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Method-dependent influence of environmental variables on reef fish assemblages when comparing trap and video surveys

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Abstract Despite substantial survey effort and a large body of literature on abiotic and biotic factors in temperate reef ecosystems, knowledge of the complex and interactive effects of environmental variables on those communities is limited. Various survey methods have been developed to study environmental predictors of biodiversity, but there remains a gap in our understanding of how survey results are influenced by environmental factors. Here, we surveyed the fish assemblage associated with southeastern U.S. temperate marine reefs with simultaneous, paired trap and camera gears throughout a ~50,000 km^2 area during 2011-2013, and assessed the influence of environmental variables on the trap- and video-surveyed assemblages. Predictor variables in the multivariate general linear models included depth, temperature, month, year, location, substrate relief, percent sessile biota, biota type, and turbidity. Depth and latitude had the greatest influence on the fish assemblage for both gears. The influence of habitat variables differed between methods and percent biota explained more variation in the fish assemblage when assessed by traps, while substrate relief and biota type explained more variation in the fish assemblage when assessed by video. In general, habitat complexity was positively related to the abundance of fishes in the video survey, but there was a negative relationship in the trap survey. Differences between gears were species-specific and the influences of environmental variables were similar for some species such as *Haemulon plumierii* and *Hyporthodus niveatus*. The methods presented here can be used to assess method-dependent differences in fish assemblages, which is a necessary precursor to assess the effect of environmental variables on the accuracy of surveys.

Keywords Fisheries, Habitat, Hard bottom, Marine ecosystems, Species composition, Survey methods

Introduction

In both terrestrial and aquatic ecosystems, communities vary over time and space due to natural and anthropogenic factors. Determining the factors that affect community dynamics requires accurate data on both the community assemblage and potential driving factors through space and time (Hughes et al. 2005). Surveys that encompass a wide variation in factors and taxa abundance are needed to quantify the effect of abiotic and biotic variables on species distributions.

The distribution of fishes can be affected by many factors, including but not limited to depth (Mitchell et al. 2014), season (Musick and Mercer 1977), temperature (Langlois et al.

2012; Bacheler et al. 2014), habitat (Sluka et al. 1998; Kendall et al. 2008), fishing (Kendall et al. 2008) and intraspecific interactions (Kendall et al. 2008). Understanding the driving factors affecting fish distribution is important for both conservation efforts and for fisheries management. The influence of factors on surveyed abundance can change depending on the sampling method. For example, the detection of some fish species using video increased with improved water clarity, while detection of multiple fish species using a trap survey decreased with increasing hard substrate (Bacheler et al. 2014). In addition, the survey method used to measure fishes can alter the species observed as well as their abundance (Colton and Swearer 2010; Harvey et al. 2012; Bacheler et al. 2017). Thus, the survey technique used can also affect our understanding of species distribution.

Two commonly used techniques to survey marine fishes are traps and video. Traps are an inexpensive survey method and are often used in complex habitats (Collins 1990; Miller 1990). Video surveys are increasingly common, and video sampling can be used in combination with bait to attract fish (Colton and Swearer 2010; Watson et al. 2010; Harvey et al. 2012). Video sampling is primarily limited by the ability to see and identify focal species, which could be affected by turbidity and habitat complexity, while traps are limited by the extent to which focal species will enter and remain in traps (Miller 1990; Stoner 2004; Bacheler et al. 2013a). Determining if and how environmental variables affect measured abundance and diversity is needed to gain a better understanding of the relationship between survey estimates and true communities, as well as to determine which survey methods are most appropriate depending on environmental factors and study goals.

Studies that measure the influence of environmental variables on fish abundance often focus on ecologically or economically important species. However, the transition from managing species individually to ecosystem-based management approaches (Leslie and McLeod 2007) necessitates a more holistic approach to assessing survey methods. Analyses with distance-based similarity matrices, such as permutational-multivariate analysis of variance (PERMANOVA), offer a concise and practical way to identify and assess the factors affecting both the diversity and abundance of species surveyed (hereafter referred to as the “assemblage”). However, PERMANOVA can confound location (the mean within multidimensional space) and dispersion effects, and multivariate general linear models (MGLM) have been implemented to improve statistical tests of communities because mean-variance relationships can be specified and verified

(Wang et al. 2012; Warton et al. 2015). Multivariate statistics have been used to determine that fish assemblages are affected by depth and habitat (Chatfield et al. 2010; Moore et al. 2010; Parsons et al. 2016). The assemblage, as determined by multivariate statistics, is regarded as the best response variable to quantify drivers of community dynamics (Legendre and Gauthier 2014).

Here we compare the fish assemblages quantified by trap and video surveys conducted concurrently for temperate reef fishes over 3 years and a large spatial area (>50,000 km^2). Environmental variables measured included depth, temperature, location (longitude and latitude), turbidity, habitat availability, habitat type, and habitat complexity. Our objective was to quantify and compare the influence of multiple environmental variables through space and time on the trap- and video-assessed fish assemblage. Identifying variables that have different effects on the assemblage when quantified by different survey techniques is a necessary first step in then determining which method is more accurate for measuring the natural community. Our null hypothesis was that environmental variables will explain similar amounts of variation in fish assemblages for trap and video surveys.

