NORTHERN ANCHOVY SCHOOL SHAPES AS RELATED TO PROBLEMS IN SCHOOL SIZE ESTIMATION

JAMES L. SQUIRE, JR.[1]

ABSTRACT

Horizontal fish school profiles of the northern anchovy, *Engraulis mordax*, taken from day aerial photographs and video tapes of school bioluminescence at night were examined to determine the percentage of school area within a circular field of view and the school length and width ratios. Schools observed during the day had an average length to width ratio of 2.09:1, at night the ratio was 2.53:1. The percent coverage of the school's area in relation to a circle drawn tangent about the school averaged 42.1% during the day and 29.2% during the night. The effect of school shape on estimation of individual school area as observed with a side-looking sonar was determined. School width measurements, similar to that obtained by the sonar, were used to determine school area and indicated a possible average overestimate of the actual school area of 1.72:1. The relation of school length and width to the error was determined, indicating the greater the length to width ratio the greater the error.

Profiles of fish schools as viewed and photographed in the horizontal plane from an airborne platform have been published by numerous authors. Radakov (1972), in his review of fish schooling, described the characteristic horizontal shapes of fish schools in nature as being very diverse and extremely changeable. He stated that a spherical shape of a school is the rarest of all and also that a school's shape, size, or density is a result of the interaction between the fish and the physical and biological environment.

School shape and behavior in nature have been studied with such techniques as aerial observation, hydroacoustic measurements, and underwater observation. Each of these methods has limitations. Underwater visual observations are subject to restrictions due to illumination and restricted visibility. Aerial observation is limited in the day by water transparency, illumination, and reflectance from the water surface resulting from wind and wave action. Visual observation of school shape at night, as outlined by bioluminescent organisms, is limited to the moon's dark cycle or to periods of no moon, and is affected by water transparency and the density of bioluminescent organisms present in the water. Both day and night observations are limited by the school's proximity to the surface in relation to the factors affecting water visibility.

Hydroacoustic observations using lower frequency sounders of the type used commonly in sonar fish surveys give imprecise images of fish schools in the form of echograms that must be interpreted. Greater resolution of fish school shapes, but with limited range, can be obtained with ultrasonic scanning equipment (Voglis and Cook 1966).

All of these observation techniques may alter the environment and in many cases may result in modification of fish school behavior. Fish school behavior is affected when in close proximity to ships, submersibles, and divers, and aircraft (noise, shadow) could possibly modify the school, though this is not documented.

Surveys and research studies using variations of these three observation techniques are currently in use for direct biomass estimation of fish populations by observation of individual schools, school groups, and the internal structure of the school.

Hydroacoustic research on schooling fish is currently being conducted by the Southwest Fisheries Center (Smith 1970; Hewitt et al. 1976). Coastal, hydroacoustic surveys are conducted by the State of California (Mais 1974) to determine a relative abundance estimate of the northern anchovy, *Engraulis mordax*. These surveys are conducted during the daylight hours, as comparative tests indicate an increased probability of detection during this period (Smith 1970).

Aerial observations by commercial fish spotters, in the form of school counts and estimates of total tonnage, are being used by the Southwest

[1]Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.

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Fisheries Center to calculate indices of apparent abundance for several coastal species, including the northern anchovy (Squire 1972). To aid in the detection and quantification of pilchard, *Sardinops ocellata*, shoal occurrence off South Africa, Cram (1974) used an airborne, low-light-level, electron image intensifier to view the ocean's surface, detecting the bioluminescence of fish schools. During these night aerial surveys the school's horizontal surface area was interposed on the instrument's circular field of view, and running estimates of the percentage of coverage were made. These percentage estimates were then used in the computation of biomass estimates.

The intensifier used by the Sea Fisheries of South Africa has been used by the author off the southern California coast on an experimental basis. Due to the highly variable school shapes encountered, making estimates of the percentage of school coverage in the circular field of view are difficult. Experience indicated that examination of aerial color photographs and night low-level video tapes of anchovy school shapes for determination of the percentage of school coverage within a circle would be useful, particularly if in the future, surveys were to be conducted at night using this method for the development of biomass estimates for the northern anchovy and other near-surface schooling pelagic species.

