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IMPACTS OF THE 1981 AND 1982 TEXAS CLOSURE ON BROWN SHRIMP YIELDS

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National Oceanic and Atmospheric Administration
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John V. Byrne, Administrator

NATIONAL MARINE FISHERIES SERVICE
William G. Gordon, Asst. Administrator for Fisheries

INTRODUCTION

Between May 22 and July 15, 1981, and again between May 26 and July 14, 1982, trawl fishing was prohibited in the 200 mile Fishery Conservation Zone (FCZ) off the Texas coast. The FCZ was closed to implement part of the "Fishery Management Plan for the Shrimp Fishery in the Gulf of Mexico," developed by the Gulf of Mexico Fishery Management Council. The main purpose of the regulation was to improve yields by allowing newly recruited brown shrimp (*Penaeus aztecus* Ives) to grow larger before beginning harvesting.

Since 1959, Texas state waters (the Territorial Sea, 0-9 nautical miles from the coast) have been closed for 45-60 days every year during the May-July period. The Texas FCZ was closed for the first time in 1981. This paper examines the effects of the Texas FCZ closure on yields of brown shrimp in the Texas FCZ area, and on yields from the Gulf-wide brown shrimp stock. The analysis of the 1981 closure is a final report; analysis of the 1982 closure is a preliminary report only, with a final report projected for December 1983. Analyses for both years contain three analytical facets:

(1) Description of the size structure of the brown shrimp population in the FCZ, as deduced from a cooperative research cruise program.

(2) A yield per recruit analysis for the Texas FCZ area, using the population structure from the research cruises, growth information derived by Parrack (1981), and mortality estimates developed by Nichols (1982).

(3) A simulation of Gulf-wide fishing patterns and resulting yields that could have been expected in 1981 and 1982 had the FCZ been open. This analysis is based on a virtual population analysis of historical brown shrimp catches developed by Nichols (1981).

Additionally, more empirical analyses of catch per unit effort and effort patterns are presented in a discussion of both years together.

The analyses presented here differ in several ways from the preliminary reports on the 1981 closure presented in December 1981. The virtual population analysis of brown shrimp developed by Parrack (1981) that was used as a baseline in the preliminary report has been updated and extended (Nichols 1982), incorporating six important changes:

(1) Analyses were extended to include inshore as well as offshore catches.

(2) Results of intensive examination, editing, and correction of the historical fishery statistics have been incorporated.

(3) Procedures for estimation of size composition of box graded catches were modified.

(4) Age determination of brown shrimp was modified to allow for better representation of the effects of sexually dimorphic growth.

(5) Procedures for estimating effort where no direct interview observations exist were modified.

(6) Development of the natural mortality rate estimate was re-examined and a new estimate was reported.

Details of these changes were reported by Nichols (1982).

ANALYSIS FOR 1981

SIZE STRUCTURE IN THE FCZ

The OREGON II conducted a trawl survey off the Texas coast from June 6 until July 2 1981, in part to estimate the size composition of the shrimp population in the FCZ. Data from cruises by the GUS III during the 1960's were used to design the OREGON II cruise, in an attempt to maximize the precision of the estimates of the population's size composition. The GUS III showed a strong relationship between shrimp mean size and depth, with a weaker relationship between CPUE and depth. Day/night differences in CPUE were indicated. Large variations in CPUE along shore were observed, but no systematic variation useful to sampling design was detected. Variations in CPUE and size with calendar time were confounded with along-shore, depth, and time of day variations in the complete data set. Examination of subsets of the data suggested that any relationships between average size or CPUE and calendar time were weak, and probably varied from year to year.

The strategy employed was to sample in detail along the depth gradient. Sampling would be conducted as close to the end of the closure period as possible, and be restricted to less than 3 weeks duration to minimize calendar time effects. All sampling would be done at night. One hundred samples were believed possible with these restrictions. Variations along shore were assumed to be random. Economy of operation required that samples be taken in non-random order, eliminating any possibility of isolating calendar time effects, and time x along-shore interactions. Operation of the OREGON II is limited to depths over 5 fathoms.

The Texas coast was stratified by 1 fathom increments (except for two deeper strata of 30-35 and 35-50 fathoms). The number of samples in each stratum were allocated based on variances of CPUE from the GUS III data and spatial area in each stratum. Each sample was taken by trawling across the entire width of its stratum in the direction of maximum depth gradient (40 ft. shrimp trawl, 8 foot by 40 inch wood door). To avoid overloading the net and reducing CPUE, trawls were raised after 30 minutes, emptied, and trawling resumed for those samples where stratum "width" exceeded thirty minutes.

Sampling for the size distribution study took place between June 6 and June 28. Problems in operations prevented sampling the 35-50 for strata as designed. Three non-random, nighttime samples taken for other purposes (2 of them on July 1) were available, and were treated as if they were random samples. Apparent low abundances outside 35 fathoms probably minimize negative impacts from this substitution. Shrimp CPUE's proved to be high, and subsampling of trawl hauls was instituted during operations. All shrimp caught were counted by species. Subsampled shrimp were sexed and measured for total length. Total lengths were converted to tail lengths using Brunenmeister's (1980) conversions.

The fraction of the population in any sex and size category was estimated using a ratio estimator:

$$P_i = \frac{\sum_{k=1}^{K} \frac{A_k}{\sum_{j=1}^{J_k} a_{jk}} \sum_{j=1}^{J_k} n_{ijk}}{\sum_{k=1}^{K} \frac{A_k}{\sum_{j=1}^{J_k} a_{jk}} \sum_{j=1}^{J_k} N_{jk}}$$

where

P_i = the fraction of the population in the ith sex and size class

K = the number of depth strata

J_k = the number of samples in the kth stratum

A_k = the fractional area of the kth stratum

a_{jk} = the length of the jth trawl in the kth stratum (a random variable in this formulation)

n_{ijk} = the number of shrimp in size class i in the jth trawl in the kth stratum

N_{jk} = the number of shrimp in all sex and size classes in the jth trawl in the kth stratum

For comparison with 1982, and to adjust for growth taking place during the cruise, all samples were projected to the size expected on July 1, 1981 using the growth curves derived by Parrack (1981).

The estimated size and sex composition in the FCZ for July 1, 1981 is shown in Fig. 1. Ultimately, the age composition of the population at the beginning of the closure period is required. Assuming that the mortality rate is constant over the size range considered, that the growth curves derived by Parrack (1981) hold, and that migration may be ignored, the population structure in the FCZ was projected back to May 22, 1981 (Fig. 2).

YIELD PER RECRUIT ANALYSIS FOR THE TEXAS FCZ

The effects within the FCZ of allowing fishing vs. closure in the Texas FCZ were examined using a yield per recruit type model, substituting the population structure of May 22 for "recruitment". The effects of growth, natural mortality, and fishing mortality were simulated using a weekly time step. Estimates of fishing mortality rate (F) for the FCZ alone are not available, so results are presented as a function of F. Migration across the boundaries of the Texas FCZ was assumed to be zero during the closed period. As a practical matter, this implied that all shrimp detected in the FCZ during the cruise were there throughout the closed period, and that no shrimp entered the Texas FCZ after the cruise. I believe the effects of this simplification are minor, causing if anything an overestimate of any gain due to closure.

Yield per recruit results are very sensitive to estimates of natural mortality rate (M). Nichols (1982) concluded that the best, stockwide estimate of M was 0.28 per month, but that values between 0.15 and 0.4 should be considered plausible. For analyses like this closure analysis, where only part of the range of the stock is considered, possible regional variation in M may also be considered. Evidence for regional variation in M is weak, but what evidence there is suggests that M for offshore Texas waters may be lower than the stockwide average:

(1) Results of a 1960's tagging experiment off the Texas coast, with sufficient effort data to allow a meaningful estimate, produced an estimate of M of 0.22 per month (Parrack 1981). Additionally, errors commonly associated with tagging experiments tend to produce overestimates of M.

(2) Analysis of catch and effort data from restricted alongshore areas of the Gulf suggest the M may be lower in Texas and extreme western Louisiana than elsewhere (Nichols, unpublished). Estimates made for arbitrary subsets of the data should be used only for exploratory purposes, not for firm estimates, but a trend is suggested (Fig. 3).

For these reasons, yield per recruit results are presented for two estimates of M: 0.15 per month (Fig. 4) and 0.28 per month (Fig. 5).

Increases in yield per recruit with closure of the FCZ are indicated for both M estimates for moderate to high values of F (above 0.5 per month), and even with low values of F (down to 0.1 per month) with M = 0.15. Assuming that closing the FCZ only delayed fishing, and that fishing intensity would be the same whenever the area opened, the percent gain in yield from the FCZ can be calculated (Fig. 6). Projected gain is much larger if M is low (e.g. 37% at F = 1.0), but marked gain is projected even with M = 0.28 (e.g. 14% at F = 1.0). If fishing intensity increased after the closure above the level that would have occurred without closure, the percent gain would be reduced. Thus, Fig. 6 shows the theoretically maximum gains for the two values of M presented.

GULF-WIDE YIELDS, HAD THE FCZ BEEN OPEN

Part of the difficulty in evaluating the FCZ closure is that any effects must be recognized in a fishery where annual yields have varied up to four fold primarily due to variations in recruitment. The most direct way to account for variation due to recruitment is to estimate recruitment strength via virtual population analysis (VPA). Fishing on this estimated recruitment, had the FCZ been open, can be simulated by computer and compared with observed yields.

The VPA analysis for 1960-1981 presented by Nichols (1982) was extended to August 1982. Procedures were the same as used by Nichols (1982) except for estimation of "starting F" for cohorts extant in August 1982. Estimates of age-specific F's for August were based on August fishing effort, the distribution of the stock in August as inferred from CPUE, and past (1971-1980) observed relationships between F, fishing effort, and CPUE-derived stock distribution patterns (from Nichols 1982) using a procedure similar to the effort standardization procedure of Honma (1974). (This same procedure was used in the preliminary report.)

The complete virtual population analysis provided estimates of age-specific fishing mortality rate and stock size estimates on a monthly basis from 1960 to August 1982. Recruitment in 1981 appears to have been very strong, roughly similar to 1977 and 1978 levels.

Probably the most reasonable prediction of what fishing mortality rate would have been had the FCZ been open can be derived using the age-specific F estimates from recent years when the FCZ was open. I generated fishing mortality rate estimates using the average 1977-1978 F's from the virtual population analysis. These years appear to be most comparable to 1981 in both recruitment and fishing intensity. To set the magnitude of F's for 1981, I assumed that effort expended in August indexed the effort "available" for 1981, which was 93.7% of the average effort for 1977-78 in August. Fishing mortality rates for May-December 1981, had the FCZ been open, were estimated to be 0.937 times 1977-78 average levels using this "August multiplier". The January-April fishery (prior to closure) in 1981 had contracted considerably from previous years, in that effort was only 31.9% of the 1977-78 winter levels. Assuming that this contraction represents a change (probably in fuel price economics) that would have continued, winter fishing had the FCZ been open was simulated by multiplying 1977-78 F levels by 0.319. Only small contributions to yields from shrimp protected during the 1981 closure can be expected after April 1982, and these yields would enter into the analysis of the 1982 closure, so estimation of changes in yield due to the 1981 closure was terminated at the end of April 1982.

Gulf-wide yields observed with the FCZ closed were higher than yields projected for fishing with the FCZ open by 3.9 million pounds. Virtually all the increase was attained in July, August, and September (yields up 4.4 million pounds), more than counterbalancing the reduction in yield in May and June (down 0.7 million pounds). The change in yield with closure estimated by market size category is shown in Figure 7. Strong gains occurred in the 31-40 and 26-30 count categories. A marked increase in the 68+ category is also evident.

The estimated benefit of 3.9 million pounds agrees very well with the projected benefit of 4.1 million pounds made in the preliminary report. The major difference between the preliminary findings and these final estimates is a modification of the preliminary estimates of high short term (May-August) gain in yield (12 million pounds), and concomitant reduction standing stock (20%). At the time of the preliminary report, the best available estimates (Parrack 1981) of directed fishing effort indicated that 1981 effort was markedly lower then 1977-78 effort. New effort estimates have been calculated by Nichols (1982) and it now appears that the estimated effort for 77-78 was too high by 50%. Because of this, the preliminary estimates of short term increase and reduction in standing stock appear to be overestimates. May to August yield changes due to closure are now estimated to be 3.3 million pounds, with a 4% reduction in August standing stock.

ANALYSIS FOR 1982

SIZE STRUCTURE IN THE FCZ

Survey cruise activity for the 1982 closure was part of the cooperative SEAMAP program for sampling the entire northern and western Gulf. For this report, only the results for the Texas FCZ portion are discussed. For the SEAMAP work, the coastal waters (between 5 and 50 fm) were stratified by depth (1 fm strata to 25 fm, $2^1/2$ fm strata to 30 fm, 5 fm strata to 50 fm) and alongshore using the commercial statistical areas (2 areas per stratum). Four vessels participated in the sampling relevant to the Texas FCZ. Unfortunately, comparability experiments were conducted only between two of the vessels, and by chance, these experiments took place in an area of very low shrimp densities, and thus were not very useful. Therefore, no "standardization" for vessel was performed for these calculations. Procedures for estimating population size distribution were the same as those applied in 1981.

The size and sex composition of the FCZ population (projected to July 1) is depicted in Fig. 8. By comparison with the 1981 data of Fig. 1, the 1982 size distribution is shifted toward larger sizes. The catch rates indicate that abundance (by number) in the FCZ in 1982 may have been only one tenth the 1981 level. The projected age composition at the beginning of closure is shown in Fig. 9.

YIELD PER RECRUIT ANALYSIS FOR THE TEXAS FCZ

The same procedures used for the 1981 data were used for 1982. Yield per recruit values (as functions of fishing mortality rate) are presented for M = 0.15 (Fig. 10) and for M = 0.28 (Fig. 11). Estimated maximum changes in yield (%) are shown in Fig. 12. For M = 0.15, a benefit from closure is indicated for F's greater than 0.4, but the size of the benefit is considerably lower than that indicated for 1981 (e.g. about 10% gain for F = 1.0, vs. 37% for 1981). For M = 0.28 a net loss is indicated for 1982 (about 10% at F = 1.0), versus a net gain (14% at F = 1.0) for 1981.

