

THE BIOLOGY OF THE NIGHT SMELT,
[*Spirinchus starksi* (Fisk 1913)],
OFF NORTHERN CALIFORNIA

by

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ABSTRACT

The general biology of the night smelt, *Spirinchus starksi*, was studied from April 1992 through September 1993 at Freshwater Beach in northern Humboldt County, California. Forty-five sampling trips over two spawning seasons, March to September, yielded a total of 9,310 fish. Most smelt were caught during receding high tides, at night, in slow moving surf, over a gravel substrate. Males outnumbered females 22:1 and attained greater average standard lengths (99.0 vs 91.4mm) and weights (10.10 vs 7.86 g). Females produced two size classes of eggs. Although this suggests a protracted spawning season, the ratio of the mean number (548) of mature eggs (1.2 mm diameter), per female, to the mean number (1,424) of immature eggs (0.3 mm diameter), per female, did not change over the spawning season. Scale analysis indicated that night smelt spawn at two years of age and then probably die before age three. Their diet consists mainly of gammarid amphipods, mysid shrimp and onuphid worms.

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INTRODUCTION

Night smelt, *Spirinchus starksi*, is a poorly known species belonging to the family Osmeridae, a group of small schooling fishes found in littorphylic waters throughout the northern hemisphere. Night smelt are not included in the reviews on smelt by Kendall (1927), and Hart and McHugh (1944). McAllister (1963), Miller and Lea (1972), and, Eschmeyer and Herald (1983) all conclude that little is known of night smelt biology. In addition, much of the information available on night smelt is contradictory. A California Fish and Game (CF&G 1919) article reports of the misidentification of night smelt as grunion (*Leurestes tenuis*) or capelin (*Mallotus villosus*). Cannon (1967) reported the maximum length of night smelt to be 10 inches, nearly twice the maximum size reported by Miller and Lea (1972). The early literature (Roedel 1948; Cannon 1967) also confuses this species with the whitebait smelt, *Allosmerus elongatus*.

There are freshwater (1), anadromous (5), marine (5), and landlocked (2) forms of smelt (McAllister 1963). Smelt fecundities range from 4,820 for pond smelt, (*Hypomesus olidus*), (Gritsenko et al. 1984a), to 61,910 for American smelt, (*Osmerus eperlanus mordax*), (Saunders and Power 1970). Mysid shrimp, isopods, copepods, gammarid amphipods, eggs, small fish, and aquatic worms are typical prey of most smelt species (Hoover 1936; Hart and McHugh 1944; Dryfoos 1965;

Altukhov and Yerastova 1974; Sterligova 1979; Gritsenko et al. 1984a; Haldorson and Craig 1984; Moyle and Herbold 1992). Smelt life spans range from 2 years, for surf smelt, *Hypomesus pretiosus pretiosus* (Rosa 1946), to 7 years for American smelt (Bailey 1964) and rainbow smelt, *Osmerus eperlanus eperlanus* (Sterligova 1979).

Although variable between sexes, life history descriptions do exist for most other osmerids (smelt). Smelt maximum standard lengths range from 120 mm for delta smelt, *Hypomesus transpacificus*, (Moyle 1976) to 300 mm for eulachon, *Thaleichthys pacificus*, (McAllister 1963). Night smelt have the third shortest maximum standard length (112 mm) of all smelt species (McAllister 1963). Three of the four shortest smelt species are within the genus *Spirinchus*. Male capelin (Pitt 1958a; Jangaard 1974) and longfin smelt, *Spirinchus thaleichthys*, (Moulton 1974) are longer than females. Conversely female pond smelt (Gritsenko et al. 1984a), and rainbow smelt (Ivanova and Polovkova 1972) are longer than males.

The scant biological information available on night smelt is as follows. They are found in coastal waters of the north-eastern Pacific Ocean between Shelikof Bay, Alaska (Dryfoos 1961), and Pt. Arguello, California (Miller and Gotshall 1965). Night smelt spawn at night on beach shores (Rosa 1946; McAllister 1963; Holm 1972; Hart 1973). Spawning is most intense from January to March, but extends into July (Rosa 1946). Similar spawning behavior is seen in surf smelt (Schaefer 1936; Thompson et al. 1936; Pentilla 1976), capelin, (Jangaard

1974; Pitt 1958a), and American smelt may also spawn similarly on beaches of large lakes (Lievense 1954; Rupp 1965).

During the spawning season night smelt segregate into schools by sex with males inhabiting shallower waters than females (Fitch and Lavenberg 1971). When ripe, females swim toward shore to spawn. When a critical ratio of males to females is reached, (8:1), the smelt spawn over coarse sand or gravel (Fitch and Lavenberg 1971). The sex ratio will eventually rise to 100:1. Any combination of actively feeding sea birds, sea lions, and seals or gentle waves and small gravel are indirect indices of a spawning site (Miller and Gotshall 1965). The fertilized eggs sink, adhere to the gravel substrate and are buried by drifting sand. Females return to the school after spawning. This cycle may occur more than once for each female within a season (Fitch and Lavenberg 1971).

Incubation time for night smelt eggs is 14 days (Fitch and Lavenberg 1971). Similar durations have been established for other smelt species (Hoover 1936; Hart and McHugh 1944; McAllister 1963; Misitano 1977; Sterligova 1979; Gritsenko et al. 1984b; Moyle 1992). Night smelt larvae have an average of 5 caudal melanophores and 17 melanophores along their ventral gut margin (Dryfoos 1965; Mataese et al. 1989). Night smelt larvae may be differentiated from other smelt larvae by the number and pattern of the preanal ventral midline melanophores (Morris 1953; Young 1984). Night smelt larvae are presumably carried offshore by ocean currents after hatch. Juvenile night smelt (40-60mm) are consistently caught offshore of Eureka, California in benthic otter

trawls over sandy bottoms from September to October by Humboldt State University scientists (Mulligan 1994). They have also been found in offshore waters to 200 feet deep between Pt. Arguello and Morro Bay, California (Fitch 1949).

The objective of this study was to present an overview of the literature, and to determine and compare biological information on the size, reproductive ecology, age, and diet, of northern California night smelt with other osmerids.

Taxonomy and Etymology

Osmeridae belong to the order Salmoniformes. Within the family there are two subfamilies, six genera and ten species and thirteen forms counting monotypic species and subspecies (McAllister 1963). The recognized genera are *Allosmerus*, *Hypomesus*, *Mallotus*, *Osmerus*, *Spirinchus*, and *Thaleichthys*. *Spirinchus*, was first used by Johnston as an unestablished name for the genus, but was later formally designated a subgenus of *Osmerus* (Jordan and Evermann 1896). *Spirinchus* was later recognized as a genus (Hubbs 1925) to include former *Osmerus* species *O. lanceolatus*, *O. thaleichthys*, and *O. starksi*. McAllister (1963) made no changes to the genus in his review of the smelts.

Spirinchus contains three species, longfin smelt (*S. thaleichthyes* Ayres), shishamo (*S. lanceolatus* Hikida), and night smelt (McAllister 1963). Longfin smelt are typically anadromous but may also live in lakes. They range from Prince

William Sound, Alaska to San Francisco Bay but are most common in the Puget Sound area (Dryfoos 1965). Shishamo are also anadromous and are found on the eastern coast of Hokkaido Island, Japan (McAllister 1963).

Night smelt were first described by Fisk (Fisk 1913) who named the species for her Stanford University professor E. C. Starks (Fitch and Lavenberg 1971; Hart 1973). *Spirinchus* means smelt in medieval latin (Hart 1973). Moyle (1976) further states that the latin translation of *Spirinchus* is "breath-beginning" referring to the duct which connects the air bladder and gut. There are several theories on the origin of the term "smelt". Moyle (1976) claims "smelt" may have originated from the fish's peculiar cucumber-like odor (smell=smelt). McDowall et al. (1993) have linked the cucumber-like odor, present in all osmerids, to Trans-2-cis-6-nonadienal in the skin. The function of this compound is unknown. Greek translation of Osmeridae is "odorous family" (Lamb and Edgell 1986). Similarity between the words "smelt" and "smolt" have also created theories.

The American Fisheries Society's official common name for *Spirinchus starksi* is night smelt (Amer. Fish. Soc. 1991). Northern California fishers refer to the species as "night fish" as opposed to surf smelt which are referred to as "day fish". Early literature may incorrectly refer to night smelt as "whitebait" or "longfin" smelt (Jordan and Gilbert 1881; Jordan and Gilbert 1882). Other unofficial common names observed in the literature include sandsmelt, night surf

smelt, whitefish, surf smelt, frittura, small fry, and pertin (Roedel 1948; Cannon 1967; Holm 1972).

Fishery

Indian - Historical

Night smelt have been a valuable food source for centuries. Indian tribes would travel from inland areas to the coast for the smelt spawning season (Bonnot 1930). Fish were caught with A-frame nets similar to the nets used today. The net fibers were constructed from stinging nettle *Urtica dioica* (Bonnot 1930). Whole fish were preserved dry (CF&G 1919) or smoked for the winter. Indians avoided cutting the smelt out of fear that spawning schools would not return the following year (Swan 1880).

Recreational/Commercial - Present

Various gears have been used to catch night smelt. Some of these methods are hook and line, snag lines, two-man jump nets, dip nets, beach seines, and Hawaiian style throw nets. The most popular commercial and sport gear is the "A" frame net (Cannon 1967; Fitch and Lavenberg 1971; Holm 1972). Current California fishing regulations restrict commercial "A" frame nets to a length of seven feet. No limit is placed on catch. Sport fishers may use any size dip net. Throw nets and 7/8" mesh beach seines, no longer than 20 feet in length, may be used north of Pt. Conception, California. The California sport fishing catch is

limited to 25 pounds per day (CDF&G 1993). Smelt sportfishers in Oregon are not required to possess a fishing license and are also limited to 25 pounds of smelt per day (Ore. Dept. Fish & Wild. 1993).

Night smelt catch statistics were not kept for California prior to 1991. They were combined with surf smelt and whitebait under the heading "smelt, various species". Older catch statistics for "jacksmelt" may also be included in the smelt category, these include the atherinid species, topsmelt (*Atherinops affinis*), jacksmelt (*Atherinopsis californica*) and occasionally grunion, (*Leuresthes tenuis*), (Clark 1928; Fitch and Lavenberg 1971). California night smelt landings ranged from 665,050 to 897,113 pounds per year from 1991 to 1993 with an average of 672,690 pounds (Calif. Dept. Fish & Game 1991-93).

Night smelt are marketed fresh in retail markets for human consumption or for bait (Holm 1972). They are also sold to marine aquaria parks as marine mammal food (Miller and Gotshall 1965).

STUDY SITE

Night smelt were caught over the entire span of Freshwater Beach, Redwood National Park, California (Figure 1). The study site, west of highway 101, is 65 km north of Eureka, California. The 2 km long beach is bounded to the south by Freshwater rocks and to the north by Lookout Point and Redwood Creek Beach. Due to free R/V camping and close proximity to Redwood National Park attractions, the beach is heavily impacted by tourists and sportfishers during the summer. The beach site averages 114 vehicles per night between June and August (U. S. Dept. of Int., Nat. Park Serv., Mon. Serv. Rep. 1990-1993).

Freshwater Beach has mild surf, ample sand, and a relatively flat bank during the spring and summer (Res. Agency of Cal. 1965). The high and low tides are generally less extreme during this period than in the winter. During the fall and winter, ocean currents along the spit move offshore (Resources Agency of Calif. 1965).

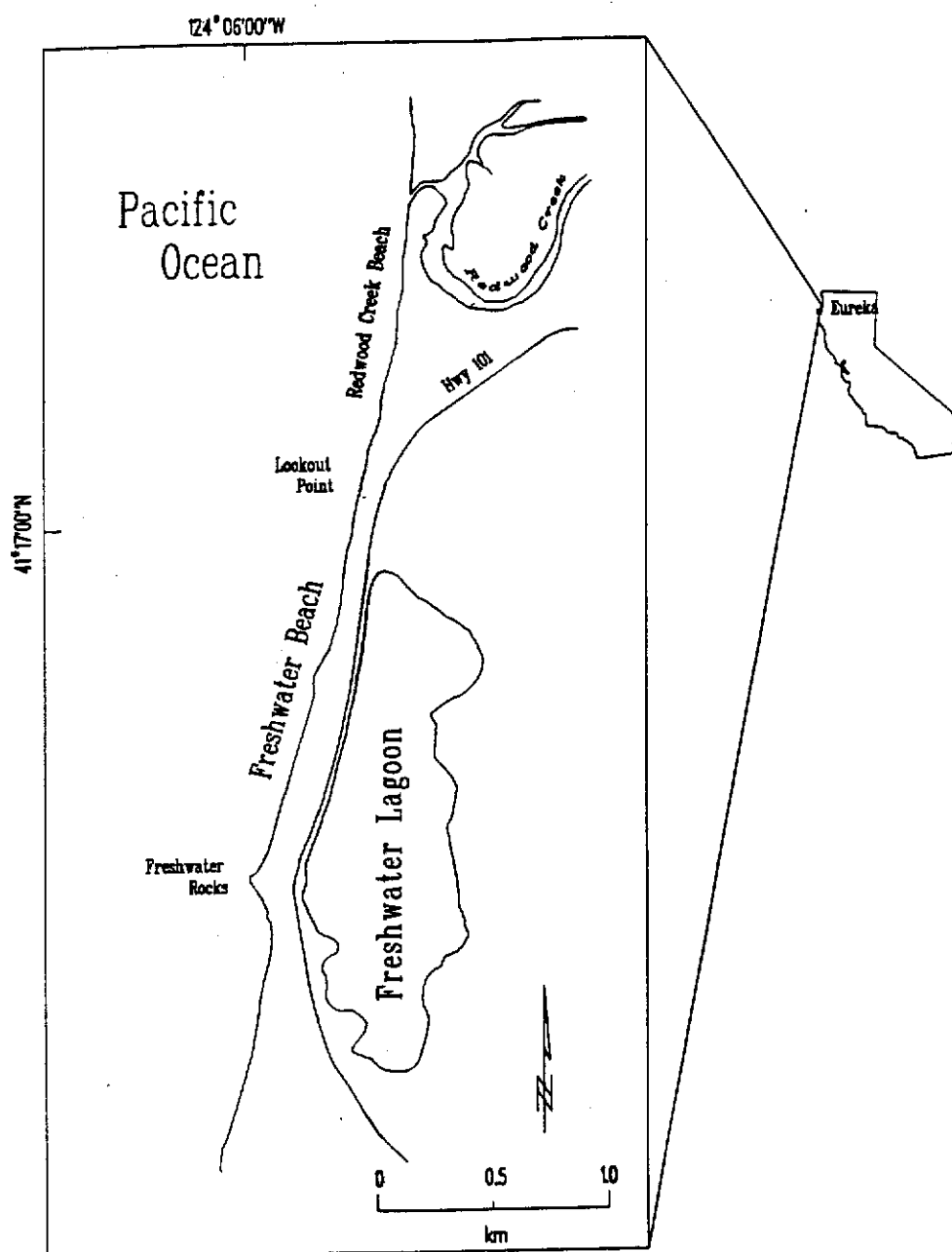


Figure 1. Freshwater Beach, 65 km north of Eureka, California.

METHODS

Sampling

Nighttime sampling trips were made at approximately one week intervals over the duration of the 1992 (March to October) and 1993 (February to September) spawning seasons. Sampling was conducted under conditions recommended by local smelt fishers (Compton et al. 1993). Occasionally four wheel drive vehicles equipped with hand held search lights were used to locate spawning smelt visible at the base of waves as they were curling. A six foot "A" frame surf net with 15 mm mesh was used in all sampling. The one-man net is placed in knee deep water ahead of incoming waves. After the wave has passed through the net, the net is reversed to catch the smelt in the backwash of the returning wave. A thermometer and refractometer were used to measure the temperature and the salinity, respectfully, of a half liter water sample taken waist deep at the spawning site on each sampling trip. The length of time fished was recorded, and catch per unit effort (number of fish caught per minute) was computed for each sample. Qualitative descriptions of substrate type and size, the grade of the wave slope, weather, amount of ambient light, the severity of the surf, and any discernable pattern in wave action were also recorded.

Analyses

Fish were fixed in 10% formalin and transferred to 40% isopropyl alcohol for preservation. For individual identification, fish were strung in sets of 100, through gill openings, on monofilament fishing line and assigned reference numbers.

Male and female SL, weight, and condition factor sample means were compared by Welch's approximate *t*, to account for the samples' differing variances (Zar 1984). Tests for significance of correlations were carried out according to Zar (1984). All other statistical analyses followed those of Samuels (1989). Statistical consultation was provided by Mike Moore, and Professor Yoon Kim of the Humboldt State University Mathematics Department.

Length

Standard length (SL) was measured from the tip of the lower jaw with the mouth closed, to the caudal flexure (McAllister 1963) using vernier calipers accurate to 0.1 mm. Means ($\bar{x}$), variances, standard errors of the $\bar{x}$, and 95% confidence intervals were computed for sample, seasonal, and overall male and female SLs. Seasonal standard length means were statistically compared by one tailed student *t*-tests. Congruency of male and female SL $\bar{x}$ s were examined over the 1992 and 1993 seasons, and over the two season sampling period by analysis of variance (ANOVA). Male and female $\bar{x}$ s were compared by regression and

covariance analysis. Length to weight regressions were calculated for both males and females.

Weight

Weights of preserved and blotted dry smelt were measured to the nearest 0.01 g using an electronic balance (Sartorius 1202 MP). Means, variances, standard errors of the $\bar{x}$, and 95% confidence intervals were computed for sample, seasonal, and entire study, male and female weights. Seasonal weight means were statistically compared by one tailed students t-test. Congruency of male and female weight $\bar{x}$ s were examined over the 1992 and 1993 seasons, and over the entire two season sampling period by ANOVA. Male and female $\bar{x}$ s were compared by linear regression and covariance analyses.

Health and Condition Factor

Condition factor was calculated as:

$$CF = \frac{W \times 10^5}{L^3}$$

where W is weight in grams and L is SL in mm (Bolger and Connolly 1989).

Means, variances, standard errors of the $\bar{x}$, and 95% confidence intervals were computed for sample, seasonal, and entire study, male and female condition factors.

Condition factor $\bar{x}$ s were statistically compared by two tailed students t-tests.

Congruency of male and female condition factor $\bar{x}$ s were examined over the 1992 and 1993 seasons, and over the entire two season sampling period by ANOVA. Male and female $\bar{x}$ s were compared by regression and covariance analyses.

Smelt were examined internally and externally for macroparasites. Parasites were identified to genera using Kozloff (1987).

Sex Ratio

The percentage of male fish in each sample was calculated. To determine if males significantly outnumber females, the sample, 1992, 1993, and the two season sampling period percentages were examined using Chi-square tests.

Eggs per Female

An attempt to determine the true fecundity of night smelt was not made because samples were taken during the spawning period, thus sampling both prespawned smelt and postspawned smelt. Therefore, an estimation of fecundity would most likely be biased. The study instead is intended to provide researchers with an initial fecundity survey from which future experiments can be based.

Sex was determined by gross inspection of the gonads. Mature eggs and ovaries were removed. All mature eggs were counted while immature egg laden ovaries were weighed to the nearest 0.01 g using an electronic balance. Immature eggs were counted from ten randomly selected ovaries. A conversion factor for ovary weight to immature eggs was made by dividing the sum of the 10

immature egg subsamples by the sum of the 10 ovary weights. A dissection microscope equipped a reticular eyepiece was calibrated to measure egg diameters to (± 0.1 mm)..

Means, variances, standard errors of the mean, and 95% confidence intervals were computed for mature, immature and total egg fecundities of samples, seasons, and the two season sampling period. Congruency of mature, immature, and total eggs per female $\bar{x}$ s were examined over the 1992 and 1993 seasons, and the entire two season sampling period by ANOVA. Correlations were made between mature, immature and total egg fecundities to SL, and to weight. The mean percentage of mature eggs was calculated for each sample. Mature and immature $\bar{x}$ s were compared by analyses of covariance.

Diet.

The stomach, from the anterior end of the body cavity to the pylorus, was opened by cutting with a scalpel. The contents were removed and grossly identified to crustaceans, polychaetes, fish eggs, fish, detritus, sand, miscellaneous, or empty. Invertebrate stomach contents were later identified to genus using Kozloff (1987). Individual and group percent frequency of occurrences were calculated for prey types. Individual percent frequency of occurrence was determined by dividing the number of fish in which a particular prey type occurred by the total number of fish sampled, while group percent frequency of occurrence was determined by dividing the number of fish in which a particular prey type occurred by the number of fish with stomachs that contained a prey type of any

kind. Graphic comparisons of prey type occurrence percentages were made between sexes.

Aging

Individuals were aged by scale analysis. Scales ventral to the adipose fin and dorsal to the lateral line (Dryfoos 1965) were examined from subsamples of each sample. Random sampling, stratified by sex and SL, was used in the selection of 10 males, and 2 females from each sample (Ketchen 1950). In addition, scales from all small and large male (<90 or >115 mm SL) and female (<80 and >100 mm SL) smelt were also examined. Annuli were identified by a progressive shortening of the incomplete circuli from the focus outward and "shiny lines or scars" when present, see McKenzie (1958). Circuli were counted between annuli. Fish were categorized into 6 circuli pattern types (A-F). These types were not validated by other means so reference to time period (e.g. year) is for convenience only.

- 1) "A". full year - partial year
- 2) "B". partial year - full year
- 3) "C". partial year - full year - partial year
- 4) "D". full year - full year
- 5) "E". full year - full year - partial year
- 6) "F". partial year - full year - full year

Full year segments were identified by 10 to 19 circuli and partial years were determined to contain 1 to 8 circuli. Comparisons of circuli patterns and $\bar{x}$

numbers of circuli within segments were made between males and females, large and small smelt, and the random subsamples over the sampling period.

Spawning Site

Substrate

Two, two-liter substrate samples were taken during low tide on five occasions from areas where spawning fish were sampled. A 1/8" thick piece of plexiglass was used to remove the uppermost surface layer of the beach slope. Substrate samples were first wet sieved, then baked, and then dry sieved for accurate measurement (Ingram 1971). Four sieve sizes were used for both wet and dry sieving (25, 12.5, 2, and 1 mm). Each substrate size class was weighed using an electronic balance accurate to 1 g (Ohaus CT6000-S) and its percentage by weight calculated. The two sample percentages from each date were then averaged.

Conditions

Tidal height and rate were calculated using the "Tides 1.6" software program (Wallner 1990). Catch per unit effort (CPUE) was plotted against tidal height, and rate.

RESULTS

Histograms of SLs, weights and condition factors for males and females, as well as histograms of the number of eggs per female, percentages of males, prey types, circuli patterns, and spawning substrate sizes are located in the appendix. Other figures in the appendix include SL, weight, condition factor, the number of eggs per female, the percentage of males, prey types, circuli patterns, and catch per effort against calendar days. Also included are scatterplots for male vs female SLs, weights, and condition factors, and eggs per female vs SL and weight, as well as catches per effort vs tidal height and rate.

Length

Male SLs for 1992 and 1993 appear to be normally distributed and ranged from 83.4 to 118.0 mm with a $\bar{X}$ of $98.95 \text{ mm} \pm 0.10$ (Tables 1,2,3,4). Significant differences ($p < .001$) were found between $\bar{X}$ s within each year and for both years combined (Table 5). No significant difference was found between 1992 and 1993 SL $\bar{X}$ s (Table 6). Significant correlations ($p < .05$) were found between SL and weight for the 1992, 1993, and two season sampling period, $r=0.76$, $r=0.73$, and $r=0.75$ respectfully (Table 7).

Table 1. Summary of the Number of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

Calendar day	Date	Males	Females
112	22Apr92	173	5
147	27May92	898	25
169	18Jun92	595	22
173	22Jun92	756	15
190	9Jul92	478	7
194	13Jul92	150	2
204	23Jul92	480	23
205	24Jul92	65	5
211	30Jul92	395	9
218	6Aug92	219	44
222	10Aug92	547	36
224	12Aug92	568	6
230	18Aug92	492	18
239	27Aug92	509	44
245	2Sep92	75	3
253	10Sep92	261	7
268	25Sep92	142	10
269	26Sep92	328	11
279	6Oct92	4	1
79	20Mar93	58	2
101	11Apr93	517	41
118	28Apr93	544	12
129	9May93	141	3
139	19May93	157	6
193	12Jul93	208	11
212	31Jul93	2	0
165	7Aug93	109	13
236	24Aug93	35	18
263	20Sep93	5	0

Table 2. Means and Standard Errors of the Mean of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992.

	22Apr	27May	18Jun	22Jun	9Jul	13Jul	23Jul	24Jul	30Jul
STANDARD LENGTH									
Males									
mean	100.16	100.32	99.86	101.18	98.41	99.80	97.32	99.04	97.47
SE	0.36	0.16	0.20	0.18	0.20	0.40	0.20	0.62	0.24
Females									
mean	83.86	91.50	91.14	90.72	90.36	97.40	91.24	89.64	90.49
SE	2.00	1.47	1.36	1.52	3.24	3.00	1.28	3.53	2.58
WEIGHT									
Males									
mean	9.41	9.67	9.36	9.87	9.88	10.80	9.62	11.39	10.47
SE	0.10	0.05	0.06	0.05	0.06	0.14	0.07	0.20	0.08
Females									
mean	5.26	6.99	7.03	6.97	7.77	9.73	7.53	9.01	8.09
SE	0.43	0.41	0.38	0.46	1.04	1.53	0.39	0.95	0.64
CONDITION FACTOR									
Males									
mean	0.93	0.95	0.93	0.96	1.03	1.08	1.04	1.17	1.13
SE	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00
Females									
Mean	0.89	0.89	0.91	0.92	1.02	1.04	0.97	1.24	1.08
SE	0.02	0.01	0.02	0.02	0.03	0.07	0.02	0.06	0.04
EGGS PER FEMALE									
Mature									
Mean	130.60	602.24	387.68	593.80	999.00	823.50	253.17	1,626.00	651.89
SE	52.67	172.44	119.52	263.42	389.49	734.50	101.46	245.72	297.65
Immature									
Mean	1,219.36	1,413.75	1,466.63	1,491.01	1,389.10	2,209.99	1498.95	1485.11	1532.26
SE	123.07	108.94	79.04	126.75	157.56	88.40	105.23	64.96	171.82

Table 2 (Con't). Means and Standard Errors of the Mean of Male and Female Night Smelt, *Spirinchus starksii*, Sampled at Freshwater Beach, California in 1992.

	6Aug	10Aug	12Aug	18Aug	27Aug	2Sep	10Sep	25Sep	26Sep	6Oct
STANDARD LENGTH										
Males										
Mean	96.89	97.51	98.03	97.08	98.80	97.73	98.51	98.86	98.58	95.35
S.E.	0.32	0.19	0.20	0.21	0.20	0.52	0.30	0.41	0.27	2.37
Females										
Mean	90.54	93.56	90.77	87.78	94.85	96.40	89.81	94.23	95.94	95.70
S.E.	0.94	1.09	2.57	1.38	1.02	1.82	1.84	1.82	1.38	-
WEIGHT										
Males										
Mean	9.99	10.60	10.39	10.44	10.32	10.58	10.60	11.47	10.14	10.73
S.E.	0.11	0.06	0.07	0.07	0.07	0.18	0.10	0.15	0.09	1.54
Females										
Mean	8.10	9.31	7.90	7.39	8.95	9.94	7.49	9.79	9.17	9.25
S.E.	0.35	1.01	1.01	0.38	0.35	0.69	0.42	0.64	0.52	-
CONDITION FACTOR										
Males										
Mean	1.09	1.14	1.10	1.14	1.06	1.13	1.10	1.18	1.05	1.21
S.E.	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.08
Females										
Mean	1.07	1.12	1.03	1.08	1.03	1.11	1.03	1.16	1.03	1.06
S.E.	0.02	0.01	0.05	0.02	0.02	0.03	0.02	0.03	0.02	-
FECUNDITY										
Mature										
Mean	717.18	709.19	963.17	511.22	675.64	689.67	833.71	442.30	438.82	591.00
S.E.	136.81	128.49	405.26	103.30	127.40	367.86	237.18	267.13	231.29	-
Immature										
Mean	1,311.93	1,603.47	1,134.46	1,321.08	1,372.20	1,620.66	1,389.14	1,414.39	1,478.69	1,237.60
S.E.	78.87	68.85	276.19	116.88	76.39	369.21	128.99	189.14	86.85	-

Table 3. Means and Standard Errors of the Mean of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1993.

	20Mar	11Apr	28Apr	9May	19May	12Jul	31Jul	7Aug	24Aug	20Sep
STANDARD LENGTH										
Males										
mean	101.91	100.17	100.15	99.11	98.13	98.12	98.35	96.51	97.15	100.26
SE	0.48	0.90	0.20	0.42	0.38	0.29	0.55	0.34	0.71	0.98
Females										
mean	98.45	87.04	88.39	83.43	93.48	92.91	-	92.20	93.86	-
SE	2.05	0.14	1.82	3.49	2.71	2.15	-	1.34	1.67	-
WEIGHT										
Males										
mean	12.42	11.25	9.46	10.87	11.37	8.56	8.32	7.95	9.23	11.78
SE	0.19	0.07	0.06	0.13	0.13	0.08	0.08	0.10	0.23	0.55
Females										
mean	10.51	6.88	6.20	5.90	8.95	6.73	-	6.45	8.19	-
SE	1.92	0.07	0.06	1.23	0.82	0.55	-	0.31	0.41	-
CONDITION FACTOR										
Males										
mean	1.17	1.12	0.94	1.11	1.20	0.90	0.88	0.88	1.00	1.17
SE	0.01	0.00	0.00	0.01	0.01	0.27	0.02	0.01	0.01	0.03
Females										
mean	1.09	1.03	0.88	0.99	1.09	0.82	-	0.82	0.98	-
SE	0.13	0.01	0.02	0.14	0.06	0.03	-	0.02	0.02	-
FECUNDITY										
Mature										
mean	1,047.00	309.12	420.92	571.67	956.33	339.09	-	11.85	348.89	-
SE	1,007.00	74.13	184.69	570.67	248.66	148.41	-	10.93	111.15	-
Immature										
mean	2,165.79	1,571.79	1,384.93	1,267.06	1,650.13	956.32	-	1,196.80	1,365.28	-
SE	221.00	71.04	87.95	261.90	149.09	84.13	-	83.51	94.33	-

Table 4. Summary of Night Smelt, *Spirinchus starksi*, Biological Data from Samples Collected at Freshwater Beach, California in 1992 and 1993.

