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Factors affecting catch of long lines, evaluated by simulation model of long line fishing

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Abstract

Factors affecting long line catches were assembled into a complex conceptual model of long line fishing (Figure 1). Available quantitative knowledge about these factors was evaluated and a numerical model designed to simulate long line fishing with variable technical, biological, and environmental parameters as inputs.

The main purposes of the simulation model are to study the sensitivity of different parameters on the catch rate, to guide and prioritize technological developments as well as applied fisheries research on long line fishing, and to suggest improvements in the present interpretation of catch per unit effort in long line fisheries.

Some general conclusions from the use of this model are: that the rate of bait loss from various causes within a few hours after the setting largely determines the rate of catch, and the catch rate is a complex function of fish density that reaches a "saturation level" at higher fish densities. The setting time of the day in relation to the daily feeding periods of fish also has considerable influence on the catch rate. Methods for estimating relative fish density from long line catch and bait loss data are discussed.

Facteurs qui affectent la capture de poissons à ligne longue, évalués par modèle simulateur de pêche à ligne longue

Résumé

Des facteurs qui affectent les captures de poissons à ligne longue ont été rassemblés dans un modèle conceptuel complexe de la pêche à ligne longue (figure 1). Les données quantitatives disponibles concernant ces facteurs ont été évalués et un modèle numérique dessiné pour la pêche à ligne longue avec comme information de base des paramètres variables portant sur la technique, la biologie, et l'environment.

Le modèle simulateur a été concu en vue d'étudier la sensibilité des paramètres variés sur le taux de capture, de guider les développements technologiques aussi bien que les recherches appliquées des pêcheries et d'en suggerer leur ordre d'importance, et de suggérer des améliorations dans l'interprétation actuelle de l'effort capture-par-unité en pêcheries à ligne longue.

Quelques conclusions générales provenant de l'emploi de ce modèle sont: que le taux de perte d'appât due à causes variées en l'espace de quelques heures apres le placement des hameçons détermine pour la plupart le taux de captures; que le taux de captures est une fonction complexe de densité de poissons qui atteigne un "point de saturation" à densités élevées de poissons. L'heure de placement de l'appât en relation avec les heures quotidiennes d'alimentation des poissons, a aussi une influence considérable sur le taux de captures. Nous discutons des méthodes d'estimer la densité relative des poissons à la base de données sur les captures à ligne longue et sur la perte d'appât.

1. Factors affecting catch of long lines

The present study is an attempt to establish a comprehensive theory, *via* a conceptual model, and to design a numerical simulation of interactions in the fish capture processes of long lining, taking into account not only gear parameters, but also variables relating to the environment and to the target fish. Relevant data have been extracted from a number of sources, some of which have not previously been published, and the concept and development of the model draws to a large extent on unpublished observations and experiences in different commercial long line fisheries.

The main objective of the study has been to elucidate interactions between factors of the fishing gear *per se*, the target species, and the ambient environment that affect the processes of fish capture with baited long lines. The conceptual model of factors and interactions is presented in graphical form in Figure 1. A detailed description of the model, including a review of present state of knowledge of relevant factors and interactions, is given in a technical report (Olsen and Laevastu, 1983a). This review has shown that existing quantitative knowledge of many interactions is rather incomplete, requiring further experimental work.

The attraction of fish to bait with olfactory stimuli was investigated with another numerical model (Olsen and Laevastu, 1983b) where the effects of near-bottom currents on long line fishing was explored. The conceptual model served as the basis for the design of a numerical simulation, which utilizes factors and interactions that have been at least partially investigated and quantified in the past.

