2007 Lummi Clam Survey Summary

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Executive Summary

In 2007 Lummi Natural Resources surveyed clam densities on several important reservation beaches. A total of 1,819 samples were dug, which is equivalent to 11,619 square feet. Legal biomass estimates for each area were: Lummi Bay - 1,149,489 lbs, and Portage Bay – 260,581 lbs.

Results for most management areas, except northern Lummi Bay, showed modest increases or very slight decreases from densities observed in the previous most recent survey.

Recommended harvest levels would provide **235,856** lbs in the coming year. This compares to last year's harvest of 261,238 lbs for the same beaches. However, these figures do not include any harvest taken from Lummi Shore Road (S4), Inside Portage Bay (S6), or Inside Brant Point (S7A. Typically, S4, S6, and S7A combined add a further 10,000 lbs per 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).

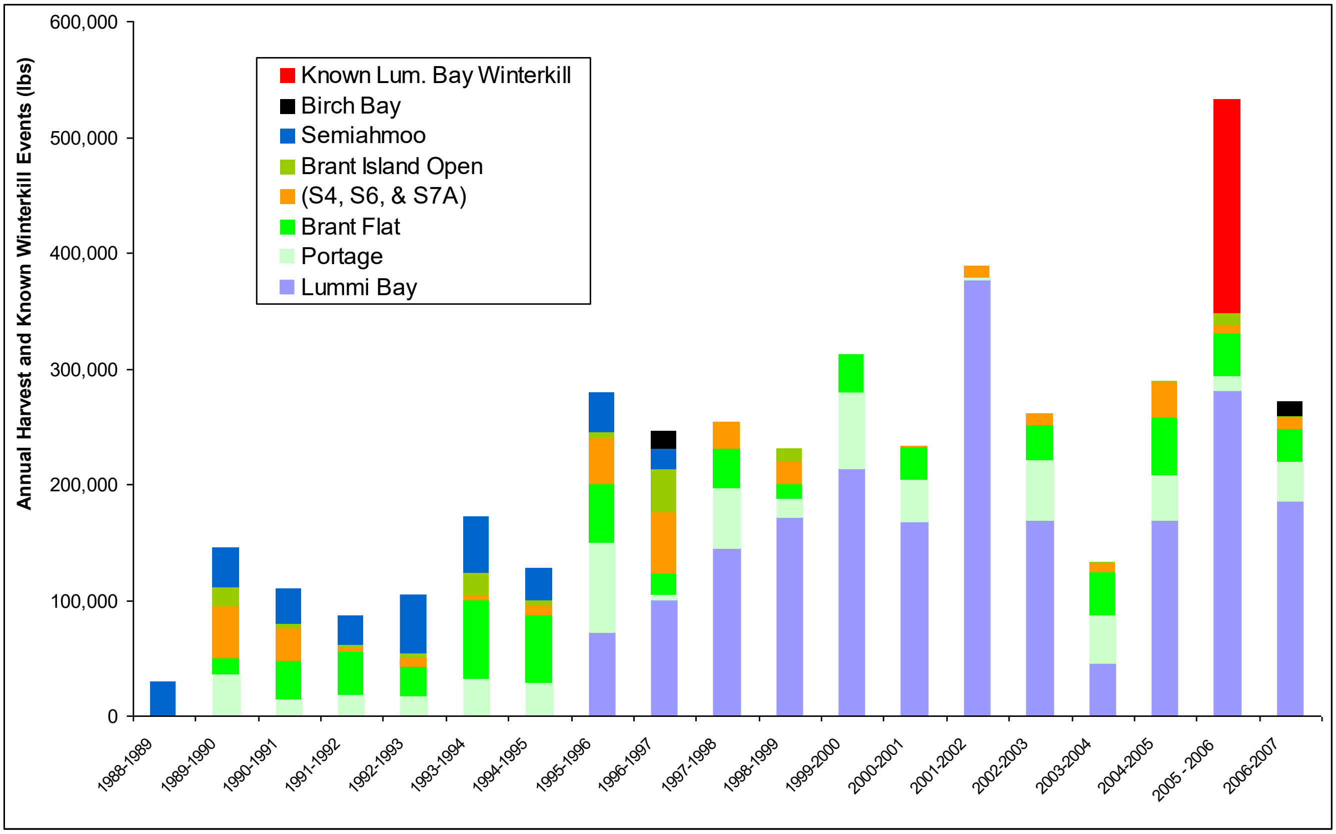

Figure 1. Recorded harvests since 1989 (Portage Beaches) and 1996 (Lummi Bay beaches).

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.

