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Status of Atlantic salmon in Salmon Fishing Area 21,

in 1997, 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 1997 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. A count-based estimate of the production of wild smolts above Morgan Falls in 1997 indicated about 16,520 or 0.66 smolts per 100 m^2. Return rate of hatchery smolts was the lowest in the twenty-four year record. Egg deposition above Morgan Falls in 1997 was 54% of the conservation objective of 1.96×10^6 eggs. The modal deposition for the entire LaHave River basin was 35% of the basin-wide required conservation escapement of fish and 53% of the basin-wide required deposition of 4.74×10^6 eggs. Increase in egg deposition relative to escapement was due to a decrease in male hatchery fish. The most probable pre-fishery abundance for eleven other rivers of SFA 21 was 3,117 salmon (1,829 - 5,289; 5^{th} and 95^{th} percentiles) and the most probable spawning escapement for these rivers was 2,221 fish, a 58% decrease from 1996. Status of stocks for SFA 21 rivers is uncertain because of acidification resultant of acid precipitation and the undetermined effectiveness of standard conservation requirements. The 1997 LaHave River angling catch rate was 34.7% and exploitation was 29%. Forecasts to Morgan Falls for 1998 indicate a deficit above Morgan Falls assuming a hook-and-release fishery for salmon (≥63 cm) and retention of grilse (≤63 cm) below Morgan Falls. No harvest (exploitation) is available for 1998 for a risk neutral (50^{th} percentile) chance of achieving conservation escapement. Short-term prognosis for the LaHave River relative to the interim conservation requirement was not favorable. The long-term prognosis was not expectant of increased returns.

Résumé

L'état des échappées de géniteurs de saumon de l'Atlantique de 1997 de la rivière LaHave, en amont de Morgan Falls, est présenté en fonction des besoins de conservation. L'état des autres stocks de la ZPS 21 est déduit à partir des captures de la pêche récréative et d'une distribution des taux d'exploitation probables estimés des pêcheurs à la ligne de la rivière LaHave. Une estimation, basée sur les dénombrements, de la production de saumoneaux sauvages en amont de Morgan Falls en 1997 indique une abondance de 16 520 saumoneaux ou 0,66 saumoneau par 100 m^2. Le taux de remontée des saumoneaux de pisciculture était le plus faible des 24 années pour lesquelles nous disposons de données. La ponte en amont de Morgan Falls en 1997 correspondait à 54% de l'objectif de conservation de $1,96 \times 10^6$ oeufs. La ponte modale dans l'ensemble du bassin de la rivière LaHave correspondait à 35% de l'échappée de conservation et à 53% de la ponte nécessaire, de $4,74 \times 10^6$. L'augmentation de la ponte par rapport à l'échappée s'expliquait par une baisse du nombre de poissons mâles produits par pisciculture. L'abondance d'avant la pêche la plus probable pour les 11 autres rivières de la ZPS 21 s'élevait à 3 117 saumons (1 829-5 289, 5^e et 95^e percentiles) et l'échappée de géniteurs la plus probable de ces rivières s'élevait à 2 221 poissons, soit une augmentation de 58% par rapport à 1996. L'état des stocks de la ZPS 21 demeure incertain à cause de l'acidification des eaux causée par des précipitations acides et l'efficacité inconnue des exigences de conservation standard. Le taux de capture des pêcheurs à la ligne dans la rivière LaHave en 1997 s'élevait à 34,7% et le taux d'exploitation à 29%. Les prévisions pour Morgan Falls en 1998 font état d'un déficit en amont si l'on suppose une pêche par capture et remise à l'eau (≥63 cm) et la conservation des madeleineaux (≤63 cm) en aval de Morgan Falls. Il n'y a aucune récolte (exploitation) en 1998 qui correspond à un risque neutre (50^e percentile) d'atteindre l'échappée nécessaire à la conservation. Le pronostic à court terme pour la rivière LaHave, fondé sur les besoins de conservation provisoires, n'est pas favorable. Le pronostic à long terme ne fait pas état d'une augmentation des remontées.

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 and 1997.

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 counted in 1997.

The SFA 21 management advisory committee met April 17, 1997. The committee reviewed the 1996 fishery, the biological advice for 1997 and heard recommendations from stakeholders concerning the 1997 salmon angling season. Based on the low numbers of fish forecast to return in 1997 and the low returns from 1993 to 1995, biological advice to the committee was to proceed cautiously with harvests in 1997. Expectations for 1997 were for returns similar to 1996. Forecasts showed that most returns in excess of requirements were hatchery grilse, the majority of which are males. An in-season assessment and management review was conducted July 4, 1997. The assessment was conducted two days earlier than usual because July 6, 1997, was a Sunday and the fishway was closed. 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 1997, 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 1997 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) and smolts are stocked to provide harvest fisheries.

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 applied to estimates of angling catches in other rivers of SFA 21 as indicators of possible returns and escapements to those rivers in 1997; 4) a further 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 1998; and 6) risks of not 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 298,091 hatchery smolts and 175,724 fall fingerlings were stocked in rivers of SFA 21 in 1996 which contributed to one-sea-winter (grilse) returns in 1997 (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 1997, and to provide advice to managers and stakeholders on July 4 and 15, 1997.

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 eggs m^{-2} * 100, stock characteristics as in the LaHave River and assuming non-acid impacts can provide 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 1997 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 53 male hatchery grilse was removed for First Nations use before the river was closed to all harvests on July 11, 1997, because of low returns.

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 in 1997, were, 7 grilse from the Gold River, 5 grilse from the Medway River, and 5 grilse from the LaHave River.

Angling fishery

Eight tags for salmon <63.0 cm were issued with the purchase of each 1997 Nova Scotia salmon angling licence. Salmon angling regulations were modified throughout SFA 21 in 1997 in order to decrease exploitation. Three measures were: 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 July 4, 1997, using the Morgan Falls count. As a result of the in-season assessment and a special meeting of the Zone Management Committee for SFA 21 on July 8, 1997, a variation order closing the angling season in SFA 21 rivers sustaining wild stocks was issued for July 10, 1997. Angling in rivers containing only stocked hatchery salmon closed as usual on September 30, 1997 (Table 3).

A total of 6,518 rod days of effort was expended on 14 rivers of SFA 21 in 1997 (Table 1). Effort was down 65% from 1996. A total of 690 grilse was reported retained and 87 released, which was a 72% decline from 1996. The 87 salmon reported released was a 87% decrease from 1996. Catch rod^{-1}day^{-1} decreased to 0.166 in 1997 from 0.1862 in 1996. Effort, number of grilse retained and numbers of grilse and salmon released in 1997 were all less than the 1992-to-1996 means.

Water levels for fish migration and for angling experienced in 1997 were only adequate early in the season (Figure 4). Daily river discharge in June, measured at West Northfield on the upper LaHave River, was lower than 1996 and about equal to the 1980-to-1996 average discharges. July discharge was below normal. Water levels were low throughout July and into November.

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 1997.

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[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

The moratorium in the Newfoundland commercial salmon fishery, which began in 1992, remained in effect in 1997. The Labrador commercial fishery harvested 15,116 salmon in 1996. The majority (52%) were non-maturing 1SW salmon. According to previous tag recapture data from the LaHave and Medway rivers (Ritter 1989), few if any of these salmon are southern Nova Scotia origin. The Greenland offshore commercial fishery took 12,350 non-maturing North American origin 1SW salmon in 1996 (potentially affecting the 1997 two-sea-winter return). Twenty-five percent of all marine recaptures of LaHave River and Medway River tagged smolts were derived from the Greenland fishery. The 1996 Greenland fishery was, however, less than 10% of peak historic catches of North American salmon harvested in Greenland.

Research data

This assessment utilises counts at Morgan Falls in 1997 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 1997. 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 1997. Minimum catch rates applied to 1997 catches were used to estimate maximum (95^{th} percentile) pre-fishery population estimates.

Morgan Falls fishway operated April 28 to August 1, and September 19 to November 11, 1997. 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 and 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 1996. In some years of higher summer flows and populations, the fishway remained open for more of the summer period.

Cumulative counts of wild and hatchery grilse and salmon were reported every two weeks to stakeholders in 1997 (Table 4). These counts continue the 27-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 broodstock (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 1997 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, 1997. These data provided the opportunity to estimate the wild smolt production above Morgan Falls in 1997. 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 1997 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 1997 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 1996. 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 4, 1997, the earliest date at which the width of the 90% confidence interval around the average (1980-1996) cumulative count can approximate the average (a coefficient of variation of approximately 25%). Historically (1970 to 1996), 45% of the return to Morgan Falls passed before July 6.

The regression equation ($p<0.001$; $R^2_{adj}=0.774$; $n=17$) for forecasting on July 6 the 1997 end-of-season count of total returns has a standard error of the estimate of 472 fish and is of the form:

$$\text{Total returns} = 714.9 + 1.479 * \text{Count to July 6}$$

where new values of the constant (714.9) and proportion of the count (1.479) were determined for each two-week period for the years 1980 to 1996.

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 out 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 (1997 in this case) posterior distribution of the probabilities of basin-wide population estimates.

Catch Rates

Assuming that estimates of angling catches and releases are measured without bias, then annual (1997 in this case) estimates of a range of possible catch and exploitation rates may be derived from the posterior estimates of population probabilities. Assuming that the annual catch rate for LaHave River is similar to other rivers in SFA 21, then posteriors of possible pre-fishery population estimates for rivers with reported angling catches may be constructed. Counts at Morgan Falls have been correlated with catches as far away as the St. Mary's River in SFA 20 on the eastern shore of Nova Scotia (O'Neil et al. 1997).

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 fecundity of females by origin and sea-age at maturity, where fecundity was 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 1997

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 1997 was estimated using the count at Morgan Falls minus 10% of the total river angling catch.

Wilkie et al. (1996) 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. Nonetheless, while much of the angling fishery takes place before temperatures reach this level, 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 and returning to Morgan Falls, are available for each year since 1971. These survival estimates are based on numbers of smolts adjusted for the proportion "good quality" as

determined by the annual smolt evaluation assessment (Frantsi et al. MS1972). 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 estimated to Morgan Falls and for the first time estimates of return rates to the river are derived, ie. adjusted for removals by the angling fishery below Morgan Falls.

Annual estimates of the return to the LaHave River of hatchery-stocked smolts may be obtained by adding the catch of hatchery grilse or salmon to the count at Morgan Falls. This is complicated by the return and angling of hatchery fish stocked below Morgan Falls. The number of hatchery fish stocked above and below Morgan Falls is known and therefore can be accounted in the potential returns to Morgan Falls.

In order to estimate river return rates an estimate of hatchery fish destined to above Morgan Falls but angled below is required. Tagged hatchery smolts stocked above Morgan Falls 1977 to 1986 provide a relationship between the proportion of hatchery grilse or salmon originating from above and angled below in the total catch of grilse or salmon and the proportion of hatchery grilse or salmon in count at Morgan Falls. This relationship and the proportion of the hatchery smolts originating from above Morgan Falls can be used to derive the number of hatchery grilse or salmon angled below, but destined to above Morgan Falls. These estimates can then be used to derive a river return rate for hatchery stocked smolts.

Forecasts of counts to Morgan Falls and returns to LaHave River in 1998

As in 1997; regression of counts of wild two-sea-winter salmon (1975-1997) on wild one-sea-winter salmon (1974-1996) and the count of wild one-sea-winter salmon in 1997 were used to forecast the count of wild two-sea-winter salmon in 1998. A similar procedure for hatchery two-sea-winter count is based on the counts of hatchery one-sea-winter grilse. Multi-sea-winter forecasts were estimated from Bayes posterior probability distributions of estimates assuming normal distribution of residuals and no prior weighting.

Two methods were used to forecast the count of wild 1SW fish to Morgan Falls in 1998:

1. The mean and standard deviation of the mean counts from 1993 to 1997.
2. The distribution of possible wild smolt populations above Morgan Falls in 1997 and the modal return rate of 1996 wild smolts.

Three methods were used to estimate the 1998 1SW hatchery return to Morgan Falls:

1. Regression of counts at Morgan Falls with numbers of hatchery smolts stocked in the previous year.
2. The return rate of hatchery smolts for the previous five years (1993 - 1997) was used to forecast the 1998 return of hatchery grilse. Confidence limits for this forecast were obtained from the mean and $\pm t_{.05,df=4}$ *standard deviation of the mean. All other forecasts were as above.
3. The count of wild and hatchery smolts above Morgan Falls and the 1997 return rates of wild and hatchery smolts to 1SW returns.

The posteriors of these estimates were used to estimate probabilities associated with various fisheries management goals, i.e., catches, counts and escapements.

Assessment results

Smolt production above Morgan Falls 1997

A total of 26,442 hatchery-produced one year old smolts of LaHave River origin was released above Morgan Falls on eight dates in May 1997 (Table 9). Most of these smolts were released on May 8, 20 and 28, 1997. Some smolts were expected from age-0+ parr released in 1995 (Table 10). The total estimated hatchery-origin smolt output above Morgan Falls in 1997 was 23,968.

A total count of fish passing through the assessment facility at Morgan Falls Power was kept in 1997. Counts were conducted daily from May 6 to May 30, 1997 (Table 11). Totals of 11,000 hatchery smolts, including 2,085 tagged hatchery smolts, and 8,616 wild smolts were counted through the facility in 1997.

