

# Imaging fish otoliths retrieved from seal scat samples: acquisition, taxonomic identification, and fish length reconstruction

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## INTRODUCTION

- Long-term data collected by The New Jersey Seal Study has helped resolve the diet of pinnipeds overwintering in the Mullica River-Great Bay Estuary (New Jersey).
- Analyzing hard parts from scat samples recovered at haul out sites in the area are an invaluable resource for determining diet variability.
- Otoliths are calcium carbonate “ear bones” of fishes and can be used to identify species and reconstruct lengths of prey items consumed by piscivorous pinnipeds. The “sagittal” otoliths recovered from scat samples are usually the largest of the three pairs of otoliths found within fish (Fig. 6 and Fig. 7).

Order/Family/Genus species	Total Count	Average Otolith Length (mm)	Average Corrected Otolith Length (mm)	Average Fish Length (mm)
<b>Clupeiformes</b>	<b>145</b>	<b>3.78</b>	<b>5.14</b>	<b>325.31</b>
Clupeidae				
<i>Alosa pseudoharengus/aestivalis</i>	22	4.14	5.19	n/a
<i>Clupea harengus/Brevoortia tyrannus</i>	32	4.01	5.10	325.31
UNK	91	3.61	n/a	n/a
<b>Gadiformes</b>	<b>500</b>	<b>4.47</b>	<b>8.40</b>	<b>177.53</b>
Gadidae				
<i>Gadus morhua</i>	2	10.42	13.44	444.44
Lotidae				
<i>Brosme brosme</i>	6	9.70	n/a	n/a
Merlucciidae				
<i>Merluccius bilinearis</i>	5	4.04	5.72	114.54
Phycidae				
<i>Urophycis regia/chuss</i>	141	6.12	8.41	176.67
Phycidae/Merlucciidae/Gadidae				
UNK	346	3.68	n/a	n/a
<b>Perciformes</b>	<b>7</b>	<b>6.46</b>	<b>n/a</b>	<b>n/a</b>
Labridae				
<i>Tautoga onitis</i>	5	3.04	n/a	n/a
Pomatomidae				
<i>Pomatomus saltatrix</i>	2	16.15	n/a	n/a
<b>Pleuronectiformes</b>	<b>110</b>	<b>3.48</b>	<b>5.02</b>	<b>375.39</b>
Pleuronectidae				
<i>Pseudopleuronectes americanus</i>	26	4.11	5.45	371.32
Pleuronectidae/Scophthalmidae				
UNK	26	3.67	n/a	n/a
Pleuronectidae/Scophthalmidae/Paralichthyidae				
UNK	24	2.31	n/a	n/a
Scophthalmidae				
<i>Scophthalmus aquosus</i>	34	3.61	4.58	n/a
<b>UNK</b>	<b>70</b>	<b>3.08</b>	<b>n/a</b>	<b>n/a</b>
UNK				
UNK	70	3.08	n/a	n/a
<b>Total Average</b>	<b>832</b>	<b>4.12</b>	<b>2.58</b>	<b>215.16</b>