Portage Bay Clam Harvest History

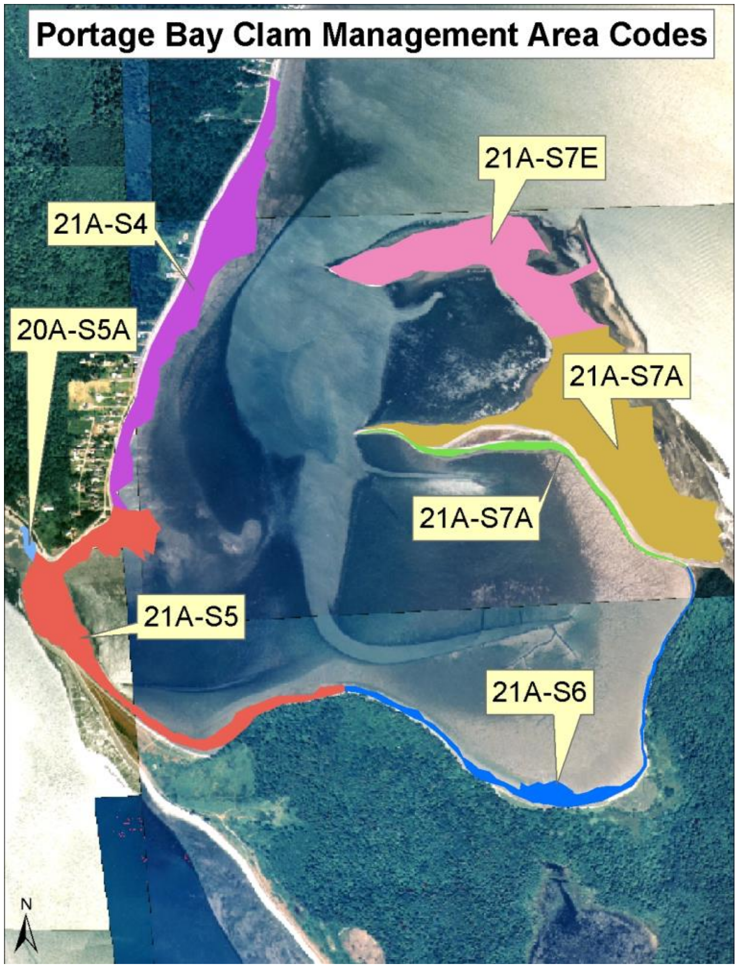

Figure 2. Portage Bay Clam Management Area Codes

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. Finally, in June 2006, Brant Island and the northernmost end of the Senior's Beach were also reclassified to an approved classification. 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 due to buyer preferences for the larger, Lummi Bay clams in that year. In the last four seasons, the harvest from Portage Bay has averaged 99,962 lbs and buyer preferences returned to the more normal inclination towards the smaller clams from Portage Bay.

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.

Lummi Bay Clam Harvest History

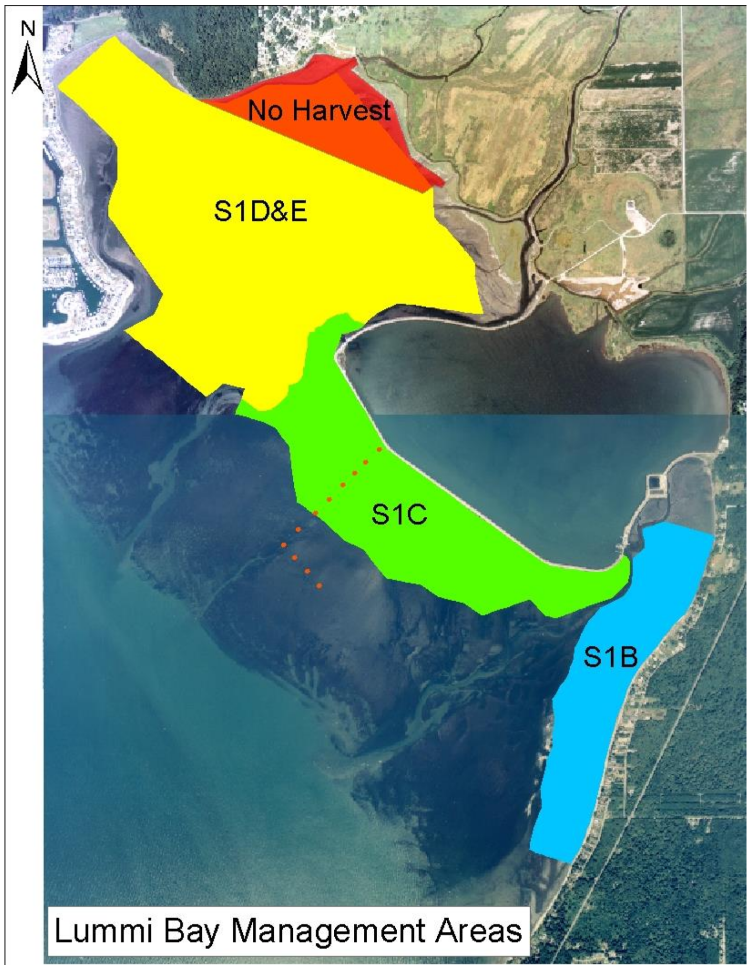

Figure 3. Lummi Bay Clam Management Area Codes

Harvest records for Lummi Bay beaches only go back as far as 1994-1995, when 780 lbs were 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. Surveys showed increasing clam biomass in northern Lummi Bay from 2002 onwards with a peak abundance in the summer of 2005. Accordingly, harvest amounts also increased and reached 280,000 lbs in the 2005-2006 season. Unfortunately, a significant winter-time die-off of clams occurred in the same season (Dolphin, 2005a) leading to a removal of 465,000 lbs of legal-sized biomass from Lummi Bay (Harvest and winterkill combined). A subsequent survey in 2006 confirmed the extent of the winterkill event and showed significant drop in the clam biomass that is similar in magnitude to the expected harvest for one year. Furthermore, sub legal-sized clams also perished in the winterkill event leading to predictions of reduced recruitment to the fishery in the 2006-2007, 2007-2008, and 2008-2009 seasons (newly settled clams are estimated to take 3 – 3 ½ years to reach legal size).

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. Harvest effort in S1C has been limited to seniors or diggers with medical issues since 2005 to allow the beds to recover. However, recovery on this area was setback by the winterkill event. Harvest effort in S1B (Robertson Road) has been sporadic as survey data suggests that biomass in this area is more sensitive to harvest activities than fish ticket data would suggest should be the case. It is possible that unreported, illegal harvesters may be targeting this area in particular.

General Harvest Strategy

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. Generally speaking, diggers collectively choose where and when to focus harvest efforts temporally and spatially until the harvest targets have been met. However, clam digger attendance and participation at scheduled meetings remains low.

2006 – 2007 Harvest

259,137 lbs of Manila clams were harvested from reservation beaches in the past year (Figure 1). Of this, 186,592 lbs were harvested from Lummi Bay beaches, and 72,545 lbs were taken from Portage Bay beaches. Lummi diggers also harvested a further 12,070 lbs of clams from Birch Bay State Park. This is the first off-reservation harvest opportunity for tribal diggers since the 1996-1997 season.

