Abstract–Visual estimates of reef-fish length are a nondestructive and useful way of determining the biomass, mean length, or length frequency of reef fish. Consequently, visual estimates of reef-fish length are often an important component of reef-fish monitoring programs, many of which increasingly use volunteers. We compared estimates of the length of plastic fish silhouettes determined visually by experienced scientific and novice SCUBA divers. Novice divers showed a similar level of accuracy (mean error: 2.3 cm) to that of experienced scientific divers (mean error: 2.1 cm). Significant improvements in accuracy and precision were provided by a stereo-video system (mean error: 0.6 cm). After minimal training in the use of hardware and software, volunteers can obtain a high degree of measurement accuracy and precision with a stereo-video system, allowing them to assist with monitoring reef-fish lengths.

A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system

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The marine environment is affected by many anthropogenic activities (e.g. the exploitation of marine resources for food, medicine, and curios) with the result that many environments are compromised by siltation and pollution. Reef fish, an important commercial, recreational, and cultural resource, are likewise being exploited at an increasing rate. Consequently, it is important that environmental managers and scientists have objective evidence of the magnitude and effect of these impacts. Data on the community structure of reef-fish assemblages, including precise and repeatable estimates of the length frequency and abundance of individual species, provide this information. Information on the length frequency of a fish population when linked with even a rudimentary knowledge of the biology of the species may allow estimates of recruitment to the adult population, fishing intensity, and rates of recovery from fishing (McCormick and Choat, 1987) or other impacts.

Accurate and precise length and abundance data are difficult to obtain because fish occupy different habitats and display varying behavior over a range of spatial and temporal scales. Environmental surveys are commonly used to determine the abundance and length frequency of reef-fish assemblages with SCUBA divers who count and visually estimate the length of individual reef fish (Jones and Chase, 1975; Harmelin-Vivien and Bouchon-Navaro, 1981; Russ, 1985; Bellwood, 1988; Bellwood and Alcala, 1988; Kulibicki, 1989; Samoilys, 1989; Francour, 1991, 1994). Visual census techniques have many advantages, compared with other sampling techniques, in that they are quantitative, quick, nondestructive, and repeatable (English et al., 1994). The disadvantages of visual census techniques is that the observers undertaking the sampling need to be trained and must have experience to identify, count, and estimate the length of reef fish accurately (English et al., 1994). In addition, visual census techniques involving SCUBA divers are restricted to shallow depths owing to the constraints of decompression diving.

Two important sources of error affect the accuracy and precision of visual length estimates:

1 The estimation of the length of reef fish underwater is complicated by the air-water interface in the diver's mask which causes objects to be magnified in size by a factor of 1.3 and to appear to be closer to the observer than they actually are;
2 Researchers using SCUBA have been shown to be inefficient when performance underwater is compared with similar activities in air (Hollien and Rothman, 1975). The accuracy and precision of diver's estimates of reef-fish length is probably affected by the detrimental physiological effects related to SCUBA diving (Baddeley, 1965; Baddeley et al., 1968; Baddeley, 1971).

The level of precision and accuracy associated with visual length estimates influences comparisons of data over different temporal or spatial scales in two distinct ways. First, bias in the estimates can make the results of the analysis less reliable. Second, any lack of precision in the estimates arising from both sampling error and measurement error tends to reduce the power of the statistical analysis. The Great Barrier Reef Marine Park Authority (GBRMPA, 1979), Bell et al. (1985), and Polunin and Roberts (1993) have performed calibration studies in order to quantify measurement error and have concluded that such error is relatively small and can be ignored. However, they did not directly assess the extent to which such error reduces the precision of a statistical analysis. Harvey and Shortis (1996) demonstrated that subjectivity in visual length estimates can be overcome, and the accuracy and precision of length estimates enhanced, by using a simple and relatively inexpensive underwater stereo-video system.

The objectives of our study were 1) to compare the accuracy and precision of stereo-video measurements of reef-fish length with visual estimates made by novice and experienced scientific SCUBA divers; 2) to evaluate the effect of operator training and experience on the precision and accuracy of length measurements made with a stereo-video system; and 3) to assess the effect of water clarity on the accuracy and precision of stereo-video measurements.

Methods of optimizing the accuracy and precision of stereo-video length estimates are discussed and the accuracy and precision of experienced divers' estimates are compared to one other study.

Materials and methods

Comparison of length estimates made by novice and experienced scientific divers with estimates generated by a stereo-video system

The accuracy and precision of length estimates were tested by a simple procedure that is used routinely for calibrating diver estimates of the lengths of reef fish (GBRMPA, 1979; Bell et al., 1985; English et al., 1994). Typically, polyvinyl chloride (PVC) sticks or silhouettes of fish are placed in the water and their lengths estimated. The accuracy of the diver estimate is then assessed from the difference between the real size and the estimate. In this study, 16 plastic silhouettes of fish, ranging from 10 to 49 cm in length, were placed at distances of between 3.0 and 6.6 meters from a transect rope. Each diver moved along the transect rope estimating the length of each of the sixteen silhouettes when they were opposite them. Each diver repeated this process five times, i.e. five transects each with estimates of the lengths of the sixteen silhouettes. Five transects were completed with the stereo-video system in the same manner. The distances from the transect rope and the order of the individual silhouettes were kept constant throughout the trial. All silhouettes were weighted in a way that their length orientation remained perpendicular to the transect. Therefore, the error measures presented here do not take into consideration that in the field the divers may have to make length estimates where orientation of the live fish in relation to the diver changes.

