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The Status of the Alewife and Blueback Herring Trap-net Fishery of the Saint John River, New Brunswick

by

B.M. Jessop
Freshwater & Anadromous Division
Department of Fisheries and Oceans
P.O. Box 550
Halifax, N.S.
B3J 2S7

ABSTRACT

Landings for the gaspereau (alewife and blueback herring collectively) fishery of the lower Saint John River have declined from a peak of 6,269 t in 1971 to 703 t in 1984. Effort, in terms of trap-net licenses issued, has increased from 86 to 125 trap-nets during the same period. Commercial catch per trap-net license was used, in combination with biological data, to assess the status of the gaspereau stock. The Graham-Schaefer and Pella-Tomlinson surplus production models were used to estimate maximum sustainable yield (MSY) for the substocks of Fishery Statistical Districts (FSDs) 56, 56 and 57 combined, and 55, 56, and 57 combined. The estimated MSY for all FSDs combined ranged from 2,500 to 2,700 t, of which 1,800-1,900 t derives from FSD 56. About 70 nets are required to harvest the MSY for all FSDs combined but 125 are presently licensed. Yield per recruit analyses indicated that, for the Washademoak Lake, Grand Lake and Oromocto River substocks, the value of $F_{0.1}$ ranges from about 0.43 to 0.54 and F_{max} ranges from 1.85 to 3.56. At calculated F values, the yield per recruit is near maximum for these substocks. The conclusion is that the yield, yield per unit effort and stability of the stock biomass could be much improved by reducing the fishing effort to a level of about 70-80% of that required to harvest the MSY.

RESUME

Dans la pêche du gaspareau et de l'alose d'été sur le bassin inférieur de la rivière Saint-Jean, les débarquements sont passés d'un maximum de 6 269 t en 1971 à 703 t en 1984. L'effort, en termes de permis de pêche au filet-trappe délivrés, a augmenté de 86 filets-trappes à 125 au cours de la même période. Les prises commerciales par permis de pêche au filet-trappe ont été utilisées en conjonction avec des données biologiques pour évaluer l'état du stock de gaspareau. Les modèles de production excédentaire Graham-Schaefer et Pella-Tomlinson ont été utilisés pour évaluer le rendement maximum soutenu (RMS) pour les sous-stocks des districts de statistiques sur les pêches (DSP) 56, 56 et 57, et 55, 56, et 57 ensemble. Les RMS estimatif pour tous les DSP combinés était de 2 500 à 2 700 t dont 1 800-1 900 dérivaient du DSP 56. Il faut environ 70 filets pour capturer le RMS pour l'ensemble des DSP mais il y en a actuellement 125 pour lesquels des permis ont été délivrés. Le rendement par analyse de recrutement révèle que pour les sous-stocks du lac Washademoak, du lac Grand et de la rivière Oromocto, la valeur de $F_{0.1}$ est d'environ 0,43 à 0,54 et F_{max} est de 1,85 à 3,56. A des valeurs F calculées, le rendement par recrue est près du maximum pour ces sous-stocks. On en conclut que le rendement par unité d'effort et la stabilité de la biomasse du stock pourraient être grandement améliorés en réduisant le niveau de l'effort de pêche à environ 70-80 % de ce qui est requis pour capturer le RMS.

INTRODUCTION

The Saint John River, New Brunswick (Fig. 1), supports a major gaspereau (refers collectively to the alewife (Alosa pseudoharengus) and blueback herring (A. aestivalis)) fishery. This paper reviews the status of this two species fishery, including aspects of the biology of the species, the collection of fishery statistics and the conduct of the fishery in that portion of the river downstream of the Mactaquac Dam. The status of the gaspereau returns to the Mactaquac Dam have been described elsewhere (Jessop, MS 1986.)

Biology

Maturing gaspereau may move into the lower Saint John River, i.e. Kennebecasis and Bellisle bays, as early as January but the major upstream spawning migration begins in late April, peaks in late May or early June and is completed by mid-July. Alewives enter the river first, followed by blueback herring 2-3 weeks later. The run peaks progressively later with distance travelled upstream. The pattern of the fishery follows the temporal pattern of upstream migration.

The available evidence indicates that gaspereau are capable of homing to a natal stream. They can detect "home" water by olfactory means (Thunberg 1971) and their offspring return to previously barren streams after stocking (Rounsefell and Stringer 1943). The Saint John River gaspereau stock consists of several geographically separated substocks, i.e. Kennebecasis Bay, Bellisle Bay, Washademoak Lake, Grand Lake, Oromocto River and Mactaquac Dam, distinguished by differences in life history characteristics such as species and age composition, percentage of repeat spawners, etc. (Jessop 1977 a,b,c; Jessop et al. 1983) and by meristic and morphometric characteristics (Messieh 1977). Tagging studies have confirmed that, while straying of upriver destined stocks into downstream tributaries occurs during upstream migration, both alewives and blueblack herring exhibit a relatively high degree of homing ability (Jessop, unpublished data). The data available indicate that, with the exception of Washademoak and Grand lakes, straying may be relatively minor. The degree of straying is assumed to be constant from year to year.

Alewives and blueback herring recruit by platoons to the spawning stock and thus to the fishery over 2-4 years. Significant spawning occurs first in both species at age 3 and essentially all recruits have spawned by age 6. The mean age at first spawning is older for alewives than for blueback herring and typically older for females than for males of each species. For example, in 1983, the mean age-at-first spawning for alewives from Washademoak Lake was 4.6 years; for blueback herring it was 4.2 years. The mean population age is typically older for alewives than for blueback herring. Repeat spawners form a high proportion (35-90%) of the stocks of both species. Fish with up to 7 spawning marks have been recorded.

Commercial Fishery

The Saint John River gaspereau fishery is primarily a trap-net fishery conducted in the tributary rivers and lakes of Fishery Statistical Districts (FSD)

55, 56 and 57 (Fig. 1). No trap-net fishing is permitted in the main stem although a small ($<1\%$ of total catch in FSDs 56 and 57) set gill-net fishery operates there and in the lakes in FSDs 55 to 57. A more active, but still relatively insignificant (1970-84 mean catch of 65.2 t or 3% of total river catch) drift gill-net fishery is conducted in the Saint John harbour (FSDs 48 and 49). Note that, with the exception of the fishery at the Mactaquac Dam, gaspereau catches in FSD 58 are not included because they originate in the Miramichi River. There is no commercial gaspereau fishery in FSD 58 of the Saint John River.

Depending upon seasonal weather, ice conditions and water levels, trap-net fishing may begin in late April to early May in FSDs 55 and 56 and will be underway in all FSDs by mid-May. By late June, some nets in all FSDs will have stopped fishing and all cease fishing by June 30, the closure date. Catches peak from mid-May to mid-June.

