Long-term Residency of Benthic Fishes at an Artificial Patch Reef Using Hourly Ultra-short Videos

Videos Ultra Cortos, por Hora, para Establecer Residencia a Largo Plazo de Peces de Profundidad (Benticos) en un Área de Arrecife Artificial

Résidence à Long Terme des Poissons Benthiques dans un Petit Récif Artificiel en Utilisant des Vidéos Ultra-courts une Fois par Heure

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ABSTRACT

Few artificial reefs (ARs) have received intensive, long-term study. In 1999, a small "patch" (~177 m^2) AR was created in an undisclosed location 72 km off the coast of Georgia, United States, in 26 m of water. Ten-sec videos (77,593) were recorded hourly by up to six diurnally operated cameras viewing ~ 360°. Through September 2008, 106 taxonomic identifications included 40 benthic resident species, 34 mid-water visitors, 12 benthic cryptic species, and 12 supra-benthic nomads. The six benthic "resident" fishes/groups (*Haemulon aurolineatum*, *Rhomboplites aurorubens*, *Balistes capriscus*, *Chaetodipterus faber*, *Centropristis* sp. and *Mycteroperca* sp.) exhibited unexpectedly low presence (range: 4 - 50%). A Generalized Additive Model explained more deviation in residents' presence (26.4 ± 2.4%; mean ± SE) than a Generalized Linear Model (18.9 ± 2.7%), among 13 covariate terms across species. Year, the interaction between temperature and salinity and season each explained more variance than water temperature or salinity, suggesting that yearly and seasonal conditions may have contained multiple factors not among those measured. Significant inter-annual trends in presence between 2000 and 2008, were shown by *C. faber* (Atlantic spadefish) downward during the spring seasons and by *R. aurorubens* (vermilion snapper) upward during the summer seasons. Despite their low short-term presence and high variability, the frequency of observations of resident fishes of the patch reef remained relatively stable over eight years. This study reinforced the utility of fixed remote video for assessment of long- and short-term temporal trends.

KEY WORDS: Long-term residency; video monitoring; artificial patch reef

INTRODUCTION

Although attraction of fishes, particularly adult life stages, to ARs shortly after reef deployment is well documented (Pickering and Whitmarsh 1997, Brickhill et al. 2005), few studies of species persistence over time in reef areas exist (Bohnsack and Sutherland 1985). Also, variation in density within habitat types is less well understood (Schobernd and Sedberry 2009). Despite high quality spatial coverage from submersible video such as that used by Schobernd and Sedberry (2009), single observations are inadequate for characterizing temporal changes in fish presence; such information can only be obtained through long-term monitoring repeatedly at the same sites.

Long-term variability in a species' residence may contribute significantly to shifts in the reef fish assemblage composition (Parker and Dixon 1998) as well as to fish assemblage succession at ARs (Bohnsack and Sutherland 1985). There is speculation that resident *Centropristis striata* may be displaced by increases in size and number of *Mycteroperca* sp. grouper over many years at a given site (Melvin Bell, South Carolina Marine Resources Division, personal communication). Also, since fisheries independent sampling to monitor changes in population relative abundance, are often multi-seasonal, variability in the seasonal presence of residents at a local habitat could, potentially, influence interpretation of sampling results. Short-term variability in fishes' seasonal and long-term residency and persistence should be of concern in the interpretation of estimates of relative abundance based upon one time/site sampling for comparisons of long-term species trends in abundance.

Catch rates, historically have been a data source of choice for defining characteristics of larger reef fishes, however they do not always reflect true species relative abundance (or absence) given gear selectivity and avoidance (Rose et al. 2005).Visual census methods provide a non-destructive sampling alternative and are less biased than catch rates (Clark and Edwards 1994, Harmelin-Vivien et al. 2008). Despite the proven efficacy, repetitive remote video sampling over extended observation periods has been conducted predominantly at nearshore reef habitats (Lowry et al. 2011, Malcolm et al. 2007, Pelletier et al. 2012, Watson et al. 2005, 2007). Long-term monitoring projects, spanning several years of observation, are also not widely reported for ARs or natural reef habitats (Jan et al. 2007, Mills et al. 2005, Smith and Tyler 1973). One notable exception is a long-term research program at an experimental AR system in the northeast Gulf of Mexico (Lindberg et al. 2006) that has included underwater video (Mason et al. 2006).

We describe the long-term patterns of variance in frequency of presence/absence (residency) by season and the relative importance of water temperature and salinity on frequency of presence of six benthic resident species/groups at a patch AR (objectives 1 & 2). We also report inter-annual trends in frequency of presence by season for benthic resident species between 2000 and 2008 (objective 3).

