Assessment of Marine Renewable Energy Installation Siting
Final Project Report – December, 2015

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Background: Outer-Continental Shelf (OCS) blocks have been identified as high priority wind energy areas (WEAs) for development in New Jersey, Delaware, Maryland, and Virginia. Additional sites in Rhode Island and Massachusetts are under consideration (Bureau of Ocean Energy Management 2012a, b). Additional WEAs have been proposed for Maine, North Carolina, South Carolina, Texas, Michigan, California, Oregon, and Washington. However, no WEA's have yet been developed in the U.S. The Maryland WEA includes 9 whole and 11 partial OCS blocks (Fig. 1). The western edge of the area is approximately 10 nmi from Ocean City, Maryland, and the eastern edge is approximately 23 nmi from Ocean City (Fig. 1). Understanding the long term impact of installing wind energy turbines requires knowledge of sediments, habitat types, fish and benthic community assemblages. This information is currently lacking for most WEAs. The goal of this project is to address these significant knowledge gaps by conducting surveys of benthic habitats and biota in the affected region. Specific objectives are to document distribution of benthic sediments and habitat types, and the abundance and distribution of mobile and sedentary organisms.

Project Description:

Previous Research

In 2012 we surveyed offshore habitats of the Maryland WEA (OCS Blocks 6774, 6775, and 6776) in order to answer the following questions:

1. What are average grain sizes throughout the region?
2. How are fish assemblages associated with benthic habitat?
3. What is the relative density, diversity, and abundance of epibenthic fauna?

We spent over 20 days at sea in 2012 sampling benthic habitats using a benthic camera sled and ponar dredge, during which we completed 22 video transects, and collected over 60 sediment samples. Sled 1 was equipped with a low-light analog video camera connected to a data logger and monitor in the boat, and three GoPro Hero (Woodman Labs – GoPro USA) cameras facing in different directions, plus battery-powered LED lights. Temperature was recorded during the entire transect using waterproof data loggers. The sled was towed at low speeds of 1-2 knots along transects of approximately 3 nautical miles in length, spaced at approximately 3/5 mile, or about 1 km. The vessel tracks were recorded with commercial navigation software. Secchi depth was recorded, and benthic samples were taken with a ponar grab at the start, middle, and end of transects for grain size analysis. Video frames were analyzed using a systematic sampling technique, and all bottom types and fauna were recorded.

Data were used to determine associations between habitat and fauna, and to develop habitat classifications based using the NOAA Coastal and Marine Ecological Classification Standard (CMECS), and mapped using GIS. One minute of continuous video was analyzed from each 10 min recorded. Observed demersal fauna included 41 species, with northern sea robins and

Cancer crabs being most common, followed by skates, flounders, and other species. One site was characterized by anoxic mud sediments occupied by sea robins and skates, and may be a unique and critical habitat. Sediment grabs were made with a ponar dredge and sorted to determine mean grain size. Results revealed a mix of sand and shell bottoms, muddy bottoms, bottoms of large pebbles, and those with an abundance of sand dollars. Cluster analysis indicated 4 community types bases on percent cover of shell, sea grape (ascidians), and sand dollars, and species presence of most commonly observed species groups. All four communities were intermingled across the survey area, although one cluster contained sites with high densities of sand dollars. Principal component analysis revealed that Axis 1 accounted for 30% of variance and was primarily influenced by depth and percent shell cover, whereas Axis 2 accounted for 20% of variance, and was more heavily influenced by species counts. All but one of the sediment samples was composed of >97% sand (>63µm); the single outlier was from the muddy site, which was >50% silt and clay (<63µm). These data were included in the MS Thesis submitted to UMES by Emily Tewes, in December 2012.

Data collected in 2012 gave us a general description of sediment, habitat, and faunal distribution in the OCS blocks studied. Several technical problems with CamSled 1 became apparent early in the study. Our low-light camera was also a low-definition camera, and produced blurred images at typical towing speeds of 1-2 knots, and resolution was poor, such that it was difficult to identify or count individual animals smaller than 10 cm in frame grabs (Fig. 2). In addition, our first set of lights did not work at all due to a design fault so we had to rely on a set of battery powered lights that were sub-optimal.

<u>Year 2 Goals and Objectives</u>

In this project we proposed the following goals. Because sediments examined in 2012 were rather uniform, we did not continue sediment sampling.

1) In order to obtain images with greater resolution, we designed and built a new CamSled (#2) to include a high definition camera with synchronized flash systems, on-board recording, and GPS/depth overlay.
2) We proposed to sample two OCS blocks (6725 and 6726) north of the three blocks surveyed in 2012.
3) Although not included in our original proposal, we conducted an additional beam trawl study to compare species presence and abundance with CamSled counts.

<u>Methods</u>: Our specific objectives for each goal:

1) <u>Camera Sled Construction</u>. Our team included an aquatic engineer (Mark Blakeslee) with experience designing, operating, and repairing remotely operated vehicles and camera sleds, and a NOAA scientist (Scott McIntyre) who specializes in designing UW video camera systems for research. CamSled 2 was designed with the following specifications.
    a. <u>Sled:</u> CamSled 2 was designed with the camera in a vertical position, shooting directly downward with a field of view about 1.1 m wide. This eliminated parallax error and allowed measurement of animals or surface features. The sled (approx. 2 m x 1 m x 1.5 m) was built of aluminum round and flat bar and can be dis-assembled for transport (Fig 3A).
    b. <u>Electronics</u>: A digital machine vision camera (Point Gray Zebra2) was housed in a custom-built aluminum tube with a quartz dome port (Fig. 3B). Three strobed

LED arrays were housed in separate custom-built housings. A single board computer (ADS solutions) was built into a custom-built aluminum tube, with a power source, heat sinks, fan, control circuit board, 500 GB storage disk, and Ethernet converter. The computer tube is attached to the sled for on-board control and data storage. A digital compass and GPS were integrated to the system, and those data overlaid on each image frame. A single 4-strand, Kevlar strengthened umbilical cable of 150 m length delivers power to the sled and brings data and images back to the surface. A 24-V battery on the sled stores high current required by the strobe lights, and is continuously charged by 24V from the tow cable.

c. Operation: In practice, CamSled 2 was towed at 2-3 knots to keep it on bottom. The onboard computer communicated with a laptop on the vessel via an ethernet connection, allowing us to control camera operation. High definition digital images were recorded directly to the on-board hard drive at about 5 frames/second at an exposure of 10 msec with synchronized strobes, using a custom built software application. Live feed to the surface allowed us to observe frames as they were captured. Images have about 25% overlap, so that any feature or organism on the seafloor shows up in 3-5 consecutive frames. At such high shutter speeds, motion is stopped, and high resolution images are captured that allow easy identification of species down to sizes of about 2 cm (Fig. 6).

d. Timeline: Because of the complex and custom nature of the camera sled, it required longer than expected to complete it. Although we had planned to begin work in summer of 2013, the sled was not completed until June of 2014, so work was delayed for a year and the contract extended with a no-cost extension.

2) Video survey transects were conducted in adjacent OCS blocks 6725 and 6726 during July-August 2014. Nine transects were spaced 1 km apart and oriented in a N-S fashion, similar to work done in 2012 (Fig. 4).
3) Beam Trawl Survey: During July 2014, we conducted trawling with a small mesh (5 mm) beam trawl (Fig. 5, 6). Although not part of our initial plan, the beam trawl survey was conducted in order to verify species identifications, provide voucher specimens, and to provide data that could be used to either complement or compare to the video surveys. Tows were conducted for 10 min at 15 stations distributed evenly throughout the two OCS blocks 6724 and 6725 (Fig. 5). All specimens caught were counted and identified to lowest possible taxon. One large catch of >3600 sand dollars was subdivided into 6 approximately equal trays; one tray was fully counted, and the total catch estimated by expansion. The beam trawl survey was partially paid for by the NSF-funded REU program, and involved a minority undergraduate female student.

