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GROWTH RATE, DISTRIBUTION, AND POPULATION DENSITY OF THE NORTHERN QUAHOG *MERCENARIA MERCENARIA* IN LONG BEACH, CALIFORNIA

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A population of *Mercenaria mercenaria* (northern quahog) unique to the West Coast of the western hemisphere is shown to be well established in a lagoon in Long Beach, California. An estimated 300,000–500,000 individuals appear to be displacing the native bivalve species by out-competing other species for food sources and by being able to survive greater environmental stress, e.g., sewage spills, introduction of sodium hypochlorite. Population densities of *Mercenaria* reach 556 individuals per square meter.

Individual growth rates averaged 7.2 mm/year (0.28 in) with a gain of 25.3 g/year (0.89 oz). There appeared to be better growth in fine sediment than in coarse sand with the most rapid growth in all substrates occurring in the smaller (<80mm) clams. Breeding time for *Mercenaria* is from June through August when the surface temperatures are above 23 C (73 F).

The origin of the quahog in the lagoon is not known. Because of the ease with which they may be dug and the consequent heavy clamming pressure, the lagoon has been closed to all clamming since March, 1971. Recommendations for the preservation and use of this resource are presented which include keeping the lagoon closed to clamming for four more years to permit reestablishment of the population.

INTRODUCTION

Although the Atlantic quahog (cherrystone clam) *Mercenaria mercenaria* has been known to occur in the Colorado Lagoon, a tidegate controlled extension of Alamitos Bay, Long Beach, California, since 1967, (John Fitch, California Department of Fish and Game, pers. comm.) its presence was not recorded until 1971 (Salchak and Haas, 1971). From the spring of 1970 to June 1973, a more extensive survey of the Lagoon was conducted by Cerritos College, Norwalk, California, under a contract with the California Department of Fish and Game, to determine growth rates, distribution, spawning, and density of that clam population as well as to explore some of the environmental parameters that might contribute to the success of this species in this particular area.

The Colorado Lagoon is a Y-shaped body of water which contains about 189,000,000 l (50,000,000 gal) of seawater and has a low tide perimeter of 1,720 m (5,643 ft) (Figure 1). There are six storm drains which empty water from adjacent streets into the Lagoon. The East end, at the base of the "Y", has a tidegate which is generally left open all winter (mid September–May 1). Since the Lagoon is used for recreational swimming, the tidegates are closed for several days at a time during the summer to ensure sufficient water for swimming. Approxi-

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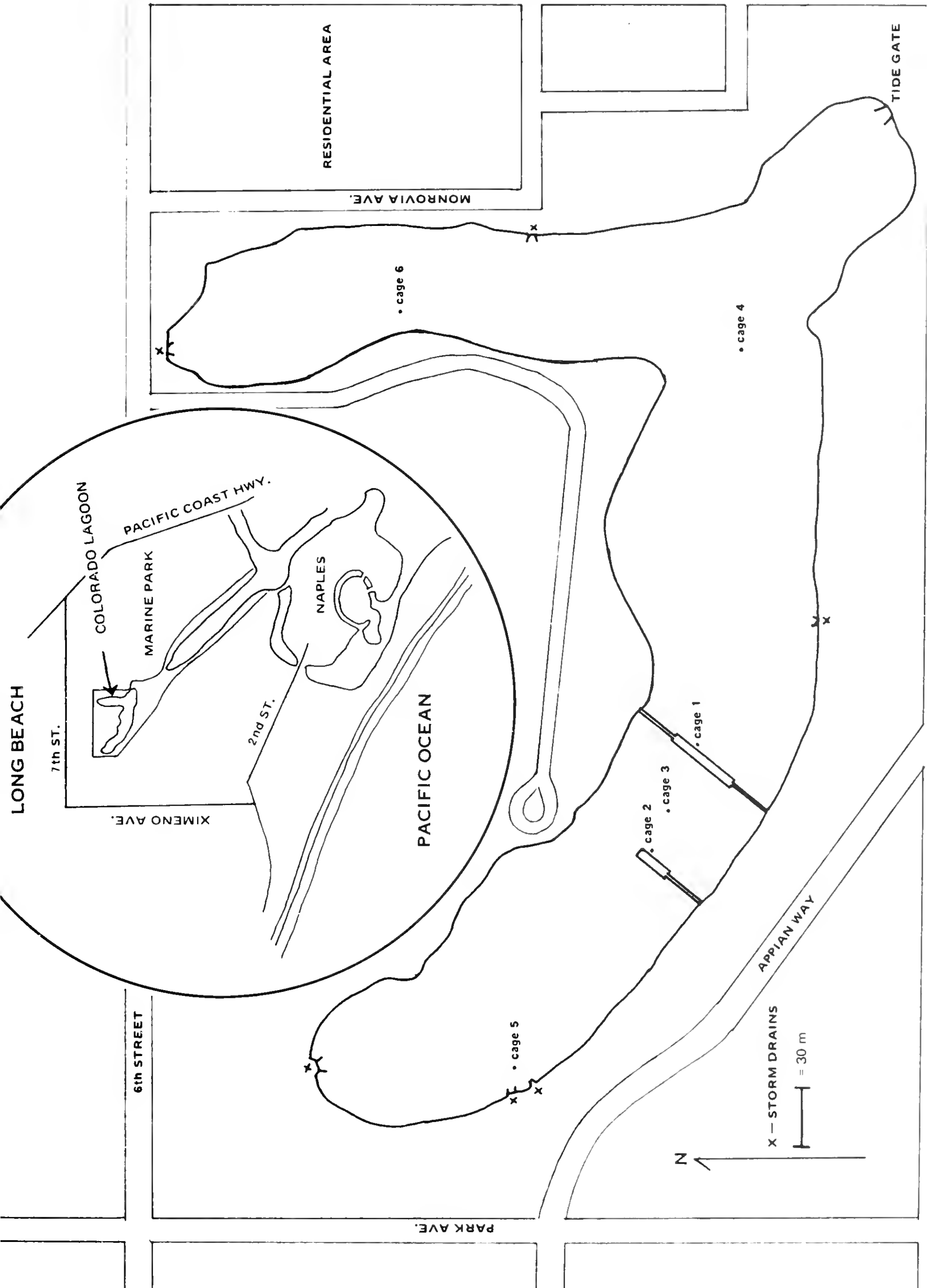

FIGURE 1. Colorado Lagoon, Long Beach, California.

mately 700 m (2,297 ft) of the perimeter is used as a recreational beach area by utilizing ocean beach sand replenished annually. This area is on the North and South sides of the central part of the West arm of the Lagoon. The East side of the northern arm has about 300 m (984 ft) of coarse sand which appears to be native to the area. The northern arm is closed to swimmers. The remaining perimeter is loosely consolidated fine sand, silt, and clay. The bottom grades rapidly into fine sand, silt, and clay sediments rich in organic debris. The maximum depth is about 7.6 m (25 ft) and occurs in the middle of the area where the two arms of the Lagoon divide. Most of the bottom profiles show a more or less shallow basin curve. In the tidegate area, however, there is a sharp drop off on both sides and a long steep slope extending westward along the southern border from the tidegate for about 360 m (1,181 ft).

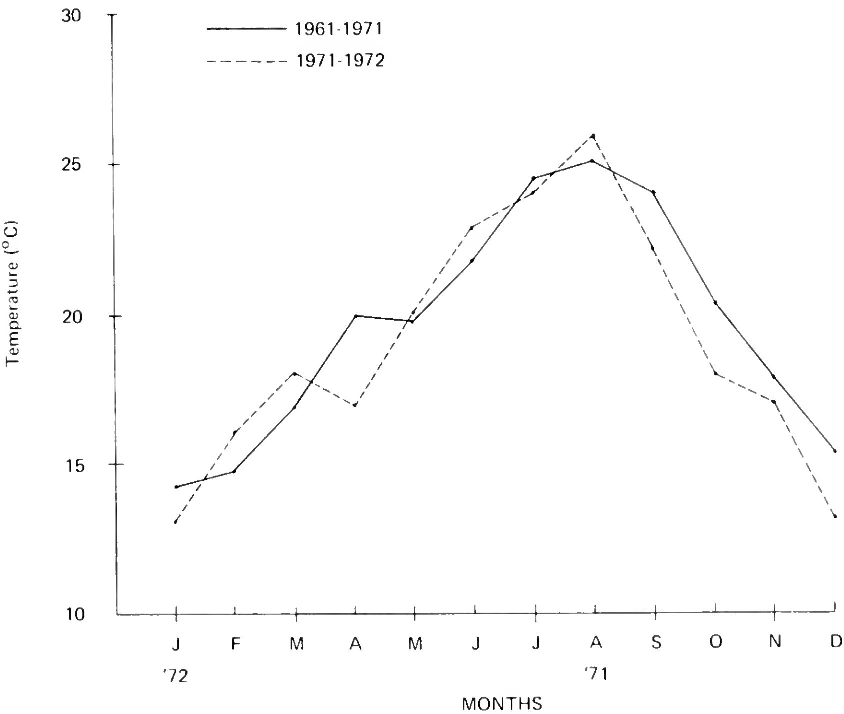

FIGURE 2. Comparison between ten-year average surface temperature (1961–1971) and the year August 1971–August 1972.

Average annual surface temperature ranges for the years 1961–1971 ran from a low of 14.3 C (57.7 F) in January to a high of 25 C (77 F) in August (Figure 2). Surface dissolved oxygen averaged 6.9 ppm with a monthly high of 8.3 (April) and low of 5.8 (December) for the same period (Figure 3).

Salinity determinations were made with an American Optical Company hand-held refractometer. Salinities averaged 33‰ (N = 32) with one maximum reading of 35‰ in July and a minimum of 28‰ following a rain in November. No ten-year data were available for comparison.

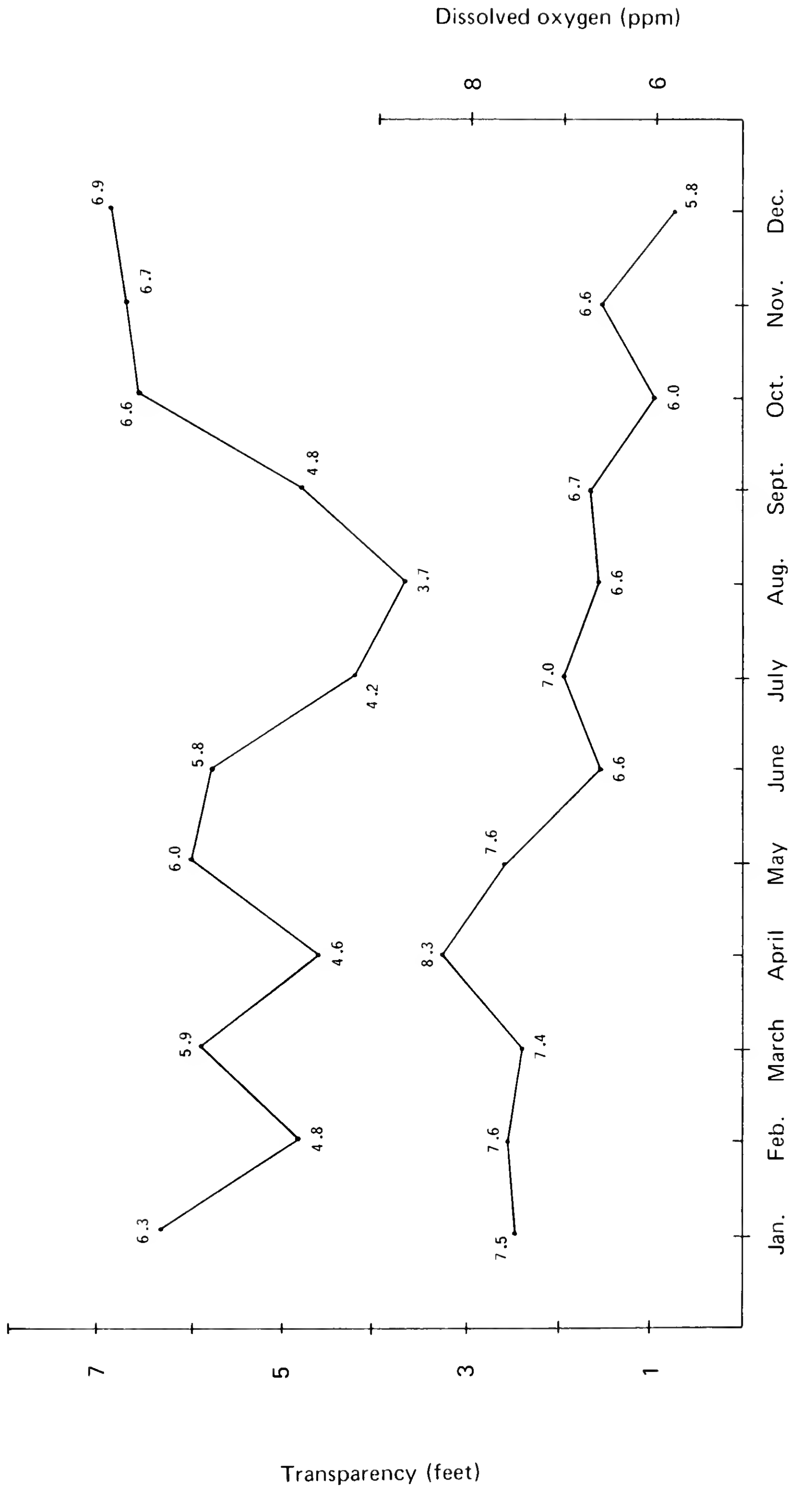

FIGURE 3 Monthly averages of dissolved oxygen and transparency in the Colorado Lagoon (1961–1971). Raw data courtesy of Dr. Y. Ibata, Engineering Department, City of Long Beach, California.

The common pelecypods observed in the Lagoon are quahogs (*Mercenaria mercenaria*), cockles (*Chione undatella, C. fluctifraga*), little-necks (*Protothaca staminea*), jackknife clams (*Tagelus californicus*), and mussels [*Arcuatula* (*Modiolus*) *demissa*, *Mytelis edulis*]. Those found occasionally are the yellow apolymetis (*Florimetis obesa* = *Apolymetis biangulata*) and the yellow cockle (*Laevicardium elatum*). These pelecypods are competing for food year-round with the abundant tunicate, *Styella plicata*, and during the summer with *Ciona intestinalis*, as well as with numerous fishes.

Despite extensive sampling, very few empty *Mercenaria* valves were found. This is in contrast to the abundant shell remains of the other resident pelecypods. The only occasion when *Mercenaria* shells were apparent was when sampling the densest *Mercenaria* bed. Dead juveniles were found here. This is attributed to the fact that this dense bed represents a climax community and there simply is no way newly settled juveniles can out-compete the resident population.

