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CHAPTER II A PROPOSED METHODOLOGY FOR RECOMMENDING STREAM RESOURCE MAINTENANCE FLOWS FOR LARGE RIVERS

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CHAPTER II A PROPOSED METHODOLOGY FOR RECOMMENDING STREAM RESOURCE MAINTENANCE FLOWS FOR LARGE RIVERS [1]

ABSTRACT

A literature review of ecological requirements of select fish species was conducted. Despite voluminous literature on the life histories of fishes, comparatively little is known about their specific ecological requirements. Lack of knowledge relating to these requirements has been a major constraint in the development of stream resource maintenance flow methodologies.

Currently used methodologies were reviewed. Approaches span the range from those which are basically subjective to ones based upon in-depth quantification of a number of variables which can be related to ecological requirements of fish species. No available methodology was considered adequate for direct application to a large river system.

A basic methodology is proposed for recommending stream resource maintenance flows for large rivers. This approach addresses environmental requirements of fish species for passage, spawning and rearing. The basic distinction between the proposed approach and those presently in use is its predictive component. Other field oriented methodologies are based upon data collected at several flows while the proposed method requires only one set of field observations. A computer model developed by the Bureau of Reclamation is used to predict channel morphometry and hydraulic characteristics at specified lower or higher discharges. From these predictions, changes in stream habitat can be determined. Field data needs for using the model, data processing, and computer output are described.

Application of the proposed methodology to the Snake River for meeting ecological requirements of white sturgeon, smallmouth bass, and channel catfish is described. In general, it is assumed that if requirements for spawning and rearing of white sturgeon are met, requirements of other species will also be met. Research to determine ecological requirements of white sturgeon is recommended.

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1/ This is contribution No. 4 of the Forest, Wildlife and Range Experiment Station.

INTRODUCTION

The major objective of this portion of the study was to develop methodology for use in establishing stream resource maintenance flow recommendations for large streams and for streams with a predominance of warm water fish species. This objective also included a review of presently available methodologies for the purpose of determining their applicability and/or limitations for use in making stream resource maintenance flow recommendations. The Idaho Cooperative Fishery Research Unit, University of Idaho, was sub-contracted by the Idaho Department of Fish and Game to develop this methodology.

Two review papers dealing with stream resource maintenance flow methodologies have become available since the initiation of this study. Giger (1973) presented a summary of literature on stream flow requirements of juvenile salmonids and reviewed approaches to stream flow recommendations used by the U. S. Forest Service, U. S. Geological Survey and the states of California, Montana and Oregon. A more recent paper by Bovee (1974) presents an extensive literature review of the discharge requirements of various components of a warm water fishery, reviews methods used in recommending stream resource maintenance flows and proposes a methodology for recommending minimum discharge for a warm water fishery. In an earlier contribution, Hooper (1973) presented a useful evaluation of the effects of flows on trout stream ecology and summarized methodologies relating to evaluating spawning flows. Together, these papers present a comprehensive review of currently available methodologies.

In general, approaches span the range from those which are basically subjective, relying upon little or no field data, to ones based upon in-depth quantification of a number of variables which can be related to ecological requirements of fish species. Subjectively-based recommendations of an experienced fishery biologist have, in some instances, provided similar stream flow recommendations to those developed by quantitative methods. However, because these recommendations lack field quantification, they are more difficult to defend from a legal standpoint. Methodologies utilizing field measurements are more costly but provide biologically reliable and defendable information with a minimum amount of subjective judgement involved.

The most critical problem in recommending stream resource maintenance flows for fish species is that of relating the physical characteristics of the stream to the ecological requirements of the fish. Despite voluminous literature dealing with the life histories of fishes, comparatively little information has been accumulated on specific ecological requirements. Many studies have described food habits and the general habitat occupied by a particular species but few have ascertained the specific physical requirements of the species or of its food sources. Knowledge of instream flow requirements of salmonid species is the most advanced but even in this extensively studied group information concerning rearing requirements is lacking. Much less is known about all phases of the life histories of many non-salmonid species. Lack of knowledge of ecological requirements of certain fish species has been a major constraint in the development of methodologies.

Prior to Bovee's (1974) proposed methodology for recommending stream resource maintenance flows for warm water fishes, all methods were directed toward meeting flow requirements of salmonids, with emphasis upon anadromous forms. Further, those methodologies involving field measurements were tailored to relatively small, wadable, cold water streams.

