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Growth and Histological Effects to *Protothaca staminea* (Littleneck Clam) of Long-Term Exposure to Chlorinated Sea Water

Prepared by C. I. Gibson, R. E. Hillman, P. Wilkinson, D. L. Woodruff

Pacific Northwest Laboratory
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ABSTRACT

There has been considerable concern about the potential for long-term effects to marine organisms from chlorinated sea water. As part of a larger study to investigate the effects of materials resulting from seawater chlorination on marine organisms, groups of littleneck clams, Protothaca staminea, were exposed to sea water that had been chlorinated. Two experiments were conducted. In one test, groups of littleneck clams were exposed to dilutions of chlorinated sea water that had average chlorine produced oxidant (CPO) concentrations of 16 µg/ℓ or less. In the second test, groups of clams were exposed to chlorinated seawater-unchlorinated seawater mixtures that had target CPO concentrations of 0, 6, 12, 25, 50 and 100 µg/ℓ. In the first experiment, length measurements were made on all clams at approximately one-month intervals for three months. In the second test, length, weight, depth, width and edge etching were used to measure growth, and subsamples were harvested and measured at one-month intervals. In addition, clams were preserved for histological examination.

The clams in the first experiment all had negative growth. In the second test, growth was inhibited under all conditions through the first four months of exposure. During the last four months, there was positive signs of growth at the 0, 6 and 12 µg/ℓ CPO test conditions.

Histological examination indicates that P. staminea does not adapt well to being held in aquaria. Most clams, from all test and control conditions, showed evidence of necrosis at one month. This condition seemed to improve with longer exposure at lower CPO concentrations but persisted at CPO concentrations of 25 µg/ℓ and higher. Other histological effects were apparent at the higher exposure concentrations as the length of exposure increased.

SUMMARY

Studies of the effects of long-term exposure to chlorinated sea water on the growth of littleneck clams (Protothaca staminea) were initiated in 1977, as a subtask to the program on the synthesis and effects of halogenated organics created by the chlorination of cooling water at nuclear fueled steam electric stations. The objective of this subtask was to determine the effect on clam growth of exposure to chlorinated sea water. The initial experimental design had five groups of 60 clams being exposed to Sequim Bay sea water that had been chlorinated at a level of approximately 1.5 mgCl/ℓ with sodium hypochlorite and then diluted with untreated sea water to obtain 0, 2, 4, 6 and 12-fold dilutions of the chlorinated sea water. A sixth tank containing 60 clams and receiving untreated sea water was used as a control. Total length measurements were made on the clams at approximately 1-month intervals for a period of three months.

Over the course of the exposure, the total average net growth for all clam groups was negative (-0.08 mm to -0.13 mm). The average CPO in the tanks during the period ranged from 0.016 mg/ℓ to 0.00 mg/ℓ. The cause of the negative growth in all tanks was not identified, but a number of factors were suggested, e.g., insufficient food supply, routine disturbance, chlorine produced oxidant effects, tank stress and lack of sensitivity of the length measurement over the test period.

A second series of growth experiments were conducted in the winter and spring of 1978, using a new delivery system and protocol. To alleviate what was thought to be factors that may have contributed to the negative growth in the earlier test, feeding with algal culture was planned for this test, and weight, width, thickness, and edge marking were done in addition to the length measurement. In addition, individual clams would be disturbed only at the initiation of the experiment and at harvest time. Finally, clams would be preserved for histological examination for any tissue abnormalities.

The new delivery system delivered a mixture of chlorinated and unchlorinated sea water to the test tanks so that the respective groups of clams had target CPO concentrations of 0, 6, 12, 25, 50 and 100 µg/ℓ. The 0 µg/ℓ test tank received only untreated sea water, and the 100 µg/ℓ test tank received only chlorinated sea water. The initial chlorination rate was approximately 1.5 mg/ℓ chlorine per liter of sea water. Subsamples of clams were harvested from each test tank at approximately 30-day intervals for measurements and preservation for histological examination.

Shell deposition, measured by the etched edge markings, indicated that no growth took place in any of the test tanks until the fifth month at which time there were positive signs of growth in the control and in the 6 and 12 µg/ℓ test conditions. Positive growth was noted in these tanks after six and eight months also. No signs of positive growth occurred

at the 25, 50 and 100 µg CPO/ℓ. The other measurements supported the shell deposition finding but indicated that linear measurement is not a good parameter to use to measure growth in littleneck clams under these conditions.

Histological examination of the clams indicated that the clams were under some stress when collected from the field. However, the clams appeared to recover during the first month of testing, and then the organisms at the higher CPO concentrations (50 and 100 µg/ℓ) developed tissue abnormalities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This report includes data and analysis for the Marine Biology Task of the program on Biocide By-Products in Aquatic Environments.

Reports prepared for the entire program are:

Title	Author
• Investigation of Halogenated Components Formed from Chlorination of Natural Waters: Preliminary Studies, NUREG/CR-1299	Roger M. Bean Robert G. Riley
• Acute Toxicity and Bioaccumulation of Chloroform to Four Species of Fresh Water Fish *Salmo gairdneri*, Rainbow Trout *Lepomis macrochirus*, Bluegill *Micropterus salmoides*, Largemouth Bass *Ictalurus punctatus*, Channel Catfish, NUREG/CR-0893	David R. Anderson E. William Lusty
• Chronic Effects of Chlorination By-Products on Rainbow Trout, *Salmo gairdneri*, NUREG/CR-0892	David R. Anderson Roger M. Bean Roger E. Schirmer
• Toxicity, Bioaccumulation and Depuration of Bromoform in Five Marine Species *Protothaca staminea*, Littleneck Clam *Mercenaria mercenaria*, Eastern Hard Clam, Quahog *Crassostrea virginica*, Eastern oyster *Penaeus aztecus*, Brown Shrimp *Brevoortia tyrannus*, Atlantic Menhaden, NUREG/CR-1297	Charles I. Gibson Fredrick C. Tone Peter Wilkinson J. W. Blaylock Roger E. Schirmer
• Growth and Histological Effects to *Protothaca staminea*, (Littleneck Clam) of Long-Term Exposure to Chlorinated Sea Water, NUREG/CR-1298	Charles I. Gibson Robert E. Hillman Peter Wilkinson Dana L. Woodruff
• Analysis of Organohalogen Products from Chlorination of Natural Waters Under Simulated Biofouling Control Conditions, NUREG/CR-1301	Roger M. Bean Dale C. Mann Robert G. Riley
• Biocide By-Products in Aquatic Environments, Final Report Covering Period September 10, 1976 through September 30, 1979, NUREG/CR-1300	Roger M. Bean Charles I. Gibson David R. Anderson

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INTRODUCTION

Studies of the effects of long-term exposure to chlorinated sea water on the growth of littleneck clams (Protothaca staminea) were initiated in 1977 as a subtask to the program on the synthesis and effects of halogenated organics created by the chlorination of cooling water at nuclear fueled steam electric stations. Numerous studies had been conducted on the acute toxicity of chlorine and chlorine produced oxidants (CPO) to fish and other marine organisms (1,2,3,4,5,6). However, little information was available on the effects of long-term exposure (months) of organisms to CPO. In addition, findings of halogenated organics created by chlorination of fresh and marine waters presented another group of compounds that may cause deleterious effects to exposed organisms (7,8,9).

The objective of the research discussed here was to expose littleneck clams to sea water that had been chlorinated at a rate similar to expected rates at operating steam electric stations. To insure that the clams would not die from the acute toxic effects of CPO, the CPO concentration was reduced by aging (natural demand) and dilution with control sea water. Two tests were conducted.

The first experiment was designed to test the delivery system and look at the response of littleneck clams to long-term holding in laboratory tanks. This experiment was run with set dilutions of the chlorinated sea water delivered to the individual aquaria holding the clams, and only clam length was measured. Based on the results of the first test, a number of modifications were made to the delivery systems and the biological measurements to be collected. Using the modified delivery system, the second test was conducted using target concentrations of CPO of 0, 6, 12, 15, 50, and 100 µg/ℓ.

First Experiment

Littleneck clams were collected from Kiapot Point, Sequim Bay, Washington on 11/28/76, and held in a large circular tank receiving raw Sequim Bay sea water. Additional food was provided to the clams daily in the form of a slurry of ground Fusia sp., Ulva sp. and alfalfa flour. On 12/15/76, 50 clams were randomly selected and placed in one of the six 120 ℓ glass exposure aquaria (Figure 1). The aquaria contained 12-13 cm of sand as a substrate for the clams to bury in. The clams were observed for burying activity, and all but 2 were buried within 8 hours. On 12/19/76, 50 clams were introduced into each of the remaining five exposure tanks, and chlorination of the sea water was begun. Temperature was maintained at 15°C. The clams were observed daily and individuals that did not bury or ones that surfaced were replaced. From 12/19/76 through 2/1/77, a total of 12 clams were removed (from the 6 tanks) and replaced with new individuals.

On 2/1/77, the clams in each tank were removed for measuring and numbering. The procedure was to remove all the clams from a tank, and blow them

with an air gun until the shells appeared "bone dry." Length measurements were then made and the individuals numbered with Flecto® Varathane #101 orange paint. The paint was allowed to dry for six hours before the clams were returned to their respective tanks. The clams were out of the tank for approximately 8 hours.

The tanks were then observed daily for clams that surfaced and died. At monthly intervals the clams were removed and length measurements made (Tables 1 to 25). Also at monthly intervals, 5 clams were removed for future histopathological examination and chemical analysis. To maintain even densities throughout the exposure the removed clams were replaced with new individuals. CPO, temperature, salinity, pH and dissolved oxygen measurements were made approximately daily (Tables 26 & 27). CPO was measured by the potentiometric method (10).

The length measurements indicated that the clams were not growing and appeared to have been experiencing shell erosion or negative growth (Tables 28 to 34). Several factors could have contributed to this, including disturbance by the monthly measuring routine, lack of sufficient food, adverse reaction to being confined in the tank, and exposure to chlorinated sea water. Since the control showed the same negative length change, the chlorine exposure could not be singled out as the factor causing growth suppression.

However, the major objective of this experiment was satisfied. That is, it was found that littleneck clams could be held in aquaria for periods of up to 6 months without massive mortalities, and they also could survive in sea water that had been chlorinated at a rate of 1 to 2 mg/ℓ but had low (≤0.02 mg/ℓ) CPO concentrations. The cause of the negative growth could not be related to a single factor, and, because of this, the second experiment included a number of modifications.

Second Experiment

The next experiment was designed to monitor more parameters that would be indicators of growth and to monitor their health by histological examination. To reduce some of the suspected compounding factors thought to exist in the first experiment, the following changes were made. The clams were not measured every month. Instead, only those individuals that were harvested for other purposes were measured. Additional food, in the form of cultured algae, was provided. Proportional dilutions of the chlorinated sea water were not used, instead, target CPO concentrations were maintained in each tank. The shell edge was etched to provide a more sensitive indicator of growth. Body measurements, in addition to the length, were taken.

The Mount-Brungs type delivery system used in the first test was replaced by a manifold type system shown in Figure 2. The clam exposure tanks were the same 120ℓ aquaria used in the initial test and the bottom was covered with 12-13 cm of sand. The sea water on the chlorinated side

was chlorinated at a rate of approximately 1.5 mg/ℓ Cl_2. The exposure tanks received chlorinated and control sea water in proportions that produced the target in tank CPO concentrations. The control tank received 100% control water, and the 100 µg/ℓ CPO tank received only chlorinated sea water. The flows to the individual tanks varied in order to maintain the appropriate CPO. The control tank received 450 to 500 mℓ/min and the other tanks received at least that amount. In general, the flows remained between 500 and 1000 mℓ/min.

Clams were collected from Pitship Point, Sequim Bay, Washington and held for marking in running, raw sea water. Clams were randomly selected, marked with a motorized engraver, edge-etched, weighed, measured for length, width and thickness, and placed into the individual exposure tanks. Initial tank loading was 60 clams. Ten clams were preserved for histopathological examination, and 10 clams were frozen for chemical analysis.

Feeding was provided by first drawing the water level in the tanks down by removing the stand pipe, then replacing the stand pipe and adding Monochrysis sp. culture to provide a cell density of approximately 200,000/mℓ in the full tank. The exposure tank was then allowed to fill gradually with its normal mixture of control and chlorinated sea water. The control and chlorinated sea water was filtered (100 µm) so that the only food received by the clams was through the feeding. After three months, problems developed with the filter apparatus and in the phyto-plankton culture, and the exposure system was switched to raw sea water and no feeding.

At approximately one-month intervals, 8 clams were harvested from each tank. The harvesting was done in a manner that caused miminal disturbance to the remaining individuals. The harvested clams were measured and weighed, and checked for positive signs of shell deposition on the etched edge. Four were frozen in glass jars for chemical analysis, and 4 were preserved in Davidson's fixative for histological examination. The measurement and weights are presented in Tables 35 to 47. The measured CPO concentrations in the tanks are presented in Table 48.

The clams that were fixed in Davidson's fixative were shipped to Battelle's William F. Clapp Laboratories, Duxbury, Massachusetts where they were embedded in paraplast, sectioned at 6 µm and stained with hemotoxilin and eosin. The sections were then examined by Dr. Robert E. Hillman. The results of these examinations are presented in Tables 49 to 63. A summary of these results is provided in Table 63.

The clams that were frozen for chemical examination were shipped frozen to the Battelle Northwest Richland Laboratories for analyses by Dr. Roger Schirmer. As a result of the work done under the analytical portion of this program, these tissues were analyzed for bromoform. Other compounds were checked for but only bromoform results are presented in Table 64.

Analysis of tissues was done by homogenizing the tissue in water at 0°C and diluting with enough water to obtain a concentration of approximately one gram of tissue per 10 mℓ of tissue suspension. Ten to 20 mℓ aliquots of the aqueous tissue suspension were extracted with two 5 mℓ portions of hexane containing 1-, 3-dibromopropane as an internal standard. The microliter samples of the hexane solution were injected into a gas chromatograph fitted with an 18" Porapak Q® column and a ^{63}Ni electron capture detector. The column was operated isothermally at 185°C. The limit of detection of this procedure was 0.0005 µg/g, and the coefficient of variation ranged from 1% at the 1 to 8 µg/g level to 3% at levels below 0.1 µg/g. The coefficient of variation was calculated from 16 replicate analyses of each of 9 tissue samples.

DISCUSSION

A summary of histological observations is given in Table 63. Of the 10 clams fixed prior to the start of exposure, 6 had some necrotic tissue, and 2, including one of the necrotic specimens, had metaplastic digestive tubules, with the normally columnar epithelium being reduced to a low cuboidal form (Figure 2). This condition persisted in the 1-month exposure series with most of the clams showing evidence of necrosis; half of them having general necrosis throughout the viscera. Improvement in tissue condition was noted with longer exposure at lower chlorine concentrations, but necrosis persisted at 25 µg/ℓ and higher after 2 and 3 months exposure. At 4 months exposure, metaplasia of the digestive tubules increased at 12, 25, and 50 µg/ℓ. This condition improved after 5 months but returned after 6 months. Leukocytic infiltration into the tissues increased during the first 2 months and remained at about the same level throughout the 6 months of exposure. There was general necrosis and autolysis of connective tissues after 6 months exposure at 50 and 100 µg/ℓ. Vacuolization of stomach and intestinal epithelium (Figure 3) was common in the clams exposed to 50 and 100 µg/ℓ CPO after the first 2 months of exposure.

