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Abstract—A remote underwater video camera system was used to observe black sea bass (*Centropristis striata*) on natural bottom habitats in waters off Maryland. Videos were collected from June to August 2011 at 6 hard bottom sites by deploying a fish trap equipped with multiple cameras. Data obtained from videos included fish counts and general fish behaviors observed around the camera system. We were able to distinguish between 2 categories of fish (i.e., with and without a nuchal forehead hump) and among three different habitat types appearing on videos. Counts of this species differed among habitat types with the highest counts occurring on rocky and reef habitats. Common behaviors exhibited by all fish included resting and aggregating on sand and around structures, whereas fish with nuchal humps exhibited antagonistic and territorial behaviors. On the basis of our results, we conclude that underwater video has the potential to provide useful information about the abundance and behavior of black sea bass in waters off the coast of Maryland.

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Use of an underwater video system to record observations of black sea bass (*Centropristis striata*) in waters off the coast of Maryland

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Located along the U.S. Atlantic coast, the coastal shelf waters of the Mid-Atlantic are characterized by a southward narrowing of shelf width from approximately 150 km off New York to 30 km off Cape Hatteras, NC (Townsend et al., 2006). Dominated by sand, bottom sediments in the Mid-Atlantic also include clay, gravel, silt, and shell. Bottom habitats, known as hard bottom habitats (defined by Steimle and Zetlin (2000) as “multi-dimensional hard structured habitat,”) in Mid-Atlantic waters, including those off the coast of Maryland, consist of natural reefs comprising low relief rocky outcroppings, gravel, boulders, stony and sea whip corals, shellfish beds, mud, and peat deposits (Steimle and Zetlin, 2000; Ross et al., 2016). Other hard bottom structures include shipwrecks, artificial reefs, and other manmade objects. Although scarce compared with soft bottoms, hard bottom habitats support a variety of invertebrate and commercially important fish species, including black sea bass (*Centropristis striata*) (Steimle and Zetlin, 2000).

In Mid-Atlantic waters, the black sea bass is migratory and individuals inhabit coastal hard bottom and reef habitats, often at depths of 20 m to 60 m, during spring and summer and offshore shelf waters in late autumn and winter when water temperatures decline (Moser and Shepherd, 2009). Black sea bass are protogynous hermaphrodites that are born female and some change sex to male later in life (Lavenda, 1949). During the spawning season from April to October, mature males may develop a blue nuchal hump anterior to the dorsal fin, making them distinguishable from females and other males (NEFSC[1]). Inshore black

[1] NEFSC (Northeast Fisheries Science Center). 2012. 53rd northeast regional stock assessment workshop (53rd SAW) assessment report. Northeast Fish. Sci. Cent. Ref. Doc. 12-05, 559 p. [Available from website.]

sea bass are primarily targeted by recreational hook-and-line and commercial trap fisheries, and bottom trawls are the chief gear used to harvest fish offshore (Shepherd and Terceiro, 1994). Annual spring bottom trawl surveys conducted by the National Marine Fisheries Service are the primary source of fishery independent data on abundance of black sea bass (NEFSC[1]). The trawl gears used during these surveys generally perform better on softer sediments than on hard bottom habitats occupied seasonally by black sea bass (NEFSC[1]; Ross et al., 2016). Population estimates are based on survey indices, as well as landings from commercial trap and recreational hook-and-line fisheries. However, the effectiveness of traps and other gears to adequately sample black sea bass is poorly understood. The lack of data on abundance of black sea bass in habitats that cannot be trawled effectively is a key uncertainty in assessment and management (NEFSC[1]; Ross et al., 2016). Therefore, fishery-independent data collected for black sea bass on hard bottom habitats with alternative sampling gears (e.g., video, traps) may provide important information for improving both stock assessments and management (NEFSC[1]).