After examining the stream resource maintenance flow methodologies available, it becomes increasingly clear that no single method will be adequate to meet physical and biological needs of the wide variety of fish species found in a geographic diversity of habitats. This is not to suggest that the basic approach should be different. In all instances the basic premise behind recommending stream resource maintenance flows is to provide flows which accommodate the habitat requirements of the species at each stage of its life history. Ideally, standard methodologies will be developed which will apply to a group of species with generally similar biological and physical needs (i.e. resident salmonids). Specific requirements of a particular species within this group (i.e. cutthroat trout) would be accommodated by altering the physical and biological criteria, not the procedure for measuring these criteria. Recommendations based upon standardized methodologies would provide additional credibility in establishing and enforcing stream resource maintenance flows.

Despite gaps in our knowledge, it is timely for agencies to develop interim stream resource maintenance flow recommendations based upon our present understanding of the fluvial ecosystem and to proceed as rapidly as possible with research directed toward meeting informational needs.

PROPOSED METHODOLOGY

Determining stream resource maintenance flows for large river has been and will continue to be a difficult problem with which managers must deal. All available methodologies were found to be inadequate for direct application to large river systems.

Not unlike other methodologies, the proposed approach addresses the environmental requirements of fish species at each life history stage. In comparison with available methodologies, it is most closely allied to the Oregon Method in that it uses a modification of the "usable width" approach and considers discharge requirements of fish species for successful passage, spawning and rearing.

This methodology is founded upon the basic concept of predicting loss of habitat at reduced discharge and relating the predicted loss to physical and biological requirements of key fish species. Considering our limited understanding of the intricacies of the large river ecosystem, this appears to be the most realistic approach.

The basic distinction between the proposed methodology and those presently available is its predictive component. Other methodologies are based upon field data collected at several flows while the proposed method requires only one set of field observations. By way of a predictive computer model these data are used to predict channel morphology and hydraulic characteristics at any specified lower or higher discharge.

Independently, the Idaho Cooperative Fishery Research Unit, Montana Fish and Game Department and the United States Forest Service began efforts toward developing this approach. A number of predictive models are available for analyzing field data. These range from a simple model developed by the Forest Service to the complex model developed by the Bureau of Reclamation. Both the Forest Service and Bureau of Reclamation models are based upon linear cross sectional transect analysis. Although data needs are similar for the two approaches, the Bureau of Reclamation model has the capability of partitioning a transect into as many as nine parts and predicting hydraulic characteristics for the transect as a whole and for each subsection. This is a distinct advantage since it allows the investigator to examine specific portions of a cross section for suitability in meeting the needs of a species for a particular biological activity. If, for example, we were specifically interested in that portion of a transect which provided adequate habitat for spawning, changes in mean depth and velocity and in total surface width for that linear length could be predicted for any specified discharge. This model gives us a much more refined capability of estimating the effects of various discharges on each phase of a fish's life history. The Forest Service model predicts mean depth and velocity (and other parameters) for the entire transect but does not have the partitioning capability.

Montana Fish and Game Department, in cooperation with the Bureau of Reclamation through its Federal Technical Assistance Program, has used the Bureau's model with satisfactory results and is planning to further test this approach during 1975. Much of the following description of the model and its use is taken from the proceedings of a workshop conducted by personnel of the Bureau of Reclamation for Montana Fish and Game biologists and is used with permission of the authors (Dooley and Keys 1975).

Application of Bureau of Reclamation Program: Water Surface Profile

The Water Surface Profile program was designed to perform the tedious computations necessary to estimate water surface elevations at various cross sections in a particular reach of channel. From one set of field observations at known discharge, the program allows the user to predict and study various changes in stream characteristics at many different discharges.

Field Data Requirements

Field data should be collected at the lowest practical discharge and should include:

1. Map showing stream reach being studied and cross section locations.
2. Photographs of stream reach being studied and of each cross section location.
3. Description of bank and overbank material and vegetation (trees, brush, grass, logs).
4. Cross sectional survey data including.
   a. Total width (water surface)
   b. Depth profile
   c. Distance from shore-water intercept to each depth measurement
   d. Velocity (for determining discharge)
5. Description of stream bottom materials along each cross section.
6. Identification of points where streambed material and vegetation change within the cross section.

7. Distance between cross sections.
8. Measured flow in cubic feet per second and the corresponding water surface elevations at each cross section.

Maps, photographs and descriptions of bank and overbank material are used by the hydrologist as part of the evaluation process.

