2008 Lummi Clam Survey Summary

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Executive Summary

In 2008 Lummi Natural Resources surveyed clam densities on several important reservation beaches. A total of 2,507 samples were dug, which is equivalent to 12,822 square feet. Legal biomass estimates for each area were: Lummi Bay - **1,166,425** lbs, and Portage Bay – **227,408** lbs.

Recommended harvest levels would provide **197,130** lbs in the coming year. This compares to last year's harvest of 204,548 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 although 28,228 lbs were reported from those beaches last 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).

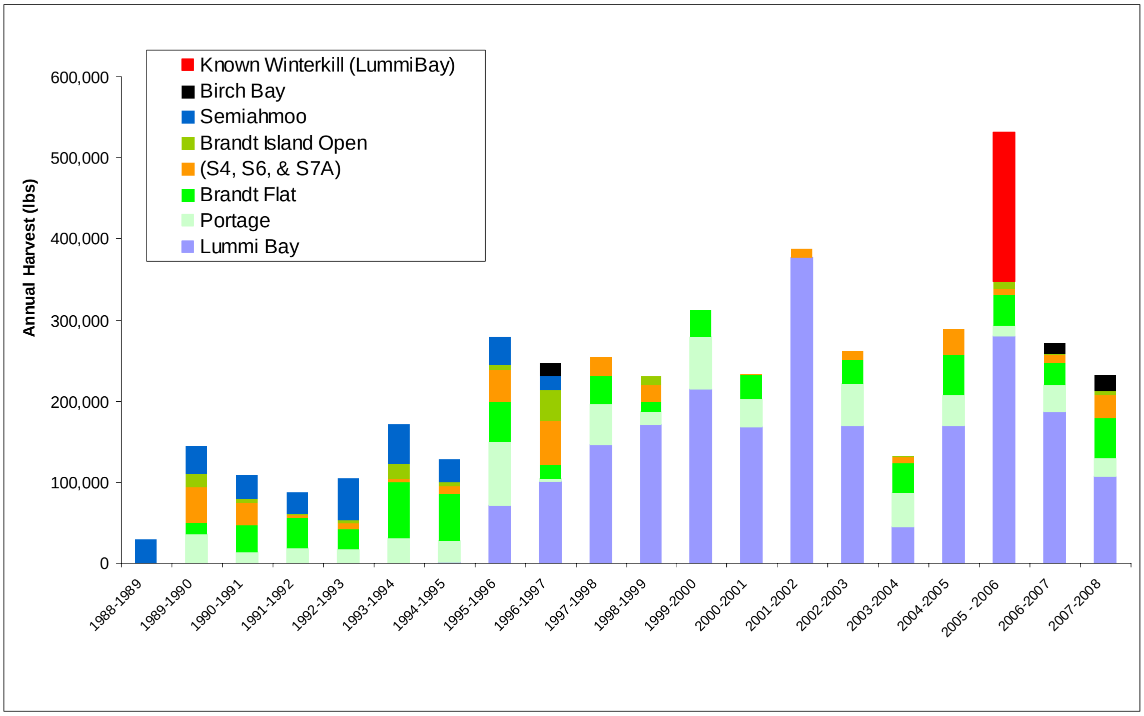

Figure 1. Recorded harvests (and significant known natural mortality events) since 1989 (Portage Beaches) and 1996 (Lummi Bay beaches).

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

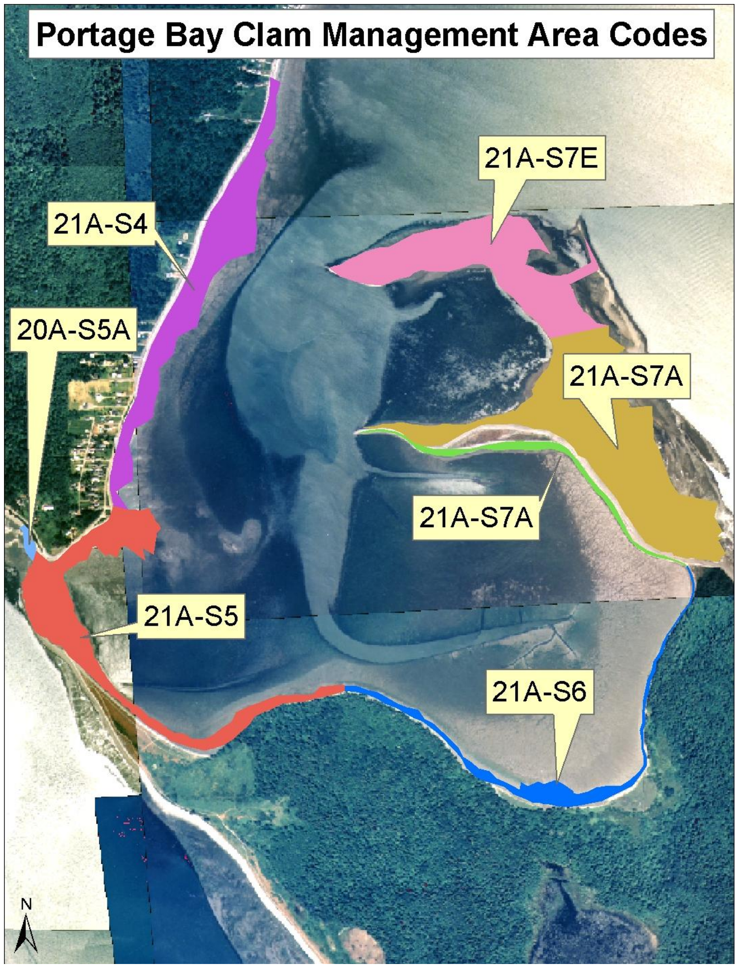

Figure 2. Portage Bay Clam Management Area Codes

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 primarily due to buyer preferences for the larger, Lummi Bay clams in that year. From 2002-2007, the harvest from Portage Bay averaged 98,654 lbs and buyer preferences reverted to a preference for smaller clams from Portage Bay rather than large Lummi Bay clams.

