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VISUAL CENSUS OF REEF FISH ASSEMBLAGES: A COMPARISON OF SLATE, AUDIO, AND VIDEO RECORDING DEVICES

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ABSTRACT: Fish assemblage data were recorded using slate, audio, and video techniques with a point-count visual census technique under controlled conditions. The community variables (number of species, number of individuals, and species diversity) describing the assemblage were generally similar for all three recording methods but audio recorded parameters were higher in magnitude. Slate and audio techniques were more similar to each other than each was to video with regard to the assemblage variables. Community resemblances were high for pairwise comparisons for all three recording methods. Users should be aware that certain species are more likely to contribute to differences in faunal comparisons than others. The simultaneous recording of fish assemblage date *in situ* using audio/video is recommended.

There has been much recent interest in obtaining accurate and precise *in situ* data on the fish assemblages associated with both natural and artificial reefs. These data are needed to assess and monitor these biotopes as well as test various ecological hypotheses (*e.g.*, Bohnsack and Sutherland, 1985; Hixon and Beets, 1989; Sale 1980). Concomitant with the increase in interest in obtaining these data has been the implementation of a variety of sampling methods (*e.g.*, Barans and Bortone, 1983; Harmelin-Vivien *et al.*, 1985). Evaluating the implementation of these methods under various conditions has also been the subject of many recent studies as well (Bortone, Hastings, and Oglesby, 1986; Bortone, Kimmel, and Bundrick, 1989; Brock, 1982; DeMartini and Roberts, 1982; Kimmel, 1985; Sale and Douglas, 1981; Sale and Sharp, 1983; Sanderson and Solonsky, 1986; Thresher and Gunn, 1986). Somewhat separate from the methods used to assess fish assemblages *in situ* is the technique used to record the data. The "standard" technique of writing data on an underwater slate (Helfman, 1983) has given way to more sophisticated audio, video, and audio/video recording devices (*e.g.*, Alevizon and Brooks, 1976; Bortone *et al.*, 1986; Smith and Tyler, 1973). While each of these *in situ* data recording techniques has advantages and disadvantages it is especially significant for researchers to be aware of the effect that different methods of data recording may have on the statistical description of the faunal assemblage. This is especially true when comparing data that have been recorded by different methods within a study or when comparisons are being made to previously published studies using differnt recording techniques.

Greene and Alevizon (1989) recently conducted a preliminary evaluation of different *in situ* recording techniques as part of a general comparison of several visual assessment methods. The present study is a more detailed examination of their initial assessment. We compare faunal population variables as attributes of the data recording technique to determine which are comparable between recording techniques. Also, we examine the factors attributable to faunal composition that most significantly affect the comparison. The results herein should facilitate the decision process when researchers choose recording techniques in future studies.

METHODS

As in the study by Greene and Alevizon (1989), "The Living Seas" exhibit at Walt Disney World, EPCOT center was chosen as the site to evaluate the *in situ* data recording techniques (see Greene and Alevizon, 1989:901, fig 1. for a diagram of the facility). The 62 m diameter, 8 m deep, 21.5 million liter aquarium held a fish assemblage of about 1800 Carolinian and Caribbean province fishes of 65 species during the 20–24 March 1989 study period. The facility proved advantageous to the objectives of this study as it provided a controlled environment with a population of fishes that remained unaffected by the immigration-emigration features normally associated with natural fish populations. No additional fish were added to the assemblage during the study and the brief sampling period limited the impact of mortality. The surveys were conducted in an area of the aquarium with moderate relief (<1 m) that had attracted predominantly reef-associated fish species. Through our experience of observing reef fishes under natural conditions we concluded that fish behavior appeared "normal" during the study period. Colors on some individual surgeonfish (*Acanthurus* spp.) were somewhat "faded" making accurate species determinations difficult hence they were "lumped" together in the species abundance matrix. Personnel at the "Living Seas" were extremely helpful during the project and restricted their daily maintenance activities to times that did not interfere with our observations. Visibility was greater than 30 m throughout the study.

Surveys were conducted using a point-count *in situ* visual assessment method (after Bohnsack and Bannerot, 1986 but modified by Bortone *et al.*, 1989) having a 5.64 m radius ($=100$ m^2) from the same central point for all recording techniques. The observer (SAB) occupied a position at the central point and recorded the abundance of each species entering the circle premarked with plastic tape to clearly define the limits of the sample area. The observer turned slowly, completing the rotation and survey in 5 min. Criteria for including individuals and schools of fishes during a survey follows Brock (1954) where no individual fish was recounted if it could be determined that it was previously counted and if one member of a school passed into the survey area then all members of the school were included in the count as well. Species abundance surveys for the slate recording technique were conducted alternatively with the audio/video recordings which were conducted simultaneously. In the later case the observer operated the video camera while recording audio data by observing over the top of the video camera housing. Thus the video tape had both audio and video information recorded on it at precisely the same time.

