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Recruitment variation in Atlantic salmon stocks of the inner Bay of Fundy

by

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ABSTRACT

The status of Atlantic salmon stocks for rivers of the inner Bay of Fundy is reviewed with emphasis on the 1986-89 period when a general decline in recruitment occurred. Recreational catches were independent of an Atlantic coast grilse stock; in synchrony within the Bay and improved in 1989. In three rivers diver counts of grilse were at or above requirements while salmon (repeat spawners) counts were not.

Juvenile densities in 1989 were not significantly lower than historic means in two rivers. Index stock and recruitment relationships have performed erratically as forecast models in recent years and are no longer statistically significant. Tag returns from hatchery releases were completely absent from any fishery.

Disease surveys did not reveal any epizootic conditions in the freshwater phase or in adult returns in 1989. Exposure to pathogens, detected by anti-gen anti-body agglutinations, were inconclusive to a cause and effect hypothesis. Hypotheses for the general synchrony and extreme range in marine survival for these stocks are examined for their likelihood and a proposal to test a disease impact hypothesis is presented. Interim management measures are suggested to bridge the recent low escapements and a prognosis for future stock response is presented.

RESUME

On examine l'état des stocks de saumon de l'Atlantique dans les rivières de l'arrière-baie de Fundy, en s'attardant sur la période 1986-1989, caractérisée par une baisse générale du recrutement. L'existence d'un stock de madeleineaux sur la côte Atlantique n'a pas influencé les prises sportives, qui étaient concordantes dans l'ensemble de la baie et à la hausse en 1989. D'après des recensements effectués par plongée dans trois rivières, le nombre de madeleineaux était égal ou supérieur aux besoins, mais le nombre de saumons (géniteurs multifrais) était insuffisant.

Les densités de juvéniles relevées en 1989 n'étaient pas notablement inférieures aux moyennes historiques. L'utilisation des rapports entre les stocks indicateurs et le recrutement comme modèles de prévision a donné des résultats irréguliers au cours des dernières années et ne présente plus grand intérêt statistique. Aucune étiquette de saumon d'écloserie n'a été retournée par les pêcheurs, sportifs ou autres.

On n'a pas décelé de maladie épizootique dans le saumon d'eau douce ou dans les remontées d'adultes en 1989. Des agglutinations d'anticorps et d'antigènes ont révélé une exposition à des agents pathogénes, mais on n'a pu établir de rapports de cause à effet. L'auteur examine ici la vraisemblance d'hypothèses sur la synchronie générale et sur les variations extrêmes dans la survie en mer des stocks et présente une proposition visant à vérifier une hypothèse sur les répercussions des maladies. Il suggère d'adopter des mesures de gestion transitoires pour compenser les bas niveaux d'échappées obtenus récemment et formule des pronostics au sujet de leurs effets éventuels sur les futurs stocks.

INTRODUCTION

Atlantic salmon stocks of the inner Bay of Fundy, defined as rivers emptying into the Bay of Fundy east of Annapolis Basin in Nova Scotia and east of the Saint John River New Brunswick, are similar in stock characteristics, migration and recruitment pattern (Amiro, 1987). Levels of recruits (maiden grilse) have been linked to environmental variables acting on recruits the summer previous to smoltification and sea-surface temperatures the spring and early summer of migration.

Forecast models (Amiro and McNeill, 1986, Amiro, 1987) correctly indicated the drastic downturn that catches took in 1987 for the Big Salmon and Stewaicke rivers but catches in 1988 did not recover as forecasted.

The general downturn in inner Bay of Fundy rivers in 1987 and again in 1988 raised concerns with the public and fisheries managers that stocks were declining to irrevocable levels and they requested a careful second-look at general stock status, analysis of causes for the decline, prognosis for future returns and management alternatives to prevent potential irrevocable losses.

This document reviews hypotheses of these previous documents, addresses concerns of resource users, managers and researchers, postulates a diagnosis and prognosis for stocks and plots a course for research into inner Bay of Fundy stocks.

DATA and METHODS

Recreational catches (Table 1) for 23 of 37 potential rivers of the inner Bay of Fundy are reported by Swetnam and O'Neil (1984), O'Neil and Swetnam (1984), O'Neil et al. (1985-1989). Catches in 1989 for Nova Scotia rivers and (S.F. O'Neil per.comm.[1]) and New Brunswick rivers are preliminary estimates.

Mid-October diver counts of adult salmon in the Alma and Point Wolfe rivers were provided by Parks Canada (F. Granger pers. comm.)[2].

Juvenile densities in the Stewiacke are from Amiro et al. (1989) for 1984 to 1988 and from Amiro (1990) for 1989. Juvenile densities from the Big Salmon River are those reported by O'Neil et al. (1989).

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Precipitation data for Upper Stewiacke was reported by Atmospheric Environment Service and discharge for the Point Wolfe River by Inland Waters Directorate of Environment Canada.

Stock-recruitment analysis for the Stewiacke River follows procedures described by Amiro (1987 and 1990).

Estimates of index stock eggs and index recruit eggs were calculated per Amiro (1987) but with the years 1970-1983 adjusted to equate to the angler stub return estimates of catches. Adjustment to license stub equivalents for data prior to 1984 was made by using the correction factor of 1.3 determined in 1983, the final year of Fishery officer reports and first year of stub returns (S. F. O'Neil pers comm.)

In summary the stock side of the relationship is derived from an estimate of the numbers of eggs contributing (year i-4 and year i-5) to a recruit year (i=1, maiden grilse), proportioned by smolt age contribution as indexed from the record of angling catches and calculated at mean size and fecundity. The recruit eggs are indexed from the reported grilse catch in the recruit year.

Stock and recruitment egg indexes were regressed with July precipitation at Upper Stewiacke in year i-2 of grilse catches rather than the average of July to September precipitation as in the 1986 assessment (Amiro, 1987).

Recruitment for the Big Salmon River was calculated similar to Amiro (1987). Reported catches of grilse (index recruits) were regressed with Point Wolfe River discharge in yr i-2 of recruits and with sea surface temperatures at St. Andrews in year i-1 of recruits. Unlike previous models the data were not geometrically transformed.

Disease analyses were conducted by the Fish Health Unit of the Halifax Research Laboratory. Disease profiles for active pathogens were by their standard techniques and by geometric titration dilutions for anti-body response to specific laboratory-grown antigens (Webber and Zwicker, 1979).

RESULTS

Catch trends in the inner Bay of Fundy

Annual, 1970-1989, recreational catches of both grilse and salmon in inner Bay of Fundy rivers are highly variable (Table 1). Total annual recreational catches reached a record low in 1987 and showed little improvement in 1988 (Fig. 1).