Enteromorpha intestinalis is the dominant macroscopic alga. Specimens of *Ulva lobata* are found occasionally. To keep the area relatively free of *Enteromorpha*, the Lagoon perimeter in the swimming area is raked by hand once or twice a year and the algae hauled away to a dump. The perimeter was raked in October 1971, and March 1972 during our study. Included in the wrack thus accumulated were numerous juvenile clams, including *Mercenaria*. Random sampling on October 6, 1971 of a one m^2 pile of *Enteromorpha* yielded 9 live *Mercenaria* ranging in length from 8 to 16mm. Judging by the rapid growth rate in the early stages, we estimate that these spat represented the June–August spawning time. At the same time, an estimated 36,000 juvenile (16–64mm) *Tagelus californicus* were killed in an 800 m^2 (8611 ft^2) area. This die off was probably due to the tidegates having been left closed at a minus tide after the raking had left the clams exposed to an unusually hot, sunny day. This practice was somewhat improved in March 1972 when the removal of algae was accomplished without digging in so deeply with the rakes and by leaving the tidegates open more during the process.

Because of a dramatic increase in clamming activity in the Lagoon (estimate maximum of 4,000 clams removed/hour at lowest tides) during the winter of 1970–71, the Lagoon was closed to all clamming by the California Fish and Game Commission on March 12, 1971.

SEWAGE CONTAMINATION

On April 29, 1972 the Lagoon experienced an influx of 3,407,000 l (900,000 gallons) of raw sewage, 1,890,000 l (500,000 gallons) of fresh water (used to flush the streets), and 318 kg (700 pounds) of sodium hypochlorite (HTH) as the result of a failure in the sewage pumping station nearest the West end of the Lagoon. The area was closed to the public and the tidegates were kept closed until May 6, when the surface coliform count had dropped sufficiently for gradual flushing through the tidegates to be considered safe. The area was re-opened to the public May 12, 1972.

The appearance of the water in the Lagoon on May 1, 1972, was brownish and it had the odor of an open sewer. Examination of clams in the western swimming area suggested that *Protothaca staminea* and *Chione fluctifraga* were experiencing some physiological stress as evidenced by weakened adductor muscles and reduced body fluids. In contrast, *Mercenaria mercenaria* appeared quite normal in these two respects.

General examination of the area at that time, and subsequently, revealed no indication of mass mortality in any of the macroscopic biota. Surface sample coliform counts taken by the Long Beach Health Department dropped sharply over a period of 7 days without any artificial techniques being employed to "clear" the water. For the eight stations taken in the Lagoon during this period, the maximum surface coliform count dropped from 700 MPN (Most Probable Number)/ml on May 1 to 24 MPN/ml on May 2, 2.3 MPN/ml on May 3, to 0.6 MPN/ml by May 4, 1972.

The dissolved oxygen content (DO) measured on May 1 by the Long Beach Engineering Department was 2.1 ppm (10 year average for May = 7.6 ppm) with a coliform count on that day of 62.0 MPN/ml. The next lowest recorded DO since June 1961 is 2.8 ppm (December 1961) when the coliform count was over 70 MPN/ml.

It is worth noting that specimens of *Mercenaria* in lab aquaria are also extraordinarily hardy. This was evidenced by their survival in the laboratory after short (2–3 days) exposure to temperatures of 27 C (81 F) and salinities over 45‰. In an accidentally "fouled" tank containing *Chione fluctifraga, Protothaca staminea* and *Mercenaria mercenaria,* only the *Mercenaria* survived.

In summary, the sewage exposure of April 29, 1972 appears to have had no noticeable ill effects on the population of *Mercenaria* in the Colorado Lagoon.

ORIGINAL SOURCE OF *MERCENARIA* IN THE LAGOON

There is no record of the northern quahog being introduced in Southern California waters since 1940. Spat were shipped to the west coast in the early 1960's from the National Marine Fisheries Laboratory, Milford, Connecticut (Lossanoff, pers. comm.), but there is no indication that they were introduced in the Southern California area. In the winter of 1951–52, one half bushel of cherrystones ("between cherrystone and quahog size") flown in from Long Island Sound, New York, were illegally introduced into a restricted area of Alamitos Bay by a local delicatessen owner. They were maintained in the Bay until 1954 when construction of a bridge destroyed the bed. No specimen of *Mercenaria mercenaria* has been found in the bay since then despite intensive surveys conducted over the last 15 years (Reish, 1968, 1969), and none have been reported from any area south of Humboldt Bay, California.

In view of the fact that the Colorado Lagoon clam colony is so extensive and that the largest quahogs from there (113mm) may be at least 15 years old, it seems possible that they are the descendants of the illicit 1951–54 colony. The probability remains, however, that there was a subsequent similar introduction directly into the Lagoon.

CLAM DISTRIBUTION AND DENSITY

The areas of highest *Mercenaria* density in the Lagoon reflect the areas where clammers could not reach the clams, either because they were too deep to obtain without diving or because the area was inaccessible (Figure 4). The low density areas around the perimeter are clearly due to clamming. As an example, one perimeter station sampled in summer, 1970 yielded 53 clams/m^2 (4.9 ft^2), while the same station had a density of 1–2 clams/m^2 in the summer of 1971. During that year, clamming activity was observed on several occasions in that particular area.

Diver transects were examined on September 15, 1972 (Figure 4, A–A′ through F–F′). Clam distribution and density was determined by hand digging along the length of the transect. The lowest estimates of density were used in evaluating the data. Precise area counts were made near the east end of the densest bed to define its perimeter. It is useful to note that at the western, denser end of the bed the proportion of breeding size (>40mm) clams to juveniles is 12:1, but where the bed begins to train off, the proportion is 4:1. This is interpreted to mean that the bed is developing in an easterly direction.

Eighty-six stations were established at 20 m (64 ft) intervals around the Lagoon at the –0.5 to –1.0 tide line. Samples were screened through $\frac{1}{4}$ inch mesh wire screen at each station from an area of 1 m^2 (10.76 ft^2) dug to a depth of 20 cm (8 in). The clams thus obtained were weighed and measured in the field and returned to the station area. The perimeter sampling data were lumped according to arbitrary density figures (Figure 4). The highest measured density occurred off the main float where 556 *Mercenaria mercenaria* were counted in 1 m^2 (10.76 ft^2). Extrapolating perimeter and diving stations, a conservative estimate would place the Lagoon population of *Mercenaria mercenaria* from 300,000–500,000 clams. Most of these are in water that is more than three feet deep at low tide.

GROWTH RATE DETERMINATIONS

In the summer of 1971, six growth cages, each consisting of 6.35 mm ($\frac{1}{4}$ in) iron rods welded into a 61 cm x 61 cm x 15 cm (2 ft x 2 ft x 0.5 ft) framework, covered with $\frac{1}{2}$ inch nylon fish netting, were stocked with clams and placed in different locations in the Lagoon (Figure 1). The clams were measured in their maximum dimension with calipers, weighed on field balances, and various numbers of clams were placed in the cages. Clams in cages 1, 2, and 3 were marked with individual painted numbers, and all clams were marked along the margin with felt tip red ink marking pens. Divers retrieved the clams at varying intervals over the following year. The cages and clams were all replaced for a future possible study after all the clams were measured in August 1972. The average annual length increase for the 227 clams thus measured was 7.2 mm (0.28 in) with a concurrent average weight increase of 25.3 g (0.89 oz) (Table 1).

Using the individually marked clams, which were measured more often, it was possible to develop some idea of seasonal variation in growth rate.

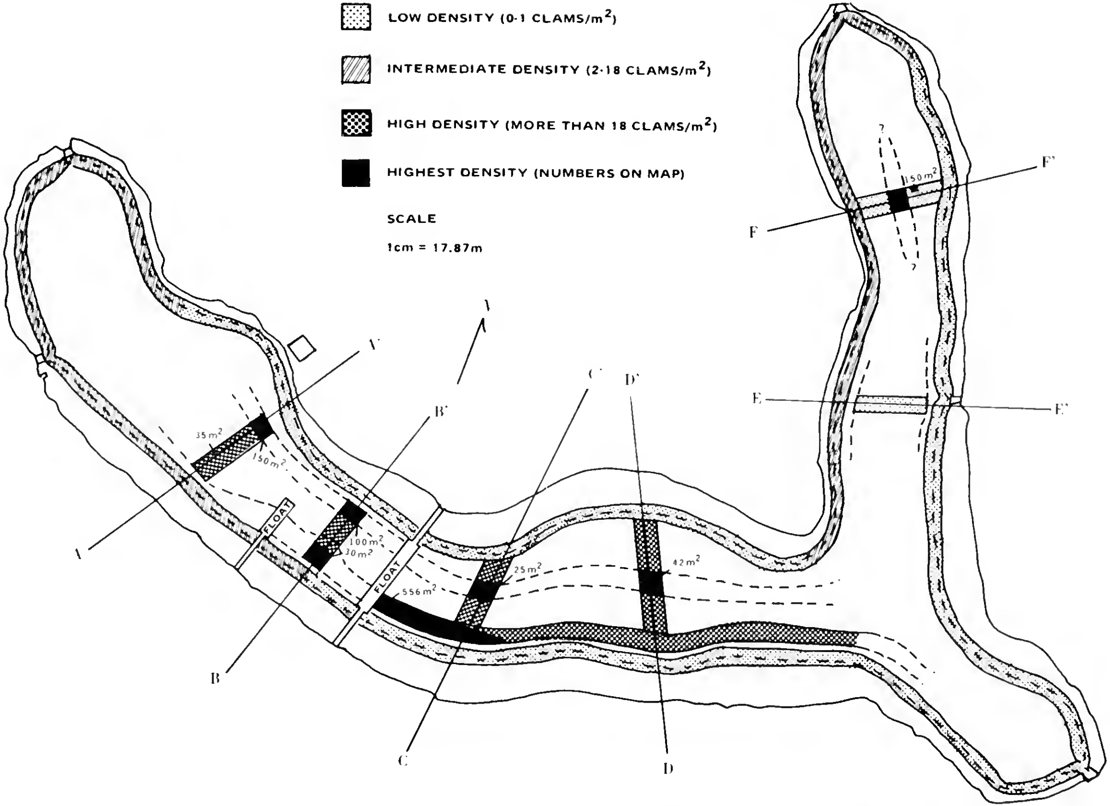

FIGURE 4. Map showing distribution and densities of *Mercenaria mercenaria* in the Colorado Lagoon. Diver transects indicated by A–A′ to F–F′.

TABLE 1—Average Annual Growth of *Mercenaria mercenaria* in the Colorado Lagoon Summer 1971–Summer 1972 (N = 227)

Cage number	X Length mm (range)	X Weight g	Comments
1 (N = 25)	9.3 (1.7–24.6)	25 (8½ mon.)	Clams measured 4 times
2 (N = 25)	4.1 (0.0–9.8)	18 (8½ mon.)	Clams measured 4 times; growth initially obstructed by tunicates
3 (N = 14)	4.9 (1.3–9.1)	23	Clams measured 4 times; loss of clams due to tear in netting
4 (N = 50)	3.9	20	Clams measured 3 times
5 (N = 52)	13.9	43	Clams measured 3 times
6 (N = 61)	7.1	23	Clams measured 2 times
Overall average	7.2	25.3*	

* Minimum figure due to shorter growth period recorded in Cages 1 & 2.

The period June to November reflected a growth rate almost three times that in the November to June time span (Table 2).

TABLE 2—Average Monthly Growth Rate by Season, 1971–1972 (N = 64)

Cage number	Nov.–June	June–Nov.
1 (N = 25)	0.4 mm	1.20 mm
2 (N = 25)	0.2 mm	0.53 mm
3 (N = 14)	0.2 mm	0.65 mm
6 month X	0.27 mm	0.79 mm

Using standard soil screens, an attempt was made to determine the relationship, if any, between sediment particle size and growth rate. Sediment samples were taken from the cage area, dried, and each particle size weighed to obtain the percentage of that size in the sample.

TABLE 3—Percent Substrate Particle Size Related to Growth Rate

	Particle size (%)				
	>4.76–2.38	2.37–0.59	0.58–0.149	<0.149	Annual growth rate (annual average in mm)
Cage 1	1.2	14.4	62.3	22.8	9.3
2	1.8	9.4	45.0	43.8	4.1
3	0.0	2.3	32.7	65.1	4.9
Est. * 4	0.3	5.4	37.3	57.1	3.9
5	0.3	10.1	59.5	30.1	13.9
6	5.9	20.7	61.2	12.2	7.1

* Part of sample lost in weighing.

Note that the ratio of 0.58–0.149 to <0.149 particle size is greatest in cages 6, 1, and 5 which contained the clams showing the highest annual growth rate. The ratio is reversed in cages 2, 3, and 4 which show the least growth. However, since the cages were widely separated throughout the Lagoon, it is reasonable to suppose that the amount of nutrients available to the clams was not constant, and that would influence their growth. It is interesting to note that the cage nearest the storm drains (cage 5) showed the highest growth rate (Table 3).

GROWTH BY SIZE CLASSES

Based on the growth data for the individually marked clams in cages 1, 2, and 3, there appears to be a tendency for the clams to decrease in length increments as they get larger. This is especially noticeable in clams over 80 mm (Table 4). Further comment on the larger quahogs would be speculative in view of the small sample size.

TABLE 4—Average Annual Length Increase by Size Classes

Cage #	Time period (months)	Size class (mm)		
		40–60	61–80	81–100
1	12	12.9mm (N = 8)	8.2mm (N = 16)	0 (N = 1)[1]
2	12	4.4mm (N = 5)	4.2mm (N = 19)	2.3mm (N = 1)[2]
3	12	3.0mm (N = 1)	$_{5}$0mm (N = 12)	0 (N = 1)[3]
		X_Δ = 6.7mm	X_Δ = 5.9mm	

[1] Original length = 97 mm.
[2] Original length = 86 mm.
[3] Original length = 82.7.

Weight increment data must be viewed in light of the fact that final measurements were made in August and many of the clams may have spawned out. Also the time period for cages 1 and 2 is different than the full year for cage 3 which has the smallest sample size. These data are included merely to give some idea of the order of magnitude of clam weight increase (Table 5).

TABLE 5—Average Annual Weight Increase by Size Classes

Cage #	Time period (months)	Size class (mm)		
		40–60	61–80	81–100
1	8.5	29.3g (N = 8)	24.4g (N = 16)	4.0g (N = 1)[1]
2	8.5	10.7g (N = 5)	19.2g (N = 19)	17.0g (N = 1)[2]
3	12.0	13.0g (N = 1)	24.2g (N = 12)	13.0g (N = 1)[3]

[1] Original weight = 290g.
[2] Original weight = 195g.
[3] Original weight = 158g.

PLANKTON SAMPLING

Surface plankton tows were made weekly from June 1972–June 1973. Samples were collected between 8 and 9 am along the east side of the longer float, using a standard $\frac{1}{4}$ m plankton net. All samples were preserved in either 40% isopropyl alcohol or in a Lugol solution made up of 10 g KI in 20 ml H_2O, and 5 g I_2 in 50 ml H_2O to which 5 g

$NaC_2H_3O_2$ was added. Three drops of this solution were used as a preservative for a 100 ml sample. This latter solution proved advantageous in revealing structural detail not visible with the alcohol preservative. A 1 ml sample from each collecting vial was examined in a Sedgewick Rafter counting chamber using a Whipple micrometer (APHA, 1971). Veligers appeared continuously in the samples from early May through mid-September, with the highest count of 419 individuals occurring in mid-July. No veligers appeared in samples taken the remainder of the year, except for a short period from late December to mid-January when a small number (less than 10) appeared in the samples (Figure 5).