Novice divers   Novice divers were defined as experienced SCUBA divers who had made few, if any, estimates of the lengths of reef fish underwater. Eight novice divers made length estimates in a saltwater pool at the Portobello Marine Laboratory (PML) between May 1994 and January 1995. No more than two transects were completed on any one day, except one diver who completed four consecutive transects in one day. Between transects and dives, data were not available to divers in order to avoid memorization of previous estimates or of silhouette lengths. The novice divers made only 594 of a possible 640 length estimates because 46 silhouettes (7%) were not recorded. The majority of the missing estimates were from the smaller silhouettes (approximately 10 cm long) or from a silhouette placed farthest from the transect (6.6 meters).

Experienced scientific divers   Experienced scientific divers were considered active marine scientists who had been, or who were currently involved in research that required them to make estimates of reef fish length. Six experienced scientific divers estimated the length of the plastic silhouettes between October 1994 and June 1996. Three of the divers made their estimates in a saltwater pool at PML, whereas the other three made their estimates in freshwater swimming pools elsewhere. A total of 480 length estimates were made, and all silhouettes were recorded. Owing to time constraints, all of the length estimates were made on consecutive transects during one dive.

Stereo-video measurements   For interested readers a comprehensive description of the design and calibration of the stereo-video can be found in Harvey and Shortis (1996, 1998) and will not be described here.

Stereo-video length estimates were made in the same way as those made by the divers; the stereo-video system recorded the silhouette as it was moved along the transect line by a diver. Measurements were made in the University of Melbourne swimming pool in July 1994. 80 silhouettes were recorded (16 silhouettes×5 transects). Four sets of images were rejected because the orientation of the

silhouette to the stereo-video rig was greater than 50 degrees, resulting in a deterioration of the accuracy and precision of measurements (Harvey and Shortis, 1996). Thus, 76 pairs of images were retained for analysis, from each of which ten measurements were made.

To test whether measurements made by an inexperienced volunteer using the stereo-video software would differ from those made by an experienced operator, two volunteers were given brief instructions on how to operate the stereo-video software and were asked to make measurements of the silhouettes. Measurements made by the inexperienced operators were then compared with those made from the same images by an experienced operator.

To determine whether changes in the water clarity affect the accuracy and precision of length estimates made by the stereo-video system, a further three transects were sampled in a saltwater swimming pool at the PML during August 1994. Water clarity was measured with a tape measure to record the distance to the farthest, clearly visible silhouette. A silhouette was clearly visible at up to 25 meters in the swimming pool at the University of Melbourne and up to 5.5 meters in the saltwater pool at PML.

We expected that the accuracy of measurements obtained with the stereo-video system would improve with operator experience. To evaluate the effect of experience, the same operator remeasured the images recorded in the swimming pool in Melbourne, approximately one year after the initial analysis. In the intervening period the operator routinely used the stereo-video system for analysis of fish lengths and was by far the most experienced person using the system.

Analysis of data

Four measures of error were used to summarize the accuracy of each length estimate. If the observed fish length is O and the true length is T, these four measures are

Error: $\quad\quad\quad\quad E = O - T$;
Relative error: $\quad RE = (O - T)/T = E/T$;
Absolute error: $\quad AE = |O - T| = |E|$;
Relative
$\quad$ absolute error: $\quad RAE = |O - T|/T = |E|/T = |RE|$.

The four measures provide different types of information. The error E will be positive or negative according to whether the observed length is an overestimate or an underestimate. If the mean of E is close to zero, the reason might be that all the estimates are accurate or that some are overestimates and others are underestimates to approximately the same degree. The absolute error AE ignores the direction of the error, and thus would provide different mean values for these two scenarios. The relative errors RE and RAE are of interest because it might be expected that these would be consistent across a range of fish lengths. The measure of accuracy used by St John et al. (1990) was simply $RE + 1$.

The results for the novice and experienced scientific divers were summarized prior to further analysis by calculating, for each silhouette and each observer, the mean length estimate over all transects. The repeat transects were therefore used solely to provide a reliable estimate of the error made by each observer on each silhouette. If the transects were truly independent, use of the mean would tend to provide a conservative estimate of the error a diver would make on one transect. Because the transects were swum in quick succession, they were not independent and therefore the degree to which their error was underestimated should be small. Each mean length estimate was then used to derive the four summaries of error, for each silhouette and each observer. For each measure of error, a two-factor analysis of variance was performed, the factors being type of observer and silhouette length. The individual observers provided the replication needed for this analysis.

To summarize the estimates made by using the stereo-video, the mean length estimate over all ten measurements was calculated (for each silhouette, transect, and operator). The mean of these over all five transects was then calculated for each silhouette and operator and converted to the four summary measures of error. For each measure of error, a one-factor analysis of variance was performed, with silhouette length being the factor. The individual operators (one experienced and two inexperienced) provided the replication needed for this analysis.

