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Status of Oregon bay clam fisheries, stock assessment, and research

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Justin C. Ainsworth
Anthony F. D'Andrea
Mitch Vance
Scott D. Groth
Elizabeth A. Perotti

Oregon Department of Fish and Wildlife
Marine Resources Program
2040 SE Marine Science Drive
Newport, Oregon 97365, U.S.A.

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Chapter 1 Introduction

Clams can be found in a variety of habitats, but it is the most accessible species that earn the attention of clam diggers. In Oregon, the largest clam fisheries are for razor clams (*Silqua patula*) along the open coast, and for a group of clams collectively known as bay clams found, as the name implies, within the state's many bays and estuaries. Bay clams (cockles (*Clinocardium nuttallii*), butter clams (*Saxidomus gigantea*), gaper clams (*Tresus capax* and *T. nuttallii*), and native littleneck clams (*Leukoma staminea*)), have long been the target of recreational and commercial harvest in Oregon. While Hunter (2008) described the fishery, research, and management of razor clams in Oregon, the harvest, stock assessment, habitat studies, and other research on bay clams are the focus of this report.

Management of Oregon's bay clam resource and habitat is the responsibility of the Oregon Department of Fish and Wildlife (ODFW) Shellfish Program (ODFW 2008). Starting in 2008, with funds generated by the implementation of a recreational shellfish license in 2004, the ODFW Shellfish Program began several projects to monitor bay clam fisheries, assess their population and distribution, inventory habitats, and conduct relevant research to assist in bay clam management needs. The results of these projects, through 2012, are reported here.

Several of the projects described herein are still ongoing, and have expanded in time and/or geographic extent. The Shellfish and Estuarine Assessment of Coastal Oregon (SEACOR) project has completed work in Coos Bay and Tillamook Bay (summary reported here), but continues to conduct studies in Yaquina Bay and Netarts Bay. Recreational fishery creel surveys continue during the spring and summer low tides, monitoring for fishery trends over time. The bay clam commercial fishery is dynamic, and continual monitoring of the harvest is essential for evaluating regulations. As a result, while some of the projects reported here have been completed, much of this report reflects the status of continuing projects.

The findings from these research and fishery monitoring projects are synthesized and applied to managing bay clam fisheries and habitats. Demand on the resource from recreational and commercial fisheries is continually evolving and management must respond to changes with the best science available. By objectively reporting on clam populations and fisheries, this report will provide much of the data needed to address current and future management questions. The connections between stock assessment, biology, and fishery harvest are continually updated, and are reflected in adapting regulations to meet management objectives.

Bay clam populations, fisheries, and habitats have been monitored historically, leading to reports that have assisted ODFW (and its predecessor, the Fish Commission of Oregon, or FCO) sustainably manage bay clam fisheries and protect vulnerable habitat. These “status” reports compiled fishery independent data with recreational and commercial fishery data to provide an overview of the current state of the bay clam resource. These reports were summaries of stock assessment and habitat studies (e.g., Hancock et al. (1979) and Bottom et al. (1979)), and fishery survey reports (e.g., Gaumer et al. (1973) and Gaumer (1990)).

Nearly 100 years ago, Edmonson (1920) described bay clam stocks, mapped their presence, and documented commercial fishery landings at the time. Tollefson (1948) also described bay clam stocks and fisheries, and provided information that led to restrictions of the gaper clam harvest season. Marriage (1954) continued with general species descriptions, but also provided information on the importance of recreational clam digging to coastal communities. Recreational and commercial fisheries and stock assessment studies of the 1950s through the 1970s were detailed in FCO (1975). Gaumer et al. (1979) provided summaries of recent age and growth research, clam habitat studies, and commercial clam fishery development activities.

Gaumer and McCrae (1990) dug deeper into the data collected from stock assessments, presented summaries of recent fishery surveys, and analyzed fishery regulations. They showed that variations in abundance due to recruitment can be reflected in the recreational catch. In addition, they showed environmental influences were found to affect bay clam populations, as they described floods and, separately, the tsunami from the 1964 Alaska earthquake, killing clam beds in Tillamook and Yaquina bays. During this period, commercial harvest of bay clams was on the increase, and Gaumer and McCrae documented management actions to restrict harvest methods. Their description of the stock status and fisheries in each bay was extensive. They felt that while bay clam stocks appeared healthy, they expressed concern about habitat loss from the filling in of tideflats for development purposes.

The information compiled in this report is a comprehensive summary of the current status of Oregon’s bay clams and will hopefully be an important reference for effective management of the resource. In addition, we also hope that this report will reach a larger audience, especially the recreational and commercial bay clammers who have funded much of the research through license and permit fees. We hope that these studies on bay clams will help us understand the impacts of fisheries, assess regulations, and prioritize management objectives, ensuring that habitats are protected and bay clam populations can sustain productive fisheries for future generations.

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Chapter 2 Recreational bay clam fishery creel survey

INTRODUCTION

The ODFW Bay Clam Data Series Reports, released annually from 1983 to 1998, documented efforts between 1975 and 1998 to assess the status of Oregon's recreational bay clam fishery (Gaumer 1990; Johnson 1998). The Bay Clam Data Series Reports described recreational clam digger creel surveys (a technique to estimate catch and effort through interviews) conducted at the popular clam beds of Tillamook, Netarts, Yaquina, and Siuslaw bays continuously for most of the time series. Nestucca, Coos, and Alsea bays were added in the 1980s, and two clam beds in the Umpqua estuary were surveyed in the early 1990s. Between 1975 and 1983, staff members interviewed harvesters from each of the clam beds three or four times per season. From 1984 to 1991, survey effort was reduced, and the beds were surveyed twice per season. The bay clam creel survey program was eliminated due to budget constraints in 1991, but volunteers were able to collect creel survey data from 1992 through 1998. The Bay Clam Data Series Reports evaluated the status of clam stocks using clam digger catch rates and biological data (Gaumer and McCrae 1990), but estimates of total annual clam digger effort were not made. Prior to the present study, total annual bay clam digger effort has not been estimated since 1971 (Gaumer et al. 1973).

Presented here are results from a resurrected recreational bay clam creel survey begun in 2008 with funding from the recreational shellfish license created by the 2003 Oregon State Legislature. Currently, the survey monitors the bay clam harvest in Tillamook, Netarts, Yaquina, and Coos bays, providing the Shellfish Program staff with the information necessary to manage this important fishery.

Clams targeted by diggers in Oregon's bays include butter clams (*Saxidomus gigantea)*, cockles (*Clinocardium nuttallii)*, gaper clams (*Tresus capax* and *T. nuttallii*), and native littleneck clams (*Leukoma staminea*). Collectively known as “bay clams”, ODFW regulations allow a daily limit of 20 bay clams per person, 12 of which may be gaper clams. Eastern softshell (*Mya arenaria*) and purple varnish clams (*Nuttallia obscurata*) are both introduced species and have daily bag limits of 36 and 72 clams per person, respectively. Although there is harvest activity on clam beds containing eastern softshell and purple varnish clams, the bay clam creel survey is primarily focused on the beds of the four native bay clam species.

The goal of the bay clam creel survey is to provide estimates of clam digging effort and harvest in Oregon estuaries. A comprehensive study of all clam-bearing bays along the coast would be time- and cost-prohibitive, so creel surveys are focused on the most utilized clam digging seasons (spring and summer) in the four estuaries with the most active bay clam fisheries. Samplers intercepted and interviewed clam diggers upon finishing their clam digging activities to estimate catch rates of the various clam species. Total effort was estimated from instantaneous counts of clam diggers. With estimates of catch rates and total effort, this study estimates the total number of clam digger visits to, and clams harvested in, four Oregon bays from 2008 to 2012.

METHODS

Study Sites

Within each of the four bays surveyed, individual clam beds were usually distinct regions with a limited number of access points. Many of the clam beds were identical to the beds identified in the Bay Clam Data Series Reports of the 1970s and 1980s, allowing comparisons to be made between the studies.

Tillamook Bay

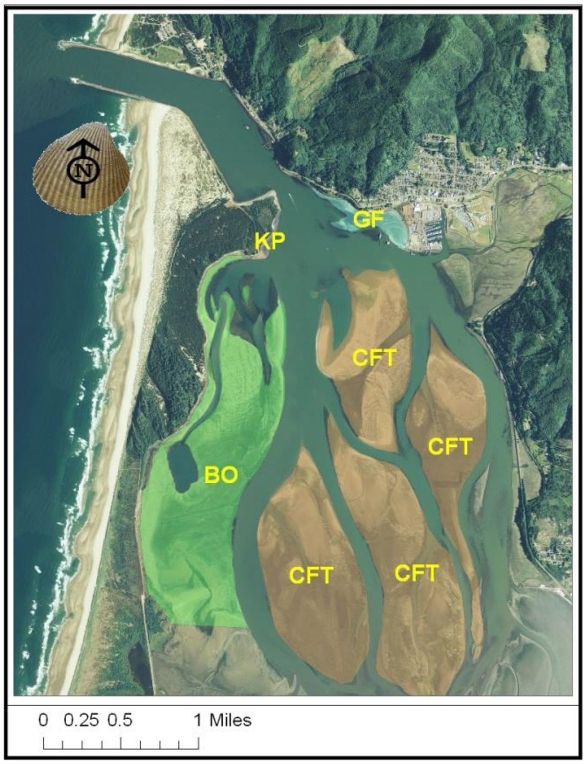

Figure 2-1. Tillamook Bay clam beds.

Tillamook Bay was divided into four areas (Figure 2-1). Garibaldi Flat (GF) is a popular and easily accessible clam bed located just west of the Garibaldi Marina, just off of 12th Street. Central Flat (CFT) is a complex of islands located across the main navigational channel from Garibaldi. Accessing these islands requires a boat. Kincheloe Point (KP) is a small clam bed just north of Bayocean (BO). Most clam diggers in these two areas access the beds with boats, but both of these locations can be accessed from the Bayocean Peninsula.

Netarts Bay

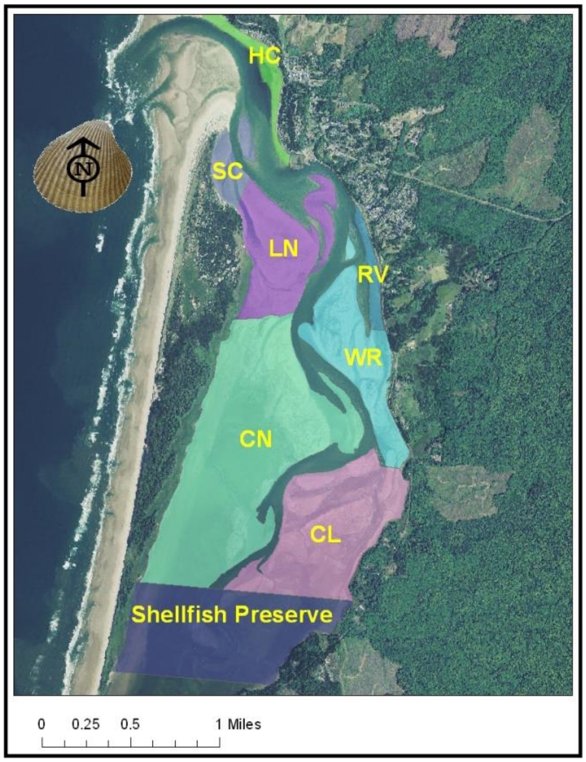

Figure 2-2. Netarts Bay clam beds.

Netarts Bay was divided into six areas (Figure 2-2). Happy Camp (HC), located near the mouth of the bay, can be accessed at the end of Happy Camp Road. Along the Netarts Bay Road, south of the Netarts Marina, a clam bed can be accessed across the street from Netarts Bay RV Park (RV). A large and popular clam bed along the east side of Netarts Bay, named Whiskey River (WR), is accessible from parking areas at the confluence of Netarts Bay Road and Whiskey Creek Road. Further south is another clam bed named Cape Lookout (CL). The clam beds on the west side of the channel running through Netarts Bay are only accessible by boat. These areas are Schooner (SC), Lower Netarts (LN), and Central Netarts (CN).The Netarts Bay Shellfish Preserve in the upper bay is an area set aside for shellfish research, and harvest is not allowed within its boundaries.

Yaquina Bay

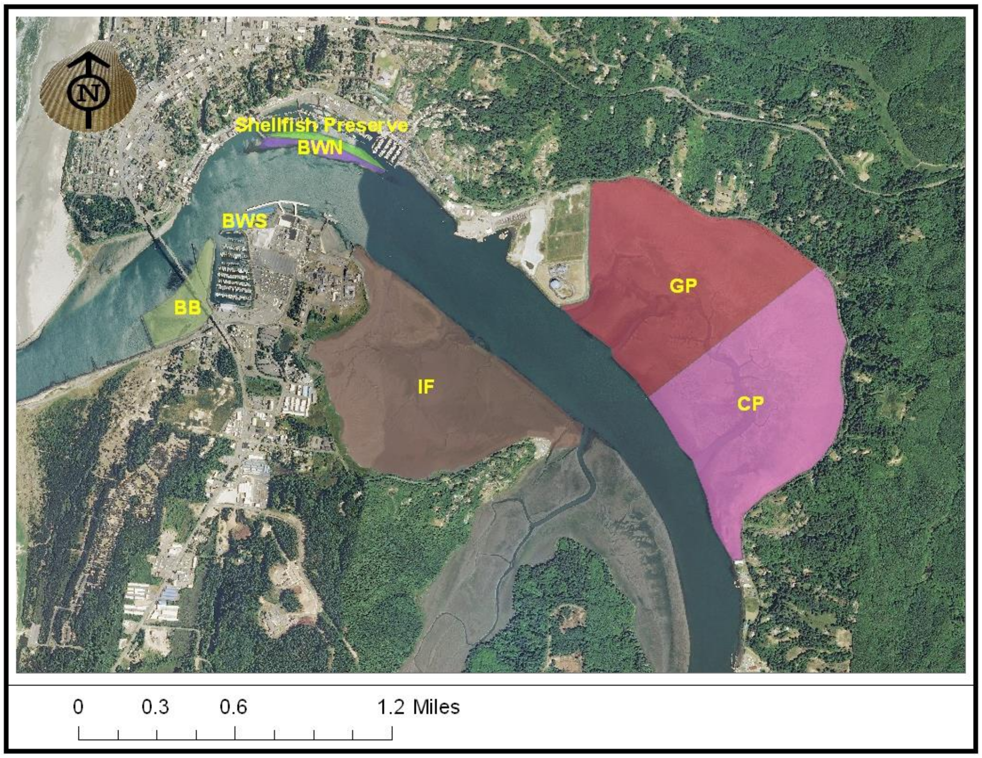

Figure 2-3. Yaquina Bay clam beds.

Yaquina Bay has six clam beds that were surveyed (Figure 2-3). The Bridge Bed (BB), located under the south end of the Yaquina Bay Bridge, is a popular clam bed bordered on the west by a finger jetty and on the east by another jetty forming the Port of Newport's South Beach Marina. The Breakwater North (BWN) clam bed is located on the south side of the island breakwater protecting the Port's Commercial Marina, and is accessible only by boat. The tideflat north of the breakwater wall is the Yaquina Bay Shellfish Preserve, where clam harvest is prohibited. Breakwater South (BWS) is located just north of the South Beach Marina, adjacent to the National Oceanographic and Atmospheric Administration's Marine Operations Center-Pacific facility. The Idaho Flat (IF) clam bed is accessed from the Hatfield Marine Science Center to the west, and from various access points at the tip of Idaho Point. Gas Plant (GP) and Coquille Point (CP) clam beds are two halves of the tideflat known as Sally's Bend.

Coos Bay

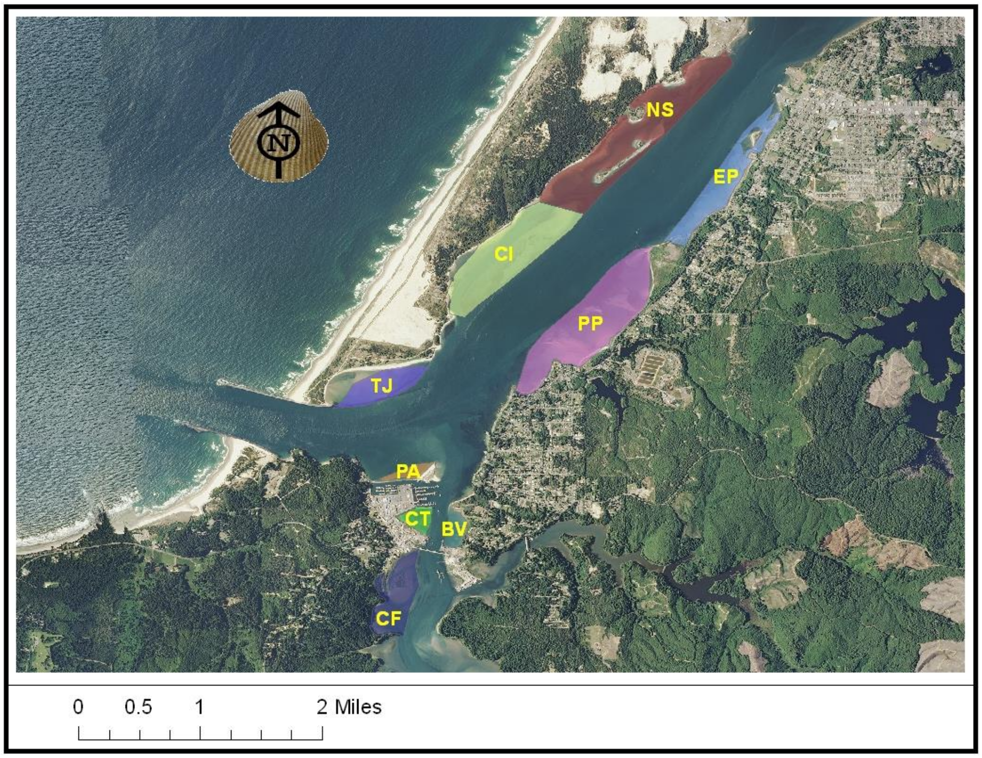

Figure 2-4. Coos Bay clam beds.

Eight clam beds in Coos Bay were surveyed (Figure 2-4). The North Spit (NS) area includes the shoreline and one island and is accessed from shore or by boat. The nearby Clam Island (CI) area is also accessed by boat and from shore, and includes an island that is submerged at high tide. The Training Jetty (TJ) area is a tideflat that does not contain any significant bay clams and was therefore not surveyed for this report. Point Adams (PA) clam bed is located just north of the Charleston Marina. Charleston Triangle (CT) and Charleston Flat (CF) are two popular and easily accessible clam beds near Charleston. The Barview (BV) clam bed is accessed from the Barview State Wayside. The clam bed near Pigeon Point (PP) is accessed by paths at the northern and southern ends. The clam bed near Empire (EP) District of Coos Bay is accessed by a trail near the wastewater treatment plant.

Estimation

Effort

Estimating daily clam digging effort begins with making instantaneous counts (IC) of bay-wide effort (number of diggers) on days with low tides 0.0 ft from mean lower low water (MLLW) and lower. Counts were completed at or near the time of low tide on all clam beds of an estuary. These counts were expanded to estimate whole day effort (E) using a formula derived from a model termed the Effort Distribution Ratio (EDR). The EDR model was adapted from techniques used by the Washington Department of Fish and Wildlife to model effort in Puget Sound bivalve fisheries (Strom and Bradbury 2007).

The EDR model relies on the relationship between instantaneous counts and the total numbers of diggers that visit a clam bed on a given day. An instantaneous low tide count does not estimate the total number of diggers because diggers that have left before the count, or diggers who arrive after the count, are not included (Strom and Bradbury 2007). To estimate the total daily number of diggers from instantaneous counts, samplers conducted whole day effort counts of clam digging effort. Samplers arrived on the clam bed 3 hours before low tide and stayed until 3 hours after low tide time while conducting 13 discrete instantaneous counts every 30 minutes. The middle count (#7) was made at exactly the time of low tide. These counts rise and fall, mimicking the ebb exposing the clam bed before the flood covers it again.

Diggers present on the bed for an hour or more will be included in multiple instantaneous counts; therefore the total number of daily diggers is not the sum of the instantaneous counts. At the same time as instantaneous counts were completed, a census was conducted by recording the total number of diggers for the whole day. This was a continuous process of tallying the diggers as they exited the clam bed at the completion of their trip, and yielded an unbiased census of whole day effort.

From each of the whole day effort counts, a series of ratios of instantaneous counts to a single census effort count were established such that:

$$EDR_t = IC_t / E_{census}, \quad (1)$$

where t=13 for each EDR day. Since 13 instantaneous counts were made for each EDR count day, a table of 13 ratios is created. On a typical day, these values will rise and fall as the effort increases with the ebb before decreasing with the flood.

Whole day effort observations on 12 different beds from all four of the bays sampled were pooled together to create the EDR model. For each of the 13 ratios that compose the model, a mean value and standard error (SE) can be calculated,

$$\overline{EDR_t} = \sum_{n=1}^{n} (IC_t / E_n) \tag{2}$$

$$SE(\overline{EDR_t}) = {sd(EDR_t)}\big/{\sqrt{n}} \tag{3}$$

where n is the number of whole day effort observations.

The EDR model expands instantaneous counts by using the $\overline{EDR_t}$ values. By rearranging equation (1), the whole day effort ($\hat{E}_d$) from an instantaneous count (IC_d) on day d at time t can be estimated with:

$$\hat{E}_d = IC_{d,t} / EDR_t , \tag{4}$$

where t represents the proximity to the time of low tide the instantaneous count was completed. The EDR model's 13 distinct values (EDR_t) can be applied to instantaneous counts for estimating the whole day effort depending on when the count was completed.

Upper and lower 95% confidence intervals of the estimated whole day effort were approximated by creating an upper and lower EDR model. Therefore, for each day an instantaneous count of clam diggers was conducted, an upper, lower, and mean estimate of whole day effort was computed. The upper and lower EDR model equations are:

$$EDR_{t-upper} = \overline{EDR_t} - t_{\alpha/2,n-1} * SE(\overline{EDR_t}) \tag{5}$$

$$EDR_{t-lower} = \overline{EDR_t} + t_{\alpha/2,n-1} * SE(\overline{EDR_t}) \tag{6}$$

and the associated estimates of whole day effort ($\hat{E}_{d-upper}$ and $\hat{E}_{d-lower}$),

$$\hat{E}_{d-upper} = IC_{d,t} / EDR_{t-upper} \tag{7}$$

$$\hat{E}_{d-lower} = IC_{d,t} / EDR_{t-lower} . \tag{8}$$

Effort counts for each bed were conducted on weekends and weekdays with predicted tide levels at or below 0.0 ft MLLW. Clam diggers are motivated to dig clams for many reasons, but the lowest tides of the year (e.g., -3.0 feet) draw more effort than do the moderate low tides (e.g., -0.3 feet) simply because the lowest tides reveal more habitat and allow more harvest time. In addition, the bay clam fishery, like many other fisheries, has increased effort on weekend days and holidays.

To isolate the effect of tide level and/or day, low tide days were classified by tide type (extreme or moderate) and day type (weekday or weekend/holiday). Days with tides that fell before 06:00 or after 19:00 were excluded because little clamming effort occurs in the dark. Extreme low tide days were defined as days with a predicted low tide less than -1.0 ft MLLW and moderate as those with a predicted low tide between 0.0 and -1.0 ft MLLW. Thus, four strata of days (day-types) were created: weekday moderate (DAYMOD), weekday extreme (DAYEX), weekend moderate (ENDMOD), and weekend extreme (ENDEX).

Effort counts from sampled days enable total seasonal effort to be estimated through extrapolation. First, mean values of whole day effort for each of the four day-type strata *j* were found with

$$\overline{E}_j = \frac{1}{d_j} \sum_{d=1}^{d_j} \hat{E}_{d,j} , \tag{9}$$

where d is the total number of days sampled within stratum j. Second, this was reiterated for each of the three EDR models ($\overline{EDR_t}$, $EDR_{t-upper}$, $EDR_{t-lower}$) to find a mean, upper, and lower estimate of whole day effort in each of the four strata, for each clam bed. The total estimated effort on a clam bed for all days of the season (D) in stratum j is simply expressed as

$$\hat{E}_{j(year)} = D_j \overline{E}_j , \tag{10}$$

and the total season-long effort on a bed for all four day-type strata:

$$\hat{E}_{(year)} = \sum_{j=1}^{4} \hat{E}_{j(year)} .$$

Catch Rate

Clam diggers were interviewed upon completion of their clam digging trip. The number of each species harvested was recorded from each encounter. Subsamples of clams from each species were weighed for estimating mean weight. The species harvested included butter clams, cockles, gaper clams, native littleneck clams, and “other” clams. Catch per unit effort (CPUE) was defined as the total number of clams per digger. For each clam species k in each clam bed, a CPUE was calculated within each of four day- tide type strata j such that

$$(CPUE)_{k,j} = \frac{1}{N} \sum_{i=1}^{N} C_k , \tag{11}$$

where the total catch (C) of species k from all interviews (i) is divided by the total interviews (N).

Seasonal Harvest

Total harvest was estimated for each species and day-type,

$$\hat{C}_{j,k} = (CPUE)_{j,k}\left(\hat{E}_{j(year)}\right) \tag{12}$$

where $\hat{C}_{j,k}$ is the total yearly catch (harvest, in numbers of clams) of species *k* for day-type strata *j*.

Harvested clams were weighed with a hanging brass scale (Chatillon 2 kg or 6 kg capacity) during the interview process. Usually, all clams of a single species in an individual digger's catch were weighed in aggregate and the number of individuals counted. Mean weight, $\hat{W}_k$, of species *k* was calculated for each bay, dividing the summed weights of all clams weighed by the number of clams weighed, with the equation:

$$\hat{W}_k = \frac{\sum w_k}{\sum n_k}. \tag{13}$$

Total weight of harvested clams was estimated with the simple product of the total catch $\hat{C}_{j,k}$ by the mean weight $\hat{W}_k$ of each species.

RESULTS

Effort Distribution Ratio Model

On twelve different clam beds in four estuaries, a total of eighteen EDR counts were completed (Figure 2-5). Effort was highest 0.5 hours after low tide. The EDR mean model value at this time was 0.634, or, in other words, the average number of clam diggers counted at this time represents 63.4% of the total estimated whole day effort.

On individual days, the effort curves differ in magnitude and/or range. Some peaked in the hour before low tide, some after. Occasionally, curves reached an EDR value of 1.0, meaning the effort counts at this time counted every clam digger that visited the clam bed that day. Many factors likely influence the shape and magnitude of these curves including the total whole day effort, the species targeted, tide height, weather, etc.

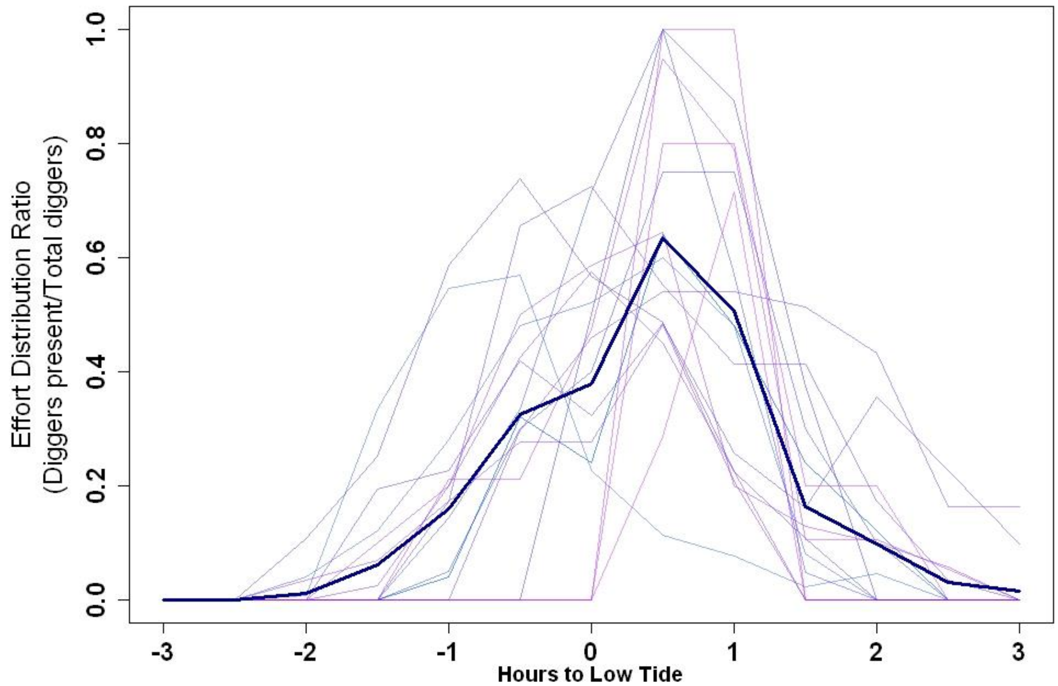

Figure 2-5. Effort Distribution Ratio.

Effort counts conducted at low tide were expanded to estimate whole day effort using the EDR models. Although the actual peak of effort was generally 0.5 hours after low tide, the effort count at low tide was referred to as the "peak count". The mean number of diggers in each day-type stratum was calculated using expanded peak counts. Mean diggers per day-type were then extrapolated to unsampled days to estimate seasonal effort.

Effort and Harvest

Effort estimates, and the total harvest estimates derived from them, are subject to two types of uncertainty related to the model predictions. First, when instantaneous counts are used to estimate total daily effort using the EDR model, the variation inherent in the EDR yields a range of daily effort estimates. In other words, on any given day, a count of clam diggers, expanded with the EDR model, can estimate a mean (Equation 4), upper (Equation 7), and lower (Equation 8) estimate of the total number of clams diggers for the day. The second source of uncertainty with effort estimation arises from the extrapolation of sampled days to unsampled days. The variation among the sampled days within a stratum affects the variation (and confidence) of the estimate. Therefore, these two sources of variation, within each day's estimate and among all days sampled, affects the confidence in the total estimated effort within each strata. To reduce uncertainty, sampling frequencies were maximized (to reduce variation among sampled days) and EDR model counts were made as often as possible (to decrease confidence intervals within daily estimates). The resulting mean effort estimates within each stratum are presented with an accompanying standard error (SE) in Appendix A. All other estimates of effort are presented using the mean estimate.

Tillamook Bay

The bay clam recreational fishery in Tillamook Bay was generally surveyed between April and August, with an annual average of 28% of the potential survey days sampled (Appendix A). In each of the five years surveyed, ENDEX day-type had the highest average number of diggers (Appendix B). The total number of estimated clamming trips per year during the sampling season ranged from just over 6,000 in 2010 and 2011, to over 11,000 in 2012 (Table 2-1 and Table 2-2). The easily accessible Garibaldi Flat (GF) was the most popular clam bed every year of the survey.

Table 2-1. Estimated number of clam digging trips to Tillamook Bay during the sampling season among the four day-types.

Day-Type	**DAYEX**	**DAYMOD**	**ENDEX**	**ENDMOD**		**95 %**
Tide Height	<-1.0 ft	0 to -1.0 ft	<-1.0 ft	0 to -1.0 ft		**Confidence**
Day	Weekday	Weekday	Weekend	Weekend	**Total**	**interval**
2008	4,409	924	1,343	3,157	9,832	8,213-11,451
2009	4,095	517	3,838	768	9,218	8,404-10,032
2010	1,829	636	2,938	804	6,207	5,632-6,783
2011	1,871	1,214	1,940	1,109	6,134	5,362-6,905
2012	4,636	1,870	1,279	3,232	11,018	9,848-12,188

Table 2-2. Estimated number of clam digging trips to Tillamook Bay during the sampling season among the four clam beds. See Figure 2-1 for map of clam bed locations and Table 2-1 for 95% confidence intervals on annual total effort estimates.

