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Status of Atlantic Salmon in Salmon Fishing Area 21,

in 1996, with emphasis on the upper LaHave River, Lunenburg Co., Nova Scotia

by

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Abstract

The status of Atlantic salmon spawning escapement for 1996 in the LaHave River above Morgan Falls relative to conservation is presented. The status of stocks in other rivers of SFA 21 is inferred from reports of recreational catches and a distribution of probable angling exploitation rates estimated for the LaHave River. Non-return fallback at Morgan Falls is estimated at about 40% and its impact on the assessment of the status of the stock is reviewed. A count-based estimate of the production of wild smolts above Morgan Falls in 1996 indicated about 20,650 or 0.79 smolts per 100 m^2. Egg deposition above Morgan Falls in 1996 was 94% of the conservation objective of 1.96×10^6 without non-return fallback and 56% if non-return fallback was 40%. The modal deposition for the entire LaHave River basin was 75.5% of the basin-wide required conservation escapement of fish and 80% of the basin-wide required deposition of 4.74×10^6 eggs. The most probable pre-fishery abundance for eleven other rivers of SFA 21 was 7,368 salmon (6,087 - 9,608; 5^{th} and 95^{th} percentiles) and the most probable spawning escapement for these rivers was 4,861 fish, a 16% increase from 1995. Status of stocks for SFA 21 rivers is uncertain because of acidification resultant of acid precipitation and the undetermined effectiveness of standard conservation requirements. Egg depositions to the entire LaHave river increased in 1996 because of increased returns to the river, hook-and-release angling and sizes of fish-at-age. The 1996 LaHave River angling catch rate was 44% and exploitation was 30%. Forecasts to Morgan Falls for 1997 indicated a deficit above Morgan Falls assuming a hook-and-release fishery for salmon (>63 cm) and retention of grilse (≤63 cm) below Morgan Falls if non-return fallback at Morgan Falls is 40%. However, escapements may be in excess of spawning requirements below Morgan Falls in 1997, if returns are as forecast and exploitation is as in 1996. Risk to conservation at various exploitation rates for the 1997 returns was estimated. Return rate of hatchery smolts slightly improved in 1996. Short-term prognosis for the LaHave River was favourable with reduced exploitation warranted to improve opportunity for recovery to higher returns.

Résumé

Nous faisons le point sur l'échappée de reproducteurs de saumon atlantique, en 1996, dans la rivière LaHave au-dessus des chutes Morgan, dans une perspective de conservation. L'état des stocks des autres cours d'eau de la ZPS 21 est déduit à partir des rapports sur les prises de la pêche sportive, et nous calculons la distribution des taux probables d'exploitation de la pêche sportive pour la rivière LaHave. Nous estimons à environ 40 % la proportion des poissons qui renoncent à franchir les chutes dès leur premier essai, et nous examinons l'impact de ce phénomène sur l'évaluation de l'état du stock. Une estimation par dénombrement de la production de smolts sauvages en amont des chutes Morgan en 1996 donne un résultat de 20 650, soit 0,79 smolts par 100 m^2. La ponte en amont des chutes en 1996 atteignait 94 % de l'objectif de conservation, fixé à $1,96 \times 10^6$, si on ne tenait pas compte des saumons qui renoncent au premier essai, et 56 % si la proportion des saumons qui renoncent était de 40 %. Pour l'ensemble du bassin de la rivière LaHave, la ponte modale correspondait à 75,5 % de l'échappée nécessaire pour satisfaire aux exigences de la conservation, et à 80 % de la ponte nécessaire à l'échelle du bassin, soit $4,74 \times 10^6$ oeufs. Le niveau le plus probable d'abondance avant la pêche pour 11 autres cours d'eau de la ZPS 21 était de 7 368 saumons (6 087 - 9 608; 5^e et 95^e percentiles), et le niveau le plus probable de l'échappée de géniteurs pour ces cours d'eau était de 4 861 poissons, soit une hausse de 16 % par rapport à 1995. L'état des stocks des rivières de la ZPS 21 est incertain, à cause de l'acidification due aux précipitations et de l'incertitude quant à l'efficacité des exigences fixées pour la conservation. La ponte a augmenté en 1996 sur l'ensemble de la rivière LaHave à cause de l'accroissement des remontes, de la pratique de la capture avec remise à l'eau et de la taille des poissons selon l'âge. Le taux de capture de la pêche sportive dans la rivière LaHave était de 44 %, et le taux d'exploitation de 30 %. Pour 1997, les prévisions aux chutes Morgan indiquent un déficit au-dessus des chutes si l'on suppose la

pratique de la pêche avec remise à l'eau pour les grands saumons (> 63 cm) et la rétention des madeleineaux (` 63 cm) en aval des chutes Morgan, si la proportion des poissons qui renoncent à franchir les chutes dès leur premier essai est de 40 %. Toutefois, il est possible que les échappées dépassent les besoins de la ponte en aval des chutes en 1997, si les remontes correspondent aux prévisions et que le taux d'exploitation est le même qu'en 1996. Nous avons estimé les risques sur le plan de la conservation à divers taux d'exploitation pour les remontes de 1997. Le taux de retour des smolts d'élevage était légèrement en hausse en 1996. Le pronostic à court terme pour la rivière LaHave est favorable, car une baisse de l'exploitation va à coup sûr améliorer les possibilités de rétablissement et d'augmentation des remontes.

Introduction

Salmon Fishing Area (SFA) 21 includes the counties of Digby, Yarmouth, Shelburne, Queens, Lunenburg, and the south-westerly quarter of Halifax County in Nova Scotia (Figure 1). The number of rivers in SFA 21 that historically produced Atlantic salmon (*Salmo salar)* is unknown. Salmon production potential is currently listed for eighteen rivers of SFA 21 (Figure 2).

Atlantic salmon stocks of SFA 21 are impacted by acidification of the water. Watt (1986, 1989, 1997) (Table 1) estimated that nine rivers of SFA 21 have completely lost their salmon populations (Category 1, mean pH <4.7), nine rivers have only remnant populations (Category 2, mean pH 4.7-5.0), six rivers were impacted (Category 3, mean pH 5.1-5.4) and four are unaffected by acidification (Category 4, mean pH >5.4) principally due to acid rain.

In addition to water quality impacts, hydroelectric impacts occur on the Mersey, Tusket, Medway, Sissiboo, Indian, Ingram, Jordan and Roseway rivers. A low-head hydro project at Morgan Falls, LaHave River, went into operation during January, 1996. A fish collection facility installed below the by-pass louvers provided the opportunity to count and examine out-migrating smolts from above Morgan Falls in 1996.

Fish passage facilities are in place on the Tusket, Medway, Mersey, Sackville and LaHave rivers. Fish passage facilities do not exist or are ineffective on the Indian, Mersey, Roseway, Sissiboo and Bear rivers. A natural obstruction to fish passage on the Meteghan River prevented natural production of salmon above the falls until 1993, when fish were lifted above the falls.

Complete counts of salmon are taken at Morgan Falls on the LaHave River (Figure 3). Counts of salmon are taken while collecting broodstock from a fishway on the Tusket River. However, Tusket River counts are perhaps not indicative of the total population because counts are not taken over the entire run of salmon. No counts of salmon are taken at Harmony Mills on the Medway because of the irregular operation and use of the fishway. Salmon runs through the Sackville River fishway were not enumerated in 1996.

The SFA 21 management advisory committee met May 2, 1996. The committee reviewed the 1995 fishery, the biological advice for 1996 and heard recommendations from stakeholders concerning the 1996 salmon angling season (Appendix 1). Based on the low numbers of fish forecast to return in 1996, the low returns from 1993 to 1995, and the unfavourable conditions for Atlantic salmon in the North Atlantic Ocean in 1995 and early 1996, biological advice to the committee was to proceed cautiously with harvests in 1996. An in-season assessment and management review was conducted July 8, 1996. On average, about 50% of the end-of-season count passes Morgan Falls by the end of the first week of July.

The purpose of this document is to review the status of Atlantic salmon stocks in rivers of SFA 21 in 1996, as indexed by the status of the stock above Morgan Falls on the LaHave River. The river above Morgan Falls has an average pH of 5.7 and is minimally impacted by acidification. Three tributaries, the Ohio River, Meadow Brook and Bob and Joan Brook (3.3% of the habitat area above Morgan Falls) have average annual pHs less than 5.1, a pH below which salmon production is severely affected. The population above Morgan Falls has developed since the installation of the fishway in 1971. A conservation requirement, based on a subjective assessment of the habitat area and productivity, was established and the status of Atlantic salmon in SFA 21 for 1996 is indexed from that area above Morgan Falls on the LaHave River.

Status is normally reviewed in relation to a defined conservation requirement. However, most rivers of SFA 21 are impacted to various degrees by acidification of the water, principally from acid rain. Conservation requirements are undefined for losses in production caused by pH toxicity. Detailed water chemistry data necessary to derive river-specific conservation requirements for salmon are not presently available. Therefore, conservation requirements for salmon are undefined

for most rivers of SFA 21. Conservation of salmon is not required for rivers where natural production of salmon is impossible because of acidity or obstructions (Clyde, Jordan and Mersey rivers).

This document provides : 1) estimates of the wild and hatchery smolt migration above Morgan Falls on the LaHave River; 2) counts to Morgan Falls and estimates of spawning escapements from these counts i) to above Morgan Falls and ii) to the entire LaHave River; 3) estimates of angling catch rates and exploitation rates in LaHave River are applied to estimates of angling catches in other rivers of SFA 21 as indicators of possible returns and escapements to those rivers in 1996; 4) an estimate of non-return fallback (fish which ascend the fishway, fall back over the falls and do not re-ascend the fishway) at Morgan Falls and its impact on assessment of escapements above Morgan Falls; 5) forecasts of counts to Morgan Falls for 1997; and 6) risks to attaining conservation requirements above Morgan Falls associated with forecasts, requirements and exploitation scenarios.

Stocking programs

Nine rivers in SFA 21, including the Clyde and Jordan rivers, are no longer capable of maintaining Atlantic salmon because of acidification of the water (Table 1). The Mersey River is no longer self-sustaining because of fish passage availability/effectiveness and flooded juvenile salmon habitat. Three rivers, the Clyde, Jordan and Mersey, are stocked with hatchery smolts of LaHave River origin to provide harvest fisheries. Supplementary stocking of LaHave River hatchery smolts was conducted in the Petite and Mushamush rivers. Re-colonisation and enhancement programs are in progress in the Sackville River with LaHave stock and in the Bear River with Tusket River stock. Broodstock are also collected for stocking in four other acid-impacted rivers of SFA 21, the Gold, Medway, Tusket, and Salmon (Digby) rivers. Totals of 242,833 hatchery smolts and 1,192,175 fall fingerlings were stocked in rivers of SFA 21 in 1995 which contributed to one-sea-winter (grilse) returns in 1996 (Table 2).

Conservation requirements

Above Morgan Falls on the LaHave River

A conservation requirement of 1,320 fish is required above Morgan Falls. This value was derived based on the 3,312 fish for all utilizable habitat in the LaHave River (Cutting and Gray MS 1984) and the approximate 40% of the Cutting and Gray production area estimated for above Morgan Falls. This value (1,320) was used to assess the risk to conservation by harvests within the river in 1996, and to provide advice to managers and stakeholders on July 8, 15; August 1; and September 15, 1996.

Other rivers in SFA 21

Conservation requirements for rivers of SFA 21 have not been established because of the uncertainty involved in managing Atlantic salmon stocks in acid-impacted rivers. Conservation requirements based on remote-sensed stream area with stream gradient greater than 0.12%, standard 240 egg 100^{-1} m^2, stock characteristics as in the LaHave River and assuming non-acid impacts can provide preliminary perfunctory estimates. However, conservation requirements derived in this fashion have unknown bias. Establishing habitat and water-quality-sensitive estimates of conservation requirements for rivers of SFA 21 remains a priority for research.

Description of fisheries and harvests

First Nation fisheries

Atlantic salmon harvesting plans in 1996 called for harvests of 200 grilse removed from the Morgan Falls fishway; 80 grilse by angling, snaring, or dip nets in the Mersey River; 20 grilse by

angling, snaring, or dip nets in the Gold River; 50 grilse by angling, snaring, or dip nets in the Medway River; and 50 grilse by angling, snaring, or dip nets in the Tusket River.

A total of 218 male hatchery grilse was removed for First Nations use before the fishway was closed due to low water on August 23, 1996. Harvests by First Nations from other rivers in SFA 21 were unreported.

Aboriginal Peoples' fishery

The aboriginal peoples of Nova Scotia, under an agreement with the Native Council of Nova Scotia, could have registered 276 harvesters in SFA 21 and issued 2,760 tags. Harvests were to be conducted under the Netukulimk[1] understanding. Reported harvests by the Netukulimkewe'l Commission, for SFA 21, were 20 grilse. Harvests were 15 grilse from the Medway River, 3 grilse from the Gold River and 2 grilse from the LaHave River.

Angling fishery

Eight tags for salmon <63.0 cm were issued with the purchase of each 1996 Nova Scotia salmon angling licence. Salmon angling regulations were modified throughout SFA 21 in 1996 in order to decrease exploitation. Three measures were taken: 1) salmon angling was for hook-and-release only from May 10 to May 31 in all rivers except the Clyde, Jordan and Mersey rivers where retention was permitted; 2) retention of grilse (≤63 cm) from June 1 (June 15 on the Petite Riviere) to August 15, except for the Clyde, Jordan and Mersey rivers where retention angling remained open until September 30; and 3) a daily fish retention limit of one grilse for the entire SFA 21 (Table 3).

In-season assessments of the status of the LaHave River salmon run were conducted every two weeks after July 8, using the Morgan Falls count. As a result of the in-season assessment, angling seasons remained open, in SFA 21 rivers sustaining wild stocks, until August 15, 1996. Angling in rivers containing only stocked hatchery salmon closed on September 30, 1996.

A total of 18,350 rod days of effort was expended on 16 rivers of SFA 21 in 1996 (Table 1). Effort was up 35% over 1995. A total of 2,180 grilse was reported retained and 557 released, which was a 66% increase from 1995. The 530 salmon reported released was a 42% increase over 1995. Catch rod*day^{-1} increased to 0.178 in 1996 from 0.112 in 1995. Effort, number of grilse retained and numbers of grilse and salmon released in 1996 were all greater than the 1991 to 1995 means.

Good-to-excellent water levels for fish migration and for angling were experienced in 1996 (Figure 4). Daily river discharge in June, measured at West Northfield on the upper LaHave River, was lower than 1995 and about the same as average 1980-to-1995 discharges. July discharge was above normal. Water levels were maintained throughout July and into August. August discharges began at higher percentile values and declined to lower percentile values. Heavy rain on September 3, 1996, increased discharges to record highs throughout September. October discharges were within October observations of 1980 to 1995.

Commercial fisheries

Tagged LaHave River salmon have been recaptured in the Greenland salmon fishery, the Newfoundland salmon fishery, and in the Nova Scotia salmon and mackerel (*Scomber scombrus*) fisheries.