Results:

Beam Trawl Study: Beam trawl data were analyzed to determine species diversity and community structure. We captured 8432 specimens representing 22 species, of which 17 produced more than two individuals (Table 1). Of these, 6961, or 82.6% were a single species, the sand dollar *Echinarachnius parma*, of which >3600 were caught in one tow at station BT-15. Ten species were identical to those captured by a mid-winter shelf survey on the outer shelf conducted by UMES students and faculty in February 2012, including the top 3 fish species. Cluster analysis with Euclidean distance was used to determine association between stations, using the 14 taxa with counts ≥ 5 individuals. Cluster analysis defined 3 distinct benthic communities that were loosely organized along depth and sediment gradients (Figs. 7, 8). Overall diversity was low, and decreased from inshore to offshore (east to west). We calculated three diversity indices including Shannon's H (the uncertainty of species identification; mean = 1.628); lambda (the probability that any two randomly selected individuals belong to the same species; mean = 0.481); and Hill's N2 (the effective number of abundant species; mean = 2.787; this number represents the top 3 species accounting for 92% of all organisms) (Ludwig and Reynolds, 1988). Hill's N2 is shown for each of the 3 main community clusters in Fig. 8. Sand dollars were the dominant species in cluster 3, comprising most of OCS block 6725, and producing very low diversity in that block (Hill's N2 = 2.09).

CamSled Survey: In 2014, we were able to complete 7 of the 9 (80%) scheduled camera sled transects (Fig. 4). Two transects in block 6725 were not completed due to time and weather constraints. Overall, we have about 20 hr of CamSled observations, comprising about 360,000 photo frames. Prior to analysis, a test to determine the appropriate intervals for sampling frames was conducted. Time and funding prevent viewing and analyzing every frame, so two sampling routines were tested, including systematic and random sampling. The goal was to find the sampling design which provides the closest approximation to the complete data set, with the least amount of effort. Most of the work was conducted by graduate student Wilmelie Cruz-Marrero.

Sampling Technique: Because of frame overlap, every organism shows up in 3-5 frames, so not all frames need to be examined. Analyzing all of those for data would take considerable effort, so the first objective was to determine the most efficient way to sample them. In order to accomplish this, we examined 9155 sequential frames, collected during 30 minutes on Transect 5, and all organisms observed (>2.5 cm) were counted. From all those frames we selected subsamples using either a systematic or a random sampling design. For the systematic sample, frames were selected at intervals of 1, 2, 4, 8, 16, 32, 64,128, 256, 512, 1024, and 2048 frames; for the random samples, a number of frames were selected randomly, comprising from 4% to 20% of the total. Each of these samples was conducted up to 10 times. Observed organisms were identified to the nearest taxonomic level, and counted within each frame (Fig. 9). Habitat and substrate were recorded, along with geographic position. Numbers of species and individuals, and diversity were compared between sampling schemes. In the completely analyzed sample, we annotated 1,141 organisms representing 13 species. The most abundant species were hermit crabs (9.3 %), whereas the most common organism in beam trawl samples were sand dollars (Tables 1 & 2). Four species were identical to those captured by a mid-winter shelf survey on the outer shelf conducted by UMES students and faculty in February 2012, but many species that we caught in summer 2014 were not observed in winter 2012.

We calculated community diversity using Hill's N2. The systematic sampling technique showed that diversity leveled off (i.e. approached the value for the completely analyzed sample) at a sample size of about 316 frames, which represented about every 30th frame in the sample (Fig. 11). Since we intended to sample in 15 minute segments, transect 5 frames were divided in half for random sampling, with each half consisting of 4577 frames. Random sampling of frames, and calculation of diversity indices, was conducted for both data sets separately. This technique was repeated ten times for each sample of frames, but only one example is shown for each sample (Fig. 12). Diversity leveled off at sample sizes of $10^{2.4}$ (250 frames) in Transect 5A, and at a sample size of $10^{2.2}$ (160 frames) in transect 5B, corresponding to sampling intervals of 18-28 frames, respectively. Based on these results, we concluded that unbiased estimates of diversity could be obtained by sampling of all remaining image files at intervals of 30 frames.

Camera sled Survey Results

All remaining frames captured by the CamSled were sampled (at intervals of 30 frames), and organisms were counted during fall 2015. Some sections of transects were not photographed due to equipment failures, or were photographed but could not be counted due to poor image quality. Although time codes were recorded on the photographs taken for Transects 5-7, they were not recorded for Transects1-4 due to technical issues. For this reason, we cannot subdivide the Transects into smaller samples for comparison to beam trawl samples. At a rate of 5 frames/sec, the CamSled produces 300 photographic frames/min, or 18,000 frames per hour, and most transects lasted from 60-90 min. When sampled at intervals of 30 frames, a one-hour transect would produce 600 sampled frames. The total number of usable frames counted was 4393. Numbers of usable frames per transect varied from 34 to 1036 (Table 3, Fig. 16).

Organisms were observed in 1463 frames (33.3%), whereas the majority of frames (2930 or 66.6%) were empty (Fig. 13). A total of 3035 individual organisms representing 23 taxonomic groups were counted, grouped into seven taxonomic Classes. We were able to identify some organisms to the level of species (e.g. sand dollars), whereas others could only be identified to the level of Order (e.g. Brachyura) or Class (anemones). Because the level of identification varied, most analyses were conducted on data at either the level of Class or Order, in order to avoid comparing numbers between different taxonomic levels.

Taxonomic names, numbers and proportions observed are shown in Table 2. The most common species were sand dollars (*Echinarachnius parma*), hermit crabs (*Paguridae*), sand lance (*Ammodytes hexapterus*), Astarte clams (*Astarte castanea*), and Forbes seastar (*Asterias forbesi*) (Fig. 14). The proportion of organisms in each taxonomic class, by transect number is shown in Fig. 15. This shows that Echinoderms (e.g. sand dollars) were most frequent on transects 1 and 5, whereas hermit crabs were most abundant on transects 5, 6, and 7.

Diversity of the CamSled sample was calculated from the proportion of total organisms (p) in each taxon using Shannon's H' and Hill's N2, where

$$H = -\text{sum}(p*\log(p)) \quad \text{and} \quad N2 = 1/\text{sum}(p^2)$$

(Ludwig and Reynolds, 1988). Values of H' and N2 for the complete data set were 1.74 and 3.208, respectively, when organisms were analyzed at the Order level, and were 1.266 and 2.917 when analyzed at the Class level. This indicates that the number of dominant species was about 3, and did not change with level of analysis because they were all in different orders (sand dollars, hermit crabs, and sand lance). When analyzed at the Class level for individual Transects, diversity (Hill's N2) was greatest on Transects 2-4, where it ranged from 2.07 to 2.92, and lowest on Transects 5-7 (range 1.36-1.56) (Fig. 16, Table 3).

CamSled frame counts were compared between transects using cluster analysis. Data (counts) were centered (i.e. each was expressed as a residual from the overall mean) and scaled (i.e. to units of standard deviation). A distance matrix was calculated using Euclidean distance, and the cluster analysis was conducted using Ward's minimum variance method. The resulting dendrogram shows three groups of clusters (Fig. 17): Transects 1 and 3 were most similar to each other, Transects 2 and 4 were similar, and Transects 5, 6, and 7 were similar. This finding is supported by the pattern of taxonomic distribution shown in Fig. 15, and the diversity values shown in Fig. 16.

