

2005 Lummi Clam Survey Summary

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Executive Summary

In 2005 Lummi Natural Resources surveyed clam densities on important reservation beaches, as well as Birch Bay State Park. A total of 4,147 samples were dug, which is equivalent to 16,954 square feet and required 976 man-hours. Legal biomass estimates for each area were: Birch Bay – 97,133 lbs, Lummi Bay - 1,654,201 lbs, and Portage Bay – 343,741 lbs.

Results for most management areas, except Portage Spit, showed modest increases from surveyed densities in 2003. The population in northern Lummi Bay continued to expand despite being harvested at the estimated production rate.

The evidence presently available indicates that the production models used 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 **416,638** lbs. in the coming year. This assumes that all beaches are harvested completely, that Brant Island is re-opened for harvest, 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).

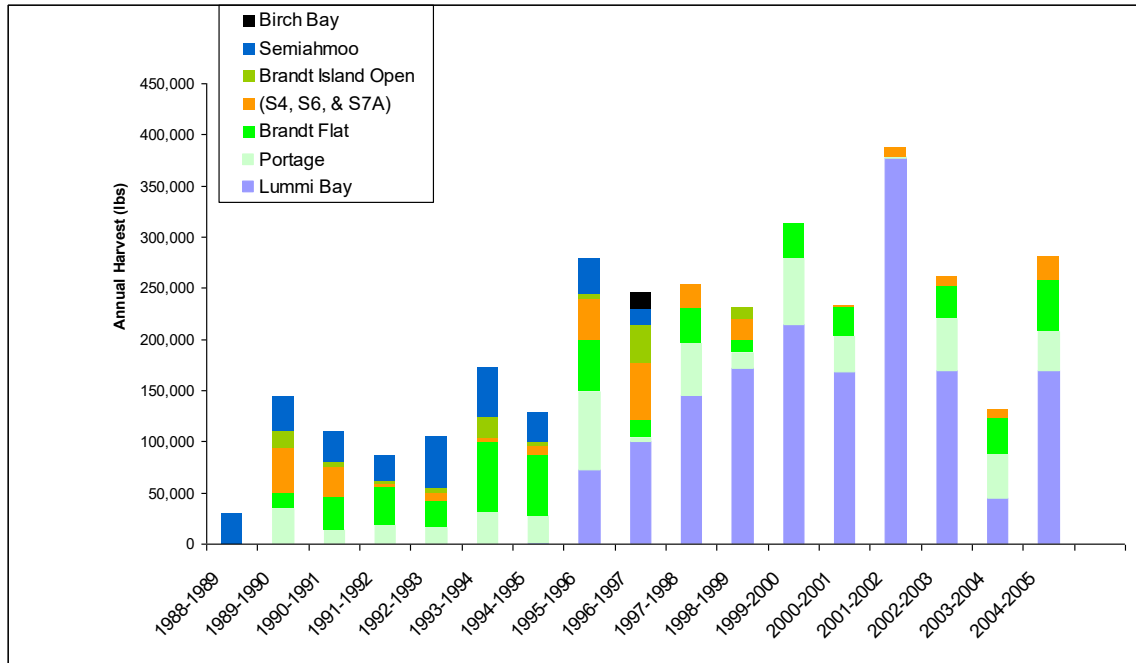


Figure 1. Recorded harvests since 1989 (Portage Beaches) and 1996 (Lummi Bay beaches).

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. In 2003 a portion of the restricted area in Portage Bay was reclassified to an approved status and much of the more productive area was thereby reopened. As of 2005, only Brant Island and the northernmost end of the Senior's Beach remains closed. In the 2000 – 2001 season almost no harvest was taken from Portage Bay. This closure was partly due to perceptions of a decline, but also from buyer preferences for larger, Lummi Bay clams. In the last three seasons, the harvest from Portage Bay has averaged 103,000 lbs and buyer preferences have returned to the more normal preference for smaller clams from Portage.

Harvest records for Lummi Bay beaches only go back as far as 1994-1995, when 780 lbs were reportedly harvested. The following season 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.

In an attempt to spread the harvest effort throughout the year, 'openings' during the year have sometimes been limited, and daily limits for diggers have also periodically been used.