	BO	CFT	GF	KP	Total
2008	1,413	1,051	7,133	235	9,832
2009	1,247	853	6,604	514	9,218
2010	889	477	4,756	86	6,207
2011	609	632	4,610	282	6,134
2012	800	1,037	8,810	372	11,018

A total of 1,995 interviews of recreational clam diggers were conducted in Tillamook Bay during the survey (Appendix C). Most of the clam diggers interviewed had dug clams at Garibaldi Flat (GF). Clam diggers were most successful at GF and Bayocean (BO), where the total clams per digger was almost 20 (the daily bag limit) in every year of the survey (Appendix C and Figure 2-6). Due to the high level of effort and digging success at Garibaldi Flat, the total clams harvested is higher there than any other clam bed in Tillamook Bay (Figure 2-7). Over the five years of the survey, the annual estimated number of clams harvested averaged 149,000 clams, with cockles being the most common species harvested.

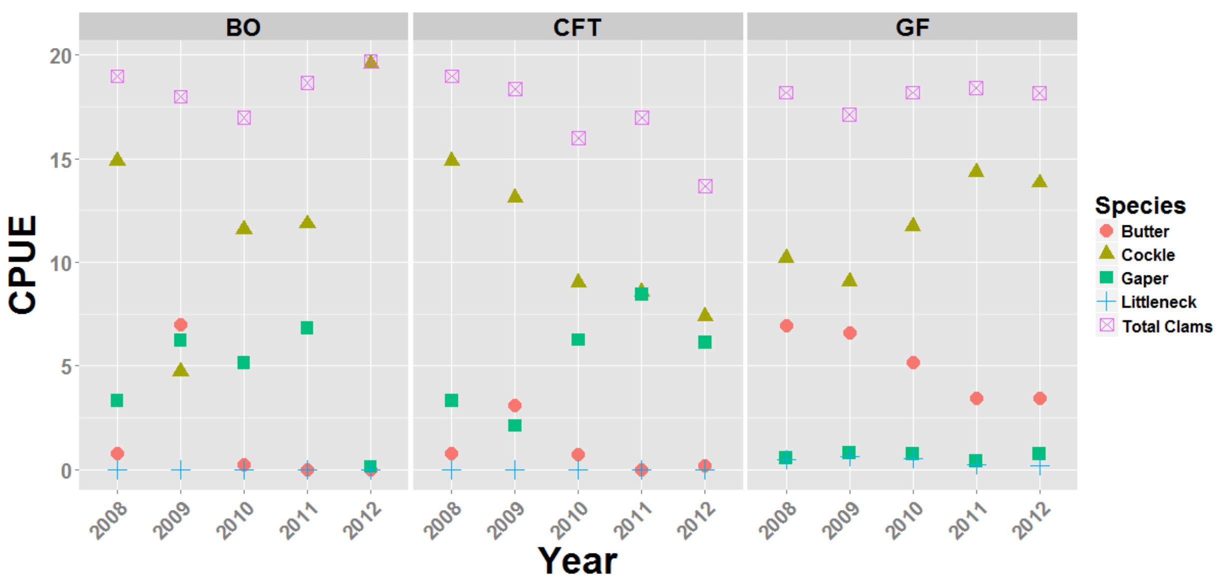

Figure 2-6. Clam digging CPUE (clams/person) for three clam beds in Tillamook Bay. Insufficient interview data from KP prevented CPUE calculation.

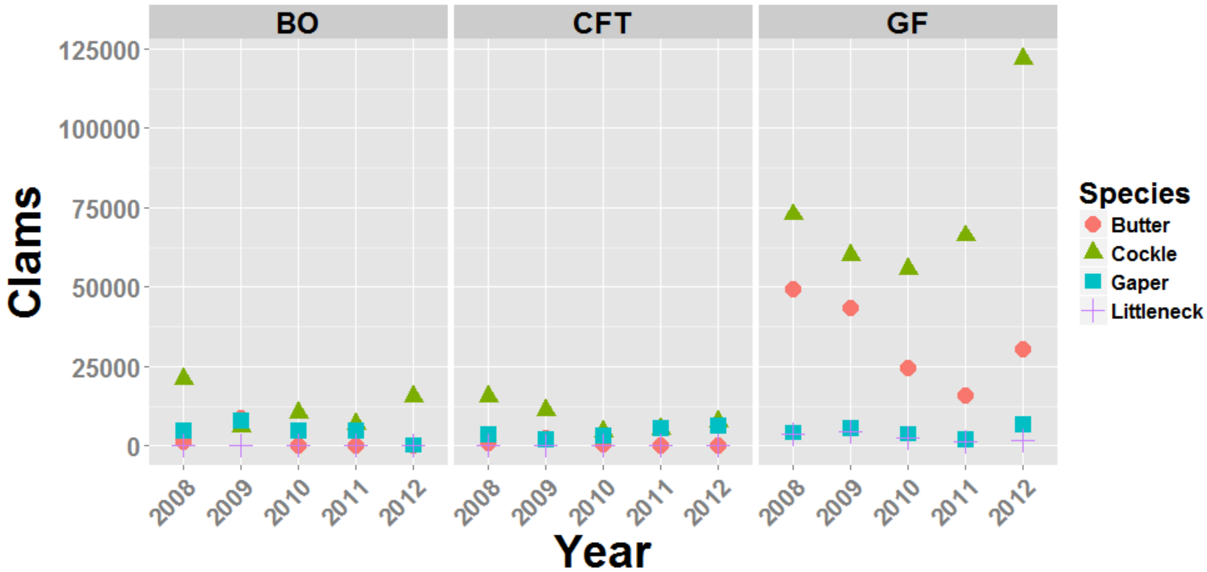

Figure 2-7. Estimated total clams harvested on three clam beds in Tillamook Bay. Insufficient interview data from KP prevented harvest calculation.

Netarts Bay

Recreational clam digging effort and catch were surveyed during the spring and summer at Netarts Bay. Of the potential low tide survey days during the sampling period, the mean number of days sampled was 32% annually (Appendix A). Most often, and not unexpectedly, ENDEX day-type had the highest number of mean estimated diggers (Appendix B). In 2009, due to several high effort counts, the estimated number of diggers on ENDMOD days was much higher than in other years. The total number of estimated clamming trips per year during the sampling season was variable (Table 2-3 and Table 2-4). By far the most utilized clam bed was WR.

Table 2-3. Estimated number of clam digging trips to Netarts Bay during the sampling season among the four day-types.

Day-Type	**DAYEX**	**DAYMOD**	**ENDEX**	**ENDMOD**		**95 %**
Tide Height	<-1.0 ft	0 to -1.0 ft	<-1.0 ft	0 to -1.0 ft		**Confidence**
Day	Weekday	Weekday	Weekend	Weekend	**Total**	**interval**
2008	2,680	1,305	4,588	3,507	12,081	10,333-13,829
2009	7,574	2,257	2,372	11,059	23,262	19,938-26,586

2010	1,417	3,578	3,461	2,721	11,177	9,632-12,722
2011	2,466	1,975	1,276	4,068	9,786	8,746-10,825
2012	3,418	2,138	1,258	6,840	13,653	12,313-14,994

Table 2-4. Estimated number of clam digging trips to Netarts Bay during the sampling season among the seven clam beds. See Figure 2-2 for map of clam bed locations and Table 2-3 for 95% confidence intervals on annual total effort estimates.

	HC	**SC**	**LN**	**CN**	**RV**	**WR**	**CL**	**Total**
2008	649	841	178	719	789	8,476	428	12,081
2009	940	759	450	1,746	1,135	17,492	740	23,262
2010	699	470	313	553	261	7,558	1,323	11,177
2011	362	218	151	614	276	7,490	674	9,786
2012	1,190	90	160	440	208	10,846	718	13,653

A total of 2,782 interviews of recreational clam diggers were conducted in Netarts Bay during the survey (Appendix C). Two-thirds of the interviews conducted were from WR. Clam diggers were successful (taking close to a full daily limit of 20 clams) at most clam beds in Netarts Bay except Happy Camp and, in some years, RV (Appendix C and Figure 2-8). The catch composition varied among clam beds; the catch at SC was mostly butter clams, at CL it was littlenecks, and WR was a mixed catch every year. Due to the high level of effort and digging success at WR, the total clams harvested was higher there than any other clam bed in Netarts Bay (Figure 2-9). Over the five years of the survey, the annual estimated number of clams harvested averaged 232,000 clams, with cockles being the most common species harvested.

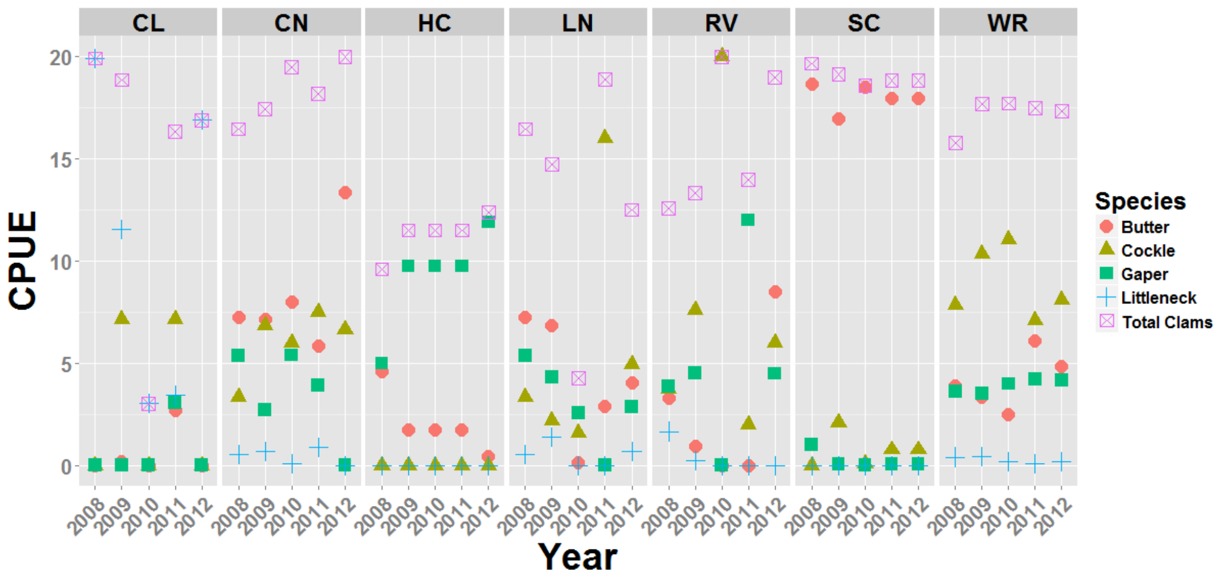

Figure 2-8. Clam digging CPUE (clams/person) for seven clam beds in Netarts Bay.

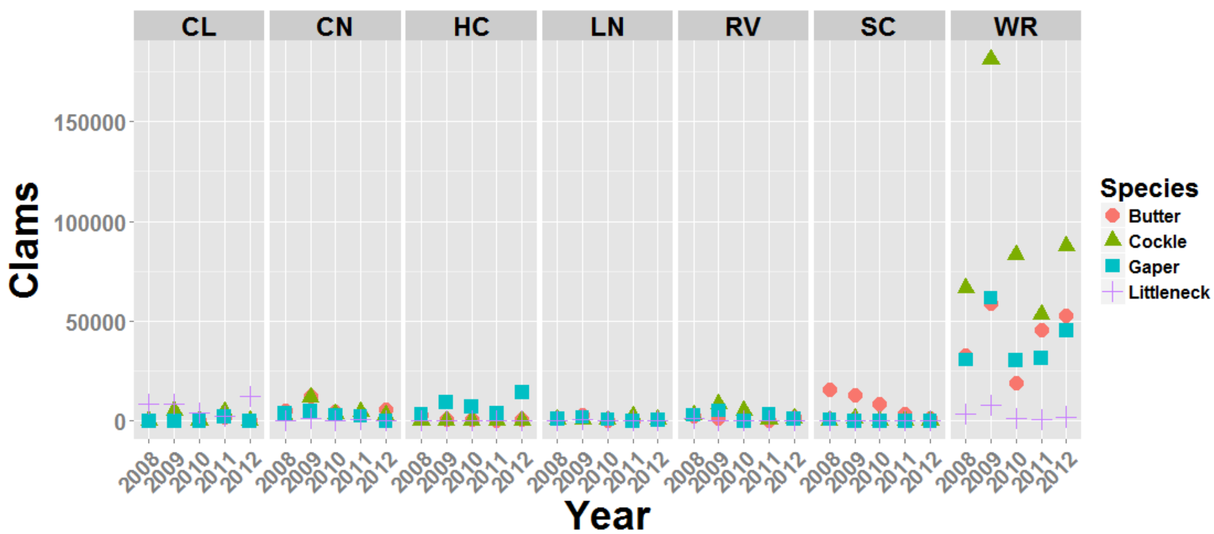

Figure 2-9. Estimated total clams harvested on seven clam beds in Netarts Bay.

Yaquina Bay

Surveys of the recreational bay clam fishery in Yaquina Bay spanned several months longer each year than in other bays. The sampling season started as early as January or February in some years and lasted through August (Appendix A). ENDEX day-types had the highest mean number of diggers (Appendix B). The estimated total number of clam digging trips during the sampling season was greatest on days with extreme low tides (DAYEX and ENDEX day-types, Table 2-5), and Bridge Bed (BB) was the most popular clam bed (Table 2-6).

Table 2-5. Estimated number of clam digging trips to Yaquina Bay during the sampling season among the four day-types.

Day-Type	**DAYEX**	**DAYMOD**	**ENDEX**	**ENDMOD**		**95 %**
Tide Height	<-1.0 ft	0 to -1.0 ft	<-1.0 ft	0 to -1.0 ft		**Confidence**
Day	Weekday	Weekday	Weekend	Weekend	**Total**	**interval**
2008	2,524	396	2,348	846	6,114	5,273-6,956
2009	6,386	1,610	3,541	1,466	13,002	11,680-14,324
2010	4,304	1,339	5,514	805	11,961	10,599-13,324
2011	3,184	827	2,809	543	7,363	6,284-8,441
2012	2,840	195	2,608	1,409	7,052	6,284-7,820

Table 2-6. Estimated number of clam digging trips to Yaquina Bay during the sampling season among the six clam beds. See Figure 2-3 for map of clam bed locations and Table 2-5 for 95% confidence intervals on annual total effort estimates.

	BB	**BWS**	**BWN**	**CP**	**GP**	**IF**	**Total**
2008	2,372	324	668	297	707	1,745	6,114
2009	5,195	658	1,289	373	1,942	3,546	13,002
2010	5,776	416	982	192	1,532	3,063	11,961
2011	3,090	201	656	147	863	2,405	7,363
2012	3,037	231	1,220	117	475	1,972	7,052

A total of 1,613 interviews of recreational clam diggers were conducted in Yaquina Bay during the survey (Appendix C). Overall, 41% of the interviews were at BB, 32% were from Idaho Flat, and the remaining 27% of interviews were conducted at the four other clam beds of Yaquina Bay. Clam digging success in many beds was influenced to a large degree by many diggers preferring to harvest limits of gapers (12 per person) without filling their total daily limit of 20 clams total (Appendix C and Figure 2-10). The catch composition at BB, BWN, and BWS was mostly gapers with some cockles and butter clams, while at GP and IF, cockles were the most common clams dug. The three most popular clam beds in Yaquina Bay, BB, GF, and IF, provided the largest share of the total annual clams harvested (Figure 2-11). The annual estimated number of clams harvested averaged 120,000 clams, with cockles and gapers being the most common species harvested.

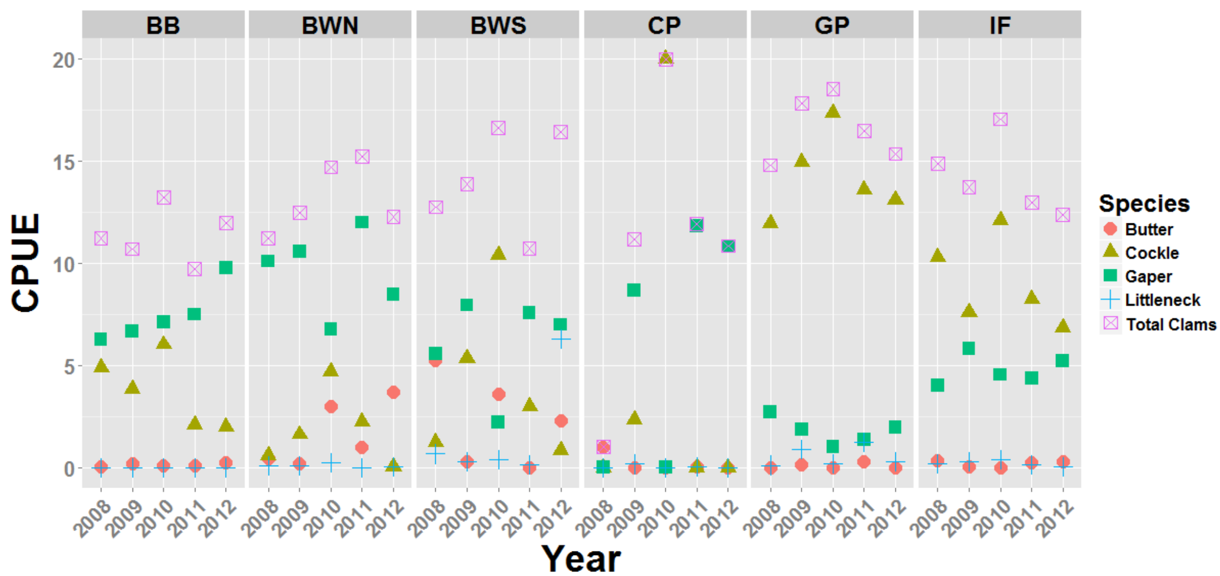

Figure 2-10. Clam digging CPUE (clams/person) for six clam beds in Yaquina Bay.

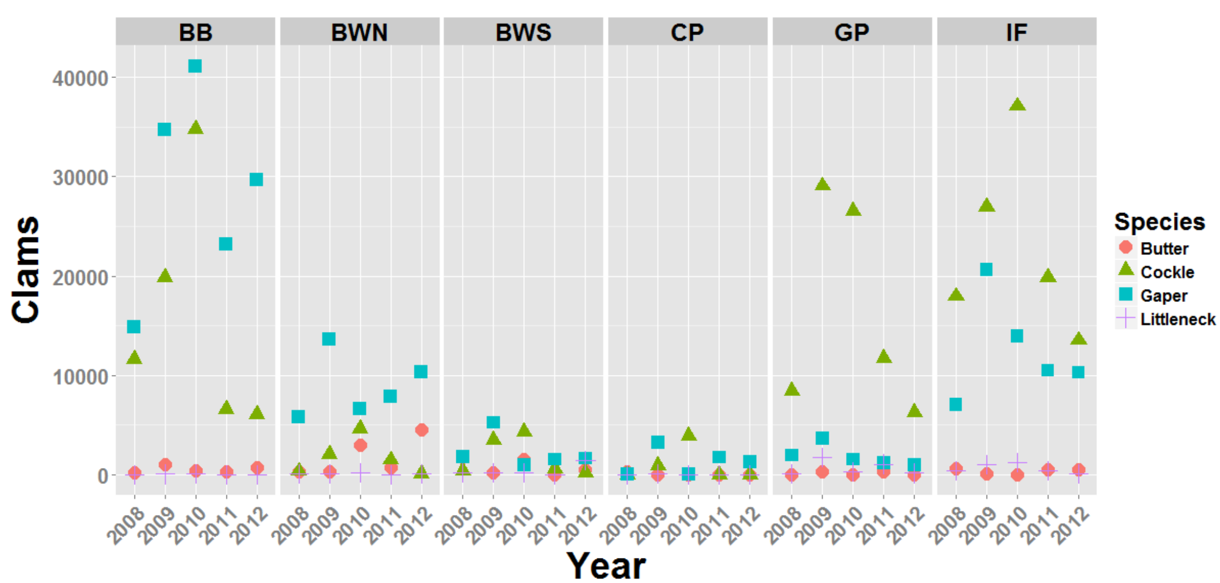

Figure 2-11. Estimated total clams harvested on six clam beds in Yaquina Bay.

Coos Bay

The bay clam recreational fishery was surveyed in Coos Bay during the spring and summer, and an average of 33% of the potential survey days were sampled (Appendix A). The highest mean number of estimated diggers by day-type was variable; in 2008 and 2011, DAYEX had higher mean number of diggers compared to ENDEX days which had the highest number of diggers the other three years of the survey (Appendix B). The total number of estimated clamming trips per year during the sampling season averaged approximately 12,500 (Table 2-7 and Table 2-8). Clam digging effort in Coos Bay was more evenly dispersed than in the other bays sampled.

Table 2-7. Estimated number of clam digging trips to Coos Bay during the sampling season among the four day-types.

Day-Type	**DAYEX**	**DAYMOD**	**ENDEX**	**ENDMOD**		**95 %**
Tide Height	<-1.0 ft	0 to -1.0 ft	<-1.0 ft	0 to -1.0 ft		**Confidence**
Day	Weekday	Weekday	Weekend	Weekend	**Total**	**interval**
2008	6,015	2,649	2,401	2,534	13,598	12,289-14,907
2009	5,673	2,644	4,418	2,694	15,428	14,138-16,719
2010	4,694	2,074	4,069	2,193	13,030	12,180-13,881
2011	4,905	2,611	2,306	1,291	11,113	10,217-12,009
2012	3,934	2,079	1,686	2,029	9,729	8,924-10,533

Table 2-8. Estimated number of clam digging trips to Coos Bay during the sampling season among the eight clam beds. See Figure 2-4 for map of clam bed locations and Table 2-7 for 95% confidence intervals on annual total effort estimates.

	BV	**CF**	**CI**	**CT**	**EP**	**NS**	**PA**	**PP**	**Total**
2008	1,431	2,790	2,149	2,137	1,087	1,163	202	2,638	13,598
2009	659	3,410	4,204	2,148	1,071	1,635	262	2,040	15,428
2010	878	2,729	3,193	2,286	810	1,076	116	1,943	13,030
2011	636	1,740	2,895	1,120	907	1,746	43	2,025	11,113
2012	990	1,347	1,703	1,069	1,419	1,966	41	1,194	9,729

A total of 1,448 interviews of recreational clam diggers were conducted in Coos Bay during the survey (Appendix C). Interviews were spread fairly evenly among the popular clam beds. Overall catch was good in most beds for most years, with BV and PP having some of the highest CPUE (Appendix C and Figure 2-12). In other clam beds where gapers are commonly dug, EP for instance, many clam diggers will not take more than a limit of 12 gaper clams, thereby skewing the overall CPUE lower compared to beds where more diggers achieve a limit of 20 bay clams. Clam diggers seeking butter clams had the most success at BV and PP, and gaper clams were dug at most clam beds in Coos. CI and PP were the clam beds with the highest total number of clams harvested, accounting for, on average, 23% and 17% of the total catch, respectively (Figure 2-13). The annual estimated number of clams harvested averaged 200,000 clams, with butter clams and gaper clams accounting for 40% and 43% of the catch, respectively.

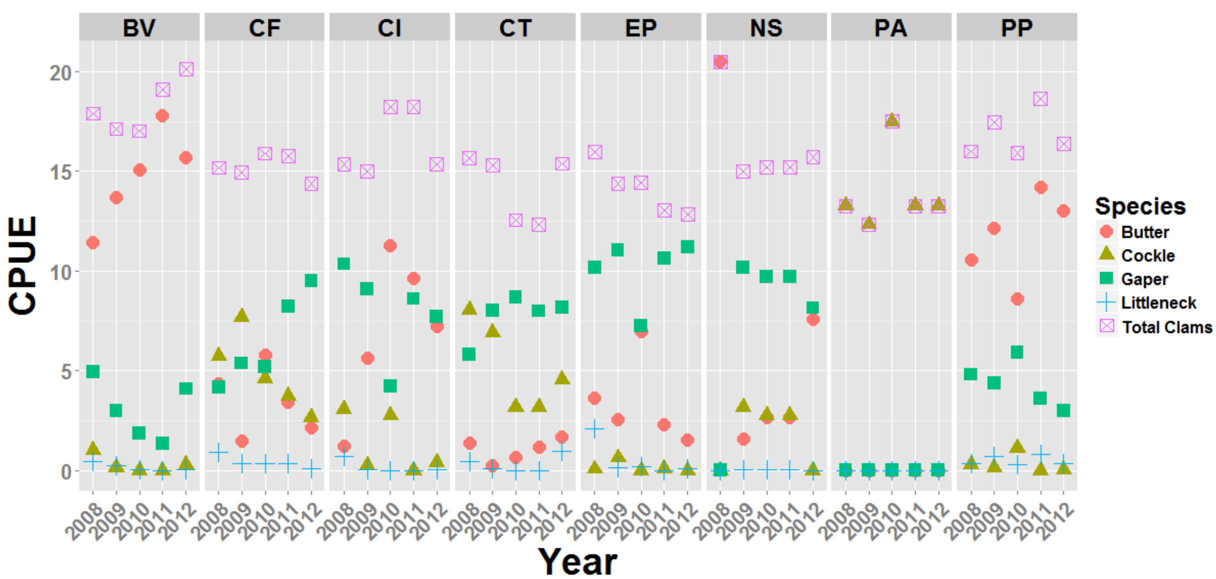

Figure 2-12. Clam digging CPUE (clams/person) for eight clam beds in Coos Bay.

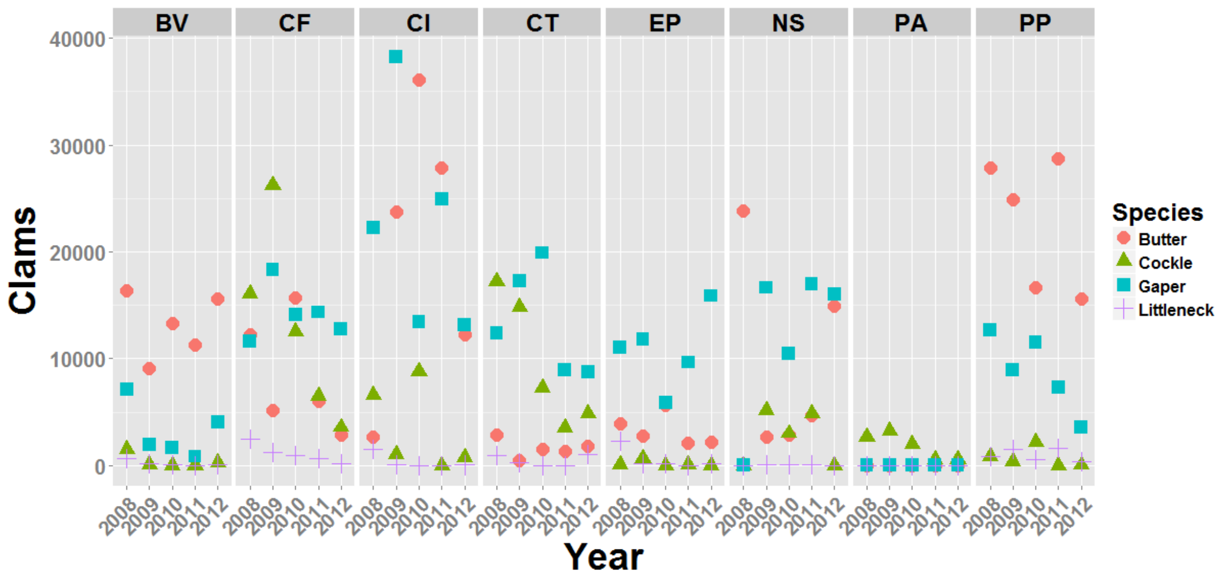

Figure 2-13. Estimated total clams harvested on eight clam beds in Coos Bay.

Travel Analysis

Hometown ZIP codes of clam diggers were used to determine their county of residence. The results from each bay were analyzed and mapped with ArcGIS (Figure 2-14). Common to each bay was the tendency of clam diggers to utilize the bay nearest their residence. Most of the clam diggers interviewed in Coos Bay were from Coos County or nearby Douglas County. Tillamook Bay and Netarts Bay, both in Tillamook County, were frequented most often by Tillamook County residents and the nearby counties in the Portland metropolitan area. Yaquina Bay clammers hailed most frequently from the local county, Lincoln, and from the nearby counties of Benton and Linn, located in the Willamette Valley.

Historically, instead of ZIP code, the recreational bay clam surveys would ask clam diggers if they were local (reside in the same county of the bay in which they were interviewed), Oregon residents (but not local), or were out-of-state residents. ZIP code data from the current bay clam survey were grouped using the same criteria to compare if the composition of clam digger origin has changed over time (Figure 2-15). In every bay, out-of-state residents made a small percentage of clam diggers interviewed, and this trend appears to not have changed over time. In addition, the percentage of clam diggers who were local or Oregon residents also appears to have not changed much over time.

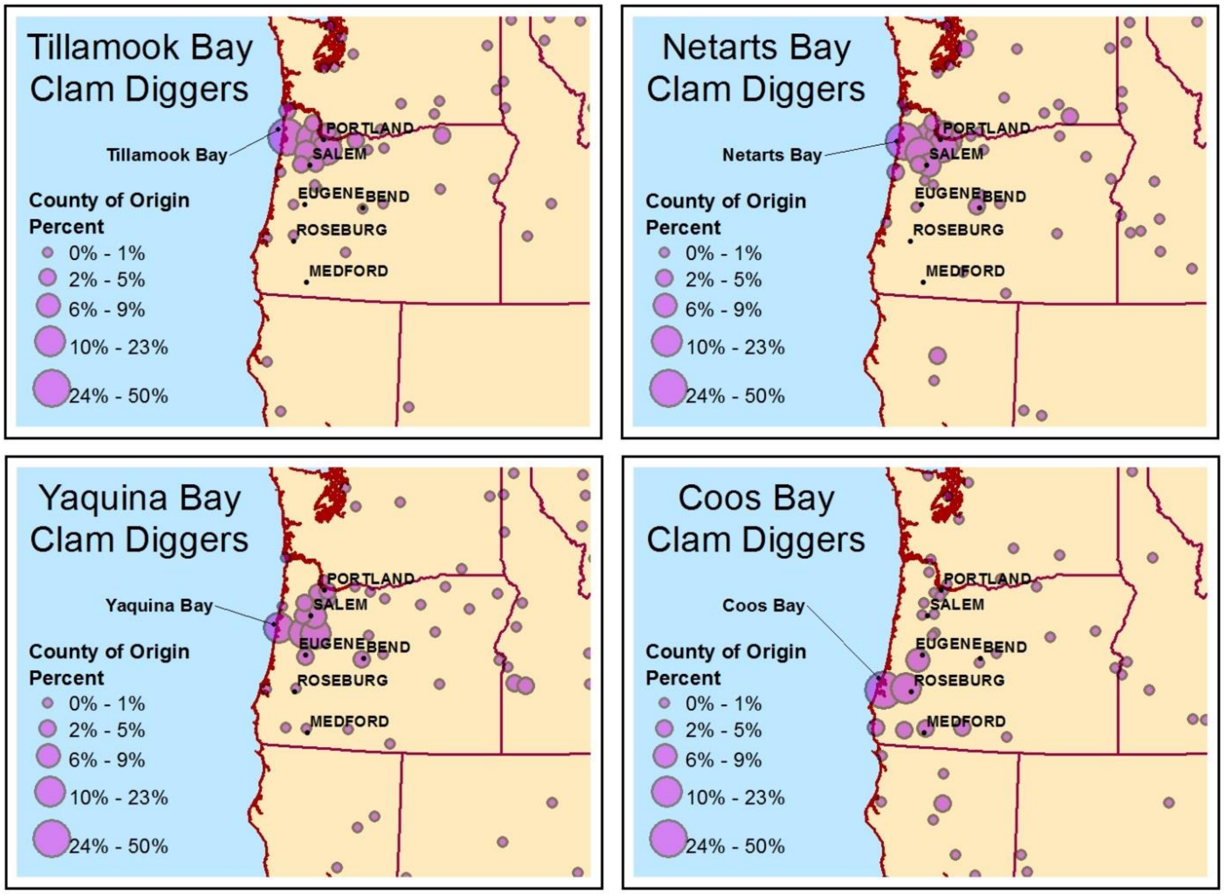

Figure 2-14. County of residence of clam diggers interviewed during the recreational bay clam survey in 2008-2012.

