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Status of Saint John River, N.B., Atlantic Salmon in 1985 and Forecast of Returns in 1986

by

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Abstract

Estimated total returns to the Saint John River in 1985 were 12,246 1SW and 14,753 MSW salmon. Homewater removals of 5,147 1SW and 5,635 MSW fish led to an estimated 1985 spawning escapement of 91 percent of the target number of MSW spawners. The forecast of 1986 homewater returns is 9,418 1SW fish (1,818 more than the target escapement) and 13,591 MSW salmon (2,991 fish more than the target escapement and hatchery broodstock requirements). Homing tendencies of the MSW salmon to 'above' and 'below' Mactaquac origins will result in surpluses to spawning requirements of 3,936 fish 'above' Mactaquac and -945 fish 'below' Mactaquac.

Résumé

On a estimé à 12,246 unibermarins (un hiver en mer) et à 14,753 redibermarins (plusieurs hivers en mer) le nombre de saumons qui sont revenus dans le fleuve Saint-Jean en 1985. Des captures, dans les eaux d'origine, de 5,147 unibermarins et de 5,635 redibermarins ont permis de déterminer que l'effectif de frai atteignait en 1985 environ 91 pour cent de nombre cible établi pour les reproducteurs redibermarins. On prévoit qu'en 1986 les retours dans les eaux d'origine se chiffreront à 9,418 unibermarins (soit 1,818 de plus que l'effectif de frai cible) et à 13,591 redibermarins (soit 2,991 de plus que l'effectif de frai cible et que le stock reproducteur requis pour la pisciculture). Les tendances de retour des redibermarins dans les eaux d'origine en "amont" ou en "aval" du barrage de Mactaquac se traduiront par un surplus de 3,936 poissons en aval et de -945 poissons en amont, par rapport à l'effectif de frai cible.

Introduction

This document is the basis of advice for managing Atlantic salmon stocks of the Saint John River, New Brunswick, and as such, documents data and analyses relevant to stock status in 1985 and forecasts for 1986.

Background

Physical attributes of the Saint John River drainage, salmon production area, barriers to migration, fish collection and distribution systems, the role of fish culture operations and status of the salmon stocks since 1970 have previously been described by Marshall and Penney (MS 1983) Penney and Marshall (MS 1984), and Marshall (MS 1984).

Forecasts made in 1984 (Marshall, MS 1984) suggested that total 1985 homewater returns would number approximately 17,400 1SW and 15,500 MSW salmon. CAFSAC advised managers (CAFSAC Advisory Document 84/22) that for 1985 there would be 9,800 1SW and 4,900 MSW salmon surplus to spawning requirements above Mactaquac Dam and 1,700 1SW and 500 MSW fish below Mactaquac.

In 1985, as in 1984, there was a total ban on homewater commercial fisheries and a prohibition on the retention of MSW salmon captured in the sport fisheries. Changes from the 1984 fishing plan included negotiation of June 30 to July 17 and July 28 to Aug. 14 closures within the June 1 to October 15 'open' season of the Kingsclear food fishery (quota remained at 900 'fish') and an extension of the angling season in certain areas by up to two weeks. The reduction of open commercial seasons in Newfoundland 1984 and 1985 and closure of Nova Scotia commercial fisheries in 1985 may be reflected in homewater returns but not in the existing forecasting models. River water levels were low in August and September. Sport fishing success was generally regarded as "good", and up from 1984.

In general, estimates of total returns, removals, required spawners in 1985 and forecasts for 1986 were determined in a manner similar to that of Marshall, (MS 1984). However, as in 1983, returns/removals below Mactaquac were based on preliminary sport fish removals and a 14-year mean exploitation rate for the Nashwaak River. Also, forecasts of 1SW hatchery returns, 1986, were based on adjusted return rates of 1-year smolts to Mactaquac and Kingsclear, 1976, 1978 and 1979 and the numbers of smolts (fish greater than 12 cm fork length) released in April - May 1985.

Methods

Total River Returns, 1985

Total returns of 1SW and MSW salmon of both wild and hatchery origin from both 'above' and 'below' Mactaquac Dam consist of the summation of Mactaquac counts, estimated catches by the Kingsclear Indian Band located between the Mactaquac Dam and Mactaquac Fish Culture Station, estimated angling catches in

the mainstem area immediately below the Mactaquac Fish Culture Station, and estimated by-catch and estimated returns to tributaries below Mactaquac Dam.

Mactaquac counts consist of those fish captured at the fish collection facilities at the Mactaquac Dam and at the smolt migration channel (MC) at the Mactaquac Fish Culture Station. The discontinuation in 1984 of clipping the adipose fin from smolts originating at Mactaquac Fish Culture Station meant that the identification of 1SW returns in 1985 was dependent on fin erosion (principally dorsal fin) and on interpretation of freshwater growth on scales.

Estimates of removals by Kingsclear were obtained from both federal and provincial sources. Relative exploitation rates for 1SW and MSW salmon of hatchery origin (previous tag recovery information) and proportion of hatchery and wild fish at the Dam were used to proportion total removals into hatchery/wild and 1SW/MSW components.

Estimates of by-catch removals were obtained from federal sources. Their subdivision into 1SW/MSW components was approximated using the proportion of both hatchery and wild 1984 homewater returns that the wild 1SW (0.75%) and MSW (3.24%) salmon by-catch were of the potential total homewater wild return to Mactaquac in 1982 (Penney and Marshall, MS 1984; Table 12). Division as to 'above' or 'below' Mactaquac origins was approximated by multiplying 1SW and MSW components by a 15-year mean proportion of wild production above and below Mactaquac weighted by the number of hatchery smolts released both above and below that would have contributed to returns in 1985. Hatchery/wild components of each were reapportioned on the basis of the relative contribution to Mactaquac of the 1983 (MSW) and 1984 (1SW) smolt releases.

The total angling catch from the main stem 'below' Mactaquac was estimated from a creel survey supervised by personnel of the New Brunswick Dept. Forests, Mines and Energy (DFME)(Cronin, pers. comm.). Proportions of 1SW and MSW fish (outside of July and August when each was recorded) and hatchery and wild are assumed to be the same as at the Mactaquac Dam, migration channel and Kingsclear fishery for the appropriate time periods. Ten percent of MSW reported catch was considered to have been removed from the spawning escapement either because of illegal retention or delayed-release mortality after angling.

