Population Studies Of Marine Animals In Bolinas Lagoon

G. Chan

by Gordon Chan

COLLEGE OF MARIN
Kentfield, California

POPULATION STUDIES of MARINE ANIMALS

in

BOLINAS LAGOON

November, 1967

by

Gordon L. Chan, B. A., M. A.
Staff, Bolinas Marine Station

College of Marin
Kentfield, California 94904

TABLE of CONTENTS

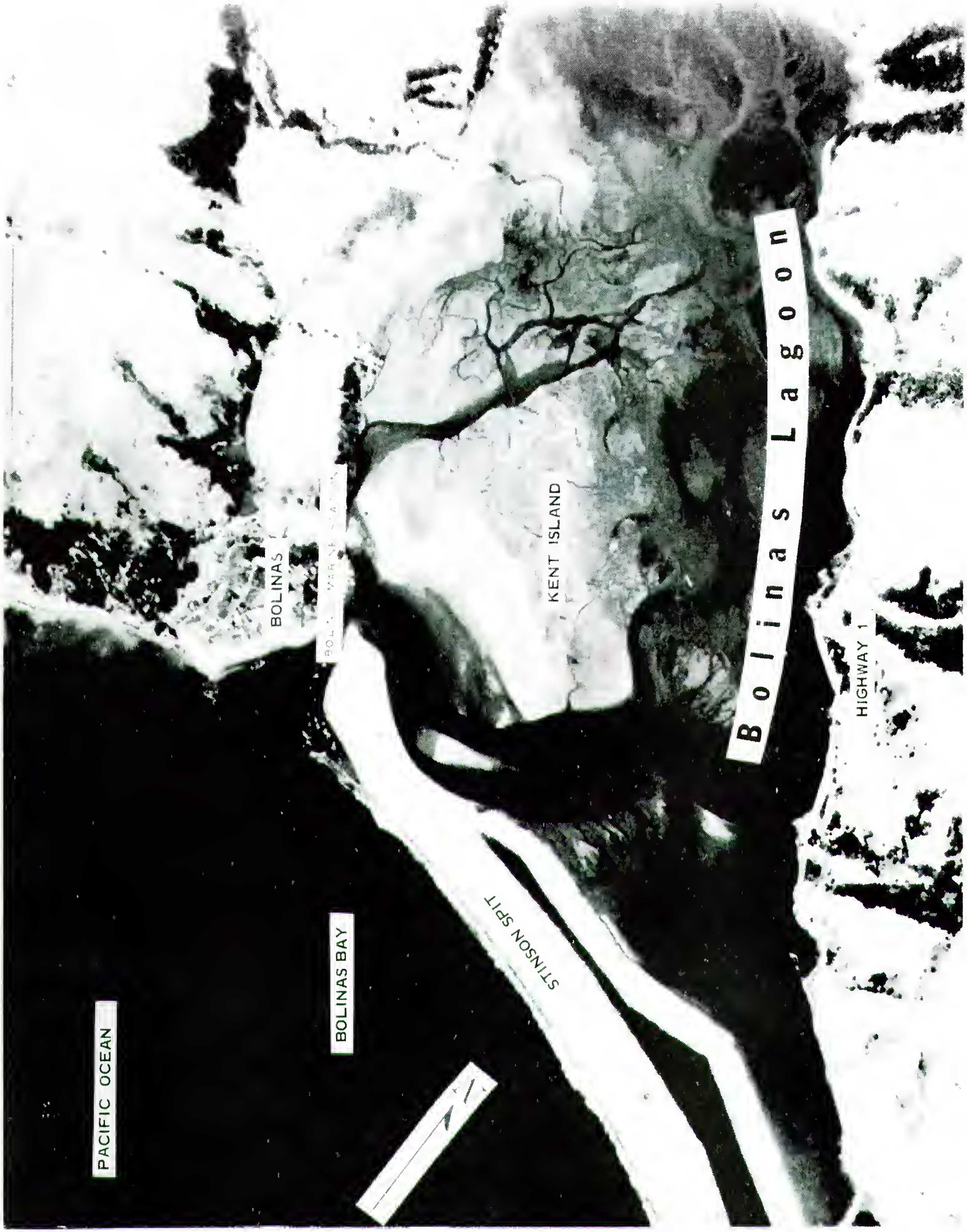
PREFACE

In the organization of this report, the following individuals were part of the research team that gathered the statistical data on the Bolinas Lagoon organisms:

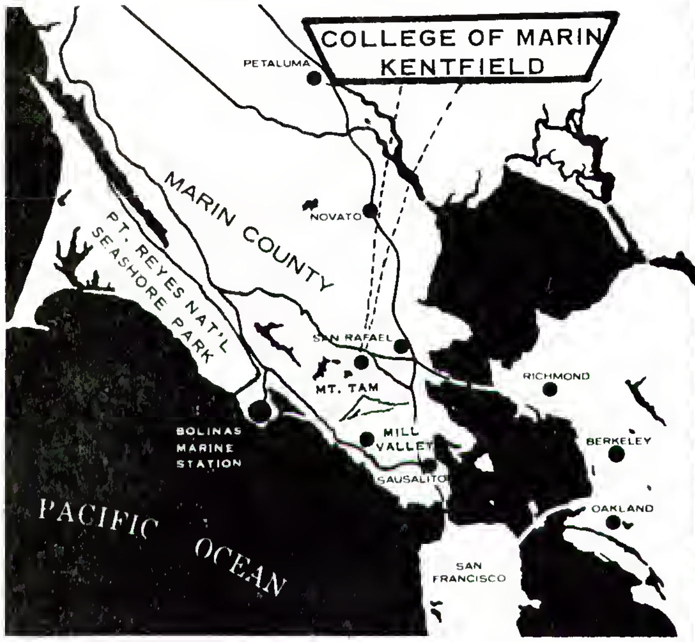
Bolinas Marine Station Staff Instructor	- Mr. Al Molina
Bolinas Marine Station Technician	- Mr. Craig Hansen
Summer Laboratory Assistant	- Terry McGuire
James Fowle - - - - - - - - - - - -	- <u>Hemigrapsus oregonensis</u>
Karen Fuller and Donna Schultz - - - - - - - -	- <u>Tresus nuttallii</u>
Terrance Gosliner - - - - - - - -	- Plankton, <u>Hermissenda crassicornis</u>
Ken Kornelis - - - - - - - - - - - -	- <u>Cerithidea californica</u>
Ron Nolan - - - - - - - - - - - -	- Fishes
Melvin Stanley - - - - - - - - - -	- <u>Olivella biplicata</u>
Tinsley Stetson - - - - - - - - - -	- <u>Orchestoidea californiana</u>
Melvin Verzi - - - - - - - - - -	- <u>Callianassa californiensis</u> <u>Upogebia pugettensis</u>
Gary Williams - - - - - - - - - -	- Plankton
Dr. Joel Gustafson - - - - - - - -	- Advisor, San Francisco State College

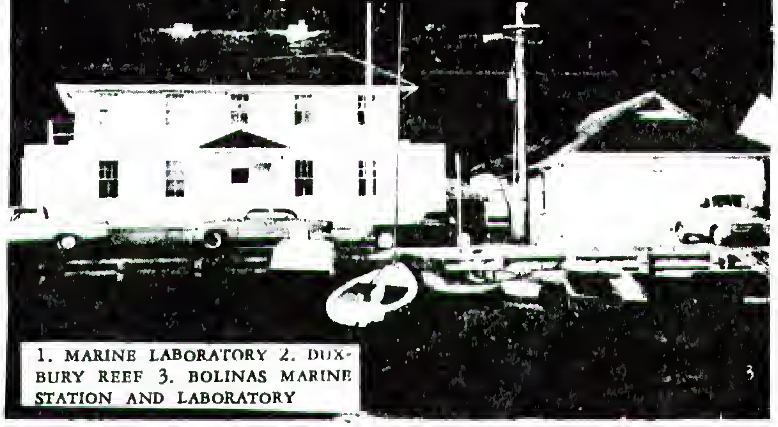
My thanks to the above hard working individuals. Some of the charts and area plots in this report are the creditable work of this group. My interpretations and revisions of their graphs, tables, and maps are included and summarized in this report.

G. L. C.


PACIFIC OCEAN
BOLINAS BAY
STINSON SPIT
BOLINAS
KENT ISLAND
Bolinas Lagoon
HIGHWAY 1

BOLINAS MARINE STATION





1. MARINE LABORATORY 2. DUXBURY REEF 3. BOLINAS MARINE STATION AND LABORATORY

Facilities

Classroom and laboratory study is conducted at the College of Marin's Bolinas Marine Station. This marine laboratory is situated in the ocean-side community of Bolinas, California 22 miles north of San Francisco, and 30 miles from the college main campus at Kentfield. The Marine station complex includes a marine laboratory equipped with 20 student stations.

A circulating sea water system supplies laboratory aquaria for instructional research purposes. Adjoining the laboratory is a two story station house with a marine library, research rooms and offices, sleeping quarters and kitchen for overnight field trips.

Ecological Studies Areas

Within one mile of the Bolinas station are some of the most outstanding marine intertidal regions of the Pacific Coast. This headland region offers acres of shale reefs with an abundance of invertebrate organisms. The "front yard" of the marine station is the famous Bolinas Lagoon with its massive marshes, mudflats, and bird sanctuary. The station also has two Boston whalers and a 32-foot Diesel boat for shallow and deep water studies. Marine investigations are conducted the year around by class groups and by individuals working on research projects.

OCEANOGRAPHY STUDIES

GROUP FISH STUDIES 6. INDEPENDENT STUDIES ON A BASKING SHARK

I. POPULATION STUDY of MARINE ANIMALS in BOLINAS LAGOON

Introduction

All along the Pacific Coast, the shoreline is blessed with bodies of marine water that are enclosed by a sandy bar or spit. These captured marine enbayments with an opening to the ocean are called " lagoons ". The author has visited every listed lagoon in California, ranging from Mission Bay in San Diego up to Arcata in Northern California.

There is no question that the Bolinas Lagoon and Limantour Lagoon in Marin County have the most abundance and diversity of animal life. The basic reason here is that the other "natural" lagoons have all been changed by man with no thought as to planning or preserving the marine organisms. A good example of "no planning" was given in a speech by Mr. Dale H. Levander, Principal in the firm, Development Research Associates of Los Angeles, at the Ocean Industry Conference, October 10-11, 1967, at Los Angeles, California. His statements are as quoted:

"In 1966, the U.S. Department of Commerce estimated that 125 million people used the beaches in California. Moreover, 50 million people participated in boating in both marine and fresh water. To provide for the increase in recreation, Southern California has created sixteen large boat marinas, with about eight of these constructed within the last ten years. With the projected growth in additional recreation, six additional marinas are needed. These will probably be island marinas that are built out from the coastline down to an approximate depth of 40 feet, involving about one billion dollars in coastal real estate. There are no attempts now to include a study of what will happen to the ecology in Southern California."

This master planner also showed slides of a marshland which he called "wasteland", followed with a slide of a marina clogged with boats -- he called this latter slide, "beautiful". Most of the Ocean Industry conferees disagreed with the ideals promoted by this speaker.

The famed marine biologist Ed Ricketts, of the John Steinbeck era, once wrote about the "teeming" marine life in Mission Bay and Newport Bay of Southern California. These two areas are now part of the sixteen large boat marinas in the southern part of the state. In contrast to this past picture, the state of California has established the Governor's Advisory Commission on Ocean Resources (GACOR) and the Interagency Council on Ocean Resources (ICOR) to study and coordinate the master plan for the orderly long-range conservation and development of the total resources of the marine and coastal environment throughout the state of California which will insure wise multiple use in the total public interest. The goals and proceedings of GACOR may be reviewed in the State of California published report: Governor's Advisory Commission on Ocean Resources, May 26-27, 1967, and June 30, 1967.

Dr. Dixie Lee Ray, marine zoologist at the University of Washington, has stated that population studies of "standing marine stocks" are indeed rare among science research; thus, this paper is an attempt towards understanding the lagoon population parameters. The total summation of all the reports concerning Bolinas Lagoon will certainly be classified as uniquely important throughout the United States. One of the hopes of this project is that many will come to Bolinas to utter a future epitath, saying, "Here man contributed instead of depleted."

II. STATISTICAL REFERENCES

Sampling Techniques

The following techniques were utilized throughout these reported studies of marine organisms in the Bolinas Lagoon.

Sample Plots

Quadrads were plotted in each of the studies. Samples were taken at the intersection of quadrangel lines. Distances between quadrads differ according to the experimenter and contour of the study areas.

Sampling Methods

To insure a fairly accurate unbiased estimate of the sample statistics, random sampling techniques were used to select the sample quadrad intersections. Two are described below:

(1) Intersection of quadrangel lines were numbered and drawn randomly from a common box.

(2) A sampling board was divided into quadradic plots and a pebble was tossed on to the board to select the sample quadrad.

Two assumptions underlie the statistics: Normality of population distribution curves (pictured thusly- ) and independence between and within sample groups.

All attempts of random sampling were designed to eliminate the bias of sampling areas of greater density of organisms. This was especially true of investigators tossing the pebble to choose the sample quadrad plots in these higher density areas. Unconscious bias may have influenced some of the statistical summaries listed in this report. However, the overall picture must be assumed to fall into the general picture of true random sampling.

Maps

The overall maps of Bolinas Lagoon enclosed in this paper describing the area of each organism are not accurate scaled drawings of the exact study area: i.e., Map 8, 10, etc.. These overall maps are only used to approximate the study area. Other englarged study area maps do indicate exact locations. To determine the specific area, the interested investigator needs to consult the overall study map which is permanently housed at the Bolinas Marine Station.

STATISTICAL FORMULAE[1]

The formulas below were utilized in the statistical computation of the population density of the Bolinas Lagoon organisms.

A. Sample Estimators

Ungrouped Data Mean: $\bar{X} = \sum_{i=1}^{n} \frac{x_i}{n}$ where $n =$ sample size

Grouped Data Mean: $\bar{X} = \sum \frac{x_k f_k}{n}$

Variance: $s^2 = \frac{n \sum x_i^2 - [\sum (x_i)]^2}{n(n-1)}$

Standard Deviation: $s = \sqrt{\text{Variance}}$

B. Population Esimates

The 95% confidence interval is the most common interval estimate for the population. This states that, on the basis of repeated sampling with 95% confidence interval of μ (population mean) computed for each sample, we would expect 95% of these intervals to actually contain the true population mean.

Three interval formulas were used:

1. For known population variance, Z tables, regardless of sample size:

$$P\left(\bar{X} - Z_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} \leq \mu \leq \bar{X} + Z_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}\right) = 1 - \alpha$$

2. For unknown population variance, sample size less than 30:

$$P\left(\bar{X} - Z_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}} \leq \mu \leq \bar{X} + Z_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}\right) = 1 - \alpha$$

3. For unknown population variance, sample size greater than 30:

$$P\left(\bar{X} - t_{\frac{\alpha}{2}, n-1} \frac{s}{\sqrt{n}} \leq \mu \leq \bar{X} + t_{\frac{\alpha}{2}, n-1} \frac{s}{\sqrt{n}}\right) = 1 - \alpha$$

For estimate of the total population size, the sample mean (average number of organisms per square meter) was multiplied by the study area explored.

---

[1] Simpson, George Gaylord; Roe, A.; Lewontin, R. C., Quantitative Zoology, Revised Ed. 1960, Harcourt, Brace, & World, Inc.

C. CLASSIFICATION of SEDIMENT SIZES (after Neeb)[2]

Sediment sizes used in this report:

Particle	Diameter in meters	Rule of Thumb Method
Boulders	over 10 cm	
Cobbles	6 - 10 cm	
Pebbles (Gravel)	2 mm - 6 cm	
Sand		10 - 1000 per inch
Coarse	1 mm	
Medium	.5 mm	
Fine	.1 mm	
Silt		1000 - 10,000 per inch
Coarse	.03 mm	
Fine	.005 mm	
Clay	.001 mm	finer than 10,000 per inch

[2] Strahler, A.N., Physical Geography, 2nd Ed. 1960, John Wiley & Sons, Inc., p. 280

III. TRESUS NUTTALLII

A. Classification

Phylum: Mollusca
Class: Lamellibranchia
Order: Eulamellibranchia
Family: Mactridae
Genus-species: Tresus (Schizothaerus) nuttallii (Conrad, 1837)

Figure 1a. Tresus nuttallii (adult size) contracted siphon

Figure 1b. Tresus nuttallii (adult size) relaxed siphon

B. Natural History

Common names: Horseneck clam, gaper clam, big neck clam.

Range: Vancouver, Canada, to Seammons Lagoon, Baja California.

Habitat: Vertical burrower, 1 - 4 feet depth; average depth - 3 feet. The substrata varies from medium sand to clay, silt and organic materials. Inhabits sandy mud in bays, sloughs, estuaries and other sheltered areas along the coast. Can be near the high tide line to depths of over 100 feet deep.

Important Morphology

Adult shell ranges in length from 6 to 8 inches (Figure 1.) Average age may be approximately 12-15 years. Weighs up to 4 pounds.

C. Description

Considered to be the largest and one of the most common California bivalves. The shell or valves are thin, white and covered with a thick brown protective membrane called the periostracum. On older adults the cover may be badly eroded. The siphon is covered with a thick black epidermis containing incurrent and excurrent tubes. The tip of the siphon is covered with a pair of thick cutaceous plates; the siphon cannot retract within the shell. When the siphon is extended, disturbance will cause the siphon to contract and a miniature geyser results from the extrusion of water from the force of contraction. The sexes are separate; the eggs and sperms are discharged almost simultaneously into the water through the excurrent siphon tube. Larvae forms (veligers) are free swimmers until they burrow into the sand.

Dissections of a few individuals have shown that stomach contents are basically plankton and organic detritus.

D. Ecology

Fish, sharks, bat rays prey on the extended siphon tips when it is high tide. Siphon tips were found in stomachs of these predators. Siphon tips can be

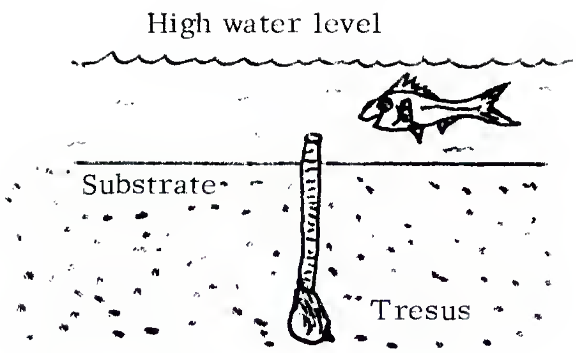


Figure 2. One Tresus predator

regenerated after a period of time. Man is also a predator. feasting on the total siphon. No figures are available, but populations of these clams have disappeared under the shovel of man from San Diego to Bodega Bay. Tomales Bay clam beds are disappearing at an alarming rate, as the perimeter of clams around Lawson's Flat near the Tomales Bay opening is becoming very difficult to find. Commensal pea crabs, primarily Fabia subquadrata, are very common in Tresus' mantle cavity.

E. Sample Statistics of Tresus nuttallii

The statistical tables 1-7 were compiled by Fuller and Schultz through the dates June 23 to July 13, 1967, by counting the siphon and siphon openings of these clams at low tides. Young Tresus siphons were not counted as their openings were difficult to determine. Adults made up the density count.

Rule of thumb guesses about the size of the Tresus clam were as follows:

Young Clam - Siphon opening less than one finger thickness (These were generally not counted as they were difficult to distinguish from worm and crustacean holes).

Young Adult - Siphon opening about the same size as one finger thickness.

Average size Adult - Siphon opening about the same length as the width of two fingers inserted into the siphon opening.

Large size Adult - Siphon opening permitting the entry of three fingers into the opening.

Sample plots of one square meter were selected randomly by the "drawing out of a box" technique; this method was used to compile the data for tables 1-7.

A summary of each clam bed is as follows:

CLAM BED No. 1
Date: June 23, 1967
Tide: -1.6 at 7:20 A.M.
Weather: clear
See Table 1, Map 1

The estimate of 79,500 individuals mark this area as the major clam bed area in Bolinas Lagoon. Map 1 and Map 8 indicate its approximate size and location within the lagoon. The mean is 5.3 clams per m^2 and the 95% confidence interval is between 2.2 and 8.4 clams per square meter (see page 14).

Although man frequently preys on these individuals, his success is limited because of the coarse pebbles made loose by much substrate water. It is a chore to dig these clams out of their three-foot nestling spot.

The great abundance of clams is probably associated with the exposed tidal flushing adjacent to the lagoon opening, bringing to this area a constant replenishment of organic food. Although no sample was taken under the nearby wharf pilings, Tresus is abundant there also because of proximity to nutrient-tidal action of the lagoon mouth.

As in almost all of the mudflats throughout the lagoon, many associate invertebrates were living as species relations to the Tresus clam. For the most part, the invertebrates most dense in numbers are Polychaete worms and small crustaceans. A higher form of worm Urechis caupo (see Figure 2a) is very abundant in this Clam Bed No. 1. The story of this Urechis worm is fascinatingly described by the famous marine zoologist, G. E. MacGinitie.[3] The population density of Urechis caupo is not a part of this report. Statistical counting of this organism is dependent upon a more efficient digging technique than the hand operation, as this worm lives about two feet down in the loose pebbly substrate.

Figure 2a. Urechis caupo

[3] G. E. MacGinitie and N. MacGinitie. Natural History of Marine Animals, McGraw-Hill, 1949

CLAM BED No. 2a, 2b
Date: June 28, 1967
Tide: 0.5 at 11:00 A.M.
Weather: clear
See Table 2, Map 2

Of the 16 sample plots, the mean was 4.8 clams per square meter (see page 16). The estimated population total here is 5,040 individuals. Previous to the year 1960, this area was fairly abundant with Tresus nuttallii. The substrate contains few pebbles and the fine sand makes digging easy. No population counts are available, but the reliability of this area is placed upon the experience of the author here between the years 1945-1959. Since 1960, with the increased popularity of clam digging, the clams have disappeared from the higher tidal zones and the number that remains borders at the low tide channel where digging is not feasible. This example of extinction reflects the status of clams throughout our state and could mirror the depletion of the existing beds of clams in Bolinas Lagoon if controls are not set up and enforced.

CLAM BED No. 3
Date: July 11, 1967
Tide: -0.7 at 9:00 A.M.
Weather: overcast
See Table 3, Map 3

Mean here is 4.6 clams per square meter (see page 18). Total estimated population for this area is 9,936. The abundance of Ulva here might account as detritus for the relatively dense population. Substrate is silt, firmly packed.

CLAM BED No. 4a, 4b
Date: June 25, 1967
Tide: -1.0 at 9:00 A.M.
Weather: overcast
See Table 4, Map 4

The two areas here yielded averages of 4.0 and 3.6 clams per square meter (see pages 20, 21) and a total estimate of 8,150 clams. Bed 4b has a substrate of pebbles similar to Bed No. 1.

CLAM BED No. 5a, 5b, 5c
Date: July 6, 1967
Tide: -0.9 at 6:00 A.M.
Weather: overcast
See Table 5, Map 5

Small population of clams here. Mean is 1.0 per square meter (see page 23) and a total population of 800 individuals. Fewer clams in this area may indicate a lack of nutrients and circulation needed for food and propagation of species.

CLAM BED No. 6a, 6b
Date: July 11, 1967
Tide: -0.7 at 9:00 A. M.
Weather: overcast
See Table 6, Map 6

The two area means are 2.1 and 2.3 per square meter (see pages 25, 26) and the total population estimate for both areas is 1,592 clams. This area is adjacent to the seal resting mudflat area and is covered with a dense black organic layer about one-half inch at the top of the surface.

In area 6b, plot X-15 yielded 23 clams for the square meter plot, the highest count in the lagoon survey. The areas around it are nearly void of clams. This little one square meter plot is certainly evidence of a crowded island!

CLAM BED No. 7
Date: July 13, 1967
Tide: 0.4 at 10:30 A. M.
Weather: clear
See Table 7, Map 7

The total area yielded a mean of .9 individuals per square meter (see page 28). The total estimate is 13,500 clams. However, a drainage tide channel running west from the area contained the major Tresus beds. In this smaller division of 25 meters x 150 meters, the mean was 1.7 clams per square meter and total population here was 9,375 individuals.

An interesting side note is that the Washington clam, Saxidomus nuttalli, is the dominant clam in this area. More discussion on this clam follows the reporting of Tresus nuttallii.

