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INDIRECT ESTIMATE OF ATLANTIC SALMON ESCAPEMENT IN QUEBEC RIVERS.

by

Jérôme Guillouët[1] & François Caron[2]

(1) E.N.S.A.R. Unité halieutique. 65, rue de Saint-Brieuc, 35042 Rennes Cédex, France.

(2) M.E.F. Service Faune Aquatique. 150, Bd René Lévesque, 5è .Québec, QC, G1R 4Y1, Canada.

ABSTRACT

The management of Atlantic salmon stocks in Quebec is based on the "spawning stock target concept". Annual escapement estimates are required to match the expected annual targets.

The objective of the present work is to develop an annual escapement estimation method for each river.

Models including annual escapement as the response variable, sport catches, fishing regulations, river flow and biological characteristics of stocks as predictor variables, have been fitted by using multivariate linear regressions on available data (from 1984 to 1991). Models have been obtained by considering predictor variables such as : sport catches, average daily flow, daily catch limit and fishing season length (r^2=0.92, p<0.001). The significance of these predictor variables in these models is discussed. Such models should provide annual escapement estimate.

Introduction

In the province of Québec (Canada), MLCP[1] is in charge of salmon fishery management. MLCP's first objective is to insure salmon resource conservation. In this way, MLCP's strategy is based on spawning stock target concept in order to obtain the optimal production in each salmon river (Caron, 1990). Each year, achievement of spawning stock target must be assessed. Several methods for counting adults are available :

-Direct counts : visual counts by diving or with canoes, counts at fish barriers (Lévesque & Banville, 1990).

- indirect counts : tagging, abundance indexes, etc... (Ouellet, 1990).

Actually, counts can be made where fish barriers exist and by diving where and when water transparency is sufficient. These cases are located essentially on the South coast of Saint-Lawrence gulf and on Anticosti island (Fig. 1). But many stocks located on North coast of Saint-Lawrence gulf cannot be estimated with these methods because of water turbidity. Diving is expensive in human and time resources. Indirect methods become of special interest for every stock in reducing costs and permitting estimates where they are not yet possible.

This paper describes an attempt to develop an indirect method for salmon stock estimation based on sport catches results.

Method and data

As commercial fisheries have been largely reduced in the past decade and that sport fishery is the last exploitation before spawning, we made the following assumptions :

1 - Sport catches can provide a valuable index for spawning stock.

2 - Fishing regulations, environmental factors and biological stocks characteristics may influence relationships between sport catches and the corresponding stock. River flow effect on fishing success and escapements is shown in many papers (Alabaster, 1970 ; Alabaster & Graham, 1988 ; Banks, 1969 ; Glova, 1988 ; Millichamp & Lambert, 1967 ; Stewart, 1972). Other variables of interest as water temperature and rainfall demonstrate evident relations with river flow but are less available than river flow. For these reasons, as environmental factor, we used only river flow.

Fishery data :

Each catch is reported by fishermen at local office of MLCP. Daily fishing effort is known, for each river, by obligatory registration before reaching fishing places. Daily escapements values used here, are measured by one of the direct methods described above.

In 1984, databases have been created which compile sport catch results and sport fishing effort. Our data are extracted from databases compiled by each regional office of MLCP. All regional databases have the same fixed format organised by "saumon" software (Genest, 1989). Each salmon catch record includes : date, weight, fork length, river. Effort is measured for each river and reported by number of fishermen per day.

Our database for analysis contained all cases between 1984 and 1991, where escapement, catch and effort were available and reliable. We have eliminated all cases where corrections, due to partial lack of data, were made on escapement, catches or effort. Such corrections have been identified in accordance with the biologist in charge of the corresponding

[1] Ministère du Loisir, de la Chasse et de la Pêche. Now, Ministère de l'Environnement et de la Faune (MEF)

river. After these controls, 204 cases (river-year) were available for analysis. Note that some fishing years from 1984 to 1991 are lacking for some rivers.

Other data :

We extract for all of the previous 204 cases, following parameters (Tab. 1).

Statistical method :

For prediction purposes and because almost our variables are continuous, we used multiple linear regression.

Model we attempted to adjust is therefore : $N_{y,r}=f(C_{y,r} ; X_{i,y,r})$ where N are annual escapements, C are annual sport catches and X_i is the ith variable entering significantly in the model. y : year and r: river.

