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Diver Accuracy in Estimating Lengths of Models of the Parrotfish, *Sparisoma cretense, in situ*

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DIVER ACCURACY IN ESTIMATING LENGTHS OF MODELS OF THE PARROTFISH, *Sparisoma cretense, in situ*

The use of underwater visual survey techniques to assess fish communities has increased over the past decade (e.g. Barans and Bortone, 1983; Bohnsack and Bannerot, 1986; Bortone *et al.*, 1992). Introduced by Brock (1954), observations recorded *in situ* by researchers have proven to produce reliable data without intruding upon the environment (Bortone and Kimmel, 1991). Data recorded *in situ* by divers often included the abundance and size (total length) of fish that enter the given survey area. If the length-weight relationships of the different species are known, the mass of the fish within a surveyed area can be computed (Brock and Norris, 1989), but the accuracy of such biomass estimates depends on the ability of observers to accurately estimate fish lengths underwater.

The visual environment underwater is much different from that in air: visibility is greatly reduced; colors are differentially absorbed as depth increases; and light is refracted one third more than it is in air. Together these physical factors create an optical distortion that produces an image on the diver's retina significantly different from that on land. The human mind, however, has the ability to adapt to and compensate for these optical distortions to various degrees; a diver's visual perception, therefore, is a product of both physical conditions and mental interpretations.

Many psychologists have studied the visual preception of divers (e.g. Adolfson and Berghage, 1974; Emmerson and Ross, 1987; Luria and Kinney, 1970; Ross *et al*, 1969, 1990; Woods and Lythgoe, 1971). They agree that an important factor in size estimation underwater is the relationship between size and distance perception as described by the size-distance invariance hypothesis. Ross and others have described that an object may be perceived either as 4/3 its true size at the actual distance or may be perceived its true size at 3/4 the actual distance from the observer (Ross, 1965). Studies have found some combination of these two extremes of perception usually causes objects to be perceived as slightly larger and closer than they actually are. Adaptation over time has been documented and shows divers eventually are able to achieve accurate size-constancy relationships when underwater (Ross, 1965).

The belief that the sizes of objects observed underwater are overestimated has become "common knowledge" among divers, most likely as a result of the research described above. The PADI diver manual, a text used in many diver training courses throughout the world, states "Objects appear 25% larger and closer underwater." (PADI, 1990).

With the growing importance of non-invasive visual assessment as a method in aquatic ecology, increased attention by researchers other than psychologists has been drawn to size perception underwater. Bell *et al.* (1985) performed an experiment, similar to the one described herein. Three divers estimated the lengths of PVC conduit sticks placed along a transect line. Informed of their biases, the divers were sent through the transect until no significant variation between observed and expected sizes were determined. The results of their experiment showed initial underestimation of stick length by all divers followed by rapid improvement after six trials that produced length frequency distributions not significantly different from the expected distribution. The authors attributed the initial underestimates to overcompensation that arose from the common knowledge that underwater objects

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appear about 25% larger than they really are.

Crucial as length estimates are to assessment and, ultimately, management of fish communities, the accuracy of such estimates has not been critically tested by researchers using visual survey techniques. This study focuses on the accuracy of estimates of the lengths of the parrotfish, *Sparisoma cretense*, that were being studied in point-count visual surveys on an EARTHWATCH research expedition in the waters of Gran Canaria, Spain.

MATERIALS AND METHODS

Wooden models were constructed to simulate visual perception of parrotfish. Four different sizes were cut out of ¾″ pine, each size consecutively 40% smaller with the largest being 50 cm, the maximum length of this species. This produced models of 11, 18, 30, and 50 cm with a mean size of 27.2 cm, the later being comparable with the observed mean size of the species during actual surveys of the area (25 cm, unpublished data). The models were painted according to sex (Fig. 1): half were painted grey (male) and half were painted red with grey saddles (female). Monofilament line was attached to either end of a model and then to an iron rod that was buried in the sand to anchor the model 1.5 meters above the bottom so the model was observable at eye level (visual angle at about 0°).