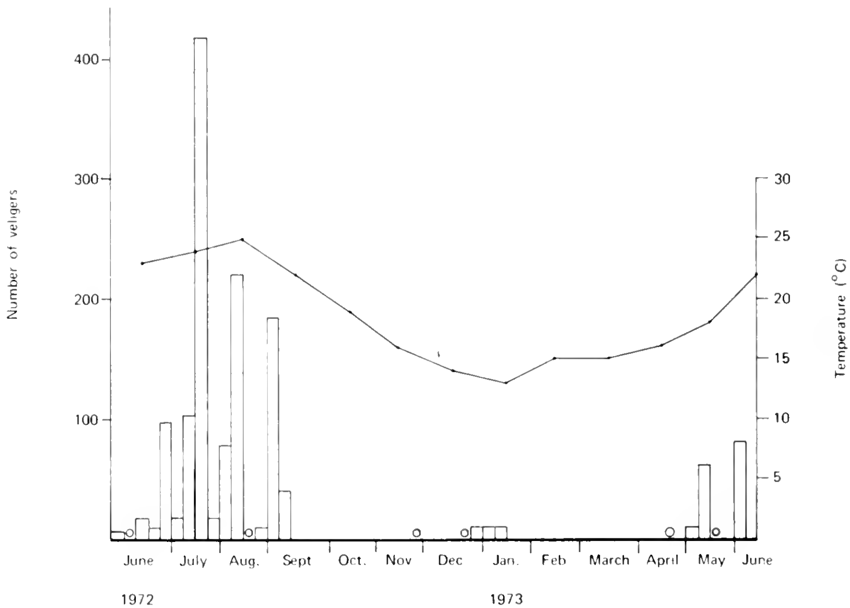

FIGURE 5. Number of straight hinge veligers per 1 ml concentrated sample from weekly plankton tows in the Colorado Lagoon, June 1972–June 1973.

It is difficult to distinguish among the species of veligers present in the plankton samples. Based on comparison with the veligers raised in the laboratory, we judge that the samples in June, July, and August contained *Mercenaria mercenaria*. In addition, the appearance of large numbers of straight hinge veligers in the plankton during July and August corresponds to an increase in surface temperature above 23 C (73 F). No information is available on bottom temperatures. However, laboratory observations show that this race of *Mercenaria mercenaria* will spawn spontaneously at 22 C (72 F) and can be induced to spawn from 22–25 C (72–77 F) (see section on spawning).

There are four morphologically different veligers, including the *Mercenaria* type, in the summer samples. The winter pelecypod spawning represents a single genus, probably not *Mercenaria*. We conclude that *Mercenaria* is among other clams spawning in June, July, and August in the Lagoon in response to higher ambient temperatures.

SPAWNING EXPERIMENTS

In our experiments with spawning we varied the methods of Loosanoff (1937) and Loosanoff and Davis (1950) in their study of the east coast *Mercenaria mercenaria*.

The procedure for spawning "summer" clams (those taken directly from the Colorado Lagoon from June through August) was to put them directly in enamel 4 l (1.1 gallon) trays (spawning trays) each with 3 l (.79 gallon) of sea water in a constant temperature bath set at 25 C (77 F). Spawning resulted from simply transferring clams from the 22–23 C (72–73 F) temperature in the holding tank to the 25 C (77 F) temperature in trays. However, greater and more regular success was obtained when sperm from a freshly killed and gonadectomized male was pipetted into the incurrent siphons of the clams in the trays. Spawning usually occurred 1–2 hours after the introduction of sperm to "ripe" clams.

After the clams had spawned, they were removed from the trays. The water in the trays was then stirred to insure maximum fertilization. After 30 minutes, the sperm-egg suspension was introduced into 1.5 l (0.40 gallon) fingerbowls containing sea water which had been filtered through cotton. The amount of suspension added to the fingerbowls varied with the spawning activity. A heavy spawning required about 100 ml of suspension to insure that the larval population did not exceed the 250 larvae/ml level suggested by Loosanoff (1963). Our experiments indicate that for small scale culturing, 100–200 larvae/ml is probably a more desirable level.

Spawning "winter" clams (i.e., those taken from the Lagoon in winter or those maintained in refrigerated tanks in the laboratory) was more difficult. The water temperature was raised gradually over a 3–4 week period to 22 C (72 F). At the same time, the feeding was double the normal daily amount of 1.8 mg (6×10^{-5} oz) of ground up *Enteromorpha* to one g (0.035 oz) of clams in a total tank volume of 208 l (55 gallons). At the end of the temperature raising period, the clams were placed into spawning trays and the procedure was then the same as for the "summer" clams.

"Summer" clams which have spawned in the lab should be able to spawn again in the same season at least once. In the lab we have had one group of clams spawn twice, on July 3, 1971 and on September 1, 1971.

Clams fresh from the Lagoon were induced to spawn on six occasions from early July to late August. Since plankton samples taken from the Lagoon during June, July, and August contained larvae of *Mercenaria mercenaria*. We are thus led to conclude that this species spawns continuously in the Lagoon during the summer months.

Larvae from the successful attempts survived well for at least two days to the straight-hinge veliger stage after the spawnings which were observed. After two days problems with feeding, over-crowding, waste products and the most suitable culture vessel hindered our attempts to raise larvae to settling stage.

A spawning experiment was performed on clams that had been held under lab conditions for nine months. These clams had been collected from the Colorado Lagoon in November, 1970 and were kept at 20 C (68 F) until May 11, 1971 when they were switched to a refrigerated tank at 13 C (55 F). From July 3 to July 19, 1971, the temperature was gradually raised to 21 C (70 F) and maintained at 21–22 C (70–72 F) for 34 days. At this time, the clams were placed in spawning trays at 25 C (77 F) and after 3 hours, a sperm suspension from a dissected male was added. Eleven clams ranging from 53 mm (2.7 in) to 93 mm (3.6 in) responded by spawning within 50 minutes. The two 43 mm (1.7 in) clams remained inactive.

This experiment shows (at least in one case) that *Mercenaria mercenaria* from the Colorado Lagoon can be maintained under laboratory conditions for extended periods of time (at least 10 months) and still be spawned successfully.

In determining sexual maturity we utilized three methods: observing spawning directly, drilling to aspirate gonadal material, and dissecting to obtain gametes from different size groups.

Spawning experiments were performed using separate trays for each of the following size classes: 40–50 mm (1.6–1.9 in) (N = 2), 51–60 mm (2.0–2.3 in) (N = 7), 61–70 mm (2.4–2.7 in) (N = 10), 71–80 mm (2.8–3.1 in) (N = 8), 81–93 mm (3.2–3.6 in) (N = 5). All but the two smallest clams were induced to spawn.

We had success with drilling clams with small dental drills. The holes were drilled about ¼ of the distance from the umbo to the shell margin, approximately on the midline. The needle of a 1 cc syringe was inserted into the hole into the visceral hump and the aspirated material examined. The hole in the shell was filled with paraffin and sealed with collodion. We had about 40% mortality among drilled *Mercenaria mercenaria*. In drilling, it was discovered that clams 40 mm (1.6 in) and larger apparently had mature gametes. One clam 28.9 mm (1.1 in) was examined but no mature gametes were found.

The third method of determining sexual maturity was dissection and examining for gametes. All of the 12 clams from 51.9 mm to 82.3 mm (2.0–3.2 in) checked were found to be mature.

CONCLUSIONS AND RECOMMENDATIONS

The colony of *Mercenaria mercenaria* in the Colorado Lagoon is a well established breeding population on the order of magnitude of one half million individuals. The species appears to out-compete native pelecypods for food, and for this reason will either replace indigenous species or at least suppress their growth. The implications in this statement should be noted if consideration is given to future introductions of *M. mercenaria* elsewhere on the West Coast.

The hardiness of *Mercenaria mercenaria* commends it for laboratory experimentation and aquacultural investigations.

It would appear that there is a direct relationship between water temperature and the spawning of *Mercenaria*. For this "race", the optimum spawning temperature lies between 22–25C (72–77F).

The present condition of the Lagoon is such that it seems probable that the *Mercenaria* colony there will continue to thrive, providing no drastic changes are made in the environment, e.g., cementing in the Lagoon, changing the storm drains, building a freeway adjacent to the Lagoon, dredging, etc.

Since it is quite possible that this particular stock represents a race of *Mercenaria mercenaria* which is uniquely suited for survival in California waters, use of these specific clams for laboratory breeding purposes, as well as for a pool for stocking breeders elsewhere, would seem appropriate.

Leaving the Lagoon closed to clamming for four years should give the beds sufficient time to recover from the intensive clamming pressure.

Bag and size limits specifically for this genus should be established prior to reopening the area.

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OTTER TRAWL COD-END ESCAPEMENT EXPERIMENTS FOR CALIFORNIA HALIBUT[1]

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Two otter trawl cod-end escapement experiments were conducted to test escapement of sub-legal unmarketable California halibut *(Paralichthys californicus)* through large and small meshed cod ends. Most sub-legal halibut (less than 22 inches TL) escaped through the 7½-inch mesh cod end. Fewer halibut of higher average weight, but with greater total weight, were captured by the 7½-inch mesh cod end, than by the cod ends of smaller mesh size.

INTRODUCTION

Experience gathered during the tagging of about 14,000 California halibut, captured in otter trawls equipped with 5-inch mesh cod ends, showed that mortality increased rapidly with length of trawling (dragging) time. The optimum trawling time that nets could be fished, yet leave captured fish in prime condition for tagging and release, was no longer than 30 min. Fishing periods of 1 to 4 hr demonstrated a progressive increase in mortality, particularly of sub-legal sized (less than 22 inches TL) unmarketable fish. Most sub-legal halibut are juveniles. At the termination of a 4 hr drag most sub-legal fish were dead and we believe that the remainder were unlikely to survive.

From this experience, and because most commercial halibut drags are of 1 to 4 hr duration, we felt a significant number of sub-legal (undersized) halibut was being destroyed by commercial trawl gear and that larger meshed cod ends might provide suitable escapement for these fish.

In December 1964, we began experiments to determine the cod-end mesh size that would provide optimum escapement for sub-legal halibut while still retaining the larger sized fish.

Trawling operations were conducted off Long Beach and Huntington Beach utilizing 6½-, 7- and 7½-inch mesh cod ends. The smallest halibut captured by the 6½-inch cod end was 449 mm (17.8 inches); by the 7-inch cod end, 494 mm (19.4 inches); and by the 7½-inch cod end, 525 mm (20.7 inches).

Experiments were designed and conducted with two identical 5-inch mesh trawl nets. One net was equipped with a 5½ (the second experiment used a 5)-inch cod end and the other utilized a 7½-inch mesh. All cod ends were 6.1 m (20 ft) in length and made of #80 nylon twine.

Machine manufactured mesh sizes are measured from center of knot to center of knot resulting in an actual opening size of less than this figure. The true escapement size of the mesh was determined by measuring the webbing openings from knot to knot with a knife-edge inside

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caliper. This was done immediately after trawling operations when the cod-end webbing was wet and subjected to loadstrain of the catch. Ten measurements each of the 5-, 5½- and 7½-inch meshes resulted in average size openings of 4.91, 5.41 and 7.31 inches respectively, but subsequent reference to mesh size will be 5-, 5½- or 7½-inches.

Size of the cod-end mesh first used in each set of paired drags was serially chosen from a table of mesh sizes (Table 1). This table was constructed from random numbers using odd and even numbers to represent 7½-inch and 5½- (or 5-) inch cod-end webbing. In the event of a torn net, loading and stoppage of the cod end with moss or kelp or, if the drag was terminated before the prescribed trawling time was completed, the results of the pair of drags were discarded and the next sequential mesh size taken from the table for the next pair of drags.

TABLE 1—Random Cod-end Mesh Size Drag Sequence

Drag number	Mesh size (inches)	Drag number	Mesh size (inches)	Drag number	Mesh size (inches)
1	7½	18	5½	35	7½
2	5½	19	7½	36	5½
3	5½	20	5½	37	5½
4	7½	21	7½	38	7½
5	7½	22	5½	39	7½
6	5½	23	5½	40	5½
7	7½	24	7½	41	7½
8	5½	25	7½	42	5½
9	7½	26	5½	43	5½
10	5½	27	5½	44	7½
11	7½	28	7½	45	7½
12	5½	29	7½	46	5½
13	7½	30	5½	47	5½
14	5½	31	7½	48	7½
15	5½	32	5½	49	7½
16	7½	33	7½	50	5½
17	7½	34	5½		

Trawling drags were conducted in pairs. A drag was made in one direction using a net with one size cod end and then the second net with the other cod end was towed in the opposite direction. Both trawling experiments were conducted in 3–20 fm from off Ventura to Port Hueneme and off Santa Barbara, California.

EXPERIMENT I, RESEARCH CRUISE 65-A-1

In January 1965 the Department of Fish and Game launched research cruise 65-A-1 on the M/V ALASKA to compare halibut retention in nets having 5½- and 7½-inch mesh cod ends.

Twenty-two paired drags, each drag of 40 min duration, were made from February 24 to March 5, 1965. Seventeen species of teleosts, 13 species of sharks and rays and 23 species of invertebrates were taken (Tables 2, 3, and 4). The three dominant species captured were California halibut, 337 fish; hornyhead turbot *(Pleuronichthys verticalis)*, 326 fish; and fantail sole *(Xystreurys liolepis)*, 68 fish (Figures 1, 2, and 3 respectively).

TABLE 2—**Teleosts Captured in the 5½- and 7½-Inch Trawl Cod Ends. Cruise 65-A-1**

Species	Cod end 5½-inch	Cod end 7½-inch	Size range (mm)
Paralichthys californicus	231	106	351–980
Citharichthys sordidus	1	--	162
Xystreurys liolepis	44	24	242–522
Hippoglossina stomata	5	1	295–362
Parophrys vetulus	20	14	220–387
Pleuronichthys coenosus	3	1	256–349
Pleuronichthys decurrens	1	--	257
Pleuronichthys ritteri	7	--	212–265
Pleuronichthys verticalis	205	121	199–332
Hypsopsetta guttulata	18	3	258–359
Genyonemus lineatus	2	--	170–245
Menticirrhus undulatus	1	--	605
Amphistichus argenteus	1	2	251–280
Phanerodon furcatus	1	--	205
Rhacochilus toxotes	1	--	335
Scorpaena guttata	1	3	281–308
Merluccius productus	1	--	652

The 5½-inch mesh cod end captured nearly twice as many hornyhead turbot and fantail sole as the 7½-inch mesh cod end (Figures 2 and 3). More large fish escaped from the 7½-inch mesh than from the 5½-inch mesh; however, many smaller fish, though exposed to the same 7½-inch mesh, were retained.