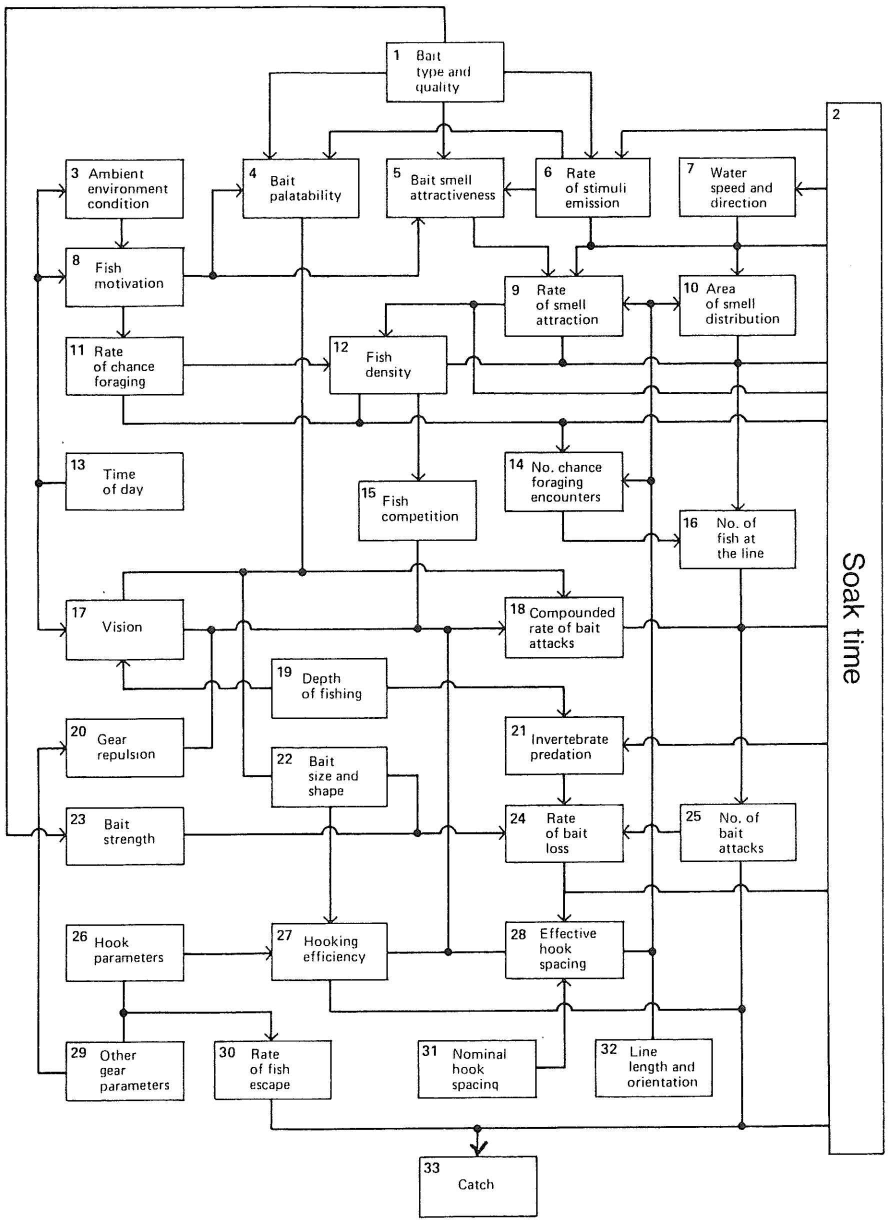

Figure 1.--A conceptual model of factors and interactions affecting long line catch.

2. Simulation model of long line fishing

Empirical (rational) formulas of the simulation are given below; a full description of their derivation and of the values of parameters used in the simulations are found in Olsen and Laevastu, 1983a.

The "effective fish density" (E) (i.e., number of fish at the line) is computed with the following formula:

$$E_t = D_{ad}\ L_{ad}\ e^R \tag{1}$$

where D_{ad} is the time-adjusted prescribed fish density:

$$D_{ad} = D^{0.62}\ (t_d^{\ 0.14}/1.7) \tag{2}$$

D is the estimated fish density (initial input, a relative value, 1 to 12) and t_d is time step in 10 minutes.

