Estimation of Natural Mortality from Selection and Catch Length-Frequency Data: A Modification of Munro's Method and Application Example

JACQUES MOREAU
Fisheries Department
ENSAT
Avenue de Muret
31076 Toulouse
France

Introduction

Munro (1983) developed a method to estimate natural mortality in an exploited fish population from length-frequency data (N_i) representing a steady-state distribution and the probabilities of capture of the gear that is exploiting the population in question (P_i).

This method implies first the estimation of total mortality (Z) from the relative number of fish between adjacent length classes (after the length-frequency data have been corrected for selection via $A_i = N_i/P_i$ and using the parameter L_∞ and K of the von Bertalanffy growth equation to estimate Δt_i, the time needed for the fish to grow through a given length class i).

The estimated value of Z can then be plotted against the value of P with a linear relationship

$$Z = a + P^*Z \qquad \ldots 1)$$

where a = M and in which $s.d._{(a)}$ is an estimate of the standard error of M. Munro's method is implemented through the following steps:

i) for each length class L_i, obtain the probability of capture (P_i) by the gear that is exploiting the stock,

ii) correct available length-frequency sample for the effect of selection using either the probabilities of capture of the gear in (i) (if the sample at hand was obtained with such gear) or using the probabilities of a gear (P_{si}) used only for sampling (this latter case is not discussed in Munro (1983) but is implicit in his method; see below). This leads to apparent relative abundance $A_i = N_i/P_i$ (or $A_i = N_i/P_{si}$),

iii) estimate true relative abundance $R_i = A_i/\Delta t_i$,

iv) estimate the mortality Z_j rate between two adjacent length classes from the R_i values,

v) plot the Z_j against the corresponding probabilities of capture P_j, the latter obtained by averaging P_i and P_{i+1}. (This point is not made explicitly in Munro (1983), but is unavoidable given that the P_i values pertain to the center, and not the limits of class ((i); see Fig. 1A),

vi) plot the Z_j *vs* the P_j values and estimate M via equation (1).

This ingenious method has, as originally presented, three small disadvantages:

1) The observed and entered P_i values are not those that are used for equation (1) (see Fig. 1A),

2) The variability of the estimated Z_j values is unnecessarily high, and finally,

3) An application example demonstrating the practical usefulness of the method has been hitherto lacking.

Items (1) and (2) can be remedied quite straightforwardly by using interpolated values of Z_i (which thereby become less variable) and by plotting these against their corresponding values of P_i (i.e., to use the observed values of P_i; see Fig. 1B). This approach implies that steps (i) to (iii) above remain unchanged, and that the following steps are:

iv) Estimate Z_i from the mean of the estimate of Z for the classes L_{i-1} to L_i ad L_i to L_{i+1},

v) plot estimates of Z_i *vs* observed estimates of P_i and obtain M via equation (1).

Application example

Table 1 illustrates the proposed approach and its difference to Munro's original method, and is based on data pertaining to brown trout from the Vèbre River, France. As might be seen from Fig. 2, the points resulting from the modification proposed here have a higher correlation than using the

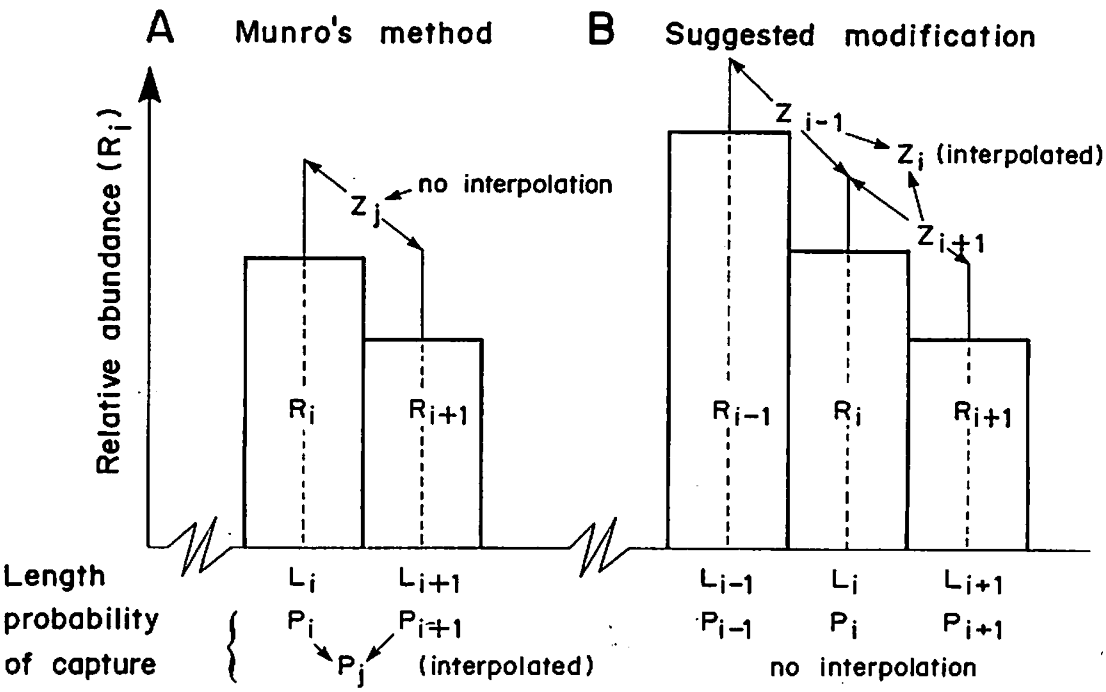

Fig. 1. Schematic representation of differences in computations of Z and P values in Munro's original method and the modification proposed here (see also Table 1 and text).

