An analysis of 2003 Clam Surveys

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Executive Summary

In 2003 Lummi Natural Resources surveyed clam densities on important reservation beaches, as well as Birch Bay State Park, western Drayton Harbor, and also the mouth of California Creek as it emerges into Drayton Harbor. A total of 3,366 samples were dug, which is equivalent to 14,917 square feet. Legal biomass estimates for each area were: Drayton Harbor - 104,567 lbs; California Creek - 16,620 lbs, Birch Bay - 75,647 lbs, Lummi Bay - 1,002,275 lbs, and Portage Bay - 271,438 lbs.

Results for all on-reservation management areas, except northern Lummi Bay, showed large declines from surveyed densities in 2002. At Portage spit and the open portion of Brant Flats, the decline was in line with the predicted decline based on 2002 production estimates and actual harvest. However, all other areas showed larger than anticipated declines even in the absence of recorded harvest. The only area to show improved clam densities was northern Lummi Bay.

Production estimates based on the 2003 population data suggest a lower recruitment of new clams reaching legal size in Lummi Bay during the coming year. Consequently, production estimates are lower for Lummi Bay overall, even though overall biomass in northern Lummi Bay has increased slightly. By contrast, Brant Flats and Brant Island appear to be experiencing a spike in recruitment of new legal clams this year, and production estimates are higher even though actual clam densities are lower than in 2002. Portage Spit appears to have a similar recruitment level to last year, but the decline in remaining clam biomass has lowered the production estimate for the coming year. Comparison of 2002 and 2003 population data suggests that the following year will have a much lower recruitment rates in Brant Island and Brant Flats.

The evidence presently available indicates that production models used are typically over-optimistic. Reasons for the model failure are not certain but we are conducting some preliminary research to ascertain if the growth rates and/or survival rate information used in the production estimate is at fault. Alternative reasons may include misreported harvest and/or undocumented harvest activities.

Recommended harvest levels would provide **308,746** lbs. in the coming year, but *this level of harvest is unlikely to continue beyond the next year* due to declining clam densities and suspected weaknesses in clam year classes that will reach legal size in the next two years.

Introduction

General Harvest History

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

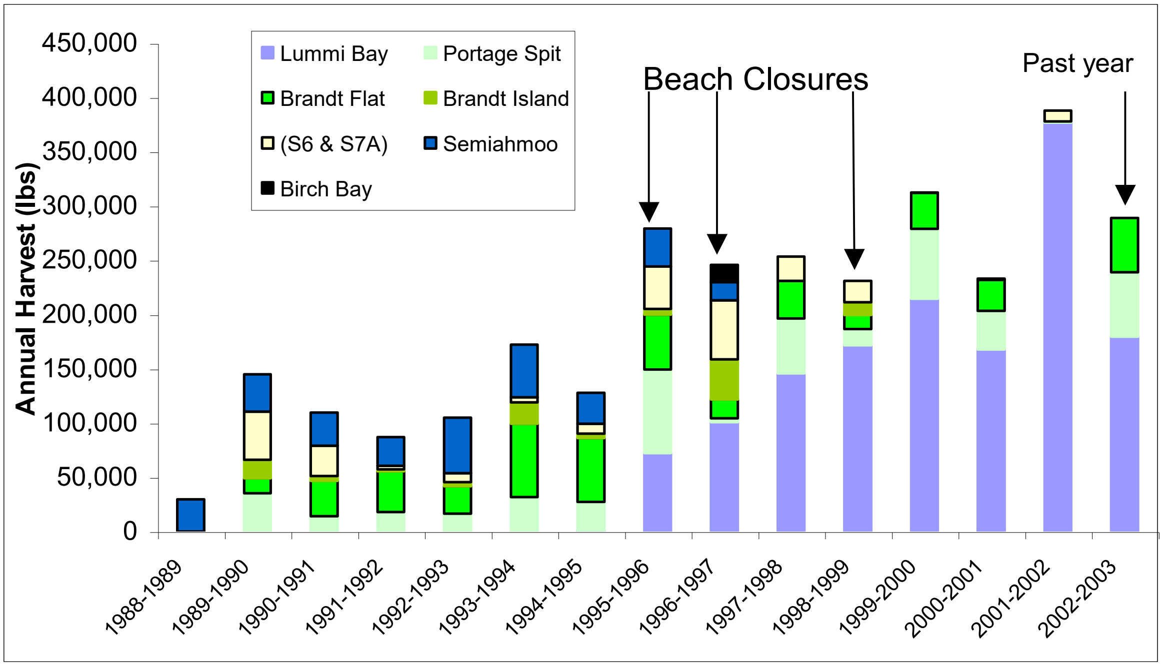

Figure 1. Recorded harvests since 1989 (Portage Beaches) and 1996 (Lummi Bay beaches).

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

From 1995 to 1999, fishing pressure in Portage Bay increased with average landings reaching approximately 113,000 lbs per year. During this time, some clam beaches in Semiahmoo were closed during 1995, and the remainder closed in 1999. Similarly, portions of Portage Bay were closed in 1997 and another portion in 1999. Since the closure of Brandt Island and Brandt Flat in 1999, Portage beaches have yielded an average harvest of 58,000 lbs per year although this is primarily due to a relocation of effort to Lummi Bay beaches.

Harvest records for Lummi Bay beaches only go back as far as 1994-1995, when 780 lbs were reportedly harvested. The following season, 1995-1996, resulted in over 70,000 lbs being harvested. Annual harvests from Lummi Bay increased by approximately 30,000 to 40,000 lbs per year to reach over

214,000 lbs during the 1999-2000 season. The 2000-2001 season saw the first reduction in harvest when 165,000 lbs were taken. However, these harvest reductions were overshadowed during the 2001-2002 season when a massive 376,000 lbs of clams were harvested from Lummi Bay.

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

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

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

2002 – 2003 Harvest

288,806 lbs of Manila clams were harvested from reservation beaches in the past year (Figure 1). Of this, 179,529 lbs were harvested from Lummi Bay beaches, and 109,276 lbs were taken from Portage Bay beaches. This is the 4th largest harvest in tribal history, and the 3rd largest taken solely from on-reservation beaches. However, it is considerably lower than the record harvest of the preceding year (c. 386,000 lbs). This reduction comes despite the decision to over-harvest the estimated sustainable harvest level by 20%.

