

2018 Lummi Clam Survey Summary



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Executive Summary

Lummi Natural Resources conducted a stock assessment survey of harvestable Manila clams on tidelands within Lummi Nations Usual and Accustom area (U & A) in the summer of 2018. The results from this survey provide critical data for the management of the commercial Manila clam fishery and provide the basis for setting harvest quotas. Beaches open to harvest were surveyed in Portage Bay and Lummi Bay on-reservation and in Drayton Harbor off-reservation.

Beaches were surveyed following the Lummi Survey Protocol (Dolphin 2013), a modification of the standard Washington State adopted protocol (Campbell 1996), consistent with past survey methods. Surveys are carried out using a systematic random design with a series of parallel transects to determine the legal pounds per square foot of Manila clams. The sample clam densities are spatially weighted and the weighted average Manila clam density (lb/ft²) for each management area is then multiplied by the area surveyed to estimate the total biomass of legal size Manila clams.

Portage Bay has a total of 226,795 lb of harvestable Manila clams and Lummi Bay has a total of 1,173,693 lb of harvestable Manila clams. Management areas within both bays had similar average Manila clam densities (0.01-0.03 lb/ft²), but Lummi Bay has considerably more clams because Lummi Bay has 1,236 acres of clam habitat whereas Portage Bay only has 216 acres of habitat. Drayton Harbor had a much higher density of Manila clams (0.14 lb/ft²) and only 33 acres of habitat equally 203,266 lb of harvestable Manila clams.

Recommended harvest levels for the 2018-2019 commercial clam season were set at rates that should sustain the populations of Manila clams for generations to come. Harvest rates were set relatively low (10% of the harvestable biomass) due to the significant decline in harvestable Manila clams on-reservation beaches from the winterkill event of 2017. The 2018-2019 total allowable catch (TAC) for on reservation beaches totals 186,172 lb, with 22,679 lb from Portage Bay and 117,369 lb from Lummi Bay.

Beaches off-reservation are co-managed with the State of Washington and harvest quotas are set based on the previously agreed upon harvest rate of 33% and then the quota is split between the state and the tribes. The TAC of Manila clams for Drayton Harbor is split evenly between Lummi and the state guaranteeing Lummi 33,539 lb of harvestable Manila clams. Lummi also has harvest rights to 32,423 lb of harvestable Manila clams from Birch Bay, the other beach actively co-managed between the state and Lummi.

There are a total of 202,953 lb of harvestable Manila clams available for harvest opportunities in the 2018-2019 management year.

Survey Objectives

The purpose of the 2018 Manila clam survey was to provide critical data for the management of the commercial Manila clam fishery. This work estimates the harvestable biomass of Manila clams on clam beaches within Lummi Nations Usual and Accustom area (U & A), and makes sustainable harvest recommendations for the 2018—2019 clam fishery season. Additionally, this survey has been used to estimate the loss associated with the Winterkill event in 2017. Beaches were surveyed in Lummi Bay, Portage Bay, and Drayton Harbor.

Methods

Field Protocol

Due to the vast area of clam beds on most beaches, it has never been feasible to use the standard State adopted survey protocol (Campbell 1996) to survey on-Reservation beaches. Instead, the Lummi survey protocol (Dolphin 2013), was developed to attain a precision of $\pm 30\%$ of the final estimate of biomass constant with the state guidelines while employing a much larger block size. This is attainable by increasing the size of the sampling quadrat therefore reducing the variance between samples allowing the decrease of sampling density while still maintaining sufficient precision.

Similar to the Campbell protocol, the Lummi protocol uses a series of parallel transects that extend from the shore to the water that are sampled at regular intervals across the beach a predetermined number of steps apart. The orientation of each transect line is maintained by using distant visual reference points, such as mountain peaks, houses etc, and walking directly toward that same reference point after each sampling station is determined. The spacing between the transect lines and samples is pre-determined following the methods used in past surveys. The number of paces between stations in each transect line is varied according to the size of the beach, the variability in clam densities, the beach slope and the length of the transect line to achieve the desired precision.

Spacing between transects and samples is specific to each beach and management area (Table 1). All distances between transects and samples have been determined in number of steps and 1 step is equivalent to approximately 3 feet. Transect lines are spaced between 30 and 200 steps (~90-600 feet) apart and sample quadrats are spaced between 10 and 60 steps (~30-180 feet) apart. Intervals between samples smaller than 10 steps are not possible due to the limitations on the precision of the relatively inexpensive handheld GPS unit used to spatially geolocate each station.

Considerable emphasis is placed on proper completion of data sheets. Each survey has one main datasheet with all of the general survey information recorded (i.e. data, bay, beach ID, quadrat size, block size, start and end time, surveyors, start and end coordinates, total number of transects sampled, and number of datasheets, Appendix) and sample datasheets.

On each sample datasheet, the date, beach name, surveyors, and quadrat size will be recorded in addition to the sample information. Sample information includes GPS coordinates of each sample station, the size of all Manila clams, and total counts for many other shellfish in the sample.

At each sample station a GPS is used to determine the latitude and longitude of the sample position and the coordinates are recorded.

A sampling quadrat (either 2.25 ft² or 9 ft² depending on the beach, Table 1) is placed in the center of the sample station. The top 4 - 6 inches of the substrate is excavated using various implements such as garden rakes modified into clam rakes. Technicians were welcome to bring their own clam rake to the survey.

The substrate was sorted for all clams of all species to the best ability of each digger and piled in a way to ensure none of the clams would rebury themselves. The width of each Manila clam (Figure 1) was measured to the nearest millimeter using calipers and recorded. The identification of Manila clams is based on the external morphology of the shell. Total counts were taken for other species of shellfish, Native Littleneck (*Leukoma staminea*), Cockles (*Clinocardium nuttalli*), Butter Clams (*Saxidomus giganteus*), Varnish Clams (*Nuttalia obscurata*), Horse clams, and Pacific oysters, and recorded. However, counts of species other are probably incomplete because they typically live deeper in the substrate than Manila clams and could easily be missed using this protocol. The clamshell dimension chosen for measurement in the Lummi surveys protocol is shell width, rather than the more customary metric of shell length, because overall shell width is a marginally better predictor of actual clam weight than shell length (Unpublished data, Dolphin 2005). All clams are returned to the excavated holes and remain on the beach.

Table 1. Beach specific survey design

Survey Area	Steps between Transect Lines	Steps between Quadrats	Quadrat Size to be Used
Portage Bay – S4 & S5	30	15	2.25 ft ²
Portage Bay – S7D & S7E	50	15	2.25 ft ²
Portage Bay – S7D (Brant Pt Bay)	30	10	2.25 ft ²
Lummi Bay – S1C, S1D&E	200	60	9 ft ²
Lummi Bay – S1B	100	60	9 ft ²
Drayton Harbor	45	10	2.25 ft ²



Figure 1. Top view of Manila clam identifying the “shell width”, the dimension measured in the survey.

The 2018 clam survey was conducted from May 18th to July 25th 2018 during low tides. The survey took a total of 29 days to complete (Portage Bay = 15 days, Lummi Bay = 10 days, and Drayton Harbor = 4 days). The survey covered 216.1 acres in Portage Bay, 1236.7 acres in Lummi Bay, and 33.1 acres in Drayton Harbor for a total of 1485.8 acres. It took longer to complete the survey in Portage Bay (15 days) while covering less acreage (216 acres) than Lummi Bay (10 days, 1236.7 acres) because the larger sample quadrat and increased distance between samples reduces the total number of samples collected in Lummi Bay.