Cross sectional survey data provides the core information from which changes in habitat are predicted. The specific characteristics of the study section determine the number of cross sections needed.

For accurate predictions, a minimum of four cross sections are needed for each study reach with a maximum of 100. In establishing cross sections it is important that the transect be located at right angles to the stream flow. In addition to those cross sections taken in areas of representative habitat suitable for one or more of the biological activities of fish species for which flows are being recommended, cross sections must also be taken at each flow control section in the study reach. When islands are located within a study reach, cross sections should be taken upstream and downstream from the island and where each channel around the island begins and ends. If a bridge is included in a study reach, cross sections should be established at the site and approximately 15 m (50 ft) above and below the bridge. If other controls such as log or debris jams are within the study reach, cross sections should be established 15 m (50 ft) above and below these controls.

The frequency of the depth measurements along a transect varies depending upon the purpose of data acquisition and the channel configuration. For discharge measurements in large rivers, depth is measured with sounding equipment at 3-m (10-ft) intervals along the transect. Standard U. S. Geological Survey methods should be followed. For other transects the distance between depth measurements may vary as long as sufficient measurements are taken to provide an adequate description of the channel profile.

Because of the predictive capacity of the model, velocity measurements are not required except for calculating discharge. However, it is useful to have some velocity data, particularly in those portions of a transect which are critical for passage or spawning. These data can be used to evaluate the accuracy of predicted velocities. Velocity measurements are taken with a direct readout current meter using standard U. S. Geological Survey criteria.

Substrate description is important both for use by the hydrologist in determining roughness coefficients and for evaluating habitat. Substrate particle size is defined as: sand-silt, 2.5 mm (0.1 in) diameter; gravel, 2.5-73.7 mm (0.1-2.9 in) diameter; cobble (smooth) or rubble (angular) 76.2-304.8 mm (3-12 in) diameter; boulder, 304.8 mm (12 in) diameter; and bedrock. Predominant substrate composition is estimated and categorized by the observer. Where visual observations are not possible, depth soundings will facilitate evaluation of bottom composition.

The basic program is designed for study reaches no greater than 9,999.9 units (m or ft) in length, but adjustments can be made to accommodate greater distances. Measured distance between cross sections should represent, as near as possible, the distance along the line of flow or thalweg. This can be approximated by shoreline distance except for meanders or stream bends which should be measured along the inside and outside edges.

At least one flow measurement must be made when taking field data (unless a gaging station is within the study reach) and must be identified with the water surface elevation at each cross section. Since all cross sections within a study reach may not be measured on the same day, and consequently at the same discharge, water surface elevations should be marked at each cross section location so that these elevations can be identified with the measured discharge. Although not necessary, it is also useful to identify high water marks and tie them into the cross section. This will give another set of elevations to firm up the field data and to help determine the proper energy slope of the specific stream reach being studied. If the discharge changes at some point within the study reach, such as a diversion or tributary inflow, the program has the capability of making adjustments for this if discharge measurements are available. However, for simplicity, these kinds of areas should be avoided if possible.

The quality of field data determines the accuracy of computed results. If elevations are taken within ± 3 cm (0.1 ft), the predicted water surface elevations will be within ± 3 cm (0.1 ft). The most important aspect of field data collection is consistency. Cross sections should originate from the same side of the stream, left and right streambanks should be identified (left bank is defined as being left when looking downstream) and cross sections should be taken progressing in an upstream or downstream order; one person should work with the surveying instrument. In general, good surveying technique must be used.

After field data are collected, individual cross sections are plotted. Plots should include identification of streambed material, types of vegetation on overbank, left and right streambank and subsections to be analyzed for meeting biological criteria of fish species. Cross sections need not contain an equal number of subsections but are limited to a maximum of nine.

Data Processing

Field data are reviewed with the hydrologist, key punched and edited. Roughness coefficients are determined from field data, observations, photographs and good hydraulic handbooks. An energy slope is computed from the streambed thalweg and observed water surface elevations. As previously pointed out, these observed water surface elevations must be tied to the specific stream flow measured at those elevations.

These data are run through the water surface profile program which analyzes them from the most downstream cross section through the most upstream cross section, using an energy balance computation.

The model is calibrated to the stream section by examining the output for the observed flow to determine if predicted water surface elevations match observed values. Adjustments in roughness coefficients ("n" values), cross sections and station distances are made to bring predicted values within ± 3 cm (0.1 ft) of observed values. After these calibrations have been made, a series of flows including the observed historic low flow and/or mean historic low flow for the time period of interest are selected and analyzed by the program.

