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RESEARCH ON THE FISHERY AND BIOLOGY OF THE HAGFISH

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November 1990

Prepared for the California Environmental Protection Agency

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ABSTRACT

In order to gain a better understanding of both the fishery and biology of the Pacific hagfish, (Eptatretus stoutii), a one year study was conducted in the Santa Barbara Channel. Pacific hagfish are eel-like fish found in relatively deep water off the coast of North America from Baja California to Southeast Alaska. Males and females grow to approximately equal sizes. The largest male captured during this study was 645 mm (25.4 inches), while the largest female was 595 mm (23.4 inches). The size of both sexes was greatest in samples taken from the shallowest depth fished; 30 fathoms. Males mature at a smaller size than females; all males were mature by 405 mm (15.9 inches) and all females by 495 mm (19.5 inches). There does not appear to be a discrete spawning season for this species in the Santa Barbara Channel. The number of near fully developed eggs carried by females ranged from 5 to 82 with an average of 23. Larger females carried more eggs than smaller females. Overall, catch rates were greatest in depths between 50 and 200 fathoms. No hagfish were ever captured in 300 fathoms. Korean-style traps yielded greater catches when compared with 5 gallon buckets over short time periods (up to 4 hours), but less over longer times (24 hours). We detected no difference in catch rates from traps baited with different types of mackerel, however, increasing the amount of bait increased catches. Genetic analysis of hagfish taken from the Santa Barbara Channel and San Pedro indicates that the composition of their DNA differs enough to allow us to identify each population.

ACKNOWLEDGEMENTS

We thank Gordon Cota for the use of his vessel, the F/V Genoa, during the initial portion of this study. Mark Sheldon also provided invaluable assistance. Sus Kato of the National Marine Fisheries Service, Tiburon, Kristine Barsky of the California Department of Fish Game, Santa Barbara and Eric Johnson of the Moss Landing Marine Labs, Moss Landing provided much unpublished data. Dr. Ken Jones of the California State University, Northridge performed the DNA analysis. Finally, Molly Webb of the University of California, Santa Barbara assisted in the lab and tirelessly entered line upon line of data.

This report was submitted in fulfillment of contract number A800-185, "Research on the Fishery and Biology of the Hagfish", by Robert Reid under the sponsorship of the California Environmental Protection Agency. Work was completed as of 15 November 1990.

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SUMMARY AND CONCLUSIONS

In order to gain a better understanding of both the fishery and biology of the Pacific hagfish, a one year study was conducted in the Santa Barbara Channel. Commercial hagfish traps of various types were set at five depths, 30, 50, 100, 200 and 300 fathoms, and allowed to fish for times ranging from one to twenty-four hours. Sets were also made in 100 fathoms at Santa Cruz Island and near a commercial oil platform. Fishing was done during four seasons; Winter 1989, Spring 1990, Summer 1990 and Fall 1990. Traps were usually baited with frozen Pacific mackerel, although other baits and types of mackerel were tried. All captured hagfish were counted, measured and weighed. If possible, the sex and stage of reproductive maturity was determined. Genetic analysis was preformed on the DNA of hagfish taken in samples from Santa Barbara and San Pedro.

Overall, fish were most common in depths between 50 and 200 fathoms. Throughout all seasons except the Fall of 1990, the greatest catches were made in 100 fathoms. The decline in catches from 100 fathoms during the Fall 1990 period may be correlated with the presence of two large factory ships targeting hagfish at the 100 fathom stations during this time. Catch rates in 100 fathoms at two relatively unfished areas near oil production platform Habitat and off Santa Cruz Island did not display the same decrease at this time. No fish were ever captured in 300 fathoms. Hagfish captured in 30 fathoms were larger than those captured in other depths. Korean-style traps yielded greater catches when compared with 5 gallon buckets over relatively short periods of time (less than 4 hours), but less over longer times (24 hours). Experiments using different types of mackerel as bait showed no difference in catch rates, but mackerel was found to be superior to sardine. Lengthening soak times and increasing the amount of bait used increased catches. Hagfish traps produced very little incidental catches of other species.

Length/weight relationships did not differ between males and females and both sexes grow to approximately equal sizes. The largest male captured during this study was 645 mm (25.4 inches), the largest female was 595 mm (23.4 inches). Males mature at a smaller size and at a slightly faster rate than females; all males were mature by 405 mm (15.9 inches) and all females by 495 mm (19.5 inches). There does not appear to be a discrete spawning season for Pacific hagfish in the Santa Barbara Channel. Over 90% of the males and 70% of the females captured in 30 fathoms were mature during all seasons. This is probably due to the larger sized fish there. The number of near fully developed eggs carried by females ranged from 5 to 82 with an average of 23. Larger females were found to carry more eggs than smaller females.

The DNA taken from fish captured in two areas was sufficiently different to allow the characterization of the two populations. This suggests that individuals from separate geographic locations experience very little mixing. It is conceivable that marker fragments could be found that would identify the specific population from which an individual fish was obtained.

INTRODUCTION

In 1989, a commercial fishery for Pacific hagfish, Eptatretus stoutii, was initiated in the Santa Barbara Channel to supply skins to the Korean leather industry. In the first year of operation, Santa Barbara hagfish landings totaled 869,000 pounds, worth approximately $388,000.00 to fishermen, making it the fifth largest fishery in Santa Barbara behind sea urchins, abalone, lobster and California halibut. Santa Barbara landings alone constituted 33% of all hagfish taken in California during 1989 (California Department of Fish and Game, pers. com.).

If sustainable, this fishery offers several advantages to the local commercial fishermen. First and most important, hagfish seem abundant in the Santa Barbara area over a wide range of depths. Second, operations can be conducted from relatively small vessels and require little expense in terms of new gear. Third, because the fishery utilizes specialized traps, there is little or no by-catch of other species, particularly those targeted by sport fishermen. Finally, the deployment and retrieval of the gear used in this fishery is likely to cause only minimum disturbance to the ocean bottom. This study was undertaken to assess the current fishing operations within the Santa Barbara Channel and to provide much needed information on hagfish biology to aid in the rational development and management of this fishery.

METHODS

Hagfish were collected from two sites in each of 5 depths (30, 50, 100, 200 and 300 fathoms) during four seasons (November-December 1989 = Winter, March-April 1990 = Spring, June-July 1990 = Summer and August-September 1990 = Fall) using standard Korean eel traps. We attempted to sample each individual site three times during each season. In order to prevent one site from becoming "fished out" during any one season due to repeated sampling, we conducted fishing operations around but not on 10 fixed locations (2 sites x 5 depths). These fixed locations are given in Table 1. All traps were set within 1 nautical mile (n. mi.) of a fixed site, never closer than 1 n. mi. to another set of traps, and no traps were ever set at the exact same coordinates more than once per season. No depth was ever fished on two consecutive days.

Twenty-five traps were baited using a single thawed frozen mackerel (approximately 10-14 oz.) and attached to either weighted polypropylene line or leaded halibut groundline at approximately 4 meter (12 feet) intervals. Trap lines were anchored at both ends using either small Danforth anchors or ten pound concrete blocks and marked using a single bamboo flag. Normal fishing time was one hour. This was measured from the time the second anchor hit bottom upon deployment until the time the first anchor left the bottom upon retrieval. Fishing was done between 6:00 am and 3:00 pm on all days. Starting times were randomized so that no one particular depth was consistently fished at any one specific time, i.e. early morning or late afternoon, within any one season.

After retrieval of the gear, all fish from each individual

trap were placed in labeled bags and stored on ice for transportation to the lab at the University of California, Santa Barbara. Fish were maintained in the lab at -20°C (-4°F) for later examination. After thawing, each hagfish was measured (total length to the nearest mm), weighed (to the nearest 0.1 gram) and dissected to determine sex. An estimate of the degree of sexual maturity for each fish was determined using a set of criteria developed by Dr. William Barss of the Oregon Department of Fish and Wildlife (Table 2). All females with eggs greater than 5 mm (0.2 inches) or with empty ovarian follicles and all males with testicular follicles equal to or larger than 1 mm (0.04 inches) were considered mature. Fish lacking any visible differentiation of the gonad into either ovary or testis were considered to be sex "Unknown" and immature. Any eggs over 5 mm (.2 inches) were counted and a subsample of these eggs was removed, labeled and frozen for later measurements. Unfortunately, time commitments prevented the Fall 1990 samples from being worked up to this degree. In these samples, only a count of the numbers of individuals captured on each day and at each depth were recorded.

Additional experiments were carried out to determine the effects of different trap types, various soak times, and different amounts and types of bait on catch rates. These experiments were carried out in 100 fathoms near the oil production platform "Habitat" and off Santa Cruz Island. Both of these areas were less heavily fished by the commercial hagfish fleet than the 100 fathom stations listed in Table 1 (M. Sheldon, pers. com.). Traditional Korean-style traps and 5 gallon bucket traps were compared by alternating them on two replicate trap lines of twenty traps each. All traps received the same amount of bait and replicate sets were allowed to fish for one, four or twenty-four hours. Four hour soak times correspond to that used by Korean fisherman (S. Kato, pers. com.), while twenty-fours hours is the usual time favored by Santa Barbara fishermen (R. Reid, pers. com.). Comparisons of catches resulting from the use of four different types of bait were made in two ways. In the first, three separate lines of twenty-five traps each were baited with an equal amount of either thawed Pacific mackerel (Scomber japonicus), thawed jack mackerel (Trachurus symmetricus), often referred to by commercial fishermen as "Spanish mackeral", or a thawed mixture of the first two which had previously been ground-up and allowed to fish for one hour. This experiment was repeated twice. In the second, traps on each line were baited at random with either Pacific mackerel, Spanish mackerel or Pacific sardine (Sardinops sagax caeruleus) and again allowed to fish for one hour. This experiment was repeated six times. The importance of the specific amount of bait used in each trap was investigated by baiting Korean traps with one, two or three Pacific mackerel and by baiting both Korean and 5-gallon buckets with either one or five Pacific mackerel. The former experiment was done at both platform "Habitat" and Santa Cruz Island, the latter only at "Habitat".

Finally, DNA isolated from the slime glands of 20 hagfish, 10 taken from Santa Barbara and 10 from Long Beach, was purified and cut into several fragments using EcoRI and PstI restriction

enzymes. The points at which the enzymes cut the DNA varies with the base pair sequence of the DNA (the "genetic code") and thereby generates variations in the sizes of the various fragments produced. These fragments were then separated based on their size utilizing gel electrophoresis. The differences in the frequency of occurrence for each of the fragments in the two geographic groups was then used to provide a quantitative basis for identifying a specific population.

RESULTS AND DISCUSSION

Biology:

Growth - A total of 2,279 hagfish was examined during the course of this study. Fish ranged in size from 65 mm (2.6 inches) to 645 mm (25.4 inches) with a mean length of 305 mm (12 inches) (Figure 1). This corresponds well with the size ranges reported in other sources (Eschmeyer, Herald and Hammann, 1983; Conel, 1931; Worthington, 1905). Males and females appear to reach the same approximate maximum size; 645 mm for males versus 595 mm (23.4 inches) for females. However, with no accurate method available to determine the age of these fish, it is impossible to determine if the two sexes grow at the same rate.