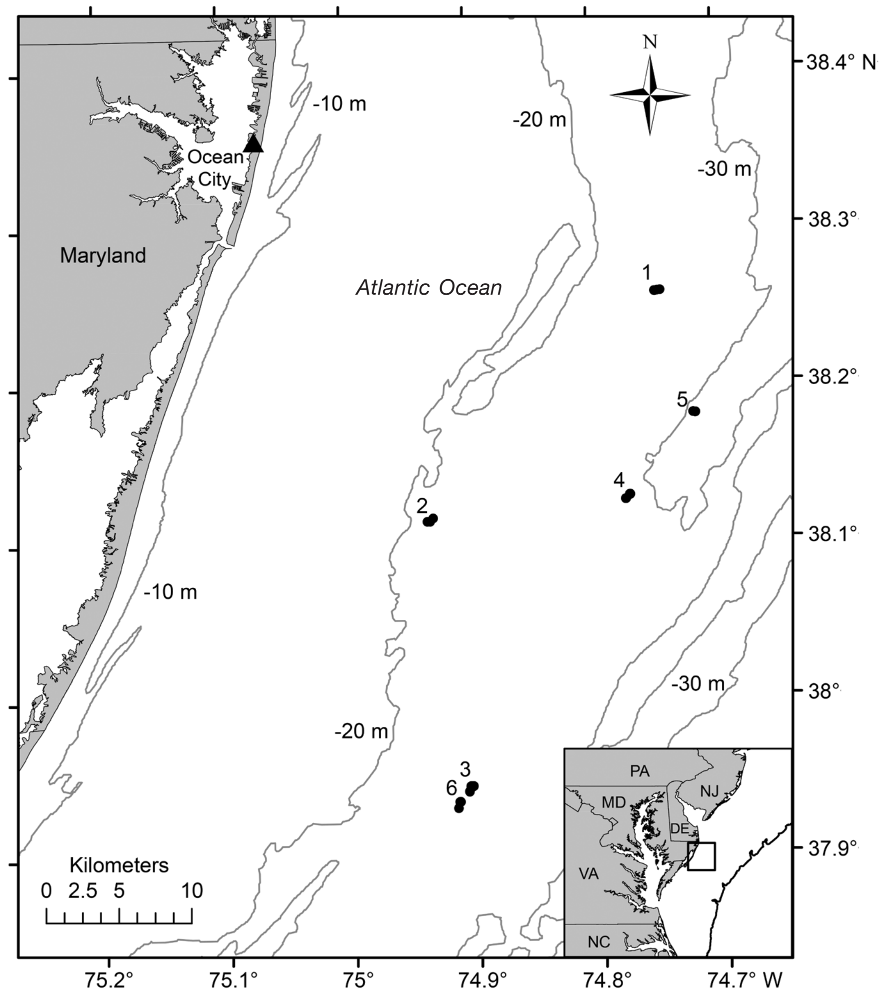

Figure 1

Map of the sampling region depicting the locations of 6 sites (numbered 1–6) off the coast of Maryland, where underwater video of black sea bass (*Centropristis striata*) was collected with a fish trap and camera system from 14 June to 4 August 2011. Overlapping black circles indicate the positions of multiple deployments of the fish trap and camera system per site. The inset shows the location of the sampling region off Maryland along the U.S. Atlantic coast.

Underwater videos, including those that involve remote video camera systems, have been used to assess the abundance of reef fish (Ellis and DeMartini, 1995; Harvey and Shortis, 1996; Burge et al., 2012; Lowry et al., 2012). Remote camera systems typically consist of 1 (single video) or 2 (stereo video) analog or digital video cameras in a waterproof housing fixed to a metal frame in a manner that allows a vertical or horizontal field-of-view (Harvey and Shortis, 1996; Willis and Babcock, 2000; Watson et al., 2005; Cappo et al., 2007; Harvey et al., 2007). We constructed and deployed a remote camera system with a fish trap as a base to collect video recordings of black sea bass *in situ*, to identify important natural bottom habitats, and to determine whether or not male fish with nuchal humps could be distinguished from other life stages. Our camera system included a fish trap as a base because a fish trap was easy to deploy and haul from depth and was simple to modify with a metal frame for attaching multiple cameras. Additionally, it allowed us to collect other information including recordings of behavioral responses of black sea bass to traps (e.g., entries, escapes) which could be used for further analysis (see Cullen and Stevens, 2017). The underwater video collected with the camera system was used to address the following objectives: 1) to observe and count black sea bass on natural hard bottom habitats and 2) to make observations of behavior of black sea bass on natural hard bottom habitats.

Materials and methods

Study area and sampling with video system

The study was conducted in waters off the coast of Maryland (Fig. 1). Sampling occurred on 10 days, during the period from 14 June to 4 August 2011. With-

Table 1

Average values of *MeanCount*, the mean number of fish counted in a sample of frames from a video, for black sea bass (*Centropristis striata*) observed in the 3 classified habitat types (sand, sand+rock, live bottom) in videos collected from 14 June to 4 August 2011 at 6 sampling sites in waters off the coast of Maryland. Values are given for 2 categories: all black sea bass and nuchal black sea bass (or fish that were distinguishable from other individuals by a darker body coloration, a nuchal hump, and white fin stripes). Average values of *MeanCount*, with 95% confidence intervals in parentheses, and mean depths (in meters), with standard deviations (SDs) in parentheses, for all daily deployments (4 per day) are provided for each site and date.

			All black sea bass			Nuchal black sea bass		
Site	Date	Depth (SD)	Sand	Sand+rock	Live bottom	Sand	Sand+rock	Live bottom
1	14 Jun 2011	22.1 (0.3)	0.19 (–0.21–0.40)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.01 (–0.01–0.03)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
2	16 Jun 2011	25.9 (2.1)	0.11 (–0.01–0.23)	0.07 (0.00–0.00)	0.00 (0.00–0.00)	0.03 (0.00–0.06)	0.02 (0.00–0.00)	0.00 (0.00–0.00)
3	23 Jun 2011	30.8 (0.5)	0.70 (–0.25–1.65)	0.00 (0.00–0.00)	9.28 (8.84–9.72)	0.43 (–0.17–1.03)	0.00 (0.00–0.00)	1.38 (0.87–1.89)
2	28 Jun 2011	25.9 (2.6)	0.15 (0.07–0.23)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.05 (0.00–0.10)	0.00 (0.00–0.00)	0.00 (0.00–0.00)
4	8 Jul 2011	29.1 (2.6)	0.00 (0.00–0.00)	0.20 (0.00–0.00)	12.17 (1.85–22.49)	0.00 (0.00–0.00)	0.08 (0.00–0.00)	1.83 (0.43–3.23)
4	18 Jul 2011	29.1 (2.5)	0.11 (–0.10–0.32)	4.38 (–0.93–9.69)	0.00 (0.00–0.00)	0.03 (–0.04–1.0)	1.05 (0.23–1.87)	0.00 (0.00–0.00)
5	20 Jul 2011	29.7 (2.4)	0.00 (0.00–0.00)	1.02 (–0.07–2.11)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.11 (–0.02–0.24)	0.00 (0.00–0.00)
6	26 Jul 2011	30.4 (1.8)	2.12 (0.00–0.00)	3.78 (0.73–6.83)	2.47 (0.00–0.00)	0.00 (0.00–0.00)	0.48 (0.46–0.50)	0.50 (0.00–0.00)
6	1 Aug 2011	30.3 (1.6)	1.85 (1.16–2.45)	0.00 (0.00–0.00)	2.54 (1.48–3.60)	0.47 (0.14–0.80)	0.00 (0.00–0.00)	0.35 (0.12–0.58)
6	4 Aug 2011	30.1 (1.3)	0.00 (0.00–0.00)	8.93 (2.23–15.63)	3.90 (0.00–0.00)	0.00 (0.00–0.00)	0.88 (0.32–1.44)	0.77 (0.00–0.00)

