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A review of the biology of the Atlantic argentine, with particular reference to the Scotian Shelf[1]

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Distribution and Abundance

The Atlantic argentine, or greater silver smelt (Argentina silus Ascanius) is a low arctic-temporate species with an amphi-Atlantic distribution occurring in the northeastern Atlantic from as far south as Coral Bank (49°32'N) north to Spitsbergen (75° 51'N) and in the Barents Sea. It occurs around the Faroes and Iceland, off east Greenland (to 65°33'N) in the Davis Strait (to 62°30'N), off Labrador, and on the Grand Banks, Nova Scotia Banks and Georges Bank to 40°N (Borodulina, 1964, 1968; Wood and Raitt, 1968).

The argentine is a member of the upper continental slope fauna. Although occasional specimens have been reported from as shallow as 28 fm (Emery and McCracken, 1966) it is seldom caught shallower than 80 fm and has been recorded to depths of 600 fm (Fridriksson, 1937). It is most abundant in depths of 100-300 fm (Borodulina, 1964; Chrzan and Zukowski, 1966; Keysler, 1968; Wood and Raitt, 1968) and peak catches in the northwestern Atlantic have been reported from about 100-160 fm by a number of authors (Emery and McCracken, 1966; Ikeda, 1971; McKenzie, MS 1966, MS 1967; Scott, MS 1971).

Depth distribution varies with fish size, smaller fish occurring in the upper part of the species depth range and increasingly larger fish at greater depths (Borodulina, 1964; Chrzan, 1967; Chrzan and Zukowski, 1966; Emery and McCracken, 1966; McKenzie, MS 1966, MS 1967). Emery and McCracken (1966) present the most comprehensive data based on six years survey catches by vessels of the Fisheries Research Board of Canada on the Scotian Shelf. The following table summarises their results:

Depth (fm)	50	70	90	110	130
Mean fork length (cm)	21.9	23.4	24.5	25.9	27.6

The authors indicate that there are seasonal and geographic variations in this relationship.

Argentines have been caught at temperatures ranging from 0.0°C to 12.0°C (Emery and McCracken, 1966; Ikeda, 1971). However, preferred temperatures are 4.0 - 9.0°C (Emery and McCracken, 1966; Ikeda, 1971; Keysler, 1968; Kotthaus and Krefft, 1957; McKenzie, MS 1966, MS 1967).

In the northwestern Atlantic, argentines are scarce off Labrador and only moderately abundant on the Grand Banks (Borodulina, 1964; Pinhorn, personal communication) . However, large concentrations occur along the edge of the Scotian Shelf particularly in the area of Browns Bank (Emery and McCracken, 1966; McKenzie, MS 1966, MS 1967; Scott, MS 1971; personal observation). Abundance is also high on the eastern edge of Georges Bank where catch rates (lbs/

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tow) were higher than on the Scotian Shelf in Canadian exploratory fishing cruises (McKenzie, MS 1966). Similarly, in the northeastern Atlantic, abundance is highest in the southern part of the species range (Wood and Raitt, 1968).

Canadian research vessel cruise results, combined for the 1958-1968 period, indicate highest catch rates (lbs/hr) occurred at 150-200 fm in Div. 4X (622 lb/hr) and Div. 4W (427 lb/hr), and at 100 - 150 fm in Div. 4Vs (394 lb/hr) (Scott, MS 1971). However, biomass estimates (i.e. catch rates x area of distribution) indicate that the bulk of the population occurs in 100 - 150 fm in Div.4X and 4Vs, but in 50 - 100 fm in Div 4W.

Although there have been no studies of the vertical distribution of argentines in the water column, the preponderance of pelagic and bathy-pelagic species in its food indicates that it habitually feeds well above bottom (Borodulina , 1964; Keysler, 1968; Scott, 1969; Wood and Raitt, 1968). Echo-sounder traces made synchronously with bottom tows which caught large quantities of argentines have shown strong echos above bottom -presumably these were argentines (McCracken, personal communication). Ikeda (1971) concludes that argentines make strong diurnal migrations as catch rates of Japanese bottom trawlers in Div. 4X in the winter of 1970 varied from 4.65 tons/hr in daytime to 1.17 tons per hour at night. Thus, only a portion of the population is available to bottom trawlers, at least at night.

Stock Structure

European and North American populations are sufficiently distinct morphometrically to be considered separate stocks. (Borodulina, 1964). Borodulina suggests that ICNAF Div. 30, Div. 4W, and Div. 4X populations are also distinct on the basis of differences in mean length at age and in otolith weight - fish length relationships. However, this conclusion is based on very scant data. Shevchuk (MS 1973a) confirmed stock differences between argentines in Div. 4W and Div. 4X on the basis of differences in vertebral number, snout length, pre-anal distance, otolith length-breadth ratio, otolith weight, and linear and weight growth rates. Lesser differences between Div. 4W and Div. 4V samples possibly also indicate stock separation.

However, a northeast-southwest cline in infestation of Scotian Shelf argentine by the trematode parasite Lecithophyllum botryophorum suggests a fairly continuous distribution of argentines with no large migratory movements or stock separations (Scott, 1969). The incidence of other trematode parasites has proved of no value in distinguishing argentine stocks.

Personal observations on vertebral counts (excluding urostyle) are given below:

Area of capture	Number	Mean Vertebral count
St. Pierre Bank (Div. $3P_s$)	100	65.91
Banquereau (Div. $4V_s$)	100	65.93
Banquereau (Div. $4V_s$)	50	65.78
Banquereau (Div. $4V_s$)	100	65.67
S. of Western Bk. (Div. 4W)	100	65.75
SW of Emerald Bk. (Div. 4W)	100	65.65
SW of Emerald Bk. (Div. 4W)	100	65.54
Emerald Basin (Div. 4W)	100	65.54
Emerald Basin (Div. 4W)	100	65.38
SW of La Have Bk. (Div. 4X)	100	65.56
SE of Browns Bk. (Div. 4X)	79	65.56
Fundian Channel (Div. 4X)	8	(65.13)
Georges Bank	50	65.50

Differences in vertebral count among areas from St. Pierre Bank to Georges Bank are small and form a cline from high values in the northeast to low values in the southwest. Dismissing the Fundian Channel sample as being too small to be meaningful, argentines from Georges Bank to Emerald Bank have vertebral counts of 65.50 - 65.60, with the exception of one sample from Emerald Basin. Argentines from Emerald Bank to Banquereau have counts of 65.65 - 65.80, and those from St. Pierre Bank and some Banquereau fish have counts of 65.90 - 65.95. These data conflict with those of Shevchuk (MS 1973 a) who obtained values of 65.71 vertebrae in Div. 4X and 66.39 in Div. 4W. Wood and Raitt (1968) obtained a mean vertebral number of 66.55 for argentines from the Grand Bank which is in keeping with the cline found in more westerly regions.