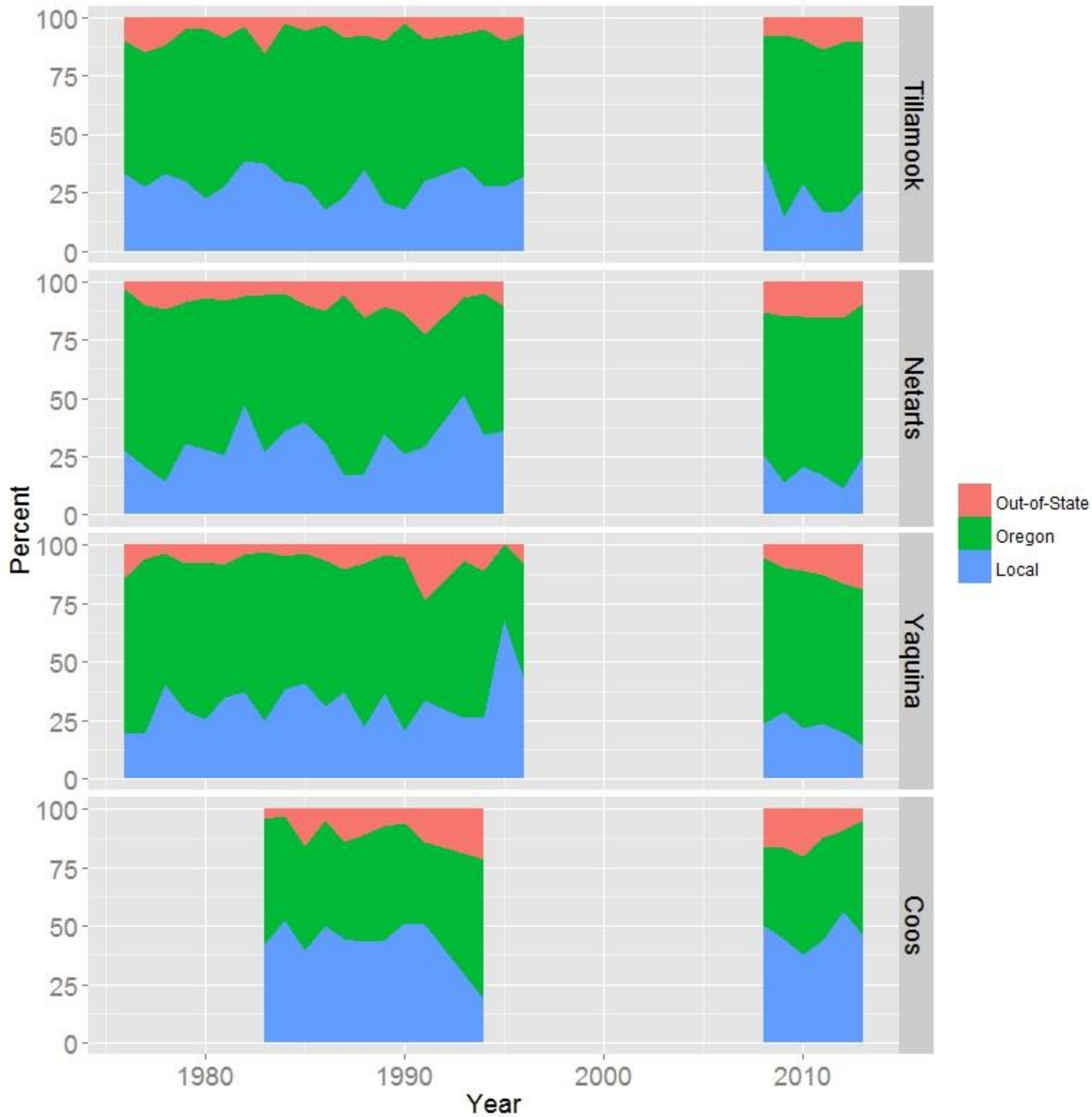

Figure 2-15. Comparing the frequency of local county residents, Oregon residents outside of county, and out-of-state residents among clam diggers interviewed during recreational bay clam surveys.

Statewide Summary

The recreational bay clam surveys produced annual estimates of total clamming effort (total number of trips) based on the expansion of effort counts using the EDR model (Figure 2-16). The total number of days sampled varied among the bays and years of the survey, and annual estimates reflected this variation. Overall, the range of annual effort estimates within a bay over the years sampled illustrate the magnitude of effort in each bay. Total annual effort estimates from 1971were corrected for sampling season and location to compare with the present study's results and are included in Figure 2-16. Overall, the estimates from 1971 are similar for Netarts and Coos bays, but the figure suggests that overall effort has declined in Tillamook and Yaquina bays.

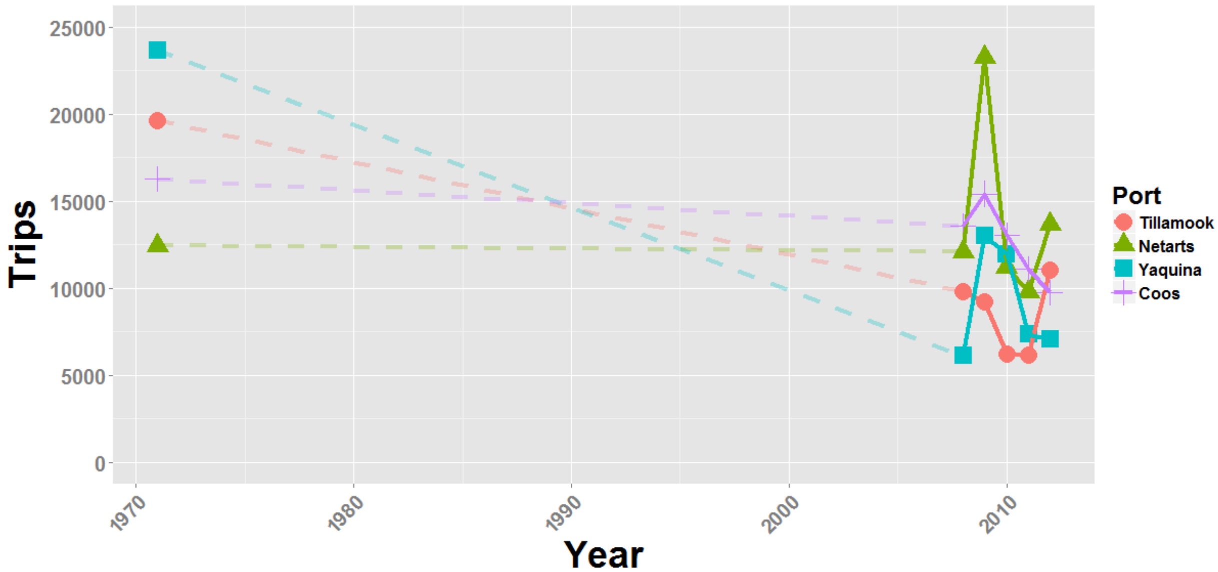

Figure 2-16. Annual number of clam digging trips in Tillamook, Netarts, Yaquina, and Coos bays from the present study (2008-2012) compared to estimates from the 1971 Resource Use Study, corrected for sampling seasons and locations.

The CPUE and total effort data from each area in each bay were used to estimate the total number of clams harvested during the sampling season using Equation 13 (Figure 2-17). In all bays, littleneck clams were the least harvested. The few exceptions were areas of Netarts Bay where clam diggers found native and Manila littlenecks somewhat consistently. The presence of Manila littlenecks in Netarts Bay, and to a much lesser degree in some other bays, is a vestige of planting efforts by ODFW in the '60s, '70s, and '80s to produce a sustainable fishery for this popular species. Netarts Bay had the greatest mean annual number of clams harvested (232,000) followed by Coos, Tillamook, and Yaquina bays with 192,000, 148,000, and 120,000 clams, respectively.

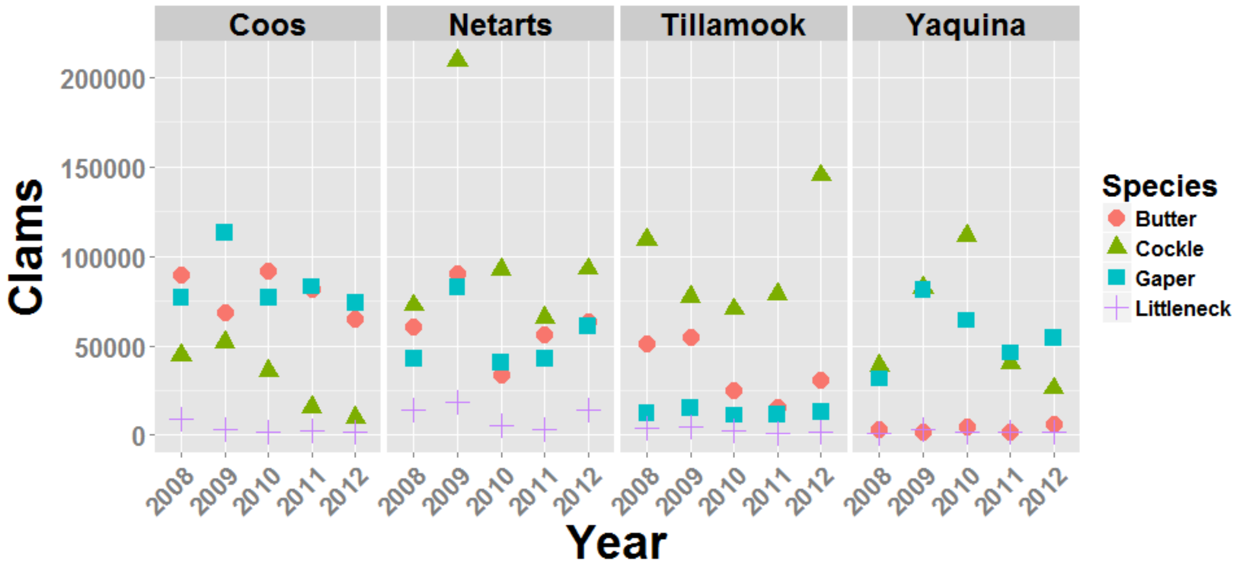

Figure 2-17. Estimated total clams harvested among all bays sampled.

Mean weights were estimated from clams taken by the recreational fishery (Figure 2-18). Not surprisingly, gaper clams were found to have the greatest mean weight, followed by butter clams, cockles, and littlenecks, respectively. In Netarts, Tillamook, and Yaquina bays, a declining mean weight was observed in gaper clams over the years of the study. The decreased mean weight (and corresponding size frequency) of clams in 2011 and 2012 was likely a result of a new recruit of small clams available to clam diggers. Gaper clams will not successfully recruit new clams to the fishery every year, but instead have an episodic recruitment.

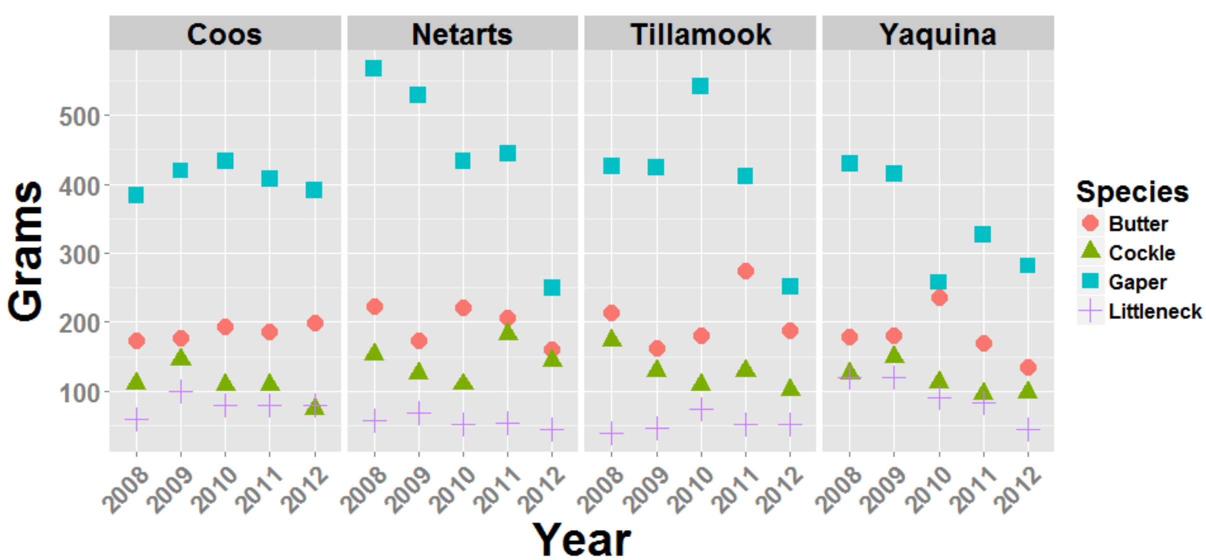

Figure 2-18. Mean weight (grams) of bay clams among all bays sampled.

Total harvested weight of each species in each bay was estimated, first in kilograms and then converted to pounds (Figure 2-19). Total pounds harvested varied among the bays sampled, and also among the years within one bay. Coos Bay had the highest estimated annual pounds harvested, with a mean value of 118,000 pounds. Netarts Bay had a mean annual estimate of 112,000 pounds. Yaquina Bay annual harvest had a mean value of 59,000 pounds. The estimated pounds of clams harvested in Tillamook Bay averaged 55,000 pounds per year.

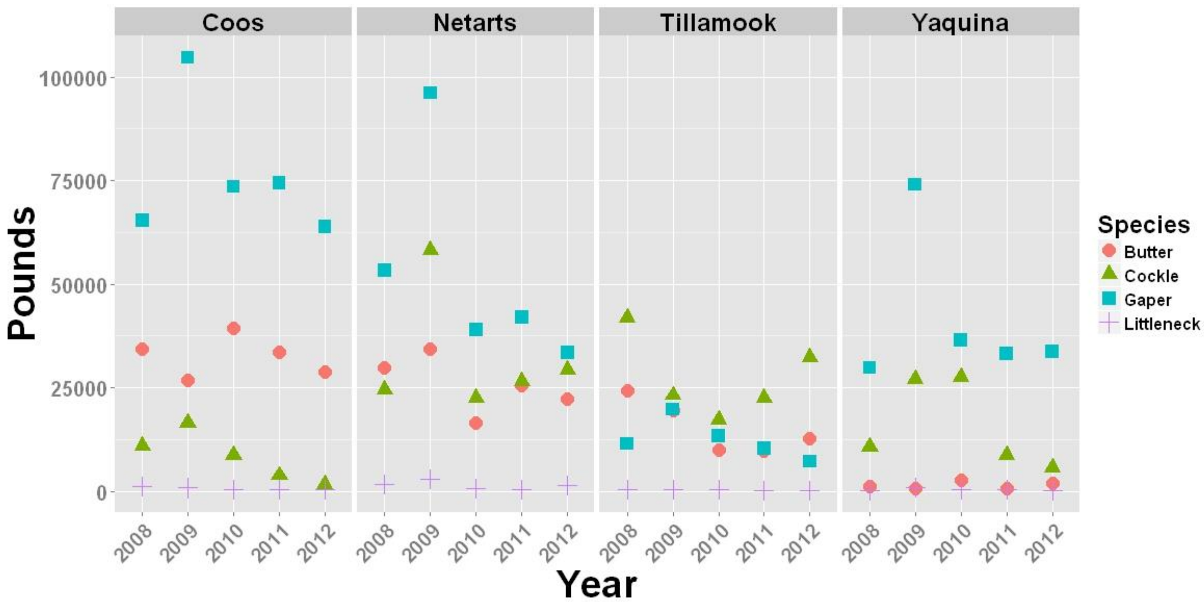

Figure 2-19. Estimated total pounds of clams harvested among all bays sampled.

DISCUSSION

The recreational bay clam creel survey results clearly show that clam digging in Oregon's bays draws thousands of Oregonians and out-of-state visitors. Part of the Oregon coast culture and cuisine, bay clamming is an activity often involving families of multiple generations and/or groups of friends. While fishery participation (total number of trips) in Netarts and Coos bays appears similar to estimates from 1971, declines are evident in Yaquina and Tillamook bays. With Oregon's population growth during the intervening four decades being over 80% (Bureau 2011), the percentage of Oregonians who participate in clamming appears to be declining. Possible explanations for the decline could be related to the fishery itself (e.g., decreased satisfaction by participants) or other reasons which have led to an overall decline in fishing and hunting participation nationwide (Interior 2011).

Those who do participate in the fishery rely on the resource to be in adequate supply for their effort to be worthwhile and productive. In order to achieve this goal, management of the resource needs fishery independent data (stock assessment of the resource available for harvest) in addition to fishery dependent data (to estimate harvest of the resource). For some bays, stock assessment data has been collected (see Chapter 4) and this bay clam recreational effort and catch study fulfills the need for fishery data. Data on catch and effort, or any changes in scale and composition, are useful for identifying trends that may indicate a need for management action.

Clam diggers interviewed for this study were finding clams; mean CPUE at many clam beds approached the daily limit of 20 clams (Appendix C). However, some popular clam beds had a CPUE that was much less than 20 (e.g., BB in Yaquina Bay or EP in Coos Bay). Rather than inferring that these beds are less productive than others, another explanation may be that clam diggers are targeting gaper clams and will stop digging when reaching their daily sublimit of 12 gaper clams. For example, the overall CPUE at bed PP in Coos Bay (Figure 2-12) appears to be much less than other beds in the bay. This is likely due to clam diggers frequently taking only 12 gaper clams, as evidenced by the frequency distribution of total clams in each clam diggers catch (Figure 2-20). Diggers are not always after maximizing their catch, and their preferences, therefore, play an important role in determining what is being harvested at each clam bed.

The catch composition from most clam beds during the five years of this study remained fairly static. Other beds showed some interesting shifts in catch composition even within the relatively short time frame of this survey. The overall annual CPUE at GF in Tillamook Bay, for example, was consistently around 18 clams per person, but there were some interesting changes over the five years. Cockles became a larger component of the mean CPUE and harvest while butter clam mean CPUE and harvest declined. Similar trends were seen in other clam beds as well (e.g. BV and CF in Coos Bay), suggesting that rather than random variation, interannual changes in abundance and/or density of some clams may be reflected in the CPUE of clam diggers. The variation could be from recruitment patterns or natural and fishing mortality.

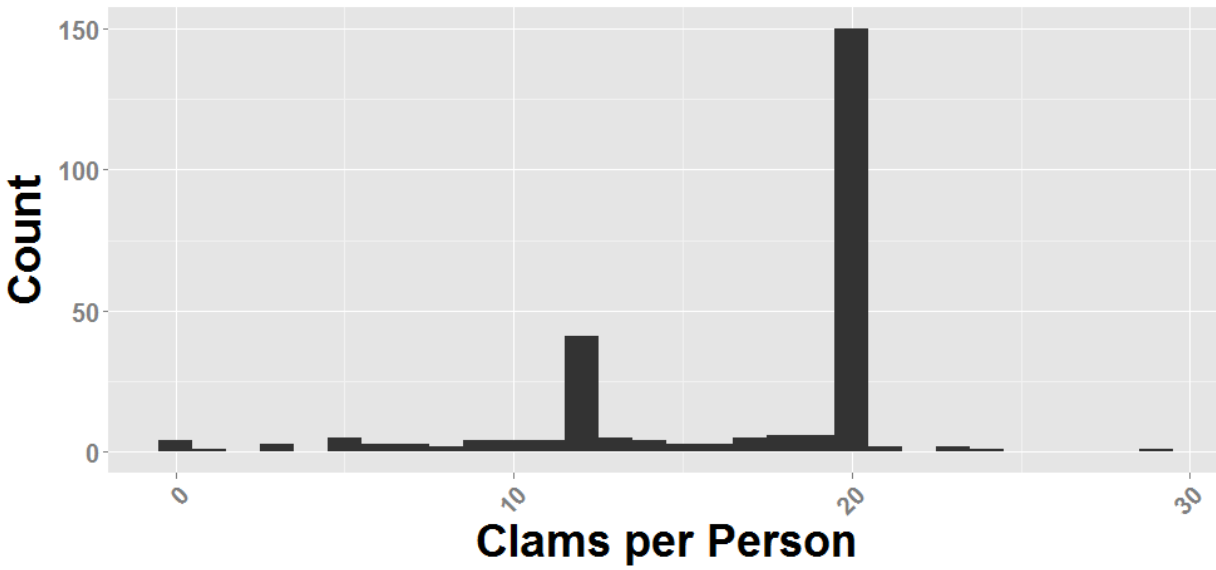

Figure 2-20. Frequency distribution of the total CPUE of all clam diggers visiting the PP clam bed in Coos Bay, showing peaks at 20 (the total daily bag limit) and 12 (the bag limit for gaper clams). Note that although the legal daily limit of all bay clams is 20, occasionally the limit is exceeded.

Variation in the catch composition among years is apparent when observing CPUE from historic creel surveys. For example, for several years in the late 1970s, butter clams composed 10-20% of the catch at Garibaldi Flat before a jump in the 1980s when butter clams were consistently around 40% of the catch (Figure 2-21). One potentially alarming shift is the decline in the percentage of littleneck clams to less than 5% of the annual catch in recent years.

The recreational bay clam survey continues to operate in Tillamook, Netarts, Yaquina, and Coos bays. The fishery status overall appears healthy and sustainable. The next step will be to evaluate current regulations in light of trends in CPUE reported here in conjunction with stock assessment data.

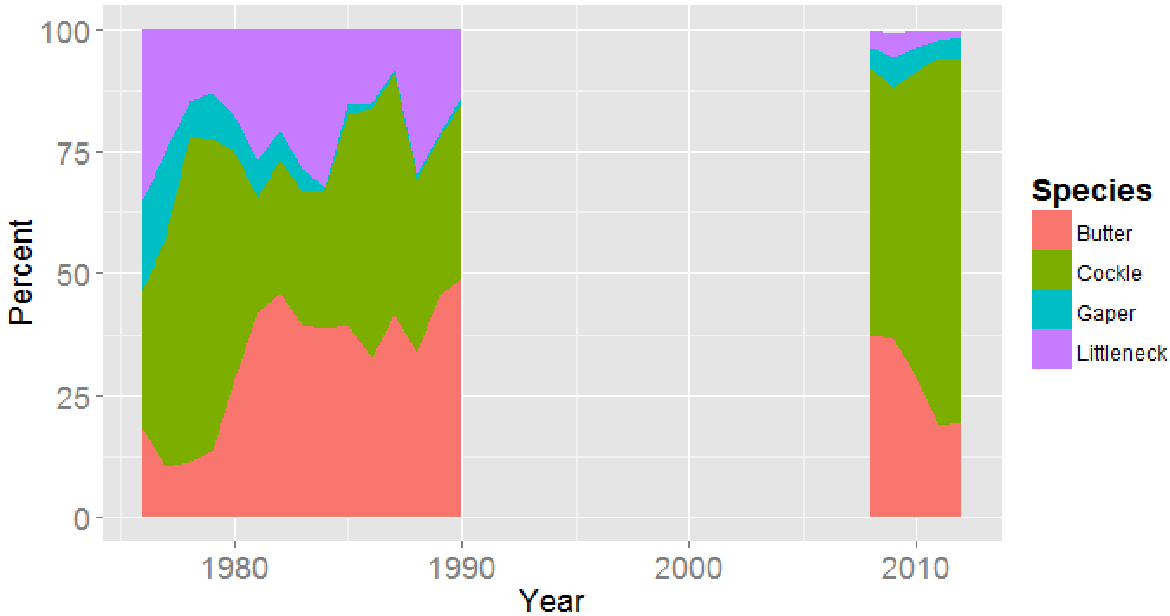

Figure 2-21. Mean annual catch composition of bay clams from creel surveys conducted at GF in Tillamook Bay from 1976-1990 and 2008-2012; each vertical black line represents a year that a survey was conducted (20 years sampled, n = 6,412 interviews).

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Appendix A. Sampling days summary

Bay clam survey season start and end months in Tillamook, Netarts, Yaquina, and Coos bays for the years 2008-2012, total days within each day-type, and the percent sampled of days within each season among all day-types.

Port	Year	Start	End	DAYEX	DAYMOD	ENDEX	ENDMOD	Total Days	Percent Sampled
Tillamook	2008	April	July	24	26	5	21	76	51.3
	2009	April	August	29	34	12	19	94	21.3
	2010	April	August	25	33	13	7	78	25.6
	2011	April	August	24	35	10	13	82	17.1
	2012	May	September	19	40	5	28	92	22.8
Netarts	2008	April	August	25	35	7	24	91	39.6
	2009	April	September	27	42	12	21	102	30.4
	2010	April	October	19	60	11	17	107	36.4
	2011	April	September	18	44	4	20	86	24.4
	2012	May	August	16	30	5	17	68	29.4
Yaquina	2008	February	August	30	48	14	20	112	39.3
	2009	January	August	37	41	17	23	118	33.1
	2010	January	September	41	57	20	15	133	30.1
	2011	February	August	35	44	14	15	108	36.1
	2012	April	August	29	29	9	21	88	30.7
Coos	2008	March	December	38	75	16	27	156	39.1

Port	Year	Start	End	DAYEX	DAYMOD	ENDEX	ENDMOD	Total Days	Percent Sampled
Coos	2009	February	September	27	51	14	21	113	45.1
	2010	February	August	26	52	13	12	103	29.1
	2011	March	August	27	41	11	15	94	27.7
	2012	April	August	27	30	7	22	86	22.1

Appendix B. Effort estimations

Mean number of estimated diggers, and standard error of the mean, for the four day-types in Tillamook, Netarts, Yaquina, and Coos bays for the years 2008-2012. "NA" values for standard error are a result of a sample size of 1.

Port	Year	DAYEX		DAYMOD		ENDEX		ENDMOD	
		Diggers	SE	Diggers	SE	Diggers	SE	Diggers	SE
Tillamook	2008	184	38	36	6	269	24	150	47
	2009	141	16	15	6	320	51	40	NA
	2010	73	14	19	6	226	NA	115	NA
	2011	78	30	35	14	194	27	85	22
	2012	244	44	47	9	256	23	115	8
Netarts	2008	107	20	37	6	655	111	146	57
	2009	281	51	54	10	198	33	527	136
	2010	75	21	60	11	315	108	160	59
	2011	137	64	45	9	319	NA	203	44
	2012	214	29	71	18	252	NA	402	66
Yaquina	2008	84	14	8	2	168	31	42	14
	2009	173	22	39	6	208	33	64	21
	2010	105	17	23	5	276	51	54	NA
	2011	91	10	19	4	201	58	36	8
	2012	98	13	7	3	290	56	67	18
Coos	2008	158	21	35	5	150	29	94	21

Port	Year	DAYEX		DAYMOD		ENDEX		ENDMOD	
		Diggers	SE	Diggers	SE	Diggers	SE	Diggers	SE
Coos	2009	210	26	52	5	316	59	128	21
	2010	181	21	40	6	313	21	183	31
	2011	182	22	64	10	210	26	86	33
	2012	146	16	69	13	241	70	92	17

Appendix C. Interview results

Total number of interviews, mean number clams and standard error of the mean for each species for each clam bed in Tillamook, Netarts, Yaquina, and Coos bays for the years 2008-2012. "NA" values for standard error are a result of a sample size of 1. “Other” clams include eastern softshell, *Macoma* spp., purple varnish clam, Manila littleneck, etc.

