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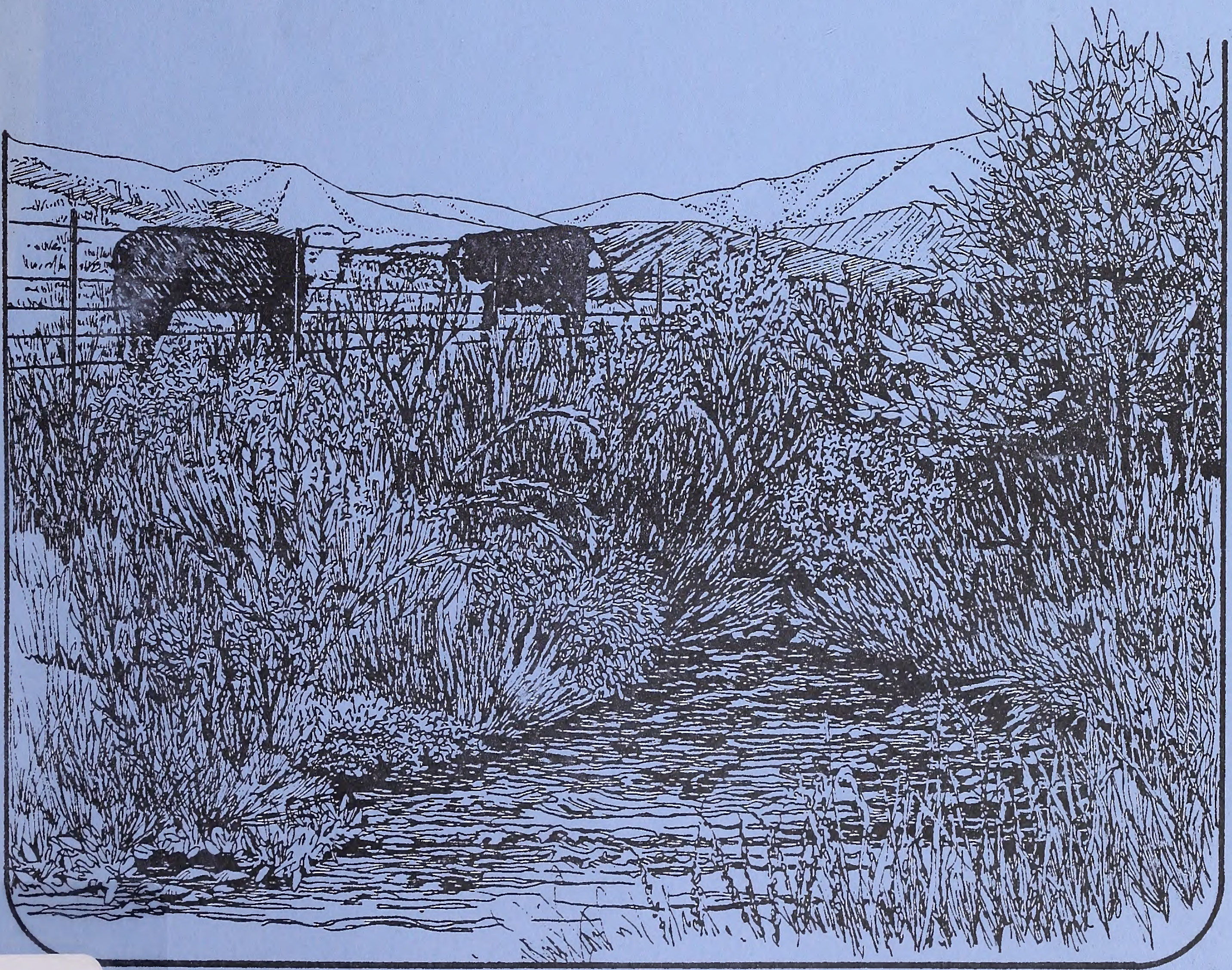
Livestock-Fishery Interaction Studies