In addition, an analysis of anchovy horizontal school shapes may assist hydroacoustic researchers in determining error parameters for computation of sonar biomass estimates. Hydroacoustic surveys currently conducted for the northern anchovy use both side- and vertical-looking sonar to detect and measure fish schools and school groups during the day along a predetermined survey track line. The acoustic "beam" used in these surveys varies according to the unit and is of ±5° to 10°. When detecting the school, the side-looking sonar measures the maximum dimension in one aspect of the school, either normal to or parallel to the ship's track. For the purpose of calculating horizontal area, in contrast to the aircraft's vertical view of the actual horizontal school area, the echogram school width is assumed to be elliptical (Smith 1970). Preliminary attempts at biomass estimation from sonar surveys have used the simple assumption that a series of estimates of the width of an elliptical school from random aspects will result in an unbiased estimate of school horizontal area. In a side-looking sonar the school width is measured and provides two points of reference with the orientation of these points about the school's profile being unknown. If an ellipse is fitted randomly between these two points, the resulting average area will equal a circle, a condition that was not observed in aerial photographs of anchovy schools.

METHODS

To examine the shape of northern anchovy schools as observed during day and night and to determine what percentage the school occupies of a circle tangent to two points along the school's edge and containing the school inside the circle, a circle was drawn about school profiles obtained from a series of 20 day oblique aerial color photographs (from the photographic files of the Southwest Fisheries Center) and of 20 night photographs of fish school bioluminescence. The bioluminescent anchovy school shapes were photographed from a television monitor as it projected video tapes recorded from an airborne low-light-level television camera used during anchovy resource surveys off northwestern Mexico. The night photographs were made available through the courtesy of Zapata, Inc.[2] (Zapata Fisheries), Houston, Tex. The night surveys using low-light-level television were conducted at elevations of up to 1,828 m (6,000 ft) and this survey technique is effective because the northern anchovy commonly migrates to the near-surface area during hours of darkness (Squire 1972).

The actual area of the schools observed in the photographs are unknown due to lack of data on the aircraft's altitude, camera angle, and camera geometry; however, all were taken from angles approaching vertical. However, all area calculations are expressed in percentages of a circle drawn tangent about the school's edge.

The day school profiles were further analyzed to determine what the school area would be if the width measurement were considered to be equal to the school's diameter and what the area would be if viewed systematically from six points 30° arc) about an arc of 180° around the school (based on school width or diameter as determined similar to the measurements made from a hydroacoustic sounder). These area data calculated from the six points of observation to determine school width were then compared to the actual school area.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

School length to width ratios were determined for both day and night schools.

The school area, as expressed in terms of percentage of the circle drawn about it, was determined by tracing the school profile upon paper, cutting the school out of the circle and weighing both the school profile and the nonschool portion of the circle on a sensitive laboratory balance. School areas for the six points of school width (diameter) measurement about the 180° arc were computed statistically.

RESULTS

Night Observations

Figure 1 illustrates the profiles of schools recorded by the airborne low-light-level television system. On each figure are given the area percentage of a tangent circle that the fish school occupies and the length to width ratio.

The average percent coverage of a night anchovy school, in relation to the circle tangent to the school, is 29.2%. The average ratio of school length to width is 2.53:1.

Day Observations

Figure 2 illustrates profiles of schools observed during the day. On each figure are given the percentage of a circle tangent to the school that is occupied by the fish school, the length to width ratio, and the 30° arc points that were used to determine the school's estimated diameter and area, simulated as randomly viewed by a side-looking sonar. The ratio of the actual school area to the calculated area of the school's average, high and low estimate, as viewed every 30° of a 180° arc based on simulated sonar measurements of width, is given in Table 1.

The average percent coverage of a day anchovy school to the tangent circle about the school is 42.1%. The average length to width ratio for all day schools is 2.09:1. The ratio of estimate of the area of all day schools, as calculated from measurements from 30° arc points about the school, to the actual area of the school is 1.72:1. The ratios, length to width, and estimate of school area to actual school area were compared and Figure 3 graphs the relationship. The graph displays the variables plotted on log-log paper showing two main points: One, that the variance is changing proportionally to the mean. This is expected as there should be more variation as the school length to width increases. Two, the plotted regression line indicates that more bias (higher estimated actual school ratio) is introduced as the school length to width ratio increases. The line is significant at the 95% confidence interval as proven by the t-test ($1.98 < 2.298$). The confidence limits are from 0.0545 to 0.734.

TABLE 1.—Ratio of the actual anchovy school area to the average area based on six points of observation as viewed every 30° of a 180° area, and the high and low ratio.

