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A Method for Quantifying Biogenic Habitat from Stationary Underwater Video

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Introduction

Benthic habitat structure is an important predicator of species distribution, diversity, and abundance, for marine fishes (Jennings et al. 1996; Friedlander and Parrish 1998; Hallenbeck et al. 2012). Habitat structure is often described by the type of geologic substrate (i.e. bedrock, sand, etc.), the structural relief (i.e. rugosity), and the diversity of substratum within a given area. Yet, habitat structure is not exclusively comprised of geologic substrates, but also by the sessile, biogenic life inhabiting these geologic substrates (Gratwicke and Speight 2005; Reed and Hovel 2006). The composition and diversity of *both* geologic and biogenic habitat structure can be described as habitat complexity. Moreover, fish species richness and abundance has been shown to increase with increasing habitat complexity (Gratwicke and Speight 2005), where complexity was scored based on both geological characteristics (i.e. substratum, rugosity) as well as biogenic characteristics (i.e. biogenic growth form diversity, height, size, and cover). Many of the studies evaluating both geologic and biogenic habitat metrics occur in shallow systems such as coral reefs (Friedlander and Parrish 1998), seagrass beds (Reed and Hovel 2006), and kelp forests (Bodkin 1988) or in deep-water, soft bottom habitats (Du Preez and Tunnicliffe 2011). Species-habitat correlations in temperate, rocky reef habitats of the Northeast Pacific, relating specifically to biogenic structure, are much less common (but see Holbrook et al. 1990; Hartney and Grorud 2002).

The limited number of biogenic habitat studies in the Northeast Pacific may reflect the few survey tools capable of withstanding the adverse sea conditions and complex rocky habitats that characterize temperate reefs in this region. However, recent advances in underwater video technologies deployed on a variety of platforms including stationary landers, remotely operated vehicles (ROVs), and sleds are becoming more common to quantify fish assemblages and their associations with geologic habitats (Tissot 2008; Pacunski et al. 2008; Hannah and Blume 2012). Video quality is improving while the cost of these systems continues to decline, making simple deployment platforms such as a video lander a cost-effective monitoring tool for long-term data collection (Cappo et al. 2003; Watson and Huntington 2016). These video approaches are appealing due to their ability to collect large amounts of data across a variety of geologic substrates and depth ranges, without extraction, providing an opportunity to observe fish *in situ*. With increased use of underwater video landers to monitor fish populations within nearshore environments (including protected areas like marine reserves) there is an opportunity to quantify biogenic habitat in the same rigorous and repeatable manner as current fish abundance and geologic habitat assessments.

In Northeast Pacific nearshore rocky reef environments, the Oregon Department of Fish and Wildlife (ODFW) has successfully used underwater video surveys to enumerate fish assemblages, describe the geologic substrate, and connect fish occurrence to the available geologic habitat (Fox et al. 2004; Hannah and Blume 2012; Easton et al. 2015). For a detailed description of the lander design and configuration see Watson and Huntington 2016. The goal of the current project was to develop a repeatable protocol for quantifying biogenic habitat from video lander data in order to more fully describe habitat complexity observed from stationary underwater video, and enhance ODFW's ability to establish robust fish-habitat relationships. We developed an approach, similar to the Braun-Blanquet cover-abundance scale used in seagrass bed surveys, to quickly assess the abundance of five classes of biogenic structure (Braun-Blanquet, 1972). Training materials were created to instruct video reviewers in this new scoring protocol and then inter-reviewer repeatability was assessed. Lastly, simple correlations between biogenic structure and the fish community were explored using lander drops from one of Oregon's marine reserves to test the utility of the biogenic data generated to inform fish-habitat associations.