Catch and Effort Statistics

Catch statistics (more properly sales statistics) are available from 1950 onwards for each Fishery Statistical District (Table 1, Fig. 2). Effort statistics in the form of numbers of trap-net licenses issued per FSD are available for FSDs 56 and 57 from 1950 and for FSD 55 from 1965 (one license represents one trap-net). Inaccuracies in these statistics must be expected since records were not routinely kept of the FSD in which licenses were actually fished. Also, it is assumed that the number of licenses reliably reflects annual fishing effort even though some licenses may be issued but not fished and the fishing time for a net may vary between locations and years. The number of licenses requested may also be influenced by anticipated market conditions and the success of the fishery the preceeding year.

Beginning in 1979, a voluntary logbook system was available to fishermen of FSDs 56 and 57 to record their daily catches and fishing effort. In 1980, this system was expanded to include all FSDs of the Saint John River. Not all fishermen cooperated in completing the forms and those that did were not always conscientious in doing so. Nonetheless, the total catch as reported by logbook represented 83% of the total catch reported by sales slips in 1979 and averaged 112% of the total catch between 1980 and 1984. Catches per net day were calculated for individual fishermen and averaged for each Fishery Statistical District.

Life History Data

Comprehensive age- and size-composition data for the alewife and blueback herring stocks of the lower Saint John River are only available for five years between 1973 and 1983. Consequently, age-structured yield models more complex than a simple yield per recruit model cannot be employed to evaluate the population dynamics of these stocks.

METHODS

Parameters of the Graham-Schaefer and Pella-Tomlinson surplus production models were estimated for the gaspereau fisheries of FSD 56, FSDs 56 and 57 combined and FSDs 55, 56 and 57 combined using the methods described by Rivard (1982). In both models, the catch per unit effort (CPUE) in a given year was related to the fishing effort averaged over three years - the number of years that a year-class contributes significantly to the catch. Observed and estimated catch and CPUE were plotted against effort as were the residuals.

These models assume that, in the absence of exploitation, the abundance or biomass of the population will tend to increase towards some environmentally set maximum, and that the rate of this increase is a function of stock size. They also assume that the population is closed and in equilibrium; that the catchability is constant and the catch per unit effort is proportional to stock size; that the instantaneous fishing mortality rate is proportional to fishing effort; and that population level is not affected by the time lag between spawning and recruitment.

Estimates of yield per recruit at various levels of fishing mortality were calculated by the method of Thompson and Bell (Ricker 1975; Rivard 1982) for stocks from Washademoak and Grand Lakes (the latter including French, Indian and Maquapit lakes) and the Oromocto River. The instantaneous rate of natural mortality (M) was assumed to be 0.20. Yield per recruit and catch rate (relative yield per unit of fishing effort) were plotted against fishing mortality. The age composition, weight-at-age and "partial recruitment" to fishing mortality values, i.e., the proportion of fishing mortality which can be allocated to a specific age group were calculated from weighted averages of five years of data collected between 1973 and 1983. This method also assumes that the stock is in equilibrium. Thus, at each age, the instantaneous rates of mortality (M) and growth (G) are assumed constant over the observed range of population densities and environmental conditions and that there have been no changes in the selectivity of the fishing gear or in minimum size regulations. Total instantaneous mortality rates (Z) were estimated from the distribution of fully recruited age-groups ($\geq$ age 6) of each species and both species combined using a least squares method (Jensen 1985). The survival rate is assumed to be constant with age following recruitment to the fishable stock, recruitment to be constant, and sampling to be representative of the population age structure.

RESULTS

Since 1950, the total catch of gaspereau from the Saint John River fishery (FSDs 55, 56, 57) has shown marked fluctuations, reaching peaks in 1954 and 1971, followed by a decline to recent low values (Fig. 2; Table 1). If the harvests at the Mactaquac Dam, which was completed in 1968 and where a fishery began in 1974, are excluded, the 1984 landings are the lowest since 1950. Fishermen state that the 1985 fishery was worse than the 1984 fishery but statistics are not yet available. The value of landings from FSDs 55, 56 and 57 (combined) peaked in 1978 at $291,000 (over $383,000 if the harvest from Mactaquac Dam is included). The Saint John harbour fishery (FSDs 48 and 49) is of relatively low value.

Since 1971, landings in FSDs 55, 56 and 57 have declined while fishing effort, in terms of licenses issued, has increased (Table 1). In all FSDs, the catch per license of recent years is amongst the lowest recorded. Between 1979 and 1984, total reported catches declined about 50%. The decline from the 1971 peak was almost 900%.

The number of nets licensed prior to 1979 is believed to be indicative of the number of nets fished. For this analysis, it is assumed that all licenses issued are fished. However, the number of licenses issued may overestimate the number fished and consequently underestimate the CPUE. This result is probably most severe at high levels of licensing (effort).

Between 1979 and 1982, over 90% of the licenses issued were actually fished; after 1982, 80% were fished (Table 2). Market conditions and catches were better during the former period than during the latter. Thus, when market conditions and catches are relatively good, the error in assuming that the number of licenses issued equals the number fished is likely to be small and may not be excessive even with poor markets. The largest differences between numbers of licenses fished and issued occurred in FSD 55, which contributes least to the total catch and effort. The effect on surplus production model calculations of such differences between 1980 and 1984 are minimized by the use of a moving three year average of fishing effort. The logbook records support the declining trends in catch and relatively stable effort (except in 1984; Table 3).

The regressions of CPUE on effort for the data from FSD 56, FSDs 56 and 57 (combined), and FSDs 55, 56 and 57 (combined) were significant ($p < 0.001$) for both the Schaefer and Pella-Tomlinson models. For District 57, the regressions were not significant ($P > 0.50$). Regressions were not calculated for District 55 because too few years of data were available but it was included in summaries to obtain a view of the entire fishery. For FSD 56, and FSDs 56 and 57 (combined), and FSDs 55, 56 and 57 (combined), the Schaefer model regressions account for 53, 46 and 43 percent, respectively, of the variability in the relationships. Figure 3 illustrates the case for all FSDs combined. Residual plots for FSD 56 and and all FSDs combined showed no particular pattern, thereby implying that little bias exists in the resulting parameter estimates (Fig. 4). Bias is generally small when, as here, observation numbers exceed about 30.