out prior knowledge about the distribution or extent of the bottom topography in the sampling region, we consulted with commercial trap fishermen of black sea bass regarding locations where fish might be observed. Because the goal of this study was to use underwater video to observe and count black sea bass on natural habitats, sampling locations were not selected at random. Instead, 6 hard bottom sites ranging in depth from 22 to 31 m (Table 1, Fig. 1) were chosen because they were primarily characterized by hard bottom substrates or other natural structures that offered the best chance to observe and count fish; sites were visited 1–3 times during the study period.

At each sampling site, videos were collected during daylight hours (0900 to 1500 Eastern Daylight Savings Time) by using a camera system that incorporated a rectangular fish trap as a base (dimensions: 107 cm length×53 cm width×31 cm height; 3.8-cm^2 mesh, 12-gauge plastic coated wire) (Fig. 2). A frame (dimensions: 107 cm length×53 cm width×86 cm height) constructed of galvanized and zinc-plated slotted steel angle was bolted to 15-cm sections of slotted angle positioned inside the trap at each corner. This fixed the frame height at 71 cm above the bottom of the trap and 38 cm from the top. Weight was added to the trap (with 4 bricks weighing ~2.7 kg each) to ensure that it landed flat on the bottom so that the frame stood upright. Five GoPro HD Hero 1[2] digital video cameras (720-pixel resolution, 170° angle of view) were bolted to the steel frame with tripod mounts, 38 cm above the top of the trap. Four cameras faced outward, one on each side at a 45° angle to obtain a standardized view of fish and the bottom habitat near the trap during each deployment. An additional camera looking downward at a 45° angle over the top of the trap was mounted to capture any behavioral responses (e.g., entries, escapes) of black sea bass to the trap that may have occurred during each deployment (Cullen and Stevens, 2017).

Because hard bottom habitats in the coastal waters of Maryland are patchy and sparsely dispersed among soft bottom habitats (e.g., sand), we were concerned that the number of videos depicting black sea bass on these habitats would be limited. Therefore, to account for the potential spatial variation in habitat at sampling sites and to help ensure that we obtained observations of fish on hard bottom habitats, four 60-min continuous deployments of the video camera system were made at a given site per day (n=10 d). Deployment locations for the camera system were based on observations from a fish finder (FCV-582L; Furuno Electric Co. Ltd., Nishinomiya City, Japan) and incorporated a flat bottom area, adjacent to structure. The system was then lowered to the bottom slowly, from the deck of a chartered commercial vessel, with a rope that was attached to a marker buoy and flag at the surface. After 1 h, the system was lifted to the surface with a hydraulic pot-hauler. The vessel was then moved ~200 m to the north, south, east, or west from the deployment site and repositioned over new bottom habitat. The system was then dropped down for the next video sample. After the first 2 deployments, the system was hauled to the vessel where the camera batteries were changed. The final 2 samples of video were collected in the same manner as that described previously, and with a distance of ~200 m between deployment loca-

[2] Mention of trade names or commercial companies is for identification purposes only and does not imply endorsement by the National Marine Fisheries Service, NOAA.

