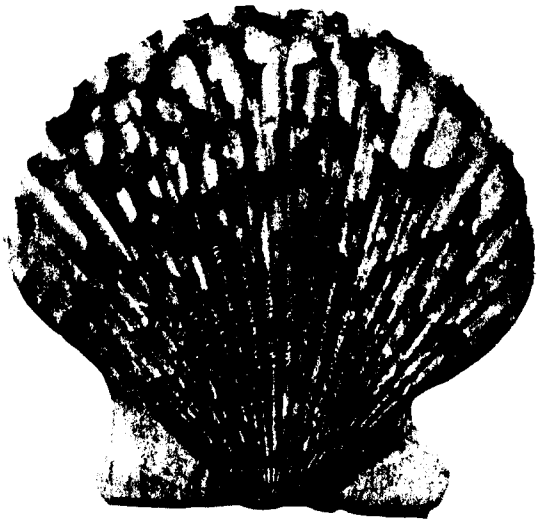
The Speckled Scallop, *Argopecten circularis*, in Aqua Hedionda Lagoon, San Diego County, California



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CALIFORNIA DEPARTMENT OF FISH AND GAME
MARINE RESOURCES
TECHNICAL REPORT NO. 57

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State of California
The Resources Agency
Department of Fish and Game

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ABSTRACT

Speckled scallops, *Argopecten circularis* (Sowerby, 1835), were sampled at Agua Hedionda Lagoon, Carlsbad, San Diego County from March 1984 to October 1986, to obtain basic life history data. Monthly samples of scallops were collected, measured, and released to obtain length frequency data for estimates of growth, life span, and spawning period. Subsamples of scallops were collected for determination of gonadal-somatic and adductor muscle-somatic indices.

In 1984 large concentrations of speckled scallops were found on the sand-silt bottom of the lagoon, closely associated with eelgrass, *Zostra marina*. During the course of the study the numbers of scallops declined, until their virtual disappearance at the end of 1986. Monthly length frequency plots from 24,375 scallop measurements indicate that this is a rapidly growing species with a short life span. Gonadal- and adductor muscle-somatic indices from subsamples of 1,714 scallops indicate first spawning at age one and a relationship between temperature and spawning.

Based on this study management recommendations are made for the speckled scallop.

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ACKNOWLEDGMENTS

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INTRODUCTION

The speckled scallop, *Argopecten circularis* (Sowerby, 1835) inhabits shallow bays and sloughs, particularly where there are eelgrass beds, and calm offshore areas along southern California. Occasionally it is found as far north as Elkhorn Slough, Monterey County, California (McLean 1978, Haderlie and Abbott 1980). In addition to Agua Hedionda Lagoon, populations of speckled scallops were found in the San Diego River flood control channel and Mission Bay. The next known southern concentration of *A. circularis* occurs in Laguna San Ignacio at Ballenas Bay, Baja California, Mexico (Debra Dexter, San Diego State University, pers. comm.). Speckled scallops also occur in the Gulf of California (Coan 1968).

A commercial speckled scallop fishery existed in California during the early part of this century (Weymouth 1920). However, few details are available, perhaps indicating that it was a small, localized fishery. By the 1950s, this scallop had disappeared. "Only one specimen...has been found on the California coast during the past seven years..." (J. Fitch in Grau 1959, page 103). The speckled scallop was subsequently protected from all harvesting by the Fish and Game Commission because the "formerly abundant, bay scallops in southern California bays have become very scarce. Only complete protection for a few years will bring them back." (Minutes of the California Fish and Game Commission, January 8, 1954).

For years, the speckled scallop was forgotten. Then in 1984, California Department of Fish and Game (DFG) wardens reported that speckled scallops were being harvested illegally from Agua Hedionda Lagoon. DFG biologists confirmed the presence of large numbers of speckled scallops at several locations in the outer lagoon and throughout the lagoon complex.

Few facts concerning the biology of the speckled scallop were found in the literature. Thus, we initiated a monthly sampling program at Agua Hedionda Lagoon with the goal of learning about the biology of this scallop, emphasizing aspects that would allow us to make recommendations regarding its status.

Various generic and specific names have been applied to the speckled scallop. In recent times, the name *Argopecten aequisulcatus* (Carpenter, 1864) has been used for the scallop, with a range of Elkhorn Slough to Bahia San Quintin, Baja California, Mexico (McLean 1978, Haderlie and Abbott 1980). Other authors consider *A. aequisulcatus* to be a northern subpopulation of *A. circularis*, with a range of Elkhorn Slough to Paita, Peru (Grau 1959). Grau details the taxonomy of this species. Taxonomic problems remain, however, and the name *A. circularis* will likely be set aside (T. R. Waller, National Museum of Natural History, Washington, D. C., pers. comm.). We have chosen to follow Bernard (1983) in his usage of *A. circularis* (Sowerby, 1835).

METHODS

The study site is located in the outer (western) third of Agua Hedionda Lagoon at Carlsbad, San Diego County, California , Lat 33° 08.7' N, Long 117° 20.2' W (Figure 1). This site includes a broad expanse of sand inshore, a stand of eelgrass, *Zostera marina*, to a depth of about 3 m, and then a moderate drop-off to about 8 m. The study site also formed the northern boundary of a channel which leads from the sea to the middle and inner lagoons. Bradshaw et al. (1976) provides a comprehensive description of Agua Hedionda Lagoon.

Monthly sampling surveys began in March 1984, and continued through October 1986. In addition, from February through August 1985, weekly samples were taken for gonadal-somatic index determinations. No samples were obtained during November 1985 because of poor weather. In 1986, it was difficult to collect the desired number of scallops because the population throughout the lagoon, and in other known southern California sites, was declining. We ended the study in October.

Scuba divers collected scallops by hand, and samples were stratified by a rough indication of depth. Shallow samples were taken from within the eelgrass, and deep samples came from areas below the margin of the eelgrass and out into the channel. All scallops were brought to the shore in net bags, and kept immersed in seawater. The length (Figure 2) of each scallop was measured to the nearest mm with vernier calipers, and a subsample of 10 scallops from each of the 10 mm groups, down to a size of 30 or 40 mm, was retained for laboratory analysis. The remaining scallops were returned alive to the lagoon.

All subsamples were processed on the day of collection or the following day. Beginning in June 1984, subsamples were transported to the laboratory in aerated seawater to maintain the scallops alive. Subsample analyses included measurement of length, height, total weight, visceral (total soft tissue) weight, gonad weight, meat (adductor muscle) weight, and a subjective indication of gonad color/condition. From February to August 1985, weekly subsamples were collected and brought to the laboratory for analysis.

Monthly length-frequency distributions (Figures 3, 4, and 5) were constructed from measurements of all scallops sampled, regardless of whether they came from shallow or deep areas. Cohort size limits were determined by inspecting the length-frequency distributions. Throughout much of the year it was clear which modal group represented a particular cohort, but when two cohorts merged a subjective decision was made as to the size limit for each cohort. The average size for each month was calculated for scallops in shallow, deep, and combined collections (Tables 1, 2, 3, and 4). Graphs of shallow, deep and combined growth also were constructed (Figure 6A, 6B). The average size of scallops in the deeper areas was slightly larger than that for the shallow areas throughout the year. Average lengths of all scallops

combined were used throughout this study, and a second degree equation adequately described the trend of the average monthly size. Cohort size ranges were used to assign individual scallops in laboratory analysis samples to a cohort.

For individual scallops gonadal-somatic (GSI) and adductor muscle-somatic (MSI) indices were calculated as a percentage of the gonad weight and adductor muscle weight, respectively, of the total soft tissue weight. An average index was then calculated for each subsample. A curve (Figures 7B, 7C) was fitted to the data using a stepwise polynomial regression procedure. A fifth degree equation provided the best fit for both indices.

Average daily temperatures (Figure 7A) were measured at the intake of the Encina Power generating station located at the south end of the outer lagoon (Figure 1), and were provided by the San Diego Gas and Electric Company (SDGE). Heated discharge water is not returned to the lagoon. Average ocean temperatures were provided by Scripps Institution of Oceanography (SIO). SDGE water temperatures were converted to degrees C.

