Pinniped Abundance and Distribution and the Effects of Tidal Phase and Bathymetry in the San Juan Channel during Fall 2012

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Pelagic Ecosystem Function Apprenticeship Fall 2012

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Abstract:

In the San Juan Archipelago two species of pinnipeds are abundant: *Phoca vitulina,* the harbor seal, and *Eumetopias jubatus,* the Steller sea lion. This study focused on the pelagic environment where pinnipeds are believed to be feeding. The strip transect method was used on both large and fine scales to determine the effects of tides and bathymetry on pinniped abundance and distribution. Populations have been stable for the past eight years for both species in the channel. Harbor seals were found throughout the channel, but distributional patterns changed on coarse scales. Steller sea lions were concentrated in the southern part of the channel in close proximity to their haul out site. Fine spatial and temporal transects showed little correlation between harbor seals and tidal phase or bathymetry. Steller sea lions were present in the water during faster currents, especially with floods. They also showed a relationship with the bathymetric effect. This study will allow for further research on the relationship of pinnipeds and tides.

Introduction:

The San Juan Archipelago is a bathymetrically and tidally complex ecosystem that is home to five species of pinnipeds. The harbor seal, *Phoca vitulina*, and Steller sea lion, *Eumatopias jubatus* are relatively abundant in this area. Harbor seals are smaller (1.2-2m, 150-170 lbs), dark or light gray with spots, and lack external ear flaps. Steller sea lions are much larger (2-3 m, 580-1200 lbs), light brown in color, possess external ear flaps, and have a long neck and large hind and forelimbs making them agile on land.

Present year round in large numbers, harbor seals are currently the most abundant marine mammal in the Salish Sea (Keple 2002). In the first half of the 21st century, there was a bounty program for harbor seals which caused populations to plummet. After the introduction of the Marine Mammal Protection Act in 1972, populations have recovered. The Salish Sea now has an approximate population of 4,000 seals and has been at or near carrying capacity for over a decade despite worldwide declines of many other marine species (Jefferies et al 2003). Steller sea lions are non-breeding winter and fall visitors in the Salish Sea. World populations of Steller sea lions have decreased by two-thirds since 1980 and all populations are listed as either endangered or threatened. However, Steller sea lions are now considered stable from the coast of SE Alaska to Oregon (Trites et al 1996). In the San Juan Channel specifically, comprehensive population studies of this sea lion species have not been done over long periods of time so local status is not well known. Since 2005, PEF apprentices have done boat surveys for both species of pinnipeds and show that both populations have been stable in recent years (Vermeire 2010).

Both Steller sea lions and harbor seals are found throughout the San Juan Channel, but their distributions differ (Vermeire 2010). Past studies have shown pinniped distribution is dependent upon the location of their terrestrial haul out sites and availability of prey (Lance et al 2007). Local haul out sites are well documented, but feeding sites are not (Jefferies et al 2000). Prey availability is known to be affected by bathymetry, water depth, and tidal currents (Zamon 2000, 2001). A clear understanding of how pinniped abundance and distribution vary with tides would be an important step to understanding local foraging patterns in the San Juan Archipelago. Previous studies by PEF apprentices have looked at this relationship on a coarse spatial and temporal scale, but with inconclusive results, perhaps due to survey methods (Wilkins 2011, Vermeire 2010). Studies at finer scales may allow us to see the relationship more clearly.

The objectives of this study were to 1) Determine the abundance and distribution of harbor seals and Steller sea lions in the San Juan Channel in Fall 2012, 2) Compare the abundance of harbor seals and Steller sea lions in Fall 2012 to past years, and 3) Determine how bathymetry and tidal currents affect the abundance and distribution of pinnipeds at fine spatial and temporal scales.

Methods:

Study Sites

Two sites were used throughout this study, both located in the San Juan Channel in the Salish Sea, east of San Juan Island. The larger study site began in the northern area of the channel with coordinates 48°35'N, 123°02,54'W and ends just outside of Cattle Pass in the southern part of the San Juan Channel with coordinates 48°25'N, 122°56,59'W. The transect measured 21.11 km and was separated into six zones based upon both bathymetric characteristics and identifiable landmarks. Zone one has coordinates 48°35'N, 123°02,54'W with a surface area of 1.26 km^2. Zone two has coordinates 48°33', 122°59'67'W with a surface area of 0.96 km^2. Zone three has coordinates 48°32'N, 122°58'W with a surface area of 0.93 km^2. Zone 4 has coordinates 48°31'N, 122°56,89'W with a surface area of 1.68 km^2. Zone 5 has coordinates 48°28'N, 122°57,17'W with a surface area of 1.17 km^2. Zone 6 has coordinates 48°26'N, 122°56,72'W with a surface area of 0.45 km^2 (Figure 1).

The smaller transect site was located in Zone 4 of the larger transect, just outside Griffin Bay. The starting point at the south end has coordinates 48°28,256'N 122°57,517'W and the ending point at the north end was 48°30,250'N 122°57,837'W. The port side of the boat covered a shallow area while the starboard side covered the deeper area.

Centennial Data Collection

For this study the strip transect method was used to identify and count the number of harbor seals and Steller sea lions in the San Juan Channel for Fall 2012. Two transects were taken each day on September 28th, October 10th, 17th, 23th, and 30th, and November 7th and 14th upon the research vessel, R/V Centennial. The first transect started in the morning and went from the northern to southern part of the channel (Zone 1 to 6). The second transect was done in the afternoon and went south to north (Zone 6 to 1). A minimum of two observers and one recorder were placed on each the port and starboard side of the bow of the boat, approximately 4 meters above sea level. As the Centennial moved throughout the six zones at a speed of 5 to 8 knots, all pinnipeds were identified and counted. This was done by visual observations with binoculars within a distance of 200 m per side for a total transect width of 400 m (Figure 2). A total distance of 118.22 km was sampled for all transects this fall.

To look at tidal data, the NOAA tide station at Turn Point was used which is stationed at 48.5567°N, 122.9983°W. The data was then separated into 7 tidal categories for current speed and direction: fast ebb, medium ebb, slow ebb, slack, slow flood, medium flood, and fast flood. The fast currents were any over 1 knot, the medium currents between .5 and 1 knot, the slow between 0 and .5 knots, and the slack at zero knots. For harbor Seal comparisons with tides, zones three and four were used and for Steller sea lions zone 5 was used.

Small Boat Data Collection

Data collected on the small boat, the Bufflehead, was done with the same strip transect method, but on a finer scale. The transects were run in thirty minute intervals during days of high water mass exchanges, mostly during flooding tides. One observer and one recorder were placed on each side of the boat with the same channel width of 400 m. Bathymetric preferences were then looked at for this season and then throughout the tidal cycle. The tidal cycle phases were labeled as slack low, slow flood 1, fast flood 1, fast flood 2, slow flood 2, slack high, slow ebb 1, fast ebb 1, fast ebb 2, and slow ebb 2 (Figure 3). Tidal data was taken from two NOAA sites: San Juan Channel South Station and Turn Point and were averaged for current speed and tidal phase.

To get a better resolution throughout the tidal cycle, each small boat transect was averaged by current speed and abundance of pinnipeds. The days of similar flooding tides were used to look for patterns of pinnipeds abundance from slack to flood. This information was then averaged over all four days to look for stronger trends.

Data Analysis

All analyses were done using Microsoft Office Excel 2007. Averages were calculated by taking total numbers of individuals and dividing by the surface area being analyzed. Error bars were calculated with 95% confidence intervals.

Results:

Centennial: Abundance

During Fall 2012, we observed a total of 253 harbor seals on Centennial transects, for an average density of 2.14 individuals/km^2. Steller sea lions were less abundant with a total of 146 sea lions this season for an average density of 1.24 individuals/km^2. These numbers were consistent with past years. From 2007 to 2011, mean harbor seal density ranged from approximately two to four seals/km^2 (Figure 4). Density in 2012 was lower than the peak densities (> 4.0/ km^2) that were observed in 2010 and 2011. Steller sea lion density did not vary significantly during 2007 to 2011, ranging from one to two individuals/km^2.

Centennial: Distribution

During fall 2012, harbor seals were found in all 6 zones of the San Juan Channel (Figure 5). Highest numbers were found in zones 3, 4, and 5 where densities ranged from three to five seals/km^2. Densities in all other zones were below 2.0 individuals/km^2. Steller sea lions were also distributed in all zones, but in lower densities, except in zone 5 (Figure 6). In zone 5, the average density of Steller sea lions was over six individuals/km^2. No other zone had a density greater than one sea lion/km^2.

The pattern of average harbor seal and Steller sea lion distribution, described above, did not hold for all weekly Centennial cruises. On September 28th the highest densities (>4.0) of harbor seals were found in zones 5 and 6, the southern part of the channel (Figure 7a). For the next survey on October 10th distribution was different with higher numbers farther north in the channel. On that date density exceeded 17 seals/km^2 in Zone 3 and was moderately high (>4.0/ km^2.) in zones 3, 4, and 5 (Figure 7b). On October 17th, the highest densities again were found in the southern part of the channel, specifically zone 5 (Figure 7c). This pattern of shifting distribution where with highest abundances alternated between the southern and northern part of the channel, continued throughout the 7 cruises in fall 2012 (Figures 7d-g).

The variable distribution pattern observed in harbor seals correlated with two tidal factors, the direction of the tidal current and whether it was during a neap or spring tide (Table 1). Whenever a southern distributional pattern was observed, it was during a spring tide and during the change from ebb to flood. Each time a northern pattern was observed, the tide was during a neap tide and during the change from flood to ebb. No surveys were conducted on days when there was a neap tide changing from ebb to flood or a spring tide changing from flood to ebb.

Daily variation in Steller sea lion distribution occasionally mirrored that of harbor seals, but overall did not show a clear pattern. For example on October 10th, Steller sea lions were widely dispersed, including the Northern part of the channel (Figure 8a), but on October 17th, they were mostly restricted to the Southern part of the channel (Figure 8b). Other surveyed dates did not follow this pattern, but Steller sea lion numbers were relatively low in abundance throughout the channel (Figures 8a, 8d-g). Overall Steller sea lions were most abundant in zone 5 than in any other zones on every trip.

Centennial: Tides

During weekly Centennial transects there was high within day and between day variability in harbor sea and Steller sea lion density, even in their zones of highest abundances. For harbor seals in zones 3 and 4, density ranged from zero to 10.5/ km^2.. High densities (>6.0/ km^2.) were recorded on four transects, 3 during fast flood and one during slow ebb (Figure 9a-b). Lower numbers (<3.0/ km^2.) were observed on 19 of 28 transects and no harbor seals were observed on 10 transects, covering the complete range of tidal conditions. Overall, variability in harbor seal density did not correlate well with the differences in tidal conditions.

For Steller sea lions in zone 5, densities also varied by transect, but did appear to correlate with tidal conditions. Generally abundance was higher during fast and medium ebbs and fast floods than during slower tidal currents (Figure 10). Interestingly, day to day differences were often greater than within day differences, especially for Steller sea lions. For example, the two transects where sea lion densities were highest were both on October 17^{th}. Similarly the two highest densities for harbor seals in zone 3 were on October 10^{th}.

Bufflehead Surveys

On small boat transects, harbor seal densities were higher than Steller sea lions with an average density of 4.18/km^2 compared to 0.74/km^2. During these finer scale transects, seal and sea lion densities showed clearer trends with bathymetry and tidal conditions.

Bufflehead Bathymetry

Overall, harbor seals showed no preference for deep versus shallow water (Figure 11). They had an average density of 2.41/km^2 in deep water and 2.31/km^2 in shallow water. Steller sea lions showed a slight preference for shallow water, but this was not statistically significant. They had an average density of 0.53 sea/km^2 in shallow water and 0.31 sea lions/km^2 in deep water.

Water depth preference patterns described above did not always hold throughout the tidal cycle. For harbor seals densities were higher in shallow water six out of ten tidal phases, and lower only once during the slow ebb (Figure 12). Overall harbor seals did not show a clear preference for water depth during the flooding part of the cycle, but they appeared to prefer shallow waters during the ebbing cycle. For Steller sea lions density was higher in shallow waters from slack low through fast flood one, but even for the rest of the flood. Too few animals were seen in the ebbing currents to be able to see water depth preference (Figure 13).

Bufflehead: Tides

At fine temporal scales, Steller sea lion and harbor seal average densities varied across the phases of the tidal cycle. Steller sea lions increased steadily in abundance from slack low through the flooding tides reaching peak density at slow flood two. They were absent at slack high and reappeared during fast flood one, and peaked again during fast ebb two (Figure 14). Overall densities were higher with faster tidal currents. Harbor seals were present during all tidal phases. On the flooding tide density peaked during slow flood one then declined through slack high. Density remained low until peaking again at fast ebb two. Densities then remained at moderate levels through slack low.

On four days of similar tidal conditions Steller sea lion abundance showed a consistent pattern. There were low numbers at slack low, then a period where none were observed for an hour to an hour and a half during the slow flood. Sea lions increased thereafter and appeared to remain throughout the flooding cycle (Figure 15a-d). Harbor seals show no consistent daily pattern (Figure 16a-d). Two days many seals were observed and the other two days there were fewer, but abundance did not correlate with tidal patterns. On October 28th and 24th there is a similar pattern to Steller sea lions observed, but this pattern was not seen on October 25th or 26th; however, on these days harbor seals were present from the end of ebb through maximum flood.

When these four days are averaged, for the period slow ebb two through slow flood one, we saw that Steller sea lions varied consistently with tidal phase, but harbor seals did not (Figure 17). Steller sea lions showed up at slack low, but then disappeared until showing up in the faster parts of the flood. They remained in the transect throughout the rest of the flood and it is unclear where they drop off again. In contrast, harbor seals were present throughout all phases of the tidal cycle in relatively high numbers.

Discussion

Abundance

Year to year fluctuations in harbor seal numbers can usually be explained by changes in oceanography and prey availability. It was interesting to see that abundance was lower this year than the past two years despite high densities reported in both birds and porpoises for 2012 (Teller 2012, Albrecht 2012). Diet varies by species so perhaps there are decreases in the preferred prey for harbor seals this year. The decrease does not appear to be explained by the oceanographic data as the past three years have been fairly similar in terms of the oceanographic data collected (Williams 2012).

The data suggests little change in the San Juan Channel habitat from 2007-2012 due to no net change being observed in harbor seal abundance. This is supported by the stability seen in Steller sea lion abundance in this time. Harbor seals have been at carrying capacity for over a decade which is unusual as many species are declining worldwide. This should be of concern in the San Juan Channel because if populations continue to grow they could have a large impact on the ecosystem due to their size and high metabolic rate (Keple 2012). Multiple studies have shown this could be a problem for some species of declining fish populations, such as endangered salmon and rockfish (Lance et al 2012). This shows the importance of the study to really understand populations of pinnipeds in relation to lower trophic levels.