Returns of wild salmon to tributaries 'below' Mactaquac in 1985 were based on estimated angler harvests in the Nashwaak (DFO), Hammond and Kennebecasis (Pettigrew pers. comm.) rivers and a 14-year mean angler exploitation rate (0.33) for the Nashwaak River. Expansion of these returns to those of the drainage below Mactaquac was done in a fashion similar to that of Penney and Marshall (MS, 1984). Hatchery returns to all tributaries 'below' Mactaquac were calculated as the product of the number of smolts released and the return rate for fish of Mactaquac origin returning to Mactaquac + Kingsclear + the main stem sport fishery.

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Total River Removals, 1985

Total removals include those fish to the Kingsclear Indian Reserve, mainstem sport fishery, 'above' and 'below' Mactaquac, Tobique, Nashwaak, Hammond and Kennebecasis sport catches and the by-catch fishery. Additional removals include fish captured in the Mactaquac collection facilities and transferred to the Aroostook River or retained at Mactaquac for broodstock, mortalities encountered during collection-handling operations, and some fish sacrificed for analysis.

Angling catches for the main stem 'above' Mactaquac and for the Tobique River were guesstimated by DFO personnel. Proportions of 1SW/MSW and hatchery/wild were based on the proportions presumed to be available from releases to each area. Angling catches of 1SW and MSW fish in the Nashwaak River were also estimated by DFO authorities. Division of 1SW and MSW fish into wild and hatchery components was based on the number of smolts released to the Nashwaak, return rates for Mactaquac releases and the 0.33 angler exploitation rate. Estimates of catch in the Kennebecasis and Hammond rivers were provided by Pettigrew, (pers. comm.). Hatchery composition of 1SW and MSW fish was determined in the same manner as for the Nashwaak.

Required Spawners

An accessible salmon-producing substrate of 12,261,000 m^2 'above' Mactaquac and 15,928,000 m^2 'below', an assumed requirement of 2.4 eggs/m^2, a length-fecundity relationship ($\log_e Y_{(eggs)} = 6.06423 + 0.03605X_{(length)}$) applied to MSW and 1SW fish, 1972-1982 and the 1SW:MSW ratios in those years suggest that, on average, approximately 4,400 and 5,700 MSW fish are required 'above' and 'below' Mactaquac (Marshall and Penney, MS 1983). Because 1SW fish contribute so few eggs (fewer than 5% female) a management philosophy was proposed that limited 1SW requirements to that number which provided males for MSW females unaccompanied by MSW males, i.e., 3,200 'above' and 4,000 'below' (Marshall and Penney, op. cit).

Stock Forecasts

a) Wild 1SW salmon 'above' Mactaquac

The forecast of wild 1-SW returns originating 'above' Mactaquac was derived from a regression of total wild 1SW fish returning to the Saint John River which were produced 'above' Mactaquac, 1973-1983, on adjusted egg depositions in the Tobique River, 1968-1969 to 1978-1979 (update of Marshall, MS 1984). Returns of 1SW fish originating above Mactaquac in 1983 were changed in accordance with a redivision of the by-catch to 'above' and 'below' origins. This change resulted from the utilization of 1985 fry densities in the Nashwaak

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River to reconstruct spawning escapement and returns to the Nashwaak River 1984 (Penney and Marshall MS, 1984) and revision of the exploitation rate and angler harvest on the Kennebecasis and Hammond rivers.

Egg depositions for the period 1978-1979 were adjusted in the same manner as Penney and Marshall (MS 1984)using freshwater age composition from 526 wild 1SW fish sampled at Mactaquac in 1985. Adjustment of the 1981 and 1982 egg depositions, principal contributors to 1SW returns in 1986, was done with the use of angular-transformed mean proportions for age 2:1's and age 3^{+}:1's in the 1969 to 1980 year-classes.

To make multiplicative effects of environment, competition, variability in recruits, etc. amenable to linear regression analysis, the natural logarithms of the observed values were used (Ricker, 1975). The geometric mean (GM) Y resultant of the logarithmic relationship was converted to an arithmetic mean (AM) by the formula $\log_{10}(AM/GM) = 0.2172\ s^2\ (N-1)/N$, where s is the standard deviation from the regression line of the normally-distributed natural logarithms of the variates (Ricker, 1975, p. 274).

b) Wild MSW salmon 'above' Mactaquac

The 1986 forecast of MSW returns to homewaters which originated 'above' Mactaquac was based on the regression of the estimated MSW returns to Mactaquac 1971-1985 on the estimated numbers of 1SW fish originating 'above' Mactaquac and returning to Saint John River in the previous year. As in the forecasting of 1SW salmon, analyses included the use of natural logarithms and conversion of the GM to AM.

c) Wild 1SW salmon 'below' Mactaquac

The 1986 return to homewaters of 1SW fish which originated 'below' Mactaquac was estimated from the regression of the estimated numbers of 1SW fish originating 'below' Mactaquac on the estimated number of 1SW fish originating 'above' and returning to Mactaquac in the same years, 1970 to 1984. Because the data were independent of each other, they were not transformed.

d) Wild MSW salmon 'below' Mactaquac

The 1986 return to homewaters of MSW salmon which originated 'below' Mactaquac was based on a regression of the estimated returns of MSW fish 'below' Mactaquac on the number of 1SW returns 'above' Mactaquac. As in previous methods where independent and dependent variables are offset by one or more years, the data were transformed with natural logarithms and GM converted to AM.

e) Hatchery 1SW salmon

The release in 1985 of all 1-year smolts as opposed to principally 2-year smolts, prevented the forecasting of 1SW hatchery returns as the product of the mean 1974-84 return rate for 1SW fish of hatchery origin and the number of smolts released. Instead a return rate for 1SW salmon from 1-year smolts was

derived from experiments in which both 1-year and 2-year tagged smolts were released from Mactaquac in 1976, 1978 and 1979. 1SW return rates of 0.15% for 1-year and 2.7% for 2-year smolts were proportionately adjusted to 0.13% and 2.3% respectively in order to represent 1974-84 average return rates.