No licensed commercial salmon fishers remain in SFA 21 and the fishery was reduced in 1983 and closed since 1985. Interception of salmon in other gear of SFA 21 is unreported for 1996. The moratorium in the Newfoundland commercial salmon fishery, which began in 1992, remained in

[1] Mi'kmaq Fisheries, Netukulimk, Towards a Better Understanding, 1993 Native Council of Nova Scotia, Language Program - Truro, Nova Scotia B2N 5N2. ISBN: 0-929073-86-X

effect in 1996. The Greenland offshore commercial fishery did not occur in 1995 (potentially affecting the 1996 two-sea-winter return).

Research data

This assessment utilises counts at Morgan Falls in 1996 to estimate the total river return based on the results of a mark-and-recapture experiment carried out in 1983 to calibrate the Morgan Falls counts to total river returns. This total river return estimate is used to derive a range of possible catch and exploitation rates for the LaHave river. Angling catches are available, through the Nova Scotia License Stub return system, for all rivers of SFA 21 where angling effort was expended and reported in 1996. The range of possible catch rates determined for the LaHave River were applied to reported catches from other rivers in SFA 21 to derive pre-fishery salmon population estimates in 1996. Minimum catch rates applied to 1996 catches were used to estimate maximun (95th percentile) pre-fishery population estimates.

Morgan Falls fishway operated April 29 to August 23, and September 4 to November 1, 1996. Mid-summer closure occurred during low water levels when fish were not moving through the fishway. Operation was Monday to Friday except for mid-June when runs were high and the fishway was operated for seven days a week. A double trap arrangement reduced backlogs during high use periods. All salmon and grilse were counted through the fishway. All salmon and every fifth grilse were weighed, measured, scale sampled (one to three scales removed). A small hole was punched through the caudal fin of all fish passing through the fishway. Fish may fall back over the falls during high water either over a low-head dam at the top of the falls established in the summer of 1995 or through a fish passage notch in the dam. Fish that reused the fishway were noted and not included in the cumulative counts. This operational schedule was similar to most years of operation from 1970 to 1995. In some years of lower summer flows and populations, the fishway remained closed for more of the summer period.

Cumulative counts of wild and hatchery grilse and salmon were reported every two weeks to stakeholders in 1996 (Table 4). These counts continue the 26-year record of counts at Morgan Falls (Table 5; Figure 5).

The age composition, length and weight of wild and hatchery salmon returns (Table 6) together with gender-specific length and weight data (Table 7), the record of fish removed for brood stock (Table 8) and the numbers of fish angled and harvested (Table 1) provide essential information for the derivation of age, size and origin-specific potential egg depositions, recruitment and return rates of hatchery smolts.

Assessment methodology

Smolt production above Morgan Falls

An assessment facility installed downstream of the fish louver by-pass screens in the intake canal to the Morgan Falls Power Company's low-head 1.5 kW hydro generating plant provides the opportunity to capture and examine smolts moving downstream through the facility. Fish are deflected to a holding tank, where most of the water necessary to attract the fish away from the power intake is separated and discharged to the river. The assessment facility is operated by manipulating a gate system such that smolts can be collected in a shallow assessment tank and examined before being re-routed to the downstream by-pass.

Historic information (Hayes 1953) on the timing of the smolt run in the LaHave River suggested that the majority of the smolts migrate in May. A mark-and-recapture experiment was conducted, utilizing hatchery smolts released above Morgan Falls at five dates in May 1996 and operation of the assessment facility for four to five hours from sundown. The facility was operated by Department of Fisheries and Oceans personnel for five evenings a week during the month of May, 1996. These data provided the opportunity to estimate the wild smolt production above

Morgan Falls in 1996. Additional data were provided by the Morgan Falls Power Company and by the LaHave River Salmon Association collected while conducting by-pass assessments at other times of the day. Smolts were counted and examined for tags and finclips, a sign of hatchery production, the information was recorded and the smolts were released. Petersen and Bayesian (Gazey and Staley 1986) population estimates were constructed for these data.

In-season assessments

The probability of not achieving the 1996 interim conservation target of 1,320 Atlantic salmon above Morgan Falls on the LaHave River was estimated as the season progressed. This is called an in-season assessment.

The 1996 end of season count of total returns to the counting facility at Morgan Falls fishway was estimated from the relationship between total end-of-season count at Morgan Falls and cumulative count to date for the years 1980 to 1995. Bi-weekly dates were selected to provide a series of in-season estimates of the end-of-season total count of fish. An in-season forecast was also made on July 6, the earliest date at which the width of the 90% confidence interval around the average (1980-1995) cumulative count can approximate the average (a coefficient of variation of approximately 25%). Historically (1970 to 1995), 43% of the return to Morgan Falls passed before July 6.

The regression equation ($p<0.001$; $R^2_{adj}=0.817$; $n=16$) for forecasting on July 6 the 1996 end of season count of total returns has a standard error of the estimate of 421 fish and is of the form:

$$\text{Total returns} = 784.6 + 1.4696 \times \text{Count to July 6}$$

where new values of the constant, 874.7, and proportion of the count, 1.417, were determined for each two-week period for the years 1980 to 1995.

Estimates of the 5^{th} and 95^{th} percentiles associated with each in-season forecast were obtained using Bayes' theorem (Gazey and Staley 1986), which assumes a normal distribution of the residuals from the regression. A Bayesian posterior probability distribution was estimated, from the above equation and the data, to assess the probability of counting less than the required number of spawners by the end of the season. The effectiveness of this procedure was evaluated by Amiro et al. (MS1996).

LaHave River salmon population based on counts at Morgan Falls

The principal assessment tool for SFA 21 is the Morgan Falls fishway. The fishway is located 25.3 km above the head of tide and above two major tributaries, West Branch and North Branch. An estimate of the proportion of the total salmon population counted at Morgan Falls is necessary in order to calibrate the count at Morgan Falls to the total river return of salmon. An experiment conducted in 1983, whereby adult salmon and grilse were tagged at Pleasantville on the west side of the LaHave River estuary, provides the only experimental basis, to date, to calibrate Morgan Falls counts to a basin-wide population estimate.

The estuarial trap operated from May 21 to August 7, 1983. A total of 204 tags (199 Carlin tags and 5 floy tags) was applied and 13 fish were found dead in the mesh of the trap (see Amiro et al. MS 1996). Four Carlin-tagged salmon were recaptured at the trap in a median of 14 days later (range 5 to 24d). One tag was recaptured the next day in another commercial salmon trap farther up the estuary at Upper LaHave. Recaptures numbered 42 at Morgan Falls, a median of 46 days later; four at Indian Falls on the North Branch, a median of 116 days after tagging; and two fish were angled in the LaHave below Morgan Falls, four days after tagging. A total of 1,469 fish was counted at Morgan Falls; 31 fish were counted at Indian Falls (a partial barrier) in 1983.

Estimates of total population may be derived from various combinations of these data. Because we are interested in the count at Morgan Falls as an indicator of the basin-wide population estimate and because constructing a basin-wide estimate based on all recaptured tags involves adjusting the tags available for recapture using additional assumptions about the proportion of North Branch salmon tagged, our analysis was constructed on the count and tags at Morgan Falls. Using a tag loss rate of 1% per day (developed on the Margaree River; Chaput et al. MS 1994) and the 46 day median time to recapture, an estimated 100 tags were available for recapture at Morgan Falls.

Petersen and Bayesian (Gazey and Staley 1986) population estimates were constructed for these data. Assuming the 1983 estimate is an unbiased estimate of the 1983 population and that Morgan Falls consistently measures a similar portion of the total population, then the posterior of the Bayes estimate may be calibrated to the count at Morgan Falls and produce an annual (1996 in this case) posterior distribution of the probabilities of basin-wide population estimates.

Catch Rates

Assuming that estimates of angling catches are measured without bias, then annual (1996 in this case) estimates of a range of possible exploitation rates may be derived from the posterior estimates of population probabilities. Assuming that the annual exploitation rate for LaHave River is similar to other rivers in SFA 21, then posteriors of possible population estimates for rivers with reported angling catches may be constructed.

Egg depositions

Potential egg deposition was estimated from the number of fish by origin and sea-age at maturity minus removals (broodstock, Native harvest, retained angled fish and hook-and-release mortality) times mean length of females by origin and sea-age at maturity, where fecundity was $\text{Eggs} = 446.54 * e^{(0.0362 * \text{Fork length})}$ (Cutting et al. MS 1987). Potential egg depositions were estimated for the area above Morgan Falls based on the count at Morgan Falls and for the LaHave River based on the basin-wide population estimate.

Estimated escapement and egg deposition above Morgan Falls in 1996

Voluntary angler log books collected in 1992 to 1995 indicated 4 to 17% of the fish angled in the LaHave River were taken above Morgan Falls. Escapement above Morgan Falls in 1996 was estimated using the count at Morgan Falls minus 10% of the total river angling catch.

Wilkie et al. (in press) examined hook-and-release mortality with respect to water temperatures and found minimal mortality at water temperatures less than 20°C. Mortality increased rapidly over 22.5°C. Maximum daily water temperatures exceeded 22.5°C beginning August 6, 1996, as compared to June 20, 1995. Nonetheless, to be conservative we use 10% hook-and-release mortality to estimate fish surviving to spawning escapement after release by angling above Morgan Falls.

Hatchery-origin smolt return rates

Annual estimates of marine survival for LaHave River hatchery-reared smolts, stocked above Morgan Falls, are available for each year since 1971. Numbers of smolts are adjusted for the proportion "good quality" as determined by the annual smolt evaluation assessment (G. Farmer pers. comm.[2]). Smolts of hatchery origin derived from stocking marked parr above Morgan Falls were estimated using over-winter survival rates of 0.6 for age-0+ to age-1+ parr and 0.4 for age-1+ parr to two-year smolt. Return rates are to Morgan Falls and are unadjusted for removals by the angling fishery below Morgan Falls.

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Forecasts of counts to Morgan Falls and returns to LaHave River in 1997

Counts of wild multi-sea-winter salmon to Morgan Falls in 1997 are based on regression of counts of wild two-sea-winter salmon (1975-1996) on wild one-sea-winter salmon (1974-1995) and the count of one-sea-winter salmon in 1996. A similar procedure was used to estimate the hatchery two-sea-winter count based on the counts of hatchery one-sea-winter grilse. The count of hatchery one-sea-winter grilse at Morgan Falls in 1996 was forecast from a regression through the origin (intercept not significant) of hatchery one-sea-winter counts (1973-1996) on the estimate of smolts output above Morgan Falls (1972-1994) and the 1996 estimate of smolts originating from hatchery stocking. The wild one-sea-winter count at Morgan Falls was forecast as the 1992-1996 mean count. All forecasts were converted to Bayes posterior probability distributions assuming a binomial distribution of residuals. The posteriors of these estimates were used to estimate probabilities associated with various fisheries management goals, i.e., counts and escapements.

Assessment results

Smolt production above Morgan Falls 1996

A total of 49,326 hatchery-produced one year old smolts of LaHave River origin was released above Morgan Falls on five dates in May 1996 (Table 9). Most of these smolts were released on May 1, 8 and 15, 1996. Also, some smolts were expected from age-0+ parr released in 1994, and the total estimated hatchery origin smolt output above Morgan Falls in 1996 was 52,139 (Table 10). Also, 300 tagged wild large (> 13 cm) parr were potentially available to the assessment facility from large parr tagging conducted above Morgan Falls in 1995.

Counts were conducted almost daily May 3 to May 23, 1996 (Table 11). Totals of 11,323 hatchery smolt, and 4,453 wild smolt were counted through the facility. More fish passed through the facility during other times but were unrecorded.

These data provided a modal estimate of 73,090 (72,320 - 73,530; 5^{th} and 95^{th} percentiles) smolts above Morgan Falls of which 52,439 were hatchery or tagged wild smolts. The most probable wild smolt migration in 1996 was 20,651. At 26,052 x 100 m^2 of production area, with a map-derived stream gradient greater than 0.12% (Amiro et al. MS 1996), the production rate was 0.79 smolts per 100 m^2. This is 30% of the average of 2.6 smolts measured in the Pollett River, 1953 to 1960 (Elson 1975), and less than the lowest observed index of 1.1 smolts per 100 m^2 in the 1958 migration from the Pollett River.

In-season assessments above Morgan Falls 1996

The total cumulative count to July 6, 1996, was 1,052 fish. This count indicated an end of season count of 2,270 fish (1,595 - 2,935, 5^{th} and 95^{th} percentiles), which over-estimated the actual end of season total count (1,324 fish) by 71.5% (Table 4 and Figure 6). As of July 6, 1996, the probability of passing 1,320 fish above Morgan Falls by the end of the season was 98.9% and no adjustments to the fishing season were made. Subsequent, July 15, August 1 and September 15, assessments declined to 1,995; 1,785 and 1,580 fish respectively. No changes were made to the fishing season based on the assessments conducted on July 15 or August 1. These over-estimates were the result of the earliest cumulative run timing in the sixteen-year record of counts at Morgan Falls (Figure 7).

Estimates of the 1996 total LaHave River salmon population

Based on the 1983 Bayes modal estimate of 3,500 (2,700 - 4,940, 2.5^{th} and 97.5^{th} percentiles) fish, the 1983 count at Morgan Falls of 1,469 was 0.49 of the post-fishery total river population estimate. The 0.49 proportion and the 1996 Morgan Falls count of 1,324 fish, applied to the 1983 posterior probability distribution, indicated a modal value of 2,720 fish in the post-fishery total river population estimate (2,040 - 3,910 fish, 5^{th} and 95^{th} percentiles) in 1996. The 1996 pre-fishery population estimate was 3,913 fish (3,233-5,103 fish, 5^{th} and 95^{th} percentiles). This was

estimated by adding the post-fishery abundance, the angling harvest and 10% hook-and-release mortality.

By this method the most probable 1996 basin-wide escapement of salmon was 2,502 (2,720-218 harvest at fishway) (1,822 - 3,692 fish, 5th and 95th percentiles). At this escapement level, 75.5% of the 3,312 conservation requirement escaped to spawn in 1996. The fishway harvest was all hatchery male grilse which would not have affected the egg deposition. The probability that at least the basin-wide conservation requirement of 3,312 fish escaped to spawn in 1996 was 13.9%, derived for the value 3,530 fish (3,312 + 218; because a harvest at fishway was not conducted at the time of the 1983 estimate).

Estimates of returns and spawners to eleven other rivers in SFA 21, 1996

The 1996 LaHave River total angling catch of 1,732 fish (Table 2) and the Bayes posterior of possible populations for 1995 indicate a modal angling catch rate of 0.442 (0.339 - 0.535, 5th and 95th percentiles) (Table 12, A). Populations for eleven other rivers of SFA 21 were derived using this distribution and the 1996 angling catches (Table 12, B).

