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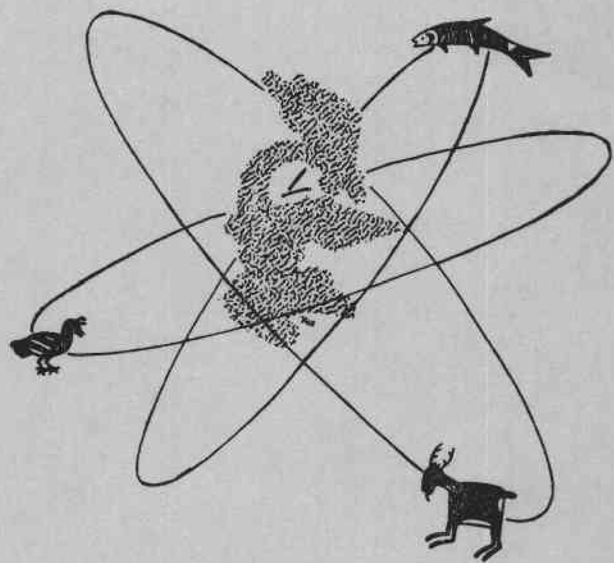

RESEARCH AND DEVELOPMENT SECTION

Oregon Department of Fish and Wildlife

AFS-62 Streamflow Requirements of Salmonids

ANNUAL PROGRESS REPORT

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GENERAL INTRODUCTION

Since 1973, the Research and Development Section, Oregon Department of Fish and Wildlife has been conducting research on salmonids with the goal of developing techniques that can be used to estimate the effect of stream discharge on fish production. Emphasis has been placed on the development of a model which will predict salmonid standing crop from measurements of stream habitat. Until 1977, most of this research was conducted at Elk Creek, Clatsop County where water diversion facilities were constructed to allow the study of various levels of dewatering. One objective of the Elk Creek study was to examine the effects of dewatering on stream invertebrates. This part of the project was implemented during the summers of 1975 and 1976 and the results are included in this report.

In 1976 we expanded our studies of coho salmon and cutthroat trout at Elk Creek to other north coast streams (Nickelson and Reisenbichler 1977). We expanded the study again in 1977 to include streams of the Rogue River Basin in southern Oregon. Our sampling in 1977 also included steelhead trout. Additional research was added in 1977 through a contract with the Office of Biological Services, U. S. Fish and Wildlife Service to examine cutthroat and steelhead trout in Willamette Basin streams (Nickelson and Beidler 1978). Data collected under both contracts will be discussed in this report.

INVERTEBRATE STUDIES

Introduction

Aquatic invertebrates are considered the major food source of salmonids (Demory 1961; Breuser 1961; Schutz and Northcote 1972; Griffith 1974; Idyll 1942; Chaston 1968); so the effect of reduced streamflows on the aquatic invertebrate community can be an important factor influencing the survival of juvenile salmonids.

The objectives of the invertebrate study were:

1. To determine the effects of decreased streamflow on the availability of insects as fish food.
2. To determine the effects of decreased streamflow on insect biomass and population densities during the summer low-flow period.

Methods and Materials

All samples of invertebrates were taken from the North Fork of Elk Creek which was described by Keeley and Nickelson (1974). Four flow levels were studied in the summers of 1975 and 1976 (Table 1); each level was maintained for 2 weeks, after which it was adjusted to the next lower level. Once in 1975 and twice in 1976 heavy rains caused floods which interrupted the sequence of experimental flows.

Table 1. A summary of flow experiments conducted at Elk Creek in 1975 and 1976.

Experiment number	Dates	Flows (l/sec)	% decrease from initial flow
1975			
I	8 - 23 July	84	0
II	24 July - 6 Aug.	63	25
III	7 - 20 Aug.	42	50
IV	5 - 19 Sept.	21	75
1976			
I	14 - 28 July	168	0
II	29 July - 11 Aug.	112	33
III	25 Aug. - 8 Sept.	63	63
IV	15 - 29 Sept.	42	75

Drift samples

Drift samples were collected at seven sites in 1975, including one site above the weir as a control. Two drift nets, described earlier (Keeley and Nickelson 1974), were placed at each site at the tail of a riffle, one-fourth and one-half the distance across the stream.

Drift was sampled during three time periods at the beginning and end of each two week experiment: 1) a 2 hour sample ending at sunset; 2) an overnight sample from sunset to sunrise; and 3) a 2 hour sample beginning at sunrise. Depth and velocity were measured at the mouth of each drift net at each experimental flow.

Artificial substrate samples

The artificial substrates consisted of a rectangular basket 40 x 30 x 10 cm formed from 1.3 cm mesh screen. The frame held twelve, 10 cm^2 strawberry baskets, also with a 1.3 cm mesh. The baskets were filled with gravel from the stream, placed in the rectangular frame, and then the entire artificial substrate was buried in the stream bottom so the top was flush with the natural substrate. The artificial substrates were placed in the stream 2 weeks before the beginning of the first experimental flow and remained in place through all four experimental flows.

In 1975, six artificial substrates were placed in each of three riffles, and in 1976, seven artificial substrates were placed in each of two riffles. One riffle above the weir was used as a control each year.

Artificial substrates were sampled at the end of each 2 week experiment by removing two adjacent strawberry baskets from each wire basket. This gave a 2000 cm^3 sample. Depth and velocity were measured at each artificial substrate on each sampling date.

Hess samples

In 1975 benthic invertebrates were also collected with a Hess sampler that was decribed by Keeley and Nickelson (1974). Samples were collected at the beginning, middle and end of the summer study, on the downstream side of each artificial substrate. Each sample enclosed 50 cm^2 of stream bottom.

Floating trap samples

Floating traps, designed to capture invertebrates landing on the surface film, were made from plastic trays 40.6 x 30.5 x 5.1 cm. Foam plastic was cut to fit around the outside of the trap so they floated one to three cm above the water surface. The trays were filled with water and a surfactant (RB11 commercial spreader), causing invertebrates alighting to quickly sink and drown. Four floating traps were used in this study and were sampled weekly.

Fish stomach samples

In 1975 age 0+ coho salmon were collected for stomach analysis with 6, 19, and 33 fish sampled in Experiments II, III, and IV, respectively. In 1976, 4, 7, 5 and 25 age 0+ coho were collected for stomach analysis in Experiments I, II, III, and IV, respectively. In addition 20 age 0+ cutthroat and 15 age 1+ cutthroat were collected in Experiment IV.

Age 0+ fish were placed directly into 80% ethyl alcohol, while only the excised alimentary canals of age 1+ fish were preserved in alcohol. The stomach contents were removed in the laboratory, and the food organisms sorted and identified to family and genus when possible.