The recovery of 2,085 tagged hatchery smolts from the 4,000 tagged smolts released in 1997 and the 8,616 wild smolts captured provided a modal estimate of 20,526 (19,880, 21,200; 5^{th} and 95^{th} percentiles) smolts above Morgan Falls of which 4,000 were tagged hatchery smolts. The most probable wild smolt migration in 1997 was 16,520. 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 0.63 smolts per 100 m^2 which is a 20% decline from 1996. This smolt production rate is 24% 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, 1997

The total cumulative count to July 4, 1997, was 355 fish. This count indicated an end-of-season count of 1,254 fish (500 - 1,990, 5^{th} and 95^{th} percentiles), which over-estimated the actual end of season total count (581 fish) by 54% (Table 4 and Figure 6). As of July 4, 1997, the probability of passing 1,320 fish above Morgan Falls by the end of the season was 43.3% and the angling fishery and First Nations harvest at the fishway was discontinued midnight, July 10, 1997. The subsequent July 15 assessment declined to 1,065 fish (415 - 1,720, 5^{th} and 95^{th} percentiles). No changes were made to the variation order closing all harvests and no further in-season assessments were conducted. Over-estimates were the result of the early run timing observed in 1997 (Figure 7).

Estimates of the 1997 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 1997 Morgan Falls count of 581 fish, applied to the 1983 posterior probability distribution, indicated a modal value of 1,200 fish in the post-fishery total river population estimate (500 - 2,380 fish, 5^{th} and 95^{th} percentiles) in 1997. The 1997 pre-fishery population estimate was 1,694 fish (994 - 2,875 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 1997 basin-wide escapement of salmon was 1,147 (1,200-53; harvest at fishway) (447 - 2,327 fish, 5^{th} and 95^{th} percentiles). At this escapement level, 35% of the 3,312 conservation requirement escaped to spawn in 1997. 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 0.4%, derived for the value 3,365 fish (3,312 + 53; because a harvest at fishway was not conducted at the time of the 1983 estimate).

Estimates of catch and exploitation rates for LaHave River, 1997

The 1997 LaHave River total angling catch of 587 fish (Table 1) and the Bayes posterior of possible populations for 1997 indicate a modal angling catch rate of 0.3465 (0.5905 - 0.2042, 5th and 95th percentiles) (Table 12, A). By a similar method and using only the retained grilse and a 10% hook-and-release mortality on released salmon and grilse (Table 1) the exploitation rate was 0.2916 (0.1719 - 0.4970, 5th and 95th percentiles) in 1997.

Estimates of returns and spawners to eleven other rivers in SFA 21, 1997

Populations for eleven other rivers of SFA 21 were derived using this distribution and the 1997 angling catches (Table 12, B).

The most probable pre-fishery total population of Atlantic salmon for SFA 21 for 1997, estimated from the total angling catches and the 1997 Bayes posterior of probable exploitation rates for the LaHave River, was 3,117 (1,829 - 5,289; 5th and 95th percentiles) (Table 12, B). This is a 58% decrease from the 1996 estimate of 7,368 Atlantic 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 2,221 fish = 3,117 - (780 (retained angled fish) + 53 (Native harvest LaHave) + 19 (Aboriginal Peoples' harvest) + 44 (angling hook-and-release mortality of 10%)). This total is a 54% decrease from the 1996 estimated spawning escapement of 4,841 salmon in SFA 21.

Estimated escapement and egg deposition above Morgan Falls in 1997

Native fishery harvests totalled 53 male hatchery grilse at the fishway. A total of 104 broodstock (Table 8) was removed at Morgan Falls in 1997. Estimated removals by angling above Morgan Falls, including 10% for hook-and-release mortality, was 36 fish. Total spawning escapement above Morgan Falls was 389 fish. Egg deposition was 1,049,793 eggs or 54% 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 1997 run indicated an average eggs*fish^{-1} of 2,196 or 33% greater than the average eggs*fish^{-1} estimated by Cutting and Gray (MS 1984). The estimated egg deposition above Morgan Falls in 1997 was a 43% decrease from the 1996 estimated deposition of 1,845,466 eggs (Table 14).

There were 2.79 male hatchery grilse for every female hatchery grilse counted at the fishway in 1997 (Table 13). There were 335 male and 247 female wild and hatchery fish counted at the fishway in 1997. After the removal of 53 hatchery male grilse there were 1.14 male fish for every female fish. At a required 1:1 ratio of males to females, 35 male grilse were surplus above the fishway in 1997. Assuming spawning proportions as observed in the counts, 6 male hatchery grilse were surplus to the interim conservation requirement above the fishway in 1997.

Estimated egg deposition in the LaHave River, 1997

The modal post-angling fishery population estimate (1,147) and the 5th and 95th percentiles, together with the 1997 egg deposition*fish^{-1} of 2,196 eggs, indicate a modal deposition of 2.51 $\times 10^6$ eggs (0.98×10^6 - 5.11×10^6, 5th and 95th percentiles). The modal deposition is 53% 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

Counts of smolts at Morgan Falls Power in 1997 indicated that 9 hatchery smolts migrated before any smolts were stocked in 1997 (Table 11). These smolts were the residual population from the 1996 smolt stocking. A total of 131 wild smolts was counted before May 12, 1997, when the hatchery smolts were stocked. These 131 wild smolts represent 0.0152 of the 1997 wild smolt run. Using this proportion then, the 9 hatchery smolts represent a 0.0152 portion of 591, residual

population of 1996 hatchery smolts. A total of 49,526 hatchery smolts were stocked in 1996. The proportion good quality was 0.78. If 1.0-0.78=0.22 remained in the river for the year (an assumption used in estimating the annual hatchery smolt migration) then 591 of 10,895 smolts stocked in 1996, or 0.0542 of the residual population, migrated in 1997. This value (0.0542) was used to estimate the portion of the residual population migrating in Year i+1 of stocking for the years 1970 to 1997 (Table 10).

One-sea-winter hatchery return to Morgan Falls, 1997

The estimated hatchery-origin smolt output above Morgan Falls in 1997 was 23,968 smolts comprised of 88% of the 26,442 age-1 smolts stocked in 1997 and 1.2% of the 49,526 age-1+ smolts stocked in 1996 (Table 10). The return of 144 one-sea-winter fish of hatchery origin to Morgan Falls in 1997 and the estimated hatchery-origin smolt output in 1996 indicate a return rate of 0.306% to Morgan Falls. This is the lowest in the 25-year record.

One-sea-winter hatchery return to LaHave River, 1997

The relationship between proportion of tagged hatchery grilse in the total catch and the proportion of hatchery grilse and the count at Morgan Falls was:

Proportion Hb = 0.6497*Proportion of hatchery at fishway + 0.0052 (N=9; p. of null<0.05; R^2=0.6638)

This relationship and the proportion of smolts stocked above Morgan Falls (Table 15) were used to estimate the numbers of hatchery fish angled below Morgan Falls but destined to above Morgan Falls for the years prior to and after the tagging experiment (Table 16). Return rate to LaHave River of 1SW salmon stocked as smolts in 1996 was 0.469%, the lowest in the 25-year record (Figure 8).

Two-sea-winter hatchery origin smolt return rate to Morgan Falls

The return of 67 two-sea-winter hatchery salmon in 1997 yields a return rate of 0.20%. The total return for the 1995 smolt class was 1.59%, a 26% increase from the 1994 year class (Table 10).

Two-sea-winter hatchery origin smolt return rate to LaHave River

The relationship between the proportion of hatchery salmon in the count at Morgan Falls and the portion of hatchery salmon originating from above and angled below in the tagging data of 1977 to 1986 was not statistically significant. Estimates of the number of hatchery salmon destined to above Morgan Falls but angled below were derived from the estimate of salmon mortalities (assumed 0.10 proportion hook-and-release mortality) and the average portion of hatchery salmon angled below of the total hatchery and wild salmon angled below (Table 10). Return rate to LaHave River of 2SW salmon stocked as smolts in 1995 was 0.22%, among lower values observed in the 24-year record (Table 10; Figure 8).

Forecast counts at Morgan Falls for 1998

All forecast methods assume average (0.29) exploitation rate below the fishway.

Multi-sea-winter forecasts - wild

The forecast count of wild multi-sea-winter returns to Morgan Falls in 1998 was estimated from the wild one-sea-winter returns to Morgan Falls (Table 5) by the regression:

$WMSW_{(1974\text{-}1997)} = 49.602 + 0.169 * W1SW_{(1973\text{-}1996)}$ (p=0.00005, Adj R^2 = 0.51, SE = 131.03;N=24)

and the 303 wild one-sea-winter returns counted in 1997. These parameters were used to construct a Bayesian posterior distribution of possible returns which indicated a most probable count of 100 (15 - 325, 5th and 95th percentiles) wild multi-sea-winter fish in 1998. The probability of counting at least 106 MSW fish in 1998 (the number required in 1997 to meet the egg deposition target of 1.96×10^6 eggs) was 38%.

Multi-sea-winter forecasts - hatchery

The forecast count of hatchery multi-sea-winter salmon to Morgan Falls in 1998 was estimated from the count of hatchery one-sea-winter fish at Morgan Falls by the regression:

$HMSW_{(1974\text{-}1997)} = 7.668 + 0.2434 * H1SW_{(1973\text{-}1996)}$ (p=0.00005, Adj $R^2 = 0.5062$, SE = 75.87; N=24)

and the 144 hatchery one-sea-winter returns counted in 1997. These parameters were used to construct a Bayesian posterior distribution of possible returns which indicated a most probable count of 43 (6 - 175, 5th and 95th percentiles) hatchery multi-sea-winter fish in 1998. The probability of counting at least 115 HMSW fish in 1998 (the number required in 1997 to meet the egg deposition target of 1.96×10^6 eggs) was 23%.

One-sea-winter forecasts - hatchery

1. The count of hatchery one-sea-winter fish to Morgan Falls in 1998 was forecast 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:

$H1SW_{(1973\text{-}1997)} = 0.013443 * Smolts_{(1972\text{-}1996)}$ (p=0.002451, SE = 264.9088)

and the 23,968 smolts estimated output from above Morgan Falls in 1997. These parameters were used to construct a Bayesian posterior distribution of possible returns and indicated a most probable count of 326 (55 - 753, 5th and 95th percentiles) hatchery one-sea-winter fish in 1998. The probability of achieving 190 hatchery grilse (the requirement at 1997 biological characteristics) in the 1998 count at Morgan Falls was 78%.

2. The mean five-year return rate of hatchery smolts to Morgan Falls as 1SW fish was 1.21% ± 0.7182 SD. This return rate and the 23,968 hatchery smolts migrating in 1997 forecast 290 (188 - 768; 95%CL) hatchery grilse to return in1998.

3. The 1977 return rate of 1SW hatchery fish to Morgan Falls was 0.3057%. The 1996 smolt class return rate and the 23,968 smolts migrating in 1997 forecast a count of 73 hatchery-origin 1SW fish to Morgan Falls in 1998.

One-sea-winter forecasts - wild

1. The count of wild one-sea-winter salmon to Morgan Falls in 1998 was forecast as the mean number of wild one-sea-winter fish counted at Morgan Falls from 1993 to 1997(Table 5). A total count of 617 wild grilse (304 - 895, 5th and 95th percentiles) was forecast for 1998. The probability of achieving 310 wild grilse in the count at Morgan Falls (the requirement at 1997 biological characteristics) was 94.7%.

2. The modal estimate of wild smolts migrating from above Morgan Falls in 1997 was 16,520. The modal estimate of the return rate from the 1996 wild smolt migration was 0.0218 (0.0225 - 0.02125; 5th and 95th percentiles) (Amiro MS1998). These return rates forecast 361 (351- 372; 5th and 95th percentiles) wild 1SW fish to Morgan Falls in 1998.

Total forecast count at Morgan Falls for 1998

Using the same method as for 1997 (all method 1 forecasts for 1SW) a forecast count of 1,086 total fish at Morgan Falls in 1998 can be derived from the sum of the most probable forecasts and the five-year mean one-sea-winter wild grilse count assuming a retention fishery below the falls as included in the data used to forecast the count. This count would not allow a harvest above Morgan Falls in 1998. In fact, at the long-term average exploitation rate of 0.29 for fish <63.0 cm the probability of obtaining at least 1,320 fish in the count at Morgan Falls in 1998 is approximately 40%. The angling exploitation rate (retained fish only) in 1997 was 0.348 for hatchery grilse (Table 16) or 0.2916 for all fish (see Estimates of catches and exploitation rates). Native Peoples' harvest was 53 male hatchery grilse or 3.1% (53/1,694).

The basin-wide forecast using the 1983 Morgan Falls calibration and the 1998 forecast count of 1,086 fish indicates a post-angling stock of 2,163 fish to the entire river. If a 1998 angling exploitation rate were similar to that of 1997 (0.2916), then total returns to the river could be 3,053 fish in 1998. Using the modal estimate of 3,053 fish and the 3,312 fish conservation requirement for the entire LaHave River, no fish would be surplus to requirements in the entire basin in 1998.