In Lummi Bay, the bulk of the harvest (182,000 lbs) was again taken in northern Lummi Bay (S1D & S1E) with 4,592 lbs being harvested from the central area of the bay (S1C). Based on survey results in 2006, Robertson Road (S1B) was not opened in 2006-2007 in order to harvest to facilitate ongoing stock recovery after the 2005 winterkill.

In Portage Bay the harvest was split mainly between Portage Spit (S5), where 32,927 lbs were harvested, and the approved portion of Brant Flats (S7D), where 27,627 lbs were harvested. Only 2,022 lbs were taken from 21A-S7E (Brant Island). A further 9,969 lbs were taken from the unsurveyed areas of 21A-

S6 (Inside Portage Bay), 21A-S7A (Inside Brant Point), and 21A-S4 (Seniors Beach, Lummi Shore Road).

Survey Aims

The purpose of the 2007 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, how last year's harvest had affected clam densities on the reservation, and whether populations were recovering from the 2005 winterkill as expected.

In 2006 we trialed contracting out the routine aspects of the clam survey to a contractor (Wilbert Hillaire) who employed key staff members who had previously worked for LNR as clam surveyors. After training the contractor's staff as to the methods and protocols to be used, data subsequently provided by the contractor was compared to data collected by LNR to ensure accuracy. The final result of the trial was deemed successful and the same approach was taken in 2007 using the same contractor and key staff. The methods and protocols used by the contractor are summarized below. Unfortunately, funding for the work was not made available until late July when few daytime tides remained. Consequently, it was not possible to survey Brant Island or Birch Bay State Park at all, and only ~50% of Brant Flats was surveyed.

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 50 steps apart in the Portage area surveys, 200 steps in Lummi 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 15 - 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 (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 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 shell 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 Access database. 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 database was used to export a table with the following columns: latitude, longitude, and legal pounds per square foot. This dbf file was imported into ESRI ArcMap 9.1 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 9.1 (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:

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

…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.

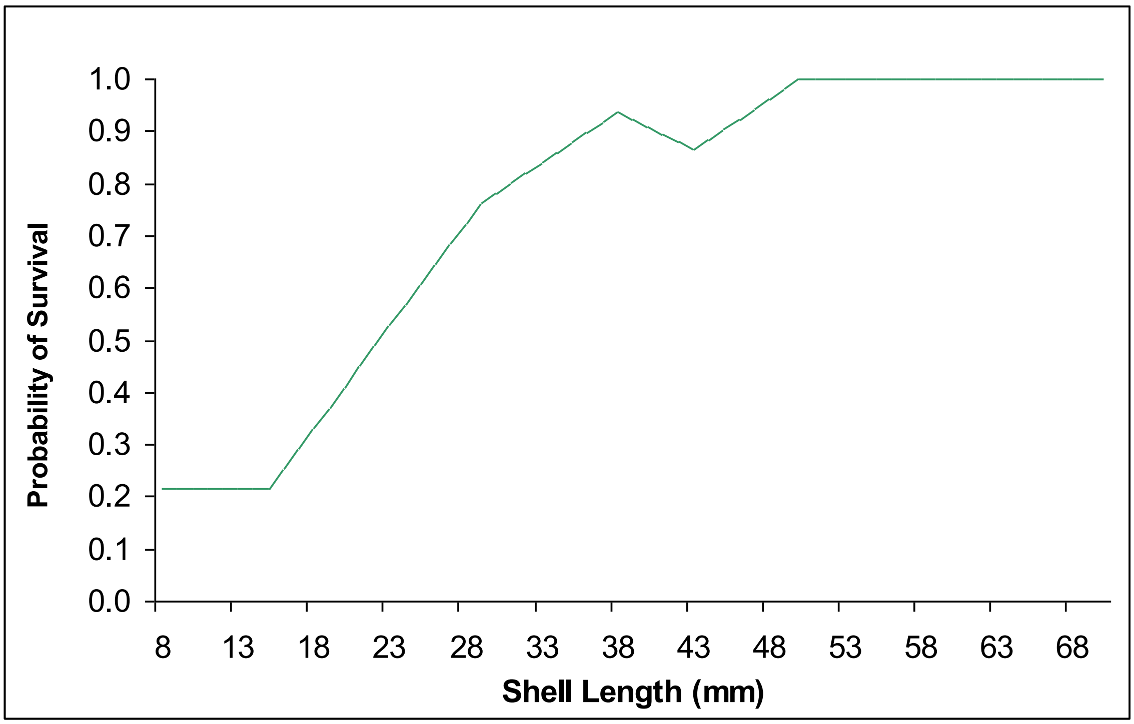

Figure 4. Survival rates used in calculating Production Estimates (from Dolphin, 2004b).

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 4 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.