School	Average	High	Low
1D	1:2.61	1:3.95	1:0.83
2D	1:1.96	1:2.91	1:0.90
3D	1:1.22	1:1.56	1:0.85
4D	1:2.12	1:3.71	1:0.63
5D	1:1.13	1:1.41	1:0.80
6D	1:2.73	1:4.53	1:1.18
7D	1:1.50	1:2.35	1:0.00
8D	1:1.32	1:2.00	1:0.54
9D	1:1.49	1:1.88	1:1.19
10D	1:1.31	1:1.60	1:1.04
11D	1:2.65	1:4.82	1:0.62
12D	1:1.33	1:2.02	1:0.85
13D	1:1.47	1:2.35	1:0.77
14D	1:1.68	1:2.54	1:0.49
15D	1:1.97	1:3.30	1:0.65
16D	1:1.60	1:2.69	1:0.44
17D	1:1.38	1:2.10	1:0.84
18D	1:1.38	1:2.00	1:0.68
19D	1:1.99	1:3.52	1:0.42
20D	1:1.77	1:2.90	1:0.66

SUMMARY AND COMMENTS

The data on day-night school length to width ratios support what is commonly known about the schooling shapes of the northern anchovy. They are more common in the near-surface area at night, generally in large elongate thin surface schools. These elongate schools tend to group together in the early morning hours and descend to depth to form more compact schools during the day (Mais 1974). Studies by Squire (1972) of aerial fish spotter data show anchovy schools to be more frequently observed, and observed in larger quantities at night, when compared with day observations.

The schools percent area coverage of the tangent circle at night is 12.9% less than its coverage during the day and the length to width ratio is greater by 0.44. In addition, analysis of school length to width ratios compared to the ratio of estimated school size to actual size (Figure 3) shows that as the length to width ratio increases a greater error in school area estimate will occur. Schools with a length to width ratio of 2:1 have an estimated to actual error of about 1.5:1 while more elongate schools of a ratio of 3:1 have an estimated error of about 1.75:1.

FIGURE 1.—Profiles of anchovy schools observed at night off southern California, indicating the width to length ratio and the percentage of a tangent circle about the school.

