

Habitat preference of the Pacific Sand Lance
(*Ammodytes hexapterus*) in the San Juan Channel in
the fall: 2014 season and interannual comparison
2012-2014

Kailee Bynum

Fall 2014

Pelagic Ecosystem Function Apprenticeship, University of Washington

Email: bynumk@myuw.net

Keywords: Sand lance, sediment, San Juan Channel,

Abstract:

Previous studies have found that the Pacific Sand Lance prefer to bury into sediment that is mainly composed of coarse sand and low gravel. This study explored whether that was the case for sand lance buried in the sand wave field in the San Juan Channel in fall 2014. This study also investigated trends and correlations between fish size and sediment composition and compared these results to data from fall 2012 and fall 2013 in the sand wave field. Results showed no strong relationship between fork length and sediment size but did find large fish (110mm and larger) were found in areas of very high coarse sand and low gravel, which contrasted results found in 2012. Although this research was not able to definitively associate size of fish with age, this suggests that larger fish, as a group, are using and responding to benthic habitat in ways that are common among that group but distinct from smaller/younger fish.

Introduction:

The Pacific sand lance are an integral part of the pelagic ecosystem of the San Juan Channel. According to Robards, M., Willson, M., et. al (1999), sand lance are an important food source for “40 species of birds, 12 species of marine mammals, 45 species of fishes, and some invertebrates.” They have a high lipid content, making them optimal prey for predators (Van Pelt, 1997), especially for nestling of Rhinoceros Auklet (Bertram & Kaiser, 1993). Therefore, it is an important fish to study as its population and abundance affects much of the ecosystem in the Salish Sea.

The Pacific sand lance has developed a behavioral strategy for avoiding predation. They feed at dawn and dusk in the water column, and then bury into the sediment during the night (Hobson, 1986). Sand Lance lack a swim bladder, which makes for a higher energy expenditure when swimming in the water column, but allows them to bury into the sediment with less resistance (Cianelli, 1997). This morphology trait facilitates their behavioral strategy. In late fall/early winter, the sand lance bury

into the sediment till spring (Healy, 1984). This dormancy period had been shown to be occur when there is a low abundance of food available (Pearson, Woodruff, & Sugarman, 1983).

The Pacific sand lance has a range from Southern California to Alaska and Japan (Robards, M., Willson, M., et. al,1999). A study done by Green (2011) identified areas around the San Juan Channel where sand lance may be present. The main area sampled for Pacific sand lance in the San Juan Channel is an area known as the central Sand Juan Channel sand wave field. It is located between Pear Point on San Juan Island and Lopez Island and has a depth of 60-80mm (Green 2011). It has been shown that sand lance prefer sediment composition of a high percentage of coarse sand and a low percentage of gravel (Green, 2011).

Studying this forage fish's unique behavior is important because the sand lance has been shown to influence their predators, like humpback whales diel behavior (Friedlaender et. al., 2009). More knowledge is needed about the sand lance relationship to the sediment, as one study found that oil contamination in sediment could have detrimental affects on sand lance health and on their ability to stay buried in sediment (Pearson, Woodruff, & Sugarman, 1983). Therefore, knowing what types of sediment sand lance prefer is an important first step in knowing how environmental factors might affect sand lance population. Since sand lance play such a large role in the health of the pelagic ecosystem In the Salish Sea, it is important to understand the factors that influence their population and abundance.

This study examined the sand lance in fall 2014 in the central San Juan Channel sand wave field, looking at the substrate composition sand lance were burying into to determine if sand lance of different sizes preferred different sediment compositions. These results were compared to previous results collected by two different studies, one in fall 2012 (Thomson) and 2013 (Lopez).

Methods:

Sediment was collected from the central San Juan Channel sand wave field. A Van Veen was dropped from the *R/V Centennial* or the small motor boat, *Auklet*, directly over the sand wave field. The app, NAVIONICS, was used for fine scale mapping. Sampling was done in areas where sand lance had previous been found. The Van Veen was pulled up and classified as either successful or unsuccessful. A successful grab was classified as a fully closed grab with no sediment leakage. An unsuccessful grab was classified as a grab where the trap did not fully close, thus sediment was lost. The collection of sediment in grabs that have fish present as well as those without fish would enable a comparison and contrast between sediments that represent suitable habitat and those sediments that do not support fish. In 2014, sediment was only kept from successful grabs that had fish present. After removing all fish from the sediment, two large shovelfuls of sediment were set aside as a subsample. Later, the subsamples were taken to lab. Water was drained from the top of the sediment through a siphon with a filter on it (Fig 1, panel A). This minimalized the amount of silt lost. An amount of roughly 1800g was dried in a Precision oven for roughly 8 hours (Fig 1, panel B). Once

dry, the sample was cooled in a desiccator (Fig 1, panel C). About 1500g of the sediment was sieved by a Ro-Tap for 15 minutes (Fig 1, panel D). Each sieve size (8mm, 4mm, 2mm, 1mm, 500 μ m, 250 μ m, 125 μ m, and 63 μ m) was weighed out and classified to an explicit phi size and qualitative descriptive category using the Wentworth Scale (Williams, et. al., 2006) (Table 1). They were then binned into six categories: medium & fine gravel, very fine gravel, very coarse sand, coarse sand, medium & fine sand, and very fine sand & silt. The percentage of a sample that each category composed was calculated by taking the weight of each category and dividing it by the total sample sieved.