Over the range of uncertainty for natural mortality rate, possible benefits in yield per recruit near likely values for F range between plus and minus 10%. It is not possible to put definitive confidence limits on yield per recruit results, but most experts would not attach much significance to changes under 10%. I believe the best interpretation of the 1982 data is that benefits from the closed area, if any, were small.

GULF-WIDE YIELDS, HAD THE FCZ BEEN OPEN

The procedures used to estimate Gulf-wide benefits for 1981 were applied to 1982 for May through August, and projections were made for the rest of the 1982 fishing season (through April 1983). Recruitment levels for 1982 (estimated via the VPA) appear similar to 1979 levels. 1979 and 1982 are also years of poorer recruitment following years of very high recruitment, so fishing mortality rates for 1979 were used as the baseline pattern for what fishing would have been had the FCZ been open. The "August multiplier" to adjust the 1979 pattern to 1982 effort levels was 1.02. Fishing mortality rates projected for September through December were 1.02 times 1979 values for both the FCZ open and closed cases. Winter rates (January through April) were assumed to be 0.328 times the 1979 level with the FCZ open. The winter rates for 1982 (i.e. following the 1981 closure) were used to simulate winter fishing for 1983 with the FCZ closed.

A net decrease in yield is projected in response to the FCZ closure for 1982. Short term (May-August) estimated changes in yield is -1.3 million pounds. For the May-April 1982-83 season, a -1.4 million pound change is projected. Thus, the estimated increase in July of 1.9 million pounds was insufficient to offset the estimated decrease in yield of 2.2 million pounds in May and June. By August, increases in catch rates off Texas due to closure were essentially gone, and a 1 million pound decrease in yield was estimated for August. Estimated changes in catch by market size category through August 1982 are shown in Fig. 13.

The simulation results just presented used the most straightforward choice for fishing had the FCZ been open, but the 2.2 million pound reduction predicted for May and June may be unrealistic. (The May-June reduction estimated for 1981 was only 0.7 million pounds). Examination of 1979 fishing effort and fishing mortality levels indicated in 1979 particularly intense fishing in May and June, rather uniquely so compared to other years, so May-June 1982 fishing might not have reached 1979 levels had the FCZ been open. An alternative simulation was conducted, replacing the 1979-based fishing mortality rates for May and June with the 1982 rates, effectively assuming that impacts of the closure on May-June yields were negligible. This assumptions is in accord with 1981 findings, and represents a current "best estimate" for an upper limit on effects of the 1982 closure.

The alternative simulation predicts a small net benefit from the 1982 closure. Short term gain is estimated to be 0.5 million pounds. Over the entire season, a 0.4 million pound gain is projected. A 1.3 million pound gain is projected for July, but a 0.9 million pound reduction is projected for August. Under this scenario, any benefit from the protection of the closure was realized in July, but the actual August effort distribution was slightly less "efficient" than the simulated fishing, had the FCZ been open.

ADDITIONAL ANALYSES

Some simpler, more empirical techniques can provide insight into the effects of closure on abundance and effort patterns. Looking at CPUE alone over several years incorporates both recruitment variation and possible closure effects. However, as a first approximation, a "good year" in one area tends to be a good year throughout the Gulf. Therefore, examining the ratio of "CPUE off Texas:CPUE elsewhere" may eliminate some of the effects of variation due to recruitment. Similarly, studying the fractional distribution of effort in the Gulf yields a different perspective than a study of effort rates directly.

For both July (Fig. 14) and August 1981 (Fig. 15) the ratio of CPUE for offshore Texas to offshore CPUE elsewhere in the Gulf was the highest ever observed. Additionally, the few years that approached 1981 in either July or August did not approach 1981 in both months, so 1981 was quite unique compared to all preceding years. Unusually high recruitment in Texas compared to Louisiana could also produce the high 1981 ratios, but inshore sampling in Texas and Louisiana (through E. Klima, pers. comm.) indicated a fairly average recruitment year in Texas, and an outstanding year in Louisiana, exactly the opposite of the offshore ratios in July and August, so the uniquely high values appear to be attributable to the closure. Any increased depletion of stocks elsewhere in the Gulf as well as enhancement off Texas can contribute to the high 1981 ratio, but no negative impacts of any depletion in 1981 seem likely. Since 1960, CPUE's offshore (for areas other than Texas) have exceeded 1981 levels in both July and August only in 1960, 1967, 1971, and 1977.

The CPUE ratios for the rest of the 1981 fishing season are shown with the 1960-1980 average values in Figure 16. The high ratios of July and

August were above the long term (1960-1981) average, but by September the ratios had fallen to just below the long term average, and remained near that average for the rest of the season. The "Texas advantage" in CPUE associated with the 1981 closure was apparently fully utilized by September.

In 1982, the July CPUE ratio was again high compared to pre-closure years, but lower than the 1981 value (see Fig. 14). By August 1982, the ratio dropped just below the long term average (see Fig. 15). The CPUE advantage in Texas associated with the 1982 closure appears to have been used up in the first 2-3 weeks of the season.

If the fishing effort formerly exerted off Texas simply moved to other areas in the Gulf during the 1981 and 1982 closures, the ratio of June effort to August effort (Gulf wide) might be expected to remain at levels prevailing before the closure. If that pre-closure Texas effort simply tied up, the June:August effort ratio should show a drop for 1981 and 1982. The observed pattern (Fig. 17) could be interpreted either way: 1981 and 1982 show a drop compared to the most recent years (1978-1980), but do not show a drop relative to either the long term average (1960-1980) or to more recent years preceding 1978. Prior to 1976, a substantial portion of the Gulf wide effort in June was exerted off Texas (Fig. 18). Since 1976, the fraction of effort has been dropping, suggesting that for most recent years there was very little effort for the Texas closure to exclude. Whether the patterns of the most recent years in June:August ratio and percent of June effort off Texas represent a short term fluctuation or trends that would have continued in 1981 and 1982 is not clear, so I conclude that this empirical evidence is not conclusive regarding possible shifting of effort from Texas to elsewhere during the closure.

Texas' fraction of Gulf wide brown shrimp effort exerted in August was higher in 1981 than in all but two years since 1960 (Fig. 19). For both 1981 and 1982 the percent of effort off Texas stands above values seen throughout the 1970's, indicating that a definite shift associated with the closure has occurred. Although the percent of effort off Texas in 1981 and 1982 was only slightly higher than the values for the early 1960's, the amount of effort has increased so much that comparison of 1981 and 1982 with the early 1960's does not appear very meaningful. Actual August efforts off Texas in 1981 and 1982 were the highest ever, with only 1972 approaching them. I conclude that the Texas closure inspired a shift of effort to offshore Texas after the area opened.

The preferential shift of effort to Texas in 1981 appears to have continued through the fall (Fig. 20), even though the CPUE advantage associated with the closure was gone by September. Apparently the catch rates off Texas, although no longer markedly higher than elsewhere, remained high enough (on the strength of the high recruitment in 1981) that much of the effort that shifted to Texas in August remained there.

DISCUSSION

A marked difference was indicated in effects of closure in 1981 and 1982, primarily due to differences in offshore recruitment pattern. Shrimp in the FCZ were smaller in 1981 than in 1982, and thus had more growth potential, and benefited from protection. Because the 1982 shrimp in the FCZ had attained a larger size, they had less growth potential left to benefit from closure. Whether the potential change in yield in the FCZ in 1982 was plus or minus is hidden in the uncertainty around the natural mortality rate estimates, but in any case, the change was small. Behavior of the CPUE ratios suggested that elevated abundance off Texas from the 1981 closure lasted into September. For 1982, a Texas abundance "advantage" appeared in July only, and was essentially used up by early August.

The reason why shrimp in the FCZ were larger in 1982 is not certain, but several factors may have contributed:

(1) the main wave of inshore recruitment may have been earlier in 1982 than 1981, such that when the shrimp moved offshore (even if at the "normal" time), they had already attained a larger size

(2) only the "early" portion of recruitment survived to enter the FCZ waters, and thus the average size was larger. Two factors might produce such a pattern:

   a. high pre-recruit natural mortality of the potential "middle" part of the recruitment wave

   b. high fishing mortality in the inshore waters

(3) migration of shrimp did not extend as far offshore in 1982 as it did in 1981.

(4) lower population sizes in 1982 could allow some compensatory increase in growth at the early ages

It is not clear at the time whether the recruitment pattern of 1981 or 1982 has been or will be more common. Klima et al. (this report to Council) have noted that although (inshore) recruitment was lower in 1982 than 1981 (by the VPA in this paper, 22% lower), 1982 inshore catches were down only 5% in Texas, and down less than 1% in Louisiana compared to 1981. This suggests the role of inshore fishing mortality may have been particularly important.

I must stress that the estimated changes in gulfwide yield of +3.9 million pounds in 1981, -1.4 to +0.4 million in 1982 represent small percentage changes (about +4%, and -2% to +1%). Even the 1981 changes are not sizeable enough to be considered detectable by the simulation techniques available had they not been attained in a predictable pattern over a short portion of the year's landings. Because of this, some investigations were made on the sensitivity of the simulation results to the input data. I believe there are four areas where consequences of particular assumptions and specific parameter estimates warrant expanded discussion. The natural mortality rate (M) estimate, the "August multiplier" assumption for determining F had the FCZ been open, the effects of discarded or otherwise unreported catch, and the estimation of "starting-F" for the initial population analysis.

To examine the effects of the natural mortality rate estimates of changes in yield, the virtual population analysis and the simulations of fishing with the FCZ open were rerun using M values of 0.15 and 0.4 per month. These values appear to be limits for a "plausible range" (Nichols 1982). Changes in yield (million pounds) for these different values of M are (along with the best estimate of 0.28):

	M = 0.15	M = 0.28	M = 0.4
1981 Final (May-April)	+1.8	+3.9	+3.6
1982 May-August base estimate	-1.3	-1.3	-0.3
1982 Projection (May-April)	-1.3	-1.4	-0.4

The estimates of change in yield are surprisingly stable for the three choices of M. Note that the directions (sign) of change were not modified by varying M.

Sensitivities of yield estimates to changes in the "August multiplier" values were tested by varying the values between 0.5 and 2. Results for 1981 are shown in Fig. 21; 1982 in Fig. 22. For 1981, the estimate of the benefit changes rapidly as 1981 effort is decreased relative to 1977-78, but the sign of change is positive throughout the range. For the 1982 base estimate, the pattern is very similar, but the estimated change is shifted downward. Overall projected benefit would become positive if the effort level for 1982 were higher or lower relative to 1979.

If discarding were a constant fraction of landings for the FCZ both open and closed, the effects of ignoring discards in the analysis would probably be minimal. The extent of discarding probably varies in a complex manner in response to relative abundances of small and large shrimp, total catch rates, prices, and since 1981, changes in regulations. Analytically, it is not possible to separate rigorously the effects of the changes in the count law from the closure effects; examination of the 1981 estimated catches of 68+ count shrimp with and without closure showed an increase with closure/Texas count law change, but virtually all the increase was in May and June, when fishing in Texas waters was low. I concluded I could not predict changes in discarding practice, and must ignore any effects. Qualitatively, the FCZ closure might be expected to reduce discarding, so any gains from closure may be underestimated.

Discussions of the sensitivity of VPA results in general to problems with estimation of "starting-F" are widespread in the fisheries literature. Over the entire catch history of a cohort, inaccuracy in the starting F estimate tends to be damped out as one works backward toward estimates of F and stock size shortly after recruitment. For the analysis of the 1982 closure, the relevant history is currently only 4 months long, so any inaccuracy in starting F can still have a major effect on the analyses. Particularly because the changes in yield estimated with closure are so small, it must be stressed that changes in yield estimated for 1982 are <u>preliminary</u>. Upon the near-completion of the catch histories for 1982 recruitment in 1983, confidence in the accuracy of the 1982 analysis should be improved.

Some concern has been expressed about the possible effects of the sudden pulse of activity upon opening the closed area in 1981, particularly regarding depleting of the stock to the detriment of subsequent recruitment. This problem is unlikely to have occurred. For one thing, the preliminary estimate of 20% reduction in August 1981 stock was too high; a 4% reduction appears more realistic. Second, brown shrimp stocks have not shown much predictable relationship between parent stock size and subsequent recruitment (see Fig. 23). Third, parent stock for the 1982 recruitment were at levels similar to those of the recent several years (Fig. 24). Fourth, 1982 recruitment, although weaker than 1981 recruitment, was not all that low (down 22% from 1981, and slightly higher than 1980, according to the VPA estimates). A higher percentage of the 1982 recruitment does appear to have been cropped in inshore waters than in 1981, however.

CONCLUSIONS

Closure of the Texas FCZ appears to have produced an ample increase in yields, both from the FCZ, and gulfwide, in 1981. For 1982, benefit in the FCZ, if any, was small, and a small gulfwide loss is possible. Changes in yield for 1982 are smaller as a percentage than 1981, and are not really detectable in any meaningful sense. With 1981 and 1982 taken together, the base estimate of benefit from the closure is +2.5 million pounds.

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NICHOLS, S. 1982. Updated historical assessments of the brown and white shrimp fisheries in the U.S. Gulf of Mexico. Paper presented at the Workshop on Stock Assessment. Miami, Florida. August 1982.

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Figure 1. Estimated size and sex composition of brown shrimp in the Texas FCZ on 1 July 1981.