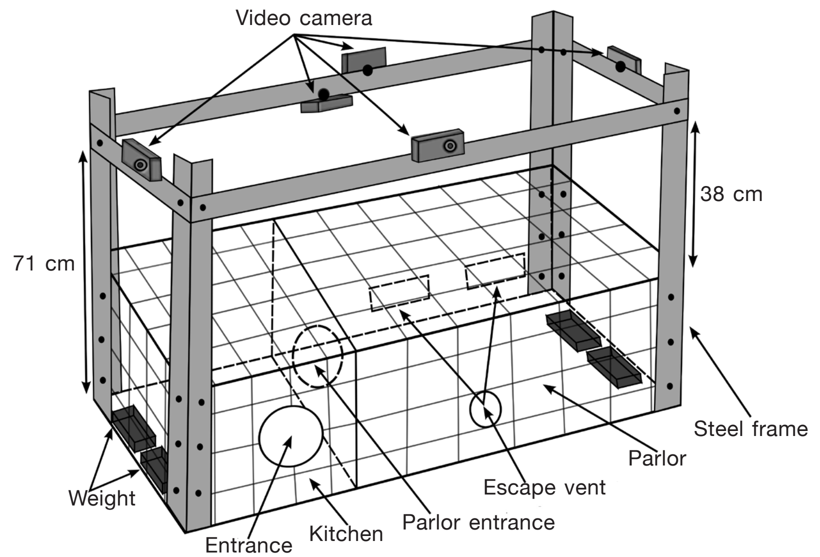

Figure 2

Diagram of the camera system used to collect video of black sea bass (*Centropristis striata*) from 14 June to 4 August 2011 at 6 sampling sites in waters off the coast of Maryland. The system consisted of a rectangular fish trap as a base, with a steel frame equipped with 5 GoPro HD Hero 1 cameras mounted over the top. Four cameras were faced outward at 45° angles to obtain a standardized view of fish and bottom habitat near the trap. A fifth camera was faced downward at a 45° angle over the top of the trap to capture behavioral responses of black sea bass to the trap that may have occurred during each deployment of the fish trap and camera system.

tions. Approximately 20 min were allowed to elapse between each deployment.

With the intention of obtaining observations of responses of black sea bass to the trap, we baited the trap with ~230 g of northern shortfin squid (*Illex illecebrosus*) during the first 2 deployments per day. For these deployments, whole frozen squid were thawed, cut into strips, placed in a plastic mesh bait bag, and hung inside the trap kitchen. The bait bag was removed for the last 2 deployments.

Video analysis

Nearly 160 h of video were collected during the study period. Videos used for analysis were selected randomly. The 4 outward facing cameras were assigned a number 1 to 4 and a random number generator was used to select one camera for each sampling date. Although 4 cameras were used, a single video was chosen from each of the 4 deployments made each day to help reduce recounts of fish moving in and out of multiple camera views. The 40 selected videos were viewed on a wide-screen monitor with standard video editing software (Adobe Premiere Pro CS5; Adobe Systems Inc., San Jose, CA); no videos were excluded from analysis or substituted with others from another camera because all displayed a clear view of the bottom habitat and fish when present. Video processing began ~1 min after the camera view was clear of silt or debris suspended when the camera system landed on the bottom. Habitat appearing on videos was classified into 3 types: 1) sand—smooth or coarse sand and gravel adjacent to structure, bivalve shells were often present but no rocks or boulders (i.e., small cobble to large rocks; sediment types were identified based on definitions from Wentworth [1922]), 2) sand+rock—sand with scattered rocks and boulders but no rocky outcroppings or coral species present, and 3) live bottom—complex reef habitats with boulders, rocky outcroppings, and possibly other structures colonized by gorgonian sea whips (*Leptogorgia* spp.) and stony corals. Bottom habitats were classified as live bottom because they were frequently occupied by other species in addition to black sea bass and corals, including cunner (*Tautogolabrus adspersus*), American lobster (*Homarus americanus*), and crabs (*Cancer* spp.). In video frames where more than sand habitat was present, the habitat was classified as sand+rock only when rocks or boulders were present but no rocky outcroppings or coral species and as live bottom only when corals (sea whips, stony corals) were present in addition to other species and habitat features.

On the basis of the pattern of counts of black sea bass over time (i.e., fish counts generally increased to a maximum within the first 5–10 min followed by a steady decline in all videos), we chose a 30-min segment from each video for counting fish. Once the camera view was clear of suspended silt and debris, counts were made for 2 categories of black sea bass: all black sea bass and then separately for those with a nuchal hump (i.e., fish that were distinguishable from other individuals by their darker body coloration, a nuchal hump with the usual blue color appearing grayish-white on the videos, and white fin stripes; hereafter referred to as *nuchal black sea bass*) from each video using a variable called *MeanCount*, which is an alternative counting metric to others commonly reported in the literature (e.g., MaxN; maximum number of individuals of a particular species present at one time in any single point on the video) (Schobernd et al., 2014; Bacheler and Shertzer, 2015). *MeanCount* is the mean number of fish counted in a sample of frames from a video (Schobernd et al., 2014). In this case, 60 single frames were sampled systematically, one every 30 s for 30 min of videotaping. Counts from the sampled frames were then averaged to obtain values of *MeanCount*. We chose *MeanCount* because, unlike *MaxN*, it has been shown by Schobernd et al. (2014) to be relatively unbiased and linearly related to true abundance but has similar variation to that of *MaxN*.

Fish behavior during the selected 30 min of a video was evaluated by noting (in minutes) the time of first arrival (TFA) of fish within the camera view followed by general observations of behavior around the camera system. TFA was included as a behavioral measure to examine whether faster arrival times to the camera view could be related to greater densities of fish in the surrounding area. Additionally, we wanted to determine whether the presence of bait in the trap would result in fish appearing on cameras earlier than when bait was not present in the trap. Swimming, resting, and habitat-associating behaviors were recorded by selecting individual fish within the camera field-of-view. Swimming fish were followed until they left the camera view; no more than 3 fish were followed at any one time. Resting and habitat-associating behaviors were recorded if, or when, a swimming fish stopped to rest on the bottom or near structures such as rocky outcroppings or boulders. These behaviors were also noted for fish already resting on the bottom when the camera frame landed. Aggregating behaviors were documented for fish resting on the bottom in groups of 2 or more, and antagonistic behaviors were noted only when nuchal males were observed chasing smaller non-nuchal fish.