1992	Mean	SE	n	max	min
MALES					
Standard Length	98.82	0.06	7135	117.70	83.40
Weight	10.09	0.04	7135	18.00	5.40
Condition Factor	1.04	0.00	7135	1.55	0.60
FEMALES					
Standard Length	91.88	0.38	293	111.20	77.70
Weight	8.13	0.12	293	15.28	3.89
Condition Factor	1.03	0.01	293	1.39	0.66
Mat. Eggs per Female	618.25	46.00	293	3,794.00	0.00
Immat. Eggs per Female	1,428.51	28.10	293	3,270.00	0.00
Tot. Eggs per Female	2,046.76	61.79	293	6,249.79	0.00
1993	Mean	SE	n	max	min
MALES					
Standard Length	99.43	0.11	1776	118.00	84.10
Weight	10.16	0.03	1776	16.53	5.12
Condition Factor	1.03	0.00	1776	1.71	0.71
FEMALES					
Standard Length	90.07	0.60	106	105.00	74.10
Weight	7.11	0.16	106	12.95	3.77
Condition Factor	0.96	0.01	106	1.27	0.70
Mat. Eggs per Female	353.17	49.62	106	2,109.00	0.00
Immat. Eggs per Female	1,412.73	37.89	106	2,828.80	88.40
Tot. Eggs per Female	1,765.90	69.04	106	6,249.80	581.00
1992 and 1993	Mean	SE	n	max	min
MALES					
Standard Length	98.95	0.05	8911	118.00	83.40
Weight	10.11	0.02	8911	18.00	5.12
Condition Factor	1.04	0.00	8911	1.71	0.66
FEMALES					
Standard Length	91.42	0.32	399	111.20	74.10
Weight	7.86	0.10	399	15.28	3.77
Condition Factor	1.01	0.01	399	1.39	0.66
Mat. Eggs per Female	547.83	36.29	399	3,794.00	0.00
Immat. Eggs per Female	1,424.32	23.10	399	3,270.79	0.00
Tot. Eggs per Female	1,972.15	48.97	399	6,249.79	0.00

Table 5. Summary of Analyses of Variance tests between Standard Length, Weight, and Condition Factor, Sample Means of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

Source	df	SS	MS	F	p
1992					
Standard Length					
between	18	13149.53	730.53	-	-
within	7116	159767.18	22.45	-	-
total	7134	172916.71	-	32.54	<.001
Weight					
between	18	1594.59	88.59	-	-
within	7116	16348.07	2.3	-	-
total	7134	17942.66	-	38.56	<.001
Condition Factor					
between	18	41.55	2.31	-	-
within	7116	108.46	0.02	-	-
total	7134	150.01	-	151.44	<.001
1993					
Standard Length					
between	9	3083.41	342.60	-	-
within	1766	35493.49	20.10	-	-
total	1775	38576.90	-	17.05	<.001
Weight					
between	9	2595.85	288.43	-	-
within	1766	3466.28	1.96	-	-
total	1775	6062.13	-	146.95	<.001
Condition Factor					
between	9	21.20	2.36	-	-
within	1766	9.56	0.01	-	-
total	1775	30.76	-	435.34	<.001
1992 and 1993					
Standard Length					
between	28	16232.94	579.75	-	-
within	8882	195260.67	21.98	-	-
total	8910	211493.61	-	26.37	<.001
Weight					
between	28	8075.98	149.66	-	-
within	8882	19814.35	2.23	-	-
total	8910	27890.33	-	67.09	<.001
Conditon Factor					
between	28	67.75	2.24	-	-
within	8882	118.02	0.01	-	-
total	8910	185.77	-	168.66	<.001

Table 6. Summary of Students t-tests between Standard Length, Weight, Condition Factor, and Eggs per Female Seasonal Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

1992 vs 1993	t	df	p
MALES			
Standard Length	0.03	8,909	>.05
Weight	0.03	8,909	>.05
Condition Factor	1.14	8,909	>.05
FEMALES			
Standard Length	0.05	397	>.05
Weight	0.27	397	>.05
Condition Factor	7.18	397	<.001*
Mature Eggs per Female	0.00	397	>.05
Immature Eggs per Female	0.00	397	>.05
Total Eggs per Female	0.00	397	>.05

* Significant

Table 7. Summary of Correlations between Standard Length, Weight, and the Number of Eggs per Female Sample Means of Female Night Smelt, *Spirinchus starksi*, Collected at Freshwater Beach, California in 1992 and 1993.

1992 FEMALES	SL	Wt.	M.F.	I.F.	T.F.
Standard Length	1.00				
Weight	0.89	1.00			
Mature Eggs per Female	0.32*	0.62	1.00		
Immature Eggs per Female	0.60	0.58	0.28*	1.00	
Total Eggs per Female	0.43	0.68	0.90	0.70	1.00
1993 FEMALES	SL	Wt.	M.F.	I.F.	T.F.
Standard Length	1.00				
Weight	0.84	1.00			
Mature Eggs per Female	0.37*	0.62	1.00		
Immature Eggs per Female	0.32*	0.58	0.28*	1.00	
Total Fecundiy	0.43	0.75	0.84	0.75	1.00
1992 and 1993 FEMALES	SL	Wt.	M.F.	I.F.	T.F.
Standard Length	1.00				
Weight	0.88	1.00			
Mature Eggs per Female	0.34*	0.54	1.00		
Immature Eggs per Female	0.55	0.62	0.31*	1.00	
Total Eggs per Female	0.51	0.69	0.89	0.71	1.00
Male Standard Length to Weight Correlations					
1992	0.76				
1993	0.73				
1992 and 1993	0.75				

* Not Significant ($p > .05$)

Female SLs for 1992 and 1993 also appeared to be normally distributed and ranged from 74.10 to 111.20 mm with a $\bar{X}$ of 91.42 mm $\pm$ 0.66 (Tables 1,2,3,4). Significant differences were found between $\bar{X}$ s within 1992 ($p < .01$) and 1993, and for both years combined ($p < .001$) (Tables 8,9,10). No significant difference was found between 1992 and 1993 SL $\bar{X}$ s (Table 6). Significant ($p < .05$) correlations between SL and weight for 1992, 1993, and the two years combined were $r = 0.89$, $r = 0.84$, and $r = 0.88$, respectfully (Table 7).

Male SL $\bar{X}$ s were significantly ($p < .05$) greater than female SL $\bar{X}$ s in 22 of the 26 samples (Tables 11,12). Male 1992, 1993, and the two year combined SL $\bar{X}$ s were statistically ($p < .001$) greater than female SL $\bar{X}$ s (Table 13). Covariance was -0.62 between 1992 and 1993 combined male and female SL $\bar{X}$ s (Table 14). Male SL $\bar{X}$ s declined slightly with calendar days ($r = -0.62$) a weaker correlation was found for females SL $\bar{X}$ s ($r = 0.39$), while the correlation between male and female SL $\bar{X}$ was $r = -0.01$.

Weight

Male weights for 1992 and 1993 appeared to be normally distributed and ranged from 5.12 to 18.00 g with a $\bar{X}$ of 10.11 g $\pm$ 0.03 g (Tables 2,3,4). Significant differences ($p < .001$) were found between $\bar{X}$ s within each year and for both years combined (Table 5). No significant difference ($p < .05$) was found

Table 8. Summary of Analyses of Variance tests between Standard Length, Weight, Condition Factor, and the Number of Eggs per Female Sample Means of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992.

Source	df	SS	MS	F	p
Standard Length					
between	18	1771.61	98.42	2.38	<.01
within	274	11316.69	41.30	-	-
total	292	13088.30	-	-	-
Weight					
between	18	3537448.31	196524.91	46969.99	<.001
within	274	1146.43	4.18	-	-
total	292	3538594.74	-	-	-
Condition Factor					
between	18	2.09	0.17	12.26	<.001
within	274	2.60	0.01	-	-
total	292	4.69	-	-	-
Mature Egg Eggs per Female					
between	18	15877565.40	882086.97	1.42	>.05
within	274	169910409.60	620111.00	-	-
total	292	185787975.00	-	-	-
Immature Egg Eggs per Female					
between	18	602435971.00	33468665.06	144.71	<.001
within	274	63370893.97	231280.67	-	-
total	292	665806864.97	-	-	-
Total Egg Eggs per Female					
between	18	19933481.92	1107415.66	0.99	>.05
within	274	306469967.80	1118503.53	-	-
total	292	326403449.72	-	-	-

Table 9. Summary of Analyses of Variance tests between Standard Length, Weight, Condition Factor, and Eggs per Female Sample Means of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1993.

Source	df	SS	MS	F	p
Standard Length					
between	7	1739.13	193.24	5.09	<.001
within	98	67043.78	37.96	-	-
total	105	68782.91	-	-	-
Weight					
between	7	1675829.29	186203.25	290.08	<.001
within	98	4742.98	2.69	-	-
total	105	1680572.27	-	-	-
Condition Factor					
between	7	1.51	0.17	56.99	<.001
within	98	14.23	0.01	-	-
total	105	15.74	-	-	-
Mature Egg Eggs per Female					
between	7	11516168.48	1279574.28	4.90	<.001
within	98	460854813.70	260959.69	-	-
total	105	472370982.18	-	-	-
Immature Egg Eggs per Female					
between	7	279096448.40	31010716.49	144.71	<.001
within	98	271431780.10	153698.68	-	-
total	105	550528228.50	-	-	-
Total Egg Eggs per Female					
between	7	10016378.09	1112930.90	29.51	<.001
within	98	892388961.30	505316.51	-	-
total	105	902405339.39	-	-	-

Table 10. Summary of Analyses of Variance tests between Standard Length, Weight, Condition Factor, and Eggs per Female Sample Means of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

Source	df	SS	MS	F	p
Standard Length					
between	26	3124.26	120.16	2.97	<.001
within	372	15037.12	40.42	-	-
total	398	18161.38	-	-	-
Weight					
between	26	4840871.10	186187.35	254.60	<.001
within	372	1409.63	3.79	-	-
total	398	4842280.73	-	-	-
Condition Factor					
between	26	3.27	0.13	13.79	<.001
within	372	3.39	0.01	-	-
total	398	6.66	-	-	-
Mature Egg Eggs per Female					
between	26	355325605.40	955176.36	1.82	<.01
within	372	13662892.32	525495.86	-	-
total	398	368988497.72	-	-	-
Immature Egg Eggs per Female					
between	26	812076753.80	31233721.30	146.71	<.001
within	372	78130431.49	210028.04	-	-
total	398	890207185.29	-	-	-
Total Egg Eggs per Female					
between	26	39966238.10	1537163.00	1.61	<.05
within	372	355990986.00	956965.02	-	-
total	398	395957224.10	-	-	-

Table 11. Summary of Welch's approximate t-tests between Standard Length, Weight, and Condition Factor Sample Means of Male and Female Night Smelt, *Spirinchus Starksii*, Sampled at Freshwater Beach, California in 1992.

	22Apr	27May	18Jun	22Jun	9Jul	13Jul	23Jul	24Jul	30Jul	6Aug	10Aug	12Aug	18Aug	27Aug	2Sep	10Sep	25Sep	26Sep
STANDARD LENGTH																		
t=	7.59	8.79	8.17	7.92	4.69	0.69	6.36	3.89	4.30	7.69	4.92	3.72	8.11	5.34	0.50	4.75	2.85	1.77
p=	<.001	<.001	<.001	<.001	<.001	>.05	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	>.05	<.001	<.01	<.05
WEIGHT																		
t=	4.84	0.71	0.66	1.00	0.96	0.81	0.58	1.38	1.08	0.41	0.30	1.35	1.04	0.31	0.46	2.02	0.84	0.41
p=	<.001	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	>.05	<.05	>.05	>.05
CONDITION FACTOR																		
t=	1.68	4.34	1.53	0.51	0.39	0.53	4.01	1.73	1.50	1.84	1.17	1.96	2.99	2.59	0.44	2.90	1.00	0.93
p=	<.05	<.001	>.05	>.05	>.05	>.05	<.001	<.05	>.05	<.05	>.05	<.05	<.01	<.01	>.05	<.01	>.05	>.05

Table 12. Summary of Welch's Approximate t-tests between Standard Length, Weight, and Condition Factor Sample Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1993.

	20Mar	11Apr	28Apr	9May	19May	12Jul	31Jul	7Aug	24Aug	20Sep
PERCENTAGE MALE										
%	96.67	92.65	97.84	97.91	96.32	94.97	100.00	89.34	66.04	100.00
X ²	7.23	20.15	22.56	11.50	11.83	13.31	1.41	8.69	2.34	2.24
STANDARD LENGTH										
t=	1.33	17.88	8.55	5.36	2.29	3.81	-	3.97	2.13	-
p=	>.05	<.001	<.001	<.001	<.05	<.001	-	<.001	<.05	-
WEIGHT										
t=	1.46	1.02	1.14	3.31	1.33	0.54	-	0.37	0.30	-
p=	>.05	>.05	>.05	<.001	>.05	>.05	-	>.05	>.05	-
CONDITION FACTOR										
t=	1.73	5.73	3.52	2.46	3.05	4.38	-	3.93	1.03	-
p=	<.05	<.001	<.001	<.01	<.01	<.001	-	<.001	>.05	-

Table 13. Summary of Students t-tests between 1992 and 1993 Standard Length, Weight, Condition Factor, and Eggs per Female Seasonal Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California.

Males vs Females	t	df	# tails	p
1992				
Standard Length	18.27	7,428	1	<.001
Weight	16.26	7,428	1	<.001
Condition Factor	3.05	7,428	2	<.01
1993				
Standard Length	15.40	1,882	1	<.001
Weight	18.76	1,882	1	<.001
Condition Factor	7.68	1,882	2	<.001
1992 and 1993				
Standard Length	67.70	9,308	1	<.001
Weight	33.97	9,308	1	<.001
Condition Factor	1.80	9,308	2	>.05*

* Not Significant

Table 14. Summary of Standard Length, Weight, Condition Factor, and the Number of Eggs per Female Sample Mean Covariances from Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

	Standard Length	Weight	Condition Factor	Eggs per Female
MALE - FEMALE				
1992	-0.87	0.52	0.01	
1993	0.17	1.32	0.01	
1992 and 1993	-0.62	0.78	0.01	
MATURE - IMMATURE EGGS PER FEMALE				
1992				8,748.17
1993				83,439.77
1992 and 1993				31,130.79

between 1992 and 1993 seasonal weight $\bar{x}$ s (Table 6). A correlation of $r=.65$ was found between 1992 SL and calendar days.

Female weights for 1992 and 1993 appeared to be normally distributed and ranged from 3.77 to 15.28 g with a $\bar{x}$ of $7.86 \text{ g} \pm 0.21 \text{ g}$ (Tables 2,3,4). Significant differences ($p<.001$) were found between $\bar{x}$ s within each year and for both years combined (Table 8,9,10). No significant difference was found between 1992 and 1993 seasonal weight $\bar{x}$ s (Table 6).

Male weight $\bar{x}$ s were significantly ($p<.05$) greater than female weight $\bar{x}$ s in 23 of 26 samples (Tables 11,12). Male 1992, 1993, and the two year combined weight $\bar{x}$ s were statistically ($p<.001$) greater than female weight $\bar{x}$ s (Table 13). Covariance was 0.78 between 1992 and 1993 combined, male and female weight $\bar{x}$ s (Table 14) while the correlation between male and female weight $\bar{x}$ was $r=0.63$.

Health and Condition Factor

Male condition factor calculations for 1992 and 1993 appeared to be normally distributed and ranged from 0.66 to 1.71 with a $\bar{x}$ of 1.04 ± 0.002 (Tables 2,3,4). Significant differences ($p<.001$) were found between $\bar{x}$ s within each year and for both years combined (Table 5). No significant difference was found between 1992 and 1993 seasonal condition factor $\bar{x}$ s (Table 6).

Female condition factor calculations for 1992 and 1993 appeared to be normally distributed and ranged from 0.66 to 1.39 with a $\bar{X}$ of 1.01 ± 0.01 (Tables 2,3,4). Significant differences ($p < .001$) were found between $\bar{X}$ s within each year and for both years combined (Tables 8,9,10). A significant difference ($p < .001$) was found between 1992 and 1993 seasonal condition factor $\bar{X}$ s (Table 6).

Female condition factor $\bar{X}$ s were determined to be statistically ($p < .05$) different from male condition factor $\bar{X}$ s for 10 of 26 samples (Tables 11,12). Male condition factor $\bar{X}$ s were statistically greater than the female $\bar{X}$ s in 1992 ($p < .01$) and 1993 ($p < .001$), no significant difference was found between the two season sampling period male and female $\bar{X}$ s (Table 13). Covariance was 0.01 between 1992 and 1993 male and female condition factor $\bar{X}$ s (Table 14). The correlation between male and female $\bar{X}$ s was $r = 0.91$.

Parasites

Coiled larval *Anasakis* nematodes (5-20 mm) were found along the gut walls of male and female night smelt. *Anasakis*' life cycle continues in the muscle of night smelt predators. Juvenile parasitic isopods, (*Lironeca vulgaris*), 15-25 mm, were found beneath the hosts' gill covers. No effort was made to quantitatively examine the abundance or impact of either parasite.

Sex Ratio

The distributions of the 1992 and 1993 sample percentages of males appear to be negatively skewed. The percentages ranged from 66.04% to 100.00% with a $\bar{X}$ of $95.71\% \pm 7.79\%$ (Table 15). Chi - square tests confirm significant departure from a 1:1 sex ratio. Males significantly ($p < .001$) outnumbered females in 18 of 19 1992 samples, and seven of ten 1993 samples, or all samples where $n > 53$ (Table 15). Tests of homogeneity among samples in 1992, 1993 and two season combined failed to detect differences between samples (Table 16). There was a correlation of $r = 0.53$ between the number of males and the number of females per sample over the two season sampling period.

Eggs per Female

The number of mature eggs per female over the 1992 and 1993 seasons appeared to have a positively skewed distribution and ranged from 0 to 3794 with a $\bar{X}$ of 547.83 ± 73.01 eggs (Tables 2,3,4). Significant ($p < .01$) differences were found between mature eggs per female $\bar{x}$ s over the entire sampling period ($p < .001$) and over the 1993 season ($p < .01$) (Tables 8,9). No significant difference was found between mature eggs per female $\bar{x}$ s over the 1992 season (Table 10). No significant difference was found between 1992 and 1993 seasonal mature eggs per

Table 15. Chi - Square Tests of 1:1 Sex Ratio in Night Smelt, *Sprinichus starksi*,
Sampled at Freshwater Beach, California in 1992 and 1993.

Date	%	X ²	p
122Apr92	97.19	55.31	<.001
27May92	97.29	441.56	<.001
18Jun92	96.43	266.07	<.001
22Jun92	98.05	356.08	<.001
9Jul92	98.56	228.70	<.001
13Jul92	98.68	72.05	<.001
23Jul92	95.42	207.60	<.001
24Jul92	92.75	25.22	<.001
30Jul92	97.77	184.40	<.001
6Aug92	83.27	58.22	<.001
10Aug92	93.82	223.95	<.001
12Aug92	98.96	275.62	<.001
18Aug92	96.47	220.27	<.001
27Aug92	92.04	195.50	<.001
2Sep92	96.15	33.23	<.001
10Sep92	97.39	120.36	<.001
25Sep92	93.42	57.32	<.001
26Sep92	96.76	148.21	<.001
6Oct92	100.00	0.90	>.05*
20Mar93	96.67	26.13	<.001
11Apr93	92.65	203.03	<.001
28Apr93	97.84	254.52	<.001
9May93	97.91	66.13	<.001
19May93	96.32	69.94	<.001
12Jul93	94.97	88.61	<.001
31Jul93	100.00	1.00	>.05*
7Aug93	89.34	37.77	<.001
24Aug93	66.04	2.73	>.05*
20Sep93	100.00	2.50	>.05*

* Not Significant

Table 16. Chi - Square Tests of the Homogeneity of the Sample Proportions of Male Night Smelt, *Sprinichus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

	%	X ²	df	p
1992	96.10	0.92	18	1
1993	94.38	0.71	9	1
1992 and 1993	95.71	0.97	28	1

female $\bar{x}$ s (Table 6). The percentage of mature to immature eggs per female varied without a trend over the 1992 or 1993 seasons. Mean mature egg diameter was determined to be 1.2 mm.

One gram of ovary weight was calculated to contain 8,836 immature eggs. Immature egg diameter was determined to be 0.3 mm. Immature eggs per female for 1992 and 1993 appeared to be normally distributed and ranged from 0 to 3270.79 with a $\bar{x}$ of 1424.32 ± 46.27 eggs (Tables 2,3,4). Significant ($p < .001$) differences were found between immature eggs per female $\bar{x}$ s over the 1992, 1993 and two season sampling period (Tables 8,9,10). No significant ($p < .05$) difference was found between 1992 and 1993 $\bar{x}$ s (Table 6).

The total number of eggs (combined mature and immature eggs) per female for 1992 and 1993 appeared to be normally distributed and ranged from 0 to 6249.79 with a $\bar{x}$ of 1972.15 ± 97.87 eggs (Tables 2,3,4). No significant difference was found between total eggs per female $\bar{x}$ s over the 1992 season (Table 8). Significant differences were found between total eggs per female $\bar{x}$ s over both years combined ($p < .05$) and over the 1993 season ($p < .001$) (Tables 9,10). No significant difference was found between 1992 and 1993 $\bar{x}$ s (Table 6).

The correlation of SL to mature, immature, and total eggs per female over the two season sampling period was $r=0.36$, 0.55 , and 0.51 respectively (Table 7). The significant ($p < .05$) correlations of weight to mature, immature, and total eggs per female over the two year sampling period was $r=0.54$, 0.62 , and 0.69

respectfully (Table 7). Covariance was 31130.79 between 1992 and 1993 mature and immature sample fecundities (Table 14).

Diet

Crustaceans and onuphid worms were the most common prey taken by males over the 1992 and 1993 seasons. Crustaceans were found in 9.8% of male stomachs (Table 17). These primarily consisted of gammarid amphipods and mysid shrimp, although diastylid cumacea, and brachyura larvae were also observed. Onuphid worms were found in 2.64% of male stomachs. *Crangon* shrimp, and larval fish and embryos were found to a lesser extent. Advanced stages of digestion prevented the identification of the larval fish and eggs.

Male diet lacked a consistent pattern over the sampling period. The 1992 percentage of occurrence for onuphid worms peaked at 15.92% on May 27th but was 0% for 6 of 18 samples (Table 18). The 1993 occurrence percentage for crustaceans (36.8%) was considerably greater than the 1992 percentage, 3.0% (Table 19). Eighty six and a half percent of male stomachs were empty in 1992 compared to only 48.9% of 1993 stomachs. On the other hand the 1992 occurrence percentage for onuphid worms (2.7%) is similar to 1993 levels (2.5%), and the 1992 percentage of occurrence for crustaceans varied little (0 - 8.09%).

Onuphid worms (3.0%) were the most prominent prey type for females over the two year sampling period (Table 17). Crustaceans (gammarid amphipods,

Table 17. Summary of Seasonal Diet Occurrence Percentages, as Defined in Text, of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

	Onuphid Worms	Crustacea Sp.	Crangon Sp.	Fish Embryos	Fish Larvae	Misc.	Detritus	Empty
MALES								
1992								
count	191	217	27	4	2	443	37	6173
% group	19.9%	22.6%	2.8%	0.4%	0.2%	46.1%	3.9%	-
% indiv.	2.7%	3.0%	0.4%	0.0%	0.0%	6.2%	0.5%	
86.5%								
1993								
count	44	654	56	5	5	70	51	867
% group	4.8%	72.0%	6.2%	0.6%	0.6%	7.7%	5.6	-
% indiv.	2.5%	36.8%	3.2%	0.3%	0.3%	3.9%	2.9%	
48.8%								
1992 and 1993								
count	235	871	56	9	7	513	88	7040
% group	14.2%	52.7%	6.2%	0.5%	0.4%	31.0%	5.3%	-
% indiv.	2.6%	9.8%	3.2%	0.1%	0.8%	5.8%	1.0%	
79.0%								
FEMALES								
1992								
count	8	1	0	0	0	3	0	244
% group	16.3%	2.0%	0.0%	0.0%	0.0%	6.1%	0.0%	-
% indiv.	2.7%	0.3%	0.0%	0.0%	0.0%	1.0%	0.0%	
83.3%								
1993								
count	6	1	0	0	0	1	1	40
% group	3.2%	0.5%	0.0%	0.0%	0.0%	0.5%	0.5%	-
% indiv.	5.7%	0.9%	0.0%	0.0%	0.0%	0.9%	0.9	
37.7%								
1992 and 1993								
count	14	2	0	0	0	4	1	284
% group	6.0%	0.9%	0.0%	0.0%	0.0%	1.7%	4.3%	-
% indiv.	1.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	
71.2%								

Table 18. The Percent Frequency of Occurrence of Dietary Groups for Samples of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992.

	22Apr	27May	18Jun	22Jun	9Jul	13Jul	23Jul	24Jul	30Jul	6Aug	10Aug	12Aug	18Aug	27Aug	2Sep	10Sep	26Sep
MALES																	
Onuphids	4.05	15.92	1.51	0.00	1.67	0.00	0.42	0.00	0.50	0.46	1.10	0.18	0.41	0.00	0.00	0.38	2.74
Crustacean	8.09	2.56	2.35	3.31	1.67	4.67	1.04	0.00	11.63	1.37	0.73	1.05	2.64	3.14	0.40	1.92	7.01
<i>Crangon</i>	2.31	0.33	0.34	0.00	0.00	2.67	0.00	0.00	1.73	0.00	0.37	0.18	0.00	0.59	0.00	0.00	0.30
Fish Eggs	0.00	0.11	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Larv.	0.00	0.11	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc.	5.78	6.68	19.83	4.63	5.44	8.67	5.63	0.00	8.42	4.11	0.91	1.41	1.22	6.68	1.33	1.92	15.85
Detritus	3.47	0.67	0.00	0.79	0.63	0.67	0.42	0.00	0.25	1.37	0.55	0.18	0.00	0.39	0.00	0.00	1.22
Empty	76.30	73.50	75.46	90.61	89.33	89.33	92.50	100.00	76.98	92.69	95.98	96.31	94.11	88.80	94.67	95.79	69.51
FEMALES																	
Onuphids	0.00	24.00	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crustacean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00
<i>Crangon</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Larv.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc.	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Detritus	0.00	0.00	0.00	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.00	0.00	0.00
Empty	100.00	36.00	86.36	46.67	100.00	100.00	78.26	100.00	88.88	100.00	91.67	100.00	100.00	86.36	100.00	100.00	100.00

Sand has been excluded from the analysis and does not appear in the table, see text page 64, therefore some columns do not sum to 100%.

Table 19. The Percent Frequency of Occurrence of Dietary Groups for Samples of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1993.

	20Mar	11Apr	28Apr	9May	19May	12Jul	31Jul	7Aug	24Aug	20Sep
MALES										
Onuphid Sp.	1.72	2.13	0.37	3.55	0.64	5.77	3.33	5.50	5.71	20.00
Crustaceans	29.31	16.05	22.79	42.55	61.15	12.50	0.00	21.10	14.29	0.00
<i>Crangon</i> Sp.	0.00	1.16	5.70	4.96	0.00	0.96	0.00	1.83	14.29	0.00
Fish Eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00
Fish Larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00
Misc.	5.17	3.09	4.23	2.13	4.46	3.85	0.00	1.83	14.29	0.00
Detritus	3.45	1.55	4.41	5.67	1.27	1.92	0.00	0.00	0.00	0.00
Empty	58.62	75.24	62.13	41.13	32.48	73.08	66.67	56.88	51.43	80.00
FEMALES										
Onuphid Sp.	0.00	0.00	0.00	0.00	0.00	27.27	0.00	0.00	16.67	0.00
Crustaceans	0.00	0.00	0.00	0.00	0.00	9.09	0.00	0.00	0.00	0.00
<i>Crangon</i> Sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Eggs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish Larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Misc.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.69	0.00	0.00
Detritus	0.00	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00
Empty	100.00	46.34	25.00	33.33	50.00	27.27	100.00	15.38	38.89	100.00

Sand has been excluded from the analysis and does not appear in the table, see text page 64, therefore some columns do not sum to 100%.

mysid shrimp, *Crangon* shrimp, diastylid cumacea, and brachyura larvae), larval fish, and embryos were found to a lesser extent.

Female diet fluctuated greatly over the sampling period. In 1992 the occurrence percentage for onuphid worms ranged from 0%, in 16 of 18 samples, to 24.00% on May 27th (Table 18), and in 1993 it ranged from 0%, in eight of 10, samples to 27.27% on July 12th (Table 19). Finally stomachs of females in 1992 (83.3%) were over twice as likely to be empty compared to those in 1993 (37.7%) (Table 17).

The percentages of occurrence for crustaceans, *Crangon* shrimp, and larval smelt and eggs, were greater for males than for females in 1992 and 1993 (Table 17). The difference between male (9.8%) and female (0.3%) two year occurrence percentages for crustaceans is particularly great (Table 17).

