Fall 2008

Fisheries Techniques (AQFI 2147)
Format for Laboratory Reports

In this class, laboratory reports will be written as scientific articles. They are not required to be as technical or thorough as published articles, but should follow the same general format as used in scientific journals. You will not be required to cite literature extensively in lab reports for this class.

Requirements for all reports:

1) Must be type-written, double-spaced, using 12-point Times New Roman font
2) Must conform to minimum page limits – title pages, tables, and figures do not count towards the minimum page limit (5 pages will be required unless directed otherwise)
3) Tables and figures are to be done using standard software (e.g., Word for tables and Excel for figures) following examples provided and in scientific articles and placed on separate pages, figures should be pasted into the Word document so the report can be submitted as one document
4) Reports must have a minimum of five non-internet citations – individual book chapters can count as different citations
5) Websites can be cited but do not count as one of the citations prescribed above
6) Citation (i.e., References) must be formatted as specified by American Fisheries Society (AFS) (see attached article) – that is, books are cited as books should be, articles as articles should be, and so forth.
7) Each report should have a title page with only the title of the report, the name(s) of the author(s), the class, and date. This does not count towards page lengths.

As for report format, use the sample report that has been provided. For specific details on formatting, follow the AFS instructions to authors and sample article, and the sample report as provided as guides. Follow all instructions and be consistent throughout the report. Also, see my "23 tips for writing scientifically" provided in class.

Reports should contain the following sections:

Title page:
The title should be as brief as possible and allow the reader to know exactly what the lab was about. The title page should contain only the title of the report, the name(s) of the author(s), the abstract (see further instructions below), the class, and date. Center on the page accordingly. This constitutes page one of the report, but does not count towards minimum page lengths.

Abstract:

An abstract is a very brief synopsis or summary of what was done. The abstract must be able to stand alone from the rest of the report. Abstracts should not exceed 150 words, do not contain references to tables or figures, and do not contain literature cited. The abstract will usually contain an introductory sentence, 1-3 sentences on methods, 2-4 sentences of results, and 1-2 sentences of discussion. However, this is only a rough guideline (I won't be counting words or sentences). Abstracts are single-spaced and placed on the title page of the report.

Introduction:

The introduction should give the reader some "context" for the study. It should mention why this study is important, and possibly some background information on the topic. Much of what you'll need will be provided during labs. If your study has never been done before, that is important – state this in the introduction. The introduction should always conclude with a statement of the objective (or objectives) of the study. The Introduction will begin on page two of the report (and be the first page counted towards the minimum page length).

Methods:

The methods section contains a detailed description of exactly what was done in enough detail for the reader to duplicate what you did. It should include the date(s) of sampling, the sites sampled, the gear used, the data collected (i.e., what measures did you take?), all analytical techniques (e.g., all statistics), and a description of anything you did that was not standard protocol. Methods are usually cited in the references section unless you developed the method yourself. You can cite your Techniques book for most of our methods, but do it using the correct citation format. In addition, any deviation to the sampling design should be mentioned here. For example, if sites 1-3 were sampled on one day, but site 4 was sampled a week later because of bad weather, state this in the methods section. The Methods section will begin after the Introduction section.

Results:

Report only the results here, and not discussion. In other words, report your data and findings here - do not offer interpretation of the results to any large extent. Be brief but include everything that is needed. You do not report individual data points in the results section. Data should be summarized in tables and figures and referred to from the text. Most of your references to tables and figures will occur in this section, though occasionally you may need to refer back to a table or figure in the discussion (this is okay). The Results section begins after the Methods section.

Discussion:

The discussion is where you explain the importance of your results to the reader. This is where you summarize the main findings of your study and highlight their importance. You may also elaborate on how your results compare to other studies (some citing of literature will be required for this), and how they are important in a "larger" context. Why are the results important to anyone? For instance, your results for largemouth bass in Lake Pine Bluff may shed insight into largemouth bass populations in other Arkansas lake – the discussion will make this connection. A general guideline is to establish the three most important findings of your study and write a 5-sentence paragraph on each finding. The first sentence is your topic sentence, the next three discusses your main findings, and the last sentence either ties the paragraph together or states the larger significance of your findings. This framework generally works well in many cases – the five sentences is only a guideline – six or more sentences also can be used with this approach. Again, I won't require extensive citing of references, but will expect them when warranted. The Discussion begins on the next page after the Results.

References:

You need to cite literature if you make a statement or draw a specific conclusion that requires such. For instance, if you state in your discussion that "...growth of largemouth bass in Lake Pine Bluff was considered typical of Arkansas lakes...", you must cite a reference to support this contention. Citing other items such as "…trap nets are considered the gear of choice for crappies…." can be done using your Techniques book. Extensive justification of the use of certain sampling methods or analytical techniques will not be required in this class.

Cite individual literature using the AFS standard format (see attached), which can be found in any AFS article (also see attached). Examine these formats closely in the article provided – regular articles, book chapters, and books are cited differently. As I mentioned, I won't expect extensive citation of literature, but will expect at least one citation per page in the report. The references section begins on the next page after the discussion.

In nearly all cases, paragraphs exceeding one page should be avoided. If this seems necessary, split the paragraph somewhere and make two paragraphs.

Tables and figures:

You will be expected to use Word to make your tables and Excel to make your graphs. Think about how the data should be presented *before* you write the results section. Personally, I graph and table all of my data before I write a word – I find this helps me to get my thoughts together and write a better report. Plus, you need to know exactly what your results are before you write them up.

Figure captions go underneath; table captions go on top. For tables, use the three-line style – one line above and below your column headings, and one line at the bottom of the table. No other lines are necessary. Tables should not contain vertical lines, and you should not use fancy table options such as double lines (or thicker lines), box outlines, shadings, or 3-D fonts (see attached article for examples). For graphs, make sure your graph axes are labeled and that the bars, lines, symbols, etc. that you use are clear and visible. Similarly, do not use 3-D options, colored lines, or shading/hatching options. All graphs should be simple black and white images.

Tables and figures are printed on separate pages and inserted in order (tables first, then figures) after the References section. Excel graphs need to be cut and pasted into the main report document (i.e., Word file), and inserted in the correct place. Thus, the whole report should be contained in and printable from a single file. Please do not send me a bunch of files for me to print and collate.

If anything else comes up or if something is not clear, come see me before you proceed. But the attached AFS journal article contains many examples of what's acceptable for our class.

One final note:

The reports that you submit for this class should be cosmetically similar to the sample report I have provided. The topics for this class will be different, but if the report you intend to submit does not at least look like the sample report, you very likely need to continue working on it, probably focusing on formatting the most. Students who simply cut and paste sections of Excel spreadsheets into their reports and call them tables or graphs won't get many points.

Remember, for our reports, the effort put forth will count for as much as your technical knowledge of the subject

****** The following is a sample class report. It is from a different subject altogether and also from a graduate-level class. However, it is organized and presented in the fashion that I will expect for your reports. Please examine the format closely and follow as much as possible.***

Determination of hemolymph volume in the freshwater shrimp *(Macrobrachium rosenbergii*) by a radioisotope dilution method

Fisheries Techniques - AQFI 2347 - Laboratory Report #1

Your name here

Abstract

Hemolymph (blood) volume in organisms can be estimated using several techniques. The primary objective of this laboratory was to estimate blood volume of freshwater shrimp *Macrobrachium rosenbergii* using a radioisotope dilution technique and ascertain its relationship with organism size. Estimated blood volume of individual shrimp (size range 13.7 g to 56.1 g) ranged from 3.4 mL to 21.7 mL. Relative blood volume (blood volume/organism weight) of shrimp averaged 17.9% ($\pm$ 3.6%=1SE) and ranged from 11.2% to 38.7%. The relationship between shrimp body weight and blood volume was direct and highly significant (r^2=0.68, P=0.0220). Relative blood volume also exhibited a direct relationship with shrimp weight, but the relationship was only marginally significant (r^2=0.57, P=0.0500). This experiment strongly suggests that total and relative blood volumes in freshwater shrimp *M. rosenbergii* were linear functions of body weight, which corroborates previous work with other crustacean species. This experiment also demonstrates the utility of radioisotopes in a wide array of disciplines.

October 30, 1998

Introduction

Hemolymph volume in organisms can be estimated using several techniques, however isotope dilution methods are frequently used due to their simplicity and reliability (Rhodes 1982). The weight and blood volume of aquatic organisms are commonly related (Riegel and Parker 1960, Rhodes 1982), though blood volume per unit weight (i.e., "relative blood volume") is usually similar across size ranges of individuals. Relative blood volume is also greater in organisms from evolutionarily older phylogenetic lines. In fishes, relative blood volume is twice greater in hagfishes and lampreys than in elasmobranchs and modern teleosts (Farrell 1993). The likely reason(s) for this are the more sophisticated and efficient physiological mechanisms for gas exchange in the more modern fish groups.

The use of isotopes has been increasingly used by researchers as "tracers" of material flow in biological, physiological, ecological, and biogeochemical processes (Peterson and Fry 1987). Because "stable" isotopes are non-radioactive and remain relatively constant or fractionate predictably through biological processes, isotopes of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), and sulfur ($\delta^{34}S$) have been widely used in fish feeding and food web dynamic studies (Peterson and Fry 1987). Nevertheless, "unstable" radioactive isotopes are also useful since radio-labeled compounds are easily traced through processes. Furthermore, since many isotope half-lives are known, process rates can be estimated directly (e.g., $\delta^{14}C$ dating of rocks). In many studies, isotopes serve the dual purpose of contributing source-sink as well as process rate information.

The primary objective of this laboratory was to estimate blood volume of freshwater shrimp *Macrobrachium rosenbergii* using a radioisotope dilution technique and ascertain its relationship with organism size. A secondary objective was to become familiar with the use of radio-labeled compounds as material tracers in metabolic processes.

Methods

Shrimp were provided by the South Farm aquaculture facility at Mississippi State University. Specimens were placed into 200-L aquaria approximately 24 hours prior to examination at densities of 2-3 per aquaria. Specimens were kept segregated in aquaria by use of dividers. Specimens were individually removed, injected with 100 μL of ^{3}H-inulin (tritiated inulin, specific activity = 4.5 x 10^4 disintegrations/min or dpm) beneath the membrane of the fourth periopod, and returned to aquaria for approximately 15 minutes to allow circulation of the marker compound. One individual served as a control, thus no inulin injection was conducted. Following this period, cold syringes were used to draw a 100 μL hemolymph sample from the dorsal sinus, a connective membrane between the cephalothorax and abdomen. Blood samples were placed into scintillation vials with scintillation fluor added. Samples were placed into a scintillation counter which obtained counts per minute (cpm) of light radiated from the emission of beta particles during the disintegration of the ^{3}H atoms. Resulting cpm data were adjusted for the efficiency of the scintillation counter (ca. 43%) and reported as total dpm. The relative proportion of dpm from the injected inulin (reported above) to the total dpm from the hemolymph sample was used to estimate total blood volume in mL. Thus,

$$\text{Blood volume} = [(4.5 \times 10^4 \text{ dpm} / \text{dpm of } 100\ \mu\text{L hemolymph sample})] \times 0.1.$$

Relative blood volume was determined by division of the total blood volume by the shrimp wet weight and expressed as mL hemolymph/g wet weight (= % body weight). Individual samples were prepared by five different laboratory teams and data were pooled for analysis.