Results and Discussion

A total flow reduction of 75% apparently had only minor effects on aquatic invertebrates. Drift (biomass and numbers) showed the most obvious effect of reduced flow (Figs. 1 and 2): there was a decrease in drift immediately after a flow reduction followed by an increase in drift during the 2 week test interval. This pattern could have resulted from an initial stranding of invertebrates as riffle areas decreased, followed by emigration due to crowding. This pattern of drift was reversed during the lowest experimental flow

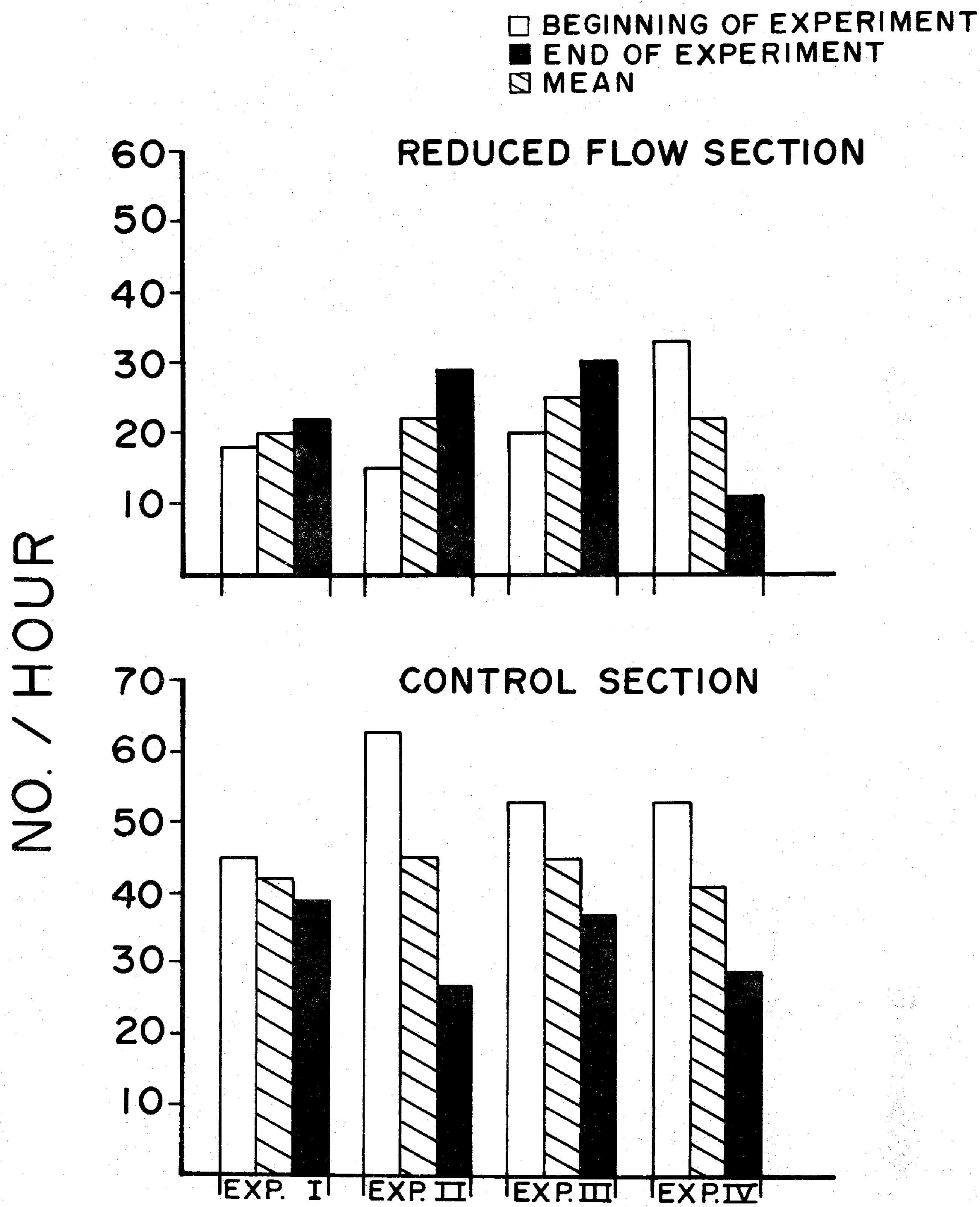

Fig. 1. Drift rates (no./hour) at the beginning and end of each experiment for the control and reduced flow sections.

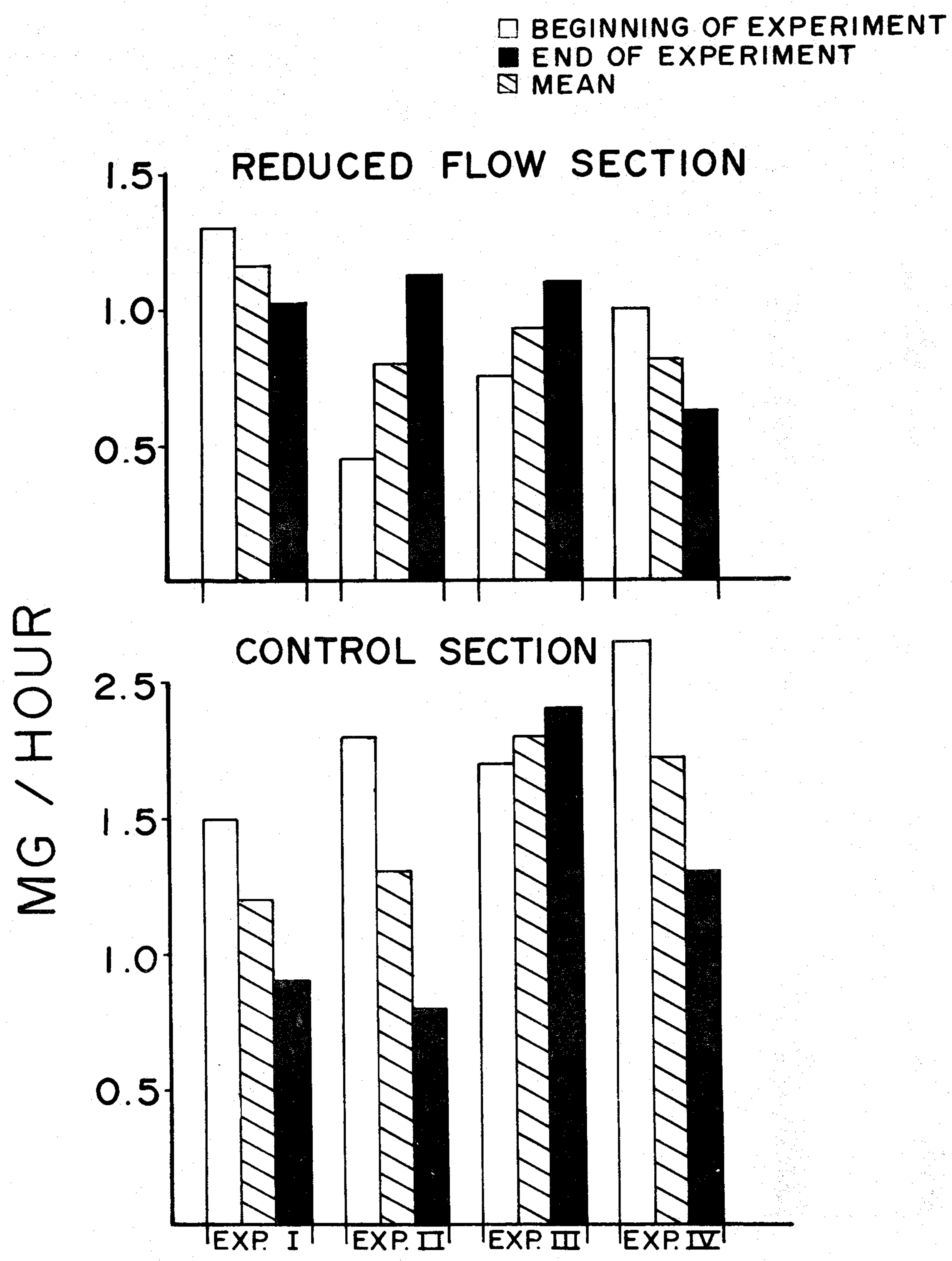

Fig. 2. Changes in biomass of drifting invertebrates per hour in the control and reduced flow sections at the beginning and end of each experiment.