Length/weight relationships - Length/weight relationships for males and females calculated by linear regression of log transformed length and weight data (Figures 2-3), show that males were slightly heavier within the study sample than females at any given length. The difference in the rates at which the two sexes increase in weight as they increase in length (Figures 4-5) is not significant.

Sex Ratio - Of the 2,279 examined, 840 were males, 1229 were females and 210 could not be assigned to either sex. This yields an overall male:female sex ratio of 1:1.5. Sex ratios calculated by season and depth also show a slight female bias. A recent study by Gorbman (1990) notes that sexual differentiation occurs earlier in female hagfish than in males (203 mm vs. 279 mm respectively). This result is borne out by the findings of our study. We had trouble reliably determining the sex of small hagfish less than about 270 mm (10.6 inches). If the majority of our "Unknown" sex category represent undifferentiated males, then our sex ratio approaches 1:1.2.

Size at first, 50% and 100% maturity - Males in our study generally started to mature at a smaller size than females; 255 mm versus 295 mm, respectively (10.0 vs. 11.6 inches)(Figures 6-7). These are much less than the values of 351 mm for males and 399 mm for females calculated by Gorbman and Dickhoff (1978). In the present study, all males were mature by 405 mm (15.9 inches) and females by 505 mm (19.9 inches). These values approximate those for 100% maturity calculated by Gorbman and Dickhoff (1978). Since it is not known if the fish from these two studies grew at the same rate, it is hard to directly compare the two sets of values. Figures 8 and 9 show the proportion of fish captured in each depth which were mature during the first three seasons of the study. At least half of all males taken in each depth during almost all

seasons were found to be mature. This is especially true for 30 fathoms, where nine out of every ten males captured were mature. Conversely, females exhibited a much lower proportion of mature individuals in all depths and during most seasons. Only in 30 fathoms does the proportion regularly exceed one half. This disparity is clarified if the lengths at which half of the sex is expected to be mature (299 mm for males; 340 mm for females) is compared with the mean size of each sex taken in each depth during the three seasons reported (Figures 10-11).

Fecundity - The number of near fully developed eggs (>10 mm) carried by females ranged from 5 to 82 with a mean of 23. This agrees with range of 20-30 near term eggs per female reported by Gorbman and Dickhoff (1978). Like many other fish species, the number of near term eggs per female increases with increasing female size, particularly for females greater than 400 mm (Figure 12).

Spawning season - We detected no discrete spawning period for Pacific hagfish in the Santa Barbara Channel. Females were found with near term eggs during all four seasons studied. Other studies (Conel, 1931; Worthington, 1905) also failed to detect a specific spawning period. There may be a slight peak in spawning activity in the early spring as numerous small individuals began to appear in our March (Spring 1990) samples from 50 and 100 fathoms.

DNA analysis - Results from the DNA analysis performed by Dr. Ken Jones of California State University at Northridge indicates that the DNA taken from hagfish populations in Santa Barbara differs sufficiently to allow us to characterize each of the populations. The ability to identify specific populations makes feasible studies on population movement, the extent of gene flow (a measure of how much separate populations interbreed) between populations and various other aspects of population dynamics without having to resort to expensive and time consuming mark and recapture programs.

Fishery:

Catch per unit effort (CPUE) - Catch rates, expressed as the number of fish caught per trap per hours fished, were highest in the intermediate depths of 50, 100 and 200 fathoms (Figure 13). The only exception to this pattern occured during the Winter, 1989 samples taken in 50 fathoms. No fish were recovered from this depth during this time period and we have no way of knowing whether this represents a seasonal change in abundances and/or distribution at this depth or simply a fluke in the data. No hagfish were ever caught at either of the two 300 fathom stations, even though this depth is well within the established range for this species (Eschmeyer, Herald and Hammann, 1983). The absence of fish from our 300 fathom samples is probably due to the anoxic conditions which exist at this depth within the Santa Barbara Channel. We noted the presence of a strong hydrogen sulfide odor in mud brought up on or in many of our traps set in this depth. Overall, catches in the remaining depths were fairly consistent both among depths for any given season and within seasons for any given depth. Catch rates did decline in both 30 and 100 fathoms between the Summer and

Fall 1990 surveys. Data presented by Conel (1931) suggests that hagfish may migrate from shallower waters (<35 fathoms) into deeper waters between August and September. If catch rates are a true reflection of population abundances, than this would explain the slight increase in the catch rates seen at our 50 and 200 fathom stations during this same time period. The decline in catches from 100 fathoms is harder to explain. It may reflect the presence of two large "factory ships" which were catching large quantities of hagfish very near our 100 fathom stations. A comparison of catch rates in 100 fathoms at both Santa Cruz Island and near platform "Habitat" (Figure 14) shows that these areas did not exhibit a decline similar to that experienced by our "fixed" 100 fathom sites.

Effect of varying the amount of bait - A very simple relationship was discovered between the amount of bait placed in a trap and the number of hagfish subsequently caught by that trap; CPUE increased as the amount of bait used increased (Figure 14). This was found to be true for both types of traps used in this study (Figure 15). Hagfish traps will continue to attract fish only as long as bait remains in the trap. Using more bait may overcome the abilities of the first few individuals entering the trap to fully consume the bait before the end of the set. This is especially true for sets lasting longer than one hour (Figure 15).

Effect of trap type - The more traditional Korean traps yielded greater CPUEs when compared with 5 gallon bucket traps over time periods lasting four hours or less, but lower CPUEs when compared over longer time periods, i.e. twenty-four hours (Figure 15). The larger total volume of the 5 gallon buckets allows for a potentially greater catch if the traps fill to their maximum capacity as would be expected in sets with long soak times. In contrast, the placement of the entrance to the trap is closer to the substrate in the Korean traps and this may allow fish to locate the opening more quickly and thus provide greater catches for these traps during sets with short soak times.

Effect of varying the soak time - The above pattern of CPUEs experienced with Korean and bucket traps during long and short sets also holds true for the proportion of traps in a set containing at least one hagfish (Figure 16). However, this difference is not as great between the two trap types in long sets as is the difference between CPUEs. If hagfish are able to escape from the traps by exiting back through the funnel as has been suggested by Ed Melvin (pers. com.), the larger volume of the 5 gallon buckets may make it harder to locate the funnel. This would explain the decrease in CPUE experienced by the Korean traps over time, especially when little bait is used (Figure 15). The lack of a decline in the proportion of Korean traps containing fish over time is also understandable in this light as every fish contained in several traps would have to escape before the proportion would decrease.

Type of bait used - We detected no real differences between the CPUEs resulting from the use of any type of mackerel. All three mackerel baits were found to be superior to sardines (Figure 17).

SUGGESTIONS FOR MANAGEMENT OF THE FISHERY

If sustainable, the Santa Barbara fishery for Pacific hagfish offers several advantages to local commercial fishermen. Fishing can be done from relatively small vessels with a one or two man crew and minimal start up costs. There is little or no interaction with species of interest to recreational fishermen and, finally, no interaction with marine mammal or birds. Unfortunately, management of this fishery to ensure sustainable yields may not be an easy task. To date, no one has successfully aged a Pacific hagfish and future prospects to do so do not appear encouraging. Tagging experiments conducted to determine population sizes and study movement have also been less than successful. This lack of information on such important population parameters as population size, age specific growth and mortality rates, mean batch fecundity at age and migration rates makes it difficult to propose specific management options for this fishery.

It is possible, however, to make recommendations based on a series of "educated guesses" given the data at hand. The low value of average female batch fecundity found in samples taken for this study is reminiscent of values for many species of sharks and rays. These species tend to be long lived, are usually characterized by a relatively late age of first maturity and have proven to be extremely vulnerable to overfishing. If this case holds true for the Pacific hagfish, then care must be taken to ensure that enough individuals of the species survive to an age at which they can reproduce and replace members removed by the fishery.

This goal of preventing the over-harvesting of the resource can be accomplished by the use of several management strategies used individually or in concert. In theory, the relative youth of the fishery, 1-2 years in operation, suggests that the imposition of a limited entry fishery utilizing some type of permitting process should be possible. The number of vessels seriously participating in the Santa Barbara fishery to date has not grown to such a size that limiting the total number of vessels allowed would result in a large number of already "geared-up" fishermen being excluded from the fishery. If further reduction in the total effort expended by the fishery is needed, limits on the total number of traps carried by each vessel could be established. This would prevent overcapitalization in gear and could be more easily adjusted from year to year based on population size estimates than the number of permits issued. Alternatively, it should also be possible to impose a minimum size limit on individuals in the catch. This would ensure that most fish are not removed from the fishery until they have had at least an initial opportunity to reproduce. Currently, hagfish are not generally considered to be marketable until they reach a size of about 14 inches. Hagfish smaller than 14 inches are sorted from the catch, returned to the water and can usually be seen swimming vigorously towards the bottom (Reid, pers. obs.). Since this size is slightly greater than the size at which 50% of both sexes were found to be mature in our samples (Figures 6 & 7), it would appear that the current fishery is already concentrating largely upon reproductive individuals. To

further insure that the proportion of small individuals in the catch is minimized, fishing in the Santa Barbara area could be limited to depths of less than 50 fathoms. Data from this study indicate that individuals of both sexes taken from these shallower depths are likely to be mature and greater than 14 inches in size (Figures 8-11).

Data taken from the DNA analysis suggests that individual populations of Pacific hagfish may not mix to any great degree. If true, populations which are overfished may not be replenished from nearby underfished populations. As a result, management of this fishery will almost assuredly have to be done on a very fine scale; perhaps even within a region. Without a reliable way to measure population levels a priori, i.e. by means of mark/recapture data, fisheries managers will need to monitor the effort expended in each area of the fishing grounds and its subsequent catch. In this way, catch per unit effort relationships can be constructed for individual areas and these sites closed to fishing when CPUE begin to decline.

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Table 1:

HAGFISH STUDY STATION LOCATIONS

DEPTH	STATION	LATITUDE	LONGITUDE
30	1	34°22.87	119°43.60
	2	34°22.80	119°44.93
50	1	34°20.69	119°46.69
	2	34°19.96	119°45.21
100	1	34°19.86	119°47.61
	2	34°20.34	119°49.10
200	1	34°19.86	119°52.58
	2	34°20.51	119°53.63
300	1	34°18.08	120°00.42
	2	34°18.19	120°00.80

DEPTH	STATION	LOP 1	LOP 2
30	1	41575.6	27988.6
	2	41580.9	27984.7
50	1	41578.8	27978.3
	2	41569.2	27982.3
100	1	27975.2	41578.9
	2	41587.4	27971.1
200	1	41599.7	27960.7
	2	41607.1	27958.0
300	1	41624.0	27937.1
	2	41626.1	27936.0

Table 2:

Gonad condition criteria applied to the genus *Eptratretus* from samples collected in Oregon, 1989.