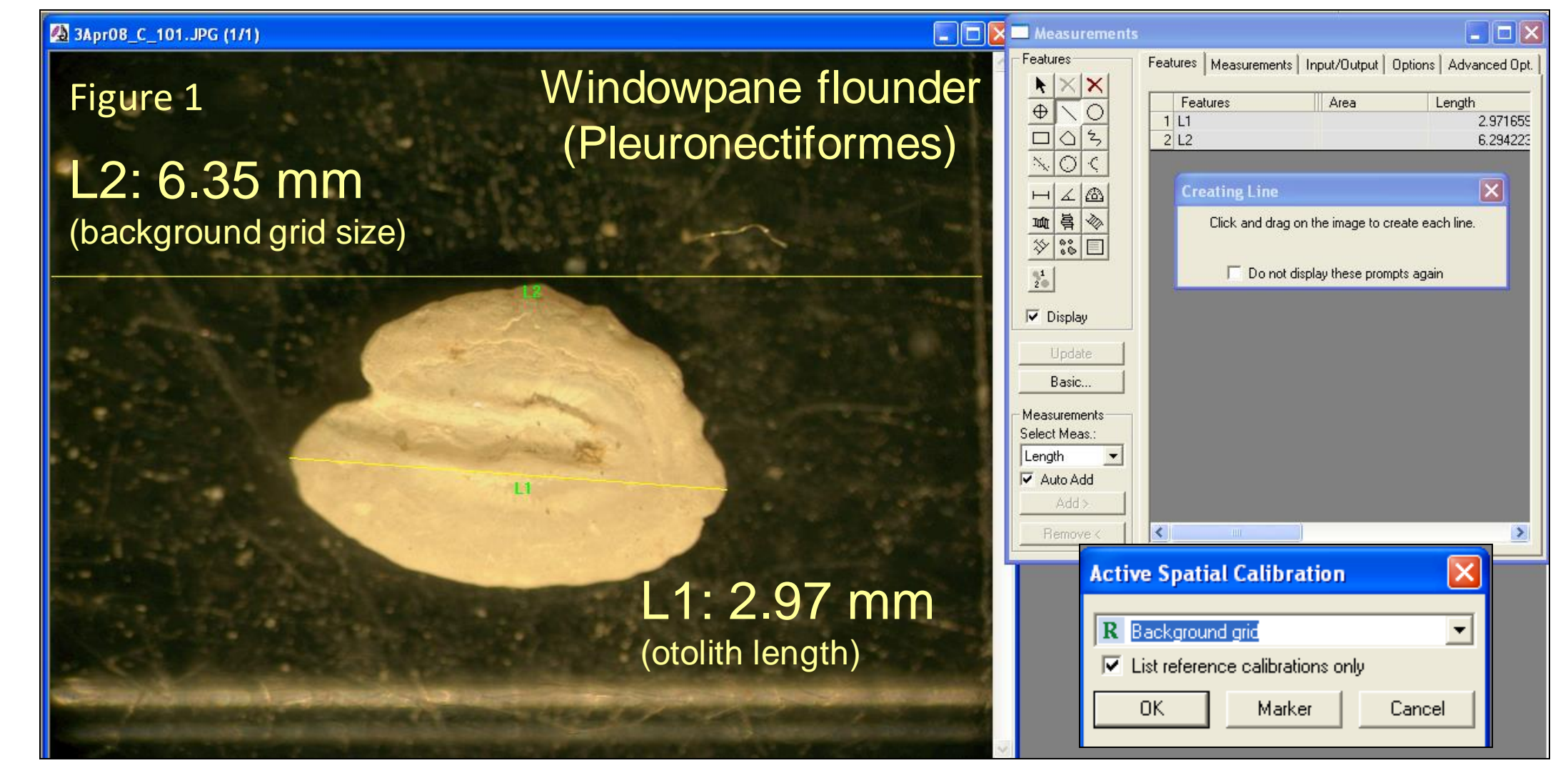
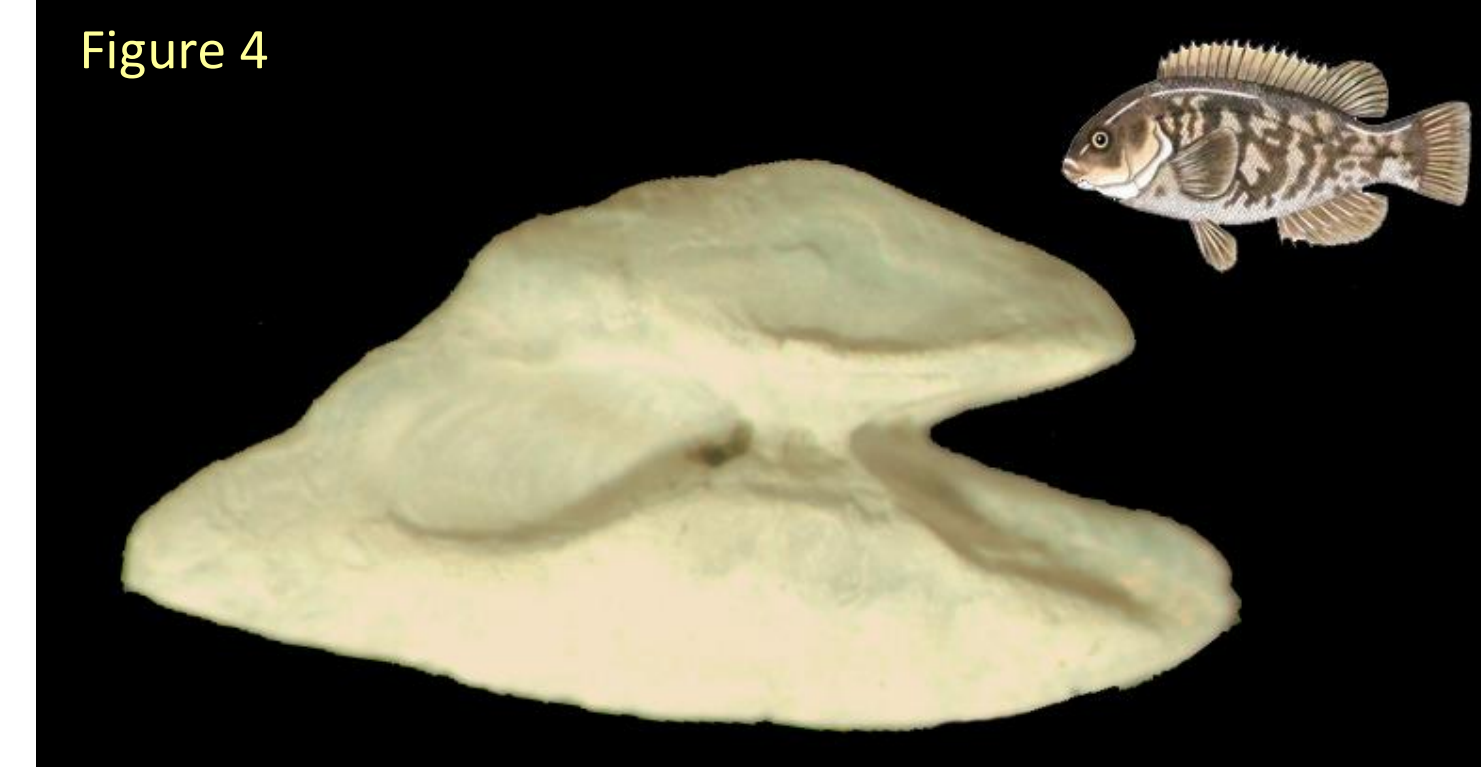