Data were tabulated and possible outliers were removed from the analysis. Simple linear regression was conducted on the remaining data points to examine possible functional relationships between total blood volume and shrimp wet weight (SAS Institute, Inc. 1994). Significance for the analysis was declared at an alpha level of 0.10 or less.

Results

Radiation level in the control sample was zero, thus no background radiation was present in shrimp and no correction of the data was necessary. A scatterplot of the raw data indicates a general direct relationship with some variation existing at the ends of the data range, with small individuals in particular (Figure 1). The scatterplot excluded the control which was not injected (thus, no calculation of blood volume was possible) and two extreme outliers in which the estimated blood volume (in mL) exceeded the shrimp wet weight (in g). Estimated blood volume of the remaining shrimp ranged from 3.4 mL to 21.7 mL; shrimp wet weights ranged from 13.7 g to 56.1 g (Table 1).

Prior to linear regression analysis, two additional data points considered to be outliers were also discarded (as instructed). Thus, seven data points were used for the assessment of the functional relationship between shrimp blood volume and wet weight (Figure 2). The resulting relationship was highly significant (r^2=0.68, P=0.0220) and shrimp blood volume was depicted as a linear function of shrimp wet weight by the equation:

Total blood volume in mL = -12.923 + 0.4995 (wet weight in g).

If the largest individual shrimp (wet weight 56.1 g) was discarded from this analysis, the relationship became more significant (P=0.0028) and the r^2 increased to 0.91.

Relative blood volume of shrimp averaged 17.9% (± 3.6%=1SE) and ranged from 11.2% to 38.7% (Table 1). As before, if the largest individual was discarded, the upper end of the range was only 19.2%. Because of this apparent outlier, relative blood volume showed a slight, but significant (r^2=0.57, P=0.0500), direct relationship with shrimp weight (Figure 3). Thus, relative blood volume was also described as a linear function of size by the equation:

Relative blood volume in mL/g wet weight = -0.109 + 0.0068(wet weight in g)

Because this relationship "appeared" dominated by the largest individual in the analysis, an additional analysis was done excluding this data point. Surprisingly, the relationship became more significant (r^2=0.73, P=0.0314). Thus, the data point in question may have been an outlier, but was not dominating either relationship to any large extent.

Discussion

This experiment strongly suggests that total and relative blood volumes in freshwater shrimp *M. rosenbergii* are linear functions of body weight. If a larger sample size had been used, it is possible that the latter relationship may not have been significant. The trend was contrary to conventional wisdom concerning blood volume and organism sizes and has not been reported widely in the literature. Otherwise, results were consistent with previous studies on other invertebrate species (e.g., Prosser and Weinstein 1950, Rhodes 1982). Rhodes (1982) cites several studies reporting relative blood volumes for different crustacean groups [*Orconectes virilis* (crayfish) mean 25.1%, *Homarus amercianus* (lobster) mean 17%, *Maja* sp. (crab) range 8-29%]. Values for *M. rosenbergii* from this experiment appear comparable to those reported. In contrast, Riegel and Parker (1960) reported similar blood volumes (range 8-35%) in two species of crayfish (*Procambarus clarkii* and *O. virilis*), but hemolymph volume *decreased* with increased body weights. Possible reasons for this observation were unclear.

Rhodes (1982, p.57) reported that blood volume increased linearly with body weight (or body part measures indicative of) in the crayfish *Austropotamobius pallipes* (Decapoda: Astacidae) and reported regression constants similar to, but lower than, those reported in the present experiment. However, when the largest individual from our analysis was discarded (same as before), the resulting slope was more similar to that reported by Rhodes (1982) (0.268 to 0.119 reported by Rhodes, but still twice greater). Nevertheless, our regression constants were from not only a different species within Decapoda, but also a different family. Thus, group-specific differences in the rate of change in the relationship might be expected.

Another consideration from this experiment was the metabolic state of the organisms used. Blood volumes in other organisms have been reported to vary with molting stages, reproductive cycles, and levels of starvation (Rhodes 1982). Two of individuals from this experiment were females with eggs and one had recently molted. However, none of the individuals were classified as outliers in this analysis with all having estimated blood volumes well within the expected range. A larger sample of specimens with different metabolic states may have been required to better examine this possibility.

Linear regression analysis (Y=a+bX) is the most straight-forward approach in assessing functional relationships between variables. However, biological variables often exhibit “non-linear” associations, thus their relationships are better described by other mathematical functions, many with polynomial or exponential terms. In considering this possibility, it is found that a *reciprocal straight line function* better described the relationship between total blood volume and shrimp wet weight. The form of the equation was:

$$\text{Total blood volume in mL} = 1 / (0.5261 - 0.0083(\text{wet weight in g})).$$

This model is merely the reciprocal of a linear regression model and was highly significant (P=0.0001) with an r^2 value of 0.91. Additionally, the relationship between relative blood volume and wet weight was described by several complex exponential and logarithmic functions (all with r^2 values >0.85). However, the much simpler reciprocal straight line function also performed adequately with this dataset (r^2=0.75, P=0.0001). The form of the equation was:

Relative blood volume in mL/g wet weight = 1 / (14.03 - 0.1774(wet weight in g)).

Although it must be remembered that sample size was only seven and many models will likely provide an adequate fit (high order polynomials in particular), this underscores the need to consider other functional forms of relationships besides linear ones.

This experiment also demonstrates the utility of radioisotopes in a wide array of disciplines. Although radioisotopes are more difficult to work with for obvious reasons, the experiment clearly shows their usefulness in even a basic physiological application. Due to their ease in working with, stable isotopes may have a wider array of uses, particularly in ecological experiments where large-scale system process rates are of interest.

References

Farrell, A.P. 1993. Cardiovascular system. Pages 219-250 *in* D.H. Evans, editor. *The physiology of fishes*. CRC Press, London.

Peterson, B.J. and B. Fry. 1987. Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics* 18:293-320.

Prosser, C.L. and S.J. Weinstein. 1950. Comparison of blood volume in animals with open and closed circulatory systems. *Physiological Zoology* 23:113-124.

Rhodes, C.P. 1982. The relationship between body size and blood volume in the crayfish *Austropotamobius pallipes* (Decapoda, Astacidae). *Crustaceana* 43:51-59.

Riegel, J.A. and R.A. Parker. 1960. A comparative study of crayfish blood volumes. *Comparative Biochemistry and Physiology* 1:302-304.

SAS Institute, Inc. 1994. Statistical Analysis Software, Version 6.10, Cary, NC.

Table 1. Summary of raw data from this experiment including wet weight (g), specific activity of hemolymph sample (dpm), estimated total blood volume (mL), and relative blood volume (mL/g wet weight) of the freshwater shrimp *Macrobrachium rosenbergii*. Excludes three data points (two outliers and the control).

Shrimp Wet Weight (g)	Hemolymph Specific activity (dpm)	Total Blood Volume (mL)	Relative Blood Volume (mL/g)
13.7*	247.2	18.2	-
24.1*	606.0	7.4	-
27.2	1307.9	3.4	0.126
33.8	1186.2	3.8	0.112
37.4	827.4	5.4	0.145
40.8	899.1	5.0	0.123
49.5	524.2	8.6	0.173
52.4	448.4	10.0	0.192
56.1	207.5	21.7	0.387

* values excluded for linear regression analysis.

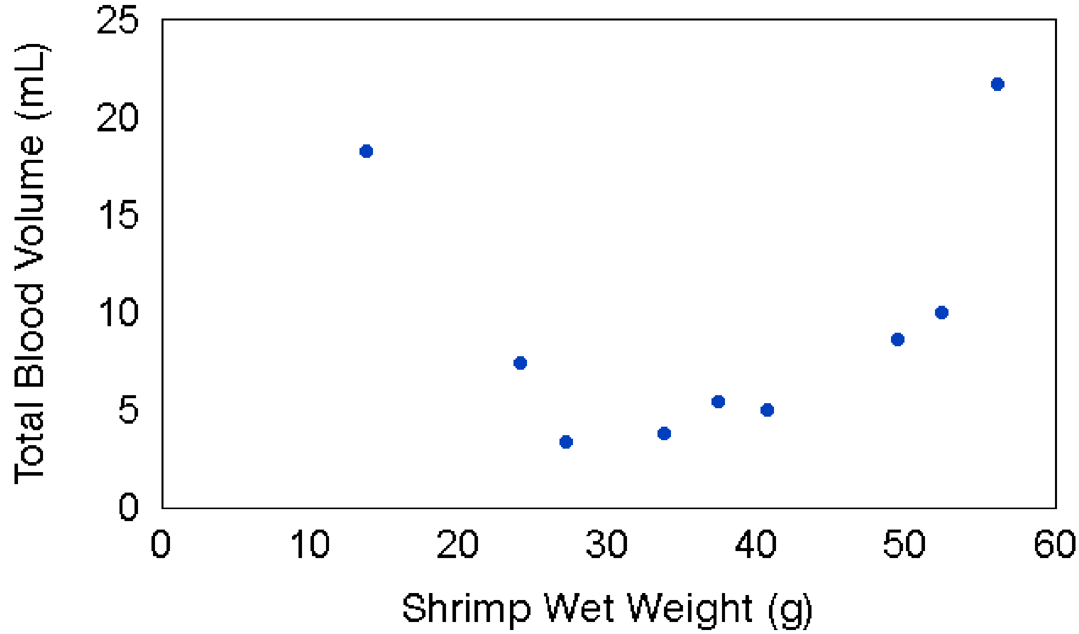

Figure 1. Scatterplot of wet weight vs. total blood volume in freshwater shrimp *Macrobrachium rosenbergii*.

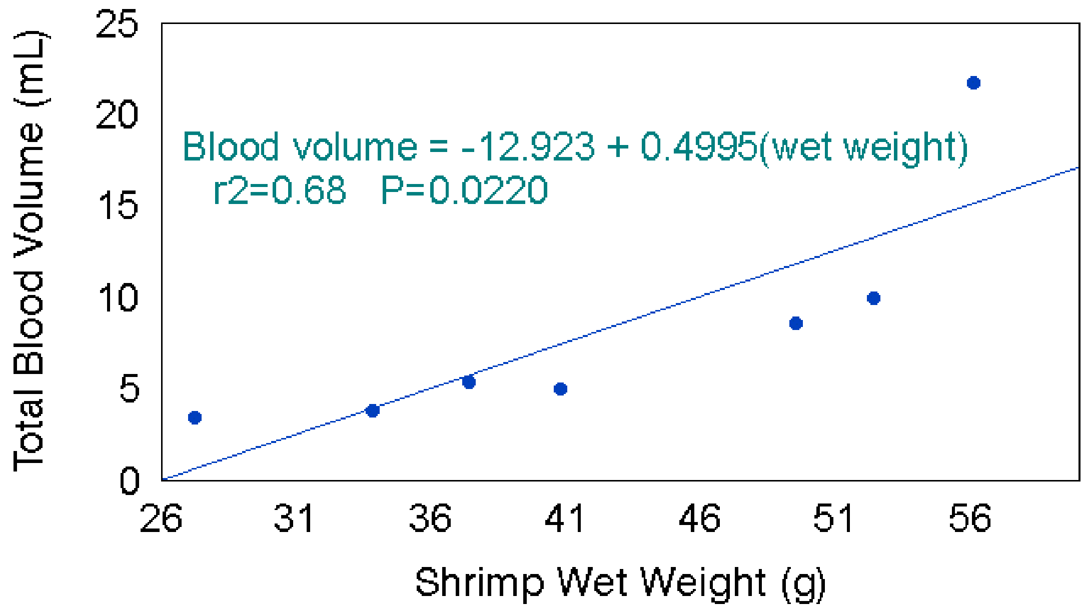

Figure 2. Linear regression analysis of wet weight vs. total blood volume in freshwater shrimp *Macrobrachium rosenbergii*.