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, records indicate that the lion's share of the harvest initially came from S1C, but more recently the effort has been focused on S1D and S1E. Following the first wide-scale survey of clam distributions in Lummi Bay (Dolphin, 2002) it was clear that there was no meaningful break in the population between areas S1D and S1E and, consequently, both of these areas are now managed as one area.

2004 – 2005 Harvest

285,003 lbs of Manila clams were harvested from reservation beaches in the past year (Figure 1). Of this, 169,607 lbs were harvested from Lummi Bay beaches, and 115,936 lbs were taken from Portage Bay beaches.

In Lummi Bay, the bulk of the harvest (168,205 lbs) was taken in northern Lummi Bay (S1D & S1E) with only 782 lbs being harvested from the central area of the bay (S1C). Based on survey results in 2004, Robertson Road (S1B) was not opened to harvest to facilitate stock recovery.

In Portage Bay the harvest was split mainly between Portage Spit (S5), where 38,399 lbs were harvested, and the approved portion of Brant Flats (S7D), where 49,764 lbs were harvested. A further 13,976 lbs were taken from the unsurveyed area in 21A-S6; and 9,461 lbs were taken from the unsurveyed area of S7A. Only 746 lbs were taken from the open portion of S7E.

Survey Aims

The purpose of the 2005 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 off-reservation beaches that have previously been harvested by Lummi clam diggers to determine if there is 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 ft² (Birch Bay, Portage Bay) or a 9 ft² (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 ± 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 shells of the manila clams were then measured, to the nearest 1mm, with a pair of plastic calipers with 1mm graduations. The dimension chosen for measurement this year was shell width. This was because comparative data on shell width and length measurements indicated that; overall, shell width is a marginally better predictor of actual clam weight than shell length (Unpublished data, Dolphin 2005). 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 widths were entered into a Microsoft Excel spreadsheet. In the past, Length-weight data from a WDFW Manila clam survey in Birch Bay were used to convert individual clam lengths into individual clam weights. However, in 2005 we collected our own size-weight data using an Acculab AL 203 electronic scale and freshly caught, live clams from Lummi Bay, Portage Bay, and Birch Bay State Park. Beach specific width weight relationships were used to derive clam weight from the field data that we collected.

Since the calipers we use in the field can only measure clams to the nearest 1mm increment, it is reasonable to assume that half of the clams that were in the 1mm size class equal to the legal limit would have been sublegal, and half were legal. Consequently, the weight for all threshold size clams was included when summing up legal biomass in each sample, but the weight for each of these threshold clams was halved. The threshold shell width (equivalent to a shell length of 38mm) was estimated to be 20mm at both Birch and Portage

Bays, while the more globular-shaped clams at Lummi Bay had a threshold shell width was 21mm.

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, longitude, 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 occurred. 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:

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

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:

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

And the Standard Error is calculated using the equation:

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

...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:

$$Var_w = s^2 \cdot \left(\sum_{i=1}^n w_i^2 \right) \quad \dots \text{Equation 4}$$

...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.