The Graham-Schaefer and Pella-Tomlinson surplus production models indicate a maximum sustainable yield (MSY) for Fishery Statistical Districts 55, 56 and 57 (combined) of between 2,500 and 2,700 t of which the bulk (1,800 - 1,900 t) derives from FSD 56 (Table 4). Each model indicates that the MSY yield may be taken by about 70 nets, of which about 47 should be in FSD 56. By comparison, the number of nets presently licensed for all FSDs combined and for FSD 56 is, respectively, 125 nets and 98 nets (Table 2). The catch rate at MSY is estimated to be 38 $t \cdot net^{-1}$ but the present CPUE is <15 $t \cdot net^{-1}$ for FSD 56 and all FSDs combined. Similar calculations using effort data modified (reduced) by logbook information for the 1980-84 period produced results similar to those previously given (<5% difference in all cases).

Yield per recruit analyses indicate that, for gaspereau stocks in the lower Saint John River, the value for $F_{0.1}$ ranges from about 0.43 to 0.54 with F_{max} values from 1.85 to 3.56 (Fig. 5). When M=0.20 and Z=1.42, 1.08 and 1.13 for Washademoak Lake, Grand Lake and Oromocto River, respectively (Table 5), F values (Z-M) of 1.22, 0.88 and 0.93 suggest that the yield per recruit is near maximum at all three sites and the yield per unit of effort could be greatly improved by reducing the fishing effort. For example, a reduction of fishing effort to achieve an $F_{0.1}$ of 0.5 should approximately double the yield per unit of effort at all sites. Assuming a higher natural mortality rate (M=0.25) produces higher $F_{0.1}$ and Fmax values. For Washademoak Lake, Grand Lake and the Oromocto River the values for $F_{0.1}$ = 0.49, 0.54 and 0.60, respectively and for Fmax = 3.56, 6.52, and 9.17, respectively. The increase in $F_{0.1}$ with increasing M is almost linear while for Fmax it is non-linear and increases sharply at about M > 0.2 (White 1983).

Although gaspereau total mortality rates declined between the 1973-75 and 1981-83 periods for all sites (Table 5) and may reflect a reduction in the numbers of licenses fished, even the lowest total mortality rates imply fishing mortality rates much in excess of estimated $F_{0.1}$ values. Total mortality rates were higher for alewives than for blueback herring for both periods and all sites. Consequently, the proportion of alewives in the fishery has declined between 13 and 32% with the largest declines occurring in Washademoak Lake and the Oromocto River where total mortality rates for alewives are highest (Table 6). Total mortality rates for blueback herring for the period 1973-83 were similar at all sites.

DISCUSSION

Simple stock production models such as the Schaefer model have been criticized for their statistical difficulties in parameter estimation and lack of biological realism yet have been widely used in fisheries management where biological data sufficient for more complex models does not exist (Roff and Fairbairn 1980; Uhler 1980; Ludwig and Walters 1985). Recent work by Deriso (1980) and Schnute (1985) have linked catch and effort models with age-structured models. Hilborn (1979), Ludwig and Hillborn (1983) and Ludwig and Walters (1985) have supported the use of production models for stock assessments based on catch/effort data even when more realistic and structurally correct models are available if sufficient contrast has occurred in the historical data base. Such contrast exists, I believe, in the gaspereau catch/effort data for FSD 56 and FSDs 55, 56 and 57 combined. The reliability of the MSY estimates is improved by the use of a relatively long time series (34 years) and by the presence of building and overfishing phases in the data (Mohn 1980). Extension of the single species Schaefer and Pella-Tomlinson surplus production models to consider two or more species is relatively straightforward (Kirkwood 1982). The single species model was used in this case because the very similar life histories of alewives and blueback herring was believed to permit their treatment as one species without much model bias or loss of biological realism. However, the MSY of a multi-species fishery will be lower than if both species could be fished separately.

The influence of deviations from the model assumptions is often difficult to evaluate. Thus, while no evidence exists of any long term trends in conditions that would influence the carrying capacity of the environment and the stocks can be considered essentially closed (Messieh 1977; Jessop, unpublished data), the stocks cannot be considered to be in equilibrium. Nor can the catchability coefficient (q) be considered constant. Ulltang (1980), Peterman and Steer (1981), Peterman et al. (1985), and Creco and Savoy (1985) provide evidence for species such as Atlantic herring (*Clupea harengus*), chinook salmon (*Oncorhynchus tshawytscha*) and American shad (*Alosa sapidissima*) supporting the hypothesis by Palohiemo and Dickie (1964) that the catchability coefficient is inversely related to stock size. Acceptance of this relationship will result in conservative fishery management. For example, Creco and Savoy (1985) conclude that, for American shad, commercial catch/effort data seriously underestimate the decline in stock size when catchability is inversely related to abundance. This relationship can result from the spatial patchiness (schooling) of fish, such as American shad and gaspereau, relative to the area being fished which allows high catch rates to occur at low stock size, and from the tendency of fishermen to fish nonrandomly, i.e., to fish productive areas and more heavily during the peak of a run (Palohiemo and Dickie, 1964).

Consequently, catch and effort data and yield per recruit and surplus production models will be misleading at high levels of fishing effort and will tend to underestimate the seriousness of a stock decline. As Creco and Savoy (1985) note, a given increase in fishing effort would produce a greater rise in F and corresponding reduction in stock size than if the catchability coefficient were constant. This would ultimately cause recruitment failure unless fishing effort was greatly reduced at the first sign of stock collapse. Fishing mortality rates would rise steadily while abundance declined even if fishing effort was held constant. Once the stock is severely reduced, a small or moderate reduction in fishing effort may have little effect on the levels of F. Such expectations are consistent with the observed trend in the Saint John River gaspereau trap-net fishery. Although recruitment overfishing (to which clupeid stocks are most vulnerable) may be difficult to prevent because levels of fishing effort at which recruitment failure occur are difficult to determine due to environmentally induced fluctations in the stock-recruitment relationship, fishery managers have also been slow to react to signs of recruitment failure because two or three weak year-classes are not generally accepted as sufficient evidence of overfishing. At exploitation rates exceeding 0.3 (which roughly equals F=0.3), such as found for the Saint John River gaspereau stocks, Doubleday (1985) concludes that the "decline of spawning stock size to less than one average recruiting year-class must be expected more than once every 10 yr." The Saint John River gaspereau fishery has clearly had more than several weak year-classes.