Responses to the trap, including entries through the entrance funnel, half entries (entering the entrance funnel but backing out), and exits (exiting the trap through the entrance funnel or through one of the escape vents in the parlor) were noted on videos captured by the camera facing downward over the top of the trap for each deployment (Fig. 2). These data were collected on 9 of the 10 sampling days and were used to examine the influence of trap soak time on catches of black sea bass in fish traps in a complementary manuscript (i.e., Cullen and Stevens, 2017).

Data analysis

We tested for differences in *MeanCount* among the 3 classified habitat types. Because *MeanCount* is a continuous variable and repeated deployments were made at a site on each sampling day, we used linear mixed-effects models to test for differences in *MeanCount* for the categories of all black sea bass and nuchal black sea bass separately among the 3 classified habitat types (sand, sand+rock, live bottom). Linear mixed-effects models can be used as alternatives to methods of repeated-measures analysis of variance (ANOVA) when data are unbalanced, and they allow modeling of covariance structures (Pinheiro and Bates, 2000). In our models, habitat type was treated as a fixed effect; however because of limited knowledge of bottom types at sampling sites, equal replication of habitats across video deployments was not possible *a priori*. Bait method (i.e., baited trap, unbaited trap) was dummy coded (i.e., the categorical variable bait method was converted to a continuous variable by assigning values of 0 for baited trap deployments and values of 1 for unbaited trap deployments) and the continuous variable was included as a covariate in the models to control for its possible influence on values of *MeanCount*. Sampling site was treated as a random effect because consecutive camera system deployments provided multiple, non-independent samples per site (Zurr et al., 2009). This method, which was equal to fitting a model with a compound symmetrical correlation structure, provided a random intercept term for each site, and allowed the variance in values of *MeanCount* within sites to be separated from the residual variance (Pinheiro and Bates, 2000). Linear mixed-effects models with *MeanCount* as the response variable were fitted by using the nlme package, vers. 3.1-129 (Pinheiro et al., 2017) in the R statistical environment, vers. 3.3.2 (R Core Team, 2016). *MeanCount* data were checked for normality and variance homogeneity and log-transformed (by taking a natural logarithm of the variable+1; i.e., $\log_e[MeanCount+1]$, 1 was added to *MeanCount* because the data contained some 0 values) before analysis to help meet the assumptions of the linear mixed-effects models. Corrected Akaike information criterion (AICc), which is recommended for small sample sizes (Burnham and Anderson, 2002) was used to compare 3 model types: models with random effect for site, models without the random effect for site, and weighted models with the random effect for site. The latter models were weighted by using a constant variance function (i.e., weights produced with the varIdent function in the nlme package) to correct for heteroscedasticity or different variances for *MeanCount* data among habitat types (Pinheiro et al., 2017). The constant variance function in weighted models allowed the variance to differ for each level of habitat type.

Table 2

Results from analysis of variance for the best linear mixed-effects (LME) models, determined by using the corrected Akaike information criterion. These results were used to compare the influence of habitat type (sand, sand+rock, live bottom) on values of the counting metric *MeanCount* for black sea bass (*Centropristis striata*) observed on videos collected from 14 June to 4 August 2011 at 6 sampling sites in waters off the coast of Maryland. Results are given for 2 categories: all black sea bass and nuchal black sea bass (the latter fish were distinguishable from other individuals by a darker body coloration, a nuchal hump, and white fin stripes). The standard error (SE) for the random effects represents the variance for each sampling site around the common intercept. *MeanCount* data were log transformed (by taking a natural logarithm of the variable+1; i.e., $\log_e$[*MeanCount*+1]) before analysis to help meet the assumptions of the LME models. ICC=interclass correlation coefficient, which represents the correlation of observations from the same sampling site.

Category	Parameter	df	*F*-value	*P*-value
All black sea bass	Intercept	1, 31	17.658	<0.001
	Habitat type	2, 31	22.364	<0.001
	Bait method	1, 31	1.318	>0.05
	Random effects	SE	0.142	
	Residuals	Variance	0.028	
		ICC	0.838	
Nuchal black sea bass	Intercept	1, 31	17.447	<0.001
	Habitat type	2, 31	17.973	<0.001
	Bait method	1, 31	0.805	>0.05
	Random effects	SE	0.015	
	Residuals	Variance	0.017	
		ICC	0.469	

All models were first fitted with maximum likelihood estimation and compared with AICc by using the AICcmodavg package, vers. 2.0-3 (Mazerolle, 2016) in R. The AICc best models were refitted with restricted maximum likelihood, which estimates the variance components separately from the fixed effects, thereby providing unbiased estimates for the variance components (Zurr et al., 2009). ANOVA, with type-II sums of squares for unbalanced data, was used to extract *F*-values and Wald test *P*-values for the fixed effect habitat type. Normal quantile-quantile plots, box plots, and scatter plots of the residuals were examined for model validation. Tukey's honestly significant difference tests, with *P*-values adjusted by using a Bonferroni correction, were conducted for multiple comparisons if the ANOVA indicated a significant difference in values of *MeanCount* between habitat types for either category of black sea bass. Results were obtained by using the multcomp package, vers. 1.4-6 in R, which provides multiple comparisons tests for linear mixed-effects models (Torsten et al., 2008).

