The biomechanics and burrowing methods of *Ammodytes hexapterus*

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Abstract

The Pacific sand lance, *Ammodytes hexapterus,* was tested for burrowing speed in a tank filled with sediment topped with seawater. Results show that in fine sand (0.520mm in diameter) young of the year sand lance burrow on average 0.03 seconds faster than do immature/sub adults. These characteristics may be useful in predicting and identifying sand lance burrowing sites in the future, which is extremely important due to their ecological importance as prey species for many other marine species. This could be useful in identifying breeding sites for sand lances that can later be used as feeding grounds for marine species whose populations may be threatened.

Introduction

Pacific sand lance, *Ammodytes hexapterus* (Family Ammodytidae), are small (15-20 cm) schooling fish abundant off the coast of Washington (Gidmark et al. 2007b). Sand lance play a major role in the ecosystem as key prey for mammals such as seals and sea lions; marine fish, such as salmon and rockfish; and birds, such as cormorants (Robards 2002). As a prey species, the sand lance is a vital part of the marine life ecosystem, which makes it extremely important for researchers to monitor the health of the sand lance population in order to preserve the health of species that rely on sand lances as part of their diet. Identifying the sediments that sand lances prefer at different stages of their maturation process will allow scientists to better identify possible sand lance habitats and monitor the health of the sand lance populations throughout different stages of their life.

During the day, sand lance school in the water column while foraging for zooplankton. Unlike some marine species, the pacific sand lance do not make large scale migrations, but instead prefer to inhabit areas having a sandy substrate, where they can utilize their unique ability to burrow in the sand for cover and spawning. (Hiss 1985). This sandy substrate provides a protective barrier for the fish to burrow into and remain during their dormant period, which is from early fall to spring, as well as cover from any predators that they may encounter while active (Hiss 1985).

The burrowing mechanism that sand lances have evolved is accomplished by swimming quickly downwards from the water column and continuing to swim even after they have hit the sand. By continuing their swimming motion even after the initial impact with the ocean floor sand lance can completely dive into sand, thereby escaping potential dangers (Gidmark et al. 2007a).

The objective of this study is to determine whether or not burrowing time in sediment is dependent upon sediment size and sexual maturity. Sexual maturity in sand lance is measured by length with 60-80mm young of the year, 80-110mm immature/sub adult and >110mm adult (Bizzarro 2011). Fish develop at different stages in life and therefore their size was carefully monitored throughout this study to ensure that the sand lances were categorized properly. If exposed to the same sediment, younger sand lances should be able to burrow faster than more mature sand lances because they are smaller and have less body mass to submerge.

Materials and Methods

Thirty-four *Ammodytes hexapterus* were collected off the coast of San Juan Island on the R/V Centennial using a Van Veen sediment grab on April 22, 2011. They were then transported to Friday Harbor Laboratories located on San Juan Island and kept in a round tank approximately 72" x 54" that had a constant flow of sea water running through it, but no sediment at the bottom for the fish to burrow into. Further efforts to obtain additional sand lances at a beach seine at Jackson Beach and night lighting off the Friday Harbor Laboratories' dock were unsuccessful. Two plankton tows a day were done to collect zooplankton food for the fish to ensure that they remained in good condition.

Sediments were placed inside 20-gallon aquariums 24" x 12" x 16" with a constant flow of seawater for forty-eight hours prior to adding sand lance. The seawater flow was necessary to ensure the sediment was aerated.

Sediment was placed freely on the bottom of each tank (figure 1). Tank A was filled with 6 centimeters of 0.520mm in diameter sediment with a water pipe connected to a main seawater supply nearby and a constant flow of running water. A mesh covering was placed over the tank to ensure no fish were able to swim out. Tank B was filled with 8.89 centimeters of 1mm in diameter sediment with a water pipe connected to a main seawater supply nearby and a constant flow of running water. 12 young of the year sand lance were placed in tank A and 12 immature/young adults were placed in tank B.

Two other setups were attempted to offer sand lance a choice of sediment size in which to burrow. First, two 20-gallon aquariums each with its own tinfoil tub was filled with sediment. Tank A with 2mm sediment and tank B with 0.125mm sediment. Each sediment was exchanged after twenty-four hours. In tank A 0.520mm sediment, and tank B 1mm sediment. Second, two tinfoil tubs were placed side by side in each tank and foil was used to cover holes where sand lance would be able to fit around the edges thus forcing them to chose a sediment (figure 2). By using two tinfoil tubs no glass floor would be accessible for sand lance the rest on (figure 3). In tank A, 2mm and 0.520mm were placed side by side and in tank B, 1mm and 0.125mm.