The growth data indicates that under the conditions of the test, clams were not in a very active growth mode. Vanderhorst and Wilkinson (MRL unpublished data) found, in field studies with Protothaca staminea during the active growing season in spring and summer, that the initiation of new shell growth can be very sporadic once the clams are disturbed. It appears that during the study, the clams were slow to initiate new growth and, in fact, by the last harvest date (8 months of holding) only 36% (4 of 11) in the control had laid down new shell. In the two previous harvest dates (5 and 6 months), only 1 of 8 (13%) had shell deposition. However, there appears to be a pattern with growth evident at the control and lower two test levels (6 µg/ℓ and 12 µg/ℓ CPO) and no growth at the higher three test concentrations (25 µg/ℓ, 50 µg/ℓ and 100 µg/ℓ). This same pattern is evident from the width and weight data.

The weight data could be considered the most indicative measure with the fact that shell growth can be very sporadic, particularly after handling. Of interest here is the fact that at the control and lower two concentrations there was some positive weight gain in each test and no individuals with weight loss, whereas, at the high concentrations (25 µg/ℓ, 50 µg/ℓ and 100 µg/ℓ) the opposite was true. The histological data indicates that at these higher CPO concentrations the amount of tissue damage, particularly in the stomach, intestine and digestive tubules, is significant and could have reduced the clams' ability to feed and digest food. In addition, the amount of necrosis and autolysis evident at the higher concentrations could lead to premature death.

In the higher CPO concentrations the proportion of food (planktonic organisms) exposed to chlorine was higher than at the lower concentrations and, therefore, could have served as an additional stress on the organisms. If phytoplankton was destroyed by the chlorination process, these clams would have received less food in the last five months which could be a factor in their growth.

Since the clams were collected in March, the initial samples might have been stressed by winter conditions, which could account for the pathological conditions observed in those specimens and the 1-month exposures. Recovery was slower at higher concentrations and considerably inhibited at 50 and 100 µg/ℓ.

The tissue analysis data for bromoform must be viewed with caution because of suspected contamination in the exposure system. During the period of March through June, bromoform was being used in the same room as the long-term chlorinated seawater exposure was being conducted. In another series of tests, we found that it was difficult to obtain a bromoform/seawater solution. Therefore, the possibility of cross contamination by bromoform vapor from the chlorine test system was not considered. The results of the tissue analyses indicate that our assumption was wrong. However, these data do indicate that if bromoform is present, it will be accumulated by the clams.

The results of the second experiment indicate that long-term exposure of littleneck clams to chlorinated sea water with CPO concentrations above 50 µg/ℓ has an effect. The effects observed in this test were inhibition of growth, as determined by new shell deposition and weight change, and tissue damage observed by histological examination. From the results it appears that the length measurement used in the first study is the least reliable parameter to use when determining the growth of littleneck clams. The width measurements showed a more consistent trend than the length measurement, for, as the concentration of CPO increased, there was a decrease in the number of clams which increased in width over the 8-month exposure period. The weight measurement provides the most consistent trend, with the number of individuals that were larger at the end of the exposure period being 0 at the three higher CPO concentrations, while the number which decreased in weight was 0 in the control and lowest two concentrations and was 1, 6, and 2 in the three higher exposure

conditions. It must be noted, however, that the sample size was limited, and further testing is needed to refine the results.

Shell deposition, as indicated by edge etching, appears to be the best sign of positive growth. However, it needs to be coupled with weight gain to provide an indication that the clam was not using stored energy to repair a damaged shell but was healthy and able to add tissue at the same time.

The histological examination of the clams provided the most detailed data for determining their health. However, because of the limited data base on normal clam tissue and the variety of factors that can cause specific histological changes, it is difficult to definitely identify cause and effect at this time. From the results of this study it appears that the higher CPO concentrations had an adverse effect on the clam, and the tissue damage observed could be the reason for no growth at these exposure concentrations. In addition to this apparent effect, the tissue pathology that was present early in the testing in much of the clam population indicates that attention needs to be paid to the initial health of test organisms. Laboratory experiments that are attempting to determine the long-term effect of man-produced stress must be aware of all the compounding factors that can affect the results, and that traditional methods of assessing health may not be enough to tell the whole story.

The histological data from these studies provides a good basis for field validation of effects from chlorinated sea water. To determine if a chlorinated discharge is having an effect, the histological condition of organisms being impinged upon by the discharge could be compared to a population outside the discharge's influence but still within the same natural physical, chemical and biological environment.

CONCLUSIONS AND RECOMMENDATIONS

Under the test conditions used, CPO concentrations of 50 and 100 µg/ℓ had an adverse effect on the growth of littleneck clams.

Under the test conditions used, the control group and groups exposed to target CPO concentrations of 6, 12, and 25 µg/ℓ had positive growth.

Histological examination of the clams showed stress conditions at the beginning of the exposure, but the clams in the control and lower CPO concentrations (6, 12 and 25 µg/ℓ) recovered while those at the higher concentrations (50 and 100 µg/ℓ) had significant tissue damage at the end of the test period (6 months).

The ultimate consequences of the lack of growth and tissue damage on the ability of the clams to survive and reproduce was not determined. However, the data indicates that clam populations that are continually exposed to CPO concentrations of 50 µg/ℓ or higher will be under greater stress than those exposed to concentrations of 25 µg/ℓ or less.

Field sampling of mollusk populations exposed to CPO should be undertaken to verify the existence of similar tissue damage in the natural environment.

REFERENCES

1. Brungs, W. A. "Effects of Residual Chlorine on Aquatic Life," J. Water Pollut. Control Fed. 45(10):2180-2193 (1973).

2. Brungs, W. A. "Effects of Wastewater and Cooling Water Chlorination on Aquatic Life," EPA-600/3-76-098 (Washington, D. C.: U. S. Environmental Protection Agency, 1976).

3. Gibson, C. I., T.O. Thatcher and C. W. Apts. "Some Effects of Temperature, Chlorine and Copper on the Survival and Growth of the Coon Stripe Shrimp," in Thermal Ecology II. Proceedings of 1975 Symposium, Augusta, Georgia, G. W. Esch and R. W. McFarlane, Eds. U. S. ERDA Report No. CONF-750425 (Arlington, Virginia: National Technical Information Service, 1976).

4. Roberts, M. H., Jr., R. Diaz, M. E. Bender and R. Huggett. "Acute Toxicity of Chlorine to Selected Estuarine Species," J. Fish. Res. Board of Can., 32(12):2525-2528 (1975).

5. Goldman, J. C., J. M. Capuzzo, and G.T.F. Wong. "Biological and Chemical Effects of Chlorination of Coastal Power Plants," in Water Chlorination Environmental Impact and Health Effects, Vol. 2, R. L. Jolley, H. Grochev and D. H. Hamilton, Jr., Eds. (Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1978), pp. 291-305.

6. Thatcher, T. O. "The Relative Sensitivity of Pacific Northwest Fishes and Invertebrates to Chlorinated Sea Water," in Water Chlorination--Environmental Impact and Health Effects, Vol. 2, R.L. Jolley, Ed. (Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1978), pp. 341-350.

7. Jolley, R. L., G. Jones, W. W. Pitt and J. E. Thompson. "Chlorination of organics in cooling waters and process effluents," in Water Chlorination: Environmental Impact and Health Effects, Vol. 1, R. L. Jolley, Ed. (Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1978), pp. 105-138.

8. Bean, R. M., R. G. Riley and P. W. Ryan. "Investigation of halogenated components formed from chlorination of marine water," in Water Chlorination--Environmental Impact and Health Effects, Vol. 2, R. L. Jolley, H. Gorchev, D. H. Hamilton, Jr., Eds. (Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc., 1978), pp.223-234.

9. Carpenter, J. H. and C. A. Smith. "Reactions in Chlorinated sea water," in Water Chlorination--Environmental Impact and Health Effects, Vol. 2, R. L. Jolley, H. Gorchev, D. H. Hamilton, Jr., Eds. (Ann Arbor, Michigan: Ann Arbor Science Publishers, 1978), pp. 195-208.

10. American Public Health Association. Standard Methods for the Examination of Water and Wastewater, 13th ed. (New York:APHA, 1971), pp. 834-845.

Table 1. Initial clam length in exposure tank receiving 100% control sea water. Date: 2/1/77

Clam #	Length (inches)	Clam #	Length (inches)
1	2.216	26	1.391
2	1.886	27	1.501
3	1.791	28	1.564
4	1.469	29	1.774
5	1.724	30	1.662
6	1.958	31	1.598
7	1.659	32	1.785
8	2.045	33	1.804
9	1.413	34	1.896
10	1.503	35	1.604
11	1.943	36	1.643
12	1.558	37	2.038
13	1.660	38	1.911
14	1.942	39	2.061
15	2.298	40	2.142
16	1.715	41	1.892
17	1.857	42	2.111
18	1.676	43	1.866
19	1.524	44	1.853
20	1.681	45	2.031
21	1.338	46	1.826
22	1.403	47	1.882
23	1.653	48	1.561
24	1.328	49	1.797
25	1.462	50	1.861

Table 2. Initial clam length in exposure tank receiving 94% control sea water, 6% chlorinated sea water. Date: 2/1/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.244	26	1.829
2	1.302	27	2.835
3	1.354	28	2.027
4	1.366	29	2.078
5	1.391	30	2.031
6	1.437	31	1.794
7	1.402	32	1.921
8	1.412	33	1.831
9	1.504	34	2.059
10	1.462	35	1.903
11	1.496	36	1.868
12	1.540	37	1.980
13	1.659	38	1.855
14	1.647	39	2.040
15	1.694	40	2.049
16	1.685	41	2.131
17	1.745	42	1.909
18	1.710	43	2.028
19	1.845	44	2.100
20	1.832	45	2.089
21	1.852	46	2.188
22	1.869	47	2.208
23	1.946	48	2.138
24	1.897	49	2.176
25	1.842	50	1.566

Table 3. Initial clam length in exposure tank receiving 88% control sea water, 12% chlorinated sea water. Date: 2/2/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.142	26	1.875
2	1.212	27	1.919
3	1.235	28	1.802
4	1.166	29	1.945
5	1.208	30	1.997
6	1.317	31	2.065
7	1.345	32	2.065
8	1.341	33	1.945
9	1.309	34	2.039
10	1.456	35	2.106
11	1.416	36	2.020
12	1.414	37	2.102
13	1.463	38	1.992
14	1.492	39	1.905
15	1.508	40	2.011
16	1.634	41	2.068
17	1.586	42	2.112
18	1.585	43	2.107
19	1.530	44	2.089
20	1.673	45	2.180
21	1.543	46	2.144
22	1.744	47	1.848
23	1.696	48	2.220
24	1.774	49	2.309
25	1.794	50	2.259

Table 4. Initial clam length in exposure tank receiving 75% control sea water, 25% chlorinated sea water. Date: 2/2/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.005	26	1.994
2	1.044	27	1.918
3	1.093	28	1.904
4	1.093	29	2.040
5	1.125	30	1.986
6	1.144	31	1.807
7	1.331	32	1.905
8	1.386	33	1.999
9	1.345	34	2.074
10	1.399	35	2.007
11	1.492	36	2.020
12	1.429	37	2.007
13	1.498	38	2.075
14	1.581	39	2.209
15	1.572	40	2.053
16	1.571	41	2.001
17	1.545	42	1.977
18	1.562	43	2.105
19	1.615	44	2.095
20	1.469	45	2.063
21	1.604	46	2.303
22	1.769	47	2.201
23	1.736	48	2.206
24	1.817	49	2.202
25	1.850	50	1.500

Table 5. Initial clam length in exposure tank receiving 50% control sea water, 50% chlorinated sea water. Date: 2/2/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.249	26	1.831
2	1.337	27	1.909
3	1.337	28	1.888
4	1.398	29	1.893
5	1.412	30	1.899
6	1.490	31	1.910
7	1.568	32	1.964
8	1.565	33	1.844
9	1.596	34	2.125
10	1.563	35	1.967
11	1.518	36	1.951
12	1.504	37	2.048
13	1.610	38	2.079
14	1.580	39	2.000
15	1.675	40	2.106
16	1.619	41	2.105
17	1.638	42	2.079
18	1.589	43	2.188
19	1.596	44	2.195
20	1.723	45	2.153
21	1.696	46	2.127
22	1.708	47	2.289
23	1.788	48	2.105
24	1.854	49	2.233
25	1.780	50	2.189

Table 6. Initial clam length in exposure tank receiving 100% chlorinated sea water. Date: 2/3/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.118	26	1.837
2	1.242	27	1.800
3	1.325	28	1.739
4	1.297	29	1.858
5	1.357	30	1.964
6	1.402	31	1.877
7	1.570	32	1.845
8	1.629	33	1.940
9	1.600	34	1.969
10	1.585	35	1.961
11	1.380	36	1.985
12	1.598	37	2.070
13	1.626	38	2.001
14	1.609	39	2.155
15	1.663	40	2.121
16	1.638	41	1.952
17	1.645	42	2.169
18	1.670	43	2.004
19	1.660	44	2.044
20	1.658	45	2.105
21	1.693	46	2.169
22	1.714	47	2.000
23	1.693	48	2.112
24	1.837	49	2.051
25	1.789	50	2.173

Table 7. Length of clams in tank receiving 100% control sea water after 1 month of exposure. Date: 3/1/77

Clam #	Length (inches)	Clam #	Length (inches)
1	2.215	26	1.387
2	1.884	27	1.496
3	1.787	28	1.564
4	1.468	29	1.770
5	1.723	30	1.656
6	1.952	31	1.593
7	1.654	32	1.784
8	2.042	33	1.800
9	1.407	34	1.915
10	1.500	35	1.590
11	1.933	36	1.636
12	1.555	37	2.030
13	1.658	38	1.914
14	1.937	39	2.054
15	2.295	40	2.140
16	1.716	41	1.889
17	1.850	42	2.110
18	1.675	43	1.857
19	1.522	44	1.850
20	1.678	45	2.027
21	1.333	46	1.822
22	1.400	47	1.877
23	1.651	48	1.561
24	1.326	49	1.796
25	1.461	50	1.857

Table 8. Length of clams in tank receiving 94% control sea water, 6% chlorinated sea water after 1 month of exposure. Date: 3/1/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.242	26	1.825
2	1.300	27	2.829
3	1.352	28	2.019
4	1.362	29	2.073
5	1.389	30	2.080
6	1.432	31	1.791
7	1.400	32	1.922
8	1.412	33	1.835
9	1.501	34	2.055
10	1.480	35	1.900
11	1.494	36	1.863
12	1.539	37	1.977
13	1.657	38	1.851
14	1.643	39	2.036
15	1.689	40	2.048
16	1.684	41	2.124
17	1.741	42	1.903
18	1.712	43	2.035
19	1.839	44	2.097
20	1.830	45	2.086
21	1.890	46	2.185
22	1.866	47	2.208
23	1.944	48	2.134
24	1.890	49	2.173
25	1.836	50	1.586

Table 9. Length of clams in tank receiving 88% control sea water, 12% chlorinated sea water after 1 month of exposure. Date: 3/2/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.139	26	1.870
2	1.216	27	1.916
3	1.234	28	1.800
4	1.163	29	1.939
5	1.206	30	1.996
6	1.315	31	2.061
7	1.342	32	2.062
8	1.338	33	1.943
9	1.307	34	2.037
10	1.453	35	2.100
11	1.412	36	2.018
12	1.411	37	2.100
13	1.460	38	1.988
14	1.490	39	1.900
15	1.507	40	2.013
16	1.632	41	2.064
17	1.583	42	2.109
18	1.586	43	2.108
19	1.532	44	2.085
20	1.670	45	2.178
21	1.540	46	2.143
22	1.742	47	1.846
23	1.694	48	2.218
24	1.772	49	2.308
25	1.793	50	2.257