The most probable pre-fishery total population of Atlantic salmon for SFA 21 for 1996, estimated from the total angling catches and the 1996 Bayes posterior of probable exploitation rates for the LaHave River, was 7,368 (6,087 - 9,608; 5th and 95th percentiles) (Table 12, B). This is a 40% increase over the 1995 estimate of 5,239 salmon.

Spawning escapement for all SFA 21 rivers is estimated by subtracting all known removals from the total SFA 21 estimate. Spawners are estimated to have numbered 4,841 fish = 7,368 - (2,180 (retained angled fish) + 218 (Native harvest LaHave) + 20 (Aboriginal Peoples' harvest) + 109 (angling hook-and-release mortality of 10%)). This total is a 16% increase over the 1995 estimated spawning escapement of salmon in SFA 21.

Estimated escapement and egg deposition above Morgan Falls in 1996

Native fishery harvests totalled 218 male hatchery grilse at the fishway. A total of 95 broodstock (Table 8) was removed at Morgan Falls in 1996. Estimated removals by angling above Morgan Falls, including 10% for hook-and-release mortality, was 130 fish. Total spawning escapement above Morgan Falls was 881 fish. Egg deposition was 1,845,466 eggs or 94% of the interim required egg deposition of 1.96×10^6 eggs (1,320 fish at an average of 1,482 eggs*fish^{-1}) (Table 13). The stock composition of the 1996 run indicated an average eggs*fish^{-1} of 1,501 or 1.3% greater than the average eggs*fish^{-1} estimated by Cutting and Gray (MS 1984). The estimated egg deposition above Morgan Falls in 1996 was a 24% increase over the 1995 estimated deposition (Table 14).

There were 5.09 male hatchery grilse for every female hatchery grilse counted at the fishway in 1996 (Table 13). There were 883 male and 442 female wild and hatchery fish counted at the fishway in 1996. After the removal of 218 hatchery male grilse there were 1.5 male fish for every female fish. At a required 1:1 ratio of males to females, 441 male grilse were surplus above the fishway in 1996. Assuming spawning proportions as observed in the counts, 110 hatchery grilse were surplus to the interim conservation requirement above the fishway in 1996.

Estimated egg deposition in the LaHave River in 1996

The modal post-angling fishery population estimate (2,502) and the 5th and 95th percentiles, together with the 1996 egg deposition*fish^{-1} of 1,501 eggs, indicate a modal deposition of 3.75×10^6 eggs (2.73×10^6 - 5.54×10^6, 5th and 95th percentiles). The modal deposition is 80% of the 4.7×10^6 egg deposition requirement for the LaHave River as determined by Cutting and Gray (MS 1984).

Hatchery-origin smolt return rates

The estimated hatchery-origin smolt output above Morgan Falls in 1995 was 28,497 smolts comprised of 93% of the 19,155 age-1 smolts stocked in 1995 and 24% of the 44,512 age-0+ fall parr stocked in 1993 and migrating as age-2 smolts in 1995 (Table 10). The return of 396 one-sea-winter fish of hatchery origin to Morgan Falls in 1996 indicates a return rate of 1.39%, an increase from the 1.05% observed in 1995 and the highest since 1992 (Figure 8).

The return of 78 two-sea-winter hatchery salmon in 1996 yields a return rate of 0.22%. The total return for the 1994 smolt class was 1.27%, an increase from the 1993 year class (Table 10).

The estimated output above Morgan Falls of hatchery-origin smolts for 1996 was 52,007 fish. This is an 83% increase from the 1995 estimate (Table 10).

Forecast counts at Morgan Falls for 1997

The forecast count of wild multi-sea-winter returns to Morgan Falls in 1997 was estimated from the wild one-sea-winter returns to Morgan Falls (Table 5) by the regression:

$WMSW_{(1974\text{-}1996)} = 56.66 + 0.167 * W1SW_{(1973\text{-}1995)}$ ($p=0.00008$, Adj $R^2 = 0.507$, SE = 132.01)

and the 735 wild one-sea-winter returns counted in 1996. These parameters were used to construct a Bayesian posterior distribution of possible returns which indicated a most probable count of 179 (32 - 396, 5th and 95th percentiles) wild multi-sea-winter fish in 1997. The probability of counting at least 101 MSW fish in 1997 (the number required in 1996 to meet the egg deposition target of 1.95×10^6 eggs) was 79%.

The count of hatchery multi-sea-winter salmon to Morgan Falls in 1997 was estimated from the count of hatchery one-sea-winter fish at Morgan Falls by the regression:

$HMSW_{(1974\text{-}1996)} = 9.939 + 0.2421 * H1SW_{(1973\text{-}1995)}$ ($p=0.00008$, Adj $R^2 = 0.5045$, SE = 77.217)

and the 396 hatchery one-sea-winter returns counted in 1996. These parameters were used to construct a Bayesian posterior distribution of possible returns which indicated a most probable count of 106 (18 - 232, 5th and 95th percentiles) hatchery multi-sea-winter fish in 1997. The probability of counting at least 72 HMSW fish in 1997 (the number required in 1996 to meet the egg deposition target of 1.95×10^6 eggs) was 73%.

The count of hatchery one-sea-winter fish to Morgan Falls in 1997 was estimated from the regression through the origin (no stocking = zero hatchery returns) of estimated smolt output above Morgan Falls (Table 9) and the number of returns of hatchery-origin one-sea-winter grilse by the regression:

$H1SW_{(1973\text{-}1996)} = 0.014248 * Smolts_{(1972\text{-}1995)}$ ($p=0.00077$, SE = 250.093)

and the 52,007 smolts estimated output from above Morgan Falls in 1996. These parameters were used to construct a Bayesian posterior distribution of possible returns and indicated a most probable count of 743 (324 - 958, 5th and 95th percentiles) hatchery one-sea-winter fish in 1997. The probability of achieving 451 hatchery grilse (the requirement at 1996 biological characteristics) in the 1997 count at Morgan Falls was 88%.

The count of wild one-sea-winter salmon to Morgan Falls in 1997 was forecast as the mean number of wild one-sea-winter fish counted at Morgan Falls from 1992 to 1996. A total count of 938 wild grilse (195 - 1,890, 90% confidence limits) was forecast for 1997. The probability of

achieving 851 wild grilse in the count at Morgan Falls (the requirement at 1997 biological characteristics) was 61%.

A forecast count of 1,966 total fish at Morgan Falls in 1997 can be derived from the sum of the most probable forecasts and the five-year mean one-sea-winter grilse count assuming a retention fishery below the falls as included in the data used to forecast the count. This count would allow for a harvest of 646 fish, or 33%, of the population above Morgan Falls. The angling exploitation rate (retained fish only) in 1996 was 0.305 (1,193/3,913) or 30.5% and harvest for Native Peoples was 218, or 5.6%. If the counts were biased by 40% and the fishery were to operate below the falls, then no surplus fish would be available for harvest above Morgan Falls in 1997.

The basin-wide forecast using the 1983 Morgan Falls calibration and the 1997 forecast count of 1,966 fish indicates a post-angling stock of 4,012 fish. If angling exploitation rate were similar to that of 1996 (0.305), then total returns to the river could be 5,773 fish. Using the 3,312 fish requirement, about 700 fish would be surplus to requirements in the entire basin in 1997.

Non-Return Fallback at Morgan Falls

A concern of previous LaHave River assessments has been the possibility that escapements based on counts at Morgan Falls are biased because fish passing through Morgan Falls back down-river and are removed or spawn below the fishway. This non-return fallback would over-estimate escapements above Morgan Falls. Re-cycling of fish through the fishway cannot estimate these numbers. Anecdotal information from anglers has suggested that fish tail-punched at the fishway were angled substantial distances below the Morgan Falls and in other branches of the river below Morgan Falls.

An experiment using esophageal-implanted long-duration (four to six month) radio tags to examine non-return fallback was initiated in 1996. Over the course of the season 17 tags were implanted in 18 fish (one tag was removed and replanted in another fish) at Morgan Falls (Table 15). These fish had esophageal-implanted radio tags and yellow Carlin tags applied at the base of the dorsal fin. The fish were held for at least 24 hours in a shore-based 3-m holding tank and released in the same manner as all fish counted at the fishway. The method of release is a chute leading to a holding area in front of the top of the fishway.

On November 5, 1996, an aerial survey of the river by helicopter at low elevation, 20 m., and with a signal receiver tuned to the frequency of the tags, 7 transmitting tags were located below Morgan Falls (Table 16). Two of these tags were far below Morgan Falls and one was in the North Branch of the LaHave River. Three tags were located above Morgan Falls. No tags passed the falls in either direction during the fall season when the fishway was open for free ascent by salmon. No salmon with rejected radio tags were observed passing the fishway and no radio-tagged salmon were reported angled above or below Morgan Falls.

These data indicate that at least 7 of 18 or 39% of radio-tagged fish spawned below Morgan Falls after being counted in the return to Morgan Falls.

The magnitude of this non-return fallback estimate initiated a review of the down-river trucking experiments conducted in 1987, 1988 and 1989. In these years between 395 and 632 fish captured at Morgan Falls were fitted with dorsal-tied Carlin tags and trucked down-river to Cooks Falls, the first pool on the river (Table 17). Over the course of these seasons, the return and angling of these fish was recorded. Using the count of returns to Morgan Falls and accounting for a non-reporting bias in the angled fish of 20%, the non-return rate was 30.8 to 49.5%. The mean non-return rate was 39.7%.

The implications of a 40% non-return fallback to assessment of escapements above Morgan Falls since 1983 (ten years after establishment of the run to above the falls) are that the

required escapement of 1,320 fish would not have been met in 6 of 13 years (Figure 9). Five of the six years have occurred since 1991, a period when marine survival has been low. Without accounting for non-return fallback only three years of escapements less than conservation were noted (Figure 4).

If non-return fallback were 40% in 1996, then escapement above Morgan Falls was 60% of the required escapement in fish and 56% in egg deposition. The higher numbers of angled fish relative to the count at Morgan Falls in 1996 (particularly released multi-sea-winter salmon) and the increase in eggs*spawner^{-1} to 1,501 in 1996 (mostly because of the increased sizes-at-age) contributed to the greater achievement, 80% of the required egg deposition for the entire river as compared to 56% above Morgan Falls.

A 40% non-return fallback at Morgan Falls applied to the 1997 forecast return of 1,966 fish would contribute about 90% of the required spawning escapement above Morgan Falls after average exploitation in the angling fishery below the falls. The high numbers of hatchery fish expected in 1997 and the prevalence of male grilse in both wild and hatchery fish suggests greater uncertainty in achieving the required egg deposition.

Concerns and sources of uncertainty in the assessment

Establishing a consensus among biologists, managers and stakeholders of required spawning escapement for above Morgan Falls and for the entire river must be a priority for future assessments. The interim target of 1,320, based on the estimate of 40% of utilizable area above Morgan Falls, agrees with the 42% of the portion of the population estimated above Morgan Falls in 1983 but not with the 51.2% proportional estimate of total area greater than 0.12% water surface grade by remote sensing (Amiro et al. MS 1996). The low smolt production, 0.79 per 100 m^2 measured in 1996 and the higher achievement of escapement for stocks below Morgan Falls in 1996 suggest that colonization of the area above Morgan Falls may not be complete and/or that the assumption of equal deposition of spawners to all utilizable habitats is incorrect.

Counts of salmon at Morgan Falls are conducted by DFO personnel using stated sampling protocols. The time series of these data provide a reliable post-fishery indicator of abundance and escapement above Morgan Falls. However, the non-return fallback estimated here is the first attempt to adjust Morgan Falls counts. The 40% scenario posed here approximates the average of four estimates, all of which may be biased by the experimental effect of tagging. Nonetheless, non-return fallback is a reality of counts at Morgan Falls and needs to be addressed in both the estimates of escapement and in the management plan. Ideally a model incorporating the uncertainty of the forecast, the non-return fallback and the exploitation rate would contribute to the assessment of risk of failing to achieve the conservation requirement with a variety of fishing plans. Further development is warranted (See Prognosis).

Scaling the count at Morgan Falls to a basin-wide estimate introduces a further source of uncertainty. The observation of non-return fallback and the difference in levels of achievement of spawning escapement above and below Morgan Falls increase the merit of this basin-wide approach. The implications can be seen in the forecast surplus in 1997, which will for the most part be for below Morgan Falls. This is not surprising since the population below is well established while that above is historically new. Anecdotal information persists of higher abundance of salmon in branches below Morgan Falls.

The essential assumption in using the 1983 mark-and-recapture experiment to estimate 1996 basin-wide populations is an unbiased 1983 estimate. If the 1983 estimate were biased, then the 1996 estimate will also be biased. The assumption is that the true value is included in the percentile range used. However, establishing an estimate of error for the proportional representation of the Morgan Falls count to the LaHave River basin would increase confidence in

using this technique and provide the data to estimate better the uncertainty of the total LaHave River population for years when a mark-recapture population estimate is not conducted. This, or a similar, experiment should be repeated for three to five years.

Mark-recapture estimates of populations of this size, with marks and recaptures in these ranges (about 200), are particularly sensitive to the number of marks available for recapture. Population estimates by the mark-recapture technique are sensitive to tag loss for the marked fish parameter in the estimate. Tag loss and mortality rates of tagged fish need to be established for the LaHave River.

The use of an annual exploitation rate determined at Morgan Falls and applied to other rivers in SFA 21 is appealing because of the modest cost and availability of angling data. The assumption of no difference in catch rates among rivers of SFA 21, inherent in the analysis, needs to be tested. Also, an estimate of the error of the number of angled salmon would enable further development of probabilities associated with assessments and forecasts. The only other independent assessment of returns and escapements in SFA 21 is for the Sackville River. Late season snorkel counts of marked and unmarked salmon in that river indicated a population of 721 (541 - 1,241; 5^{th} and 95^{th} percentiles) salmon of all ages (Table 18). The reported angling catch of 43 fish indicated an exploitation rate of 6.0%. This is less than the 5^{th} percentile estimate for LaHave River (33.9%). However, these data may not be compared fairly since the Sackville River is a recent re-developing and colonizing salmon run, has not had an established fishery for many years, and acceptance of harvesting is undecided among users.

Ecological considerations

The ecological implications of extremes or anomalies in environmental events, both in the freshwater and marine stages of Atlantic salmon, are difficult to interpret. Atlantic salmon stocks of SFA 21 are known to utilize the North Atlantic for winter foraging. Environmental conditions, potentially negatively affecting salmon at sea, have been documented (Reddin and Friedland 1993). Only slight improvement in conditions in the North Atlantic in 1996, potentially affecting returns of 2SW salmon in 1997, has been observed (Anon. MS 1996).

Fish assemblages in the North Atlantic have also changed in the 1990s. Atlantic cod (*Gadus morhua*), a predator of post-smolt salmon, is known to be at low population levels and salmon fisheries have been closed, but returns and return rates of salmon remain low.