The two types of diver data and all video data were analyzed separately, rather than in a single analysis of variance because for each silhouette the variation between video operators was found to be much lower than that between experienced scientific divers and novice divers, making the usual assumption of equal variance invalid (Underwood, 1981). Comparison of the video technique with that of the experienced scientific divers and novice divers was therefore made by comparing 95% confidence intervals. The purpose of the analysis of variance for the video data was to provide an estimate of the standard error associated with the mean (for each measure of error) over all silhouettes.

To compare the data of experienced and inexperienced stereo-video operators, the mean estimated length over the ten repeat measurements obtained per image was calculated. These means were then converted to the four measures of error. Each measure of error was then analyzed by using a two-factor analysis of variance, with operator and silhouette as the factors. In this analysis, therefore, unlike those for comparing estimates from divers with those produced with the stereo-video system, the transects provided replication against which to compare operators. This analysis is reasonable, because in comparing the operators, the transects can be regarded as independent.

To compare the use of a stereo-video system under the two water-clarity conditions, a three-factor analysis of variance was performed on the individual errors. In this analysis, the factors were water clarity, silhouette, and transect (nested within each combination of water clarity and silhouette). Prior to this analysis, the estimates for one of the silhouettes in 5.5-m water clarity were removed because this silhouette was 6.6 meters from the transect and could not be seen clearly.

For the 1994 and 1995 stereo-video data used to assess operator experience, a three-factor analysis of variance

was performed on the individual errors, the factors being year, silhouette, and transect (nested within each combination of year and silhouette).

With the stereo-video system, the mean of ten measurements should result in greater accuracy and precision than use of a single measurement. In order to assess the extent of this improvement, the above analysis was performed a further five times by using the first 1, 2, 4, 6, and 8 measurements.

One of the most commonly cited papers on the training of divers to estimate fish lengths with accuracy and precision is that of Bell et al. (1985). The data for this paper originated from a report published by the Great Barrier Reef Marine Park Authority (GBRMPA, 1979). Tables 7, 10, 12, and 15 in that report contain underwater length estimates of pieces of orange PVC conduit (cut into 50 lengths ranging from 6 to 94 cm) determined by experienced scientific divers. Three experienced divers undertook four transects estimating the lengths of the conduit seen. The estimates of a fourth diver are also included in Tables 10, 12, and 15 of the report. We have chosen to disregard this diver's data because he was considered inexperienced at the time. We have summarized these results by first calculating the mean length estimate over all four transects for each silhouette and diver. Each of these means was then expressed by using the four summary measures of error described: error, absolute error, relative error, and relative absolute error. For each measure of error, a one-factor analysis of variance was performed, with silhouette being the factor. The individual divers provided the replication needed for this analysis.
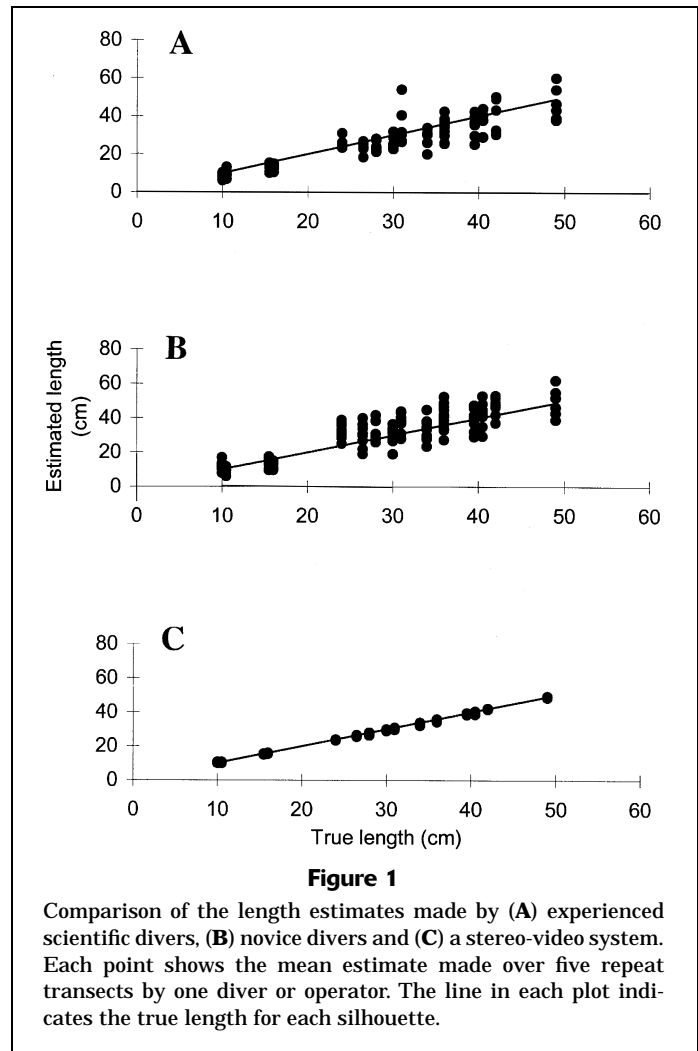
Results

Comparison of length estimates made by novice and experienced scientific divers with estimates generated by a stereo-video system

Figure 1 shows the range of length estimate means over five transects for the novice and experienced scientific divers and for the stereo-video system. The variability of the estimates was greatest for the novice divers and slightly less for the experienced scientific divers. By comparison, the length estimates made by the stereo-video system showed little variability around the true lengths.