Dense spawning concentrations have been located along the edge of Browns Bank (Div. 4X) and in Emerald Basin (Div. 4W) but spawning fish have been caught at numerous locations along the edge of the Scotian Shelf (personal observation).

Thus, the Scotian Shelf is apparently inhabited by a complex of stock units with limited mixing among adjacent units, resulting in observable clines in morphometric characteristics and biological parameters. It is likely that this is also true in other areas of the northwestern Atlantic.

Growth

The argentine is a slow growing, long-lived fish. The largest recorded specimen is 55 cm caught off Greenland (Keysler, 1968) and a number of specimens over 50 cm have been captured off Iceland and northern Norway. Specimens aged at over 20 years are not uncommon, and Chrzan (1966) reports "some individuals" were 30 years old in Scotian Shelf catches.

Wood and Raitt (1968) found that mean length at age in a wide variety of localities in the northeastern Atlantic was very similar with the exception that Icelandic argentines were larger at age than in other localities. Keysler (1968), who obtained mean lengths at age for Norwegian and Icelandic fish which were somewhat higher than those of Wood and Raitt, found that argentines from Greenland were even larger at age than those from Iceland but concludes, without explanation, that these are old mature fish of the Icelandic stock. He also found that Newfoundland argentines were of similar length at age to those off Norway.

Several authors give data on growth of Scotian Shelf argentines (Borodulina, 1968; Chrzan and Zukowski, 1966; Emery and McCracken, 1966; Shevchuk, MS 1973 b; Zukowski, MS 1970). Mean lengths at age given are in all cases lower than those of Keysler for Newfoundland waters and those of Wood and Raitt for the northeastern Atlantic. Borodulina's data are only presented graphically and are difficult to compare with those of other authors. However, her data support the conclusion that Scotian Shelf argentines are smaller at age than those from the Grand Banks. Unfortunately, the Scotian Shelf data are in poor agreement among themselves (Fig. 1). They do indicate however, that females are slightly larger at age than males in the northwest, as in the northeast, Atlantic. The mean lengths cited by Emery and McCracken are the highest although they represent fork lengths in contrast to those of the other authors which are most likely total lengths, although this is not clear from the papers. Were Emery's and McCracken's data transformed to total length, they would be only slightly lower than mean lengths given by Wood and Raitt for the northeastern Atlantic and almost identical to Keysler's for Newfoundland. (Total length is approximately equal to 1.10 x fork length - personal observation.) These differences in mean length at age for Scotian Shelf fish are

not readily explainable other than that there are substantial differences in ageing technique, and in some cases the data are seriously biased by unrepresentative sampling.

The following von Bertalanffy growth parameters have been presented:

Area	Sex	L_∞	K	t_0	Author
Div. 4X	♂	46.5	0.091	-3.87	Shevchuk, MS 1973b.
	♀	54.4	0.066	-9.23	" " "
	♂♀	65.3	0.047	-7.97	" " "
Div. 4W	♂	51.8	0.065	-9.49	" " "
	♀	73.3	0.038	-10.59	" " "
	♂♀	42.6	0.109	-3.32	" " "
Div. 4W-X	♂	37.9	0.145	-0.75	Zukowski, Ms 1970
	♀	41.4	0.129	-0.75	" " "

Shevchuk (MS 1973 b) gives similar data for growth in weight. However, the substantial differences in the results of different workers imply that it would be unwise to use any of the available growth data in calculation of potential fisheries yields other than in a most general way. A critical evaluation of ageing techniques is called for.

Mortality

Mortality estimates for argentine have been made only for those of Browns Bank (ICNAF Div. 4X). From the catch curve of ages 5-20 in Polish research vessel catches in 1964-67 combined, total mortality was estimated at Z = 0.28 (Zukowski, MS 1970). Similarly, average Soviet research catches in Div. 4X in 1968-70 gave an estimated Z = 0.24 for ages 7 - 12 (Shevchuk, MS 1973 b). From the same data Shevchuk obtained a value of Z = 0.21 using the formula

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L'} \quad \text{(Beverton and Holt, 1956).}$$

As the size, and hence age, of argentines caught is stongly dependent on depth fished, serious biases could result in mortality estimates if differences in fishing intensity with depth are not taken account of in the analysis. The distribution of fishing with depth is not described in the papers of Shevchuk or Zukowski. Thus, it is not possible to draw conclusions directly on the direction or likely magnitude of biases. However, in both cases young fish are well represented in the catches. Thus, a serious underestimate of Z seems unlikely.

Reproduction

The eggs of *A. silus* are bathy-pelagic, normally occurring at depths greater than 100 fm over the edge of the continental shelf in the northeastern Atlantic (Schmidt, 1906) and this has been confirmed for the northwestern Atlantic by the author (unpublished).

The most comprehensive age at maturity data for A. silus are those of Wood and Raitt (1968) for the northeastern Atlantic. At the southern extremity of the species range on Coral Bank, maturity occurs in some fish at age 3 and in all fish by age 5. More northerly populations mature progressively later, and around Iceland and northern Norway it is not until age 6 that maturation begins in some fish and all are mature by age 12. Borodulina's (1968) results are in general agreement with those of Wood and Raitt, but Keysler (1968) found that argentines from Norway and Iceland begin maturing at age 3 and all are mature by age 7. However, Keysler's conclusions were based to a large extent on interpretation of otolith ring structure whereas Wood's and Raitt's were based on direct gonad examination. This difference in technique, or differences in age determination, may explain the different conclusions.

Keysler concludes that argentines mature mainly between the lengths of 27 cm and 32 cm off Norway and between 31 cm and 36 cm off Iceland. The smallest mature fish observed was 25 cm and the largest juvenile was 34 cm.

In the northwestern Atlantic McKenzie (MS 1966, MS 1967) states that, in ICNAF Subareas 4 and 5, argentines mature between 26 cm and 33 cm. (fork length). The smallest mature male observed by Emery and McCracken (1966) in Emerald Basin (Div. 4W) was 24 cm, and the smallest mature female was 28 cm (fork length). The youngest mature fish they observed were age 4 for females and age 5 for males according to their graphical presentation of their data. However, in the text of their paper they state that the youngest mature males were age 4, and the youngest mature females were age 6. Emery's and McCracken's age frequency histogram for spawning fish has a mode at about age 9, implying that most argentines are recruited to the spawning stock by age 9. Borodulina (1968) gives age at maturity at 6-10 years for north-western Atlantic argentines based on otolith characteristics which is in agreement with Emery's and McCracken's data.

