3,681,494				1981-82	2,274,201			
1983-84	3,513,494		mean =	0.000248	1982-83	3,681,494		mean =	0.000054
1984-85	3,054,952		SD =	0.000058	1983-84	3,513,494		SD =	0.000009
1985-86	4,932,923				1984-85	3,054,952			
					1985-86	4,932,923			

1. See Table 18.
2. See Table 6.
3. The fishway trap at Liscomb Falls was not operated in 1977 or 1978; hence, there is no estimate of egg depositions in these years.

Table 20. Estimated smolt output from hatchery-origin juvenile Atlantic salmon releases above Liscomb Falls, finally adjusted numbers of adult hatchery returns, and calculated return rates based on sea age-class adjusted counts of adults, 1977-86.

Year of release (t)	Juvenile stage	Number released[1]	Estimated smolt output			Number of tagged/marked hatchery returns Number of unmarked + marked hatchery returns % of tagged/marked smolt output		
			Marked or tagged	Unmarked & untagged	Total	1SW	MSW	Total
1977	1+ smolt	3,968	7,779	0	7,779	NA	2	NA
	2+ smolt						2	
1978	1+ smolt	9,140	46,982	0	46,982	485	51	536
	2+ smolt	38,219				485	51	536
	1+ parr	1,424				(1.03)	(0.11)	(1.14)
1979	1+ smolt	7,416	55,275	2,852	58,127	931	73	1,004
	2+ smolt	50,329				977	76	1,058
						(1.68)	(0.13)	(1.82)
1980	1+ smolt	4,795	26,755	60	26,815	217	41	258
	2+ smolt	22,112				217	41	258
						(0.81)	(0.15)	(0.96)
1981	1+ smolt	3,001	39,854	2,486	42,340	827	176	1,003
	2+ smolt	39,393				881	186	1,067
	Unfed fry	2,076				(2.08)	(0.44)	(2.52)
1982	1+ smolt	3,019	43,170	0	43,170	481	49	530
	2+ smolt	40,241				481	49	530
						(1.11)	(0.11)	(1.23)
1983	1+ smolt	17,269	60,158	199	60,357	324	49	373
	2+ smolt	43,692				326	49	375
	0+ parr	37,736				(0.54)	(0.08)	(0.62)

Table 20. (Cont'd)

Year of release (t)	Juvenile stage	Number released[1]	Estimated smolt output: Marked or tagged	Unmarked & untagged	Total	Number of tagged/marked hatchery returns / Number of unmarked + marked hatchery returns % of tagged/marked smolt output: 1SW	MSW	Total
1984	2+ smolt	40,119	40,464	0	40,464	175	146	321
	1+ smolt	11,972				175	146	321
						(0.43)	(0.36)	(0.79)
1985	1+ smolt	4,897	42,503	0	42,503	728	NA	NA
	2+ smolt	27,043				728		
	1+ parr	16,311				(1.71)		
	Unfed fry	600						
1986	1+ smolt	14,636	20,526	0	20,526	NA	NA	NA
	1+ parr	3,885						

Mean return rate and SD for 1SW fish (1978-85): x=1.17, SD=0.59
Mean return rate and SD for MSW fish (1977-84): x=0.18, SD=0.14

1. From Table 2.
2. See materials and methods section for estimating outputs of hatchery smolts.
3. Non-underlined figures are from sea age-class adjusted adult counts of Table 5 for years t+1 (1SW) and t+2 (MSW); underlined figures are the finally adjusted counts of hatchery returns (marked and unmarked) at Liscomb Falls which were derived from the percentage returns in years t+1 (1SW fish) and t+2 (MSW fish) of marked/tagged smolt outputs in year t applied to the total output of marked and unmarked smolts in year t.