Comparison of retention of California halibut in the 5½- and 7½-inch mesh cod end showed that almost all sub-legal fish escaped through the 7½-inch mesh but many were retained by the 5½-inch mesh (Figure 1). The 5½-inch mesh captured 134 (58%) sub-legal halibut that weighed a total of 161.1 kg (358 lb), and 97 (42%) legal sized fish weighing

TABLE 3—**Sharks and Rays Captured in the 5½- and 7½-Inch Trawl Cod Ends. Cruise 65-A-1**

Species	Cod end 5½-inch	Cod end 7½-inch
Cephaloscyllium ventriosum	5	1
Mustelus californicus	2	--
Mustelus henlei	1	1
Triakis semifasciata	--	1
Squalus acanthias	1	2
Squatina californica	13	11
Platyrhinoidis triseriata	7	3
Rhinobatos productus	28	6
Torpedo californica	10	11
Raja inornata	1	--
Raja rhina	1	--
Gymnura marmorata	1	--
Myliobatis californica	14	5

318.1 kg (707 lb). The 7½-inch mesh cod end retained 6 (6%) undersized halibut that weighed a total of 4.9 kg (11 lb) and 100 (94%) legal sized fish weighing 379.3 kg (843 lb).

Sixty-one kg (135 lb) more legal sized halibut were captured by the 7½-inch cod end than by the 5½-inch, but the 5½-inch cod end retained 128 more undersized, unmarketable fish than the 7½-inch.

The legal sized halibut captured in the 7½-inch mesh cod end weighed more and averaged 5 kg (1.1 lb) heavier than those retained by the 5½-inch mesh. In addition, the 7½-inch mesh cod end provided almost perfect escapement for sub-legal unmarketable fish.

EXPERIMENT II. RESEARCH CRUISE 65-A-4

The second escapement experiment was conducted in May 1965 on the M/V ALASKA, research cruise 65-A-4. The cruise was designed to test the effect of longer trawling periods upon halibut escapement from 5- and 7½-inch mesh cod ends.

Fourteen paired drags, each of 90 min duration, were made May 11–26, 1965. Eleven species of teleosts, 10 species of sharks and rays and 16 species of invertebrates were taken (Tables 5, 6, and 7). The four dominant species captured were California halibut, 615 fish; English sole (*Parophrys vetulus*), 408 fish; hornyhead turbot, 236 fish; and sand sole (*Psettichthys melanostictus*), 95 fish (Figures 4, 5, 6, and 7).

About 2½ times more English sole were retained by the 5-inch mesh cod end than by the 7½. The frequency distribution of fish captured

TABLE 4—Invertebrates Captured in the 5½- and 7½-Inch Trawl Cod Ends. Cruise 65-A-1

Species	Cod end	
	5½-inch	7½-inch
Astropecten sp.	147	44
Pisaster ocraceus	9	9
Pisaster giganteus	30	33
Patiria miniata	11	32
Cancer anthonyi	151	78
Cancer gracilis	37	12
Cancer antennarias	3	2
Cancer productus	6	1
Loxorhynchus grandis	24	90
Loxorhynchus crispatus	54	19
Portunus xantusii	5	--
Pugettia producta	--	1
Randallia ornata	38	14
Hemisquilla stylifera	20	18
Feather hydroids, scoops of	--	3
Sea pens, estimated count	3,000	3,000
Kelletia kelleti	8	21
Forerria belcheri	1	1
Polinices sp.	366	121
Trachycardium quadragenarium	4	--
Nudibranchs	1	--
Squid eggs, scoops of	4	--
Pelagic tunicates	9	--
Bryozoans, scoops of	125	122
Kelp, assorted, scoops of	107	29

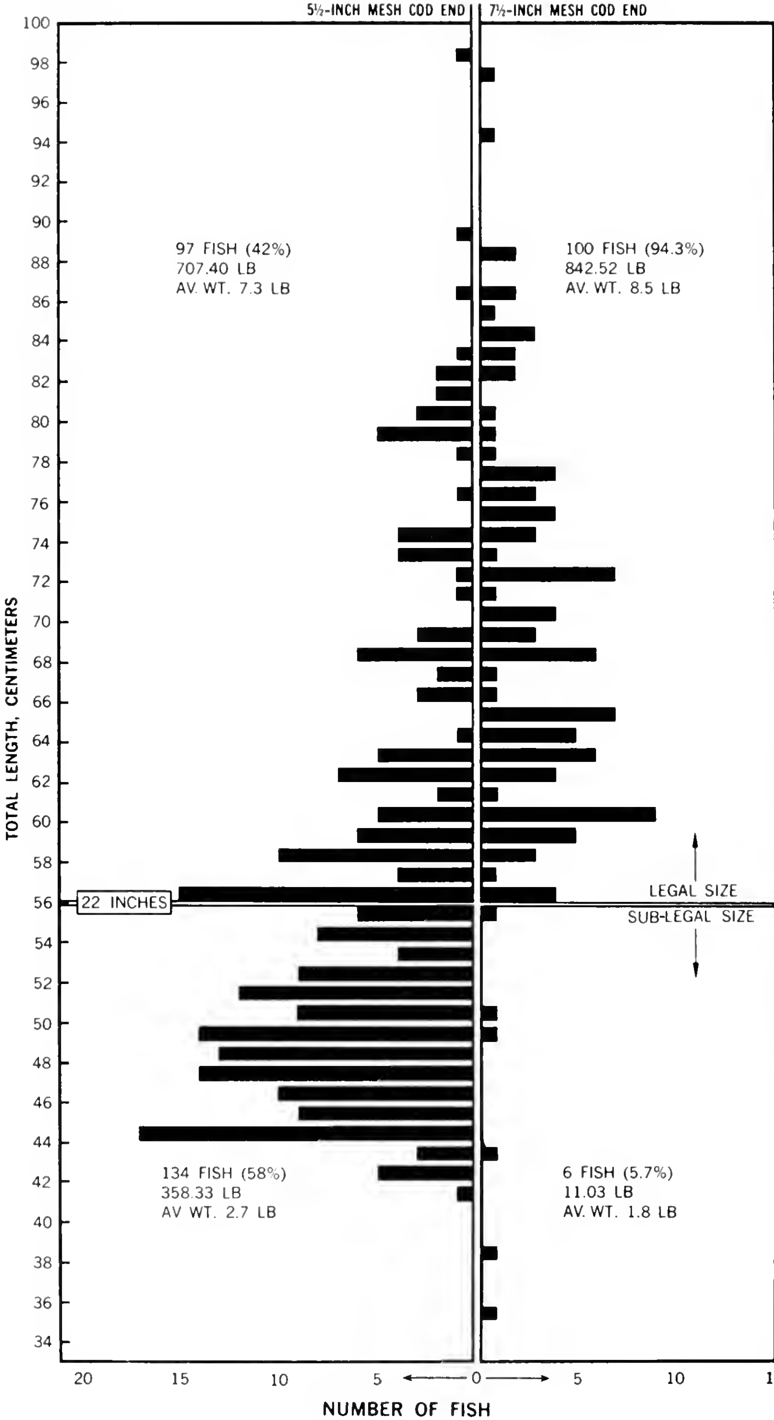

FIGURE 1. Comparison of Retention of California Halibut Captured in the 5½- and 7½-Inch Mesh Cod End. Weights are Calculated. Twenty-two Paired Drags, 40 Min Each. Cruise 65-A-1.

by both mesh sizes was about the same but more of the larger fish escaped through the 7½-inch mesh (Figure 5).

Retention of hornyhead turbot by the 5-inch was about 7½ times greater than through the 7½-inch. Forty-eight fish longer than 300 mm (11.8 inches) were retained by the 5-inch but none was captured by the 7½-inch (Figure 6).

More than four times as many sand sole were captured in the 5-inch mesh cod end than in the 7½-inch, and the 7½-inch mesh retained more large fish than short ones (Figure 7).

Retention of California halibut in the 5- and 7½-inch mesh cod end replicated in most respects what had been demonstrated by Experiment I. Two hundred seventy sub-legals were captured by the 5-inch

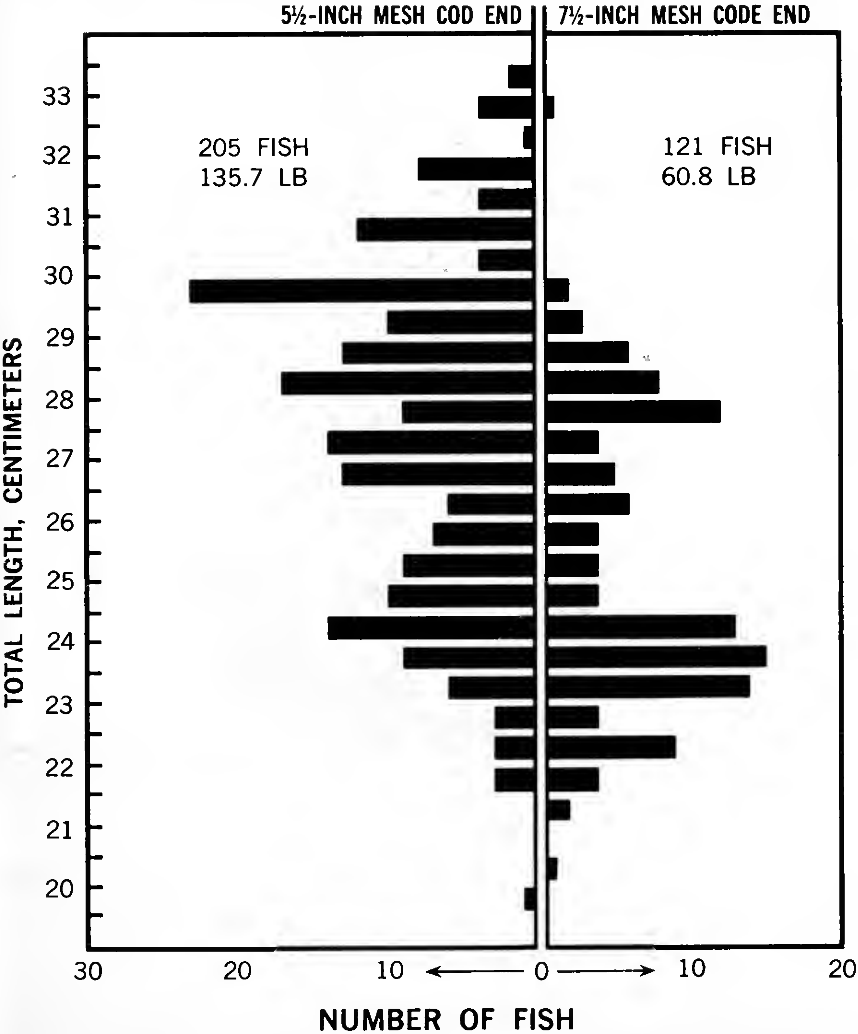

FIGURE 2. Comparison of Retention of Hornyhead Turbot in the 5½- and 7½-Inch Mesh Cod End. Weights are Calculated. Twenty-two Paired Drags, 40 Min Each. Cruise 65-A-1.

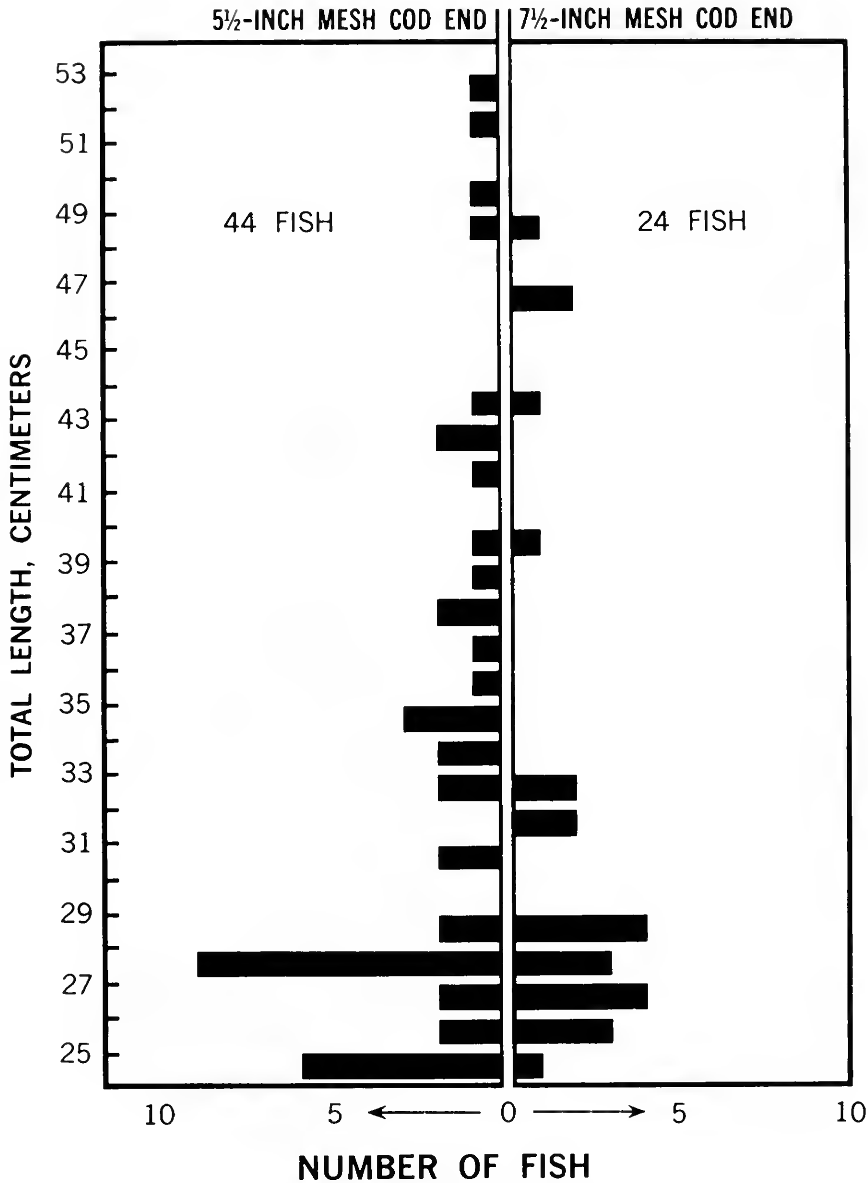

FIGURE 3. Comporison of Retention of Fantail Sole in the 5½- and 7½-Inch Mesh Trawl Cod End. Twenty-two Paired Drags, 40 Min Each. Cruise 65-A-1.

mesh cod end but only 12 were retained by the 7½-inch (Figure 4). One hundred seventy-seven legal sized fish weighing 658.4 kg (1463 lb), with average weight of 3.72 kg (8.27 lb), were taken in the 5-inch cod end and 156 fish weighing 614.7 kg (1366 lb), with an average weight of 3.94 kg (8.76 lb), were retained by the 7½-inch mesh. The 7½-inch

TABLE 5—Teleosts Captured in the 5- and 7½-Inch Cod Ends. Cruise 65-A-4

Species	Cod end		Size range (mm)
	5-inch	7½-inch	
Paralichthys californicus	447	168	318–1,160
Parophrys vetulus	294	114	226– 397
Pleuronichthys decurrens	1	--	241
Pleuronichthys ritteri	7	--	212– 265
Pleuronichthys verticalis	208	28	193– 396
Xystreurys liolepis	17	2	232– 468
Platichthys stellatus	2	4	421– 474
Psettichthys melanostictus	77	18	234– 517
Symphurus atricauda	--	1	206
Genyonemus lineatus	26	2	176– 326
Amphisticus argenteus	20	7	220– 379
Damalichthys vacca	3	--	249– 400
Scorpaena guttata	1	--	298