The experiment took place in open sandy areas at a depth of 12 m. Horizontal visibility was from 17 to 29 m. Water temperature remained at 22°C ± 2°C. The survey method used by divers in the experiment was the point-count visual survey technique as described by Bortone *et al.* (1989) in which the diver knelt at the center of a circle having a 5.6 m radius (a weighted line was used to estimate the circle radius), inside of which all species were recorded over a 5-minute period. Eight fish models were placed symmetrically around the circumference. No one model was adjacent to another of the same size, and sexes of each size were placed opposite each other in the circle. This placement of the sexes controlled for color so that the order viewed was constant with only the variable color changed as the diver viewed the models. Two circles were arranged with the

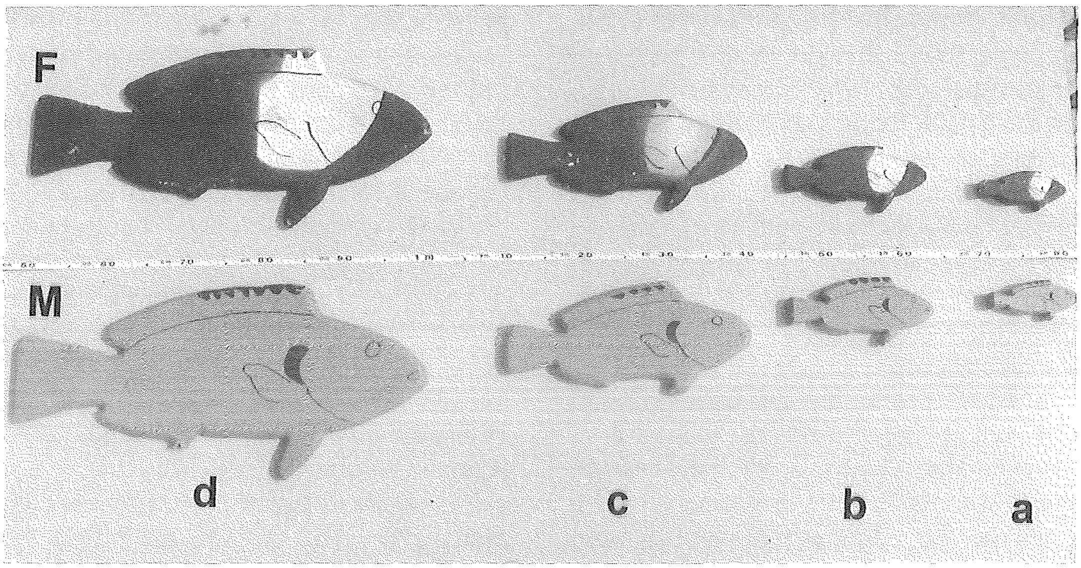

Figure 1. Color patterns on the wooden models of the parrotfish, *Sparisoma cretense*. (A = length 11 cm, b = length 18 cm, c = length 30 cm, d = length 50 cm) (M = grey [male], F = red with grey saddle [female]).

models at a constant distance from the diver. Location 1 was not visible from Location 2. All models at Location 1 were placed at a distance of 5.6 m; those at Location 2 were placed at 3.4 m. The arrangement of models at each location was identical, but divers were directed to begin their successive, clockwise observations with a different model number in each sequence. A dive-slate (sandpaper-roughened, plastic board), similar to the ones used in actual fish surveys, was given to each diver. The slate served as a means to record their estimates and also boar a scale marked off in centimeter intervals to aid in size estimation. Divers were asked to record their estimates to the nearest centimeter while continuing to kneel at the center of the circle.

Fifteen divers (7 male and 8 female) were tested over three seperate research teams (Figure 2). In most cases, their previous diving experience was solely as a sportdiver and experience ranged from less than 1 year to 35 years. The majority of divers were from the Untied States and the others from England. The diversity of the group sampled represented the typical background of the dive teams of similar research expeditions using visual census techniques in the past.