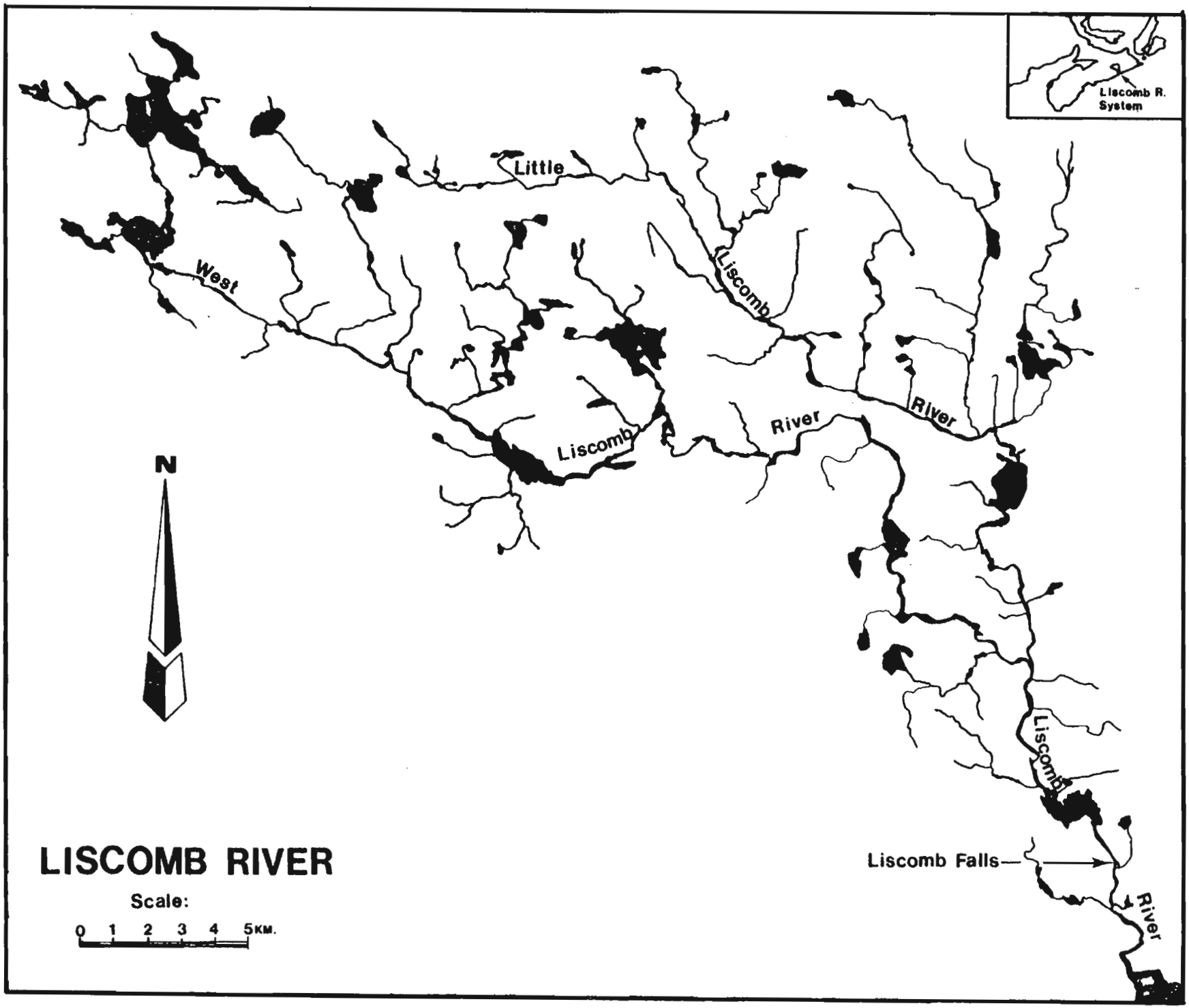

FIGURE 1. Geographic location of Liscomb River and the Liscomb Falls fishway.