Table 1. Table of otolith counts per order / genus species, average otolith and corrected otolith length per order / genus species, and average fish length per order / genus species. Fig. 1. Screen shot of Image Pro Plus imaging software used to measure otolith lengths.



Genus species	Family	Order	Equation	Reference
<i>Clupea harengus</i>	Clupeidae	Clupeiformes	$L(mm) = 69.23(OL\ mm) - 27.48$	Recchia and Read 1989
<i>Gadus morhua</i>	Gadidae	Gadiformes	$(\ln)FL(mm) = 3.3138 + 1.6235 \ln(OL\ cm)10$	Harkonen (1986)
<i>Merluccius bilinearis</i>	Merlucciidae	Gadiformes	$(\ln)FL(mm) = 3.0111 + 1.0276 \ln(OL\ cm)10$	Harkonen (1986)
<i>Urophycis regia</i>	Phycidae	Gadiformes	$L(mm) = (1.52(OL\ mm)1.1456)10$	Bowen and Harrison 1994
<i>Urophycis chuss</i>	Phycidae	Gadiformes	Used <i>U. regia</i> equation	
<i>Pseudopleuronectes americanus</i>	Pleuronectidae	Pleuronectiformes	$FL(mm) = -8.559 + 8.389(OL\ mm)10$	Harkonen (1986)