L_{ad} is the hook spacing, bait type, and fish motivation factor:

$$L_{ad} = f_a d^{0.25}\ p^{0.5} \tag{3}$$

f_a is fish motivation index, d is hook spacing in meters, and p is bait attractiveness (1 to 3).

R is the smell area factor:

$$R = v\ c-(0.021\ t_d c) \tag{4}$$

v is current direction index during the time of setting (0.2 to 0.5) and c is current speed at the depth of fishing (0.2 to 2 cm/sec used here for bottom lines).

The effective fish density takes into consideration the diurnal feeding periods through adjustment of the fish motivation index:

$$f_a = f + mf\ (\cos \alpha t + \kappa) \tag{5}$$

where m is relative magnitude of diurnal feeding intensity (0 to 1), α is phase speed (0.5 degrees per minute for semidiurnal period), t is time in minutes and κ is phase lag, presenting the setting time of the line (90° - 6a.m., 180° - noon, 270° - 3 a.m., etc.).

The number of baits left at each time step (B_t) (10 min.) is computed in two steps: bait loss due to invertebrate predation (B_c), and bait loss due to multiple attacks by fish (A_c).

$$B_t = B_c - A_c \tag{6}$$

$$B_c = B_{t-1}\, e^n \tag{7}$$

where B_{t-1} is the number of baited hooks at the end of the previous time step, and the exponent n is:

$$n = b_c + (0.15 b_c\, t_d^{0.28}) \tag{8}$$

and

$$b_c = b\, s\, d_\ell \tag{9}$$

where b is the bait loss exponent (due to invertebrate predation) (0.02 to 0.04), s is the bait strength factor, and d_ℓ is a hook spacing factor (0.7 to 1.1).

Bait loss due to multiple attacks (A_c) is computed from:

$$A_c = E_t\, e^{qk(1-h)}\, B_t/B_o\, U \tag{10}$$

where $U = \ell\, d^{0.32}$ (11)

q is the probability of fish making repeated attacks (0.4 to 0.75), k is related to bait type (palatability), h is hooking rate (0.2 to 0.4), B_o is initial number of baited hooks (100), and ℓ is line type index (or gear repulsion factor (0.8 to 2.5).

Numbers of fish hooked is computed as :

$$H_b = h\, A_c\, s \tag{12}$$

where s is bait strength factor which indicates the ability of bait to withstand multiple attacks.

Number of fish remaining hooked after each time step (F_t) is:

$$F_t = H_b\, e^i \tag{13}$$

where:

$$i = -a + (a\ g\ t_d) + g_c\ y) \tag{14}$$

a is escape rate (0.03 to 0.06), g is escape rate change (0.008), y is hook type parameter (1 to 3), and g_c is a constant with identical value to g.

Total catch is:

$$C_{h(t)} = \sum_{o}^{t} F_t \tag{15}$$

3. Some results from numerical experiments

The simulation (or rather its input parameters) must be tuned to particular target species subject to long line fishing (e.g., halibut, cod, or sablefish). The simulation described in this paper was not tuned to specific target species, but rather is intended to study some general factors affecting all types of long line fishing. Only a few general results are described below to illustrate the use of the simulation.

Figure 2 shows bait loss and catch with time at three different initial fish densities and specific input parameters. Some obvious conclusions can be drawn from this figure: First, the high bait loss during the first few hours of soaking largely determines the initial high rate of hooking and the ultimate catch. Thus, any measure which decreases early bait loss will increase the total catch. Second, after a few hours of soak time the catch increases only slightly. Third, catch (rate) is not a linear function of fish density; the rate decreases with increasing fish density as a result of gear saturation. This is shown in Figure 3 which also demonstrates the importance of more accurate knowledge of hooking rate. A further conclusion from Figure 3 is that long lining is most effective when fish density is low, and that its relative effectiveness decreases with increasing fish density. Simple CPUE estimates from long line fishing are, therefore, likely to distort changes in fish abundance.