Additional analyses included Spearman's rank correlation analysis to examine the relationship between *MeanCount* for nuchal and non-nuchal black sea bass (without nuchal humps) and between *MeanCount* and TFA for both categories of black sea bass with deployments as samples (n=40). Further, separate correlations were calculated between *MeanCount* and TFA for both categories of black sea bass for deployments with bait (n=20) in the trap and without (n=20). Correlations were obtained by using the stats package in R (R Core Team).

Results

Habitat appearing in the camera view during deployments (n=40) consisted primarily of smooth and coarse sand, rock, corals (i.e., sea whips, stony corals), and shell. In total, 19 (47.5%) deployments were made in sand, 13 (32.5%) in sand+rock, and 8 (20.0%) in live bottom habitats. In general, values of *MeanCoun*t were greatest in the first 5–10 min of video followed by a variable decline. Values of *MeanCount* varied by site and date and were highest for both categories of black sea bass in sand+rock and live bottom habitats (Table 1). The proportion of nuchal black sea bass observed in the 3 classified habitats were 31.2% in sand, 15.1% in sand+rock, and 18.2% in live bottom. A total of 9 black sea bass, of which 5 had nuchal humps, were caught in the trap, 6 during baited trap deployments and 3 during unbaited trap deployments.

Weighted linear mixed-effects models (i.e., with the random effect for sampling site) that included a constant variance function that allowed the variance to differ for each level of habitat type were identified by AICc as the best models for the categories of all black sea bass and nuchal black sea bass. The variance for the residuals and the standard error (SE) of the random effects around the population intercept were relatively small for each model (Table 2). However, intraclass correlation coefficients (ICC=[Intercept SE]/[Intercept SE+Residual variance]; Zurr et al., 2009) were fairly high, indicating moderate to strong correlations between *MeanCount* observations from the same sampling sites. On average, untransformed values of *MeanCount* and their associated variances (all black sea bass, sand=0.51, sand+rock=19.21, live bottom=27.07; nuchal black sea bass, sand=0.05, sand+rock=0.25, live bottom=0.57) were greatest in live bottom habitats (Fig. 3). Log-transformed values of *MeanCount* were significantly different between habitat types for both categories of black sea bass (Table 2; Fig. 3); bait method was not significant (P>0.05). Results from pairwise Tukey's honestly significant difference tests with a Bonferroni correction indicated that log-transformed values of *MeanCount* differed significantly between sand and sand+rock habitats (all black sea bass, P=0.004; nuchal black sea bass, P=0.016) and between sand and live bottom habitats (all black sea bass, P=0.003; nuchal black sea bass, P=0.002) but not between sand+rock and live bottom habitats (P>0.05).

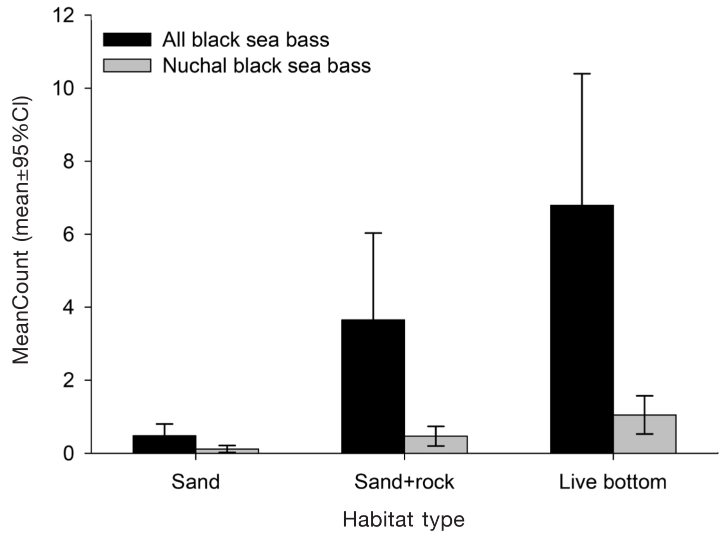

Figure 3

Average values of *MeanCount*, the mean number of fish counted in a sample of frames from a video, for black sea bass (*Centropristis striata*) observed in the 3 classified habitat types (sand, sand+rock, live bottom) on videos collected from 14 June to 4 August 2011 at 6 sampling sites in waters off the coast of Maryland. Average values are given for 2 categories: all black sea bass and nuchal black sea bass, (the latter fish were distinguishable from other individuals by a darker body coloration, a nuchal hump, and white fin stripes). The error bars indicate the 95% confidence intervals.

