The Effects of Training with Fish Models in Estimating Lengths of Fish Underwater

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ABSTRACT

This study describes the application of fish models to train divers to improve accuracy and precision of estimating lengths of fish underwater. Two divers were tested and trained with a fish model training set. Training models were plywood silhouettes of perciform shaped fishes which ranged from 5-25 cm total length. Before training, a paired t-test was run comparing diver estimates against actual lengths of fish models and live fish (trap-caught and spear collected). Diver 2 significantly ($p < .05$) underestimated fish models, while diver 1 showed no difference. Neither diver over or underestimated live fish. Training followed with each diver subject to three 30 minute training sessions. After training, divers were again tested with fish models and both types of live fish estimations. Paired t-test results of trained divers were non significant ($p > .05$) in all respects, suggesting improved accuracy. Training appeared to remove under and overestimating bias. Fmax-test, comparing variance before and after training, showed significantly lower variability ($p < .01$) was associated with trained divers, indicating increased overall precision of length estimates. A one-way ANOVA comparing fish model, trap-caught and speared fish estimates of trained divers showed no significant difference in accuracy or precision. Similarly, ANOVA comparing variability among trained divers showed no significant difference in accuracy or precision. The results provide evidence that fish models are an effective tool for training divers to achieve acceptable standards of underwater fish-length estimation.

INTRODUCTION

Underwater visual census techniques provide fisheries workers with a non-destructive, efficient means of assessing reef fish populations. Although generally looked upon favorably by fish ecologists since its introduction (Brock, 1954), visual census techniques have yet to receive widespread acceptance among fisheries biologists, specifically in terms of their application as a fisheries management tool. Most surveys have concentrated on estimating density (Keast and Harker, 1977; Sale and Douglas, 1981; Brock, 1982; Sale and Sharp, 1983). However, data would be of greater value, for both population biology and fisheries management, if accurate and precise estimates of length- frequency distributions could be obtained. This information in conjunction with empirically derived length-weight relationships could be combined with density estimates to estimate species-specific biomasss (Russel *et al.*, 1978).

Length-frequency distributions are also valuable in estimating species-specific growth and mortality rates (see *e.g.* Pauly and Morgan, 1987).

A variety of techniques have been proposed to increase accuracy and precision of underwater length estimations. The simplest method involves equipping divers with an underwater ruler or related instruments providing size reference (Bohnsack and Bannerot, 1986). Alternatively, recent interest has focused on training underwater observers prior to visual assessment with sets of different sized objects, anticipating that their ability to distinguish the size of such objects can be transferred to the estimation of live fish. Proposed methodologies include using "sticks" of P.V.C. conduit (GBRMPA, 1979; Bell *et al.*, 1985) and fish models or live fish (GBRMPA, 1979; Harmelin-Vivien *et al.*; 1985, Bell *et al.*, 1986). Similarities in shape between fish models and live fish improve estimation by reducing bias introduced when transferring estimation skills from "sticks" to fish (Bell *et al.*, 1986).

Previous studies utilizing fish models have primarily focused on large demersal fishes (GBRMPA, 1979; Bell *et al.*, 1986). Models were generally up to 100 cm total length (TL) with a mean value of 50 cm. Coral reef fishes found in Puerto Rico and throughout the West Indies are generally much smaller. This situation is typical of many overfished regions of the world. In this study fish-model methodology focuses on small-sized fish (< 25 cm TL) with emphasis on the effort required to increase accuracy and precision of underwater length-estimates. We describe a simple and efficient training program for developing in-situ fish-length estimating skills.

METHODS

Study Area

This study was conducted on shallow water fore and backreef sections of Cayo Ahogado and Cayo Laurel located off La Parquera, Puerto Rico. Both areas consisted of a well defined reef crest dropping off into sand and seagrass flats at approximately 3-5 m.