METHODS

In May 1999, a research site was initiated on the mid-continental shelf 72 km off the coast of Georgia (32°N), United States, within a hydrographically-dynamic region at a water depth of about 26 m. The research site consisted of six clusters of two concrete Fish Haven™ pyramids (Artificial Reefs, Inc.; Pensacola, Florida) that measured 2.5 m (base width) x 1.5 m (height) arranged in a circle (~15 m diameter) around a centrally located remote underwater video system (Barans et al. 2005). This arrangement created a habitat footprint of ~81 m^2 (13 pyramids) that encompassed 46% of the circular area (176.6 m^2). The research site was situated on an otherwise sandy bottom widely separating the low relief, sporadic "live bottom" sponge/coral or "hard-bottom" habitats that typify the continental shelf (Struhsaker 1969). To reduce the probability of fishing, the location of the patch AR was not disclosed to the public; however, by winter 2006 the patch AR had been discovered by a local spear fisher, who only occasionally removed *C. striata*; thus, we considered this site to have remained relatively un-fished.

Fisheries video data collection began on 27 August 1999. Six black and white security cameras (Supercircuits PC-23C) with wide-angle lenses (8 mm, 12° angle of view), low light capabilities (< 0.04 lux), and relatively low resolution (460 lines) collected short (≤ 10 s) video data files each hour during daylight. Sampling frequency and duration represented a compromise. Previous experience demonstrated that fish identifications to species level were greatly facilitated by changes in fish aspect to the camera, usually occurring during 10 s but not in single still images. Limited band width available for transmissions from the U.S Navy required use of short video data sets, but allowed replication by six cameras and hourly sampling. Video data files were transmitted via a single coaxial cable from the cameras to a capture computer located in a Navy communication tower (Seim 2003) 0.8 km away, and then to shore via microwave.

Trained personnel recorded qualitative scores estimating the depth of field in each video data file. Only video data files collected under "good" (within and beyond the AR units) and "fair" (full extent of the closest units) visibility were analyzed. Similarly, only video data files with < 50% biogenic fouling on the camera windows were analyzed. Less than10% of video data files from periods of acceptable visibility were excluded due to fouling, except for April through June 2004 and January through March 2007 when 87% (1390 out of 1593) and 29% (297 out of 1014) of videos, respectively, were excluded. High seas and vessel breakdowns often delayed routine maintenance. All organisms observed in each video data file were identified to the lowest taxonomic level, and the degree of reviewer identification confidence (1 = positive, 2 = confident, 3 = uncertain) was also included. Relative abundance scores for each taxon were assigned as follows: 1 = < 5, 2 = 5 to 20, and 3 = > 20 individuals.

Statistical analysis of long-term temporal change in frequency of occurrence was conducted for six benthic resident species/groups common to the study region (Chester et al. 1984, Parker et al. 1994), seen in multiple years, and hence, presumed to be resident (Powers et al. 2003) without knowledge of any variations in species' presence. These species/groups included *Haemulon aurolineatum*, *Rhomboplites aurorubens*, *Balistes capriscus*, *Chaetodipterus faber*, sea basses (*Centropristis* sp.), and groupers (*Mycteroperca* sp.).

Time of day increments were defined as:
  i)   < 10:00 local standard time (LST),
  ii) 10:00 - 13:00 LST,
  iii) 13:00 - 16:00 LST, and
  iv) >16:00 LST.

Annual data were partitioned by year and season, where the latter was defined as Jan - Mar (1), Apr - Jun (2), Jul - Sep (3), and Oct - Dec (4). Replicate video data files for cameras 1 to 6 were pooled by each of the four time of day increments for each day (often representing > 18 video data sets). Species were considered present if seen in any of the videos. By pooling data, multiple sightings of the same fish or of a species were reduced to one value of presence or absence and maximized the probability of seeing any species present during that part of the day providing the most conservative indication of occurrence. Data were compartmentalized into seasons to capture the unique differences in multiple factors among seasons. Seasons with fewer than 25 observation periods, either due to insufficient numbers of video data files and/or incomplete environmental data, were excluded from analyses. Environmental data for each observation period consisted of mean bottom water temperature (°C) and salinity (Practical Salinity Units, PSU), which were computed from six minute observations recorded < 1 km away by data loggers (Seim 2003).

Temporal, environmental and experimental conditions were investigated as possible predictors of species/group occurrence at the patch AR. Presence and absence data (the response term) for each species were analyzed in the software program "R" (Version 2.13.0; R Core Team, Vienna, Austria) with both a generalized linear model (GLM, via the *MASS* package), and a generalized additive model (GAM, via the *mgcv* package). Species presence/absence was fit to a binomial distribution using the "logit" link function (default R link function for binomial distribution) and examined for relationships with the potential predicator variables year, season, time of day bin, camera, mean water temperature, and mean salinity. Mean water temperature and salinity during each three-hour observation period were entered into the model as smoothed terms using splines checked by varying effective degrees of freedom for the smoother function (to examine the complexity of smoother fits). Year also entered the model as a continuous, smoothed term, while the model terms

season, time of day, and camera were analyzed as factors. Magnitude changes were associated with temporal progression for season (cyclical) and time of day (cyclical); however, we analyzed these terms as factors instead of as quantitative variables given the small range and fixed increment changes in magnitude for both. The null model contained four interaction terms (identified by Pearson's r > 0.3): year x season; water temperature x season; salinity x year; and salinity x water temperature.

