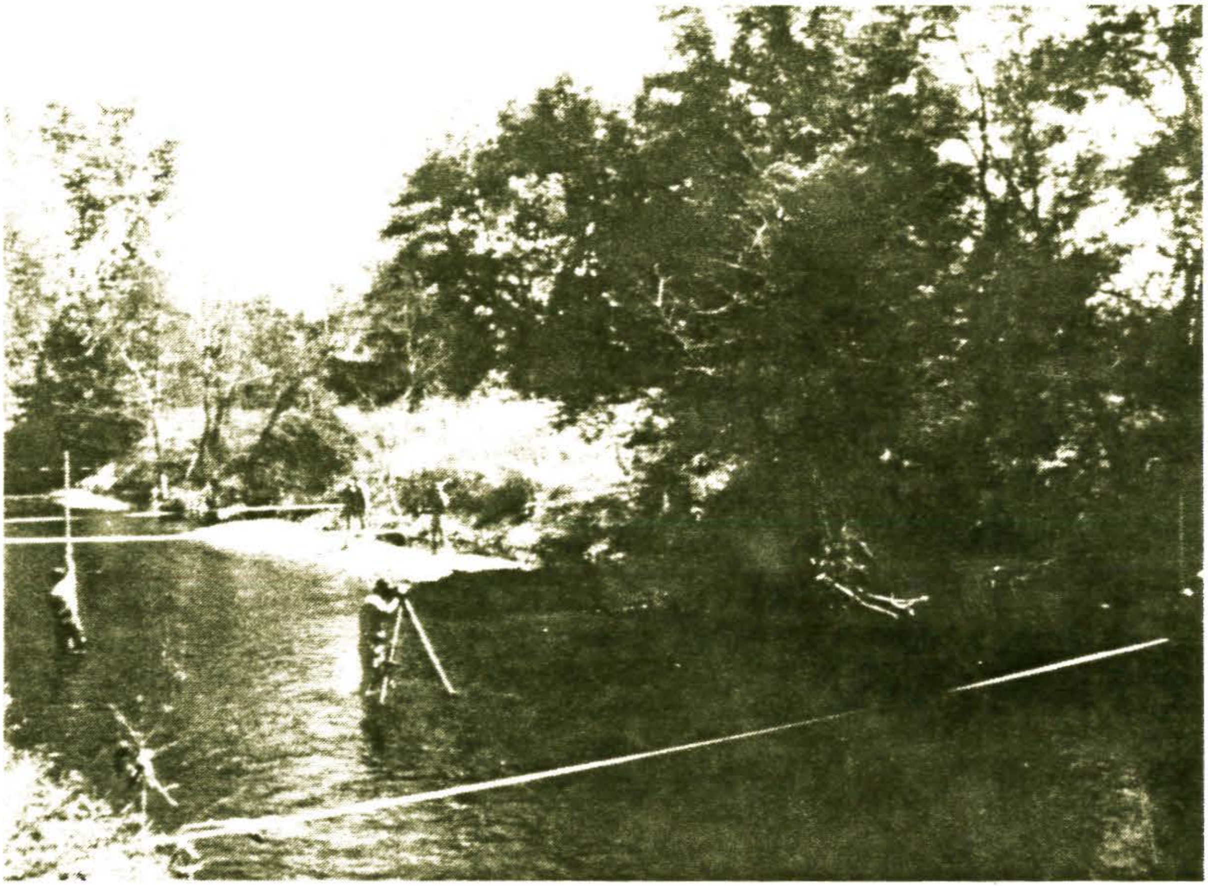
JUNE SUCKER —
PROVO RIVER INSTREAM FLOW ANALYSIS



Cooperative Agreement

Utah Division of Wildlife Resources/
U.S. Bureau of Reclamation

87-2

UTAH
NATURAL RESOURCES
Wildlife Resources

JUNE SUCKER

PROVO RIVER INSTREAM FLOW ANALYSIS

March, 1987

United States Bureau of Reclamation

Contract 8-07-40-S0634

Modification No. 4

Prepared by

Randy D. Radant
Maureen M. Wilson
Dennis Shirley

Utah State Division of Wildlife Resources
1596 West North Temple
Salt Lake City, Utah 84116-3154

87-2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

INTRODUCTION

The June sucker (Chasmistes liorus) is endemic to Utah Lake, Utah. Suckers in the genus Chasmistes are lake dwelling midwater planktivores that fossil records indicate once occurred throughout the West (Miller and Smith 1981). Today, the June sucker is one of only three species of Chasmistes known to exist. The cu-ui sucker (Chasmistes cujus) occurs in Pyramid Lake, Nevada and is federally listed as endangered. The shortnose sucker (Chasmistes brevirostris) is found in the Klamath River Basin of Oregon and California and is being considered for possible federal listing as an endangered or threatened species. Since early settlement around Utah Lake, June sucker numbers have been reduced from reportedly "millions" (Carter 1969) to probably less than 1,000 adult individuals today (U.S. Fish and Wildlife Service 1984). Because of its declining population and present low numbers, the June sucker is threatened with extinction. Consequently, the U.S. Fish and Wildlife Service (FWS) designated the June sucker as an endangered species in March 1986 (U.S. Fish and Wildlife Service 1986).

The Provo River, the largest tributary to Utah Lake, provides the only known spawning site for June suckers. Operation of Deer Creek Reservoir and irrigation diversions largely control flows into Utah Lake. Low flows during June sucker spawning in June are believed to adversely affect reproductive success. In the late 1800's an estimated 1,500 ton (t) of spawning suckers were killed when approximately 2.1 miles of the Provo River were dewatered. Soon after 1923, 2.5 t of suckers were removed from a dewatered irrigation ditch (Carter 1969). Because these sucker losses were reported when June sucker spawning occurs, it is inferred that they were June suckers which were lost rather than Utah suckers (Catostomus ardens), which spawn in April. From 1979 to 1985 the number of spawning June suckers present in the river has never exceeded an estimated 500 individuals (Radant and Sakaguchi 1981, Dennis Shirley, UDWR, pers. comm. 1984).

Because of potential impacts to the June sucker resulting from development of the Bonneville Unit of the Central Utah Project (CUP), a cooperative agreement was established between the Utah Division of Wildlife Resources (UDWR) and the U.S. Bureau of Reclamation (USBR) to examine instream flow requirements for spawning and young-of-the-year (YOY) June sucker. Major objectives of this study were to develop water depth, water velocity, and substrate probability of use curves for spawning and YOY June sucker; and using these data, to recommend minimum, maximum, and optimum instream flows in the Provo River during the period of June sucker use. This report summarizes and presents the results of this study.

DESCRIPTION OF THE STUDY AREA

The end of the lake/riverine transition area, 1.6 mi above the Utah Lake State Park (Center St.) bridge, to the Tanner Race Diversion (Columbia Lane Diversion) in Provo is the only known spawning area for June suckers (Figure 1). This river section has experienced extreme annual flow fluctuations ranging from 0 to 2,520 ft^3/s over the period of record. Water diversions typically cause extremely (0-3 ft^3/s) low

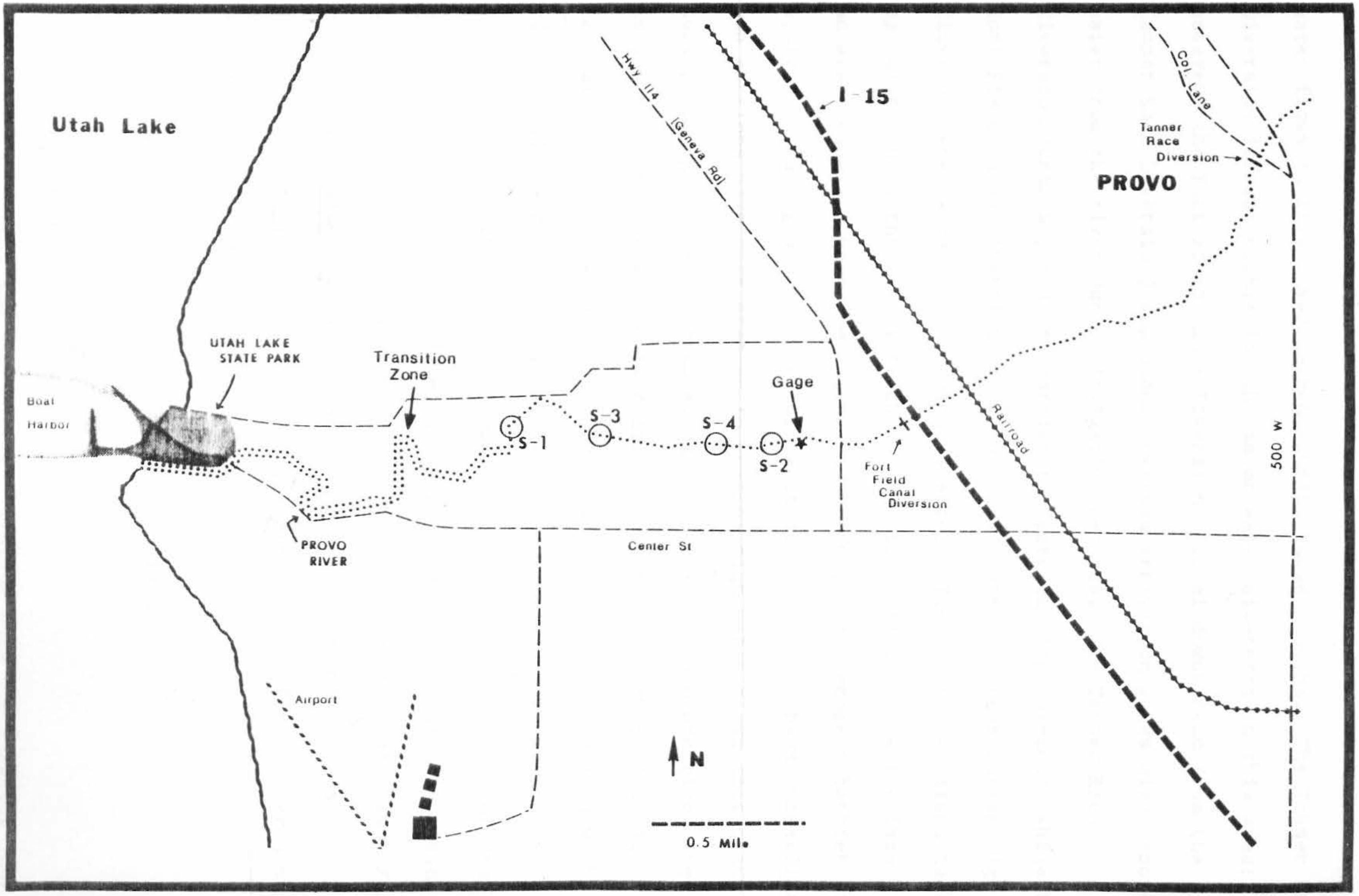


Figure 1. Provo River study area, Provo, Utah.

water flows in this river segment during summer months. The Tanner Race Diversion is responsible for the major water diversion in this area; however, the Fort Field Canal Diversion (1.5 mi downstream from the Tanner Race Diversion) and other onstream irrigation gates also remove water from the river during irrigation periods. The Tanner Race Diversion forms a permanent barrier to upstream fish movement, while the Fort Field Canal Diversion gates lay on the stream bottom during high flows and when water is not being diverted. The gates are raised to back up water behind the structure during low flows to divert water into adjacent canals. When the gates are upright, they become a barrier to upstream fish migration. The entire study section has been channelized and portions have been dredged to control high water flows that occur during spring snowmelt. Because of channelization and dredging, the area is generally characterized by riffles and runs with few pools. The predominant substrate is rubble and gravel. Bank stabilization with rip-rap and concrete slabs is evident along much of the reach.