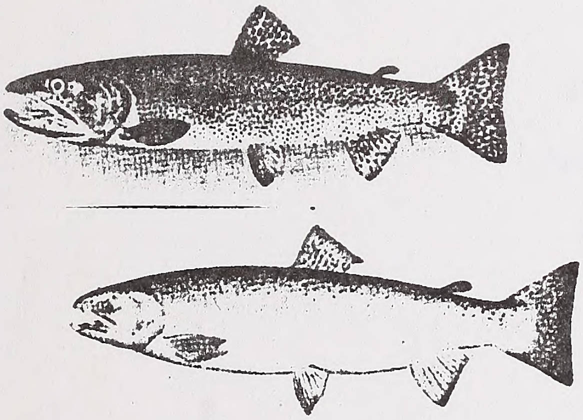
OTTER CREEK — UTAH



FOREST SYSTEM COOPERATIVE FORESTRY FORESTRY RESEARCH
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

OTTER CREEK — UTAH



LIVESTOCK-FISHERY INTERACTION STUDIES

OTTER CREEK, UTAH

USDI - Progress Report 1 to the Bureau of Land Management

Salt Lake City, Utah

July, 1979 to May, 1980

William S. Platts

Rodger Loren Nelson

Susan B. Martin

USDA - Forest Service, Intermountain Forest and Range Experiment

Station, Boise, Idaho

PREFACE AND ACKNOWLEDGEMENTS

This progress report represents the results of the study and integration of informative material from various sources, all of which are listed in the "References" and "Publications Cited" sections. All of the specific information regarding the history and condition of the South Narrows Allotment, including photographs, was obtained from material kindly provided by Mr. David Young, Fisheries Biologist, USDI, Bureau of Land Management, Sevier River Resource Area, Richfield, Utah. In order to limit distraction created by abundant and unwieldy referencing, much of this official information was integrated and presented without specific references. In cases where the material requires documentation, of course, specific references are cited and listed at the end of this paper. Fishery study field data and analysis is the product of work performed by the authors pursuant to Interagency Agreement UT-910-IA9-0675. Additional appreciation is extended to the Utah Division of Wildlife Resources (DWR) personnel for their cooperation and assistance in fish population sampling, and to Mr. Don Duff, Fishery Biologist, USDI, Bureau of Land Management, Utah State Office, Salt Lake City, Utah, for his efforts in coordinating this study.

CONTENTS

INTRODUCTION

There are 1.9 billion acres of land in the 48 conterminous United States, of which some 1.2 billion (63 percent) are rangelands; as of 1970, 69 percent of this range was grazed by domestic livestock. In the western United States, most of these rangelands are public lands administered by federal agencies. In Utah, for example, 66 percent of the state is federally owned and of this, some 24 million acres (43 percent) is administered by the USDI Bureau of Land Management (BLM)[1/].

Many streams of various sizes traverse this vast area, but despite their prevalence (Utah, for example, has some 2500 miles of streams on BLM land) they represent relatively little acreage. These streams, together with their adjacent riparian zones, contribute significantly to the productivity of the range, especially in arid and semi-arid regions, and present unique problems in multiple-use management. Unfortunately, this fact has only recently become widely appreciated and streams and riparian zones have frequently been ignored in rangeland planning and management in the past, largely due to their small relative size.

The various classes of livestock utilize the range in different ways, necessitating different management practices to increase the compatibility of grazing with riparian and aquatic habitat. Cattle, for example, usually congregate on lesser slopes and bottomlands, while sheep, which are less dependent on water (Stoddert and Smith 1955), usually favor steeper slopes and upland areas. Since sheep are also usually herded and cattle generally are not, management techniques to keep watersheds from being seriously altered differ between these two classes of livestock. The more commonly used cattle management techniques are suspected to be less congenial than those used with sheep and are therefore the focus of this study.

Since the riparian zone, which forms the interface between the aquatic and the dryer terrestrial range ecosystems, is disproportionately important to both regions, application of effective management techniques is critical. Because of soil moisture, soil fertility, and related factors, the riparian ecosystem is more productive than the drier upland range, and its vegetation is generally more palatable. Coupled with this are other riparian features, such as gentler terrain, shade, and drinking water, which add to the attractiveness of this habitat to cattle and lead to preferential use.

