

University of Colorado Law School

Colorado Law Scholarly Commons

Instream Flow Protection in the Western United States: A Practical Symposium (March 31-April 1)

1988

3-31-1988

Establishing the Quantity of Necessary Flow

Berton L. Lamb

Follow this and additional works at: <https://scholar.law.colorado.edu/instream-flow-protection-in-western-united-states>



Part of the [Hydrology Commons](#), [Natural Resources and Conservation Commons](#), [Natural Resources Law Commons](#), [Natural Resources Management and Policy Commons](#), [Property Law and Real Estate Commons](#), [State and Local Government Law Commons](#), [Water Law Commons](#), and the [Water Resource Management Commons](#)

Citation Information

Lamb, Berton L., "Establishing the Quantity of Necessary Flow" (1988). *Instream Flow Protection in the Western United States: A Practical Symposium (March 31-April 1)*.
<https://scholar.law.colorado.edu/instream-flow-protection-in-western-united-states/3>

Reproduced with permission of the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment (formerly the Natural Resources Law Center) at the University of Colorado Law School.



William A. Wise Law Library
COLORADO **LAW**
UNIVERSITY OF COLORADO **BOULDER**



Getches-Wilkinson Center Collection

Berton L. Lamb, *Establishing the Quantity of Necessary Flow, in* INSTREAM FLOW PROTECTION IN THE WESTERN UNITED STATES: A PRACTICAL SYMPOSIUM (Natural Res. Law Ctr., Univ. of Colo. Sch. of Law 1988).

Reproduced with permission of the Getches-Wilkinson Center for Natural Resources, Energy, and the Environment (formerly the Natural Resources Law Center) at the University of Colorado Law School.

ESTABLISHING THE QUANTITY OF NECESSARY FLOW

Berton L. Lamb
Policy Analyst
National Ecology Research Center
U. S. Fish and Wildlife Service
Fort Collins, Colorado

INSTREAM FLOW PROTECTION IN THE WESTERN UNITED STATES:
A PRACTICAL SYMPOSIUM

A Short Course Sponsored by the
Natural Resources Law Center
University of Colorado
School of Law

March 31-April 1, 1988

DRAFT

)

)

)

ESTABLISHING THE QUANTITY OF NECESSARY FLOW

Each western state faces unique instream flow problems. Special considerations guiding the choice of technology for instream flow needs assessments include statutory authority, history of water use, technical orientation, available fiscal resources, and time allowed to complete studies. Overlaying all of these variables is an on-going debate disputing the relative scientific merits of competing instream flow assessment technologies (see generally Granholm, et.al, 1984; Mathur, et. al, 1985; and Orth and Maughn, 1986). These factors combine in each state to make the job of selecting instream flow levels challenging.

When choosing a technology, concentration is often given first to the plethora of procedures concerning measurement of stream transects, and operation of computer models. Typically, the professional biologists and engineers who conduct these analyses come to recognize that cutting through the often bewildering technical considerations depends on answering harder policy questions. Analysts decide to use a technique as much because it fits the circumstances of their state as because the technology meets some scientific standard (see generally Lamb, 1986)

1

The important work of Almond and Verba (1963) showed how policy is influenced by cultural factors. Lamb (1984) described some of the cultural influences that seem to affect the ways States approach instream flow problems.

These circumstances can be conveniently divided into two categories of action: long-range planning, and project bargaining. Negotiation is an integral part of all decision-making on instream flow issues, but this dichotomy focuses on the objectives of the decision process. In long-range planning, the analyst is called upon to recommend an instream flow level that is to guide general--usually low-intensity--preliminary planning. Project bargaining envisions high intensity, high stakes negotiations over specific development projects. Rather than a clear dichotomy, it may be best to picture these two types of decision-making as antipodes on a continuum ranging from the setting of standards for planning to conflict over incremental differences in flow levels.

Different technical solutions are appropriate for each of the two poles on this continuum. On the one hand, inexpensive, straightforward, rule-of-thumb solutions are best suited to long-range planning tasks. For these tasks the considerations are certainty that the planning objectives will be met, and ease in communicating recommendations to policy-makers. On the other hand, project bargaining requires a deep knowledge of the flow requirements of fish and wildlife, recreation, water quality, and other instream uses, as well as the ability to integrate these concerns into plans for a project.

Much of the controversy that surrounds the instream flow technology debate is not about the approaches best suited to the antipodes. The most intense argument is over technologies for

those conflicts that fall in the middle. In this mid-range, conflicts may have long time-horizons while still leading to identifiable projects. Inevitably, a quick rule-of-thumb method will be found wanting and complicated analysis with demands for compromise will follow. In this case, the choice of instream flow technique is muddied by the need for speed and low cost in making the first recommendation. That first recommendation preceeds a period of wrangling over project benefits and then negotiation of more in-depth studies. Finally, these discussions conclude in the form of an expensive technical analysis and hard bargaining over the professional judgments of those making and challenging the never-quite-final recommendations. Other scenarios can be found and imagined that could also fill this middle ground between long-range planning and project negotiations. However, it should suffice to say that the choice of initial and follow-on technologies in these sorts of disputes is very tricky.

The first simple technology chosen will be linked through the study design to the ultimate negotiation. How well this linkage can be accomplished depends on a number of factors including statutory authority, fiscal resources, training of personnel, and management support for the investigations. Most of all, success in moving from planning studies to hard bargaining depends on whether or not the analysts guessed correctly about what would happen to their first recommendations (Olive and Lamb, 1984).