Forecasts of hatchery returns in 1986 were then the product of the 0.13% return rate and the number of smolts (greater than 12 cm) released 'at' and 'below' Mactaquac in 1985.

f) Hatchery MSW salmon

Forecasts of MSW returns largely resulting from releases in 1984 of 2-year hatchery-reared smolts 'above' and 'below' Mactaquac were based on the regression of the number of hatchery MSW returns 1976 to 1985 on the number of hatchery 1SW returns 1975 to 1984. As in previous regressions of data from off-set years, analyses included the use of natural logarithms and conversion of the GM to AM.

Results

Total River Returns, 1985

Estimated homewater returns in 1985 totalled 12,246 1SW fish (8,482 originating 'above' and 3,764 originating 'below' Mactaquac) and 14,753 MSW fish (10,907 originating 'above' and 3,846 originating 'below' Mactaquac; Table 1). Hatchery returns comprised 20.5 and 7.8% of the total 1SW and MSW returns, respectively.

Counts at Mactaquac were 83.4% of the 1SW and 63.8% of the MSW fish estimated to have originated 'at' or 'above' Mactaquac (Table 1).

The total removal at Kingsclear was conservatively estimated at 3,000 fish. Proportioning on the basis of the 0.0414 and 0.2193 mean exploitation rates for hatchery 1SW and MSW fish at Kingsclear, 1978-1984, (Table 2) provided estimates of 483 1SW and 2,517 MSW salmon.

Subdivision of a total of 2,825 salmon in the by-catch suggested that 1SW and MSW components could number 531 1SW and 2,294 MSW fish respectively, (Table 1). Mainstem angling yielded an estimated 607 1SW and 58 MSW fish.

Returns of 3,310 wild 1SW and 3,553 wild MSW salmon to tributaries 'below' Mactaquac were based on estimated 1985 angler catches of 800 1SW and 450 MSW fish on the Nashwaak, 175 1SW and 300 MSW fish on the Hammond and Kennebecasis rivers combined and a 14-year mean exploitation rate of 0.33 for the Nashwaak River (Tables 3 and 4). The mean exploitation rate reflects estimated removals from the Nashwaak in 1984 by Cronin (pers. comm.) rather than DNR "Fissys" and an estimated deposition of 9.7 million eggs in the Nashwaak (back-calculated from a mean density of 22.5 fry/100 m^2 in 1985)(Table 3).

Releases of 48,772 and 46,126 hatchery smolts 'below' Mactaquac in 1983 and 1984 respectively, and the 1984 return rates of 0.997% and 0.595% for smolts released at Mactaquac (Table 5) in the same years suggested respective returns of approximately 460 1SW fish and 290 MSW fish below Mactaquac.

Total River Removals, 1985

Total river removals, numbered 5,147 1SW and 5,635 MSW fish (Table 6). Approximately 77% and 82% of 1SW and MSW fish removed originated 'above' Mactaquac. The estimated angling kill was 4,035 1SW salmon and 323 MSW fish.

Spawning Escapement, 1985

Collation of the total returns (Table 1), total removals (Table 6) and numbers of fish required to meet an egg deposition of 2.4 eggs/m^2 indicates that 143% and 49% of the required MSW spawners for 'above' and 'below' Mactaquac, respectively, were attained (Table 7). For 1SW fish, 141% of requirements were met 'above' Mactaquac; 59% of requirements were met 'below' Mactaquac.

Stock Forecasts

a) Wild 1SW salmon above Mactaquac

The 1986 forecast of wild 1SW fish returning to Mactaquac in the absence of homewater removals was based on the regression of returns to homewaters of 1SW fish which originated 'above' Mactaquac (Table 8) on estimated Tobique River egg depositions (Table 9) adjusted for smolt age (Tables 10 and 11). 1SW returns and adjusted egg depositions provided a log-transformed equation and AM estimate for 1986 of 5,075 1SW fish (95% C.L. 3,871-6,655) (Table 12).

b) Wild MSW fish 'above' Mactaquac

Based on the regression $\log_e Y = 4.546 + 0.496 \log_e X$ (n=15, r=0.70, p= 0.004) the 6,422 1SW returns in 1985 (X) provide a forecast of 7,702 MSW fish (95% C.L. 6,031-9,835) originating 'above' Mactaquac which will return to homewaters in 1986 (Table 12).

c) Wild 1SW fish 'below' Mactaquac

Regression of the estimated returns of 1SW fish 'below' Mactaquac on the number of 1SW returns 'above' Mactaquac, 1970-1984, (data from Table 8) resulted in the equation $Y = 2479.702 + 0.329 X$; r=0.58; p = 0.023. The forecast value of 5,075 1SW fish to Mactaquac yielded an estimate of 4,151 1SW fish (95% C.L. 3,458-4,844) destined for tributaries 'below' Mactaquac in 1986.

e) Wild MSW fish 'below' Mactaquac

Regression of the estimated returns of MSW fish 'below' Mactaquac (Table 8) on the number of 1SW returns 'above' Mactaquac (Table 8) resulted in the equation $\log_e Y=5.406 + 0.335 \log_e X$; r=0.53; p=0.04. AM Y(1986) was 4,501 MSW salmon (95% C.L. 3,471-5,838) originating 'below' Mactaquac.

e) Hatchery 1-SW salmon

The product of the 0.13% return and 89,051 smolts (1-year fish greater than 12 cm fork length) released at Mactaquac and 56,992 smolts released below Mactaquac in 1985 resulted in respective forecasts of 117 and 75 1SW fish returning in 1986. Release of an additional 143,658 and 211,665 1-year fish less than 12 cm fork length 'above' and 'below' Mactaquac respectively, will require attention in forecasts for 1987.

f) Hatchery MSW salmon

Regression of the estimated MSW returns 1976 to 1985 on 1SW returns 1975 to 1984 (Table 5) resulted in the equation $\log_e Y = 2.288 + 0.613 \log_e X$; r = 0.76; p = 0.01, n = 10. Solving 'Y' for an 'X' value of 2,060 1SW fish to Mactaquac in 1985 yielded an estimate of 1,134 MSW fish (95% C.L. 753-1,710). The 1,134 MSW fish would represent a return rate of 0.0055 (1134/206,462), limits of 0.0036 to 0.0083, which when applied to 46,134 smolts released 'below' Mactaquac in 1984 would forecast 254 (166-383) MSW returns 'below' Mactaquac in 1986.

