RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3811
(D.c.3)

ICNAF Res.Doc. 76/VI/31

ANNUAL MEETING - JUNE 1976

A review of stock size estimates of squid (*Loligo* and *Illex*) in Subarea 5 and Statistical Area 6

by

Michael P. Sissenwine
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

Introduction

Several researchers have considered the size of the populations of *Loligo pealei* and *Illex illecebrosus* in Subarea 5 and Statistical Area 6. Their work is critically reviewed in this paper.

Stock size estimates by areal expansion

Ikeda and Nagasaki (1973 and 1975) estimated by areal expansion the number of *Loligo* in the area of the Japanese winter squid fishery for the 1968-1969 to 1973-1974 seasons. The fishing ground is located along the 200-meter depth contour within divisions 5Zw, 6A and 6B. Stock size estimates and the area of the fishing ground for each season are given in Table 1.

At the beginning of the season *Loligo* are assumed to immigrate onto the ground while later in the season they are assumed to emigrate from the ground. The point in time where catch per tow reaches its maximum is assumed to represent the density of the entire stock to occupy the ground during the season minus the catch to this data in the season. The number of individuals is estimated by the product of the catch in numbers per tow and the ratio of the area of the fishing ground to the area swept by each tow. To this value, the number of individuals captured during the season prior to reaching the maximum catch per tow is added. The result is an estimate of the total number of *Loligo* occupying the ground during the season. This estimate ignores *Loligo* which are in other areas in SA 5 and 6, but presumably the fishing ground is located in an area of particularly high *Loligo* concentration.

The areal expansion method was also used by Tibbetts (1975) to estimate stock sizes of both *Loligo* and *Illex* within SA 5Z and 6 based on Fall USA bottom trawl survey cruises. Three estimates were made for each year of 1967-1974 and each species. The first is the product of the mean weight caught per tow and the ratio of the area considered to the area swept by each tow. The second and third estimates adjust the mean weight caught per tow upward to correspond to day tows (when bottom gear is more efficient for squid) and then to correspond to a larger more efficient trawl (Yankee 36 vs. 41 net). The third set of estimates has been recalculated for 1968-1975 for all of SA 5+6 using a more accurate conversion from the 36 to the 41 net (Table 2). An estimate of the number of each species in SA 5+6 was obtained by dividing by the mean weight of all individuals sampled during each cruise. These estimates are considerably higher than those made by Ikeda and Nagasaki (1975) in part reflecting the larger area considered.

Lipinski (1975, Remarks of possible yield of shortfinned squid (*Illex illecebrosus*) in Subarea 5;unpublished paper) provides data adequate for estimating the size of the stock of *Illex* exploited by the Polish fleet within SA 5 and 6. For the Polish vessels, the average tow swept an area of 0.8 km^2.

For an average of 3 tows per day, an average catch of 9.8 tons per day for the most successful vessel in the fleet, a mean weight of 120 g per *Illex* and a 11,000 km^2 fishing ground, an estimate of $45x10^6$ *Illex* is obtained for 1973. This value is similar to the estimate reported in Table 2 for a much larger area.

Efanov and Puzhakov (1975) estimated by areal expansion the size of the stock of *Illex* south of Nova Scotia and on Georges Bank as 110,000 tons for June 1971. Using the approximate mean weight of *Illex* in the June 1974 catch (88 g) an estimate of 1.25 billion individuals is obtained. No description of details of the method are given therefore it is difficult to judge the accuracy of this estimate.