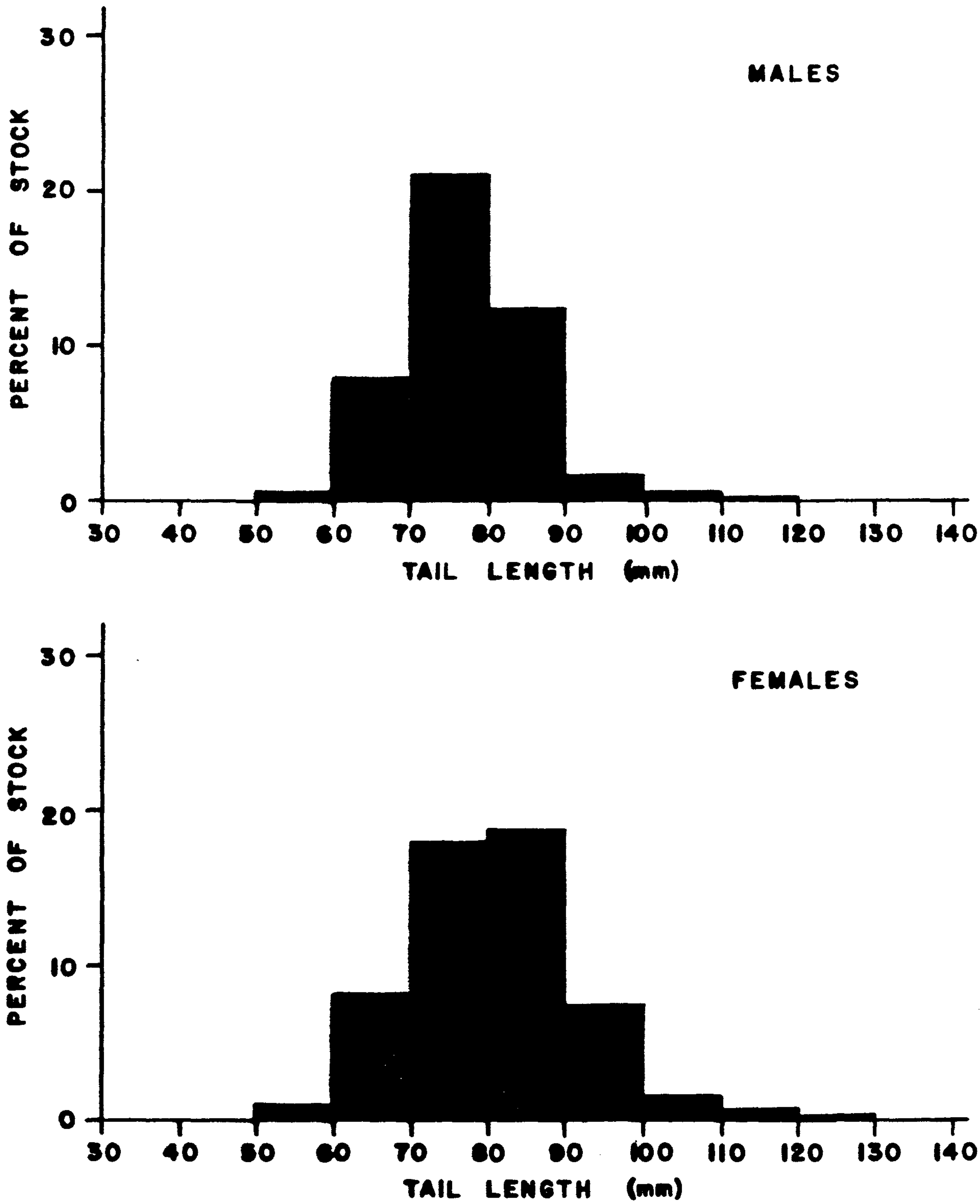

Figure 2. Projected age distribution of brown shrimp in the Texas FCZ at the start of the 1981 closure.

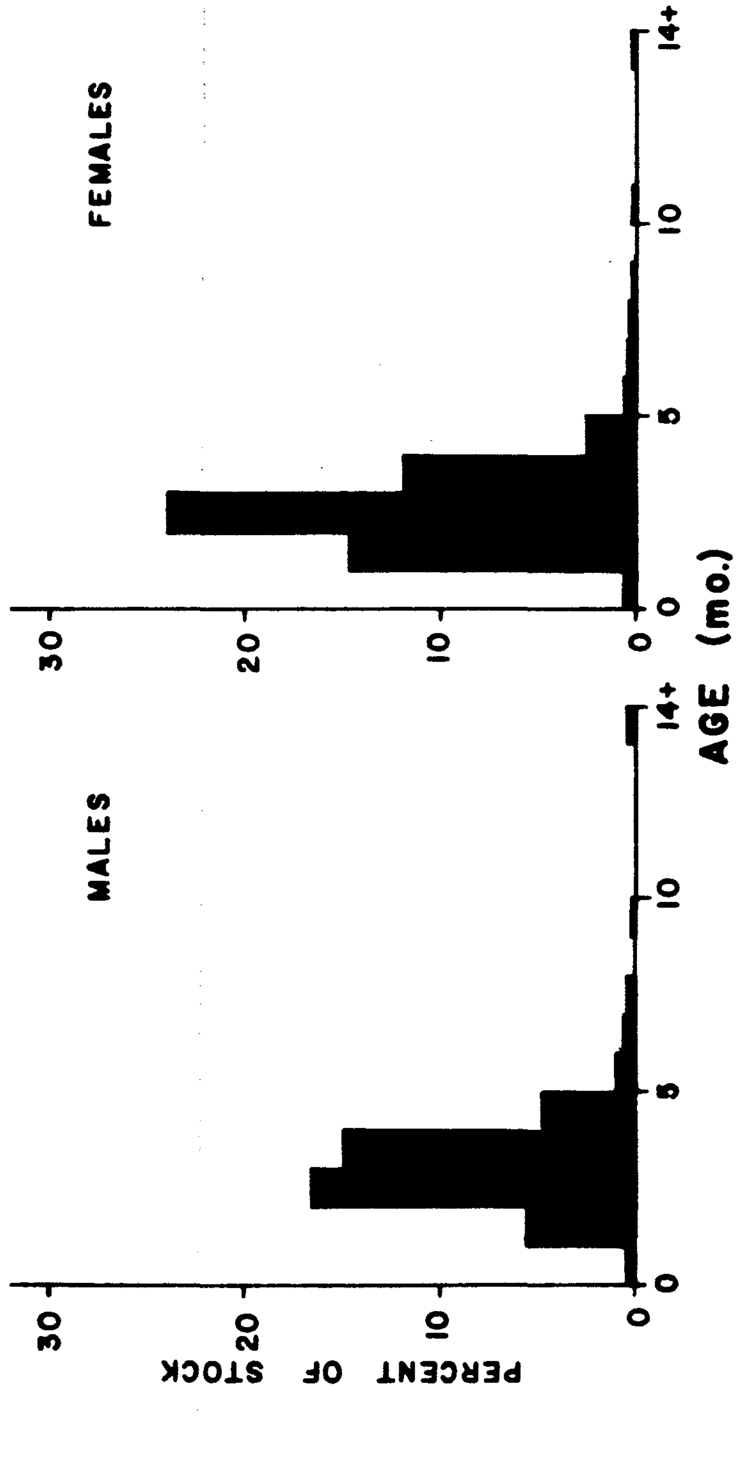

Figure 3. Possible alongshore trend in natural mortality rate. Values were obtained by taking Gulf Coast Shrimp Data five statistical areas at a time (centered at the area shown on the x-axis). Total mortalities were estimated from declines in CPUE, and M was estimated from total mortality rate vs. fishing effort relationships.

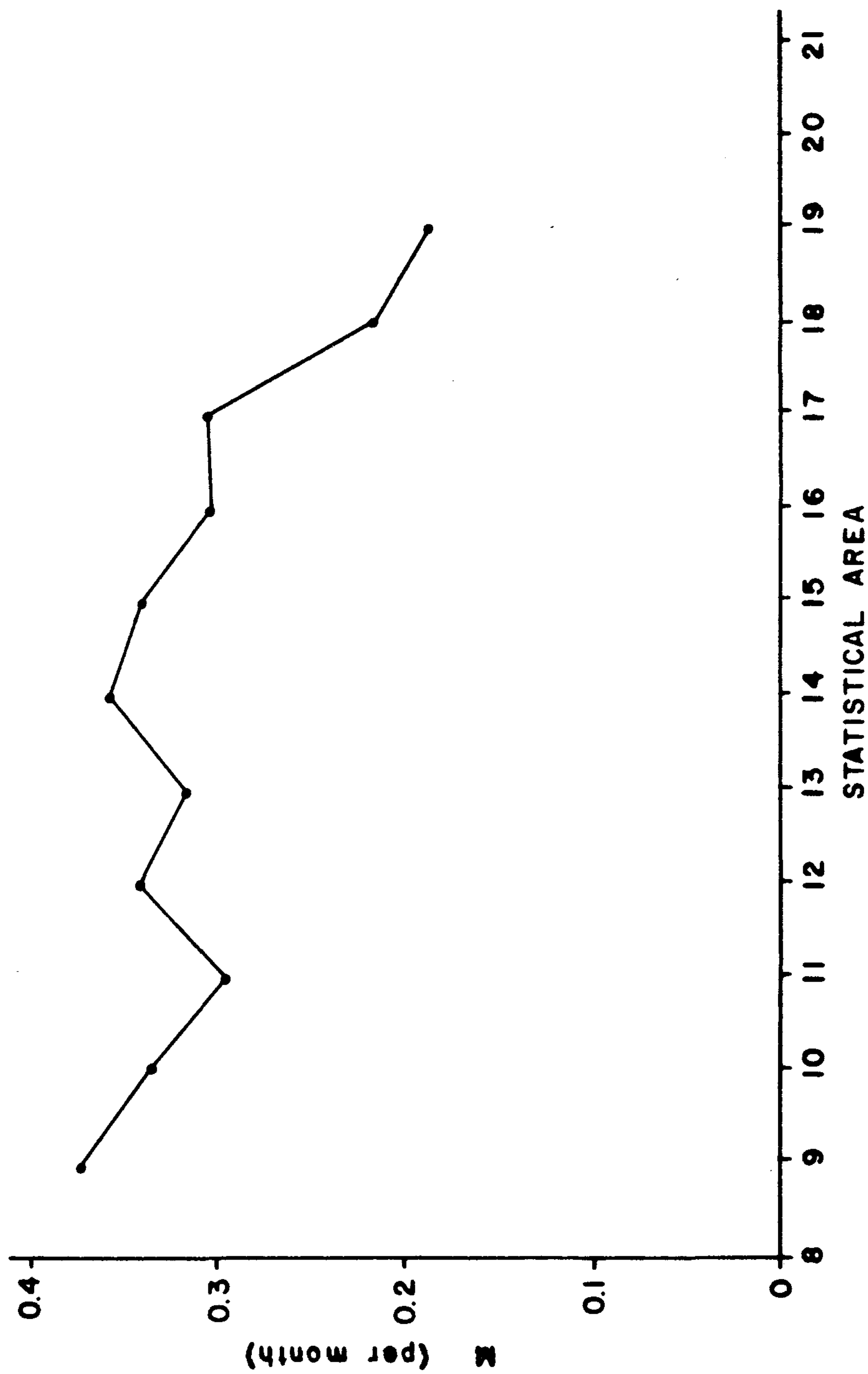

Figure 4. Potential yield per recruit from the Texas FCZ for 1981, if M = 0.15 per month.

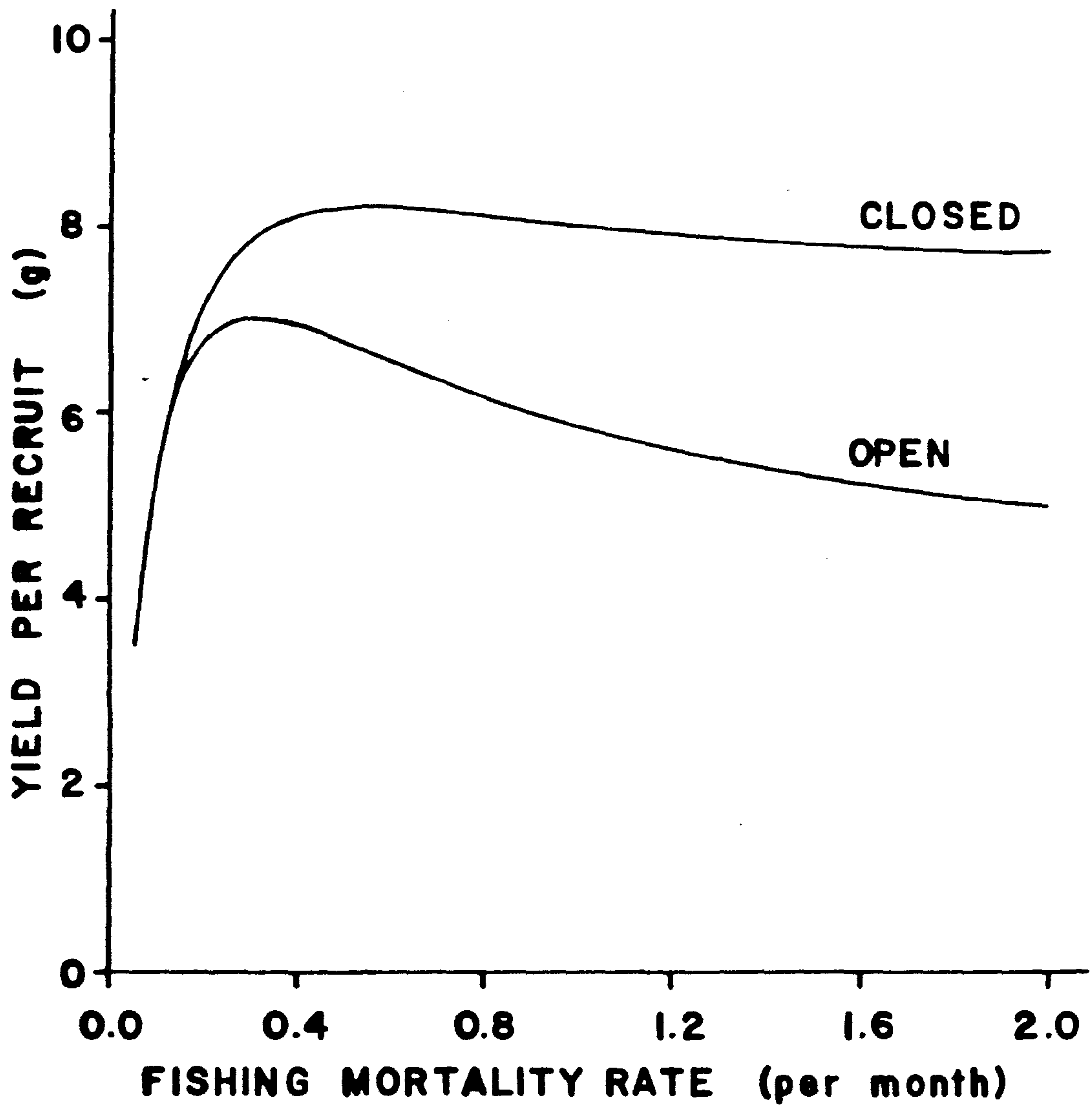

Figure 5. Potential yield per recruit from the Texas FCZ for 1981, if M = 0.28 per month.