Forecast Summary

The forecast of total homewater returns (Table 13) to the Saint John River in 1986 is 9,418 1SW (9,226 of wild and 192 of hatchery origin) and 13,591 MSW fish (12,203 of wild and 1,388 of hatchery origin). For the total Saint John River the forecast returns minus the spawning requirements results in a potential surplus of 1,818 1SW and 2,991 MSW salmon. Separation to 'above' and 'below' Mactaquac origins indicates a surplus over target escapements of 1,992 1SW and 3,936 MSW salmon for the former and deficits of 174 1SW fish and 945 MSW salmon for the latter.

Discussion

Total river returns in 1985 of 12,246 1SW and 14,753 MSW fish were 70% and 95% of forecast returns. Returns of wild 1SW fish 'above' and 'below' Mactaquac were 90% and 65%, respectively, of forecasts; wild MSW fish 'above' and 'below' were 119% and 60% of the respective forecast values. Hatchery 1SW and MSW fish were 48% and 99% of forecasts. Spawning requirements for MSW fish 'above' Mactaquac were exceeded by 43%; escapement below was about 50% of requirements.

Estimated total river removals (excl. of broodstock) in 1985 numbered some 10,200 salmon - over 50% of which were attributed to the by-catch and native

fisheries. The by-catch and native fisheries were the highest and second highest, respectively in recent record (Table 14).

Estimation of salmon returning and forecast to return to the Saint John River 'below' Mactaquac is of concern. Estimation of 1984 spawners in the Nashwaak from 1985 fry densities reduced estimates of 1SW and MSW salmon from those determined by the proportionate production method (Marshall, MS 1984) by 56% and 45%, respectively. Use of a mean exploitation rate of 0.33 to describe a rate which could range from 0.2 to 0.5 and estimates of sport catch which may vary according to source by a factor of two highlight the potential for error.

Returns counted 'at' Mactaquac and those estimated to have been intercepted in homeriver fisheries remain as the basis of the assessment. For these stocks, sufficient data may now be in hand to define stock and recruitment parameters essential to better assessments of stocks 'below' Mactaquac.

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Table 1. Estimated total returns of wild and hatchery 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam to the Saint John River, N.B., 1985.

Sea-age	Components	Number of fish: Origin above Mactaquac Wild	Hatch.	Total	Origin below Mactaquac Wild	Hatch.	Total	Total Wild	Hatch.	Total
1SW										
	Mactaquac counts	5,331	1,742	7,073	-	-	-	5,331	1,742	7,073
	Kingsclear catch[a]	389	94	483	-	-	-	389	94	483
	Angled MS below Mactaquac	460	147	607	-	-	-	460	147	607
	By-catch[b]	242	77	319	201	11	212	443	88	531
	Returns to tribs. below Mactaquac	-	-	-	3,109	443	3,552	3,109	443	3,552
	Totals	6,422	2,060	8,482	3,310	454	3,764	9,732	2,514	12,246
MSW										
	Mactaquac counts	6,391	565	6,956	-	-	-	6,391	565	6,956
	Kingsclear catch[a]	2,337	180	2,517	-	-	-	2,337	180	2,517
	Angled MS below Mactaquac	53	5	58	-	-	-	53	5	58
	By-catch[b]	1,266	110	1,376	890	28	918	2,156	138	2,294
	Returns to tribs. below Mactaquac	-	-	-	2,663	265	2,928	2,663	265	2,928
	Totals	10,047	860	10,907	3,553	293	3,846	13,600	1,153	14,753

a estimated at 2,800 fish and an additional 200 fish "poached"
b estimated at 2,825 fish

Table 2. Tag recoveries from 1SW and MSW salmon of hatchery origin taken at Mactaquac Dam and Kingsclear, 1976-1985.

	1SW			MSW		
	No. tag returns		Exploit.	No. tag returns		Exploit.
Year	Mact. Dam	Kingscl.	rate	Mact. Dam	Kingscl.	rate
1976	271	0	0.0	74	0	0.0
1977	252	2	0.0079	109	13	0.1066
1978	109	3	0.0268	94	20	0.1754
1979	300	11	0.0354	71	20	0.2198
1980	838	42	0.0477	197	50	0.2024
1981	185	9	0.0464	126	33	0.2076
1982	92	4	0.0417	54	39	0.4194
1983	51	1	0.0192	20	2	0.0909
1984	47	0	0.0000	54	9	0.1429
1985[1]	97	0		47	0	
1978-1984	1622	70	0.0414	616	173	0.2193

[1]Counts at Mactaquac Dam for entire season; tag returns from Kingsclear are not necessarily complete.

Table 3. Parameters and derivation of total returns of salmon and of angling exploitation rates for the Nashwaak River, 1970-1985.