Fish Processing

Sand lance caught by the Van Veen were euthanized using MS222. Fish were preserved in a 10% buffered Formalin solution, ten minutes after the last gill movement. At the lab, fish were processed in a hood, using a caliper to obtain total and fork length. A scale measuring to the closest 0.1g was used to obtain the wet weights. Dry weight was measured after the fish were dried in a hood for approximately four hours. Any fish that were decomposing or damaged by sampling were not processed.

Results:

Eighty-six grabs were taken in total. Out of these grabs, twenty were incomplete, ten were complete, but no fish were present, and fifty-six were complete grabs with at least one fish present. Overall, 605 fish were caught. Size of the fish ranged from 61mm to 139mm with the mean fork length being 85mm \pm 10 SD.

This study examined if sand lance prefer certain sediment compositions. Preference was determined by examining the sediment composition fish were found in and the relative abundance of fish in different sediment types, accounting for sampling effort. CPUE (Catch per Unit Effort) measures the amount of fish caught per a standard unit of effort. In the case of sampling fish in the sediment using a Van Veen grab, each deployment of the Van Veen grab sampled a standard planar area of the seafloor, therefore a standard area or effort. This allowed us to treat each independent grab as a standard unit of effort and compare relative abundance of fish across individual grabs. CPUE was graphed out for each sediment category and an exponential decay fitted to the data (Fig. 2). There was no significant relationships between CPUE and sediment type, but there were two trend seen overall. Higher CPUEs were associated with lower gravel composition (<10%), high quantities of coarse sand (~60%), and low amounts of silt (<0.1%).

To determine overall trends in sediment affinity, each fish was examined as a separate individual associated with the sediment from an individual grab (v). For each grab, the percentage of sediment in each sediment category for each grab ($\% \phi_v$) was determined from relative weight of each sediment type to the total weight of all sediment in that particular Van Veen grab (Equation 1).

$$\% \phi_v = \frac{(S_{\phi,v})}{T_v} \cdot 100 \quad \text{Equation 1}$$

Then each fish was associated with the particular grab in which it was found and overall trends (mean \pm SD) were determined on the basis of all fish for percent sediment type.

This showed the average sediment composition of the sand lance was composed of high levels (~60%) coarse sand, medium levels (20%) of very coarse sand and medium & fine sand. Gravel made up about 5-10% of the average sediment composition (Fig 3.). This sediment composition of high composition of coarse sand, low composition of gravel and minimal silt is considered prime habitat.

To determine if different sized sand lance prefer different sediment composition, all fish were separated into age classes based on their fork length. Young of the Year were classified as having a fork length between 0-69mm, Age 1 between 70-109mm, and Age 2 & 3 were greater than 109mm. The mean phi size of each fish in an age class were plotted and a linear regression was fit to the data. Mean phi size for each Van Veen grab ($\overline{\varphi}_v$) was determined as a function of the sum across all sediment phi sizes (i to n) of the product of φ and the relative weight of sediment at that φ , divided by the overall weight of all sediment in the grab (Equation 2).

$$\overline{\varphi}_v = \frac{\sum_i^n (\varphi_i \cdot S_{\varphi,v})}{T_v} \quad \text{Equation 2}$$

Where $\overline{\varphi}_v$ is the mean phi size for Van Veen grab v , φ is the phi size for the sediment category in Van Veen (v), S is the weight of the particular sediment category φ in grab v and T is the total sediment weight within the grab v . A regression was fit between fish size and mean phi size. There was no relationship found between all the fish and $\overline{\varphi}_v$ (Fig 6). There was no significant relationship between Young of the Year and $\overline{\varphi}_v$ (Fig. 3). Similarly, there was no relationship between Age 1 fish and $\overline{\varphi}_v$ (Fig. 4). There was a significant relationship ($R^2= 0.3336$, $P = 0.039$) between Age 2 & 3 fish

and $\overline{\varphi}_v$ (Fig. 5). Only 12 fish were caught in the Age 2 & 3 class, while there were 17 Young of the year and 560 Age 1 sand lance. The low sample size in the Age 2 & 3 category may be causing the significance. From Fig 3 and Fig 4, it can be seen that there is some wider variation in the sediment compositions, while the Age 2 & 3 category (Fig 5) seem to be in areas with a high percentage of coarse sand (Phi 1).