In Lummi Bay, the bulk of the harvest (100,600 lbs) was taken in northern Lummi Bay (S1D & S1E), with 49,839 lbs coming from the Robertson Road beach (S1B), and a relatively small 29,090 lbs being harvested from the central area of the bay (S1C).

In Portage Bay the harvest was split between Portage Spit (S5), where 59,355 lbs were harvested, and the approved portion of Brant Flats (S7D), where 49,921 lbs were harvested.

Survey Aims

The purpose of the 2003 survey program was to continue to delineate clam population distribution and abundance on reservation beaches, as well as provide data critical for making harvest management decisions such as how many pounds remain, and how last year’s harvest had affected clam densities on the reservation. An additional goal was to survey some off-reservation beaches that have previously been harvested by Lummi clam diggers to determine if there is still opportunity for harvest outside of the reservation boundaries. This opportunity, of course, depends on department of health certification and agreements with other agencies. However, there is little point in making the effort to organize a harvest if there is no worthwhile harvest to be taken.

Methods

Field Protocols

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

The orientation of each transect line was maintained by using distant visual reference points such as mountain ranges, etc and always walking directly toward that reference point. The spacing between transect lines was determined using a pre-set number of paces along the beach, and varied depending on factors such as staff availability, and the amount of area to be covered in the time available. Typically, transect lines were 80 -90 steps apart in the Portage area surveys (30 apart in Brant Point Bay), 200 steps in Lummi Bay, 50 steps at Birch Bay, and 90 steps in Drayton Harbor (except at California Creek where spacing was 40 steps). 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 - 60 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 or a 9 ft^2 PVC quadrat. The size of the quadrat being used was noted at the bottom of each data sheet. The position of each station was determined using a hand-held WAAS enabled Garmin GPS unit (“Etrex legend”), set to display decimal degrees (NAD 83), and recorded on a data sheet. The Etrex has a theoretical accuracy of $\pm$9 ft with WAAS enabled, but typical operating accuracies vary between 15 and 25 feet.

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

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

Data Processing

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

The Excel spreadsheet was then converted into a dbf file with the following columns: latitude, longtitude, quadrat number, legal clams found, sublegal clams found, total clams found, total pounds per square foot, legal pounds per square foot, and sublegal pounds per square foot. This dbf file was imported into ESRI ArcMap 8.3 G.I.S. software and displayed using the GPS coordinates to determine the location of each quadrat. At this point, the data was overlaid with rectified and registered aerial ortho-photographs of the tidelands to check for data entry errors. The positions of any quadrats that were obviously out of their correct place were checked against the original data sheets, and corrected if a data entry error was found. 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 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 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 interpolated using the Spatial Analyst extension to the ArcMap 8.3 software. The interpolation method used was 'kriging'. Kriging is essentially a method of calculating a 'moving average' for areas that lie between sample points and weights this average by the relative proximity of contributing samples. Therefore, samples that are closest to the location are weighted more heavily than stations that are further away. For this analysis, only the 3 nearest samples were used to predict the values for the cells in the output. The cell size used was chosen arbitrarily to be 4m by 4m for most areas. The output of this kriging interpolation was a rectangular raster grid with predicted values for each 4m x 4m square across the full vertical and horizontal extent of the survey data points.

Because the interpolation process creates a rectangular area with dimensions equal to the full horizontal and vertical extent of the survey data, there were areas within the grid that were outside of the known area of the beach that was surveyed. To remove these, it was necessary to create another raster data set (surveyarea) that only had cells within the survey area. This file is needed to trim the rectangular grid layer down to exclude 'artifact' cells in areas beyond the extent of the survey data.

To do this, a polygon shapefile was created within ArcMap that connected up all the end points of the transect lines, and formed a polygon enclosing the surveyed area. The 'snapping' feature of the shapefile editor was used to get the best possible accuracy. The resulting polygon shapefile was then converted into a raster grid using the spatial analyst 'convert feature to raster' function. The same cell sizes were used as in the kriging raster, and all cells were assigned a zero value.

When the raster calculator function in spatial analyst is used to add the kriging grid to the survey area grid, only the cells common to both raster grids are retained. Thus, the kriging raster was trimmed down to include only the cells within the boundaries of the survey. The values of the survey area grid cells were zero so adding this grid layer to the original kriging layer meant that the values of the cells in the final grid were identical to those in the original kriging raster.

Once the kriging raster had been trimmed down, the individual cells could be thought of as a network of separate 4m x 4m quadrats covering the entire survey area, with each cell containing an estimate of legal clam density. Consequently, the average value of all the cells throughout the survey area represents a *spatially unbiased* estimate of the true population density. By creating several raster grids to represent the extent of each management area, and also for the open or closed harvest areas, it was possible to subdivide the overall kriged raster into different sub-areas, and obtain separate estimates for each area of interest.

To calculate the area covered by the survey…

The polygon shapefiles created to generate the raster grids of the survey areas were retained, and the Xtools extension in ArcMap was used to calculate the dimension of each polygon in acres, and also in square feet.

To calculate the final legal clam biomass…

The final legal clam biomass in each area was determined by simply multiplying the average cell value for the kriged clam density raster (lbs/ft^2) by the square feet of that area (ft^2).

Precision of the estimate

Although I understand that it is possible to calculate an estimate of precision for kriging, I do not have the expertise, or access to the necessary software, to undertake this process. Preliminary modeling work on a hypothetical known population, however, suggests that the variability associated with kriging analysis of regular sample surveys are comparable to the variability associated with the variability found using the ordinary sample average (although kriging/spatial analysis performs significantly better than sample averages in a fully random survey design). Consequently, I believe that the statistical precision of the sample average probably approximates the statistical precision of the kriged estimate. Hopefully advances in the available software will allow us to measure the precision associated with kriging more directly in the future.

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 kriged 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.