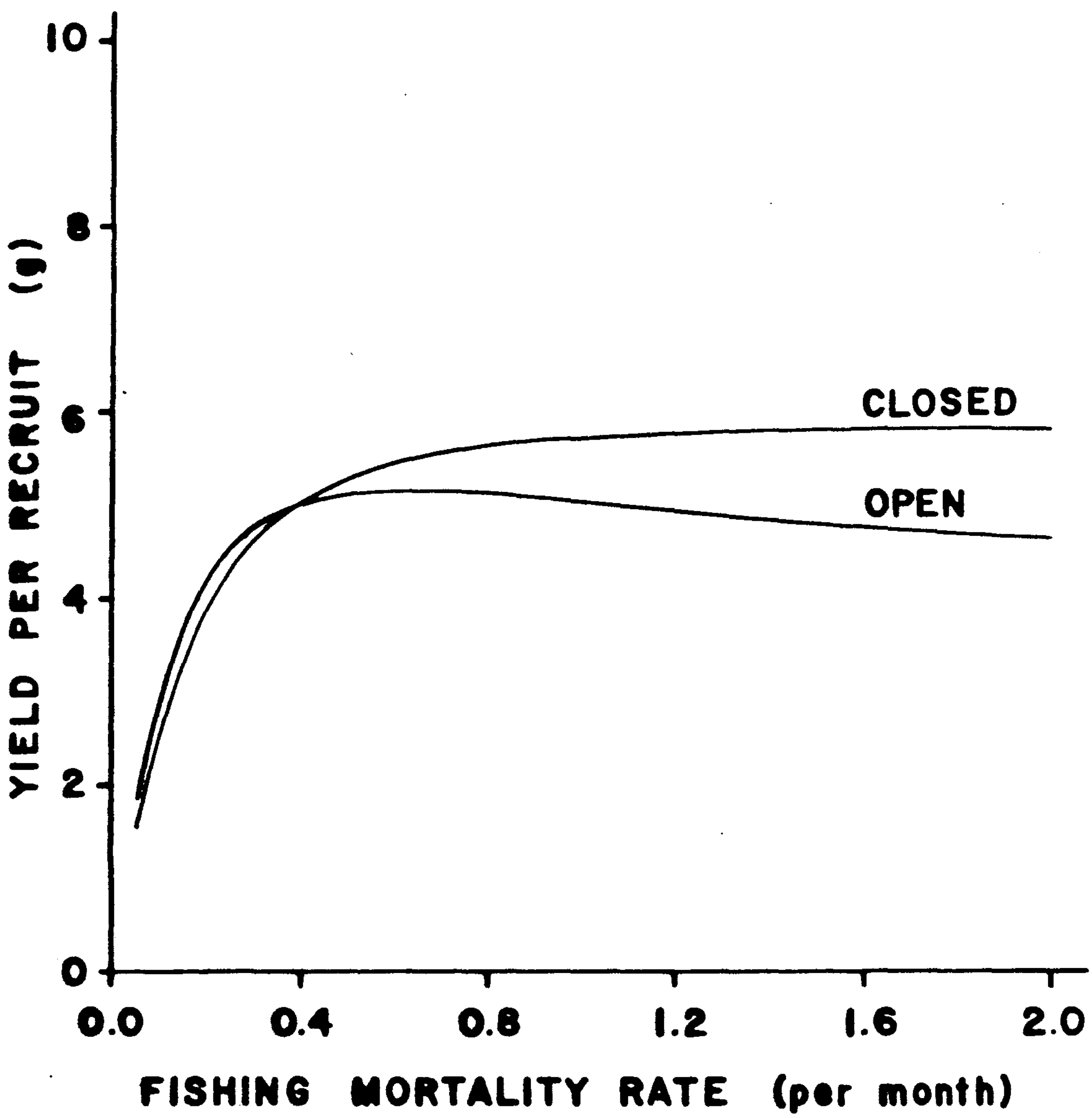

Figure 6. Possible percentage change in 1981 yield per recruit in the Texas FCZ resulting from closure.

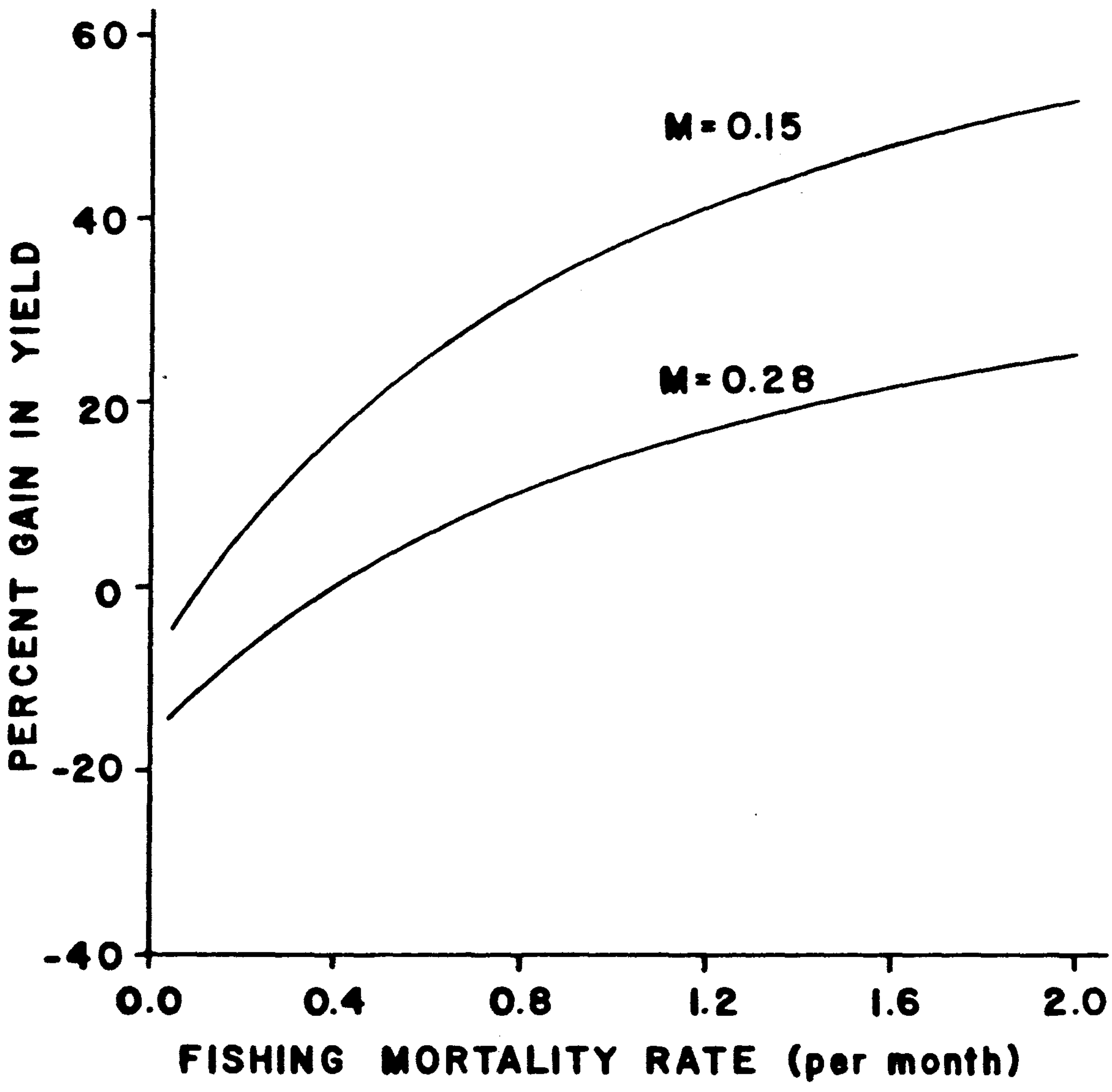

Figure 7. Estimated change in gulfwide brown shrimp yield due to 1981 closure, by market size category.

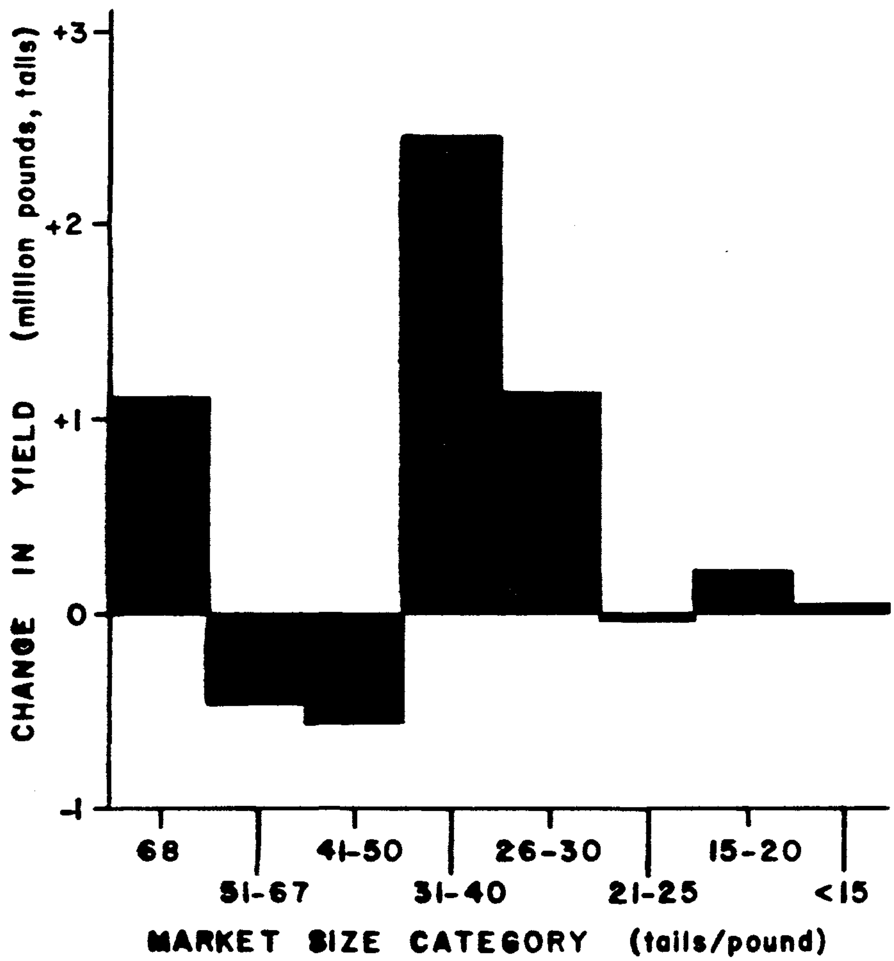

Figure 8. Estimated size and sex composition of brown shrimp in the Texas FCZ on 1 July 1982.

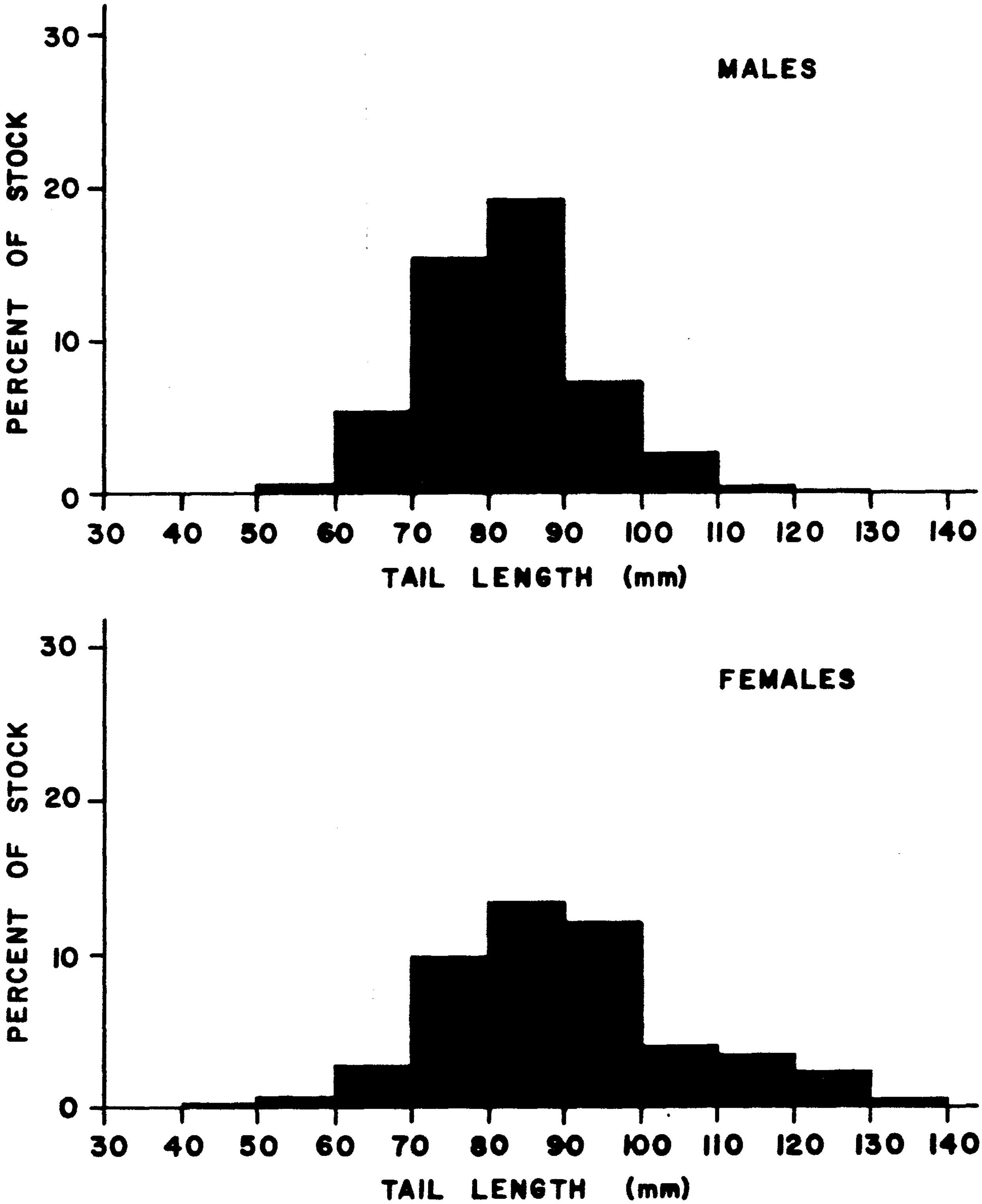

Figure 9. Projected age distribution of brown shrimp in the Texas FCZ at the start of the 1982 closure.