To further examine if there was a relationship between fish size and sediment composition, a linear regression was run on all fish caught, plotted against a sediment type. There was a significant relationship ($R^2 = 0.0146$, $P = 0.0032$) between the percentage of very fine gravel and fish size. The linear relationship showed that as percentage of very fine gravel increased, the size of fish decreased (Fig 7). There was also a significant relationship ($R^2 = 0.0066$, $P = 0.048$) between fish size and the percentage of coarse sand. The linear regression showed that as the percentage of coarse sand increased, the size of fish decreased (Fig. 8).

This study compared the data collected fall 2014 to previous fall data from 2012 (Thomson) and 2013 (Lopez). Fall 2012 found that there was a strong correlation between fish size and sediment composition, while in fall 2013, there was no strong correlations found. To compare between years, the variations in the number of grabs, areas sampled, and sediment composition had to be standardized. Taking all grabs for a fall year and finding the average of the sediment collected that fall season gave a baseline. This baseline divided against each age class's average sediment composition. This yielded a ratio of each type of sediment, which allowed the years to be compared. A ratio above one suggested that the sand lance were selecting higher amounts of that

type of sediment, while a number below one suggested that the sand lance were actively selecting areas low in that sediment type.

From this ratio, the Young of the Year, Age 1 and Age 2 & 3 were compared across fall 2012-2014. No Young of the Year were caught in 2013, so only 2012 and 2014 were compared for sediment composition for this age class. In 2014, the young of the year were caught in sediment with high gravel, low sand, which is not considered prime habitat for sand lance. The young of the year in 2012, however, were found in sediment compositions of low gravel, high sand; a sediment composition that is considered prime habitat (Fig. 9, Graph A). In all years, Age 1 fish were found in areas of prime habitat (low gravel, high coarse sand). (Fig. 9, Graph B). For Age 2 & 3 category, in 2014 this age category was found in prime habitat, while in 2013 sand lance were in coarser sediment composition, and in 2012, sand lance were in marginal habitat (high gravel, low sand) (Fig. 9, Graph C).

Further comparison among 2012-2014 showed differences in sand lance abundance and population demographics. Fall 2012 and 2014, the population had a similar age structure consisting of mainly Age 1, with Young of the Year and Age 2 & 3 being present, but lower in numbers (Fig. 10). Fall 2013 was comprised of mostly Age 1 and Age 2 fish, with no Young of the Year and few Age 3 fish. Fish abundance varied greatly among the years. The mean CPUE for fall 2014 was 10 fish/grab, while in 2013 it was 5 fish/grab, and in 2012 it was 24 fish /grab.

Discussion:

The results of this study showed that while Pacific Sand Lance can live in a wide range of sediment composition, they prefer a sediment composition mostly composed of coarse sand and low gravel composition (Fig. 3). This is consistent with other studies finding of sediment preference in sand lance (Lopez, 2013; Thomson 2012, Green 2011). The Van Veen grab contributes a slight bias, as its sampling efficiency decreases in higher gravel content due to rocks causing incomplete grabs. This bias is very minimal, as lab studies also find sand lance prefer a sediment composition with a high percentage of sand and a low percentage of gravel and silt (Wright et. al., 2000). One hypothesis given for why this sediment composition is ideal for sand lance is that fine sediment and silt clog the gills of the sand lance, which would put them in a hypoxia situation. Therefore they avoid areas of high silt (Wright et. al., 2000). It has been suggested areas with a high percentage of might be preferred, due to it being more permeable (Wright et. al, 2000).

Since sand lance having limited oxygen availability when buried in the sediment and sediment composition being a factor of oxygen availability. This study examine if the size of fish influenced the sediment choice based on the question: Are sand lance of different sizes able to utilize habitats that are either coarser or finer and does that compare with what we think is prime versus marginal habitat? This study found no strong significant relationship between fork length and sediment composition for Fall 2014, although large fish (Age 2 & 3) and medium sized fish (Age 1) were found in areas

of high sand, while Young of the Year were found in areas of more coarse sediment composition (Fig. 9). A study done in fall 2013 (Lopez) found no significant relationship between fork length and sediment composition. This contrasted the result found in fall 2012 (Thomson), where there was a very strong correlation between fork length and sediment composition. Fall 2013 had a small range of fish sizes caught, no Young of the Year, and mostly Age 1, Age 2, and some Age 3. Fall 2012 and 2014 had a wider range of fish sizes: some Young of the Year, mostly Age 1, and some Age 2 and 3 (Fig 10). If the age structures in fall 2012 and fall 2014 are similar, why was there different trends in size of fish and sediment choice between these years? This suggests that sediment composition choice is determined by more than just the size of fish.

