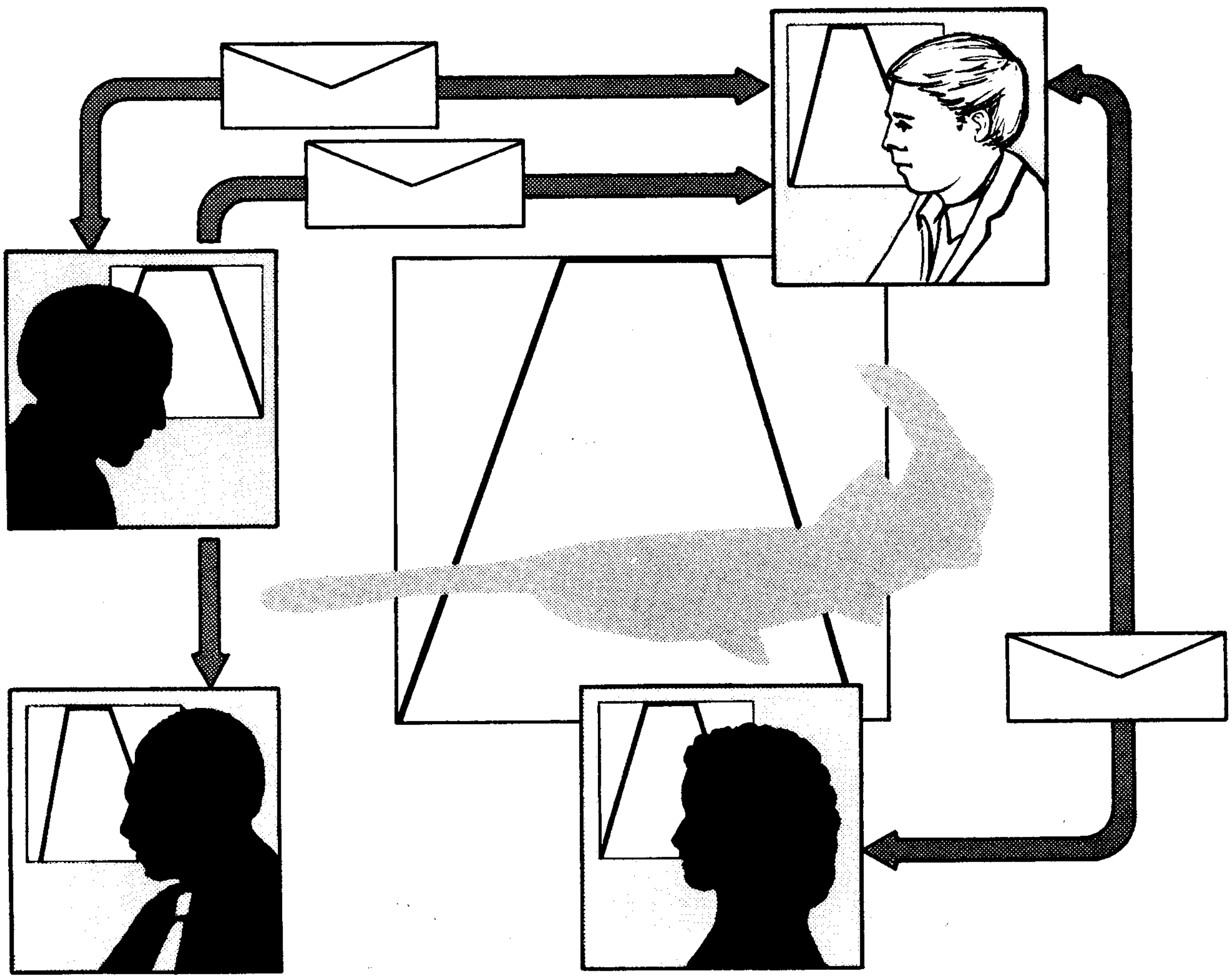
BIOLOGICAL REPORT 82(10.134)
APRIL 1987

GUIDELINES FOR USING THE DELPHI TECHNIQUE TO DEVELOP HABITAT SUITABILITY INDEX CURVES



Fish and Wildlife Service

U.S. Department of the Interior

Biological Report 82(10.134)
April 1987

GUIDELINES FOR USING THE DELPHI TECHNIQUE TO DEVELOP HABITAT SUITABILITY INDEX CURVES

by

Johnie H. Crance
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

National Ecology Center
Division of Wildlife and Contaminant Research
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This report should be cited as:

Crance, J.H. 1987. Guidelines for using the Delphi technique to develop habitat suitability index curves. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.134). 21 pp.

CONTENTS

ACKNOWLEDGMENTS

The following reviewers are gratefully acknowledged for useful comments on earlier drafts of this paper: Prescott Brownell, U.S. Fish and Wildlife Service, Ecological Services, Charleston, South Carolina; Jim Henriksen, U.S. Fish and Wildlife Service, National Ecology Center, Fort Collins, Colorado; Mel Schamberger, U.S. Fish and Wildlife Service, National Ecology Center, Fort Collins, Colorado; J.S. Wakely and an anonymous reviewer, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi; and Douglas Winford, U.S. Fish and Wildlife Service, Ecological Services, Cookeville, Tennessee.