Table 10. Length of clams in tank receiving 75% control sea water, 25% chlorinated sea water after 1 month of exposure. Date: 3/4/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.003	26	1.893
2	1.042	27	1.918
3	1.090	28	1.904
4	1.092	29	2.036
5	1.123	30	1.985
6	1.141	31	1.805
7	1.330	32	1.904
8	1.382	33	1.995
9	1.343	34	2.072
10	1.396	35	2.005
11	1.490	36	2.015
12	1.422	37	2.004
13	1.495	38	2.073
14	1.576	39	2.203
15	1.576	40	2.049
16	1.568	41	1.999
17	1.543	42	1.969
18	1.562	43	2.113
19	1.610	44	2.095
20	2.230	45	2.065
21	1.600	46	2.305
22	1.760	47	2.206
23	1.730	48	2.205
24	1.812	49	2.200
25	1.846	50	1.498

Table 11. Length of clams in tank receiving 50% control sea water, 50% chlorinated sea water after 1 month of exposure. Date: 3/4/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.250	26	1.828
2	1.335	27	1.908
3	1.336	28	1.888
4	1.398	29	1.898
5	1.410	30	1.892
6	1.488	31	1.909
7	1.569	32	1.962
8	1.563	33	1.842
9	1.596	34	2.124
10	1.561	35	1.965
11	1.517	36	1.949
12	1.500	37	2.042
13	1.610	38	2.076
14	1.579	39	1.999
15	1.673	40	2.100
16	1.618	41	2.105
17	1.636	42	2.079
18	1.588	43	2.183
19	1.595	44	2.196
20	1.722	45	2.153
21	1.695	46	2.128
22	1.707	47	2.287
23	1.788	48	2.105
24	1.859	49	2.233
25	1.778	50	2.188

Table 12. Length of clams in tank receiving 100% chlorinated sea water after 1 month of expsoure. Date: 3/4/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.118	26	1.836
2	1.240	27	1.798
3	1.324	28	1.738
4	1.296	29	1.857
5	1.356	30	1.964
6	1.400	31	1.876
7	1.565	32	1.844
8	1.628	33	1.933
9	1.598	34	1.967
10	1.584	35	1.960
11	1.380	36	1.985
12	1.593	37	2.069
13	1.625	38	2.100
14	1.607	39	2.153
15	1.663	40	2.120
16	1.638	41	1.950
17	1.644	42	2.168
18	1.670	43	2.003
19	1.658	44	2.043
20	1.658	45	2.104
21	1.690	46	2.175
22	1.713	47	2.202
23	1.694	48	2.111
24	1.837	49	2.055
25	1.788	50	2.175

Table 13. Length of clams added to tanks to replace animals removed for chemical and histological examination.

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
CONTROL		88 % SEA WATER, 12% CHLORINATED SEA WATER		50% SEA WATER, 50% CHLORINATED SEA WATER	
51	1.923	51	1.880	51	1.764
52	1.979	52	1.868	52	1.903
53	1.893	53	1.878	53	1.845
54	1.968	54	2.008	54	1.736
55	1.788	55	1.824	55	1.771
56	1.770	56	1.659	56	1.834
57	1.867	57	1.915	57	1.745
58	1.884	58	1.921	58	1.767
59	2.056	59	1.909	59	1.781
60	1.912	60	1.710	60	2.071
94% SEA WATER, 6% CHLORINATED SEA WATER		75% SEA WATER, 25% CHLORINATED SEA WATER		100% CHLORINATED SEA WATER	
51	1.916	51	1.698	51	1.664
52	1.919	52	1.890	52	1.556
53	1.893	53	1.892	53	1.767
54	1.879	54	1.692	54	1.783
55	1.709	55	1.902	55	1.659
56	1.813	56	1.911	56	1.544
57	1.610	57	1.789	57	1.607
58	1.722	58	1.921	58	1.771
59	1.950	59	2.054	59	1.879
60	1.724	60	2.011	60	2.004
				61	1.529
				62	1.875

Table 14. Length of clams in tank receiving 100% control sea water after 2 months of exposure. Date: 4/4/77

Clam #	Length (inches)	Clam #	Length (inches)
1	2.215	31	1.592
2	1.884	32	1.781
3	Removed*	33	1.800
4	1.465	34	1.913
5	Removed*	35	1.598
6	1.951	36	Removed*
7	Removed*	37	2.029
8	Removed*	38	1.912
9	1.406	39	Removed*
10	1.501	40	2.140
11	1.932	41	1.889
12	1.556	42	2.108
13	1.656	43	1.857
14	1.936	44	1.849
15	2.294	45	Removed*
16	1.713	46	1.822
17	1.849	47	Removed*
18	1.674	48	1.561
19	1.521	49	1.796
20	Removed*	50	1.857
21	1.332	51	1.922
22	1.400	52	1.977
23	1.650	53	1.890
24	1.326	54	1.965
25	1.460	55	1.787
26	1.386	56	1.768
27	Removed*	57	1.866
28	1.562	58	1.883
29	1.770	59	2.054
30	1.654	60	1.911

* Removed for Chemical or Histological Analysis.

Table 15. Length of clams in tank receiving 94% control sea water, 6% chlorinated sea water after 2 months of exposure. Date: 4/5/77

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
1	1.242	21	Removed*	41	2.123
2	1.298	22	1.867	42	1.903
3	1.352	23	1.943	43	2.034
4	1.361	24	1.891	44	2.098
5	1.389	25	Removed*	45	Removed*
6	1.430	26	1.825	46	2.185
7	1.401	27	1.829	47	Removed
8	1.411	28	Removed*	48	Removed*
9	1.501	29	2.072	49	Removed*
10	1.460	30	2.081	50	1.565
11	1.487	31	1.791	51	1.916
12	Removed*	32	1.925	52	1.919
13	1.656	33	1.834	53	1.892
14	1.643	34	2.057	54	1.879
15	1.688	35	1.898	55	1.709
16	1.685	36	1.874	56	1.811
17	1.740	37	1.977	57	1.609
18	1.711	38	1.850	58	1.722
19	Removed*	39	2.035	59	1.950
20	Removed*	40	2.047	60	1.726

* Removed for Chemical or Histological Analysis.

Table 16. Length of clams in tank receiving 88% control sea water, 12% chlorinated sea water after 2 months of exposure. Date: 4/5/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.139	31	2.062
2	1.216	32	2.061
3	1.234	33	1.942
4	1.164	34	2.034
5	1.205	35	2.100
6	1.315	36	2.013
7	Removed*	37	Removed*
8	1.337	38	1.988
9	Removed*	39	1.901
10	1.452	40	2.022
11	Removed*	41	2.064
12	1.410	42	2.108
13	1.460	43	2.107
14	1.490	44	2.094
15	1.507	45	Removed*
16	1.632	46	Removed*
17	1.583	47	1.846
18	Removed*	48	2.216
19	1.525	49	2.309
20	1.670	50	Removed*
21	1.539	51	1.880
22	1.741	52	1.868
23	1.695	53	1.876
24	Removed*	54	2.008
25	Removed*	55	1.823
26	1.870	56	1.656
27	1.915	57	1.904
28	1.800	58	1.921
29	1.939	59	1.909
30	1.995	60	1.709

* Removed for Chemical or Histological Analysis.

Table 17. Length of clams in tank receiving 75% control sea water, 25% chlorinated sea water after 2 months of exposure. Date: 4/5/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.003	31	1.804
2	1.040	32	Removed*
3	1.090	33	1.994
4	1.090	34	2.071
5	1.123	35	2.005
6	1.141	36	2.011
7	Removed*	37	Removed*
8	1.381	38	2.073
9	1.344	39	2.206
10	1.396	40	Removed*
11	1.488	41	1.999
12	1.422	42	1.980
13	1.496	43	Removed*
14	1.576	44	2.096
15	1.570	45	2.069
16	1.569	46	Removed*
17	Removed	47	Removed*
18	1.562	48	2.204
19	1.610	49	2.200
20	2.229	50	1.500
21	1.600	51	1.699
22	1.760	52	1.890
23	1.734	53	1.894
24	1.814	54	1.692
25	Removed*	55	1.901
26	1.892	56	1.912
27	Removed*	57	1.783
28	Removed*	58	1.921
29	2.035	59	2.067
30	1.985	60	2.010

* Removed for Chemical or Histological Analysis.

Table 18. Length of clams in tank receiving 50% control sea water, 50% chlorinated sea water after 2 months of exposure. Date: 4/6/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.246	31	1.908
2	1.335	32	1.960
3	Removed*	33	1.841
4	1.392	34	2.121
5	1.408	35	1.968
6	1.486	36	Removed*
7	Removed*	37	Removed*
8	1.562	38	Removed*
9	Removed*	39	Removed*
10	1.559	40	2.100
11	1.514	41	2.102
12	1.499	42	2.077
13	1.609	43	2.180
14	1.575	44	2.191
15	1.671	45	2.152
16	1.612	46	2.125
17	1.634	47	2.286
18	1.587	48	2.110
19	Removed*	49	Removed*
20	1.722	50	2.190
21	1.692	51	1.763
22	1.705	52	1.902
23	1.786	53	1.844
24	1.852	54	1.735
25	1.778	55	1.770
26	1.827	56	Removed 3/30/77
27	1.907	57	1.743
28	1.886	58	1.767
29	Removed*	59	1.780
30	1.890	60	2.065

* Removed for Chemical or Histological Analysis.

Table 19. Length of clams in tank receiving 100% chlorinated sea water after 2 months of exposure. Date: 4/6/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.116	31	1.875
2	Removed*	32	Removed*
3	1.315	33	1.936
4	1.295	34	1.966
5	1.355	35	1.963
6	1.400	36	1.984
7	1.566	37	Removed*
8	1.627	38	2.097
9	1.597	39	2.153
10	1.582	40	2.117
11	Removed*	41	Removed*
12	Removed*	42	Removed*
13	1.625	43	Removed*
14	1.604	44	2.042
15	1.662	45	2.104
16	1.637	46	2.170
17	1.644	47	2.002
18	1.673	48	2.115
19	Removed*	49	2.055
20	1.656	50	2.173
21	1.690	51	1.664
22	Removed*	52	1.555
23	1.694	53	1.764
24	1.836	54	1.782
25	1.789	55	1.660
26	Removed*	56	1.562
27	1.799	57	1.605
28	Removed*	58	1.770
29	1.856	59	1.879
30	1.963	60	2.005

* Removed for Chemical or Histological Analysis.

Table 20. Length of clams in tank receiving 100% control sea water after 3 months of exposure. Date: 5/2/77

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
1	2.213	28	1.560	55	1.784
2	1.883	29	1.769	56	1.765
3	Removed*	30	1.651	57	1.863
4	Removed*	31	Removed*	58	1.879
5	Removed*	32	1.778	59	2.051
6	1.950	33	1.799	60	1.910
7	Removed*	34	Removed*	61	1.432
8	Removed*	35	Removed*	71	1.279
9	1.404	36	Removed*	72	1.175
10	Removed*	37	Removed*	73	1.209
11	1.930	38	1.912	74	1.292
12	Removed*	39	Removed*	75	1.359
13	1.655	40	2.138	76	1.177
14	1.934	41	1.888	77	1.288
15	2.293	42	Removed*	78	1.396
16	1.711	43	1.854	79	1.265
17	1.847	44	1.847	80	1.200
18	1.673	45	Removed*		
19	1.519	46	1.820		
20	Removed*	47	Removed*		
21	Removed*	48	Removed*		
22	1.398	49	1.795		
23	Removed*	50	1.855		
24	1.324	51	1.920		
25	1.454	52	1.974		
26	1.385	53	1.888		
27	Removed*	54	1.964		

* Removed for Chemical or Histological Analysis.

Table 21. Length of clams in tank receiving 94% control sea water, 6% chlorinated sea water after 3 months of exposure. Date: 5/3/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.240	36	1.860
2	1.297	37	1.974
3	1.349	38	Removed*
4	Removed*	39	2.034
5	Removed*	40	2.045
6	1.428	41	2.122
7	1.399	42	Removed*
8	1.409	43	Removed*
9	1.499	44	2.094
10	1.458	45	Removed*
11	Removed*	46	2.185
12	Removed*	47	Removed*
13	1.654	48	Removed*
14	Removed*	49	Removed*
15	1.687	50	1.563
16	1.683	51	1.913
17	1.739	52	1.916
18	1.710	53	1.889
19	Removed*	54	1.876
20	Removed*	55	1.707
21	Removed*	56	1.800
22	1.865	57	1.607
23	1.942	58	1.717
24	Removed*	59	1.948
25	Removed*	60	1.722
26	1.823	71	1.430
27	1.825	72	1.390
28	Removed*	73	1.339
29	Removed*	74	1.216
30	2.029	75	1.173
31	Removed*	76	1.338
32	1.923	77	1.529
33	1.831	78	1.416
34	2.053	79	1.158
35	1.897	80	1.314

* Removed for Chemical or Histological Analysis.

Table 22. Length of clams in tank receiving 88% control sea water, 12% chlorinated sea water after 3 months of exposure. Date: 5/4/77

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
1	1.137	27	1.914	53	1.873
2	Removed*	28	1.796	54	2.008
3	1.232	29	Removed*	55	1.821
4	1.160	30	1.992	56	1.658
5	Removed*	31	2.059	57	1.913
6	1.314	32	Removed*	58	1.919
7	Removed*	33	Removed*	59	1.904
8	1.335	34	2.035	60	1.706
9	Removed*	35	2.098	61	1.134
10	1.450	36	2.015	71	1.515
11	Removed*	37	Removed*	72	1.219
12	1.408	38	1.985	73	1.413
13	1.457	39	1.899	74	1.116
14	1.488	40	2.003	75	1.381
15	1.504	41	2.063	76	1.207
16	Removed*	42	Removed*	77	1.363
17	1.581	43	2.108	78	1.418
18	Removed*	44	2.084	79	1.323
19	Removed*	45	Removed*	80	1.543
20	1.669	46	Removed*		
21	1.537	47	Removed*		
22	Removed*	48	2.215		
23	Removed*	49	2.305		
24	Removed*	50	Removed*		
25	Removed*	51	1.878		
26	1.868	52	1.864		

* Removed for Chemical or Histological Analysis.

Table 23. Length of clams in tank receiving 75% control sea water, 25% chlorinated sea water after 3 months of exposure. Date 5/4/77

Clam #	Length (inches)	Clam #	Length (inches)
1	1.000	36	2.019
2	1.039	37	Removed*
3	1.087	38	Removed*
4	Removed*	39	Removed*
5	1.120	40	Removed*
6	Removed*	41	1.998
7	Removed*	42	Removed*
8	Removed*	43	Removed*
9	1.342	44	2.093
10	1.395	45	2.073
11	Removed*	46	Removed*
12	1.420	47	Removed*
13	1.493	48	Removed*
14	1.574	49	Removed*
15	1.568	50	1.496
16	1.567	51	1.696
17	Removed*	52	1.887
18	1.560	53	1.892
19	Removed*	54	1.692
20	Removed*	55	1.896
21	Removed*	56	1.909
22	1.758	57	1.780
23	1.735	58	1.919
24	1.812	59	2.068
25	Removed*	60	2.017
26	1.889	61	1.197
27	Removed*	71	1.442
28	Removed*	72	1.329
29	2.037	73	1.215
30	1.983	74	1.307
31	1.803	75	1.204
32	Removed*	76	1.355
33	1.992	77	1.293
34	2.070	78	1.404
35	2.004	79	1.318
		80	1.128

* Removed for Chemical or Histological Analysis.