Methods

1. Protocol Development

Identifying five classes of Biogenic Structure

Within Oregon's productive nearshore rocky reefs, biogenic habitat is common and can include mounding sponges, fleshy macroalgae, large anemones, and minute crusts. After an initial review of our nearshore stationary lander video, it was determined that species specific identification was consistently poor due to limited water visibility, limited light availability, and low taxonomic distinctness. However, sessile organism height and form were consistently identifiable in most videos. Therefore the protocol was developed to group biogenic habitat into five classes based on height and functional form (Table 1). **Canopy** was defined as canopy forming algal species and often viewed in benthic lander video as stipes and holdfasts only (frequently *Nereocystis luetkeana*). **Midstory** was defined as any algal species with visible blades and a height >25cm. **Understory** was defined as any biogenic material 5-25cm in height including macroalgae, coralline algae, sponges, and gorgonians. **Turf/Crust** was defined as biotic crusts, turfs or mats, encrusting sponges, and tunicates <5cm in height. Finally, **Seagrass** is defined as the subtidal vascular seagrasses of any size (frequently *Phyllospadix sp.*). Lasers, mounted on the lander 10cm apart, were used to estimate the height of observed biogenic habitats. Mobile organisms were not enumerated in this protocol as they do not comprise sessile, biogenic habitat.

Developing a cover-abundance scale

The rapid visual assessment technique developed by Braun-Blanquet (1972) was created to assign an abundance score based on the cover of that biogenic class within a defined area. This approach has been used in a variety of systems, both terrestrial and marine, to rapidly assess the abundance of biogenic groups in a repeatable and robust fashion (Wikum and Shanholtzer 1978; Fourqurean et al. 2001). Here, the abundance of the five classes of biogenic habitat described above were classified using an index score ranging from 0-5 (Table 2). Each biogenic habitat present was assigned to a single class with an index score based on the percent cover of that habitat within the field of view. Several video scoring rules accompanied these index values in order to improve scoring consistency among reviewers. For example, biogenic habitat was scored based on the average percent cover observed over the duration of the video. Additionally, reviewers only scored the area of the screen that was clearly visible, and considered that to be 100% of the scorable area. Index scores for the scorable area therefore, should not exceed 100%.

Training Material Development

Based on a test panel of four reviewers, problematic areas of the new protocol were identified and training materials were developed to ensure biogenic habitat scoring would be both consistent among reviews and repeatable. Training materials included still images describing the five biogenic classes, a detailed written protocol (Appendix), as well as a training video comprised of lander footage highlighting common mistakes identified by the test group. These training materials were then used to train five reviewers who subsequently scored videos from 17 lander drops. The scores from these reviewers were used in our final evaluation of inter-observer repeatability.

2. Protocol Evaluation

Abundance scores from the 17 scored videos were evaluated for consistency among reviewers (n=5) and for consistency among biogenic classes (canopy, midstory, understory, turf/crust, seagrass). In order to evaluate patterns of variance, each reviewer's abundance scores for each biogenic category were compared against scores assigned by author KL, hereafter referred to as the standard score. Reviewer error (E) was calculated as the absolute value of the difference between standard score and reviewer score;

$$E = |standard - reviewer|$$

The response variable E could not be transformed to meet parametric assumptions, so non-parametric one-way Wilcoxon Rank Sums Tests (factor: reviewer) were used to test for significant differences among reviewers and biogenic classes.

3. Fish-Habitat Associations

Lander video data collected from 2010-2015 were used to assess fish-biogenic habitat relationships. The dataset was restricted to only include lander drops that encountered bedrock as the primary geologic substrate (n=124). Selecting for a single geologic substrate type allowed for isolation of responses due to biogenic habitat rather than variations in the geologic features. We assume that fish did not respond to any rugosity differences that may have been present in the bedrock. Additionally, analysis was restricted to species occurring in >1 of the 124 drops in the dataset, eliminating variance due to highly rare species. Finally, we limited our analysis to a relatively small spatial area (7km^2) encompassing the Otter Rock Marine Reserve and Cape Foulweather Comparison Area. Due to the shallow (<20m) nature of this rocky reef, biogenic habitats were abundant and diverse.