If we accept that overfishing has occurred, we must then consider what reduction in fishing effort is appropriate to restore the stock(s) to an acceptable abundance level. The possibility of catch quotas are not considered because of the difficulty of enforcement and of both predicting and determining the size of the annual return. The best economic yield is taken at a level of fishing mortality less than that at which the greatest catch is taken ($< F_{max}$). A fishing mortality rate of $F_{0.1}$ has been accepted for setting catch levels for many species. However, Doubleday (1985) recommends that "a target fishing mortality rate of 0.2 is more appropriate for management of herring fisheries on a sustainable basis than is $F_{0.1}$" because herring stocks are susceptible to recruitment overfishing and have little resilience at low biomass. This advice might reasonably apply to gaspereau fisheries also. At an average exploitation rate of 0.2 of the spawning stock about 70-80% of the theoretical MSY could be harvested without greatly reducing or destabilizing the spawning stock. Independent support for a fishing mortality rate of 0.2 (or less) comes from the stock-recruitment relationship for Mactaquac Dam gaspereau where F=0.14 at MSY (Jessop MS 1986). A desirable level of fishing effort for FSD 56 would thus be 32 nets and for all FSDs combined would be 48 nets or about 33% and 38% of existing licensing levels. Given that a total of 16 nets are available for allocation between FSDs 55 and 57, I suggest, based on the historical catch and license record of the two FSDs and their relative productive area, that about 7 licenses be issued in FSD 55 and 9 licenses issued in FSD 57.

The greater exploitation of alewives relative to blueback herring is to be expected because of their earlier run timing and greater exposure to the fishery and greater marketability resulting from their larger mean size and firmer flesh (consequent to their capture when water temperatures are cooler). Proposals for changes in fishing season regulations designed to decrease the relative exploitation of alewives and increase that of blueback herring must consider the marketability factor.

CONCLUSIONS

The concurrent exploitation of two species, particularly highly productive species such as alewives and blueback herring, presents difficult management problems. When exploitation is within MSY limits, it benefits productive stocks because it stabilizes an abundance that inherently oscillates in the absence of fishing. Over the past 35 years, the Saint John River gaspereau fishery has had two peaks of catch abundance followed by sharp reductions. This pattern may reflect a "fishing up" effect in which the maximum catch exceeds the sustainable yield, thus encouraging a high level of overfishing which is then followed by a stock collapse (Ricker 1975).

The gaspereau stocks of the lower Saint John River are presently at a low level and evidence has been presented that they are heavily overfished. They are unlikely to provide harvests substantially increased over their present low level until fishing effort is sharply reduced. One management objective is to have a sustainable harvest of about 70-80% of MSY (a level almost three times greater than the 1984 harvest) which should lead to long term stability in the fishery.

Exploitation can be reduced most effectively by reducing the number of trap-nets fished (and not permitting any substantial increase in any other type) although some scope exists for reducing the duration of the fishing season to enhance alewife escapement. Delay in implementing corrective action not only delays the day of improvement in the fishery (4-5 years are required for a new year class to enter the fishery) but will likely increase the damage to an already crippled fishery.

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Table 1. Reported catch (t) of gaspereau and fishing effort (trap-nets licensed), by Fishery Statistical District, for the Saint John River, 1950-1984.[1]

Year	FSD 55			FSD 56		
	Catch	Effort	CPUE	Catch	Effort	CPUE
1950	54.0	-[2]	-	193.7	4	48.4
1951	98.0	-	-	464.4	15	31.0
1952	242.2	-	-	537.0	16	33.6
1953	148.2	-	-	2,795.5	39	71.7
1954	56.7	-	-	3,659.4	43	85.1
1955	36.3	-	-	3,110.2	41	75.9
1956	4.5	-	-	1,675.3	60	27.9
1957	12.2	-	-	2,175.1	67	32.5
1958	131.1	-	-	650.3	76	8.6
1959	43.5	-	-	492.1	77	6.4
1960	44.4	-	-	1,540.6	83	18.6
1961	100.2	-	-	959.2	61	15.7
1962	140.6	-	-	938.8	81	11.6
1963	66.2	-	-	662.6	59	11.2
1964	261.2	-	-	589.6	71	8.3
1965	120.2	8	15.0	1,528.3	77	19.8
1966	260.8	18	14.5	1,104.8	67	16.5
1967	184.1	18	10.2	414.1	62	6.7
1968	193.7	14	13.8	975.1	63	15.6
1969	129.7	8	16.2	1,669.8	50	21.6
1970	161.5	16	10.1	1,035.8	55	31.8
1971	114.3	7	16.3	4,768.7	64	74.5
1972	249.9	9	27.8	2,568.7	64	40.1
1973	230.4	9	25.6	1,287.1	67	19.2
1974	263.5	8	29.1	1,516.1	65	23.3
1975	152.8	9	17.0	953.7	75	12.7
1976	150.1	5	30.0	949.7	66	14.4
1977	155.1	7	22.2	1,653.5	75	22.1
1978	177.8	12	14.8	1,322.0	81	16.3
1979	142.0	12	11.8	1,079.0	81	10.9
1980	88.0	12	7.3	910.4	83	11.0
1981	22.0	12	1.8	874.3	88	9.9
1982	13.0	16	0.8	964.4	96	10.0
1983	30.0	16	1.9	904.2	98	9.2
1984	17.0	16	1.1	621.8	98	6.3

[1] Data from the Statistics and Licensing Divisions, DFO Halifax and/or District Fishery Officers. From 1979 onwards, offical catch values may be incorrect and have been modified on the basis of voluntary logbook data except in FSD 55 where logbook coverage was least complete. The logbook data for each FSD is known to be incomplete and to underestimate true values. From 1980 onwards, the effort values presented here may differ from those presented in CAFSAC Advisory Document 86/12 because they are based on licenses issued and are not adjusted on the basis of logbook data.

[2] No data available.

Table 1 (continued).