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Tillamook	2008	GF	686	6.95	0.32	10.23	0.35	0.57	0.07	0.51	0.08	0.01	0.01	18.26	0.15
		GM	100	0.80	0.36	14.88	0.70	3.31	0.50	0.00	0.00	0.82	0.72	19.81	0.60
	2009	BO	8	7.00	3.00	4.75	1.92	6.25	1.98	0.00	0.00	0.00	0.00	18.00	1.36
		CFT	17	3.12	1.25	13.12	1.55	2.12	1.04	0.00	0.00	0.00	0.00	18.35	0.91
		GF	245	6.58	0.51	9.07	0.53	0.81	0.14	0.65	0.13	0.08	0.06	17.20	0.30
		GM	2	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00
		KP	1	0.00	NA	8.00	NA	12.00	NA	0.00	NA	0.00	NA	20.00	NA
	2010	BO	25	0.24	0.24	11.60	1.29	5.16	1.01	0.00	0.00	0.04	0.04	17.04	0.88
		GF	246	5.15	0.49	11.72	0.56	0.77	0.15	0.55	0.09	0.00	0.00	18.20	0.24
		KP	3	0.00	0.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00
	2011	BO	28	0.00	0.00	11.86	1.30	6.82	1.08	0.00	0.00	0.00	0.00	18.68	0.47
		CFT	34	0.00	0.00	8.56	1.19	8.44	0.95	0.00	0.00	0.00	0.00	17.00	0.60
		GF	245	3.44	0.40	14.33	0.49	0.41	0.08	0.24	0.05	0.26	0.21	18.69	0.30
	2012	BO	7	0.00	0.00	19.57	0.30	0.14	0.14	0.00	0.00	0.00	0.00	19.71	0.29
		CFT	32	0.19	0.14	7.38	1.39	6.13	0.87	0.00	0.00	0.03	0.02	13.69	0.88
		GF	308	3.44	0.37	13.83	0.46	0.74	0.14	0.18	0.04	0.00	0.00	18.21	0.22
		HP	12	0.00	0.00	19.42	0.50	0.08	0.08	0.00	0.00	0.08	0.08	19.50	0.50
Netarts	2008	CL	12	0.00	0.00	0.00	0.00	0.00	0.00	19.92	0.08	0.00	0.00	20.00	0.00

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Netarts		HC	5	4.60	2.82	0.00	0.00	5.00	2.05	0.00	0.00	0.01	0.01	9.60	0.81
		NM	180	7.24	0.63	3.33	0.42	5.37	0.41	0.52	0.20	0.13	0.04	16.58	0.37
		RV	21	3.29	1.22	3.76	1.48	3.86	1.01	1.67	0.68	2.19	1.30	14.76	1.19
		SC	3	18.67	0.88	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	19.67	0.33
		WR	410	3.98	0.31	8.03	0.41	3.70	0.24	0.42	0.08	0.20	0.05	16.33	0.26
	2009	CL	15	0.20	0.20	7.13	2.42	0.00	0.00	11.53	2.50	0.07	0.07	18.93	1.07
		CN	65	7.17	1.10	6.86	1.11	2.71	0.59	0.69	0.43	0.98	0.48	18.42	0.48
		LN	23	6.87	1.77	2.17	1.25	4.30	1.02	1.39	0.65	1.00	0.55	15.74	1.31
		NM	9	6.33	2.70	4.11	1.70	7.78	1.38	0.00	0.00	0.00	0.00	18.22	0.91
		RV	23	0.96	0.47	7.61	1.58	4.52	1.00	0.26	0.11	0.04	0.04	13.39	1.38
		SC	24	16.96	1.31	2.08	1.16	0.08	0.08	0.00	0.00	0.00	0.00	19.13	0.50
		WR	415	3.35	0.30	10.36	0.44	3.52	0.24	0.46	0.10	0.09	0.05	17.78	0.26
	2010	CL	145	0.00	0.00	0.00	0.00	0.00	0.00	3.06	0.59	16.79	0.61	19.84	0.10
		CN	45	8.02	1.34	6.00	1.04	5.40	0.82	0.07	0.07	0.22	0.14	19.71	0.14
		LN	14	0.14	0.14	1.57	0.84	2.57	1.37	0.00	0.00	9.57	1.72	13.86	1.35
		RV	4	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00
		SC	42	18.52	0.51	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	18.60	0.48
		WR	445	2.52	0.28	11.06	0.40	4.00	0.28	0.17	0.05	0.06	0.03	17.82	0.22
	2011	CL	134	2.78	0.53	7.35	0.76	3.17	0.43	3.52	0.62	0.19	0.15	17.01	0.43
		CN	75	6.03	0.97	7.69	0.94	4.04	0.61	0.92	0.46	0.00	0.00	18.68	0.42
		LN	10	2.90	1.93	16.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	18.90	0.74

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Netarts		RV	1	0.00	NA	2.00	NA	12.00	NA	0.00	NA	0.00	NA	14.00	NA
		WR	183	6.13	0.60	7.14	0.61	4.23	0.38	0.09	0.03	0.03	0.02	17.62	0.32
	2012	CL	51	0.00	0.00	0.00	0.00	0.00	0.00	16.90	0.99	2.75	0.97	19.65	0.28
		CN	6	13.33	4.22	6.67	4.22	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00
		HC	11	0.45	0.45	0.00	0.00	11.91	0.09	0.00	0.00	0.00	0.00	12.36	0.47
		RV	2	8.50	7.50	6.00	2.00	4.50	4.50	0.00	0.00	0.00	0.00	19.00	1.00
		WR	409	4.87	0.37	8.10	0.41	4.16	0.26	0.20	0.04	0.01	0.01	17.34	0.22
Yaquina	2008	BB	164	0.07	0.03	5.24	0.55	6.68	0.41	0.00	0.00	1.12	0.27	13.10	0.43
		BWN	40	0.43	0.25	0.60	0.22	10.10	0.47	0.10	0.07	0.63	0.32	11.85	0.72
		BWS	12	5.25	2.27	1.25	0.70	5.58	1.40	0.67	0.28	0.00	0.00	12.75	1.63
		CP	3	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	15.33	8.09	16.33	8.95
		GP	23	0.00	0.00	13.52	1.75	3.09	1.06	0.13	0.10	0.00	0.00	16.74	0.97
		IF	169	0.37	0.16	10.53	0.63	4.13	0.40	0.20	0.04	0.18	0.08	15.40	0.43
	2009	BB	147	0.20	0.07	4.01	0.58	7.00	0.50	0.01	0.01	1.29	0.32	12.50	0.52
		BWN	21	0.19	0.09	1.62	0.97	10.57	0.74	0.10	0.07	0.00	0.00	12.48	0.74
		BWS	20	0.30	0.30	5.35	1.95	7.95	1.26	0.30	0.25	1.70	1.27	15.60	1.44
		CP	6	0.00	0.00	2.33	1.05	8.67	2.12	0.17	0.17	2.00	2.00	13.17	4.13
		GP	54	0.15	0.15	14.96	0.91	1.87	0.53	0.87	0.38	0.72	0.67	18.57	0.93
		IF	102	0.03	0.02	8.20	0.81	6.27	0.52	0.29	0.20	0.59	0.32	15.38	0.60
	2010	BB	120	0.08	0.03	6.28	0.69	7.42	0.56	0.01	0.01	0.95	0.26	14.73	0.53
		BWN	27	3.00	1.39	4.70	1.24	6.78	1.13	0.22	0.15	2.30	0.77	17.00	1.06

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Yaquina		BWS	17	3.59	1.90	10.41	2.00	2.24	1.07	0.41	0.17	0.24	0.24	16.88	1.37
		CP	2	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00
		GP	41	0.00	0.00	17.34	0.75	1.00	0.34	0.20	0.11	2.17	1.02	20.71	1.20
		IF	63	0.00	0.00	12.30	1.04	4.62	0.67	0.41	0.18	0.08	0.08	17.41	0.56
	2011	BB	134	0.11	0.04	2.22	0.43	7.90	0.56	0.00	0.00	1.22	0.25	11.45	0.50
		BWN	8	1.00	1.00	2.25	1.28	12.00	0.00	0.00	0.00	0.38	0.38	15.63	1.63
		BWS	7	0.00	0.00	3.00	1.86	7.57	2.11	0.14	0.14	0.00	0.00	10.71	2.58
		CP	16	0.06	0.06	0.00	0.00	11.81	0.10	0.06	0.06	0.00	0.00	11.94	0.06
		GP	54	0.30	0.21	14.37	1.06	1.43	0.51	1.30	0.51	0.02	0.02	17.41	0.63
		IF	134	0.25	0.11	9.05	0.86	4.78	0.51	0.16	0.04	1.59	0.32	15.83	0.91
	2012	BB	102	0.24	0.12	2.08	0.45	10.25	0.32	0.01	0.01	0.78	0.22	13.36	0.39
		BWN	32	3.69	1.37	0.06	0.04	8.47	0.88	0.06	0.04	0.03	0.03	12.31	0.85
		BWS	7	2.29	1.32	0.86	0.34	7.00	2.36	6.29	2.80	0.00	0.00	16.43	1.27
		CP	7	0.00	0.00	0.00	0.00	10.86	0.74	0.00	0.00	0.00	0.00	10.86	0.74
		GP	27	0.00	0.00	13.59	1.64	2.04	0.76	0.30	0.14	1.00	0.53	16.93	1.42
		IF	54	0.31	0.30	7.87	1.14	5.98	0.72	0.06	0.06	0.44	0.21	14.67	0.86
Coos	2008	BV	66	11.44	1.05	1.03	0.33	4.95	0.68	0.47	0.31	0.00	0.00	17.89	0.47
		CF	100	4.42	0.70	5.81	0.80	4.20	0.50	0.90	0.25	0.37	0.22	15.70	0.57
		CI	17	1.24	1.00	3.06	1.31	10.35	1.05	0.71	0.65	0.00	0.00	15.35	1.00
		CT	59	1.37	0.57	8.19	1.04	5.90	0.70	0.46	0.18	0.24	0.10	16.15	0.70
		EP	30	3.63	0.84	0.07	0.07	10.17	0.91	2.10	1.02	0.03	0.03	16.00	0.97

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Coos		NS	2	20.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.50	0.50
		PP	75	10.55	1.04	0.31	0.24	4.81	0.63	0.33	0.10	0.03	0.03	16.03	0.56
	2009	BV	48	13.71	1.12	0.15	0.09	3.00	0.69	0.27	0.11	0.04	0.03	17.17	0.68
		CF	127	1.51	0.41	7.76	0.73	5.43	0.47	0.37	0.10	0.29	0.13	15.35	0.45
		CI	97	5.64	0.75	0.25	0.21	9.10	0.49	0.02	0.01	0.00	0.00	15.01	0.46
		CT	94	0.22	0.07	6.91	0.81	8.03	0.53	0.12	0.04	0.24	0.11	15.53	0.44
		EP	41	2.56	0.66	0.63	0.33	11.05	0.45	0.12	0.07	0.00	0.00	14.37	0.60
		NS	65	1.60	0.44	3.17	0.78	10.18	0.53	0.05	0.03	0.06	0.04	15.06	0.46
		PA	9	0.00	0.00	12.33	3.08	0.00	0.00	0.00	0.00	2.00	1.24	14.33	2.25
		PP	80	12.18	0.85	0.16	0.10	4.39	0.57	0.73	0.20	0.01	0.01	17.46	0.48
	2010	BV	32	15.56	1.24	0.00	0.00	1.94	0.73	0.06	0.04	2.02	0.56	17.56	0.84
		CF	55	5.76	1.09	4.60	1.31	5.18	0.74	0.35	0.13	0.00	0.00	17.91	0.78
		CI	24	11.29	1.79	2.75	1.28	4.21	1.17	0.00	0.00	0.00	0.00	18.25	0.65
		CT	34	0.68	0.32	3.18	1.13	8.71	0.76	0.00	0.00	0.00	0.00	12.56	0.79
		EP	19	6.95	2.13	0.00	0.00	7.26	1.25	0.21	0.14	0.00	0.00	14.42	1.21
		PA	2	0.00	0.00	17.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	17.50	2.50
		PP	44	8.98	1.13	1.18	0.68	6.20	0.84	0.30	0.11	0.00	0.00	16.66	0.75
	2011	BV	9	17.78	2.22	0.00	0.00	1.33	1.33	0.00	0.00	0.00	0.00	19.11	0.89
		CF	25	3.44	1.21	3.72	1.35	8.24	1.03	0.36	0.15	0.00	0.00	15.76	0.96
		CI	18	9.61	1.74	0.00	0.00	8.61	1.30	0.00	0.00	0.17	0.17	18.22	0.81
		CT	6	1.17	0.54	3.17	3.17	8.00	2.53	0.00	0.00	0.00	0.00	12.50	2.42

Port	Year	Bed	Interviews	Butter	SE	Cockle	SE	Gaper	SE	Littleneck	SE	Other	SE	Total	SE
Coos		EP	20	2.30	1.34	0.10	0.07	10.65	0.78	0.00	0.00	0.03	0.03	13.05	0.70
		PP	16	14.19	2.09	0.00	0.00	3.63	1.25	0.81	0.60	0.00	0.00	18.63	1.35
	2012	BV	43	15.70	1.73	0.28	0.28	4.09	0.83	0.05	0.05	0.00	0.00	20.12	1.70
		CF	20	2.15	0.70	2.65	1.39	9.50	1.00	0.10	0.07	0.00	0.00	14.40	1.08
		CI	55	7.20	1.12	0.42	0.36	7.71	0.74	0.02	0.02	0.03	0.03	15.98	0.58
		CT	34	1.71	0.46	4.56	1.36	8.18	0.86	0.94	0.61	0.13	0.13	15.41	0.74
		EP	30	1.53	0.51	0.00	0.00	11.20	0.56	0.10	0.07	0.00	0.00	12.97	0.54
		NS	7	7.57	3.48	0.00	0.00	8.14	2.12	0.00	0.00	0.00	0.00	15.71	1.58
		PP	43	13.65	1.12	0.02	0.02	3.12	0.74	0.35	0.12	0.00	0.00	17.14	0.74

Chapter 3 Commercial bay clam fishery

HISTORY AND TRENDS IN LANDINGS

The harvest of bay clams (cockles, butter clams, gaper clams, and native littleneck clams) for commercial purposes occurs in several estuaries in Oregon. Commercial harvest of this resource has occurred since at least 1891, when over 28,000 pounds of bay clams were harvested. Throughout time, bay clam landings have varied due to market demands, effort, and harvest methods. Harvest may experience dramatic increases with either a single species or a single bay causing a spike in overall landings. It was not until 1978 that bay clam landings began to be reported by individual species.

Commercial fishery landings were historically grouped into categories, such as “Clams, Mixed”, which were highly variable in the composition of the species caught among years, therefore compositions could not be estimated. Although direct comparisons between current and historical landings composition is not possible, reconstructed historical commercial landings enable comparison of total clam landings (Karnowski et al. 2012). Cleaver (1951) provided some of the earliest details of commercial bay clam landings species composition, from the 1940s:

> *“During the period 1943-1949 an average of 47 percent of the total production was horseclams [gaper clams], 34 percent was cockles, and 19 percent was softshell clams. All three species are used in the restaurant and fresh food trade. Cockles have additional use as fish and crab bait which takes a large part of the total cockle catch.”*

The total landings of all commercial bay clams harvested in Oregon from 1927 – 2012 are shown in Figure 3-1. During the past 20 years (1994 – 2012), 85-90% of that harvest has occurred in Tillamook Bay (Figure 3-2). Bay clam harvest in Coos Bay in recent years represents a small fishery supplying cockles for local commercial Dungeness crab fishermen. Recent interest in Netarts Bay cockles has been on the increase. Landings in bays other than Tillamook, Netarts, and Coos are sporadic and minor, with combined mean annual landings of just over 3,000 pounds.

The majority of the clams harvested in Tillamook Bay has consisted of cockles (Figure 3-3), but interest in gaper clams has recently increased. Cockle landings in the Tillamook Bay subtidal dive fishery are limited by an annual quota of 90,000 pounds, which recently has been achieved in the first six months of the year. After the Tillamook Bay dive cockle quota is reached, some clam divers will then turn their attention to harvesting gaper clams (open season July 1 – December 31) to supply bait for the commercial Dungeness crab fishery. Figure 3-4 chronicles major regulation milestones in the history of Oregon commercial clam fisheries.

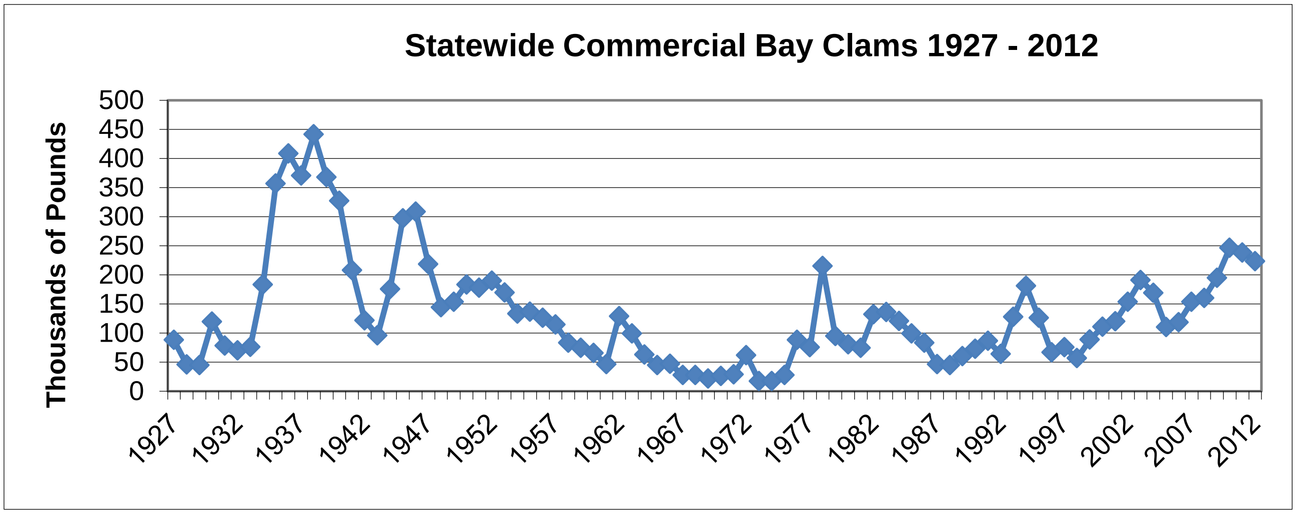

Figure 3-1. Landings of all commercial bay clams, 1927-2012.

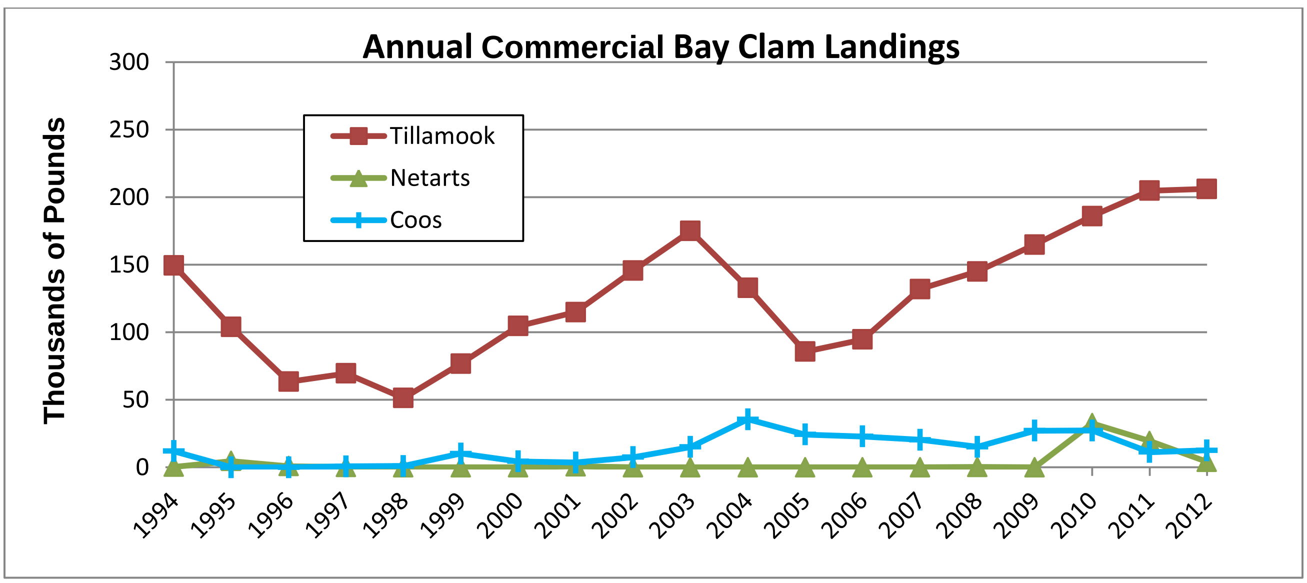

Figure 3-2. Landings of all commercial clams for Tillamook, Netarts, and Coos bays, 1995-2012.

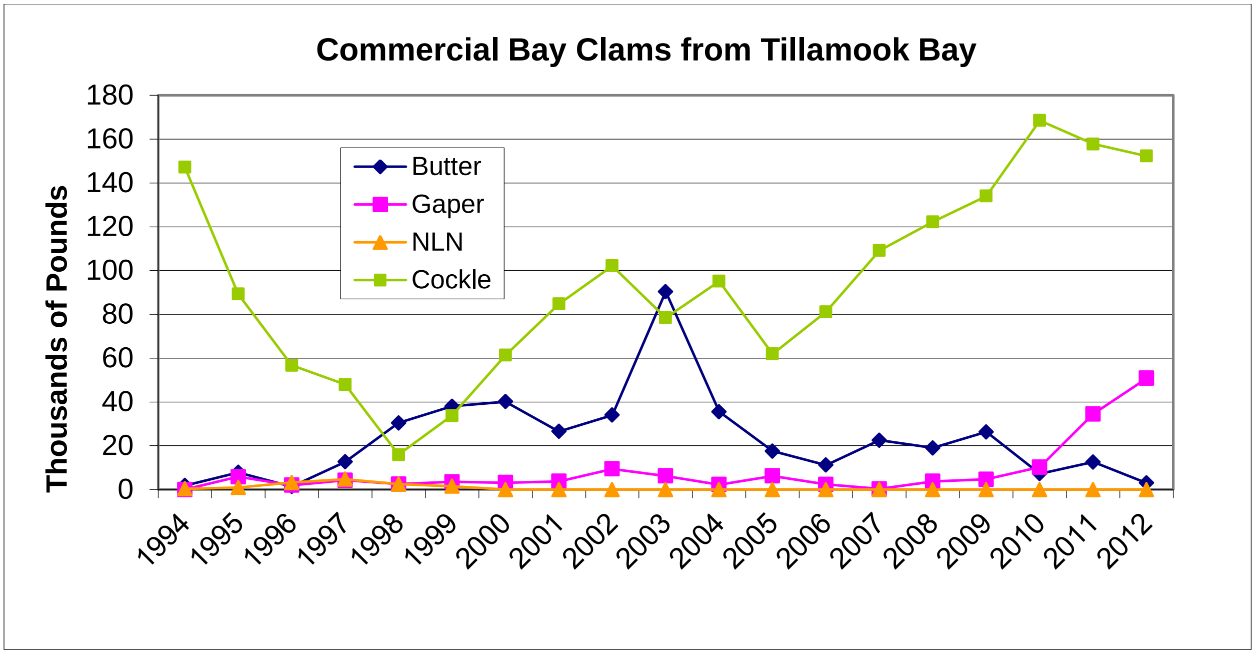

Figure 3-3. Landings of all commercial bay clams in Tillamook Bay, 1994-2012.

Although bay clams are a prized food taken by recreational diggers, the commercial harvest in Oregon currently is primarily sold as bait to commercial Dungeness crab fishermen. Only an estimated 2.6% of the bay clams harvested in 2012, for instance, was likely sold to the public for food. Low market demand and lack of interest by the industry have resulted in little success in developing a human consumption market for bay clams. While niche markets have developed intermittently, there has not been a large, long-term human consumption market. If clams are harvested and sold for human consumption, harvesters and dealers must satisfy Oregon Department of Agriculture sanitation requirements to protect consumer safety.

INTERTIDAL AND DIVE FISHERIES

Commercial clammers work either intertidally with rakes or subtidally using dive gear. The two fisheries harvest the same species but differ in permitting requirements and harvest methods. The commercial clam fisheries are regulated by Oregon Administrative Rules 635-005-0305 through 635-005-390 and by Oregon Revised Statutes (Table 3-1).

The intertidal clam fishery is an open access fishery with generally between 30 to 60 permits sold each year. Of those, only about 30 license holders make significant landings in a given year. The intertidal harvesters focus primarily on cockles and the vast majority of this fishery happens in Tillamook Bay. All bay clam species may be taken in most of Oregon's larger estuaries, except in Netarts Bay, where only cockles may be taken. Areas closed to the commercial harvest of bay clams include the shellfish preserves in Netarts and Yaquina bays, specific areas of Tillamook, and any areas closed by the Oregon Department of Agriculture due to marine biotoxins or other public health hazard.

The bay clam dive fishery is managed separately and consists of 15 permits (ten of which allow bay clam harvest in any estuary open to bay clam harvest, and five permits restricted to estuaries south of Heceta Head). This fishery has undergone some changes in the recent past. In 2005, it was converted from a developmental fishery to a limited entry fishery. The developmental fishery phase lasted several years during which time the participants worked closely with ODFW to develop regulations for the fishery. The limited entry permit system controls the effort and potential harvest in the fishery, promoting sustainability.

The permits for the dive bay clam fishery are not transferable, unlike permits in some other limited entry fisheries. The permit must be designated by the permit holder as either an individual permit associated with the person, or a vessel permit associated with a boat. The permits can be renewed each year as long as the qualifying landings have been made. Each permit must show at least 5 deliveries of at least 100 pounds each or an overall total of 5,000 pounds. Logbooks must be filled out for each dive and submitted for each active month. If renewal requirements are not fulfilled, that permit will be offered for reassignment through a lottery.

Commercial clam harvest is tracked by logbooks and fish tickets. Each harvester is required to log each clamming trip in a logbook. They must sell their catch to a licensed dealer within 48 hours of harvest. The dealer fills out a fish ticket for each purchase and submits those fish tickets within five working days of the purchase to ODFW headquarters in Salem. Oregon Revised Statutes require that dealers pay an *ad valorem* tax equal to 2.25% of each transaction. The combined intertidal and dive bay clam fishery produced just over 223,000 pounds in 2012 with an ex-vessel value of $120,000. This total harvest was achieved by just over 45 participants, some of whom worked both the dive fishery and the intertidal fishery.

1948: State is granted jurisdiction over fishery. Seasons and bag limits first established.
1960: Prior to the 1960s, virtually all clams were harvested intertidally by hand.
1963: Mechanical harvest of intertidal clams disallowed.
1963: Permits required for mechanical harvest of subtidal clams.
1985: Commercial Shellfish Harvest Permit required for any estuarine clam harvest.
1986: Dying required for clams harvested for bait.
1988: Mechanical gear harvest permits for subtidal clams discontinued.
1996: Developmental Fishery permits required for dive fishery; 20 allowed.
Quotas set on cockles to prevent over-harvest by divers; (90,000 pounds in Tillamook; 8,000 pounds in Netarts).
1997: Dive permits reduced to 10. May be associated with either a diver or a boat.
1998: Logbooks required.
1999: 5 "South Coast" dive permits added.
2003: Gaper clam by-catch allowed during closed season when harvesting butter clams.
2006: Fishery moved to limited entry. 10 coastwide, 5 south coast permits.
Size restrictions on cockles and gapers. Some restricted areas defined.

Figure 3-4. Timeline of regulation history of the commercial bay clam fishery.

Table 3-1. Rules and regulations of the intertidal and dive bay clam fisheries.

	Intertidal	**Dive**
License	Commercial fishing license or bait fishing license	Commercial fishing or bait fishing license
Permit	Shellfish Harvest Permit (open access)	Bay Clam Dive Permit (limited entry; 10 coast-wide and 5 south-coast permits)
Logbook	Commercial Shellfish Logbook	Dive Logbook
Open Season	Year-round, except gaper clams are closed January through June	Year-round, except gaper clams are closed January through June
Area	All areas open except: Nestucca; Salmon; Siletz; Preserves in Netarts and Yaquina; Netarts (except cockles); special areas in Tillamook	All areas open except: Nestucca; Salmon; Siletz; Preserves in Netarts and Yaquina; Netarts (except cockles); special areas in Coos and Tillamook
Size Limit	None	Cockles 2 ¼"; gaper clams 4"
Other	All clams harvested for bait must be dyed; ODA Shellfish Sanitation Certificate required for human consumption harvest	All clams harvested for bait must be dyed; ODA Shellfish Sanitation Certificate required for human consumption harvest

REFERENCES

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Chapter 4 Shellfish and Estuarine Habitat Assessment of Coastal Oregon

INTRODUCTION

SEACOR

In the 1970s, the Oregon Department of Fish and Wildlife (ODFW) partnered with Oregon Sea Grant and the Department of Land Conservation and Development to fund extensive surveys of shellfish populations and estuarine habitats in 15 Oregon estuaries (Figure 4-1). The results of these studies were published as estuary-specific “Raccoon reports” (Bottom et al. 1979), a moniker reflecting the prominent raccoon presented on the cover, as well as the Hancock report (Hancock et al. 1979). These decades-old reports are still the primary source for Oregon bay clam population and habitat information, and therefore the need for more recent information is paramount.

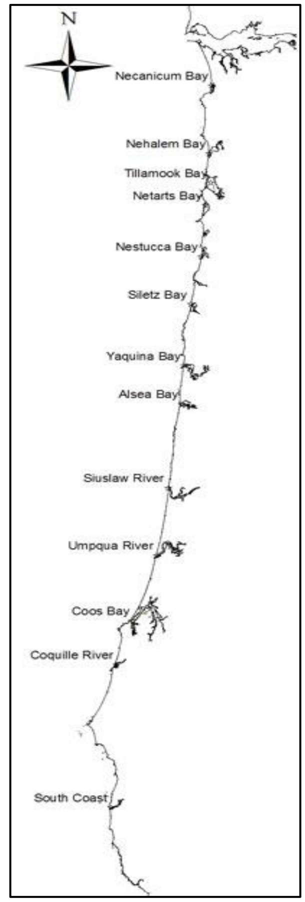


Figure 4-1. Major Oregon estuaries surveyed by ODFW in the 1970s

Budget restrictions severely limited studies of bay clam populations in the 1980s and 1990s. This changed in 2004 when the Oregon State Legislature approved a recreational shellfish license with funds dedicated to support a shellfish program within ODFW. In 2008, the Shellfish and Estuarine Assessment of Coastal Oregon (SEACOR) project was established as a pilot program to repeat the extensive estuarine surveys from the 1970s, with Coos Bay as the pilot site. The Oregon State Legislature made SEACOR a permanent project in ODFW in 2010. Recreational license fees continue to directly fund the SEACOR program research used for managing shellfish resources.

Project Goals

The primary SEACOR project goal is to complete bay clam population and estuarine habitat studies throughout all the bays along the coast of Oregon using a rigorous and robust scientific methodology. The project focuses on four primary objectives: 1) describe estuarine habitats, 2) describe the spatial distribution of recreationally-targeted bay clams, 3) describe the ecological variables driving (or correlated with) bay clam distribution, and 4) estimate bay clam abundance. SEACOR surveys target the popular recreationally harvested clams: butter clams (*Saxidomus gigantea*), cockles (*Clinocardium nuttallii*), gaper clams (*Tresus capax*), and native littleneck clams (*Leukoma staminea*). However, the project also collects information on other shellfish species utilizing the estuaries, such as softshell clams (*Mya arenaria*), razor clams (*Siliqua patula*), and juvenile Dungeness crabs (*Cancer magister*). This supports ODFW's mission "to protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations."

SEACOR delivers a variety of resources and products for the public, legislators, researchers, and state agencies. ODFW is charged with ensuring access to marine resources like bay clams and SEACOR provides bay clam distribution maps for popular public clamming areas that are accessible online (http://www.dfw.state.or.us/mrp/shellfish/seacor/maps_publications.asp) or as a hard copy at coastal ODFW offices. Data gathered from these studies are also used to track invasive species in Oregon estuaries, evaluate changes in bay clam populations over time, and for stock estimates, which inform management strategies and provide guidance to policy makers and regulators. Lastly, this research fills gaps in information on basic clam biology that can help prioritize research efforts for agencies and the scientific community.

METHODS

General Approach

SEACOR surveys a broad range of potential clam habitats and important areas for recreational and commercial clam harvest in each study estuary. The sampling design employs two assessment strategies: (1) a Rapid Assessment Method (RAM) applied extensively across the study area in either a systematic grid sampling pattern (typically 100 x 100m) or at randomly selected points, and (2) a Detailed Assessment Method (DAM) applied only to random-stratified sampling points. All sampling sites were stratified into several tidal elevation strata to isolate the effect of tide height. Thus, the first step in each study was to gather or collect bathymetry data and create the tidal strata. Sites were then selected randomly using ArcGIS®(ESRI 2009; ESRI 2012) and surveyed using RAM and DAM. Since conducting the Coos Bay pilot study in 2008, methods have been modified to address challenges observed in the field and additional information needs. Two major changes in methodology that resulted from the Coos Bay pilot study were: 1) employing a suction dredge system ("megacore") that allowed for efficient shellfish extraction for DAM surveys, and 2) surveying entire tidal flats instead of targeting clam beds. The specific variables measured and methods employed for Coos Bay and Tillamook Bay are presented in Appendix A.

Bathymetry

Bathymetry is a necessary component of SEACOR surveys to estimate tidal elevation and create tidal strata for the random-stratified sampling design. For Coos Bay, tide heights were estimated using boat transects with line-to-bottom measurements. Bathymetry for Tillamook Bay was derived from a combination of U.S. Army Corps of Engineers surveys (1995) and Oregon LiDAR surveys (Oregon Department of Geology and Mineral Industries 2011). Once tide heights were known for the study regions, tidal strata were created using ArcGIS® by comparing tidal elevation to MLLW. The tidal strata were: subtidal (Sub) < -0.5 m, low (L) = -0.5 to 0.0 m, mid (M) = 0.0 to 0.5 m, high (H) = 0.5 to 1.0 m, high high (HH) >1 m. Not all of these strata were sampled in each bay.

Rapid Assessment Method (RAM)

Environmental and biological data were collected at each RAM sampling site within a 1-m^2 quadrat. Environmental variables included substratum type, sediment type, sediment temperature, and depth of anoxic layer. Biological variables included percent cover of algal functional groups, cover and shoot density of eelgrass, shrimp (*Neotrypaea californiensis* and *Upogebia pugettensis*) burrow hole density, and presence of various shellfish species. Clam abundance was estimated by counting the number of visible burrow "shows" (butter and gaper clams) or raking the top 15 cm of sediment (cockles and littleneck clams). Presence of living specimens of invertebrate species observed inside or within 2 m of the quadrat was also recorded. Common organisms observed were crabs (e.g., Dungeness crab, red rock crab, shore crabs), polychaetes (e.g., *Pista* spp, *Abarenicola pacifica*, *Mediomastus* sp.), diatom mats, and bivalves (e.g., target clam species, softshell clams, Pacific oysters). Appendix A presents a complete list of these variables, the spatial scales on which these variables were measured, and the methodology used to collect these data.