Distribution

Patterns in distribution of both pinnipeds can be explained by haul out sites and feeding location. Harbor seals have haul out sites located all throughout the San Juan

Channel on intertidal rocks, reefs, and islands (Jefferies et al 2000). Occasionally they will utilize more than one haul out site, but it is more common to use one on a regular basis (Yochem 1987). Harbor seals will typically stay within 10 km of this site while searching for food which, compared to our 21.11 km long transect on the Centennial, is a fairly large distance (Lance et al 2007). Steller sea lions on the other hand congregate in zone 5 where their only haul out site in the channel is located. Past studies have shown Steller sea lions may travel great distances for food (up to 24 km), but this does not seem to be the case in the San Juan Channel based on the data collected in this study (Fiscus 1966). This is most likely due to the large availability of food in this portion of the channel so there is no need to exert the energy to travel far.

Tides and Bathymetry

From this study we can see that tides have a strong influence on the abundance and distribution of pinnipeds in the San Juan Channel. This almost certainly is related to tidal influence on foraging opportunities and marine mammals will concentrate in regions of high prey density (Sih 1984). On the coarse scale surveys two distributional patterns for harbor seals correlated within day with ebbing or flooding tides, and week to week with spring or neap tides. Positive feeding anomalies have been observed in the past with flooding tides as more plankton are moving into the channel. This causes fish to become more dispersed in the water column as they are foraging and become more vulnerable to feeding pinnipeds (Zamon 2003). Based on finer scale abundance changes with tides, harbor seals are most likely traveling with the tidal current as it floods into the channel.

The weekly scale with spring and neap tides could influence the mixing of prey and stronger currents could potentially increase feeding opportunities. However, this should affect abundance, not the distribution. It is possible that as the harbor seals are following the tides up and down the channel, their distances will be greater as more water is passing through, but the same pattern would be observed.

In contrast, harbor seal abundance did not correlate well with tidal current speed and direction based on observations in zones three and four. The study was not well designed to really quantify this relationship at this coarse temporal scale. The small boat surveys at fine scales were expected to find a clearer understanding of this relationship, but abundances and tidal phase did not correlate. Consistency of harbor seal abundance throughout tidal phases suggest they are using the water for more than just feeding or are feeding on different prey throughout the tidal cycle, depending on what is available. In the fall season, harbor seal diet consists mainly of walleye pollock, English sole, and Pacific cod (Everitt 1980). While they will eat some salmon, most of their prey consists of demersal fish species which may not be strongly influenced by tides. Given that harbor seal abundance did not vary with tide, it is not surprising that abundances in deep and shallow water were nearly equal throughout the tidal cycle. The bathymetric effect is strongly related to phases of the tidal cycle. Due to harbor seal feeding strategies, depth does not appear to be a factor.

Steller sea lions showed a very different reaction on coarser scales compared to the harbor seals in that the sea lions did not show much variation with tide. Highest densities were seen during faster currents, but this was not always the case and this varied day to day. On the other hand, Steller sea lions appeared to be responding to tides on a finer scale, which is what the small boat transects show. Since Steller sea lions were present in the faster parts of the flooding cycle, this supports floods having the best feeding opportunities. At Cattle Point, just south of the transect, the channel is much narrower. As the flooding tide comes in at faster speeds, larger quantities of plankton are pushed through, increasing fish abundance, which is believed to bring in the sea lions (Zamon 2002, Petersen et al 1998). Steller sea lions are known to have some diet similarities with harbor seals in terms of flatfish, walleye pollock, herring, and cephalopods, but in the fall are eating a lot more salmon which seem to come into the channel with flooding tides (Everitt 1980). Low abundances during the ebbing cycle show that this is not the ideal feeding time for Steller sea lions in this location.

Since Steller sea lions showed a strong correlation with the flooding tide, it makes sense that there was a bathymetric effect. The bathymetric effect in the small boat transects is linked to the continental shelf present at the mouth of Griffin Bay (Petersen et al 1998). This is an area where the water depth goes from shallow to deep rather abruptly. As plankton are being pushed into the channel with the flooding tides, the water is hitting the shelf where turbulent mixing occurs. This turbulent mixing increases prey availability by physical force, concentrating plankton at the shelf (Zamon 2002). Fish are either coming from depth or following the current to food, which increases feeding for the sea lions.

During the beginning of a flood is when this bathymetric effect is mostly influencing Steller sea lion abundances. In this time the concentration of prey is greater in the shallow part of the channel. This supports past studies which have shown Steller sea lions prefer to feed in shallow waters (Fiscus 1966). However, as the flood continues and the Steller sea lions are found in both the shallow and deeper waters in even numbers, at some point this concentration at the shelf is pushed around and dispersed. During the ebbing cycle this effect is not as strong and lower numbers of sea lions were feeding.

Future Studies

There are a number of studies that could be done to continue to understand the relationship of pinnipeds with tides. Sampling year round and identifying food sources would be useful to interpret distributional patterns of harbor seals throughout the seasons. Collecting more data on finer scales during ebbing cycles would help to get an idea of what is happening all throughout the tidal cycle. The sampling method in this study made it difficult to consider animals underwater or moving in response to the boat. Keeping the width of the transect constant was challenging as well, but all these problems were controlled as much as possible throughout the study. The one uncontrollable factor that could have had an effect on the results was weather conditions. Days when the water was choppy or the sun was reflecting off the water made observations more difficult, but most days the weather did not appear to be an issue.

Implications:

Since pinnipeds are apex predators in the San Juan Channel, it is critical to continue studies of abundance and distribution, especially when considering conservation and management strategies (Keple 2002). In my opinion the most important part of this study is the importance of tides. Both pinnipeds respond to tides, but do so differently. Harbor seals respond at the coarser temporal and spatial scale and show no clear trends with fine temporal scales. Steller sea lions are responding at fine temporal and spatial scales, but not at coarser scales. This study is a good starting point for understanding the relationship of pinnipeds with tides.

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Tables and Figures:

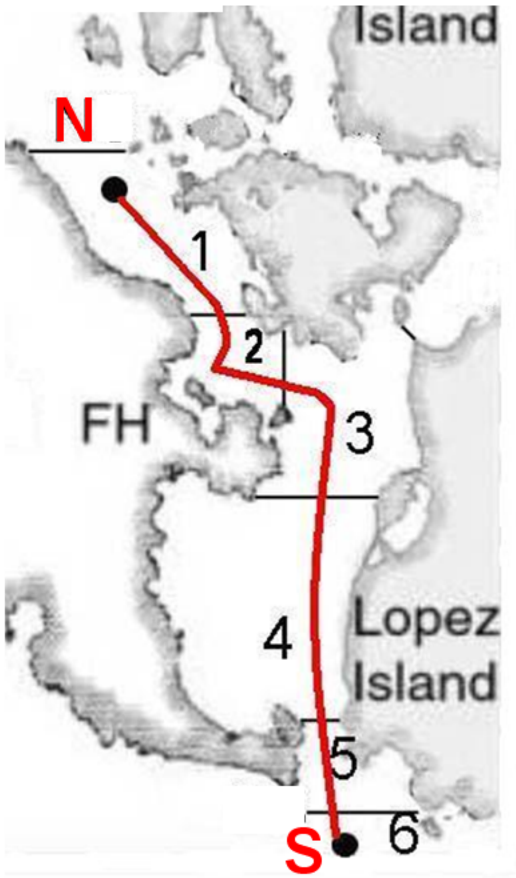

Figure 1. Study Site. This is the area of the San Juan Archipelago that was surveyed on the Centennial (Leal 2007).

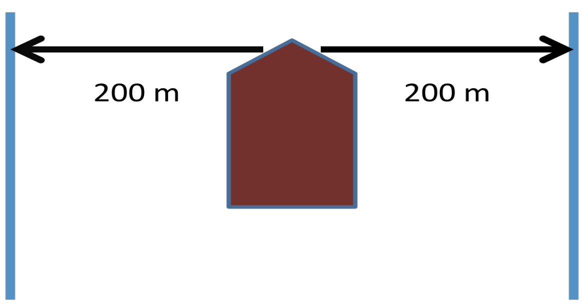

Figure 2. Survey Method. Here is a diagram of the strip survey method used. The pentagon shape represents the boat, the outer lines are the outside lines of the transect, and the arrows show the distance and direction pinnipeds were counted in.

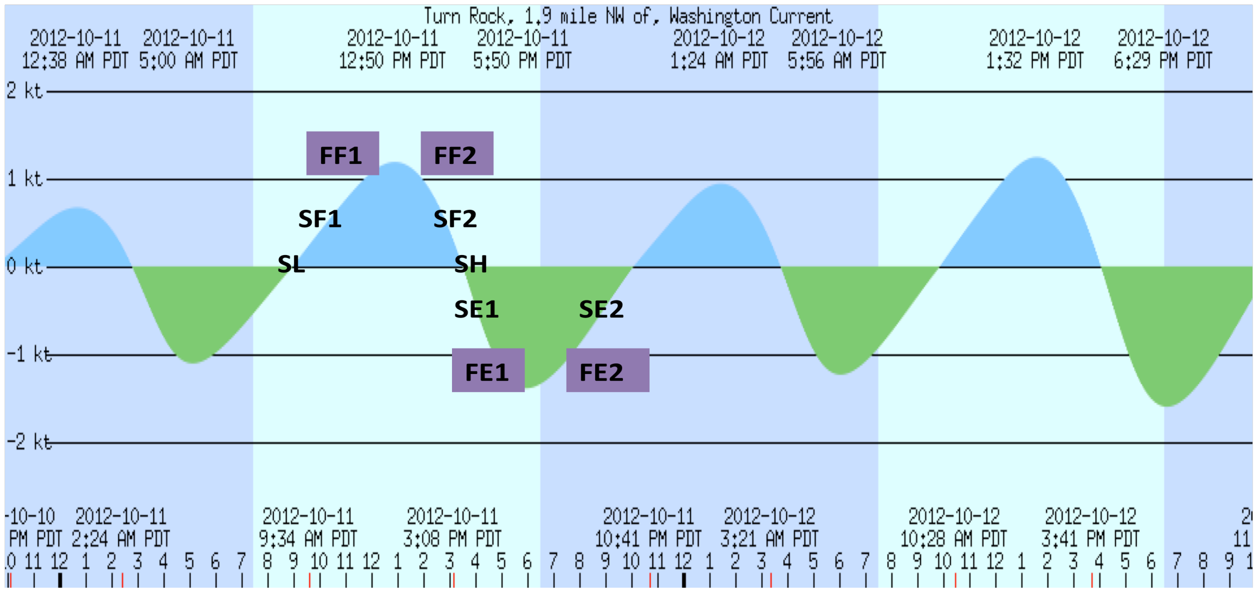

Figure 3. Tidal Phase Classification. This shows how the tidal cycle was split up into the various tidal phases. SL stands for Slack low, SF means slow flood, FF means fast flood, SH means slack high, SE means slow ebb, and FE means fast ebb. All slacks and fast currents were an hour long and all slow currents were an hour and a half.

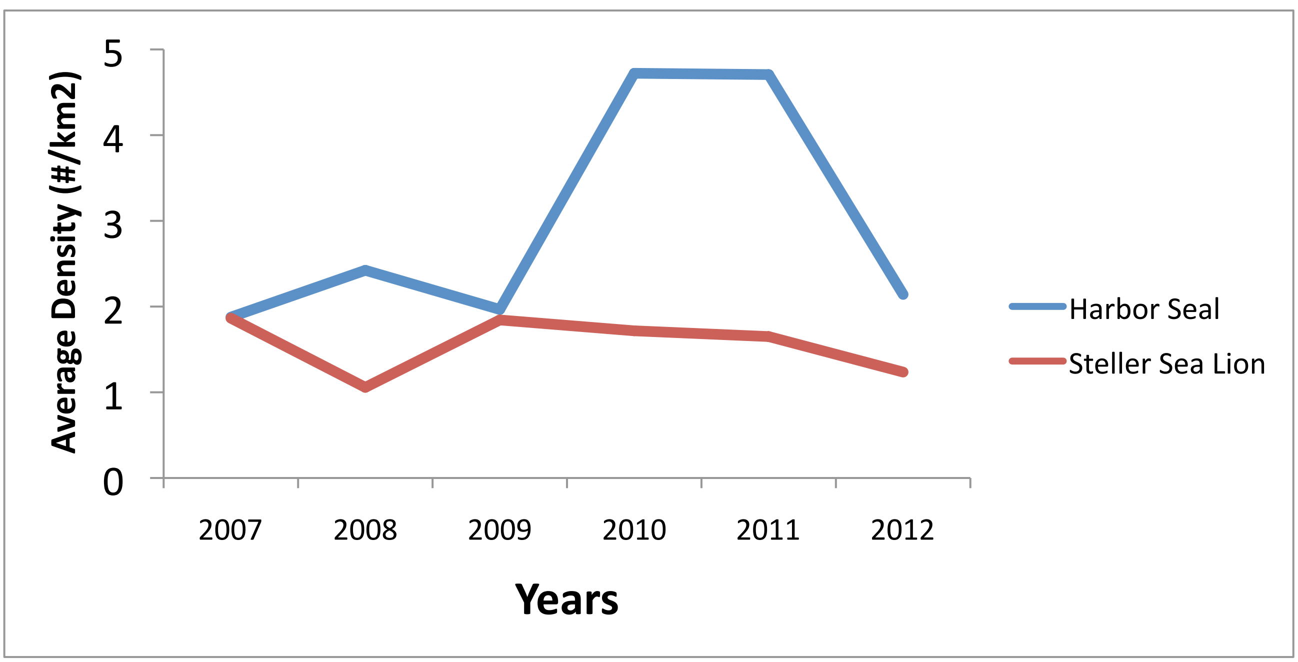

Figure 4. Inter-annual Abundance. This graph shows the total average abundance of the harbor seals and Steller sea lions from 2007 through 2012 (adapted from Vermeire 2010).

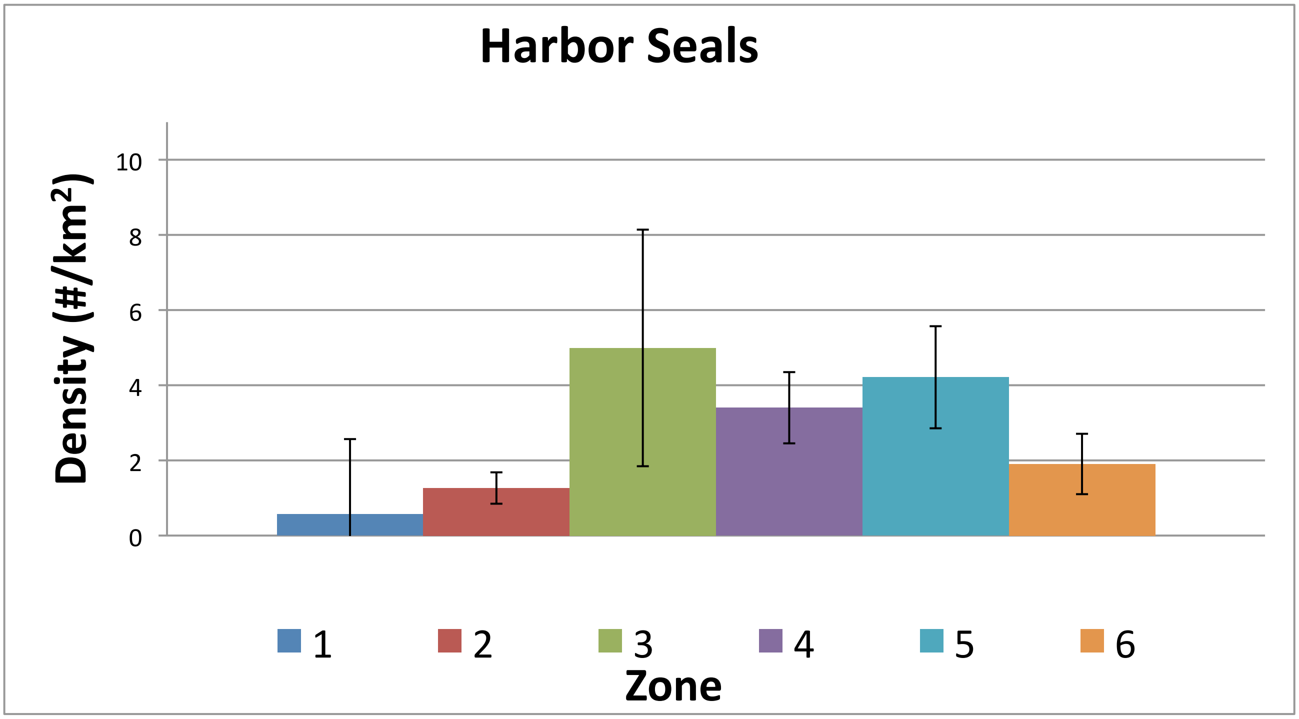

Figure 5. Harbor Seal Distribution Fall 2012. Average distribution of harbor seals across all zones is represented here, showing zone preferences throughout the channel this Fall.