Year	FSD 57 Catch	FSD 57 Effort	FSD 57 CPUE	FSDs combined[1] Catch	FSDs combined[1] Effort	FSDs combined[1] CPUE
1950	158.7	4	39.7	352.4	8	441.1
1951	44.9	3	15.0	509.3	18	28.3
1952	523.8	13	40.3	1,060.8	29	36.6
1953	771.0	15	51.4	3,566.5	54	66.0
1954	1,237.2	28	44.2	4,896.6	71	69.0
1955	820.9	26	31.6	3,931.1	67	58.7
1956	948.8	12	79.1	2,624.1	72	36.4
1957	568.7	17	33.5	2,743.8	84	32.7
1958	620.9	24	25.9	1,271.2	100	12.7
1959	1,005.4	28	35.9	1,497.5	105	14.3
1960	389.1	17	22.9	1,929.7	100	19.3
1961	453.5	18	25.2	1,412.7	79	17.9
1962	707.5	26	27.2	1,646.3	107	15.4
1963	127.4	12	10.6	790.0	71	11.1
1964	195.5	20	9.8	785.1	91	8.6
1965	916.1	21	43.6	2,564.6	106	24.2
1966	321.1	20	16.1	1,686.7	105	16.1
1967	972.8	19	51.3	1,571.0	99	15.9
1968	927.0	16	58.2	2,095.8	93	22.5
1969	711.1	16	44.8	2,510.6	74	33.9
1970	1,453.1	15	97.6	2,650.4	86	30.8
1971	1,385.9	15	92.4	6,268.9	86	72.9
1972	1,195.5	20	59.8	4,014.1	93	43.2
1973	975.5	20	48.8	2,493.0	96	26.0
1974	1,337.4	26	51.4	3,117.0	99	31.5
1975	763.7	15	50.9	1,870.2	99	18.9
1976	971.9	22	44.2	2,071.7	93	22.3
1977	649.9	22	29.5	2,458.5	104	23.6
1978	719.7	24	30.0	2,219.5	117	19.0
1979	644.0	24	26.8	1,865.0	117	15.9
1980	319.2	16	20.0	1,317.6	111	11.9
1981	88.0	13	6.8	984.3	113	8.7
1982	118.1	13	9.1	1,095.5	125	8.8
1983	66.0	11	6.0	1,000.2	125	8.0
1984	64.2	11	5.8	703.0	125	5.6

[1]FSD 55 data omitted 1950 to 1964.

Table 2. Number of trap-net licenses issued and fished in Fishery Statistical Districts 55-57 of the Saint John River, N.B., 1979-1985.

	Licenses issued Statistical District				Licenses fished Statistical District			
Year	55	56	57	Total	55	56	57	Total
1979	12	81	16[1]	109	12	81	13	106
1980	12	83	16	111	12	82	13	107
1981	12	88	13	113	7	83	10	100
1982	16	96	13	125	5	80	10	95
1983	16	98	11	125	4	88	8	100
1984	16	98	11	125	4	88	11	103
1985	16	98	11	125	3	88	8	99

[1] Omits eight licenses issued but not fished due to court order.

Table 3. Annual logbook records of catch, effort and CPUE, of gaspereau, by Fishery Statistical District, from the trap-net fishery of the Saint John River, N.B., 1979-1984.

	Fishery Statistical District			
Year	55	56	57	Total
Catch (kg)				
1979	-[1]	1,078,985	307,535	1,386,520
1980	53,501	751,731	319,211	1,124,443
1981	16,397	874,266	87,997	978,660
1982	8,485	964,405	118,139	1,091,029
1983	17,925	904,192	66,031	988,148
1984	-	621,765[2]	64,229	685,994
Effort (net hours)				
1979	-	56,568	7,440	64,008
1980	7,768	46,752	12,312	66,832
1981	6,817	67,684	6,364	80,865
1982	2,648	60,508	6,290	69,446
1983	5,166	58,097	7,308	70,571
1984	-	28,825	4,884	33,709
CPUE ($kg \cdot net\ hour^{-1}$)				
1979	-	19.07	41.34	21.66
1980	6.89	16.08	25.93	16.82
1981	2.41	12.92	13.83	11.98
1982	3.20	15.94	21.20	15.81
1983	3.47	15.56	9.04	14.00
1984	-	21.57	13.15	20.35

[1] No data available.
[2] Data is missing for two major fishermen on Washademoak L.

Table 4. Estimates by Fishery Statistical District, of the catch·unit effort-1 (CPUE) at maximum sustainable yield (MSY), the fishing effort (nets) giving MSY and the MSY (t) for the Graham-Schaefer and Pella-Tomlinson surplus production models. The regression coefficients, with fishing effort averaged over three years, were significant at $P < 0.001$.

Fishery Statistial District	CPUE at MSY	Fishing Effort giving MSY(nets)	MSY (t)
Graham-Schaefer			
56	0.1	47.0	1,883
56, 57 combined	42.3	61.3	2,592
55, 56, 57 combined	37.2	67.9	2,529
Pella-Tomlinson			
56	40.1	47.2	1,893
56, 57 combined	41.4	65.4	2,709
55, 56, 57 combined	37.8	70.2	2,653

Table 5. Instantaneous rates and variance of total mortality (Z) by time period, for alewives and blueback herring from sites in FSD 56 and 57 of the lower Saint John River, N.B.

		Time Period					
		1973-75		1981-83		1973-1983	
Site	Species	Z	s^2	Z	s^2	Z	s^2
Washademoak L.	Alewife	1.73	0.086	0.97	0.005	1.42	0.004
(FSD 56)	Blueback	1.73	0.001	0.66	0.005	0.90	0.001
	Combined	1.78	0.087	1.05	0.016	1.42	0.013
Grand L.	Alewife	1.38	0.014	0.88	0.015	1.07	0.009
(FSD 56)	Blueback	1.33	0.106	0.62	0.016	0.82	0.012
	Combined	1.37	0.010	0.90	0.019	1.08	0.012
Oromocto R.	Alewife	1.77	0.005	1.00	0.015	1.27	0.009
(FSD 57)	Blueback	-[1]	-	0.88	0.026	0.84	0.034
	Combined	1.54	0.016	0.95	0.008	1.13	0.011

1 Sample size too small.

Table 6. Species composition (%) of samples from the commercial gaspereau fishery at sites in FSD 56 and 57 of the lower Saint John River, N.B.

		Year						
Site	Species	1973	1974	1975	$\bar{x}$	1981	1983	$\bar{x}$
Washademoak L.	Alewife	73	81	65	74	50	53	51
(FSD 56)	Blueback	27	19	35	26	50	47	49
	n	750	600	449		676	753	
Grand L.	Alewife	85	83	91	85	81	66	72
(FSD 56)	Blueback	15	17	9	15	19	34	28
	n	727	1,046	298		1,100	1,585	
Oromocto R.	Alewife	88	94	96	93	77	52	61
(FSD 57)	Blueback	12	6	4	7	23	48	39
	n	300	396	250		583	999	