TABLE 1. CLAM BED No. 1

Sample Number	Number of Individuals	Number Squared	Soil Description
X-1	0	0	medium sand with pebbles
X-2	1	1	medium sand with pebbles
X-3	2	4	medium sand with pebbles
X-4	13	169	fine sand
X-7	4	16	pebbles with fine sand
X-9	20	400	fine sand
X-10	1	1	medium sand with pebbles
X-11	0	0	medium sand with pebbles
X-12	3	9	pebbles with fine sand
X-13	5	25	pebbles with fine sand
X-14	3	9	medium sand and pebbles
X-16	6	36	pebbles and medium sand
X-17	12	144	loose pebbles
X-18	11	121	loose pebbles
X-19	4	16	pebbles and medium sand
X-20	0	0	
Total:	85	951	

Mean of Sample Population: $\overline{X} = \frac{85 \text{ individuals}}{16 \text{ samples}} = 5.3$ individuals/m^2

Variance: $s^2 = \frac{16(951) - (85)^2}{16(15)} = 33.3$

Standard Deviation: $s = 5.77$

95% Confidence Interval of Population Mean: $2.2 \leq \mu \leq 8.4$ individuals /m^2

Rough Population Estimate: Area of 75m x 200m = 15,000m^2

15,000m^2 (5.3/m^2) = 79,500 individuals

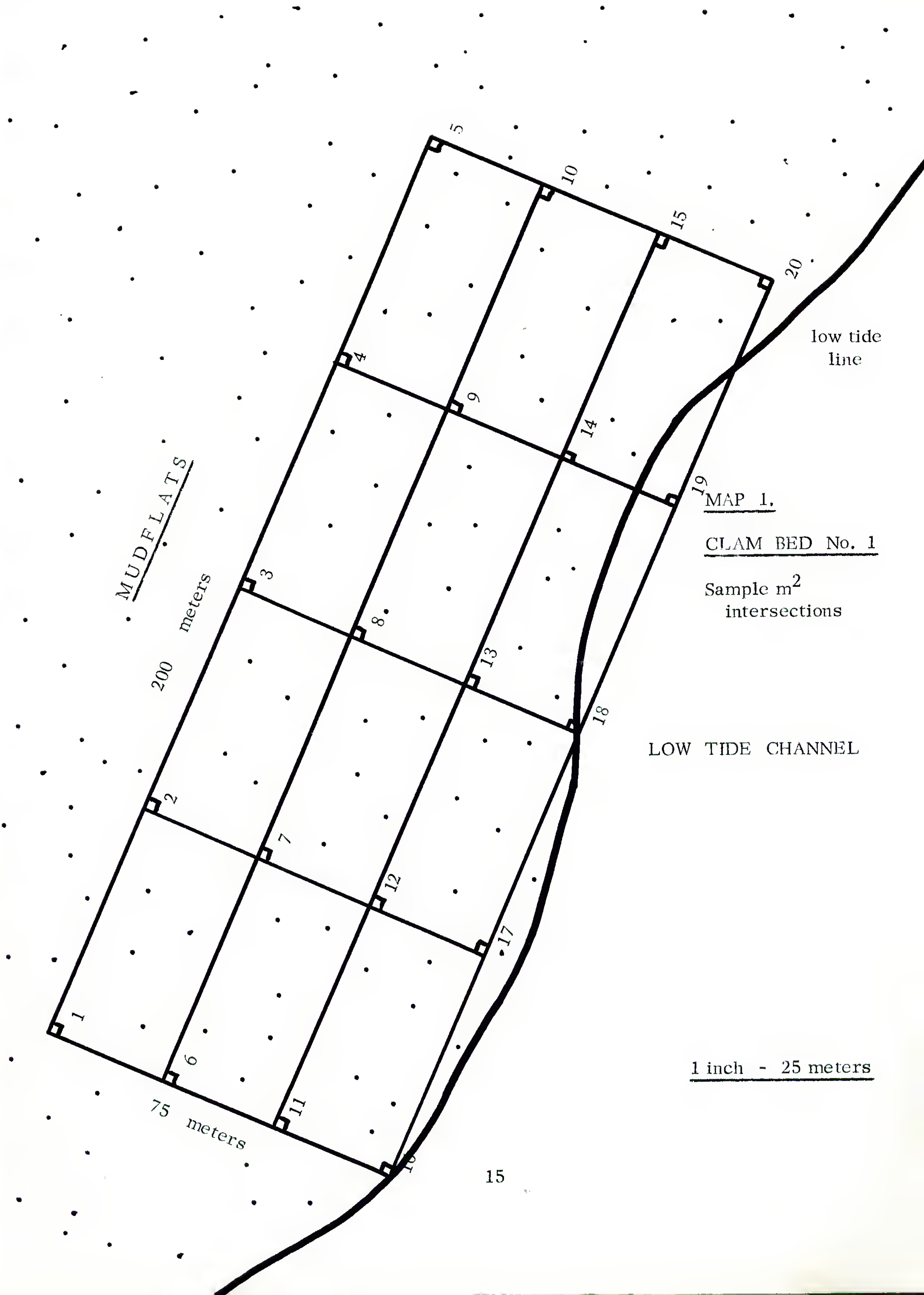

MUDFLATS
200 meters
75 meters
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
low tide line
MAP 1.
CLAM BED No. 1
Sample m2 intersections
LOW TIDE CHANNEL
1 inch - 25 meters

TABLE 2. CLAM BEDS No. 2a and 2b

Sample Number	Number of Individuals	Number Squared	Soil Description
X-2	3	9	fine sand
X-4	1	1	fine sand
X-7	1	1	fine sand
X-9	5	25	underwater, fine sand
X-10	25	625	edge of water, fine sand
X-12	16	256	edge of water, fine sand
X-14	0	0	underwater, fine sand
X-15	4	16	underwater, fine sand
X-18	4	16	fine sand
X-20	1	1	fine sand
X-22	1	1	fine sand
X-25	1	1	(lower) underwater, fine sand
X-27	0	0	underwater, fine sand
X-30	7	49	underwater, fine sand
X-31	8	64	underwater, fine sand
Total:	77	1065	

Mean of Sample Population:

$$\bar{X} = \frac{77 \text{ individuals}}{16 \text{ samples}} = 4.8 \text{ individuals/m}^2$$

Variance:

$$s^2 = \frac{16(1065) - (77)^2}{16(15)} = 45.9$$

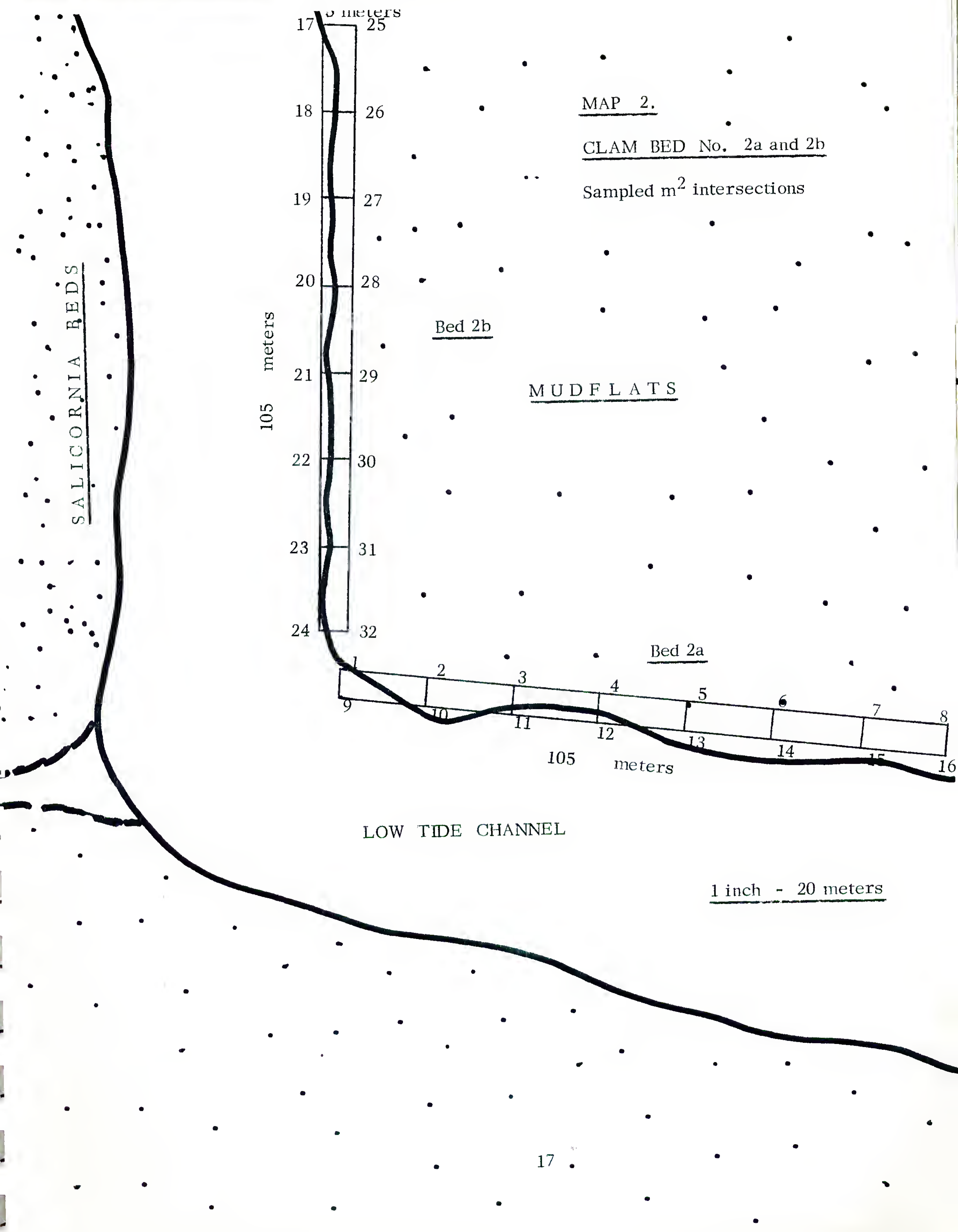
Standard Deviation: $s = 6.77$

95% Confidence Interval of Population Mean: $1.2 \leq \mu \leq 8.4$ individuals/m^2

Rough Estimate of Population in Clam Bed 2a and b:

Area of 2(105m x 5m) = 1,050m^2

1,050m^2 (4.8/m^2) = 5,040 individuals



MAP 2.
CLAM BED No. 2a and 2b
Sampled m² intersections
SALICORNIA BEDS
MUDFLATS
Bed 2b
Bed 2a
105 meters
105 meters
LOW TIDE CHANNEL
1 inch - 20 meters
17 18 19 20 21 22 23 24
25 26 27 28 29 30 31 32
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16

TABLE 3. CLAM BED No. 3

Sample Number	Number of Individuals	Number Squared	Soil Description
X-1	1	1	The whole bed was loose silt bordered by firmly packed silt.
X-2	0	0	
X-3	2	4	
X-4	0	0	
X-6	1	1	
X-9	4	16	
X-10	0	0	
X-11	5	25	
X-13	3	9	Ulva was found growing on the rest of the bed.
X-14	11	121	
X-15	6	36	
X-16	8	64	
X-18	10	100	
X-19	6	36	
X-20	3	9	
X-21	13	169	
Total:	73	591	

Mean of Sample Population: $\bar{X} = \frac{73 \text{ individuals}}{16 \text{ samples}} = 4.6 \text{ individuals/m}^2$

Variance: $s^2 = \frac{16(591) - (73)^2}{16(15)} = 17.2$

Standard Deviation: $s = 4.2$

95% Confidence Interval of Population Mean: $2.54 \leq \mu \leq 6.7$

Rough Estimate of Population in Clam Bed No. 3:

Area of $90\text{m} \times 25\text{m} = 2,160\text{m}^2$

$2,160\text{m}^2 (4.6 \text{ individuals/m}^2) = 9,936$ individuals

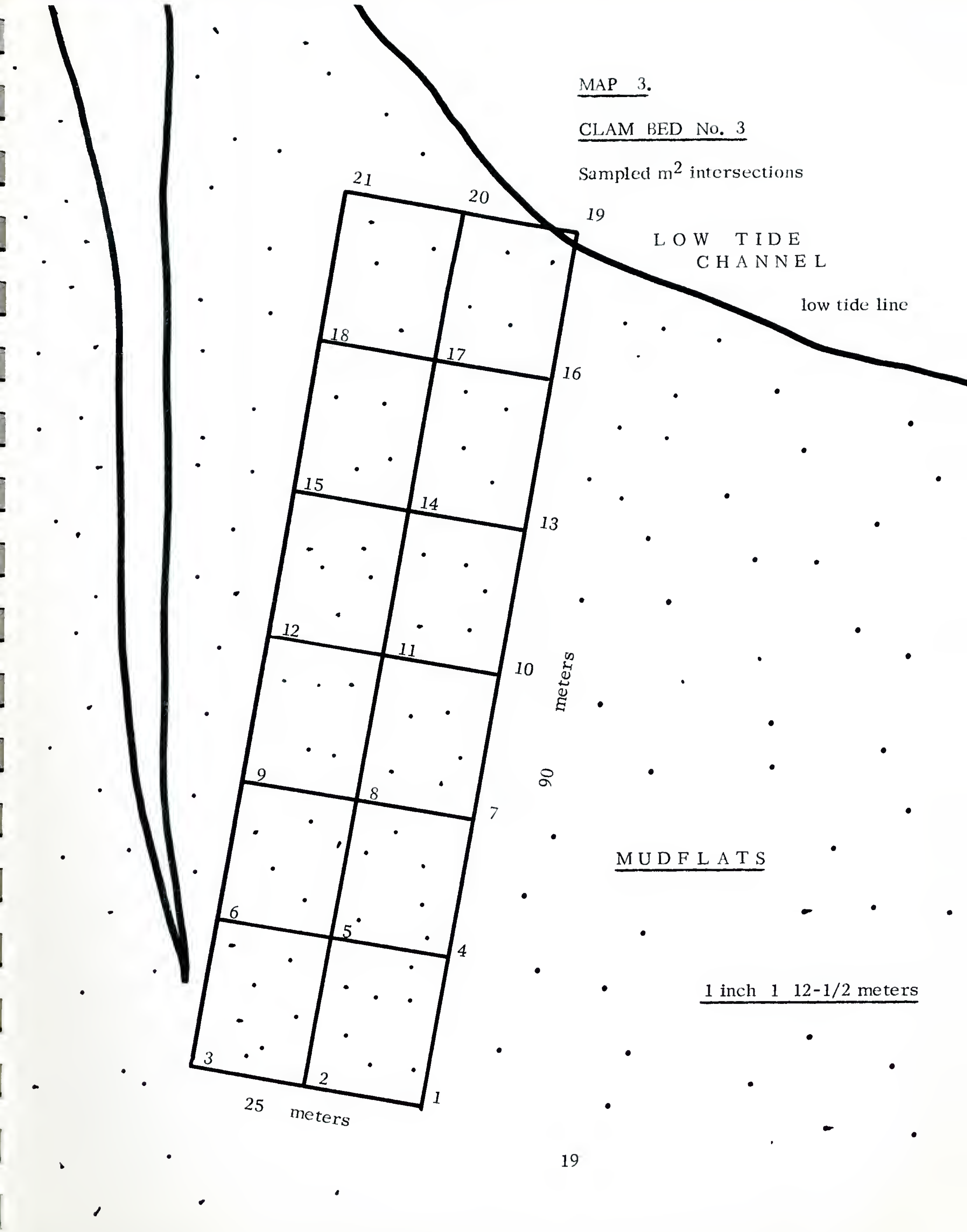

MAP 3.
CLAM BED No. 3
Sampled m2 intersections
LOW TIDE CHANNEL
low tide line
MUDFLATS
1 inch 1 12-1/2 meters
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
90 meters
25 meters

TABLE 4. CLAM BED No. 4a

Sample Number	Number of Individuals	Number Squared	Soil Description
X-1	0	0	hard silt
X-6	4	16	fine sand
X-11	0	0	mixed hard silt and fine sand
X-12	10	100	mixed hard silt and fine sand
X-13	6	36	mixed hard silt and fine sand
X-16	5	25	medium sand
X-23	3	9	medium sand
Total:	28	186	

Mean of Sample Population: $\bar{X} = \frac{28 \text{ individuals}}{7 \text{ samples}} = 4.0$

Variance: $s^2 = \frac{7(186) - (28)^2}{7(6)} = 12.8$

Standard Deviation: $s = 3.58$

95% Confidence Interval of Population Mean: $.7 \leq \mu \leq 7.3$ individuals/m^2

Rough Estimate of Population in Clam Bed No. 4a: Area of 70m x 5m $= 350m^2$

$350m^2(4.0/m^2) = 1,400$ individuals

TABLE 4. (continued) CLAM BED No. 4b

Sample Number	Number of Individuals	Number Squared	Soil Description
X-2	0	0	soft silt
X-3	1	1	soft silt
X-6	1	1	hard pebbles
X-8	0	0	hard silt
X-11	5	25	mixed pebbles, fine sand and silt
X-12	0	0	hard silt
X-15	5	25	mixed fine sand, silt
X-16	9	81	silt and pebbles
X-17	8	64	very soft silt
X-18	3	9	very soft silt
X-7	7	49	soft silt
Total:	39	255	Substrata has black layer about one inch below surface, but there is no strong odor.

Mean of Sample Population: $\bar{X} = \frac{39 \text{ individuals}}{11 \text{ samples}} = 3.6 \text{ individuals/m}^2$

Variance: $s^2 = \frac{11(255) - (39)^2}{11(10)} = 11.7$

Standard Deviation: $s = 3.42$

95% Confidence Interval of Population: $1.2 \leq \mu \leq 5.8 \text{ individuals/m}^2$

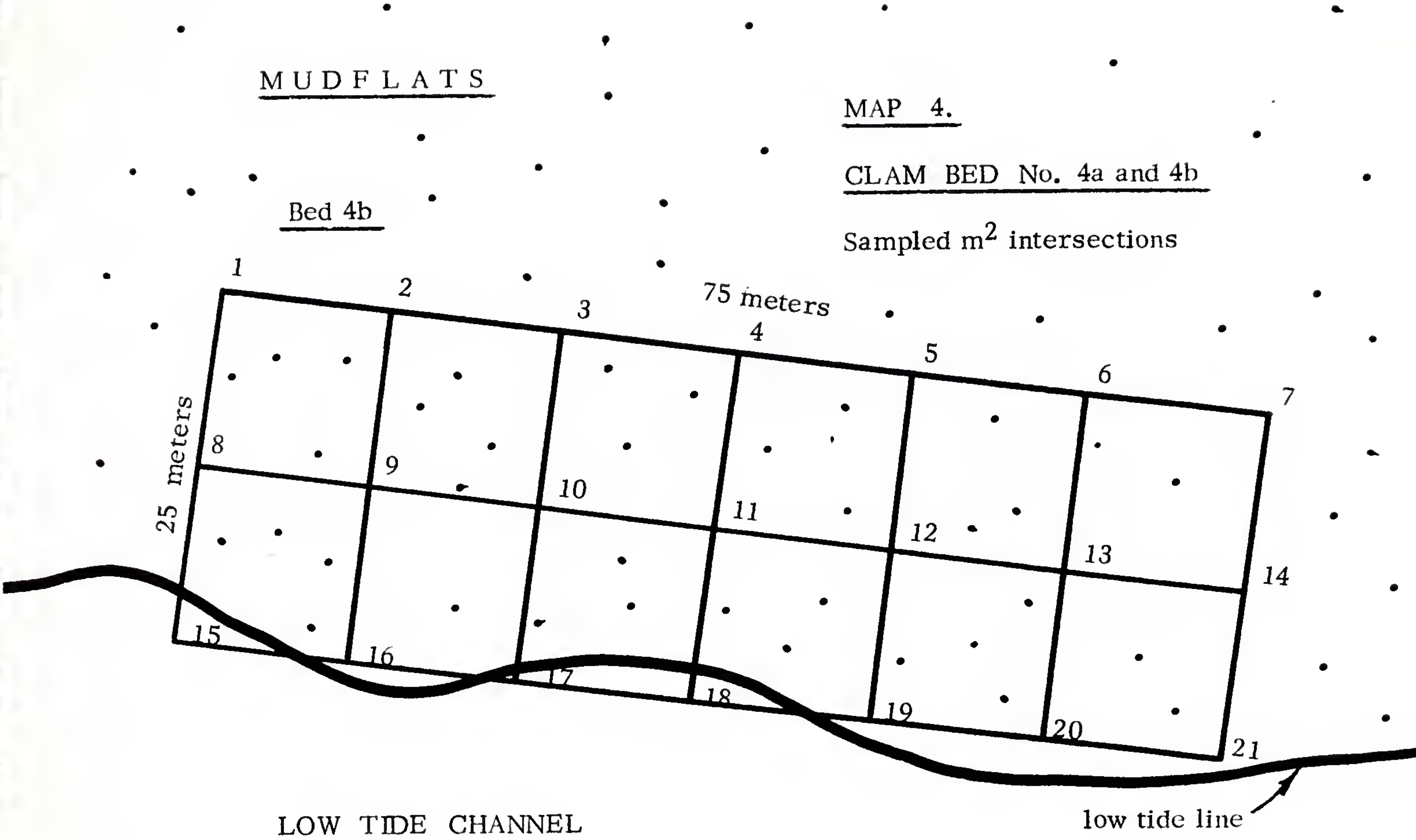
Rough Estimate of Population: Area of 75m x 25m $= 1,875 \text{ m}^2$

$1,875\text{m}^2 \, (3.6/\text{m}^2) = 6,750$ individuals.

MAP 4.

CLAM BED No. 4a and 4b

Sampled m^2 intersections



1 inch - 12-1/2 meters

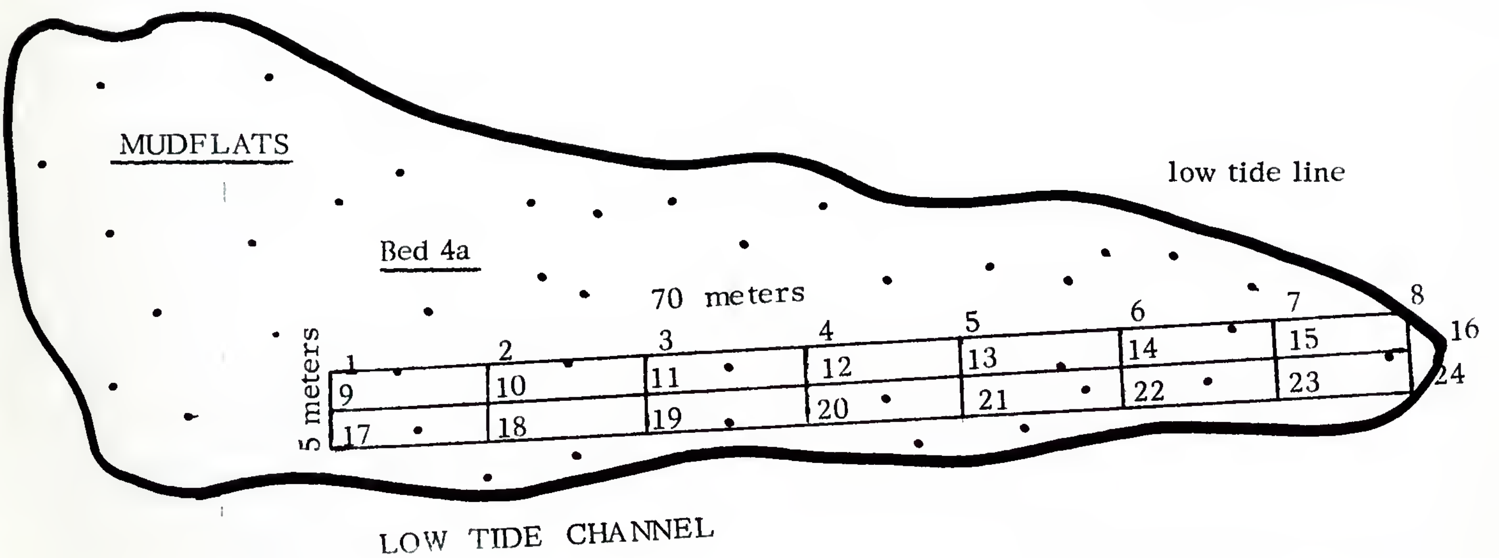


TABLE 5. CLAM BED No. 5a

Sample Number	Number of Individuals	Number Squared
X-1	0	0
X-2	1	1
X-3	2	4
X-4	1	1
X-6	1	1
X-7	0	0
X-9	2	4
X-10	1	1
X-12	1	1
Total:	9	13

Soil Description

All samples were silt (loose) with a black layer one inch below the surface, again with no strong odor.

Mean of Sample Population: $\bar{X} = \frac{9 \text{ individuals}}{9 \text{ samples}} = 1.0$ individuals/m^2

Variance: $s^2 = \frac{9(13) - (9)^2}{9(8)} = .5$

Standard Deviation: $s = .707$

95% Confidence Interval of Population Mean: $.5 \leq \mu \leq 1.5$ individual/m^2

Rough Estimate of Population : Area of 5m x 50x = $250m^2$
$250m^2$ $(1.0/m^2)$ = 250 individuals

CLAM BED No. 5b *

Rough Estimate of Population: Area of 5m x 50m = $250m^2$
$250m^2$ $(1.0/m^2)$ = 250 individuals

CLAM BED No. 5c *

Rough Estimate of Population: Area of 5m x 60m = $300m^2$
$300m^2$ $(1.0/m^2)$ = 300 individuals

* Clam Beds 5b and 5c have the same mean, confidence interval and population estimate as Clam Bed 5a.

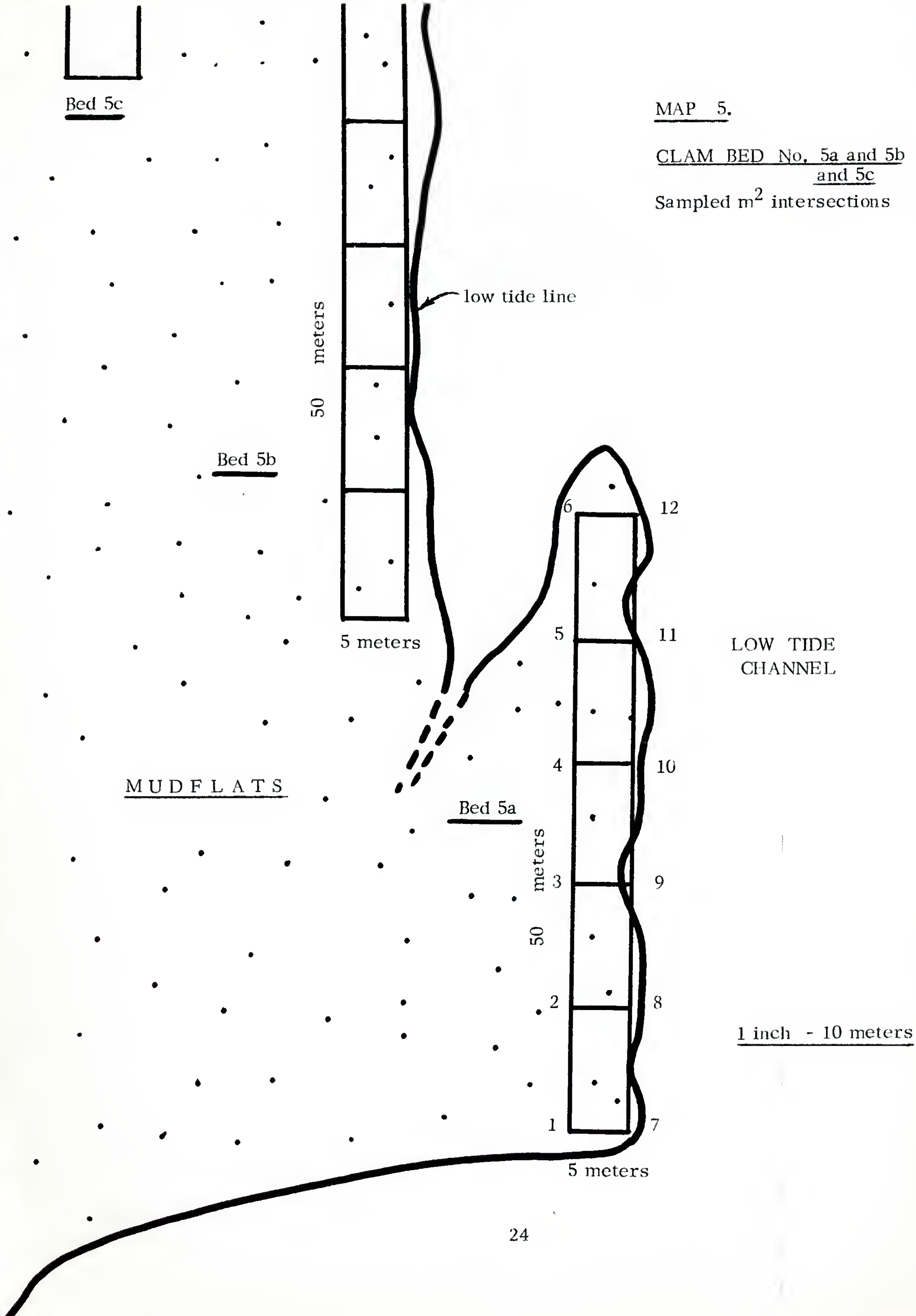

MAP 5.
CLAM BED No. 5a and 5b and 5c
Sampled m2 intersections
Bed 5c
Bed 5b
Bed 5a
50 meters
5 meters
low tide line
MUDFLATS
LOW TIDE CHANNEL
1 inch - 10 meters
1
2
3
4
5
6
7
8
9
10
11
12

TABLE 6. CLAM BED No. 6a

Sample Number	Number of Individuals	Number Squared
X-2	5	25
X-3	0	0
X-4	0	0
X-6	2	4
X-7	1	1
X-8	7	49
X-9	6	36
X-10	2	4
X-11	1	1
X-13	1	1
X-14	0	0
X-15	0	0
Total:	25	121

Soil Description

Fine sand with black organic materials about 1/2 inch below surface. Various places with loose silt on top.

Mean of Sample Population: $\bar{X} = \frac{25 \text{ individuals}}{12 \text{ samples}} = 2.1 \text{ individuals}/m^2$

Variance: $s^2 = \frac{12(121) - (25)^2}{12(11)} = 6.7$

Standard Deviation: $s = 2.5$

95% Confidence Interval of Population Mean: $.68 \leq \mu \leq 3.5 \text{ individuals}/m^2$

Rough Estimate of Population of Clam Bed No. 6a: Area of $8m \times 40m = 320m^2$

$320m^2 (2.1/m^2) = 672$ individuals

TABLE 6. (continued) CLAM BED No. 6b

Sample Number	Number of Individuals	Number Squared	Soil Description
X-2	0	0	Fine sand with more black organic materials than Clam Bed No. 6a about 1/2 inch below surface.
X-4	0	0	
X-5	2	4	
X-7	1	1	
X-8	1	1	
X-9	0	0	
X-10	0	0	
X-12	0	0	packed fine sand
X-13	1	1	
X-14	0	0	
X-15	23	529	Wow!
X-16	0	0	
Total:	28	255	

Mean of Sample Population: $\overline{X} = \frac{28 \text{ individuals}}{12 \text{ samples}} = 2.3$ individuals/m^2

Variance: $s^2 = \frac{12(255) - (28)^2}{12(11)} = 17.2$

Standard Deviation: $s = 4.2$

95% Confidence Interval of Population Mean: $-.1 \leq \mu \leq 4.7$ individuals/m^2; this confidence interval is not significant since it crosses 0.

