Species traits and habitat quality drive differences in fish detectability between visual survey techniques: implications for coral reef monitoring design

Los rasgos de las especies y la calidad del hábitat impulsan las diferencias en la detectabilidad de peces entre las técnicas de levantamiento visual: implicaciones para el diseño de monitoreo de arrecifes de coral

Les caractéristiques des espèces et la qualité de l'habitat entraînent des différences dans la détectabilité des poissons entre les techniques de relevé visuel : implications pour la conception de la surveillance des récifs coralliens

IRIS M GEORGE[1], ALEXANDRA CD DAVIS[2], JOHN L AKINS[3], ALLISON C CANDELMO[4], STEPHANIE J GREEN[5]
[1] *University of Alberta, 1101 7A St. NW, Calgary, AB T2M 3J5, Canada, irisgeorge@shaw.ca*
[2] *University of Alberta, Z-630 Biological Sciences Building, Edmonton, AB T6G 2E9, Canada, acdavis@ualberta.ca*
[3] *Reef Environmental Education Foundation and Frost Museum of Science, 98300 Overseas Hwy, Key Largo, FL 33037, United States*
[4] *Reef Environmental Education Foundation, 98300 Overseas Hwy, Key Largo, FL 33037, United States*
[5] *University of Alberta, Z-622 Biological Sciences Building, Edmonton, AB T6G 2E9, Canada, sgreen1@ualberta.ca*

EXTENDED ABSTRACT

Accurately assessing reef fish community assemblages is an important feat for ecosystem health, fisheries regulations, and invasive species monitoring which allows for the design of meaningful management strategies (Larsen et al 2011). Several surveying techniques exist to do this, including underwater visual census (UVC) methods which are performed in-situ using SCUBA (Murphy and Jenkins 2010) and have unique benefits and drawbacks. Stationary visual censuses (SVCs) are performed by a stationary diver rotating in a circle of a fixed radius and recording all species seen, and were specifically designed to capture commercial species such as grunt and snapper (Brandt et al. 2009). Belt transects (Brock 1954) and underwater roving surveys (Green et al. 2012) are alternate UVC techniques which involve more thorough coverage of the reef, and record all species and only large predator species, respectively. UVC techniques in general are thought to underestimate fish density, particularly for small cryptic species (Willis 2005), but we hypothesized this bias to be more prominent in SVC surveys due to their low reef coverage. We compared density estimates across reef fish species for all three survey types using data from the Florida Keys region to determine SVC performance and looked at these differences in relation to habitat traits, survey traits, and species traits to allow for more general comparisons of survey methods across broad regions and to maintain a link to the ecological function of the fish fauna (Bremner 2008). Only our findings for the comparison between SVC and belt transect surveys are discussed here.

Data on reef fish communities was collected from 42 sites spanning 140 km along the Florida Reef tract in the southeastern United States. The sites are located in two management areas: the Florida Keys National Marine Sanctuary (FKNMS, n=26) and Biscayne National Park (BNP, n=16). We visited each site to survey reef fish communities in September 2014, March 2015, and October 2015. SVC and belt transect surveys were performed at the same site during the same visit, and recorded the abundance and lengths of all species observed. Individual fish observations across surveys were grouped into one of six size classes, and the differences between these densities were calculated between SVC and belt transect surveys. Density differences were log transformed to maintain normality, and linear mixed effects models were performed to analyze these differences in relation to trait predictors. Traits of the fish species included their water column position (benthic or demersal), behavior (aggregating behavior, presence/absence of cryptic behavior, nocturnal behavior), and morphology (coloration, body shape, maximum length). Traits of the habitat included reef type (patch or continuous), percentage of octocoral and stony coral at the site, depth (m), and measures of vertical relief (cm), which were collected at each survey site. Size class was also included as a predictor. An automated model selection process was carried out using the "dredge" function from the R package MuMIn (Barton 2009; R Development Core Team 2020) and top models with the highest likelihood were analyzed for overall predictor significance and effects.

We compared SVC and transect surveys across 111 individual sessions and for 157 total species from 33 families. We identified six linear mixed effects models predicting log density difference between SVC and transect surveys with delta AICc values less than four. The top models were composed of 11 predictors and one interaction between size class and shape, whose effects are summarized in Figure 1. The only two variables not included in any of the top models were vertical relief and average depth as well as the interaction between size and colouration. Variation was found in SVC performance compared to belt transect surveys, with transects recording higher densities across most trait groups. SVC surveys captured significantly lower densities of camouflaged, cryptically-behaving, and small species, compared to larger silvering individuals. SVC detection with fish size showed variation across different body shapes of species, with elongated species, such as gobies and barracuda, showing a large increase in recorded densities between small and large-bodied individuals, but compressed species, such as butterfly and angelfish, continuing to be recorded at similar SVC densities across