Results of Spearman's rank correlation analysis indicated that values of *MeanCount* for nuchal black sea bass were significant and positively correlated with those for non-nuchal black sea bass (ρ=0.829, P<0.001). Time of first arrival, ranging from 0.5 to 27.5 min, was latest in sand habitats and earliest in live bottom habitats for both categories of black sea bass. The range of TFA was 0.5–21.5 min for baited trap deployments, with a mean of 2.9 min (95% confidence interval [CI]: 1.7–5.1), and 0.5–27.5 min for unbaited trap deployments, with a mean of 3.8 min (95% CI: 0.8–6.8). *MeanCount* was significantly and negatively correlated with TFA for all black sea bass (ρ= −0.397, P=0.011) but not for nuchal black sea bass (P>0.05). Black sea bass also arrived earliest in live bottom habitats and latest in sand habitats when the trap was baited. Mean TFA was 3.4 min (95% CI: −0.3–7.1) in sand, 2.7 min (95% CI: −0.2–5.6) in sand+rock, and 0.5 min (95% CI: 0.0–0.0) in live bottom and 8.6 min (95% CI: 2.2–15.0) in sand, 0.6 min (95% CI: 0.4–0.8) in sand+rock, and 0.5 min (95% CI: 0.0–0.0) in live bottom for baited and unbaited trap deployments, respectively. TFA was significantly and negatively correlated with *MeanCount* for the category of all black sea bass during baited trap deployments (ρ=−0.738, P<0.001) but not for unbaited trap deployments or for nuchal black sea bass for either baited or unbaited trap deployments (P>0.05).

It was clear from processing videos that general behaviors observed around the camera system depended on the type of habitat in the camera view regardless of whether bait was present in the trap or not. On sand habitats, fish swam past quickly or entered the view slowly by moving short distances of 1 m or so before stopping and resting on the bottom; some fish would lie on the bottom without moving for up to 10 min or more. Infrequently, antagonistic behaviors were observed when large nuchal males chased smaller fish out of the camera view. Fish also aggregated when nuchal and non-nuchal fish would lie next to each other in groups of 2 or more. Other behaviors included nipping at the sediment and 'back rubbing' when fish turned over and rubbed their dorsal surface or head on the sand. On structured (e.g., rocks, boulders) and live bottom habitats, fish were generally present when the camera system landed on the bottom. Occasionally black sea bass approached the camera system, however they spent the majority of the time swimming around and above structures or resting on the bottom next to or under rocks and in holes or crevices of outcroppings. Approximately 20–30% of the behaviors displayed by nuchal black sea bass were antagonistic and territorial. For example, in one case, a large nuchal male continuously returned to and swam around the same rocky outcropping after repeatedly chasing other nuchal and non-nuchal fish away.

Discussion

We used our analysis of video collected with a remote underwater camera system to observe and count black sea bass, examine behavior, and distinguish between life stages (i.e., black sea bass with and without nuchal humps) and bottom types. Our camera system allowed a comparison of values of *MeanCount* among sand, sand+rock, and live bottom habitats, as well as an examination of behavioral responses to fish traps. We found values of *MeanCount* to be significantly higher in live bottom and sand+rock habitats than in sand habitats. An important aspect of this study was that we were able to observe and discriminate between nuchal and non-nuchal black sea bass. Values of *MeanCount* for nuchal black sea bass were positively correlated with those for non-nuchal black sea bass, which may be an indication that greater numbers of male fish were present when densities of black sea bass were higher. However, a method to identify individual fish would be necessary to avoid recounts in order to verify whether values of *MeanCount* are an adequate index for the number of mature males available for spawning on different habitats. For most deployments, bottom types and black sea bass were relatively easy to observe despite variability among sites in factors such as water depth, turbidity, and cloud cover that resulted in reduced visibility around the camera system. On most days (7 of 10), bottom visibility was ~10 m or more but on others it was as little as ~5–6 m. Low visibility as a factor limiting the quality of videos has been reported in other studies using an underwater video technique as a sampling method (Pratt et al., 2005; Bacheler et al., 2014). For example, in the south Atlantic, Bacheler et al. (2014) examined the influence of environmental factors and habitat features on trap and video detection probabilities for reef fish and found that black sea bass and 2 other species were more likely to be observed on videos as water clarity increased. In our study, sampling was conducted during daylight hours to help ensure that natural bottom lighting was adequate. The use of artificial lighting may have increased visibility during periods of low light (~30% of videos in our study); however, our camera system did not include lights because it was not known if or how lights would affect fish behavior.

Habitat type was the most significant factor for observing black sea bass. This result was not surprising given the species strong affinity for structurally complex habitats during their inshore residency. Ross et al. (2016) examined fish communities on soft, natural hard, and shipwreck habitats near Norfolk Canyon, off the coast of Virginia, and observed black sea bass on both soft and hard bottom habitats although they were found primarily on the latter. Despite fish being observed on soft bottoms, Ross et al. (2016) noted that, like other dominant hard bottom species, they were generally not observed far from reef structures. In another study, Fabrizio et al. (2013) examined habitat associations and dispersal of black sea bass with acoustic telemetry at a temperate reef off the coast of New Jersey and found that throughout the summer and fall fish primarily used shallow areas (depths <27 m) with coarse grain materials. Similarly, we observed the majority of black sea bass on hard and rocky bottoms at depths from 19 to 31 m. Conversely, despite the lack of bottom structure, we did observe fish on sand habitats, possibly because fish were attracted to the camera system as an additional or novel source of habitat because black sea bass are regularly caught by the commercial fishery using unbaited traps (Shepherd et al., 2002). Another reason for this finding may be related to feeding activities. Steimle and Figley (1996) examined diets of black sea bass in coastal waters off New Jersey and found that sandy bottom areas adjacent to artificial reefs were very important for feeding. They concluded that much of the diet of black sea bass consists of prey items that are not closely affiliated with reef structure. Lastly, the high percentage of nuchal males that we observed on sand habitats may be related to movements between adjacent hard bottom sites (Bacheler and Ballenger, 2015). Fabrizio et al. (2013) reported on the dispersal of black sea bass from a reef off the coast of New Jersey and found that fish, mostly nuchal males, began to leave the site in early summer, possibly for other reef areas.