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. Estimates of the number of fish re-cycling through the fishway cannot estimate non-return fallback numbers. Anecdotal information from anglers has suggested that fish tail-punched at the fishway were angled substantial distances below Morgan Falls and in other branches of the river below Morgan Falls. Radio tagging information gathered in 1996 corroborated information derived from experimental recycling (downstream trucking) of fish 1987 to 1989. These data suggest that about 40% of the fish counted at Morgan Falls fall back and do not contribute to the egg deposition above Morgan Falls (Amiro and Jefferson MS 1997).

A radio tracking experiment using esophageal-implanted long-duration (four to six month) radio tags to examine non-return fallback was repeated in 1997(Table 17). A total of 13 fish was implanted with radio tags, 16 with similar size and weight dummy tags complete with attached antenna and 16 fish were Carlin-tagged only and released downstream of the fishway. All fish were Carlin-tagged and caudal-punched (as are all fish that utilize the facility). Tags were applied in proportion to the composition at the fishway. The experiment intended to apply 23 radio tags and twice as many Carlin and dummy tags. The paucity of fish in 1997 did not allow the complete application of the tags available. Radio-tagged 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. All but one radio-tagged fish was released above the fishway. Fish released on June 23, 1997, were trucked 1 km below the fishway and released. All subsequent downstream releases were at the bottom of the fishway.

Continuous monitoring is maintained at Morgan Falls for tag presence. Mobile (foot, vehicle and boat) searches for tags located all but two tags released upstream. These two tags were not observed passing downstream of Morgan Falls. All but two (15.4%) radio-tagged fish eventually passed upstream. Only four dummy-tagged fish of 16 returned to the fishway. Non-return fallback for dummy-tagged fish was 75%. Seven of the 16 (44%) Carlin-tagged fish did not return to the fishway. Overall 42% of the tagged fish were not above Morgan Falls by November 15, 1997, when spawning was taking place throughout the river system.

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 7 of 14 years (Figure 9). Six of the seven years have occurred since 1991, a period when marine survival has been low. Without accounting for non-return fallback, only four years of escapements less than conservation were noted (Figure 5).

If non-return fallback were 40% in 1997, then escapement above Morgan Falls was 27% of the required escapement in fish and 28% in egg deposition.

A 40% non-return fallback at Morgan Falls applied to the 1998 forecast return of 1,062 fish would contribute about 48% of the required spawning escapement above Morgan Falls after average exploitation in the angling fishery below the falls. Non-return fallback at Morgan Falls would not affect estimates of escapements to the entire LaHave River as long as non-return fallback was the same in 1983, when the Morgan Falls calibration was conducted.

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 remains 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 0.63 per 100 m^2 in 1997, suggests that colonisation 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. The relative contribution of habitat types to production needs to be assessed and incorporated into the production estimates and requirements for egg deposition.

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 second attempt to adjust Morgan Falls counts. The 40% scenario posed here approximates the average of five estimates, all of which may be biased by the experimental effect of tagging. The experiment conducted in 1997 further demonstrates that non-return fallback of salmon is a significant factor in assessing escapements above Morgan Falls.

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. 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 1997 basin-wide populations is an unbiased 1983 estimate. If the 1983 estimate were biased, then the 1997 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 significant 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 return of 1SW hatchery fish to Morgan Falls in 1998 may be influenced by the 20,524 age-1^{+} smolt stocked below Morgan Falls and above Wentzel's Lake (Appendix I). Some of these fish may ascend to the fishway in 1998. These fish may influence the return rate estimated in 1998.

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). Improvement in conditions in the North Atlantic in 1996, potentially affecting returns of 2SW salmon in 1997, was observed (Anon. MS 1996); however, returns declined.

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 92t of which 37.5t were of North American origin.

Returns to most rivers in North America were much below expectations in 1997. Coherence among Atlantic salmon stocks of North America has been previously noted. Until the variation in recruitment to North American stocks of Atlantic salmon is better accounted, forecasts to individual river stocks are unlikely to be acceptably accurate. In the meantime, if achieving conservation escapements to individual rivers is the goal of Atlantic salmon management then accurate in-season assessments are necessary. In-season assessments not only must be accurate but also timely in order to attain harvest goals within the conservation constraint. Improvements to in-season assessment tools is therefore a priority for management of Atlantic salmon in LaHave River, the major assessment site for the Atlantic coast of Nova Scotia.

The earlier run timing observed at Morgan Falls in 1996 and 1997 was not forecast and has yet to be accurately modeled. Modeling run timing would be beneficial and contribute to more accurate in-season management advice. Variance from the mean run time was not correlated with river discharge or cumulative discharge (Amiro et al. MS 1996). A examination of

the timing of the retreat of the ice cover on the Newfoundland shelf of the North Atlantic suggests more accurate in-season forecasts may be derived using these data (Harvie and Amiro, 1998).

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 1998 looks poor compared to the previous four years. Returns are not expected to be much different than in 1997. Alternate analysis using the estimates of wild smolts and recent return rates suggest even lower returns in 1998 (Table 5) to a low count of 514 total fish. Despite the increased winter habitat area of the North Atlantic, returns of Atlantic salmon continue to decrease. Escapements, production and hatchery output has increased yet returns are lower. This observation suggests that until the mechanisms controlling marine survival are better understood or incorporated in forecasting methodologies, only a consistent pattern of improved marine survival will lead to a more positive short-term prognosis.

Even without the implications of 40% non-return fallback at Morgan Falls, the usual 30% exploitation rate would over-harvest relative to the conservation requirement. The management actions in place in 1997, i.e., one fish per day and no retention until June 1, would not likely be sufficient in 1998 even with an in-season assessment on July 6, 1998. Further reduction in exploitation rate is necessary if a lower risk of not attaining the conservation requirement is desired.

Using forecasts from methods 1, the range of exploitation rates of grilse (<63.0 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 were estimated (see Amiro and Jefferson MS 1997 for method): (Note, NP= Not Possible)

Conservation requirement	Risk levels						
	.10	.25	.40	.50	.60	.75	.90
1,320	NP	NP	NP	0.15	0.29		
2,200	NP	NP	NP	NP	NP	0.51	

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 26 to 62% of the conservation egg deposition requirement. Ignoring non-return fallback the egg depositions were 36 to 124% 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. 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 (Watt, 1997). This loss in addition to that of lower-than-average escapements in the past four years place these rivers in jeopardy of not achieving their conservation escapements, based on standard conservation requirement rates, i.e., 2.4 eggs$*m^{-2}$, without in-river exploitation.

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Table 1. Rearing areas of rivers on the south shore of Nova Scotia (Salmon Fishing area 21) grouped by pH impact category (Watt 1986) and Atlantic salmon sportcatch and effort for 1996 and 1997, contrasted with mean catches and effort 1992 - 1996.

	pH impact	Rearing	1997 Preliminary				1996				1992 - 1996 means							
	Category	area	Grilse		Salmon		Grilse		Salmon		Grilse				Salmon		Effort	
River	Watt (1986)	(100 sq. m)	retained	released	released	Effort	retained	released	released	Effort	retained	95% C.I.	released	95% C.I.	released	95% C.I.	roddays	95% C.I.
Broad	1										0	N/A	0	N/A	0	N/A	0	N/A
Clyde	1	24,256	20	0	3	238	37	9	14	749	49	47	7	7	10	5	657	105
Jordan	1	15,777	0	0	0	3	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	20	0	3	241	37	9	14	750	49	47	7	7	10	5	658	105
Percent of total		15	3	0	1	4	2	1	2	4	3	4	2	2	3	2	4	1
East: Lunen	2	3,969	0	0	1	4	0	1	2	45	0	0	0	1	0	1	13	22
Ingram	2	3,702	0	0	0	40	5	2	0	109	5	1	3	3	5	8	128	80
Mersey	2		1	0	1	62	5	0	0	440	14	22	1	2	2	3	991	675
Middle: Lun	2	9,270	1	0	0	12	11	2	0	43	4	6	3	2	0	1	22	24
Sackville	2	6,485	12	4	0	217	51	90	14	915	22	23	27	48	7	8	472	364
Tusket	2	65,764	23	4	22	342	104	29	55	972	69	56	14	14	31	20	1023	404
Sub-total		89,190	37	8	24	677	176	124	71	2524	114	108	48	70	45	41	2649	1569
Percent of total		31	5	9	8	10	8	18	11	14	8	10	17	21	11	18	15	21
Gold	3	17,741	111	20	27	565	168	20	71	1329	156	94	20	17	35	27	1737	857
LaHave	3	50,848	373	43	171	3187	1088	426	327	8751	744	493	166	197	221	97	7724	2898
Medway	3	67,653	93	12	56	1484	446	44	88	3574	265	233	25	22	55	27	3498	1369
Salmon: Dig	3	7,727	0	0	3	49	83	11	44	547	32	36	3	6	13	22	300	180
Sub-total		143,969	577	75	257	5285	1785	501	530	14201	1197	856	214	242	324	173	13259	5304
Percent of total		50	84	86	85	81	84	74	83	77	82	77	75	71	81	75	76	71
Martins	4	5,441								N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meteghan	4						2	10	5	102	1	1	5	6	3	3	45	59
Mushamush	4	2,303	2	0	0	22	17	2	2	190	12	9	2	2	2	3	103	80
Petite Rivier	4	6,444	54	4	20	293	98	27	16	632	80	85	11	13	14	5	805	398
Sub-total		14,188	56	4	20	315	117	39	23	924	93	95	18	21	19	11	953	537
Percent of total		5	8	5	7	5	6	6	4	5	6	9	6	6	5	5	5	7
Totals		290,714	690	87	304	6518	2115	673	638	18399	1452	1106	287	340	398	230	17519	7515

Table 2. Distribution of hatchery stocked Atlantic salmon smolts and fall fingerlings to rivers of SFA 21 during 1996.

	River	pH category	Origin of stock	Number of Smolt	Percent of SFA 21	Number of fall fingerlings
	Clyde	1	LaHave	18,559	6	
	Jordan	1	LaHave	5,000	2	1,001
Sub-total				23,559	8	
	Mersey	2	LaHave	18,000	6	
	Sackville	2	LaHave	1,852	1	
	Sackville	2	Sackville	16,101	5	14,009
	Tusket	2	Tusket	50,044	17	31,004
Sub-total				85,997	29	
	Gold	3	Gold	15,000	5	
	LaHave	3	LaHave	49,376	17	40,703
	Medway	3	Medway	50,634	17	37,990
	Salmon River - Digby	3	Salmon River	19,040	6	15,003
Sub-total				134,050	45	
	Meteghan	4	Tusket			10,014
	Mushamush	4	LaHave	21,440	7	13,000
	Petite	4	LaHave	21,440	7	13,000
Sub-total				42,880	14	
	Bear River		Tusket	11,605	4	
Total				298,091		175,724

Table 3. Atlantic salmon fishing seasons and variations for Salmon Fishing Area 21, Southwestern Nova Scotia, 1997.

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 July 10
(d)	Ingram River		June 1 to July 10
(e)	Jordan River		May 10 to Sept. 30
(f)	LaHave River downstream from	Morgan Falls	May 10 to July 10
	(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 July 10
	(Hook and release only from		May 10 to May 31)
(I)	Medway River downstream from	McGowan Lake	June 1 to July 10
(j)	Mersey River		May 10 to Aug. 15
		and	Sept. 1 to Sept. 30
(k)	Meteghan River		Aug. 1 to Sept. 30
(l)	Mushamush River		June 1 to July 10
(m)	Petite Riviere		June 15 to July 10
(n)	Salmon River		June 1 to July 10
(o)	Sackville River		June 1 to July 10
(p)	Tusket River		June 1 to June 11(1)
			June 12 to July 10(2)

*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 1997.

		Salmon		Grilse		Total count
Month	Day	Wild	Hatchery	Wild	Hatchery	to date
May	30		1			1
June	6		2			2
	13	3	10	3	3	19
	20	16	24	23	16	79
	27	23	38	94	72	227
July	4	31	46	179	99	355
	11	35	47	184	104	370
	18	35	48	187	114	384
	25	35	48	189	114	386
August	1	35	48	189	114	386
	8	35	48	189	114	386
	15	35	48	189	114	386
	22	35	48	189	114	386
	29	35	48	189	114	386
September	5	35	48	189	114	386
	12	35	48	189	114	386
	19	38	50	191	115	394
	26	38	50	191	115	394
October	3	38	50	191	115	394
	10	38	50	191	115	394
	17	38	50	191	115	394
	24	38	50	191	115	394
November	31	67	67	303	144	581

Table 5. Stock origin and sea-age composition of Atlantic salmon counted at Morgan Falls fishway, LaHave River, 1970 - 1997, and forecasts for 1998 using regression models (A), 5-year mean return rates (B), and counts of smolts and 1997 return rates (C).