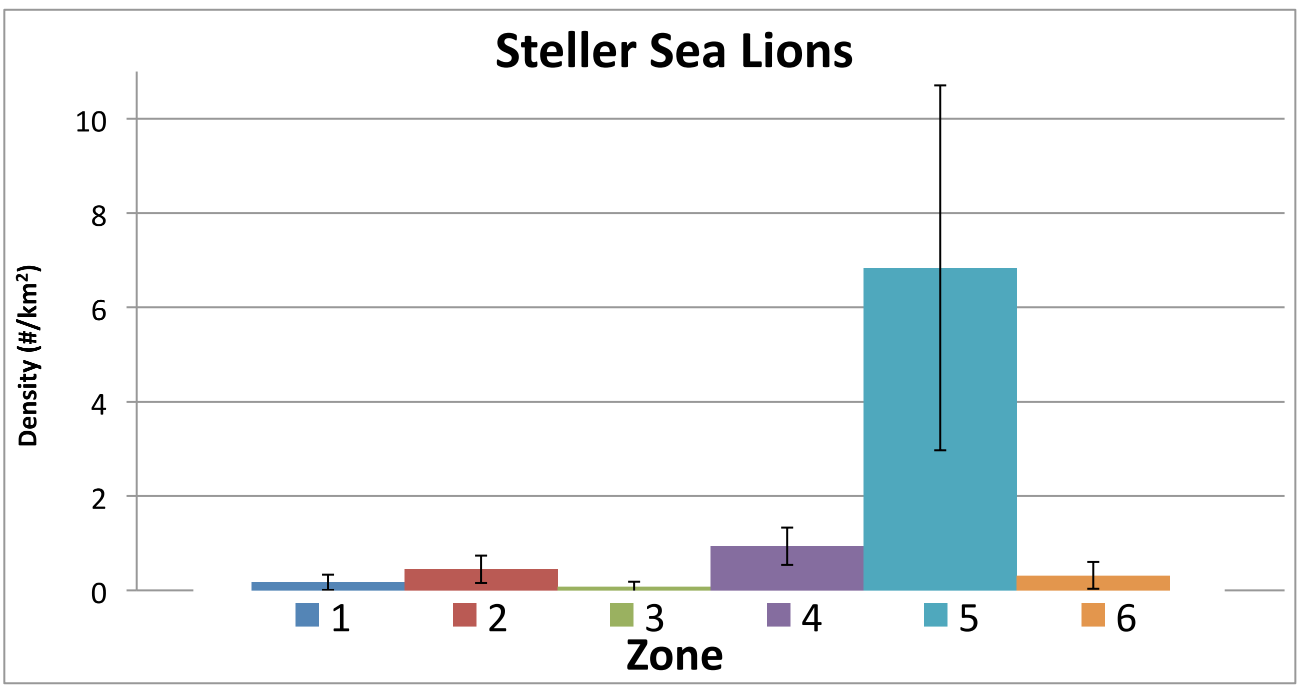

Figure 6. Steller Sea Lion Distribution Fall 2012. Average distribution of Stellers across all zones is represented here, showing zone preferences throughout the channel this Fall.

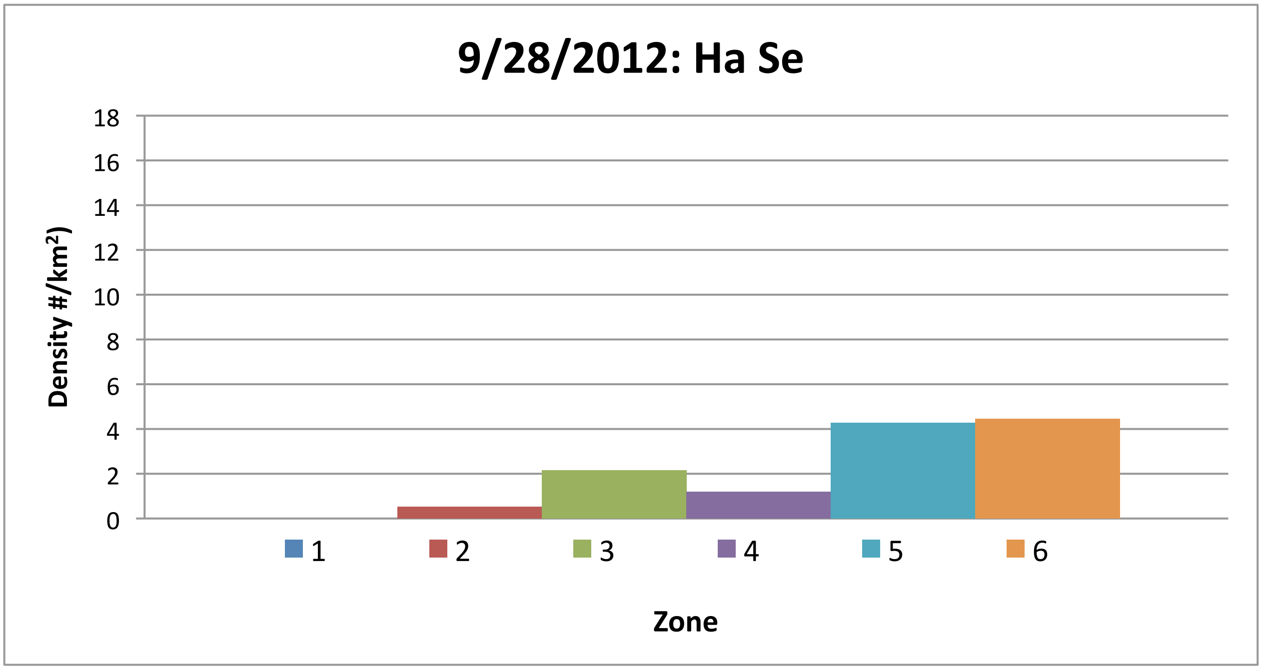

Figure 7a. Harbor Seal Distribution 9/28/2012. These graphs show the distribution of harbor seals throughout the San Juan Channel each week on the Centennial cruises. Each graph is averaged with the two transects taken on each day. Here a southern pattern is shown.

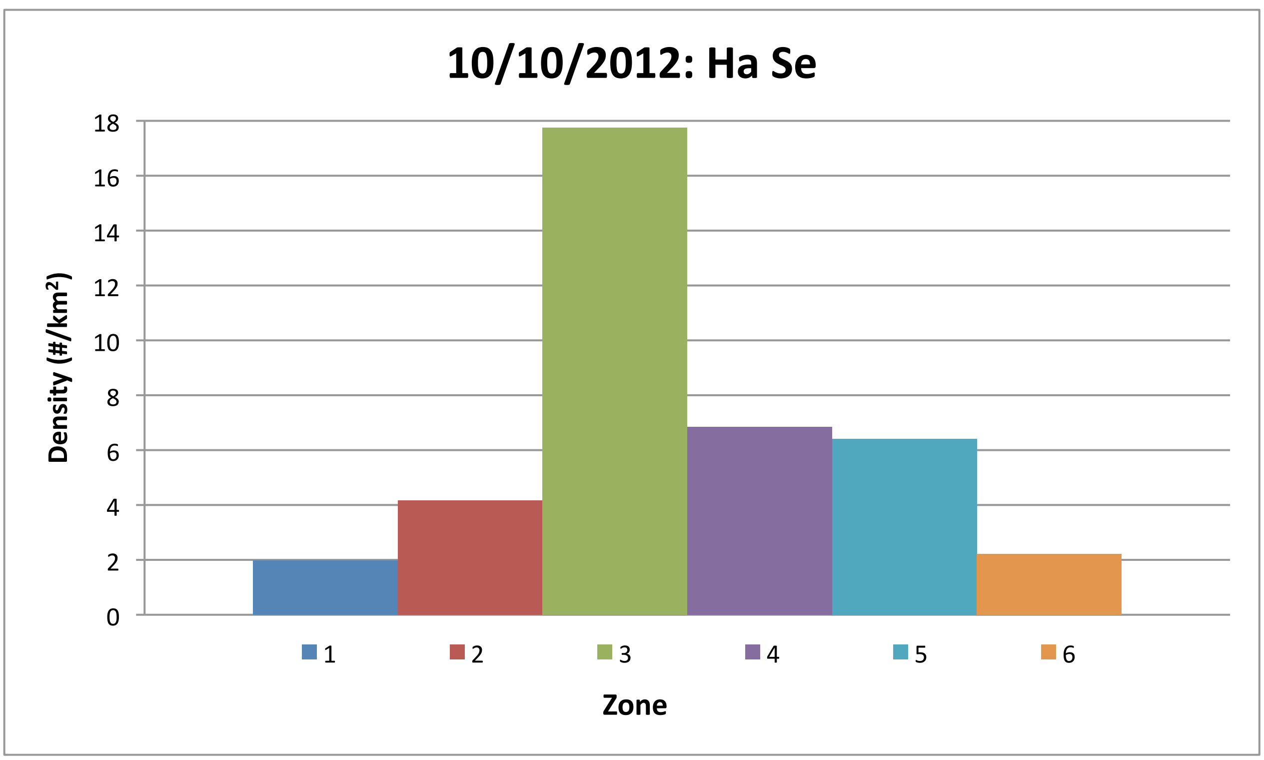

Figure 7b. Harbor Seal Distribution 10/10/2012. This day shows a northern pattern.

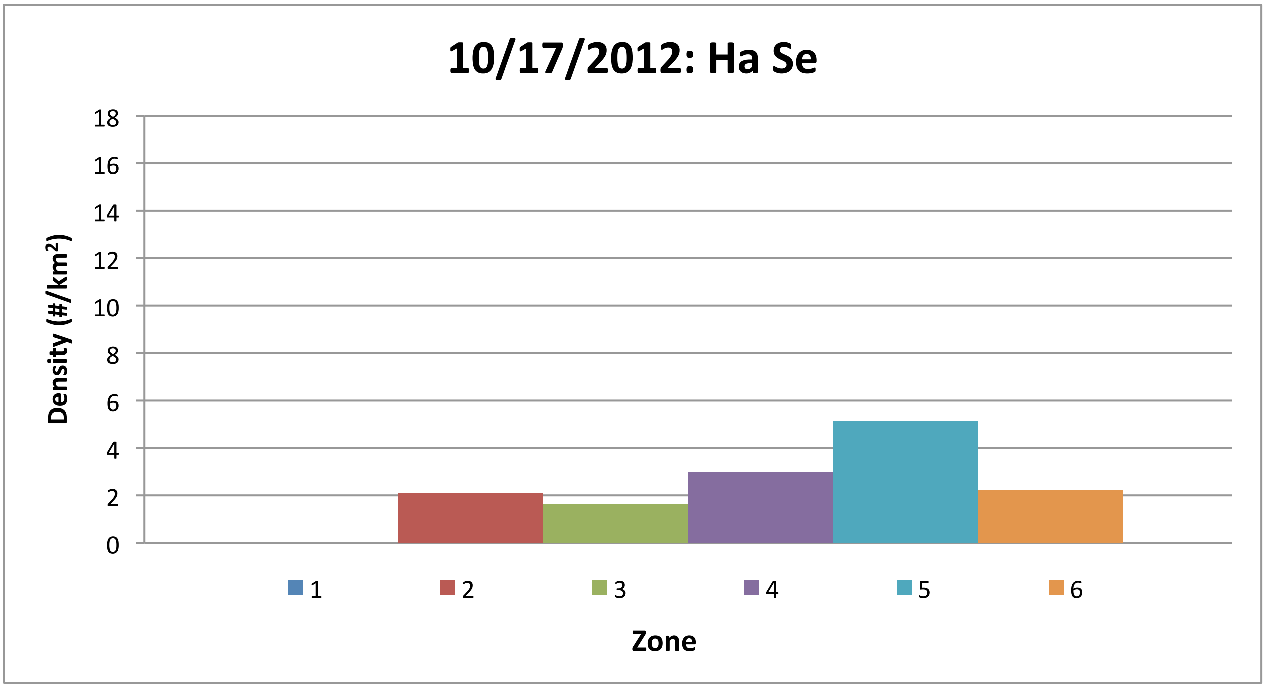

Figure 7c. Harbor Seal Distribution 10/17/2012. This day a southern pattern was observed.

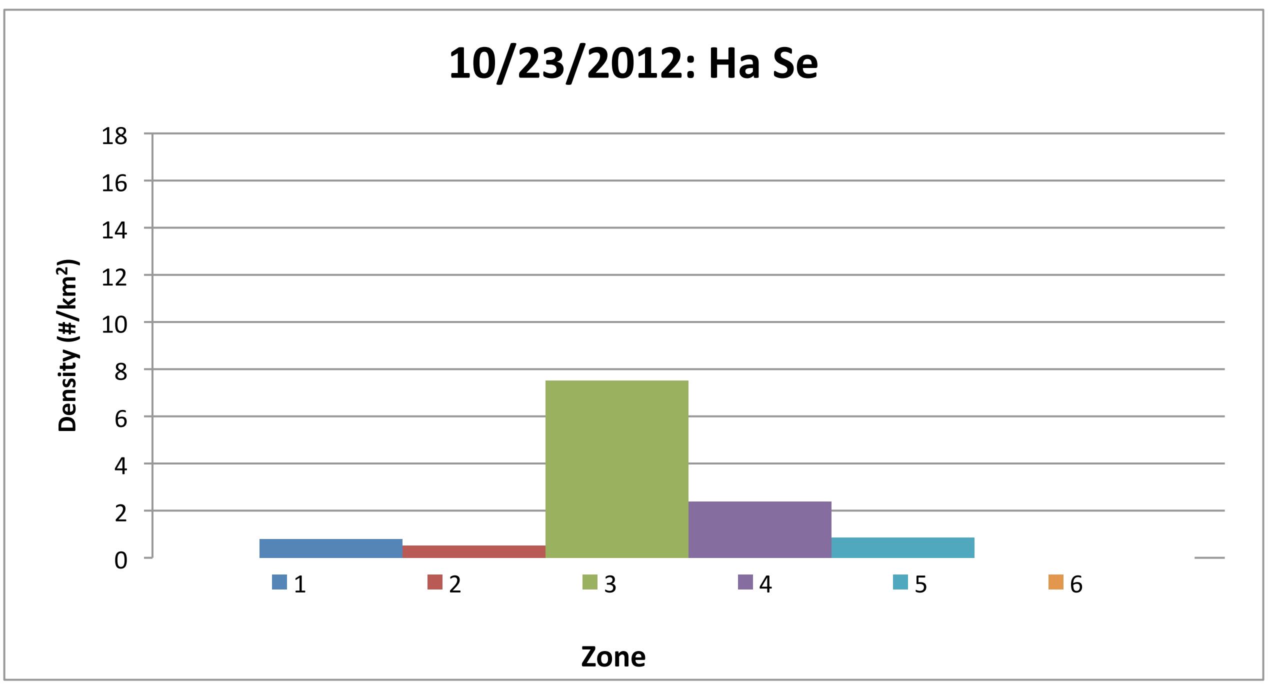

Figure 7d. Harbor Seal Distribution 10/23/2012. This day a northern pattern was observed.