Rough Estimate of Population: Area of 5m x 80m = $400m^2$

$400m^2 (2.3/m^2) = 920$ individuals

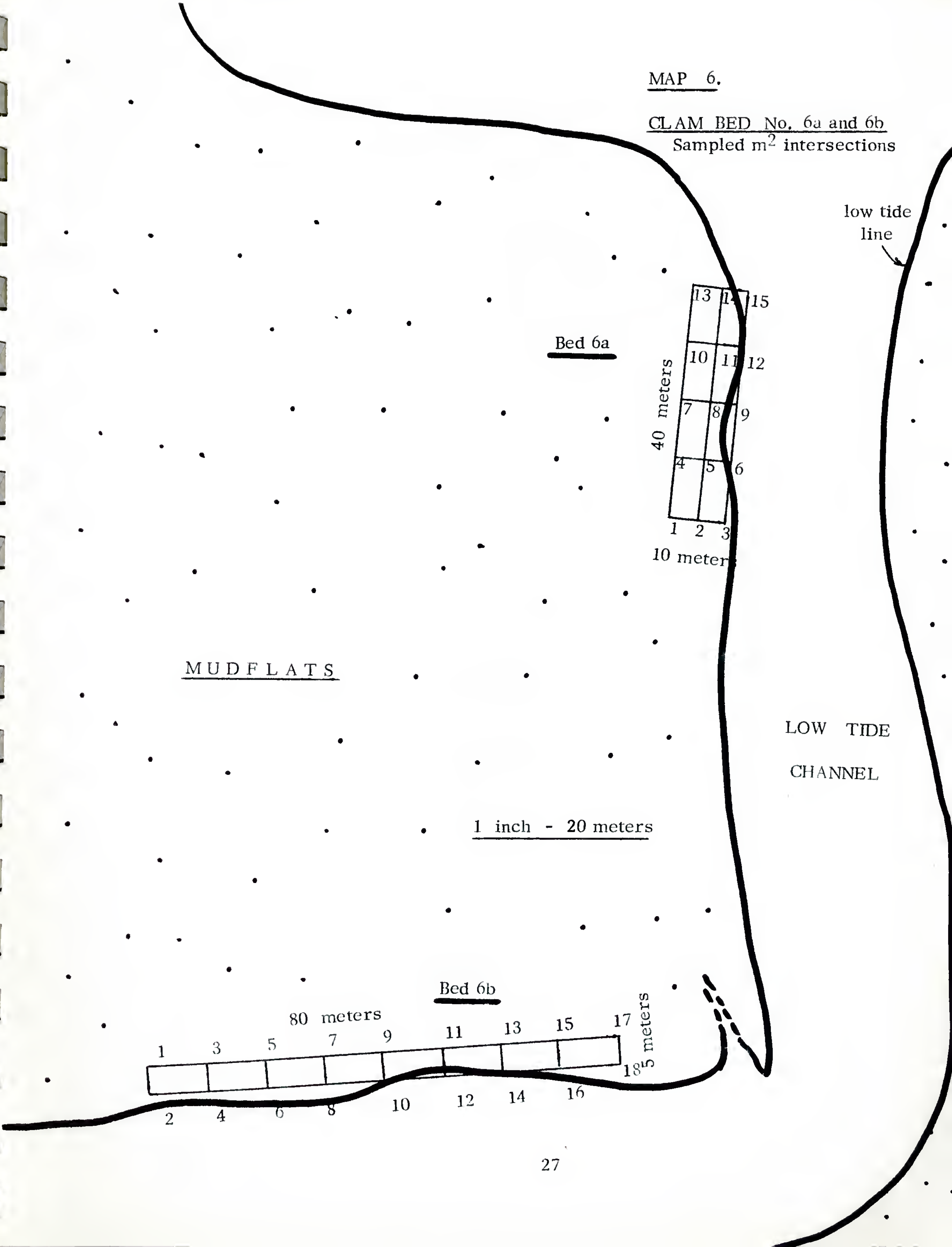

MAP 6.
CLAM BED No. 6a and 6b
Sampled m2 intersections
low tide
line
Bed 6a
40 meters
10 meters
MUDFLATS
LOW TIDE
CHANNEL
1 inch - 20 meters
Bed 6b
80 meters
5 meters

TABLE 7. CLAM BED No. 7

Sample Number	Number of Individuals	Number Squared	Soil Description
X-1	4	16	mixed medium and fine sand
X-2	5	25	mixed medium and fine sand
X-3	0	0	mixed medium and fine sand
X-4	0	0	mixed medium and fine sand
X-5	0	0	mixed medium and fine sand
X-6	1	1	mixed medium and fine sand
X-8	0	0	silt
X-9	0	0	silt
X-10	0	0	mixed medium and fine sand
X-12	0	0	mixed medium and fine sand
X-13	0	0	silt
X-15	0	0	silt with Ulva on surface
X-16	5	25	mixed medium and fine sand
X-17	0	0	mixed medium and fine sand
X-19	0	0	silt with Ulva on surface
X-20	0	0	silt with Ulva on surface
Total:	15	66	Underlined samples are located along drainage channel

Mean of Sample Population: $\bar{X} = \frac{15 \text{ individuals}}{16 \text{ samples}} = .9 \text{ individuals/m}^2$

$\left(\bar{X}_c = \frac{10 \text{ individuals}}{6 \text{ samples}} = 1.7 \text{ individuals/m}^2 \right)$

Variance: $s^2 = \frac{16(66) - (15)^2}{16(15)} = 3.5$

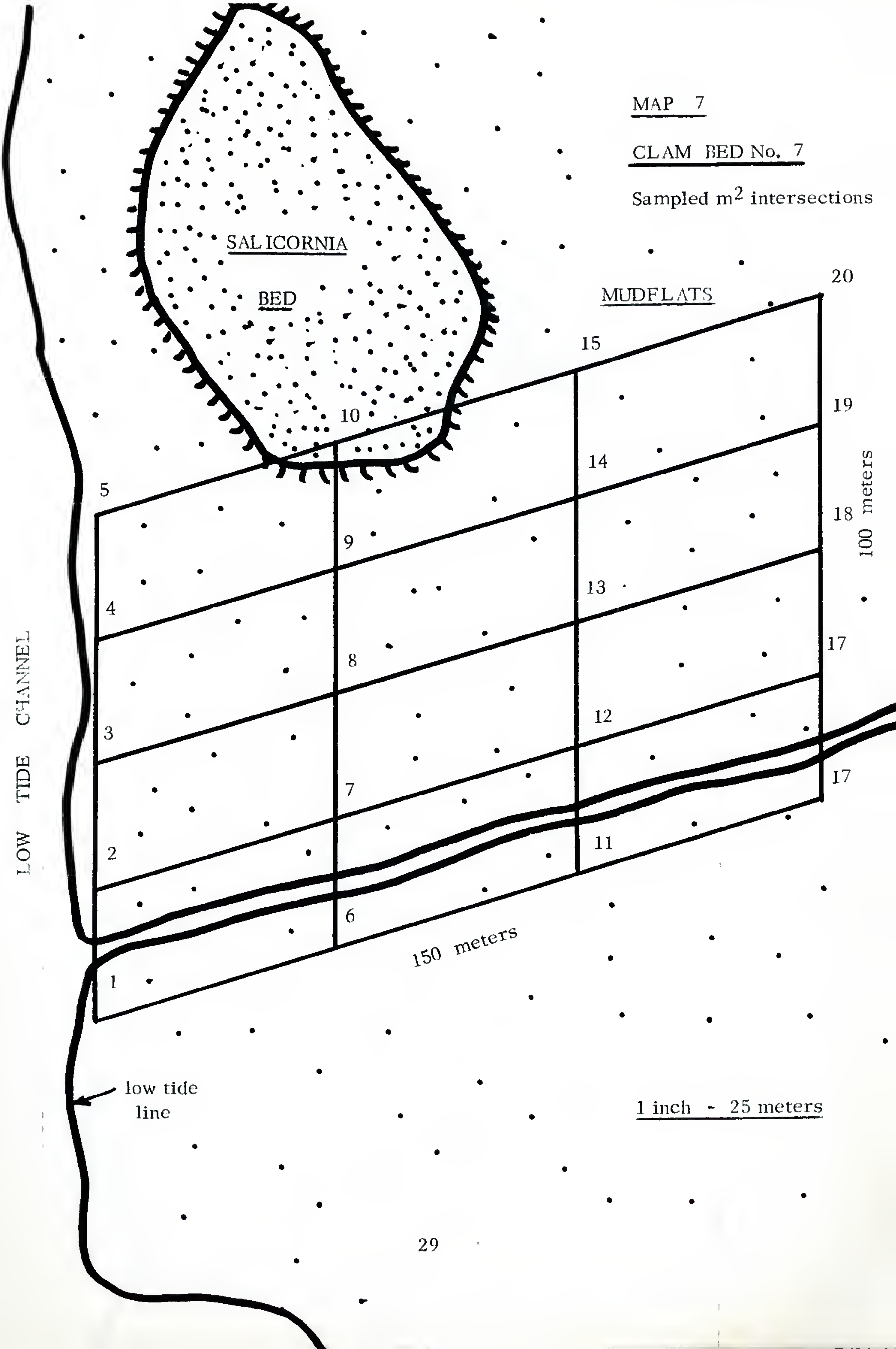
$\left(s_c^2 = \frac{6(42) - (10)^2}{6(5)} = 5.07 \right)$

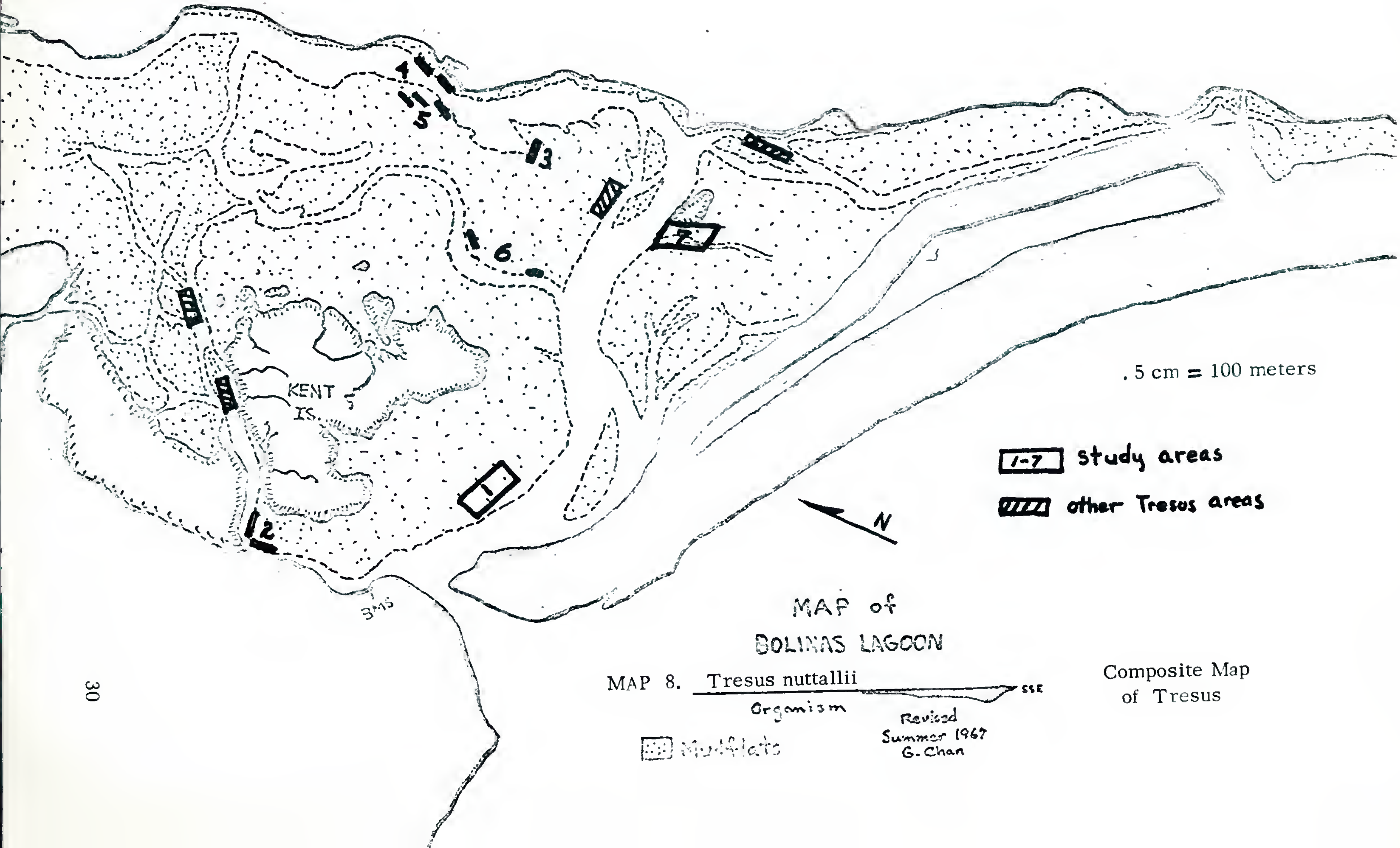
Standard Deviation: $s = 1.9$ $(s_c = 2.6)$

95% Confidence Interval of Population Mean: $-.03 \leq \mu \leq 1.8$ $(-.38 \leq \mu \leq 3.9)$ Confidence intervals are not significant since they cross 0

Population Estimate of Clam Bed No. 7: Area of 100m x 150m = 15,000m^2
15,000m^2 (.9/m^2) = 13,500 individuals

Population Estimate of Drainage Channel Area:
(Area of 25m x 150m = 3,750m^2
3,750m^2(1.7/m^2) = 6,375 individuals)


MAP 7
CLAM BED No. 7
Sampled m2 intersections
SALICORNIA
BED
MUDFLATS
LOW TIDE CHANNEL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
17
17
18
19
20
100 meters
150 meters
low tide line
1 inch - 25 meters



MAP 8. Tresus nuttallii
Organism

Composite Map of Tresus

TABLE 8. Summary Statistics of Tresus nuttallii

Sample Bed No.	Area Size	Number of Samples X	Number of Organisms	Mean, X, Average no. per meter^2	95% conf. interval of pop. mean	see page no.	Estimate of population size	Substrate
1	200m x75m 15,000 m^2	16	85	5.3	2.2-8.4	14	79,500	med. sand to pebbles
2	2(105m x5m) 1,050 m^2	16	77	4.8	1.2-8.4	16	5,040	fine sand
3	90m x 25m 2,160 m^2	16	73	4.6	2.5-6.7	18	9,936	silt covered with Ulva
4a	70m x 5m 350 m^2	7	28	4.0	.7-7.3	20	1,400	hard silt to med. sand
4b	75m x25m 1,875 m^2	11	39	3.6	1.2-5.8	21	6,750	silt to fine sand
5a, b, c	see notes 800 m^2	27	27	1.0	.5-1.5	23	800	silt
6a	8m x 40m 320 m^2	12	25	2.1	.68 - 3.5	25	672	fine sand
6b	5m x 80m 400 m^2	12	28	2.3	not sig.	26	920	fine sand
7	100m x 150m 15,000 m^2	16	15	.9	not sig.	28	13,500	silt to med. sand
(7) (channel)	(25mx150m 3,750 m^2)	(6)	(15)	(2.5)	not sig.		(9,375)	(silt to fine sand
TOTALS 7	36,955 m^2	133	397				118,518	silt to sand to pebbles

F. Conclusion

From Table 8 and Map 8, a summary of all the study areas is seen. The highest density of Tresus nuttallii was observed at Clam Bed No. 1 at 5.3 individuals per square meter. Again, the density might be attributed to the nutrient flushing of the area, but I would hypothesize that the major reason for the large number of clams is that the area is too difficult to dig into and the clams have been blessed with this favorable substrate. The total estimate of 79,500 clams for this area represents about 95% of the estimated total population of Tresus in Bolinas Lagoon. Moreover, with all the other invertebrate species in this same area, this Clam Bed No. 1 then becomes the major and dominate marine organism habitat in the entire lagoon - an area for vital conservation and study.

Map 8 illustrates other areas of the lagoon which contain other small beds of Tresus nuttallii that were not surveyed. The northwest area or upper back portions of the lagoon is void of these clams. Poor flushing and circulation probably does not enable the clam veliger larvae to support themselves in this environment. Notice then, Map 8 shows that the majority of the clam beds are adjacent to good tidal circulation of water. Where tidal scouring is evident, there were no clams observed as this physical action might be too severe a handicap for youngster to survive. Areas with a deep black surface layer were also lacking in clams, as these areas were generally a large distance from tidal channels.

The total estimate of the surveyed plots indicate the population of Tresus nuttallii to be approximately 118,518. The surveying team of Fuller and Schultz hypothesize this number to be close to 80% of the entire lagoon population. Future density counts of unsurveyed areas might illuminate this 80% to be a close approximation. Certainly, this survey does indicate the major proportion of the population of Tresus nuttallii.

Future studies of this clam will involve:

1. Resurvey of the population work performed by Fuller and Schultz. This could enhance statistics of any depletion by nature or by man in the future.

2. Additional survey to account for at least 90% of the total population within the lagoon.

3. Study the natural history of the clam: its stomach contents, growth rate and size, siphon regeneration, vertical and horizontal substrate movement, bacterial limitation, specific larval life cycles, and predator food web relationships.

At any rate, Tresus nuttallii becomes the dominate mollusk in Bolinas Lagoon and we hope this status continues for many more years to come.

IV. SAXIDOMUS NUTTALLI

A. Classification

Phylum: Mollusca
Class: Lamellibranchia
Order: Eulamellibranchia
Family: Veneridae
Genus-species: *Saxidomus nuttalli* Conrad, 1837

Figure 3.
Saxidomus nuttalli

B. Natural History

Common name: Washington Clam

Range: Humboldt Bay, California, to San Quintin Bay, Baja California.

C. Description

The bivalves are thick, stained black with mud, oval in outline and have many wave-like concentric ridges. Siphons are fused together and can be retracted between the valves; however, the smooth purple tips can be seen between the valves. The extended siphon can stretch to three feet. At the surface, the siphon makes a narrow one-half inch keyhole slit.

D. Habitat

Lives at depths of 12 to 24 inches in silt (mud) - sandy lagoons, bays, and estuaries. Reported to be common in areas north of Morro Bay to Humboldt Bay. This clam is highly esteemed by clam diggers for food.

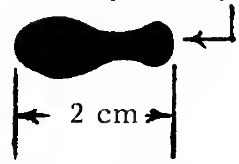
Man seems to be the major predator in California. At low tide, the siphon rarely comes up to the surface for exposure. At high tide the siphon tips do not extend much beyond the substrate mud and have not been observed in stomachs of marine fishes.

E. Statistics of Saxidomus nuttalli

Date: July 13, 1967
Tide: 0.4 at 10:30 A.M.
Weather: clear
See Table 9, Map 9

This area is located at the lower, southeastern part of the Bolinas Lagoon. The size of the area is 100 meters by 150 meters.

Fifteen one-meter sample plots were randomly selected on a quadrad board and then surveyed. The clams were counted by observing the number of siphon keyhole apertures observed. Drawing is approximate life size.



The sample means was 3.2 individuals per square meter and the 95% confidence interval for the population mean is 1.4 to 4.7 clams per square meter (see page 36). The estimate of this area's population is 48,000 clams.

The substrate ranged from silt to medium sand. There was a three-inch layer of black silt on the mudflat surface furthest away from the low tide channels. The clams are approximately two feet down from the surface. Adults measure approximately 5 inches in shell length.

F. Conclusion

The lagoon has a large population of this Washington Clam. No attempt was made to survey this clam in Clam Bed 1 and other lagoon areas. Assuming that they are quite abundant, we took a survey of the highest density area of Saxidomus (see Map 9). In fact, this spot has the most clams the author has observed anywhere in California. This clam represents the second major bivalve in Bolinas Lagoon (following Tresus nuttallii, the Horseneck Clam).

Already, at low tides, many clam diggers are observed gathering their limits of 10 per person. I have even seen families with children under age 16, each having secured a limit of 10 through the courtesy of their adult leaders. I fear for the population in this choice spot in years to come, where the digging is relatively easy.

Future studies should involve the natural history of this organism in the lagoon along with a repeated and more thorough population study.

TABLE 9. CLAM BED of SAXIDOMUS NUTTALLI

Date: July 13, 1967
Tide: 0.4 at 10:30 A.M.
Weather: Clear

Sample Number	Number of Individuals	Number Squared	Soil Description
X-1	0	0	mixed medium and fine sand
X-3	4	16	silt
X-4	0	0	silt
X-5	0	0	mixed medium and fine sand
X-7	4	16	mixed medium and fine sand
X-8	3	9	silt
X-10	0	0	silt with Ulva on surface
X-12	10	100	mixed medium and fine sand
X-13	7	49	mixed medium and fine sand
X-14	4	16	mixed medium and fine sand
X-16	0	0	silt with Ulva on surface
X-17	6	36	mixed medium and fine sand
X-18	3	9	mixed medium and fine sand
X-19	2	4	mixed medium and fine sand
X-20	4	16	mixed medium and fine sand
Total	48	262	

Mean of Sample Population: $\bar{X} = \frac{48 \text{ individuals}}{15 \text{ samples}} = 3.2$ S. nuttalli /m^2

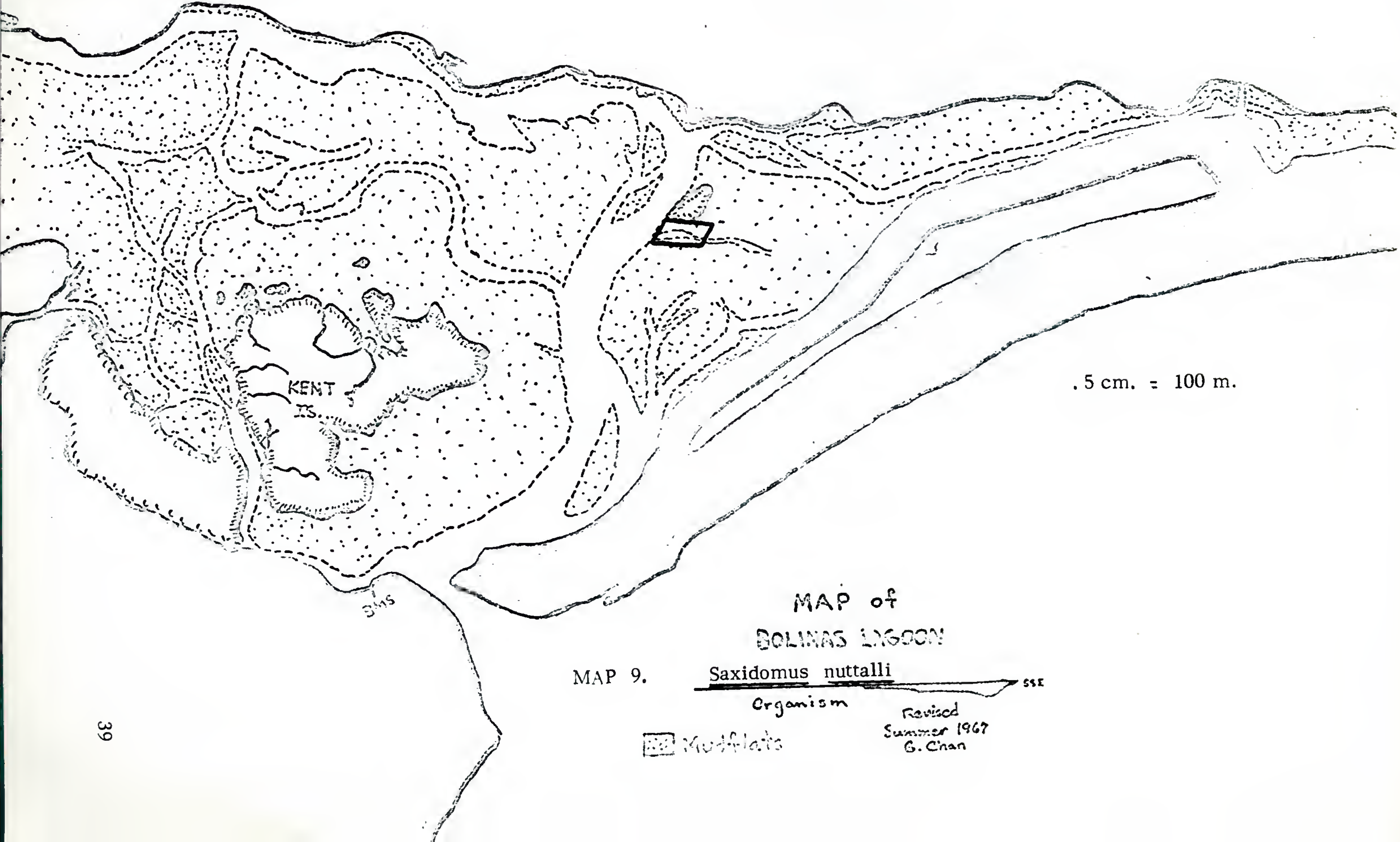
Variance: $s^2 = \frac{15(262) - (48)^2}{15\,(14)} = 7.3$

Standard Deviation: $s = 2.7$

95% Confidence Interval of Population Mean: $1.7 \leq \mu \leq 4.7$

Population Estimate: Area of 100m x 150m = 15,000 m^2

$15,000\ m^2(3.2/m^2) = 48,000$ individuals



MAP 9. Saxidomus nuttalli

V. CERITHIDEA CALIFORNICA

A. Classification

Phylum: Mollusca
Class: Gastropoda
Subclass: Prosobranchia
Order: Pectinibranchia
Suborder: Taenioglossa
Family: Cerithiidae
Genus-species: Cerithidea californica Haldeman, 1840

Figure 4. Cerithidea californica

B. Natural History

Common name: California Horn Shell

Range: Reported from Bodega Bay to San Diego, California

C. Description

A spinelike shell, about one and one-half inches tall. There are about 10 rounded whorls, decorated with vertical ribs and revolving ridges. The color is dark brown, almost black at times. Aperture is closed by a dark, circular, horny operculum.

D. Ecology

In California this is a common gastropod in mudflats so far back from the tidal surf that it tolerates high temperatures and salinities. In one of the pools in Bolinas Lagoon, researcher K. Kornelis found about 2,000 Cerithidea living in water temperature of 26^{o} C and a salinity of 45 parts per thousand.

A red diatomaceous film around their habitat seems to be the chief food for these Horn snails. Tidal action would wash away this film, so "quiet" pools are important. Algae detritus probably also form part of their diet.

Neighbors include Hemigrapsus oregonensis(mud crab), Clevelandia ios (Goby fish), and various Polychaete worms. Abundant plants include Salicornia (Pickleweed), Ulva, and Enteromorpha (Green algae).

E. Statistical Sampling of Cerithidea californica

Sampling dates: June 29 - July 19
Tides: -0.9 to -1.3
See Table 10, Map 10

Sampling Techniques: Map 10 points out the general location of the linear transects that were sighted in with sextants by K. Kornelis. (His report should be consulted at the Bolinas Marine Station for further study.) Each transect was divided into intersections, and by use of a square meter frame, all the Horn snails within the frame were counted. The substrate was silt to fine sand.

Cerithidea californica was found in the canal or creek pools that intersected with the transect lines. Where the transects intersected with the Salicornia (Pickleweed) beds, no C. californica were observed. Hence, these snails must only live in estuarine pools. The area of study has four major "creeks" running from the high Kent Island berm through the Salicornia beds to the sandy mudflats. These creeks were measured "roughly" to obtain their approximate square meters (excluding the small tributaries running off each creek). If we average the width of the creeks to be $5m^2$, the totals for each would be:

Creek 1 - 1,829 m^2
Creek 2 - 1,220 m^2
Creek 3 - 2,438 m^2
Creek 4 - 1,000 m^2
6,487 m^2 (a conservative measurement)

Data

Transect B: 30 samples, 2,182 Horn snails, $\bar{X}$ mean = 145.46/m^2
(Transect V did not contain any snails as this was through Salicornia beds)

Transect C: 6 samples, 7,990 Horn snails, $\bar{X}$ mean = 1,331.0/m^2

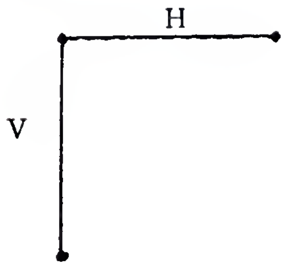
Totals: 36 samples, 10,172 Horn snails, $\bar{X}$ mean = 282.6/m^2

With the 6.487 m^2 of estimated area of the four creeks, the total estimate of the population in the creeks would be: 1,833,226. This number would place Cerithidea californica as one of the major organisms (in number) within the lagoon.