We conducted simple linear regressions to evaluate the relationship between biogenic habitat and the fish community from underwater lander video. The biogenic habitat variables included biogenic habitat diversity (i.e. the number of biogenic classes present; ranging from 0-5) and a measure of biogenic complexity (the sum of biogenic index scores across all present classes) per lander drop. The fish community variables included species richness and total relative abundance (i.e. the sum of species-specific MaxN values). MaxN is a common metric for estimating fish abundance from stationary underwater video (Watson et al. 2005; Harvey et al. 2007; Watson and Huntington 2016) and represents the maximum number of fishes of a given species seen in any single frame of the video. The fish community variables were averaged by the biogenic habitat variable to reduce the variance observed in this large dataset in order to describe trends between the fish community and biogenic habitat.

Results

1. Protocol Use

Each reviewer spent less than one hour reviewing and scoring the 17 videos. In a post-review survey, reviewers rated the ease of using the abundance index scores (0-5) as “good” (options were; poor, fair, good, excellent). On average, the reviewers indicated the number of classes used (5) were sufficient to describe the habitat viewed in the videos and recommended keeping them as they were written.

2. Protocol Evaluation

Index scores were consistent among reviewers. The mean error among the five reviewers were statistically similar (Figure 1; Wilcoxon test, P = 0.07) when all biogenic classes were pooled. When we look at each biogenic class individually, error scores were also consistent among reviewers (Wilcoxon test, P > 0.33).

While reviewers were consistent in their ability to score each biogenic class, the amount of error did vary among the classes (Figure 2). Seagrass and canopy classes were scored the most accurately; errors for these two classes were significantly lower than the other three classes. Midstory was statistically distinct from all biogenic classes having a higher error value than canopy and seagrass but lower than understory and turf/crust. Understory and the turf/crust classes had the highest errors of all classes. Interestingly, reviewer error was negatively correlated with biogenic class height. In other words, as biogenic habitat height decreased, reviewer error increased.

3. Fish-Habitat Associations

The average relative number of fishes observed (total MaxN) and the diversity of those fishes (species richness) increased significantly with greater biogenic complexity (measured as the sum of all biogenic index scores; Figure 3 and 4). No relationship was found between biogenic habitat diversity and the fish response variables of total MaxN or species richness.

Discussion

The nearshore waters of the Northeast Pacific is a productive ecosystem with an abundance of biogenic habitat structures present (Allen and Horn 2006). Biogenic structure contributes to the overall structural complexity of benthic habitat and can play a role in shaping species distributions, including species of commercial and management importance (Gratwicke and Speight 2005). This necessitates quantification of biogenic habitat in a consistent, robust, and repeatable manner. Here we developed, evaluated, and applied a new method for rapidly assessing biogenic habitat structure from underwater video. Using a modified percent cover protocol and delineating five classes of biogenic habitat, we demonstrated that biogenic habitats can be consistently scored among differing trained reviewers. These results indicate that the scoring protocols and associated training materials helped create data consistency and repeatability.

Evaluation of video reviewer error revealed both consistency between, and an acceptable level of error among reviewers. Error across all reviewers was within ± 0.5 scoring index value, indicating that difference among reviewers would be unlikely to change mean estimates in cover based on an integer scale. Greater errors were seen in comparing between the five biogenic classes, not between reviewers. All reviewers consistently scored biogenic classes with larger sized organisms (seagrass, canopy, and midstory species) with better accuracy. This likely reflects that larger organisms are more readily distinguished from video and often not as abundant as their smaller counterparts. Indeed, the biogenic classes with the highest mean index scores also had the highest errors (i.e. understory and turf/crust). Further training for consistently delineating index scores representing <25% cover may help improve accuracy for abundance biogenic classes.