Correlation of catches

The hypothesis that annual recruit survival of inner Bay of Fundy rivers is independent from other 1SW stocks was examined by calculating rank correlations of annual sport catches for 24 inner Bay of Fundy rivers with that of Moser River (SFA 20, eastern shore of Nova Scotia). No spearman correlation coefficient was significant ($P = 0.05$) for catches in 1970 to 1989 between Moser River and any of the 24 inner Bay of Fundy rivers.

The hypothesis that recruits of inner Bay of Fundy rivers are in phase was examined by rank correlation between catches of grilse 1970 to 1989. Spearman cross-correlations were significant ($P=0.05$) in many cases and indicated a general uniformity in annual levels of recruits. The number of significant correlations between a particular river and the remaining set ranged from highs of 13 for the Stewiacke River and 10 for the Big Salmon River to lows of 2 significant correlations for rivers such as Cornwallis, Great Village, Petticodiac, Pollet, Shepody and St. Croix (Table 2).

Stock status - Parr

Stewiacke River

Mean densities of age-1+ parr 1984 to 1989 (Table 3) indicate two years of higher densities, 1985 and 1987 and less varying densities between 16 and 18 age-1+ parr unit^{-1} (10^2 m^2) for other years. Densities of age-2+ parr were lower and ranged from 5.5 to 8.1 age-2+ parr unit^{-1}. Peaks of age-2+ parr densities lag age-1+ densities by one year. Total age-1+ and 2+ parr densities ranged from 23.8 to 39.2 fish unit^{-1}.

Standard deviations of annual mean parr densities were large. Some annual means had coefficients of variation approaching or greater than 100%, particularly in years of high densities. Annual group variance was not homogeneous between years precluding post hypothesis contrast comparisons of years.

Annual mean parr densities were compared by examination of Box plots (Fig. 2). Box plots use ranked data to calculate the median, hinges (quartiles), outlying data and 95% confidence limits of the groups. Visual inspection of these figures indicate that no one year median is outside the inner quartile of another year and therefore the probability of a significantly different annual age 1+, 2+ or total parr density is low. Data collected in 1985 and 1987 had 3 values outside the range of the inner or outer hinges.

Big Salmon River

Total age-1+ and age-2+ parr densities measured at four sites in

1989 averaged 19.6 parr unit^{-1}. Age-0+ parr averaged 41.4 parr unit^{-1} at these same sites. These values are 47% of the total age-1+ and 2+ parr and 64% of the age-0+ parr densities obtained at these same sites in 1982. The average 1SW sport catch 1986-1988, the years from which the 1989 juveniles were recruited, was 20% of the 1970-1988 mean of 311 1SW fish. The 1979-1981 average catch, from which the 1982 juveniles were recruited was 170% of the mean.

- Adults

Diver counts of adults have been conducted annually by Parks Canada employees since 1983 in the Alma and since 1985 in the Point Wolfe River (Table 4). The Point Wolfe River is not included in the list of inner Bay of Fundy rivers because angling is not permitted on the river. Salmon stocks in the Point Wolfe River are developing since improvements to fish passage which began in 1985.

Diver counts on the Point Wolfe River declined to a low of 49 fish in 1988. The 1989 count increased six-fold in the number of smaller fish thought to be 1SW maiden grilse. The number of salmon or larger fish thought to be repeat spawning grilse has declined since 1987 and reflects the decline in recruit grilse in 1987 and 1988. The 1989 count did not meet the target egg deposition derived from a target spawning escapement of 139 grilse and 63 salmon (F. Granger pers. comm.).

Diver counts in the Alma River show a similiar decline in grilse count since 1983. Mean counts of grilse decreased nine-fold 1986-1988 from those of 1983-1985. Numbers of repeat-spawning salmon declined consistantly since 1983 and moderately recovered in 1989. Counts of both grilse and salmon increased in 1989 but did not reach 1983-1985 average counts.

Diver counts in the Big Salmon River after the angling season indicate a total escapement of about 1,000 fish 2.5 to 3.5 times that of 1988 and a number approaching target spawning requirements. Age interpretation from 45 fish sampled during a broodstock collection, October 20, 1989, indicated 74% recruit grilse, 22% repeat spawning grilse and 2% maiden 2SW salmon (Table 5). The proportion of recruit grilse differs from the average of 25% determined from over 3,000 fish sampled in 1965-1973 (Jessop 1986).

Recruitment

Recruitment and stock and recruitment models have been calculated for both the Stewiacke River (Amiro and McNeil 1986, Amiro 1987, and 1989) and the Big Salmon River (Amiro 1987).

Stewiacke stock and recruitment

The relationship for 1975-1988 was calculated by regression of Grilse Recruit eggs ($Z_{year\ i}$) on Contributing Stock eggs(X)*July precipitation($Y_{year\ i-2}$) (Table 6) and was significant (p=0.055) without log transformation of the data (Fig. 3). The equation;

$$Z_{Recruit\ eggs}=215.5 + 0.005*(X_{Stock\ eggs} * Y_{July\ precip.})$$

accounted for 21% of the variance. The July precipitation alone accounted for 18% of the variance. The regression had a standard error of the estimate equal to $947*10^3$ recruit eggs and a non-significant (p=0.742) constant. When the 1989 data point was included in the regression the relationship was not significant (p=0.26).

Big Salmon River recruitment

Mean discharges (Table 7) for the months June to October in year i-2 were regressed with the number of angled recruits in year i and September was found to account for the most variance. Sea surface temperatures at St. Andrews (Table 8) were not significant as a second variable in the regression. The regression of angled grilse (1970-1989) on September discharge (1968-1987) was significant (p=0.002) and accounted for 39% of the variance in catches (Fig 4). There was one point of undue influence and one significant residual without logarithmic conversion of the data.

Hatchery releases

Juvenile salmon have been released to both the Stewaicke and Petitecodiac Rivers. Returns to either river have been minimal and of the 10,574 tagged smolts released into the Stewiacke River not a single adult or post-smolt tag has been returned.

Disease status

Exposure to endemic pathogens such as *Aeromonas salmonicida, Vibrio sp.*(3) and Bacterial Kidney Disease (BKD) have been detected by anti-body anti-gen agglutinations from blood sera taken from Stewiacke and Big Salmon River fish collected for broodstock in 1988. No significant differences were detected between stocks or between the control stock, Moser River and the Stewiacke River. While the agglutinations for *Vibrio ordalii* (Bay of Fundy strain) were not detected in the Stewiacke and Moser River samples the low titration required for zero detection in the Big Salmon River samples forces a constrained interpretation of their significance.
Active pathogens were not detected in these same samples.

Infectious pancreatic necrosis virus (IPNV) was detected in one of the broodstock sampled from the Big Salmon River but further sampling could not identify the individual or uncover further infected individuals.