Since there was no overall trend in the size of fish and sediment size, the study compared the different age classes and the sediment composition they were choosing over the years. The Young of the Year fish were found in different sediment composition, with fall 2014 fish being found in area of marginal habitat and fall 2012 fish found in areas of prime habitat. No Young of the Year were caught in 2013. In fall 2014, the Young of the Year were in a range of sediment composition, making it difficult to say if there is a trend in what sediment composition Young of the Year fish choose. Age 1 fish for all years (2012-2014) were found in prime habitat, although in fall 2013 age 1 was in areas of slightly higher gravel content than the other two years (Fig. 10, Graph C). This shows that Age 1 fish strongly select for prime habitat. Further research should be done on Age 1 sand lance, to verify if this selection is as strong as shown in this study or if this preference is statistically bias because Age 1 made up a majority of the population

in fall 2012 and 2014. Age 2 & 3 sand lance varied between the 2012-2014 in what type of sediment they chose; in fall 2014 they were strongly grouped in areas of prime habitat, while in fall 2013 they were in areas coarser than the ideal, and in fall 2012 they were in areas of marginal sediment composition. Since the overall sand lance demographics were very similar between 2012 and 2014, this doesn't explain why the larger sand lance were choosing different sediment composition.

The noticeable difference between the sand lance population in 2012 and 2014 is in the density of sand lance in the sand wave field between those two years, as shown by CPUE (Table 2). Fall 2012 had twice as many fish per grab than fall 2014, suggesting that density of sand lance in the sand wave field was twice as much as the density in fall 2014. Therefore, a possible explanation for the difference in sediment composition choice between the years could be due to a competition over a limited resource. The sand wave field is a limited amount of space and thus could be a limited resource for the Pacific sand lance when the population is high. Since fall 2014 had a smaller population of sand lance, the Age 2 & 3 sand lance may have been able to access the ideal sediment because there was less competition for space. Due to the high numbers of sand lance in fall 2012, there might have been some competitive exclusion and the larger fish were forced to choose areas of less ideal sediment composition.

More research is needed to conclude if sand lance are affected in sediment choice due to density of sand lance in the sand wave field in the San Juan Channel. Further research should be done on where the sand lance that bury in the sand wave field are eating and how far they are traveling from the sand wave field so there is a

better understanding of their population. More data should be collected over the next few years to compare against the interannual finding described in this paper to see if fall 2014 was an unusually low abundance year for sand lance or if fall 2012 was an extremely high abundance year. If fall 2014 was an unusually low abundance year, further studies should examine what may have caused this low abundance. All these studies compared were conducted in fall, when sand lance are starting to bury into the sand wave field for a dormancy period. To determine if different size sand lance are choosing different sediment compositions, it may be important to look at what sediment the Pacific sand lance is burying into during their typical diurnal pattern day. Finally, other sand wave fields around the San Juan Channel should be sampled to gain a broader look at the sand lance population in the San Juan Channel.

Acknowledgements:

Thank you to Matt Baker, Breck Tyler, and Jan Newton for their guidance and support. A huge thank you to the RA Becca Guenther for always being willing to help me. Thank you to my fish teammates: Emily Burke and Olivia Graham for making all of the long hours in the lab and field fun. Thanks to the rest of the PEF group for the encouragement and support. Finally, thank you to Friday Harbor Labs for being so supportive and making sure we had everything needed to complete our studies.