Information to support a hypothesis that marine survival has declined, independent of uncertainties in freshwater production, may be provided in the return of hatchery smolts. Hatchery-origin smolt output above Morgan Falls was estimated taking into account the numbers, stage and quality of smolt at release (Table 10). These data indicate that survival of smolts to adult recruits has not increased to levels observed in the 1980s (Figure 8). Marine survival remains low in spite of the prevalence of closed interceptory fisheries. The Greenland commercial fishery had a total allowable catch of 174 t in 1996 but took only 85t.

The earlier run timing observed at Morgan Falls in 1996 was not forecast and has yet to be accurately modeled. Modeling run timing would be beneficial and contribute to more accurate inseason management advice. Variance from the mean run time was not correlated with river discharge or cumulative discharge (Amiro et al. MS 1996). We note that the early run-timing in 1996 was not resultant of extreme discharges in June when river entry began to surpass previous records (Figures 4 and 7).

Juvenile salmon production is not analyzed in this document. The low levels of parr observed in the LaHave River have been modeled in the Atlantic Salmon Regional Acidification Model (ASRAM) and are associated with the amount of low gradient habitat and acidification (Korman et al. 1994). Although escapements and returns to Morgan Falls are somewhat uncertain, juvenile data would add little additional critical information to the assessment above

Morgan Falls without direct assessment of egg-to-juvenile salmon survival rates. Juvenile data below Morgan Falls may provide information on the relative production below and assist in calibrating an ASRAM for the area below. Chemistry data necessary to run the ASRAM analysis below Morgan Falls are not presently available.

Prognosis

Short term

The prognosis for 1997 looks favourable compared to the previous four years. Returns, however, are not expected to reach the high levels experienced in the 1980s. This prognosis is based on the recent low survival rates of hatchery smolts, the low index of marine habitat and the five-year run of low returns.

The implications of 40% non-return fallback at Morgan Falls are that the usual 30% exploitation rate would over-harvest relative to the conservation requirement. The management actions in place in 1996, i.e., one fish per day and no retention until June 1, would not likely be sufficient in 1997. Further reduction in exploitation rate is necessary if non-return fallback occurs and if a lower risk of not attaining the conservation requirement is desired.

The range of exploitation rates of grilse (>63 cm) with fixed exploitation of salmon of 3%, associated with various risks of not meeting the conservation requirement (the interim requirement of 1,320 and the 2,200 requirement adjusted for 40% non-return fallback) above Morgan Falls, are (see Appendix 1 for derivation):

Conservation requirement	Risk levels						
	.10	.25	.40	.50	.60	.75	.90
1,320	0.07	0.33	0.52	0.64	0.78	>1.0	>1.0
2,200	0+	0+	0.11	0.22	0.33	0.52	0.81

Long term

The long-term prognosis for the LaHave River seems stable if in-river exploitation is reduced in years of low returns. If non-return fallback is 40% then egg depositions in three of the last four years have been 50 to 55% of the conservation egg deposition requirement. Ignoring non-return fallback the egg depositions were still only 76 to 85% of the requirement. These escapements set up the next four to five years with reduced wild smolt outputs. These reduced outputs could easily be overcome by increased marine survival. The upturn in hatchery smolt survival in 1996, if repeated in 1997, may serve to compensate to some degree, for the low recent escapements. Unless marine survival increases substantially in the next three to five years, the probabilities for returns in excess of requirements will not be large.

Other rivers in SFA 21, which are impacted by acid precipitation to greater degrees than LaHave River, are subject to losses consequent of increased acid depositions. This loss in addition to that of lower-than-average escapements in the past four years places these rivers in jeopardy of not achieving their conservation escapements, based on standard conservation requirement rates, i.e., 2.4 egg m^{-2}, without in-river exploitation.

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Literature cited

Amiro,P.G., Eric M. Jefferson and Carolyn J. Harvie. MS 1996. Status of Atlantic salmon in Salmon Fishing Area 21, in 1995, with emphasis on the upper LaHave River, Lunenburg Co., Nova Scotia. Atl. Fish. Res. Doc., 96/126, 52 p.

Anon. MS 1996. Report of the Working Group on North Atlantic Salmon. ICES CM 1996/Assess:11 Ref. M.

Chaput, G., R. Jones, L. Forsyth and P. LeBlanc. MS 1994. Assessment of the Atlantic salmon (*Salmo salar*) stock of the Margaree River, Nova Scotia, 1993. Atlantic Fisheries Res. Doc. 94/6. 64 p.

Cutting, R.E. and R.W. Gray. MS 1984. Assessment of the status of the salmon stocks of the LaHave River, Nova Scotia. CAFSAC Res. Doc. 84/40. 44 p.

Cutting, R.E., E.M. Jefferson and S.F. O'Neil. MS 1987. Status of the Atlantic salmon of the LaHave River, Nova Scotia, in 1986 and forecast of returns in 1987. CAFSAC Res. Doc. 87/106. 18 p.

Elson, P.F. 1975. Atlantic salmon rivers, smolt production and optimal spawning. Int. Atl. Sal. Found. Sp. Pub. Series. No. 6, pp. 96 - 119.

Gazey, W.J. and M.J. Staley. 1986. Population estimation from mark-recapture experiments using a sequential Bayes algorithm. Ecol. 67:941-951.

Hayes, F.R. 1953. Artificial freshets and other factors controlling the ascent and population of Atlantic salmon in the LaHave River, Nova Scotia. F.R.B. of Can. Bulletin N0. 99, 47 p.

Korman, J., D.R. Marmorek, G.L. Lacroix, P.G. Amiro, J.A. Ritter, W.D. Watt, R.E. Cutting and D.C.E. Robinson. 1994. Development and evaluation of a biological model to assess regional-scale effects of acidification on Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 51:662-680.

Reddin, D.G. and K.D. Friedland. 1993. Marine environmental factors influencing the movement and survival of Atlantic salmon. Pages 79 - 103 *in* D. Mills [Ed.], Salmon in the Sea and New Enhancement Strategies. Fishing News Books, Blackwell Scientific Publications Ltd., London.

Watt, W.D. 1997. The Atlantic region acid rain monitoring program in acidified Atlantic salmon rivers: Trends and present status. Can. Stock Assess. Res. Doc. 97/28, 21 p.p.

Watt, W.D. 1989. The impact of habitat damage on Atlantic salmon (*Salmo salar*) catches. Pages 154 - 163 *in* C.D. Levings, L.B. Holtby, and M.A. Henderson [Ed.], Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105.

Watt, W.D. 1986. The case for liming some Nova Scotia rivers. Water, Air and Soil Pollution 31:775 - 789.

Wilkie, M.P., M.A. Brobbel, K. Davidson, L. Forsyth, and B.L. Tufts. *In press.* The influence of temperature on the post-exercise physiology and survival of Atlantic salmon. Can. J. Fish. Aquat. Sci.

Table1. Rearing areas of rivers on the south shore of Nova Scotia grouped by pH impact category (Watt 1986) and Atlantic salmon sportcatch and effort for 1995 and 1996, contrasted with mean catches, 1991-95.

River	pH impact Category Watt (1986)	Rearing area (100 sq. m)	1996 Preliminary Grilse retained	Grilse released	Salmon released	Effort	1995 Grilse retained	Grilse released	Salmon released	Effort	1991 - 95 means Grilse retained	95% C.I.	Grilse released	95% C.I.	Salmon released	95% C.I.	Effort roddays	95% C.I.
Broad	1										0	N/A	0	N/A	0	N/A	0	N/A
Clyde	1	24,256	50	13	15	765	35	1	6	546	44	47	6	8	7	7	579	176
Jordan	1	15,777	0	0	0	2	0	0	0	1	0	N/A	0	N/A	0	N/A	1	N/A
Nine Mile	1	3,334								0	0	N/A	0	N/A	0	N/A	0	N/A
Sub-total		43,367	50	13	15	767	35	1	6	547	44	47	6	8	7	7	580	176
Percent of total		15	2	2	3	4	4	1	2	4	4	4	3	4	2	4	4	2
East: Lunen	2	3,969	0	0	0	4	0	0	0	4	0	0	0	0	0	0	7	5
Ingram	2	3,702	7	0	0	140	4	4	15	239	5	2	3	4	5	8	120	87
Mersey	2		6	0	0	255	0	0	1	422	26	34	2	4	6	11	1353	836
Middle: Lun	2	9,270	15	0	0	47	7	5	0	41	2	4	2	3	0	1	14	20
Sackville	2	6,485	39	74	7	712	22	4	2	476	15	12	10	20	7	8	368	196
Tusket	2	65,764	104	30	68	1127	42	11	16	736	60	51	10	10	30	18	1089	429
Sub-total		89,190	171	104	75	2285	75	24	34	1918	108	102	28	41	49	44	2951	1572
Percent of total		31	8	19	14	12	8	16	9	14	9	10	17	21	15	27	18	20
Gold	3	17,741	187	20	61	1509	156	27	32	1636	132	109	17	19	26	10	1689	910
LaHave	3	50,848	1133	346	253	9053	557	79	240	6340	573	492	90	86	184	69	6845	3297
Medway	3	67,653	429	35	54	3237	106	6	32	2135	186	219	16	20	47	15	3310	1446
Salmon: Dig	3	7,727	81	9	48	508	20	1	11	258	19	8	2	2	5	5	261	83
Sub-total		143,969	1830	410	416	14307	839	113	315	10369	910	828	125	127	262	100	12105	5735
Percent of total		50	84	74	78	78	84	76	84	76	80	77	74	67	79	61	73	72
Martins	4	5,441								0	0	N/A	0	N/A	0	N/A	0	N/A
Meteghan	4		0	0	2	14	2	9	6	88	1	1	3	5	2	3	24	47
Musharnush	4	2,303	11	0	0	152	14	2	1	79	11	8	2	2	2	3	72	57
Petite Rivier	4	6,444	118	30	22	825	32	0	11	605	67	87	6	8	12	7	787	415
Sub-total		14,188	129	30	24	991	48	11	18	772	78	96	10	15	16	13	884	519
Percent of total		5	6	5	5	5	5	7	5	6	7	9	6	8	5	8	5	6
Totals		290,714	2180	557	530	18350	997	149	373	13606	1141	1074	170	191	334	164	16520	8003

Table 2. Distribution of hatchery-stocked Atlantic salmon smolts and fall fingerlings to rivers of SFA 21 during 1995.

	River	pH Category	Origin of stock	Number of smolt	Percent of SFA 21	Number of fall fingerlings
	Clyde	1	LaHave	15019	6	
	Jordan	1	LaHave	5000	2	
Sub-total				20,019	8	
	Mersey	2	LaHave	14001	6	
	Sackville	2	LaHave	17102	7	
	Sackville	2	Sackville		0	22592
	Tusket	2	Tusket	35742	15	991061
Sub-total				66,845	28	
	Gold	3	Gold	15282	6	12334
	LaHave	3	LaHave	50006	21	54107
	Medway	3	Medway	51355	21	54026
	Salmon River - Digby	3	Salmon River	12522	5	19923
Sub-total				129,165	53	
	Meteghan	4	Tusket			20007
	Mushamush	4	LaHave	13327	5	7250
	Petite	4	LaHave	13477	6	10875
Sub-total				26,804	11	
	Bear River		Tusket		0	
Total				242,833		1,192,175

Table 3. Atlantic salmon fishing seasons and variations for Salmon Fishing Area 21, Southwestern Nova Scotia, 1996

2 (a)	SALMON FISHING AREA 21 (Southwestern Nova Scotia) and all waters of the Province flowing into that Area except the waters referred to in paragraphs (b) to (p)		June 1 to Aug. 15
(b)	Clyde River		May 10 to Sept. 30
(c)	Gold River		June 1 to Aug. 15
(d)	Ingram River		June 1 to Aug. 15
(e)	Jordan River		May 10 to Sept. 30
(f)	LaHave River downstream from	Morgan Falls	May 10 to Aug. 15
	(Hook and release only from		May 10 to May 31)
(g)	LaHave River upstream from Morgan Falls except the waters referred to in paragraph (h)		Closed all year
(h)	LaHave River between the bridge on the Lower Branch Road (Varner's Bridge #2) in New Germany and Cherryfield Bridge at Cherryfield, not including tributaries		May 10 to Aug. 15
	(Hook and release only from		May 10 to May 31)
(I)	Medway River downstream from	McGowan Lake	June 1 to July 31
(j)	Mersey River		May 10 to Aug. 15
		and	Sept. 1 to Sept. 30
(k)	Metaghan River		Aug. 1 to Sept. 30
(l)	Mushamush River		June 1 to Aug. 15
(m)	Petite Riviere		June 15 to Aug. 15
(n)	Salmon River		June 1 to Aug. 15
(o)	Sackville River		June 1 to Aug. 15
(p)	Tusket River		June 1 to Aug. 15

*NOTE: THE DAILY BAG LIMIT FOR SALMON LESS THAN 63 CM IN LENGTH IS REDUCED TO ONE (1) PER DAY FOR ALL RIVERS IN SALMON FISHING AREA 21. THE SEASONS AND DAILY BAG LIMIT ARE SUBJECT TO IN-SEASON ADJUSTMENTS. FROM MAY 10 TO MAY 31 HOOK AND RELEASE ANGLING ONLY IS PERMITTED ON THE LAHAVE RIVER.

Table 4. Cumulative counts of wild and hatchery Atlantic salmon to Morgan Falls fishway on the LaHave River by weekly dates in 1996.

		Salmon		Grilse		Total count
Month	Day	Wild	Hatchery	Wild	Hatchery	to date
June	1		1		1	2
	8	9	10	6	4	29
	15	29	26	39	23	117
	22	37	30	143	79	289
	29	52	44	360	172	628
July	6	71	60	587	294	1012
	13	79	64	633	335	1111
	20	89	66	675	355	1185
	27	93	70	687	361	1211
August	3	96	72	696	370	1234
	10	96	73	702	378	1249
	17	98	73	707	379	1257
	24	98	73	707	379	1257
	31	98	73	707	379	1257
September	7	98	73	707	379	1257
	14	100	75	715	380	1270
	21	102	77	722	384	1285
	28	105	78	730	387	1300
October	5	108	80	732	392	1312
	12	112	81	734	393	1320
	19	112	81	734	393	1320
	26	112	81	734	395	1322
November	2	112	81	735	396	1324

Table 5 Stock origins and sea-age composition of Atlantic salmon returns to the Morgan Falls fishway, LaHave River, 1970 - 1996, and forecasts for 1997.