Mean depth for all transects was 24.5 m, with a range from 15.1 to 26.8. The distribution of observed sediment types is shown in Fig. 18. The most common bottom substrate viewed in CamSled images was sand. Transect 2 had a large amount of clay and Transects 5 and 6 had more silt than other transects. There was little gravel or other hard substrata observed in any of the camera frames. Cluster analysis of sediment types (Fig. 19) complements the distribution shown in Fig. 18, and shows that Transects fell into three groups: Transects 5 and 6 were most similar, Transect 2 stood by itself, and all other Transects fell into the third group. Sediment type at Transects 5 and 6 probably has a strong influence on the biological community, as those two Transects also formed a unique biological cluster.

CamSled vs Beam Trawl: Three species were among the top 6 in both the beam trawl and CamSled surveys (sand dollars, hermit crabs, and seastars). The beam trawl samples were examined closely so that small invertebrate and fish species could be identified, and many of these were <5 cm, including nudibranchs, sand shrimp, and sea cucumbers, all of which were too small to identify to species in CamSled frames. Though rare, squid were observed by both sampling gears. The beam trawl also dug into the sediment slightly, accounting for the presence of many small organisms, such as auger shells, shrimp, and nudibranchs that were less commonly observed in CamSled frames. Small fish observed by the CamSled could not be identified to species so were listed as "flounder" or "Osteichthes". The majority of auger shells identified in the beam trawl were inhabited by hermit crabs, so all similar shells were identified as hermit crabs in the CamSled frames. Although sand dollars were the most abundant species in the beam trawl samples, most of them came from station BT-15, and the remainder were mostly from stations BT-12 through BT-14, on Transects 7 and 9. In contrast, the CamSled photos showed that sand dollars were most abundant on Transects 1 and 3 (which included trawl stations BT1-3 and BT7-9), whereas Transects 8 and 9 were not sampled with the CamSled due to time constraints.

Considering the difference in size resolution, and combining of similar-looking species, the top species in both lists were hermit crabs (= auger shells), sea stars, flounders or other fish, and sea robins, followed by other snails and crabs in various orders. Therefore, we believe the CamSled is as good as the beam trawl for observing and identifying the most common macro-invertebrates, and provides much better spatial resolution, although the beam trawl is better for identifying small and cryptic species.

Ecological Interpretation

Within the area studied, there was little variation in sediment type or depth, except for Transect 1, which was considerably shallower than the others. Transects 2, 5, and 6 had slightly lower proportions of sand than other transects. There is a slight gradient in depth, sediment type, and community structure from east to west. Both the beam trawl and CamSled surveys showed that diversity decreased from east to west, most likely due to the dominance of hermit crabs in the western-most transects. Thus, these two OCS blocks were similar to the three blocks surveyed in 2012, in terms of sediment type, and lack of hard substrate. The community of benthic organisms observed is made up primarily of semi-mobile benthic organisms (sand dollars, clams), mobile epifauna (crabs, snails, seastars), and highly mobile fish. Very few sedentary organisms (i.e. those that need to attach to hard substrata) were observed, except for a few anemones and sea whips. The overall conclusion of this study is that the epibenthic community of the study area can be characterized as one that is comprised of mobile species that are adapted to highly unstable substrata (sand).

In conclusion, it seems unlikely that construction of wind turbines in the studied OCS blocks would produce any significant long-term disturbance to the epibenthic communities present within them. Furthermore, these biological communities would probably recover rapidly from any temporary disturbance.

Benefits of the study

This study addressed gaps in current data on benthic communities and fish assemblages in the Maryland nearshore region. Approximately 85% of commercial fishing conflict lies in areas south of row 6774, the row of interest in this study. However, OCS Block 6775 contains documented slow-growing cold-water corals, and portions of all three specified blocks have been used as commercial or recreational fishing grounds (DNR Chesapeake and Coastal Program 2010). There is also a wreck documented in OCS 6825, which was not examined in 2012. The data we gathered will be usable for studying the long term impacts of WEA development. This document provides background information usable for planning prior to construction or installation of wind turbines, and which can be used for comparison to future, post-construction surveys. The information presented herein will be used for a graduate thesis at the University of Maryland Eastern Shore. The results will also be presented at numerous scientific meetings, and published in peer-reviewed scientific journals. Presentations of the work will be given to project managers and other interested parties.

Acknowledgements

This research benefitted greatly from assistance provided by Capts. Chet and Wes Townsend, who shared many fun days and lobster sandwiches with us aboard their boat, the F/V *Andrew G*. We also appreciate the assistance of interns from the UMES Research Experience for Undergraduates Program, especially Najja Gay, and other graduate and undergraduate students who assisted with the field work. This research was supported by Contract No: # 14-13-1680 MEA from the MD Dept. of Natural Resources. Salary for B. Stevens was provided by the NOAA Living Marine Resources Cooperative Science Center, Grant No. NA11SEC4810002.

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Table 1. List of species captured from small mesh beam trawl survey, proportion of total, and rank. WSS Rank is from the 2012 LMRCSC winter shelf survey, among fish (F) or invertebrates (I).

	Common Name	Scientific Name	Total	Percent	Rank	WSS Rank*
1	plain sand dollar	*Echinarachnius parma*	6961	82.6%	1	I 10
2	long-clawed hermit crab	*Pagurus sp*	464	5.5%	2	
3	auger snail	*Terbra dislocata*	296	3.5%	3	
4	Forbes sea star	*Asterias forbesi*	165	2.0%	4	I 17
5	Gulf stream flounder	*Citharichthys arctifrons*	133	1.6%	6	F 1
6	Rock crab	*Cancer irroratus*	134	1.6%	5	I 6
7	warty nudibranch	*Onchidoris sp ?*	61	0.7%	7	
8	spotted hake	*Urophysis regia*	50	0.6%	8	F 5
9	sand shrimp	*Crangon septemspinosa*	43	0.5%	9	I 1
10	northern sea robin	*Prionotus carolinus*	30	0.4%	10	F 2
11	American sand lance	*Ammodytes americanus*	29	0.3%	12	
12	chestnut astarte clam	*Astarte castanea*	29	0.3%	12	I 23
13	moon snail	*Lunatia sp*	12	0.1%	13	
14	lady crab	*Ovalipes ocellatus*	5	0.1%	15	
15	sea cucumber	*Pentamera sp*	5	0.1%	15	
16	surf clam	*Spisula solidissima*	3	0.0%	17	I 38
17	lined sea horse	*Hippocampus erectus*	3	0.0%	17	
18	windowpane flounder	*Scopthalmus aquosus*	2	0.0%	20	
19	northern pipefish	*Syngnathus fuscus*	2	0.0%	20	
20	four spot flounder	*Paralichthys oblongus*	2	0.0%	20	F 3
21	squid	*Loligo or Illex sp*	2	0.0%	20	
22	winter skate	*Raja ocellata*	1	0.0%	22	
	Total individuals		8432			
	Total species		22			
	Species counts ≥ 5		14			

Table 2. Numbers of species observed with the CamSled survey, and their proportion and total.