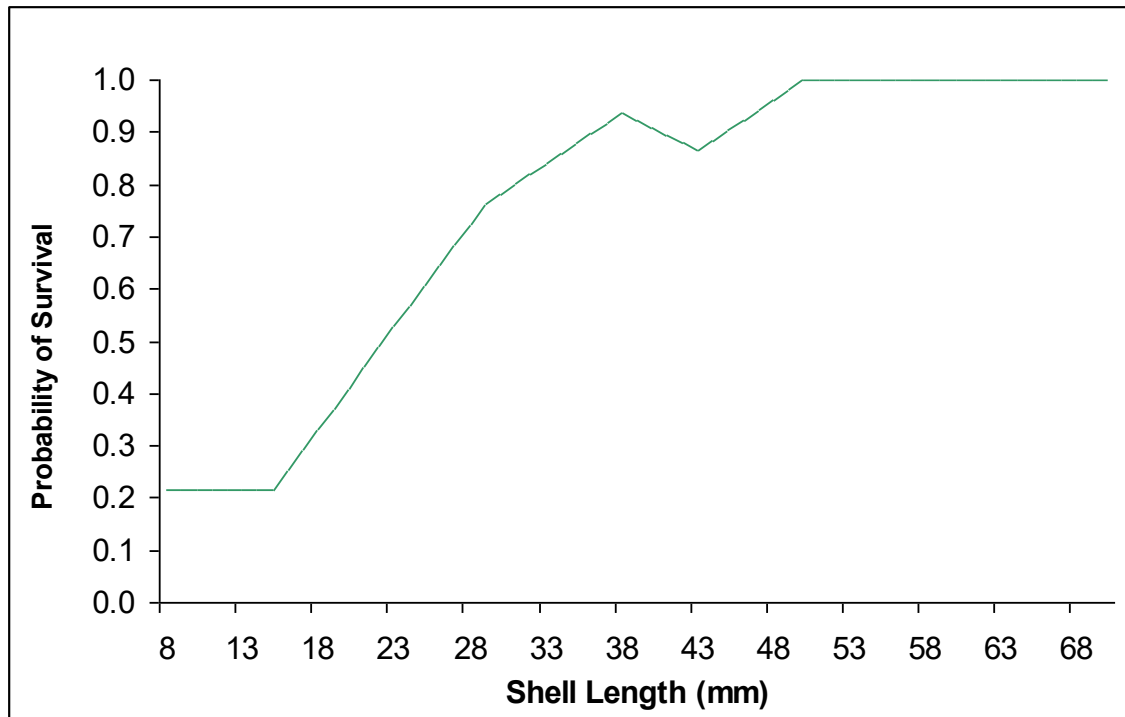


Figure 2. Survival rates used in calculating Production Estimates (from Dolphin, 2004b).

Previously we had used fixed survival rates for legal-sized and sub legal clams based on undocumented 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 this survival rate data is extremely limited and more work is needed to better understand this critical parameter.

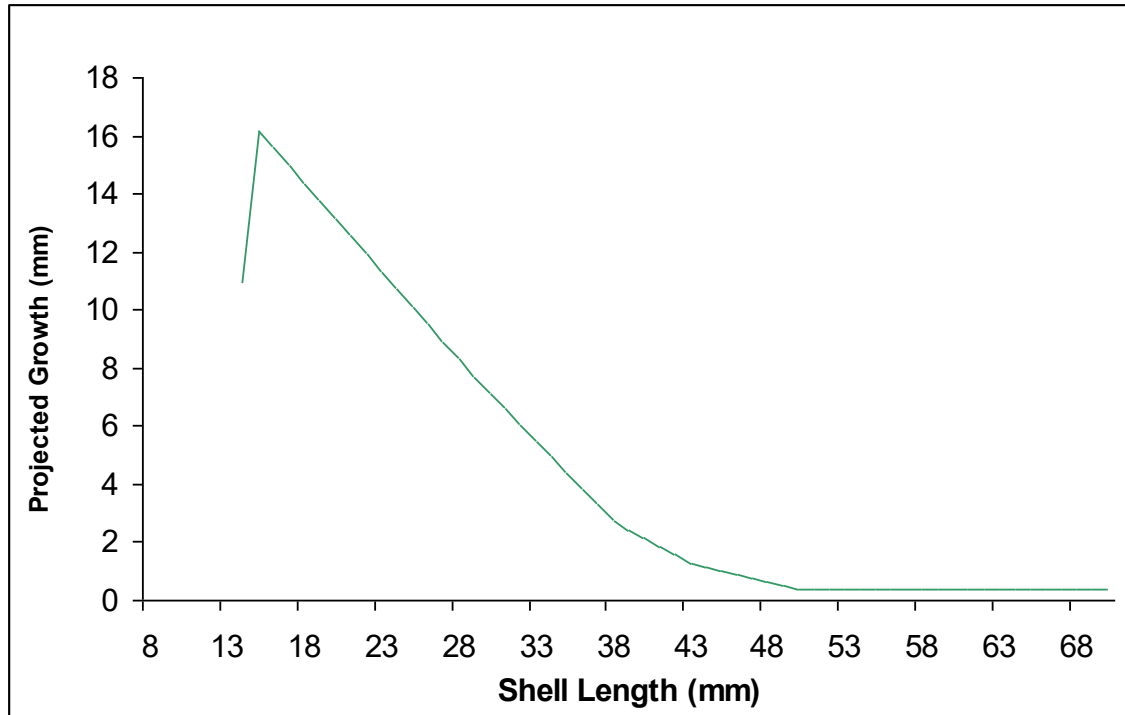


Figure 3. Annual size-specific growth rates used in calculating production estimates.