TABLE 6—Sharks and Rays Captured in the 5- and 7½-Inch Trawl Cod Ends. Cruise 65-A-4

Species	Cod end	
	5-inch	7½-inch
Galeorhinus zyopterus	--	1
Mustelus henlei	3	4
Squalus acanthias	3	--
Squatina californica	3	--
Platyrhinoidis triseriata	21	1
Rhinobatos productus	410	190
Torpedo californica	4	4
Raja binoculata	2	--
Raja rhina	6	4
Myliobatis californica	94	182

TABLE 7—Invertebrates Captured in the 5- and 7½-Inch Cod Ends. Cruise 65-A-4

Species	Cod end	
	5-inch	7½-inch
Astropecten sp.	11	12
Pisaster giganteus	72	52
Patiria miniata	--	5
Cancer anthonyi	126	69
Cancer gracilis	37	12
Cancer antennarias	1	1
Loxorhynchus grandis	14	27
Loxorhynchus crispatus	230	66
Randallia ornata	30	8
Hermit crabs (in moon snail shells)	2	0
Hemisquilla stylifera	1	--
Forerria belcheri	6	2
Polinices sp.	219	19
Jellyfish, large	--	1
Aphrodita sp.	1	--
Bryozoans and hydroids	1½ tons	--
Kelp, scoops of	9	11

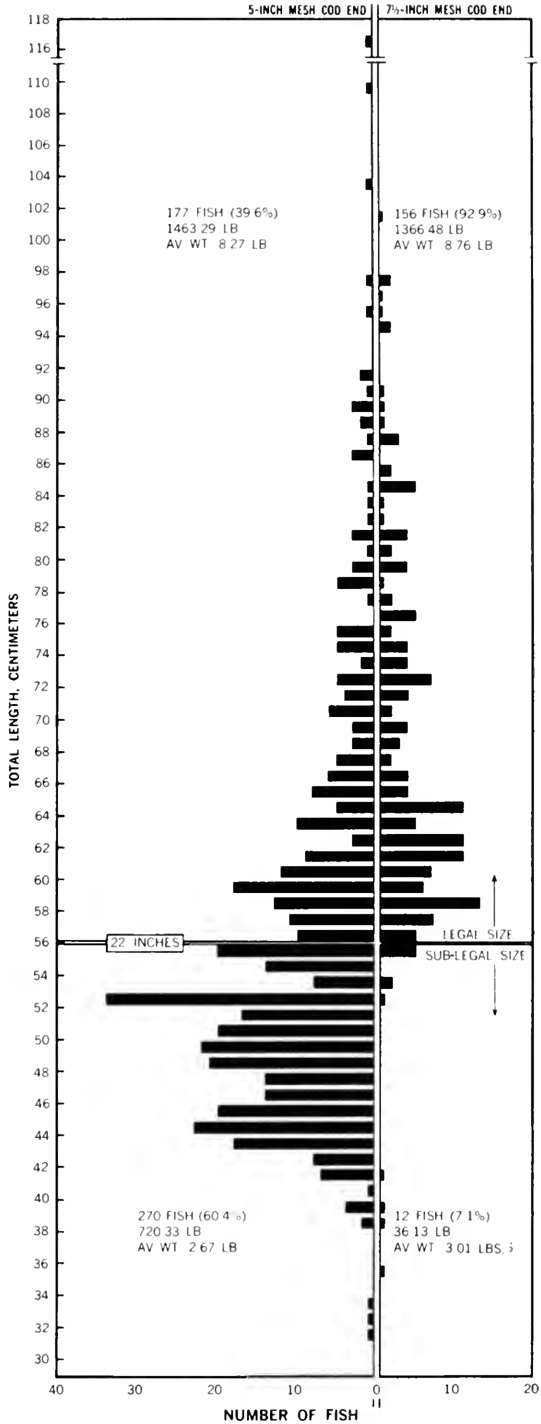

FIGURE 4. Comparison of Retention of California Halibut Captured in the 5- and 7½-Inch Mesh Cod Ends, 14 Paired Drags, 90 Min Each. Cruise 65-A-4.

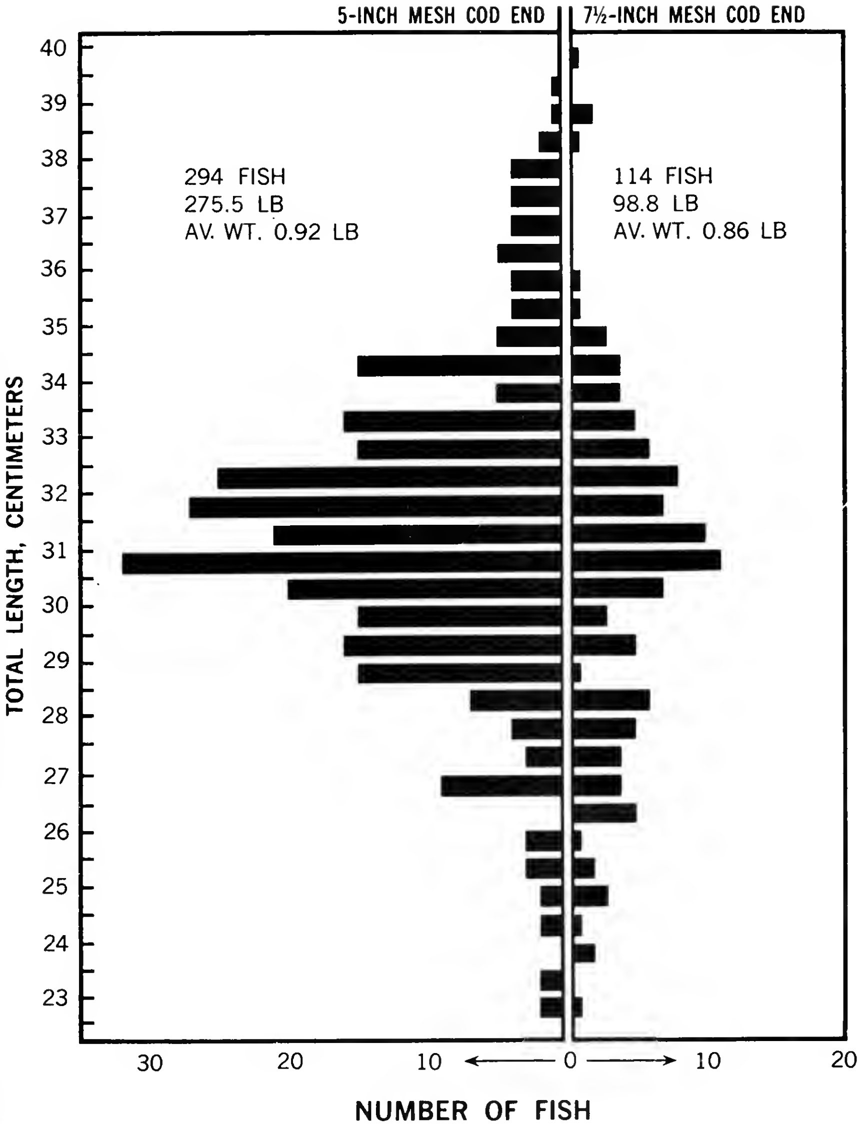

FIGURE 5. Comparison of Retention of English Sole in the 5- and 7½-Inch Mesh Cod Ends, 14 Paired Drags, 90 Min Each. Cruise 65-A-4.

mesh cod end captured 43.7 kg (97 lb) and 21 fish less than the 5-inch mesh cod end, but the average weight of these legal fish was .20 kg (0.44 lb) greater. The capture of the two largest halibut taken in the same 5-inch mesh drag, may have been by chance. If these two fish had not been taken it would nearly cancel out the total weight differences of the 5- and 7½-inch mesh catches.

Experiment I and II differed by about 2½ months and II had about 25% more trawling time. Differences observed in species composition and escapement may be linked to seasonal behavioral patterns. Somewhat greater retention of fish by the 5-inch cod end used in Experiment II, compared to the 5½-inch mesh catch of Experiment I may have been related to greater seasonal availability, smaller cod-end mesh,

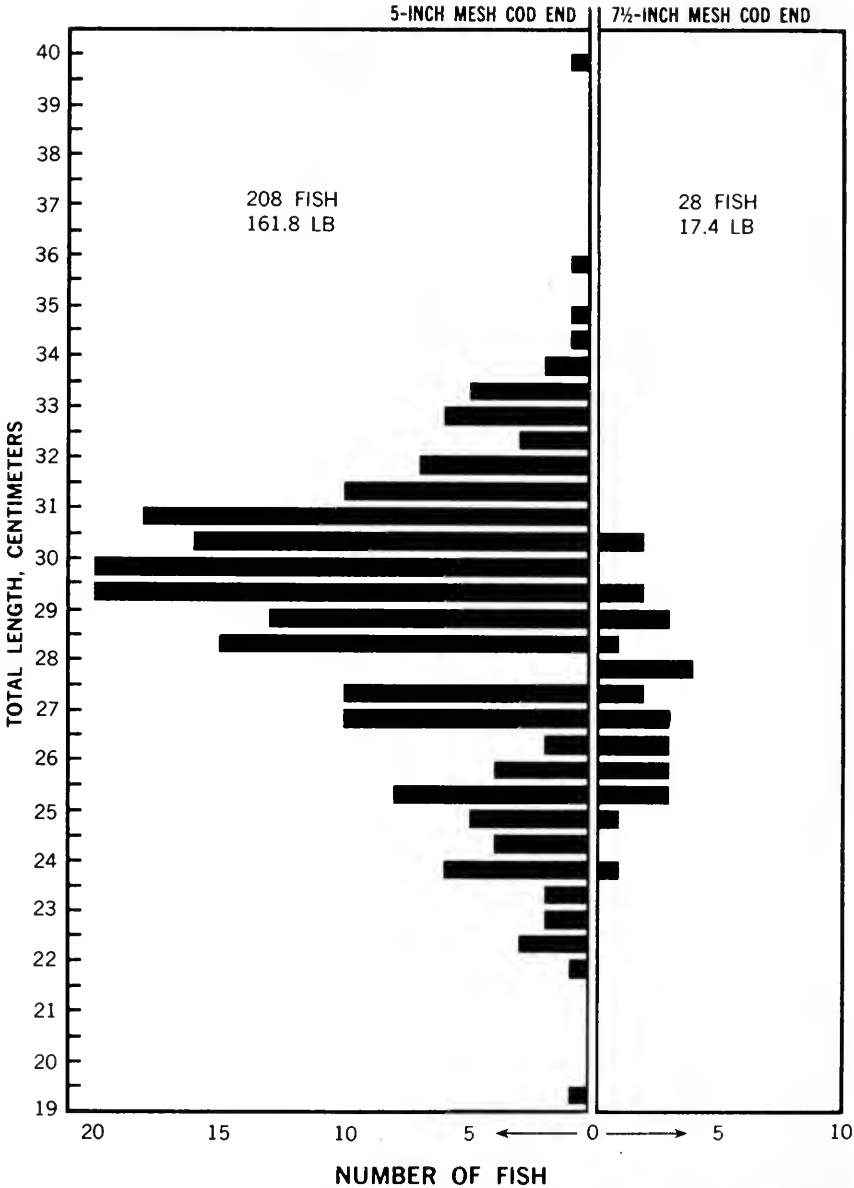

FIGURE 6. Comparison of Retention of Hornyhead Turbot in the 5- and 7½-Inch Mesh Cod Ends, 14 Paired Drags, 90 Min Each. Cruise 65-A-4.

longer dragging time and perhaps to species spawning behavior. More kinds of invertebrates, sharks and rays, and teleosts were captured in Experiment I than in Experiment II.

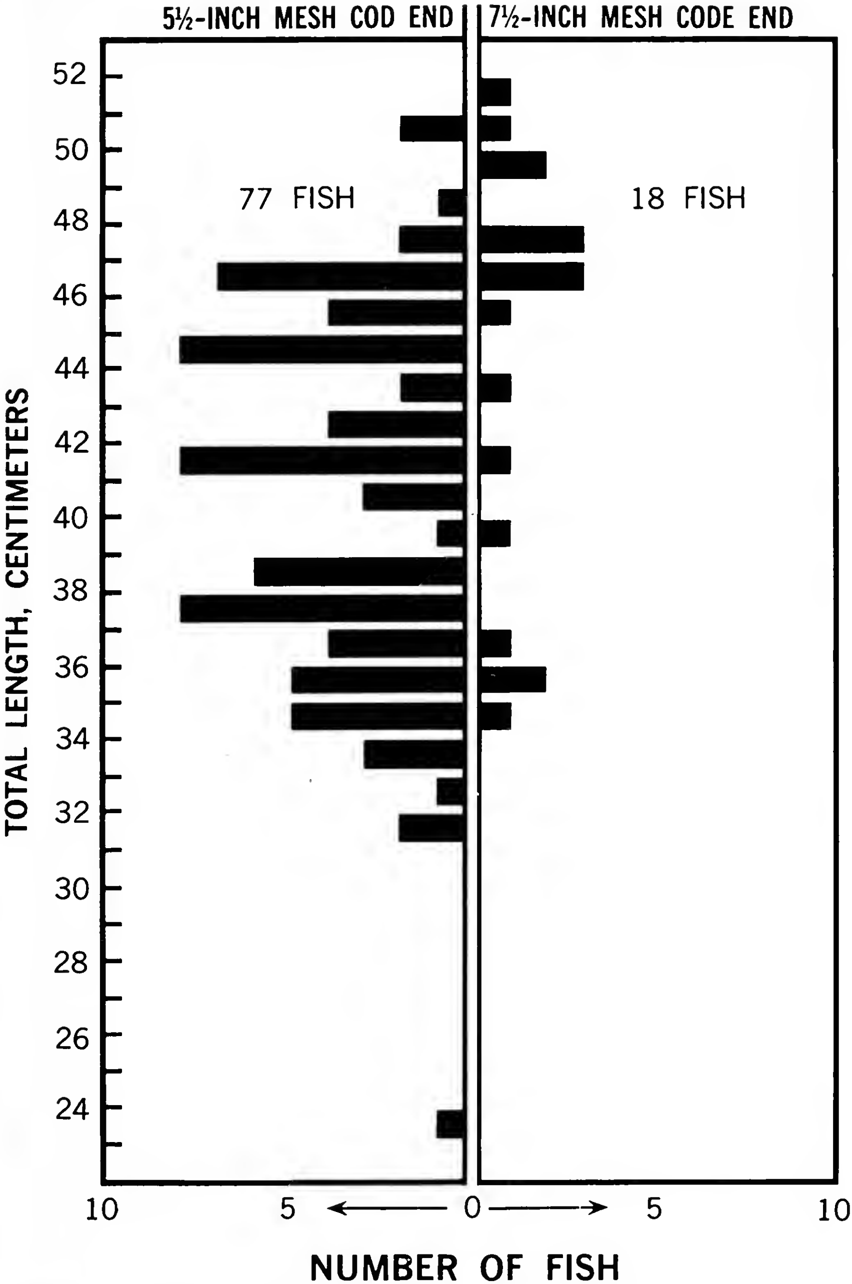

FIGURE 7. Comparison of Retention of Sand Sole in the 5- and 7½-Inch Mesh Cod Ends, 14 Paired Drags, 90 Min Each. Cruise 65-A-4.