Word processing was provided by Elizabeth Barstow, Patricia Gillis, and Dora Ibarra. Funding for preparation and publication was provided by the Terrestrial Systems Branch of the National Ecology Center. The cover was designed by Susan Strawn. Editorial assistance was provided by Jim Zuboy.

INTRODUCTION

Habitat Suitability Index (SI) curves are one method of presenting species habitat suitability criteria. The curves are often used with the Habitat Evaluation Procedures (HEP) and are necessary components of the Instream Flow Incremental Methodology (IFIM) (Armour et al. 1984). Bovee (1986) described three categories of SI curves or habitat suitability criteria based on the procedures and data used to develop the criteria. Category I curves are based on professional judgment, with little or no empirical data. Both Category II (utilization criteria) and Category III (preference criteria) curves have as their source data collected at locations where target species are observed or collected. Having Category II and Category III curves for all species of concern would be ideal. In reality, no SI curves are available for many species, and SI curves that require intensive field sampling often cannot be developed under prevailing constraints on time and costs. One alternative under these circumstances is the development and interim use of SI curves based on expert opinion. The Delphi technique (Pill 1971; Delbecq et al. 1975; Linstone and Turoff 1975) is one method used for combining the knowledge and opinions of a group of experts. The purpose of this report is to describe how the Delphi technique may be used to develop expert-opinion-based SI curves.

Delphi was the name of a meeting site in ancient Greece where Oracles (people through whom a deity was believed to speak) met, held discussions, and gave wise or authoritative decisions or opinions. The modern day Delphi was first applied to a strategic planning exercise sponsored by the United States Air Force in about 1953 (Dalkey and Helmer 1963). Subsequently, the methodology was widely accepted and applied in corporate planning (Fusfeld and Foster 1971) and used in the field of renewable resources management (Ludlow 1972a,b; Zuboy 1981; Heller et al. 1983). More recently, it has been used to develop expert-opinion-based SI curves for some fish species (Crance 1984, 1986, 1987a,b; Stier and Crance 1985).

Pill (1971) gave a comprehensive review of the Delphi technique and provided an annotated bibliography on the subject. Basically, a Delphi exercise is a discussion by knowledgable participants in hopes of reaching an agreeable conclusion. The concept is based on the premises that: (1) opinions of experts are justified as inputs to decisionmaking where absolute answers are unknown; and (2) a consensus of experts will provide a more accurate response to a question than a single expert. If these premises are valid or acceptable to those that will receive and act on the product of the exercise, the conclusions reached (or SI curves developed using the technique) should have utility.

At least three separate groups of individuals that perform three different roles are needed to conduct a Delphi exercise (Turoff 1970): (1) the decision-makers--the group that will receive and act on the product of the exercise; (2) a group (or person) that designs the initial questionnaire, summarizes the returns, and redesigns the follow-up questionnaire; and (3) a respondent group whose judgments are being sought and are asked to respond to the questionnaires.

The general procedures for a Delphi exercise are as follows: (1) the experts are polled on a question or series of questions; (2) the responses are tabulated, analyzed, and fed back to the experts; and (3) the experts reanswer the questions in light of the information generated by the aggregate responses. This process is repeated until a consensus is reached.

The primary characteristic of Delphi is anonymity. Correspondence is the communication mode normally used. An exercise to develop Delphi-based SI curves for a species would likely operate as follows. A group of experts is identified. The objectives and procedures of the Delphi exercise are explained to each expert. The experts agree to participate as panelists. Each panelist gives his opinion or estimate on the inquiry. The results, including rationale given by each panelist, are summarized and fed back to each panelist, ending the first iteration or round. Panelists answer the inquiry again, in light of the information generated by the collective response to round 1. This process is repeated until a consensus or acceptable level of agreement is reached. The exercise is terminated (usually after four rounds) and the procedures and results are documented, including all rationale for agreement or disagreement. An overview of this process is illustrated in Figure 1.

GUIDELINES

The following guidelines for developing Delphi-generated SI curves are based primarily on procedures developed and used by Crance (1987b). Much of the information reported by Delbecq et al. (1975) is also incorporated.

NUMBER OF PANELISTS

The best number of panelists for a Delphi exercise has not been determined. The number is generally governed by the number of respondents needed to constitute a representative pooling of judgments and by the information-processing capabilities of the design and monitoring team (Delbecq et al. 1975). Hodgetts (1977) indicated that at least eight panelists are needed, but did not provide rationale for this minimum number. A panel consisting of about 10 experts is probably ideal, but more than 10 may be used if desired. The panel should represent a diversity of knowledge about habitat use by the species of interest, but priority should be given to selecting panelists who are knowledgable about habitat suitability for the species. Overrepresentation by "stakeholders" or individuals from a single agency, interest group, or geographical area should be avoided where possible.