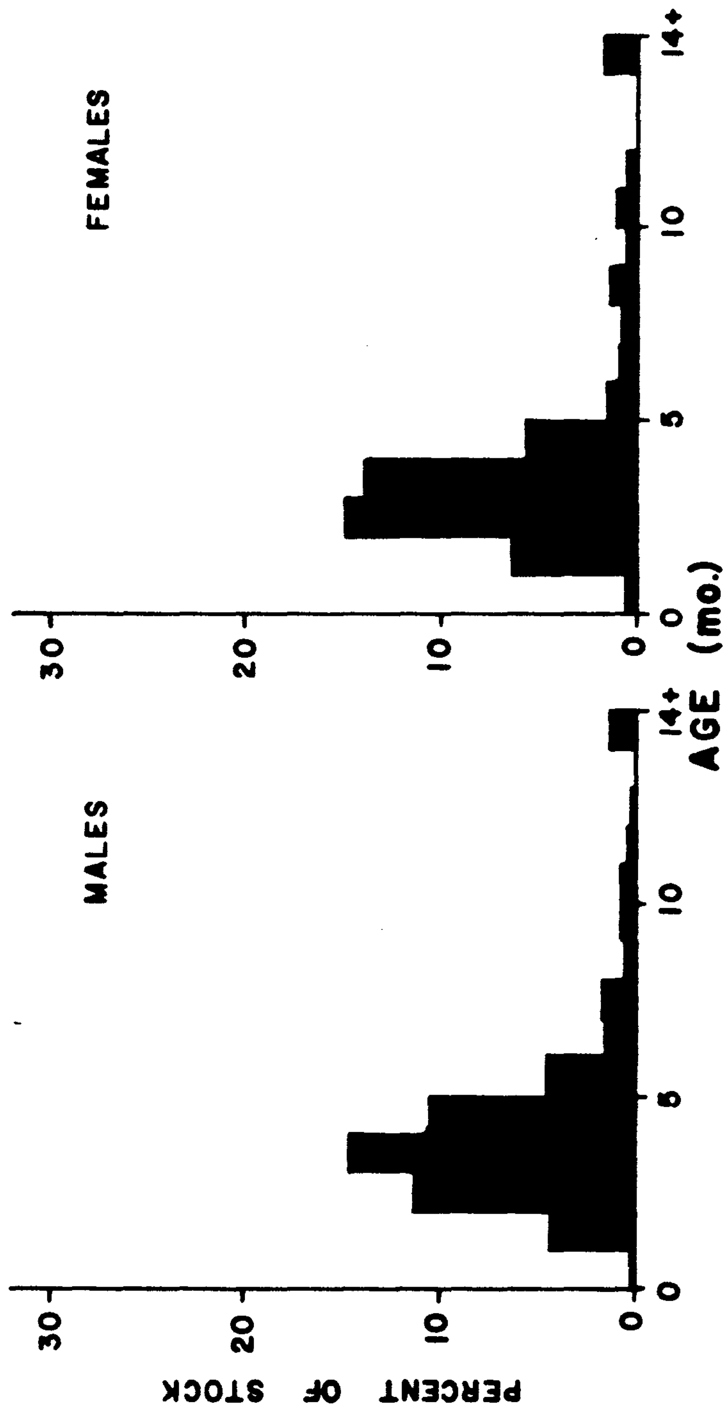

Figure 10. Potential yield per recruit from the Texas FCZ for 1982, if M = 0.15 per month.

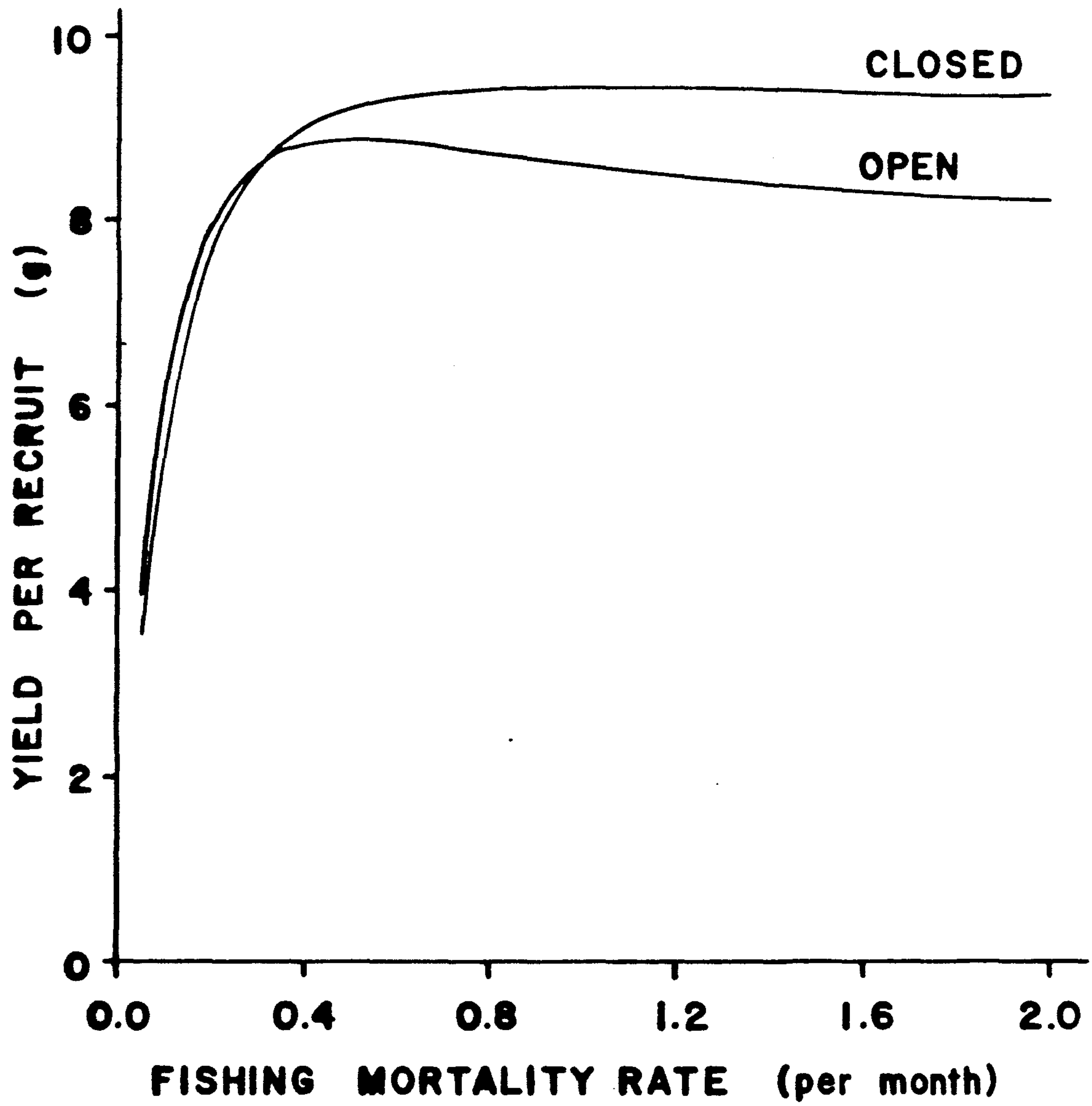

Figure 11. Potential yield per recruit from the Texas FCZ for 1982, if M = 0.28 per month.

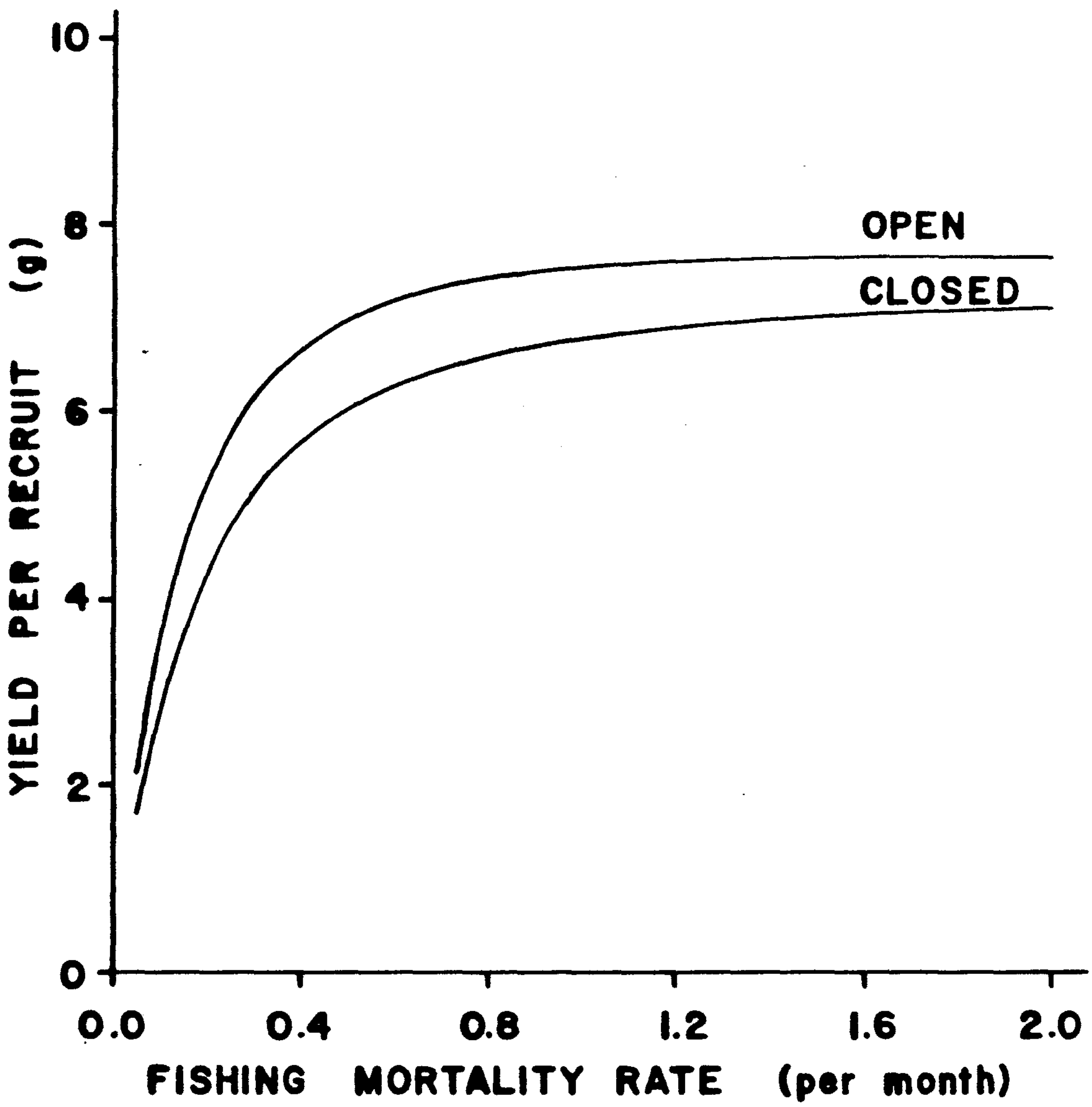

Figure 12. Possible percentage change in 1982 yield per recruit in the Texas FCZ resulting from closure.

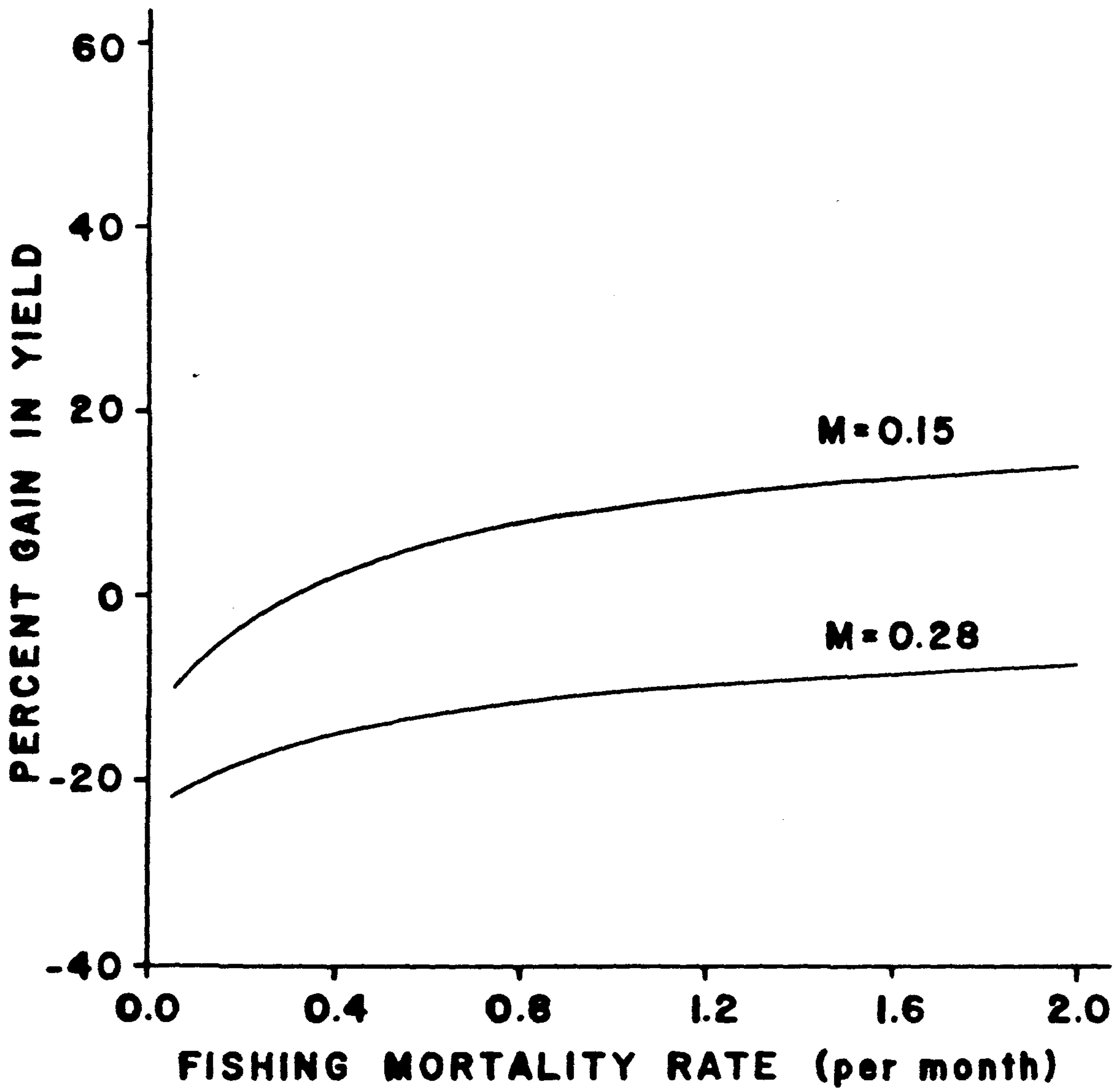

Figure 13. Estimated change in gulfwide brown shrimp yield due to closure, May-August 1982.

