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AFS 62 STREAMFLOW REQUIREMENTS OF SALMONIDS

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ABSTRACT

A methodology is being developed that can be used in natural streams to estimate the influence of stream discharge on carrying capacity of salmonids. A habitat rating system has been developed for juvenile coho salmon which explains 72% of the variation recorded in fish biomass in six study sections at three different flow levels in Elk Creek, near Cannon Beach, Oregon. Methods are proposed for evaluating instream flows for salmonid rearing which combine an evaluation of habitat quality and water quality over a range of flow levels.

INTRODUCTION

The maintenance of adequate instream flows to support aquatic life is recognized as a major problem. In Oregon the primary concern is the protection of resident and anadromous salmonids. The Oregon Department of Fish and Wildlife has recommended minimum and optimum flows by month for several hundred streams based on the passage, spawning, incubation and rearing requirements of the salmonid species present (1). Of these requirements, the relationship between rearing and flow is the least understood.

In 1968 the Environmental Management Section of the (then) Oregon Wildlife Commission requested that research be initiated to develop improved methods for recommending rearing flows for salmonids. As a result, a literature survey was initiated in 1971 (2) and preliminary investigations into possible research designs and methods were conducted on Elk Creek, a coastal stream, in the summers of 1973 (3) and 1974 (4). A study designed to measure and evaluate salmonid habitat and carrying capacity over a range of controlled constant flows was implemented in summer 1975.

OBJECTIVE

To determine techniques that can be used in natural streams to estimate the influence of stream discharge on fish production.

PROCEDURES

A. Collect production data from fish and aquatic invertebrate populations in study stream sections subjected to differing streamflow regimes between July 1 and October 31, 1975.

B. Map the physical character of stream channels and document changes in stream hydraulics and fish shelter conditions at different discharge stages between July 1 and September 31, 1975.

C. Analyze contents of fish stomachs and samples of benthos and invertebrate drift organisms collected during the summer field season.

D. Analyze field data from physical and biological investigations through development and utilization of specialized computer programs and statistical techniques and conduct regression analyses of production and physical data.

E. Design and implement similar research under revised flow regimes scheduled for the 1976 field season.

METHODS

A wood piling weir and a 76 cm diameter corrugated metal pipe divert water from the North Fork to the West Fork of Elk Creek (3). A head gate provides control of flows through the study area. The weir is located on the North Fork 1.2 km upstream from its confluence with the West Fork.

Six 30 m study sections were established in the stream below the flow control facility. Each study section was separated from the remainder of the stream by screens and traps. Each section was stocked at a rate of 2 fish/m^2

with age 0+ coho salmon *(Oncorhynchus kisutch)* and age 0+ trout *(Salmo clarki and Salmo gairdneri)* collected elsewhere in the stream.

Summer floods limited the project to four constant discharge levels each of which was studied during individual two-week experiments. The flows were 3.00, 2.25, 1.50 and 0.75 cfs and represent the approximate 5-year recurrence interval, 7-day average low flow[1/] and 25%, 50% and 75% reductions from the same. In each experiment, depths and velocities were measured on 22 cross-sectional transects (at 1-2 m intervals) in each study section. Substrate and cover types were evaluated for each transect in the first experiment. At the end of each experiment fish biomasses were estimated. Water chemistry and temperature were monitored weekly and continuously, respectively.

Rick Hafele, an Oregon State University graduate student in entomology, is studying the effects of reductions in flow on the aquatic insects of Elk Creek. Drift nets, artificial substrates, a benthic sampler and floating traps were used to collect insect samples. Salmonid stomachs were also collected and later examined for food content. Sampling was done systematically following a rigid schedule.

RESULTS

A flood of 165 cfs following Experiment 3 altered the study sections and Experiment 4 could not be compared to the previous three experiments. Study sections 4 and 6 were eliminated from Experiment 4 due to considerable changes in the streambed and a lack of fish with which to restock. Experiment 4 was included in the data summaries presented, however it was not included in further analysis.

