Final Report of the Kachemak Bay Shellfish Nursery Culture Project 1997-98

Seed Production and Nursery Performance

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Project Completion Report
To
The Alaska Science and Technology Foundation
Alaska Department of Fish and Game

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Introduction

Growing Pacific oysters (*Crassostrea gigas*) in the cold coastal waters of Alaska requires two to three years to produce a crop of $2^1/_2$ – 3" size halfshell oysters, nearly twice the time required in the state of Washington. Alaska Department of Fish and Game regulation also restricts the size of imported oyster seed, purchased from out-of-state shellfish hatcheries, to less than 20 mm in shellfish length. Oyster farmers contend that the long growout time and the high variability in survival of seed grown at farm sites are problems that can be solved by providing farms with larger seed. To test the prospect of increasing oyster seed size, a proposal was funded in 1993 by the Kenai Peninsula Borough Economic Development District and the U.S. Economic Development Administration that built and operated a floating upwelling system (FLUPSY). A FLUPSY system was chosen because of its widespread use in Europe, and the state of Washington.

A FLUPSY is a raft constructed with several culture chambers that hold oyster seed. Sea water is pumped through the culture chambers at a rate that far exceeds what is available through natural currents (Appendix Figure 1). The enhanced water flow enables young oysters greater access to abundant planktonic feed and can potentially increase the seed growth rate and survival.

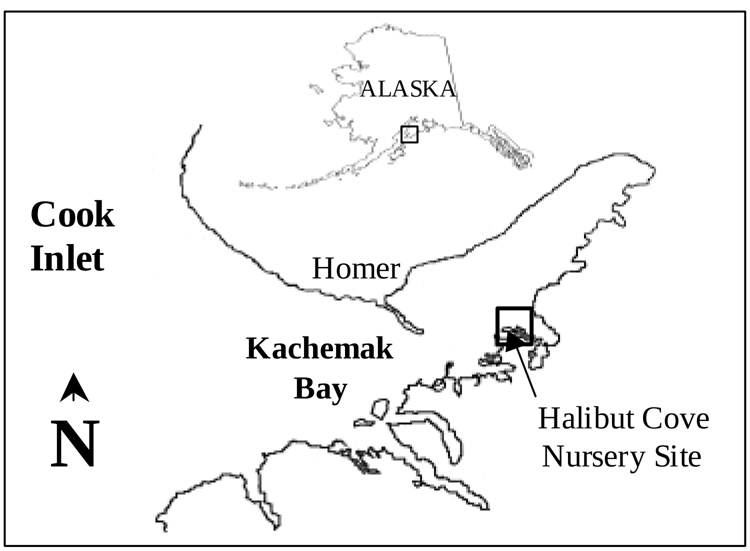

Figure 1. Location of the Halibut Cove FLUPSY nursery in Kachemak Bay, Alaska.

The 1993 study found that the mean shell height of oyster seed grown in the nursery was significantly larger than the seed grown in traditional tray culture, (19.5 mm and 11.45 mm respectively). Nursery cultured seed was better conditioned as indicated by the larger single seed volume and their length/weight condition factor (RaLonde 1993). In nursery culture, unhealthy seed died early, and poor growing seed were easily identified for their inability to grow above ¼" sorting size. Consequently, elimination of unhealthy seed and culling the slow growers while in the nursery reduces the variability of growth and survival of oyster growout on the farm. The results of the pilot project were so encouraging that a site selection study was initiated in 1995 to determine the best location to construct a production size FLUPSY nursery in Kachemak Bay. Of the three sites studied (Seldovia, Jackalof Bay, and Halibut Cove) the most suitable site; based on biological, logistic, economic, and community acceptance criteria; was Halibut Cove (Figure 1) (RaLonde and Bradley 1996).

The Halibut Cove FLUPSY, was constructed in 1997 with funds from the Exxon Valdez Oil Spill litigation settlement. A two-year research project on nursery culture, initiated by the Kachemak Shellfish Mariculture Association (KSMA) and the University of Alaska Marine Advisory Program (MAP), continued with a grant from the Alaska Science and Technology Foundation.

The objectives of the nursery culture research project were to:

1. Construct, install, test, and operate a prototype FLUPSY nursery culture system.
2. Evaluate the design and operation of the prototype nursery for compatibility with the Alaska marine environment and make appropriate modifications if necessary.
3. Measure and develop a water flow model to assist in developing an operational protocol for FLUPSY culture of oyster seed.
4. Determine the optimum stocking densities that will assure maximum production of oyster seed.
5. Develop and test methods of determining oyster seedbed fluidization.
6. Develop a method for estimating sorting times in order to segregate fast and slow growing seed into separate culture chambers.
7. Test the use of a pump to remove and restock seed into culture chambers.
8. Measure the cost of operation and determine the overall economic viability of nursery culture in Alaska.
9. Provide technology transfer to the Alaska shellfish culture industry by making annual presentations of progress at the annual meetings of the Alaskan Shellfish Growers Association and the Kachemak Shellfish Mariculture Association.
10. Write a technical publication on FLUPSY design and operation that will enable expansion of this technology to other locations in Alaska.

The research program began with the first production cycle on May 16, 1997 by stocking the FLUPSY with 1.3 million oyster seed. A second production cycle started on May 13, 1998 with stocking of 1.5 million seed, and an additional stocking of 1 million seed occurred on August 15, 1998. All oyster seed purchased in 1997 and 1998 were 2 mm in shell height and originated from Lummi Shellfish Hatchery from the state of Washington.

FLUPSY design, construction, and deployment

The pilot nursery FLUPSY used in 1993 was constructed primarily of wood and employed a propeller pump to supply water to the oyster seed culture chambers (Figure 2). For the production size nursery, construction materials were selected to address the extreme weather conditions of Alaska's climate. Use of wood is minimal. The frame of the FLUPSY raft is made of welded marine grade aluminum, the decking is concrete, and the culture chambers are custom made of fiberglass with stainless steel bottom 2 mm mesh size screens (Appendix Pictures 1-3). Total flotation is 20,000 lbs. provided by Styrofoam blocks. The durable construction of the FLUPSY should enable an expected life of 20 years.

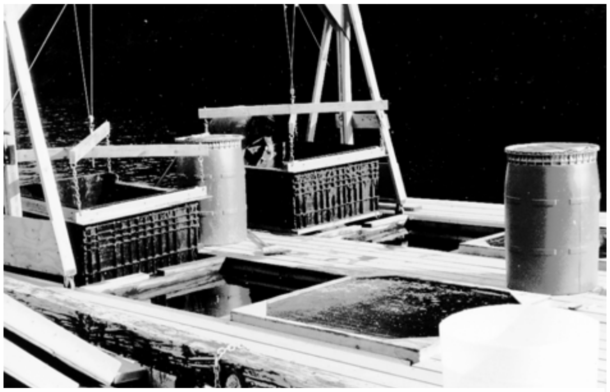

Figure 2. Pilot FLUPSY made of wood, and fiberglass tote bins for culture chambers. Culture chambers are removed from their chambers for cleaning.

The FLUPSY is constructed with eight 36"x36" culture chambers. A paddle wheel pump, with vane dimensions 21" high and 36" wide, was chosen because greater water flow was necessary to operate the larger nursery than could be achieved with a propeller pump used in the pilot project. Power to the paddle wheel is supplied by a 2 hp electric engine and delivered to the paddlewheel with a 60:1 gear reduction chain drive. Construction drawings and pictures of the FLUPSY are located in Appendix Drawings 1-10.

Research design and data collection

The goal of the project is to develop an efficient method of producing larger oyster seed. To reach that goal requires constructing an effective FLUPSY and developing operational protocols that will maximize oyster seed production of the nursery. In practical terms, to produce larger seed requires monitoring and modifying the FLUPSY design to optimize performance, describing environmental conditions that effect seed growth, and testing various operational practices to maximize the quality and quantity of seed production. Consequently, systematic data collection was necessary to provide guidance in making design and operational modifications.

Oceanographic data

The following data were collected for the duration of the project.

- Surface temperature – Surface water temperatures were recorded with Seamon-mini constant temperature recorder set to measure temperature every 6 hours to account for temperature differences that may occur during tidal changes. The daily temperature was computed as an average of four daily measurements.

- Salinity – Surface salinity was measured periodically. Salinity was not considered to be a limiting factor for growth and survival of oyster seed based on the 1996 site selection report for Halibut Cove (Bradley and RaLonde 1996). However, salinity data is useful as an indicator of fresh water influence at the site that may effect primary production and subsequent growth of seed.
- Secchi disk depth - Secchi disk depths were periodically measured. A secchi disk is a white disk lowered into the water. The depth where the disk can no longer be seen from the surface is termed the secchi disk depth. In marine waters not affected by turbidity from freshwater runoff , phytoplankton is a primary cause for reduced water clarity. Consequently, secchi disk depth is an indirect measure of phytoplankton abundance and thus an indication of food available for shellfish growth. For example, a time of shallower secchi disk depths is an indication of greater food abundance for the nursery cultured oyster seed.

Shellfish growth data

- Shellfish growth - Samples of oyster seed were collected from each chamber at approximately two-week intervals. Each sample, consisting of 50 individual seed, was measured for:
    - *Shell height* - The longest part of the shell from the hinge to the opposite edge in millimeters (Figure 3).
    - *Shell length* - The widest part of the narrow dimension of the shell, perpendicular to the shell height in millimeters (Figure 3).
    - *Weight* – Individual seed weight in grams.
    - *Volume* - Dry volume of the entire sample, then converted to number of seed per milliliter (Collected only during the 1997 growing season).

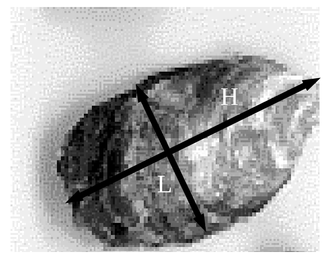

Figure 3. Length (L) and height (H) measurements.

Water flow measurements and fluidization of the seedbed

Efficient operation of a floating upwelling system (FLUPSY) nursery requires water flowing through the culture chambers be of sufficient quantity to "fluidize" the bed of oysters. Theoretically, fluidization optimizes each oyster seed’s accessibility to food supplied by the flowing water (Ver and Wang 1995). As seed grow, the weight of seed in the culture chambers increases, requiring greater water flow into the chambers to fluidize the seed bed.

Ultimately, the weight of the seed bed in the culture chamber will increase to a point where the maximum water flow can no longer fluidized the seed bed. To determine the maximum fluidized seed weight a culture chamber can hold, measured amounts of seed of a given sorted size were incrementally added to a clean empty culture chamber, and the pumping volume increased to fluidize the bed. When fluidization of the seedbed was achieved, water velocity and flow were measured. Seed additions continued until the paddlewheel pump could no longer fluidized the seedbed. The fluidization capacity for a given size of seed in a culture chamber is the maximum weight of the seedbed capable of fluidization.

Seed sorting

To promote maximum growth of oyster seed, periodic sorting for size and segregating seed into like-size lots for restocking culture chambers is necessary. For this project, sorting was performed with a modified onion sorter (Appendix picture 2e). Sorting screen sizes were: $^{1}/_{4}$" (6.3 mm), $^{3}/_{8}$" (9.5 mm), and $^{5}/_{8}$" (16 mm). After sorting, the weight of seed restocked in each chamber was recorded, and water flow adjusted to fluidized the seed bed.

The frequency of sorting is a function of the growth rate of the seed, and varies within and between growing seasons. Sorting seed is the most labor intensive and time-consuming aspect of nursery culture. Thus, to effectively manage a nursery culture operation, a simple test for determining the time for seed sorting is very beneficial. During the first year of this study, pre and post sort samples of seed were collected, and statistical analyses of the growth measurement were performed. The reason for the statistical analysis were to:

1. Test the effectiveness of the sorter to separate various size classes of seed.
2. Determine if a pre-sort size characteristic of the seed could be used to indicate that sorting is necessary.

Economic information

As oyster seed become larger, their value increases. Thus, nursery culture adds value to the original size oyster seed stocked in the nursery. For this study the following values, based on current market price, were assigned to the various size classes (Table 1).

The costs of construction, operation and increase in seed value from nursery culture were used to conduct an economic evaluation of the FLUPSY. For this study, oyster seed grew from 2 mm valued at $5.50/1,000 seed to 8-25 mm worth between $12.00-$25.00/1,000.

Table 1. Value of oyster seed by size class

Size class	Value per 1000
25 mm	$25.00
15-20 mm	$22.00
10-15 mm	$15.50
< 10 mm	$12.00
2-3 mm	$5.50

Data Analysis

Oceanographic data analysis

Oceanographic data is presented in tabular and graphic form (Figure 5, Appendix Tables 1 and 2). Surface temperature data was converted to thermal units (T.U.) using the following formula:

$$\text{T.U.} = \Sigma \text{ Daily temperature } ^{o}\text{C}$$

Accumulated temperature days, computed as thermal units, is a means to account for water temperature through time and its contribution to growth of seed. Since this study encompassed two production cycles, computation of thermal units for each cycle assists in interpreting growth differences between years.

Growth measurement analysis

The following descriptive statistics for growth measurements were calculated:

- Mean shell height
- Mean shell length
- Mean shell weight
- Mean ovoid approximation of surface area
- Variance of each measurement
- Standard deviation of each measurement
- 95% confidence estimate for each measurement
- Skew estimate of each measurement frequency distribution
- Kurtosis estimate for each measurement frequency distribution

Oyster seed initially received by the nursery will have been sorted for their ordered size, in this case 2-3 mm. These sorted seed will be expected to show a range of sizes that, when graphed, will display a normal frequency distribution (Figure 4a).

As oyster seed grow, their weight, shell length, shell width, or ovoid area frequency distributions may shift away from a normal distribution (Figure 4a). Two possible distributions shifts we examined were kurtosis, where the bell-shaped normal distribution curve is flattened (Figure 4b); and the skew, where the frequency distribution is misshapen with the peak shifting to the left or right (Figure 4c,d). Kurtosis indicates that the culture chamber has concurrently fast and slow seed, causing the peak of the normal curve to flatten, while skew shows that the slow growing (stunted) or faster growing seed dominates the population through time. In either instance, the seed in the culture chamber must be sorted to separate fast and slow growing seed.

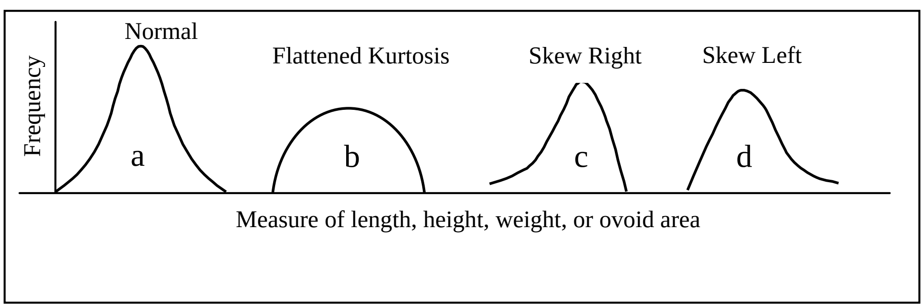

Figure 4. Frequency distributions examined to test the need to sort seed.

The statistical analyses of the growth measurements were intended to test the prospects of using a descriptive statistic as a means of determining the necessity of sorting. For example, if the height, length, or weight distribution of an oyster seed sample shows significant variance, skew, or kurtosis; sorting the seed may be necessary to optimize growth.

Growth data for the two years of the project included three seed production cycles since two seed shipments were received in 1998. Seed growth and inventory data is compiled into a comprehensive tables (Appendix Tables 3-6):

Results

General aspects about the FLUPSY operation

The project progressed well, despite some data gaps and equipment failures during the 1997 growth cycle. Inability of the data collector to visit the site during the 1997 growing season was a primary cause of infrequent secchi disk depth measurements. This problem was corrected for the 1998 project season.

Working the FLUPSY for two growing seasons provided important experience since variant oceanographic conditions and seed quality caused substantial differences in seed growth between years. Results of the study provide the practical details necessary for inclusion in a FLUPSY operation manual, and business plan development.

Several recommended modifications of the FLUPSY design improved the reliability and efficiency of operation. The most significant design changes are the following.

- The motor driving the paddlewheel was increased from 1.5 to 2 hp. This modification prevented downtime cause by engine overload.
- A $^{5}/_{8}$" screen appears to be too large for the next sorting size above $^{3}/_{8}$". Addition of a $^{1}/_{2}$" screen should enable more timely segregation of faster growing shellfish from the culture chambers.
- During the 1997 season, the power hoist failed and no alternate mechanism was immediately available to lift the culture chambers for removal of fouling or sorting. A mechanical hoist must be available for a backup.

Regular maintenance of the FLUPSY included fouling removal, adjustments to the paddlewheel pump, and sorting seed into various size classes. In testing various methods of operation, a better understanding of the effects of water flow, fouling of the bottom screens, and fluidization of the seed on the growth of oyster seed was achieved by a simple procedure. We discovered that the rheostat (Appendix picture 2b), that regulates the rpm of the paddlewheel, set at 40% to 50% optimumizes water flow. The optimal flow rate that fluidizes the seed bed usually occurs immediately after cleaning the bottom screens of the culture chambers. With normal operation, fouling will clog the screens to the culture chambers that restricts the flow through the screens, requiring an increase in the rheostat setting to achieve seedbed fluidization. Monitoring seedbed fluidization and the corresponding rheostat setting will help to determine if the bottom screens need cleaning. In practice, a rheostat setting between 40% - 50% is optimal, 60% is acceptable, but if 80% is required for seedbed fluidization the bottom screens need cleaning. Visually, if the water level of the central trough drops, resulting in the exit water from the culture chamber falling into the central trough, cleaning the bottom screens is also recommended.

Regulation of water flow to fluidize the seedbed is important. Therefore, recognition of a fluidized seedbed is imperative. Two primary characteristics are useful in recognizing seedbed fluidization. Typically, when the water flow is adequate to fluidize the seedbed, agitation, caused by the flowing water, will visibly stir oyster seed in some areas of the seedbed. Another useful method utilizes a five pound lead cannon ball tied to an eight foot line. The cannon ball is lowered into the culture chamber and set on the top of the seedbed. With increases in water flow the cannon ball eventually sinks into the seedbed, indicating fluidization.

A number of fouling removal procedures were tested during the study. Methods included back flushing, fire hose washing, scrubbing the screens while culture chambers were in operation, and complete removal of the culture chamber, brushing, and washing both sides of the bottom screen. Only the later procedure provides adequate results. A visual illustration of fouling removal is shown in Appendix pictures 3a-c.