Age

Night smelt scales, ventral to the adipose fin and dorsal to the lateral line, showed six distinct circulli patterns coded and described as:

- 1) "A". full year - partial year
- 2) "B". partial year - full year
- 3) "C". partial year - full year - partial year
- 4) "D". full year - full year
- 5) "E". full year - full year - partial year
- 6) "F". partial year - full year - full year

Male and female smelt ranged in age from 1+ (circuli types A and B) to 2+ years (types E and F). The "A" type circuli patterns were the most common circuli patterns for small (<90mm) (63.8%) and large (>115mm) (35.3%) males (Table 20). The "E" and "F" circuli patterns were rare for small (1.6% and 1.6% respectively) and large (0.0% and 5.9% respectively) males. The $\bar{X}$ number of circuli prior to the first annulus in circuli pattern "A", of small (12.9) and large (17.5) males was greater than any other full or partial growth segment in any of the other male circuli patterns. The average number of circuli within circuli pattern segments, with the exception of the first segment of pattern "A", is similar between scales of large males than in small males.

No trend was found between male circuli patterns over either the 1992 or 1993 seasons (Table 21). In 1992 and 1993 the total number of circuli per scale $\bar{X}$ s fluctuated over the seasons. The $\bar{X}$ number of total circuli per scale over the 1992 and 1993 seasons was 22.03.

The "A" circuli patterns were the most common circuli patterns for small (<80mm) (28.6%) and large (>100mm) (51.2%) females (Table 20). The "E" and "F" circuli patterns were rare for small (2.4% and 0.0% respectively) and large (0.0% and 0.0% respectively) females. The $\bar{X}$ number of circuli prior to the first annulus in circuli pattern "A", of small (12.5) and large (14.1) females were greater than in any other full or partial growth segment in any of the other female circuli

Table 20. Summary of Circuli Patterns, as defined in text, of Large and Small Male (>115; <90) and Female (>100; <80) Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

	Number of Circuli between Annuli			Total Circuli	n	%
	1st	2nd	3rd			
MALES						
Small						
A	12.87	5.16	-	17.81	118	63.78
B	6.60	12.40	-	19.00	5	2.70
C	4.80	12.02	4.71	21.53	45	24.32
D	10.71	9.57	-	20.29	7	3.78
E	9.67	11.33	3.00	24.00	3	1.62
F	3.33	11.00	9.33	23.67	3	1.62
Large						
A	17.50	5.50	-	21.67	6	35.29
B	5.50	12.00	-	17.50	4	23.53
C	3.5	13.00	7.00	23.50	2	11.76
D	11.33	11.67	-	23.00	3	17.65
E	-	-	-	-	0	0.00
F	6.00	13.00	12.00	31.00	1	5.88
FEMALES						
Small						
A	12.50	1.50	-	14.00	2	28.57
B	-	-	-	-	0	0.00
C	3.00	10.00	1.00	14.00	1	14.29
D	5.00	6.00	-	11.00	1	14.29
E	-	-	-	-	0	0.00
F	-	-	-	-	0	0.00
Large						
A	14.10	6.10	-	19.90	21	51.22
B	8.00	13.50	-	21.50	2	4.88
C	4.80	13.00	6.60	24.40	5	12.20
D	12.50	11.25	-	23.75	4	9.76
E	13.00	11.00	4.00	28.00	1	2.44
F	-	-	-	-	0	0.00

Table 21. Summary of Circuli Patterns, as defined in text, from a Subsample of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

Calendar day	Date	Circuli Types					
		A	B	C	D	E	F
112	22Apr92	3	5	1	0	1	-
147	27May92	4	2	1	1	1	-
169	18Jun92	5	2	1	2	0	-
173	22Jun92	4	1	1	3	1	-
190	9Jul92	5	0	2	1	2	-
194	13Jul92	4	0	4	1	1	-
204	23Jul92	6	2	0	1	0	-
205	24Jul92	3	1	3	1	2	-
211	30Jul92	2	0	3	3	2	-
218	6Aug92	3	0	3	4	0	-
222	10Aug92	4	1	1	3	1	-
224	12Aug92	3	0	2	5	0	-
230	18Aug92	7	0	3	0	0	-
239	27Aug92	1	1	2	3	2	-
245	2Sep92	6	2	1	1	0	-
253	10Sep92	2	3	2	0	3	-
268	25Sep92	4	0	1	5	0	-
269	26Sep92	1	0	2	6	1	-
279	6Oct92	0	1	0	3	0	-
79	20Mar93	4	4	0	2	0	-
101	11Apr93	2	2	2	2	0	2
118	28Apr93	5	1	2	1	1	-
129	9May93	2	2	4	1	1	-
139	19May93	4	2	1	1	2	-
165	7Aug93	-	-	-	-	-	-
236	24Aug93	9	0	2	0	0	-
263	20Sep93	4	0	0	0	1	-

patterns. The average number of circuli within every circuli pattern segment is greater in scales of large females than in small females.

No trend was found between female circuli patterns over either the 1992 or 1993 seasons (Table 22). Total circuli per scale $\bar{x}$ s fluctuated over the seasons. The $\bar{x}$ number of total circuli per scale over the 1992 and 1993 seasons was 14.65.

The combined male and female $\bar{x}$ number of circuli per full year segment was 13.06. Scales from males (22.03) averaged more total circuli than female (14.65) scales. Mean numbers of circuli within circuli pattern segments, were similar between males and females.

Spawning Site Conditions

Spawning site substrate ranged in diameter from less than 1.0 mm, to approximately 6.0 mm (Table 23). The smallest substrate size class (<1 mm) had the highest percentage by weight in four of the five samples examined. The second smallest substrate size class (1-2 mm) had the next highest percentage by weight in four of the five samples.

Spawning smelt were found more often in greater numbers during outgoing tides between four and five feet in depth, especially a low high tide followed by a high low tide.

Table 22. Summary of Circuli Paterns, as defined in text, from a Subsample of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

Calendar day	Date	Circuli Types					
		A	B	C	D	E	F
112	22Apr92	1	1				
147	27May92			1			
169	18Jun92	1					
173	22Jun92					1	
190	9Jul92	1					
194	13Jul92	1					
204	23Jul92	1					
205	24Jul92	1			1		
211	30Jul92	1	1				
218	6Aug92				1	1	
222	10Aug92	1		1			
224	12Aug92	1			1		
230	18Aug92					1	
239	27Aug92	1					
245	2Sep92				1		
253	10Sep92	2			1		
268	25Sep92				2		
269	26Sep92	1			1		
279	6Oct92		1				
79	20Mar93	1					
101	11Apr93	2					
118	28Apr93	1					
129	9May93		1				
139	19May93	1					
165	7Aug93						
236	24Aug93	1					

Table 23. Summary of Night Smelt, *Spirinchus starksi*, Spawning Substrate on Freshwater Beach, California in 1992 and 1993.

Date	< 1mm	1- 2mm	2-6mm
22Apr92	43.8%	35.4%	20.9%
12Jul93	36.7%	63.4%	2.0%
31Jul93	67.5%	18.5%	14.1%
7Aug93	89.1%	9.7%	1.3%
19Aug93	89.6%	10.1%	0.3%

Fish were highly photophobic to spotlights of any kind, but aversion to the light of the moon was not seen. The largest spawning schools were most consistently observed under dim skies at dusk during favorable tides.

Salinity ranged from 30 to 32‰ with an $\bar{X}$ of 31.2‰ while temperature ranged from 10 to 16°C with a $\bar{X}$ of 12.5°C (Tables 24,25).

Smelt were found spawning between March and October. The greatest concentrations were found in July. In 1992 CPUE peaked at 156.2 fish/minute on June 22nd, while CPUE remained low throughout the 1993 season (Tables 24,25).

Table 24. Summary of Field Data Taken at Time of Sampling at Freshwater Beach, California in 1992.

Date	CPUE (fish/min)	Tidal Height (ft)	Tidal Rate (ft/sec)	Temperature (°C)	Salinity (‰)
22Apr	59.33	3.57	0.31	-	-
27May	6.15	1.44	-0.25	14.5	16.0*
12Jun	0	3.33	-1.87	12.0	31.8
18Jun	30.85	4.42	0.86	12.0	31.0
22Jun	154.20	3.18	-0.81	12.0	31.0
9Jul	48.50	4.61	-1.67	16.0	32.0
13Jul	3.04	2.41	-1.78	13.0	32.0
23Jul	8.38	2.93	-1.24	13.0	32.0
24Jul	1.56	3.72	-1.44	12.5	32.0
30Jul	40.40	2.89	-2.23	13.5	32.0
6Aug	5.84	3.82	-1.48	13.0	33.0
10Aug	9.72	3.45	-1.61	13.0	32.0
11Aug	0	6.82	0.28	-	-
12Aug	28.70	5.07	-1.43	13.0	32.0
18Aug	11.33	1.25	-0.05	13.0	32.0
27Aug	14.55	5.37	-1.80	13.0	32.0
2Sep	2.60	0.75	-0.80	13.0	32.0
10Sep	4.47	4.87	-1.23	12.0	32.0
25Sep	2.53	1.42	-1.47	13.2	32.0
26Sep	-	-	-	-	-
4Oct	0	4.7	-0.88	12.0	30.5
6Oct	0.08	3.69	-1.16	12.0	32.0
16Oct	0	1.63	-1.41	11.0	33.0

*Perhaps an error in data recording.

Table 25. Summary of Field Data Taken at Time of Sampling at Freshwater Beach, California in 1993.

Date	CPUE (fish/min)	Tidal Height (ft)	Tidal Rate (ft/sec)	Temperature (°C)	Salinity (‰)
13Feb	0	4.47	-0.15	12.0	32.0
1Mar	0	4.08	0.24	10.0	30.0
20Mar	0.80	4.83	-0.97	13.5	28.0
28Mar	0	4.77	-1.29	11.0	32.0
31Mar	0	4.97	-0.18	10.5	32.0
11Apr	12.40	3.17	-0.40	11.0	29.0
18Apr	0	5.52	-1.01	13.0	31.0
20Apr	0	2.80	-1.48	13.0	31.0
28Apr	7.41	3.80	-0.56	11.5	32.0
6May	0	7.35	1.03	12.5	32.0
9May	2.40	3.89	0.88	11.0	32.0
19May	1.81	3.94	-1.59	13.0	32.0
14Jun	0	4.95	-1.18	15.0	28.0
12Jul	2.09	1.56	-0.50	12.0	32.0
19Jul	0	7.74	-0.10	12.0	32.0
31Jul	0.01	6.74	-0.97	13.0	32.0
7Aug	2.03	2.11	0.63	-	32.0
24Aug	1.33	2.03	-1.38	12.5	32.0
2Sep	0	5.17	-1.15	11.5	32.0
11Sep	0	5.30	-1.09	13.5	32.0
20Sep	0.08	4.71	-0.92	12.0	32.0
28Sep	0	4.49	-1.28	13.0	32.0

DISCUSSION

Size

Differences observed between male SL $\bar{x}$ s within the 1992 and 1993 seasons may be due to the presence of older, longer smelt, born early in the season of their first year. These smelt most likely took advantage of good growing conditions and matured earlier, therefore appearing at the spawning grounds prior to younger, smaller smelt, which were born later in the season of their first year. The difference in SL $\bar{x}$ s could be due to either a replacement of longer smelt with shorter fish, or an increase in the percentage of smaller smelt as the season progresses. Such differences in SL over the spawning season have been observed in American smelt, (McKenzie 1958; Bailey 1964; Jilek 1979). Local fishers have also observed such differences. They report that sales of equivalently sized servings of fresh smelt to local restaurants requires more fish later in the season. They also noticed that more smelt are required to package kippered smelt into equivalent sized jars later in the season.

A difference was not found between 1992 and 1993 male SL $\bar{x}$ s.

Because only two years were examined it is not possible to suggest a two year age cycle. Podushko (1970) noticed SLs of rainbow smelt increased in years of low

abundance. We did not observe this trend in our data despite decreased abundance of night smelt in 1993, SLs remained constant between 1992 and 1993.

Female SL $\bar{x}$ s varied significantly without any discernable trend over the 1992 and 1993 seasons. Relatively small female sample sizes, compared to males, may account for the dramatic fluctuations in female SL $\bar{x}$ s. Despite large fluctuations in SL $\bar{x}$ s over each of the 1992 and 1993 seasons, there was no significant difference between the two seasonal $\bar{x}$ s. This may be attributed to large variances as well, or may further substantiate conclusions drawn on male seasonal results. The correlation between female lengths and weights ($r=0.88$) was surprisingly stronger than males ($r=0.75$) considering the wide range of eggs per female observed between individuals.

A noticeable difference was observed between male and female SLs. Male SL $\bar{x}$ s were significantly larger than female SL $\bar{x}$ s in every sample of 163 or more smelt. Local fishers have reported similar findings. Night smelt are one of three smelt species in which the males are reported to be longer than the females, capelin (Pitt 1958a; Pitt 1958b; Jangaard 1974) and longfin smelt (Moulton 1974) are the others. Shishamo remain the only *Spirinchus* species in which males have yet to be shown longer than females.

The increasing trend of 1992 male weight $\bar{x}$ s is contrary to the slight decreasing trend of SL $\bar{x}$ s over the same season. This finding is similar to American smelt (Jilek 1979) but does not support the claims of local fishers

mentioned above. Despite significant differences between male weight $\bar{x}$ s within both the 1992 and 1993 seasons, no significant difference was found between 1992 and 1993 seasonal $\bar{x}$ s.

Female weight $\bar{x}$ s varied significantly over the 1992 and 1993 seasons. Sample weight $\bar{x}$ s may have a slight increasing trend in 1992, while 1993 weights varied too much for any trends to be recognized.

Male weight $\bar{x}$ s were significantly greater than female weight $\bar{x}$ s in 23 of 26 samples. Differences were greater between male and female weights than lengths in American smelt (Warfel et al 1943). In our study male and female weights tracked each other across each season suggesting a pairing of smelt in similar levels of sexual maturity.

Male and female condition factor $\bar{x}$ s displayed an increasing trend in 1992. The trend is reflective of the combination of both a decreasing trend in SL $\bar{x}$ s and a rise in weight $\bar{x}$ s over the same period. It is difficult to explain why the 1992 female condition factor seasonal $\bar{x}$ was greater than 1993 levels when no difference was shown for either SL or weight. A greater covariance was found between male and female condition factor $\bar{x}$ s (.01) than between either male and female SL or weight $\bar{x}$ s. This is due primarily to the tracking pattern observed between male and female weights, because covariance between SLs was minimal. Mean male (1.04) and female (1.00) night smelt condition factors are greater than those of rainbow (0.82) (Sterligova 1979), and American (0.60) (Jilek et al. 1979)

smelts. However, comparisons between species may not be made accurately due to inherent differences in species morphologies. Levels may also be incomparable due to differences in reproductive states.

Reproduction

The timing and duration of the spawning season, varies between smelt species. Like night smelt, pond (Gritsenko et al. 1984a), chika, *Hypomesus pretiosus japonicus* (McAllister 1963), wakasagi, *Hypomesus transpacificus transpacificus* (McAllister 1963), delta (Moyle 1976; Moyle and Herbold 1992), American (Hoover 1936; Jilek 1979), rainbow (Altukov and Yerastova 1974), and longfin (Moyle 1992) smelt spawn in the spring. Shishamo, (McAllister 1963) and surf smelt (Rosa 1946) spawn in the summer.

Spawning migrations have been widely reported for many marine, freshwater and anadromous smelt species. However, specific spawning behaviors are poorly known for most smelt species. Male American smelt force females to the substrate and remain anterior and dorsal to them during the release of gametes (Hoover 1936). Females release approximately fifty eggs twice a run and may run more than once per season. Density dependent intergroup stimulation appears to be the most important factor for spawning (Rupp 1959). Small schools of ripe female capelin leave large female offshore schools to join near shore male schools at night prior to spawning (Jangaard 1974). In 15 cm of water, male surf smelt, position

themselves posterior and parallel to the female and press against her, while each maneuver to bring their vents close. Gametes are released near the substrate just prior to the backwash of the wave (Thompson et al. 1936). Sexually dimorphic characteristics (nuptial tubercles and midlateral ridges) are present in those smelt species which have documented courting behavior (i.e. American, caplin, surf and rainbow). Male eulachon use elongated anal fins to prepare hollows in the sand for eggs (Pitt 1966). The lack of well defined sexually dimorphic characteristics in spawning night smelt may suggest a minimal level of male - female courtship or nesting behavior. Due to a lack of light and the movement of the waves, night smelt mating behavior could not be thoroughly examined.

With the exception of three dramatic drop offs occurring on 6 August and 6 October of 1992, and 24 Aug of 1993, which most likely are the result of small sample sizes, the percentage of males remained consistent over the two year sampling period. Male percentage estimates at the spawning site may not, and probably do not provide an insight to the populations sex ratio away from the spawning grounds. Male smelt may reestablish a critical state of sexual maturity after spawning more quickly than female smelt. Therefore males may spawn more frequently than females thus biasing the estimated male percentage of the population. Spawning in the strong currents of the ocean surf may necessitate an elevated level of male gametes to ensure fertilization.

The percentage of spawning male night smelt is high, and consistent, compared to those of other smelt species which vary drastically. The percentage of

male American smelt ranges from 99.6% prior to spawning, to 33% upon commencement of spawning, to 100% after spawning (Hoover 1936). However, the sex ratio may also vary within the spawning season for this species (Beckman 1942). Surf smelt, another marine species which spawns on beach shores, undergoes a segregation behavior, and at spawning, males represent 66% of all individuals (Hart and McHugh 1944). Although it has been suggested by Fitch and Lavenberg (1971) it could not be determined if night smelt sexually segregate because all fish caught appeared to be spawning and were not in waiting. However, numerous birds circling and feeding two to three hundred meters offshore during the day, may indicate the presence of night smelt and a male waiting behavior.

The mature eggs per female $\bar{x}$ s varied over the season due to the differing reproductive states of the females at time of capture. A female caught prior to the release of her eggs will obviously contain more eggs. The varying number of mature eggs found in females of similar size may indicate that females do not discharge all mature eggs simultaneously. Thus, the release of all mature eggs within the ovary may take place over several spawning episodes. The capture of females in various states of egg deposition would account for the high 1992 and 1993 sample variances, and the failure to show a difference between sample $\bar{x}$ s despite their great range. The number of mature eggs was found to covary with the number of immature eggs. Covariance should not be seen between mature and immature egg fecundities if females deposit mature eggs at a rate dissimilar to the

maturation rate of immature eggs. If the deposition of mature eggs is prolonged, covariance could be shown. The production of immature eggs most likely is timed with the maturation process of mature eggs.

Variance estimates were considerably smaller for immature eggs than mature eggs. This is because the number of immature eggs per female, unlike the number of mature eggs per female, are not effected by the female's state of deposition at time of capture. The maximum number of immature eggs per female (3271) coincides with the maximum number of mature eggs per female (3794). Therefore night smelt may be fractional spawners, i.e. following the complete discharge of mature eggs, immature eggs may mature and be released later in the season. The immature eggs could possibly mature the following season. The number of immature eggs per female $\bar{X}$ (1424) is nearly three times the number of mature eggs per female $\bar{X}$ (548), therefore immature eggs may mature and also be deposited over several spawning episodes.

It is unclear whether females leave spawning schools while the immature eggs are maturing because many females were caught without mature eggs. Most of these females were small however, and may have spent their few mature eggs just prior to capture. The observation of immature females at the spawning grounds within the hostile surf zone is perplexing. Additionally, one would expect greater consistency between spawning run sizes if nonreproductive fish were involved.

The $\bar{X}$ number of total eggs per female (1,972) of night smelt, would be the second lowest fecundity of any osmerid. Smelt fecundity estimates vary considerably within and between species. American smelt fecundity estimates range from 29,045 (Altukhov and Yerastova 1974) to the highest fecundity estimate of any smelt species 44,964 (Saunders and Power 1970). Longfin smelt, the only other species within the genus *Spirinchus* with published fecundity estimates, average 18,104 eggs (Dryfoos 1965), nearly three times the maximum fecundity of night smelt (6,250).

Weak but significant relationships were shown between SL and mature, immature, and total fecundities. Low correlations are most likely a result of the capture of females in varying states of sexual maturation. Longer females had greater maximums for mature, immature, and total number of eggs per female than shorter females. One would expect the $\bar{X}$ number of eggs per female to follow a similar pattern. The correlations between weight and mature, immature, and total number of eggs per female were each greater than those of SLs. This is attributed to the greater variance in weights at a particular length than lengths at a particular weight. Despite the increased level of correlation, predictability was poor.

A relationship between SL and fecundity could not been shown for delta smelt, (Moyle 1976; Moyle and Herbold 1992) or longfin smelt (Dryfoos 1965) but has been reported for surf smelt (Fitch and Lavenberg 1971). Altukhov and Yerastova (1974) claim the ratio of fecundity to SL varies between

stocks of rainbow smelt. Whether night smelt make up into distinct stocks is unknown.

The mature egg diameters of night smelt are relatively large. The much larger American smelt has smaller diameter eggs (0.86-0.89 mm) (Langlois 1935; Bailey 1964) than night smelt (1.2 mm). Bailey (1964) found no relationship between either SL or weight to egg diameter in American smelt. Similar to our findings Dryfoos (1965) noted two size classes of longfin smelt eggs (1.0 and 0.65 mm) with the larger being partially spent.

Night smelt eggs are negatively buoyant and slightly adhesive similar to delta smelt (Moyle 1976) and surf smelt (Fitch and Lavenberg 1971) eggs which are demersal and adhesive. Night smelt eggs have an adhesive disk which will bond with a single substrate grain, which helps to ensure their demersal settlement (Morris 1953). Surf smelt eggs have pedestals that attach to gravel substrate (Thompson et al. 1936). Similarly, an adhesive substance for substrate attachment, is released when the outer membrane of eulachon eggs ruptures (Hart and McHugh 1944).

Night smelt are part of the dungenous crab's (*Cancer magister*) diet in northern California during the months of October and November (Gotshall 1977). This may be an indication of a die off of spawned (male, female or both) smelt following the conclusion of the spawning season. Eulachon (Hart and McHugh 1944), male longfin smelt (Moyle 1992), capelin (Jangaard 1974), rainbow smelt (Ivanova 1988) and possibly surf smelt (Hart and McHugh 1944) die after

spawning. The lifespan of rainbow smelt is reduced in individuals which grow rapidly during their first year and sexually mature in their second year, a situation similar to night smelt (Ivanova 1980).

Diet

Male night smelt fed predominantly on onuphid worms and crustaceans. Onuphid worms were found inconsistently between samples whereas gammarid amphipods and mysid shrimp were found with more regularity. This variation may be due to smelt feeding on worms, only when they are undergoing planktonic spawning migrations. It is more likely however that worm distributions are spotty while occurring along with the gammarid amphipods, mysid shrimp, diastylid cumacea, and brachyura larvae. All such prey items are found on shallow sandy ocean bottoms (Kozloff 1987) similar to those off Freshwater and neighboring beaches (Cambell 1969).

Adult night smelt may be cannibalistic of their young and may therefore make migrations offshore to avoid utilizing the same area. In 1992, 86.0% of the male stomachs were empty compared to 49.0% in 1993. These high percentages are similar to other freshwater and marine smelt species but contrary to anadromous species. American (Mac Crimmon and Pugsley 1979; Haldorson and Craig 1984), longfin (Dryfoos 1965), rainbow (Altukhov and Yerastova 1974), and surf smelt (Hart and McHugh 1944) diets also diminish during the spawning season while

eulachon do not eat at all during freshwater spawning runs (Hart and McHugh 1944).

The importance of onuphid worms in female diets was similar to that of males. However, male stomachs contained a greater number of crustaceans. This may indicate that male and female night smelt, like American smelt (Rupp 1959) and surf smelt (Fitch and Lavenberg 1971), school in different areas as suggested by (Fitch and Lavenberg 1971). Sand was common in female stomachs. It is probably swallowed in the feeding, spawning, or capturing processes. However, it is not known why sand was rare in the stomachs of male night smelt.

Prey items are similar between smelt species despite their varied environments. Pond (Gritsenko et al. 1984a), delta (Moyle and Herbold 1992), surf (Hart and McHugh 1944), rainbow (Altukhov and Yerastova 1974), American (Mac Crimmon and Pugsley 1979), and longfin smelt (Dryfoos 1965) all feed on invertebrates such as mysids, gammarids, isopods, and copepods as well as fish larvae and eggs.

Age

Circuli patterns suggest that spawning night smelt were one plus (types "A", "B"), two ("C" and "D") and two plus years (types "E" and "F") of age at time of spawning. However, SL and weight histograms appear to show a single age class. The lengths of American smelt beyond age one are poor indices of age

(Bailey 1964). Prior to counting inconspicuous "shiny lines or scars" as annuli, McKenzie's (1958) data on American smelt was similarly confusing. Other species of smelt have also proven difficult to age. A defined annulus was not found in pond smelt scales (Gritsenko et al. 1984a) while annuli formation was inconsistent in longfin smelt scales (Dryfoos 1965). Hart and McHugh (1944) could not find a first year annulus on scales of surf smelt. Like surf smelt, night smelt most likely do not form a first year annulus unless hatched early in the season, but unlike American smelt (Murawski and Cole 1978) they lay down annuli prior to spawning.

Night smelt, like other *Spirinchus* species are short lived. Longfin smelt rarely reach 3 years of age (Dryfoos 1965), while shishamo may reach 4 years (McAllister 1963). American (Bailey 1964) and rainbow smelt (Podushko 1970) are the longest lived smelt species occasionally reaching 7 years of age.

Scales of longfin smelt have 14 circuli by November of the first year and 30 circuli by November of the second year (Dryfoos 1965). The combined $\bar{x}$ number of male and female night smelt circuli in all full year segments of each circuli type was 13.1. No trend was seen between male or female total circuli $\bar{x}$ s across either the 1992 or 1993 spawning seasons. Therefore circuli may not be formed during the spawning season, or older individuals may be consistently replaced or joined by younger individuals.

All night smelt with type "A" circuli patterns may not be hatched at the same time, because type "A" patterns were prevalent in both large and small size classes. However, if first year circuli and annuli were not formed, or detected in

larger smelt, their circuli pattern could be misidentified as type "A". Early circuli near the focus of the scale are not as distinct as circuli beyond the first annulus. First year annuli on American smelt scales are usually "shiny lines" or "scars" and difficult to see (McKenzie 1958). Circuli patterns, despite their distinctiveness may not indicate time of hatch, because the proportions of circuli patterns are similar between large and small smelt. However, circuli of larger smelt generally had greater distances between them. This most likely indicates greater growth rates, and would explain why large and small smelt could have the same circuli pattern. Circuli patterns with two years of full growth ("E" and "F") usually had closely spaced circuli and were more often found on scales of large than small smelt.

Spawning Site Conditions

Night smelt were found spawning over various sized substrates (<1 mm to approximately 6 mm). It is unclear whether there is a preference for a particular size. However, eggs were not found at low tide in the coarse sand wave slopes of spawning sites. Rosa (1946) reported similar difficulties.

Specific spawning substrates do not appear necessary for other smelt species. For example, surf smelt, eulachon and capelin, may spawn on sand or gravel, while American, rainbow, pond, and delta smelt appear to be even less selective and may spawn on sand, boulders, or even plants (Kendall 1927; Hoover 1936; Thompson et al. 1936; Hart and McHugh 1944; Pitt 1958b; Rupp

1959; Rupp 1965; Altukhov and Yerastova 1974; Sterligova 1979; Gritsenko et al. 1984a; Moyle and Herbold 1992).

The largest congregations of night smelt were found over coarse sand (1-2 mm), especially when cobble (10-30 mm) was present. Cobble could be heard moving with the wash of the waves and was often caught in the net. The greatest concentration of cobble was within troughs at the base of the wave slope. The cobble troughs appeared to be buried by sand and were submerged below the low tide mark when substrate samples were taken.

Pentilla (1976) found that 80% of the spawning substrate of surf smelt in Puget Sound was 1-7 mm in diameter. He concluded that a typical spawning site included a complex mosaic of substrate size classes and speculated that larger cobble, deeper in the surf zone, provides protected and moist crevices for eggs to settle, and possibly be buried by sand. This appears to be the case for night smelt as well.

Night smelt seemed to prefer spawning on fairly flat wave slopes. Local fishers believe that the wave slope must be flat enough to provide night smelt ample time to spawn but sloped enough to ensure their return within the backwash of the wave. The summer beach face profile steepened from 1992 to 1993 due to landward erosion (Klein 1993). The steeper wave slope in 1993 may be partially responsible for the decreased abundance of spawning smelt over the same period. Lower abundances in 1993 may have also been the result of unfavorable ocean conditions for larvae spawned in the previous two years. Eulachon larvae rely on

currents for transportation to areas of high euphausiid abundance (Barraclough 1964). The maturation rate of rainbow smelt depends on water temperature and food supply during the larval period (Ivanova and Volodin 1981).

Night smelt were found spawning in various tidal conditions. The largest concentrations of smelt were noted in small waves of outgoing neap tides between four and five feet. They may be preferred for several reasons. These tides may transport and deposit an insulating layer of sand over the fertilized eggs within the cobble crevices. Outgoing tides may also limit the number of stranded smelt on the wave slope. Incoming tides may aid in the inshore migration prior to spawning. Local fishers report similar observations, but despite their experience they have yet to determine a definitive link of smelt spawning to tidal conditions. Spawning activity increased in surf smelt at high tides and calm conditions (Schaefer 1936). A combination of internal drives and external cues are most likely needed to induce spawning. The stronger the internal drives, the less ideal the environmental conditions must be and vice versa (Tinbergen 1951).

Night smelt spawning behavior appeared unrelated to ocean temperature or salinity. However, little variation in either occurred over the two year sampling period. Similarly, no relationship was found between either temperature or salinity and surf smelt spawning behavior (Schaefer 1936).

Night smelt spawning occurred under various light conditions. Spawning was observed under relatively lighter skies at dusk and during full moons, as well as in complete darkness. No aversion to moonlight was seen.