Categorical variables (commercial fishing, presence of fish barrier...) were included in analyses after dummy coding. Models were fitted using stepwise procedure (forward and backward) from MGLH module from SYSTAT software (SYSTAT, 1992). We checked following statistical assumptions for each model obtained :

- each variable coefficient must be significantly different from 0 ($p<0.05$);
- collinearity between variable is assessed by tolerance values (Baillargeon et Rainville, 1979);
- residual homoscedasticity is checked visually;
- auto correlation is checked by Durbin-Watson statistic (accepted if DW statistic between $2\pm4\sqrt{\text{number of cases}}$);
- residuals with particular influence are identified by leverage and student statistic (Mélard, 1990).

For each model obtained, residuals are plotted against variables not used in model in order to show relations. In case of relation, variable is eventually transformed before being re-included in stepwise procedure.

Results

Minimum exploitation for reliable relation between escapements and sport catches.

From plot between annual catches and escapements (Fig 2), it appeared there were numerous low values for these two variables. Low values for catches show very variable values for escapement. This could be explained by the fact that very low exploitation intensity cannot help to get reliable information on escapements. Examination of data showed that some rivers are fished by only 3 fishermen for 82 days fishing season duration and 27 km accessible river length to salmon. Other bigger rivers (104 km accessible length for salmon) are fished by 100 fishermen for 92 days. These examples showed that fishing intensity can be low due to fishing effort diluted in time and space. In order to assess the lowest exploitation limit for getting valuable information on relation between escapements (N) and catches (C), we studied exploitation rate coefficient of variation (abbreviated CV of C/N) against f/duration/accessible length (abbreviated f/dur/lgacc). f/dur/lgacc represents effort (f) with respect to space (lgacc = accessible length for adult salmon) and time (dur = fishing period duration). Figure 3 shows that for values of f/dur/lgacc between 0.86.and 0.52, CV of C/N is low but few cases are concerned. Increase of CV of C/N for f/dur/lgacc=0.5 is due to high value of C/N from one river only. This is a particular case because of early close of fishing season (Matane river in 1989, Fig. 2). Next important change in CV of C/N is for f/dur/lgacc=0.04. This value has been chosen as lower limit of f/dur/lgacc for which relation between catches and escapements is reliable. Number of cases for which f/dur/lgacc is higher than 0.04 is137.

Models

Model 1 :

For model 1, dependent variable is log(N) and independent variables are log(C), individual daily quota, duration of fishing period and log(daily mean flow).

Logarithm transformations for N and C have been made in order to obtain residual homosedasticity. From the 137 cases of dataset, four are missing (missing values for flow) and two are deleted because of being atypical (Matane river, 1989 has an early close of fishing season. No obvious reason was found for influence of Bec-scie river in 1989).

Results for the first model retained accordingly to regression assumptions are described in table 2. Residual characteristics of model 1 are presented in fig 4 .

Model 2 :

In second model, data are divided in two sets, each side of 90 days fishing season duration. For each sub-model, dependent variable is log(N) and independent varaible si log (C). Logarithm transformations have been used for the same reason as in model 1. From the 137 cases of dataset, the same cases as in model 1 have been deleted for the same reasons.

Results for the two sub-models (a&b) of the second model retained (model 2) are described table 3. Residual characteristics of model 3 are presented in fig 5.

Discussion

Model 1 provides best adjusted squared multiple r (r^2_{adj}) and standard error of estimate (SEE). It includes four parameters from which two refer to fishing regulations.

Catch is the most important variable in the model and is positively correlated with escapements. Other variables take a much lower part of variance. Coefficient of flow and quota variables is negative. This is the expected sign since the more favourable the quota value is, the more should be annual catch for explaining the same escapement value. With a similar interpretation, duration was expected to have the same sign. Duration showed a positive significant ($p<0.05$) correlation with escapements. In fact, high duration values are found on rivers with the highest escapements values (Matane, de la Trinité and Godbout rivers) and on rivers with poor escapement values (as many rivers located on the North coast of Saint-Lawrence gulf). Additive explanation for the positive sign of duration could be that it is not a limitation for exploitation because the greatest part of exploitation is done early in season. The last part of fishing season is not used by fishermen who look for large salmons (multi sea winters) arriving earlier than grilses.