Year	Sea-age	Eggs/F[a]	Prop. F	Prop. pop'n[b]	Eggs/fish[c]	Egg prop's	Total eggs[d] (1,000's)	No. F's[e]	No. M+F[f]	No. angled	Total returns	Exploit. rate
1970	1SW	3,592	.23	.487	402	.118	1,226.6	341	1,484	811	2,295	.35
	MSW	6,828	.86	.513	3,012	.882	9,167.9	1,343	1,561	854	2,415	.35
1971	1SW	3,389	.23	.781	609	.323	1,448.2	427	1,858	733	2,591	.28
	MSW	6,778	.86	.219	1,277	.677	3,035.7	448	521	205	726	.28
1972[g]	1SW		.32							581	1,205	.48
	MSW		.83							926	1,890	.49
1973[g]	1SW		.20							408	1,447	.28
	MSW		.86							923	3,456	.27
1974	1SW	3,238	.16	.533	276	.074	1,049.1	324	2,025	495	2,520	.20
	MSW	8,182	.90	.467	3,439	.926	13,127.9	1,604	1,783	433	2,216	.20
1975	1SW	3,238	.23[h]	.587	437	.138	1,290.7	399	1,733	663	2,396	.28
	MSW	7,677	.86[h]	.413	2,727	.862	8,061.9	1,050	1,221	467	1,688	.28
1976	1SW	3,692	.23	.650	552	.198	1,666.0	451	1,962	1,746	3,708	.47
	MSW	7,441	.86	.350	2,240	.802	6,748.3	907	1,055	941	1,996	.47
1977	1SW	3,492	.23	.479	385	.102	1,012.9	290	1,261	1,096	2,357	.46
	MSW	7,551	.86	.521	3,383	.898	8,917.4	1,181	1,373	1,190	2,563	.46
1978	1SW	3,676	.23	.469	397	.100	1,574.7	428	1,862	451	2,313	.20
	MSW	7,775	.86	.531	3,551	.900	14,172.6	1,823	2,120	511	2,631	.19
1979	1SW	3,368	.23	.813	630	.328	1,443.1			960	2,823	.35[i]
	MSW	8,018	.86	.187	1,289	.672	2,956.6			221	650	.35[i]
1980	1SW	3,891	.23	.483	432	.114	1,252.5	322	1,400	1,107	2,507	.44
	MSW	7,548	.86	.517	3,356	.886	9,734.5	1,290	1,500	1,183	2,683	.44
1981	1SW	3,233	.23	.685	509	.201	1,986.1	614	2,671	1,085	3,756	.29
	MSW	7,455	.86	.315	2,020	.799	7,894.8	1,059	1,231	498	1,729	.29
1982	1SW	4,084	.23	.617	580	.192	1,098.8	269	1,170	1,278	2,448 (2,164)[j]	.52
	MSW	7,390	.86	.383	2,434	.808	4,624.3	626	728	792	1,520	.52
1983	1SW	3,512[k]	.23	.618	499	.166	1,186.9	338	1,470	420	1,890 (1,750)[j]	.22
	MSW	7,609[k]	.86	.382	2,500	.834	5,963.3	783	910	260	1,170 (1,127)[j]	.22
1984	1SW	3,512[k]	.23	.510	412	.114	1,101.7	314	1,365	434[n]	1,799 (1,639)[m]	.24
	MSW	7,609[k]	.86	.490	3,206	.886	8,562.0	1,125	1,308	41	1,349 (1,233)[m]	—
1985	1SW									800[p]	2,424 (2,230)[q]	.33[r]
	MSW									45	1,364 (1,281)[q]	—

[a] values for wild fish at Mactaquac.
[b] From Prov. angling.
[c] Product of first 3 columns.
[d] Egg prop.'s x eggs
[e] Eggs/eggs per F.
[f] No. F's/prop. F.
[g] Derived from fence data.
[h] Mean of fence and Westfield data.
[i] Mean of arcsin transformed data, 1970-1982
[j] Wild fish only; see footnote 'k' in Table 16 of Penney and Marshall (MS, 1984).
[k] Eleven-year mean at Mactaquac.
[m] Wild fish only (hatchery 1SW, 16,000x.01; hatchery 2SW, 18,000x.00646).
[n] Cronin, pers. comm.
[p] DFO estimate
[q] Wild fish only (hatchery 1SW, 20,164x.00960; hatchery 2SW, 16,000x.00519).
[r] 14-year mean of arcsin transformed data.

Table 4. Estimated returns of 1SW and MSW salmon to tributaries[a] below Mactaquac Dam, Saint John River, 1970-1985.

Sea-age	Year	No. of wild salmon				
		Nashwaak	Nashwaak x 0.16	Kennebecasis and Hammond	Kennebecasis and Hammond x 0.49	Total
1SW	1970	2,295	368	46	23	2,732
	1971	2,591	415	126	62	3,194
	1972	1,205	193	15	7	1,420
	1973	1,447	232	477	234	2,390
	1974	2,520	403	1,060	519	4,502
	1975	2,396	383	394	193	3,366
	1976	3,708	593	1,446	709	6,456
	1977	2,357	377	628	308	3,670
	1978	2,313	370	154	75	2,912
	1979	2,823	452	1,212	594	5,081
	1980	2,507	401	592	290	3,790
	1981	3,756	601	1,251	613	6,221
	1982	2,164	346	1,227[b]	601	4,338
	1983	1,750	280	1,314[b]	645	3,989
	1984	1,639	262	1,038[cd]	509	3,448
	1985	2,230	357	350[ef]	172	3,109
MSW	1970	2,451	392	62	30	2,935
	1971	726	116	146	72	1,060
	1972	1,890	302	57	28	2,277
	1973	3,456	553	229	112	4,350
	1974	2,216	355	674	330	3,575
	1975	1,688	270	537	263	2,758
	1976	1,996	319	814	399	3,528
	1977	2,563	410	2,177	1,067	6,217
	1978	2,631	421	340	167	3,559
	1979	650	104	326	160	1,240
	1980	2,683	429	1,292	633	5,037
	1981	1,729	277	571	280	2,857
	1982	1,520	243	823	403	2,989
	1983	1,127	180	709[b]	347	2,363
	1984	1,233	197	1,346[cd]	660	3,436
	1985	1,281	205	790[ef]	387	2,663

[a] where Nashwaak represents 31.0 percent and Hammond + Kennebecasis equals 42.9% of production area below Mactaquac Dam.

[b] wild fish only (hatchery fish removed as per footnote j, Table 3, where hatchery smolt releases to Kennebecasis + Hammond were 24,518 in 1981 and 24,714 in 1982).

[c] based on DNR 'Fissys' estimate (303 1-SW and 359 M-SW) and exploitation rate of 0.24.

[d] wild fish only (hatchery fish removed per the product of 24,714 smolts in 1982 and a return rate of 0.00646 and 23,000 smolts in 1983 and a return rate of 0.01).

[e] based on estimate of 175 1-SW and 300 M-SW fish (Pettigrew, pers. comm.).

[f] hatchery fish from 23,000 smolts in 1983 and 18,760 smolts in 1984, removed using respective return rates of 0.00519 and 0.00960.

Table 5. Estimated total returns to the Saint John River from hatchery-reared smolts released at Mactaquac, 1974-1985.