Computer Output

Available output from the program includes specific data on each cross section and summary tables of predictions for all flows analyzed. Specific cross sectional output include discharge, water surface elevation and slope at each cross section and mean velocity, conveyance area, top width and hydraulic radius for the cross section as a whole and for each subsection examined. From these data, wetted perimeter can be calculated and point depths determined. Summary tables are printed and include water surface elevations, velocities, discharges, roughness coefficients and main channel distances.

Application of Proposed Methodology to the Snake River

General field data requirements for predicting channel morphometry and hydraulic characteristics of streams at specified flows were described above. The next step is to define general study sites which will provide meaningful data relative to meeting the ecological requirements of select fish species and to describe how these data can be used in recommending stream resource maintenance flows.

Three key fish species inhabiting the Snake River have been identified by Idaho Department of Fish and Game as species which must be accommodated by the recommended flows. These include white sturgeon (*Acipenser transmontanus*), smallmouth bass (*Micropterus dolomieui*), and channel catfish (*Ictalurus punctatus*). The proposed methodology requires that flow recommendations meet needs of fish species for biological activities related to passage, spawning, and rearing.

Study areas are selected after thorough reconnaissance of the river segment for which stream resource maintenance flows are to be recommended. Study reaches should include representative habitat types which can be evaluated for passage, spawning and rearing of key fish species.

Passage

Channel catfish have been reported to migrate long distances (Scott and Crossman 1973) while smallmouth bass (in the Snake River) are rather sedentary (Munther 1967, 1970). Neither species is confined to large river systems in distribution and each is adaptable to a wide range of flows. The white sturgeon, however, inhabits only large rivers. Historically, this species was anadromous in the Snake River and therefore has well developed migratory behavior. Flows suitable for passage of white sturgeon should also accommodate smallmouth bass and channel catfish.

Unfortunately, little is known about the extent of movement in the present land-locked white sturgeon population or about specific requirements for passage or for other biological activities. Mr. John Coon, Graduate Student, University of Idaho, is conducting a comprehensive ecological study of white sturgeon in the middle Snake River, the results of which will provide valuable input into establishing criteria for use in recommending stream resource maintenance flows. Prior to completion of this study, certain assumptions and inferences drawn from the literature must suffice in developing flow recommendations.

A spawning migration of land-locked white sturgeon in the Snake River is assumed to occur, but its extent is unknown. Little movement was documented by Coon (1974) for small sturgeon <1.1 m (3.5 ft) in the middle Snake River while sturgeon greater than 1.8 m (6 ft) in length were observed to be quite mobile. Large individuals showed movements covering a succession of two or three holes in a 0.8-km (0.5-mi) section of river, within a 2-day period; constant up- or downstream movement of as much as 4.8 km (3 mi) was also observed. Such movement may be necessary for large sturgeon to obtain an adequate food supply. Based upon this information, passage becomes an important consideration throughout much of the year.

To evaluate passage, shallow riffles or sandbars which would possibly impede up- or downstream movement are located. Since these areas will probably not be located at right angles to the flow, a varying number of transects will be needed to describe a potential passage block (Fig. 1). One depth profile along the shallowest course of the riffle or bar should be made. This information will be useful in final analysis and in determining the location and number of transects needed. For analysis, the shallow area of each transect is partitioned from the remainder of the transect and depth and velocities predicted for the range of flows desired.

Predicted depths and velocities of the critical segment of each transect are then examined and channel characteristics are projected for the total linear length of the potential passage block. From these projections, a minimum passage flow is recommended for those months in which sturgeon are active (mid-February to mid-November).

The Oregon Method recommends a minimum flow for passage as one which creates a continuous portion of the cross section transect encompassing 10% of its total length (shallowest course) and which provides at least 25% of the total transect length suitable for passage of adult salmonids (Thompson 1974). For paddlefish, Bovee (1974) recommends that 50% of the total transect length, as measured by the Oregon Method, meet clearance criteria with a continuous portion equalling at least 30% of the total transect length.

Until flow criteria for passage of white sturgeon are determined, it is recommended that a minimum continuous depth of 1.5 m (5 ft) be maintained over 25% of the length of the potential block. Adjustments in these criteria will probably be necessary based upon field observations.