Return	Hatchery		Wild		Totals		
Year	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	3,055	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	144	67	303	68	447	135	582
1998							
A) 1998 Forecast	***326***	***43***	***609***	***100***	***935***	***143***	***1,078***
Upper 95th percentile	753	175	918	396	1,671	571	2,242
Lower 5th percentile	55	6	296	32	351	38	389
B) Using 5yr. means for wild grilse and 5yr return rates for hatchery grilse.							
1998 Forecast	***290***	***43***	***609***	***100***	***899***	***143***	***1,042***
Upper 95th percentile	768	175	918	332	1,686	507	2,193
Lower 5th percentile	188	6	296	16	484	22	506
C) Using count of wild and hatchery smolts and 1997 return rates for grilse.							
1998 Forecast	***73***	***43***	***361***	***100***	***434***	***143***	***577***
Upper 95th percentile	73	175	372	332	445	507	952
Lower 5th percentile	73	6	351	16	424	22	446

Rates and population estimates used:					
1997 H1SW %rtn=	0.306	1991-1996 mean % rt	1.209	W1SW Mode return	0.0218
1996 Wsmolt mode=	16,520	std. dev. =	0.7182	W1SW 5th	0.0225
5th	15,880			W1SW95th	0.0213
95th	17,200	Hsmlt 1997=	23,968		
		Wsmolt 1997=	16,520		

Table 6. Age and size composition of wild and hatchery adult Atlantic salmon sampled at Morgan Falls on the LaHave River, May to November, 1997. 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			4	55.7	52.5	58.0	2.1	4	16.0	1.4	19.0	2.0
	1	1			3	58.0	54.0	60.0	2.8	3	20.0	1.7	25.0	3.0
	2	1			113	55.1	49.6	60.3	2.4	113	18.0	1.3	28.0	2.0
	3	1			31	58.3	53.5	63.5	2.6	31	20.0	1.3	25.0	3.0
	0	2			1	69.5	69.5	69.5	0.0	1	32.0	3.2	32.0	0.0
	1	2			1	58.0	58.0	58.0	0.0	1	19.0	1.9	19.0	0.0
	2	2			38	72.6	66.8	77.3	2.6	38	44.0	3.2	56.0	5.0
	3	2			2	73.3	70.5	76.0	2.8	2	45.0	3.6	53.0	9.0
	2	2	1		1	58.2	58.2	58.2	0.0	1	17	1.7	17.0	0.0
	2	3	1		9	76.5	71.9	83.5	3.2	9	5.3	4.4	6.7	0.7
	3	3	1		3	77.6	76.5	79.2	1.2	3	5.1	4.3	5.5	0.5
	2	3	2		2	77.8	73.5	82.0	4.3	2	5.5	5.0	6.0	0.5
	2	4	2		6	84.9	82.3	89.0	2.4	6	6.9	6.1	8.5	0.8
	3	4	1	3	1	79.8	79.8	79.8	0.0	1	5.2	5.2	5.2	0.0
Hatchery														
	0	1			2	55.3	54.5	56.0	0.8	2	1.7	1.6	1.7	0.1
	1	1			28	56.9	52	62.5	3.1	28	1.9	1.4	2.7	0.3
	2	1			10	56.2	52.4	60.5	2.6	10	2.1	1.8	2.5	0.2
	3	1			2	54.9	51.3	58.5	3.6	2	2.0	1.5	2.4	0.5
	1	2			50	73.1	53.7	80.0	4.0	50	4.4	1.9	5.7	0.7
	2	2			2	74.1	73.4	74.8	0.7	2	4.4	3.8	5.0	0.6
	1	3	1		4	75.6	74.9	76.2	0.5	4	5.3	4.6	6.0	0.5
	1	4	2		4	87.5	80.0	99.9	7.6	4	6.7	5.4	7.6	0.8

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, 1997.

	Sea		Length (cm)			Weight (kg)		
Origin	age	Gender	Number	Mean	Std. dev.	Number	Mean	Std. dev.
Wild	1SW	Female	44	55.3	2.6	44	1.91	0.3
Hatchery	1SW	Female	11	56.2	3.0	11	2.10	0.4
Wild	1SW	Male	107	56.0	2.8	107	1.85	0.3
Hatchery	1SW	Male	31	56.7	2.9	31	1.89	0.3
Wild	MSW	Female	57	74.0	5.5	57	4.68	1.1
Hatchery	MSW	Female	54	73.8	5.5	54	4.54	0.8
Wild	MSW	Male	7	76.3	4.6	7	5.04	0.8
Hatchery	MSW	Male	6	77.9	3.3	6	5.58	0.9

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, 1997.

			Length (cm)			Weight (kg)		
Origin	Age	Gender	Number	Mean	Std. Dev.	Number	Mean	Std. Dev.
Wild	2.1	Female	18	55.5	1.9	18	1.90	0.2
	3.1	Female	3	58.6	2.0	3	2.20	0.3
Hatchery	1.1	Female	1	54.5	0.0	1	1.50	0.0
	3.1	Female	1	58.5	0.0	1	2.40	0.0
Wild	1.1	Male	1	60	0.0	1	1.90	0.2
	2.1	Male	31	56.1	2.3	31	1.80	0.2
	3.1	Male	9	58.8	1.8	9	2.00	0.2
Hatchery	1.1	Male	12	56.8	2.4	12	1.80	0.2
	2.1	Male	3	58.8	1.7	3	2.20	0.2
Wild	1.2	Female	1	58	0.0	1	1.90	0.0
	2.2	Female	11	70.6	4.8	11	4.10	0.9
Hatchery	1.2	Female	7	73.2	2.9	7	4.70	0.6
	2.2	Female	1	73.4	0.0	1	5.00	0.0
Wild	2.2	Male	3	73.9	1.3	3	4.60	0.6
Hatchery	1.2	Male	2	76.9	3.2	2	5.00	0.7
Total			104					

Table 9. Numbers, locations, dates and markings of Atlantic salmon hatchery reared smolts released in the LaHave River, 1997.

Realease Date	Turbine mort. trial	Forebay * (marked two grps)	New Germany Lake Tagged	New Germany Lake Untagged	Above Morgan Falls	Below Morgan Falls	Grand Total
08-May			1,333	7,000		16,000	
12-May						4,524	
20-May			1,333	7,000			
21-May		200 n					
22-May		200 n					
23-May		200 n					
26-May	150 t						
28-May			1,333	7,692		7,967	
Totals	150	600	4,000	c 21,692	26,442	28,491	54,933

(Note:All smolts are adipose clipped)

n two marks applied (RV and LV).

t Tagged small green carlin separate series.

c Combined tag numbers only

Table 10. Numbers of marked LaHave River parr and smolt stocked above Morgan Falls from the Mersey FCS and estimated hatchery-derived smolt output at year of release of smolts, numbers of marked returns and percent return as recruit one-sea-winter (1SW) and two-sea-winter (2SW) adult salmon.

Year of release	0+ parr	1+ parr	1+ smolt		2+ smolt	Estimated smolt output[1]	Hatchery adult returns to MF yr+1 and yr+2			Hatchery stk.abv.& angled below		Return rate					
				Proportion								To LaHave River			To Morgan Falls		
	Number	Number	Number	good quality	Number		1SW	2SW	Total	1SW	2SW	1SW	2SW	Total	1SW	2SW	Total
1970										0	19						
1971		9,440	4,892			4,892				104	22						
1972		6,790	8,400		6,450	18,626	138	19	157	353	19	2.64	0.21	2.84	0.74	0.10	0.84
1973	51,643 u	43,133	9,166		18,526	30,408	442	62	504	514	47	3.14	0.36	3.50	1.45	0.20	1.66
1974	0	3,735	19,815		14,435	51,503	466	72	538	346	23	1.58	0.18	1.76	0.90	0.14	1.04
1975	0	18,883	0		0	13,888	468	34	502	471	13	6.76	0.34	7.10	3.37	0.24	3.61
1976	0	6,875	45,259	0.87	5,769	52,698	974	197	1,171	387	42	2.58	0.45	3.04	1.85	0.37	2.22
1977	0	44,314	74,577	0.79	5,370	67,356	567	99	666	120	45	1.02	0.21	1.23	0.84	0.15	0.99
1978	0	7,108	72,067	0.78	0	74,791	1,064	524	1,588	480	95	2.06	0.83	2.89	1.42	0.70	2.12
1979	30,753 u	0	33,910	0.56	0	22,697	336	184	520	61	86	1.75	1.19	2.94	1.48	0.81	2.29
1980	10,626 u	0	62,225	0.73	16,039	62,276	1,186	113	1,299	556	34	2.80	0.24	3.03	1.90	0.18	2.09
1981	0	0	25,482	0.91	0	31,485	623	54	677	189	11	2.58	0.21	2.79	1.98	0.17	2.15
1982	NO STOCKIN	0	0		0	2,675	25	33	58	5	3	1.13	1.36	2.49	0.93	1.23	2.17
1983	0	0	28,451	0.69	0	19,631	249	61	310	89	39	1.72	0.51	2.23	1.27	0.31	1.58
1984	32,900 u	0	15,000	0.48	0	7,681	105	55	160	68	13	2.25	0.88	3.14	1.37	0.71	2.08
1985	10,804	0	4,996	0.55	0	3,173	133	55	188	32	10	5.19	2.06	7.25	4.19	1.74	5.93
1986	55,722	0	16,864	0.92	0	23,533	564	50	614	305	6	3.69	0.24	3.93	2.40	0.21	2.61
1987	19,650	0	33,353	0.73	0	27,014	1,059	268	1,327	291	14	5.00	1.04	6.04	3.92	0.99	4.91
1988	42,481	0	16,018	0.84	0	27,319	442	85	527	273	12	2.62	0.36	2.97	1.62	0.31	1.93
1989	0	0	30,004	0.86	0	30,659	592	69	661	309	3	2.94	0.23	3.17	1.93	0.22	2.15
1990	82,432	0	15,970	0.97	0	25,915	109	45	154	26	4	[illegible]	0.19	0.19	[illegible]	0.17	0.17
1991	83,223	0	21,943	0.78	0	17,142	617	79	696	156	5	4.51	0.49	5.00	3.60	0.46	4.06
1992	48,587	0	27,516	0.94	0	45,912	383	104	487	195	2	1.26	0.23	1.49	0.83	0.23	1.06
1993	44,512	0	19,748	0.86	0	37,047	207	77	284	21	5	0.62	0.22	0.84	0.56	0.21	0.77
1994	34,827	0	26,110	0.91	0	35,572	372	78	450	141	7	1.44	0.24	1.68	1.05	0.22	1.26
1995	0	0	19,155	0.93	0	28,625	396	58	454	251	4	2.26	0.22	2.48	1.38	0.20	1.59
1996	0	0	49,526	0.78	0	47,111	144			77	0	0.4692			0.3057		
1997	0	0	26,442	0.88	0	23,968											

Table11. Counts made at the assessment facility and in the by-pass tank at Morgan Falls Hydro, 1997

Daily Count Taken By LRSA, SEG, & DFO

Bypass Counts

					Test #1	Test #2	Test #3	Test #4	Test #5	Test #6
Date	W Smolt	H Smolt	H Tagged	W Parr	R Vent Clip	L Vent Clip	L Vent Clip	R Vent Clip	R Vent Clip	L Vent Clip
06-May-97	10	1	0	1						
07-May-97	14	4	0	1						
08-May-97	49	1	0	8						
09-May-97	15	3	0	2						
10-May-97	37	0	0	0						
11-May-97	6	0	0	1						
12-May-97	195	13	2	2						
13-May-97	308	13	3	8						
14-May-97	917	86	0	26						
15-May-97	1049	90	19	12						
16-May-97	863	100	20	10						
17-May-97	925	97	19	14						
18-May-97	86	18	5	4						
19-May-97	488	50	18	8						
20-May-97	491	524	109	9						
21-May-97	299	969	227	7	25	29				
22-May-97	229	1492	339	13	59	29	55	28	77	79
23-May-97	442	508	61	15			50	40	24	22
24-May-97	148	124	20	9					3	1
25-May-97	319	98	10	30					2	
26-May-97	791	145	26	11						
27-May-97	0	0	0	0						
28-May-97	356	1393	305	42						
29-May-97	404	1018	269	58						
30-May-97	165	2170	627	28						
Totals	**8616**	**8915**	**2085**	**319**	**84**	**58**	**105**	**68**	**106**	**102**

Total Hatchery Smolt *	11000
Total Wild Smolt	8616
Total Parr	319

* Test hatchery smolt not included

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 1997 and the probability distribution of the 1983 mark and recapture population estimate(A); Pre-fishery population estimates derived by applying the 1997 LaHave River catch rate to the estimated angling catches reported for 11 other rivers of SFA 21(B).