Stock size estimate by the areal expansion method are subject to errors for at least the following reasons:

a) Individuals in the path of the net may avoid capture. Also individuals over the bottom area affected by the net, but above the headrope are not captured. The result is that stock size is underestimated. These factors are often assumed to be the major source of bias in estimates based on the areal expansion method.

b) Individuals outside the area sampled are not considered. This results in underestimating the stock size in SA 5 and 6 except for the estimates in Table 2 for which most of the area was randomly sampled.

c) The areal expansion method provides an estimate of standing crop, but does not provide an estimate of the flux of individuals that occupy an area over an interval of time. For stocks which migrate on and off a fishing ground simultaneously, the areal expansion method will underestimate the number of individuals that at some time occupy the ground during the fishing season.

d) The area affected by a trawl may be broader than the width of the gear at the wings, since the doors and bridle may herd individuals into the path of the net. The result is that stock size may be overestimated.

e) Fishing intensity may not be uniform over the fishing area. It is reasonable to assume that fishing effort is concentrated at locations of high abundance within the fishing area. Therefore the average catch per tow may overestimate the average relative abundance over the area considered. The result is an overestimate of stock size. Since sampling is random for the USA bottom trawl survey, the estimateds in Table 2 would not suffer from this potential bias.

Loligo stock size estimate by cohort analysis

Ikeda (1975; Tables 1-3-squid-Subarea 5 and Statistical Area 6, unpublished paper) hypothesized the mean length of April, May and June broods of *Loligo* during each month for October-April of the 1972-1973 fishing season. Using these mean lengths and the length frequency of the Japanese catch in SA 5 and 6, the number captured from each brood at the mean length of the brood is estimated for each month. Pope's (1972) cohort analysis is then applied to estimate the stock size at mean length on October 1, 1972 for each brood. The monthly rate of exploitation estimated for the April, May and June broods during October were 0.023, 0.008 and 0.002, respectively. The arithmetic average rate for these 3 broods was 0.01. Ikeda and Nagasaki (1975) divided the catch of *Loligo* during October 1972 by the exploitation rate resulting in a stock size estimate of $1.5X10^9$ individuals. Several possible sources of error in this analysis are discussed below:

a) While the growth of *Loligo* has been generally described (Summers, 1971) there is considerable variability in growth. Therefore, individuals at the mean length for a brood in a particular month may not be at the mean length for the brood in following months. Therefore, changes in virtual population at the mean length for hypothetical cohorts may reflect variability in growth as well as mortality. This situation introduces an additional source of error into cohort analysis. For most applications of cohort analysis the age composition of the catch is estimated by applying the age composition of a sample from the catch to the entire catch. Thus variability in the growth rate of the species does not effect the estimate of age composition.

b) Cohort analysis requires estimates of natural mortality for all months and of fishing mortality during the final month of exploitation. The results are not sensitive to the estimate of fishing mortality (Ikeda assumes 0.1), but they do reflect the assumption of natural mortality. Ikeda (1975) assumes a natural mortality rate of 0.03 per month which is less than a third of the rate hypothesized by Au (1975). Tripling the assumed natural mortality rate results in about a 30% reduction in the estimate of exploitation rate during October derived for Ikeda's data by cohort analysis. A 30% reduction in estimated exploitation rate results in about a 43% increase in estimated population size.

c) The exploitation rate for October was estimated as 0.01 by taking the arithmetic average rate for April, May and June broods. But these broods account for less than 14% of the catch during October as indicated in Table 3. Table 3 also indicates that the rate of exploitation increases as length increases. Since most of the remaining 86.3% of the catch is made up of individuals larger than 9.8 cm, it is likely that the exploitation rate of these individuals is at least 0.023. Therefore the weighted average exploitation rate of the stock could be estimated as

$$(0.002)(0.0103)+(0.008)(0.0403)+(0.023)\ (0.0868+0.863) = 0.022$$

For 15×10^6 individuals in the catch and a monthly exploitation rate of 0.022, the stock would be estimated at 682×10^6 individuals, about the same values as Ikeda and Nagasaki (1975) arrived at by areal expansion. Note that Au's (1975) yield per recruit analysis indicated an exploitation ratio of 55% to maximize catch. For a monthly instantaneous natural mortality rate of 0.1 (about the rate assumed by Au), a 55% exploitation ratio is equivalent to a monthly exploitation rate of 0.11.

