method used in selecting the sample sites. All four factors are important and need to be considered in the planning of rotenone sampling studies.

ACKNOWLEDGMENTS

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A BRIEF APPRAISAL OF DATA ANALYSIS METHODS EMPLOYED IN DETERMINING STANDING CROPS OF FISH

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The need for the extension and refinement of our ability to estimate the size and composition of fish populations is widely recognized as paramount. Optimum yield prediction—the essential ingredient of management policy—cannot be attempted unless the fishery worker has concrete evidence of the total standing crop involved. The increasing number of detailed standing crop studies now being undertaken must, therefore, be accompanied by the development of better methods of field estimation, statistical treatment, and presentation.

LARGE LAKE ANALYSIS

In conducting detailed population analyses of large lakes, pilot mathematical models should be constructed if possible and referred to during the course of the study. Without a carefully conceived plan, time, energy and funds can be lost by collecting insufficient or superfluous data. The advisability of advance planning in mark-and-recapture standing crop studies is underlined by the work of Cooper and Lagler (1956) in laboratory experiments with colored beans. Using a two-gallon minnow pail with internal rotating baffles as a "lake", and beans as "fish", they observed the mechanics of indirect sampling methods under controlled conditions in order to gain an understanding of estimation methodology and to test assumptions appearing in field applications. The bean experiments afford clues to the number of days required to obtain a "good" estimate with sample size and total population size previously established.

An example of the applicability of their laboratory models to field studies is afforded by the conduct of estimations of crappie populations in 184-acre Ardmore City Lake, Oklahoma (Jenkins, 1955). The lake was partially treated with rotenone in September, 1953, and great numbers of black and white crappie were produced in 1954. The uniformity in size (4-6 inches) of this single year-class admirably fulfilled the conditions which must be met in mark-and-recapture population studies. Comparison of the daily population estimates of black and white crappie caught in wire traps with that produced by two trials of a laboratory model with similar relative sample-sizes of Cooper and Lagler (1956; Figure 5) shows close agreement (Figures 1 and 2). The average daily sample size of black crappie equalled 0.15 percent of the final estimated population (P), and 0.11 percent of the white crappie P, compared to 0.10 percent in the model. Cooper and Lagler present data which indicate that the relationship of days required for a "good" estimate (within 5 percent of the actual) to sample

Figure 1. Comparison of the progress of population estimates of a laboratory model (Cooper and Lagler, 1956, Figure 5 [times 10]) and yearling black crappie in Ardmore City Lake, 1955, using Schnabel (1938) formula.

