International Council for
the Exploration of the Sea

Shellfish Committee
C.M. 1980 / K: 37

PRELIMINARY ESTIMATES OF MORTALITY PARAMETERS FOR NORWAY LOBSTER IN BAY OF BISCAY AND IN THE CELTIC SEA *

By Gérard CONAN

Centre Océanologique de Bretagne, CNEXO, B.P. 337, 29273 Brest Cedex, France.

SUMMARY

The catch curves of Nephrops caught in Bay of Biscay and in the Celtic Sea are analyzed into component molt groups. Total mortality coefficients (Z) are estimated from the respective contribution in number of the different molt groups to the catch curve. Z would be equal to 1.35 for males and to 1.34 for females in Bay of Biscay. In the Celtic Sea the Z values would be equal to 1.01 for the males and to 0.91 for the females.

An estimate of the fishing mortality F in the Bay of Biscay is obtained from available data on fishing effort and from an estimate of the capturability coefficient c derived from a surplus production model. F would be equal to 0.907. The instantaneous mortality coefficient M would be equal to 0.45 for the males and to 0.95 for the females.

The adequacy of the mortality estimates is checked by using a computer simulation of the fishery which generates size frequency distributions for a simulated catch under given conditions of mortality. Save for

---

* Il existe une version française de cette communication.

minor ajustments the simulated distributions compare well with the actual ones. According to the simulation results, Nephrops would recruit at 1.5 years in the Bay of Biscay and at 3 years in the Celtic Sea.

RESUME

Les courbes de capture de langoustines pêchées dans le Nord du Golfe de Gascogne et en Mer Celtique ont été décomposées en groupes de mue. Des coefficients de mortalité totale (Z) ont été estimés à partir des effectifs appartenant aux differents groupes de mue. Z serait égal à 1.35 pour les mâles et à 1.34 pour les femelles du Golfe de Gascogne. En Mer Celtique Z serait égal à 1.01 pour les mâles et à 0.91 pour les femelles.

La mortalité par pêche F des langoustines dans le Nord du Golfe de Gascogne a été estimée à partir de données d'effort de pêche et d'une estimation du coefficient de capturabilité obtenue après ajustement d'un modèle de production. F serait égal à 0.907. Le coefficient instantané de mortalité naturelle serait de 0.45 pour les mâles et de 0,95 pour les femelles.

La qualité des estimations de mortalité est évaluée par simulation de la pêcherie sur ordinateur. Les simulations génèrent des distributions de fréquence de taille qui sont fonction des coefficients de mortalité choisis et peuvent être comparées avec les distributions de fréquence observées dans les captures. Après de légers réajustements de valeurs pour des coefficients de mortalités par pêche propres à chaque âge un assez bon ajustement est obtenu. Les simulations indiqueraient que les langoustines sont recrutées à l'âge de 1.5 ans dans le Golfe de Gascogne et à 3 ans en Mer Celtique.

INTRODUCTION

This paper was originally written as an appendix to the 1980 report of the ICES Nephrops working group which has already been turned in.

Natural mortality is the most difficult population parameter to assess in a harvested stock. It is likely to be age dependent, and to vary seasonally. Natural mortality may be correlated with fishing effort, either negatively for instance in a multispecies fishery when the predators are removed, or positively when the habitat is modified by the fishing gear for instance in a trawl fishery. In yield models however, it is generally assumed for the purpose of simplification that natural mortality is a parameter constant over time. Constant values ranging from .2 to .4 are traditionally assumed for instantaneous mortality in harvested fish stocks, there is however very little evidence in most cases that the appropiate value will actually be limited to that range of variation. Natural mortality estimates for crustacean populations are even scarcer than for fish. This is mainly because crustaceans cannot be directly aged by counting rings on hard structures and because their growth pattern through molting makes it difficult to sort out age groups from the size frequency distributions.

Total mortality Z can be estimated by analysis of a catch curve either in age (Ricker, 1975) or size (Van Sickle, 1977) of a population in a steady state. Combining the size or age distributions in the catch over a series of years will somehow smooth out the bias introduced by recruitment variability. It is not usually possible to estimate simultaneously fishing and natural mortalities (F and M) by direct analysis of a catch curve. Cohort or virtual population analysis methods (Pope, 1972) will not provide simultaneous estimates of F's and M's. The relative contributions of F's and M's to the total mortality Z is however determinant for yield estimates, the predictions of losses or gains in the case of a change in mesh size or fishing effort can be reversed for a constant Z when varying the values of M.

For a given value of Z the ratio of the yield to the abundance of the stock on the ground will vary as a function of M. Therefore when some direct censuses of abundance can complement estimates of Z obtained from the catch curve and estimates of the overall catch, it will be possible to make some inferences on the values of M.

In this paper I used a different approach. First I analyzed the catch curves of Nephrops caught in Bay of Biscay and in the Celtic Sea and estimated Z. Later, I used independent information on capturability coefficients obtained from a surplus production model to estimates F as a function of the fishing effort in the Bay of Biscay. I assumed on a preliminary basis that F and M were constant over the fishable life span. Substracting F from Z gave an estimate for M in the Bay of Biscay. I assumed that M's were equal in the Celtic Sea and in the Bay of Biscay and calculated F in the Celtic Sea by substracting M from Z. I later checked the adequacy of the estimates of M's and F's and the assumption of their constant value over the fishable life span by simulating the size frequency distributions in the catch (Conan and Morizur, 1979). I finally made minor ajustments in the values of F at age in order to improve the fit of the simulated to the observed size frequency distributions.

MATERIAL AND METHODS.

1) Estimation of total mortality by analysis of the size frequency distributions in the catch.

Size frequency distributions of the catch of Nephrops from the Bay of Biscay (Division VIIIa) have been sampled montly by Charuau (ISTPM, France) from 1971 to 1978. Measures were made to the nearest mm on board of commercial fishing boats. The samples of the distributions were combined over the whole sampling period, in order to smooth out variability in recruitment. The catch curves for males and females were studied separately because growth and availability to the fishery are sex dependent (Conan, 1978). Similar data sampled by Charuau from 1978 to 1979 in the Celtic Sea (area VIIg) were processed in the same way.

In a seasonal environment slow growing Crustacea such as Nephrops will tend to have molting events more or less synchronized within a population. For adult Nephrops there are two periods of molt a year, one in the spring, the other in the fall. Most adult females will molt only once in the spring. Most adult males will molt both in the spring and in the fall (Farmer, 1973; Conan, 1975).

The size frequency distributions can be splitted in molt groups rather than in age groups. By combining distributions sampled all year round an "average" picture of the proportion of individuals in each molt group is obtained. A predictive linear regression of natural logarithm of abundance in molt groups completely recruited to the fishery vs average age at which individuals enter a molt group will provide an estimate for a constant total mortality rate.

I used the maximum likelihood technique, described by Hasselblad (1966) and modified by Tomlinson (1970), for sorting out the contribution in number of each component molt groups to the size frequency distributions combined by sex. The general growth pattern of Nephrops caught in the Bay of Biscay had been previously assessed (Charuau, 1977; Conan, 1978). I therefore gave narrow bounds for the estimates of the means and standard deviations and used the iterative procedure mainly for estimating the proportion of individuals in each molt group.

2) Estimation of fishing mortality in the Bay of Biscay.

The fishing effort in the Nephrops fishery of northern Bay of Biscay has been fairly stable from 1971 to 1978, it averages 32.5 10^3 boat day at fishing per year. Conan, Depois and Charuau (1977) have applied the surplus production model of Fox (1975) to 17 years of data on fishing effort and capture per unit effort from northern Bay of Biscay. They calculated by the multiplicative error method of Fox an average capturability coefficient c of 2.098 10^{-5} for all age groups and sexes combined and for a time unit of one year.

Data on capture per unit effort tends to show that the capturability coefficient varies seasonally and differs for males and females.

In the present paper I did not attempt to quantify seasonal variations of c for the males. Adult females are available during only .43 of the year in the Bay of Biscay fishery (Conan and Morizur, 1979). I attempted to estimate from c an instantaneous capturability coefficient c' assumed to be constant all year round for the males and either constant over .43 of the year or equal to 0 over the rest of the year for adult females.

In the Bay of Biscay fishery the sex ratio in the catch is about 50% in April May when males and females seem to be equally available to the fishery (Conan, 1975). The sex ratio in the population is likely to be well balanced.

If N_1 is the number of individuals at the end of the year, N_o at the beginning of the year, with f the fishing effort assumed constant over the year, c the average capturability coefficient over one year:

for both sexes combined:

$$N_1 = N_o \exp (-(M + cf))$$

for the males:

$$N_{1,1} = N_o / 2 \exp (-(M + c'f))$$

for the females:

$$N_{1,2} = N_o / 2 \exp (-(M + 0.43 c'f))$$

Since $N_1 = N_{1,1} + N_{1,2}$ Then:

$$N_o \exp (-(M + cf)) = N_o/2 \exp (-(M + c'f)) + N_o/2 \exp (-(M + 0.43 c'f))$$

$$\exp (-M) \exp (-cf) = 1/2 \exp (-M) (\exp(-c'f) + \exp (- 0.43 c'f))$$

$$(1/2 (\exp(-c') + \exp (0.43 c')) - \exp (-c))^f = 0$$

$$\exp c' + \exp (0.43 c') - 2 \exp c = 0 \qquad (1)$$

(1) is solved for c' by iteration

for the males:

$$M_1 = Z - c'f$$

for the females:

$$M_2 = Z - 0.43 c'f$$

3) Simulation of size frequency distributions and estimates of yield per recruit and number of eggs produced per female.

All individuals in an age group do not molt exactly at the same time, the spring and fall molt periods in the Bay of Biscay extend over two to three months. Individuals of the same age can be harvested simultaneously in two molt groups. Intermolt periods extend over 2 to 4 months. Therefore the technique of calculating total mortality by regression of natural logarithms of abundances in the molt groups vs average age at which the individuals enter the molt group is only approximate. In order to check how good was this approximation, I ran a computer simulation of the fishery. This computer simulation provides estimates of the size frequency distribution of the catch as well as yield per recruit and number of eggs produced per female (Conan and Morizur, 1979). I used in input the same parameters as in 1979, save for the natural and fishing mortalities values which are estimated in the present work. The program was slightly modified, it now takes in account the discarding and partial survival of small Nephrops in the catch.*

Slight modifications were made in the input values of F in order to make the fishing mortality slightly age specific when I attempted to improve the fit of the simulated size frequency distributions to the observed ones. In all cases M was kept constant for all harvested age groups.

The simulation technique also provided means of defining an age at recruitment of Nephrops to the Bay of Biscay and Celtic Sea fisheries. This age at recruitment is independent of the selectivity of the fishing gear and originates from changes in behavior of Nephrops.

RESULTS

The observed size frequency distributions, together with the ajusted ones (after analysis by the Hasseblad method) are presented in figures 1 to 4. The estimated means, the standard deviations and the proportions pertaining to each of the component molt groups in the size fre-

* A listing of this program in H.P. 9845 B BASIC is available in appendix.

quency distributions of the catch are presented in tables 1 to 4.

The predictive regressions of natural logarithms of abundance in each molt group vs average age of the individuals entering the molt groups are presented in figures 5 to 8. The instantaneous rates of total mortality Z was estimated in the Bay of Biscay data as 1.35 and 1.34 respectively for the males and the females. The value of Z for the Celtic Sea data were estimated as 1.01 and 0.91.

The value of the fishing mortality F= c'f for the Bay of Biscay was estimated as 0.907 ($c' = 2.79\ 10^{-5}$, $f = 32.5\ 10^{3}$). Substracting F from Z, I obtained $M_1 = 1.35 - 0.907 = 0.45$ for the males and $M_2 = 1.34 - (0.907 \times 0.43) = 0.95$ for the females. Substracting M_1 from the Z estimate for the Celtic Sea provides a fishing mortality estimates of 0.56 for the males. The method is inconsistent for the females, M_2 being larger than Z.

The size frequency distributions of the simulated captures when M and F were kept constant for all age groups are presented in figures 9 to 11 together withthe observed size frequency distributions. Size frequency distributions simulated using a constant M and slightly ajusted age specific values for F are presented in figures 12 to 16. Age at recruitment as inferred from the simulations would be 1.5 years in the Bay of Biscay and 3 years in the Celtic Sea.

DISCUSSION

The computer simulation of size frequency distributions in the catch show that the estimates of total mortality are fairly accurate. Splitting the catch curve into molt groups and calculating a predictive linear regression of abundance in the molt groups vs average age of the individuals entering the molt group seems to be a reasonably good way of estimating a total mortality coefficient averaged for all age groups.

The method I used for estimating the relative contributions of F and M to Z gives preliminary estimates. The capturability coefficient obtained from a surplus production model is a yearly average for all capturable age groups of each sex. The technique I used for restituting sex specific instantaneous capturability coefficients is approximative. Any how in the lack of better information this approach shows that natural mortality in the Bay of Biscay Nephrops stock is likely to be high.

The alternative method for estimating the relative contribution of F and M to Z, through direct censuses of population abundance also has its draw backs. The distribution of Nephrops is known to be extremely patchy. Sampling such a distribution will give very imprecise results unless the patches have been accurately mapped and a stratified sampling strategy has been used. When confidence limits are set on density estimates for such patchy distributions the limits are often as large as the estimate itself. Further fishermen do not fish blindly, their own "sampling strategy" is to look for places where the Nephrops are the most abundant. The landings give therefore a very biased picture of "what should be the yield" if the fishermen fished randomly the stock. Actually the spacial distribution of population abundance should be somehow weighted by the spacial distribution of fishing effort in order to compare with the landings/predicted yield per recruit ratio. The use of this ratio will always provide over estimates of the true population abundance leading to under estimates of the natural mortality M.

Direct censuses of population abundance of Nephrops stocks are complicated by the fact that all individuals are never capturable at a time. Assessing Nephrops population density by counting Nephrops holes on underwater photographs or an underwater T.V. screen, implies that the average number of holes per Nephrops be estimated by a diver. In the Bay of Biscay and in the Celtic Sea Nephrops are caught between 70 and 130 meters depths, out of the range of a regular scuba diver.