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. The relationships in figure 2 and 3 were converted to equivalent shell lengths for use in the production rate model.

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 the legal threshold (or above) after one hypothetical year was then 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.

Results

A total of 1,013 man-hours were spent surveying clam populations in 2005. Survey activities began on May 9th and continued through almost all of the available daylight tides until August 3rd. This year Lummi Natural Resources surveyed clam populations in Birch Bay State Park, Lummi Bay, and most of Portage Bay: including all of S6 and S7A for the first time. We were unable to survey along Lummi Shore Road because this was considered to be a low priority beach and resources were limited. 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. Summary of 2005 Survey Results.

Birch Bay								
Area Description	Thiessen Polygons	Individual Station Areas (ft²)	Acres surveyed	lbs/ft²	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
20A-060	529	2.25	36.8	0.0606	16.5%	81,106	97,133	113,160
Portage Bay								
Area Description	Thiessen Polygons	Individual Station Areas (ft²)	Acres surveyed	lbs/ft²	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S5	819	2.25	43.41	0.036415	13.3%	59,580	68,704	77,827
S6	245	2.25	14.55	0.051704	24.0%	24,919	32,779	40,640
S7A	144	2.25	6.71	0.051426	33.9%	9,930	15,030	20,129
S7D	887	2.25	68.75	0.054399	12.2%	143,051	162,931	182,811
S7E	447	2.25	47.24	0.031241	21.0%	50,813	64,297	77,780
All Combined	2,542		180.66	0.0437	16.1%	288,293	343,741	399,187
Lummi Bay								
Area Description	Survey Stations	Individual Station Areas (ft²)	Acres surveyed	lbs/ft²	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S1B	242	9	238.3	0.02328	16.0%	203,047	241,722	280,398
S1C	292	9	374.2	0.02384	28.7%	277,099	388,638	500,177
S1D & S1E	542	9	919.9	0.02555	11.9%	902,004	1,023,841	1,145,678
All Combined	1,076		1532.4	0.0248	16.4%	1,382,150	1,654,201	1,926,253
* Precision estimates used here are spatially weighted estimates derived from the Thiessen Polygon Analysis. See methods for fuller discussion of this parameter.								