Scientific Name	Common name	Class	Number	Percent
Echinarachnius parma	sand dollar	Echinodermata	1294	42.6%
Paguridae	hermit crabs	Crustacea	880	29.0%
Ammodytes americanus	sand lance	Osteichthyes	231	7.6%
Astarte castanea	Astarte clam	Bivalvia	213	7.0%
Pagurus longicarpus	long-clawed hermit	Crustacea	159	5.2%
Asterias forbesi	Forbes seastar	Echinodermata	85	2.8%
Polinices duplicatus	moon snail	Gastropoda	63	2.1%
Prionotus carolinus	Sea robin	Osteichthyes	52	1.7%
Pleurobranchaea tarda	warty sea slug	Gastropoda	14	0.5%
Cancer sp	Cancer crab	Crustacea	13	0.4%
Anemone unk	anemone	Cnidaria	5	0.2%
Leptogorgia virgulata	sea whip	Cnidaria	4	0.1%
Cancer irroratus	rock crab	Crustacea	4	0.1%
Raja eglanteria	clearnose skate	Chondricthyes	4	0.1%
Osteichthyes	bony fish	Osteichthyes	3	0.1%
Limulus polyphemus	horseshoe crab	Merostomata	2	0.1%
Pagurus sp	hermit crabs	Crustacea	2	0.1%
Centropristis striata	black sea bass	Osteichthyes	2	0.1%
Busycotypus canaliculatus	channeled whelk	Gastropoda	1	0.0%
Brachyura	crabs	Crustacea	1	0.0%
Bothidae	Left-eyed flounder	Osteichthyes	1	0.0%
Citharichthys arctifons	Gulfstream fldr	Osteichthyes	1	0.0%
Scopthalmus aquosus	windowpane fldr	Osteichthyes	1	0.0%
Total species			27	
Total individuals			3035	

Table 3. Mean values of depth (m), frames counted, Shannon's H', and Hill's N2 diversity indices for all data and for each Transect.

Data	Depth (M)	Frames	Shannon H	Hill's N2
All	24.5	4393	1.266	2.917
Trans1	15.1	563	1.072	2.072
Trans2	22.8	34	0.974	2.462
Trans3	24.4	806	1.223	2.560
Trans4	24.4	35	0.970	2.419
Trans5	26.5	1036	0.587	1.357
Trans6	25.8	1007	0.780	1.559

Trans7	26.8	912	0.576	1.361

Figures

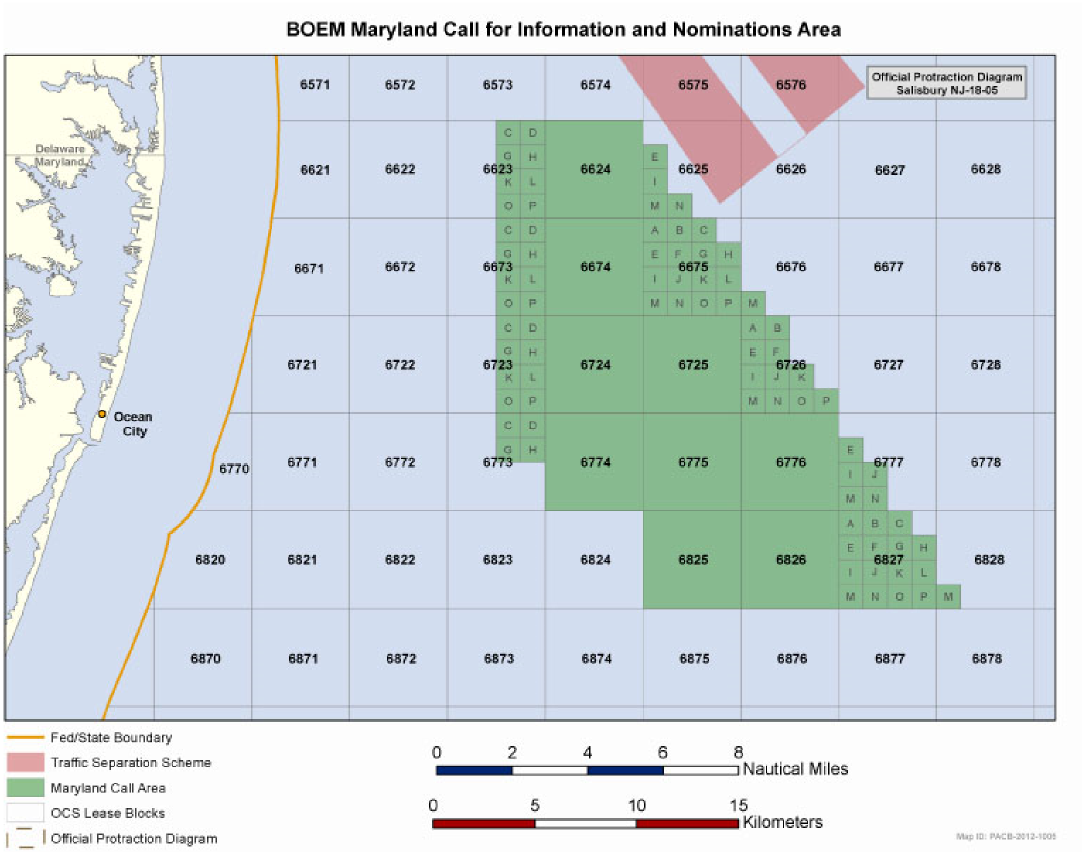

Figure 1: OCS blocks in the Maryland Wind Energy Area. Green blocks are those of greatest interest; Red areas are ship traffic lanes to and from Delaware Bay. Image credit: BOEM 2012.

Figure 2. Image taken in 2012 with low-light black-and-white NTSC video camera at a resolution of 720x 480; note vignetting at corners;

A **B**

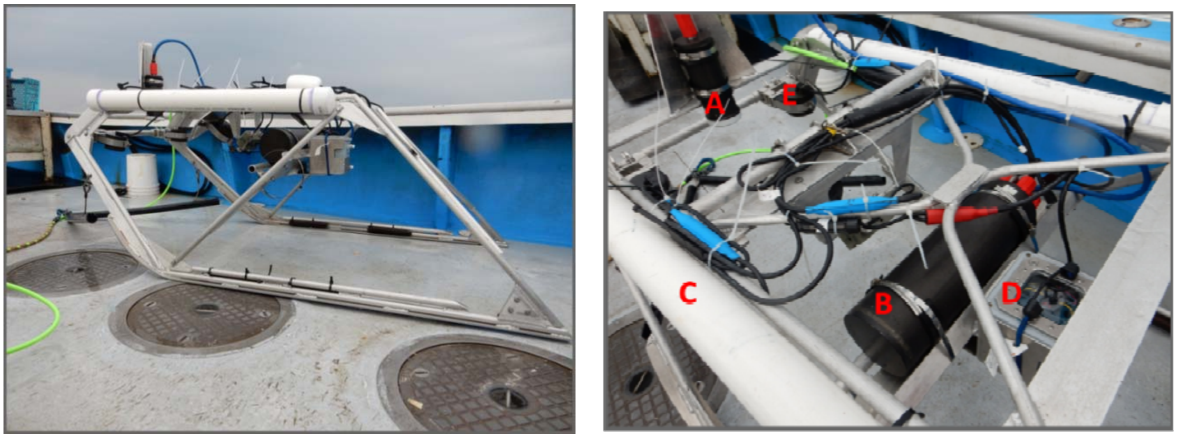

Figure 3. A) Camera Sled; B) Camera sled components: A) Camera, B) On-board Computer, C) Floats, D) Battery, E) Strobes lights