(Figs. 1 and 2). Chironomid larvae and *Baetis* nymphs were the dominant taxa present in the drift in numbers and biomass.

The combination of large variance between benthic samples and small sample size reduced the sensitivity of the data to detect differences in the benthic invertebrate population measured during the different flows. Table 2 summarizes the results of the benthic sampling.

The effects of reduced flows on food availability appeared related to changes in the invertebrate populations, but also to the time of year, and age and species of the fish. Analysis of the contents of coho salmon stomachs indicated that immature aquatic invertebrates were the primary food of coho until the last experiment in 1975 and 1976 (Table 3) at which time there was a shift to terrestrial and adult aquatic invertebrates. The age 1+ cutthroat sampled in the last experiment of 1976 were also feeding heavily on invertebrates falling onto the water surface while 0+ cutthroat were feeding primarily on subsurface invertebrate drift. Surface food was available, however, to coho during the first three experiments and in fact it was utilized by them to varying degrees (Tables 3 and 4). The shift which took place during the last experiment may have been due to an increase in the availability of surface food. Unfortunately our sampling trays were lost in a flood just prior to the start of that experiment.

Table 2. Numbers and biomass of invertebrates for the artificial substrate (A.S.) and Hess samples.

	Density (no./m^2)				Biomass (mg/m^2)			
	Exp. I	Exp. II	Exp. III	Exp. IV	Exp. I	Exp. II	Exp. III	Exp. IV
1975								
Sec. 2								
A.S.	418	1,072	834	490	4,550	19,800	10,900	14,250
Hess	418	-	465	646	2,900	-	4,840	7,300
Sec. 4								
A.S.	922	4,087	3,141	198	15,950	77,100	37,700	7,950
Hess	58	-	699	145	1,750	-	7,430	1,420
Sec. 7 (control)								
A.S.	1,533	-	4,957	743	28,750	-	33,150	19,550
Hess	234	-	451	19	1,160	-	3,380	640
1976								
Sec. 1								
A.S.	293	304	678	292	9,200	6,600	12,700	10,850
Sec. 5 (control)								
A.S.	147	295	615	879	1,850	2,650	6,200	7,400

Table 3. The total and average number of food items, and the percentage of food from subsurface and surface origins at each experimental flow for stomach samples of coho salmon collected in 1975 and 1976 and cutthroat trout collected in 1976. Number of fish sampled at each experiment in parentheses.

	1975 0+ coho			1976 0+ coho				1975 1+ trout	1976 1+ trout
	Exp. II (6)	Exp. III (19)	Exp. IV (33)	Exp. I (4)	Exp. II (7)	Exp. III (5)	Exp. IV (25)	Exp. IV (15)	Exp. IV (20)
Streamflow (liter/sec)	63	42	21	168	112	63	42	42	42
Total no.	99	1,988	299	135	140	117	894	188	415
Avg. no./fish	17	105	9	34	20	23	36	13	21
% subsurface	86	94	42	69	52	60	16	19	72
% surface	14	6	58	31	48	40	84	81	28

Table 4. The total number of invertebrates (aquatic plus terrestrial) per 0.5 m^2 per day collected from floating traps in the first three experiments in 1975.

	Number/0.5 m^2/day					
Exp.	Riffle Sec. 2	Pool Sec. 2	Total	Riffle Sec. 4	Pool Sec. 4	Total
I	51	85	136	-	150	150
II	315	90	405	123	300	423
III	117	97	214	134	124	258

SALMONID STUDIES

Introduction

The approach which we are taking in our research is to develop models of stream habitat which will predict the potential of a stream to rear salmonids at any given flow during the summer low flow period. Essentially we are developing two types of models: 1) habitat models which describe the relationship between stream habitat and the rearing potential for salmonids (measured in grams of standing crop) during the low flow period; and 2) a model which will predict the amount of habitat at any given flow based on measurements of habitat made at one flow. The flow model is a modification of a hydraulic model such as the Water Surface Profile (WSP) model of the Bureau of Reclamation. In addition to predicting the effects of stream dewatering, these models could be used in other areas of fisheries stream management requiring habitat evaluation.

Methods

Elk Creek and 16 streams in the Rogue River basin were sampled between May 1 and September 30, 1977 (Table 5). In addition 15 streams in the Willamette River basin were sampled in another segment of the study (Table 6). Flows in the streams at the time they were sampled ranged from 0.02-1.20 m^3 (0.7-42.9 cfs).

Table 5. A summary of the streams sampled in the Rogue River basin in 1977.

Stream	Location	Month	No. of study section	Predominant species
Taylor Cr.	T35S,R8W	August	6	Steelhead
Evans Cr.	T33S,R2W	August	6	Steelhead
W. Fk. Evans Cr.	T33,34S,R3W	September	7	Steelhead
Briggs Cr.	T36S,R8W	September	7	Steelhead
Elk Cr.	T41S,R9W	September	6	Steelhead, cutthroat, & coho
Sugarpine Cr.	T32S,R1E	June	8	Steelhead
Jumpoff Joe Cr.	T35S,R5W	June	7	Steelhead
Galice Cr.	T35S,R8W	June	8	Steelhead
Althouse Cr.	T40S,R7W	July	5	Steelhead
Greyback Cr.	T39S,R6W	July	6	steelhead
Grave Cr.	T33S,R4W	July	7	Steelhead
Rancheria Cr.	T34,35S,R3,4E	July	8	Cutthroat
Copeland Cr.	T30S,R4E	August	1	Brook
Crater Cr.	T30S,R4E	August	6	Rainbow & brook
Steve Fork Cr.	T40S,R5W	August	8	Steelhead
Castle Cr.	T30S,R3W	August	4	Rainbow
Flat Cr.	T30S,R3W	August	8	Brown, rainbow cutthroat & brook

Table 6. A summary of the streams sampled in the Willamette River basin in 1977.