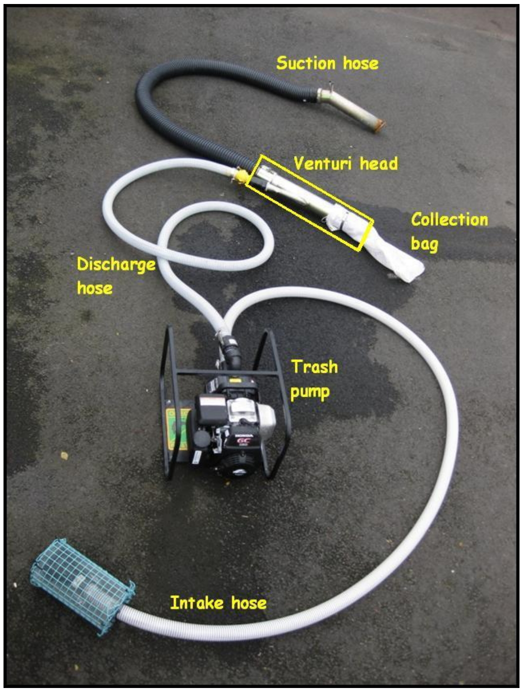
SEACOR biologists digging at a DAM site

Detailed Assessment Method (DAM)

For rigorous statistical analysis, the DAM survey utilized a stratified random sampling design based on tidal flat (region) and tidal elevation. In addition to the environmental and biological data collected for RAM surveys, SEACOR began to collect above-ground eelgrass and sediment samples in 2010. All native (*Zostera marina*) and introduced (*Zostera japonica*) eelgrass was collected in a randomly-selected quadrant (0.25 m^2 and 0.01 m^2, respectively) within the site quadrat. Eelgrass was cut at the sediment surface at the base of the rhizome and frozen until analyzed for above-ground eelgrass biomass. Sediment samples were also collected using a 60-ml syringe at locations within the quadrat selected using a random number generator. Using the syringe, the top 6 cm of sediment was collected and stored at 4°C for particle size analysis to describe grain size distribution. The top 2 cm of sediment from two other syringe samples were collected, frozen, and analyzed to quantify total volatile solids (TVS), an estimate of the sediment total organic matter at our sample sites.

Shellfish were also extracted for measurement and density estimates at each DAM site. Extraction methods and spatial scale have evolved since sampling began and are detailed in Appendix B. In 2008-2009, shellfish extraction for DAM surveys in Coos Bay was conducted entirely by digging a core 1m x 1m area marked by 4 aluminum blades to a depth of 0.35 m. This digging method was time consuming and relied on hand collection of each specimen.

In 2010, SEACOR began using a megacoring suction pump system for DAM shellfish extraction. After a RAM survey described above was completed at each DAM site, SEACOR biologists returned to the site when the tide brought the water level to approximately 0.5 m at the site. An aluminum barrel (0.5 m^2) was positioned in the middle of the site to a depth of 0.35 m. Shellfish were then extracted using a Venturi megacoring suction pump system (after Hancock et



SEACOR's Venturi megacoring suction dredge system used to extract shellfish

al. 1979). In this system, water flows from the intake hose through the pump and out the discharge hose through the Venturi head. The negative pressure in the Venturi head creates suction at the suction hose end. Samples are collected in a bag with mesh size of 8 mm at the end of the Venturi head, where the water is discharged. Shellfish were then sorted and measured. A comparison between digging and suction dredging methods clearly identified that suction dredging was both more efficient and that smaller size classes of clams were captured since it minimized observer bias during hand collection (i.e., digging). Most of the Tillamook Bay sites were sampled using the megacoring method. This method increased the number of DAM sites by an order of magnitude, providing a more statistically robust way to evaluate clam populations.

Each clam extracted either by digging or dredging was measured for maximum anterior-posterior length, maximum lateral width, and wet weight. Other shellfish such as shrimp and crabs were also measured (details provided in Appendix B).

<u>Subtidal</u>

Subtidal surveys were conducted in a subset of bays to estimate clam populations in the deeper tidal channels. SEACOR launched a pilot study in collaboration with the Oregon Coast Aquarium (OCAq) in Coos Bay. OCAq divers collected habitat information in fall 2008, which provided useful information for guiding future subtidal dive surveys. Tillamook Bay (2012) subtidal habitats were surveyed in a stratified-random design by region (tidal channel) using a similar suction dredge system as that used for DAM surveys using contracted divers to operate the suction end of the system. An aluminum or stainless steel ring (0.5 m^2) was lowered to the sediment surface once the site was located by boat GPS. Divers extracted shellfish from the top 1.0 m of sediment using the suction dredge system; these samples were sorted and measured using the same methods as the DAM surveys. This subtidal sampling depth is greater than the 0.35 m surveyed in the intertidal (i.e. DAM). These depths were chosen for logistical purposes given that no standard has been established in the literature or by the Department for these types of surveys. Density and biomass estimates of intertidal samples were considered conservative compared to subtidal estimates because the difference in sampling depth may have undersampled some clams, such as *T. capax*, which can be found at depths greater than 0.35 m.

Data Analysis

Distribution

Environmental and biological variables were mapped using ArcGIS®. These maps illustrated the geographic distribution of key estuarine habitat features and physical and biological variables. These variables were also graphed by region and tidal strata allowing further comparisons of variables.

Relationships

Several statistical approaches were used with data collected from both RAM and DAM to determine how environmental and biological variables were structured across the regions and among the tide height strata. Parametric tests of differences (e.g., ANOVA, t-test) in variables such as eelgrass bed type and clam density among these strata were conducted if the data met the assumptions of these tests using JMP® or Systat®(SAS Institute 2012; Systat Software 2011). Nonparametric tests were used when these assumptions were not met (e.g., Welch's t-test). Multivariate statistical tests were used to describe biological variables within our factors (e.g., region, tidal strata, bed type, etc.) using PRIMER® and PC-ORD®(Clarke and Gorley 2009; McCune and Mefford 2011). Multi-dimensional scaling (MDS) plots, cluster analysis, PERMANOVA and ANOSIM post-hoc analyses were used to describe how region and tidal strata contributed to community structure. In addition, multiple step-wise logistical regression in R examined how each environmental variable correlated with each clam species.

Population Estimates

Population estimates were calculated two ways for the Coos Bay pilot project. First, abundance was calculated using RAM burrow data and treated as "estimated density" since shellfish were not extracted during RAM. The second method used DAM biological data and was treated as "actual density" because clams were extracted directly from the site. For more information regarding calculations of these two density estimates, refer to the Coos Bay Final Report (in prep.). Coos Bay estimates based on actual density (DAM) were limited by small sample size (n=15 per region) and differed from estimates based on estimated density (RAM), as discussed in Coos Bay: Population Estimates. For these reasons, only quantitative clam data from DAM surveys are reported.

The adoption of the more efficient megacore suction dredge system in subsequent surveys increased sample size and improved population estimate precision using the density and weight data from the DAM sites. Abundance (i.e., total number of clams) was estimated using the mean density per m^2 within each region multiplied by the area of the study region. Similarly, mean weight (g/m^2) within each region was multiplied by the area of the study region to estimate clam biomass. Study region totals were then summed to estimate total abundance and biomass for the estuary.

Presented here are summaries of SEACOR survey results for Coos Bay and Tillamook Bay. More detailed and comprehensive reports are being prepared for each estuary SEACOR surveyed and will be published in future reports.

COOS BAY SURVEY (2008-2009)

INTRODUCTION

Coos Bay was selected as SEACOR's pilot site because it is Oregon's largest outer coast estuary, has a long history of supporting recreational and commercial clam harvest, and has experienced increasing urbanization and industrialization since the late 1800s. Coos Bay is a proposed site for a large liquid natural gas facility which would require additional dredging of the channel, an activity that first occurred in 1927. The increasing importance of Coos Bay as a shipping port since its early colonization resulted in physiographic changes primarily from dredging and filling in addition to community compositional changes from introductions and extractions. Updating our understanding of estuarine habitats and the abundance and spatial distribution of Coos Bay's clam populations was valuable and necessary to measure these changes in habitat and community structure.

STUDY REGIONS

SEACOR surveyed Coos Bay during the 2008-2009 biennium. This 18-month study focused on six regions, which encompassed three tidal strata (L, M, H) (Figure 4-2). These regions were identified by a "scouting" method not employed with the subsequent estuary studies. Scouting was accomplished using a team transect approach. Team members spaced 10 m apart recorded habitat information every 10 m along transects from shore to channel. The team was repositioned every 100-300 m along the shore of lower Coos Bay. Based on scouting, regions were selected for sampling when the following criteria met: (1) the area was composed of unconsolidated sediment suitable for burrowing organisms, (2) the area was located in the marine-dominated region of the estuary (Davidson 2006), (3) the area was large enough to collect a representative number of samples, (4) the area was known to be or likely to be used by recreational clam harvesters, and (5) the area was likely to support clam species at some population level, based on previous studies. This last criterion highlights a key change made for future estuarine studies. Entire tidal flats were surveyed in Tillamook Bay instead of targeting clam bed areas as was done for the Coos Bay pilot study. Six regions were selected based on these criteria:

Figure 4-2. RAM and DAM sites for the 6 study regions in Coos Bay.

five regions located along the main Coos Bay shipping channel, and one region located in the South Slough (Figure 4-2).

Airport (Air) region is composed of several contiguous extensive tide flats that border the Southwest Oregon Regional Airport runway on three sides and a section of the shoreline that extends south. On the northern border of the Airport runway, there is an extensive, sandy, shrimp-dominated tide flat. To the west of the Airport, there is a heterogeneous and broad tide flat that forms a small peninsula. The peninsula is composed of soft mud close to the runway and to the east, sand at the western edge, a small terrestrial island in the center, and a mixed sediment eelgrass habitat to the far south.

Clam Island (CI) region is emergent only at lower tides and is entirely isolated from land by water during all tides. It is bordered by an unmaintained channel to the west (demarcated by pole markers at the north and south end of the island) and by the federally-maintained navigational channel to the east. The southern end is lower in tidal elevation than the northern end, and there is a depression at the southern end with abundant eelgrass. This region is popular among recreational clammers. The adjacent channels are also popular for recreational crabbers.

Empire (Emp) region is a relatively narrow strip of two distinct tide flats partially separated by a small dune headland. The larger portion of this region is to the south and the entire region is bordered to the east by low-lying dunes and a densely urban neighborhood.

North Spit (NS) region contains a terrestrial island surrounded by areas of soft mud and other areas of sand. The dune area to the north of the region is lightly-developed with industrial buildings, and is a natural area with limited public access (four-wheel-drive vehicle on sand or boat access only).

Pigeon Point (PP) region is the most heterogeneous, with separate areas dominated by cobble, nearly pure sand, and nearly pure mud. There are several dredge spoil piles, not emergent at high tide, that are composed largely of cobble that form a barrier across the edge of the region and separate the bulk of the exposed tide flat from the shipping channel. There are two permanent pools, one to the north that is shallow and is highly vegetated with eelgrass and algae and a second pool in the central area that is filled with soft mud and light vegetation. This region is named after “Pigeon Point,” a highly-developed residential neighborhood that borders the south edge. The eastern edge is also highly-developed with residential buildings. In contrast, the northern border is a low-lying dune habitat situated on landfill. Access to this region is fairly easy, with paths leading down the bluff face at both the northern and southern ends.

South Slough (SS) region refers to an area that contains three discrete tide flats with the largest of the three locally called the "South Slough Flat". The "South Slough Flat" is bordered by the Charleston Bridge at its northern edge, the Metcalf Marsh at its western edge and by the lightly-developed forested bluff known as Collver Point to the south. There is a large cluster of hummocks (raised areas), vegetated with salt marsh plants that are entirely submerged only at extreme high tides. There are also two major drainage channels from the Metcalf Marsh, one to the south and one to the north of the hummock cluster. There is abundant native eelgrass (*Z. marina*) in the lower intertidal areas. This region is a very popular area for clammers and also for fishermen harvesting burrowing shrimp for bait. The SS region also includes the smaller "Charleston Triangle" and "Fisherman's Grotto" (a restaurant at the access point) tide flats, which were only sampled during RAM surveys. Both of these tide flats are located just north of the Charleston Bridge, are heavily used by clammers, and are adjacent to the marina and fish processing plants.

This study assessed 450 ha of tide flats of which 150 ha were surveyed by DAM. RAM surveys were conducted in all 6 regions, whereas DAM surveys (n=45 sites) were only conducted in CI, PP, and SS. The results below focus on these 3 flats. All results are detailed in the SEACOR Coos Bay Final Report (in prep.).

MAJOR FINDINGS

Bay Clam Distribution

Clam beds were present in all study regions in Coos Bay. Clam Island (CI) and Pigeon Point (PP) supported the most clam beds. In general, butter clams and gaper clams were much more abundant than cockles and littleneck clams. Butter clams were most prevalent in unvegetated sandy areas, whereas cockles were often associated in areas with high algal cover. Gapers were present at the greatest densities in low intertidal habitats. Littleneck clams were rare compared to other bay clams in all regions surveyed.

Clam Island supported high densities and diverse assemblages of bay clams (Figure 4-4). Butter clams were throughout Clam Island (region mean=4.6 clams m^{-2}). Cockles were least abundant at Clam Island, compared to the other tide flats surveyed by DAM (mean = 0.6 clams m^{-2}). Gaper clams exhibited the greatest densities at Clam Island (mean=19.9 clams m^{-2}). Native littleneck clams exhibited low densities at all three regions (mean=0.7 clams m^{-2}), including Clam Island (mean=0.4 clams m^{-2}).

Pigeon Point exhibited the highest densities of butter clams (Figure 4-5), particularly in sandy areas. Cockles were not very abundant at Pigeon Point (mean=1.0 clams m^{-2}) relative to other bay clam species. Gapers were less abundant at Pigeon Point compared to Clam Island (mean=3.1 clams m^{-2}). Littleneck clams exhibited the highest densities at Pigeon Point (mean=1.4 clams m^{-2}) and were present throughout the intertidal.

South Slough exhibited the lowest density of butter clams (mean=2.1 clams m^{-2}), but they were still abundant compared to other clams such as cockles and littlenecks (Figure 4-6). The highest densities of cockles occurred at South Slough (mean=1.5 clams m^{-2}). The largest cockles were also collected at South Slough (mean shell length=70.2 mm). Gapers were least abundant at South Slough (mean=1.8 clams m^{-2}) among the three regions sampled by DAM and smaller size classes were not detected at sampled sites. Littleneck clams were least abundant at South Slough (mean=0.3 clams m^{-2}) (Figure 4-6) and were absent at many waypoints surveyed by DAM.

Relationships between clam abundance and environmental variables

Regression analysis revealed several patterns in spatial distribution and abundance within Coos Bay. Butter clams were negatively associated with algal presence and were most commonly found in non-vegetated habitats. Conversely, cockles had a positive association with algal cover and were also positively correlated with more aerobic (oxygenated) sediments. Gaper clams also exhibited a positive relationship with algal cover, whereas they were negatively correlated with temperature of sediment at depth. Littleneck clams were more abundant in more aerobic sediments and were positively correlated with native eelgrass *Z. marina* cover. However, few littlenecks were observed or collected in any of the study regions in Coos Bay.

Population estimates

There were significant differences between abundance estimates between the RAM and DAM. Staff were able to conduct RAM surveys much more quickly than DAM surveys, allowing for greater areal coverage and number of sites sampled within tide height and region strata. One drawback of RAM surveys is estimation of shellfish abundance and presence using only burrow or siphon shows. RAM burrow counts either misidentified or did not detect presence of butter clams for 46% of the DAM sites. RAM gaper clam burrow counts were incorrect for 14% of sites. The inaccuracy of clam burrow counts in predicting the presence of clams made RAM data inappropriate for estimating populations. The small sample size of DAM sites for this pilot study (N=45, total) was also inadequate for bay clam stock estimates. Therefore, population estimates are not published for the Coos Bay pilot study using these data.

TILLAMOOK BAY SURVEY (2010-2012)

INTRODUCTION

Tillamook Bay, the second largest outer coast estuary in Oregon, is fed by five major rivers that have supported timber, farming, and fishing since the 1880s. Tillamook Bay supports more than 70% of the state's commercial bay clam fishery and has had an important recreational bay clam fishery for generations. Over time, natural and anthropogenic factors contributed to the degradation and filling of the estuary, impacting the natural resources of this region. In the early 1990s, local citizens raised concerns about the watershed's declining water quality, commercial shellfish closures, and loss of salmon spawning and rearing habitats. Additionally, insufficient data pertaining to the sustainability of clam harvest fueled a growing conflict between commercial and recreational users. While ODFW conducted surveys of Tillamook Bay in 1974-1976, 1984-1985, and 1996, the SEACOR survey aimed to provide rigorous, quantitative data to address these concerns, increase the extent of habitats surveyed, and serve as a comprehensive baseline for tracking changes in shellfish populations and habitats.

Two major changes differentiate the SEACOR Tillamook Bay project from the Coos Bay pilot study and previous studies in Tillamook Bay by ODFW. First, this study extended the area surveyed in both intertidal and subtidal habitats. Large subtidal clam populations in Tillamook Bay have been the focus of previous studies as they are thought to be important for supporting both the commercial and recreational clam fisheries. This survey extended the area beyond the regions of subtidal channels and intertidal flats that were surveyed previously. Second, SEACOR employed a megacoring suction system (described in Methods: DAM) that allowed for increased efficiency of DAM shellfish extraction. For example, more than 460 sites across three regions were sampled using DAM in Tillamook Bay compared to 45 sites across three regions in Coos Bay.

STUDY REGIONS

Intertidal

SEACOR conducted intertidal surveys in Tillamook Bay during 2010-2011. Study regions encompassed tidal flats that were currently or historically utilized for commercial or recreational clam harvest, and areas surrounding known bay clam regions that had not been surveyed previously.

Garibaldi Flat (GAR) is the primary recreational flat for bay clam harvest in Tillamook Bay. This region is easily accessed by foot, with access to parking, public restrooms, and a concrete stairway. The western portion of Garibaldi Flat, where most of the recreational harvest occurs, is dominated by cobble and gravel. The eastern part of the flat near the Coast Guard station is sandy with a small eelgrass bed and plentiful shrimp beds.

Bay Ocean Flat (BO) is another area easily accessed by the public, with parking available at the southern end of the region and trails leading to the tide flat. Bay Ocean is characterized by a large, extensive eelgrass bed. The deep pool in the north is a popular fishing spot. Historically, Bay Ocean has been a popular location for recreational clamming for cockles and gaper clams. Currently, this area is the primary site for commercial oyster leases in the bay.

Middle Flat (MF) is accessible only by boat and is situated next to the main subtidal channel supporting most of the recent commercial dive fishery. While it has not been a major site for recreational harvest, this region has been the primary location for the intertidal commercial cockle rake fishery since 2003. Middle flat is characterized by sandy substrata. The western peninsula of this intertidal flat was not sampled since it is a harbor seal haul-out area.

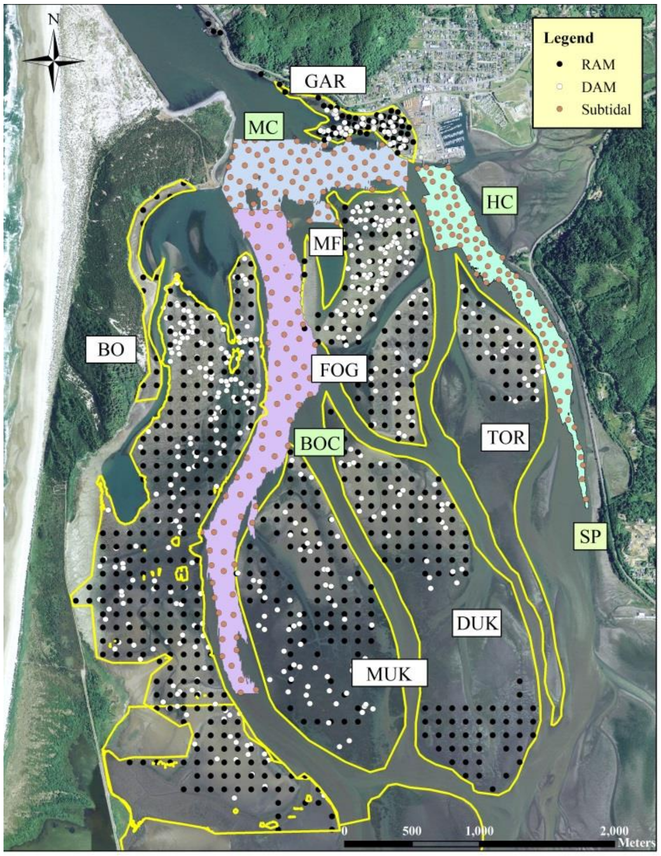


Figure 4-3. Intertidal and subtidal study regions and DAM and RAM sites sampled by SEACOR in Tillamook Bay (2010-2012). Abbreviations: BOC=Bay Ocean Channel; BON=Bay Ocean North; BOS=Bay Ocean South; DUK=Duck Flat; FOG=Fog Flat; GAR=Garibaldi Flat; HC=Hobsonville Channel; MC=Main Channel; MF=Middle Flat; MUK=Muk Flat; TOR=Torch Flat

Fog Flat (FOG) is a mostly sandy area with limited recreational effort for bay clams. However, ghost shrimp are harvested commercially as bait.

Duk Flat (DUK), **Muk Flat (MUK)**, and **Torch Flat (TOR)** are the boat-accessible tide flats included in this study. There is limited information about habitat or shellfish, as they were not previously surveyed. Generally, these areas are characterized by high eelgrass cover and burrowing shrimp beds.

Subtidal

In 2012, SEACOR conducted subtidal surveys of major channels in Tillamook Bay.

Hobsonville Channel (HC) is the historical location for commercial dive fisheries in Tillamook Bay. There have also been subtidal surveys conducted by ODFW for the past four decades. The southern portion of this region is an area closed to commercial subtidal clam harvest, established with the goal of protecting part of Tillamook Bay's subtidal habitats and shellfish populations and minimizing user conflict with other fisheries.

Main Channel (MC) is a deep channel with strong tidal currents and a rocky and cobble-dominated substratum. Most of the commercial dive fishery effort, which has recently focused on cockle and gaper clam resources, occurs within this area. Habitat data were collected for this subtidal region in the 1970's and again in 1995.

Bay Ocean Channel (BOC) is the largest marine-influenced channel in Tillamook Bay and surrounds recreationally important flats. This subtidal region is also a site of expansion for the bay clam dive fishery. There were no previous surveys conducted in this region.

MAJOR FINDINGS

Bay Clam Distribution: Intertidal

Garibaldi Flat (GAR) was a unique habitat compared to other intertidal flats surveyed. The western cobble-dominated environment supported the highest densities of cockles, butters, and native littlenecks (Figure 4-7). While these clams were dense, they tended to be smaller than clams found in MF or BO. Butter clams reached densities of 3.2 clams m^{-2} and were most abundant in the mid-intertidal across all tide flats where they occurred (mean=0.8 clams m^{-2}). Cockles, while abundant (mean=5.5 clams m^{-2}), were small, averaging 28 g and were the only clam observed on the eastern, sandy part of GAR. Gaper clams were more abundant in GAR than MF. While common in GAR (mean=1.3 clams m^{-2}), they were smaller (mean length=63.5 mm) and lighter (mean=70.8 g) than BO. Native littleneck clams were also most abundant in GAR (mean=1.1 clams m^{-2}), but were rare across the entire study area compared to other bay clams.

Middle Flat (MF) supported gaper and cockle clams (Figure 4-8). Cockles were as abundant in MF as BO (mean=0.91 clams m^{-2}). Gaper clams were least abundant here (mean=0.47 clams m^{-2}) compared to the two other recreationally important flats (i.e., GAR, BO). Butter clams were only observed at one site and native littleneck clams were entirely absent from study sites in this region.

Bay Ocean Flat (BO) supported the most gaper clams (mean=1.7 clams m^{-2}), which were larger (mean length = 88.9 mm) than either GAR or MF with some clams weighing almost 4 lbs. (Figure 4-9). They were most abundant in the northern region and at low tidal elevations (mean=3.3 clams m^{-2}). Cockles were also abundant at BO (mean=0.92 clams m^{-2}). Butter clams were much less abundant at BO (mean=0.16 clams m^{-2}) than GAR (mean=3.2 clams m^{-2}) and were only observed in the region north of the deep pool. Native littleneck clams were only observed at one site.

Other flats surrounding the main recreational and commercial flats did not support many clams (data not shown). None of the target clam species were observed at **Torch Flat (TOR)**. Cockles and gapers were present at only 3 sites in **Fog Flat (FOG)**. **Muk Flat (MUK)** also only had gapers and cockles at 1 and 2 sites, respectively (2 clams m^{-2}). Only one site at **Duk Flat (DUK)** had gapers (2 clams m^{-2}). Butters and native littleneck clams were entirely absent from all sites surveyed with these three tide flats.

Bay Clam Distribution: Subtidal

The **Hobsonville Channel (HC)** supported all the target clam species (Figure 4-10). Butter clams (mean=16.3 clams m^{-2}) were most abundant in this subtidal region. Cockles were also very abundant in the HC (mean=9.3 clams m^{-2}). While gaper (mean=1.1 clams m^{-2}) and native littleneck clams (mean=0.5 clams m^{-2}) were present, they were not observed at high densities.

The **Main Channel (MC)** exhibited high densities of most of the target clam species. Butter clams (mean=12.6 clams m^{-2}) were almost as abundant as the HC (Figure 4-11). Both cockles (mean=13.0 clams m^{-2}) and gaper clams (mean=26.4 clams m^{-2}) were most abundant in the MC. The highest mean density for native littlenecks (mean=0.7 clams m^{-2}) occurred in this subtidal region, but this clam was still rare compared to the other target species.

Few clams were observed in the large **Bay Ocean Channel (BOC)** (Figure 4-12). Both butter clams and native littleneck clams were absent from the sites surveyed in this region. Cockle clams (mean=1.8 clams m^{-2}) and gaper clams (mean=0.5 clams m^{-2}) exhibited the lowest densities in the BOC compared to the other subtidal regions.

Relationships between clam abundance and environmental variables

The bay clam community structure in Tillamook Bay was strongly influenced by eelgrass presence, shoot density, and above-ground and below-ground biomass. For example, cockles and gapers were more abundant and larger at sites with eelgrass present. Bay clam communities were also negatively correlated with the presence of burrowing shrimp throughout the bay. At GAR, bay clam presence was positively associated by substratum type, particularly the presence of cobble.

Population estimates

Biomass estimates for regions and tide elevation were calculated using only data from DAM surveys (i.e., extracted clams). Biomass are estimates reported here for bay clam species if there was an adequate sample size to estimate mean biomass and 95% confidence intervals. BO supported the greatest biomass of butter, cockle, and gaper clams (Figure 4-13). Native littleneck biomass was low for all three intertidal flats. Generally, the High intertidal did not support many clams (Figure 4-14). The low sample sizes of cockles, gapers, and littleneck clams occurring at high tidal elevations were not adequate to present biomass estimates for this stratum. Subtidal clam biomass was large in the MC and HC for all bay clam species except native littlenecks (Figure 4-15). The BOC did not support a large biomass of any of the bay clam species, and butter and native littleneck clams were not observed at any sites sampled in this region.

SUMMARY

Coos Bay (2008-2009) served as a pilot study for developing research priorities and testing study design and methods. This study was an excellent opportunity to gather baseline data for important intertidal flats for Coos Bay as well as identify logistical constraints and data needs. When SEACOR became a permanent project supported by funding from shellfish license fees in 2010, lessons learned from Coos Bay were translated to methodological changes conferring greater statistical power. Changes that enhanced the study in Tillamook Bay (2010-2012) included employing a megacore suction system that increased sampling intensity by more than 10X, and conducting subtidal surveys of clam populations. The increase in efficiency and areal coverage provided more comprehensive information that can be used for management of estuarine resources.

SEACOR continues to conduct shellfish and estuarine habitat assessments and other research to meet information needs for resource management. Four major estuaries are currently targeted for repeated surveys over a decadal scale: Coos Bay, Tillamook Bay, Yaquina Bay, Netarts Bay. Yaquina Bay was surveyed in 2012 (data in preparation) and SEACOR concluded a 2-year study of Netarts Bay in 2014.