<u>Step 1 (preliminary), 3 weeks</u>

Select panel of experts. Prepare information packet (see Appendices A-H) and mail to panelists.

<u>Step 2 (round 1), 3 weeks</u>

Panelists review information packet, complete questionnaires (see Appendices D-H), write comments, and mail comments and completed questionnaires to monitor.

<u>Step 3 (round 1), 3 weeks</u>

Monitor summarizes results of round 1, prepares preliminary SI curves based on composite of panelists' estimates, and mails summary and SI curves to panelists for consideration.

<u>Step 4 (round 2), 3 weeks</u>

Panelists review summary and preliminary curves resulting from round 1, indicate agreement or disagreement for each curve and mail results, opinions, and comments to monitor.

<u>Step 5 (round 2), 3 weeks</u>

Monitor summarizes results of round 2, modifies preliminary curves based on new information, and mails summary and curves to panelists for reconsideration.

<u>Steps 6 and 7 (round 3), 6 weeks</u>

Repeat process used for steps 4 and 5 until a consensus or an acceptable level of agreement has been reached.

<u>Steps 8 and 9 (round 4), 6 weeks</u>

If fourth round is necessary, repeat steps 6 and 7.

<u>Step 10 (completion), 3-4 weeks</u>

Prepare completion report and mail to each participant.

Figure 1. An overview of the activities and approximate calendar time (weeks) associated with each major step of a Delphi exercise for developing SI curves.

SELECTION OF PANELISTS

Typically, the selection of panelists for a Delphi exercise to develop SI curves for a species would proceed as follows. Two or three individuals considered to be experts on the species are found. One is called and interviewed. The objectives of the proposed exercise, the Delphi process in general, and the need for SI curves are discussed with the expert, and he is asked the following questions: Do you feel comfortable being considered an expert on the species? Would you agree to serve as a panelist for the proposed Delphi exercise? Whom do you consider to be highly knowledgable about habitat suitability for the species? Responses to these questions should give some indication of the possibility of the expert being a panelist and should expand the list of potential experts.

The above process is repeated until a list of 15 to 20 potential panelists is obtained, or until no new names are suggested to the interviewer. If the list contains more experts than desired for the panel, priority should be given to those with the best knowledge about habitat requirements of the species, those whose expertise represents an important geographical area within the range of the species, and those who show a high degree of interest and willingness to participate in the exercise.

ROUND 1

Each panelist is mailed an information packet to begin round 1. Examples of items included in the initial information packet are shown in Appendices A-H. Additionally, general information on SI curve development and use and background on the Delphi technique may be included in the packet.

Appendix A is an example of a letter of confirmation and an expression of appreciation to panelists for agreeing to participate. The letter also reiterates the purpose of the exercise and gives the panelist guidelines on responding. A response time of 10 days is probably realistic; less time may discourage some panelists. Panelists who do not respond within 10 days should be contacted and tactfully encouraged to respond as soon as possible.

Appendix B is an example of instructions to help panelists focus on the relationships between habitat variables and habitat suitability.

Definition of terms relevant to the SI curves to be developed need to be explicit and acceptable to all panelists early in the exercise. Examples of some preliminary definitions for inclusion with the information packet for round 1 are given in Appendix C.

Examples of tables useful for recording estimates of variable values and SI's for some life stages and activities of a species are given in Appendices D-G. Estimates, comments, references, and logic recorded by panelists in these tables in round 1 provide a basis for the preliminary SI curves for use in round 2.

Cover utilization by some fish species is difficult to classify and quantify. Tables similar to those shown in Appendices D-G may not be useful for estimating cover variables and SI's during the initial round if important cover variables for the species are unknown. Appendix H is an example of a query that was useful during round 1 for obtaining opinions on the importance of cover to a fish species. Responses to the query were summarized and are presented in Appendix I.

The amount of time between mailing an information packet to panelists to begin round 1 and the beginning of round 2 will likely be 4 to 6 weeks. This includes time to prepare a summary of the results of round 1 and for typing and mailing. The summary of round 1 includes a set of preliminary SI curves for each variable and life stage considered to be important by panelists. Panelists' comments pertinent to the curves should be included in the summary, but slight revisions or omissions may be needed to preserve anonymity.

The medians of estimates provided by the experts for each variable and life stage should be useful as coordinates for the preliminary SI curves. Appendix J is an example of how first-round estimates of water temperature suitability for a fish species were summarized to show the lower and upper quartile ranges and the median of the estimates. In this example, some panelists indicated that water temperature never increases or decreases to a level where SI=0. This was due to some panelists interpreting the question to relate to stream temperature in their area only, where, under normal conditions, stream temperatures never increased or decreased to a level where SI=0.

Preliminary curves resulting from round 1 may also be based on the lowest and highest estimates given for a variable. For example, if several panelists estimated that the optimum range for percent of habitat with suitable cover is 20% to 70%, and several other panelists estimated the optimum range to be 30% to 80%, 20% to 80% would be used for the preliminary curve. In this example, all of the initial estimates would be included in the preliminary curve. Opportunity for agreement or disagreement and adjustment of the optimum range could occur (if justified) during round 2, based on a composite of the information in hand.