Juvenile samples collected from the Stewiacke and Big Salmon rivers in 1989 did not reveal any active pathogens. Live Stewiacke wild smolts stressed in freshwater did not develop undue mortality due to the above mentioned diseases (G. Oliver pers. comm.[3]).

A single parr sampled from Big Salmon River in 1989, and tested for exposure to endemic pathogens by antigen-antibody agglutination tests, indicated a recent exposure to *Vibrio ordalii* (Bay of Fundy strain) (B. Zwicker pers. comm.[4]). This case could be the first indicated exposure to *Vibrio* in freshwater but is not interpretable because of the sample size.

DISCUSSION

Atlantic salmon stocks of the inner Bay of Fundy can be grouped as separate and unique from adjacent outer Bay of Fundy or Atlantic coast stock complexes. The life history pattern, virtually all maturing after 1SW and returning for up to six consecutive years does not make them unique because other stocks such as Moser River, Grand River and perhaps some stocks from Newfoundland have similar life history patterns. Inner Bay of Fundy stocks however do not regularly replace themselves in one generation (are dependant on repeat spawners for population stability), experience lower average smolt to recruit survival ie. 6.0% than other grilse type stocks (Ritter 1989) and do not migrate to the North Atlantic. Recruitment of inner Bay of Fundy stocks was found to be generally rank order correlated while that of the control river (Moser) was not correlated with any inner Bay of Fundy river and is further evidence for the singular stock complex hypothesis.

Recruitment in all inner Bay of Fundy stocks declined to very low levels in 1987 and 1988. This downturn was forecast for 1987 but not for 1988. Catches and counts of recruits in 1989 indicate a recovery which on the Stewiacke River was 5.7 times the recovery

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forecast by the latest stock and recruitment model and nullifies the statistical significance of the relationship. A plot of the Stewiacke model shows the scatter of the 1987-1989 points (Fig. 2).

A similar result can be seen in the Big Salmon River recruitment model but the 1989 point does not show the same degree of recovery. This is likely the result of a reduced angling catch due to restrictions placed on the fishery in 1989. (Retention of any fish was prohibited until a diver count of the stock indicated spawning escapement would likely be met.)

Extreme variation in recruitment to inner Bay of Fundy rivers has been postulated to be a function of the variability in environmental conditions in the river the year previous to smoltification and stock strength. The possibility that stock alone could account for the extremes in recruitment is not supported by the apparent stability in juvenile densities observed in the rivers under extremes in index escapements (stock). However it remains to be seen if average parr densities accurately indicate pre-smolt population size.

Extremes in marine survival has been observed at Big Salmon River where survival of untagged wild smolts ranged from 1 to 24% and in multiple spawners where survival between consecutive spawnings ranged from 23 to 78% (Jessop 1986, Ritter 1989).

Attempts to model recruitment in these stocks without accounting for variation in marine survival are destine to fail. Successful recruitment models involve an environmental variable which could easily be a surrogate for marine survival. Why then did these models drastically fail in 1988? Why have recruits been consistently below expectations since 1986? Why a sudden recovery in 1989?

Possible mechanisms for high variation in marine survival for inner Bay of Fundy stocks include: 1)Exploitation 2)Predation 3)Competition 4)Environmental and 4)Disease.

Exploitation of inner Bay of Fundy stocks has never been found to be high. Tag returns from commercial fisheries during the 1960's never amounted to a great number for the Big Salmon River. The few tags returned were from the now closed drift net fishery and a few from the now substantially reduced numbers of commercial fish weirs. Commercial salmon fisheries were closed in 1984 before the recent decline in stocks. The reward for a single tag was increased to $10.00 in 1987 and is more than twice the minimum hourly wage. No tags were returned or even "spoke of" from the extensive herring roe fisheries, sardine fishery or from the remaining commercial weirs in the Bay of Fundy when 10,574 Stewiacke tags were at large. It is unlikely that a general decline in inner Bay of Fundy stocks could be attributed to near complete similutaneous exploitation of all the stocks.

Predation in the marine environment on Atlantic salmon has not been shown to be a major portion of marine mortality. Species of fish known to predate on salmon are also targets of major commercial fisheries and certainly not at all-time high levels. Some non-traditional commercial species that are presently high in abundance, like the dogfish (*Squalus acanthias*) have been suspected as predators of salmon. However, the 1989 counts and indexes of returns were resultant of years when dogfish were abundant. The possibility that environmental conditions in the Bay of Fundy effect the abundance or distribution of predators is still a question in 1989 because temperatures were lower in 1988 than in recent years and according to earlier models, favour an increase in marine survival. The presence or duation of exposure to specific predators could be influenced by temperature.

Predation by marine mammals could be affected by temperatures for the same reasons as piscivorous predators.

Competition for resources is an unlikely cause of a complete failure in recruitment. Competition would more likely place a ceiling on marine survival. It is difficult to imagine that even complete loss of one primary forage species such as herring could not easily be replaced by another. While some degree of population reductions have occurred in principle forage species total recruitment failure has not been documented for any.

The environment of the Bay of Fundy has been the subject of many recent studies connected to the possible development of tidal power. No wide-spread environmental catastrophes have been documented. The possibility that an occasional and repeated environmental event is causal to the extreme variation in marine survival of inner Bay of Fundy Atlantic salmon is remote.

Diseases such as BKD, furunculosis and vibriosis are common to Bay of Fundy and other Atlantic salmon stocks. BKD can now be said to be ubiquitous to most salmon stocks in eastern Canada. Rarely has the disease been indicated as a major cause of increased marine mortality outside of hatchery programs. The presence of BKD in a epizootic state can be detected in the routine sampling of the population in the freshwater. Surveys to date have not indicated this state.

Furunculosis manifests itself in freshwater at the adult stage. Sampling of adults did not reveal acute infections. Autopsied recovered adult mortalities in the Big Salmon River were not attributable to acute furunculosis.

Vibriosis has long been a problem at Atlantic salmon research facilities in the Bay of Fundy. Facilities holding broodstock from early (season) collections have had problems with development of the

the outcome it remains that recruitment models for stocks of the inner Bay of Fundy require a better surrogate for marine survival than pre-smolt water conditions. While pre-smolt water conditions may affect the ability of post-smolts to tolerate the disease there may as well be a connection between environmental conditions at two different locations and times and an interaction with other species or predators.

The presence of anti-bodies to the specific *Vibrio ordalii* (BF) antigen in parr also requires further examination. While researchers are unsettled as to the interpretation of anti-body anti-gen reactions the possible presence of the disease in freshwater raises some interesting questions. How did the parr develop the specific anti-body? Will anti-body positive fish be more tolerant of the disease in salt water? These questions hinge on results of further sampling in fresh water.