Two high definition Flip video cameras were set up on tripods 20 centimeters from tank A and B. After 11 burrowing events were observed the two high-definition Flip cameras were moved to tank B and five burrowing events were recorded of immature/young adults in 1mm sediment. After all young of the year (YOY) were recorded, they were placed into a large holding tank and immature/sub adult switched into tank A to be recorded.

Results

Using 0.520mm sediment at the bottom of the aquarium, it took a young of the year sand lance an average of 1.89 ± 1.99 seconds to burrow into the sediment whereas it took the immature/sub adult 1.60 ± 0.76 seconds (Figure 4). During the experiment it was found that two of the YOY fish, as well as one of the immature/sub-adults did not completely burrow (e.g. left part of their tail out of the sediment), and so the results of these replicates were excluded from any further calculations.

A Mann-Whitney Rank Sum test was conducted and the difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability, giving a P value of 0.164 and t-value 189.500 (Table 1). Since P= 0.164, we see that sub adults have a tendency of burrowing faster than YOY in 0.520mm sediment (Table 1). The shortest recorded burrowing time was 0.2 seconds for young of the year and 0.5 seconds for immature/sub adult (Table 2). The longest observed time was 4.9 seconds in young of the year and 2.7 seconds in immature/sub adult (Table 2).

When finer sand made up of 0.125mm sized grains was set at the bottom of the tank, instead of .520mm, three of the immature/sub-adult sand lances were unable to fully burrow into the sediment. Furthermore, although the sample sizes varied, immature/sub-adults were able to burrow into sediment made up of coarser, 1.0mm size grains, an average of 0.99 seconds faster than into 0.520mm sediment (Table 3). A ttest was performed comparing sediments 1mm and 0.520mm for the immature sub/adult and revealed $t=2.78$ with 14 degrees of freedom ($P = 0.015$) (table 4).

Three sand lances were observed swimming downwards towards sediment 0.120mm but were unable to burrow. This sediment appeared to be to compact/hard and thus the sand lance bounced backwards. Sediment 0.120mm was aerated again yet no sand lance were observed or found to have burrowed into it. To scare the sand lance out of sediments a stick was used to gently mix the top layer of sediment.

All data was uploaded to a MacBook5, 1 using the Flip video software. The data was later transferred into iMovie and edited. A total of nineteen burrowing attempts for YOY, twelve immature/sub adults in 0.520mm sediment and seven immature/sub adult in 1mm sediment was observed.

Discussion

Since immature/sub adults are anywhere between 0.01 mm-50mm longer than young of the year, it was my initial belief that their larger body sizes would cause them to take more time to burrow than the smaller, less mature ones. However, contrary to my original hypothesis, when using sediment composed of 0.520mm grains, the immature/sub adult sand lances burrow quicker than the young of the year ones by an average of 0.03 seconds. This result is useful for further studies comparing whether slower burrowing times of the year of the young sand lances make them more vulnerable than their more mature counter parts. If efforts are not made to keep the habitats of sand lances protected, especially from human development, the youngest, most vulnerable members of the population will begin to decline which could cause a ripple effect throughout the ecosystem.

In addition to using sediment of 0.520mm size grains, the immature/sub adult were also timed on burrowing into coarser sediment (1mm) as well as finer sediment

(0.125mm). The results show that the coarser (1mm) sediment is significantly easier to burrow into than either of the finer (0.520mm) sedimentsv(table 4). By assuming that sand lances will prefer to inhabit an area that provides easier protection, we can infer that mature sand lances will inhabit areas that have coarser sediment because they can burrow into the sediment easier. Predicting the habitat of sand lances is vitally important when considering predation because predators will have a significantly easier chance in capturing immature/sub adults in finer sediment areas since their tails will be out of the sediment for a longer period of time.