RESULTS

In Agua Hedionda Lagoon, speckled scallops were found on sandy and silty sand substratum, generally near stands of eelgrass. The densest scallop concentrations occurred in and adjacent to the eelgrass. Scallop densities declined with distance from the eelgrass and with depth. Few scallops were found on the shoreward margin of the eelgrass, as this area is periodically exposed during very low tides. In deeper water, below the edge of the eelgrass, the largest scallops were found.

In 1984 there was a dense population of speckled scallops at the study site and at other locations in the lagoon. A few random transects yielded as many as 646 scallops per m^2, ranging in size from 15 to 64 mm. Time did not allow us to continue density measurements during this study.

Speckled scallops move by expelling water between their valves. In this manner, they can move a meter or more up into the water column and several meters horizontally. These movements, random in direction, can be provoked by the approach of a diver, by pounding on the substrate, or by placing a predatory snail or sea star nearby. Apparently such movement helps them to escape slower predators, and may account for the presence of scallops outside the confines of eelgrass beds.

Generally, smaller scallops were attached to the substrate by byssal threads. In the summer of 1984, large numbers of newly settled scallops (2-20 mm) were observed on stems and blades of eelgrass, aluminum cans, plastic sheeting, large live scallops, and shells.

The scallop population persisted throughout 1985, but in 1986 a general decline in numbers occurred. In 1985 dredging of the

outer lagoon (October 20 to November 20) cleared the deeper areas of scallops. Although the study area was not directly affected, indirect effects cannot be eliminated. The decline was also observed in other parts of the lagoon, and in Mission Bay and the San Diego River flood control channel. By the fall of 1986, when the study concluded, few scallops could be found at the study site.

Length-Frequency Distributions

A total of 24,375 scallops was measured (Figure 2), from March 1984, through October 1986, and monthly length-frequency distributions were constructed (Figures 3, 4, and 5).

The progression of the modes in the length-frequency distributions (Figures 3, 4, and 5) is indicative of a rapidly growing species. While the overall annual pattern of the distributions is similar, certain important details varied from year to year.

The 1984 length-frequency distribution (Figure 3) displays the 1983 cohort, which grew to an average size of 52.6 mm by March (Table 1). The 1983 cohort persisted through the year, though the numbers of scallops declined. By the end of December 1984, the average size had increased to 65.9 mm, reflecting a reduction in growth rate with age.

In May 1984 the first newly settled scallops appeared (average size = 11.1 mm, Table 2), indicating that some spawning may have occurred in April. Settlement continued into September. Thus, in 1984, spawning may have taken place over a 6 month period.

The length-frequencies for 1985 (Figure 4) continued to show traces of the 1983 cohort, though greatly reduced in numbers. By the beginning of 1986, the 1983 cohort had disappeared. The 1984 cohort attained an average size of 38.5 mm in January 1985 (Table 2) and continued to be strong through the year.

Newly settled scallops appeared in August 1985 (Figure 4) and exhibited a bimodal settlement pattern. The size range of the young scallops indicated that spawning may have occurred during June and July. Some settling occurred in September. Thus spawning may have occurred over a 4 month period in 1985. By the end of December 1985 the 1984 cohort had attained a size of 53.5 mm (Table 2), while the 1985 cohort averaged 31.1 mm (Table 3).

The 1986 length-frequencies (Figure 5) continued to display the very strong and persistent 1984 cohort, with the 1985 cohort merging. Newly settled scallops appeared in June 1986. There is some evidence of a bimodal settlement pattern in July. Actual spawning may have occurred in May. These scallops grew quickly so that by October, the end of the study, they averaged 37.3 mm (Table 4).

Life Span

The life span of speckled scallops can be estimated from the length-frequencies. Though the beginning of the 1983 cohort was not observed, we can see that it was strong and persisted for 12 months (March 1984-March 1985). Adding January and February 1984, and 6 months of 1983 yields an age of 20 months for the 1983 cohort. The 1984 cohort was observed for 24 months (May 1984-April 1986), while the life span of the 1985 cohort was about 14 months.

In the fall, older scallops showed signs of senescence. The gonads (post-spawning) were flaccid, the entire visceral mass was watery, and the scallops had a tendency to gape when disturbed. Many scallops were seen gaping with deteriorating tissue. It appeared that a significant number of scallops died in this manner. Smaller scallops of the newly settled cohort did not exhibit any of these symptoms.

Reproduction

The speckled scallop is a functional hermaphrodite. The gonad is a curved, conical structure containing the ovarian tissues distally and the testicular tissues basally.

Gonad color is closely associated with maturation. Very small scallops have clear or tan, fluid filled gonads. As size increases, the ovarian tissues become orange, while the testicular tissues become tan. After spawning, the gonads are colorless flaccid sacs.

Gonadal-Somatic Index

A total of 1,714 scallops sampled during length-frequency measurements were used to determine GSI. Gonadal maturation was determined by using a graph of monthly GSI, expressed as a percent (Table 5) of each cohort plotted against time (Figure 7B). The relative increase in weight of the gonads was used to indicate maturity. The GSI of the 1983-1985 cohorts peaked during June 1984, June 1985, and May 1986, respectively, indicating spawning. A comparison of these peaks with the initial occurrence of newly settled scallops in the length-frequency distributions (Figures 3, 4, and 5) established the time of spawning, and demonstrated that the GSI is useful for the determination of spawning time.

The average GSI varied for each cohort. The 1983 cohort attained an average maximum GSI of just under 8%, while the following two cohorts attained 16 and 13%, respectively (Figure 7B).

Adductor Muscle-Somatic Index

The speckled scallop is relatively small, and yields a small adductor muscle or "meat". The MSI was monitored throughout the year to assist in the determination of the most appropriate time

for any future harvest.

A total of 1,714 scallops sampled during length-frequency measurements was used to determine MSI. A graph of MSI through time reveals that muscle weight increases proportionally to the growth in total weight during the first half of life (Figure 7C, Table 6), then declines. A comparison of the MSI with the GSI (Figures 7B,7C) reveals that the MSI peaks in advance of the GSI, reflecting the diversion of energy from growth in size to the development of reproductive processes. There is a post spawning increase in the MSI for the surviving adults.

Length-Height Relationship

Shell height is closely correlated ($r = 0.983$, $n = 1343$) with shell length measurements (Figure 2). Formulae for converting one measurement to the other are:

$$l = -2.791 + 1.111\ h$$

and

$$h = 4.298 + 0.896\ l$$

Where l = length and h = height.

Temperature

The average monthly water temperatures recorded by SDGE were similar to those measured at SIO (Figure 7A), reflecting the ocean influence on lagoon waters. Several trends are apparent in year-to-year temperature comparisons, including declines in maximum average, maximum range, and minimum range. These cooling trends represent the waning of the influence of the 1982-84 El Niño. Additionally, the time of maximum average temperatures varied, occurring during August and September of 1984, August of 1985, and July of 1986.

DISCUSSION

The life history of speckled scallops in Agua Hedionda Lagoon is similar to that of the bay scallop, *A. irradians*, found along the Atlantic coast. Gutsell (1931), Belding (undated), and Spitsbergen (1979) detail life history information on the bay scallop. Bay scallop information is useful in the interpretation of data collected in Agua Hedionda Lagoon.

Habitat

Both the speckled and bay scallops are found in shallow water bays and estuaries closely associated with stands of eelgrass. Both scallops may be found occasionally in atypical habitats, such as muddy coastal areas or the open coast (Gutsell 1931). Speckled scallops not closely associated with eelgrass have been

taken on low offshore reefs and from power generation forebay screens (Donald Cadien, MBC Applied Environmental Sciences, Costa Mesa, CA, pers. comm.).

The presence of eelgrass does not assure the occurrence of scallops. Eelgrass habitat at two locations in San Diego Bay was inspected but scallops were not observed. Scallop distribution may depend upon several factors. Belding (undated) noted that sets of scallops varied from area to area, and that all suitable areas were not utilized every year.

Reproduction

Speckled and bay scallops spawn approximately one year following settlement, and both species have a spawning period of several months. The bay scallop is considered a fall spawner, but spawning may occur from mid-summer to as late as January. The peak in the monthly plot of the GSI was useful in describing the time of spawning, and agreed closely with the appearance of newly settled scallops in the length-frequency histograms (Figure 3, 4 and 5). At Agua Hedionda Lagoon, the speckled scallop spawned from May to September 1984 (Figure 3), with the GSI peaking in June; during June through September 1985 (Figure 4), with the GSI peaking in June; and in May 1986 (Figure 5), with the GSI peaking in May. Spawning generally occurred during a period of increasing water temperature.