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

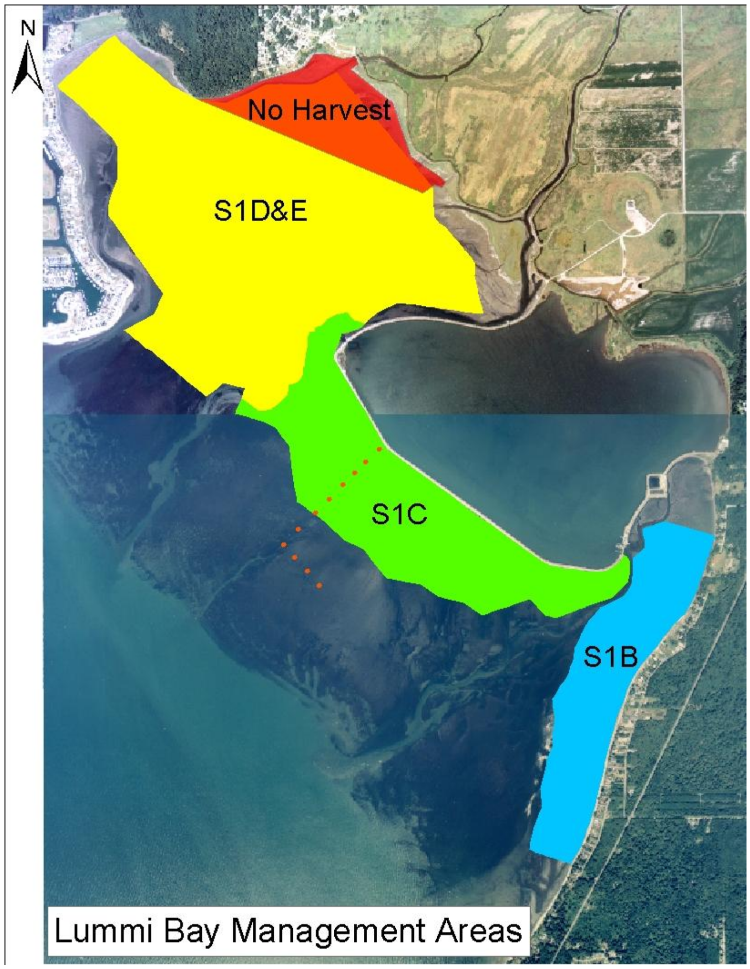

Figure 3. Lummi Bay Clam Management Area Codes

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 following year saw the first reduction in harvest when 165,000 lbs were taken. However, these harvest levels were greatly eclipsed 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 wintertime 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 a significant decline in the remaining clam biomass, which was 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 due to ease of access.

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.

2007 – 2008 Harvest Results

216,250 lbs of Manila clams were harvested from reservation beaches in the past year (Figure 1), Lummi tribal diggers also harvested a further 20,701 lbs of clams off-reservation at Birch Bay State Park. The total harvest taken by tribal diggers in 2007-2008 was 236,951 lbs, which is about 34,194 lbs lower than the average total harvest from 1995 to 2006, and is the fifth lowest total harvest in the last 13 years.

Of the on-reservation harvest, 108,229 lbs were harvested from Lummi Bay beaches, and 108,021 lbs were taken from Portage Bay beaches.

In Lummi Bay, the bulk of the harvest (55,071lbs) was again taken in northern Lummi Bay (S1D & S1E). The quota for this area was greatly reduced from previous years due to survey results in 2006 showing a large decline in the clam population, as well as reduced recruitment caused by the 2005 winterkill event. 10,145 lbs were harvested from the central area of the bay (S1C), and one opening for all diggers was allowed in S1C to help offset the reduction in quote in S1D&E. Similarly, 43,013 lbs were harvested from the Robertson Road (S1B) area based on better than expected survey results for that area, and by way of temporarily allowing a higher risk to be taken so that clam diggers would be less impacted by the quota reduction in S1D&E.

In Portage Bay the harvest was split mainly between Portage Spit (S5), where 20,891 lbs were harvested, and Brant Flats (S7D), where 50,552 lbs were harvested. Only 4,175 lbs were taken from 21A-S7E (Brant Island). A surprisingly high 22,228 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). However, it is possible that some clam diggers misreported the catch area where the clams were harvested to the monitor at checkout, and actually dug on the Portage Spit, so some of this catch may actually be attributable to Portage Spit instead.

Survey Aims

The purpose of the 2008 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 still recovering from the 2005 winterkill as predicted.

The routine aspects of the clam survey were once again contracted out to a private contractor (Wilbert Hillaire), who also successfully conducted the survey field efforts in 2006 and 2007.

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 survey 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). 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 Access 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 9.2 (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:

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

And the Standard Error is calculated using the equation:

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

…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.