Much of the study section flows through residential areas of Provo City. Provo City has developed a parkway and jogging path along much of the river. During favorable water conditions, the study area supports a brown trout (Salmo trutta) fishery. These attractions and its accessibility to the public make this portion of the Provo River a highly used recreational area throughout the year.

METHODS AND MATERIALS

Habitat Use Curves

Velocity, depth, and substrate utilization data for spawning June suckers were collected in June 1982, 1983, and 1984. Measurements were taken by directly observing spawning aggregations of suckers, noting specific locations of individual fish, and recording the velocity, depth, and substrate information for each specific sucker located.

Channel and bottom water velocity measurements were obtained using a direct reading Marsh-McBirney (Model 201) portable electro-magnetic current meter. Corresponding water depth was measured with a calibrated wading rod or meter ruler. Substrate composition was described using a modified Wentworth particle size scale (Bovee and Cochnauer 1977).

Probability of use curves were constructed using methods described by Bovee and Cochnauer (1977). These curves were subsequently examined by Dominque and Bovee (1986) (FWS Instream Flow Group) and the velocity and depth curves smoothed using a running-median process.

Instream Flow Analysis

Two study stations (S-1 and S-2) were established in 1982 and two additional study stations (S-3 and S-4) were established in 1985 at observed June sucker spawning sites (Figure 1). All of the stations were located within a 1 mi reach below the USGS Provo River at Provo Gage No. 1016300. Physical stream data were measured along three cross section transects in 1982 and along five cross section transects in 1985. Cross section transects in 1985 were identified by an interagency team comprised of representatives of the UDWR, FWS, and USBR. Stream features intersected by the cross section transects, and station lengths are presented in Tables 1 and 2.

Table 1. Stream features sampled by cross section transects, Provo River, 1982.

Station	Cross Section Number	Description	Distance Upstream to Next Cross Section (ft)
1	1	Hydraulic control; tail of pool gravel bar	0
	2	Midway to tail of pool	21.6
	3	Deepest portion of pool	24.9
		Total length	46.5
2			
	1	Hydraulic control	0
	2	Tail of pool	45.3
	3	Upper pool; dividing line between gravel and boulder-cobble	25.9
		Total length	71.2

Table 2. Stream features sampled by cross section transects, Provo River, 1985.

Station	Cross Section Number	Description	Distance Upstream to Next Cross Section (ft)
3	1	Hydraulic control	0
	2	Area of known use by spawning June sucker, transect crosses gravel bar near left bank, present at very low flows.	44
	3	Transect crosses pool near left bank run area and gravel bar near left bank.	56
	4	Change in elevation--features similar to transect 3	36
	5	Transect crosses riffle above gravel bar near left bank.	76
		Total Station Length	212
4	1	Hydraulic control	0
	2	Change in elevation; transect crosses run near right bank, gravel bar with back water at low flow near left bank.	57
	3	Area observed to have most use by spawning June sucker in study section. Transect crosses pool and run areas.	42
	4	Transect crosses riffle and glide areas	67
	5	Top of riffle	139
		Total Station Length	305

Physical stream data were collected at three flows during June and July 1982 and three flows during August and October 1985 for calibration of the IFG-4 hydraulic simulation model (Table 3). Methodology used is described by Bovee and Milhous (1978). Weighted usable habitat area was calculated at discharges ranging from 20 to 900 cfs for the stations established in 1982. Weighted usable habitat area for the two stations established in 1985 was calculated for discharges ranging between 0 to 1500 cfs.

RESULTS AND DISCUSSION

Habitat Use Curves

Probability of use curves are based on the assumption that individuals of a species will select the most preferred conditions in a stream when given their choice. Less favorable conditions will also be used, but with the probability of use decreasing as conditions approach the ends of the range of acceptability. It is further assumed that individuals elect to leave an area when conditions become unsuitable.

A total of 132 separate observations were recorded for spawning June suckers in June 1982, 1983, and 1984. Because individual observations were typically taken from an aggregate of June suckers, these data theoretically represent many more individuals than indicated.

Original study objectives identified developing similar habitat use probability curves for YOY June suckers based upon the belief that they used the Provo River as nursery habitat. Larval suckers collected from the lower Provo River in 1982, 1983, and 1986 were sent to the Colorado State University Larval Fish Laboratory for identification. None of the

Table 3. Calibration flows (ft^3/s) measured for IFG-4 hydraulic simulation model, Provo River.

Date	Station			
	1	2	3	4
07/19/82	22	21		
06/24/82	139	107		
06/29/82	165	163		
08/05/85			55	57
10/15/85			132	153
10/16/85			307	356

specimens examined were June sucker (Synder 1986). Additionally, larval suckers obtained from the Provo River in 1985 were reared in an isolated water. These suckers were later identified as mountain sucker (Catostomus platyrhynchus). Consequently, since no data are available to substantiate the Provo River as a nursery area for YOY June sucker, no habitat use evaluations are presented in this report for this life stage.

Substrate

Substrate used most by spawning June suckers ranged from coarse gravel to small cobble 100-120 mm in median particle size (Figure 2). This substrate does not appear to be limited within the study area. Spawning sites selected by June suckers were frequently in reaches where channel hydraulics had established larger deposits of the preferred substrate than elsewhere in the river. These sites were generally relatively clean of silt and periphyton growth, but June suckers were also noted to clean substrates by their spawning activity. Tabulated data for the substrate probability of use curve is presented in Appendix Table II-1.

Water Depth

Selected water depths for 132 spawning June suckers ranged from 1.0 ft to 2.5 ft. Probability of use curves were converted by using a running-median process to show the suitability index (Figure 3). Dominque and Bovee (1986) analyzed the water depth suitability curve and found a negative correlation between flow and preferred depth. It is thought that this relationship of decreasing depth preference with increasing discharge is caused by an avoidance of high velocities and a relatively weak preference for depth.

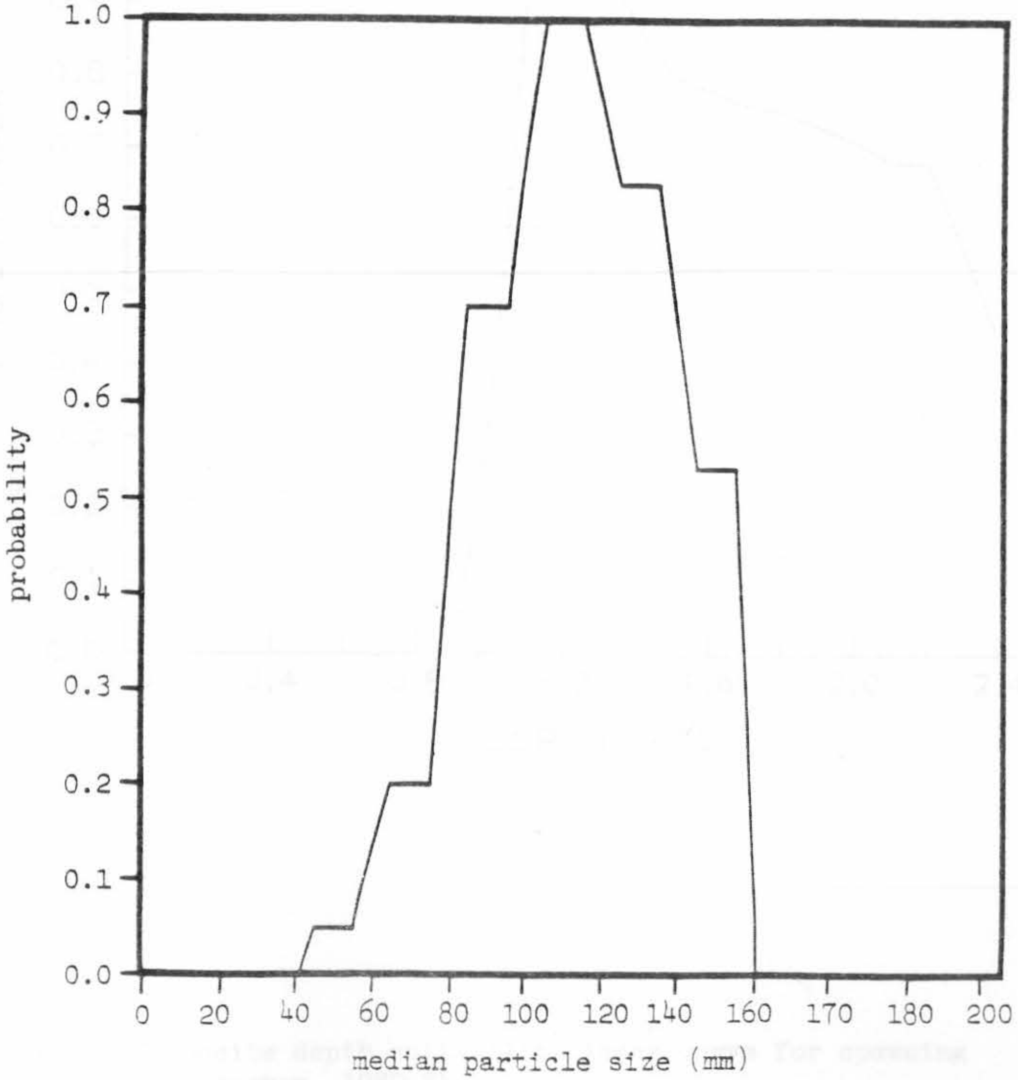


Figure 2. Probability of use for substrate, spawning June sucker, 1982-84.