Each diver was tested twice: before being trained and then after two weeks of actual surveying, with a total average of 13 hours of bottom-time per diver. In preparation for the first test, one dive was performed the day before testing to allow acclimation to the local underwater environment and water conditions. Also, detailed instructions were given about the point-count visual survey technique. No information was revealed regarding past experimentation, previous results, or the rational behind the experimental design. Divers were instructed to descend a buoy line that placed them in the center of the circle and prevented their approaching any model. Divers estimated model lengths from the center of the circle with a dive slate scale held at arm's length. The divers were not permitted to discuss their estimates with the other divers until both testing periods had been completed, nor were the results of each diver's

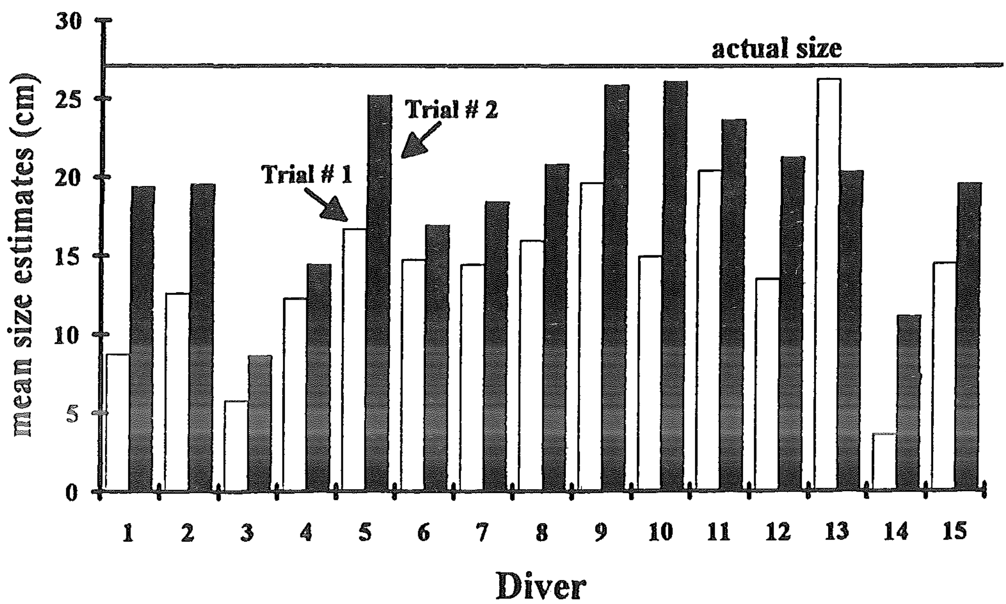

Figure 2. Graph of averages for each diver's estimates compared. 27 cm is the average of the actual sizes. Divers 1-7 participated on team I, 8-12 on team II, and 13-15 on team III.

estimates revealed until after all testing.

During the next two weeks, the divers used the point-count technique in the field to survey natural parrotfish populations. To test and train themselves in size estimation underwater, divers were asked during the first few minutes of each survey to pick an object in the distance (e.g., a rock or sea urchin), estimate its length, and then swim to it and measure its actual size. After the two-week period, the divers again participated in an identical experiment using the same circles of models.

The data were analyzed for repeated variance (ANOVA) using the BMDP statistical program and graphs were produced using Microsoft EXCEL.

RESULTS

All fifteen divers underestimated all sizes during both trial one and trial two (Fig. 2). Contrary to findings of visual study psychologists, no diver overestimated size. A signficiant increase ($p \leq 0.05$) in the accuracy of the estimates was observed after the two week period between trials. All divers improved their estimates with the exception of one, Diver 13, whose estimates worsened with trial two, but still remained better than the mean length estimate. Estimates were from 7% to 87% below the actual value with a standard deviation of ±20%. The mean of each diver's size estimates for trial one showed a 47.6% underestimation and a 27.2% underestimation from Trial 2 (Fig. 3). Figure 3 also shows that the divers underestimated the larger models slightly more than the smaller models, suggesting that inaccuracy increases with object size. The variables "distance" and "color" did not significantly effect their estimates ($p = 0.55$ and $p = 0.02$, respectively).

DISCUSSION

The major findings of this study indicate underestimation with significant improvement over time by divers estimating lengths of wooden fish models underwater. The results were repeated by three separate teams of EARTHWATCH volunteers over the course of the summer, emphasizing the apparent trends towards underestimation (Fig. 2). These findings have potentially high consequences in visually assessing fish communities if, in fact, the experimental conditions are comparable to living fish during actual surveys.