GSI appeared to be inversely related to the strength of the resulting year class. In 1984, GSI values peaked at 8% and resulted in a persistent, very strong cohort. In 1985 and 1986, the GSI peaked at 16 and 13%, respectively, and yielded progressively weaker cohorts. Comparison of the fitted growth curves (Figures 8A, 8B, 8C) with the fitted GSI curves suggests an explanation for this relationship. The growth curve extrapolation to zero occurs before peaking of the GSI in 1984 (Figure 8A). In the following two years, this point occurs after the GSI curve peaks (Figure 8B, 8C). Assuming that the extrapolations similarly reflect growth for each year, in 1984 spawning began well before the GSI peaked and continued well afterwards. It may be that an extended period of suitable conditions allowed prolonged spawning and produced a strong cohort. In the following years, spawning conditions may have come later and been of shorter duration, resulting in the observed buildup of the GSI and a weaker cohort. In 1986, the conditions were so shortened, that when spawning finally occurred the cohort failed.

The bimodal length-frequency distributions of the newly set speckled scallops (Figures 3, 4, and 5), and the early points in the GSI plots (Figure 7B), indicate two peaks in spawning activity. Each peak may represent a separation of spawning by sex, as occurs in bay scallops (Belding 1931, Loosanoff and Davis 1963). Separate release of eggs and sperm would prevent self-fertilization and prolong the spawning period.

Growth

The comparisons of the growth curves, length-frequencies and GSI indicate that the speckled scallop has a short pelagic life. Speckled scallops attain 40 mm by the end of the year in which they settle, and average 60 mm when a year old and getting ready to spawn. At an age of about 20 months they exhibit some post-spawning mortality.

The life span of the speckled scallop may extend beyond 2 years. At the lagoon, the 1984 cohort attained an age of 28 months, and some individuals of the previous cohort could also have reached 24 months (Figure 3 and 4). The 1985 cohort attained an age of 14 months. Some factors which would cause variation in the life span include the time of spawning, and the growth rate. Both of these factors are at least partly dependent upon temperature.

Grau (1959) reported a speckled scallop with a length of 106 mm. The largest live scallop observed in Agua Hedionda Lagoon was 93 mm in length, and most did not exceed 80 mm.

We found a reciprocal relationship between GSI and MSI, the latter declining as the former increased. The MSI attained a maximum before the GSI (Figure 7B, 7C). This phenomenon is likely the result of the shift from overall growth in size to growth in reproductive potential.

The graphs of the MSI for the 1984 cohort, which persisted well into 1986, show an increase in the MSI after spawning, reflecting the recovery of the surviving scallops.

Speckled scallop natural history closely corresponds with that of the bay scallop. The bay scallop has a pelagic life of about 6 to 8 days (Tettelbach and Rhodes 1981) and attain a size of about 75 mm in an optimal year. They also exhibit some post-spawning mortality at an age of about 20 months. The life span of the bay scallop is 20 to 26 months, but very few live two years (Belding 1931). Spitsbergen (1979) showed a reciprocal relationship between GSI and MSI in bay scallops.

Temperature Influences

The effect of the local ambient seawater temperature is an important factor controlling speckled scallops at Agua Hedionda Lagoon; and bay scallops (Sastry 1966, Tettelbach and Rhodes 1981). Fortunately daily temperatures were available throughout the study (Figure 7A).

Several trends in the monthly lagoon temperature are apparent. The maximum annual temperature occurred in September 1984 and 1985, and in July 1986 when it declined. The highest minimum annual temperature occurred in August 1984 and 1985, and July 1986, declining throughout the study. Such variations are reflective of a return to cooler seawater conditions following the El Niño.

Estimated spawning periods from the length-frequency plots (Figure 3, 4, and 5), specifically the appearance of newly settled scallops, are May-September 1984, June-September 1985, and May 1986. Comparing these ranges with the temperature curves, the average lagoon temperature at the beginning of each estimated spawning period was ≈18°C, ≈18.5°C, and ≈18°C, for these years respectively.

GSI (Figure 7B) peaked in June 1984 and 1986, and May 1985. The values fell within the estimated spawning periods in each year. These peaks occurred during periods of increasing average water temperature. Data suggest that spawning was cued on some minimum temperature, perhaps 18-19°C. Prolonged higher temperatures after spawning contributed to successful settlement and survival.

Temperature control of spawning and post-spawned scallop populations would not be unexpected in a species living near its zoogeographical boundary, and would explain the ephemeral nature of this scallop in southern California.

The Peruvian scallop *A. purpuratus*, population expanded rapidly during the 1982-83 El Niño (Wolff 1984). This was attributed to the elevated water temperature, which exhibited a 10°C positive anomaly; and to other oceanographic and meteorological factors, which tend to retain larvae in the area of the adults. Spawning in this scallop, which is probably of tropical origin, was intensified by the elevated water temperatures. Larvae developed more rapidly in the warmer water, leading to decreased predation and drift loss of the larvae, and thus to increased survival. We hypothesize a similar set of circumstances for an increase in speckled scallops in southern California, in response to warm water intrusion.

Since the closest population of speckled scallops south of southern California is far down the Baja California peninsula, the question of how the larvae reach southern California waters during warm water years remains to be answered. It seems unlikely that a pelagic larval stage of short duration could be transported the 300 miles northward to southern California and remain viable.

From the data we collected at Agua Hedionda Lagoon, and comparisons made with the similar bay scallop, it is apparent that a large population of speckled scallops in southern California is ephemeral, depending on the occurrence of warmer than average water temperatures. Such a condition would be expected in a population occurring near its range extremity. Consequently, an uncritical extension of our data to populations further south should be made with care.

Mariculture Possibilities

Several features of the life history of speckled scallop indicate that this shellfish would have mariculture possibilities. It is fast growing, attaining 50 to 60 mm, average, in a year. Optimum

meat size occurs at a little less than a year, so some reproductive stock would have to be kept aside or only post-spawning individuals could be harvested, as on the Atlantic coast. Preliminary investigations of laboratory spawning are encouraging (Art Hazeltine, Granite Canyon Marine Culture Laboratory, Monterey, CA, pers. comm.). In California, a source of warm water, such as a cooling water discharge from a power generating station, would be required to initiate spawning in most years.

Since this species is a native, though sporadic, inhabitant of California, few problems, such as the introduction of exotic parasites or diseases would be anticipated in establishing a mariculture operation.

A ready market exists for scallops, and since the speckled scallop is similar to the highly desirable bay scallop of the east coast, much of the technology used in the harvest and mariculture of the bay scallop would be applicable here.

CONCLUSIONS

1. Speckled scallops are generally inhabitants of protected shallow water bays and estuaries, especially where eelgrass is found.

2. The occurrence of this species in California is ephemeral, and appears to be strongly related to episodes of increased ocean temperatures.

3. Scallops attained a length of about 60 mm during the first year.

4. The life span is less than two years.

5. Spawning occurs at age one.

6. The peak MSI occurs before first spawning.

RECOMMENDATIONS

1. Present protection and prohibitions from any take of the speckled scallop, commercial and recreational, should be maintained.

2. Areas recently, or presently supporting populations of speckled scallops should be identified and protected. Areas in northern Baja California which might support scallop populations, and provide a source of larvae to southern California during warm water years, should be identified as well.

3. Areas which have suitable speckled scallop habitat, especially eelgrass, should be identified and protected.

4. The life history parameters of this species make it a potential candidate for mariculture.

5. Non-native species of the genus *Argopecten* should not be introduced into California marine waters. Introduced diseases, parasites, and/or competators could be detrimental to *A. circularis*.

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FIGURE 1. Map of Agua Hedionda Lagoon, Carlsbad, San Diego County, California, showing study area.