LONG-RANGE PLANNING TECHNIQUES

In order to put mid-range conflicts into perspective it is important to first look at the technologies appropriate for long-range planning. In this type of low intensity scenario not much detail is required because the questions are fairly straight forward. This means that a quick, reconnaissance-level, and office-type approach may be used. Of the many techniques, the quickest involve using the hydrologic records of a stream. The use of stream gage records assumes that measured flows support aquatic resources at present and acceptable levels (Wesche and Rechard, 1980). It is safe to make this assumption only where streams are virtually undeveloped.

A number of eastern states face planning problems such as this, yet most western states encounter stream resources already encumbered with sophisticated development projects. Where streamflow is depleted or regulated, gage records can be modified by accounting for water diversions and stream modifications to reconstruct the natural flow regime (Bayha, 1978). This approach is satisfactory where the analyst knows about the condition of the fishery before development. Even then, it is difficult to say much about future impacts.

On some developed streams channel structure and fish populations have adjusted to the new flow regime. It is possible that such water developments may have dampened out chronic low-flow events, thus enhancing the fishery. Developing a knowledge of post-project conditions will require field investigations. In any case, selecting flows from historic records in the presence of

existing development is a limited long-range planning technique.

Where it is possible to use historic records, a number of questions arise. For example, is it best to recommend a flow based on the natural or altered conditions? The most common question for those relying on hydrologic analysis is: what percentage of the historic streamflow should be recommended? One solution is the "aquatic base flow" (Larson, 1981). This technique pegs the median flow for the lowest flow month (typically August or September) as adequate throughout the year, unless additional flow releases are necessary for spawning and incubation needs. Another planning scheme is to use median monthly flows (Bovee, 1982). This level is a surrogate for natural variation because it provides a flow that was historically present half the time.

The most renowned of the long-range planning tools is that recommended by Tennant (1976). In its original form, the Tennant Method displays flow levels for seasonal periods based on percent of mean annual flow. He used ten years of personal observations to categorize streams into varying quality trout habitat based on recorded flow.

Tennant also recommended that periodic high flows be provided to remove silt, sediment, and other bed load material. Recently, the U.S. Forest Service (1984) has argued that an annual

high flow occurrence is necessary to protect the channel structure in aluvial streams.² Because Tennant originally had in mind more of a scouring purpose, his approach is not based on these morphological considerations.

Table 1 displays Tennant's recommendations for trout habitat based on these observations. Some states recognize that they cannot transport Tennant's recommendations to their own streams without first making adjustments. In these cases modifications are made for the species of interest and types of streams in a particular state.

TABLE 1 ABOUT HERE

Tennant's and other table-top tools anticipate that hydrologic records are available. Where this is not the case, instream flows can still be recommended based on some surrogate indicator. Drainage area is one example for managed streams. This technique recommends a minimum instream flow value of 0.5 cubic feet per second per square mile of drainage area (cfsm) for summer months. Higher flows in the fall and spring periods are used to accomodate spawning and incubation for anadromous species (Larson, 1981). Of course, using this technique for other species would require a different set of rules.

2

The U.S. Forest Service, using the work of David Rosgen, Owen Williams, and others, has developed a five-part methodology to quantify channel maintenance flows (U.S. Forest Service, 1984).

These simple, rule-of-thumb techniques are very useful for long-range planning recommendations. The more difficult question arises when a problem is presented as long-range planning, but will clearly become an intense negotiation within a very short time. Sometimes, this happens because decision-makers do not understand instream flow analysis but believe that a simple one-time answer will accommodate a complex project. Othertimes, policy requires a level of analytic effort commensurate with some larger public purpose. Colorado, Wyoming, and Montana are examples of states that seem to mandate a fairly high standard in quantifying instream flow water rights (CRS 37-60-101 et.seq.; Wyo. Stat. 41-3-1004(a); MCA 85-2-316(1)). In most western states, streams are extensively developed. Any recommended flow level will likely result in immediate challenge and negotiation. At the same time a call goes out for a speedy³ recommendation, the expectation is for a sophisticated answer.

MID-RANGE TECHNIQUES

At the lower end of these sorts of problems, where the controversy is not intense and yet time is still a constraint, a specially tailored Tennant approach might be applied. This means repeating all of Tennant's steps. In this case the analyst would begin by observing key habitats and studying the stream during flows approximating various percentages of the mean annual flow.

³ For a discussion of this phenomenon in public policy implementation see Schlesinger, 1968.

After collecting data on cross-sectional width, depth, and velocity of the stream at each flow, a set of recommendations could be made to resemble Table 1. The difference would be that the new table would reflect the empirical observations of the analyst--instead of Tennant--and would be addressed specifically to the species and stream of interest.

The wetted perimeter technique (Nelson, 1980) is another that is frequently used with some success. This is a hydraulic approach that estimates a desired low-flow value by using a habitat index that incorporates stream channel characteristics. (Trihey and Stalnaker, 1985). In using this tool, the analyst selects a critical area (typically a riffle) that can stand as an index of habitat for the rest of the stream. When a riffle is used as the indicator area, the assumption is that minimum flow satisfies the needs for food production, fish passage, and spawning. Once this level of flow is estimated, it is assumed that other habitat areas, such as pools and runs, are also satisfactorily protected.

The term wetted perimeter refers to that radius of the stream cross-section that is estimated to minimally protect all habitat needs. The relationship of wetted perimeter to cross-section is represented in Figure 1. The usual procedure is to choose the break or "inflection" point in the relationship as a surrogate for minimally acceptable habitat. Because the shape of the channel influences the results of the analysis, this technique is usually applied to wide, shallow, and rectangular cross-sections.