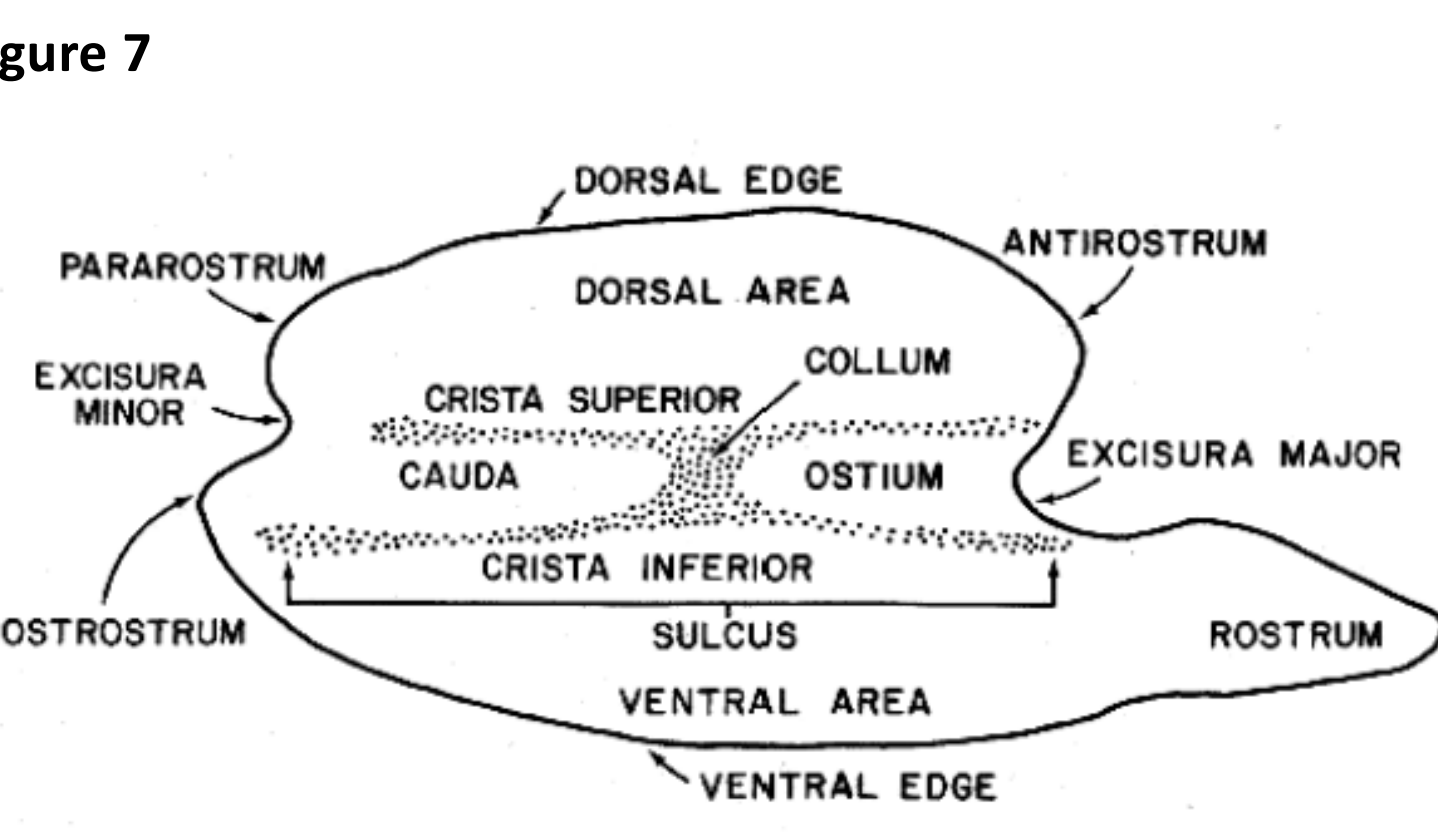
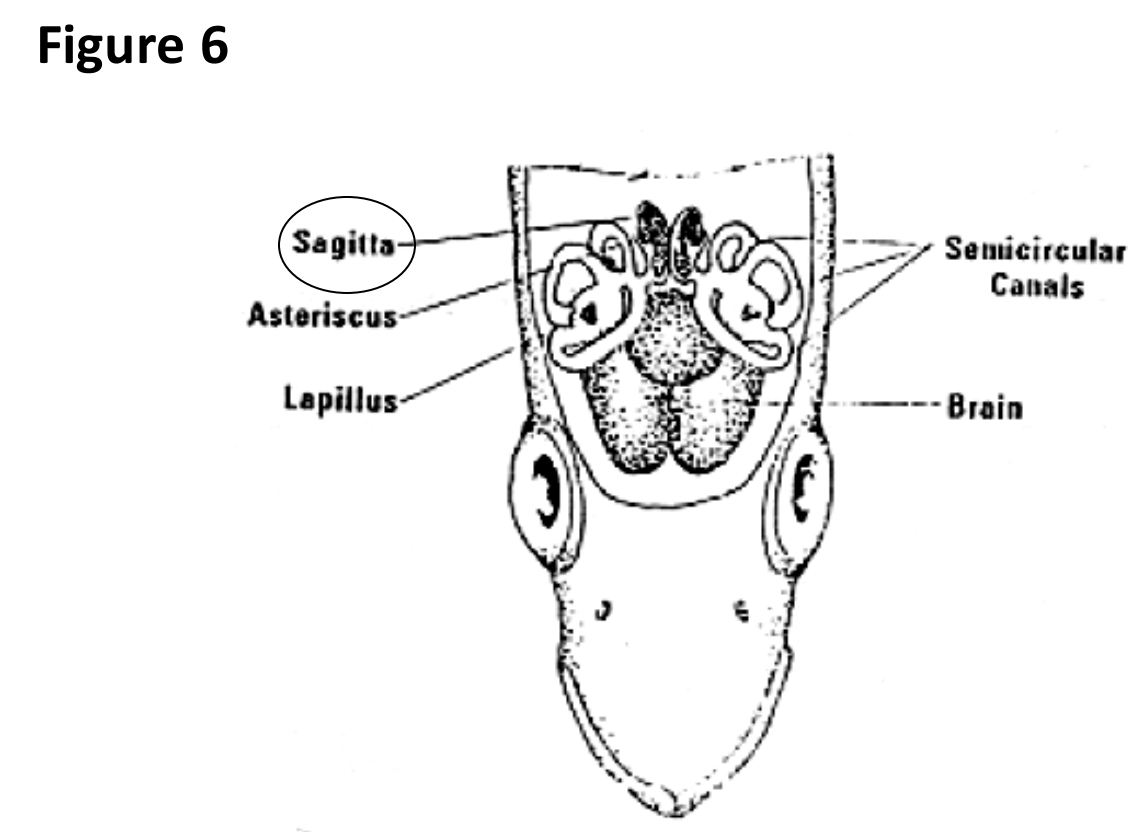