The coefficient of variation (CV=standard deviation/mean) was significantly lower for the stereo-video than it was for either the experienced scientific or the novice divers (Fig. 2).
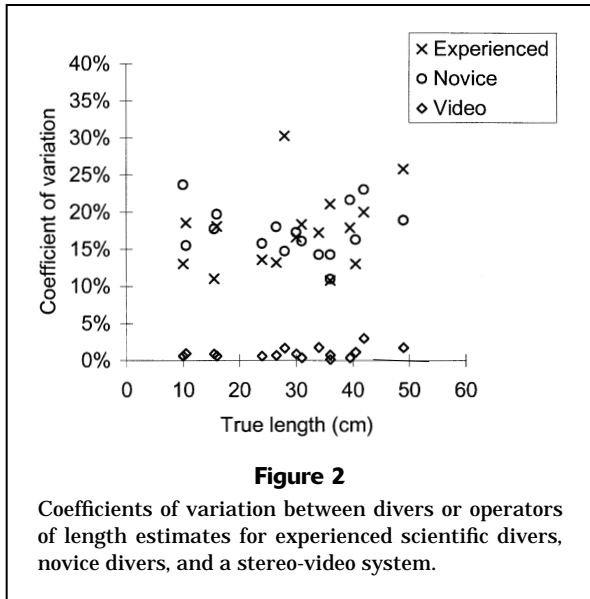
For all four measures of error (E, RE, AE, and RAE), there was no significant interaction between type of diver and silhouette size, suggesting that any differences between experienced scientific and novice divers were consistent across the silhouettes. For this reason, the results are presented as means across all silhouettes (Fig. 3). For both E and RE, the difference between the experienced scientific and novice divers was highly significant (P<0.0001); for AE and RAE, the difference was close to significant at

Figure 1

Comparison of the length estimates made by (**A**) experienced scientific divers, (**B**) novice divers and (**C**) a stereo-video system. Each point shows the mean estimate made over five repeat transects by one diver or operator. The line in each plot indicates the true length for each silhouette.

the 5% level (P=0.08 and P=0.05 respectively; $F_{1,91}$=5.96 [E], =1.75 [AE], =6.28 [RE], =1.94 [RAE]).

For both the diver and stereo-video data, there were significant differences (at the 5% level) between silhouettes, for all measures of error except RAE on the diver data. Inspection of the silhouette means showed no clear pattern for these differences. Any pattern would be difficult to interpret because the silhouettes were placed at different distances from the transect line in order to provide a range of sizes at a range of distances from the transect line and thus make the comparison of means in Figure 3 widely applicable.

The GBRMPA divers had a mean measurement error of –2.4 cm (SE=0.2 cm) which is similar to the –2.1 cm (SE=0.6 cm) mean error recorded by the experienced scientific divers used in our study (Fig. 3). Because 26 of the silhouettes used in the GBRMPA study were larger than any of those used in our study, it might be argued that the relative errors are more directly comparable. The mean RE for the GBRMPA divers was –4.6% (SE=0.5%), compared with a mean of –8.6% (SE=1.9%) for the experienced scientific divers used in our study. These results suggest that the experienced divers in the two studies had comparable skills.

Figure 2

Coefficients of variation between divers or operators of length estimates for experienced scientific divers, novice divers, and a stereo-video system.

Figure 3

Means and 95% confidence intervals for each measure of error, for each method of estimating fish length. E = experienced divers; N = novice divers; V = stereo-video system, GBPRMA= Great Barrier Reef Marine Park Authority data.

For all four measures of error, there was no significant interaction between software operators and silhouette, but there was a significant operator effect (Fig. 4). This finding suggests that the differences between operators were consistent across silhouettes. Although the differences between the operators were statistically significant, they were small compared with the differences between divers and the stereo-video system (cf. Figs. 3 and 4). ($F_{2,180}$=6.0, P=0.003 [E]; $F_{2,180}$ =14.6, P<0.001 [AE]; $F_{2,180}$= 3.6, P=0.029 [RE]; $F_{2,180}$=10.2, P<0.001 [RAE]).

There is little difference in the accuracy of measurements made under poor water clarity (mean E=−0.99 cm) compared with those made under good water clarity (mean E=−0.6 cm). The RAE is more consistent across silhouettes for good water clarity than it is for poor clarity. For the larger silhouettes, the RAE is lower under poor water clarity than under good water clarity (Fig. 5). This is probably a result of lower contrast, permitting more accurate pointing to the tail and snout of each silhouette (discussed further in the next section).

For all four measures of error, there was no significant interaction between years and silhouette, but highly significant differences (P<0.001 in all cases, $F_{1,121}$=15.0 [E]; $F_{2,180}$=27.1 [AE]; $F_{2,180}$ =14.6 [RE]; $F_{2,180}$=25.8 [RAE]) between years (Fig. 6). These results suggest that with increasing operator experience the measurement error can improve. This is probably a consequence of the operator learning to distinguish and select the edges of objects of interest accurately.