The riparian zone also provides crucial fishery habitat components which are largely determined by streamside vegetation. Overhanging vegetation and undercut streambanks are an important source of protective cover, food, and shade. Shading prevents water temperatures from rising or fluctuating drastically, which can lead to shifts in species composition from salmonids to more tolerant species of non-game fish (Platts 1980). In addition, detritus formed from terrestrial plants is a principal source of food for aquatic invertebrates and ultimately fish (Minshall 1967). Streamside vegetation also serves as a barrier to terrestrial pollutants and controls water velocity and streambank erosion. Since these features are all susceptible to alteration by grazing animals the needs of the resident fishery and the stockman can conflict.

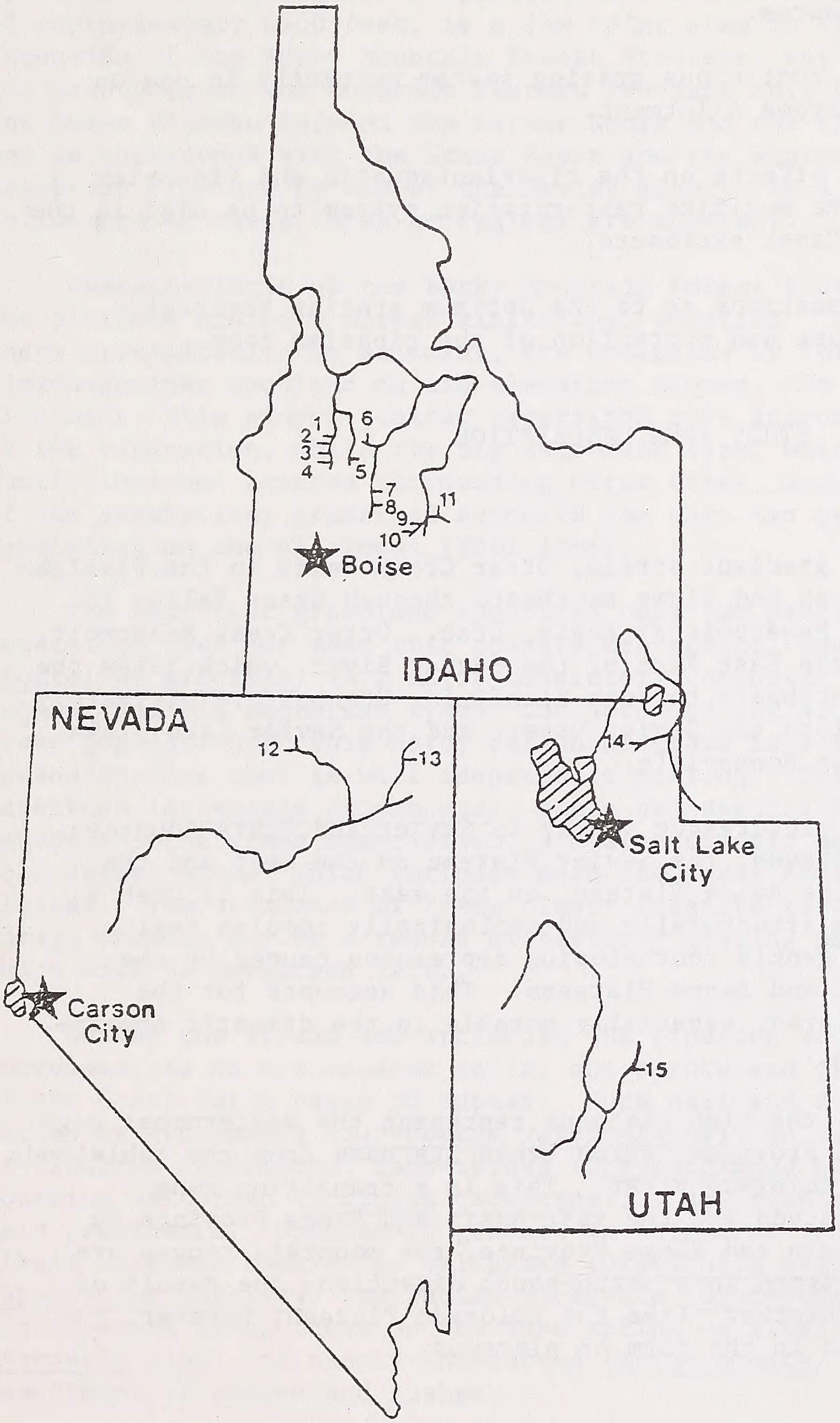
[1/] Duff, D. 1980. Personal correspondence. USDI, Bureau of Land Management, Utah State Office, Salt Lake City, Utah.