American smelt (Rupp 1959; Jilek 1979), rainbow smelt (Podushko 1970), capelin (Jangaard 1974), and shishamo (McAllister 1963) also spawn at night. Like night smelt, American smelt show no relationship between the size of spawning schools and moonlight (Rupp 1959), but negative phototropic reactions to flashlights have been reported in American smelt (Lievense 1954). By spawning in the afternoon (Schaefer 1936) and in areas of shade (Pentilla 1976) surf smelt also appear to avoid spawning during times of direct sunlight. Predation by gulls, (*Larus spp.*), and seals, (*Phoca vitulina*), is most likely reduced for all night spawners. By spawning at night, night smelt may also avoid competition for spawning grounds with surf smelt, although both have been witnessed spawning together.

Surprisingly no trend was seen between the number of immature eggs per female over either 1992 or 1993 seasons. Failure to see a significant decline over the course of the season, coupled with the various distinct circuli patterns found, may suggest that spawning might also take place offshore over sandy bottoms later in the year, a pattern seen in capelin (Jangaard 1974).

SUMMARY

The largest congregations of spawning night smelt were found over coarse sand wave slopes with cobble troughs. It is assumed that deposited eggs remain moist and protected beneath a layer of sand within the crevices of the cobble. Small outgoing tides at dusk appeared to be preferred. Incoming tides may aid the smelt's migration to the spawning site, while outgoing tides would help seat and bury the fertilized eggs within the cobble trough. Nighttime spawning may limit predation. Spawning schools are predominantly male (95.7%), possibly to ensure fertilization within the turbulent surf zone. Evidence suggests a possible die off following spawning.

Males are longer than females, a characteristic of several other smelt species. Male and female weights tracked each other over the course of both seasons. Two size classes of eggs were found. It is unclear whether the smaller eggs (immature) develop into larger eggs (mature) as the large eggs are deposited, or if they mature later in the year. The large eggs appear to be deposited over several spawning episodes. The majority of the spawning smelt were one to two years of age. Various patterns of circuli were found on similarly sized and aged smelt, supporting other researchers claims of smelt's unusual and unpredictable formation of annuli. Their diet consists mainly of benthic invertebrates such as

onuphid worms, gammarid amphipods, and mysid shrimp, which are common to local nearshore sandy bottoms.

In light of the low percentage of spawning females, which one might conclude to be a potentially limiting factor in night smelt spawning success, I recommend the following future experiment. Fish two nets of differing mesh size and compare the percentage of females caught in each net (Levy 1990). If a mesh size that allowed the passage of smaller females, yet retained the larger males could be used, spawning females would be spared.

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PERSONAL COMMUNICATION

Compton, R. 1993. Orick Fisheries, Orick, Calif.

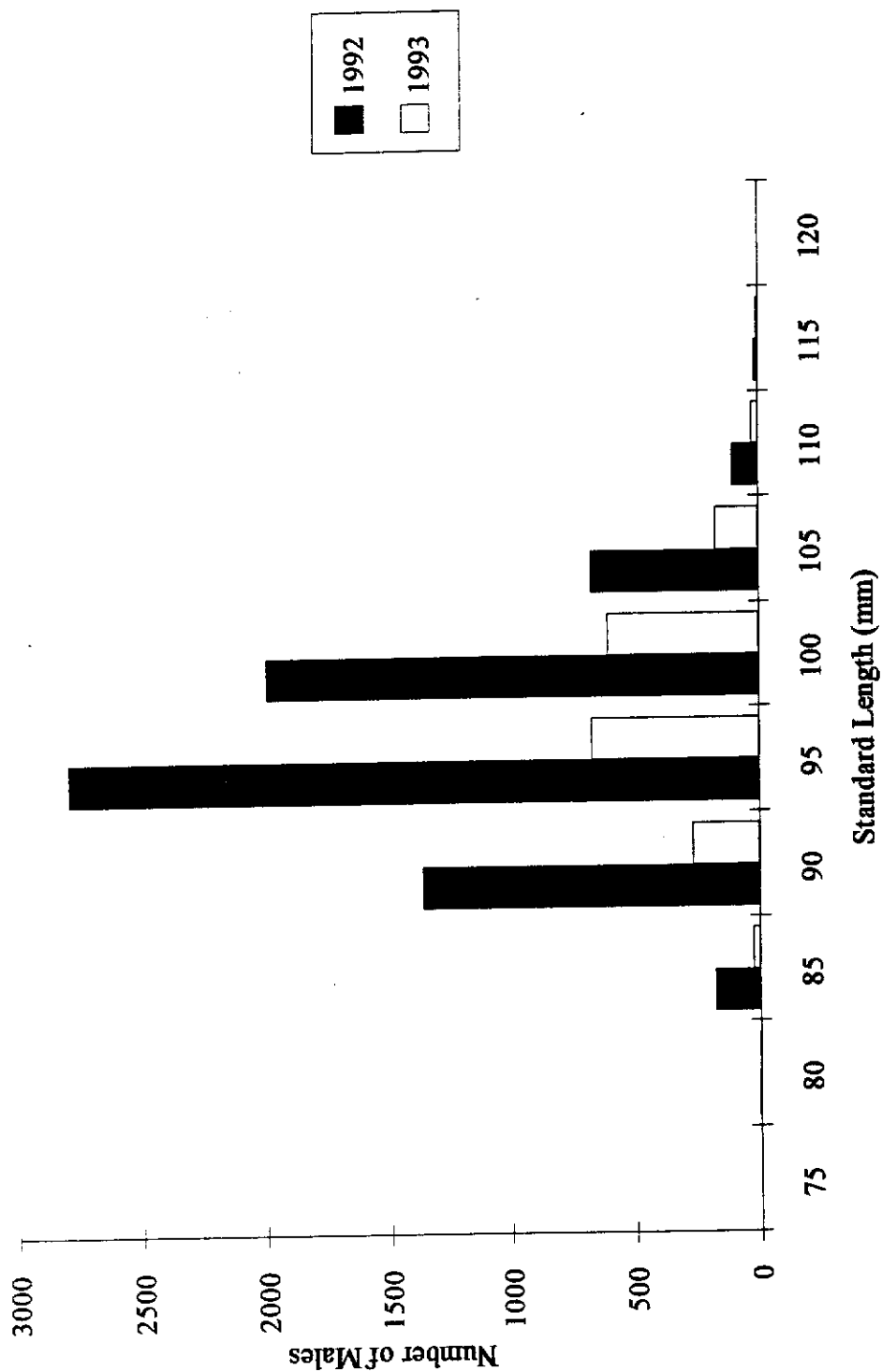
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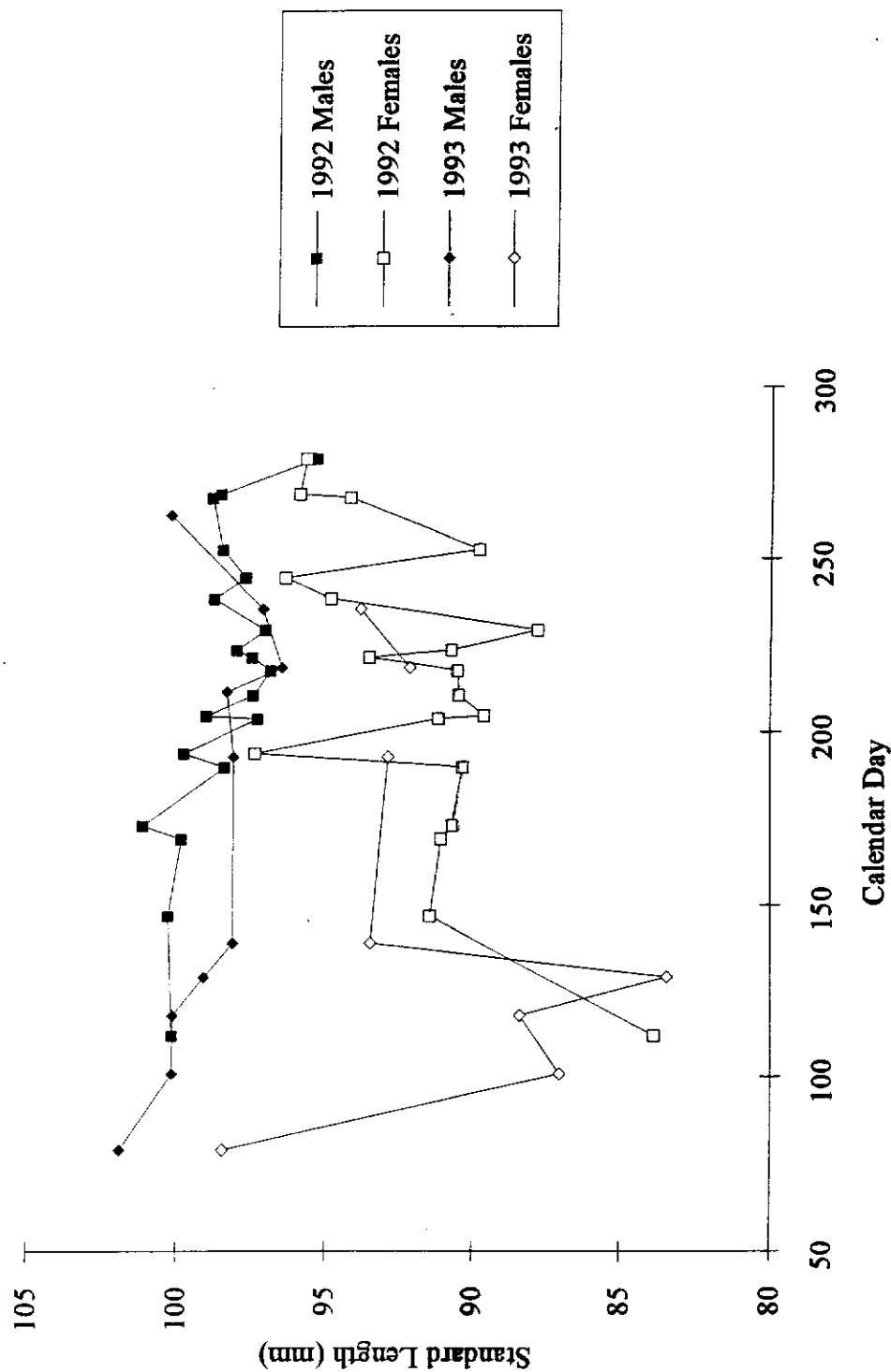
APPENDIX

APPENDIX A.



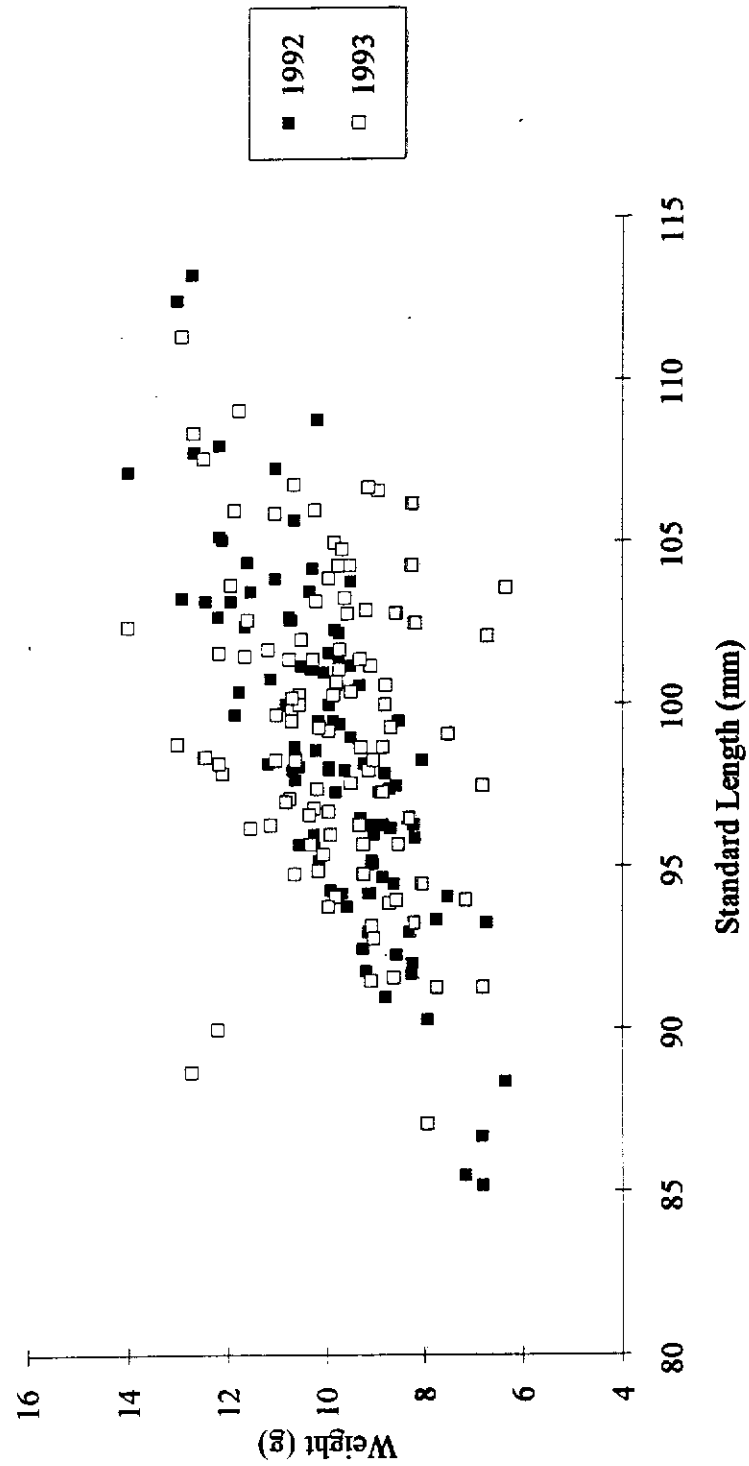
APPENDIX A. Length Frequencies of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX B.



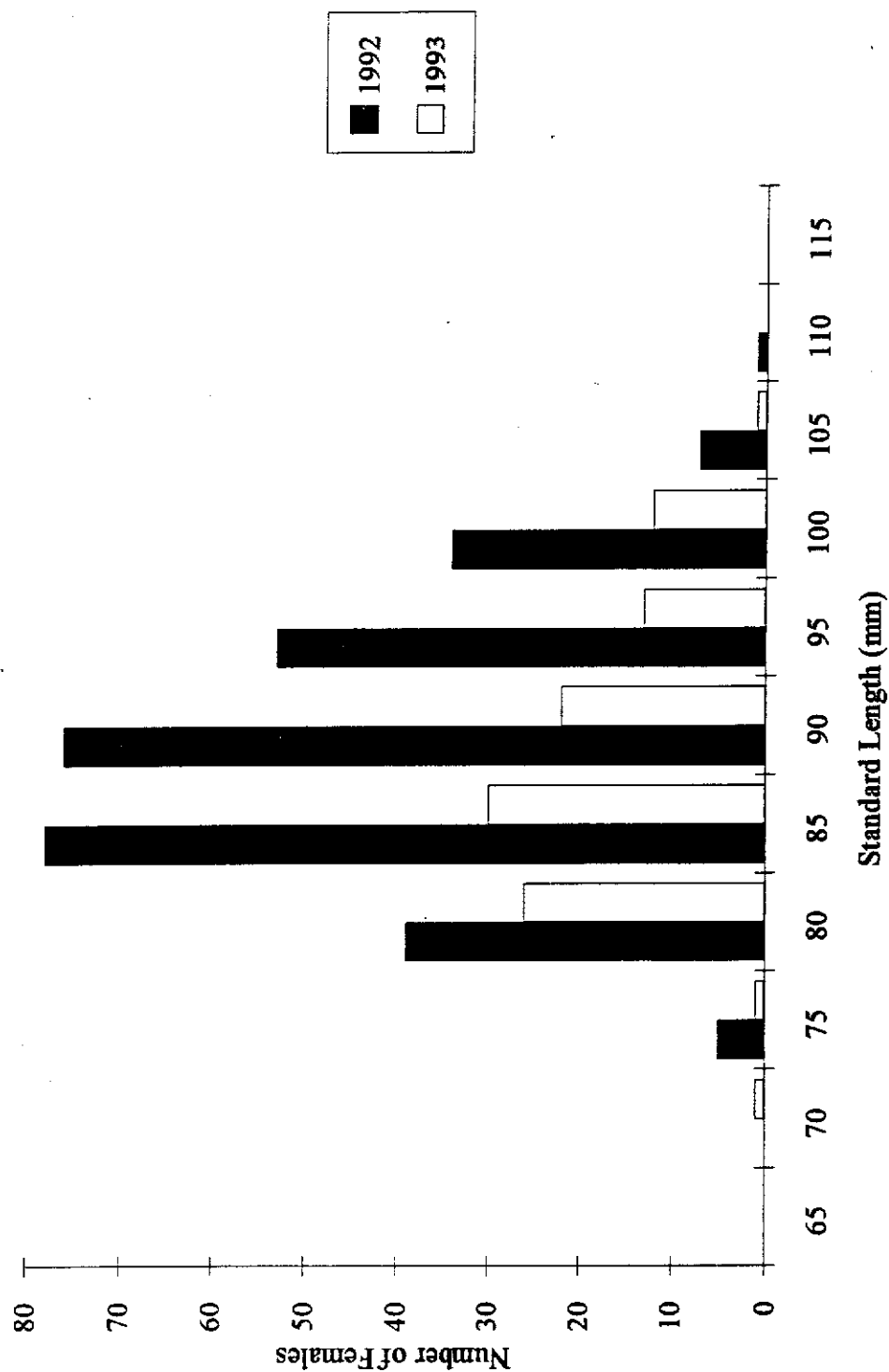
APPENDIX B. Length Sample Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX C.



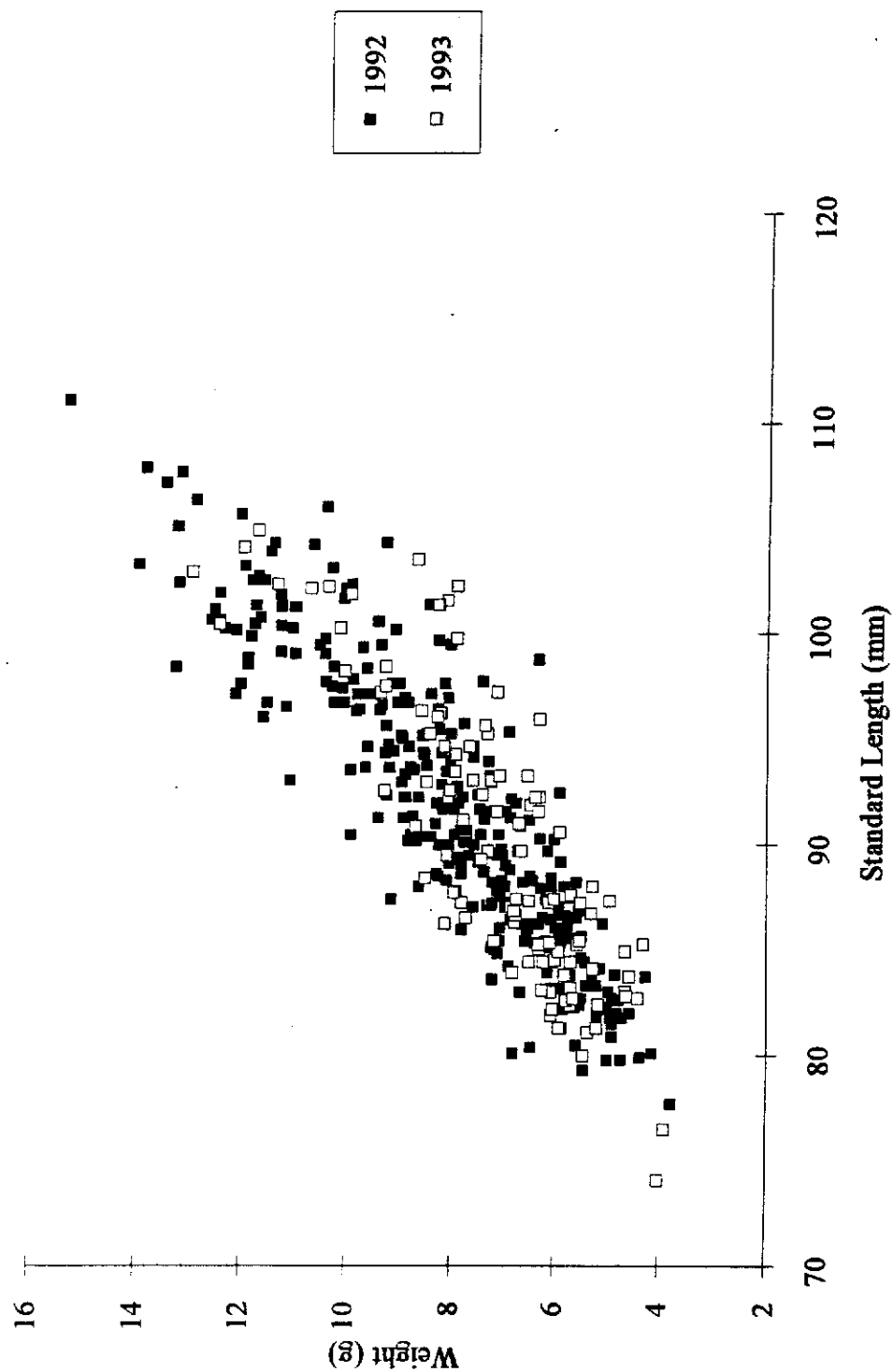
APPENDIX C. Length - Weight Relationship of random subsamples of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 (n=100) and 1993 (n=100).

APPENDIX D.



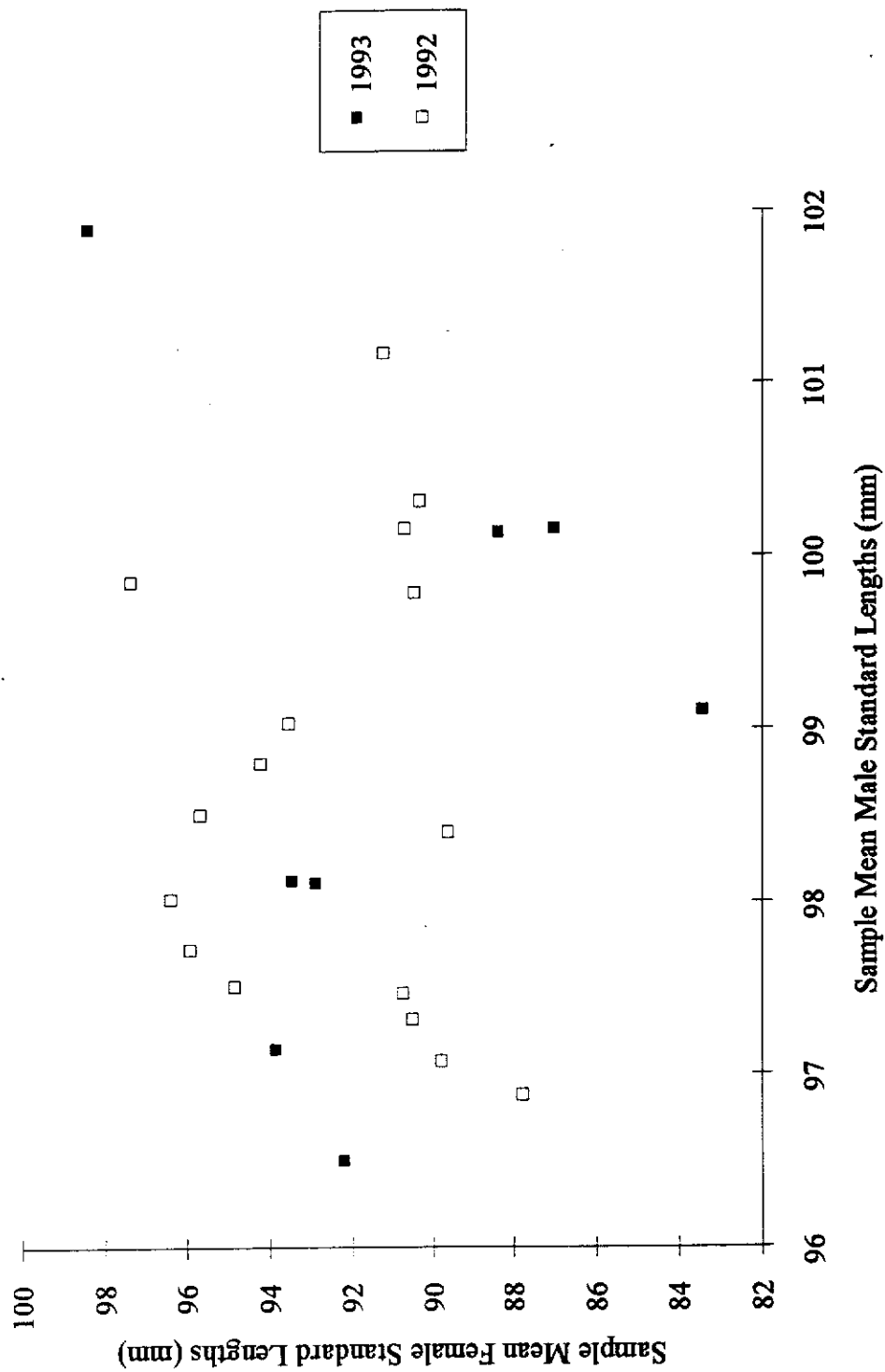
APPENDIX D. Length Frequencies of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX E.

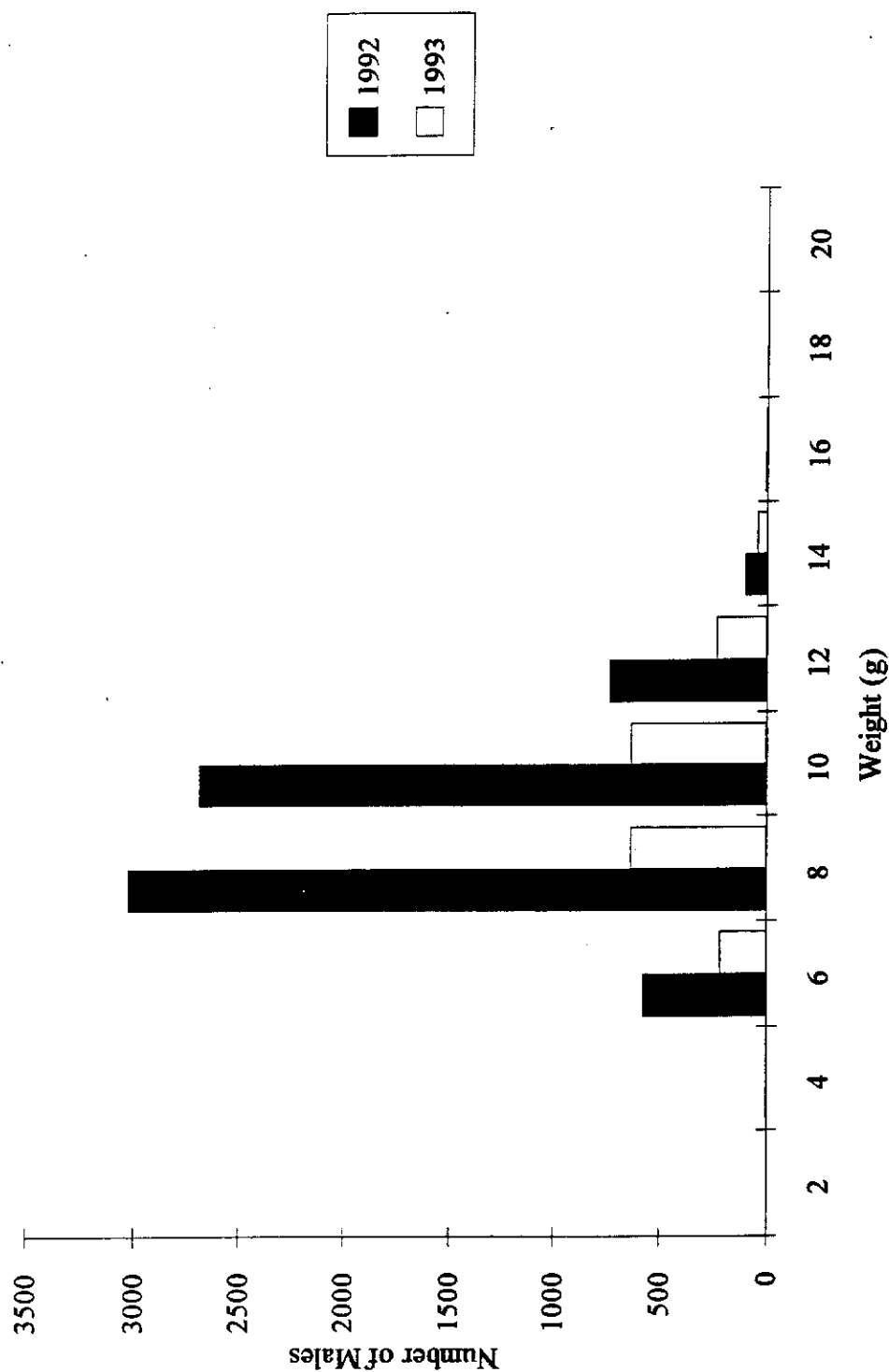


APPENDIX E. Length-Weight Relationship of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993

APPENDIX F.