The implications of the *Vibrio* hypothesis being true are not particularly negative. The prognosis for the stocks would remain much the same in an environment where aquaculture vaccinates all its smolt, boost vaccinates broodstock or carry-over fish and treats any infected population. The vectors for the disease would be perhaps no greater than without an industry. Stocks have maintained themselves in low recruitment years with minimum escapements. These stocks are robust, by nature of their life history strategy, to temporary declines in marine survival. The scenario for a longer downturn in production is set if recruitment is very poor three years in a row.

Monitoring of the juvenile populations remains a priority in the next four years. Juvenile populations will be resultant of minimum escapements and will indicate the impact of two consecutive years of recruitment downturns. This information will assist in re-evaluating the level of recruits required to maintain the populations.

Some recovery in recruitment is forecast in 1990. However, harvest strategies must remain conservative after 1990. In an era when recruitment can be expected to be low from both the stock and environment perspectives a sudden re-occurrence of low marine survival will place the stocks in greater jeopardy. The strategy in place on the Big Salmon River in 1989 assured the first objective of management (spawning escapement) while maintaining the possibility for a fishery.

Continuation of the hook-and-release of fish >= 63cm was beneficial to these stocks particulary when declines in the number of repeat spawners was expected. However while stability in production may be maintained by repeat spawners, recruitment must first be ensured.

One proposal for management of inner Fundy Stocks would be to continue to monitor juvenile populations in Stewiacke River (since disease. Treatment with antibiotics has become standard practice for facilities holding adult fish in marine or brackish enclosures or pumping facilities. Mortalities occur under stressed conditions such as high temperatures and fish densities.

The full impact of the vibriosis problem was first realized with the development of the Atlantic salmon aquaculture industry. Aquaculturists soon realized that without vaccination smolts suffered high mortality when acclimated to salt water and when exposed to increasing summer temperatures. Vaccinations were soon the rule for a successful operation. Early vaccines were developed with species of *Vibrio* ubiquitous to the east coast and later with species from the west coast as well. Results were irregular and products improved with the introduction in 1989 of a vaccination including the *Vibrio ordalii* (Bay of Fundy strain).

Vaccinated Penobscot River (Baum et al. 1982) and Saint John River origin smolts[5] released to the wild indicated no improved return rate for treated vs. untreated groups. These studies conflict with the idea that vibrio is a major factor in reduced marine survival of hatchery smolts. The trials however could not be expected to produce the same results as Saint John stocks stocked in enclosures in the Bay of Fundy. Saint John River smolts are known from post-smolt recoveries to move across the Bay of Fundy and along the coast of Nova Scotia on their way to the North Atlantic. This migration pattern places them outside of the Bay of Fundy in the warmer months of July and August when the disease has an opportunity to develop. Even if they had contacted the bacteria while in the Bay of Fundy, by moving north they would encounter colder water and slow the development of the bacteria. This could hardly be considered a fair trial of the vaccine for stocks of the inner Bay of Fundy which have never been found outside the Gulf of Maine.

The hypothesis that *Vibrio* sp. is and has been ubiquitous in the Bay of Fundy and causes extremes in the marine survival of Atlantic salmon begs examination. The aquaculture industry cannot be singled out as the cause of this disease since infections were suspected well before the industry took off from 5 permits in 1983 and developed to 34 permits by 1987. However, it may be that the disease was more rapidly spread during the early years of development of the industry when mortalities were higher in the cages and an epizootic condition could have occurred.

The hypothesis that *Vibrio* is a major contributor to marine mortality in inner Bay of Fundy salmon stocks will be tested in 1990 and 1991 with vaccine trials on inner Bay of Fundy smolts. Whatever

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the program is already in place) and to monitor adult returns to the Big Salmon River by diver observation. Harvests in any other inner Bay of Fundy river could be made contingent upon escapement, thru diver counts, being met on the Big Salmon River. This scheme both optimizes the resources available to conduct the work and concentrates on the two most indicative rivers of the inner Bay of Fundy. The ability to monitor returns to the Stewiacke River would be especially beneficial to the monitoring of the stock and the assessment of hypotheses concerning recruitment.

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Table 1. Grilse (G) and large salmon (S) angled on inner Bay of Fundy rivers, 1970-89
(-999 indicates a missing value).*

River	1970		1971		1972		1973		1974		1975		1976		1977		1978		1979	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
Alma (Upper Salmon)	34	33	39	3	60	20	50	24	148	66	58	15	79	23	69	9	52	5	199	6
Apple	0	0	0	0	0	0	0	1	11	0	3	5	22	2	0	0	0	0	8	0
Big Salmon	231	260	191	75	182	96	378	130	373	106	187	94	664	207	200	136	360	228	932	389
Chiganois	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	9	3	1	1
Cornwallis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coverdale	3	5	20	1	10	0	30	8	11	0	0	0	2	0	1	0	0	0	0	0
Debert	2	2	61	2	17	18	68	38	84	31	60	6	61	36	17	65	154	39	38	24
Economy	6	6	115	4	17	15	54	35	92	39	54	9	106	49	8	60	168	26	60	44
Folly	16	5	73	6	31	29	196	61	61	10	87	31	87	31	15	70	303	53	77	53
Great Village	4	0	0	0	0	5	0	0	0	0	3	0	5	1	0	3	16	5	7	3
Irish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kennetcook	0	0	0	0	0	0	0	0	0	0	0	0	21	10	0	0	0	0	0	0
Maccan	102	29	125	32	145	42	70	32	95	32	43	19	129	36	65	20	65	21	140	40
Mosher	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North (col.)	4	0	24	0	5	8	3	4	51	21	16	2	77	24	28	125	121	31	14	10
Petitcodiac	43	2	31	0	5	0	5	1	27	0	15	2	70	0	51	0	11	0	1	0
Pollet	7	0	4	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Portapique	19	9	72	11	8	10	44	19	72	37	12	2	50	22	5	17	59	11	32	24
River Hebert	0	0	55	15	70	25	33	12	48	5	6	0	40	5	10	0	0	0	75	0
Salmon (Col.)	0	0	0	0	0	0	0	0	21	13	12	6	70	24	11	40	120	14	17	8
Shepody	0	0	0	0	0	0	2	0	2	0	1	0	2	0	2	0	0	0	4	0
Shubenacadie	24	9	57	4	6	9	46	23	126	61	50	24	235	63	7	70	23	5	60	16
Stewiacke	355	163	337	46	343	265	520	224	1087	355	442	180	940	198	104	370	545	75	681	239
St. Croix (Hants)	0	0	0	0	23	5	47	10	12	4	17	0	8	10	4	0	21	0	0	0
Annual catches	850	535	1204	199	925	547	1548	622	2321	780	1066	395	2674	741	597	985	2027	516	2346	857
Total catches	1385		1403		1472		2170		3101		1461		3415		1582		2543		3203	