A

	Max. Prob.	5^{th} %	95^{th} %
1996 Angling Catch Rate	0.3465	0.5905	0.2042

B

River	Angling catch	Population Estimate Max. Prob.	5^{th} %	95^{th} %
Clyde	23	66	39	113
Gold	159	459	269	779
Ingram	0	0	0	0
LaHave	587	1,694	994	2,875
Medway	161	465	273	788
Meteghan	0	0	0	0
Middle: Lunenburg Co.	1	3	2	5
Mushamush	3	9	5	15
Petite Riviere	78	225	132	382
Sackville	16	46	27	78
Salmon: Digby Co.	3	9	5	15
Tusket	49	141	83	240
Total for SFA 21	1,080	3,117	1,829	5,289

Table 13. Spawning escapement relative to requirements based on numbers of Atlantic salmon counted and aged at Morgan Falls fishway in 1997, 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 yields 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	88	0.15	21	6	55.3	3,306	243,213	23.2	137
	Male	215	0.37	41	15	56.0				
Multi-sea-winter	Female	61	0.10	12	2	74.0	6,505	326,854	31.1	94
	Male	7	0.01	3	0	76.3				
Hatchery										
One-sea-winter	Female	38	0.06	2	3	56.2	3,415	131,128	12.5	72
	Male	106	0.18	15	61	56.7				
Multi-sea-winter	Female	60	0.10	8	2	73.8	6,458	348,598	33.2	101
	Male	7	0.01	2	0	77.9				
Totals		582	1.00	104	89		4,921	1,049,793	100	
Escaped female spawners		247			-12					235
Required female spawners =										403
Surplus (Deficit) =										**(168)**

Required egg deposition = 1.96E+06 Eggs/fish 1997 = 2,196

One-sea-winter angling retained total =	368	Preliminary
One-sea-winter angling released total =	46	
Multi-sea-winter angling released total =	162	

Proportion angled above Morgan Falls= 0.10

Table14. Estimated egg depositions ('000's) by Atlantic salmon above Morgan Falls, LaHave River, with no adjustment for unknown losses, 1973 - 1997. 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
1997	570	480	1,050

Table15. Proportions of hatchery smolts stocked above, angled above, hatchery one-sea-winter (grilse) and two-sea-winter (salmon) at Morgan Falls fishway, 1970 - 1997.

Return Year i	Prop. stocked above MFyr-1	Prop. angled above	Prop.1SW hatch. of 1SW at fishway[a].	Prop. 2SW hatch. of 2SW at fishway[a].
1970	1.00	0.00		
1971	1.00	0.00		
1972	1.00	0.00	0.529	
1973	1.00	0.00	0.908	0.000
1974	1.00	0.00	0.938	0.905
1975	1.00	0.00	0.925	0.932
1976	1.00	0.00	0.724	0.824
1977	1.00	0.00	0.769	0.771
1978	1.00	0.00	0.673	0.757
1979	1.00	0.00	0.554	0.596
1980	1.00	0.00	0.169	0.641
1981	1.00	0.00	0.387	0.399
1982	1.00	0.00	0.437	0.477
1983	1.00	0.00	0.022	0.313
1984	0.35	0.10	0.109	0.078
1985	0.50	0.10	0.072	0.108
1986	0.19	0.10	0.077	0.117
1987	0.42	0.10	0.185	0.134
1988	0.43	0.10	0.301	0.138
1989	0.33	0.10	0.177	0.425
1990	0.29	0.10	0.241	0.224
1991	0.47	0.10	0.179	0.272
1992	0.48	0.10	0.240	0.217
1993	0.54	0.10	0.327	0.430
1994	0.38	0.10	0.244	0.482
1995	0.48	0.10	0.392	0.373
1996	1.00	0.10	0.350	0.420
1997	1.00	0.10	0.322	0.496

[a]. From LAHSR.xls;Recruit_w

Table 16. Numbers of wild and hatchery salmon and grilse angled, proportions and numbers of hatchery fish angled below Morgan Falls but destined to Morgan Falls, estimated through annual tagging data and by relation between the proportion observed at the fishway and that estimated from tag recaptures with a 0.2 non-reporting rate. The resulting angling exploitation and catch rates for hatchery fish adjusted for angling below Morgan Falls are shown.

	Angled grilse							Angled salmon									
Return	Wild & Hatchery			prop. Hb		est. prop.	Hatchery destined to above	Wild & Hatchery			prop. Hb		Destined abv.	exploitation rate of hatchery		catch rates of hatchery	
Year i	retained	released	total morts	Hb	of Hb+Wb	Hb	but angled bl.	retained	released	total morts	Hb	of Hb+Wb	angled bl[1]	grilse	salmon	grilse	salmon
1970	557		557					93		93			19				
1971	411		411					119		119			25				
1972	306		306			0.34	104	93		93			19				
1973	604		604			0.58	353	107		107			22				
1974	850		850			0.60	514	92		92			19	0.538	0.503	0.538	0.503
1975	581		581			0.60	346	224		224			47	0.426	0.432	0.426	0.432
1976	1,012		1,012			0.47	471	110		110			23	0.502	0.242	0.502	0.242
1977	1,468		1,468	387	0.26	0.26	387	232		232	13	0.06	13	0.284	0.284	0.284	0.284
1978	175		175	120	0.69	0.69	120	167		167	42	0.25	42	0.175	0.175	0.175	0.175
1979	1,365		1,365	480	0.35	0.35	480	107		107	45	0.42	45	0.311	0.311	0.311	0.311
1980	1,273		1,273	61	0.05	0.05	61	520		520	95	0.18	95	0.153	0.153	0.153	0.153
1981	1,637		1,637	556	0.34	0.34	556	442		442	86	0.20	86	0.319	0.319	0.319	0.319
1982	785		785	189	0.24	0.24	189	180		180	34	0.19	34	0.233	0.233	0.233	0.233
1983	259	28	262	5	0.02	0.02	5	200	12	201	11	0.06	11	0.172	0.172	0.191	0.172
1984	1,339	143	1,353			0.07	89		167	17			3	0.262	0.010	0.290	0.096
1985	1,683	185	1,702	68	0.04	0.04	68		994	99	39	0.40	39	0.393	0.039	0.436	0.393
1986	1,844	271	1,871	32	0.02	0.02	32		951	95	13	0.14	13	0.192	0.019	0.220	0.192
1987	2,618	389	2,657			0.11	305		475	48			10	0.351	0.015	0.402	0.152
1988	1,518	134	1,531			0.19	291		310	31		Average	6	0.216	0.011	0.234	0.114
1989	2,445	409	2,486			0.11	273		669	67		= 0.21	14	0.382	0.005	0.445	0.050
1990	2,008	373	2,045			0.15	309		581	58			12	0.343	0.012	0.406	0.125
1991	233	44	237			0.11	26		142	14			3	0.195	0.004	0.231	0.041
1992	1,021	102	1,031			0.15	156		181	18			4	0.201	0.008	0.221	0.078
1993	919	201	939			0.21	195		241	24			5	0.337	0.006	0.409	0.060
1994	136	24	138			0.15	21		118	12			2	0.093	0.002	0.109	0.023
1995	557	79	565			0.25	141		240	24			5	0.275	0.006	0.313	0.062
1996	1,088	426	1,131			0.22	251		327	33			7	0.388	0.008	0.535	0.081
1997	373	44	377 p			0.20	77		171	17			4	0.348	0.006	0.389	0.058

Estimated from relationship of Hb_{yr}=0.6497*prop. at $fishway_{yr}$ - 0.0052

1. Estimated from the average Hb determined from tagging data.

Table 17. Record of esophageal-implanted radio, dummy radio and Carlin tagged Atlantic salmon captured at Morgan Falls on the LaHave River, 1997.

Salmon Number	Stock	Length (cm)	Weight (kg)	Sex	Date Tagged	Date Released	Carlin Tag #	Radio Tag Frequency	Radio Tag Channel	Radio Tag Code	Release Location	Re-observations
68	Hatchery	57.5	2.2	Male	20/06/97	23/06/97	1538	149.440'	7	46	Down Stream	Wentzells Lake, (Bl. MF), July 15
64	Wild	53	1.8	Male	20/06/97	23/06/97	1549		Dummy Tag		Down Stream	Fishway, Nov 3
78	Wild	49.8	1.5	Female	20/06/97	23/06/97	1531		Carlin Tag Only		Down Stream	Fishway, Nov 3
75	Hatchery	57.1	1.8	Female	20/06/97	23/06/97	1547		Carlin Tag Only		Down Stream	
72	Hatchery	51.6	1.4	Male	20/06/97	23/06/97	1569		Dummy Tag		Down Stream	Fishway, Nov 3
58	Wild	70.8	4.2	Female	20/06/97	23/06/97	1589		Dummy Tag		Down Stream	
59	Hatchery	77.2	4.9	Female	20/06/97	23/06/97	1593		Dummy Tag		Down Stream	
69	Wild	69.2	3.2	Female	20/06/97	23/06/97	1541		Carlin Tag Only		Down Stream	
121	Wild	75.6	5.2	Female	24/06/97	24/06/97	1595	149.440'	7	44	Up stream	Above New Germany Lake,(Abv. MF), July 15
122	Hatchery	72.8	4.6	Female	24/06/97	24/06/97	1581	149.380'	4	47	Down Stream	Wentzells Lake (Bl. MF), Oct. 20; Fishway, Nov. 3
123	Wild	56.1	2	Female	24/06/97	24/06/97	1565	149.440'	7	45	Up stream	Eddy Pool (Bl. MF), July10; Fishway, Nov. 3
124	Wild	74.5	4.8	Female	24/06/97	24/06/97	1588		Dummy Tag		Down Stream	Fishway, Nov. 3
125	Hatchery	55	2.1	Male	24/06/97	24/06/97	1576		Dummy Tag		Down Stream	Fishway, Nov. 5
200	Wild	70	4.3	Female	26/06/97	27/06/97	2278	149.380'	4	48	Up stream	New Germany Lake (Abv MF), July11
201	Wild	56.7	2	Female	26/06/97	27/06/97	2298	149.380'	4	49	Up stream	New Germany Lake (Abv MF), July14; Rail Bridge Above N
203	Wild	55.5	4.3	Male	26/06/97	27/06/97	2276	149.380'	4	50	Up stream	Wentzells Lake,July 10; Fishway, Nov 3
204	Wild	52.3	2	Female	26/06/97	27/06/97	2290		Dummy Tag		Down Stream	
205	Wild	52.1	2.1	Female	26/06/97	27/06/97	2277		Dummy Tag		Down Stream	Fishway, Nov. 3
206	Hatchery	52.7	1.6	Female	26/06/97	27/06/97	2287		Dummy Tag		Down Stream	Fishway, Nov. 3
207	Wild	52.4	1.6	Female	26/06/97	27/06/97	2289		Carlin Tag Only		Down Stream	Fishway, Nov. 3
208	Wild	52	1.8	Female	26/06/97	27/06/97	2286		Carlin Tag Only		Down Stream	Fishway, July 14
216	Hatchery	71.8	1.8	Female	26/06/97	27/06/97	AA79792		Carlin Tag Only		Down Stream	
217	Hatchery	73	4.1	Female	26/06/97	27/06/97	AA79746		Dummy Tag		Down Stream	
232	Wild	70.6	5	Female	02/07/97	03/07/97	AA79720	149.380'	4	51	Up stream	New Germany Lake, July 15
233	Hatchery	74.9	5.5	Female	02/07/97	03/07/97	AA79707		Carlin Tag Only		Down Stream	Fishway, Nov. 3
250	Wild	54	1.8	Male	02/07/97	03/07/97	AA79734		Carlin Tag Only		Down Stream	Fishway, Nov. 3
284	Wild	55	2.2	Male	02/07/97	03/07/97	AA79753	149.440'	7	43	Up stream	New Germany Lake, July 14; Rail Bridge Above New Germ
302	Wild	57.7	1.9	Male	02/07/97	03/07/97	AA79750		Dummy Tag		Down Stream	Fishway Nov. 3
329	Hatchery	68	3.8	Female	02/07/97	03/07/97	FF91706		Dummy Tag		Down Stream	
365	Wild	76.7	5.6	Female	10/07/97	11/07/97	AA79754		Dummy Tag		Down Stream	
366	Hatchery	53.5	5.6	Male	10/07/97	11/07/97	AA79777		Dummy Tag		Down Stream	
368	Wild	74.3	5.6	Male	10/07/97	11/07/97	AA79788	149.420'	6	9	Up Stream	New Germany Lake, July 14; Rail Bridge Above New Germ
370	Wild	55.2	2.1	Male	10/07/97	11/07/97	AA79758		Carlin Tag Only		Down Stream	
371	Hatchery	55.3	2.3	Male	10/07/97	11/07/97	AA79722	149.420'	6	8	Up Stream	Eddy Pool(Bl. M.F.), July 16, Aug. 13
373	Wild	80	6	Female	10/07/97	11/07/97	AA79757		Carlin Tag Only		Down Stream	
384	Wild	69.5	3.2	Female	18/09/97	19/09/97	2279		Dummy Tag		Down Stream	
386	Wild	57.2	1.9	Female	18/09/97	19/09/97	1556		Carlin Tag Only		Down Stream	
387	Wild	84.2	6.1	Female	18/09/97	19/09/97	2291	149.480'	9	40	Up Stream	Bl. M.F. Sept. 20; Nov. 3 to 10
388	Wild	71.5	3.8	Female	18/09/97	19/09/97	2296		Carlin Tag Only		Down Stream	
389	Wild	57.1	2	Female	18/09/97	19/09/97	1573	149.480'	9	39	Up Stream	Cherryfield Brdg.(abv MF), Nov. 4; M.F. Nov 14 to 15
390	Hatchery	58.6	2.1	Male	18/09/97	19/09/97	1552		Dummy Tag		Down Stream	
509	Hatchery	75	3.88	Male	03/11/97	03/11/97	1582		Carlin Tag Only		Down Stream	Fishway, Nov 4 @15:00
511	Hatchery	79.8	5.1	Female	03/11/97	03/11/97	1544		Carlin Tag Only		Down Stream	Fishway, Nov. 5 @ 08:00
513	Wild	56.5	1.7	Male	03/11/97	03/11/97	1545		Carlin Tag Only		Down Stream	Fishway, Nov. 5 @ 08:00
517	Wild	56.4	1.7	Female	03/11/97	03/11/97	1526		Carlin Tag Only		Down Stream	Fishway, Nov. 4 @15:50

Table 18. Proportion non-returning Atlantic salmon marked at Morgan Falls fishway, LaHave River, 1997, by origin, stage (grilse <= 63 cm; salmon > 63 cm), tag applied, release location relative to fishway, number of fallbacks from upstream releases, number returned to fishway trap, number non-returned and proportion non-returned.