ROUND 2

A new information packet is mailed to each panelist to begin round 2. The packet includes a summary of the results of round 1, a set of preliminary SI curves, questionnaries, and instructions for round 2. Areas of agreement and disagreement are identified and discussed, and definitions are clarified, if necessary. The questionnaires for round 2 are essentially the preliminary SI curves developed from a composite of the information accumulated during round 1. Panelists respond to the questionnaires by reviewing the information and indicating agreement or disagreement with each preliminary SI curve. If a panelist disagrees with a curve, he sketches his own version of the curve and gives its x,y coordinates. He then writes comments, references, and logic to support his version. If he agrees with a preliminary SI curve, he gives reinforcing comments to support his position. Responses to round 2 are summarized and evaluated by the monitor and fed back to the panelists for reevaluation during round 3. The preliminary curves are modified by the supporting information, if warranted.

SUBSEQUENT ROUNDS

Procedures used in round 2 are repeated in subsequent rounds. The exercise is terminated when a consensus or an acceptable level of agreement has been reached on the curves. An example of how a consensus on estimates of water temperature for spawning evolved during a 4-round Delphi exercise is given in Appendix K.

FINAL REPORT

The final report provides feedback to the panelists and other participants that contributed both time and work to the effort. The final report summarizes the goals and process, as well as the results; agreements and disagreements (if any) resulting from the exercise, and names of all participants, are included in the final report.

DISCUSSION

Delbecq et al. (1975) presented some advantages and disadvantages of the Delphi technique and the Nominal Group Technique (NGT). The NGT employs structured face-to-face meetings to obtain and combine expert opinion and may be used to develop SI curves. A decisionmaking process involving the choice of the Delphi technique or the NGT for developing expert-opinion-based SI curves will likely reflect real-world constraints, such as the amount of time required, costs, travel ceilings, and the proximity of participants. On the basis of time and costs required for participants, the Delphi technique is superior to the NGT. If participants have the time and no large travel costs, however, the NGT requires less administrative costs and efforts, and the information can be collected in less time. A Delphi exercise conducted by Crance (1987b) to develop SI curves for redbreast sunfish lasted 8 months and the effort required was about 50 person-days (one fishery biologist = 22 days, one typist = 6 days, and 11 panelists x 0.5 days per round x 4 rounds = 22 days). Because a Delphi exercise does not require face-to-face contact, it is particularly useful for involving experts, users, or administrators who cannot come together physically. The technique may also be used to aggregate judgments where people are hostile toward one another, or where individual personality styles would be distracting.

The amount of effort, calendar time, and money required are concerns of potential developers and users of SI curves. The Delphi technique is not a "quick fix" or a "free lunch" approach to SI curve development. Use of the technique to develop SI curves is still more art than science. The amount of calendar time required to develop SI curves can probably be reduced with increased use of the technique for this purpose. The number of rounds required to complete an exercise can be kept to a minimum by providing the panelists clear objectives, definitions, guidelines, and instructions at the beginning of round 1. The purpose of most Delphi exercises that I have conducted was to develop SI curves for variables commonly considered in the assessment of habitat of riverine fish species. The exercises were started with a request that each panelist focus on the relationships between habitat suitability and each of the variables commonly used with the IFIM (i.e., velocity, depth, temperature, substrate, and cover). The experts were given an opportunity to identify other variables considered to be important, but they were asked to focus on variables commonly used with the IFIM. The identification and importance of variables that affect habitat suitability for a species could be the single subject of a Delphi exercise that may last three or four rounds.

I have not used the Delphi technique to modify SI curves, but feel that the technique has potential for this purpose. An exercise to modify SI curves could begin at step 4 (Figure 1), reducing the calendar time needed to complete the exercise by about 6 weeks. Another potential (but untested) use of the Delphi technique is the formulation of a suitable aggregation equation to combine the individual SI values for each variable used in a model.

Delbecq et al. (1975) pointed out that like all group responses, the quality of Delphi responses is very much influenced by the interest and commitment of the participants. Delphi exercises require especially high motivation by participants, since other people are not present to provide stimulation.

Fish were used as examples in this report because my application of the Delphi technique has been limited to fish species. The technique should be equally applicable to terrestrial species. Some questions that will probably arise during a Delphi exercise for a fish species are: Where is water velocity measured? What are the temporal and spatial limitations for the curves being developed? Should food abundance and availability be considered as important variables? Are backwater areas of large river reservoirs lentic or lotic? An easy or standard answer may not be available, but such questions need resolution to the satisfaction of all participants.

Delphi exercises provide a more updated and lively exchange of scientific or technical information than a literature search, but the technique is not a replacement for scientific methods traditionally used to gather information for SI curve development. However, it is an option that should be considered when SI curves or data for developing needed SI curves are unavailable.