Table 24. Length of clams in tank receiving 50% control sea water, 50% chlorinated sea water after 3 months of exposure. Date: 5/5/77

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
1	1.245	27	Removed*	53	1.842
2	Removed*	28	Removed*	54	1.731
3	Removed*	29	Removed*	55	1.769
4	Removed*	30	1.888	56	Removed*
5	1.407	31	1.906	57	1.742
6	1.484	32	Removed*	58	1.766
7	Removed*	33	1.840	59	1.778
8	1.560	34	2.119	60	2.063
9	Removed*	35	Removed*	61	1.302
10	1.557	36	Removed*	71	1.425
11	1.513	37	Removed*	72	1.225
12	1.498	38	Removed*	73	1.216
13	1.607	39	Removed*	74	1.410
14	1.575	40	2.098	75	1.196
15	1.669	41	2.100	76	1.119
16	Removed	42	2.075	77	1.568
17	Removed*	43	2.178	78	1.204
18	1.585	44	Removed*	79	1.355
19	Removed*	45	2.150	80	1.442
20	1.725	46	2.123		
21	1.690	47	Removed*		
22	1.703	48	2.109		
23	1.785	49	Removed*		
24	1.849	50	2.189		
25	1.776	51	1.762		
26	1.825	52	1.900		

* Removed for Chemical or Histological Analysis.

Table 25. Length of clams in tank receiving 100% chlorinated sea water after 3 months of exposure. Date: 5/5/77

Clam #	Length (inches)	Clam #	Length (inches)	Clam #	Length (inches)
1	Removed*	25	1.787	49	2.044
2	Removed*	26	Removed*	50	2.168
3	1.313	27	Removed*	51	1.662
4	Removed*	28	Removed*	52	1.554
5	1.354	29	1.855	53	1.762
6	1.398	30	1.961	54	1.780
7	1.569	31	1.874	55	1.659
8	1.625	32	Removed*	56	1.559
9	1.595	33	1.934	57	1.604
10	1.583	34	1.964	58	1.768
11	Removed*	35	1.961	59	1.877
12	Removed*	36	Removed*	60	2.004
13	1.623	37	Removed	61	1.526
14	Removed*	38	2.098	62	1.874
15	Removed*	39	Removed*	71	1.464
16	1.635	40	2.117	72	1.319
17	1.642	41	Removed*	73	1.343
18	1.668	42	Removed*	74	1.126
19	Removed*	43	Removed*	75	1.362
20	1.654	44	2.039	76	1.156
21	1.689	45	Removed*	77	1.400
22	Removed*	46	2.169	78	1.349
23	Removed*	47	Removed*	79	1.254
24	1.835	48	2.109	80	1.344

* Removed for Chemical or Histological Analysis.

Table 26. Dissolved oxygen, temperature, salinity and pH of sea water in tank receiving 75% control sea water and 25% chlorinated sea water.

Date	Temperature °C	Salinity °/₀	Dissolved Oxygen mg/ℓ	pH
2/2/77	15.0	31.0	8.15	7.8
2/4/77	14.9	30.3	8.04	7.9
2/6/77	15.0	31.0	8.10	7.9
2/8/77	15.1	31.0	7.98	8.0
2/9/77	15.0	30.3	7.74	7.8
2/11/77	15.1	30.8	8.05	8.0
2/13/77	15.1	30.0	8.12	8.0
2/14/77	14.8	31.0	8.04	8.0
2/16/77	15.2	30.6	7.45	7.9
2/18/77	15.1	30.4	8.10	8.0
2/21/77	15.2	30.4	8.07	8.0
2/23/77	15.0	30.6	7.78	7.7
2/25/77	15.0	30.7	7.88	7.9
2/28/77	15.3	30.0	7.94	8.0
3/2/77	15.3	29.8	8.00	8.0
3/4/77	15.6	30.1	8.10	7.8
3/7/77	15.2	30.0	7.98	8.0
3/9/77	15.1	30.3	8.20	8.0
3/11/77	15.3	30.4	8.30	7.9
3/14/77	15.1	30.7	8.20	8.1
3/16/77	15.0	30.6	8.15	7.9
3/18/77	15.0	30.7	8.18	7.9
3/21/77	15.0	30.0	8.14	8.0
3/23/77	15.2	29.5	8.04	8.0
3/25/77	14.8	30.0	8.28	7.9
3/28/77	14.8	30.4	8.34	7.9
3/30/77	14.5	30.4	8.35	7.9
4/1/77	15.0	30.3	8.40	7.9
4/4/77	15.0	29.9	8.10	8.0
4/6/77	15.0	30.0	8.04	7.8
4/8/77	15.1	30.0	8.14	8.0
4/11/77	15.2	30.4	8.20	7.9
4/13/77	15.2	30.4	8.25	8.0
4/15/77	15.0	30.6	8.25	8.0
4/18/77	14.8	30.2	9.04	8.0
4/20/77	14.9	30.2	8.68	8.0
4/22/77	14.7	30.3	8.16	8.0
4/25/77	14.8	30.3	8.16	8.0
4/27/77	14.8	30.2	8.30	8.0
4/29/77	14.9	30.6	8.25	8.1
5/2/77	14.8	30.2	8.23	8.1
5/4/77	14.2	30.4	8.26	8.1
5/6/77	15.0	30.0	8.10	8.1
5/9/77	14.7	30.3	8.24	8.1

Table 27. Chlorine produced oxidant concentrations in clam exposure tanks (mg/ℓ).

Date	Control Sea Water/Chlorinated Sea Water 100%/0%	94%/6%	88%/12%	75%/25%	50%/50%	0%/100%
2/2/77	.00	--	--	--	.01	.01
2/4/77	.00	--	--	--	.01	.02
2/8/77	.00	--	--	--	.01	.01
2/9/77	.00	--	--	--	.01	.01
2/11/77	.00	--	--	--	.01	.01
2/14/77	.00	--	--	--	.01	.01
2/16/77	.00	--	--	--	.01	.02
2/18/77	.00	--	--	--	.01	.02
2/21/77	.00	--	--	--	.01	.01
2/23/77	.00	--	--	--	.01	.01
2/25/77	.00	--	--	--	.01	.01
2/28/77	.00	--	--	--	.01	.01
3/2/77	.00	--	--	--	.01	.01
3/4/77	.00	--	--	--	.01	.01
3/7/77	.00	--	--	--	.01	.01
3/9/77	.00	--	--	--	.01	.01
3/11/77	.01	--	--	--	.01	.01
3/14/77	.00	--	--	--	.01	.02
3/16/77	.00	--	--	--	.01	--
3/18/77	.00	--	--	--	.01	.02
3/21/77	.00	--	--	--	.01	.02
3/23/77	.00	--	--	--	.01	.02
3/25/77	.00	--	--	--	.01	.02
3/28/77	.00	--	--	--	.01	.02
3/30/77	.00	--	--	--	.01	.02
4/1/77	.00	--	--	--	.01	.02
4/4/77	.00	--	--	--	.01	.01
4/6/77	.00	--	--	--	.00	.01
4/8/77	.00	--	--	--	.01	.02
4/11/77	.00	--	--	--	.01	.02
4/13/77	.00	--	--	--	.01	.02
4/18/77	.00	--	--	--	.01	.02
4/20/77	.00	--	--	--	.01	.02
4/22/77	.01	--	--	--	.02	.02
4/25/77	.01	.01	.01	.01	.02	--
4/27/77	.00	.01	.01	.01	.01	.02
4/29/77	.00	.01	.01	.01	.02	.03
5/2/77	.01	.01	.01	.01	.01	.02
5/4/77	.01	.01	.01	.01	.01	.03
5/6/77	.01	.01	.01	.01	.01	.03
5/9/77	.00	.01	.01	.01	.01	.03

Table 28. Length change in clams from tank receiving 100% control sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}	Clam #	ΔLength (inches) x 10^{-3}
1	-3		
2	-3	26	-6
6	-8	28	-4
9	-9	29	-5
11	-13	30	-9
13	-5	32	-7
14	-8	33	-5
15	-5	38	+1
16	-4	40	-4
17	-10	41	-4
18	-3	43	-12
19	-5	44	-6
22	-5	46	-5
24	-4	49	-2
25	-8	50	-6

Table 29. Length change in clams from tank receiving 94% control sea water, 6% chlorinated sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}
1	-4
2	-5
3	-5
6	-9
7	-3
8	-3
9	-5
10	-4
13	-5
15	-7
16	-2
17	-6
18	0
22	-4
23	-4
26	-6
27	-10
30	-2
32	+2
33	0
34	-6
35	-6
36	-8
37	-6
39	-6
40	-4
41	-9
44	-6
46	-3
50	-3

Table 30. Length change in clams from tank receiving 88% control sea water, 12% chlorinated sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}
1	-5
3	-3
4	-6
6	-3
8	-6
10	-6
12	-6
13	-6
14	-4
15	-4
17	-5
20	-4
21	-6
26	-7
27	-5
28	-6
30	-5
31	-6
34	-4
35	-8
36	-5
38	-7
39	-6
40	-8
41	-5
43	+1
44	-5
48	-5
49	-4

Table 31. Length change in clams from tank receiving 75% control sea water, 25% chlorinated sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}
1	-5
2	-5
3	-6
5	-5
9	-3
10	-4
12	-9
13	-5
14	-7
15	-4
16	-4
18	-2
22	-11
23	-1
24	-5
29	-3
30	-3
31	-4
33	-7
34	-4
35	-3
36	-1
41	-3
44	-2
45	+10
50	-4

Table 32. Length change in clams from tank receiving 50% control sea water, 50% chlorinated sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}
1	-4
5	-5
6	-6
8	-5
10	-6
11	-5
12	-6
13	-3
14	-5
15	-6
18	-4
20	+2
21	-6
22	-5
23	-3
24	-5
25	-4
26	-6
30	-11
31	-4
33	-4
34	-6
40	-8
41	-5
42	-4
43	-10
45	-3
46	-4
48	+4
50	0

Table 33. Length change in clams from tank receiving 100% chlorinated sea water after 3 months of exposure.

Clam #	ΔLength (inches) x 10^{-3}
3	-12
5	-3
6	-4
7	-1
8	-4
9	-5
10	-2
13	-3
16	-3
17	-3
18	-2
20	-4
21	-4
24	-2
25	-2
29	-3
30	-3
31	-3
33	-6
34	-5
35	0
38	-3
40	-4
44	-5
46	0
48	-3
49	-7
50	-5

Table 34. Summary of length changes at all test conditions after 3 months of exposure.

TANK Control/Chlorinated	Average Difference (inches x 10^{-3})	S.D. (x 10^{-3})	Number
100%/0%	-6	3	29
94%/6%	-5	3	30
88%/12%	-5	2	29
75%/25%	-5	2	27
50%/50%	-4	3	30
0%/100%	-4	2	28

Table 35. Length, width, thickness, and weight measurements of clams in control exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
1	39	35	21	16.35
2	40	37	23	19.11
3	40	37	23	21.24
4	27	25	14	5.93
5	32	30	18	10.29
6	29	26	14	6.64
7	28	24	14	5.32
8	31	28	17	8.65
9	26	22	12	4.05
10	30	28	17	8.15
11	27	24	14	5.66
12	32	29	17	9.24
13	27	24	14	5.63
14	29	26	15	7.24
15	33	29	17	9.50
16	40	37	22	19.09
17	40	36	22	19.40
18	38	34	21	15.70
19	34	31	18	11.80
20	34	30	18	10.90
21	39	35	20	18.08
22	36	32	19	12.55
23	36	33	19	12.58
24	30	27	15	7.12
25	38	33	20	14.80
26	40	35	21	16.89
27	33	30	18	10.38
28	35	32	18	12.02
29	30	28	16	8.08
30	36	33	20	13.50
31	40	36	21	16.60
32	41	37	22	19.74
33	32	29	17	8.94
34	31	29	18	9.78
35	28	24	14	5.53
36	45	42	27	28.66
37	32	28	17	8.78
38	39	36	21	17.74
39	35	32	19	12.46
40	35	32	18	11.88
41	36	33	19	14.21
42	41	36	21	19.13
43	36	32	19	12.68
44	37	34	21	15.57
45	31	29	17	9.38
46	37	33	20	14.73
47	32	28	16	8.96
48	31	29	17	9.15
49	40	35	21	17.36
50	30	27	16	7.55
51	26	23	14	5.15
52	35	30	20	11.65
53	37	34	21	15.04
54	25	23	13	4.42
55	40	35	20	15.73
56	37	33	20	13.89
57	27	25	14	5.33
58	29	24	13	6.38
59	27	25	15	5.92
60	33	31	18	10.81

Table 36. Length, width, thickness, and weight measurements of clams in 6 µg/ℓ CPO exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
101	30	29	17	9.25
102	28	25	14	6.10
103	25	22	13	4.22
104	32	29	17	9.57
105	38	35	21	16.40
106	28	26	15	22.06
107	42	37	24	6.18
108	35	32	19	12.51
109	25	23	13	4.74
110	35	32	20	13.42
111	29	25	14	6.03
112	25	22	12	4.17
113	26	23	13	4.75
114	26	23	12	4.49
115	34	32	17	9.66
116	30	27	16	8.07
117	37	34	20	13.89
118	38	35	20	15.65
119	37	34	21	16.13
120	41	37	22	19.77
121	36	32	18	12.56
122	40	37	22	19.26
123	26	23	13	4.67
124	29	26	15	6.23
125	34	30	18	10.98
126	31	28	16	8.23
127	27	24	15	5.43
128	30	26	16	7.41
129	25	22	12	4.13
130	27	25	15	5.91
131	28	25	14	5.89
132	29	27	15	7.63
133	29	25	15	5.63
134	27	25	15	5.96
135	34	32	19	12.22
136	34	30	19	11.40
137	32	29	17	9.35
138	32	29	17	9.11
139	35	33	20	13.76
140	33	31	18	10.84
141	30	26	16	7.96
142	29	27	16	7.72
143	36	33	21	14.85
144	25	23	12	4.28
145	38	35	21	16.43
146	31	29	18	9.91
147	32	29	18	9.91
148	36	33	21	14.82
149	35	31	17	11.30
150	32	29	17	9.61
151	34	30	17	10.35
152	35	32	18	11.95
153	35	32	20	13.49
154	33	30	17	10.07
155	39	36	20	17.22
156	37	34	19	14.48
157	39	36	21	16.76
158	41	38	23	20.90
159	38	33	20	14.72
160	35	31	19	12.32