Spawning

Smallmouth bass in the middle Snake River spawn from late May to early July with peak spawning activity between 15 June and 1 July (Keating 1970). Nests are built over sand, gravel or rock substrate at depths of 0.6-6.1 m (2-20 ft) and spawning occurs when water temperature is between 12.8 and 20.0 C (55-68 F) (Scott and Crossman 1973). Channel catfish spawn at temperatures ranging between 23.9 and 29.5 C (75-85 F) in secluded, semidark nests in holes, undercut banks, log jams or rocks. Spawning probably occurs in

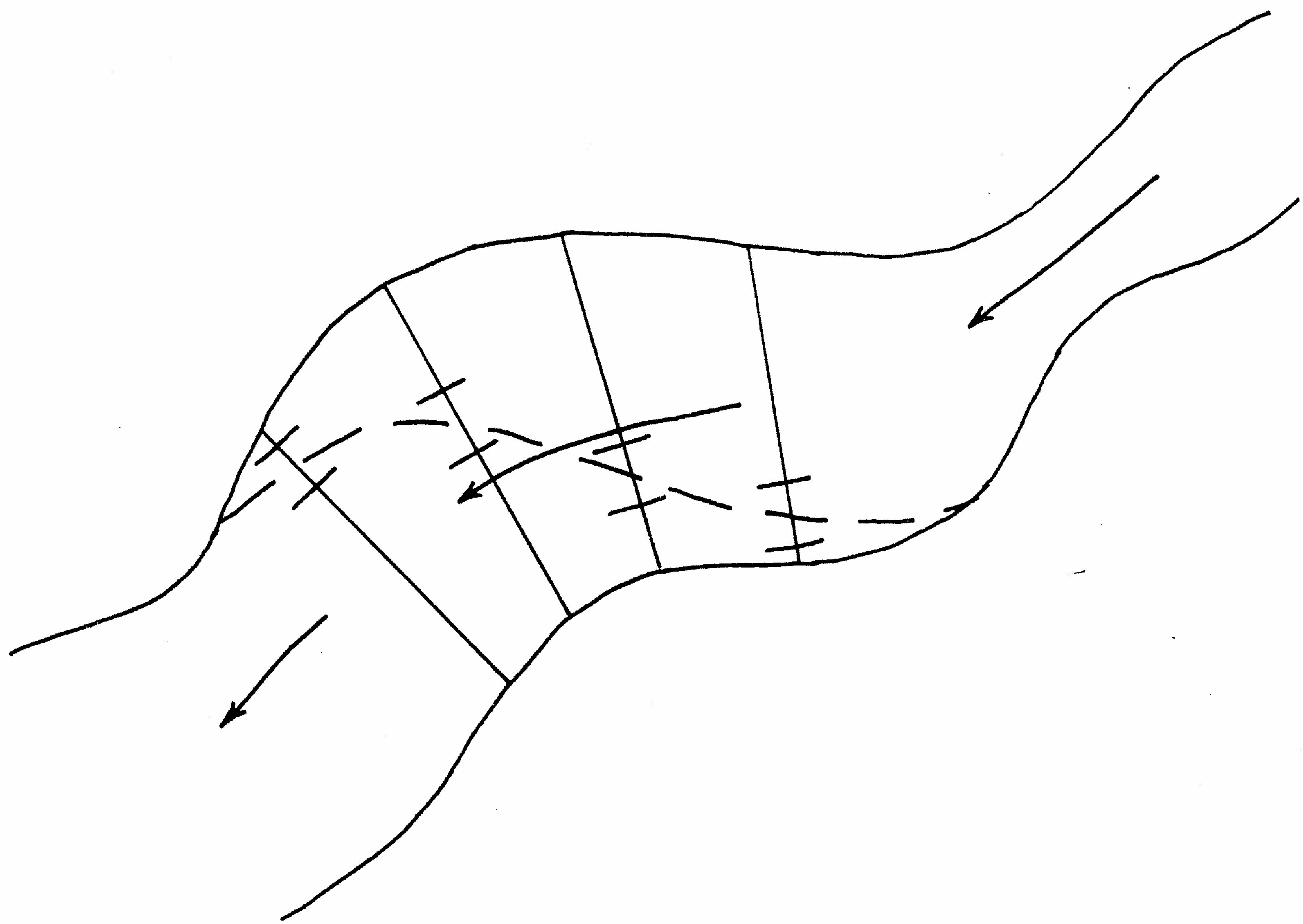

Figure 1. Location of transects for passage flow requirement evaluation. Broken line represents shallowest course as used in Oregon Method. Brackets on linear transects indicate partitioned segments.

the Snake River in August.

