YIELD PER RECRUIT ANALYSES FOR SQUID, *LOLIGO PEALEI* AND *ILLEX ILLECEBROSUS*

by

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Introduction

This paper presents results of yield per recruit analyses for Loligo pealei and Illex illecebrosus fisheries off the Northeast coast of the U.S.A. The potential effects on yields for several choices of mesh size are compared. These analyses, using the Ricker equilibrium yield model (NEFC, Stock Assessment Program - FMBRIKR; see also Paulik and Bayliff 1967), were based on the typical seasonality of the fisheries during 1977-1979, estimates of mesh selection factors, and growth and length-weight relationships from other studies. Various values of instantaneous monthly natural mortality rates (M_t), ranging from 0.0 to .30, were also used.

Methods and Materials

Parameters of the yield per recruit model, for each species, (Tables 1 and 2 for L. pealei and I. illecebrosus, respectively) included estimates of monthly instantaneous growth rates during the fishable lifespan. For L. pealei, Summers' (1971) growth scheme for the July brood was used to develop von Bertalanffy growth functions for male and female individuals. Monthly length at age values were than calculated and averaged over sex. The length-weight function: $W = 0.25662\ L^{2.15182}$ (Lange and Johnson 1979) was used to convert length to weight (g). Instantaneous growth was obtained using the relationship: $g_t = \log_e \left(\frac{W_{t+1}}{W_t} \right)$, where g_t = instantaneous average growth rate during the period t to t+1 and W_t = average weight of an individual at age t.

Growth in length for I. illecebrosus was represented by the function given by Efanov and Puzhakov (1975): $\ell_t = 33.4\ (1-e^{-0.14(t+2.9)})$, assuming that hatching occurs in January. Instantaneous growth rates were calculated as for L. pealei, with weight at age obtained from the length-weight relationship: $W = 0.04810\ L^{2.71990}$ (Lange and Johnson, 1979).

Estimates of monthly natural mortality rates are not currently available, so a range of M_t's was used for each species, based primarily on estimates of lifespan (Au 1975) and spawning mortality rates (Sissenwine and Tibbetts 1977). For L. pealei, these values ranged from 0.00 to 0.20; while for I. illecebrosus, assumed to be shorter lived than L. pealei, the range was from 0.00 to 0.30.

To reflect the seasonal nature of these fisheries, and since instantaneous fishing mortality rates are not available for either species, monthly catches of each species from the 1977-1979 fisheries were used to establish monthly fishing mortality, relative to the month with the highest average catch (Sissenwine and Tibbets 1977). These relative F_t's were based on the present (1977-1979) fishery and assume a 45 mm mesh, though it is known some vessels used 60 mm mesh.

A cohort of L. pealei first appears, in significant numbers, in December, as the offshore fishery, which starts in November, begins to catch 8-9 cm individuals. The fishery peaks in January and February, tapering off in March, as L. pealei moves inshore to spawn. The area is closed to foreign vessels between 1 April and 15 June, and any fishing mortality during that time is caused by the U.S. fleet. Catches in May reflect increased U.S. pressure on spawning concentrations while catches from June through October are greatly reduced. Distant water fleet catches again increase in November as the squid move offshore for the winter.

Illex illecebrosus have been taken in the present distant water fleet fishery as small as 6 cm, corresponding to an age of about 4 months (Efanov and Puzhakov 1975); this occurs in April, for individuals probably hatched in January. Catches in April and May are primarily the result of by-catches in the U.S. groundfish fishery, and are much less than those taken offshore. The distant water fleet fishery opens in mid-June and catches increase, peaking in July, but tapering off during August and September, as the species moves to inshore areas not accessible to the foreign fleets. In November, a slight increase in catches occurs as the stock returns to the offshore areas and is taken as by-catch in the directed L. pealei fishery. Decreased availability from December through March is the result of offshore spawning and over-wintering.

Multipliers of F, ranging from 0.05 to 0.5, were used to simulate a variety of possible monthly fishing mortality rates over the lifespan of each species.

The Ricker model was used to simulate the yield per 1000 recruits under the present mesh regulations, for different assumptions of M and F. Yield under different mesh regulations was then estimated based on assumptions of selection sizes of squid for those meshes.

A selection factor of 1.92, found for Loligo sp. in the Eastern Central Atlantic (pers. comm. Ikeda, 1973), was assumed appropriate for L. pealei. This corresponds to a 50% retention length of 8.6 cm for 45 mm mesh, as is the case in the present fishery. It also implies a 50% retention of 11.5 cm individuals for 60 mm mesh and 17.3 cm individuals for 90 mm mesh. Values of relative fishing mortality from the present fishery were then reduced according to approximated selection curves, corresponding to 60 mm and 90 mm mesh, for the months prior to the time when mean lengths reached these retention sizes (Table 1). Thus, relative fishing mortalities were reduced for the first 3 months (December-February) and 7 months (December-June) of the fishery, for 60 mm and 90 mm mesh, respectively, after which selection was assumed to be comparable to the present fishery. Mesh studies for I. illecebrosus (Clay 1979) indicate 50% retentions at approximately 14.4 cm for 60 mm and 18.0 cm for 70 mm meshes. Relative fishing mortalities, based on the present fishery and assuming 45 mm mesh, for months when mean lengths were less than these retention sizes were reduced (Table 2), as described for L. pealei. These new sets of relative fishing mortality rates were then used in the Ricker yield model and the resulting yields were compared to those estimated under the present conditions.