The optimal analytical method was chosen after comparing the lowest Akaike's Information Criterion (AIC) score and the residual deviance of the "best-fit" GLM and GAM models. Final model selection was accomplished through a backward stepwise regression based on comparison of the lowest AIC terms and unbiased risk estimator (UBRE) scores between competing models and using additional standard methods, including plotting quantile residuals (Dunn and Smyth 1996).

Linear regression was performed in Minitab 15® to assess relationships between null model AIC scores and overall frequency of observation, overall frequency of observation and explained model deviance, and inter-annual trends by mean frequency of observation by season (for each of the 4 seasons, 6 species/groups). Chi-squared contingency tests and linear regressions were performed in Minitab 15® to test for proportionate differences and linear inter-annual trends, respectively, for observation or observation period distributions for selected model terms.

Long-term trends were evaluated for six benthic resident species/groups during 7,515 observation periods (Table 1); each period represented up to 6 camera videos/hr. pooled to four times (samples)/day, which spanned 802 observation days between 4 January 2000 and 30 September 2008. Sixty-five percent (4,917 out of 7,515) of observation periods occurred in the final two years of this study, and 69% (5,214 out of 7,515) of observation periods occurred between April and September. Inter-annual trends in resident species/groups presence were evaluated on a season-specific basis, to reduce any effects of seasonal presence on annual presence. The number of seasons for which samples were available was often less than four.

Table 1. Numbers of the 7,515 observation periods (pooled data from ≤ 6 cameras for 3 - 4 hours) used to evaluate temporal trends in six resident reef fish species at a small, patch AR on the middle continental shelf off Georgia between 4 January 2000 and 30 September 2008.

Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total
2000	74	243	58	35	410
2002	---	---	---	676	676
2004	36	82	118	709	945
2005	139	251	102	---	492
2006	---	---	29	46	75
2007	250	835	1,538	---	2,623
2008	336	832	1,126	---	2,294
Total	835	2,243	2,971	1,466	7,515

RESULTS

Between 27 August 1999 and 30 September 2008, a total of 77,593 video data files were collected. Thirty-three percent (25,482) of all video data files collected were deemed suitable for analysis based on underwater visibility and depth of field. Among video data files analyzed, 44,487 observations comprising 106 species designations were recorded (Supplement 1). Benthic residents (40) were most numerous, followed by mid-water visitors (34), benthic cryptic species (16), supra-benthic nomads (12), commensal species (3), as defined by Smith and Tyler (1973) and one avian species.

All six benthic resident species/groups were observed year-round. Seventy-three percent of *Centropristis* sp. observations (755 out of 1,036) were further identified to *C. striata*. Among grouper observations, 52% (855 out of 1,646) were identified to *M. microlepis* and 6% (107 out of 1,646) were identified to *M. phenax*. *B. capriscus*, *Centropristis* sp., and *Mycteroperca* sp. occurred almost exclusively (≥ 88%) in groups of fewer than five individuals, thus favoring presence-absence analysis. Relative abundances for *C. faber*, *H. aurolineatum*, and *R. aurorubens* were more variable, but were predominantly (≥ 45%) associated with one relative abundance score (i.e., < 5, 5 to 20, or > 20 individuals).

Resident species were observed at the patch reef much less frequently than expected and their presence was highly variable. Overall frequency of observation ranged from 4% (308 out of 7,515 periods) for *B. capriscus* to 50% (3,721 out of 7,515 periods) for *H. aurolineatum* (Table 2). Null model AIC scores (representing our method of choosing the best analytical model) ranged from 2,573.6 (*B. capriscus*) to 10,427.5 (*H. aurolineatum*), and increased significantly with greater frequency of observation ($F_5 = 21.85$; $p = 0.009$; $r^2 = 0.81$). The amount of deviation explained, however, was not related to frequency of observation for the GLM ($F_5 = 0.60$; $p = 0.482$; $r^2 = 0.00$) or the GAM ($F_5 = 0.23$; $p = 0.653$; $r^2 = 0.00$). Mean explained deviance was 26.4 ± 2.4% (mean ±SE) for the GAM and 18.9 ± 2.7% for the GLM. For all six species/groups, the GAM always explained more deviance than the GLM (Table 2).

