2004 Lummi Clam Survey Summary

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Executive Summary

In 2004 Lummi Natural Resources surveyed clam densities on important reservation beaches, as well as Birch Bay State Park. A total of 2,704 samples were dug, which is equivalent to 13,475 square feet and required 611.25 man hours of field work. Legal biomass estimates for each area were: Birch Bay - 89,326 lbs, Lummi Bay - 1,087,954 lbs, and Portage Bay – 305,996lbs. The Birch Bay estimate for biomass within the State Park boundaries was 75,820 lbs.

Results for most management areas, except Robertson Road and Brant Island, showed modest increases from surveyed densities in 2003. The only area to show decreased clam densities was Robertson Road.

The evidence presently available indicates that the production models used have performed somewhat better than last year, thanks to new information on growth and mortality rates, but are still performing unrealistically for some beaches. Reasons for the model failure may include lack of beach specific growth/mortality rate information for many beaches and areas. Alternative reasons may include misreported harvest and/or undocumented harvest activities.

Recommended harvest levels would provide **324,702** lbs. in the coming year, but *this level of harvest is unlikely to continue beyond the next year* because it is largely the result of accumulated biomass on several beaches that were not fully harvested last year. This assumes that all beaches are harvested completely, and that we harvest at Birch Bay State Park this year.

Introduction

General Harvest History

Tribal fishermen have commercially harvested reservation tidelands since at least 1985, but harvest data is only available from 1989 onwards for Portage Bay beaches and 1996 for Lummi Bay beaches (Figure 1).

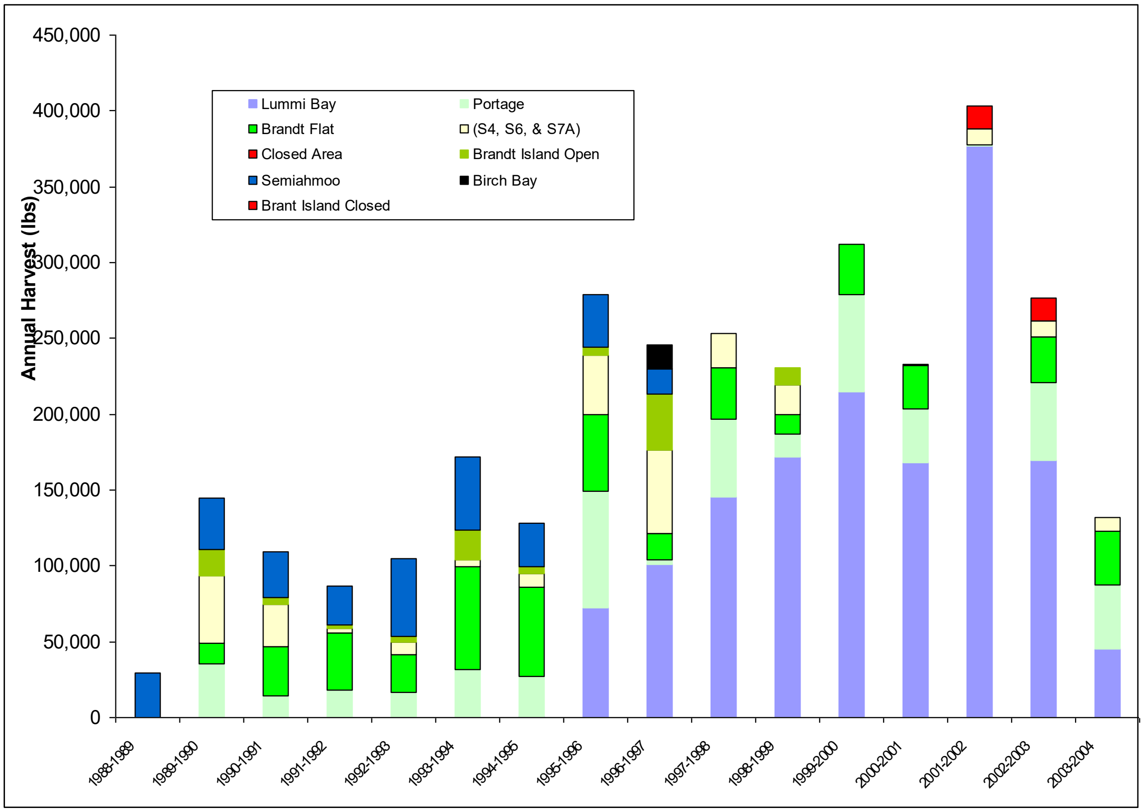

Figure 1. Recorded harvests since 1989 (Portage Beaches) and 1996 (Lummi Bay beaches).

In the early 1990's (1989-1995) the fishery was primarily based out of Portage Bay beaches. Total landings from Portage beaches averaged approximately 80,000 lbs, with another c. 33,000 lbs harvested from Semiahmoo.

From 1995 to 1999, fishing pressure in Portage Bay increased with average landings reaching approximately 113,000 lbs per year. During this time, some clam beaches in Semiahmoo were closed during 1995, and the remainder closed in 1999. Similarly, portions of Portage Bay were closed in 1997 and another portion in 1999. Since the closure of Brandt Island and Brandt Flat in 1999, Portage beaches have yielded an average harvest of 58,000 lbs per year although this is primarily due to a relocation of effort to Lummi Bay beaches. In 2003 a portion of the restricted area in Portage Bay was reclassified to an approved status. Much of the productive area was thereby reopened. At this time, only Brant Island and the northernmost end of the Senior's Beach remains closed. As a result, the 2003-2004 harvest from Portage Bay increased to approximately 86,000 lbs.

Harvest records for Lummi Bay beaches only go back as far as 1994-1995, when 780 lbs were reportedly harvested. The following season, 1995-1996, resulted in over 70,000 lbs being harvested. Annual harvests from Lummi Bay increased by approximately 30,000 to 40,000 lbs per year to reach over 214,000 lbs during the 1999-2000 season. The 2000-2001 season saw the first reduction in harvest when 165,000 lbs were taken. However, these harvest reductions were overshadowed during the 2001-2002 season when a massive 376,000 lbs of clams were harvested from Lummi Bay. However, in 2002-2003 this number dropped back to ~170,000 lbs, and in 2003-2004 dropped further to 45,000 lbs. The large drop in harvest in the 2003-2004 season was primarily the result of poor market conditions for Lummi Bay clams, not reduced clam abundance.

Management of the resource has been achieved primarily by limiting 'openings', as well as individual daily limits for diggers, in an attempt to spread the harvest effort throughout the year.

The bulk of the harvest in Portage is derived from two areas: Portage Spit (S5) and Brandt Flats (S7D) which have typically averaged ~31,000 and 34,000 pounds respectively. Next in importance is Brandt Point (S7A; 15,000 lbs per year) and then Brandt Island (S7E; 12,000 lbs per year). Portage Bay (S6) usually provides only a small amount (~5,000 lbs) and S5A and S4 have seldom been commercially targeted. S4 is designated as an area to be dug by tribal seniors only.

