RAB 81/002/21

DEVELOPMENT OF FISHERIES IN AREAS OF THE RED SEA AND GULF OF ADEN

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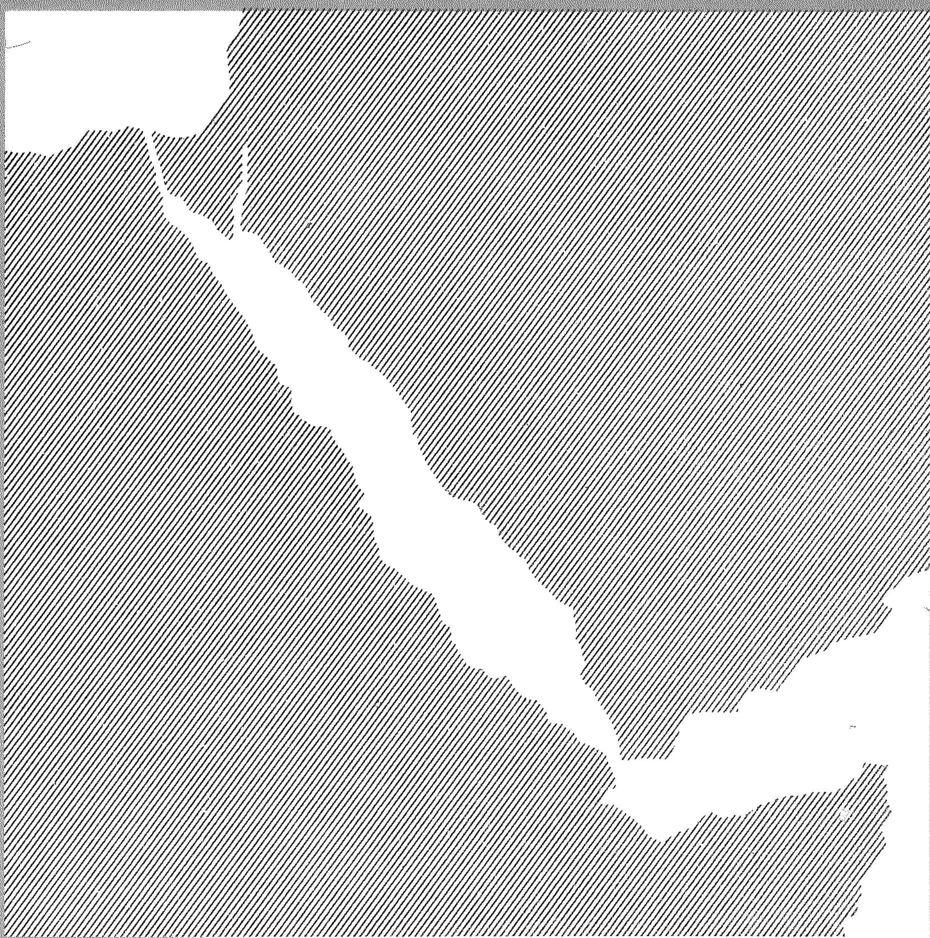

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

STOCK ASSESSMENT FOR THE ROCK LOBSTER (*Panulirus homarus*) INHABITING THE COASTAL WATERS OF THE PEOPLE'S DEMOCRATIC REPUBLIC OF YEMEN

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Project for Development of Fisheries in Areas of the Red Sea and Gulf of Aden

May 1984

ACKNOWLEDGEMENT

Various staff from within the PDRY's Ministry of Fish Wealth provided assistance. In particular, Messrs. Omar Moshama, Fouad Bahouine, Salah Bahoual and others of the Mukalla Branch, who undertook the catch sampling and some data analyses. Messrs. Abdul Wahab Mahboob, Abdul Wahab Musaibli and others of the Aden office, also assisted with data analyses.

SYNOPSIS

The report provides an assessment based principally on the sampling of catches at the Mukalla Cold Store and associated landing sites during the three seasons from and including 1980/81. Cohort identities were established using the method of Bhattacharya. The estimates obtained for the von Bertalanffy growth parameters for length at age were L_∞ = 22.7 cm (tail length), K = 0.45, and t_o = 0.58 yr;with no significant difference between the sexes.

Spawning was concluded as occuring twice each year, in the month prior to February and again sometime between May and October. The mean age at first sexual maturity for the females was found to be t_m= 2.0 to 2.5 yr. This compares with the mean age at recruitment determined as t_r = 2.2 yr for the males and t_r = 2.5 yr for the females.

The estimate obtained for the total mortality coefficient was Z_{ann} = 2.2 for the sexes combined. The males were found to have slightly higher values than the females. The natural mortality coefficient was determined as M = 0.85

Yield per recruit analyses indicated that modest increases in annual catch would result from increasing the fishing mortality coefficient. To the extent of six percent more catch if the fishing mortality coefficient was increased by 25 percent; and 13 percent if the latter was increased by 67 percent.

It was suggested that management action to seek these increases in annual catch might not be justified, particularly if associated with the introduction of substantial additional costs.

In resepct to the adjacent fisheries for lobster, that associated with the Thabut Cold Store was considered near to being fully exploited, while substantial additional catch was suggested as possible from the fishery at Socotra.

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INTRODUCTION

Following the commencement of the UNDP/OPEC funded FAO Project RAB/81/002 (previously RAB/77/008), the PDRY's Ministry of Fishwealth sought its assistance in undertaking an assessment of the rock lobster stocks. Agreement was reached for a joint study and this was commenced at the beginning of the 1980/81 fishing season. The study methodology was based on the sampling of catches by the staff of the Mukalla Branch of the Ministry's Research Department. The assessment documented in this report is based principally on the data derived from this sampling over the subsequent three seasons.

SUMMARY DESCRIPTION OF THE FISHERY

In the PDRY the fishery for rock lobsters takes place in the shallow waters along the eastern coastline to the border with Oman. A small catch is also taken from the waters around Socotra. The fishery is seasonal; usually from the beginning of October to the end of April. During the off season period, fishing is limited by the occurence of rough seas caused by the south west monsoon.

The catching method almost exclusively involves the use of entangling set nets. Typically some three to five of these nets, each about 100 metres long and several metres in depth, are operated by each crew. The catches are removed each morning, and the nets relocated when necessary. The method requires the use of boats and these are commonly about seven metres in length, and powered by ten horsepower outboard motors. Crew usually comprise of four or five persons per boat.

In addition to the set nets, cast nets are sometimes used in very shallow water, by fishermen without access to a boat. During recent seasons, the Ministry of Fishwealth has attempted to encourage the set net fishermen to commence using wooden lobster traps.

All the catches are purchased by the Coastal Fisheries Department who arrange collection and transport from the landing sites to their Cold

Stores at Mukalla and Thabut. As the fishermen are paid on the basis of whole weight, each catch is weighed at the landing sites. After this, the lobsters are dismembered, with only the tails being transported to the Cold Stores.

There are seventeen principal landing sites, and these are shown in Figure 1. Produce from the landing sites westwards of and including Saker are taken to Mukalla, while that from the landing sites east of Saker go to Thabut. Catches from Socotra and the adjacent islands are landed at Mukalla. At the Cold Stores the tails are sorted into grades by weight, and are then packaged into cartons of ten kilograms capacity. Almost all the output from the Cold Stores is exported.

GENERAL STUDY METHODS

The investigation confined itself almost exclusively to that part of the fishery supplying the Mukalla Cold Store. The lobster catch was sampled at both the Cold Store, as well as the associated landing sites. This resulted in the collection of two largely independent sets of data.

In respect to the landing sites,most were visited on one day during each month of fishing. On each such day for each landing site, the following data were recorded for each of about 100 lobster; tail length, tail weight, total length, whole weight, sex and whether the females were bearing external eggs.

All the individuals in the catches being sampled were usually measured; with often the total sample on a particular day coming from two or three catches.

The length measurements were made on whole lobster, along the mid-dorsal line. Tail lengths were measured from the most posterior part of the carapace to the most posterior part of the telson. Total lengths were measured along a linejoining the tips of the post-orbital spines to the most posterior part of the telson. These bases of measurement are shown in Figure 2.

Coincident with the catch sampling, interviews were held with those fishermen whose catches were sampled, as well as other fishermen landing on that day. Information was obtained from each about the type and quantity of fishing gear used during the most recent trip, as well as fishing times and locations. The total weight of each catch landed during the day was also obtained at this time from the records of the Mukalla Cold Store.

Sampling at the Cold Store also involved visits during one day per month, and was greatly assisted by the commercial practice previously mentioned of grading the lobster tails according to weight. The weight basis for each grade is given in Table 1. The procedure involved examining the contents of one carton (rarely two) from each grade during each month of fishing. In respect to each of these samples, the number of tails in each category of sex and egg bearing state were recorded. The measurement of tail lengths was not permitted.

Monthly catches for each landing site were obtained from the records of the Mukalla Cold Store. These were in whole weight units, and based on the weighing of catches at the landing sites. Records of the weights of tails packaged during each month in each tail grade category and the number of purchases in each month were also obtained. The extent by which tails packaged at the beginning of a month were from lobsters caught in the previous month was considered to be small. Another minor discrepancy between the two sets of catch records resulted from losses during transport.

The initial data analyses involved estimating the numbers of lobster caught during each month, according to each category of tail length (in the case of sampling at the landing sites) or tail weight (in the case of sampling at the Cold Store), sex and egg bearing state. In respect to the data from each landing site, this involved 'raising' the numbers in each category within each months samples by the raising factor 'total catch weight for month/total sample weight for month'. These results were summed to provide estimates for the landing sites combined.

A similar procedure was adopted in respect to the data from sampling at the Cold Store. The sample numbers in each category of sex and egg bearing state within each grade, were multiplied by the raising factor 'total catch weight in grade for month/total sample weight in grade for month'. No stratification by landing sites was possible, as the tails from the various landing sites were mixed prior to grading.

These estimates of the numbers of lobsters caught in each month within each tail length and tail weight category, were used with the method described in Bhattacharya (1967) in order to separate the distributions into their cohort components. This was assisted through the use of a programme written for Hewlett Packard 67 and 97 calculators by Pauly and Caddy (in press). The output from the programme are estimates of the mean length ,the standard deviation of the length, and the frequency of individuals, for each of the identified cohorts. The data for the males and females were analysed separately.

In respect to some of the distributions, it was not possible to characterise all of the cohorts present when using the programme. The approach adopted in such a case was to subtract those that were, from the total distribution, and then to apply the programme again with the residuals. In the few instances when the programme did not characterise any of the cohorts, this was done by extrapolating from a knowledge of the cohort components in the distributions of adjacent months.

Another aspect of the initial data analyses involved the estimation of the monthly fishing efforts. Firstly the efforts associated with taking the interview catches were combined for all landing sites in each month separately. The total fishing efforts in each month were then estimated by multiplying these by the raising factor 'total catch weight for all landing sites for month/total interview catch weight for all landing sites for month'. The fishing efforts determined in this way were numbers of boat fishing days and numbers of net fishing days.

RESULTS AND DISCUSSION

Catch Weights and Fishing Efforts

The catch weights recorded at the landing sites, and available from the records of the Mukalla Cold Store for each month of the study period, are shown in Table 2. They are given in whole weight units. The annual catches for each year were 125.5. tonne, 108.1 tonne, and 183.1 tonne respectively. The highest catches were generally made in the early months of each season and later, in the months between about January and the end of the season.

The associated fishing efforts, estimated from the data obtained during the interviews with fishermen, are also included in Table 2. The annual fishing efforts for each year are 10385 boat days or 36140 net days for 1980/81; 11039 boat days or 45541 net days for 1981/82; and 14849 boat days or 63597 net days for 1982/83.

In respect to the three years, the estimate for the mean number of nets used during a boat day is 4.0. In each year the fishing efforts tended to be highest at the beginning of each season and then again between about January and the end of the season.

The catch weights per unit fishing effort, estimated as the quotient of the catch weights and the above mentioned fishing efforts, are also given in Table 2. These are presumed to reflect the abundance of lobsters during the period. The estimated mean catch weights per unit effort in each year are 12.1 kg/boat day or 3.5 kg/net day in 1980/81; 9.8 kg/boat day or 2.4 kg/net day in 1981/82; and 12.3 kg/boat day or 2.9 kg/net day in 1982/83.

Also obtained from the Mukalla Cold Store were the weights of tails packaged in each tail weight grade for each year including 1972/73 to the present. These data are given in Table 3, and show that the annual throughput remained reasonably constant during the years including 1967/77 to the present; at about half or less of the values for the earlier years. The quantities handled at the Cold Store during recent years was about 47 tonne.

Advice was received that the Coastal Fisheries Department had been established in 1969/70. The first year of substantial catch was in 1972/73,when three trawlers operated under joint venture arrangements with Kuwait. These were used to encourage the development of the fishery, particularly as 'mother ships' associated with the daily purchase of catches from the artisanal fishermen. Prior to the establishment of the Cold Store at Thabut in 1974/75, the Mukalla Cold Store received lobster from landing sites in addition to those presently serviced.

The number of purchases of lobster during each month were also obtained from the Mukalla Cold Store, and are shown for each year including 1977/78 to the present in Table 4. The total number of purchases in each year appear to have been reasonably constant for the years subsequent to 1978/79; and are slightly higher than for the earlier two years.

The number of purchases has been presumed to reflect the amount and distribution of fishing effort. As with the fishing efforts resulting from the interviews with the fishermen, the annual numbers of purchases increased slightly throughout the study period. Also within each year the numbers of purchases were generally highest in the early months of each season and again between about January and the end of the season.

Tail Length/Age Relationships

The investigation of these relationships was based on an interpretation of the estimated mean tail lengths for the individual cohorts identified within the monthly catches. The mean tail lengths were determined by the application of the Bhattacharya method to the estimated numbers in each tail length category occuring in the monthly catches. The latter were previously estimated from the data obtained during sampling at the landing sites.

Histograms of the numbers within each length category in the monthly catches are shown for the males and females separately in Figures 3, 4 and 5. The data upon which these histograms are based are given in Appendices 1, 2 and 3.

Recorded immediately below each histogram, and adjacent to each cohort identified by the Bhattacharya programme, are the estimated mean lengths and the associated pre-set correlation coefficients (in brackets). The lines drawn parrallel to the x-axes and passing through the means depict ± 2 times the standard deviations of the lengths of the individuals comprising the cohorts. Mean lengths not associated with a correlation coefficient are those estimated other than by the Bhattacharya programme.

Each identified cohort was assigned an age; relative to an arbitrarily chosen birthday date of January 1st. The differences in mean lengths between consequetive cohorts within the data for each month were taken as annual growth increments. Mean tail lengths at age were then estimated from the data for all the months, and these are shown in Table 5. Growth was assumed to conform to the von Bertanlanffy equation:

$$L_t = L_\infty (1 - e^{-k(t - t_o)})$$

and the constants L_∞, K and t_o determined from these mean tail lengths at age.

The estimation procedure involved assuming values for L_∞, and undertaking linear regressions of $\log_e (1 - L_t/L_\infty)$ against age, to provide associated values for K (= - slope), Kt_o(= y-intercept) and hence t_o = (= - y.intercept/slope). Tail lengths for each assigned age were then estimated for each L_∞, K and t_o combination, and a (geometric mean) linear regression analysis undertaken of these against the respective observed tail lengths.

The 'best choice' value for L_∞, and hence also K and t_o, was determined from the values for the y-axis intercept, slope and coefficient of determination. Identifying the 'best choice' was based on seeking a y-axis intercept of zero, a slope of unity, and the maximum value for the coefficient of determination.

The estimates so obtained for the growth constants were L_∞ = 22.6 cm, K = 0.455 and t_o = 0.619 yr in respect to the males; and L_∞ = 22.8 cm, K = 0.443 and t_o = 0.534 yr for the females. The small differences between the sexes could not be considered as 'real', in that a 'students't' test found no significant difference (at P = 0.95) between the sexes in respect to the observed tail lengths at age.

Estimates of the tail lengths for each assigned age based on the above growth constants, are shown alongside the observed tail lengths at age given in Table 5. The derived relationships between tail lengths and ages are shown plotted in Figure 6, along with the mean observed tail lengths for each month of each year.

The estimated lengths appear to be in close agreement with the observed tail lengths at age, except for the cohorts of age about one year. The data for these cohorts were not used when estimating the growth constants, in the belief that they were biassed towards representing only the larger individuals within the cohorts.

In the estimation of the growth constants, growth in length was assumed to be a continuous process. This assumption is obviously invalid as applied to individual lobsters, which are known to grow intermittently, at each moult. Notwithstanding, the estimation of the constants on the assumption of continuous growth was considered acceptable. This was in the context that moulting is believed to occur twice annually, and the constants were intended for use in describing the growth of composites of lobster rather than the growth of individuals.

Estimates of the growth constants were also obtained for the purpose of determining ages from given lengths. The assumption was made that the asymptotic length in this relationship is $L'_\infty = (L_\infty /0.95)/0.95$. The underlying assumption is that $L_\infty = L_{max} \times 0.95$ and $L'_\infty = L_{max}/0.95$; where L_{max} is the observed maximum length from a substantial sampling of the stock prior to its exploitation. The associated K' and t_o' values were determined from the linear regression of $\log_e(1 - L_t/L'_\infty)$ against age as described earlier.

The estimates so obtained are L'_{∞} = 25.0 cm, K' = 0.342 and t'_o = 0.372 yr in respect to the males; and L'_{∞} = 25.3 cm, K' = 0.326 and t'_o = 0.241 yr for the females. Estimates of the ages for each 'observed' length based on these growth constants, are shown alongside the assigned ages at length given in Table 5. The estimated ages appear to be in close agreement with the observed ages at length.

Tail Weight/Tail Length Relationships

The relationships between tail weight and tail length were determined from the data for the individual lobsters measured during the sampling at the landing sites. They were assumed to conform to the power curve equation:

$$W = aL^b$$

where a and b are constants; see Gulland (1969). Values for the constants were obtained for each month, by undertaking power curve 'geometric mean' regression analyses of the tail weights against tail lengths.