As a general conclusion, the length of each creek and tributary should be accurately measured with a meter tape; and the total ecology of this hardy snail should be one of the prime studies for future marine biologists.

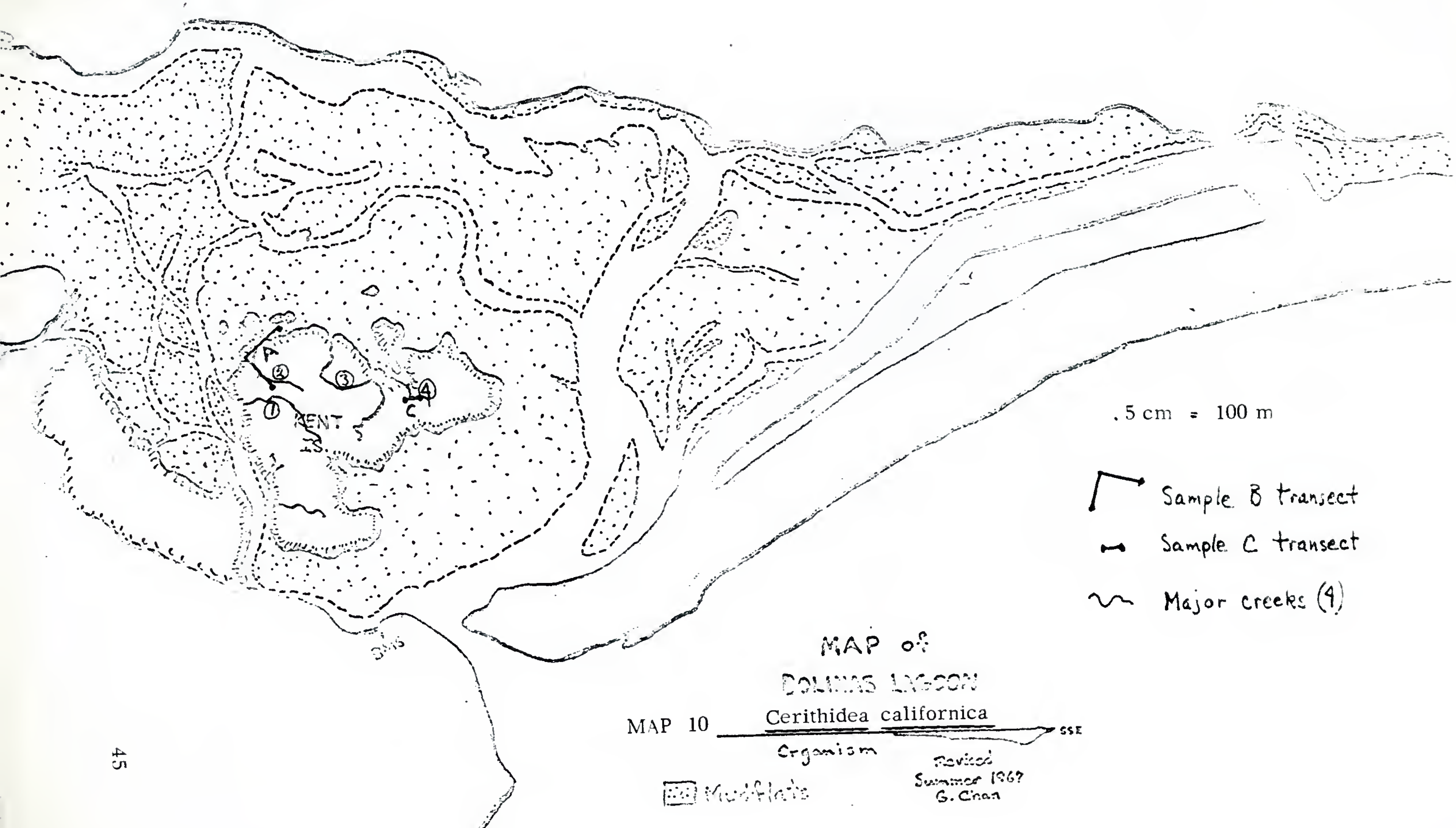
TABLE 10. Sampling *Cerithidea californica*

Sample Transect	Length of Transects	Transect One-meter^2 Sample plots	Total no. of shells on transects per meter^2	Sample mean per meter^2
Transect B	150 meters each	Line H		
		15 m^2		
		X_1	1 silt	
		X_2	0 p.w.*	
		X_3	0 p.w.	
		X_4	0 p.w.	
		X_5	39 pool	
		X_6	390 pool	
		X_7	422 pool	
		X_8	0 p.w.	
		X_9	0 p.w.	
		X_{10}	1188 (large pool)	
		X_{11}	6 silt	
		X_{12}	0 p.w.	
		X_{13}	136 pool	
		X_{14}	0 p.w.	
		X_{15}	0 p.w.	
		15	2182	$\bar{X}$ = 145.46
		Line V		
		15 m^2	all 0 (Pickleweed)	
Transect C	60 meters	X_1	2024 pool	
		X_2	2016 pool	
		X_3	1746 pool	
		X_4	2133 pool	
		X_5	8 silt-p.w.	
		X_6	63 silt-p.w.	
		6	7990	$\bar{X}$ = 1331.0
TOTALS		36 samples	10,172	$\bar{X}$ = 282.6



6,487 m^2 ---- Total square meters for the four creek areas-
1,833,226 ---- Total estimate of the sample population

* p.w. = Salicornia (Pickleweed)


A
C
KENT
.5 cm = 100 m
Sample B transect
Sample C transect
Major creeks (4)
MAP of
BOLINAS LAGOON
Cerithidea californica
Organism
SSE
Revised
Summer 1967
G. Chan
Mudflats

MAP 10

VI. OLIVELLA BIPLICATA

A. Classification

Phylum: Mollusca
Class: Gastropoda
Subclass: Prosobranchia
Order: Pectinibranchia
Suborder: Stenoglossa
Family: Olividae
Genus-species: Olivella biplicata (Sowerby, 1825)

Figure 5.
Olivella biplicata

B. Natural History

Common name: Purple Olive Shell

Range: British Columbia to Baja California, with the heavy density appearing between Bodega Bay to San Diego.

C. Description

The shell averages about one inch (25mm) long, with a range of 15 to 25 mm in length. There are about four whorls, with the surface polished smooth with a color mixture of white, gray and purple. The aperture is long, narrow at the top and wide at the bottom (Figure 5).

D. Ecology

Common habitat is shallow water and sand flats, living in colonies, burrowing just under the sand when the tide goes out. Investigator, M. Stanley, found that

Olivella biplicata is very sensitive to a pebble substrate and must have fine sand for its burrowing activities.

Stanley's observation of the feeding habitat found that the animal is a detritus feeder, with a heavy emphasis on the algae detritus of Ulva spp. and Enteromorpha spp. . He also discovered a large amount of sand in each stomach, and hypothesized that it is accidently ingested with the algae material.

E. Statistics on Olivella biplicata

Date: July 5-19, 1967
Tides: -0.6 to -1.3
See Table 11, Map 11

Sampling techniques: Linear quadrads. Random sampling of 9 square-meter plots at four different areas (see Map 11). The investigator, M. Stanley, sifted his hands through each square meter plot to a depth of about two inches - this would sample any O. biplicata that have burrowed.

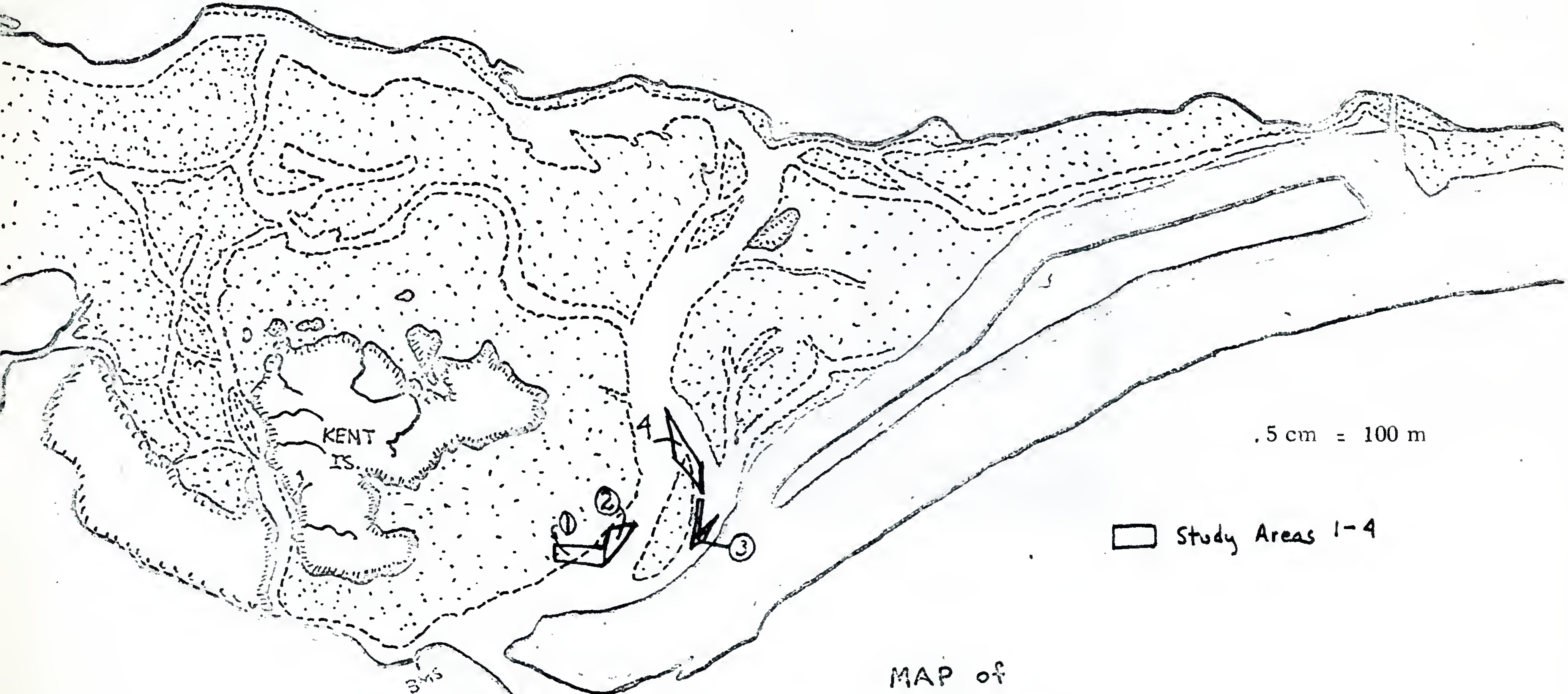
F. Conclusion

Observing Table 11, we notice the high density of O. biplicata in area 3 (see Map 11) for the general area. For a more specific dimension, consult the Bolinas Marine Station Study Map and Report. Area 3 is not in the direct scouring channel as area 2 and hence may have the appropriate ecological balance to maintain a healthy colony. This spot is consistent in having fine sand as a substrate, while there is an abundance of Ulva and Enteromorpha growing from the inner tide area of the Stinson spit.

The more favorable habitat, area 3 and area 1, supports means of 36.5 and 4.9 O. biplicata per square meter respectively. Area 2 has a mean of 1.8 per square meter, while area 4 is negligible with .55 per square meter (see page 49). The total estimate of the sample areas is 78,797, making this the second most dominant gastropod within the sandy mudflats of Bolinas Lagoon. Generally speaking, Olivella biplicata is not found in abundance elsewhere in the lagoon as in the study areas 1-4; thus, the estimate of this habitat would closely approach the true parameter estimates for the entire lagoon.

TABLE 11. *Olivella biplicata*

Area	No. of Samples	Number Observed	Sample Mean/m^2	95% conf. interval/m^2	Area m^2	Total Sample Estimate	Substrate
1	X_1	5					
	X_2	6					
	X_3	0					
	X_4	2					
	X_5	7					
	X_6	5					
	X_7	5					
	X_8	14					
	X_9	0					
	9	44	4.9	3.3-6.5	2700	13,230	fine sand to gravel
2	X_1	3					
	X_2	1					
	X_3	2					
	X_4	2					
	X_5	3					
	X_6	2					
	X_7	1					
	X_8	1					
	X_9	1					
	9	16	1.8	.2 -3.4	1361	2,450	fine sand
3	X_1	140					
	X_2	15					
	X_3	27					
	X_4	38					
	X_5	3					
	X_6	5					
	X_7	22					
	X_8	72					
	X_9	7					
	9	329	36.5	24.9-42.9	1408	51,392	fine sand
4	X_1	0					
	X_2	0					
	X_3	1					
	X_4	1					
	X_5	1					
	X_6	0					
	X_7	1					
	X_8	0					
	X_9	1					
	9	5	.55	.044-.956	21319	11,725	fine sand
TOTALS	36	394				78,797	fine sand to gravel



MAP of
BOLINAS LAGOON

MAP 11. Olivella biplicata
Organism
SSE
Revised
Summer 1967
G. Chan

Mudflats

VII. CALLIANASSA CALIFORNIENSIS

A. Classification

Phylum: Arthropoda
Superclass: Crustacea
Class: Malacostraca
Subclass: Eucarida
Order: Decapoda
Tribe: Anomura
Family: Callianassidae
Genus-species: Callianassa californiensis Dana, 1854

Figure 6a. Callianassa californiensis

Top: female
Bottom: male

B. Natural History

Common name: White Ghost Shrimp

Range: Dwells in the mud-silt of marine sloughs and bays from Alaska to Baja California.

C. Description

White to yellow in color, though somewhat transparent. Adults are two to three inches in length. Outstanding morphology: the shrimp has ten legs; the fore pair pincers are of uneven length (see Figure 6a). The longer pincer may be either the right or the left, being very pronounced on the males. The second and third pair of legs are the primary appendages used for digging their mud burrows.

In its life of digging burrows, the shrimp sifts the soil for organic detritus with its maxillipeds. Cylindrical-like castings are often observed at the volcanic-conelike opening of its mud burrow. At least two openings to the water surface must be provided to allow circulation for respiration. Burrows go down to a maximum depth of 30 inches.

UPOGEBIA PUGETTENSIS

A. Classification

Phylum: Arthropoda
Superclass: Crustacea
Class: Malacostraca
Subclass: Eucarida
Order: Decapoda
Tribe: Anomura
Family: Callianassidae
Genus-species: Upogebia pugettensis (Dana, 1852)

Figure 6b.
Upogebia pugettensis

B. Natural History

Common name: Blue Mud Shrimp

Range: In mud of sloughs and bays from Alaska to Baja California.

C. Description

Bluish in color, unlike its Callianassa neighbor, Upogebia's fore appendages are even-length chelae; the first four pairs of anterior appendages are used for digging its burrows (see Figure 6b).

The burrows averaged in depth about eighteen inches, and two to three feet in horizontal burrows. Like Callianassa, it strains the mud for organic detritus, and it also shows more dexterity by being able to take detritus from the water with its two fore pairs of appendages - the hairy edges of these legs act as combs to strain the organic material. Chief predators of both shrimps seem to be the lagoon fishes, as many parts were found in the stomachs of all species.

D. Statistical Sampling of Callianassa californiensis and Upogebia pugettensis.

Dates: June 21-30, 1967
Tides: -1.7 on June 21
See Table 12, Map 12A, 12B

Sampling techniques: Employing quadrad grids and choosing the intersection numbers randomly from a hat. Ten intersections of one square meter each were sampled. The technique for determining if a burrow contained a living specimen of either Callianassa or Upogebia was to count conelike burrows that contained the fecal pellets of the two shrimps that were shrewn around the burrow aperture. See the below diagram. (See Figure 7.)

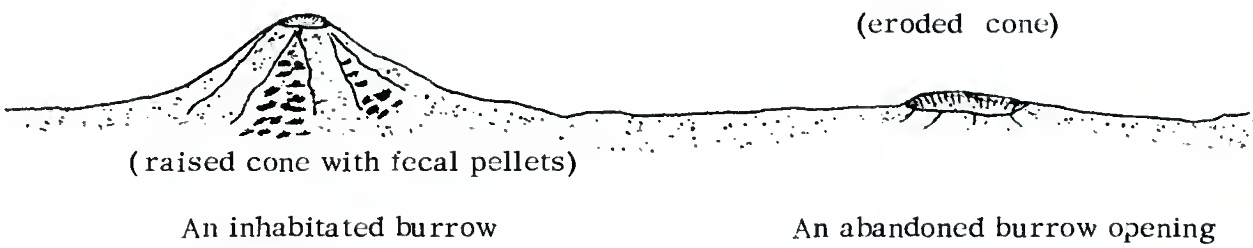


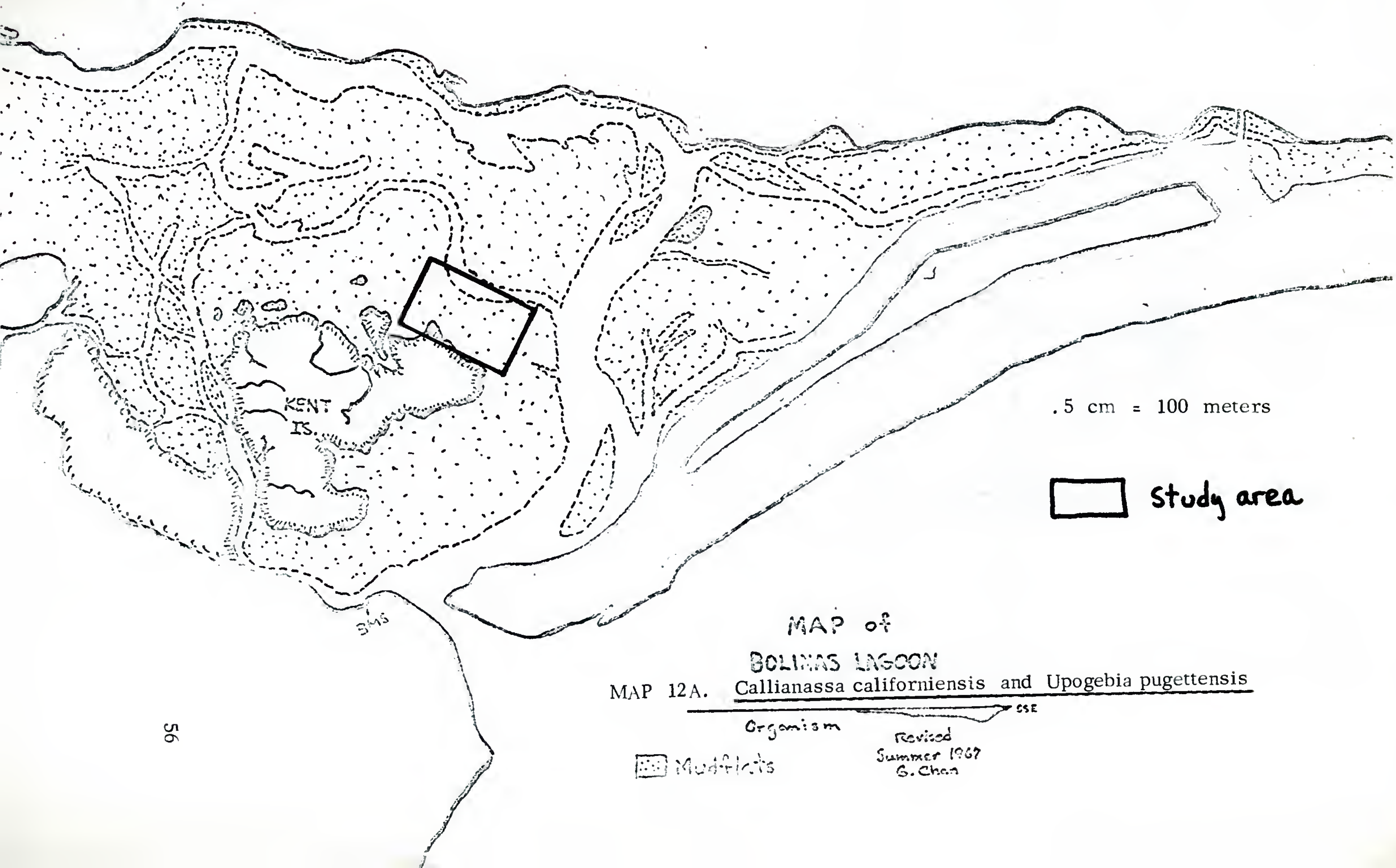
Figure 7. Shrimp Burrows

The investigator, M. Verzi, could find no differences which would detect whether the occupant was Callianassa or Upogebia. Digging for the animals revealed that half were Callianassa and half were Upogebia. So, a burrow represented both organisms. Apparently, they are good neighbors!

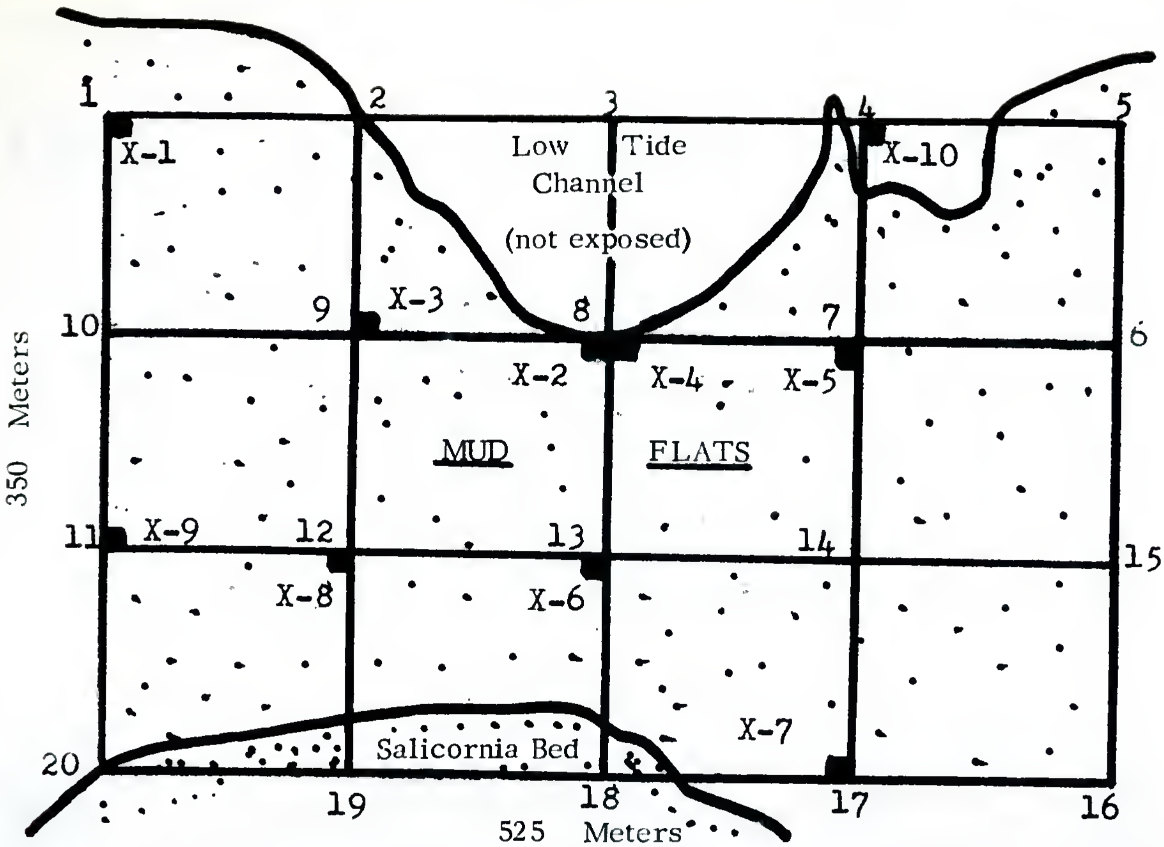
Location: See Map 12A for the overall area, 350 meters by 525 meters. Map 12B indicates the enlargement of the location in Map 12A. The filled in spots indicate the sampled square-meter plots.

E. Conclusion

The sample population estimate for this area is 1,414,875 Callianassa and Upogebia shrimps. This total represents but a small portion of the total numbers available. The mud throughout the lagoon will probably yield a fantastic number of these organisms. Their burrows are literally observed in almost every soft mudflat area within the lagoon. Future research might be an additional sampling of all areas; the sample of 10 in this study is considered "small". Certainly, the natural history and ecology of the organisms need to be further explored. The two species should be studied and contrasted in all aspects of their ecology.



MAP 12A. Callianassa californiensis and Upogebia pugettensis



MAP 12 B. Enlargement of Study Area for Callianassa and Upogebia (1" = 100 meters)

TABLE 12. Sample - Survey of Callianassa and Upogebia (by M. Verzi)

Sample No.	No. of Burrows	Substrate
X_1	8	Fine sand, small burrows, soft substrate
X_2	5	Medium sand, few Salicornia on edges, diatoms on the surface
X_3	8	Medium sand, some Salicornia on edges
X_4	13	Fine sand, Salicornia on edges
X_5	7	Six-inch Black silt, very moist, soft substrate
X_6	16	Black silt, soft substrate
X_7	12	Silt to medium sand, soft substrate
X_8	3	Fine sand, soft substrate
X_9	4	Fine sand, soft substrate
X_{10}	1	Submerged (under water)
	77	

$\bar{X} = 7.7/m^2$

$s^2 = 22.68$

$s = 4.76$

95% confidence interval for the population mean:

$$4.75 \leq \mu \leq 10.65$$

Study Area = $183,750 m^2$

Approximate total number of Callianassa and Upogebia in the Study Area = 1,414,875

VIII. HEMIGRAPSUS OREGONENSIS and PACHYGRAPSUS CRASSIPES

A. Classification

Phylum: Arthropoda
Superclass: Crustacea
Class: Malacostraca
Subclass: Eucarida
Tribe: Brachyura
Family: Grapsidae
Genus-species: *Hemigrapsus oregonensis* (Dana, 1951)

and

Pachygrapsus crassipes Randall, 1839

Figure 8a. *Hemigrapsus oregonensis*

Figure 8b. *Pachygrapsus crassipes*

B. Natural History

Common name: *H. oregonensis* is Mud Crab

P. crassipes is Lined Shore Crab

Range: Alaska to San Diego, California

C. Habitat

Both crabs are scavenger feeders, covering a wide range of habitat. *P. crassipes* (Figure 8b) has great diversity, being found at the open shore coast line, under wharf pilings, and in bays and lagoons. This crab generally occupies the higher vertical tidal zones, - zone 2, and rarely will venture into the lower intertidal region.

H. oregonensis occupies a lower intertidal zone, zone 4 and 3, and is always found in bays and estuaries. Researcher, J. Fowle, calls *P. crassipes* the upstair tenants and *H. oregonensis* the downstair dwellers, both living in mud burrows in their respective vertical zones.

In the morphology of these two crabs, the carapace is nearly square with the eyes at the anterolateral corners. *P. crassipes* has numerous transverse lines on the carapace surface, while *H. oregonensis* lacks these lines and is usually dullish green in color and has hairy legs.

An interesting study was the observance of thousands of dead crabs washed up at the high tide debris line at the north end of Kent Island. Mr. J. Fowle counted 900 crabs for one square meter area and this was multiplied against a linear 50 meters to give an estimated 45,000 dead crabs in a small area. No sound theories as to the causes of this mortal pictorial has been offered, although high temperature and pollution are possible causes.

D. Sampling Techniques

Date: June 21-July 14, 1967
Tide: -1.7 to 1.1
See Table 13, Map 13

Four major areas were used to study the population densities (see Map 13). The sampling methods were:

- Area 1. The eastern mudflats of Kent Island. Random sampling of m^2 plots using a transect - tossing rock technique.
- Area 2. Northwest shoreline of the western shore low tide channel. Quadrad random sampling of the mud and berm - m^2 plots.
- Area 3. Western shoreline extending under the piling homes. Random sampling of m^2 plots by randomly choosing marked rocks.
- Area 4. The East shoreline; examining m^2 plots at each 250 meter transect.

Specific details for the m^2 plots for each area may be obtained by referring to the report of J. Fowle and the Master Bolinas Lagoon map at the Bolinas Marine Station.