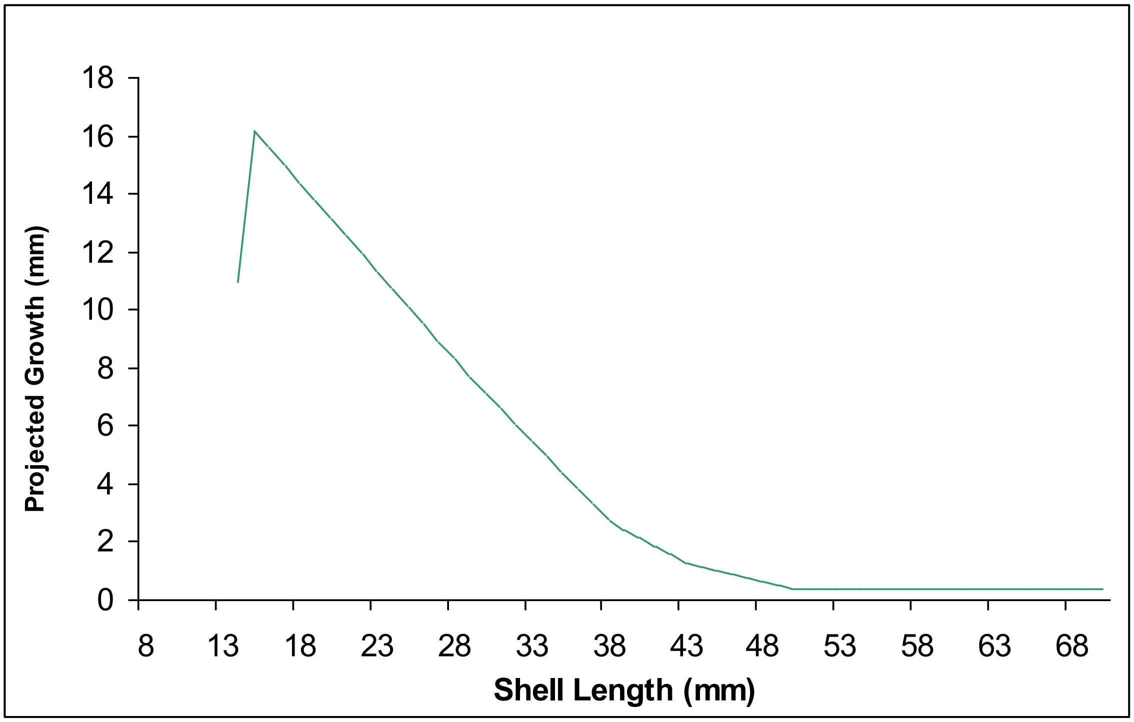

Figure 5. Annual size-specific growth rates used in calculating production estimates.

Annual growth rates used to 'grow-out' the observed size-frequency distribution by one year are shown in Figure 5. These values were obtained from the same grow-out experiment as used to determine the survival rates shown in Figure 4. The relationships in figures 4 and 5 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

Survey activities began on July 31st and continued through almost all of the available daylight tides until September 6th. This year clam populations were surveyed in Lummi Bay, and the most important Portage Bay beaches (Portage Spit and Brant Flat). Survey results are presented in Table I. Clam density maps for Lummi Bay, Portage Spit, and Brant Flat are presented in Figures 6,7, and 8 respectively.

Table I. *Summery of 2007 Survey Results.*

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*
S4	Not Surveyed							
S5	**376**	**2.25**	22.46	0.07870	12.38%	67,476	**77,009**	86,543
S6	Not Surveyed							
S7A	Not Surveyed							
S7D	**328**	**2.25**	68.75	0.06380	17.29%	147,849	**183,572****	219,296
S7E	Not Surveyed							
All Combined	**704**		91.21			215,325	**260,581**	305,839

Lummi 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*
S1B	**355**	**9**	240.6	0.02504	14.6%	224,106	**262,453**	300,799
S1C	**285**	**9**	291.8	0.02176	20.8%	219,181	**276,664**	334,146
S1D & S1E	**475**	**9**	946.8	0.01480	15.9%	513,603	**610,372**	707,141
All Combined	**1,115**		1,479.2		16.4%	956,890	**1,149,489**	1,342,086

* Precision estimates used here are spatially weighted estimates derived from the Thiessen Polygon Analysis. See methods for fuller discussion of this parameter.
** Biomass Estimate for S7D has been adjusted based on a common-area analysis for the surveyed area to also estimate abundance in the unsurveyed portion of S7D.