Methods

This study utilized data collected in 2011-2013 by the Southeast Reef Fish Survey (SERFS), a standardized, fishery-independent survey that uses chevron traps and video cameras attached to the traps to assess spatiotemporal patterns in reef fish distribution and abundance in continental shelf and shelf-break waters from North Carolina to Florida (Ballenger et al. 2011; Bacheler et al. 2014; Fig. 1). SERFS is a collaboration between the South Carolina Department of Natural Resources' Marine Resources Monitoring, Assessment, and Prediction program and the National Marine Fisheries Service (NMFS) Southeast Fishery-Independent Survey, both of which are funded by NMFS. SERFS targets economically and ecologically important reef fishes that are associated with hard bottom habitat, which is sparsely distributed throughout the soft substrate-dominated coastal shelf of the southeastern United States (Sedberry and Van Dolah 1984).

Hard bottom sampling locations for each year were selected in one of three ways. First, most sites were randomly selected from a sampling frame that consisted of approximately 3,000 sampling stations on or very near hard bottom habitat. Second, some stations in the sampling frame were sampled opportunistically even though they were not randomly selected for sampling in a given year. Third, new hard bottom locations were sampled using information from fishermen, charts, and historical surveys. These new locations were investigated using a vessel echosounder or drop camera and sampled if hard bottom was detected. All sampling for this study occurred during daylight hours on the R/V *Savannah*, R/V *Palmetto*, or the NOAA Ship *Pisces*.

Chevron traps, wire (3.4 × 3.4 cm mesh) traps shaped like an arrowhead (1.7 m × 1.5 m × 0.6 m; Collins 1990), were set from April to October each year. A Canon Vixia HFS-200 video camera in a Gates underwater housing was attached to the top of each trap facing outward from the entrance of the trap to quantify fish abundance and habitat characteristics. A second camera (GoPro Hero® or Nikon Coolpix S210/S220) was attached to the opposite end of the trap to quantify habitat characteristics but not fish abundance. Traps with attached video cameras (from now on referred to as traps) were usually set in groups of six, with a minimum distance of 200 m between traps. Traps were baited with 16 menhaden (*Brevoortia* spp.) divided evenly on 4 stringers and 8 additional menhaden unattached to stringers. Traps were set in water depths between 13 and 100 m. Trap sampling duration (time from when the trap entered the water until retrieval began) was approximately 90 minutes, and ranged from 70 to 154 minutes. The following information was recorded for each trap: depth, sampling duration, location (latitude and longitude), and date. Bottom water temperature (°C) was measured for each group of simultaneously deployed traps using a Sea-Bird CTD.

Habitat characteristics associated with each trap deployment were assessed from video recorded by the camera with the greater (of the two trap-mounted cameras) percent hard substrate in its field of view (i.e., no habitat data were used from the camera with the lesser percent hard substrate in its field of view). Four habitat characteristics were assessed. Percent hard substrate was defined as the estimated percent of benthic habitat covered by rocks estimated to be greater than 5 cm in diameter or by hard pavement substrate. Substrate relief was the maximum estimated change in substrate height (due to ledges or outcrops) and was recorded as low (<0.3 m) or high (>0.3 m). Estimated percent of the benthic habitat covered by erect biota (e.g., macroalgae, sponges, coral) was recorded as percent biota. Finally, the primary biota type was characterized into three categories based on estimates of biotic coverages: macroalgae (sessile biota was >50% macroalgae), other biota, which was primarily coral, sponge, or gorgonians (sessile biota was >50% other biota), or none (no sessile biota). Habitat variables were only estimated when visibility was high enough that the substrate could be seen. Turbidity was characterized into two categories: high (only substrate directly adjacent to trap was visible, visibility < ~2 m) or low (substrate was visible beyond the trap > ~2 m).

Trap abundance was the number of all fish retrieved in the trap, which were identified to the lowest possible taxon. Video abundance was quantified using the MeanCount method (Schobernd et al. 2014), in which fish were enumerated in a series of video segments, and a mean count for each taxon was calculated from each of the segment-specific counts. For each video, one second of video was "read" (i.e., individuals of all taxa present enumerated) every 30 seconds for a 20-minute period, beginning 10 minutes after the trap settled to the benthos. A taxon-specific MeanCount was then calculated from the resulting 41 counts. Due to logistical constraints, only fishes in the following categories (107 species were on the identification list) were quantified and analyzed as the fish assemblages for the video survey: (1) those listed in the U.S. National Oceanic and Atmospheric Administration's Fish Stock Sustainability Index (http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/fssi.html), (2) highly migratory species such as sharks, mackerels, and tunas, and (3) the invasive lionfish *Pterois* spp.

Predictor variables initially considered for analyses were depth, temperature, longitude and latitude (here after *x* and *y*), month, year, turbidity, percent hard substrate, substrate relief, percent biota, and biota type. For all analyses, latitude and longitude were transformed into UTM x and y coordinates so that the units were identical (km). Data from an individual trap/video set were included in analyses when at least one fish was caught in the trap and one fish was recorded in the video, and all predictor variables were quantified. Histograms of each predictor variable and scatter plots of all combinations of variables were examined to ensure there were no extreme outliers, the data were not heavily skewed, and there was no multi-collinearity (variance inflation factor > 3; Zuur et al. 2013), which can bias linear-based analyses (Legendre and Anderson 1999). Predictor variables were scaled because of the large difference in magnitude and variation. No outliers were evident. Multi-collinearity existed between percent hard substrate and percent biota and preliminary analysis indicated that percent biota explained more variation in both trap- and video assessed fish assemblages. Thus, percent hard substrate was not included in the analyses, although it would likely have explained a similar amount of variance as percent biota.