Fig. 2. Clupeiform otolith (fish image courtesy of Penobscot River Restoration Trust). Fig. 3. Pleuronectiform otolith (fish image courtesy of State of Delaware Division of Fish and Wildlife). Fig. 4. Perciform otolith (fish image courtesy of the Marine Department of Resource). Fig. 5. Gadiform otolith (fish image courtesy of NOAA). Table 2. Table of otolith length-to-fish length conversion equations. Fig. 6. Image illustrating location of the sagittal otolith in a typical teleost fish (image courtesy of Secor et al. “Manual for Otolith Removal and Preparation for Microstructural Examination”). Fig. 7. Image illustrating the morphology of a typical sagittal otolith (image courtesy of Brodeur’s “Guide to Otoliths of Some Northwest Atlantic Fishes”).

## METHODS

- A total of 832 otoliths were analyzed from recovered seal scat. Each otolith was inventoried using a stereo microscope, an attached digital camera, and image analysis software.
- Individual images were examined and identified to order, family, and, where possible, the genus species level using reference images and otolith identification manuals (Table 1). There were four primary orders identified: Clupeiformes (Fig. 2), Pleuronectiformes (Fig. 3), Perciformes (Fig. 4), and Gadiformes (Fig. 5).
- Each otolith was assigned an erosion grade based on the condition of the otolith after passage through the digestive tract (Fig. 8). This scale was from 1 (low) - 3 (high) (Fig. 10, Fig. 11, Fig. 12). Otoliths recovered directly from a fish are classified as 0 (Fig. 9). Each erosion grade value was used as a correction factor when calculating fish prey lengths.
- Otoliths were measured (to mm) using Image Pro Plus 7 software (Fig. 1). Corrected otolith measurements were entered into equations taken from peer-reviewed resources to calculate fish length (Table 1 and Table 2). Equations for some genus species were not available or deemed inappropriate for certain length classes.