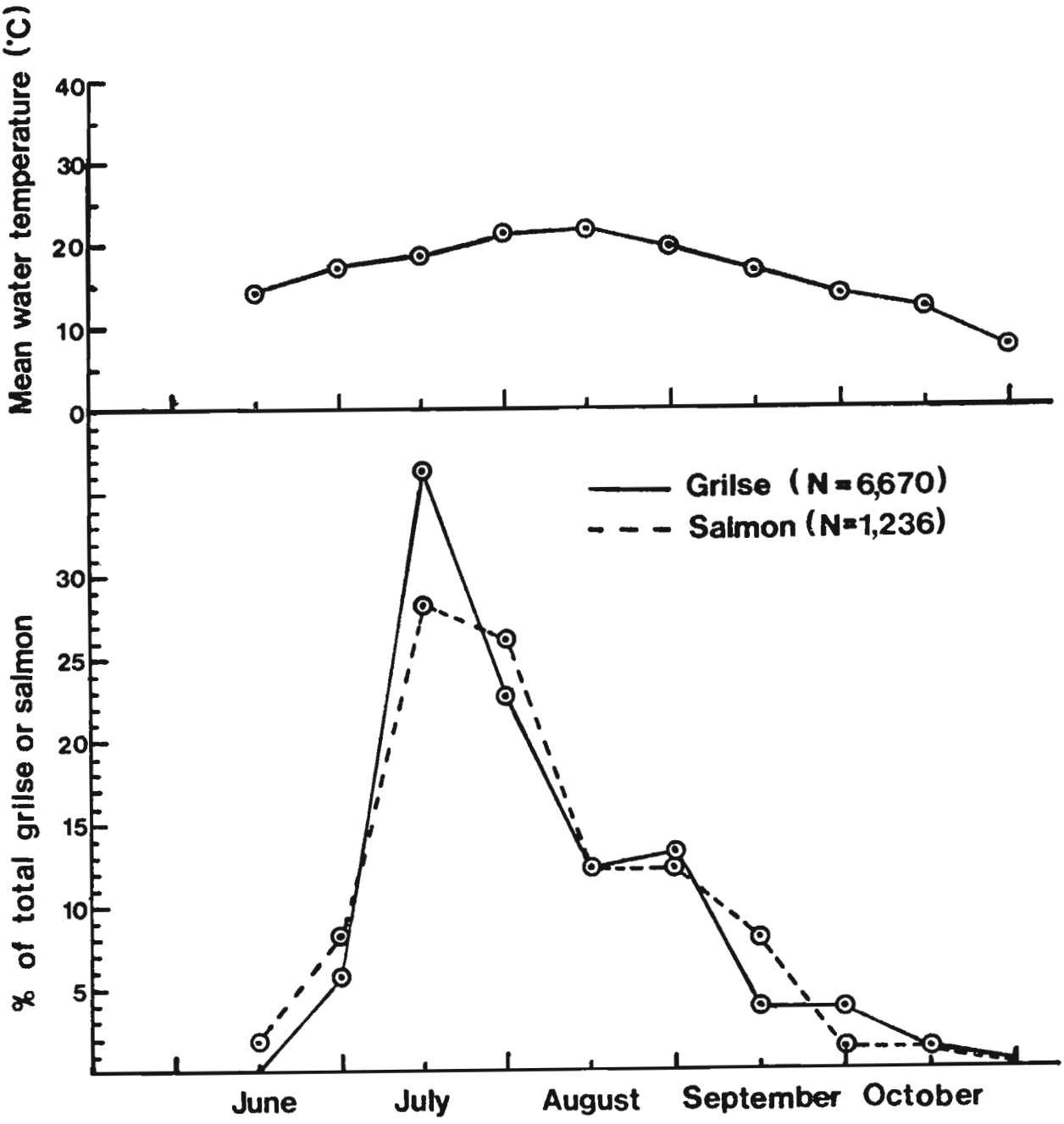

FIGURE 2. Mean daily water temperatures and percentage of the total runs of grilse and salmon enumerated at Liscomb Falls fishway, arranged by semi-monthly period. Data were pooled for all years, 1979-86.