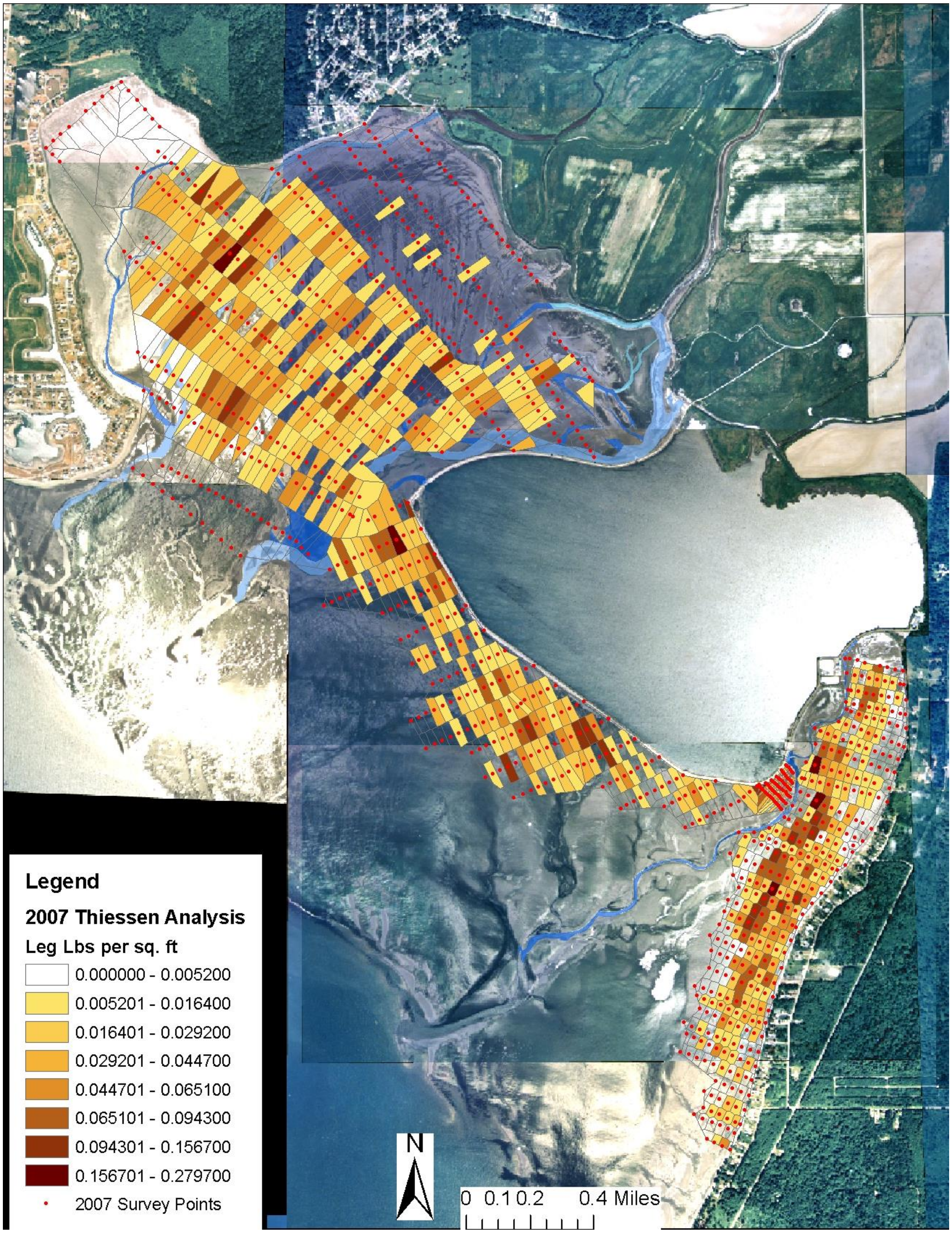

Figure 6. Legal-sized Manila Clam densities in Lummi Bay based on 2007 survey data.

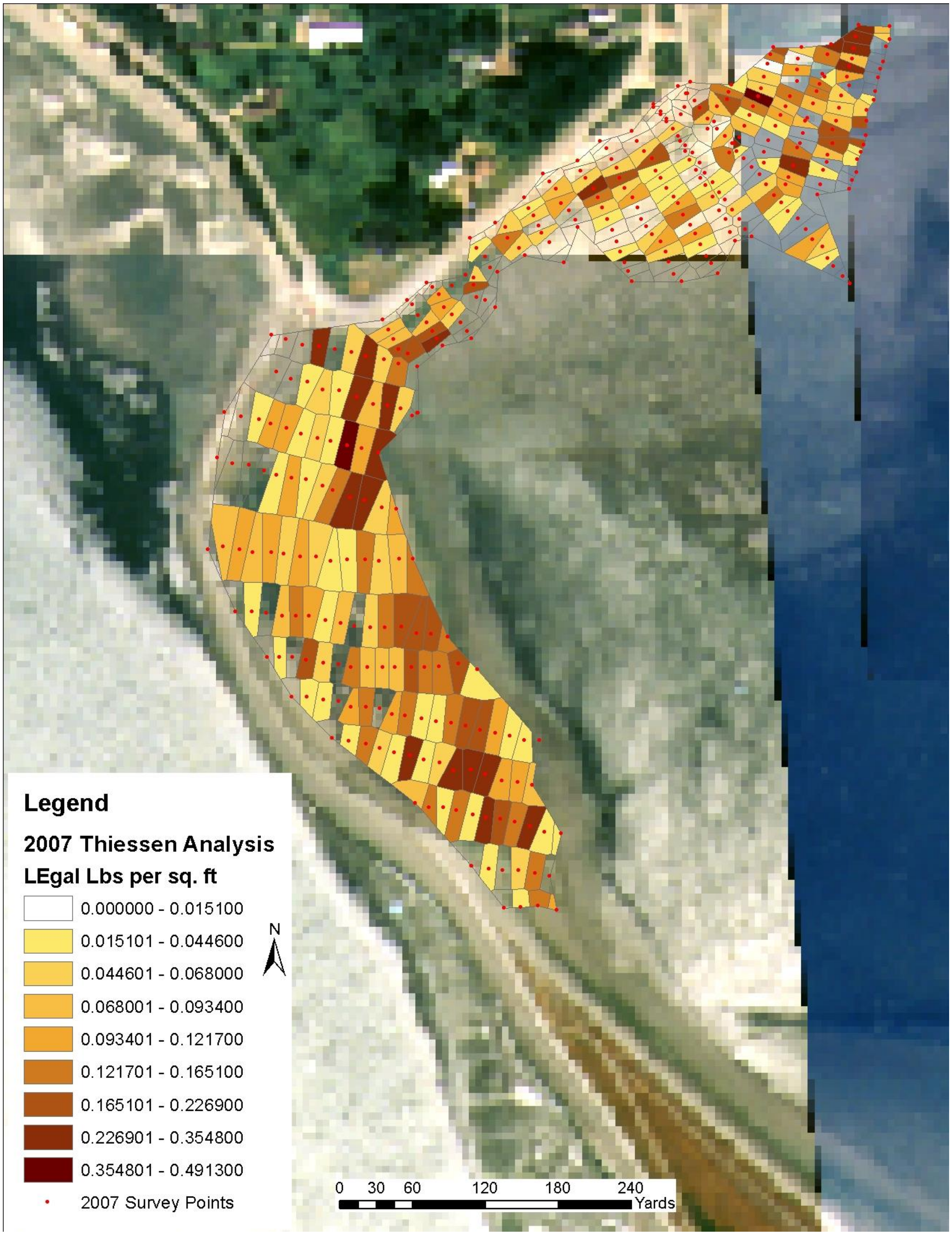

Figure 7. Clam densities at Portage Spit based on 2007 survey data.