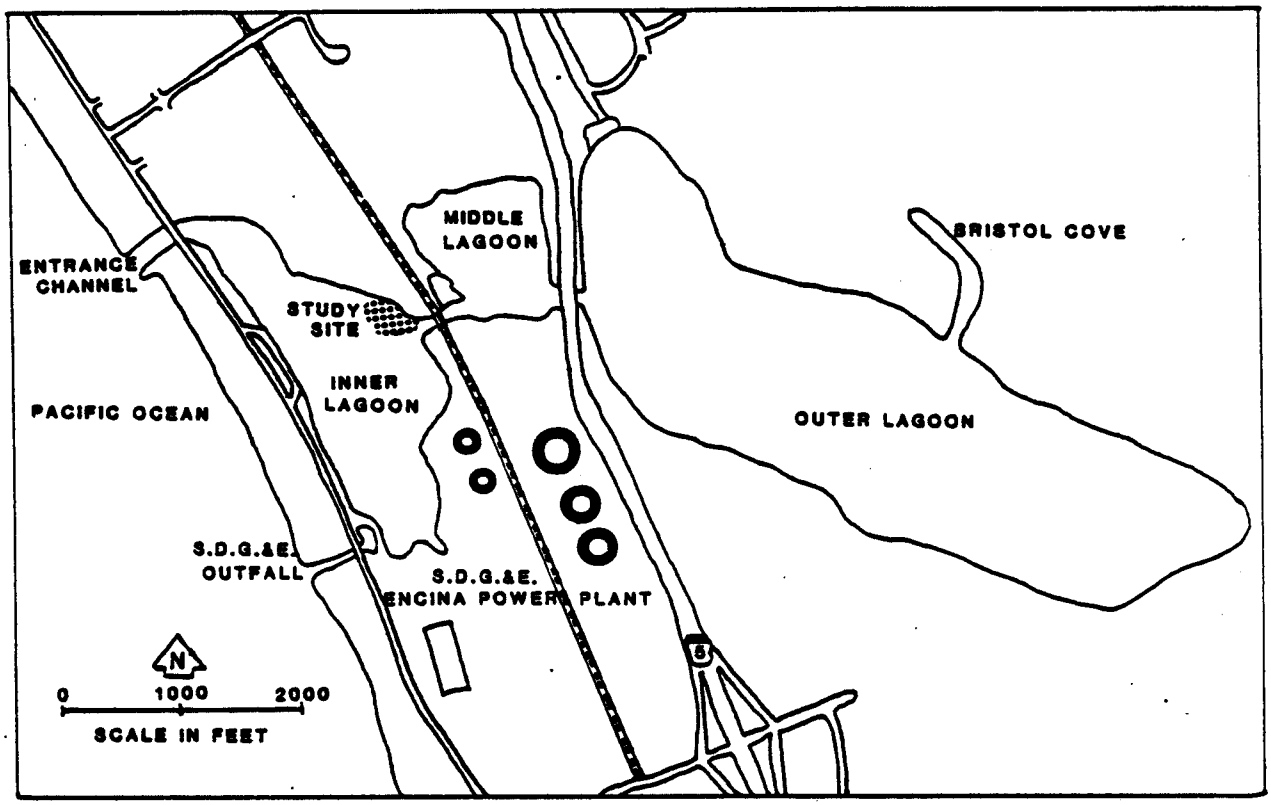


FIGURE 2. Speckled scallop, *Argopecten circularis*, showing dimensions used in this study.

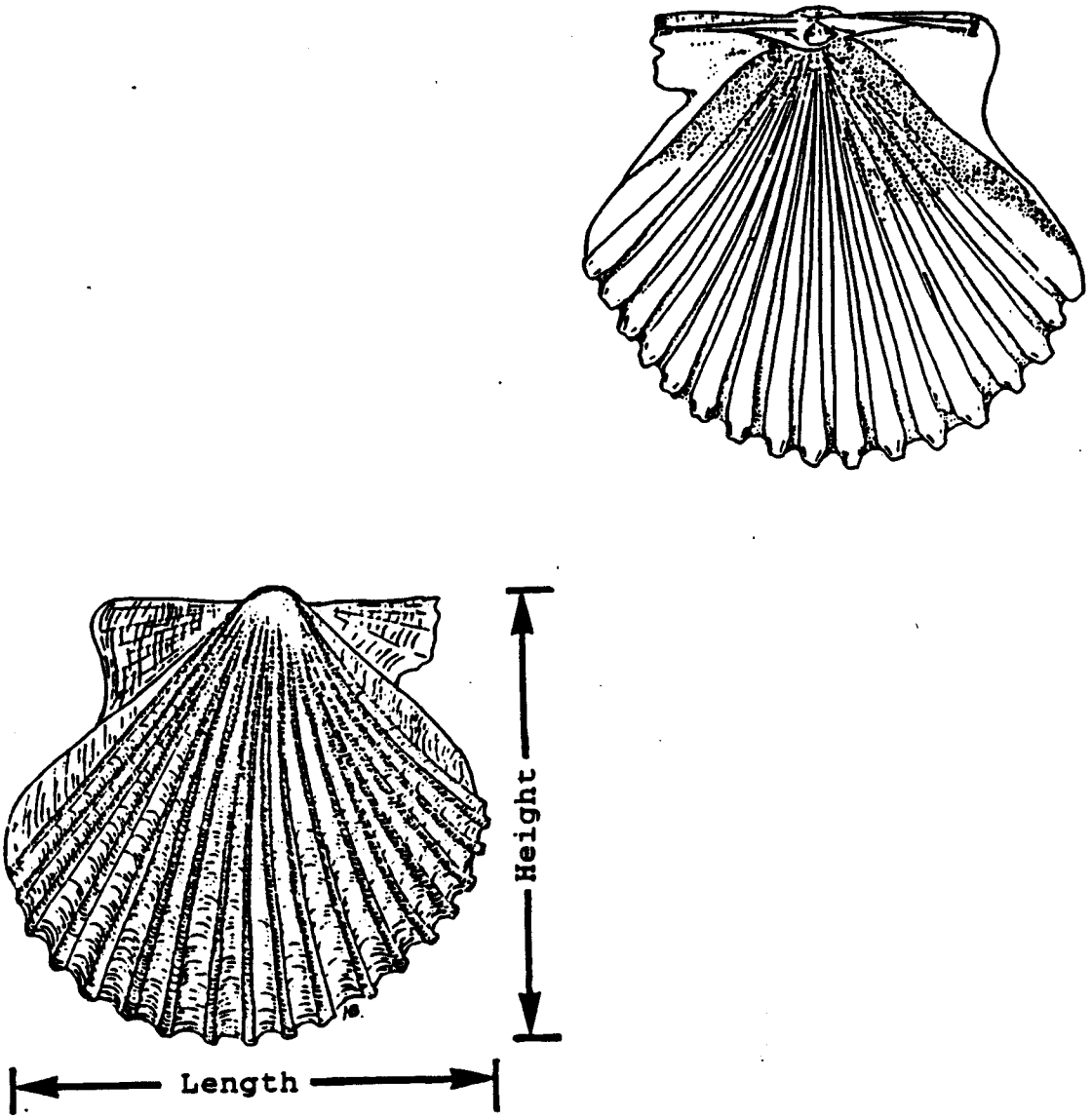


FIGURE 3. Length-Frequency distribution of speckled scallops in Agua Hedionda Lagoon, March-December 1984.

Figure 3.