To date, few Delphi-derived SI curves for a fish species have been compared to criteria developed from data obtained by sampling the species in its habitat. Baldridge (1981) compared SI curves for spawning pink salmon generated by professional judgment with SI curves subsequently generated from data obtained from sampling pink salmon spawning habitat. The two sets of criteria were very similar.

Delphi-derived SI curves represent "average" values of habitat quality for a species and will be useful only for predicting "average" SI's. Potential users of SI curves should scrutinize the information used to develop the curves and judge the adequacy of the curves for a specific need. Bovee (1986) stated that decisions regarding water management will proceed regardless of the quality of the biological information and may be made with no input from the biological community. In view of this, Delphi-derived SI curves are likely to be vastly superior to no SI curves.

At the conclusion of several Delphi exercises I conducted, the panelists were requested to comment on the Delphi process in general and on their participation in the exercise. Some selected comments that resulted from the requests follow:

> "I believe that the Delphi exercise was a worthwhile effort and a learning experience, and that it is a feasible method for developing SI curves for selected species."

> "Curves for this species probably could not have been accomplished using only the information currently available in the literature."

> "I believe the Delphi technique is a reasonable replacement for hard data. Even with hard data, it would be difficult to get a consensus. The results of this exercise are probably the best information available on the species."

> "This has been a valuable technique for assembling data based on a wealth of experience by utilizing a number of participants with an adequate background."

> "The Delphi technique allows field people to obtain a good idea of what other specialists are thinking and forces each individual panelist to probe a little deeper as to why one person answered the way he did."

> "This is a good method to collect and amass existing data on the parameters included. The information could be helpful to water quality monitoring agencies and fishery biologists."

> "I found the exercise very interesting and informative. However, it relies on a consensus of experts. There are instances in the history of science where the general consensus of experts has been wrong."

> "Biologists do not like to give opinions which may subsequently be erroneously interpreted and reported as data."

> "The Delphi technique can go astray if a few people with strongly held opinions refuse to acknowledge one person's opinion backed by data."

> "One weakness of the Delphi technique is that it tends to dilute a single minority opinion which in some cases may be more accurate than the majority opinion."

"We should be more careful in concealing the identity of panelists. It is possible to determine the identity of panelists by the flavor of their comments and references to geographical areas in the summary of a round."

"The SI curves should be updated and/or validated periodically."

"Being asked specific questions and being required to be specific and quantify answers was good for forcing my thought processes."

"I enjoyed participating in the Delphi exercises even though it was time consuming."

"Probably the most useful attribute of the Delphi technique is identification of areas that need further research for the species."

REFERENCES

Armour, C.L., R.J. Fisher, and J.W. Terrell. 1984. Comparison of the use of the Habitat Evaluation Procedures (HEP) and the Instream Flow Incremental Methodology (IFIM) in aquatic analyses. U.S. Fish Wildl. Serv. FWS/OBS-84/11. 30 pp.

Baldridge, J.E. 1981. Development of habitat suitability criteria: appendix 3. Pages 357-419 in W.J. Wilson, E.W. Trihey, J.E. Baldridge, C.D. Evans, J.G. Thiele, and D.E. Trudgen, eds. An assessment of environmental effects of construction and operation of the proposed Terror Lake hydroelectric facility, Kodiac, Alaska. Arctic Environmental Information and Data Center, University of Alaska, Anchorage.

Bovee, K.D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper 21. U.S. Fish Wildl. Serv. Biol. Rep. 86(7). 235 pp.

Crance, J.H. 1984. Habitat suitability index models and instream flow suitability curves: inland stocks of striped bass. U.S. Fish Wildl. Serv. FWS/OBS-82/10.85. 63 pp.

____________. 1985. Delphi technique procedures used to develop habitat suitability index models and instream flow suitability curves for inland stocks of striped bass. U.S. Fish Wildl. Serv. WELUT-85/W07. 58 pp.

____________. 1986. Habitat suitability index models and instream flow suitability curves: shortnose sturgeon. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.129). 31 pp.

____________. 1987a. Habitat suitability curves for paddlefish developed by the Delphi technique. N. Am. J. Fish. Manage. 7:123-130.

____________. 1987b. Results on the use of the Delphi technique for developing Category I habitat suitability criteria for redbreast sunfish. Proceedings of Species Criteria Workshop, Fort Collins, CO, Dec. 10-12, 1986. In Press.

Dalkey, N.C., and O. Helmer. 1963. An experimental application of the Delphi method to the use of experts. Mgmt. Sci. 9:458-467.

Delbecq, A.L., A.H. Van deVen, and D.H. Gustafson. 1975. Group techniques for program planning - a guide to nominal group and Delphi processes. Scott Foresman and Company, Glenview, IL. 194 pp.

Fusfeld, A.R., and R.N. Foster. 1971. The Delphi technique: survey and comment. Business Horizons 14(6):63-74.

Heller, D.A., J.R. Maxwell, and M. Parsons. 1983. Modeling the effects of forest management on salmonid habitat. U.S. Dept. Agric., For. Serv., Siuslaw Natl. For., Gresham, OR. 63 pp.