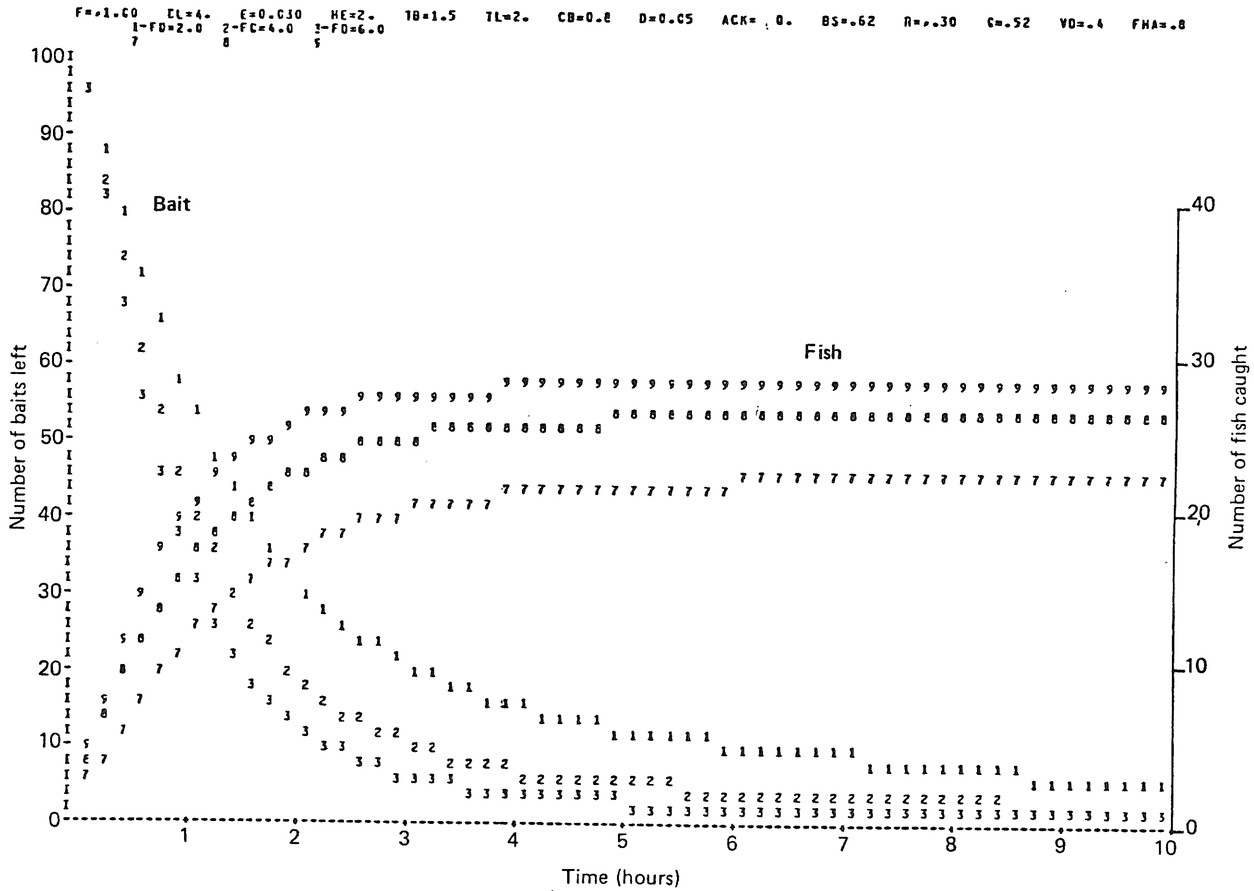

Figure 2.--Bait loss and long line catch of fish with time at three different "effective fish densities" (2,4, and 6). Setting time 6 a.m. (Bait loss exponent = 0.03, hook spacing = 4 m, hooking rate = 0.3).