One hundred and twenty point-count surveys (40 for each recording mode) were recorded: on a white plastic slate (roughened with sand paper and using a pencil); on audio tape using a full-face dive mask; or simultaneously on video tape using a video recorder in an underwater housing. The audio recorded data were transcribed from the tape without reference to the video data. One week later the video recorded data were transcribed from the tape without reference to the audio portion of the tape. The data (species and number of individuals) were entered into a data base, analyzed and compared for their similarity in recording the following dependent variables: number of species, number of individuals, and Shannon-Weaver species diversity (H'; Pielou, 1966). In addition, similarity coefficients such as the Jaccard Coefficient, Quotient of Similarity, Percent Similarity, Morisita's Index and Horn's Index were calculated between recording method pairs using a computer program from Oakleaf Systems, Inc. (Decorah, Iowa). Pearson product and Spearman rank correlation coefficients were calculated on species abundance between recording methods using the SAS statistical program (SAS, 1985). The population variables and mean abundance for each species were compared using Student's t-test for slate versus audio and slate versus video recorded data. A paired t-test was used to compare variables between the audio and video recorded data because these data do not represent independent samples. The level of significance used to reject the hypothesis that there was no difference between recording methods was $p<0.05$ unless otherwise indicated.

RESULTS

A comparison of the descriptive statistics for the fish assemblage variables (*i.e.*, mean number of species, individuals, and species diversity) indicates a general faunal similarity between the slate and audio recording techniques (Table 1). There was no statistical difference in the mean number of species or the species diversity measure using these two methods. These two variables were significantly lower when recorded using video than with the other two techniques. No recording technique was similar to another with regard to the number of individuals recorded. The video technique produced a statistical description that was lower than the other two techniques for all three variables tested.

A summary of the species abundance matrix (Table 2.) indicates that some species are more responsible for the differences in the assemblage parameters than others. The grunt species (genus *Haemulon*) were not only some of the more abundant species but they were species that often showed differences in abundance between recording techniques. It appears that species which occurred in mobile schools such as grunts (*Haemulon* spp.) and surgeonfish (*Acanthurus* spp.) contributed more to the differences recorded between methods.

In a pairwise comparison between the faunal similarity attributable to the three recording techniques there is a strong overall agreement in the faunal assemblage they each describe (Table 3.). Jaccard Coefficients, Quotient of Similarity, Percent Similarity, Morisita's Index, and Horn's Index all indicate a strong faunal resemblance recorded among the three techniques. Another indication of the overall faunal resemblance similarity recorded can be seen in an examination of the correlation coefficients. Both Spearman rank and Pearson product correlation coefficients were high and significant for all combinations ($p<0.0001$).

DISCUSSION

Greene and Alevizon (1989) determined from their study that audio recorded data were more accurate than were data recorded by slate and video techniques. They based this conclusion after comparing their data to what they considered to be a known standard reference. One of the major differences between their study and ours is that, our sample size was larger (20 versus 40) and we employed only one visual survey

Table 1. Comparison of descriptive statistics for the three recording methods used to assess the reef fish assemblage in "The Living Seas." The asterix (*) indicates variables tested with a t-test. A continuous line under the corresponding numbers indicates statistical similarity.

Variable	Slate	Audio	Video
Minimum Number of Species	9	13	7
Maximum Number of Species	23	27	23
Mean Number of Species*	17.23	18.15	13.73
Standard Deviation (No. Sp.)	2.83	3.14	3.16
Minimum Number of Individuals	68	72	61
Maximum Number of Individuals	137	193	158
Mean Number of Individuals*	109.80	125.28	96.30
Standard Deviation (No. Ind.)	15.37	25.50	21.93
Mean Species Diversity (H')*	1.75	1.69	1.54
Number of surveys	40	40	40

method thus avoiding bias due to the assessment technique itself.

The high scores of the similarity coefficients comparing the faunas recorded herein by the three recording techniques indicates that all three methods provide a reasonable and comparable description of a fish assemblage. The slate and audio recorded variables tended to be more similar to each other than either was to the variables recorded using video. An *a priori* assumption could be that audio would be a superior recording device over slate. This is because when an observer uses a slate considerable time (and therefore effective observation time) is spent looking at the slate instead of the assemblage. Although audio did tend to produce higher values for all variables when compared to slate these differences were generally not significant.