To test the applicability of this protocol, we explored the relationship between the nearshore fish community observed within a single geologic substrate (bedrock) in shallow, nearshore waters within increasing amounts and diversity of biogenic structure. In this habitat, both fish abundance and species diversity increased with greater biogenic complexity. This complexity reflects both abundance *and* diversity of the biogenic classes. These trends were established using mean values of the fish response variables for each level of biogenic complexity. High variance in the raw data suggests that these trends may also be influenced by other parameters not specifically addressed in this analysis. However, these result do parallel similar findings from other marine systems such as coral reefs where more complex coral communities support more diverse and abundant fish communities (Pittman et al. 2007).

At present, this protocol is most appropriately applied to habitats where biogenic structure falls within the established categories (i.e. shallow rocky reefs). Further testing of the protocol needs to include its applicability to deeper habitats, as well as over larger spatial and temporal scales. While the current method was developed and tested using stationary video from underwater landers, the protocols can be applied to different video platforms (i.e. ROV). Considering new attributes to extract from existing video data expands on the utility of these tools to describe marine communities. By using video data in this way, we are able to address an important component in the larger goal of species-habitat correlation; the ability to link habitat data (both geologic and biogenic) to observations of mobile biota.

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Tables

Table 1. The definition of the five classes of biogenic habitat based on functional forms and height.

Class	Size	Definition	Common Species/examples
Canopy	>25cm	Large kelps, only stipes and/or holdfasts in view	*Nereocystis luetkeana*
Mid-story	>25cm	Large algae with stipes and blades in view	*Laminaria sp*.
Understory	5-25cm	Medium algae, and sessile invertebrates	*Metridium farcimen*, sponges
Turf/Crust	< 5 cm	Small algae, crustose and encrusting algae, encrusting invertebrates	*Callophyllis sp.*, crustose coralline algae, encrusting sponges)
Seagrass	All sizes	Seagrasses (Alismatales)	*Phyllospadix sp.*

Table 2. The definition of abundance index scores assigned to each biogenic habitat class based on % cover.

Score	Definition
0	None
1	< 5% of cover
2	5 – 25 %
3	26 – 50 %
4	51 – 75 %
5	76 – 100 %

Figures

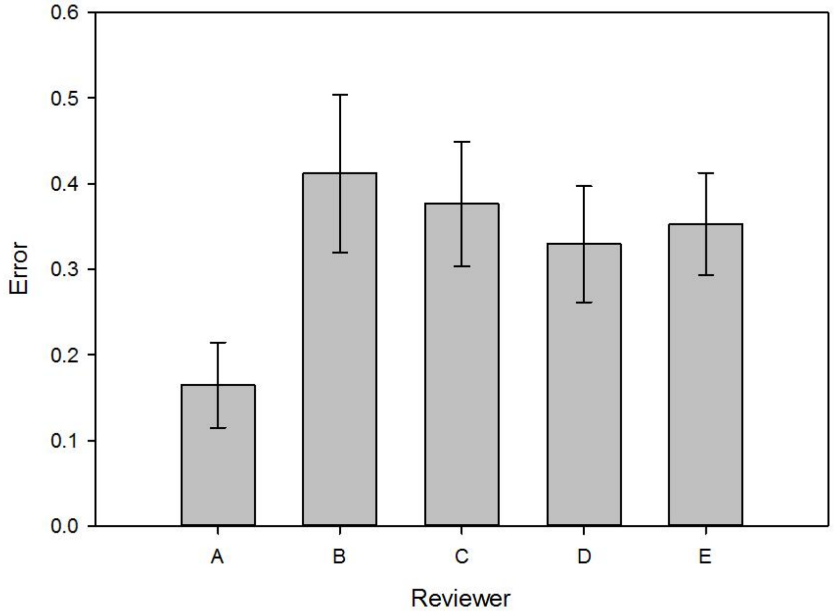

Figure 1. Mean inter-reviewer index score error (*E*) ± SE. All reviewers were statistically similar (Wilcoxon Rank Sums test, $P > 0.05$).