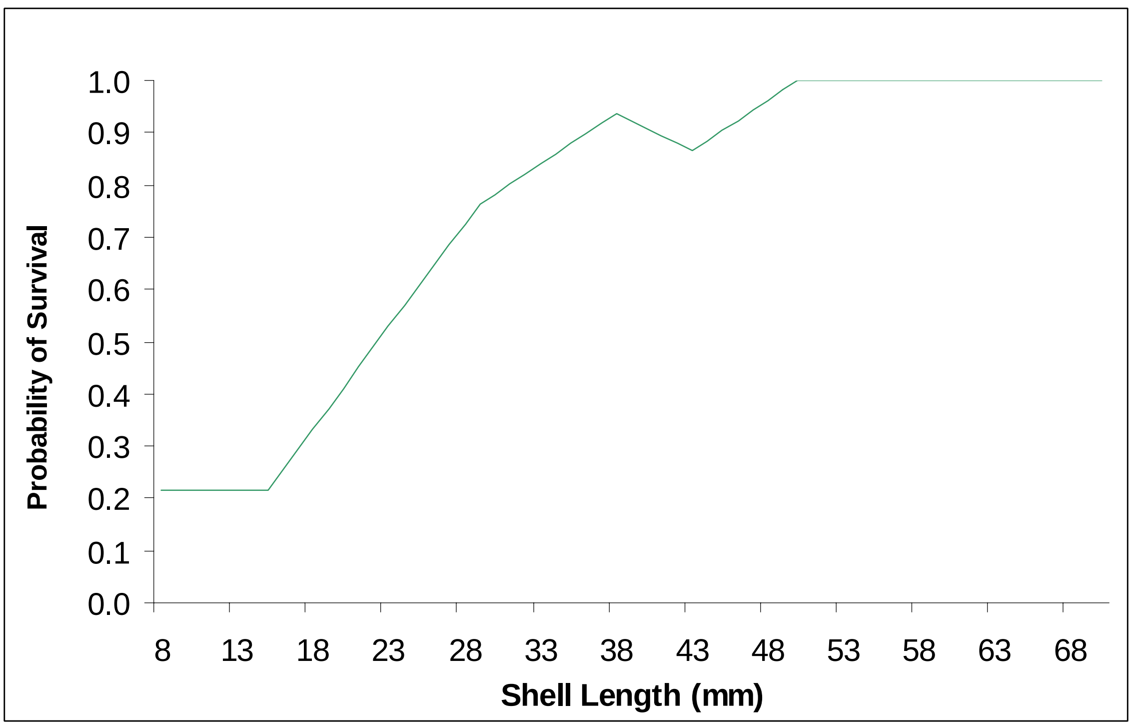

Figure 4. Survival rates used in calculating Production Estimates (from Dolphin, 2004b).

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 much more work is needed to better understand this critical parameter.

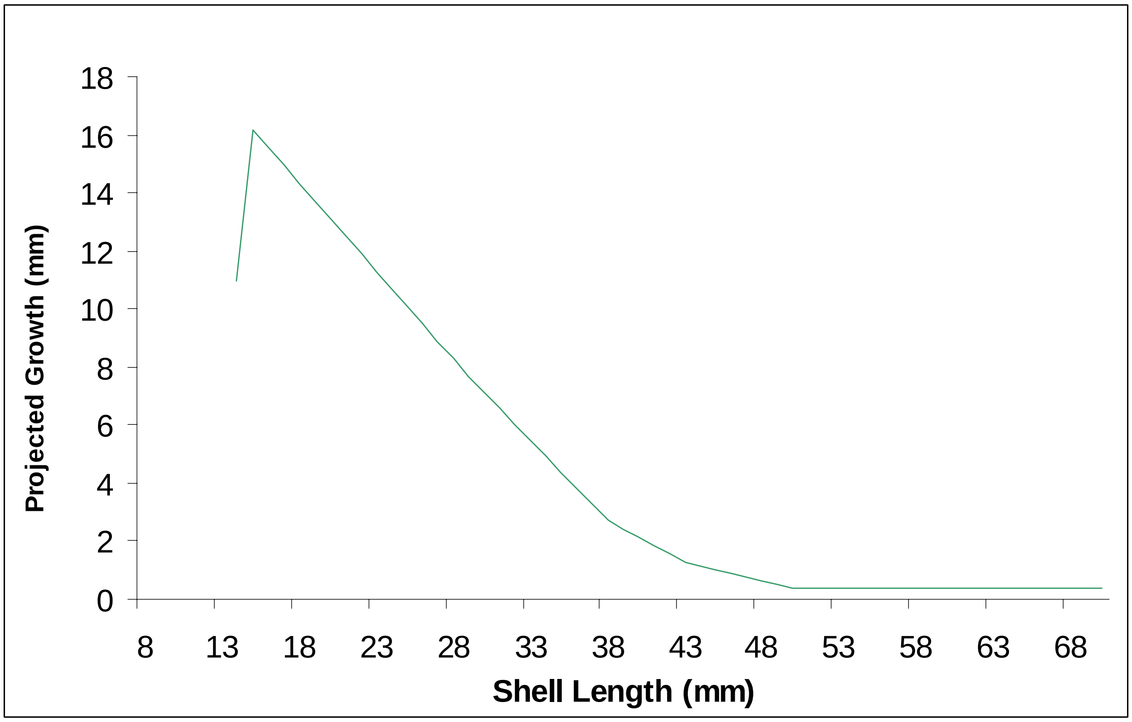

Figure 5. Annual size-specific growth rates used in calculating production estimates.