Among resident species/groups, the greatest amount of variation in observation frequency (presence) was explained by annual differences, although the deviation explained was low (mean ± SE = 7.3 ± 2.0%). Considerable variability was noted in the relative importance of model parameters among species, as evidenced by large SE relative to mean values (Table 3). All model parameters were retained as significant terms for at least one species, and parameters were only retained as non-significant terms in eight instances. The interaction between water temperature and salinity explained the second greatest amount of deviance (7.0 ± 1.5%), largely as a result of observations of *H. aurolineatum* and *R. aurorubens* (Table 3). Individually, neither salinity (0.7 ± 0.2%) nor water temperature (0.2 ±

Table 2. Percent observation (pct. present) is given for the overall data set (7,515 observation periods) and among seasonal blocks with 835 to 2,971 observation periods each. Underlined values are highest seasonal presence. The generalized additive model (GAM) was selected over the generalized linear model (GLM) for analyzing model parameter influences and temporal observation tends for six resident reef fish species/groups at the small, patch AR, based on lower Akaike's Information Criterion (AIC) scores and a greater percent of model deviance explained.

Overall	B. capriscus	C. faber	R. aurorubens	H. aurolineatum	Centropristis sp.	Mycteroperca sp.
Periods present	308	1447	1475	3721	861	1376
Pct. Pres. overall	4	19	20	50	11	18
Pct. Pres. Jan to Mar	3	<u>49</u>	3	47	22	20
Pct. Pres. Apr to Jun	5	25	6	41	11	16
Pct. Pres. Jul to Sep	1	14	<u>39</u>	<u>71</u>	3	18
Pct. Pres. Oct to Dec	<u>9</u>	4	11	21	<u>24</u>	<u>22</u>
GLM						
AIC null	2573.6	7367.7	7447.4	10427.5	5353.6	7159.6
AIC final	2109.5	6033.3	5849.7	7800.0	4272.7	6769.8
Deviance null	2571.6	7365.7	7445.4	10425.5	5351.6	7157.6
Deviance final	2063.5	5987.3	5803.7	7754.0	4226.7	6723.8
Deviance Explained	19.8	18.7	22.1	25.6	21.0	6.1
GAM						
AIC null	2573.6	7367.7	7447.4	10427.5	5353.6	7159.6
AIC final	1960.0	5883.5	5185.7	7293.7	3821.7	6061.1
Deviance null	2571.6	7365.7	7445.4	10425.5	5351.6	7157.6
Deviance final	1874.5	5770.5	5084.4	7193.6	3730.9	5953.8
Deviance Explained	27.1	21.7	31.7	31.0	30.3	16.8

Table 3. The percent of deviance (relative influence) explained by 13 model terms on the frequency of observations among six benthic resident species/groups at the patch AR. Generalized Additive Model terms: Factor (F); Smooth (S). Term of greatest influence on each spp. underlined.

Terms		6 spp. Mean	SE	B. capris	C. faber	Centrop. sp.	H. aurolin	Myctero sp.	R. aurorub.
Season	(F)	1.7	0.5577	1.6	2.0	0.5	1.3	0.4	4.1
Time of day	(F)	2.5	0.6257	1.4	2.4	1.1	5.0	1.5	3.6
Camera	(F)	2.9	1.2630	1.5	3.9	8.9	0.9	1.1	1.4
Season x year	(F)	1.7	0.5962	1.6	2.2	0.0	1.5	0.5	4.2
Year	(F)	7.3	1.9623	<u>11.0</u>	0.1	<u>13.8</u>	7.2	<u>7.2</u>	4.4
Temperature	(S)	0.2	0.1548	0.0	1.0	0.1	0.0	0.0	0.1
Temp x Jan-Mar	(S)	0.2	0.1588	0.9	0.0	0.0	0.0	0.5	0.0
Temp x Apr-Jun	(S)	1.2	0.4948	3.1	1.0	0.5	2.3	0.0	0.4
Temp x Jul-Sep	(S)	0.1	0.0829	0.0	0.0	0.0	0.0	0.5	0.0
Temp x Oct-Dec	(S)	1.0	0.2412	0.0	0.6	1.5	1.0	1.3	1.5
Salinity	(S)	0.7	0.2259	0.9	0.8	0.2	0.0	0.8	1.6
Salinity x Year	(S)	0.0	0.0024	0.0	0.0	0.0	0.0	0.0	0.0
Salinity x Temp	(S)	7.0	1.4809	<u>5.1</u>	<u>7.7</u>	<u>3.8</u>	<u>11.9</u>	<u>3.0</u>	<u>10.4</u>
TOTAL (all terms)				27.1	21.7	30.3	37.0	16.8	31.7

0.2%) explained much deviance. Mean (SE < 0.1°C) seasonal water temperatures ranged from 16.4°C between January and March to 26.2°C between July and September; mean (± SE) water temperatures were similar during April to June (22.2 ± 2.7°C) and October to December (21.2 ± 2.7°C). Mean salinity throughout the study was 35.6 PSU (SE < 0.1 PSU), but varied from a low of 32.7 PSU (October to December 2002) to a high of 36.3 PSU (October to December 2006).