Data Processing

All survey data including GPS coordinates, quadrat size, and individual shell widths are entered into a custom-built Microsoft Access database. The following data processing occurs within the Microsoft Access database built by Craig Dolphin.

Beach-specific shell-width-weight relationships for Manila clams were used to estimate individual clam weights based on the shell-width data that is collected in the field (unpublished data, Dolphin 2005).

The legal size threshold shell width (equivalent to a shell length of 38mm) was estimated to be 20mm at both Birch Bay and Portage Bay beaches, while the more globular/walnut-shaped clams at Lummi Bay had a threshold shell width of 21mm.

Since the calipers used in the field can only measure clams to the nearest 1mm increment, it is assumed that only half of the clams that are recorded to be equal to the legal-size threshold were actually legal-sized, and the remaining half would have been marginally sublegal. Unfortunately, it is not possible to determine which of these threshold-sized individuals were sublegal during data analysis and including all of these clams as legal-sized could artificially inflate the final biomass estimate. Consequently, the approach used in our analysis is to include all threshold individuals as if they were legal-sized, but assign each of these threshold-sized clams half of their probable weight.

The legal size clam weights for each quadrat are determined by summing the weight of all legal size clams and converted into a density (legal size clam weights/square foot) by dividing the summed weight by the area of the sample quadrat used.

The clam survey database is then used to export a table with the following columns: latitude, longitude, and legal pounds per square foot. This table is imported into ESRI ArcMap 10 GIS software and displayed using the GPS coordinates to determine the spatial location of each quadrat. The data is overlaid with rectified and registered aerial orthophotographs of the tidelands to check for data entry and transcription/transposition errors in the coordinates. Any errors in the coordinates are then rectified and a final point shapefile is finally created and used as the basis for subsequent analysis.

Data Analysis

The placement of sample quadrats is systematically distributed but sampling density can vary between and within management areas, a simple average of the measured clam densities could result in significant bias since clam densities vary spatially. Consequently, spatial analysis of the data is undertaken in order to account for any spatial bias in the survey layout.

Spatial analysis of clam densities

To remove spatial bias introduced by unequal sample densities, the point data in the survey shapefile is analyzed using Thiessen polygons (Dolphin, 2004a). The software used is ArcGIS 10 (ESRI), which includes ArcMap, ArcCatalog, and ArcToolbox.

All spatial analysis is performed on each bay independently (i.e. Portage Bay, Lummi Bay, and Semiahmoo) including all management areas for the bay.

Firstly, point shapefiles imported into GIS from the database including all sampling information for each sample quadrat (survey date, year, beach, quadrat size, latitude, longitude, quadrat ID, and legal pounds of clams per square foot) are projected to match the projection of all other data in the map. All data are projected in NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet. [ArcToolbox: Data Management Tools: Projections and Transformations: Project]

Polygon shape files that enclose the entire area of each beach surveyed are needed. These survey area polygons are used to set the boundary extents for the Thiessen polygon analysis. For Lummi and Portage Bay the survey extended throughout multiple management areas within each bay and the Thiessen polygon analysis needs to be cropped to each management area. Therefore, the polygon shapefiles of harvest areas for Portage Bay and Lummi Bay are used as the boundary extents and then cropped further. These shapefiles include the separate harvest management divisions for the beaches. For Semiahmoo a unique polygon shapefile is created within ArcMap that connects the end points of the transect lines to enclose the survey area because there is only one management area far extends the survey area. The polygon shapefile was created using the mean high water level as the beach boundary, and then each point was buffered by 25ft (the approximate spacing between quadrats) and the boundary was drawn to the buffered distance from the end of each transect sampled. Semiahmoo is one harvest management area so no further division was needed.

A Thiessen polygon layer is then created from the survey data point shapefile using the Thiessen Polygon Tool in ArcToolbox. The Thiessen polygon files are saved into a geodatabase "ClamDensityHelper.gdb" created by Gerry Gabrisch that automatically queries the Thiessen polygons to calculate the area of the polygon in square feet. To reduce the output to match the shape of the survey area, this Thiessen polygon layer is clipped to match the survey area polygon layer using the Intersect Tool in ArcToolbox. The result of this process is a new polygon shapefile that has a polygon surrounding the area represented by each of the survey points, and limited to the boundaries of the survey area. For the Semiahmoo survey a polygon was created that bordered the survey area, so the Erase Tool in ArcToolbox was used to clip the Thiessen polygon shapefile to the area surveyed. These final polygon shapefiles are stored and saved in the ClamDensityHelper geodatabase.

This shapefile is used as the basis for estimating biomass in the total surveyed area, and is also subsequently clipped into separate management areas, using the management area polygons derived earlier, to calculate individual biomass estimates for each management area. The management area boundaries within surveyed beach areas do not fall along the exact boundaries of the polygons generated by the Thiessen Polygon analysis; therefore some Thiessen polygons were split into two during the clipping process to management areas. Consequently, the summed number of polygons for each management area sometimes exceeded the total number of polygons generated for the total survey area.

Calculate total biomass and accuracy

To complete further analysis the data need to be exported into a spreadsheet format such as Microsoft Excel or CSV. Data from the Thiessen Polygon analysis are exported into Excel using the Conversion Tool in ArcToolbox (Conversion Tools: Excel: Table to Excel)

From the Thiessen polygon output data we calculate: the total area surveyed, the spatially weighted average clam density, precision of the density estimate, total clam biomass estimate for the management area, and 95% confidence intervals for the biomass estimate.

The estimations of error around the spatially weighted mean need to be calculated based on a weighted variance. All of these calculations were preformed in R programming, software for statistical computing. The Hmisc package was used to calculate the weighted mean and variance.

The standard deviation is calculated by **Equation 1:**

$$\text{Standard deviation} = \sqrt{\text{Var}_w}$$

Var_w equals the weighted variance

The standard error is calculated by **Equation 2:**

$$\text{Standard Error} = \frac{s}{\sqrt{n}}$$

s equals the standard deviation, and

n equals the number of samples or observations (Thiessen Polygons)

The confidence around the estimate of the mean is represented by 95% confidence intervals (the mean +/- 95% C.I.).

95% confidence intervals are calculated by **Equation 3:**

$$95\% \text{ Confidence Interval} = 1.96 * \text{Standard Error}$$

Precision is a measure of how close each of your measurements is to the mean of your measurements, or the spread of your data. The precision is calculated by dividing the half width of the 95% Confidence Interval by the spatially weighted average clam density, and then multiplied by 100 to be represented as a percentage.

$$\text{Precision} = \frac{95\% \text{ confidence interval}}{x_i} * 100$$

These calculated values are used to estimate the total biomass of harvestable clams for each beach management area. The spatially weighted mean clam density (lb/ft²) is multiplied by the total area surveyed to determine the mean biomass estimate. To calculate the lower and upper biomass estimate the weighted mean clam +/- 95% Confidence Interval is then multiplied by the total area.



Figure 2. A photo showing adult and juvenile Manila clams from a survey sample station with some of the field equipment used in the survey.