I used annual survivorship rates of 64% for all sublegal clams (i.e., 32 - 37 mm) and 84% for all legal clams (i.e. 38 mm or larger). The estimate of natural survivorship for legal clams is a WDFW estimate; the lower 64% value is an arbitrary one that my predecessor used, since he felt that sublegal clam survival would be somewhat lower than the 84% rate. Since only clams 32mm or larger are likely to reach legal size, the 64% value may be somewhat conservative as used to predict recruitment of sublegal clams into the fishery.

Annual growth rates used are described by the following equation:

$$\text{Size Increase (mm)} = -6.0433 * \ln(\text{Current Size (mm)}) + 26.921$$

This equation is derived from a subjective interpretation of cohorts in size-frequency data from the 2002 survey of Lummi Bay. Each cohort was assumed to represent a year class. The resulting growth rate is shown in Figure 2 where it is presented compared to Manila Clam growth rates derived from available literature. Clearly, the growth rates used in the spreadsheet are well within, and at the lower end of, the range of growth rates published in scientific journals.

By predicting the growth of clams in each size increment, and the reduced frequency of clams after natural mortality, it is possible to recalculate the collective weight of clams in each size increment for the following year. The cumulative weight of all size increments that had reached 38mm or above, rounded to the nearest millimeter, was divided by the sampled area to predict the legal sample density for next year. The predicted sample estimate was corrected for spatial bias by factoring in the kriged 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 produced.

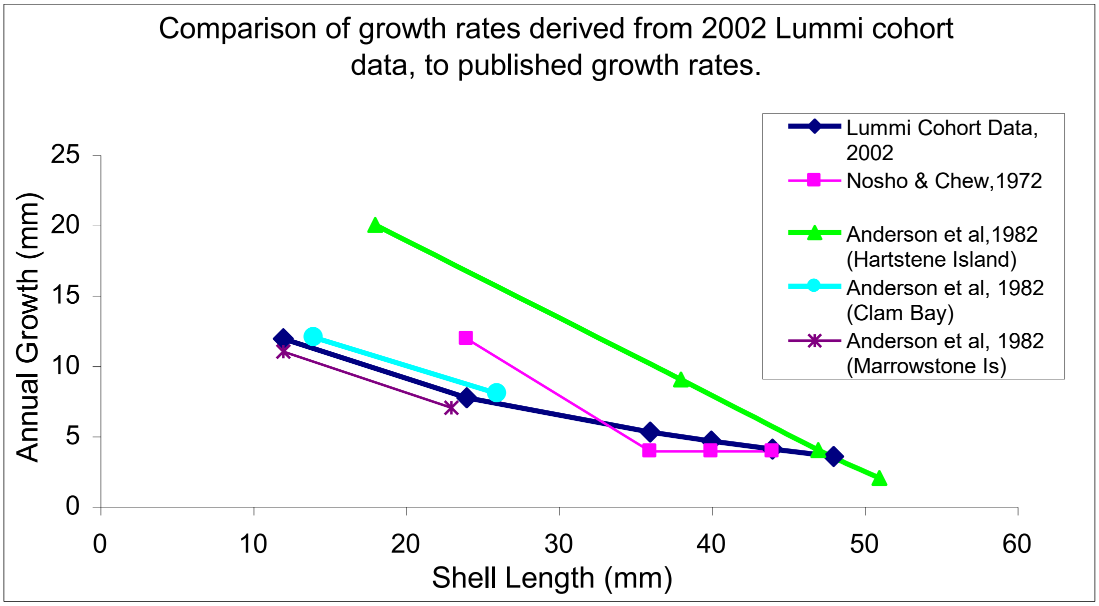

Figure 2. Comparison of the Lummi growth rates, used to predict the future growth of clams, to growth rates available in the scientific literature.

Results

Survey activities began on May 5th and continued through almost all of the available daylight tides until August 12. Lummi Natural Resources surveyed clam population in western Drayton Harbor, California Creek mouth, Birch Bay State Park, Lummi Bay, and the most productive parts of Portage Bay. We were unable to survey along Lummi Shore Road or the majority of management area S6 because we ran out of daylight tides and these were considered low priority beaches. Survey results are presented in Table I. Clam density maps for Lummi Bay and Portage Bay are presented in Figures 3 and 4 respectively. Clam density maps of the Drayton Harbor, California Creek, and Birch Bay State Park are shown in Figures 5, 6, and 7.

Table I. *Summery of 2003 Survey Results (Portage Open/Closed refers to DOH restricted areas prior to the October 2003 reclassification)*

California Creek

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
None	178	2.25	4.1	0.093	20.0%	13,295	**16,619**	19,942

Drayton Harbor

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
01, 02, 03	561	2.25	39.0	0.0615	22.7%	80,830	**104,567**	128,304

Birch Bay

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
060	394	2.25	44.8	0.0388	21.7%	59,231	**75,647**	92,062

Portage Bay

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S5	**251**	**2.25**	24.3	0.067	16.9%	58,679	**70,613**	82,547
S6 (Creek mouth)	**47**	**2.25**	4.6	0.041	51.9%	3,887	**8,081**	12,275
S7D (closed)	**233**	**2.25**	31.7	0.048	21.4%	52,204	**66,418**	80,631
S7D (open)	**272**	**2.25**	32.8	0.052	20.8%	58,478	**73,827**	89,175
S7E (closed)	**320**	**2.25**	44.4	0.026	23.1%	38,463	**50,012**	61,561
Open Areas Pooled	**570**	**2.25**	61.6	0.057			152,521	
Closed Areas Pooled	**553**	**2.25**	76.0	0.035			116,430	
All Combined	**1,123**	**2.25**	137.7	0.045			**268,951**	

Lummi Bay

Area Description	Survey Stations	Individual Station Areas (ft^2)	Acres surveyed	lbs/ft^2	statistical precision* of estimate	lower 95% biomass estimate*	mean biomass estimate	upper 95% biomass estimate*
S1B	**291**	**9**	197.3	0.016	23.1%	107,785	**139,968**	172,267
S1C	**311**	**9**	463	0.014	18.4%	193,139	**236,574**	280,009
S1D & S1E	**428**	**9**	919	0.016	12.2%	562,365	**640,434**	718,503
All Combined	**1,030**	**9**	1,579.3	0.0148			**1,016,976**	

* Precision estimates used are those calculated for the spatially 'biased' sample estimates from the stations within the indicated area, not for the spatially unbiased kriged estimate of clam density within that area. See methods for fuller discussion of this parameter.
**biomass estimates presented here for the closed portions of S7D and S7E do not include any clam biomass from unsurveyed portions of those areas.