Although camera number, time of day, season, and the interaction between season and year (Table 3) each explained a small amount of the variation in the frequency of observation of each resident species/group, the mean deviance was not statistically different ($H_3 = 1.03$, $p = 0.795$) among these model parameters. The greatest deviance explained by camera number (2.9 ± 1.3%) was for

Centropristis sp. (Table 3), for which 47% (408 out of 861) of observations were associated with camera 5. All observation periods analyzed in 2000 were associated with camera 5, while the proportion of observation periods associated with camera 5 in the remaining years ranged from 8% (2005) to 30% (2004). For *H. aurolineatum* time of day of observations (2.5 ± 0.6%) explained the greatest amount of deviation (Table 3); they were seen significantly less often ($\chi^2 = 87.6$, $p < 0.001$) prior to 10:00 LST (40%; 656 out of 1,628 observation periods) compared to other time of day blocks (48 - 54%; 1,838 - 2,096 observation periods). Significant seasonal variability in observation was detected ($\chi^2 = 1,141$, $p < 0.001$) for *R. aurorubens* which contributed to the deviations in observed frequencies for season (1.7 ± 0.6%) and the interaction between year and season (1.7 ± 0.6%). Between July and September, *R.*

aurorubens was observed in 39% (1,145 out of 2,971) of observation periods, compared to just 3 - 11% (835 - 2,243 observation periods) of other seasonal blocks. Annually, the proportion of data collected between July and September ranged from 12% (118 out of 945 observation periods) in 2004 to 59% (1,538 out of 2,623 observation periods) in 2007; however, a significant linear trend among observation frequencies was not detected ($F_5 = 7.31$, $p = 0.054$, $r^2 = 0.56$).

All six benthic resident species/groups were observed to be present during all seasons; however, with the exception of *Mycteroperca* sp. frequencies of observation among seasons within a given year and within a season among years were highly variable (Table 4). The mean probability of observation for the four seasons ranged from < 0.1 (all six species/groups) to 0.758 (± 0.002 SE) for *H. aurolineatum* in July to September 2007.

The residents exhibited varying trends in the frequency of observations across years. Between 2004 and 2008, *B. capriscus* and *Centropristis* sp. decreased in frequency of observation, while *H. aurolineatum* increased, but none significantly. Both *C. faber*. and *R. aurorubens* demonstrated significant inter-annual trends in observed frequencies during spring (decrease) and summer (increase) seasons, respectively (Table 5). Between springs (April and June) the observation probability for *C. faber* systematically declined from a peak of 0.484 in 2000 to a low of

0.153 in 2008 ($F_4 = 43.71$; $p = 0.007$; $r^2 = 0.91$. During the summers (July through September) the frequency of observation of *R. aurorubens* increased from 0.002 in 2000 to 0.326 in 2008 ($F_4 = 8.67$; $p = 0.032$; $r^2 = 0.56$).

DISCUSSION

Infrequent observation of benthic "resident" species/groups (range in presence: 4 - 50%) in this study was surprising given routine observation of these species in other studies conducted in the general study region (Parker et al. 1994, Sedberry and Van Dolah 1984). Yet, the term "resident" is justified by the fact that all six species/groups persisted at the site throughout the eight year study. Habitat size of the patch AR (ie. invertebrate carrying capacity) or structure size/shape may have limited the short-term persistence of some species. Our frequency of observations may have been reduced for species/groups such as *Mycteroperca* sp. that prefer habitats of high vertical relief (Burge et al. 2012, Kendall et al. 2008). Also, most previous studies utilized spatial, continuous sampling transects, whereas the present study conducted repetitive temporal sampling at a stationary location. The short video durations in the present study should not have negatively influenced our findings because Barans et al. (2005) reported observation of at least one animal species in > 77% of a 28 month sub-set of the video data files examined here.

Table 4. Mean seasonal observation frequency (presence) of six benthic residence species/groups at a small, patch AR in the middle continental shelf off the coast of Georgia, United States between years 2000 - 2008. Highest seasonal presence (2000; 2004; 2007) are **bold font**.