The following observations have been published on A. silus fecundity:

Location	No. of observ.	Lowest count	(Fish length)	Highest count	(Fish length)	Author.
S. of Ireland	8	7,700	(31.7cm)	10,700	(35.6cm)	Wood & Raitt(1968)
N. Norway	28	6,700	(34.1cm)	26,300	(47.5cm)	" " " "
Iceland	9	9,200	(47.9cm)	28,500	(50.0cm)	" " " "
" Rost Bk (68°26'N, 11°30'E)	50	10,000	(37cm)	38,600	(44.5cm)	Borodulina (1964, 1968)
Eastern Atlantic	19	9,300	(33cm)	28,400	(51 cm)	Keysler (1968)
Nfld. Grand Bks.	8	8,200	(40.6cm)	13,600	(41.2cm)	Wood & Raitt(1968)

Keysler (1968) calculated the following relationships between fecundity and fish length and weight:

$$F = 1.106\ L^{2.5826} = 125.7\ W^{0.7671}$$

The paucity of published fecundity estimates for the northwestern Atlantic is obvious from the above table. Several hundred unpublished fecundity counts made by the author for Scotian Shelf argentines suggest that fecundity is lower than in the northeastern Atlantic. The majority of counts for fish 30 - 45 cm total length lay in the range of 5,000 - 10,000 eggs and the highest count obtained was 18,900 eggs in a fish of 42 cm.

There is a latitudinal cline in spawning time in the northeastern Atlantic, spawning becoming progressively earlier from southern to northern populations (Wood and Raitt, 1968), the earliest spawning taking place in April.

Emery and McCracken (1966) record that argentines captured in Emerald Basin (ICNAF Div. 4W) in March 1965 were just beginning to spawn, and Noskov and Zakharov (1964) report "mass spawning" of argentines in the Emerald Bank area in March 1963.

The Emerald Basin spawning concentration was investigated in more detail by the author (unpublished) in five research vessel cruises in 1967 and 1968. In the period 12-19 February 1968, argentines were scarce in Emerald Basin but moderate catches of ripening argentines were made in 170-200 fm along the adjacent continental slope to the south. In 1967, substantial concentrations were found in Emerald Basin on 13-16 April and less than 15% of these fish were spent, the remainder being in late ripening and spawning stages. Argentine eggs were present in four of five plankton tows made in the area. On 2 May 1967, three trawl sets in the area of major concentration found two weeks earlier, yielded only a few argentines, but substantial concentrations of spent and resting fish were located along the adjacent upper continental slope. This contrasts with results obtained on 1-4 May 1968 when catch rates similar to those of mid-April 1967 were obtained, although at this time 40% to 75% of the fish caught in each tow were fully spent indicating that spawning was at an advanced stage. By 1 July 1967, all the argentines caught in Emerald Basin were spent or recovering (with the exception of one ripening female). However, many appeared newly spent, indicating that cessation of spawning was recent.

Thus a persistent, though probably small, spawning stock of argentines occurs in Emerald Basin. These fish concentrate in the deepest part of the Basin (maximum depth, 148 fm) in late February or early March with major spawning occurring in April and in some years into May. Some spawning probably occurs throughout May and possibly also into June.

Soviet observations on gonad condition suggest that argentine spawn from late February to May on the slopes of Browns Bank, in March-April on Sambro Bank (i.e. Emerald Basin) and in April-May on Banquereau Bank (Konstantinov and Noskov, 1972) and those of the author (unpublished) suggest that there are a substantial number of spawning locations between Browns Bank and Banquereau.

Length-Weight Relationship

In September 1969, Div. 4X argentines had the following length-weight relationship (Kohler *et al.*, M.S. 1970):

$$W = 0.0000131 \ L^{3.0615}$$

where W = total weight in pounds and L = fork length in cm. Calculated weight per cm length group is given in table 1.

Keysler (1968) examined the "condition factor"

$$K = \frac{W \times 100}{L^3}$$

for argentines from Norway, Iceland and Newfoundland obtaining average values of K = 0.71, 0.71, 0.77 respectively. However, there was considerable variation with fish size, 11-14 cm argentines having K = 0.57 and those of 45 - 49 cm a K = 0.80 off Norway, and similar variations were observed in the other areas.

The Fishery

The argentine fishery in the northwestern Atlantic was initiated in 1963 by the USSR and nominal catches ranged from 12,000 - 49,000 metric tons in 1963-66 (Table 2). (Nominal catches are from ICNAF Statistical Bulletins Vols. 13 - 21, and ICNAF Summ. Doc. 73/17 (revised)). Catches declined to 5,500 tons in 1968, but increased to 14,500 tons in 1971 in part due to the entry of Japan to the fishery. Increased USSR catches raised 1972 landings to almost 39,000 tons. Almost all catches originated from Subareas 4 and 5, with Subarea 5 catches being the greater (Table 3).

All Subarea 4 catches are from the Scotian Shelf, particularly Div. 4W and Div. 4X (Table 4). Catches have shown no consistent trends ranging from 2,700 tons to 15,000 tons, averageing 6,300 tons annually in 1963-72.

Soviet Research Reports (ICNAF Redbook Pt. II, 1964, 1967, 1968, 1969, 1970, 1971, 1972) describe the USSR argentine fishery in Subarea 4. In 1963, the fishery was conducted mainly in the spring in the Emerald Bank area, but by 1966 the fishery had extended along the edge of the shelf from Banquereau to Browns Bank, the bulk being taken on the slopes of Browns Bank. In 1967, landings were lower and originated mainly from Div. 4X in April to October. Landings declined further in 1968 to 1,600 tons as "concentrations were not stable and usually they were found on slope areas with snaggy ground" hence little fishing effort was directed to argentines. With a substantial increase in the silver hake fishery in 1969, argentines which were mainly a bycatch in this fishery were caught on the slopes of Middle, Emerald, and Browns Banks in spring and autumn and landings increased to 4,100 tons. The decline in landings to 1,600 tons in 1970 was attributed to the Div. 4X haddock spawning grounds closure which included much of the continental slope in Div. 4X and thus also restricted the argentine fishery. The haddock closure regulations were modified in 1972 to allow fishing along most of the continental slope of Div. 4X. Soviet landings increased to 5,400 tons in 1972 mainly as bycatch in the silver hake fishery on the continental slope in Div. 4W and Div. 4X. Catches were mainly in April on argentine spawning grounds.

There are no descriptions in Soviet Research Reports of their Subarea 5 argentine fishery except for 1972 (ICNAF Redbook 1973 Pt. II). In that year dense pre-spawning concentrations in Georges Basin immediately adjacent to Div. 4X were fished in April, accounting for most of the catch of 32,700 tons. It is stated in the Report that these fish had essentially the same size and age composition as Div. 4X caught fish and that the concentrations fished belong to the Browns Bank stock.

As Georges Basin and the Fundian Channel are currently among the most productive argentine fishing grounds, and as the dividing line between Subareas 4 and 5 puts part of these grounds in each Subarea, there is not a clear cut division between argentine fisheries and stocks in these Subareas.

Soviet catches in Subarea 4 in 1968 were composed of fish 20 - 43 cm long - presumably total length to the nearest centimetre (ICNAF Redbook 1969 Pt. II). Mean lengths of Browns Bank catches were 27.3 cm in May, 30.0 cm in September, 30.3 cm in October, and 30.8 cm in November. In 1969, Soviet scouting vessels caught argentines aged 2 - 15 yrs., but mainly 6 - 10 yrs.

with a modal age of 8 yrs., in February-April in the Emerald - LaHave Banks region. These catches may be representative of the commercial catch. However, no Soviet commercial sampling data has been presented in ICNAF Sampling Yearbooks for argentines from any area.