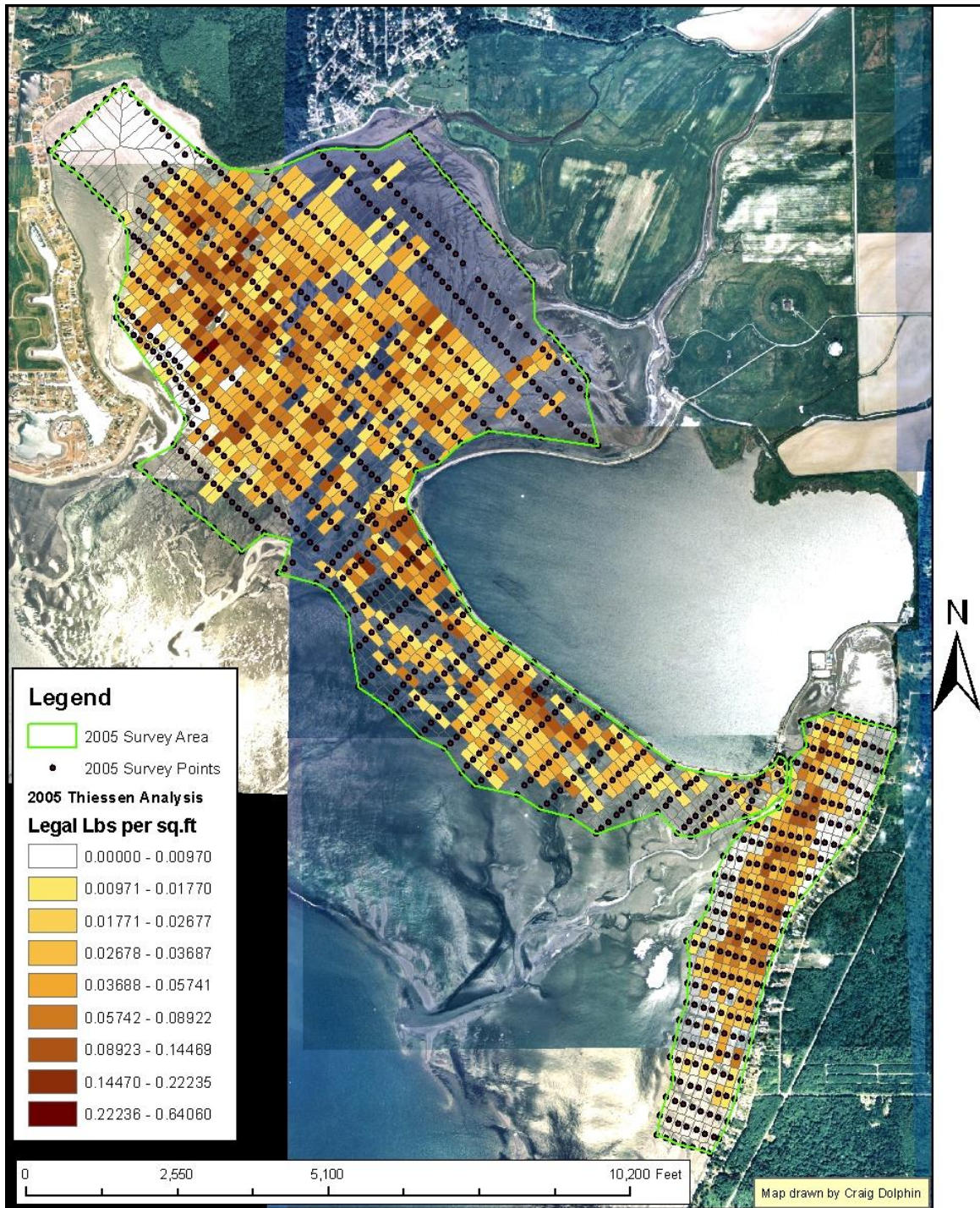


Figure 4. Legal-sized Manila Clam densities in Lummi Bay based on 2005 survey data.



Figure 5. Clam densities in Portage Bay based on 2005 survey data and interpolated using 3-pt kriging.