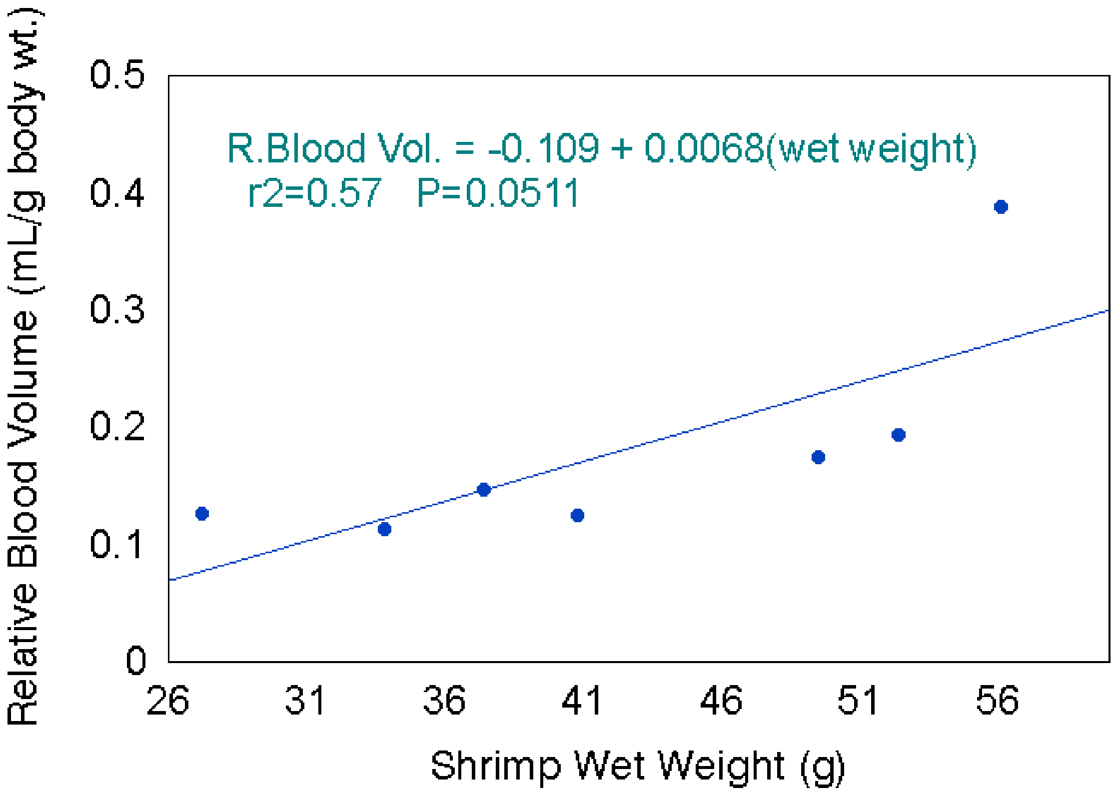

Figure 3. Linear regression analysis of relative blood volume vs. wet weight in the freshwater shrimp *Macrobrachium rosenbergii*.

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TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

Guide for Authors

Editorial Policy

We encourage submission of original, high-quality, English-language works in fisheries science to the *Transactions.* Broadly construed, fisheries science includes genetics, physiology, biology, ecology, population dynamics, economics, health, culture, and other topics germane to marine and freshwater finfish, exploitable shellfish, and their respective fisheries. We judge papers for their scientific competence, for their integration with existing knowledge, and for their contribution to our understanding of basic principles.

Generally, we favor works that address functional questions (How? Why? When?), but we appreciate that many aspects of fisheries science still lack a basic descriptive foundation (What? Where? How much?). Descriptive papers relevant to an understanding of functional processes are acceptable, particularly if they are based on comparative research (among species, habitats, etc.).

We do not proscribe any subject within fishery science, but as the preceding remarks suggest, some treatments of a topic are more appropriate for the *Transactions* than others. For example, we will consider a good paper on fish systematics, but not a taxonomic one; a biogeographic analysis, but not a report of range extensions. Papers devoted wholly to new techniques should clearly advance the research capabilities within a discipline; equipment modifications and minor analytical innovations usually can be presented within a full scientific report. Baseline data, faunal surveys, anatomical anomalies, and other raw data or curiosities should be withheld from the *Transactions* until scientific inferences can be drawn from them. Papers dealing with management applications of fisheries science are often more appropriate for our companion publication, the *North American Journal of Fisheries Management.* Papers on practical aquaculture may be submitted to the *North American Journal of Aquaculture* (formerly *The Progressive Fish-Culturist*). Papers that address the health of fishes and other aquatic organisms may be submitted to the Society's *Journal of Aquatic Animal Health.*

The *Transactions'* emphasis is on basic and applied research, but we value synthesis and will consider commentary or review papers for publication. In such papers we will look for critical assessments, innovative interpretations, and distillation of principles and generalities.

We strongly discourage the fragmented reporting of scientific results. Whenever possible, coherent research should be published in a single comprehensive paper. If this is not feasible, we recommend that related papers be coordinated, cross-referenced, and submitted together. Authors should not republish their original data without full attribution and explicit permission; see ''Dual Publication of Scientific Information,'' *Transactions* 110:573–574 (1981).

Manuscript Submission and Review

Manuscript Categories

Manuscripts may be up to 150 pages long (including tables and figures), the equivalent of 50 printed pages. (Longer papers should be submitted as Monographs, for which we require external publishing funds.) Manuscripts may be submitted to any of the following categories. (1) *Articles* comprise full scientific reports and critical reviews. (2) *Notes* are short papers of inherent value but limited scope, brief reports of important but unrefined experiments that the author is unable to repeat (for nontechnical reasons), and observations on methodology and protocol. (3) *Forum* papers, a new category, may be in-depth essays, perspectives, or commentaries on current fisheries topics (see TAFS 127:838). (4) *Comments* are critiques of data and interpretations already published in the *Transactions*, responses to which will be invited from the original authors. We also publish corrections (errata) of papers previously published in this journal.

Submittal Procedures

Submit new manuscripts and associated correspondence at the journal's online manuscript submission and peer review site: tafs.allentrack.net. You may also access the manuscript submission site through the Publications pages on the American Fisheries Society's Web site (www.fisheries.org). On your first visit to the journal site, you will need to register for an account. If you have completed the expert database form on the Society's Web site, you may already have an account.

In that case, your login name and password will be sent to you by e-mail during the registration process. This login name and password can be used on all of the Society's journal submission sites; there is no need to register again for each journal. You will be able to submit text, tables, and figures online. More detailed instructions, including acceptable file formats, are available on the site.

Publication charges are US$75 per printed page and will be billed when the paper is in proof. Partial or full subsidy of page charges may be provided to voting members of the American Fisheries Society (only) who certify that grant or agency funds are severely limited or unavailable. Manuscript reviews are unaffected by requests for subsidy; however, at least one author of a subsidized paper must be or must become a member of the Society *before* a subsidized paper can be published. Every paper published in the journal is subject to a $30 fee to offset handling costs associated with the proof. Authors may purchase reprints of their papers from the printer when they receive their proofs.

Review Process

Articles and notes normally will be critically reviewed by at least two outside experts in the relevant discipline. However, we may return to authors without review any manuscript that we judge to be of low technical or rhetorical quality or simply inappropriate for this journal. Reviewers and authors have the option of anonymity. Authors who wish to exercise this option should structure their manuscripts accordingly.

Because the review process depends on volunteers, it sometimes can be a lengthy process; however, we strive to get evaluations of well-written papers back to authors within 8–12 weeks after submission. Authors should do their part by revising papers promptly, ideally within 3 months of the time the paper is evaluated by the editor. Papers that have been out for revision for 6 months or more will be considered withdrawn, and revisions completed after that time will be considered new submissions.

Reviewers (and editors) react positively to concisely written and well-organized papers and are likely to give such papers priority attention. Careless preparation of manuscripts implies careless research and thought and may lead to negative critiques. Authors can greatly help their own cause if they (1) write direct, unambiguous, grammatically correct prose and avoid redundancy and wordiness; (2) clearly establish the intellectual context and practical or theoretical importance of their work; (3) provide all methodological information needed to understand and interpret their results, without unnecessary details; (4) prevent statistical or analytical sophistication from upstaging biological insight; (5) integrate their results broadly but relevantly with the published literature; (6) forgo trivia and unwarranted speculation; and (7) follow the journal's style and format.

Authors for whom English is not their primary language are strongly encouraged to seek help from someone for whom it is when they prepare their papers for submission to the journal.

Preparation of Manuscripts

Our standard for word definition and spelling is *Webster's Third New International Dictionary,* as updated by the latest edition of *Merriam Webster's Collegiate Dictionary.*

For taxonomic and vernacular names of North American fish species, we follow the American Fisheries Society's most recent edition of *Common and Scientific Names of Fishes from the United States, Canada, and Mexico.* For other fish and invertebrate species, we encourage readers to follow the Society's companion publications: *World Fishes Important to North Americans* and *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada* (*Mollusks*, 2nd edition, *Decapod Crustaceans,* and *Cnidaria and Ctenophora* are currently available in the latter series). Common names sanctioned by these lists may be used freely in this journal, but they must be accompanied by their respective scientific names when first mentioned in the abstract and text. Always use full common names: ''largemouth bass,'' not ''bass.'' Some plural forms of common names differ from the singular forms; consult a dictionary.

For analyses of fish population dynamics, we prefer the notation as used by W. E. Ricker in his *Computation and Interpretation of Biological Statistics of Fish Populations* (Fisheries Research Board of Canada Bulletin 191, 1975). However, all such symbolism should be defined anew in each manuscript. Our standards for chemical names are the current editions of the *Merck Index* (Merck & Co., Rahway, New Jersey) and *Enzyme Nomenclature* (Academic Press, San Diego, California). Geneticists should use the ''Gene Nomenclature for Protein-Coding Loci in Fish'' by J. B. Shaklee et al. (*Transactions of the American Fisheries Society* 119:2–15, 1990).

Writing for Fishery Journals, edited by John Hunter (1990, American Fisheries Society), contains an excellent chapter on graphic and tabular display of data; other chapters provide advice about statistical and word usage. An extensive style guide for AFS publications is available on the AFS Journals page of the Society's website (www.fisheries.org). In addition, several other style manuals provide useful guidance for the preparation of manuscripts, among them are the latest editions of *Scientific Style and Format* (Council of Biological Editors, Chicago), and the *Chicago Manual of Style* (University of Chicago Press, Chicago). The *Elements of Style* by Strunk and White (Macmillan, New York) continues to be an excellent guide to English usage. Accuracy and precision in scientific writing are just as important as accuracy and precision in scientific measurement. Lapses in either context invite criticism.

Format Conventions

Whenever authors follow the style and format of the journal for which they write, they earn the appreciation of reviewers, editors, and typesetters, and save themselves extra revisionary work. The following conventions apply to this journal.

(1) Use line spacing of at least 1.5 for all material, including title, abstract, footnotes, references, tables, and table and figure legends.

(2) Enable continuous line numbering for all manuscript pages. Number all pages sequentially, including title page, abstract, tables, and figure legends. Make sure that headers or footers will not be confused with the text.