Table 1. Cont'd

	1980		1981		1982		1983		1984		1985		1986		1987		1988		1989**	
	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S	G	S
Alma (Upper Salmon)	2	7	76	6	34	21	72	4	44	0	44	0	6	0	0	0	3	0	-999	-999
Apple	4	6	8	4	16	5	18	7	29	7	12	6	3	13	3	0	0	0	11	2
Big Salmon	5	223	645	304	456	328	339	178	373	27	318	0	124	0	31	0	30	0	150	-999
Chiganois	0	0	1	1	5	7	3	1	0	0	1	0	0	0	0	0	0	0	-999	-999
Cornwallis	1	1	0	11	0	6	5	0	0	0	1	2	20	14	0	2	1	1	6	0
Coverdale	0	0	0	0	0	0	0	0	6	0	6	0	0	0	0	0	0	0	-999	-999
Debert	11	32	14	12	85	45	113	20	54	11	64	24	14	24	1	1	21	5	26	9
Economy	4	9	56	48	86	23	83	29	26	4	42	16	12	4	2	4	10	1	8	2
Folly	11	63	62	54	132	76	67	12	57	16	71	29	14	2	4	0	50	7	43	11
Great Village	3	5	2	0	3	2	0	0	1	0	1	0	4	3	0	1	2	1	41	2
Irish	0	0	10	12	5	5	6	1	16	0	14	0	6	0	0	0	0	0	-999	-999
Kennetcook	0	0	0	0	0	0	0	0	1	0	8	2	1	0	0	0	0	0	0	0
Maccan	36	40	36	15	45	22	242	50	140	28	117	14	90	18	12	5	39	4	160	32
Mosher	0	0	10	8	7	7	0	0	23	0	28	0	6	0	0	0	0	0	-999	-999
North (col.)	5	22	24	16	103	27	43	5	69	6	77	3	63	25	14	4	103	11	151	8
Petitcodiac	0	0	0	0	0	0	0	0	6	0	11	0	0	0	0	0	0	0	-999	-999
Pollet	0	0	0	0	0	0	0	0	4	0	12	0	0	0	0	0	0	0	-999	-999
Portapique	7	17	32	26	23	17	12	2	10	1	17	1	2	1	3	0	15	1	19	0
River Hebert	4	8	11	4	27	9	194	28	66	9	81	17	31	8	4	2	7	0	109	8
Salmon (Col.)	3	9	34	32	57	18	123	16	89	13	164	28	67	39	18	19	40	16	128	22
Shepody	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	-999	-999
Shubenacadie	6	73	176	27	45	14	232	54	55	17	191	40	102	79	54	36	33	13	58	14
Stewiacke	41	203	531	89	307	97	1619	317	425	140	1037	361	495	580	149	215	247	89	1323	223
St. Croix (Hants)	1	1	3	0	0	45	92	8	78	12	68	9	3	0	0	0	0	0	14	0
Annual catches	144	719	1731	669	1436	774	3263	732	1572	291	2392	552	1063	810	295	289	601	149		
Total catches		863		2400		2210		3995		1863		2944		1873		584		750		

* 1970-82 data were based on Fishery Officer estimates of killed fish on all rivers; 1983-89 data were based on license stubs for Nova Scotia rivers and on Fishery Officer and Park Warden estimates for New Brunswick rivers.

** Preliminary estimates.

Table 2. Number of rivers with which significant (p=.05) spearman rank correlation coefficients occur in the cross correlation matrix of 24 rivers of the inner Bay of Fundy and a "control" river (Mosers River) 1970-1989.

River	Numbers of rivers with significant correlation
Alma	6
Apple	8
Big Salmon	10
Chiganois	9
Cornwallis	2
Coverdale	4
Debert	8
Economy	7
Folly	6
Great Village	2
Irish	5
Kennetcook	5
Macccan	5
Mosher	4
North	3
Petitcodiac	2
Pollet	2
Portapique	5
Hebert	5
Salmon	8
Sheppody	2
Shubenacadie	7
Stewiacke	13
St. Croix	2
Moser	0

Table 3. Annual means and standard deviation of age-1+ and age-2+ densities as determined by mark-recapture electrofishing at sites in the Stewiacke River 1984-1989.

	Year and number of sites					
	1984	1985	1986	1987	1988	1989
Age	44	27	38	36	29	31
1+						
Mean	17.0	28.9	16.0	33.6	18.5	16.1
SD.	13.2	26.7	13.0	44.7	9.0	13.7
2+						
Mean	6.8	6.8	8.1	5.5	7.0	6.7
SD.	7.9	8.3	8.9	4.8	5.1	5.7
Total						
Mean	23.8	35.7	24.2	39.2	25.5	22.4
SD.	19.0	34.2	18.4	47.8	10.7	16.1

Table 4. Number of Atlantic salmon, grilse and salmon counted by under-water observation in the Point Wolfe and Alma rivers, SFA 23, 1983-1989. (F. Granger pers. comm.)

	Point Wolfe		Alma	
Year	Grilse	Salmon	Grilse	Salmon
1983	-	-	372	168
1984	-	-	200	183
1985	196	4	276	95
1986	66	29	37	66
1987	36	39	23	29
1988	25	24	33	24
1989	161	17	250	41

F. Granger, Environment Canada, Fundy National Park, Alma N.B.

Table 5. Post-smolt age, spawning history, number caught and percent of sample of Atlantic salmon collected from Big Salmon River October 20, 1989.

Post smolt (years)	Caught	Percent
1	34	73.9
2 sp.1	5	10.8
3 sp.1.2	1	2.2
4 sp.1.2.3	3	6.5
5 sp.1.3	1	2.2
2	1	2.2
?	1	2.2
Totals	46	100.0

Age at smoltifcation ; 2's - 52.6%
; 3's - 39.9%
; 4's - 7.5%

Table 6. Recreational catch including releases of Atlantic salmon from the Stewiacke River 1970 to 1989 with estimated number of spawner eggs (from yr i-4 and i-5 of sport catch) contributing to recruit eggs returned in year i, precipitation at Upper Stewiacke in July and August of year i-2 and estimated index egg deposited in year i.