In Lummi Bay, the lion's share of the harvest has previously come from S1C and, intermittently, from S1D.

2003 – 2004 Harvest

132,180 lbs of Manila clams were harvested from reservation beaches in the past year (Figure 1). Of this, 45,235 lbs were harvested from Lummi Bay beaches, and 86,265 lbs were taken from Portage Bay beaches. This is the lowest total harvest since the 1994-1995 season, which was just prior to the start of harvesting clams in Lummi Bay.

In Lummi Bay, the bulk of the harvest (37,795 lbs) was taken in northern Lummi Bay (S1D & S1E), with 6,475 lbs coming from the Robertson Road beach (S1B), and only 965 lbs being harvested from the central area of the bay (S1C).

In Portage Bay the harvest was split mainly between Portage Spit (S5), where 41,990 lbs were harvested, and the approved portion of Brant Flats (S7D), where 35,890 lbs were harvested. A further 7,335 lbs were taken from an unsurveyed area in 21A-S6.

Survey Aims

The purpose of the 2004 survey program was to continue describing the clam population distribution and abundance on reservation beaches, as well as provide critical data for making harvest management decisions such as how many pounds remain, and how last year's harvest had affected clam densities on the reservation. An additional goal was to survey some off-reservation beaches that have previously been harvested by Lummi clam diggers to determine if there is still opportunity for harvest outside of the reservation boundaries. This opportunity, of course, depends on department of health certification and agreements with other agencies. However, there is little point in making the effort to organize a harvest if there is no worthwhile harvest to be taken.

Methods

Field Protocols

Due to the size of the area to be covered at most beaches, and limitations in staff availability, it was not possible to use Department of Fisheries and Wildlife clam surveying protocols to survey beaches. Instead, the Lummi method uses a series of parallel transects that extend across the beach. Along each transect, a series of samples are taken at a predetermined number of steps apart.

The orientation of each transect line was maintained by using distant visual reference points such as mountain ranges, etc and always walking directly toward that reference point. The spacing between transect lines was determined using a pre-set number of paces along the beach, and varied depending on factors such as staff availability, and the amount of area to be covered in the time available. Typically, transect lines were 90 steps apart in the Portage area surveys (30 apart in Brant Point Bay), 200 steps in Lummi Bay, and 30 - 50 steps at Birch Bay. Along each transect line a predetermined number of paces separated each sample station. The number of paces between stations in each transect line varied according to the beach slope and the overall length of the transect line. Distances between samples typically ranged from 10 - 70 paces, depending on the area. Intervals between samples smaller than 10 steps were not possible due to limitations on the precision of the GPS unit.

At each sample station, a quadrat was established, using either a 2.25 ft^2 (Birch Bay, Portage Bay) or a 9 ft^2 (Lummi Bay) PVC quadrat. The size of the quadrat being used was noted at the bottom of each data sheet. The position of each station was determined using a hand-held WAAS enabled Garmin GPS unit ("Etrex legend"), set to display decimal degrees (NAD 83), and recorded on a data sheet. The Etrex has a theoretical accuracy of $\pm$9 ft with WAAS enabled, but typical operating accuracies vary between 15 and 25 feet.

The top 4 - 6 inches of the substrate was excavated using various implements, such as specially sharpened, cut-down rakes. All Manila clams found in the quadrat were removed, to the best ability of each digger, as the ground was excavated and piled on a plastic bag to ensure none re-buried while the rest of the quadrat was being excavated. The longest dimension of the shells of the manila clams were then measured, to the nearest 1mm, with a pair of plastic calipers with 1mm graduations. The dimensions of each clam were recorded on a data sheet beside the GPS coordinates for that quadrat. The number of native littleneck clams (*Protothaca staminea*), Mahogany clams (*Nuttalia obscurata*), and cockles (*Clinocardium nuttalli*) were also counted, but no size measurements were taken. Other clams such as, Softshell clams (*Mya arenaria*), and butter clams (*Saxidomus giganteus*) were also encountered occasionally but not recorded. However, counts of all species, except Manila Clams and Cockles, are probably incomplete because they typically live deeper in the substrate than Manila clams and could have been missed by the digger.

The identification of Manila clams was primarily based on external morphology. In particular, this was accomplished using the presence of a 'scooped out' hollow found immediately posterior to the dorsal hinge. The same area in native littleneck shells usually has a small ridge extending up to the hinge and looks less 'scooped out'. Any clams that were difficult to identify using overall shell shape, and the 'scooped out hollow' characteristics, were opened up and internal shell characteristics were used (such as the purple suffusion found inside manila shells but absent in littlenecks, or the tiny ridges on the inside 'lips' of native littlenecks shells, but not manilas). However, only 3 clams required the use of internal shell morphology to definitively identify the individuals. All other clams were returned to the excavated holes and given the opportunity to rebury themselves.

Data Processing

GPS co-ordinates, quadrat size, and individual shell lengths were entered into a Microsoft Excel spreadsheet. Length-weight data from a WDFW Manila clam survey in Birch Bay were used to convert individual clam lengths into individual clam weights. The weights of all clams in each sample, and also legal-sized clams (≥ 38mm SL) only, were obtained. Sub-legal clam weights in each quadrat were determined by subtracting the legal clam weight for each quadrat, from the total clam weight for each quadrat. Legal clam densities for each quadrat were determined by dividing the summed weight of the legal-sized clams found in the quadrat by the area of the quadrat used.

The Excel spreadsheet was then converted into a dbf file with the following columns: latitude, longtitude, quadrat number, legal clams found, sublegal clams found, total clams found, total pounds per square foot, legal pounds per square foot, and sublegal pounds per square foot. This dbf file was imported into ESRI ArcMap 8.3 G.I.S. software and displayed using the GPS coordinates to determine the location of each quadrat. At this point, the data was overlaid with rectified and registered aerial ortho-photographs of the tidelands to check for data entry errors. The positions of any quadrats that were obviously out of their correct place were checked against the original data sheets, and corrected if a data entry error was found or if a transcription error may have occured. If the GPS coordinate was recorded incorrectly, and data points existed on either side of the wrongly recorded data, a position midway between the two 'good' points was used, and the revised data was imported into the ArcMap GIS software. This process was done iteratively to minimize data errors. From the revised dbf file, a final point shapefile was created and used as the basis of the actual data analysis.

Data Analysis

Because the placement of quadrats was not randomly determined, and because sample density varied with area, a simple average of the combined samples could result in significant bias since clam densities also vary spatially. Consequently, spatial analysis of the data was undertaken in order to remove potential spatial bias in the survey layout.

To get the best estimate of clam density…

To remove spatial bias introduced by unequal sample densities, the point data in the survey shapefile was analyzed using Thiessen polygons (Dolphin, 2004a). The software used was ArcMap 8.3 (ESRI) with a specialty extension named 'CreateThiessenPoly (Terrace GIS).