Year of release (i)	Number of smolts	Prop. 1-yr smolt	Year of return	Number of returns: Mactaquac MC	Mactaquac Dam	Kingscl.	Angled MS	By-catch	Comm-ercial	Total	% Return
			i+1								
1974	337,281	0.00		1,771	3,564	28	977	34		6,374	1.890
75	324,186	0.06		2,863	4,831	219	1,129	32		9,074	2.799
76	297,350	0.14		1,645	4,533	36	708	70		6,992	2.351
77	293,132	0.26		777	1,779	49	369	70		3,044	1.038
78	196,196	0.16		799	2,722	100	186	20		3,827	1.951
79	244,012	0.09		3,072	6,687	335	640	59		10,793	4.423
80	232,258	0.12		921	2,861	139	350	74	385	4,730	2.037
81	189,090	0.08		828	1,464	64	267	21	202	2,846	1.505
82	172,231	0.06		374	857	39	69	11	95	1,445	0.839
83	144,549	0.22		476	828	36	61	47	0	1,448	1.000
84	206,462	0.28		454	1,288	94	147	77	0	2,060	0.998
85	89,051	1.00									
1974-1984	2,636,747									52,633	1.996[a]
1974	337,281		i+2	310	1,313	392	267	20		2,302	0.683
75	324,186			341	1,727	206	417	34		2,725	0.841
76	297,350			223	1,728	368	165	50		2,534	0.852
77	293,132			145	747	210	65	21		1,188	0.405
78	196,196			302	1,992	506	146	46		2,992	1.525
79	244,012			126	963	252	125	147	999	2,612	1.070
80	232,258			88	640	462	181	50	110	1,531	0.659
81	189,090			44	255	76	17	23	166	581	0.307
82	172,231			84	722	199	5	102	0	1,112	0.646
83	144,549			73	492	180	5	110	0	860	0.595
84	206,462										
85	89,051										
1974-1983	2,430,285									18,437	0.759[a]

[a] unweighted.

Table 6. Estimated homewater removals of 1-SW and M-SW salmon originating 'above' and 'below' Mactaquac Dam on the Saint John River, N.B., 1985.

Sea-age	Components	Number of fish								
		Origin above Mactaquac			Origin below Mactaquac			Total		
		Wild	Hatch.	Total	Wild	Hatch.	Total	Wild	Hatch.	Total
1SW										
	Kingsclear Indians	389	94	483	-	-	-	389	94	483
	Angled									
	Tobique River	1,808	452	2,260	-	-	-	1,808	452	2,260
	Mainstem above Mact.	160	33	193	-	-	-	160	33	193
	Mainstem below Mact.	460	147	607	-	-	-	460	147	607
	Nashwaak River	-	-	-	736	64	800	736	64	800
	Hammond River	-	-	-	19	31	50	19	31	50
	Kennebecasis River				96	29	125	96	29	125
	Trucked to Aroostook R.	-	95	95	-	-	-	-	95	95
	Hatchery broodfish	-	-	-	0	0	0	0	0	0
	Mortalities, etc.	0	3	3	0	0	0	0	3	3
	By-catch	242	77	319	201	11	212	443	88	531
	Totals	3,059	901	3,960	1,052	135	1,187	4,111	1,036	5,147
MSW										
	Kingsclear Indians	2,337	180	2,517	-	-	-	2,337	180	2,517
	Angled[a]									
	Tobique River	140	10	150	-	-	-	140	10	150
	Mainstem above Mact.	36	2	38	-	-	-	36	2	38
	Mainstem below Mact.	53	5	58	-	-	-	53	5	58
	Nashwaak River	-	-	-	42	3	45	42	3	45
	Hammond River	-	-	-	8	1	9	8	1	9
	Kennebecasis River	-	-	-	20	3	23	20	3	23
	Trucked to Aroostook R.	-	24	24	-	-	-	-	24	24
	Hatchery broodfish	297	75	372	26	4	30	323	79	402
	Mortalities, etc.	56	13	69	4	2	6	60	15	75
	By-catch	1,266	110	1,376	890	28	918	2,156	138	2,294
	Totals	4,185	419	4,604	990	41	1,031	5,175	460	5,635

[a] 10% of angled MSW fish assumed to be lost from spawning escapement.

Table 7. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam, Saint John River, 1985.

Sea-age	Category	Numbers of fish: Origin above Mactaquac Wild	Origin above Mactaquac Hatch.	Origin below Mactaquac Wild	Origin below Mactaquac Hatch.	Total Wild	Total Hatch.	Total Both
1SW								
	Homewater returns	6,422	2,060	3,310	454	9,732	2,514	12,246
	Homewater removals	3,059	901	1,052	135	4,111	1,036	5,147
	Spawners	3,363	1,159	2,258	319	5,621	1,478	7,099
	Target spawners	3,200		4,400				7,600
	Percentage of target spawners	141		59				93
MSW								
	Homewater returns	10,047	860	3,553	293	13,600	1,153	14,753
	Homewater removals	4,185	419	990	41	5,175	460	5,635
	Spawners	5,862	441	2,563	252	8,425	693	9,118
	Target spawners	4,400[a]		5,700				10,100[a]
	Percentage of target spawners	143		49				90

[a] Excludes 500 broodfish required at Mactaquac FCS.

Table 8. Estimated total returns of wild 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam, Saint John River, 1970-1984.