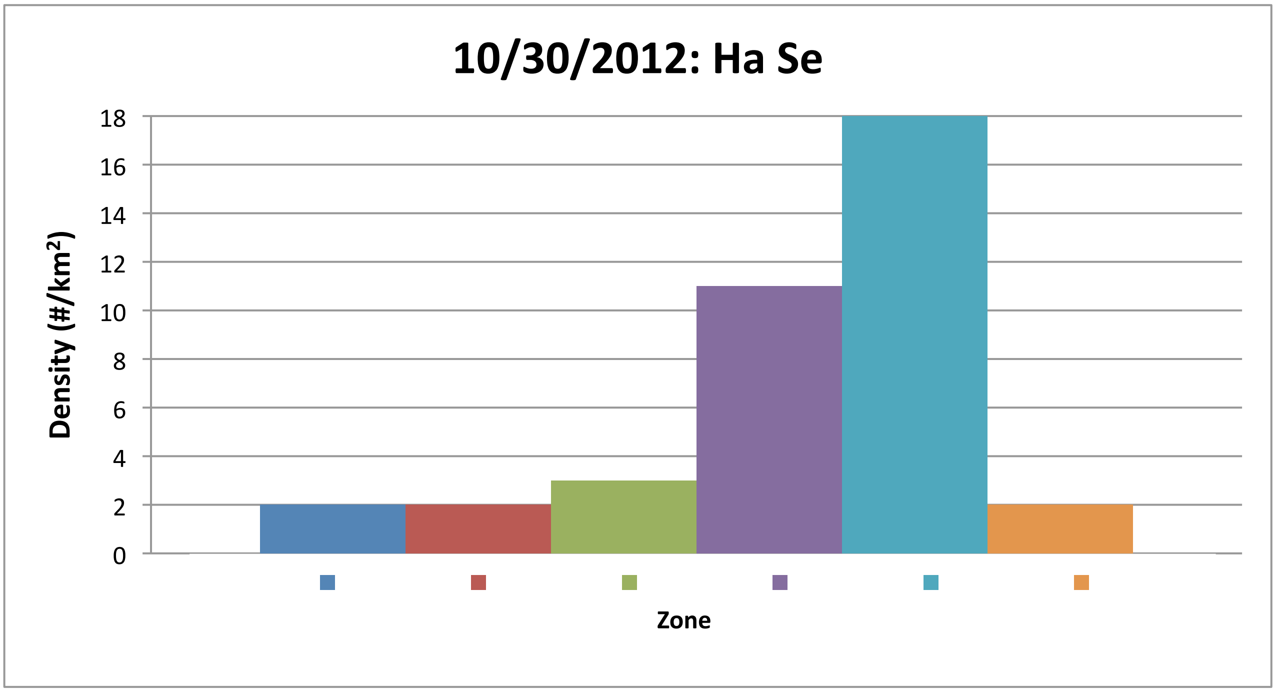

Figure 7e. Harbor Seal Distribution 10/30/2012. On this day a southern pattern was observed.

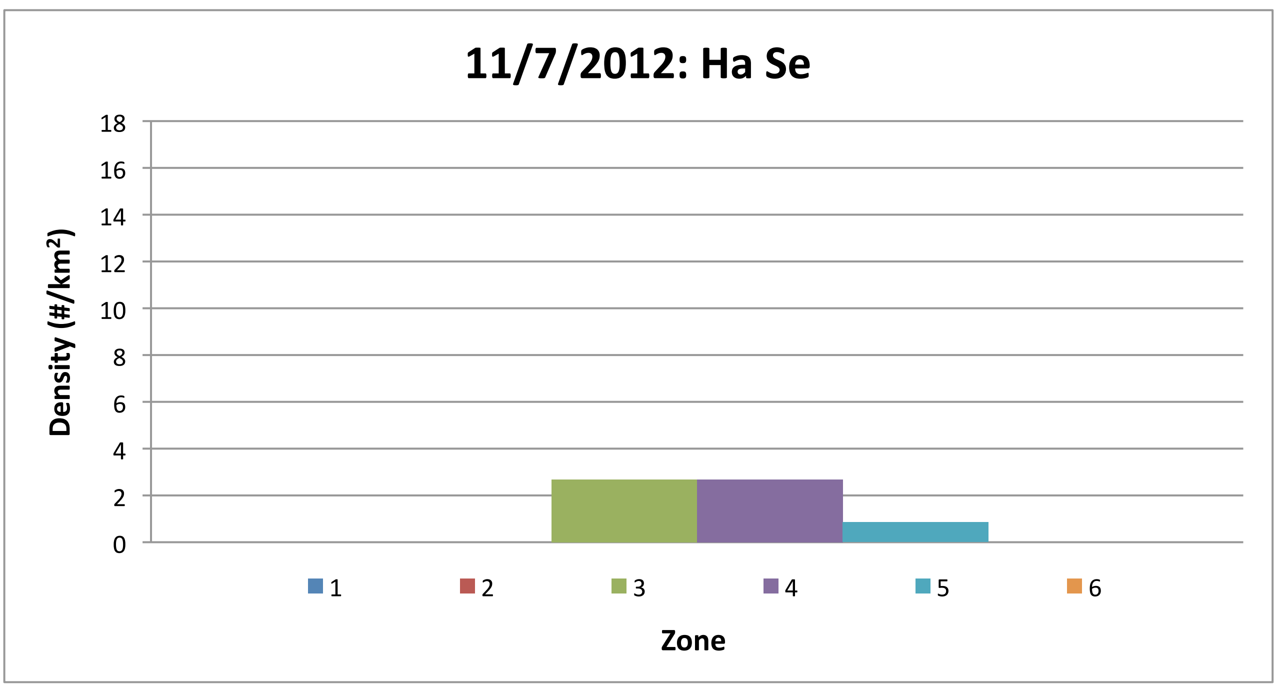

Figure 7f. Harbor Seal Distribution 11/7/2012. This graph shows a northern pattern.

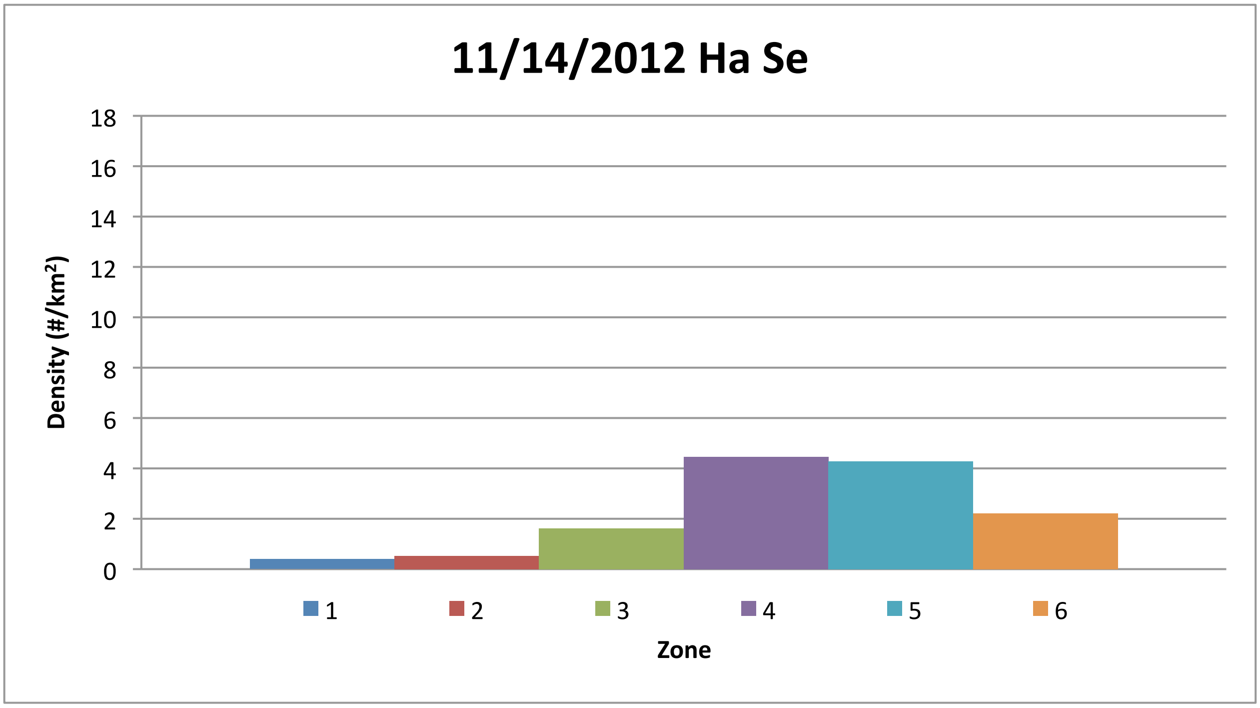

Figure 7g. Harbor Seal Distribution 11/14/2012. This graph shows a southern pattern for this day.

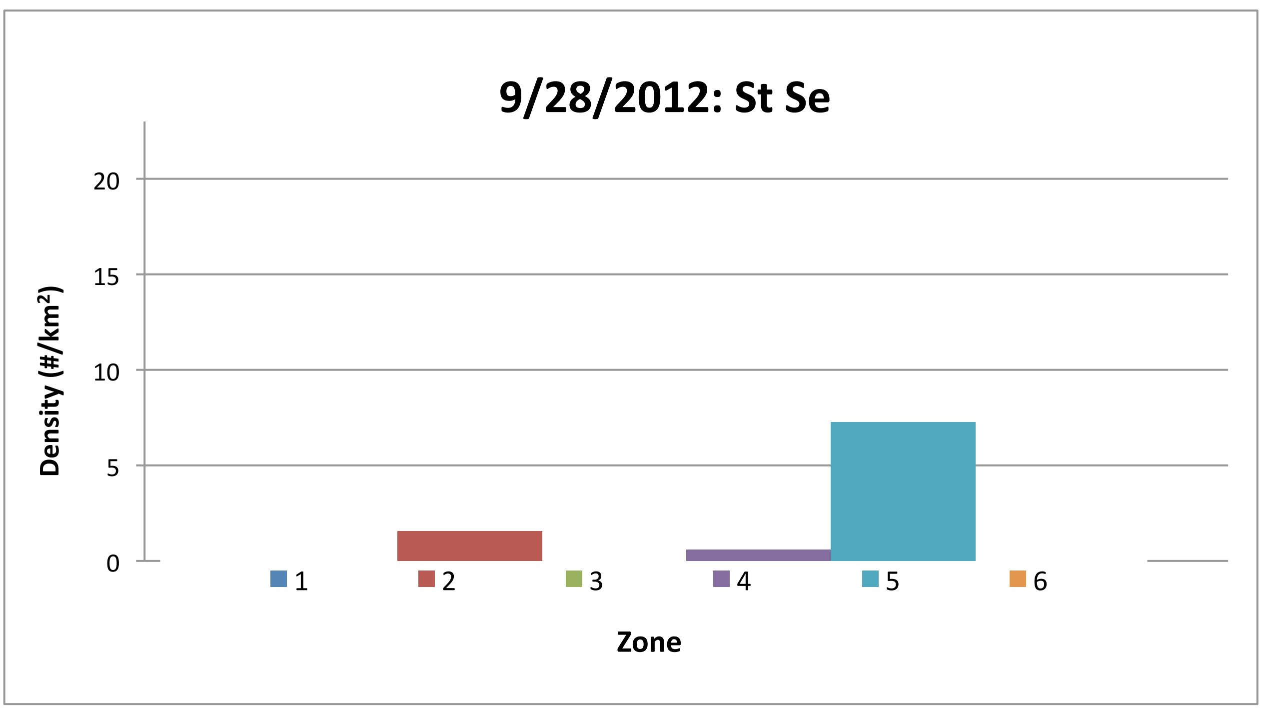

Figure 8a. Steller Sea Lion Distribution 9/28/2012. These graphs show the distribution of Steller sea lions throughout the San Juan Channel each week on the Centennial cruises. Each graph is averaged with the two transects taken on each day.

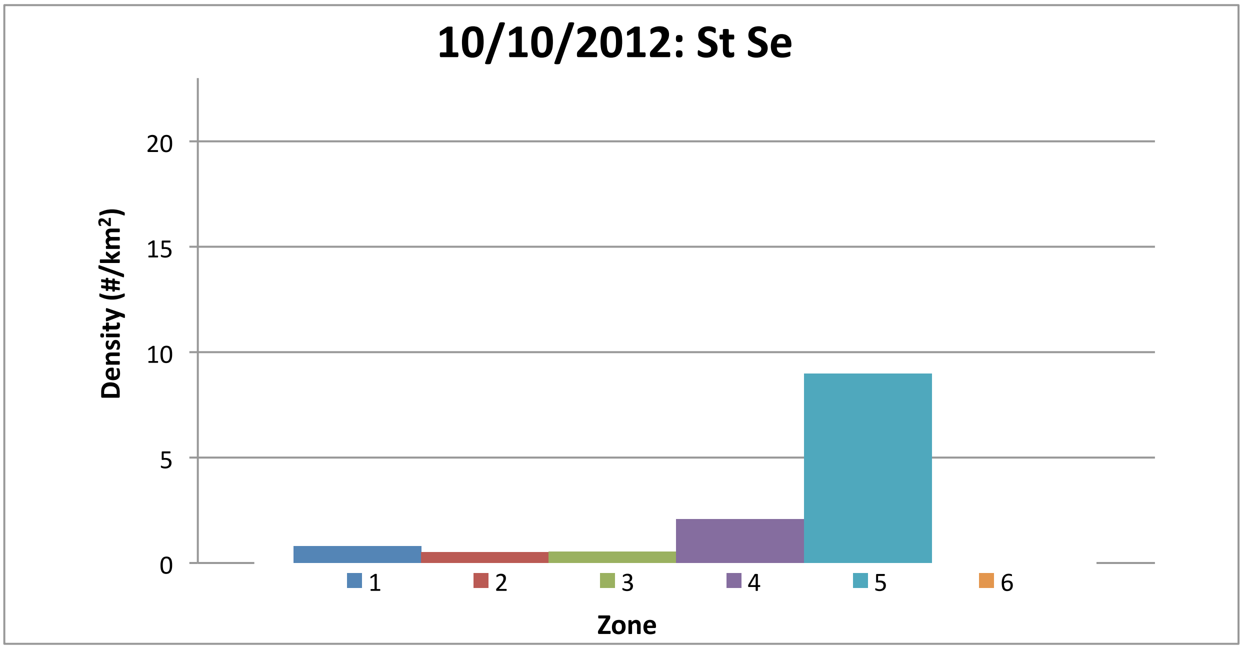

Figure 8b. Steller Sea Lion Distribution 10/10/2012.