Oceanographic information

Water temperatures remained above 10°C for most of the summers of 1997-98, enabling growth throughout the entire period of the study (Appendix Table 1). A temperature drop

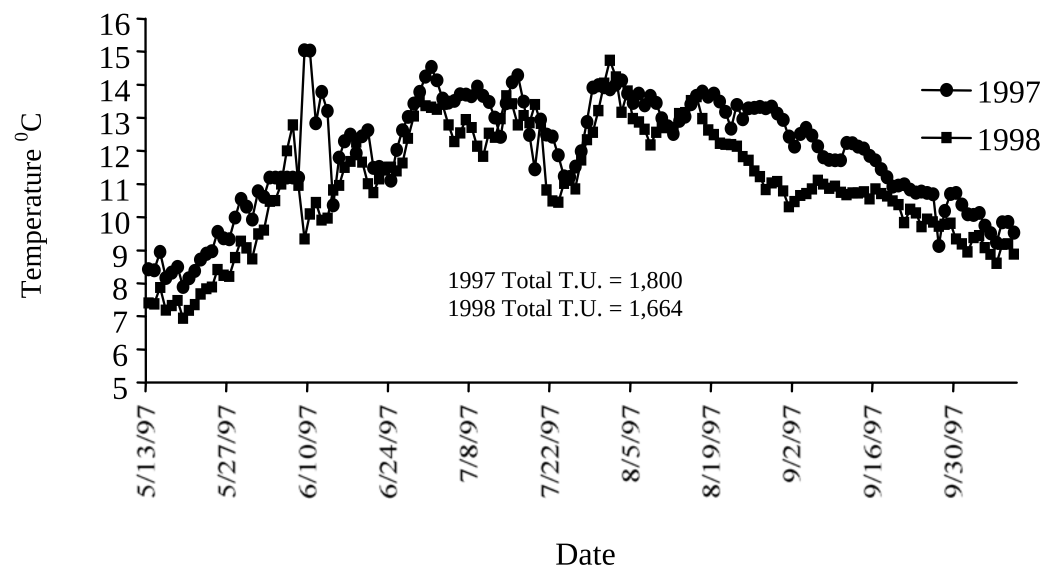

Figure 5. Water temperature data collected for the 1997 and 1998 growing seasons. Total temperature units (T.U.) are the daily additive temperatures in °C.

occurred during the last week of July in both years, but in 1997 quickly recovered in August. The temperature drop did not appear to be the result of glacier runoff because there was no effect on surface salinity or secchi disk measurements.

Water temperatures in 1997 were significantly warmer than in 1998, particularly for the month of June and from August to October (Figure 5, Appendix Table 1). Salinity levels were good for growth, and secchi disk depths were relatively deep, indicating that phytoplankton production was low to moderate (Appendix Table 2). Experience has shown that, even with apparently poor productivity, as indicated by deep secchi disk measurements, oyster seed continued to grow remarkably well.

Oyster Growth

Production year 1997

The oyster seed grew very well during the 1997 cycle, and the final seed quality exceeded expectations. The average seed size was 20.45 mm by October 10, while the largest size lot of seed reached 24.67 mm in shell height (Figure 6). Both years of the study, seed size exceeded the maximum growth of 19.5 mm shell height achieved from the 1993 nursery study.

The growth rate of the small to moderate seed size groups appeared to decline after the July 27 sorting. The decline in growth was possibly attributed to reduced water temperature during late July and then again in September, however the larger size seed for the same time period continued to grow at a faster rate (Figure 6). A possible solution to correct the declining growth rate of the moderate size seed is to add an additional sort, using a $^{1}/_{2}$" (12.7 mm) screen, in August.

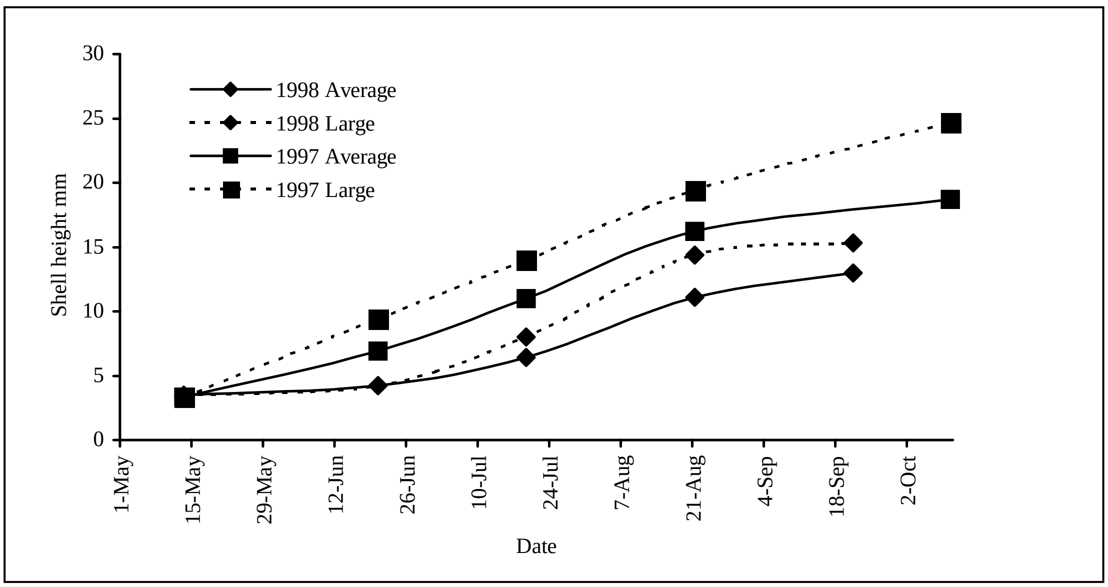

Figure 6. Growth comparison of oyster seed for 1997 and 1998 production years for the Halibut Cove Nursery.

Since oyster seed shell shape tends to be irregular, particularly seed less than $^{3}/_{8}$" sorting size, length or height alone is not an accurate means of representing shell size. Instead, shell area, computed as an ovoid approximation, that includes both the shell length and width in the calculation, is a more consistent measure of seed size.

An accurate measure of shell size is particularly important when choosing a dimensional measurement to compute a size-weight conversion function. An ovoid area/weight conversion function was developed (Figure 7), and the fit well (R^2=.95 for 1997 and R^2=.92 for 1998). An accurate size-weight conversion function is useful as a condition index to compare growth of different growout lots by comparing the slope of the weight-ovoid area relationship.

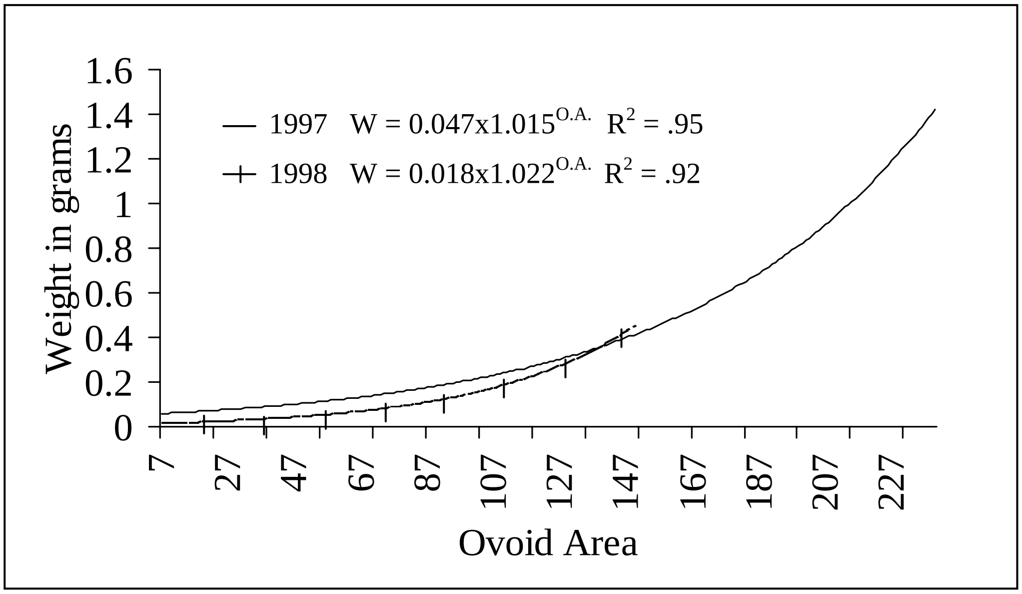

Figure 7. Ovoid area-weight relationship for 1997 and 1998 seed produced at the Halibut Cove nursery.

By the project completion date three sizes classes of oyster seed were available for distribution to the farmers (Table 2).

Production year 1998

The maximum size reached was 17.22 mm for the larger (above $^3/_8$") sorted size class while the smaller size class (below $^3/_8$") averaged 8.0. The slowest growth, as indicated by the slope of the growth curves, occurred during the months of June and September (Figure 6). See Table 3 for the final inventory of 1998 seed production.

Growth comparison for 1997-1998

Oyster seed during the 1998 cycle grew significantly slower than in 1997, ending with 17.22 mm and 24.67 mm maximum shell height respectively. Water temperature differences between years likely played a significant role in growth differences. Comparing the

Table 2. Inventory of the final sort of the oyster seed produced at the Halibut Cove nursery-October, 1997

Sorted lot sizes, weights and numbers for each culture bin									Proportion Below $^3/_8$"	Proportion $^3/_8$ to 5/8"	Proportion above $^5/_8$"
Less than $^3/_8$"			$^3/_8$" to $^5/_8$			Greater than $^5/_8$"					
Bin No	Weight Kgs	Number	Bin No	Weight Kgs	Number	Bin No	Weight Kgs	Number			
1	64.0	53,782							100.0%		
			2	58.8	33,034		186.20	66,500		33.2%	67.8%
			3	311.7	175,112		72.40	25,857		78.2%	22.8%
			4	310.6	181,637		60.90	21,523		89.4%	10.6%
			5	119.6	69,942		311.40	110,035		38.9%	61.1%
			6	136.0	61,818		194.20	57,118		52.0%	48.0%
			7	133.2	60,545		90.50	26,618		69.5%	30.5%
						8	183.80	38,292			100.0%
Totals	64.0	53,782		1069.9	582,088		915.60	307,651			
Total Weight		2,018.0									
Total Number		943,521									

Note: $^3/_8$" = 9.5mm, $^5/_8$"= 16mm

Table 3. Final inventory for oyster seed produced at the Halibut Cove Nursery-October, 1998.

Sorted lot sizes, weights and numbers for each culture bin								
Less than $^{1}/_{4}$"			¼ to $^{3}/_{8}$"			Greater than $^{3}/_{8}$"		
Bin No	Weight Kgs	Number	Bin No	Weight Kgs	Number	Bin No	Weight Kgs	Number
			1	78.14	308,044			
2	43.8	644,752						
						3	97.5	226,406
						4	33.0	304,339
						5	97.3	232,832
						6	93.5	217,113
						7	101.2	160,344
						8	90.7	143,640
Totals	43.8	644,752		78.14	308,044		513.2	1,284,674

Total Weight	635.0
Total Number	2,237,470

Note: $^{3}/_{8}$" = 9.5mm, $^{5}/_{8}$"= 16mm temperature data for the months of June and September (Figure 5) with the growth rate differences for the same period (Figure 6) shows a clear correlation of temperature and growth difference between the two years of production. However, the quality of the seed may have also contributed since the 1998 seed required more accumulated thermal units (T.U.), to reach a given sorting size than seed from 1997. One example is that 1998 seed required 1,143 T.U. to reach $^{3}/_{8}$" sorting size while 1997 needed only 714 T.U. The large disparity in T.U. requirements is likely caused by seed quality difference. Comparison of the ovoid-weight relationship shows that 1998 seed were not as well conditioned at the smaller size classes, but in time appear to catch up with 1997 seed condition about approximately 135 mm^2 ovoid area (Figure 7). The quality of initial seed received from Lummi Shellfish Hatchery is also suspected as a partial cause of slow growth since farmers have reported that 1998 Lummi seed growth performance has been poor (Rodger Painter and Don Nickolson, personal communication).

Effects of sorting

The sorted size of a seed is the size that either falls through or remains on the sorting screen. If seed is above an indicated sorting size, the seed maximum width along its narrowest axis, referred to in this report as the shell length, is wide enough to prevent the seed from falling through the sorting screen.

The modified onion sorter worked extremely well sorting for seed size. The sorting process is efficient, requiring approximately one man-day of labor to sort the entire nursery. The labor time also included cleaning fouling from the bottom screens. A visual display of the sorting process is shown in Appendix pictures 3d-f.

Statistical analysis of the growth measurements from the 1997 data indicates no kurtosis shift pattern of shell size or weight (Figure 8 and 9). The skew computation for individual seed weight, however, indicated a highly positive skew, (Sk= 0.30-1.5) prior to sorting, that is reduced to an insignificant level (Sk = 0.01-0.03) after the sort (Figure 10 and 11). The occurrence of weight skew shift is consistent for all sorted size classes of seed. If such a pattern is consistent, periodically collecting a seed sample, weighing approximately 50 shellfish, and computing skew may be a method to determine when seed need sorting.

During the 1998 growing season, calculation of seed weight skew was computed to determine time of sorting, however, no skew pattern occurred. I suspect that the slow growth of the seed in 1998, may have dampened the appearance of any size distribution shift. Thus, use of skew to determine sorting time needs further examination, and its application may be dependant on the growth rate of the seed.

Flow of water required for fluidization of the seedbed

The fluidization and water flow relationship shows that an upper weight limit exists for each size category of seed where fluidization is no longer possible (Table 4). The upper flow limit is reached when the resistance of the water flow through the seedbed is great enough to decrease the exit flow from the culture chamber. Decreased flow into the central trough

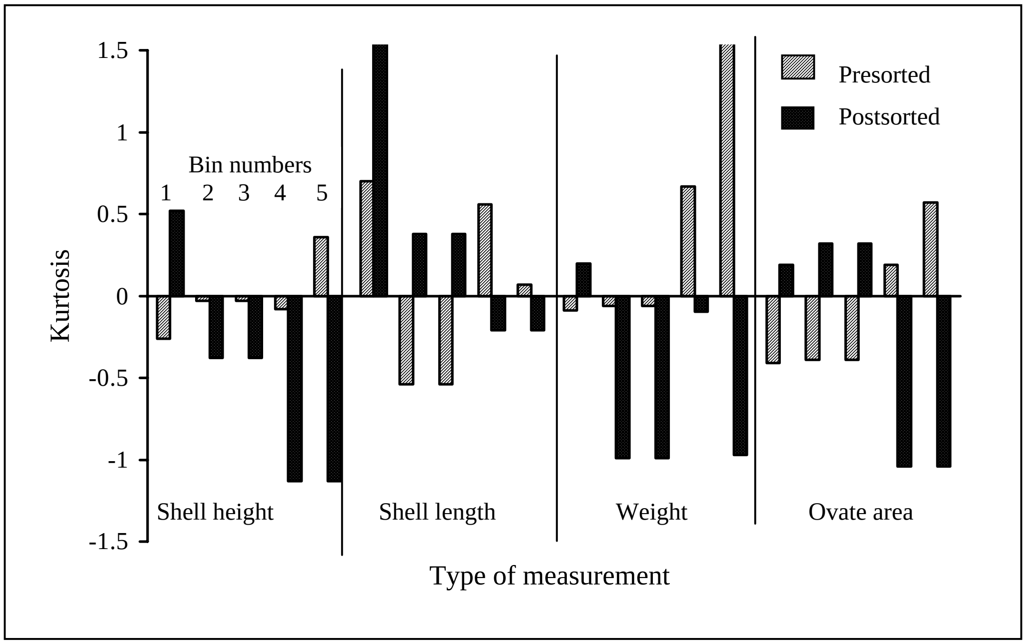

Figure 8. Pre and post sorting kurtosis of the shell height, shell length, weight, and ovate area for each nursery bin. Oyster seed size ranges from the smallest size lot bin 1 to the largest lot in bin 5.

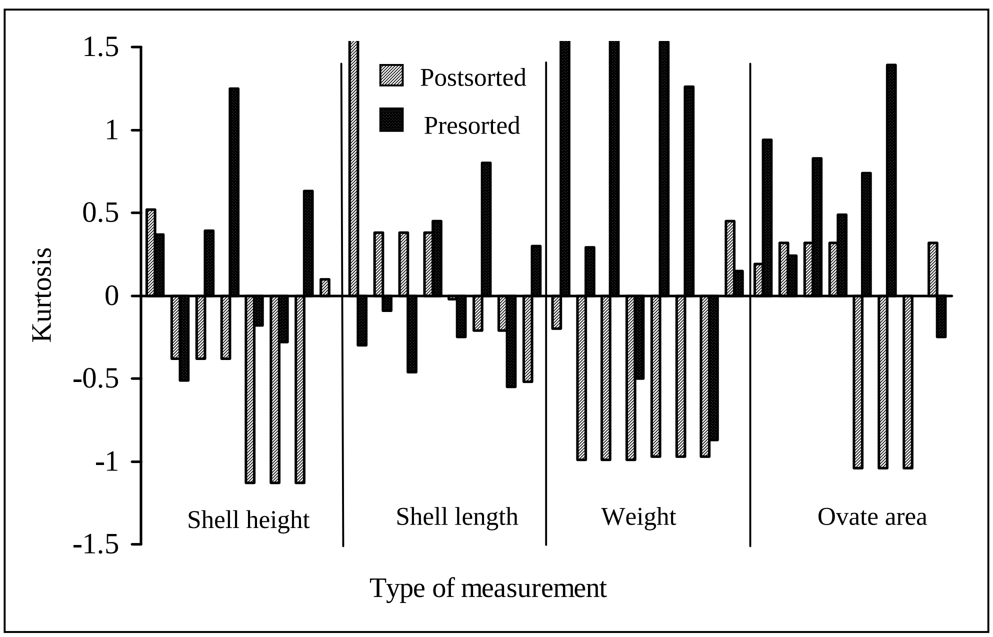

Figure 9. Pre and post sorting kurtosis of the shell height, shell length, weight, and ovate area for each nursery bin. Oyster seed size ranges from the smallest size lot in bin 1 to the largest lot in bin 8.

