Comparison of Standard Length, Fork Length, and Total Length for Measuring West Coast Marine Fishes

REINA G. KAHN, DONALD E. PEARSON, and EDWARD J. DICK

Introduction

Reproducibility and consistency of measuring fish lengths depends greatly on the method used. The lack of a standard method of measuring fish is a problem for researchers using data from different sources, often requiring length conversion factors such as those given by Echeverria and Lenarz (1984) for rockfishes (genus *Sebastes*), which can be imprecise. Three common ways of measuring fish for research purposes are: standard length, fork length, and total length as described by Miller and Lea (1972). Standard length measures the distance from the tip of the longest jaw to

Reina Kahn's current address is 2065 Royal Oaks Drive, Apt. 202, Sacramento, CA 95815. Donald Pearson and Edward Dick are with the National Marine Fisheries Service, NOAA, Southwest Fisheries Science Center, Santa Cruz Laboratory, 110 Shaffer Road, Santa Cruz, CA 95060.

ABSTRACT—Measurements of adult marine fishes on the U.S. west coast are usually made using one of three methods: standard length, fork length, or total length. Each method has advantages and disadvantages. In this paper we attempt to determine whether one method is faster and/or more reliable than the other methods.

We found that all three methods were comparable. There was no appreciable difference in the time it took to measure fish using the different methods. Fork length had the most reproducible results; however, it had the highest level of bias between researchers. We therefore suggest that selection of measurement type be based on what other researchers have used for the species under study. The best improvement in measurement reliability probably occurs by adequate training of personnel and not type of measurement used.

the end of the hypural bone or caudal peduncle; however, there has been a debate regarding where the caudal peduncle or hypural bone ends (Howe, 2002). Fork length measures from the tip of the longest jaw to the center of the fork in the caudal fin. Total length measures the length from the tip of the longest jaw or the end of the snout to the longest caudal lobe pushed together.

Currently, on the U.S. west coast, standard length is typically used when measuring juvenile and larval fish (Moser, 1996) although some researchers use that measurement for adult fish as well. As the fish grow, total length and fork length are more commonly used for research and stock assessment purposes.

Prior to 1990, total length was the conventional method for measuring groundfish species (i.e. rockfish, flatfish, sablefish, lingcod, and other species of roundfish) in California, while in both Oregon and Washington, researchers have used fork length. This created confusion among researchers using data from all three states. In 1991, California began using fork length to end the confusion. While it was not clear that fork length was a more precise method, it did offer the advantage of standardization (Erwin[1]). Total length is commonly used for length regulations in both commercial and sportfishing on the west coast of the United States because no training is required to make the measurement, perhaps making it the most desirable measure.

We undertook this study to determine which measurement type was the most precise, and to see if one method was

[1]Erwin, B. 2003. Pacific States Fisheries Management Commission, 350 Harbor Blvd., Belmont, CA 94002. Personal commun.

appreciably faster. To accomplish this, we measured a variety of fish using the three measurement methods and recorded the amount of time it took. We then examined the variances in length associated with each type of measurement.

Materials and Methods

In this study we used 50 groundfish of various species and lengths. We measured 25 sablefish, *Anoplopoma fimbria*; 7 blackgill rockfish, *Sebastes melanstomus*; 6 aurora rockfish, *Sebastes aurora*; 8 greenspotted rockfish, *Sebastes chlorostictus*; 3 greenstriped rockfish, *Sebastes elongatus;* and 1 rosethorn rockfish, *Sebastes helvomaculatus*. All fish were collected by longline gear as part of our groundfish ecology cruise program at the NMFS Southwest Fisheries Science Center's Santa Cruz Laboratory.

The size of the fish ranged from approximately 200 mm to 650 mm. The fish were placed on ice at sea and brought back to the laboratory for examination. Each fish was tagged with a unique number using a tagging gun to allow multiple length measurements to be associated with each fish.

Two researchers (hereafter called either reader or recorder) measured each fish 9 times: three times each for total length, standard length, and fork length. The reader's measurements were timed by the recorder using a stopwatch and included the reader calling out the fish number and then the measurement. After obtaining one set of total length, standard length, and fork length measurements, the researcher stopped measuring and then recorded data while the other researcher repeated the same process. Each researcher performed 450 measurements for a total of 900 measurements in the
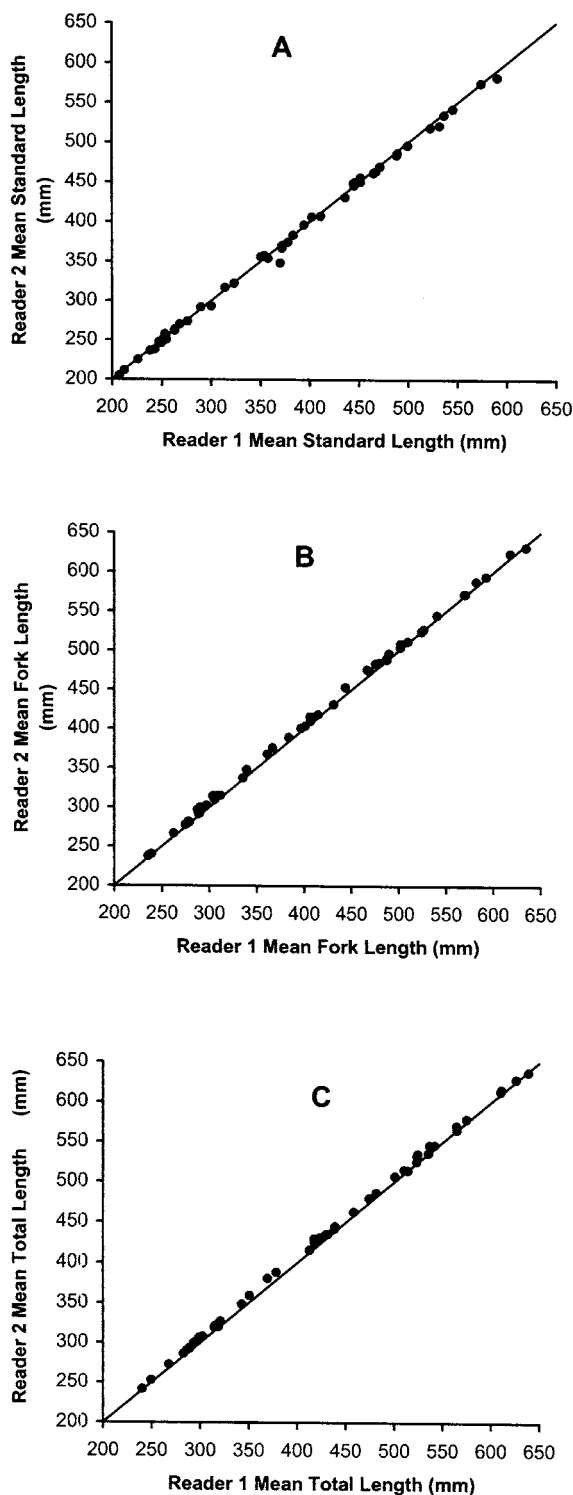
Figure 1.—Comparison of mean fish lengths obtained by two readers using three different measurement methods: standard length (A), fork length (B), total length (C). A line of equality is shown on each plot. (*N*=50 fish, each fish was measured 3 times, for each method, by each reader).