[1/] John F. Orsborn, Washington State University, personal communication.

A summary of the mean width, depth and velocity of the study sections during each experiment is presented in Table 1. Sections 2 and 4 had the highest and lowest mean velocity respectively, and also had the lowest coho salmon biomasses (Table 2).

Table 1. Mean width, depth and velocity of six Elk Creek study sections at four different flows.

Sec.		Exp. 1 3.00 cfs	Exp. 2 2.25 cfs	Exp. 3 1.50 cfs	Exp. 4 0.75 cfs
#1	Width	7.04 m	6.92 m	6.52 m	6.34 m
	Depth	16.4 cm	15.0 cm	15.1 cm	13.6 cm
	Velocity	18.1 cm/sec.	14.5 cm/sec.	10.4 cm/sec.	8.4 cm/sec.
#2	Width	2.68 m	2.59 m	2.37 m	2.08 m
	Depth	13.3 cm	11.5 cm	10.6 cm	7.9 cm
	Velocity	34.8 cm/sec.	28.9 cm/sec.	21.7 cm/sec.	17.1 cm/sec.
#3	Width	5.98 m	5.80 m	5.11 m	4.40 m
	Depth	18.0 cm	16.3 cm	17.5 cm	18.0 cm
	Velocity	13.4 cm/sec.	9.6 cm/sec.	7.9 cm/sec.	4.7 cm/sec.
#4	Width	6.61 m	6.31 m	6.13 m	
	Depth	28.6 cm	28.5 cm	27.6 cm	
	Velocity	8.5 cm/sec.	6.5 cm/sec.	5.9 cm/sec.	
#5	Width	6.02 m	5.84 m	5.63 m	5.27 m
	Depth	23.2 cm	22.2 cm	21.2 cm	22.7 cm
	Velocity	19.8 cm/sec.	15.9 cm/sec.	14.7 cm/sec.	8.1 cm/sec.
#6	Width	8.24 m	7.56 m	6.72 m	
	Depth	15.2 cm	15.0 cm	14.4 cm	
	Velocity	14.9 cm/sec.	12.3 cm/sec.	10.3 cm/sec.	

The higher biomass present in the study sections at the end of Experiment 4 compared to that present at the end of Experiment 3 was due in part to a delay of two weeks, caused by the midsummer flood, between the end of Experiment 3 and the beginning of Experiment 4.

Table 3 contains a summary of the water chemistry in the study area during each experiment. Values presented are means of values for each individual study section.

Table 2. Biomass of age 0+ salmon and trout in the six Elk Creek study sections at four constant discharge levels.

Section		Biomass (g/m^2) Exp. 1 3.00 cfs	Exp. 2 2.25 cfs	Exp. 3 1.50 cfs	Exp. 4 0.75 cfs
1	Salmon	3.39	2.65	2.53	4.23
	Trout	0.29	0.23	0.13	0.06
2	Salmon	0.74	0.69	0.64	0.87
	Trout	0.11	0.14	0.12	0.47[a]
3	Salmon	3.31	3.07	2.89	4.41
	Trout	0.14	0.11	0.04	0.03
4	Salmon	2.02	1.82	1.93	
	Trout	0.08	0.06	0.09	
5	Salmon	2.64	2.75	2.51	3.13
	Trout	0.07	0.05	0.06	0.28[a]
6	Salmon	2.15	2.70	2.69	
	Trout	0.62	0.33	0.54	

[a] 10 additional trout were stocked in each of these sections at the beginning of Experiment 4.

Table 3. Mean values for five water chemistry parameters for each experiment.