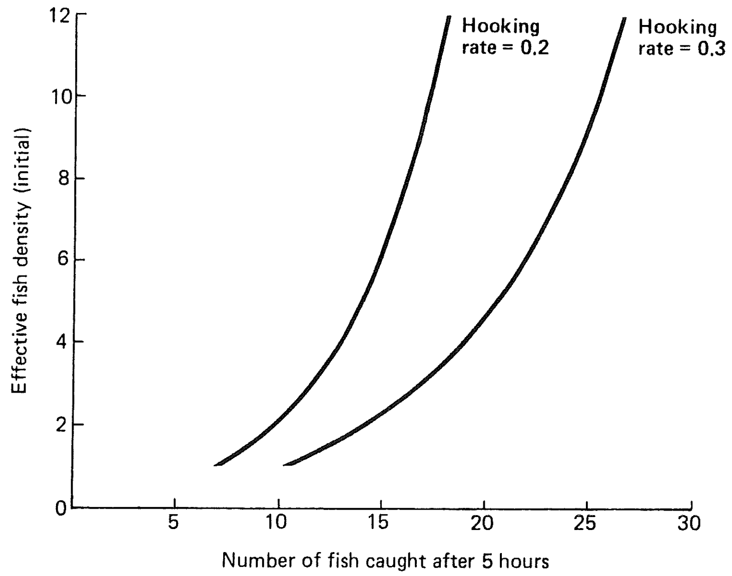

Figure 3.--Catch with long line (100 hooks) after 3 hours soak time with different "effective fish densities". Setting time 9 a.m. (Hooking rates = 0.2 and 0.3.)

The high bait loss in the first few hours of soaking is not only caused by invertebrate predation, but also by multiple attacks by fish, which interact with each other.

The setting of long lines shortly before the maximum foraging time (which in some species might occur at 6 a.m. and 6 p.m.) would give the highest catches. This is demonstrated in Figures 2 and 4 which show the results of setting times at 6 a.m. and at 12 noon.

4. Estimation of relative fish density from long line catches

Relative fish density is here defined as the average number of fish present during a given soak time in the immediate vicinity of a long line with specified length and number of hooks.

Unbiased estimates of relative fish density may be possible from long line catch data if reliable assessments can be made of bait loss parameters and of individual or single attack hooking rate.

The separation of bait loss due to invertebrate and fish predation might be possible by extrapolating observation data on baits retrieved at the time of hauling the line, provided the observations cover a fair range of fish densities and soak times.

The fish bait predation which is the result of hooking and of baits being stolen in the multiple attacks made by the fish without becoming hooked, needs, however, to be investigated further.

This multiple attack bait loss is a function of the probabilities or rates of repeat attacks, the strength of the bait to withstand these attacks, and of the individual hooking rate. While the two latter parameters are considered unaffected by the density and feeding motivation of the fish, and may, therefore,