FIGURE 1 ABOUT HERE

All the methods discussed above result in a single stream flow value, each recommended for a defined period of time in individual streams. It is these methods that have given rise to the term "minimum flow." These methods have been labeled "standard-setting" because they set a limit below which water cannot be diverted (Trihey and Stalnaker, 1985). Such recommendations are hard to use in negotiation due to lack of information to allow informed compromise. Much more must be done to answer the hard questions that are bound to be negotiated.

To answer these hard questions requires moving away from tools leading only to minimum flows. Techniques need to show the relationship between the amount of habitat and stream flow. Such approaches allow the analyst to display impacts on the resource for any given flow. The tools that can be used to achieve this result fall into two categories.

First, are those approaches that use statistical analysis to correlate stream environmental features with fish population size. An example of this type of analysis is Wyoming's Habitat Quality Index (Binns, 1982). This procedure is stream specific and the recommendations are tied to critical low flows. Second, are those approaches that link open channel hydraulics with known elements of fish behavior. Examples of these are the habitat mapping suggested by Morhardt (1983), and the Physical Habitat Simulation System (PHABSIM) that was first presented by Bovee and

Milhous (1978) and discussed again by Bovee (1982) in the users guide to the more extensive Instream Flow Incremental Methodology (see also Milhous, et.al, 1984).

Use of the PHABSIM requires field data collection of stream cross-section and habitat features, hydraulic simulation to evaluate habitat variables at different flows, and species suitability criteria to correlate stream characteristics with available habitat at different flows. Depending on the amount of complexity in the proposed project, and the complexity of the stream under study, the amount of field data collected may vary from inexpensive and cursory to expensive and time-consuming. Neither PHABSIM nor HQI should be used without an analysis of water supply.

The PHABSIM tool is able to inform decision-makers about the impacts on the fishery of different flow levels for different life stages. Attention is typically given to those life stages of fish species that are of special concern for management, or that are deemed to be most sensitive to change. The resulting flow versus habitat relationship generated by linking species criteria with flow-dependent stream channel characteristics (Figure 2), aids the negotiation process by clearly depicting the effect that less-than-optimum flow will have on habitat (see generally Geer, 1980).

Figure 2 About Here

Even the best of mid-range techniques leave the analyst open to criticism. The most criticized feature of the PHABSIM analysis is species suitability criteria. These are estimated species responses to stream variables normalized onto a curve. These criteria may be established by any number of routines ranging from solicitation of expert opinion to site-specific field data collection and verification (Bovee, 1986). It is important to note that the species criteria, along with the significance of PHABSIM's driving variables such as depth, velocity, substrate, and cover, form the basis for most critiques of this technique (Morhardt, 1986). To satisfy such criticisms, more in-depth analysis must be undertaken than is usually done in simple PHABSIM or HQI studies.

PROJECT BARGAINING

The mid-range techniques essentially provide snap-shots in time of stream resources. When the imperatives of negotiation or court proceedings require a more dynamic look at the instream flow question, other techniques are essential. These problems have been labeled "incremental" (Trihey and Stalnaker, 1985) because a deep knowledge must be developed to respond in negotiations that involve a sequence of proposals on project changes and impacts.

These project bargaining problems can form a labyrinth of choices for the analyst who tries to anticipate questions and designs stream flow research to accommodate these needs. A simple PHABSIM or HQI analysis will not be sufficient in this setting. Sometimes, new steps can be added to mid-range processes to help

them fit more demanding scenarios. More often, as Olive and Lamb (1984) have reported, some comprehensive approach must be chosen. With these more complex tools, the analysis itself may require as many as two years to complete. Each study is preceded by negotiations covering study design and followed by negotiations debating results. The total elapsed time may be more than three years. Replicate habitat sampling, biological sampling to develop species habitat suitability criteria, sediment and water routing studies, as well as physical habitat, temperature, and water quality simulations may all be necessary to accurately depict the effects of project operations (Sale, 1985). These steps go far beyond what might be accomplished with mid-range techniques.

The Instream Flow Incremental Methodology is one overarching process designed to accomplish this sort of intricate research. Trihey and Stalnaker (1985) have pointed out that processes like the Instream Flow Incremental Methodology should be properly referred to, not as methods, but as methodologies. Where the word method connotes a single tool or concept, a methodology implies linking steps--perhaps from a number of disciplines--to characterize a multi-faceted ecosystem. Many methods make up these complex methodologies.

In addition to the comprehensive study design needed for all project negotiation problems, the analyst must be in a position to rigorously document the scientific acceptance of all the technologies used. Especially in these intense negotiations the

assumptions of each method should be well understood and careful planning should anticipate what special studies or modifications to a methodology are needed. The result should be the ability to predict changes in habitat across time, make recommendations for wet and dry years, and demonstrate habitat duration phenomena similar to the safe yield concept in hydrology (Trihey, 1981). Figures 3 and 4 depict the relationships that can be developed by using such a methodology.

FIGURES 3 AND 4 ABOUT HERE

Another extension of these incremental, project bargaining methodologies leads to predicting population responses to habitat change. In an approach such as the Instream Flow Incremental Methodology this will typically include habitat models, sediment transport, water quality, and temperature analyses as well as trophic level studies, species criteria validation, and studies of biomass plus population dynamics (Bovee, 1982).

An alternative to combining these models into one predictive methodology would be very long-term observations of fish behavior. Such studies would document population responses to carefully controlled changes in flow over perhaps 20 years. Recent research on the South Platte River by Bovee and Nehring (1988) demonstrates the rigorous analysis necessary to show the relationship between flow and population. Their work highlights the fact that these relationships can be established in theoretically sound, intuitively satisfying directions. Figure 5 shows the form that these population responses to changes in flow

over time are likely to take.