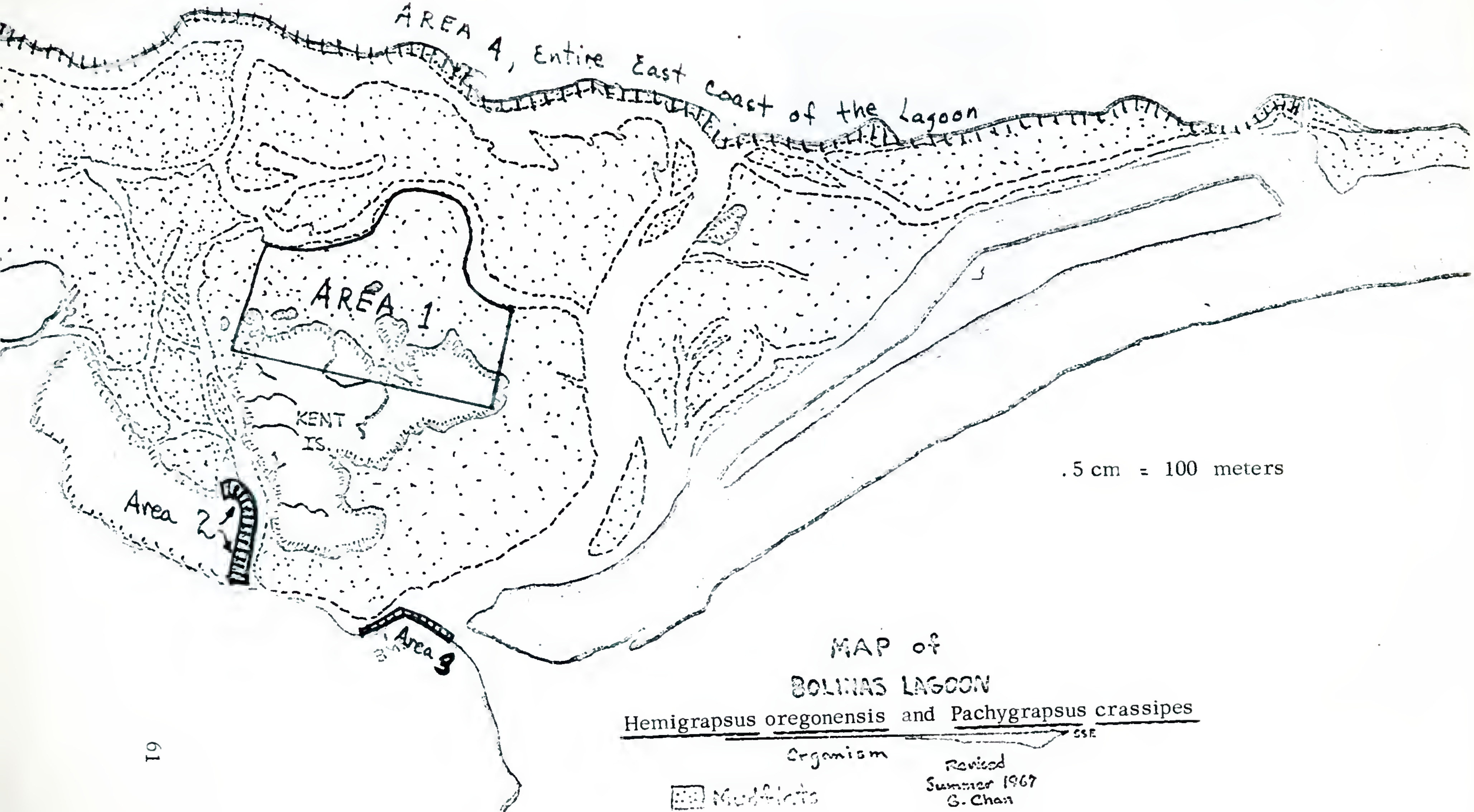
The investigator generally had to dig in each square meter in order to insure counting the crabs burrowed in mud holes.

E. TABLE 13. Statistics on H. Oregonensis and P. crassipes

Area	No. of Samples	No. of crabs per sample	Mean per m^2	95% C. I. /m^2	Size of Area m^2	Estimated Area Pop.	Substrate
1	25	278 (both crabs)	11.1	6.3-15.9	80,000	888,000	sand to Salicornia
2	16	130 H. o. 192 P. c. 322	20.1	-	200	4,020	silt to medium sand
3	16	103 (both)	6.4	3.8-9.0	100	640	silt to pebbles
4	25	385 (both)	15.4	-	60,000 (length:6000m) (width: 10m)	924,000	sand to cobbles
Totals:	82	1,088			140,300	1,816,660 crabs	

F. Conclusion

The basic conclusion is that the two crabs are widespread throughout the lagoon. There are probably many other areas with population of both crabs in greater density than any of the sample means/m^2 listed in the above statistics. In particular, the southeast corner of the lagoon, near the dredge barge wreck, has a great density of observed Hemigrapsus oregonensis per square meter. Higher in the intertidal zone, burrowed against the berm are many more thousands of Pachygrapsus crassipes. The future additional population studies would certainly indicate that this is one of the most abundant organisms in the entire lagoon, probably numbering into the millions. The ecology of both crabs also remains as a future study.



MAP 13. FOUR STUDY AREAS

IX. ORCHESTOIDEA CALIFORNIANA

A. Classification

Phylum: Arthropoda
Superclass: Crustacea
Class: Malacostraca
Subclass: Peracarida
Order: Amphipoda
Suborder: Gammaridea
Family: Talitridae
Genus-species: Orchestoidea californiana (Brandt, 1851)

Figure 9. Orchestoidea californiana

male

B. Natural History

Common name: Beach Flea or Beach Hopper

Range: British Columbia to southern California

C. Description

A crustacean with flattened body from side to side, with long legs; the males have large antenna longer than the body. Their color is faintly bluish, generally grayish. They occupy the coastal sandy beaches at the crest of the berm. T. Stetson found they do not like saturated sand - too difficult to dig in. Their activities are very pronounced at night, and during the day they burrow from 2 to 12 inches below the surface of the sand or hide under algal masses or driftwood.

As for their diet, investigator T. Stetson discovered that they are truly first class scavengers - eating seaweed, meat, wood, paper, cloth, and even the carcasses of flies or other deceased beach hoppers. Dr. Joel Hedgpeth states that these creatures "do their best to keep the beach clean, although they have not learned to eat cans, bottles, and plastic containers".[4]

In hopping from one spot to another, O. californiana does a full flip in mid-air, probably because of the peculiar propulsion from the appendages; then too, he gains more distance with this "flip"!

D. Sampling Techniques

Date: June 20 through July 2, 1967
Time and tides: Both day and night observations; tides varied - as the animal inhabits the high tide zones
See Tables 14A, 14B, Map 14

Samples: Six areas were surveyed (see Map 13). Each area was divided into linear transects, and intersections were numbered, randomly drawn for square meter plot counts. At night, O. californiana was counted at the surface, and during the day, the investigator, T. Stetson, dug for the sample counting.

[4] Hedgpeth, Joel W., Introduction to Seashore Life, University of California Press, 1962, p. 81

TABLE 14A. Comparing Day and Night Population Counts of O. californiana

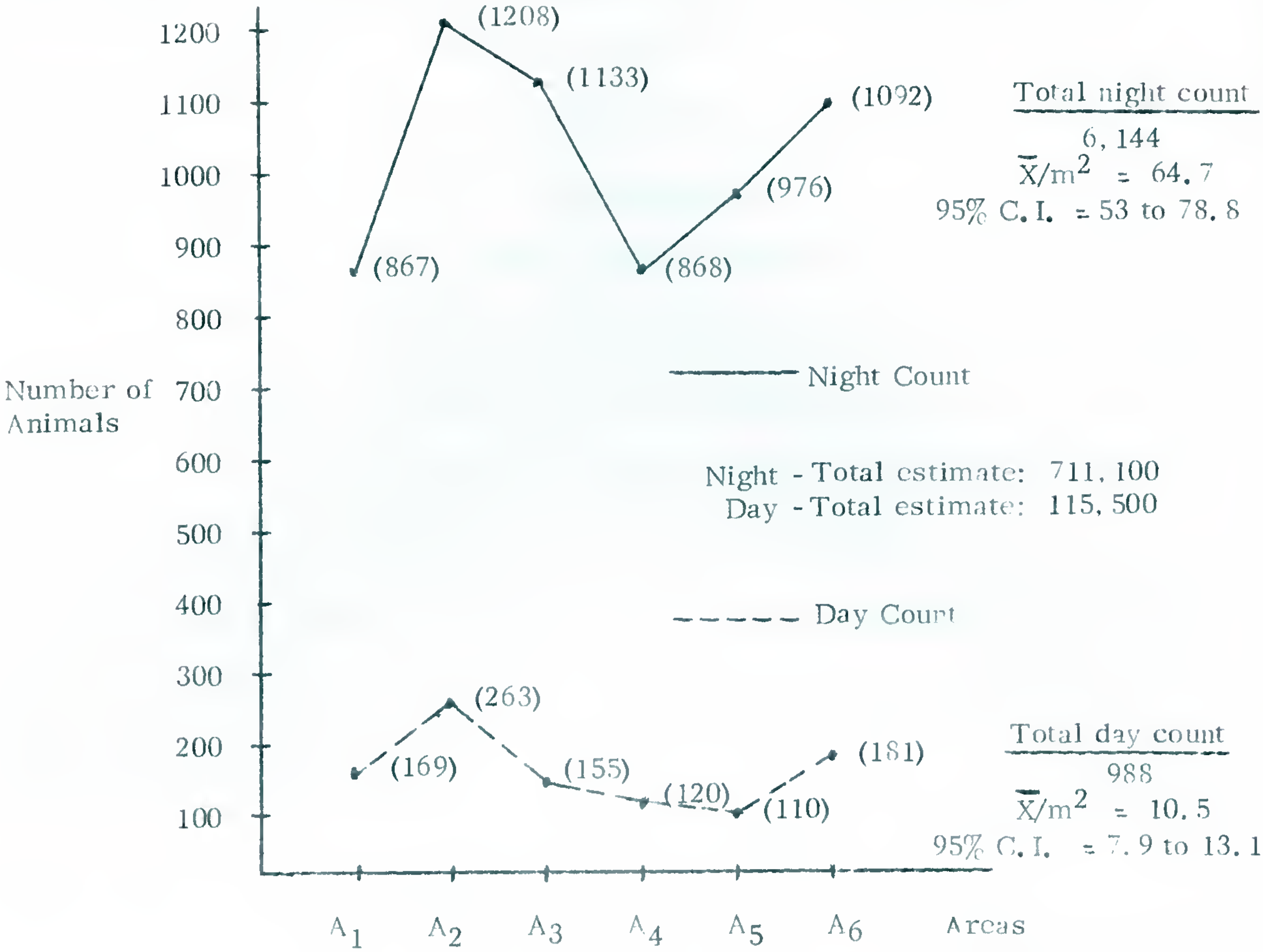


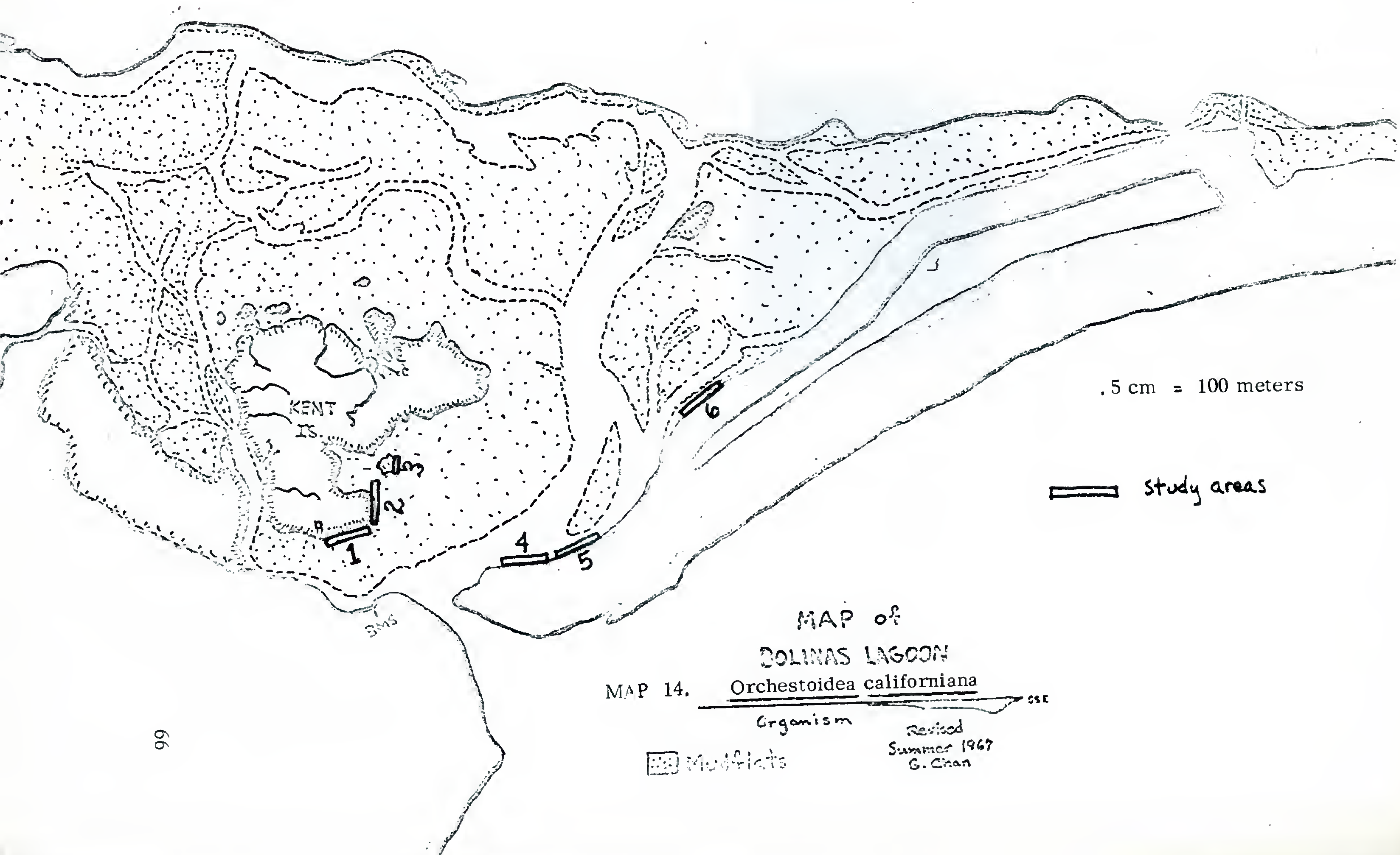
TABLE 14B. Sample Statistics on Orchestoidea californiana

Area	No. of Samples	Total Night Count	Mean/m^2 Night Count	Size of Area	Total Estimate Sample Area	Substrate
1	15	867	57. 8	200m x 10m	115, 600	fine-medium sand
2	15	1, 208	80. 5	200m x 10m	161, 000	fine-med. - coarse sand
3	15	1, 133	75. 5	100m x 10m	75, 500	fine sand
4	15	868	57. 8	200m x 10m	115, 800	fine, med. sand, pebbles
5	20	976	48. 8	200m x 10m	97, 600	fine-coarse sand. pebbles
6	15	1, 092	72. 8	200m x 10m	145, 600	fine-coarse sand, pebbles
TOTAL (Night)	95	6, 144		11, 000 m^2	711, 100	

F. Conclusion

One of the outstanding achievements in this study of Orchestoidea californiana is the sampling of the standing stock at night. The total day count was 998 individuals, and the total night count was 6,258 O. californiana. The six sample areas totaled 11,000 square meters. We use the night population count because this gives a more accurate number of beach hoppers. We also realize that there are a few night sleepers among O. californiana who refuse to hop around at night and allow the investigator to count them. The total estimate for the night population is 711,100. This arthropod is among the most abundant intertidal terrestrial organisms.

Aside from the studies of feeding habits, T. Stetson recorded temperature and sediment sizes of the sample plots. For all references to exact sample plots, one should study his detailed report.



MAP 14. Orchestoidea californiana

X. HERMISSENDA CRASSICORNIS

A. Classification

Phylum: Mollusca
Class: Gastropoda
Subclass: Opisthobranchia
Order: Nudibranchia
(Section) (Sacoglossa)
Family: Aeolidiidae
Genus-species: Hermissenda crassicornis (Eschscholtz, 1831)

Figure 10.
Hermissenda crassicornis

B. Natural History

Common name: Rainbow Sea Slug

Range: Puget Sound, Washington, to San Diego, California

C. Description

One of the most common sea slugs on this coast. Up to two inches long, this red-tipped dorsal plume nudibranch is found in a variety of habitats - open coast rocky reef pools, as well as in wharf piling pools and floating docks.

The sea slug fluctuates in abundance. In past years, early spring and late summer seemed to be the best months for their abundance. They generally lay eggs during these months. In the winter time their numbers are very scarce. At the Bolinas wharf pilings, Hermissenda was not found in large numbers in the piling pools nearest the shoreline of the lagoon nor near the sea wall foundations of the homes. The middle piling pools were the area of greatest density. This middle area probably provides for the optimum conditions favoring the sea slug - stable salinity, temperature, and an abundance of hydroids (Obelia sp.) to feed on.

The ecology of this sea slug needs to be studied the year around.

D. Statistics on Hermissenda crassicornis

Date: June 23, 1967
Tide: -1.6 at 7:24 A.M.
Water Temperature: 16° C.
See Table 15, Map 15

Site Selection: Two houses were selected (see Map 13). The pilings under the houses were numbered and samples were recorded at each piling that contains a tide pool. Pilings 1, 2, 5, 6, 7, 9, 10, 11, 12, 14, 15, 16, 20, 21, 29, 31, 32, and 37 contained little or no water and hence no sea slugs. They were not used in the sample statistics. The remaining 25 pilings and their pools established the data.

TABLE 15. Hermissenda Data

Pilings with Pool	No. of Hermissenda
3	0
4	0
8	0
13	0
17	0
18	4
19	0
23	0
24	0
25	3
26	1
27	1
28	3
30	0
33	5
34	3
35	14
36	3

Pilings with Pool	No. of H.
38	0
39	0
40	0
41	6
42	4
43	0
44	0
25	47

$\overline{X}$ (mean)/ m^2 = 1.9

s^2 = 9.7

s = 3.1

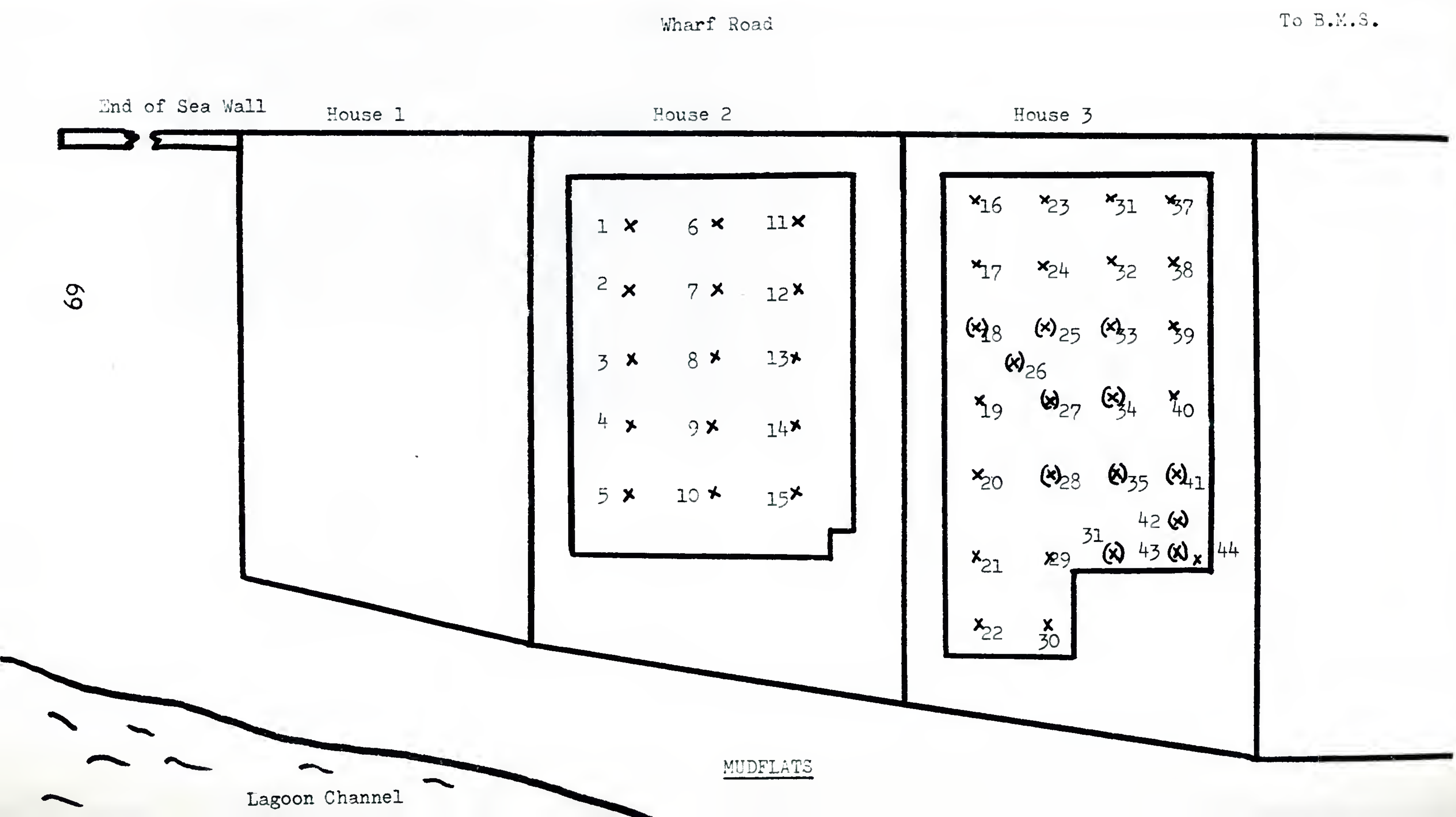
95% C.I.: $-13.32 \leq \mu \leq 17.22$

crosses 0; C.I. is not significant

No attempt was made to determine the total estimate for other piling pools

MAP 15. HERMISSENDA CRASSICORNIS AREAS

x = Pilings
(x) = Pilings with pools



XI. WHARF PILING ORGANISMS

The following list of organisms (see page 71) was compiled as a summary of recorded organisms observed in a vertical zonated piling area under the Bolinas Lagoon Wharf. The list is a composite of the common organisms seen over the years 1957 through 1966.

In the future, a study to determine the population density of these organisms on specific pilings will be attempted, and possibly a comparison of the pilings from one house to another. Moreover, a density comparison between wood pilings and concrete pilings should be interesting.

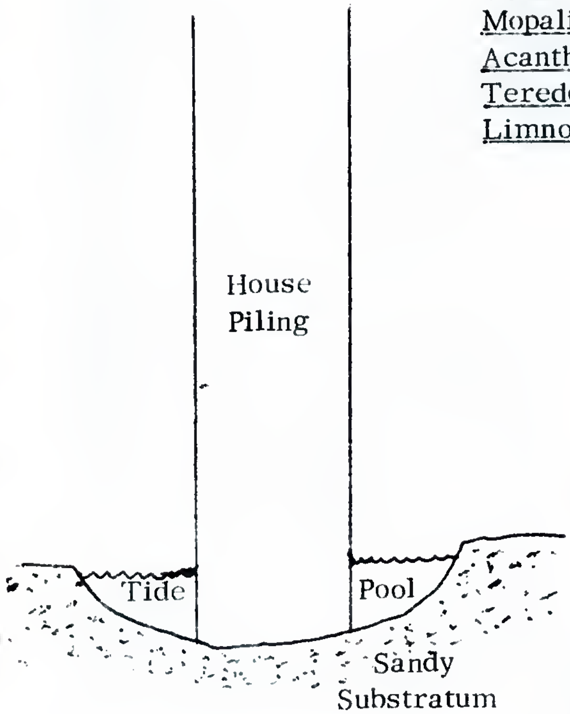
The ecology of the area, together with bacterial plate counting, might also be another avenue of investigation.

Figure 11a.
Bolinas Wharf Pilings

Figure 11b.
Piling with Pool

FIGURE 12. WHARF PILING ORGANISMS - sampled 1957 - 1966

*** very abundant
** abundant



House Pilings

Balanus glandula (barnacle) ***
Littorina scutulata (perwinkle snail) ***
Acmaea digitalis (limpet) **
Mytilus edulis (bay mussel) **
Mopalia mucosa (chiton)
Acanthina spirata (snail) **
Teredo navalis (boring mollusk)
Limnoria spp. (coring isopod)

Tide Pool Area

Obelia longissima (hydroid) ***
Tubularia marina (hydroid)
Hermissenda crassicornis (seaslug)**
Enteromorpha spp. (algae) ***
Ulva spp. (algae) **
Polysiphonia sp. (algae) **
Cancer magister (blue crab)
Cancer antennarius (cancer crab)
Anthopleura elegantissima (sea anemone) **
Diadume spp. (sea anemone) **
Hemigrapsus oregoniensis (mud crab) **
Citharichthys sordidus (Sanddab fish) **
Crago nigromaculata (bay shrimp) **
Olivella biplicata (olive snail)

Sandy Substratum

Eudistylia vancouveri (feather worm)
Eudistylia polymorpha (feather worm)
Phoronis vancouverensis (loph worm, 1958) *** (not found in 62-66)
Nephtys californiensis (bristle worm) **
Cryptomya californica (mud clam)
Saxidomis nuttalli (Washington clam)
Cirriformia spirabrancha (thread worm) ***
Tresus nuttalli (horseneck clam) ***
Notomastus tenuis (bristle worm) ***
Urechis caupo (weeny worm) **
Zirfaea pilsbryi (mud piddock) **
many other minor worms

XII. BOLINAS LAGOON PLANKTON

A. General Characteristics of Plankton

1. The word "plankton" comes from a Greek word that means "that which is made to wander or drift". Plankton organisms are generally divided into two groups: Phytoplankton (plant forms) and Zooplankton (animal forms).

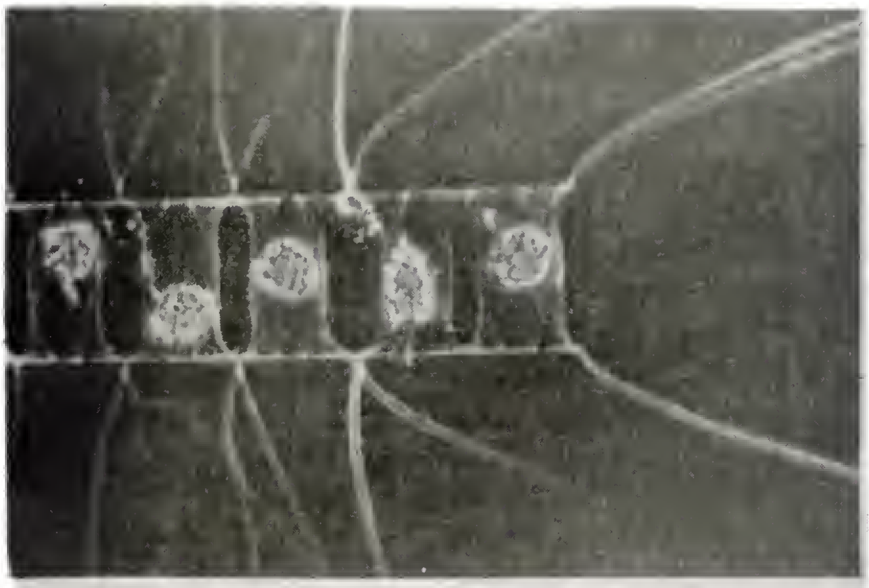


Figure 13a. Phytoplankton

Chaetoceros sp. (X 430)

Figure 13b. Zooplankton (X 30)

2. Nearly all the major groups of animals are represented in Plankton either as adults or larvae forms. Their locomotion is by current drifting or aquatic swim-

ming action.