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FIGURES

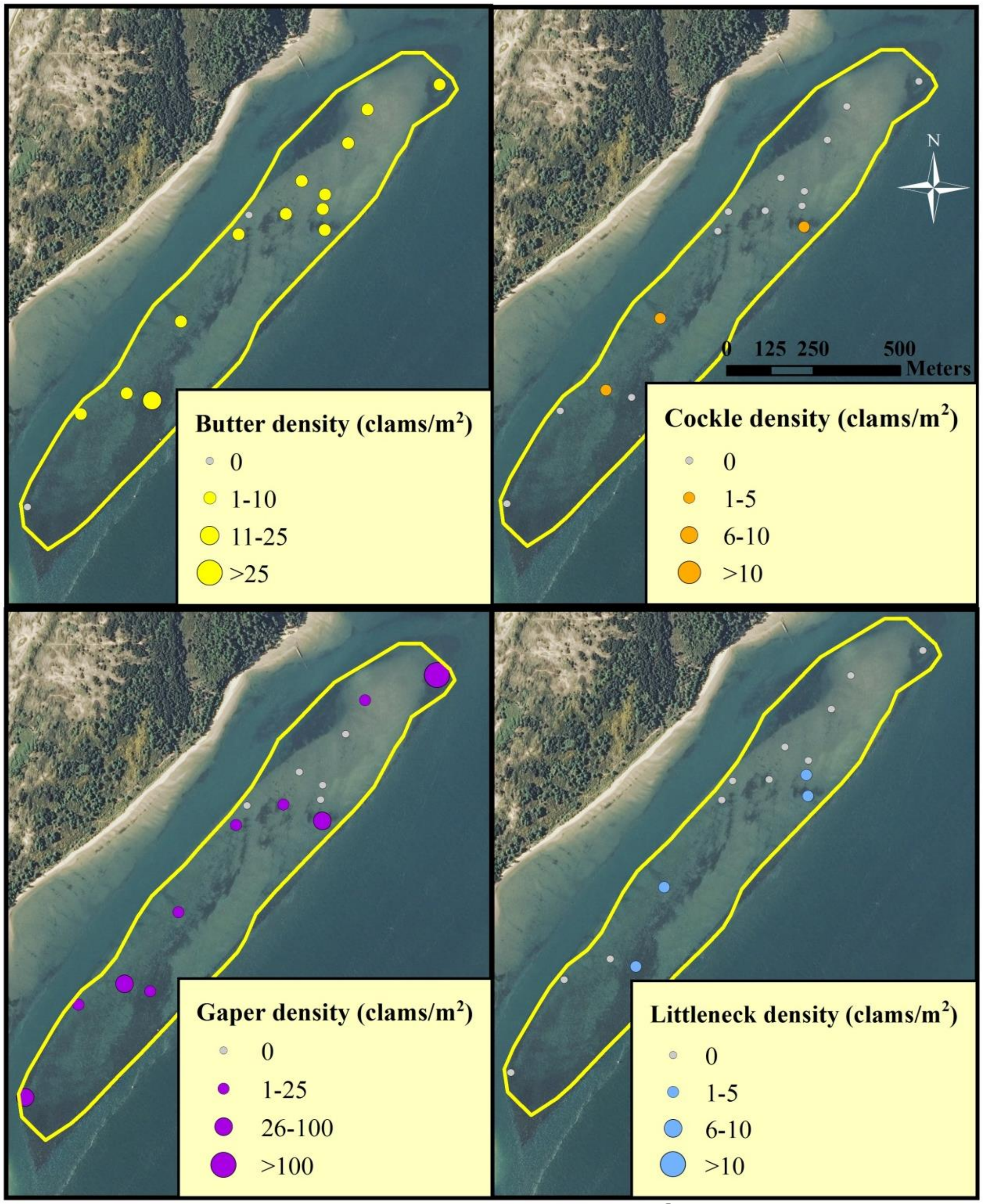

Figure 4-4 Clam distribution and abundance (clams per m^2) at the Clam Island region (CI) of Coos Bay (2008-2009). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

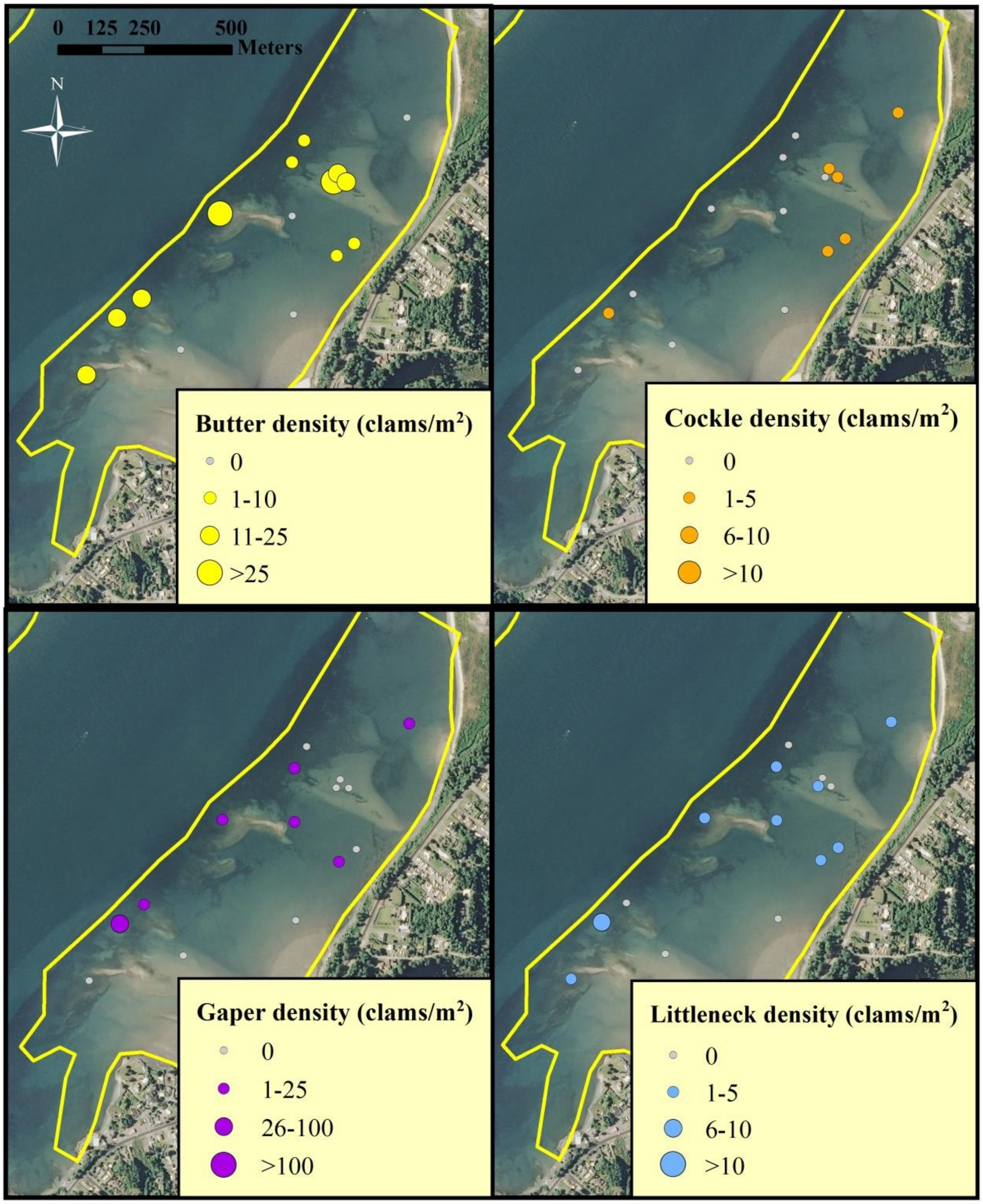

Figure 4-5 Clam distribution and abundance (clams per m^2) at the Pigeon Point region (PP) of Coos Bay (2008-2009). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

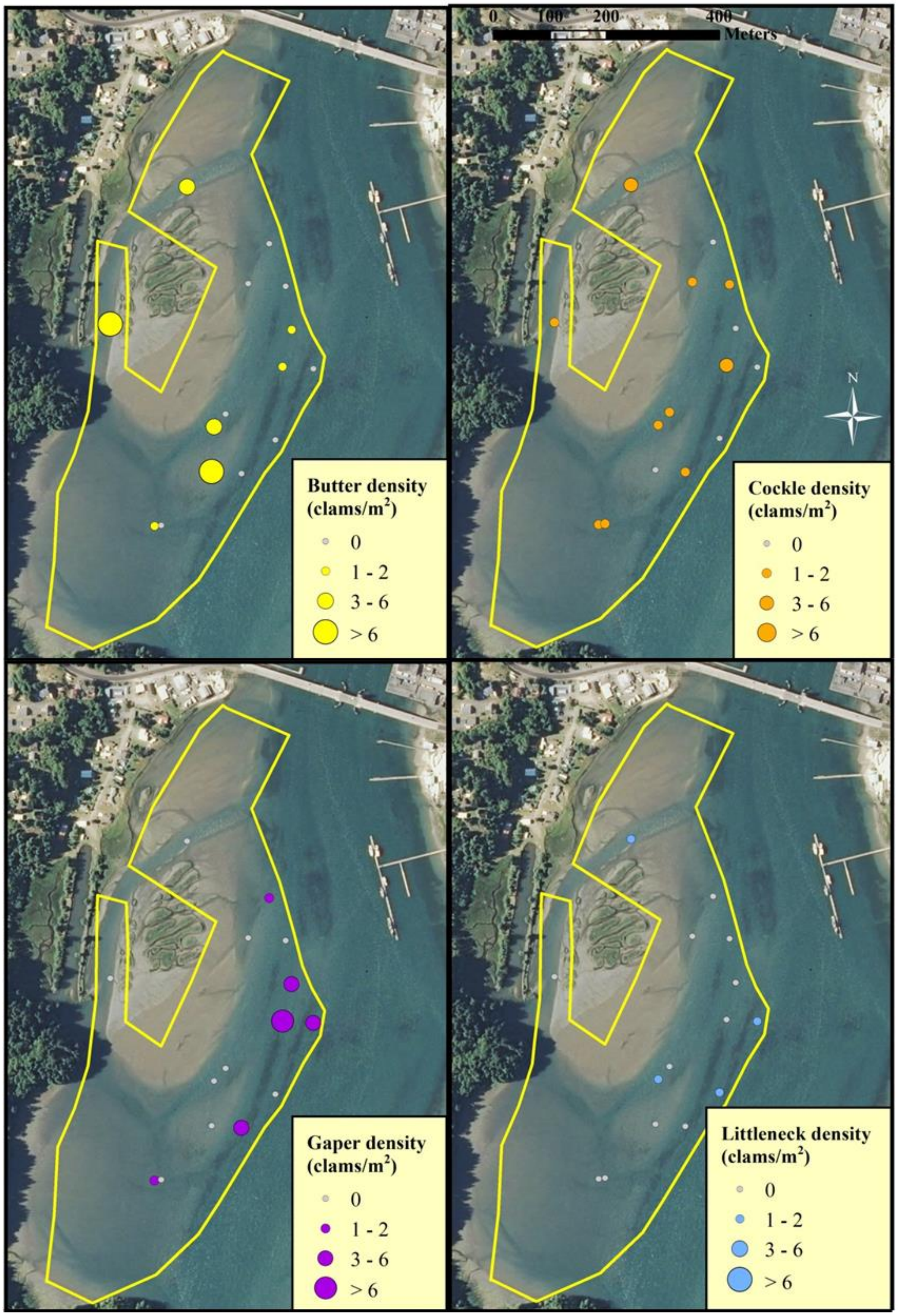

Figure 4-6 Clam distribution and abundance (clams per m^2) at the South Slough region (SS) of Coos Bay (2008-2009). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

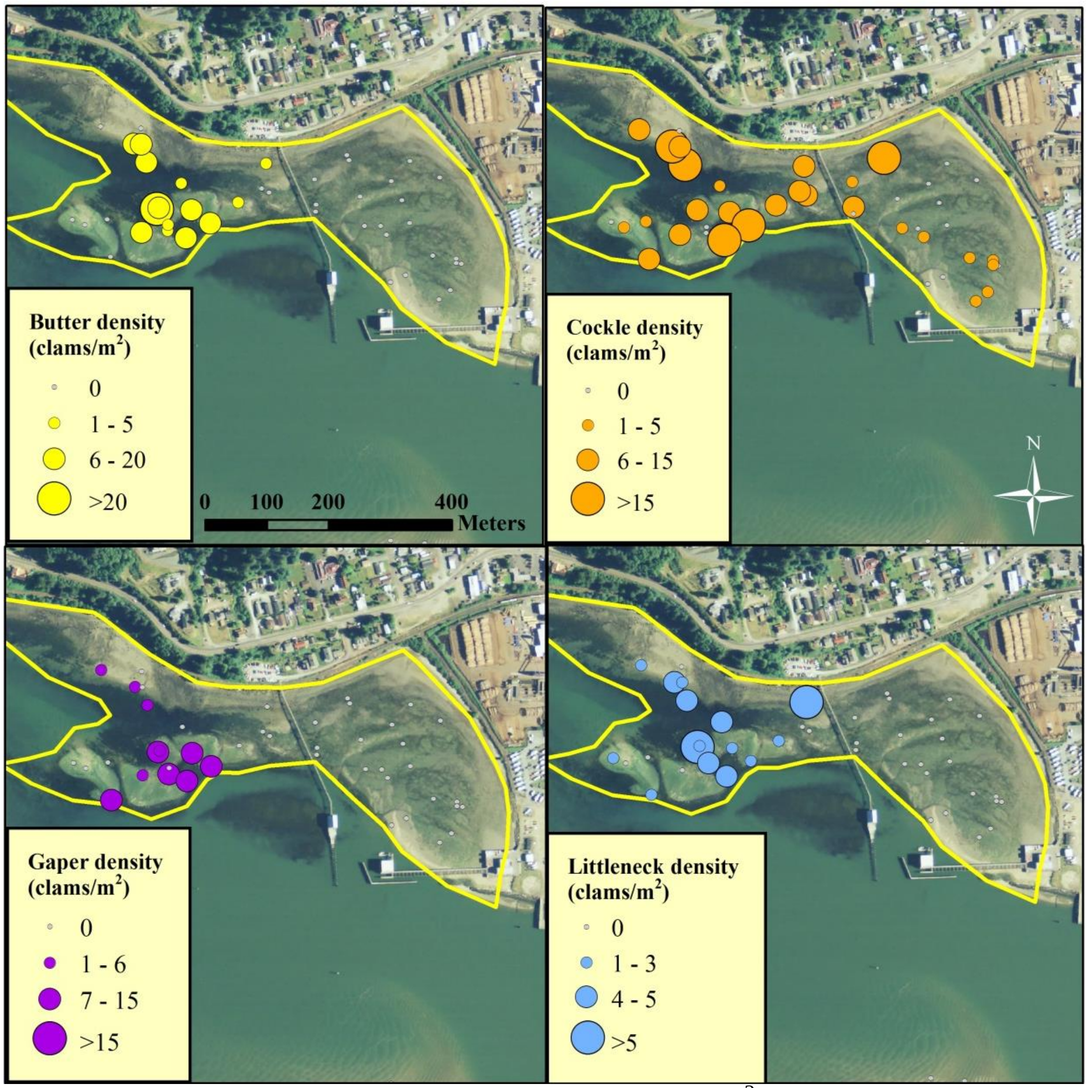

Figure 4-7 Clam distribution and abundance (clams per m^2) at the Garibaldi region (GAR) of Tillamook Bay (2010-2011). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

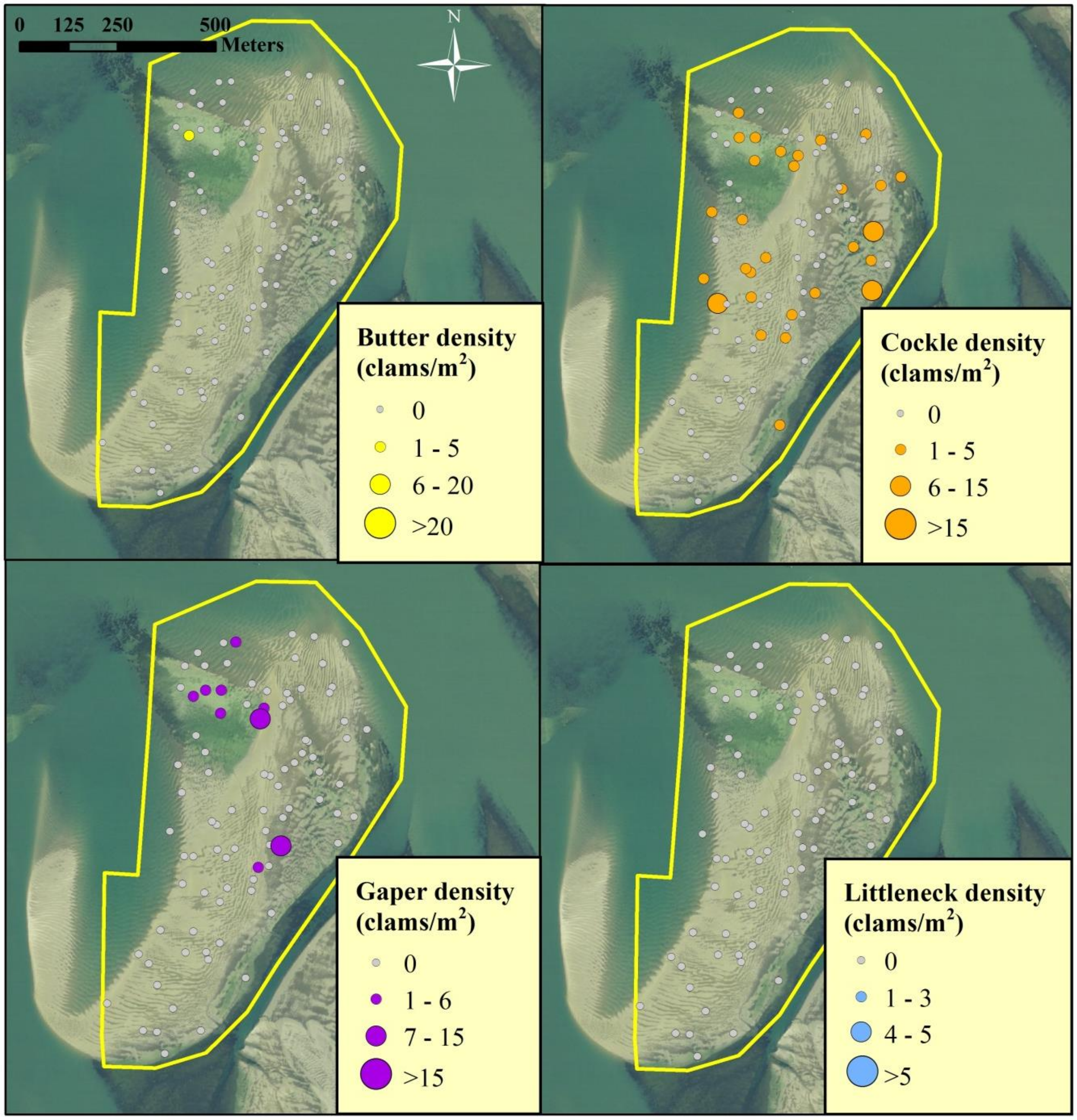

Figure 4-8 Clam distribution and abundance (clams per m^2) at the Middle Flat region (MF) of Tillamook Bay (2010-2011). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

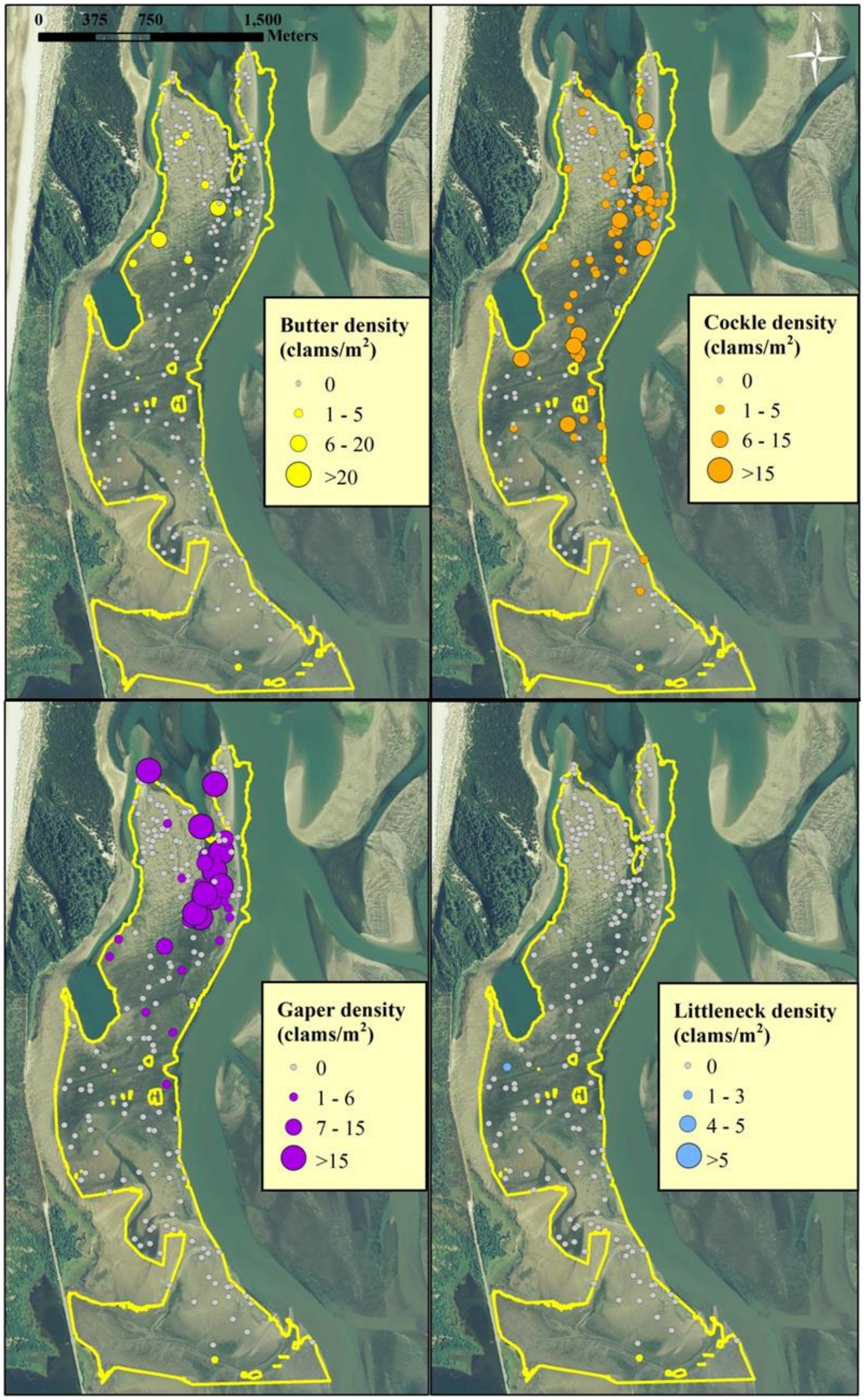

Figure 4-9 Clam distribution and abundance (clams per m^2) at the Bay Ocean Flat (BO) of Tillamook Bay (2010-2011). Note the difference in scale for each clam species. Data presented are from DAM surveys only.

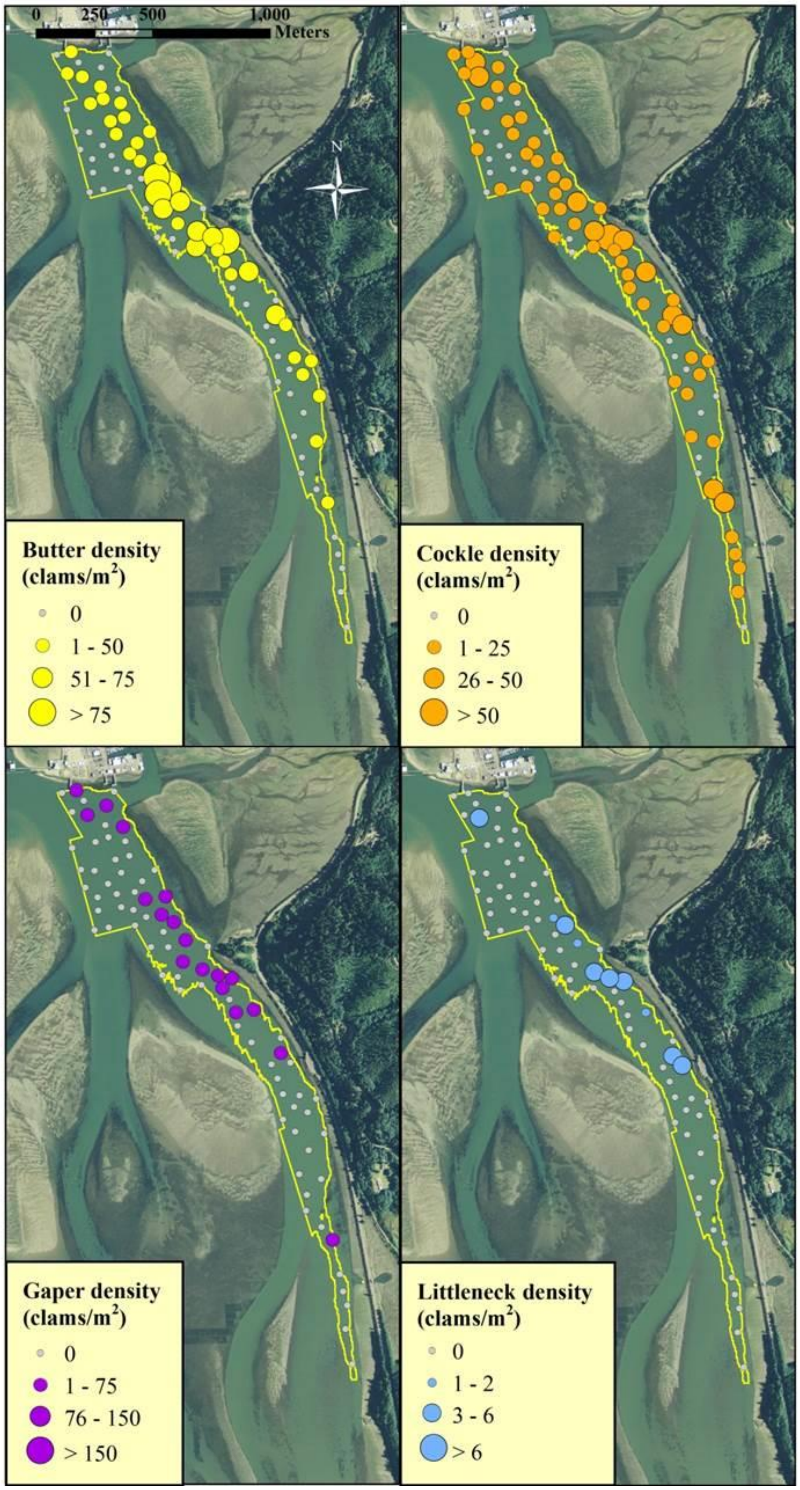

Figure 4-10. Subtidal clam distribution and abundance (clams per m^2) at the Hobsonville Channel region (HC) of Tillamook Bay (2012). Note the difference in scale for each clam species.

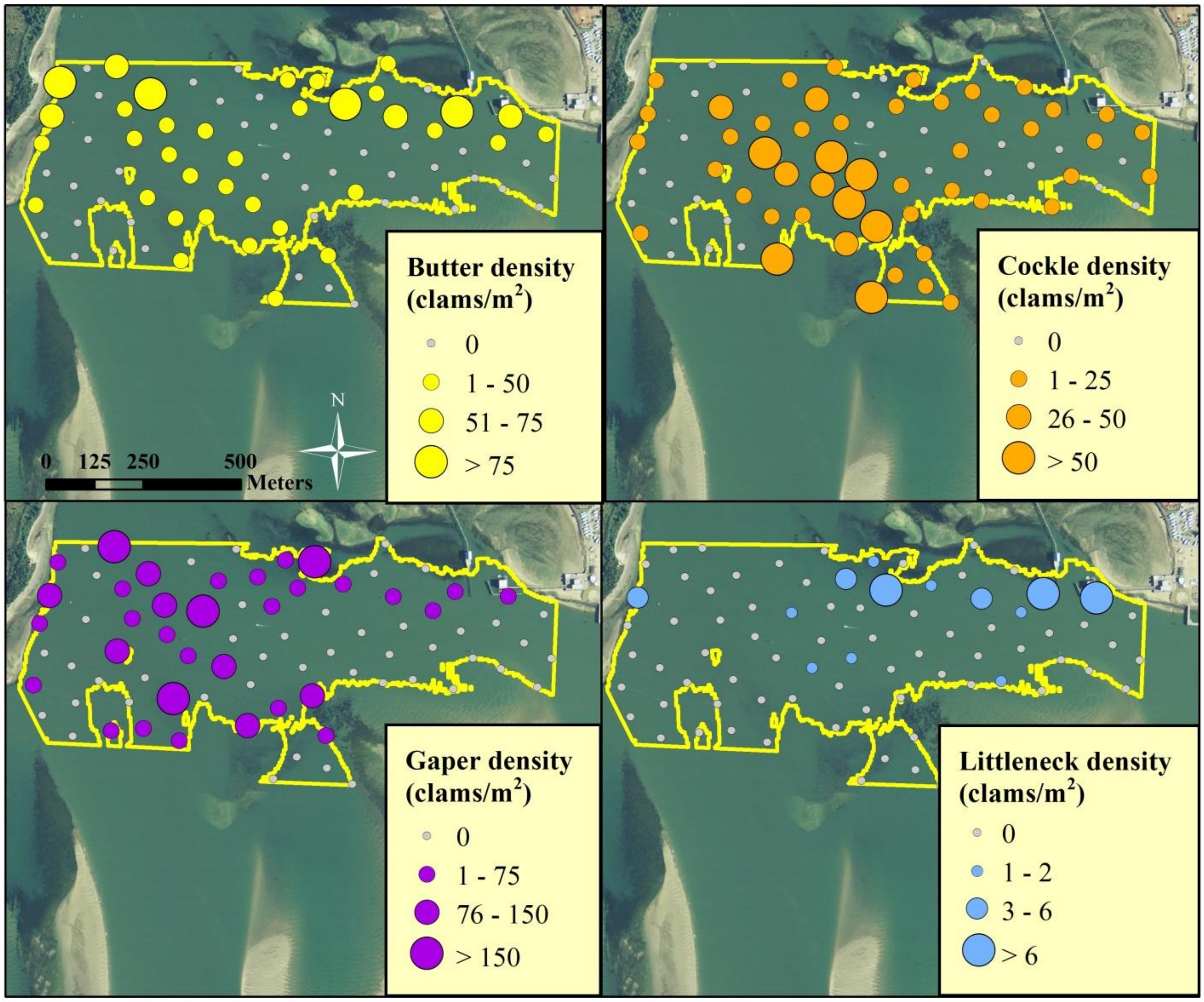

Figure 4-11. Subtidal clam distribution and abundance (clams per m^2) at the Main Channel (MC) region of Tillamook Bay (2012). Note the difference in scale for each clam species.

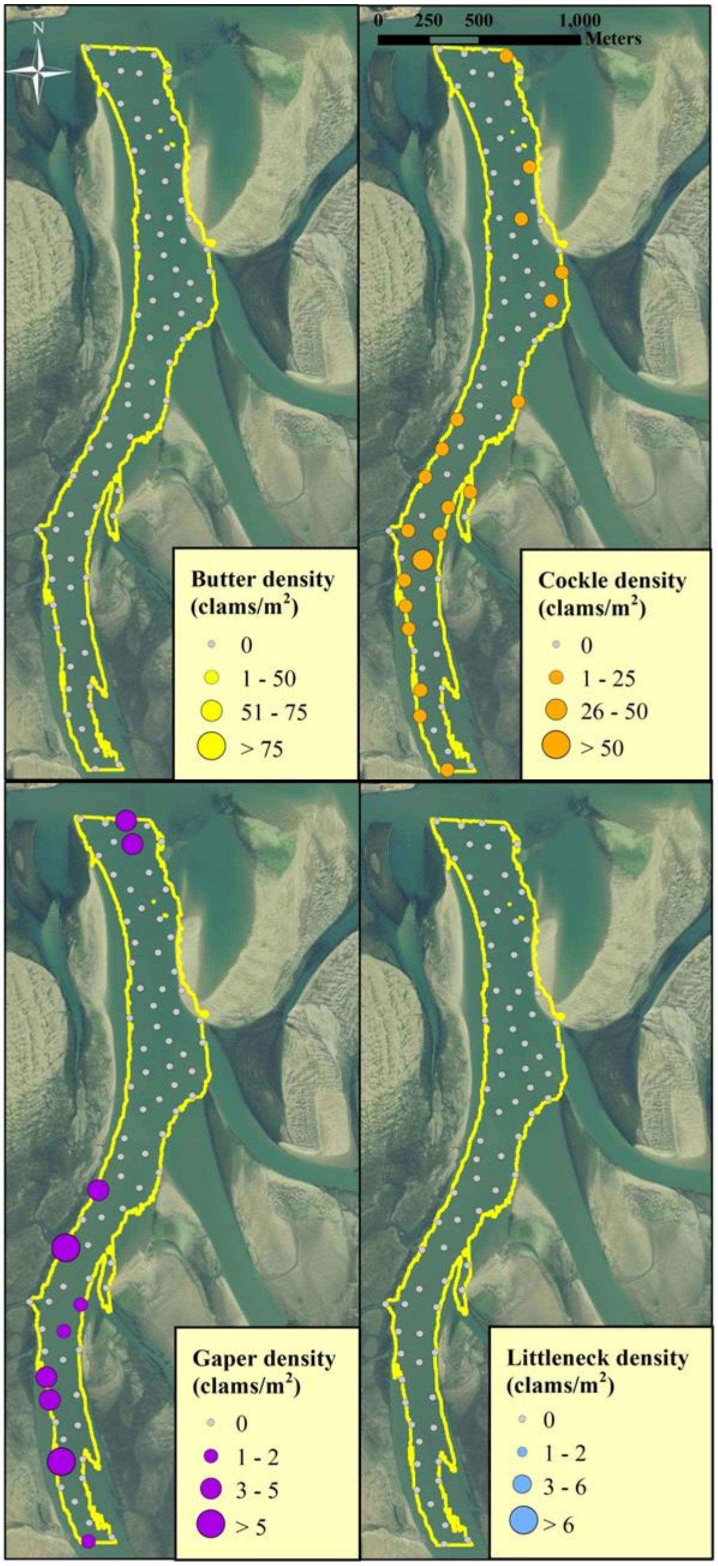

Figure 4-12 Subtidal clam distribution and abundance (clams per m^2) at the Bay Ocean Channel (BOC) region of Tillamook Bay (2012). Note the difference in scale for each clam species.

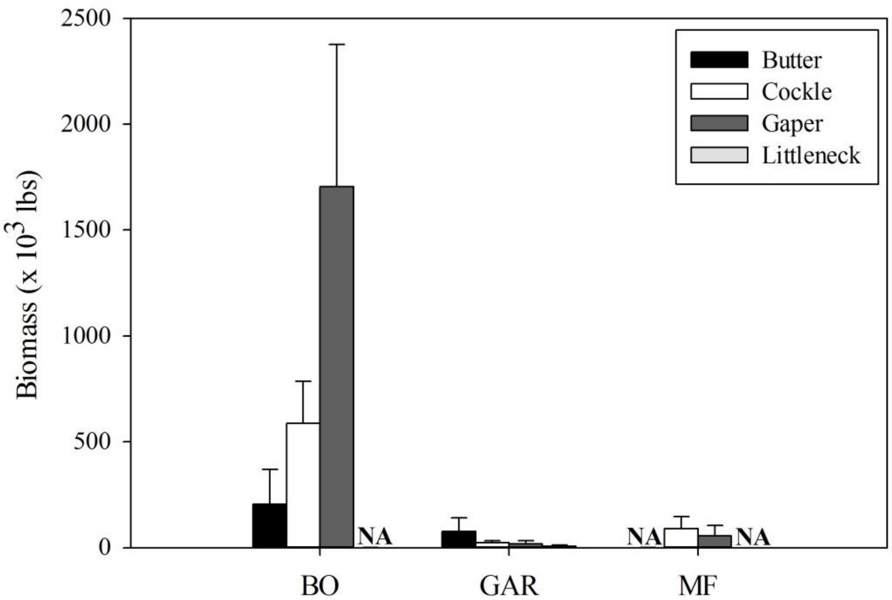

Figure 4-13. Mean bay clam biomass for each commercially or recreationally important intertidal region. Error bars reflect 95% confidence interval. Abbreviations: BO = Bay Ocean Flat; GAR = Garibaldi Flat; MF = Middle Flat; NA indicates that confidence interval crossed zero and no estimate was provided.