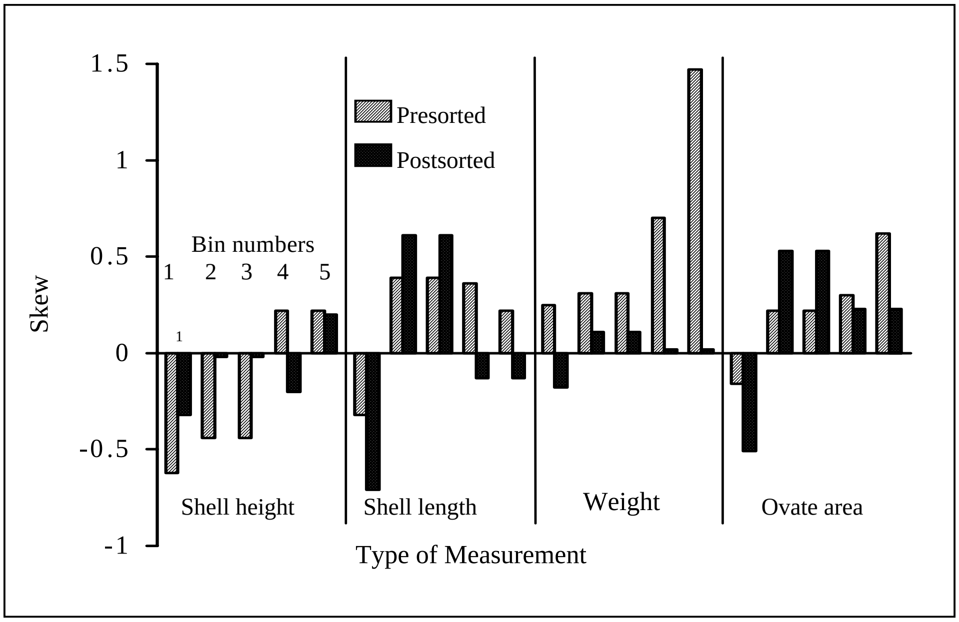

Figure 10. Pre and post sorting skew of the shell height, shell length, weight, and ovate area for each nursery bin. Oyster seed size ranges from the smallest size lot in culture chamber 1 to largest in chamber 5.

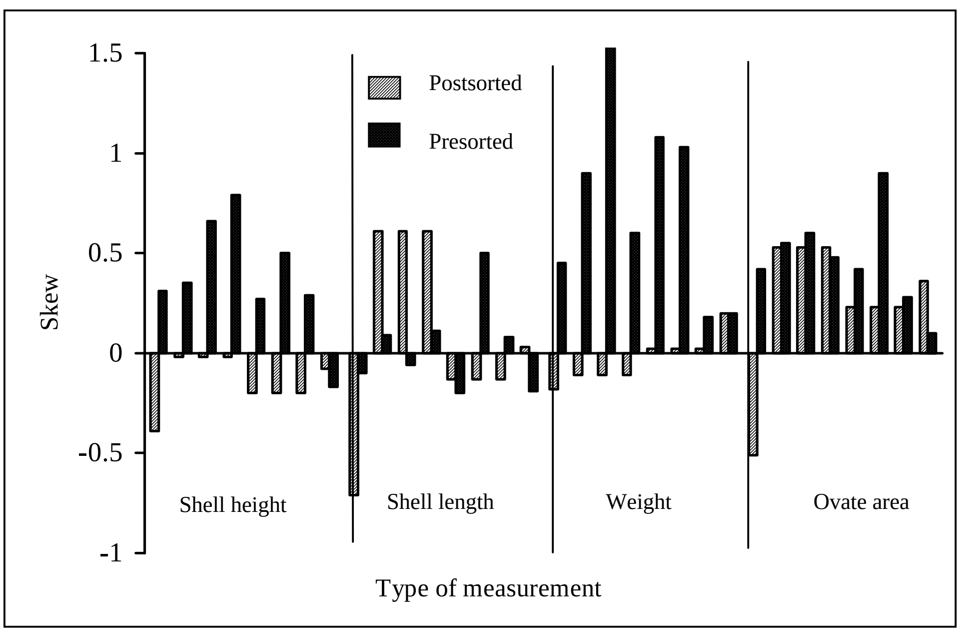

Figure 11. Pre and post sorting skew of the shell height, shell length, weight, and ovate area for each nursery bin. Oyster seed size ranges from the smallest size lot in bin 1 to the largest lot in bin 8.

Table 4. Flow requirements for fluidization and carrying capacities of nursery culture chambers.

Seed less than 5/8" and greater than 3/8"

							Fluidization	
Total weight Kg	Total volume liters	Depth cms	Rheostat setting percentage	Outfall width cms	Outfall depth cms	Velocity cms/sec	Flow liter/minute	Flow gal/minute
30.57	37.24	4.45	25.0	60.96	8.31	1.880	952.37	251.42
45.52	55.86	6.68	25.0	60.96	8.31	1.770	896.64	236.71
60.52	74.48	8.91	25.0	60.96	8.31	1.750	886.51	234.04
75.52	93.10	11.13	25.0	60.96	8.31	2.100	1,063.81	280.85
90.52	111.72	13.36	27.5	60.96	8.31	2.100	1,063.81	280.85
105.52	130.34	15.59	27.5	60.96	8.31	2.050	1,038.48	274.16
120.52*	148.96	17.82	30.0	60.96	8.31	2.100	1,063.81	280.85

* Maximum fluidization weight

Numbers per kilogram calculations

Grams per spat	Carrying capacity at fluidization kgs	Spat length in mm	Spat height in mm	Grams/bin at fluidization	Number of spat
1.01	120.52	14.05	17.70	120,522.73	119,329.44

Seed greater than 5/8"

							Fluidization	
Total weight Kg	Total volume liters	Depth cms	Rheostat setting percentage	Outfall width cms	Outfall depth cms	Velocity cms/sec	Flow liter/minute	Flow gal/minute
30.91	37.24	4.45	30	60.96	8.31	2.88	1,458.94	385.16
61.82	74.48	8.91	35	60.96	8.31	2.69	1,362.69	359.75
92.72*	111.72	13.36	40	60.96	8.31	2.23	1,129.67	298.23

* Maximum fluidization weight

Numbers per kilogram calculations

Grams per Spat	Carrying capacity at fluidization kgs	Spat length in mm	Spat height in mm	Grams/bin at fluidization	Number of Spat
1.78	92.73	16.93	22.64	92,730.00	52,095.51

Note: Fluidization velocity reaches a maximum value because the water level in the central trough drops below the level of the exit slot. Consequently, the water flow through the bin is maximized because the paddle wheel cannot pull additional water, and the water flow through the chamber is regulated only by the head differential between the sea water level and the water level in the chamber.

from the culture chambers drops the water level of the central trough below that of the culture chamber. As a result, the water from the culture chamber drops vertically into the central trough and is no longer pulled through by pumping of the paddlewheel. See Appendix Figure 2 for a more complete explanation.

<u>Culture chamber carrying capacity</u>

The definition of carrying capacity for this study is the amount of seed a culture chamber can hold and continue optimal seed growth. Determining carrying capacity is a complex process that considers the flow rate of water through the chamber, size of the seed, and the ocean conditions such as temperature and primary productivity. Of the factors that
effect carrying capacity, the FLUPSY operator can control the following.

- Seed size in the chambers by regular sorting.
- The pump flow by cleaning the bottom screens of the chambers, and keeping the seedbed fluidized controls flow rate of the water.
- The amount of seed to stock in each culture chamber

The ocean environment cannot be controlled, and because this study encompassed two years of nursery growout, we had the opportunity to experience two very difference ocean environmental conditions. The differing ocean conditions had profound effects on seed growth, sorting requirement, and the carrying capacities of the culture chambers.

<u>Results of sorting, carrying capacity, and environmental productivity on seed growth and FLUPSY operation.</u>

Seed 2 mm in length are generally slow growers until they are large enough to sort above ¼" in size. From ¼" to above $^{3}/_{8}$", growth is fastest, then slows as seed length nears $^{5}/_{8}$" sorting size. Seed larger than $^{5}/_{8}$" grow slower in the nursery than seed planted on the farms. Results of a comparative growth study, from the 1997 production, shows that seed above $^{5}/_{8}$" planted on farms out performed seed that remained in the nursery. For the growth period October 1997 to June of 1998, farmed seed grew 59.7% faster than those remaining in the nursery, finishing at a shell height 36.1 and 22.6 mm respectively.

The frequency of seed sorting depends on the seed growth rate. Good growing conditions, as experienced during 1997, required more frequent sorting than the poor growing conditions evident in 1998. The decision to sort also requires that enough seed of a given sort size be available to completely cover the culture chamber bottom screen. Sorting too often may result in inadequate numbers of seed in a sort size class to completely cover the bottom of the culture chamber. Incomplete bottom coverage causes channeling of water flow through barren sections of the screen, where water resistance is reduced, thus depriving the seed of food. Infrequent sorting will slow seed growth because the optimum stocking densities of the chambers will be exceeding as the seed biomass increases. Since environmental conditions that effect seed growth were different for the two growing seasons of the study, the sorting practices and carrying capacity requirements for slow and fast growing years are different.

General rules for carrying capacity and sorting: Fast growing conditions

Good growing conditions were available in 1997. Of the oceanographic data collected, the best early indicator of good growing conditions was water temperature. In 1997, the average June water temperature was 13.3^{o}C while in 1998 was 12.3^{o}C. If good growing conditions are indicated, the following operational scheme is recommended.

1) Stocking 500,000 seed (2-3 mm in size) per chamber in mid May takes approximately 5 weeks to reach first sorting size of ¼".
2) At 5 weeks, sort with ¼" screen (seed are likely to be less than $^{3}/_{8}$"). Average water temperature was 10.9^{o}C and T.U. accumulation of 509. At this point 60% of the seed were over ¼" sorted size. Sorting could have been performed earlier, at approximately 450 T.U.
   a) Seed sorted less than ¼" stock at maximum density of 500,000 seed per chamber. In good growing conditions expect a doubling of size in 14 days.
   b) Seed sorted greater than ¼" stock at maximum density of 300,000 per chamber.
3) In two weeks, sort at $^{3}/_{8}$". Average water temperature was 13.7^{o}C and T.U. accumulation of 205 (Total T.U. 714). In this trial we waited four weeks before sorting, however over 90% sorted above $^{3}/_{8}$". As a result two or three weeks is a better time for sorting.
   a) Seed sorted less than $^{3}/_{8}$" stock at maximum density of 300,000 per chamber.
   b) Seed sorted greater than $^{3}/_{8}$" stock at maximum of 200,000-250,000 seed per chamber.
4) In four weeks, sort at $^{5}/_{8}$". Average water temperature was 13.5^{o}C and T.U. accumulation of 337 (Total T.U. 1,051). At this time (August 22) only 6.7% of the seed was larger than $^{5}/_{8}$".
   a) Seed sorted less than $^{5}/_{8}$" stock at maximum density of 200,000-250,000 seed per chamber.
   b) Sell oysters larger than $^{5}/_{8}$". Oysters over $^{5}/_{8}$" will grow faster in growout conditions on the farm than in the nursery. The project ended October 10 with 35.2% of the seed above $^{5}/_{8}$" and a total T.U. accumulation of 1,800.

In the fast growing scenario, the nursery may be able to support two crops during the year. One seed stocking in early May and a second in late August. The second crop would not be available for stocking on the farm until early summer of the next year.

General rules for carrying capacity: Slow growing scenario

In 1998, water temperatures were significantly colder than in 1997, particularly during June and mid August through October. These colder conditions and a suspicion that the seed purchased for the project were poor performers, lead to significant reduction of final seed growout size.

1) Stocking seed in mid May requires 6.5 weeks to grow seed from 2 mm to the ¼" sort size. Grown at similar stocking densities as 1997 seed required 32% longer growing time.
2) At 6.5 weeks, sort with ¼" screen. Average water temperature for growth period was 9.7^{o}C and a T.U. accumulation of 447.
   a) Seed over ¼" stock in chambers at maximum of 350,000 per chamber. Note: In this study the chambers were stocked between 345,136 and 408,480 seed. The carrying capacity of the chambers was likely exceeded because seed stocked in the lower density chambers grew at

twice the rate as the more density stocked chambers.

b) Seed less than ¼" stock at a maximum of 400,000 seed per chamber.

c) Note: With such poor growth performance, you may wish to reduce stocking densities, as long as space is available and the bottom screen is covered.

3) In 3 weeks, sort again at ¼". Average water temperature for growth period was 12.9^{o}C and a T.U. accumulation of 284 (Total T.U. 731)

a) Seed over ¼" stock in chambers at maximum of 300,000 per chamber.

b) Seed less than ¼" stock at maximum of 400,000 seed per chamber.

c) See suggestion 2c.

4) In 4 weeks, sort at $^{3}/_{8}$". Average water temperature for growth period was 12.6^{o}C and a T.U. accumulation of 403 (Total T.U. 1,143)

a) Seed sorted at less than $^{3}/_{8}$" stock at maximum density of 300,000 per chamber.

b) Seed sorted greater than $^{3}/_{8}$" stock at maximum density of 200,000 seed per chamber.

c) See suggestion 2c.

5) In 1998 seed did not achieve a $^{5}/_{8}$" final growout size. Total T.U.1,663.

These scenarios of seed growout are approximations based on experience and interpretation of the oceanographic data. Slight operational changes may occur from year to year based on seed condition and ocean productivity. An experienced operator equipped with water temperature data should be able to develop an operational protocol appropriate for the growing conditions.

Economic evaluation

With construction cost, operational costs, and income produced by the value added to the seed; an economic model for operation of the FLUPSY was developed. The purpose of the model is to determine what production capacity and price should be offered for the seed to pay for operation and replacement of the FLUPSY. For replacement time, we estimated 20 years meaning that to maintain the FLUPSY, income to break even should include the total cost of the facility operation plus 5%. The cost and operation for the FLUPSY are found in Table 5. From the data, the nursery is a profitable operation with adequate income from sales to meet FLUPSY operational, maintenance, and replacement expenses (Table 5). Profit from operation assumes that all the seed are sold at the current market price. If the Kachemak Shellfish Mariculture Association wishes to provide a price reduction, caution should be taken to ensure that facility maintenance and replacement funds are adequate to meet the long-term economic viability of the nursery.

Summary

This study provided extensive data that was useful in modifying the Halibut Cove FLUPSY nursery to operate with no mechanical problems during the 1999 growing season. Operational procedures are developed that will enable optimization of seed production from the nursery. An on-going growout study of nursery produced seed is now underway, and preliminary results show the potential for a one-year reduction on growout time.

A number presentations about the FLUPSY project were given at meetings and scientific symposia, to include: The Alaska Shellfish Growers Association (two meetings), National Shellfisheries Association, Pacific Coast Oyster Growers Association, Kachemak Shellfish Mariculture Association, and the World Aquaculture Association. Five aquaculture workshops throughout Southeast Alaska included nursery culture information, and four fisheries classes at the UAF School of Fisheries and Ocean Sciences were taught nursery culture techniques. A proposal to publish a FLUPSY construction and operations manual has be accepted by the Alaska Sea Grant Program and funding, from ASTF, has been allocated for the publication. Information from this report will be included in the manual.

Construction of additional nurseries in Alaska has been slow. A current proposal to the Southeast Conference is now funded to begin construction of a FLUPSY near Craig, Alaska. Information from this study will be valuable in developing the design and operational protocols, and the primary investigator from this study will assist with construction and initial operation of the new nursery.

There remains considerable need for more nursery culture operations in Alaska, and the Marine Advisory Program aquaculture office will continue to pursue opportunities to expand seed production and the geographical range of nursery operations in Alaska.

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Table 5. Economic evaluation of the Halibut Cove FLUPSY operation (1997-98).

Construction expenses

Construction items	Cost
Construction materials	$66,599
Shipping materials	$4,928
Fabrication labor	$11,750
On-site assembly	$2,160
Electrical assembly	$2,348
Misc labor	$3,000
Total Construction cost	$90,784

Annual Replacement cost set aside considering a 20 year life = $4,539

Value of seed produced by the nursery

Seed size	Number	$ per 1,000	Total Income
1997			
25 mm	38,292	$25.00	$957
15-20 mm	307,651	$22.00	$6,768
10-15 mm	582,088	$15.50	$9,022
< 10 mm	53,782	$12.00	$645
Total income			$17,393
1998			
25 mm			
15-20 mm	428,984	$22.00	$9,437
10-15 mm	980,690	$15.50	$15,200
<10 mm	644,752	$ 12.00	$7,737
Total income			$32,375

Cost of operation

Per year total FLUPSY cost 1997

Set aside for FLUPSY	$4,539
Electricity	$984[1]
Cost of operation (labor)	$3,537
Seed cost	$7,150
Total cost	$16,437

Per year total FLUPSY cost 1998

Set aside for FLUPSY	$4,766
Electricity	$327[2]
Cost of operation (labor)	$ 5,010
Seed cost	$12,150
Total cost	$22,253

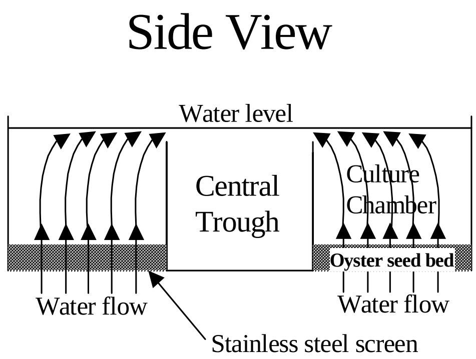
1: Includes hookup charge,
2: Electrical charges only

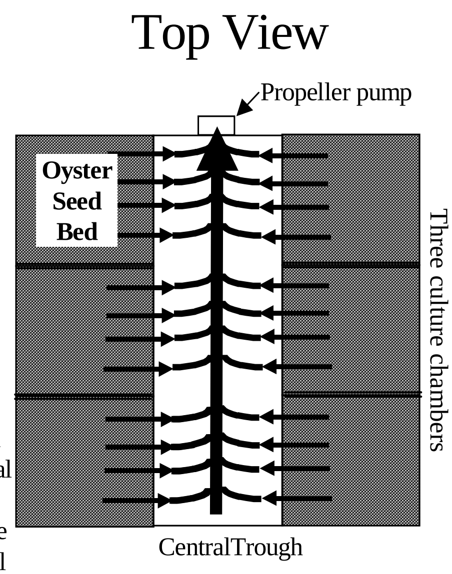
Net Profit or Loss

Year	Profit	Loss
1997	$956	
1998	$10,122	

APPENDIX

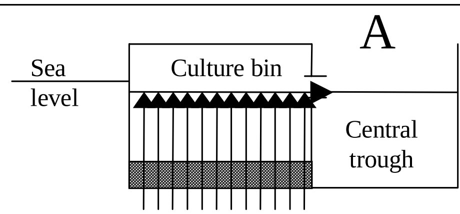
Figure and Tables





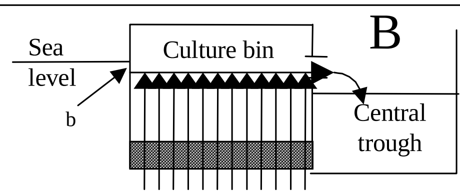
The water flows through a FLUPSY by the propeller pump removing water horizontally through the exit of the central trough. The water in the central trough. Exiting water is replaced with water flowing from the culture chambers. The culture chambers are filled with water that flows through the stainless steel bottom screen and through the oyster seed bed.