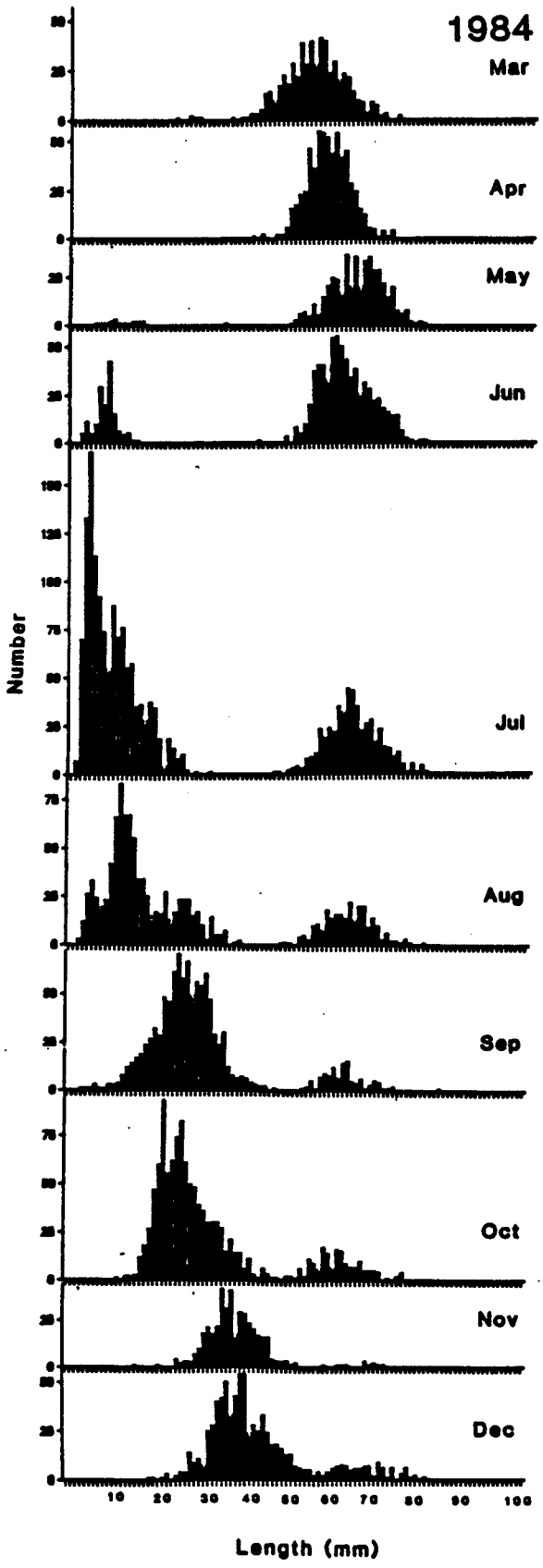

1984
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Number
10
20
30
40
50
60
70
80
90
100
Length (mm)

FIGURE 4. Length-Frequency distribution of speckled scallop in Agua Hedionda Lagoon, January-December 1985.

Figure 4.

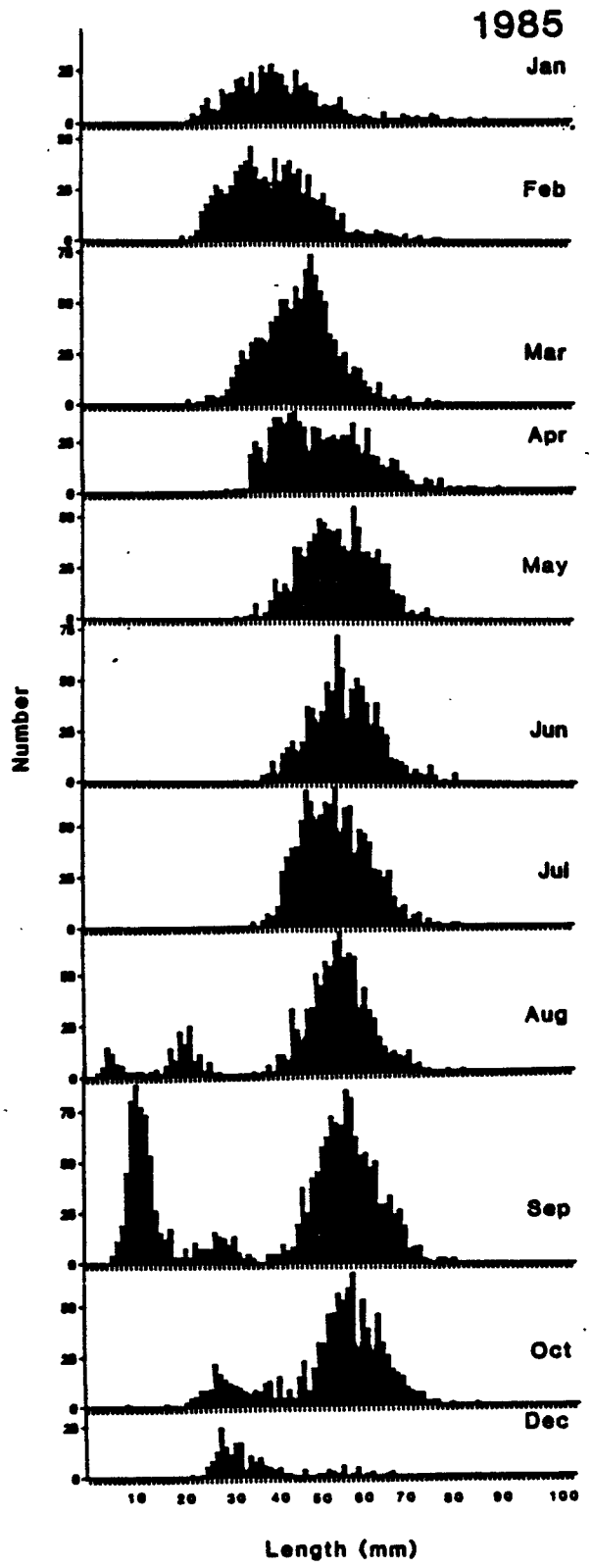

1985
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Dec
Number
10
20
30
40
50
60
70
80
90
100
Length (mm)

FIGURE 5. Length-Frequency distribution of speckled scallop in Agua Hedionda Lagoon, March-December 1986.

Figure 5.

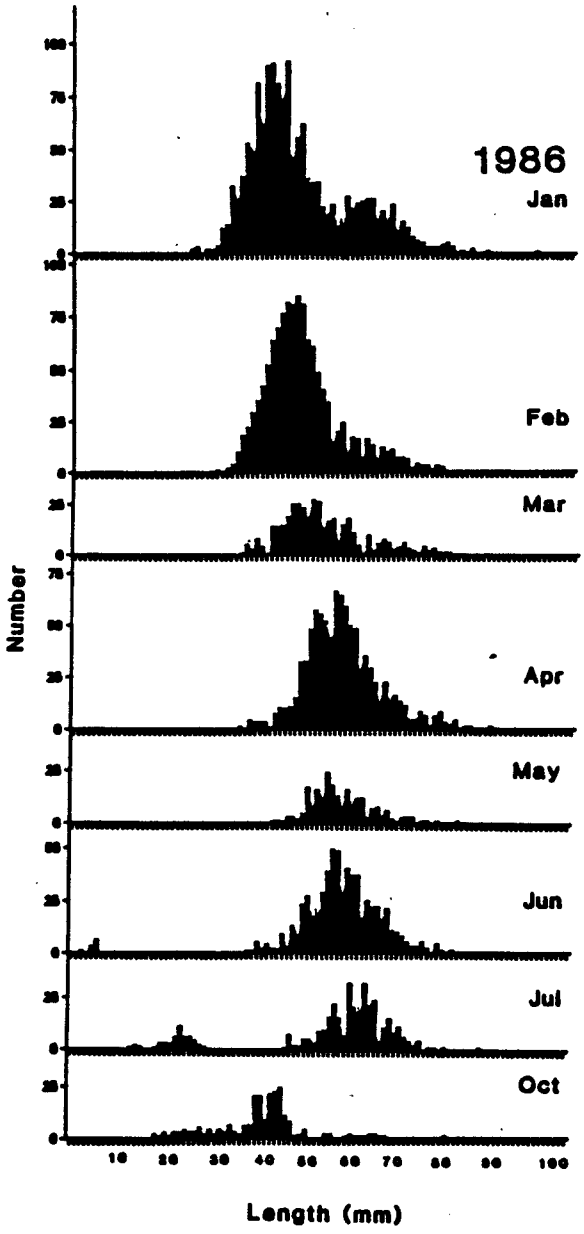


FIGURE 6A. Average monthly size of speckled scallops collected in shallow and deep samples at Agua Hedionda Lagoon for years 1984-1986.

FIGURE 6B. Combined average monthly size of speckled scallops collected at Agua Hedionda Lagoon for years 1984-1986.

Figure 6.