Stream	Location	Month	No. of study section	Predominant species
Rock Cr.	T12S,R6W	May September	6 8	Cutthroat & steelhead
S. Fk. Rock Cr.	T12S,R7W	May August	5 5	Cutthroat
Oliver Cr.	T14S,R6W	May August	7 7	Cutthroat
Ferguson Cr.	T15S,R6W	May	9	Cutthroat
Big R.	T23S,R2W	August	7	Cutthroat
Little Fall Cr.	T18S,R1E	September	5	Cutthroat
Hehe Cr.	T18S,R3E	June	6	Steelhead
Portland Cr.	T18S,R2E,R1E	July	5	Steelhead & Cutthroat
Mill Cr.	T16S,R1W	June September	6 6	Cutthroat
Little Wiley Cr.	T14S,R2E	June September	5 5	Steelhead
Elk Cr.	T11S,R4E	June	5	Steelhead & Cutthroat
Galena Cr.	T11S,R4E	June	4	Cutthroat
Rock Cr.	T10S,R3E	July	5	Steelhead
Cougar Cr.	T6S,R4E	August	5	Steelhead
Lukens Cr.	T6S,R4E	July	5	Steelhead

On each stream, 1-10 study sections were established. Study sections consisted of one riffle and one pool or in some cases a series of small riffles and pools and ranged in length from 20 to 70 m. For each section standing crop of salmonids[1/] was estimated by species using an estimate of population size, made by the removal method (Zippon 1958), and the mean weight of the fish captured.

The habitat of each section was described using the transect method. Depth, velocity, cover and substrate were measured at a minimum of 200 locations per study section on transects placed perpendicular to the thalweg. For a detailed description of methods see Nickelson and Reisenbichler (1977).

Results and Discussion

At the time the study streams were selected, we had no estimate of the size of their salmonid populations, although we tried to select streams which were likely to have good populations of either cutthroat or steelhead trout. The population levels varied greatly from stream to stream. Mean densities of trout were 0.54-7.04 g/m^2 for 16 "steelhead" streams and 0.25-2.51 g/m^2 for 10 "cutthroat" streams.

Coho salmon

The only significant coho population sampled in 1977 was Elk Creek (Clatsop County). Five study sections were added to the seven sampled on three coastal streams in 1976 (Nickelson and Reisenbichler 1977). With the 12 stream sections combined, pool volume explained 93.5% (Fig. 3) of the variation in standing crop of juvenile coho. The regression equation presented by

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[1/] For the purpose of this study trout standing crop includes only age 1+ and older fish while salmon standing crop includes age 0+ and 1+ fish.

Nickelson and Reisenbichler (1977) changed slightly with the addition of the new data. We are in the process of collecting more data to add to the model.

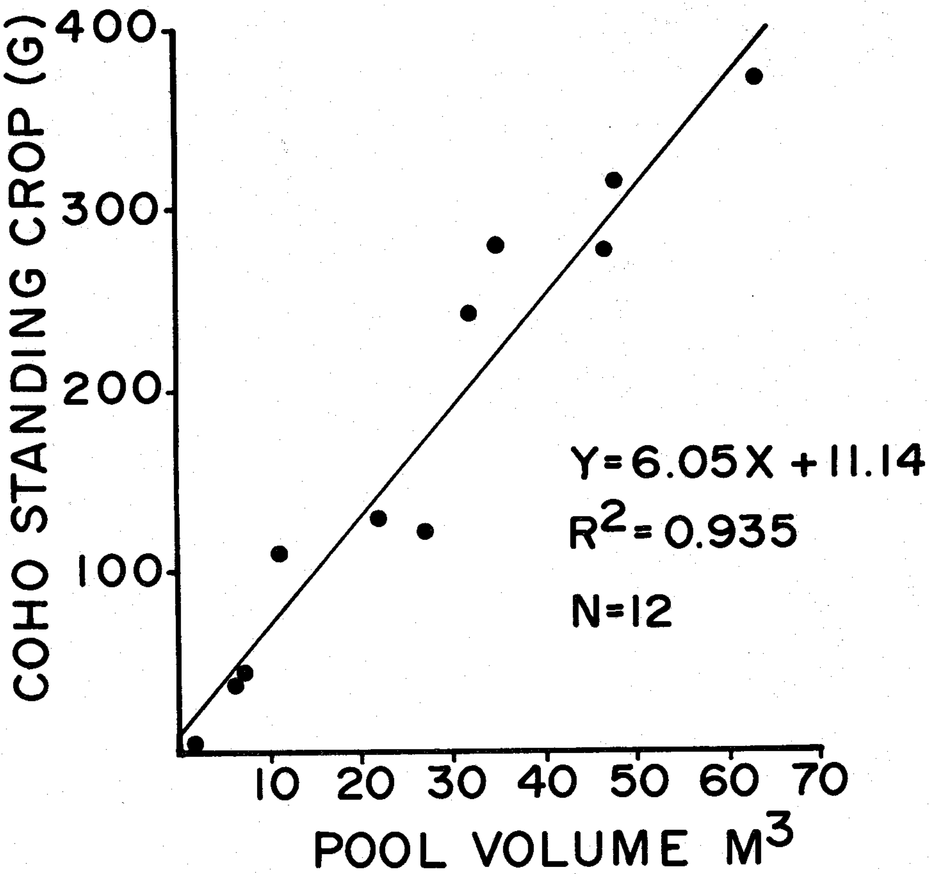

Fig. 3. The relationship between pool volume and juvenile coho salmon standing crop.

Cutthroat trout

We have constructed two habitat models for cutthroat trout. They explain 91% and 87% of the variation in cutthroat standing crop in 29 study sections of six streams (Figs. 4 and 5, and Table 7). The models compute a habitat quality rating (HQR_{ct}) which is the product of a cover value (C_{ct}), a velocity preference factor (p) and the wetted area of the study section (A). They differ in the way the cover value is calculated:

$$C_{ct1} = 13.859\,(D1) + 12.726\,(D2) + 13.591\,(EC) + 12.966\,(OH) + 93.298\,(T) \quad (1)$$

and

$$C_{ct2} = D1 + D2 + EC + OH + T + VS \quad (2)$$

where:

D1 = frequency of depths 46-60 cm;

D2 = frequency of depths greater than 60 cm;

EC = frequency of escape cover where the depth is greater than 5 cm (undercut banks, rootwads, undercut boulders, etc., within 50 cm upstream of the observation point);

OH = frequency of overhanging cover within 1 m of the surface where the depth is greater than 5 cm;

T = frequency of turbulance where the stream bottom is not visible and the depth is greater than 5 cm; and

VS = frequency of velocity shelter where the depth is greater than 5 cm (logs or boulders within 50 cm upstream of the observation point which slow the velocity).

The coefficients used in the calculation of C_{ct1} have no biological meaning and are not necessarily a unique solution to the equation. For this reason a simpler equation was constructed (C_{ct2}) and is proposed as an alternative model.

Using equations (1) and (2) we obtain the following:

$$HQR_{ct1} = (C_{ct1})\,(A)\,(p) \quad (3)$$

and

$$HQR_{ct2} = (C_{ct2})\,(A)\,(p) \quad (4)$$

The velocity preference factor (p) is determined from the curve in Fig. 6 which was developed from a plot of standing crop and mean velocity for sections having similar cover values.