Arrival time at a camera system may be related to densities of fish in the surrounding area. Ellis and DeMartini (1995), Willis and Babcock (2000), and Stoner et al. (2008) compared the TFA of fish species in the camera view with their metric for relative abundance and found moderate to strong negative correlations between the 2 metrics. In our study, TFA was moderately correlated with *MeanCount* for all black sea bass—a finding that is in agreement with results from Ellis and DeMartini (1995) and Willis and Babcock (2000) and suggests that faster arrival times for black sea bass are likely due to higher densities of fish in the area. This was the case in our study with fish appearing on cameras earlier for videos collected in live bottom and sand+rock habitats. Fish also arrived earlier in sand habitats when the trap was baited.

Compared with other serranids that have been reported to primarily use their caudal fin while swimming (Fulton, 2007), the main swimming mode of black sea bass appeared to involve the use of both the caudal and pectoral fins for propulsion. In all habitats, black sea bass swam both with and against the current, although fish were often observed swimming close to the bottom and stopping or resting next to rocks or in the crevices of outcroppings when the current appeared to be particularly strong. Resting by black sea bass may be a type of station-holding behavior where fish use substrates as a refuge from flow at higher current speeds (Gerstner, 1998). In high-current flows, black sea bass might seek refuge next to or between bottom structures—a strategy that could possibly reduce the number observed on videos although this may not be the case because Bacheler et al. (2014) found that the likelihood of observing black sea bass on videos increased, although only marginally, from low to high relief habitats in their study. Additionally, guarding territory was a behavior exhibited by nuchal black sea bass around rocky outcroppings and may be an indication that outcroppings, along with other structures, are important for activities such as spawning (Fabrizio et al., 2013).

There was one key limitation to our sampling approach, which involved the use of bait only during the first 2 deployments on each sampling day. It is possible that the bait may have attracted black sea bass to the area, where they remained for some time afterward, and may have resulted in recounts on videos from subsequent deployments despite the ~200 m distance between each deployment. Additionally, the re-use of bait after the first baited drop may have reduced its quality and ability to produce an adequate odor plume for attracting fish to the trap. Nevertheless, the earlier TFA of fish to the camera system, as well as higher trap entries and catches when the trap was baited compared with the period when it was unbaited (Cullen and Stevens, 2017), may be an indication that bait would improve underwater video sampling for black sea bass. Because of the high variability in deployment locations in relation to habitat structure at each site and the small sample size (n=20 deployments with bait, n=20 without bait), a statistically significant result for bait method was not found; a power analysis (power=0.8) indicated that, when the trap was either baited or unbaited, only a 200% change in *MeanCount* could be detected with a 2-tailed test for our sample size. Exploratory plots of *MeanCount* for baited and unbaited trap deployments and for bait methods (i.e., baited, unbaited) within each habitat type provided no indication that the use of bait resulted in higher counts. However, we believe that the influence of bait on video counts of black sea bass in coastal waters off Maryland and the Mid-Atlantic coast should be investigated once a method is developed for identifying habitats before sampling. We recommend that samples be collected over a greater temporal and spatial scale with a paired design with equal replication of habitat types across deployments. Unbaited deployments should be conducted first, followed by baited deployments with fresh bait to ensure independence of samples and bait quality (Harvey et al., 2007; Bernard and Götz, 2012). Further, a stand-alone camera system with a clear view of the bait should be used in place of a baited trap (Harvey et al., 2007). Lastly, because fish and crustaceans have been shown to be the most important components of diets of black sea bass (Byron and Link, 2010), the use of an oily fish such as Atlantic menhaden (*Brevoortia tyrannus*) (Wells et al., 2008; Bacheler et al., 2013) or crushed crabs (*Cancer* spp.) may be more effective at attracting black sea bass to the camera system.

Our results indicate that underwater video has the potential to provide information on the abundance of black sea bass during their inshore residency on hard bottom habitats. However, we suggest that changes be made to the sampling method to help reduce variability in abundance estimates. Despite the efforts of the captain to position the vessel directly over bottom structure, it was not possible to determine where the camera system landed in relation to structure after it was deployed. The high variation between successive deployments in relation to habitat appearing in the camera field-of-view resulted in less samples in sand+rock and live bottom habitats than in sand habitats. We suggest, on the basis of the higher values of *MeanCount* for both categories of black sea bass observed for sand+rock and live bottom habitats than in sand habitats, that efforts to reduce the inconsistency related to deployment locations should include the use of a sampling scheme with sites stratified by habitat type. Methods to identify habitats before sampling may include the use of a remotely operated vehicle or camera sled (Harvey et al., 2007). Scuba divers may also be used to identify suitable locations for deployment and arrange the system so that the camera(s) has a sufficient view of the reef or other habitat (Burge et al., 2012). Further, a system with live video feed to the surface would allow a view of deployment locations where the investigator could make adjustments to the position of the vehicle or camera system if necessary (Stoner et al., 2008).

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