Year	Hatchery		Wild		Totals		
	1SW	MSW	1SW	MSW	1SW	MSW	Combined
1970	--	--	2	4	2	4	6
1971	--	--	3	--	3	--	3
1972	9	--	8	2	17	2	19
1973	138	9	14	7	152	16	168
1974	442	19	29	2	471	21	492
1975	466	68	38	5	504	73	577
1976	468	108	178	23	646	131	777
1977	974	84	292	25	1,266	109	1,375
1978	567	209	275	67	842	276	1,118
1979	1,064	99	856	67	1,920	166	2,086
1980	336	524	1,648	294	1,984	818	2,802
1981	1,186	232	1,880	349	3,066	581	3,647
1982	623	234	804	257	1,427	491	1,918
1983	25	99	1,118	217	1,143	316	1,459
1984	249	33	2,041	392	2,290	425	2715
1985	105	76	1,348	629	1,453	705	2158
1986	133	78	1,584	589	1,717	667	2384
1987	564	81	2,491	524	3,155	605	3660
1988	1,059	62	2,465	388	3,524	450	3974
1989	442	290	2,053	392	2,495	682	3177
1990	592	110	1,866	382	2,458	492	2950
1991	109	87	499	233	608	320	928
1992	617	60	1,950	217	2,567	277	2844
1993	383	83	788	110	1,171	193	1364
1994	207	119	641	128	848	247	1095
1995	372	85	577	143	949	228	1177
1996	396	81	735	112	1,131	193	1324
1997 Forecast	***741***	***106***	***938***	***179***	***1,679***	***285***	***1,964***
Upper 95th percentile	958	232	1,890	396	2,848	628	3,476
Lower 5th percentile	324	18	195	32	519	50	569

Table 6. Age and size composition of wild and hatchery adult Atlantic salmon sampled at Morgan Falls on the LaHave River, May to November, 1996. Age is shown as years to smolt (fresh), post-smolt years (sea) and ages at previous spawnings (s1,s2).

	Age				Fork Length (cm)					Weight (kg)				
Origin	Fresh	Sea	s1	s2	Number	Mean	Min.	Max.	Std. dev.	Number	Mean	Min.	Max.	Std. dev.
Wild														
	0	1			3	54.9	53.2	56.0	1.2	3	2.1	2.0	2.2	0.1
	2	1			137	55.0	50.0	62.0	2.6	137	2.0	1.2	2.7	0.3
	3	1			44	55.4	50.8	61.4	2.5	44	2.1	1.5	2.9	0.3
	4	1			1	60.0	60.0	60.0	0.0	1	2.7	2.7	2.7	0.0
	0	2			1	73.5	73.5	73.5	0.0	1	5.4	5.4	5.4	0.0
	2	2			74	71.7	62.0	82.6	3.3	74	4.3	3.0	6.5	0.6
	3	2			9	72.4	68.5	75.5	2.0	9	4.4	3.8	4.9	0.3
	2	3			1	86.7	86.7	86.7	0.0	1	9.5	9.5	9.5	0.0
	2	2	1		2	61.0	60.2	61.8	0.8	2	2.5	2.2	2.7	0.3
	2	3	1		11	76.7	73.5	80.0	2.1	11	53.0	4.0	6.3	0.7
	0	3	2		1	84.5	84.5	84.5	0.0	1	6.2	6.2	6.2	0.0
	2	3	2		6	76.9	72.0	83.5	3.9	6	4.8	4.0	5.7	0.7
	2	4	2		2	89.1	88.9	89.2	2.0	2	7.2	4.7	9.6	0.0
	2	3	1	2	1	73.0	73.0	73.0	0.0	1	3.8	3.8	3.8	0.0
	2	4	1	3	1	76.0	76.0	76.0	0.0	1	5.2	5.2	5.2	0.0
	3	4	1	3	1	84.0	84.0	84.0	0.0	1	6.0	6.0	6.0	0.0
	2	4	2	3	1	83.5	83.5	83.5	0.0	1	5.6	5.6	5.6	0.0
	2	5	2	4	1	95.0	95.0	95.0	0.0	1	9.3	9.3	9.3	0.0
Hatchery														
	1	1			47	55.8	50.7	61.0	2.6	47	2.1	1.5	2.9	0.4
	2	1			1	54.2	54.2	54.2	0.0	1	2.0	2.0	2.0	0.0
	3	1			1	53.2	53.2	53.2	0.0	1	2.0	2.0	2.0	0.0
	0	2			2	73.8	71.4	76.2	2.4	3	4.8	4.6	4.9	1.0
	1	2			75	72.2	65.8	79.2	2.8	75	4.5	3.0	6.0	0.6
	2	2			1	72.4	72.4	72.4	0.0	1	5.0	5.0	5.0	0.0
	1	2	1		1	62.8	62.8	62.8	0.0	1	2.7	2.7	2.7	0.0
	1	4	2		2	86.9	83.7	90.0	3.2	2	7.8	6.5	9.1	1.3

Table 7. Length and weight of wild and hatchery male and female one-sea-winter (grilse) and multi-sea-winter Atlantic salmon sampled at Morgan Falls fishway on the LaHave River,

Origin	Sea age	Gender	Length (cm)			Weight (kg)		
			Number	Mean	Std. dev.	Number	Mean	Std. dev.
Wild	1SW	Female	51	55.2	2.7	51	2.02	0.3
Hatchery	1SW	Female	8	56.9	2.3	8	2.40	0.4
Wild	1SW	Male	134	55	2.3	134	1.97	0.3
Hatchery	1SW	Male	41	55.5	2.6	41	2.06	0.3
Wild	MSW	Female	103	73.2	4.8	103	4.62	1.1
Hatchery	MSW	Female	72	72.0	4.0	72	4.56	0.8
Wild	MSW	Male	9	75	9	9	4.43	1.2
Hatchery	MSW	Male	10	73.5	6.5	10	4.63	1.0

Table 8. Number, mean length and weight by origin, age (smolt and post smolt) and gender of Atlantic salmon selected for broodstock from Morgan Falls fishway on the LaHave River, 1996.

Origin	Age	Gender	Length (cm)			Weight (kg)		
			Number	Mean	Std. dev.	Number	Mean	Std. dev.
Wild	2.1	Female	8	54.2	2.0	8	1.70	0.2
	3.1	Female	4	54.9	1.7	4	2.10	0.2
Hatchery	1.1	Female	2	55.5	1.5	2	2.20	0.1
Wild	2.1	Male	20	55.9	2.1	20	1.90	0.2
	3.1	Male	2	57.2	2.2	2	2.00	0.0
Hatchery	1.1	Male	19	55.1	2.4	19	2.00	0.3
Wild	2.2	Female	14	71.6	1.8	14	4.10	0.4
	3.2	Female	3	71.9	1.1	3	4.60	0.2
Hatchery	1.2	Female	16	72.9	2.5	16	4.50	0.6
Wild	2.2	Male	1	73.5	0.0	1	4.40	0.0
Hatchery	1.2	Male	6	72.9	2.0	6	4.60	0.7
Total			95					

Table 9. Releases of Atlantic salmon hatchery-reared smolts to LaHave River, 1996.

	Release Locations				
	Forebay	Lwr.Brdg N.Ger.			
	(marked	(known tag	Meisners Section		Total
Realease Date	three grps)	numbers)	Tagged	Untagged	above MF
01-May			1000	14333	
08-May	287	990	1000	14333	
15-May		999	1100	14333	
22-May	300 t	551			
29-May	150				
Totals	737	2540	3100	42999	49376

(Note:All smolts are adipose-clipped)
t = tagged

Table 10. Numbers of marked LaHave River parr and smolt stocked above Morgan Falls from the Mersey FCS and estimated hatchery-derived smolt ou of release of smolts, numbers of marked returns and percent return as recruit 1SW and 2SW adults. Number in bold is a forecast. (see text for method)

Year of release	0+ parr	1+ parr	1+ smolt		2+ smolt	Estimated smolt output[1]	Adult returns to trap yr+1 and yr+2			Return rate per smolt * 100		
	Number	Number	Number	Proportion good quality	Number		1SW	2SW	Total	1SW	2SW	Total
1971		9,440	4,892			4,892						
1972		6,790	8,400		6,450	18,626	138	19	157	0.74	0.10	0.84
1973	51,643u	43,133	9,166		18,526	30,408	442	68	510	1.45	0.22	1.68
1974	0	3,735	19,815		14,435	51,503	466	108	574	0.90	0.21	1.11
1975	0	18,883	0		0	13,888	468	84	552	3.37	0.60	3.97
1976	0	6,875	45,259	0.87	5,769	52,698	974	209	1,183	1.85	0.40	2.24
1977	0	44,314	74,577	0.79	5,370	67,036	567	99	666	0.85	0.15	0.99
1978	0	7,108	72,067	0.78	0	73,938	1,064	524	1,588	1.44	0.71	2.15
1979	30,753u	0	33,910	0.56	0	21,833	336	232	568	1.54	1.06	2.60
1980	10,626u	0	62,225	0.73	16,039	61,463	1,186	234	1,420	1.93	0.38	2.31
1981	0	0	25,482	0.91	0	30,569	623	99	722	2.04	0.32	2.36
1982	0	0	0		0	2,550	25	33	58	0.98	1.29	2.27
1983	0	0	28,451	0.69	0	19,631	249	76	325	1.27	0.39	1.66
1984	32,900u	0	15,000	0.48	0	7,200	105	78	183	1.46	1.08	2.54
1985	10,804	0	4,996	0.55	0	2,748	133	81	214	4.84	2.95	7.79
1986	55,722	0	16,864	0.92	0	23,411	564	62	626	2.41	0.26	2.67
1987	19,650	0	33,353	0.73	0	26,941	1,059	290	1,349	3.93	1.08	5.01
1988	42,481	0	16,018	0.84	0	26,828	442	110	552	1.65	0.41	2.06
1989	0	0	30,004	0.86	0	30,519	592	87	679	1.94	0.29	2.22
1990	82,432	0	15,970	0.97	0	25,686	109	60	169	0.42	0.23	0.66
1991	83,823	0	21,943	0.78	0	17,116	617	83	700	3.60	0.48	4.09
1992	48,587	0	27,516	0.94	0	45,649	383	119	502	0.84	0.26	1.10
1993	44,512	0	19,748	0.86	0	37,101	207	85	292	0.56	0.23	0.79
1994	34,827	0	26,110	0.91	0	35,421	372	78	450	1.05	0.22	1.27
1995	0	0	19,155	0.93	0	28,497	396			1.39		
1996	0	0	49,376	0.884*	0	52,007	***741***					
									Five Year average =	1.49	0.29	

u. unmarked fry

[1] Survival values used to estimate smolts:

fry to 0+ parr	0.8	0+ to smolt unknown
0+ parr to 1+ parr	0.6	
1+ parr to 2yr smolts	0.4	

* assumed preliminary value

Table 11. Daily counts of wild and hatchery-origin Atlantic salmon smolts and parr in the by-pass assessment facility of the Morgan Falls Power Company on the LaHave River at New Germany, Nova Scotia, during May, 1996.

Daily Counts taken by SEG & LRSA				Daily Counts taken by D.F.O.			
Date	W Smolt	W Parr	H Smolt	W Smolt	W Parr	H Smolt	Temp. [C]
May 1/96							
May 2/96							
May 3/96	143	3	72				
May 4/96	258		152				
May 5/96	400	14	215				
May 6/96	82		41	551	77	476	13
May 7/96	155	8	126	511	37	471	12
May 8/96	93	5	101	510	16	994	12
May 9/96	108	7	265	249	40	1276	13
May 10/96	18	1	74	259	11	948	12
May 11/96				294	10	937	11.5
May 12/96				197	6	467	10.6
May 13/96				225	25	603	10.5
May 14/96	4		8	37	3	96	10.5
May 15/96				144	3	1483	11.5
May 16/96				59	3	1411	12.5
May 17/96				17	6	233	11.5
May 18/96				20	1	53	14
May 19/96				21		325	13.5
May 20/96							
May 21/96				20	1	53	14
May 22/96				21	3	325	13.5
May 23/96				57	8	118	15.5
May 24/96							
May 25/96							
May 26/96							
May 27/96							
May 28/96							
May 29/96							
May 30/96							
May 31/96							
TOTAL	1261	38	1054	3192	250	10269	**Total**
						H. Smolt	**11,323**
						W. Smolt	**4,453**
						Total	**15,776**

Table 12. Estimated angling catch rates (maximum probable, 5th and 95th percentiles) for the LaHave River determined from a total river population estimate which was based on the Morgan Falls count in 1996 and the probability distribution of the 1983 mark and recapture population estimate(**A**); Pre-fishery population estimates derived by applying the 1996 LaHave River catch rate to the estimated angling catches reported for 11 other rivers of SFA 21(**B**).

A

	Max. Prob.	5th %	95th %
1996 Angling Catch Rate	0.4426	0.5357	0.3394

B

	Angling	Population Estimate		
River	catch	Max. Prob.	5th %	95th %
Clyde	78	176	146	230
Gold	268	606	500	790
Ingram	7	16	13	21
LaHave	1,732	3,913	3,233	5,103
Medway	518	1,170	967	1,526
Meteghan	2	5	4	6
Middle: Lunenburg Co.	15	34	28	44
Mushamush	11	25	21	32
Petite Riviere	170	384	317	501
Sackville	120	271	224	354
Salmon: Digby Co.	138	312	258	407
Tusket	202	456	377	595
Total for SFA 21	3,261	7,368	6,087	9,608

Table 13. Spawning escapement relative to requirements based on numbers of Atlantic salmon counted and aged at Morgan Falls fishway in 1996, removals, size-at-sea-age, fecundity, contribution to egg deposition and required adult salmon. Standing spawning requirements are based on 1,320 fish which at 1,482 eggs per fish yeilds 1.96 x 10^6 eggs.

Origin Post-smolt age	Gender	Number at age	Prop.	Broodstock removals	Angling+ Native harvest above	Mean length females (cm)	Mean fecundity (eggs)	Eggs contributed	Percent cont. to egg dep.	Required female spawners
Wild										
One-sea-winter	Female	203	0.15	12	23	55.2	3,294	703,250	38.1	226
	Male	529	0.40	22	59	55.0				
Multi-sea-winter	Female	103	0.08	17	2	73.2	6,319	556,154	30.1	93
	Male	9	0.01	1	0	75.0				
Hatchery										
One-sea-winter	Female	65	0.05	2	7	56.9	3,503	244,339	13.2	74
	Male	331	0.25	19	255	55.5				
Multi-sea-winter	Female	71	0.05	16	1	72.0	6,051	341,722	18.5	60
	Male	14	0.01	6	0	73.5				
Totals		1,324	1.00	95	348		4,792	1,845,466	100	
Escaped female spawners		442			-33					408
Required female spawners =										453
Surplus (Deficit) =										**(45)**

Required egg deposition =	1.96E+06	Eggs/fish 1996 =	1,501
One sea winter angling retained total =	1133		
One sea winter angling released total =	346	Preliminary	
Multi sea winter angling released total =	253		
Proportion angled above Morgan Falls=	0.10		

Table 14. Estimated egg depositions ('000's) by Atlantic salmon above Morgan Falls, LaHave River, with no adjustment for unknown losses, 1973 - 1996. Requirement is 1.96×10^6 eggs.