Year	Sport catch[a]		Spawner eggs*1000			Recruit eggs*1000	Precipitation (mm) in recruit yri-2		Egg deposit *1000
i	Grilse	Salmon	Grilse	Salmon	Total	Grilse	July	August	yr=i
70	462	212							
71	438	60							
72	446	345							
73	676	291							
74	1,413	462							
75	575	234	1,052	456	1,508	1,360	151.4	110.2	2,435
76	1,222	257	1,051	1,242	2,292	2,893	106.9	54.6	4,075
77	135	481	1,459	1,400	2,859	320	28.4	14.7	2,528
78	709	98	2,892	1,915	4,807	1,677	46.2	51.0	2,125
79	885	311	1,876	1,346	3,222	2,096	129.7	82.5	3,522
80	53	264	2,494	1,154	3,648	126	54.7	28.9	1,338
81	690	116	989	1,941	2,930	1,634	164.1	177.9	2,165
82	399	126	1,324	905	2,230	945	116.0	45.4	1,524
83	1,619	317	1,987	1,172	3,159	3,833	138.2	67.2	5,288
84	425	140	638	1,267	1,906	1,006	110.8	100.4	1,649
85	1,037	361	1,242	708	1,950	2,455	177.9	193.4	4,112
86	495	579	1,124	566	1,691	1,172	55.6	160.4	3,830
87	148	216	3,082	1,227	4,309	350	53.0	130.0	1,342
88	247	119	1,741	854	2,595	585	151.6	89.4	1,131
89	1,323	223	2,078	1,393	3,472	3,132	44.4	70.2	4,156
90			1,505	2,398	3,903		148.6	120.4	
91			564	1,425	1,989				
92			524	662	1,186				

a. Data prior to 1983 increased by 30%

Grilse avg.length = 55.2 cm.==>3.288 eggs/female @ 72% of the grilse population.
Salmon avg length = 71.3 cm.==>5,962 eggs/female @ 77% of the salmon population.

Proportion of eggs destined to 2yr smolt==> 0.74 of yri-4 of recruits(grilse).
Proportion of eggs destined to 3yr smolt==> 0.26 of yri-5 of recruits(grilse).

Table 7. Mean monthly discharges (cms) for the Point Wolfe River, 1968-1988.

Year	June	July	Aug.	Sept.	Oct.
68	4.18	1.04	0.49	0.50	3.39
69	3.27	4.49	2.07	1.84	2.55
70	3.42	4.03	2.47	3.88	6.54
71	2.17	1.51	3.28	1.82	4.59
72	7.04	3.99	2.89	1.83	7.98
73	4.53	8.05	6.80	1.00	0.67
74	4.34	3.42	0.82	2.69	5.39
75	2.69	1.51	0.66	1.77	3.46
76	1.52	6.83	2.98	4.04	8.06
77	10.40	2.34	2.61	5.09	12.30
78	3.60	1.05	0.39	0.46	3.05
79	3.90	4.77	6.96	7.25	6.33
80	2.11	2.52	1.20	1.77	4.40
81	7.58	2.39	3.03	1.22	19.70
82	2.23	3.50	3.89	3.42	1.19
83	4.43	1.63	1.50	1.49	3.68
84	7.08	5.74	1.43	1.60	1.26
85	7.90	2.03	0.68	0.33	0.79
86	2.25	1.79	5.41	2.38	2.41
87	2.12	0.55	0.30	2.55	4.68
88	1.67	1.44	1.97	2.31	3.75

Table 8. Mean monthly water temperature (C) taken twice daily at St. Andrews, N.B., DFO wharf, 1969 to 1989.

Year	Temperature		
	May	June	July
69	6.8	9.9	12.1
70	8.2	10.1	13.3
71	7.8	10.5	13.4
72	7.1	10.2	12.0
73	6.9	9.1	12.3
74	6.2	9.8	12.3
75	6.3	9.3	11.9
76	8.9	11.8	13.9
77	6.6	10.5	11.9
78	7.5	9.9	12.3
79	7.9	10.8	12.7
80	6.8	9.3	11.5
81	7.3	9.8	12.6
82	7.2	9.6	12.0
83	7.9	11.0	12.0
84	6.7	10.2	12.6
85	–	8.7	11.9
86	–	9.4	12.2
87	–	–	–
88	–	9.4	10.8
89	–	9.2	11.7