Testing and Training Divers

Twenty "fish models" (plywood silhouettes) of a standard perciform shape were constructed in 1 cm size classes ranging from 5-25 cm TL. Fish models were attached by monofilament line to snap-swivels to facilitate rapid changing of models when testing or training. Models were either anchored to a single weight, weighted rope or framework training structure (Figure 1). Fish model training proceeded in the following manner: Divers were initially tested on their ability to estimate fish models, trap-caught fish, and spear-collected fish (estimates taken before spearing). After initial testing was completed, each diver underwent three 30 minute training sessions with the models. Final testing followed, with divers once again being tested with fish models and both sources

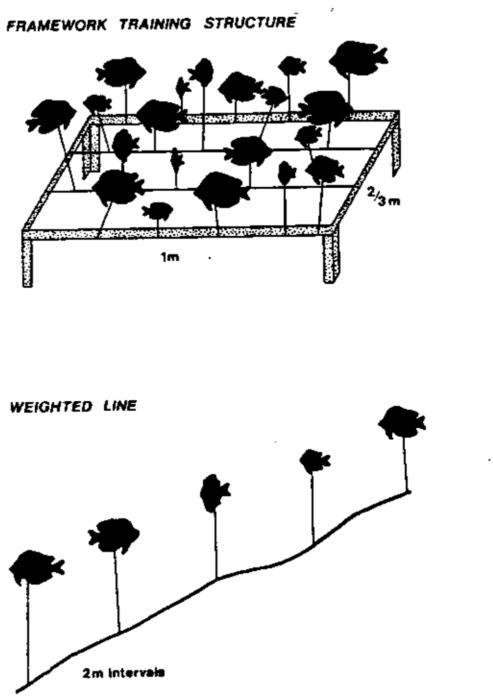

Figure 1. Framework structure and weighted line methods of model attachment for training.

of live fish. Initial testing, training and final testing occurred in one week intervals over a three week period.

For each type of test, diver estimates were based on total length (TL) and given to the nearest cm. Divers were positioned approximately 3 m from the subject, and estimates were recorded on an underwater slate.

Testing procedure for all three test types

Fish models — Divers subject to testing were stationed 3 m from an anchored test site. A sample of 20 randomly chosen models from the given size range, with replacement, were attached by snap-swivel to the bottom anchor. Models were displayed individually and replaced after each estimation. To alleviate the problem of size-cueing on other objects, the diver undergoing testing was asked to turn away during model exchange, and the bottom anchor was hidden.

Speared fish (live) — Divers would begin by allocating a common fish. Each diver then estimated the length of selected individual. After estimates were recorded, fish were collected by spear. Each fish collected was placed in separately numbered storage bags. Once on board the boat, fish were sorted and measured.

Trap-caught fish (live) — Standard Antillean traps were placed at the test site prior to testing days. Divers would locate traps and estimate the lengths of all fish present. If a number of the same species were present, divers were asked only to estimate those which could easily be separated on board. Actual length measurements were taken in the boat after the trap was pulled.

Training sessions were based on an approach we termed "direct model learning", rather than trial methodology (Harmelin-Vivien *et al.*, 1985; Bell *et al.*, 1986). Direct model learning involves marking the actual TL on one side of each model. When training, this allows divers to compare the marked length of each model directly against its estimated length. Thus, divers receive immediate feedback on the accuracy of their prediction. During training, fish models were presented to the divers in two ways. The first method involved attaching the models in 2 m intervals along a weighted anchor rope (Figure 1). Alternatively, the second method involved using a 1 x 2/3 m metal framework containing crosswires for model attachment (Figure 1). For both methods, divers were instructed to make predictions and check these against true values. The process was repeated many times during each training session with different model arrangements.

Training began in thirty minute sessions utilizing both anchored rope and metal framework methods of model attachment. Models attached in intervals along the weighted rope appeared to simulate actual visual censusing procedures (*i.e.*, strip transects) and gave no size reference as to where the model fit into the given size distribution. On the other hand, models attached to the metal framework allowed divers to observe the entire range of models simultaneously, permitting size class comparisions.

Statistical Analysis

A paired t-test (Sokal and Rohlf, 1981) was used to compare predicted and actual values of fish model, trap-caught and spear- collected live fish length estimates before and after training. Paired t-test results were used to determine the accuracy of length estimations and if under or overestimating bias was present among divers. A F-max test was employed to examine variability associated with length estimations before and after training, thus, determining the effect of training on the precision of length estimates. One-way ANOVA examined how accuracy and precision varied among trained divers and estimation type (fish model and live fish). ANOVA tests were based on mean differences ($\bar{D}$) between predicted and actual TL. A modified ANOVA for unequal variances (Sokal and Rohlf, 1981) was employed when the ANOVA assumption for homogeneity of variances was not met as indicated by Fmax-test results.

Accuracy was regarded as a systematic bias or closeness of estimated values to the true value. Precision was defined as the closeness of repeated measurements or spread of the variance (confidence intervals).