Sex, stage	Condition	Criteria
Females		
1	Immature	Round eggs 1mm or less in size, eggs may appear as bubbles in anterior half of narrow (<2mm) gonad
2	Maturing (not mature)	Oblong eggs >1 mm, but < 5 mm in length and no large empty ovarian capsules (egg sacks)
3	Mature-ova developing	Oblong eggs >5 mm in length, without hooks (exclude fish in Mature-spent condition)
4	Mature-developed	Large eggs (>20 mm) with hooks
5	Mature-spent	Large empty ovarian capsules and also maturing or mature eggs
Males		
1	Immature	Posterior end of gonad small (about 1 mm) and almost colorless (slightly milky)
2	Maturing (?not mature?)	Posterior end of gonal with small (<1 mm) round white follicles
3	Mature-developed	Posterior end of gonad with large (>1 mm) (>1mm) round, white to brown follicles
Unknown		
1	Immature	Empty gonad, no testis or eggs observed
Hermaphrodite		
1	Hemaphrodite	Both eggs and follicles of testis present

Figure 1:

Length/Frequency - All Fish

Eptatretus stouti

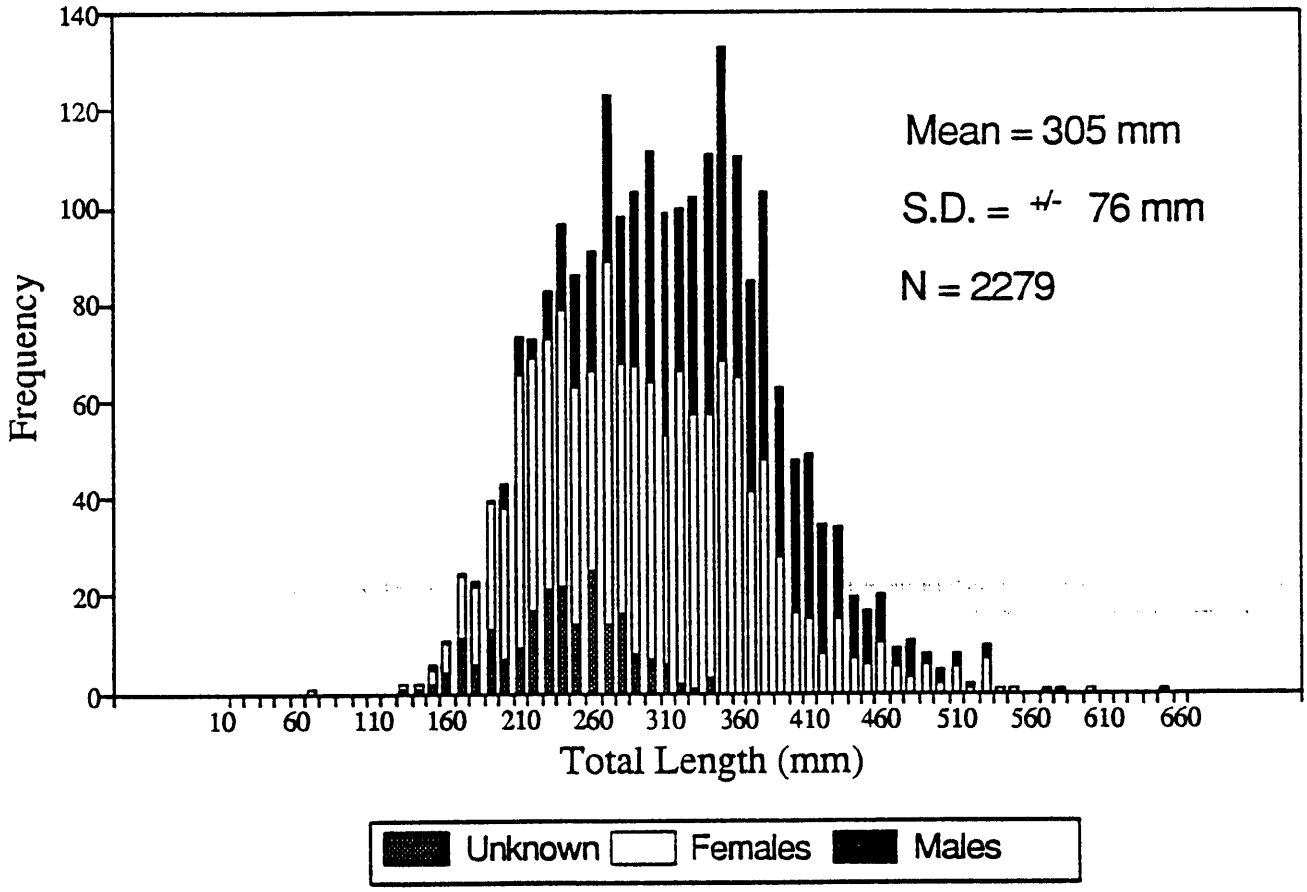


Figure 2:

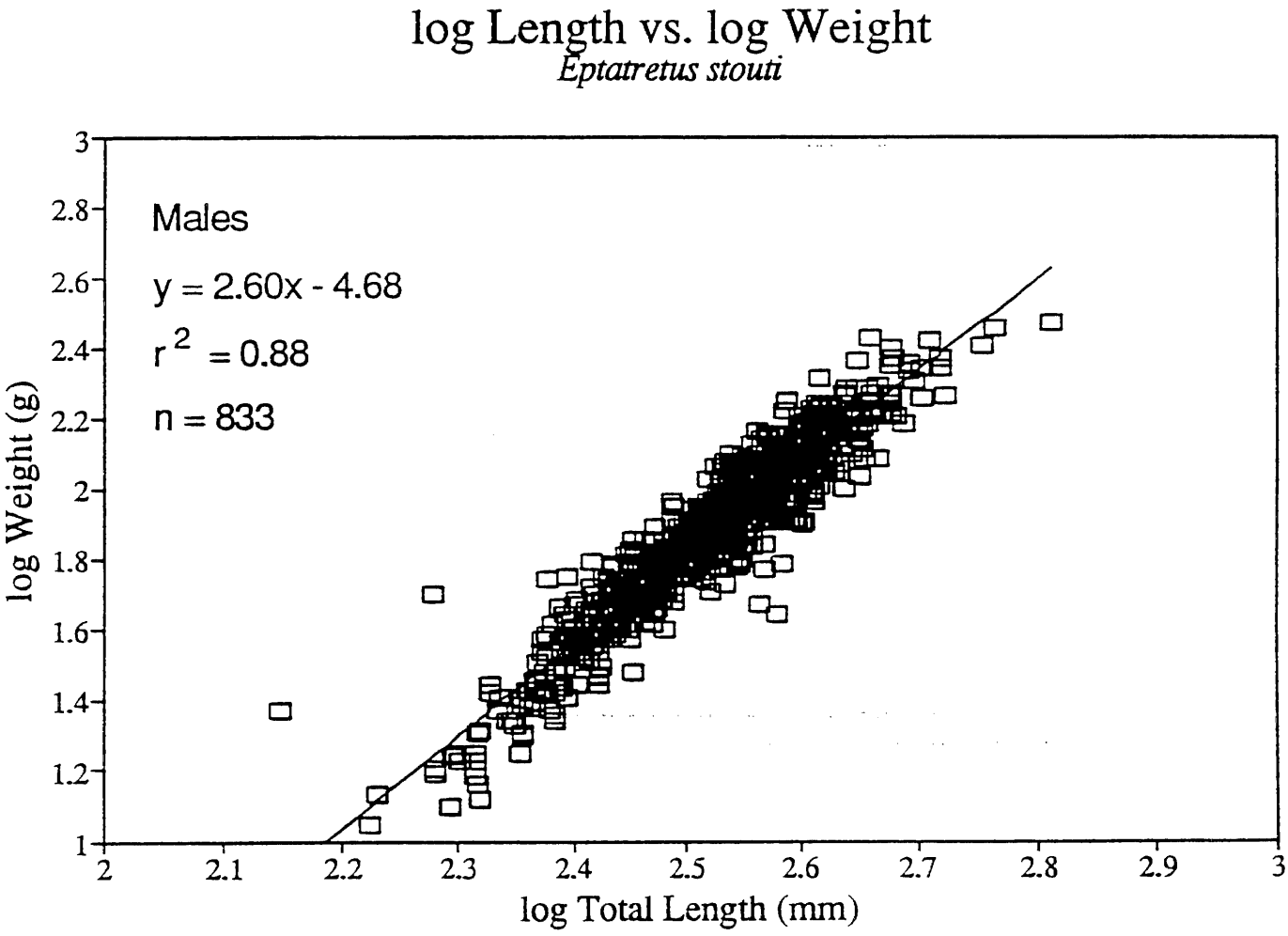

log Length vs. log Weight
Eptatretus stouti
Males
y = 2.60x - 4.68
r 2 = 0.88
n = 833
log Weight (g)
log Total Length (mm)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

Figure 3:

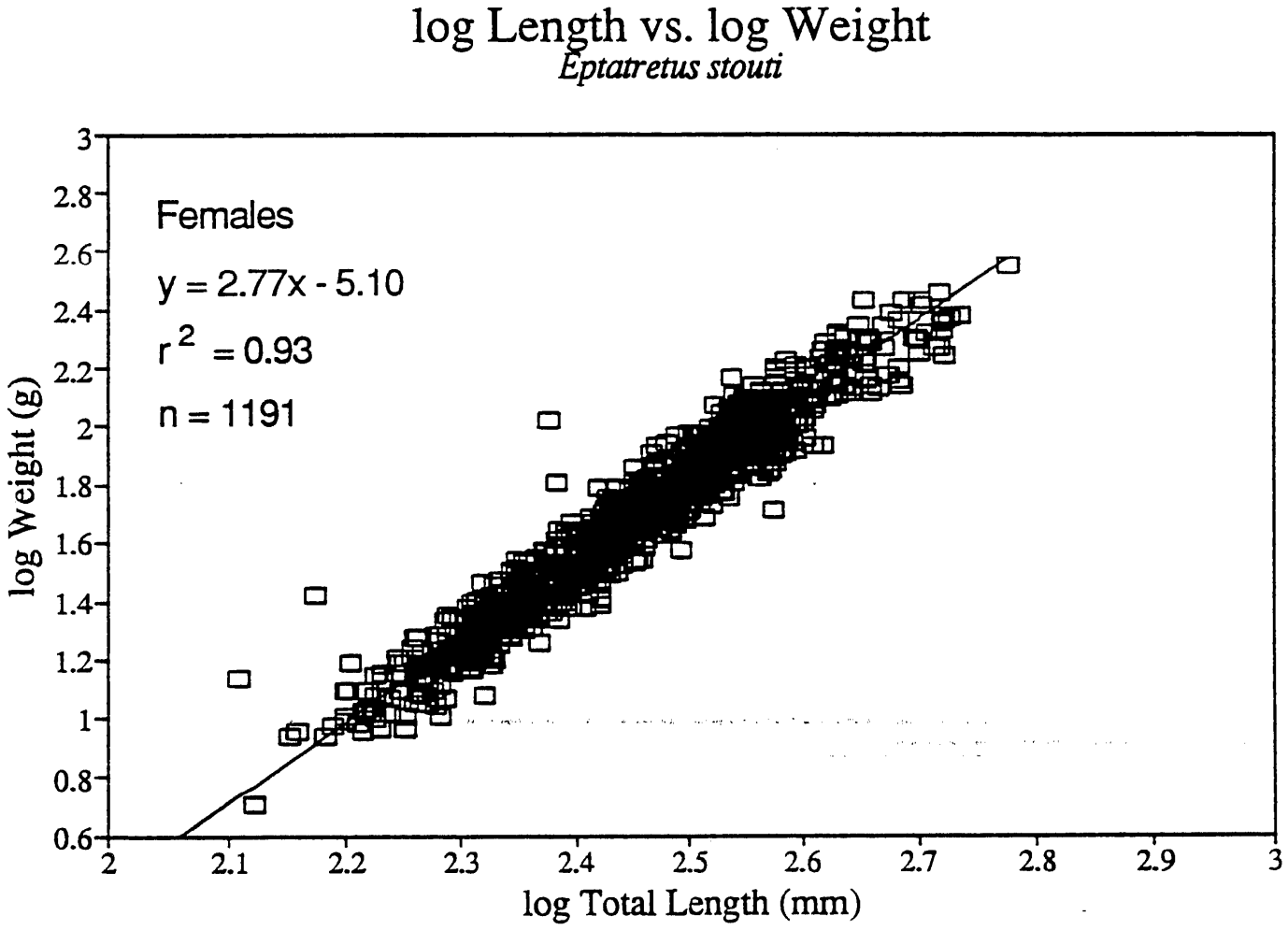

log Length vs. log Weight
Eptatretus stouti
Females
y = 2.77x - 5.10
r 2 = 0.93
n = 1191
log Weight (g)
log Total Length (mm)
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
2
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