We have chosen to present here two models because the first one needs flow value. Flow is not always easily available and mean daily flow for fishing season duration needs more calculations. Model 2 can operate without this flow parameter. Model 2 splits data in two sets relating difference in fishing season duration. One for short season durations (most of them equal 82 days) and the other one for long season durations (from 92 to 108 days). For each sub-model a and b, catch is the only explicative variable. The two sub-models are significantly different (slope homogeneity test, $p<0.05$) showing that fishing season duration is a meaningful factor in relation between escapement and catches. Because one of sub-model (2b) has lower adjusted r^2 and SEE than model 1, we consider model 1 should be used rather than model 2 when flow data are available.

Conclusion

Results show that relation between annual salmon sport catches and annual escapement would permit escapements estimation provided that exploitation intensity is strong enough.

Flow as environmental factor and individual daily quota as fishing regulation factor, have significant effects on relation between annual escapements and catches. Fishing duration season is useful for estimates although his effect is unclear.

Further research would emphasise study on effects of fishing regulations against exploitation. Models fitted in this study could be used for predictive purposes with software providing easier calculations.

Acknowledgements

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Table 1: parameters extracted for analysis.

fishing regulations[3]	- individual daily quota - individual quota for whole fishing season - duration of fishing period - river length available for fishing - river length without fishermen number limit
biological stocks characteristics	- multi-sea winter salmon proportion in catches - multi-sea winter salmon proportion in escapements
river flow[4]	- daily mean flow during fishing season[5] - number of shift trends in flow during fishing season[4]
fishing success	- daily cpue mean - number of days with no catch and effort different from 0 - number of fishermen in days with no catch
other variables	- presence of fish barrier (fish barriers could inform fishermen of salmon new arrivals and then modify fishing effort) - presence of commercial and native fisheries

[3] source : from fishing books supplied by Quebec government for each salmon fisherman.

[4] source : from data of Ministère de l'Environnement, direction du réseau hydrique.

[5] Flow is not available for each river. Some extrapolations had to be made. For not gauged rivers , we used data from other rivers. Two criterion of extrapolation have been used : 1- watersheds proximity ; 2 - similar value of watershed areas.

Table 2 : Regression results for model 1

Dependant variable : LN
Number of cases:131
r=0.959 , r^2=0.921 , r^2_{adj}=0.918
Standard error of estimate=0.292

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P
CONSTANT	1.752	0.268	0.000	.	6.544	0.000
DURATION	0.007	0.002	0.116	0.615	3.622	0.000
QQT	-0.145	0.059	-0.083	0.555	-2.467	0.015
LC	0.765	0.025	0.907	0.702	30.279	0.000
LQM	-0.101	0.044	0.059	0.941	-2.268	0.025

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	124.466	4	31.117	365.181	0.000
RESIDUAL	10.736	126	0.085		

LN : annual escapement (logarithms)
DURATION : fishing season duration (days)
QQT : individual daily quota
LC : annual catch (logarithms)
LQM : mean daily flow during fishing season (logarithms)

Table 3 : Regression results for model 2 (two sub-models a and b)

MODEL 2a (duration≥90 days)

Dependant variable : LN
Number of cases = 47
$r = 0.972$, $r^2 = 0.945$, $r^2_{adj} = 0.944$
Standard error of estimate = 0.269

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P
CONSTANT	2.161	0.171	0.000	.	12.671	0.000
LC	0.858	0.031	0.972	1.000	27.917	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	56.506	1	56.506	779.343	0.000
RESIDUAL	3.263	45	0.073		

MODEL 2b (duration<90 days)

Dependant variable : LN
Number of cases = 90
$r = 0.944$, $r^2 = 0.891$, $r^2_{adj} = 0.890$
Standard error of estimate = 0.304

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P
CONSTANT	2.571	0.144	0.000	.	17.897	0.000
LC	0.758	0.028	0.944	1.000	26.865	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	66.718	1	66.718	721.740	0.000
RESIDUAL	8.135	88	0.092		

LN : annual escapement (logarithms)
DURATION : fishing season duration (days)
LC : annual catch (logarithms)