Presently, there is an unfortunate dearth of factual information regarding the impacts of livestock grazing on riparian and aquatic ecosystems. As yet, only limited research has been directed toward lessening these impacts, though the constant increase in range use by cattle since the late 1800's has generally degraded rangelands and led to altered riparian habitats (Platts 1978). The resulting controversy surrounding the use of public rangelands by livestock and potential conflicts with fishery needs has led to the emergence of livestock management as a national environmental issue (Leopold 1975, Platts 1978).

Working in this information vacuum, fisheries biologists have intuitively hypothesized that grazing of the riparian zone can significantly alter a fishery. Such alteration is believed to occur through physical modification of key stream features. Such changes as increased channel breadth, decreased depth and pool-riffle ratio, loss of vegetative and structural cover, accelerated bank erosion, channel sedimentation, and increased water temperature, are expected to alter the character of the fishery. These changes however, have yet to be sufficiently evaluated and identified for routine inclusion in management strategies. Additional studies that will provide solutions to these potential problems need to be conducted (Meehan and Platts 1978, Platts 1978).

Against this background of limited information, it should come as no surprise that little help can be given the land manager in determining alternate strategies in situations where livestock are known to be exerting undue stress on the fishery. Valid analytical techniques for assessing the magnitude of livestock impacts have yet to be fully developed. Without these tools, it is difficult to determine whether changes in grazing patterns are indicated and, if so, what strategies should be implemented.

The Otter Creek study is part of a comprehensive program to develop and test an array of field techniques which, when coupled with computerized analysis, will accurately identify the complex interactions that occur between different grazing intensities, management strategies, classes of livestock, and the fishery. Studies are currently being conducted on eleven sites in Idaho, two sites in Nevada, and two sites in Utah (Figure 1). The Idaho studies monitor impacts to streams in moist, forested, high mountain meadows, while the Utah and Nevada studies monitor impacts to streams in the more arid sagebrush type meadows. These studies are structured to allow time-trend analysis of livestock impacts on streams on public multiple-use lands in order to help the land manager select grazing systems that are as compatible as possible with fishery needs.



SALMON RIVER DRAINAGE

1 Stolle-Lower
2 Stolle-Cougar
3 Stolle-Guard
4 Stolle-Upper
5 Johnson Creek
6 Elk Creek
7 Bear Valley-Mace
8 Bear Valley-Upper
9 Frenchman-Lower
10 Frenchman-Upper
11 Pole Creek-Tributary

HUMBOLDT RIVER DRAINAGE

12 Gance Creek
13 Tabor Creek

BEAR RIVER DRAINAGE

14 Big Creek

SEVIER RIVER DRAINAGE

15 Otter Creek

Figure 1. Distribution of livestock-fishery study sites

This progress report deals exclusively with the Otter Creek, Utah, study which has the following objectives:

1. Determine the rehabilitation potential of Otter Creek based on past, present, and future use strategies.

2. Evaluate the efficacy of excluding livestock from the Otter Creek riparian zone by studying protected habitat within fenced exclosures.

3. Evaluate the continuous grazing system currently in use on the South Narrows Allotment.

4. Evaluate the effects on the riparian/aquatic and fisheries habitat of the modified rest-rotation system to be used in the upper Otter Creek exclosure.

5. Make recommendations as to the optimum grazing strategies relative to use and protection of the riparian zone.

STUDY AREA DESCRIPTION

Physiography

A meandering, low gradient stream, Otter Creek heads in the Fishlake Mountains of central Utah and flows southward through Grass Valley to empty into Otter Creek Reservoir at Angle, Utah. Otter Creek Reservoir, in turn, empties into the East Fork of the Sevier River, which joins the Sevier River flowing northward through Richfield, Utah before ultimately turning southwestward into the Sevier Desert and the Sevier Lake playa, remnants of ancient Lake Bonneville.