RESULTS

Training was discontinued after three sessions because divers expressed high levels of confidence in their ability to accurately distinguish model sizes. Also, continued training with a limited number of models could lead to observers memorizing model features (*i.e.*, wood grain patterns), rather than actually differentiating sizes.

A paired t-test performed on the two divers indicated that before training diver 2 significantly ($p < .05$) underestimated fish models, while diver 1 showed no significant ($p > .05$) difference in model estimations. Also, before training neither diver significantly under or overestimated live-fish estimates. After training, the test was employed again. Training appeared to remove individual bias and generally improved overall accuracy of length estimations. Trained diver's, fish-model and live-fish estimates were not significantly ($p > .05$) different from true values. It appears that initial underestimation bias associated with model estimates of diver 2 was removed (Table 1). Figure 2 displays how accuracy, closeness of mean difference ($\bar{D}$) to zero, varied before and after training.

F_{max}-test results, comparing variances before and after training, showed that variances were significantly heterogeneous. Table 2 displays before and after training comparisons for fish model and live- fish estimations. Significant reduction in variance suggests that precision, as indicated by the spread of the variance, significantly improves with training. Diver 1 showed significant ($p < .01$) reduction in variances for all three types of estimates after training. Similarly, fish model and trap-caught fish estimates of diver 2 displayed significantly ($p < .01$) lower variability after training. In general, all divers significantly reduced variability in length estimation by training and thus significantly improved overall precision of length-frequency distribution estimates on fish models and differences ($\bar{D}$) are included (Table 2). In all instances, 95% confidence intervals are reduced with training, indicating increased precision.

Three estimation types (models, trap-caught and speared fish) were used throughout this study. Each estimation type accurately reflected the skill level possessed by the tested diver. A one-way ANOVA was employed to compare accuracy associated with the different estimation types for each trained diver (Table 3). ANOVA results for divers 1 and 2 were $F = 0.9959$ ns and $F = 0.1467$

Table 1. Paired t-test results comparing predicted and actual total lengths of fish models, trap-caught and spear collected fish before and after training for each diver.

	BEFORE TRAINING			AFTER TRAINING		
	ts	df	P	ts	df	P
DIVER 1						
Fish Models	0.7180	19	ns	0.5672	19	ns
Trap Fish	1.6140	19	ns	1.6138	19	ns
Speared Fish	1.1476	19	ns	0.4219	19	ns
DIVER 2						
Fish Models	2.4787	19	*	2.0000	19	ns
Trap Fish	1.9689	19	ns	2.0413	19	ns

* $p \leq .05$

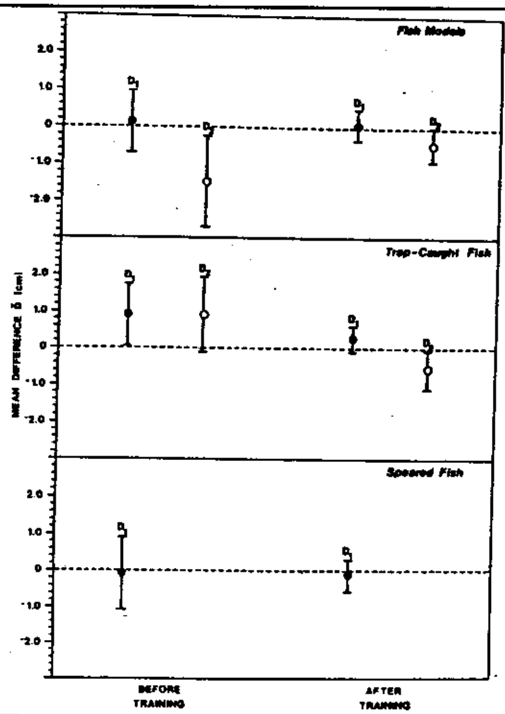

Figure 2. Mean difference ($\overline{D}$) values and associated 95% confidence intervals for divers 1 (D1) and 2 (D2) before and after trainng for each estimation type (model, trap and spear).

Table 2. Fmax-test results comparing precision of fish model and live fish length estimates before and after training. Mean difference ($\bar{D}$), standard deviation (SD) and 95% confidence interval values are included.