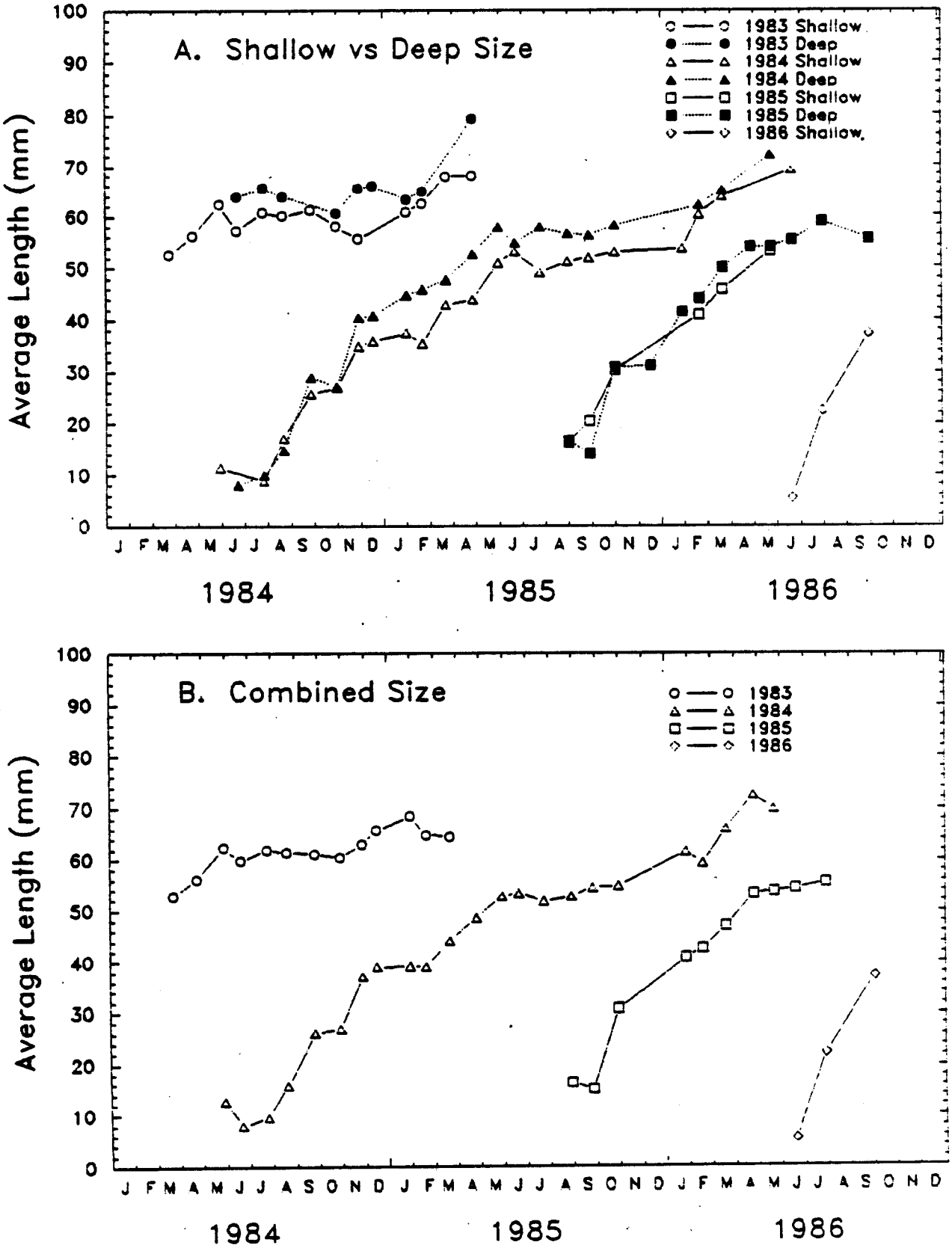

A. Shallow vs Deep Size
1983 Shallow
1983 Deep
1984 Shallow
1984 Deep
1985 Shallow
1985 Deep
1986 Shallow
Average Length (mm)
0
10
20
30
40
50
60
70
80
90
100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986
B. Combined Size
1983
1984
1985
1986
Average Length (mm)
0
10
20
30
40
50
60
70
80
90
100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986

FIGURE 7A. Average monthly sea water temperature recorded at the Scripps Institution of Oceanography and Agua Hedionda Lagoon, with monthly maximum and minimum ranges at the latter Site. 1984-1986.

FIGURE 7B. Fitted curves of average monthly gonadal-somatic indices for the speckled scallop at Agua Hedionda Lagoon, 1983, 1984, and 1985 cohorts.

FIGURE 7C. Fitted curves of average monthly aductor muscle-somatic indices for the speckled scallop at Agua Hedionda Lagoon, 1983, 1984, and 1985 cohorts.

Figure 7.

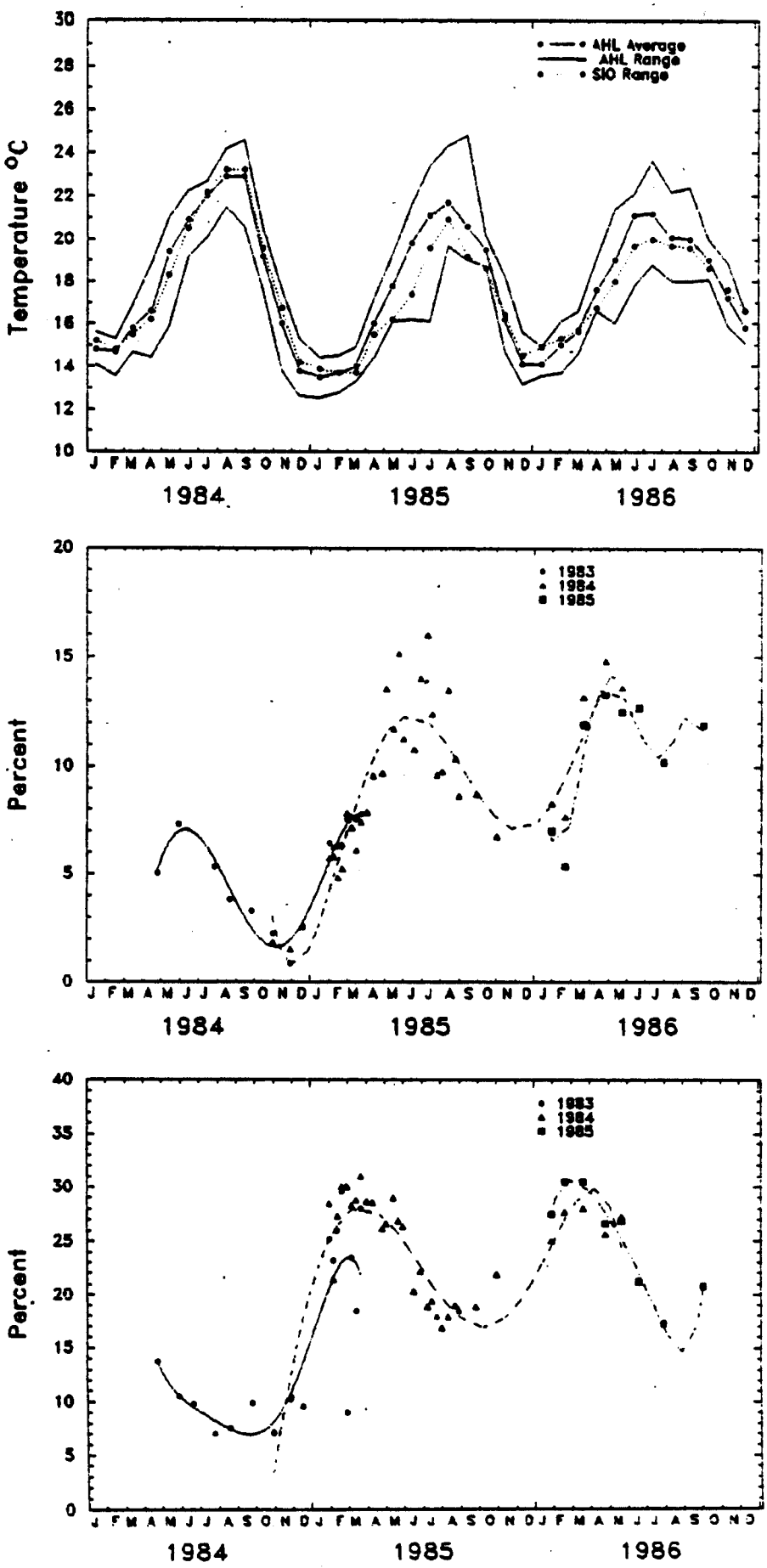
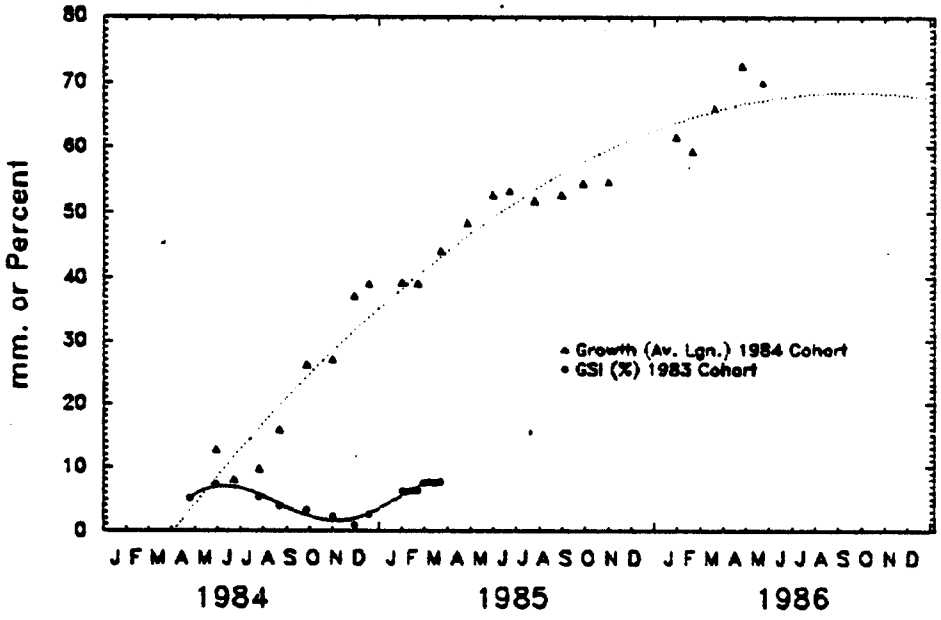