Appendix Figure 1. Diagrammatic representation of FLUPSY design and function.



Arrows show water flow through the perforated plate and oyster seed bed.

In operation A, the water level of the central trough is the same level as the culture bin. The water is a continuous mass being being pulled vertically through the perforated plate at the bottom of the culture bin, out the exit into the central trough, out the end of the central trough by the paddlewheel pump.



In operation B, the water level of the central trough is lower than the exit of the culture bin, falling from the exit into the central trough. As a result, the paddle wheel pump no long pulls the water through the culture bin. The water flow is generated by the head differential (b) that exists between the sea level outside the trough the the water level of the culture bin.

Appendix Figure 2. Diagrammatic description of the water flow limitation that effects fluidization of the seed bed.

Appendix Table 1. Average daily water temperatures for 1997-1998 at the Halibut Cove shellfish nursery.

Date	Temperature	Date	Temperature	Date	Temperature	Date	Temperature
2-Jun-97	11.20	21-Jul-97	12.49	9-Sep-97	11.71	29-Oct-97	7.29
3-Jun-97	11.20	22-Jul-97	12.43	10-Sep-97	11.71	30-Oct-97	7.38
4-Jun-97	11.20	23-Jul-97	11.87	11-Sep-97	12.24	31-Oct-97	7.49
5-Jun-97	11.20	24-Jul-97	11.24	12-Sep-97	12.23	1-Nov-97	7.43
6-Jun-97	11.20	25-Jul-97	11.22	13-Sep-97	12.13	2-Nov-97	7.42
7-Jun-97	11.20	26-Jul-97	11.53	14-Sep-97	12.07	3-Nov-97	7.34
8-Jun-97	11.20	27-Jul-97	11.99	15-Sep-97	11.85	4-Nov-97	7.23
9-Jun-97	15.05	28-Jul-97	12.88	16-Sep-97	11.71	5-Nov-97	6.94
10-Jun-97	15.04	29-Jul-97	13.91	17-Sep-97	11.44	6-Nov-97	6.68
11-Jun-97	12.83	30-Jul-97	13.99	18-Sep-97	11.21	7-Nov-97	6.71
12-Jun-97	13.78	31-Jul-97	13.92	19-Sep-97	10.93	8-Nov-97	6.68
13-Jun-97	13.21	1-Aug-97	13.86	20-Sep-97	10.96	9-Nov-97	6.74
14-Jun-97	10.35	2-Aug-97	14.01	21-Sep-97	10.99	10-Nov-97	6.81
15-Jun-97	11.80	3-Aug-97	14.13	22-Sep-97	10.83	11-Nov-97	6.68
16-Jun-97	12.30	4-Aug-97	13.74	23-Sep-97	10.74	12-Nov-97	6.79
17-Jun-97	12.49	5-Aug-97	13.45	24-Sep-97	10.77	13-Nov-97	6.71
18-Jun-97	11.93	6-Aug-97	13.74	25-Sep-97	10.73	14-Nov-97	6.48
19-Jun-97	12.44	7-Aug-97	13.39	26-Sep-97	10.69	15-Nov-97	6.79
20-Jun-97	12.63	8-Aug-97	13.67	27-Sep-97	9.13	16-Nov-97	7.02
21-Jun-97	11.49	9-Aug-97	13.45	28-Sep-97	10.19	17-Nov-97	7.14
22-Jun-97	11.52	10-Aug-97	12.99	29-Sep-97	10.70	18-Nov-97	6.83
23-Jun-97	11.46	11-Aug-97	12.74	30-Sep-97	10.73	19-Nov-97	6.74
24-Jun-97	11.10	12-Aug-97	12.51	01-Oct-97	10.38	20-Nov-97	6.77
25-Jun-97	12.03	13-Aug-97	12.91	02-Oct-97	10.09	21-Nov-97	6.88
26-Jun-97	12.63	14-Aug-97	13.04	03-Oct-97	10.06	22-Nov-97	6.71
27-Jun-97	13.03	15-Aug-97	13.41	04-Oct-97	10.13	23-Nov-97	6.81
28-Jun-97	13.43	16-Aug-97	13.66	05-Oct-97	9.74	24-Nov-97	6.79
29-Jun-97	13.78	17-Aug-97	13.79	06-Oct-97	9.51	25-Nov-97	6.25
30-Jun-97	14.25	18-Aug-97	13.64	07-Oct-97	9.23	26-Nov-97	6.44
1-Jul-97	14.54	19-Aug-97	13.74	08-Oct-97	9.85	27-Nov-97	6.54
2-Jul-97	14.13	20-Aug-97	13.49	09-Oct-97	9.86	28-Nov-97	6.86
3-Jul-97	13.58	21-Aug-97	13.18	10-Oct-97	9.53	29-Nov-97	6.99
4-Jul-97	13.46	22-Aug-97	12.68	11-Oct-97	9.40	30-Nov-97	6.86
5-Jul-97	13.51	23-Aug-97	13.40	12-Oct-97	9.31	1-Dec-97	6.93
6-Jul-97	13.72	24-Aug-97	12.96	13-Oct-97	8.99	2-Dec-97	6.86
7-Jul-97	13.71	25-Aug-97	13.29	14-Oct-97	8.72	3-Dec-97	6.67
8-Jul-97	13.65	26-Aug-97	13.30	15-Oct-97	8.46	4-Dec-97	6.47
9-Jul-97	13.95	27-Aug-97	13.33	16-Oct-97	8.38	5-Dec-97	6.59
10-Jul-97	13.66	28-Aug-97	13.29	17-Oct-97	8.31	6-Dec-97	6.65
11-Jul-97	13.48	29-Aug-97	13.34	18-Oct-97	8.09	7-Dec-97	6.27
12-Jul-97	13.01	30-Aug-97	13.13	19-Oct-97	8.06	8-Dec-97	6.41
13-Jul-97	12.42	31-Aug-97	12.94	20-Oct-97	8.20	9-Dec-97	6.18
14-Jul-97	13.44	1-Sep-97	12.43	21-Oct-97	8.24	10-Dec-97	6.06
15-Jul-97	14.08	2-Sep-97	12.13	22-Oct-97	8.18	11-Dec-97	5.95
16-Jul-97	14.29	3-Sep-97	12.51	23-Oct-97	7.96	12-Dec-97	6.23
17-Jul-97	13.49	4-Sep-97	12.70	24-Oct-97	7.77	13-Dec-97	6.14
18-Jul-97	12.48	5-Sep-97	12.46	25-Oct-97	7.30	14-Dec-97	5.88
19-Jul-97	11.44	6-Sep-97	12.14	26-Oct-97	7.20	15-Dec-97	5.57
20-Jul-97	12.95	7-Sep-97	11.81	27-Oct-97	7.20	16-Dec-97	5.38
21-Jul-97	12.49	8-Sep-97	11.72	28-Oct-97	7.34	17-Dec-97	5.31

Appendix Table 1 (cont.)

18-Dec-97	5.13	8-Feb-98	3.26	1-Apr-98	4.59	23-May-98	7.83
19-Dec-97	5.20	9-Feb-98	3.04	2-Apr-98	4.56	24-May-98	7.89
20-Dec-97	5.12	10-Feb-98	3.32	3-Apr-98	4.85	25-May-98	8.41
21-Dec-97	4.86	11-Feb-98	3.40	4-Apr-98	5.01	26-May-98	8.24
22-Dec-97	4.61	12-Feb-98	3.42	5-Apr-98	4.91	27-May-98	8.21
23-Dec-97	4.63	13-Feb-98	3.29	6-Apr-98	5.01	28-May-98	8.78
24-Dec-97	4.38	14-Feb-98	3.14	7-Apr-98	5.08	29-May-98	9.28
25-Dec-97	4.37	15-Feb-98	3.09	8-Apr-98	4.98	30-May-98	9.07
26-Dec-97	4.08	16-Feb-98	3.24	9-Apr-98	5.09	31-May-98	8.74
27-Dec-97	4.23	17-Feb-98	3.33	10-Apr-98	5.03	1-Jun-98	9.49
28-Dec-97	4.10	18-Feb-98	3.54	11-Apr-98	5.15	2-Jun-98	9.61
29-Dec-97	4.25	19-Feb-98	3.67	12-Apr-98	5.25	3-Jun-98	10.48
30-Dec-97	3.91	20-Feb-98	3.74	13-Apr-98	5.22	4-Jun-98	14.94
31-Dec-97	3.72	21-Feb-98	3.78	14-Apr-98	5.40	5-Jun-98	14.55
01-Jan-98	3.68	22-Feb-98	3.79	15-Apr-98	5.66	6-Jun-98	13.18
02-Jan-98	3.62	23-Feb-98	3.79	16-Apr-98	5.75	7-Jun-98	12.78
03-Jan-98	3.28	24-Feb-98	3.72	17-Apr-98	5.86	8-Jun-98	10.96
04-Jan-98	3.07	25-Feb-98	3.94	18-Apr-98	5.78	9-Jun-98	9.34
05-Jan-98	2.81	26-Feb-98	3.98	19-Apr-98	5.67	10-Jun-98	10.10
06-Jan-98	2.70	27-Feb-98	4.11	20-Apr-98	6.09	11-Jun-98	10.44
07-Jan-98	2.84	28-Feb-98	4.08	21-Apr-98	6.54	12-Jun-98	9.91
08-Jan-98	2.92	1-Mar-98	3.98	22-Apr-98	6.76	13-Jun-98	9.97
09-Jan-98	3.16	2-Mar-98	3.99	23-Apr-98	7.11	14-Jun-98	10.82
10-Jan-98	3.50	3-Mar-98	3.98	24-Apr-98	7.15	15-Jun-98	10.96
11-Jan-98	3.84	4-Mar-98	3.94	25-Apr-98	6.99	16-Jun-98	11.51
12-Jan-98	3.69	5-Mar-98	4.12	26-Apr-98	6.54	17-Jun-98	11.68
13-Jan-98	3.39	6-Mar-98	4.30	27-Apr-98	6.45	18-Jun-98	12.27
14-Jan-98	3.19	7-Mar-98	4.25	28-Apr-98	6.01	19-Jun-98	11.66
15-Jan-98	3.13	8-Mar-98	4.42	29-Apr-98	5.99	20-Jun-98	11.01
16-Jan-98	3.21	9-Mar-98	4.53	30-Apr-98	5.93	21-Jun-98	10.74
17-Jan-98	3.28	10-Mar-98	4.61	1-May-98	6.12	22-Jun-98	11.15
18-Jan-98	3.13	11-Mar-98	4.58	2-May-98	6.59	23-Jun-98	11.44
19-Jan-98	2.94	12-Mar-98	4.78	3-May-98	6.93	24-Jun-98	11.51
20-Jan-98	2.93	13-Mar-98	4.91	4-May-98	7.17	25-Jun-98	11.39
21-Jan-98	2.94	14-Mar-98	5.01	5-May-98	6.62	26-Jun-98	11.63
22-Jan-98	3.05	15-Mar-98	5.11	6-May-98	6.50	27-Jun-98	12.38
23-Jan-98	2.92	16-Mar-98	4.98	7-May-98	6.89	28-Jun-98	13.05
24-Jan-98	2.88	17-Mar-98	4.90	8-May-98	7.36	29-Jun-98	13.49
25-Jan-98	2.86	18-Mar-98	4.86	9-May-98	7.02	30-Jun-98	13.36
26-Jan-98	3.12	19-Mar-98	5.04	10-May-98	6.95	1-Jul-98	13.32
27-Jan-98	3.33	20-Mar-98	5.08	11-May-98	6.85	2-Jul-98	13.26
28-Jan-98	3.48	21-Mar-98	5.24	12-May-98	7.27	3-Jul-98	13.41
29-Jan-98	3.52	22-Mar-98	5.51	13-May-98	7.41	4-Jul-98	12.78
30-Jan-98	3.43	23-Mar-98	5.56	14-May-98	7.38	5-Jul-98	12.29
31-Jan-98	3.32	24-Mar-98	5.43	15-May-98	7.87	6-Jul-98	12.54
01-Feb-98	3.19	25-Mar-98	5.36	16-May-98	7.19	7-Jul-98	12.95
02-Feb-98	3.26	26-Mar-98	4.82	17-May-98	7.32	8-Jul-98	12.71
03-Feb-98	3.32	27-Mar-98	4.89	18-May-98	7.48	9-Jul-98	12.14
04-Feb-98	3.34	28-Mar-98	4.91	19-May-98	6.94	10-Jul-98	11.84
05-Feb-98	3.42	29-Mar-98	5.04	20-May-98	7.18	11-Jul-98	12.53
06-Feb-98	3.35	30-Mar-98	4.86	21-May-98	7.36	12-Jul-98	12.41
07-Feb-98	3.37	31-Mar-98	4.76	22-May-98	7.68	13-Jul-98	12.98

Appendix Table 1 (Cont)

14-Jul-98	13.66	4-Sep-98	10.71
15-Jul-98	13.43	5-Sep-98	10.85
16-Jul-98	12.78	6-Sep-98	11.11
17-Jul-98	13.07	7-Sep-98	11.00
18-Jul-98	12.86	8-Sep-98	10.87
19-Jul-98	13.41	9-Sep-98	10.94
20-Jul-98	12.83	10-Sep-98	10.75
21-Jul-98	10.82	11-Sep-98	10.68
22-Jul-98	10.49	12-Sep-98	10.73
23-Jul-98	10.45	13-Sep-98	10.73
24-Jul-98	11.02	14-Sep-98	10.76
25-Jul-98	11.11	15-Sep-98	10.55
26-Jul-98	10.85	16-Sep-98	10.85
27-Jul-98	11.72	17-Sep-98	10.71
28-Jul-98	12.34	18-Sep-98	10.64
29-Jul-98	12.56	19-Sep-98	10.49
30-Jul-98	13.22	20-Sep-98	10.38
31-Jul-98	14.05	21-Sep-98	9.84
1-Aug-98	14.74	22-Sep-98	10.24
2-Aug-98	14.24	23-Sep-98	10.13
3-Aug-98	13.17	24-Sep-98	9.71
4-Aug-98	13.81	25-Sep-98	9.94
5-Aug-98	12.98	26-Sep-98	9.86
6-Aug-98	12.88	27-Sep-98	9.72
7-Aug-98	12.66	28-Sep-98	9.78
8-Aug-98	12.18	29-Sep-98	9.81
9-Aug-98	12.56	30-Sep-98	9.34
10-Aug-98	12.70	1-Oct-98	9.19
11-Aug-98	12.72	2-Oct-98	8.94
12-Aug-98	12.71		
13-Aug-98	13.13		
14-Aug-98	13.16		
15-Aug-98	13.52		
16-Aug-98	13.64		
17-Aug-98	12.98		
18-Aug-98	12.64		
19-Aug-98	12.49		
20-Aug-98	12.23		
21-Aug-98	12.20		
22-Aug-98	12.19		
23-Aug-98	12.14		
24-Aug-98	11.83		
25-Aug-98	11.71		
26-Aug-98	11.39		
27-Aug-98	11.23		
28-Aug-98	10.83		
29-Aug-98	11.03		
30-Aug-98	11.07		
31-Aug-98	10.79		
1-Sep-98	10.31		
2-Sep-98	10.47		
3-Sep-98	10.66		

Appendix Table 2. Salinity and secchi disk measurements at the Halibut Cove shellfish nursery during the 1998 growing season.

Date	Sechhi Disk Depth in Meters	Salinity (ppt) by depth Surface	2 meters	4 meters	6 meters
1-June-97	5.2	27.3			
15-June-97		27.3			
21-June-97		27.7			
25-June-97		28.5			
6-July-97		29.9			
9-July-97		26.4			
21-July-97		26.8			
27-July-97	4.3	27.8			
2-Aug-97	4.9	25.2			
5-Aug-97	4.0	26.8			
11-Aug-97	3.0	25.1			
14-Aug-97	4.3	25.8			
18-Aug-97	5.5	26.4			
18-Jun-98	5.5	25.7	28.5	29.0	30.4
22-Jun-98	6.4	28.7	29.3	29.6	30.4
27-Jun-98	4.9	27.5	29.3	29.6	31.0
2-Jul-98	2.4	24.6	27.0	28.4	30.1
6-Jul-98	3.4	25.7	27.3	29.7	32.2
9-Jul-98	3.0	25.9	27.0	28.7	30.5
12-Jul-98	3.7	26.8	27.7	29.5	29.8
17-Jul-98	4.0	27.4	27.3	27.4	27.6
20-Jul-98	1.8	29.2	29.4	30.1	31.1
26-Jul-98	2.7	27.9	28.3	28.6	29.0
3-Aug-98	4.0	23.0	23.5	24.7	27.0
13-Aug-98	5.2	28.8	29.9	30.4	30.6
17-Aug-98	4.6	29.3	29.3	29.4	29.9
20-Aug-98	4.6	29.3	29.7	30.6	30.7
23-Aug-98	4.0	29.1	29.2	29.3	29.7
26-Aug-98	4.9	29.2	29.6	30.6	31.6
4-Sep-98	3.0	29.9	30.5	30.9	31.3
21-Sep-98	3.4	29.0	30.8	31.2	31.5
24-Sep-98	3.4	28.6	29.2	29.7	30.1
28-Sep-98	4.3	28.7	29.7	30.2	31.3
1-Oct-98	4.6	28.6	29.8	30.1	31.0
5-Oct-98	5.8	32.1	31.9	31.9	31.9
8-Oct-98	5.2	32.5	32.3	32.3	32.4
12-Oct-98	4.6	32.4	32.4	32.4	32.5
15-Oct-98	4.9	30.4	32.2	32.6	32.6
19-Oct-98	5.8	31.7	32.4	32.5	30.5
22-Oct-98	5.2	32.1	32.6	32.6	32.7

Appendix Table 3 Summary of descriptive statistics for growth measurements of oyster seed for the Halibut Cove shellfish nursery project, 1997.