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 2008 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	**426**	**2.25**	20.86	0.051359	12.37%	40,888	**46,663**	52,437
S6				Not Surveyed				
S7A				Not Surveyed				
S7D	**712**	**2.25**	49.17	0.066329	12.72%	124,016	**142,096**	160,176
S7E	320	2.25	26.6	0.033356	23.57%	29.539	38,649	47,759
All Combined	**1,458**		96.63			194,443	**227,408**	260,372

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	**266**	**9**	192.5	0.022970	15.76%	162,256	**192,621**	222,986
S1C	**243**	**9**	293.6	0.022202	19.16%	229,544	**283,958**	338,371
S1D & S1E	**635**	**9**	916.4	0.017281	12.99%	600,253	**689,846**	779,440
All Combined	**1,144**		1,402.5			992,052	**1,166,425**	1,340,798

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

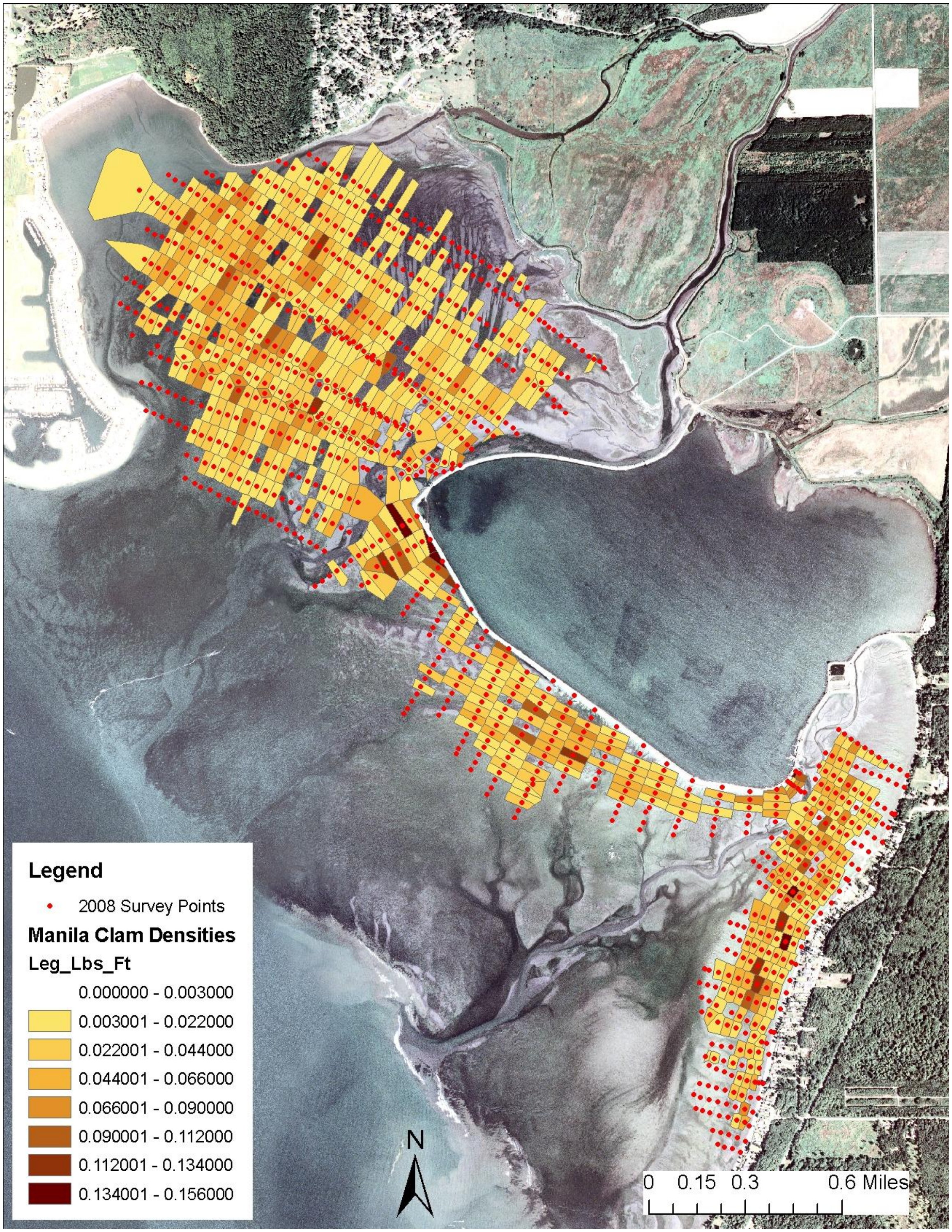

Figure 6. Legal-sized Manila Clam densities in Lummi Bay based on 2008 survey data.