Parameter	Exp. 1	Exp. 2	Exp. 3	Exp. 4
Water Temp. (°C)	14.00	15.08	14.66	13.94
Dissolved oxygen (mg/l)	9.33	9.25	9.08	7.63
pH	7.08	7.03	7.00	6.80
Total alkalinity (mg/l $CaCO_3$)	25.33	21.50	21.75	20.38
Carbon dioxide (mg/l)	9.67	9.75	10.50	6.70

The results of the analysis of the stomach contents of 59 salmonids, presented in Table 4, indicate that terrestrial and adult aquatic insects landing on the surface were more important as food in September than in August. Unfortunately data on the relative abundance of organisms landing on the surface is available only through the middle of August (Table 5). The floating traps used to collect the insects were either lost or severely damaged by the

the flood which occurred in late August, thus preventing further sampling.

Table 4. A breakdown of the insects found in the stomachs of 59 juvenile salmonids collected from Elk Creek.

Date	No. of fish sampled	Number of food items	
		Terrestrial and adult aquatic insects	Aquatic nymphs
8/5/75	6	9 (9.5%)	86 (90.5%)
8/21/75	19	147 (7.2%)	1900 (92.8%)
9/3/75	1	10 (20.4%)	39 (79.6%)
9/15/75	33	184 (62.4%)	111 (37.6%)
Total	59	350 (14%)	2136 (86%)

Table 5. The number of terrestrial and adult aquatic insects collected in 4 four floating traps during 7-day periods from July 14 to August 18, 1975.

Week ending	No. of insects		
	Terrestrial	Adult aquatics	Total
7/21/75	35	446	481
7/28/75	100	1542	1642
8/4/75	49	883	932
8/11/75	62	816	878
8/18/75	99	537	636
Total	345	4224	4569

EVALUATION OF STREAM HABITAT FOR SALMONIDS

As a result of research conducted on Elk Creek in 1975 a system for evaluating coho salmon habitat has been developed. This system is based on a weighting of individual observations taken on cross-sectional transects. The weighting factor consists of a "habitat index" and a species-specific cover preference factor. The "habitat index" is the sum of values developed for a water type, cover, and substrate associated with each observation. These values are derived from a numerical ranking of specific types within each of the three categories (Table 6). The ranking is based on the relative value as coho salmon habitat of one type compared to other types in the same category.

Table 6. Criteria for rating the habitat of two different types of streams for two different salmonid species.

HABITAT INDEX CRITERIA		
A. Species: Coho Salmon - Age 0+		
Stream: Elk Creek		
Habitat Categories:		
Water Type		Value
Prime	Depth >30 cm Velocity <30 cm/sec	2
Marginal	Depth ≤30 cm Velocity <30 cm/sec	1
Cover Type		
Undercut banks and submerged roots		2
Overhanging cover and submerged logs and limbs		1
No cover		0
Substrate Type		
Cobble		2
Gravel		1
Sand, Silt or Clay		0
B. Species: Brown Trout - ≥15.2 cm (6 in.)		
Stream: Little Deschutes River		
Habitat Categories:		
Water Type		Value
Prime	Depth >30 cm Velocity 12-21 cm/sec	2
Marginal	Depth ≤30 cm Velocity ≤21 cm/sec	1
Cover Type		
Undercut banks, overhanging willows and submerged roots		2
Aquatic vegetation and submerged logs and limbs		1
No cover		0
Substrate Type		
Cobble		2
Gravel		1
Sand, Silt, Clay or Bedrock		0

Water Type

This category is used to rank depth and velocity at a given observation point in terms of the requirements for coho salmon habitat. Coho juveniles prefer depths >30 cm and velocities <30 cm/sec. Depth and velocity combinations within these ranges are considered to be prime habitat and are given a value of "2". Depths <30 cm combined with velocities <30 cm/sec are considered marginal habitat and are given a value of "1". Locations with velocity observations of 30 cm/sec or greater are considered unsuitable habitat for coho salmon. Observations from locations unsuitable for coho salmon habitat receive a "habitat index" value of "0".