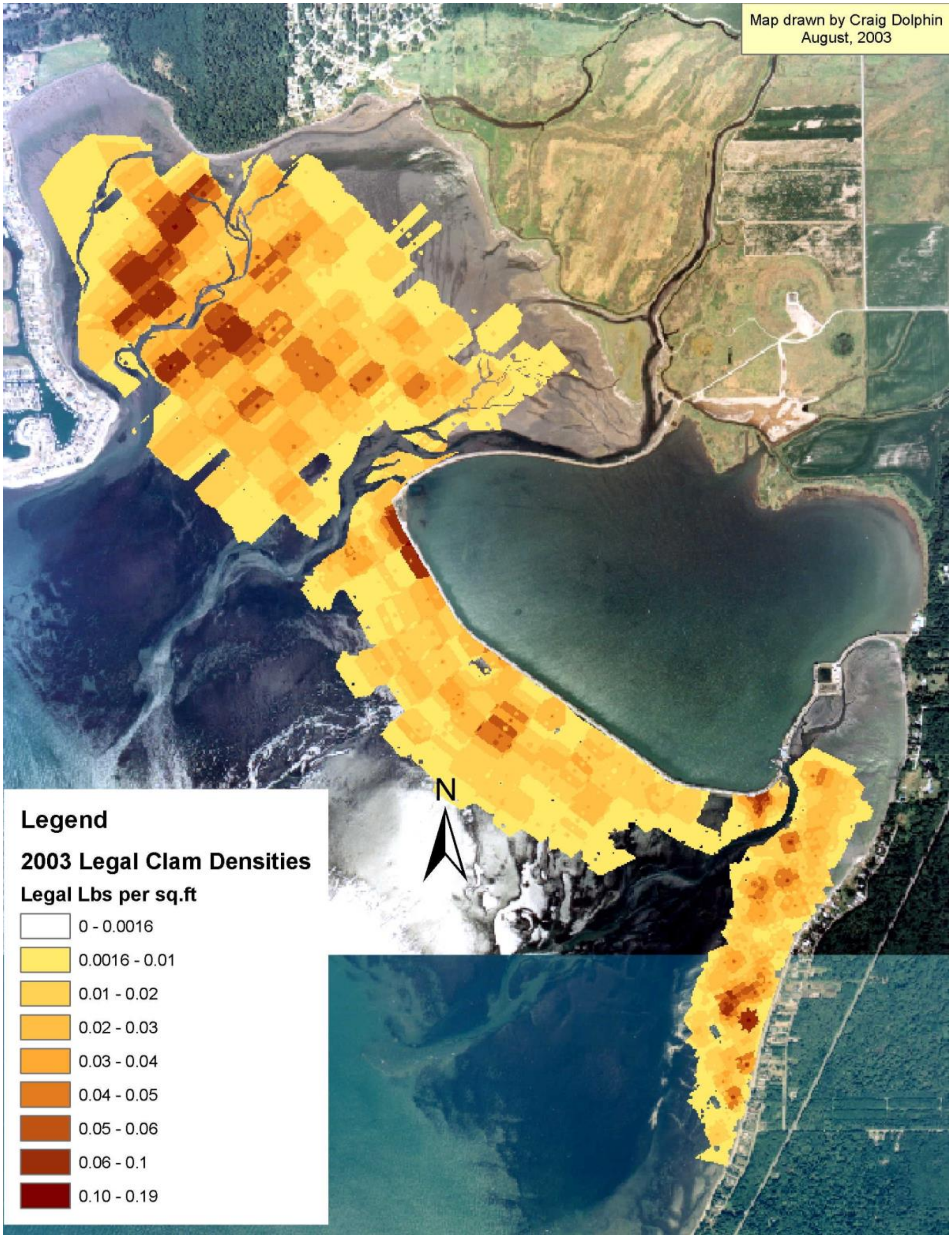

Figure 3. Clam densities in Lummi Bay based on 2003 Survey Data.