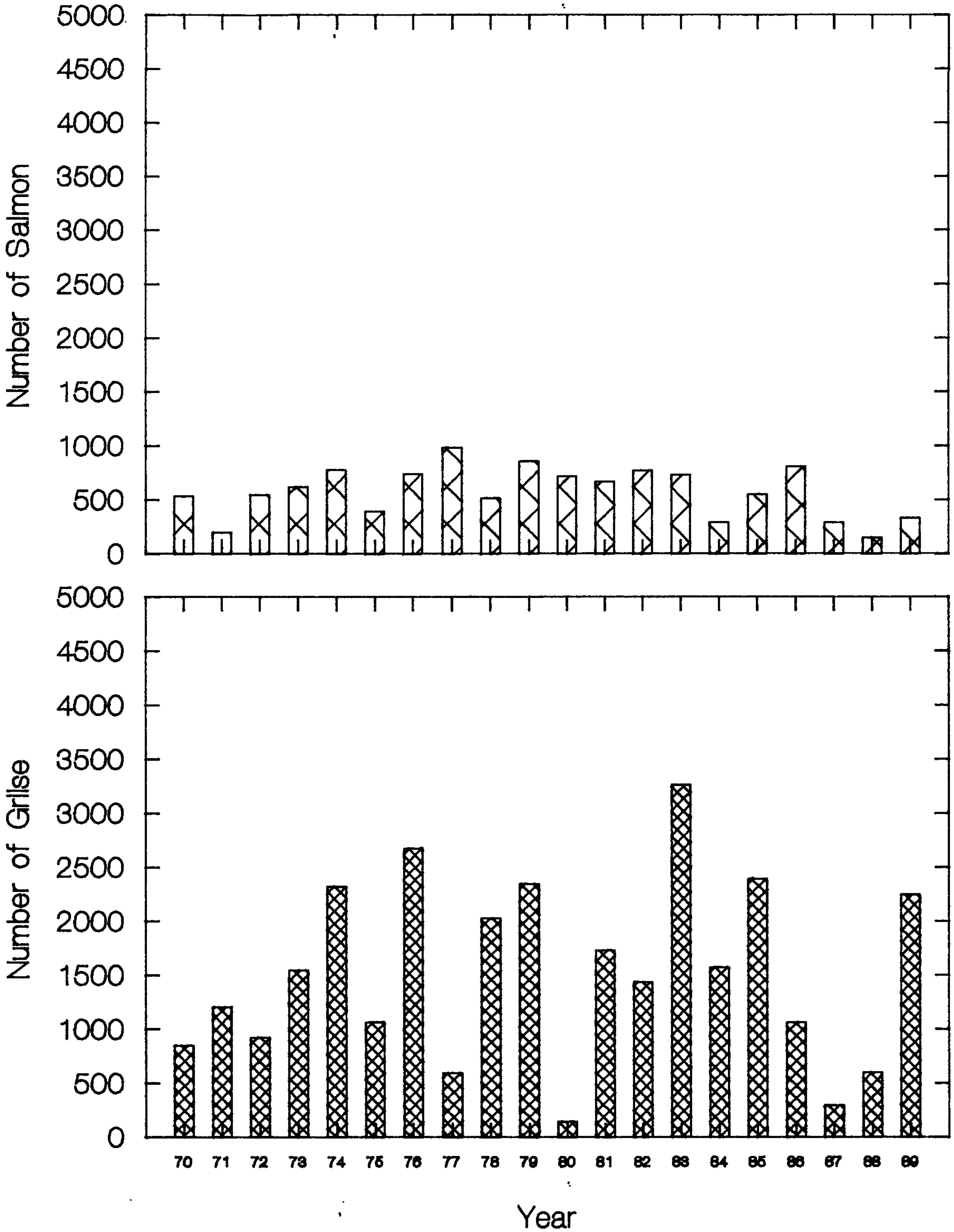

Fig. 1. Total recreational catch of Atlantic salmon (upper) and grilse (lower) in 24 rivers of the inner Bay of Fundy, 1970-89.

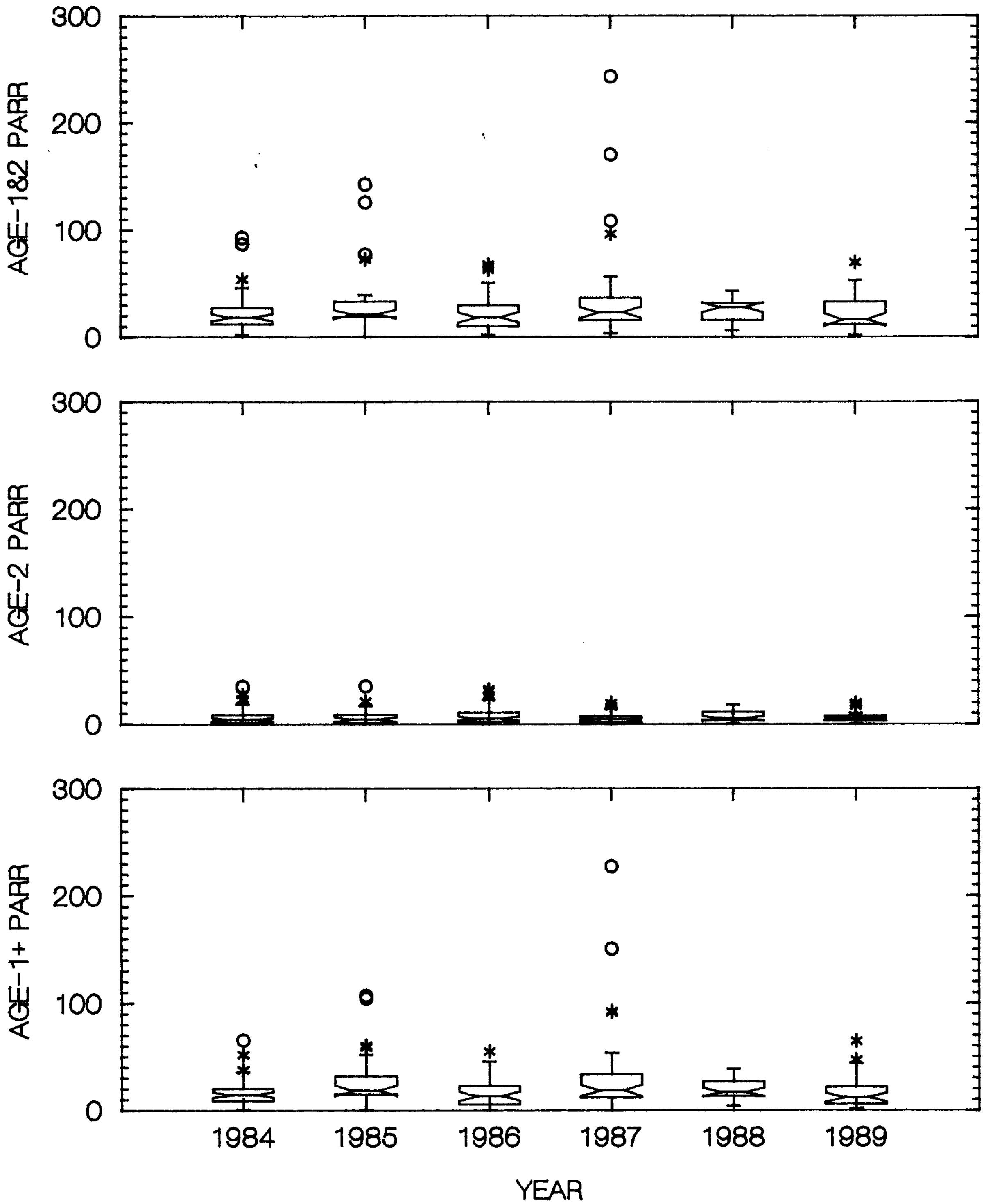

Fig. 2. Box plots of median ranks (notches), quartiles (wide and narrow lines), 95% confidence interval outliers of inner quartiles (*) and outer quartiles (o) of age-1+ parr (lower), age 2+ parr (middle) and age-1 and 2+ parr (upper) densities (10^{-2} m^2) of Atlantic salmon electrofished in the Stewiacke River 1984 to 1989.