Figure 4:

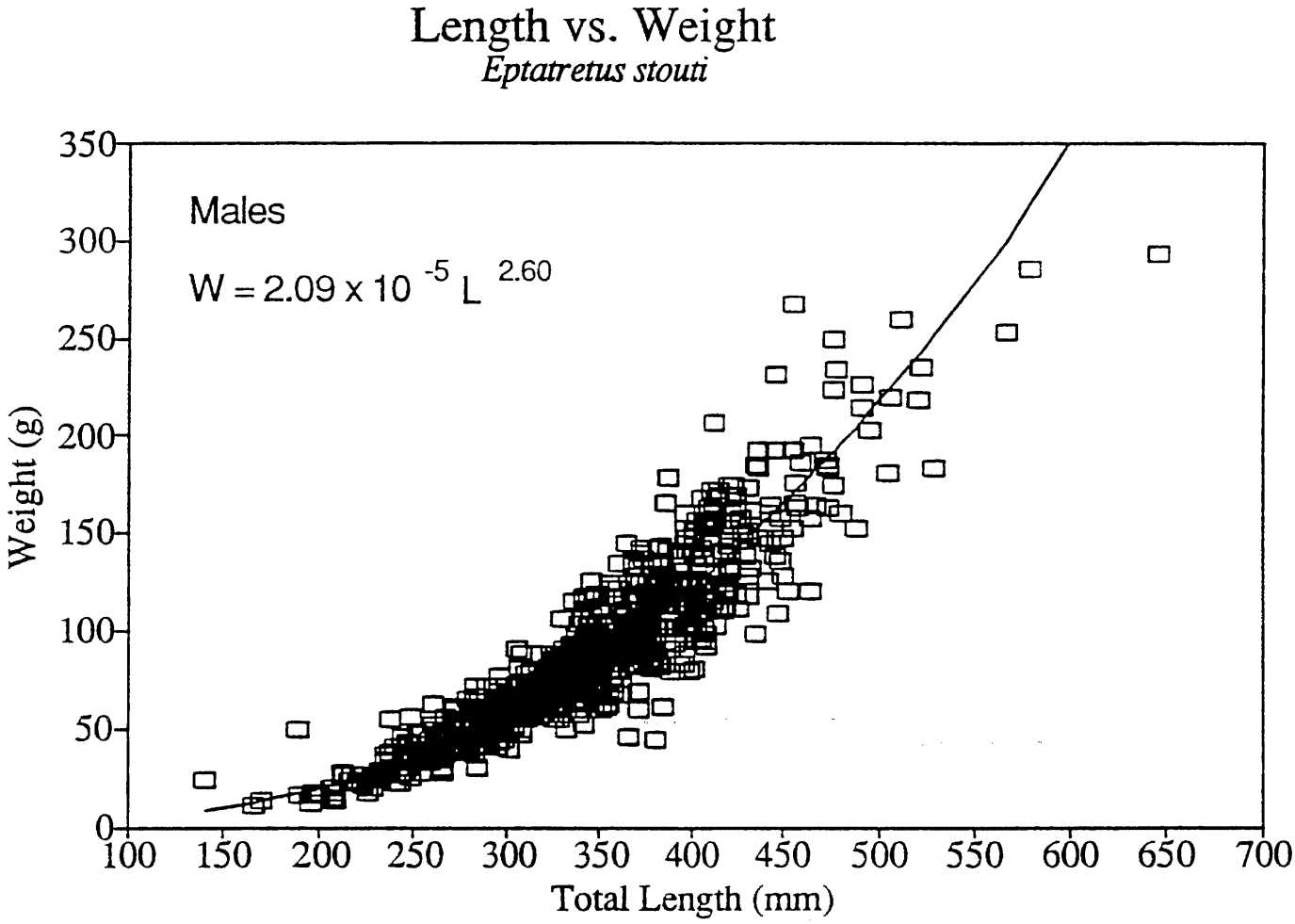

Length vs. Weight
Eptatretus stouti
Males
W = 2.09 x 10 -5 L 2.60
Weight (g)
Total Length (mm)
0
50
100
150
200
250
300
350
100
150
200
250
300
350
400
450
500
550
600
650
700

Figure 5:

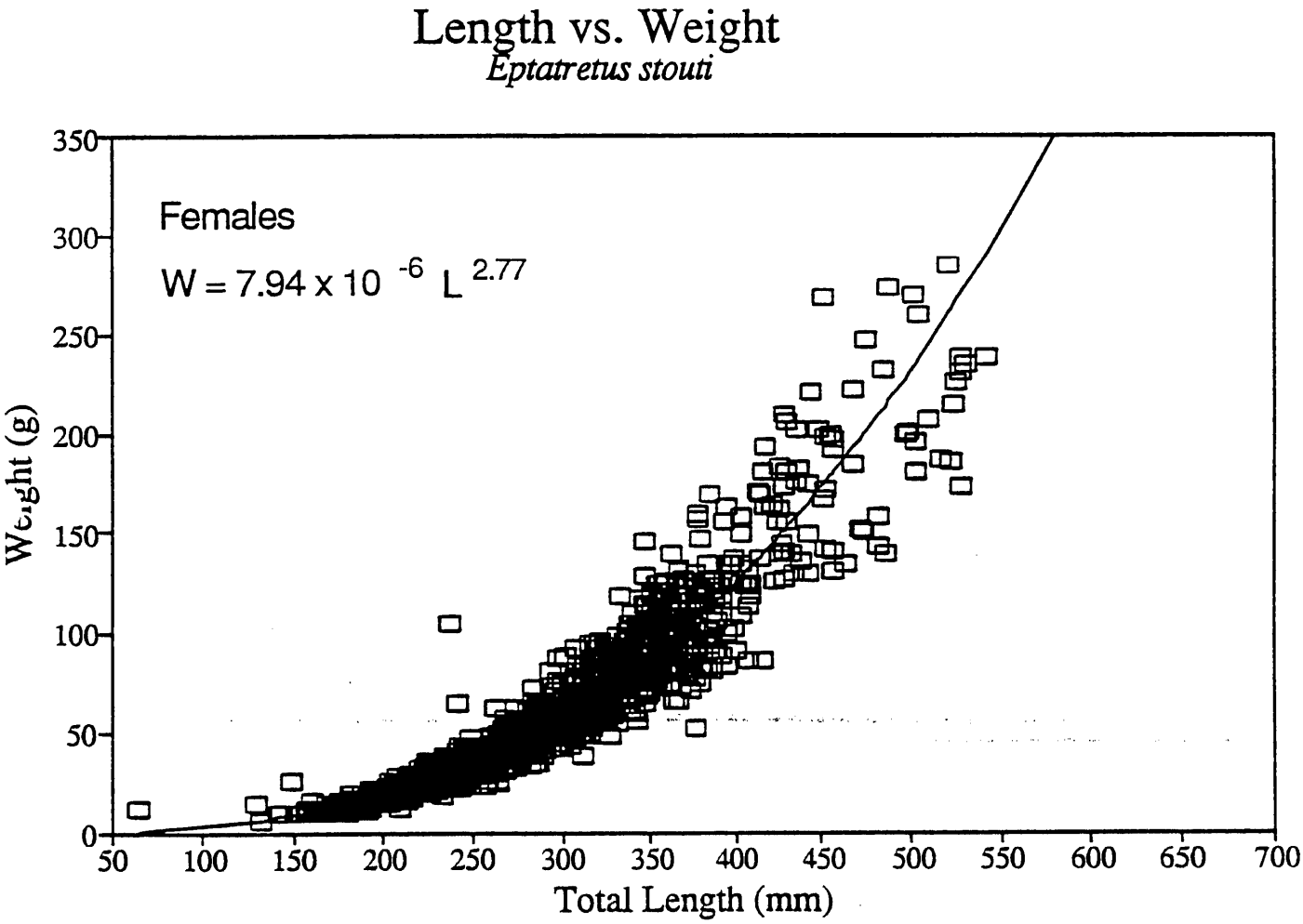

Length vs. Weight
Eptatretus stouti
Females
W = 7.94 x 10 -6 L 2.77
Weight (g)
Total Length (mm)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700