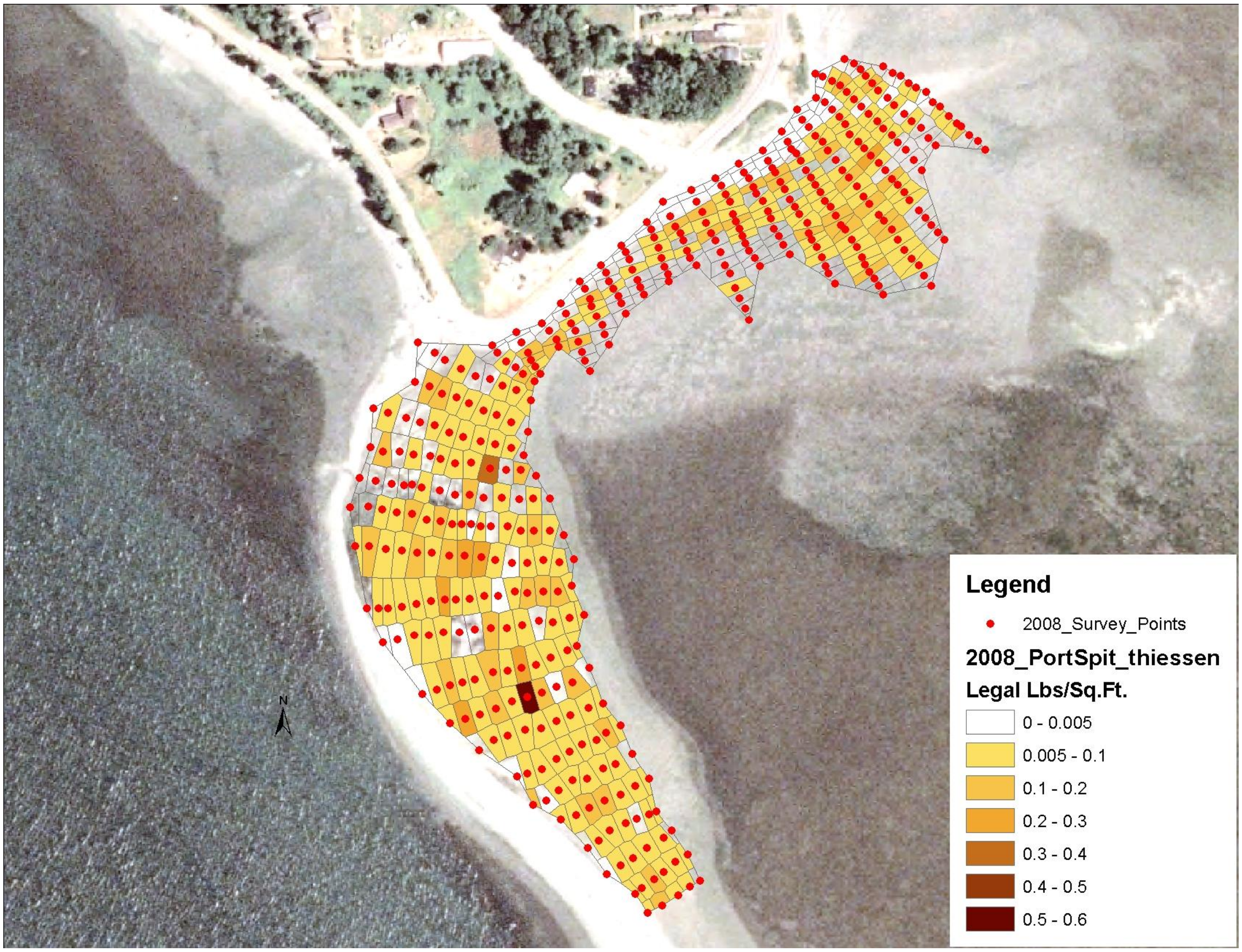

Figure 7. Clam densities at Portage Spit based on 2008 survey data.