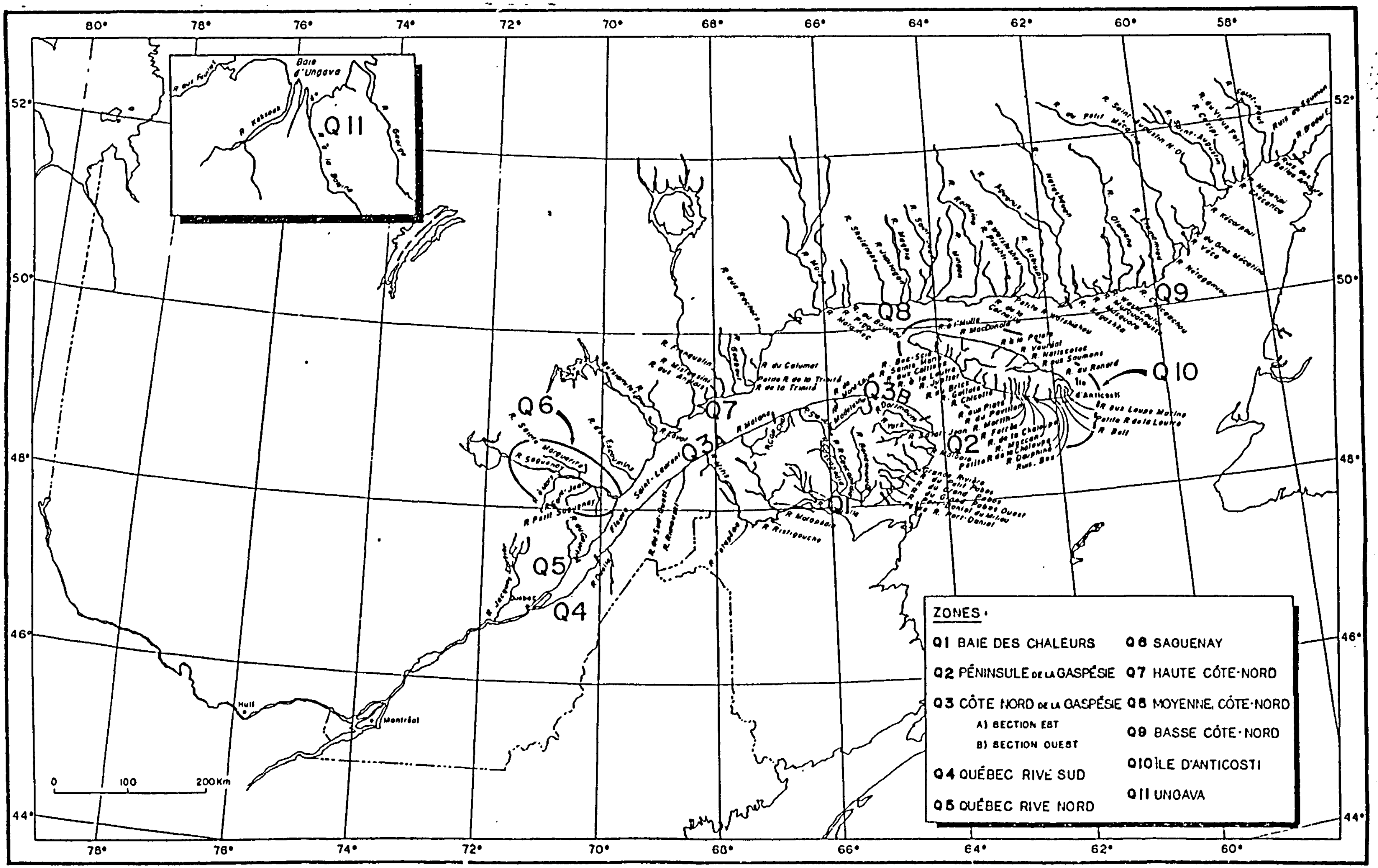

Figure 1. Salmon rivers in Quebec with regional zones.