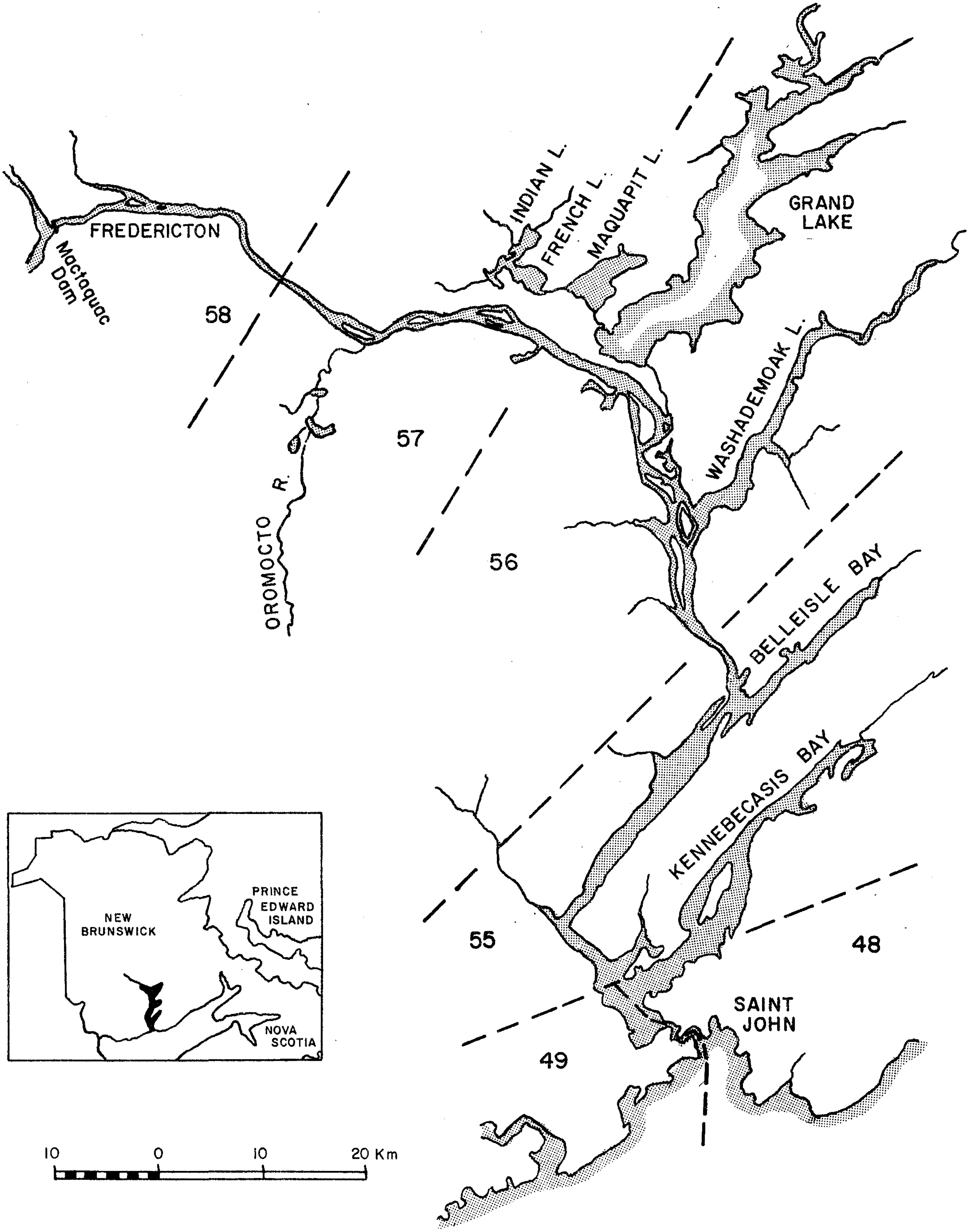

Fig. 1. Fishery Statistical Districts of the lower Saint John River.

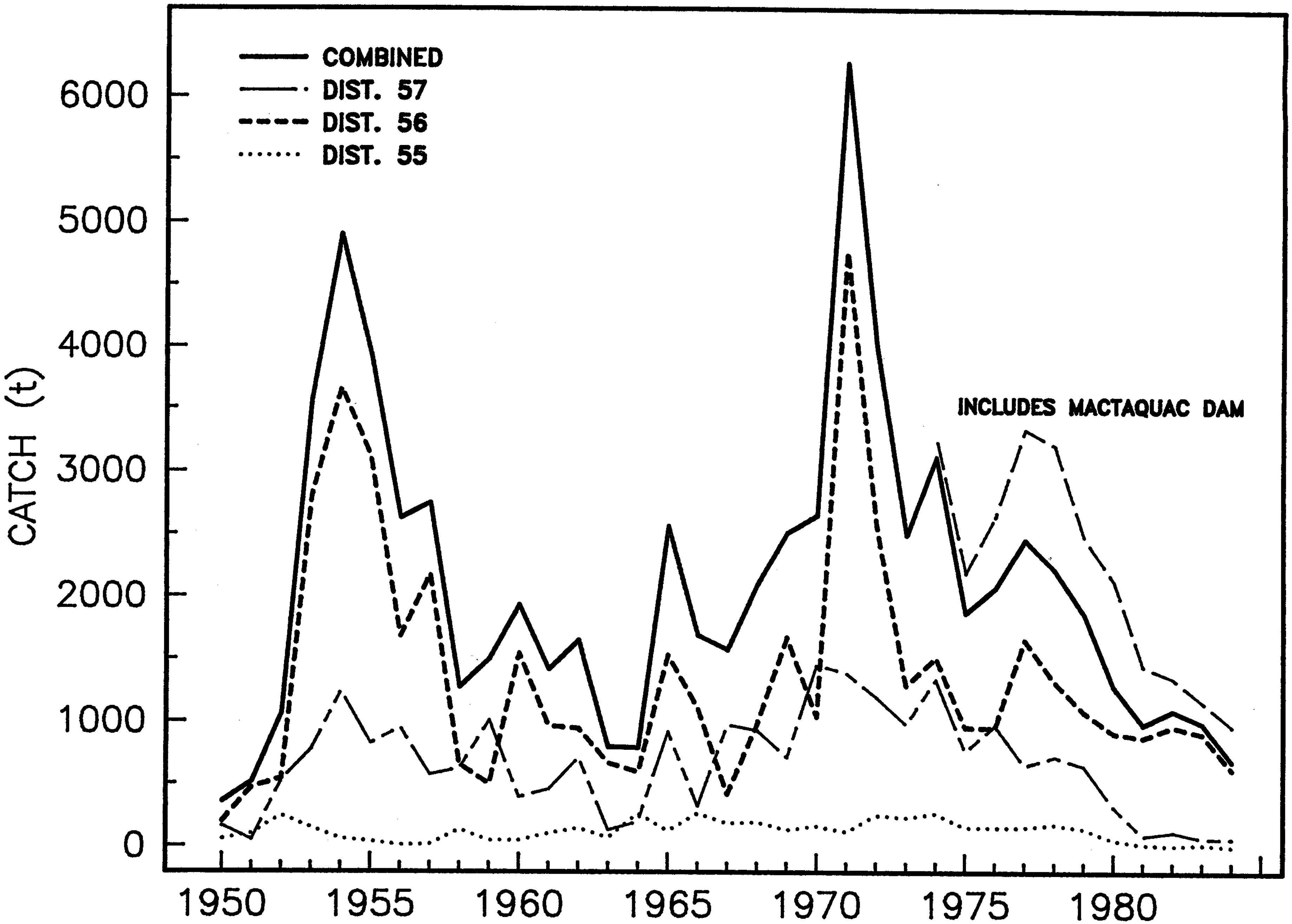

Fig. 2. Annual reported catch (t) of gaspereau, by Fishery Statistical District for the Saint John River, N.B., 1950-1984. Catches for the downriver fishery prior to 1979 are from official statistics; later catches may be modified by logbook data from the trap-net fishery (refer to Table 1.)