H = Shell height
L = Shell length
W = Weight
O = Ovoid area

2-Jun **Bin 1&2**

	H	L	W	O
Mean	3.34	2.65	0.04	7.39
Variance	0.68	0.38	0.00	11.04
SD	0.83	0.62	0.02	3.32
95% Conf	0.17	0.12	0.00	0.67
Skew	0.32	0.47	0.32	0.71
Kurtosis	-0.60	0.84	0.15	-0.11

28-Jun **Bin 1**

	H	L	W	O
Mean	6.91	5.63		32.03
Variance	2.15	0.79		121.85
SD	1.46	0.89		11.03
95% Conf	0.41	0.25		3.09
Skew	0.27	0.18		0.78
Kurtosis	0.03	1.32		1.21

28-Jun **Bin 3**

	H	L	W	O
Mean	9.04	7.80	0.11	57.36
Variance	2.17	2.73	0.00	425.89
SD	1.47	1.65	0.06	20.64
95% Conf	0.41	0.46	0.02	5.78
Skew	0.44	0.59	1.60	0.97
Kurtosis	0.41	0.14	3.02	0.94

28-Jun **Bin 4**

	H	L	W	O
Mean	9.09	7.69	0.12	57.05
Variance	1.81	2.42	0.00	289.70
SD	1.34	1.56	0.04	17.02
95% Conf	0.40	0.46	0.01	5.03
Skew	0.42	0.48	1.05	0.43
Kurtosis	-0.23	0.41	2.29	-0.09

13-Jul **Bin 1**

	H	L	W	O
Mean	10.96	8.02	0.12	72.44
Variance	4.69	1.73	0.00	498.87
SD	2.17	1.32	0.05	22.34
95% Conf	0.60	0.37	0.01	6.19
Skew	0.22	-0.32	0.45	0.33
Kurtosis	0.34	-0.40	0.16	0.18

13-Jul **Bin 3**

	H	L	W	O
Mean	12.65	9.88	0.20	101.20
Variance	3.47	2.15	0.02	712.50
SD	1.86	1.47	0.12	26.69
95% Conf	0.53	0.42	0.03	7.55
Skew	0.28	0.31	4.14	1.05
Kurtosis	0.76	0.65	23.14	3.63

13-Jul **Bin 4**

	H	L	W	O
Mean	11.09	9.06	0.18	81.50
Variance	3.04	2.71	0.00	583.25
SD	1.74	1.65	0.06	24.15
95% Conf	0.50	0.47	0.02	6.90
Skew	-0.08	0.23	1.16	0.39
Kurtosis	1.43	0.68	1.67	0.80

Appendix Table 3 (Cont.). Summary of descriptive statistics for growth measurements of oyster for the Halibut Cove shellfish nursery project.

27-Jul Bin 1

	H	L	W	O
Mean	14.78	11.42	0.36	136.87
Variance	3.81	3.23	0.01	1313.61
SD	1.95	1.80	0.08	36.24
95% Conf	0.54	0.50	0.02	10.05
Skew	0.61	0.70	0.92	1.11
Kurtosis	-0.29	0.56	1.35	1.23

27-Jul Bin 3

	H	L	W	O
Mean	13.93	10.56	0.28	119.85
Variance	4.26	3.06	0.01	1075.86
SD	2.06	1.75	0.08	32.80
95% Conf	0.62	0.52	0.02	9.80
Skew	-0.24	0.33	0.57	0.58
Kurtosis	0.86	-0.51	0.08	0.44

27-Jul Bin 4

	H	L	W	O
Mean	13.58	10.14	0.28	112.40
Variance	4.98	2.12	0.01	945.10
SD	2.23	1.46	0.08	30.74
95% Conf	0.62	0.40	0.02	8.52
Skew	0.50	0.70	0.24	0.68
Kurtosis	-0.37	0.25	-0.16	0.26

27-Jul Bin 5

	H	L	W	O
Mean	15.15	11.76	0.38	144.54
Variance	5.74	3.20	0.02	1654.44
SD	2.40	1.79	0.14	40.67
95% Conf	0.66	0.50	0.04	11.27
Skew	0.63	0.66	0.75	0.98
Kurtosis	-0.80	0.26	-0.27	-0.08

27-Jul Bin 6

	H	L	W	O
Mean	15.35	11.68	0.41	145.37
Variance	4.75	2.51	0.02	1107.90
SD	2.18	1.59	0.13	33.29
95% Conf	0.60	0.44	0.04	9.14
Skew	0.79	-0.23	0.96	0.52
Kurtosis	1.005	0.28	2	1.02573

22-Aug Bin 2

	H	L	W	O
Mean	17.07	12.82	0.72	184.33
Variance	14.63	9.18	0.12	5224.89
SD	3.83	3.03	0.35	72.28
95% Conf	0.75	0.59	0.07	14.17
Skew	-0.62	-0.32	0.25	-0.1623
Kurtosis	-0.26	-0.7	-0.09	-0.408

22-Aug Bin 3

	H	L	W	O
Mean	15.94	12.36	0.47	160.82
Variance	6.55	5.21	0.02	2304.22
SD	2.56	2.28	0.13	48.00
95% Conf	0.72	0.64	0.04	13.44
Skew	-0.44	0.39	0.31	0.22
Kurtosis	-0.03	-0.54	-0.06	-0.39

22-Aug Bin 4

	H	L	W	O
Mean	15.94	12.36	0.47	160.82
Variance	6.55	5.21	0.02	2304.22
SD	2.56	2.28	0.13	48.00
95% Conf	0.72	0.64	0.04	13.44
Skew	-0.44	0.39	0.31	0.22
Kurtosis	-0.03	-0.54	-0.06	-0.39

22-Aug Bin 5

	H	L	W	O
Mean	15.76	12.6	0.56	160.258
Variance	6.31	3.959	0.04	1555.07
SD	2.51	1.99	0.2	39.4343
95% Conf	0.70	0.557	0.06	11.0414
Skew	0.22	0.356	0.7	0.30236
Kurtosis	-0.08	-0.56	0.67	0.18855

22-Aug Bin 6

	H	L	W	O
Mean	16.84	12.7	0.68	174.318
Variance	8.014	3.14	0.05	2454.56
SD	2.831	1.77	0.23	49.5435
95% Conf	0.793	0.5	0.06	13.8719
Skew	0.225	0.22	1.47	0.62313
Kurtosis	0.361	0.07	2.78	0.57172

Appendix Table 3 (Cont.). Summary of descriptive statistics for growth measurements of oyster seed for the Halibut Cove shellfish nursery project.

After sorting

22-Aug Bin 1

	H	L	W	O
Mean	11.46	8.66	0.22	80.40
Variance	2.70	1.21	0.00	283.56
SD	1.64	1.10	0.06	16.84
95% Conf	0.46	0.31	0.02	4.71
Skew	-0.39	-0.71	-0.18	-0.51
Kurtosis	0.52	3.61	-0.20	0.19

22-Aug Bin 2

	H	L	W	O
Mean	16.28	11.82	0.53	157.10
Variance	5.76	2.15	0.02	1392.18
SD	2.40	1.47	0.13	37.31
95% Conf	0.67	0.41	0.04	10.45
Skew	-0.02	0.61	-0.11	0.53
Kurtosis	-0.38	0.38	-0.99	0.32

22-Aug Bin 3

	H	L	W	O
Mean	16.28	11.82	0.53	157.10
Variance	5.76	2.15	0.02	1392.18
SD	2.40	1.47	0.13	37.31
95% Conf	0.67	0.41	0.04	10.45
Skew	-0.02	0.61	-0.11	0.53
Kurtosis	-0.38	0.38	-0.99	0.32

22-Aug Bin 4

	H	L	W	O
Mean	16.28	11.82	0.53	157.10
Variance	5.76	2.15	0.02	1392.18
SD	2.40	1.47	0.13	37.31
95% Conf	0.67	0.41	0.04	10.45
Skew	-0.02	0.61	-0.11	0.53
Kurtosis	-0.38	0.38	-0.99	0.32

22-Aug Bin 5

	H	L	W	O
Mean	17.88	13.18	0.73	190.563
Variance	3.169	2.232	0.04	965.102
SD	1.78	1.494	0.19	31.0661
95% Conf	0.493	0.414	0.05	8.61091
Skew	-0.2	-0.13	0.02	0.22837
Kurtosis	-1.13	-0.21	-0.97	-1.04

22-Aug Bin 6

	H	L	W	O
Mean	17.88	13.18	0.73	190.56
Variance	3.17	2.23	0.04	965.10
SD	1.78	1.49	0.19	31.07
95% Conf	0.49	0.41	0.05	8.61
Skew	-0.20	-0.13	0.02	0.23
Kurtosis	-1.13	-0.21	-0.97	-1.04

22-Aug Bin 7

	H	L	W	O
Mean	17.88	13.18	0.73	190.56
Variance	3.17	2.23	0.04	965.10
SD	1.78	1.49	0.19	31.07
95% Conf	0.49	0.41	0.05	8.61
Skew	-0.20	-0.13	0.02	0.23
Kurtosis	-1.13	-0.21	-0.97	-1.04

22-Aug Bin 8

	H	L	W	O
Mean	19.46	15.38	0.95	240.3435
Variance	4.74	2.975	0.06	2094.114
SD	2.18	1.725	0.25	45.76149
95% Conf	0.60	0.478	0.07	12.68419
Skew	-0.08	0.025	1.11	0.360079
Kurtosis	0.10	-0.52	0.45	0.321115

10-Oct Bin 1

	H	L	W	O
Mean	15.82	11.74	0.54	152.15
Variance	7.91	2.97	0.04	1868.81
SD	2.81	1.72	0.20	43.23
95% Conf	0.79	0.48	0.05	12.10
Skew	0.31	-0.10	0.45	0.42
Kurtosis	0.37	-0.30	1.64	0.94

10-Oct Bin 2

	H	L	W	O
Mean	18.74	14.14	0.93	215.10
Variance	7.34	3.80	0.07	2626.48
SD	2.71	1.95	0.26	51.25
95% Conf	0.76	0.55	0.07	14.35
Skew	0.35	0.09	0.90	0.55
Kurtosis	-0.51	-0.09	0.29	0.24

10-Oct Bin 3

	H	L	W	O
Mean	22.86	16.60	1.42	310.18
Variance	15.10	3.47	0.17	5910.42
SD	3.89	1.86	0.41	76.88
95% Conf	1.09	0.52	0.11	21.53
Skew	0.66	-0.06	1.97	0.60
Kurtosis	0.39	-0.46	7.14	0.83

10-Oct Bin 4

	H	L	W	O
Mean	19.18	13.9	0.93	217.0004
Variance	5.32	3.552	0.07	1993.236
SD	2.31	1.885	0.27	44.64567
95% Conf	0.65	0.528	0.08	12.50054
Skew	0.79	0.114	0.6	0.477027
Kurtosis	1.25	0.453	-0.5	0.486411

10-Oct Bin 5

	H	L	W	O
Mean	21.02	15.46	1.20	265.06
Variance	9.65	4.58	0.17	4174.17
SD	3.11	2.14	0.41	64.61
95% Conf	0.87	0.60	0.12	18.09
Skew	0.27	-0.20	1.08	0.42
Kurtosis	-0.18	-0.25	1.53	0.74

10-Oct Bin 6

	H	L	W	O
Mean	20.83	15.56	1.31	264.23
Variance	10.10	4.76	0.17	4832.36
SD	3.18	2.18	0.41	69.52
95% Conf	0.89	0.61	0.12	19.46
Skew	0.50	0.50	1.03	0.90
Kurtosis	-0.28	0.80	1.26	1.39

10-Oct Bin 7

	H	L	W	O
Mean	20.30	15.24	1.18	251.00
Variance	6.34	4.06	0.10	3160.37
SD	2.52	2.02	0.32	56.22
95% Conf	0.70	0.56	0.09	15.74
Skew	0.29	0.08	0.18	0.28
Kurtosis	0.63	-0.55	-0.87	0.00

10-Oct Bin 8

	H	L	W	O
Mean	24.67	18.12	1.98	366.595
Variance	18.18	9.629	0.33	10391.92
SD	4.26	3.103	0.57	101.9408
95% Conf	1.29	0.938	0.17	30.8298
Skew	-0.17	-0.19	0.2	0.095369
Kurtosis	0.00	0.303	0.15	-0.24602

Appendix Table 4. Inventory, growth, and thermal unit accumulations data for each sorting date for the Halibut Cove oyster nursery.

28-Jun-97

Bin no	Sorted size	No./ml	Total bin kgs	Total number	Depth cms
1	<3/8"	10.31	29.86	475,111	5.5
3	>3/8"	5.11	34.50	307,106	7.1
4	>3/8"	5.21	45.55	390,555	8.9

27-Jul-97

Bin no	Sorted size	No./ml	Total bin kgs	Total number	Depth cms
1	<3/8"	1.15	28.64	79,555	8.2
3	<3/8"	2.80	65.90	235,389	10.7
4	<3/8"	2.25	63.63	227,272	12.1
5	>3/8"	1.72	115.00	302,631	12.0
6	>3/8"	1.80	82.30	200,731	13.3

22-Aug-98

Bin no	Sorted size	No./ml	Total bin kgs	Total number	Depth cms
1	<3/8"	2.48	14.77	67,136	2.9
2	>3/8"	1.61	53.70	101,320	8.6
3	>3/8"	1.61	99.94	188,566	16.4
4	>3/8"	1.61	99.94	188,566	16.4
5	<5/8"	1.06	81.70	111,917	12.9
6	<5/8"	1.06	81.70	111,917	12.9
7	<5/8"	1.06	81.70	111,917	12.9
8	>5/8"	0.44	60.23	63,397	7.3

10-Oct-97

Refer to table 4 in report for final inventory

Appendix Table 5. Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

	Initial planting May 13, 1998				June 10, 1998								June 20, 1998			
	Bin 1				Bin 1				Bin 2				Bin 2			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	2.667	3.467	0.011	7.536	4.250	5.300	0.023	17.898	4.250	4.900	0.017	16.431	4.065	4.971	0.017	16.410
Variance	0.279	0.356	0.000	4.984									0.419	0.807	0.000	28.492
SD	0.528	0.597	0.005	2.233									0.647	0.898	0.008	5.338
95% Conf	0.148	0.167	0.001	0.625									0.181	0.252	0.002	1.495
Skew	-0.024	0.455	0.624	0.647									1.006	0.280	1.016	0.825
Kurtosis	1.993	0.556	0.573	1.275									0.346	0.173	-0.193	0.412

	June 30, 1998							
	Bin 1				Bin 2			
	L	H	W	O	L	H	W	O
Mean	4.233	5.167	0.022	17.931	4.400	5.159	0.028	18.541
Variance	0.681	1.190	0.000	46.989	0.990	1.108	0.000	49.933
SD	0.825	1.091	0.008	6.855	0.995	1.052	0.016	7.066
95% Conf	0.231	0.305	0.002	1.919	0.279	0.295	0.004	1.979
Skew	0.874	-0.076	0.510	0.793	0.866	0.362	1.013	0.628
Kurtosis	1.281	0.534	-0.028	0.860	-0.044	-1.394	0.988	-0.833

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

July 19, 1998

	Bin 1				Bin 2				Bin 3				Bin 4			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	4.871	6.429	0.027	25.816	5.091	6.442	0.025	26.683	6.130	8.182	0.045	41.545	6.363	7.984	0.076	41.350
Variance	0.747	1.722	0.000	76.149	0.726	1.124	0.000	64.041	2.280	2.282	0.001	228.632	1.105	1.837	0.001	180.640
SD	0.865	1.312	0.013	8.726	0.852	1.060	0.020	8.003	1.510	1.510	0.024	15.121	1.039	1.369	0.039	13.367
95% Conf	0.242	0.367	0.004	2.443	0.239	0.297	0.006	2.241	0.423	0.423	0.007	4.234	0.291	0.383	0.011	3.743
Skew	0.163	-0.613	2.155	0.433	0.077	0.251	0.032	0.416	-0.498	0.017	1.304	0.530	0.302	1.027	1.396	1.330
Kurtosis	0.465	1.411	8.630	1.394	-0.389	-0.456	5.953	-0.628	0.413	0.085	2.410	0.006	-0.520	1.364	2.683	2.308

August 9, 1998

	Below 1/4"				Above 1/4"				Above 1/4"				Below 3/8"			
	Bin 1				Bin 2				Bin 3				Bin 4			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	5.265	6.919	0.044	30.527	7.348	9.476	0.103	56.570	7.121	9.072	0.079	52.379	6.897	9.155	0.089	51.424
Variance	1.210	2.950	0.000	161.305	1.528	1.458	0.002	253.285	1.243	1.846	0.001	189.160	0.835	2.062	0.001	200.424
SD	1.100	1.718	0.021	12.701	1.236	1.208	0.041	15.915	1.115	1.359	0.035	13.754	0.914	1.436	0.036	14.157
95% Conf	0.308	0.481	0.006	3.556	0.346	0.338	0.011	4.456	0.312	0.380	0.010	3.851	0.256	0.402	0.010	3.964
Skew	-0.266	-0.279	-0.170	0.392	0.213	0.887	1.095	0.837	-0.095	-0.444	0.634	0.001	0.969	0.757	0.696	1.136
Kurtosis	-0.120	0.264	-0.307	0.110	-0.726	0.808	0.787	0.415	-0.701	-0.506	1.195	-0.261	0.652	1.102	0.054	0.974

August 9, 1998

	Below 3/8"				Above 3/8"				Above 3/8"				Above 3/8"			
	Bin 5				Bin 6				Bin 7				Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	7.946	10.675	0.145	69.416	8.453	10.533	0.141	71.605	9.921	12.307	0.220	97.639	10.700	13.100	0.276	112.997
Variance	1.296	3.386	0.003	306.040	0.972	1.945	0.001	256.165	0.998	1.681	0.002	280.113	2.263	4.131	0.029	943.882
SD	1.138	1.840	0.052	17.494	0.986	1.395	0.038	16.005	0.999	1.296	0.046	16.737	1.504	2.032	0.171	30.723
95% Conf	0.319	0.515	0.015	4.898	0.276	0.390	0.011	4.481	0.280	0.363	0.013	4.686	0.421	0.569	0.048	8.602
Skew	-1.159	-0.863	0.144	-1.136	-0.067	0.622	0.014	0.383	-0.082	0.132	0.119	0.881	0.785	0.417	2.439	1.040
Kurtosis	2.178	2.399	-0.792	2.014	-1.052	0.271	-0.960	-0.362	0.463	2.043	0.450	4.678	0.185	-1.031	7.406	0.734

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

August 21, 1998

	Bin 1				New Seed Planting Bin 2				Bin 3				Below 3/8" Bin 4			
					L	H	W	O					L	H	W	O
Mean					3.270	4.100	0.013	11.188					8.773	11.085	0.166	78.044
Variance					3.871	5.443		3790.997					0.912	1.670	0.002	252.237
SD					0.833	0.993		5.487					0.955	1.292	0.049	15.882
95% Conf					0.233	0.278		1.536					0.267	0.362	0.014	4.447
Skew					0.052	1.453		1.663					1.569	1.322	0.721	2.550
Kurtosis					-0.361	4.123		4.156					5.088	1.549	0.210	9.529