Results:

The results of the 2018 clam survey estimate the total biomass of harvestable Manila clams for each management area (Table 2). The average density of clams is an order of magnitude greater in Drayton Harbor (~ 0.14 lb/ft²) than any of the beaches on the Lummi Nation Reservation (~ 0.01 - 0.03 lb/ft²). A total of 1,485 acres were surveyed, 33.1 acres in Drayton Harbor, 216.1 acres in Portage bay, and 1,236 acres in Lummi Bay (Table 2). The overall estimated biomass of Manila Clams is 1.6 million pounds from the surveyed beaches within Lummi's U & A.

Table 2. Summary of the estimated Manila Clam biomass determined from the 2018 clam survey of beaches within Lummi Nations U & A.

Drayton Harbor								
Management Area	Thiessen Polygons	Sample Size (ft ²)	Mean lb/ft ²	Acres Surveyed	Statistical Precision	Lower Biomass Estimate	Mean Biomass Estimate	Upper Biomass Estimate
20A-001	422	2.25	0.14116	33.1	19.77%	163,081	203,266	243,451
Portage Bay								
Management Area	Thiessen Polygons	Sample Size (ft ²)	Mean lb/ft ²	Acres Surveyed	Statistical Precision	Lower Biomass Estimate	Mean Biomass Estimate	Upper Biomass Estimate
21A-S4	759	2.25	0.03638	45.6	12.15%	63,452	72,224	80,996
21A-S5	529	2.25	0.01441	48.7	19.16%	24,700	30,552	36,404
21A-S7D	499	2.25	0.02653	71.6	17.74%	68,066	82,744	97,421
21A-S7E	315	2.25	0.01884	50.3	21.78%	32,288	41,275	50,263
Lummi Bay								
Management Area	Thiessen Polygons	Sample Size (ft ²)	Mean lb/ft ²	Acres Surveyed	Statistical Precision	Lower Biomass Estimate	Mean Biomass Estimate	Upper Biomass Estimate
20A-S1B	230	9	0.02236	204.5	13.96%	171,323	199,125	226,928
20A-S1C	203	9	0.01001	279.4	22.61%	94,316	121,864	149,412
20A-S1DE	413	9	0.026	752.8	13.75%	735,449	852,704	969,959
Total Biomass Estimate							1,603,754	

The density of Manila clams varies throughout the beaches, which shows that clams are not distributed evenly throughout the clam band on these beaches. The densities of clams throughout the surveyed area on all beaches are shown in figures 3-7. Clam densities are presented in the same scale for all beaches on the Lummi Nation Reservation (Portage Bay and Lummi Bay), and Drayton Harbor is presented on a larger scale due to higher densities of clams. The location of sample points and identification of the management areas is shown in figures 8-10.

Portage Bay has a total of 226,795 lb of harvestable Manila clams and Lummi Bay has 1,173,693 lb of harvestable Manila clams (Table 2). Both bays on reservation open for commercial clam harvest have similar densities of clams, but because Lummi Bay is five times larger it has five times as many harvestable pounds of clams.

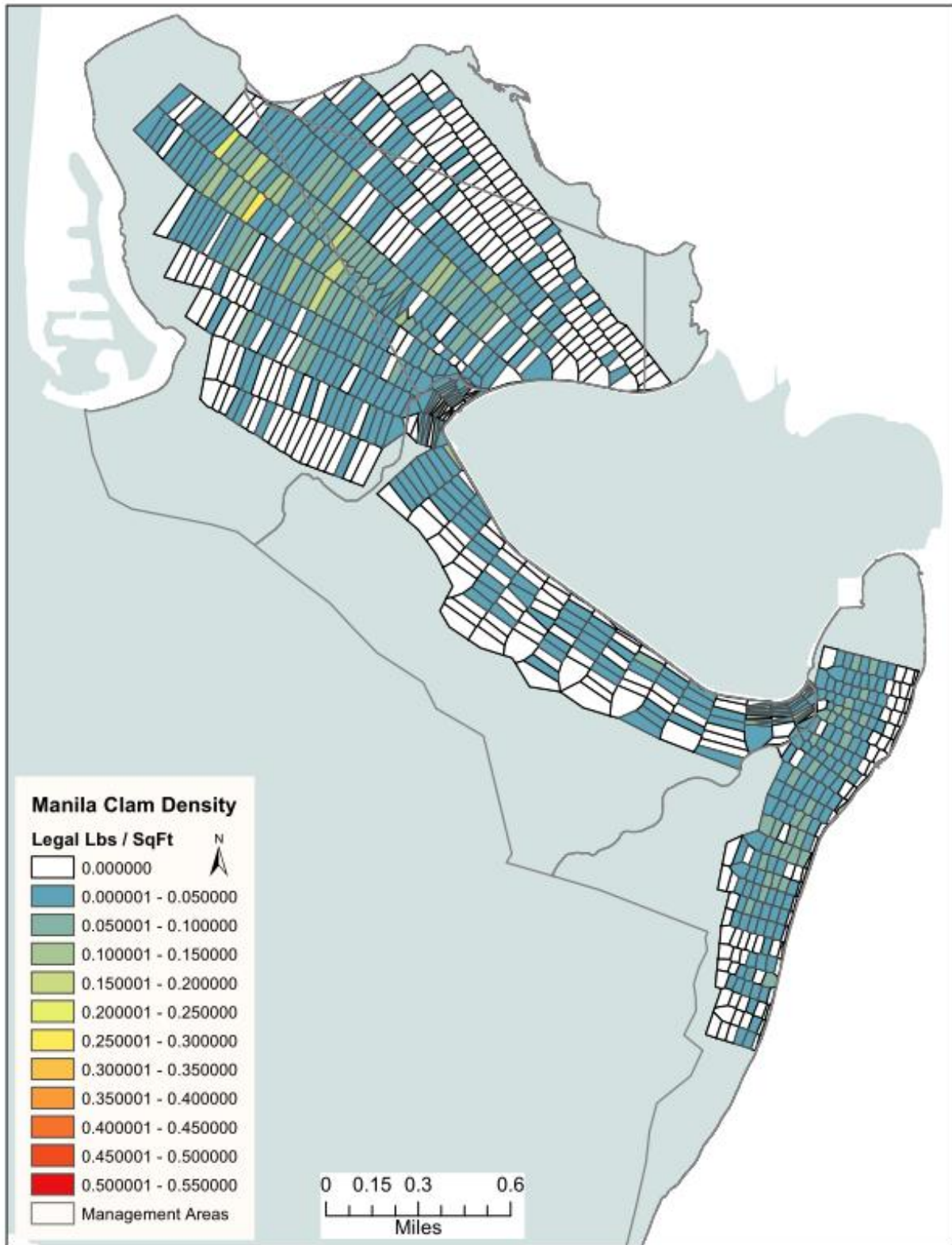


Figure 3. The densities of legal size Manila Clams within all of Lummi Bay based on the 2018 clam survey.