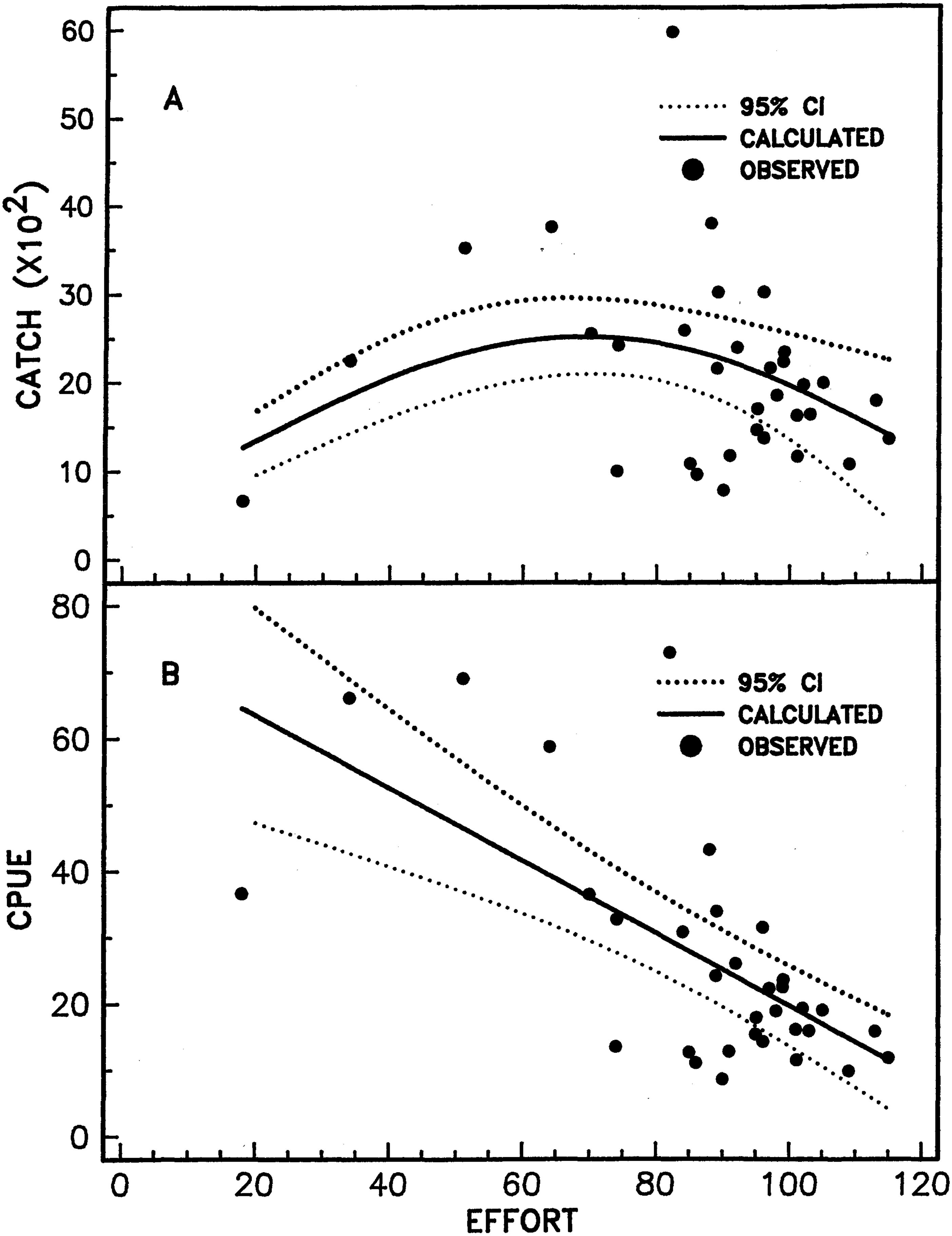

Fig. 3. Schaefer model relationship between (a) catch (t) and fishing effort (net) and (b) CPUE ($t \cdot net^{-1}$) and fishing effort (net) for the gaspereau trap-net fisheries of FSDs 55, 56 and 57 (combined), Saint John River, N.B., 1950-1984. Data are from Table 1; effort has been averaged over three years.