The observed mean tail weights in each category of tail length, sex and egg bearing state, for each month of sampling are given in Tables 6, 7 and 8. The tail weights are shown in grams and the tail lengths in centimetres. Estimates of the constants based on these data are shown in Table 9. The values obtained in respect to the three years data combined are a = 0.1195 and b = 2.765 for the males, a = 0.1187 and b = 2.717 for the females without eggs, and a = 0.2505 and b = 2.506 for the females with eggs.

Plots of the relationships between tail weight and tail length based on these values for the constants are shown in Figure 7. When comparing lobster of given tail lengths, females with eggs have substantially heavier tails than females without eggs. The estimated difference at a tail length of 15 cm. is 36 gm; and 49 gm at a tail length of 20 cm. The males also have heavier tails for given lengths than the females without eggs. The estimated difference at a tail length of 15 cm is 27 gm; and 66 gm at a tail length of 20 cm.

Tail Weight/Age Relationships

One approach to investigating these relationships involved using the previously presented values for the growth constants L_∞, K and t_o, as well as the values for the constants in the tail weight against tail length relationships, with the following weight version of the von Bertalanffy equation:

$$W_t = W_\infty (1 - e^{-K(t - t_o)})^b$$

The procedure includes pre-determining the weight equivalents of L_∞, the values so obtained being W_∞ = 610 gm for the males and W_∞ = 581 gm for the females (without eggs). The relationships between tail weights and age derived in this way are shown plotted in Figure 8.

An alternative approach was attempted, involving the application of the Bhattacharya method to the numbers in each tail weight grade in each months catches. Mean tail weights were determined for each of the identified cohorts, and the cohorts were assigned ages as discussed previously in the section dealing with the relationships between tail length and age.

The data upon which these analyses were based are given in Appendices 4, 5 and 6 ; and as previously mentioned they were determined from the sampling at the Mukalla Cold Store. Histograms of the numbers within each tail weight category in the monthly catches are shown in Figures 9, 10 and 11. Values for the mean tail weights for each identified cohort, along with the associated standard deviations and correlation coefficients, are shown adjacent to the histograms.

These observed mean tail weights at age for each month of each year are included in Figure 8, to allow visual comparison with the relationships between tail weights and age determined earlier. The mean tail weights at age obtained from combining these over all months are given in Table 10. The table also includes estimates of the tail weights at the same ages, from using the growth constants and the constants in the tail weight against tail length relationship, with the weight version of the von Bertalanffy equation.

There appears to be a generally close agreement between the observed and estimated tail weights at age results; although the former tended to be lower at the higher ages. In this context it is relevant to note that the Bhattacharya method assumes that the separate cohort components in a frequency composition are normally distributed. This requirement is not likely to be well met when applying the method to the catch numbers in each tail weight category, and would tend to provide under-estimates of the mean tail weights particularly for the older cohorts.

In respect to considering whether the tail weights at age relationships differ between the sexes, the two sets of results are somewhat contradictory. According to the observed tail weights at age relationships, the females have heavier tails than the males at the same age; and vice versa for the estimated tail weights at age relationships. In both cases however the differences are small.

Total Length/Tail Length Relationships

As with the relationships between tail weight and tail length, these relationships were derived from the measurements undertaken on individual lobster during the sampling at the landing sites. The relationship was assumed to conform to the following linear equation:

$$L_{Total} = a + b\, L_{Tail}$$

where a and b are constants. Values for these constants were obtained for each month, by undertaking linear 'least square' regression analyses of the total lengths against tail lengths.

Estimates of the constants so obtained are shown in Table 11. These are based on both lengths being measured in centimetres. The values obtained in respect to the three years data combined are a = 1.21 and b = 1.55 for the males, a = 2.65 and b = 1.40 for the females without eggs, and a = 3.61 and b = 1.35 for the females with eggs.

Plots of the relationships between total length and tail length based on these values for the constants are shown in Figure 12. When comparing lobster of given tail lengths, the total lengths of the males are generally greater than for either category of females. The estimated difference at a tail length of 15 cm is 0.81 cm compared with the females without eggs, and 0.60 cm compared with the females with eggs. At a tail length of 20 cm, the respective differences are 1.56 cm and 1.60 cm.

Spawning Seasons

This aspect of reproduction was investigated indirectly using principally the data describing the number of females in each category of egg bearing state in each months catches. Spawning (egg hatching) was taken to occur during the months coinciding with the periods when the percentages of females with eggs were generally declining.

Plots of the percentages of egg bearing females in each month are given in Figure 13. These show that females with eggs are present within the population throughout all of the fishing season. Lowest percentages occured at around February from which it is presumed that spawning had occured during the preceding months.

Moulting and hence growth can be expected to follow shortly after spawning. As such the observed increases in the mean tail lengths and mean tail weights for the identified cohorts at around February, shown by the histograms in Figure 3, 4, 5, 9, 10 and 11, provided some confirmation of spawning occuring prior to February.

Whether there is more than one spawning season during each year is unclear from the results shown in Figure 13. The plot resulting from the sampling at the Mukalla Cold Store suggests only one spawning season, while that based on the sampling at the landing sites seems more compatable with the existence of two spawning seasons. No explanation can be offered at this time for the difference in the results from the two sampling sites.

The observed increases in the mean tail lengths and mean tail weights for the identified cohorts at around February, also has relevance to this matter of whether there is more than one period of spawning. The extent of the tail length and tail weight increases are generally less (roughly half) the tail length and tail weight differences between consequetive cohorts. This suggests that the lobster are moulting more than once during the interval of time reflected by the age difference between consequetive cohorts.

The age difference between consequetive cohorts can be expected to be equal to the time difference between consequetive recruitments. On the basis of a visual examination of Figures 3, 4, 5, 9, 10 and 11 it appears clearly that the recruitment of consequetive cohorts occurs annually at about February for the males, and prior to October for the females.

Accepting that the age difference between consequetive cohorts is one year, leads to the conclusion that there is more than one (probably two) spawning periods in each year. One of these is taken as occuring in the months prior to February, and the other is presumed to occur sometime during the closed season from April to October.

First Sexual Maturity

As with the consideration of spawning seasons, this matter was investigated through an examination of the monthly catch data for the females; in particular the relationships between the percentages of females with eggs and each of tail length and tail weight. This involved combining the data for all months, and estimating the size at which 50 percent of the lobster (of that size) first attain the egg bearing condition; using the 'equating areas' method described in the "Trawl Selection" sub-section of Gulland (1969).

Plots of the percentages of females with eggs in each tail length and tail weight category are shown in Figures 14 and 15. Estimates of the tail lengths and tail weights corresponding to the 50 percent (of the asymptotic value) egg bearing state are respectively $L_{50\%m}$ = 13.2 cm and $W_{50\%m}$ = 4.6 oz (= 129.5 gm). These values when converted to their age equivalents gave estimates of $t_{50\%m}$ = 2.5 yr and $t_{50\%m}$ = 2.6 yr respectively.

Accepting that the duration of egg incubation ranges between one and two months, as suggested by Berry (1971), it is reasonable to presume that the age at first sexual maturity is between 2 yr and 2.5 yr.

Total Mortality Estimates

Various methods were used in the investigation of total mortalities. Some of these utilised the estimated numbers in each cohort component in the catches for each month. These had been obtained from applying the Bhattacharya method to the size composition in each months catches as previously described.

The estimated numbers in each cohort component are shown before, and after 'raising' (in round brackets) to the estimated total numbers in the monthly catches, adjacent to each of the identified cohorts in the histograms of Figures 3, 4, 5, 9, 10 and 11. Also shown above each identified cohort (in square brackets) are the associated catch numbers per unit fishing effort.

One approach to estimating total mortality coefficients involves undertaking exponential regression analyses of the catches per unit effort against time; with the resulting values for the (negative) slopes being estimates of the coefficients; see Gulland (1969). This method was applied to the mean catches per unit effort for groups of cohorts of the same age; estimated from the data for all years and both sampling sites combined. Plots of the natural logarithms of these mean catches per unit effort are shown in Figures 16 and 17.

Also shown are the estimates for the total mortality coefficients and associated coefficients of determination, relevant to each period of time during which it appeared that the changes in catches per unit effort were not being affected by recruitment. The separate estimates appear in reasonable agreement both within and between sexes.

Accepting that those for the cohorts older than two and a half years are the more reliable, in being less likely to be influenced by recruitment, these were used in estimating a mean total mortality coefficient for each sex separately and combined. When estimating these means the individual coefficients were 'weighted' by $1/(1 - r^2)$. The values so obtained are Z_{Seas}=3.57 for the males, Z_{seas} = 3.04 for the females, and Z_{seas} = 3.34 for the sexes together.

These values relate to the period of each year from the beginning of October through April, expressed as if applying equally for the full year. The actual total mortality coefficients for the full year can be expected to be lower. These were estimated as the differences between the natural logarithms of the annual mean catches per unit effort , for the cohorts of ages two and a half to three and a half years and the cohorts older than three and a half years. (The 'position' of these means are shown as A and B respectively in each of Figures 16 and 17). The estimates so obtained are Z_{ann} = 2.41 for the males, Z_{ann} = 2.03 for the females, and Z_{ann} = 2.20 for the sexes together.

These values are likely to be under-estimates, particularly for the females, and slightly so for the males. This is believed to be due to the recruitment of cohorts of ages two and a half to three and a half years not being completed until mid-season. A fuller discussion of this is given in a later section.

The alternative data available for estimating total mortality coefficients are the estimated numbers of lobster in the catches of each year by tail length and tail weight categories. These are given in Appendices 1, 2, 3, 4, 5, and 6 in respect to the sampling during the three study years; and in Table 3 for the years 1972/73 to the present from the records of the Mukalla Cold Store. These data were used with the method of Jones and von Zalinge (1978), which also requires knowledge of the von Bertalanffy growth constants L'_{∞} and K' relevant to estimating ages from tail lengths.

When the catch numbers by tail weight categories were used, it was necessary to estimate the tail lengths corresponding to the lower end of each tail weight category. This was done using the constants presented earlier for the relationships between tail weight and tail length.

Also, in respect to the data available for the years prior to the current study, the catch weights in each tail weight grade required to be converted to catch numbers. This was done from a knowledge of the mean number of lobster per unit weight in each grade, available from the data collected during the study period.

The values for the total mortality coefficients estimated in this way from the data for the three study years are given in Table 12. Those derived from the sampling at the landing sites are similar to those derived for the same years from sampling at the Mukalla Cold Store. In all instances the estimates obtained for the females were lower than those obtained for the males.

The mean values obtained after combining the estimates for the two sampling sites and the three years are $Z_{ann} = 2.33$ for the males, $Z_{ann} = 2.04$ for the females, and $Z_{ann} = 2.10$ for the sexes together. The values are similar to those obtained from the method discussed previously.

The estimates obtained from applying the Jones and van Zalinge method to the data presented in Table 3 are given in Table 13. These values are for the sexes combined, and are relatively high for all years. The period of highest values is for 1973/74 through 1976/77 and are presumably related to relatively high fishing efforts in those years.

Natural Mortality Estimates

A variety of methods were available for estimating the natural mortality coefficients. The first of these involved determining the differences between the total mortality coefficients applying annually and those relevant to the duration of the fishing season. The relationship assumed to exist between these total mortality coefficients and the natural mortality coefficient is described by the following equation:

$$Z_{ann} = 7/12.Z_{seas} + (12 - 7)/12.M$$

where the 7 refers to the duration (in months) of the fishing season.

When using the estimates of the total mortality coefficients presented earlier*, the estimates of the natural mortality coefficients obtained were M = 0.69 for the males and M = 0.63 for the females. As some of the values for Z_{ann} are likely to be under-estimates, these values for the natural mortality coefficients can be expected to be under-estimates also; particularly that for the females.

Another method for obtaining estimates for the natural mortality coefficients is from the differences in the natural logarithms of the catch numbers per unit effort between the end of one season and the beginning of the next; after appropriate adjustment for the time difference. This approach was applied to the data depicted in Figures 16 and 17; in particular to the mean catch numbers per unit effort for the cohorts of 3+ years of age at mid-April and mid-October. The latter avoided the need to assume no between seasons recruitment. The estimates of the natural mortality coefficient so obtained are M = 1.03 for the males and M = 2.06 for the females. The former value seems reasonable, while the latter is obviously invalid.

Another estimate of the natural mortality coefficient was obtained using the following equation from Pauly (1980a):

$$\text{Log}_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where L_{∞} and K are the von Bertalanffy growth constants relevant to estimating length from age, and T (in $^{\circ}$C) is the mean annual water temperature. Extrapolating from the water temperature data summarised in Vidal-Junemann (1981) relevant to the south west coast of Oman, it is likely that the mean water temperature adjacent to Mukalla is between 20 to 25°C. The estimate for the natural mortality coefficient corresponding to these temperatures and the previously presented growth parameters (after converting the L_{∞} values from tail length to total length units) is about M = 0.9

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* Simple means were taken of the two sets of annual total mortality coefficients.

It should be appreciated that the application of this method is not strictly correct, in that the above equation was determined from data for fish. As such the value obtained for the natural mortality coefficient should be treated with reservation, even though it is very similar to those obtained from some of the alternative methods.

The method of Rikhter and Efanov (1976) was also used for estimating the natural mortality coefficient. It requires a knowledge of the age of first sexual maturity, which has a relationship with M according to the following equation:

$$M = 1.521/(t_m)^{0.720}.-0.155$$

An estimate of the age at first sexual maturity (for the females) was given in an earlier section as between 2 years and 2.5 years; from which the natural mortality coefficient can be presumed to be between M = 0.77 and M = 0.63. Similarly to the previous method, these estimates should be treated with reservation, as the above equation was derived from data for fish.

The presumption that within an unexploited stock, 1 in 300 individuals will survive to maximum age was also used to provide an estimate of the natural mortality coefficient; see Sanders and Kedidi (1983). The operative equation is $M = -\log_e(1/300)./t_{max}$. Under the exploitation regime presently applying to the lobster stock, it appears that very few survive beyond an age of four years. As such it seems reasonable to assume that the maximum age that might have prevailed prior to exploitation was around seven years. The estimate for the natural mortality coefficient based on this choice of maximum age is M = 0.81.

The estimates of the total mortality coefficients presented earlier are invariably higher for the males than for the females. There are also higher proportions of males in the catches, and the first recruitment of males occurs at a younger age than for the females. These findings, which are referred to again in later sections, prompted the use of the method of Sanders (1977) for estimating the natural mortality coefficient .

The method requires knowledge of the proportions of each sex in the catches, as well as the total mortality coefficients and ages at first capture. When it is assumed that the natural mortality coefficients for the two sexes are the same, the operative equation is :

$$M\Delta t_c = \log_e \left(\frac{C_m}{C_f} \cdot \frac{Z_m}{Z_f} \cdot \frac{Z_f - M}{Z_m - M}\right)$$

where Δt_c is the difference between the lengths at first capture (= $t_{cf} - t_{cm}$) and the m and f refer to the males and females respectively,

The various parameter values used with the equation are given in Table 14. The estimate of the natural mortality coefficient obtained by iteration is M = 0.99.

It was not clear whether the differences between the sexes in the total mortality coefficients was due to differences in the fishing mortality coefficients, natural mortality coefficients, or both. As such the alternative approach of assuming the fishing mortality coefficients are the same, and the natural mortality coefficients are different was also tried. The operative equation in this case is:

$$\frac{C_f}{C_m} = \frac{Z_m}{Z_f} \cdot e^{(Z_m - Z_f)t_{cf} - M_m\Delta t_c}$$

which enables the solution of M_m by iteration and hence also $M_f (= Z_f - Z_m + M_m)$

Again the parameter values given in Table 14 were used. The estimates obtained for the natural mortality coefficients were $M_m = 4.79$ and $M_f = 4.50$. As these values are unrealistic, it is presumed the assumption that the fishing mortality coefficients for the two sexes are the same is invalid.

A final estimate of the natural mortality coefficient was obtained from the linear (geometric mean) regression analysis, of the previously determined annual total mortality coefficients against the sum of the annual fishing efforts for the same and the previous year. The values used for the annual fishing efforts were the numbers of purchases by the Mukalla Cold Store for 1977/78 to the present from Table 4. The values for the total mortality coefficients were those for the relevant years from Table 13.

The relationship between these total mortality coefficients and fishing efforts is shown plotted in Figure 18. The estimate obtained for the natural mortality coefficient (= y-axis intercept) is M = 1.44. The catchability coefficient given by the slope of the relationship is q = 1.161×10^{-4}. These values should be considered with substantial reservation in view of the small number of data sets used in the regression analysis.

Recruitment Estimates

In an earlier section it was concluded that only one new cohort enters the fishery in each year; at mid-season in the case of the males, and prior to the commencement of the season for the females. It was also concluded that there are two spawning seasons during each year; from which it seems to follow that one of the spawning seasons is 'unsuccessful', in that it does not lead to the subsequent recruitment of a new cohort.

The explanation for this unusual phenomena is unknown. Possibly it is linked with the south west monsoon, which occurs during May through August, and is associated with rough sea conditions and the incursion inshore of cold oxygen depleted nutrient rich water. Mass mortalities of fish have been reported during the monsoon season; see Vidal-Junemann (1981).

The above relates to the periodicity with which consequetive cohorts enter the fishery. The available data also allowed for a consideration of the pattern of recruitment for individual cohorts. These data are the mean catch numbers per unit fishing effort for each month, shown plotted after conversion to natural logarithms in Figures 14 and 15.

Normally it is expected that the individuals of a particular cohort would all recruit into the exploited stock during a single time period. These data however indicate that for lobster there are four such periods.

In respect to the males, the four periods are immediately prior to the beginning of October when aged 1+ years and 2+ years, and at the following two mid-seasons. These recruitments, at least those occuring at mid-season, appear to occur 'instantaneously' over a short period of time. The same applies with respect to the females, except that the first mid-season recruitment is not 'instantaneous', and continues throughout the remainder of the season, at a magnitude exceeding mortality.