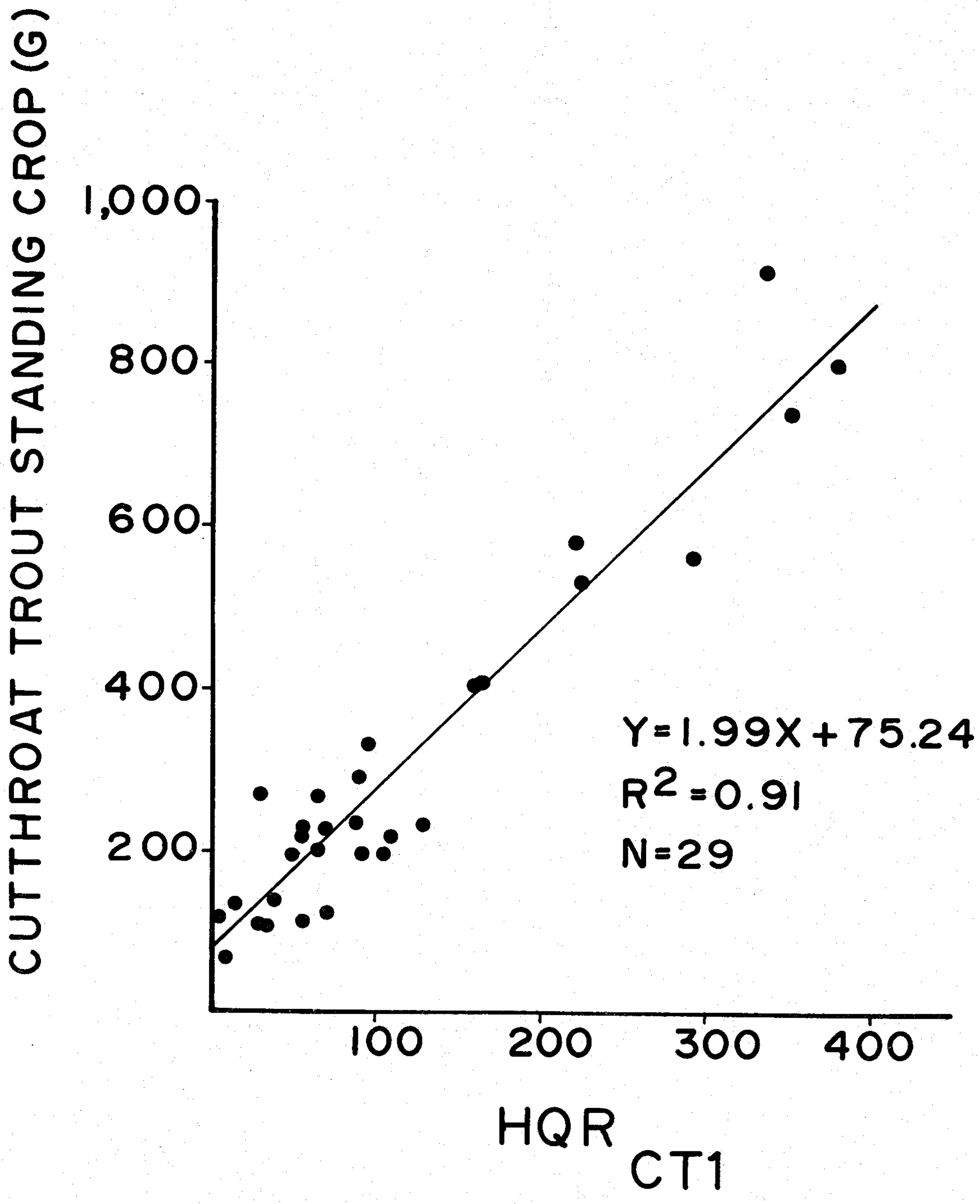

Fig. 4. The relationship between HQR_{CT1} and cutthroat trout standing crop.

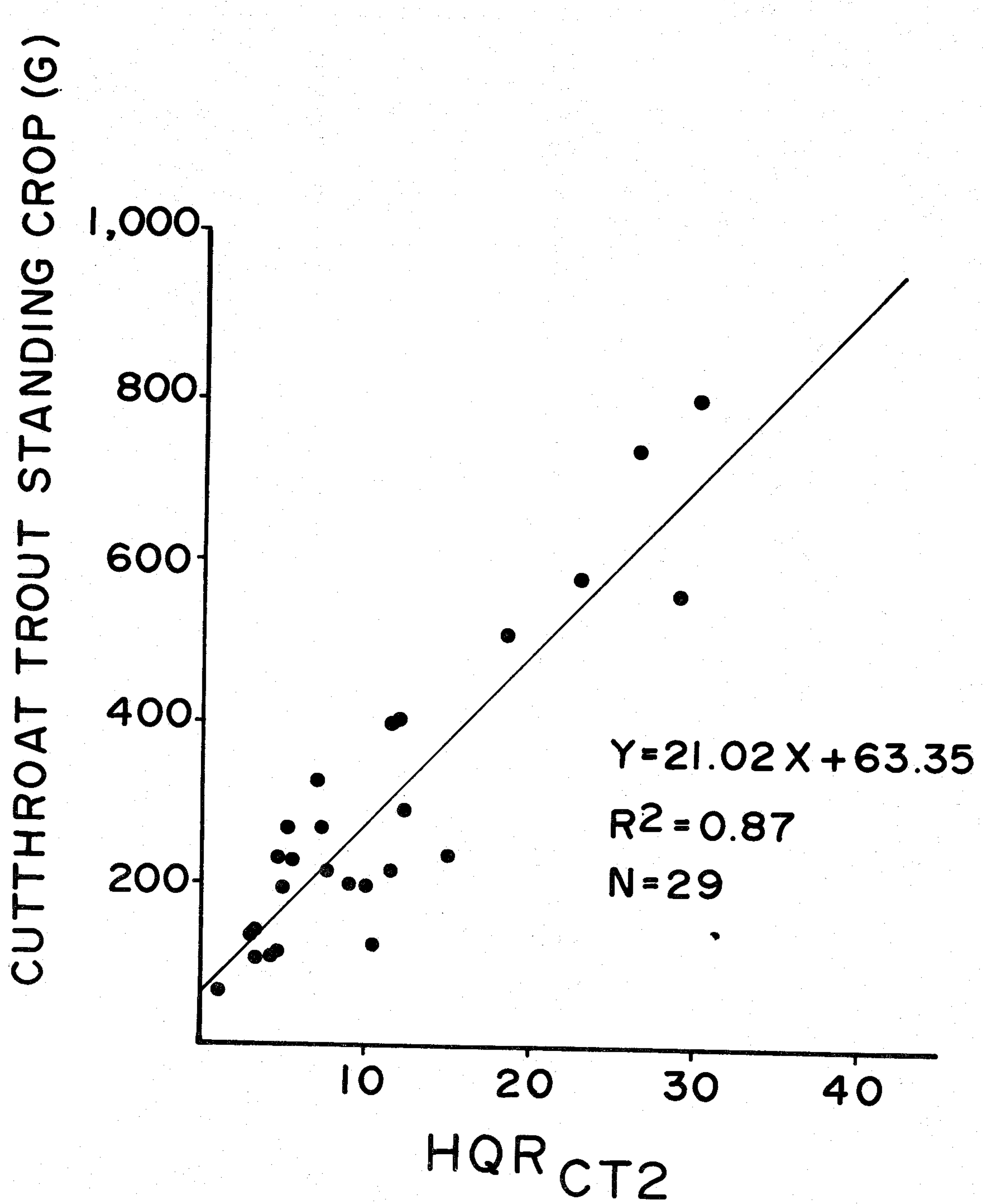

Fig. 5. The relationship between HQR_{CT2} and cutthroat trout standing crop.