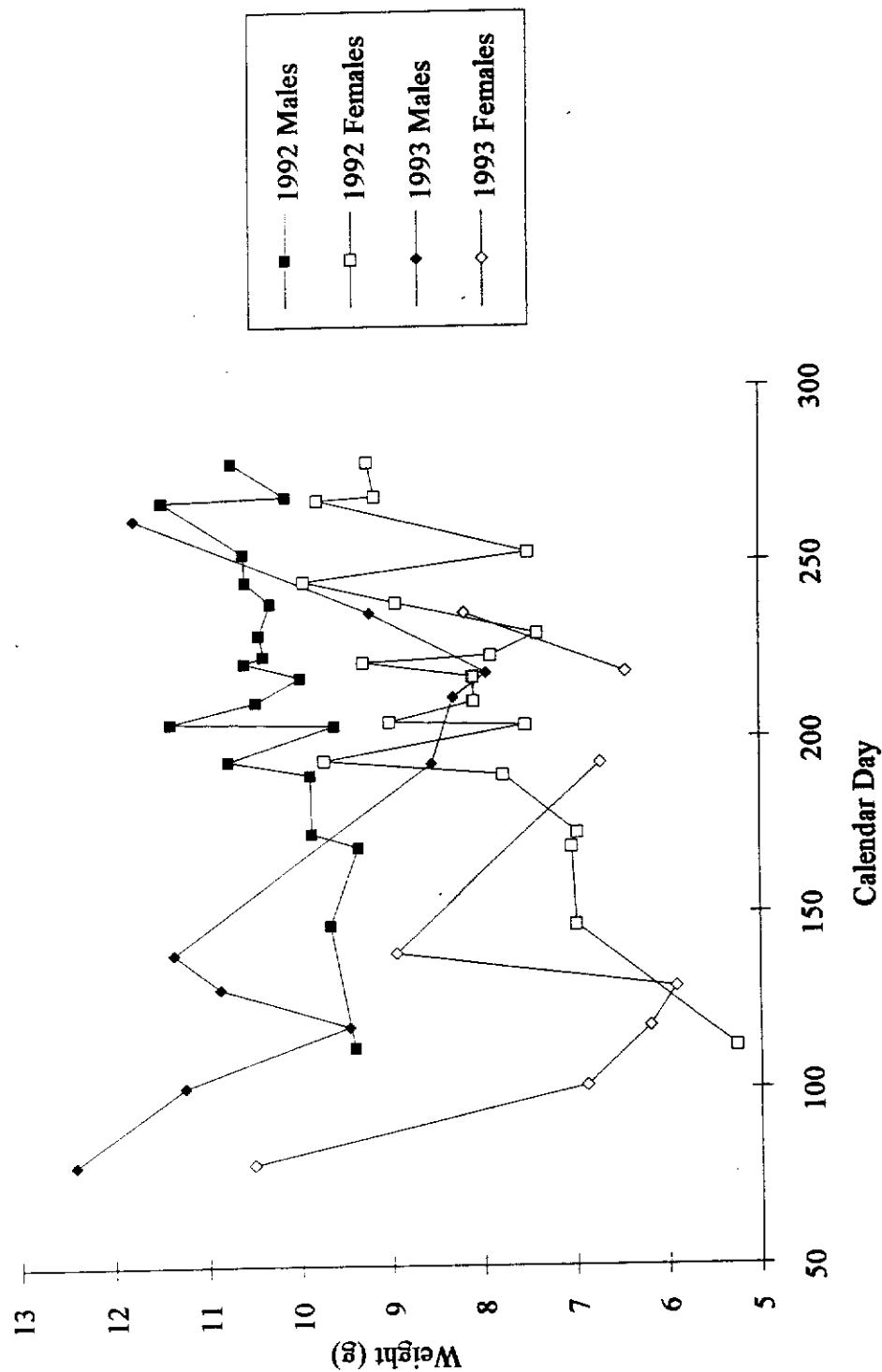


APPENDIX G.



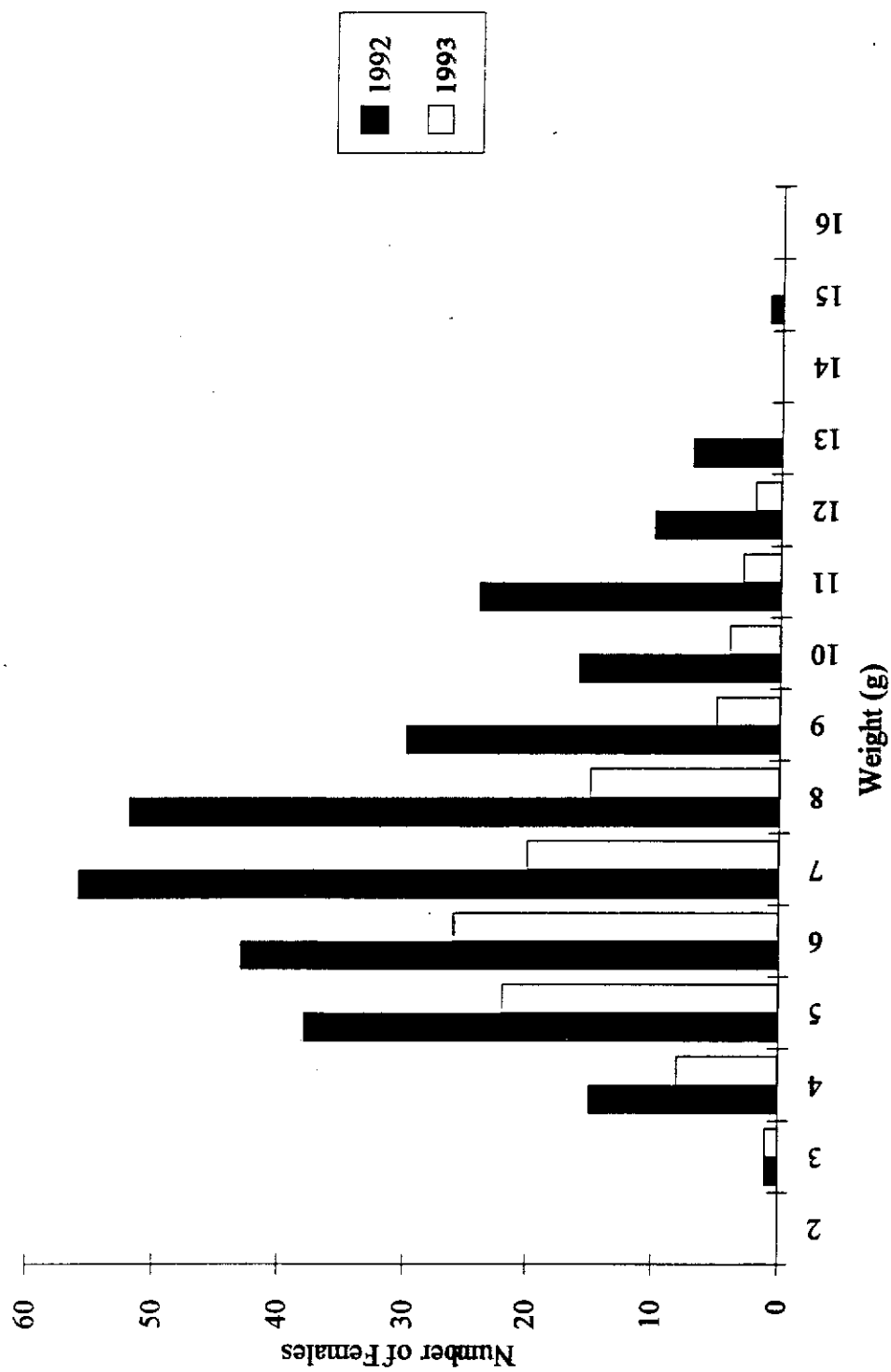
APPENDIX G. Weight Frequencies of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX H.



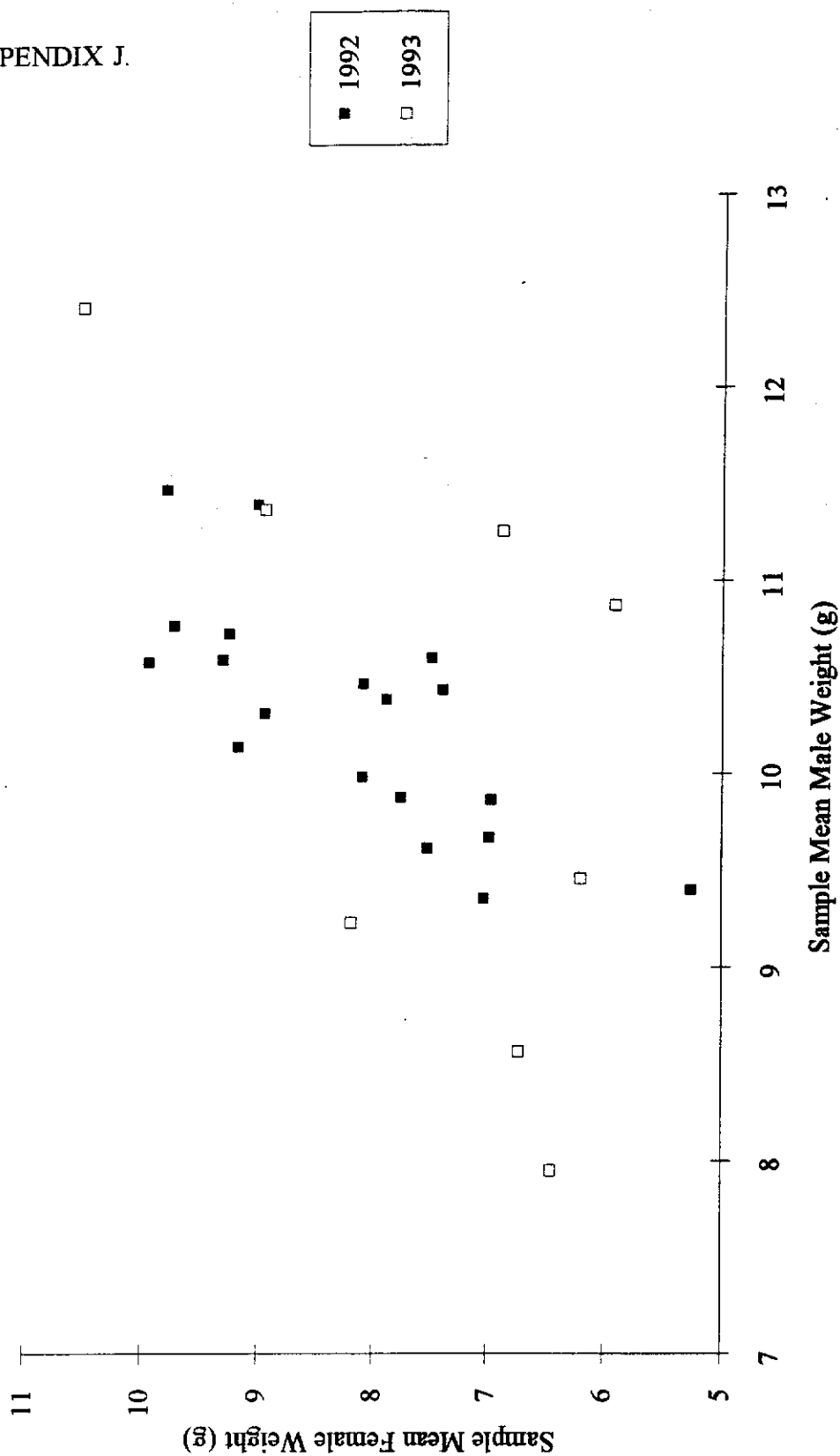
APPENDIX H. Weight Sample Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX I.

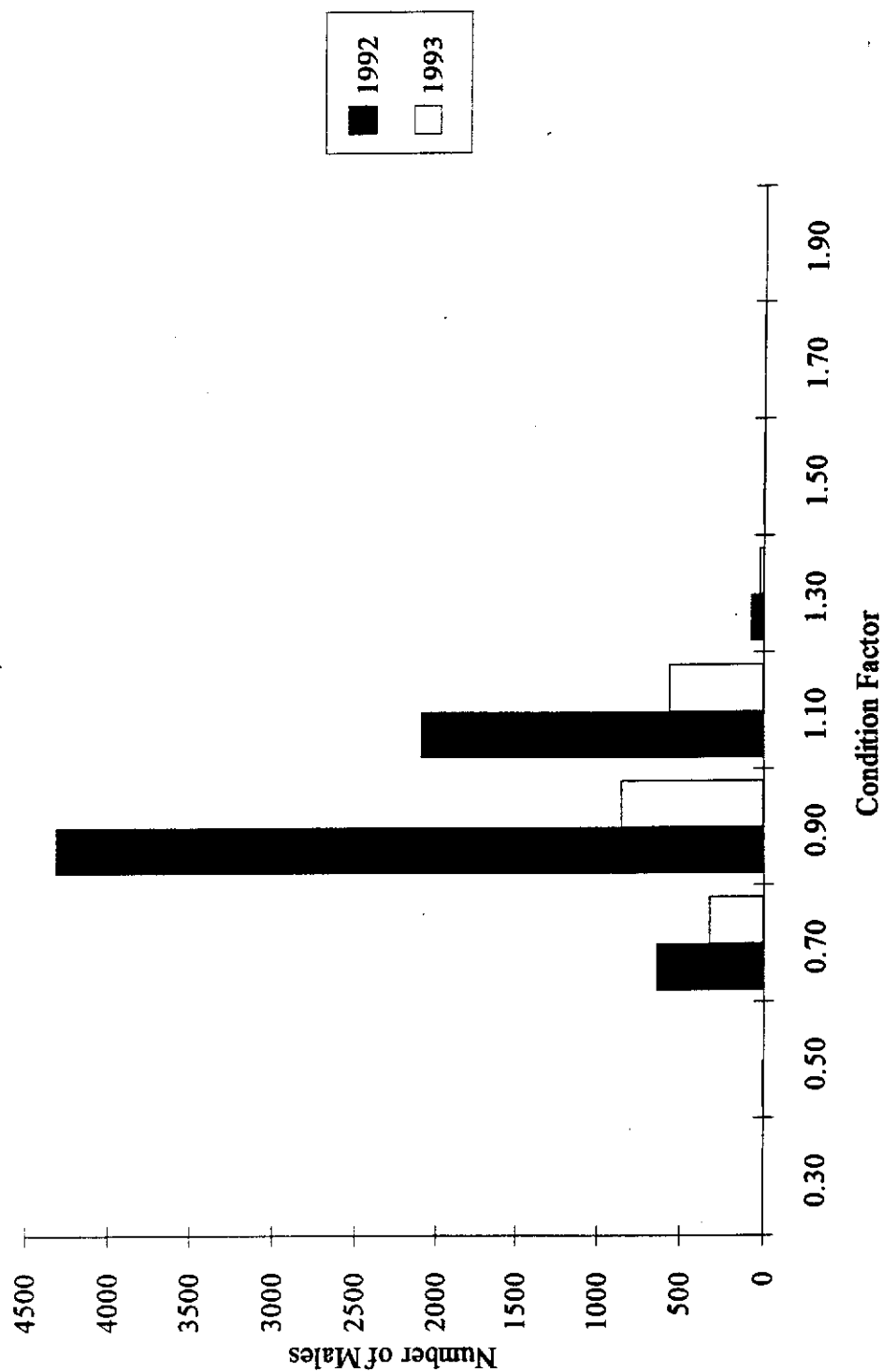


APPENDIX I. Weight Frequencies of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX J.

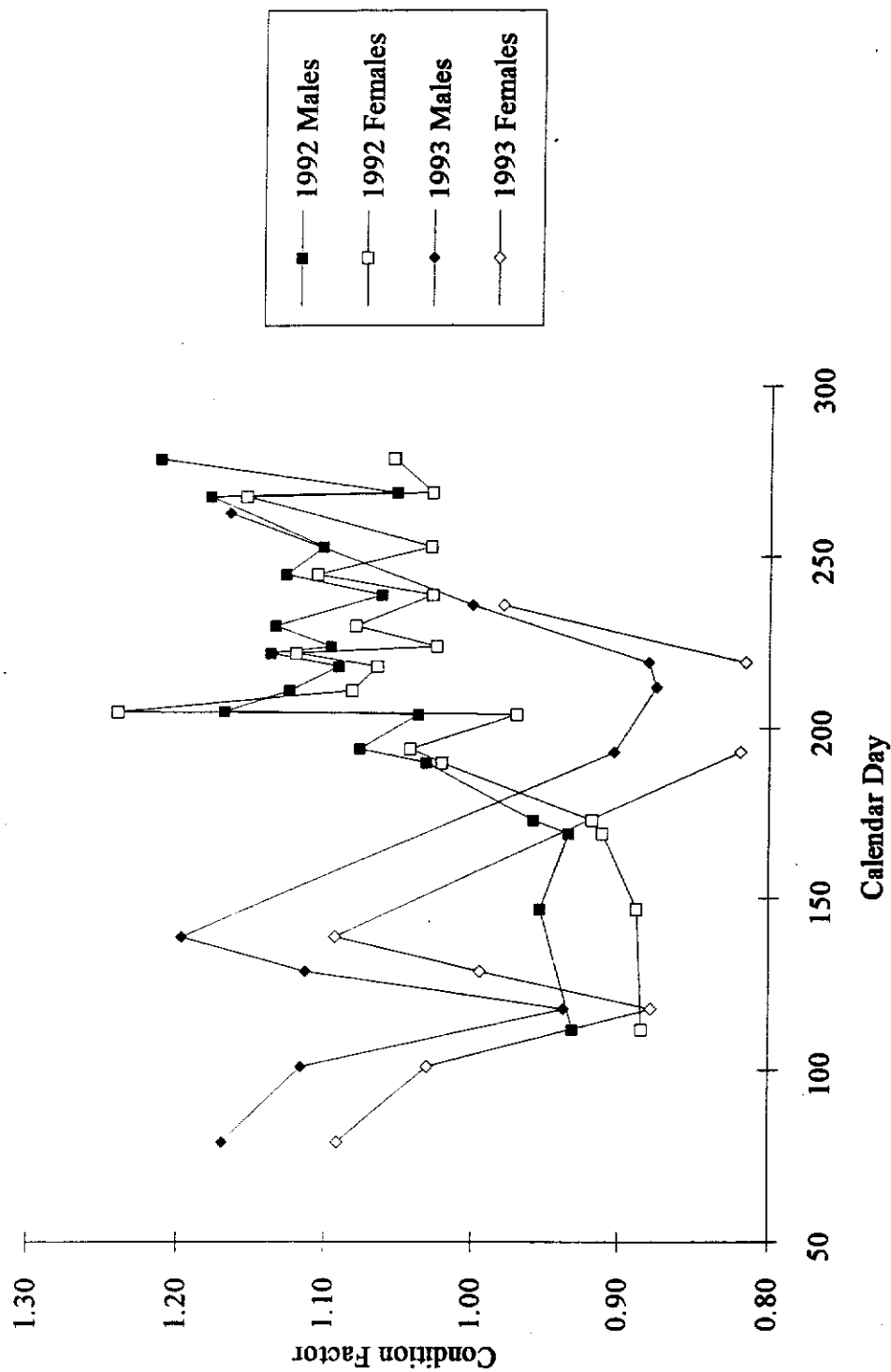


APPENDIX K.



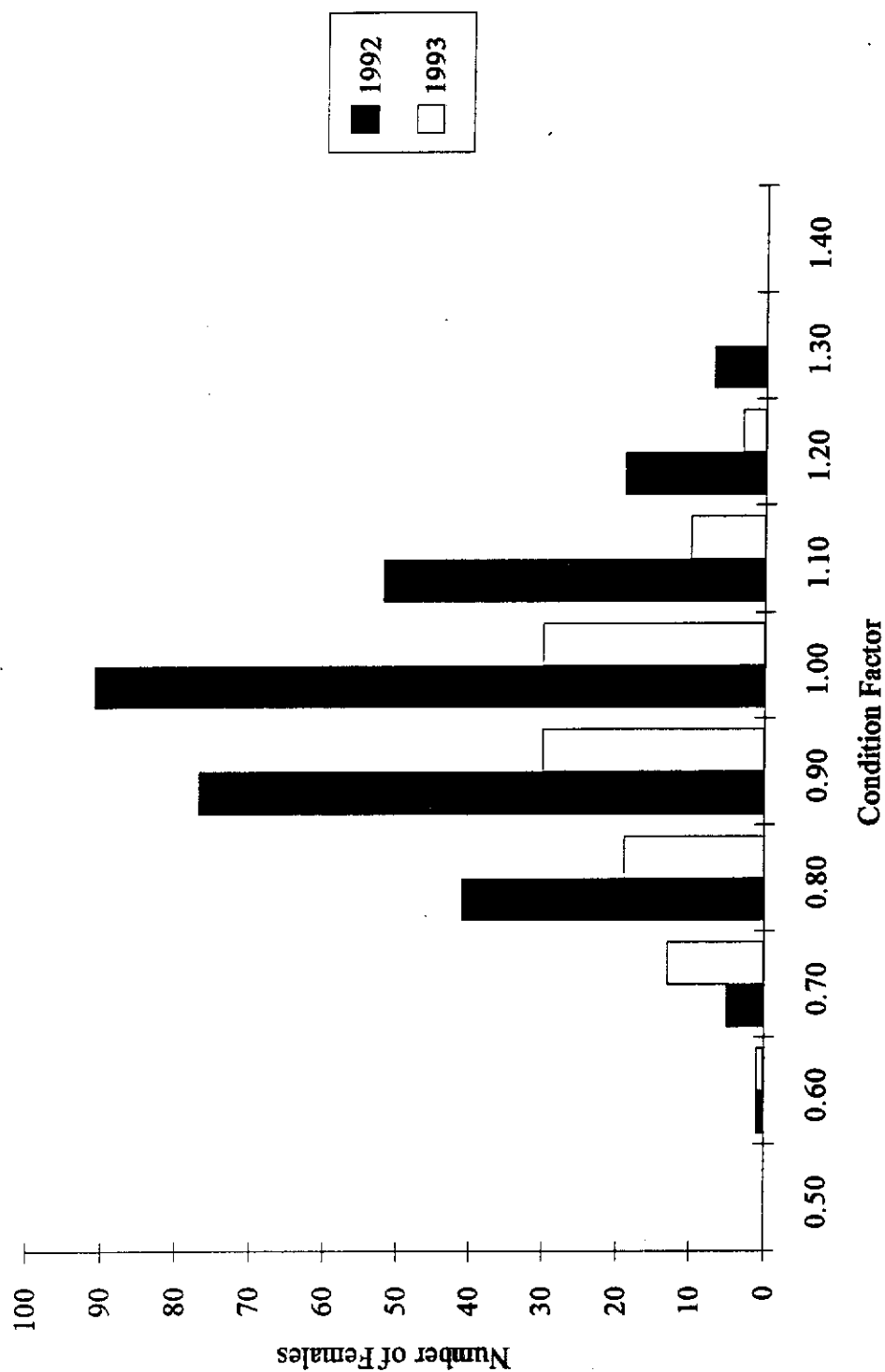
APPENDIX K. Condition Factor Frequencies of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX L.



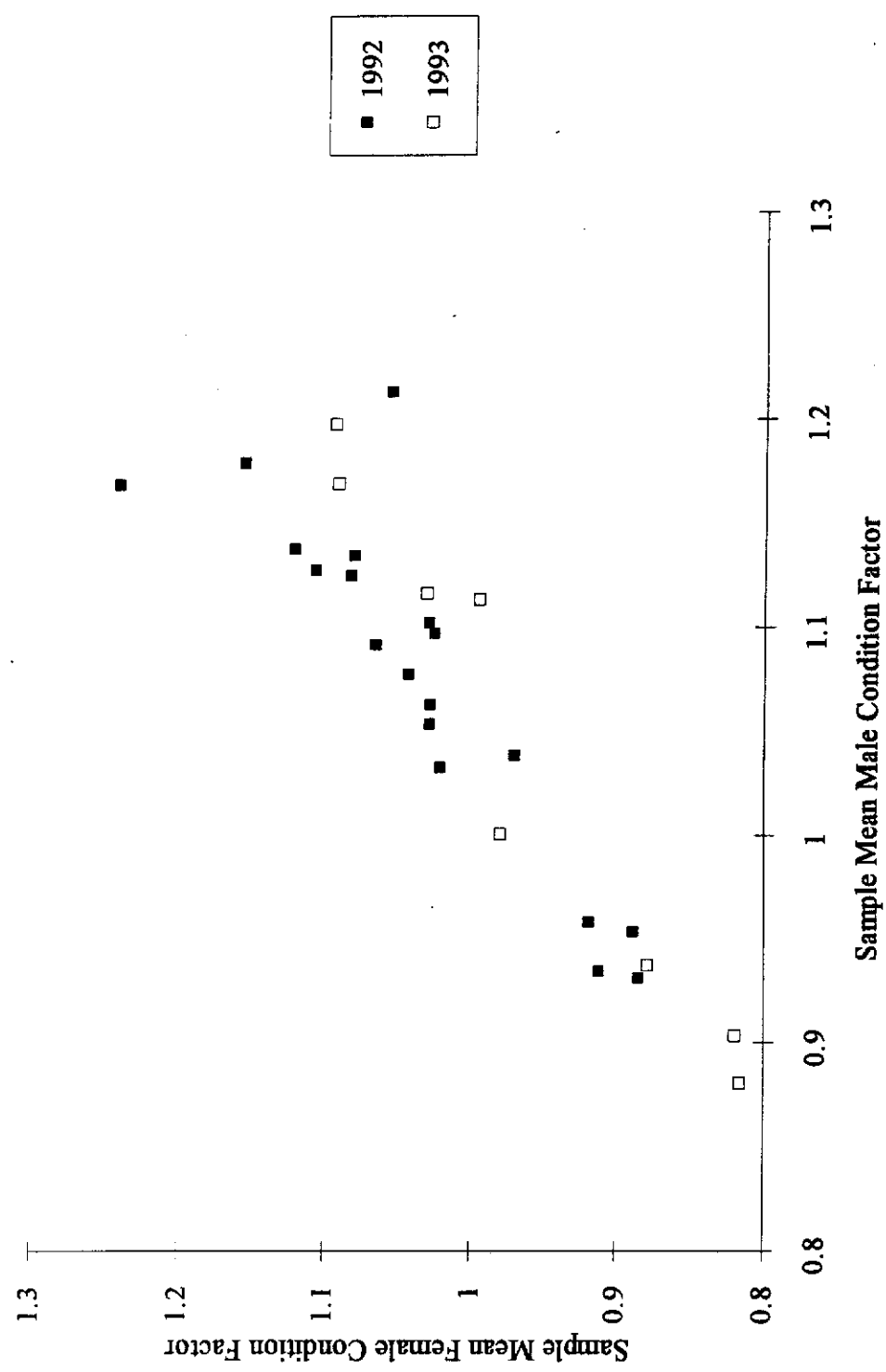
APPENDIX L. Condition Factor Sample Means of Male and Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX M.



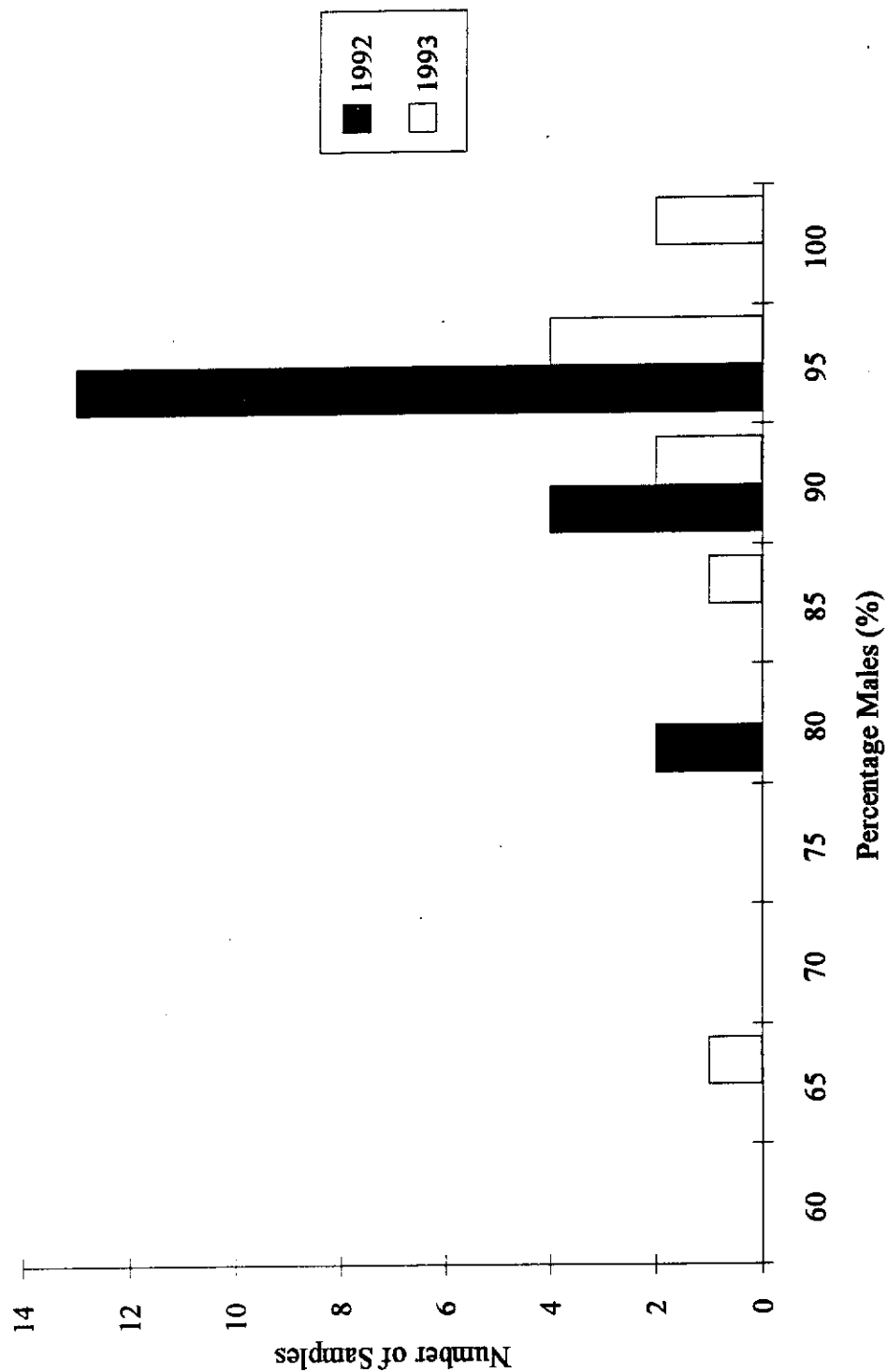
APPENDIX M. Condition Factor Frequencies of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX N.