August 21, 1998

	Above 3/8" Bin 5				Below 3/8" Bin 6				Above 3/8" Bin 7				Above 3/8" Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	9.981	13.100	0.227	105.037	8.773	11.085	0.166	78.044	9.981	13.100	0.227	105.369	11.018	14.391	0.331	127.860
Variance	0.597	1.688	0.002	219.793	0.912	1.670	0.002	252.237	0.597	1.688	0.002	225.954	1.227	3.452	0.007	663.238
SD	0.773	1.299	0.045	14.825	0.955	1.292	0.049	15.882	0.773	1.299	0.045	15.032	1.108	1.858	0.082	25.753
95% Conf	0.216	0.364	0.013	4.151	0.267	0.362	0.014	4.447	0.216	0.364	0.013	4.209	0.310	0.520	0.023	7.211
Skew	0.491	0.545	0.085	0.558	1.569	1.322	0.721	2.550	0.491	0.545	0.085	0.495	0.702	0.961	0.492	1.109
Kurtosis	2.035	0.497	-0.718	-0.773	5.088	1.549	0.210	9.529	2.035	0.497	-0.718	-0.863	0.253	0.822	-1.199	1.687

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

September 6, 1998

	Sorted above 1/4 below 3/8" Bin 1				New Seed from Hatchery Bin 2				Below 3/8" Bin 3				Below 3/8" Bin 4			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	7.665	9.820	0.084	60.884	4.836	5.679	0.022	22.044	8.677	11.648	0.133	81.686	8.516	11.894	0.138	82.695
Variance	0.882	2.175	0.001	210.309	0.427	0.705	0.000	29.935	0.656	1.847	0.001	208.694	0.588	3.930	0.003	343.888
SD	0.939	1.475	0.024	14.502	0.654	0.840	0.009	5.471	0.810	1.359	0.036	14.446	0.767	1.982	0.050	18.544
95% Conf	0.263	0.413	0.007	4.060	0.183	0.235	0.002	1.532	0.227	0.381	0.010	4.045	0.215	0.555	0.014	5.192
Skew	-0.783	-0.526	0.098	-0.299	-0.918	-0.882	0.552	-0.600	0.010	0.320	0.816	0.461	0.230	0.923	0.091	0.937
Kurtosis	0.811	-0.103	-0.042	0.197	1.635	-0.066	-0.327	0.244	-0.296	-0.437	-0.120	-0.678	-0.185	1.584	1.609	1.774

September 6, 1998

	Above 3/8" Bin 5				Below 3/8" Bin 6				Above 3/8" Bin 7				Above 3/8" Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	10.570	14.340	0.228	122.894	8.565	11.848	0.131	82.283	10.968	13.076	0.189	122.569	9.942	13.203	0.186	105.638
Variance	1.070	4.510	0.004	609.550	0.510	1.563	0.001	171.339	40.382	2.578	0.016	12033.752	0.749	1.433	0.001	205.503
SD	1.035	2.124	0.063	24.689	0.714	1.250	0.035	13.090	6.355	1.606	0.125	109.698	0.866	1.197	0.038	14.335
95% Conf	0.290	0.595	0.018	6.913	0.200	0.350	0.010	3.665	1.779	0.450	0.035	30.715	0.242	0.335	0.011	4.014
Skew	0.774	0.695	0.022	1.199	-0.840	0.531	-0.092	-0.145	0.056	0.064	-0.038	0.508	-0.143	-0.342	-0.139	-1.068
Kurtosis	1.526	0.036	-1.044	0.839	-0.064	0.323	-0.465	-0.191	30.178	-0.802	11.478	29.377	1.861	0.232	1.486	2.035

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

September 21, 1998

	Below 3/8" Bin 3				Below 3/8" Bin 4			
	L	H	W	O	L	H	W	O
Mean	9.866	13.763	0.182	110.401	9.919	12.841	0.168	102.359
Variance	0.882	3.154	0.065	402.775	0.781	2.207	0.002	300.758
SD	0.939	1.776	0.254	20.069	0.884	1.486	0.048	17.342
95% Conf	0.263	0.497	0.071	5.619	0.247	0.416	0.013	4.856
Skew	-0.188	1.175	0.708	0.921	-0.439	0.801	0.559	0.407
Kurtosis	-0.758	1.432	14.411	0.588	0.256	1.283	0.632	0.064

September 21, 1998

	Less than 3/8" Bin 5				Below 3/8" Bin 6				Above 3/8" Bin 7				Above 3/8" Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	10.178	12.947	0.170	106.128	10.016	12.745	0.158	102.362	11.794	14.856	0.233	140.476	11.144	15.294	0.231	138.050
Variance	2.113	3.056	0.002	450.749	0.885	2.337	0.001	297.630	1.701	2.054	0.004	735.863	1.292	2.840	0.002	513.873
SD	1.454	1.748	0.048	21.231	0.941	1.529	0.037	17.252	1.304	1.433	0.061	27.127	1.136	1.685	0.046	22.669
95% Conf	0.407	0.489	0.014	5.945	0.263	0.428	0.010	4.830	0.365	0.401	0.017	7.595	0.318	0.472	0.013	6.347
Skew	0.653	-0.861	-0.195	-0.897	0.729	0.307	0.600	0.488	2.267	0.595	1.136	2.320	0.700	0.085	-0.168	0.530
Kurtosis	1.194	0.898	0.258	1.217	-0.376	-1.939	-1.807	-1.734	8.261	0.663	2.363	8.254	1.368	-0.131	-0.473	0.025

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

September 28, 1998																
	Below 3/8" Bin 1				New Spat Bin 2				Below 3/8" Bin 3				Below 3/8" Bin 4			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	9.372	11.609	0.207	88.591	5.99688	7.00625	0.0541	34.290	10.699	13.272	0.305	114.434	11.216	14.238	0.349	128.314
Variance	2.527	4.611	0.007	840.481	1.224	2.173	0.001	142.906	1.699	3.752	0.011	757.600	0.938	3.409	0.011	601.302
SD	1.590	2.147	0.084	28.991	1.106	1.474	0.027	11.954	1.303	1.937	0.107	27.525	0.969	1.846	0.105	24.521
95% Conf	0.445	0.601	0.024	8.117	0.310	0.413	0.008	3.347	0.365	0.542	0.030	7.707	0.271	0.517	0.029	6.866
Skew	0.075	0.863	0.663	0.821	-0.093	-0.010	0.861	0.111	-0.904	0.118	0.509	0.025	0.902	-0.349	-0.089	-0.092
Kurtosis	-0.059	1.447	0.641	0.842	0.122	0.548	0.575	0.011	1.003	-0.465	0.336	-0.392	0.674	-0.343	-0.550	-0.891

September 28, 1998																
	Below 3/8" Bin 5				Below 3/8" Bin 6				Above 3/8" Bin 7				Above 3/8" Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	10.750	14.181	0.361	123.071	10.594	12.903	0.316	109.394	12.031	15.247	0.430	147.362	11.922	16.078	0.466	155.225
Variance	1.195	3.171	0.009	576.351	1.360	2.580	0.012	486.856	1.444	4.234	0.027	853.667	1.639	3.631	0.009	908.929
SD	1.093	1.781	0.095	24.007	1.166	1.606	0.109	22.065	1.201	2.058	0.163	29.218	1.280	1.905	0.097	30.148
95% Conf	0.306	0.499	0.027	6.722	0.327	0.450	0.030	6.178	0.336	0.576	0.046	8.181	0.358	0.534	0.027	8.441
Skew	0.298	0.317	0.367	0.867	-0.378	0.869	0.929	0.618	0.204	0.641	0.768	0.820	1.202	0.067	0.595	0.676
Kurtosis	0.030	1.031	-0.273	1.927	-0.388	0.704	1.632	0.027	-0.939	0.190	3.767	0.024	4.670	-0.901	0.232	-0.168

Appendix Table 5. (Cont.) Summary data for growth of oyster seed for the Halibut Cove nursery, 1998.

October 17, 1998

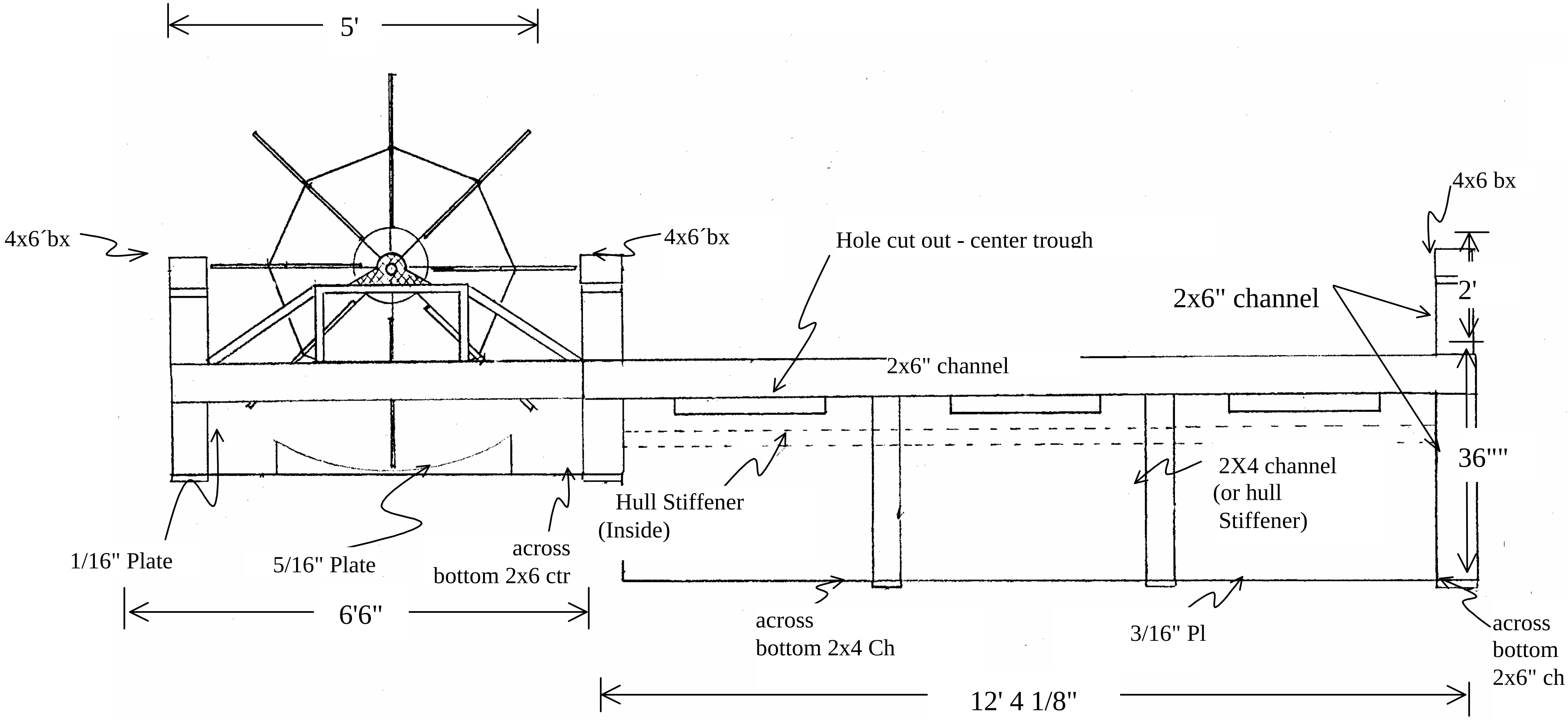
	Above 1/4" Bin 1				Below 1/4" Bin 2				Above 3/8" Bin 3				Below 3/8" Bin 4			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	10.683	13.033	0.310	111.698	5.45333	6.22667	0.041	27.154	11.986	15.380	0.527	148.253	7.204	8.865	0.097	51.987
Variance	1.717	2.506	0.015	612.570	0.47267	0.77067	0.000	43.930	1.514	3.883	0.066	815.444	1.324	2.987	0.002	320.383
SD	1.310	1.583	0.123	24.750	0.688	0.878	0.014	6.628	1.230	1.971	0.256	28.556	1.151	1.728	0.042	17.899
95% Conf	0.367	0.443	0.034	6.930	0.192	0.246	0.004	1.856	0.344	0.552	0.072	7.996	0.322	0.484	0.012	5.012
Skew	0.378	0.238	1.149	0.476	0.238	-0.092	0.366	0.149	0.399	0.962	3.151	0.668	0.450	1.120	1.650	1.372
Kurtosis	0.222	-0.241	1.650	0.299	-0.784	-1.526	-0.355	-1.377	0.521	0.496	13.634	-0.418	0.328	0.672	3.505	2.223

October 17, 1998

	Above 3/8" Bin 5				Above 3/8" Bin 6				Above 3/8" Bin 7				Above 3/8" Bin 8			
	L	H	W	O	L	H	W	O	L	H	W	O	L	H	W	O
Mean	11.653	15.488	0.456	145.848	11.272	14.822	0.405	134.621	13.148	17.223	0.552	184.039	12.641	16.709	0.560	170.454
Variance	1.036	4.679	0.308	780.226	1.008	4.264	0.012	540.732	9.433	7.984	0.049	2589.133	1.303	5.112	0.024	967.565
SD	1.018	2.163	0.555	27.933	1.004	2.065	0.108	23.254	1.619	2.826	0.220	50.884	1.142	2.261	0.156	31.106
95% Conf	0.285	0.606	0.155	7.821	0.281	0.578	0.030	6.511	0.453	0.791	0.062	14.247	0.320	0.633	0.044	8.709
Skew	0.153	0.436	-0.337	0.382	0.152	0.346	0.168	-0.037	0.449	1.410	0.122	1.480	0.915	-0.397	0.652	0.153
Kurtosis	2.015	0.024	14.536	-0.208	-1.033	0.162	0.071	-0.436	-0.190	3.105	0.612	2.942	1.679	-0.190	0.664	0.575

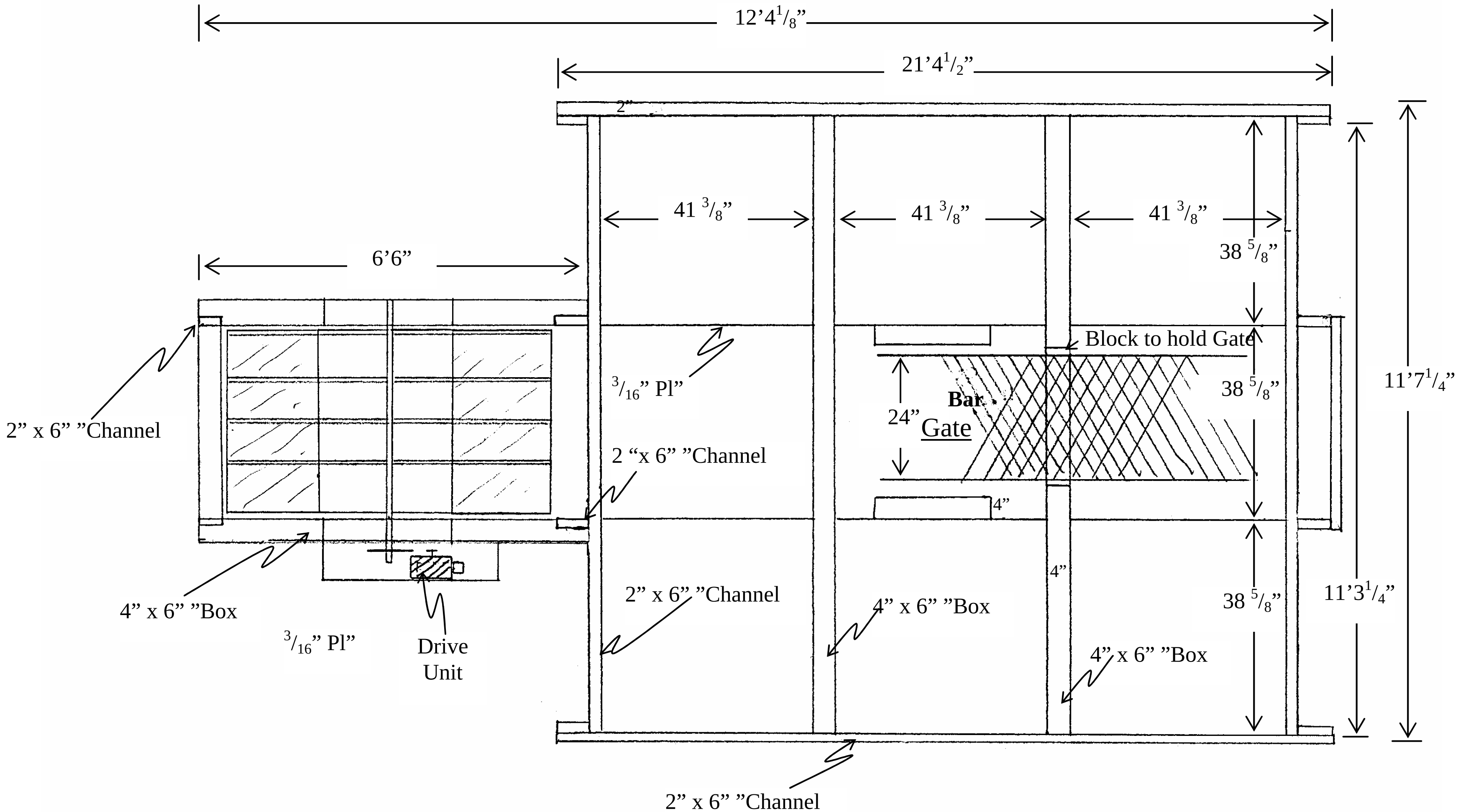
APPENDIX

Drawings and Pictures



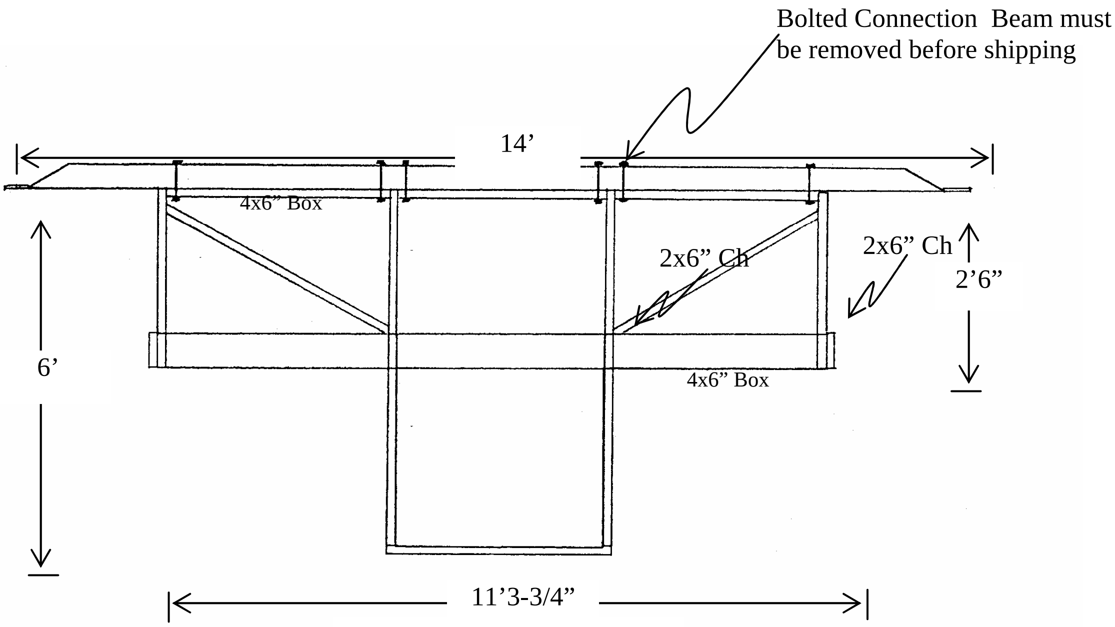
Side View

Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Side View Detail Drawing one of Ten