Origin	Stage S/G	Tag D/C/R[1]	Release location	Number	Number fallback	Upstream returned	Non-returned	Prop. non-return
H	G	D	Down	5	na	3	2	0.40
W	G	D	Down	4	na	3	1	0.25
H	G	C	Down	1	na	0	1	1.00
W	G	C	Down	8	na	6	2	0.25
H	G	R	Down	1	na	0	1	1.00
H	G	R	Up	1	1	0	1	1.00
W	G	R	Up	5	2	2	0	0.00
H	S	D	Down	3	na	0	3	1.00
W	S	D	Down	4	na	1	3	0.75
H	S	C	Down	4	na	3	1	0.25
W	S	C	Down	3	na	0	3	1.00
H	S	R	Down	1	na	1	0	0.00
W	S	R	Up	5	1	0	1	0.20
Totals				45	4	19	19	0.42

1. Dummy radio tag; Carlin monotie; Radio esophageal implant
na = not applicable

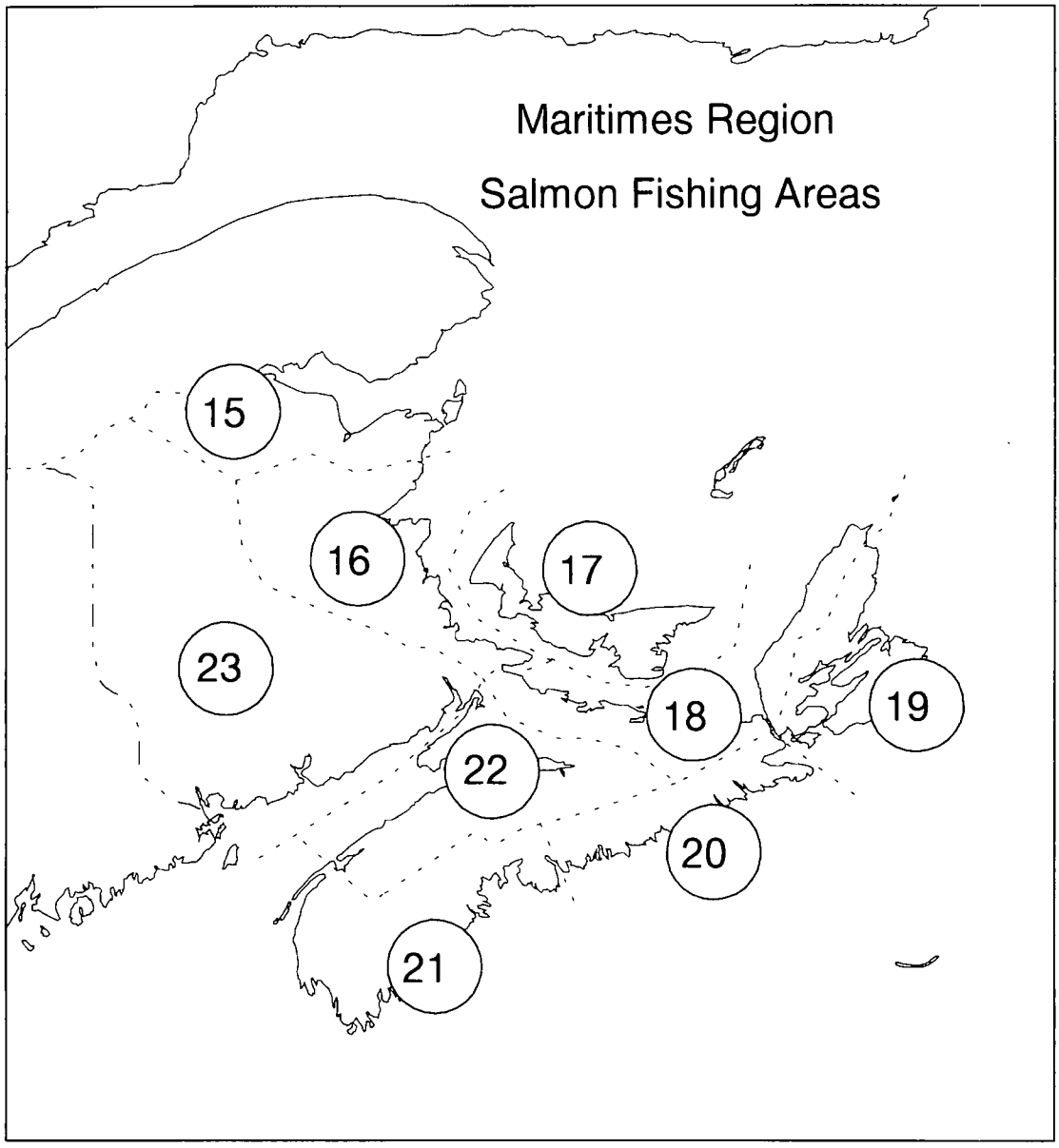

Figure 1. Map of Salmon Fishing Areas of the Maritimes Region of the Department of Fisheries and Oceans, Canada.

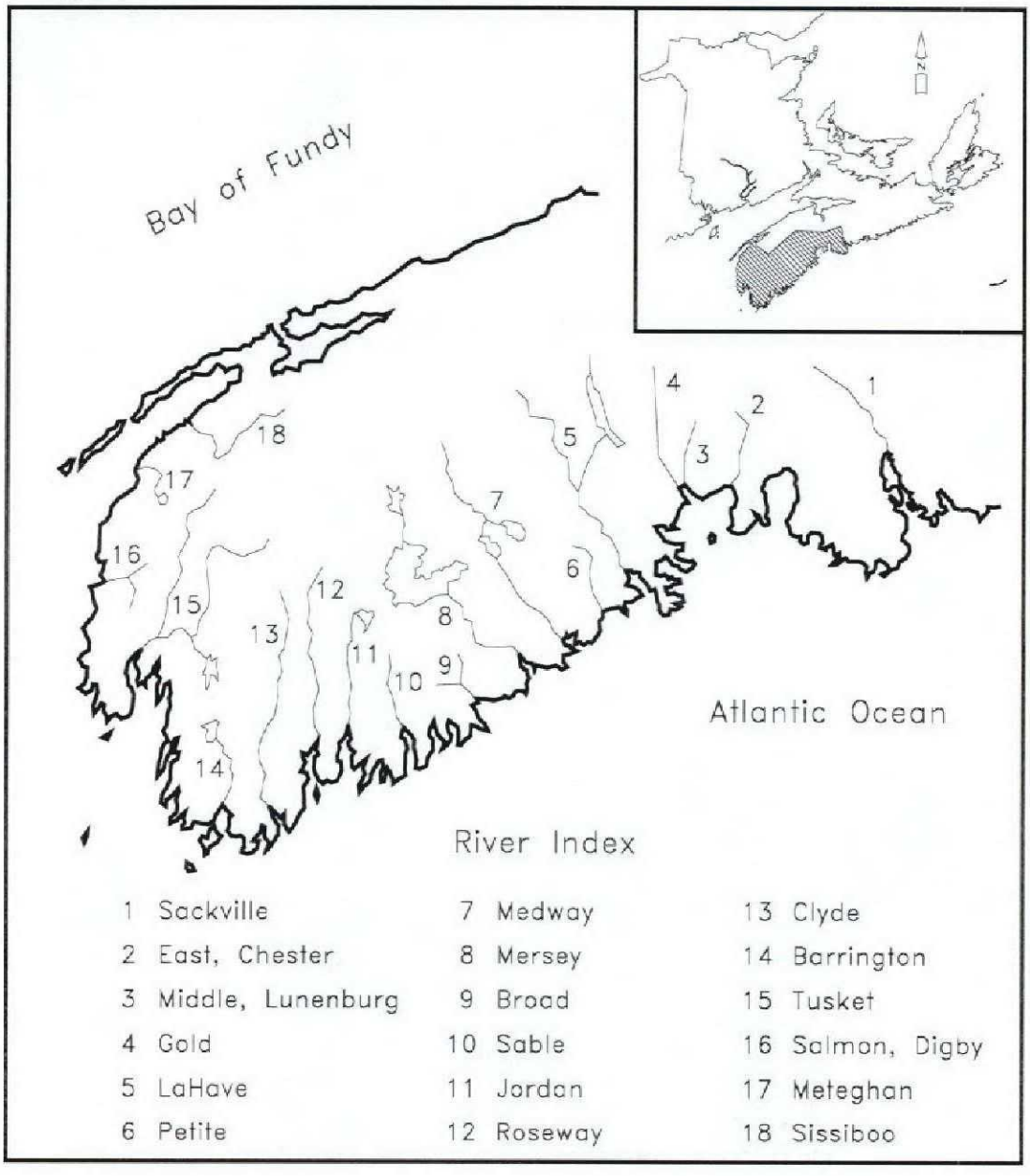

Figure 2. Locations of eighteen rivers of Salmon Fishing Area 21 where potential Atlantic salmon production is defined.

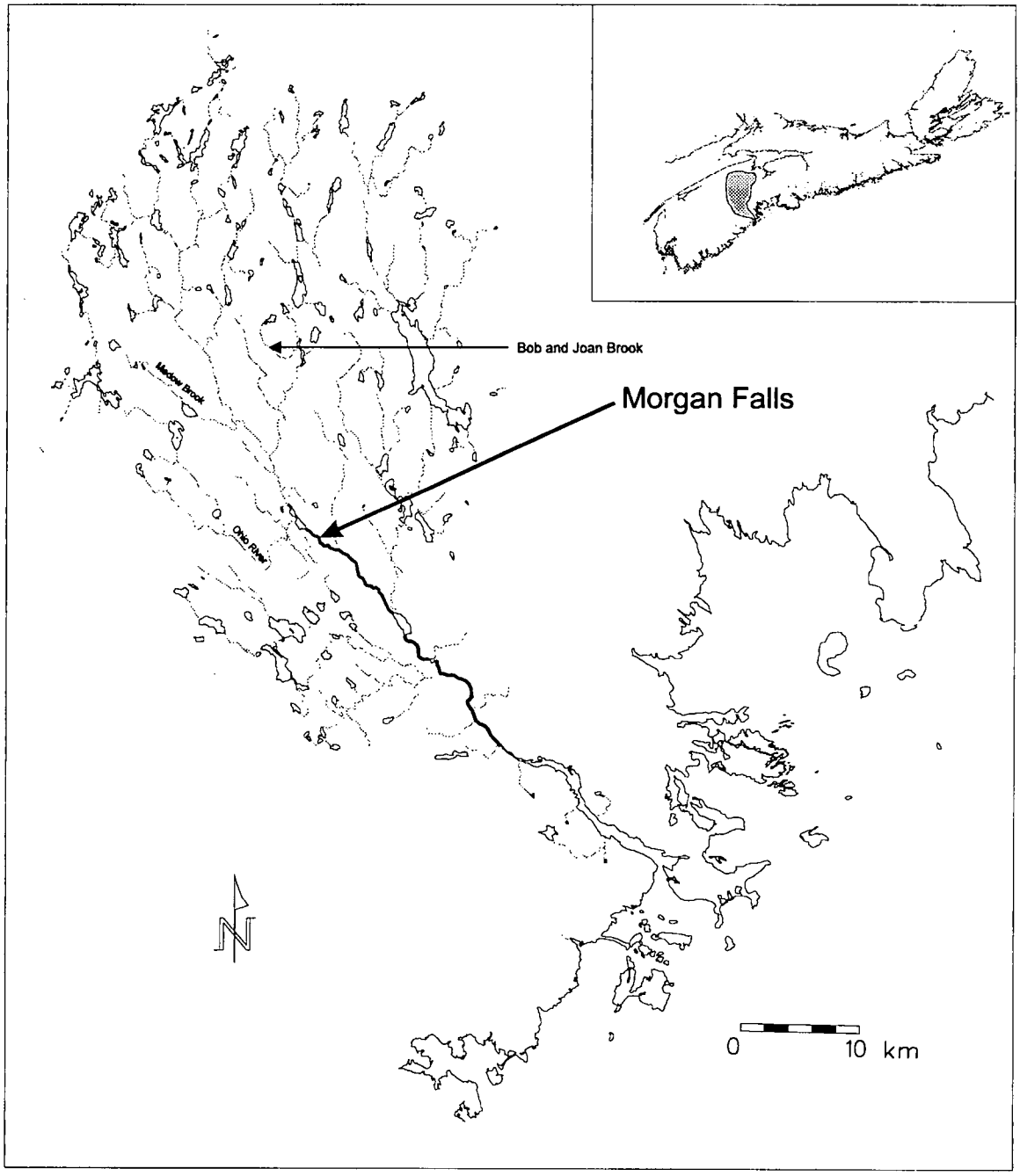

Figure 3. Map of LaHave River, Lunenburg County, Nova Scotia showing location of Morgan Falls and three tributaries above that have reduced Atlantic salmon production due to acidity.