These recruitments were quantified in relative terms, in units of catch numbers per unit fishing effort. The magnitude of the initial recruitment was taken as the estimated catch numbers per unit fishing effort at the beginning of October. The differences between the estimated catch numbers per unit effort at the end of January and that estimated for *the beginning of February were taken as the mid-season recruitments.* The recruitment during the off season was determined as the estimated catch numbers per unit fishing effort at the beginning of October less the estimate of that remaining from the end of the previous season. The latter was obtained by applying natural mortality to the estimated catch numbers per unit fishing effort at the end of April.

The above procedure was applied equally to the data for the two sexes , except in respect to the first mid-season recruitment for the females. Here it was estimated as occuring 'instantaneously' at the beginning of February. The catch number per unit fishing effort at the beginning of February was estimated as that which produced the 'observed' catch number per unit fishing effort at the middle of April. The difference between this and the estimated catch number per unit fishing effort at the end of January was taken as the recruitment at the beginning of February.

These various estimates of relative recruitment are shown in Table 15. It appears that the total number of males recruited into the catches is greater than for the females, and is presumed to be the consequence of the males generally entering at a younger age. A mean age of recruitment was estimated for each sex; these are t_r = 2.23 yr, for the males and t_r = 2.50 yr for the females. The corresponding estimates of the mean tail lengths at recruitment are L_r = 11.8 cm for the males and L_r = 13.3 cm for the females.

The explanation for the recruitment of each cohort occuring at four discrete times is presently unknown. The phenomena possibly results from the lobster stocks re-distributing at each moult period, causing a 'net' movement onto the exploited grounds from adjacent unexploited grounds. The suggested synchronisation between recruitment and moulting is supported by the coincidence of the 'observed' mid-season recruitment and moulting periods.

Yield per Recruit Estimates

The procedures for determining yields per recruit involved separately considering each month of the post-recruitment life of the lobster. The two sexes were considered together.

A recruitment of 10000 individuals was assumed to occur each year; an initial recruitment of 1662 at the beginning of October, followed by 4069 at the beginning of February, 3446 at the beginning of October and 823 at the beginning of the next February. These values are in proportion to the relative recruitments shown in Table 15.

Starting with the first month following the initial recruitment, the number of lobsters remaining at the beginning (N_1) and end (N_2) of each month were estimated using the equation:

$$N_2 = N_1 \; e^{-(F_{month} + M_{month})}$$

The catch number (c) during each month were then estimated using the equation:

$$c = (F_{month}/Z_{month})(N_1 - N_2)$$

The product of each catch number and the mean tail weight for individuals of the cohort at mid-month, provided the catch weights for each month.

The values for the mean tail weights of individuals were previously obtained, from firstly using the available growth constants in the von Bertalanffy equation to determine the mean tail lengths of individuals at mid-month. These were then converted to tail weights, using the pre-determined constants in the relationship between tail weight and tail length.

The catch weights over the full life span of the cohort, were determined as the sum of the monthly catches. These were taken to be the same as the sum of the catch weights from all post-recruit cohorts during a single year. The latter was based on the assumption that the recruitment regime is constant between years.

Catch weights were estimated in this way for a range of alternative values for the annual fishing mortality coefficient from F_{ann}=0.5 to F_{ann}=2.5, and for a range of tail lengths at first capture from L_c = 10.0 cm to L_c = 12.0 cm. The duration of the fishing season was always taken as seven months, from the beginning of October to the end of April.

The values used for the other parameters in the calculations were L_∞ = 22.7 cm , K = 0.45, and t_o = 0.58 yr for the von Bertalanffy growth constants; a = 0.119 and b = 2.74 for the constants in the relationship between tail weight and tail length; and M = 0.85 for the natural mortality coefficient. The results from an example set of calculations are given in Appendix 7.

The yield per recruit estimates for each combination of annual fishing mortality coefficient and tail length at first capture are given in Table 16, and shown plotted in Figure 19. These indicate that increasing the annual fishing mortality coefficients through the range investigated, results in increases in the yields per recruit.

The contemporary value of the annual fishing mortality coefficient applying to the sexes together appears to be at about F_{ann} = 1.35. This reflects the difference between the previously presented estimates for the total mortality coefficient of about Z_{ann} = 2.2 and the natural mortality coefficient of about M = 0.85.

According to the results of the yield per recruit analyses, increasing the amount of fishing beyond the contemporary level would produce only modest increases in the annual catches. For example, increasing the annual fishing mortality coefficient to F_{ann} = 1.5 would result in about two percent more catch, and at F_{ann} = 2.5 the catch would be about eight percent higher.

The annual catches of tails recorded at the Mukalla Cold Store in recent years have been around 47 tonne. As such the above-mentioned two percent is equivalent to 0.9 tonne of tails, and the eight percent is equivalent to 3.9 tonne of tails.

In respect to the lengths at first capture, the results indicate that the yields per recruit are almost identical for each of L_c = 10 cm , 11 cm and 12 cm. This occurs generally over the full range of annual fishing mortality coefficients tested.

CONCLUDING COMMENTS

In the above discussion it was suggested that increasing the amount of fishing to above the contemporary level would produce modest increases in the annual catches. Whether it was justifiable for management to seek these potential increases would very much depend on whether such action was likely to be associated with substantial additional costs.

According to the results of the yield per recruit analyses, in order to gain the two percent increase in annual catch, the annual fishing mortality coefficient would need to be increased by 11 percent. Gaining the eight percent increase would require the annual fishing mortality coefficient to be increased by 85 percent. If such increases in the coefficients were to be associated with proportional increases in costs, then seeking the increases in catch is unlikely to be justified.

Employing more fishermen and boats in the fishery in order to increase the annual fishing mortality coefficient and hence also the annual catches, would introduce substantial additional costs into the fishery. Encouraging the existing fishermen to use more effective fishing methods and fishing gears would be a much less costly way to achieve an increase in the catches.

In respect to the tail length at first capture, it appears from the results of the yield per recruit analyses, that about the same annual catches would be obtained with any value of the length at first capture within the range tested. The optimum value was determined as about t_c = 11.0 cm, which is very similar to the size at which the lobster were 'observed' to initially recruit into the fishery. Even if it were necessary, it is unlikely that changes to the length at first capture could be effected with the fishing methods and gear presently in use.

The finding that each lobster cohort recruits into the catches at four discrete ages , has some relevance in the context of future management. If the explanation for this phenomena is that a substantial stock exists 'outside' the areas presently being exploited, then the possibility exists for substantially increasing the annual production. Further consideration of this matter would appear to justify some priority.

All the previous results and discussion have related directly to the fishery supplying the Mukalla Cold Store. They also have relevance to the fishery supplying the Thabut Cold Store and to the fishery at Socotra. If it is assumed that the potential annual catches per length of coastline are the same for the three fisheries, then an estimate of the annual catches corresponding to full exploitation would be 30 tonne for the fishery supplying the Thabut Cold Store and 50 tonne for the fishery at Socotra.

These estimates are based on 55 tonne of tails being the annual catch at full exploitation for the fishery supplying the Mukalla Cold Store, and the lengths of coastline as measured from an Admiralty chart, using a planimeter. These were determined as 358 km for the fishery supplying the Mukalla Cold Store, 183 km for the fishery supplying the Thabut Cold Store, and 325 km for the fishery at Socotra (and nearby islands).

According to the records of the Coastal Fisheries Department the quantity of tails packaged during 1982/83 at the Thabut Cold Store was 44 tonne ; while 5 tonne of tails was the catch from the fishery at Socotra. As such it would appear that the stock relevant to the Thabut Cold Store is fully exploited, and that an additional 45 tonne of tails is possible from Socotra.

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Figure 1 Locations of places named in the text.

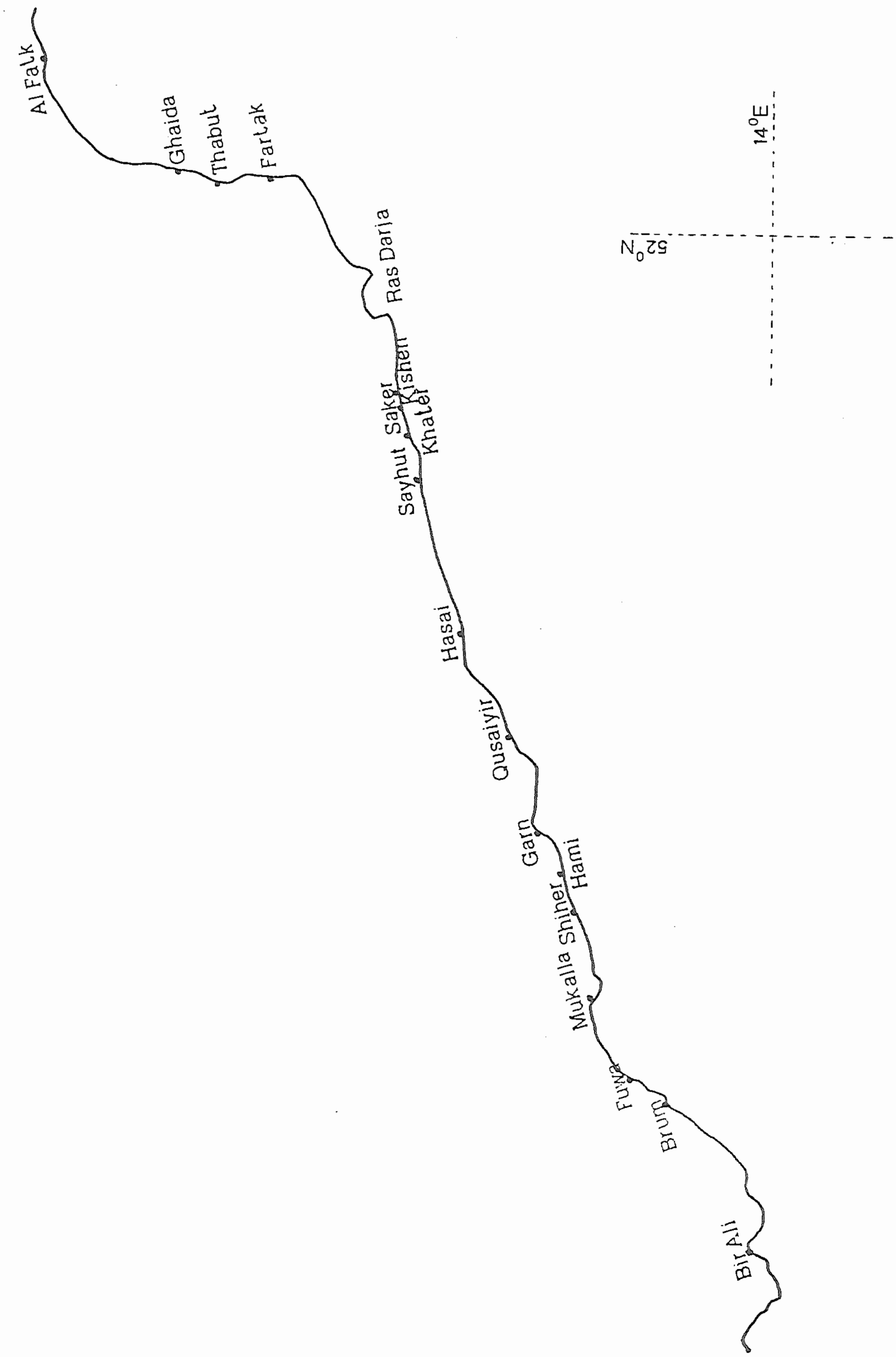

Figure 2 Showing length dimensions observed during the study.

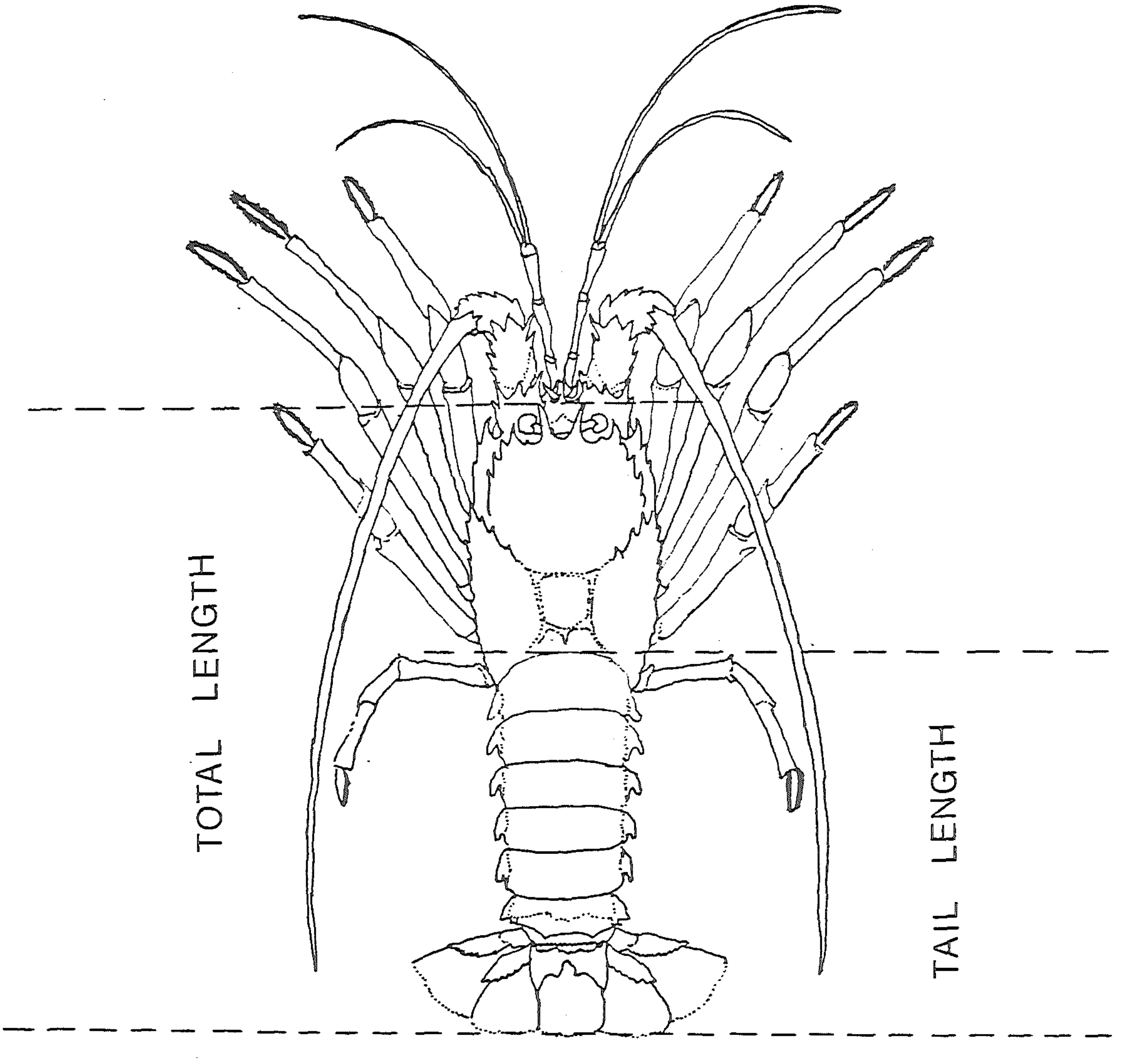

Figure 3 Histograms of estimated catch numbers by tail length category, by sex and by month for 1980/81.

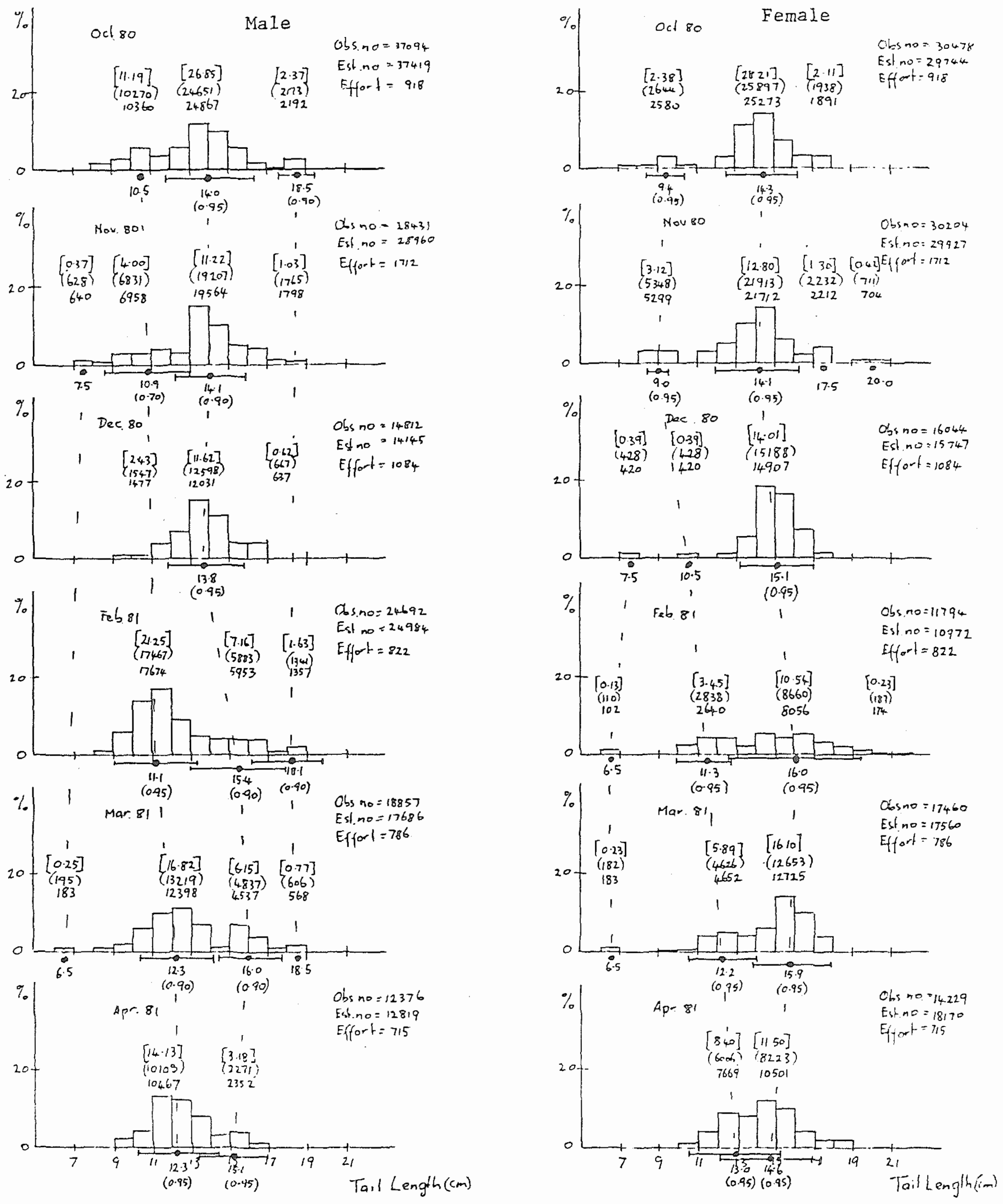

Figure 4 Histograms of estimated catch numbers by tail length category, by sex and by month for 1981/82.