Grass Valley is a picturesque valley in Sevier and Piute Counties, flanked by two high plateaus; the Sevier Plateau on the west and the Parker Range, part of the Awapa Plateau, on the east. This is Utah's high plateau country, a structurally and ecologically complex region. The valley itself is a gentle southsloping depression caused by the uplifting of the Sevier and Awapa Plateaus. This accounts for the variable relief of the area, especially notable in the dramatic escarpment of the Parker Front.

Physiographically, the high plateaus represent the westernmost edge of the Colorado Plateau Province, which takes its name from the tablelands surrounding the middle Colorado River. This is a transition zone between the Colorado Plateau and the vast Basin and Range Province to the west. As in the Basin and Range Province, the mountain ranges are generally linear and aligned in a north-south direction; the result of the uplifting of fault-blocks. Like the Colorado Plateau, however, the mountains are folded and in the form of plateaus.

Vegetation

Ecologically, the high plateaus also show this integradation. This is particularly evident in Grass Valley, which, employing the classification system of Bailey (1978), represents a transitional area between three separate ecoregions. Specifically, Grass Valley, at an elevation of approximately 6500 feet, is a low lying area in the southwesternmost extension of the Rocky Mountain Forest Province, but is separated from the main body of the Colorado Plateau Province only by a depression in the Awapa Plateau between the Parker Range and the Fishlake Mountains, and is continuous with the Great Basin and the expansive Intermountain Sagebrush Province by way of the Sevier River. As a result, ecological influences of these three ecoregions are apparent.

Characteristic of the Rocky Mountain Forest Province, vegetation on the plateaus exhibits marked altitudinal zonation. Highland areas, where precipitation is abundant, are dominated by forest, grading into pinyon-juniper woodland on mid-elevation slopes. On the South Narrows Allotment, this pinyon-juniper vegetation type accounts for 46 percent of the vegetation, while the big sagebrush type, which dominates the gently inclined benches surrounding Otter Creek, accounts for 45 percent of the vegetation; grassland accounts for only two percent of the vegetation on the allotment (USDI 1968).

The fact that grassland comprises only two percent of the total vegetation does not mean that grasses are scarce, however, as blue-grama (Bouteloua gracilis) is a major understory component in both the pinyon-juniper and big sagebrush types, and accounts for 43 percent of the grass population;[2/] this hardy perennial grass is a sod-forming, warm-season species that is well adapated to grazing. Together with big sagebrush (Artemesia tridentata), these two species are known as the sagebrush-blue grama association, a characteristic association of the cold desert biome, which includes both the Great Basin and the Colorado Plateau. The abundance of these plants relative to more desireable forage species may be a result of historic grazing patterns, a point which will be developed later.

Nearer the stream and including the riparian zone, soil moisture increases, as do accumulated salts, and shrubs and grasses representative of the Great Basin begin to appear. Such salt and alkali tolerant shrubs as greasewood (Sarcobatus vermiculatus), an indicator of saline or alkaline conditions, rabbitbrush (Chrysothamnus nauseosus), and fourwing saltbrush (Atriplex canescens), a desireable browse species, gain prominence. Understory grasses in this area include salt and alkali tolerant species as saltgrass (Distichlis stricta), alkali sacaton (Sporobolus auroides) and Indian ricegrass (Oryzopsis hymenoides). Interspersed among these on the less saline or alkaline sites are redtop (Agrostis alba) and needle-and-thread (Stipa comata); accompanied by an assortment of sedges and rushes.

2/ Young, D. 1980. Personal correspondence. USDI, Bureau of Land Management. (1977 range survey data on file at Sevier River Resource Area Office, Richfield, Utah.)

Climate

Climatic conditions along Otter Creek are highly variable. Maximum summer temperatures can be as high as 105°F (41°C) with winter minimum temperatures sometimes reaching -20°F (-30°C). Annual precipitation averages about 9 inches, and ranges from a high of nearly twelve inches to a low of less than five inches.