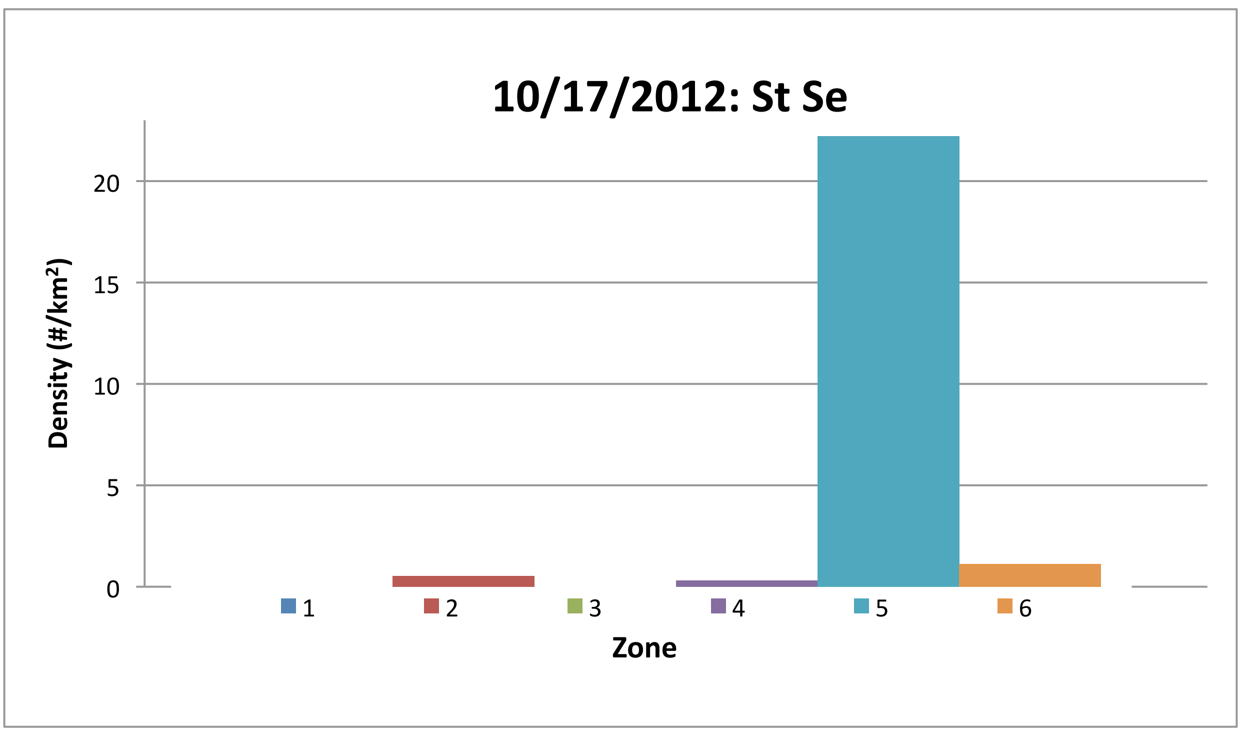

Figure 8c. Steller Sea Lion Distribution 10/17/2012.

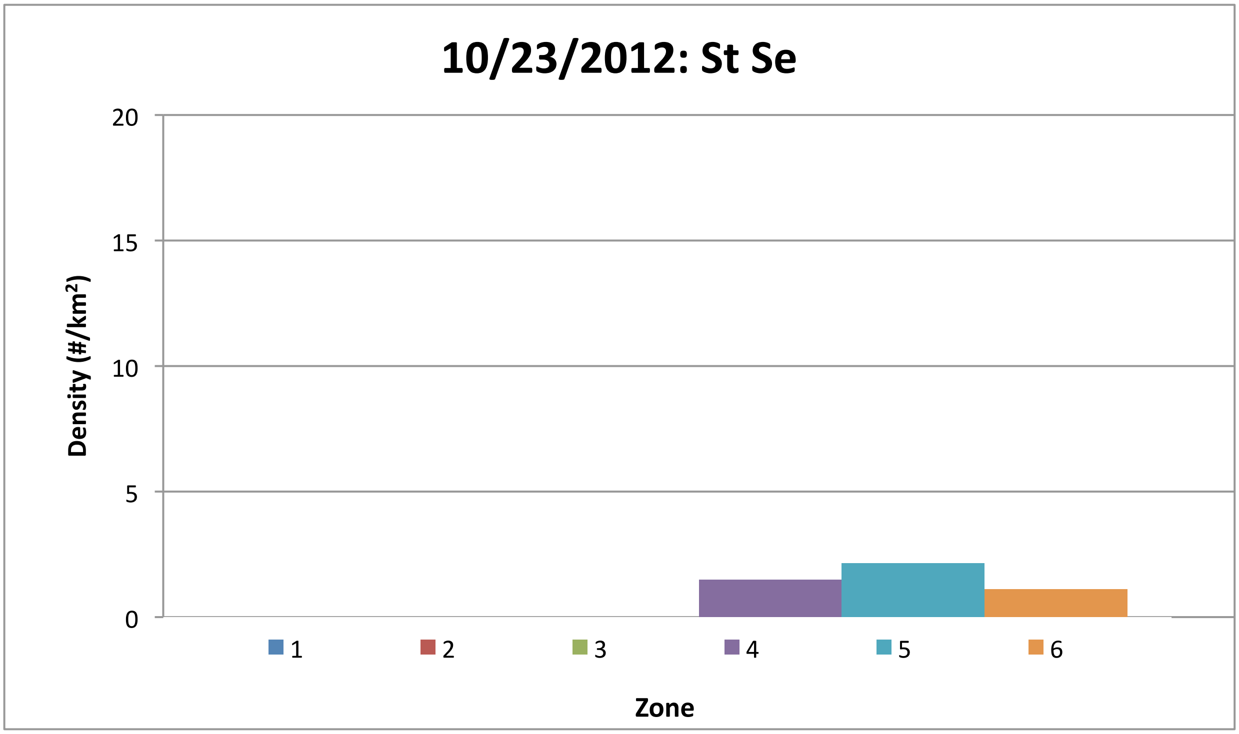

Figure 8d. Steller Sea Lion Distribution 10/23/2012.

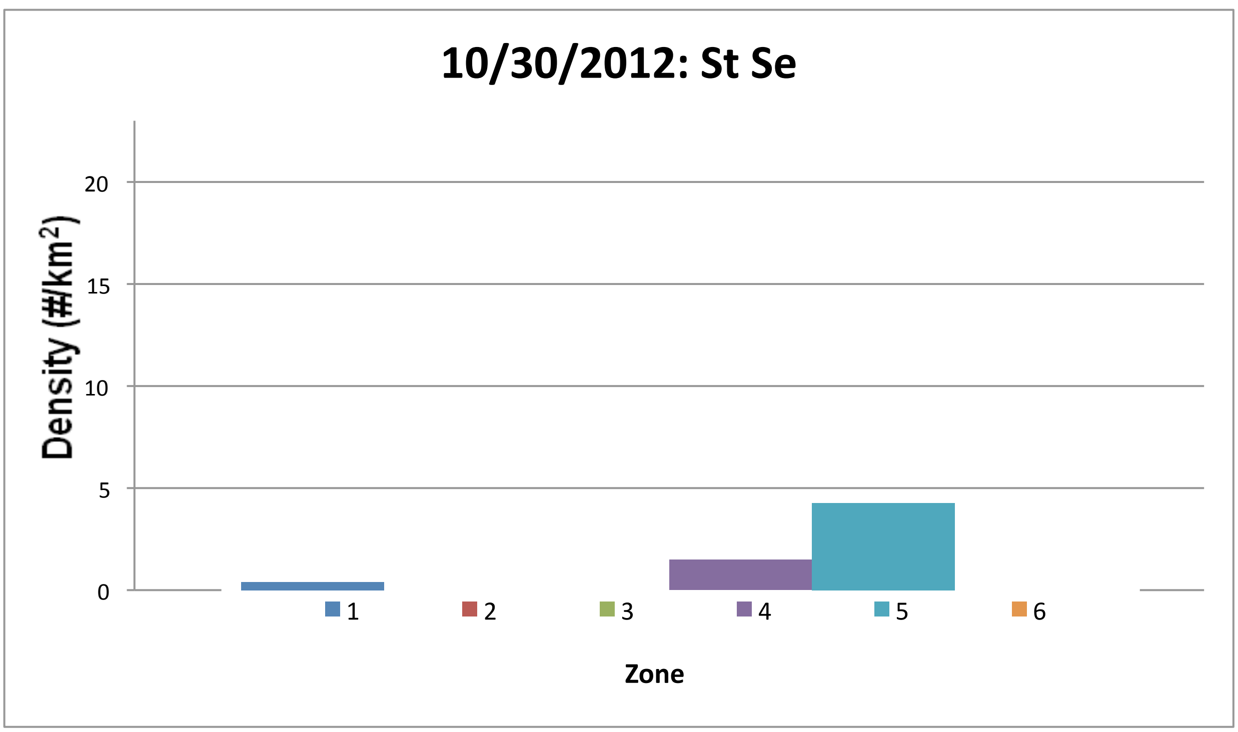

Figure 8e. Steller Sea Lion Distribution 10/30/2012.

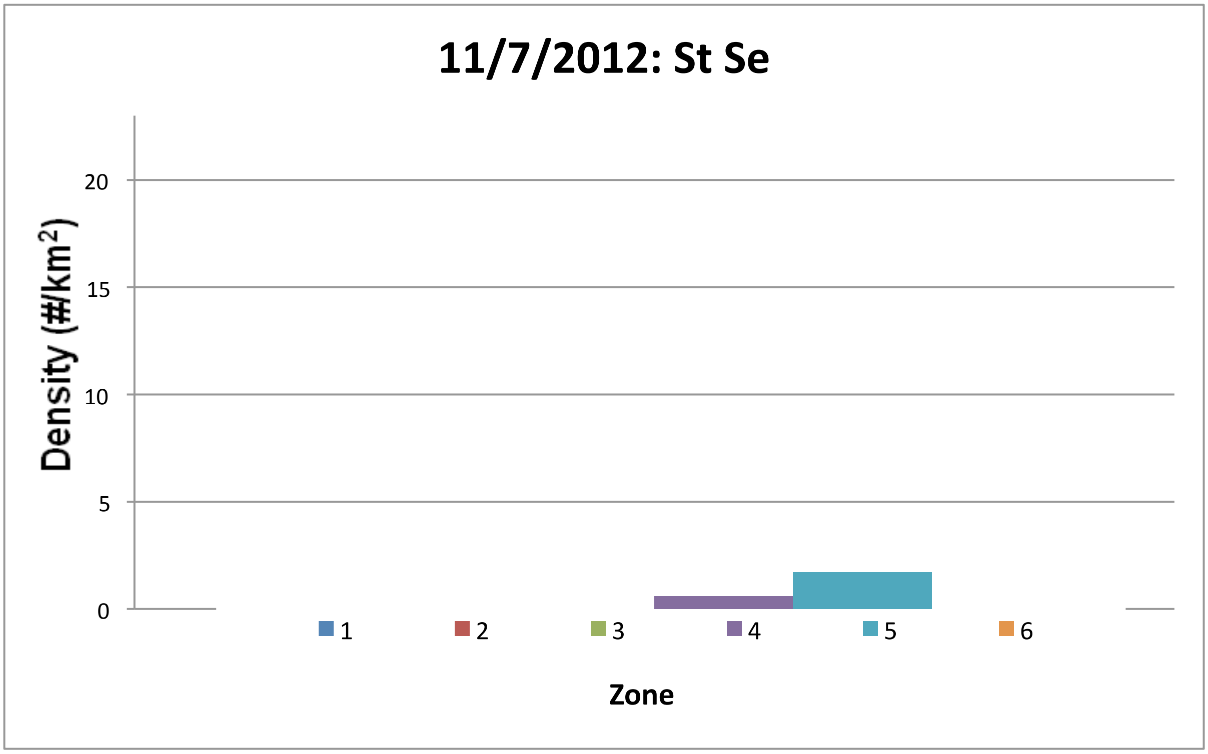

Figure 8f. Steller Sea Lion Distribution 11/7/2012.

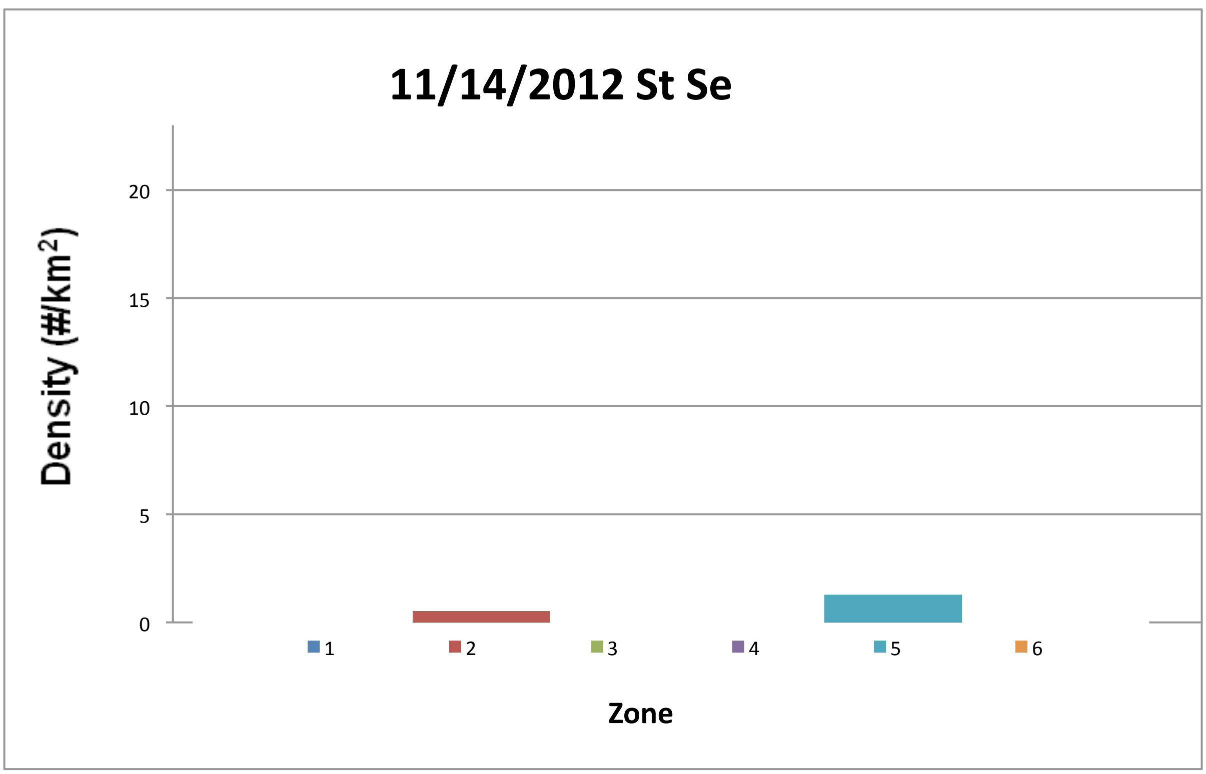

Figure 8g. Steller Sea Lion Distribution 11/14/2012.