Results and Discussion

Yield per recruit estimates for L. pealei for both the 60 mm and 90 mm meshes were consistantly greater than for the 45 mm mesh for all choices of the fishing mortality multiplier, when monthly natural mortality rates (M_t) were less than 0.13 (Figure 1). For $M_t = 0.13$ and multipliers of .25 and greater, the 60 and 90 mm meshes also produced somewhat greater calculated yields than the 45 mm mesh. However, as M_t was increased to 0.20 and losses due to natural mortality became more significant, differences in yield between 45 and 60 mm mesh became insignificant, while yield from 90 mm mesh was always substantially less than from either of the smaller meshes.

Yield of *L. pealei* appears to be more sensitive to changes in natural mortality than to mesh selection. Although at low levels of M_t, size at entry (caused by mesh selectivity) is an important factor in potential yields, this factor becomes much less important as M_t increases. Increases to maximum yield for the different levels of fishing mortality chosen ranged from 1.9 (M_t = .02, mesh = 60 mm) to 4.1 (M_t = .2, mesh = 90 mm) times the minimum values.

Yield per recruit estimates for *I. illecebrosus*, at low levels of fishing mortality, were similar for each value of size at entry (based on mesh selection); while, as the fishing mortality (F multiplier) was increased to .3, .35, .6, and 1.0 for M_t values of .05, .10, .20, and .30, respectively, calculated yields from the 60 mm and 70 mm meshes became significantly greater than those of the present (45 mm) mesh. However, these high levels of F are probably unrealistic for the *I. illecebrosus* fishery. Therefore, as with *L. pealei*, yields of *I. illecebrosus* seem to be more sensitive to levels of natural mortality than to changes in mesh.

Although an increase in mesh size from 45 mm to 60 mm will not significantly reduce the yield in either squid fishery, under any of the assumptions or ranges of natural or fishing mortality used in this paper, yield per recruit of both *L. pealei* and *I. illecebrosus* may be significantly increased in some instances, by the resulting increase in size of entry to the fishery. Also, yield analyses for butterfish (Murawski and Waring 1979) and silver hake[1], major by-catch species in

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[1]Personal communication, E. Anderson, NMFS, NEFC, 1979.

the L. pealei and I. illecebrosus fisheries, respectively, indicate that 60 mm mesh would produce greater yield per recruit for both these species than would the smaller mesh.

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Table 1. Parameter Values for *L. pealei* Yield per Recruit Analysis

t (1	g_t (2	F_t - by mesh (mm) (3 45 (present)	60	90
5	.34	.9	.3	.1
6	.30	1.	.5	.3
7	.24	1.	.8	.5
8	.20	.9	.9	.4
9	.20	.1	.1	.1
10	.17	.3	.3	.2
11	.16	.1	.1	.1
12	.13	.1	.1	.1
13	.14	.1	.1	.1
14	.12	.1	.1	.1
15	.10	.1	.1	.1
16	.11	.6	.6	.6
17	.09	.9	.9	.9
18	.09	.1	.1	.1
19	.08	1.	1.	1.
20	.08	.9	.9	.9
21	.07	.1	.1	.1
22	.07	.3	.3	.3
23	.07	.1	.1	.1

Parameters held constant for each run, and chosen values

M - 0.02, 0.05, 0.13, 0.20
Multipliers - 0.05, 0.10, 0.15, 0.20, ..., 0.50
Initial number of recruits - 1000.
Initial biomass - 1.0

[1] Age in months - assume enter fishery in December, at length of 8.6 cm.

[2] Instantaneous monthly growth rate.

[3] Fishing mortality relative to highest monthly values, with increasing mesh size, small individuals are less vulnerable to the gear and the F ratio decreases.

Table 2. Parameter Values for *I. illecebrosus* Yield per Recruit Analysis

t[1]	g_t[2]	F_t - by mesh (mm)[3] 45 (present)	60	90
4	1.04	.1	.0	.0
5	.89	.1	.0	.0
6	.58	.4	.1	.0
7	.41	1.0	1.0	.4
8	.33	.6	.6	.5
9	.24	.3	.3	.3
10	.21	.1	.1	.1
11	.16	.4	.4	.4
12	.13	.1	.1	.1
13	.11	.1	.1	.1
14	.10	.1	.1	.1
15	.07	.1	.1	.1
16	.08	.1	.1	.1
17	.06	.1	.1	.1

Parameters and chosen values:

M - 0.05, 0.1, 0.2, 0.3
Multipliers - 0.05, 0.10, 0.15, ..., 0.45, 0.50, 0.60, 0.75, 1.0, 1.2, 1.5
Initial number of recruits - 1000.
Initial biomass - 1.0

[1]Age in months - assumed to enter fishery in April at about 6 cm.