AHL Average
AHL Range
SIO Range
Temperature °C
30
28
26
24
22
20
18
16
14
12
10
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986
1983
1984
1985
Percent
20
15
10
5
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986
1983
1984
1985
Percent
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986

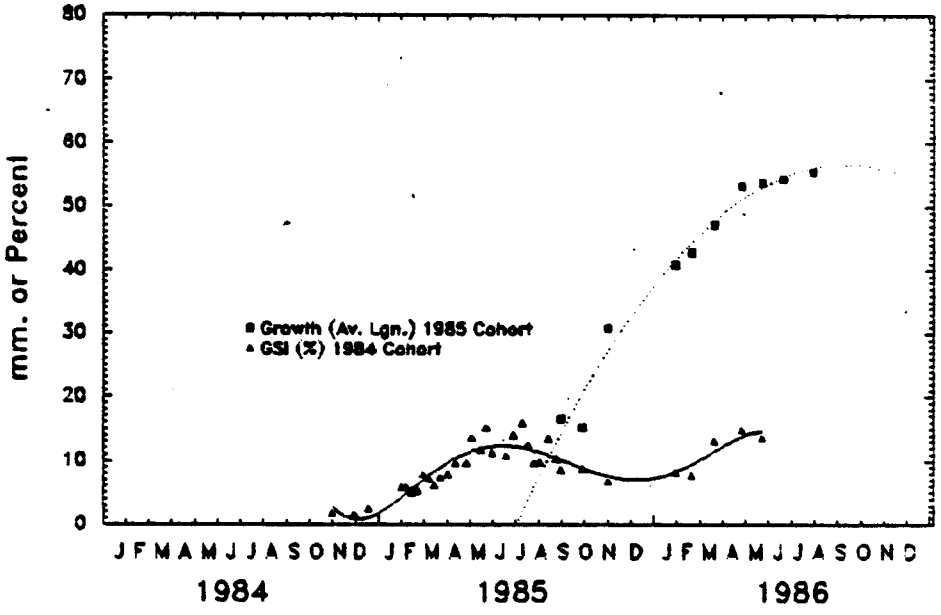
FIGURE 8A. Fitted curves of 1983 cohort average gonadal-somatic indices and the 1984 average monthly size for the speckled scallop at Agua Hedionda Lagoon.

FIGURE 8B. Fitted curves of 1984 cohort average gonadal-somatic indices and the 1985 average monthly size for the speckled scallop at Agua Hedionda Lagoon.

FIGURE 8C. Fitted curves of 1984 cohort average gonadal-somatic indices and the 1985 average monthly size for the speckled scallop at Agua Hedionda Lagoon.

Figure 8.


mm. or Percent
Growth (Av. Lgn.) 1984 Cohort
GSI (%) 1983 Cohort
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986


mm. or Percent
Growth (Av. Lgn.) 1985 Cohort
GSI (%) 1984 Cohort
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986

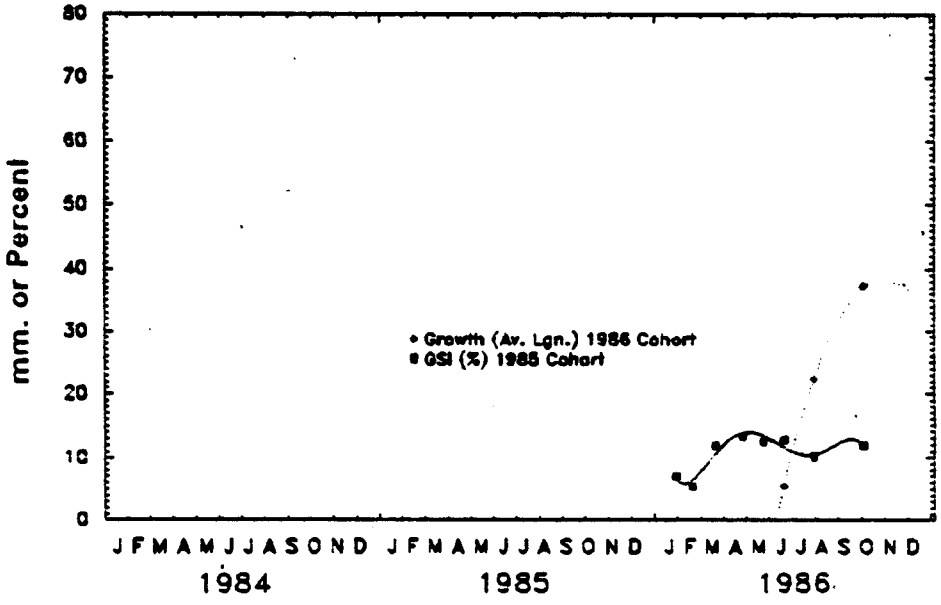

mm. or Percent
Growth (Av. Lgn.) 1986 Cohort
GSI (%) 1985 Cohort
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1984
1985
1986

Table 1. Average Monthly Size of the 1983 Cohort of Speckled Scallops at Agua Hedionda Lagoon for Shallow and Deep Collections. Days Refers to the Number of Days Since January 1, 1984. Av. Size is Mean Size, n is the Number of Scallops Measured.

	Days	Shallow Av. size	n	Deep Av. size	n	Combined Av. size
Jan 1984		-	-	-	-	-
Feb		-	-	-	-	-
Mar	84	52.6	553	-	-	52.6
Apr	115	56.1	628	-	-	56.1
May	150	62.3	471	-	-	62.3
Jun	173	57.2	412	63.9	262	59.8
Jul	207	60.7	373	65.6	127	62.0
Aug	233	60.0	157	63.8	93	61.4
Sep	269	61.2	114	-	-	61.1
Oct	303	58.0	10	60.6	153	60.5
Nov	332	55.5	2	65.5	11	63.9
Dec	351	-	-	65.9	102	65.9
Jan 1985	395	60.7	19	63.2	28	62.2
Feb	416	62.4	5	64.8	24	64.8
Mar	447	67.8	4	-	-	67.8
Apr	482	67.9	18	79.2	5	70.4
May	-	-	-	-	-	-

Table 2. Average Monthly Size of the 1984 Cohort of Speckled Scallops at Agua Hedionda Lagoon for Shallow and Deep Collections. Days Refers to the Number of Days Since January 1, 1984. Av. Size is Mean Size, n is the Number of Scallops Measured.