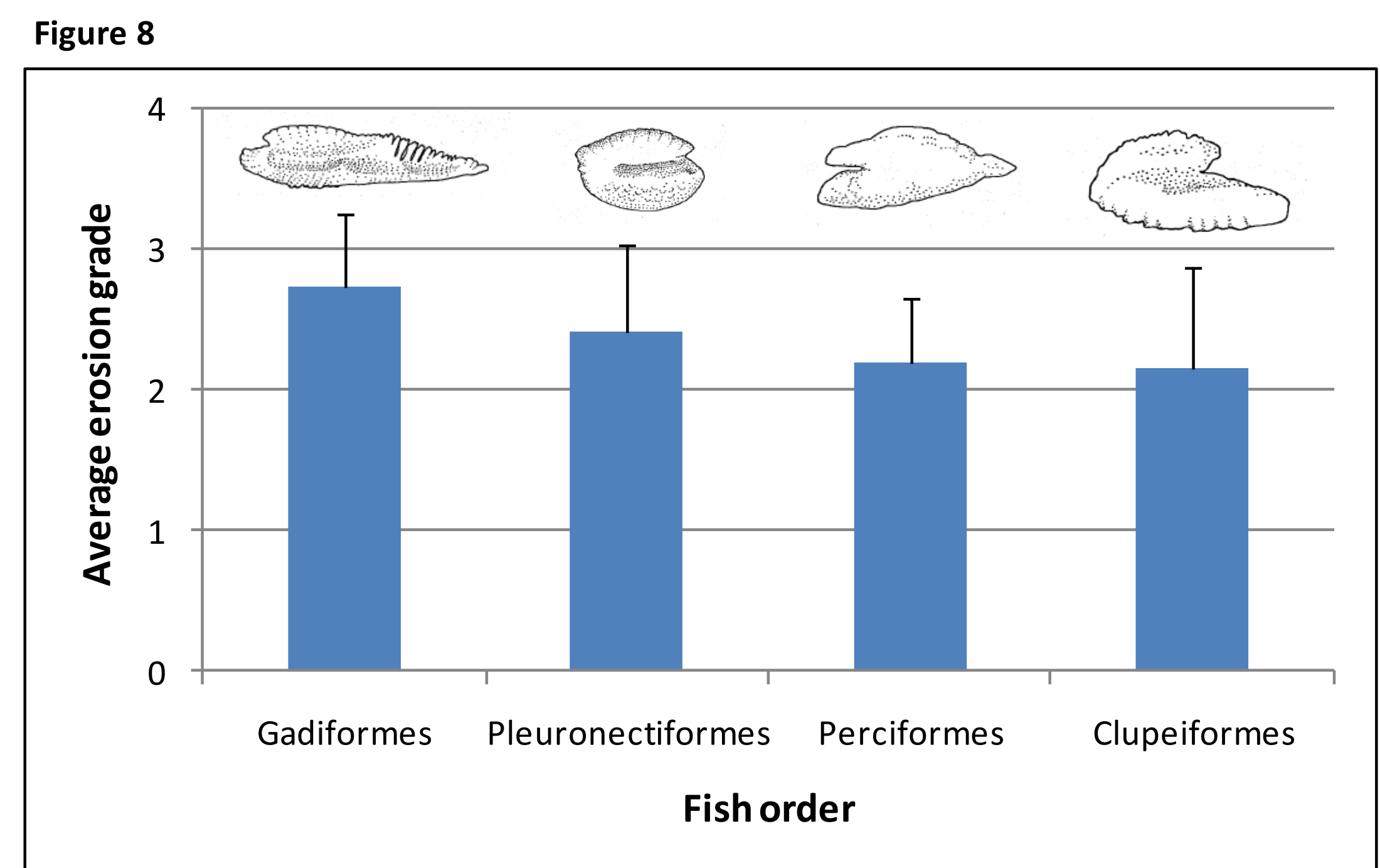


Fig. 8. Graph illustrating average erosion grade of each fish order. Fig. 9. Erosion Grade 0 of a Gadiform otolith. Fig. 10. Erosion Grade 1 of a Gadiform otolith. Fig. 11. Erosion Grade 2 of a Gadiform otolith. Fig. 12. Erosion Grade 3 of a Gadiform otolith.

## RESULTS/CONCLUSIONS

- Few otoliths were identified down to the genus species level due to the high degree of erosion in most otoliths - making positive identification difficult. At the order level, there were 500 Gadiformes, 145 Clupeiformes, 110 Pleuronectiformes, 7 Perciformes, and 70 Unknown (Table 1).
- The Gadiformes had the highest rate of erosion, with an average of 2.73 out of 3. Clupeiformes had the lowest average rate of erosion (2.16 out of 3). Otolith lengths were successfully corrected using conversion factors from studies of seals fed in captivity.
- Gadiform prey were on average 177.53 mm in length (small for the order as a whole). Clupeiformes (325.31 mm) and Pleuronectiformes (375.39 mm) were, on average, much larger (Table 1). Equations for identified Perciform genus species were unavailable and no lengths calculated.
- These results indicate pinnipeds in the Mullica River-Great Bay Estuary area feed partially on small, numerous Gadiform fishes.
- These results suggest that imaging of scat-derived otoliths is a powerful tool for cataloging, measuring, correcting, and ultimately reconstructing seal diets.

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