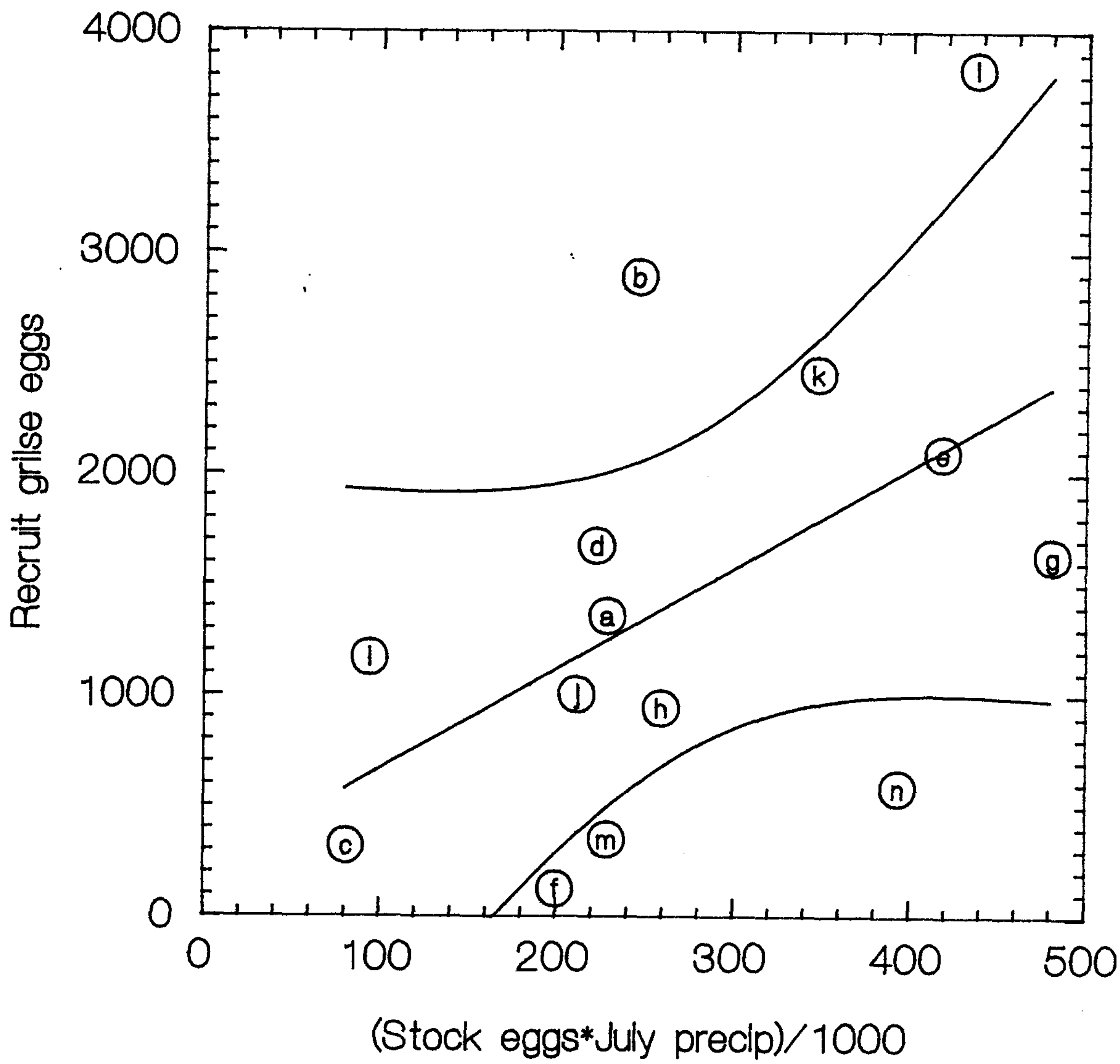

Fig. 3. Linear regression and 95% confidence limits of recruit grilse eggs (1975-88) indexed from the Stewiacke River sport catch and contributing spawner egg index (1970-83) multiplied by the total July precipitation at Upper Stewiacke. Letters a through n correspond to the angling years 1975-88.

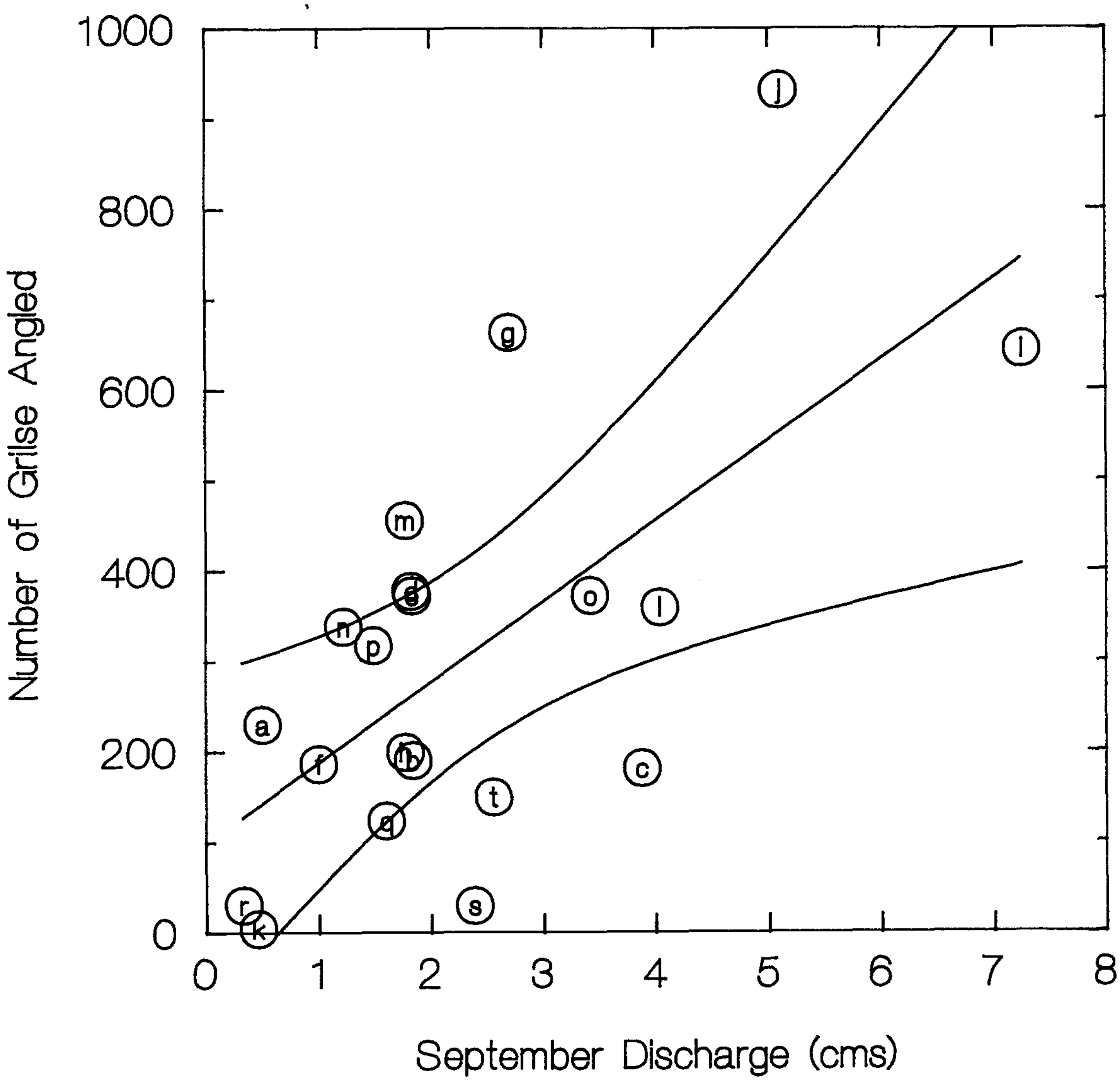

Fig. 4. Linear regression and 95% confidence limits of the numbers of grilse angled in the Big Salmon River in yr i and September discharge in Point Wolfe River in yr(i-2). Letters a through t correspond to angling years 1970-89.