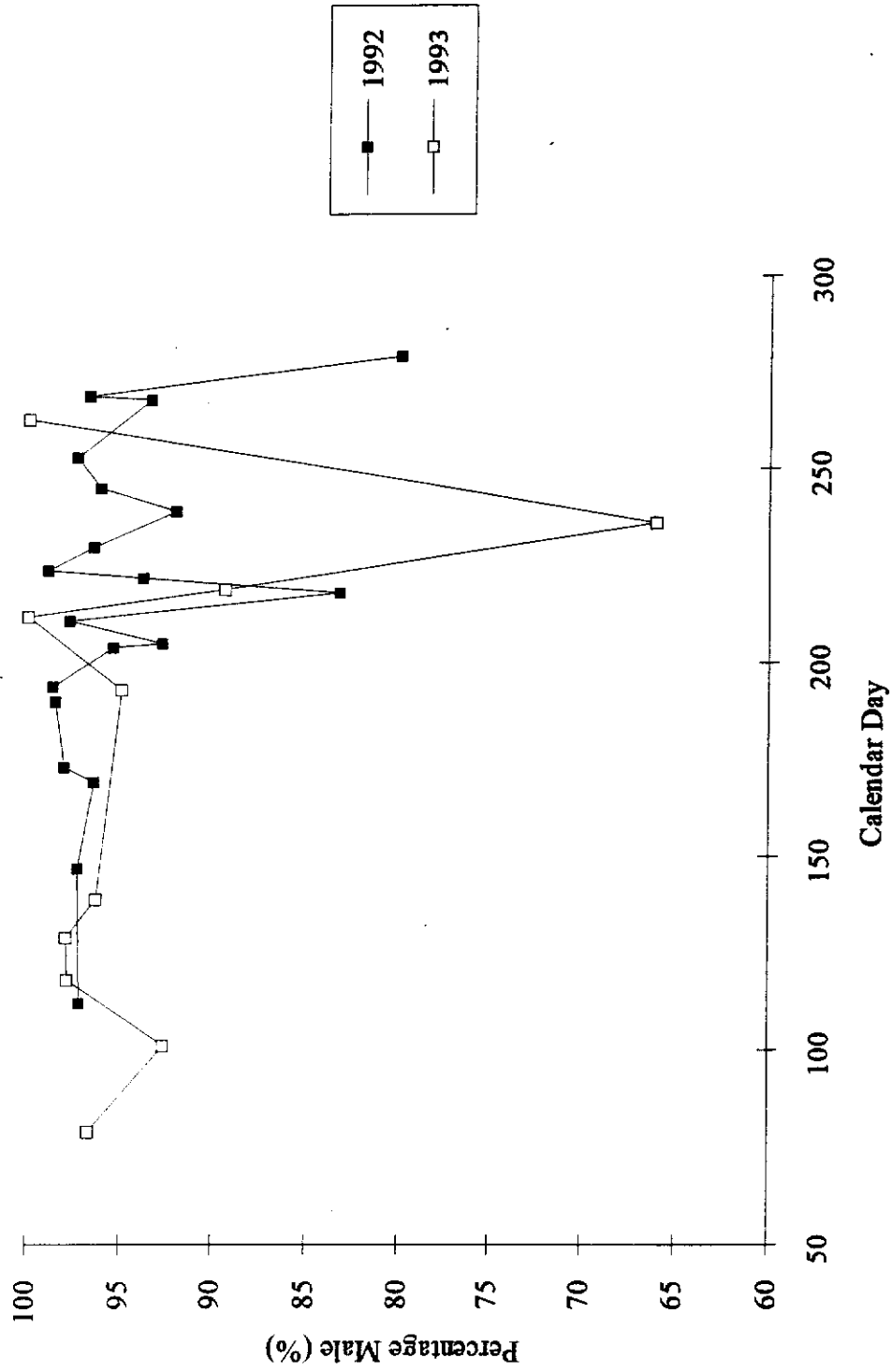
APPENDIX N. Condition Factor Relationship between Male and Female Night Smelt, *Spirinchus starksi*, For Each Sample collected at Freshwater Beach, California in 1992 and 1993.

APPENDIX O.



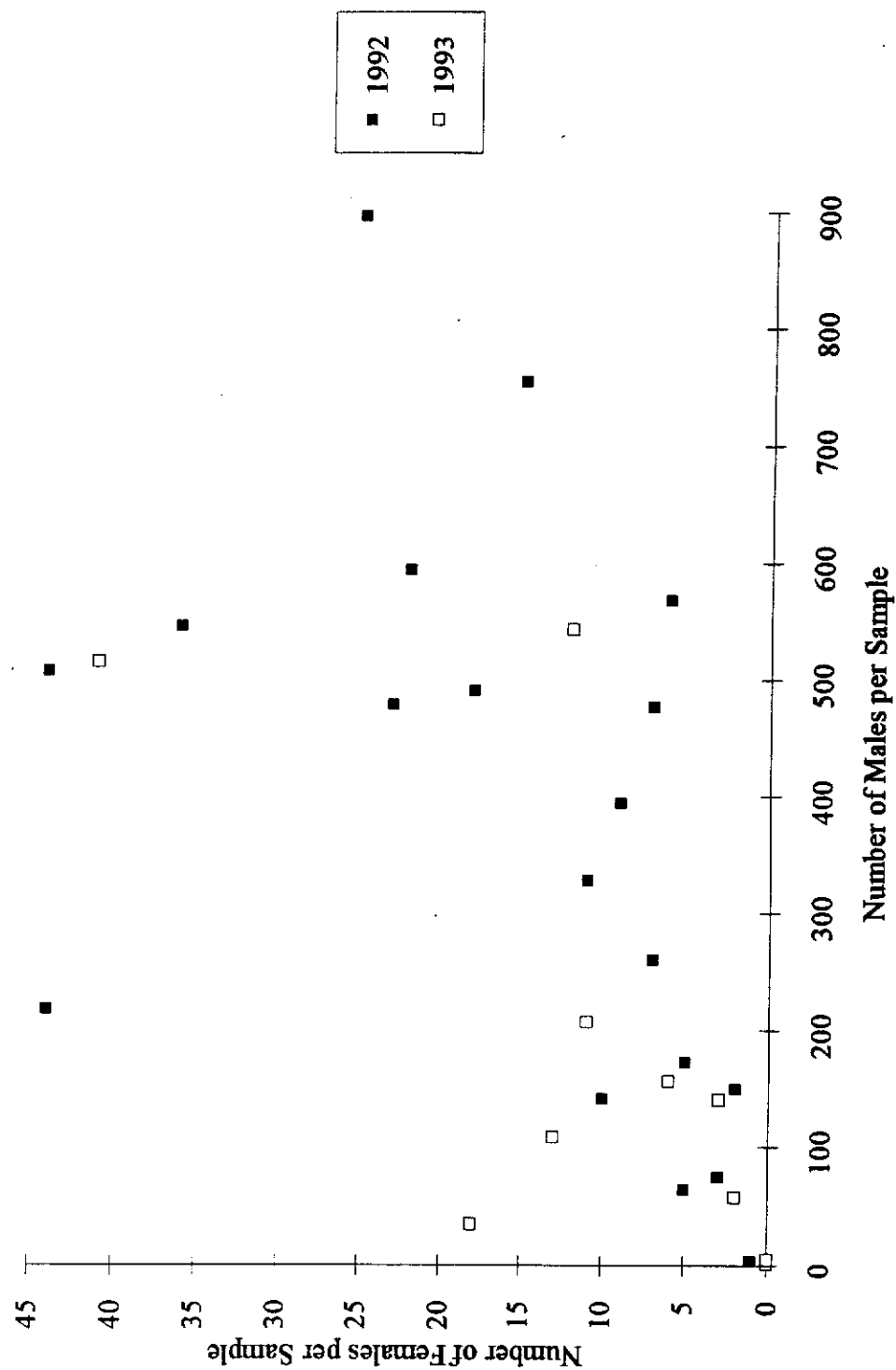
APPENDIX O. Percentage Frequencies of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX P.



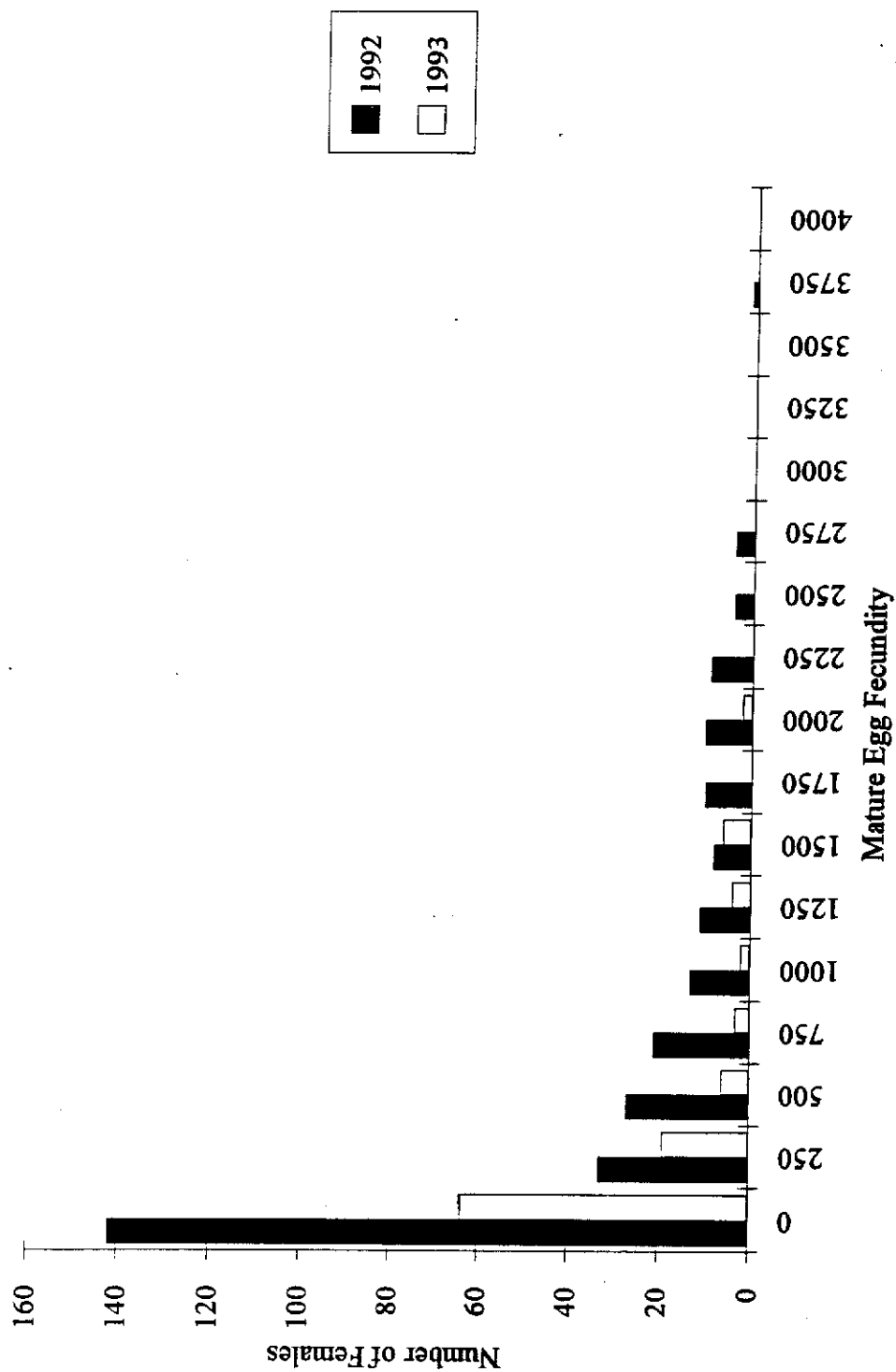
APPENDIX P. Sample Percentages of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX Q.



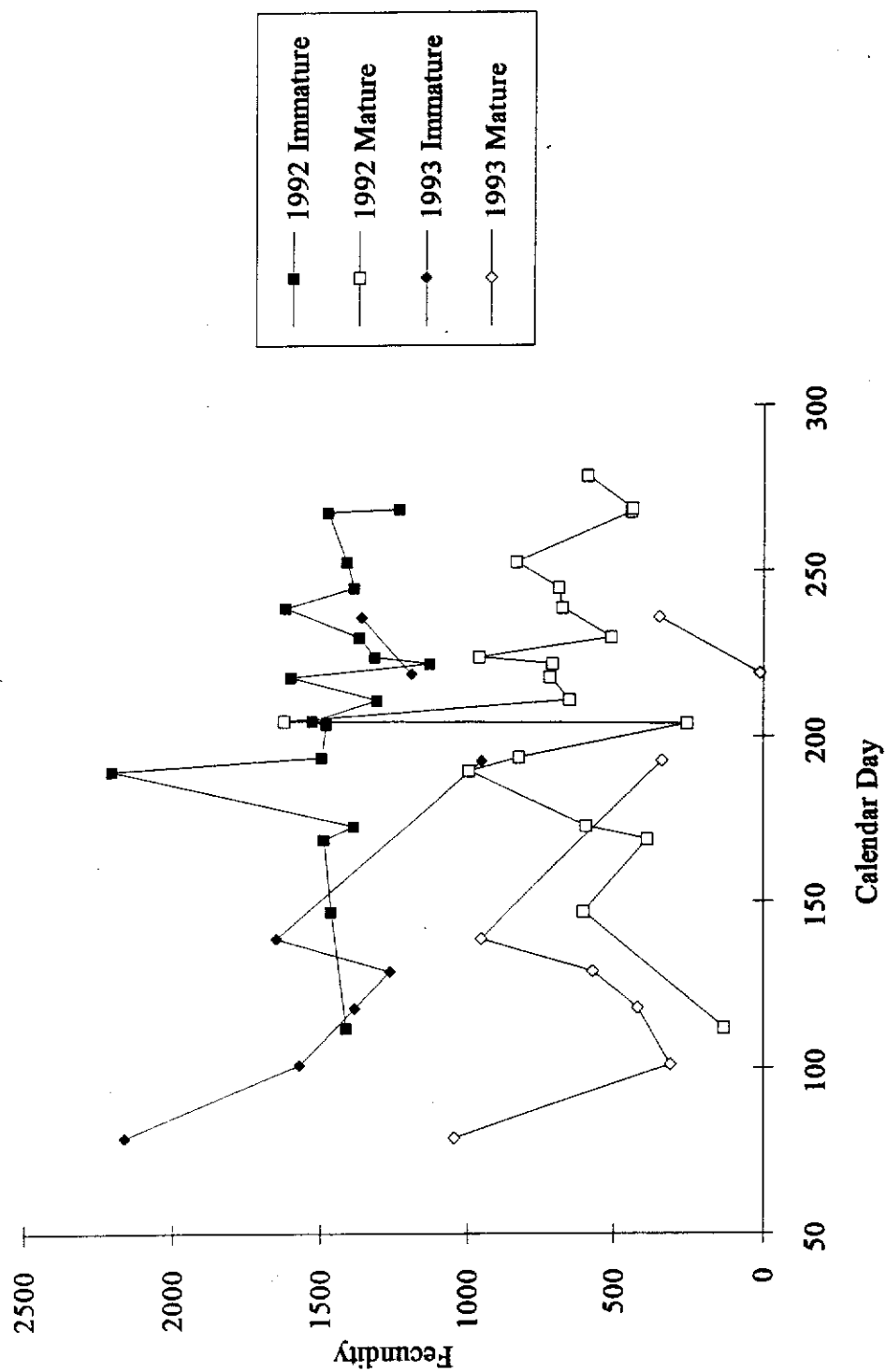
APPENDIX Q. Male - Female Sample Ratios of Night Smelt, *Spirinchus starksi*, For Each Sample Collected at Freshwater Beach, California in 1992 and 1993.

APPENDIX R.



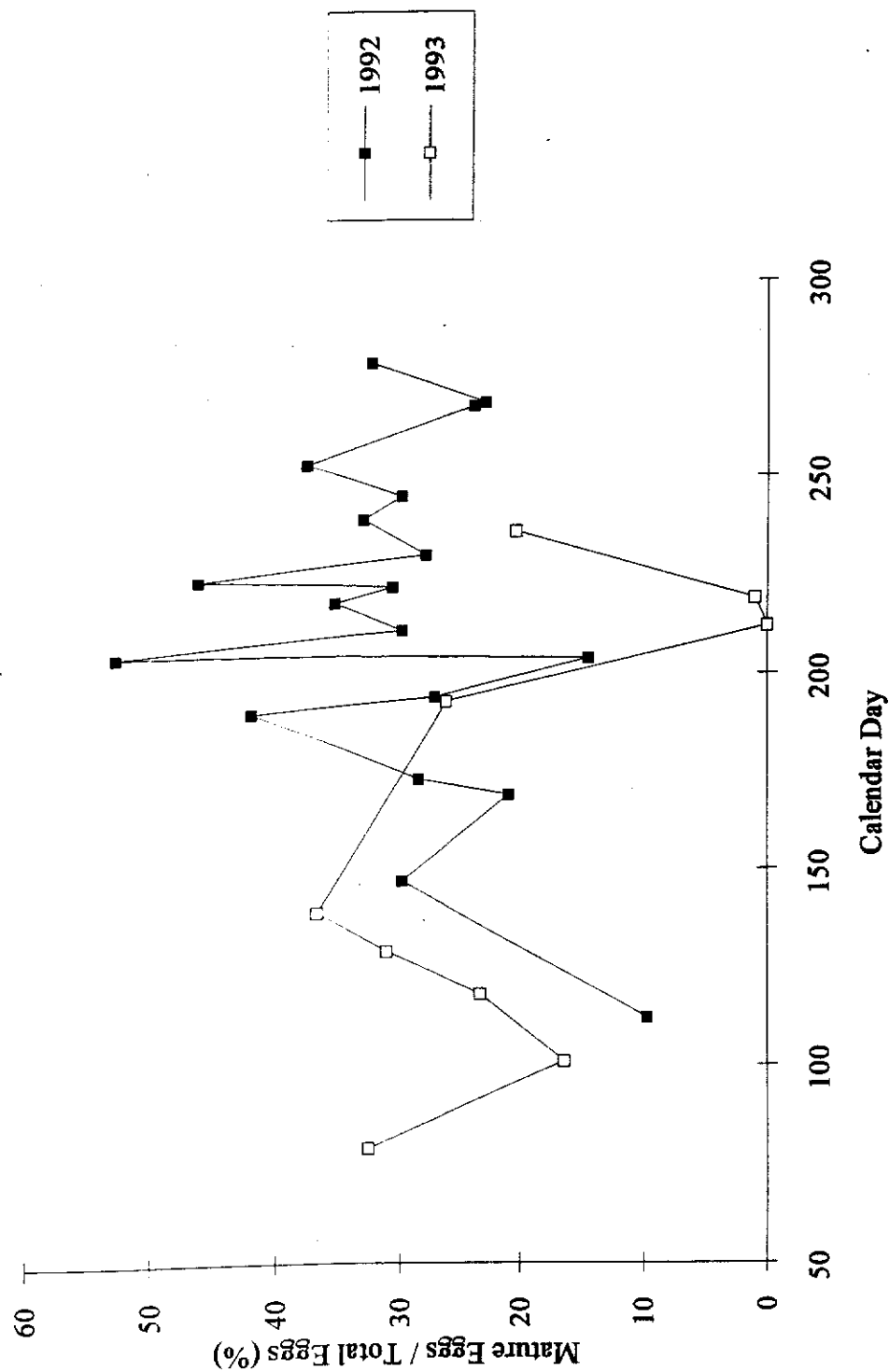
APPENDIX R. Mature Egg Fecundity Frequencies of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX S.



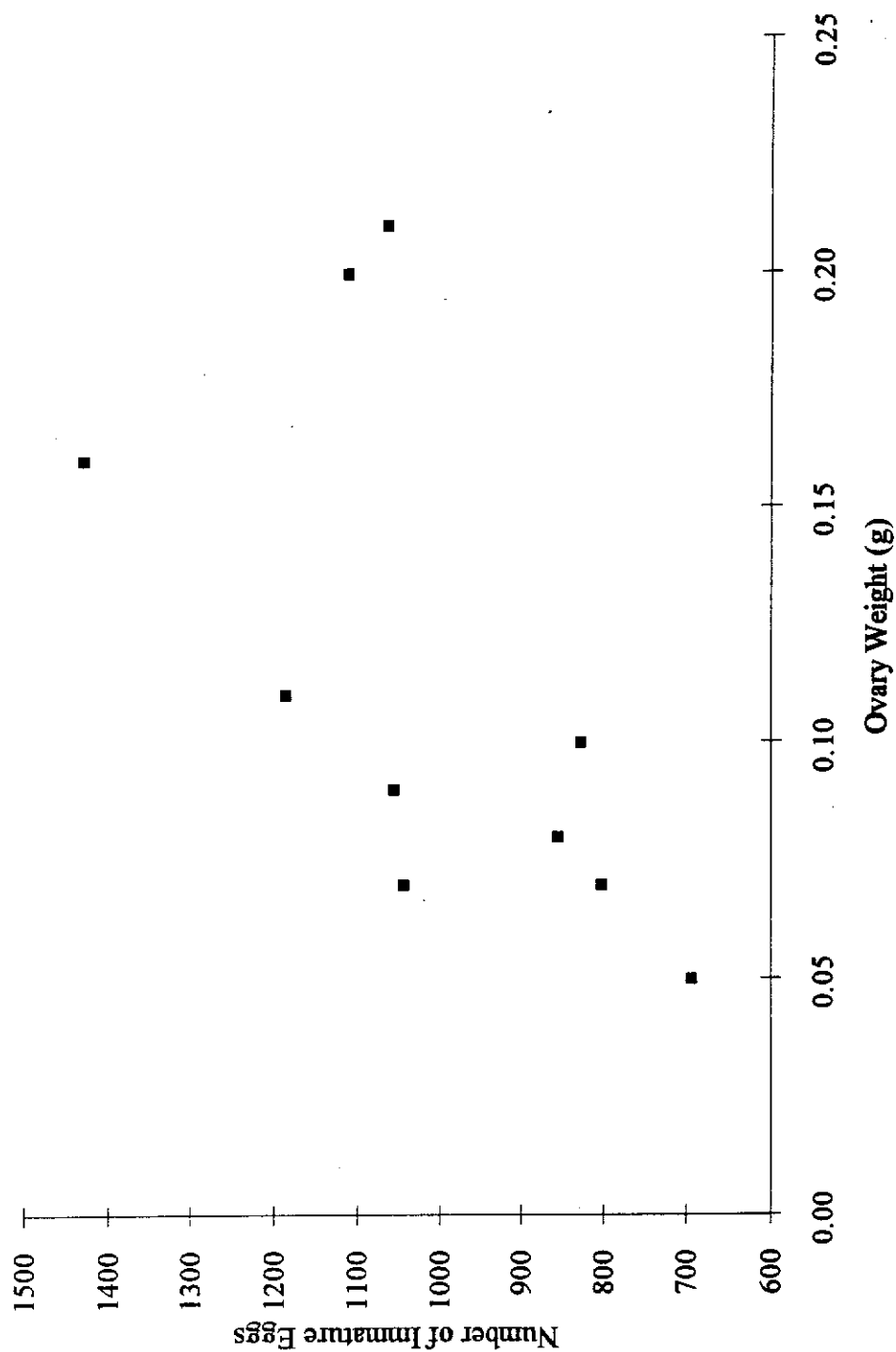
APPENDIX S. Fecundity Sample Means of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX T.



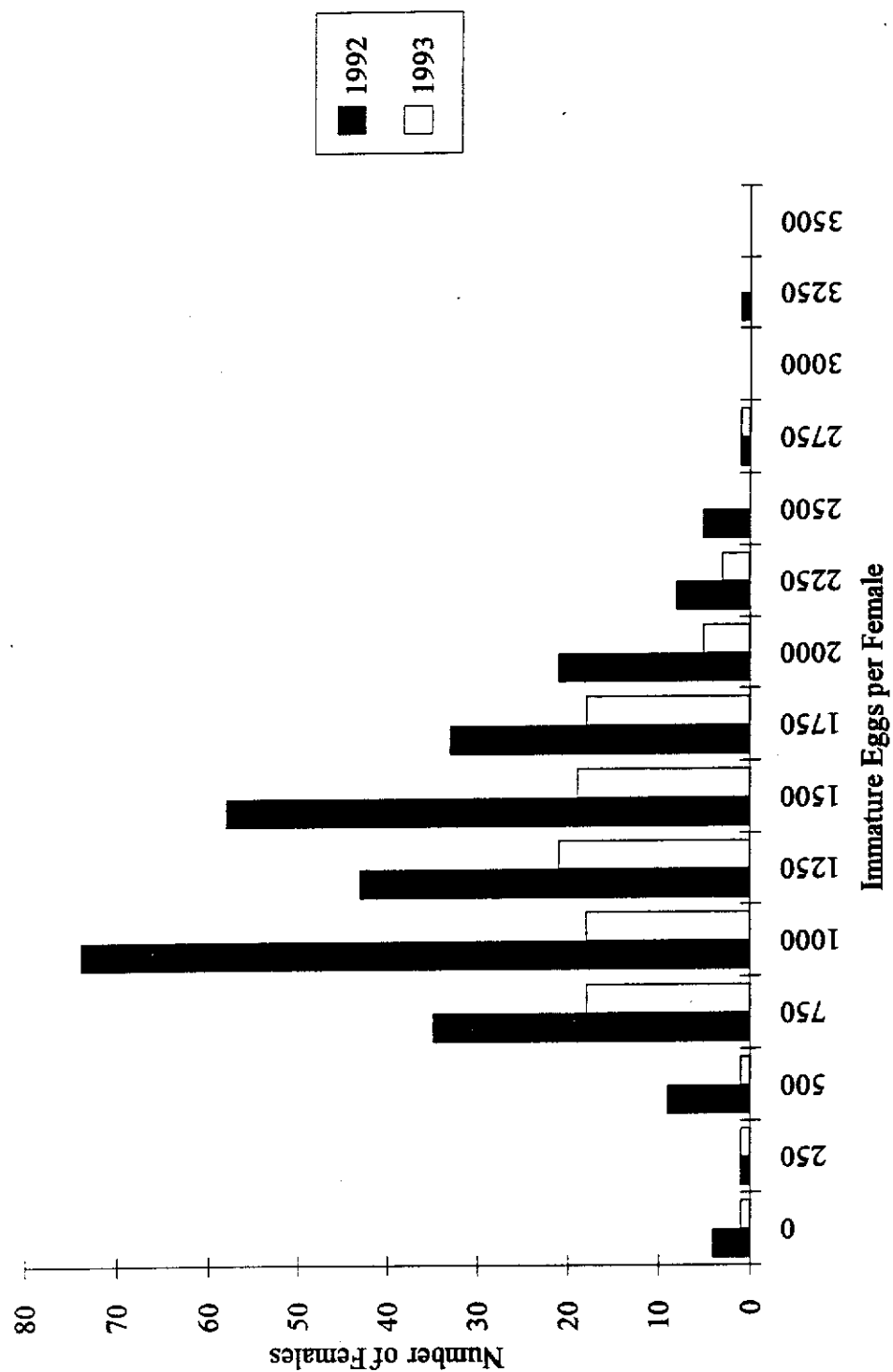
APPENDIX T. Mature Egg Percentage Sample Means of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX U.



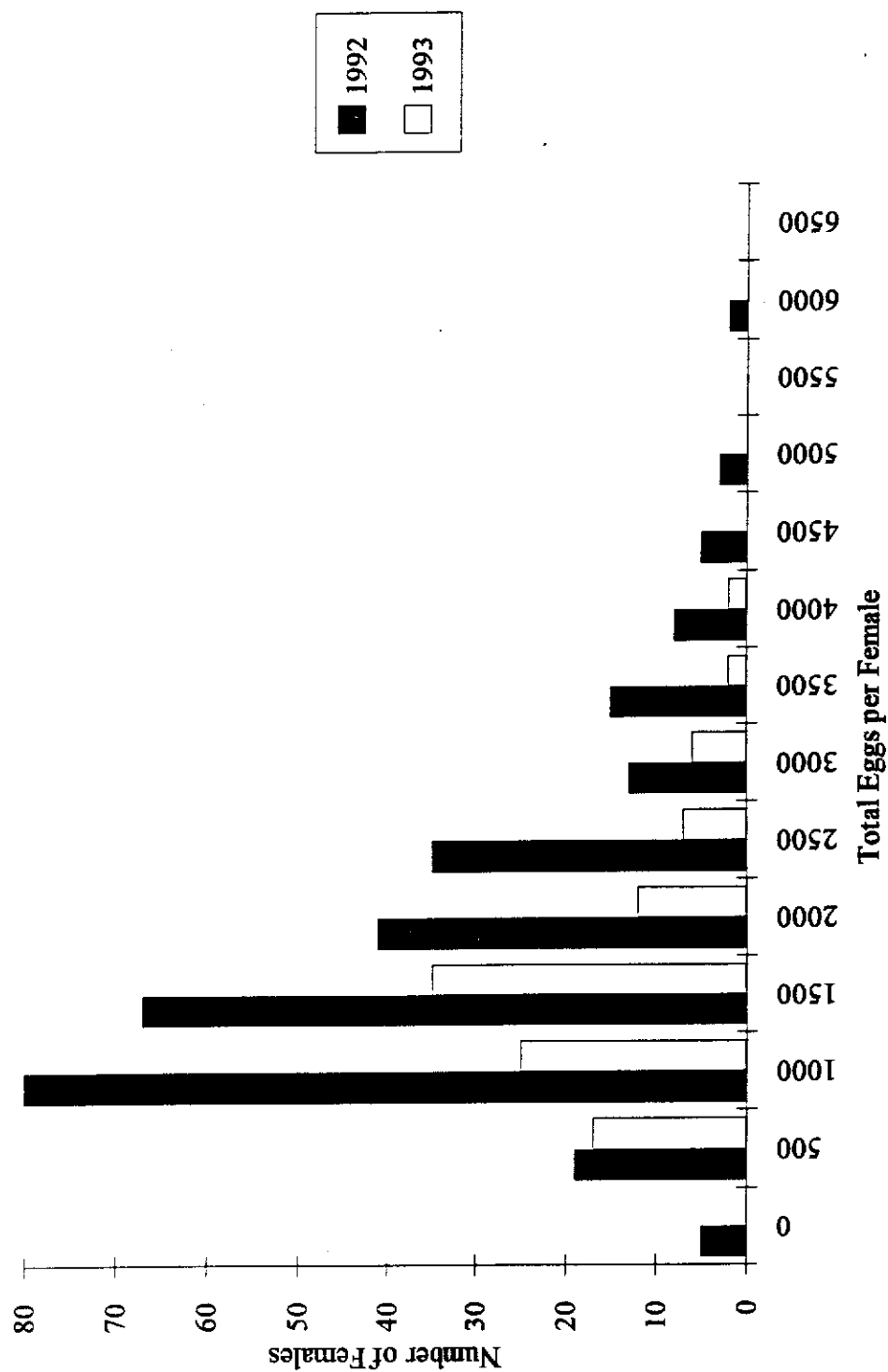
APPENDIX U. Immature Egg - Ovary Weight Relationship of a subsample ($n=10$) of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX V.