Figure 6

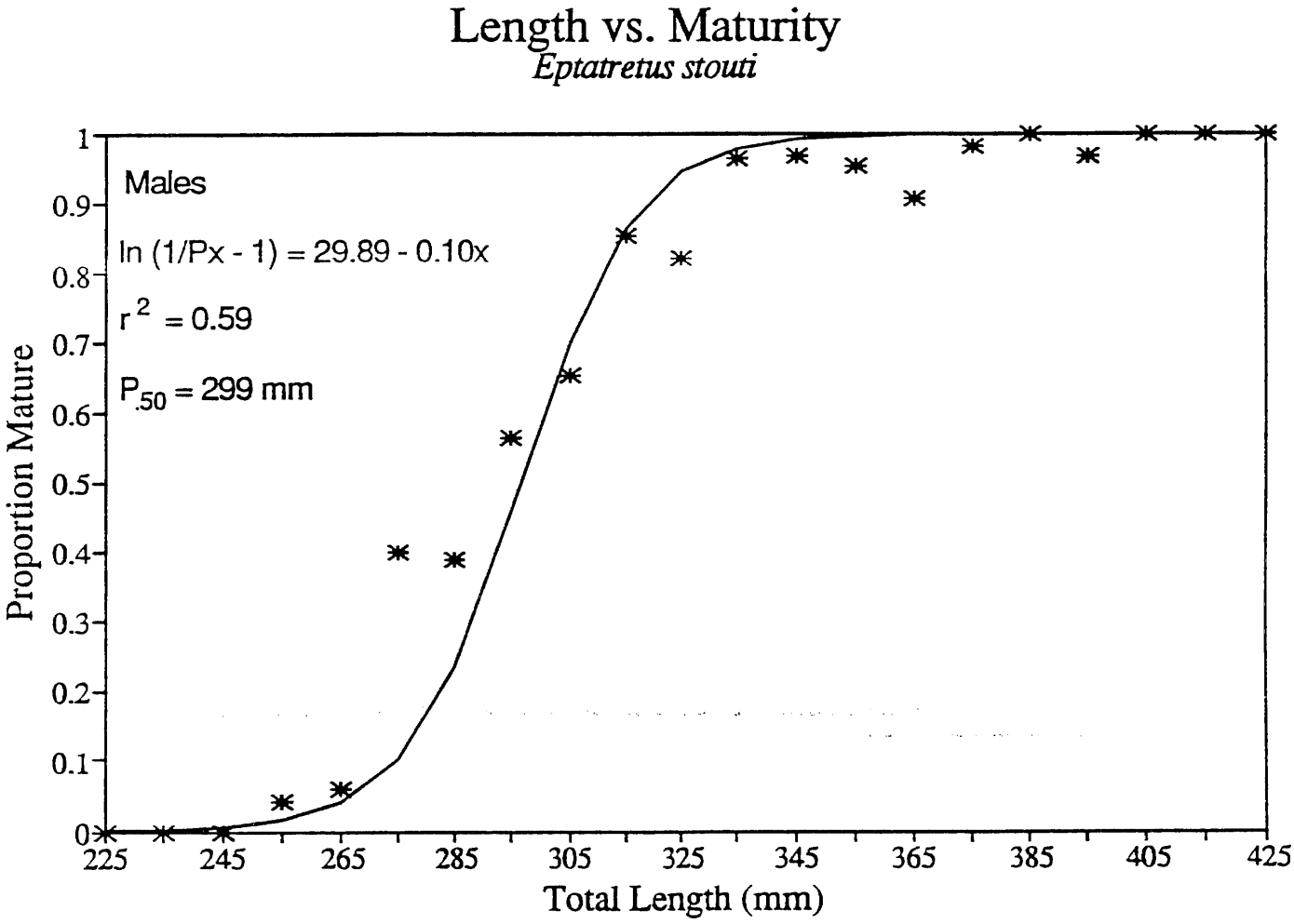

Length vs. Maturity
Eptatretus stouti
Males
ln (1/Px - 1) = 29.89 - 0.10x
r 2 = 0.59
P.50 = 299 mm
Proportion Mature
Total Length (mm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
225
245
265
285
305
325
345
365
385
405
425

Figure 7

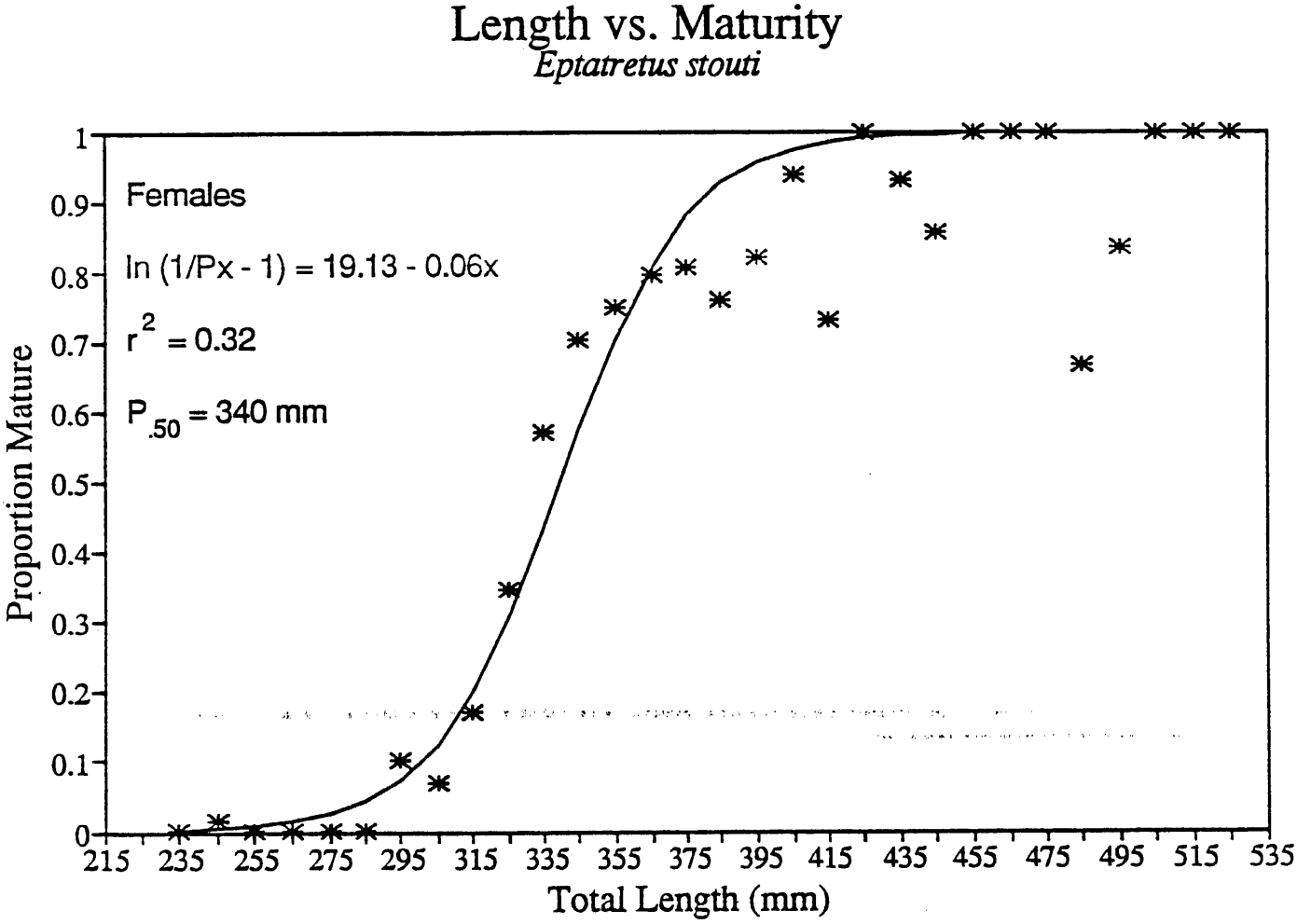

Length vs. Maturity
Eptatretus stouti
Females
ln (1/Px - 1) = 19.13 - 0.06x
r 2 = 0.32
P .50 = 340 mm
Proportion Mature
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
215 235 255 275 295 315 335 355 375 395 415 435 455 475 495 515 535
Total Length (mm)

Figure 8

Maturity for 4 Depths and 3 Seasons
Eptatretus stouti

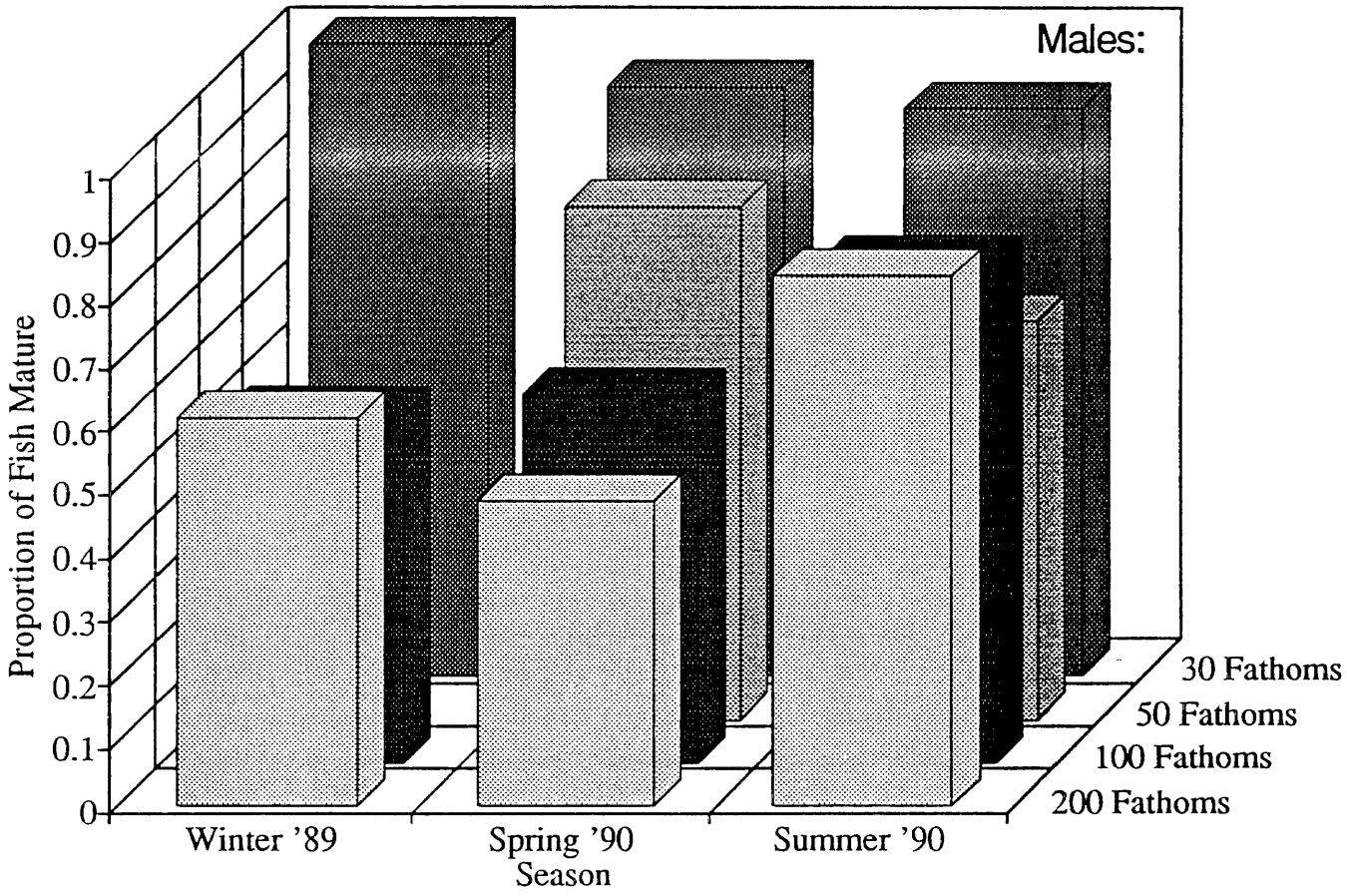


Figure 9:

Maturity for 4 Depths and 3 Seasons
Eptatretus stouti

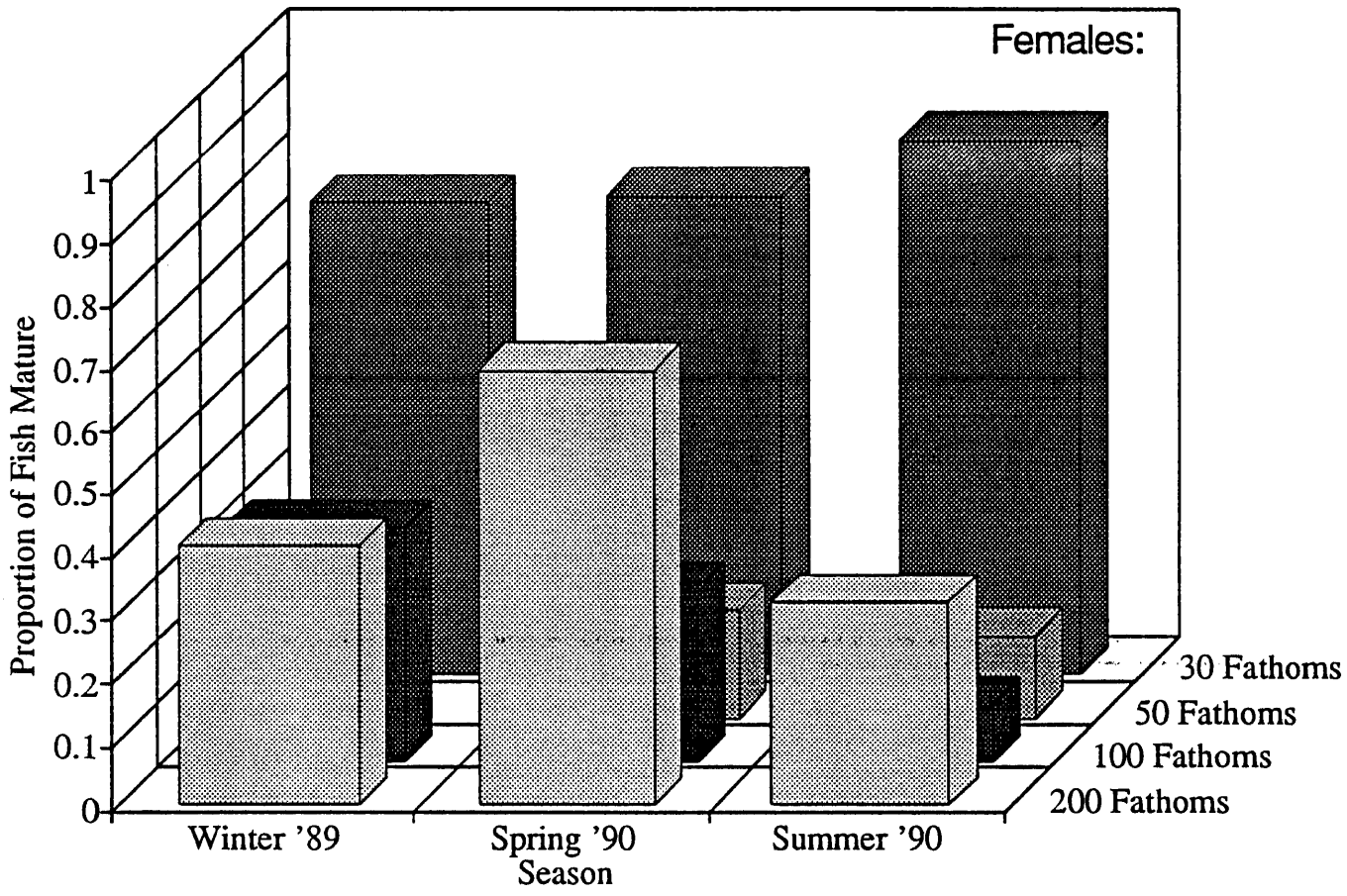


Figure 10:

Mean Lengths for 4 Depths and 3 Seasons
Eptatretus stouti

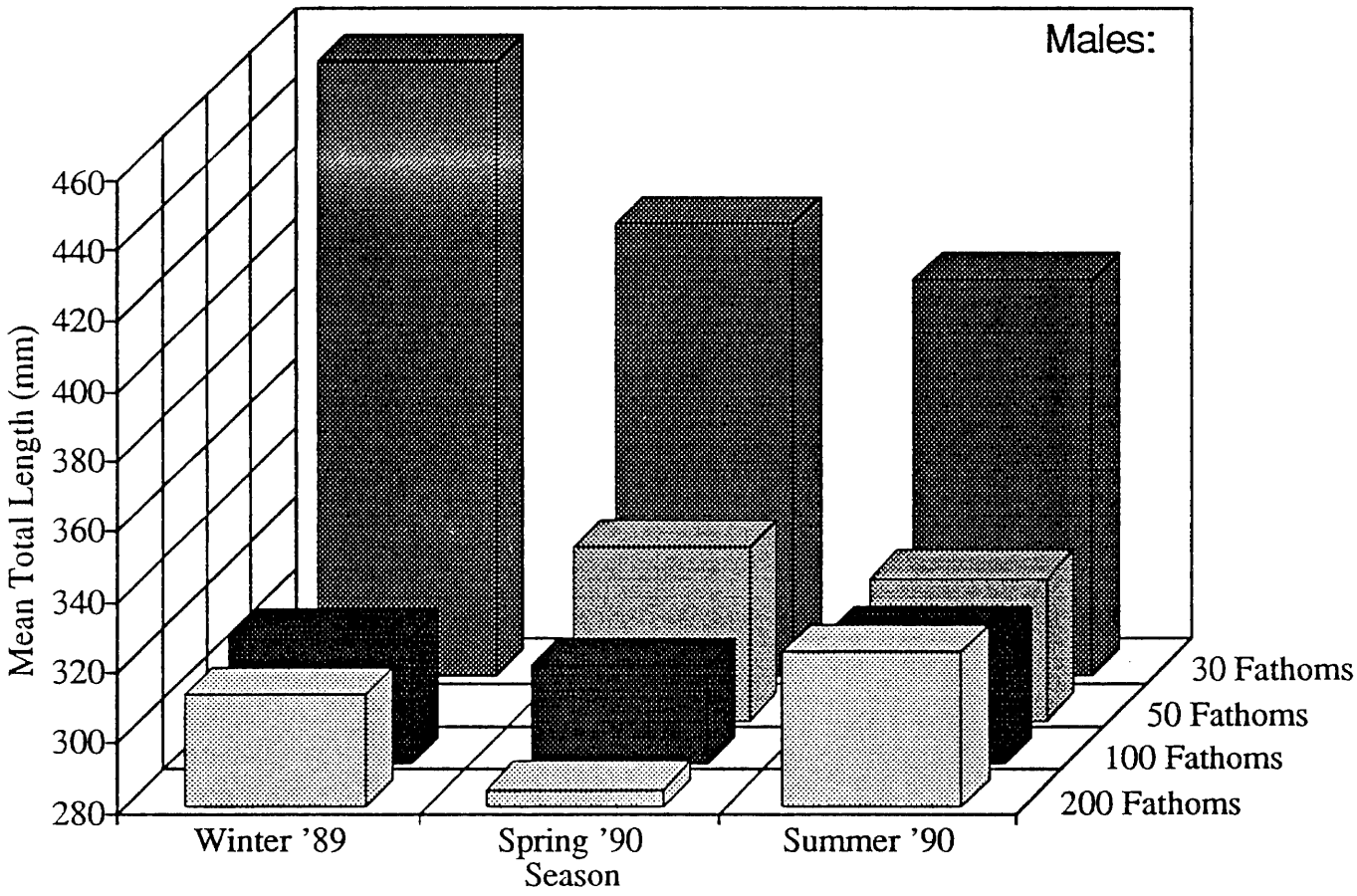


Figure 11:

Mean Lengths for 4 Depths and 3 Seasons
Eptatretus stouti

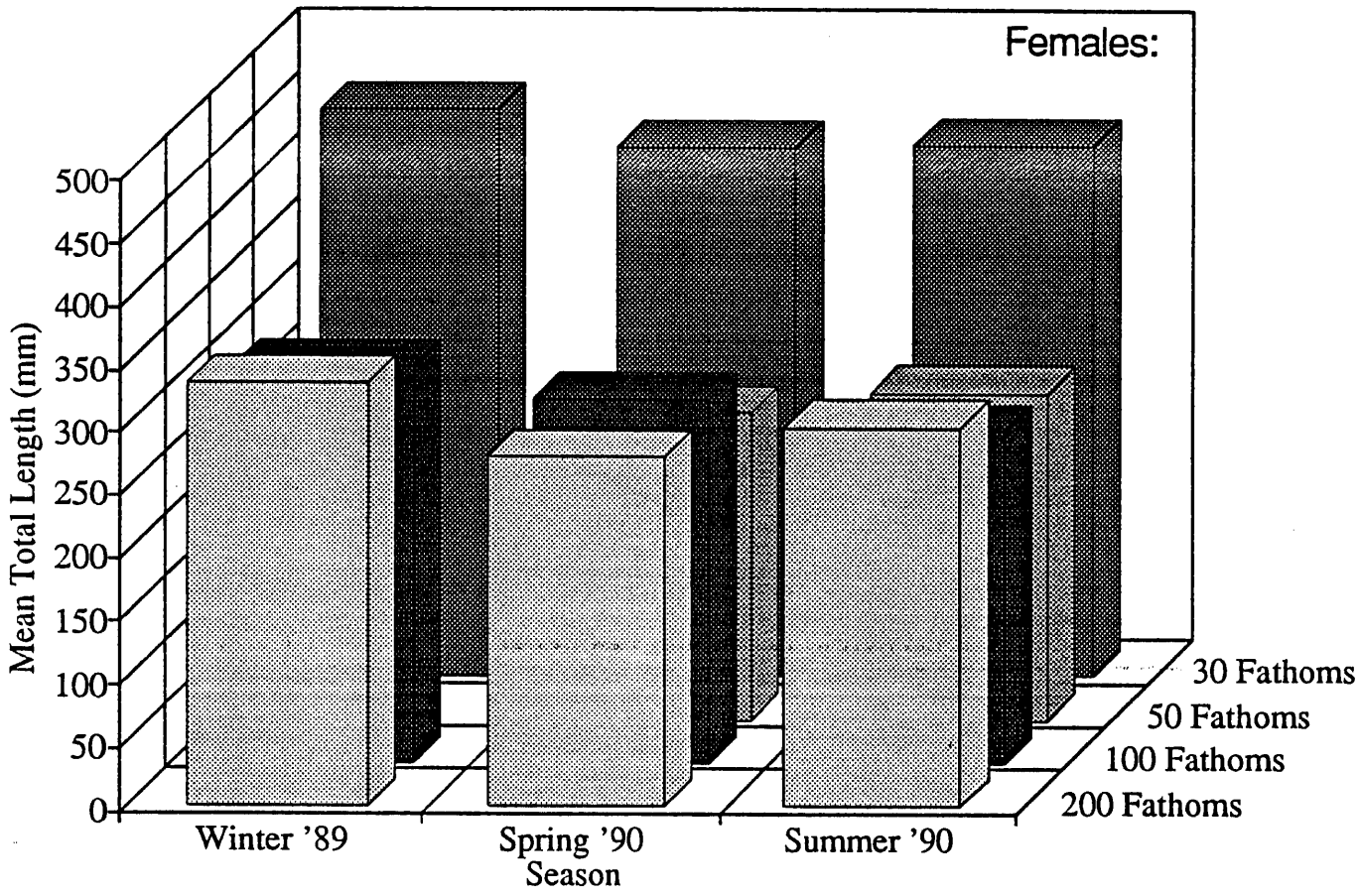


Figure 12:

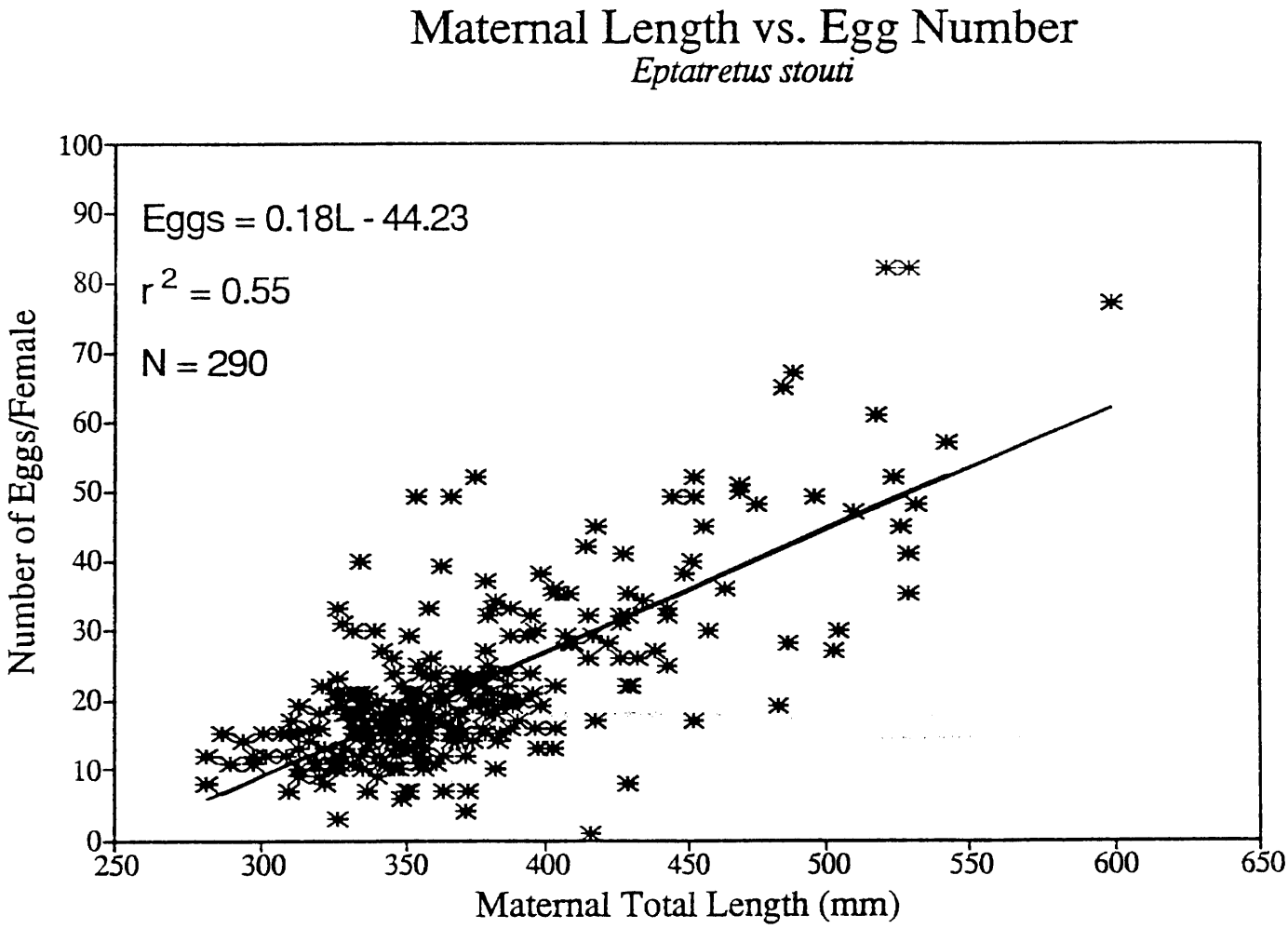

Maternal Length vs. Egg Number
Eptatretus stouti
Eggs = 0.18L - 44.23
r 2 = 0.55
N = 290
Number of Eggs/Female
Maternal Total Length (mm)
0
10
20
30
40
50
60
70
80
90
100
250
300
350
400
450
500
550
600
650

Figure 13:

Catch per Unit Effort (CPUE)
Eptatretus stouti

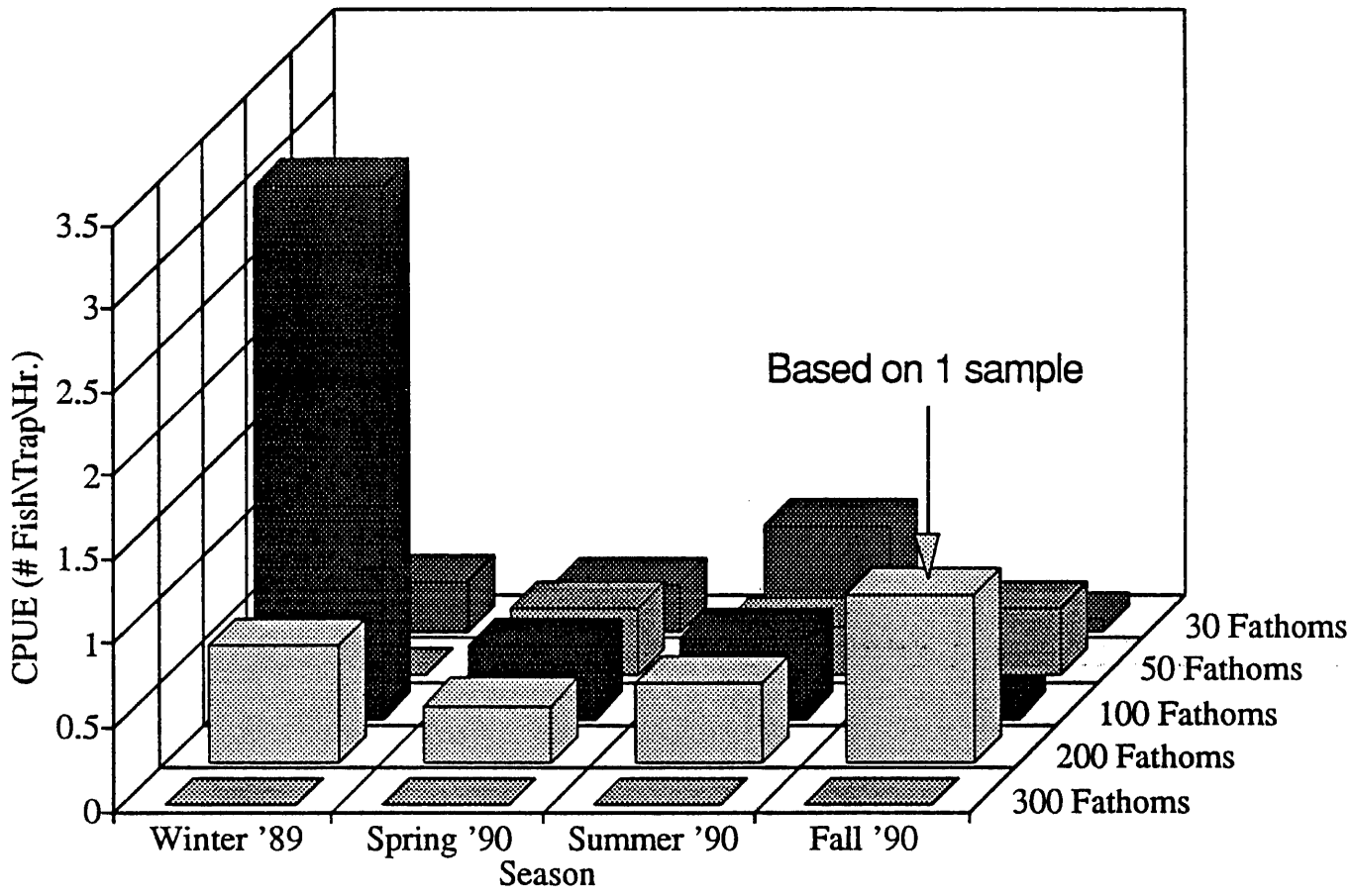
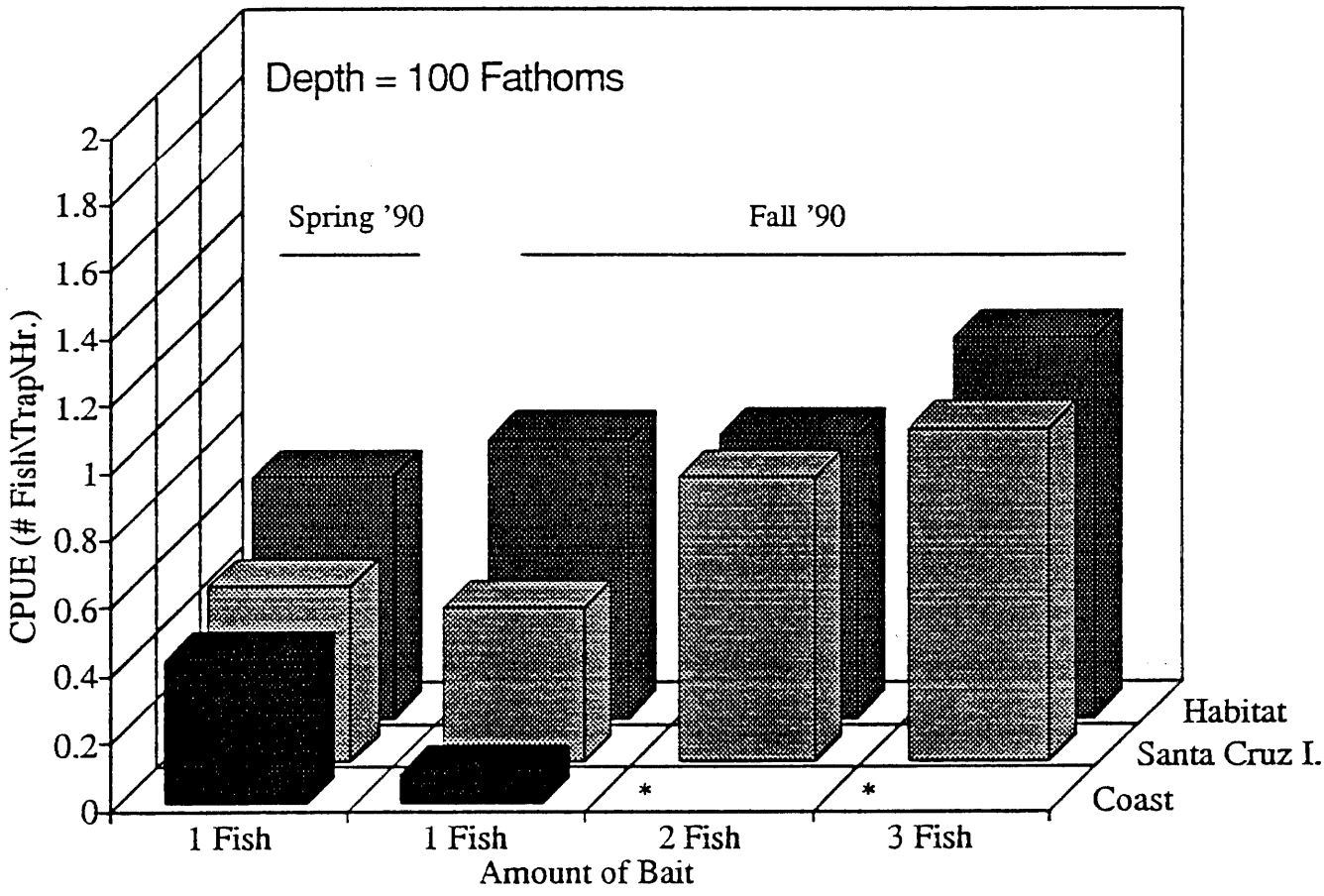


Figure 14:

CPUE at Several Locations
Eptatretus stouti



* No Data Taken

Figure 15:

Effect of Time and Amount of Bait

Eptatretus stouti

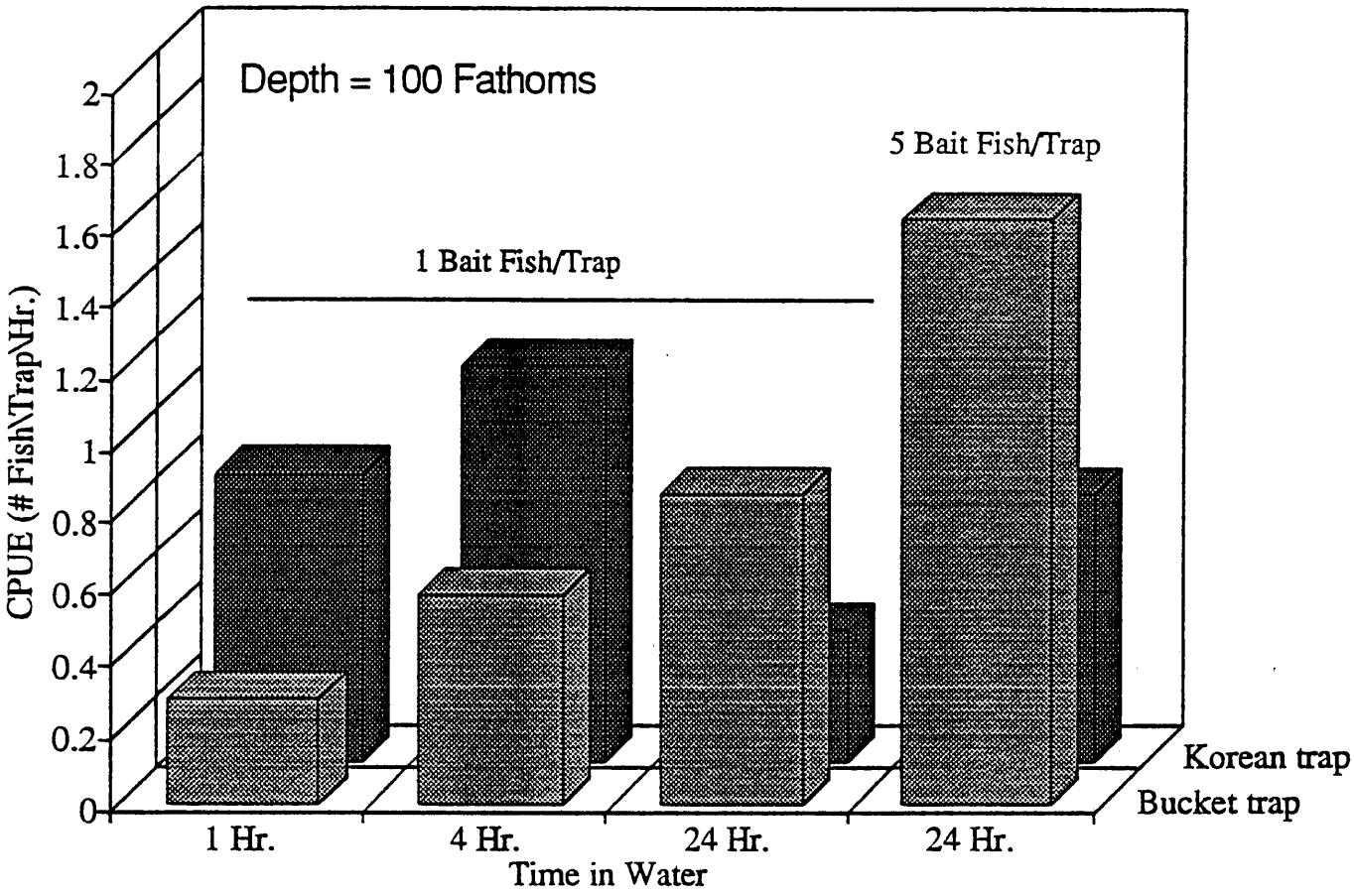
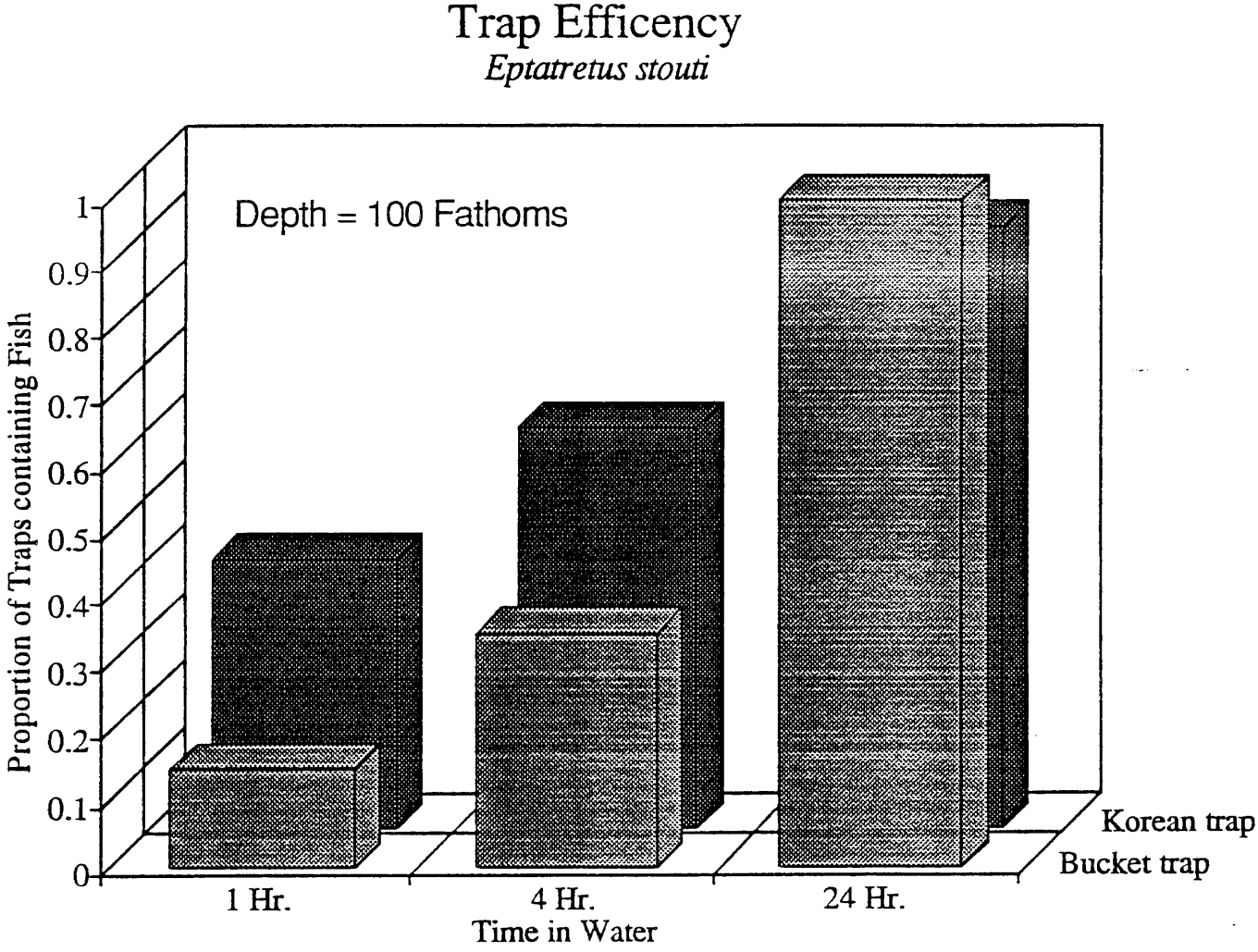
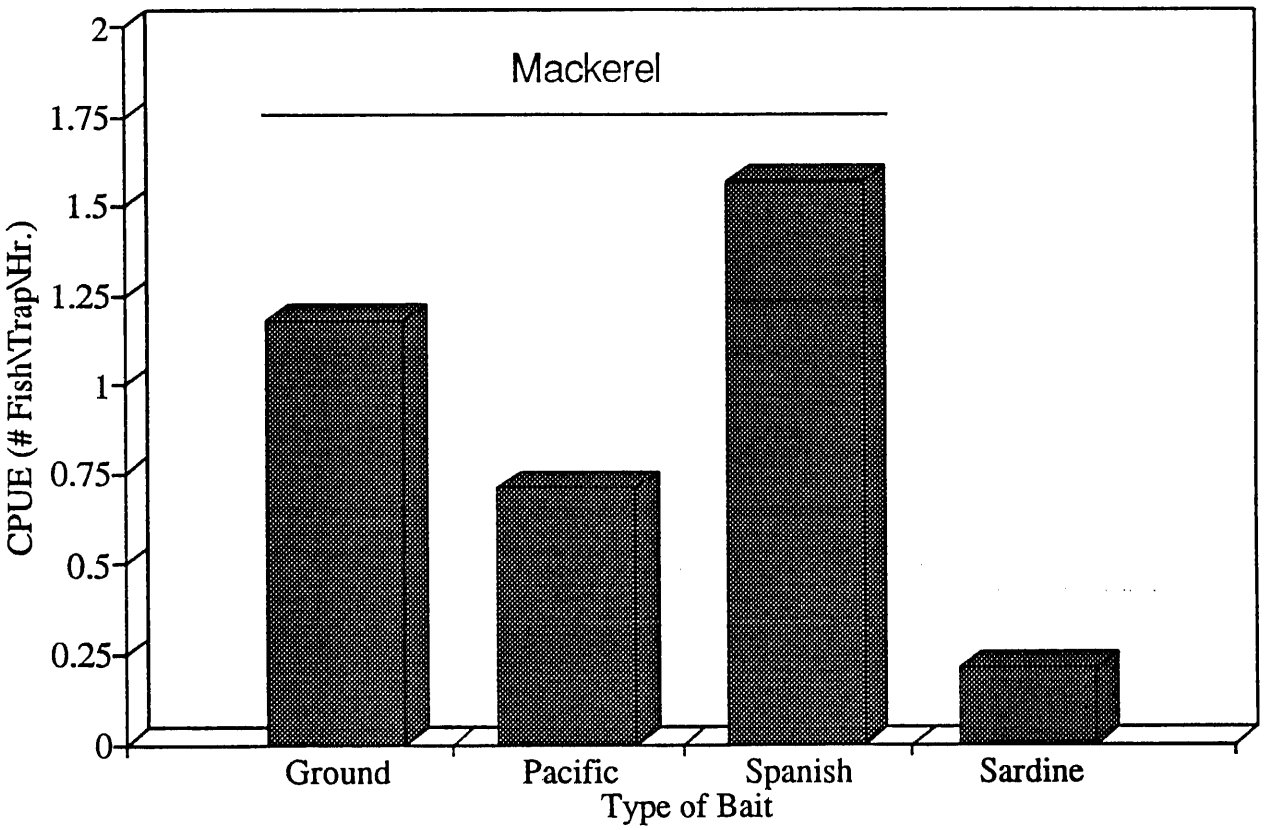


Figure 16:



00001928
ASSET

Figure 17:

Bait Efficency

Eptatretus stouti