3. The sizes of plankton range from small baceria (ultraplankton) to large swimming vertebrates (macroplankton). Sizes of plankton are usually classified as:

Ultraplankton, smaller than 5 microns
Nannoplankton, 5 to 10 microns
Microplankton, 10 microns to 1 mm
Macroplankton, 1 mm to several feet

4. The rate of sinking is important to plankton. Various morphological characteristics are observed in their attempt to reduce their specific gravity:

a. Reduced skeletons, no or very little calcium-shell deposits.
b. Some produce ballonlike bodies for floatation.
c. Diatoms to fishes produce body oils to increase floatation.
d. Fish have buoyant swim bladders and oil-rich livers.
e. Some have gas floats (Velella) and gas chambers in bone pockets.
f. Others reduce their surface resistance by creating other special floatation means - color, appendages, etc..

5. Limiting factors on Phytoplankton are:

a. Light and temperature
b. Turbulence
c. Phosphate depletion
d. Phytoplankton respiration
e. Grazing by zooplankton and others

B. Sampling Techniques used in the Bolinas Lagoon

Investigators T. Gosliner and G. Williams completed the first quantitative study of plankton in the Bolinas Lagoon under the direction of the author of this ecological report. Their findings are of much significance and will generally reappear in the next succeeding pages.

Number of tows: 5 in Area A (See Maps 16A, 16B, 16C - pages 76-78)
3 in Area B
8 Total
Plankton Net: Diameter of opening = 24 cm; mesh 12
Length of Tows: 200 meters
Collecting: Each tow material was rinsed into an 8 oz, 475 cc jar.
Abiotic Factors: Tow dates: June 29 - July 13, 1967 (See Chart 3 - page 75)

Density Analysis Technique [5]

1. Fixed sample in 4% rose bengel formaldehyde
2. Calculate the amount of plankton in a given water column

$$V_w = \pi r^2 l$$

π is 3.14
r is radius of the plankton net opening
l is distance of the tow

3. Let plankton settle in a jar (475 cc). Determine the volume of plankton in the jar:

$$V_p = \pi r^2 d$$

r is radius of the jar
d is depth of settled plankton

4. Determine ratio of plankton to water column:

$$\frac{V_p}{V_w} = \frac{1 \text{ (one part plankton)}}{x \text{ (unknown parts water)}}$$

5. Agitate 1 ml of filtrated plankton into 100 ml of water. Pipette out 1 ml into a grid counting dish. Count the number of species in 1 cm^2 area of grid x number of grids covered by the 1 ml sample.

6. N_1 (no. of species in 1 ml of lab sample) is equal to number of species counted in one grid multiplied by the number of grids covered by the sample.

7. N_w (no. of species in 1 ml or 1 cm^3 of water column) is found by:

$$\frac{100}{x} = \frac{N_w}{N_1} \quad \text{or} \quad N_w = \frac{100 (N_1)}{x}$$

8. Letting S be the number of species for the given water column, the final calculation is:

$$S = V_w N_w$$

C. Population Statistics

CHART 1. Summary of Plate Counts

	Tow I	Tow II	Tow III	Tow IV	Tow V	Tow VI	Tow VII	Tow VIII
d (cm)	.3	.2	.2	1.0	.7	.2	.2	.3
No. of organisms counted in 1 grid	10	9	9	31	31	8	11	19
No. of grids covered by sample	9	9	9	9	9	9	9	9

[5] Chan, G. L., Plankton Analysis Technique, June 1965, Bolinas Marine Station, Bolinas, California

CHART 2. Statistical Values of Areas A and B

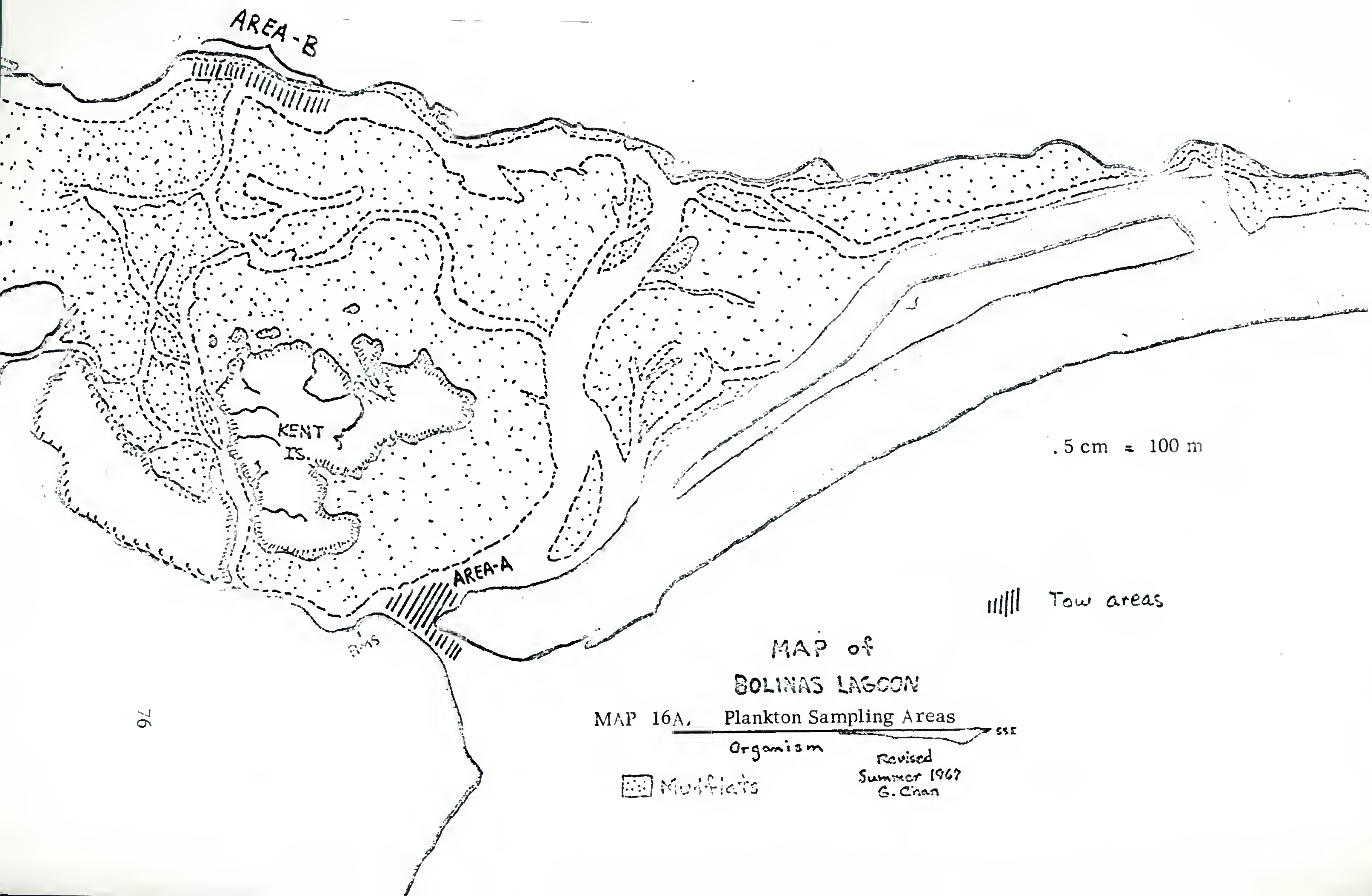
Area A	V_w	V_p	x	N_I	N_w	S
TOW I	$9.0 \times 10^5 cm^3$	$1.9 \times 10cm^3$	4.5×10^5	90	.02	1.8×10^5
TOW II	$9.0 \times 10^6 cm^3$	$1.2 \times 10cm^3$	7.5×10^5	81	.01	9.5×10^4
TOW III	$9.0 \times 10^6 cm^3$	$1.2 \times 10cm^3$	7.5×10^5	81	.01	9.5×10^4
TOW IV	$9.0 \times 10^6 cm^3$	$6.3 \times 10cm^3$	1.43×10^5	279	.2	1.8×10^6
TOW V	$9.0 \times 10^6 cm^3$	$4.4 \times 10cm^3$	2.0×10^5	279	.13	1.2×10^6

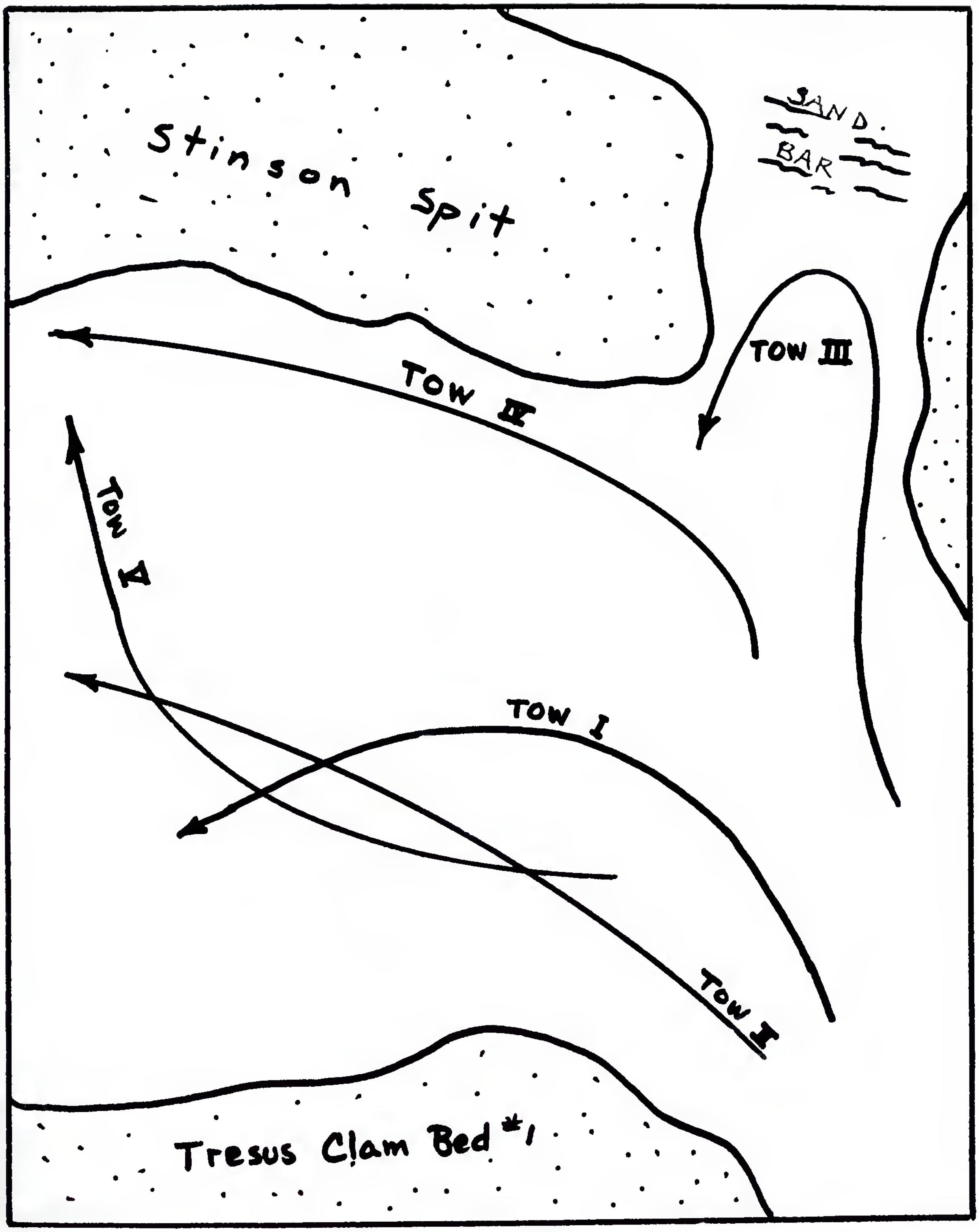
Area B						
TOW VI	$9.0 \times 10^6 cm^3$	$1.2 \times 10cm^3$	7.5×10^5	72	.009	8.1×10^4
TOW VII	$9.0 \times 10^6 cm^3$	$1.2 \times 10cm^3$	7.5×10^5	99	.01	9.0×10^4
TOW VIII	$9.0 \times 10^6 cm^3$	$1.9 \times 10cm^3$	4.5×10^5	198	.04	3.6×10^5

TOTAL of both areas - 3.901×10^6

CHART 3. Abiotic Factors - Slack or Low Water

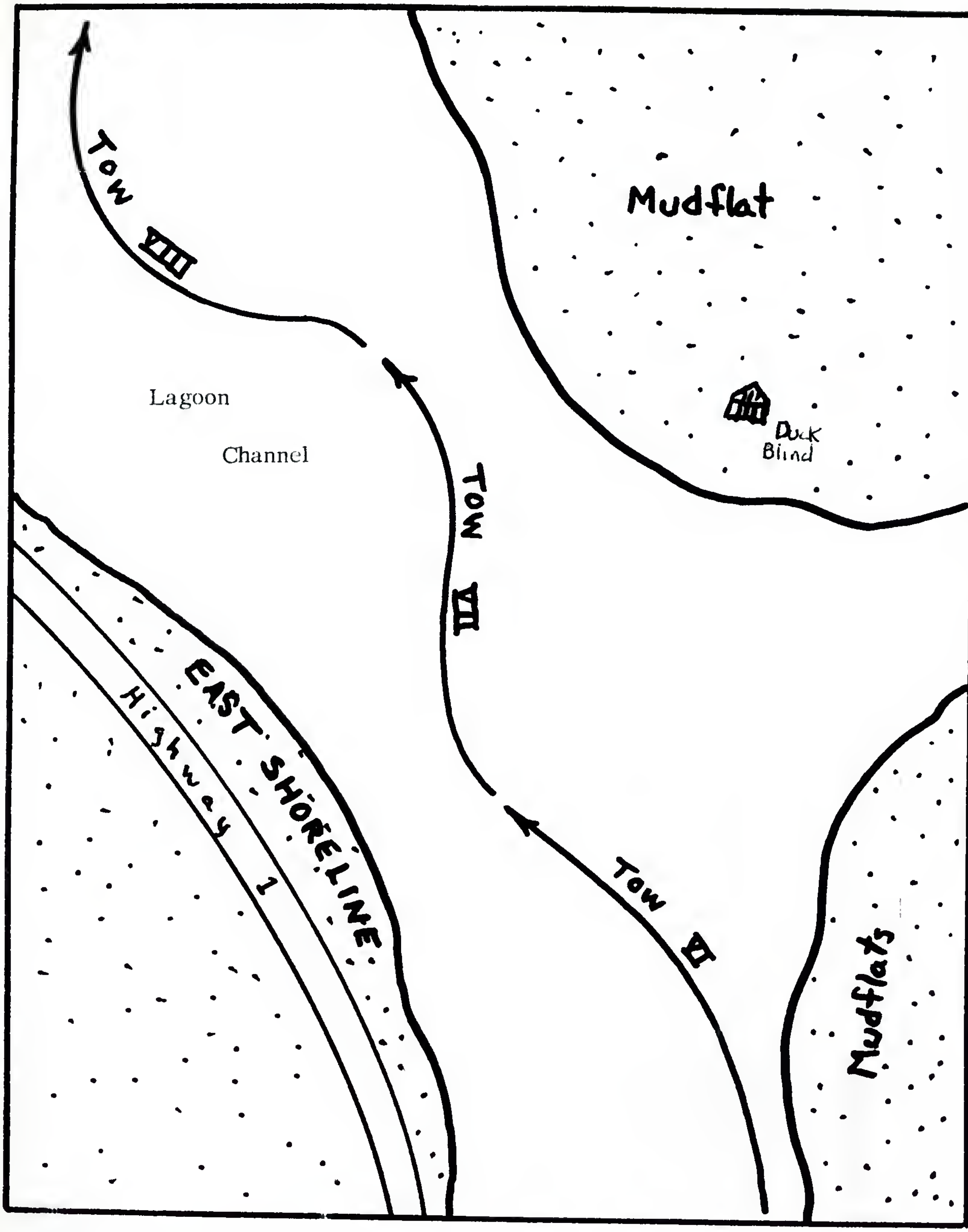
	Sample	Date	Time	Air Temp.	Water Temp.	Salinity	Weather Conditions
Area A	Tow I	6-29-67	11:30 am	20°C	13.4°C	35 ‰	Partly Cloudy
	Tow II	6-30-67	11:30 am	21°C	13.8°C	35 ‰	Partly Cloudy
	Tow III	6-30-67	11:30 am	20°C	13.7°C	35 ‰	Partly Cloudy
	Tow IV	7-3-67	11:30 am	20°C	13.5°C	35 ‰	Clear
	Tow V	7-3-67	11:30 am	20°C	13.5°C	33 ‰	Clear
Area B	Tow VI	7-13-67	11:30 am	24°C	20.0°C	33 ‰	Clear
	Tow VII	7-13-67	11:30 am	24°C	22.0°C	33 ‰	Clear
	Tow VIII	7-13-67	11:30 am	24°C	22.0°C	33 ‰	Clear


AREA-B
AREA-A
KENT IS.
.5 cm = 100 m
Tow areas
MAP of
BOLINAS LAGOON
MAP 16A, Plankton Sampling Areas
Organism
Revised
Summer 1967
G. Chan
Mudflats



MAP 16B MAP OF AREA A -- PLANKTON TOWS

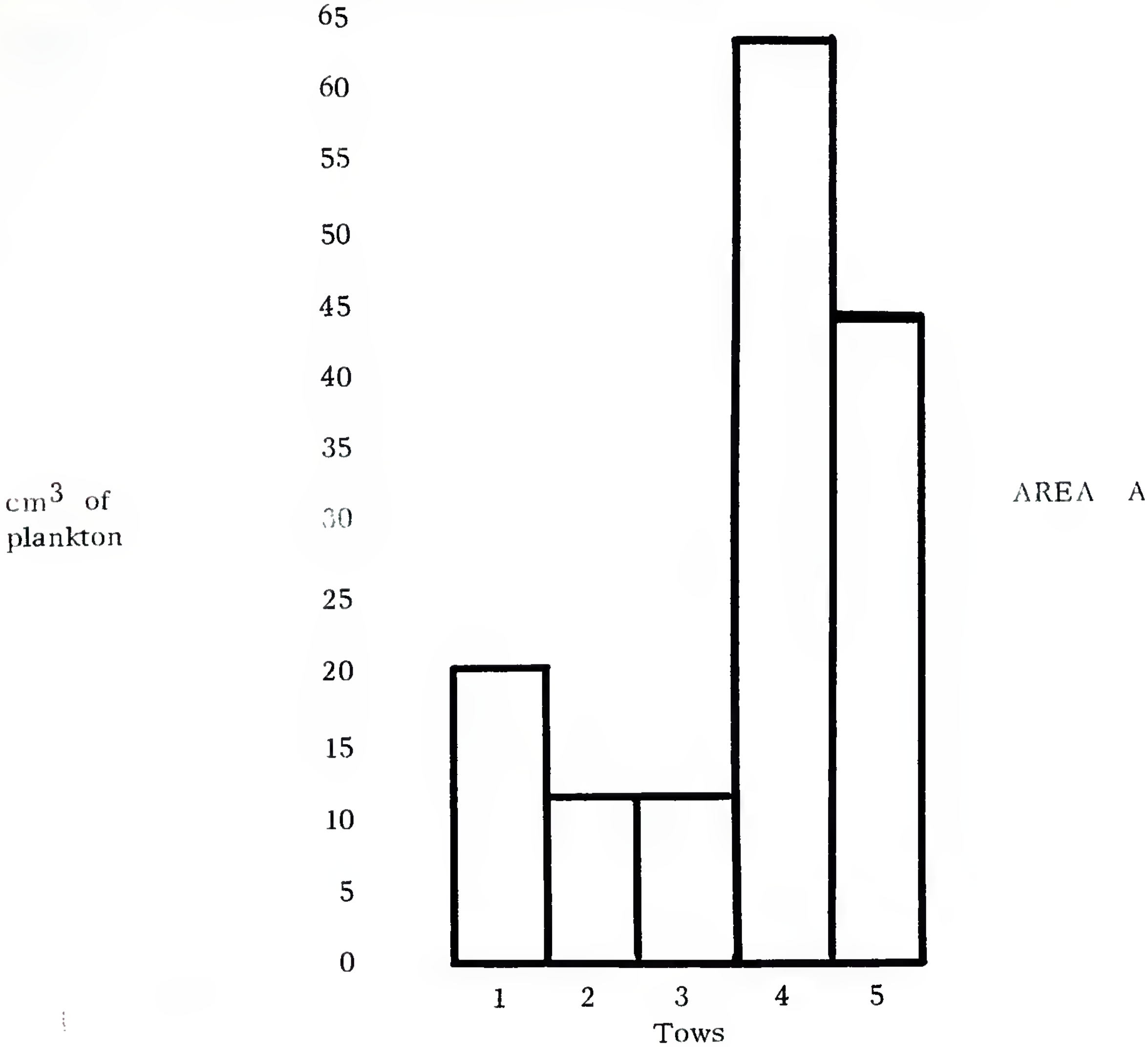
Five Tows, each 200 meters long at slack tide

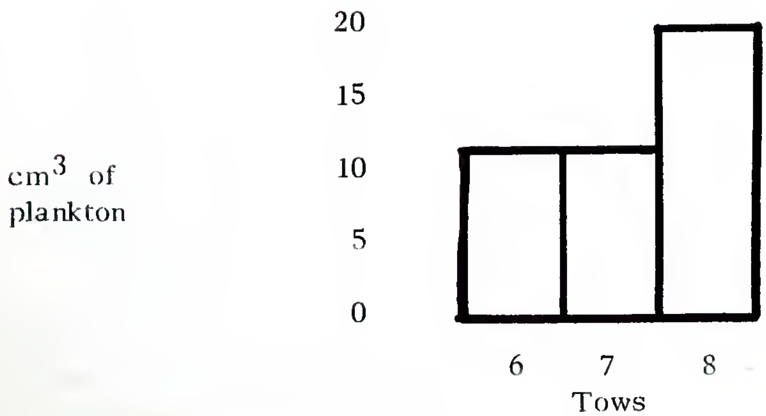


MAP 16 C   MAP OF AREA B - TOWS

Three Tows, each 200 meters long at slack tide

CHART 5. Comparing Volume of Plankton between Areas A and B





AREA B

D. SPECIES LIST from AREAS A and B

SPECIES LIST from AREA A

Microplankton (10 microns to 1 mm)

Noctiluca scintillans (Protist)
Bougainvillia sp. (Anthomedusae)
Obelia sp. (Hydroid medusae)
Glycerid Larvae (Polychaete Larvae)
Oikopleura sp. (Tunicate Larvae)
Psammechinus sp. (Echinoderm Larvae)
Carcinus sp. (Brachyuran Larvae)
Calanus spp. (Copepod)
Nauplii (Barnacle Larvae) (species?)
Chaetoceros spp. (Diatom)
Coscinodiscus spp. (Diatom)
Cerithiopsis sp. (?) (Gastropod veliger larvae)
Rotifer (species?)
Thalassionema sp. (Diatoms)
Nitzshia spp. (Diatoms)
Thalassiosira spp. (Diatom)
Eucampia spp. (Diatom)
Pleurosigma spp. (Diatom)

Macroplankton (1 mm to several feet)
Mesoplankton (1 mm to 1 foot)
Velella lata
Polyorchis pacifica
P. peninsulata
Negloplankton (1 foot to several feet)
Aurelia aurita
Chrysaora melenaster

SPECIES LIST from AREA B

Microplankton (10 microns to 1 mm)

Asterionella notata (Diatom)
Nauplii (Barnacle Larvae) (species?)
Psammechinus sp. (Echinoderm Larvae)
Chaetoceros spp. (Diatoms)
Coscinodiscus spp. (Diatoms)
Calanus spp. (Copepod)
Bougainvillia ramosa (Anthomedusae)
Ostracos (species?)
Ampithoe spp. (Amphipod)

Macroplankton (1 mm to several feet)
Mesoplankton (1 mm to 1 foot)
Siriella sp. (?) (shrimp)

Negloplankton (1 foot to several feet)
(None observed)

E. OTHER SPECIES LIST of PREVIOUS YEARS

Bolinas Bay Plankton - sampled, summer of 1964, 65, 66

*** very abundant in the summers
** relatively abundant
(no asterisk - small sample)

Phytoplankton (algae-diatoms)

Chaetoceros affinis ***
Chaetoceros distans ***
Chaetoceros spp. ***
Coscinodiscus perforatus ***
Coscinodiscus spp. ***
Rhizosolenia sp. ***
Fragilaria spp. ***
Pediastrum Biwae **
Nitzschia paradoxa **

Zooplankton (dinoflagellate)

Noctiluca scintillans (red tide) ***
Ceratium spp. ***
Peridinium conicum **
Peridinium spp.

Zooplankton (crustaceans)

Calanus finmarchicus ***
Calanus spp. ***
Barnacle nauplius ***
Zoea larvae **
Cypris larvae **
Arcardia spp. ***

Zooplankton (Coelenterata)

Chrysoara melanaster
Polyorchis penicillatus
Aequorea sp.
Obelia medusae **
Aurellia aurita **
Pelagia panopyra

Zooplankton (other phyla)

Pleurobrachia bachei **
Rotifera spp. ***
Pluteus larvae **
Polychaeta larvae **
Oikopleura larvae spp. ***
Sagitta spp.

CHART 6. Comparison of the Most Dominant Organisms in Area A and Area B.