	BEFORE			AFTER				
	$\bar{D}$	SD	95%CI	$\bar{D}$	SD	95%CI	Fmax	P
DIVER 1								
Fish Models	0.160	1.7506	±0.8193	0.095	0.7549	±0.3533	5.3784	**
Trap Fish (Live)	0.909	1.8540	±0.8676	-0.265	0.7343	±0.3436	6.3753	**
Speared Fish	0.075	2.1232	± 0.9937	-0.145	0.9127	± 0.4270	5.4113	**
DIVER 2								
Fish Models	-1.495	2.2670	± 1.2389	-0.430	0.9243	±0.4326	±8.2029	**
Trap Fish (Live)	-0.925	2.1674	± 1.0143	-0.555	1.0975	±0.5137	3.8994	**

** $p \leq .01$

Table 3. One-way ANOVA comparison of accuracy and precision among estimatations types (fish model, trap fish, and spear fish) for each diver after training. Diver 1 results compare fish models, trap fish, and spear fish. Diver 2 results compare fish models and trap fish. Fmax results are included.

	SOURCE OF VARIATION	df	SS	MS	
DIVER1	Among Groups	2	1.30013	0.6506	F = 0.9959 ns
	Within groups	57	37.2405	0.6533	Fmax = 1.1577 ns
	Total	59	14.0273		
DIVER2 2	Among groups	1	0.1562	0.1562	F = 0.1467 ns
	Within groups	38	40.4545	1.0645	Fmax = 1.3033 ns
	Total	39	40.6077		

Table 4. One-way ANOVA comparing accuracy of fish model estimates between divers 1 and 2 after training. Fmax-test examines precision.

DIVER COMPARISONS	F	P1	Fmax	P2
Divers 1 and 2 (Untrained)	5.1149	**	2.2866	*
Divers 1 and 2 (Trained)	1.6217	ns	1.6212	ns

* $p \leq .05$
** $p \leq .01$

ns, respectively. Consequently, accuracy of each estimation type did not significantly vary among trained divers. Fmax-test results were 1.5778 (ns) and 1.3033 (ns) for divers 1 and 2, suggesting that precision was not significantly different among trained divers (Table 3). Thus, the ability to differentiate fish-model sizes had been effectively transferred from fish model sizes had been effectively transferred from fish models to live fish estimations.

To focus on the importance of standardizing sampling effort a one-way ANOVA and associated Fmax-test were used to examine diver related variability of fish model estimates before and after training (Table 4). Before training divers 1 and 2 showed significantly different levels of both accuracy ($p < .01$) and precision ($p < .05$). However, after training the precision and accuracy of fish-model estimates were not significantly ($p > .05$) different for diver 1 or 2. Thus, sampling effort becomes standardized with training.

DISCUSSION

Whether related to individual bias or lack of ability, most underwater observers do not naturally possess the necessary skills to accurately and precisely estimate lengths of fish underwater. Training divers with fish models and live fish gives them the opportunity to compare and contrast predicted estimation against actual values. By allowing divers to compare estimates directly against actual values (direct model learning) the ability to accurately and precisely estimate length-frequency distributions can be attained rapidly.

Although results are very encouraging, a few considerations should be taken into account before accepting fish-model training as a complete methodology for acquiring necessary skills to accurately assess length-frequency distributions in the field. Certain effects, such as density, diversity and variability of body shapes, time allowed for prediction and distance from the fish, may all influence or bias length estimations in some way. For instance, a large percentage of fish occur in schools ranging from few to hundreds of individuals. Often these groups are continually moving in and out of the surveyed area. At times, it is difficult enough to obtain accurate density estimates, let alone estimate the length of all fish in the limited time they remain present. We believe these factors may significantly influence or bias length estimations and consequently, warrant further consideration.

The training procedure outlined in this study was basically simplistic in design and relatively time efficient, yet, it produced significantly improved diver estimations in terms of both accuracy of trained diver estimates was within 1 cm of actual size and precision as indicated by 95% confidence intervals was within approximately 1 cm. These results seem within acceptable standard required for most population biology and fisheries management models. Also, skill levels of trained divers were extremely similar with little among-diver variability. This is important because any comprehensive study will require considerable sampling effort. Given decompression limits on diving, this means that several divers will necessarily be used in any survey. With our training technique different divers can be standardized to supply similarly accurate and precise length-frequency estimates. Also, since diving safety requires two persons in the water at all times, paired divers could be used to provide simultaneous replicate samples.

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