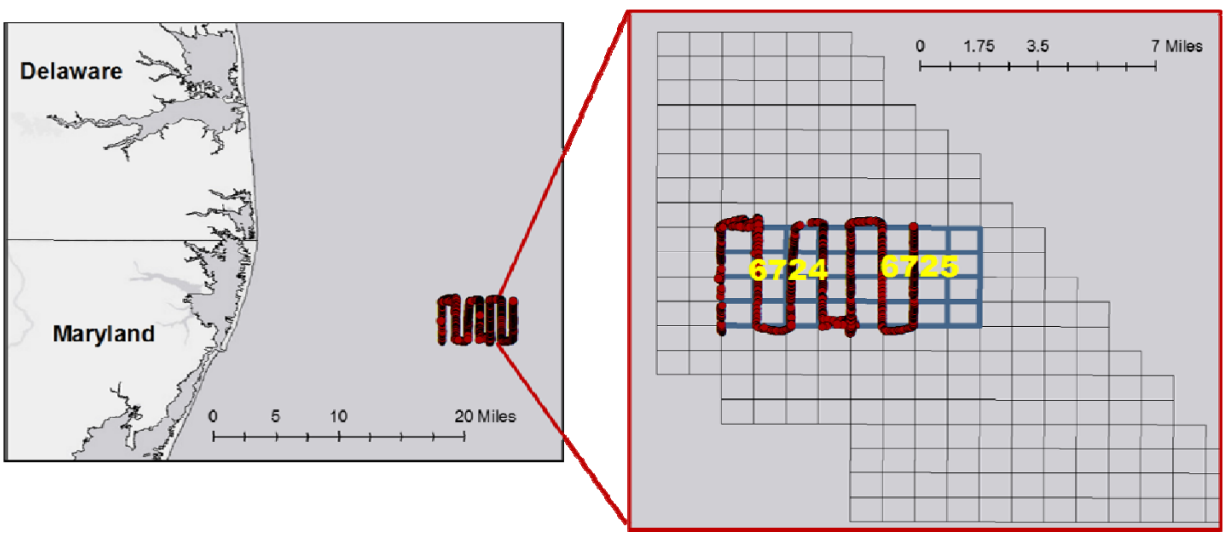

Figure 4. Map of transects completed in OCS blocks 6724 and 6725. The last two transects on the eastern edge were not completed.

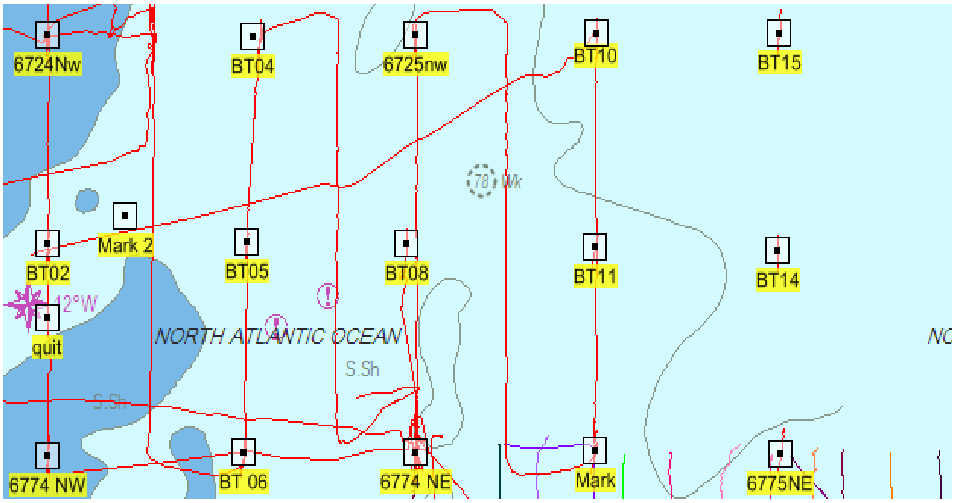

Figure 5. Map of transects completed in OCS blocks 6724 and 6725. Squares indicate location of beam trawl samples (BT01-BT15. The last two transects on the eastern edge were not completed.

Figure 6. (Left) setting the beam trawl from the F/V *Andrew G*. (Right) Sorting the catch.

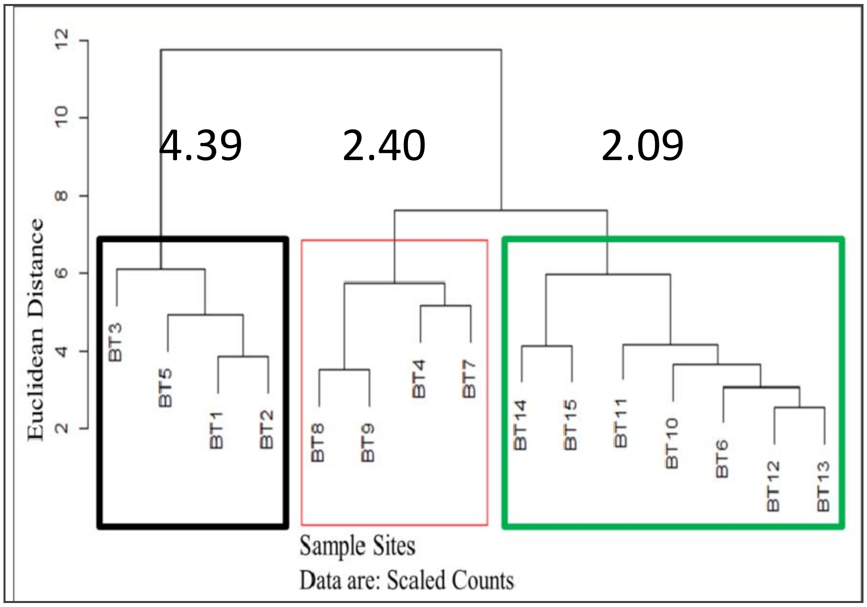

Figure 7. Dendrogram from cluster analysis of beam trawl samples based on species abundance. Bold numbers represent Hill's N2 diversity index, which represents the effective number of abundant species in each cluster. Cluster 3 (green) was dominated by sand dollars.

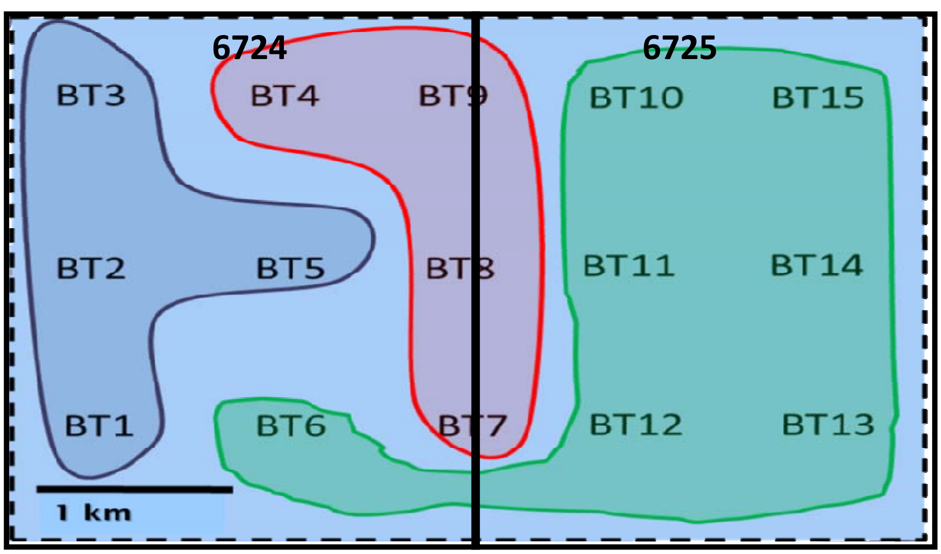

Figure 8. Geographic distribution of benthic communities in OCS blocks 6724 and 6725, based on species abundance from beam trawl samples. Colors (Gray, red, green) correspond to the clusters in Fig. 6.