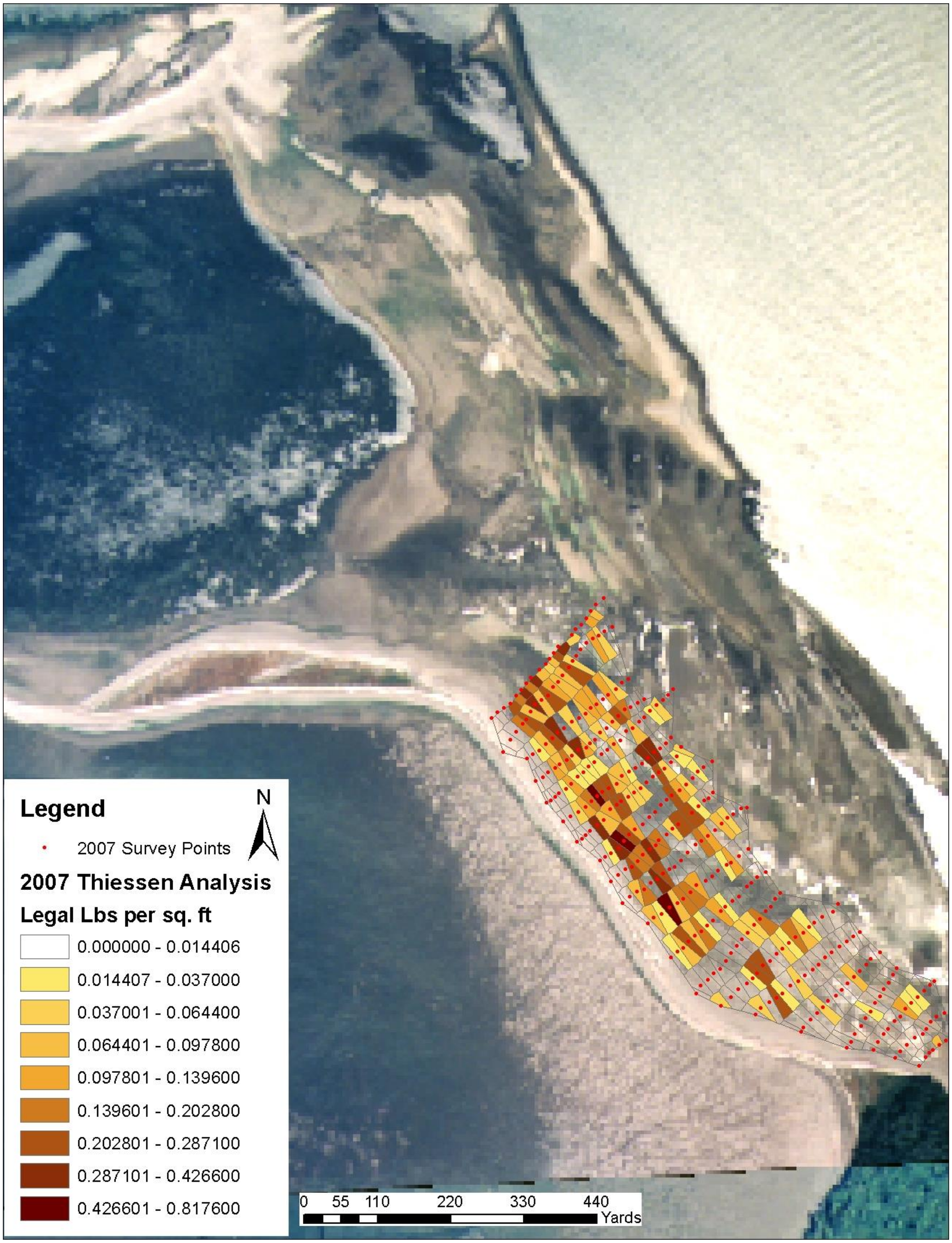

Figure 8. Clam densities in a portion of Brant Flat from 2007 Lummi survey data.

Because the survey areas differed somewhat between the 2002, 2003, 2004, 2005, 2006, and 2007 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 9 shows the relative change in the biomass present in the each management area surveyed in Lummi Bay, and Figure 10 shows relative change in biomass in management areas in Portage Bay.

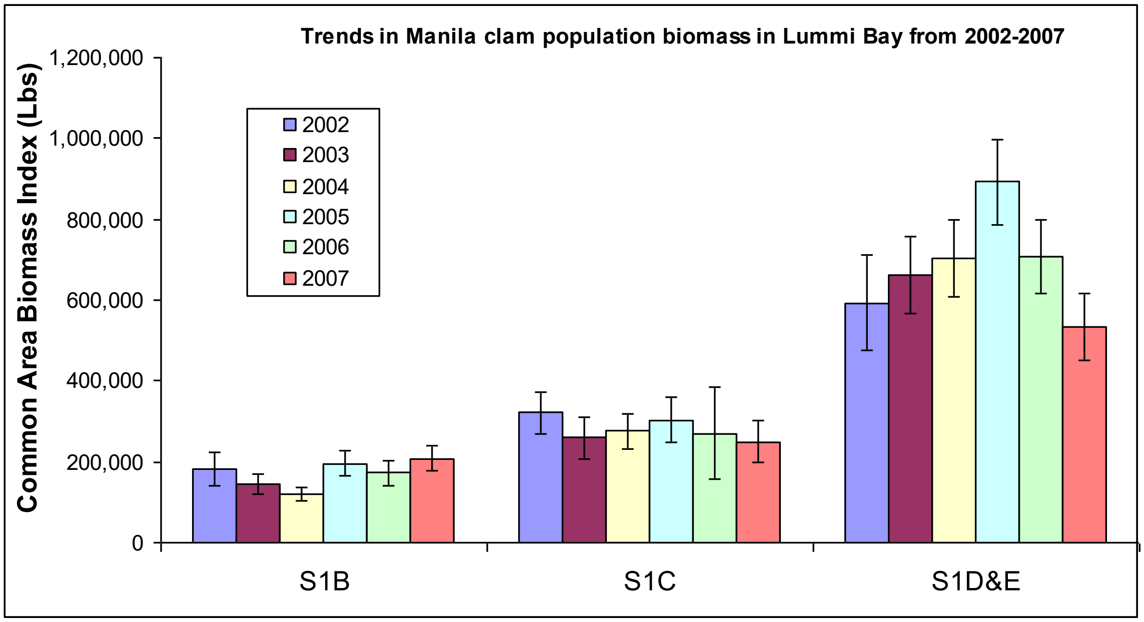

Figure 9. Relative change in legal clam biomass in Lummi Bay from 2002 to 2007 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