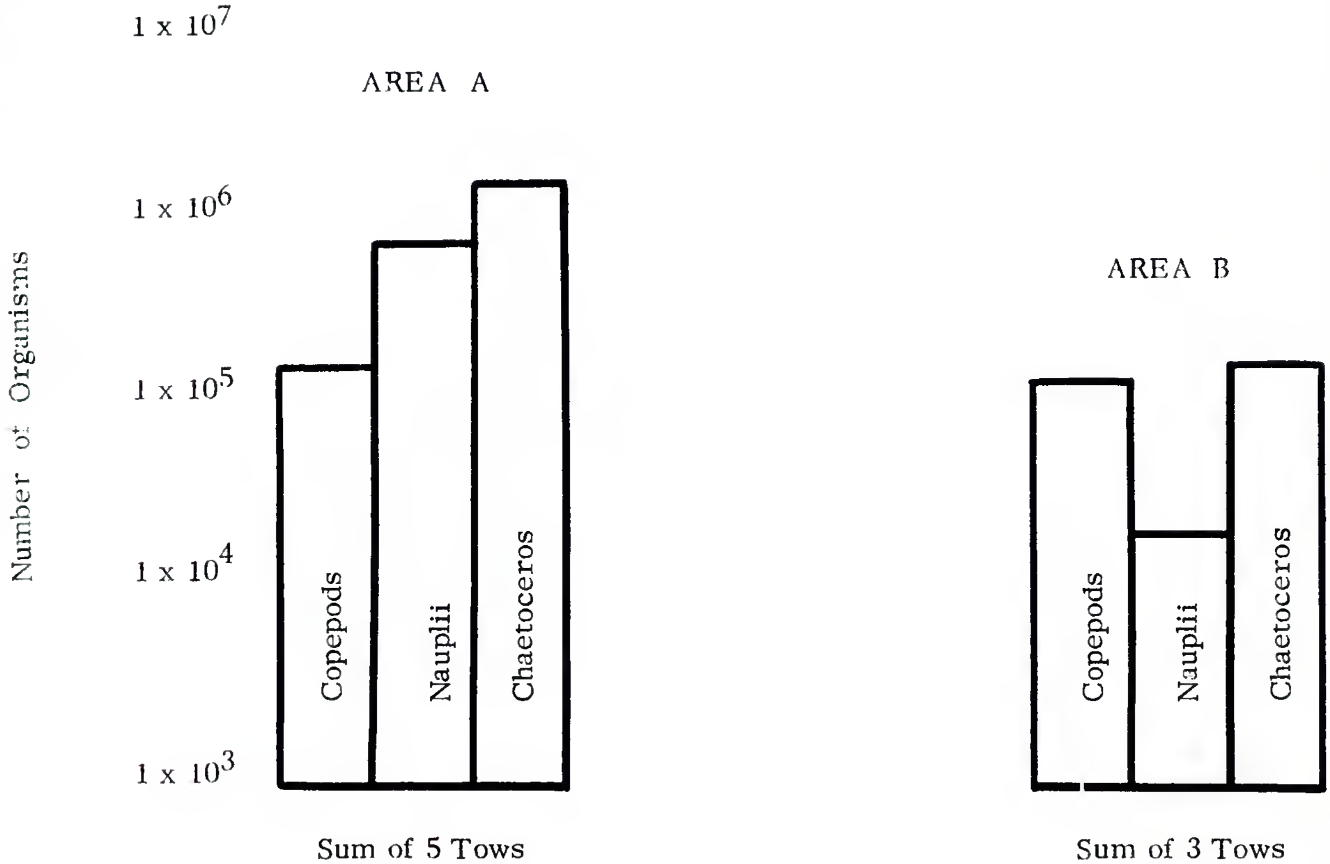
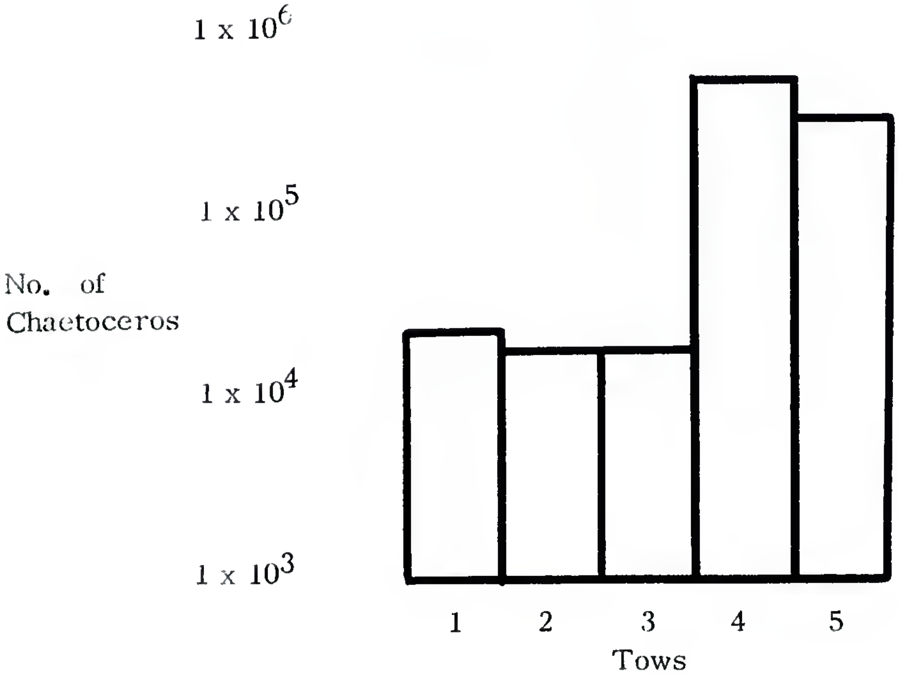
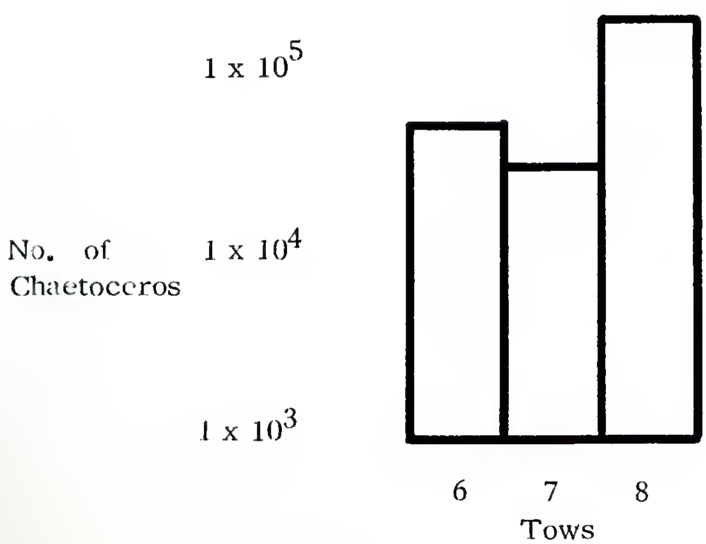


CHART 7. Comparing the Population of Chaetoceros spp. in each Tow



AREA A



AREA B

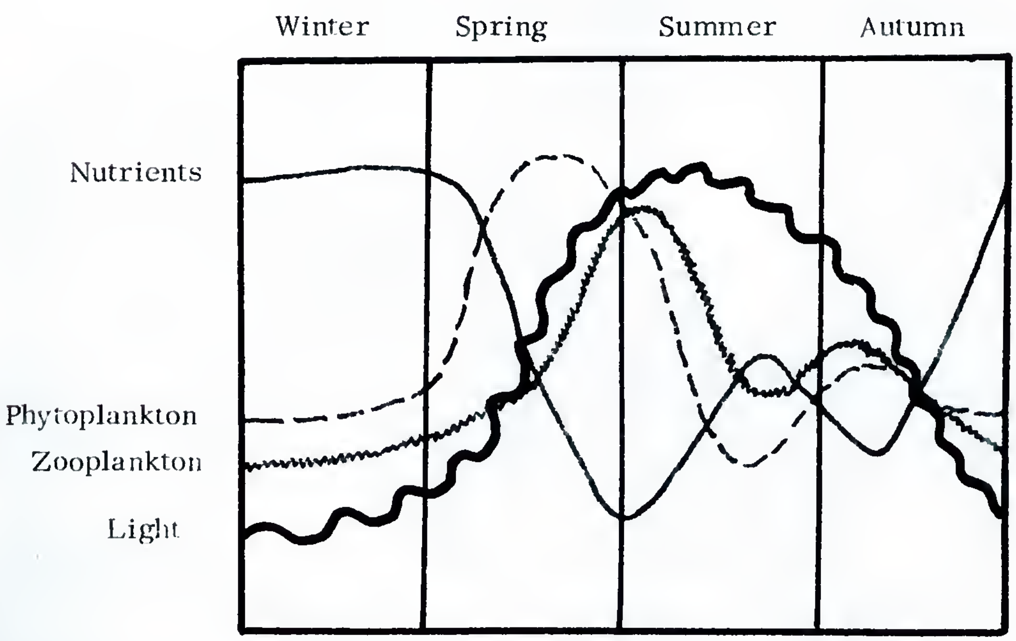
F. POPULATION SPECIES COUNT

	DOMINANT ORGANISM	No. in 1.6 cm^3 Grid	S value (No. of organisms in Tow)
AREA A			
TOW I	*Calanus spp.* (Copepods)	1	1.8×10^4
	Nauplii (Barnacle Larvae)	3	5.4×10^4
	Chaetoceros spp.	2	3.2×10^4
	Bougainvillia sp. (Anthomedusae)	2	3.2×10^4
	Carcinus sp. (Brachyuran Larvae)	2	3.2×10^4
TOW II	*Calanus spp.*	2	2.0×10^4
	Nauplii	6	6.0×10^4
	Carcinus sp.	1	1.0×10^4
TOW III	*Calanus spp.*	3	3.0×10^4
	Nauplii	2	2.0×10^4
	Carcinus sp.	1	1.0×10^4
	Coscinodiscus spp.	1	1.0×10^4
	Chaetoceros spp.	2	2.0×10^4
TOW IV	Nauplii	7	4.0×10^5
	Rotifer (species ?)	4	2.3×10^5
	Coscinodiscus spp.	2	1.0×10^5
	Calanus spp.	1	5.0×10^4
	Noctiluca scintillans	3	1.7×10^5
	Oikopleura sp. (Tunicate Larvae)	1	5.0×10^4
	Chaetoceros spp.	12	7.0×10^5
	Psammechinus sp. (Echinoderm Larvae)	1	5.0×10^4
TOW V	Nauplii	6	3.0×10^5
	Rotifer (species ?)	2	1.0×10^5
	Coscinodiscus spp.	5	2.5×10^5
	Calanus spp.	1	5.0×10^4
	Noctiluca scintillans	2	1.0×10^5
	Chaetoceros spp.	14	6.0×10^5
	Psammechinus sp. (Echinoderm Larvae)	1	5.0×10^4
AREA B			
TOW VI	Nauplii	1	1.0×10^4
	Calanus spp.	1	1.0×10^4
	Psammechinus sp.	1	1.0×10^4
	Chaetoceros spp.	5	5.0×10^4
TOW VII	*Bougainvillia sp.*	1	8.0×10^3
	Coscinodiscus spp.	3	2.4×10^4
	Calanus spp.	2	1.6×10^4
	Chaetoceros spp.	4	3.2×10^4
	Nauplii	1	8.0×10^3
TOW VIII	*Pleurosigma sp.*	3	6.0×10^4
	Calanus spp.	4	8.0×10^4
	Chaetoceros spp.	8	1.6×10^5
	Coscinodiscus spp.	3	6.0×10^4
	Nauplii	1	2.0×10^4

CHART 10. LIST of the TEN MOST COMMON ORGANISMS

Species	Total Number	Species	Total Number
1. Chaetoceros spp.	1.594×10^6	6. Noctiluca scintillans	2.7×10^5
2. Nauplii Larvae	8.72×10^5	7. Psammechinus sp.	1.1×10^5
3. Coscinodiscus spp.	4.44×10^5	8. Pleurosigma sp.	6.0×10^4
4. Rotifer	3.3×10^5	9. Carcinus sp.	5.2×10^4
5. Calanus spp.	2.74×10^5	10. Oikopleura sp.	5.0×10^4

CHART 11. SEASONAL PERIODS of PLANKTON PRODUCTION in NORTHERN TEMPERATE WATERS of the PACIFIC OCEAN[6]



[6] Rolf Bolin. Natural History of Marine Organisms Notes. July 1959. Hopkins Marine Station. Pacific Grove, Calif.

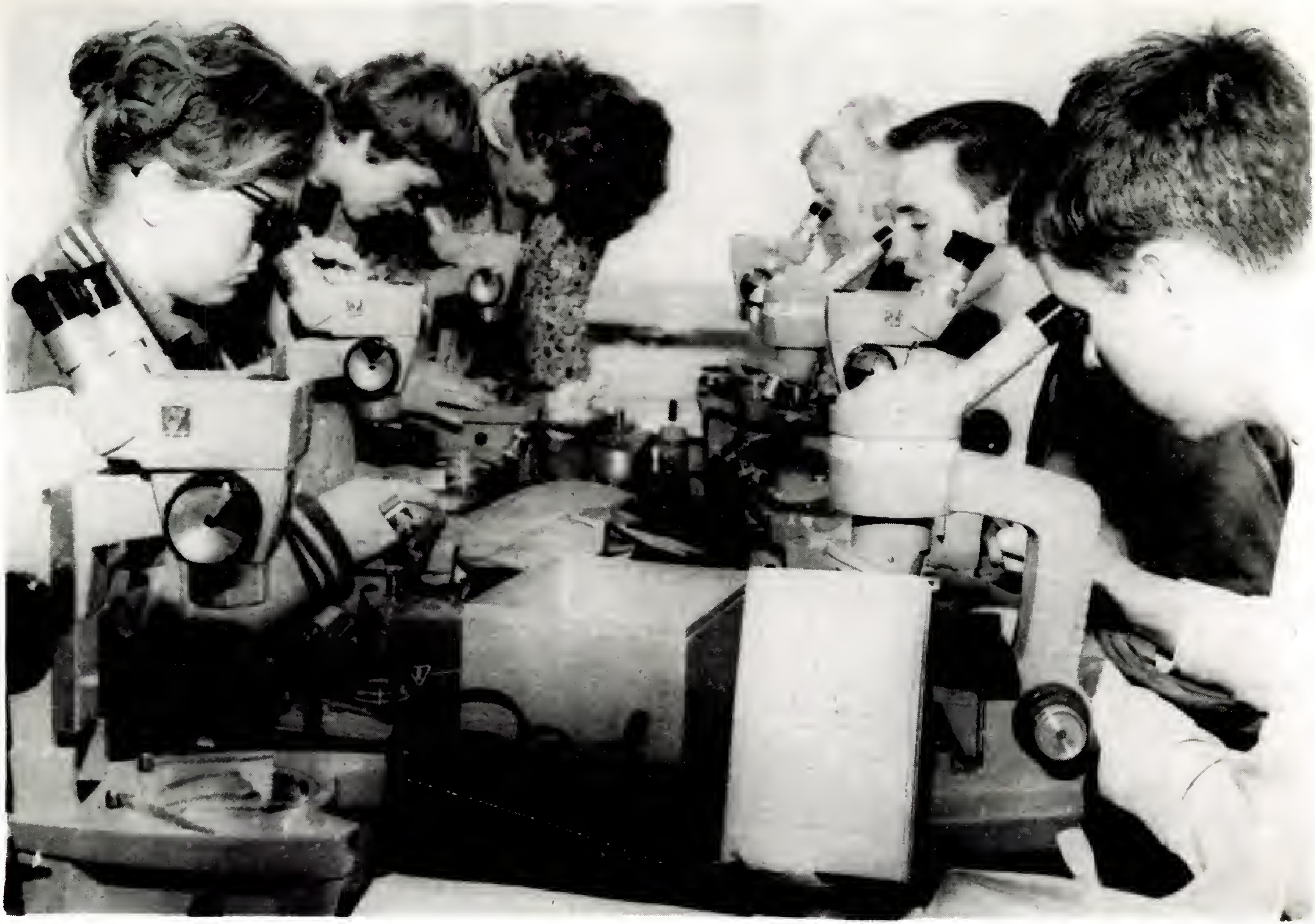


Figure 13c. PLANKTON SORTING TEAM - Isolating different species at the Bolinas Marine Laboratory

G. Conclusion on Plankton

In review of the density of plankton, the total major species of organisms in the eight tows were as follows (see Chart 10):

Chaetoceros (diatom)	1,594,000
Nauplii (barnacle) larvae	872,000
Coscinodiscus (diatom)	444,000
Rotifers	333,000
Copepods	274,000
Notiluca (dinoflagellate)	270,000

A total of 33 species of plankton were observed between June and July. Although the total numbers of plankton seem small, additional grid countings to determine the averages of each species in the water column would promote for greater accuracy. The total overall estimate of plankton in the eight tows is 3,901,000 plankton.

The volume of plankton accelerated in the later tows (July), due to the bloom of the diatoms Chaetoceros and Cosinodiscus. Moreover, the numbers of Copepods and Nauplii larvae were also accelerating in the July tows and probably if samples were taken in August, these zooplankton would outnumber the phytoplankton. See Charts 6 through 9.

The plankton in the Bolinas Lagoon follows the seasonal productivity cycles as seen previously in Chart 11. The June tows indicated a predominance of barnacle larvae and copepods. The tows in July indicated the opposite trends - there was an abundance of primary producers, in particular, the diatom Chaetoceros. The volume of plankton increased in the July tows, see Chart 5, Area A. Tows later in the month of July should indicate a rise in primary consumers. An interesting hypothesis arises:

In August, Roccus saxatilis, the Striped Bass, is abundant in this area and continues in large numbers through early fall. They probably are feeding on the abundantly young Jacksmelt, and Topsmelt also, which in turn are probably feed-

XIII. FISHES OF THE BOLINAS LAGOON

A. Introduction

The Bolinas Lagoon waters are rich in diversity of fish species. The species list was compiled beginning in the summer of 1964 through the past summer of 1967. The list (Figure 15) certainly does not enumerate all of the potential species in the lagoon, but does present the significant species which inhabit these estuarine waters. Some of the outstanding fish ecology are described below:

1. Like many lagoons throughout California, Bolinas Lagoon's shallow waters are inhabited by sharks and rays. Besides Bolinas, both Tomales Bay and Limantour Bay, each having a similar ecology, are abundant with all varieties of sharks and rays. By boating at low tide at the back portions of the Bolinas Lagoon, one can observe in the shallow waters many forms of sharks and rays swimming slowly in the waters.

A future study concerning the ecology of these sharks and rays in these waters would be invaluable to any lagoon studies. Some of the questions might deal with breeding and feeding habits of these primitive fish. Generally then, very little is known about the natural history of the relationship of lagoon waters to the presence of cartilaginous fish.

2. A present study of the stomach contents of all fishes is being carried out by Dr. Joel Gustafson, the leader of the Bolinas Lagoon Ecological Study Committee. The role of these vertebrates in the total ecological food web of the lagoon waters certainly is an important parameter to determine.

3. Many of the game fish species are young specimens. This may indicate that lagoon waters are favorable breeding areas for game fishes, and if this is so,

then the importance of preservation looms even more important. The Bolinas Marine Station personnel is currently beginning seining surveys which will determine the measured length of the fishes throughout the year in the lagoon waters. By the end of the summer of 1968, we should have some indication as to the mean size of game fishes, as well as other fishes. In Figure 15, listing the species of fishes, the small letter (g) indicates major game fishes.

4. There are several species of fish that are in abundance during different years and at different times of the season, indicated as letter (a), Figure 15. The most obvious of the species which are abundant is the common sculpin, Chinocottus analis. This little fish is so adept at escaping from the sweep of the inshore seine net that very few are trapped and caught. Its movements are reminiscent of a breakaway halfback in football seeking a hole. By and large, this fish with no economic importance seeks shelter down low in the sand as the net passes over him.

Another species which was not caught is the popular game fish, Roccus saxatilis, the Striped Bass. If additional seines were in operation in late August and in September, the number of young specimens would be numerous within the lagoon. This was evident during the late August seines of 1964.

B. Sampling Techniques

Area of the Seines: All seines at E-1 (East 1) station, Bolinas Lagoon, see Map 17.

Substrate of the station: Sand to pebbles, cobbles, boulders. Basically, of cobbles size.

Seine Size: 35 ft. long, 6 ft. wide, Mesh 1/4 inch. (see Figures 14a and b)

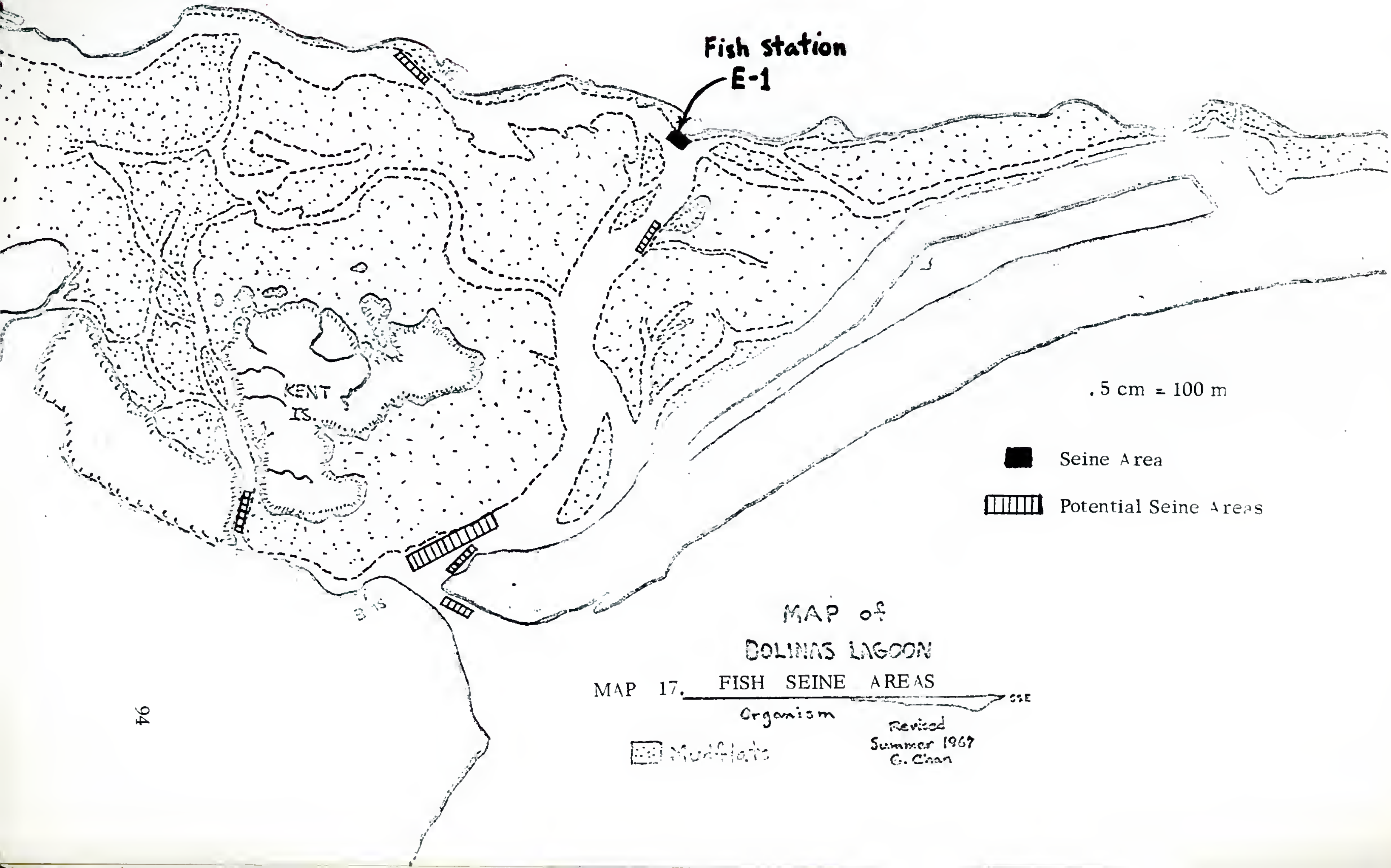
Figure 14a. Two-man Fish Seine

Figure 14b. Bolinas Lagoon Fishes in a 1/4 inch mesh seine.

SEINE DATA:

Sample Number	Seine Dates	Low Tide @ G. Gate	Time of Seines*	No. of Seine Hauls	Water Temp.	Water Density	No. of Species	TOTAL Fishes
1	7/12/67	-0.2 @ 0948	L-1106	3	20°C	Turbid	12	116
2	7/19/67	-1.3 @ 0500	L-0650	3	17.1°C	Turbid	18	117
3	7/19/67	4.6 @ 1206	H-1606	3	19.5°C	Clear	4	24
4	7/26/67	0.6 @ 0930	L-0950	3	18.3°C	Clear	13	81
5	8/2/67	-0.1 @ 0400	L-0600	3	16.5°C	Clear	16	265
								650

* L - low
H - high



MAP 17. FISH SEINE AREAS

FIGURE 15. Taxonomic Fish Species List - Bolinas Lagoon 1964 through August 1967

	1967 Summer Census Seine Hauls 1	2	3	4	5	Total
Chrondrichthyes (Sharks and Rays)						
1. Triakis semifasciata Girard (Leopard Shark) (a)				1		1
2. Rhinotriacis henlei Gill (Brown Smoothhound)						
3. Squalus acanthias Linnaeus (Dogfish Shark)	1					1
4. Myliobatis (formerly Holorhinus) californicus (Gill) (Bat Stingray) (a)		2				2
5. Torpedo californica Ayres (Electric Ray)						
Osteichthyes (Bony Fishes)						
6. Hypomesus pretiosus (Girard) (Surf Smelt)						
7. Microgadus proximus (Girard) (Pacific Tomcod) *		1				1
Flatfishes						
8. Citharichthys sordidus (Girard) (Pacific Sanddab)						
9. Citharichthys stigmaeus Jordan & Gilbert (Speckled Sanddab)	15	15	5	17	26	78
10. Parophrys vetulus Girard (English Sole)	19	20	13	8	40	100
11. Platichthys stellatus (Pallas) (Starry Flounder) (g)				1		1
12. Pleuronichthys decurrens Jordan & Gilbert (Curlfin Turbot)		1				1
13. Symphurus atricauda (Jordan & Gilbert) (California Tonguefish)						
Other Bony Fishes						
14. Roccus saxatilis (Walbaum) (Striped Bass) (g) (a)						
15. Atherinopsis californiensis Girard (Jacksmelt) (a)		1			4	5
16. Atherinops affinis (Ayers) (Topsmelt)	14	3				17
17. Hyperprosopon argenteum Gibbons (Walleye Surfperch)		2			5	7
18. Embiotoca jacksoni Aggassiz (Black Perch) *	2	4		8	23	37
19. Cymatogaster aggregata Gibbons (Shiner Perch)	77	23	5	31	123	259
20. Micrometrus minimus (Gibbons) (Dwarf Perch) *	7	6			6	19
21. Damalichthys vacca Girard (Sea Perch) *		1			3	4
22. Sebastodes rastrelliger (Jordan & Gilbert) (Grass Rockfish)*					5	5
23. Sebastodes auriculatus (Girard) (Brown Rockfish)*		4		1	4	9
24. Ophiodon elongatus Girard (Lingcod) (g)	5	5		2	3	15
25. Leptocottus armatus armatus Girard (Staghorn Sculpin)	12	11		6	12	41
26. Scorpaenichthys marmoratus (Ayres) (Cabezon) (g)	2	7			5	14
27. Hexagrammos decagrammus (Pallas) (Greenling Seatrout)*(g)	3	6		1	3	13
28. Gillichthys mirabilis Cooper (Mudsucker or Sand Goby)						
29. Clevelandia ios (Jordan & Gilbert) (Mud Goby)	6			2		8
30. Porichthys notatus Girard (Midshipman)						
31. Clinocottus analis Girard (Common Sculpin) (a)						
32. Enophrys bison (Girard) (Buffalo sculpin) *				2	1	3
33. Pholis ornata (Girard) (Green Blenny) *		5		1	2	8
34. Apodichthys flavidus Girard (Brown Blenny) *			1			1
	163	117	24	81	265	650

$\overline{X}$ = 43.3 per seine

* New fishes added to the species list in 1967

(g) Major game fishes

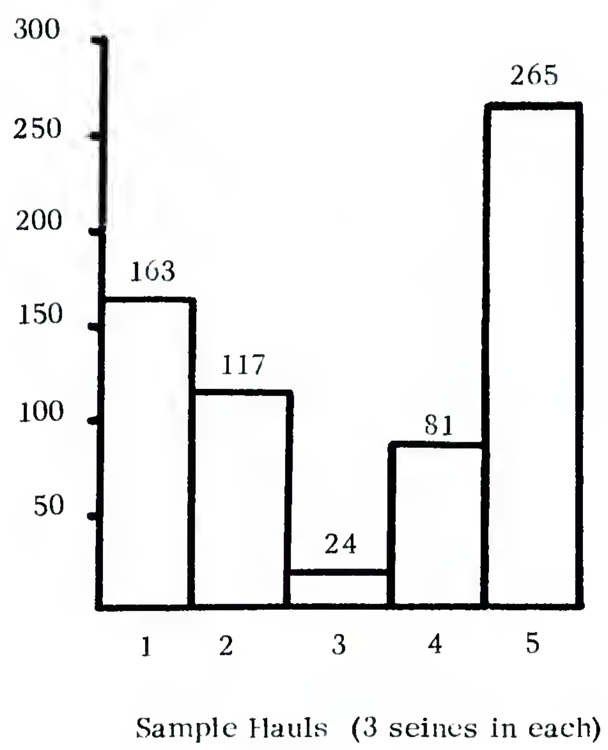
(a) Abundance at different years and seasons, besides the 1967 survey

C. Total Number of Fish Sampled in Each Haul

There were five sample hauls of three seines in each haul. The total number of fish is listed in the table below. The last haul, Sample No. 5. contained the most number of fish, 265! Also, with each seine, less fish are caught. For example, in Sample Haul No. 5, Seine 1 would capture more fish than seine 2 and 3 -- the total for all three seines is 265.

It is interesting to note that the water of the last three sample hauls was clear. It was first assumed that in clear water, the fish would see the net and swim away. However, the abundance of fish in Haul No. 5 may disprove this hypothesis, although additional samples should be taken to correctly measure this assumption. Furthermore, there are other factors of plankton turbidity and other biotic variables that determine the presence of fishin abundantor less abundant numbers.