Hodgetts, R.M. 1977. Applying the Delphi technique to management gaming. Simulation 29(1):209-212.

Linstone, H.A., and M. Turoff, eds. 1975. The Delphi method. Addison-Wesley, Reading, MS. 620 pp.

Ludlow, J.D. 1972a. Evaluation of methodology in the University of Michigan's Sea Grant Delphi inquiry. University of Michigan Sea Grant Tech. Rep. 22. Ann Arbor, MI. 90 pp.

_____________. 1972b. Substantive results of the University of Michigan's Sea Grant Delphi inquiry. University of Michigan Sea Grant Tech. Rep. 23. Ann Arbor, MI. 102 pp.

Pill, J. 1971. The Delphi method: substance, context, a critique and an annotated bibliography. Socio-Econ. Plan. Sci. 5:57-71.

Stier, D.J., and J.H. Crance. 1985. Habitat suitability index models and instream flow suitability curves: American shad. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.88). 34 pp.

Turoff, M. 1970. The design of a policy Delphi. Technological Forecasting and Social Change 2:149-171.

Zuboy, J.R. 1981. A new tool for fishery managers: the Delphi technique. N. Am. J. Fish. Manage. 1:55-59.

Appendix A. Letter mailed to panelists to begin round 1 of a Delphi exercise conducted to develop SI curves for redbreast sunfish.

Thank you for agreeing to serve as a panelist for the redbreast sunfish Delphi exercise.

The purpose of the exercise is to develop Suitability Index (SI) curves for use with the Instream Flow Incremental Methodology (IFIM) in the assessment of riverine habitat of redbreast sunfish. The Delphi technique is being used because field data and information available in the literature are inadequate for developing SI curves for the species. Available information on redbreast sunfish will be used in developing the curves, but opinions of the Delphi panelists will be the primary basis for the resultant curves.

General information about the Delphi technique and SI curve development, and instructions and materials for completing the first round of the exercise are enclosed. A few hours of your time will be required to complete the first and subsequent rounds of the Delphi. You, no doubt, have many demands on your time but please respond to each round promptly. We should complete the exercise in about 6 to 8 months, assuming that four or five rounds will be required and that all panelists respond to each round within 10 days after receipt of material. You may wish to get an associate to serve as panelist in your behalf if you are unable to respond within 10 days.

I will serve as monitor of the exercise. This means that I will prepare the material for each round, summarize responses, and prepare a final report, including rationale for the curves developed. Anonymity among panelists will be maintained until the exercise is completed.

Thank you again for consenting to be a panelist. I look forward to receipt of your input.

Appendix B. Instructions used by panelists to begin round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

---

1. Consider the relationships between riverine habitat suitability for redbreast sunfish for each of the variables -- velocity, depth, substrate, cover, and temperature. What is the relationship between each variable and habitat suitability for each life stage or activity (e.g., spawning, incubation, larval, juvenile, adult, or other life stage or activity)?

2. Next, complete the attached tables (Appendices D-G). Information that you enter in the tables will serve as the basis for preliminary SI curves that will be developed by the monitor. These preliminary SI curves will be presented for consideration during round 2.

3. List references, data sources, or any information available that you wish to use as the basis of your curve. It is important that you use your "gut" feeling or opinion, even if no data are available. You may choose to ignore all available data or information and use <u>only</u> your "gut" feeling or opinion as the basis of your curve. If you mention a reference, please give the complete citation or send the monitor a copy of the report. If the reference has been published in a popular journal or has been widely circulated and is likely available in small libraries, you need not send it.

4. Write comments, ideas, logic, reference, etc., at the bottom of each table or on the reverse of the page.

5. If you feel that a variable or a life stage other than those listed in a table is important and should be considered for an SI curve, please clearly define the variable, explain how the variable is quantified, and give the specific size-group, season, or unique life stage or activity the variable applies to.

6. If you have questions, you may call me. Please return your response within 10 days.

Appendix C. Preliminary definitions of some terms considered by panelists at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

The redbreast sunfish Delphi exercise will be concerned with the riverine (lotic) habitat used by the various life stages of the species. A definition of some terms likely to be used during the exercise has been assumed. If you disagree with a general definition listed below, please give your definition of the term and/or any other terms that you feel need clarification.

Spawning habitat. Crucial habitat for adults during spawning, including courtship, the release of eggs and sperm, and fertilization.

Incubation habitat. Crucial habitat of eggs during incubation.

Larval habitat. Crucial habitat of larvae from hatching to juvenile stage or while the fish are a specified length or age.

Juvenile habitat. Crucial habitat of juveniles until sexual maturity is reached or while the fish are a specified length or age.

Adult habitat. Crucial habitat of sexually mature fish (excluding spawning activities). If crucial habitat requirements for a particular size, age, or activity differ, specifics are needed.

Appendix D. Table used for soliciting opinions on water velocity suitability at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

DELPHI ROUND 1 - WATER VELOCITY   Date ________   Panelist ____________________

Complete this table by filling in each column with the water velocity[a] (ft/s) considered to be appropriate for each life stage or activity of the species.