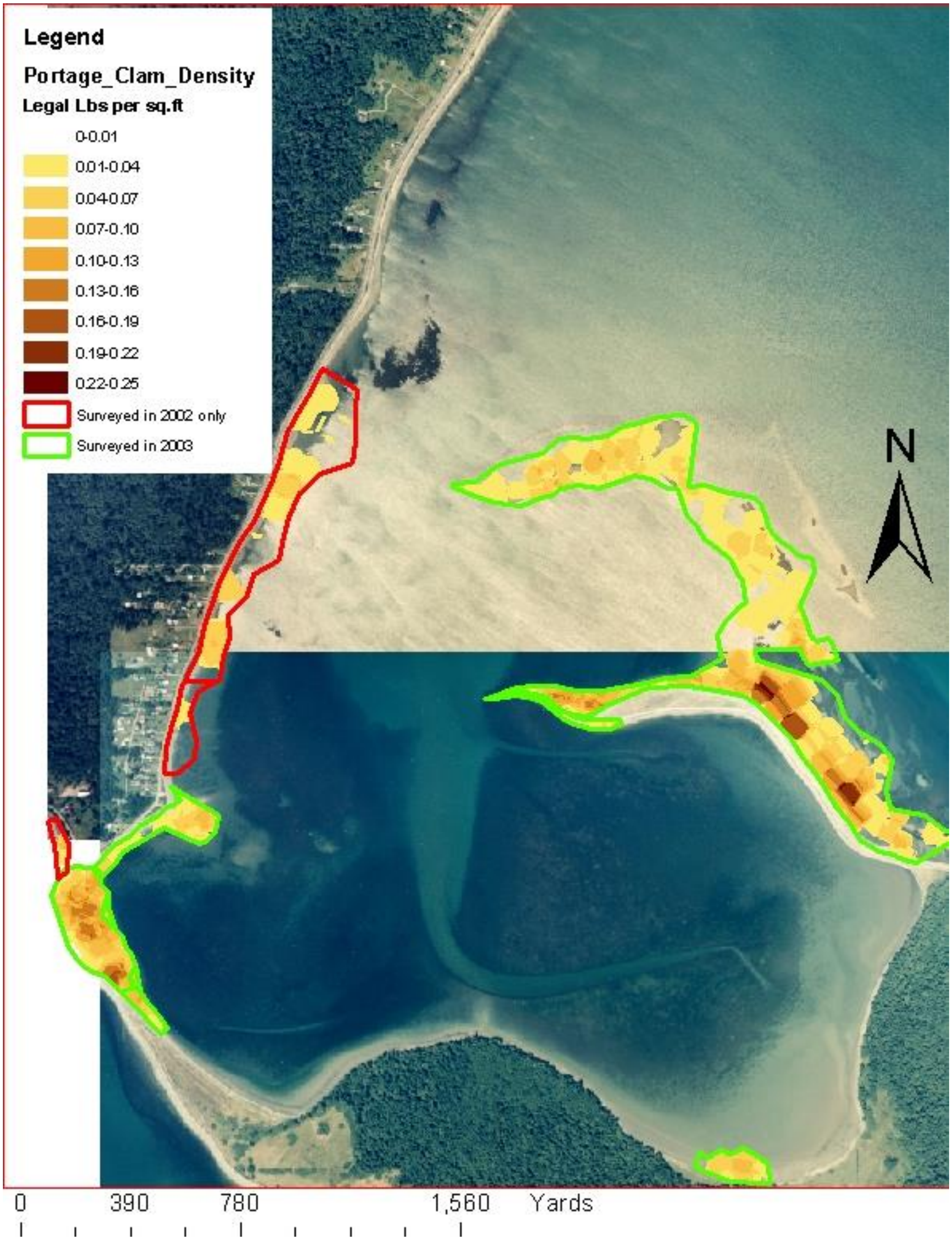

Figure 4. Clam densities in Portage Bay based on combined 2002 and 2003 Survey Data. Areas enclosed by green lines were surveyed in 2003. Areas enclosed by red lines were surveyed in 2002, but not 2003.

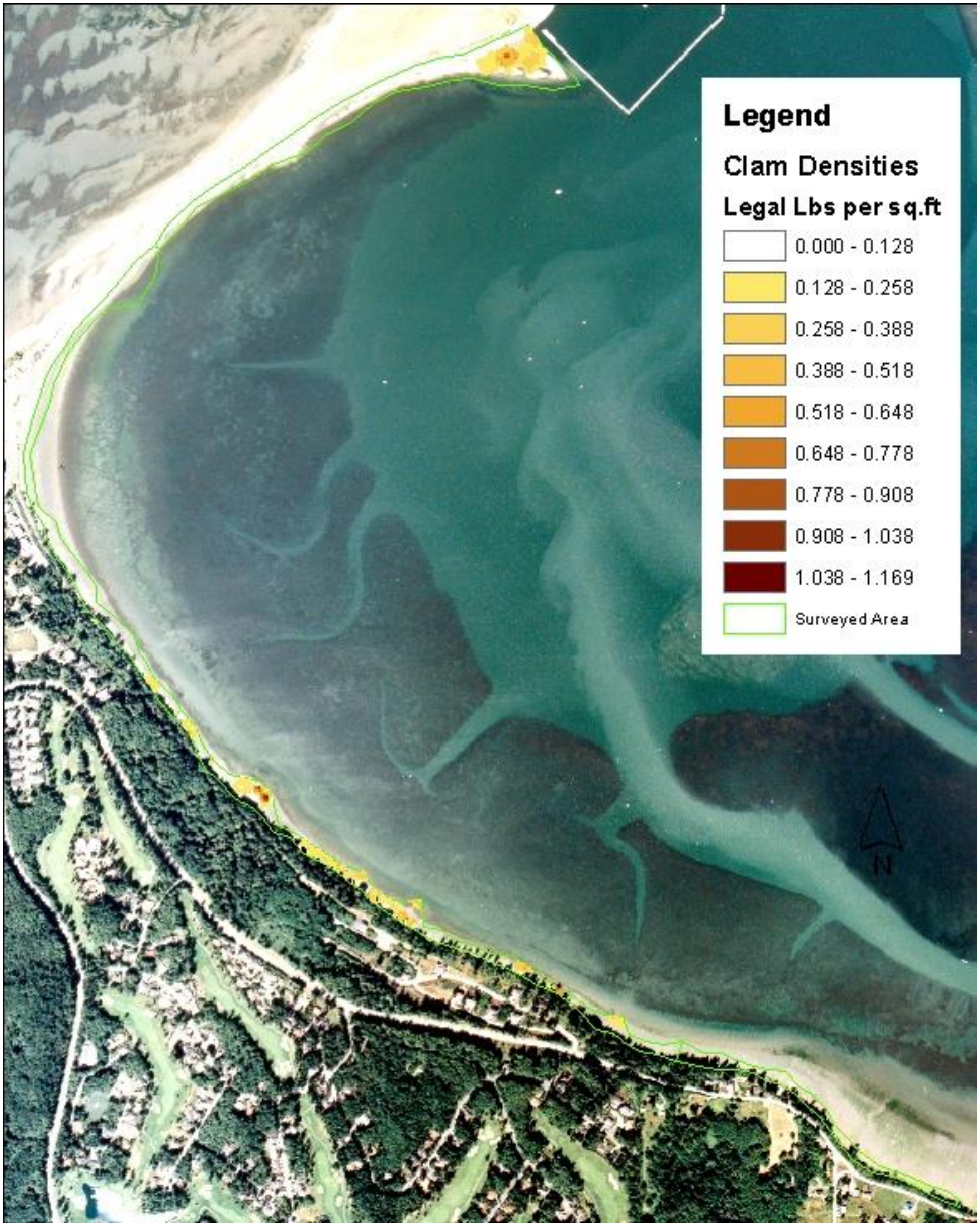

Figure 5. Clam densities in western Drayton Harbor based on 2003 Survey Data.