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008
Centropristis sp.									
Summer	0.169		0.089		0.370	0.042	0.055	0.012	0.009
Fall	0.215		0.236		0.248		0.115	0.001	
Winter	**0.378**				0.434	0.394		**0.157**	0.138
Spring	0.258				0.682	0.137		0.055	0.051
Mycteroperca sp.									
Summer	0.000		0.015		0.066	0.161	0.297	**0.293**	0.038
Fall	**0.040**		0.255		0.192		0.283	0.003	
Winter	0.027				**0.229**	0.462		0.329	0.043
Spring	0.003				0.090	0.265		0.287	0.051
C. faber									
Summer	0.236		0.154		0.147	0.074	0.258	0.145	0.142
Fall	0.019		0.020		0.043		0.242	0.000	
Winter	**0.498**				**0.519**	0.585		**0.493**	0.440
Spring	0.484				0.371	0.352		0.228	0.153
H. aurolineatum									
Summer	**0.564**		0.289		0.105	0.345	0.544	**0.758**	0.753
Fall	0.377		0.218		**0.177**		0.352	0.229	
Winter	0.137				0.022	0.059		0.515	0.723
Spring	0.080				0.024	0.026		0.332	0.735
R. aurorubens									
Summer	0.002		0.019		0.018	0.108	0.145	**0.494**	0.326
Fall	0.016		0.142		<u>0.067</u>		0.478	0.000	
Winter	0.000				0.002	0.005		0.046	0.035
Spring	**0.140**				0.016	0.032		0.078	0.038
B. capriscus									
Summer	0.040		0.025		0.159	0.040	0.012	0.003	0.006
Fall	0.109		0.078		0.107		0.010	0.001	
Winter	0.099				0.215	0.075		**0.005**	0.006
Spring	**0.189**				**0.357**	0.093		**0.005**	0.008

Table 5. Statistical results from 24 linear regressions of mean seasonal model fits (frequency of presence) for each of the six benthic resident fish species/groups at the patch AR between the years 2000 - 2008. An * denoted a significant linear trend; degrees of freedom ranged from 3 (Oct - Dec) to 5 (Jul - Sep).

Season	Species/Group					
Jan-Mar	*B. capriscus*	*Centropristis sp.*	*C. faber*	*H. aurolineatum*	*Mycteroperca sp.*	*R. aurorubens*
F-stat	1.36	3.61	0.30	3.19	0.24	5.06
p-value	0.328	0.154	0.620	0.172	0.655	0.110
r^2	0.083	0.395	0.000	0.354	0.000	0.504
Apr-Jun						
F-stat	1.86	0.76	43.71	3.00	0.87	1.87
p-value	0.266	0.488	0.007*	0.182	0.421	0.264
r^2	0.177	0.000	0.914	0.333	0.000	0.179
Jul-Sep						
F-stat	0.50	1.55	0.51	1.47	2.57	8.67
p-value	0.511	0.268	0.506	0.280	0.170	0.032*
r^2	0.000	0.085	0.000	0.072	0.207	0.561
Oct-Dec						
F-stat	7.71	4.70	0.49	0.25	0.01	0.38
p-value	0.069	0.119	0.533	0.649	0.947	0.583
r^2	0.627	0.481	0.000	0.000	0.000	0.000

Both season and year contributed to the variance in presence of the six resident species/group at the patch AR, but the environmental components that we measured, considered "key factors" (i.e., temperature and salinity) in presence or movements of other species, were much less important than a seasonal component. Clearly, important factors were not quantified for inclusion into the models, although similar results were found previously with Principal Components Analyses which included 11 environmental factors. Unmeasured factors could have included behaviors modulated by internal clocks responding to combinations of seasonal factors, each representing only a small part of the seasonal environmental change when taken independently.

Species responses to dynamic environmental cues other than temperature or salinity may explain the low (but variable) observed presence of resident species at the patch AR. Although water temperature changes considerably on an annual basis, temperature variability in the analyzed data was reduced due to a preponderance of data originating in spring and fall at similar temperatures. Salinity variability was also negligible due to the mid-shelf study location. Sanders et al. (1985) found that the abundance of *H. aurolineatum* and *B. capriscus* was significantly related to water temperature at two ARs in the northeastern Gulf of Mexico. They suggested that spring recruitment may have contributed greatly to the relationship, especially for *H. aurolineatum*; however, none of the factors that they tested explained "much of the total variation" (in abundance).

Decreases in observed frequencies over time may have reflected a regional decline in relative abundance of the same species. The catch-per-unit-effort (CPUE) index of *C. striata* at the nearby Gray's Reef National Marine Sanctuary (GRNMS) decreased appreciably between 2006 and 2007 (David Wyanski, South Carolina Marine Resources Division (SCMRD), personal communication), while a standardized CPUE index declined from 2004 through 2009 throughout the region (Joseph Ballenger, SCMRD, personal communication). However, the same data set also indicated a decrease for *H. aurolineatum*, and *R. aurorubens*, during the same period when increased observation frequency was found at the patch AR in the present study. Absence of *C. striata* and *B. capriscus* could have reflected the limited sessile invertebrate populations available as forage for either species. Both *C. striata* (Sedberry 1988, Steimle and Figley 1996) and *B. capriscus* (Kurz 1995, Vose and Nelson 1994) forage extensively on AR epifauna, or on benthic infauna adjacent to reefs.