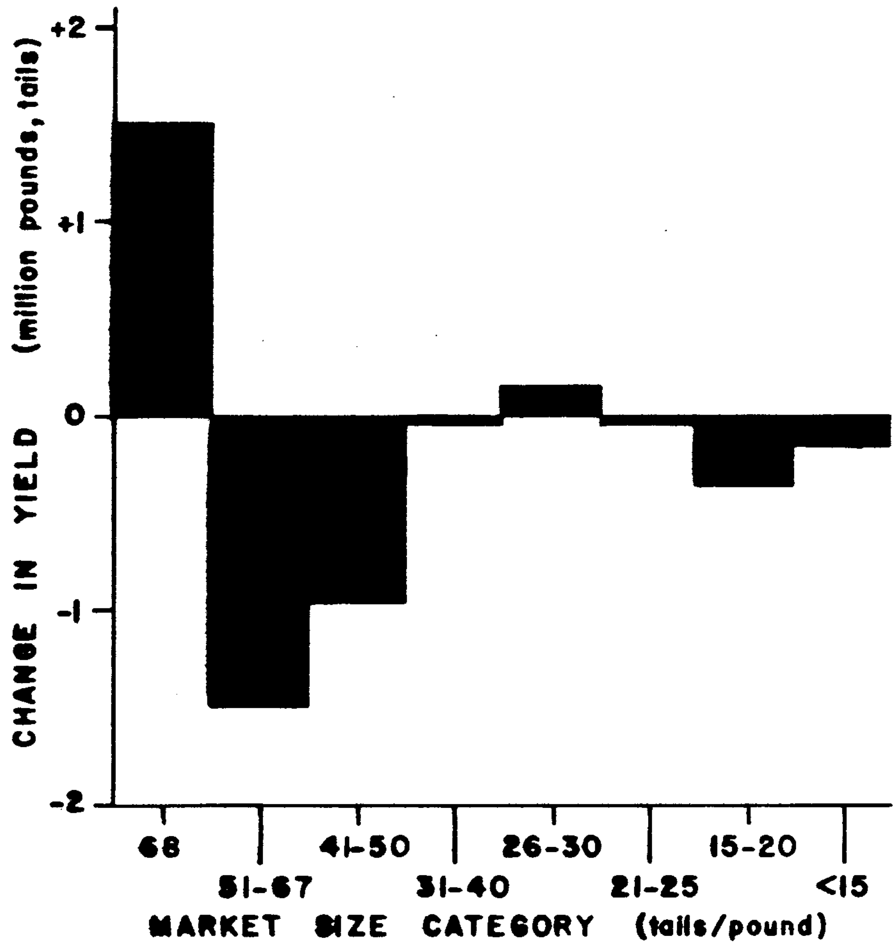

Figure 14. Ratio of offshore catch per unit effort (CPUE) for Texas: offshore CPUE elsewhere for July, 1960-1982.

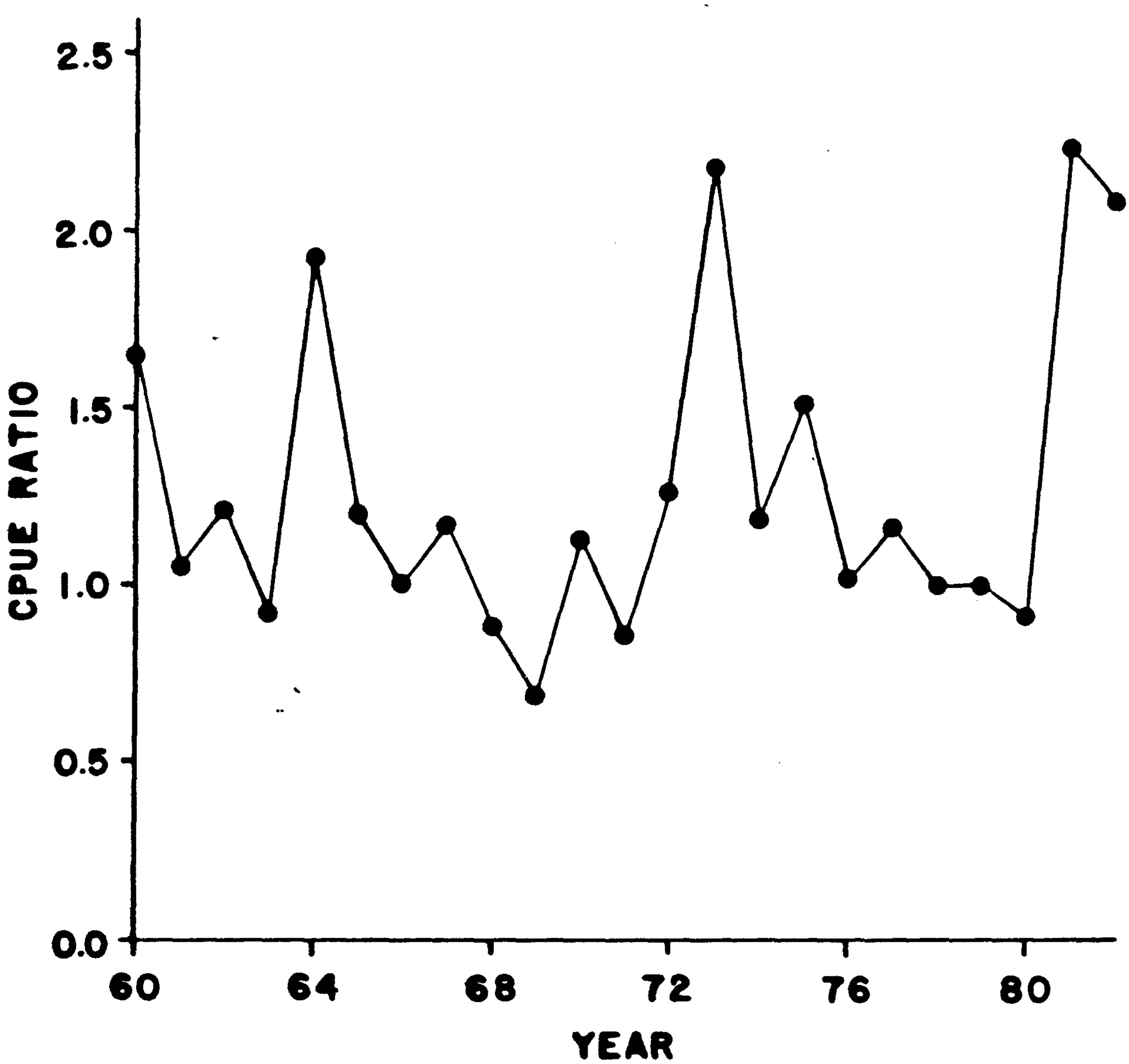

Figure 15. Ratio of offshore CPUE for Texas: offshore CPUE elsewhere for August, 1960-1982.

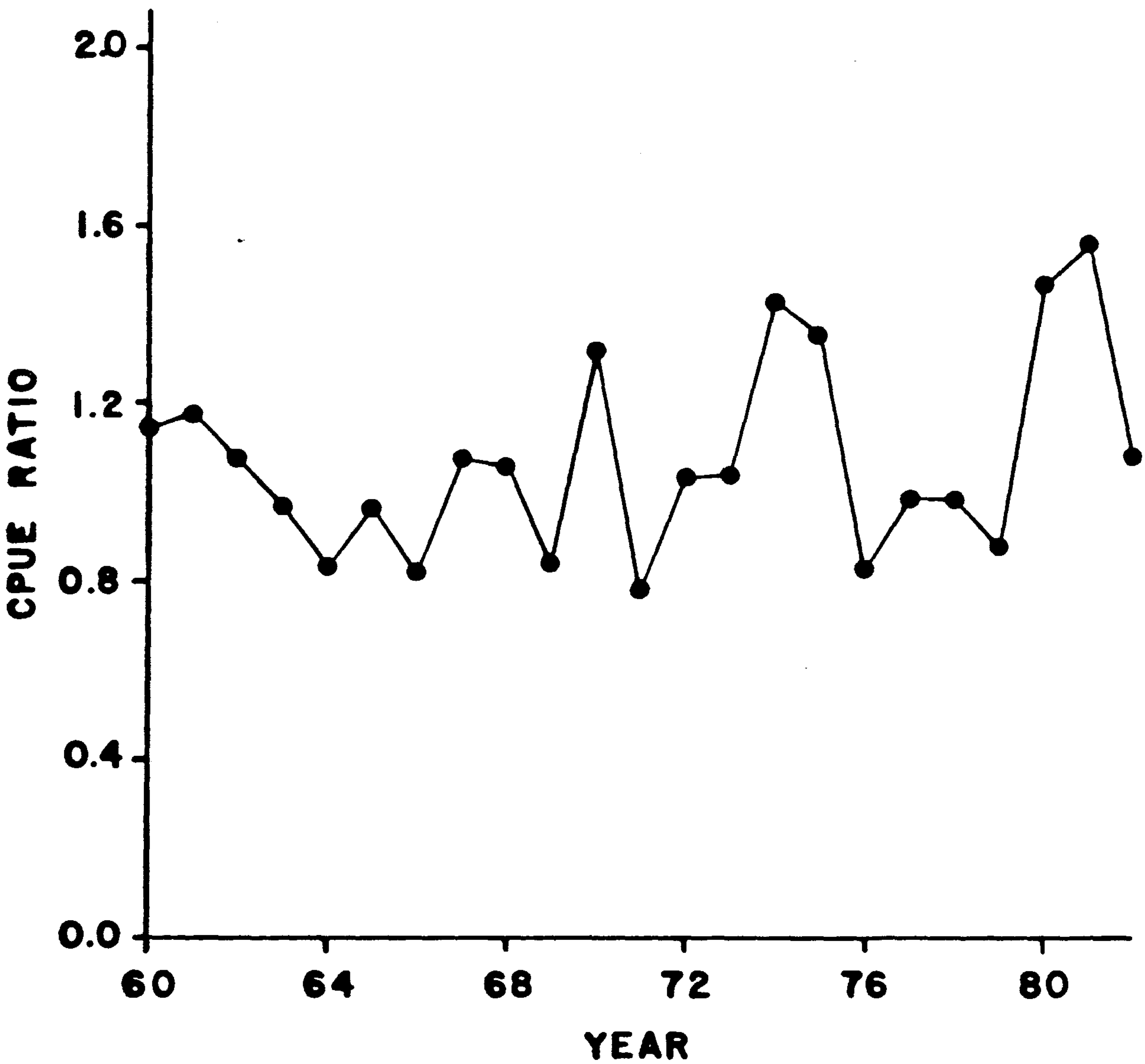

Figure 16. Ratio of offshore CPUE for Texas: offshore CPUE elsewhere vs. month. Solid line is 1960-1980 average. Points are 1981 fishing season values.

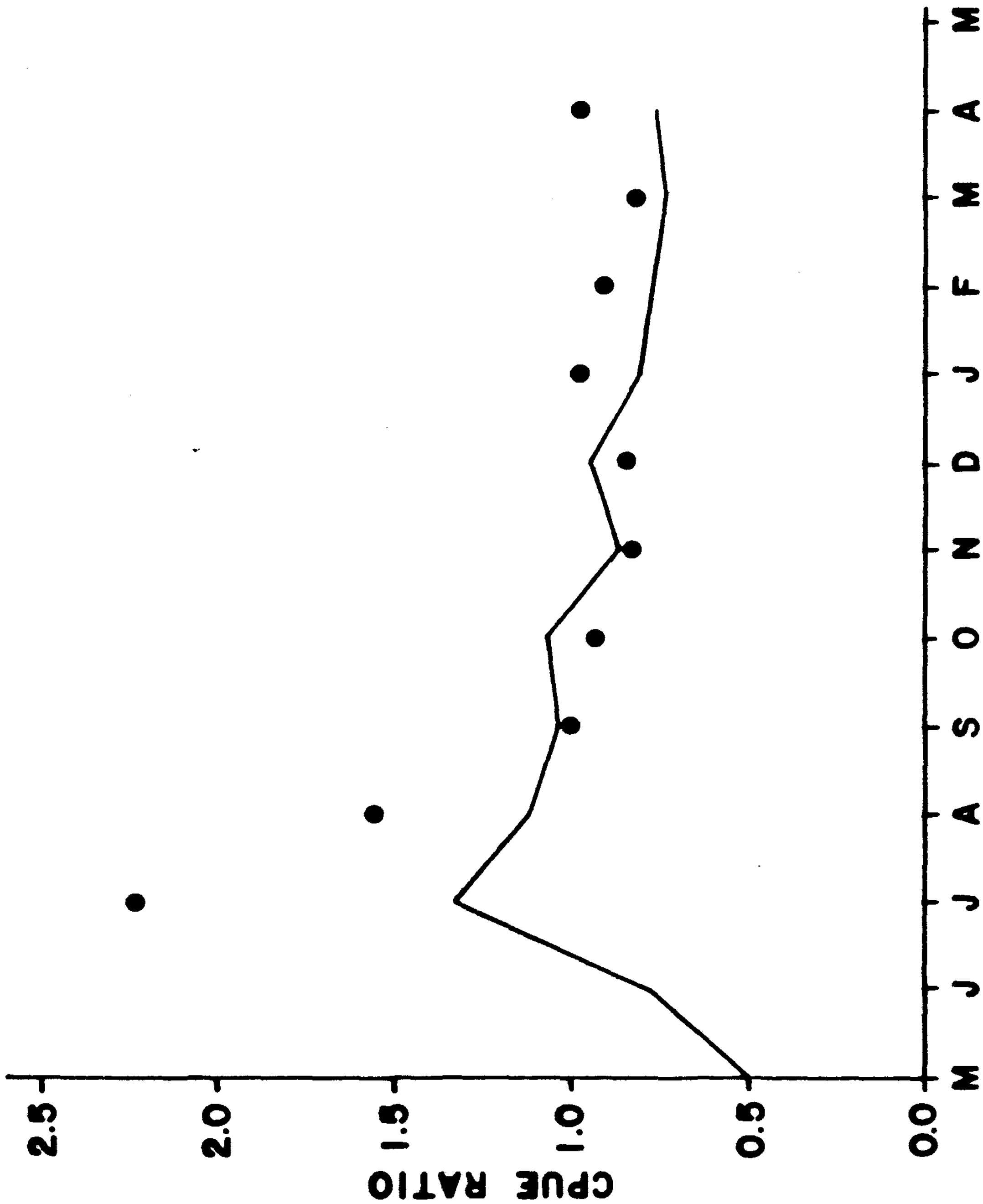

Figure 17. Ratio of June effort: August effort (Gulf-wide), 1960-1982. Horizontal line is 1960-1980 average.