Japanese catches in Subareas 3, 4, and 5 were sampled in 1970 and 1971 (ICNAF Sampling Yearbooks Vols. 15 & 16). In 1970, Div. 4Vs catches in June ranged in length (fork length to nearest centimetre) from 25 cm to 42 cm, the bulk of the catch lying in the range 31 - 41 cm (mean = 35.1 cm). In Div. 4W, the length range was 24 - 38 cm, most fish being in the range 29 - 33 cm in January (mean = 30.6 cm) and February (mean = 31.9 cm) and 25 - 34 cm in June (mean = 29.2 cm). In Div. 4X, the length range was 23 - 44 cm. In January to March modal length was 31 cm or 32 cm, most of the catch being in the range 29 - 33 cm (monthly means = 32.3 cm, 31.7 cm, 32.3 cm respectively). June and July catches contained more smaller fish and modal length was 29 cm, however mean length of catch remained much the same (June = 31.8 cm, July = 31.0 cm) as larger fish were also better represented. August catches were composed of fish mainly over 30 cm with a modal length of 34 cm (mean = 33.5 cm). Fig 2. presenting these data graphically is reproduced from the Japanese Research Report for 1970 (ICNAF Redbook 1971 Pt. II). Subarea 3 and 5 samples have similar mean lengths and ranges to those in Subarea 4.

In May-June 1971, Japanese catches in Div. 4X were predominantly fish 30 - 40 cm in length with a mode at 35 cm. in contrast to the higher occurrence of small fish in June 1970. Subarea 5 catches in 1971 ranged from 24-44 cm, with larger fish being taken in March-April than in May-June (Fig. 3) (reproduced from Japanese Research Report for 1971, ICNAF Redbook 1972 Pt. II).

Thus, Soviet catches, at least in 1968, were composed of fish smaller than those taken in the Japanese fishery in 1970-71, but there are insufficient data to establish with accuracy the size composition, and none to establish the age composition, of total removals by the fishery.

Potential Yield From Subarea 4

Difficulties in representatively sampling argentine populations, and probably also differing interpretation of otolith ring structure in determining age, have resulted in substantially different estimates of growth rate in Subarea 4 argentines and may have biased mortality estimates. However, there is little doubt that A. silus is a slow growing fish apparently taking 5 - 8 years to attain a total length of 30 cm. and 25 - 30 years to reach 45-50 cm. Sexual maturation occurs late, probably between ages 5 and 10 along the Scotian Shelf, and fecundity is low, ranging from 5,000 - 20,000 eggs. Entry to the fishery occurs at about, or just below, the length at maturity, thus the entire spawning stock is subject to the fishery. Natural mortality, M, is unknown but likely to be low. Comparison with stocks of other species with comparable longevity suggest that M is unlikely to exceed 0.20 and may be lower. Estimates of total mortality, Z, range from 0.21 - 0.28 at average annual landings of about 6,000 tons. Thus, it can be anticipated that the ratio of yield to biomass will be low, and that recovery would be slow if spawning stocks were depleted.

From Canadian research vessel surveys on the Scotian Shelf in 1958-68, Scott (M.S. 1971) obtained an average "uncorrected" biomass estimate for argentine of 62,000 metric tons. This estimate was obtained by stratifying each of the ICNAF Divisions 4Vs, 4W, and 4X into five depth ranges from 0-400 fm and, assuming that the numerous tows in each stratum (total = 2,741 tons) were essentially randomly distributed, average catch per standard tow was adjusted up on the ratio of area fished to total stratum area. In the strata in which argentine were

most abundant, fishing was directed toward argentine in a number of years. Hence, Scott's biomass estimate is possibly biased upward. As argentines are not common in Div. 4Vn, omission of this Division in the analysis does not prevent the results from being representative of the Scotian Shelf as a whole.

Scott's biomass estimate of 62,000 tons is minimal as the entire population of argentines in the water column above the area of bottom swept by the gear would not be caught by the trawl. The trawls used had headrope heights of approximately 10 feet (Carrothers and Foulkes, M. S. 1971). Scott assumed that, although argentines were in areas accessible to fishing at all times of the year, on average only 60% of the population lay within the path of the gear used and of these, only 50% were caught. Hence, his biomass estimate represented 30% of the actual biomass, giving a corrected biomass estimate of 200,000 tons.

Ikeda (1971) noted strong diurnal migrations of argentines south of Browns Bank in the winter, catch rates of bottom trawlers being almost four times larger during daytime than at night. Assuming all argentines were available to the gear during daytime, about 60% of the population would be available in a 24 hr. period. This suggests that Scott's estimate of 60% available to the smaller Canadian research vessel trawls may be too high.

Unfortunately, there are no data to indicate what the vulnerability of argentines to the gear may be. In Scott's calculations, area swept by the nets was measured from wingtip to wingtip. However, the gears used were equipped with ground-wasps and bridles, hence door spread would be considerably larger. Herding effects make the actual area swept by the gear greater than that used by Scott, at least for some species. When wingspread is used in calculations, availability factors for cod and haddock on the Scotian Shelf, are close to, and possibly greater than 1.0 (Grosslein and Halliday, M.S. 1972). Thus, vulnerability of argentines is unlikely to be extremely low and 50% seems a reasonable "educated guess".

If Scott's availability factor is reduced to 40% and vulnerability taken as 50%, the biomass estimate becomes 300,000 tons. Thus, current best estimates of average argentine biomass on the Scotian Shelf in 1958-68 is 200,000-300,000 tons.

In the first five years of this period argentines were unexploited, and in the latter six years landings averaged 6,800 tons. Thus, for the 11 years landings averaged 3,700 tons. Thus, the estimates above essentially represent the virgin biomass of argentines on the Scotian Shelf.

Alverson and Pereyra (1969), quoting Gulland, conclude that, as a rough approximation,:

$$C_{max} = 0.4\ M\ B_0$$

where C_{max} = maximum sustainable yield, M = instantaneous natural mortality, B_0 = virgin biomass. From this equation, the sustainable yield of Subarea 4 argentines, if M is taken as 0.20, is 16,000-24,000 tons.

It is fully appreciated that the many assumptions required to arrive at these estimates must result in low confidence in their accuracy.

Discussion

This review brings to attention the paucity of information available for assessment of the status of argentine stocks. It is particularly important that ageing techniques be re-evaluated and compared among workers, and that a more rigorous sampling design be employed which takes account of differential depth distribution with size, if reliable estimates of growth and mortality are to be obtained. Sampling of the catches by all major sectors of the international fleet is also essential for adequate assessment.