FIGURE 5 ABOUT HERE

CONCLUSION

Various states have made use of these procedures. The Tennant Method is widely used in the early stages of planning throughout the country. Wetted Perimeter is used in Montana and has seen a number of applications in the west. The wetted perimeter and conceptually similar approaches concentrating on passage for upstream migrating salmon, are important first cut analytical tools. The PHABSIM method is commonly used as a way to look at hydroelectric power projects (Bovee, 1985), to set standards on controversial streams (Washington Department of Ecology, 1987), and to develop conditions on federal permits and licenses (see generally Cavendish and Duncan, 1986). The Instream Flow Incremental Methodology is often employed in the most controversial project assessments (for example, see Olive and Lamb, 1984).

Naturally, all of this experience with instream flow technology has led to a literature of evaluation and criticism. In particular, the work by Morhardt (1986), Loar (1985), Bain (1982), Orth and Maughn (1982) and Wesche and Reschard (1980) provide useful insights into choosing and employing instream flow assessment technologies.

Experience and the critical literature teach that there is simply no one-best-way. The choice of method or methodology depends on

circumstance. Some reviewers have identified dozens of approaches, models, and tools (Morhardt, 1986). Each of these was developed to satisfy some need. To establish the quantity of necessary flow, the analyst must know the history and purpose of these techniques and must use this knowledge to make an informed choice.

Acknowledgements: The author expresses deep appreciation to Mary G. Cavendish whose earlier summary of these technologies forms the basis for this paper, and to Kara L. Lamb for helpful editorial comments.

BIBLIOGRAPHY

Almond, G. A. and S. Verba, 1963. The Civic Culture: Political Attitudes and Democracy in Five Nations. Princeton, N. J.: Princeton University Press.

Bain, M. B., et. al, 1982. An Evaluation of Methodologies for Assessing the Effects of Flow Fluctuations on Stream Fish. Final Technical Report. U.S. Fish and Wildlife Service, FWS/OBS 82.63. 199pp.

Bayha, K., 1978. Fish and Wildlife, in 1976 National Water Assessment, U.S. Department of the Interior, Washington, D.C., pagination not cumulative.

Binns, N. A., 1982. Habitat Quality Index Procedures Manual. Wyoming Game and Fish Department, Cheyenne, WY., 209pp.

Bovee, K. D. and B. Nehring, 1987. Unpublished data, Aquatic Systems Branch, National Ecology Research Center, U. S. Fish and Wildlife Service, Fort Collins, CO 80526-2899.

Bovee, K.D. 1986. Development and Evaluation of Habitat Suitability Criteria for Use in the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 21. U. S. Fish and Wildlife Service, Biological Report 86(7), 235pp.

_____, 1985. "Evaluation of the Effects of Hydropeaking on Aquatic Macroinvertebrates Using PHABSIM," in F. W. Olson, R. G. White, and R. H. Hamre, eds., Proceedings of the Symposium on Small Hydropower and Fisheries. The American Fisheries Society, Denver, CO. pp. 236-242.

_____, 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 12. U.S. Fish and Wildlife Service, FWS/OBS-82/26, 248pp.

Bovee, K. D. and R. T. Milhous, 1978. Hydraulic Simulation in Instream Flow Studies: Theory and Techniques. Instream Flow Information Paper No. 5. U.S. Fish and Wildlife Service, FWS/OBS-78-33, 130pp.

Cavendish, M. G. and M. I. Duncan, 1986. "Use of the Instream Flow Incremental Methodology: A Tool for Negotiation," Environmental Impact Assessment Review. Vol. 6, pp. 347-363.

Geer, W. H. 1980. Evaluation of Five Instream Flow Needs Methodologies and Water Quality Needs of Three Utah Trout Streams. Utah Division of Wildlife Resources, Publication No. 80-20, 227pp.

- Granholm, S., S. Li, and B. Holton, 1985. "Warning: Use the IFIM and HEP with Caution," Hydro Review. Winter, pp. 22-28.
- Lamb, B. L., 1986. "Meeting the Challenge of Policy-Relevant Science: Lessons from a Water Resource Project," Water Resources Bulletin. Vol. 22, No. 5, October, pp. 811-815.
- _____, 1984. "Predicting the Results of Instream Flow Policies," in M. A. Collins, ed., Proceedings of Water for the 21st Century: Will It Be There? Center for Urban Water Studies, Southern Methodist University, Dallas, TX., pp. 840-847.
- Larson, H. N., 1981. New England Flow Policy. Memorandum, Interim Regional Policy for New England Stream Flow Recommendations, U.S. Fish and Wildlife Service, Region 5, Boston, MA. (February), 3pp.
- Loar, J. M. (ed.), 1985. Application of Habitat Evaluation Models in Southern Appalachian Trout Streams. Oak Ridge National Laboratory, Oak Ridge, TN. Environmental Sciences Division, Publication No. 2383. ORNL/TM-9323, 310pp.
- Mathur, D., W. H. Bason, E. J. Purdy, and C. A. Silver, 1985. "A Critique of the Instream Flow Incremental Methodology," Canadian Journal of Fisheries and Aquatic Sciences. Vol. 42, No. 4, pp. 825-831.
- Milhous, R. T., D. L. Wegner, and T. Waddle, 1984. Users Guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper No 11, U. S. Fish and Wildlife Service, FWS/OBS-81/43 (revised), Washington, D. C.
- Morhardt, J. E. 1986. Instream Flow Methodologies. Electric Power Research Institute. Palo Alto, CA. Pagination not cumulative.
- _____, 1983. "Instream Flow Analysis: Increased Accuracy Using Habitat Mapping," in Proceedings of Waterpower '83. Vol 3, Knoxville, TN: Tennessee Valley Authority, pp. 1294-1304.
- Nelson, F. A., 1980. "Evaluation of Selected Instream Flow Methods in Montana," in Proceedings of the Western Association of Fish and Wildlife Agencies. Kalispell, MT. pp. 412-432.
- Olive, S. W. and B. L. Lamb, 1984. Conducting a FERC Environmental Assessment: A Case Study and Recommendations from the Terror Lake Project. U.S. Fish and Wildlife Service, FWS/OBS-84/08, 62pp.
- Orth, D. J. and O. E. Maughn, 1986. "In Defense of the Instream Flow Incremental Methodology" (with response by Mathur, et. al), Canadian Journal of Fisheries and Aquatic Sciences. Vol. 43, No. 5. pp. 1093-1094.