The decline in presence of *C. striata* after 2006 may have occurred due to fishing pressure. Declines in *B. capriscus* and *Centropristis* sp. in all seasons after 2006 coincided with discovery of the AR by an offshore spear fisher, who occasionally harvested "many very large" *C. striata* (but never *Mycteroperca* sp.) from the small patch AR. Simulated harvest fishing at a similar, but much larger, AR off South Carolina resulted in a significant decrease in the abundance of targeted species (*B. capriscus, C. striata, M. microlepis* and *M. phenax* combined) (Kolmos 2007). Fishing pressure can decrease the mean size of local target species as well as local abundances. *M. microlepis* and *M. phenax* were smaller in areas of intensive fishing than in areas of low fishing effort within similar habitats (Kendall et al. 2008).

Competition between *Centropristis* sp. and *Mycteroperca* sp. groupers for shelter at the small AR may have contributed to their somewhat opposite trends in relative abundance between 2005 - 2008, despite differences in habitat preferences between the two groups (Kendall et al. 2008). Observations of *Mycteroperca* sp. increased notably after 2006. Although little is known of inter-specific competition for space among the fishes within a temperate reef assemblage, Lindberg et al. (2006) demonstrated that intra-specific densities of *M. microlepis* are dependent on habitat size and shelter and that their growth and condition

are influenced by their densities, The decline in *Centropristis* sp. (2005 - 2008) from removal by fishing may have reduced competition for limited AR shelter space, thereby allowing *M. microlepis* to increase in abundance. Potential competition for space could have been compounded by simultaneous competition for food resources. Both *C. striata* and the *Mycteroperca* groupers access the same schools of forage species when prey species are forced to near bottom by large pelagic predators (Auster *et al*. 2009). Alternatively, increased presence of *Mycteroperca* sp. at the AR (2005 - 2007) may have influenced an exodus of *Centropristis* sp. (2005 - 2008), which are generally a smaller grouper, as well as *B. capriscus* as part of a natural assemblage succession effect (Thanner et al. 2006). Kendall et al. (2008) found that *C. striata* were present in a lower abundance where the *Mycteroperca* groupers were present at natural reefs within the same general area as the patch AR.

The presence of *C. faber* decreased each year of the study showing a significant inter-annual trend. Also, *C. faber* decreased linearly among seasons. Because the most important model term for *C. faber* was the interaction between temperature and salinity, the significant decline in presence of *C. faber* that occurred between April and June in later years may have resulted from their movement inshore in response to seasonal hydrographic conditions. Hayse (1990) suggested that *C. faber* collected from nearshore (< 20 m) waters in summer aggregate further offshore (28 - 56 m) in the winter.

In contrast, *R. aurorubens* increased significantly in presence during the eight year study. Also, a pronounced seasonal variation in observation of *R. aurorubens,* which was four times that of other species*,* was consistent with findings from trawl surveys at natural reefs in the same general area (Sedberry and Van Dolah 1984) and that *R. aurorubens* were not observed at temperatures below 16°C (Parker 1990). Seasonal differences in observation frequency among and within species may have reflected large scale species movements.

Variation in the presence of resident species suggests that fisheries managers should exercise caution when interpreting trends in catch rates spanning short sampling durations, since most resident species at the patch AR demonstrated significant inter-annual differences without significant inter-annual trends in presence during eight years. McGovern et al. (1998) found a non-linear pattern of catch rates of demersal reef species during a thirteen year period associated with intense fishing pressure. Unexplained deviance in fisheries data is often considered "random", although the effects of stochastic events have been reported (see review by Charles 1998). Despite the fact that most of the deviance in our long-term data could not be fully explained by standard environmental model terms, future studies could further explain the variable presence of reef fishes by long-term monitoring with a combination of fixed video and additional environmental sensors (i.e., pressure, current, etc.).

We feel that the use of fixed video systems should be expanded to address long- and short-term questions on reef fish assemblages (Burge et al. 2012), and where observations are validated, for collecting stand alone relative abundance data (Watson et al. 2005). The intense replication of diel observations (802 days during eight years) enabled confident examination of within and among season comparisons, despite the offshore challenges of transmission, fragile electronics, poor visibility and fouling. More frequent visits to research sites by scientific divers would reduce the extensive data loss due to fouling of camera windows and storm damage, as occurred in this study, while multiple video sites would allow assessment of foraging capacity at research and appropriate control sites (Brickhill et al. 2005). Video data loggers (Lowry et al. 2011) might be used to reduce discovery of any future study location by fishers during camera servicing to only those essential maintenance periods. In addition to fixed video, acoustic telemetry receivers could be deployed to continuously monitor a subsample of tagged fish (Arendt et al. 2001) to differentiate between visual and true absence from a study location.