To compare the variation in trap- and video-assessed fish assemblages explained by abiotic and biotic factors, we analyzed trap and video data using multivariate generalized linear modeling (MGLM; Warton et al. 2015). This model-based approach to multivariate data is more statistically explicit than distance-based analysis (PERMANOVA) and the distribution can be specified to account for mean-variance relationships and model fit can be assessed by evaluating residual and fitted values (Hui et al. 2015; Warton et al. 2015). MGLMs were created using the 'manyglm' function in the *mvabund* package (Wang et al. 2012) in R version 2.15.0 (R Development Core Team 2012). Trap and video data were transformed to presence/absence so both analyses used a binomial distribution with a log-log link, which resulted in models with a negligible pattern among residuals and samples or taxa, and the normal quantile plot was linear (Wang et al. 2012). Variable significance was calculated using the Wald statistic with 1000 permutations and correlation among variables was included in the analysis (anova function, cor.type=R; Warton et al. 2015). *P*-values for individual species were adjusted for multiple tests using a step down resampling procedure. The test statistic indicates the influence of the respective predictor variable and the test statistic for each taxon signifies which taxa were driving the overall significance for individual predictor variables. This is analogous to the SIMPER analysis for distance-based metrics (Clarke and Gorley 2006), but is less biased by mean-variance relationships (Warton et al. 2012). To assess whether the influence (test statistic) and directional effect (positive or negative, coefficient) of specific predictor variables was similar for trap- and video-assessed species, we calculated the covariance of the test statistics and the coefficients of the predictor variables for each of the 14 species quantified in both trap and video surveys.

Results

There were 1953 trap/video sets with all predictor variables and 1249 of these quantified fish in both methods. The number of trap/video sets increased with each successive year with 274, 485, and 490 sets in each year from 2011 to 2013, respectively. The trap catch included 47 taxa (41 taxa to species and 6 taxa assigned to genus; ESM 1)of which the following were collected in greatest abundance: *Centropristis striata* (53% of total individuals caught), *Haemulon aurolineatum* (16%), *Stenotomus* spp. (7%), *Pagrus pagrus* (6%), *Rhomboplites aurorubens* (6%) and *Centropristis ocyurus* (5%; ESM 1). Video counts included 52 priority taxa (49 taxa were identified at the species level and 3 to genus; ESM 1), of which the following were observed in greatest abundance: *R. aurorubens* (40% of total individuals quantified), *P. pagrus* (20%), *C. striata* (13%) and *Balistes capriscus* (7%). Almost all the video counts were taxa from the Fish Stock Sustainability Index, while highly migratory taxa individually occurred in less than 0.02% of the videos and lionfish were recorded in 2.7% of the videos (ESM 1).

All variables explained a significant amount of variation in fish assemblages for trap and video surveys (Table 1). Depth and latitude (y) had the greatest influence on the fish assemblage for both surveys based on the test statistic (Fig. 2). Temperature and percent biota were of moderate importance, while month and substrate relief were less important for traps. For the video survey, substrate relief and biota type were of moderate importance while time (year and month) were less important in explaining variation in the fish assemblage.

Trap and video showed different patterns in taxa grouping when clustered by the test statistic of the variables (Fig. 2). Traps had a cluster of taxa, including *C. striata*, *H. aurolineatum*, and *B. capriscus*, with primarily negative associations with the majority of the significant variables. Many taxa that were not significantly influenced by multiple variables were present in the middle cluster. A final group contained taxa with a positive association with latitude (y) and a negative association with year, turbidity, percent biota and biota type. This group included *Haemulon plumierii*, *Stenotomus* spp., and *C. ocyurus*. Video taxa were clustered with a group of taxa that had strong associations with depth, turbidity and biota type, and included *C. striata*, *P. pagrus* and *H. plumierii*. Similar to the trap, video had a cluster of multiple species with minimal significant variables. Finally, taxa quantified in videos had a third group with negative associations with depth, percent biota, turbidity, and substrate relief. This cluster included *Seriola rivoliana*, *Mycteroperca phenax*, *Lachnolaimus maximus* and *Pterois* sp.

Most of the taxa present in both surveys had a positive covariance between variable test statistics of the trap and video surveys (10 of 14 taxa, Table 2), suggesting that the predictor variables had similar explanatory power for both methods on these taxa. However, only 4 taxa had a positive covariance of the coefficients, indicating that there was minimal similarity in the surveys because only these taxa had the same relationship between abundance and predictor variables for both survey methods. Three species had a positive covariance for both the test statistic and coefficient, indicating similar influence of predictor variables on abundance recorded by both methods and included *Caulolatilus microps*, *Hyporthodus niveatus*, and *H. plumierii*.

Discussion

The association between predictor variables and the fish assemblage was distinct for the two survey methods. Depth and latitude had the most influence on both methods but the other predictor variables were different between the survey techniques. For example, temperature and percent biota explained more variation for traps compared to video, while substrate relief and biota type explained more variation for video compared to traps. Differences between the survey methods derived more from the direction than the strength of the association between taxa abundance and predictor variables, as suggested by covariance of the test statistic and coefficients of taxa caught in both surveys. The discrepancy in the amount of the assemblage variation explained by individual predictor variables between the two methods highlighted differences in these commonly used survey methods, including what species were captured or included in the video counts.