	Days	Shallow Av. Size	n	Deep Av. Size	n	Combined Av. Size
Jan 1984	-	-	-	-	-	-
Feb	-	-	-	-	-	-
Mar	-	-	-	-	-	-
Apr	-	-	-	-	-	-
May	150	11.1	17	-	-	11.1
Jun	173	-	-	8.1	154	8.1
Jul	207	8.8	344	10.1	958	9.7
Aug	233	17.1	408	14.8	459	15.9
Sep	269	25.7	799	28.9	151	26.2
Oct	303	27.0	636	27.1	354	27.0
Nov	332	35.0	235	40.43	169	37.3
Dec	351	35.9	230	40.8	439	39.1
Jan 1985	395	37.5	388	44.7	66	38.5
Feb	416	35.5	559	45.8	298	39.1
Mar	447	42.8	676	47.6	415	44.6
Apr	482	43.8	414	52.5	398	48.1
May	516	50.8	660	57.7	246	52.7
Jun	538	53.0	681	54.6	198	53.4
Jul	571	49.0	766	57.7	373	51.9
Aug	607	51.1	605	56.4	273	52.8
Sep	635	51.8	465	56.1	690	56.1
Oct	669	52.9	488	58.1	312	54.9
Nov		-	-	-	-	-
Dec	715	53.5	27	-	-	53.5
Jan 1986	758	60.1	30	61.9	294	61.8
Feb	780	63.6	82	64.8	24	63.8
Mar	810	-	-	-	-	-
Apr	846	-	-	72.0	39	72.0
May	873	68.9	16	-	-	68.9
Jun		-	-	-	-	-
Jul						
Aug						
Sep						
Oct						

Table 3. Average Monthly Size of the 1985 Cohort of Speckled Scallops at Agua Hedionda Lagoon for Shallow and Deep Collections. Days Refers to the Number of Days Since January 1, 1984. Av. Size is Mean Size, n is the Number of Scallops Measured.

		Shallow		Deep		Combined
	Days	Av. Size	n	Av. Size	n	Av. Size
Jan 1985	395	-	-	-	-	-
Feb	416	-	-	-	-	-
Mar	447	-	-	-	-	-
Apr	482	-	-	-	-	-
May	516	-	-	-	-	-
Jun	538	-	-	-	-	-
Jul	571	-	-	-	-	-
Aug	607	16.6	156	16.3	15	16.5
Sep	635	14.2	584	20.5	58	14.8
Oct	669	30.9	173	30.4	14	30.8
Nov	-	-	-	-	-	-
Dec	715	31.1	156	-	-	31.1
Jan 1986	758	41.4	303	40.8	367	41.0
Feb	780	43.9	816	45.8	298	44.4
Mar	810	49.9	408	-	-	49.9
Apr	846	53.8	745	53.1	158	53.7
May	873	53.8	220	-	-	53.8
Jun	901	55.2	637	-	-	55.2
Jul	941	58.6	335	-	-	58.6
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	1002	55.4	25	-	-	55.4

Table 4. Average Monthly Size of the 1986 Cohort of Speckled Scallops at Agua Hedionda Lagoon. Days Refers to the Number of Days Since January 1, 1984. Av. Size is Mean Size, n is the Number of Scallops Measured.

	Days	Shallow Av. Size	Shallow n	Deep Av. Size	Deep n	Combined Av. Size
Jan 1986	753	-	-	-	-	-
Feb	780	-	-	-	-	-
Mar	810	-	-	-	-	-
Apr	846	-	-	-	-	-
May	873	-	-	-	-	-
Jun	901	5.4	10	-	-	5.4
Jul	941	22.4	50	-	-	22.4
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	1002	37.3	205	-	-	37.3

Table 5. Number of Individuals (n) and the Calculated Mean Gonadal-Somatic Index (GSI), Expressed as a Percent, for Each Collection Date, by Cohort.

Date	1983 Cohort		1984 Cohort		1985 Cohort	
	n	GSI(%)	n	GSI(%)	n	GSI(%)
1984						
04/24	50	5.05	-	-	-	-
05/29	127	7.34	-	-	-	-
06/21	45	2.75	-	-	-	-
07/25	36	5.35	-	-	-	-
08/20	31	3.84	-	-	-	-
09/25	22	3.31	-	-	-	-
10/29	42	2.23	16	1.82	-	-
11/27	26	.86	13	1.53	-	-
12/17	41	2.61	18	2.55	-	-
1985						
01/29	35	6.43	19	5.75	-	-
02/05	9	6.21	21	5.81	-	-
02/12	20	6.30	20	4.83	-	-
02/19	12	6.35	28	5.23	-	-
02/27	14	7.55	16	7.83		
03/07	12	7.68	20	7.16	-	-
03/14	8	7.56	20	6.09	-	-
03/22	15	7.78	24	7.43	-	-
04/01	-	-	38	7.87	-	-
04/11	-	-	30	9.57	-	-
04/26	-	-	42	9.70	-	-
05/02	-	-	31	13.56	-	-
05/14	-	-	40	11.71	-	-
05/22	-	-	29	15.15	-	-
05/30	-	-	40	11.25	-	-
06/17	-	-	30	11.48	-	-
06/21	-	-	41	10.78	-	-
06/27	-	-	34	14.04	-	-
07/09	-	-	30	16.00	-	-
07/16	-	-	32	12.39	-	-
07/24	-	-	41	9.61	-	-
08/01	-	-	38	9.77	-	-
08/12	-	-	33	13.49	-	-
08/23	-	-	28	10.37	-	-
08/29	-	-	35	8.65	-	-
09/26	-	-	40	8.72	-	-
10/30	-	-	36	6.77	-	-
1986						
01/27	-	-	29	8.29	25	7.01
02/18	-	-	25	7.61	24	5.37
03/20	-	-	22	13.18	18	11.90
04/25	-	-	13	14.82	37	13.28
05/22	-	-	11	13.61	27	12.50
06/19	-	-	-	-	40	12.70
07/28	-	-	-	-	39	10.20
10/02	-	-	-	-	32	11.88

Table 6. Number of Individuals (n) and the Calculated Mean Adductor-Somatic Index (MSI), Expressed as a Percent, for Each Collection Date, by Cohort.

Date	1983 Cohort n	1983 Cohort MSI(%)	1984 Cohort n	1984 Cohort MSI(%)	1985 Cohort n	1985 Cohort MSI(%)
1984						
04/24	50	13.78	-	-	-	-
05/29	127	10.49	-	-	-	-
06/21	45	9.81	-	-	-	-
07/25	36	7.03	-	-	-	-
08/20	31	7.53	-	-	-	-
09/25	22	9.87	-	-	-	-
10/29	42	6.98	16	7.26	-	-
11/27	26	10.28	13	10.62	-	-
12/17	41	9.54	18	9.67	-	-
1985						
01/29	35	25.21	19	28.49	-	-
02/05	9	23.14	21	21.46	-	-
02/12	20	25.94	20	27.30	-	-
02/19	12	29.55	28	30.05	-	-
02/27	14	29.02	16	30.01	-	-
03/07	12	23.43	20	28.28	-	-
03/14	8	18.45	20	28.77	-	-
03/22	15	27.99	24	31.03	-	-
04/01	-	-	38	28.66	-	-
04/11	-	-	30	28.53	-	-
04/26	-	-	42	26.16	-	-
05/02	-	-	31	26.63	-	-
05/14	-	-	40	29.00	-	-
05/22	-	-	29	26.88	-	-
05/30	-	-	40	26.36	-	-
06/17	-	-	30	21.44	-	-
06/21	-	-	41	20.37	-	-
06/27	-	-	34	22.18	-	-
07/09	-	-	30	18.86	-	-
07/16	-	-	32	19.40	-	-
07/24	-	-	41	17.93	-	-
08/01	-	-	38	16.82	-	-
08/12	-	-	33	17.90	-	-
08/23	-	-	28	18.92	-	-
08/29	-	-	35	18.51	-	-
09/26	-	-	40	18.88	-	-
10/30	-	-	36	21.90	-	-
1986						
01/27	-	-	29	25.01	25	27.51
02/18	-	-	25	27.66	24	30.50
03/20	-	-	22	28.04	18	30.49
04/25	-	-	13	25.62	37	26.62
05/22	-	-	11	27.23	27	26.38
06/19	-	-	-	-	40	21.25
07/28	-	-	-	-	39	17.25
10/02	-	-	-	-	32	11.88