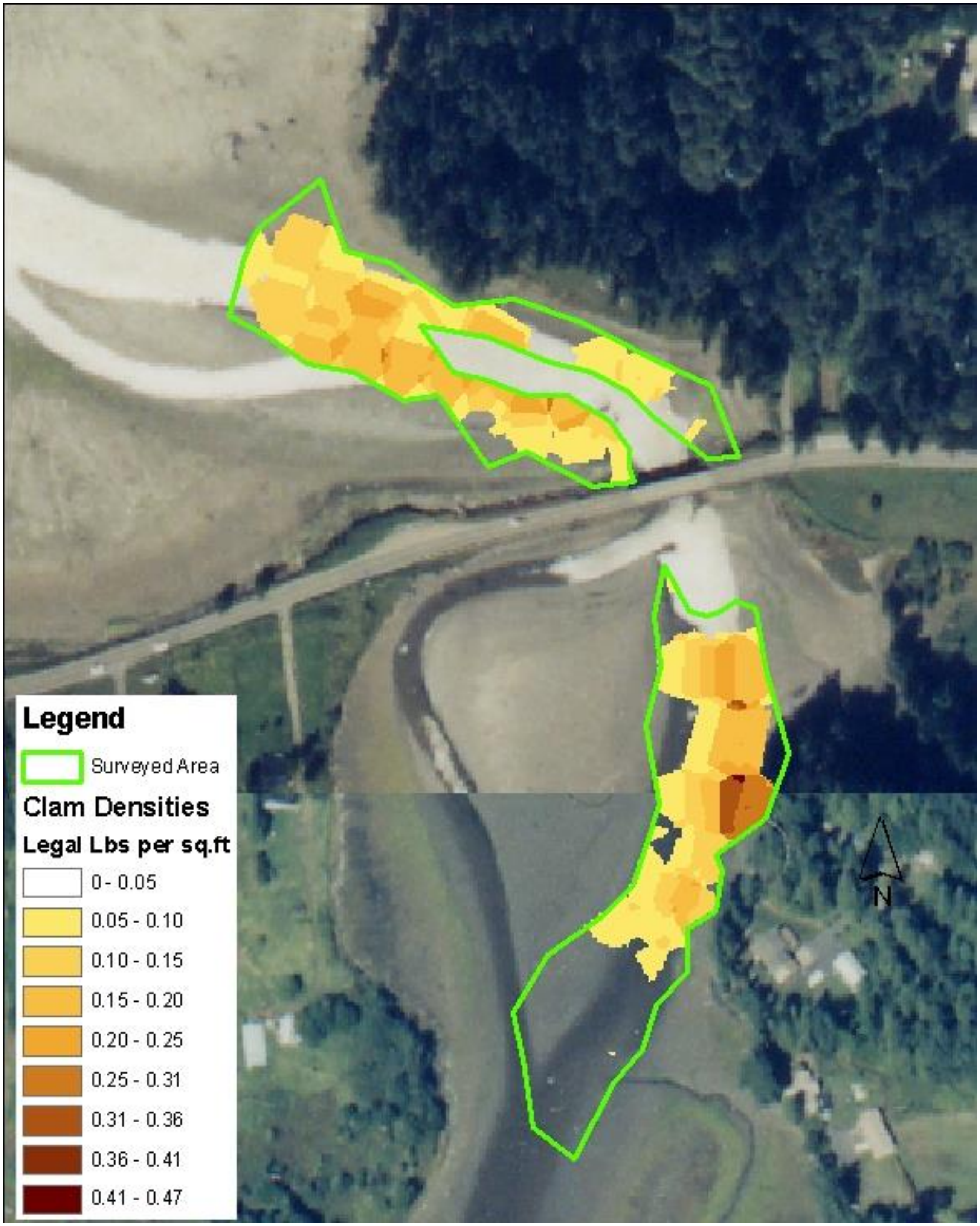

Figure 6. Clam densities at the mouth of California Creek based on 2003 survey data.