One of the advantages of stereo-video measurements over diver visual estimates is that the image is stored and it is possible to make numerous repeat measurements of the same object in the laboratory. Taking the mean of this set of measurements would result in greater accuracy and precision than using a single measurement. Improvement of the accuracy of estimates can be seen by comparing the mean error, for each of the three operators, as the number
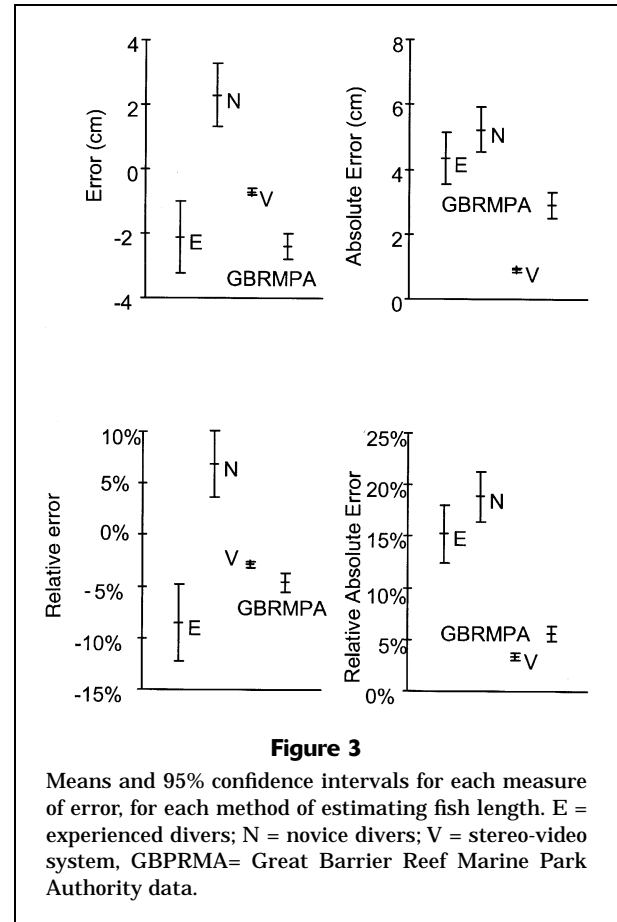
of repeat measurements is increased from 1 to 10 (Fig. 7). There is improvement in the error for both inexperienced operators and the experienced operator, even after ten repeat measurements (Fig. 7).

Discussion

Our results highlight the differences in the accuracy and precision of length estimates of silhouettes of reef fish made by novice and experienced scientific divers in comparison with those produced by a stereo-video system. Our length estimates were made under ideal conditions where the plastic models were fixed in position. Under real field conditions fish move, occur at different distances from the divers and have behavioral and morphological differences that can influence length estimates. Consequently, the measures of error presented in our study can most likely be considered a best case scenario. As with Darwall and Dulvy (1996), the results obtained by novice divers were similar to, but slightly less accurate than, those obtained by experienced scientific divers (mean errors of 2.3 cm and −2.1 cm respectively). Our results also demonstrate that significant improvements in accuracy can be obtained by using a stereo-video system (mean error −0.6 cm). Similar improvements in precision were also recorded: mean CVs
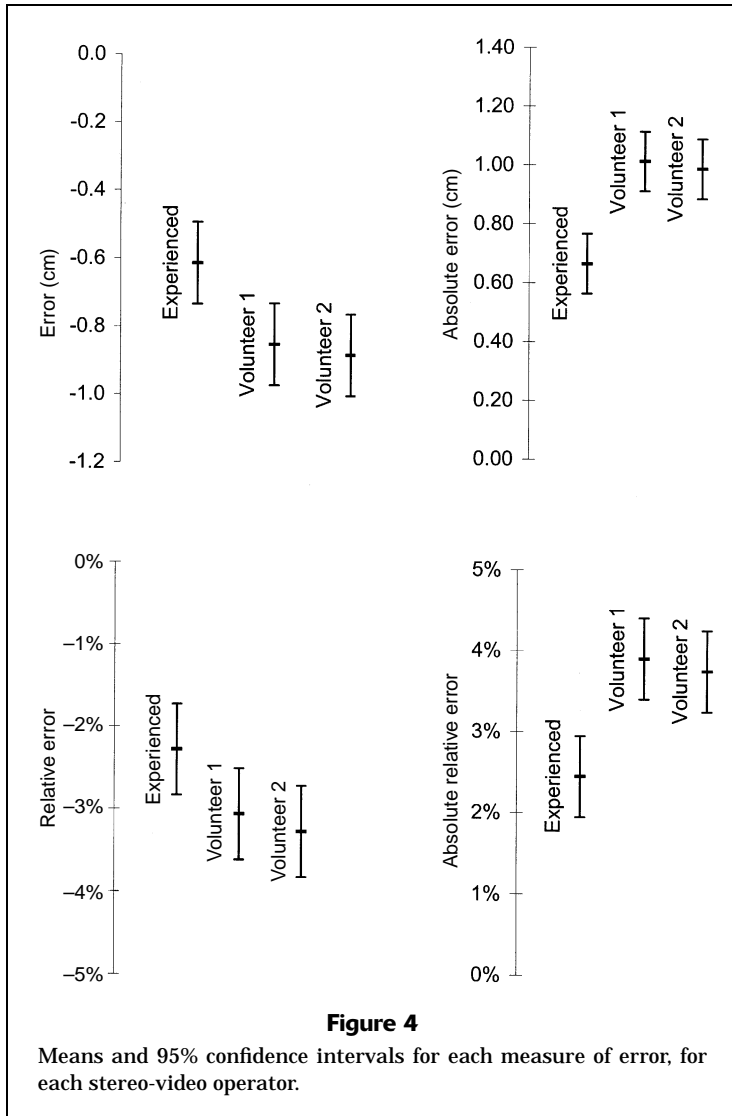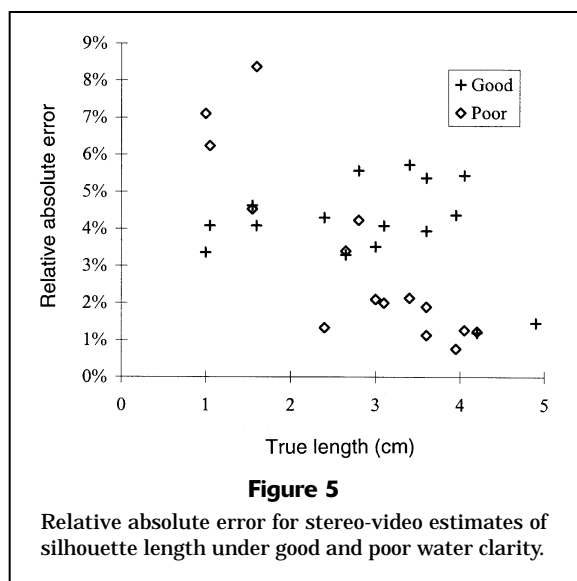
were 18.2%, 18.6%, and 1.6% for novice scientific divers, experienced scientific divers, and the stereo-video system, respectively. The results of the experienced divers' estimates are similar to those obtained in other published research studies (Bell et al., 1985).