Table 37. Length, width, thickness, and weight measurements of clams in 12 µg/ℓ CPO exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
201	29	25	14	6.40
202	29	25	14	6.34
203	38	34	21	16.38
204	31	27	16	7.81
205	29	24	14	5.69
206	41	38	23	21.91
207	39	36	22	17.89
208	34	30	18	10.86
209	37	33	20	14.88
210	33	30	18	10.90
211	26	24	14	5.30
212	31	28	17	8.42
213	28	26	14	5.39
214	31	28	16	8.39
215	31	28	16	7.96
216	31	27	16	7.33
217	26	23	13	4.54
218	33	30	17	9.82
219	38	35	22	15.93
220	33	30	17	9.35
221	31	28	17	8.90
222	33	31	17	11.16
223	35	33	20	13.15
224	35	31	17	11.72
225	41	37	23	21.94
226	39	34	21	16.57
227	44	38	23	22.53
228	34	30	18	11.12
229	35	32	19	12.77
230	39	35	21	16.75
231	39	35	35	17.45
232	38	33	21	16.59
233	40	36	21	18.13
234	39	36	21	17.14
235	39	36	21	16.99
236	42	38	22	19.61
237	42	37	22	19.59
238	33	30	18	10.44
239	37	35	21	15.97
240	32	28	16	8.65
241	34	31	18	11.50
242	35	32	20	13.50
243	32	31	17	10.50
244	36	32	20	14.40
245	36	32	19	12.70
246	40	36	20	17.80
247	43	40	23	23.90
248	39	35	21	16.40
249	42	38	24	21.80
250	39	36	21	17.90
251	35	32	19	13.45
252	33	30	18	10.95
253	38	35	21	16.55
254	37	35	20	16.59
255	41	38	23	20.98
256	35	33	19	13.30
257	37	35	21	16.40
258	35	31	19	12.60
259	38	35	22	16.90
260	37	35	21	15.90

Table 38. Length, width, thickness, and weight measurements of clams in 25 µg/ℓ CPO exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
301	29	26	15	6.8
302	38	34	21	16.6
303	37	33	19	13.4
304	32	29	17	9.6
305	36	31	18	12.4
306	38	34	20	15.7
307	34	32	±9	12.5
308	42	38	22	21.1
309	44	41	24	25.4
310	42	49	23	21.8
311	25	22	12	4.0
312	28	26	15	6.8
313	30	28	17	8.6
314	34	30	17	10.0
315	35	31	18	12.1
316	35	31	18	11.1
317	38	33	20	14.3
318	41	37	22	19.3
319	38	34	21	17.0
320	37	35	21	17.0
321	26	26	15	5.5
322	29	26	15	7.0
323	37	34	20	15.0
324	34	31	17	10.7
325	32	29	17	9.4
326	32	30	18	10.0
327	36	33	21	15.0
328	41	38	22	19.1
329	41	37	23	21.6
330	37	33	20	15.5
331	42	38	23	22.8
332	36	32	19	12.8
333	37	33	20	14.2
334	36	31	18	11.7
335	34	30	18	10.5
336	42	38	23	21.1
337	38	33	20	14.9
338	38	34	21	15.1
339	40	36	22	18.1
340	40	36	22	19.6
341	27	24	14	6.0
342	35	32	19	13.0
343	38	35	20	16.1
344	31	27	17	8.9
345	32	29	18	9.8
346	36	33	19	13.8
347	41	38	22	19.3
348	35	31	17	10.8
349	36	32	19	12.2
350	41	37	22	19.3
351	30	26	15	7.2
352	32	28	16	8.6
353	34	31	18	10.4
354	38	34	21	15.8
355	40	35	22	18.2
356	42	39	23	21.9
357	42	39	23	21.9
358	43	39	24	23.2
359	35	33	19	13.3
360	35	31	19	11.2

Table 39. Length, width, thickness, and weight measurements of clams in 50 µg/ℓ CPO exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
401	26	23	13	5.0
402	33	30	18	10.4
403	30	26	16	8.0
404	39	37	23	18.5
405	33	30	18	10.3
406	37	33	20	14.5
407	34	32	18	11.6
408	31	28	17	8.6
409	33	31	17	10.8
410	41	37	23	19.9
411	29	25	14	6.0
412	41	36	23	18.7
413	33	29	18	11.0
414	40	36	22	18.2
415	33	30	18	10.9
416	37	34	19	12.6
417	39	35	22	18.0
418	42	38	23	20.9
419	29	26	15	6.9
420	32	29	17	9.5
421	41	36	21	18.6
422	40	36	22	18.9
423	42	38	22	20.3
424	36	33	20	14.2
425	40	36	22	19.2
426	29	27	16	7.7
427	41	36	22	18.9
428	35	32	19	12.7
429	39	36	20	17.5
430	37	33	20	14.4
431	35	32	20	13.1
432	41	37	22	19.2
433	39	35	21	16.9
434	37	33	20	14.6
435	41	39	25	26.1
436	41	38	22	18.6
437	28	26	15	6.0
438	43	39	23	21.5
439	40	37	22	18.9
440	38	35	22	16.0
441	27	25	13	5.6
442	27	23	14	5.1
443	34	30	18	10.9
444	37	32	19	13.3
445	37	35	21	17.1
446	31	27	16	8.5
447	41	38	23	21.1
448	34	31	17	10.6
449	40	37	22	19.4
450	36	32	20	14.3
451	32	28	17	9.0
452	35	33	20	14.4
453	41	38	22	20.8
454	41	37	22	19.3
455	42	39	25	24.7
456	40	37	22	19.6
457	34	30	18	12.0
458	37	33	20	14.2
459	38	34	20	15.4
460	40	35	22	17.7

Table 40. Length, width, thickness, and weight measurements of clams in 100 µg/ℓ CPO exposure tank. Date: 2/27/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
501	44	41	25	24.5
502	39	37	22	18.6
503	35	32	19	12.8
504	33	30	18	10.7
505	38	35	20	15.7
506	37	34	19	14.0
507	38	35	21	15.0
508	36	33	20	13.6
509	37	34	20	14.2
510	34	31	19	12.0
511	30	26	15	6.4
512	33	30	17	9.3
513	32	29	17	10.0
514	34	31	18	11.1
515	34	31	17	10.6
516	30	26	16	7.1
517	31	28	17	9.7
518	31	28	17	8.7
519	35	32	19	12.6
520	37	33	21	15.0
521	32	30	18	11.1
522	40	37	23	20.1
523	32	30	17	10.2
524	42	37	21	19.7
525	42	40	22	21.8
526	36	32	19	13.0
527	38	34	19	14.4
528	44	39	25	24.9
529	45	41	24	16.5
530	36	34	21	16.4
531	34	31	18	11.4
532	41	37	22	19.6
533	41	37	22	19.2
534	38	35	21	17.3
535	37	33	20	14.7
536	34	32	20	12.2
537	38	34	20	14.5
538	40	36	22	18.9
539	33	30	17	10.3
540	39	36	22	18.3
541	40	36	22	17.7
542	40	36	22	19.6
543	32	28	18	9.4
544	37	33	20	14.4
545	37	32	20	13.3
546	42	38	23	20.3
547	34	31	18	11.8
548	36	35	20	15.0
549	35	33	21	13.9
550	44	40	24	24.3
551	34	31	18	11.3
552	39	36	22	19.0
553	37	35	21	15.5
554	41	37	22	19.3
555	33	29	18	10.8
556	31	27	16	8.6
557	33	30	17	9.6
558	39	36	21	16.0
559	36	32	19	13.3
560	38	35	21	15.8

Table 41. Length, width, thickness, and weight measurements of clams after one month of exposure. Date: 4/3/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
8	31	29	17	9.1
46	36	33	20	14.8
18	37	34	21	15.7
3	40	37	24	21.4
41	35	33	20	14.4
30	36	33	20	13.8
22	36	32	19	12.7
39	35	32	19	12.8
6 µg/ℓ CPO				
108	35	32	19	12.5
147	32	30	18	10.0
156	37	34	20	14.5
158	41	38	23	20.8
114	26	23	12	4.7
116	30	26	17	8.2
119	37	34	21	16.4
122	41	37	23	19.3
12 µg/ℓ CPO				
208	34	30	18	11.1
226	39	34	-	19.8
236	41	38	22	20.2
250	40	36	21	18.0
224	41	38	24	22.0
232	38	34	22	16.8
247	43	39	24	23.9
249	42	38	23	22.1
25 µg/ℓ CPO				
346	36	33	19	13.8
355	40	36	-	22.4
332	36	32	19	12.7
311	24	22	12	4.1
306	38	34	20	15.7
317	37	33	20	14.4
334	36	31	18	11.6
340	40	36	22	19.6
50 µg/ℓ CPO				
422	40	36	22	18.9
425	39	36	22	19.0
444	36	32	-	15.2
453	41	38	21	20.8
418	42	38	23	20.7
421	41	37	21	18.6
434	37	33	20	14.6
460	39	35	22	17.6
100 µg/ℓ CPO				
529	45	41	25	26.0
539	33	30	17	10.3
547	35	31	18	11.7
505	39	35	20	15.7
522	40	37	23	20.0
526	36	32	19	13.2
542	40	36	22	19.6

Table 42. Length, width, thickness, and weight measurements of clams after two months of exposure. Date: 5/1/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
17	40	36	22	195
21	38	35	20	15.5
27	32	30	18	10.4
42	41	37	22	19.1
26	40	35	21	17.1
1	38	36	21	16.3
28	35	32	19	12.5
55	39	35	19	15.8
6 µg/ℓ CPO				
106	42	39	24	22.0
155	39	36	21	17.1
118	38	35	21	15.6
109	26	23	13	4.9
159	36	34	20	15.0
110	35	32	20	13.6
143	37	33	21	14.8
138	32	29	17	9.1
12 µg/ℓ CPO				
216	29	27	16	7.6
234	39	36	21	17.1
248	39	35	20	16.3
257	38	35	22	16.4
240	31	28	16	8.7
211	26	24	14	5.3
218	32	30	17	9.8
217	26	23	13	5.0
25 µg/ℓ CPO				
331	42	39	24	22.9
333	37	33	19	14.2
344	30	27	17	8.9
348	35	31	18	10.7
309	44	41	24	25.5
305	35	31	19	12.5
304	32	29	17	9.7
323	37	34	21	14.9
50 µg/ℓ CPO				
455	42	39	25	24.3
454	41	37	22	19.1
428	35	32	19	12.6
445	38	36	21	16.9
438	43	38	23	21.7
452	36	34	20	14.4
459	38	34	20	15.4
427	41	36	22	19.0
100 µg/ℓ CPO				
538	41	36	22	18.8
515	34	31	17	10.7
553	37	35	21	15.4
556	31	28	16	8.6
510	34	31	19	12.0
517	32	28	17	9.6
535	37	33	20	14.6
548	36	34	20	15.1

Table 43. Length, width, thickness, and weight measurements of clams after three months of exposure. Date: 5/30/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
9	26	22	13	4.2
31	40	35	21	16.9
35	28	25	14	5.6
49	40	35	22	17.7
12	32	29	17	9.5
33	32	29	17	9.3
25	38	33	20	15.0
23	36	32	19	12.7
6 µg/ℓ CPO				
102	28	25	15	6.3
120	40	37	22	19.8
144	25	23	13	4.4
150	32	30	17	10.0
113	26	23	13	5.0
148	36	33	21	14.7
115	34	31	16	9.7
130	27	25	15	6.2
12 µg/ℓ CPO				
258	35	31	19	12.7
220	33	30	17	9.6
219	38	34	21	16.2
229	35	32	19	12.7
256	36	33	19	13.4
242	35	32	20	13.7
235	40	36	21	15.9
239	37	34	21	15.9
25 µg/ℓ CPO				
341	27	25	15	6.4
350	41	36	22	19.4
318	41	36	22	19.3
349	36	32	19	12.1
345..	32	29	18	9.9
357	42	39	23	22.2
327	36	33	21	15.0
330	37	34	21	15.7
50 µg/ℓ CPO				
458	37	33	20	14.1
432	41	36	22	19.1
429	39	37	20	17.5
449	40	37	22	19.3
446	31	28	17	8.4
426	29	27	16	7.6
408	31	28	17	8.7
417	39	36	22	17.9
100 µg/ℓ CPO				
527	38	34	19	14.4
537	38	34	20	14.8
524	43	38	21	19.5
541	40	36	22	17.5
503	35	32	19	12.8
544	37	33	20	14.1
534	38	35	22	17.1
560	38	35	21	15.5

Table 44. Length, width, thickness, and weight measurements of clams after four months of exposure. Date: 6/29/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
58	29	25	15	6.5
11	27	24	14	5.9
20	34	30	18	11.3
53	36	34	21	15.2
29	30	27	17	8.6
2	40	38	23	19.2
51	26	23	14	5.6
60	33	30	18	11.0
6 µg/ℓ CPO				
117	37	34	20	13.9
135	34	31	19	12.2
126	31	27	16	8.6
145	38	35	21	16.6
132	29	27	17	8.4
112	25	23	12	4.3
123	26	23	13	4.7
136	34	30	19	11.5
12 µg/ℓ CPO				
255	41	37	24	20.9
222	33	30	18	11.4
237	41	37	22	19.7
254	38	35	21	16.7
227	44	38	23	22.5
214	31	28	16	8.6
223	36	32	20	13.0
205	29	25	14	6.3
25 µg/ℓ CPO				
303	37	33	19	13.5
358	43	39	24	23.2
313	30	27	17	8.5
342	35	32	20	13.1
337	38	33	20	14.9
335	34	30	18	10.4
50 µg/ℓ CPO				
414	40	36	22	18.1
456	40	36	22	19.6
435	41	38	25	26.0
447	42	38	23	21.0
419	29	26	16	7.0
411	29	25	14	6.0
440	38	34	22	16.1
404	40	36	23	18.4
100 µg/ℓ CPO				
501	45	41	24	24.4
545	37	32	19	13.3
540	39	35	23	18.3
554	41	37	22	19.2
519	35	31	19	12.6
557	33	30	17	9.6
530	37	33	21	16.4
516	30	26	16	7.1

Table 45. Length, width, thickness, and weight measurements of clams after five months of exposure. Date: 8/1/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
15	33	29	17	9.6
47	32	29	17	9.6
44	37	34	21	15.7
48	32	29	18	9.8
57	30	26	15	7.0
10	30	28	17	8.8
59	27	25	15	6.2
50	30	27	17	7.9
6 µg/ℓ CPO				
141	30	27	17	8.4
139	35	32	20	13.9
104	32	29	18	9.9
128	30	26	16	7.9
124	29	27	15	6.8
146	32	30	19	11.1
111	29	25	15	6.2
133	29	25	14	5.8
12 µg/ℓ CPO				
259	40	35	22	17.0
233	40	35	22	18.2
230	39	35	21	17.3
231	39	35	22	17.5
252	34	31	19	12.2
202	29	25	15	6.6
251	35	32	20	13.5
253	38	35	22	17.0
25 µg/ℓ CPO				
320	38	35	21	17.2
319	38	35	22	17.4
302	38	34	21	16.8
347	41	37	22	19.3
301	30	26	15	7.0
307	34	32	19	12.6
352	32	28	16	8.9
315	35	31	19	12.5
50 µg/ℓ CPO				
415	33	30	18	11.1
423	42	38	22	20.3
412	41	36	23	18.6
436	41	37	22	18.7
431	35	32	20	13.1
441	28	25	14	5.8
402	34	30	18	10.5
443	34	31	18	10.9
100 µg/ℓ CPO				
509	37	33	20	14.5
546	42	38	23	20.2
550	44	40	24	24.1
520	37	33	21	15.0
536	36	32	20	12.1
514	34	31	18	11.0
523	33	30	18	10.1
552	40	36	22	18.9