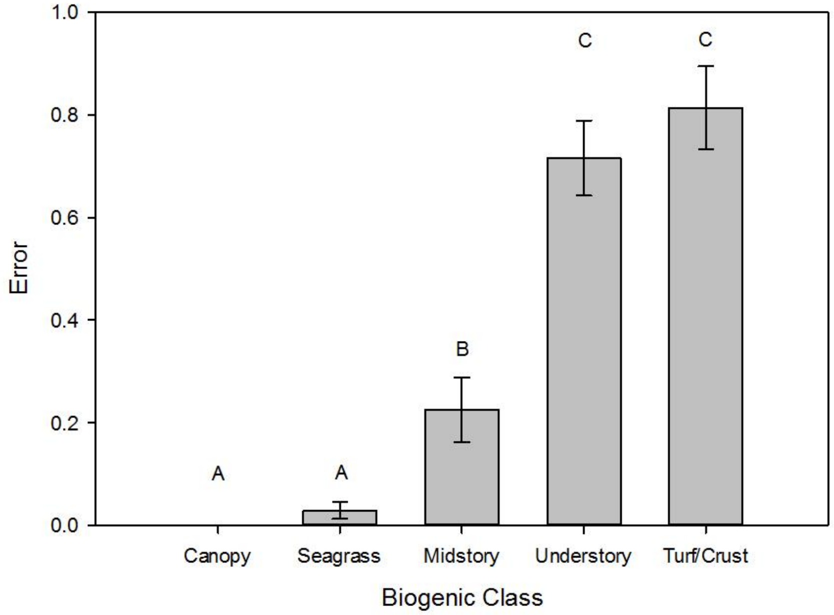

Figure 2. Mean error (±SE) among biogenic classes. Significant differences among classes are indicated by differing letter groups above the bars (Wilcoxon Rank Sums test, $P < 0.05$).

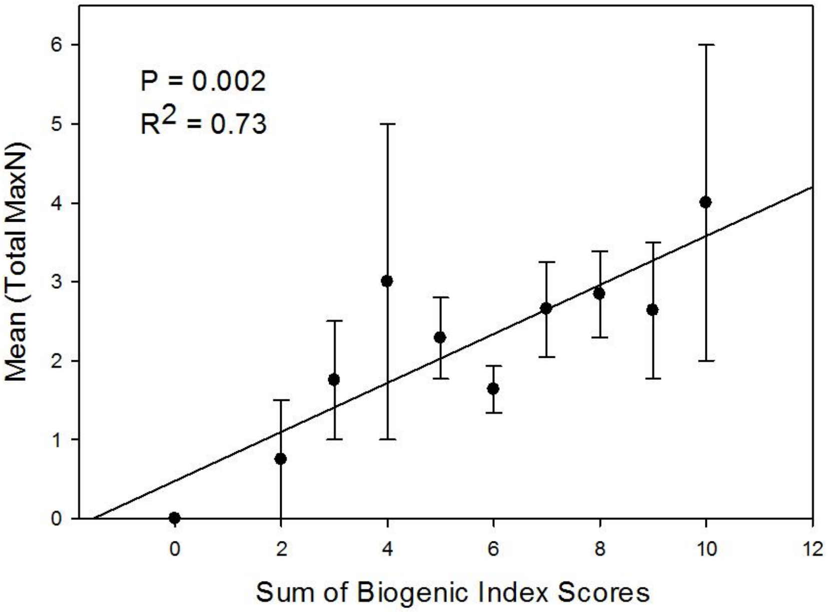

Figure 3. Linear regression of the mean total MaxN (±SE) against the sum of the biogenic index scores for each lander drop (biogenic complexity).