Fisheries

Otter Creek experiences considerable recreational fishing pressure. In 1969 the Utah Division of Wildlife Resources treated the stream to eliminate non-game fish so that salmonids subsequently stocked would experience reduced competition. The stream was then stocked with brown trout (Salmo trutta), rainbow trout (Salmo gairdneri), and eastern brook char (Salvalinus fontinalis). In addition, in 1976 the USDI, Bureau of Land Management (BLM) constructed four subsurface gabions to improve the fishery by creating pools. Otter Creek supports only limited natural reproduction, however, so the stream is managed as a put-and-take fishery to provide recreation above what the stream is capable of producing naturally.

Otter Creek Aquatic Habitat Management Area

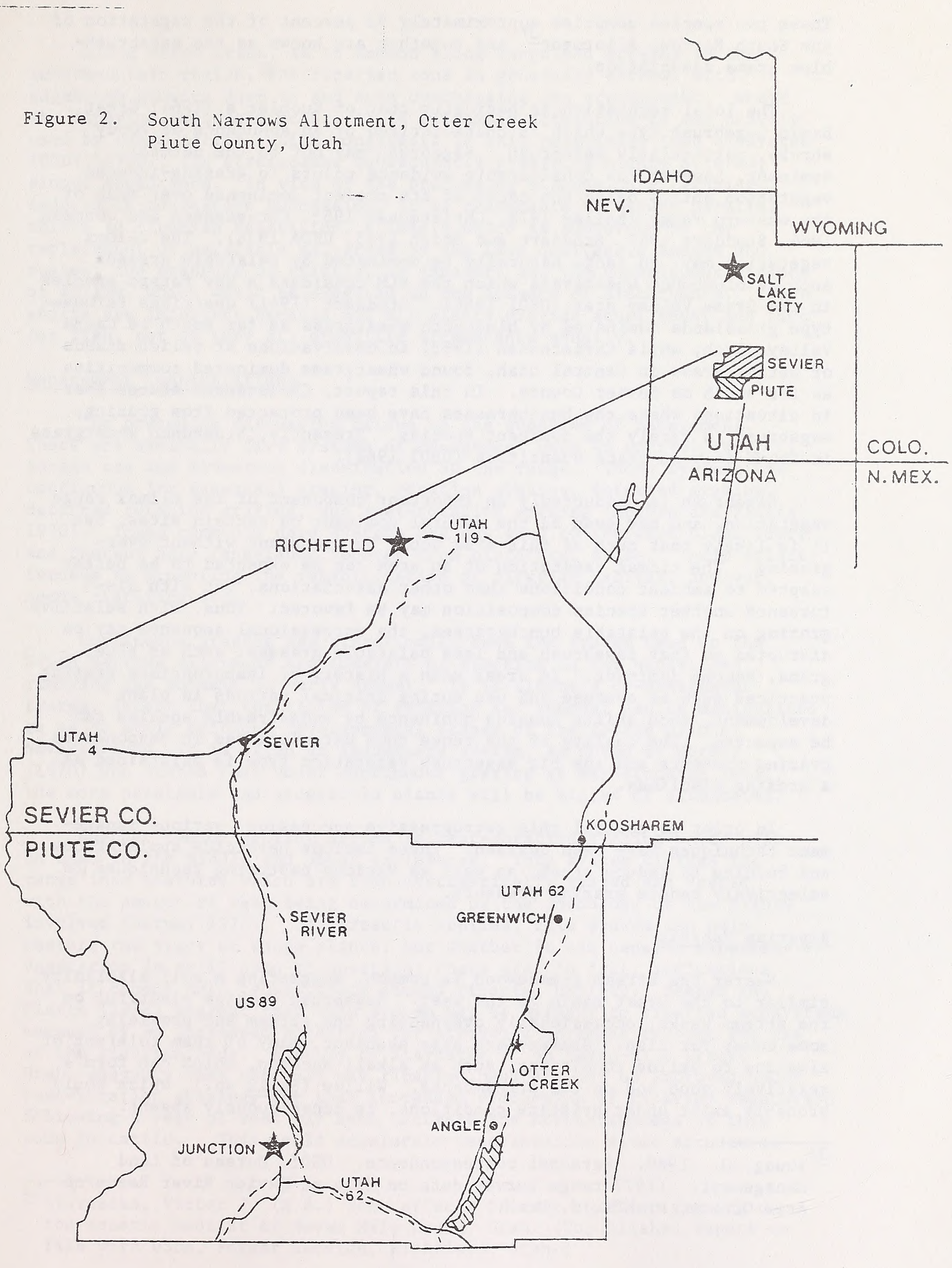
The Otter Creek Aquatic Habitat Management Area (AHMA) is a small section of Otter Creek below Grass Valley, approximately midway between the towns of Greenwich and Angle on Utah Highway 62 in Piute County. The AHMA lies wholly within the South Narrows Allotment (Figure 2), 12,588 acres of public land and 2,000 acres of state and private in-holdings administered by the BLM as part of the Piute Planning Unit. Four permittees presently use the allotment as winter and spring range for cattle and sheep. The sheep chiefly graze the higher ground below the Parker Mountains, whereas cattle are largely restricted to the stream bottomlands (USDI 1979). Three fenced exclosures have been constructed by the BLM along selected reaches of Otter Creek to allow manipulation of grazing pressure on the riparian zone.