In general, water clarity does not appear to affect the accuracy or precision of the measurements made from the stereo-video system. The accuracy of the of the stereo-video system is limited to the ability of the operator to accurately point out image locations of interest that are then recorded to subpixel resolution. Discrete sampling of the CCD (charged coupled device) sensors, combined with noise artifacts from the video tape recording and frame grabbing, tends to smear the edges of the images and blur details (Shortis et al., 1993). This result is particularly noticeable under recording conditions with good water clarity and high contrast where there is a problem with the detection of the edge of the silhouette. The edges or outline of the points of interest (in this instance, the snout and fork of the tail of each silhouette) become significantly blurred within the computer image owing to sampling and noise effects on each pixel. There is a tendency for the observer to select a location inside the true edge of the point of interest because the location most nearly matches the local appearance of the body of the object of interest. This results in the underestimation of silhouette length, as demonstrated in Figure 1. Under poor water clarity, the edges of the silhouettes have less contrast with the dark background. This lack of contrast permits more accurate pointing to the edges of the object of interest because the sampling and noise effects generate a smaller disparity between the real and apparent edges (Fig. 8). Less accurate measurements will be made when the contrast becomes so low that the operator cannot discriminate between the object of interest and the background. Hence, where there is sufficient contrast to discriminate the object from the background, lower contrast will realize more accurate values that ameliorate the underestimation of length.

Advantages of stereo-video census techniques

The use of a stereo-video system for the measurement of reef-fish length has many advantages. It significantly decreases measurement error and is relatively insensitive to operator experience. The data suggest that the stereo-video system provides far greater accuracy and precision than even experienced scientific divers, and potentially allows inexperienced volunteers to participate in monitoring programs without compromising the accuracy or precision of the data collected. This degree of accuracy and precision may be important in research where the objective is to detect small (5–30%) changes in the mean length of a population or assemblage of reef fish, with a high level

Figure 4

Means and 95% confidence intervals for each measure of error, for each stereo-video operator.