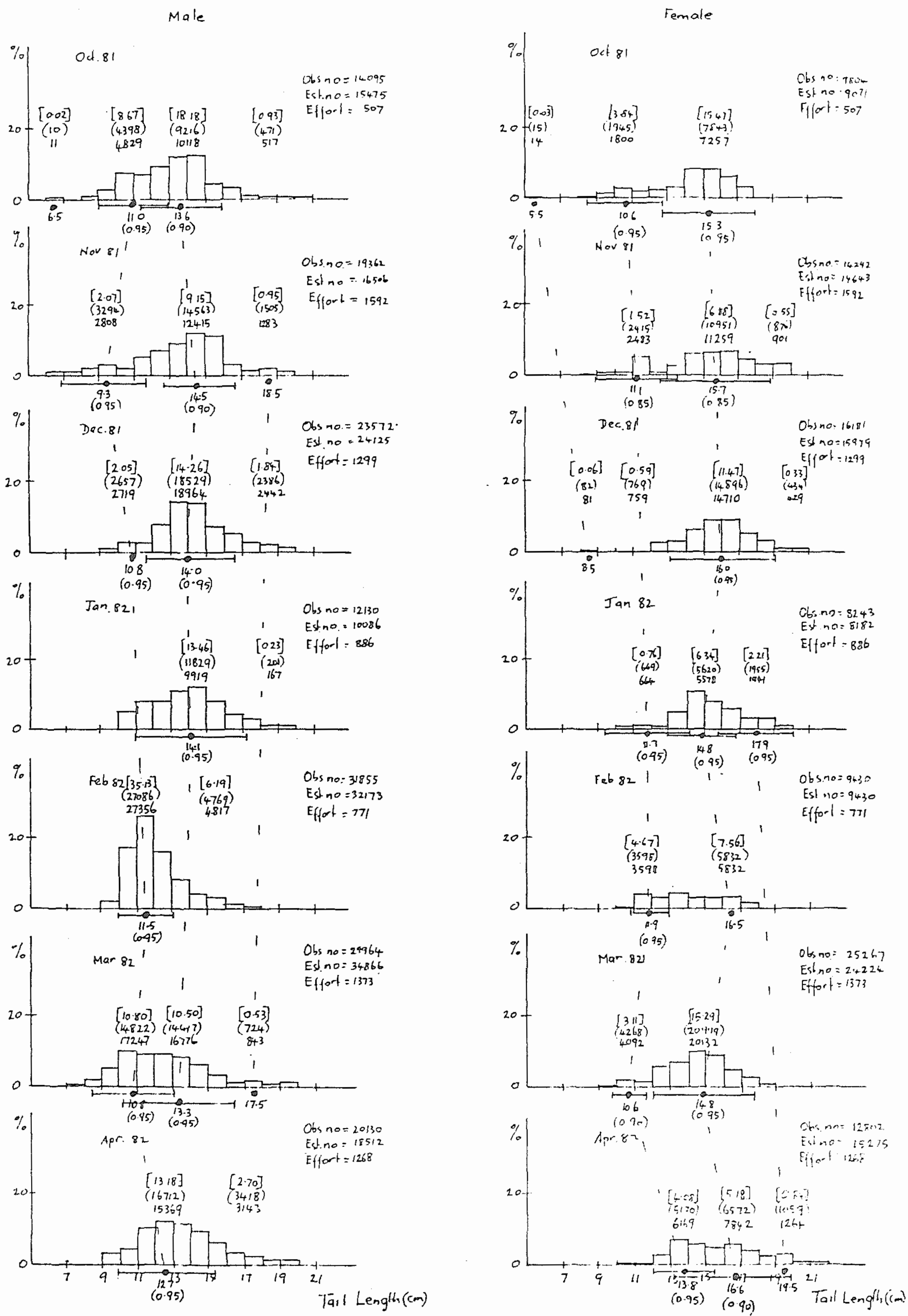

Figure 5 Histograms of estimated catch numbers by tail length category, by sex and by month for 1982/83.

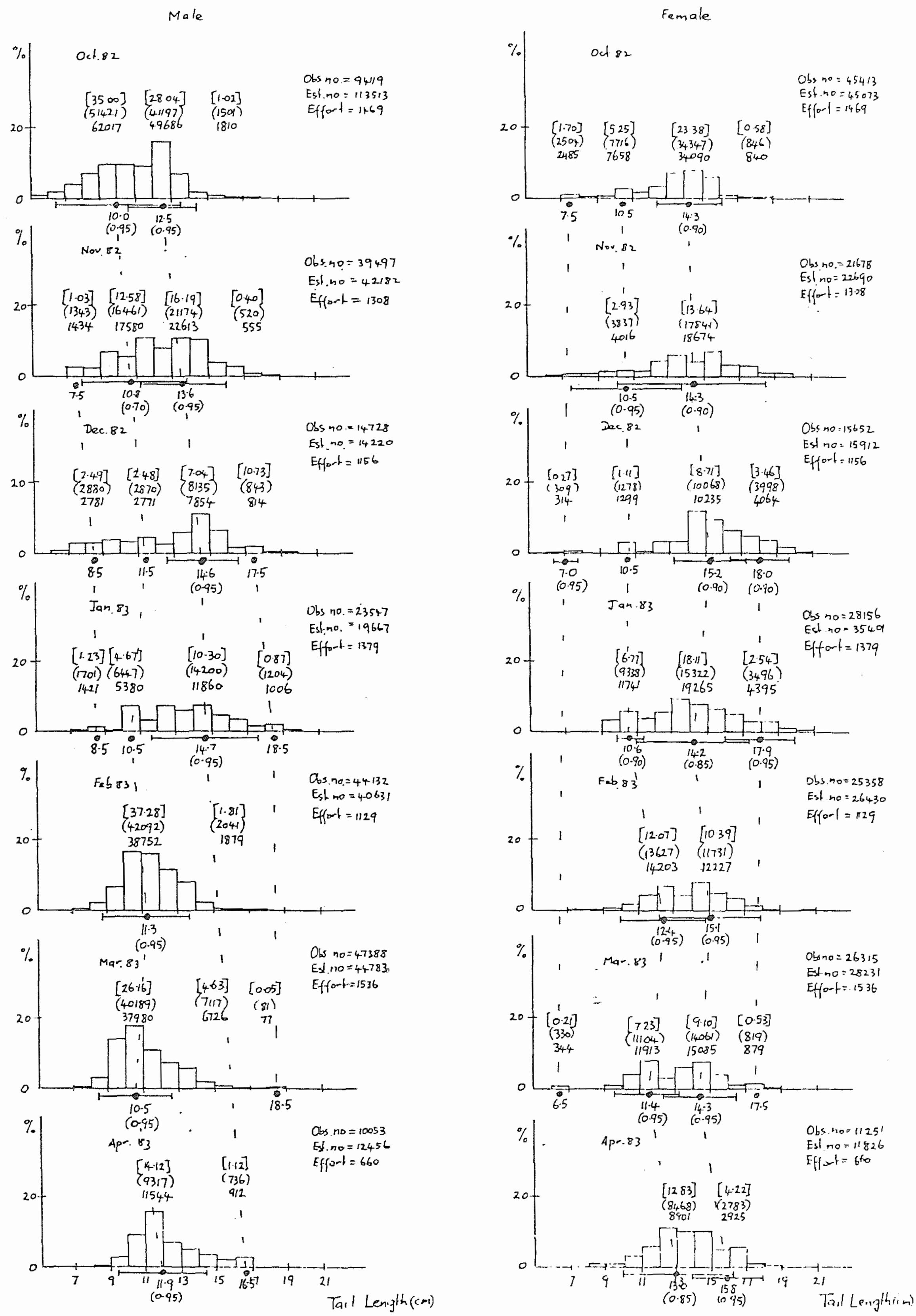

Figure 6 Plots of the relationship between tail length and age (mean tail lengths for each cohort shown for 1980/81 (•), 1981/82 (x) and 1982/83 (o).

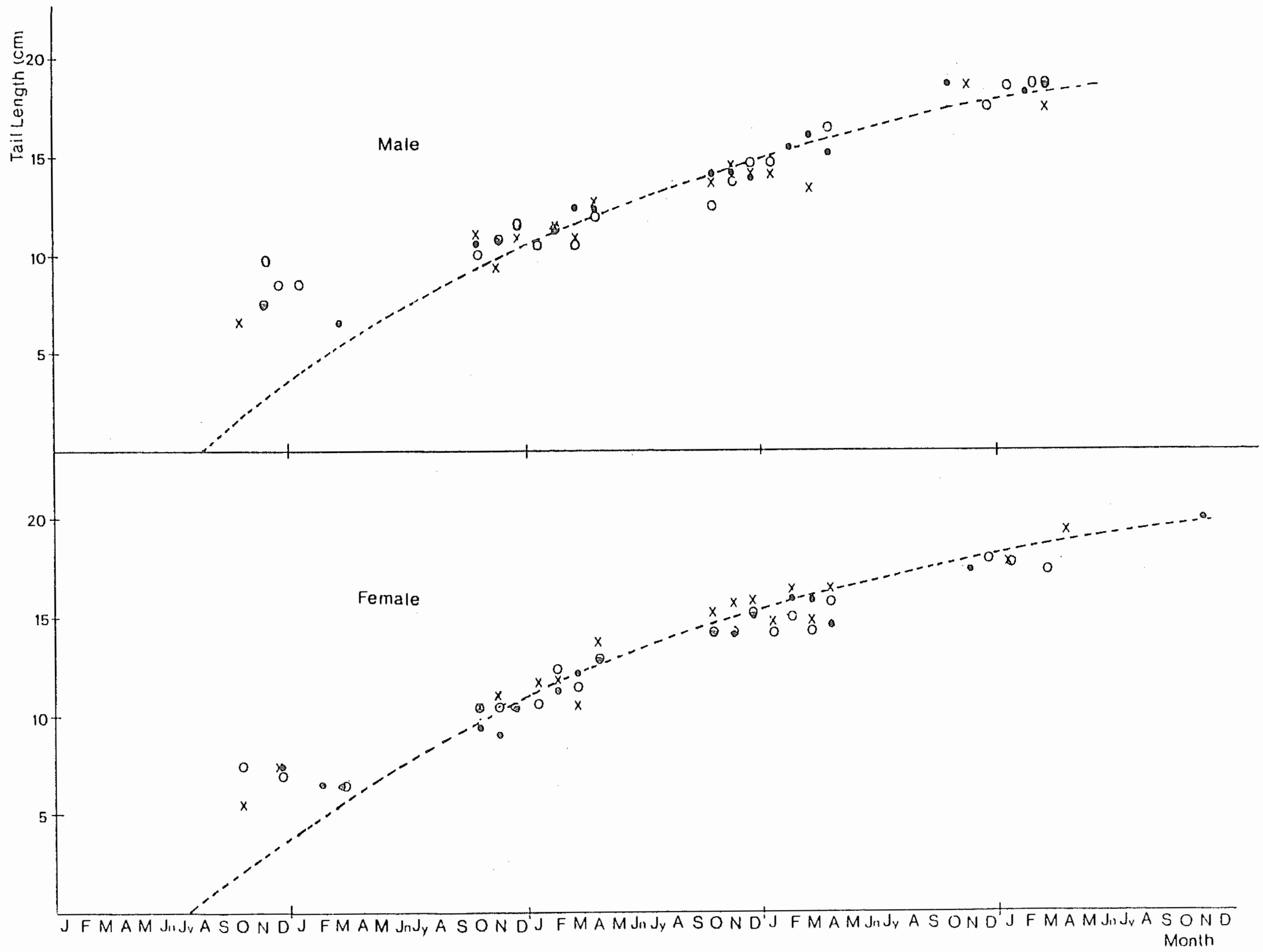

Figure 7 Plots of the relationship between tail weight and tail length.

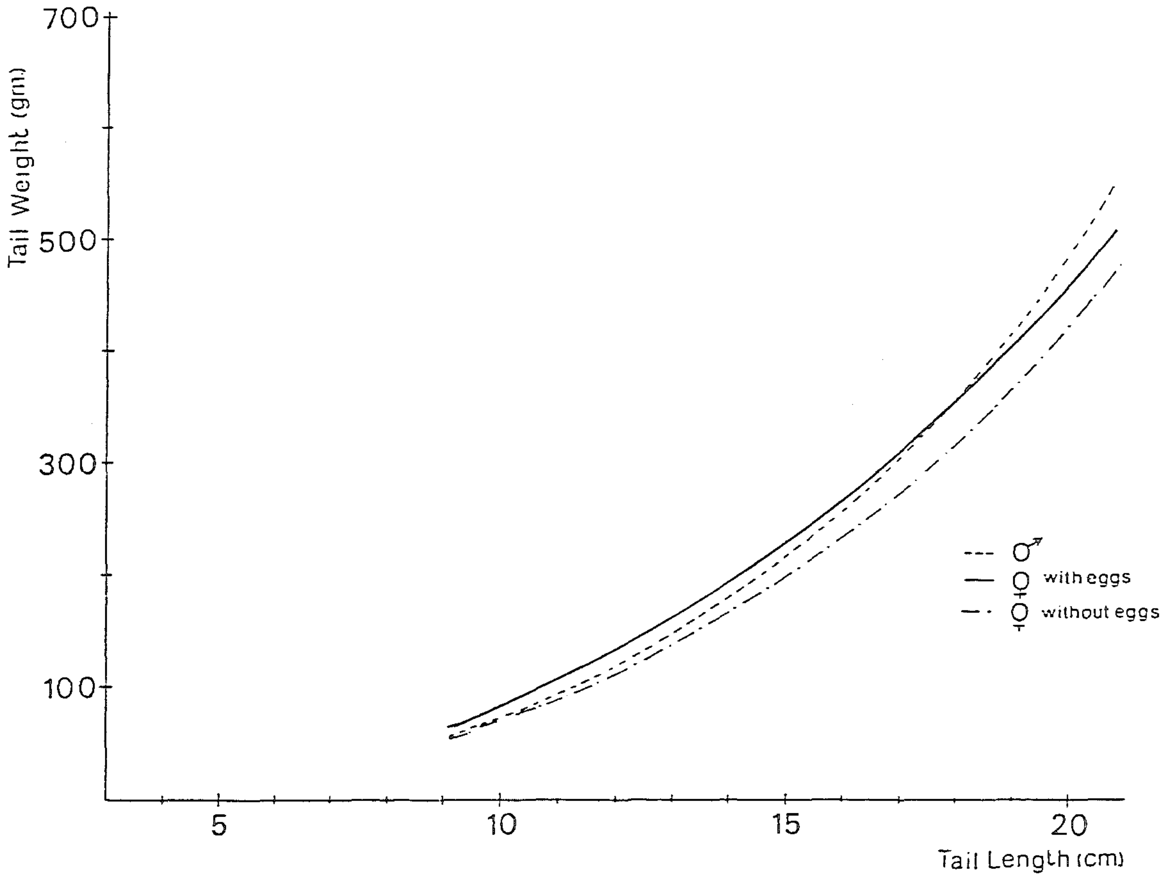

Figure 8 Plots of the relationship between tail weight and age (mean tail weights for each cohort shown for 1980/81 (•), 1981/82 (x) and 1982/83 (o)).