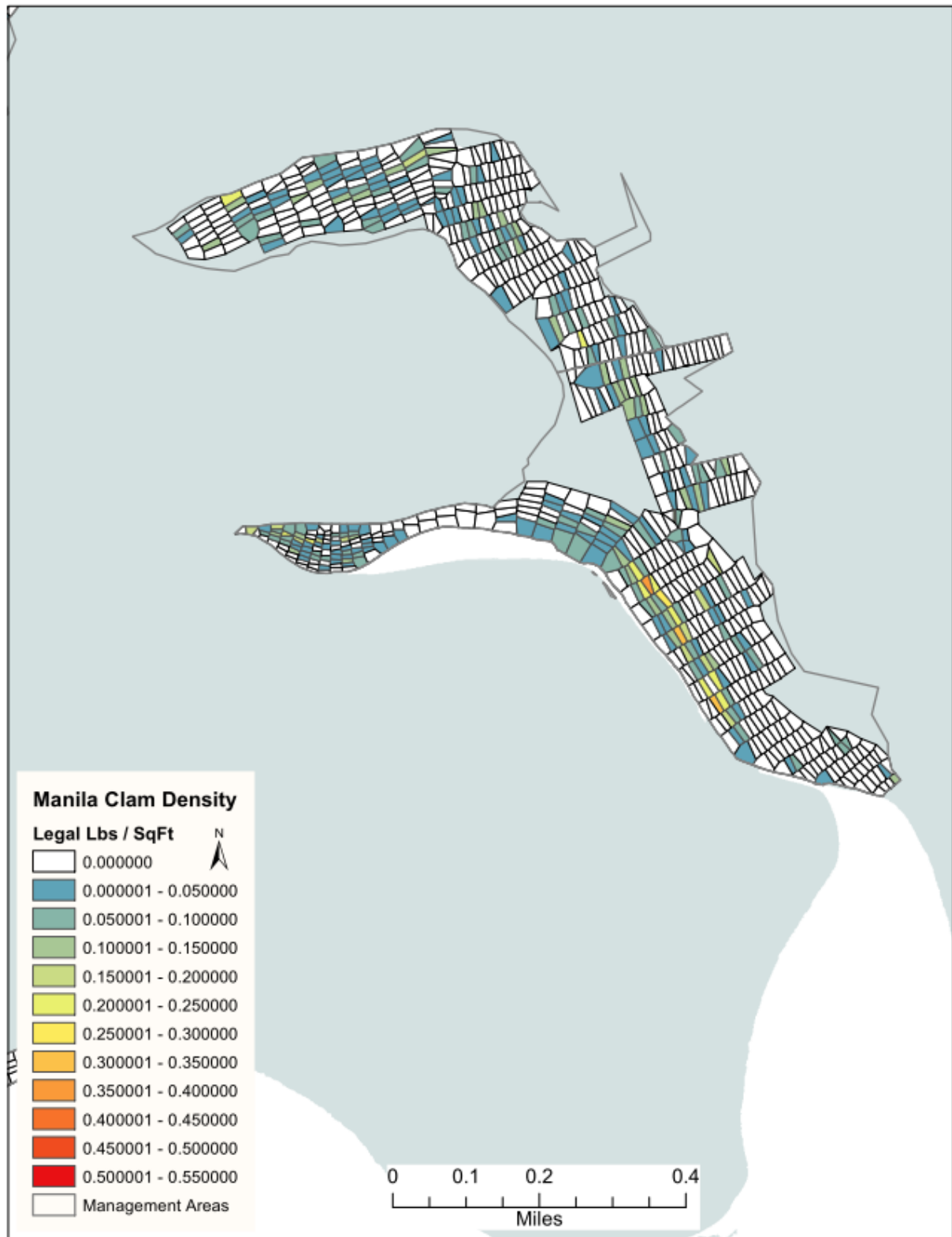


Figure 4. The densities of legal size Manila Clams within Portage Bay management areas 21A-S7D and 21A-S7E based on the 2018 clam survey.

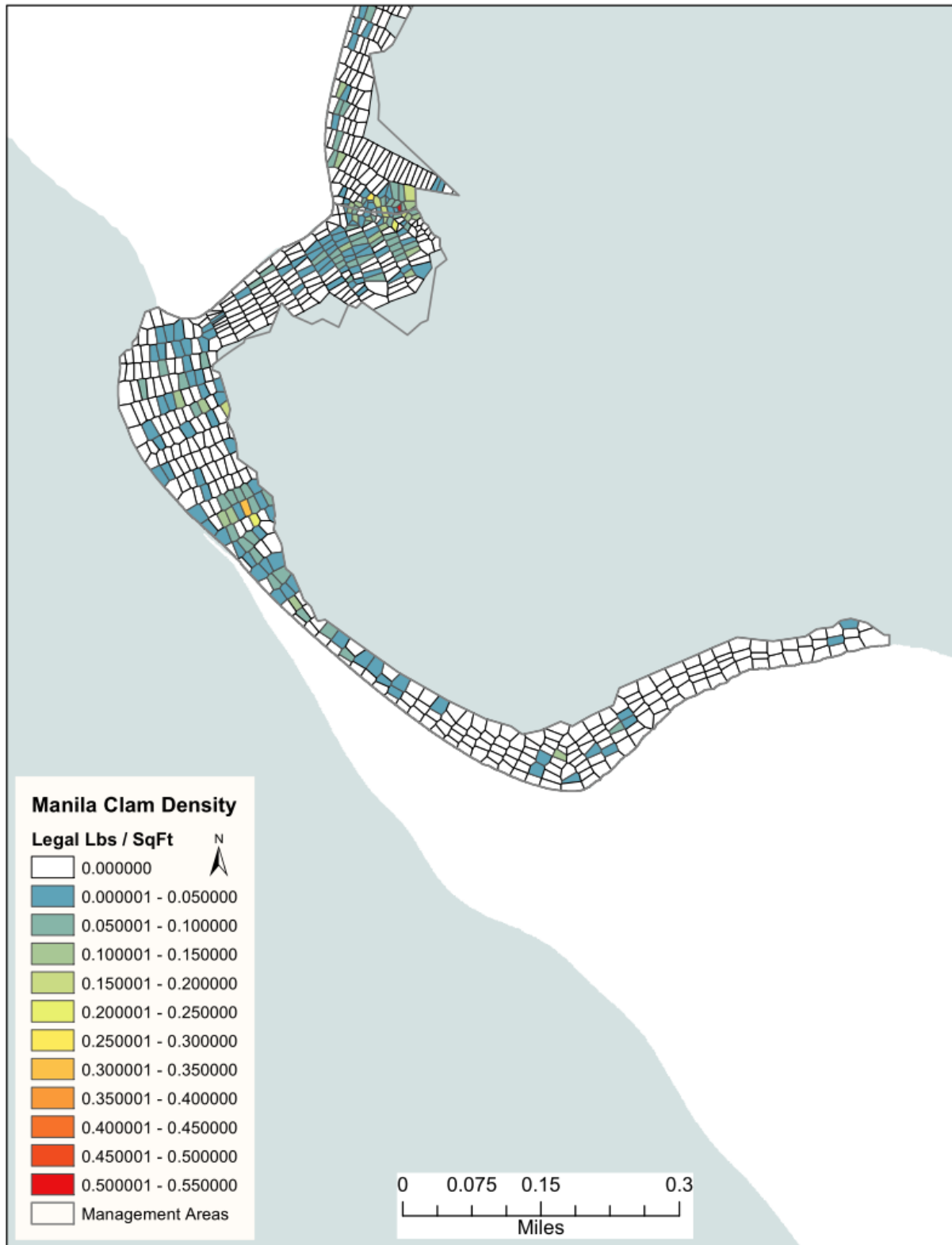


Figure 5. The densities of legal size Manila Clams within Portage Bay management areas 21A-S5 based on the 2018 clam survey.