study and measured 25 fish at a time using one method, then measured the same set of fish using a different method and repeated the process using the third method.

For the purposes of this study, we considered standard length to be from the end of the longest jaw to the end of the caudal peduncle. A straight-edge device was used when measuring standard length to line up the caudal peduncle with the length on a measuring board.

To determine the speed of each measurement method, we calculated the average amount of time it took to measure each fish, using each method, for each researcher. We then examined the results for any obvious trends.

For each measurement type, variability among readers was estimated using the differences in lengths recorded by researcher 1 and researcher 2. The standard deviation of these differences is a direct measure of reader variability for each length definition (fork, standard, and total). The mean difference among readers was recorded as a measure of bias among readers.

To determine whether variability was a function of length for any of the three methods, the ANOVA model

$$\text{length}_{ijk} = \text{intercept} + \text{reader}_i + \text{fish}_j + \text{error term}_{ijk}$$

was fitted for each measurement type, and plots of residuals vs. fitted values were visually inspected for evidence of variance heterogeneity.

Results

There was very little difference in the average amount of time it took to measure each fish using the three different methods; however, there was a substantial difference among researchers (Table 1). Reader 1 (the most experienced), averaged about 3.6 seconds to measure each fish; while Reader 2 averaged about 5 seconds per fish.

The mean size of each fish, for each method, for Reader 1 was plotted against the mean sizes obtained by Reader 2 (Fig. 1). The results showed that mean total length, standard length, and fork length were very consistent between

Table 1.—Mean time in seconds to measure a fish using three measurement methods for two readers.

Measurement type	Reader 1	Reader 2
Fork length	3.5	5.1
Standard length	3.7	4.8
Total length	3.7	5.1

readers with little evidence of bias. Mean differences in recorded length between Reader 1 and Reader 2 (measurement 1 minus measurement 2), were 1.69 mm, –4.43 mm, and –5.13 mm for standard length, fork length, and total length, respectively. This indicated that there was more bias in measurements of fork length and total length than for standard length.

Variability among readers was highest when using standard length. The standard deviation of the differences between readers was 6.60 mm. Estimates of among-reader variability were very similar for fork length (4.56 mm) and total length (4.70 mm).

Analysis of residuals from the three ANOVA models did not suggest that variance was a function of fish length when using either fork length or standard length. There was some evidence of variance heterogeneity for the model fit to total length data. Comparison of root mean squared errors among ANOVA models fit to log-transformed data (to stabilize variance) did not change the ranking of precision among the three measurement types however.

Discussion

The goals of this study were to determine whether one method of measurement was faster and more accurate in terms of reproducibility than the others and to determine how much reader variation to expect with each of the measurement types. We found that there was very little difference in the time it took to measure each fish using the three methods. Of more importance is the amount of experience the readers had with measuring fish. Reader 1 was about 25% faster than the less experienced Reader 2. The time difference among readers might be important in studies where quick measurements are desired, such as tagging studies where duration out of the water could reduce survival.

Fork length was found to be the most reproducible method of measuring fish; however, the differences were not large and there was evidence of bias among readers. Furthermore, there was very little difference in mean length among readers for the different methods (Fig. 1).

Variations in length measurements can be attributed to several factors. For example, when using standard length, determination of where the caudal peduncle ends greatly depends on the individual reader and where they feel the hypural bone ends. Other sources of variation include damage to the caudal fin, poor technique, a measuring board that is not easily readable, or inadvertently stretching the fish.

Although fork length was the most reproducible method of measuring fish in our study, it had a high level of bias among readers. While standard length had a low level of bias, it had the greatest variability in length measurements. When selecting a method, the researcher should consider the trade-off between precision and bias and evaluate the consequences for the intended use of the data.

This study suggests that there is no best way to measure fish. Proper technique and consistency is probably more important in producing reliable lengths than the method used. The decision on which method to use may best be based on what the majority of other researchers use, thus avoiding confusion and errors associated with applying length conversion factors.

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