(3) Use a standard 12-point font throughout. Use boldface type only to indicate first-level heads and vectors. Use an italic font and not underlining to indicate italics.

(4) Turn off all hypenation and justification routines. Delete all horizontal and vertical lines from tables except the horizontal lines above and below the column heads and across the bottom of the table.

(5) Avoid solid capital letters except for acronyms, which, along with abbreviations and symbols (including numerals), should never begin a sentence. Use an italic font only for scientific binomials (other Latin words and phrases are *not* italic), second- and third-level subheadings, single-letter variables and constants in mathematics and statistics, and for *occasional* emphasis.

(6) Spell out one-digit numbers unless they are used with units of measure or are directly compared with a larger number: four anglers; 5 cm; 8 bluefish and 16 striped bass. Use numerals for decimal fractions and numbers of two or more digits: 0.4 times; 17 tanks; 326 fish, but spell out any number that begins a sentence. Use commas in numbers of 1,000 and greater; use 0 before decimal fractions (0.05).

(7) Use the 24-hour clock for diel time (and spell out ''hours''): 1435 hours, not 2:35 p.m. Calendar dates can follow either of two formats: day month year (17 July 1990) or month day, year (July 17, 1990); select one style and use it consistently throughout the paper, including Tables and Figures.

(8) Follow the name-and-year system for literature citations (see References below).

(9) Keep text footnotes to a minimum and number them sequentially throughout the paper. Table footnotes take lowercase, superscript letters in alphabetical order, and the sequence starts anew with each table.

(10) Use metric units of measure without exception. Report physical measurements in accordance with the Système International d'Unités (SI). When one unit appears in a denominator, use a solidus (6 mg/L); use negative exponents and product dots ($26.4\ g\cdot m^{-3}\cdot h^{-1}$) for compound denominators.

(11) Indicate the national currency involved the first time a monetary value is given (e.g., Can$6, US$153).

(12) Give fish ages in Arabic, not Roman, numerals (age 3, not age III) and avoid plus (+) signs in the age notation. A fish is age 0 during its first year of life, which is assumed to end December 31 unless otherwise indicated. Define specialized age notations such as those used for anadromous species.

(13) A list of symbols and abbreviations that may be used without definition in this journal is provided at the end of this ''Guide for Authors.'' Some symbols are not unique (for example, N can mean newton, nitrogen, normal, or north), so terms should be spelled out if there is any chance of ambiguity. All other symbols must be defined when they are introduced in each paper; for example, ''1,000 $\times$ gravity (g)'' at first use, and ''1,000 g'' thereafter. To facilitate communication with readers, avoid excessive use of abbreviations and acronyms, and avoid abbreviations in the abstract.

Manuscript Components

Manuscripts normally should be assembled in this order: title, authors, and addresses (on one page); abstract (on the second page); introduction, study area, methods, results, discussion, acknowledgments (run-in on successive pages); references; all text footnotes (including address changes); appendixes; tables; figure captions; figures. The following notes expand on these items.

Title.—The title should accurately reflect a paper's content. The best titles—those that attract a reader's attention and interest—are usually short (a dozen words or less) and crisp. Latin binomials covered in the Society's *Common and Scientific Names of Fishes from the United States, Canada, and Mexico* should not be included in the title. Authors of scientific taxa also should be omitted from the title except when their names are absolutely needed for clarification.

Abstract.—All articles and notes require abstracts, but comments do not. The abstract should be a single paragraph of 200–300 words (75–200 words for notes) that summarizes the results and conclusions in concise and declarative prose. Abstracts should neither list the contents (this is presented; that is discussed) nor review the methods. Literature citations and footnotes are not allowed in abstracts. Abstracts obviate the need for formal text summaries. Because they are widely circulated by abstracting services, abstracts have much larger readerships than do full papers, and the abstract should represent the text fairly and accurately.

Introduction.—An introduction should set the context for the work to be reported and establish the purpose and importance of that work. It also should demonstrate the authors' awareness of the most pertinent literature, including review articles. However, a comprehensive literature survey may be deferred to the discussion section if this is more appropriate.

Study site.—A report of field studies may need a detailed site description, which can be given in a separate section of the manuscript. Limit the information to that needed for an understanding and interpretation of the results. If only a few words are needed to locate and describe the study site, include them in the introduction or methods. Maps are unnecessary if they only give information contained in standard atlases.

Methods.—Methodologies can be tedious to read, but it is better to be overly explicit than to omit details needed by a reader to evaluate the data or repeat the study. Previously published descriptions of equipment and procedures may be cited by reference, unless they are in theses, dissertations, agency reports, or other sources of limited availability. Clarity of expression is as important in the methods section as it is elsewhere in the paper. If the experimental protocol and equipment are particularly complex, they can be displayed in a table or figure. Similarly, the numerous variables needed for some mathematical developments may be listed and defined in a table.

Long papers that report diverse research may benefit if methodological details are split up and regrouped together with the respective results. This can help the reader to associate the data with the respective procedures. In such cases, a formal methods section can be restricted to matters common to all or most of the experiments: sources of fish, equipment, chemical analyses, or statistical tests, for example.

Some papers, such as those concerned wholly with techniques or models, as well as review articles, may need no separate methods section.

Results.—Results traditionally follow methods, and need not be explicitly labeled as such if a more descriptive subheading is available. If results are presented in tables or figures, it is pointless to describe them exhaustively in prose as well; the text can be devoted to summary statements and analyses. Display data in tables if precision is important, in figures if trends are paramount. Although long lists of raw data are undesirable, basic data should not be refined to the degree that a reader can neither verify the analyses nor use the information for other purposes. Statistical testing is an important part of most analyses, but it should not obscure biological insight. Most importantly, the statistical designs and models used should be appropriate for the study. Many criticisms of fishery work address statistical flaws; consult experts as necessary. Although most scientific decisions are based on a statistical probability of error of 5% or less, we have no requirements regarding significance levels. Decision probabilities should balance the sacrifice of biological information against the consequences of being wrong.

Discussion.—The value of a paper can be greatly enhanced by a good discussion. This is the place to relate what has been learned to what is known, to create new syntheses, to search for generalities, to establish basic principles. The weakest discussions are brief literature surveys appended to mechanical restatements of the results; these usually should be integrated with the results in a single section of the paper. The strongest discussions are true scientific essays that materially advance understanding of their respective fields, whether they concern fishing mortality or ecosystem function.

Most discussions fall between these extremes because they are founded on limited research objectives, but a thoughtful and scholarly discussion can transform a pedestrian paper into a remarkable one.

The quality of a discussion is inversely related to redundancy, wordiness, and unfounded speculation. It is better not to make a point than to burden it with a paragraph of qualifications. The work of others, when cited, should be attributed carefully and accurately. Transitions from evidence to intuition need explicit identifications.

Acknowledgments.—Place grant and contribution numbers in the acknowledgments. Acknowledge only people and institutions that contributed directly to the research or to the manuscript's quality. The psychic support of spouse, family, and friends can be rewarded in other ways.

References.—Select references with caution. We will not allow reference to progress reports, to unpublished papers or abstracts of papers given at conferences, or to manuscripts in preparation or under review—except to acknowledge (in the acknowledgments section) intellectual debt. Although theses, dissertations, final reports, and institutional documents of limited or no circulation often contain useful data and may be cited, such sources rarely have been subjected to external review and should be cited sparingly. Authors may be requested to provide unpublished reports if they are required by the referees. Reliance on unpublished reports reduces an author's credibility. If unpublished data or personal communications must be cited, do so parenthetically in the text, giving initials, surname, and affiliation (not address) of the source; for example, (A. B. Jones, Institute for Aquatics, personal communication). Obtain written permissions from the appropriate people to cite unpublished data and personal communications, and be prepared to show such letters to the editor.

Literature citations in the text take either of two forms, depending on the context. Note the punctuation in the following examples.

(1) Johnson (1995), Jones and Smith (1996, 1998), Rice et al. (1997), and Berger (in press) found walleyes in Lake Pollock.

(2) Walleyes occur in Lake Pollock (Johnson 1995; Jones and Smith 1996, 1998; Rice et al. 1997; Berger, in press).

Cite both of two authors, but for three or more give only the first author plus ''et al.'' Arrange multiple citations chronologically (oldest first) in a text sentence.

If their names are long, institutional authors may be cited as acronyms in the text, but such acronyms must be defined in the references. For example, ''APHA et al. (1992)'' cited in the text appears in the reference list as ''APHA (American Public Health Association), American Water Works Association, and Water Environment Federation. 1992.'' Cite ''in press'' for papers accepted for, but still awaiting, publication.

In the reference list, alphabetize entries first by the surnames of first authors or by the first word or acronym of corporate authors, then by the initials of first authors with the same surname, and finally by the surnames of coauthors. List multiple papers by the same author(s) chronologically by year of publication. Distinguish papers by the same author(s) in the same year by lowercase letters after the year (1998a, 1998b). Substitute ''in press'' for the year if a paper has been accepted for publication but page numbers are not yet available.

Completely spell out all bibliographic information, *including serial titles.* We allow only these abbreviations:

(1) first and middle initials of authors and editors;

(2) abbreviations that occur in the titles of articles and books and in the names of authors;

(3) ordinal numbers (2nd edition, 4th congress) other than those spelled out in titles.

Examples of common bibliographic formats follow.

(1) Articles in journals and other periodicals listed in *BIOSIS Serial Sources* (BIOSIS, Philadelphia), but see exception for AFS book series in (3) below: author(s); year; title; serial; volume; issue (if needed); inclusive pages. Include the issue number only when each issue starts with page 1.

Crawshaw, L. I., D. E. Lemons, M. Palmer, and J. M. Messing. 1982. Behavioral and metabolic aspects of low-temperature dormancy in the brown bullhead, *Ictalurus nebulosus.* Journal of Comparative Physiology B 148:41–47.

Hochachka, P. W. 1990. Scope for survival: a conceptual ''mirror'' to Fry's scope for activity. Transactions of the American Fisheries Society 119:622–628.

Kennedy, V. S. 1990. Anticipated effects of climate change on estuarine and coastal fisheries. Fisheries 15(6):16–24.

Kent, M. L., G. S. Traxler, D. Kieser, J. Richard, S. C. Dawe, R. W. Shaw, G. Prosperi-Porta, J. Ketcheson, and T. P. T. Evelyn. 1998. Survey of salmonid pathogens in ocean-caught fishes in British Columbia, Canada. Journal of Aquatic Animal Health 10:211–219.

(2) Book: author(s); year; title; edition (other

than 1st) or volume (if part of a series); publisher; city; state, province, or country (only if needed to locate city). Omit the number of pages.

APHA (American Public Health Association), American Water Works Association, and Water Environment Federation. 1992. Standard methods for the examination of water and wastewater, 18th edition. APHA, Washington, D.C.

Hoar, W. S., and D. J. Randall, editors. 1988. Fish physiology, volume 11, part B. Academic Press, New York.

Rheinheimer, G. 1985. Aquatic microbiology, 3rd edition. Wiley, New York.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. America Fisheries Society, Monograph 7, Bethesda, Maryland.

(3) Article in a book (including those in the AFS ''serial'' books—Special Publications, Symposia, and Monographs): author(s); year; title; inclusive pages; editor(s); book title; publisher; series name (if appropriate); city; state, province, or country (only if needed to locate city). Identify conference proceedings by year of publication, *not* by the year of the meeting, and give the publisher's name and location (i.e., where the proceedings may be obtained), *not* the location of the meeting.