Generally, except for halibut, fish of larger size escaped in greater numbers through the 7½-inch mesh (Figures 2, 3, 5, and 6). There was complete escapement (except for one fish) by hornyhead turbots larger than 300 mm (11.8 inches) from the 7½-inch mesh cod end (Figure 2 and 6). With sand sole the reverse was true, smaller fish appeared to escape while the larger ones were retained (Figure 7).

The 7½-inch mesh cod end provided almost complete escapement for halibut less than 560 mm in Experiments I and II, but the 5- and 5½-inch mesh retained many undersized unmarketable fish. Of the 422 halibut less than 560 mm (22 inches) captured in both experiments, slightly more than 4% were retained by the 7½-inch mesh cod end and almost 96% were retained by the 5- and 5½-inch mesh.

The difference in escapement between halibut and other flatfishes is likely linked to the basic behavioral pattern of the particular species. Hornyhead turbots feed mostly on clam siphons and fantail sole on crustaceans (pers. comm. John E. Fitch). These feeding habits do not require the aggressive pursuit that is needed by halibut which feed upon elusive fish. It is probable that this aggressiveness of sub-legal halibut provides motivation for their escapement through the 7½-inch cod end.

The 6.1 m (20 ft) 7½-inch mesh trawl cod end is a suitable management tool, retaining most legal sized halibut but providing escapement of undersized (less than 22 inches total length) juvenile halibut that are, by regulation, unmarketable.

The experiments show that fewer halibut of higher average weight and with greater total weight were captured by the 7½-inch mesh cod end than by the cod ends of smaller mesh size. The England Ministry of Agriculture and Fisheries (n.d.) and E. S. Russell (1926) found from their trawl experiments that this is true of other species.

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Calif. Fish and Game, 61(2): 95–103. 1975.

OBSERVATIONS ON THE FOOD HABITS OF LEOPARD SHARKS *(Triakis semifasciata)* AND BROWN SMOOTHHOUNDS *(Mustelus henlei)* [1]

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Information on the food habits of the brown smoothhound *(Mustelus henlei)* and leopard shark *(Triakis semifasciata)* was collected from May, 1970 through June, 1973. The stomach contents of 45 leopard sharks and 25 smoothhounds from San Francisco Bay, California revealed similar food habits as are found in Tomales Bay, California.

Of the smoothhounds examined, 39% contained shrimp, 35% crabs, and 22% fish. Of the leopard sharks examined, 17% contained shrimp, 16% crabs, and 19% fish. The occurence of a significant quantity of shore crabs (*Hemigrapsus oregonensis*) in smoothhounds indicates a definite intertidal feeding habit, which is not evidenced by the quality of food in leopard sharks. In addition, 17% of the leopard sharks contained fish eggs, 9% clam necks, and 19% contained worms. While shrimp, crabs and fish were important items in the diets of both sharks, leopards are distinguished by the appearance of clam necks, worms, and fish eggs in significant quantities. The occurrence of benthic forms like *Upogebia, Callianasa* and *Urechis* and various clam necks indicates a shoveling or burrowing habit by leopard sharks in capturing prey. This idea is supported by findings on concentrations of chlorinated hydrocarbons in leopard and brown smoothhound liver tissues.

INTRODUCTION

Brown smoothhounds (*Mustelus henlei*) and leopard sharks (*Triakis semifasciata*) are two of the most frequently encountered and abundant sharks inhabiting the estuarine waters of central and northern California. Brown smoothhounds are common, primarily in bays north of Monterey, with extensive populations in San Francisco, Tomales and Humboldt Bays (Herald and Ripley 1951; E. A. Best, International Pacific Halibut Commission, pers. comm.). Smoothhounds appear to be scarce in Elkhorn Slough (Herald et al. 1960) and absent in Morro Bay (Fierstine, et al. 1973). Leopard sharks are common from Magdalena Bay, Lower California to Oregon (Miller and Lea 1972).

Both leopard and brown smoothhound sharks are typical bottom forms. Both seem to spend an equal amount of time on or near the bottom, even though an earlier report indicated that leopards spend far less time near the bottom than smoothhounds (Russo and Herald 1968).

Although both of these sharks are frequently caught by sport fishermen and taken for food, little has been reported on their ecology and natural history in the estuarine ecosystem. Questions by sport fishermen on the effect of these sharks on the fisheries, along with observations of large numbers of sharks dead and dying on the beaches of

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Alameda, California (Russo and Herald 1968), prompted me to investigate the dietary habits of these elasmobranchs.

In 1951, Herald and Ripley reported that brown smoothhounds fed by preference on small crabs and shrimp in San Francisco Bay. Later, in 1960, it was reported that leopard sharks in Elkhorn Slough fed upon crabs, clams and fish, particularly the midshipman (*Porichthys notatus*) (Herald, et al 1960). Information on the food habits of both these sharks has been sketchy and general in nature.

The purpose of this study was to accumulate data on the species composition, and frequency of occurrence of their food items. In May of 1970 I began analysing stomach contents from leopard and brown smoothhound sharks as a part of a study of the sharks of San Francisco Bay. The occurrence of the Tomales Bay Shark-and-Ray Derby, sponsored by the Petaluma Outdoorsmen in June of 1971 and 1973, provided an opportunity for parallel analyses in a similar ecological situation. Difficulties in obtaining use of a vessel on a regular basis, foul weather, and problems with equipment, hampered attempts to conduct a year-round seasonal analysis in San Francisco Bay. Most of the observations made occur from the early spring months through the summer. Within San Francisco Bay a small number of samples were taken during the fall and winter months, though too few to reach conclusions about seasonal patterns.

STUDY AREA

Sharks were collected in south San Francisco Bay from subtidal waters between the Alameda Naval Air Station and Hunter's Point Naval Shipyard to the west, then south to the San Mateo Bridge. Most of the fishing was done within Alameda and San Francisco Counties. The areas fished ranged in depth from 4.57–17.08 m (15–56 ft).

METHODS

All of the San Francisco Bay specimens were collected on 152 m long (500 ft.) set lines using 5/0 hooks baited with squid. Most of the fishing was done on the bottom, although a few sets were made with the ends of the lines about 3–4.5 m (9.8 to 15 ft.) above the bottom. The center of these lines rested near the bottom. The Tomales Bay specimens were caught by rod and reel by derby contestants using squid and sardines as bait. Fishing depth, hook size, and location of capture varied.

All specimens were examined as soon as possible following capture. Some sharks were observed regurgitating under the stress of capture and handling. This may account for a small percentage of those in the "empty" category. The stomach contents of each shark were separated, analysed, identified and recorded prior to disposal. Spiral valves were not examined. In some cases of field identification, it was possible to identify individual food items to the species level, while in other cases only the generic identity was possible. Because of the volume of stomachs and contents analysed on site, it was not practical to preserve food specimens for later analysis.

TABLE 1—Food Items of Leopard Sharks From San Francisco and Tomales Bay 1970–1973

	Tomales Bay (98)*		San Francisco Bay (45)*		Totals (143)*	
	%F†	F‡	%F	F	%F	F
Shrimp						
Crago, sp.,						
Upogebia sp.,						
Callianasa sp.	14.3	14	22.2	10	16.8	24
Crabs						
Cancer Crabs						
Cancer sp.	13.3	13	22.2	10	16.1	23
Fish						
Perch						
Cymatogaster aggregata	3.06	3	--	--	2.09	3
Anchovy						
Engraulis mordax	1.02	1	4.44	2	2.09	3
Goby						
Clevelandia ios	--	--	2.22	1	.699	1
Plainfin Midshipman						
Porichthys natatus	4.08	4	4.44	2	4.19	6
Sanddab						
Citharichthys sp.	--	--	2.22	1	.699	1
Bat Ray						
Myliobatis californicus	4.08	4	--	--	2.79	4
Brown Smoothhound						
Mustelus henlei	2.04	2	--	--	1.39	2
Unidentified Fish	5.10	5	6.66	3	5.59	8
Fish Eggs						
Herring						
Clupea pallasi	--	--	15.5	7	4.89	7
Smelt						
Atherinopsis sp.	16.3	16	--	--	11.2	16
Plainfin Midshipman						
Porichthys notatus	2.04	2	--	--	1.39	2
Clam (Necks)	12.2	12	2.22	1	9.09	13
Worms						
Bristle Worm						
Nereis sp.	2.04	2	2.22	1	2.09	3
Fat Innkeeper						
Urechis caupo	16.3	16	17.7	8	16.8	24
Miscellaneous						
Squid (Bait)	9.18	9	6.66	3	8.39	12
Eelgrass						
Zostera marina	14.3	14	--	--	9.77	14
Octopus						
Octopus sp.	1.02	1	--	--	.699	1
Empty	31.6	31	17.7	8	27.3	39

* Number of shark stomachs examined.
† Percentage frequency: percentage of stomachs which contained a given food item.
‡ Frequency: number of stomachs which contained a given food item.

The data presented in Tables 1 and 2 relate only to the number of stomachs in which listed items occurred. Data on percentage frequency (%F) and frequency (F) of occurrence of food items in sharks' stomachs indicates those organisms which are commonly taken and those taken less often for food. No attempt was made to determine the percentage of volume of listed food items.

RESULTS

During the collecting period from May, 1970 to June, 1973, a total of 143 leopard sharks and 77 brown smoothhounds were processed. Forty-five leopards and 25 smoothhounds from San Francisco Bay were examined between May, 1970 and March, 1972. Ninety-eight leopards and 52 smoothhounds from Tomales Bay were analysed for food habits in June of 1971, and June, 1973.

Leopards from San Francisco Bay ranged in size from 53–130 cm (21–51 inches), while Tomales Bay specimens ranged from 72–150 cm (28–59 inches) (TL). Brown smoothhounds from San Francisco Bay ranged from 53 to 87 cm (21–34 inches), while Tomales Bay specimens ranged from 63 to 94 cm (25–37 inches) (TL).

While there is a bias in the unequal and low sampling of leopard and brown smoothhound sharks, several comparisons can be made. In both leopards and smoothhounds crabs, shrimps and miscellaneous

TABLE 2—Food Items of Brown Smoothhound Sharks From San Francisco and Tomales Bay, 1970–1973

	Tomales Bay (52)*		San Francisco Bay (25)*		Totals (77)*	
	%F†	F‡	%F	F	%F	F
Shrimp						
Crago sp.,						
Upogebia sp.,						
Callianasa sp.	30.8	16	56.0	14	38.9	30
Crabs						
Cancer Crabs						
Cancer sp.	32.7	17	40.0	10	35.1	27
Shore Crabs						
Hemigrapsus oregonensis	48.1	25	4.00	1	33.7	26
Fish						
Perch						
Cymatogaster aggregata	1.92	1	4.00	1	2.59	2
Anchovy						
Engraulis mordax	--	--	8.00	2	2.59	2
Goby						
Clevelandia ios	3.84	2	4.00	1	3.89	3
Sanddab						
Citharichthys sp.	1.92	1	--	--	1.29	1
Unidentified Fish	11.5	6	12.0	3	11.8	9
Fish Eggs						
Smelt						
Atherinopsis sp.	1.92	1	--	--	1.29	1
Worms						
Bristle Worm						
Nereis sp.	1.92	1	--	--	1.29	1
Miscellaneous						
Squid (Bait)	9.61	5	--	--	6.49	5
Sea Squirt						
Molgula manhattensis	1.92	1	--	--	1.29	1
Empty	9.61	5	12.0	4	11.6	9

* Number of shark stomachs examined.
† Percentage frequency: percentage of stomachs which contained a given food item.
‡ Frequency: number of stomachs which contained a given food item.

fishes are important food items (Tables 1 and 2). Generally, the range of items selected by leopard sharks is broader than that of smoothhounds.

Many sharks contained a variety of items, while others had fed extensively on a single type of food. It should be noted here that in all cases except one, eel grass was found in association with fish eggs. One leopard contained only a clump of eel grass within its stomach. Over 27% of the leopards and 11% of the smoothhounds examined had empty stomachs.

The composition of species taken by both sharks suggests behavioral differences between the two in the areas where feeding takes place (intertidal and subtidal) and the amount of time spent on or near the bottom.

Food Items

Shrimp:

Shrimp belonging to three generic groups occurred in 39% of the smoothhounds and 17% of the leopards. The blue mud shrimp (*Upogebia pugettensis*) and whole specimens of the bay shrimp (*Crago franciscorum*) appeared frequently: *Upogebia* and different species of *Crago* dominated the type of shrimp taken by both sharks. Often the partially digested remains of shrimp were not enough for species identification. On four occasions, pink ghost shrimp (*Callianasa californiensis*) appeared in the stomachs examined—one in a leopard and three in different brown smoothhounds.

Since both *Upogebia* and *Callianasa* are burrowing forms that rarely leave the shelter of their burrows, some questions are raised regarding how they are captured. Both shrimp rise to the mud's surface to discharge sand from their burrows and it is possible that capture might occur at this point.

Crabs:

Crabs of the genus *Cancer* sp. were found in 16% of the leopards and 35% of the brown smoothhounds. Cancer crabs measured from 1.27 cm (0.5 inch) across the carapace to over 4 cm (1.57 inches) in most cases. One partially digested cancer crab measured 8 cm (3.1 inches) in width. Cancer crabs usually occurred in quantity with as many as 14 occurring in the stomach of a brown smoothhound. Two young striped forms of *Cancer productus* were found in a leopard. Other species identification was made difficult by missing parts and advanced digestion. *Cancer* was the only genus of crabs found in leopard sharks, even though several other crabs exist in the same habitat and are potential food.

Of notable distinction was the appearance of shore crabs (*Hemigrapsus oregonensis*) in 34% of the smoothhounds. Both *Cancer* and *Hemigrapsus* crabs are staple items in the diet of brown smoothhounds. It was not uncommon to find half a dozen of each crab (*Cancer* and *Hemigrapsus*) in the stomach of a single smoothhound. The frequent occurrence of shore crabs in smoothhounds suggests intertidal feeding, which is not evident in leopard sharks. Of interest, however, was the absence in smoothhounds of other intertidal crabs such as *H. nudus* and *Pachygrapsus crassipes*, which share the same environment as *H. oregonensis*.

Fish:

Various species of fish appeared in over 19% of the leopards and 22% of the smoothhounds examined. In general, a greater diversity of fish was taken by leopards than smoothhounds. Shiner perch (*Cymatogaster aggregata*), anchovies (*Engraulis mordax*), gobies (*Clevelandia ios*), and sanddabs (*Citharichthys sp.*) were the main fishes occurring in both leopard and smoothhound stomachs. In addition to these, 4% of the leopard sharks also contained the plainfin midshipman (*Porichthys notatus*). Midshipmen occurred more frequently than any other species of fish in leopards. A 117 cm (46 inch) male leopard contained a 23 cm (9 inch) midshipman. Other midshipmen were smaller. Midshipmen were not found in smoothhounds. Anchovies appeared in 2% of the leopards and smoothhounds, and often occurred in numbers with as many as six full-grown anchovies in a shark's stomach. In July of 1972 I visited the San Rafael Bridge after receiving reports from Mike Valentine, engineer with the Division of Bay Toll Crossings. Mike had reported seeing sharks within the walls of the bridge supports. This structure appears as a concrete box with four walls that rise well above the high-tide mark and extend to within a few feet of the bottom, but supported at the corners. The opening under the support walls allows fish to move into the enclosure where currents are subdued and where the fish become temporarily trapped. During the field trip, we observed leopard sharks and spiny dogfish (*Squalus acanthias*) capturing anchovies by swimming into oncoming schools with their mouths open. No rapid or overt aggressiveness was noted. Periodically an anchovy appeared to swim right into a shark's mouth. Several leopard and dogfish sharks swam leisurely counter-clockwise to the clockwise movement of anchovies within the perimeter of the concrete walls. All of this took place at the surface, making observation easy.