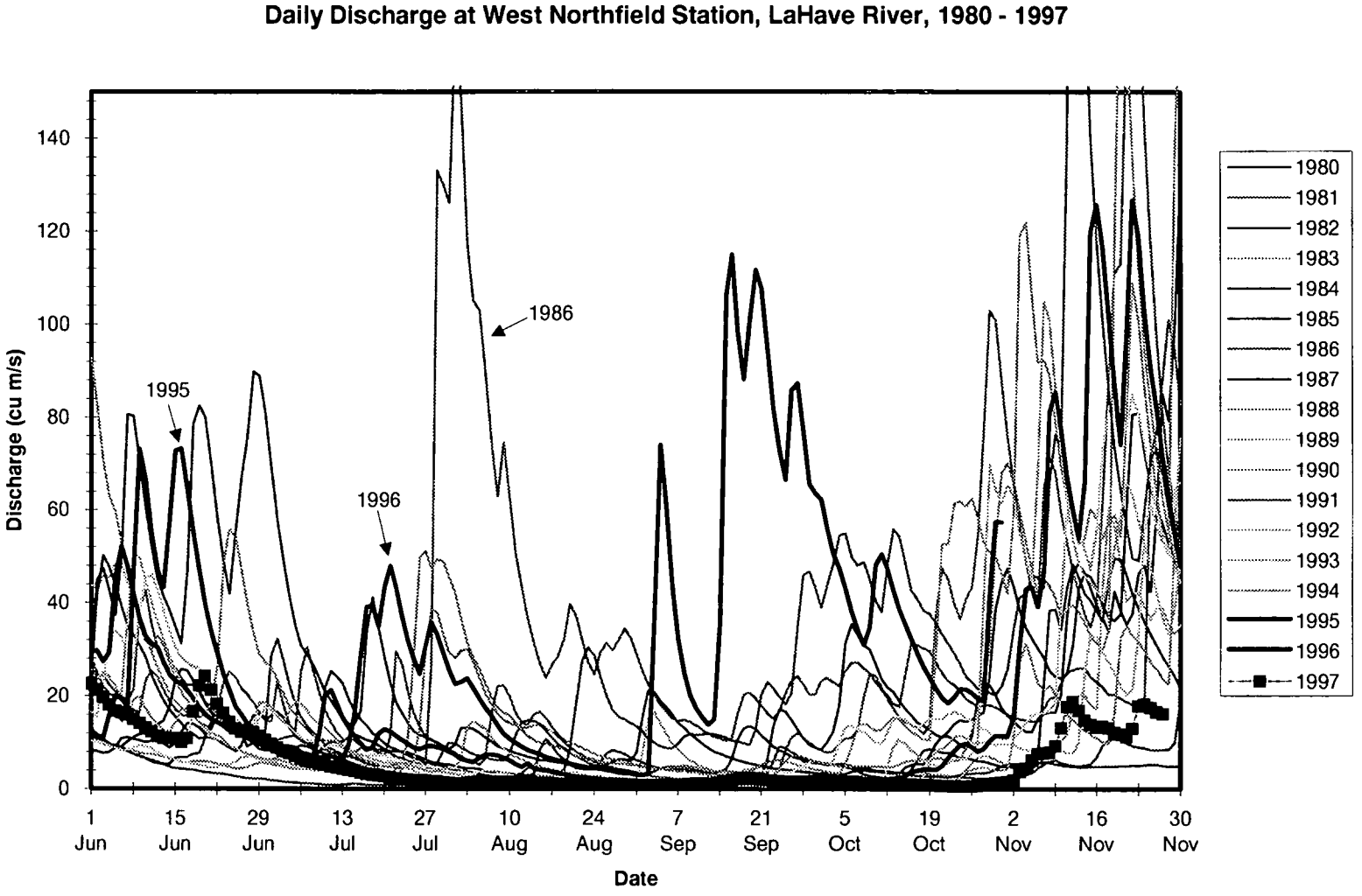

Figure 4. Discharge at West Northfield on the LaHave River 1980 - 1997.

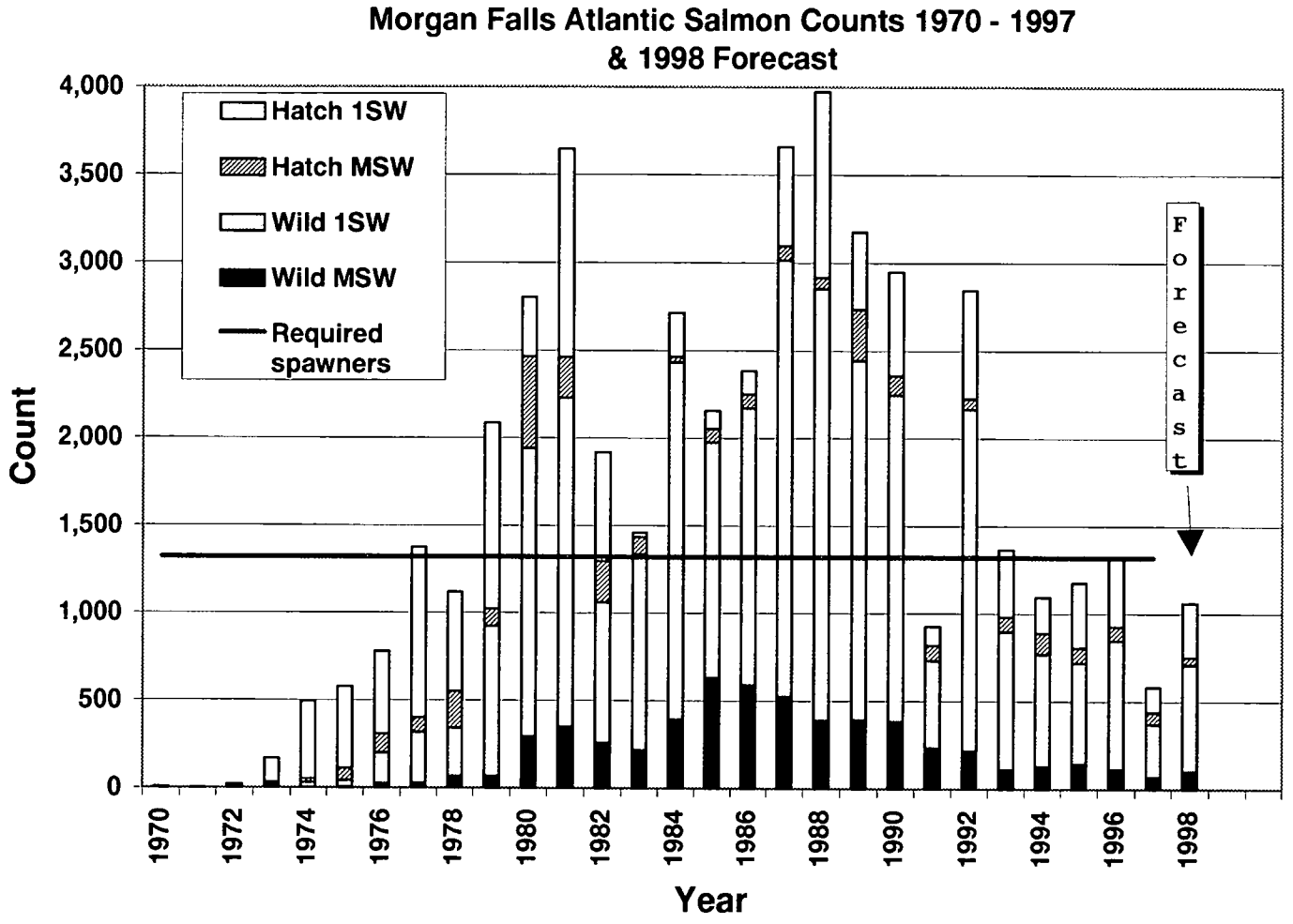

Figure 5. Counts of Atlantic salmon at Morgan Falls by sea-age classes and origin for the years 1970 to 1997 and forecast for 1998.

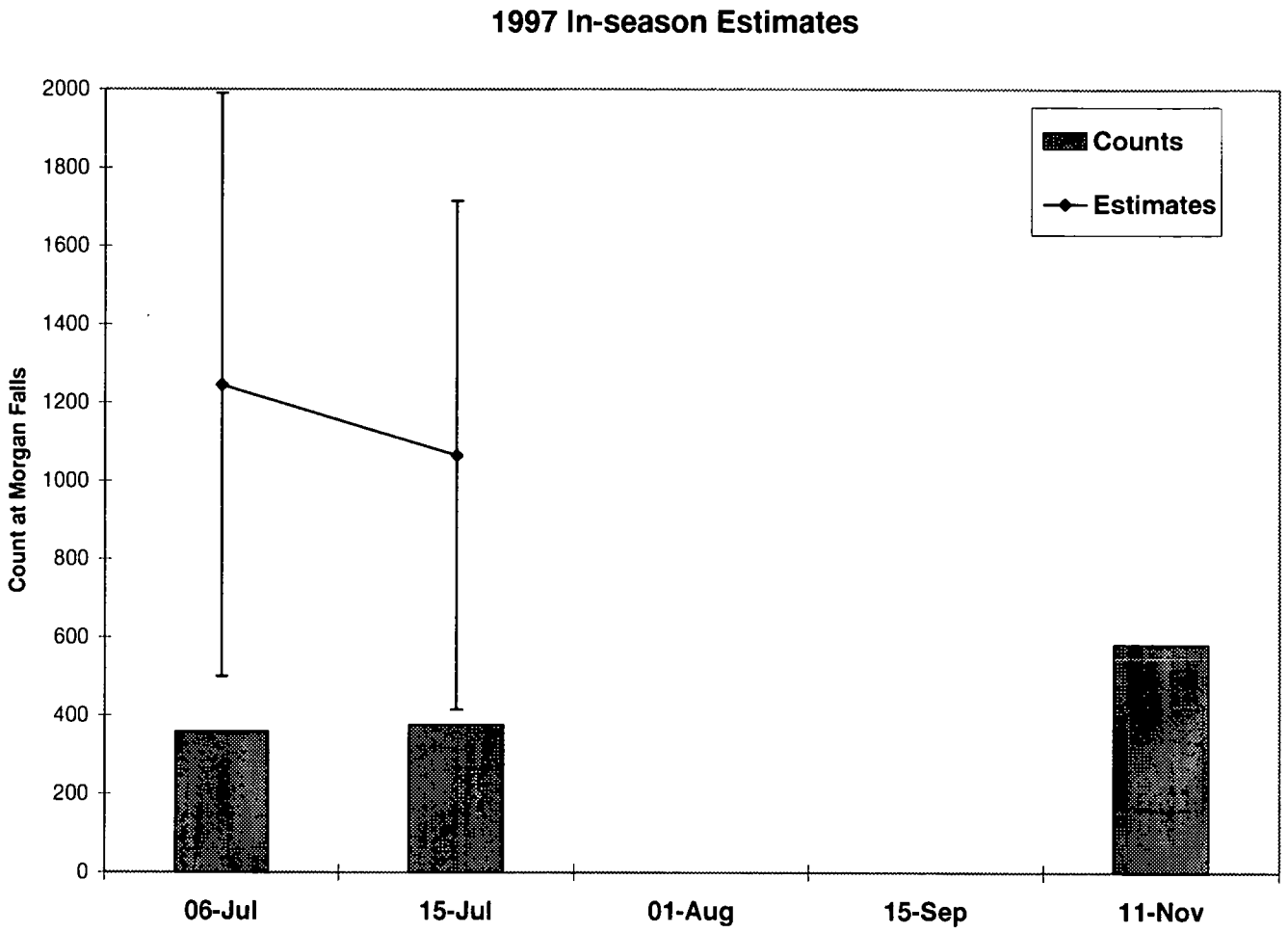

Figure 6. Count to date (bars) and in-season forecasts (dots), with 5th and 95th percentiles of error (lines), of the end of season total count of Atlantic salmon to Morgan Falls, LaHave River, 1997.