	Velocity (ft/s)					
Velocity condition	Spawning	Incubation (eggs)	Larvae	Juveniles	Adults	Other[b]
1. Level velocity must decrease to for SI=0[c] (use N if never occurs)						
2. Lowest velocity considered to be optimal (SI=1).						
3. Highest velocity considered to be optimal (SI=1).						
4. Level velocity must increase to for SI=0[c] (use N if never occurs).						
5. Velocity level(s) where SI=0.5 (use N is never occurs).						

[a]Generally the mean column velocity (velocity at 0.6 of depth measured from water surface). However, more specific measurements are used sometimes. What do you mean by velocity relative to the values you will give in this table? Underline the following phrase that most closely describes your use of velocity: Velocity at surface of water. Velocity within 6 inches of stream bottom. Velocity at site of fish/activity (e.g., nose velocity). Mean column velocity. Other (please define) ____________________.

[b]Specify any other riverine life stage or activity that you consider to be important and fill in column.

[c]Velocity level is totally unsuitable when SI=0.

Appendix E. Table used for soliciting opinions on water depth suitability at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

DELPHI ROUND 1 - WATER DEPTH   Date ________   Panelist ____________________

Complete this table by filling in each column with the water depth[a] considered to be appropriate for each life stage or activity of the species.

	Water depth (ft)					
Depth condition	Spawning	Incubation (eggs)	Larvae	Juveniles	Adults	Other[b]
1. Depth water must decrease to for SI=0.[c]						
2. Minimum depth considered optimal (SI=1).						
3. Maximum depth considered optimal (SI=1).						
4. Depth water must increase to for SI=0[c] (use N if never occurs).						
5. Depth(s) where SI=0.5.						

[a] Indicate what you mean by depth in the context of the values you will use in this table by underlining the following phrase that most clearly describes your use of depth: Average water depth. Nose depth or depth at fish/egg/activity. Other (please define) ______________________.

[b] Specify any other riverine life stage or activity that you consider to be important and fill in column.

[c] Depth is totally unsuitable when SI=0.

Appendix F. Table used for soliciting opinions on water temperature suitability at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

DELPHI EXERCISE ROUND 1 - WATER TEMPERATURE   Date ________   Panelist ______________

Complete this table by filling in each column with the water temperature (°F) considered to be appropriate for each life stage or activity of the species.

Temperature condition	Water condition (°F)					
	Spawning	Incubation (eggs)	Larvae	Juveniles	Adults	Other[a]
1. Temperature water must decrease to for SI=0.[b]						
2. Lowest temperature considered to be optimal (SI=1).						
3. Highest temperature considered to be optimal (SI=1).						
4. Temperature water must increase to for SI=0.[b]						
5. Temperature(s) where SI=0.5.						

[a] Specify any other riverine life stage or activity that you consider to be important and fill in column.

[b] Temperature is totally unsuitable when SI=0.

Appendix G. Table used for soliciting opinions on substrate suitability at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

DELPHI EXERCISE ROUND 1 - SUBSTRATE Date ________ Panelist ______________

Complete this table by filling in each column with the appropriate SI (0.0-1.0)[a] for each substrate type[b] and life stage or activity of the species.

Code	Substrate type Particle size	Suitability Index (0.0-1.0)[a] Spawning	Incubation (eggs)	Larvae	Juveniles	Adults	Other[c]
1	Organic material						
2	Mud/soft clay						
3	Silt, <0.062 mm						
4	Sand, 0.062-2 mm						
5	Gravel, 2-64 mm						
6	Cobble, 64-250 mm						
7	Boulder, 250-4000 mm						
8	Bedrock						

[a] Substrate is totally unsuitable when SI=0. If substrate is optimal, SI=1.

[b] Indicate what you mean by substrate in the context of how you will use it for this table. Underline the following phrase that most closely describes your meaning: Dominant substrate particles on surface of substrate. Material comprising highest percentage (by weight) of grab sample. Other (please define) ______________.

[c] Specify any other riverine life stage or activity that you consider to be important and fill in column.

Appendix H. Statement used for querying panelists about cover suitability at the beginning of round 1 of a Delphi exercise to develop SI curves for redbreast sunfish.

Date ____________ Panelist __________________

If you consider cover to be important to the well-being of any life stage or activity of redbreast sunfish please describe what the cover is, how it benefits a life stage or activity of the species, how it may be quantified in relation to habitat suitability, what happens if there is more cover, less cover, no cover, etc. Sketch your version of any cover SI considered to be important. Use the space below and reserve side of page, if needed.

Appendix I. A summary of responses to the cover query presented in Appendix H.

Instructions for round 2. The SI's listed below are estimates based on information provided by panelists in response to the cover query considered during round 2 of the redbreast sunfish Delphi exercise. Please consider the suitability indices for cover types listed below. If a cover type named is not important, mark it out or consolidate it with another type. If you disagree with the SI indicated, change the SI to what you feel it should be. Return your results to the Delphi monitor.