Bibliography

- Bertram, D.F., and G.W. Kaiser. 1993. *Rhinoceros auklet (Cerorhinca rnonocerata! nestling diet may gauge Pacific. Can. Fish. Aquat. Sci. 50: 1908-1 91 5*
- Ciannelli, L. (1997). Winter Dormancy in the Pacific Sand Lance (*Ammodytes hexapterus*) in Relation to Gut Evacuation Time. Forage Fishes in Marine Ecosystems. Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems. *Alaska Sea Grant College Program Report No. 97-01. University of Alaska Fairbanks*, pp. 95-104
- Friedlaender, A.S., Haxen, E.L., & et. al., (2009) Diel changes of humpback whale Megaptera novaeangliae feeding behavior in response to sand lance *Ammodytes* spp. behavior and distribution. *Marine Ecology Progress Series, Vol 395:91-100*, p. 98
- Healey, M. C., (1984) Laboratory Spawning of *Ammodytes Hexapterus* from the Pacific Coast of North America with a Description of Its Eggs and Early Larvae. *Copeia, No 1.* pg 242-244
- Hobson, E. S. (1986). Predation of the Pacific Sand Lance (*Ammondytes hexapterus*) (Pisces:Ammodytidae) during the Transition between Day and Night in Southeastern Alaska. *Copeia, Vol 1986, No 1.*, pp. 223-226
- Lopez, J. 2013. Characterization of the Habitat of *Ammodytes hexapterus* (Pacific Sand Lance) in the San Juan Channel Sand Wave. University of Washington, *Friday Harbor Labs PEF Apprenticeship*
- Monique, L. & Jeffries, S.T. (2007) Temporal and spatial variability of harbor seal diet in the San Juan Island archipelago. *Final Report for U.C. Davis Wildlife Health Center, SeaDoc Society*, p. 1
- Pearson, W.H; Woodruff, D.L., & Sugarman, P. C. (1983) The Burrowing Behavior of the Sand Lance *Ammodytes hexapterus*: Effects of Oil-Contaminated Sediment. *Marine Environmental Research Vol 11, Issue 1*, pp. 17-32
- Robards, Martin D.; Willson, Mary F.; Armstrong, Robert H.; Piatt, John F., eds. 1999. Sand lance: a review of biology and predator relations and annotated bibliography. *Res. Pap. PNW-RP-521. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.* 327 p 5.
- Thomson, A. 2012. Characterizing Pacific sand lance habitat in the San Juan channel sand wave field. University of Washington, *Friday Harbor Labs PEF Apprenticeship*
- Van Pelt, T. I., Piatt, J.F., Lance, B.K., and Roby, D.D., (1997). Proximate Composition and Energy Density of Some North Pacific Forage Fishes. *Comparative Biochemistry Physiology Vol. 118A, No 4.*, pp 1393-1398
- Vermeer, K. (1982). Comparison of the diet of the Glaucous-Winged Gull on the East and West Coasts of Vancouver Island. *The Murrelet, Vol. 63, No3*, pp. 80-85
- Williams, S.J., Arsenault, M.A., Buczkowski, B.J., Reid, J.A., Flocks, J.G., Kulp, M.A., Penland, S., and Jenkins, C.J., 2006, Surficial sediment character of the Louisiana offshore Continental Shelf

region: a GIS Compilation, U.S. Geological Survey Open-File Report 2006-1195, online at <http://pubs.usgs.gov/of/2006/1195/index.htm>

Wright P.J., Jensen, H., Tuck, I., (2000) The influence of sediment type on the distribution of the lesser sandeel, *Ammodytes marinus*. *Journal of Sea Research*. Vol 44. Issue 3-4. Pp, 243-256



Figure 1. Sediment Processing Method

Φ (Phi)	Wentworth Scale	mm
Phi -3 or greater	Medium Pebbles	8.00
Phi -2	Fine Pebbles	4.00
Phi -1	Very Fine Granules (Pebbles)	2.00
Phi 0	Very Coarse Sand	1.00
Phi 1	Coarse Sand	0.500
Phi 2	Medium Sand	0.250
Phi 3	Fine Sand	0.125
Phi 4	Very Fine Sand	0.063
Phi 5 or greater	Silt	Smaller than 0.063