Coupling the video and trap survey could introduce biases associated with the lack of independence between the samples taken by this study. However, measuring the same fish assemblage by separating the video camera and trap in space or time is probably not possible because the correlation of observations of a reef fish community is drastically reduced if not surveyed simultaneously or if observations are separated by distances greater than 20m (Karnauskas and Babcock 2012). In this study, it is possible that fish were not recorded in the video because they entered the trap, but this effect was likely minimal because the majority of fish enter traps after the 20-minute period during which video data are collected (Bacheler et al. 2013b). Simultaneously quantifying fishes with two sampling gears probably does not significantly bias our findings and, due to high spatiotemporal variation in reef fish communities, was the most feasable approach for comparison of survey techniques.

Although depth was the most influential variable for both trap- and video-assessed fish assemblages, it influenced traps more than video based on the respective test statistic. The greater importance of depth for traps was likely because *C. striata* was strongly correlated with depth and is detected in traps more often than video (Bacheler et al. 2013a). For instance, we found that *C. striata* was overwhelmingly the most abundant species in traps but the third most abundant species in videos, which likely reduced the effect of depth in videos. This difference may result from *C. striata* staying relatively close to the benthos and out of the videos, as well as entering and exiting the trap possibly for food and shelter (Bacheler et al. 2013c).

Temperature does influence local fish abundance, as individuals may respond to suboptimal temperatures by moving to colder or warmer waters. Temperature had a greater influence on the trap-assessed fish assemblage, a negative association with the majority of trap-assessed taxa, and a positive association with the majority of video-assessed taxa. Taxa that increased with temperature in videos, but decreased with temperature in traps including *B. capriscus*, and *R. aurorubens*. Lower temperatures may reduce feeding motivation and therefore reduce the number of fish entering the trap to feed (Stoner 2004), however, if traps were biased in this way then the opposite associations would have been found. The different associations with temperature for trap and video likely result from both the different taxa recorded by the methods and to a lesser extent differences in detectability between the two surveys.

Turbidity can also affect species abundance from video surveys (Cappo et al. 2004). However, turbidity had a similar influence on trap- and video-assessed fish assemblages, which was surprising given that reduced water clarity was found to decrease the detection in videos of *C. striata*, *B. capriscus* and *P. pagrus* (Bacheler et al. 2014). The minimal effect of turbidity on the video-assessed assemblage in this study could result from our methodology of removing videos that did not quantify any fish and those that did not have visible substrate. Nevertheless, the wide range of turbidity in videos that were utilized and the similar influence of turbidity on trap- and video-assessed fish assemblages suggest that video is a robust technique for quantifying the fish assemblage even when visibility is variable.

The relative influence of different habitat characteristics on the fish assemblage was dependent on survey type in this study. Studies have found survey-dependent effects of habitat. For example, trap catch can be the same or even lower as habitat complexity increases even though diver surveys have found that fish abundance increases with complexity (Acosta et al. 1994; Robichaud et al. 2000). Video surveys could underestimate the abundance of fish in more complex habitats because those habitats impede the view of benthic fishes (Stoner 2004; Colton and Swearer 2010). From analyses of concurrently collected (paired) trap and video data, Bacheler et al. (2014) found that trap detectability increased for some species as percent hard substrate decreased, while detection by video was not affected by habitat relief. Fish may be more likely to enter traps as habitat complexity decreased because fish were less attracted to traps for shelter in complex habitats, due to shelter already being provided by those habitats, or having lower feeding motivation in complex habitats because of increased prey availability.

Habitat did influence the fish assemblage in this study, consistent with previous findings that habitat characteristics affect the abundance and diversity of reef fishes (Aburto-Oropeza and Balart 2001; Harman et al. 2003; Anderson and Millar 2004; Lindberg et al. 2006; Lingo and Szedlmayer 2006; Daugherty et al. 2007; Schobernd and Sedberry 2009). However, the effect of individual characteristics was survey-dependent. Hard substrate was targeted by this survey, which could affect the relative influence of habitat on trap- and video-assessed fish assemblages. Moore et al. (2010) found that depth and boulder presence were the two most important variables in explaining variance in the temperate fish assemblage in Australia, but their study was conducted over a much smaller area (approximately 16 km^2) than our study. Another study that spanned approximately 3,500 km^2 found the most influential variable on fish distribution was substrate type (reef, sand, or cobble), followed by depth and macroalgae type (Chatfield et al. 2010). Both of these studies used video surveys to quantify fish and the latter used video to quantify habitat. This study found similar results in that the video assemblage is influenced by habitat relief and type. However, these characteristics were less important for the trap assemblage for which areal coverage of complex habitat was more important for the fish community. In addition, the majority of taxa collected in traps had negative associations with increases in the habitat characteristics, while the opposite was true for the majority of taxa recorded in videos. This could suggest that traps are less likely to catch fish as habitat availability and complexity increase while the opposite is true for video, which could mean that video detection is not reduced by greater habitat complexity.