Adams, S. M., and J. E. Breck. 1990. Bioenergetics. Pages 389–415 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Campton, D. E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: what do we really know? Pages 337–353 *in* H. L. Schramm, Jr. and R. G. Piper, editors. Uses and effects of cultured fishes in aquatic ecosystems. American Fisheries Society, Symposium 15, Bethesda, Maryland.

Livingstone, A. C., and C. F. Rabeni. 1991. Food–habitat relations of underyearling smallmouth bass in an Ozark stream. Pages 76–83 *in* D. C. Jackson, editor. The first international smallmouth bass symposium. Mississippi Agriculture and Forestry Experiment Station, Mississippi State University, Mississippi State.

(4) Dissertation or thesis: author; year; title; dissertation; university; city; state, province, or country (only if needed to locate city).

Chitwood, J. B. 1976. The effects of threadfin shad as a forage species for largemouth bass in combination with bluegill, redear, and other forage species. Master's thesis. Auburn University, Auburn, Alabama.

Hartman, K. J. 1993. Striped bass, bluefish, and weakfish in the Chesapeake Bay: energetics, trophic linkages, and bioenergetics model applications. Doctoral dissertation. University of Maryland, College Park.

(5) Government publication: author(s) or agency; year; title; agency; type and number of publication; city; state, province, or country (only if needed to locate city).

EPA (U.S. Environmental Protection Agency). 1986. Quality criteria for water. EPA, Report 440/5-86-001, Washington, D.C.

Gimbarzevsky, P. 1988. Mass wasting on the Queen Charlotte Islands: a regional inventory. British Columbia Ministry of Forests and Lands, Land Management Report 29, Victoria.

(6) Contract report: author(s); year; title; organizations that issued the report (if different from the author); organization that received the report; receiver's city; state, province, or county (only if needed to locate city).

Smith, A. B. 1986. Turbine-induced fish mortality at Highrise Dam, 1985. Report of Robertson Consultants to Prairie Utilities, Jonesville, Alberta.

(7) Internet citations: author(s) or agency; year; title; publisher; URL; month and year accessed.

Baldwin, N. A., R. W. Saalfield, M. R. Dochoda, H. J. Buettner, and R. L. Eshenroder. 2000. Commercial fish production in the Great Lakes 1867–1996. Great Lakes Fishery Commission. Available: www.glfc.org/databases/commercial/commerc.asp. (September 2000).

Note that only the first words and proper nouns of English titles are capitalized. In German titles, all nouns are capitalized. Retain italics when they are used in the titles cited.

Footnotes.—Bring all text footnotes together after the references. Keep them to a minimum. Typical footnotes give address changes for authors, availability of supplementary data, and disclaimers of product endorsement. Most other material, including personal communications (which also should be minimized), can be included in the text or the acknowledgments.

Tables.—Organize tables to convey the greatest amount of coherent information with the least amount of wasted space and redundancy. One practical constraint is the width of a journal's printed column or page (69 mm and 143 mm, respectively, in this journal). If necessary, we will split wide tables across facing pages. We do not print tables broadside (landscape) on the page; however, tables may be printed in landscape format for review purposes. In most cases, problems of space can be minimized if a table is oriented such that the number of columns is less than the number of rows. Even within these constraints, it frequently is possible to combine small but related tables into a single concise and definitive statement.

Place a zero to the left of the decimal point for fractions smaller than one. Pay attention to the number of significant digits, regardless of what a computer may have printed out. Although fractions of a percent may be statistically justified in some cases, they rarely convey more meaning in fisheries work than do rounded, whole percentages.

Use the table caption or footnotes to identify nonstandard symbols and abbreviations. Footnotes take lowercase letter superscripts, which occur in alphabetical order. List footnotes below the table.

In column and row headings, capitalize only the first word, proper nouns, and appropriate symbols. Horizontal ruled lines seldom are needed in the body of tables, and vertical lines are never allowed. Use line spacing of at least 1.5 for the caption and entries and continue the table on additional pages, if necessary. *Do not* reduce type size for tables.

Figure captions.—List all figure captions sequentially on one or more pages. Identify in the captions all symbols that are not standard or defined on the figures, and include full disclosure whenever digital images have been electronically manipulated or enhanced.

Figures.—Print photographs on glossy paper with good contrast; place symbols and scale bars so they are at least 4 mm inside the outer edges of a photograph. We will not accept xerographic copies of figures or typewritten figure labels for publication. When the substitution is feasible, we prefer line drawings to halftone illustrations. Color photos will be printed in black and white unless the author has made prior arrangements with the Journals Manager to cover the additional cost of color printing.

Labels should describe the *x*- and *y*-axes clearly. Place the *y*-axis label to the left of the axis and orient it to read sideways from bottom to top of the graph. Photomicrographs may be reduced during printing and should contain a scale bar directly on the photograph; give the equivalent length either on the bar or in the figure caption.

Most line drawings can be adequately reproduced in a single column of this journal (69 mm wide) if the lettering and data symbols are sufficiently large. All letters should be at least 1.5 mm high (or 6-point type) after the figure is reduced; avoid bold fonts. A figure that is 20 cm wide when drawn can reduce to one column if the smallest original lettering is at least 4.5 mm high (18-point type). Letter size and line thickness (including axes) should vary no more than twofold on a figure. Figure reduction can cause symbols and shadings to look alike, dashed lines to become continuous, and dotted lines to disappear, so choose elements that will retain their clarity and contrast when reduced and published. Keep graphics simple and uncluttered. Avoid unnecessary use of three-dimensional charts, black borders, and shaded fill. If shaded fill *is* used, keep it in the range of 30–70% of black for best reproduction. Keep blank space to a minimum by placing axis labels near the axes, multiple panels close together, and ‘‘outlier’’ words (compass directions, scale bars, keys) within the margins of the figure. Carefully planned figures enhance a paper’s message and can reduce authors’ publication costs.

Symbols and Abbreviations

The following symbols and abbreviations, as well as others approved for the Système International d'Unités (SI) are used in *Transactions* without definition. All others must be defined at first mention.

Prefixes

giga	(10^9)	G
mega	(10^6)	M
kilo	(10^3)	k
milli	(10^{-3})	m
micro	(10^{-6})	μ
nano	(10^{-9})	n
pico	(10^{-12})	p

Time and Temperature

day	d
degrees Celsius	°C
hour (spell out for diel time)	h
kelvin	K
minute	min
second	s

Spell out year, month, week.

Weights and Measures

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m

Spell out metric ton.

Mathematics and Statistics

all standard mathematical signs, symbols, and abbreviations	
base of natural logarithm	*e*
common test statistics (*F*, *t*, etc.)	
correlation or regression coefficient (multiple)	*R*
correlation or regression coefficient (simple)	*r*
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
logarithm (specify base)	log
minute (angular)	′
not significant	NS
percent	%
probability	*P*
probability of type I error (false rejection of null hypothesis)	P_α or α
probability of type II error (false acceptance of null hypothesis)	β
radian	rad
sample size	
population	*N*
sample	*N* or *n*
second (angular)	″
standard deviation	SD
standard error	SE
steradian	sr
variance	
population	*V* or Var
sample	var

Physics and Chemistry

all atomic symbols	
alternating current	AC
ampere	A
becquerel	Bq
calorie (joule is preferred)	cal
candela	cd
chemical acronyms listed in Webster's dictionaries (DDT, EDTA, etc.)	
coulomb	C
dextro configuration	D
dextrorotary	*d*
direct current	DC
electron volt	eV
equivalent	eq
farad	F
gray	Gy
hertz	Hz
hydrogen ion activity (negative log of)	pH
joule	J
levo configuration	L
levorotatory	*l*
lumen	lm
lux	lx
molar	M
mole	mol
newton	N
normal	N
ohm	Ω
ortho	*o*
para	*p*
pascal	Pa
per mille (per thousand)	‰
siemens (=mho, Ω^{-1})	S
tesla	T
tris(hydroxymethyl)-aminomethane	tris
volt	V
watt	W
weber	Wb

General (Some Are Restricted)

compass directions (maps and coordinates):	
east	E
north	N
south	S
west	W
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii	et al.
et cetera	etc.
filial generation	F
for example	e.g.,
international unit	IU
months (in tables, figures): first three letters (e.g., Feb, Jun, Sep)	
ploidy	n
sex (in tables, figures, hybrid crosses):	
female	♀
male	♂
that is	i.e.,
United Kingdom	UK
United States (adjective)	U.S.
United States of America (noun)	USA

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Effects of Reservoir Hydrology on Reproduction by Largemouth Bass and Spotted Bass in Normandy Reservoir, Tennessee

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Abstract.—Age-0 largemouth bass *Micropterus salmoides* and spotted bass *M. punctulatus* were collected from Normandy Reservoir, Tennessee, 1992–1996, to evaluate effects of reservoir hydrology and hatching of shad *Dorosoma* spp. on hatching and first-year growth and survival of these two species. Fish were collected in cove rotenone samples in early August and electrofishing samples biweekly throughout the summer; hatch dates and age-specific growth for both species were determined from cove samples with sagittal otoliths. Hatching of both species ranged from early April to early June. Initiation of largemouth bass spawning, but not spotted bass spawning, was positively related to the first day water levels achieved full pool. Mean hatch dates of both species were positively related to the first day of full pool. Timing of spawning for both species was not related to water temperature. Largemouth bass exhibited bimodal length-frequency distributions by midsummer in two wet years and length frequencies were unimodal in dry years; spotted bass always formed unimodal length-frequency distributions. When largemouth bass exhibited bimodal length distributions, earlier hatched fish grew faster than later hatched fish. Spotted bass grew at similar rates, regardless of hatch date, every year except during 1992 when later hatched fish grew faster than earlier hatched fish. Weekly survival of largemouth bass in their first summer was positively related to reservoir water level. First-year growth of both species was not directly affected by the timing of threadfin shad *D. petenense* or gizzard shad *D. cepedianum* hatching.

Southeastern U.S. reservoirs often experience water level fluctuations that substantially affect age-0 fish populations. High water levels inundate shoreline cover, providing increased foraging opportunities and reduced predation; low water levels result in reduced shoreline cover and increased predation on age-0 fish (Willis 1986). Management of reservoir water levels has traditionally been driven by guide curves calculated from hydrologic and economic factors that place little or no emphasis on fish populations. Increasing recognition of the economic and social importance of quality angling opportunities has raised the priority of fisheries management in reservoir operations. However, without data on the relationships between hydrologic variables and fish populations, it is doubtful that hydroelectric dam operators will be receptive to modifying existing guide curves.