Firstly, polygon shapefiles were created within ArcMap that connected up all the end points of the transect lines on each beach and formed polygons enclosing the entire surveyed area for each beach. These survey area polygons were used to set the boundary extents for the Thiessen polygon analysis. Boundary polygons for the analysis were created for entire beaches or bays where survey effort was contiguous, even where this extent included more than one management area. The 'snapping' feature of the shapefile editor was used to get the best possible accuracy, and then the polygon was buffered by a distance of 1 meter to ensure that all survey points were included in the analysis.

Separate polygon shapefiles were also created using the survey area shapefile as a basis, but with the entire polygon area broken into separate management area polygons.

The survey data point shapefile was then used to create to generate Thiessen polygons that were bounded by the buffered survey area shapefile. The point-polygon link ID field used was the density of legal sized clams found in the survey.

The result of this process was a new polygon shapefile with one polygon surrounding the area represented by each of the survey points. The attribute table for this shapefile contained fields called 'ThPolyID', 'Area', and 'Percent'. The 'ThPolyID' field contained the surveyed legal clam densities. The Area field contained the area covered by each polygon. The Percent field contained the approximate percentage of the total area of the survey that was represented by each polygon rounded to 2 decimal places. This shapefile was used as the basis for estimating biomass in the total surveyed area, and was also subsequently clipped into separate management areas, using the management area polygons derived earlier, to derive individual biomass estimates for each management area. Because the management area boundaries within surveyed beach areas did not fall along the boundaries of the polygons generated by the Thiessen Polygon analysis this meant that some polygons were split into two during the clipping process. Consequently, the summed number of polygons for each management area sometimes exceeded the total number of polygons generated for the total survey area.

To calculate the area covered by the survey…

The Xtools extension in ArcMap was used to calculate the dimension of each Thiessen Polygon in acres, and also in square feet.

Further operations necessary for further analysis

Although the Thiessen Polygon analysis provided three fields of attribute data, the percentage field was rounded to two decimal places and when there are over a thousand samples, and some represent an area less than 0.01% of the total area, then this can lead to error in the final calculation. Therefore it was necessary to import the attribute table into a spreadsheet (Microsoft Excel) to perform further mathematical operations.

Firstly, the area column was summed to derive a grand total for the area surveyed. Then the ‘Percent’ column was renamed ‘Proportion’ and the values recalculated by dividing each polygon’s area by the grand total of the surveyed area, and values were rounded to 5 decimal places. The summed values in the ‘Proportion’ column equal 1.

A new column was then created named ‘Proportion Squared’. This column contained values calculated by squaring the values in the ‘Proportion’ column.

The final column to be added to the spreadsheet was named ‘Biomass’ and the values in this column were calculated by multiplying the value in the proportion column by the corresponding value in the ThPolyID column.

To calculate the spatially weighted average clam density

The spatially weighted average clam density can be represented by the equation:

$$X_i = \sum_{i=1}^{n} w_i * x_i \quad \text{…Equation 1}$$

Where X_i represented the spatially weighted average clam density, w_i represents the proportion of the total area represented by each Thiessen polygon, and x_i represents the clam density found in each Thiessen polygon. In terms of the spreadsheet discussed above, this means that the spatially-weighted average clam density could be determined by summing all values in the biomass column.

Precision of the estimate

Precision is a comparison of 95% confidence intervals relative to the value being estimated and is expressed as a percentage. The lower the precision the more accurate the estimate is thought to be.

95% Confidence Intervals are calculated by the following equation:

$$\mathbf{95\%\ C.I. = 1.96 * Std.Error} \quad \text{… Equation 2}$$

And the Standard Error is calculated using the equation:

$$\mathbf{Std.Error = \frac{s}{\sqrt{n}}} \quad \text{… Equation 3}$$

…Where s equals the standard deviation and n equals the number of observations/samples.

However, because we are estimating the precision of a spatially-weighted average clam density, we cannot use the standard deviation of the observations in Equation 3. Instead, we need to calculate the spatially-weighted standard deviation of the spatially weighted average.

The spatially weighted Variance (Var_w) can be calculated using the following formula:

$$\mathbf{Var_w = s^2.(\sum_{i=1}^{n} w_i^2)} \quad \text{…Equation 4}$$

…where s^2 is the spatially unweighted variance of the observations, and w_i is the proportion of the total area represented by each Thiessen Polygon.

In terms of the spreadsheet above, s^2 is calculated using the spreadsheet function VAR on the values in the ThPolyID column. The value within the brackets is calculated by summing all the values in the ‘Proportion Squared’ column. The weighted variance is the product of these two values.

We can then calculate the weighted standard deviation (s_w) by calculating the square root of the weighted variance.

Once we have the weighted standard deviation, we calculate the spatially-weighted standard error of the weighted mean using equation 3, and then calculate the spatially-weighted 95% confidence interval using equation 2.

Finally the precision of the survey is determined by dividing the 95% confidence interval calculated in Equation 2 by the average clam density obtained from Equation 1, and multiplying the result by 100%.

Determining Production Rates

Size-frequency data for the clams from each management area were compiled and assumed to represent an unbiased size-frequency 'snapshot' of the population in each area. The individual weights of clams in each 1mm size increment were put in a column beside the size-frequency data, and the collective weight of all individuals within that size increment was calculated in the next column. The cumulative weight of individuals 38mm or larger was divided by the total area sampled in that management area to provide a sample estimate of legal clam density. This sample estimate was corrected for spatial bias by dividing the sample estimate of clam density by the spatially-weighted estimate of clam density for that area.

Because some clams die from natural mortality, and the surviving clams will each grow during the following year, the 'population' represented by each size-frequency distribution was 'grown out' using the spreadsheet. To do this it was necessary to make some predictions about growth rates and natural mortality rates.