Figure 5

Relative absolute error for stereo-video estimates of silhouette length under good and poor water clarity.
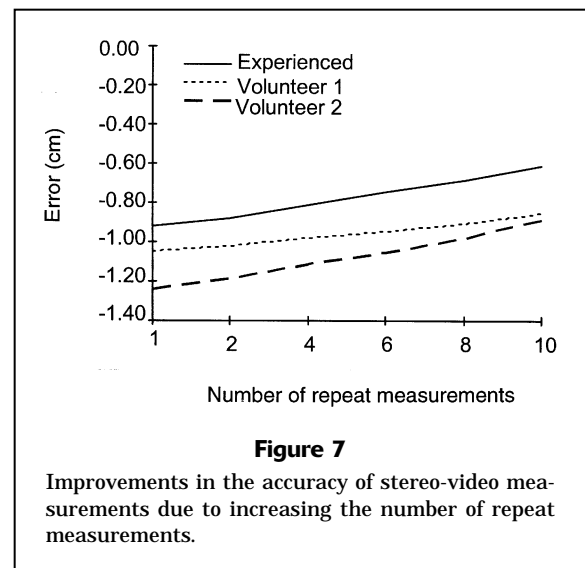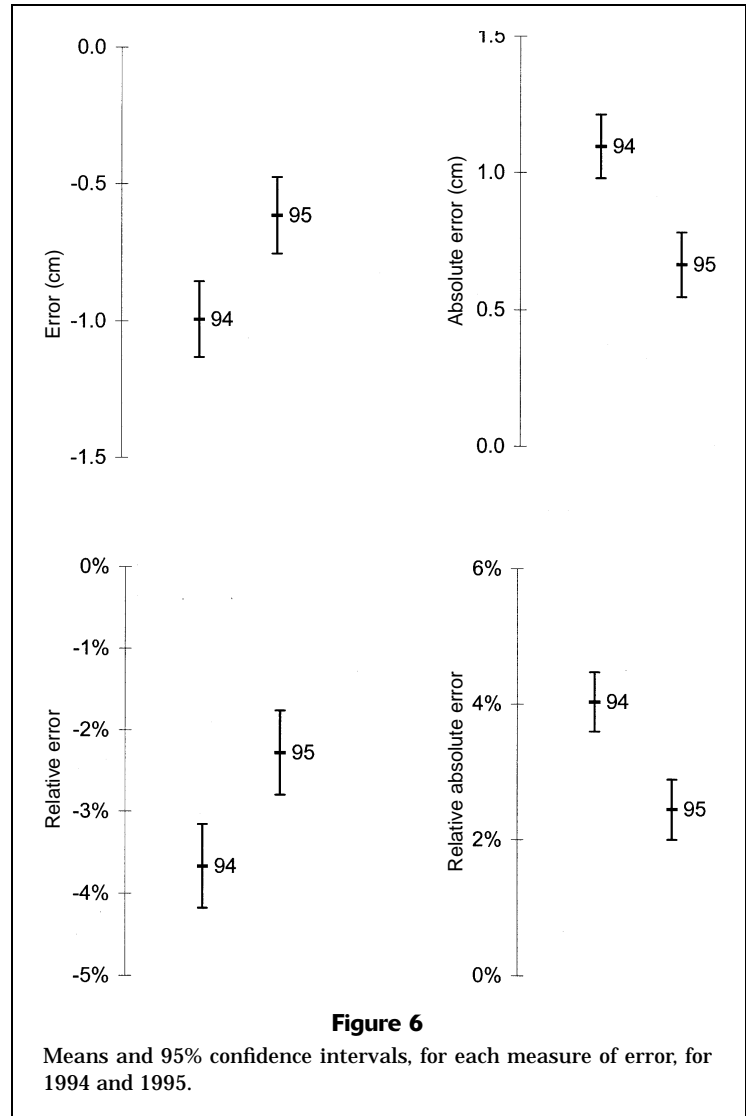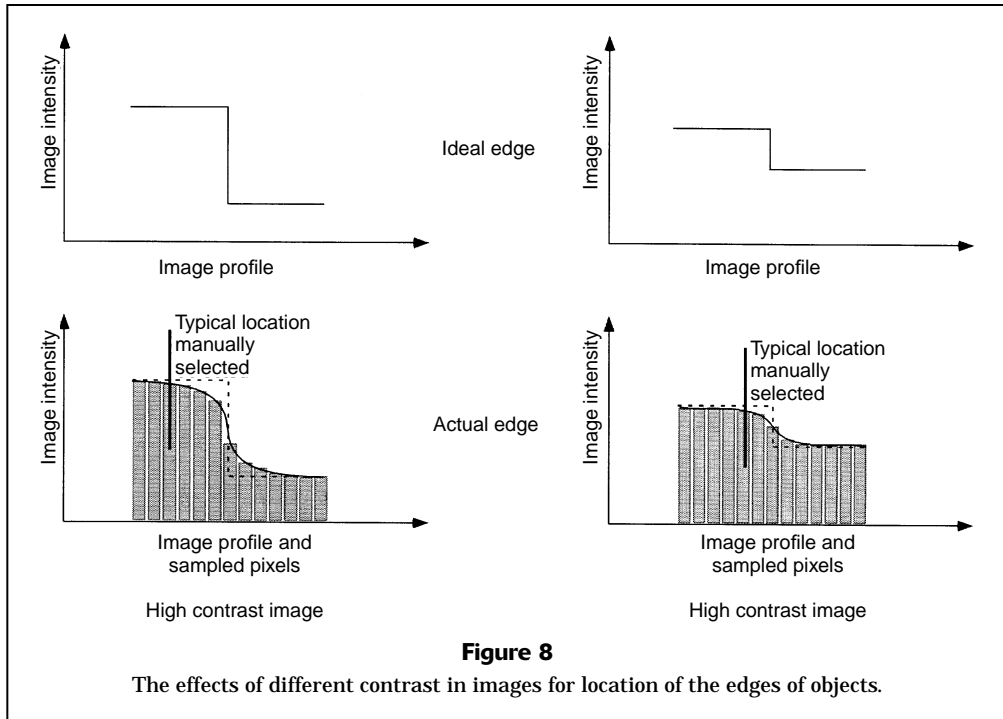
of statistical power (Harvey et al., 2000). With minimal training, volunteers can assist with the analysis of images. In addition, a remote stereo-video system can be used to record length-frequency data without harm to the fish from far greater depths and over longer periods of time than is possible by employing SCUBA divers. These advantages will likely have applications in fisheries management and deep sea biological surveys.