Orth, D. J. and O. E. Maughn, 1982. "Evaluation of the Incremental Methodology for Recommending Instream Flows for Fishes," Transactions of the American Fisheries Society. Vol. 111, No. 4. pp. 413-445.

Tennant, D. L., 1976. "Instream Flow Regimens for Fish, Wildlife, Recreation, and Related Environmental Resources." Fisheries. Vol.1, No. 4, pp. 6-10.

Trihey, E. W. and C. B. Stalnaker, 1985. "Evolution and Application of Instream Flow Methodologies to Small Hydropower Development: An Overview of the Issues," in F. W. Olson, R. G. White, and R. H. Hamre, eds., Proceedings of the Symposium on Small Hydropower and Fisheries. The American Fisheries Society, Denver, CO. pp. 176-183.

Trihey, E. W., 1981. "Using Time Series Streamflow Data to Determine Project Effects on Physical Habitat for Spawning and Incubating Pink Salmon," in Acquisition and Utilization of Aquatic Habitat Inventory Information, Proceedings of a Symposium. Western Division of the American Fisheries Society, Portland, OR. pp. 232-240.

U.S. Forest Service, 1984. Forest Service Handbook, FSH 2509.17-Water Information Management System Handbook, Chapter 30-Procedure for Quantifying Channel Maintenance Flows.

Sale, M. J., 1985. "Aquatic Ecosystem Response to Flow Modification: An Overview of the Issues," in F. W. Olson, R. G. White, and R. H. Hamre, eds., Proceedings of the Symposium on Small Hydropower and Fisheries. The American Fisheries Society, Denver, CO. pp. 25-31.

Schlesinger, J. R., 1968. "Systems Analysis and the Political Process," Journal of Law and Economics. Vol II, October, pp. 281-284.

Washington Department of Ecology, 1987. "Preferred Alternative Instream Resource and Water Allocation Program," Division of Water Resources, Washington Department of Ecology, Olympia, WA.

Wesche, T. A. and P. A. Rechard, 1980. A Summary of Instream Flow Methods for Fisheries and Related Research Needs. Eisenhower Consortium for Western Environmental Forestry Research, Water Resources Research Institute, Eisenhower Consortium Bulletin No. 9, University of Wyoming, Laramie, WY. 122pp.

Table 1. Instream flow analysis using the Tennant Method (Tennant 1976).

Health of habitat	Percent of mean annual flow (MAF)	
	Oct. to Mar.	Apr. to Sept.
Flushing or Maximum	200	
Optimum	60 to 100	
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair	10	30
Poor	10	10
Severe degradation	less than 10	