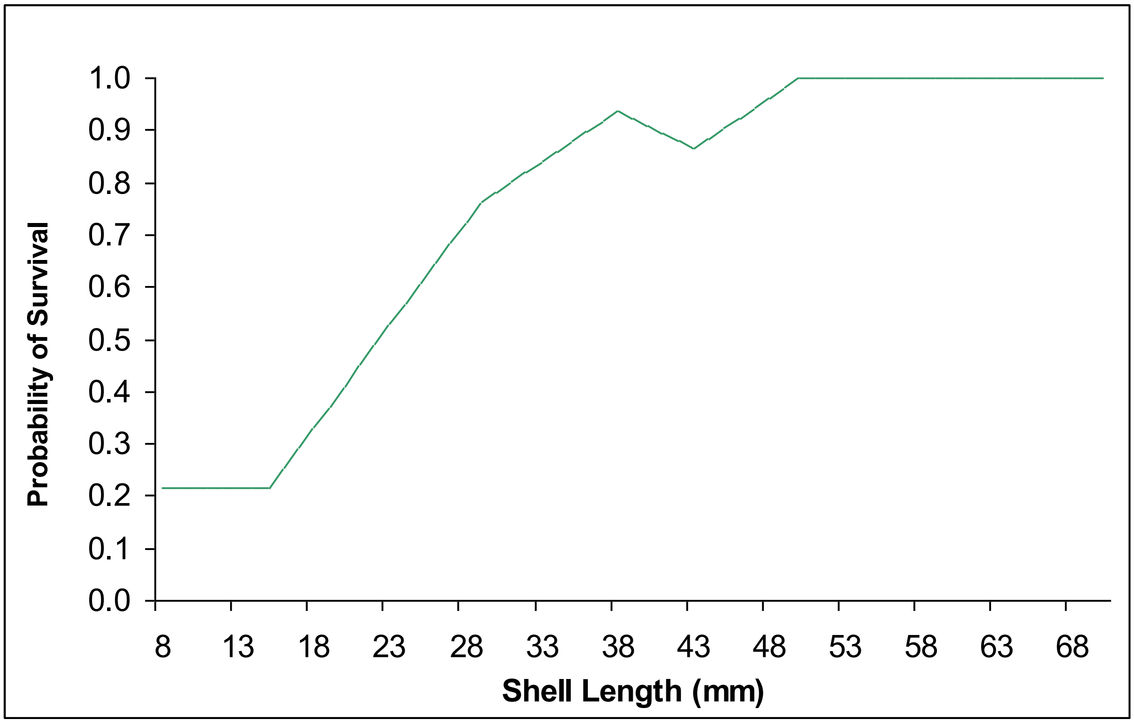

Figure 2. Survival rates used in calculating Production Estimates.

Previously we had used fixed survival rates for legal-sized and sub legal clams based on WDFW estimates. However, we now have some data on clam survival rates in Lummi Bay from a grow-out experiment (Dolphin 2004b) and have incorporated this information into the production rate calculation. Figure 2 shows the size-specific survival rates used in the process that were based on the grow-out experiment. However, it should be noted that the survival data is extremely limited and more work is needed to better understand this critical parameter.

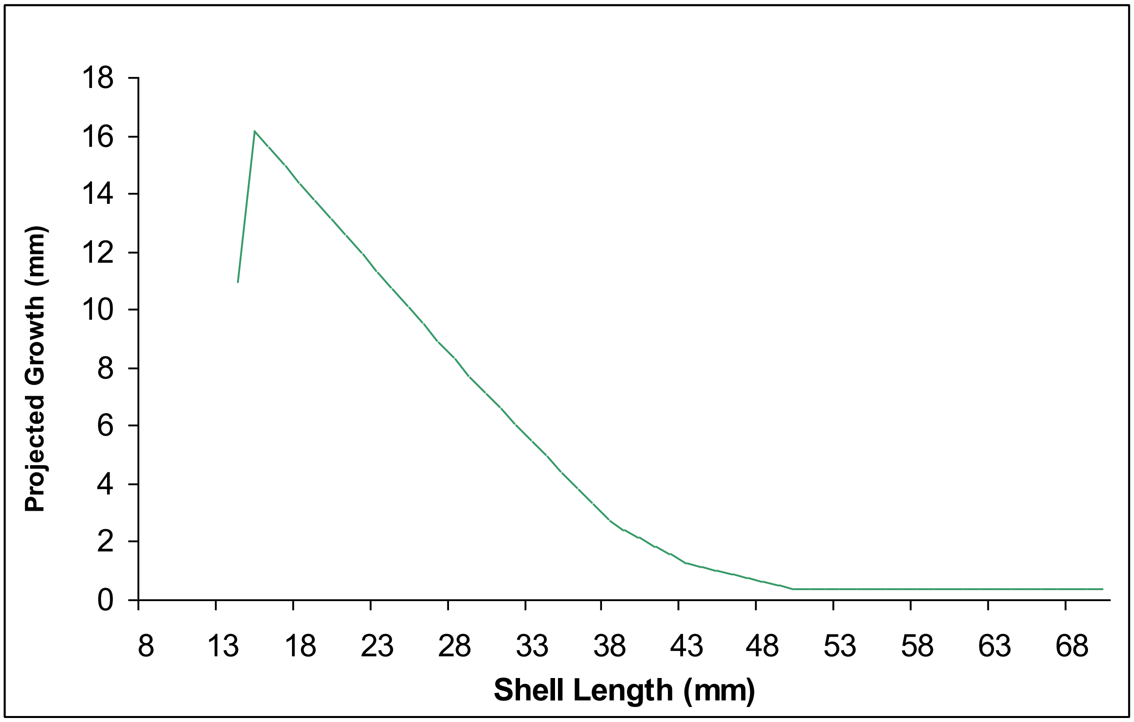

Figure 3. Annual size-specific growth rates used in calculating production estimates.

Annual growth rates used to 'grow-out' the observed size-frequency distribution by one year are shown in Figure 3. These values were obtained from the same grow-out experiment as used to determine the survival rates shown in Figure 2.

By predicting the growth of clams in each size increment, and estimating the reduced frequency of clams after natural mortality occurs, it is possible to recalculate the collective weight of clams in each size increment for the following year. The cumulative weight of all size increments that had reached 38mm or above (rounded to the nearest millimeter) was divided by the sampled area to predict the legal sample density for next year. The predicted sample estimate was again corrected for spatial bias by factoring in the spatially-weighted estimate of clam density, divided by the original sample estimate. This assumes that population distribution patterns are persistent from year to year. Next year's legal biomass could then be predicted by multiplying next year's calculated clam density by the survey area. The difference between the predicted legal clam biomass for next year and the estimate for this year is the total amount of new biomass that is expected to be produced.

Results

A total of 611.25 man-hours was spent surveying clam populations in 2004. Survey activities began on May 17th and continued through almost all of the available daylight tides until August 12. This year Lummi Natural Resources surveyed clam populations in Birch Bay State Park, Lummi Bay, and the most productive parts of Portage Bay. We were unable to survey along Lummi Shore Road or the majority of management area 21AS6 and 21A-S7A because these were considered low priority beaches. Survey results are presented in Table I. Clam density maps for Lummi Bay, Portage Bay, and Birch Bay State Park are presented in Figures 4,5, and 6 respectively.

Table I. *Summery of 2004 Survey Results (Portage Open/Closed refers to DOH restricted area boundaries established during the October 2003 reclassification)*

Birch Bay

Area Description	Thiessen Polygons	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
20A-060	516	2.25	40.54	0.050585	18.47%	72,827	**89,326**	105,824

Portage Bay

Area Description	Thiessen Polygons	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S5	**236**	**2.25**	22.9	0.088413	17.29%	72,836	**88,062**	103,289
S7D	**531**	**2.25**	71.0	0.053813	16.18%	139,559	**166,492**	193,425
S7E (open)	**110**	**2.25**	18.0	0.016241	40.13%	7,603	**12,699**	17,795
S7E (closed)	**216**	**2.25**	30.9	0.028812	28.73%	27,612	**38,743**	49,874
Open Areas Pooled	**877**	**2.25**	111.8			219,997	267,253	314,509
Closed Areas Pooled	**216**	**2.25**	30.9			27,612	38,743	49,874
All Combined	**1,093**	**2.25**	142.7					

Lummi Bay

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S1B	**351**	**9**	234	0.01292	14.1%	112,952	**131,466**	149,981
S1C	**265**	**9**	359	0.01611	15.9%	211,987	**252,068**	292,149
S1D & S1E	**479**	**9**	911	0.01775	13.7%	608,190	**704,420**	800,650
All Combined	**1,095**		1,504	0.016611	9.0%	990,365	**1,087,954**	1,185,544

* Precision estimates used here are spatially weighted estimates derived from the Thiessen Polygon Analysis. See methods for fuller discussion of this parameter.