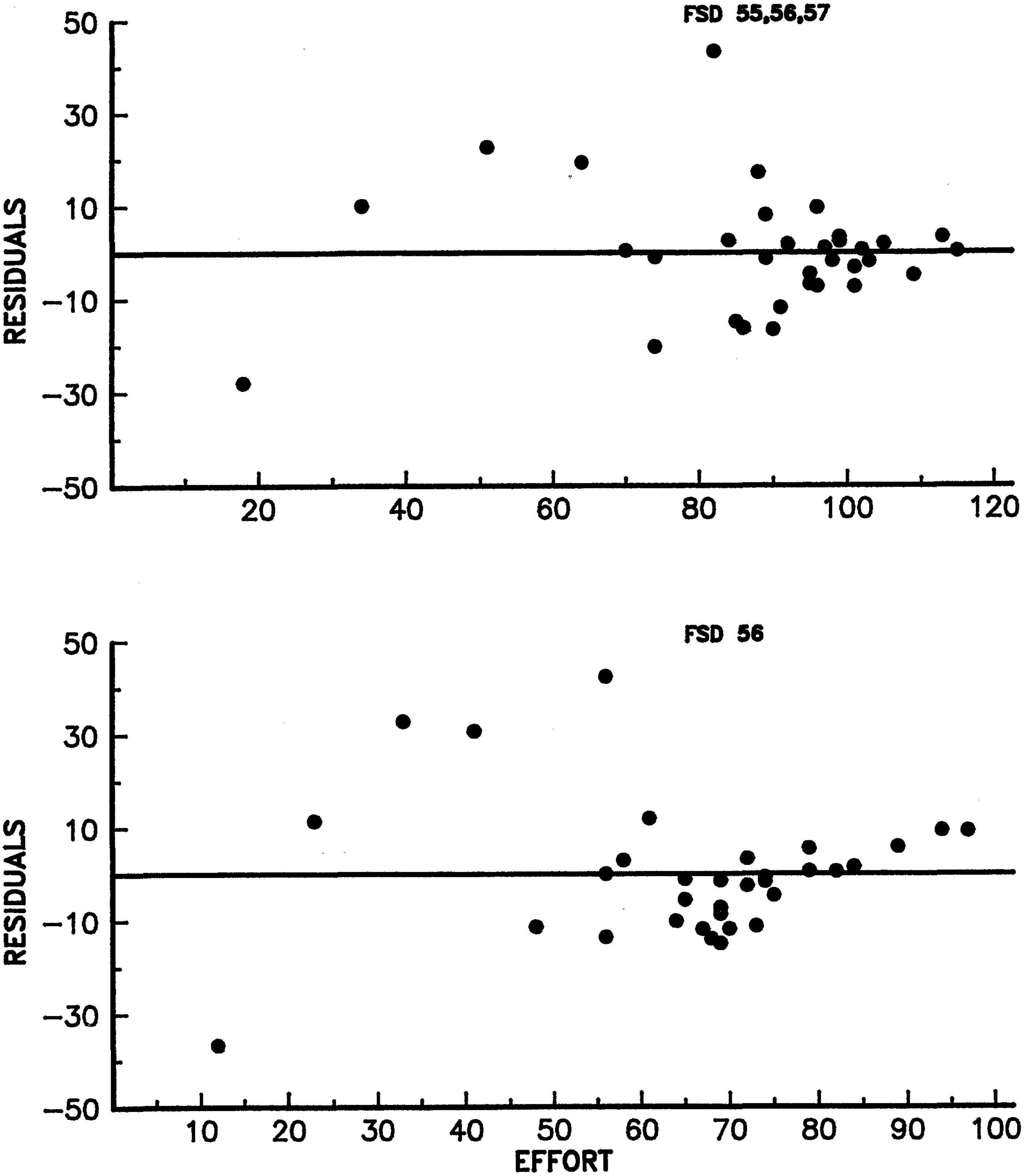

Fig. 4. Residual plot from the Schaefer model relationship between CPUE and fishing effort for the gaspereau trap-net fisheries of FSD 56 and FSDs 55, 56 and 57 (combined), Saint John River, N.B. 1950-1984.

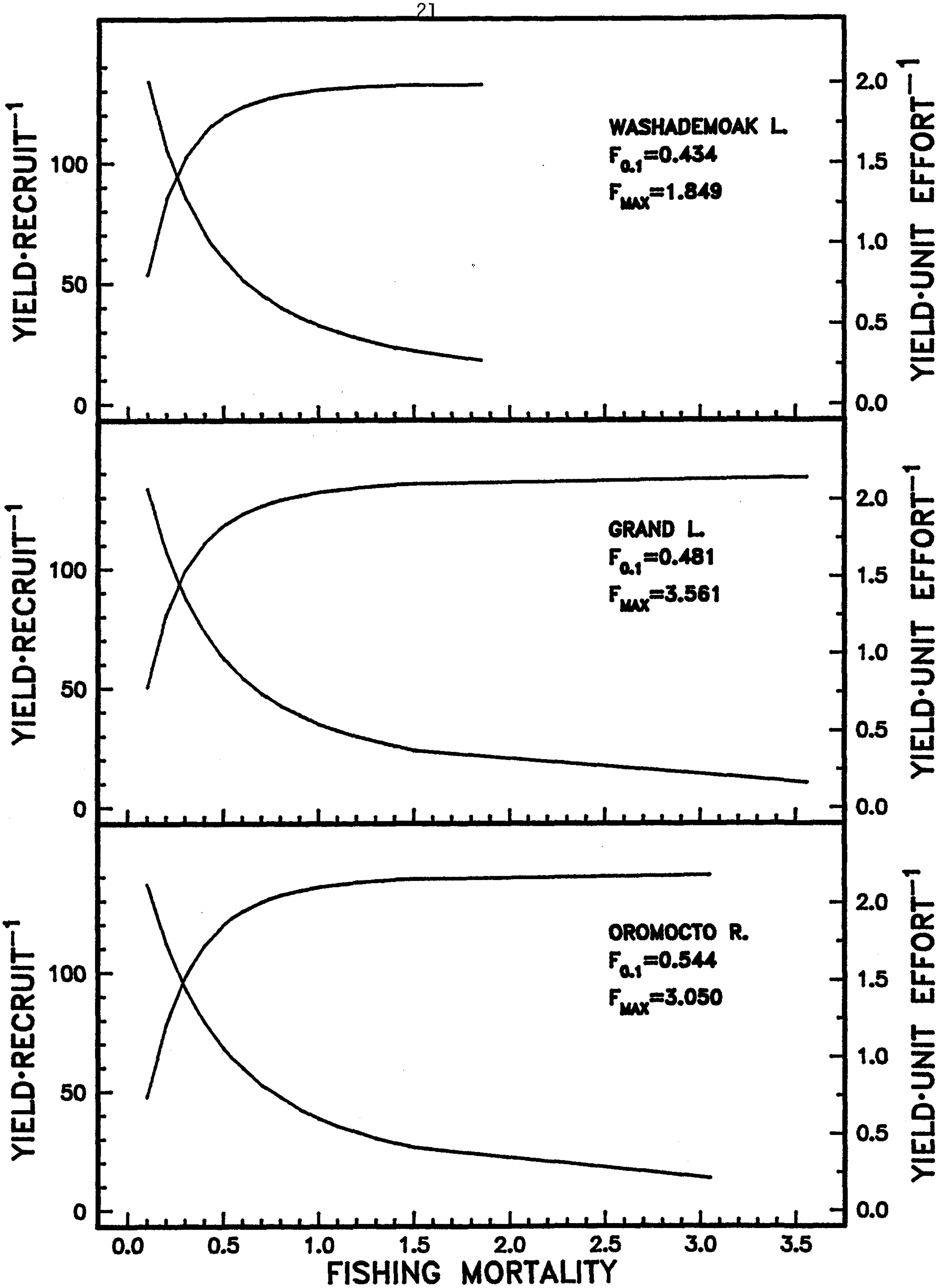

Fig. 5. Yield per recruit (g; ascending curve) and relative yield per unit of fishing effort (g·net^{-1}; descending curve) in relation to fishing mortality rate (F), calculated by the method of Thompson and Bell, for gaspereau from different locations in the lower Saint John River, N.B. M = 0.20 is assumed.