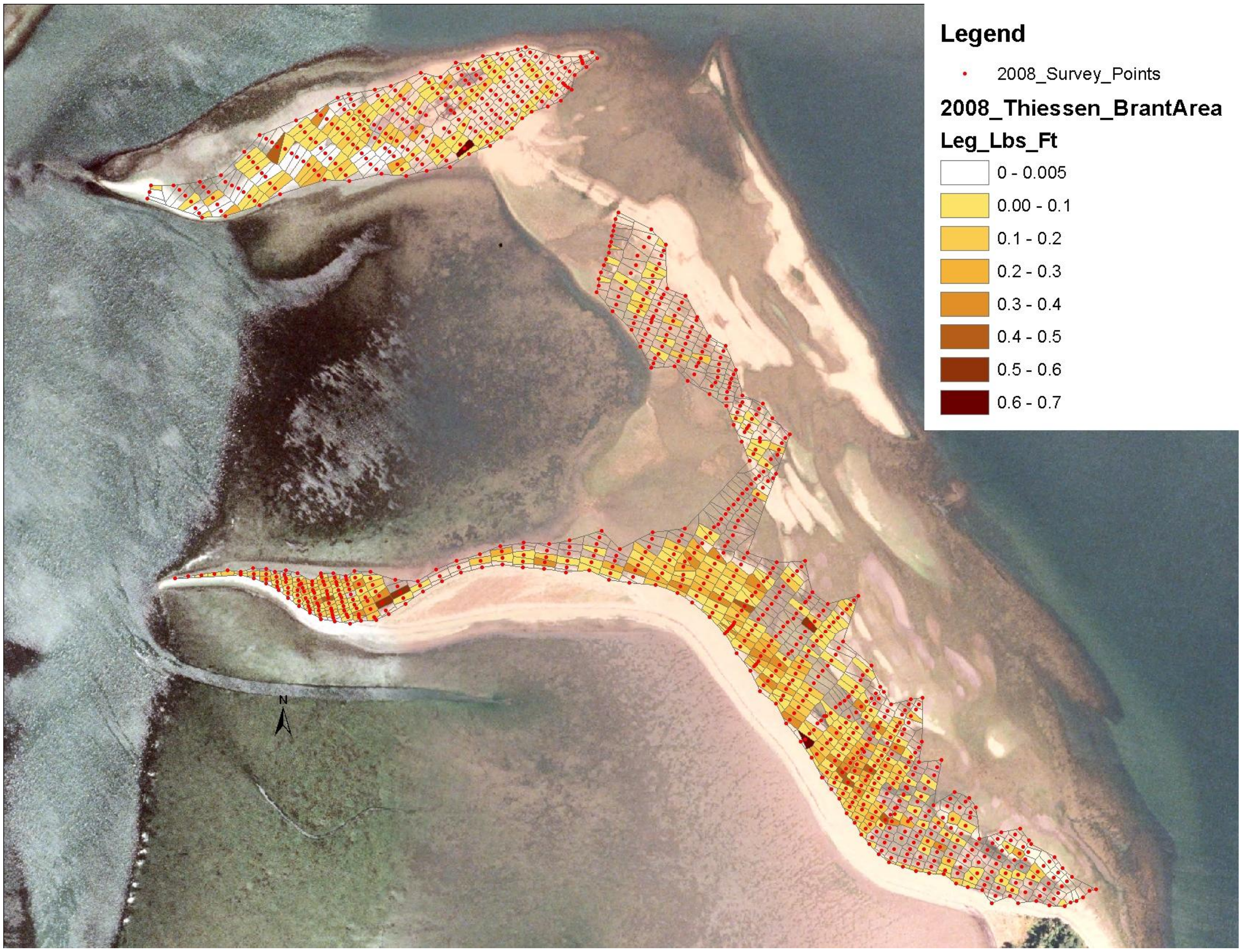

Figure 8. Clam densities surveyed at Brant Flats and Brant Island in 2008.

Because the survey areas have differed somewhat between the annual surveys conducted from 2002 to 2008, 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 each year. 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.

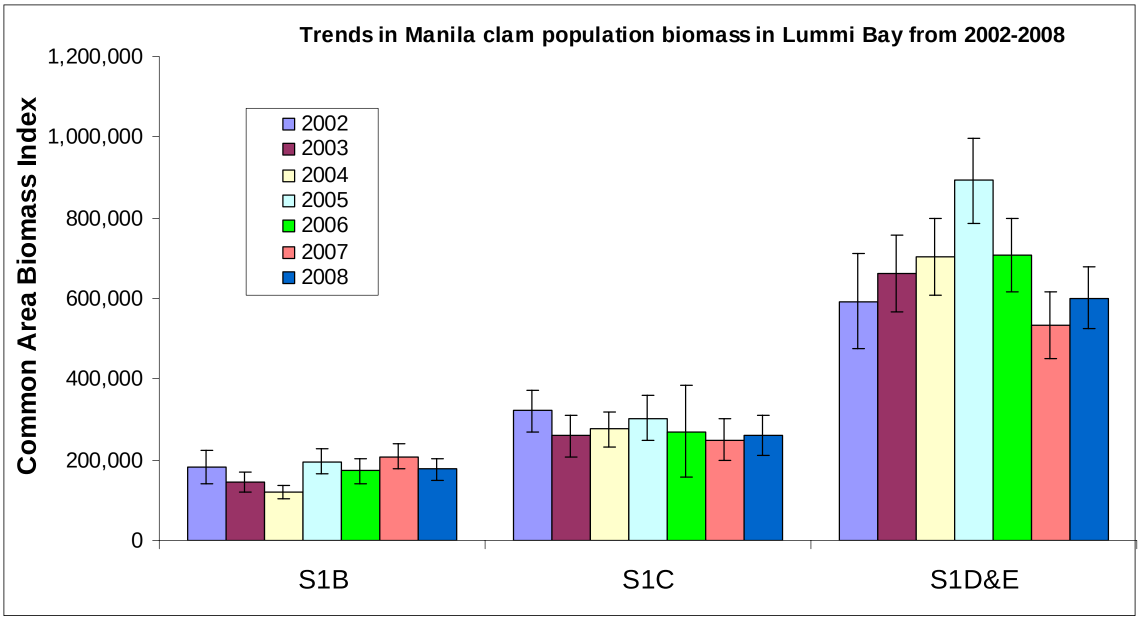

Figure 9. Relative change in legal clam biomass in Lummi Bay from 2002 to 2008 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

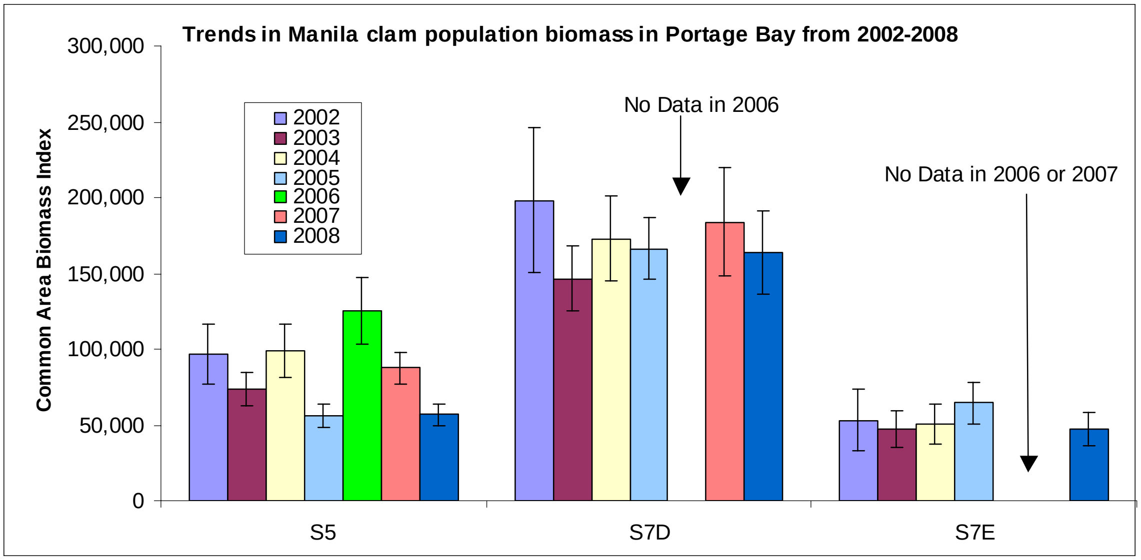

Figure 10. Relative change in legal clam biomass in Portage Bay from 2002 to 2008 based on clam survey data analyzed using Thiessen Polygons. Error bars indicate 95% Confidence Limits.