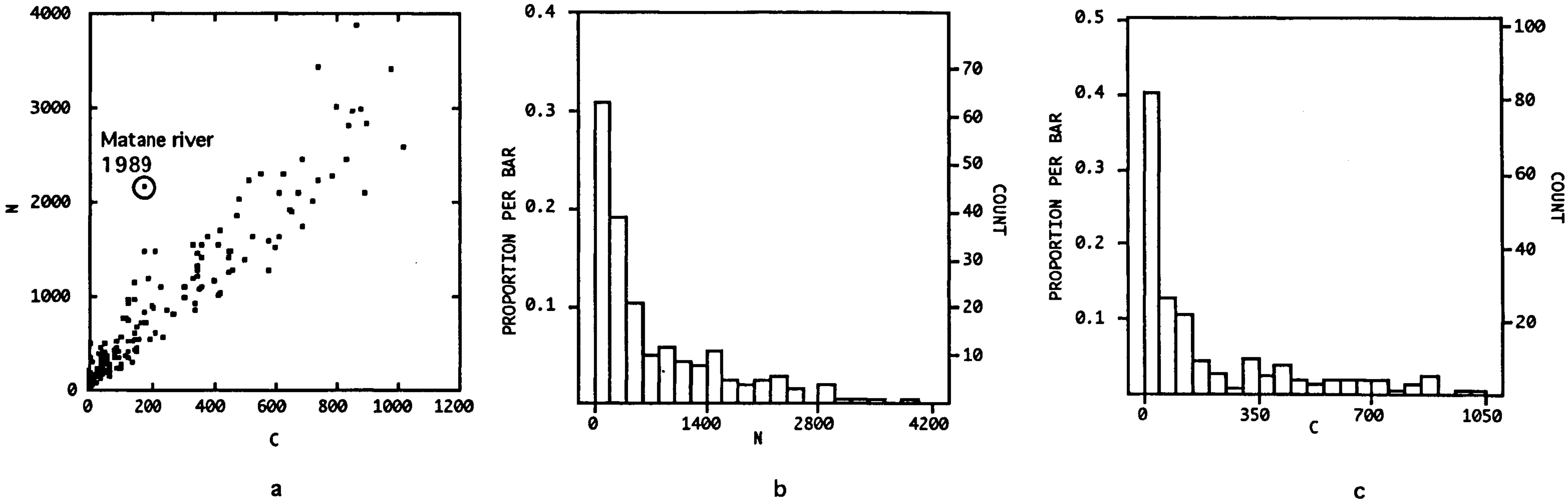

Figure 2. a) Graphical relation between annual escapements and salmon annual sport catches (1984 to 1991).
b) Distribution of values for escapements (N)
c) Distribution of values for catches (C)