**biomass estimates presented here for the closed portions of S7D and S7E do not include any clam biomass from unsurveyed portions of those areas.

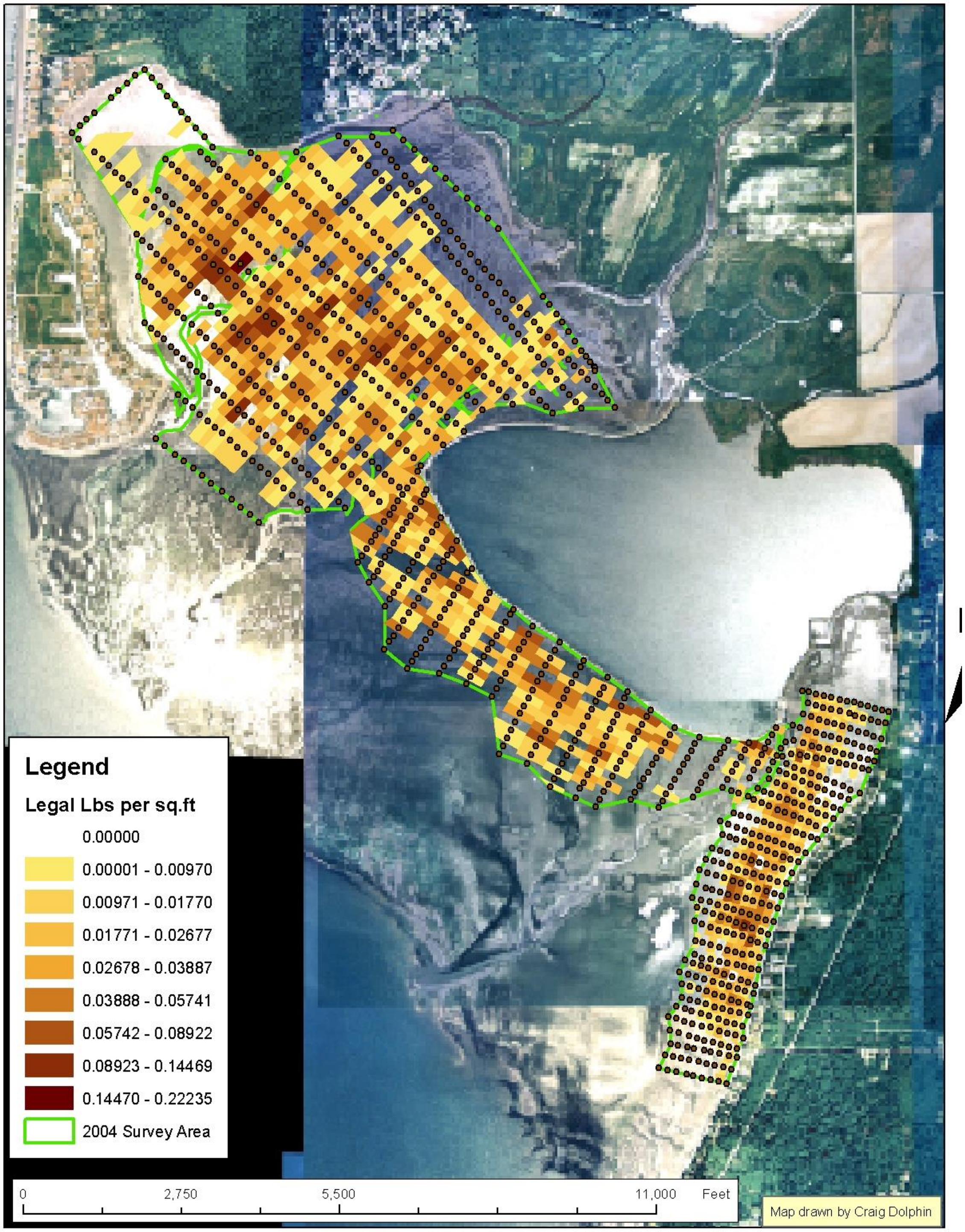

Figure 4. Legal-sized Manila Clam densities in Lummi Bay based on 2004 survey data.