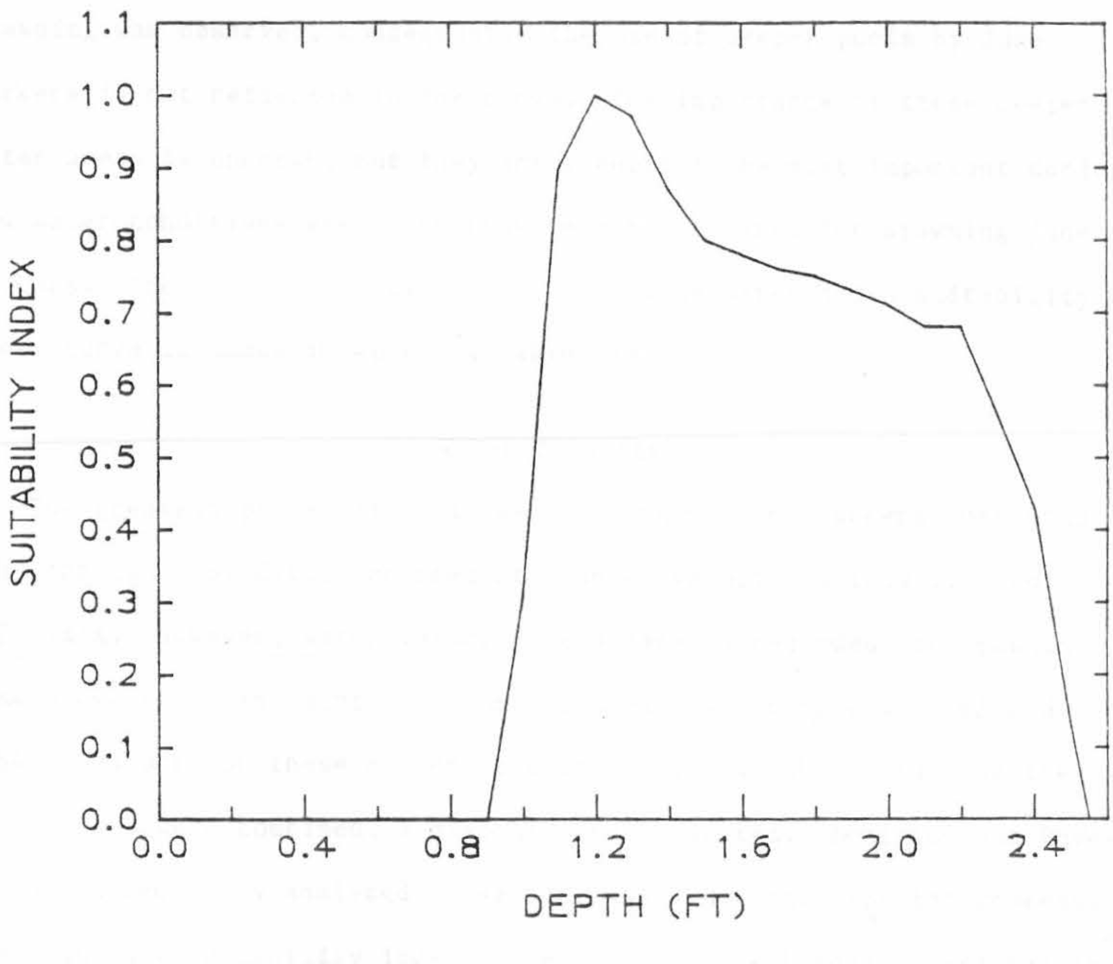


Figure 3. Composite depth suitability index curve for spawning June sucker, 1982-84.

Field observations indicate that males will maintain their position over a spawning site while females will remain in deeper pools until they are ready to spawn. When the female is ready to spawn, she will move onto the spawning site, complete spawning, and leave the river. The suitability index curve was developed only for areas where active spawning was observed, consequently the use of deeper pools by June suckers is not reflected in the curve. The importance of these deeper water areas is unknown, but they are thought to be most important during low water conditions when they provide a refuge area for spawning June suckers. The tabulated data for the composite water depth suitability index curve is shown in Appendix Table II-2.

Water Velocity

The greatest probability of use by spawning June suckers combining 1982 through 1984 data, occurred at channel velocities from 1.25 to 1.75 ft/s. However, water velocity measurements recorded for spawning June suckers in 1983 deviated from measurements recorded in 1982 and 1984. Reasons for these differences are unclear. When data from the three years were combined, a bimodal curve resulted. Dominque and Bovee (1986) subsequently analyzed these data using a running-median process. The resulting suitability index curve smoothed the bimodal character from the original probability curve (Figure 4). Tabulated data for the composite water velocity suitability index curve are listed in Appendix Table II-3.

Instream Flow Analysis

Probability of use curves developed by this study were used with the physical habitat simulation model (PHABSIM) (Milhous et al. 1984) to

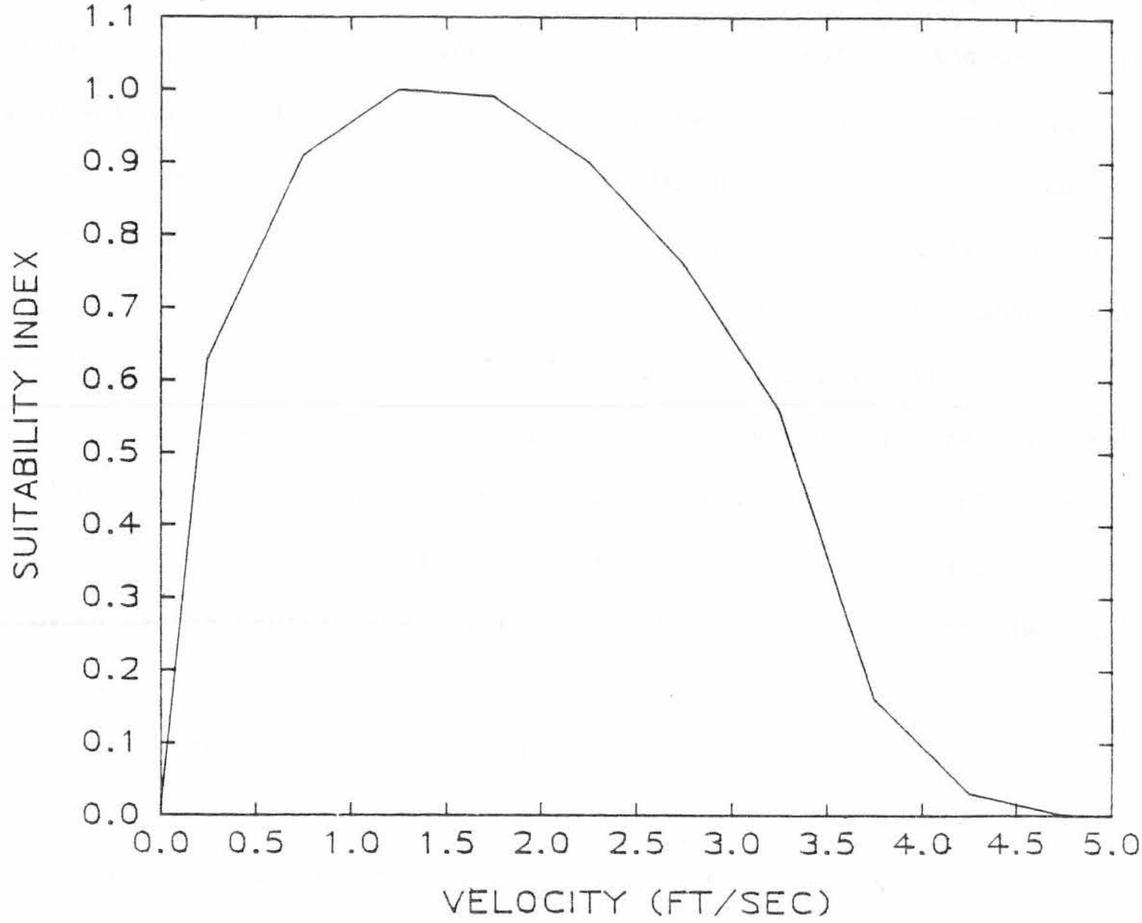


Figure 4. Composite velocity suitability index curve for spawning June sucker, 1982-84.

calculate weighted usable habitat available for spawning June sucker at the 1982 established habitat stations. The PHABSIM model results for Station 1 showed little to no spawning habitat available at any of the discharges modeled (Figure 5). Model results for Station 2 showed that maximum amounts of spawning habitat were available at 90 cfs (Figure 5).

Station 1 contained a large, deep meander pool, bordered by gravel areas. Since the deep pool area comprised the largest portion of Station 1, it was thought to have overshadowed the relative value of the small adjacent spawning habitat. This station was selected, however, because of the abundance of spawning June suckers using this location. In low water years the pool and adjacent gravel areas have contained some of the highest concentrations of spawning June suckers found in the river.

Station 2 was more representative of habitats found in the riverine portion of the lower Provo River. It was characterized by a riffle-pool area bordered by shallow gravel bars near each shoreline. Tabulated weighted usable habitat area data for stations 1 and 2 are provided in Appendix Table II-4.