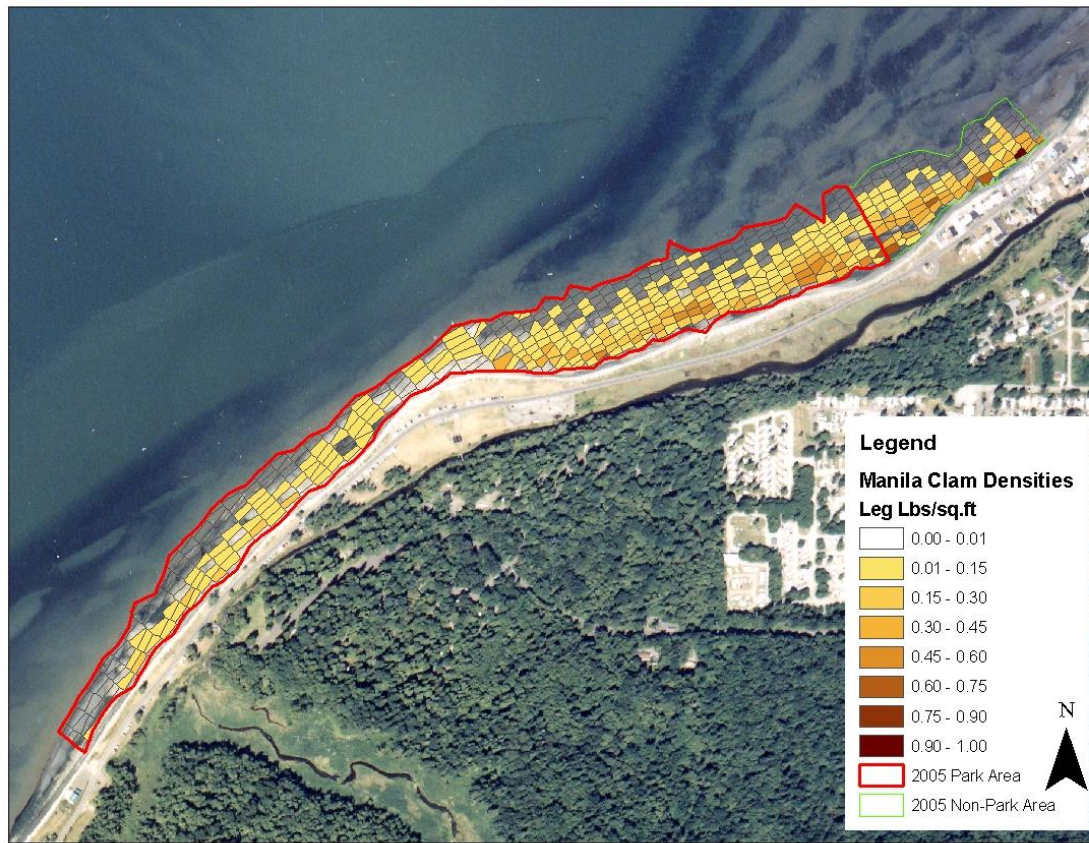


Figure 6. Clam densities at Birch Bay State Park from 2005 Lummi survey data.

Because the survey areas differed somewhat between the 2002, 2003, 2004, and 2005 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.

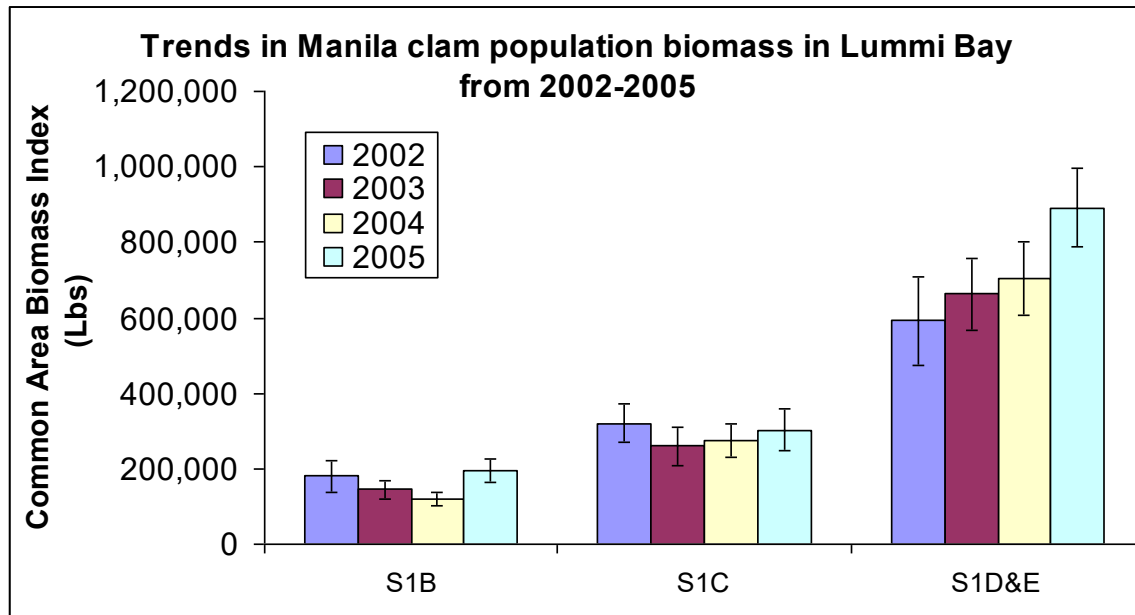


Figure 7. Relative change in legal clam biomass in Lummi Bay from 2002 to 2005 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