Table 1. Wentworth Scale

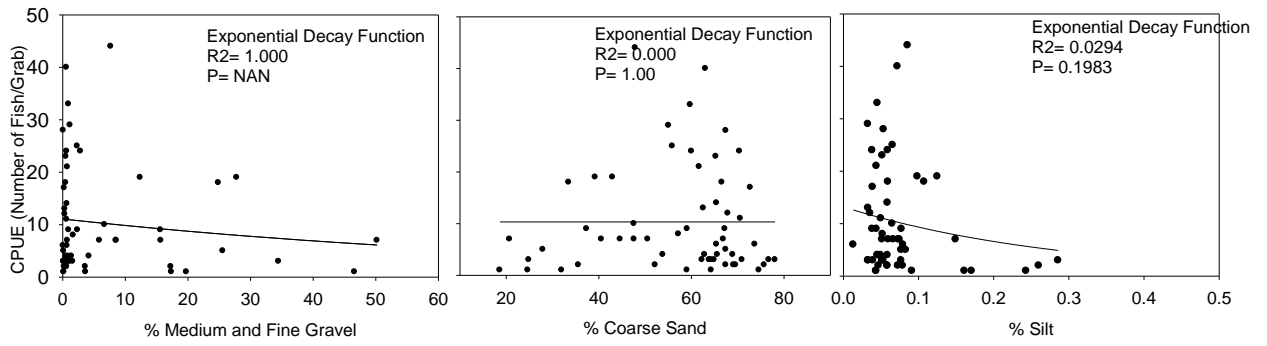


Figure 2. CPUE for different sediment types

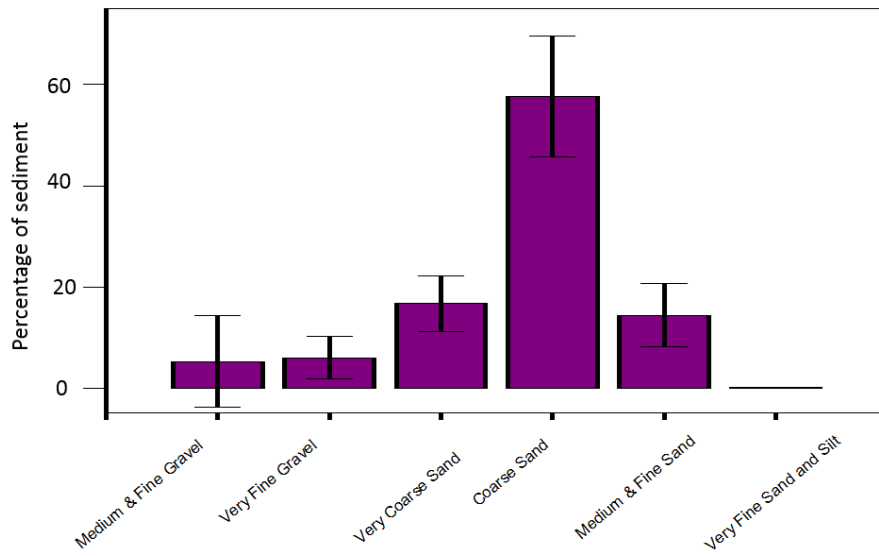


Figure 3. Average Sediment Composition of All Fish caught in fall 2014

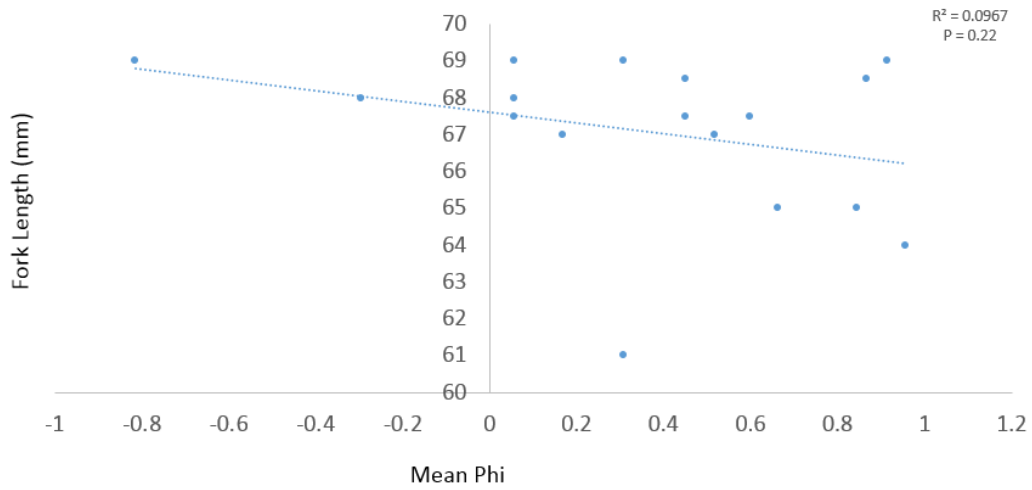


Figure 4. Mean phi for Young of the Year

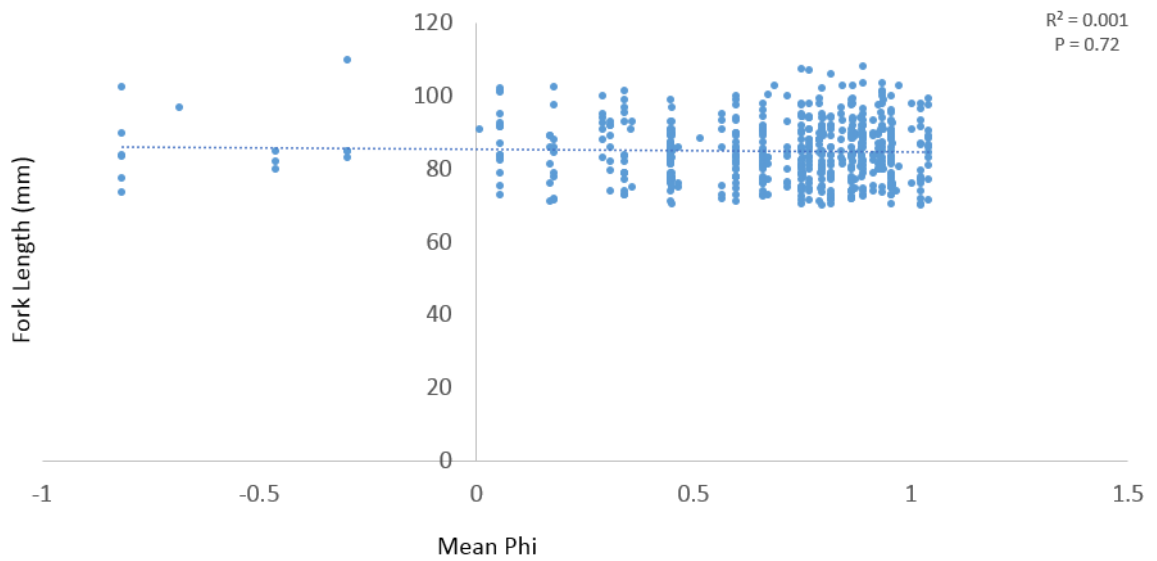