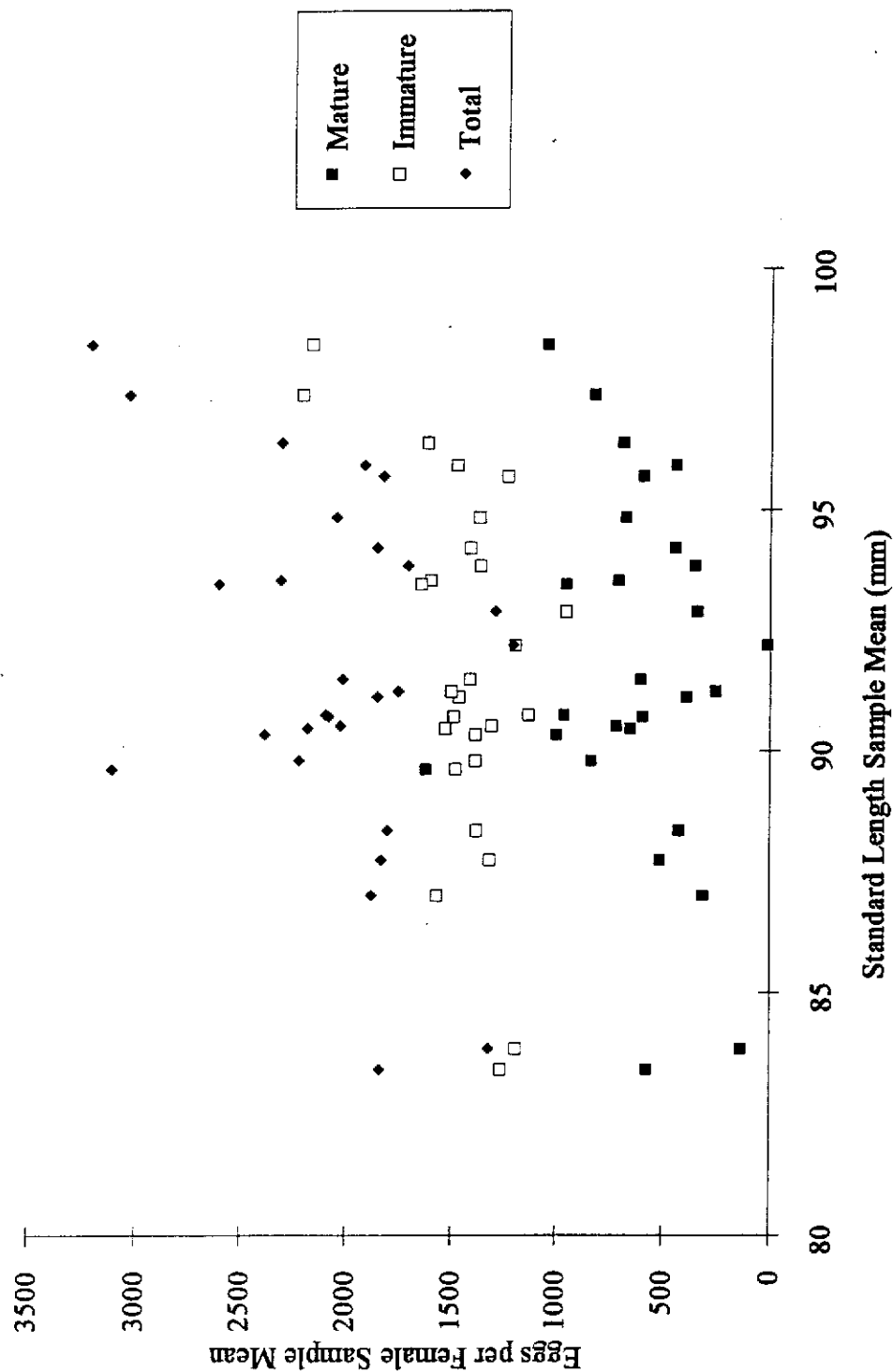
APPENDIX V. Immature Eggs per Female Frequencies of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX W.



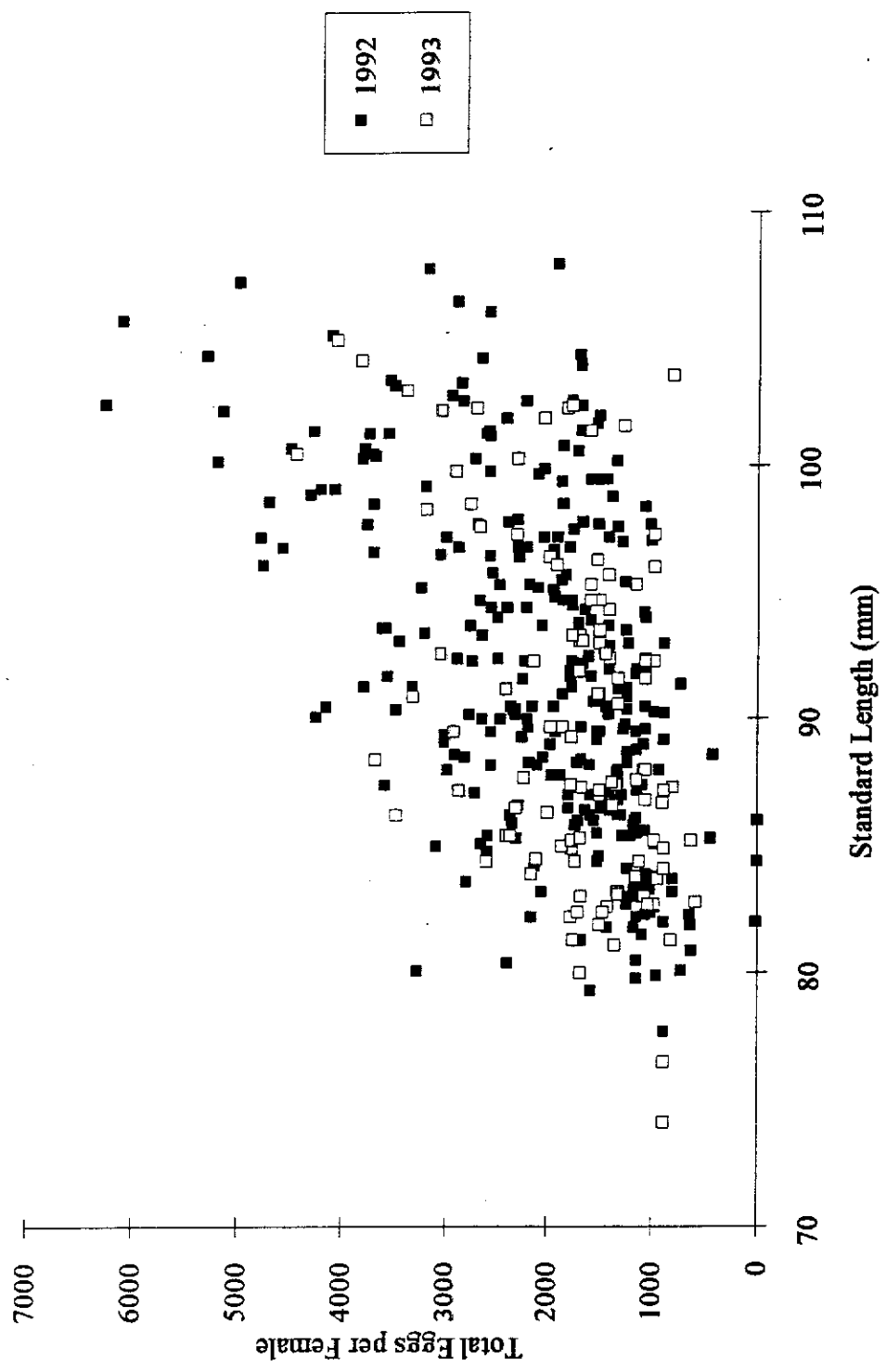
APPENDIX W. Total Eggs per Female Frequencies of Night Smelt, *Spirinchus starksi*, sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX X.



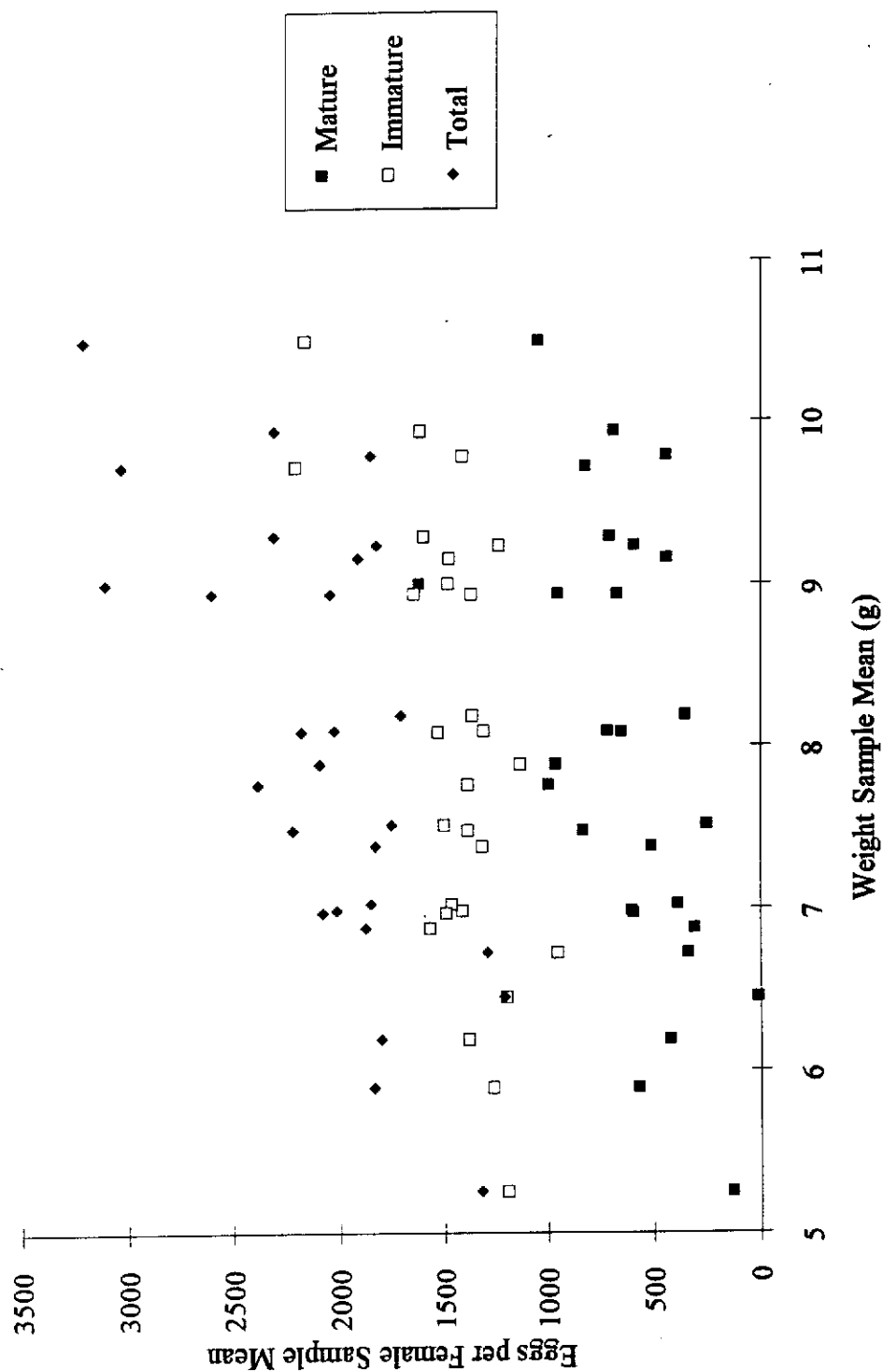
APPENDIX X. Sample Mean Length - Eggs per Female Relationships of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX Y.



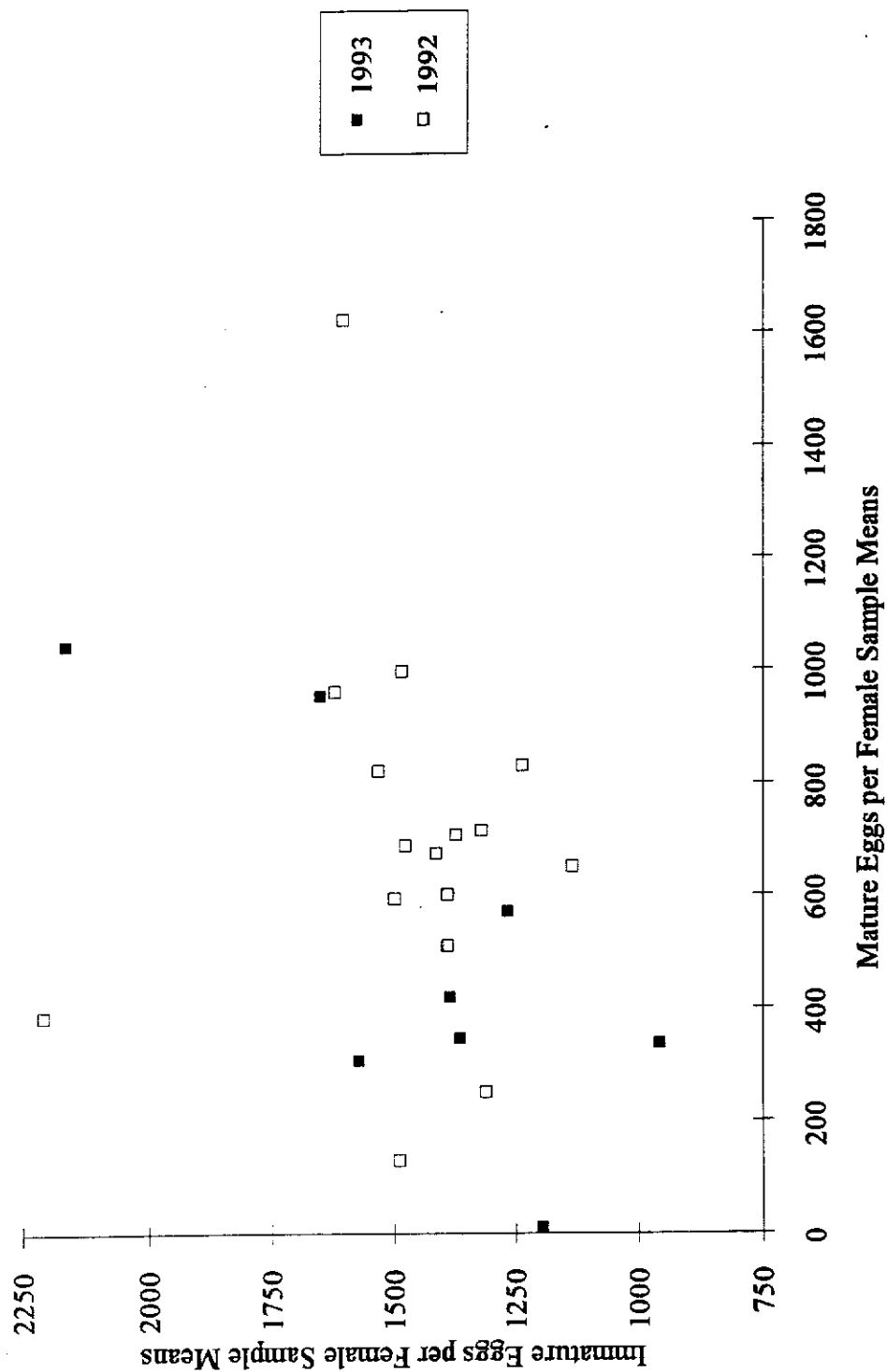
APPENDIX Y. Individual Length - Total Eggs per Female Relationship of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX Z.



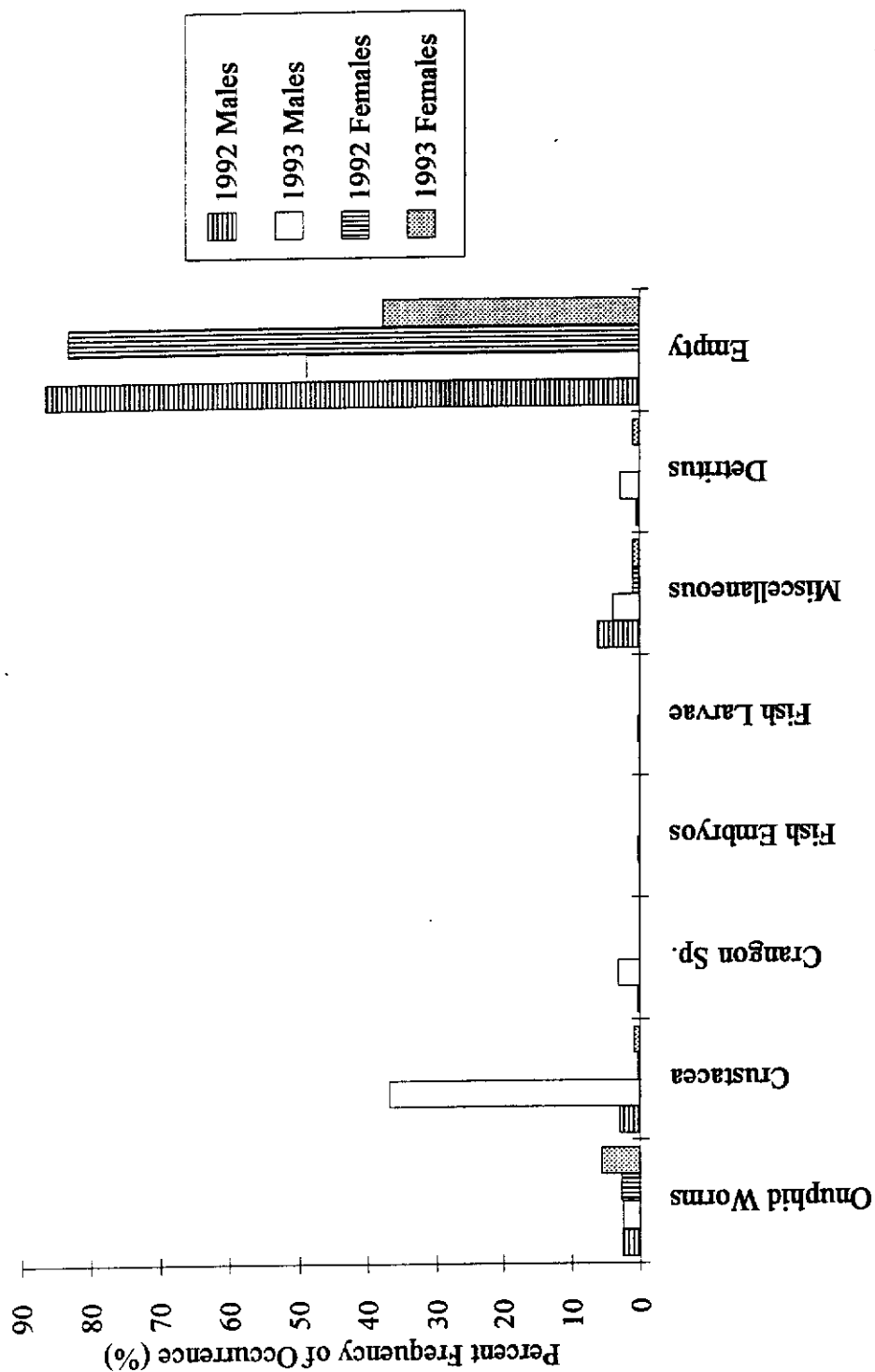
APPENDIX Z. Sample Mean Weight - Eggs per Female Relationships of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AA.

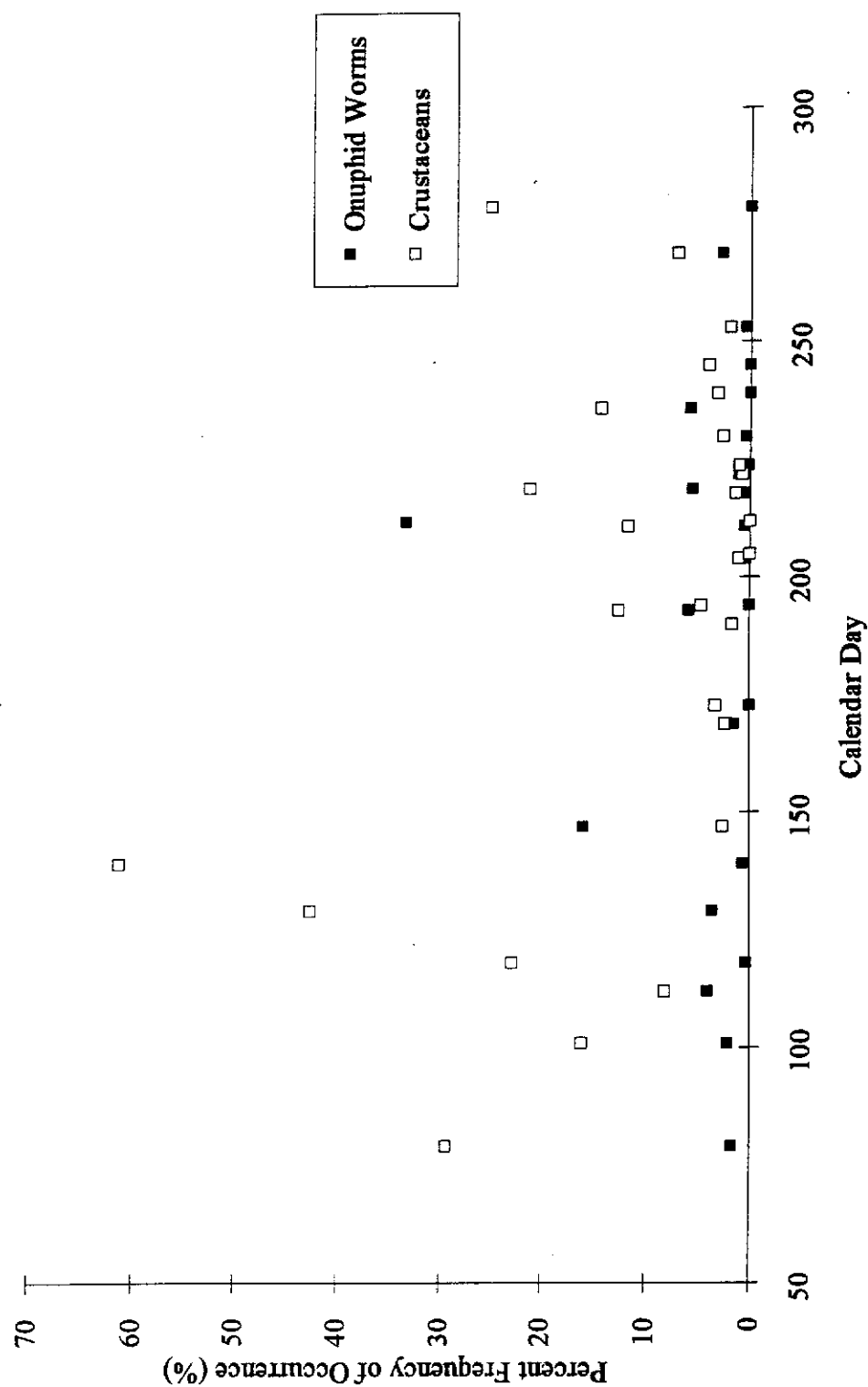


APPENDIX AA. Mature - Immature Eggs per Female Relationship of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AB.

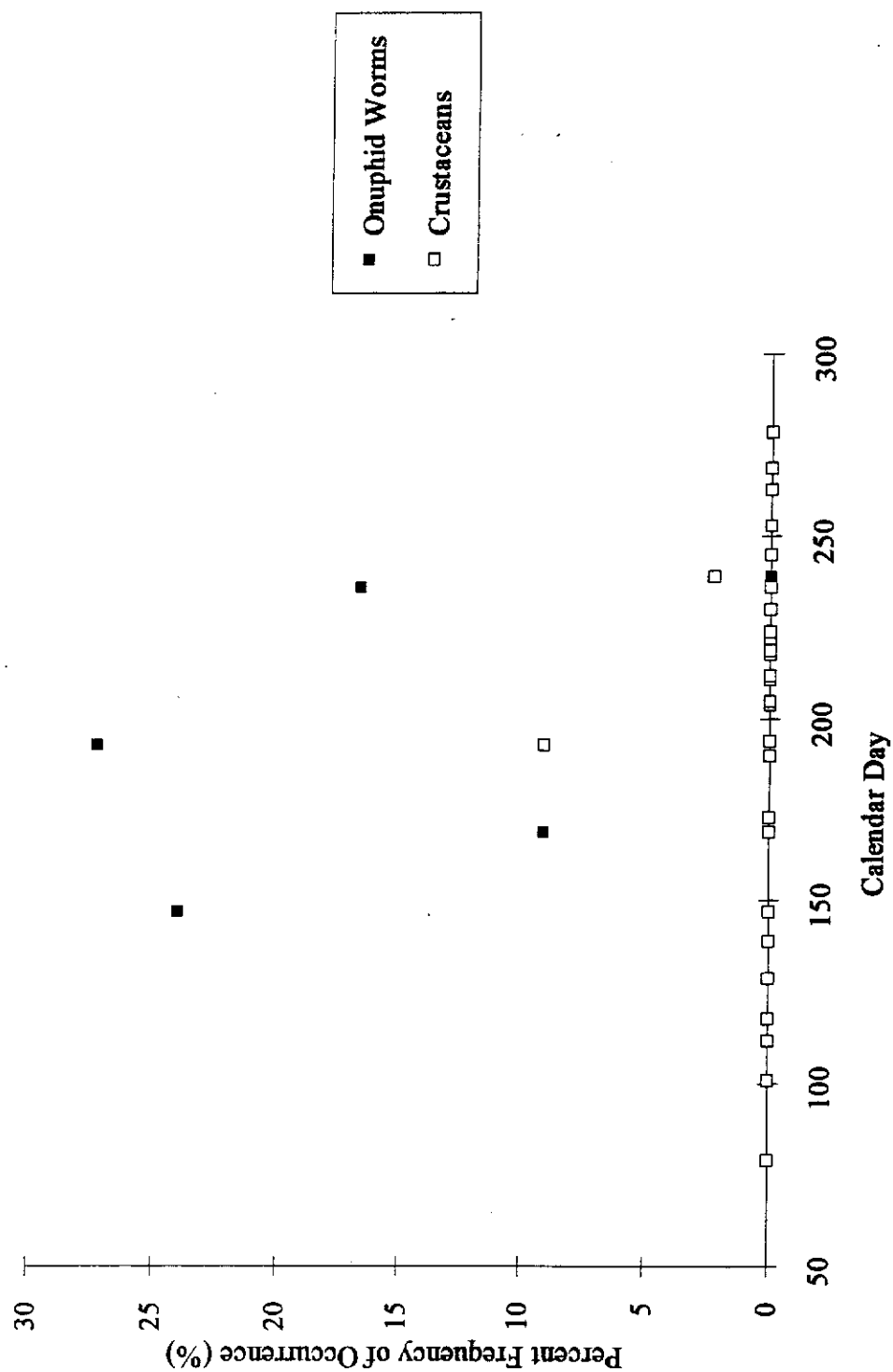
APPENDIX AB. Prey Types of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AC.