Previous studies on the effects of water levels on age-0 black bass growth, survival, and recruitment have lacked quantitative relationships between water level data and these characteristics. Several studies examined the effects of water levels on age-0 largemouth bass *Micropterus salmoides* but did not focus on relationships between water level and biological variables such as hatch dates and age-specific growth (Aggus and Elliott 1975; Keith 1975; Miranda et al. 1984). Few studies have been published on the effects of water levels on reproduction or first-year growth, survival, and recruitment of spotted bass *Micropterus punctulatus.*

In addition to water level fluctuations, the timing of spawning by threadfin shad *Dorosoma petenense* also affects largemouth bass recruitment (Adams et al. 1982). Computer models predicted that if bass spawn earlier than shad, then age-0 large-

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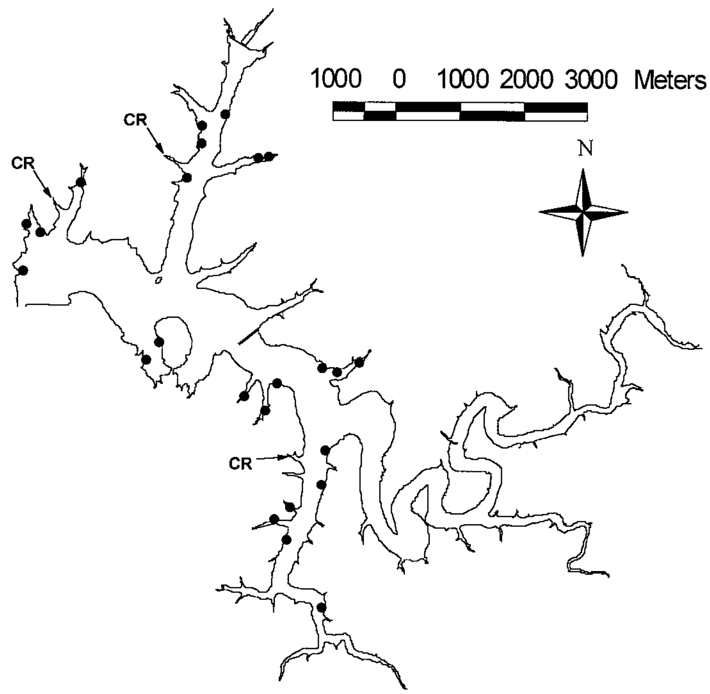

FIGURE 1.—Map of Normandy Reservoir, Tennessee, with sampling sites indicated; CR denotes coves sampled with rotenone ($N = 3$) and filled circles represent hand-held electrofishing sites ($N = 24$).

mouth bass would be more likely to prey on age-0 shad throughout the growing season, leading to larger sizes and better survival by the end of their first year (Adams and DeAngelis 1987). However, other studies have suggested that the relationship between shad and bass is probably more complex than originally thought (Jackson et al. 1991; Phillips et al. 1995). Our objectives were to relate variations in hatching periodicity, growth rates, and survival of age-0 largemouth bass and spotted bass to water level fluctuations and timing of the shad spawn during a 5-year period in Normandy Reservoir, Tennessee.

Study Area

Normandy Reservoir is a 1,307-ha eutrophic tributary impoundment on the upper Duck River in south-central Tennessee. Impounded in 1976, Normandy Reservoir is operated by the Tennessee Valley Authority and serves as a flood control and water supply impoundment. At full pool, Normandy Reservoir is 27 km long, has a shoreline length of 116 km, a mean depth of 11.2 m, and a shoreline development index of 9.0. The water level is drawn down 3.1 m each fall and returned to full pool in the spring. The most common sport and prey fishes of Normandy Reservoir include largemouth bass, spotted bass, smallmouth bass *Micropterus dolomieu,* black crappies *Pomoxis nigromaculatus,* white crappies *P. annularis,* white bass *Morone chrysops,* saugeyes *Stizostedion vitreum* × *S. canadense,* gizzard shad *Dorosoma cepedianum,* and threadfin shad. Submergent and emergent vegetation is scarce due to fluctuating water levels, steep shoreline slopes, and abundance of rocky substrates.

Methods

Age-0 bass were collected from 1992 to 1996 in cove rotenone and electrofishing samples. Three coves were treated with rotenone at 1.5 mg/L during the first week of August each year (Figure 1). Total area sampled was 2.11 ha (5.22 acres) and maximum depths ranged from 4.6 to 7.6 m. Fish were collected for 2 d and all age-0 bass were returned to the laboratory for otolith removal. In 1995 and 1996, ages were estimated for all bass collected; fish were randomly subsampled in other years. Twenty-four 100-m transects were sampled every 2 weeks from July through September with a DC electrofishing unit and a hand-held anode (Jackson and Noble 1995). All age-0 bass were identified to species, measured for total length (TL, mm), and released. Once fish recruited to the gear,

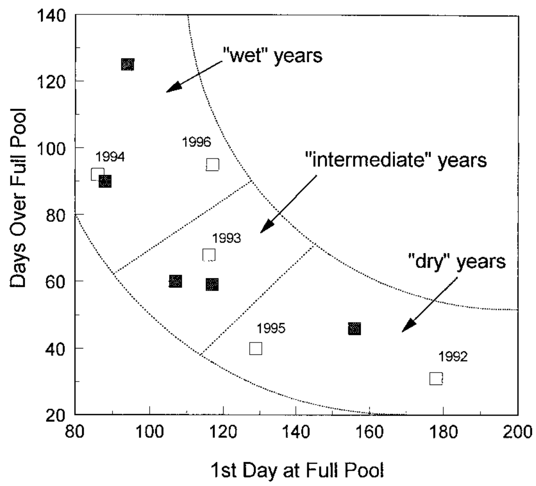

FIGURE 2.—Hydraulic plot of first calendar day at full pool versus number of days at or above full pool between April 1 and September 1 for each year from 1985 to 1996 in Normandy Reservoir, Tennessee. Open squares represent the years during this study, dark squares denote previous years, and dotted lines represent proposed demarcations between wet, intermediate, and dry years. Note that the reservoir did not attain full pool during two prestudy years.

weekly survival rates were calculated from electrofishing catch data by regressing the natural logarithm of catch against time. The slope of this regression (–Z) was then raised by an exponent equal to the number of weeks between peak catch and the last sample (7 in 1992, 8 in all other years); survival estimates were derived from the antilog of this product.

Larval shad were collected each year at night from 16 fixed sites using a 1 × 2-m neuston net (1-mm mesh) equipped with a flowmeter. Samples were collected weekly in April and May and biweekly in June and July ($N = 12$). Water temperatures were taken each week at a mid-lake location. Tow duration was usually 5 min unless large amounts of debris and invertebrates forced a reduction in towing durations to prevent clogging of the net. Samples were fixed immediately with 10% formalin and later preserved in ethanol. Shad in each sample were counted, and a random sample (>20) was measured (TL, mm) and identified to species. Given the short time between fertilization of eggs and hatching and the rapid growth of shad larvae, we assumed that catch of shad in neuston samples gave an accurate representation of the timing of shad spawning periods (Sammons et al. 1998).

Bass otoliths were mounted with thermoplastic cement, convex side down, on glass microscope slides. Daily age was determined by following the methods described by DiCenzo and Bettoli (1995). Hatch dates of individual bass were determined by using the equation modified by DiCenzo (1993):

$$\text{hatch} = \text{date} - \text{age} - X:$$

hatch = estimated hatch date,
date = calendar day of capture,
age = mean number of growth rings counted, and
X = number of days between hatching and formation of first daily increment.

Formation of the first daily increment was assumed to occur 5 d after hatch for largemouth bass and spotted bass (Miller and Storck 1984; DiCenzo and Bettoli 1995). Incremental growth rates were determined by dividing length (mm) by age (d). Only those fish collected in cove rotenone samples were used to obtain hatch dates and age-specific growth for both species, because cove samples allowed a large number of juvenile fish to be collected during a short period of time with minimal bias towards size, age, or habitat use (Reinert et al. 1997).

All statistical analyses were performed using procedures written for the Statistical Analysis System (SAS Institute 1995). Because of low sample size (5 years), significance was set at $P = 0.10$. Linear regression was used to examine relationships between water level fluctuations and hatching periodicity, growth rates, and survival of largemouth bass and spotted bass. One-way analysis of variance (ANOVA) was used to compare mean hatch date and mean TL of both species. If a significant relationship existed, means were compared using Tukey's studentized range test. Analysis of covariance (ANCOVA) was used to compare adjusted mean growth rates among years when a significant linear relation existed between hatch date and growth rate. Adjusted means were not compared unless slopes of the regression lines were similar ($P > 0.10$).

Results

Water Levels

The manner in which water levels rose each spring varied greatly among years. In two dry years (1992 and 1995), water levels were slow in coming up to full pool. During the spring of 1992 water levels did not reach full pool until July 1 (day 178; Figure 2). In 1995, the reservoir did not

TABLE 1.—Hatch date parameters for age-0 largemouth bass and spotted bass collected in cove rotenone samples from Normandy Reservoir, Tennessee, 1992–1996. Temperature is midlake water temperature taken during week that first hatch occurred for each species. Within a species, mean hatch dates followed by the same letter were similar (Tukey's test, $P = 0.10$).

Year	First day at full pool	Temperature (°C)	Date of first hatch	Mean hatch date
		Largemouth Bass		
1992	Jun 26	18.0	May 1	May 27 z
1993	Apr 26	17.5	Apr 23	May 13 x
1994	Mar 27	14.0	Apr 1	May 11 x
1995	May 9	21.0	May 6	May 26 z
1996	Apr 26	13.0	Apr 19	May 18 y
		Spotted Bass		
1992	Jun 26	18.0	May 1	May 26 z
1993	Apr 26	20.0	May 5	May 18 y
1994	Mar 27	20.0	Apr 21	May 8 x
1995	May 9	16.5	Apr 29	May 27 z
1996	Apr 26	20.0	May 6	May 19 y

attain full pool until early May (day 130). In both 1992 and 1995, the reservoir stayed above full pool only briefly (<40 d). In 1993 and 1996, the reservoir reached full pool in late April (days 116–117; Figure 2). In 1993, reservoir water levels stayed above full pool for more than 65 d before falling below full pool in early July, remaining below full pool the rest of the year. In 1994, the reservoir exceeded full pool in late March (days 85–90), and again in early April (days 98–104). In two wet years (1994 and 1996), reservoir levels remained over full pool throughout much of the summer (>90 consecutive days; Figure 2).

Hatch Dates

Largemouth bass hatch durations ranged from 35 to 68 d each year, whereas spotted bass hatch durations ranged from 26 to 42 d each year. Largemouth bass began hatching as early as April 1 and as late as May 6 (Table 1; Figure 3). Mean hatch date of largemouth bass was earliest in 1993 and 1994, approximately a week later in 1996, and latest in 1992 and 1995 (Table 1; $F = 32.11$; df $= 4, 387$; $P = 0.0001$). Spotted bass began hatching as early as April 21 and as late as May 6. Mean hatch date of spotted bass was earliest in 1994, approximately 10 d later in 1993 and 1996, and latest in 1992 and 1995 (Table 1; $F = 60.20$; df $= 4, 310$; $P = 0.0001$). Spotted bass began hatching after largemouth bass in 4 of 5 years, and hatching duration was longer for largemouth bass than spotted bass in every year except 1995. Mean

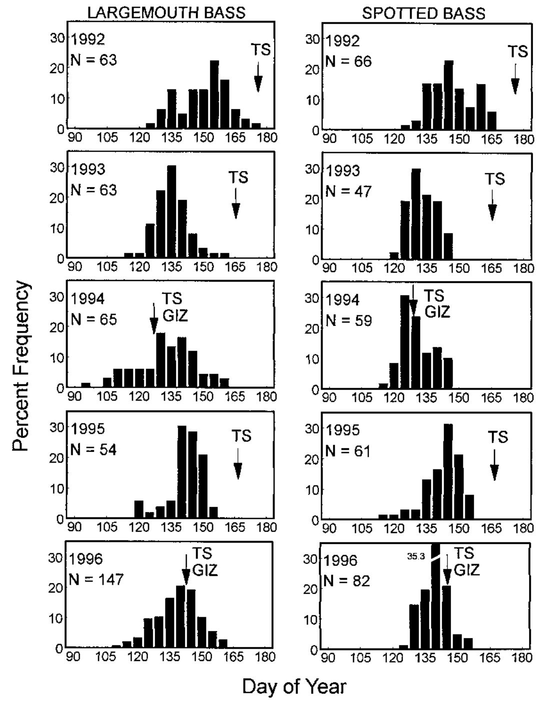

FIGURE 3.—Hatch date distributions of largemouth bass and spotted bass collected in cove rotenone samples from Normandy Reservoir, Tennessee, 1992–1996. Arrows indicate day of calendar year when larval density of threadfin shad (TS) and gizzard shad (GIZ) exceeded 0.1 fish/m^3. Day 120 corresponds to April 30.

hatch dates for both species were similar in 3 of 5 years (Table 1). First hatch day of largemouth bass was positively related to the first day water levels attained full pool in Normandy Reservoir ($r^2 = 0.71$; df $= 1, 3$; $P = 0.078$). First hatch day of spotted bass was not related to reservoir water levels ($r^2 = 0.37$; df $= 1, 3$; $P = 0.3859$). Mean hatch dates of largemouth bass ($r^2 = 0.72$; df $= 1, 3$; $P = 0.0715$) and spotted bass ($r^2 = 0.81$; df $= 1, 3$; $P = 0.0402$) were also positively related to the first day at full pool. Initiation of largemouth bass hatch occurred in water temperatures ranging from 13°C to 21°C, whereas initiation of spotted bass hatch occurred at temperatures ranging from 16.5°C to 20°C (Table 1).