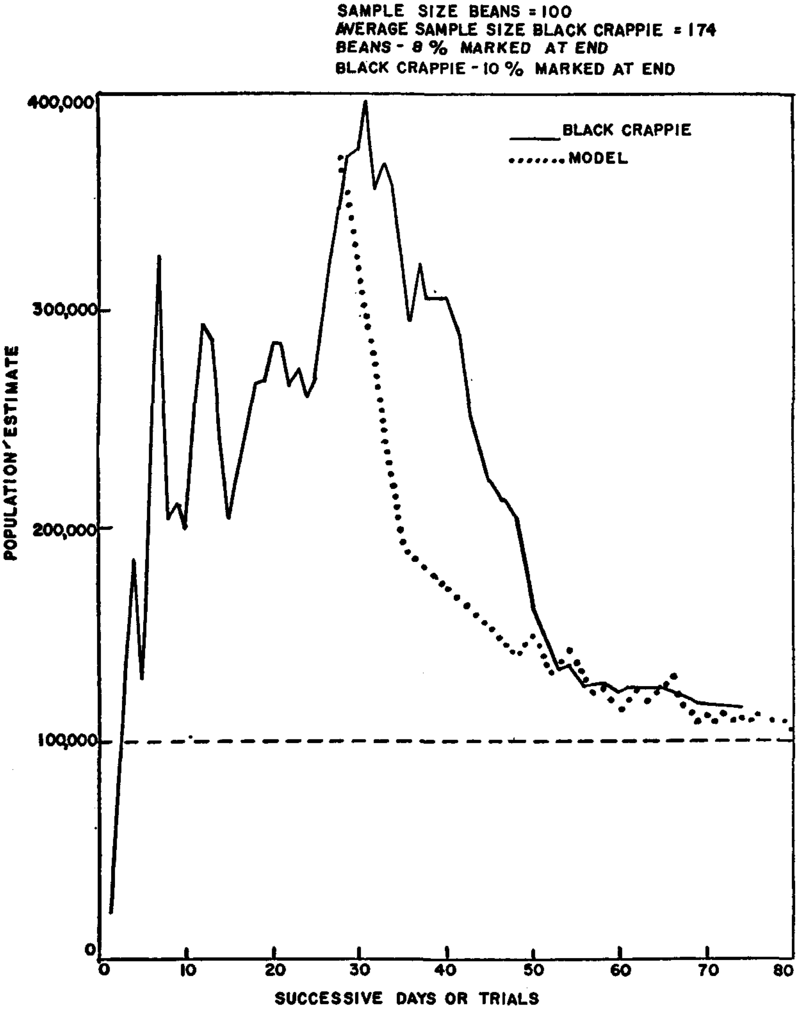
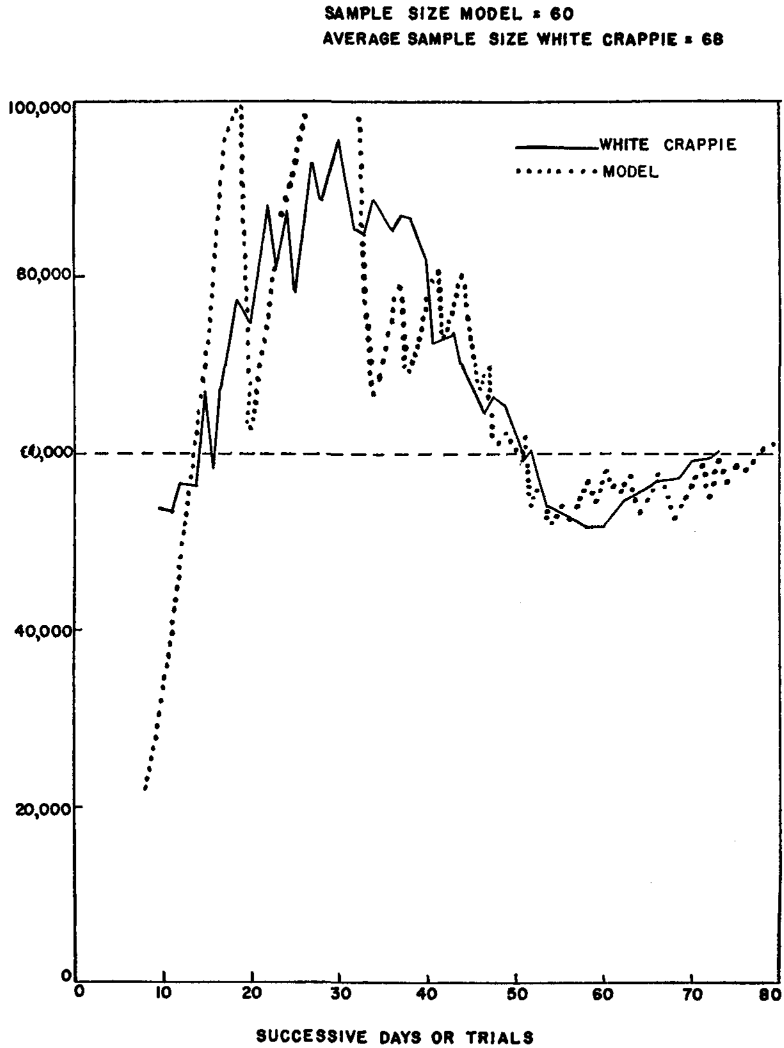


Figure 2. Comparison of the progress of population estimates of a laboratory model (Cooper and Lagler, 1956, Figure 5 [times 6]) and yearling white crappie in Ardmore City Lake, 1955, using Schnabel (1938) formula.



size is curvilinear, and that when only 0.1 percent of P is caught daily, about 80 days are required to obtain a good estimate. The studies at Ardmore City Lake conform to this pattern and delays, indecision and inconvenience which developed during the course of the field work could have been avoided had a laboratory model furnished knowledge of the time required early in the procedure. Fredin (1950) has proposed a method of determining the number of days required to obtain a good estimate which should also prove valuable in planning field operations.