	No. of eggs ('000's)		
Year	Wild	Hatchery	Total Deposition
1973	50	87	137
1974	25	372	397
1975	91	501	592
1976	190	727	917
1977	396	1,086	1,482
1978	452	1,367	1,819
1979	1,292	1,284	2,576
1980	2,698	1,680	4,378
1981	3,263	1,641	4,904
1982	1,683	1,779	3,462
1983	1,968	335	2,303
1984	3,059	248	3,307
1985	3,421	413	3,834
1986	4,079	499	4,578
1987	4,899	720	5,619
1988	4,381	958	5,339
1989	4,315	1,024	5,339
1990	3,414	652	4,066
1991	1,354	376	1,730
1992	2,867	508	3,375
1993	1,140	522	1,662
1994	1,177	455	1,632
1995	1,006	479	1,485
1996	847	477	1,845

Table 15. Record of esophageal-implanted radio tags for Atlantic salmon captured at Morgan Falls on the LaHave River 1996.

Date tagged	Length (cm)	Weight (kg)	Gender	Tag #	Radio Tag code #	Channel #	Frequency (kHz)	Release date
Jun-03	73.1	4.8	Female	AA46301	9	CH 5	149.4	Jun-07
Jun-19	71.3	4.7	Male	AA46302	1	CH 5	149.4	Jun-20
Jun-19	51.7	2.0	Male	AA46304	2	CH 5	149.4	Jun-20
Jun-24	56.0	1.9	Male	AA46300	3	CH 5	149.4	Jun-25
Jun-25	51.6	1.9	Female	AA46305	4	CH 5	149.4	Jun-26
Jun-25	68.8	3.9	Female	AA46307	5	CH 5	149.4	Jun-26
Jul-03	77.9	5.0	Female	AA46309	6	CH 5	149.4	Jul-04
Jul-04	73.3	4.5	Female	AA46306	7	CH 5	149.4	Jul-05
Jul-04	59.0	2.5	Male	AA46311	8[a]	CH 5	149.4	Jul-05
Jul-04	71.0	4.5	Female	AA46308	10	CH 5	149.4	Jul-05
Jul-04	56.3	2.3	Male	AA46312	1	CH 6	149.42	Jul-05
Jul-09	56.8	2.1	Male	AA46313	9[b]	CH 5	149.4	Jul-10
Jul-09	55.9	2.6	Female	AA46314	2	CH 6	149.42	Jul-10
Jul-09	56.5	2.0	Female	AA46315	3	CH 6	149.42	Jul-10
Jul-10	74.5	4.1	Female	AA46317	4	CH 6	149.42	Jul-11
Jul-23	67.0	3.2	Female	AA46321	5	CH 6	149.42	Jul-24
Jul-31	76.0	5.0	Female	AA46318	6	CH 6	149.42	Aug-01
Aug-01	50.8	1.7	Female	AA46316	7	CH 6	149.42	Aug-02

[a] Tag rejected but not recoverable

[b] Note: Tag # 9 CH 5 was removed on July 5 and reused on July 9.

Table 16. Locations of 10 radio tagged Atlantic salmon on November 5 ,1996, located by low level aerial reconnaissance of the LaHave River, of 17esophageal-implanted tagged salmon captured and released at Morgan Fallls.

Time	Position Lat.	Long.	Stretch Name	
1:35 PM	44.30.12	64.40.18	Above Mink Hole	Below Morgan Falls
1:38 PM	44.31.37	64.40.78	Above Mink Hole	Below Morgan Falls
1:40 PM	44.31.77	64.41.59	Above Mink Hole	Below Morgan Falls
1:41 PM	44.32.11	64.52.54	Eddy (Two Tags)	Below Morgan Falls
1:42 PM		Morgan Falls (Recorded one tag -later discovered tag was spit out by fish)		
1:43 PM	44:32:84	64.43.91	Foot of New Germany Lake	Above Morgan Falls
1:46 PM	44:38:47	64:49:09	Meisners Section	Above Morgan Falls
1:52 PM	44.40.37	64:50:04	Below Cerryfield Bridge	Above Morgan Falls
3:25 PM	44:30:00	64:37:00	Below Fancy Pool - North Branch	Below Morgan Falls
3:27 PM	44:30:86	64:38:00	Between Fancy Pool & MacKay' s Bridge	Below Morgan Falls

Table 17. Estimated non-return fallback of tagged Atlantic salmon captured at Morgan Falls, LaHave River, trucked downriver with non-return fallback determined from subsequent re-captures at Morgan Falls, angling catches below and an assumed non-reporting of tagged fish, during 1987,1988, and 1989.

Year	Number trucked	Angled below	Adjusted angling below	Returned to fishway	Estimated non-returns	Proportion non-return fallback
1987	632	17	21	298	313	0.495
1988	395	27	34	208	153	0.388
1989	561	36	45	343	173	0.308
Average						0.397

Assumed non-reporting rate = 0.2

Table 18. Number of Atlantic salmon marked at the counting fence on the Sackville River **(A)** and the number of marked fish captured during the recapture **(B)**, 1996.

(A)
Marked fish: 218 (12 large salmon and 206 grilse)

(B)
Recapture date: October 8 and October 21/96

	Hatchery				Wild				
	Salmon		Grilse		Salmon		Grilse		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
Capture (Oct. 21)	1		13	6			5	1	26
Capture (Oct. 8)	1	4	7	1			3	1	17
									43
Marks									13

Notes: 14 of the fish captured on October 21 were taken for broodstock, 7 males and 7 females. The large salmon was taken and all wild fish.

The Bayesian population estimate is 721 fish (90% CI 541-1241).

The capture at the fence was 206/218=94.5% grilse.

Estimated river return was 681 grilse and 40 large salmon.

At 681 grilse returned then based on a smolt release in 1995 of 18,200 fish, the return rate was 3.74%.

In 1994, 16,000 smolts were stocked for a large salmon return rate in 1996 of 0.25%.

The smolts stocked in 1994 and 1995 came predominately from grilse x grilse crosses so a low return rate on large salmon would be expected.

The proportion wild in the run was 15.6%.

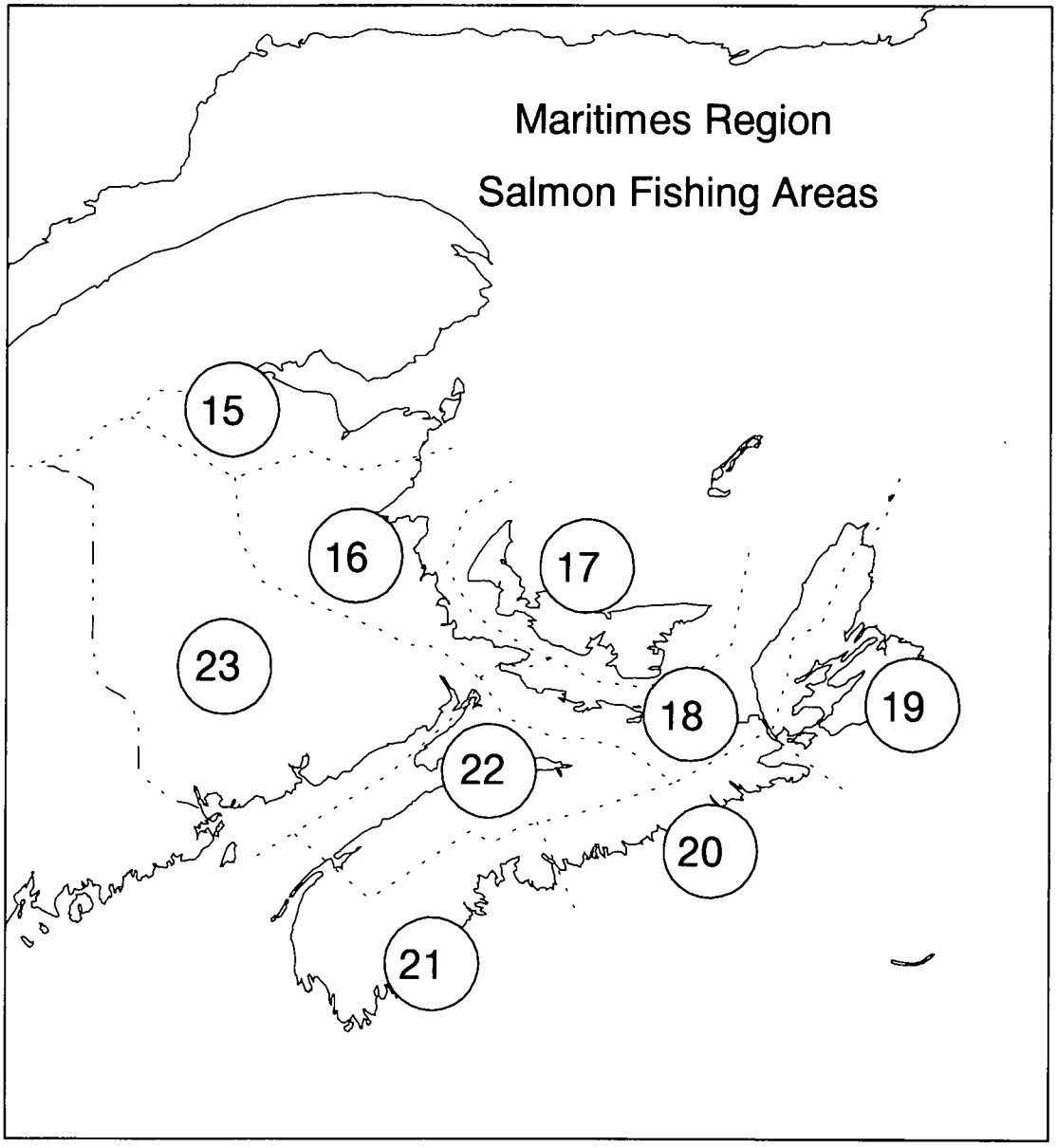

Figure 1. Map of Salmon Fishing Areas of the Maritimes Region of the Department of Fisheries and Oceans, Canada.

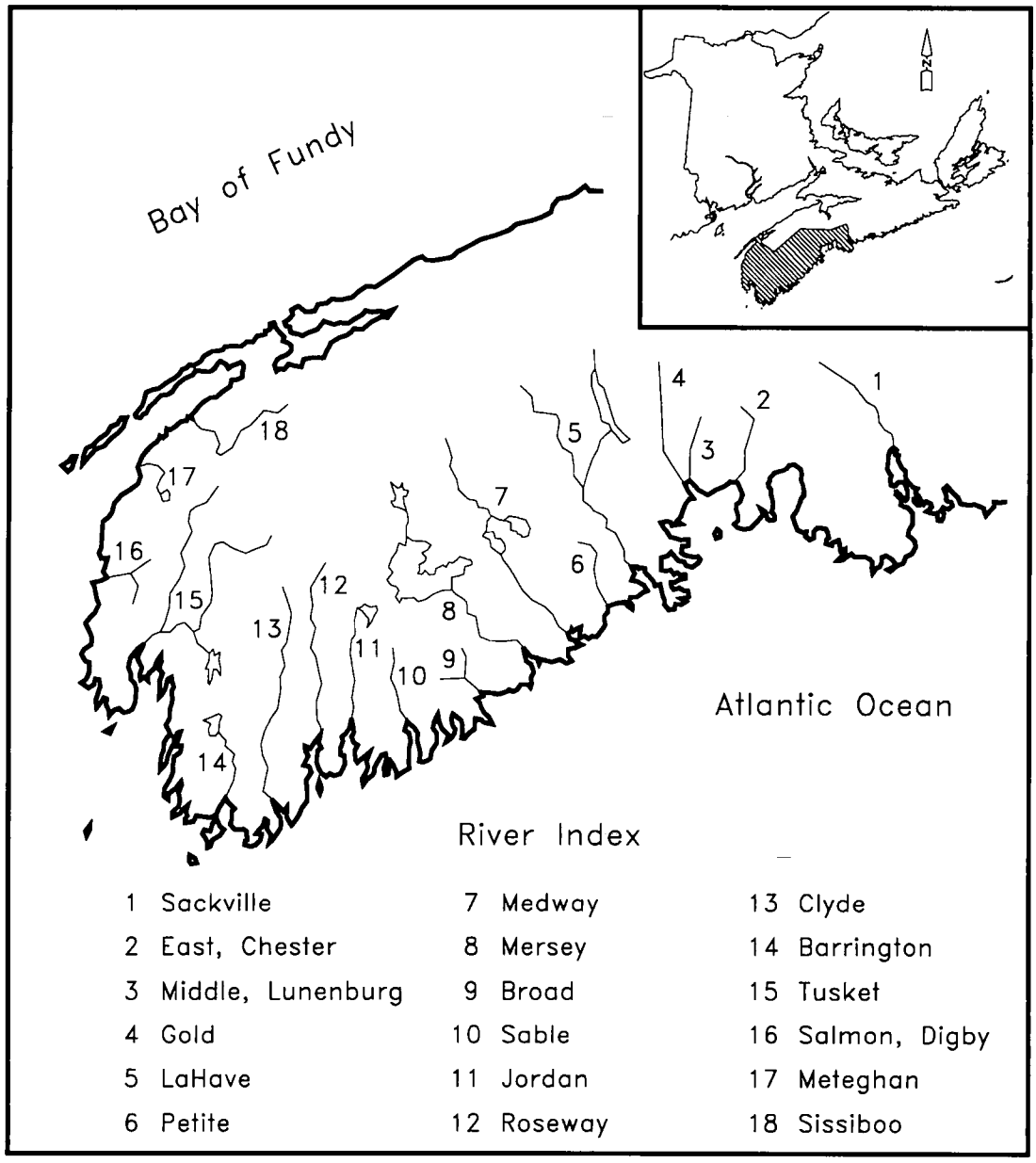

Figure 2. Locations of eighteen rivers of SalmonFishing Area 21 where potential Atlantic salmon production is defined.