Age-0 threadfin shad began hatching after largemouth bass and spotted bass every year (Figure 3). Initiation of hatching ranged from May 15 to July 25 during the 5-year period. Age-0 gizzard shad were detected in only 2 years, 1994 and 1996, and began hatching after largemouth bass and spotted bass during both years (Figure 3). Gizzard shad reproduction was variable during the study;

TABLE 2.—Mean total length (TL), density, and growth of largemouth bass and spotted bass collected in cove rotenone samples from Normandy Reservoir, Tennessee, 1992–1996. Survival estimates were calculated from electrofishing samples of largemouth bass only. Peak larval density (fish/m^3) of gizzard shad and threadfin shad are from neuston net sampling. For each species, mean growth rates and total lengths followed by the same letter did not differ (Tukey's test, $P = 0.10$).

Year	Mean TL (mm)	Cove density (number/ha)	Mean growth (mm/d)	Weekly survival	Peak density	
					Gizzard shad	Threadfin shad
			Largemouth Bass			
1992	49 z	32	0.697 yz	0.889	0.0004	0.2370
1993	61 x	68	0.677 z	0.831	0.0004	0.6340
1994	56 y	74	0.715 yz	0.924	1.1820	3.2960
1995	45 z	27	0.678 z	0.845	0.0006	0.1780
1996	57 xy	86	0.744 y	0.932	0.5620	1.0520
			Spotted Bass			
1992	48 y	29	0.691 y		0.0004	0.2370
1993	50 xy	49	0.634 z		0.0004	0.6340
1994	52 x	55	0.614 z		1.1820	3.2960
1995	47 z	35	0.704 y		0.0006	0.1780
1996	56 w	51	0.751 x		0.5620	1.0520

peak larval density ranged from 0.0004 to 1.1820 fish/m^3 (Table 2). Threadfin shad reproduction was more consistent but still varied by more than an order of magnitude among years (Table 2).

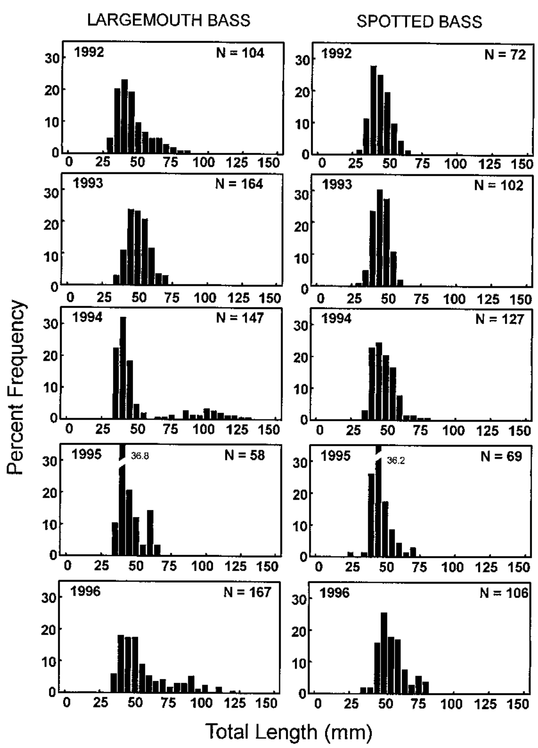

FIGURE 4.—Length-frequency distributions (5-mm increments) of age-0 largemouth bass and spotted bass collected in cove rotenone samples in Normandy Reservoir, Tennessee, 1992–1996.

Growth and Survival

Mean total lengths of age-0 largemouth bass collected in cove samples differed among years ($F = 16.07$; df = 4, 792; $P = 0.0001$). Largemouth bass were larger in 1993, 1994, and 1996 than in 1992 and 1995 (Table 2). Largemouth bass exhibited bimodal length-frequency distributions (i.e., fish greater than 80 mm TL were present) in 1994 and 1996 (Figure 4). In both years, a large cohort occurred in the 35–75-mm-TL range, and a smaller cohort occurred between 75 and 125 mm TL. In contrast, length-frequency distributions for all other years were unimodal and virtually all largemouth bass were less than 80 mm TL. Mean total length of spotted bass was greatest in 1996, intermediate in 1993 and 1994, and smallest in 1992 and 1995 ($F = 19.29$; df = 4, 488; $P = 0.0001$; Table 2). Unlike largemouth bass, spotted bass length-frequency histograms did not exhibit bimodality in any of the 5 years of this study (Figure 4).

In the 2 years when largemouth bass had bimodal length-frequency distributions, largemouth bass that hatched earlier grew faster than those hatching later (Figure 5). In 1994 and 1996, largemouth bass that hatched before May 1 (day 120) grew at rates of 0.5–1.4 mm/d (Figure 5); whereas, age-specific growth of largemouth bass hatching

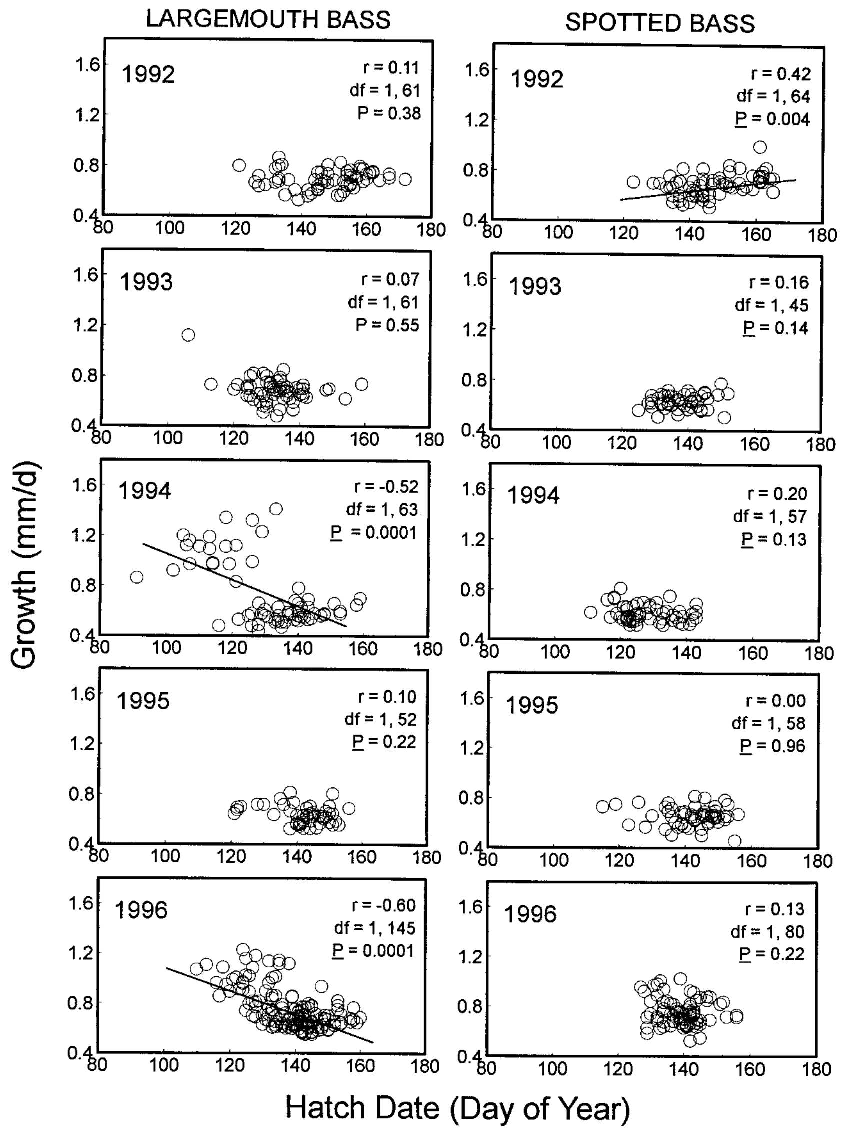

FIGURE 5.—Growth (mm/d) versus hatch date of age-0 largemouth bass and spotted bass collected in cove rotenone samples from Normandy Reservoir, Tennessee, 1992–1996. Probabilities associated with each linear model are indicated.

after May 1 ranged from 0.4 to 0.8 mm/d. No relationship existed between density of largemouth bass in coves and mean growth rates (Table 2; $r^2 = 0.46$; df = 1, 3; $P = 0.21$). The relations between hatch date and largemouth bass growth rate (i.e., slopes) were similar in 1994 and 1996 ($F = 0.01$; df = 1, 208; $P = 0.9440$), but adjusted mean growth rates differed ($F = 15.03$; df = 1, 209; $P = 0.0001$). Age-0 largemouth bass grew 14% faster in 1996 (0.77 mm/d) than in 1994 (0.67 mm/d).

In contrast, spotted bass exhibited differential age-specific growth rates only in 1992, when a positive relationship existed between hatch day and growth (Figure 5). In the other 4 years, spotted bass grew at approximately the same rates (0.4 to 1.0 mm/d) regardless of hatch date (Figure 5). Similar to largemouth bass, no relationship existed between density of spotted bass in cove samples and mean growth rates (Table 2; $r^2 = 0.12$; df = 1, 3; $P = 0.56$).

Weekly survival of age-0 largemouth bass between midsummer and September ranged from 83.1% to 93.2% each year and was positively related to the average August water level (m above or below full pool) of Normandy Reservoir (r^2 = 0.87; df = 1, 4; P = 0.021). Survival was not related to density of age-0 largemouth bass in cove samples (Table 2; r^2 = 0.17; df = 1, 3; P = 0.50). Catch rates of spotted bass with the handheld electrofishing gear were erratic each year; their catch rates did not decline with time, and calculation of survival rates was not possible.

Discussion

Water Levels and Hatch Date Distributions

Water level management in Normandy Reservoir was similar to many other reservoirs across the country (Aggus and Elliott 1975; Ploskey 1986; Miranda and Hubbard 1994) in that a winter drawdown began in August to increase storage capacity in the basin for spring rains. However, the wet years of 1994 and 1996 allowed the reservoir to stay above full pool longer than normal; high water levels in a reservoir often prove beneficial to littoral species such as black bass *Micropterus* spp. (Miranda et al. 1984; Reinert et al. 1997).