Estimates of potential yield from research vessel surveys is extremely tentative and data on catchability coefficients of survey trawls would be most valuable. However, these results suggest that the Assessments Subcommittee's guess of 50,000 tons as the potential yield of argentines from Subarea 4 is optimistic. (ICNAF Redbook 1973 Pt. I, p. 84).

The possibilities of stock intermixing between Subareas 4 and 5 should be noted in setting up a management system.

Summary

The Atlantic argentine is a low arctic-temporal species with an amphi-Atlantic distribution. It occurs along the edge of continental shelves mainly in depths of 100-300 fm, larger fish occurring in deeper water. Although catches have been made in water temperatures of 0.0-12.0°C, preferred temperature range is 4.0-9.0°C.

In the northwestern Atlantic abundance is highest in the southern part of the species range in the Browns - Georges Banks area.

Vertical migration is marked, catch rates of bottom trawlers being as much as four times higher in daytime than at night. Most of the food is composed of pelagic organisms.

Morphometrics, meristics, and parasites indicate that the Scotian Shelf is inhabited by a complex of stock units with limited mixing among adjacent units.

Argentines attain lengths of 50 cm, but growth is slow, and this may take up to 30 yrs. Sampling difficulties and ageing differences among research workers have resulted in widely differing estimates of growth pattern for Scotian Shelf fish.

Mortality estimates, which are particularly prone to sampling errors, range from Z = 0.21 - 0.28 for the Scotian Shelf.

Maturity on the Scotian Shelf occurs between 25-35 cm and ages 5-10. Fecundity is low, probably ranging from 5,000 -20,000 eggs per female annually. There are a number of spawning locations on the Scotian Shelf, peak spawning occurring in April.

The length-weight relationship of ICNAF Div. 4X argentines in September was (units lbs. and cm): $W = 0.0000131\ L^{3.0615}$.

The fishery was initiated in 1963 and Subarea 4 landings varied from 2,700 - 15,000 metric tons in 1963-72. Catches contained fish 20-45 cm long, with average lengths close to 30 cm.

Crude estimates of potential yield from Subarea 4 based on biomass estimates from research vessel surveys is 16,000 - 24,000 metric tons.

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TABLE 1 LENGTH-WEIGHT TABLE

SPECIES-ARGENTINE GEAR-OTTER TRAWL AREA-BROWNS LAHAVE 4X
DATE-SEPT.,1969 RESEARCH CRUISE P54 WEIGHT-ROUND SEX-NOT EX.

B= 3.061523 A=0.000013101 LOG A=-4.882677 NO.SAMPLED= 199

SSQX= 450.187393 SSQDEVX= 0.301384 RSSQ=0.279406

MINIMUM OBSERVED LENGTH 26. CM. MAXIMUM OBSERVED LENGTH 40. CM.

LENGTH (CM.)	COMPUTED WT. GRAMS	LBS.	OBS.WT. LBS.	LENGTH (CM.)	COMPUTED WT. GRAMS	LBS.	OBS.WT. LBS.
1.00	0.	0.00	0.00(0)	41.00	515.	1.13	0.00(0)
2.00	0.	0.00	0.00(0)	42.00	554.	1.22	0.00(0)
3.00	0.	0.00	0.00(0)	43.00	596.	1.31	0.00(0)
4.00	0.	0.00	0.00(0)	44.00	639.	1.40	0.00(0)
5.00	1.	0.00	0.00(0)	45.00	684.	1.50	0.00(0)
6.00	1.	0.00	0.00(0)	46.00	732.	1.61	0.00(0)
7.00	2.	0.01	0.00(0)	47.00	782.	1.72	0.00(0)
8.00	3.	0.01	0.00(0)	48.00	834.	1.83	0.00(0)
9.00	5.	0.01	0.00(0)	49.00	888.	1.95	0.00(0)
10.00	7.	0.02	0.00(0)	50.00	945.	2.08	0.00(0)
11.00	9.	0.02	0.00(0)	51.00	1004.	2.21	0.00(0)
12.00	12.	0.03	0.00(0)	52.00	1066.	2.34	0.00(0)
13.00	15.	0.03	0.00(0)	53.00	1130.	2.49	0.00(0)
14.00	19.	0.04	0.00(0)	54.00	1196.	2.63	0.00(0)
15.00	24.	0.05	0.00(0)	55.00	1265.	2.78	0.00(0)
16.00	29.	0.06	0.00(0)	56.00	1337.	2.94	0.00(0)
17.00	35.	0.08	0.00(0)	57.00	1411.	3.11	0.00(0)
18.00	41.	0.09	0.00(0)	58.00	1489.	3.28	0.00(0)
19.00	49.	0.11	0.00(0)	59.00	1569.	3.45	0.00(0)
20.00	57.	0.13	0.00(0)	60.00	1651.	3.64	0.00(0)
21.00	66.	0.15	0.00(0)	61.00	1737.	3.82	0.00(0)
22.00	77.	0.17	0.00(0)	62.00	1826.	4.02	0.00(0)
23.00	88.	0.19	0.00(0)	63.00	1917.	4.22	0.00(0)
24.00	100.	0.22	0.00(0)	64.00	2012.	4.43	0.00(0)
25.00	113.	0.25	0.00(0)	65.00	2110.	4.65	0.00(0)
26.00	128.	0.28	0.31(1)	66.00	2211.	4.87	0.00(0)
27.00	143.	0.32	0.31(3)	67.00	2315.	5.10	0.00(0)
28.00	160.	0.35	0.35(8)	68.00	2423.	5.34	0.00(0)
29.00	178.	0.39	0.39(15)	69.00	2533.	5.58	0.00(0)
30.00	198.	0.44	0.44(44)	70.00	2647.	5.83	0.00(0)
31.00	219.	0.48	0.49(42)	71.00	2765.	6.09	0.00(0)
32.00	241.	0.53	0.51(23)	72.00	2886.	6.36	0.00(0)
33.00	265.	0.58	0.58(17)	73.00	3010.	6.63	0.00(0)
34.00	290.	0.64	0.64(7)	74.00	3138.	6.91	0.00(0)
35.00	317.	0.70	0.72(9)	75.00	3270.	7.20	0.00(0)
36.00	346.	0.76	0.83(3)	76.00	3405.	7.50	0.00(0)
37.00	376.	0.83	0.82(11)	77.00	3544.	7.81	0.00(0)
38.00	408.	0.90	0.89(7)	78.00	3687.	8.12	0.00(0)
39.00	442.	0.97	1.00(8)	79.00	3834.	8.45	0.00(0)
40.00	477.	1.05	1.00(1)	80.00	3984.	8.78	0.00(0)

NUMBER OF FISH SAMPLED AT LENGTH IN BRACKETS

TABLE 2. Argentine (A. silus) landings from the ICNAF Statistical Area by Country (metric tons round).