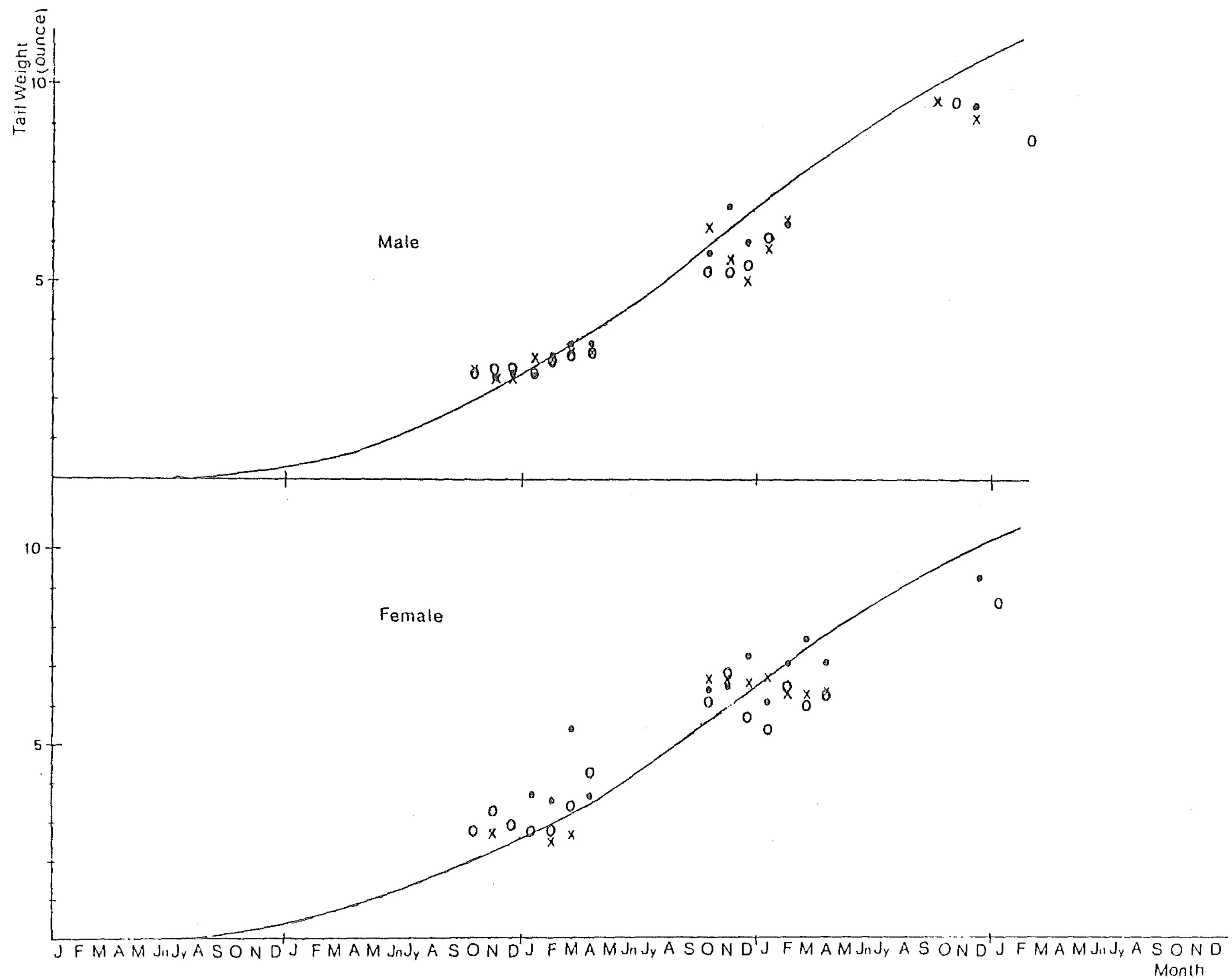

Figure 9 Histograms of estimated catch numbers by tail weight category, by sex and by month for 1980/81.

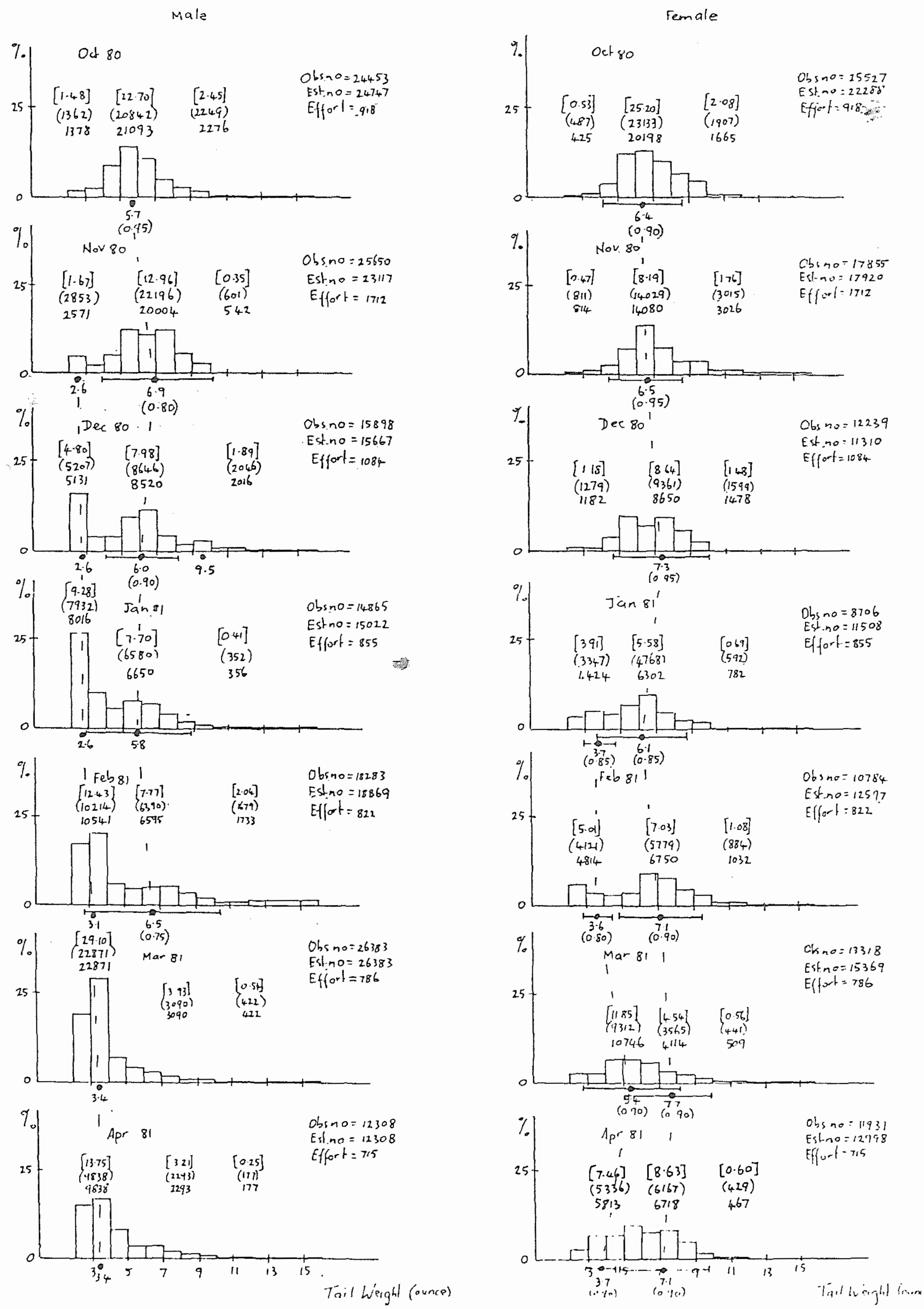

Figure 10 Histograms of estimated catch numbers by tail weight category, by sex and by month for 1981/82.

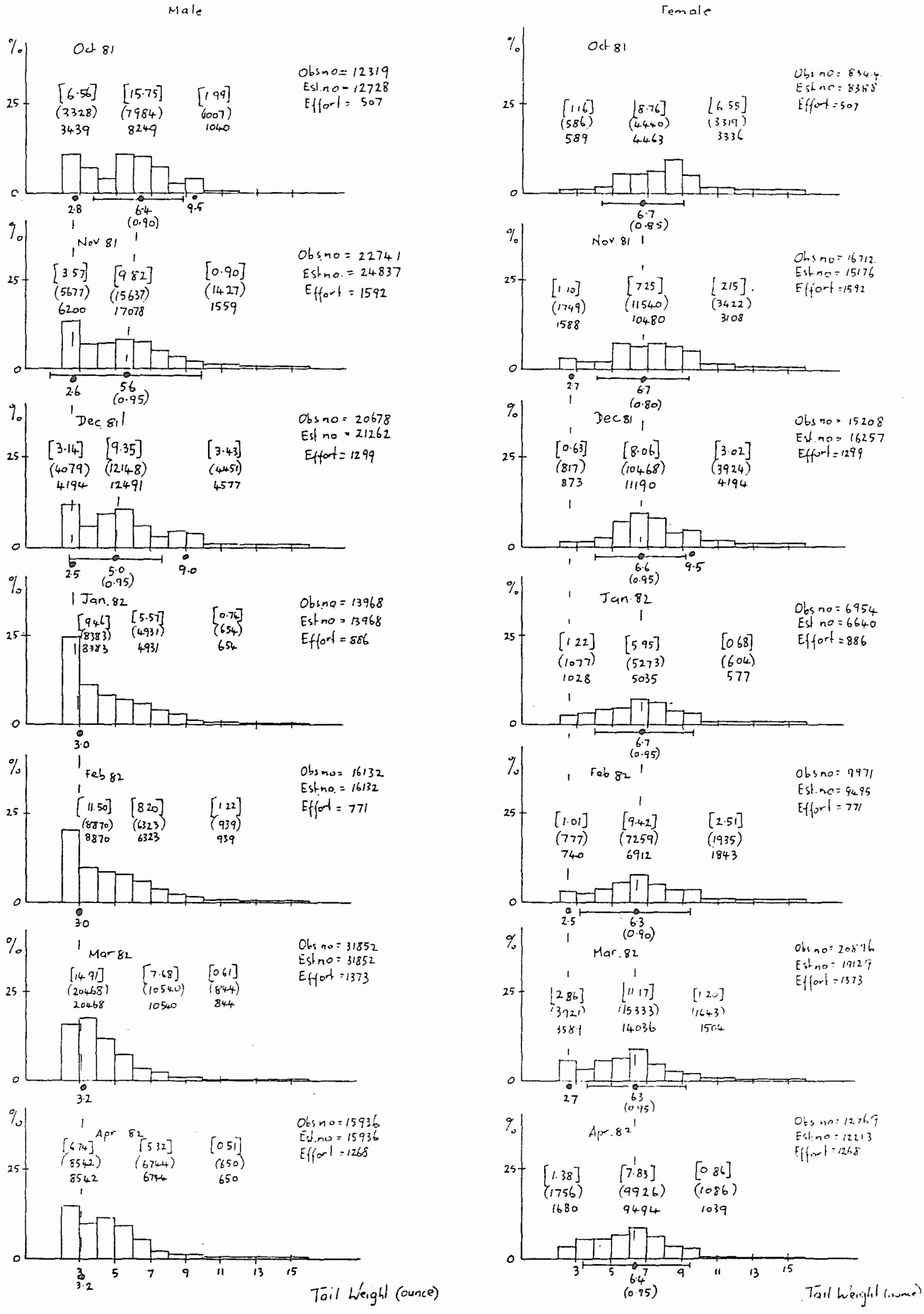

Figure 11 Histograms of estimated catch numbers by tail weight category, by sex and by month for 1982/83.

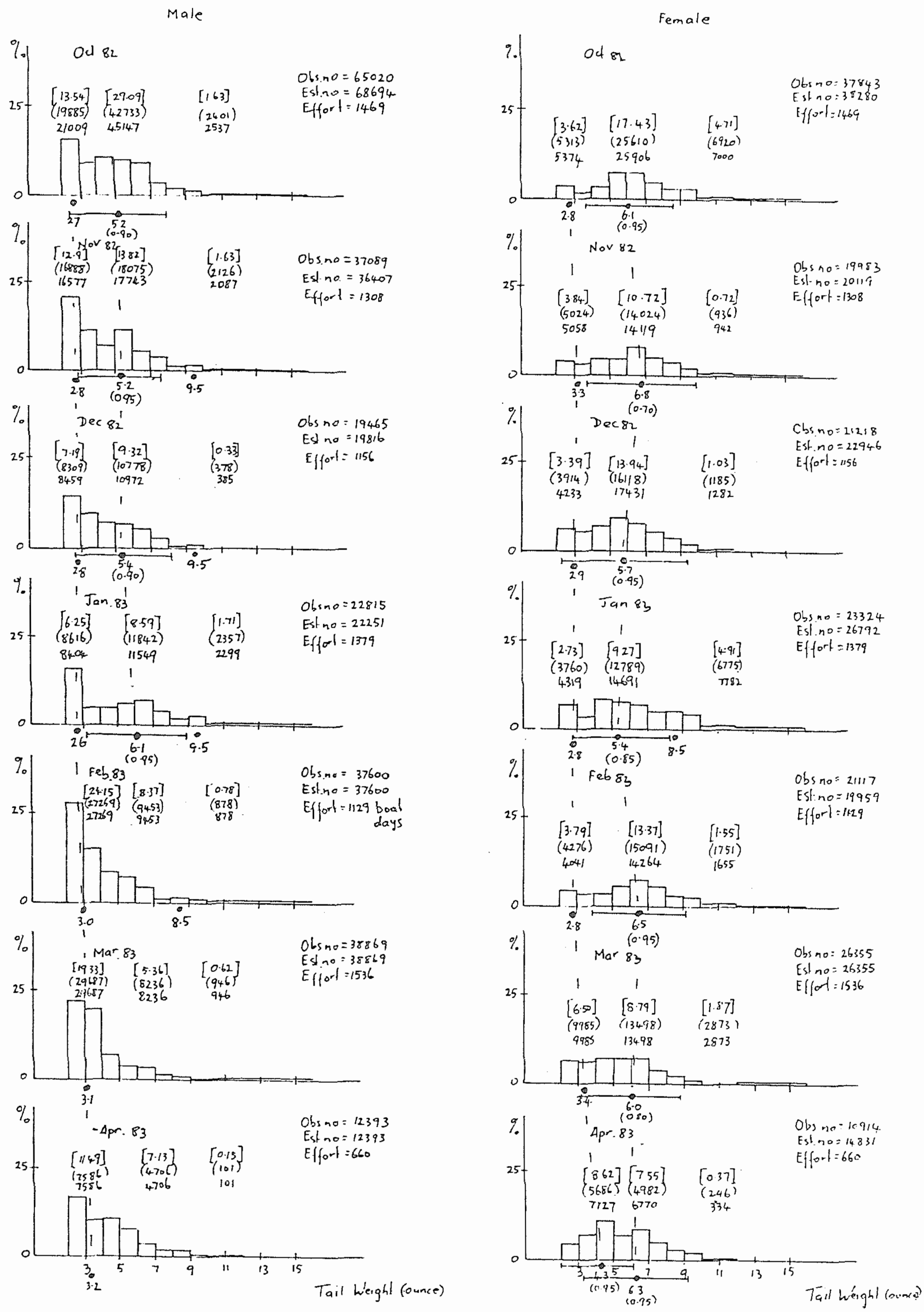

Figure 12 Plots of the relationship between total length and tail length.

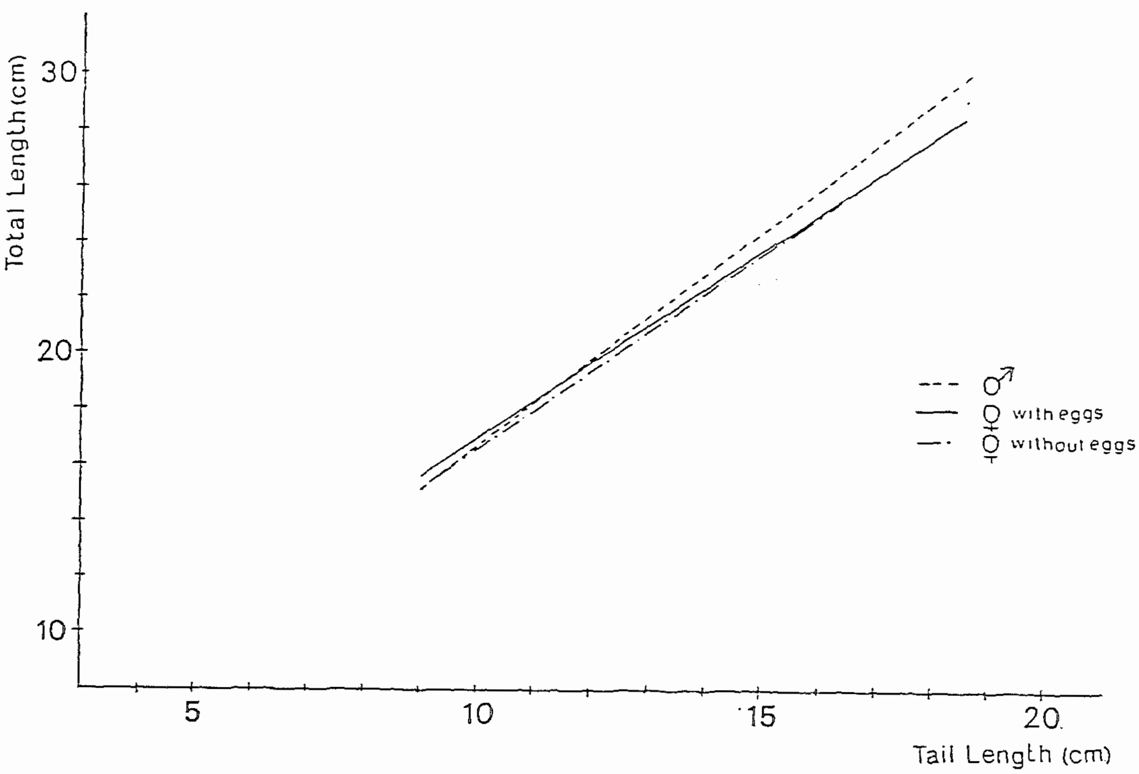

Figure 13 Plots of the percentages of egg bearing females by month; data sources are Landing Sites (a), and Mukalla Cold Store (b).