Unlike a diver who often has to make an immediate decision on the identity and length of a fish, a stereo-video system observer can review the images later and repeatedly. Multiple images of the same fish are recorded, enabling the selection of paired images with the best angle of orientation to the cameras. Moreover, where images of fish are at an acute angle to the cameras, the system is still able to make accurate measurements provided that the head and tail of the fish can be seen in both images (Harvey and Shortis, 1996). In addition, once an image is on screen, multiple measurements of one fish can be made over a short period of time (example 10 measurements in 30 seconds), further reducing measurement error. Our results suggest that at least five such measurements yield the most accurate results.

Disadvantages of an stereo-video system

One of the disadvantages of a stereo-video system is the financial cost of the equipment: two video cameras with underwater housings; a PC computer; and a suitable frame grabber required to convert video sequences to the readable format of digital images. Time constraints also need to be considered. Although approximately 3 minutes are required to complete a calibration in the water, approximately one hour is required in the laboratory to capture the 32 images and process them into a calibration file (Harvey and Shortis, 1998). The major time constraint occurs in the selection and synchronization of the paired video images from the left and right videotapes. Once the calibration and synchronization processes are complete, recording of image locations with the measurement observation system is reasonably efficient. The observer visually locates object features of interest, positions a cursor on the feature and clicks the mouse. Some physical constraints also need to be considered with a design like ours. A bar 1.5 m wide is used to separate the video cameras and may become entangled if used in large algal beds such as those of *Macrocystis pyrifera*. In addition, the underwater video housings create water resistance and the system can be difficult to maneuver into a strong current. This system is unsuitable for censusing cryptic species, because its base separation is too large to maneuver into small crevices. The system is best deployed off a boat, i.e. a boat large enough to safely carry the stereo-rig, a calibration cube (see Harvey and Shortis, 1996),

Figure 6

Means and 95% confidence intervals, for each measure of error, for 1994 and 1995.

Figure 7

Improvements in the accuracy of stereo-video measurements due to increasing the number of repeat measurements.

Figure 8

The effects of different contrast in images for location of the edges of objects.

divers, and diving equipment. Shore-based diving would be extremely difficult.

Before a stereo-video system is used to collect and measure field data, operators should practice taking measurements in the laboratory with a set of test objects of known size, so that they may learn to distinguish the edge of the object accurately within a range of water clarity.

Conclusions

Many of the problems outlined in our study can be overcome in the near future. The development of digital video cameras and frame grabbing boards have improved image quality and the ease of image acquisition and synchronization. These developments will also facilitate the analysis of streams of video images rather than single images, thereby greatly increasing the speed of image processing. In the future, the combination of stereo-videography with neural networks and fuzzy logic could facilitate automated pattern recognition, classification, and measurement of reef fish from video images.

Worldwide, temperate and tropical reefs are being threatened by anthropogenic disturbances. There is a need to describe the ecological structure and function of reef-fish assemblages and to monitor the effects of disturbance on these populations. This type of research has traditionally been carried out by government agencies and academic institutions. However, limitations in funding and resources are forcing these agencies to use supplementary sources of data. Consequently, the use of volunteers in monitoring programs is increasing (Halusky et al., 1994; Mumby et al., 1995; Darwall and Dulvy, 1996). Hunter and Maragos

(1992) suggested that new technology in computing and underwater video systems may allow recreational and volunteer SCUBA divers to assist with surveys of coral reefs without compromising the data quality. We have demonstrated that volunteers can in fact carry out surveys of the length of reef fish using a stereo-video without compromising data quality. Although the differences in the accuracy of stereo-video measurements made by an experienced operator and volunteers is statistically significant, these are negligible in comparison to errors in visual estimates by divers. Our study specifically addresses length estimates and does not address estimation of abundance. However, if someone is estimating all the lengths of a fish observed within a sample unit they are also effectively recording relative abundance. The accuracy and precision of abundance estimates is an important issue. Factors that need addressing include the accuracy of estimates made by a diver at a distance from the fish and the behavioral differences of fish at various spatial and temporal scales. These are complex issues that are beyond the scope of the present study.

Quantitative sampling of reef-fish length frequency or biomass for monitoring programs requires reliable identification skills and the ability to make precise and accurate estimates of reef-fish length. It is suggested that volunteer SCUBA divers could be trained to use a stereo-video system both in the water and in the laboratory for making measurements. Volunteers, under the guidance of professional scientists, could assist with monitoring programs of reef-fish length frequency and abundance without having any effect on the quality of data recorded. The data collected and analyzed from stereo-video images are proven to be considerably more precise and accurate than visual estimates undertaken by experienced scientific divers.

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