Table II. *Comparison of Production Estimates based on 2002 – 2008 Lummi Manila clam surveys.*

Beach		Production Estimates By Survey Year (lbs)						
		2002	**2003**	**2004**	**2005**	**2006**	**2007**	2008
Lummi Bay	**S1B**	**35,254**	**30,237**	**28,466**	**28,490**	**17,531**	**19,657**	25,251
	S1C	**36,179**	**29,448**	**10,349**	**23,904**	**41,033**	**18,529**	12,097
	S1D&E	**100,012**	**77,488**	**89,299**	**109,684**	**81,210**	**55,858**	61,445
Portage Bay	**S5**	**49,701**	**41,703**	**34,617**	**18,249**	**31,903**	**29,910**	17,685
	S7D	**65,052**	**63,159**	**58,458**	**53,381**	**N/A**	**28,236**	43,478
	S7E	**16,040**	**32,371**	**27,162**	**31,794**	**N/A**	**N/A**	14,005
Birch Bay State Park	**060**	**N/A**	**49,266**	**61,824**	**49,013**	**N/A**	**N/A**	N/A

Production estimates for each beach, based on the 2008 survey data, are presented in Table II along with the equivalent estimates based on the 2002 – 2007 survey data. Please note that these production estimates are not directly comparable for some Portage Bay beaches because of differences in the surveyed areas between years. In particular, one productive area in S7D was not surveyed in 2002 or 2007.

Because the total biomass on some beaches has declined since 2002, and on other beaches has increased, the recommended harvest strategy for 2009 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 2008, are detailed in Table III and shown compared to previous harvests for comparison in Figure 11.

Table III. *Recommended harvest targets based on 2008 survey data, by beach.*

Management Area	2009 Recommended Harvest
North Lummi Bay (S1D&E)	**69,089**
Mid Lummi Bay (S1C)	**12,097**
South-East Lummi Bay (S1B)	**25,251**
Portage Spit (S5)	**17,685**
Brant Flat (S7D)	**43,478**
Brant Flats (S7E*)	**14,005**
Birch Bay State Park	**15,526***
Overall Total	**197,130****

*** 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**

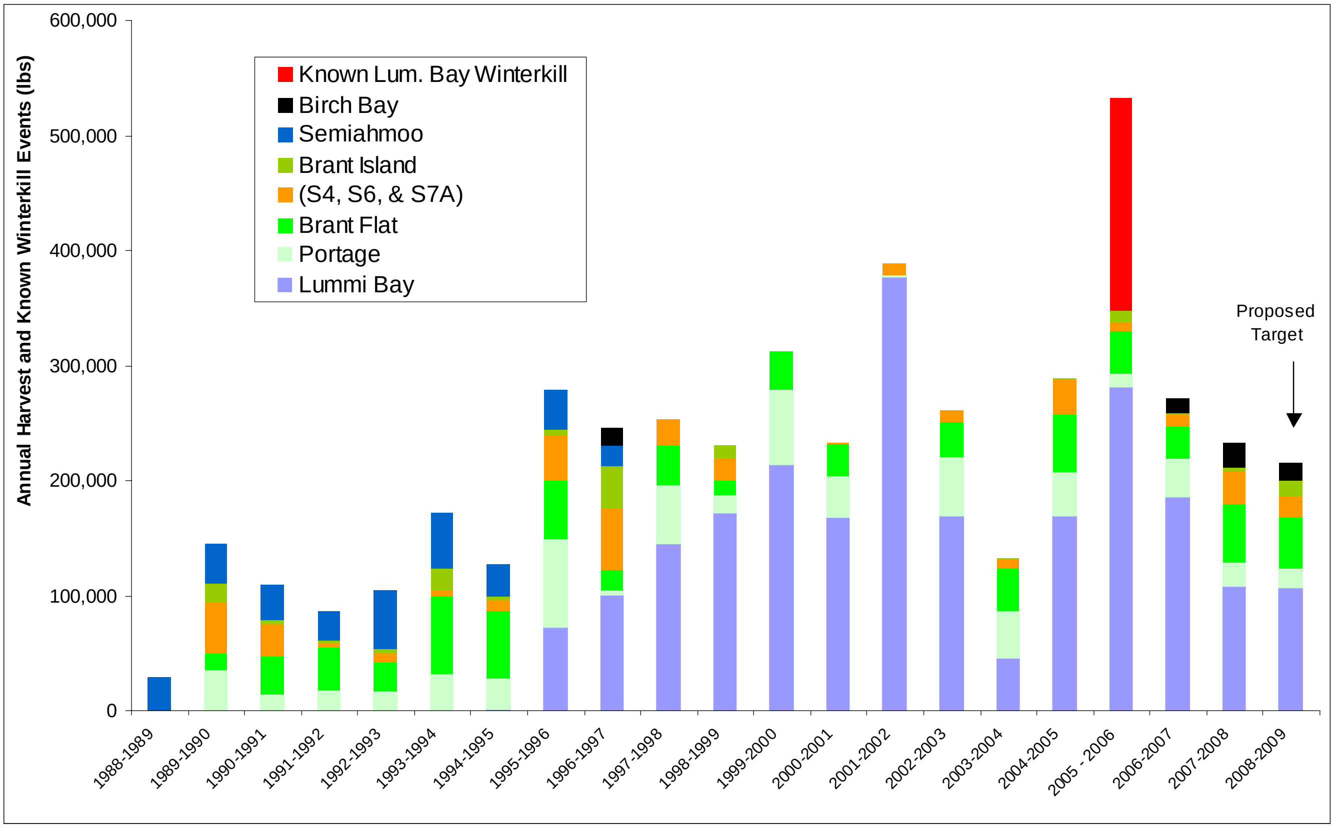

Figure 11. Comparison of proposed harvest targets to harvests in previous years. Proposed targets do not include any clams harvested in S4, S6, or S7A.