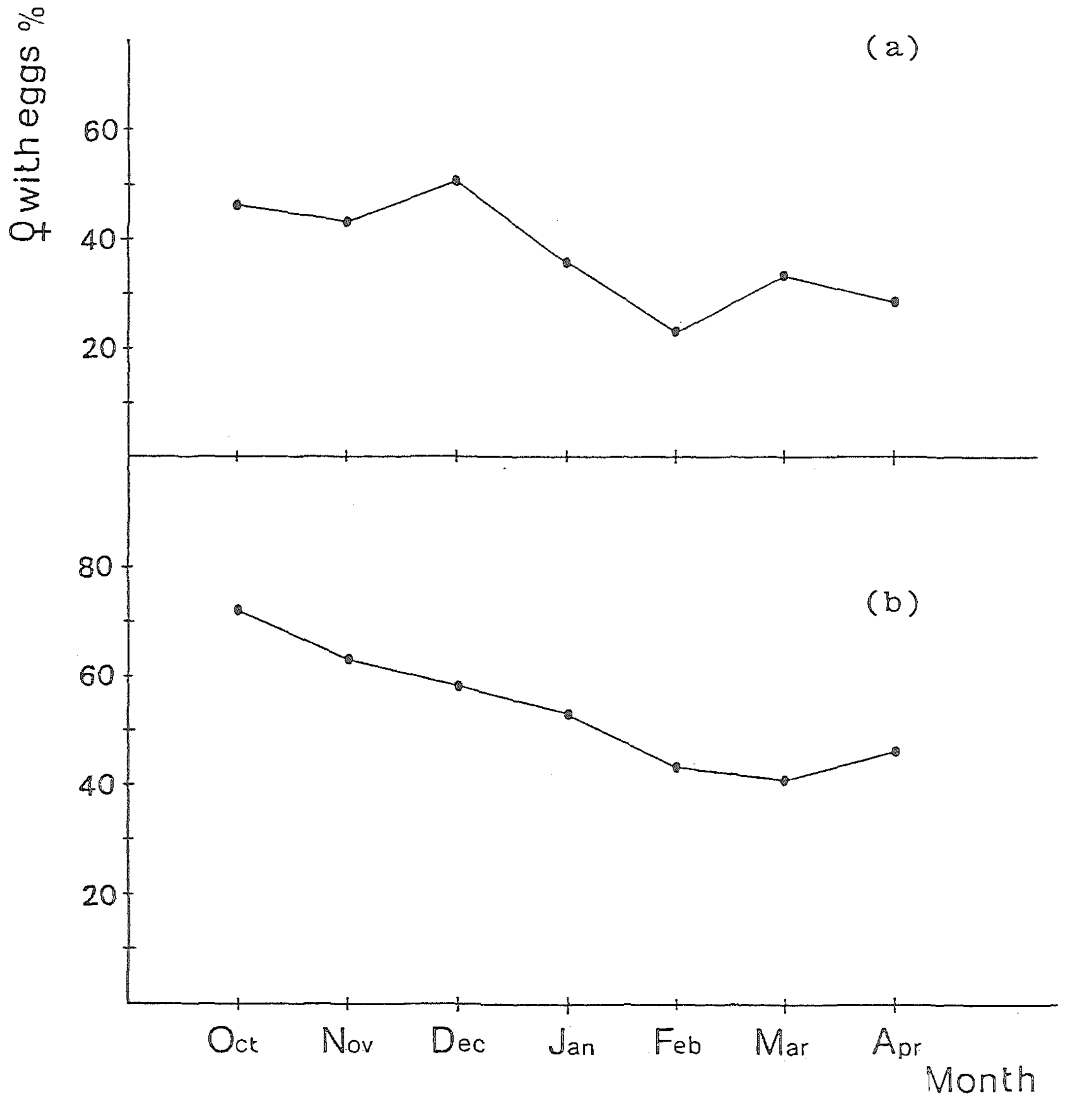

Figure 14 Plots of percentages of egg bearing females by tail length.

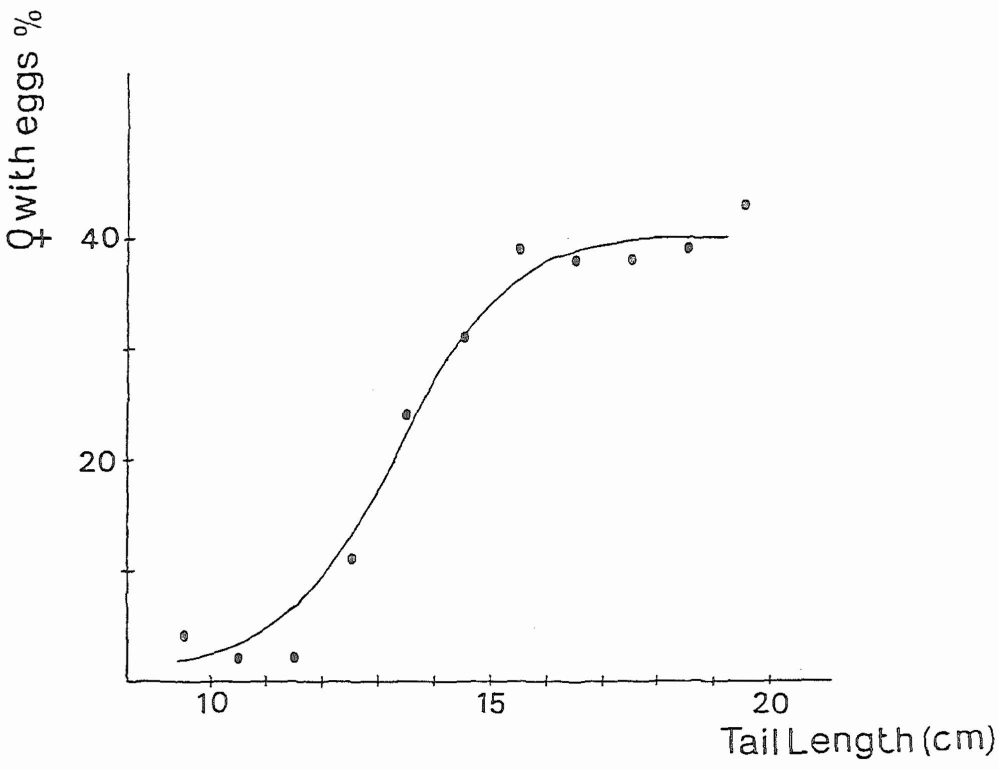

Figure 15 Plots of percentages of egg bearing females by tail weight.

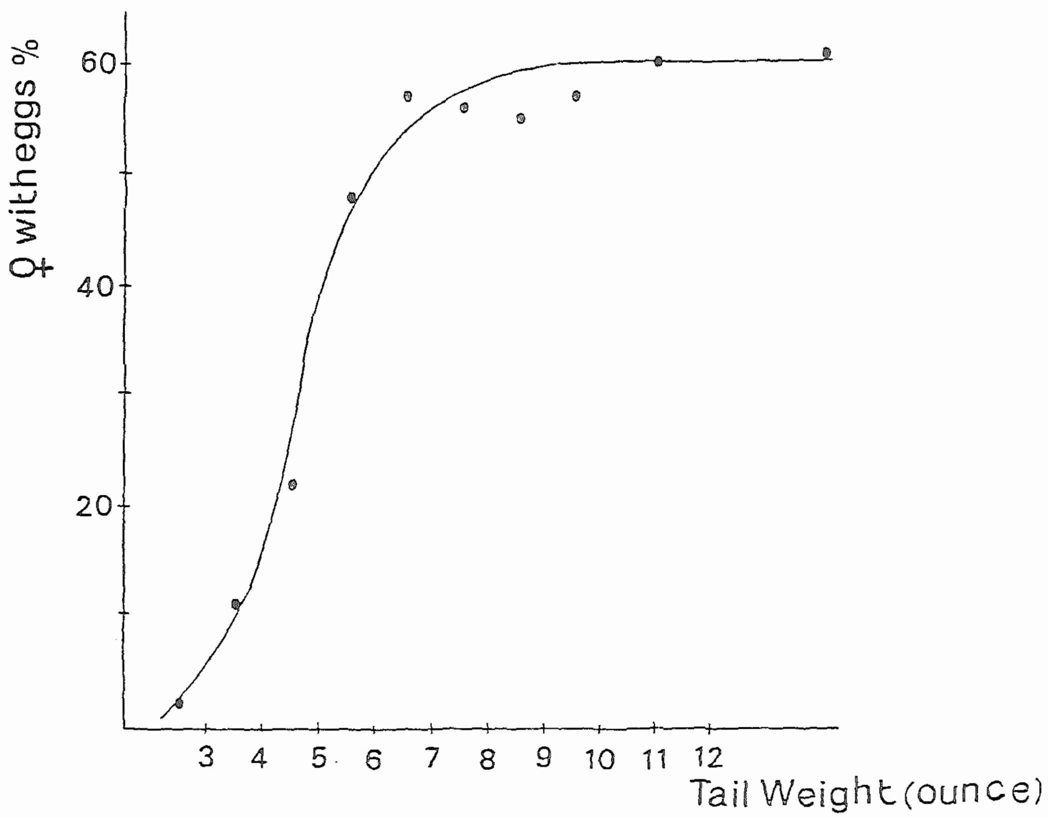

Figure 16 Plots of $\log_e$ catch numbers per unit effort by age for the males. (Vertical hatched lines represent ± a standard deviation either side of the means).

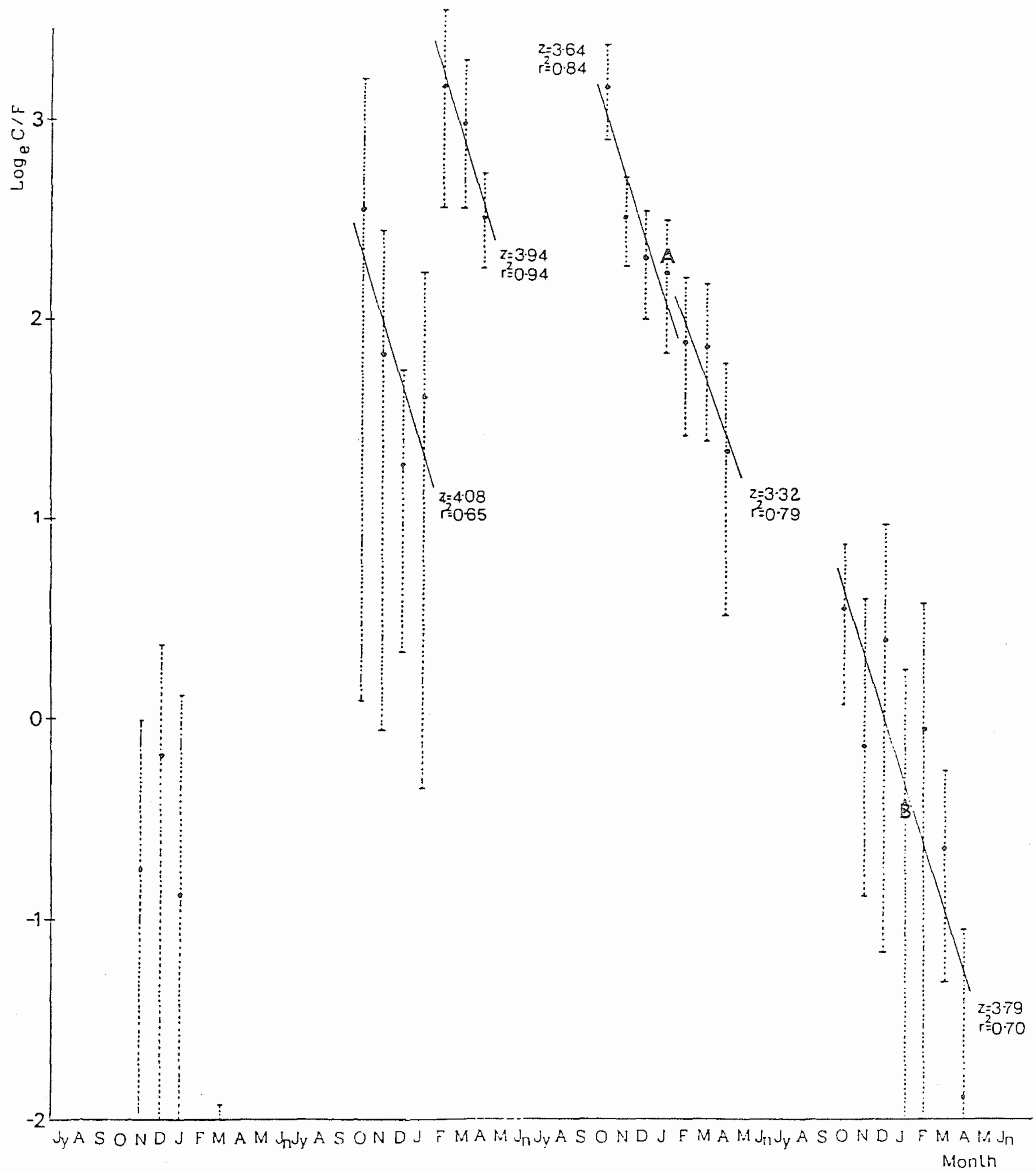

Figure 17 Plots of $\log_e$ catch numbers per unit effort by age for the females. (Vertical hatched lines represent ± a standard deviation either side of the means).

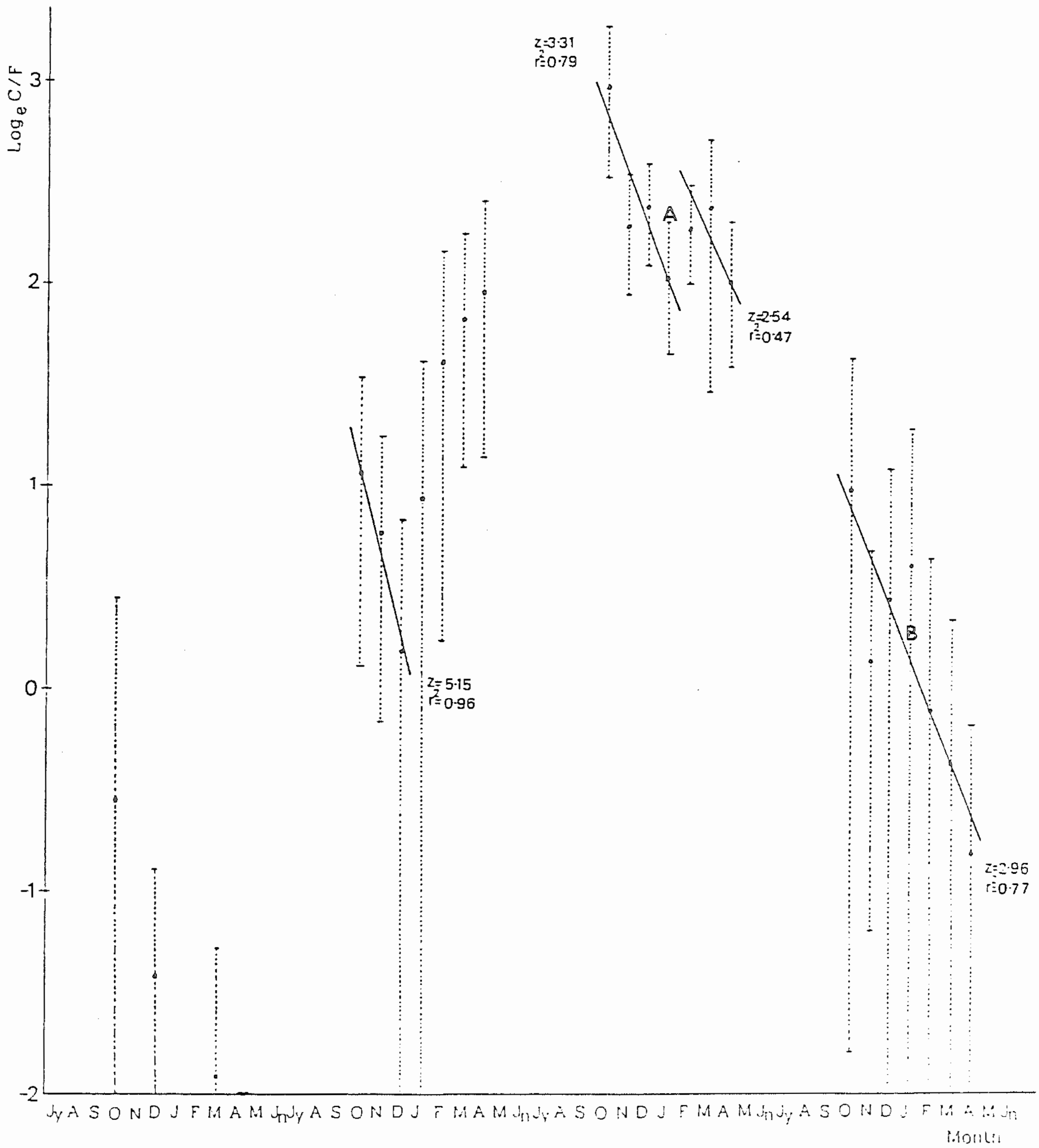

Figure 18 Plot of the relationship between total mortality coefficient and fishing effort

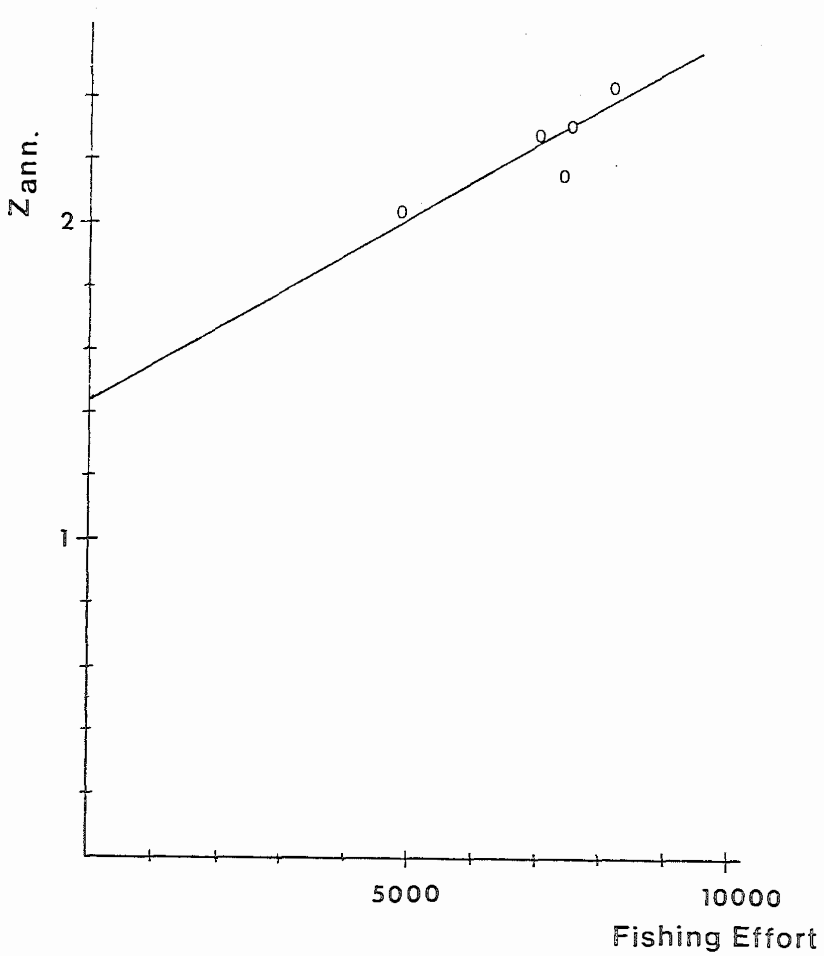

Figure 19 Plots of yields per (10000) recruits for a range of annual fishing mortality coefficients and a length at first capture of L_c = 10.0 cm.