Care should be taken in selecting the proper biometrical procedures necessary for indirect population estimation. The three commonly used formulas for estimates are those of Schnabel (1938), Schumacher and Eschmeyer (1943), and Chapman (1951), and each is best suited to particular situations, depending upon the percent of marked fish in the total population. I have found it profitable to prepare mimeographed forms containing labeled columns for the entry of data required in computing population estimates and confidence limits for each of the above formulas. Standard forms for recording original field data are a prime requisite.

Corrections for bias introduced by differential catchability of size-groups should be made whenever possible. Cooper and Lagler (1956) suggest that the breakdown into size-groups for analysis be as complete as the limits of practicality will allow. In Oklahoma studies, a division into groups characterized by distinct length-frequency modes has been employed regularly when a sufficient number of recaptures have been recorded in each subdivision. For example, in a mark-and-recapture study of the black crappie in 65-acre Pawhuska City Lake, the population estimate obtained from ungrouped data equalled 8,300, representing 26 pounds per acre. By separating the yearling fish (4-6 inches) and the adults (7-13 inches), the population estimate was changed to 14,300, and the standing crop to 38 pounds per acre. In this instance the larger individuals were much more susceptible to wire trap capture. Such calculations are time consuming, but must be performed if data analysis is to reveal facts which can be profitably applied in management techniques.

SMALL LAKE ANALYSIS

The concentrated study of lakes under 100 surface acres in area has furnished the most reliable published information concerning the total number and weight of fish existing in an area at a given time. The limited number of species and fairly uniform habitat usually represented in these smaller bodies of water facilitates detailed population analysis. There are inherent errors in most all modes of standing crop determination, however, which decrease the validity of estimates based on the short-period simultaneous mark-and-recapture method. Workers should follow up estimates made by seine, wire trap, trap net, electric shocker, or any other means of capture with complete rotenone treatment or draining in a number of instances to establish the efficiency of each sampling device which they employ.

The procedure which fishery biologists in Oklahoma now use in determining the standing crop of fish in pounds is as follows:

1. Make plane table map of lake.
2. Obtain history of lake from owner, Soil Conservation Service, etc.
3. Make pH, alkalinity, turbidity, transparency, average and maximum depth determinations, and take vertical temperature series.
4. Record drainage area soil and vegetation types.
5. Sample lake with ½-inch mesh seine, 75-150 feet long. Measure each fish caught and mark by clipping upper lobe of caudal fin or pectoral fin. Continue seine hauls until at least 100 fish per acre have been marked. Remove any marked fish which show signs of distress. (If lake unseinable, use traps.)
6. Treat lake with 1p.p.m. cubè root powder or equivalent, and pick up all fish which appear on first day (or as many as time will allow).
7. Take total length measurements of at least 20 percent of fish, and weights of sufficient number to calculate length-weight relation for each species. Weigh remainder in groups of 100. Take 30-40 scale samples over length-range of principal species, 10-20 samples of minor species. Use standard forms available at Fishery Laboratory for recording data.
8. On succeeding days pick up fish by species, count and check each for mark. Measure all fish over one-half pound.

Rigid adherence to this procedure will simplify the task of data analysis greatly, and affords a reasonably accurate estimate of the standing crop based upon the percent of marked fish which are recovered.

Draining theoretically provides the most satisfactory measure of standing crop, but is rarely a feasible technique in Oklahoma field operations. Very few lakes are constructed with adequate drains and catch basins and in addition many fish are lost in pot holes and the ooze and mud of the basin. For example, in draining 16-acre Rocket Plant Lake, the following percentage of recovery of marked individuals was attained: Largemouth bass over 10 inches—77 percent, under 10 inches—20 percent; white crappie over 8 inches—75 percent, under 8 inches—10 percent; black crappie—14 percent; black bullhead—29 percent; green sunfish—31 percent; for a combined total of 20 percent. All others were lost in small puddles in the former creek channel, in submerged aquatic vegetation, and in silt deposits up to 4 feet deep, despite persistent efforts to retrieve them. When this method is used, a known number of fish should be marked before operations begin to check on the completeness of recovery.