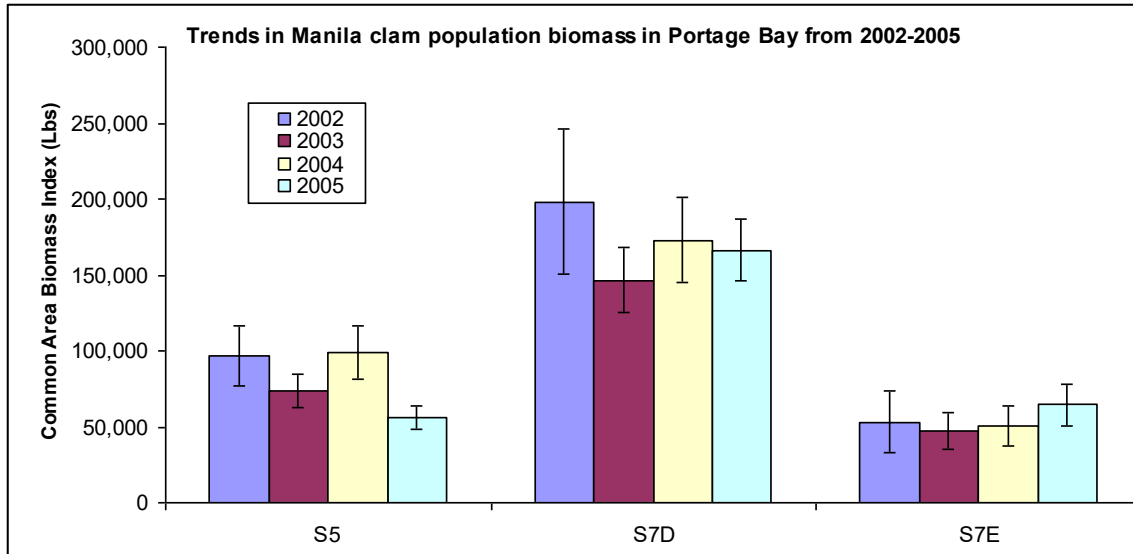


Figure 8. Relative change in legal clam biomass in Portage Bay from 2002 to 2005 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