Results from this instream flow analysis did not agree with observed use of the lower Provo River by spawning June suckers. Problems were identified with the location of Station 1, limitations with only three cross-section transects within each station, and the adequacy of only modeling flows down to 20 cfs. Because of reservations in making final flow recommendations based upon these data, it was agreed to perform additional studies in 1985 using the Instream Flow Incremental Methodology (Bovee 1982). The results from this additional work would aid in verifying and/or refining the instream flow analysis results

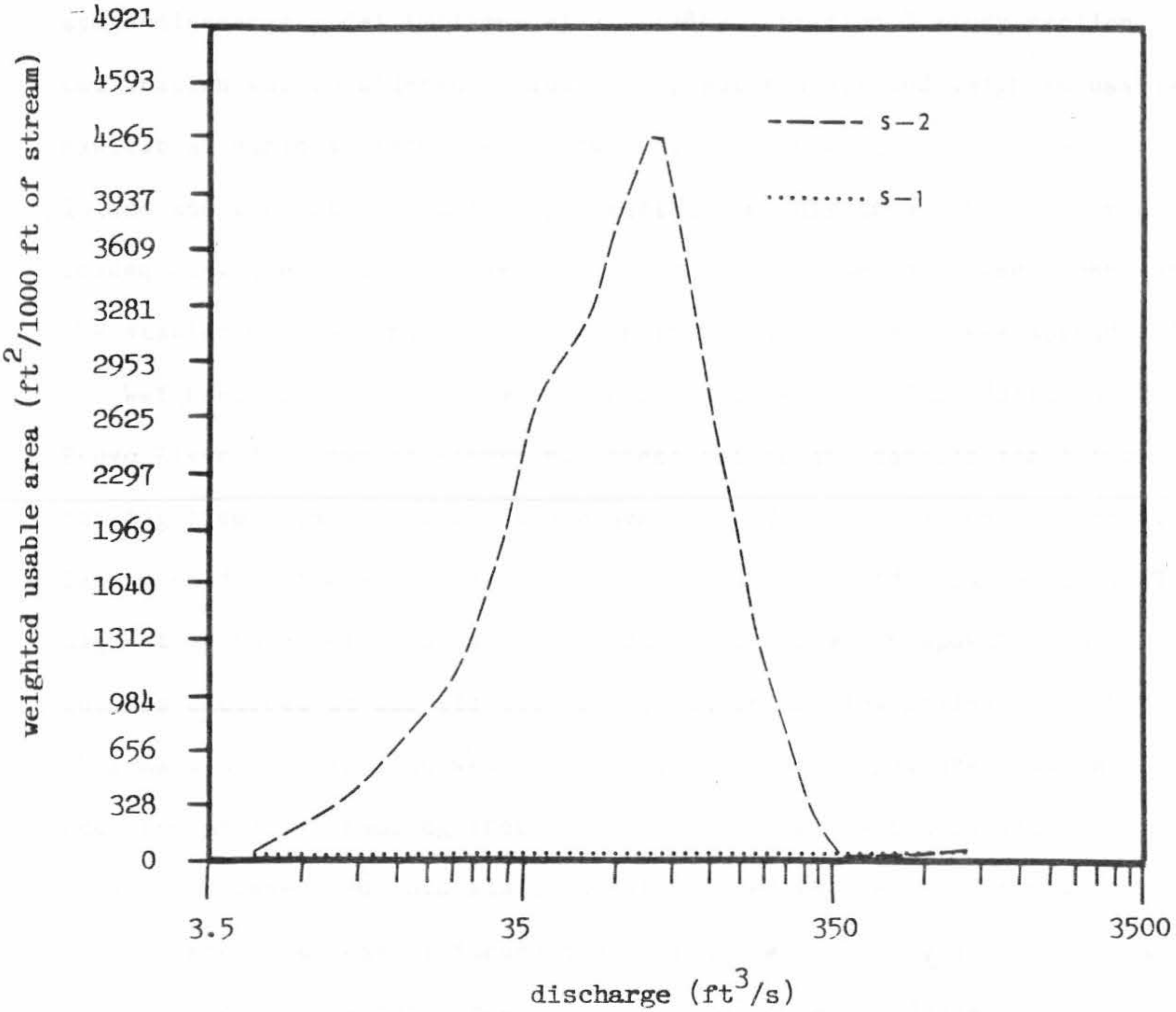


Figure 5. Weighted usable habitat area for June sucker spawning at various stream discharges, Provo River, Stations 1 and 2, 1982.

obtained from the 1982 habitat stations. Additionally, the FWS Instream Flow Group was requested to review and refine the probability of use curves developed for the June sucker.

The 1985 habitat stations were modeled using the IFG-4 stage-discharge model (Milhous et al. 1984). Station 3 study section calibration was considered adequate to predict stage and weighted usable habitat at various discharges. However, Station 4 included a gravel island and backwater, and the calibration for this area was considered inadequate. The field data were reviewed by Dominque and Bovee (1986) and the station was calibrated using four independent models (see Appendix I).

Weighted usable habitat area for June sucker spawning adults in the Provo River is shown in Figure 6. These values are modeled for flows ranging from 0 to 1500 cfs and are averages of Station 3 and Station 4. Tabulated data for each station are provided in Appendix Table II-5. The highest average weighted usable habitat area value for spawning June suckers occurred at 113 cfs discharge. Instream flow analyses of the 1982 habitat stations showed the highest usable habitat area values occurred at flows ranging from 80 to 107 cfs for Station 2, which physically resembled both stations established in the 1985 study.

To determine loss of incubation habitat (effective spawning habitat) as flows decrease after sucker spawning, Dominque and Bovee (1986) used the HABSP model described by Bovee (1985). This model provides an analysis of stranding of eggs from flow reductions which diminish the overall effective spawning area. Suitability criteria for incubation assumed that depths above 0.1 ft and velocities less than 8 ft^3/s were suitable (suitability = 1) for incubation. Results show that as spawning

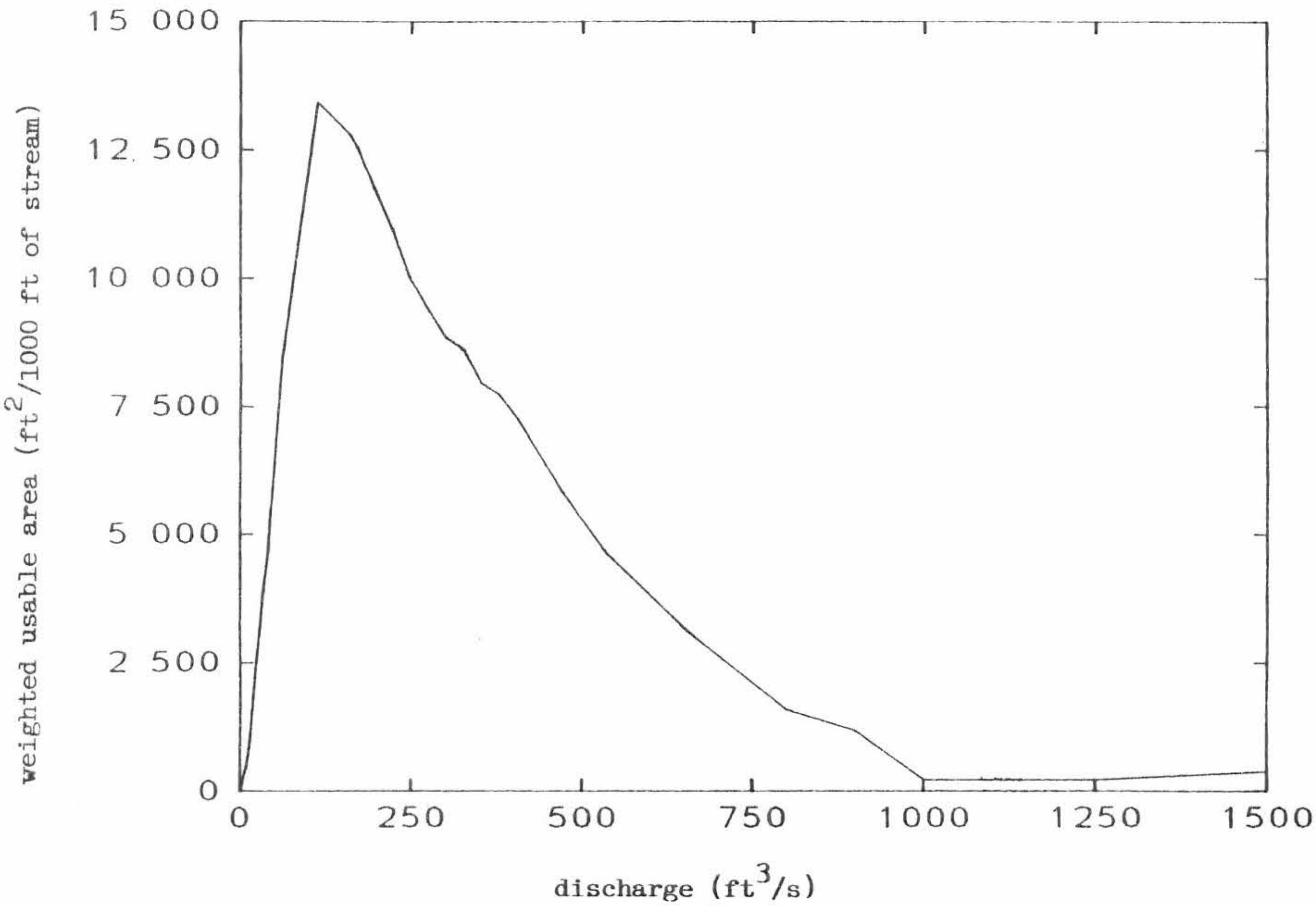


Figure 6. Weighted usable habitat area for June sucker spawning at various stream discharges, Provo River, averages of Stations 3 and 4, 1985.

flows increase, the rate at which these flows can subsequently be reduced without significant losses of incubation habitat, decreases (see example, Appendix I, Addendum I). For example, using upstream model 2, when spawning flows of 250 ft^3/s are reduced to 25 ft^3/s there is a 19 percent loss of incubation habitat. In comparison, 150 ft^3/s spawning flows reduced to 25 ft^3/s results in only a 2 percent loss of incubation habitat.

SUMMARY

Additional instream flow field studies, data analyses, and conversion to velocity and depth suitability values for spawning June suckers by Dominque and Bovee (1986) were performed to verify and refine results obtained by analyzing 1982 habitat stations. These results supported previously identified optimum flow values for spawning sucker in June and identified a flow, of 113 ft^3/s, as being most desirable for spawning June suckers within the existing Provo River channel. Predicted maximum usable habitat values for spawning June suckers were somewhat lower than anticipated based upon field observations in recent years. Figure 7 illustrates water flows in the study area in June and the period of June sucker spawning, for a 6 year period when observations were recorded. Appendix Table II-6 lists the historical flow records recorded at the USGS Provo River gage at Provo. As flows fall below 150 cfs, spawning June suckers become increasingly vulnerable to harassment by the public.