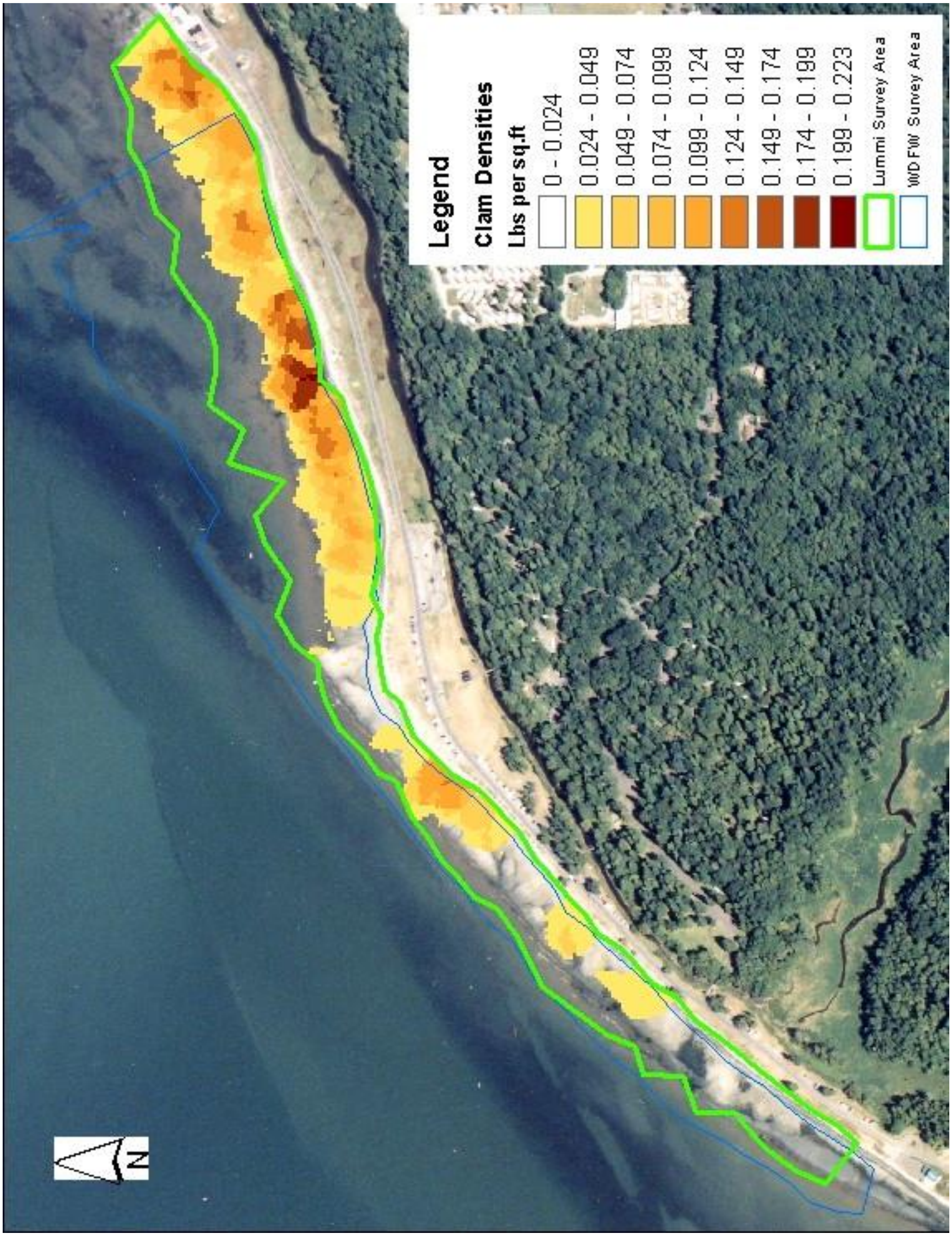

Figure 7. Clam densities at Birch Bay State Park from 2003 Lummi survey data. WDFW 2003 survey area outline is shown in blue for comparison.

Because the survey areas in Lummi Bay and Portage Bay differed between the 2002 and 2003 surveys, it is not meaningful to directly compare the different survey results to each other. However, a more meaningful comparison is possible using a comparison of densities in only the areas common to both surveys. For beaches that were surveyed both in 2002 and 2003, Table II shows the relative change in the biomass present in the area common to both surveys.

Table II. *Common area density changes between the 2002 and 2003 surveys.*

		For Beach Areas Common to Both Surveys			
		2002 Density (lb/ft^2)	2003 Density (lb/ft^2)	% Difference	
Lummi Bay	S1B	0.02117	0.01623	-23.3%	Decline
	S1C	0.01532	0.01239	-19.1%	Decline
	S1D&E	0.01476	0.01627	+10.2%	Increase
Portage Bay	S5	0.07810	0.06683	-14.4%	Decline
	S7D (open)	0.07346	0.05398	-26.5%	Decline
	S7D (closed)	0.07380	0.05776	-21.7%	Decline
	S7E	0.03267	0.02701	-17.3%	Decline

Table III. *Comparison of Production Estimates based on the 2002 and 2003 surveys, assumed growth rate, and assumed mortality rate*

	Management Area Code	2002 Production Est. (lb)	2003 Production Est. (lb)	% difference	
Lummi Bay	S1B	35,254	30,237	-14.2%	Decrease
	S1C	36,179	29,448	-18.6%	Decrease
	S1D&E	100,012	77,488	-22.5%	Decrease
Portage Bay	S5	49,701	41,703	-16.1%	Decrease
	S6	N/A	1,978	N/A	
	S7D (open)	49,701	41,703	-16.1%	Decrease
	S7D (closed)	15,351*	30,691*	99.9%	Increase
	S7E	16,040*	32,371*	101.8%	Increase
Drayton Harbor	001, 002	N/A	22,667	N/A	
California Creek	N/A	N/A	2,902	N/A	
Birch Bay State Park	060	N/A	49,266	N/A	

*Please note that these production estimates are not directly comparable because of differences in surveyed areas between 2002 and 2003.

Production estimates for each beach, based on the 2003 survey data, are presented in Table III along with the equivalent estimate based on the 2002 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. Portions of Brant Flat (S7D) and Brant Island (S7E) that were not surveyed in 2002 were surveyed in 2003. One of these newly surveyed areas proved to be quite productive.

In Fall of 2003 a large portion of the restricted beaches in Portage Bay were re-certified as approved shellfish growing areas by the Washington State Department of Health. Consequently, all of S7D (Brant Flat) and a portion of S4 (Lummi Shore Drive) and S7E (Brant Island) are now open for harvest. The recommended harvest amounts for all approved areas available for harvest, that have been surveyed in 2003, are detailed in Table IV.

Table IV. *Recommended harvest targets based on 2003 survey data, by beach.*

Management Area	2003 Recommended Harvest
North Lummi Bay (S1D&E)	**128,240**
Mid Lummi Bay (S1C)	**10,000**
South-East Lummi Bay (S1B)	**30,237**
Portage Spit (S5)	**41,703**
Brant Flat (S7D - Open)	**32,468**
Brant Flats (S7D Prev-Closed)	**30,691**
Brant Island (S7E - Prev-Closed)	**13,612**
Birch Bay State Park	**21,795**
Overall Total	**308,746**

Discussion

We expected there to be declines on most of the reservation beaches because harvest targets were set 20% higher than the production estimates that were based on the 2002 data. Unsurprisingly, all but one of the on-reservation beaches surveyed in 2002 and then again in 2003 showed a decline in clam densities. What was surprising was that the magnitude of the declines was much greater than anticipated.

For example, S1B in Lummi Bay was surveyed in 2002 and contained approximately 182,000 lbs of legal biomass. We expected a further 35,000 lbs would be produced by the growth of clams, after taking into account some natural mortality. We then harvested ~50,000 lbs from S1B. Based on the 2002 survey data and the subsequent harvest, we expected that there would be 182,000+35,000-50,000 = 167,000 lbs remaining when we surveyed the beach again in 2003. However, the 2003 biomass estimate for S1B was only c. 140,000 lbs; nearly 30,000 lbs lower than we anticipated even after such a big harvest. Similar problems abound for S1C (Lummi Bay), S7D, and S7E (Portage Bay). The biggest decline was in S1C which is concerning given the apparently light harvest there. However, the most worrying trend was the decline in areas that were supposedly not harvested at all due to Department of Health restrictions. These declines suggest that natural mortality rates between the 2002 and 2003 surveys were considerably higher than expected, or that illegal and unreported harvest activity occurred in the restricted areas. I certainly saw diggers in the restricted area while I was surveying the beaches that were deliberately targeting Manila clams. One digger had two buckets full of Manilas and was still digging when we left. Thankfully, with the reclassification of the area in 2003 we are less likely to have issues with illegal activity in the restricted area, but if large-scale illegal and unreported harvests are occurring then we will continue to see declines regardless of management actions.