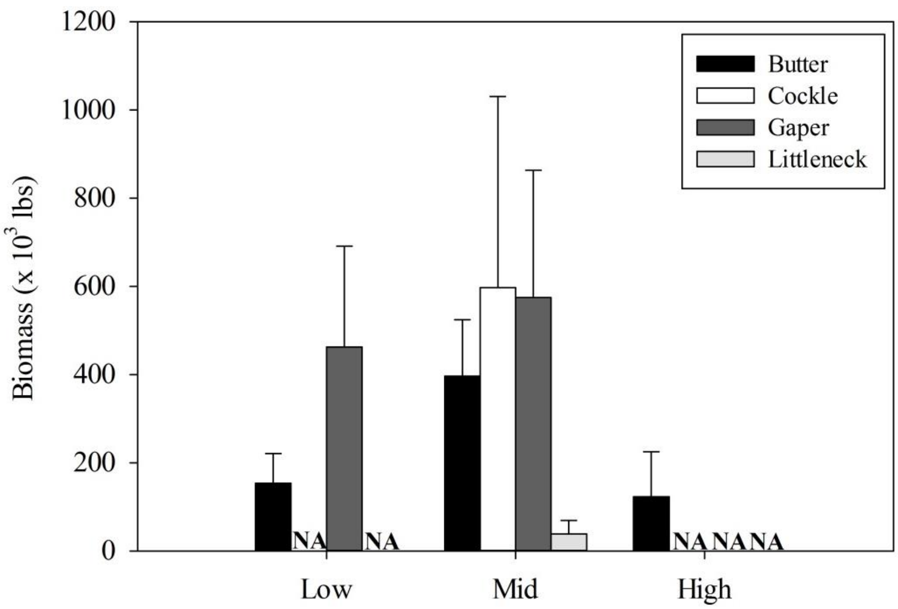

Figure 4-14. Mean bay clam biomass in three tide height strata; low (-0.5 to 0.0 m), mid (0.0 to 0.5), and high (0.5 to 1.0 m). Error bars reflect 95% confidence interval. Abbreviations: NA indicates that confidence interval crossed zero and no estimate was provided.

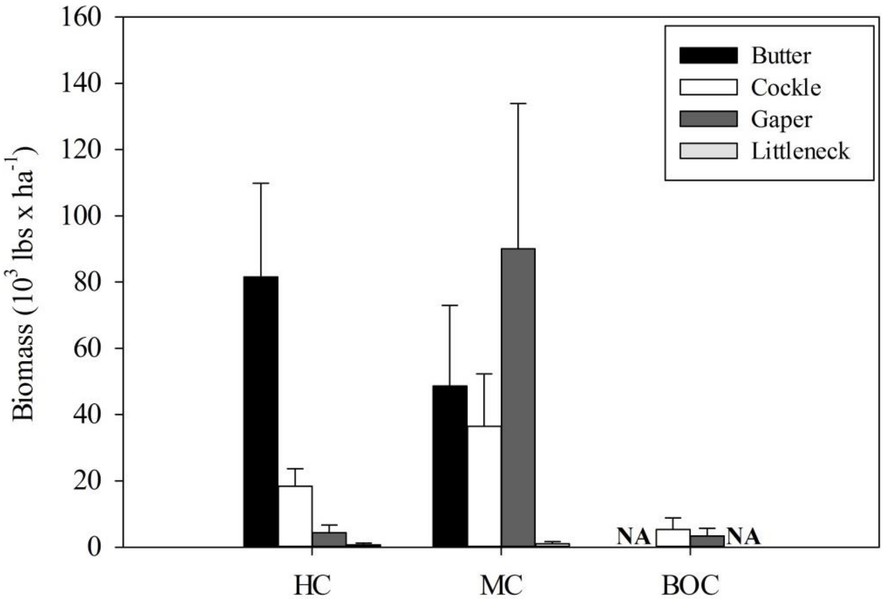

Figure 4-15. Mean bay clam biomass density for each subtidal region. Error bars reflect 95% confidence interval. Region area: BOC = 93.3 ha; HC = 45.7 ha; MC = 52.9 ha; Abbreviations: BOC = Bay Ocean Channel; HC = Hobsonville Channel; MC = Main Channel; NA indicates that confidence interval crossed zero and no estimate was provided.

APPENDICES

Appendix A. SEACOR methodology for collection of environmental and biological data (2008-2012)

Variable	Coos Bay (2008-2009)	Tillamook Bay (2010-2012)
Grid Size	200 m along shore, 50 m away from shore	100 m on most tidal flats; 30m on Garibaldi Flat
Study Region	6 RAM, 3 DAM (n=45)	8 RAM, 3 DAM (n=464)
Quadrat size	RAM: 1m^2, 4m^2 (gapers) DAM: 1m^2, 9m^2 (gapers)	RAM: 1m^2 DAM: 0.5 m^2 (dredge), 1m^2 (dig) Subtidal: 0.5 m^2
Tidal elevation	Source: SEACOR via sounding by kayak (Rumrill and Grupe 2008)	Source: USACE (1995, 2002) and LiDAR (DOGAMI)
Distance to mouth	Visual assessment (m)	N/A
Temperature	Method: surface, 10 cm depth Measure: ℃	Method: surface, 10 cm depth Measure: ℃
Salinity	Method: refractometer Measure: ppt	N/A
Sediment type	Category: sand, mud, sand/mud	Category: sand, mud, sand/mud
Substratum	% cover by category: shell, debris, cobble, boulder or bedrock	% cover by category: sediment, shell, oyster, debris, gravel, cobble, bedrock
Anoxic layer	Distance from surface (cm)	Distance from surface (cm)
Bed type	Category: bivalve, shrimp, standard mudflat	Category: clam, shrimp, oyster, clam/shrimp, clam/oyster, shrimp/oyster, standard mudflat
Algal cover	% cover by species: *Ulva lactuca*, *U. intestinalis*, *Fucus*, *Laminaria saccharina*, *Chondracanthus* sp., Other	% cover by functional group: sheet, filamentous, coarsely branched, rockweed, leathery
Z. marina cover and shoot density	% cover	% cover from 1m^2, shoot density from 0.25 m^2
Z. japonica cover and shoot density	% cover	% cover from 1m^2 , shoot density from 0.01 m^2
Butter density	# clams m^{-2}	# clams m^{-2}

Gaper density	# clams/4 m^2	# clams m^{-2}
Cockle density	Method: rake top 10 cm sediment Measure: # clams m^{-2}	Method: rake top 15 cm sediment Measure: # clams m^{-2}
Littleneck density	Method: rake top 10 cm sediment # clams m^{-2}	Method: rake top 15 cm sediment # clams m^{-2}
Shrimp density	# shrimp burrow holes per 0.25 m^2 for ghost shrimp, mud shrimp, and unknown shrimp	# shrimp burrow holes per 0.25 m^2 for ghost shrimp, mud shrimp, and unknown shrimp
Organism presence	Presence of all invertebrate species found inside or within 2m of quadrat, including any bivalve, crab, and polychaete species	Presence of all invertebrate species found inside or within 2m of quadrat, including any bivalve, crab, and polychaete species

Appendix B. Detailed Assessment Method (DAM) sampling protocols (2008-2012)

Variable	Coos Bay (2008-2009)	Tillamook Bay (2010-2012)
Grain Size	N/A	Method: EPA Particle Size Analysis (Folger 2013) Measure: grain size distribution of top 6 cm of sediment, % sand, % silt, median grain size (μm)
Water content	Method: (Goman 2001; Goman 2005) (modified) Measure: % water content	N/A
Total Volatile Solids (TVS) or Loss on Ignition	Method: EPA Standard Method 1684 (2001) Measure: % TVS of top 2 cm of sediment	Method: EPA Standard Method 1684 (USEPA 2001) Measure: % TVS of top 1 cm
Eelgrass above-ground biomass	N/A	Method: (Duarte and Kirkman 2001)(modified) Measurement: g m^{-2}
Clam extraction method	Dig: 1m x 1m x 0.35m	Dig: 1m x 1m x 0.35m Dredge: 0.5m^2 x 0.35m
Clam measurement : abundance	# individuals/species	# individuals/species
Clam measurement : wet weight w/ shell	Drain time 5-30 min g +/- 0.5	g +/- 0.01
Clam measurement: wet weight	Shell removed (gapers only) g +/- 0.5	N/A
Clam measurement: length	Maximum anterior-posterior distance to nearest mm	Maximum anterior-posterior distance to nearest 0.1 mm
Clam measurement: width	Maximum lateral (right-left valve) distance to nearest mm	Maximum lateral (right-left valve) distance to nearest 0.1 mm
Shrimp & crab measurements	N/A	Species, carapace length (0.1 mm), weight (0.01 g), sex, isopod parasite presence

Chapter 5 Other research

FISHERY SPATIAL ANALYSIS

<u>Coos Bay</u>

Introduction

Coos Bay is Oregon's largest estuary and supports the most active shipping port between San Francisco and the Columbia River. Coos Bay affords robust shellfish harvesting opportunities important to the area's economy and identity. Proposed industrial development is likely to make direct and indirect changes to areas currently used for shellfish harvest. Appropriate mitigation for these changes can be aided by estimation of summarized use (this document and Ainsworth et al. (2012)) and in greater detail by using spatially explicit data for these activities.

In this investigation, we obtained geospatial data on the activity of clammers (people actively clamming) and crabbers (locations of crab buoys). Other shellfish harvest is common (e.g., dock crabbing, bait shrimp, etc.) in Coos Bay, but not evaluated in this study.

Methods

ODFW performs low tide clam creel surveys which enumerate use by area, lumping counts in to one of eight areas within Coos Bay. In this study, we enhanced these counts by recording specific location data onto aerial photo maps. We matched landmarks on the aerial photos to best estimate position of each working clammer during these surveys. After these data were recorded onto paper maps, the points were transferred to ArcGIS manually. It is our expectation that by using these methods, these data are accurate to within 100 meters. Areas up-bay from the airport were not included as they are used far less frequently and could not be sampled due to time constraints. Those areas are primarily eastern softshell (*Mya arenaria)* beds within North Slough, Glasgow, Kentuck, and other areas.

We captured geospatial data for crab buoys by recording position of individual buoys throughout the year. We selected survey times haphazardly, when timing was convenient for staff schedules. We used the 22' boat R/V *Ophiodon* to drive along each side of the bay searching for crab buoys. We drove within 50 meters of each pot and recorded a position using GPS, then later uploaded it to the dataset.

Summarized recreational crab harvest data by area and year is available in a preceding study (Ainsworth et al. 2012). https://nrimp.dfw.state.or.us/CRL/Reports/Info/2012-04.pdf

Results

From 2011 to 2013, positions of 2,531 clammers and 915 crab buoys were captured (Table 5-1). As this sampling design is only suited to describe spatial distribution of fishery effort, these data are not appropriate to use to describe total amount of use.

Table 5-1. Sample size of clammer and crab buoy data by year.

Year	2011	2012	2013	Total
Clammers (n)	944	914	673	2,531
Crab buoys (n)	53	637	225	915

Data captured shows a geospatial picture of dispersion of shellfish harvest within Coos Bay. Data shows primary use of lower bay clam beds and the importance of the west side of the channel for crabbing (Figure 5-1).

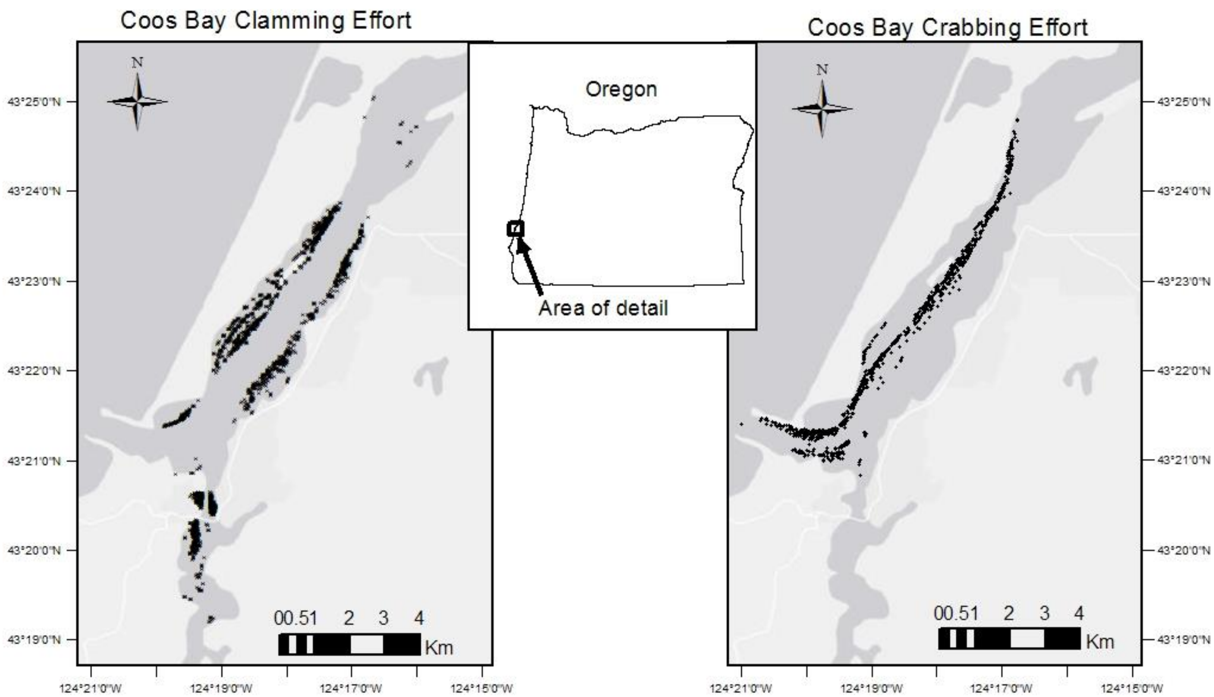

Figure 5-1. Spatial dispersion of clamming and crabbing in Coos Bay, Oregon.

Access to dataset:
Available through ODFW's data clearinghouse https://nrimp.dfw.state.or.us/DataClearinghouse

References

Ainsworth, J. C., M. Vance, M. V. Hunter, and E. Schindler. 2012. The Oregon recreational Dungeness crab fishery, 2007-2011. Oregon Department of Fish and Wildlife Information Report 2012-04.

Tillamook and Netarts bays

Oregon Department of Fish and Wildlife's (ODFW) Shellfish Program conducted a geospatial study of intertidal clam harvest in Tillamook and Netarts bays in 2011. The goal of this study was to determine the spatial distribution of intertidal harvesters and whether specific areas of concentrated effort exist. Both recreational and commercial harvester locations were surveyed. A single GPS point was taken to represent the location for a single harvester actively digging clams during each observation. Multiple observations were taken throughout each low tide and, as a result, a single harvester's position could be recorded more than once. Targeting the low tide series between March and July 2011, 26 field collection days were spent in Tillamook Bay and three were spent in Netarts Bay.

The recreational fishery within Tillamook Bay was located primarily in the northwestern portion of the bay (Figure 5-2). The most heavily harvested area was Garibaldi Flat. Recreational effort was observed throughout Netarts Bay, but was mostly contained to the central-eastern portion (Figure 5-3). Harvesters from the Tillamook Bay commercial fishery were obsereved in the northern and western portion of the bay. Overlap (areas in which harvest locations between the fisheries were less than 40 m apart) between the fisheries was small. Harvesters from the Netarts Bay commercial fishery were found only in the southern portion of the bay. No overlap was observed between the fisheries in Netarts Bay. Data from this geospatial study of intertidal clam harvest in Tillamook and Netarts bays provides valuable information that should be utilized in future studies of bay clam fisheries. The results of this study offer a geospatial understanding of the intertidal commercial and recreational clam fisheries in Tillamook and Netarts bays.

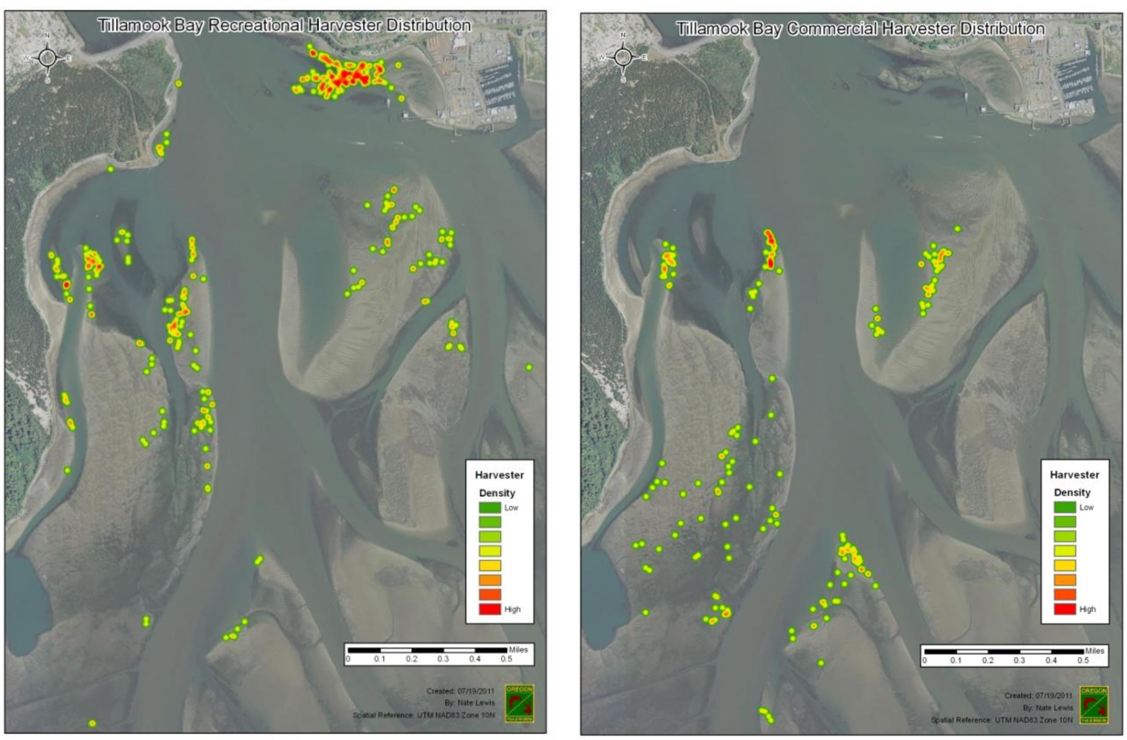

Figure 5-2. Distribution of recreational (left) and commercial (right) clam digging effort in Tillamook Bay.

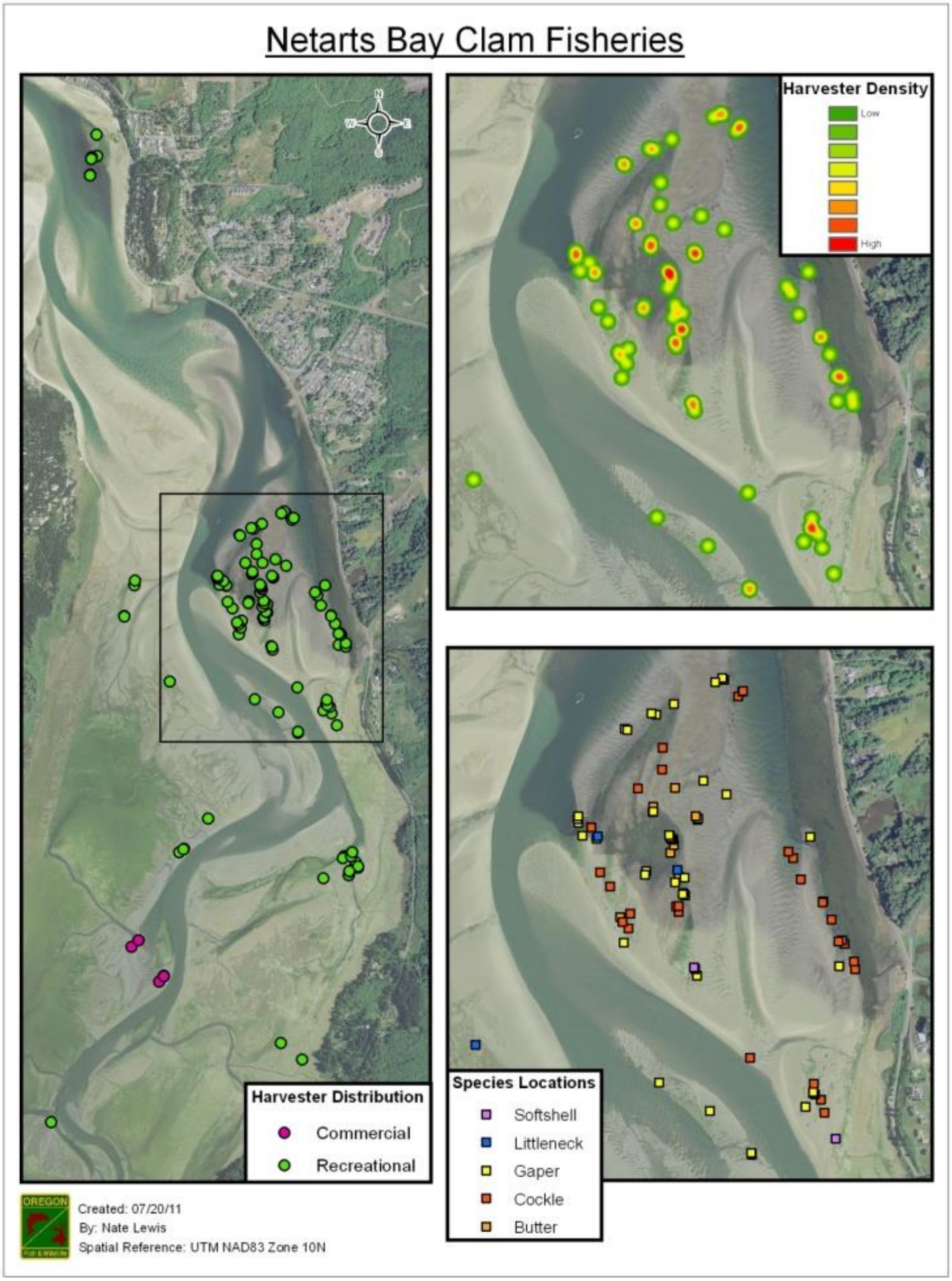

Figure 5-3. Distribution of recreational and commercial clam digging effort in Netarts Bay. Species location refers to the species of clam each harvester was digging at the time of recording.

GAPER CLAM REBURIAL STUDY

Introduction

The gaper clam (*Tresus capax*) is a very popular target for recreational clammers in Oregon. Clammers are allowed to keep 12 gapers per day as part of their 20 bay clam daily limit. One condition of that limit is that diggers must keep the first 12 gaper clams they dig “regardless of size or condition”. The reason for that regulation is that gaper clams are more susceptible to predation if they are dug up, deemed undesirable, and left on the mudflat. In addition, their large size may make reburial difficult or even impossible. In order to better understand the capability of gaper clams to rebury, we measured the rate at which they could dig into mud in a controlled environment.

Methods

Experimental tanks were set up at Hatfield Marine Science Center in 4’ diameter cylindrical flow-through seawater tanks. Individual five gallon buckets were prepared by adding 25 – 27 cm pre-sieved sediment (total height of bucket is 35 cm). The buckets were then placed in seawater tanks and the sediment was allowed to settle for at least 48 hrs before clams were added. All of the clams used for this study were collected from Yaquina Bay and measured between 60 and 120 mm in length. A total of 80 clams were used; 20 of which were used in preliminary trials and are not included in the reported data. Each study clam was marked with a unique identification number using a Sharpie® permanent marker. Shell length and wet weight were recorded for each clam.

At time zero of each trial, clams were placed in one of two treatments: 1) “surface” clams were placed on their side on the sediment surface or 2) “assisted” clams were partially reburied with the posterior end (siphon end) of their shell flush with the sediment surface (Figure 5-4). The “assisted” clams would therefore have a burial depth of zero cm (measured as the distance between the surface and the uppermost part of the shell). The “surface” clams would therefore be at some negative burial depth until the clam was able to bury itself into the sediment and get its shell below the sediment surface. The clams were observed every day and notes were taken on the position and burial depth of each clam. When they dug into the sediment so that their shell was no longer visible, the sediment was carefully probed with a thin measured dowel until it touched the top edge of the shell. That depth was then recorded as the burial depth. For example, in Figure 5-4, the clam in the picture on the right with only its siphon visible apparently has its shell buried beneath the sediment surface and might have a burial depth of 2 to 4 cm or more.

Figure 5-4. Examples of gaper clams in the reburial trials. Half of the clams were not given assistance at the beginning of the trial (such as the clams on the left), while other clams were assisted by partially reburying before the trial (far right).

Over a two month period in 2010 from late June until early August, five different trials were conducted with durations from 5 to 14 days. Observations were made by Samuel Moore, an intern with the Centers for Ocean Sciences Education Excellence - Promoting Investigations in the Marine Environment (COSEE-PRIME) program.

Results

Of the clams in the "surface" treatment, 28% buried 4 cm or more in the first 24 hrs. Clams in "assisted" treatment were more successful; 86% of these clams reached a depth of 4 cm or more in the first 24 hours. After 5 days, 66% of the surface clams reached at least the 4 cm depth. Over that same time period, 93% of the clams that were assisted were able to burrow below 4 cm.

A measure of digging success was devised to compare the digging depths of the experimental clams with burial depths of clams observed in the wild. When clams were collected for this study, over 95% of them were buried ≥ 15 cm deep. Therefore, 15 cm was established as a criterion for a successful dig to depth. At the end of all trials, regardless of trial duration or treatment type, half of the clams reached a depth of 15 cm or more and half of the clams did not reach that depth. Of the "assisted" clams, 60% reached 15 cm. Only 40% of the "surface" clams reached 15 cm.

If the total digging rates (cm/day) over the duration of each trial are compared, there is a difference between treatments. Assisted clams averaged a digging rate of 1.65 mm/day; surface clams only dug 1.32 cm/day. When those rates are examined further, smaller clams seem to dig faster. Of the assisted clams, the smaller clams (60 – 80 mm) dug at 1.97 mm/day; the larger clams in that category (81 – 120 mm) dug at only 1.29 mm/day. Of the surface clams, the smaller clams (60 – 80 mm) dug at 1.84 mm/day; the larger clams in that category (81 – 120 mm) dug at only 0.83 mm/day.

Discussion

If a gaper clam is dug up and left on the sediment surface of the intertidal mudflat, its chances of survival are probably quite low. Even if it is covered with water on top of sediment that it could potentially dig into, it would probably take at least a day or two before it could bury itself into the sediment to a depth that would provide protection from predators and environmental conditions it is not adapted to. When covered with water, an unburied clam is very susceptible to predation by crabs which feed in the flooded intertidal flats twice each day. When not covered by water, they would be quickly found by gulls, crows, raccoons, or other intertidal predators and scavengers. The results of this study provide some evidence concerning the susceptibility of exposed clams. It also shows that even larger clams do have some capability to rebury themselves after being exposed.

We also observed some evidence of smaller clams being able to right themselves and begin the digging process sooner than larger clams. This could be due to the fact that the larger clams have to extend their foot a greater distance to reach the sediment surface and get an initial purchase.

PURPLE VARNISH CLAM DISTRIBUTION SURVEYS

The purple varnish clam (*Nuttallia obscurata*) is a relative newcomer to Northeast Pacific waters. It is believed to have been transported in ballast water to British Columbia around 1990. Purple varnish clams (PVCs) have reproduced easily and are now widely distributed in estuaries from British Columbia south to at least central Oregon. They live in sandy or muddy sediments in the lower parts of estuaries and often co-occur with ghost shrimp. They seem to reach high densities in areas near freshwater runoff and occupy the higher zones of the intertidal. In an effort to begin to document the distribution and densities of this species, cores were dug in the sediment and data was collected on the infauna found. Sampling locations were selected in Siletz, Yaquina, and Alsea bays that were known to have PVCs.

Methods

Cores (572 cm^2 X 35 cm deep) were excavated by inserting a bottomless 5 gal bucket into the sand, digging out the contents, and sieving all material through 3.2 mm mesh. Cores were sampled along transect lines, within a grid, or randomly. Cores were collected from Siletz, Alsea, and Yaquina bays.

Sampling purple varnish clam spatial distribution and density in Siletz Bay

<u>Results</u>

At this time, haphazard surveys have shown that there are PVCs in most of Oregon's estuaries. Live clams have been found in Tillamook, Netarts, Nehalem, Sand Lake, Siletz, Yaquina, Alsea, Siuslaw, Coos, and Coquille bays. Of the estuaries where cores were taken and densities calculated, the single highest density found in this study was in Siletz bay (245 clams m^{-2}). Many cores in each estuary had densities between 50 – 75 clams m^{-2}. Shell lengths were measured and the size frequency distributions are shown in Figure 5-5.

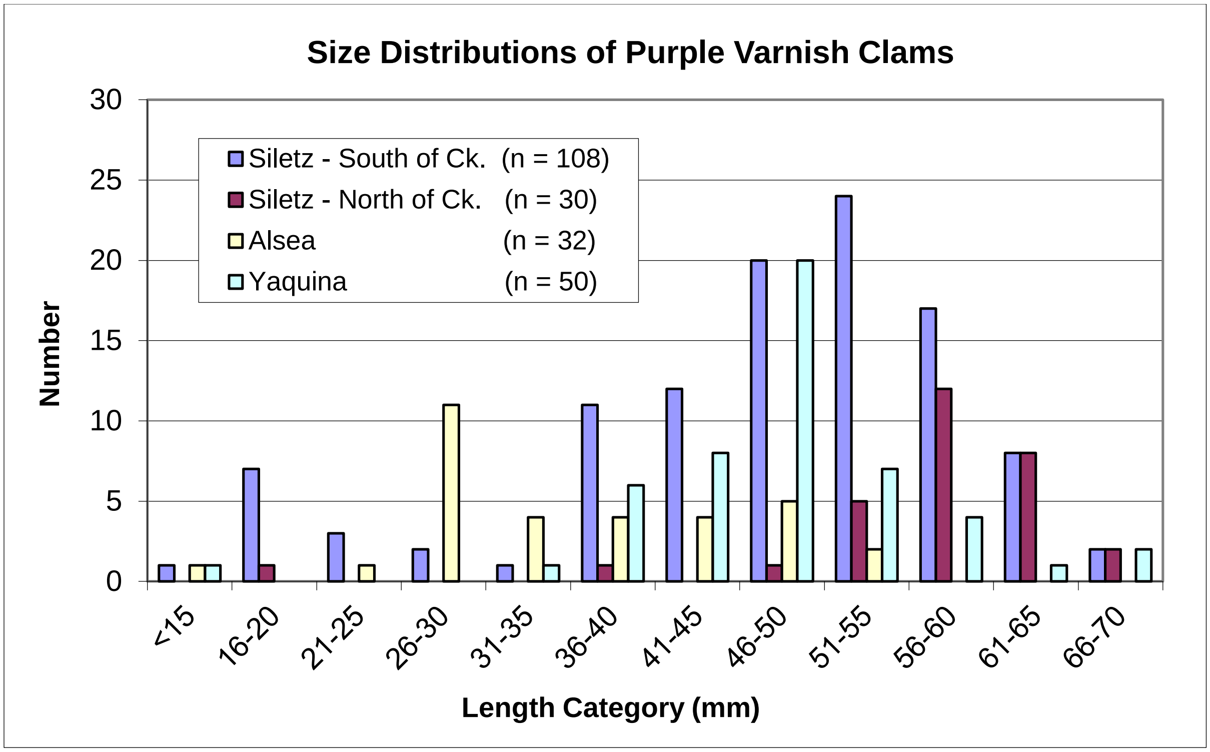

Figure 5-5. Shell length frequency distribution of purple varnish clams collected from cores taken in Siletz, Yaquina, and Alsea bays.