Cover

On streams without an overhead canopy of trees, streambank cover such as overhanging vegetation and undercut banks is an important source of shade, which salmonids prefer (5, 6). However, since much of Elk Creek has a full canopy of alder, cover is ranked on the basis of its value as a source of protection from avian predators rather than for its value as shade. Undercut banks and submerged root systems are judged to provide the best protection for juvenile coho and are given a value of "2". Overhanging cover within 1.5 meters of the surface and submerged logs and limbs are given a value of "1" and the absence of cover is given a value of "0". The value of substrate as cover will be discussed later. Individual observation points along a transect are given a cover rating based on the best cover within 30 cm.

The preference for a cover of a given salmonid species is taken into consideration in the habitat rating system. Preference for cover is ranked as follows:

high preference for cover = 3;

medium preference for cover = 2; and

low preference for cover = 1.

Examples of species with each of these preferences are brown trout *(Salmo trutta)*, rainbow trout *(S. gairdneri)* and coho salmon, respectively.

Substrate

The substrate at each observation point is ranked on the basis of size. Cobble (>75 mm diameter) is given a value of "2" because it can provide cover (7, 8) and has a greater potential for food production compared to smaller substrate (9, 10). Gravel is given a value of "1" based on its potential for food production. Sand, silt and clay have little value as cover or for food production and therefore receive a value of "0".

Habitat Quality Rating

The habitat of a section of stream is evaluated on the basis of individual observations.

Let: HI be the habitat index value which is equal to the sum of the water type value, the cover value and the substrate value and has a possible range of 1 to 6;

N be a species-specific constant which reflects the degree of preference of a given species for cover (e.g. for coho $N = 1$);

OB_{HI} be the number of observations having a value of HI; and

TOB be the total number of observations taken in the particular section of stream in question.

Then, the habitat quality (HQU) for the section of stream is calculated from the equation:

$$HQU = \sum_{HI=N}^{6} (HI - N) \frac{(OB_{HI})}{TOB} \qquad (1)$$

An example of the calculation of HQU is presented in Table 7.

Table 7. Calculation of the habitat quality *(HQU)* for coho salmon of experimental section 1 at a flow of 3.00 cfs. For coho the value of *N* is 1.

HI	*HI-N*	OB_{HI}	$\frac{OB_{HI}}{TOB}$	$(HI-N)\ (\frac{OB_{HI}}{TOB})$
6	5	0	0.000	0.000
5	4	5	0.016	0.064
4	3	10	0.032	0.096
3	2	40	0.128	0.256
2	1	174	0.558	0.558
1	0	20	0.064	0.000
0		63		
		TOB = 312		*HQU* = 0.974

At present, the habitat rating system described above is specific for coho salmon in Elk Creek. The habitat quality ratings of the six Elk Creek study sections at three flow levels explained 72% of the variation in the coho salmon biomass of the sections (Fig. 1). Additional research is underway to determine its applicability to other streams and species. An example illustrating how the system could be applied to another stream and species is presented in Table 6.

When evaluating the habitat of a different type of stream for coho salmon, alterations must be made in the "cover" and "substrate" categories to include types not found in Elk Creek. For example, on the Little Deschutes River, (Table 6, B) which lacks the alder canopy found on Elk Creek, overhanging willow is an important source of cover. On Elk Creek overhanging cover is not as important. When evaluating the habitat for a different species, the depth and velocity preferences and the value of *N* in equation *(1)* must be adapted to the new species (e.g. for brown trout, *N* = 3).