Cover type[a]	Suitability indices and life stages or activity			
	Spawning	Larvae	Juvenile	Adult
1. Logs, brush, stumps, snags	1.0	0.2	0.8	1.0
2. Boulders	0.7	0.2	0.5	0.7
3. Gravel-small cobble	0.0	1.0	0.7	0.2
4. Steep banks with over-hanging vegetation and willow roots	1.0	0.7	0.5	0.5
5. Aquatic vegetation (rooted macrophytes)	0.0	1.0	1.0	0.4
6. Plant detritus and/or organic material	0.0	0.4	0.6	0.1
7. Other				

[a]Cover can simply be described as any feature of a stream that provides reduced lighting, reduced velocity, or increased visual isolation. Even more simply, cover is something the fish can either get under or behind. Cover may also provide suitable substrate or habitat for food organisms utilized by the fish.

Appendix J. A summary of first-round estimates of water temperature suitability for sauger spawning, incubation, and adults.

Spawning - Temperature (°F)	Lower quartile range		Median	Upper quartile range	
1 Level must decrease to for SI = 0	35	38	40	40	46
2 Lowest optimum value	39	41	44	45	50
3 Highest optimum value	44	49	50	55	64
4 Level must increase to for SI = 0 (N = doesn't occur)	48	53	60	61	N
Incubation-Temperature (°F)					
1 Level must decrease to for SI = 0	33	35	39	40	46
2 Lowest optimum value	40	45	46	48	52
3 Highest optimum value	40	52	57	60	65
4 Level must increase to for SI = 0 (N = doesn't occur)	48	61	70	71	N
Adults - Temperature (°F)					
1 Level must decrease to for SI = 0	N	31	32	32	34
2 Lowest optimum value	32	36	50	64	65
3 Highest optimum value	65	67	70	71	80
4 Level must increase to for SI = 0	75	80	80	87	96

Appendix K. An example of how water temperature criteria for spawning evolved during a 4-round Delphi exercise to develop SI curves for sauger.

Results at end of round	Low temperature for SI=0		Low temperature for SI=1		High temperature for SI=1		High temperature for SI=0	
	Temperature considered	Panelists disagreeing	Temperature considered	Panelists disagreeing	Temperature considered	Panelists disagreeing	Temperature considered	Panelists disagreeing
Round 2[a]	40°F	1[b]	44°F	0	50°F	4[c]	60°F	3[d]
Round 3	39°F	0	44°F	0	55°F	0	65°F	1[e]
Round 4[f]	39°F	0	44°F	0	55°F	0	65°F	0

[a] Temperatures for round 2 were the median of the estimates given by the panelists during round 1 using a table similar to Appendix F.

[b] This panelist presented convincing rationale for lowering the temperature to 39°F.

[c] Three panelists who disagreed presented convincing information for increasing the temperature to 55°F. The other panelists indicated that the temperature should be decreased to 48°F but did not give supporting rationale.

[d] Each of the three panelists presented evidence that sauger spawn at temperatures above 60°F and, therefore, this temperature should be increased to about 65°F.

[e] This panelist indicated that 65°F would result in SI=0.2 instead of SI=0. However, he did not present supporting statements.

[f] Panelists reached a consensus on spawning temperatures at the end of round 4.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.134)	2.	3. Recipient's Accession No.

4. Title and Subtitle Guidelines for Using the Delphi Technique to Develop Habitat Suitability Index Curves	5. Report Date April 1987
	6.
7. Author(s) Johnie H. Crance	8. Performing Organization Rept. No.
9. Performing Organization Name and Address National Ecology Center U.S. Fish and Wildlife Service Creekside One Building 2627 Redwing Road Fort Collins, CO 80526-2899	10. Project/Task/Work Unit No.
	11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address Division of Wildlife and Contaminant Research Fish and Wildlife Service Department of the Interior Washington, DC 20240	13. Type of Report & Period Covered
	14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The Delphi technique is one method used for combining the knowledge and opinions of a group of experts. The primary characteristic of Delphi is anonymity; correspondence is the communication mode normally used. The concept is based on the premises that opinions of experts are justified as input to decisionmaking where absolute answers are unknown, and a consensus of experts will provide a more accurate response to a question than a single expert.

The guidelines presented are for using the Delphi technique to develop habitat Suitability Index (SI) curves. SI curves are often used with the Habitat Evaluation Procedures and are necessary components of the Instream Flow Incremental Methodology. The Delphi technique is not a replacement for scientific methods traditionally used to gather information for SI curve development, but it offers an option that should be considered when SI curves or data for developing needed SI curves are unavailable.

17. Document Analysis a. Descriptors

Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Delphi technique
Expert opinion
Habitat Suitability Index Curves

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	unclassified	21
	20. Security Class (This Page) unclassified	22. Price

(See ANSI–Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4–77) (Formerly NTIS–35) Department of Commerce

U.S. GOVERNMENT PRINTING OFFICE:1987-775-288/85132