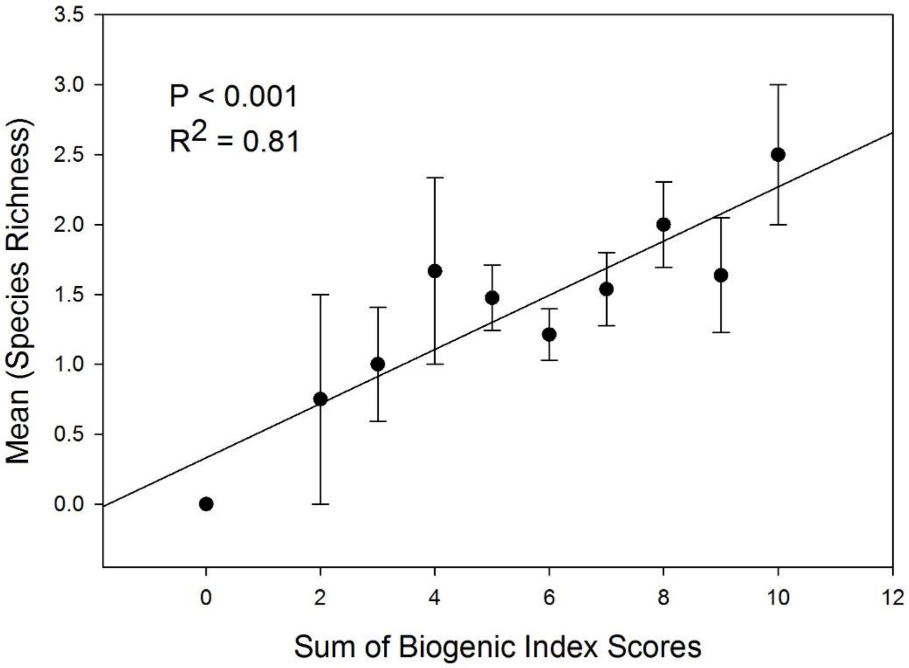

Figure 4. Linear regression of the mean species richness (±SE) against the the sum of the biogenic index scores for each lander drop (biogenic complexity).

Appendix: Video Lander Biogenic Habitat Analysis Protocol

Biogenic Habitat

Biogenic structure is grouped into 5 classes based on size and shape.

Classification	Definition
Canopy	Bull Kelp (Nereocystis)- stipes and holdfasts only
Mid-story	Smaller kelps with stipes and visible blades (Laminaria, etc.)
Understory	5-25cm kelps and sessile inverts (Metridium, tunicates)
Turf/Crust	< 5 cm kelps and encrusting invertebrates (crustose coralline algae, encrusting sponges)
Seagrass	Eelgrass (*Phyllospadix sp.)*

The distinction between "Understory biogenic" and "turf/crust" is based on height (Appendix, Fig.A1).

Score the average biogenic habitat in view over the duration of video. This means that if midstory kelp is moving in and out of the frame with the surge, you should score the point at which the estimated average amount is visible.

Determine the abundance index score based only on the field of view that can be clearly resolved (Appendix, Fig.A2). For example, if only the bottom half of the video can be scored, an algal category occupying half of this space would receive a score of 3 (the index value for 50% cover).

Score	Definition
0	None
1	< 5% of cover
2	5 – 25 %
3	26 – 50 %
4	51 – 75 %
5	76 – 100 %

New reviewers must watch the Biogenic Training Video and become familiar with scoring biogenic habitat.