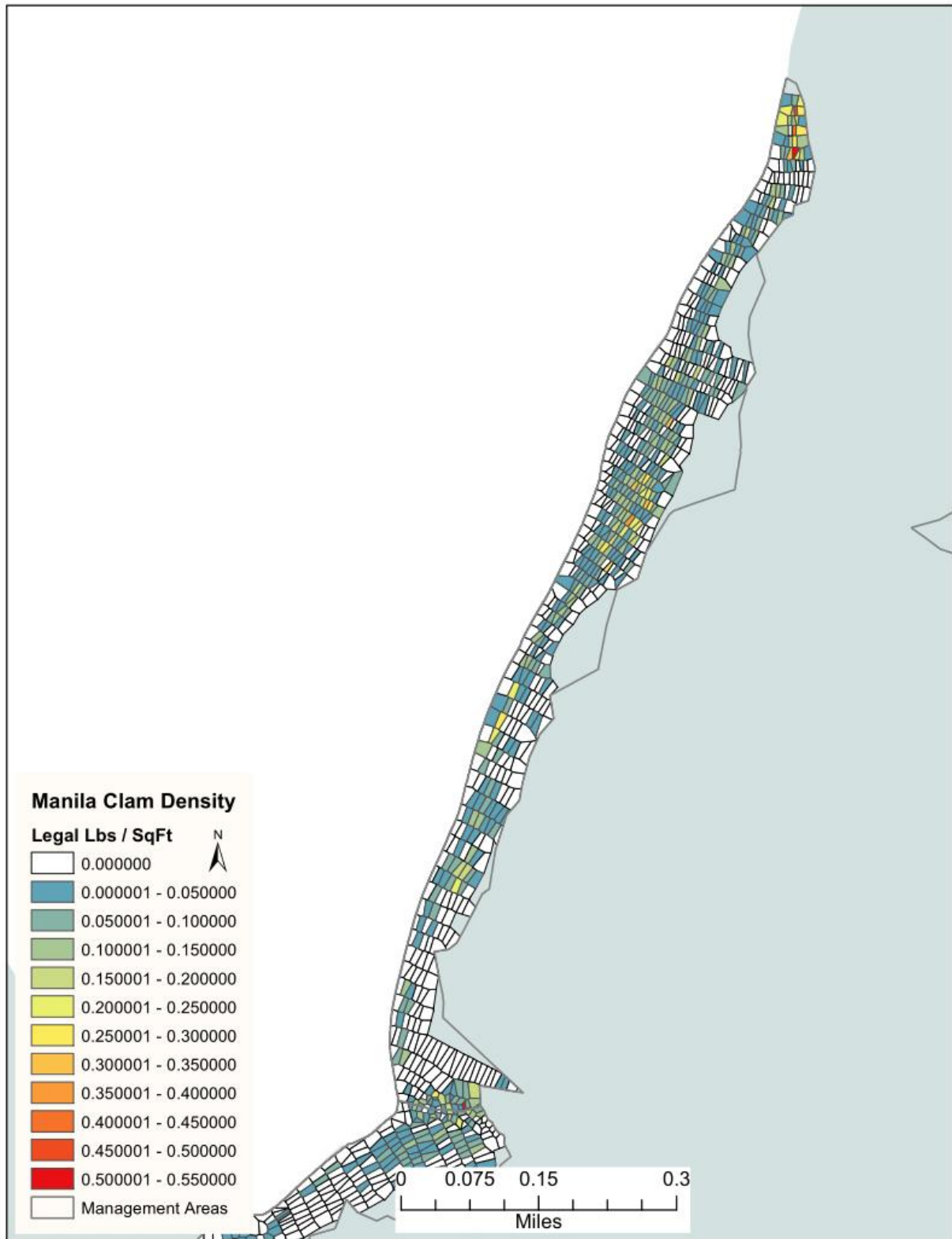


Figure 6. The densities of legal size Manila Clams within Portage Bay management areas 21A-S4 based on the 2018 clam survey.

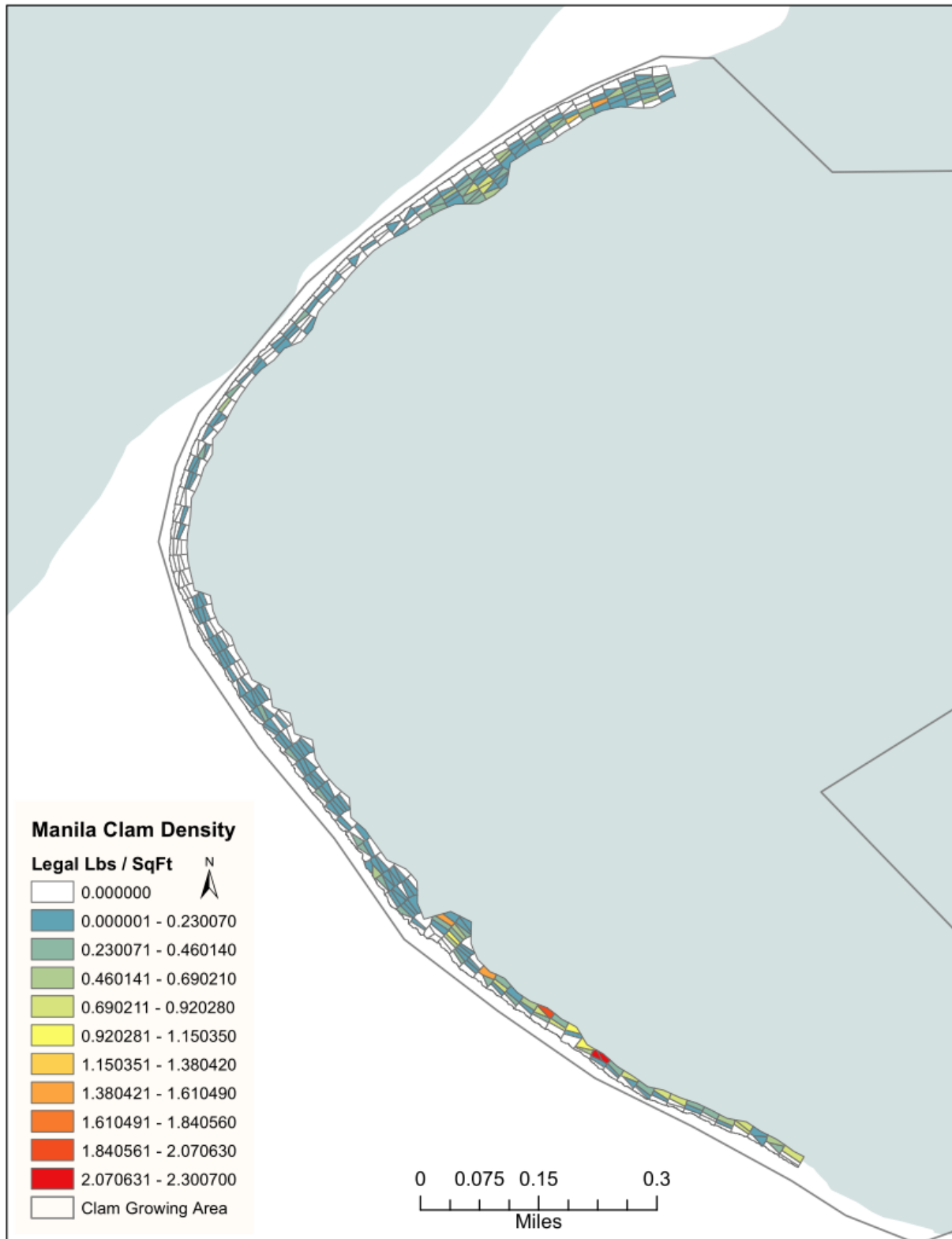


Figure 7. The densities of legal size Manila Clams within Drayton Harbor based on the 2018 clam survey. Note the difference in scale of clam densities from Lummi Bay and Portage Bay.