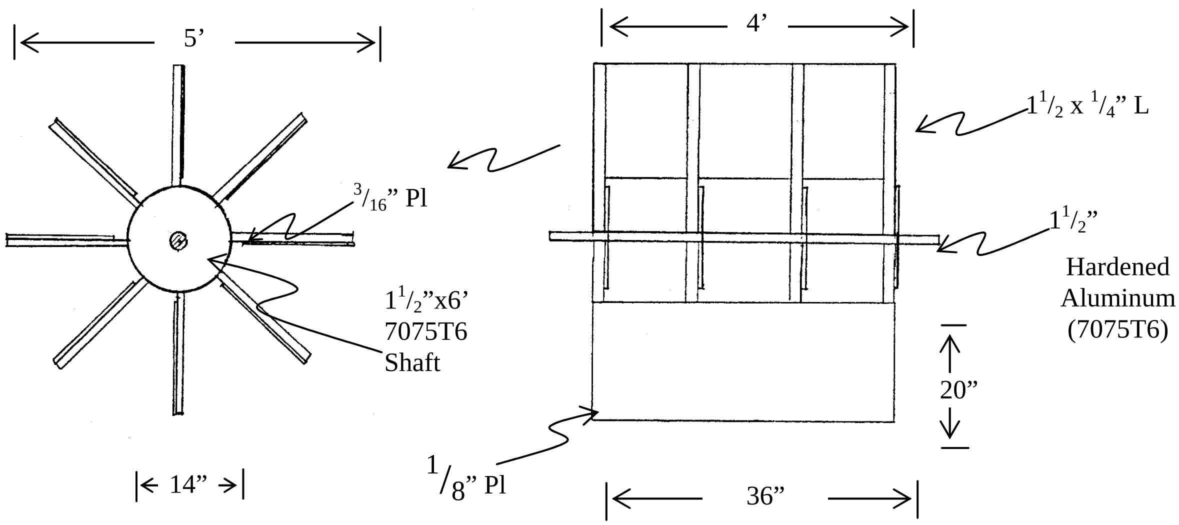


Kachemak Shellfish Mariculture Association
Nursery Culture Research Project
November 1996

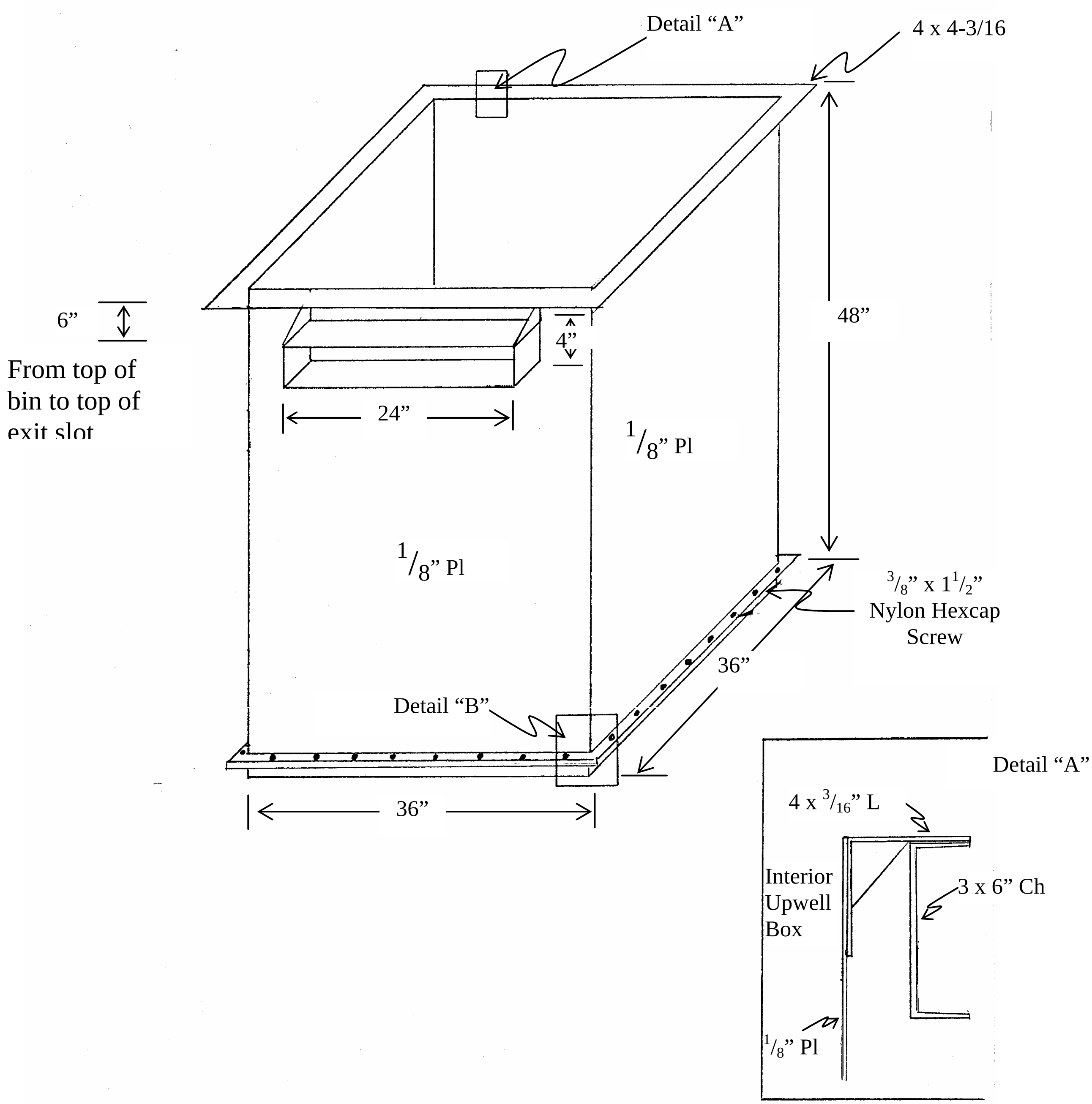
FLUPSY
Top View Detail
Drawing Two of Ten



END VIEW



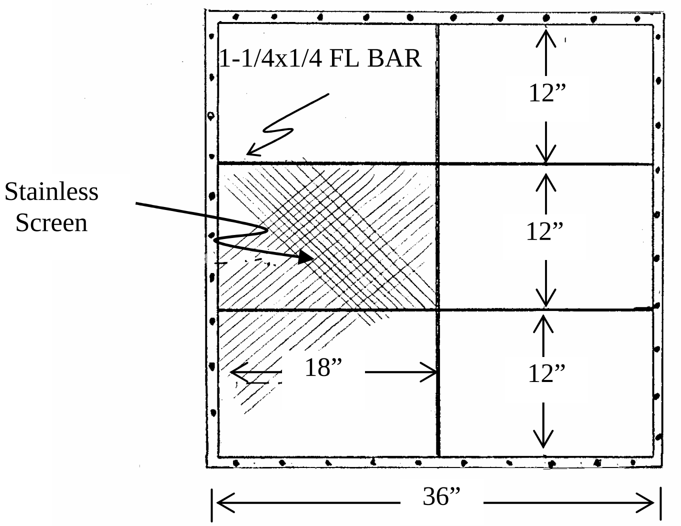
Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Paddle Wheel and End View Detail Drawing Three of Ten



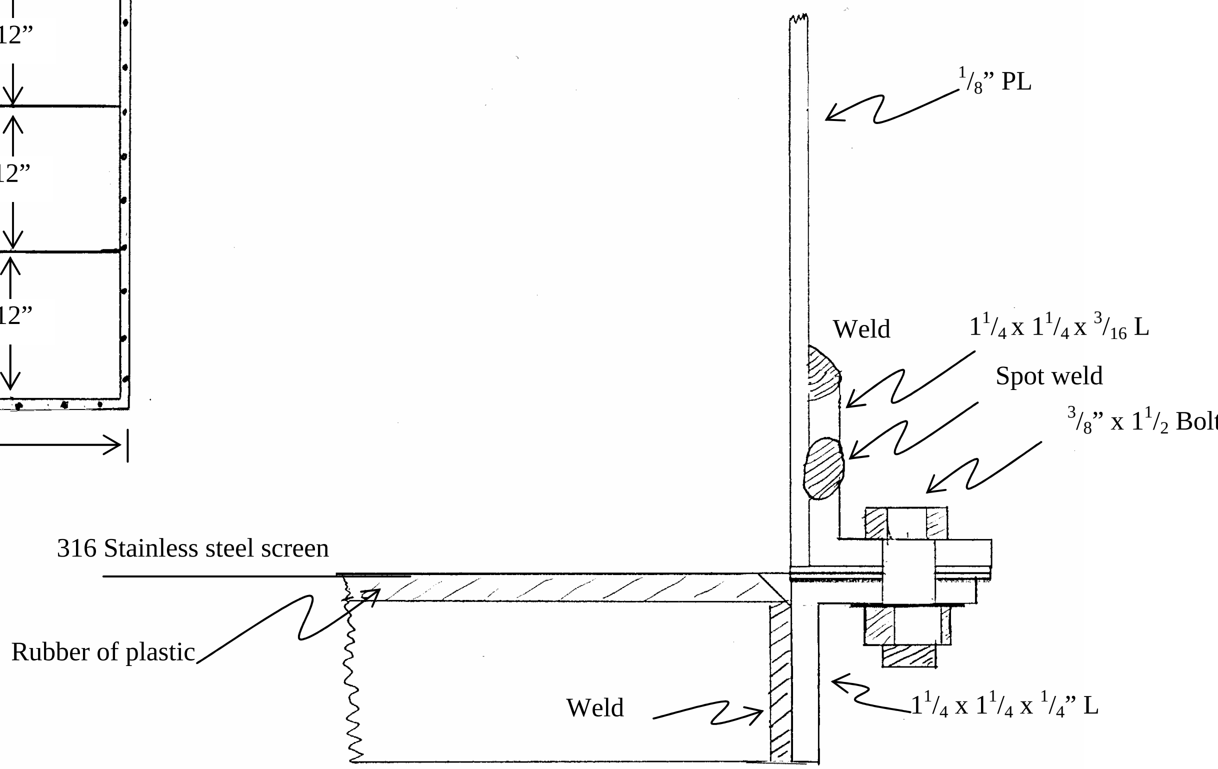
Kachemak Shellfish Mariculture Association
Nursery Culture Research Project
November 1996

FLUPSY
Culture Chamber Detail
Drawing Four of Ten

Screen Support Frame

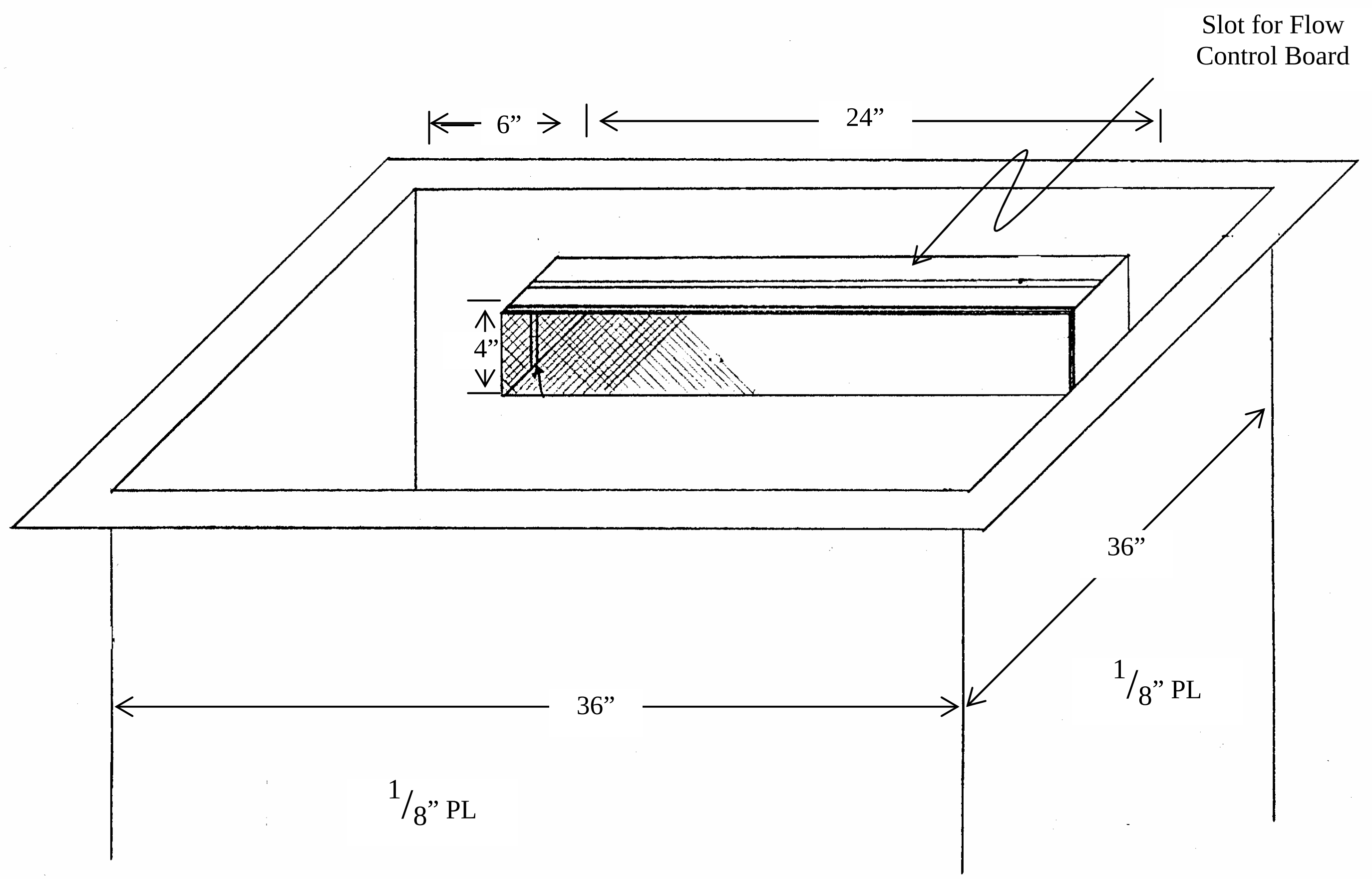


Detail "B"