Table 46. Length, width, thickness, and weight measurements of clams after six months of exposure. Date: 9/5/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
16	40	36	22	19.2
32	40	37	22	20.1
38	40	35	21	18.0
40	36	32	18	12.0
14	30	26	16	7.6
5	32	30	18	10.5
6	30	27	15	7.6
45	31	29	17	9.6
6 µg/ℓ CPO				
105	38	35	21	16.4
125	34	30	19	11.3
151	35	31	18	11.2
160	35	31	19	12.3
131	28	25	14	6.2
134	27	25	15	6.2
107	30	28	16	8.3
140	33	31	18	11.2
12 µg/ℓ CPO				
241	36	32	19	12.8
244	36	32	20	14.6
245	37	32	19	13.0
210	33	30	19	11.7
201	29	25	15	6.8
204	31	28	16	8.0
212	31	27	17	8.6
260	38	34	21	16.3
25 µg/ℓ CPO				
308	43	38	22	21.3
336	41	38	23	21.3
339	40	36	22	18.6
356	35	30	20	12.2
314	34	30	17	9.9
316	35	31	18	11.2
353	34	31	18	10.4
360	35	32	18	11.3
50 µg/ℓ CPO				
406	38	33	20	14.9
410	41	37	22	19.8
430	37	34	20	14.2
439	40	37	22	19.0
401	26	23	13	5.0
413	33	30	19	14.2
457	35	30	18	11.9
100 µg/ℓ CPO				
506	38	34	19	14.1
525	42	40	23	21.7
528	43	40	24	24.8
558	38	35	21	15.7
507	38	34	21	14.9
511	30	26	15	6.4
513	32	29	17	9.6
521	32	30	19	11.0

Table 47. Length, width, thickness, and weight measurements of clams after eight months of exposure. Date: 11/8/78

Clam #	Length (mm)	Width (mm)	Thickness (mm)	Weight (grams)
CONTROL				
24	30	27	15	7.3
7	28	24	14	6.1
19	34	31	19	12.7
43	36	32	19	12.8
37	31	28	17	8.9
34	33	30	18	11.6
54	29	26	15	7.1
13	29	26	16	7.6
52	34	31	20	11.9
4	27	25	15	6.2
56	36	33	20	13.9
6 µg/ℓ CPO				
154	37	32	20	14.2
153	36	32	20	13.7
127	26	23	15	5.5
157	39	36	21	16.9
137	32	29	17	9.9
142	30	27	16	7.8
101	30	28	17	9.6
129	25	22	13	4.4
121	36	32	18	12.9
149	35	31	18	11.5
12 µg/ℓ CPO				
238	33	30	18	11.7
221	31	29	17	9.4
243	34	31	17	10.7
213	28	26	14	5.7
246	41	36	20	18.1
215	31	27	16	8.4
224	35	31	18	12.2
25 µg/ℓ CPO				
351	30	26	16	8.0
338	38	34	21	15.2
322	30	26	15	7.2
324	34	30	18	10.8
325	32	29	17	9.7
354	37	33	21	15.8
343	38	34	21	16.1
328	41	37	22	19.0
312	28	26	15	6.9
326	32	29	18	10.0
50 µg/ℓ CPO				
409	34	30	17	10.6
442	26	23	14	5.0
403	29	26	16	8.0
420	32	29	17	9.3
433	38	35	21	16.8
437	27	25	14	5.9
451	32	28	17	8.9
100 µg/ℓ CPO				
508	37	32	20	13.7
549	35	33	21	13.9
502	39	36	22	18.5
543	32	28	18	9.5
532	42	37	22	19.6
518	31	28	17	8.6
531	34	31	18	11.5
559	36	32	19	13.3
551	35	31	18	11.3

Table 48. Measured CPO concentrations (µg/ℓ) in exposure tanks.

Date	TARGET CONCENTRATIONS (µg/ℓ) 0	6	12	25	50	100
3/1/78	0	4	6	20	32	186
3/3/78	0	4	6	22	38	98
3/6/78	0	4	6	14	28	82
3/8/78	0	4	8	20	52	116
3/9/78	0	4	8	18	32	100
3/10/78	0	6	10	18	36	98
3/13/78	0	6	8	18	32	54
3/14/78	0	6	10	22	52	104
3/15/78	0	6	10	22	46	98
3/16/78	0	8	8	20	42	84
3/17/78	0	6	8	18	30	68
3/20/78	0	6	8	16	22	46
3/21/78	0	6	10	18	40	74
3/22/78	0	6	12	22	36	76
3/23/78	0	12	20	80	100	200
3/24/78	0	6	20	28	62	100
3/28/78	0	14	16	10	96	192
3/29/78	0	6	14	66	88	188
3/30/78	0	8	16	26	98	232
3/31/78	0	6	16	28	110	256
4/3/78	0	2	6	8	26	64
4/4/78	0	2	4	6	22	64
4/5/78	0	2	6	6	78	82
4/6/78	0	4	6	4	56	50
4/7/78	0	2	8	6	24	68
4/10/78	0	8	10	12	34	88
4/11/78	0	4	8	14	45	76
4/12/78	0	4	8	22	84	138
4/13/78	0	4	8	16	68	104
4/14/78	0	6	10	18	38	96
4/18/78	0	2	8	16	26	68
4/19/78	0	4	8	22	26	58
4/20/78	0	8	10	20	42	74
4/21/78	0	4	12	24	42	72
4/24/78	4	8	14	30	42	80
4/25/78	4	8	12	34	48	100
4/26/78	4	8	14	30	46	92
4/27/78	4	10	12	32	44	92
4/28/78	4	10	12	24	46	92

Date	TARGET CONCENTRATIONS (µg/ℓ) 0	6	12	25	50	100
5/1/78	4	16	12	48	68	124
5/2/78	8	14	14	58	70	128
5/5/78	6	10	16	60	68	106
5/8/78	12	10	16	-	-	-
5/22/78	0	6	12	42	52	102
5/25/78	0	4	14	30	54	96
5/27/78	0	14	12	38	56	96
5/30/78	0	8	10	48	30	62
6/7/78	0	6	8	20	32	68
6/9/78	0	6	10	46	60	92
6/12/78	0	4	12	70	56	80
6/14/78	0	6	12	46	48	90
6/16/78	0	6	16	26	52	94
6/19/78	0	6	10	30	42	88
6/20/78	0	6	12	28	54	94
6/21/78	0	8	12	26	60	98
6/23/78	0	6	10	22	54	90
6/26/78	0	6	10	24	48	90
6/28/78	0	6	12	26	52	94
6/30/78	0	6	12	24	56	102
7/5/78	0	8	8	24	36	100
7/7/78	0	6	12	20	96	82
7/9/78	0	6	12	28	54	92
7/12/78	0	6	12	28	54	96
7/14/78	0	6	14	28	58	108
7/18/78	0	12	26	38	68	156
7/19/78	0	6	14	30	56	128
7/21/78	0	8	16	28	58	112
7/24/78	0	8	14	28	58	112
7/26/78	0	6	14	30	58	96
7/28/78	0	6	14	28	62	98
8/1/78	0	4	10	34	52	94
8/4/78	0	6	12	34	54	98
8/7/78	0	6	12	28	54	102
8/9/78	0	6	14	28	56	104
8/11/78	0	6	12	28	54	106
8/15/78	0	6	12	26	48	96
8/18/78	0	8	16	28	54	106
8/21/78	0	6	10	16	38	112
8/23/78	0	6	10	20	44	108
8/25/78	0	8	12	24	48	110
8/28/78	0	6	12	28	46	112

Table 49. Histopathological descriptions of Protothaca staminea from Sequim Bay, Washington.

R = ripe gonad; PS = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female

Identification	Specimen Number	Description
Initial Sample	79-75	S♀
	79-76	R♂; some metaplasia of digestive gland
	79-77	PS♀
	79-78	PS♀; some necrosis of stomach; some metaplasia of digestive tubules
	79-79	PS♂; metazoan parasite in gonad
	79-80	PS♀; gregarine-like parasite in mantle; some necrotic gill epithelium
	79-81	PS♀; metazoan parasite in kidney; gregarine-like parasite in gill; some necrosis in stomach
	79-82	PS♂; generally necrotic
	79-83	PS♂; generally necrotic
	79-84	PS♀; generally necrotic

Table 50. Histopathological descriptions of Protothaca staminea used as controls in Tank No. 1 of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female

Exposure Time	Specimen Number	Description
1-Month Exposure	79-85	LA♂
	79-86	PS♀; portions of gill epithelium necrotic
	79-87	R♂; metazoan parasite in kidney; necrosis of portions of gill, stomach, intestine
	79-88	PS♀; gregarine parasite; necrosis of portions of stomach, digestive tubules
2-Month Exposure	79-89	PS♀
	79-90	PS♀; metazoan parasite in kidney
	79-91	R♂; metazoan parasite in digestive gland; slight leukocytic infiltration; some necrosis of digestive gland near parasite cysts
	79-92	R♀; metazoan present in kidney
3-Month Exposure	79-93	PS♂
	79-94	PS♀
	79-95	PS♂; unidentified organism in kidney; metazoan parasite in kidney; leukocytic infiltration in area of cysts
	79-96	PS♀
4-Month Exposure	79-97	R♂
	79-98	PS♀; necrotic tissue in kidney, stomach; some digestive tubules metaplasia
	79-99	LA♂; gregarine parasite in gill, some leukocytic infiltration
	79-100	PS♀; abscess in kidney; some necrosis of stomach epithelium
5-Month Exposure	79-101	PS♂; some necrosis of digestive tubules; numerous abscesses
	79-102	PS♂; some necrosis and metaplasia of digestive tubules
	79-103	PS♂; some necrosis and metaplasia of digestive tubules
6-Month Exposure	79-105	PS♀; occasional metaplastic digestive tubules
	79-106	PS♀; gregarine parasite in gill mantle; metazoan parasite in kidney
	79-107	PS♀; metazoan parasite in kidney; some metaplasia of digestive tubules
	79-108	R♂; gregarine parasite in gill

Table 51. Histopathological descriptions of Protothaca staminea exposed to 6 ppb of chlorine in Tank No. 2 of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female

Exposure Time	Specimen Number	Description
1-Month Exposure	79-109	LA♂; some necrosis in gill; some metaplasia of digestive tubules; autolysis of Leydig cells
	79-110	LA♂; autolysis of Leydig cells; large eosinophilic leukocytes in kidney
	79-111	PS♀; metazoan parasite in kidney; abscess in kidney filled with large eosinophilic leukocytes; some necrosis of intestine
	79-112	PS♀; metazoan parasite in kidney; abscesses in kidney; large eosinophilic leukocytes; metaplastic digestive tubules; some necrosis of stomach epithelium
2-Month Exposure	79-113	S♀
	79-114	PS♀
	79-115	R♂
	79-116	LA♂; metazoan parasite in kidney; leukocytic infiltration; cluster of eosinophilic leukocytes
3-Month Exposure	79-117	LA♂
	79-118	PS♂
	79-119	PS♀
	79-120	R♂; unidentified organism in gill; some leukocytic infiltration; small abscess in mantle
4-Month Exposure	79-121	S♀; unidentified organism in gill; some leukocytic infiltration
	79-122	S♀; unidentified organism(s) in gill, kidney; metazoan parasite in kidney
	79-123	S♀; metazoan parasite in kidney; unidentified organisms; some metoplasia of digestive tubules; vacuolization of stomach epithelium
	79-124	R♂; gregarine-like parasite in foot; some metaplasia of digestive tubules; vacuolization of stomach epithelium
5-Month Exposure	79-125	S♂; metazoan parasite in kidney (heavy infection); general leukocytosis; autolysis of Leydig cells; some metaplasia of digestive tubules
	79-126	PS♂; some necrosis of stomach, kidney tubules; autolysis of Leydig cells
	79-127	S♀; metazoan parasit in kidney; leukocytic infiltration into kidney area; necrotic kidney tubules; vacuolization of stomach and intestinal epithelium
	78-128	S♂; metazoan parasite in kidney; leukocytic infiltration into kidney; some eosinophilic leukocytes
6-Month Exposure	79-129	S♀; metazoan parasite in kidney; leukocytic infiltration; some necrosis
	79-130	R♀; metazoan parasite in kidney; considerable necrosis of digestive tubules and kidney tubules; necrotic areas of stomach intestinal epithelium
	79-131	PS♀; necrosis of kidney tubules; autolysis of Leydig cells; some necrosis and metaplasia of digestive tubule epithelium
	79-132	S♀; metazoan parasite in kidney with some enlarged eosinophilic leukocytes; necrotic areas of stomach epithelium

Table 52. Histopathological description of Protothaca staminea exposed to 12 ppb chlorine in Tank No. 3 of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad, ♂ = male; ♀ = female

Exposure Time	Specimen Number	Description
1-Month Exposure	79-133	LA♂; all tissues generally necrotic, clam may have been dead
	79-134	LA♂; same as above
	79-135	PS♀; same as above
	79-136	PS♀; same as above
2-Month Exposure	79-137	PS♀; gregarine-like parasite in gill
	79-138	PS♀; some necrosis of gill and digestive tubules; autolysis of Leydig cells
	79-139	PS♀; necrosis, metaplasia of digestive tubules; autolysis of Leydig cells
	79-140	R♂; metazoan parasite in gonad
3-Month Exposure	79-141	PS♂; metazoan parasite in kidney; leukocytic infiltration into kidney; gill
	79-142	PS♀; large abscess in gonad
	79-143	R♂
	79-144	R♂
4-Month Exposure	79-145	PS♂; gregarine-like parasite in gill; metazoan parasite in kidney; leukocytic infiltration in viscera around cysts
	79-146	PS♂; basophilic granular material in gills
	79-147	PS♀; gregarine-like parasite in gill; some metaphasia of digestive tubules; some necrosis
	79-148	R♀; metazoan parasite in kidney; metaplasia of digestive tubules; some necrosis in kidney, gill, digestive tubules, stomach and intestinal epithelium
5-Month Exposure	79-149	S♂; metazoan parasite (heavy infection) in kidney; leukocytic infiltration into kidne
	79-150	PS♀; metazoan parasite in kidney; some metaplasia and necrosis of digestive tubules
	79-151	PS♀; generalized leukocytosis
	79-152	S♂; some necrosis of intestinal epithelium, stomach, digestive tubules
6-Month Exposure	79-153	S♀; some metaplasia, necrosis of digestive tubules; autolysis of Leydig cells
	79-154	PS♀; some metaplasia, necrosis of digestive tubules
	79-155	S♀; metazoan parasite in kidney, leukocytosis around cysts
	79-156	- no gonad; general leukocytosis, especially in digestive gland; fibrous deposition in digestive gland between tubules

Table 53. Histopathological description of Protothaca staminea exposed to 25 ppb chlorine in Tank No. 4 of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female
EA = early active gonad

Exposure Time	Specimen Number	Description
1-Month Exposure	79-157	R♀; complete necrosis; specimen probably dead when fixed
	79-158	PS♀; autolysis of Leydig cells; leukocytic infiltration into gills; some necrosis of digestive tubules
	79-159	R♀; complete necrosis
	79-160	LA♂; almost complete necrosis
2-Month Exposure	79-161	LA♂; gregarine parasite in mantle and digestive gland; metazoan parasite in kidney; some leukocytic infiltration into parasitized areas; autolysis of Leydig cells
	79-162	LA♂; some necrotic digestive tubule epithelium
	79-163	S♀; necrotic patches of gill, digestive tubules, stomach, intestine, kidney; sutolysis of Leydig cells
	79-164	LA♂; metazoan parasite in kidney; some leukocytic infiltration, some necrosis of kidney
3-Month Exposure	79-165	EA♂
	79-166	PS♂; metazoan parasite in kidney
	79-167	S♀; metaplasia of digestive tubules, some necrosis, some necrosis of intestinal epithelium
	79-168	PS♀; metazoan parasite in kidney; some necrosis; some necrosis of gill, intestinal epithelium, digestive tubules
4-Month Exposure	79-169	PS♀; vacuolization of intestinal epithelium; some necrosis and metaplasis of digestive tubules
	79-170	- no gonad; generalized leukocytosis; metaplasia and necrosis of digestive tubules
	79-171	S♀; general leukocytosis; metaplasia and necrosis of digestive tubules
	79-172	PS♀
5-Month Exposure	79-173	S♀; metazoan parasite in kidney; generalized leukocytisis
	79-174	PS♀; gregarine parasite in foot
	79-175	S♂; some slight metaplasia of digestive tubules
	79-176	PS♀; some general leukocytosis
6-Month Exposure	79-177	S♀; metazoan parasite in kidney; some necrosis of kidney and digestive tubules; some metaplasia of digestive tubules
	79-178	S♀
	79-179	PS♀; metazoan parasite in kidney
	79-180	S♂; some metaplasia of digestive tubules; necrotic areas of stomach epithelium