Stable flow during the spawning and incubation period of smallmouth bass and channel catfish is probably more important for spawning success than recommending a specific stream resource maintenance flow for this activity.

The spawning period of white sturgeon is reportedly May and June with spawning probably taking place over rocky substrate in swift current near rapids when water temperatures are between 8.9 and 16.7 C (48-62 F) (Scott and Crossman 1973). These general requirements are similar to requirements reported for other sturgeon species of North America and Russia (Table 1).

Since there is nearly complete overlap in the time of spawning of white sturgeon and smallmouth bass, suitable discharge for white sturgeon spawning should also provide suitable spawning conditions for smallmouth bass. Field observations will be necessary to test the validity of this assumption. Although channel catfish spawn later than either of these species in the Snake River, rearing flows (which will be discussed later) will provide sufficient discharge for spawning.

Since no specific information on the preferred location, depth or velocity for successful spawning of white sturgeon has been reported, research should be initiated to determine physical requirements. However, until specific information becomes available, inferences of the spawning requirements can be made from known requirements of other species of sturgeon. The reliability of such comparisons is not known but is considered superior to no information at all. At least among Russian species of sturgeon, spawning requirements are very similar (Khoroshko 1973).

Most sturgeon literature examined reported that spawning occurs at the foot of a riffle or below a waterfalls, in swift water over rocky substrate. Unconfirmed accounts of sturgeon spawning in the Snake River suggest that white sturgeon spawn in similar habitat.

Anadromous species of sturgeon native to Russia are reported to spawn at depths ranging from 1.5 to 5.0 m (5.0-16.4 ft) and at velocities of 0.7 to 1.1 mps (2.3-3.6 fps) (Table 1). Lake sturgeon, a smaller adfluvial species, is reported to spawn at depths ranging from 0.6-4.6 m (2.0-15.0 ft); no velocity requirements have been reported.

Until spawning requirements of white sturgeon are documented, it is recommended that minimum depth criteria for spawning be set at 1.5 m (5 ft). This estimate appears within reason when one considers the large size of mature fish and the fact that one female is accompanied by two or more males during the spawning act. A range of velocities from 0.6-1.1 mps (2.0 to 3.5 fps) is recommended.

Transects for evaluating flow suitability for meeting spawning criteria should be established in representative reaches of the river, as near the tail of riffles as physically practical for measurement. Areas of relatively uniform cross-sectional profile would facilitate analysis but are not essential. At least three potential spawning riffles of comparable size

Table 1. Spawning requirements of several sturgeon species.

Sturgeon	Literature source	Life cycle	Temperature	Time	Depth	Velocity	Habitat
White	Carlander '69 Scott & Crossman '73	Anad.	8.9-16.7 C (48-62 F)	May-June			Rocky bottom; swift current near rapids
Shovelnose	Carlander '69	Fluv.		April-July			Mississippi River and large tributaries
Lake	Carlander '69 Scott & Crossman '73	Adfluv.	12-19 C (53.6-66.2 F)	April-June	0.6-4.6 m (2-15 ft)		Swift water; often at foot of falls
Lake	Pringel & Wirth '71		11.7-15.6 C (53-60 F)	April-May			Just under water surface; outside bends of river banks, especially in upwelling current along steep angle riprap
Lake	Harkness & Dymond '61						foot of rapids
Atlantic	Carlander '69 Scott & Crossman '73	Anad.	13.3-17.8 C (56-64 F)				Assumed to spawn in pools below falls
Shortnose	Scott & Crossman '73	Anad.		April-June			Middle reaches of large tidal rivers

Adfluv. -- Adfluvial
Anad. -- Anadromous
Fluv. -- Fluvial

Table 1. Spawning requirements of several sturgeon species (continued).

Sturgeon	Literature source	Life cycle	Temperature	Time	Depth	Velocity	Habitat
Sevryuga	Khoroshko & Vlasenko '70	Anad.	?-24 C (?-75.2 F)	May-June	4-5 m (13.1-16.4 ft)	0.7-1.1 mps (2.3-3.6 fps)	Gravel bars with linear flow
Sturgeon sp.	Shilov '68	Anad.	9.5-18 C (49.1-64.4 F)	May-June	1.5-2 m (4.9-6.6 ft) (eggs found)	High	

Anad. -- Anadromous

should be examined in each study reach. Field measurements are made and the data analyzed by the Water Surface Profile program. At each of several predetermined discharges, those portions of the transects having suitable depths for spawning are partitioned and analyzed a second time for the purpose of determining velocity in these areas.