Video recorded variables had the lowest values of the three recording techniques tested here. The suggested reason for this is that the field of vision of a video recording device is much more limited than the human eye, even though one's vision is partially obscured when using a dive mask. The limited field of vision, camera angle, and lighting can lead to a reduced probability of detecting an individual when using a video recorder. The quality of the video reproduction itself may have greatly contributed to the reduced amount of information being recorded. In addition, our experience indicates that some species must be observed for a considerable time to correctly identify them in the field. The video apparatus does not permit the "eye of the observer" to move as freely as with the other two techniques employed here. Also some individuals may go undetected because the cryptic color and sedentary behavior of some species makes them difficult to detect on the video recorded format. The test conditions provided by the "Living Seas" facility were "ideal." One could expect that factors which limit the video recordings would play an even more significant role in reducing the probability of detecting an individual organism under more natural circumstances.

In the present study, audio recorded data provided faunal assessment statistics that were higher for most variables. It is a generally recognized phenomenon that visual census techniques tend to underestimate a fish community (Harmelin-Vivien *et al.*, 1985). Part of this can be attributed to reduced effective observation time when using a slate as the observer must "look down" while writing. This is not a factor with audio data recording as the observer theoretically is not so distracted. It is, therefore, not surprising that the audio technique would provide higher statistical values in a description of a fish assemblage.

It is suggested that a combination audio/video recorder be used in the *in situ* visual assessment of fish assemblages. The audio recorded data tend to produce the most information and should be used for analysis. Moreover, the video provides a permanent visual record of the sampling conditions and can serve to verify species identifications. If circumstances or conditions do not permit an audio recording device (*e.g.*, if the audio recording device does not function properly)

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Table 2. Species abundance summary for each of the three census methods. x̃ = mean, sd = standard deviation, mn = minimum number observed, mx = maximum number observed (n = 40). Beside the species name in brackets [ ] (when appropriate) are the letters sa, av, and sv indicating a significant difference (using a t-test) in the mean abundance between the recording methods: slate vs. audio; audio vs. video; and slate vs. video, respectively.