San Francisco Bay Leopard sharks have not been known to eat other elasmobranchs. Nor have other large sharks like sevengill cowsharks *Notorhynchus maculatus*, which I have examined, been known to eat leopard sharks. Two leopard sharks from Tomales Bay, however, contained brown smoothhound pups (one per shark) measuring 23 cm (9.06 inches) (TL). Other Tomales Bay leopard sharks contained prematurely born bat rays (*Myliobatis californicus*). I suspect that leopard sharks took advantage of the numbers of young rays and smoothhound pups being dropped by the pregnant adults under the stress of capture and handling. A 107 cm (42 inches) female leopard shark contained a young ray which measured 15 cm (5.9 inches) across. Two other leopard sharks also contained young bat rays. One leopard shark had bitten off the wing tip of a large ray. The piece measured 7.62 cm (3 inches) across by 2.54 cm (1 inch) thick. Mature female bat rays examined at dockside in Tomales Bay contained young of the same size and condition as those found in leopard sharks. No elasmobranchs were found in smoothhounds.

Fish Eggs:

The appearance of fish eggs in sharks' stomachs was the only clear evidence of a seasonal feeding pattern in this limited study. Fish eggs are a much more important source of food to leopard sharks than to smoothhounds. Only 1% of the smoothhounds had taken eggs, while 17% of the leopard sharks fed on fish eggs.

Leopard sharks examined in February and March from south San Francisco Bay contained large quantities of sticky eggs measuring about 2 mm. each. Masses of these eggs were also found clinging to set lines. Shark stomachs were often full of just fish eggs. Because of the time of year and general nature of the egg masses, I believe these to belong to herring (*Clupea narengus pallasi*).

Leopard sharks examined in June from Tomales Bay also included vast quantities of eggs in their stomachs. Most of these 1 mm. eggs were associated with eelgrass (*Zostera marina*). These eggs were grayish-green, possessed a prominent integument and formed grape-like clusters. Apparently these belong to smelt (*Atherinopsis sp.*) (Roger Green, "Max" Eldridge, National Marine Fisheries Service, pers. comm.). Sharks were often so engorged with eggs that regurgitation resulted from handling. The stomachs of two leopards in the study held several midshipman eggs in each. Since midshipmen normally lay their eggs on the undersides of intertidal rocks, I can only think that these eggs were taken under unusual circumstances.

During the spawning season for herring and smelt, thousands of eggs are probably consumed by leopard sharks, and possibly other sharks. This adds a new predator to the eggs of herring as discussed by Hardwick (1973).

Clam Necks:

While clam necks were totally absent in the smoothhounds examined, they appeared as an important food item in leopard sharks. Clam necks and a single clam foot appeared in 9% of the leopard sharks. The upper sections of the necks had been bitten off. Most neck pieces measured from 1.27 to 2.54 cm (0.5 to 1 inch) in length. Physical differences among these neck pieces indicated that more than one species of clam was involved. A 135 cm (53 inch) female leopard from Tomales Bay contained 6 large necks thought to belong to the gaper or horseneck clam (*Schizothaerus nuttali*). The 6 pieces measured from 8 to 13 cm (3.1 to 5.1 inches) in length, by 2.54 cm (1 inch) in diameter.

While diving I have observed the siphons of horseneck clams extending 8–10 cm (3 to 4 inches) out of the mud. The clam immediately withdraws the siphon upon the slightest contact with any object. A hungary leopard shark would have to have a quick and sharp bite to obtain a clam neck of this size without having its face pulled into the mud by the power of the horseneck. Other, smaller clams probably do not extend their necks as far as *Schizothaerus*. For the shark, this would result in smaller pieces of neck and more contact with bottom sediments.

Another difference in feeding habits between leopard sharks and brown smoothhounds was observed in the case of worms. Only one of the smoothhounds examined contained a worm of any kind. In this case it was a bristle worm (Nereis sp.). However, in the base of leopard sharks, worms—like clam necks—proved an important food item. Less than 3% of the leopards contained bristle worms, but more than 16% of the leopards held the fat innkeeper (*Urechis caupo*). In many cases, a leopard had eaten several 13 cm (5.1 inches) long whole specimens.

One leopard contained 10 whole innkeeper worms, measuring about 10 cm (4 inches) each.

MacGinitie and MacGinitie (1968) stated that "*Urechis* is readily eaten by fish or crabs, but, since it never leaves its burrow, the one that is occasionally found in the stomach of a fish must be made a available to the fish by some disturbance of the mud significantly great to expose *Urechis*." Since leopards are known to take *Urechis* frequently along with other mud-dwelling forms like *Upogebia*, *Callianasa* and clams (necks), it appears as though the leopard shark may employ some rapid burrowing, shoveling or side to side motion of the head to expose and grasp these animals. Poor visibility usually prevents observing this phenomenon in the shark's natural environment.

Miscellaneous:

The only miscellaneous items that appeared in the shark stomach samples worthy of note was a sea squirt (*Molgula manhattensis*) and an octopus (*Octopus* sp.).

A brown smoothhound from Tomales Bay contained several sea squirts along with shrimp parts and crabs. None of the sea squirts were attached to seaweed, as they are usually found in nature. On the same day a leopard was found to contain a 5 cm (2 inches) long by 2.54 cm (1 inch) thick section of an octopus tentacle. Digestion had not proceeded far and the suction discs were apparent. Another leopard shark contained two 22-caliber bullet shells, several pebbles, and a single *Urechis*.

DISCUSSION

Both leopard and brown smoothhound sharks are important elements in the food web of estuarine communities. The evidence presented indicates no significant effect on the quality of the bay sports fishery. While anchovies are taken by both sharks and while leopards feed on smelt and herring eggs, it seems doubtful that a decline in the shark population would result in an improved fishery. Too many other predators are involved. The types of other fishes taken by these sharks are not generally regarded as important forage fish for game species. Many of the clams taken are probably subtidal and beyond the reach of the sportsman.

This study suggests little or no intertidal feeding by leopards, even though they are frequently caught by inshore fishermen, while establishing such behavior for smoothhounds. Since there are also distinct differences in the types of food taken by each shark, competition is probably reduced, allowing each to co-exist in the same general environment. Because of the variety of benthic forms taken by leopards and the frequency of leopards caught on bottom set lines, this shark may spend more time on or near the bottom than previously thought.

Leopard shark feeding behavior apparently involves a disturbance of bottom sediments as indicated by the food species involved. Although shrimp are taken in quantity by smoothhounds, a similar form of behavior is not otherwise indicated. Because sediments usually have a higher concentration of pesticides than open water, bottom fishes that regularly disturb the mud in capturing food may contain higher concentrations than similar midwater fishes or bottom fishes that do not disturb the mud. This idea is supported by pesticide analysis of liver tissues from leopard and brown smoothhound sharks I collected. Pesticide analyses of 5 liver samples from each of the 2 species of sharks completed in 1969 at the Environmental Protection Agency laboratory in Alameda, California, revealed that leopard sharks contained an average concentration of PCB (polychlorinated biphenyls) of 46.9 ppm, while smoothhounds had an average of 22.5 ppm of PCB. The same liver tissues revealed an average TICH reading (total identifiable chlorinated hydrocarbons—which included DDT, DDD, DDE) of 108.2 ppm for leopards and 36.9 ppm for smoothhounds. While the effect of these concentrations on the sharks was not determined, nor was any ''normal'' concentration established, the data suggest that because of a habit of nosing into the mud, leopards concentrate higher levels of pesticides than smoothhounds who do not engage in this activity to any great extent.

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NOTES

A PRELIMINARY LIST OF FISHES COLLECTED FROM RICHARDSON BAY, CALIFORNIA 1972–1973

From June 1972 to July 1973 sampling of fish eggs and larval, juvenile and adult fishes was conducted by Tiburon Fisheries Laboratory (National Marine Fisheries Service, NOAA) in Richardson Bay, a part of the San Francisco Bay system (Fig. 1). The sampling was part of a pilot program to lead toward a more extensive baseline study of fishery resources and their ecological relationships within and dependence upon San Francisco Bay.

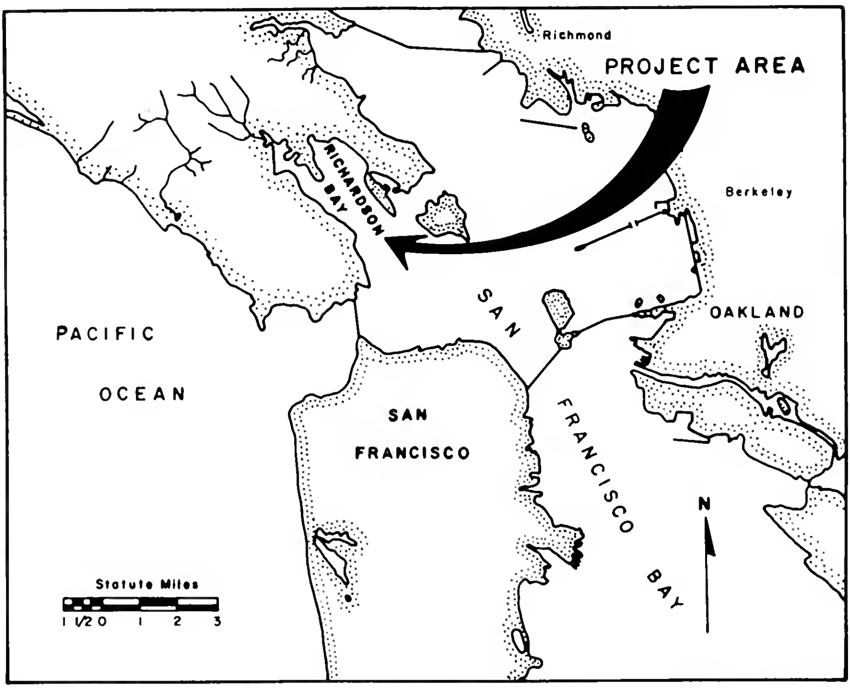

FIGURE 1. Location Map.

Sampling for adult and juvenile fishes was conducted with gill nets and trawls at 9 randomly selected stations each month with the exception of October 1972. The gill nets used were 6 ft in depth by 100 ft long and made of monofilament nylon. Each net was constructed from different panels laced together. The mesh sizes of these panels were randomly selected from 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, 4 and 6 inch stretched mesh, each size being used twice in the four nets that we used. At each station selected, one net was fished for 2 hours at the surface. Often, in waters less than 6 ft deep, the nets covered the entire water column.

The trawl was a standard shrimp "try net" with head rope length

TABLE 1—Fishes Collected From Richardson Bay, 1972–1973

Scientific name	Common name	Eggs or larvae collected	Number of juveniles or adults captured
Mustelus henlei	Brown smoothhound		38
Triakis semifasciata	Leopard shark		42
Squalus acanthias	Spiny dogfish		1
Raja trachura	Roughtail skate		1
Myliobatis californica	Bat ray		4
Acipenser medirostris	Green sturgeon		3
Alosa sapidissima	American shad		1
Clupea harengus pallasi	Pacific herring	x	22
Dorosoma petenense	Threadfin shad		7
Engraulis mordax	Northern anchovy	x	9
Hypomesus pretiosus	Surf smelt		5
Porichthys notatus	Plainfin midshipman		16
Merluccius productus	Pacific hake	x	
Microgadus proximus	Pacific tomcod		34
Brosmophycis marginata	Red brotula	x	
Atherinops affinis	Topsmelt		265
Atherinopsis californiensis	Jacksmelt		351
Syngnathus griseolineatus	Bay pipefish	x	14
Morone saxatilis	Striped bass		72
Trachurus symmetricus	Jack mackerel	x	
Cynoscion nobilis	White seabass	x	
Genyonemus lineatus	White croaker		1
Cymatogaster aggregata	Shiner perch		1,716
Embiotoca jacksoni	Black perch		49
Hyperprosopon argenteum	Walleye surfperch		23
Hypsurus caryi	Rainbow seaperch		9
Micrometrus minimus	Dwarf perch		133
Phanerodon furcatus	White seaperch		1,353
Rhacochilus toxotes	Rubberlip seaperch		8
Rhacochilus vacca	Pile perch		93
Neoclinus uninotatus	Onespot fringehead		1
Clevelandia ios	Arrow goby		1
Lepidogobius lepidus	Bay goby		3
Peprilus simillimus	Pacific pompano		1
Sebastes auriculatus	Brown rockfish		9
Hexagrammos decagrammus	Kelp greenling		1
Ophiodon elongatus	Lingcod		16
Enophrys bison	Buffalo sculpin		2
Leptocottus armatus	Pacific staghorn sculpin	x	176
Oligocottus maculosus	Tidepool sculpin	x	
Scorpaenichthys marmoratus	Cabezon		1
Citharichthys sordidus	Pacific sanddab	x	7
Citharichthys stigmaeus	Speckled sanddab		165
Paralichthys californicus	California halibut	x	
Hypsopsetta guttulata	Diamond turbot	x	3
Parophrys vetulus	English sole		674
Platichthys stellatus	Starry flounder	x	70
Symphurus atricauda	California tonguefish	x	

of 20 ft and foot rope of 23½ ft. Otter boards measured 1 ft by 2 ft and were hung from 10 ft bridles. Mesh size in the main body of the net was 1⅜ inch stretched mesh with 1 inch stretched mesh in the cod end. The trawl was always fished on the bottom. At each station, one 3-minute tow was made at a speed of 3.5 knots.

Ichthyoplankton was sampled with surface plankton tows using a half-meter net and on 24-hr monitoring stations using an anchored channel net (Lewis, *et al.* 1970). Three-minute tows were made in replicates of two at 15 randomly selected stations each 6 weeks. Each 12 weeks, 24-hr monitoring was conducted at 2 fixed stations, one in the main ship channel off the Corps of Engineers dock in Sausalito, the other inside Cone Rock, near the mouth of Richardson Bay. The direction of the channel net was reversed at each tidal change.

All of the juvenile and adult fish sampling and surface plankton tows were conducted during daylight hours.

This preliminary list (Table 1.) of fishes collected and their relative abundance in the catch is published here for the possible interest of other workers in the shallow areas of San Francisco Bay. Two species in this list have not to my knowledge been reported previously from San Francisco Bay: roughtail skate (*Raja trachura*) and white seabass (*Cynoscion nobilis*). Unaware of its rarity, I identified the male roughtail skate in the field, using Miller and Lea's (1972) guide and returned it to the water. It was caught in the trawl on May 31, 1973. The white seabass larva was collected and identified by Maxwell Eldridge (Tiburon Fisheries Laboratory) in June 1972. Identification was verified by Elbert H. Ahlstrom. The specimen is preserved in the reference collection at Tiburon Fisheries Laboratory.