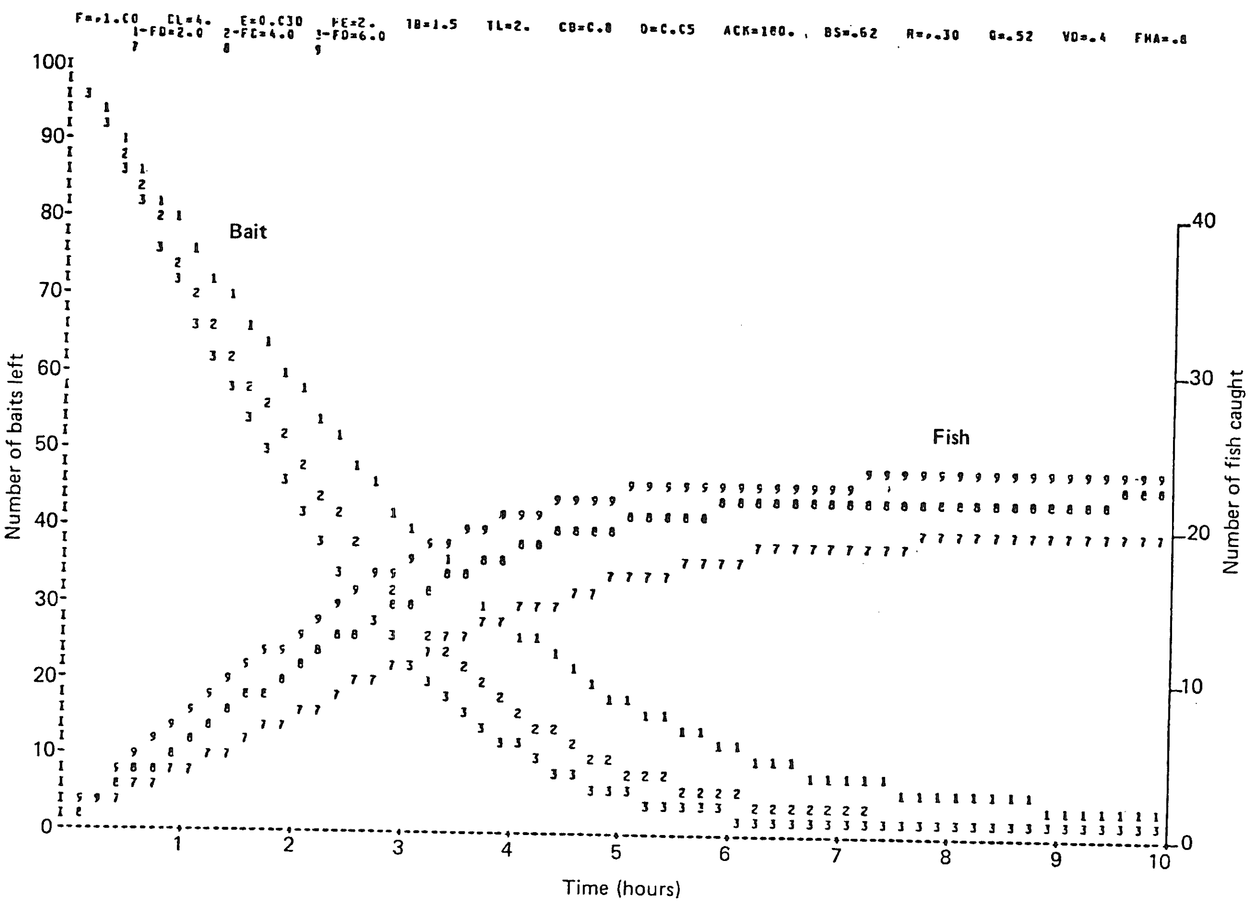

Figure 4.--Bait loss and long line catch of fish with time at three different "effective fish densities" (2, 4 and 6). Setting time at noon. (Bait loss exponent - 0.03, hook spacing - 4 m, hooking rate = 0.3).

be evaluated, at least preliminarily, from laboratory and/or field experiments; the multiple attack rates are clearly fish dependent and therefore have to be estimated from data relating to the fish actually caught.

If it can be assumed that the numbers of baits found in the stomachs of fish caught with long line are equal or closely proportional to those of the baits consumed by the fish prior to becoming hooked, counts of baits in stomachs may provide the required additional information to enumerate the multiple attacks.

Unbiased assessments of fish densities are thereby facilitated, applying the relative fish density-CPUE relationship derived from parameters tuned to the particular conditions of the relevant fishery.

5. Suggestions for further study and development of the model

It became clear during the review of available literature on long line fishing that reliable data (measurements) on many parameters which affect the long line catches and landings are scarce. The results of some past experiments are uncertain because too many factors which affect the catch varied in the experiments or were not reported properly.

The following factors are especially in need of better quantification:

a) Bait loss caused by invertebrate predation within the first few hours of soaking, by seasons, time of day, and depths of fishing.

b) Hooking rate per attack by species, bait types, and hook sizes and type, and by time of day.

c) Escape rates by species, seasons, fishing depths, and hook types and size.

d) Diurnal rhythm of feeding (and the related rate of hook attacks) by species, seasons, and soak times.

Finally, further experimental studies are needed to verify and improve the tentative methods for estimating relative fish density from long line catches.

6. References

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