Censuses of population abundance drawn from estimates of larval densities in the plankton require a good knowledge of the number of hatchings eggs produced by an average female present in the stock. Morizur et al. (1980) have shown that this number depends on the size of the females (i.e. on the size distribution of the females in the stock). Females with eggs ready to hatch are difficult to capture; it is tempting to use fecundity estimates based on the number of eggs extruded per female. But, the ratio of the number of hatching eggs to the number of extruded eggs varies from stock to stocks. This ratio should be assesses for the same stock as the larval density estimates.

Adult female Nephrops are available to the Bay of Biscay fishery only during part of the year, however the sex ratio does not seem to be drastically unbalanced and total mortality estimates are similar for males (1.35) and females (1.34). One would therefore expect that natural mortality be much higher for the females than for the males. Ovigerous females apparently have a reduced predatory behavior, feed less frequently and spend much of their activity in preserving their eggs, they may also have a higher natural mortality rate.

The 0.45 and 0.95 estimated values for natural mortality of males and females in the Bay of Biscay may seem high in regard to the figures traditionally used for fish stocks (0.2 to 0.4). Such values are not unreasonable however. For fishes, values of M as high as 2.0 are found in Beverton and Holt's recopilation (1959), and values higher than 1.0 are found in Ricker (1975). Crustaceans may have natural mortality values much higher than fishes. They are handicaped during molting process and subject to high predation rates. In aquaria most of the mortality occurs during unachieved ecdysis when individuals do not shed well their old carapace. Abramson and Tomlinson (1972) estimated M as 1.4 for ocean shrimps, Blake and Menz (1980) found 12 to 31% mortality per week for peneid shrimps, Olsen and Koblic (1975) estimated M as 0.413 to 0.651 for Palinurus argus and Conan et al. (1976) estimated that M ranged from 0.4 to 3.8 in a population of Emerita analoga.

The results of the simulations: size frequency distribution of catch, yield per recruit, average number of eggs per female show that high natural mortality values are compatible with the characteristics of the actual catch. The life strategy of a Norway lobster is different from the life strategy of an average fish of the species favored by fisheries dynamicists. The natural mortality may be high for adult Nephrops but the survival of the eggs and larvae is higher than for most fishes: the larvae hatch at an advanced stage of development from incubated eggs protected by the females, they remain in the plankton only during a few weeks. Nephrops mature and reproduce at the age of 2, which is very early for a species with a potentially long life span (possibly as much as 15 to 20 years according the size of the largest individuals). The average number of eggs produced by a female recruited to the fishery at 1.5 years ranges from 100 to 200 in the simulations; this is at least one or 2 orders of magnitude less than for most species of fishes.

The natural mortalities estimated for the Bay of Biscay do not match very well the total mortalities estimated for the Celtic Sea. Estimated total mortality for the females in the Celtic Sea is slightly smaller than the estimated natural mortality in the Bay of Biscay. However the total mortality estimates in the Celtic Sea are based on only 2 years of data of size frequency distributions. The recruitment variability cannot be smoothed out over such a short period and may bias the estimates of total mortality. Nevertheless the fishing intensity (fishing effort per unit area) is lower in the Celtic Sea than in the Bay of Biscay. Natural mortality may be positively correlated with fishing effort if the trawls disturb the physical habitat of the Nephrops by ploughing the sediment in which they dig their holes. Natural mortality could therefore be lower in the Celtic Sea than in the Bay of Biscay.

Biologically the stock from the Celtic Sea seems to be quite different from the stock of Bay of Biscay. If the growth parameters are the same in both areas, Nephrops must recruit at 3 to 4 years in the Celtic Sea instead of 1.5 years in the Bay of Biscay in order to explain the size frequency distributions of the catch observed in the Celtic Sea. The lack of small individuals in the captures cannot be explained only by selectivity effects. Age at recruitment seems to be correlated with changes in behavior due to sexual maturity in the Bay of Biscay. It would be worth checking whether age at 1st maturity is the same in the Bay of Biscay and in the Celtic Sea.

As a general conclusion high natural mortality values are not unreasonable for the Nephrops stocks of Bay of Biscay and the Celtic Sea. However it appears that the population biology of the species in these two areas may fairly differ. It should be taken great care before extrapolating results from other stocks to the Celtic Sea. Special assessments of the population parameters, for the Celtic Sea stock, should be completed before justifying definit recommendation for a change in present international regulation measures concerning this stock. Such detailed biological surveys are undertaken in the Celtic Sea on board of the fishing boats from southern Brittany, the results will be available for the 1981 ICES statutory meeting.

REFERENCES

ABRAMSON N.J. and P.K. TOMLINSON. 1972. An application of yield models to a California ocean shrimp population. Fish. Bulletin U.S.70(3): 1021-1041.

BEVERTON R.J.H. and S.J. HOLT. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. In The lifespan of animals, J. and A. Churchill Ltd. London, 5: 142-180.

BLAKE B.F. and A. MENZ. 1980. Mortality estimates for Penaeus vannamei Boone in a Mexican coastal lagoon. J. Exp. Mar. Biol. Ecol., 45: 15-24.

CHARUAU A. 1977. Essai de determination du taux d'accroissement à la mue de la langoustine dans le milieu naturel. ICES Shellfish and Benthos Committee. ICES, CM/K 25 (mimeo): 6pp.

CONAN G. 1975. Periodicité des mues, croissance et cycle biologique de Nephrops norvegicus dans le Golfe de Gascogne. C.R. Acad. Sc. Paris, serie D, 281: 1349-1352.

CONAN G. 1978. Life history, growth, production and biomass modelling of Emerita analoga, Nephrops norvegicus and Homarus vulgaris (Crustacea, Decapoda). Ph. D. dissertation, U. of California at San Diego. Univ. Microfilms Int. ed., London, 349 p.

CONAN G., DEPOIS M.N. and A. CHARUAU. 1977. Relations entre la biomasse et la production du stock de langoustines de la région Sud Bretagne. ICES, CM/K:35, 16p.

CONAN G., MELO C. and G. YANY. 1976. Evaluation de la production d'une population littorale du crabe Hippidae Emerita analoga Stimpson par intégration des paramètres de croissance et de mortalité. In 10th European Symposium on Marine Biology, Persoone and Jaspers Ed. Universa Press. Wetteren.

CONAN G. and Y. MORIZUR. 1979. Long term impact of a change in mesh size from 45-50 to 70mm on yield in weight and fecundity per recruit for Norway lobster populations. Is there a simple solution to a complex problem: a simmulation model. ICES CM/K:43, 47p.

FARMER A.S. 1973. Age and growth in Nephrops norvegicus (Decapoda, Nephropidae). J. Zool., London 174: 161-183.

FOX W.W. Jr. 1975. Fitting the generalized stock production model by least squares and equilibrium yield approximation. Fish. Bull. U.S. 73 (1): 23-36.

MORIZUR Y., CONAN G. GUENOLE A. et M.H. OMNES. 1980. Fécondité de Nephrops norvegicus dans le Golfe de Gascogne. ICES CM/K: 36, 19 p.

OLSEN D.A. and J.G. KOBLIC. 1975. Population dynamics, ecology and behavior of spiny lobsters, Palinurus argus, of St. John, U.S.V.I. (2) Growth and mortality. Nat. Hist. Mus. Los Angeles County Science Bull. 20.

POPE J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Int. Comm. Norwest. Atl. Fish. Res. Bull. 9: 65-74.

RICKER W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Fish. Res. Bd Canada Bull. 191, 382p.

TOMLINSON P.K. 1970. Program NORMSEP. Normal distribution separator. 11(1).2.1 to 11(1).2.10. In Abramson,N.J. (Comp.) FAO Fish. Tech. Pap. (101): pag. var. Computer programs for fish stock assessment.

VAN SICKLE J. 1977. Mortality rates from size distributions the application of a conservative law. Oecologia (Berl.) 27, p 311-318.

TABLE 1

Analysis of the catch curve of male *Nephrops* from Bay of Biscay.

Molt group	Mean size	Standard deviation for sizes	Proportion of individuals in the molt group
1	19.97	2.47	0.23
2	22.82	1.82	0.27
3	26.04	1.84	0.26
4	29.04	1.36	0.10
5	31.42	1.19	0.05
6	33.79	1.40	0.04
7	36.41	1.32	0.02
8	37.96	1.16	0.01
9	40.50	1.91	0.01
10	45.00	3.00	0.01

TABLE 2

Analysis of the catch curve of female *Nephrops* from Bay of Biscay.

Molt group	Mean size	Standard deviation for sizes	Proportion of individuals in the molt group
1	19.36	2.36	0.21
2	22.48	1.95	0.37
3	25.67	2.05	0.31
4	29.03	2.29	0.09
5	33.50	2.03	0.02
6	36.99	1.57	0.00
7	41.00	2.04	0.00

TABLE 3

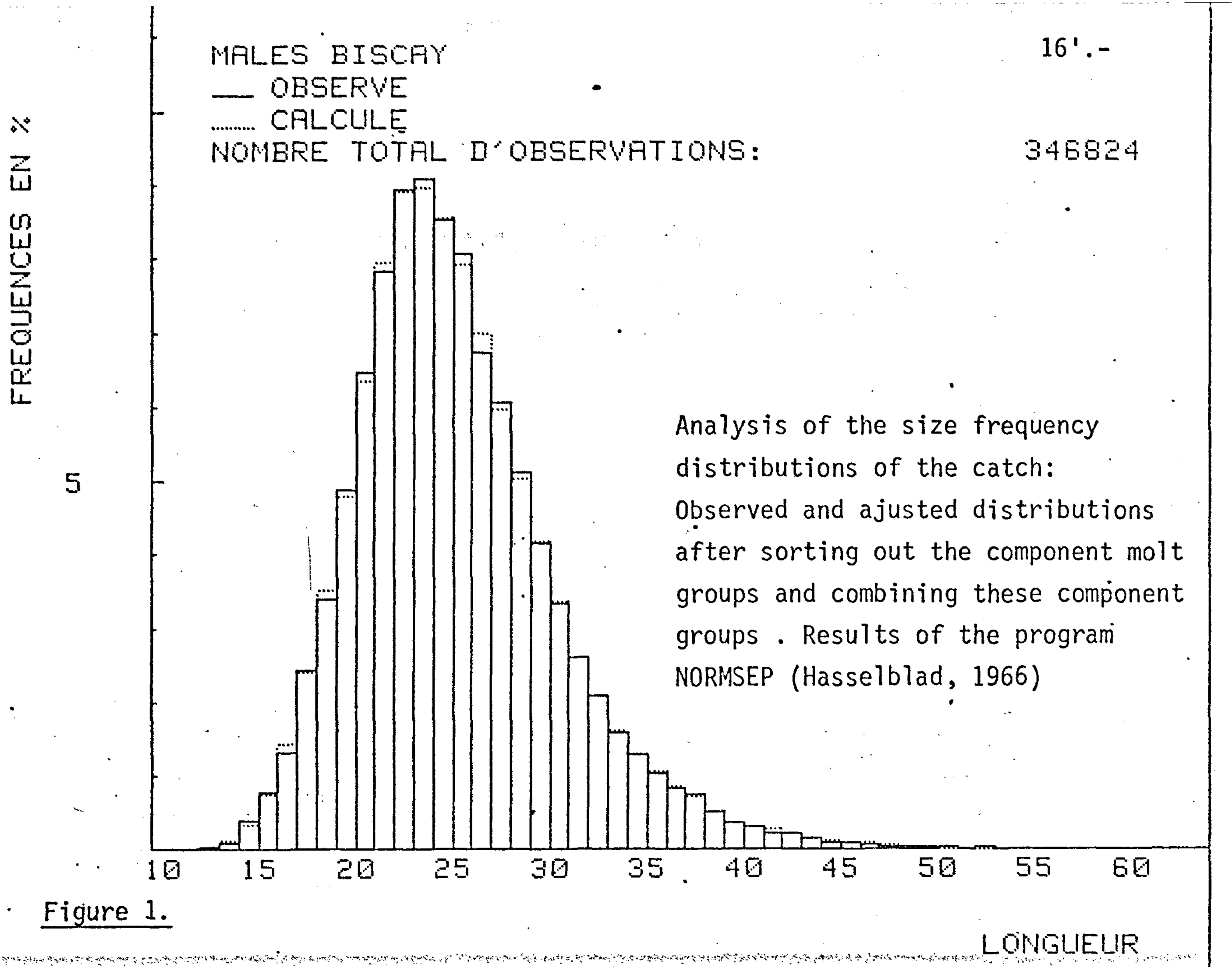
Analysis of the catch curve of male Nephrops from the Celtic Sea.

Molt group	Mean size	Standard deviation for sizes	Proportion of individuals in the molt group
1	23.00	1.43	0.01
2	25.55	1.12	0.02
3	28.80	1.45	0.16
4	30.54	1.05	0.10
5	32.50	1.34	0.33
6	35.02	1.19	0.15
7	37.43	1.01	0.06
8	39.43	1.42	0.06
9	42.75	2.25	0.07
10	47.16	2.61	0.03
11	52.02	2.51	0.01
12	57.00	3.21	0.01

TABLE 4

Analysis of the catch curve of female Nephrops from the Celtic Sea.

Molt group	Mean size	Standard deviation for sizes	Proportion of individuals in the molt group
1	21.55	1.40	0.01
2	24.39	1.21	0.03
3	28.93	2.15	0.55
4	33.01	1.92	0.20
5	36.00	1.45	0.09
6	39.19	1.77	0.09
7	43.00	1.83	0.03
8	47.33	2.52	0.00
9	51.30	3.98	0.00



Analysis of the size frequency distributions of the catch: Observed and ajusted distributions after sorting out the component molt groups and combining these component groups . Results of the program NORMSEP (Hasselblad, 1966)

Figure 1.