Mean spawnable width of transects analyzed is determined for each discharge and the flow which provides maximum spawnable width is considered optimum. The minimum sustained discharge for spawning will be some specified percentage of this value and will be determined after original data analysis. The Oregon Wildlife Commission has set minimum sustained discharge at 80% of optimum for salmonids (Thompson 1972) and Bovee (1974) recommends minimum discharge of 75% optimum for paddlefish. Optimum is defined as the maximum efficient flow for creating or maintaining suitable spawning areas.

Rearing

Rearing requirements of fishes in general are less understood than requirements for other phases of the life cycle. Successful rearing of stream fishes depends upon adequate food supply, physical habitat and suitable water quality.

Virtually nothing is known about the early life history of white sturgeon. Collection of larval white sturgeon and/or green sturgeon has been reported only once in the literature (Stephens and Miller 1970). Catches in nets set at different depths give evidence that sturgeon larvae are demersal. The area of residence of white sturgeon smaller than 381 mm (15 in) in length is not known; large sturgeon inhabit deep pools.

Sturgeon up to 482 mm (19 in) in length are reported to feed on plankton and small macroinvertebrates (Carlander 1969). Scott and Crossman (1973) report that the diet of white sturgeon in this size range is predominately chironomids (35.2% by volume) with lesser amounts of other aquatic insect larvae, crustaceans, and molluscs. Larger white sturgeon feed primarily on fish (48.6% by volume) crayfish, molluscs, and chironomid larvae. In general sturgeon are omnivores and scavengers.

Smallmouth bass habitat varies with fish size and season. Fingerlings rear in isolated pools, sloughs and shallow stillwater areas. Adults inhabit shallow, still pools in spring, eddies, pools and slow runs in summer and quiet rocky pools in late fall. In winter, they move into the substrate when water temperatures reach 6.7-7.8 C (44-46 F) (Munther 1967, 1970). In the Snake River, food of fingerling smallmouth bass is reported to be predominately aquatic insects (chironomid and mayfly) while crayfish make up 86% of the diet, by weight, of bass larger than 100 mm (4 in). The channel catfish is also a pool-associated species. Young feed primarily on aquatic insects and inhabit riffle or quiet pool environments. Adults usually inhabit deep water with sand, gravel or rubble bottom but may move into riffle areas at night to feed. Small channel catfish feed primarily on aquatic insect larvae while adults are omnivorous; crayfish constitute one of the more important food sources.

All three species which stream resource maintenance flows must accommodate require pool-associated habitat for rearing. Also each has in common two food sources: aquatic insects and crayfish. Since invertebrate production takes place primarily in riffle areas and riffles are most affected by reduced discharge, it is reasoned that maintenance of suitable riffle conditions will also maintain suitable pool conditions.

The USGS--Washington Department of Fisheries method for recommending rearing flows for Pacific Salmon species is based upon the assumption that rearing is proportional to food production, which is in turn assumed proportional to wetted perimeter (Collings 1974). No studies have been reported which were specifically designed to determine the validity of this relationship. Although studies by Ruggles (1966) and Kennedy (1967) provide some insight into the relationship, more research is needed. Until better information is obtained, I recommend that determination of rearing flows be patterned after the above method.

In determining rearing discharge, several representative, physically accessible riffles are located and one transect is established in each. Standard physical measurements are made and riffle characteristics predicted with the Water Surface Profile program. Wetted perimeter is calculated and plotted against discharge.

Starting at zero discharge, wetted perimeter increases rapidly for small increases in discharge up to the point where the river channel nears its maximum width. Beyond this inflection point, wetted perimeter increases slowly while discharge increases rapidly. The optimum quantity of water for rearing (food production) is selected near this inflection point (Fig. 2).

When physical requirements for large river macroinvertebrates are determined, these can be used to aid in evaluating rearing flows. Although much information is available on optimum range of depth and velocity for maximum macroinvertebrate production in small cold water streams, very little has been reported about requirements of macroinvertebrate populations in large rivers. In small cold water systems, maximum macroinvertebrate production occurs at depths between 7.6 and 22.9 cm (3.0-9.0 in) (Bovee 1974) and velocities of .3 to .8 mps (1.0-2.5 fps) (Giger 1973). In the Snake River, high biomass of aquatic macroinvertebrates occurs at water depths and velocities greatly exceeding those optimum for small stream species.[1]

It may be found that flows recommended for passage of white sturgeon are greater than flows determined for rearing by the above method. In this event, it would not be necessary to evaluate rearing flows.