Table 1. Harbor Seal Pattern and Tides. This table shows each date transects were taken on the Centennial, which pattern was reflected on that day for harbor seals, what the tidal direction was, and whether or not it was a Spring or Neap tide.

Date	Pattern	Tide Direction	Spring/Neap
28-Sep	South	Slow Ebb - Fast Flood	Spring
10-Oct	North	Fast Flood - Slow Ebb	Neap
17-Oct	South	Fast Ebb - Slow Flood	Spring
23-Oct	North	Fast Flood - Fast Ebb	Neap
30-Oct	South	Fast Ebb - Fast Flood	Spring
7-Nov	North	Fast Flood - Fast Ebb	Neap
14-Nov	South	Fast Ebb - Slow Flood	Spring

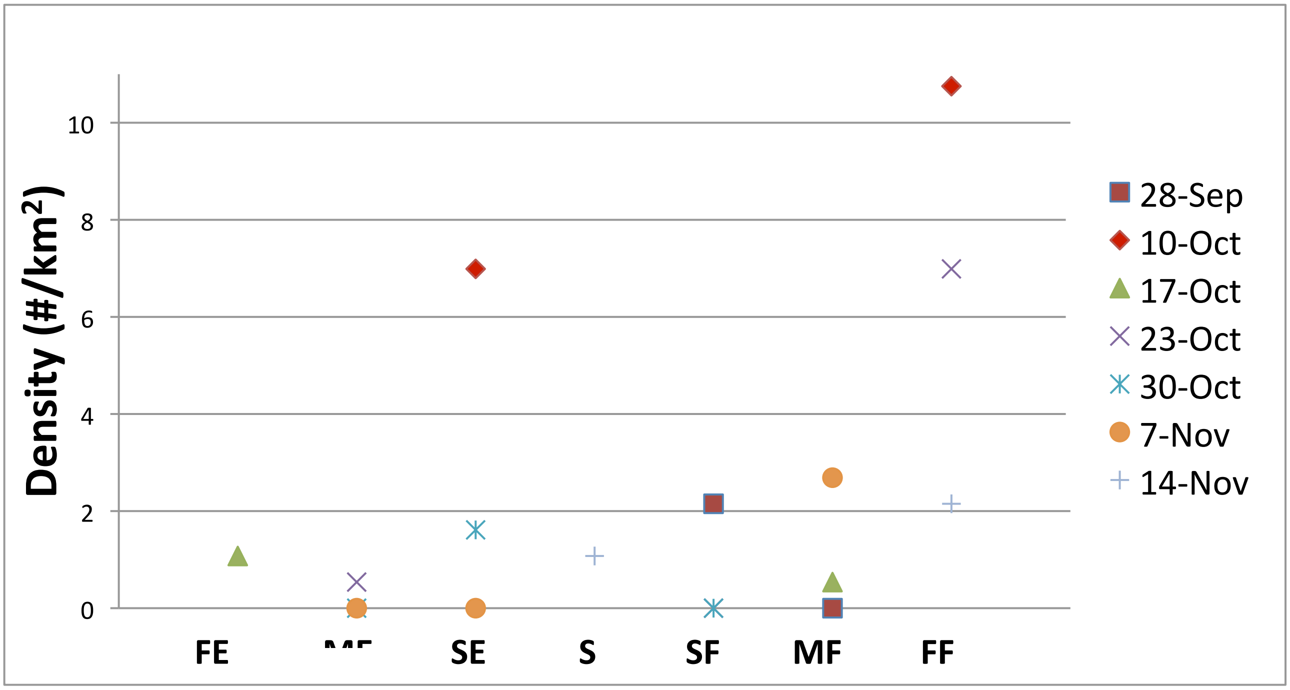

Figure 9a .Current Speed/Direction and Abundance for Harbor Seals in Zone 3. For each transect on the Centennial cruise the average current speed and direction were determined and compared to the average abundance of harbor seals throughout Zone 3 of that transect.

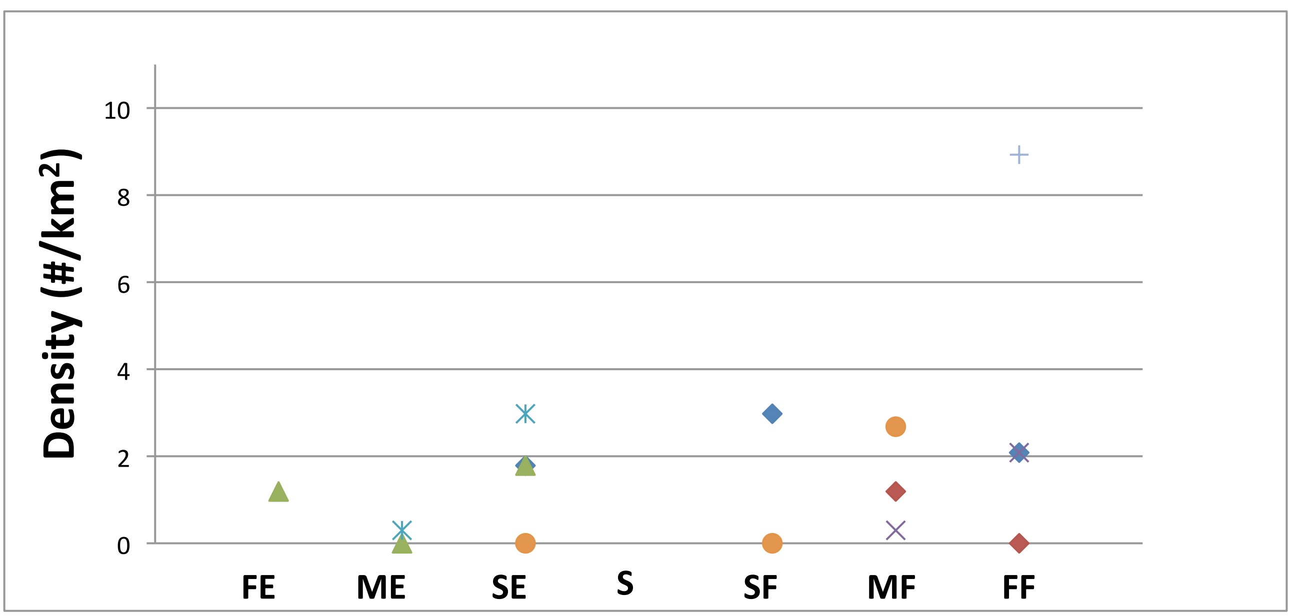

Figure 9b .Current Speed/Direction and Abundance for Harbor Seals in Zone 4. For each transect on the Centennial cruise the average current speed and direction were determined and compared to the average abundance of harbor seals throughout Zone 4 of that transect.

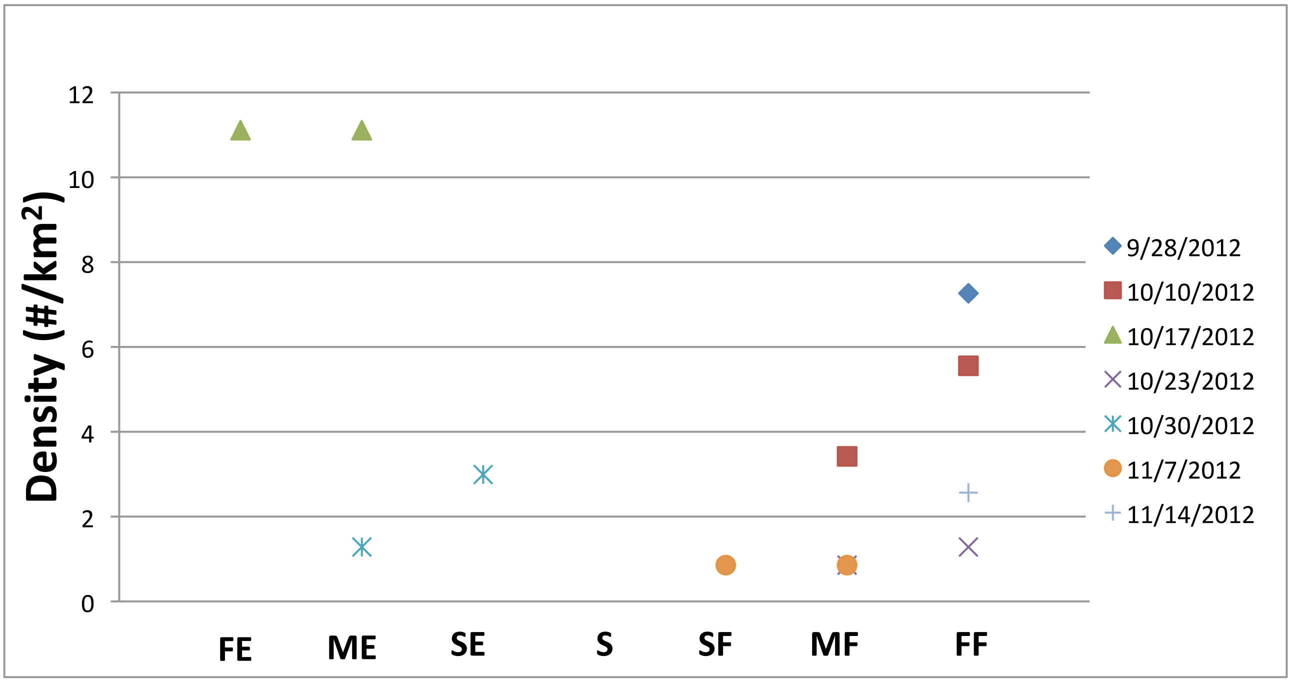

Figure 10 .Current Speed/Direction and Abundance for Stellers. For each transect on the Centennial cruise the average current speed and direction were determined and compared to the average abundance of Steller sea lions throughout Zone 5 of that transect.

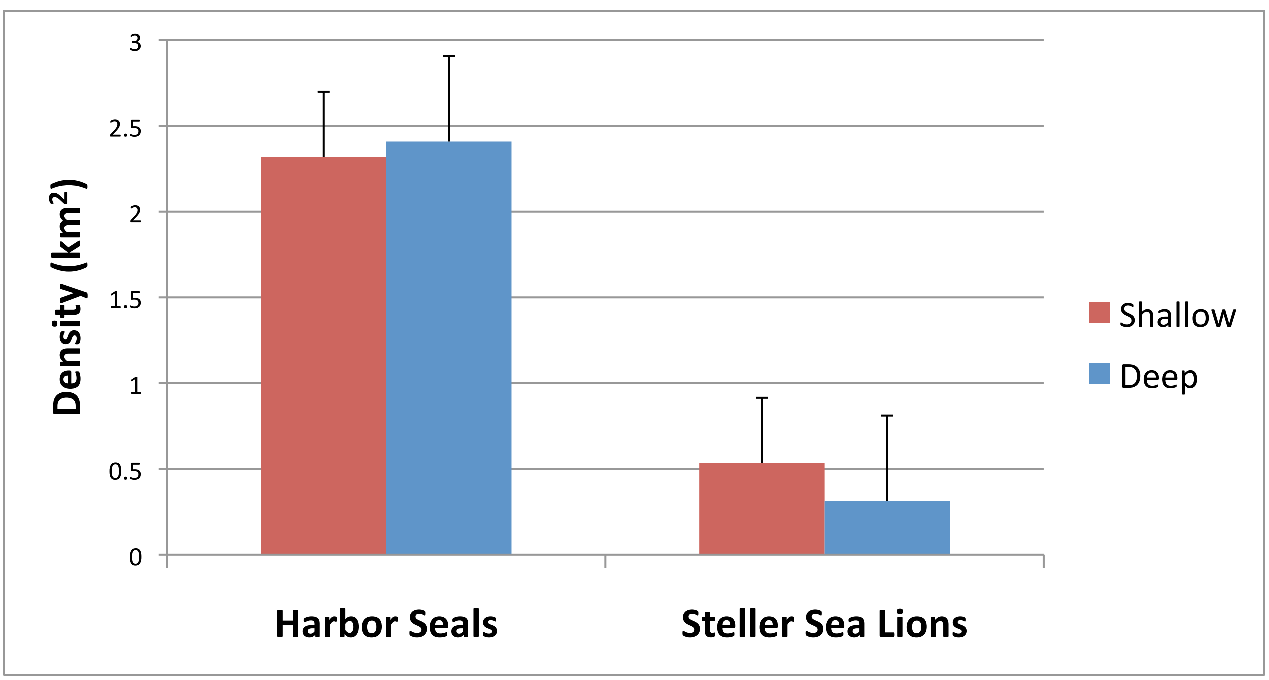

Figure 11. Bathymetric Preference for Pinnipeds in Fall 2012. This graph shows the average densities of pinnipeds throughout all small boat transects.

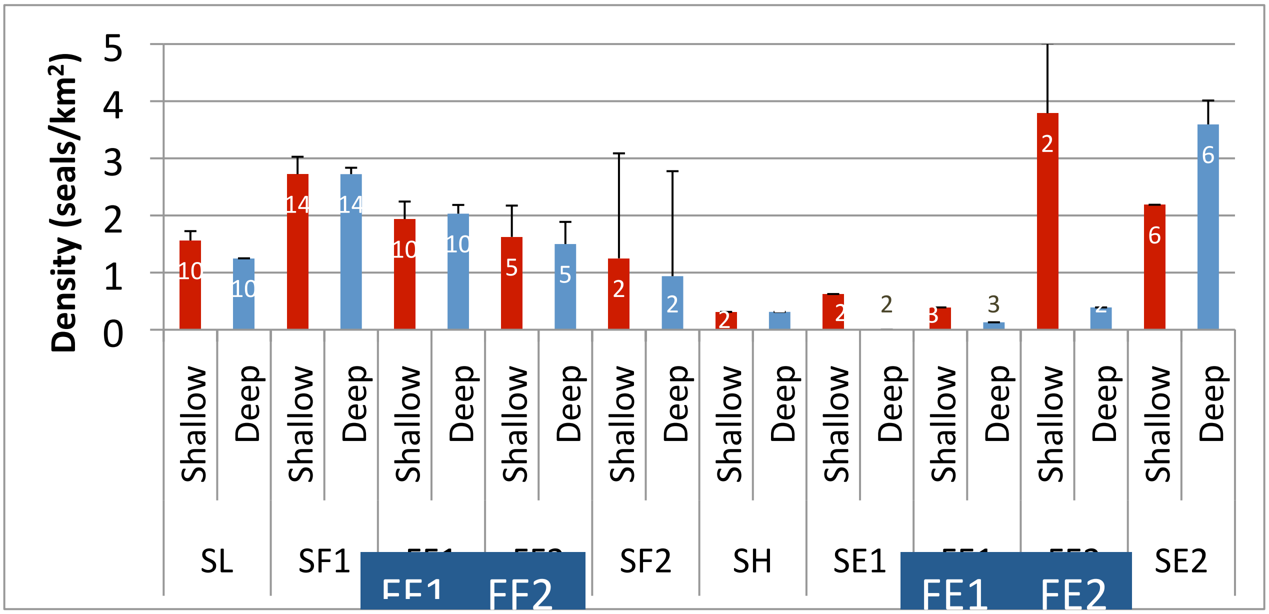

Figure 12. Bathymetric Preference of Harbor Seals throughout Tidal Cycle. This graph shows the average densities of harbor seals throughout the tidal cycle from slack low to slow ebb two. Red bars indicate average densities in shallow water while blue represents average densities in deep water. The numbers inside each bar represent the number of transects averaged for that tidal phase.