A HABSP analysis was conducted by Dominque and Bovee (1986) to determine effective spawning habitat for spawning and incubation of June suckers under various flow conditions. These data should be considered

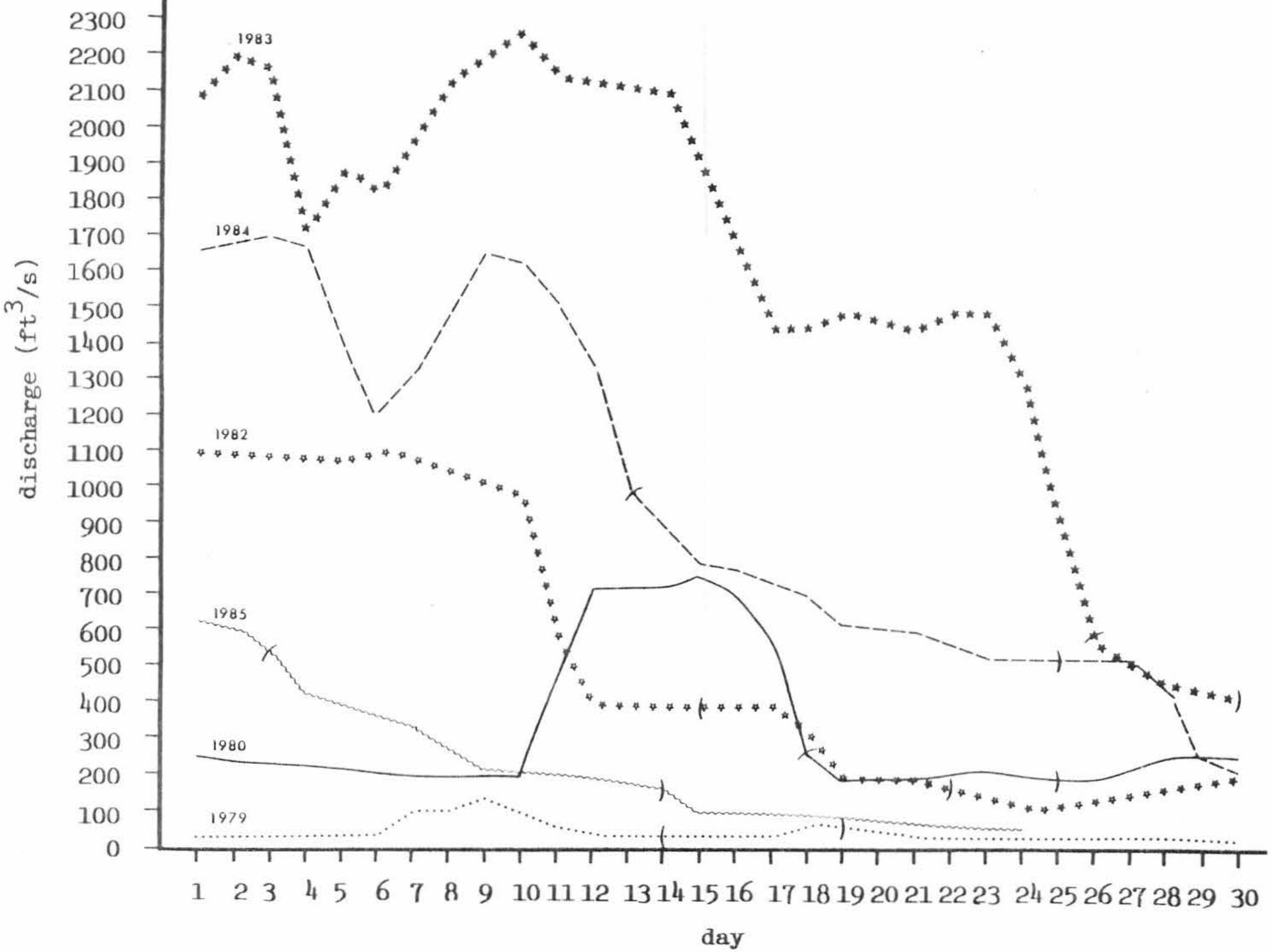


Figure 7. Six years of June flow records at the Provo River at Provo USGS gage, and period of June sucker spawning ( ) [in some cases date of first spawning activity estimated].

when reducing flows from spawning levels to base flows to prevent loss of incubating eggs and/or pre-emergent larvae. Matrices (Appendix I, Addendum 1, Table 1) of effective spawning habitat may be used as a guideline in determining appropriate rates of flow reductions.

With the exception of results from Station 1, modeling of weighted usable spawning habitat availability showed consistency between habitat Stations 2, 3, and 4. Preliminary 1985 recommendations for maintaining June sucker spawning flows between 100 to 250 ft^3/s are generally supported by additional work completed in 1985. Further field studies should be carried out to validate model results, so operational adjustments and refinement can be made where possible.

Recommendations

1. Flows below the Tanner Race Diversion should be maintained between 80 and 250 ft^3/s to provide at least 75 percent of the highest WUA for spawning June sucker. Target flows between 100 and 170 ft^3/s should be established to provide at least 95 percent of the highest WUA for spawning June sucker.
2. Spawning flows should be provided no later than 10 June and preferably by 1 June each year. These flows should be maintained until 1 July or until all June sucker spawning activity has been completed.
3. Prespawning flows in the Provo River below Tanner Race Diversion should not fall below 50 ft^3/s from 1 May to when spawning flows are provided. Although data is unavailable to suggest what flows are needed to attract spawning sucker to the Provo River a minimum flow of 50 ft^3/s is proposed.

4. Flow reduction from levels provided for June sucker spawning to base flows should be determined from a detailed composite of the two established matrices (See Appendix I, Addendum I, Table 1). Flow reduction should not cause the loss of more than 5 percent of the incubation habitat available during peak June sucker spawning activity.

5. Flow reduction criteria should be applied from 1 July through 20 July or for the period 20 days after spawning activity has ceased.

6. Studies should be initiated to validate flow recommendations, and refine timing and duration of flows required for June sucker reproduction. These studies should likely include: a) quantification of spawning June sucker using the Provo River annually and their utilization of spawning habitats at various flow regimes, b) evaluation of annual reproductive success based upon numbers of larval June suckers produced under various flow regimes, and c) refinement of early life history data, especially concerning larval fish behavior.

Ongoing Studies

The UDWR June sucker program in 1987 and 1988 will concentrate on artificially spawning ripe fish collected from the Provo River, hatching their eggs at the UDWR hatchery in Springville, Utah, and developing and maintaining at least one refugia population of genetically diverse June suckers to safeguard against loss of the wild population. Additionally, negotiations are progressing to contract with the Colorado State University Larval Fish Laboratory for completion of a larval key for June sucker, Utah sucker, and mountain sucker. Negotiations are also progressing to develop a graduate student project through the Utah State University Cooperative Fishery Research Unit to determine the emigration pattern of YOY June suckers and develop procedures to establish an index of June sucker reproductive success. The project would also determine the growth and feeding of YOY June suckers under controlled conditions.

Other work activities during this period will include: a) participation in completing a June sucker recovery plan, b) continuation of work to clarify June sucker age distribution in Utah Lake, c) investigations of potential production facilities to rear June suckers, d) formulating a design, planning, and budgeting for a fish trap in the lower Provo River to capture June suckers migrating into the river to spawn, e) determining a suitable marking technique for adult June suckers, f) refining culture techniques for June suckers, and g) continuing involvement in miscellaneous activities that affect the survival and recovery of the June sucker.

REFERENCES

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12. U.S.D.I. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-82/26. 248 pp.

Bovee, K.D. 1985. Evaluation of the effects of hydropeaking on aquatic macroinvertebrates using PHABSIM. Pages 236-241. Olson, F.W., R.G. White and R.H. Hamre, editors. Proceedings of the symposium on small hydropower and fisheries. American Fisheries Society, Bethesda, Maryland, USA.

Bovee, K.D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for insteam flow assessments: Fisheries. Instream Flow Information Paper No. 3. Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Bovee, K.D., and R. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and techniques. Instream Flow Information Paper No. 5. Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Fort Collins, CO.

Carter, D. 1969. A history of commercial fishing on Utah Lake. Masters thesis. Provo, Utah: Brigham Young University. 142 pp.

Dominque, R., and K. Bovee. 1986. Provo River June sucker habitat study. U.S. Fish and Wildlife Service Instream Flow Group. Western Energy and Land Use Team, Fort Collins, Colorado.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984 User's guide to the physical habitat simulation system (PHABSIM). Instream Flow Information Paper No. 11. Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Miller, R.R., and G.R. Smith. 1981. Distribution and evolution of Chasmistes (Pisces: Catostomidae) in western North America. Occasional papers of the Museum of Zoology, University of Michigan, Ann Arbor, MI. No. 696.

Radant, R. D., and D. K. Sakaguchi. 1981. Utah Lake fisheries inventory. U.S. Bureau of Reclamation Contract 8-07-40-S0634. Salt Lake City, Utah: Utah Division of Wildlife Resources.

Snyder, D. E. 1986. Correspondence. Utah Div. of Wildl. Resour. files, Salt Lake City, UT.

U.S. Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; proposal to determine the June sucker (Chasmistes liorus) to be an endangered species with critical habitat. Federal Register. Vol. 49, No. 128.

U.S. Fish and Wildlife Service. 1986. Endangered and threatened wildlife and plants; final rule determining the June sucker (Chasmistes liorus) to be an endangered species with critical habitat. Federal Register. 51(61):10851-10857.

APPENDIX I

Preface

Habitat analyzes were completed using larval fish data collected from the lower Provo River in 1982 and 1983. Subsequent identification of larval fishes from this area failed to substantiate the presence of June sucker larvae. Therefore, although assessments for larval fishes were completed, they were not used in the final evaluation of June sucker habitat requirements.

Provo River

June Sucker Habitat Study

by

Richard Domingue and Ken Bovee

Study Sites:

Two stream transect segments were established to represent the stream reach of interest for spawning and rearing June suckers. These two sites have been identified as Upstream (Study Site 1) and Downstream (Study Site 2). Both sites were surveyed with arbitrary datums and characterized by five strategically located cross-sections. Throughout the analysis each segment was assumed to effectively describe habitat conditions through 1/2 of the study reach. That is, they were weighted equally in the analysis.

Data:

Hydraulic data were acquired at three flows (57.2, 153.3 and 356.4 cfs) during the summer and fall of 1985. Spawning observation data was collected at flows of 153 cfs (1982), 424 cfs (1983) and 601 cfs (1984). The fry observation data were collected during July, 1982 and July through November, 1983. All hydraulic and fish data were collected by Utah Department of Wildlife personnel and Bureau of Reclamation personnel.

Hydraulic Simulation:

The Upstream segment contained a gravel island with a variable backwater. In order to adequately simulate this segment, 4 independent models were created (see Figure 1). Model 1 simulates the island segment (variable backwater) from 0 to 400 cfs at which point the island is estimated to be inundated and backwater effects eliminated. The data indicate that flows begin to overtop the island at flows above 356 cfs. Model 2 simulates the main channel portion of the stream adjacent to the island section from flows of 0 to 400 cfs. Model 3 describes that portion of the reach above the island section from flows of 0 to 400 cfs. Model 4 models the entire reach at flows above 400 cfs.