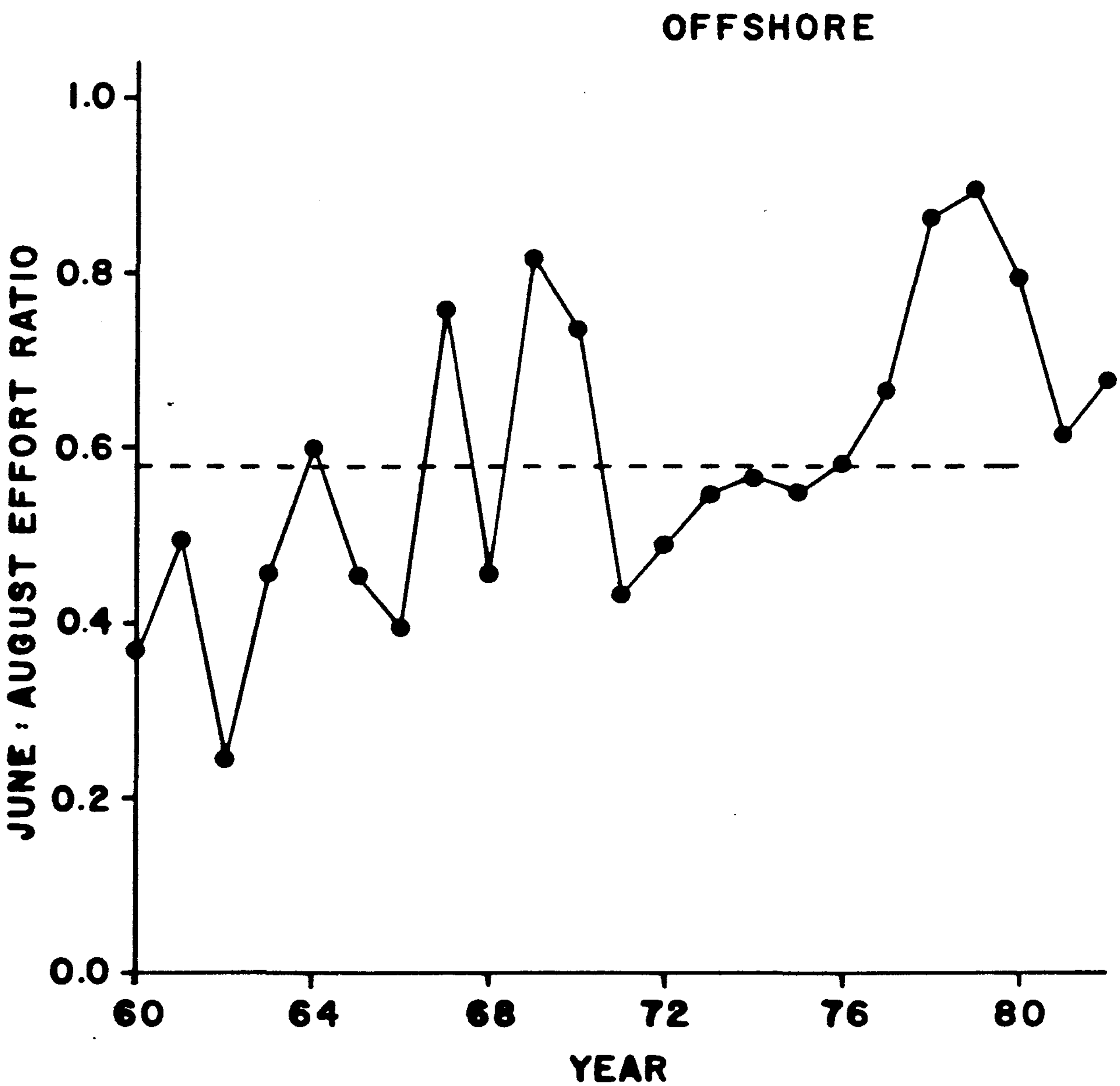

Figure 18. Percent of June (Gulf-wide) brown shrimp effort exerted off Texas, 1960-1982.

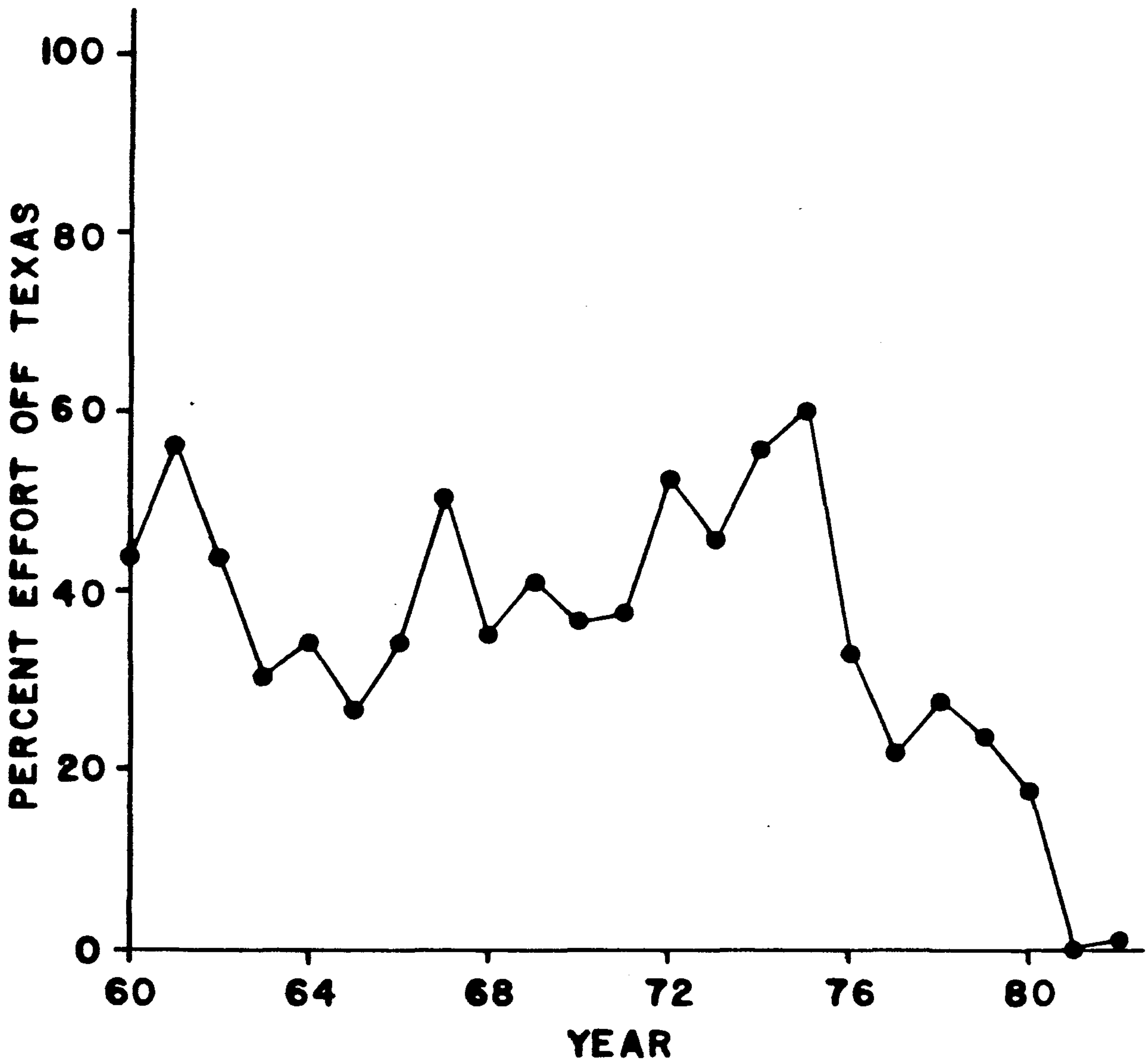

Figure 19. Percent of August (Gulf-wide) brown shrimp effort exerted off Texas, 1960-1982.

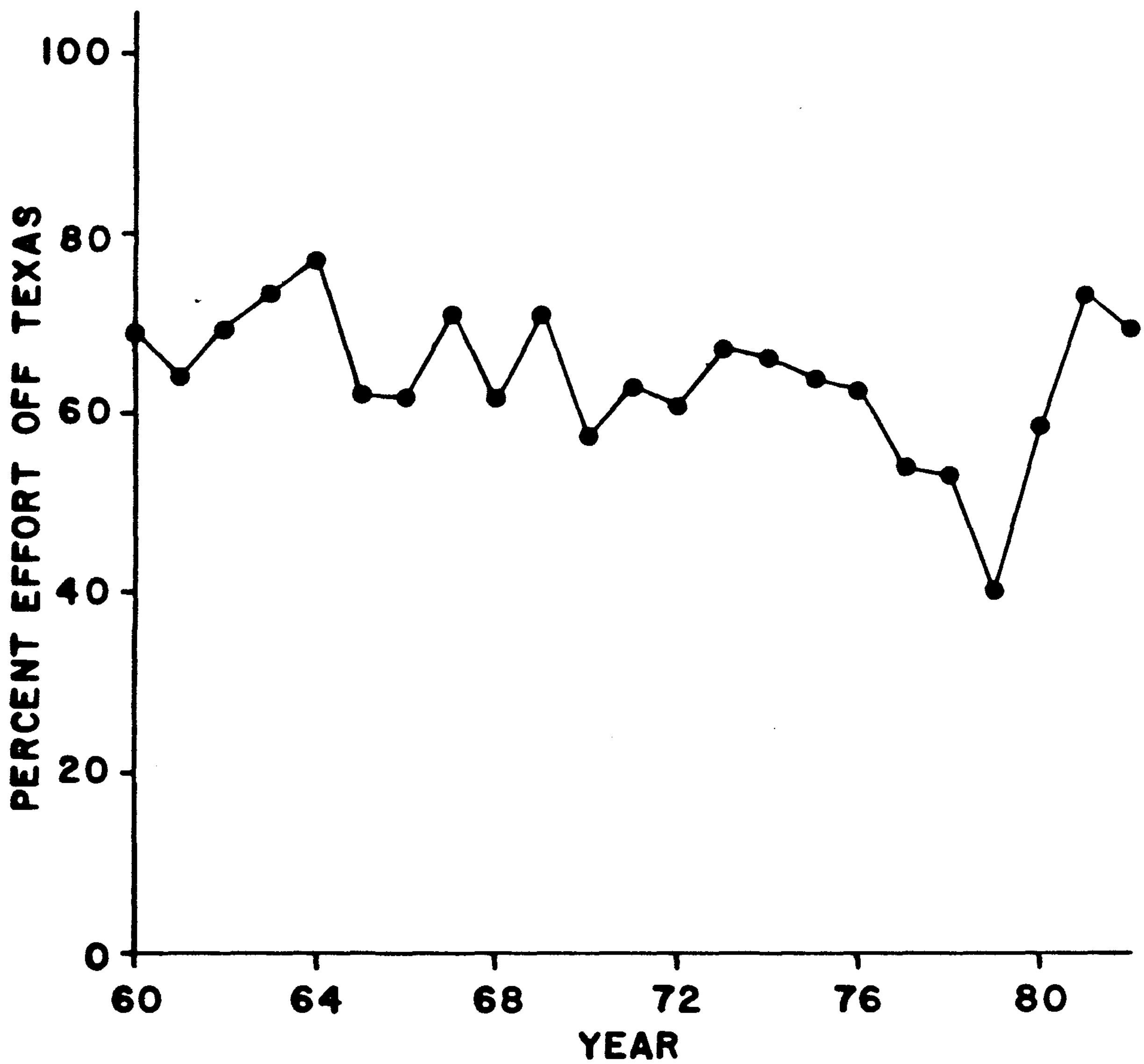

Figure 20. Percent of (Gulf-wide) brown shrimp effort exerted off Texas vs. month. Solid line is 1960-1980 average. Points are 1981 fishing season values.