Figure 5. Mean Phi for Age 1

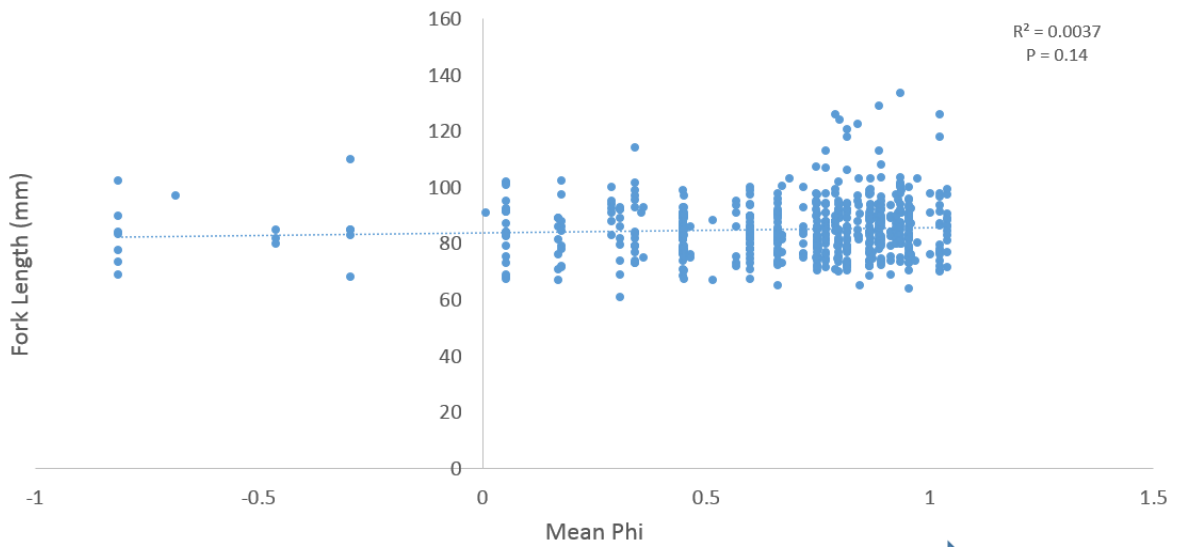


Figure 6. Mean fish for all fish caught in Van Veen grab

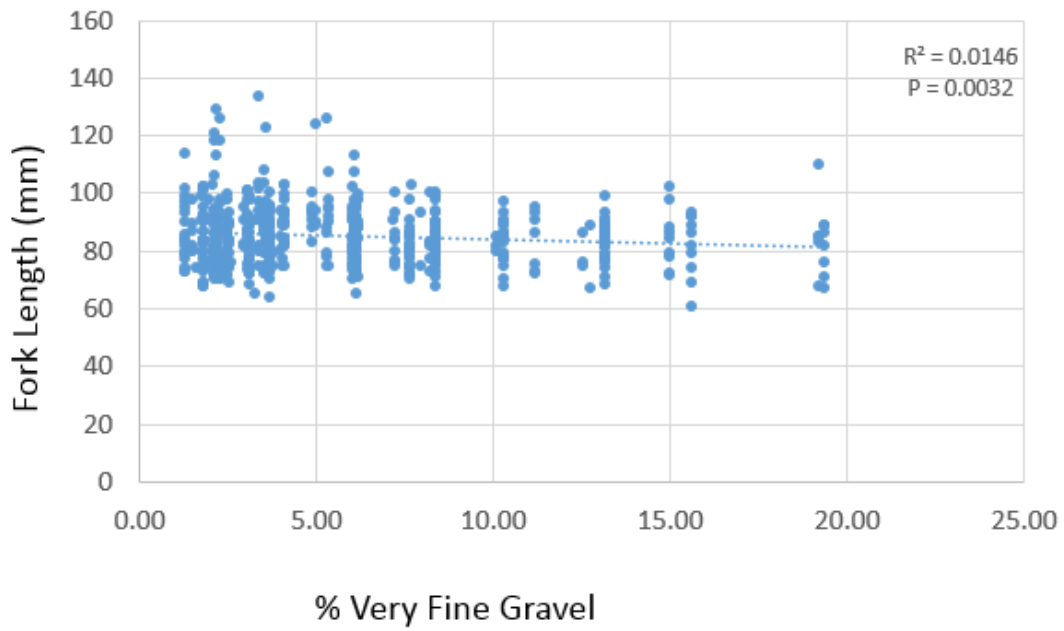


Figure 7. Percentage of Very Fine Gravel vs. Fish Size

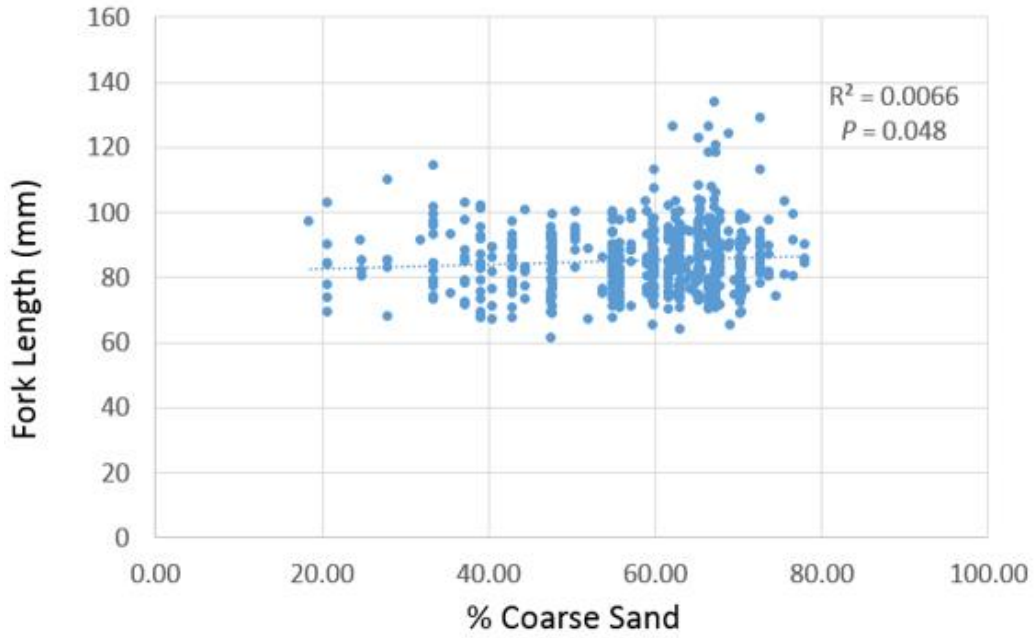


Figure 8. Percentage of Coarse Sand vs. Fish Size