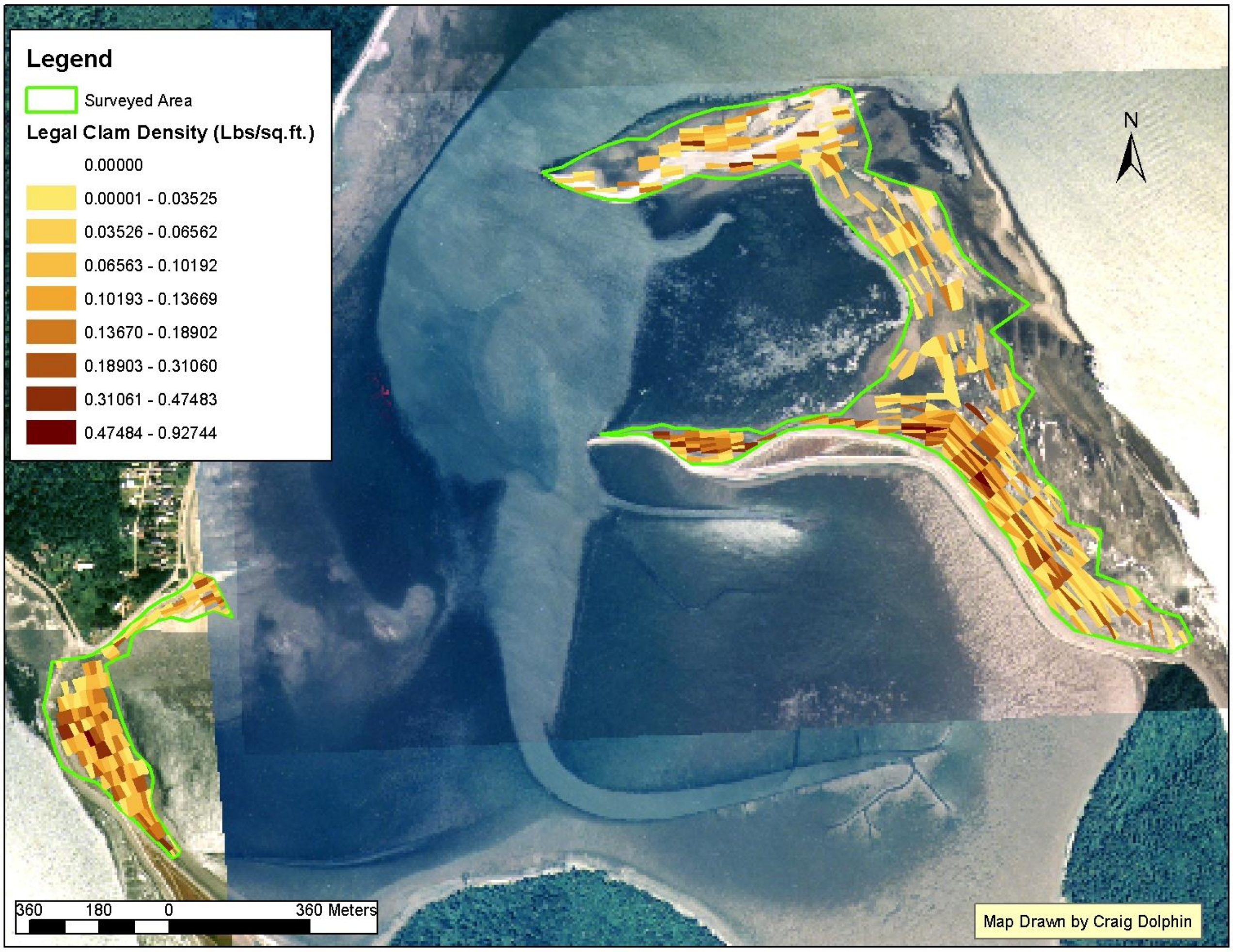

Figure 5. Clam densities in Portage Bay based on 2004 survey data and interpolated using 3-pt kriging.

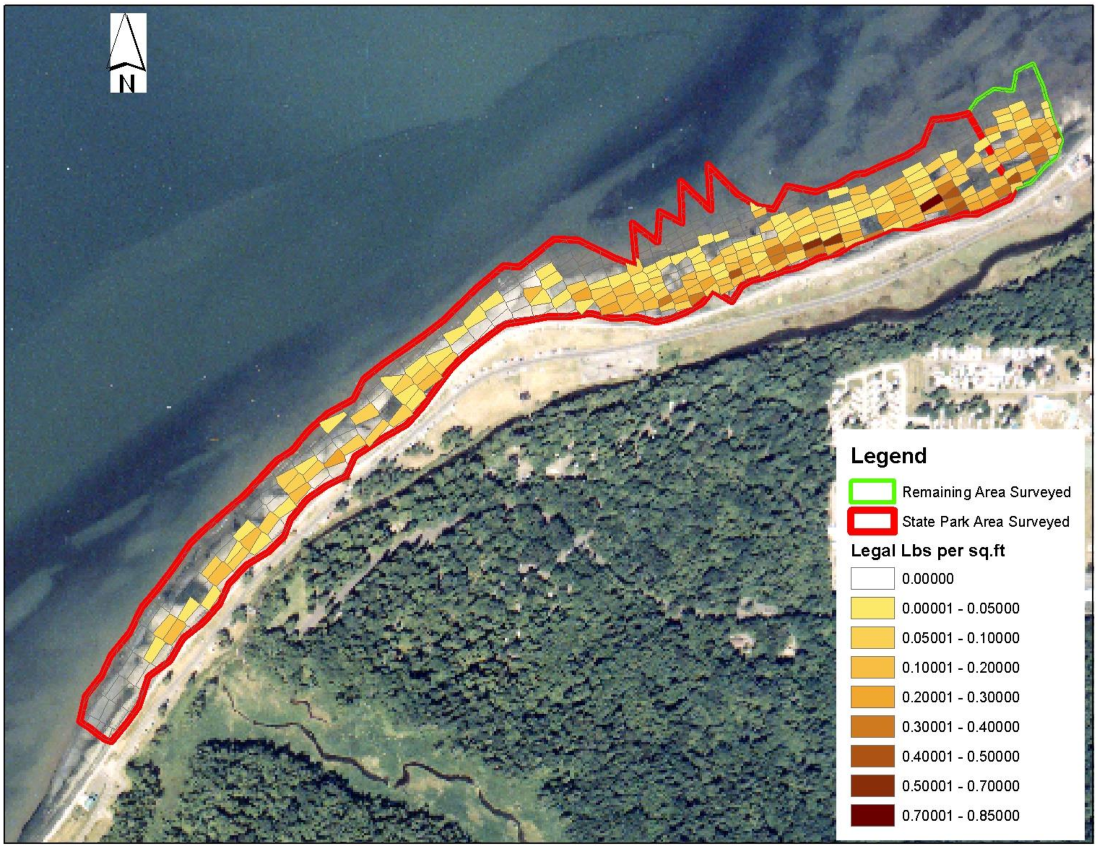

Figure 6. Clam densities at Birch Bay State Park from 2004 Lummi survey data..

Because the survey areas differed somewhat between the 2002, 2003, and 2004 surveys, it is not meaningful to directly compare the different survey results to each other. However, meaningful comparison can be made of clam biomass in the parts of the surveyed areas that was common to more than one survey and this can be used to create an index of clam biomass that approximates the total biomass present. Figure 7 shows the relative change in the biomass present in the each management area surveyed in Lummi Bay, and Figure 8 shows relative change in biomass in management areas in Portage Bay.

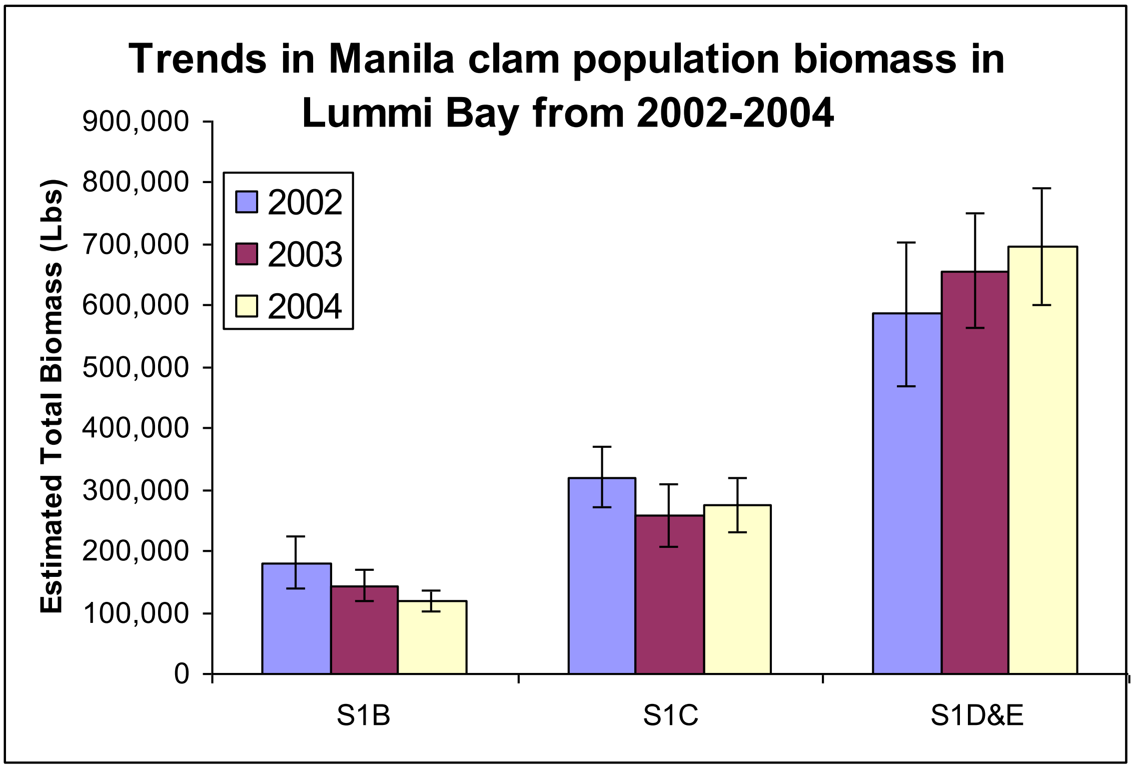

Figure 7. Relative change in legal clam biomass in Lummi Bay from 2002 to 2004 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