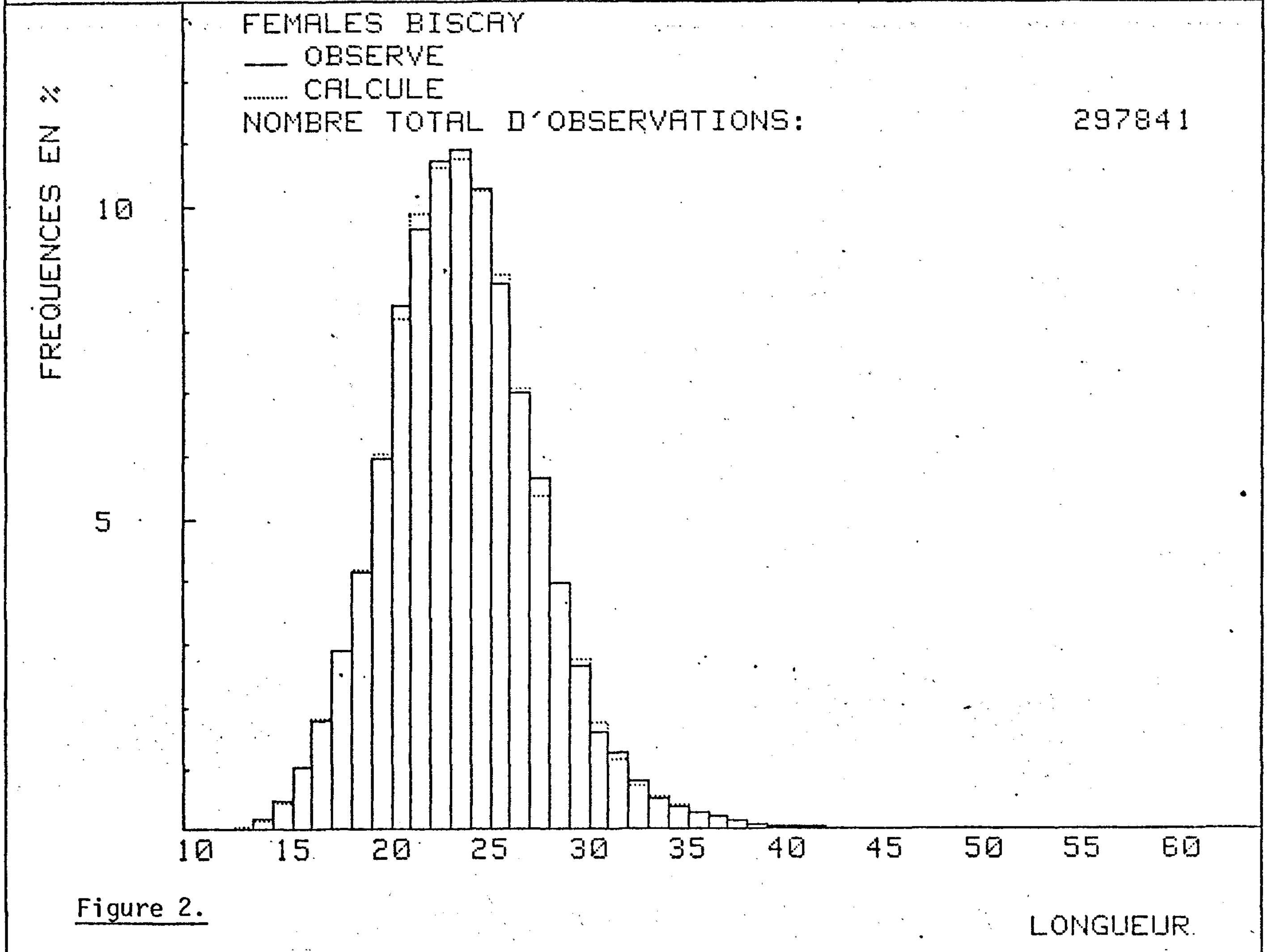


Figure 2.

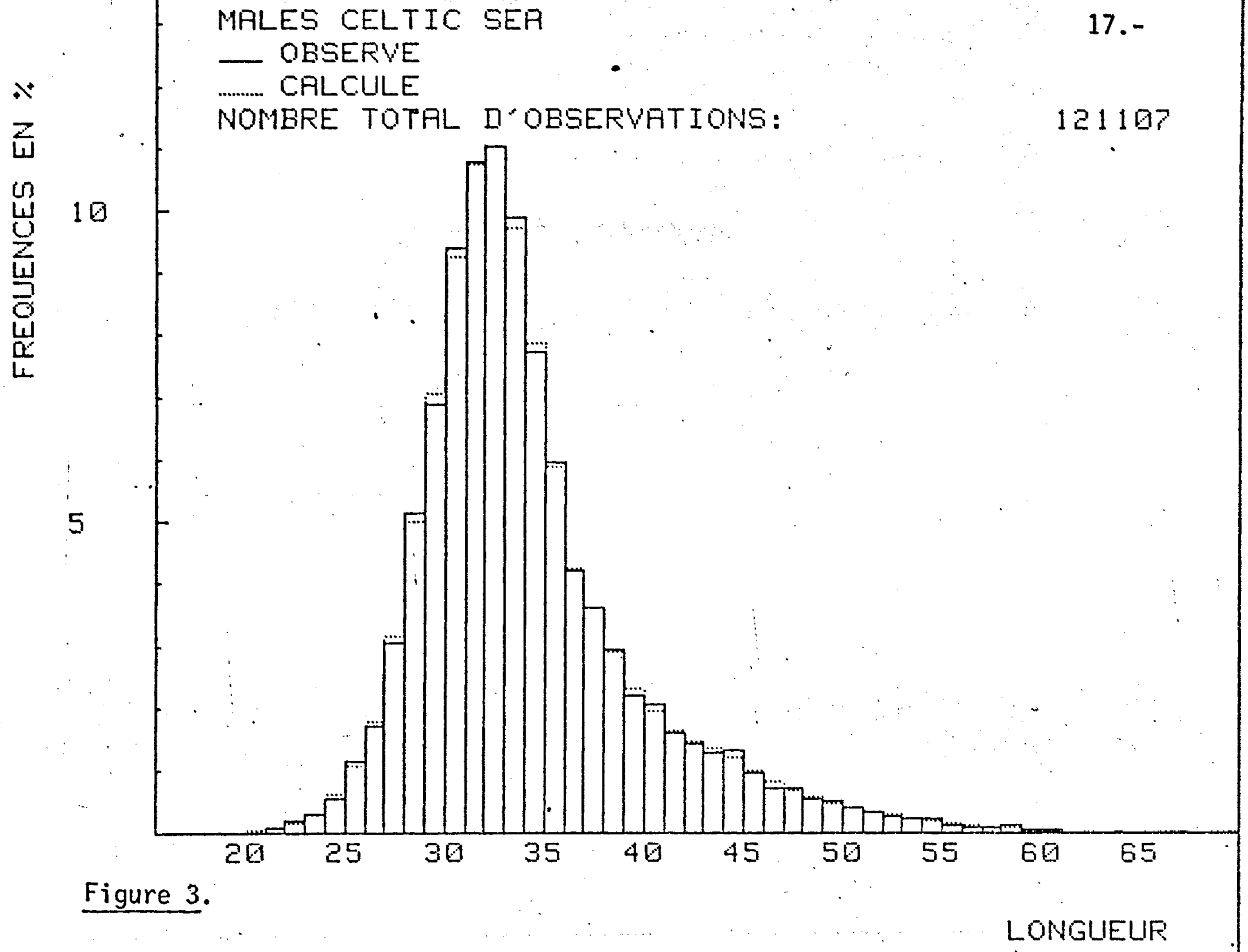


Figure 3.

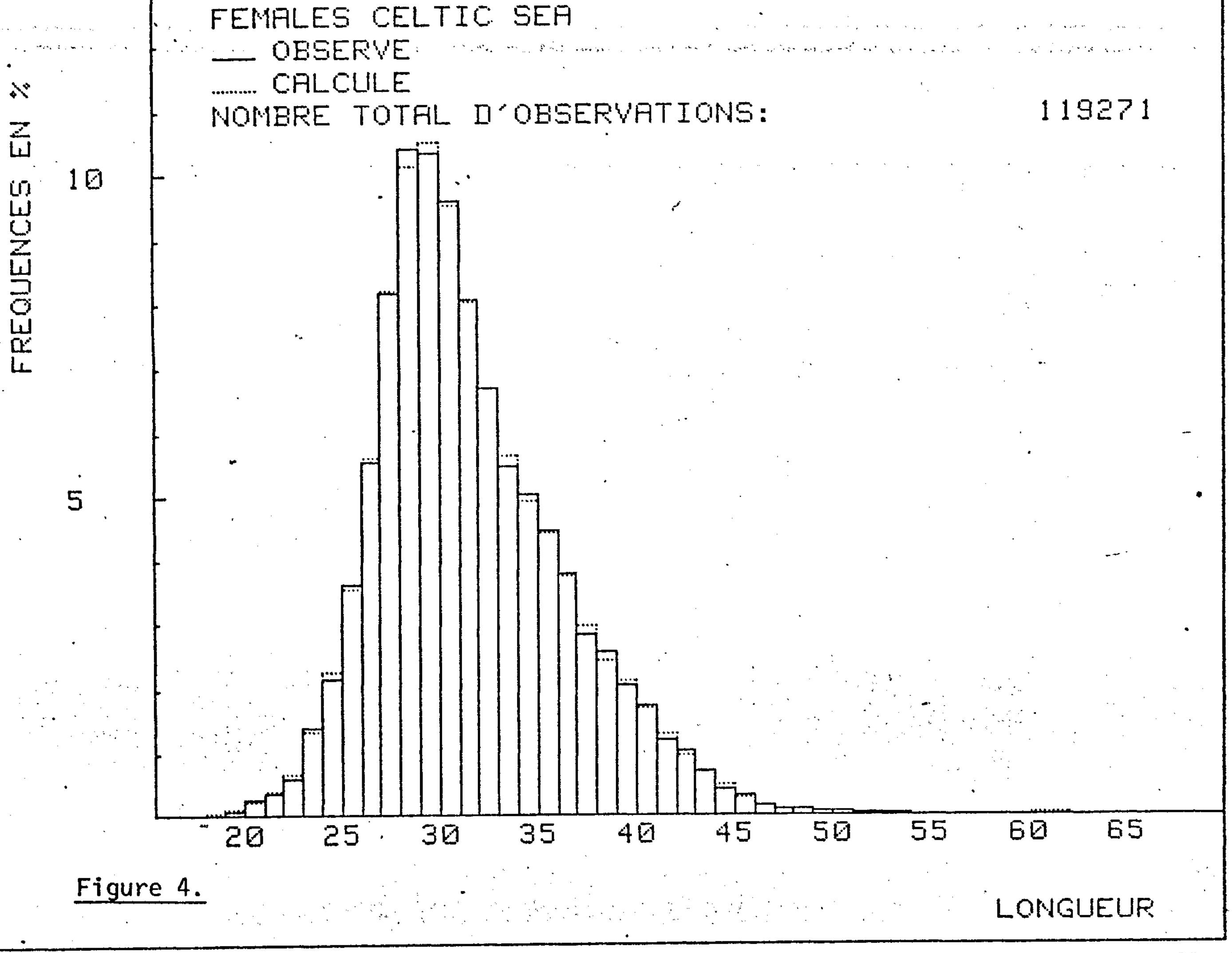


Figure 4.

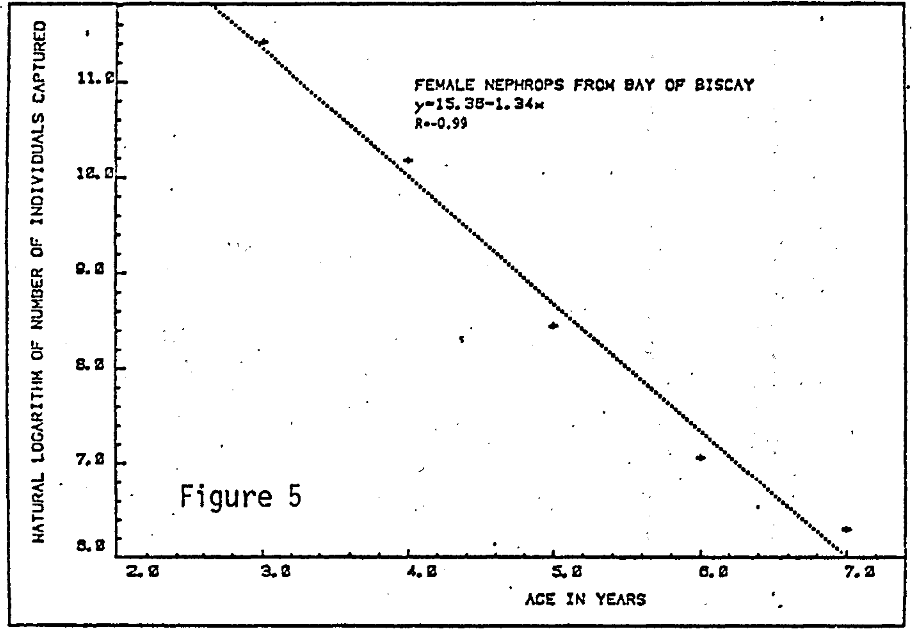


Figure 5

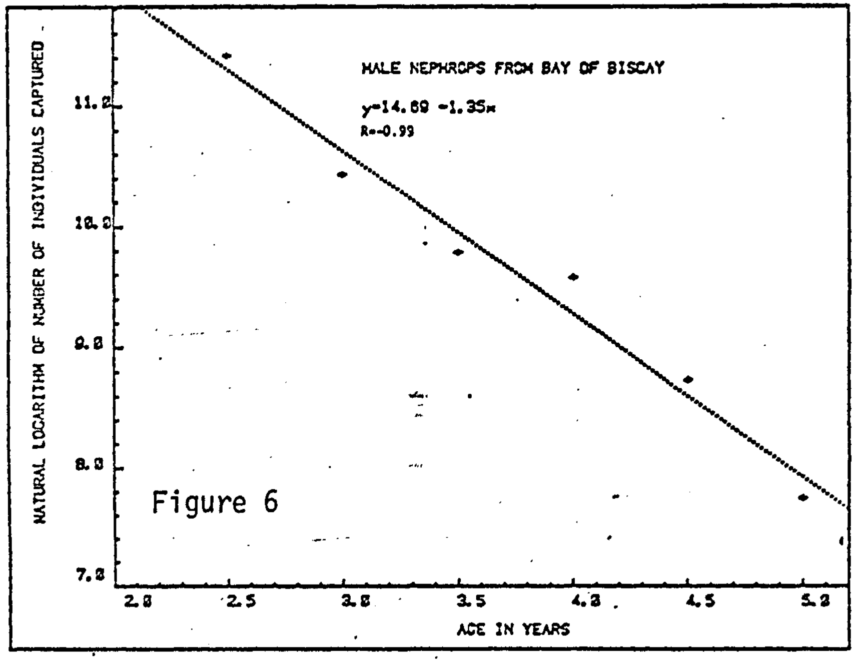


Figure 6

Predictive regressions of natural logarithms of abundance in each molt group in the catch vs average age of the individuals when they enter the molt group.