Corning, Raymond

[1] Personal communication with Dr. Merlyn A. Brusven, Aquatic Entomologist, University of Idaho, April, 1975.

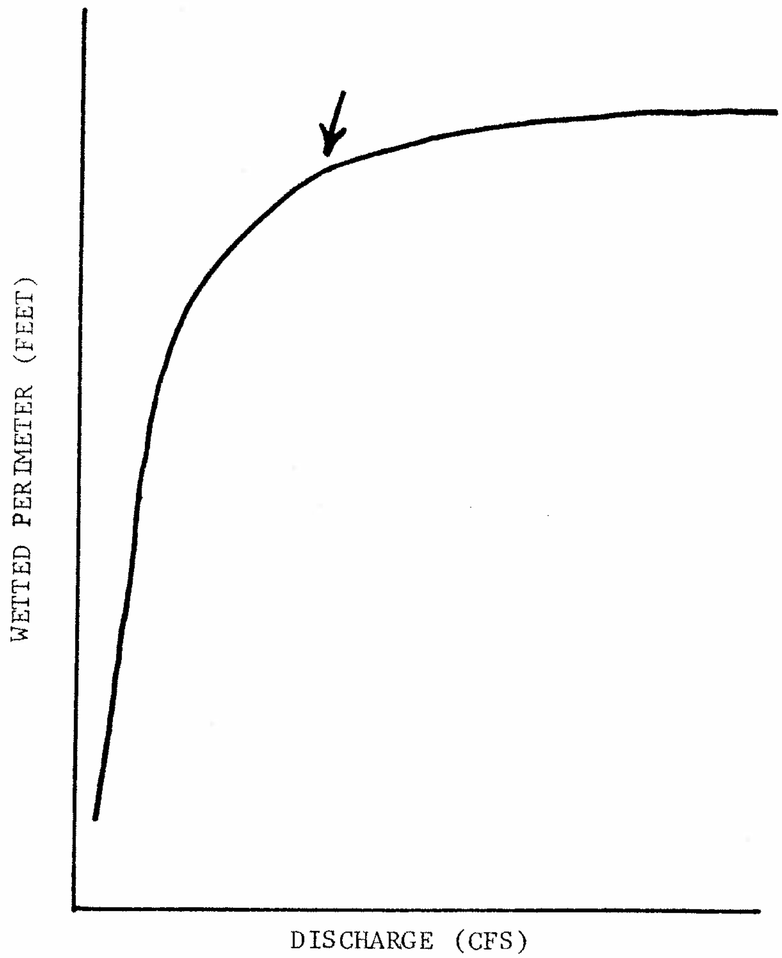

Figure 2. General representation of the wetted perimeter-discharge relationship. Arrow approximates the recommended rearing discharge.

Preparation of Recommended Flows

After analysis of field data, recommended flows are assigned by month or 2-week period for each biological activity. The stream resource maintenance flow which is the highest for the critical biological activity of any given time period is the flow selected.

Although the above approach does not take into consideration resident and/or anadromous salmonids, where these species are important, their flow requirements should be evaluated as part of the over-all recommendation.

Advantages and Disadvantages of Proposed Methodology

The major advantage of the proposed methodology over those currently available is the reduced time involved in making field observations and consequently the reduced cost of determining stream resource maintenance flows. The initial expense for field equipment, however, is greater than for methodologies currently applied to wadable streams.

A possible disadvantage of the methodology is that accuracy may not be as good as would be obtained from actual field measurements. That is the water surface profile program predicts mean values for hydraulic characteristics for each subsection (maximum of 9) within each transect. This is possibly less accurate than using actual field measurements taken at a series of reduced discharges, as is required by other methodologies employing field measurement. The weakest point in the application of the proposed methodology to the Snake River is the limited available information on certain ecological requirements of the fish species involved.

This methodology is proposed only as a starting point for developing flow recommendations for a large river and is not intended to be rigid. It is based upon the best information available and with research and field experience will hopefully evolve into a sound approach to recommending stream resource maintenance flows for large rivers (and also smaller fluvial systems).

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