Discussion

The 2005 winterkill event has continued to plague on-reservation Lummi harvests. As a result of reduced recruitment to the fishery in 2007, the 2007-2008 harvest season had already been scaled back: particularly in the most important commercial harvest area in northern Lummi Bay. Due to the economic impacts on tribal diggers, it was decided to allow a higher harvest rate in two management areas than would ordinarily have been supported by the 2007 survey data, to help offset the greatly reduced harvest opportunity in northern Lummi Bay. These two areas were 20A-S1b (Robertson Road) and 21A-S7D (Brant Flats).

It had been hoped that the large seed-set in Lummi Bay in the summer of 2005 would have helped offset the mortality event that occurred later that year, but the survey data in the past three years seems to indicate that this has not happened at all. Instead, it seems as though the impact of the winter freeze event was greatest on the youngest clams at the time, which ought to be have been recruiting to the fishery in 2008 and 2009. Interestingly, although the winterkill event did not appear to have impacted adult clams on Portage Spit, there has been a precipitous decline in the clam population there over the past 2 years which would be consistent with reduced recruitment caused by the same mortality event that was much more visible on Lummi Bay and Birch Bay beaches.

Survey results this year showed a small decline at Robertson Road (S1B) which is consistent with the increased harvest rate in that area in the 2007-2008 season. S1C appears to have remained essentially unchanged despite a small harvest (10,000 lbs).

In response to a much-reduced harvest effort, Northern Lummi Bay (S1D&E) appears to have begun to recover slightly after two straight years of large declines. However, the results are not statistically different than 2007 and are only marginally higher than the 2002 biomass level. Unfortunately, this means that this area still remains much less productive than in past years and the recommended harvest opportunity in this area is only a little higher than last year. This result is consistent with predictions from last year's surveys.

The situation on Portage Spit was unexpectedly much weaker than anticipated given that the harvest of 17,685 lbs was relatively small for the area historically, and also given the estimated productivity for the beach based on the 2007 survey data. The survey results for 2007 and 2008 are statistically different ($p<0.05$) indicating that there is a real reduction in the biomass compared to 2007. Moreover, this is the second year in a row where Portage Spit clam biomass has declined significantly. The biomass present in 2008 is equal to the lowest on record over a 7-year period. However, there is some thought that some of the catch reported as coming from the inside of Prtage Bay (S6) and

Brant Point (S7A) may actually have been misreported and was actually taken at Portage Spit instead. Some observations of diggers stopping on the spit to dig instead of traveling all the way over were made by the harvest monitor, which are consistent with this theory.

Brant Flats was harvested at a slightly higher rate in 2007-2008 than the 2007 data indicated would be sustainable. Accordingly, it is no surprise that the survey found the biomass at Brant Flats appears to have declined slightly (although the difference is not statistically significant). However, the biomass estimate is within the historical range and therefore does not appear to have caused any permanent damage.

Brant Island was opened again this year, but only 4,175 lbs was harvested compared to 2,022 lbs in the previous season. The survey results for 2008 cannot be compared to 2006 or 2007 because no surveys were done on Brant Island in those years. However, the biomass found was about the same as the lowest result for that area in surveys conducted from 2002 – 2005. Anecdotal reports suggest that the diggers are not finding Brant Island to be a particularly lucrative area to dig. It is unlikely that the recommended harvest amount of 14,000 lbs will be reached in the 2008-2009 season either.

Conclusion

Clam population on the reservation are still dealing with the ongoing impacts of the large winterkill in 2005, and it seems that Portage Spit did not entirely escape the effects as had been hoped at the time. The harvest recommended for the 2008 – 2009 season is similar in size to last year's harvest, but may actually end up as being c. 10 thousand pounds less. The only positive aspect to this is that this should be the last year where the 2005 winterkill event is likely to significantly impact the tribal harvest since clams that will be reaching legal size in the 2009-2010 season will have settled onto the tidelands in summer 2006.

References

Dolphin, C.H. 2002 *An Analysis of 2002 Clam Surveys*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2003 *An Analysis of 2003 Clam Surveys*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2004a *Evaluation of Some Spatial Analysis Methods for Analyzing Survey Results from Three Simulated Clam Populations*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2004b *Manila Clam Growth and Mortality Rates Observed in a Small-Scale Grow-out Experiment in Lummi Bay*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2004c *An Analysis of 2004 Clam Surveys*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2005a 2006 Lummi Bay Winterkill Event. Lummi Natural Resources Internal Memo.

Dolphin, C.H. 2005b *An Analysis of 2005 Clam Surveys*. Lummi Natural Resources Technical Report.

Dolphin, C.H. 2006 *An Analysis of 2007 Clam Surveys*. Lummi Natural Resources Technical Report.