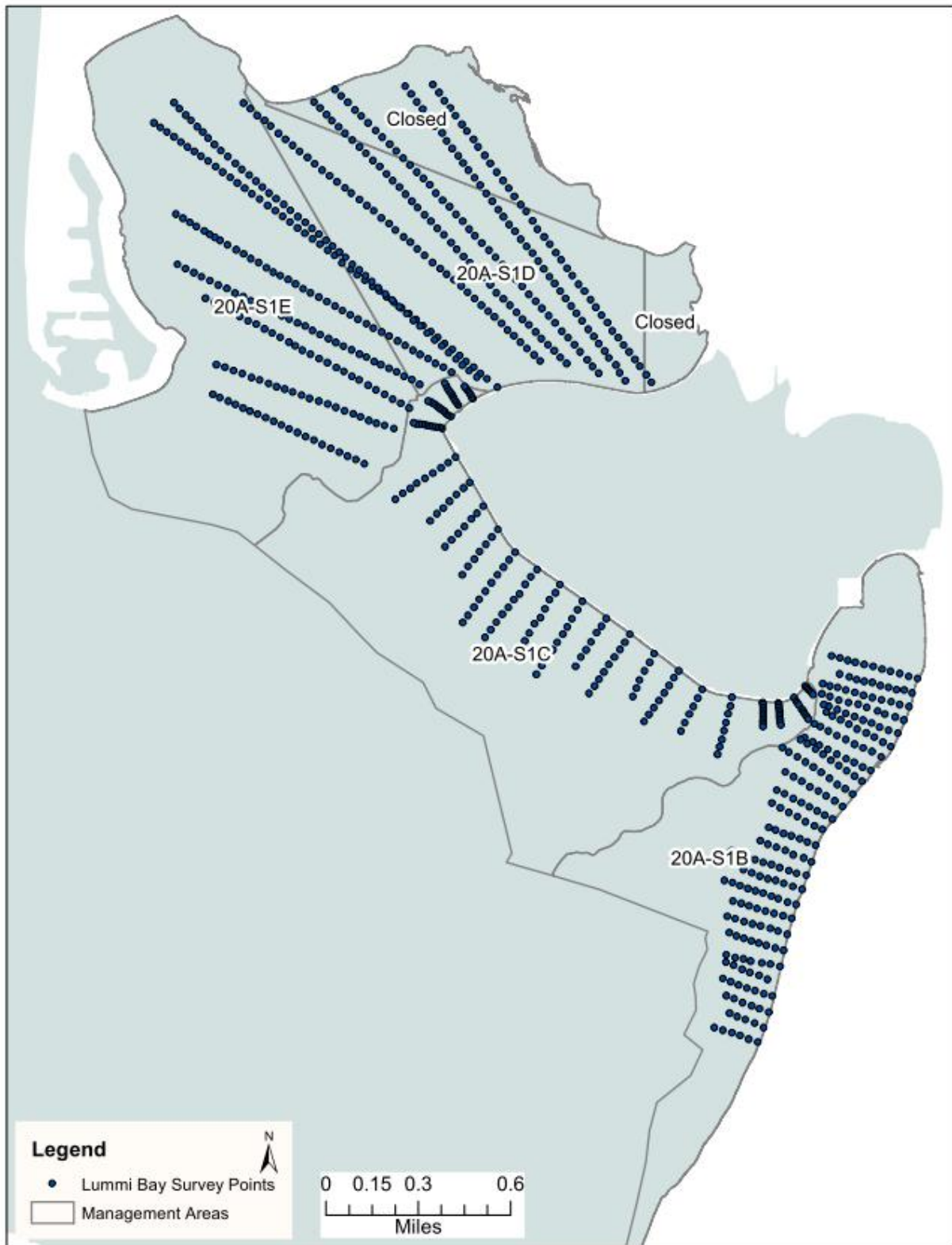


Figure 8. Survey points identifying the location of samples collected in Lummi Bay for the 2018 clam survey.



Figure 9. Survey points identifying the location of samples collected in Portage Bay for the 2018 clam survey.

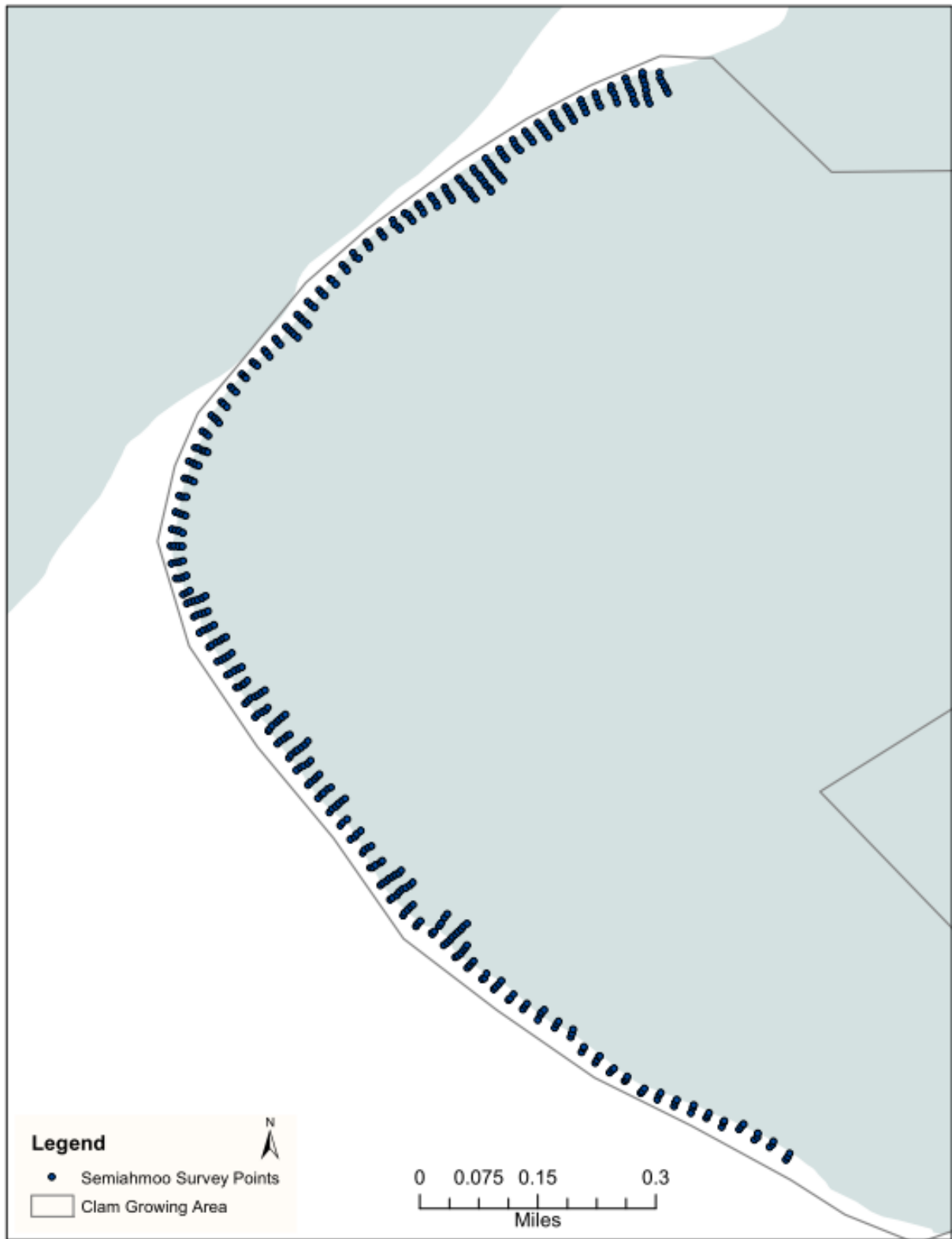


Figure 10. Survey points identifying the location of samples collected in Drayton Harbor for the 2018 clam survey.