I do not presume that the list is completely representative of fishes found in Richardson Bay. Shortcomings of gear and sampling methods normally preclude this possibility. Much of the plankton material is still being worked up. We expect additional species will show up in these collections. More detailed publications will follow a more intensive examination of our data and collected materials.

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CHANGES IN THE SPECIES COMPOSITION OF SHARKS IN SOUTH SAN FRANCISCO BAY

Sharks were collected in San Francisco Bay between the Dumbarton and San Mateo Bridges between May, 1972 and April, 1973. Data collected from this 57 km ^{2} (22 mile ^{2}) area were used to examine cyclic changes in shark species composition. Herald (1951) using data compiled from the annual summer shark derbies at Coyote Point located 3.2 km (2 miles) north of this collecting area, noted yearly changes in species composition and abundance. This is the first published study examining the general seasonal changes in shark abundance and species composition in San Francisco Bay.

Marine Ecological Institute, Redwood City, California, provided the 78-foot research vessel, *Inland Seas*, for the collection of specimens. Collection stations are shown in Figure 1. Catches from all stations have been combined for analysis.

The three capture methods used in this study were: otter trawl, deployed from the *Inland Seas*; a twelve hook set line, deployed alongside the anchored vessel; and rod and reel. The latter two methods used No. 3 snelled hooks. Cut anchovy was used for bait.

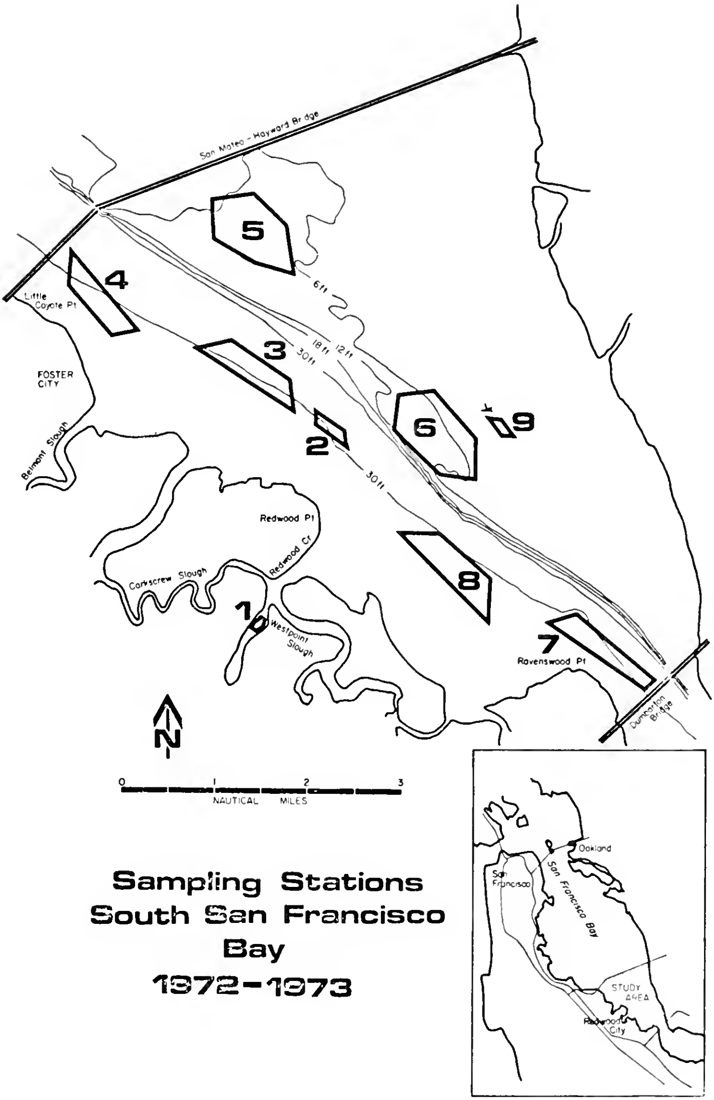

FIGURE 1. Sampling stations—South San Franisco Bay—1972–1973.

Sharks were weighed and measured and inspected for external parasites upon capture. The species, sex and general physical condition of each shark was also noted.

Shark specimens were preserved in 15% formalin. A slit through the ventral surface insured internal organ preservation. Stomachs used in food analysis were removed immediately, and only the stomach itself was preserved. Volumetric and quantitative analysis of the food items was performed within 1 week of capture.

TABLE 1—**Monthly Catches of All Species Expressed as Total Number of Individuals**

Month	No. samples*	*M. henlei*	*T. semifasciata*	*S. acanthias*	*N. maculatus*	*G. zyopterus*
May (1972)	11	6	19	0	0	0
June	4	9	5	0	0	2
July	6	28	5	0	0	0
August	4	49	7	0	0	0
September	2	3	1	0	0	0
October	5	14	8	0	1	0
November	7	18	11	10	0	0
December	3	4	16	8	0	0
January (1973)	2	0	1	2	0	0
February	5	1	2	20	0	0
March	11	0	5	17	0	0
April	3	0	12	7	0	0
Total	63	131	92	64	1	2
Percent of total		(45.2)	(31.7)	(22.0)	(0.36)	(0.74)

* Sample = One (1) deployment of each method at each station per month.

TABLE 2—**Monthly Percentages of the Shark Species Catches Expressed as Percent of the Total**

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
M. henlei	24	56	85	88	75	61	46	9	0	4	0	0
T. semifasciata	76	31	15	12	25	35	28	57	33	9	23	63
S. acanthias	0	0	0	0	0	0	26	34	67	87	77	37
G. zyopterus	0	13	0	0	0	0	0	0	0	0	0	0
N. maculatus	0	0	0	0	0	4	0	0	0	0	0	0

Numbered tags were tied around the openings of the extruded stomachs for identification. Volumetric analysis of the contents was performed using a water-filled graduated cylinder. Displacement of the water column by the added contents was measured as the total volume. Individual food items were removed and the volume of each item measured using a similar process.

Brown Smoothhound, Mustelus henlei

Constituting 45.2% (131/290) of the total catch, the brown smoothhound was most numerous in the catches from June through September (Table 1, 2). Females outnumbered males 2.3 to 1, and averaged 58.6 cm (28 inches) while the males averaged only 41 cm (20 inches). Herald (1951) states that this species constitutes about 45 to 50% of the total shark population in San Francisco Bay. The results of this study agree with this statement, however, no brown smoothhounds were collected in this study, from January through April, 1973. Therefore, it may be said that in comprising a majority of the shark population on a yearly basis, winter and spring months find few, if any, of this species present in the south bay.

Bane (1971) states that the brown smoothhound females reach maturity at about 76 cm Of the 13 specimens of this species and size, all were females, and 5 of the 13 had embryos within the uteri. Varying in degrees of development, the size of these embryos ranged from 3 to 19 cm. The smallest specimen of brown smoothhound captured in this study was a 19 cm male, collected in July, 1972; numerous brown smoothhounds ranging from 20 to 23 cm were collected throughout the summer months.

Leopard Shark, *Triakis semifasciata*

This species was the second most abundant collected in the study. Constituting 31% (92/290) of the total, leopard sharks were collected in every month of the year. The leopard shark was the dominant species in the spring months, May, 1972 and April, 1973, constituting 76 and 63% of the month's catches, respectively.

The largest shark collected in this study was a female leopard shark measuring 121 cm (59 inches) and weighing 7.7 kg (17 lbs.). This specimen had six 10 cm embryos within the uteri. No other female leopard sharks were found to have developing young, however, five females over 110 cm did have eggs within the uteri. These eggs ranged from 2 to 5 cm in diameter.

As in the brown smoothhound, females were consistently larger than males, averaging 65 and 49 cm respectively. Males and females, however, were about equal in number (45 to 47).

Spiny Dogfish, *Squalus acanthias*

The spiny dogfish, enumerated by Herald (1953) as the second most abundant shark in the south San Francisco Bay, was the dominant species during the winter months in the study. Constituting only 22% (64/290) of the total catches, this species outnumbered all others from January, 1973 through March, 1973, ten to one (Table 1, 2).

Females, outnumbered males 7 to 1 (56 to 8) and were larger, averaging 77 cm total length, and weighed, on the average, in excess of five pounds. Males ranged in length from 65 to 80 cm, averaging 71 cm.

Females were found to be numerous in the study area and tended to school by size. A large school was found near the San Mateo Bridge, in January and February, however, this species could be caught throughout the entire south bay during the winter months. As many as

TABLE 3—Percentages of the Food Items of Three Species of Sharks Collected From San Francisco Bay [1]

	Crabs	Isopods	Shrimp	Worms	Fish	Clams	Fish eggs	Misc.
M. henlei (57)[2]	28.6	27.4	19.5	12.3	5.4	0.0	0.0	6.8
T. semifasciata (26)	12.7	2.8	9.0	63.7	5.1	7.0	5.0	0.0
S. acanthias (28)	2.4	0.0	11.7	0.0	83.5	0.0	0.0	2.4

[1] Percentages indicate number of specific items/total number of all food items ×100.
[2] ( ) indicates number of stomachs analyzed.

15 spiny dogfish all within 2 cm in length were caught, using hook and line and set line methods, in one 90-minute period in January, 1973.

Soupfin Shark, Galeorhinus zyopterus

The soupfin shark, historically an important Vitamin A source (Templeman 1944), was represented by only two specimens in this study. Both of these, a 72 cm male and a 76 cm female, were collected in June, 1972. Constituting only 0.74% of the total catch, the decline of this species, apparently due to extensive fishing, has been noted by Herald (1951) and others for some time.

Sevengill Shark, Notorynchus maculatus

A single 76 cm male sevengill shark, collected in October, 1972, was the only specimen of this species collected.

Food Habits

One of the purposes of this study was to examine differences in food habits, as well as species composition of the sharks collected.

Crabs, predominantly *Hemigrapsus oregonensis*, constituted the largest number of items of brown smoothhound, followed by isopods, shrimp and polychaete worms (Table 3). Clam remains and siphons, present in the stomachs of leopard sharks were absent in brown smoothhounds. Both of these shark species are considered benthic feeders by Herald, thus the absence of clam shells and siphons in brown smoothhounds is unexplained.

Polychaete worms, constituting only 12.3% of the items in brown smoothhound were most numerous (63.7%) in the diet of leopard sharks. Crabs, shrimp, clams, and fish as well as atherinid eggs followed in abundance in the diet of leopard sharks.

Spiny dogfish apparently preferred pelagic fish to the embiotocids found in leopard sharks' diets. Consisting predominantly of striped bass (*Morone saxatilis*), and jacksmelt, (*Atherinopsis californiensis*) fish items consituted 83.5% of the food items of spiny dogfish. Scales within the stomachs of the spiny dogfish indicated that on at least one occasion, the shark had been feeding on a 7 year old striped bass. Anchovies, other than bait items, and herring also were present in the stomachs of spiny dogfish.

Distinct changes in the species composition of the shark population were observed in records of catches covering a full year. The brown smoothhound, most numerous in the summer months, disappeared from the catches in January, March and April. The leopard shark, collected every month, was the dominant species in the early spring, while the spiny dogfish appeared from November through March.

Forty-two brown smoothhound ranging in size from 19 to 25 cm constituted the smallest specimens collected. This data tends to support the premise that San Francisco Bay is indeed a nursery ground for some species of sharks, apparently brown smoothhound and spiny dogfish.

Food habit differences for the three dominant species is one reason for the coexistence of these species in a small area throughout the year.

The percentages enumerated in this study, because of the unusually heavy rainfall recorded in 1972–73 and subsequent decrease in salinity and water temperatures of San Francisco Bay, may not be indicative of a "normal" species composition of bay sharks. It is, however, indicative of distinct changes in species composition during the year.

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—*Leray A. de Wit, Dames and Moore, Marine Services, 1100 Glendon Ave., Los Angeles 90024.* *Accepted November, 1974.*

FIRST CALIFORNIA RECORD OF THE SERRANID FISH *ANTHIAS GORDENSIS* WADE

EDMUND S. HOBSON

During February, 1974, James R. Chess and I collected a single specimen of *Anthias gordensis* Wade, 102 mm (4 inches) standard length (SL) (Figure 1), at Ship Rock, Santa Catalina Island (33° 28′ N, 118° 29′ W). When speared, this fish was the only member of its species seen amid a large aggregation of blacksmith, *Chromis punctipinnis*, that hovered close above a rocky ledge at a depth of about 40 m (132 ft). The specimen, now in the fish collection at Scripps Institution of Oceanography (SIO 74-22), was identified by Richard H. Rosenblatt of that institution.

Anthias gordensis was described by Wade (1946) from a 127 mm (5 inch) SL holotype and a 130 mm (5.1 inch) SL paratype, both dredged at a depth of about 150 m (495 ft) near inner Gorda Bank, Cape San Lucas, Lower California, Mexico. Dr. Rosenblatt (pers. comm.) observed large numbers of this species from the Cousteau diving saucer at depths between 100 and 200 m (330 and 660 ft) at Cape San Lucas, but because this fish inhabits infrequently sampled deeper reefs, relatively few specimens have been collected. Until now, the northernmost record of the species is a single individual 205 mm (8.1 inches) SL taken near the bottom 110 m (363 ft) deep at Guadalupe Island, Mexico (29° N, 118° 30′ W), by Albert Stover, Scripps Institution of Oceanography (SIO 63-161).

Only one other species of this genus has been reported from the eastern Pacific: *Anthias sechurae* (Barton) from Peru, based on a 188 mm (7.4 inch) SL holotype and a 192 mm (7.6 inch) paratype (Barton 1947). Hildebrand and Barton (1949) recognized that *A. sechurae* may be a junior synonym of *A. gordensis*, with differences in descriptions being partly due to differences in size between type specimens, but the question remains unresolved.

The following combination of characters of the specimen from Santa Catalina Island confirm its identity: dorsal X, 15; anal III, 7; body depth and head both 3 in standard length; eye 3.7 in head; scales ctenoid, 48 on lateral line; head and maxillary scaled, dorsal and anal fins without scales.

Stomach contents of the specimen from Santa Catalina Island, identified by James R. Chess, and ranked as percentage by volume of identifiable material, were as follows: 67 calanoid copepods, 0.6 to 1.2 mm (0.02 to 0.05 inch) long, 75% ; 14 cyclopoid copepods, 0.8 mm (0.03 inch) long, 10% ; 6 euphausid larvae, 1.0 mm (0.04 inch) long, 5% ; and 9 fish eggs, 1.0 mm (0.04 inch) in diameter, 10%. Clearly this fish is a planktivore, as is the blacksmith (Quast 1968), with which it was swimming when collected.

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—*Edmund S. Hobson, Tiburon Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, P.O. Box 98, Tiburon, California 94920.* *Accepted November 1974.*

FIGURE 1. Specimen of *Anthias gordensis* Wade, 102 mm SL, collected at Santa Catalina Island (SIO 74-22).

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