The Downstream segment had less hydraulic variability and was sufficiently simulated with one model covering the entire reach.

Both reaches were originally modeled using the open channel hydraulics model IFG4, a stage/discharge model. Initial results of this analysis were considered good for the Downstream segment and poor for the Upstream segment. The Upstream segment displayed impossible water surface profiles (water running uphill) and poor calibration to velocities measured in the field.
To improve the calibration of the Upstream models the data were input to WSP, a mass and energy balance model, in order to predict water surface elevations at the flows of interest. The WSP sets calibrated well and the resulting WSL's were input into the IFG4 sets for final hydraulic simulations.

The results of the initial IFG4 runs showed unrealistically high Manning's n values for cells at the stream margins when calibrated to the measured velocities. This is caused by measuring velocities in very shallow water where the relative roughness (the ratio between particle size and depth) is very large. When depth increases (i.e. when discharge increases) the relative roughness decreases rapidly. Since IFG4 transposes the n values of cells at the edge of water at calibration flows to cells that were dry during the calibration measurements, it is necessary to limit n values at the edge to prevent the inclusion of artificially high n's in the model. We set maximum n values to 0.05 in the main channel and 0.15 at the stream margins to more accurately reflect the physical hydraulics of the channel. Final hydraulic simulations are considered good for the Downstream segment and for flows above 5 cfs in models 2,3 and 4 of the Upstream segment.

Below 5 cfs the upstream model required relatively large adjustments to the predicted velocities to fit the given water surface elevations.

Problems and assumptions made in modeling the variable backwater are discussed below.

Model 1:

There were two major problems encountered in simulating the hydraulics of Model 1: a distinct nonlinear stage/dicharge relationship (see Figure 2) and poor definition of the stage of zero flow.

The dogleg in the stage/discharge relationship is apparently caused by a shoal at the head of the segment controlling inflow. Flows within the segment when the stage of the river is below the elevation of the shoal appear to be interstitial or minor channel flow. As the stage of the river exceeds the elevation of the shoal a dramatic increase in side channel flow occurs. There was not sufficient information available to determine the elevation of the shoal so an assumption was made that flows over the shoal occurred at total channel flows of 154 cfs. It is clear from the data that such over shoal flows occur at flows between 154 and 356 cfs. Field measurement of the elevation of the upstream inlet to this section would improve the accuracy of this model.

After developing the stage/discharge relationship for Model 1 it was discovered that the predicted stage of zero flow was apparently somewhat higher than measured in the field. This was apparent from the flaring at low flows of the velocity adjustment factors (see Figure 3). This phenomenon often occurs when the predicted stage is too low. The estimated stage of zero flow was found by linear extrapolation of the log transform of the two lowest stage-discharge pairs (see Figure 2).The simulations were run assuming that the predicted stage of zero flow was more accurate than that measured in the field.

These corrections result in a simulation showing that more water remains in the side channel under conditions of zero flow. If the predicted stage of zero flow is incorrect, this result will also be incorrect. This segment provides a significant amount of simulated fry habitat under extremely low flow conditions. Therefore, we suggest that the presence and extent of backwater habitats be field verified under very low flow (i.e.,10 cfs) conditions.

Habitat Simulation:

In this study it was found that suitability values based on utilization alone resulted in a bimodal spawning suitability for velocity. Such a suitability curve is biologically unlikely because it implies low suitability between two intervals of high suitability for the same variable. The spawning data were collected at three different flows so it is possible that utilization was influenced by the habitat available at the time of observation. The utilization curve was converted to a preference curve by dividing utilization by availability, a process which reduces the environmental bias. The resulting curve lacked the bimodal character of the utilization function and was smoothed using a running median process. (See Figure 4).

Similar techniques were used to produce a preference curve for spawning depth. Of interest is the appearance of a strong negative correlation between flow and preferred depth - as flow increased the preferred depth decreased. It is likely that this effect is caused by avoidance of high velocities and a relatively weak preference for depth. The resulting depth function is therefore relatively broad.

Results:

The available prefered habitat area vs flow function was run through the three flow time series of interest (baseline, present and future) to produce habitat time series and duration analyses.

The final habitat time series results of the analysis are available in Appendix 2. These results are ordered by life stage and show three hydrologic scenarios: baseline vs present, baseline vs future, present vs future. A summary of available habitat and changes in available habitat is given at the beginning of Appendix 2.

Discussion and Recommendations:

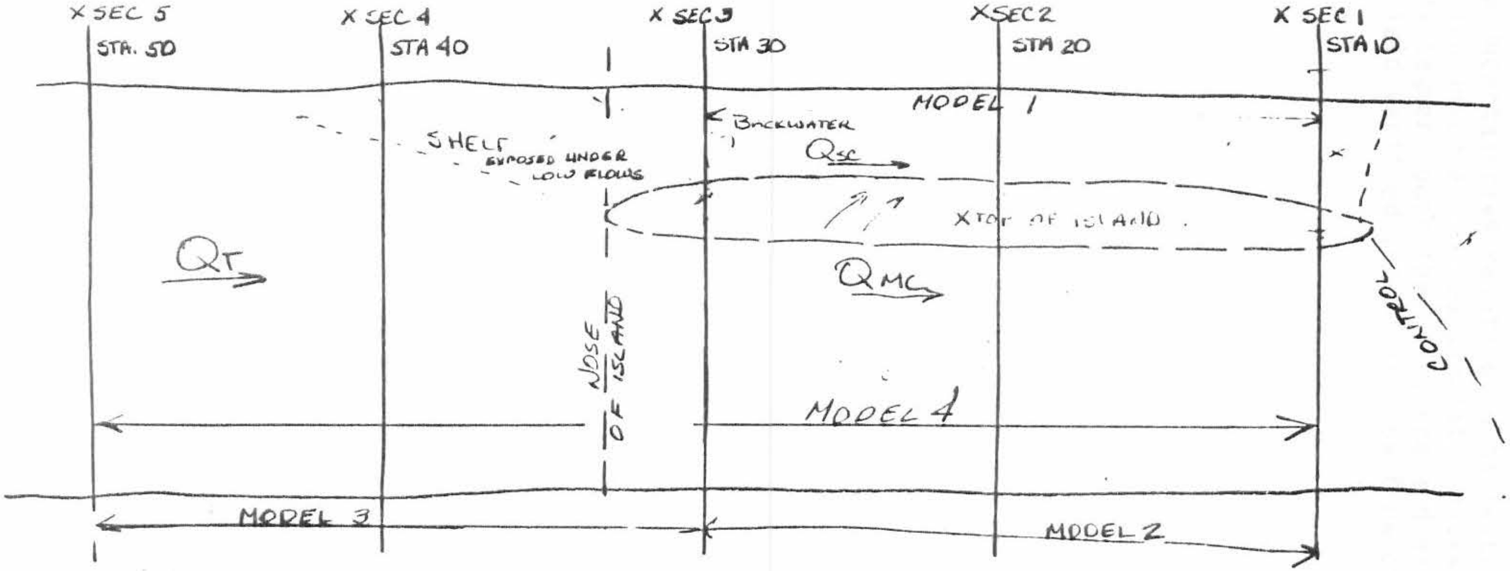
The results of the habitat time series analysis for present vs future flow conditions showed a dramatic increase in spawning habitat and losses of fry habitat during July and August.

The apparent negative impacts on fry rearing habitat are probably due to excessive velocities and a lack of backwater areas in the Provo River. Several possible alternatives are suggested by this analysis.

1. Maintenance of streamflows no greater than about 10 cfs in the lower Provo River during the period from emergence to out-migration. This alternative will also make the Provo River less attractive to walleyes, white bass and other aquatic predator species, but may result in increased terrestrial and avian predation.
2. Construction of islands or other backwater-forming structures that create effective slack water areas over a wide range of flows. This may reduce terrestrial predation, but may also provide favorable habitats for aquatic predators.
3. Combined mitigation employing both flow control and habitat construction. This alternative may provide the best overall protection from predation.

Since it appears that fry habitat will be best at very low flows, two issues remain: (a) is the simulation correct and, (b) if it is, what is the best way to reduce the spawning flow down to the rearing flows without stranding eggs or flushing fry into Utah Lake? The simulation might be experimentally verified by using existing diversions to reduce flows in the study area while monitoring the population of young June suckers for several years. Any attempt to simulate lower flow conditions during the month of June

UPSTREAM STATION
PROVO RIVER PHABSIM



LOW FLOW: $Q_{SC} \approx$ 0-5cfs, ISLAND BEGINS BEFORE STA. 30 & ENDS AFTER STA 10
$Q_T < 55$ cfs, MODEL 1, 2 & 3

MED FLOW: $Q_{SC} \ll Q_{MC}$, ISLAND BEGINS @ or around sta 30 & ENDS AFTER STA 10
$Q_T = 153$ cfs, MODEL 1, 2 & 3

HIGH FLOW: $Q_{SC} < Q_{MC}$, ISLAND COMPLETELY INUNDATED, DEPTH LESS THAN .25' FROM STA 20 thru STA 10 & BEYOND $Q_T = 356$ cfs, MODEL 4 DOMINATES

FIGURE I

should also include simulation of spawning and incubation effects as well as possible temperature effects.

Due to uncertainties relating to backwater formation and the assumption that the reach which exhibited simulated backwater conditions represented 1/2 of the study segment both the existence and extent of such backwater habitats should be field verified under very low flow conditions.