Harvest Limits:

The ultimate goal is to set sustainable harvest limits that allow the Lummi Nation to continue to harvest Manila clams for generations to come. Populations of Manila clams are at risk to decline from natural pressures, such as winterkill events and impacts of climate change, and human induced decline such as overharvest and habitat destruction. Additionally, recruitment success can vary considerably from year to year. Total allowable catch (TAC) levels should be set based on the biomass of harvestable clams on the beach. TAC is usually set as a percentage of the harvestable biomass, but there is not a “one-size-fits-all” harvest rate that is sustainable for all beaches.

Public beaches co-managed between the State of Washington and tribes set the TAC at 33% of the harvestable biomass. Almost all state and tribal sharing is 50:50, with the exception of Birch Bay State Park where Lummi Nation is allowed to harvest 80% of the TAC of Manila clams. This harvest rate however is not based on scientific inquiry and there is no evidence to show this is a sustainable harvest rate. From 2002 to 2015 TAC levels on reservation beaches were set based on expected production and the trends in the population (i.e. if the population is declining lower harvest rates were set and if the population was growing higher harvest rates were set).

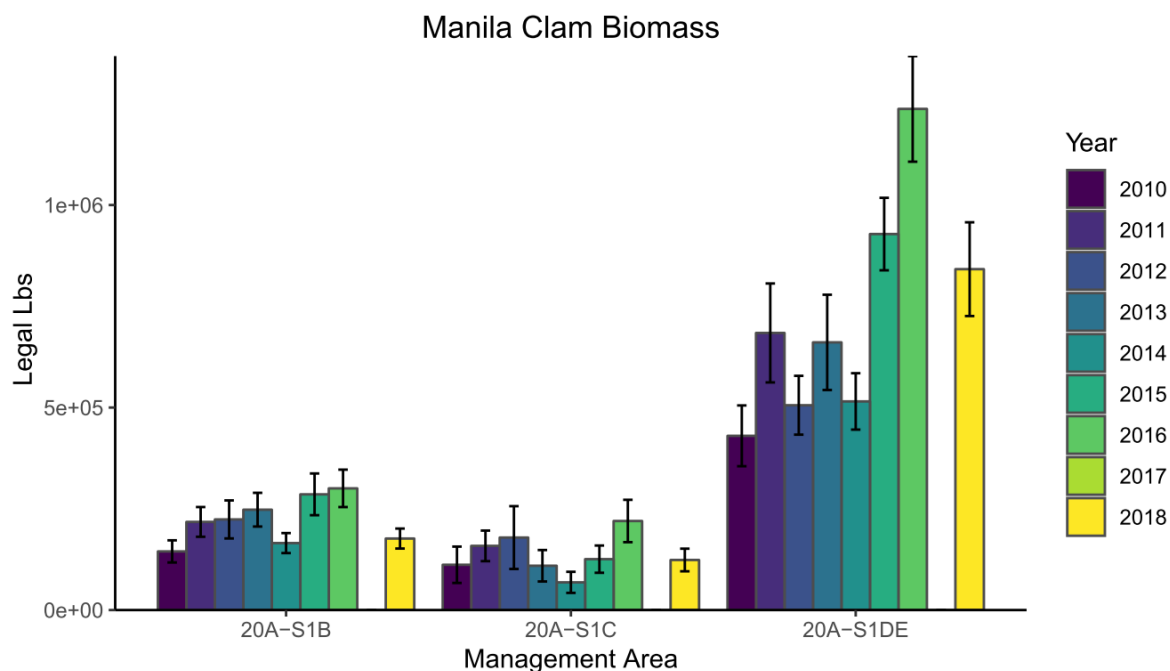


Figure 11. Change in Manila clam biomass in Lummi Bay management areas from 2010 to 2018, no survey was conducted for 2017. Manila clam biomass was calculated using the spatially weighted clam densities normalized to the average area surveyed across years because the total area surveyed varies from year to year a direct comparison of biomass estimates are not meaningful.

Sustainable harvest rates should consider long term trends in the population, minimum density required for successful reproduction, and past harvest rates that have been

successful at maintaining or growing the population. Thus, if a beach has declined significantly from overharvest or natural pressures a sustainable harvest rate would set lower TAC levels that allow the population to recover. Therefore, harvest rates should not remain constant and should account for recent changes in the population.

Current Manila Clam Population Status

Manila clam populations on the Lummi Nation Reservation declined dramatically from the last biomass survey in 2016 to now (Figure 11 and Figure 12). During the winter of 2017 there was a severe winter storm that caused a winterkill event of Manila clams. The loss of biomass attributed to this winterkill event is estimated to be 801,840 lb of harvestable clams on the reservation (Hintz 2018). On average, that equates to a 47% decline in the population across all beaches (Hintz 2018). The winterkill event had the most severe impact in Portage Bay management area 21A-S5 where the population declined by 85% (Hintz 2018). The two management areas with the smallest impact from the winterkill event, 21A-S4 in Portage Bay and 20A-S1D&E in Lummi Bay, still declined by 28%. The mass mortality of Manila clams in 2017 needs to be taken into account when setting harvest rates until the populations recover.