Table 1. Length-frequency data of brown trout from the Vèbre River, France, an illustration of difference between Munro's original method and proposed modification.

Midlength (cm)	N[a]	Input Data P_{si}[b]	P_i[c]	Data for Munro's plot[d] P_j	Z_j	Data for new plot[d] P_i	Z_i
13	2276	1	0.005			0.005	-
				0.0275[e]	0.152[e]		
15	2284	1	0.05			0.05[e]	0.143[e]
				0.075	0.134		
17	2310	1	0.1			0.1	0.253
				0.35	0.372		
19	2103	1	0.6			0.6	1.050
				0.8	1.729		
21	991	1	1			1	1.696
				0.9	1.663		
23	652	1	0.8			0.8	1.522
				0.75	1.381		
25	227	1	0.7			0.7	1.425
				0.6	1.468		
27	100	1	0.5			0.5	1.200
				0.65	0.933		
29	59	1	0.4			0.4	0.922
				0.9	0.912		
31	29	0.9	0.4			0.4	1.117
				0.375	1.322		
33	9	0.8	0.35			0.35	-

[a] from Abad (1982); the sampled trout have the growth parameters L_∞ = 45.9 cm and K = 0.161 year^{-1} with T = 10°C
[b] probability of capture of sampling device (electric fishing)
[c] probability of capture by sport fishermen (from Abad 1982)
[d] as defined in text
[e] not used

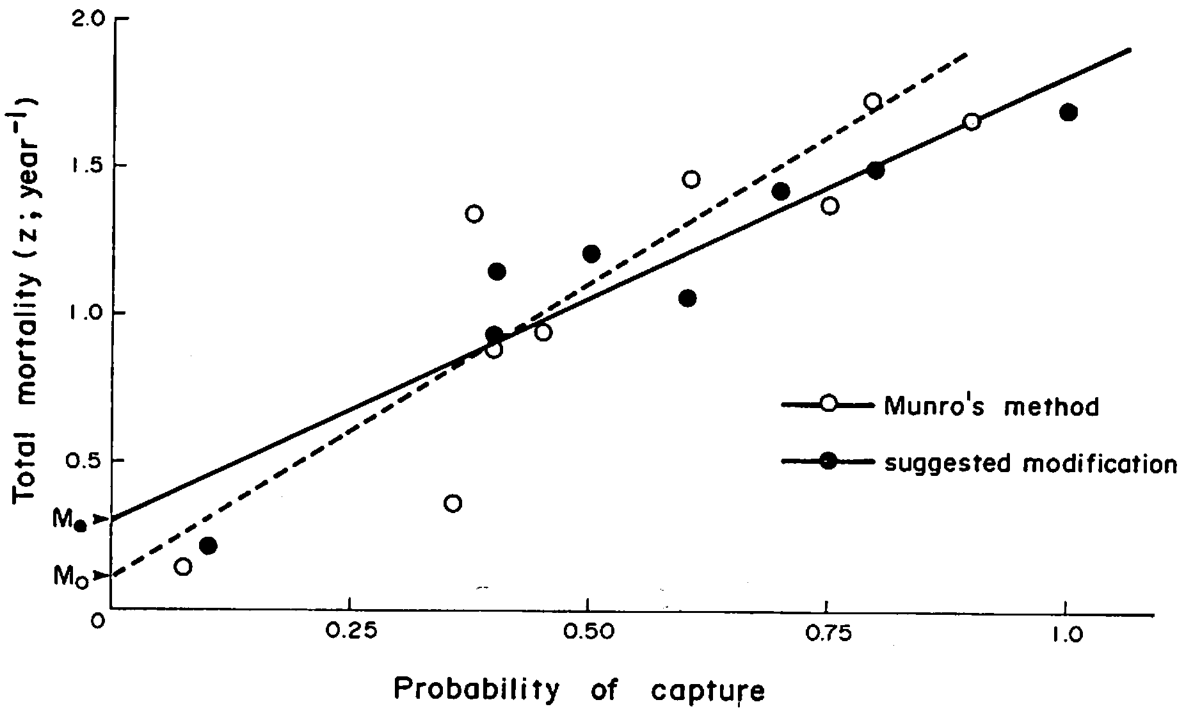

Fig. 2. Plots of Z *vs* P for estimation of M using Munro's original method and the modification proposed here (see also text).

original version of the method (r = 0.944 *vs* r = 0.887).

More importantly, the estimate of M obtained by the new method (M = 0.30 ± 0.13 $year^{-1}$) appears more credible (at least when compared with that estimated via the equation of Pauly, 1980 which is M = 0.29 $year^{-1}$) than the alternative estimate of M = 0.11 ± 0.21 $year^{-1}$.

We must note, however, that whatever its merits, this modification of Munro's method has crucial assumptions which must be met if it is to work. Of these, the most important is probably that the size frequency sample utilized (the N values in Table 1) must indeed represent a steady-state situation (i.e., be the average of a large series of seasonal or monthly samples).

Acknowledgement

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