Table 7. Streams used to develop habitat models.

Cutthroat	Steelhead
Rancheria Cr.	Evans Cr.
Flat Cr.	Briggs Cr.
Elk Cr. (Clatsop Co.)[a]	Lukens Cr.
Oliver Cr.	Cougar Cr.
Mill Cr.	
Elk Cr. (Linn Co.)[a]	

[a]*above impassable falls.*

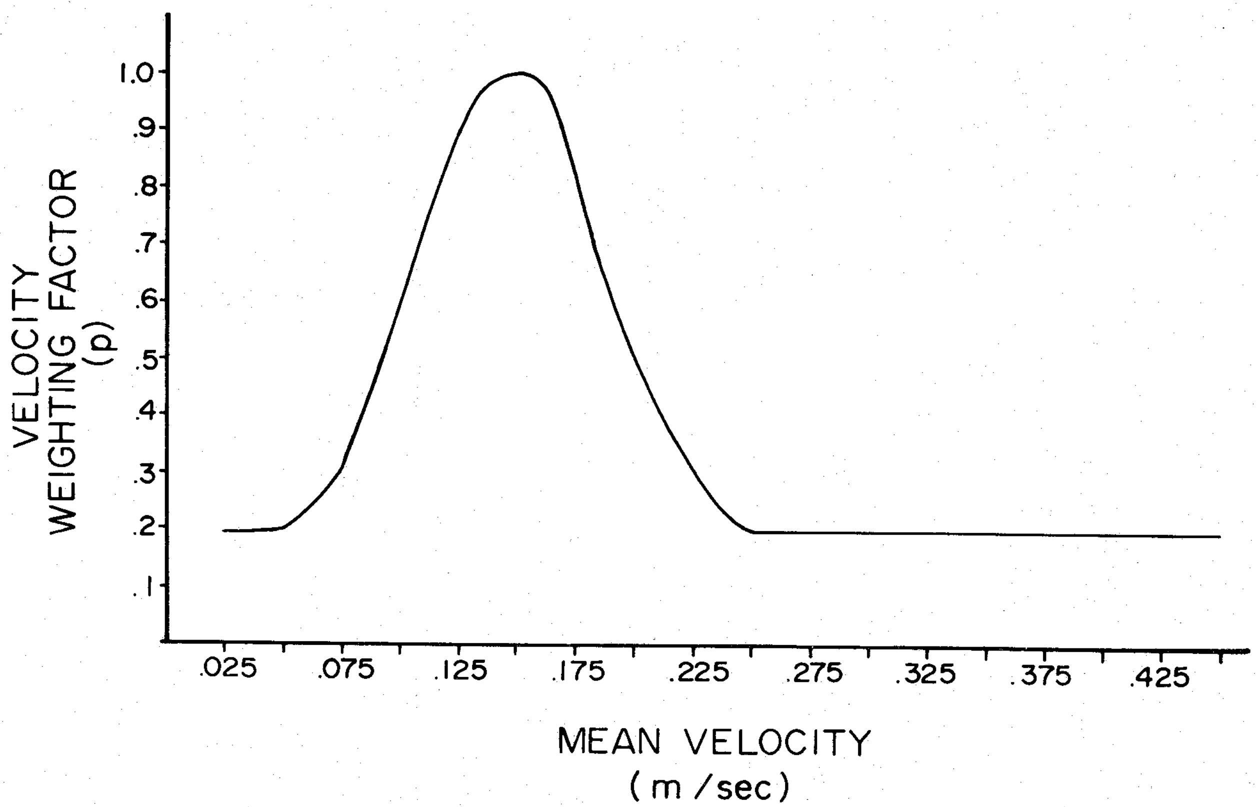

Fig. 6. The velocity rating curve used to determine the velocity weighing factor (p).

While cover (depths greater than 45 cm are treated as cover), appears to be the most important factor determining cutthroat trout standing crop (coefficient of determination of 0.22 compared with 0.05 for velocity and 0.08 for area), velocity can decrease the value of the cover in a stream section if it is faster or slower than optimum.

Steelhead trout

A habitat model has been developed for juvenile steelhead trout which explains 79% of the variation in steelhead standing crop in 23 study sections from four streams (Fig. 7 and Table 7). The model is similar to the cutthroat models in that a habitat quality rating (HQR_{st}) is calculated for a stream section. The elements of HQR_{st} are cover (C_{st}), depth and velocity (DV), and wetted area (A).

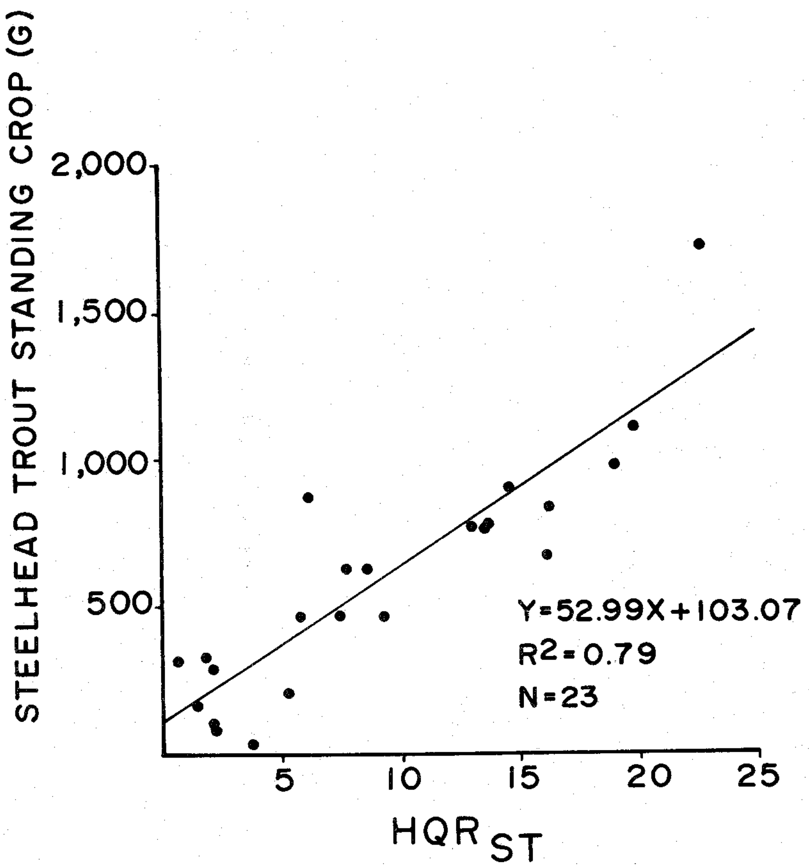

Fig. 7. The relationship between HQR_{st} and juvenile steelhead trout standing crop.