Table 54. Histopathological descriptions of Protothaca staminea exposed to 50 ppb chlorine in Tank No. 5. of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PA = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female

Exposure Time	Specimen Number	Description
1-Month Exposure	79-181	R♂; general necrosis
	79-182	LA♂; general leukocytisis; necrotic gills; digestive tubules, stomach, intestine
	79-183	LA♂; gregarine-like parasite in gill; gill necrotic
	79-184	R♂; general necrosis
2-Month Exposure	79-185	PS♂; metazoan parasite in kidney; some leukocytic inflitration around parasite
	79-186	LA♂; some necrosis of digestive tubules; large abscess in gonad/digestive gland area; diminished basophilia
	79-187	PS♀; considerable necrosis in digestive gland tubules; necrotic areas of intestine, leukocytic infiltration into gills
	79-188	LA♂; necrotic areas of digestive gland tubules; stomach epithelium
3-Month Exposure	79-189	S♂; metazoan parasite in kidney; leukocytic infiltration into infected area; leukocytosis in gonad area
	79-190	PS♂; metazoan parasite in kidney; leukocytic infiltration into infected area
	79-191	PS♀
	79-192	PS♀; metaplasia of digestive tubules
4-Month Exposure	79-193	PS♂; metazoan parasite in kidney; necrosis of kidney tubules; leukocytosis in area around cyst; metaplasia of digestive tubules
	79-194	S?; no gametes, but follicles present; general leukocytosis; metaplasia of digestive tubules; kidneys necrotic
	79-195	PS♀; some metaplasia of digestive tubules; necrotic areas of stomach and intestinal epithelium
	79-196	PS♀; metazoan parasite in kidney; vacuolization, necrosis of stomach epithelium; some metaplasia of digestive tubules; some necrotic tubules
5-Month Exposure	79-197	PS♂; autolysis of Leydig tissue, some vacuolization of intestinal and stomach epithelium
	79-198	PS♀; vacuolization, some necrosis of digestive tubules
	79-199	PS♂*; metazoan parasite in kidney; leukocytic infiltration into kidney area; necrotic kidney tubules; extensive necrosis of digestive tubules
	79-200	PS♂*; metazoan parasite in kidney, extensive leukocytic infiltration with some intensely eosinophilic leukocytes; autolysis of Leydig cells; necrotic digestive tubules, portions of intestinal epithelium
6-Month Exposure	79-201	PS♂*; metazoan parasite in kidney; gregarine-like parasite in mantle; autolysis of Leydig cells; necrotic kidney tubules, leukocytosis of kidney with eosinophilic leukocytes; necrotic digestive tubules, some metaplasia
	79-202	S♀; extensive necrosis of digestive tubules, some metaplasia; necrosis of stomach, intestinal epithelium; some vacuolization of stomach epithelium; autolysis of Leydig cells
	79-203	S♂; metazoan parasite in kidney; necrosis of kidney tubules; autolysis of Leydig cells; necrosis, metaplasia of digestive tubules; leukocytosis in viscera
	79-204	PS♀; necrosis, metaplasia of digestive tubules, vacuolization, necrosis of stomach, intestinal epithelium; mild leukocytosis in gills; abscesses in foot muscle; autolysis of Leydig cells

* Some follicles appear to be in late active state of development, but none look ripe.

Table 55. Histopathological descriptions of Protothaca staminea exposed to 100 ppb chlorine in Tank No. 6 of Chlorine Bioassay Study.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; ♂ = male; ♀ = female

Exposure Time	Specimen Number	Description
1-Month Exposure	79-205	R♂; metazoan parasite in kidney, leukocytosis; large masses of basophilic granular material in gills; necrosis of large portion of gill; leukocytosis
	79-206	LA♂; general necrosis
	79-207	LA♂; general necrosis
	79-208	R♂; metazoan parasite in kidney; general necrosis
2-Month Exposure	79-209	R♀; leukocytic infiltration into gills, gonad, digestive area; vacuolization of stomach, intestinal epithelium with some necrosis
	79-210	S♀; autolysis of Leydig cells; some leukocytic accumulation around stomach
	79-211	PS♀; metazoan parasite in gonad; autolysis of Leydig cells; necrosis of digestive tubules, portions of gills; vacuolization and some necrosis of intestinal epithelium
	79-212	LA♂; autolysis of Leydig tissues; leukocytosis of gills; vacuolization of digestive tube epithelium, some necrosis
3-Month Exposure	79-213	PS♂; autolysis of Leydig cells; necrosis, metaplasia of digestive tubules; necrosis of stomach and intestinal epithelium
	79-214	LA♂; autolysis of Leydig cells; vacuolization of stomach epithelium; some necrosis of digestive tubules; intestinal epithelium
	79-215	S♀; abscess on gill; small amount of necrosis, metaplasia of digestive tubules
	79-216	PS♀; necrotic areas of digestive gland; vacuolization, some necrosis of stomach epithelium
4-Month Exposure	79-217	LA♂; metazoan parasite in kidney; slight leukocytosis in area of parasite
	79-218	LA♂
	79-219	S♀; metazoan parasite in kidney; metaplasia, necrosis of digestive tubules
	79-220	PS♀; vacuolization of stomach and intestinal epithelium, some necrosis
5-Month Exposure	79-221	S♀; autolysis of Leydig cells
	79-222	PS♀; vacuolization of intestinal epithelium
	79-223	S♀
	79-224	S♀; vacuolization of stomach, intestinal epithelium
6-Month Exposure	79-225	S♀; autolysis of Leydig cells; general leukocytosis; metaplasia; necrosis of stomach, intestinal epithelium, kidney
	79-226	PS♀; gills necrotic; vacuolization of stomach, intestinal epithelium; vacuolization, some necrosis of digestive tubules
	79-227	R♂; necrotic areas along gills; digestive tubules almost completely necrotic; autolysis of Leydig cells; necrosis of stomach, intestine
	79-228	LA♂; vacuolization of intestinal epithelium, some necrosis; general leukocytosis; necrotic areas of gill

Table 56. Results of histopathological examination of initial sample of Protothaca staminea collected from Sequim Bay, Washington in March, 1978.

R = ripe gonad; PS= partially spawned gonad; S = spent gonad; M = Metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
79-75	S♀			some; digestive tubules		
79-76	R♂			some; digestive tubules	some; stomach	
79-77	PS♀	M; gonad				
79-80	PS♀	G; mantle			some; gill	
79-81	PS♀	M; kidney			some; stomach	
79-82	PS♂				general	
79-83	PS♂				general	
79-84	PS♀				general	

Table 57. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for one month.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-85	LA♂					
	79-86	PS♀				some; gill	
	79-87	R♂	M; kidney			some; gill, stomach, intestine	
	79-88	PS♀	G; gill			some; stomach, digestive tubules	
6 ppb	79-109	LA♂			some; digestive tubules	some; gill	autolysis of Leydig cells
	79-110	LA♂		kidney; some large eosionphilic cells			autolysis of Leydig cells
	79-111	PS♀	M; kidney			some; intestine	abscess in kidney; large eosinophilic leukocytes
	79-112	PS♀	M; kidney		some; digestive tubules	some; stomach epithelium	abscess in kidney; large eosionphilic leukocytes
12 ppb	79-133	LA♂				general	
	79-134	LA♂				general	
	79-135	PS♀				general	
	79-136	PS♀				general	
25 ppb	79-157	R♀				general	
	79-158	PS♀		gills		some; digestive tubules	autolysis of Leydig cells
	79-159	R♀				general	
	79-160	LA♂				general	
50 ppb	79-181	R♂				general	
	79-182	LA♂		general		some; gills, digestive tubules, stomach, intestine	
	79-183	LA♂	G; gill			some; gill	
	79-184	R♂				general	
100 ppb	79-205	R♂	M; kidney	kidney, gill		large portion of gill	large masses of basophilic granular material in gill
	79-206	LA♂				general	
	79-207	LA♂				general	
	79-208	R♂	M; kidney			general	

Table 58. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for two months.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-89	PS♀					
	79-90	PS♀	M; kidney				
	79-91	R♂	M; digestive gland	slight in digestive gland		some; near parasite in digestive gland	
	79-92	R♀	M; kidney				
6 ppb	79-113	S♀					
	79-114	PS♀					
	79-115	R♂					
	79-116	LA♂	M; kidney	kidney; clusters of eosinophilic leukocytes			
12 ppb	79-137	PS♀	G; gill				
	79-138	PS♀				some; gill, digestive tubules	autolysis of Leydig cells
	79-139	PS♀			digestive tubules	some; digestive tubules	
	79-140	R♂	M; gonad				
25 ppb	79-161	LA♂	G; mantle, digestive gland	some; digestive gland, kidney			autolysis of Leydig cells
	79-162	LA♂				some; digestive tubules	
	79-163	S♀				some; gill, digestive tubules; stomach, intestines, kidney	autolysis of Leydig cells
	79-164	LA♂	M; kidney	some; kidney		some; kidney	
50 ppb	79-185	PS♂	M; kidney	some; kidney			
	79-186	LA♂				some; digestive tubules	large abscess in general digestive area
	79-187	PS♀		some; gills		extensive; digestive tubules, intestine	
	79-188	LA♂				some; digestive tubules, stomach	
100 ppb	79-209	R♀		some; gills, gonads, digestive gland		some; stomach, intestine	vacuolization of stomach, intestine
	79-210	S♀		some; around stomach			autolysis of Leydig cells
	79-211	PS♀	M; gonad			some; digestive tubules, gill, intestinal epithelium	autolysis of Leydig cells; vacuolization of intestinal epithelium
	79-212	LA♂		some; gills		some; digestive tubules	autolysis of Leydig cells, vacuolization of digestive tube epithelium

Table 59. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for three months.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female; EA = early active gonad

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-93	PS♂					
	79-94	PS♀					
	79-95	PS♂	M; kidney Unidentified; kidney	some; kidney			
	79-96	PS♀					
6 ppb	79-117	LA♂					
	79-118	PS♂					
	79-119	PS♀					
	79-120	R♂	Unidentified; gill	some; gill			small abscess in mantle
12 ppb	79-141	PS♂	M; kidney	some; kidney, gill			
	79-142	PS♀					large abscess in gland
	79-143	R♂					
	79-144	R♂					
25 ppb	79-165	EA♂					
	79-166	PS♂	M; kidney				
	79-167	S♀			some; digestive tubules	some; digestive tubules, intestinal epithelium	
	79-168	PS♀	M; kidney			some; kidney, gill, intestinal epithelium, digestive tubules	
50 ppb	79-189	S♂	M; kidney	some; kidney, gonad			
	79-190	PS♂	M; kindey	some; kidney			
	79-191	PS♀					
	79-192	PS♀			some; digestive tubules		
100 ppb	79-213	PS♂			some; digestive tubules	some; digestive tubules, stomach, intestinal epithelium	autolysis of Leydig cells
	79-214	LA♂				some; digestive tubules; intestinal epithelium	autolysis of Leydig cells; vacuolization of stomach epithelium
	79-215	S♀			small amount; digestive tubules	small amount; digestive tubules	abscess on gill
	79-216	PS♀				some; digestive gland, stomach	vacuolization of stomach epithelium

Table 60. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for four months.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-97	R♂					
	79-98	PS♀			some; digestive tubules	some; kidney, stomach	
	79-99	LA♂	G; gill	some; gill			
	79-100	PS♀				some; stomach epithelium	abscess in kidney
6 ppb	79-121	S♀	Unidentified in gill	some; gill			
	79-122	S♀	Unidentified in gill, kidney M; kidney				
	79-123	S♀	M; kidney Unidentified in kidney		some; digestive tubules		vacuolization of stomach epithelium
	79-124	R♂	G; foot		some; digestive tubules		vacuolization of stomach epithelium
12 ppb	79-145	PS♂	G; gill M; kidney	in viscera around cysts			
	79-146	PS♂					basophilic material in gill
	79-147	PS♀	G; gill		some; digestive tubules	some; digestive tubules	
	79-148	R♀	M; kidney		some; digestive tubules	some; kidney, gill, digestive tubules, stomach, intestine	
25 ppb	79-169	PS♀			some; digestive tubules	some; digestive tubules	vacuolization of intestinal epithelium
	79-170	No gonad		general	some; digestive tubules	some; digestive tubules	
	79-171	S♀		general	some; digestive tubules	some; digestive tubules	
	79-172	PS♀					
50 ppb	79-193	PS♂	M; kidney	some; around parasites	some; digestive tubules	some; kidney	
	79-194	S?		general	some; digestive tubules	kidney	gonad follicles present, but no gametes
	79-195	PS♀			some; digestive tubules	some; stomach, intestines	
	79-196	PS♀	M; kidney		some; digestive tubules	some; digestive tubules	vacuolization of stomach epithelium
100 ppb	79-217	LA♂	M; kidney	slight; in area of parasite			
	79-218	LA♂					
	79-219	S♀	M; kidney		some; digestive tubules	some; digestive tubules	
	29-220	PS♀				some; stomach, intestine	vacuolization of stomach and intestine

Table 61. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for five months.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-101	PS♂				some; digestive tubules	numerous abscesses
	79-102	PS♂			some; digestive tubules	some; digestive tubules	
	79-103	PS♂			some; digestive tubules	some; digestive tubules	
6 ppb	79-125	S♂	M; kidney (heavy infection)	general	some; digestive tubules		autolysis of Leydig cells
	79-126	PS♂				some; stomach, kidney	autolysis of Leydig cells
	79-127	S♀	M; kidney	kidney		some; kidney	vaculoization of stomach and intestinal epithelium
	79-128	S♂	M; kidney	kidney; some eosinophilic leukocytes			
12 ppb	79-149	S♂	M; kidney (heavy)	kidney			
	79-150	PS♀	M; kidney		some; digestive tubules	some; digestive tubules	
	79-151	PS♀		general			
	79-152	S♂				some; intestinal epithelium, stomach, digestive tubules	
25 ppb	79-173	S♀	M; kidney	general			
	79-174	PS♀	G; foot				
	79-175	S♂			some; digestive tubules		
	79-176	PS♀		general			
50 ppb	79-197	PS♂					autolysis of Leydig cells; some vacuolization of intestinal & stomach epithelium
	79-198	PS♀				some; digestive tubules	vacuolization of digestive tubules
	79-199	PS♂	M; kidney	kidney		some; kidney, extensive; digestive tubules	
	79-200	PS♂	M; kidney	kidney (extensive); eosinophilic leukocytes		some; digestive tubules, portions of intestine	autolysis of Leydig cells
100 ppb	79-221	S♀					autolysis of Leydig cells
	79-222	PS♀					vacuolization of intestinal epithelium
	79-223	S♀					
	79-224	S♀					vacuolization of stomach and intestinal epithelium

Table 62. Summary of histological descriptions of the littleneck clam, Protothaca staminea, exposed to various amounts of chlorine for six months.