WETTED PERIMETER METHOD

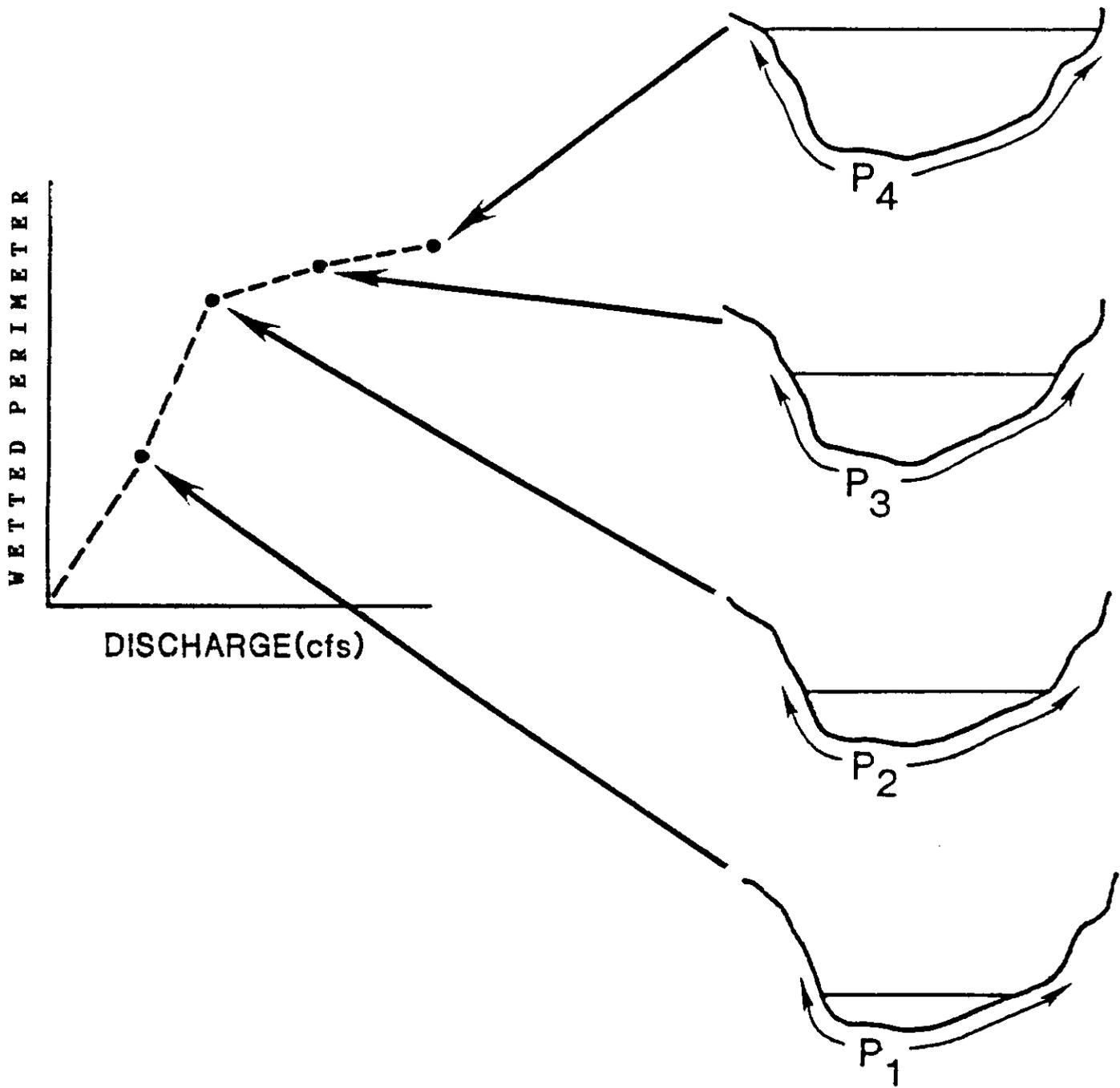


Figure 1. Use of the wetted perimeter method to estimate instream flows.

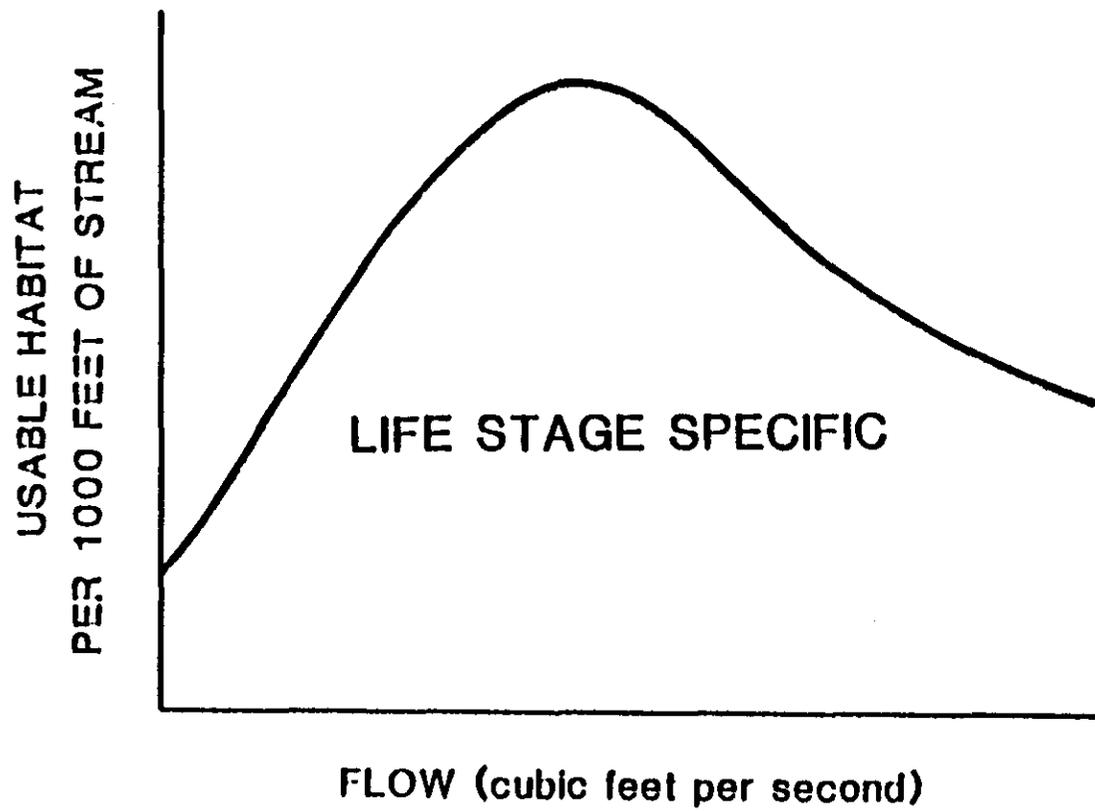


Figure 2. Flow-habitat relationship developed using PHABSIM.