	COUNTRY					
Year	U.S.S.R.	F.R.G.	Japan	Non-M.	Unknown	Total
1960	-	-	-	-	-	-
1961	-	-	-	-	-	-
1962	-	-	-	-	-	-
1963	12,337	-	-	-	-	12,337
1964	17,773	13	-	-	-	17,786
1965	15,064	-	-	-	-	15,064
1966	49,040	-	-	-	-	49,040
1967	7,015	-	42	65	-	7,122
1968	4,184	-	1,274	-	-	5,458
1969	5,707	-	2,338	28	5*	8,078
1970	2,614	-	4,100	1	10*	6,725
1971	5,535	-	9,003	2	-	14,540
1972	38,127	-	710	-	-	38,837

*Statistical Area 6 catches not broken down by country.

TABLE 3. Argentine (A. silus) landings by ICNAF Subarea (metric tons round).

	ICNAF SUBAREA						
Year	1	2	3	4	5	6	Total
1960	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-
1963	-	-	-	8,127	4,210	-	12,337
1964	13	-	-	4,943	12,830	-	17,786
1965	-	-	-	5,611	9,453	-	15,064
1966	-	-	119	14,983	33,938	-	49,040
1967	-	-	825	4,271	2,026	-	7,122
1968	-	-	449	2,675	1,481	853	5,458
1969	-	5	106	5,354	2,608	5	8,078
1970	-	-	793	4,553	1,369	10	6,725
1971	-	-	532	6,715	7,293	-	14,540
1972	-	-	262	5,868	32,707	-	38,837

TABLE 4. Argentine (A. silus) landings from ICNAF Subarea 4 by Division and Country (metric ton round).

Year	ICNAF DIVISION							Total	COUNTRY			
	4R	4S	4T	$4V_n$	$4V_s$	4W	4X		USSR	GDR	Japan	Non-M.
1960	-	-	-	-	-	-	-	-	-		-	-
1961	-	-	-	-	-	-	-	-	-		-	-
1962	-	-	-	-	-	-	-	-	-		-	-
1963	-	-	-	1	-	7,399	727	8,127	8,127		-	-
1964	-	-	-	1	-	2,337	2,605	4,943	4,943		-	-
1965	-	-	-	161	-	5,425	25	5,611	5,611		-	-
1966	-	-	-	358	-	5,929	8,696	14,983	14,983		-	-
1967	-	-	-	6	-	92	4,093	4,271	4,191		42*1	38
1968	-	-	-	-	450	878	261	2,675	1,589	-	1,086*1	-
1969	-	-	-	-	1,151	2,729	218	5,354	4,075	23	1,256*1	-
1970	-	-	-	-	133	1,530	2,890	4,553	1,615	-	2,938	-
1971	-	-	-	-	511	2,566	3,638	6,715	3,555	-	3,160	-
1972*2	-	-	-	-	446	2,085	3,337	5,868	5,412	-	456	-

*1 ICNAF Division not specified.
*2 Preliminary statistics.

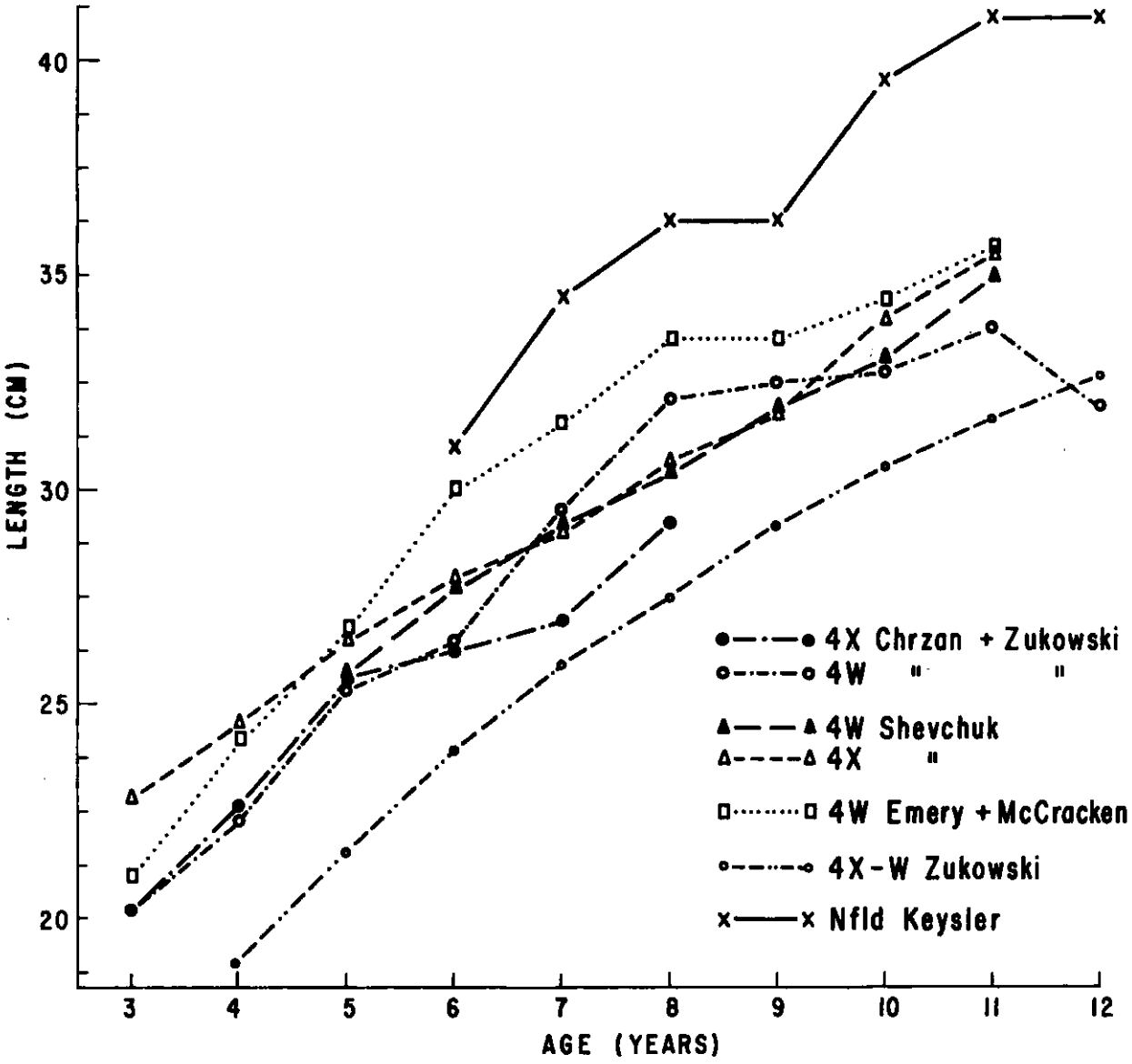
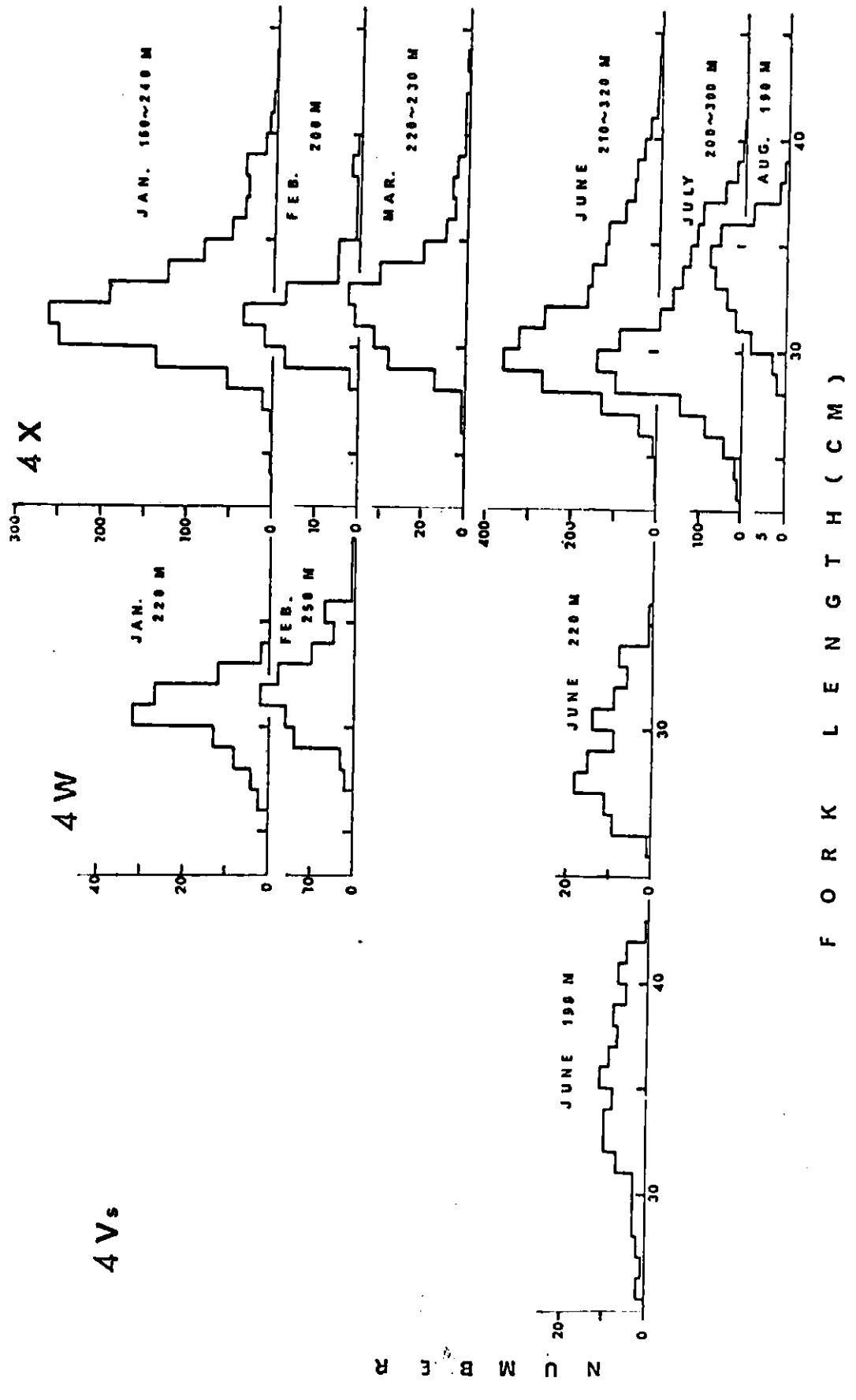