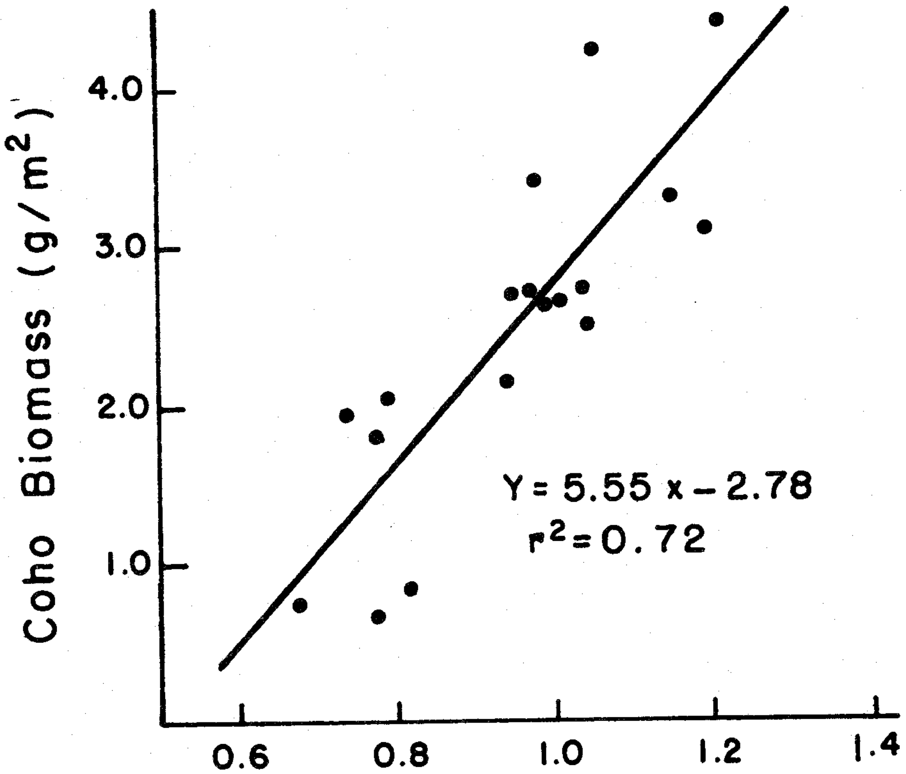

Fig. 1. The relationship between habitat quality *(HQU)* and coho salmon biomass in six Elk Creek study sections at flows of 3.00, 2.25 and 1.50 cfs.

A PROPOSED METHODOLOGY FOR EVALUATING INSTREAM FLOWS FOR SALMONID REARING

The proposed methodology for evaluating instream flows for salmonid rearing is based on the premise that the carrying capacity of a stream for a given species will change as the stream discharge changes. As the instream flow is reduced, changes which affect salmonid carrying capacity will take place not only in the habitat quality (in terms of *HQU*)but in water quality.

The important water quality parameters are water temperature and dissolved oxygen content. When the flow level drops in most streams the temperature increases and dissolved oxygen decreases. Temperatures of 22-25°C have been shown to be lethal to Pacific salmon *(Oncorhynchus spp.)* (11). Sublethal effects such as decreased growth also result from increased temperature (12). Davis (13) reports that if prolonged beyond a few hours, a dissolved oxygen level of 6.0 mg O_2/liter can result in some risk to a portion of an average freshwater salmonid population. A level of 4.16 mg O_2/liter can result in severe deleterious effects to the population. He considers a level of 7.85 mg O_2/liter to be a safe level.

There are some streams in which water quality would not be a factor limiting salmonid carrying capacity when the flow is reduced. In these streams the carrying capacity is controlled primarily by the habitat quality (Fig. 2). However, for many streams there will be a critical flow level above which carrying capacity will be determined primarily by habitat quality and below which carrying capacity will be limited by water quality (Fig. 3). This critical flow level might, for example, be the flow which results in a reduction of the dissolved oxygen content of the stream to 6.0 mg O_2/liter or an increase in temperature to 22°C.