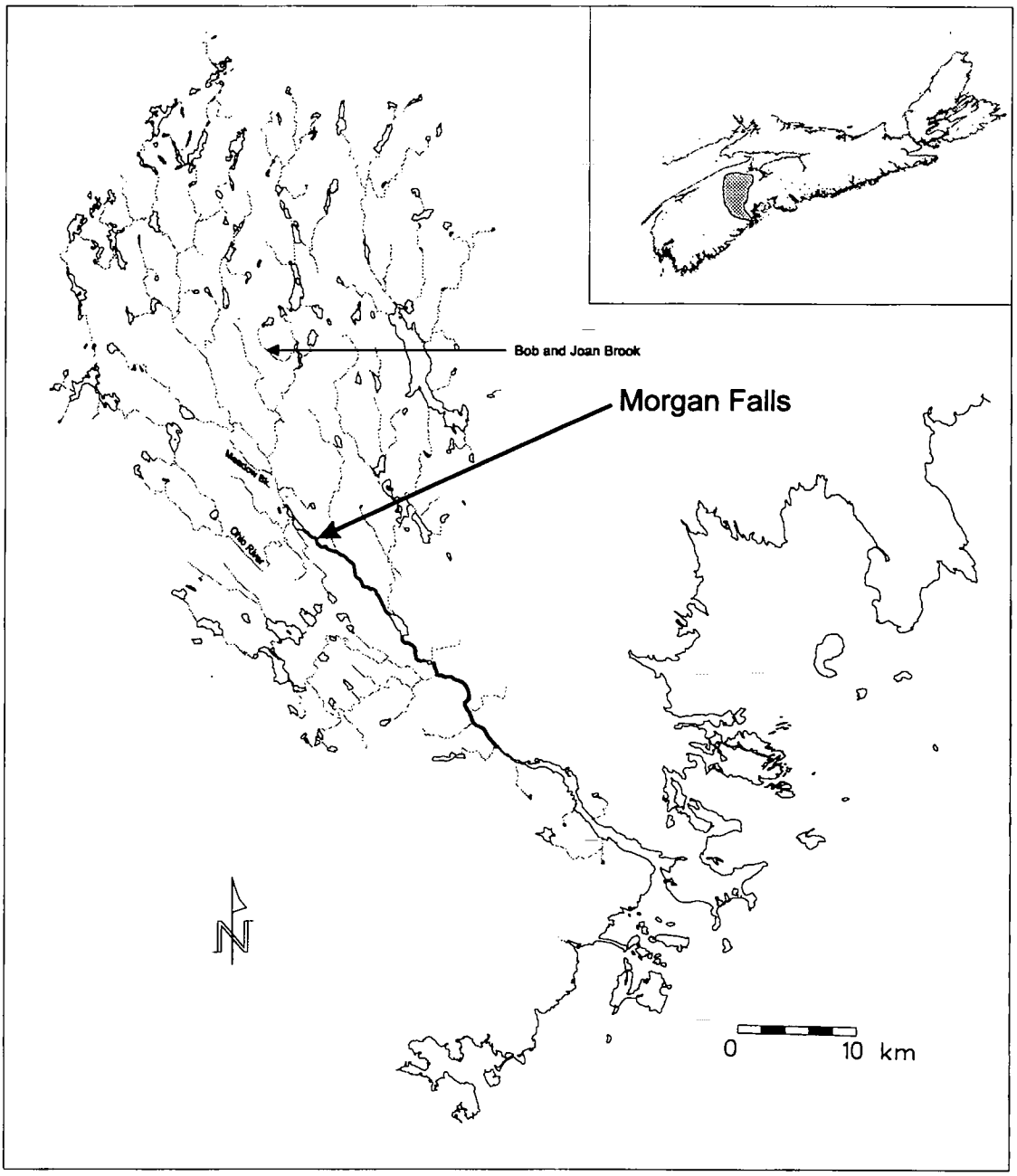

Figure 3. Map of LaHave River, Lunenburg County, Nova Scotia showing location of Morgan Falls and three tributaries above that have reduced Atlantic salmon production due to acidity.

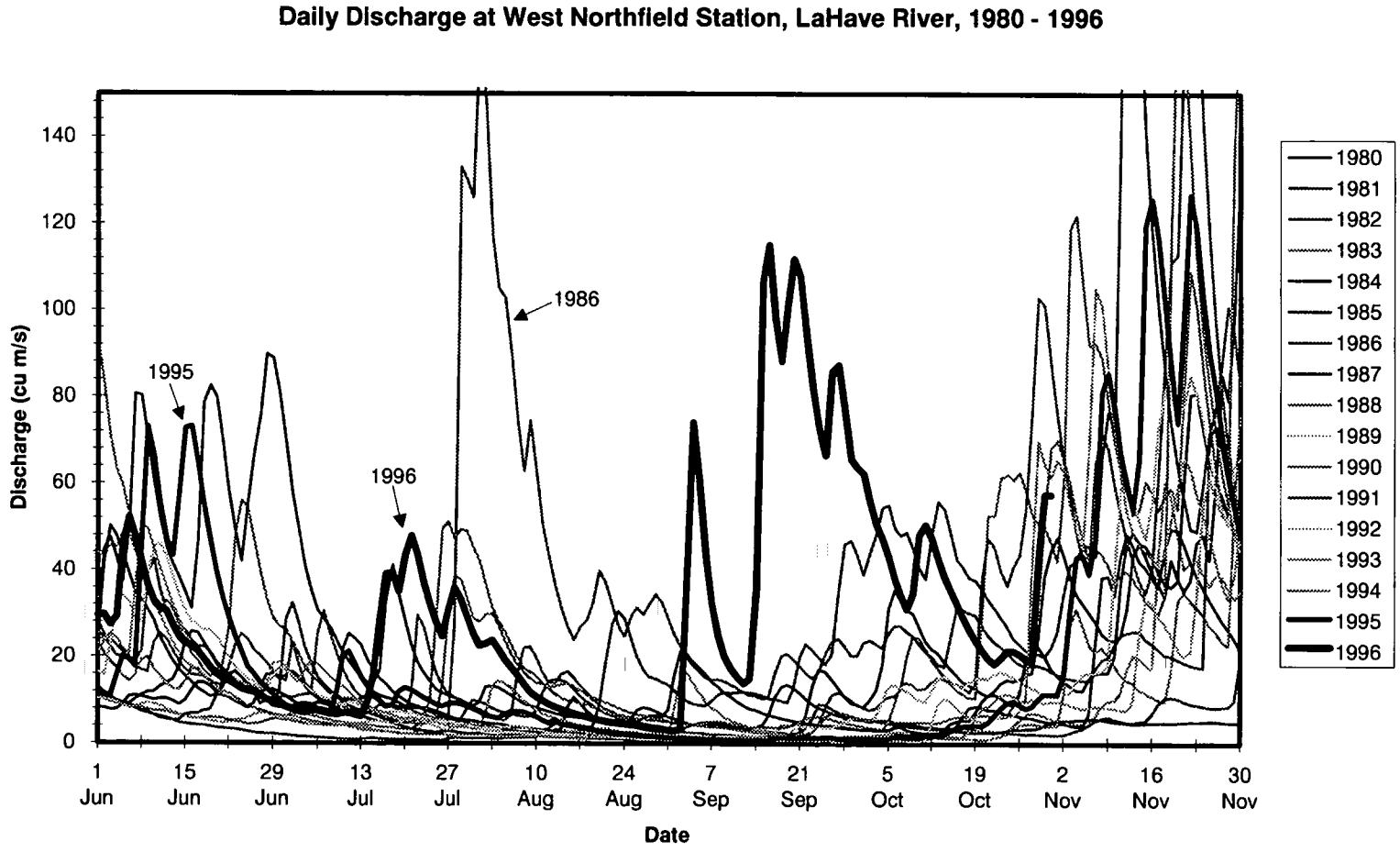

Figure 4. Daily discharge at the West Northfield gauging station, LaHave River, 1980 to 1996.

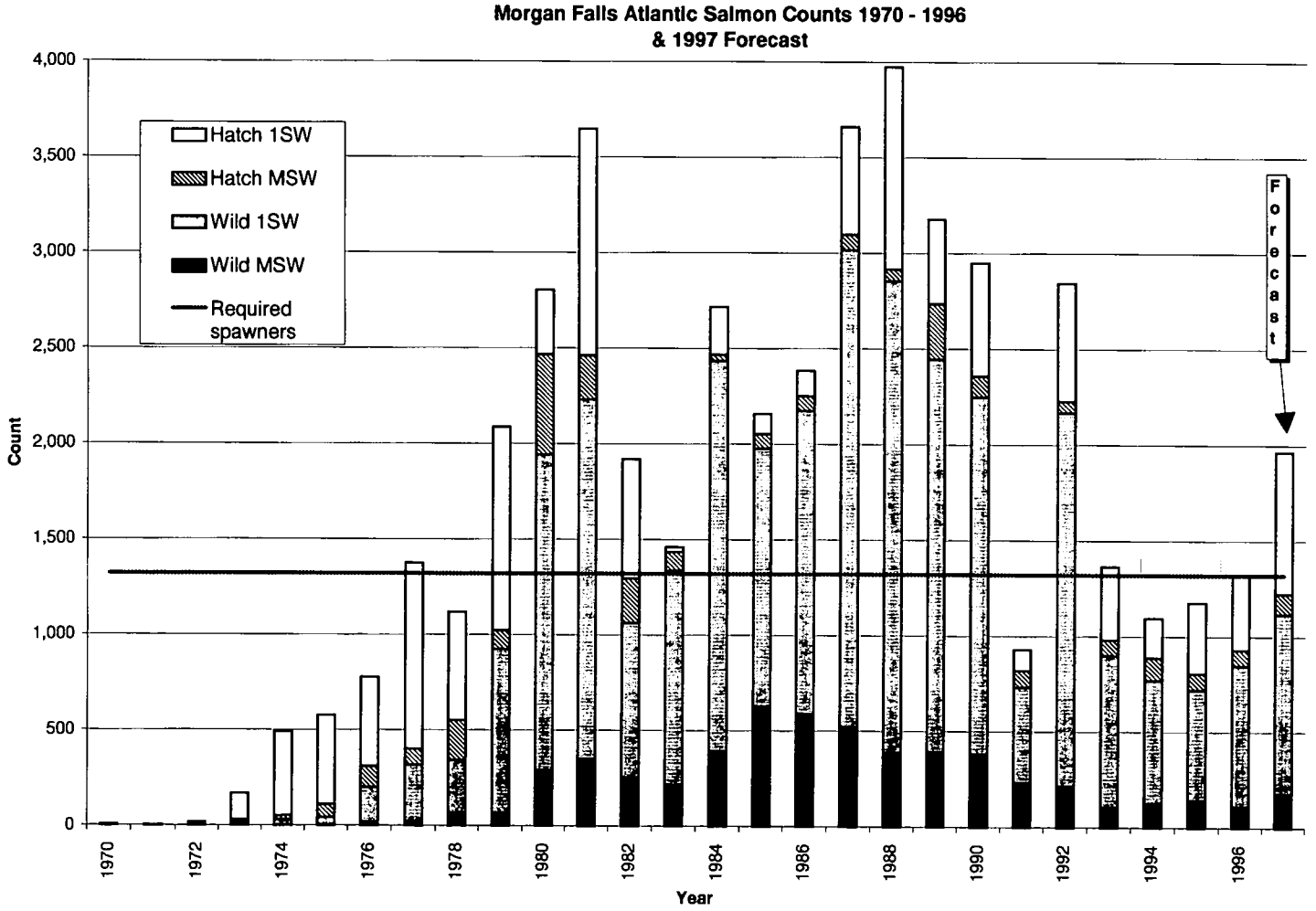

Figure 5. Counts of Atlantic salmon at Morgan Falls by sea-age class and origin for the years 1970 to 1996 and forecast for 1997.

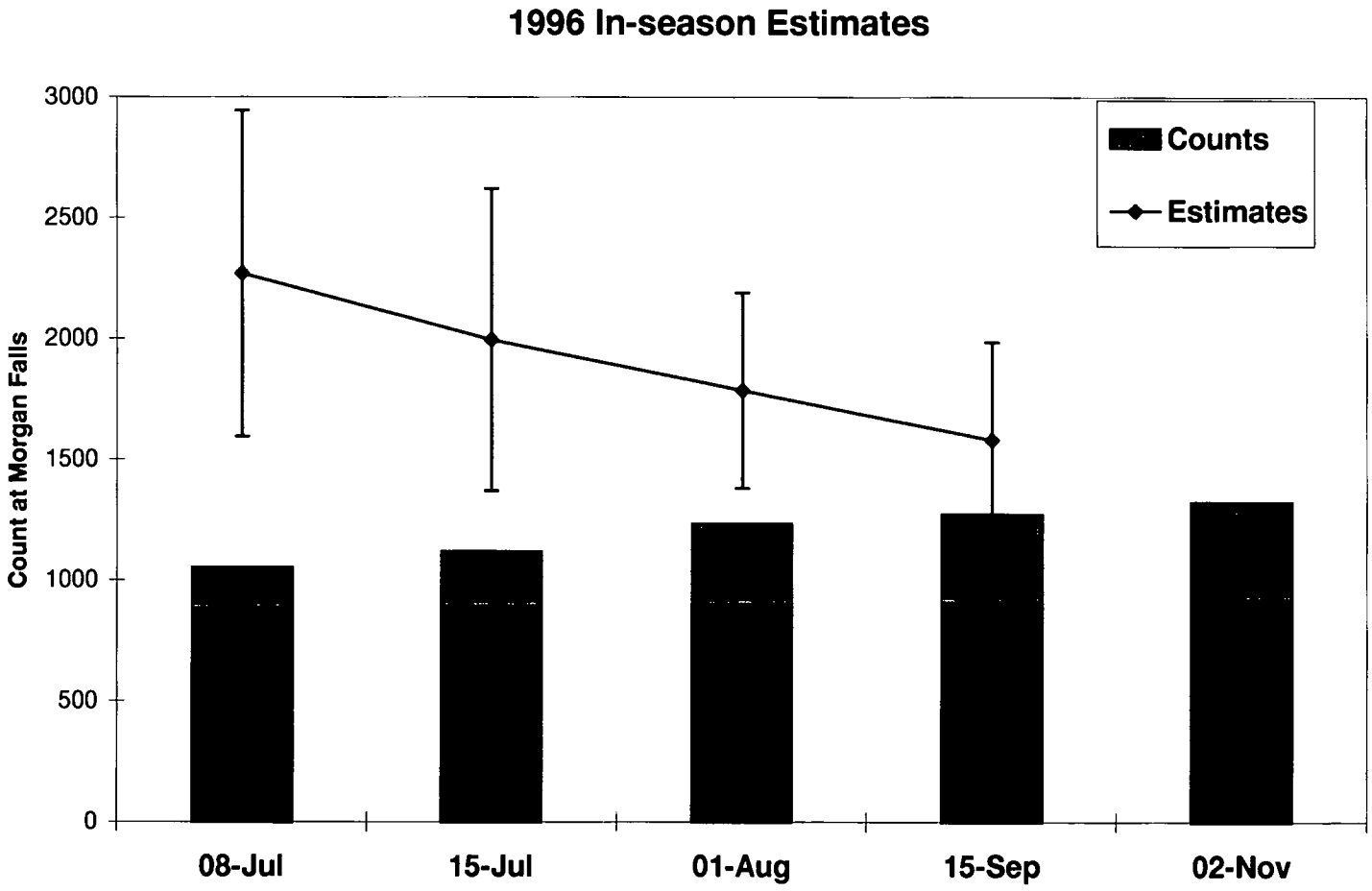

Figure 6. Count-to-date (bars) and in-season forecasts (dots), with 5th and 95th percentiles of error (lines), of the end-of-season total count of Atlantic salmon to Morgan Falls, LaHave River, 1996.