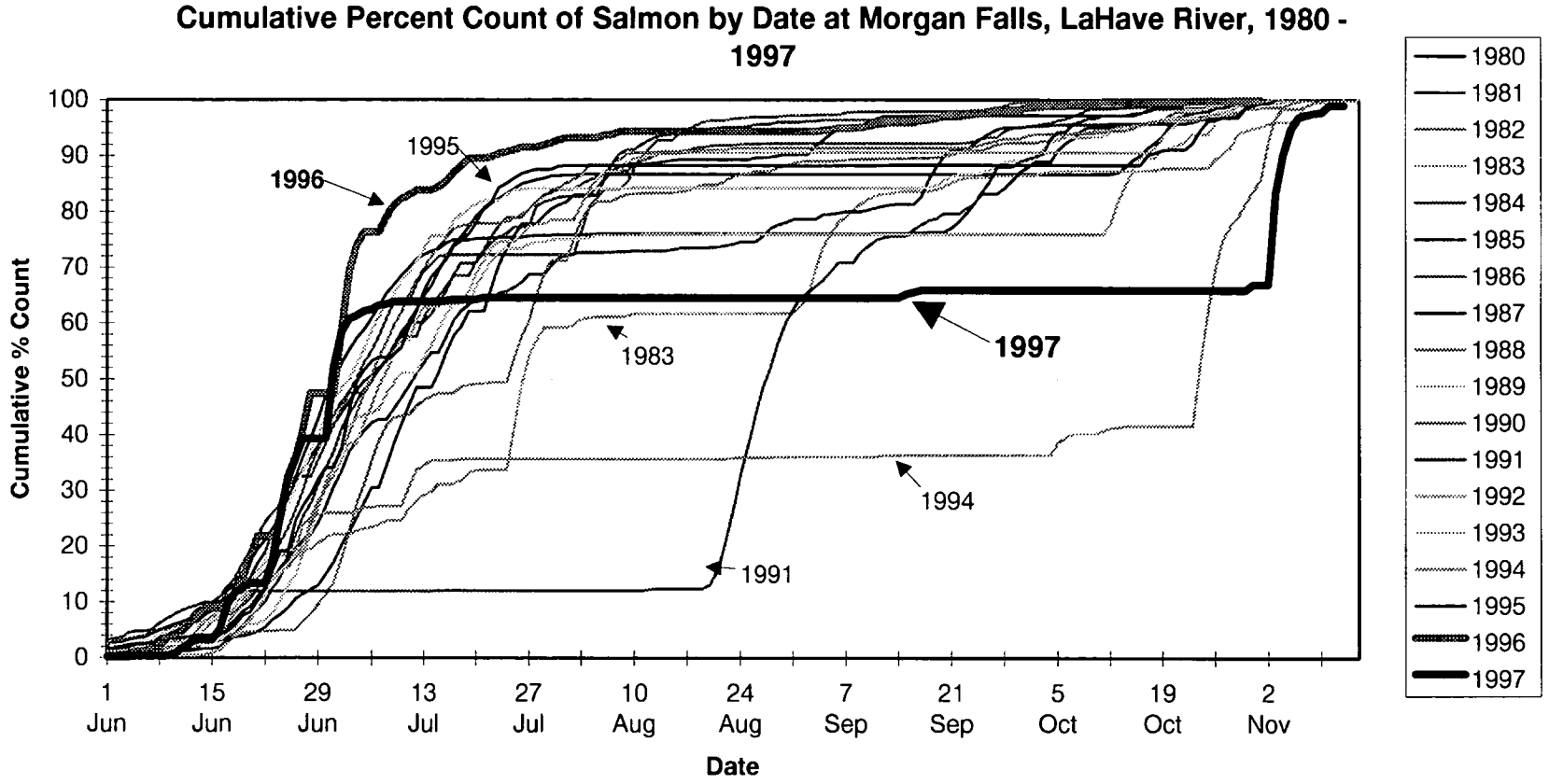

Figure 7. Cumulative percent count of Atlantic salmon at Morgan Falls Fishway on the LaHave River, 1980 - 1997.

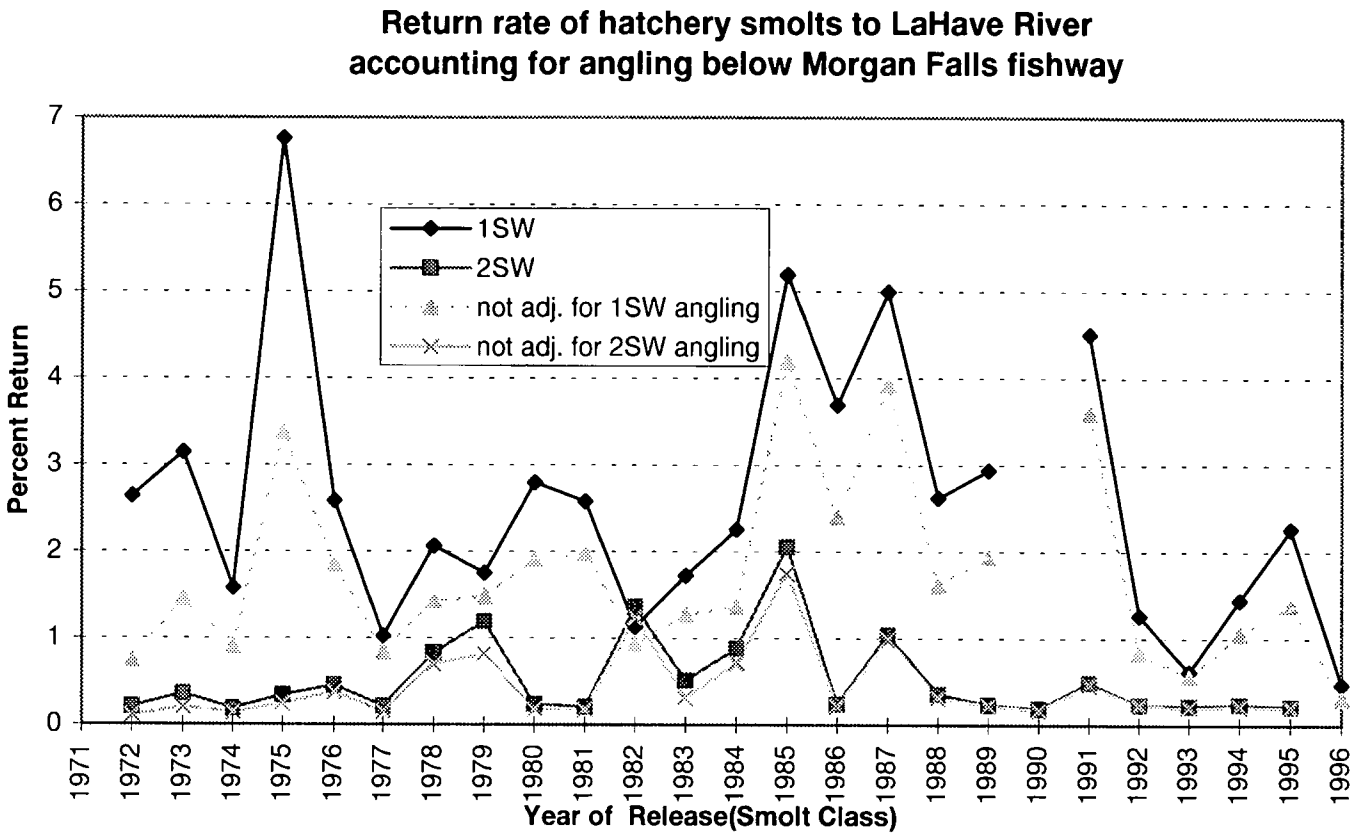

Figure 8. Atlantic salmon smolt to adult returns to Morgan Falls by sea-age at first return for marked smolts and parr stocked above Morgan Falls for smolt years 1972 - 1995.

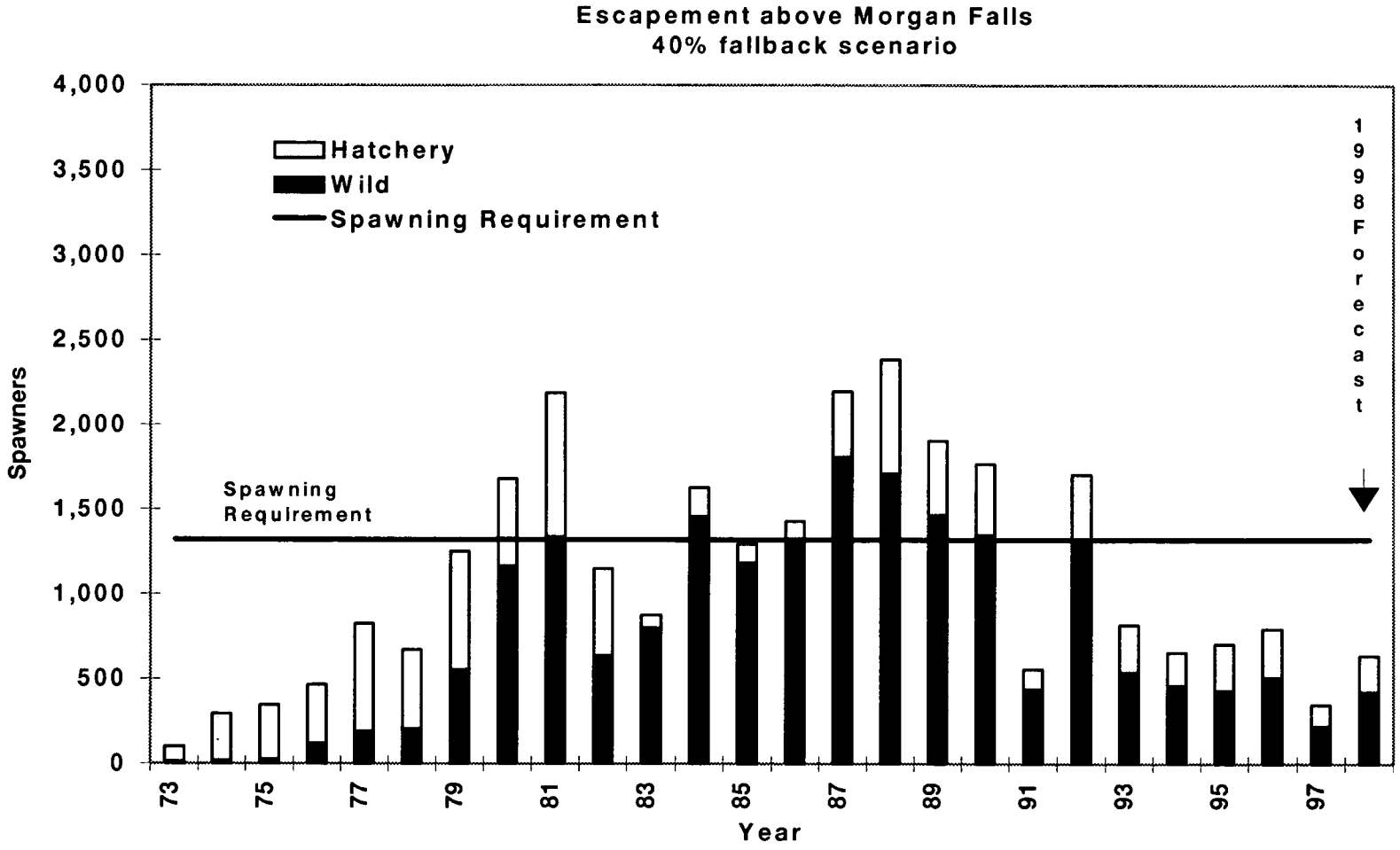

Figure 9. Escapement, numbers of wild and hatchery Atlantic salmon above Morgan Falls on the LaHave River, 1973 - 1997, and forecast for 1998, using a 40% non-return fallback applied to the counts at the fishway.

Appendix 1. Number of hatchery-reared juvenile salmon released at various locations upstream and downstream from Morgan Falls, LaHave River, 1971 - 1997.

	Above Morgan Falls								Below Morgan Falls							
	0+ Parr	1+ Parr		1+ Smolt		2+ Smolt		Total	0+ Parr	1+ Parr		1+ Smolt		2+ Smolt		Total
Year of Release		Untagged	Tagged	Untagged	Tagged	Untagged	Tagged	released above		Untagged	Tagged	Untagged	Tagged	Untagged	Tagged	released below
1971		9,440		4,892	4,892			14,332	No Stocking Below Morgan Falls							
1972		6,790		8,400	8,400	6,450	5,000	21,640	"	"	"	"	"			
1973	51,643	43,133		9,166	4,970	18,526	7,971	122,468	"	"	"	"	"			
1974		3,735		19,815	9,958	14,435	5,890	37,985	"	"	"	"	"			
1975		18,883	13,963					18,883	"	"	"	"	"			
1976		6,875		45,259	9,954	5,769	3,990	57,903	"	"	"	"	"			
1977		44,314		74,577	16,031	5,370	2,000	124,261	"	"	"	"	"			
1978		7,108		72,067	48,832			79,175	"	"	"	"	"			
1979	30,753			33,910	19,942			64,663	"	"	"	"	"			
1980	10,626			62,225	11,651	16,039	5,998	88,890	"	"	"	"	"			
1981				25,482	8,078			25,482	"	"	"	"	"			
1982	NO STOCKING OF HATCHERY REARED FISH IN THE LAHAVE RIVER IN 1982															
1983				28,451				28,451				52,803	28,227			52,803
1984	32,900			15,000	15,000			47,900	11,501			36,002	12,000			47,503
1985	10,804			4,996	4,996			15,800	28,106			37,827	2,995			65,933
1986	55,722			16,864	16,864			72,586	16,995			83,334	4,986			100,329
1987	19,650			33,353	5,240			53,003	23,720			48,888	5,228			72,608
1988	42,481			16,018	9,616			58,499	90,470			28,676	9,631			119,146
1989				30,004	7,804			30,004	53,059			19,701	2,759			72,760
1990	82,432			15,970	4,999			98,402	83,484			26,980	9,999			110,464
1991	83,223			21,943	5,001			105,166	90,370			21,929	10,003			112,299
1992	48,587			27,516	8,000			76,103	40,096			26,006	4,001			66,102
1993	44,512			19,748	8,000			64,260	55,568			49,394				104,962
1994	34,827			26,110	7,999			60,937	29,250			36,071				65,321
1995				19,155	8,000			19,155	72,200							72,200
1996				49,526	5,940			49,526	40,703							40,703
1997				25,261	3,969			25,261	46,400			20,524				66,924