The use of a Flip high-definition video camera to record the burrowing time of the sand lances creates the distinct possibility that the video recorded, and the times based off of these videos, could be a potential source of error in the final results. Unfortunately Flip video cameras are only able to record at 30 frames per second and thus the most accurate time of burrowing can only be determined to the tenth of a second. Another potential source of error is the relatively small sample size used during the experiment. All sand lances are not created equal, even those of the same maturity level, and so the relatively small sample size used in the experiment is a potential source for error because other factors, such as varying health and nutrition levels among the sampled population, may have contributed to the variations in burrowing speed.

Both of these potential sources of errors may have skewed the results during this experiment, however there are some very easy improvements that can be made in order to increase the accuracy of the results. Researchers can be much more precise when collecting data and analyzing video by using a high-speed camera that can be edited to the hundredth, or even thousandth, of a second. Furthermore, the use of a small sample size can be easily remedied by simply collecting more sand lances to increase the amount of data collected. By using a larger sample size, the potential for other factors affecting the burrowing speeds of the sand lances can be significantly reduced. Another area of improvement for future studies would be to eliminate the need to spend time doing plankton tows by conducting the experiment during a period of time when there is a sufficient amount of plankton coming through the seawater filtration system to keep all of the sand lances well nourished.

The results of this experiment are merely the basis with which future scientists can use when researching *Ammodytes hexapterus* in the wild. As a result, although the sand lance may be small in stature, the importance of these tiny fish on the marine ecosystem cannot be underestimated, and it will be very important to keep a close eye on future sand lance populations as a way to monitor the health of the ecosystem as a whole.