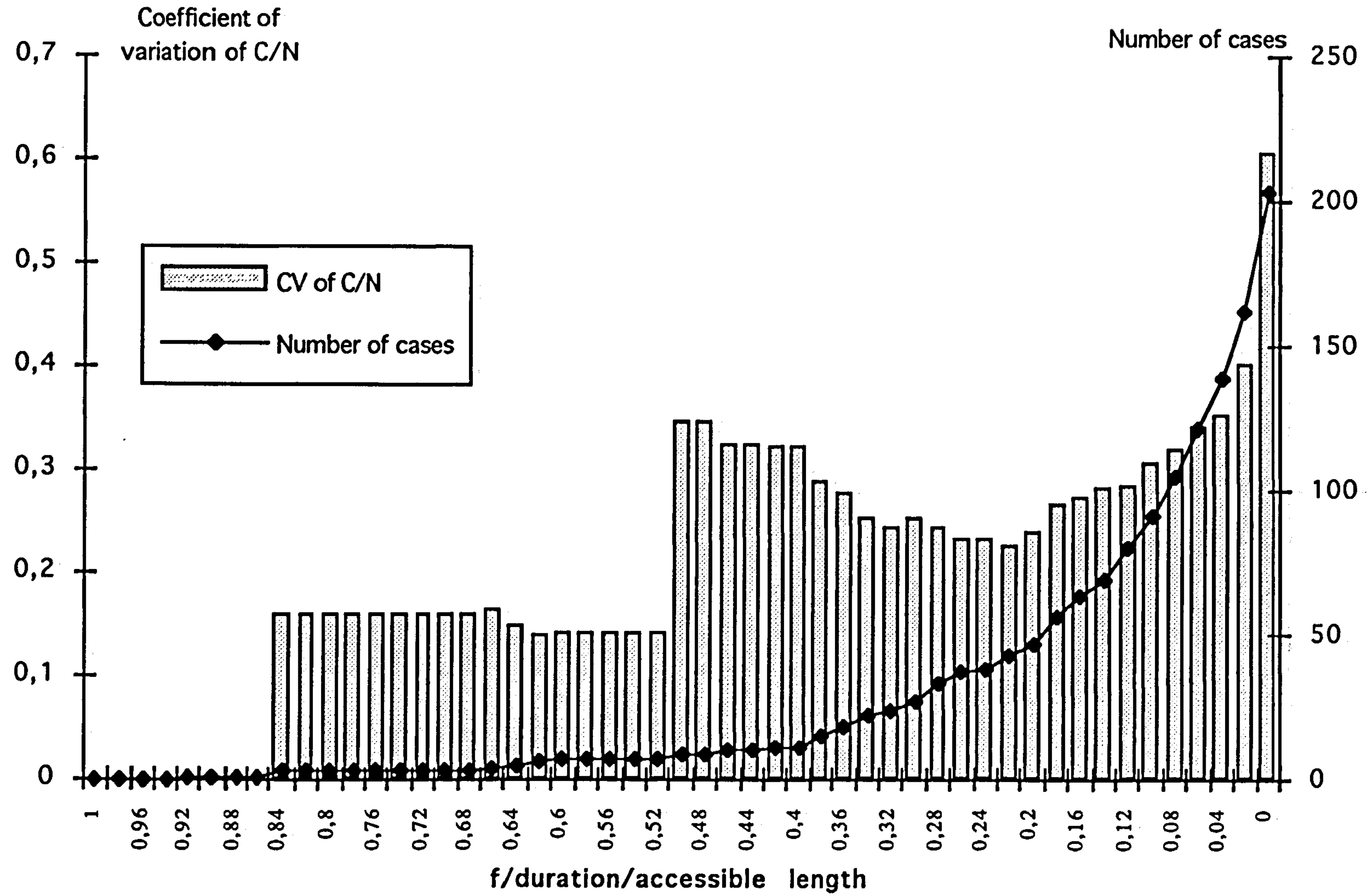

Figure 3. Relation between coefficient of variation of C/N (CV of C/N) and f/dur/lgacc.
C : annual catches. N : annual escapements. f : fishing effort. dur : fishing season duration. lgacc : accessible length for adult salmon.

Values of coefficent of variation of C/N are given for cases for which value of f/duration/accessible length is les or equal to value given on abscissa.

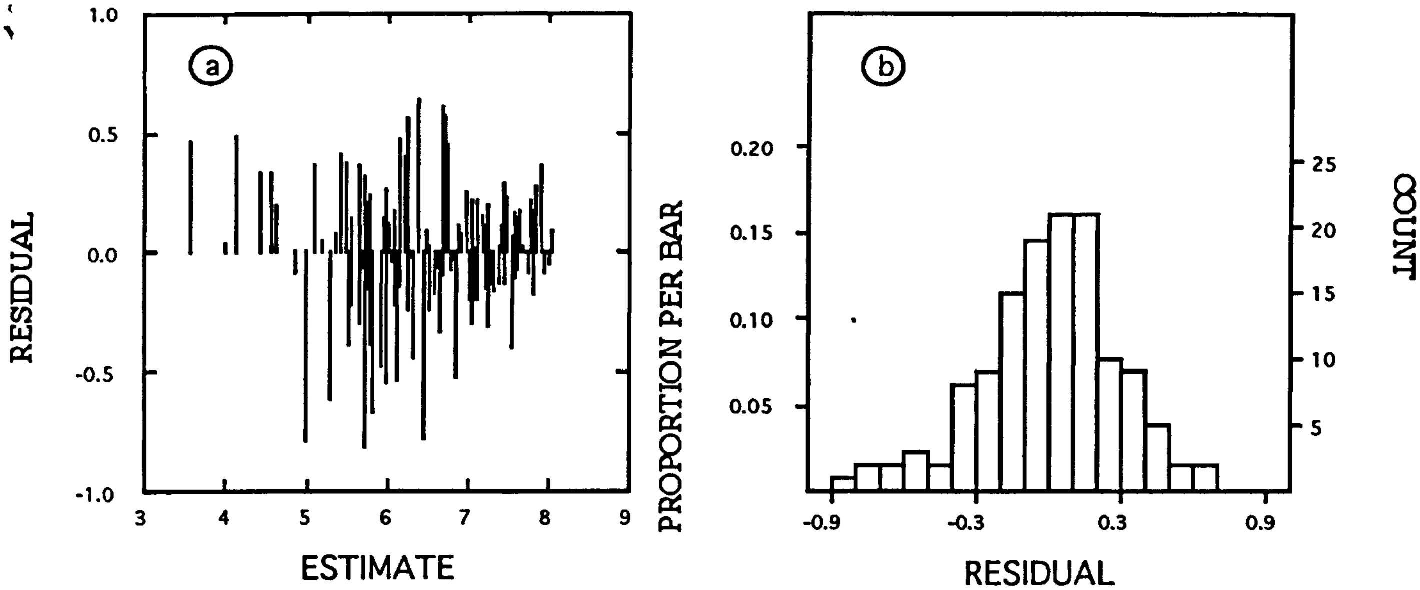

Figure 4. Residuals characteristics for model 1
a : Residuals against estimate
b : Residuals distribution