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Supplement 1. Taxonomic identifications, partitioned by ecological grouping, observed in 25,482 video data files collected during periods of suitable visibility and depth of field at a small, patch AR on the middle continental shelf off the coast of Georgia. The total number of occurrences is provided with respect to the number of observation periods (No. of periods). The chronological order of first observation (Obs. rank; 1 to 106) is also provided. "Species / groups analyzed (*)"

Benthic residents	No. of periods	Obs. rank	Mid-water visitors	No. of periods	Obs. rank	Avian	No. of periods	Obs. rank
Acanthurus bahianus	6	66	*Aurelia marginalis*	3	86	*Gavia immer*	53	21
Aluterus sp.	18	72	*Caranx* sp.	882	35			
Aluterus schoepfi	14	42	*Caranx crysos*	711	1	Cryptic, benthic	No. of periods	Obs. rank
Aluterus scriptus	1	80	*Caranx ruber*	11	33	*Apogon* sp.	160	104
Anisotremus virginicus	16	68	*Chrysaora quinquecirrha*	189	76	*Apogon pseudomaculatus*	159	16
Archosargus probatocephalus	59	45	*Clupeidae*	6	57	*Gobiesocidae*	1	48
Balistes sp.	329	50	*Ctenophora*	435	9	*Halichoeres* sp.	74	75
Balistes capriscus*	323	19	*Cyanea capillata*	2	74	*Halichoeres bivittatus*	64	77
Canthidermis sufflamen	1	64	*Decapterus* sp.	2479	2	*Inachidae*	5	53
Centropristis sp.*	1036	31	*Decapterus macarellus*	1	94	*Parablennius marmoreus*	37	51
Centropristis ocyurus	54	79	*Etrumeus teres*	13	4	*Podochela* sp.	2	83
Centropristis striata	755	23	*Euthynnus alletteratus*	138	20	*Pomacentrus* sp.	307	40
Chaetodipterus faber*	1566	17	*Loligo* sp.	1	105	*Pomacentrus diencaeus*	49	87
Chaetodon sedentarius	1	90	Mixed Forage/Juveniles	4222	13	*Pomacentrus leucostictus*	6	93
Chilomycterus schoepfi	1	73	*Mola mola*	83	26	*Rypticus* sp.	122	101
Diplodus holbrooki	1	69	*Pomatomus saltatrix*	1	88	*Rypticus maculatus*	121	54
Equetus sp.	27	59	*Rachycentron canadum*	68	32	*Serranus subligarius*	245	65
Equetus lanceolatus	1	60	*Sardinella aurita*	5	55	Unid Cryptic	260	24
Equetus umbrosus	14	71	*Selar crumenopthalmus*	195	6	Unid Invert	21	15
Haemulon sp.	4923	14	*Seriola* sp.	1163	10			
Haemulon aurolineatum*	4871	5	*Seriola dumerili*	410	41	Commensal	No. of periods	Obs. rank
Holocanthus sp.	293	78	*Seriola fasciata*	1	43	*Remora remora*	10	36
Holocanthus bermudensis	175	25	*Seriola rivoliana*	174	47	*Echeneis* sp.	14	82
Holocanthus ciliaris	5	95	*Seriola zonata*	1	103	*Echeneis naucrates*	13	81
Lactophyrs sp.	18	96	*Sphyraena* sp.	663	98			
Lactophyrs quadricornis	13	49	*Sphyraena barracuda*	659	11	Suprabenthic nomads	No. of periods	Obs. rank
Leiostomus xanthurus	1	100	*Sphyraena guachancho*	2	102	*Carcharinus* sp.	104	85
Lobotes surinamensis	1	63	*Stomolophus meleagris*	1	99	*Carcharinus brevipinna*	4	84
Lutjanus sp.	201	29	*Stronglyura marina*	38	56	*Carcharinus limbatus*	14	89
Lutjanus campechanus	23	44	UnID Finfish	516	3	*Carcharinus plumbeus*	43	8
Lutjanus cyanopterus	9	91	Unid Forage	917	7	*Carcharinus taurus*	4	58
Lutjanus griseus	8	61	Unid Jellyfish	3	97	*Caretta caretta*	37	28
Mycteroperca sp.*	1646	22	UnID Juvenile	214	27	*Dasyatis* sp.	85	38
Mycteroperca microlepis	855	39	Unid Pelagic	245	30	*Dasyatis centroura*	10	46
Mycteroperca phenax	107	37				*Ginglymostoma cirratum*	166	34
Pagrus pagrus	2	52				*Rhizoprionodon terraenovae*	1	70
Pterois volitans	37	67				Unid Elasmobranch	1	62
Rhomboplites aurorubens*	1826	12				Unid Shark	2	92
Stenorhynchus seticornis	2	106						
Unid Reef Fish	2020	18						