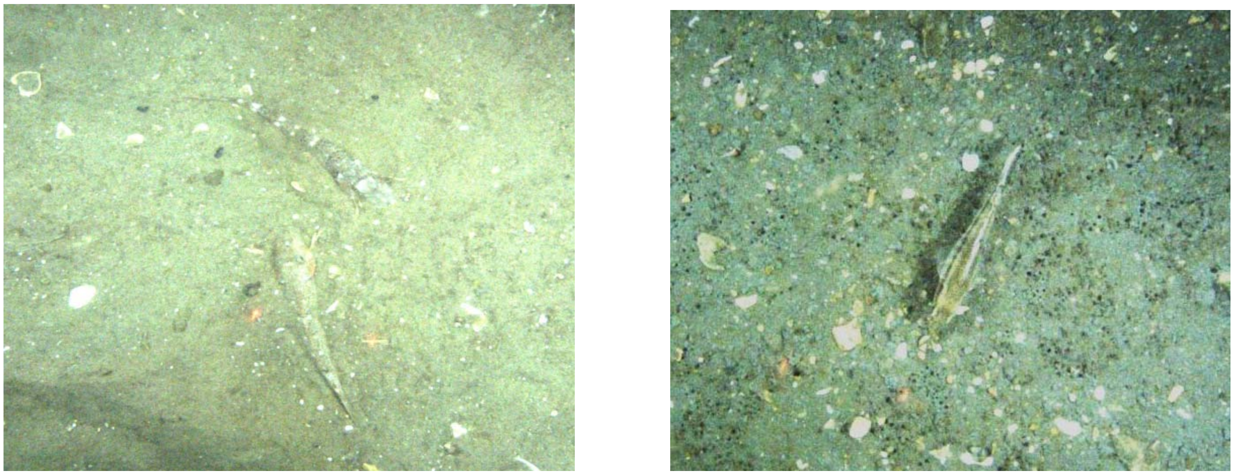

Figure 9. Example frames from the camera sled survey. (Left) Northern sea robin; (right) black sea bass. Note bright red laser dots in frame.

Figure 10. Examples of substratum classification categories.

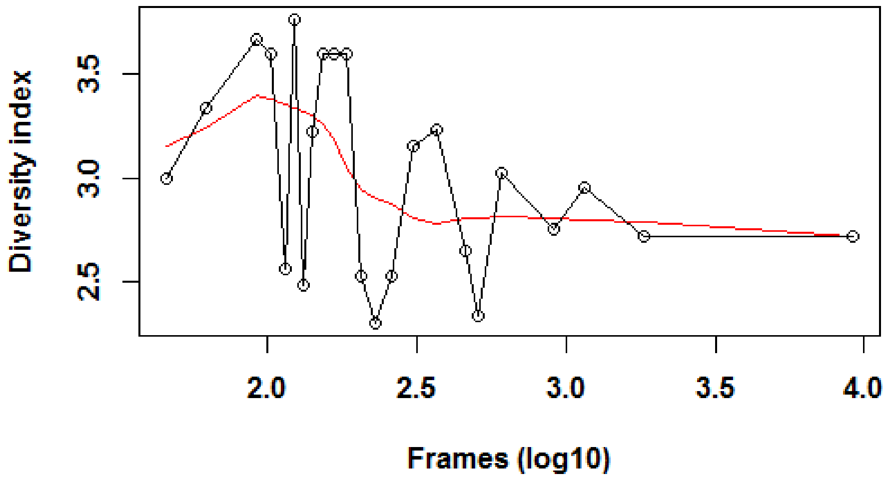

Figure 11. Systematic sampling of transect 5. Hill's N2 Diversity index is plotted along the y axis vs the log10 of number of frames sampled in the x-axis. Red line is a lowess (locally weighted) regression that levels out around $10^{2.5}$ (316 frames)

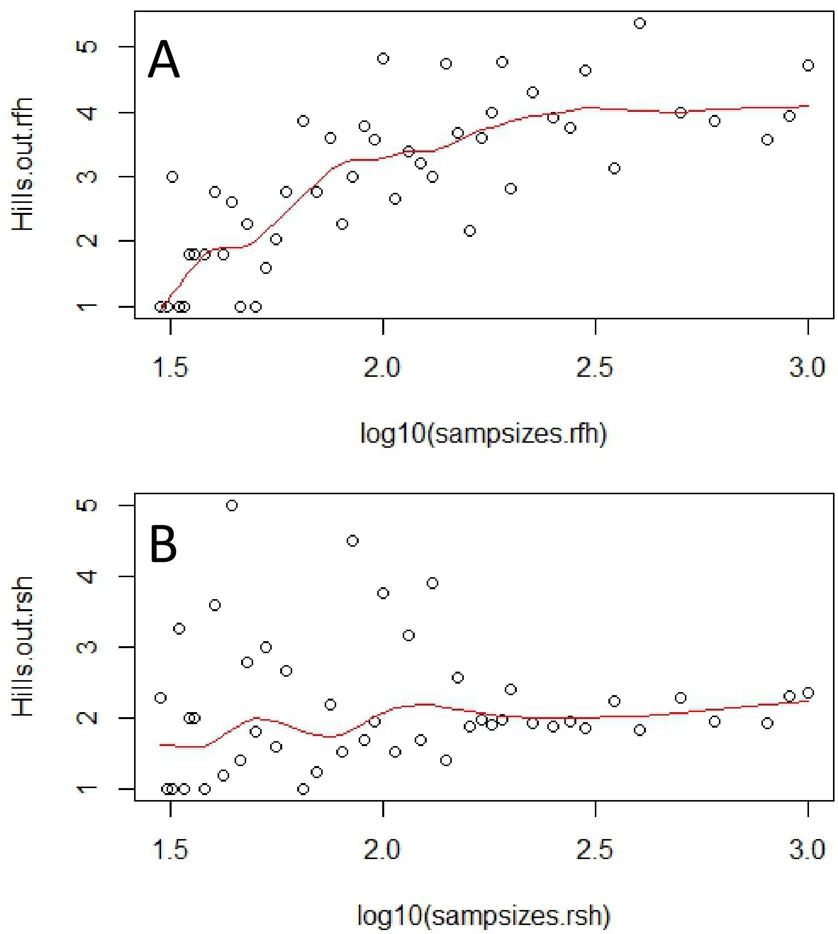

Figure 12. Random sampling of the first and second halves (15 min segments) of transect 5. Hill's N2 Diversity index is plotted along the y axis vs the log10 of number of frames sampled in the x-axis. Only one of 10 trials is shown for each half-transect. Red line is a lowess (locally weighted) regression. Diversity leveled out at sample sizes around $10^{2.4}$ (250 frames) in sample 5A, and at about $10^{2.2}$ (160 frames) in sample 5B.

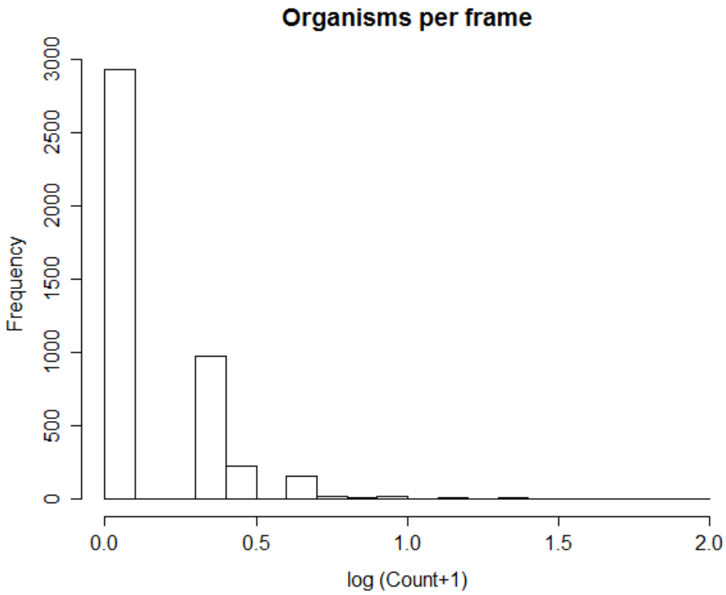

Fig. 13. Frequency of organisms counted (as log(x+1) per frame from Sledcam survey.