Comparing the abundance of fishes quantified by multiple survey techniques has shed light on the effectiveness of different techniques. For example, studies have compared 2 or 3 survey methods including diver census, baited and unbaited video, traps, and angling (Willis et al. 2000; Cappo et al. 2004; Watson et al. 2005; Harvey et al. 2007; Wells et al. 2008; Colton and Swearer 2010; Watson et al. 2010; Lowry et al. 2012; Harvey et al. 2012; Karnauskas and Babcock 2012; Bacheler et al. 2013a). These studies compared the relative abundance of individual taxa and species diversity, which is an integral step in understanding differences among techniques. However, all survey methods have imperfect detectability (Katsanevakis et al.

2012) and the influence of abiotic and biotic variables on the relationship between surveyed and true abundance is likely unique for each survey technique (Addison and Bell 1997; Stoner 2004; Geraldi et al. 2009). The next step in improving our understanding of the relationship between surveyed and true assemblages is to determine which surveys most closely track the "true" fish assemblage as environmental variables vary. Quantifying both diversity and taxa abundance is essential, because our ability to measure and predict the many anthropogenic impacts that alter ecosystems is dependent on long-term surveys that accurately measure changes in community assemblages.

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Fig. 1. Sample locations along the South Atlantic coast of the USA (A) and the setup of the trap and video cameras (B). Contour lines in A show 30 and 50 m depths, respectively.

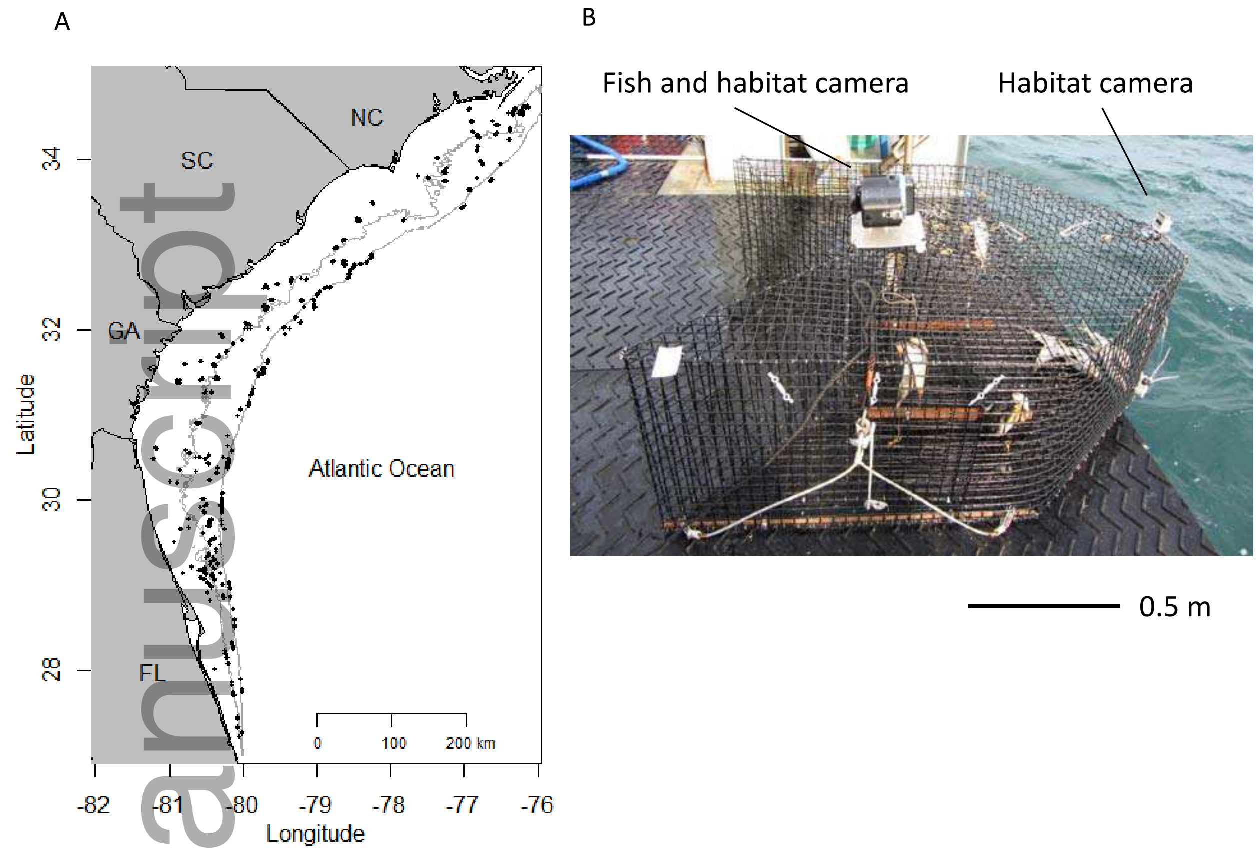

Fig. 2. Results of the multivariate general linear models for fish assemblages assessed by trap (top panel) and video (bottom panel) surveys. Text along the y-axis indicate individual taxa which are clustered by the test statistics of independent variables. The clusters are indicated by continuous colors. Significant variables ($p < 0.05$) are indicated by a green background and were adjusted for multiple tests. Magnitude of the test statistic is shown by the size of circles and the relationship between species and variables (coefficient) were shown by the color of the circle (red-positive, white-neutral, blue-negative). The test statistic and coefficient were centered and scaled within each variable.