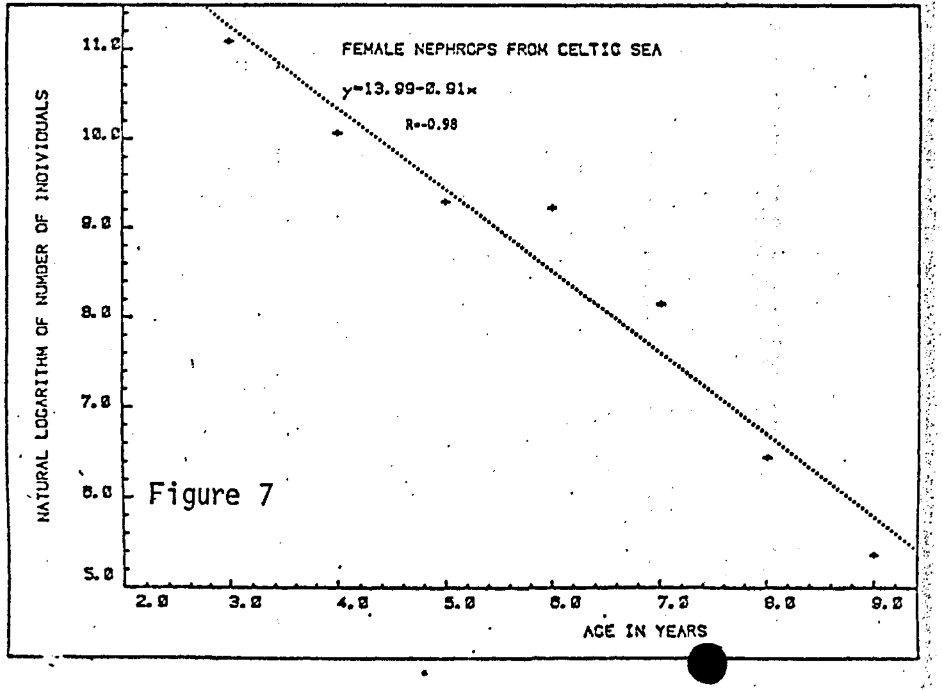


Figure 7

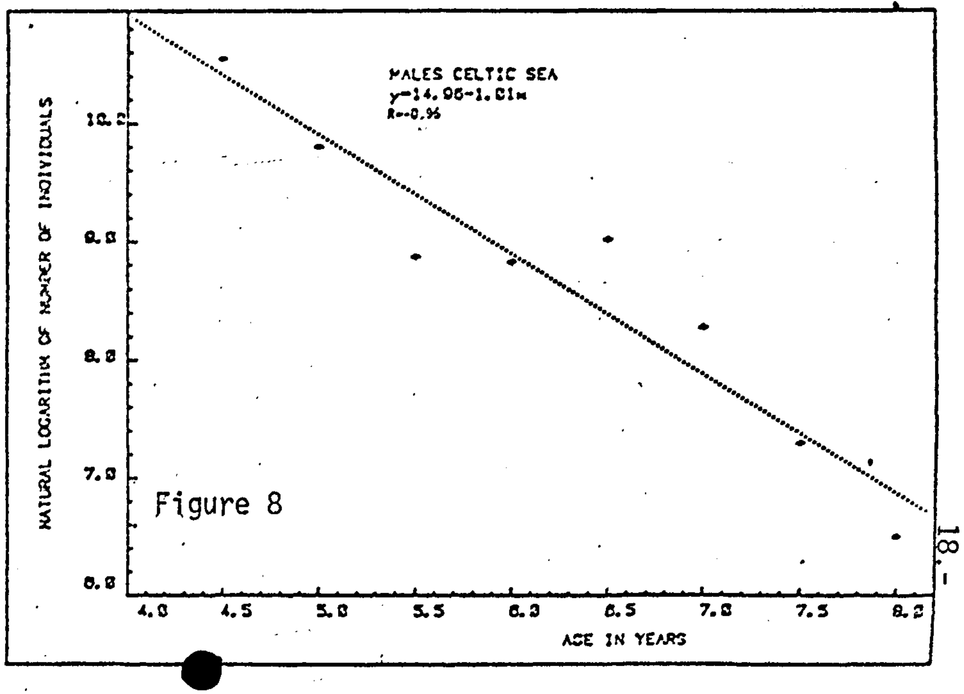
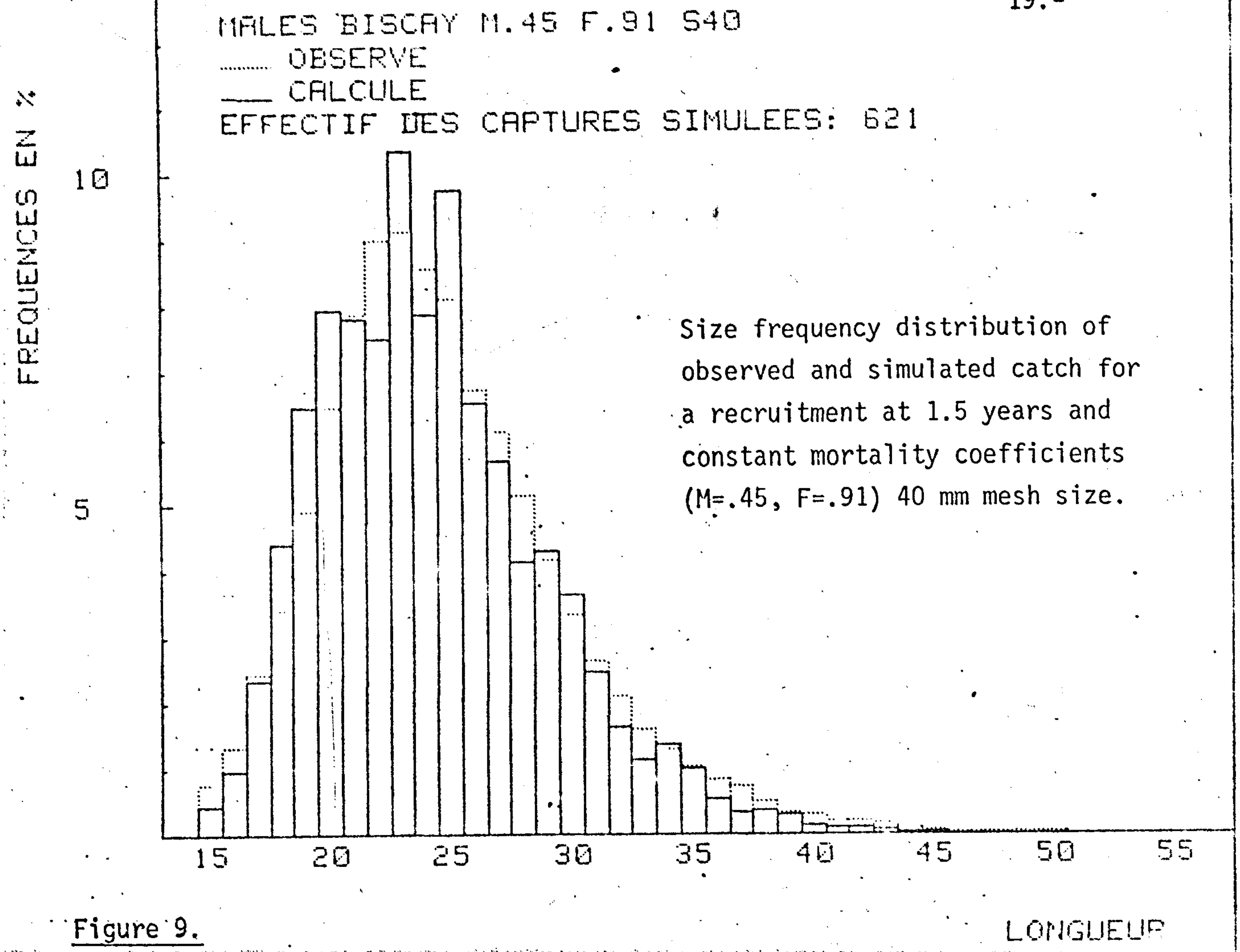
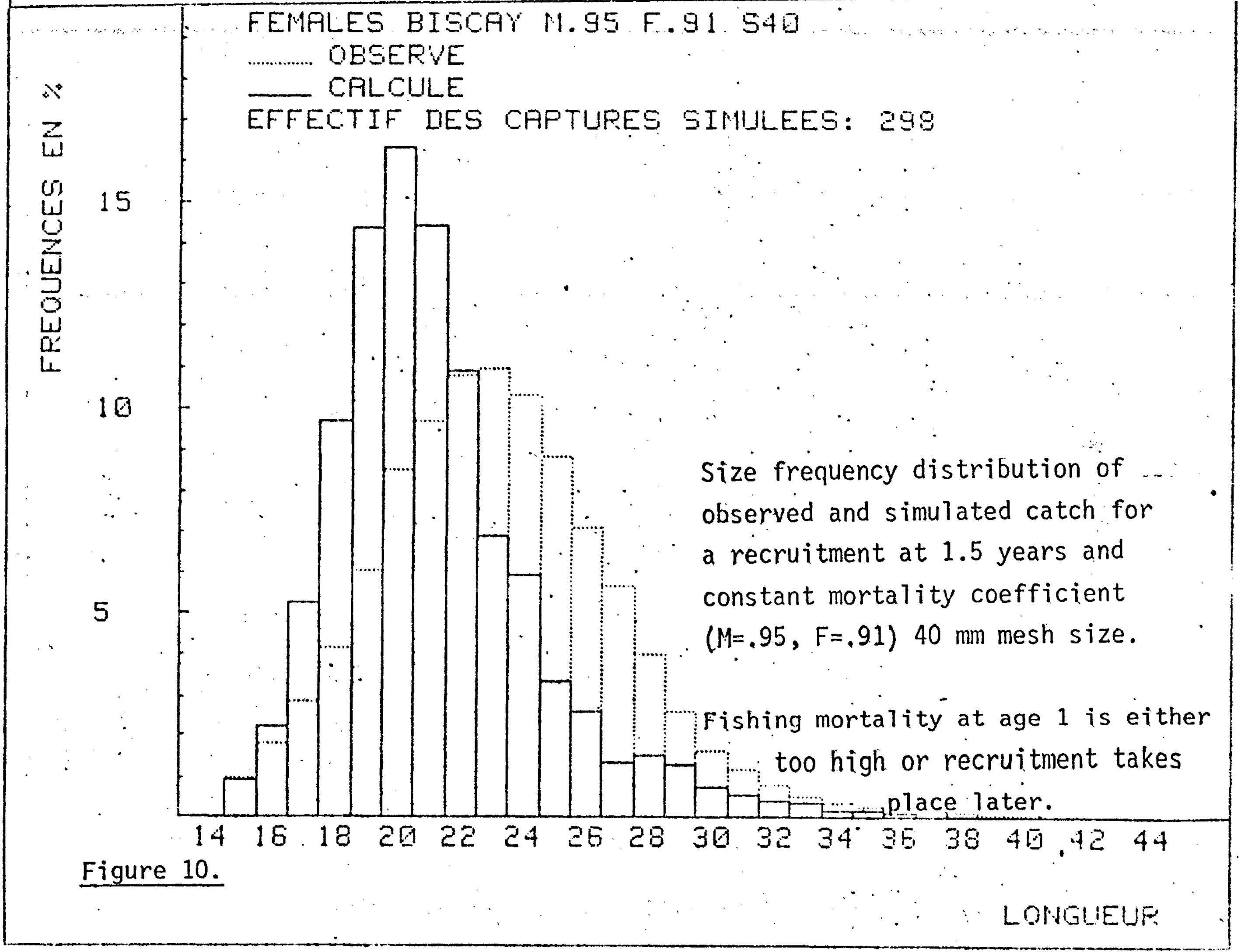


Figure 8



Size frequency distribution of observed and simulated catch for a recruitment at 1.5 years and constant mortality coefficients (M=.45, F=.91) 40 mm mesh size.