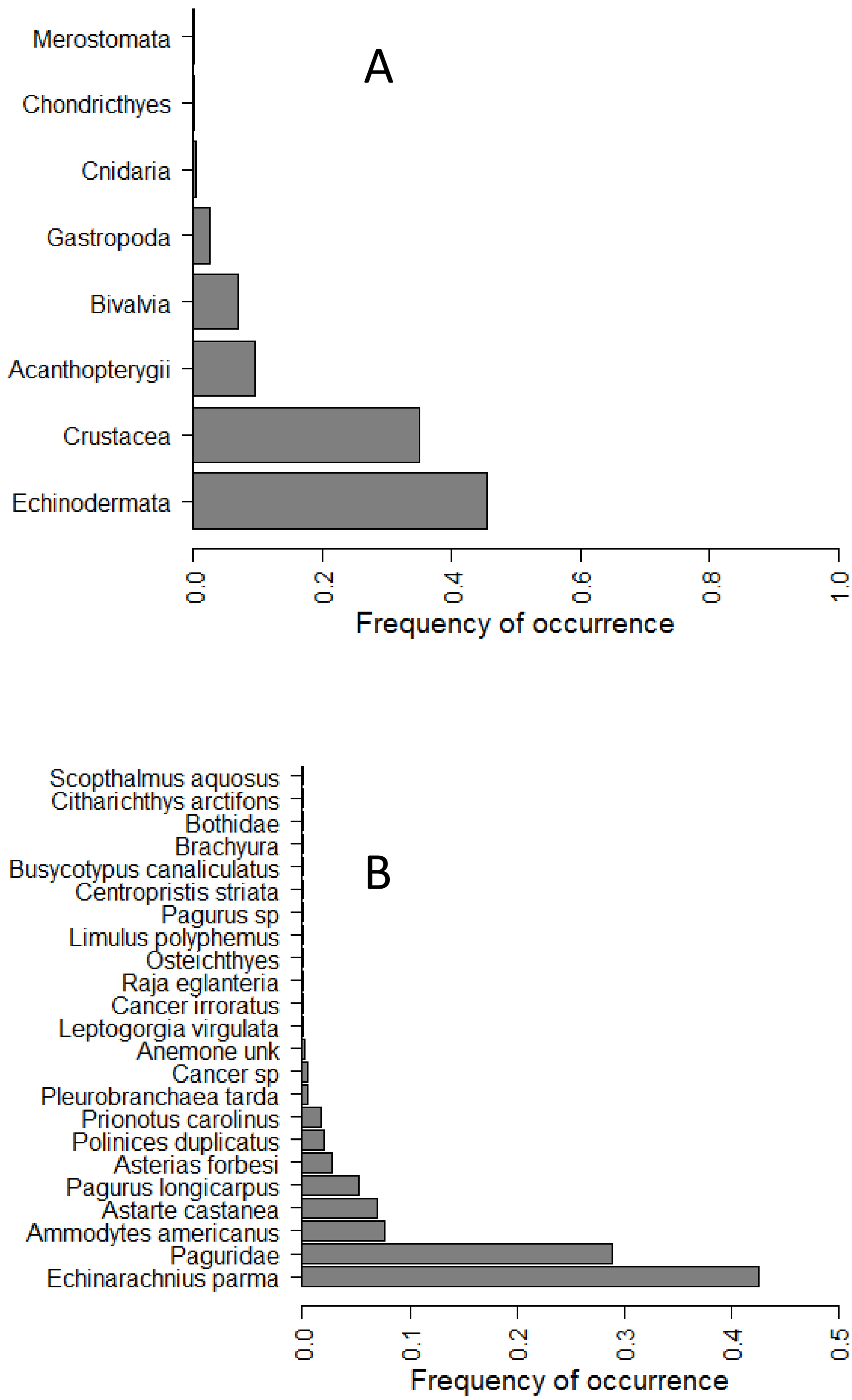

Fig. 14. Frequency of occurrence of organisms observed in Camsled frames A) by Order, and B) by lowest taxon.

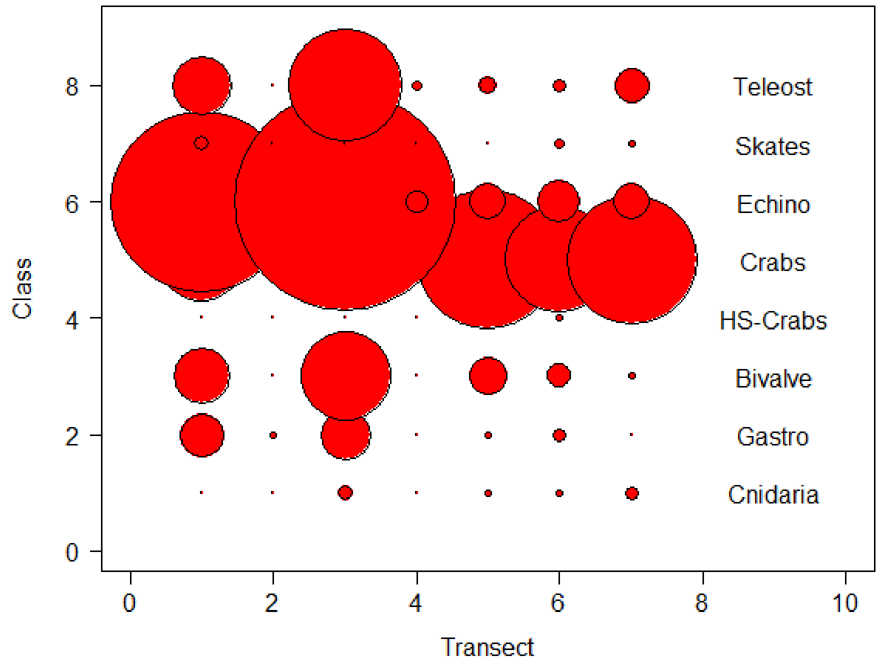

Fig. 15. Proportion of total organisms counted by class and transect.

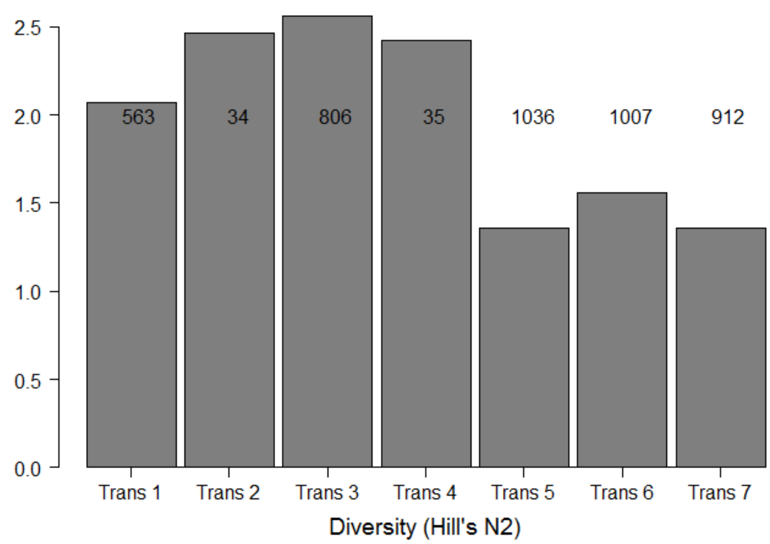

Fig. 16. Diversity (Hill's N2) for each of the CamSled transects. Numbers are frames counted in each transect.