THE SITUATION

Range Habitat

The land surrounding Otter Creek is semi-arid shrubsteppe typical of the cold desert biome. The terrain ranges from high mountains and plateaus through sloping benchlands to stream bottomlands. As is generally the case in ecosystems controlled by abiotic conditions, the plant and animal communities of the region are relatively simple and dominated by a few abundant and well-adapted species. In this case, the moderately sloping uplands support an almost uniform stand of big sagebrush, a woody shrub of relatively little value to livestock. Among these densely packed shrubs is an understory of grasses, particularly blue grama which bespeaks influence of the short grass prairies to the east.

Figure 2. South Narrows Allotment, Otter Creek
Piute County, Utah



These two species comprise approximately 93 percent of the vegetation of the South Narrows Allotment[3/] and together are known as the sagebrush-blue grama association.

The local vegetation is basically that of Kuchler's (1964) Great Basin Sagebrush type which is characterized by an abundance of woody shrubs, particularly sagebrush. Sagebrush may not be the natural dominant, however, as considerable evidence points to grazing-induced vegetation shifts being the cause of its present dominance over much of the western range (Bailey 1978, Christensen 1963, Christensen and Johnson 1964, Stoddart 1941, Stoddart and Smith 1955, USDA 1936). The climax vegetation may, in fact, naturally be dominated by palatable grasses such as bluebunch wheatgrass which the BLM considers a key forage species in the Grass Valley area (USDI 1968). Stoddart (1941) describes Palouse-type grasslands dominated by bluebunch wheatgrass as far south as Cache Valley, Utah, while Christensen (1963) in observations of relict stands of native grass in Central Utah, found wheatgrass dominated communities as far south as Sevier County. In this report, Christensen states that in situations where the bunchgrasses have been protected from grazing, sagebrush is rarely the dominant species. Presently, bluebunch wheatgrass is found only in trace quantities (USDI 1968).

Sagebrush is undoubtedly an important component of the climax range vegetation, and may even be the natural dominant on certain sites, but it is likely that much of this area would be grassland without over-grazing. The climax vegetation of an area can be expected to be better adapted to ambient conditions than other associations, but with disturbance another species composition may be favored. Thus, with selective grazing on the palatable bunchgrasses, the successional sequence may be disrupted so that sagebrush and less palatable grasses, such as blue grama, become dominant. In areas with a history of inappropriate grazing practices such as overuse and use during critical periods in plant development, such shifts towards dominance by undesireable species can be expected. The quality of the range thus deterioriates in response to grazing pressure and the big sagebrush vegetation type is maintained as a grazing disclimax.

In order to control this retrogressive succession, various management techniques have been devised. These include herbicide applications and burning to reduce brush, as well as various pasturing techniques to selectively reduce grazing pressure.

Riparian Habitat

Nearer the stream greasewood is common, suggesting a soil alkalinity similar to the Great Basin to the west. Sagebrush remains plentiful on the stream banks, occassionally overhanging the stream and providing some cover for fish. Grasses are also abundant, many of them tolerant of alkaline to saline conditions, such as alkali sacaton, which can form a relatively good sod on the streambanks. Willow (*Salix* sp.), which would probably exist under pristine conditions, is conspicuously absent.

[3/] Young, D. 1980. Personal correspondence. USDI, Bureau of Land Management. (1977 range survey data on file at Sevier River Resource Area Office, Richfield, Utah.)