We will continue to collect presence/absence data and quantify density data in unsampled estuaries as well as monitor the densities of PVCs in selected estuaries in an effort to track the status of this non-native species. Recreational harvest of this clam seems to be increasing as clammers learn where they are, how easy they are to harvest, and how to prepare them. In 2013, PVCs were given a separate daily limit of 72. Prior to that, they had been part of the "other clam" daily limit of 36.

ROCKY NEARSHORE NATIVE LITTLENECK CLAM SURVEYS OF PORT ORFORD

Introduction

Native littleneck clams (*Leukoma staminea[=Protothaca staminea])*, henceforth referred to as "littleneck clams", are venerid bivalves that occur throughout the nearshore and saline estuaries of the West Coast (Chew and Ma 1987; Shaw 1986). They are the subject of intense fisheries in Washington and British Columbia, Canada, where they are generally more abundant (DFO 1999). Littleneck clams are present in four Oregon bays: Coos, Yaquina, Netarts, and Tillamook (Marriage 1954). Additionally, populations of native littlenecks are present in a few, small, isolated pockets of Oregon's open coastline that are semi-protected and have stable rocky substrates.

Unlike shovel and rake fisheries for littleneck clams in other areas (including Oregon estuaries), rocky nearshore clammers often use pick axes, crow bars and similar levering tools to move large rocks to reveal the protected clams underneath. Rocky nearshore clam harvest is primarily of littleneck clams, whereas the more popular estuary clam harvest focuses on gaper clams (*Tresus capax*), butter clams (*Saxidomus gigantea*), cockles (*Clinocardium nuttallii*), or softshells (*Mya arenaria*).

There is recent evidence of littleneck clam population declines in Alaska (Shigenaka et al. 2007), British Columbia (Bendell 2013; Dunham et al. 2007), Washington (J. Barber, Swinomish Indian Tribal Community, unpublished data), and some estuary populations of Oregon (T. D'Andrea, ODFW, unpublished data). Population abundances in California have demonstrated high annual variability attributed to environmental factors such as sand accretion (Reilly, 2001). Understanding trends and variability of nearshore Oregon populations will be informative to management and aid range-wide understanding of the species.

Methods

Site selection

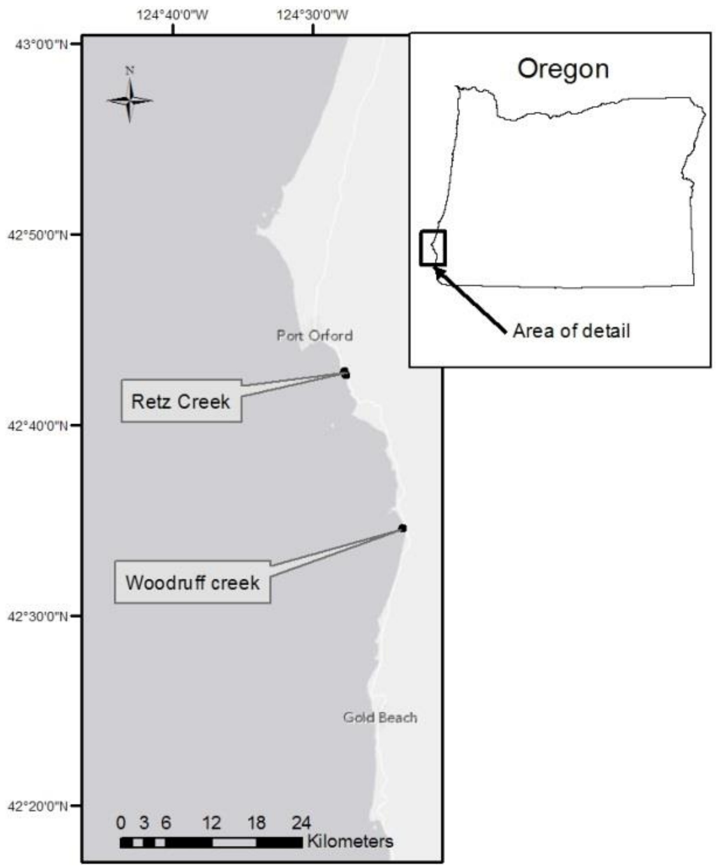

Figure 5-6. Littleneck clam population sampling areas.

We identified two study sites, both near Port Orford (Figure 5-6) and popular for recreational clamming: Retz Creek (42° 42' N, 124° 27' W) and Woodruff Creek (42° 34' N, 124° 23' W). Both sites are along the open ocean coast and have a gently sloped intertidal area where bedrock, boulders, and cobble form stable structure for clams to burrow amongst.

For each site, polygons were developed of similar size, elevation, and habitats. Sites were delineated by walking clam bed boundaries. First, the deeper boundary of each site was established at the water line when the tide was at 0 m mean lower low water (MLLW). Then, the higher elevation of the bed was identified as the water level when the tide was at +1 m MLLW. Thus, the tidal heights of polygons are estimated at between 0 and +1 m MLLW. Acquired GPS information was then imported to ArcGIS, polygons were created, and sampling locations were selected randomly within the polygon area.

Surveys were conducted in 2010 and 2013 at both sites. The 2010 sample at Retz Creek encompassed the entire bed, but was found to be too large (2.85 ha) to adequately sample. The survey area was therefore reduced to a smaller size (0.97 ha) in 2013. The Woodruff Creek site encompassed the entire intertidal clam bed was much smaller and remained constant (0.50 ha) for both years of the study.

Sampling Design

At each site, 0.25-m^2 quadrats were extracted to 30 cm depth, with the goal of achieving sampling rates suggested by similar studies (Bechtol and Gustafson 1998; Gillespie and Kronlund 1999). We navigated to each pre-selected random point, set down a rope quadrat, recorded substrate information, and began digging. Substrates were then removed using crow bars, shovels, trowels and hands. Removed fine material was hand sifted in search of small clams. Attempts were made to use standardized sifting methods, however this was found too cumbersome to be practical. In this way, detection rates are unknown, but expected to be high and consistent among samples. As these nearshore sites are extremely rugged (Figure 5-7) sampling was physically difficult, a crew of four could typically get 8 to 12 quadrats complete on one visit (2-3 hours of tide window).

Metrics

Habitat data were recorded for each quadrat prior to excavation. Littleneck clams were enumerated, shell length (posterior to anterior (nearest mm)) and weight (grams) was recorded. Occasionally, additional clams outside sampled quadrats were dug using similar methods to bolster size distribution data. For many clams, external annuli were read to determine age.

Results

Figure 5-7. Excavated 0.25-m^2 quadrat at Retz Creek

Field Observations

These two sites are among the richest rocky intertidal areas of the state, having a high diversity and abundance of fishes, invertebrates, and algae. At both sites we encountered several gaper clams, however they were exclusively recently settled juveniles, which had not yet burrowed to the depth adults are found. Although gapers are also harvested at these sites and were found within our samples, this study cannot provide abundance estimates for them as their adult burrow depth is typically below the depth we reached. Simultaneous to our surveys, we encountered experienced clammers who had harvested at these sites for many years; roughly half of the harvesters we spoke with (approximately 20 individuals) were targeting gaper clams rather than littleneck clams. Several remarked that they have observed a decrease in abundance of littleneck clams at these sites over time.

Habitat

Both sites were a mix of hard substrates interspersed with gravel and sand, and were relatively flat (Table 5-2).

Table 5-2. Prevalence of five substrate types encountered during surveys of littleneck clams at two sampling sites.

Site	Year	% Bedrock	% Boulder	% Cobble	% Gravel	% Sand
Retz Creek	2010	23.6	0.0	30.3	23.6	22.4
Retz Creek	2013	3.8	27.0	29.2	12.4	27.3
Woodruff Creek	2010	42.7	7.5	18.1	10.1	21.6
Woodruff Creek	2013	40.7	9.2	20.7	7.8	21.7

Abundance

To accommodate for the differences in polygon size in the Retz Creek sample from 2010 to 2013 an additional summary was added that only included the subset of those 2010 data that fell within the polygon created for 2013 (Table 5-3). This allows more direct comparability, albeit with a low sample size. At both sites, densities reduced over time, though the differences were not significant (Retz Creek p=0.49, Woodruff p=0.23).

Table 5-3. Littleneck clam density, variability, area, and absolute abundance by site and year.

Site	Year	n	Mean NLN/m²	95% CI	Area (m²)	Estimated # of clams (±95%CI)
Retz Creek	2010	33	2.55	1.32	28,506	72,690(±37,573)
Retz Creek (subset of 2013 polygon)*	2010	14	2.85	1.68	9,710	27,743(±16,287)
Retz Creek*	2013	45	2.22	1.16	9,710	21,556(±11,279)
Woodruff Creek	2010	37	4.65	2.52	4,962	23,073 (±12,528)
Woodruff Creek	2013	40	2.5	1.38	4,962	12,405(± 6,847)

*The 2010 survey included the entire clam bed which was later deemed to be far too large to adequately survey; these data are subset from those points that fell within 2013 survey area.

Size distribution

Size distributions indicate adult clams of many year classes make up the primary mode (Figure 5-8). At both sites and times recruitment was present, however never substantial when compared to the adult population.

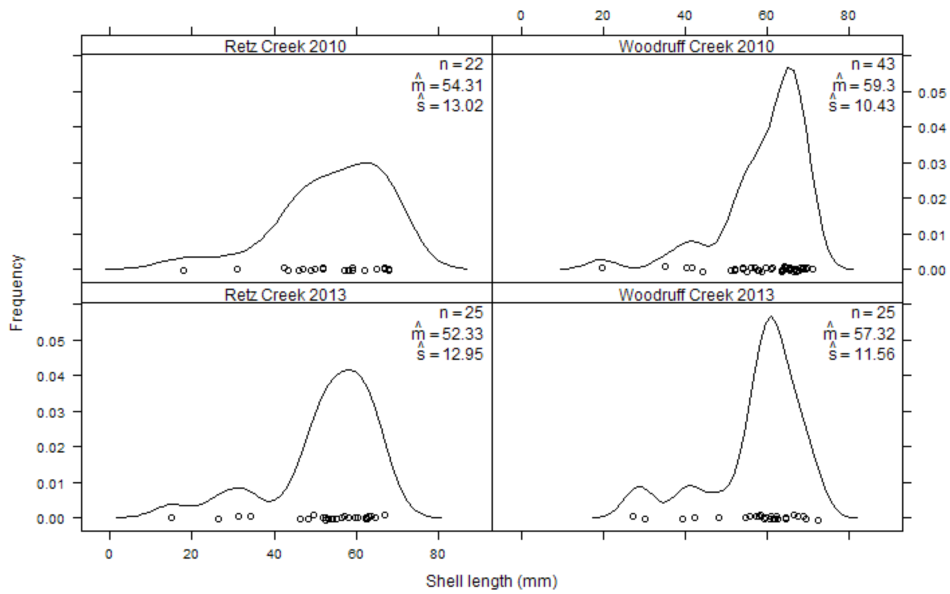

Figure 5-8. Size distributions of littleneck clams by site and year.

Size at Age

Littleneck clams at Oregon sites were found to become larger and grow faster than those from other studies. We found clams at maximum shell length of 72.4 mm at Woodruff Creek and 68 mm at Retz Creek, larger than the 64 mm maximum size previously reported (Chew & Ma, 1987). Littleneck clams from our study had a similar lifespan as those in other areas and studies (Figure 5-9).

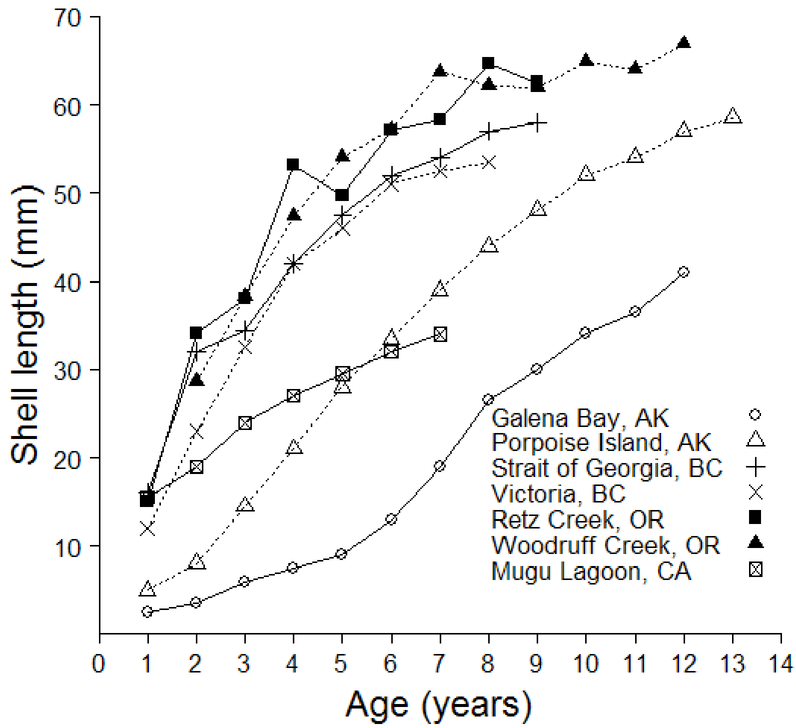

Figure 5-9. Littleneck clam size at age from multiple studies. Data from outside Oregon adapted from Chew & Ma, 1987.

Spatial dispersion

Littleneck clams were dispersed fairly evenly across the polygon (Figure 5-10). Throughout these surveys, we found clams in cavities of sand adjacent to boulders or bedrock. These particular "pockets" occurred evenly throughout the sites.

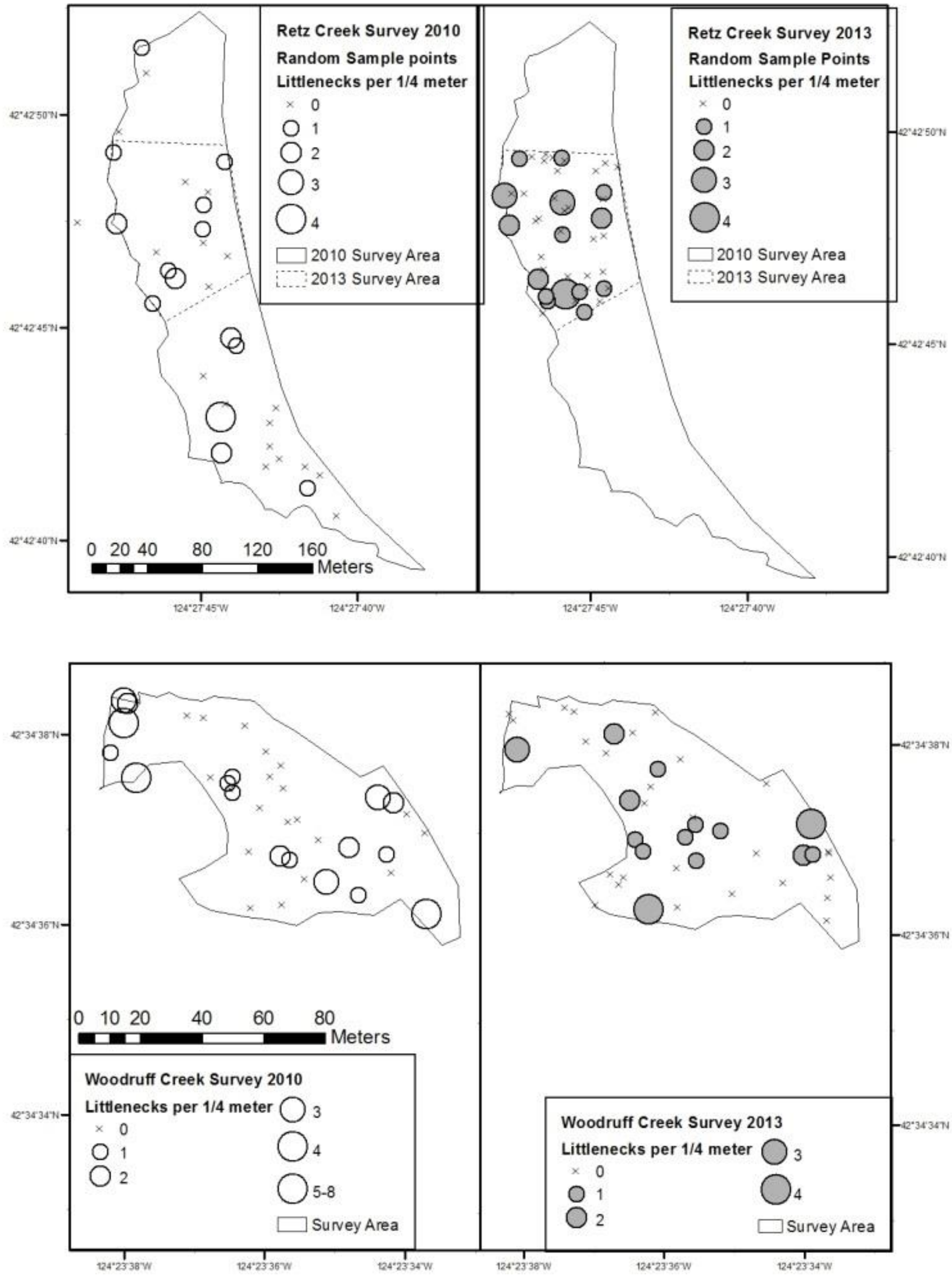

Figure 5-10. Spatial dispersion of littleneck clams by site and year.

Discussion

Littleneck clams are an important element of recreational clam harvest and these small clam beds provide unique opportunity for nearshore harvest. Though recreational clamming effort is not quantified for sites in this study, the daily bag limit of littleneck clams is 20 and during our surveys we saw approximately 20 clammers in the 12 sampling days. A low amount of clamming effort, as observed, should have a low impact on estimated absolute abundances. Similar to observations in California, sand accretion or dislodgement during storms seems likely to be a greater source of mortality.

Population abundances decreased at both sites from 2010 to 2013, though changes were not statistically significant. As littleneck clams aggregate, abundance data are strongly skewed. In this way, variability is very high and trend data may characterize populations better than ANOVA tests. For this reason, continued monitoring should be employed to determine long-term trends. Size distributions at both sites indicated larger clams, likely of an older cohort, in 2010 that did not persist to 2013 surveys. It may be possible that the natural mortality of this cohort drove not only mean size reductions, but also changes to abundance.

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COCKLE STUDIES OF SOUTH SLOUGH

Introduction

Pacific heart cockles (*Clinocardium nuttallii)* referred to here as "cockles", occur in the nearshore and estuaries along the western coast of North America. In Oregon, they are found intertidally and subtidally within highly marine-influenced estuaries. In Coos Bay, recreational clammers typically focus on gaper clams (*Tresus capax*) and butter clams (*Saxidomus gigantea*). Cockles, which are considered locally as less palatable and/or accessible, are the target of commercial clammers harvesting crab bait. The intertidal commercial cockle fishery in Coos Bay is continuous and valuable, average landings from 2003-2013 are around 18,000 pounds worth approximately $13,000 annually (ODFW 2012).

While cockle biology has been described in other areas, some key biological parameters tend to be area specific. In Coos Bay, fishery dependent data sources (landings, logbooks, market sampling, etc.) have been continuous in recent years, but can only give a limited view of the stock. We aim to gain a more comprehensive understanding of the stock dynamics for cockle populations in Coos Bay, focusing on: growth, recruitment, longevity and fishery interactions.

Methods and preliminary results

We employed intertidal clam population surveys, mark-recapture, and fishery market sampling to describe 1) temporal and spatial variability of size distributions and abundances, 2) timing and relative strength of recruitment, 3) annual and intra-annual growth, and 4) fishery effects. To describe these stock dynamics, we conducted biannual surveys at index locations and tagging studies at a heavily harvested site and a reserve site.

Study sites

Two locations were examined (Figure 5-11): a harvested site (Indian Point) and a reserve (Valino Island). For each site, polygons were developed which were of similar size (~ 1 ha), elevation (tide flat at about 0 m MLLW), and habitat (primarily sand). Surveys were conducted during February 2012 (Indian Point only), July 2012, February 2013, and July 2013. Surveys are expected to continue twice a year (winter and summer) until July 2016, when five full years of biannual survey data will be complete.

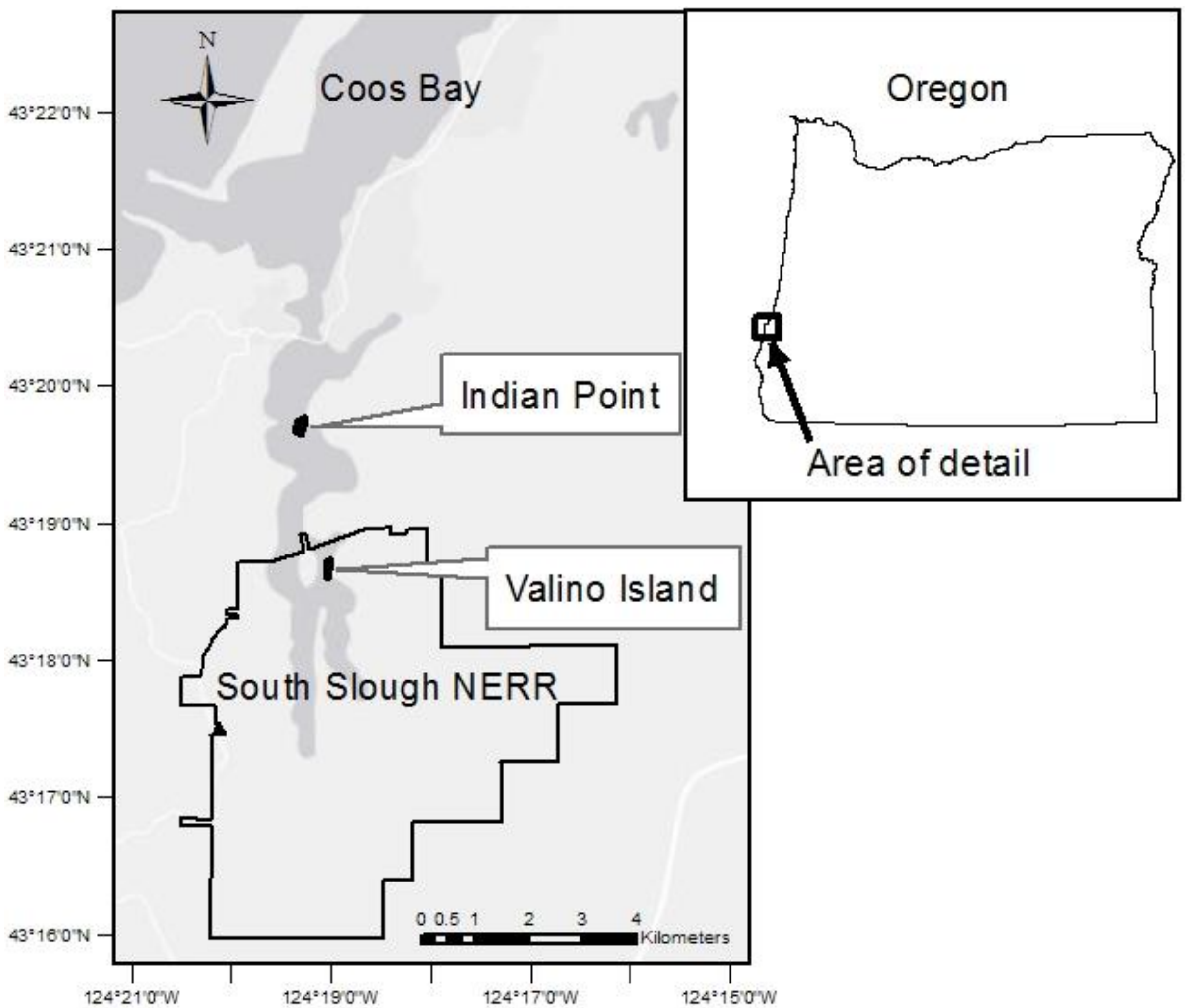

Figure 5-11. Index sampling locations for intertidal cockles.

Sample collection

Simple random sampling (SRS) was employed. In each survey, 60 random points were drawn within defined polygons using ArcGIS, and then loaded to a handheld GPS. Staff navigated to each point where a 1-m^2 quadrat was placed; substrate information recorded, and then raked using a 4-tined garden rake (127 mm wide, with 5 mm diameter tines, 30 mm apart from each other). Raking was performed to a depth of 10 cm in one direction then, repeated along a perpendicular axis. Cockle counts from the 1st swipe and 2nd swipe were recorded separately to measure variability in detection, and then the counts were combined to measure density. This technique was quick, consistent, had low variability among surveys, and allowed detection probability to be measured (Table 5-4). Shell length (SL) and weight were recorded for each cockle; in some cases extra (haphazard) quadrats were sampled to bolster size distribution data.

Table 5-4. Detection rates and sample during quadrat raking by site, season and year.

Site	Season	Year	Total Cockles Sampled	% Detected (first swipe)
	Winter	2012	93	80.6%
Indian Point	Summer	2012	127	81.1%
	Winter	2013	181	79.6%
	Summer	2013	112	85.7%
Valino Island	Summer	2012	117	74.4%
	Summer	2013	110	80.0%
	Winter	2013	118	77.1%

Recruitment indices

In Washington, cockles were found to spawn from April to November (Gallucci and Gallucci 1982). In Oregon, cockles were found to spawn from June to October (Robinson and Breese 1982). In both cases, spawning is noted to occur over a long period of time (>6 months) perhaps providing a less concentrated settlement period. Dlouhy (2012) found thread drifting juveniles (2.33 mm SL) in Coos Bay at highest abundances from late July to early August. Accounting for settlement timing and growth rates, cockles may be expected to be detected in the samples at adult habitat areas in their first winter.

The appearance of 12-25 mm SL cockles on clam beds in late winter (pers. obs.), likely represents the arrival of detectible-sized animals approximately 6 months after peak spawning. These sizes agree with Brooks (2001), who reared cockles to 19.4 mm mean shell length at 191 days in laboratory conditions. Without sifting, detectability of these very small cockles must be lower than for adults. However, similar methods through time should provide a useful index. Cohort strength can then be examined via isolating these newly settled cockles within size distribution of winter samples.

Preliminary analysis of size frequency distributions from winter vs summer surveys shows the likelihood of isolating and measuring relative annual recruitment rates. Within the samples, percentages of very small cockles (<25mm SL) were much higher in winter sampling in 2012 and 2013, 21% and 29%, respectively, compared to much lower numbers, 7% and 4%, in the summer samples.

Growth studies

External annuli reading has been used to estimate age and annual growth of clams (Ratti 1977; Weymouth and Thompson 1930). Although external annuli reading can provide a cost efficient robust data set, confidence in the data is low (Gallucci and Gallucci 1982). Use of interior (rather than exterior) check marks, was recommended by Brooks (2001), and recently endorsed by ODFW staff (Wheeler et al. 2012). We chose to attempt a tagging study to further review annuli reading and examine intra-annual growth. We may attempt to further validate external and internal annuli reading via counting these rings when work with these tagged cockles is complete.

During pilot studies of 2012, we experimented with two methods of cockle tagging: passive integrated transponder (PIT) tags and direct labeling via Sharpie® marker. After tagging, we experimented with two methods of dispersion: 1) contained (in crab pots) and uncontained (placed in the field). Uncontained cockles were successfully recovered and individual growth was recorded. On the other hand, the highly dynamic intertidal environment proved difficult for containing cockles in a crab pot, and this technique was abandoned. Both tagging methods seemed to work acceptably, however the Sharpie® method was far more efficient.

Preliminary data from 2013 and 2014 show that cockles grew slowly over the winter, quickly in the spring, and then slowly after the summer months (Figure 5-12). In 2014, we intend to Sharpie® tag 100 cockles in each of the two sites and track their growth every three months for as long as two years.

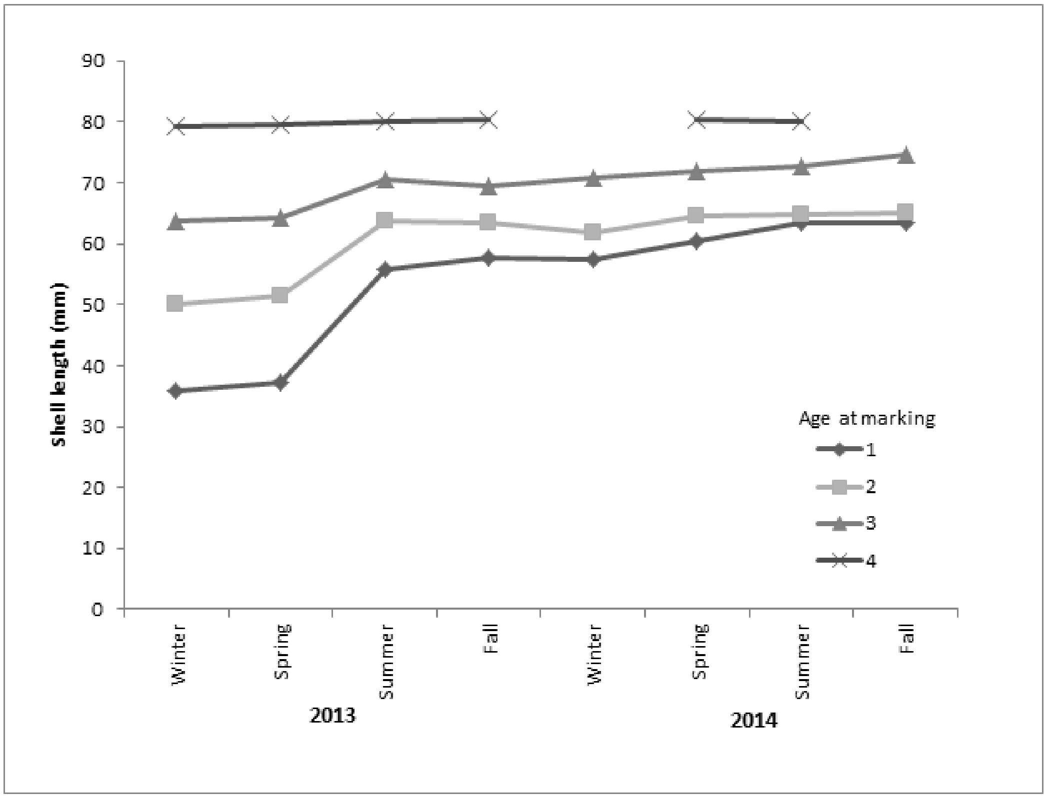

Figure 5-12. Mean growth of intertidal cockles marked and recaptured in 2013 and 2014 in Coos Bay.

Fishery effects

By studying densities at a heavily harvested area and a reserve over several years, we will be able to examine if there are differences in densities over season, year, and site using appropriate statistical tests. Relationships between annual harvest levels and corresponding site densities will be examined. To further understand fishery/ stock relationships, we plan to gain fishery market samples each year for our continuous annual South Slough cockle market sampling dataset dating back to 2010.

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OREGON Fish & Wildlife

4034 Fairview Industrial Drive SE

Salem, Oregon 97302