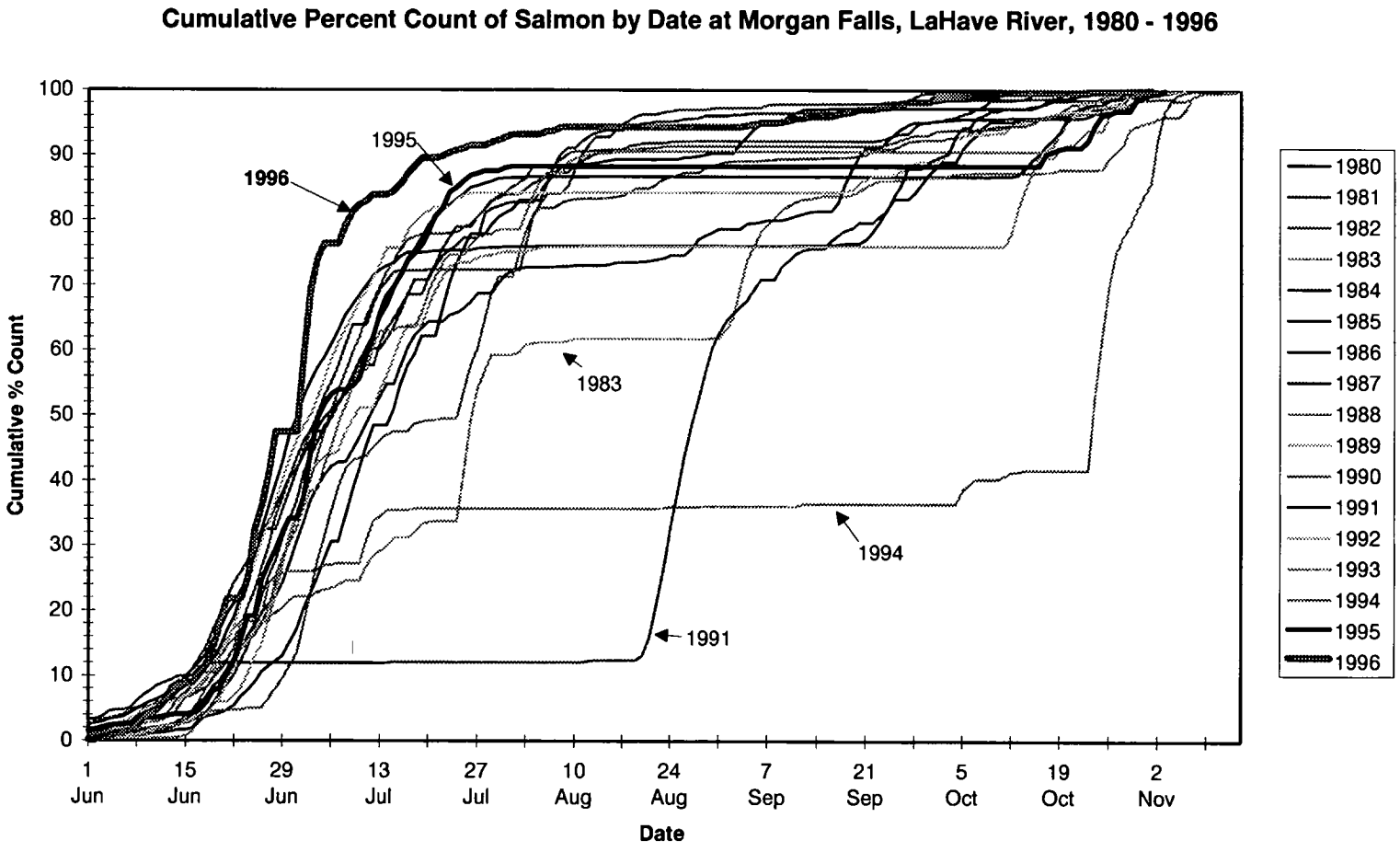

Figure 7. Cumulative percent count of Atlantic salmon by date at Morgan Falls fishway on the LaHave River, 1980 to 1996.

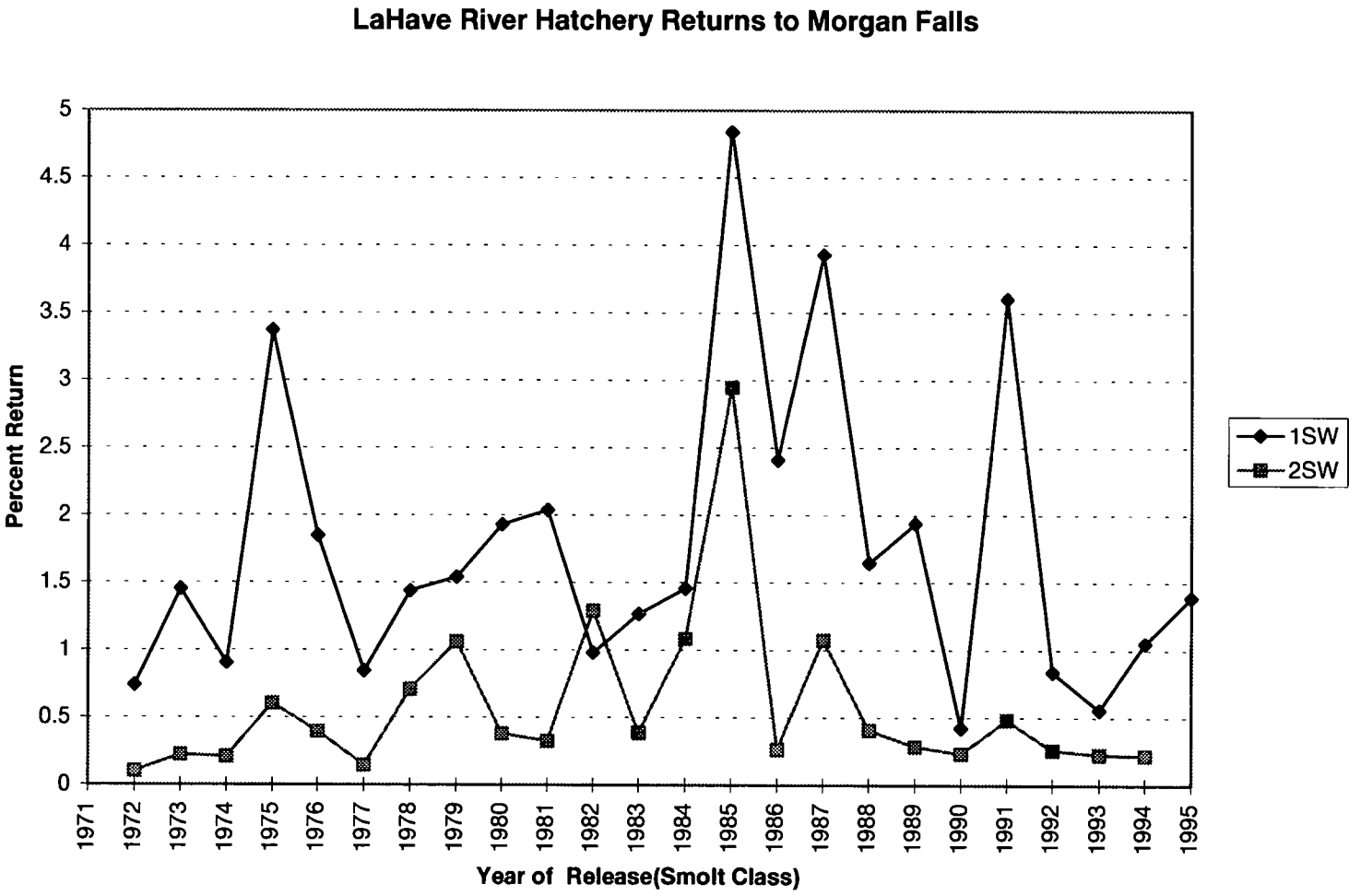

Figure 8. Atlantic salmon smolt-to-adult returns to Morgan Falls by sea-age at first return for marked smolts and parr stocked above Morgan Falls for smolt years 1972 to 1994.

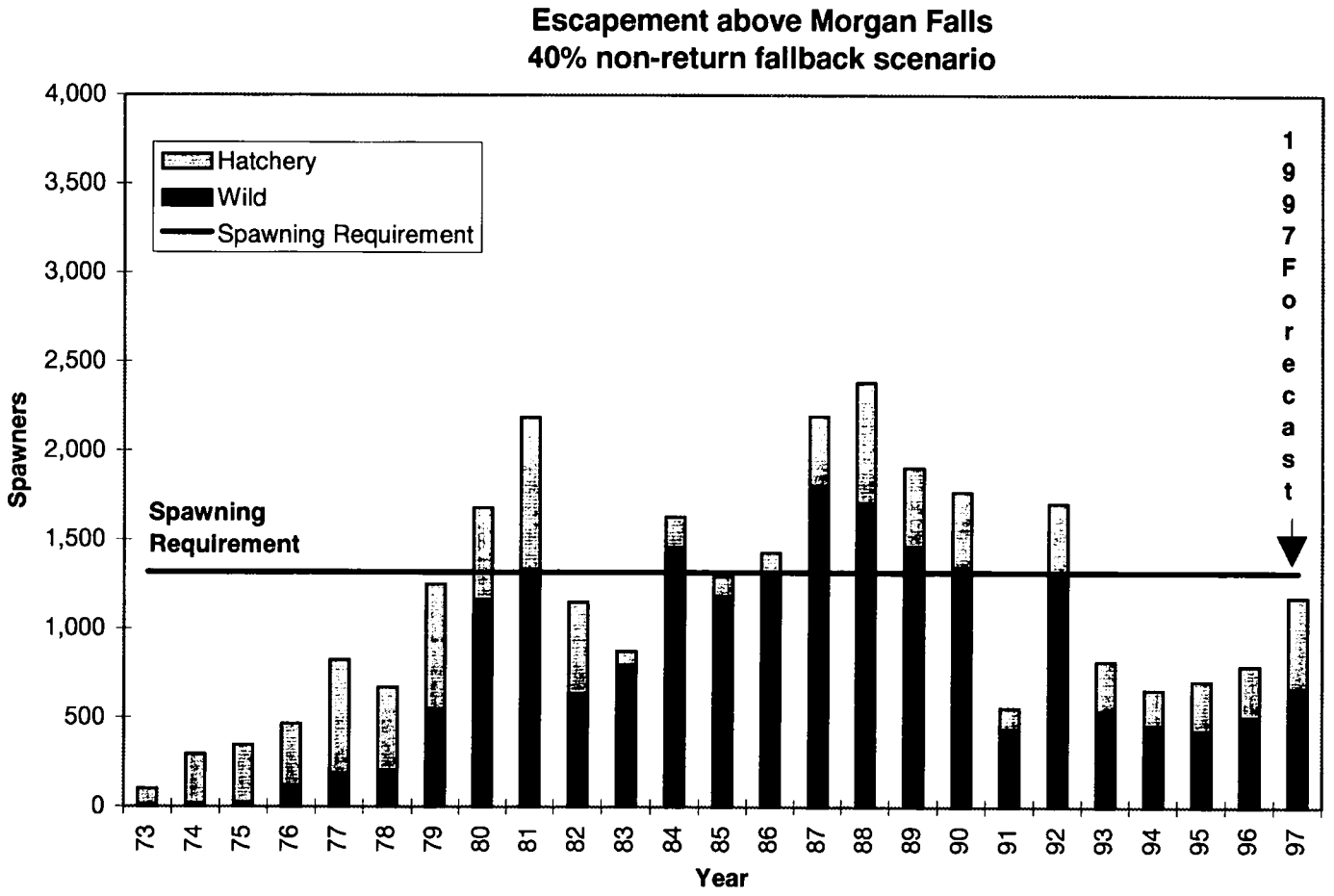

Figure 9 Escapement, numbers of wild and hatchery Atlantic salmon above Morgan Falls on the LaHave River 1973-1996, and forecast for 1997, using a 40% non-returning annual fallback suggested by distribution of angled fish and radio tagging.

Appendix I

Counts at Morgan Falls are dependent on the number of fish entering the LaHave River and the exploitation (removal) of fish below the falls and the proportion of fish destined to Morgan Falls. Essentially, within a year, if exploitation goes down counts go up.

River returns may be estimated from counts at Morgan Falls adjusted to a total river post-fishery estimate plus removals below Morgan Falls. The distribution of possible post-fishery populations was estimated from a mark-and-recapture experiment in 1983. This estimate indicated that the count at Morgan Falls was 0.486 of the modal post-fishery population estimate.

River returns are therefore:

(1) River Returns = MF Count/0.486 + Removals

Removals is a function of River Returns and Exploitation rate:

(2) Removals = River returns * Exploitation Rate

Combining these functions one gets:

(3) River Returns = MF Count/(0.486*(1-Expl. Rate))

Counts to MF are forecast separately for wild salmon, hatchery salmon, wild grilse and hatchery grilse. Cumulative probabilities for each of these forecasts are derived through Bayesien techniques (see Forecast of Counts to Morgan Falls for 1997). Therefore the probability of obtaining at least some suggested value can be estimated for all four classes of salmon. The combination of each of these estimates at a fixed cumulative probability, say 0.25, is the probability of not attaining this count. The forecasts, as conducted thus far to 1996, assume an average exploitation rate across all years; i.e., a portion of the variation in counts to MF is resultant of variable exploitation rate. An exploitation rate for the LaHave was estimated at about 30% (Cutting et al. MS 1987) and 30.5% in 1997 (see Forecast of Counts to Morgan Falls for 1997). If the exploitation rate changes in 1997 then the actual count will be different than forecast without the River Return changing.

Exploitation has been affected by changes in the fishing regulations. Hook-and-release has been both regulated and voluntary. Catch Rate (the number of fish reported retained plus the number reported released) will always be greater than the Exploitation Rate. Hook-and-release also has a mortality factor associated with capture and release. This hook-and-release mortality is also part of the exploitation rate.

Regulations designed to attain conservation objectives while maintaining economic benefits make use of the difference between Catch Rate and Exploitation Rate by restricting the Retention Season within the Open Season for Angling. An ideal management scenario would be to adjust the Exploitation Rate to attain the conservation escapement while meeting committments to aboriginal fishers and maximizing economic benefits. Management strategies that announce the harvest plan well in advance of the season provide further benefits and are a present request of management. Over-riding this ideal plan is the primary obligation of government for conservation of the resource. Forecasts, then, provide a mechanism for management to assess the risks to conservation before setting the harvest regulations. Setting these regulations requires an acceptance of risk because there are possible counts (River Returns) that are less than the requirement in the range of the forecasts. The level of acceptance of risk can be a community-wide decision.

To assist the community and management in deriving a 1997 harvest plan, particularly in light of the non-return fall back at MF, we develop exploitation scenarios for the angling fishery and assess risk to conservation (not achieving the conservation count at MF) based on the forecast counts for 1997. Exploitation rates associated with risk levels of 10, 25, 40, 50, 60, 75 and 90% of not achieving the conservation count are developed for both the 1,320 fish and 2,200 fish conservation requirements. The higher number represents a 40% fall back at MF.

Exploitation Rates that yield specified risk levels were obtained by iterating exploitations in a model of MF counts to achieve the desired conservation count. Estimating potential counts at MF for each trial exploitation rate, was done by estimating the River Return and extracting potential Removals using the trial Exploitation Rate and re-adjusting back to a MF count. Exploitation of salmon was assumed to be 3%, reflecting an assumed hook and release mortality.