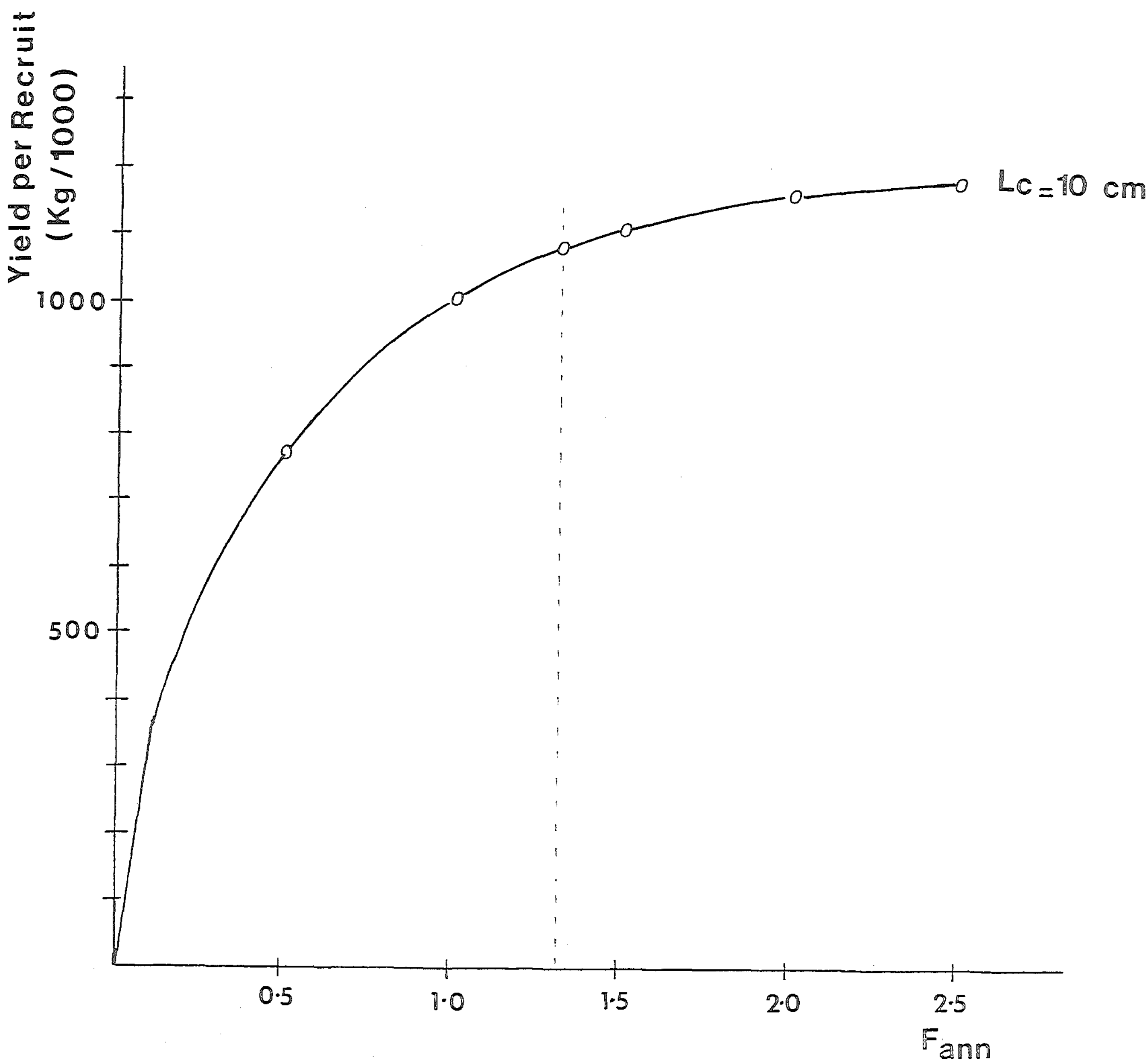

Table 1 Tail weights included in each tail weight grade

Tail Weight Grades	Tail Weights (ounces)
1	$\geqslant$ 2 to 3
2	$\geqslant$ 3 to 4
3	$\geqslant$ 4 to 5
4	$\geqslant$ 5 to 6
5	$\geqslant$ 6 to 7
6	$\geqslant$ 7 to 8
7	$\geqslant$ 8 to 9
8	$\geqslant$ 9 to 10
9	$\geqslant$ 10 to 12
10	$\geqslant$ 12 to 16
11	$\geqslant$ 16 to 20*

* Greater than 20 oz were included in a 'Mixed' category.

Table 2 Catch weights recorded at landing sites, estimated fishing efforts and associated catch weights per unit fishing efforts, by month.

Items	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.*	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980/81							1981/82							1982/83						
Catch Weights (tonne)	30.1	26.9	15.9	10.0	15.4	15.4	11.8	11.1	20.7	19.4	8.6	11.8	23.3	13.2	48.7	23.7	17.1	22.4	38.9	23.3	9.0
Fishing Efforts (boat days)	1206	4565	994	(654)	1051	1133	782	496	2241	1709	1409	996	1848	2340	2763	3357	1895	2321	1834	1998	681
Fishing Efforts (net days)	3152	12782	3472	(2641)	5125	5991	2977	2017	8847	7506	6036	6028	7794	7313	9948	14147	7866	11156	8891	8739	2850
Catches/Effort (kg/boat day)	25.0	5.9	16.0	15.4	14.7	13.6	15.1	22.4	9.2	11.3	6.1	11.8	12.6	5.6	17.6	7.1	9.0	9.7	21.2	11.7	13.2
Catches/Effort (kg/ net day)	9.6	2.1	4.6	3.8	3.0	2.6	4.0	5.5	2.3	2.6	1.4	2.0	3.0	1.8	4.9	1.7	2.2	2.0	4.4	2.7	3.2

* The small catch and effort for May has been included with the April data.

Table 3 Catch weights of tails packaged at the Mukalla Cold Store by tail weight grade and year

Years	Tail Weight Grades (kg)											Totals
	1	2	3	4	5	6	7	8	9	10	11	
1972/73	5940	14720	26460	27360	23000	19200	16860	10870	13280	8040	710	166440
1973/74	6980	9450	16040	16760	16720	10500	7300	4130	4800	2820	340	95840
1974/75	12860	10770	14950	14600	15860	11040	7300	3650	3710	1870	30	96640
1975/76	12140	10930	14620	16550	13990	9390	6190	4060	2470	1060	200	91600
1976/77	4730	4530	6660	7430	9020	6190	5970	4550	2260	1480		52820
1977/78	1020	1180	2320	4970	7730	6400	7040	6500	3730	2310		44250
1978/79	1440	1880	2570	5950	7180	4620	3810	3480	2540	2850		37040
1979/80	2740	5750	5950	7730	7740	6850	5320	4050	2270	2920		51329
1980/81	2940	3180	3700	7620	9070	7170	4500	3180	1620	2280		45260
1981/82	2870	2670	3610	5220	6030	5060	4010	3510	2310	2720		38010
1982/83	6180	5620	6550	8220	8850	5580	3860	3810	1400	2210		52280

Table 4 Numbers of purchases by the Mukalla Cold Store, by month

Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Totals
1977/78	983	494	565	407	392	271	313	227	3652
1978/79	1384	559	582	604	733	724	872	512	5970
1979/80	546	1108	1039	908	1096	1507	1154	586	7944
1980/81	918	1712	1084	855	822	786	715	96	6988
1981/82	507	1592	1299	886	771	1373	1268		7696
1982/83	1469	1308	1156	1379	1129	1536	660		8637

Table 5 Observed and estimated tail lengths at age, and observed and estimated ages at tail lengths.

Assigned Ages (yr)	Observed lengths (cm)		Est. Lengths (cm)		Est. Ages (yr)	
	Males	Females	Males	Females	Males	Females
1.79	10.5	10.2	9.3	9.7	1.96	1.82
1.87	10.3	10.2	9.8	10.2	1.92	1.82
1.96	11.2	10.5	10.3	10.7	2.11	1.89
2.04	10.5	11.2	10.8	11.1	1.96	2.03
2.13	11.3	11.9	11.2	11.6	2.13	2.19
2.21	11.2	11.4	11.6	11.9	2.11	2.08
2.29	12.3	13.3	12.0	12.3	2.35	2.53
2.79	13.4	14.6	14.2	14.4	2.62	2.88
2.87	14.1	14.7	14.5	14.7	2.80	2.91
2.96	14.1	15.4	14.8	15.0	2.80	3.12
3.04	14.4	14.5	15.1	15.3	2.88	2.85
3.13	15.4	15.2	15.4	15.6	3.17	3.06
3.21	14.7	15.0	15.6	15.8	2.96	3.00
3.29	15.8	15.7	15.9	16.1	3.30	3.21
3.79	18.5		17.3		4.31	
3.87	18.5	17.5	17.5	17.6	4.31	3.85
3.96	17.5	18.0	17.7	17.8	3.89	4.05
4.04	18.5	17.9	17.8	18.0	4.31	4.01
4.13	18.1		18.0		4.14	
4.21	18.2	17.5	18.2	18.3	4.18	3.85
4.29		19.5		18.5		4.76
4.87		20.0		19.5		5.04

Table 6 Observed mean tail weights by tail length for males.

Tail Length (cm)	Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Means
	1980/81						1981/82							1982/83							
>6 ~ 7					15 (1)									22 (3)		21 (1)					20 (5)
8				20 (1)			25 (1)					41 (7)		31 (10)	25 (5)	24 (5)	30 (2)	33 (2)	28 (3)		30 (38)
9		40 (1)		65 (2)	35 (1)	62 (2)			25 (1)			52 (8)		46 (17)	45 (13)	48 (7)	48 (5)	35 (9)	50 (14)	43 (2)	47 (82)
10	50 (1)	56 (5)	70 (1)	55 (31)	53 (6)	66 (11)	54 (15)		45 (2)		67 (4)	74 (22)	51 (9)	58 (34)	57 (25)	64 (13)	62 (9)	52 (40)	66 (52)	61 (8)	60 (288)
11	73 (5)	78 (5)	80 (1)	75 (71)	68 (11)	83 (15)	56 (10)		65 (8)	69 (10)	69 (31)	98 (44)	65 (13)	77 (44)	71 (21)	78 (24)	76 (27)	71 (81)	86 (84)	83 (20)	77 (525)
12	107 (4)	107 (7)	117 (3)	91 (76)	96 (31)	100 (64)	92 (36)	80 (3)	99 (10)	94 (19)	86 (42)	110 (48)	82 (45)	103 (52)	97 (36)	108 (24)	90 (13)	93 (74)	110 (66)	104 (39)	98 (692)
13	135 (6)	142 (6)	138 (5)	124 (53)	120 (35)	128 (54)	122 (80)	85 (4)	114 (32)	110 (20)	112 (26)	138 (45)	102 (49)	133 (55)	125 (37)	130 (20)	124 (31)	121 (62)	139 (60)	127 (20)	124 (700)
14	155 (13)	167 (28)	185 (10)	166 (32)	148 (24)	148 (40)	148 (70)	120 (1)	143 (54)	134 (21)	139 (15)	163 (44)	125 (44)	160 (45)	151 (47)	169 (44)	153 (30)	156 (52)	173 (42)	160 (18)	154 (674)
15	169 (11)	199 (28)	211 (8)	217 (40)	198 (5)	181 (19)	175 (73)	155 (6)	169 (52)	159 (27)	155 (6)	200 (34)	157 (34)	186 (45)	181 (56)	197 (57)	183 (37)	195 (32)	218 (24)	196 (15)	186 (609)
16	204 (5)	234 (15)	253 (3)	249 (32)	226 (16)	231 (16)	231 (20)	185 (4)	211 (31)	196 (21)	205 (4)	235 (15)	188 (19)	208 (11)	216 (14)	226 (32)	218 (28)	245 (5)	259 (11)	214 (9)	222 (311)
17	250 (2)	244 (11)	313 (3)	322 (24)	244 (9)	256 (7)	288 (9)	200 (1)	242 (22)	213 (10)	240 (2)	279 (5)	231 (13)	244 (6)	271 (12)	279 (8)	237 (20)	284 (5)	313 (9)	295 (6)	264 (184)
18	280 (1)	400 (2)		353 (10)	285 (2)	270 (1)	333 (3)	250 (1)	282 (10)	290 (8)	280 (1)	452 (2)	284 (8)	332 (2)	315 (3)	308 (5)	290 (5)	395 (1)			312 (65)
19		320 (1)		377 (7)	327 (3)	350 (1)	200 (1)	250 (1)	336 (8)	300 (1)			303 (2)	370 (1)	375 (1)	375 (2)	332 (5)		360 (1)		339 (35)
20				470 (2)			370 (1)		403 (7)	379 (2)			345 (2)			380 (1)					337 (15)

Table 8 Observed mean tail weights by tail length for females with eggs.

Tail Length (cm)	Oct.	Nov.	Dec.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Means
	1 9 8 0 / 8 1							1 9 8 1 / 8 2							1 9 8 2 / 8 3						
> 6 - 7																					
8																					
9																					
10										54 (1)											54 (1)
11											110 (1)	104 (1)									107 (2)
12								105 (2)			120 (1)	150 (1)									120 (4)
13	150 (1)			158 (4)	133 (1)	140 (3)	133 (3)	157 (3)	139 (1)		120 (1)	159 (3)	125 (1)	145 (3)		155 (1)		130 (1)		150 (4)	146 (30)
14	190 (2)	175 (8)	185 (2)	198 (5)	165 (2)	218 (6)	185 (4)	173 (3)	145 (4)		150 (3)	204 (14)	141 (4)	185 (9)	180 (1)	193 (5)	187 (6)	188 (3)	198 (2)	173 (2)	185 (85)
15	213 (4)	198 (9)	227 (7)	249 (11)	216 (9)	216 (5)	196 (13)	196 (9)	179 (5)	197 (8)		242 (26)	170 (12)	210 (17)	210 (6)	226 (24)	216 (7)	195 (4)	221 (5)	232 (5)	215 (186)
16	206 (5)	221 (8)	274 (8)	277 (6)	224 (14)	255 (4)	240 (13)	239 (7)	223 (15)	189 (2)	200 (1)	258 (23)	206 (11)	252 (9)	235 (9)	262 (13)	235 (10)	237 (9)	243 (3)	262 (4)	240 (174)
17	335 (2)	280 (4)	285 (4)	365 (6)	262 (6)	282 (4)	311 (14)	273 (14)	258 (13)	260 (4)	270 (1)	303 (12)	246 (7)	267 (3)	275 (3)	304 (14)	269 (7)	270 (2)	345 (2)	330 (1)	287 (123)
18		308 (4)		408 (5)	287 (3)		320 (3)	293 (13)	292 (9)	285 (4)	247 (4)	340 (7)	290 (9)	270 (1)	309 (4)	369 (7)	338 (9)	344 (5)	355 (2)	340 (1)	317 (90)
19				380 (2)		380 (1)	387 (3)	326 (14)	315 (4)	336 (3)		401 (4)	341 (4)		400 (1)	372 (6)	372 (10)				355 (52)
20				400 (1)	420 (1)			411 (7)	411 (3)	353 (3)		436 (1)	401 (6)		405 (1)	439 (5)	430 (2)				410 (30)
21									495 (2)							471 (1)	440 (1)				475 (4)

Table 9 Constants in the power curve relationship between tail weight and tail length, and associated correlation coefficients and numbers of data pairs.

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
MALES								
1980-81	$a(x10^{-4})$	1343	1030	1280		683	644	3772
	b	2.687	2.819	2.776		2.987	2.961	2.316
	r^2	0.978	0.978	0.992		0.964	0.994	0.986
	n	9	11	8		13	12	11
1981-82	$a(x10^{-4})$	1008	1143	402	1369	2017	2067	1017
	b	2.772	2.669	3.116	2.651	2.513	2.595	2.747
	r^2	0.948	0.971	0.985	0.992	0.980	0.980	0.998
	n	12	8	12	10	9	11	11
1982-83	$a(x10^{-4})$	1419	869	1174	1726	604	1110	1195
	b	2.687	2.866	2.764	2.595	3.025	2.819	2.765
	r^2	0.997	0.996	0.991	0.996	0.989	0.992	0.995
	n	13	12	14	12	11	11	9
FEMALES (WITHOUT EGGS)								
1980-81	$a(x10^{-4})$	3855	932	4965		1311	2206	6748
	b	2.273	2.784	2.239		2.720	2.498	2.086
	r^2	0.974	0.967	0.977		0.978	0.990	0.938
	n	7	13	7		12	9	11
1981-82	$a(x10^{-4})$	286	878	1017	3193	2688	1113	662
	b	3.241	2.812	2.740	2.316	2.387	2.778	2.875
	r^2	0.956	0.972	0.981	0.988	0.981	0.922	0.988
	n	13	14	12	11	7	10	13
1982-83	$a(x10^{-4})$	1227	1423	500	3894	401	2180	1051
	b	2.717	2.644	3.056	2.283	3.129	2.528	2.779
	r^2	0.996	0.997	0.978	0.987	0.992	0.994	0.981
	n	13	14	14	12	13	10	11
FEMALES (WITH EGGS)								
1980-81	$a(x10^{-4})$	3355	4615	5672		6629	3053	5081
	b	2.414	2.272	2.234		2.201	2.417	2.268
	r^2	0.821	0.976	0.948		0.923	0.977	0.929
	n	5	5	4		8	7	6
1981-82	$a(x10^{-4})$	1884	4209	1843	1408	12635	6165	1319
	b	2.615	2.302	2.585	2.660	1.858	2.214	2.690
	r^2	0.976	0.977	0.978	0.985	0.927	0.989	0.995
	n	7	9	9	7	7	10	8
1982-83	$a(x10^{-4})$	13090	4113	5549	5825	1861	2994	1974
	b	1.891	2.328	2.245	2.208	2.614	2.479	2.625
	r^2	0.936	0.979	0.991	0.983	0.962	0.922	0.976
	n	6	7	9	8	6	5	6

Table 10 Observed and estimated tail weights at age.