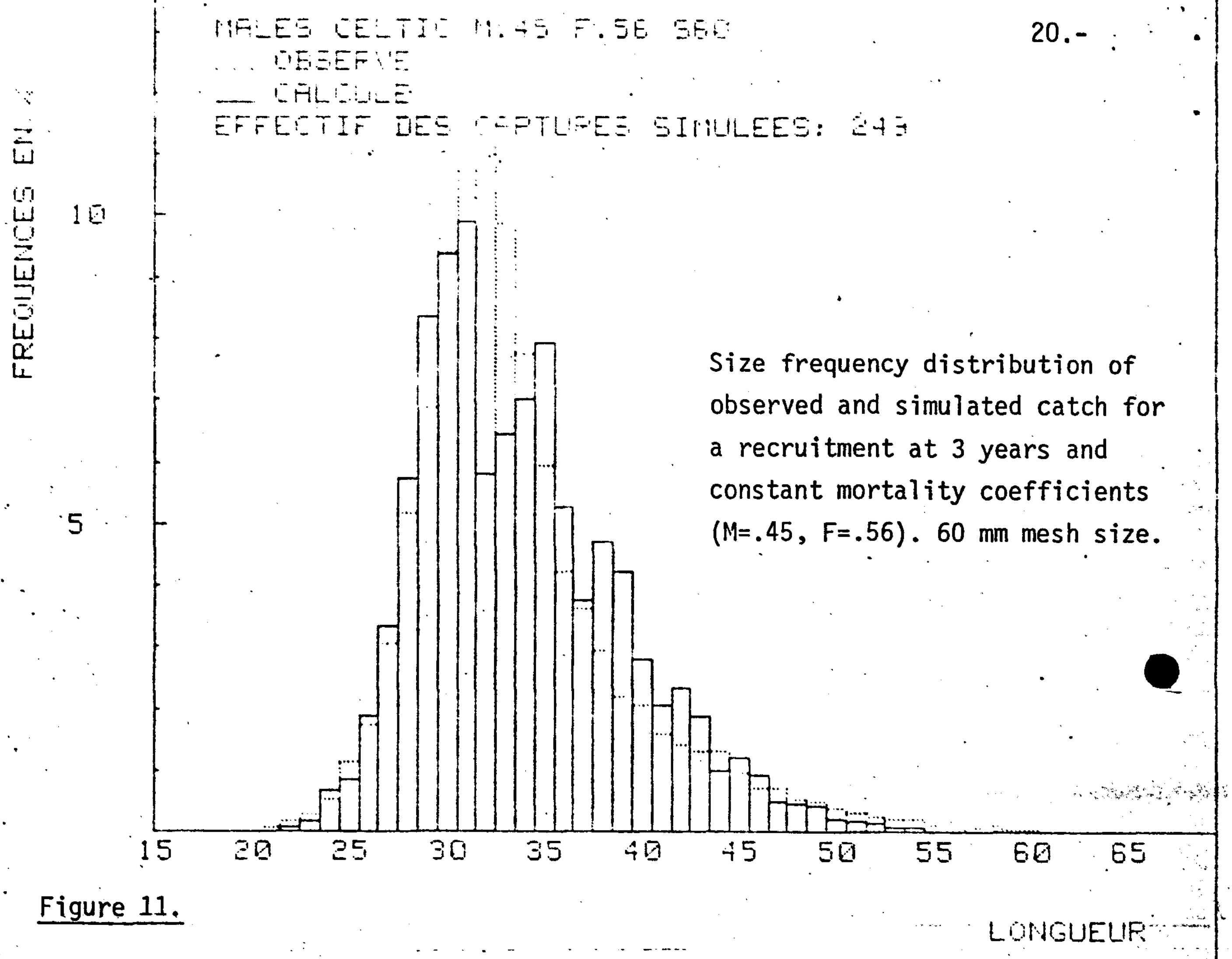
Figure 9.



Size frequency distribution of observed and simulated catch for a recruitment at 1.5 years and constant mortality coefficient (M=.95, F=.91) 40 mm mesh size.

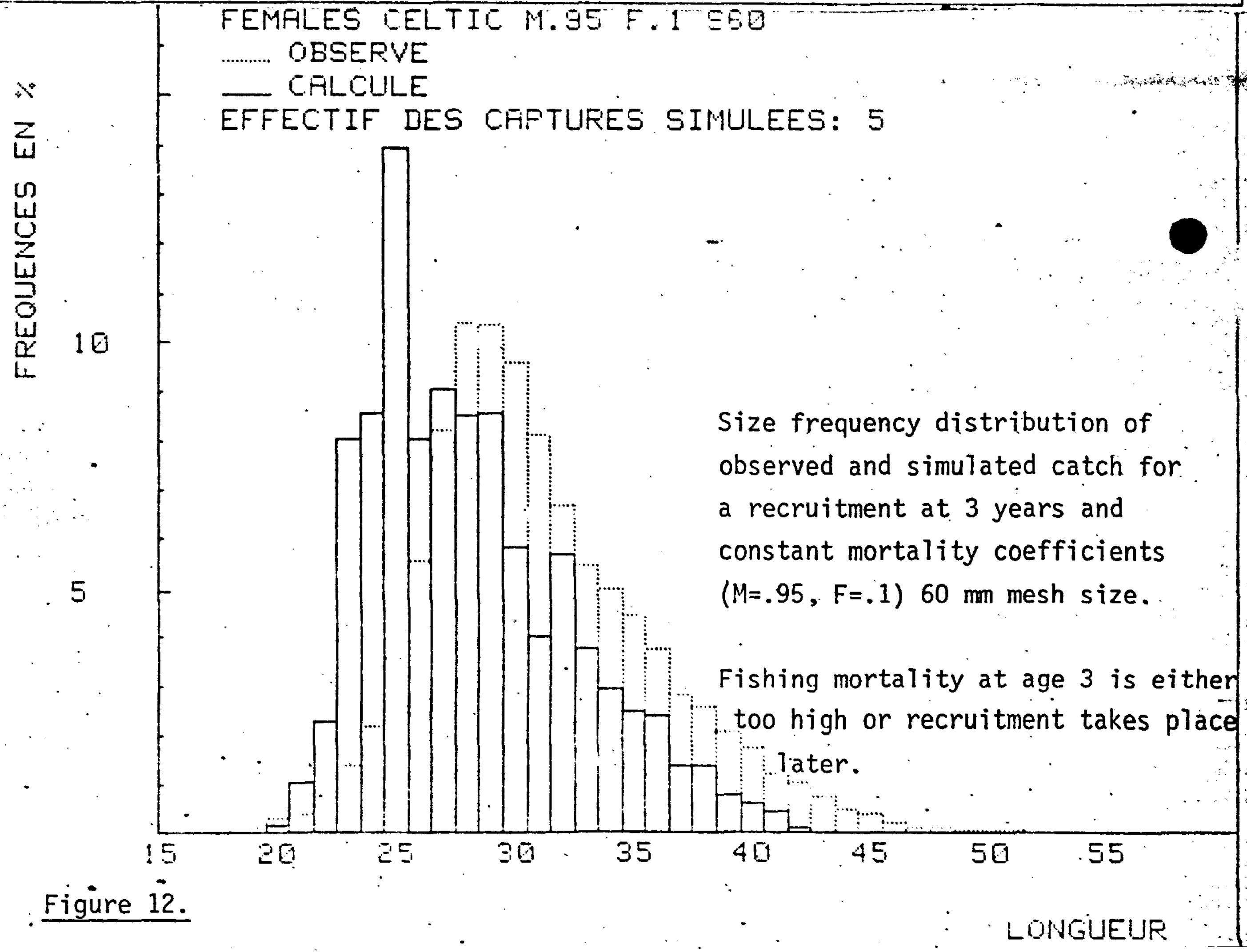
Fishing mortality at age 1 is either too high or recruitment takes place later.

Figure 10.



Size frequency distribution of observed and simulated catch for a recruitment at 3 years and constant mortality coefficients (M=.45, F=.56). 60 mm mesh size.

Figure 11.



Size frequency distribution of observed and simulated catch for a recruitment at 3 years and constant mortality coefficients (M=.95, F=.1) 60 mm mesh size.

Fishing mortality at age 3 is either too high or recruitment takes place later.

Figure 12.

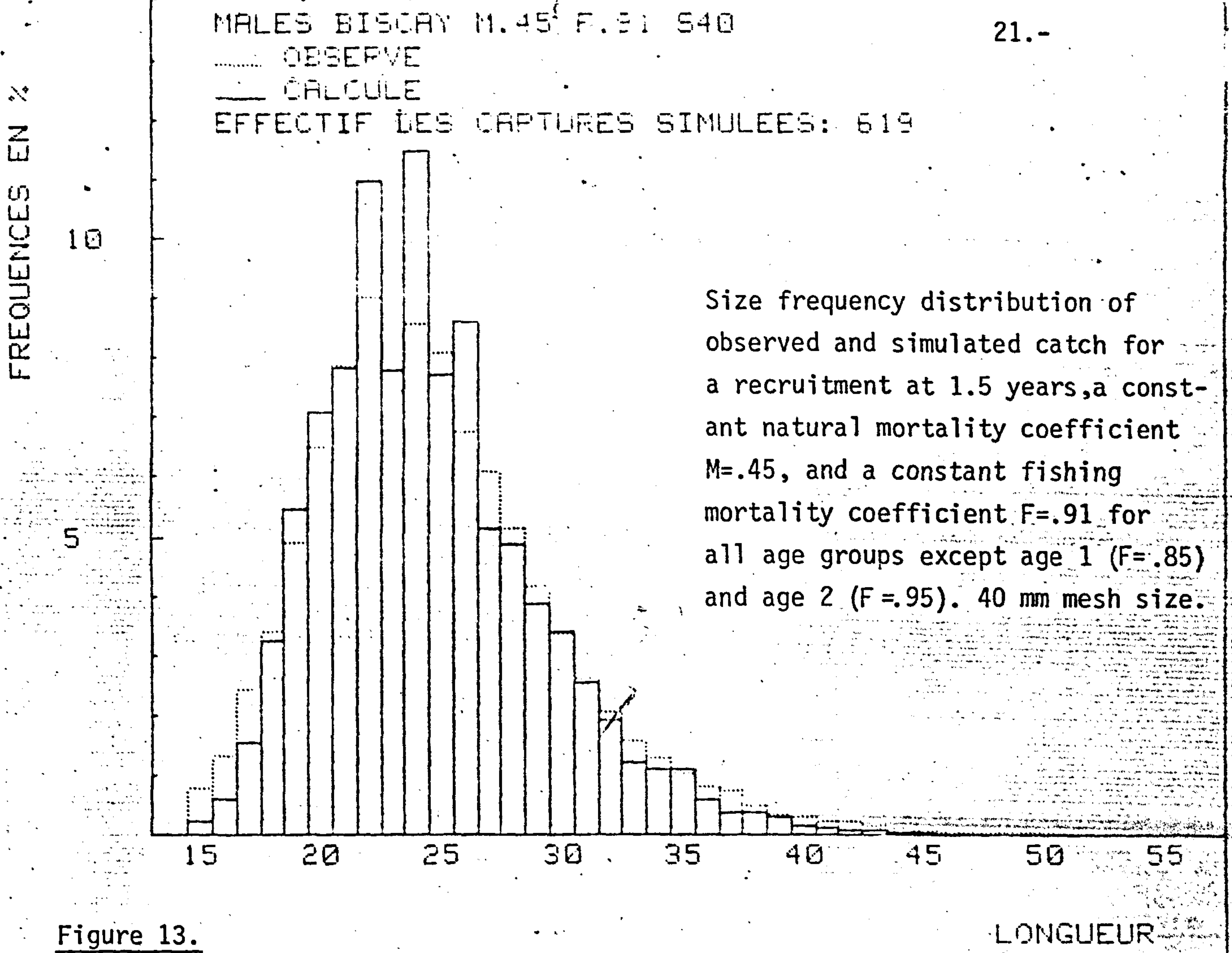


Figure 13.

Size frequency distribution of observed and simulated catch for a recruitment at 1.5 years,a constant natural mortality coefficient M=.45, and a constant fishing mortality coefficient F=.91 for all age groups except age 1 (F=.85) and age 2 (F =.95). 40 mm mesh size.