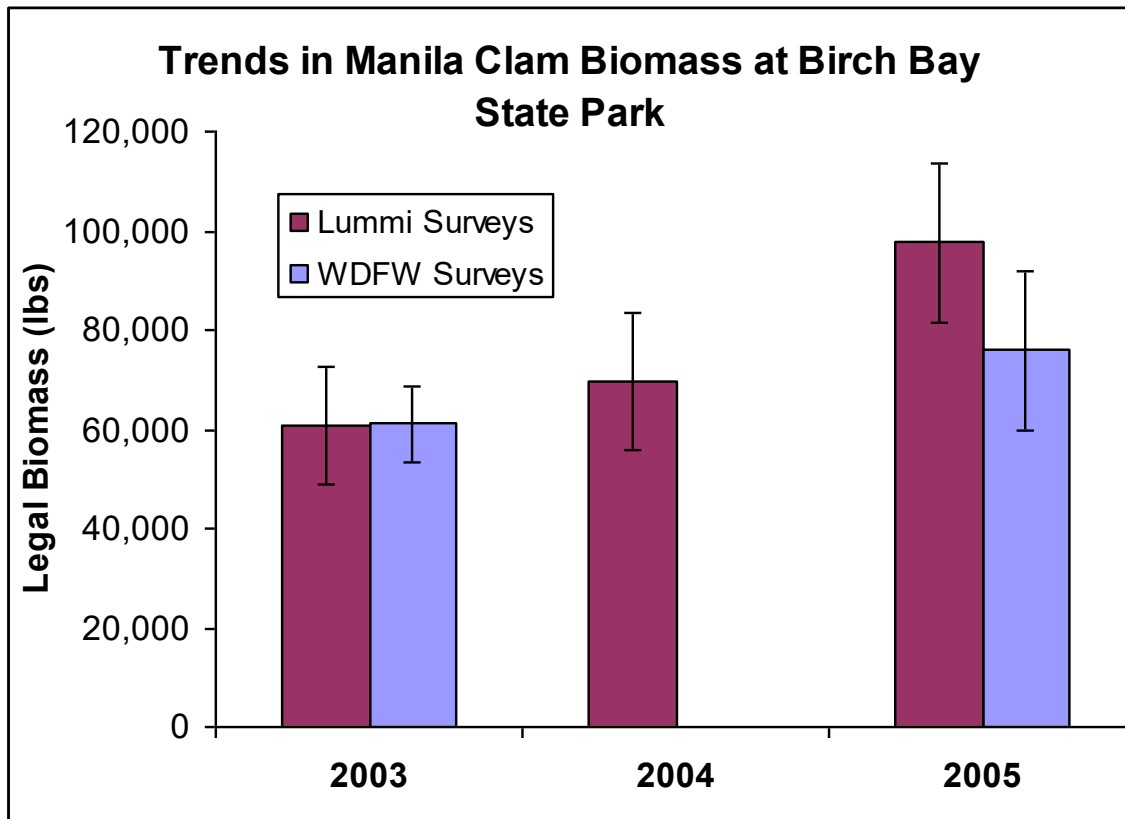


Figure 8. Relative change in legal clam biomass in Birch Bay from 2003 to 2005 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits. Data shows biomass estimates for the area within the state park boundaries only.

Table II. *Comparison of Production Estimates based on 2002 – 2005 Lummi Manila clam surveys.*

		2002 Production Est. (lb)	2003 Production Est. (lb)	2004 Production Est. (lb)	2005 Production Est. (lb)
Lummi Bay	S1B	35,254	30,237	28,466	28,490
	S1C	36,179	29,448	10,349	23,904
	S1D&E	100,012	77,488	89,299	109,684
Portage Bay	S5	49,701	41,703	34,617	18,249
	S7D	65,052	63,159	58,458	53,381
	S7E	16,040	32,371	27,162	31,794
Birch Bay State Park	060	N/A	49,266	61,824	49,013

Production estimates for each beach, based on the 2005 survey data, are presented in Table II along with the equivalent estimates based on the 2002, 2003, and 2004 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 has been surveyed each subsequent year.

Because the total biomass on some beaches has declined since 2002, and on other beaches has increased, the recommended harvest strategy for 2006 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 2005, are detailed in Table III.

Table III. *Recommended harvest targets based on 2005 survey data, by beach.*

Management Area	2005 Recommended Harvest
North Lummi Bay (S1D&E)	278,941
Mid Lummi Bay (S1C)	0
South-East Lummi Bay (S1B)	38,164
Portage Spit (S5)	10,000
Brant Flat (S7D)	37,480
Brant Flats (S7E*)	20,000
Birch Bay State Park	32,053
* Assumes Brant Island is re-approved by WA DOH	
Overall Total	416,638

Discussion

Survey results showed the first signs of rebound in S1B and S1C since harvest efforts in those areas was scaled back over the last couple of years. By contrast, the population on Portage Spit appears to have dropped precipitously even though the reported harvest pressure was not much more than average, historically speaking, and the harvested amount should have been replaced by new recruits that were sub legal in the 2004 survey. Exactly why this population has declined so much is hard to say. One explanation could be that the 2004 survey result was unrealistically optimistic and the 2005 survey result just looks bad by comparison. Another explanation could be that significant harvest of Manila clams occurred on the spit that was not reported (perhaps C&S?). Alternatively, unusually extensive digging for Butter clams could have accidentally killed large numbers of Manila clams. There were also several tire tracks on the spit on the clam beds themselves. It is possible that people driving on the clam beds contributed to the reduction in the clam population...though I think it is unlikely that the entire amount could be due to this.

Almost no harvest was taken in the open portion of 21A-S7E once again but the population grew only slightly. However, this is the first population increase in this unharvested beach that we have noticed since we began surveying in 2002. Given the lack of substantial harvest activities and only small changes 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 relatively stable, then it could be that the area is at or near the carrying capacity. 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. However, we have no indication that a winterkill occurred between the 2004 and 2005 surveys in this area.

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 method to set the harvest equal to 33% of the surveyed legal biomass.

If market conditions and other factors allow, a harvest of over 400,000 lbs is possible this year. This would be the largest tribal harvest ever. However, it should be recognized that such a large harvest is possible, in large part, because of accumulated biomass in northern Lummi Bay. It is unknown whether such a high level of harvest will be sustainable in the long term without severely impacting the resource. We know from size-frequency data for the last four years that the recruitment of seed clams in 2003 and 2004 was very low relative to that seen in 2002 and 2005. This may indicate that we have two weak year classes that will be reaching legal size in 2006 and 2007, followed by a much larger cohort in 2008. Given this information, it may be prudent to set conservative harvest targets in the next couple of years.

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