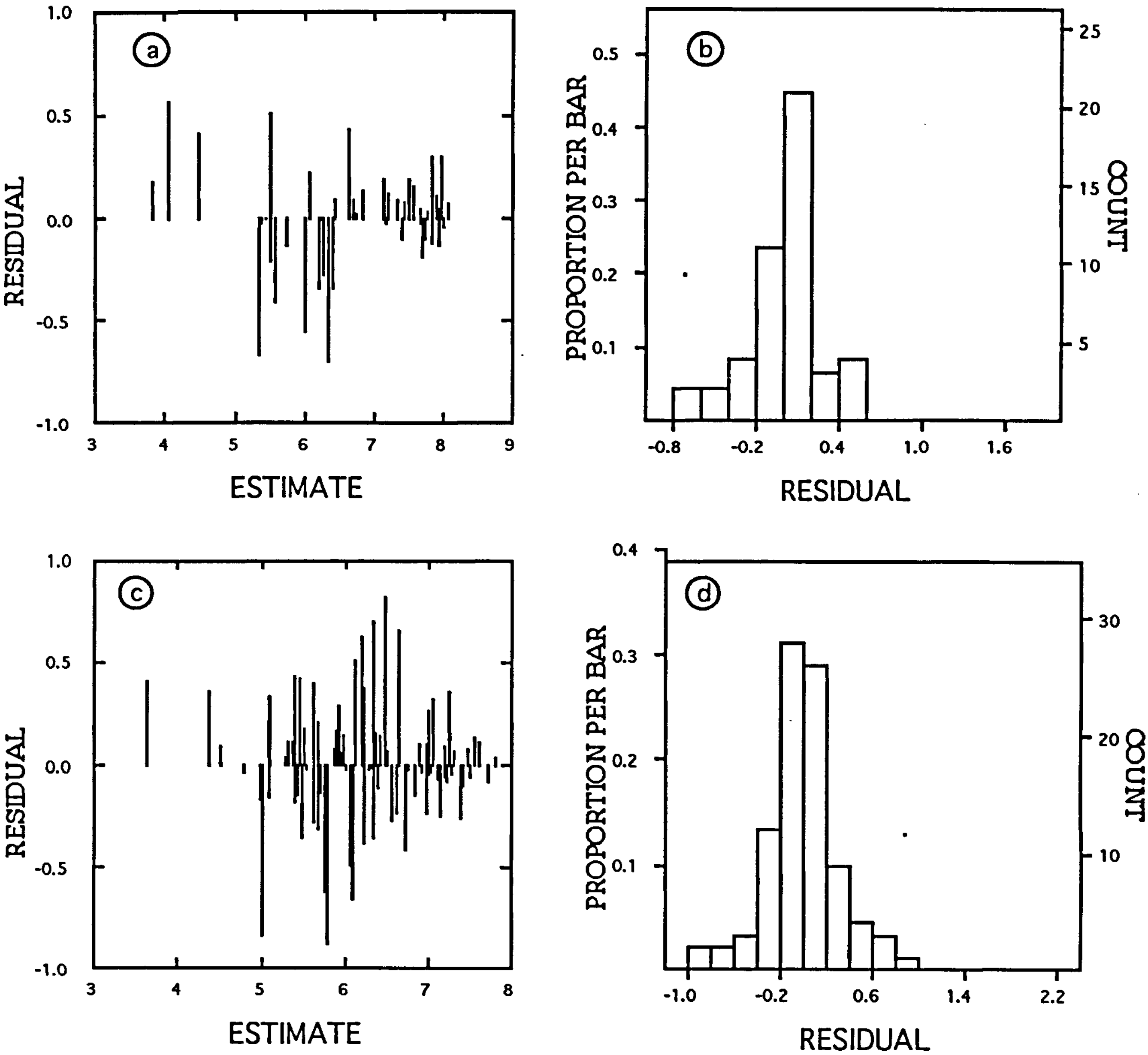

Figure 5. Residuals characteristics for model 2
a : Residuals against estimate for model 2a (duration≥90 days)
b : Residuals distribution for model 2a (duration≥90 days)
c : Residuals against estimate for model 2b (duration<90 days)
d : Residuals distribution for model 2b (duration<90 days)