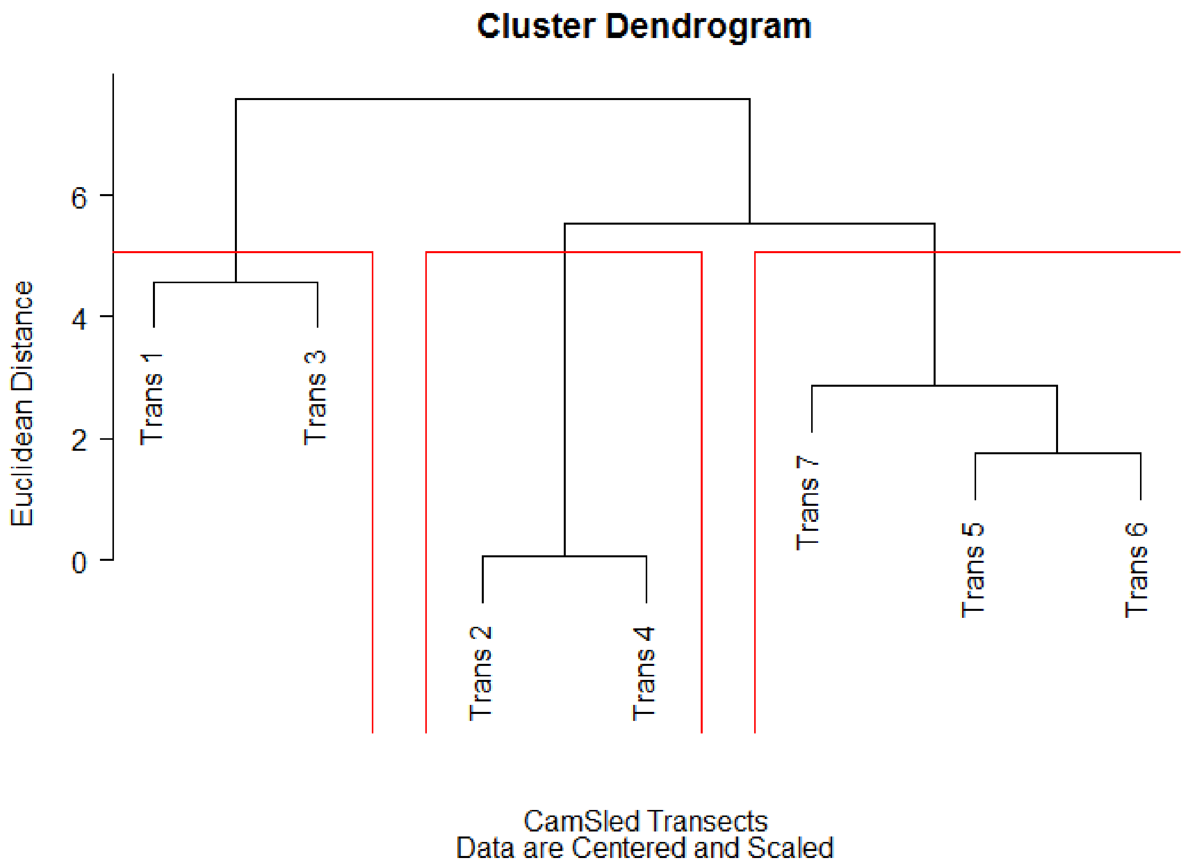

Fig. 17. Dendrogram of CamSled transect data. Counts were centered and scaled before analysis. Three groupings are identified by red rectangles.

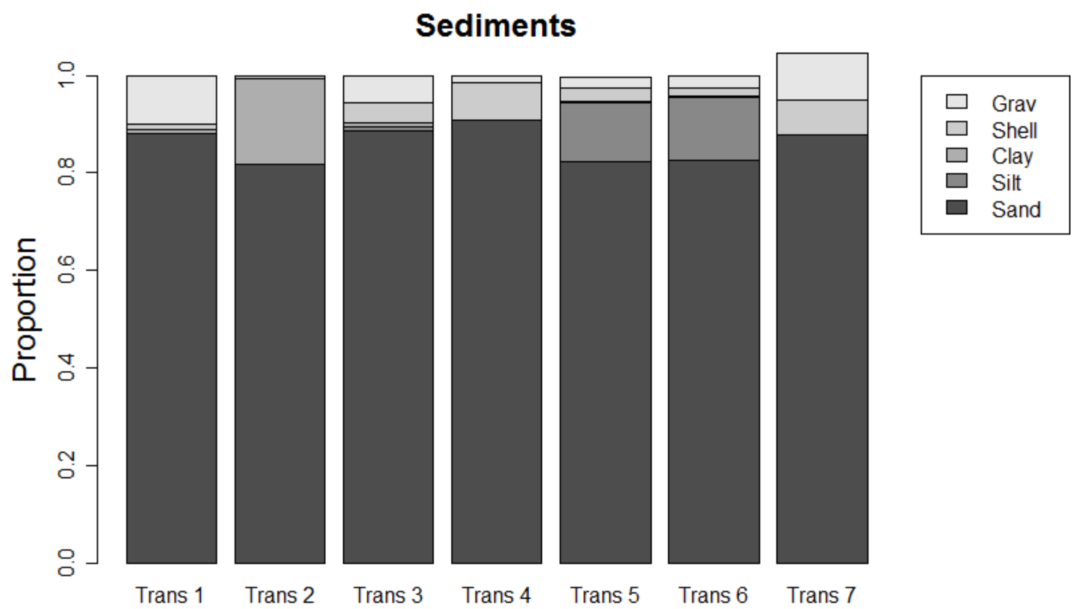

Fig. 18. Distribution of sediment types on CamSled Transects.

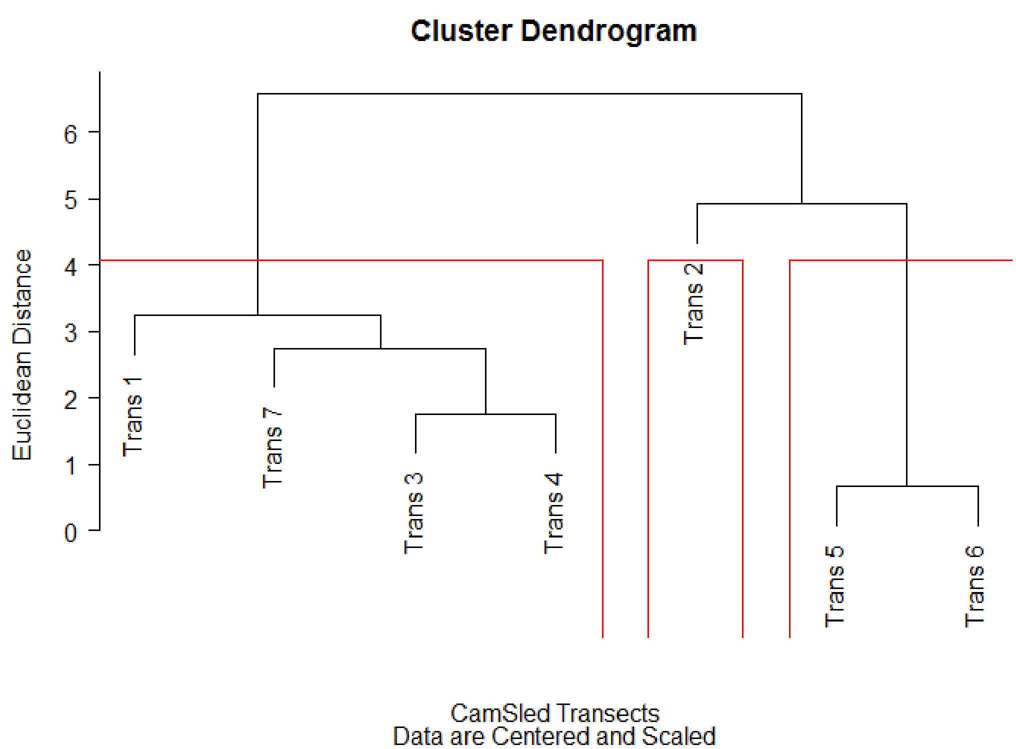

Fig. 19. Dendrogram of CamSled sediment data. Counts were centered and scaled before analysis. Three groupings are identified by red rectangles.