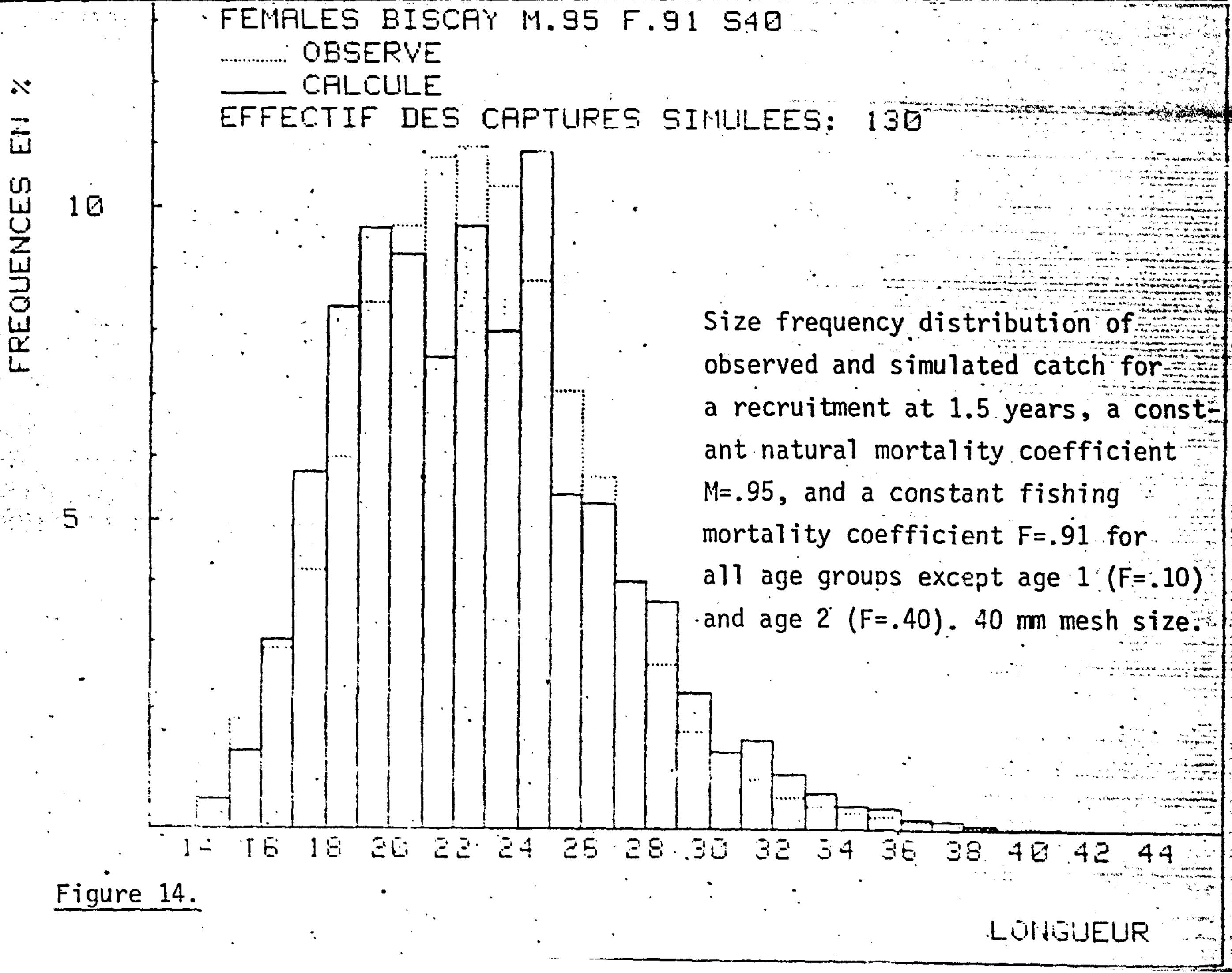
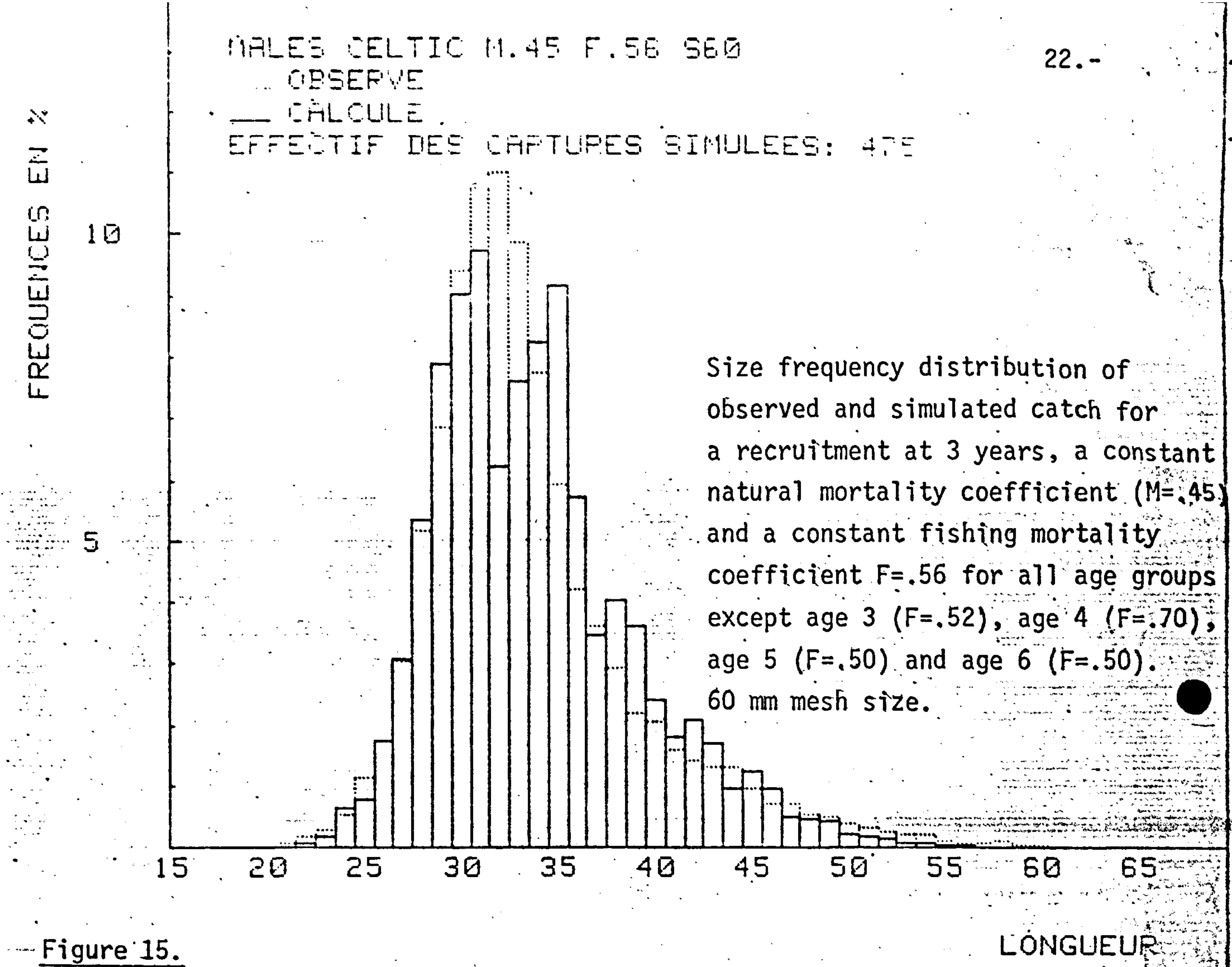


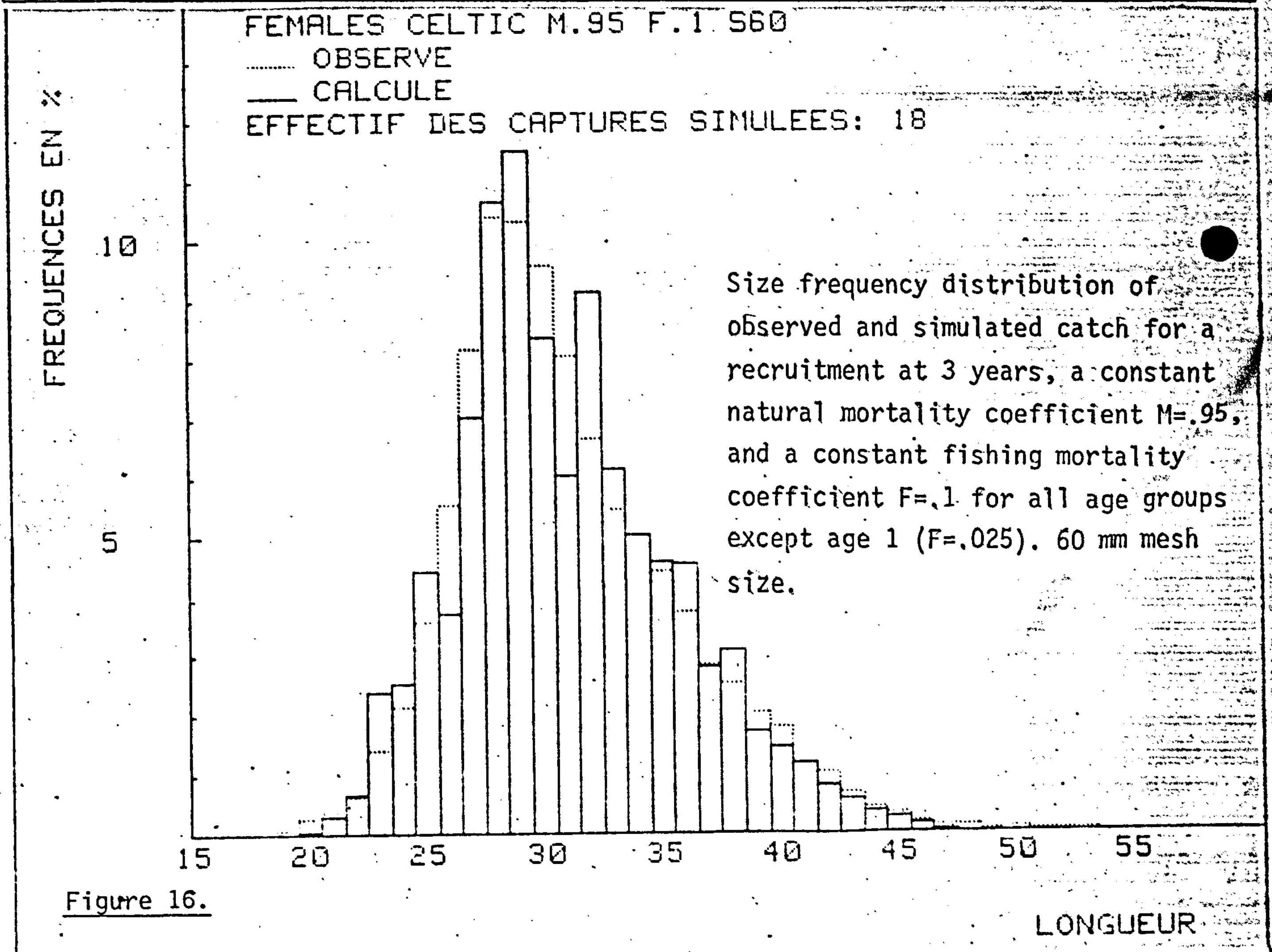
Figure 14.

Size frequency distribution of observed and simulated catch for a recruitment at 1.5 years, a constant natural mortality coefficient M=.95, and a constant fishing mortality coefficient F=.91 for all age groups except age 1 (F=.10) and age 2 (F=.40). 40 mm mesh size.



Size frequency distribution of observed and simulated catch for a recruitment at 3 years, a constant natural mortality coefficient (M=.45) and a constant fishing mortality coefficient F=.56 for all age groups except age 3 (F=.52), age 4 (F=.70), age 5 (F=.50) and age 6 (F=.50). 60 mm mesh size.

Figure 15.



Size frequency distribution of observed and simulated catch for a recruitment at 3 years, a constant natural mortality coefficient M=.95, and a constant fishing mortality coefficient F=.1 for all age groups except age 1 (F=.025). 60 mm mesh size.