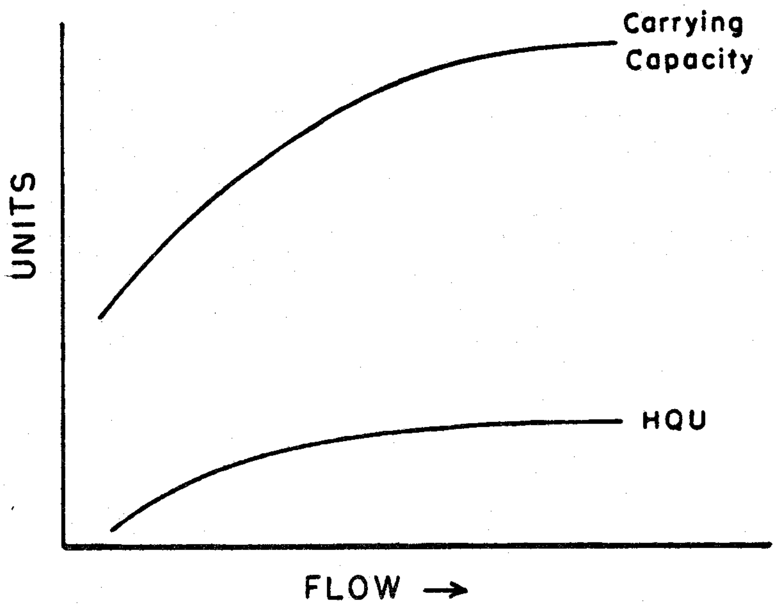

Fig. 2. A hypothetical example of flow reduction decreasing carrying capacity through changes in habitat quality *(HQU)*.

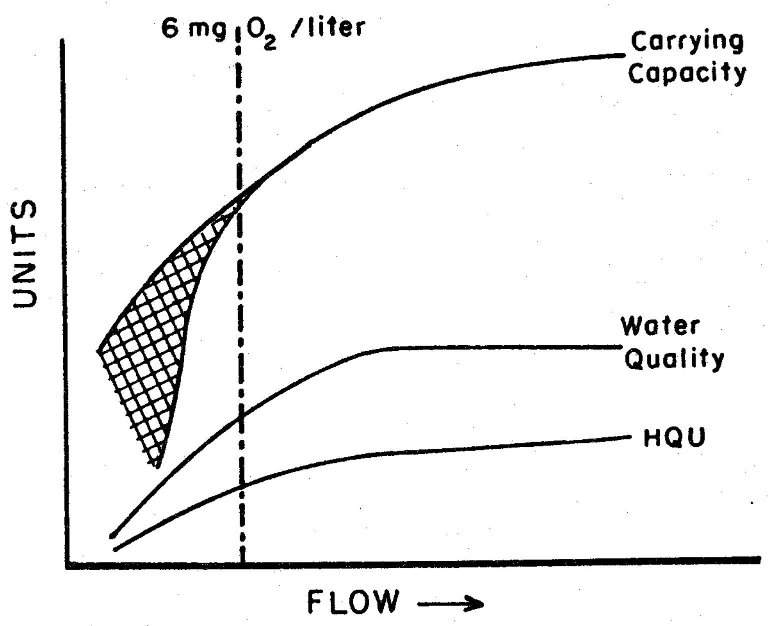

Fig. 3. A hypothetical example of flow reduction decreasing carrying capacity through changes in habitat quality *(HQU)* and then below some critical flow level through changes in water quality. Cross-hatched areas indicate decrease in carrying capacity due to water quality.

The methodology proposed consists of two parts. The first part is the identification of the critical flow level of a stream determined by monitoring water quality over a range of flows. The second part is to evaluate the habitat of a typical section of stream for the species of interest over the same range of flows using the habitat rating system described. The carrying capacity of the stream at flows above the critical level could be estimated from the habitat quality using species-specific relationships as presented in Fig. 1. The minimum flow recommendation would then be the flow which yields the lowest acceptable carrying capacity.

It should be remembered that this is a proposed methodology and has not been tested. We are continuing our work to refine the techniques employed in the methodology and to test its applicability to streams of different sizes and geographic locations.

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