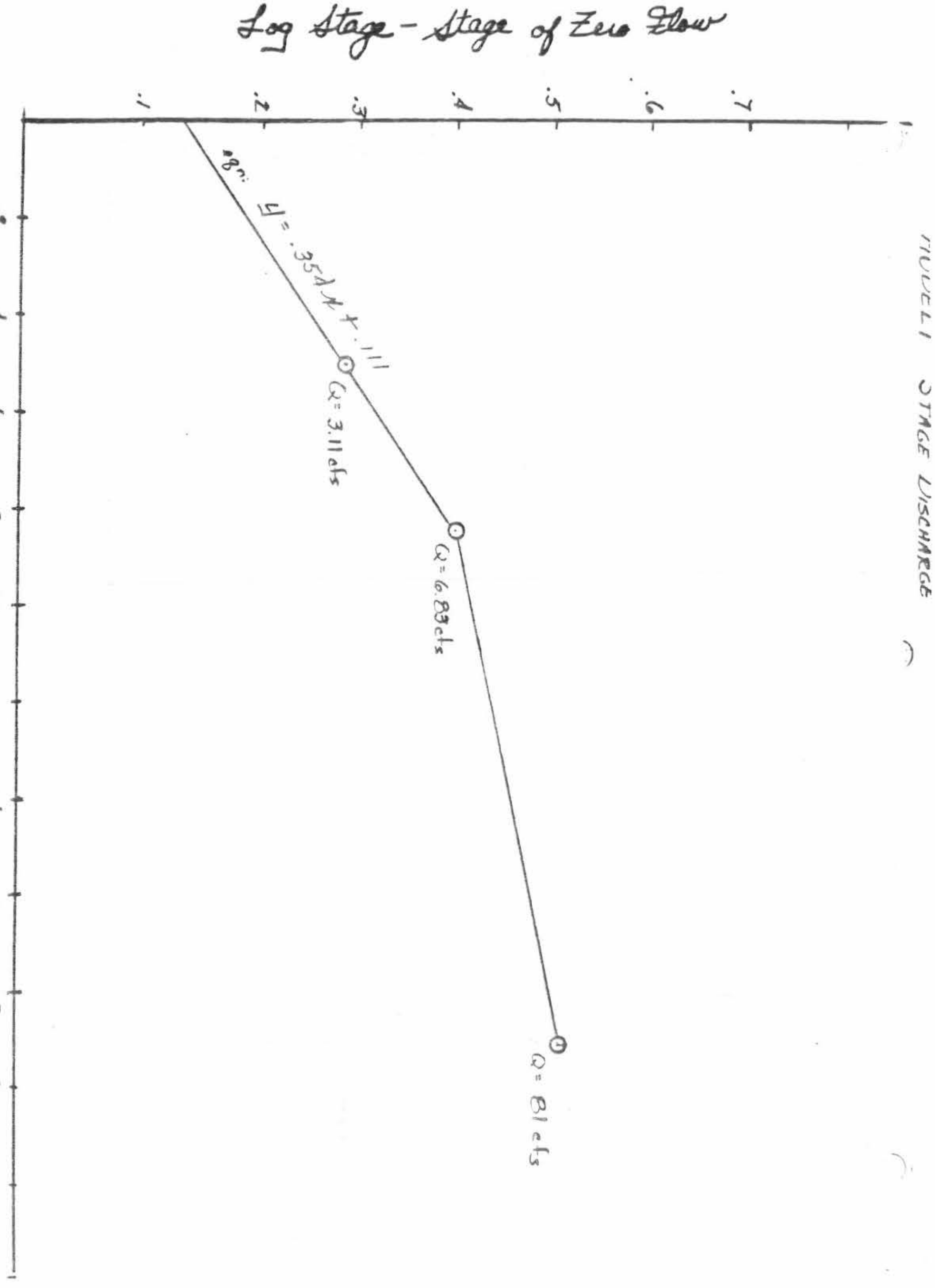
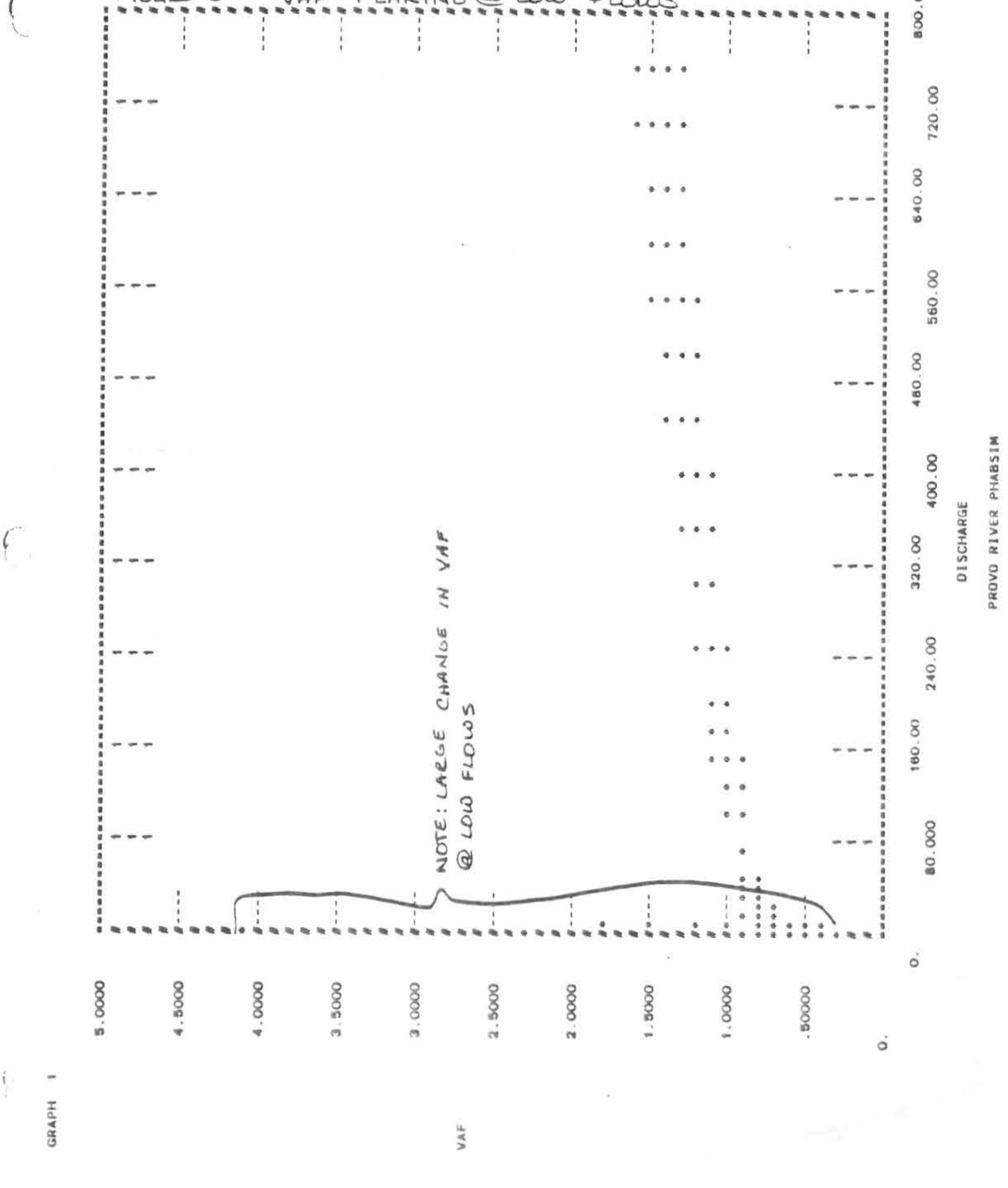


FIGURE 2 STAGE/DISCHARGE FOR MODEL I

FIGURE 3 - VAF FLARING @ LOW FLOWS



VELOCITY SUITABILITY FIGURE 4

use provsi
VARIABLES IN SYSTAT FILE ARE:

SIV	VELOCITY	SI32V	SI33V	SI34V

>submit smooth

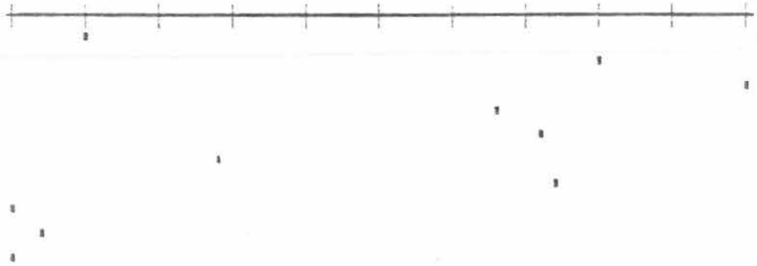
plot of unsmoothed suitability index

.5 ft/sec intervals
SIV COPIED FROM SYSTAT FILE INTO ACTIVE WORK AREA

PLOT OF SIV
NUMBER OF CASES = 10
MEAN OF SERIES = 0.443
STANDARD DEVIATION OF SERIES = 0.364

SEQUENCE PLOT OF SERIES — DIRECT RESULTS

CASE	VALUE
1	0.120
2	0.810
3	1.000
4	0.660
5	0.730
6	0.290
	0.750
	0.030
9	0.050
10	0.000



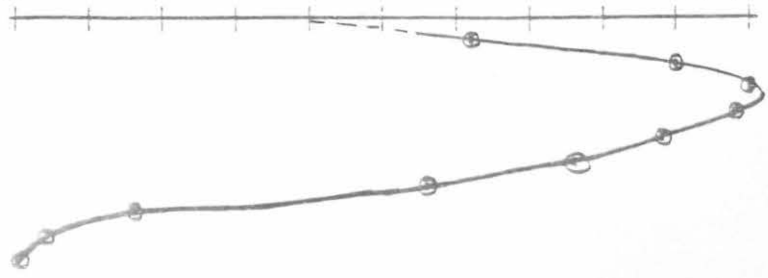
SERIES IS SMOOTHED
SERIES IS SMOOTHED
SERIES IS SMOOTHED
SERIES IS SMOOTHED
SERIES IS SMOOTHED

plot of smoothed curve

Tukeys 4253H compound smoother
PLOT OF SIV
NUMBER OF CASES = 10
MEAN OF SERIES = 0.437
STANDARD DEVIATION OF SERIES = 0.272

SEQUENCE PLOT OF SERIES - SMOOTHED RESULTS

CASE	V_i	VALUE
1	0.0-0.5	0.465
2	0.5-1.0	0.666
3	1.0-1.5	0.733
	1.5-2.0	0.723
	2.0-2.5	0.658
6	2.5-3.0	0.560
7	3.0-3.5	0.412
8	3.5-4.0	0.119
9	4.0-4.5	0.034
10	4.5-5.0	0.000



APPENDIX I

Addendum I

Addendum 1

An attempt has been made to simulate the loss of incubation habitat as flows are decreased from spawning flows down to fry rearing flows (q < 25 cfs). The HABSP model compares weighted useable area on a cell by cell basis and reports the minimum habitat area of the two life stages under conditions of two different flows. This provides an analysis of stranding and flushing of eggs which negates the effective spawning area. The Upstream model 2 and the Downstream model were analyzed with this proceedure.

The results of this analysis show that as flows increase, the rate at which spawning flows can be reduced to fry rearing flows without significant losses of incubation habitat decreases. As an example, when spawning flows of 250 cfs are dropped to 150 cfs only a 1% loss of incubation habitat occurs. However, when the 250 cfs spawning flows are reduced to the 25 cfs flow preferred by YOY there is a 19% loss of incubation habitat.