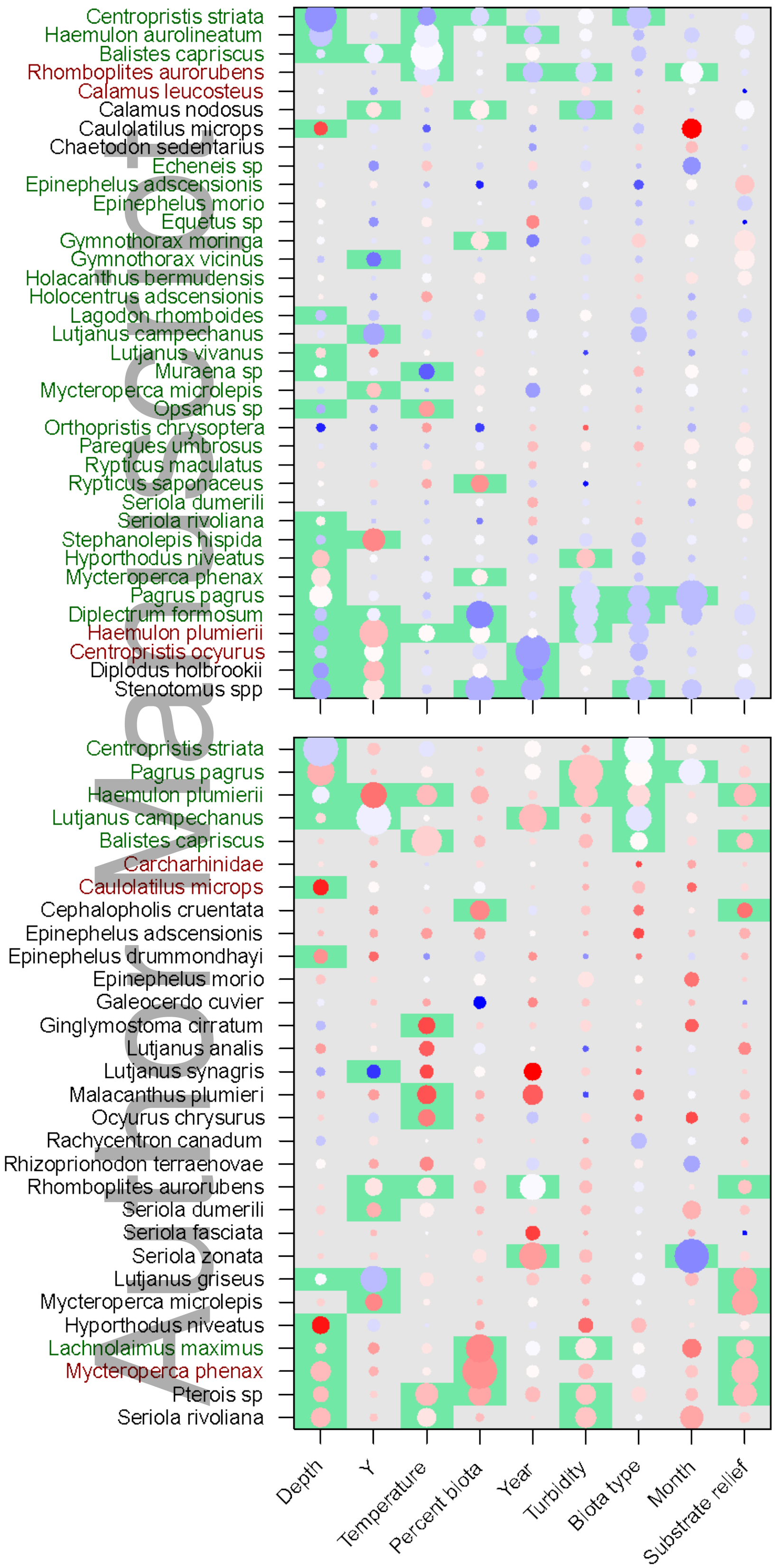
Centropristis striata
Haemulon aurolineatum
Balistes capriscus
Rhomboplites aurorubens
Calamus leucosteus
Calamus nodosus
Caulolatilus microps
Chaetodon sedentarius
Echeneis sp
Epinephelus adscensionis
Epinephelus morio
Equetus sp
Gymnothorax moringa
Gymnothorax vicinus
Holacanthus bermudensis
Holocentrus adscensionis
Lagodon rhomboides
Lutjanus campechanus
Lutjanus vivanus
Muraena sp
Mycteroperca microlepis
Opsanus sp
Orthopristis chrysoptera
Pareques umbrosus
Rypticus maculatus
Rypticus saponaceus
Seriola dumerili
Seriola rivoliana
Stephanolepis hispida
Hyporthodus niveatus
Mycteroperca phenax
Pagrus pagrus
Diplectrum formosum
Haemulon plumierii
Centropristis ocyurus
Diplodus holbrookii
Stenotomus spp
Centropristis striata
Pagrus pagrus
Haemulon plumierii
Lutjanus campechanus
Balistes capriscus
Carcharhinidae
Caulolatilus microps
Cephalopholis cruentata
Epinephelus adscensionis
Epinephelus drummondhayi
Epinephelus morio
Galeocerdo cuvier
Ginglymostoma cirratum
Lutjanus analis
Lutjanus synagris
Malacanthus plumieri
Ocyurus chrysurus
Rachycentron canadum
Rhizoprionodon terraenovae
Rhomboplites aurorubens
Seriola dumerili
Seriola fasciata
Seriola zonata
Lutjanus griseus
Mycteroperca microlepis
Hyporthodus niveatus
Lachnolaimus maximus
Mycteroperca phenax
Pterois sp
Seriola rivoliana
Depth
Y
Temperature
Percent biota
Year
Turbidity
Biota type
Month
Substrate relief

Table 1. Summary of the multivariate general linear models assessing the assemblage of fish quantified by trap and video surveys. The assemblage data was converted to presence/absence and y indicated latitude.