Sea-age	Year	(1) Mact. count	(2) Kings-clear	(3) Angled MS	(4) Trib. Returns BL. Mact.[a]	(5) Comm. fishery Total	(6) Comm. fishery Above	(7) Comm. fishery Below	(8) By-catch Total	(9) By-catch Above[c]	(10) By-catch Below[d]	Total returns (proportions) Above	Below	Total
1SW														
	1970	2,874		78	2,732	200	105[b]	98[b]	3			3,057	2,830	5,887
	71	1,592		60	3,194	166	57	109	0			1,709	3,303	5,012
	72	784		83	1,420				107	41	66	908	1,486	2,394
	73	1,854		179	2,390				81	37	44	2,070	2,434	4,504
	74	3,389	27	214	4,502				59	26	33	3,656	4,535	8,191
	75	5,725	45	1,052	3,366				54	36	18	6,858	3,384	10,242
	76	6,797	307	1,014	6,456				52	29	23	8,147	6,479	14,626
	77	3,507	28	403	3,670				76	39	37	3,977	3,707	7,684
	78	1,584	43	231	2,912				113	44	69	1,902	2,981	4,883
	79	6,234	228	331	5,081				62	35	27	6,828	5,108	11,936
	80	7,555	378	503	3,790				67	46	21	8,482	3,811	12,293
	81	4,571	222	428	6,221	730	470	260	194	91	103	5,782	6,584	12,366
	82	3,932	171	466	4,338	1,482	352	1,130	79	37	42	4,958	5,510	10,468
	83	3,623	164	207	3,989	1,091	283	808	68	32	36	4,309	4,833	9,142
	84	7,353	317	351	3,448				387[e]	271	116	8,292	3,564	11,856
Mean												4,729 (.54)	4,037 (.46)	8,766 (1.00)
MSW	1970	2,449		59	2,935	6,934	3,204[b]	3,749[b]	19			5,712	6,684	12,396
	71	2,235		89	1,060	3,473	2,391	1,082	0			4,715	2,142	6,857
	72	4,831		62	2,277				9	6	3	4,899	2,280	7,179
	73	2,367		91	4,350				165	60	105	2,518	4,455	6,973
	74	4,775	569	459	3,575				13	8	5	5,811	3,580	9,391
	75	6,200	739	446	2,758				77	56	21	7,441	2,779	10,220
	76	5,511	1,646	950	3,528				101	70	31	8,177	3,559	11,736
	77	7,247	864	1,489	6,217				184	112	72	9,712	6,289	16,001
	78	3,034	645	263	3,559				151	79	72	4,021	3,630	7,651
	79	1,993	561	152	1,240				70	48	22	2,754	1,262	4,016
	80	8,157	2,069	533	5,037				244	165	79	10,924	5,116	16,040
	81	2,441	639	282	2,857	4,983	2,291	2,692	669	338	331	5,991	5,880	11,871
	82	2,262	1,626	592	2,989	2,440	359	2,081	332	162	170	5,001	5,240	10,241
	83	1,712	512	98	2,363	2,651	986	1,665	309	139	170	3,447	4,198	7,645
	84	7,011	1,934	41	3,436				1,061[e]	767	294	9,753	3,730	13,483
Mean												6,058 (.60)	4,055 (.40)	10,113 (1.00)

[a]Reference Table 4.
[b]Values include by-catch.
[c]Columns (1+2+3+6)/columns (1+2+3+6+4+7) x Col. 8, where the 1970 and 1971 commercial and by-catch are combined and treated as by-catch in 1982; hatchery fish removed.
[d]Below = (Total-Above).
[e]Based on Fishery Officer estimates and a mean of 18.% 1SW fish among the by-catch; 1982 hatchery fish removed.

Table 9. Numbers of eggs/100 m^2 deposited in the Tobique River, 1968-1982, and derivation of weighted numbers of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-1983 and 1986 (for explanation see Penney and Marshall (MS 1984)).

Tobique egg deposition		Proportion of age at smoltification[a]		Eggs/100 m^2 contributing to 1SW fish		Total wt'd egg contrib/100 m^2 to 1SW fish @ Mact. (yr)
Year	Eggs/100 m^2	Age 2	Age 3^+	Yr i	Yr i+1	
1968	5.7	.207				
			.793		4.55	
1969	43.6	.445		19.40		23.95 (1973)
			.555		24.20	
1970	60.9	.269		16.38		40.58 (1974)
			.731		44.52	
1971	71.2	.419		29.83		74.35 (1975)
			.581		41.37	
1972	130.8	.619		80.96		122.33 (1976)
			.381		49.84	
1973	86.5	.411		35.55		85.39 (1977)
			.589		50.95	
1974	269.4	.114		30.71		81.66 (1978)
			.886		238.69	
1975	368.2	.361		132.92		371.61 (1979)
			.639		235.28	
1976	245.4	.388		95.22		330.50 (1980)
			.612		150.18	
1977	309.2	.306		94.62		244.80 (1981)
			.694		214.58	
1978	193.2	.385		74.38		288.96 (1982)
			.615		118.82	
1979	112.3	.430		48.29		167.11 (1983)
			.570		64.01	
1980	362.1					
1981	118.7					
			.643[b]		76.32	
1982	139.8	.357[b]		49.91		126.23 (1986)

[a] derived from Tables 11 and 12.

[b] mean (n=12) calculated with angular transformation.

Table 10. Freshwater age and numbers of 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1975-1985, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1975-1985.

Freshwater-age	Numbers of 1SW fish										
	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984[b]	1985
A											
2	1,941	3,962	922	391	3,166	2,214	1,280	794	2,348	4,140	1,264
3	3,727	2,658	2,545	1,160	2,974	4,986	2,861	2,902	1,264	3,132	3,913
4	57	177	39	33	94	355	430	236	11	81	144
5											5
6											5
Total	5,725	6,797	3,506	1,584	6,234	7,555	4,571	3,932	3,623	7,353	5,331
B											
2	2,325	4,749	1,046	469	3,468	2,486	1,619	1,001	2,793	4,669	1,523
3	4,465	3,186	2,887	1,393	3,257	5,598	3,619	3,659	1,503	3,532	4,714
4	68	212	44	40	103	398	544	298	13	91	173
5											6
6											6
Total	6,858	8,147	3,977	1,902	6,828	8,482	5,782	4,958	4,309	8,292	6,422

[a] changed from Penney and Marshall (MS 1984, Table 13) based on re-reading scale samples.

[b] changed from Marshall (MS 1984) based on reproportioning of by-catch.

Table 11. Numbers of wild 1SW salmon and proportion of age 2:1's of the total that would have returned to Mactaquac for the 1969-1980 year-classes (numbers of 1SW fish from Table 10 this document and Table 10, Marshall MS 1984)

Year class (i)	Numbers at age of 1SW returns to Mactaquac				Prop. 2:1's of total
	2:1 (i+3)	3:1 (i+4)	4:1 (i+5)	Total	
1968		690	41		
1969	127	451	37	615	.207
1970	1,578	1,901	68	3,547	.445
1971	1,718	4,465	212	6,395	.269
1972	2,325	3,186	44	5,555	.419
1973	4,749	2,887	40	7,676	.619
1974	1,046	1,393	103	2,542	.411*
1975	469	3,257	398	4,124	.114*
1976	3,468	5,598	544	9,610	.361
1977	2,486	3,619	298	6,403	.388
1978	1,619	3,659	13+6	5,296	.306
1979	1,001	1,503	91+6	2,601	.385
1980	2,793	3,532	173	6,498	.430
1981	4,669	4,714			
1982	1,523				

* influenced by 1977 smolt-class with its reduced survival.