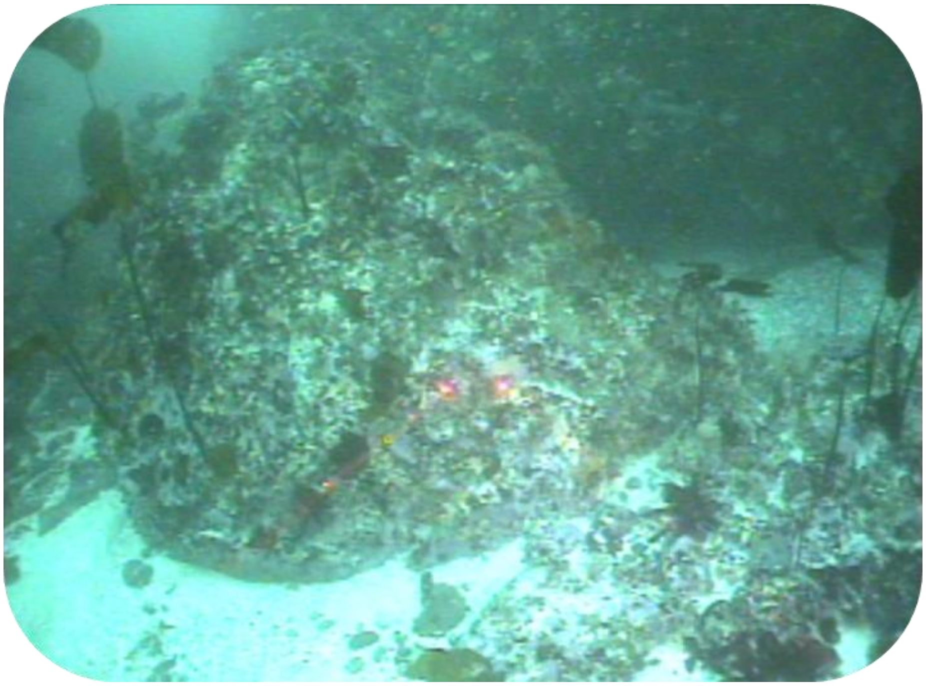

Figure A1: Screen shot from lander Screen shot from lander video showing laser points (10cm apart) used to reference scale. Note: this video contains midstory (>25cm), understory (<25cm and >5cm), turf (<5cm), as well as sandy substrate (abundance index of 0).

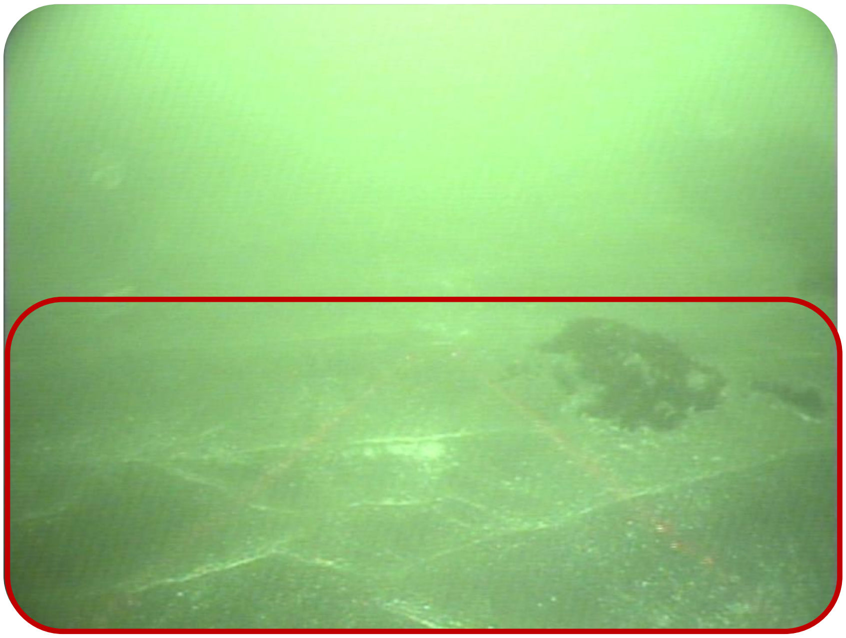

Figure A2. Scoring Field of View O*nly*: Screen shot from lander video with low visibility. The reviewer first identifies the field of view that can absolutely be resolved (Red box). Then the abundance index score is defined as the percent area within the scorable area that is covered by biogenic habitat. In this example, the Turf/Crust class covers between 5-25% of the scorable area, resulting in an abundance index score of 2. No other biogenic habitat classes are present so they all receive a score of 0.

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