Only one beach showed an apparent increase in clam densities in 2003. This was the combined area of S1D and S1E in northern Lummi Bay. Clam densities in this area increased by c. 50,000 lbs while the area immediately adjacent to it, S1C, declined by nearly 60,000 lbs more than it should have. This raises questions about the accuracy of the harvest areas reported by the diggers/monitor. If diggers were averse to crossing the channel at night, in the cold winter nighttime tides, and harvested in S1C instead while attributing the catch to S1D&E to avoid getting in trouble, then this could explain both the increase in S1D&E (less was harvested there than the data shows) and the decline in S1C (more harvested there than the data shows).

The only beach that appeared to match our expectations was Portage Spit (S5) itself where the surveyed biomass in 2003 was within 3,000 lbs of the predicted value.

Why did our production estimates prove to be so unreliably optimistic? Growth rates were based on subjective cohort analysis of Lummi Bay clams found in the 2002 survey. This growth rate is at the low end of the range of published accounts for other locations so ought to be conservative; although we do expect Lummi Bay clams to grow slower than clams from other areas. Perhaps it just wasn't conservative enough? Another issue has to do with clam survival rates from one year to the next. Perhaps more clams die in Lummi/Portage Bay than we are led to believe by data from other locations? Unfortunately, the only way we can assess that is to conduct a formal growth/mortality rate study for both Lummi Bay and Portage Bay beaches. Such a study will provide data that can be used to improve our grow-out model to reflect real-world values. Towards that end, we have established a pilot study in three locations in Lummi Bay. If successful, the study will enable better forecasting for Lummi Bay starting from next year. Hopefully we will be able to repeat and enlarge the study in Lummi Bay, and extend it to Portage Bay beaches next year.

A further disappointment in the survey results was the lack of smaller clams in the population compared to last year's survey. We appear to have had a weaker recruitment year reaching legal size in Lummi Bay this year, and there is no sign that this situation is likely to improve in the following two years. By contrast, Brant Flat and Brant Island appear to be enjoying a significantly stronger than usual year-class reaching legal size this year, but there is no sign of good year classes in the two years to come after. Portage Spit appears to be receiving a similar recruitment level as it did last year. This raises questions about whether we really want to harvest bountiful year classes as soon as they are legal size, or if we would be better to spread out harvest on that year-class over 2 or 3 years to help buffer out weak year-classes? This would result in lower than possible harvests in a few good years of clam abundance, but higher harvest than otherwise possible in the lean years.

Assuming that tribal diggers harvest exactly the amount of clams equal to the production estimates detailed in Table IV we can expect a total tribal harvest of 308,746 lbs. This compares to last year's harvest of 288,806 lbs. and would represent the third highest harvest in the tribe's history. This increase is entirely due to the re-certification of some of the beaches in Portage Bay, as well as a one-off over-harvest in northern Lummi Bay/Onion Bay. However, if clam densities continue to decline as they did last year we can expect that this level of harvest will not be sustainable without the addition of more beaches to harvest from.

One positive to come out of the 2003 survey season was that the magnitude of clam biomasses on all beaches remained the same, proving that the survey methodology produces results that are comparable from year to year. Moreover, the comparison of Lummi survey data from Birch Bay State Park to WDFW survey data for the same area shows that the Lummi methodology produces comparable results compared to more well-established survey methodologies. I have presented the details of the comparison of Lummi and WDFW surveys more thoroughly in a memo to Alan Chapman if anyone is interested in a detailed analysis of that work. Consequently, I have much greater confidence in the data, and am secure in the relative robustness of the analysis methods used. By surveying Birch Bay State Park we have also established the viability of a tribal opening there in the near future which will enable at least a little of the tribal effort to be focused on an off-reservation beach.

The production estimate for the Birch Bay State Park survey is an astonishingly high 65% of the legal biomass. This rate is higher than for the rate from any other beach surveyed in 2002 or 2003, and considerably higher than the 41% indicated by using the WDFW iterative method on the same data. Given that we have good reason to believe that our grow-out method is too optimistic, perhaps we ought to use the iterative method to determine production estimates. I should also note that the harvest rate calculated from the WDFW data was even lower than the rate determined from the Lummi survey data (34%). This may be a reflection of WDFW obtaining a smaller sample of Manila clams to work with, as well as some harvest activities between surveys.

The Drayton Harbor survey showed that clam densities there are considerably better than on the reservation or Birch Bay State Park. However, the overall area of the clam beds there is much smaller so the population legal biomass in only a little over 100,00 lbs in total. The average harvest from Drayton Harbor between 1998 and 1994 was c. 36,000 lbs. per year. The production estimate for Drayton Harbor was 22,000 lbs. based on the 2003 survey data, which is a relatively low rate compared to Birch Bay State Park or Portage Bay beaches. Why is the 2003 production estimate below the historical average, when evidence from on-reservation beaches tends to suggest production estimates are overly optimistic?

One answer might simply be that the year class reaching legal size in late 2003 and 2004 may simply be a weaker than usual cohort. Alternatively, since the population has been off-limits for harvest for several years now, it may be close to the carrying capacity of the environment with density-dependent factors limiting new production. For example, a greater proportion of slow-growing, old, large clams could exclude smaller, faster growing clams by competing for favorable habitat, or food, and even by consuming pelagic larvae as they try to settle. Another answer might be that some of the catch between 1988 and 1994 may have also come from other unsurveyed populations in Drayton Harbor. We only surveyed beaches on the west side of Drayton Harbor, and at the mouth of California Creek, this year. However, I have no information to suggest that there are also productive clam beds on the eastern portion of the Harbor, except near the mouth of California Creek. The California Creek area provided a production estimate of ~3,000 lbs. Added to the 22,000 lbs from the remaining area, this provides a sustainable harvest total of ~25,000 lbs for the coming year. Unfortunately, the area remains closed to commercial harvest due to ongoing fecal coliform contamination in the harbor.