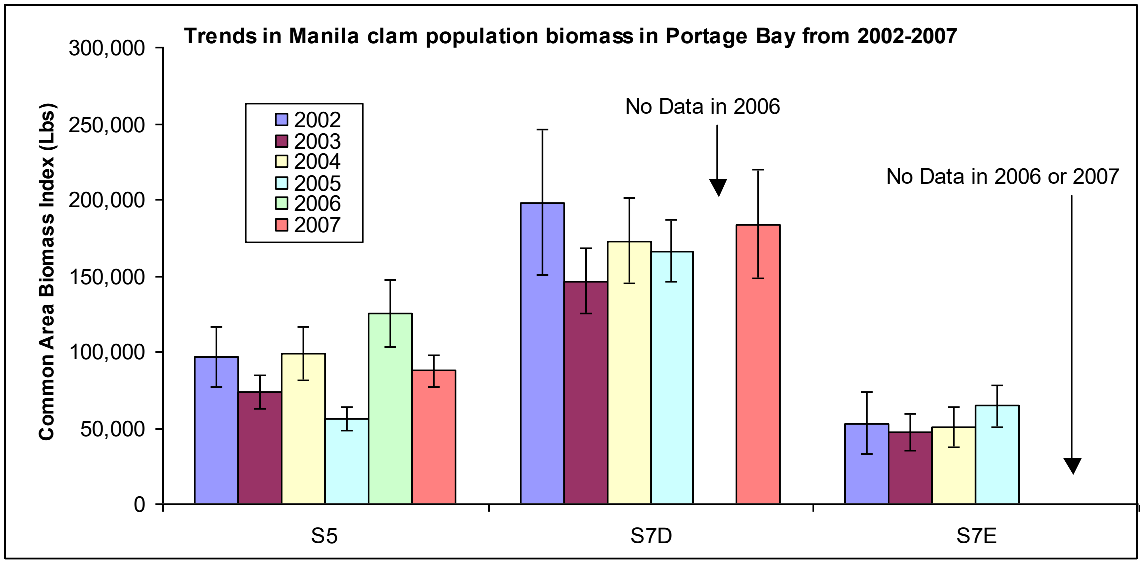

Figure 10. Relative change in legal clam biomass in Portage Bay from 2002 to 2007 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

Table II. *Comparison of Production Estimates based on 2002 – 2007 Lummi Manila clam surveys.*

Beach		Production Estimates By Survey Year (lbs)					
		2002	2003	2004	2005	2006	2007
Lummi Bay	S1B	35,254	30,237	28,466	28,490	17,531	19,657
	S1C	36,179	29,448	10,349	23,904	41,033	18,529
	S1D&E	100,012	77,488	89,299	109,684	81,210	55,858
Portage Bay	S5	49,701	41,703	34,617	18,249	31,903	29,910
	S7D	65,052	63,159	58,458	53,381	N/A	28,236
	S7E	16,040	32,371	27,162	31,794	N/A	N/A
Birch Bay State Park	060	N/A	49,266	61,824	49,013	N/A	N/A

Production estimates for each beach, based on the 2007 survey data, are presented in Table II along with the equivalent estimates based on the 2002 – 2006 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 except 2007.

Because the total biomass on some beaches has declined since 2002, and on other beaches has increased, the recommended harvest strategy for 2008 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 2007, are detailed in Table III and shown compared to previous harvests for comparison in Figure 11.

Table III. *Recommended harvest targets based on 2007 survey data, by beach.*

Management Area	2008 Recommended Harvest
North Lummi Bay (S1D&E)	**55,858**
Mid Lummi Bay (S1C)	**10,000**
South-East Lummi Bay (S1B)	**47,708**
Portage Spit (S5)	**29,910**
Brant Flat (S7D)	**50,000**
Brant Flats (S7E*)	**20,000**
Birch Bay State Park	**22,380***
Overall Total	**235,856****

*** Based on a 75% share of WDFW's surveyed biomass using a 33% per year allowable harvest formula**
****Excludes clams harvested from S4, S6, or S7A**