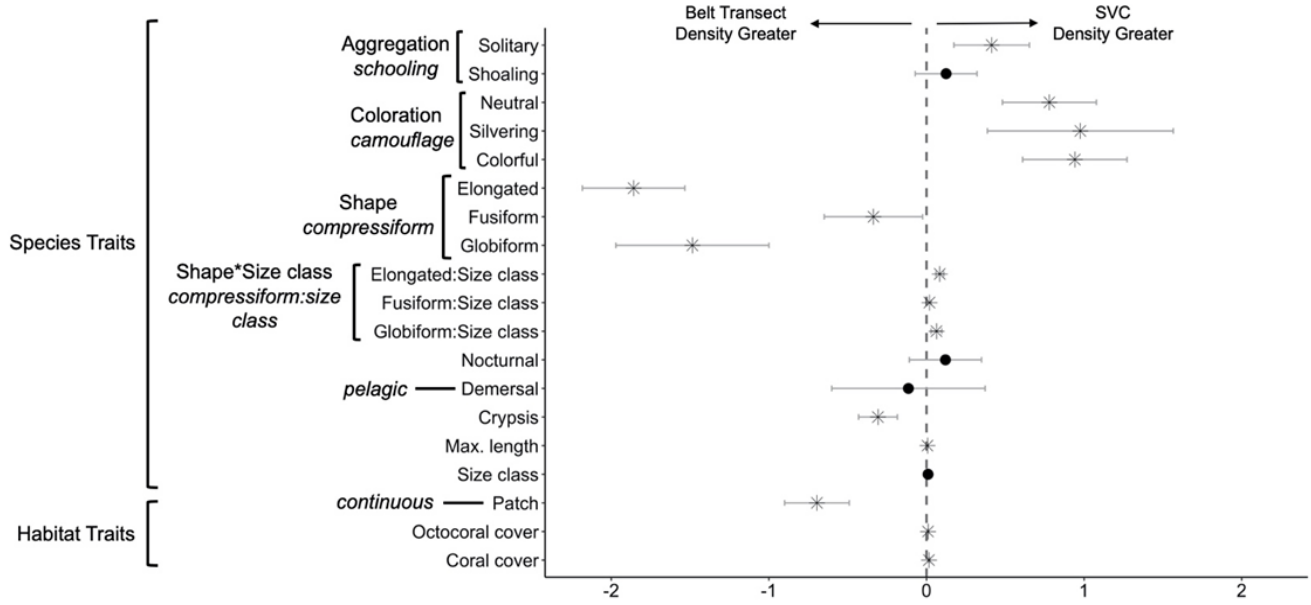

Figure 1. Average coefficients from the top models predicting density differences of fish species recorded in SVC and transect surveys. Positive estimate values indicate that the predictor results in higher average densities recorded on SVC surveys compared to belt transect surveys, and negative estimate values indicate that the predictor results in higher average densities recorded on belt transect surveys. Bars show the 95% confidence interval of the predictor. Asterisk symbols show that the predictor is significant, circles show that the predictor is insignificant. Base levels for categorical predictors are stated in italics beside them.

sizes. Overall, our results suggest issues with the ability of SVC surveys to detect cryptic fish species compared to more detailed transect survey methods. Habitat variables were also found to be significant predictors of density differences between SVC and belt transect surveys, including the percentage of stony and octocoral at survey sites. With increasing coral cover, differences in recorded fish densities between SVC and belt transect surveys decreased, though belt transect surveys continued to record higher densities than SVCs across all levels of coral cover. This suggests that higher coral cover caused SVC and belt transect surveys to detect fish at more similar rates, perhaps due to the visual barriers it creates impacting horizontal transect surveys more greatly than SVCs, where the diver is hovering vertically above the reef.

Choosing an appropriate survey method requires careful consideration of the management goal in question, and the types of species which are important to capture in order to meet these goals. Survey methods are most often chosen based on commonality within an institution, but our study reveals that many factors, including the traits of the species of interest and habitats being surveyed, must be taken into account to ensure the highest possible accuracy of the survey. SVC surveys have several inherent benefits, including their time efficiency and commonality (Bohnsack and Bannerot 1986), and we found that they capture comparable densities of large, silvering species to transect survey methods, which include many commercial species that they were designed to detect (Brandt et al. 2009). However, they failed to capture small, cryptic species, meaning they did not sample the fish community accurately as a whole. Belt transect surveys were found to capture all species and habitat trait groups at higher densities or comparably to SVC surveys, though their more detailed reef coverage means that they take more time to conduct properly (Samoilys and Carlos 2000). Based on our results, we recommend that belt transect surveys be used when the whole fish community is of interest. Our results highlight the effect of species' traits, both behavioral and physiological, on their detection and estimated density in reef surveys, and demonstrate the importance that accounting for them can have when choosing a survey method. When pre-existing survey techniques are utilized, it must be done with awareness of their limitations and the effect that these may have on monitoring or study results.

KEYWORDS: reef fish surveys, Florida Keys, habitat, underwater visual census, coral reef monitoring

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