[2]Instantaneous monthly growth rate.

[3]Fishing mortality relative to highest monthly values.

Figures

1. Yield (kg) per 1000 recruits of *L. pealei* by factors of relative fishing mortality, for 3 mesh sizes and 4 assumptions of natural mortality (M).

2. Yield (kg) per 1000 recruits of *I. illecebrosus*, by factors of relative fishing mortality, for 3 mesh sizes and 4 assumptions of natural mortality (M).

Figure 1. Loligo pealei yield per recruit analyses for 3 mesh sizes.

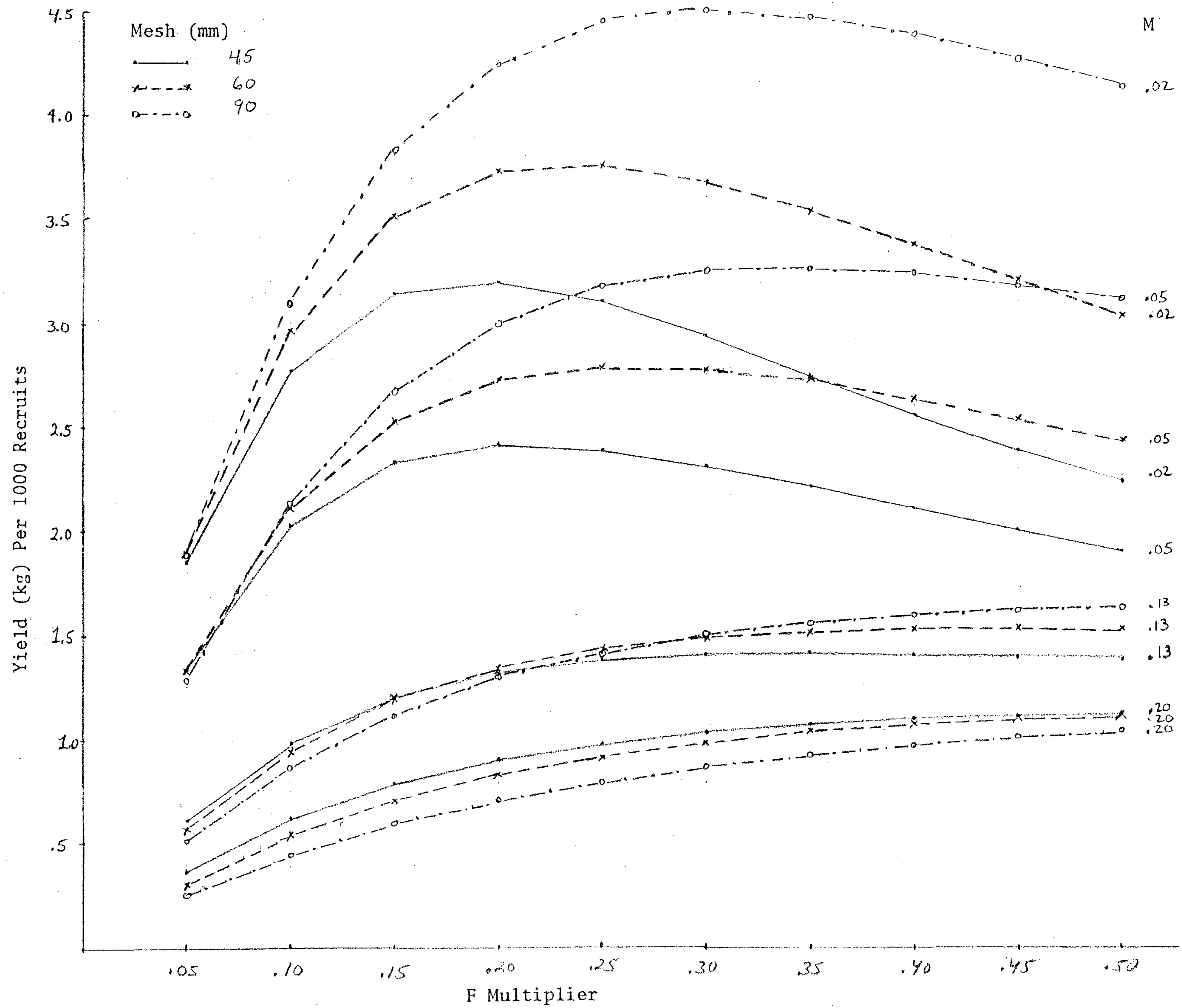

Figure 2. Illecebrosus yield per recruit analyses for 3 mesh sizes.