LA = late active gonad; R = ripe gonad; PS = partially spawned gonad; S = spent gonad; M = metazoan parasite; G = gregarine-like parasite; ♂ = male; ♀ = female

Chlorine Concentration	Specimen Number	Gonad Condition	Parasite	Leukocytosis	Metaplasia	Necrosis	Other
Control	79-105	PS♀			occasional; digestive tubules		
	79-106	PS♀	G; mantle, gill M; kidney				
	79-107	PS♀	M; kidney		some; digestive tubules		
	79-108	Rd♂	G; gill				
6 ppb	79-129	S♀	M; kidney	kidney		some; kidney	
	79-130	R♀	M; kidney			considerable; kidney, digestive tubules some; stomach, intestinal epithelium	
	79-131	PS♀			some; digestive tubules	some; kidney, digestive tubules	autolysis of Leydig cells
	79-132	S♀	M; kidney	kidney (some large eosinophilic leukocytes)		some; stomach	
12 ppb	79-153	S♀			some; digestive tubules	some; digestive tubules	autolysis of Leydig cells
	79-154	PS♀			some; digestive tubules	some, digestive tubules	
	79-155	S♀	M; kidney	kidney, around cysts			
	79-156	No gonad		general			fibrous deposits in digestive gland
25 ppb	79-177	S♀	M; kidney		some; digestive tubules	some; kidney, digestive tubules	
	79-178	S♀					
	79-179	PS♀	M; kidney				
	79-180	Sd♂			some; digestive tubules	some; stomach epithelium	
50 ppb	79-201	PSd♂	M; kidney G; mantle	kidney; some large eosinophilic cells	some; digestive tubules	some; kidney, digestive tubules	autolysis of Leydig cells
	79-202	S♀			some; digestive tubules	extensive; digestive tubules, some, intestine, stomach	some vacuolization of stomach epithelium; autolysis of Leydig cells
	79-203	Sd♂	M; kidney	viscera	some; digestive tubules	kidney; some digestive tubules	autolysis of Leydig cells
	79-204	PS♀		mild; gills	some; digestive tubules	some; stomach, intestine	autolysis of Leydig cells; abscesses in foot; vacuolization of stomach, intestinal epithelium
100 ppb	79-225	S♀		general	some; digestive cells	some; stomach, intestine, kidney	autolysis of Leydig cells
	79-226	PS♀				gills; some digestive tubules	vacuoliation of stomach, intestinal empithelium, digestive tubules
	79-227	Rd♂				portions of gill; extensive; digestive tubules; some, stomach, intestine	
	79-228	LAd♂		general		some; intestine, gill	vacuolization of intestinal epithelium

Table 63. Summary of histopathological observations of littleneck clams, Protothaca staminea exposed to various CPO concentrations for up to six months.

Number of Months Exposed	CPO Concentrations (µg/l)	No. of Clams in Sample	Number of clams with histopathological conditions: Leukocytosis	Metaplasia	Necrosis	Vacuolization of Digestive Tissues	Abscesses Autolysis, etc.
Initial Sample	0	10	0	2	6	0	0
1	0	4	0	0	3	0	0
	6	4	1	2	3	0	4
	12	4	0	0	4	0	0
	25	4	1	0	4	0	1
	50	4	1	0	4	0	0
	100	4	1	0	4	0	1
2	0	4	1	0	1	0	0
	6	4	1	0	0	0	0
	12	4	0	1	2	0	1
	25	4	2	0	3	0	2
	50	4	2	0	3	0	1
	100	4	3	0	3	3	3
3	0	4	1	0	0	0	0
	6	4	1	0	0	0	1
	12	4	1	0	0	0	1
	25	4	0	1	2	0	0
	50	4	2	1	0	0	0
	100	4	0	2	4	2	3
4	0	4	1	1	2	0	1
	6	4	1	2	0	2	1
	12	4	1	2	3	0	1
	25	4	2	3	3	1	0
	50	4	2	4	3	1	1
	100	4	1	1	2	1	0
5	0	3	0	2	3	0	1
	6	4	3	1	2	1	2
	12	4	2	1	2	0	0
	25	4	2	1	0	0	0
	50	4	1	0	3	2	2
	100	4	0	0	0	2	1
6	0	4	0	2	0	0	0
	6	4	2	1	4	0	1
	12	4	1	2	2	0	2
	25	4	0	2	2	0	0
	50	4	3	4	4	2	4
	100	4	2	1	4	2	1

Table 64. Bromoform concentrations in clams exposed to chlorinated sea water containing sublethal concentrations of chlorine produced oxidant (CPO).

CPO µg/ℓ	DATE OF HARVEST 3/1	4/3	5/2	5/30	6/29	8/1	9/5	11/8
		ng Bromoform/gram tissue wet wt.						
Control	0*	0	0	12	g	g	0	1
		226	6	5			10	9
		107	0	0			0	0[a]
		55	0					
6		97	20	0	0	2	0	0[b]
		166	15	0	0	0	0	
		0	0	0	0	0	0	
		140	0	11	0	0	0	
12		33	56	2	0	0	1	2
		183	9	169	0	10	9	40
		238	0	0	0	14	3	0[c]
		296		9	0	18	20	
							0	
25		24	72	348	17	18	0	3
		123	13	26	0	14	0	2
		74	80	20	0	14	208	2
		42	39	9	35	17		0[d]
50		107	21	7	13	4	0	2
		34	16	11	44	0	0	0[e]
		97	6	1	25	0	0	
		352	82	8	41	14	0	
100		72	150	14	g	0	6	18
		95	153	43		22	2	18
		103	64	46		26	0	22
		89	60	32		8	2	33
								0[f]

* Represents 13 individuals
[a] Represents 9 individuals
[b] Represents 11 individuals
[c] Represents 4 individuals
[d] Represents 7 individuals
[e] Represents 6 individuals
[f] Represents 4 individuals
[g] No sample

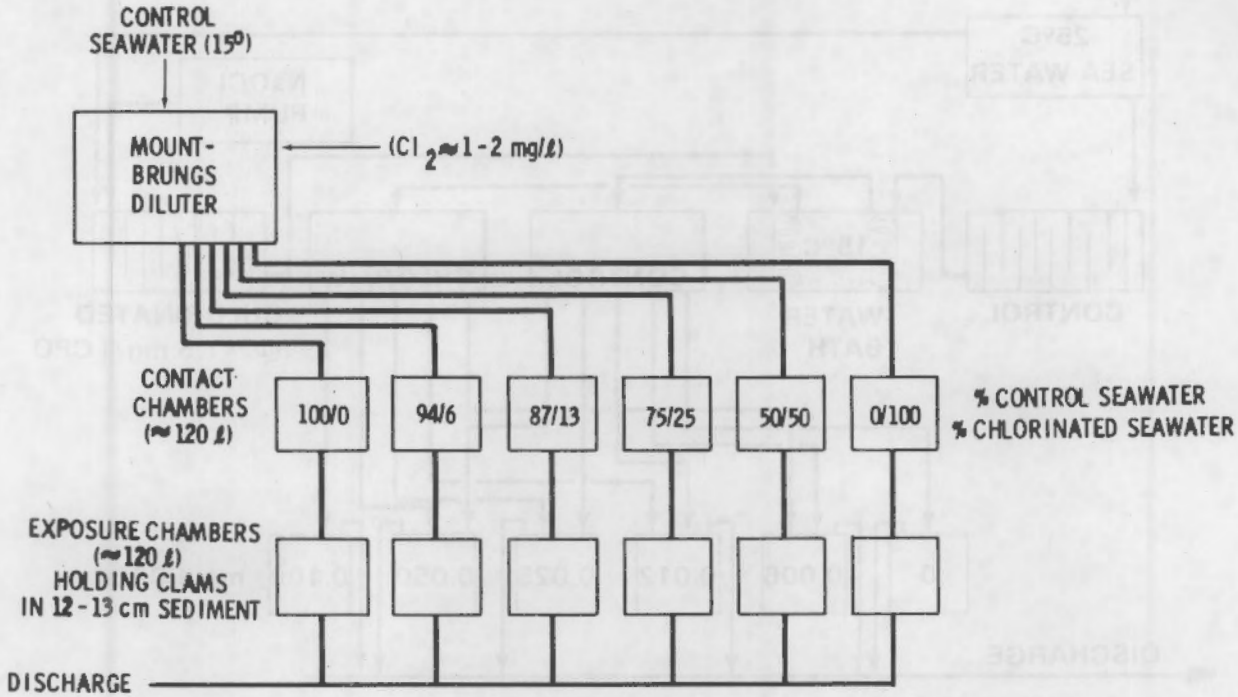


Figure 1. Exposure system used for Protothaca staminea in the first growth experiments.

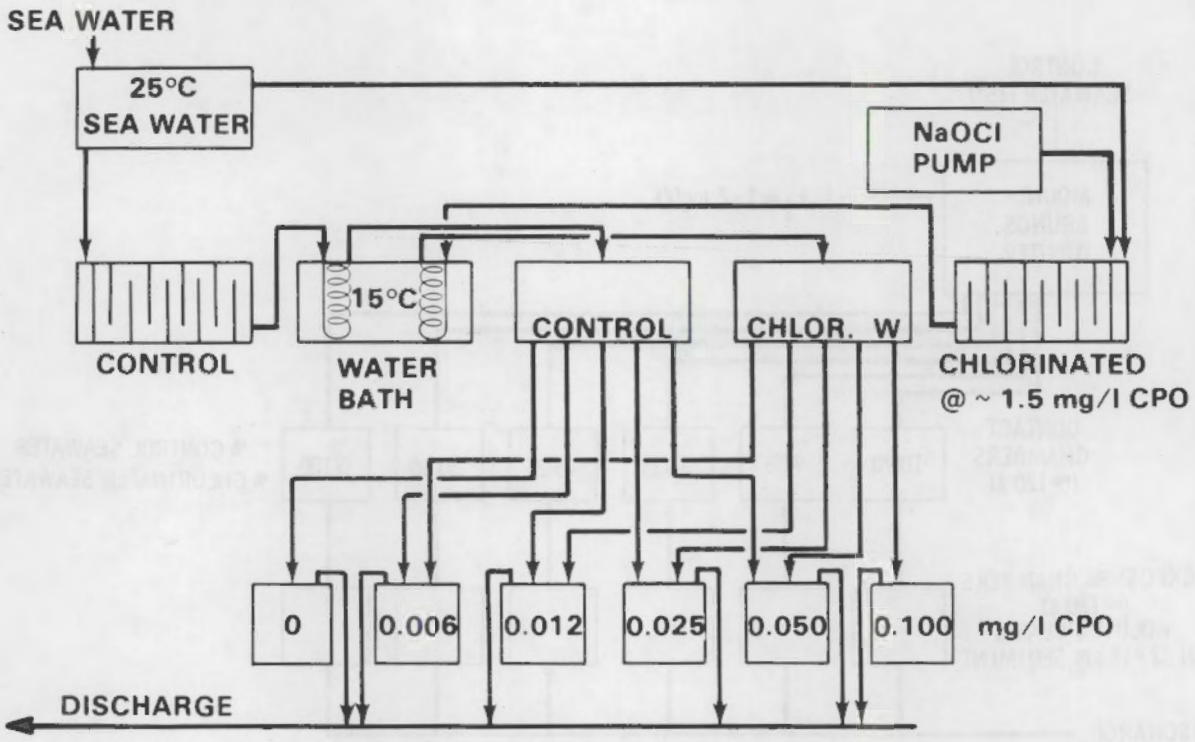
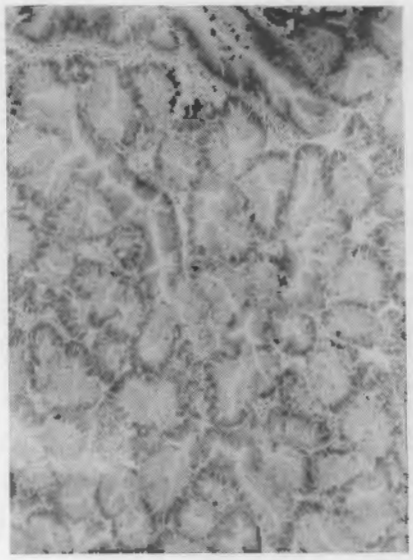
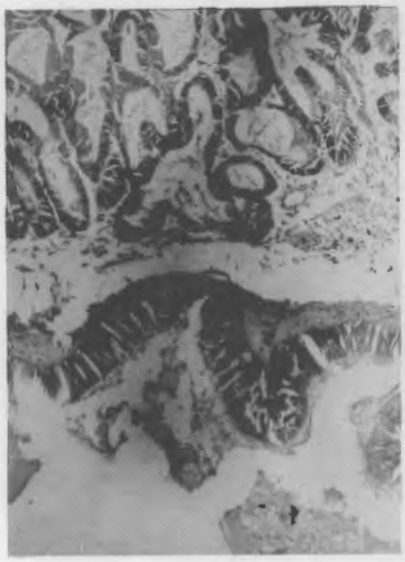


Figure 2. Exposure system used for Protothaca staminea in the second growth experiments.

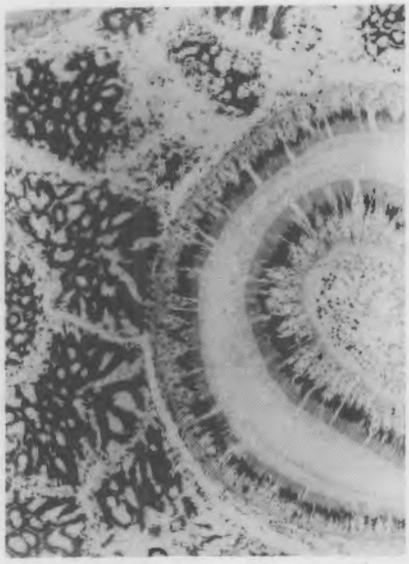


A. NORMAL DIGESTIVE TUBULE EPITHELIUM

B. NORMAL STOMACH EPITHELIUM



C. NECROTIC STOMACH EPITHELIUM (LEFT) AND METAPLASTIC DIGESTIVE TUBULE EPITHELIUM (RIGHT) OF CLAM EXPOSED FOR 6 MONTHS AT 50 ppb CPO



D. VACUOLIZATION OF INTESTINAL EPITHELIUM OF CLAM EXPOSED FOR 6 MONTHS AT 100 ppb CPO. NOTE LEUKOCYTIC INFILTRATION INTO EPITHELIUM.

Figure 3. Photomicrographs of sections through the littleneck clam, Protothaca staminea.

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There has been considerable concern about the potential for long-term effects to marine organisms from chlorinated sea water. As part of a larger study to investigate the effects of materials resulting from sea water chlorination on marine organisms, groups of littleneck clams, Protothaca staminea, were exposed to sea water that had been chlorinated. Two experiments were conducted. In one test, groups of littleneck clams were exposed to dilutions of chlorinated sea water that had average chlorine produced oxidant (CPO) concentrations of 16 µg/ℓ or less. In the second test, groups of clams were exposed to chlorinated seawater-unchlorinated sea water mixtures that had target CPO concentrations of 0, 6, 12, 25, 50 and 100 µg/ℓ. In the first experiment, length measurements were made on all clams at approximately one-month intervals for three months. In the second test, length, weight, depth, width and edge etching were used to measure growth, and subsamples were harvested and measured at one-month intervals. In addition, clams were preserved for histological examination.

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