Cover appears to be the most important factor determining the standing crop of juvenile steelhead (coefficient of determination of 0.67). Unlike C_{ct}, (equations (1) and (2)), depth is not included as a cover type in C_{st}. Thus:

$$C_{st} = EC + OH + T + VS \qquad (5)$$

Depth and velocity have been combined into the single parameter DV using probability of use criteria developed by the Cooperative Instream Flow Service Group (IFG), U. S. Fish and Wildlife Service (Bovee and Cochnauer 1977; Bovee 1978). DV is the mean of the products of the depth (DP) and velocity (VP) probabilities (Fig. 8) for each of the n sampling locations in a study section. Thus we have:

$$DV = \frac{\Sigma (DP)\ (VP)}{n} \qquad (6)$$

Using the wetted area and equations (5) and (6) the habitat quality rating of a stream section is calculated from the equation:

$$HQR_{st} = (C_{st})\ (A)\ (DV) \qquad (7)$$

Development and testing of the habitat models

Only streams with populations we believe to be at or near maximum for the available habitat during the low flow period were used in developing the habitat models. When trout standing crop was plotted against stream habitat parameters, such as surface area, depth, cover, etc., a pie-shaped distribution usually resulted (Fig. 9). The streams selected for use in developing the models were those whose study sections all fell near the upper left-hand edge of the pie (the shaded area of Fig. 9). One of the reasons some stream did not fall in the shaded area may have been that not all the components of stream habitat which are controlling salmonid standing crop were accounted for in the model. However in four out of four coho streams, six out of eight cutthroat

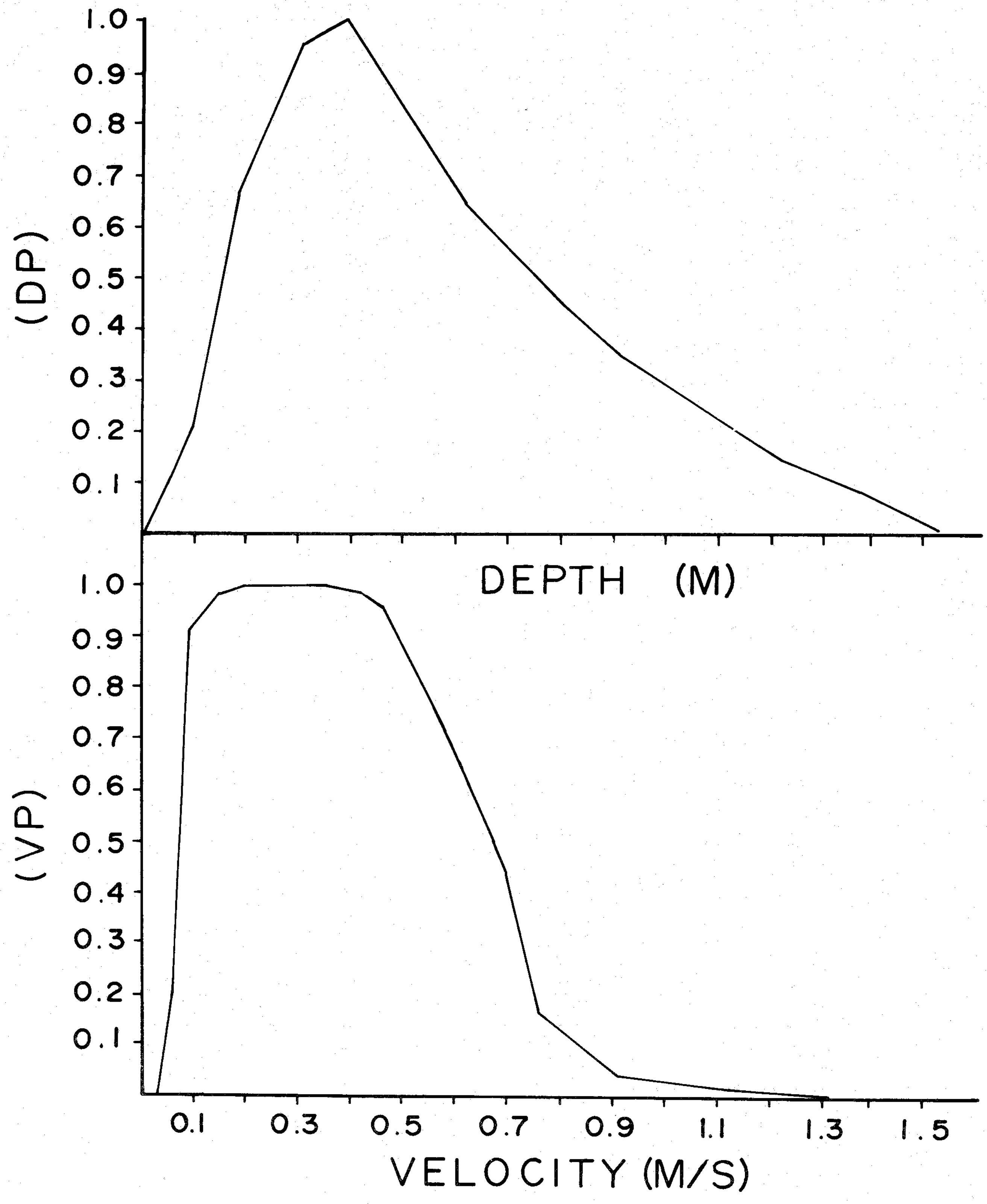

Fig. 8. Probability of use criteria for juvenile steelhead trout. Adapted from Bovee (1978).

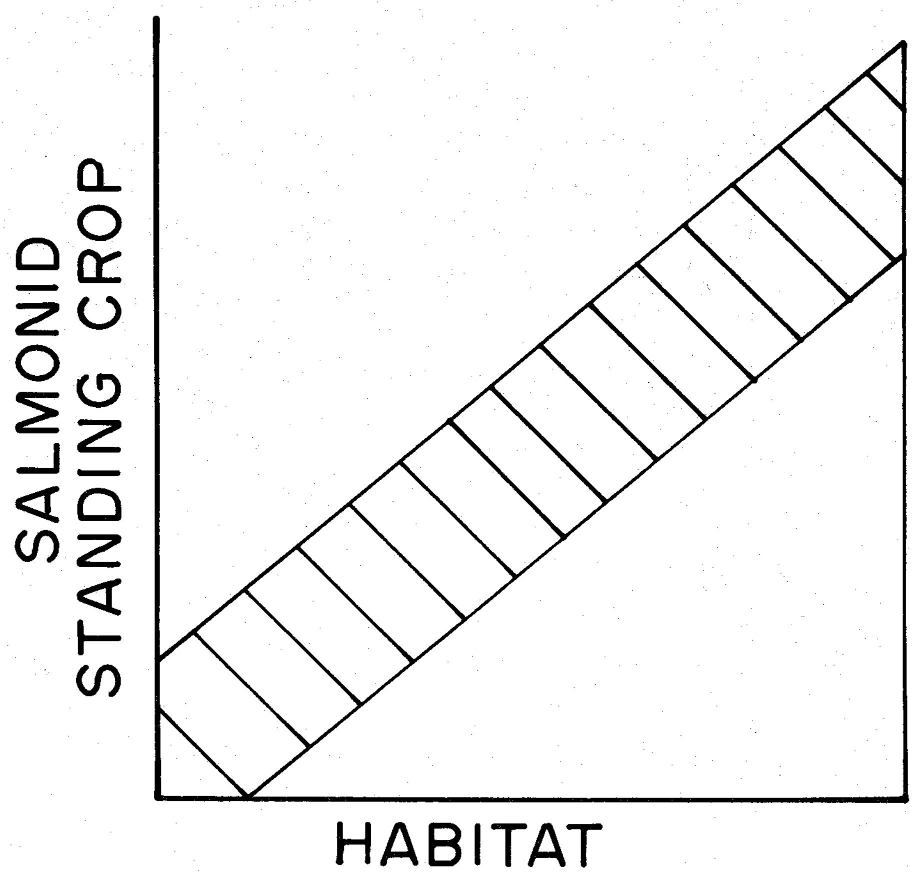

Fig. 9. A schematic of the general distribution of salmonid standing crop plotted against stream habitat. Streams whose standing crop falls in the shaded area were used in developing models of the relationships between habitats and standing crop.