Bell *et al.* (1985) found that plywood models of fish silhouettes are better than PVC sticks for training divers to estimate lengths underwater. As a more realistic study, the fish models of our experiment included colors and morphology of the parrotfish. By no means, however, do wooden models replace living fish. The behavior of living parrotfish offer opportunities for length estimates better than those of our wooden models. Parrotfish are usually found swimming slowly about rocky areas just a few centimeters above the bottom. During a survey, the diver has the opportunity to observe the fish moving at varying distances within the survey area. The rocky habitat also aides in size-distance judgement by giving visual cues to the diver. For this experiment, however, testing was conducted over open sand under identical conditions and to avoid bias between models due to unconformities in the field of vision. With the lack of visual cues, some divers felt the models were set at varying distances.

The increased accuracy of the divers' estimates after the two week period indicates significant adaptation is possible over time. Because the test was not performed more freqently, we were not able to identify the rate of adaption and the minimum time period where maximum accuracy is achieved. A diver's adaption should reflect an initial rapid increase in accuracy leading up to a period of only gradual changes in accuracy. To identify the average length of time a diver needs to attain maximum accuracy would benefit researchers in ensuring that the most accurate data would be collected after the initial adaption period.

All the volunteer divers who participated in the study had no experience using the visual survey method. Three divers who had experience with visual survey techniques and estimating lengths of fish underwater, were sent through the experiment. This includes two researchers with 5-10 years experience and one volunteer with 2 years experience. The data are sketchy, but they too exhibited underestimation of size underwater, averaging only 15% lower than the actual size (0%, 25%, and 5%, respectively). This implies that long-term adaptation is possible among divers and further questions the use of untrained volunteers for scientific studies.

Unlike research of visual studies psychologists, the goals of this study were not to address the mechanisms of visual perception as applied to the underwater environment. Divers were not asked to estimate the fish model lengths on land. Because we are not able to compare land estimates to underwater estimates, no conclusions can be made about the mental effects of visual perception effected by underwater distortion. However, it is possible that underwater observations are overestimated compared to land estimates, but at the same time underestimated as compared to the actual size. For our practical purposes though, we were only concerned with the underwater estimates as compared to the actual sizes. Most of the divers had little experience in estimating sizes even on land. In addition, most of the volunteers, being from the United States, did not regularly use the metric system. Since they had a dive slate with a rule attached, this should not have been a factor. It did present some confusion to some divers. One diver estimated length in inches and converted, in his head, to centimeters before recording the estimate.

Previous visual studies experiments have shown that visibility plays an important role in size estimation, especially as distance is varied. Visual studies psychologists have based many such theories on experiments performed in pools, water tanks, lakes, rivers, and varying coastal waters where visibility ranged from 1.5 m to 20 m. The coastal waters of the Canary Islands have excellent visibility (17 m - 29 m). With the high visibility of this experiment, we were not surprised to find that small changes in distance did not effect size estimation.

Because of the direct dependence of biomass estimates on estimates of fish lengths during visual surveys, the

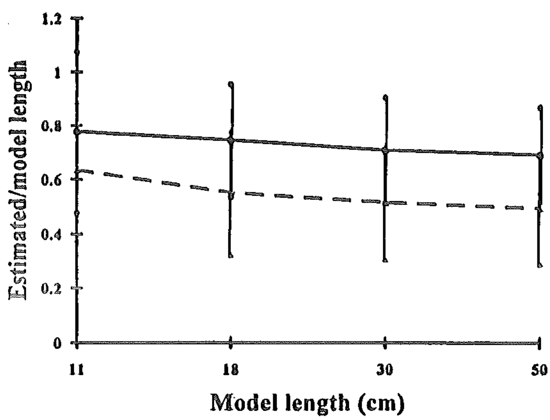

Figure 3 Mean size estimates per actual size according to model length: triangles and dashed line, first trial; circles and solid line, second trial. Error bars report ± standard deviation. ($p \leq 0.05$).

results of this study are important to researchers using the visual survey technique for assessing and managing fish communities. To begin with, divers using the visual survey technique should become more aware of their size estimates underwater. This entails the abandonment of any preconceived ideas that "objects are magnified" underwater. Most importantly, training, or at least an adaptation period, should be provided for divers to improve the accuracy of their size estimates. As this study represents a relatively small group of divers under ideal conditions, we suggest that further studies be conducted by researchers using the visual survey technique to identify any apparent trends within their own area.

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