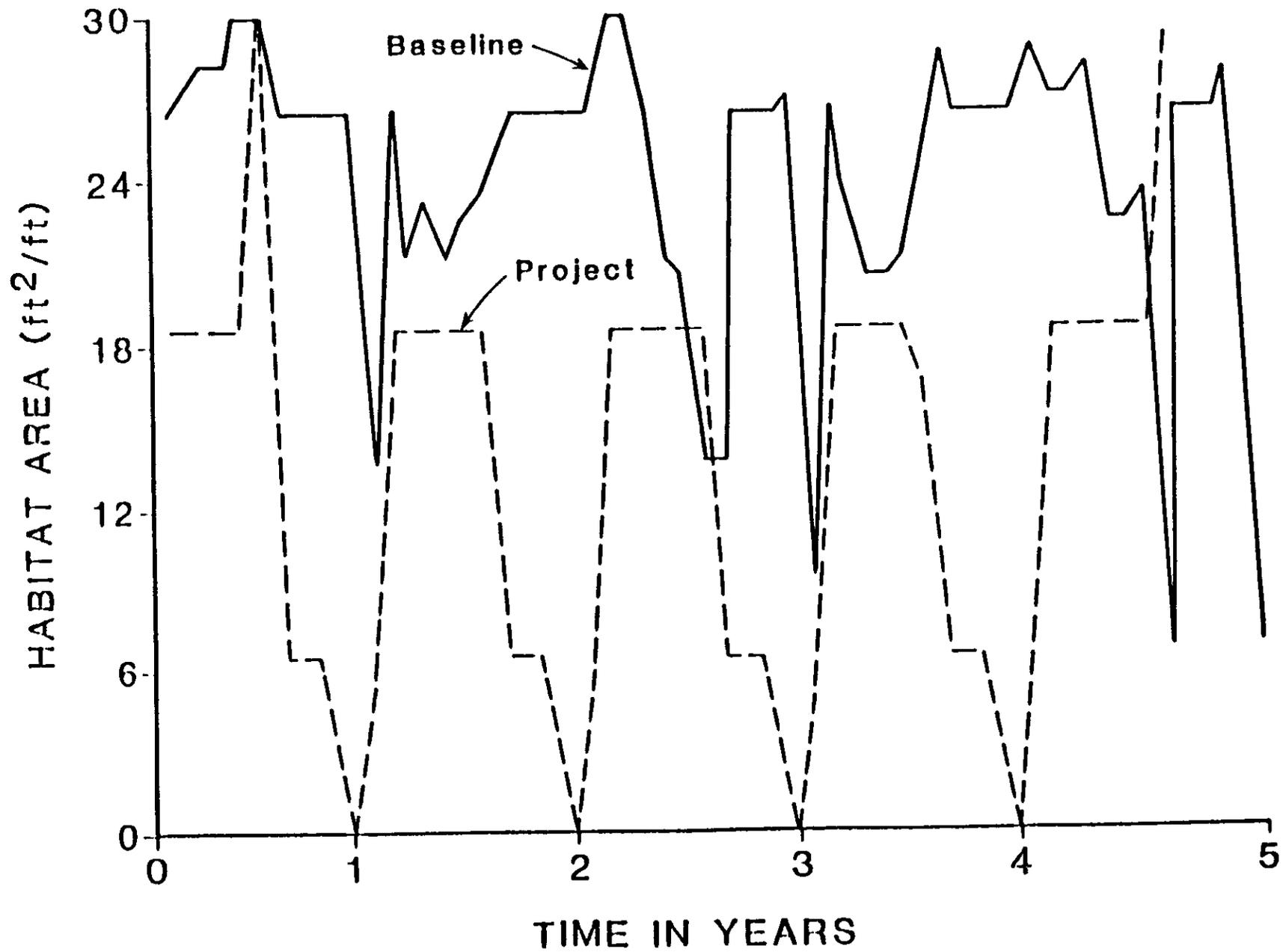


Figure 3. Time series analysis of habitat available at average monthly flows with and without project.