CHART 12. Comparison of Total Number of Fishes Surveyed in Each Sample Haul



D. <u>Totals and Proportions of Fishes in Sample Hauls</u>

CHART 13a. Total Census of the Seven Most Numerous Fishes (650 -total fishes)

Mean/seine (Total of 15 seines)

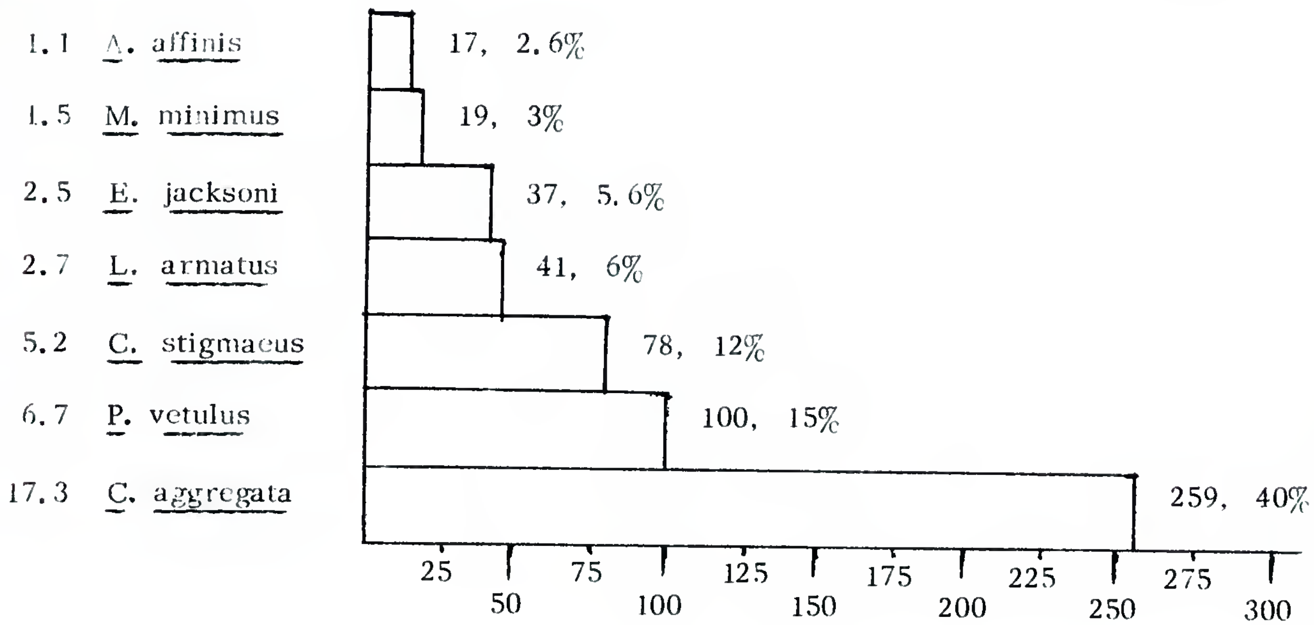
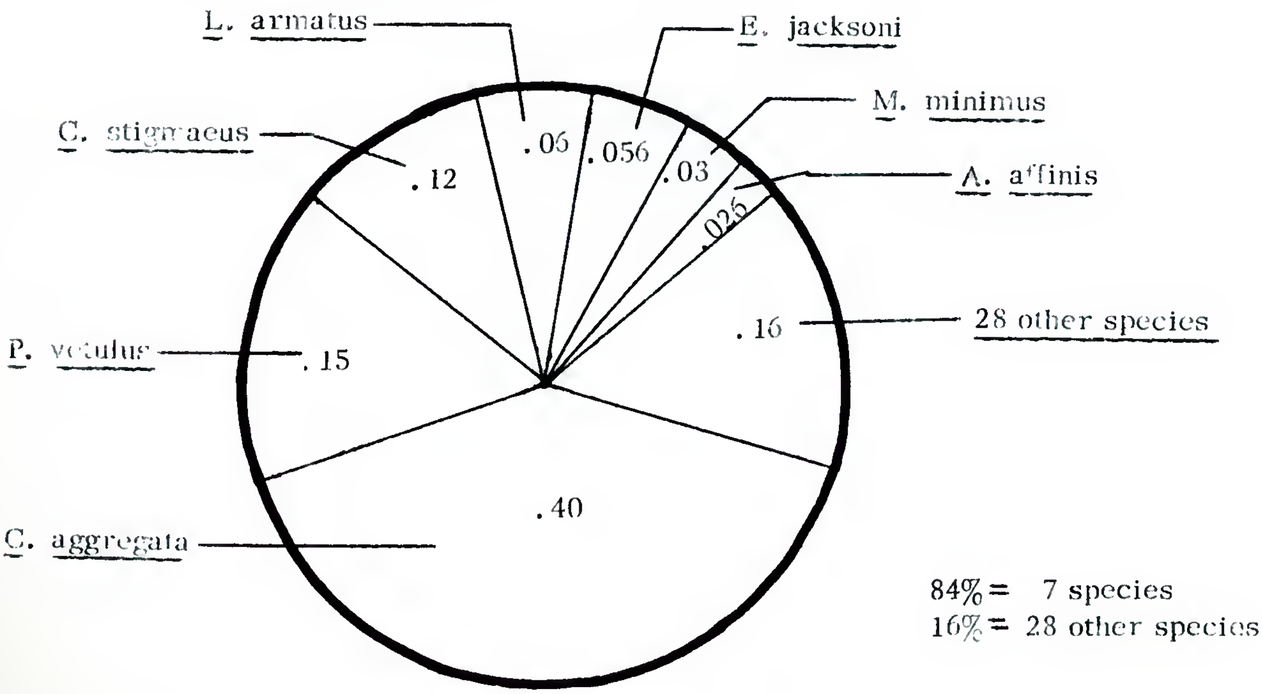


CHART 13b. <u>Species Propotions</u>



E. Conclusion on Fishes

The basic intent of the summer census of 1967 of fish in Bolinas Lagoon was to take seines from a specific spot in the lagoon - station E-1 (East - 1), see Map 17 on page 94. From this station, future seines and data collected will pivot from the information gathered at E-1 during this past summer. The species list represents fish from the entire lagoon.

Currently, the Bolinas Marine Laboratory personnel is seining at various spots throughout the lagoon - at the mouth, around the Stinson spit, in areas around Kent Island, and in the back reaches of the lagoon. We will also repeat samples at E-1. Comparison of population proportions will be the chief computational statistics drawn in the coming months. Furthermore, as previously mentioned, stomach samples of the fish catch will further piece together the ecology of these vertebrates.

In past summers, the chief fish taken near the mouth of the lagoon have been the following species: Atherinopsis californiensis and Atherinops affinis, along with the common species found at E-1, namely, Cymatogaster aggregata, Parophrys vetulus, and Leptocottus armatus armatus. All these species of fish seem to be young specimens, and there is strong indication that Bolinas Lagoon, as are other lagoons, is a breeding habitat for marine fishes. Time and additional investigation will prove this hypothesis to be either true or false.

XIV. APPENDIX

BIRD LIFE OF BOLINAS LAGOON

List #1-Species of water-inhabiting birds observed on Bolinas Lagoon since October 1963:

Loon, Common
Loon, Arctic
Loon, Red-throated
Grebe, Red-necked
Grebe, Horned
Grebe, Eared
Grebe, Western
Grebe, Pied-billed
Pelican, White
Pelican, Brown
Cormorant, Double-crested
Cormorant, Brandt's
Cormorant, Pelagic
Heron, Great Blue
Heron, Green
Egret, Common
Egret, Snowy
Heron, Black-crowned night
Brant, Black
Mallard
Pintail
Teal, Green-winged
Widgeon, American
Shoverler
Redhead
Canvasback
Scaup, Greater
Scaup, Lesser
Goldeneye, Common
Goldeneye, Barrows
Bufflehead
Scoter, White-winged
Scoter, Surf
Ruddy Duck
Merganser, Common
Merganser, Red-breasted
Vulture, Turkey
Eagle, Bald
Osprey
Rail, Clapper
Coot
Plover, Semipalmated
Killdeer
Plover, Black-bellied
Rail, Virginia
Turnstone, Black
Snipe, Common
Curlew, Long-billed
Whimbrel
Sandpiper, Spotted
Willet
Yellowlegs, Greater
Yellowlegs, Lessor
Sandpiper, Pectoral
Sandpiper, Least
Dunlin
Dowitcher, Short-billed
Dowitcher, Long-billed
Sandpiper, Western
Godwit, Marbled
Sanderling
Phalarope, Red
Phalarope, Northern
Jaeger, Pomarine
Jaeger, Parasitic
Gull, Glaucous-winged
Gull, Western
Gull, Herring
Gull, California
Gull, Ring-billed
Gull, Mew
Gull, Bonaparte's
Gull, Heerman's
Kittiwake, Black-legged
Tern, Forster's
Tern, Royal
Tern, Elegant
Term, Caspian
Kingfisher, Belted
Phoebe, Black
Swallow, Violet-green
Swallow, Tree
Swallow, Rough-winged
Swallow, Barn
Swallow, Cliff
Yellowthroat
Blackbird, Redwinged
Sparrow, Song
Wren, Long-billed Marsh

List #2-Water birds not recorded since October 1963, but to be expected on the Lagoon:

Teal, Cinnamon
Scoter, Common
Sora
Rail, Black
Turnstone, Ruddy
Sandpiper, Baird's
Phalarope, Wilson's
Owl, Short-eared

List #3-Land birds that have been observed within 100 feet of the high tide line of Bolinas Lagoon:

Hawk, Sharp-shinned
Hawk, Cooper's
Hawk, Red-tailed
Hawk, Red-shouldered
Eagle, Golden
Hawk, Sparrow
Quail, California
Dove, Mourning
Owl, Barn
Owl, Great Horned
Hummingbird, Black-chinned
Hummingbird, Anna's
Hummingbird, Allen's
Flicker, Red-shafted
Woodpecker, Acorn
Woodpecker, Hairy
Woodpecker, Downy
Phoebe, Say's
Flycatcher, Western
Jay, Steller's
Jay, Scrub
Raven, Common
Crow, Common
Chickadee, Chestnut-backed
Bush-tit, Common
Creeper, Brown
Wrentit
Wren, Winter
Wren, Bewick's
Robin
Hermit Thrush
Kinglet, Ruby-crowned
Waxwing, Cedar
Shrike, Loggerhead
Starling
Vireo, Hutton's
Warbler, Yellow
Warbler, Myrtle
Warbler, Audubon's
Warbler, Wilson's
Sparrow, House
Meadowlark, Western
Oriole, Bullock's
Blackbird, Brewer's
Cowbird, Brown-headed
Grosbeak, Black-headed
Finch, Purple
Finch, House
Goldfinch, American
Goldfinch, Lesser
Towhee, Rufous-sided
Towhee, Brown
Junco, Oregon
Sparrow, White-crowned
Sparrow, Golden-crowned
Sparrow, Fox
Sparrow, Lincoln's

List #4- Species that formerly nested on Bolinas sand spit:

Plover, Snowy
Term, Least

APPENDIX II

BLACK BRANT CENSUS ON BOLINAS LAGOON

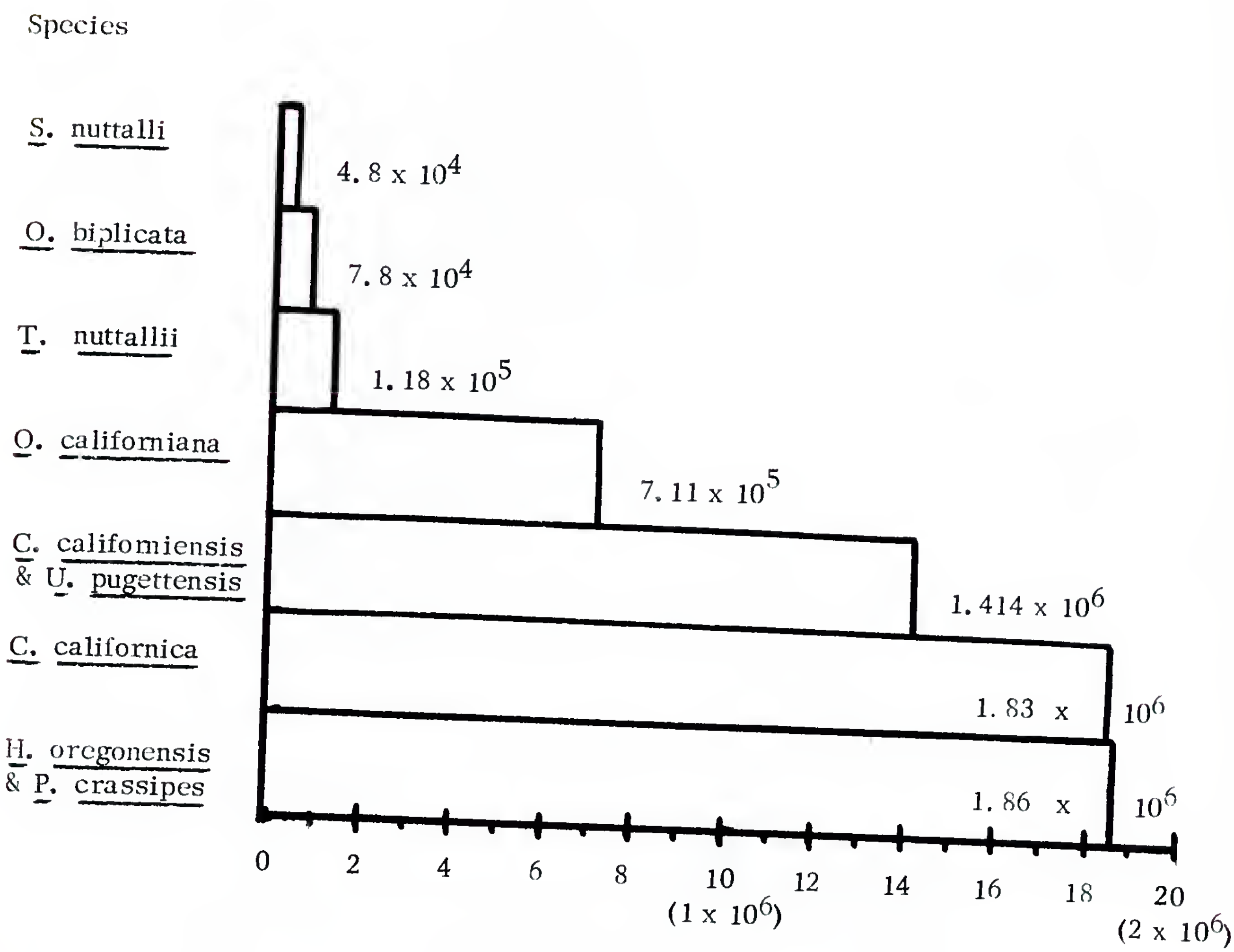
Year	February		April		May		June	
	Date	Total	Date	Total	Date	Total	Date	Total
1961	14	150	5	28	4	54	2	0
1962	19	6	9	31	4	4	4	0
1963	25	250	19	475	6	213	4	204
							21	115
1964	24	600	10	387	8	2	5	77
							22	9
1965	24	181	12	750	10	0	7	35

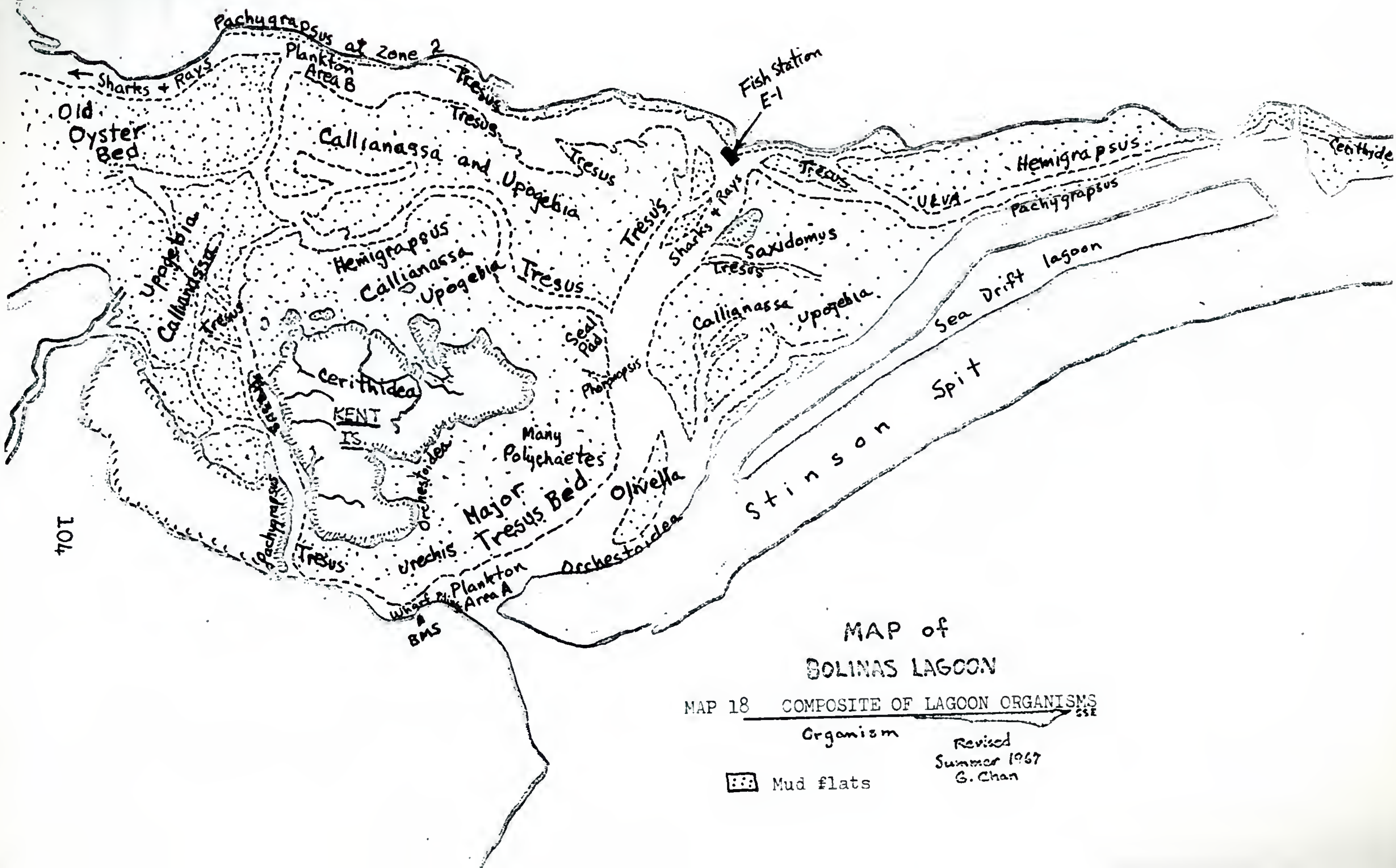
XV. GENERAL SUMMARY of the BOLINAS LAGOON SPECIES

CHART 14. Summary of Bolinas Lagoon Animals

Organism	Page Reference	No. of Samples	Organisms Counted	Average Mean-all samples	Estimate of Total Study Area - m^2	Estimated Population Size	Substrate
Tresus nuttallii	7-33	133	408	$3.1/m^2$	36,955	118,518	silt to pebbles
Saxidomus nuttalli	34-39	15	48	$3.2/m^2$	15,000	48,000	silt to med. sand
Cerithidea californica	40-45	36	10,172	$282.6/m^2$	6,487	1,833,226	silt to med. sand
Olivella biplicata	46-50	36	394	$10.9/m^2$	26,788	78,797	fine sand to gravel
Callianassa & *Upogebia*	51-57	10	77	$7.7/m^2$	183,750	1,414,875	soft silt, sand
H. oregonensis & *P. crassipes*	58-61	82	1,038	$13.3/m^2$	140,300	1,816,660	silt to cobbles
Orchestoidea californiana	62-66	95	6,144	$64.7/m^2$	11,000	711,100	sand to pebbles
Hermissenda crassicornis	67-69	25	47	$1.9/m^2$		47	silt to sand
Wharf pilings	70-71	species	---	---	---	---	sand and gravel
Plankton	72-90	6 tows	---	---	---	3,901,000	water
Fishes	91-98	15 seines	650	43.3 per seine	---	650	water
TOTALS:		453 observations	18,928		420,280 m^2 of substrate	6,021,223 (excluding plankton)	

CHART 15. Comparison of the Total Estimate Number of Marine Organisms in Bolinas Lagoon (Excluding Plankton and Fishes)





MAP of
BOLINAS LAGOON

MAP 18 COMPOSITE OF LAGOON ORGANISMS

Organism

SSE

Mud flats

Revised
Summer 1967
G. Chan

XVI. GENERAL CONCLUSION

The following are summary observations about the organisms and data sampled in the Bolinas Lagoon:

1. The most dominant organisms in the lagoon are probably the general "worms"- the Annelida Polychaete worms being the species with the greatest density. These Polychaetes are found throughout the lagoon. A special type of worm, Urechis caupo (see photo, Figure 2a, page 11), is very common in Clam Bed No. 1, living with many commensals and Tresus nuttallii.

Our data shows that Cerithidea californica has the highest species estimate, although worms and the arthropod crustaceans, Callianassa californiana or Upogebia pugettensis, might be in greater numbers if all of the lagoon area were sampled. Likewise is true for the mud crab, Hemigrapsus oregonensis, which is very numerous, and only a small sample of these crabs were recorded.

2. Chart 14 on page 102 shows that there were 453 recorded observations during the summer of 1967. Many additional observations were made but not recorded. Some 18,928 animals were observed, and excluding plankton, there is an estimation of 6 million organisms living in the study areas that were sampled. These organisms represent the major species within the lagoon.

3. The greatest species in bio-mass weight would probably be the large Horseneck Clam, Tresus nuttallii. However, the abundance of any of the greater numbers of crustaceans might total even higher if all were totalled.

4. For area density, the populace of animals is basically located at the south end or ocean end of the lagoon. This fact stands to reason, in that the circulation of food material and reproductive potentials are more favorable near the overturning

opening of the lagoon. Although not much investigation has taken place in the back reaches of the lagoon, we do not expect to find any duplicate of the great populations inhabiting the open end. Polychaete worms are the dominant forms in the back portions.

5. Many other phyla are represented in numerous quantity, but have not been sampled as to their standing crop. Many of these organisms need to be excavated by hand and I'm sure that the 1968 summer participants will enjoy shoveling the many square meters of wet substrate.

6. An organism that needs further study along the shoreline perimeters is the Butter Cockle, Protothaca staminea. Only a small remnant of this edible clam still survives and a revival of this bivalve would certainly be of measureable importance to future conservationists.

7. Some of the other much seen organisms in the lagoon need relationship studies. For instance, what specific ecological web is formed by the many birds (see Appendix) and marine invertebrates in the mudflats? What is the significance of the large herd of Harbor Seals that occupy their private sand pad southeast of Kent Island? Furthermore, what is the population and future of Crassostrea gigas, the giant Pacific Oyster that was farmed here by man in the 1940's. These oysters (see Figure 16) have survived years of sedimentation, man's shovel and sewage pollution.

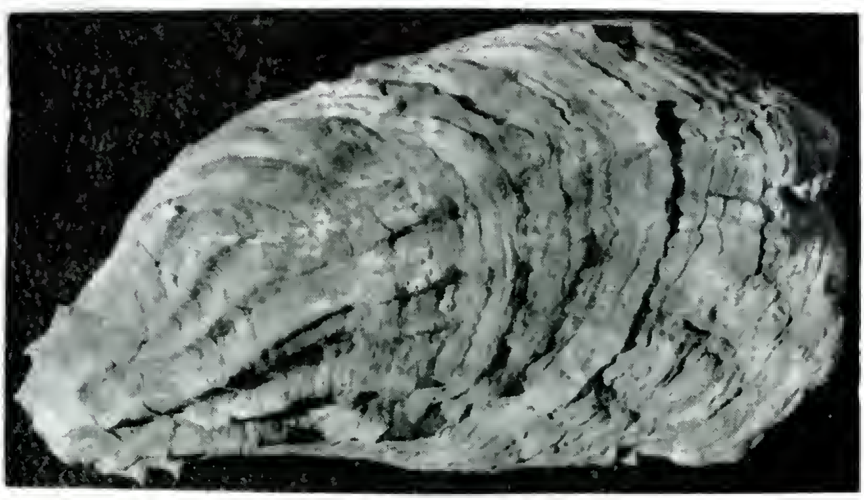


Figure 16. Crassostrea gigas

8. One area of sampling that would show great interest are the fresh water creek organisms that border the lagoon perimeter. Many of these organisms are transients between marine and fresh water, and their significance may be important to the other lagoon organisms.

9. The study of marine plants and terrestial flora is being organized and researched by Mr. Al Molina of the Bolinas Marine Station Staff. When this picture is formulated together with the animal scene, the total evolution of the lagoon organisms will be crystallized in a clearer light for the scientist to observe.

10. Finally, this report gives the estimate of the standing crop of some of the dominant marine invertebrates within the Bolinas Lagoon. The sample estimators used are illustrated on page 5 of this report. The numbers produced in these population studies are but a beginning - greater significance of these data will be highlighted in the years to come. Some of the future statistical projections will be:

	Test Statistics Formulae
a. Comparing sample estimates of one year's studies to another year's study (samples less than 30), giving valuable comparisons of the 95% confidence intervals of different time periods.	$\bar{X}_1 - \bar{X}_2 \pm t_{\frac{\alpha}{2} n_1 + n_2 - 2} \sqrt{S_p^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$
b. Using Analysis of Variance Tables to determine if the population means for the same species are equal for different time periods.	$F \text{ (table)} = \frac{MS_B}{MS_W} \sim F_{(J-1)(N-J)}$
c. Assuming there is variance of populations, the Chi-Square Analysis of Variance will be used to test the proportions of multinomial species samples.	$\chi^2 = \sum \frac{(\text{observed-expected})^2}{\text{expected}}$
d. Use statistical Correlation of Regression formula to predict future projections about a population parameter given another population variable.	Formulae computing r, the correlation coefficient

In summary, as more comparisons of data of the standing crop are obtained to illuminate the population parameters, the total ecological picture will become clearer. If ever the ecology of the lagoon is changed by man, then the comparative data will either support or condemn his actions.

It has already been pointed out that there are very few natural lagoons remaining in California. With the increase of coastal populations, we wonder about the future of man in his ever shrinking-world real estate. In oceanic conference after conference, man is being told that he must stop exploiting and hunting in the sea; rather, he is admonished to "farm the seas!" If lagoons are natural breeding places now, what role will they play in the future if man does not consider their importance today?

The combined efforts of the Bolinas Lagoon Ecological Study Committee is but an arm of the total interest of man in this area. Foresight and decision by the Marin County Planning Commission and the Bolinas Harbor District will result in the overall project being stamped as the pioneer in studying the importance of a lagoon marshland in relationship to the interest and behavior of man. This paper is but a small beginning, but it is compared to the wise old saying that "Large doors swing open on small hinges!"

THE END

XVII. BIBLIOGRAPHY

Allen, W. E. and Cupp, E. E., Plankton Diatoms of the Gulf of California, Allan Hancock Pacific Expedition, Vol. 3, No. 5, The University of Southern California Press, Los Angeles, 1938.

Bolin, Rolf, Notes on Natural History of Marine Organisms, Hopkins Marine Station, 1959, Pacific Grove, California.

Chan, G. L. Plankton Analysis and Plankton, Bolinas Marine Station Paper, Bolinas, California, 1965.

Fisher, R. A., Statistical Methods for Research Workers, Edinburgh, Oliver and Boyd, 1950.

Hedgpeth, Joel W., Introduction to Seashore Life of the San Francisco Bay Region and the Coast of Northern California, University of California Press, 1962.

Johnson, N. E. and Snook, J. H., Seashore Animals of the Pacific Coast, MacMillan Company, 1927.

Light, S. F., and others, Intertidal Invertebrates of the Central California Coast, University of California Press, 1957.

MacGinitie, G. E. and MacGinitie, N., Natural History of Marine Animals, McGraw-Hill, 1949.

Meglitsch, Paul A., Invertebrate Zoology, Oxford University Press, London, 1967.

Moore, H. B., Marine Ecology, John Wiley and Sons, Inc., New York, 1964.

Newell, G. E. and Newell, R. C., Marine Plankton: A Practical Guide, Hutchinson Educational Ltd., London, 1963.

Ricketts, E. F. and Calvin, J., Between Pacific Tides, Stanford University Press, Stanford, California, 1965.

Simpson, G. G.: Roe, Anne; and Lewontin, R. C., Quantitative Zoology. Harcourt, Brace & World, New York, 1960

Yamaji, I., The Plankton of Japanese Coastal Waters, Hoikusha, Osaka, Japan, 1962.