Table 12. Adjusted Tobique River egg deposition[a]/100 m^2 in year i and year i+1 recruiting to total wild 1SW and MSW salmon which would have returned to Mactaquac in the absence of homewater removals in year i+5 and i+6 respectively, resultant MSW:1SW salmon ratios, and forecast numbers of 1SW and MSW fish to Mactaquac in the absence of homewater removals in 1986.

Year i-i+1 (1)	Eggs/100 m^2 (2)	Total 1SW i+5 (3)	Total MSW i+6 (4)	MSW/ 1SW (5)
1965-66		3,057	4,715	1.54
1966-67		1,709	4,899	2.87
1967-68		908	2,518	2.77
1968-69	23.95	2,070	5,811	2.81
1969-70	40.58	3,656	7,441	2.04
1970-71	74.35	6,858	8,177	1.19
1971-72	122.34	8,147	9,712	1.19
1972-73	85.39	3,977	4,021	1.01
1973-74	81.66	1,902	2,754	1.45
1974-75	371.61	6,828	10,924	1.60
1975-76	330.50	8,482	5,991	0.71
1976-77	244.80	5,782	5,001	0.86
1977-78	288.96	4,958	3,447	0.69
1978-79	167.11	4,309	9,753	2.26
1979-80		8,292	10,047	1.21
1980-81		6,422	7,702[c]	
1981-82	126.23	5,075[b]		

[a] See Tables 9, 10, and 11 for weighting procedure and update of Marshall (MS 1984).

[b] Based on regression of 1SW returns to Mactaquac, 1973-1983, (col. 3) on adjusted egg deposition in Tobique River, 1968-1969 to 1978-1979, (col. 2):

$$\log_e Y = 6.626 + 0.379 \log_e X;\ n=11,\ r=0.67,\ p= 0.025$$

$$Y_{1986} = 5,075(AM);\ 95\%\ C.L. = 3,871 \text{ to } 6,655$$

[c] Based on regression of MSW returns to Mactaquac 1971-1985, (col. 4) on 1SW returns to Mactaquac 1970-1984, (col. 3):

$$\log_e Y = 4.546 + 0.496 \log_e X;\ n=15,\ r=0.70,\ p= 0.004$$

$$Y_{1986} = 7,702(AM);\ 95\%\ C.L. = 6,031 \text{ to } 9,835$$

Table 13. Summary of the 1986 salmon forecast for the Saint John River, New Brunswick (95% C.L. are shown in parentheses).

Requirement	1SW			MSW		
	Wild	Hatch.	Total	Wild	Hatch.	Total
Above Mactaquac	5,075 (3,871-6,655)	117	5,192	7,702 (6,031-9,835)	1,134 (753-1,710)	8,836
Target escpm.			3,200			4,400 + 500[1]
Surplus			+ 1,992			+ 3,936
Below Mactaquac	4,151 (3,458-4,844)	75	4,226	4,501 (3,471-5,838)	254 (166-383)	4,755
Target escpm.			4,400			5,700
Surplus			- 174			- 945
Total	9,226	192	9,418	12,203	1,388	13,591
Target escpm.			7,600			10,100 + 500[1]
Surplus			+ 1,818			+ 2,991

[1] Broodfish for Mactaquac Fish Culture Station.

Table 14. Commercial (inc. by-catch), sport (DFME bright fish) and Native (Kingsclear estimated from tags) landings of 1SW and MSW salmon on the Saint John River, 1949-1985. (Numbers of fish in 1,000s).

	Commercial[a]			Sport			Native			
Year	1SW	MSW	Total	1SW	MSW	Total	1SW	MSW	Total	Grand Total
1949	1.5	16.1	17.6							
1950	1.1	12.4	13.5							
1951	1.6	17.9	19.5							
1952	1.1	12.1	13.2							
1953	1.6	14.9	16.5							
1954	0.9	9.5	10.4							
1955	0.8	5.5	6.3							
1956	0.6	4.9	5.5							
1957	0.8	6.9	7.7							
1958	1.2	13.8	15.0							
1959	2.1	14.3	16.4							
1960	1.0	10.6	11.6							
1961	0.8	9.5	10.3							
1962	0.5	5.5	6.0							
1963	0.6	4.2	4.8							
1964	0.9	9.4	10.3							
1965	1.5	17.8	19.3							
1966	1.5	18.9	20.4							
1967	0.7	9.4	10.1							
1968	0.7	7.3	8.0							
1969	0.3	2.5	2.8	1.5	0.6	2.1				4.9
1970	0.4	5.4	5.8	1.3	1.3	2.6				8.4
1971	0.3	2.6	2.9	1.2	0.7	1.9				4.8
1972	0.1	.1	0.1	0.9	1.6	2.5				2.6
1973	0.1	0.2	0.3	1.3	1.5	2.8				3.1
1974	0.1	.1	0.1	2.0	2.5	4.5	.1	0.6	0.6	5.2
1975	0.1	0.1	0.2	2.5	1.7	4.2	0.1	0.7	0.8	5.2
1976	0.1	0.1	0.2	4.7	2.8	7.5	0.5	2.0	2.5	10.2
1977	0.1	0.2	0.3	4.3	4.4	8.7	0.1	1.1	1.2	10.2
1978	0.2	0.2	0.4	1.7	2.2	3.9	0.1	1.0	1.1	5.4
1979	0.1	0.1	0.2	3.3	0.8	4.1	0.3	0.8	1.1	5.4
1980	0.1	0.3	0.4	4.7	5.4	10.1	0.8	2.6	3.4	13.9
1981	1.4	6.8	8.2	4.1	2.0	6.1	0.4	0.9	1.3	15.6
1982	1.8	2.9	4.7	3.4	2.0	5.4	0.2	2.1	2.3	12.4
1983	1.3	3.1	4.4	2.5	1.1	3.6	0.2	0.6	0.8	8.8
1984[b]	0.4	1.2	1.6	2.8	0.3	3.1	0.4	2.1	2.5	7.2
1985[c]	0.5	2.3	2.8	4.0	0.4	4.4	0.5	2.5	3.0	10.2

[a] closure 1972 to 1980 incl., and 1984 and 1985.

[b] DFME sport stats; includes 10% of sport-caught MSW releases.

[c] preliminary; sport landings not necessarily DFME; native and by-catch estimates from DFO.