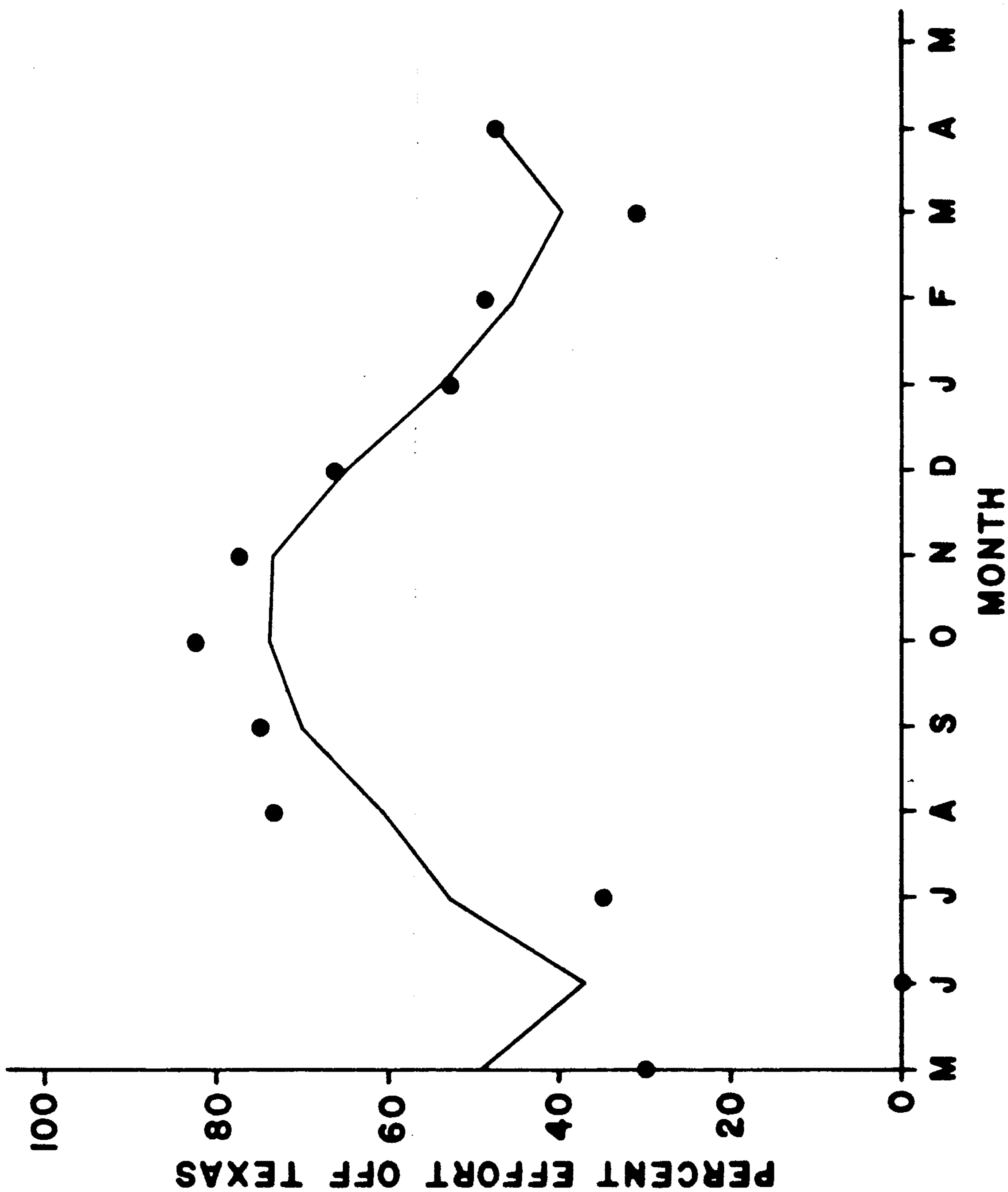

Figure 21. Estimated change in yield for the 1981 season (May-April) vs. value of the August multiplier (● marks the estimated value of the multiplier).

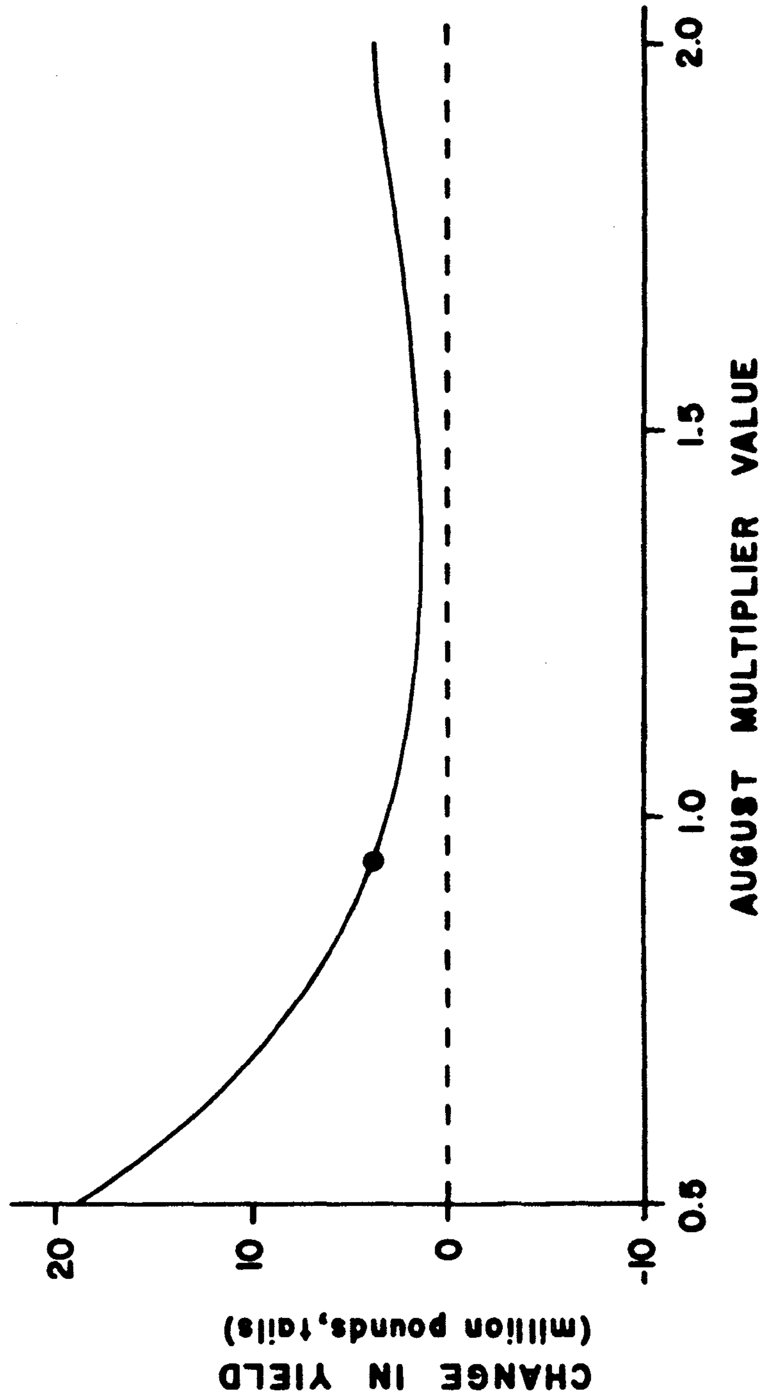

Figure 22. Estimated change in yield for the 1982 season (May-April) vs. value of the August multiplier (● marks the estimated value of the multiplier).

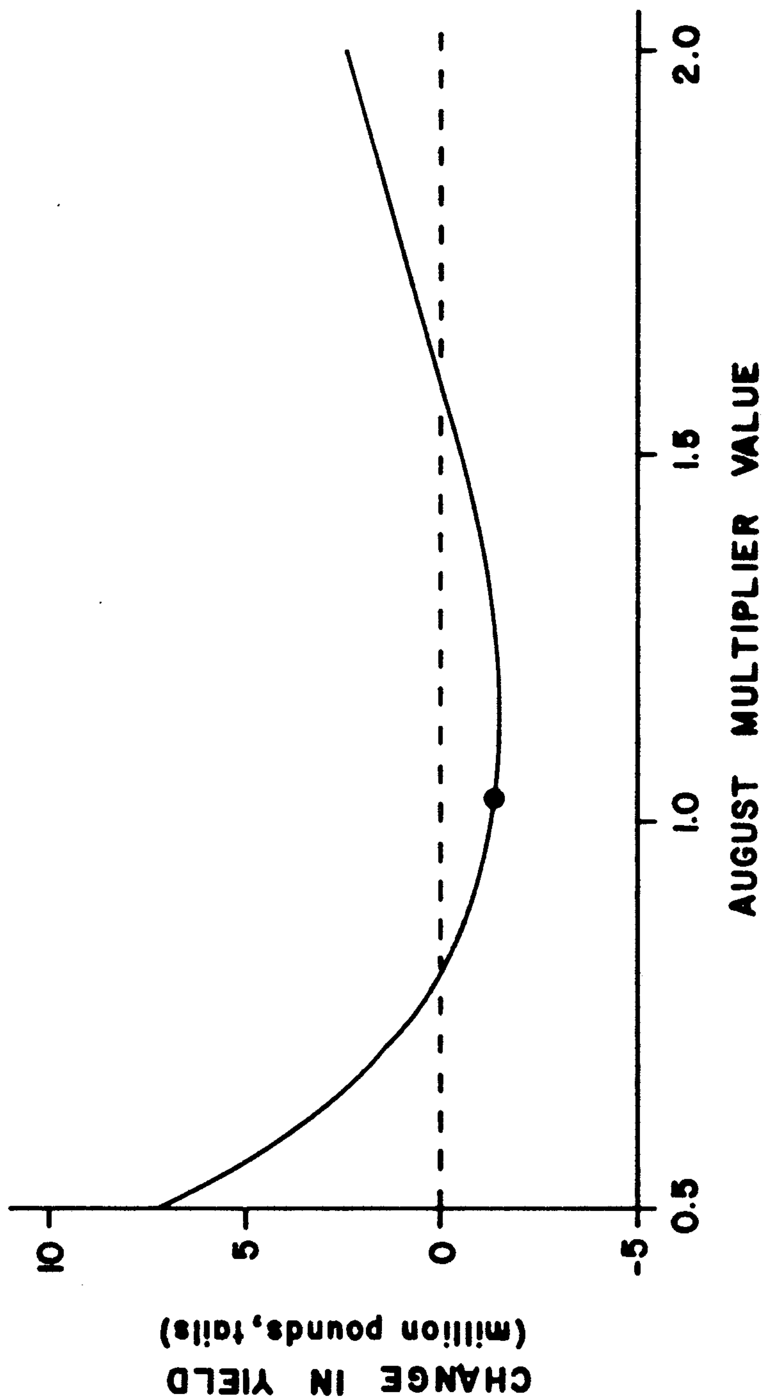

Figure 23. Annual recruitment vs parent stock size for brown shrimp (1960-1981). Estimates derived from virtual population analysis. Recruitment is summation of monthly recruitment for year. Parent stock defined as number of shrimp alive on March 1 recruited at least 8 months previously.(A similar pattern was found for parent stock estimates for preceding October, see Nichols.)

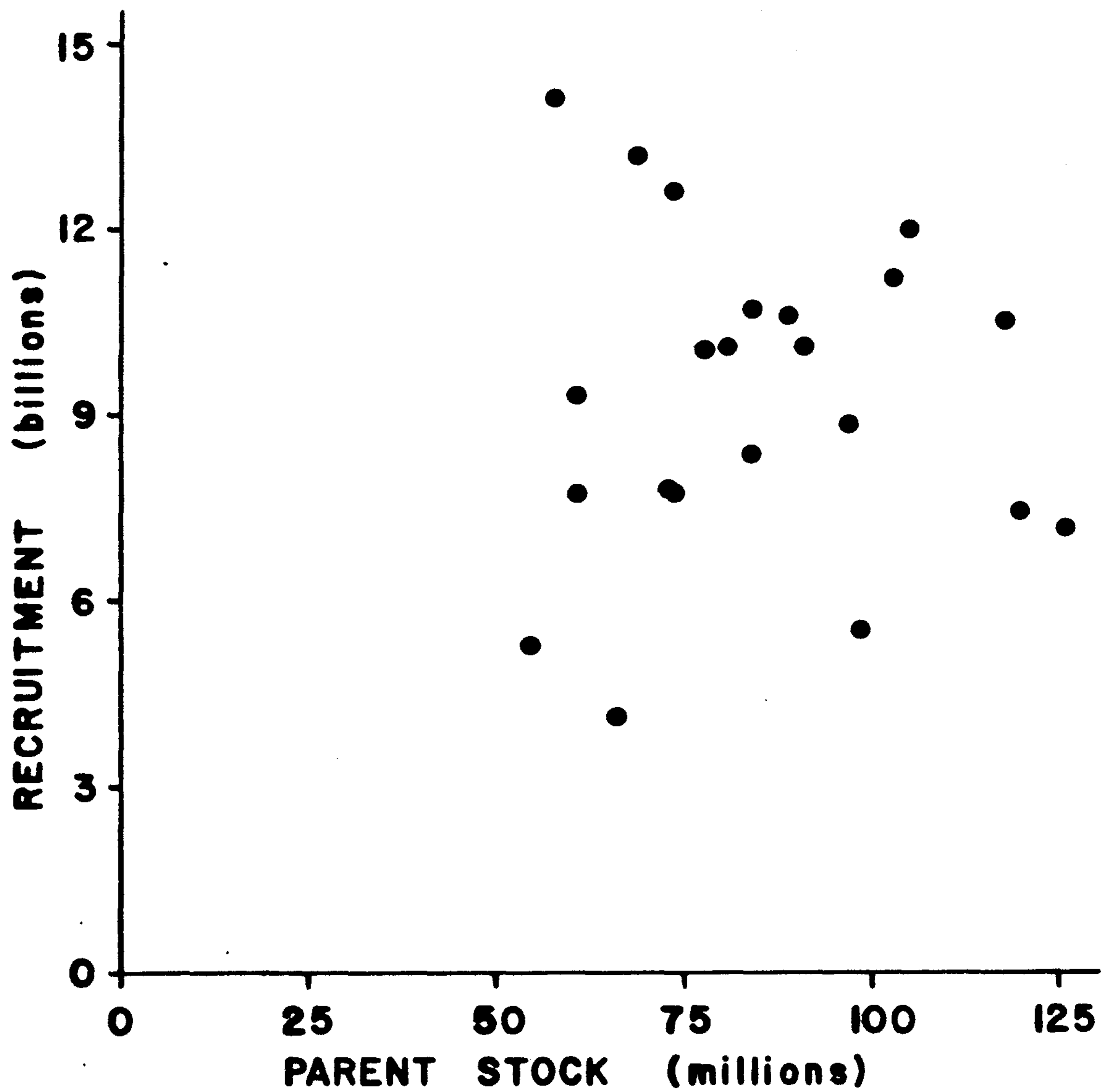

Figure 24. Estimated parent stock ages for brown shrimp 1960-1982. Parent stock was defined as number of shrimp alive on March 1, recruited at least 8 months previously. (A similar pattern holds for parent stock estimated for the preceding October, see Nichols 1982.)