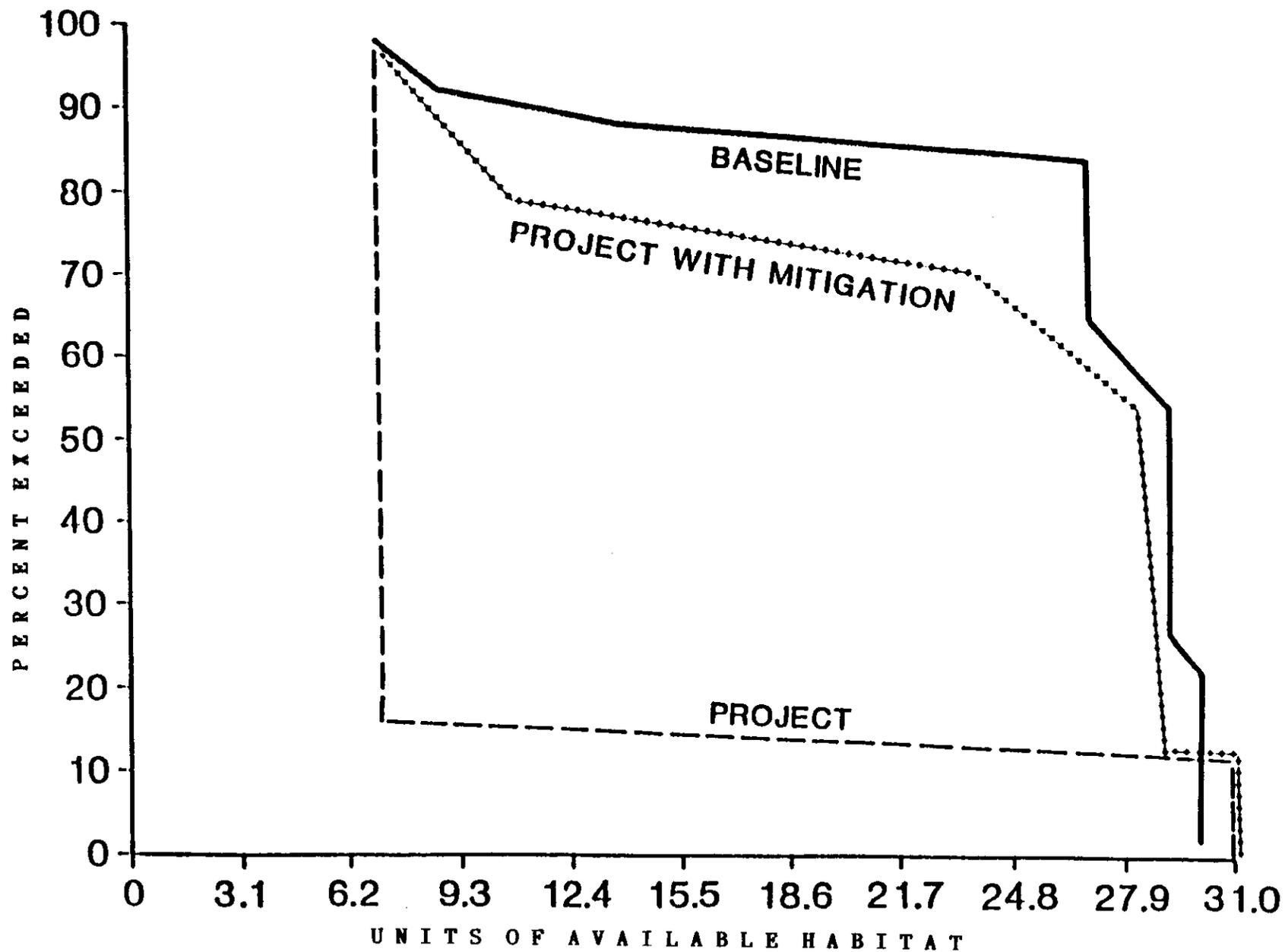


Figure 4. Duration analysis of habitat available under baseline conditions, with project, and with mitigation of project.

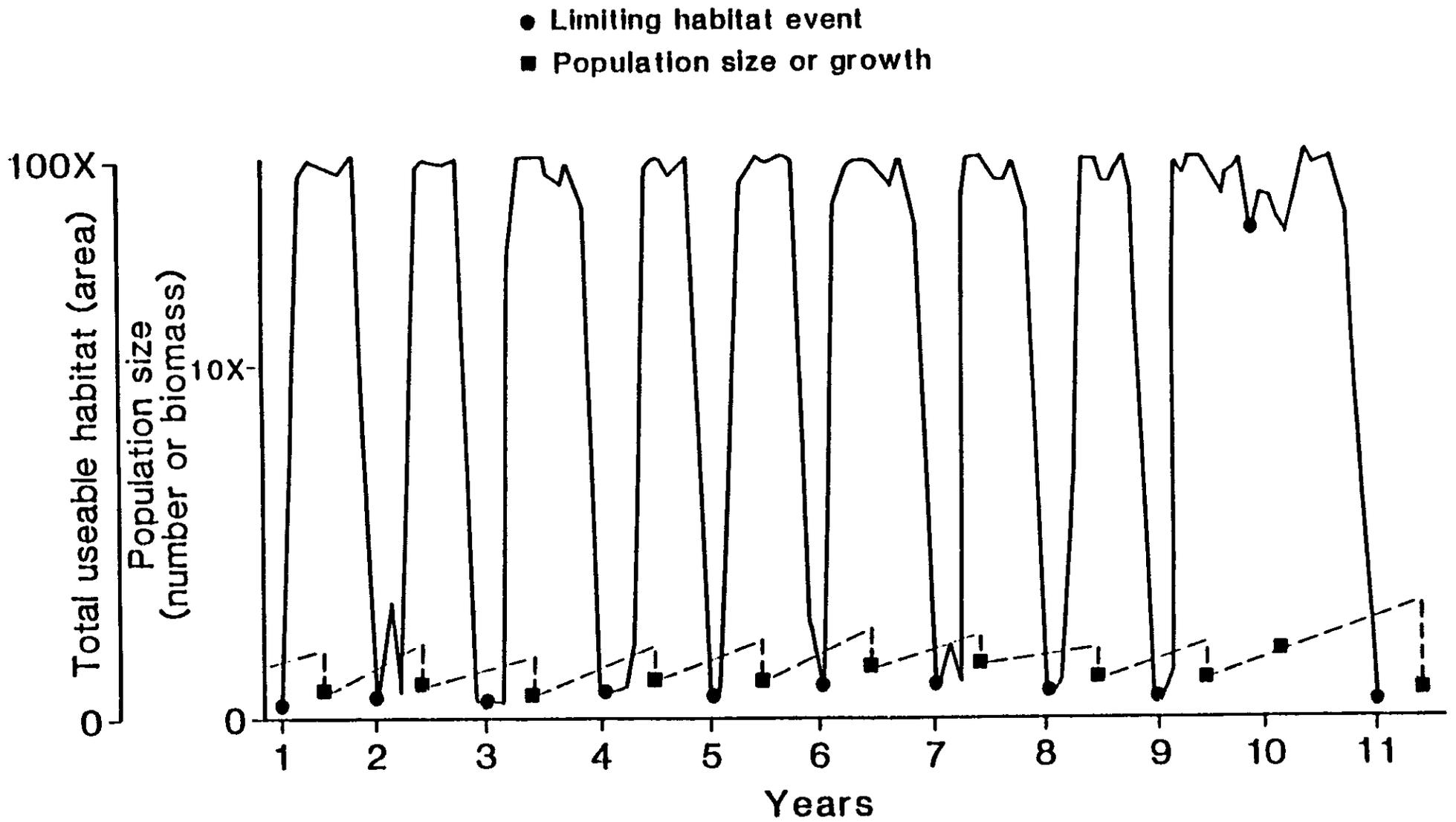


Figure 5. Fish population size related to useable habitat area using the IFIM.