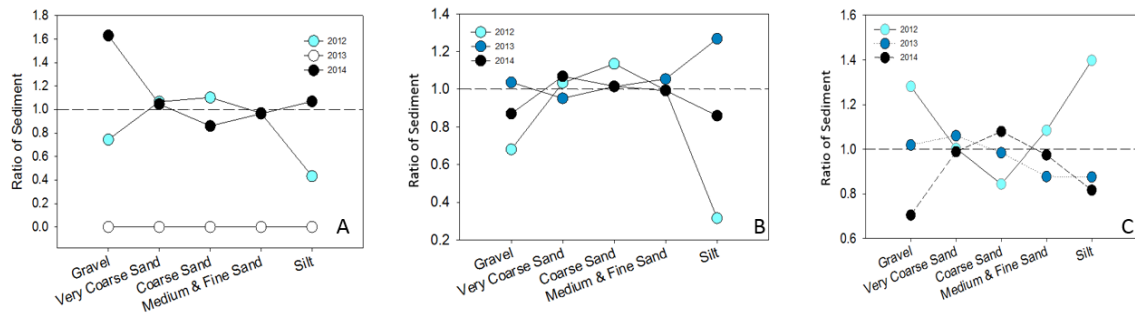


Figure 9. Age classes (A. Young of the Year, B. Age 1, C. Age 2 & 3) vs. Ratio of Sediment type. Comparison between 2012-2014

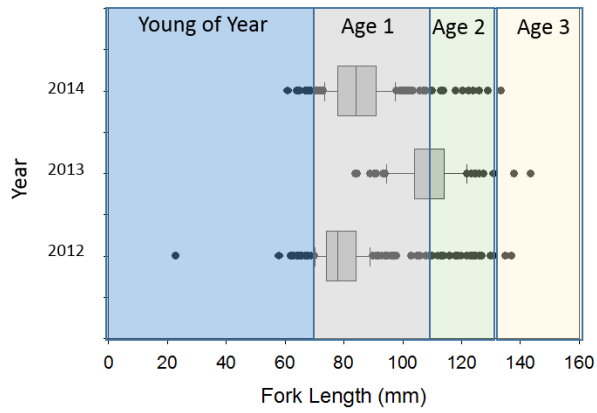


Figure 10. Demographics for fall 2012-2014

Year	Mean CPUE
2012	24 ± 10 SD
2013	5 ± 3 SD
2014	10 ± 10

Table 2. Mean CPUE for fall 2012-2014