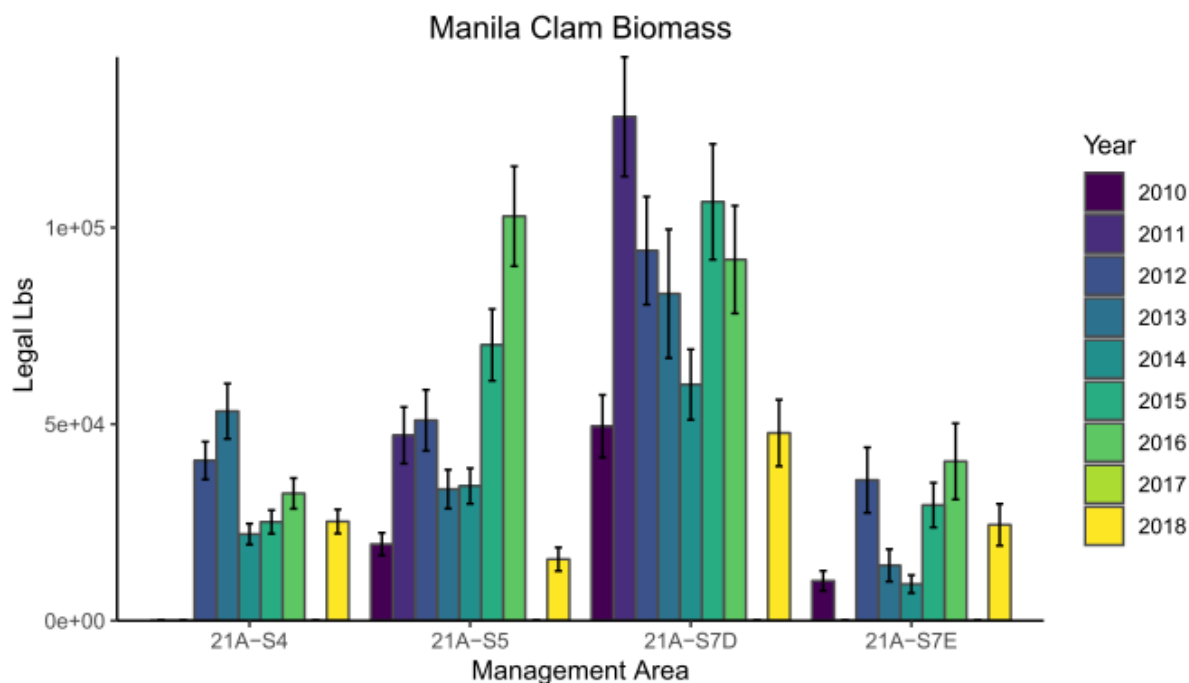


Figure 12. Change in Manila clam biomass in Portage Bay management areas from 2010 to 2018, no survey was conducted for 2017. Manila clam biomass was calculated using the spatially weighted clam densities normalized to the average area surveyed across years because the total area surveyed varies from year to year a direct comparison of biomass estimates are not meaningful.

The significant decline in clam biomass from the winterkill event was not known when harvest levels were set for the 2017-2018 management year because no clam biomass

survey had been conducted. Thus, for the 2017-2018 management year TAC was set to 25% of the biomass estimate from the 2016 biomass survey. Actual commercial harvest rates were only 14% and 9%, in Portage Bay and Lummi Bay respectively, of the 2016 biomass estimate (Table 3). Furthermore, there was much less commercial harvest (87,061 lb) during the 2016-2017 management year due to the winterkill event (Table 3).

Proposed Harvest Rates

For the 2018-2019 management year a 10% harvest rate is proposed for most on-reservation beaches (Table 3). This proposed harvest rate allows for a total of 136,994 lb of Manila clams to be commercially harvested on beaches on-reservation (Table 3). The conservative harvest rate of 10% was chosen to apply to all on-reservation beaches despite 21A-S5 in Portage Bay, which has a 0% commercial harvest rate. Even though the decline in biomass varied between management areas, a consistent rate was chosen to simplify the process and provide opportunities on most beaches. There will be zero commercial harvest in area S5 of Portage Bay to allow the population to recover from the 85% population decline.

Table 3. Comparison of Manila clam commercial harvest landings from past management years to the proposed TAC level for the 2018-2019 management year.

Area	Beach	Management year				Proposed Harvest
		2014-2015	2015-2016	2016-2017	2017-2018	10% TAC
Portage Bay	S4	14,647	1,012	-	4,969	7,222
	S5	8,445	4,651	-	8,250	-
	S7A	621	621	-	8,113	-
	S7D	14,143	14,928	-	23,967	8,274
	S7E	-	-	-	4,688	4,128
Lummi Bay	S1B	10,781	15,004	3,675	42,193	19,913
	S1C	2,317	1,147	2,278	5,837	12,186
	S1D&E	55,784	74,757	81,108	88,155	85,270
Total Pounds		106,738	112,120	87,061	186,172	136,994

The conservative harvest rate of 10% was chosen based on previous sustainable harvest rates to allow the Manila clam populations to recover from the winterkill event. Harvest rates from 2013 to 2015 allowed populations of Manila clams to recover from harvest pressure identified by the fact that the biomass of harvestable Manila clams increased in all management areas these years. Commercial harvest rates ranged from 9-24% during these years. The harvest rate chosen was at the lower end of the range because the TAC levels for commercial harvest do not take into account harvest for subsistence, ceremonies, or illegal poaching.

Considerable subsistence harvest of Manila clams occurs in both Portage and Lummi Bay. An estimated 14,906 lb and 25,988 lb are harvested annually in Portage and Lummi Bay

respectively (Mueller and Starkhouse 2018). A more realistic total harvest rate for the upcoming 2018-2019 management year including the harvest for subsistence is 17% in Portage Bay and 12% in Lummi Bay. Furthermore, these estimates of subsistence harvest do not include harvest for ceremonial purposes and illegal poaching so the actual harvest of Manila clams from on-reservation beaches will likely be higher.

From all beaches on and of reservation available to commercial harvest at this time, a total of 202,956 lb of Manila clams are subject to commercial harvest. The majority of that biomass (57%) is to be harvested from Lummi Bay. The rest of the Manila clams are to be harvested from Portage Bay (9%), Semiahmoo in Drayton Harbor (16%), and Birch Bay (16%) (Table 4). The Washington Department of Fish and Wildlife is responsible for surveying Birch Bay, and the TAC for manila clams is split between the state and Lummi 20:80.

Table 4. Summary of commercial Manila clam TAC for all beaches surveyed in 2018 combined with the estimated subsistence harvest pounds to summarize the most realistic estimate of pounds of Manila clams harvested.

General Area	Management Area	Mean Biomass Estimate (lb)	Commercial TAC	Estimated Subsistence Harvest**	Total Percent of Biomass Harvested
Birch Bay	200060	122,816	32,423*		
Drayton Harbor	20A-001	203,266	33,539*		
	21A-S4	72,224	7,222	-	
	21A-S5	30,552		-	
Portage Bay	21A-S7D	82,744	8,274	-	
	21A-S7E	41,275	4,128	-	
	All	226,795	22,679	14,906	15%
	20A-S1B	199,125	19,913	-	
Lummi Bay	20A-S1C	121,864	12,186	-	
	20A-S1DE	852,704	85,270	-	
	All	1,173,693	117,369	25,988	12%
Total Pounds			202,956	40,894	15%

* TAC levels for Drayton Harbor and Birch Bay are based on the 33% harvest rate for co-managed beaches and that share is split between the state and the tribe, for Drayton Harbor the share is split 50:50 so the tribal share is 16.5% of the biomass and for Birch Bay the share is split 80:20 so the tribal share is 26.4% of the biomass.

** Estimates of subsistence harvest from Mueller and Starkhouse (2018)

References

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Appendix: Clam survey datasheets



Clam Survey – Daily Beach Datasheet

Lummi Natural Resources

Date: _____

AREA/BAY: Lummi Bay

Beach ID: _____

Total number of
transects sampled: _____

Portage Bay

Quadrat Size: _____

of datasheets: _____

Drayton Harbor

Start Time: _____

End Time: _____

Block Size

Beach boundary line

Steps between transects: _____

Compass bearing: _____

Steps between quadrats: _____

Distance visual markers: _____

Diggers:

Surveyor:

Boundaries of area sampled (shore coordinates, beginning of transect lines):

Start:

End:

NOTES:



INITIALS/PAGE #

SHELL WIDTHS OF INDIVIDUAL MANILA CLAMS FOUND IN QUADRAT																LAT (48°) (min, 5 digits)	LONG (122°) (min, 5 digits)	OTHER SHELLFISH (#)	
																		Littleneck Cockle	Varnish
																		Butter Horse	Oyster
																		Littleneck Cockle	Varnish
																		Butter Horse	Oyster
																		Littleneck Cockle	Varnish
																		Butter Horse	Oyster
																		Littleneck Cockle	Varnish
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