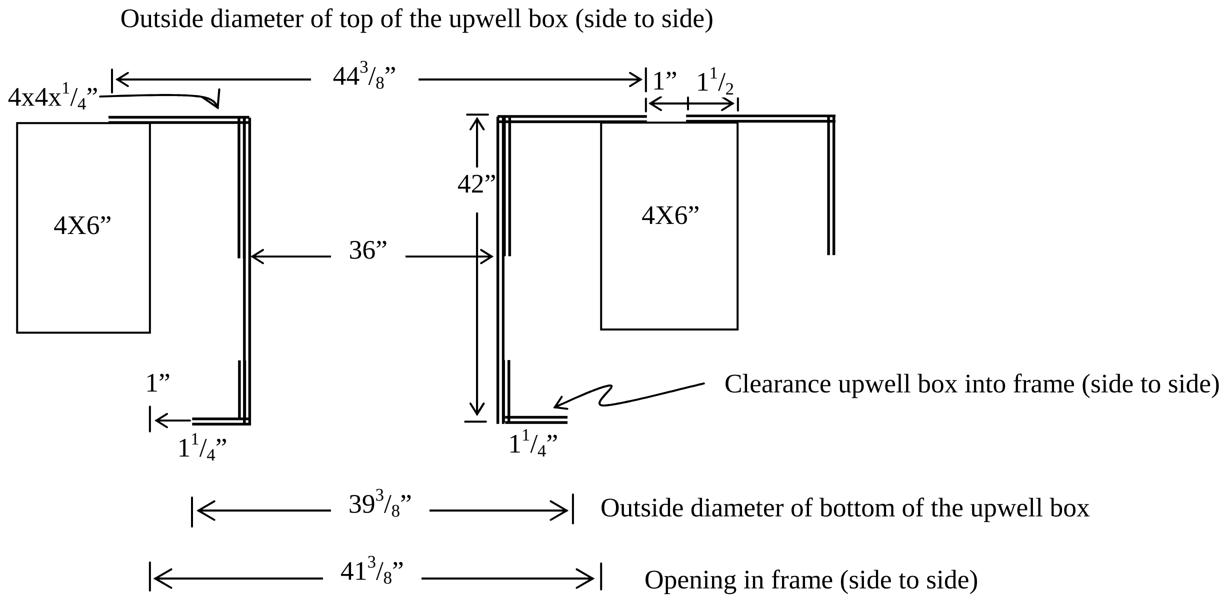


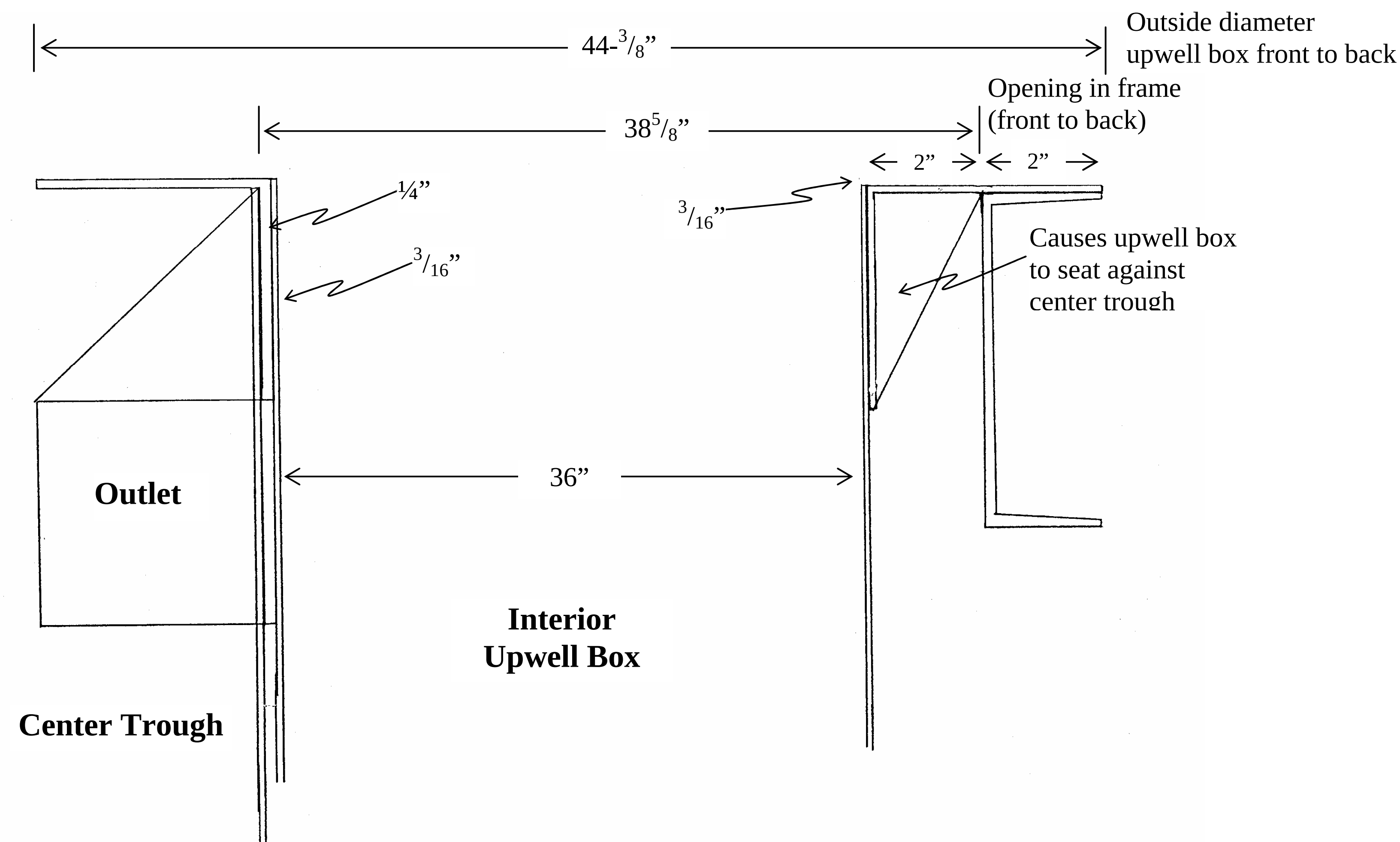
Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Culture Chamber Bottom Detail Drawing Five of Ten

Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Culture Chamber Bottom Detail Drawing Six of Ten



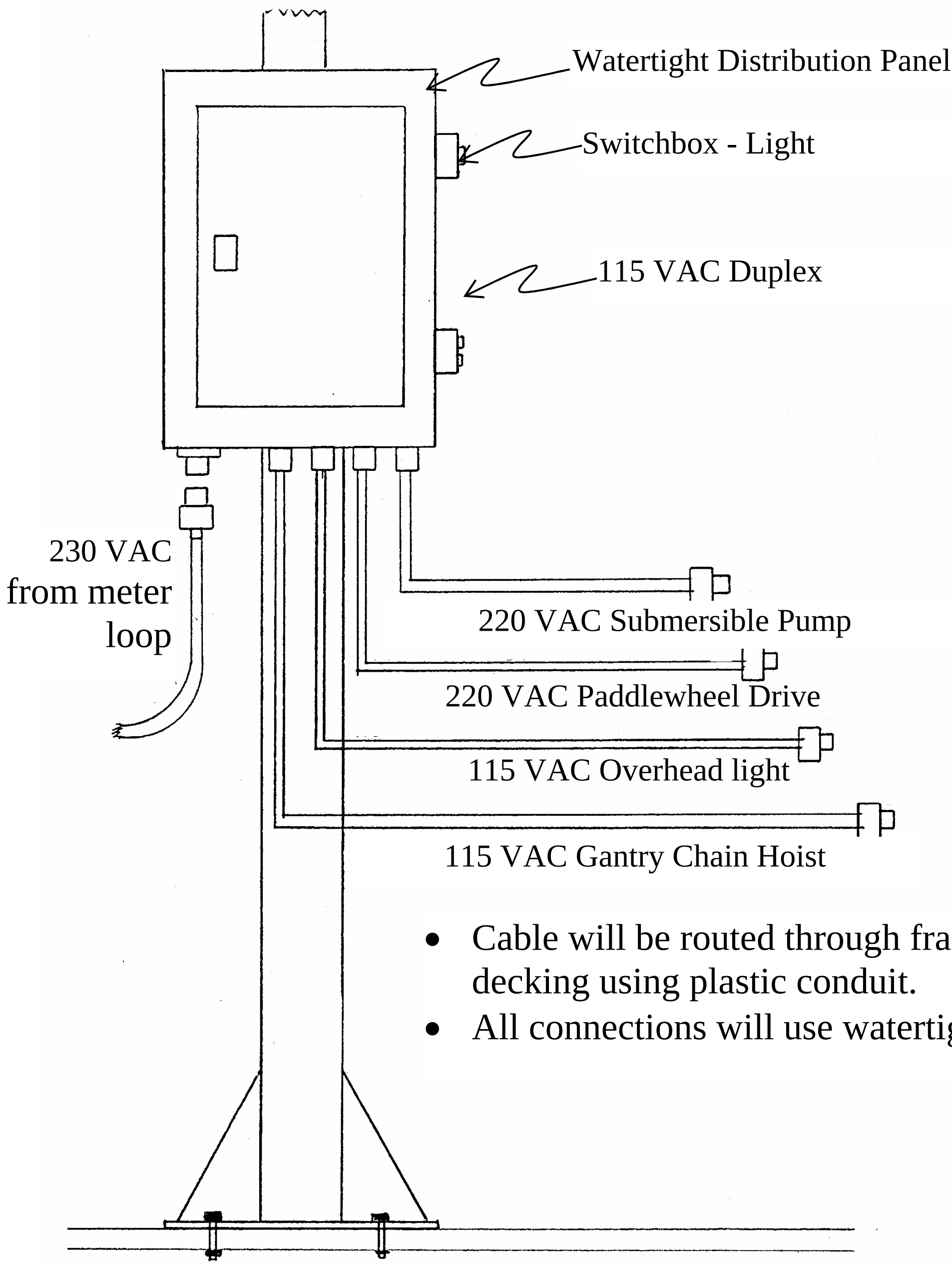
Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Chamber/Frame Clearance Side Detail Drawing Seven of Ten





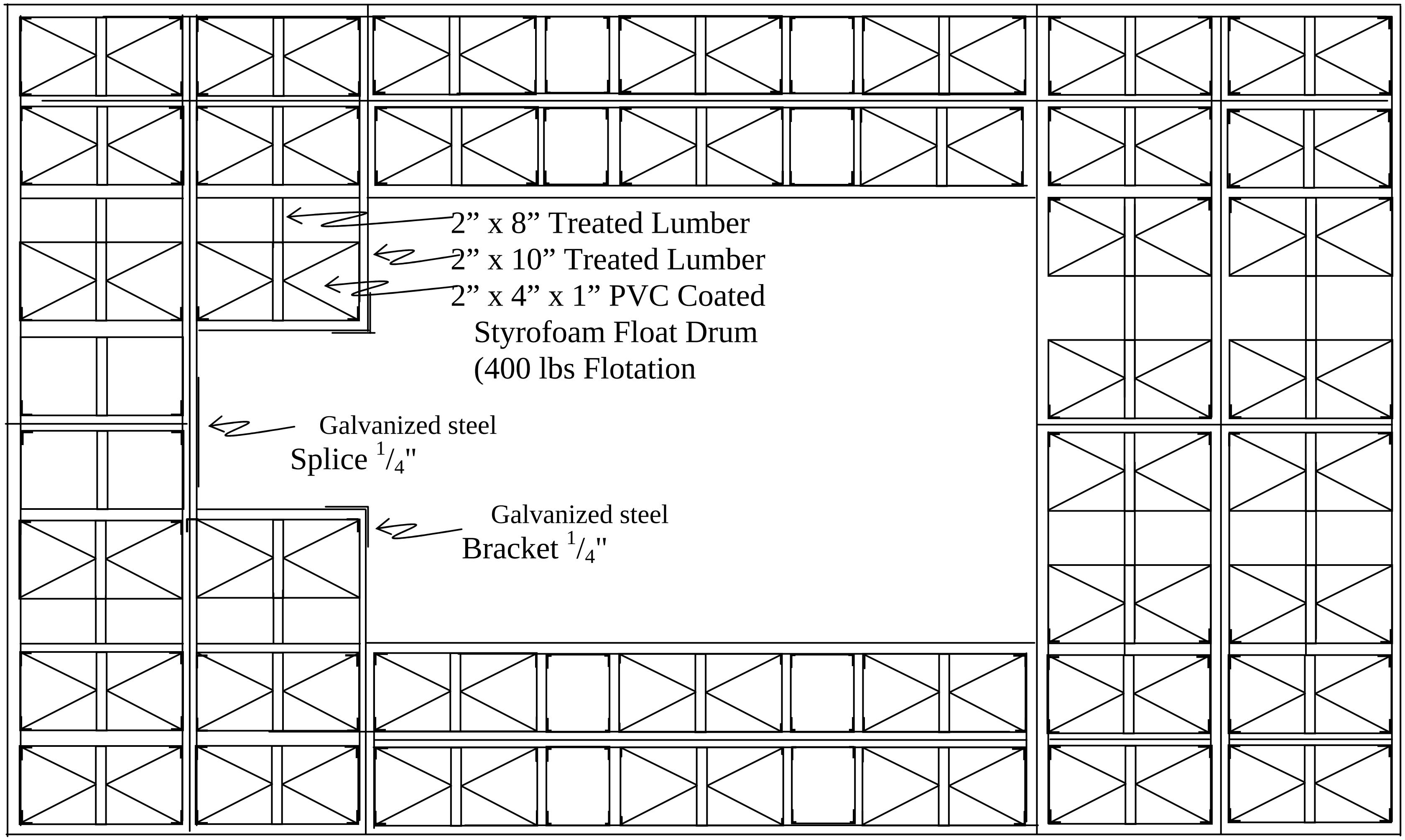
Kachemak Shellfish Mariculture Association
Nursery Culture Research Project
November 1996

FLUPSY
Chamber/Frame Clearance, Front Detail
Drawing Eight of Ten



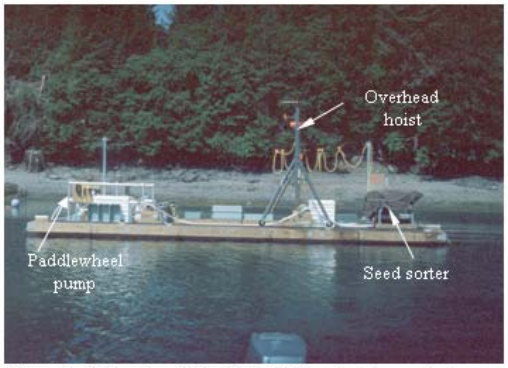
- Cable will be routed through frame under decking using plastic conduit.
- All connections will use watertight fittings

Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Electrical Distribution Box Detail Drawing Nine of Ten

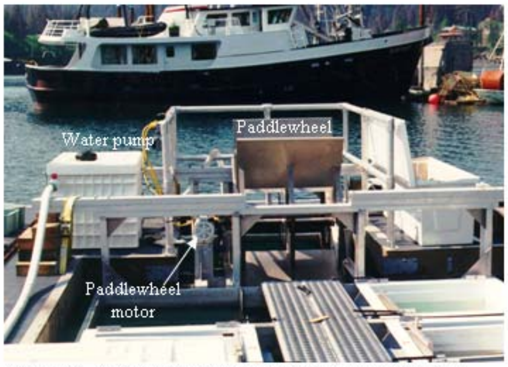


Kachemak Shellfish Mariculture Association Nursery Culture Research Project November 1996	FLUPSY Flotation Frame Detail Drawing Ten of Ten

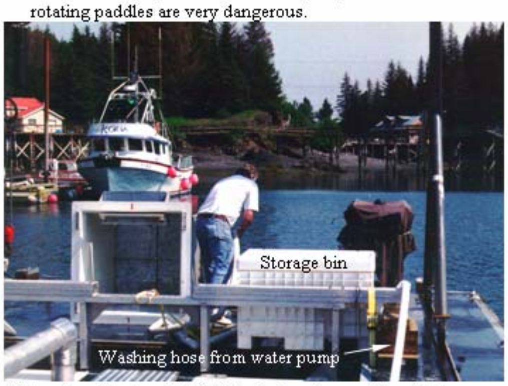
Picture 1. General overview of FLUPSY design and operation.



Picture 1a. Side view of the FLUPSY showing the seed sorter, paddlewheel pump, and moveable overhead hoist. Guard rails around the paddlewheel are very important because the rotating paddles are very dangerous.



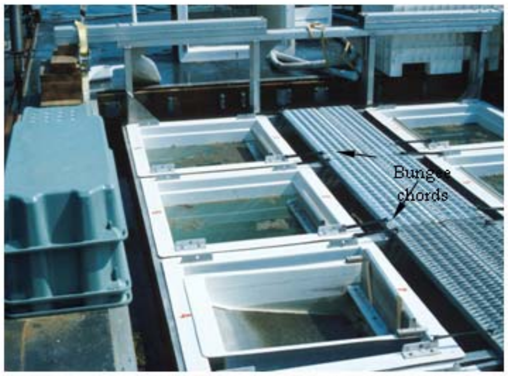
Picture 1b. Center of the FLUPSY viewing the end housing the paddlewheel. To the left is a 150 GPM electric water pump, and to the right white plastic tool storage box.



Picture 1c. Center of FLUPSY viewing the working platform end. Culture chamber laid on the side. Notice the bottom screen and aluminum cross supports. Sorter to the left is covered for protection against extreme weather.

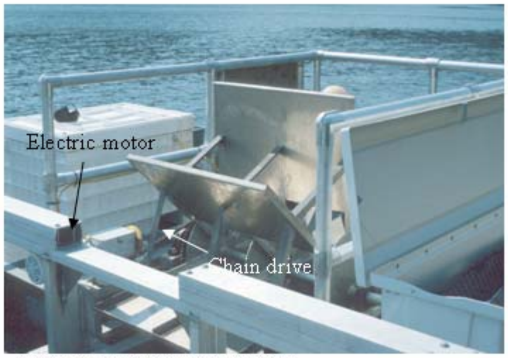
Picture 1d. Culture chamber being moved to the working platform for cleaning.

Picture 1e. Culture chambers in operational position. Notice the top, left chamber is covered with a screen to control surface algae growth and to prevent flushing of seed from the chamber.

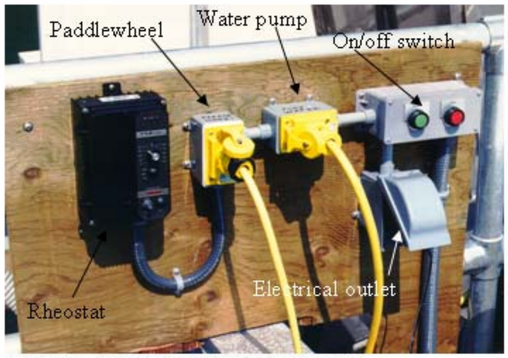


Picture 1f. Culture chambers with aluminum central walkway over the central trough. Notice the elastic bungee chords securing the culture bin against the central trough to make a leak proof seal.

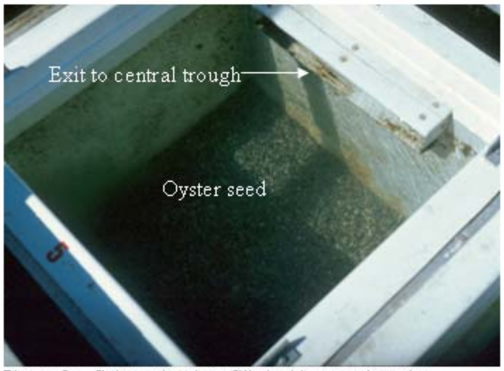
Picture 2. Design and operation of a FLUPSY.



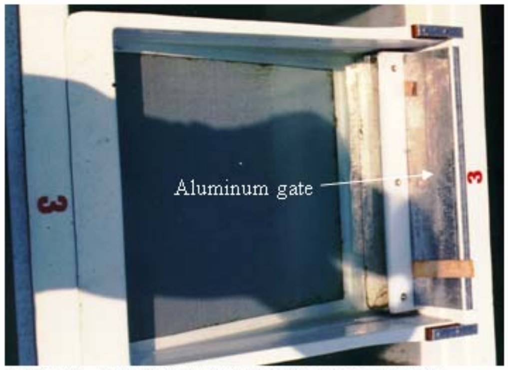
Picture 2a. Paddlewheel in operation.



Picture 2b. Electrical controls for the FLUPSY.



Picture 2c. Culture chambers filled with approximately 200,000 oyster seed.



Picture 2d. View from above removable surface screen in operational position. Note the adjustable aluminum gate to assist in controlling water flow through the culture chamber.

Picture 2e. Seed sorter with a 5/8" removable sorting plate. The plate vibrates with a reciprocating gear causing small seed to fall through the plate and larger seed move off the end at the top of the picture.

Picture 2f. Attaching bridle from the overhead hoist to the four corners of the culture chamber for lifting by the hoist.

Picture 3. Maintenance and culture practices of a FLUPSY.

Picture 3a. The first step in cleaning the culture chamber is brushing the sides before the chamber is removed for cleaning.

Picture 3b. Lifting the culture chamber from its housing. Notice that the elastic bungee chords must be removed before lifting.

Picture 3c. On the working platform, the culture chamber is tilted, one-half of the top and bottom the the screen is brushed and washed. Then the procedure repeated by tilting in the opposite direction.

Picture 3d. Sorting seed, one shovel full at a time. Sorting seed regularly into like-size lots for restocking is important to maximize growth, and cull out slow growing seed.

Picture 3e. After sorting, the seed of each size class are weighed to ensure proper loading density and recording the inventory.

Picture 3f. After weighing, the seed are restocked back into the culture chamber. Each chamber must contain like-size seed. Notice the culture chamber is partially submerged to help in leveling the seed bed after restocking.