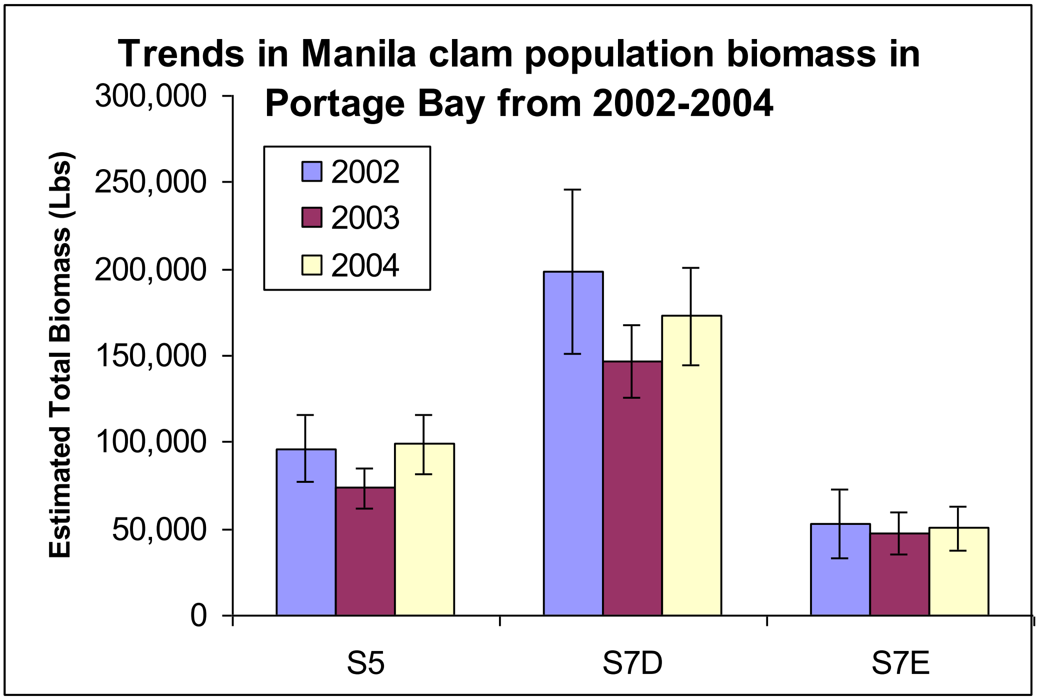

Figure 8. Relative change in legal clam biomass in Portage Bay from 2002 to 2004 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

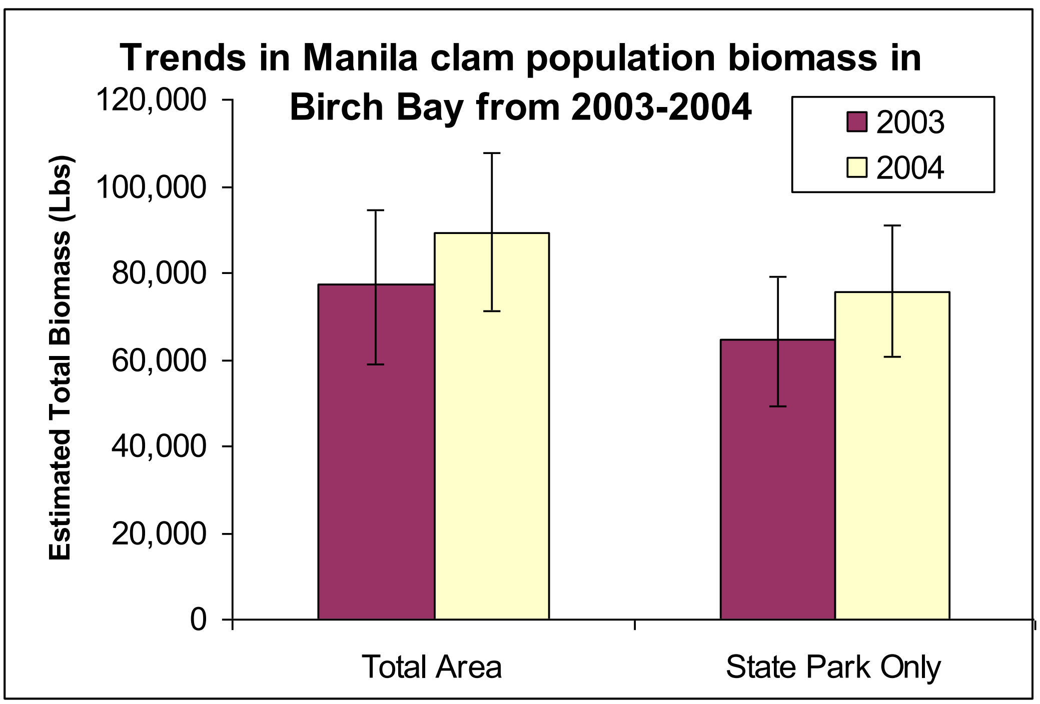

Figure 8. Relative change in legal clam biomass in Birch Bay from 2003 to 2004 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits. Data shows biomass estimates for the entire surveyed area, and for the area within the state park boundaries only.

Table II. *Comparison of Production Estimates based on the 2002, 2003, and 2004 surveys.*

		2002 Production Est. (lb)	2003 Production Est. (lb)	2004 Production Est. (lb)
Lummi Bay	S1B	35,254	30,237	28,466
	S1C	36,179	29,448	10,349
	S1D&E	100,012	77,488	89,299
Portage Bay	S5	49,701	41,703	34,617
	S6	N/A	1,978 (partial)	N/A
	S7D Total	65,052	63,159	58,458
	S7E	16,040	32,371	27,162
Birch Bay State Park	060	N/A	49,266	61,824

Production estimates for each beach, based on the 2004 survey data, are presented in Table II along with the equivalent estimates based on the 2002 and 2003 survey data. Please note that these production estimates are not directly comparable for some Portage Bay beaches because of differences in the surveyed area in 2002 and 2003. In particular, one productive area in S7D was not surveyed in 2002 but was surveyed in 2003 and 2004.