Species	Slate				Audio				Video			
	x̃	sd	mn	mx	x̃	sd	mn	mx	x̃	sd	mn	mx
Abudefduf saxatilis	1.33	1.08	0	4	1.53	1.61	0	8	1.28	1.32	0	6
Acanthurus sp. [av,sv]	0.35	0.48	0	1	0.25	0.43	0	1	0.05	0.22	0	1
Aetobatus narinari	0.30	0.51	0	2	0.40	0.73	0	3	0.25	0.54	0	2
Anisotremus surinamensis	0.25	0.49	0	2	0.18	0.44	0	2	0.15	0.42	0	2
Anisotremus virginicus [av]	49.58	16.48	18	86	52.95	17.18	22	84	47.58	15.78	21	83
Archosargus probatocephalus [sa,sv]	0.20	0.46	0	2	0.78	1.11	0	4	0.78	1.06	0	4
Balistes capriscus	0.48	0.81	0	3	0.63	0.94	0	4	0.55	0.86	0	3
Balistes vetula [av]	0.85	0.91	0	3	0.98	0.96	0	3	0.60	0.83	0	3
Calamus sp. [sa]	0.55	0.22	0	1	0.33	0.72	0	3	0.15	0.36	0	1
Caranx hippos	0.20	0.40	0	1	0.38	0.76	0	3	0.38	0.62	0	2
Caranx latus	0.05	0.22	0	1	0.00	0.00	0	0	0.05	0.22	0	1
Carcharhinus sp.	0.50	0.59	0	2	0.55	0.71	0	3	0.60	0.70	0	3
Centropomus undecimalis	0.03	0.16	0	1	0.00	0.00	0	0	0.00	0.00	0	0
Chaetodipterus faber [av]	0.68	0.98	0	3	1.10	1.43	0	5	0.48	0.74	0	2
Dasyatis americana	0.20	0.51	0	2	0.13	0.33	0	1	0.15	0.42	0	2
Epinephelus guttatus	0.08	0.26	0	1	0.03	0.16	0	1	0.03	0.16	0	1
Epinephelus morio [av]	0.73	0.77	0	3	1.05	1.02	0	4	0.53	0.74	0	3
Epinephelus nigritus	0.03	0.16	0	1	0.08	0.26	0	1	0.00	0.00	0	0
Epinephelus striatus	0.05	0.22	0	1	0.00	0.00	0	0	0.00	0.00	0	0
Ginglymostoma cirratum	0.03	0.16	0	1	0.05	0.22	0	1	0.10	0.37	0	2
Haemulon carbonarium [sa,sv]	0.13	0.33	0	1	0.00	0.00	0	0	0.00	0.00	0	0
Haemulon flavolineatum [av,sv]	0.93	0.79	0	3	0.88	0.68	0	3	0.35	0.48	0	1
Haemulon macrostomum	0.03	0.16	0	1	0.00	0.00	0	0	0.00	0.00	0	0
Haemulon melanurum [av]	0.48	0.71	0	3	0.63	0.80	0	2	0.40	0.66	0	2
Haemulon plumieri [sa,av]	27.63	9.41	3	46	34.55	11.56	15	61	24.75	8.60	10	46
Haemulon sciurus [sa,av,sv]	9.55	4.44	2	22	11.93	4.77	5	32	7.30	3.66	2	19
Holocentrus ascensionis [av,sv]	1.13	0.71	0	3	1.35	0.91	0	4	0.60	0.66	0	2
Kyphosus sectatrix	1.75	6.50	0	30	2.28	6.18	0	32	1.18	4.51	0	29
Lachnolaimus maximus	0.05	0.22	0	1	0.05	0.22	0	1	0.03	0.16	0	1
Lagodon rhomboides [sv]	0.28	0.45	0	1	0.23	0.52	0	2	0.05	0.22	0	1
Lutjanus apodus	0.55	1.48	0	8	0.43	0.70	0	2	0.35	0.61	0	2
Lutjanus campechanus	0.15	0.42	0	2	0.23	0.42	0	1	0.13	0.40	0	2
Lutjanus griseus	0.60	0.77	0	3	0.40	0.73	0	3	0.68	2.04	0	13
Lutjanus synagris [av]	0.60	0.77	0	3	0.85	1.06	0	4	0.35	0.61	0	2
Melichthys niger [av]	1.43	1.09	0	4	1.80	1.17	0	5	1.23	1.15	0	5
Mycteroperca microlepis [av]	0.45	0.59	0	2	0.60	0.66	0	2	0.25	0.58	0	2
Ocyurus chrysurus	0.63	1.28	0	6	0.98	2.21	0	11	1.28	4.67	0	27
Pomacanthus arcuatus	1.55	1.16	0	4	1.75	1.80	0	7	1.88	1.90	0	7
Pomacanthus paru [av,sv]	1.48	1.83	0	7	1.60	1.91	0	8	0.38	0.66	0	2
Pomacentrus variabilis [av,sv]	0.53	0.63	0	2	0.48	0.63	0	2	0.10	0.30	0	1
Pristis pectinatus	0.85	0.79	0	2	0.53	0.77	0	3	0.55	0.74	0	2
Scarus coelestinus	0.05	0.22	0	1	0.08	0.26	0	1	0.03	0.16	0	1
Scarus guacamaia	0.55	0.84	0	3	0.53	0.77	0	3	0.50	0.77	0	3
Scarus taeniopterus [av]	1.00	0.59	0	3	1.10	0.62	0	3	0.83	0.70	0	3
Scarus vetula	0.00	0.00	0	0	0.03	0.16	0	1	0.00	0.00	0	0
Selene vomer	0.00	0.00	0	0	0.05	0.31	0	2	0.05	0.31	0	2
Sparisoma aurofrenatum [av]	0.30	0.51	0	2	0.40	0.49	0	1	0.20	0.40	0	1
Trachinotus falcatus	0.50	2.82	0	18	0.23	0.52	0	2	0.18	0.83	0	5
Trachinotus goodei	0.00	0.00	0	0	0.00	0.00	0	0	0.05	0.31	0	2

Table 3. Community indices and correlation coefficients comparing the fish assemblages described using slate, audio, and video recording devices.

	Slate vs. Audio	Audio vs. Video	Slate vs. Video
Jaccard Coefficient	0.854	0.911	0.833
Quotient of Similarity	0.921	0.953	0.909
Percent Similarity	94.99	90.84	93.62
Morisita's Index	0.998	0.991	0.998
Horn's Index	0.994	0.988	0.987
Pearson Product	0.997	0.993	0.999
Spearman Rank	0.931	0.915	0.869
Total Number of Species	48	45	48
Number of Shared Species	41	41	40

then observers would be well advised to use the slate recording technique. One should be aware that comparisons between faunas recorded with audio and slate may be reliably conducted only if certain species, known to contribute to error in comparison, are omitted from the analysis.

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