Figure 16.

```
10    ! POPULATION SIMULATOR FOR NEPHROPS,Programmed by Conan.
20    ! INTEGATE STARTING FROM AGE A OVER N YEARS
30    INPUT "LOWER AGE LIMIT FOR YIELD INTEGRATION?",A,"NUMBER OF INTERVALS PER
YEAR?",R26
40    N=17
50    ! START WITH R25 RECRUITS
60    R25=1000
70    DIM A$[25],Input_file$(5),Output_file$(5)
80    DIM P(1:24),Q(1:24)
90    COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
100   COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
110   COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
120   DATA .003,.0032,.006,.0106,.0173,.0267,.0388,.0531,.0679,.0819,.0928,.0987
,.0987,.0928,.0819,.0679,.0531,.0388,.0267,.0173,.0106,.006,.0032,.003
130   MAT READ H
131   Normcum(0)=0
140   Normcum(1)=H(1)
150   Normcum(25)=1
160   FOR I=2 TO 24
170   Normcum(I)=Normcum(I-1)+H(I)
180   NEXT I
190   INPUT "# OF PROBLEMS ?",R18,"NAME OF OUTPUT FILE (CHOOSE A 6 CHARACTER NAM
E STARTING WITH AN UPPER CASE)?",Output_file$,"NAME OF INPUT FILE ?",Input_file$
191   INPUT "FIRST RECORD TO BE USED ON THE INPUT FILE",First_rec
200   CREATE Output_file$&":T15",R18,25+4+8*(21+21+65+65+21)+2*8
210   ASSIGN Input_file$ TO #1
220   ASSIGN Output_file$ TO #2
230   FOR Rec_number=First_rec TO R18+First_rec-1
400   Recruit_age=(A<=1)*1.5+A*(A>1)
410   PRINTER IS 0
420   FIXED 1
430   PRINT LIN(2),"************************************************************
*******************"
440   PRINT "START WITH";R25;"RECRUITS ENTERING FISHERY AT A BIRTHDAY OF";Recrui
t_age;"YEARS"
450   X=R25
460   READ #1,Rec_number;R4,R5,R11,R12,R14,R15,R16,K,L,T,C,D,E,F,H,R,T(*),V(*),A
$,Mnat(*),F(*),X(*)
470   B=0
480   PRINT LIN(1),"............................................................
...................",A$
490   IF R=1 THEN 520
500   PRINT "FEMALES"
510   GOTO 530
520   PRINT "MALES"
530   PRINT "NAME OF INPUT FILE :";Input_file$;"           NAME OF OUTPUT FILE :
";Output_file$
540   PRINT "RECORD #";Rec_number-First_rec+1,SPA(26),"RECORD #";Rec_number
550   ! SHIFT TIME ORIGIN TO BIRTHDAY
560   T(1)=T(1)-H
570   T(2)=T(2)-H
580   T(1)=T(1)+(T(1)<0)
590   T(2)=T(2)+(T(2)<0)
600   IF T(2)>=T(1) THEN 670
610   S=T(2)
620   T(2)=T(1)
630   T(1)=S
640   S=V(2)
650   V(2)=V(1)
660   V(1)=S
670   IF R=1 THEN 720
680   R11=R11-H
690   R12=R12-H
700   R11=(R11<0)+R11
710   R12=(R12<0)+R12
720   ! LOOP ON HARVESTED AGES
740   MAT G=ZER
741   MAT U=ZER
750   MAT W=ZER
```

```
751   MAT K=ZER
760   MAT A=ZER
770   FOR I=INT(Recruit_age) TO INT(Recruit_age)+N-1
790   Start=(Recruit_age-INT(Recruit_age))*(I=INT(Recruit_age))
800   IF X<1 THEN 1010
810   ! LOOP ON 1/R26ths OF YEAR
820   R20=0
830   R27=1/R26
840   FOR J=Start TO 1-R27 STEP R27
850   FIXED 5
860   DISP "AGE=";I+J
870   CALL Grow_nephrops(J+R27/2)
880   IF (R=0) AND (I+J)=2.75) THEN CALL Hatch_nephrops(J+R27/2)
890   CALL Lets_fish
900   CALL Register_catch
910   NEXT J
920   ! PRINT RESULTS FOR AGE GROUP I:
930   FIXED 0
940   PRINT LIN(1);"-------------------------------",LIN(1),"COHORT OF AGE";I;LIN
(1)
950   PRINT "# OF SURVIVORS AT END OF YEAR:             ";X
960   FIXED 3
970   PRINT "YIELD PER RECRUIT IN GRAMS:",W(I)/R25
980   IF R=0 THEN PRINT "GAIN IN # OF HATCHING EGGS PER RECRUIT =";K(I)/R25
990   NEXT I
1010  Yield=0
1020  Eggs=0
1030  FOR U=INT(A) TO A+N-1
1040  Yield=W(U)+Yield
1050  Eggs=K(U)+Eggs
1051  NEXT U
1100  ! PRINT RESULTS FOR WHOLE POPULATION:
1110  PRINT "================================="
1111  Yield=Yield/R25
1112  Eggs=Eggs/R25
1120  PRINT LIN(1),"TOTAL YIELD PER RECRUIT IN GRAMS :",Yield
1130  IF R=1 THEN 1190
1140  PRINT LIN(2),"TOTAL # OF EGGS PER RECRUIT :",Eggs
1150  PRINT LIN(1),"      AGE                              % OF EGGS",LIN(1)
1160  FOR U=INT(A) TO A+N-1
1161  K(U)=K(U)/R25
1170  PRINT SPA(5),U,SPA(12),K(U)*100/Eggs
1180  NEXT U
1190  PRINT "=================================================================
============="
1200  ! STORE CATCH FOR FURTHER ANALYSIS
1230  PRINT #2,Rec_number-First_rec+1;A$,Mnat(*),F(*),U(*),A(*),G(*),Yield,Eggs
1240  NEXT Rec_number
1250  END
1260  ! -------------------------EXTERNAL SUBROUTINES------------------------
--
1270  SUB Grow_nephrops(P1)
1280  COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
1290  COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
1300  COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
1310  DIM Z(2)
1320  ! A)------Define molting state
1330  Flag1=0
1340  IF (R=1) OR (I<2) THEN Two_molts
1350 One_molt: Flag1=1
1360  IF P1>T(2)-3*SQR(V(2)) THEN 1390
1370  Y(1)=I-1+T(2)
1380  GOTO Intermolt
1390  IF P1>T(2)+3*SQR(V(2)) THEN 1440
1400  Y(1)=I-1+T(2)
1410  Y(2)=I+T(2)
1420  W=SQR(V(2))
1430  GOTO Molting
```

```
1440  Y(1)=I+T(2)
1450  GOTO Intermolt
1460 Two_molts: IF P1>T(1)-3*SQR(V(1)) THEN 1490
1470  Y(1)=I-1+T(2)
1480  GOTO Intermolt
1490  IF P1>T(1)+3*SQR(V(1)) THEN 1540
1500  Y(1)=I-1+T(2)
1510  Y(2)=I+T(1)
1520  W=SQR(V(1))
1530  GOTO Molting
1540  IF P1>T(2)-3*SQR(V(2)) THEN 1570
1550  Y(1)=I+T(1)
1560  GOTO Intermolt
1570  IF P1>T(2)+3*SQR(V(2)) THEN 1620
1580  Y(1)=I+T(1)
1590  Y(2)=I+T(2)
1600  W=SQR(V(2))
1610  GOTO Molting
1620  Y(1)=I+T(2)
1630  GOTO Intermolt
1640  ! B)----------Compute relative S.F. distributions
1650 Molting: Flag2=0
1660  Prop=FNOrm_integr(P1+I,Y(2),W)  ! V is the proportion of post molts in coh
ort
1670  ! Frequencies:
1680  MAT M=H
1690  MAT N=H
1700  B=X*(1-Prop)
1710  MAT M=M*(B)
1720  B=Prop*X
1730  MAT N=N*(B)
1740  ! Size_classes:
1750  Y(1)=L*(1-EXP(-K*(Y(1)+R27/2-T)))
1760  Z(1)=C*EXP(D*Y(1))
1770  Z(1)=(Z(1)>3.5)*3.5+((Z(1)<=3.5) AND (Z(1)>=.75))*Z(1)+(Z(1)<.75)*.75
1780  FOR U=-12 TO 11
1790  R(U+13)=Y(1)+U*Z(1)/4+Z(1)/8
1800  NEXT U
1810  Y(2)=L*(1-EXP(-K*(Y(2)+R27/2-T)))
1820  Z(2)=C*EXP(D*Y(2))
1830  Z(2)=(Z(2)>3.5)*3.5+((Z(2)<=3.5) AND (Z(2)>=.75))*Z(2)+(Z(2)<.75)*.75
1840  FOR U=-12 TO 11
1850  S(U+13)=Y(2)+U*Z(2)/4+Z(2)/8
1860  NEXT U
1870  SUBEXIT
1880 Intermolt: Flag2=1
1890  ! Frequencies:
1900  MAT M=H*(X)
1910  MAT S=ZER
1920  MAT N=ZER
1930  ! Size classes:
1940  Y(1)=L*(1-EXP(-K*(Y(1)+R27/2-T)))
1950  Z(1)=C*EXP(D*Y(1))
1960  Z(1)=(Z(1)>3.5)*3.5+((Z(1)<=3.5) AND (Z(1)>=.75))*Z(1)+(Z(1)<.75)*.75
1970  FOR U=-12 TO 11
1980  R(U+13)=Y(1)+U*Z(1)/4+Z(1)/8
1990  NEXT U
2000  SUBEND
2010  ! ---------------------------------------------------------------------------
2020  SUB Hatch_nephrops(P1)
2030  COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
2040  COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
2050  COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
2060  IF (P1>3*R14) AND (P1<1-3*R14) THEN SUBEXIT
2070  ! XIS THE NUMBER OF INDIVIDUALS,R13 IS THE MEAN HATCHING TIME
2080  ! R14 IS THE STANDARD DEVIATION,R15 AND R16 ARE FECUNDITY PARAMETERS
2090  DIM P(1:24),Q(1:24)
2100  MAT Q=ZER
2110  MAT P=ZER
```

```
2120  ! PROPORTION OF HATCHING BROODS IN COHORT
2130  R23=(P1>3*R14)
2140  R21=FNOrm_integr(J+R27,R23,R14)
2150  P=R21-R20
2160  R20=R21
2170  Q=X*P  !NUMBER OF HATCHING EVENTS AT TIME J+R27/2
2180  MAT P=H*(Q)
2190  ! P IS THE VECTOR OF HATCHING FREQUENCIES AT TIME J+R27/2
2200  ! 90% MATURE FEMALES REPRODUCE EACH YEAR
2210  FOR U=1 TO 24
2220  Q(U)=.9*P(U)*R15*R(U)^R16
2230  K(I)=Q(U)+K(I)
2240  NEXT U
2250  SUBEND
2260  ! ---------------------------------------------------------------------
2270  SUB Lets_fish
2280  COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
2290  COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
2300  COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
2310  X=0
2320  R22=1
2330  IF R=1 THEN GOTO 2370
2340  ! FOR MATURE FEMALES CUT OFF ACCESSIBILITY R22 DURING PART OF YEAR
2350  IF Flag1 AND ((R11<R12) AND ((J<R11) OR (J>R12))) THEN R22=0
2360  IF Flag1 AND ((R11>R12) AND ((J>R12) AND (J<R11))) THEN R22=0
2370  ! CALCULATE X AT START OF J+1 AND CATCH OVER J
2380  FOR U=1 TO 24
2390  R0=FNSelectivity(R(U),R4,R5)
2400  X=X+M(U)*EXP((-F(I)*R0*R22-Mnat(I))*R27)
2410  I(U)=M(U)*F(I)*R0*R22*(1-EXP(-R27*(F(I)*R0*R22+Mnat(I))))/(F(I)*R0*R22+Mna
t(I))
2430  ! hand selectivity
2440  Size=INT(R(U)+.5)
2450  Size=(Size<15)*15+(Size>79)*79+((Size>=15) AND (Size<=79))*Size
2460  Discards=X(Size)
2470  X=I(U)*Discards*.4+X
2480  C(U)=I(U)*(1-Discards)
2490  IF Flag2=1 THEN 2600
2500  R1=FNSelectivity(S(U),R4,R5)
2510  X=X+N(U)*EXP((-F(I)*R1*R22-Mnat(I))*R27)
2520  J(U)=N(U)*F(I)*R1*R22*(1-EXP(-R27*(F(I)*R1*R22+Mnat(I))))/(F(I)*R1*R22+Mna
t(I))
2540  ! hand selectivity
2550  Size=INT(S(U)+.5)
2560  Size=(Size<15)*15+(Size>79)*79+((Size>=15) AND (Size<=79))*Size
2570  Discards=X(Size)
2580  X=J(U)*Discards*.4+X
2590  D(U)=J(U)*(1-Discards)
2600  NEXT U
2610  SUBEND
2620  ! ---------------------------------------------------------------------
2630  SUB Register_catch
2640  COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
2650  COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
2660  COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
2670  FOR U=1 TO 24
2680  G=INT(R(U))
2690  G=(G<15)*15+(G>79)*79+((G>=15) AND (G<=79))*G
2700  A(G)=A(G)+C(U)
2710  W(I)=W(I)+E*R(U)^F*C(U)
2720  G(I)=G(I)+C(U)
2730  U(G)=U(G)+I(U)
2740  IF Flag2<>1 THEN 2770
2750  MAT D=ZER
2760  GOTO 2830
2770  G=INT(S(U))
2780  G=(G<15)*15+(G>79)*79+((G>=15) AND (G<=79))*G
```

```
2790  A(G)=A(G)+D(U)
2800  W(I)=W(I)+E*S(U)^F*D(U)
2810  G(I)=G(I)+D(U)
2820  U(G)=U(G)+J(U)
2830  NEXT U
2840  SUBEND
2850  !
2860  ! FUNCTIONS--------------------------------------------------------------
2870  DEF FNSelectivity(P1,R4,R5)
2880  RETURN 1/(1+EXP(-(R4*P1+R5)))
2890  FNEND
2900  DEF FNOrm_integr(P1,P2,P3)
2910  COM C,D,E,F,I,J,K,L,M,N,R,T,Prop,X,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9,R10,R11,R
12,R14,R15,R16,R20,R25,R27,Flag1,Flag2
2920  COM A(15:79),C(1:24),D(1:24),F(0:20),G(0:20),H(1:24)
2930  COM I(1:24),J(1:24),K(0:20),M(1:24),Mnat(0:20),N(1:24),Normcum(0:25),R(1:2
4),S(1:24),T(1:2),U(15:79),V(1:2),W(0:20),Y(1:2),X(15:79)
2940  P4=(P1-P2)/P3
2950  P4=(P4<-3)*-3+(P4>3)*3+((P4>=-3) AND (P4<=3))*P4
2960  P6=4*(P4+3)
2970  P5=INT(P6)+(P6<0)
2980  P7=Normcum(P5)+(P6-P5)*(Normcum(P5+1)-Normcum(P5))
2990  RETURN P7
3000  FNEND
```

```
10 ! PARAMETER RECORDING FOR NEPHROPS POPULATION SIMULATOR
20     INPUT "NUMBER OF PROBLEMS ?",Nb_of_probs
30     OPTION BASE 1
40     DIM File_name$(5),A$(25),T(2),V(2),F(21),M(21),S(15:79)
50     INPUT " NAME OF FILE (CHOOSE A 6 CHARACTER NAME STARTING WITH AN UPPER CAS
E)?",File_name$
60     CREATE File_name$&":T15",Nb_of_probs,16*5+15*2+8*(2*21)+8*(79-15+1)+25+4
70     ASSIGN File_name$ TO #1
80     FOR J=1 TO Nb_of_probs
90     INPUT "NAME OF PROBLEM IN LESS THAN 25 CHARACTERS ?",A$
100    PRINT A$
110    PRINT "SELECTIVITY"
120    INPUT "A OF 1?",R4,"B OF 1?",R5
130    PRINT "PROPORTIONS DISCARDED?"
140    PRINTER IS 16
150    PRINT LIN(1)
160    FOR I=15 TO 79
170    PRINT LIN(-1),"SIZE CLASS",I
180    INPUT S(I)
190    NEXT I
200    PRINTER IS 6
210    PRINT A$,LIN(E(1)),"SELECTIVITY:",R4,R5
220    PRINT "PROPORTIONS DISCARDED:"
230    MAT PRINT S
240    INPUT "K FOR VON BERTALANFFY?",K,"LINFINITY FOR V.B.?",Linfinity,"TZERO FO
R V.B.?",Tzero
250    PRINT "K FOR VON BERTALANFFY";K;"LINFINITY FOR V.B.";Linfinity;"TZERO FOR
V.B.";Tzero
260    INPUT "ELEVATION FOR STANDARD DEVIATION VS MEAN LENGTH?",C,"SLOPE FOR STAN
DARD DEVIATION VS MEAN LENGTH?",D
270    PRINT "ELEVATION FOR STANDARD DEVIATION VS MEAN LENGTH",C,LIN(1),"SLOPE FO
R STANDARD DEVIATION VS MEAN LENGTH",D
280    INPUT "ELEVATION FOR W/L?",E,"SLOPE FOR W/L?",F
290    PRINT "ELEVATION FOR W/L",E,"SLOPE FOR W/L",F
300    PRINTER IS 16
310    PRINT "NATURAL MORTALITIES"
320    PRINT LIN(1)
330    FOR I=1 TO 21
340    PRINT LIN(-1),"NATURAL MORTALITY AT CLASS ",I
350    INPUT M(I)
360    NEXT I
370    PRINTER IS 6
380    PRINT LIN(1),"NATURAL MORTALITIES:"
390    MAT PRINT M
400    PRINTER IS 16
410    PRINT "FISHING MORTALITIES"
420    PRINT LIN(1)
430    FOR I=1 TO 21
440    PRINT LIN(-1),"FISHING MORTALITY AT CLASS ",I
450    INPUT F(I)
460    NEXT I
470    PRINTER IS 6
480    PRINT "FISHING MORTALITIES:"
490    MAT PRINT F
500    INPUT "AVERAGE SPRING MOLTING TIME ?",T(2),"VARIANCE ?",V(2)
510    PRINT "AVERAGE SPRING MOLTING TIME ",T(2),"VARIANCE ",V(2)
520    INPUT "AVERAGE FALL MOLTING TIME ?",T(1),"VARIANCE ?",V(1)
530    PRINT "AVERAGE FALL MOLTING TIME ",T(1),"VARIANCE ",V(1)
540    INPUT "IF MALES ENTER :1",R,"AVERAGE BIRTHDAY ?",H
550    IF R<>1 THEN 580
560    PRINT "MALES"
570    GOTO 590
580    PRINT "FEMALES"
590    PRINT "AVERAGE BIRTHDAY",H
600    IF R<>0 THEN 670
610    INPUT "ACCESSIBILITY STARTS ON ?",R11,"ACCESSIBILITY ENDS ON ?",R12
620    PRINT "ACCESSIBILITY STARTS ON ",R11,"AND ENDS ON",R12
630    INPUT "STANDARD DEVIATION FOR HATCHING TIME?",R14
640    PRINT "STANDARD DEVIATION FOR HATCHING TIME:",R14
650    INPUT "ELEVATION FOR FECUNDITY V.S. LENGTH ?",R15,"SLOPE FOR FECUNDITY V.S
```

```
. LENGTH ?",R16
660   PRINT "ELEVATION FOR FECUNDITY V.S. LENGTH ",R15,LIN(1),"SLOPE FOR FECUNDI
TY V.S. LENGTH ",R16
670   PRINT #1,J;R4,R5,R11,R12,R14,R15,R16,K,Linfinity,Tzero,C,D,E,F,H,R,T(*),V(
*),A$,M(*),F(*),S(*)
680   PRINT "STORED IN RECORD",J,"OF FILE",File_name$,LIN(3)
690   NEXT J
700   END
```

Shellfish Committee:
Communication C.M. 1980/ K:37

ERRATA AND FURTHER COMMENTS:

Preliminary estimates of mortality parameters for Norway lobsters in Bay of Biscay and in the Celtic Sea. By Gérard Conan.