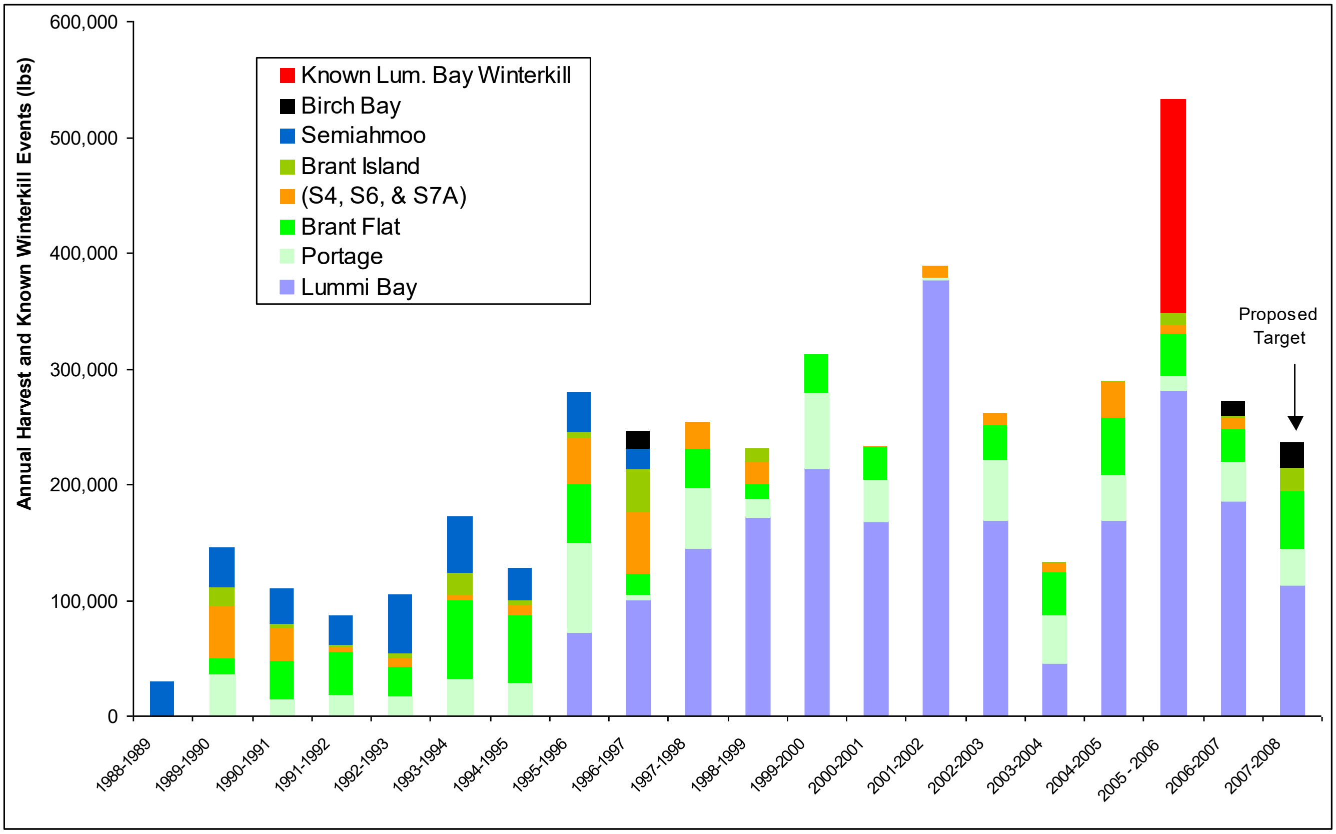

Figure 11. Comparison of proposed harvest targets to harvests in previous years. Proposed targets do not include any clams harvested in S4, S6, or S7A.

Discussion

Survey results showed some rebound in S1B in response to no harvest in that area in 2006-2007. Unfortunately, S1C appears to have declined slightly further despite only a very light harvest, and S1D&E has declined markedly for the second year in a row and now appears to have lost all the biomass gains since 2002. This means that there is no accumulated biomass above the 2002 level that can be harvested in addition to the estimated natural production of the area thus reducing the harvest targets for northern Lummi Bay in Table III. These results confirm that the 2005-winterkill event severely impacted sublegal clams and it is likely that worse than usual recruitment to the fishery will continue into next season as well.

The situation on Portage Spit was unexpectedly weaker than anticipated given that the harvest of 32,000 lbs was close to the long term average for the area and also the estimated productivity for the beach based on the 2006 survey. The survey results for 2006 and 2007 are statistically different ($p<0.05$) indicating that there is a real reduction in the biomass compared to 2006. However, the actual biomass present in 2007 is close to the average for the preceding 5 year period.

Brant Flats appears to have slightly increased in biomass since the 2005 survey and is getting close to reaching the 2002 biomass estimate again. However, because only half of the area was surveyed in 2007 it is possible that spatial differences in digger-effort and survey effort may mean that the biomass estimate is potentially flawed. Certainly, the much lower productivity estimate in 2007 may be the result of spatial patterns in recruitment interacting with an incomplete coverage of the entire area. Consequently, I think that risking a higher than usual target of 50,000 lbs for this area might be acceptable; especially given the need to make up for the much reduced harvest target in northern Lummi Bay. This harvest is much higher than the average for this area but the harvests for this area for some of the last few years have been reduced due to fecal coliform closures.

Although Brant Island was open again this year, only a little over 2,000 lbs was harvested compared to 10,000 lbs in the previous season. Although there is no survey data from 2006 and 2007, this indicates that the diggers did not find Brant Island to be particularly lucrative digging even after such a long closure period and corroborates the low productivity estimates from surveys conducted from 2002 – 2005.

In a previous survey report (Dolphin 2005b) I noted that:

"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."

The first two predictions appear to have been particularly accurate for recruitment in northern Lummi Bay, and probably made worse by the terrible winterkill in 2005. Unfortunately, because of the timing of the winterkill, we may not see a 'good' recruitment year in 2008 after all, and the survey data from 2007 indicates that this is likely to be so.

Recruitment and Potential for Enhancement

The number of seed clams settling naturally on reservation beaches is extremely hard to quantify using stock assessment survey methodology. This is because seed clams are usually so small that they are very hard to separate out from the substrate visually, and there is insufficient time to sift the substrate looking for them. However, in specific quadrat locations where the substrate contains sufficient water, a portion of the seed clams can be found visually when they get separated from the substrate in much the same way that goldminers 'pan' for gold. Even though we know we will be missing the majority of seed clams, we record these clams anyway to get a feel for relative abundance of seed clams each year.

We can calculate the number of seed clams per square foot that were seen in the survey, and thereby estimate the total number of seed clams present in the area if we are prepared to estimate what percentage of the seed clams we are likely to see. If you assume that we see one in three seed clams (probably a very optimistic estimate…I expect the number to be much lower for most quadrats), then you would estimate that the number of seed clams present in northern Lummi Bay alone would be anywhere from a minimum of 2.3 million in 2006 to as many as 178 million in 2005.

The Lummi hatchery sells manila clams of the same size for approximately $8/1,000 seed clams. If one were to spend $50,000 on seed clams you would end up with around 6.25 Million seed clams. In a particularly bad natural recruitment year like 2006, this might increase the total number of seed clams four-fold. However, in a good year like 2005 or 2002, this represents an increase of only 4% of the total. In fact, to match just one 'good' year in northern Lummi Bay, you would need to spend $1.4 million and probably increase the size of the hatchery to produce that number of seed.

Using an estimate of 64 million seed per year (average of three years data assuming a 30% finder rate) and an estimate of 1.4 million adults harvested per year (average harvest in lbs in last two years divided by the weight of a 38mm shell length clam), this indicates that 'average' unprotected survival of seed clams is approximately 2.2% (similar to the 3% finding by Michael Cochrane in 1995). This would indicate that the return on investment for enhancement in Lummi Bay would be around -42%: in other words, for every dollar you spend you'd get back ~ 58 cents.

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