Acknowledgements

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Figures

Figure 1. Sediment freely in the tank

Figure 2. Two sediments in each tank

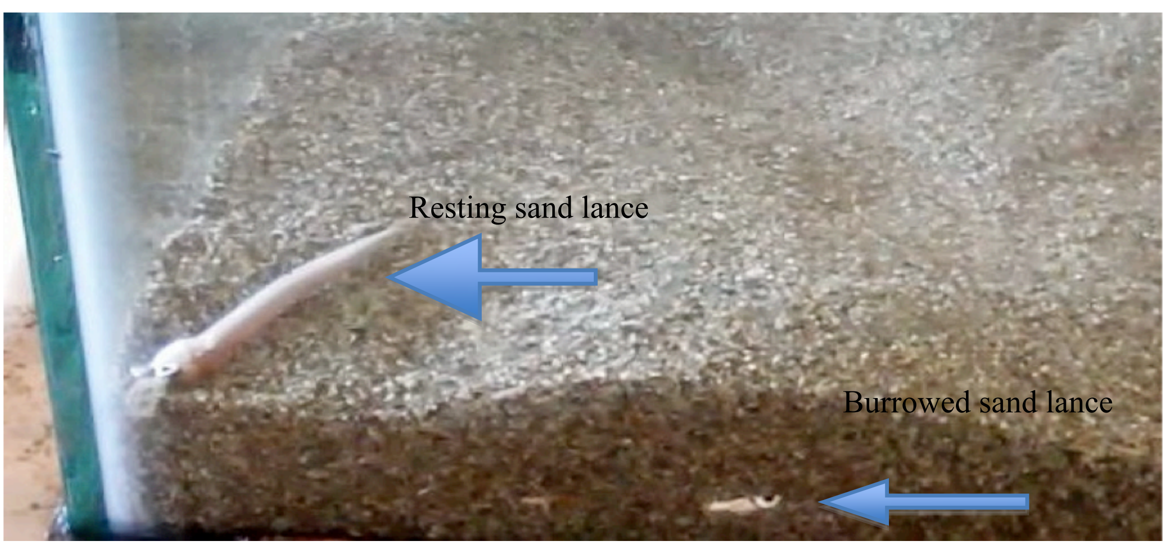

Figure 3. Resting sand lance and burrowed sand lance

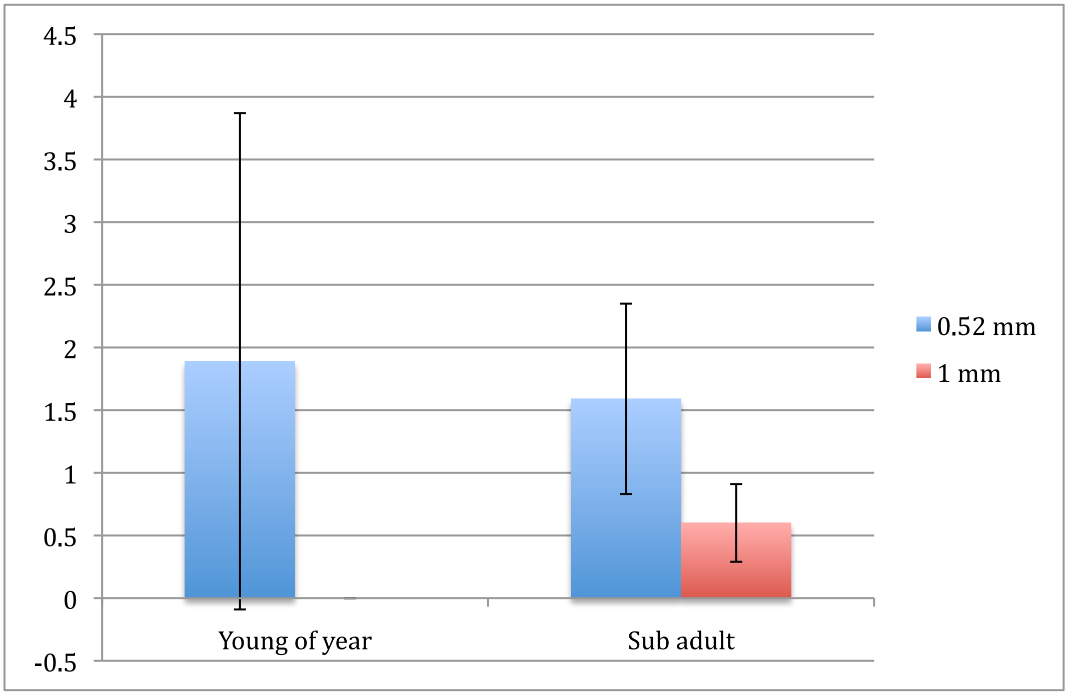

Figure 4. Burrowing averages of two different fish maturities in sediments of two grain sizes

N=17 for yoy in 0.520mm, N=0 for yoy in 1mm, N=11 for sub adult in 0.520mm, N=5 sub adult in 1mm
(#)333

Tables

Table 1. Mann-Whitney Rank Sum Test young of the year and immature/sub adult at 0.520mm sediment

Group N Missing Median 25% 75%
YOY 17 0 0.800 0.300 1.750
SUB 11 0 1.300 1.000 2.400

Mann-Whitney U Statistic= 63.500

T = 189.500 n(small)= 11 n(big)= 17 (P = 0.164)

(P = 0.164)

Table 2. Tank A 0.520 mm sediment burrowing times

Run	Young of the Year Burrowing Time *(sec)*
1	0.2
2	0.2
3	0.2
4	0.2
5	0.4 (did not finish burrowing)
6	0.4
7	0.6
8	0.8
9	0.8
10	1
11	1.7
12	1.7
13	1.7
14	1.8
15	4.3
16	4.5
17	4.9
18	6.9 (did not finish burrowing)
	AVERAGE= 1.89 sec
	STDEV=1.988

Run	Sub Adult Burrowing Time *(sec)*
1	0.5
2	0.9
3	1
4	1
5	1.2
6	1.3
7	1.9
8	2
9	2.4
10	2.6
11	2.7
12	4.3 (did not finish burrowing)
	AVERAGE=1.5909
	STDEV=0.7595

Table 3. Burrowing times for sub adult in 1mm sediment

Sub Adult Burrowing Time *(sec)*
0.4
0.4
0.4
0.7
1.1
AVERAGE=0.60 sec STDEV=0.31

Table 4. T-test comparing immature/sub adult at 0.520mm and 1mm sediment

Normality Test (Shapiro-Wilk)

Passed (P = 0.667)

Equal Variance Test:

Passed (P = 0.565)

Group Name N Missing Mean Std Dev SEM

Sub adult 0.520mm sediment 11 0 1.591 0.760 0.229

Sub adult 1mm sediment 5 0 0.600 0.308 0.138

Difference 0.991

t = 2.772 with 14 degrees of freedom. (P = 0.015)

95 percent confidence interval for difference of means: 0.224 to 1.758

The difference in the mean values of the two groups is greater than would be expected by chance; there is a statistically significant difference between the input groups (P = 0.015).

Power of performed test with alpha = 0.050: 0.676