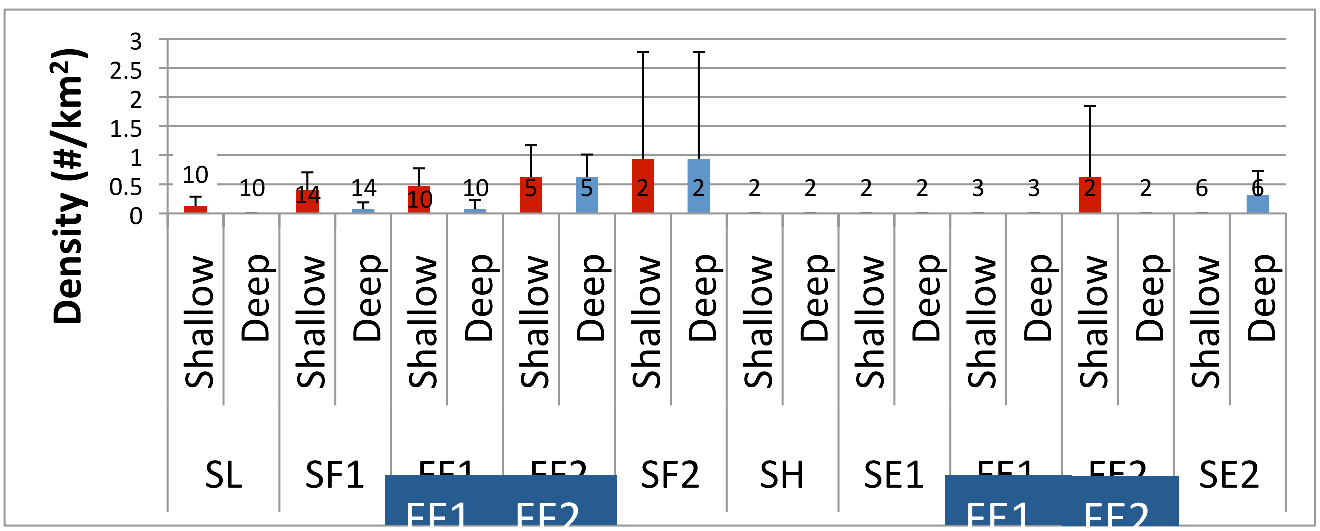

Figure 13. Bathymetric Preference of Steller Seal Lions throughout Tidal Cycle. This graph shows the average densities of Steller sea lions throughout the tidal cycle from slack low to slow ebb two. Red bars indicate average densities in shallow water while blue represents average densities in deep water. The numbers inside each bar represent the number of transects averaged for that tidal phase.

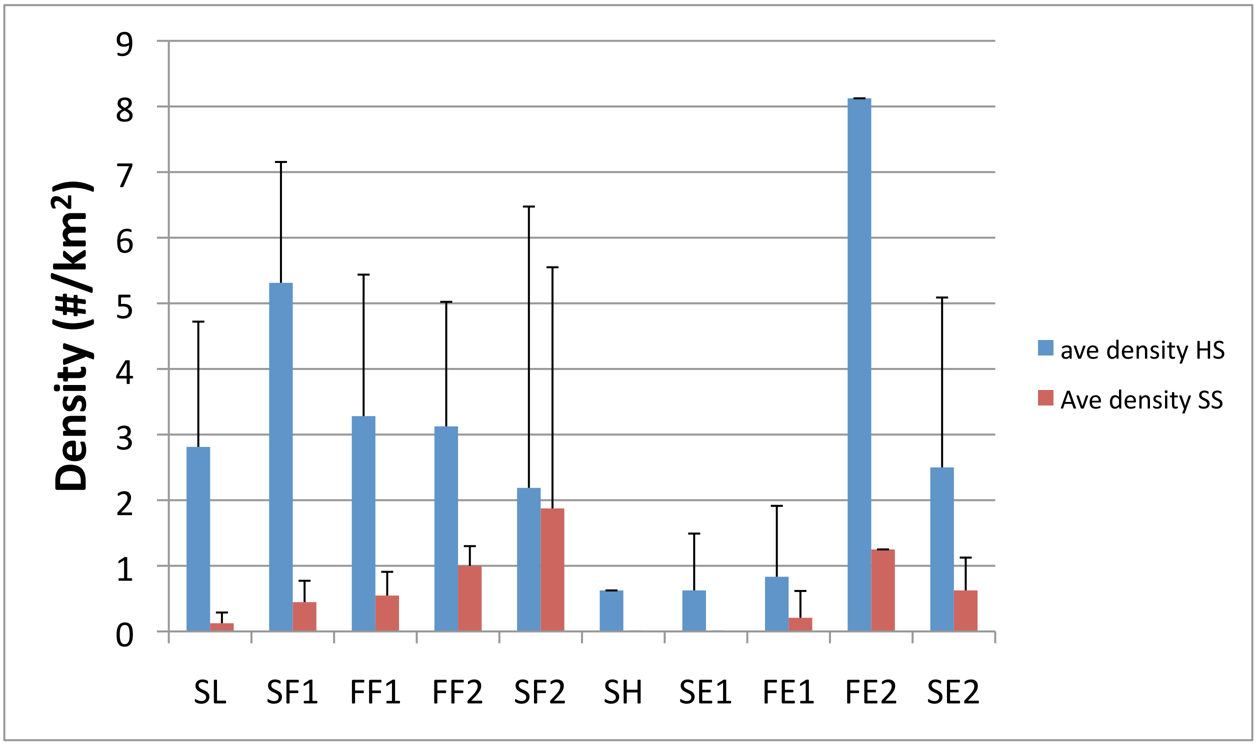

Figure 14. Abundance of Pinnipeds throughout Tidal Cycle. This graph shows the average densities of harbor seals and Stelelr sea lions throughout the tidal cycle from slack low to slow ebb two. The numbers inside each bar represent the number of transects averaged for that tidal phase.

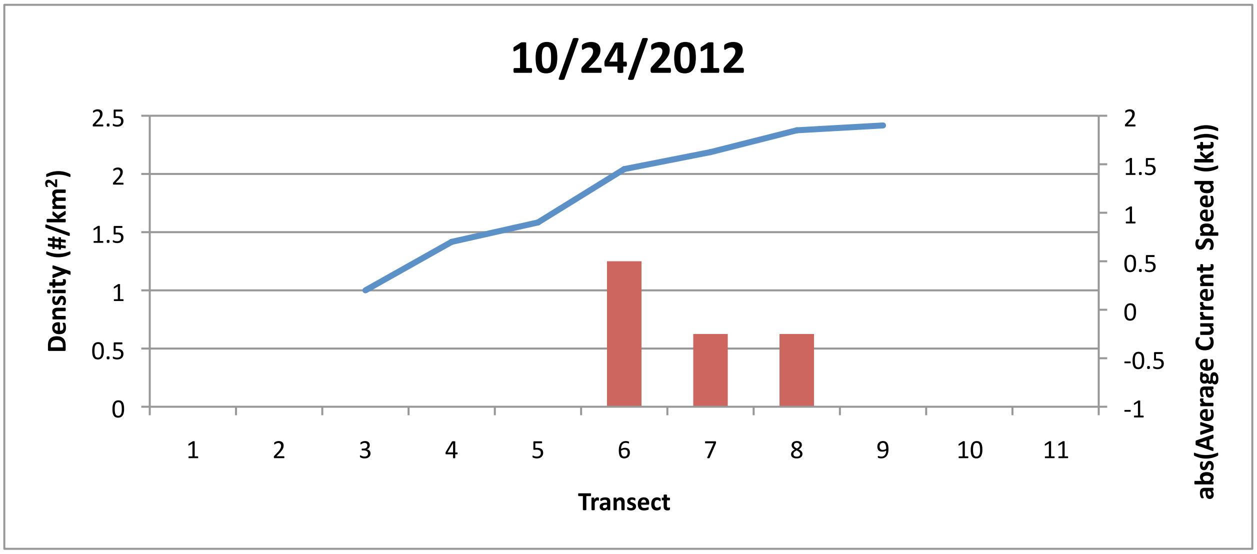

Figure 15a. Average Current Speed and Steller Sea Lion Abundance 10/24/2012. These graphs show the parts of the tidal phase split up evenly every 30 minutes by transect with average current speed at that time and abundance of sea lions. All these days had similar tidal conditions and the first three were consecutive days. Each graph is going from a slow ebb to a fast flood where 1 represents slow ebb 2, 2 is slack low, 3 through 5 are slow flood 1, 6 through 9 are fast flood 1 and 2, and 10 and 11 are slow flood 2. The blue bars show the density of sea lions during that transect and the red line shows the average current speed throughout each transect. Areas where there is a red line showing current speed are the times when we sampled. Empty spaces beyond or before the red line were created so the graphs matched up.

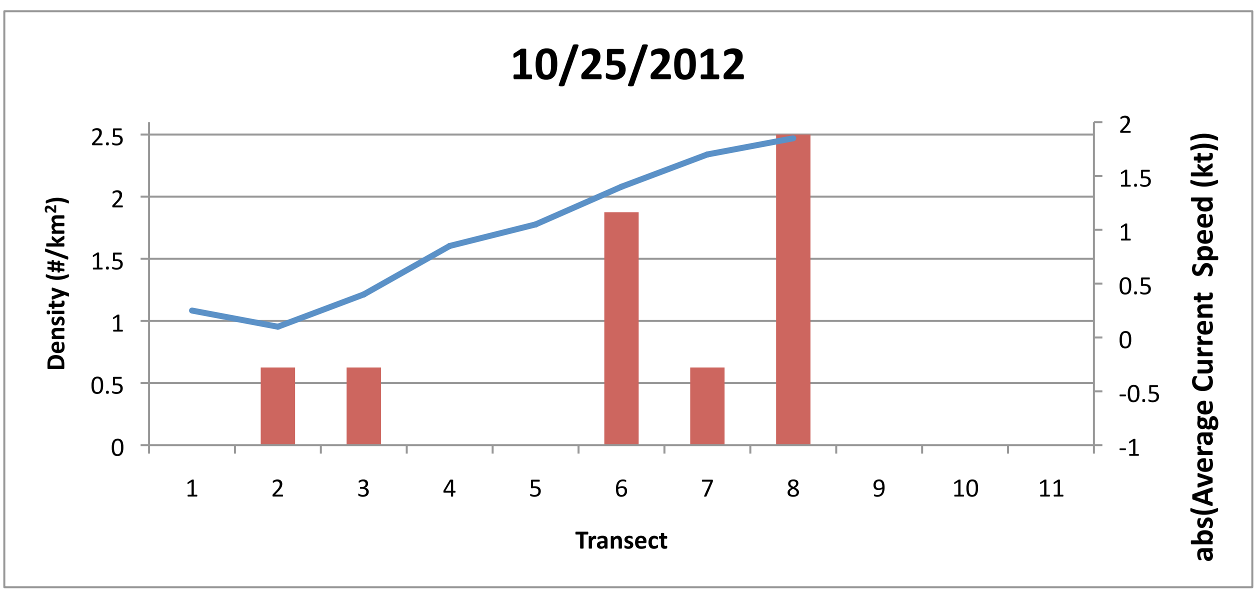

Figure 15b. Average Current Speed and Steller Sea Lion Abundance 10/25/2012.

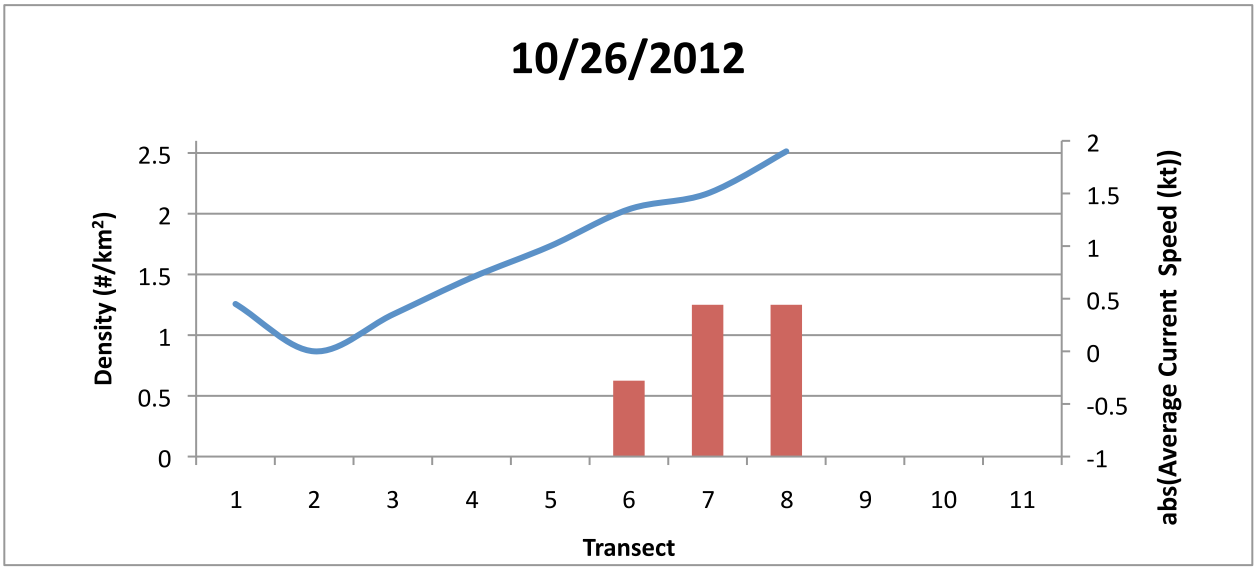

Figure 15c. Average Current Speed and Steller Sea Lion Abundance 10/26/2012.