Fig. 1. Mean lengths at age of argentines from the Scotian Shelf and Newfoundland. (Emery and McCracken's data are fork length, others are probably total lengths.)



F4

Fig. 2. Size composition of argentine by divisions and by months, for the Japanese fishery in Subarea 4 in 1970. Reproduced from Ikeda (1971) Japanese research report for 1970. ICNAF Redbook 1971, Pt II, p. 95.

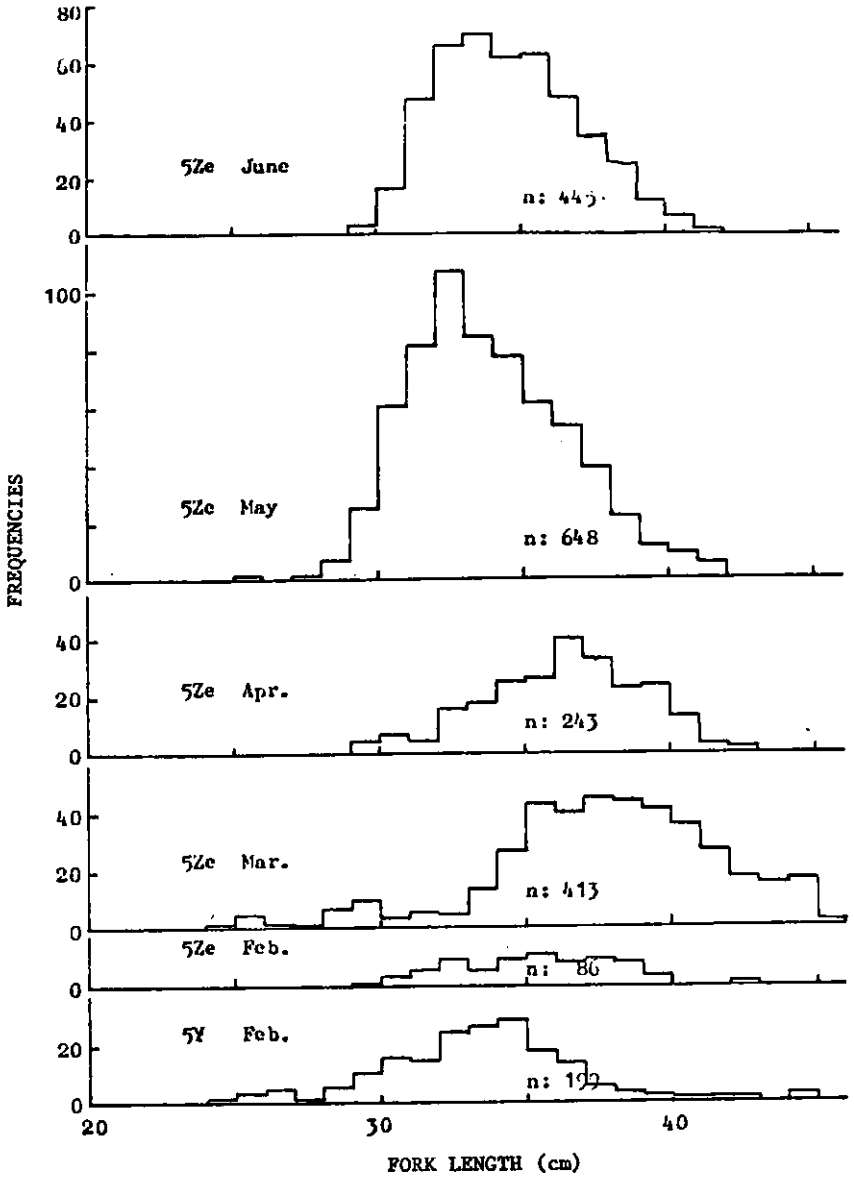


Fig. 3. Size composition of argentine by division and month for the Japanese fishery in Subarea 5 in 1971. Reproduced from Ikeda (1972) Japanese research report for 1971. ICNAF Redbook 1972, Pt. II, p.60.