Assigned Ages (yr)	Observed Weights (oz)		Estimated Weights (oz)	
	MALES	FEMALES	MALES	FEMALES
1.79	2.75	2.80	1.87	2.03
1.87	2.67	3.00	2.14	2.29
1.96	2.63	2.90	2.46	2.61
2.04	2.73	3.25	2.76	2.90
2.13	3.03	2.97	3.12	3.24
2.21	3.23	3.83	3.44	3.54
2.29	3.27	4.00	3.77	3.85
2.79	5.77	6.40	5.93	5.89
2.87	5.90	6.67	6.29	6.22
2.96	5.47	6.53	6.69	6.59
3.04	5.95	6.07	7.04	6.92
3.13	6.50	6.63	7.44	7.28
3.21	-	6.67	-	7.61
3.29	-	6.60	-	7.93
3.79	9.50	-	10.21	-
3.87	9.50	-	10.53	-
3.96	9.17	9.50	10.87	10.46
4.04	9.50	8.50	11.18	10.74
4.13	8.50	-	11.51	11.05

Table 11 Constants in the linear relationship between total length and tail length, and associated correlation coefficients and numbers of data pairs.

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Males								
1980-81	a	0.41	3.00	-0.49	-	1.37	0.48	1.92
	b	1.52	1.48	1.74	-	1.54	1.58	1.54
	r^2	0.95	0.90	0.96	-	0.94	0.96	0.91
	n	53	116	35	-	344	155	188
1981-82	a	0.75	1.20	0.55	0.22	1.26	2.00	0.21
	b	1.59	1.53	1.55	1.56	1.48	1.51	1.54
	r^2	0.92	0.94	0.97	0.98	0.94	0.94	0.98
	n	402	262	257	150	152	314	254
1982-83	a	1.13	0.37	1.02	1.00	0.79	0.28	1.94
	b	1.57	1.60	1.56	1.64	1.57	1.66	1.49
	r^2	0.95	0.98	0.98	0.98	0.88	0.98	0.96
	n	366	288	244	237	376	376	138
Females (without eggs)								
1980-81	a	3.79	2.18	3.48	-	2.54	2.33	4.30
	b	1.27	1.47	1.40	-	1.44	1.42	1.34
	r^2	0.85	0.96	0.98	-	0.93	0.92	0.86
	n	32	103	16	-	161	94	184
1981-82	a	2.03	1.74	2.44	2.16	1.57	2.12	0.62
	b	1.46	1.46	1.38	1.38	1.44	1.46	1.48
	r^2	0.97	0.94	0.96	0.98	0.92	0.94	0.99
	n	129	108	102	79	36	173	96
1982-83	a	2.90	2.02	1.88	1.31	1.48	1.69	1.76
	b	1.39	1.44	1.48	1.49	1.49	1.50	1.48
	r^2	0.83	0.97	0.97	0.97	0.95	0.98	0.98
	n	121	109	180	170	194	217	116
Females (with eggs)								
1980-81	a	6.23	6.92	-0.46	-	4.07	4.68	4.52
	b	1.14	1.17	1.66	-	1.34	1.27	1.33
	r^2	0.79	0.86	0.92	-	0.83	0.88	0.96
	n	14	33	21	-	26	38	24
1981-82	a	-0.27	6.18	2.86	2.23	3.60	2.81	1.21
	b	1.61	1.19	1.36	1.38	1.31	1.42	1.44
	r^2	0.92	0.90	0.97	0.96	0.93	0.89	0.97
	n	62	75	62	29	12	99	55
1982-83	a	4.35	1.88	3.18	1.52	-0.35	1.19	1.28
	b	1.33	1.45	1.40	1.49	1.60	1.53	1.52
	r^2	0.78	0.93	0.95	0.96	0.92	0.93	0.96
	n	49	28	78	54	27	14	17

Table 12 Estimated total mortality coefficients by sex and sampling site.

Sampling Site	Year	Males	Females	Sexes Combined
Landing Sites	1982/83	2.43	2.04	2.17
	1981/82	1.96	1.73	1.81
	1980/81	2.36	2.24	2.28
	3 years	2.25	2.00	2.09
Mukalla Cold Store	1982/83	2.73	1.94	2.18
	1981/82	2.10	1.96	1.77
	1980/81	2.41	2.30	2.38
	3 years	2.43	1.93	2.10

Years	Total Mortality Coefficients
1982/83	2.42
1981/82	2.16
1980/81	2.33
1979/80	2.26
1978/79	2.04
1977/78	1.91
1976/77	2.41
1975/76	2.97
1974/75	2.99
1973/74	2.64
1972/73	2.05

Table 14 Parameter values used in the estimation of the natural mortality coefficient.

Item	Parameter Values
Catch Numbers:	C_m / C_f = 1.43 (Mukalla Cold Store data)
	= 1.44 (Landing Sites data)
Ages at First Capture:	t_c^m = 2.233 (= t_r^m)
	t_c^f = 2.487 (= t_r^f)
Total Mortality Coefficients:	Z_m = 2.33(Jones & Van Zalinge method)
	Z_f = 2.04(Jones & Van Zalinge method)
Stock Numbers at Age Zero	N_o^m/N_o^f = 1 (assumed)

Table 15 Estimates of the relative numbers of recruits.

Sexes	Estimated Relative Number of Recruits at:				
	Beginning Oct.	Mid-Season	Beginning Oct.	Mid-Season	Combined
Males	11.82	26.21	16.62	1.26	55.91
Females	3.63	11.61	15.41	6.39	37.04
Combined	15.45	37.82	32.03	7.65	92.95

Table 16 Estimates of the yields per (10000) recruits, for combinations of annual fishing mortality coefficients and lengths at first capture.

Lengths at First Capture	Annual Fishing Mortality Coefficients 0.5	1.0	1.35	1.5	2.0	2.5
			(kg)			
10.0	786	1020	1093	1114	1159	1183
11.0		1019		1116	1164	
12.0		1004		1108	1161	

Appendix 1 Estimated catch numbers by tail length by month for males.

Tail Length (cm)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980/81							1981/82							1982/83						
5				NO SAMPLING					79												
6	69														1138						
7	192				66	183		11	235						2670		324				
8	329	640			66				318				688		5145	1434	975	359	102	460	
9	1576	296			329	205	73	99	706				929		9554	1371	975	813	1457	2475	178
10	1809	1638	420		2276	795	471	609	944	242		655	3003	825	13218	4200	1013	249	4776	10743	653
11	4097	1574	420		5121	2025	1002	1755	558	1016	1023	7123	5465	1361	13258	3615	965	3715	11411	13277	1945
12	2576	2067	1274		6037	3698	3383	1658	1658	924	1594	10908	4820	3310	12398	6683	1300	1665	11134	8123	3249
13	3837	1870	2114		3153	4107	3197	2198	2265	3007	1590	6736	4817	3960	22221	4757	825	3925	7876	5507	1412
14	8167	8790	4648		1913	2655	2088	2836	2881	5654	2269	3232	4185	3616	9936	6434	1693	3205	5496	4286	1048
15	6906	5970	3388		1480	408	834	2961	3871	5480	2493	1549	3072	2997	2771	6356	3382	3900	1598	1400	656
16	3768	2669	1274		1626	2406	950	978	3708	2790	1658	1137	1610	1837	1113	2381	1989	2300	150	662	383
17	1261	2237	1274		1395	1333	311	673	856	2017	804	342	532	1133	438	1711	473	1781	115	378	529
18	630	384			459	474	27	107	421	1091	532	173	563	721	259	459	641	629	16		
19	1877	296			582	568	40	85	469	849	85		107	185		96	105	739		77	
20					160			51	393	502	82		173	135			68	267			
21					29			74													
TOTALS	37094	28431	14812		24692	18857	12376	14095	19362	23572	12130	31855	29964	20130	94119	39497	14728	23547	44131	47388	10053

Appendix 2 Estimated catch numbers by tail length by month for females without eggs.

Tail Length (cm)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980/81							1981/82							1982/83						
6								14							259						
7		320			102	183			55						259	91	59			354	
8	137		420					25	79						1419	364	324		86		
9	260	1550					27	111	158	81					548	456			86		173
10	1452	1747			66	22	73	375	314				650	62	829	861		1826	481	738	178
11	137		420		803	341	335	727	196	161	136		1160	62	3934	921	975	3104	1417	2874	653
12		1685		NO SAMPLING	1371	1388	1084	451	1643	136	220	1820	758	123	2695	820	324	2108	3196	5612	1240
13	1261	2875	420		1314	1609	2166	427	263	843	176	1169	2954	917	2995	2609	666	2792	4631	2459	2154
14	6344	4287	840		785	1227	1961	480	686	570	880	930	2408	1821	5366	2964	811	3922	2886	3895	1830
15	6906	5956	2534		1341	1069	2825	1503	1708	1815	1722	1169	2691	819	5381	1357	2160	3410	5172	4837	1794
16	1877	2481	1694		887	3224	2299	670	1806	1998	1253	930	2901	552	5280	2044	2134	2394	2551	2553	880
17	1877	666			1406	2545	930	529	1256	1738	1030	687	1592	1346	683	1170	816	1523	1972	625	1046
18	630	1567	420		919	1249	611	431	460	1034	357	415	721	773	455	1114	1061	1013	799	569	215
19		88			619		414	386	314	847	210		348	537	129	96	913	849	234	155	42
20		88			262		40	194	510	143	41		173	430		268	318	267			
21		320			145		40			286	41			123					16		
22					29									123							
TOTALS	20881	23630	6748		10049	12857	12805	6323	9448	9652	6066	7120	16356	7688	30832	15135	10561	23208	23527	24671	10205

Appendix 3 Estimated catch numbers by tail length by month for females with eggs.

Tail Length (cm)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr
	1980/81							1981/82							1982/83						
8	260																				
9	137																				
10	260																				
11	137			NO SAMPLING								173	93								
12		88					46		111				124		200						
13	630				68	341	309	126	165	81		243	228	96	1464		362		188		188
14	1261	1789	840			157	296	250	221	570	85	655	1311	437	3962	911	238	841	218	329	261
15	2508	2128	2954		416	1042	305	335	503	570	507		2630	1220	5089	1261	1533	704	421	686	319
16	3138	927	3388		445	1864	242	1260	578	1602	433	173	2058	976	3172	2319	752	970	695	386	184
17		789	2114		379	998	180	975	1219	1877	251	482	1180	695	438	690	1119	920	218	88	47
18	1261	557			350	179	46	170	1006	1054	305	584	812	684	256	730	487	559	91	155	47
19					58			268	600	416	345		475	418		364	348	581			
20		296			29	22			391	216	210			588		268	215	303			
21										143							37	70			
TOTALS	9597	6574	9296		1745	4603	1424	3384	4794	6529	2136	2310	8911	5114	14581	6543	5091	4948	1831	1644	1046

Appendix 4 Estimated catch numbers by tail weight grade by month for males.

Tail Weight Grade	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980 / 81								1981 / 82									1982 / 83				
1	1008	2033	4416	6229	4490	7714	3622	428	2321	5318	4194	5108	5312	8316	4137	16399	12216	5874	7278	16303	14265	3882
2	1110	1076	1073	2382	5266	11622	4057	271	1491	2645	1958	2389	2438	9063	2796	9221	6541	3877	2252	8536	13132	2435
3	4343	2240	1101	1310	1570	2688	1878	439	796	2835	3176	1772	2240	6179	3218	11120	4276	2968	2206	4860	4581	2539
4	6961	5307	2613	1686	1170	1698	844	208	2271	3284	3775	1462	2044	3893	2548	10519	6538	2712	2903	4200	2678	1818
5	5476	4782	3187	1638	1203	1220	859	119	2155	2832	2016	1227	1571	1895	1528	9219	3284	2244	3203	2415	2317	828
6	2565	5430	1228	916	1342	703	386	35	1692	2107	1030	809	956	1153	658	3422	2147	1220	1865	408	950	422
7	1428	2670	529	348	815	318	306	20	553	1330	1568	547	632	510	401	1713	676	185	809	473	594	368
8	819	1397	767	165	566	226	179	17	840	830	1276	241	379	453	335	1285	814	223	1241	258	288	77
9	448	347	445	87	513	65	97	10	200	758	668	236	292	206	238	559	169	57	243	75		24
10	295	368	539	104	1348	131	80	15		801	1017	177	268	185	77	1563	428	105	815	72	64	
TOTALS	24453	25650	15898	14865	18283	26383	12308	1562	12319	22741	20678	13968	16132	31853	15936	65020	37089	19465	22815	37600	38869	12393

Appendix 5 Estimated catch numbers by tail weight grade by month for females without eggs.

Tail Weight Grade	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980/81								1981/82							1982/83						
1	35	69		842	1474	1083	684	41	221	1007	387	488	740	2739	819	3918	2269	2628	3218	2618	4004	924
2	270	174	226	879	906	1066	1481	52	203	550	412	540	521	1359	1182	2184	1480	2114	951	2037	3690	1501
3	474	509	582	417	574	2689	1297	75	206	659	719	624	726	2348	1134	2927	2182	2300	2427	1701	4581	2193
4	1001	964	1507	369	491	2288	1372	138	395	1579	1009	560	797	973	1327	2843	1760	2324	2102	2600	3855	1060
5	1519	218	769	893	1132	1650	965	126	381	1199	1474	626	956	1895	1173	2379	1708	1836	1373	2989	3658	1461
6	1287	1448	1228	229	811	854	1062	29	845	1204	950	591	526	907	767	652	1074	1220	1272	1972	1781	909
7	598	763	764	152	611	636	577	27	552	964	279	340	502	556	366	913	1284	557	1348	1247	890	325
8	431	221	426	151	302	287	358	27	252	755	271	197	330	288	244	1413	523	482	1076	1032	794	322
9	33	243	148	19	257	100	183	19	100	496	401	66	234	124	76	447	203	102	382	255		38
10	93	322	133	16	129	147	113	11	195	512	391	19	298	206	216	261	285	158	407	270	271	
TOTALS	5741	4931	5783	3967	6687	10800	8092	545	3350	8925	6293	4051	5630	11395	7304	17937	12768	13721	14556	16721	23524	8736

Appendix 6 Estimated catch numbers by tail weight grade by month for females with eggs.

Tail Weight Grade	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	1980/81								1981/82							1982/83						
1		96	337		67		40				28				133							
2	120	233	36	257		107	129	45		31	46		59	340	273			294	701	97		122
3	1203	458	583	506	151	141	313	126	59	110	174	180	202	618	429	585	436	742	1471	243		289
4	5187	2091	1307	1106	415	369	897	226	691	998	1537	380	610	2271	698	4549	754	1550	1502	500	643	505
5	4888	5869	1319	1340	1133	646	859	171	760	1307	1868	746	923	2606	1243	5353	2627	1530	1716	1381	854	487
6	3502	1810	1404	825	1118	502	821	55	363	1455	1783	678	764	1565	1151	3911	1561	1144	848	1088	416	260
7	2556	572	882	370	510	286	578	57	1216	1559	975	340	391	742	646	2170	743	1159	809	258	467	281
8	1402	882	298	220	415	205	31	47	756	1208	1237	372	493	659	533	1799	640	594	827	430	324	199
9	479	452	124	27	160	65	107	11	501	671	641	118	245	247	205	671	169	204	486	165		35
10	449	461	166	88	128	197	64	11	648	448	626	89	654	453	154	868	285	280	408	234	127	
TOTALS	19786	12924	6456	4739	4097	2518	3839	749	4994	7787	8915	2903	4341	9501	5465	19906	7215	7497	8763	4396	2831	2178

Appendix 7 Calculations of yields per (10000) recruits for annual fishing mortality coefficient of 2.0 and length of first capture of 10.0 cm.

Months	Mortality Coefficients F_{month}	M_{month}	Recruit Numbers	Numbers at Start of Month	Catch Numbers	Mean Lengths (cm)	Mean Ind. Weights (gm)	Catch Weights (kg)
Oct.		0.071	1662	1662				
½ Nov.		0.071		1548				
½ Nov.	0.286	0.071		1444	196	10.1	68	13
Dec.	0.286	0.071		1250	301	10.5	75	22
Jan.	0.286	0.071		875	210	10.9	84	18
Feb.	0.286	0.071	4069	4682	1125	11.4	94	105
Mar.	0.286	0.071		3278	788	11.8	103	81
Apr.	0.286	0.071		2295	551	12.2	113	62
May-Sept.		0.071		1607		13.2	141	
Oct.	0.286	0.071	3446	4573	1099	14.3	175	192
Nov.	0.286	0.071		3202	769	14.6	186	142
Dec.	0.286	0.071		2242	539	14.9	197	105
Jan.	0.286	0.071		1569	377	15.2	206	78
Feb.	0.286	0.071	823	1099	462	15.5	216	100
Mar.	0.286	0.071		1345	323	15.7	227	73
Apr.	0.286	0.071		942	226	16.0	237	54
May-Sept.		0.071		659		16.7	266	
Oct.	0.286	0.071		463	111	17.3	296	33
Nov.	0.286	0.071		324	78	17.5	305	24
Dec.	0.286	0.071		227	55	17.7	314	17
Jan.	0.286	0.071		159	38	17.9	323	12
Feb.	0.286	0.071		111	27	18.1	332	9
Mar.	0.286	0.071		78	19	18.3	341	6
Apr.	0.286	0.071		54	13	18.4	349	5
May-Sept.		0.071		38		18.9	372	
Oct.	0.286	0.071		27	6	19.3	396	3
Nov.	0.286	0.071		19	5	19.4	403	2
Dec.	0.286	0.071		13	3	19.5	410	1
Jan.	0.286	0.071		9	2	19.7	416	0.9
Feb.	0.286	0.071		6	2	19.8	423	0.7
Mar.	0.286	0.071		5	1	19.9	429	0.5
Apr.	0.286	0.071		3	0.8	20.0	435	0.3
TOTALS					7328			1159