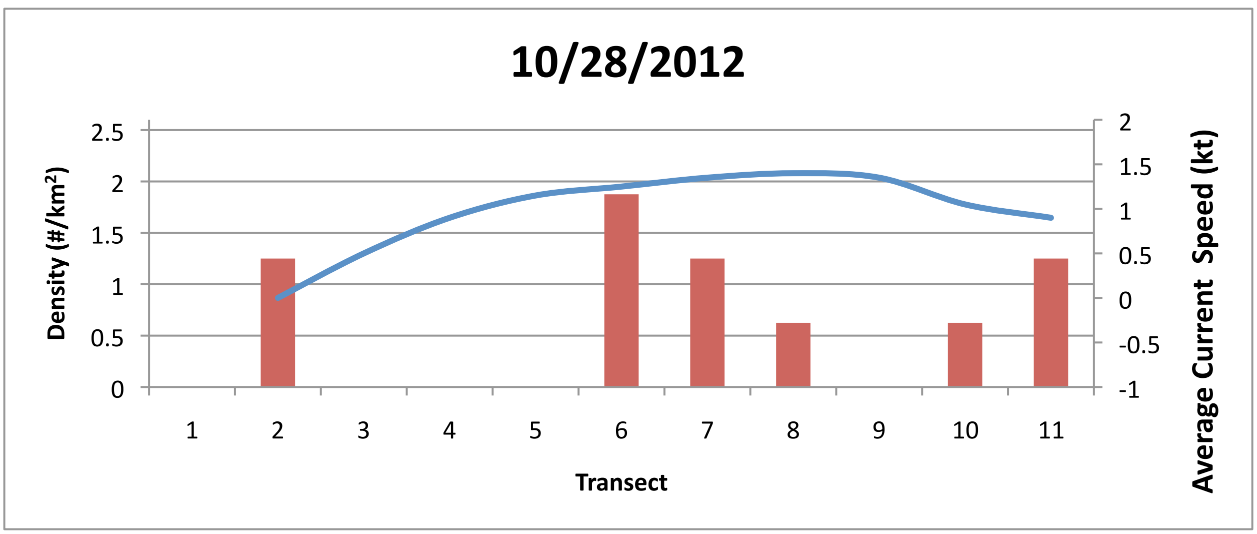

Figure 15d. Average Current Speed and Steller Sea Lion Abundance 10/28/2012.

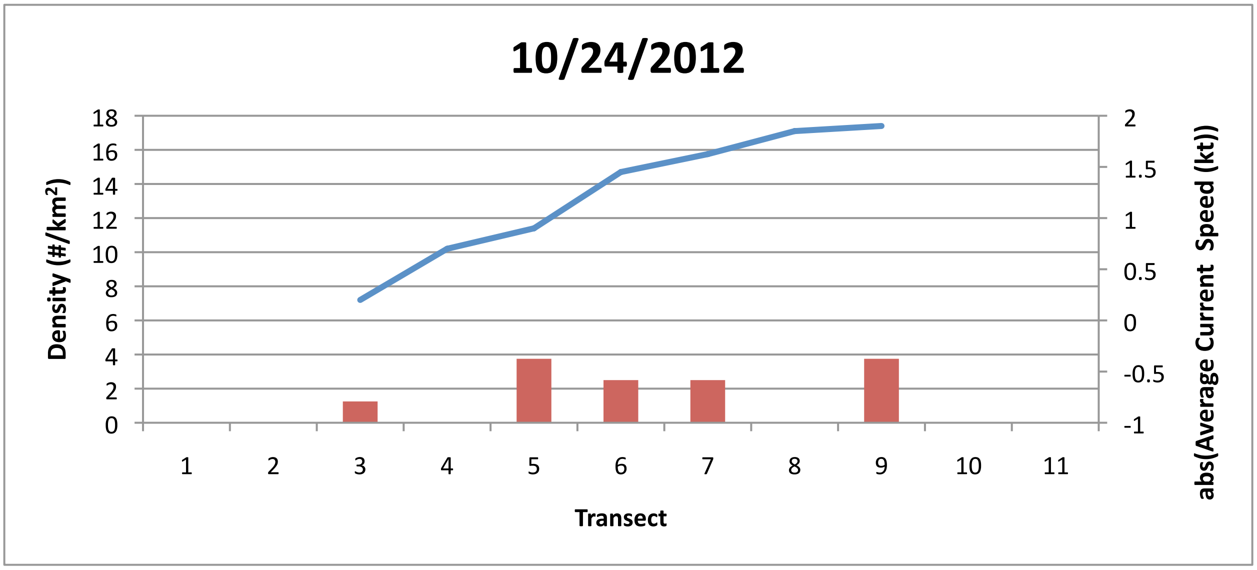

Figure 16a. Average Current Speed and Harbor Seal Abundance 10/24/2012. These graphs show the parts of the tidal phase split up evenly every 30 minutes by transect with average current speed at that time and abundance of harbor seals. All these days had similar tidal conditions and the first three were consecutive days. Each graph is going from a slow ebb to a fast flood where 1 represents slow ebb 2, 2 is slack low, 3 through 5 are slow flood 1, 6 through 9 are fast flood 1 and 2, and 10 and 11 are slow flood 2. The blue bars show the density of seals during that transect and the red line shows the average current speed throughout each transect. Areas where there is a red line showing current speed are the times when we sampled. Empty spaces beyond or before the red line were created so the graphs matched up.

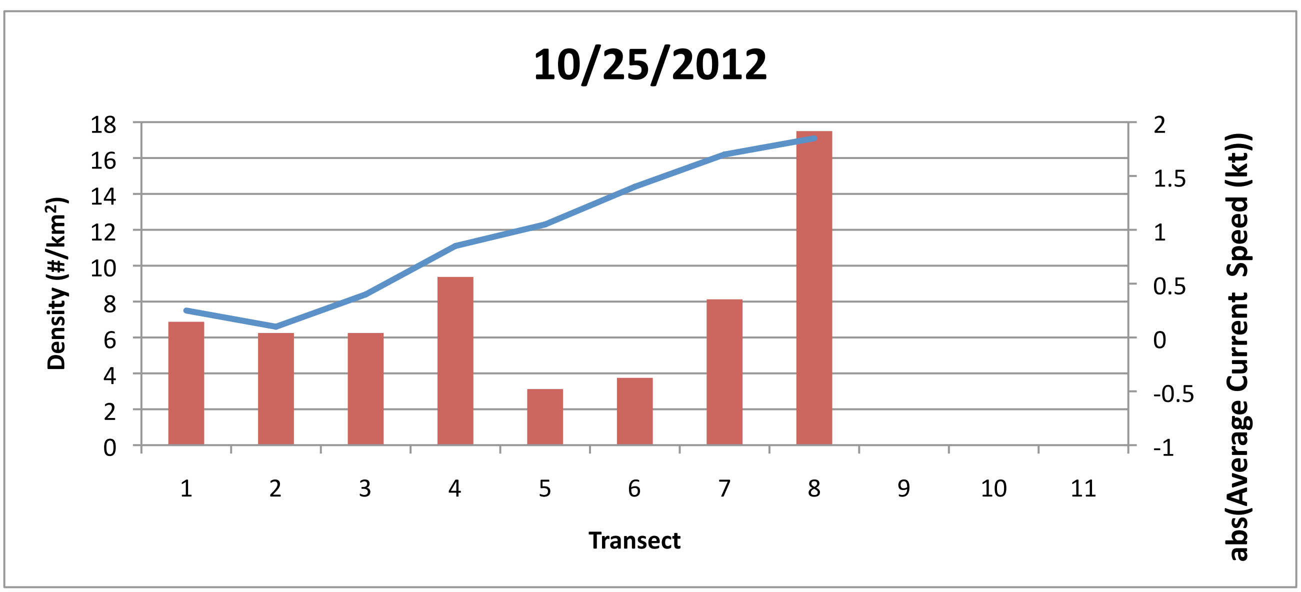

Figure 16b. Average Current Speed and Harbor Seal Abundance 10/25/2012.

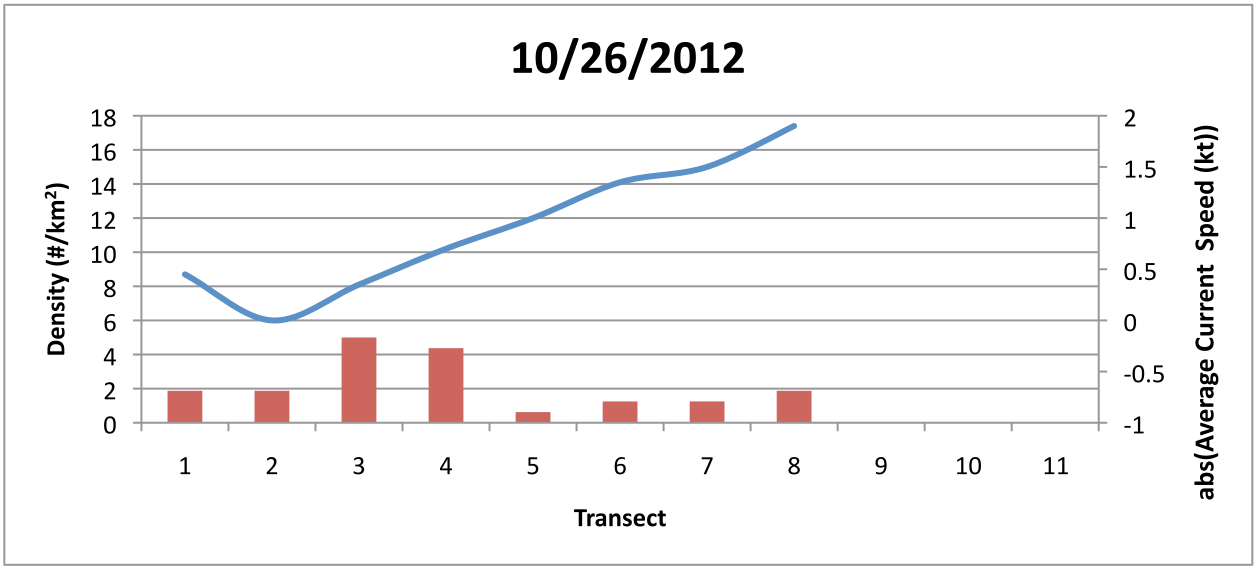

Figure 16c. Average Current Speed and Harbor Seal Abundance 10/26/2012.

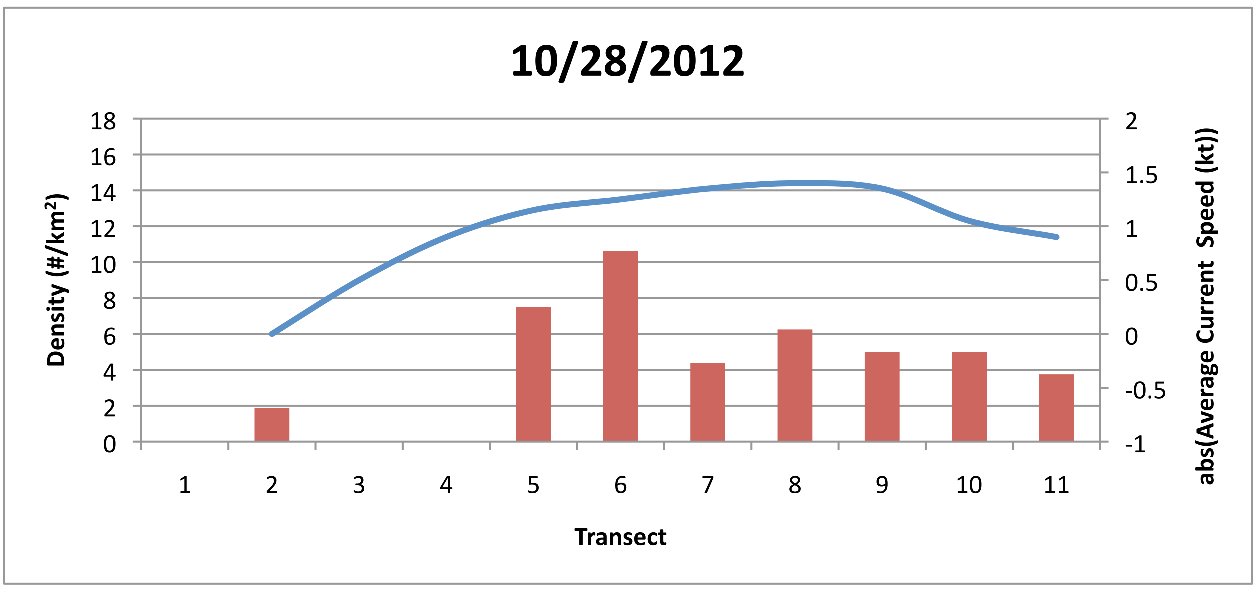

Figure 16d. Average Current Speed and Harbor Seal Abundance 10/28/2012.

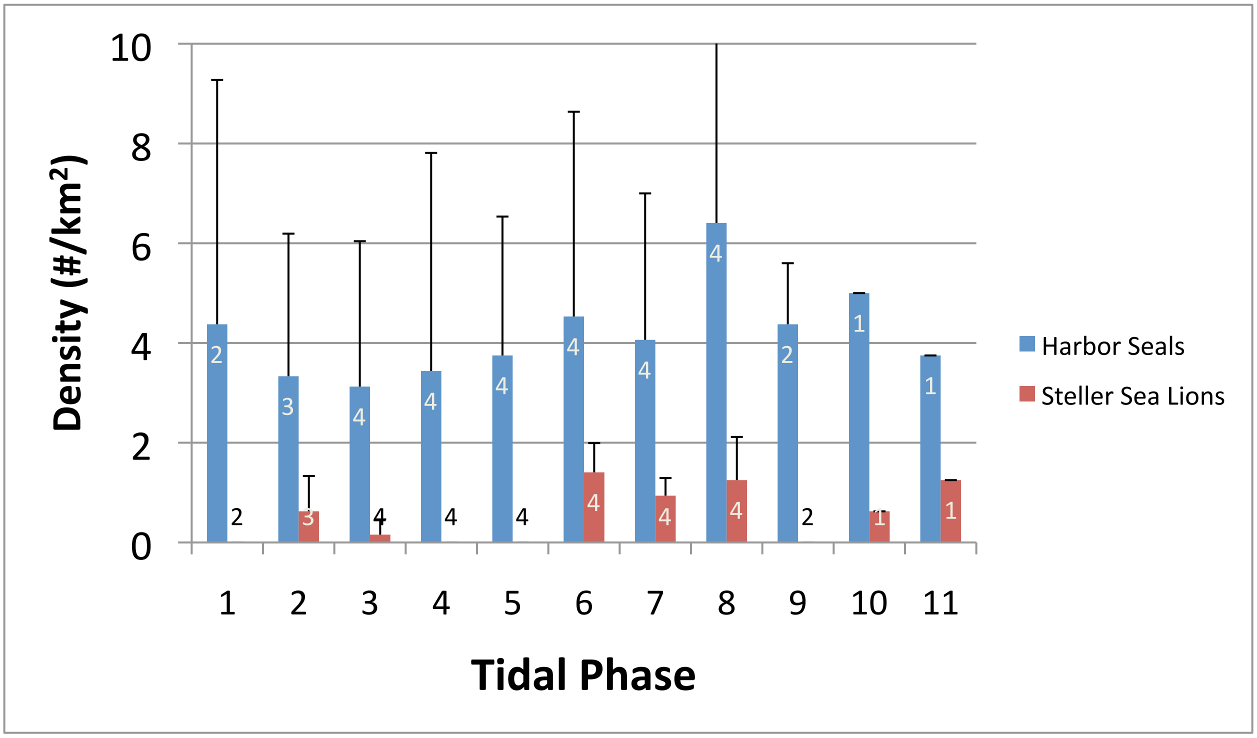

Figure 17. Pinnipeds and Tidal Phase. This is a graph of both harbor seal and Steller sea lion average abundances over a tidal phase from slow ebb 2 through slow flood 1. These are averages from the graphs in Figures 15 and 16 over the four days of similar tidal conditions.