streams and four out of eleven steelhead streams sampled during the low flow period the components of habitat included in the respective models were correlated with standing crop (Figs. 3, 4, 5 and 7) for all study sections. In three of the remaining seven steelhead streams, the habitat components included in the steelhead habitat model were correlated with standing crop in all except one study section. The models are actually one of three hypotheses that we have developed to explain the observed relationship between stream habitat and salmonid standing crop (Table 8). Since the habitat models which we've developed are still only hypotheses, they need to be tested. Ideally this testing should be done in streams which have been seeded to capacity.

To test the coho model, we will try to insure that some streams are fully seeded by stocking them with fry from wild parents. If the model is valid, the study sections sampled in these streams should fall within the 90% prediction intervals of the model's regression line.

Testing the cutthroat and steelhead models will be more difficult since the population consists of age 1+ and older fish. It would be difficult to seed streams with wild trout and duplicate a natural age structure. Therefore we will sample more streams during the summer low flow period and determine the probability of erroneously predicting standing crop using the habitat models. Essentially this means determining the probability of a study section falling outside the 90% prediction intervals of the regression line and therefore having a standing crop different from the potential standing crop predicted by the habitat model. If deemed necessary, more detailed studies would need to be designed (Fig. 10) to determine if the errors are due to Alternate Hypothesis 1 or 2 (Table 8). Studies of this type are presently being planned for coho salmon.

Table 8. Hypotheses developed to explain the relationship between habitat and standing crop of salmonids which were observed in streams.

Hypothesis

The potential of a stream to rear salmonids (measured as standing crop) during the low flow period is determined by the habitat parameters in the models we have developed. All data points for a given species should fall within the 90% prediction interval.

Alternate Hypotheses for points which don't fall on the line.

Alternate Hypothesis 1

The stream can actually rear a larger standing crop than was present when the stream was sampled, however factors other than the rearing habitat have limited the standing crop of salmonids.

Table 8 (continued)

These factors can be broken into four categories:

1. Features of the habitat such as limited spawning area or poor water quality.

2. Biological factors such as poor escapement of spawners, predation or disease.

3. Random occurrences such as floods or mudslides.

4. Harvest by anglers.

Alternate Hypothesis 2

The potential of a stream to rear salmonids during the low flow period is determined by habitat factors not included in the models presented.

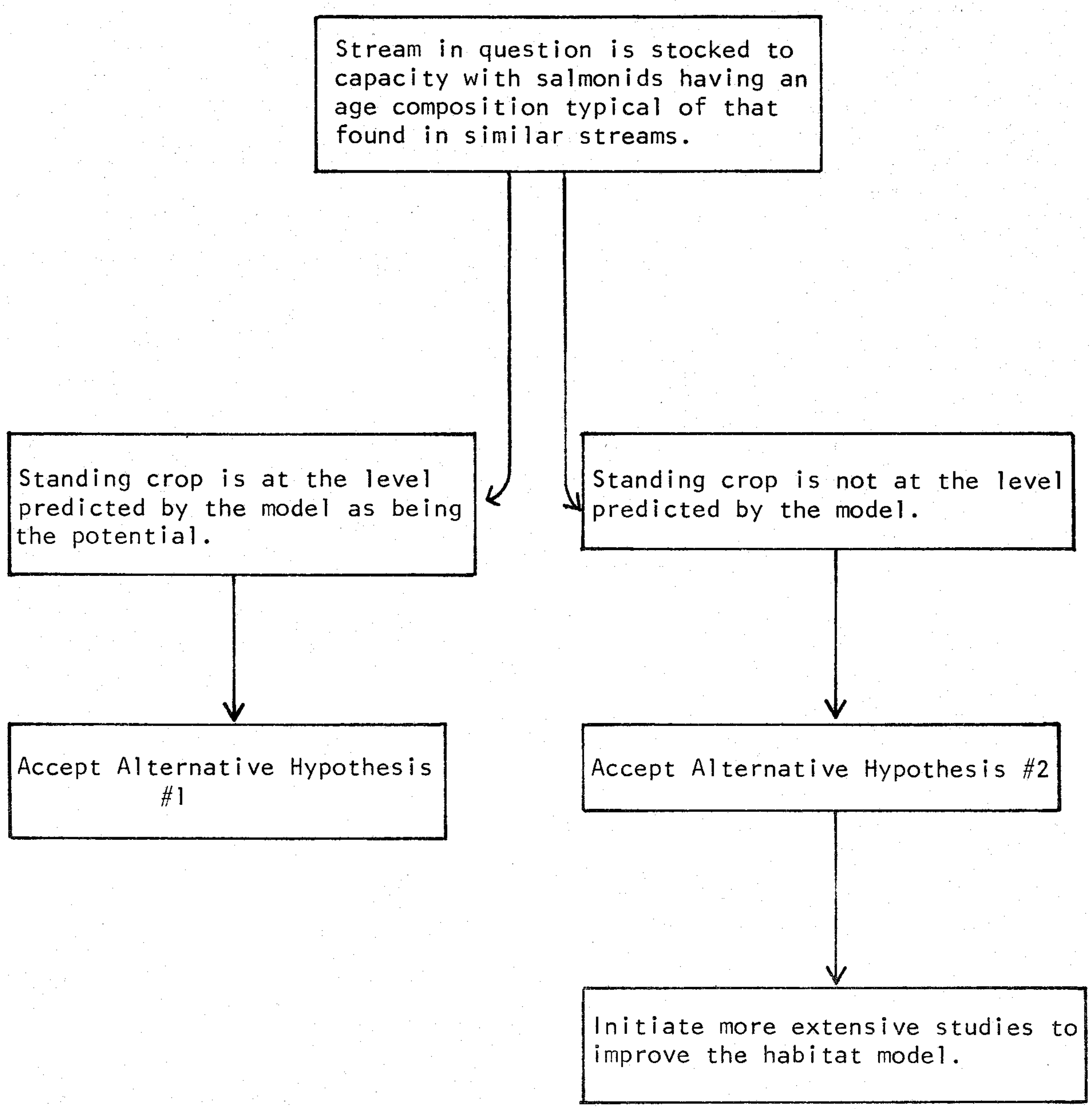

Fig. 10. A schematic showing the process of testing our hypotheses.

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