During the 1980 ICES Nephrops Working Group, I was asked why I believed natural mortality could be high for Nephrops in the Bay of Biscay. My first answer is why not ? I was told earlier that the size frequency distribution of the catch could not have the shape it affects, if natural mortality was high. The simulation model I designed in 1979 (Conan and Morizur, 1979) showed that the observed size frequency distributions could very well be explained using the high natural mortality values. The main problem in the simulation approach, however, is that the shape of the size frequency distributions is not very sensitive to changes in F and M values when the total mortality is kept constant.

During the working group, I proceeded slightly differently by estimating Z from a catch curve cumulated over 8 years of sampling * and by applying a capturability (catchability) coefficient derived from Fox PRODFIT surplus production model applied to Bay of Biscay data and to relevant data on fishing effort. This provides a provisional estimate of a fishing mortality averaged for all sexes and age groups harvested.

In the present paper, to which this erratum may be taken as an appendix, I attempted on page 6 to proceed a little further and obtain estimates of an average capturability coefficient which would be different for each sex. This would be usefull since it has been shown many times that adult female Nephrops are catchable only during part of the year. Unfortunately the method I used for calculating sex specific coefficients, turns out to be irrelevant** and the sex specific estimates must be wrong. I shall therefore keep to my earlier provisional average estimate of a common capturability coefficient for both sexes. I must therefore assume that the fishing mortality averaged over the year is equal for males and females, the instantaneous fishing mortality being therefore much higher for females than for males when both sexes are available to the fishery. These assumptions were implicitely used for my estimates of F and M at the Nephrops ICES meeting. This erratum therefore does not contradict my estimates at the meeting, it is only unfortunate that I did not suceed in improving them.

*I wish to thank A. Charuau from ISTPM for the data he provided.
**I wish to thank Dr Haren (Direction des Pêches) for his constructive criticisms.

ERRATA LIST:

Sorry for the corrections, which should be made as such:

Page 1, second paragraph, lines 4-6:

F would be equal to .68. An instantaneous mortality coefficient M averaged over the year for all age groups would be .67 for the males and .66 for the females.

Page 2, third paragraph, 4th line:

F serait egal à 0,68, le coefficient instantané de mortalité naturelle moyen sur l'année pour tous les groupes d'âges de chaque sexe serait de 0,67 pour les mâles et de à,66 pour les femelles.

Page 6, this page should be entirely rephrased as such:

In the present paper, I did not attempt to quantify seasonal variations of c for the mâles or the females. According to Ricker (1975), the value of F obtained from a surplus production model may be taken as an average value of the age specific mortality coefficient F_i for all groups and sexes, weighted for each size class j by the ratio of the biomass B(i,j) of these component groups (i,j) over the catchable population biomass $\sum B(i,j)$.

Therefore:

$$F = \frac{\sum_{i}\sum_{j} F(i)B(i,j)}{\sum_{i}\sum_{j} B(i,j)} \text{ while a more conventional average is } F' = \frac{\sum F(i)}{N}$$

I did not proceed to make inferences on the possible age, size, or sex specific variability of the fishing mortalities F(i,j). Nevertheless I used the simulation model for estimating F'by the numerical integration presented above as suggested by Ricker. I compared this F'estimate with the estimate obtained by directly applying the capturability (catchability) coefficient of the surplus production model to the fishing effort.

Page 7, lines 15-16 :

After the 1979 Statutory Meeting of ICES, and before the 1980 Nephrops working group meeting, the simulation program was slightly modified, it now takes in account the discarding and partial survival of small Nephrops in the catch.

Page 8, second paragraph:

The value of the fishing mortality F=cf for the Bay of Biscay was estimated as .68. Substracting F from Z, I obtained M=.67 for the mâles and M=.66 for the females. Substituting M from the Z estimate in the Celtic Sea provides a fishing mortality estimate of F=.34 for the mâles and F=.25 for the females.

The "improved" F' and M' estimates for the Bay of Biscay in terms of Ricker's approach are F'=.92 and M'=.43 for both sexes when the value of F=.68 drawn from Fox surplus production model is assumed to be equal to

$$F=\frac{\sum F(i)B(i,j)}{\sum B(i,j)}.$$

Page 10, third paragraph:

The .67 and .66 values for mortality...

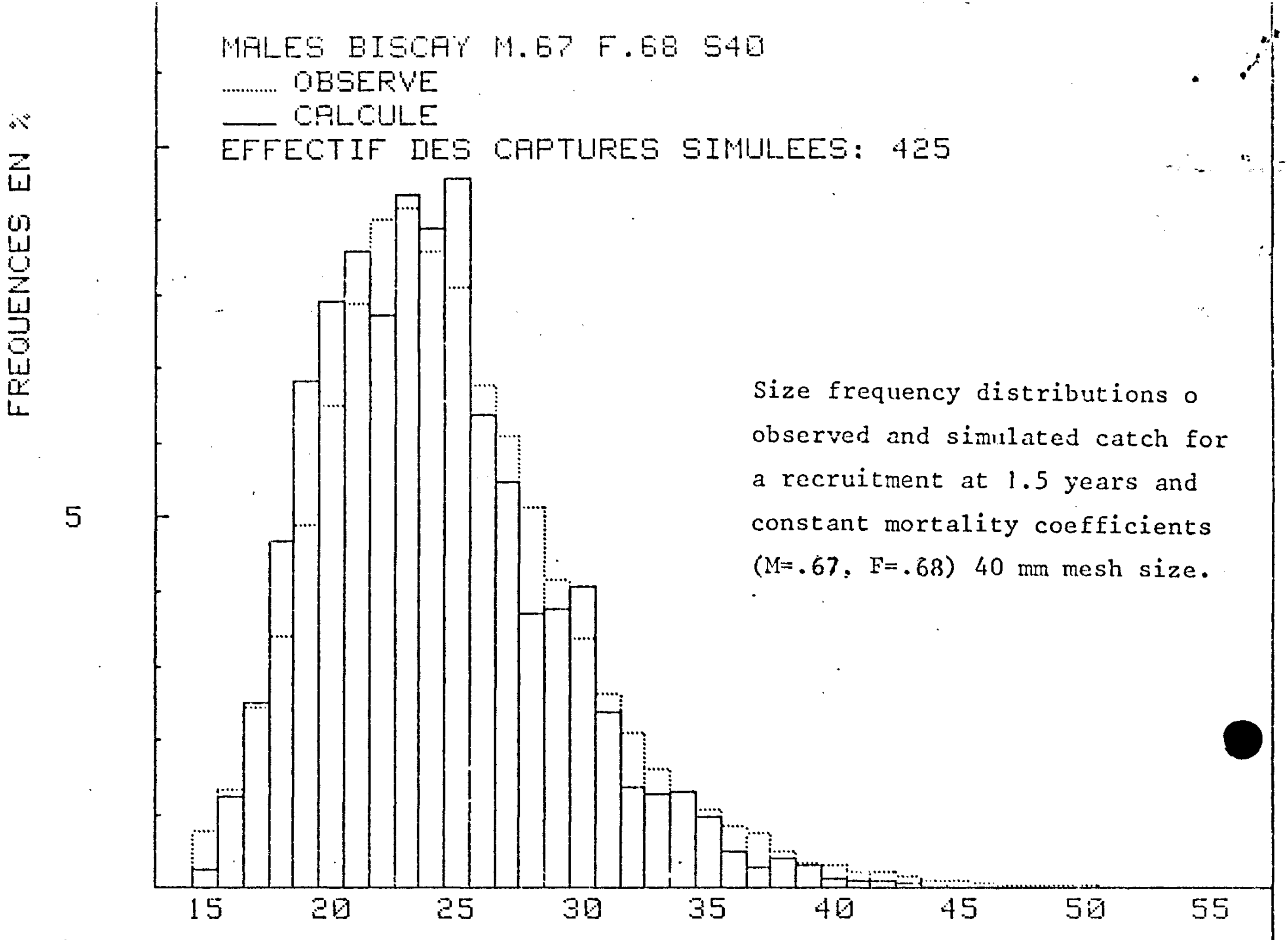
Page 11, second paragraph: please delete lines 1 to 4.

FURTHER COMMENTS.

The general meaning of the paper needs not to be revised. I have produced simulations with the present values of F.

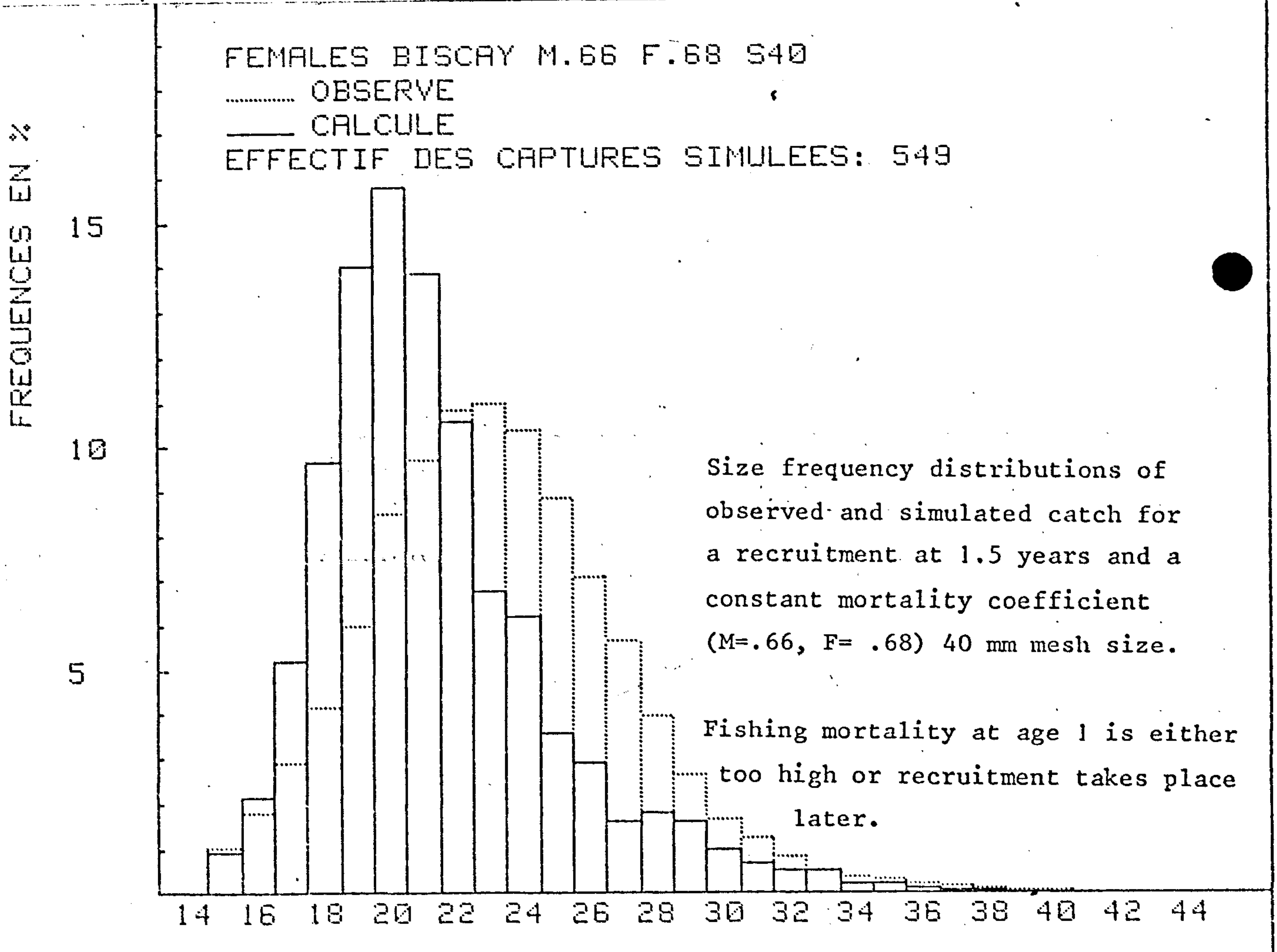
However, I would wish to stress that the present estimates should be used with great care, due to 1) the imprecision of the estimates of fishing mortality by the surplus production approach, and 2) to the imperfect concordance of what is called a capturability (catchability)coefficient in a yield model and in a surplus production model. In the absence of any better information, such a preliminary estimate is still usefull.

To my knowledge, there is not such a thing as a good estimate of natural mortality for Nephrops. Two methods have been used at the 1971 Nephrops working group. If confidence limits could be properly computed and if the bias in the computation of the estimates could be evaluated, it is likely that these estimates would not be as different as they appear. A reasonable conclusion is that neither of these estimates should be used for an other purpose than assessing a possible range for losses or gains which might arise in the case of a change in mesh size or fishing effort in the Nephrops fishery. I am not an unconditional of the .6 figure for natural mortality of Nephrops. This figure is all I have got for the moment, and I believe that in the present stage of our knowledge, it is as good as any other one available in other countries. A great deal of cooperative international research is needed before any realistic recommendations based on yield estimates be presented for management of Nephrops stocks. Up to now I see no point for revising or considerably improving the statements made by Conan and Morizur (1979) concerning these yield estimates.



Size frequency distributions o observed and simulated catch for a recruitment at 1.5 years and constant mortality coefficients (M=.67, F=.68) 40 mm mesh size.

Figure 9.



Size frequency distributions of observed and simulated catch for a recruitment at 1.5 years and a constant mortality coefficient (M=.66, F= .68) 40 mm mesh size.

Fishing mortality at age 1 is either too high or recruitment takes place later.

Figure 10.