Loligo stock size estimate by DeLury's method

For an isolated stock, without natural mortality, the relative abundance of the stock (catch per tow) should be inversely correlated with the cumulative catch from the stock. The Y intercept (where Y is catch per tow) of a line fit between these variables divided by the absolute values of the slope of the line should estimate initial stock size. Ikeda and Nagasaki (1973) applied this method to *Loligo* in SA 5 and 6 and estimated the stock size as 35.9, 94.4, 84.6 and 101.4 million individuals at the start of the 1968-1969 to 1971-1972 seasons. Major sources of errors effecting this method are as follows.

a) Stock size is underestimated by ignoring natural mortality and emigration from the ground.

b) Stock size is overestimated by ignoring immigration to the grounds.

These sources of error are particularly important at low levels of fishing mortality. Since catch was sometimes larger than the estimate of initial stock size, the application of this method to *Loligo* probably results in an underestimate of stock size.

31

Conclusion

Several estimates of stock size for *Loligo* and *Illex* within SA 5 and 6 are presently available. Estimates by Delury's method appear to underestimate the size of the *Loligo* population since they are sometimes smaller than the catch. The results of cohort analysis applied to the 1972-1973 Japanese *Loligo* catch can be interpreted to provide a stock size estimate of 1.5×10^9 or 682×10^6 individuals. Of the stock size estimates based on the areal expansion method, those using data from the USA autumn bottom trawl survey are subject to fewer sources of errors. Unless the herding effect of the fishing gear employed on USA bottom trawl surveys is unexpectedly important, an autumn stock size of at least 1 billion *Loligo* and 30 million *Illex* is reasonable. The lower estimate for *Illex* may only reflect a difference in the seasonal distribution of the species.

References

Au, David. 1975. Considerations on squid (*Loligo* and *Illex*) population dynamics and recommendations for rational exploitation. ICNAF Res. Doc. 75/61, 13 pp.

Efanov, V. N., and N. P. Puzhakov. 1975. Size composition, growth, mortality rate and condition of shortfin squid (*Illex illecebrosus*) stocks in west Atlantic. ICNAF Res. Doc. 75/58, 7 pp.

Ikeda, I., and F. Nagasaki. 1973. Stock assessment of common American squid in ICNAF Subarea 5 and Statistical Area 6. ICNAF Res. Doc. 73/62, 8 pp.

Ikeda, I., and F. Nagasaki. 1975. Stock assessment of *Loligo* in ICNAF Subarea 5 and Statistical Area 6. ICNAF Res. Doc. 75/44, 4 pp.

Summers, W. C. 1971. Age and growth of *Loligo pealei*, a population study of the common Atlantic coast squid. Biol. Bull. 141: 189-201.

Tibbetts, A. M. 1975. Squid fisheries (*Loligo pealei* and *Illex illecebrosus*) off the Northeast United States, ICNAF Subarea 5 and Statistical Area 6. ICNAF Res. Doc. 75/60, 34 pp.

Table 1. Stock size estimates by areal expansion for *Loligo* in the area of the Japanese fishery (from Ikeda and Nagasaki, 1975)

Season	Area of Fishing Ground (km^2)	Stock Size in Numbers (10^3)
1968-1969	5145	628.6
1969-1970	6688	693.1
1970-1971	7974	641.7
1971-1972	5917	634.6
1972-1973	6174	628.2
1973-1974	2830	779.3

Table 2. Stock size estimates by areal expansion of squid in SA 5 and 6 for the Fall of each year.

	Loligo		*Illex*	
Year	Biomass (tons)	Number (10^6)	Biomass (tons)	Number (10^6)
1968	72700	1800	1800	12.7
1969	57400	1400	5100	36.1
1970	35400	1000	8500	37.1
1971	22100	1200	9300	81.2
1972	29500	1200	10100	50.2
1973	77500	2700	7400	70.7
1974	72300	2400	15900	134.1
1975	97303	5600	17600	92.8

Table 3. Length frequency and exploitation rate of April, May and June 1972 broods of *Loligo* during October 1972 based on the Japanese catch.

Brood	Mean Mantle Length (cm) during October	Frequency in October Catch	Exploitation Rate in October
April	9.8	0.0868	0.023
May	8.3	0.0403	0.008
June	6.8	0.0103	0.002