Initiation of the largemouth bass hatch corresponded to increasing water levels in Normandy Reservoir. Early water level rises promote spawning of other species including yellow perch *Perca flavescens* and white bass (Martin et al. 1981). However, Kohler et al. (1993) concluded that extreme water level fluctuations disrupted largemouth bass spawning in two Illinois reservoirs; Summerfelt (1975) reported a similar relationship in Lake Carl Blackwell, Oklahoma. Spawning disruption apparently did not occur in Normandy Reservoir because no breaks in hatching occurred and water levels generally rose until reaching full pool in almost every year of this study. Phillips et al. (1995) also documented a continuous hatch of largemouth bass in B.E. Jordan Reservoir, North Carolina, in the presence of spring water level fluctuations.

Although water temperature is commonly linked to initiation of largemouth bass spawning (Kramer and Smith 1962), water temperature did not appear to be an important factor driving the hatch of largemouth bass in Normandy Reservoir. Instead, timing of largemouth bass hatching was governed by rising reservoir water levels when water temperatures were in a range suitable for largemouth bass spawning. In contrast, initiation of spotted bass hatching in Normandy Reservoir was not linked to rising water levels, and similar data from other systems are not available. The effect of temperature on hatching may have been more pronounced for spotted bass than largemouth bass, as evidenced by the narrower range of hatching temperatures observed for this species. Spotted bass prefer spawning cover like largemouth bass do (Vogele and Rainwater 1975), but water levels did not govern the beginning of spotted bass hatching. Water levels did influence when most of the hatching of spotted bass occurred.

Formation of Bimodal Length-Frequency Distributions

Bimodal length-frequency distributions in age-0 largemouth bass have been reported in other systems (Kramer and Smith 1960; Aggus and Elliott 1975; Summerfelt 1975; Shelton et al. 1979; Timmons et al. 1980; Kohler et al. 1993; Miranda and Hubbard 1994). Disruption in spawning activity was believed to create bimodal length distributions in several studies (Kramer and Smith 1960; Summerfelt 1975). However, we detected no spawning interruptions in Normandy Reservoir. Hatch date distributions of largemouth bass indicated continuous spawning from the first hatching date until hatching ceased.

Formation of bimodal length distributions in largemouth bass has been linked to the length of the spawning period. A long spawning season allows early spawning larvae to hatch in a food-rich environment before other fish do (Miranda and Hubbard 1994; Diana 1995; Ludsin and DeVries 1997). Duration of largemouth bass spawning in Normandy Reservoir was longest in 1994, when age-0 largemouth bass exhibited a bimodal length frequency. However, hatching durations were similar in 1996, when largemouth bass had a bimodal length frequency, and 1992, when largemouth bass had a unimodal length frequency. Subsequent electrofishing samples targeted at adult largemouth bass and spotted bass indicated that bimodal and unimodal length frequencies at age 0 persisted for at least 2 years for all year-classes.

Bimodal length distributions have occurred without a protracted or interrupted spawning period (Timmons et al. 1980; Keast and Eadie 1985; Phillips et al. 1995). An early spawning period provides an opportunity for genesis of a bimodal length distribution, and piscivory by age-0 largemouth bass drives the process. DeAngelis and Coutant (1982) used a simulation model to show that size-dependent food availability was responsible for formation of a bimodal length distribution in a year-class of largemouth bass from West Point Reservoir, Georgia. As the growing season progressed, availability of fish prey decreased as prey fishes grew beyond the size vulnerable to young largemouth bass. Age-0 largemouth bass in Bull Shoals Reservoir fed on fish early in high-water years and grew faster than those hatching later, which were not piscivorous (Aggus and Elliott 1975). Phillips et al. (1995) found that all sizes of age-0 largemouth bass ate fewer fish as the season progressed. However, fish hatching earlier shifted back to invertebrates much later and maintained a higher degree of piscivory than fish hatched later. Largemouth bass in Michigan natural lakes switched to piscivory when the proportion of age-0 bluegills *Lepomis macrochirus* vulnerable to predation reached a certain level (Olson 1996). This switch was independent of predator or prey density but was influenced by early growth of bass, while they were still feeding on invertebrates. Once the switch was made to piscivory, growth increased sharply. Ludsin and DeVries (1997) also documented the importance of bluegill prey to survival and growth of largemouth bass in Alabama ponds. Because growth rates are linked to piscivory (Timmons et al. 1980; Gutreuter and Anderson 1985; Bettoli et al. 1992; Miranda and Hubbard 1994; Phillips et al. 1995; Olson 1996; Ludsin and DeVries 1997), fish that can maintain piscivory longer will grow faster than conspecifics that cannot.

Many studies have focused on the importance of shad *Dorosoma* spp. as prey for juvenile largemouth bass (e.g., Adams et al. 1982; Adams and DeAngelis 1987; Jackson et al. 1991; Phillips et al. 1995). If bass can spawn significantly earlier than shad, they will be able to prey on shad throughout their entire first year, attain a larger size by the end of their first growing season, and have higher survival than if they do not feed on shad (Adams et al. 1982; Adams and DeAngelis 1987). However, the time that shad larvae appeared in Normandy Reservoir probably had little effect on largemouth bass or spotted bass growth. Both bass species had completed hatching before peak shad hatches in 3 of 5 years; 40% to 60% of the bass hatched before peak shad hatches in the other years. However, each year-class had substantially different growth rates.

Although the survival and growth of largemouth bass appeared to be correlated with larval gizzard shad densities, the relationships were presumed to be spurious for several reasons. First, survival estimates were calculated for August through September when age-0 gizzard shad were too large to be consumed by age-0 largemouth bass. Second, larval gizzard shad in 1994 and 1996 were 1–2 mm larger on average than age-0 largemouth bass at the initiation of their hatch and 3–12 mm larger in mean length at larval gizzard shad peak densities. Therefore shad larvae in Normandy Reservoir were rarely, if ever, available for predation by age-0 bass. Although shad consumption may be important for age-0 bass growth and survival in some systems, littoral species (e.g., centrarchids, cyprininds, atherinids) are often the principal fish prey of age-0 bass (Timmons et al. 1980; Jackson et al. 1991; Bettoli et al. 1992).

Similar to what we observed at Normandy Reservoir, Aggus and Elliott (1975) found that age-0 largemouth bass had bimodal length distributions and grew faster in years of high spring water levels and exhibited unimodal length distributions and grew slower in low water years. However, Ludsin and DeVries (1997) found that largemouth bass that hatched earlier had slower growth rates than later hatched fish at the same age. The early cohort hatched into lower water temperatures than the later cohorts, thus depressing growth rates. However, fish in the early cohort were still considerably larger than fish in the later cohort simply because they had more time to grow. Formation of bimodal length-frequency distributions by largemouth bass in Normandy Reservoir was probably a result of earlier hatched fish gaining a growth advantage over their later hatched counterparts. When Normandy Reservoir achieved full pool on or before May 1 and remained at full pool for an extended period of time (90+ days), bimodal length frequencies occurred. The combination of these two factors allowed an extended period when earlier hatched fish could forage more effectively, presumably on fish, and obtain growth advantages over fish hatched later in these same years. In all other years when these two water level conditions (early and extended full pool) were not present, length frequencies of largemouth bass were unimodal, virtually no individuals exceeded 80 mm by early August, and fish that hatched earlier grew at rates similar to those of fish hatched later. Bimodal length frequencies characterize populations of fast-growing largemouth bass with high survival rates (Timmons et al. 1980; Miranda and Hubbard 1994).

Unlike largemouth bass, the early life history of spotted bass in Normandy Reservoir was not tightly linked to water levels. Spotted bass inhabit deeper water than largemouth bass and often spawn deeper (Vogele 1975). Mean nest depth for spotted bass ranged between 2.3 and 3.7 m in Bull Shoals Reservoir, Missouri (Vogele 1975), and was 2.6 m in Perris Reservoir, California (Baracco 1979). Mean nest depth of largemouth bass over its range is 0.6 m (Carlander 1977). Deeper nesting depths may make spotted bass less susceptible to the effects of water level fluctuations (Baracco 1979), although this topic deserves further scrutiny in Normandy Reservoir and elsewhere. Reinert et al. (1997) related age-0 spotted bass abundance to reservoir hydrology in three of the four reservoirs they examined; however, specific life history characteristics were not examined.

Water Levels and Late-Summer Survival

Weekly survival of age-0 largemouth bass in Normandy Reservoir was positively related to summer water levels. Increased survival of largemouth bass in response to higher summer water levels has been documented in other tributary storage impoundments. Aggus and Elliott (1975) documented that the strongest year-classes in Bull Shoals Lake, Arkansas, were produced in years of high inflow and high summer water levels. High summer water levels were also linked to high survival of age-0 largemouth bass in West Point Lake, Alabama–Georgia (Miranda et al. 1984); inundation of vegetation presumably decreased predation and provided a better foraging environment for young largemouth bass. Similarly, summer drawdowns in Kansas reservoirs were shown to reduce largemouth bass abundance, presumably by exposing young fish to increased predation in the absence of shoreline cover (Willis 1986). High water also enhanced largemouth bass year-class strength in the Illinois River (Raibley et al. 1997). In fact, high water levels and wet summers have been shown to benefit largemouth bass recruitment in most systems except mainstream impoundments of large rivers such as the Tennessee River (Maceina and Bettoli 1998).

Increased survival of age-0 largemouth bass can decrease their first-year growth (Miranda and Hubbard 1994). However, this relationship was not apparent in Normandy Reservoir. Instead age-0 largemouth bass had bimodal length distributions in the same years they experienced the highest survival. Also, largemouth bass growth rates and survival were highest during years when densities were highest. Years in which age-0 largemouth bass density was low were characterized by reduced growth, lower survival, and smaller largemouth bass sizes at the end of the growing season.

Management Implications

Our results contribute to a growing body of literature that describes how water level management can play a pivotal role in producing faster-growing juvenile largemouth bass. Our results defined the combination of hydraulic factors (reaching full pool early in spring; maintaining full pool for at least 90 d) that allowed largemouth bass in Normandy Reservoir to hatch early and experience rapid growth and good survival. This knowledge is especially important in flood control reservoirs (such as Normandy Reservoir) where other environmental factors known to influence the early life history of largemouth bass (e.g., vegetation) are absent and cannot be manipulated. Although additional sampling and analyses are required to demonstrate that high water levels ultimately resulted in more largemouth bass recruiting to the fishery, the recruitment process in other reservoirs is strongly linked to the size that individual bass reach before their first winter (e.g., Miranda and Hubbard 1994; Ludsin and DeVries 1997).

We were unable to demonstrate a linkage between water levels and the early life history of spotted bass. Although the mean hatch date of spotted bass varied with spring water levels, this variation did not translate into detectable effects on growth or survival. Little published information exists on the dynamics of spotted bass populations, probably because they usually occur sympatrically with largemouth bass, and reservoir fisheries managers devote most of their management efforts towards the latter species. In Normandy Reservoir and many other Tennessee reservoirs, spotted bass are a major component of the sport fishery. Since 1991, spotted bass have represented about 40% of the total black bass catch and 60% of the black bass harvest in Normandy Reservoir (largemouth bass are protected with a 381-mm minimum size limit; TWRA 1996). As fisheries biologists continue their efforts to restrict largemouth bass harvests to conserve those fisheries, spotted bass populations will continue to meet the needs of those anglers seeking to harvest bass. Given the paucity of information on spotted bass in southern U.S. reservoirs, additional research into their ecology appears to be warranted.

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