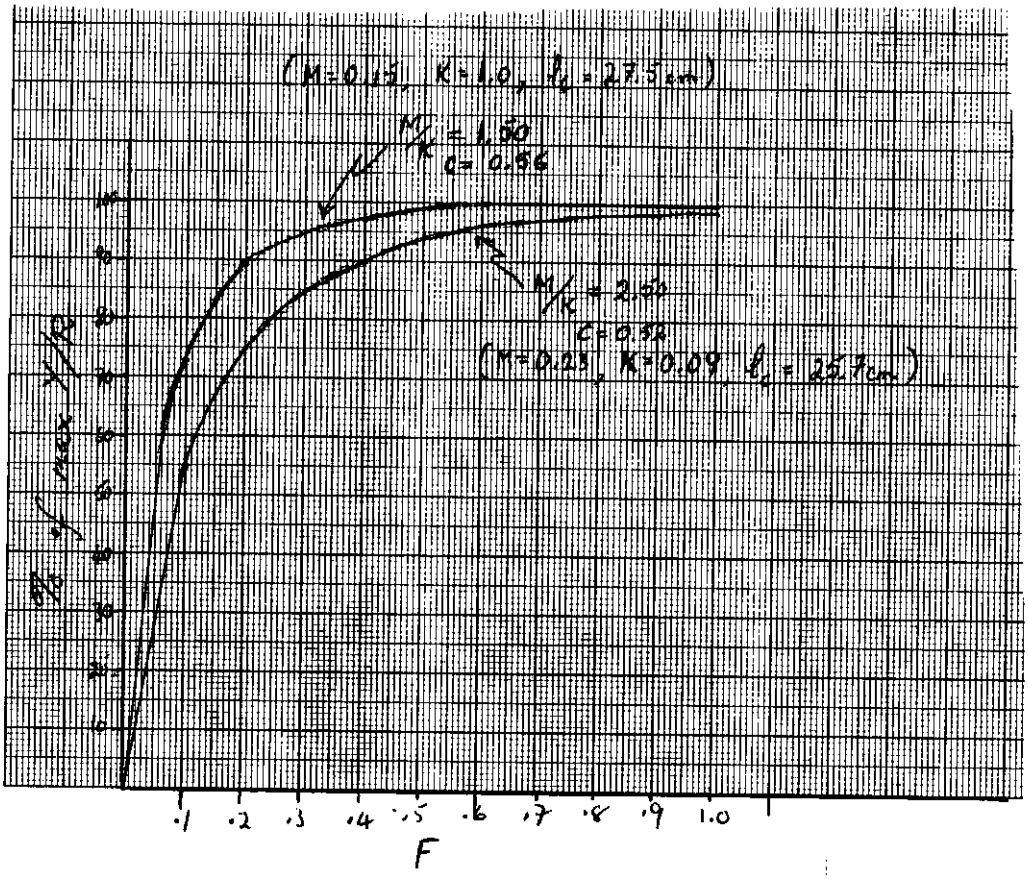


Fig. 4. Subarea 4 argentines, yield-per-recruit.

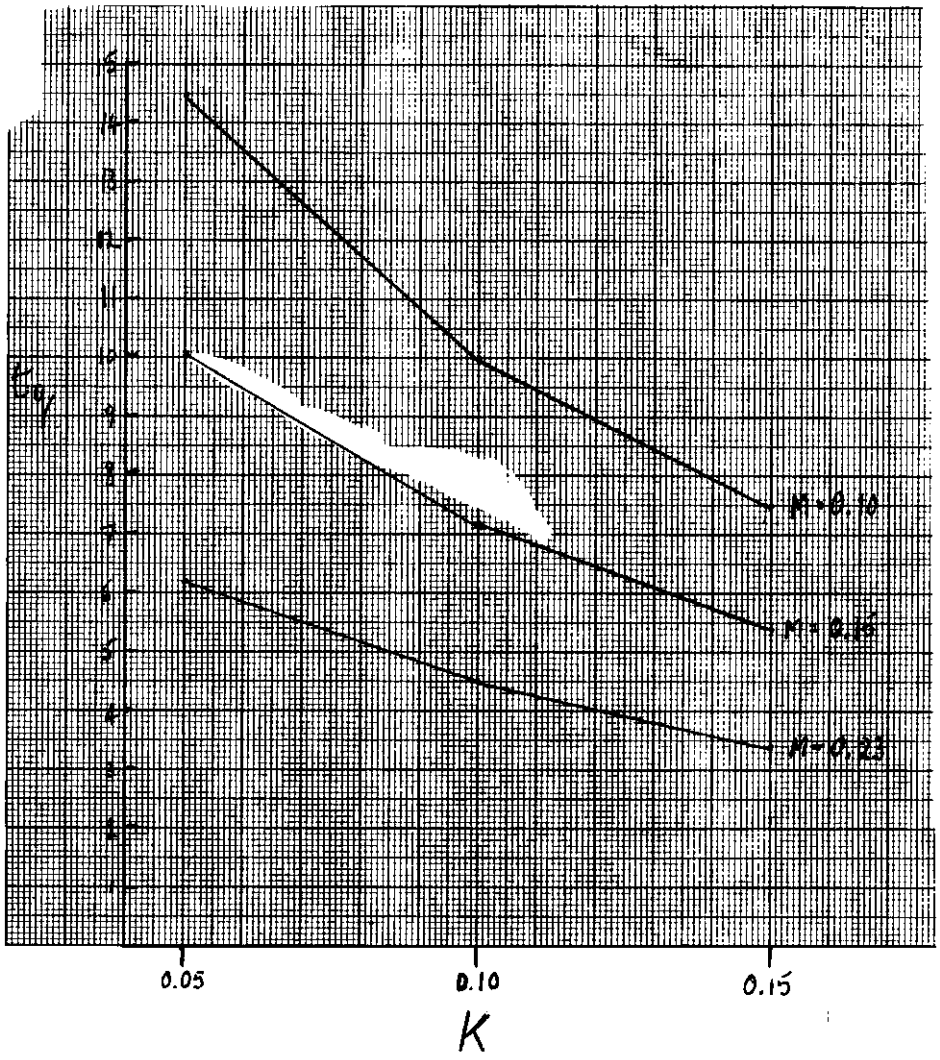


Fig. 5. Variation of "optimum age of exploitation" = tq with M and K.

$$tq = \frac{\ell n(3K + M) - \ell nM}{K} + t_o$$