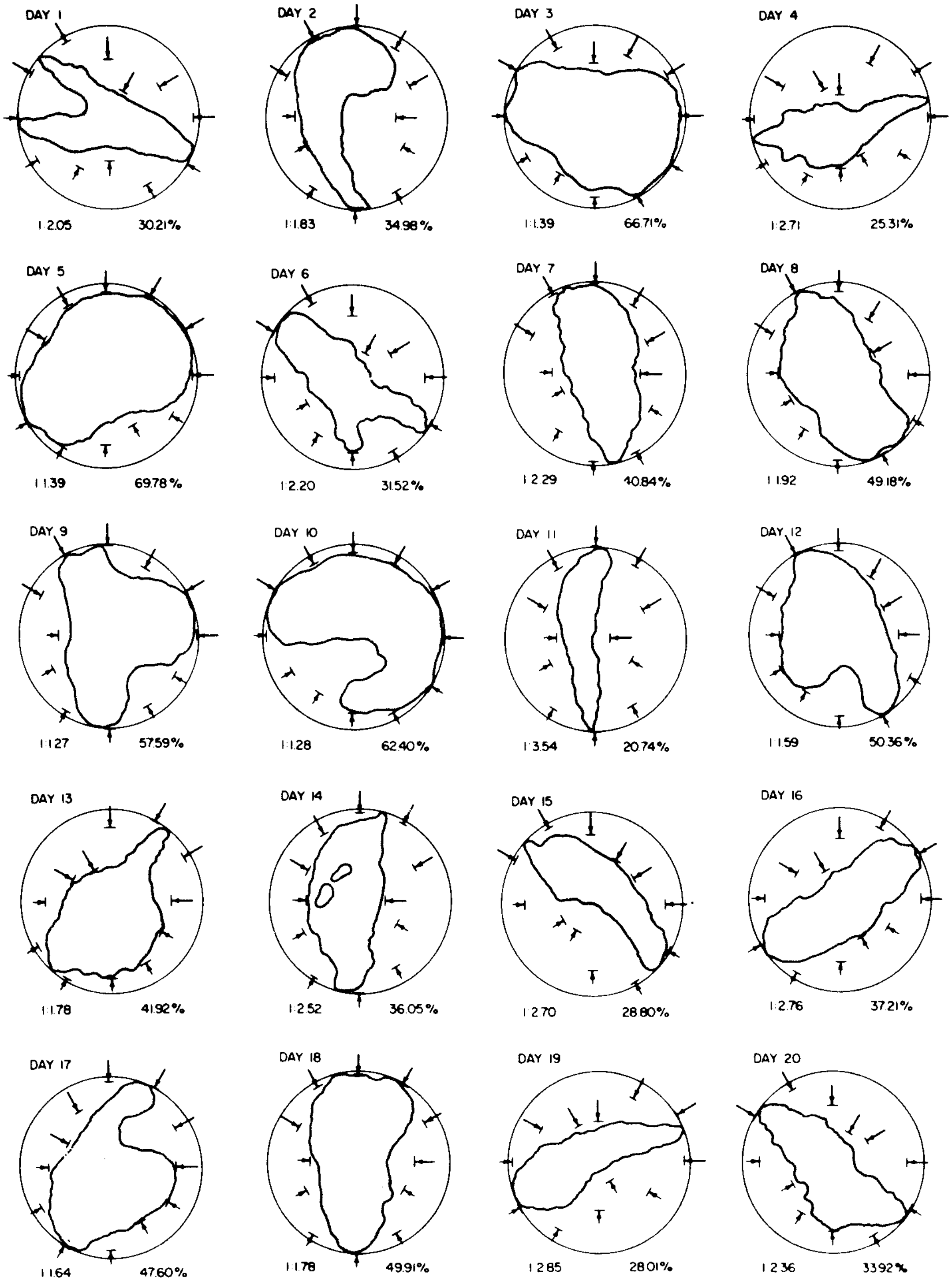

FIGURE 2.—Profiles of anchovy schools observed during the day off southern California, indicating the width to length ratio and the percentage of a tangent circle about the school. Measurements of school width were taken at the six points (long arrow shafts) indicated about a 180° arc.

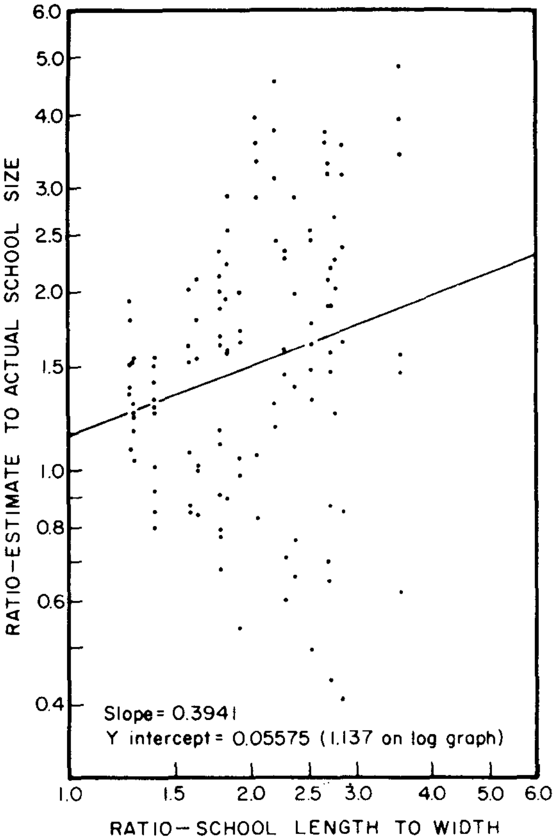

FIGURE 3.—Regression plot for the ratio estimated anchovy school size to actual size compared with the school length to width ratio.

For simulated sonar observations of school widths used in the calculation of school area, the preliminary examination of these data indicates a possible 1.72:1 average overestimate of area due to school shape deviations from a circle or ellipse.

Fish schools, being highly variable in horizontal profile, are probably equally complex in vertical structure; the relationship of horizontal complexity to vertical complexity is not known. Also unknown is the question of whether the individual school's axis is oriented in the same general direction within a group of schools, a possible factor which, if it occurs, could provide a source of substantially higher or lower school area error estimates from sonar track line surveys.

The problem of accurately estimating the percentage of school area within view of a low-light-level viewer is difficult, as the examples of school shapes within the target circle would indicate. Parameters of human viewing error could be established for this survey technique. However, the conduct of surveys using a low-light-level television system where the video signal can be recorded and later electronically analyzed with the aid of an image analyzer, should result in a higher degree of survey accuracy.

School shapes were taken from photographs randomly selected from an aerial photo file. Many of the photos were taken in the nearshore areas. There is the possibility that schools may be slightly more elliptical in shape over deep water than in the nearshore areas, but this is not documented. If this were true the error estimate would be reduced. This and other aspects of school profile and orientation should be investigated further and estimates of length to width ratios from aerial surveys, done in conjunction with each acoustic survey, may be useful for determination of a correction factor for the acoustic data.

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