When spawning flows are 150 cfs or less the need to moderate flow reductions decreases. Reducing flows from 150 cfs to 10 cfs results in incubation habitat losses of about 10%. While flows below 150 cfs are suboptimum for spawning, they may produce the greatest reproductive efficiency as they provide the best opportunity to achieve rearing habitats for YOY without significant loses of incubation habitat.

The suitability criteria for incubation assumed that depths above .1 feet and velocities less than 8 fps were completely suitable for incubation (suitability = 1). All substrate conditions were considered completely suitable. The computer output of the HABSP work is enclosed with the package of suitability criteria work. Matrices of the effective spawning habitat are attatched as Table 1. These matrices allow a comparison of effective habitat under various spawning and rearing conditions.

TABLE 1

MATRICES OF EFFECTIVE HABITAT

UPSTREAM MODEL 2

COMPOSITE WEIGHTED USEABLE AREA SQ. FT/ 1000 FT.

INCUBATION FLOWS in CFS					
250	182.1	981.2	2270	2277	1733
150	182.1	981.2	2270	2277	1721
75	182.1	981.2	2270	2275	1640
25	182.1	981.2	2253	2225	1397
10	182.1	974.9	2203	2041	1024
	10	25	75	150	250

SPAWNING FLOWS in CFS

DOWNSTREAM MODEL

COMPOSITE WEIGHTED USEABLE AREA SQ FT./ 1000 FT.

INCUBATION FLOWS in CFS					
250	18.7	1407	10833	12084	8186
150	18.7	1407	10833	12084	8186
75	18.7	1407	10833	12084	8186
25	18.7	1407	10571	11497	6213
10	18.7	1407	10571	9155	4634
	10	25	75	150	250

SPAWNING FLOWS in CFS

SELECTED COMPUTER FILES
JUNE SUCKER
IFIM STUDY

MESSAGE FILE

HABITAT DURATION ANALYSIS FILES:

FUTURE =FUTURE FRY HABITAT AREA
PRESENT=PRESENT FRY HABITAT AREA
ANNUAL =ANNUAL FRY HABITAT DURATION
MONTHLY=MONTHLY FRY HABITAT DURATION
FISHFIL=FISHFIL USED FOR FRY ONLY (FILE 200)
JUNFRY= COMPOSITE TAPE 8 FOR FRY
SPWNDUR=SPAWNING ANNUAL DURATION
SPWNFIL=SPAWNING FISHFIL (BINARY SUITABILITY)
SPAWN= SUITABILITY (READABLE) FILE FOR SPAWNING
SPAWNHB= TAPE 8 FOR SPAWNING PREFERENCE

HYDRAULIC SIMULATION FILES:

DOWNXS=COMPLETE DOWNSTREAM IFG4 MODEL
DOWNHI=HIGH FLOW DOWNSTREAM MODEL
DOWNMD=MEDIUM FLOW DOWNSTREAM MODEL
DOWNLO=LOW FLOW DOWNSTREAM MODEL
M1HIFIN=HIGH FLOW UPSTREAM MODEL 1
M1MDFIN=MEDIUM FLOW UPSTREAM MODEL 1
M1LOFIN=LOW FLOW UPSTREAM MODEL 1
M2LOFLO=LOW FLOW MODEL 2 (<40CFS)
M2LFIN=LOW FLOW MODEL 2 (>40CFS)
M2MFIN=MEDIUM FLOW MODEL 2
M2HFIN=HIGH FLOW MODEL 2
MD3LFLO=MODEL 3 LOW FLOW MODEL (<42CFS)
MD3LO=MODEL 3 LOW FLOW MODEL (>42CFS)
MD3MD=MODEL 3 MEDIUM FLOW MODEL
MD3HI=MODEL 3 HIGH FLOW MODEL
M4HI= MODEL 4 FOR HIGH FLOW CONDITIONS
(OTHER MODEL 4 SETS NOT USED)
WSPN1= WSP SET FOR MODEL1
WSPN2= WSP SET FOR MODEL2
WSPN3= WSP SET FOR MODEL3
WSP4T= WSP SET FOR MODEL 4
WSP2M= WSP SET FOR LOW FLOWS MODEL2
QPRESNT= HISTORICAL FLOWS FOR CURRENT CONDITIONS
QFUTURE= HISTORICAL FLOWS FOR FUTURE CONDITIONS
QBSLN = HISTORICAL FLOWS

END OF FILE
??

APPENDIX II

Table II-1. Probability of use data for spawning June sucker, Provo River, 1982-84.

*Substrate	Probability
0.0	0.00
4.0	0.00
5.0	0.00
5.4	0.04
5.5	0.33
5.8	1.00
6.0	0.71
6.5	0.02
7.0	0.00

* Bovee (1982)

Appendix Table II-2. Composite depth suitability data for spawning June sucker, Provo River, 1982-84.

Depth (ft)	Suitability index
0.0	0.00
0.9	0.00
1.0	0.31
1.1	0.90
1.2	1.00
1.3	0.97
1.4	0.87
1.5	0.80
1.6	0.78
1.7	0.76
1.8	0.75
1.9	0.73
2.0	0.71
2.1	0.68
2.2	0.68
2.3	0.56
2.4	0.43
2.5	0.13
2.55	0.00

Appendix Table II-3. Composite velocity suitability data for spawning June sucker, Provo River, 1982-84.

Velocity (ft/s)	Suitability index
0.00	0.00
0.25	0.63
0.75	0.91
1.25	1.00
1.75	0.99
2.25	0.90
2.75	0.76
3.25	0.56
3.75	0.16
4.25	0.03
4.75	0.00
5.00	0.00

Appendix Table II-4. Weighted usable habitat area (WUA, ft^2/1000 ft) for spawning June sucker in Provo River at model flows, 1982.

Discharge (ft^3/s)	Station 1	Station 2
5	0	49
10	0	348
20	0	991
22	0	1020
30	0	1804
40	3	2740
50	0	3015
60	0	3199
70	0	3734
80	3	3970
90	3	4265
100	0	4259
107	3	4022
150	3	2507
162	3	2218
200	7	1368
250	7	728
300	7	253
350	3	89
400	7	7
450	7	7
500	7	3
600	10	3
700	16	23
800	26	43
1000	43	75

Appendix Table II-5. Weighted usable habitat area (WUA, $ft^2/1000$ ft) for spawning June sucker in the Provo River at model flows, 1985.

Discharge (ft^3/s)	Station 3	Station 4	Average
2	0	122	61
3	0	215	107
5	0	479	240
8	0	805	403
10	18	950	484
15	326	1628	977
20	800	2732	1766
25	1379	3756	2568
30	1901	4424	3163
35	2761	4995	3878
42	3755	5590	4673
62	8136	8894	8515
113	11758	15113	13436
160	11114	14473	12794
170	10758	14331	12555
195	10029	13507	11768
221	9217	12700	10959
246	7985	12058	10022
272	6896	11952	9424
300	5808	11857	8833
326	5505	11697	8601
352	4553	11355	7954
378	4006	11432	7719
405	3450	11057	7254
470	2289	9400	5845
535	1674	7600	4637
650	918	5400	3159
800	326	3031	1585
900	139	2215	1177
1000	51	1554	803
1250	0	438	217
1500	0	770	385

Appendix Table II-6. Historical flows (ft^3/s) at the USGS Provo River gage at Provo, Utah.

YEAR	OCT	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1930	205	302	322	286	333	309	252	7	10	2	2	2
1931	268	286	273	252	252	247	86	3	0	0	0	0
1932	0	10	163	146	256	219	296	472	600	3	2	2
1933	70	193	213	236	198	301	192	5	306	2	0	0
1934	2	18	172	81	202	132	3	0	0	0	0	0
1935	0	0	114	153	180	187	193	8	390	2	0	0
1936	28	148	130	176	220	289	587	699	101	3	2	0
1937	93	252	218	237	277	307	350	530	128	3	3	5
1938	111	195	221	197	214	340	383	477	193	3	2	3
1939	91	207	223	208	209	358	229	31	3	2	2	5
1940	119	72	119	198	212	241	119	47	2	2	2	2
1941	10	94	190	198	220	273	182	163	151	3	3	7
1942	145	188	289	281	265	263	281	257	187	33	2	5
1943	41	136	200	270	349	387	492	221	272	3	3	5
1944	91	178	229	257	254	242	276	398	523	26	2	5
1945	81	188	208	276	312	361	339	493	260	3	3	50
1946	161	249	298	311	297	304	207	91	12	0	5	5
1947	130	250	550	494	310	343	366	215	67	15	8	29
1948	161	266	286	273	284	107	245	213	66	2	3	7
1949	67	193	275	280	292	307	229	228	392	3	2	37
1950	226	282	270	306	293	309	247	317	482	7	2	22
1951	115	208	311	316	333	317	254	246	205	3	1	17
1952	236	321	343	355	351	330	884	1395	538	20	15	45
1953	114	267	324	320	423	307	249	39	35	3	5	7
1954	78	229	382	346	220	48	71	11	7	3	2	3
1955	15	126	195	192	149	119	97	11	15	2	2	7
1956	34	178	236	278	328	346	180	137	321	5	3	5
1957	63	266	268	203	214	298	276	333	632	127	8	24
1958	133	234	311	289	284	342	460	236	242	5	7	18
1959	68	166	268	260	229	273	166	11	5	2	5	24
1960	169	163	171	176	164	114	49	3	3	2	2	2
1961	11	89	286	137	101	41	25	2	106	52	3	2
1962	31	118	299	190	254	454	479	602	560	34	7	7
1963	55	25	148	197	310	319	198	207	447	5	3	15
1964	63	148	203	262	148	109	309	333	892	67	3	7
1965	31	141	159	231	421	555	474	239	980	390	41	168
1966	273	280	312	312	295	234	281	203	35	7	3	8
1967	65	180	320	343	275	317	348	86	948	221	13	35
1968	[illegible]	239	345	275	175	374	403	220	459	20	26	50
1969	146	237	364	431	375	363	576	215	376	59	28	29
1970	86	308	372	316	373	220	161	86	304	21	10	20
1971	155	348	379	314	310	216	316	190	328	19	15	18
1972	250	339	329	268	293	335	284	272	496	31	1	36
1973	185	232	229	265	288	278	348	681	328	5	2	27
TOTAL	4705	8644	11517	11492	11742	12333	12350	10564	12207	1224	277	833
MEAN	107	196	262	261	267	280	281	240	277	28	6	19