Because the total biomass on some beaches has declined since 2002, and on other beaches has increased, the recommended harvest strategy for 2005 does not directly reflect the anticipated production for the coming year. The recommended harvest amounts for all approved areas available for harvest that have been surveyed in 2004, are detailed in Table III.

Table III. *Recommended harvest targets based on 2004 survey data, by beach.*

Management Area	2005 Recommended Harvest
North Lummi Bay (S1D&E)	**161,000**
Mid Lummi Bay (S1C)	**1,841**
South-East Lummi Bay (S1B)	**0**
Portage Spit (S5)	**49,147**
Brant Flat (S7D)	**64,750**
Brant Flats (S7E - Open)	**10,268**
Birch Bay State Park	**37,695 (iterative method)**
Overall Total	**324,702**

Discussion

Clam harvesting in 2003/2004 was limited primarily by market conditions and only one beach, Portage Spit, was closed due to reaching the harvest quota. Unsurprisingly, the 2004 survey found increased clam densities compared to 2003 on most beaches; and were higher on Portage Spit where densities should, theoretically, have been similar to 2003. The only two exceptions to this trend were Robertson Road (S1B) and Brant Island (21A-S7E).

Almost no harvest was taken in the open portion of 21A-S7E (635 lbs only) and the population remained almost completely unchanged since 2003 (50,947 lbs in 2004 versus 50,012 lbs in 2003). Given the lack of substantial harvest activities and negligible change in biomass, it seems clear that the production estimates for the clams in this area are not even close to reality (Either that or there is a large scale illicit harvest that we are unaware of). Since this area has not been harvested for several years now, and it appears that the population is stable and unchanging, then it could be that the area is at the carrying capacity of the environment. If this is true, then some density-dependent factor is limiting the growth of the population. If the clam population is not at the carrying capacity of the beach, then it may be that population growth has stalled due to some environmental variable that affects this beach more than other beaches. In such a scenario, the anticipated growth of the population has been almost exactly matched by some environmentally-driven mortality event. Manila clams in this area are the most exposed to low salinity water from the Nooksack. This may affect clam mortality directly or indirectly. Manila clams can survive low salinity water for extended periods but if the salinity is too low for too long then clams may die as a result of hypo salinity stress. Another method whereby low salinity water may cause mortalities is during extremely cold conditions because low salinity water will freeze before full-strength seawater will. Winter freeze events kill clams by rupturing cells, and mortality can occur several weeks after the freeze actually occurs. During December 2003 there was a prolonged cold snap (temperatures ranged from 12F to 18F for much of the time) between Christmas and New Year that coincided with a nighttime low tide series. River flows at the time were moderate (~3,100 cfs). At this time the Nooksack River froze over, and the seapond was also frozen over. It is quite likely that low salinity water froze on Brant Island as the tide receded from the tidelands. A few weeks later there were anecdotal reports of dead clams being found by people in the area, but no specific information on the locations of dead clams was available. Consequently, it is very possible that the population was adversely affected by a large winter kill before the 2004 survey that masked any population growth that may have otherwise occurred.

6,475 lbs were harvested from Robertson Road in 2003/2004 but the population appears to have declined by 9,000 lbs since 2003. This doesn’t tally with expectations because we expected there to be ~ 30,000 lbs of new biomass produced. If this new biomass were factored in, the population should have increased by ~23,500 lbs instead of declining by 9,000 lbs! Once again, it appears that either the production estimate for this area was unrealistic or that significant harvest occurred in the area that was reported as coming from other locations, or that was not reported at all.

We do know that there is a possibility of a winter kill event that may have adversely effected some clam populations. If this is the cause of the decline in clam biomass in S1B then this raises the question as to why this did not similarly affect S1C, and S1D&E? Both S1C and S1D&E are bounded by freshwater channels from the Red River so it seems likely that these beaches would have had more freshwater influence than S1B which does not have river channels. On the other hand, the northern end of S1B is dominated by fine sediments which typically characterizes slow water velocities and non-exposed beaches. It is possible that the more enclosed/protected nature of the area meant that less mixing of seawater occurred during the high tide and that water temperatures (and therefore substrate temperatures) were colder even before the tide receded. It may be that S1B is more vulnerable to temperature extremes than the other two areas. Certainly, one small manila clam bed in the area that had abundant clams last year, and was very unlikely to be targeted by diggers during the winter, had declined enormously when we went looking for broodstock for the shellfish hatchery. This small bed was not in the surveyed area so this confirms that something has reduced clam densities in the overall area.

If some clams were illegally harvested from S1B and then reported as being harvested from other beaches, then you might expect to see the biomass on those other beaches increase by more than the expected amount. One such example could be Portage Spit where biomass increased by ~20,000 lbs even though we had fully harvested the expected production from that beach. If this scenario were true, then this would raise some obvious questions about the effectiveness of harvest monitoring and enforcement.

It seems clear that the production estimates that are being generated have improved somewhat since last year, thanks largely to improved estimates of growth and mortality rates. However, the data we are using, particularly for natural mortality, are extremely limited and based on a handful of clams from very limited locations within Lummi Bay. There is an urgent need to get more reliable growth and mortality data for clams in both Lummi and Portage Bays, as well as other areas of interest such as Birch Bay State Park and Semiahmoo. Such data needs to distributed widely within these areas, and needs to be averaged across multiple years. Without good data on natural growth rates and survival rates, it will be impossible to use this kind of modeling to make reliable production estimates even in average years. It will also be next to impossible to realistically quantify losses due to natural phenomena, such as winter kills, or to anthropogenic phenomena, such as oil spills.

Nevertheless, the harvest recommendations in Table III represent the best combination of science and policy to both conserve the resource and optimize harvest opportunity. The recommended harvest amount for Birch Bay State Park was derived using the WDFW iterative method (Campbell, 1996) based on the size-frequency distribution of clams in the 2004 survey. This value is considerably lower (37,695 lbs) than the expected production based on the method used for on-reservation beaches (61,874 lbs), but substantially higher than the harvest of 20,000 lbs that was being discussed in negotiations between the tribe and WDFW in 2003. I personally suspect that there is a far larger recreational harvest of manila clams at Birch Bay than is being estimated by WDFW but, of course, this is based only on personal observations of recreational digger catches on relatively few days there. Despite this, I think that there is good scope for tribal harvest opportunity at Birch Bay State Park this year and that we should be making efforts to do so.

If market conditions and other factors allow, a harvest of 300,000 – 325,000 lbs is possible this year. This would be the second or third largest tribal harvest ever and would more than double last year's harvest. However, it should be recognized that such a large harvest is possible, in large part, because of accumulated biomass on a few beaches that were not fully harvested in 2003. Such a high level of harvest is unlikely to be sustainable in the long term without severely impacting the resource, unless resources are put into enhancement activities such as artificial seeding or predator exclusion. The cost-effectiveness of such enhancement measures would need to be very carefully scrutinized as previous experience has shown that returns would be prohibitively low.

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