Data	Variable	Residual df	Df	Test statistic	P
Trap	Depth	1247	1	33.06	0.001
	y	1246	1	18.45	0.001
	Temperature	1245	1	17.09	0.001
	Percent biota	1244	1	13.88	0.001
	Year	1243	1	13.24	0.001
	Turbidity	1242	1	12.50	0.001
	Biota type	1240	2	11.32	0.001
	Month	1239	1	10.73	0.001
	Substrate relief	1238	1	8.91	0.001
Video	Depth	1247	1	27.38	0.001
	y	1246	1	19.88	0.001
	Substrate relief	1245	1	13.69	0.001
	Biota type	1243	2	13.43	0.001
	Temperature	1242	1	11.17	0.001
	Turbidity	1241	1	10.26	0.001
	Percent biota	1240	1	10.13	0.001
	Year	1239	1	8.10	0.001
	Month	1238	1	7.63	0.002

Table 2. The covariance of trap and video surveys for species caught in both methods. The covariance was calculated using the test statistic and coefficients of each environmental variable for each species. Taxa are ordered from low to high covariance of the test statistic.

Species	Test statistic covariance	Coefficients
Seriola rivoliana	-0.2	0.2
Mycteroperca microlepis	-0.1	0.0
Seriola dumerili	0.0	-0.1
Epinephelus morio	0.0	0.0
Epinephelus adscensionis	0.1	-0.7
Caulolatilus microps	0.2	1.1
Mycteroperca phenax	0.3	-0.1
Rhomboplites aurorubens	0.3	-0.1
Hyporthodus niveatus	0.5	0.2
Haemulon plumierii	0.9	0.3
Balistes capriscus	1.0	-0.1
Lutjanus campechanus	1.1	-0.1
Centropristis striata	1.7	0.0
Pagrus pagrus	2.2	0.0

Electronic supplementary material

ESM 1. The percent composition and abundance (individuals per trap or mean count) of taxa quantified in trap and video surveys. Species recorded in the video survey are indicated in video species column.

Scientific name	Common name	Family name	Video species	% Trap catch	% Video index	Trap	Video
Auxis thazard	Frigate Mackerel	Scombridae	Yes		0.01		0.000
Balistes capriscus	Gray Triggerfish	Balistidae	Yes	3.09	6.85	0.031	0.068
Calamus leucosteus	Whitebone Porgy	Sparidae	No	0.02		0.000	
Calamus nodosus	Knobbed Porgy	Sparidae	No	0.14		0.001	
Carcharhinidae	Requiem Shark	Carcharhinidae	Yes		0.01		0.000
Carcharias taurus	Sand Tiger Shark	Odontaspididae	Yes		0.01		0.000
Carcharodon carcharias	White Shark	Lamnidae	Yes		0.01		0.000
Caulolatilus chrysops	Goldface Tilefish	Malacanthidae	Yes		0.01		0.000
Caulolatilus microps	Grey Tilefish	Malacanthidae	Yes	0.06	0.09	0.001	0.001
Centropristis ocyurus	Bank Sea Bass	Serranidae	No	2.69		0.027	
Centropristis striata	Black Sea Bass	Serranidae	Yes	52.08	13.44	0.521	0.134
Cephalopholis cruentata	Graysby	Serranidae	Yes	>0.01	0.09	0.000	0.001
Cephalopholis fulva	Coney	Serranidae	Yes		>0.01		0.000
Chaetodipterus faber	Atlantic Spadefish	Ephippidae	No	>0.01		0.000	
Chaetodon ocellatus	Spotfin Butterflyfish	Chaetodontidae	No	0.01		0.000	
Chaetodon sedentarius	Reef Butterflyfish	Chaetodontidae	No	0.01		0.000	
Diplectrum formosum	Sand Perch	Serranidae	No	0.93		0.009	
Diplodus holbrookii	Spottail Pinfish	Sparidae	No	0.47		0.005	
Echeneis sp	Remora	Echeneidae	No	0.04		0.000	
Epinephelus adscensionis	Rock Hind	Serranidae	Yes	0.01	0.09	0.000	0.001
Epinephelus drummondhayi	Speckled Hind	Serranidae	Yes	0.01	0.09	0.000	0.001
Epinephelus guttatus	Red Hind	Serranidae	Yes		0.05		0.000
Epinephelus itajara	Goliath Grouper	Serranidae	Yes		0.08		0.001
Epinephelus morio	Red Grouper	Serranidae	Yes	0.08	0.15	0.001	0.001
Epinephelus nigritus	Warsaw Grouper	Serranidae	Yes		0.03		0.000
Epinephelus striatus	Nassau Grouper	Serranidae	Yes		>0.01		0.000
Equetus sp	Drumfish	Sciaenidae	No	0.11		0.001	