STANDARDIZATION OF DATA ANALYSIS

Some uniformity in gathering and reporting standing crop data is urgently required to enable all fishery workers to use the information conclusively. Greater accuracy and completeness should be attempted in recording length frequency, length-weight, coefficient of condition, and total biomass per unit area figures in an effort to widen our knowledge of the dynamics of fish production. In addition to descriptive materials, the basic facts needed for comparative purpose include: (A) By species, the estimated number and weight per acre, average total length and length-range, average weight, and coefficient of condition at one-inch intervals. (B) Estimated total standing crop in numbers and pounds per acre. When possible, complete length-frequency distributions should be presented in graphic or tabular form. A summary of growth-rate is invaluable. A statement of the number and weight of fish per acre of immediate concern to the fisherman is also desirable. Descriptive terms encompassing this category have included "harvestable-size", "desirable-size", "legal-size", and "catchable-size" fish, which have been arbitrarily defined either by a minimum length or minimum weight. It is suggested that some agreement be reached by workers on standard definitions of this segment of the population.

Standing crop data which are not based on the recovery of marked fish from a delimited area should not be included with more reliable population enumeration data in establishing standards on a regional basis. The sources of bias entering into cove and open-water rotenone sampling, seining, and trap-netting in large lakes render most comparative analyses unreliable at present. In default of more accurate information, it is probably wisest to restrict standing crop comparisons to categories based on the method employed.

It is suggested that concentrated efforts be made to expand the collection and evaluation of standing crop data in North America begun by Carlander (1955) to serve as a guide for biologists who are conducting population studies, so that they may avoid duplication of effort and concentrate on the voids in our knowledge of fish production. Although no exact correspondence can be anticipated between standing crop and the total amount of fish produced, its measurement is very useful until much more detailed studies can be undertaken.

It is further proposed that methods of analyzing small-lake standing crop data very similar to those prescribed by Swingle (1950) be adopted throughout the U. S. The ratios which he has devised (F/C, Y/C, A_t, etc.) to provide a quantitative method of comparing populations are relatively easy to compute, and afford a convenient base for evaluating species combinations and predicting optimum yield. Precise definitions of such terms as carnivorous and forage species and their subdivisions, and other terminology concerning population structure and well-being might be mutually agreed upon after a complete review of the literature and a conference of representatives of interested research and management agencies.

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HOW FISH POPULATION SURVEYS SHOULD BE REPORTED

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ABSTRACT

To facilitate the evaluation and use of population studies, reports should include:

1. A description of the area sampled, including the chemical classification and physical type of water, the type of bottom, depth of water, speed of movement and other information necessary to describe the environment from which the population came.
2. A description of the method of sampling employed in sufficient detail to enable the results to be evaluated and compared with results of other surveys.
3. Methods of measuring the results should be stated. The report should state if an attempt was made to recover fishes of all sizes, and if all fish were weighed or partly weighed and partly estimated. Such information is necessary for evaluation of the reliability of the results.
4. The population composition should be listed by species, with the numbers and weights of fish in each inch-group. A summary of the population should state the pounds per acre where possible, the A_t value, the F/C ratio, and the E values of the component species to facilitate comparisons with other populations containing the same or different species of fishes.
5. The author should summarize and interpret the results in so far as possible.

Many population surveys are of local interest only, and should never find their way into fisheries literature. If, however, the surveys have been carefully conducted and are extensive enough, their publication may add much to our knowledge of fish populations and dynamics.

At the present time the results of thousands of surveys repose in filing cabinets waiting for that moment when the biologists responsible have nothing better to do than to buckle down to the hard task of determining whether they really mean anything. However, each is so busy making new surveys that this spare time seldom materializes.

There is lacking in fisheries literature adequate reports of the compositions of fish populations in rivers, streams, lakes and impoundments. This has handicapped the development of theories of population dynamics and of ecological successions. It has also prevented detection of possible cyclic changes in population composition affecting the standing crop and the catch. For effective theorization, there must be available a great mass of definite information upon population compositions over a long period of years in the same environments, and upon those in different environments.

To be of use for this and other purposes, the surveys should be reported in such a manner that the information is intelligible to and useable by others. The published information should include a description of the area sampled, the method of sampling, the methods used in measuring the results, the population composition and a summary of what it all means to the author.

Description of the Area Sampled: Since the environment determines in large measure the composition of a fish population, the area sampled should be ade-