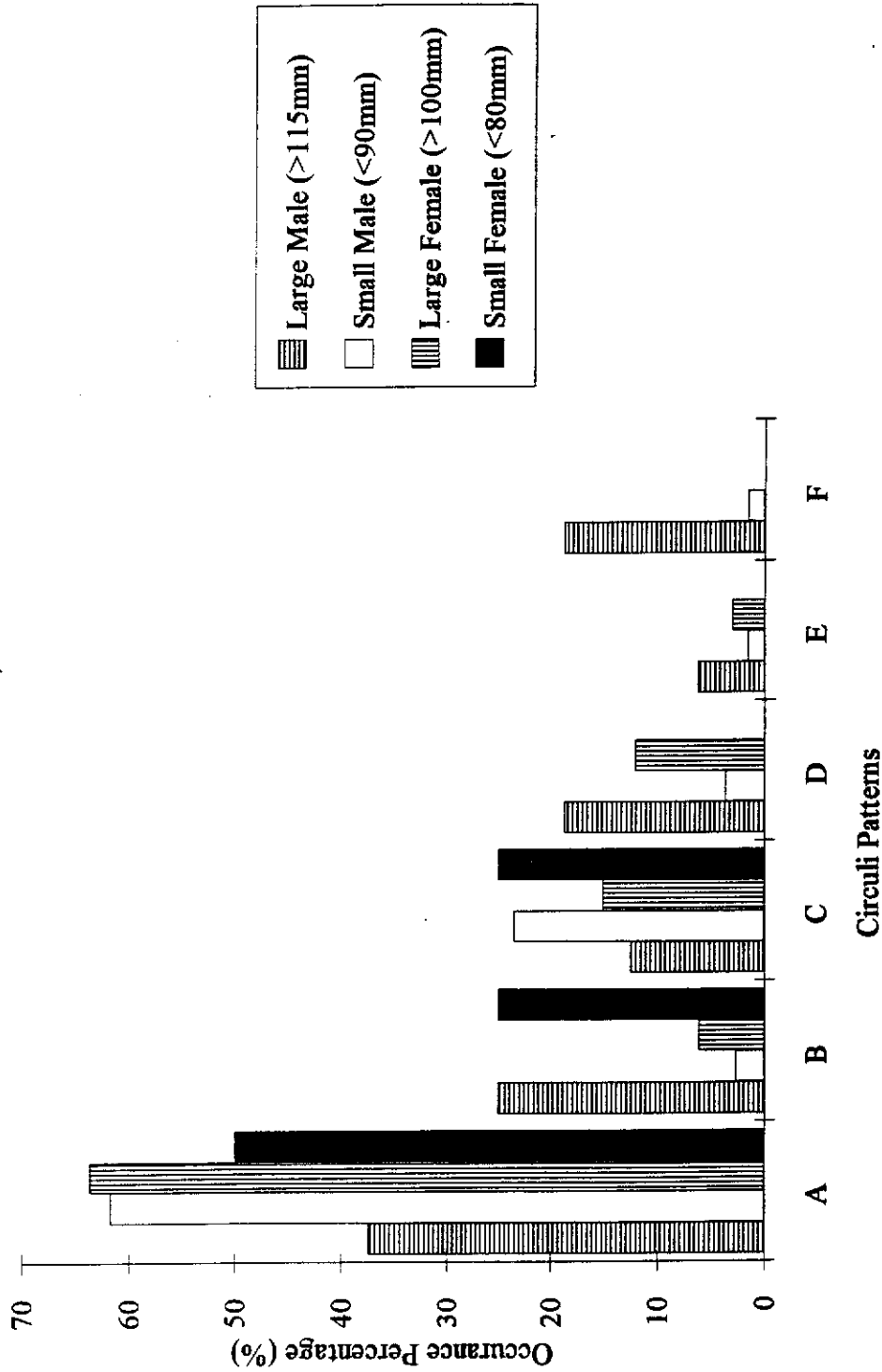
APPENDIX AC. Diet of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AD.



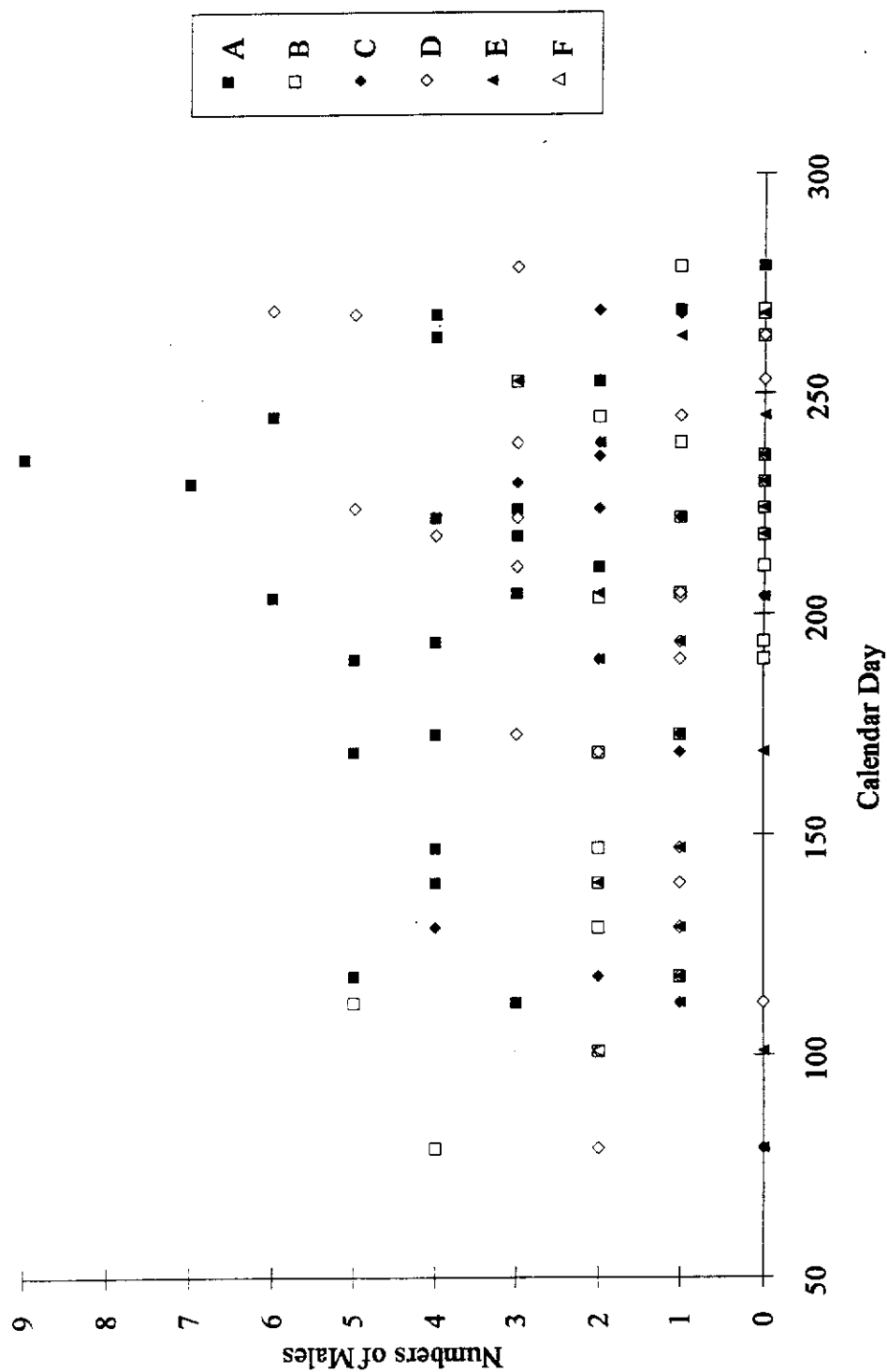
APPENDIX AD. Diet of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AE.



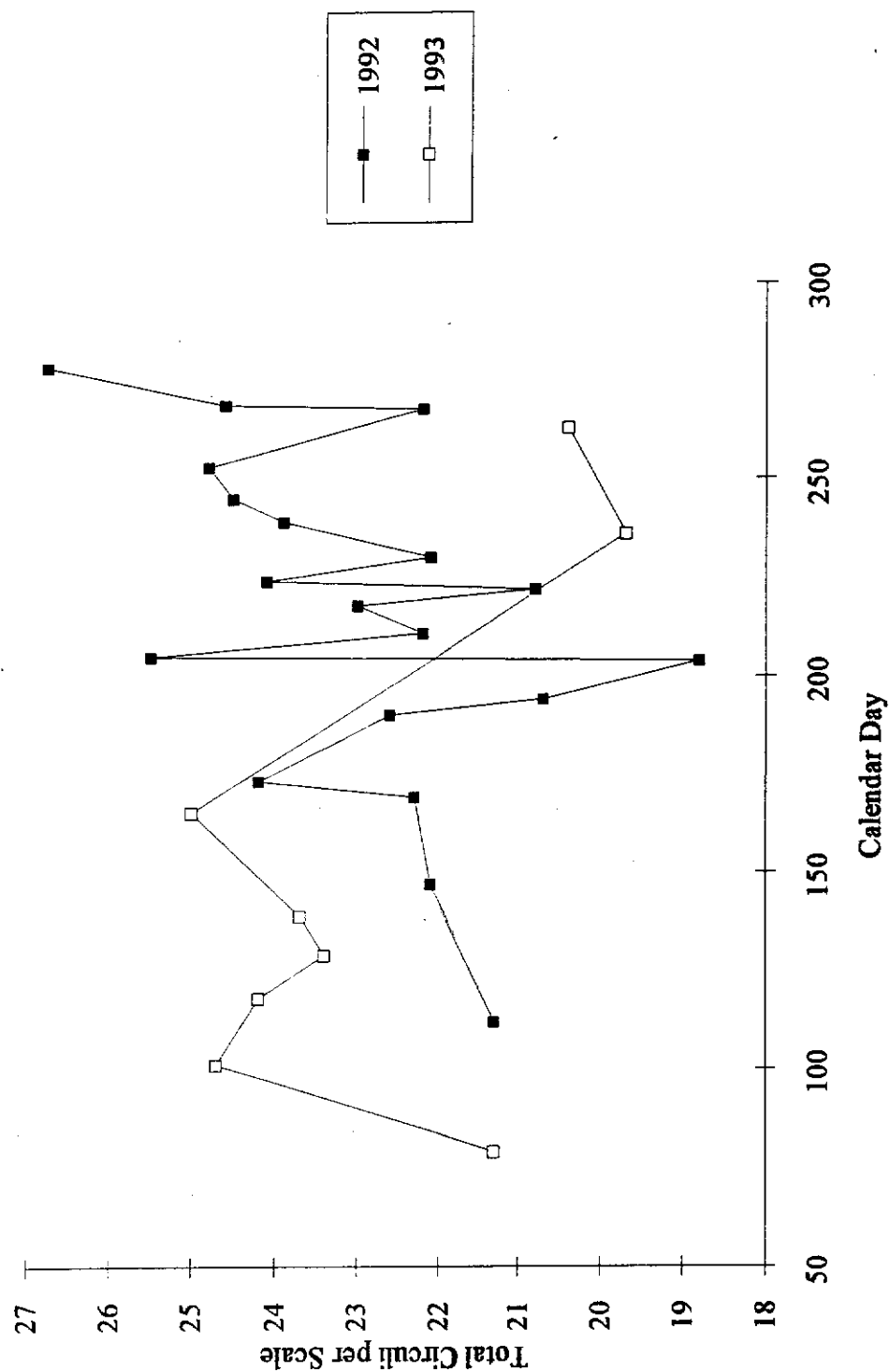
APPENDIX AE. Circuli Patterns, as defined in text, of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AF.



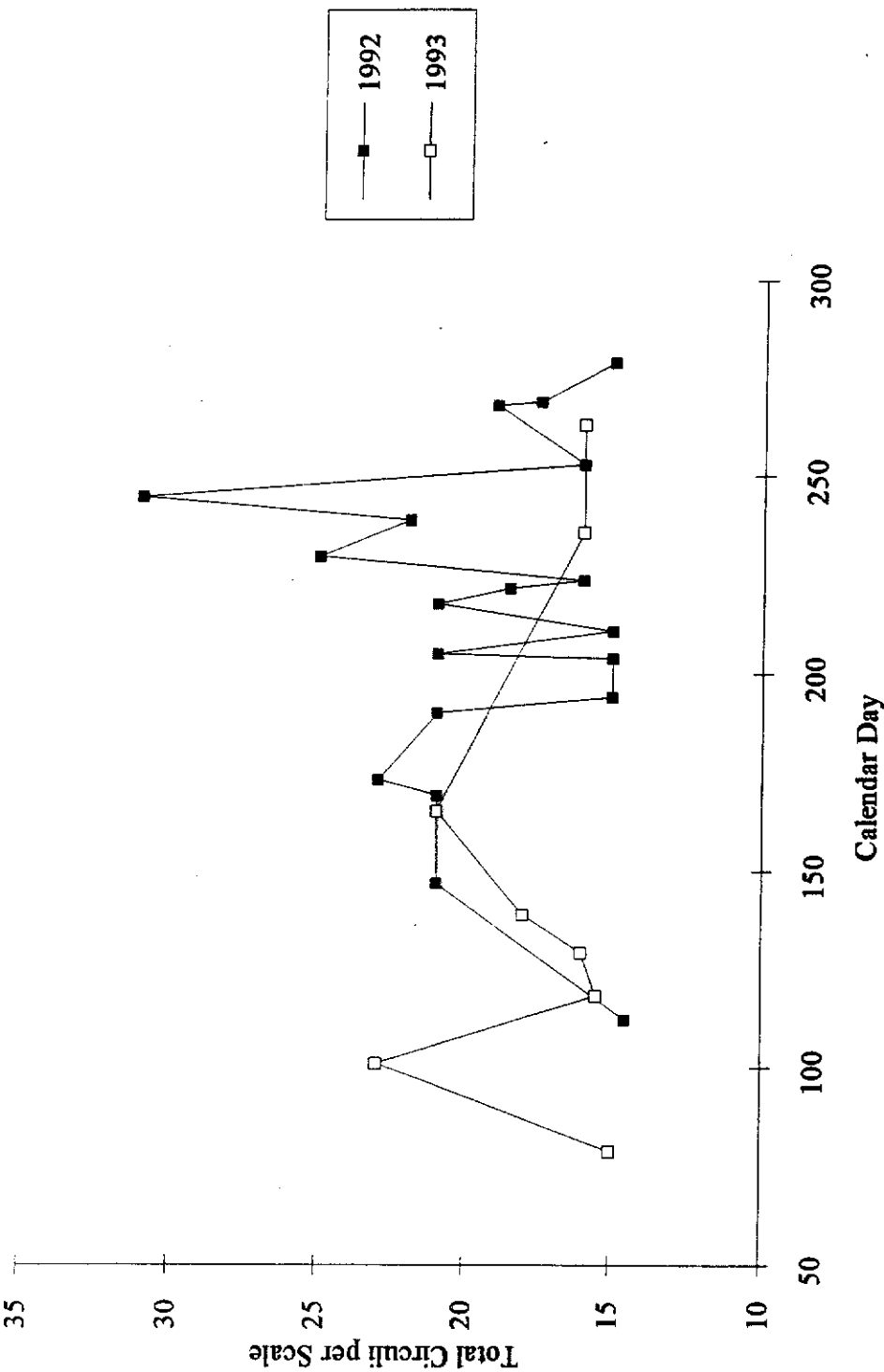
APPENDIX AF. Circuli Patterns, as defined in text, of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AG.



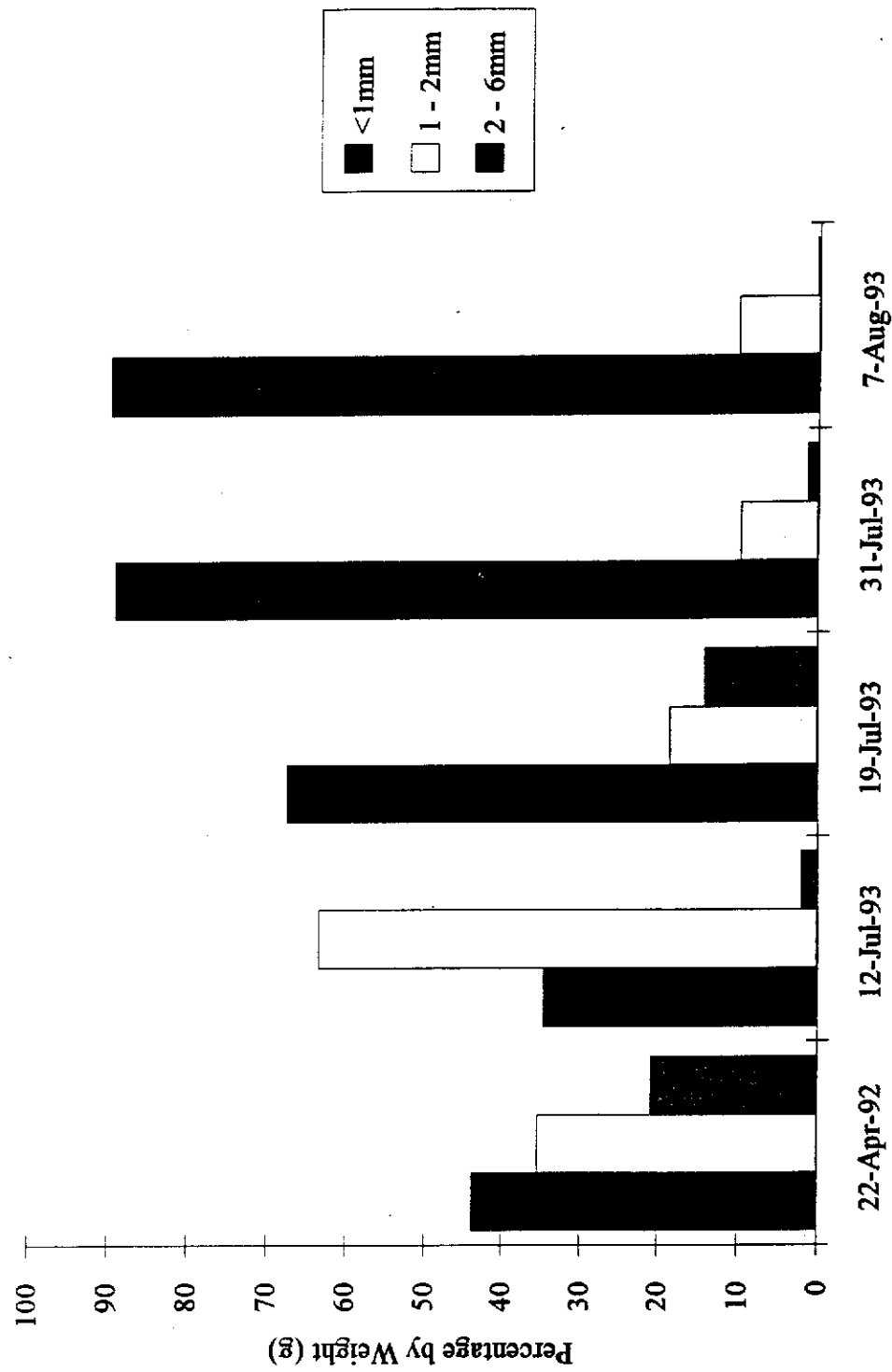
APPENDIX AG. Total Circuli per Scale Sample Means of Male Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AH.



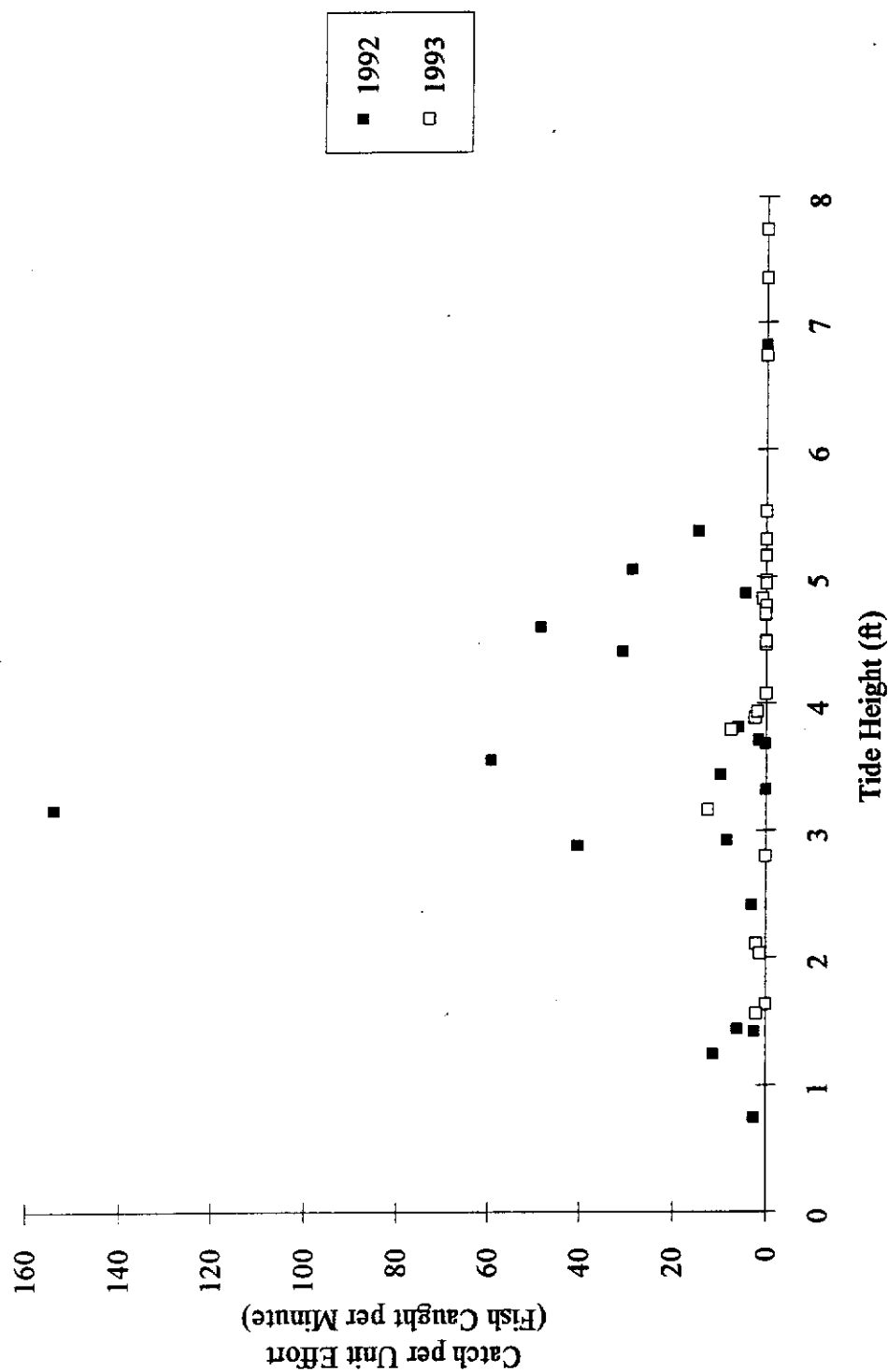
APPENDIX AH. Total Circuli per Scale Sample Means of Female Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AI.



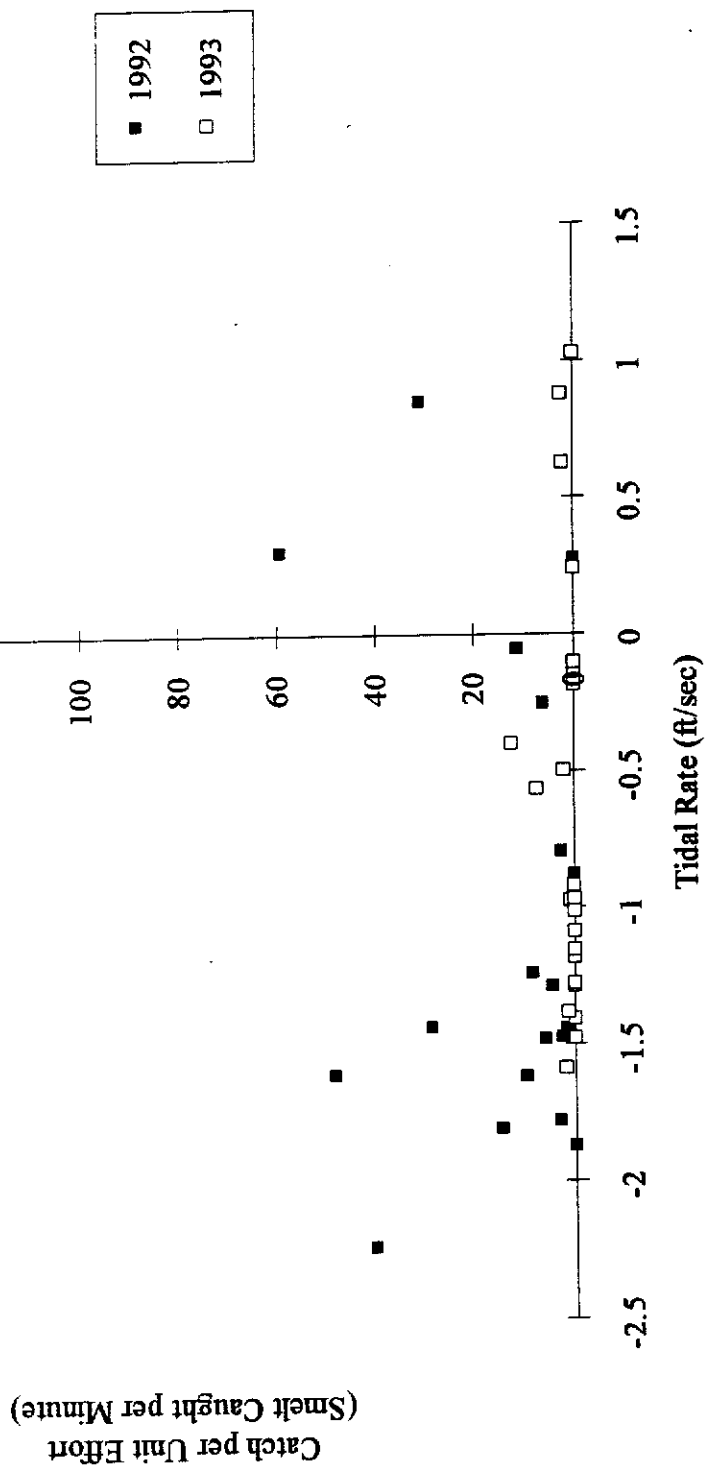
APPENDIX AI. Spawning Substrates of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AJ.



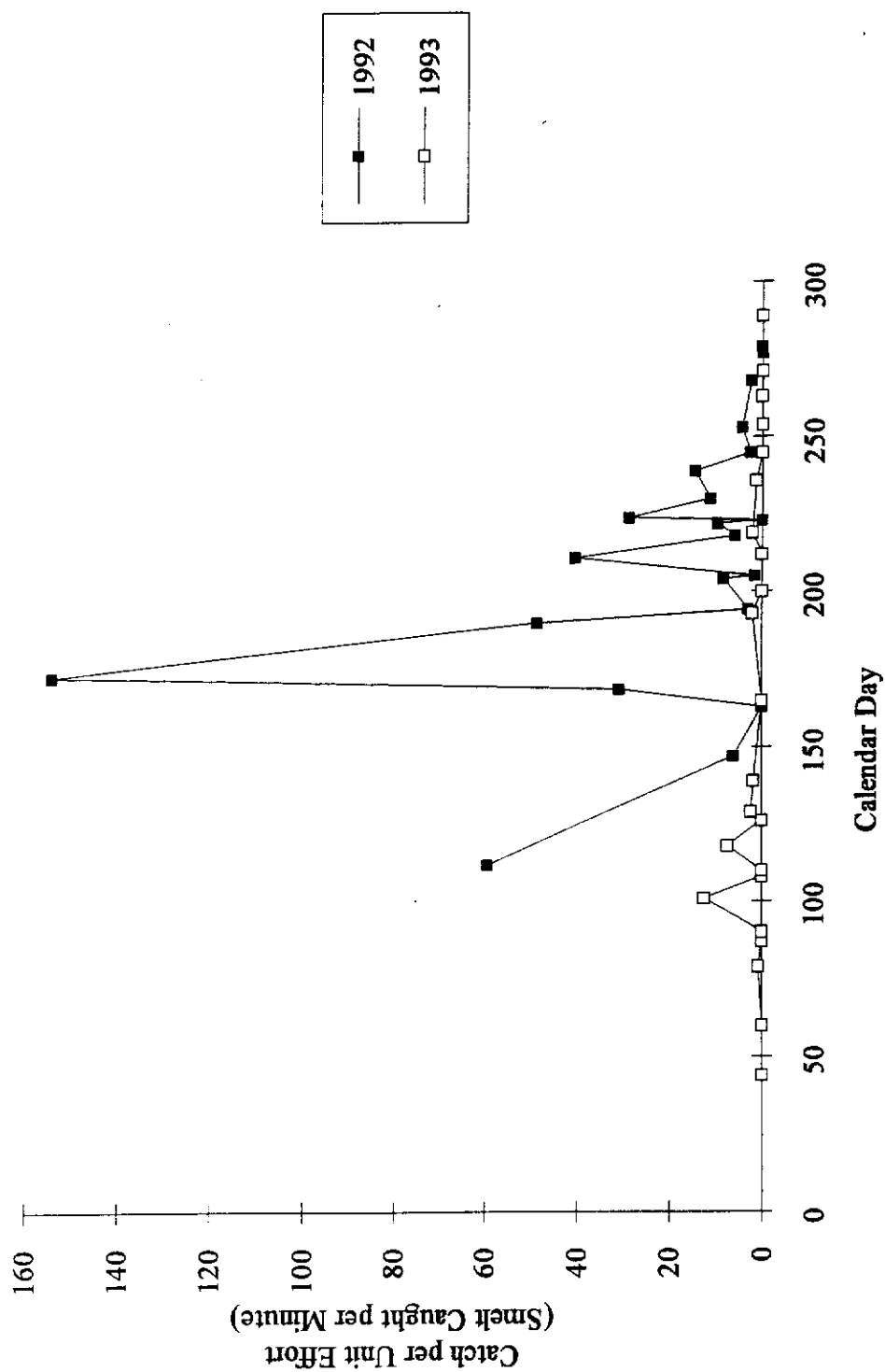
APPENDIX AJ. Catch per Unit Effort as a Function of Tidal Height of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AK.



APPENDIX AK. Catch per Unit Effort as a Function of Tidal Rate of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.

APPENDIX AL.



APPENDIX AL. Catch per Unit Efforts of Night Smelt, *Spirinchus starksi*, Sampled at Freshwater Beach, California in 1992 and 1993.