Euthynnus alletteratus	Little Tunny	Scombridae	Yes		>0.01		0.000
Galeocerdo cuvier	Tiger Shark	Carcharhinidae	Yes		0.02		0.000
Ginglymostoma cirratum	Nurse Shark	Ginglymostomatidae	Yes		0.06		0.001
Gymnothorax moringa	Spotted Moray	Muraenidae	No	0.06		0.001	
Gymnothorax saxicola	Honeycomb Moray	Muraenidae	No	>0.01		0.000	
Gymnothorax vicinus	Purplemouth Moray	Muraenidae	No	0.04		0.000	
Haemulon aurolineatum	Tomtate	Haemulidae	No	18.45		0.185	
Haemulon plumierii	White Grunt	Haemulidae	Yes	1.00	2.84	0.010	0.028
Holacanthus bermudensis	Blue Angelfish	Pomacanthidae	No	0.02		0.000	
Holocentrus adscensionis	Squirrelfish	Holocentridae	No	0.04		0.000	
Hyporthodus niveatus	Snowy Grouper	Serranidae	Yes	0.12	0.15	0.001	0.002
Lachnolaimus maximus	Hogfish	Labridae	Yes		0.15		0.002
Lagodon rhomboides	Pinfish	Sparidae	No	0.56		0.006	
Lutjanus analis	Mutton Snapper	Lutjanidae	Yes		0.03		0.000
Lutjanus buccanella	Blackfin Snapper	Lutjanidae	Yes		0.04		0.000
Lutjanus campechanus	Northern Red Snapper	Lutjanidae	Yes	0.80	4.47	0.008	0.045
Lutjanus cyanopterus	Cubera Snapper	Lutjanidae	Yes		0.00		0.000
Lutjanus griseus	Gray Snapper	Lutjanidae	Yes		1.45		0.015
Lutjanus synagris	Lane Snapper	Lutjanidae	Yes	0.01	0.04	0.000	0.000
Lutjanus vivanus	Silk Snapper	Lutjanidae	Yes	0.03	0.09	0.000	0.001
Malacanthus plumieri	Sand Tilefish	Malacanthidae	Yes		0.14		0.001
Micropogonias undulatus	Atlantic Croaker	Sciaenidae	No	>0.01		0.000	
Muraena sp	Moray Eel	Muraenidae	No	0.06		0.001	
Mustelus canis	Smooth Dogfish	Triakidae	Yes		>0.01		0.000
Mycteroperca bonaci	Black Grouper	Serranidae	Yes		0.03		0.000
Mycteroperca interstitialis	Yellowmouth Grouper	Serranidae	Yes		0.01		0.000
Mycteroperca microlepis	Gag	Serranidae	Yes	0.07	1.24	0.001	0.012
Mycteroperca phenax	Scamp	Serranidae	Yes	0.15	2.06	0.002	0.021
Mycteroperca venenosa	Yellowfin Grouper	Serranidae	Yes		>0.01		0.000
Ocyurus chrysurus	Yellowtail Snapper	Lutjanidae	Yes		0.03		0.000
Opsanus sp	Toadfish	Batrachoididae	No	0.03		0.000	
Orthopristis chrysoptera	Pigfish	Haemulidae	No	0.02		0.000	
Pagrus pagrus	Red Porgy	Sparidae	Yes	5.72	19.78	0.057	0.198
Pareques umbrosus	Cubbyu	Sciaenidae	No	0.16		0.002	
Pristipomoides aquilonaris	Wenchman	Lutjanidae	Yes		>0.01		0.000
Pterois sp	Lionfish	Scorpaenidae	No		2.65		0.027

Rachycentron canadum	Cobia	Rachycentridae	Yes		0.12		0.001
Rhizoprionodon terraenovae	Atlantic Sharpnose Shark	Carcharhinidae	Yes		0.09		0.001
Rhomboplites aurorubens	Vermilion Snapper	Lutjanidae	Yes	4.16	39.33	0.042	0.393
Rypticus maculatus	Whitespotted Soapfish	Serranidae	No	0.02		0.000	
Rypticus saponaceus	Greater Soapfish	Serranidae	No	0.01		0.000	
Scomberomorus regalis	Cero	Scombridae	Yes		>0.01		0.000
Seriola dumerili	Greater Amberjack	Carangidae	Yes	0.02	1.29	0.000	0.013
Seriola fasciata	Lesser Amberjack	Carangidae	Yes		0.02		0.000
Seriola rivoliana	Almaco Jack	Carangidae	Yes	0.04	1.42	0.000	0.014
Seriola zonata	Banded Rudderfish	Carangidae	Yes	0.01	1.43	0.000	0.014
Sphoeroides maculatus	Northern Puffer	Tetraodontidae	No	>0.01		0.000	
Sphyrna lewini	Scalloped Hammerhead	Sphyrnidae	Yes		>0.01		0.000
Sphyrna mokarran	Great Hammerhead	Sphyrnidae	Yes		>0.01		0.000
Squatina dumeril	Atlantic Angel Shark	Squatinidae	Yes		>0.01		0.000
Stenotomus sp	Scup	Sparidae	No	8.51		0.085	
Stephanolepis hispida	Planehead Filefish	Monacanthidae	No	0.16		0.002	