Along Otter Creek, as is common along rangeland streams in the intermountain region, the riparian zone is generally narrow, with sagebrush growing down to and even overhanging the streambanks. Where the riparian zone does occur, it is extremely attractive to and heavily used by range cattle, which congregate in this relatively lush ecosystem (USDI 1979b); the streambanks consequently present a highly altered, sloped appearance. In view of the preceeding discussion of grazing-induced retrogressive succession, it is reasonable to expect parallel shifts in riparian vegetation, a thesis which is supported by the replacement of palatable saltgrass by the less desireable sedges and rushes; the pressure of thistle, an invader; and the conspicuous absence of willow, which would be expected in the absence of disturbance. These shifts are important because not all plants provide equal cover and food for fish, nor do they all stabilize streambanks equally.

Management Considerations

The preceding discussion brings up the question of management. There are basically five systems of management used to control the forage use and livestock distribution on the range. These systems are continuous (or seasonal) grazing, rotation grazing, deferred grazing, deferred rotation grazing, and rest-rotation grazing (Meehan and Platts 1978). These commonly used systems are designed to increase plant vigor and thereby help rangelands recover from historical abuse. Their effectiveness in promoting the rehabilitation of riparian habitat, however, needs clarification.

Continuous grazing has historically been the system used on the South Narrows Allotment and consists of stocking in the winter and removing the animals in early summer. It is almost a no-management system, except that the timing of stocking and removal can be manipulated so as to avoid critical developmental stages of the forage plants. Nevertheless, it is often an inadequate system, as noted by Hormay (1970) who states that under continuous grazing at any stocking level, the more palatable and accessible plants will be killed or eliminated.

Another common grazing system is rest-rotation grazing which will be used in the middle and upper exclosures. This system divides the range into pastures which are then systematically grazed and rested with the amount of rest being determined by the phenology of the plants involved (Hormay 1970). If correctly applied, this system can help restore the vigor of range plants, but whether it can benefit riparian vegetation is still open to question; there are, in fact, indications that it cannot help rehabilitate abused riparian habitat. Meehan and Platts (1978) suggest that this system may be harmful to riparian ecosystems because of an increased potential for livestock movement through and use of the riparian zone. A study by Starostka [4/] on Seven-Mile Creek, Utah, suggests that not only may riparian habitats not be improved under rest-rotation grazing, but that increased production of riparian vegetation following a year of rest may even increase the attractiveness of this zone to cattle. This could accelerate deterioration since structural

[4/] Starostka, Victor J. (n.d.) Some effects of rest rotation grazing on the aquatic habitat of Seven Mile Creek, Utah. (Unpublished report on file with USDA, Forest Service, Richfield, Utah.)

damage does not recover as rapidly as vegetation, nor do all plant species recover at the same rate. Duff (1978) found that woody vegetation along Big Creek in northeastern Utah recovered more slowly than grasses, and that only six weeks of grazing were required to return riparian habitat which had been rested for four years within a grazing-protected area to pre-rest conditions. Thus, it would appear that rest-rotation grazing may be beneficial to range forage but not for riparian vegetation, and if rehabilitation of the riparian zone is the desired object of management, systems involving long periods of rest may be required; these questions can only be answered with research.

The three other systems either defer grazing for parts of the season or are combinations of seasonal deferment and rest. To date, none have clearly been shown to be effective in helping riparian vegetation recover, though some may be more helpful than others. Only one system clearly stands out as being useful in riparian recovery: complete rest. This can be accomplished by fencing and is being used by the BLM on some stream reaches of the South Narrows Allotment. This cannot be the final solution, but must be a consideration if high quality riparian habitat is to be conserved. The answer to this vexing problem should become clearer as this study progresses, as it will monitor three different grazing systems: fenced non-grazed as in the lower exclosure, rest-rotation grazing on the middle site, and continous grazing on the upstream control site.

GRAZING PATTERNS

History

Utah, along with Nevada, became part of the United States in 1848, acquired from Mexico by way of the peace treaty that ended the Mexican-American War. It was not until 1873, however, that settlers began to arrive in the Grass Valley area, and by 1911, when the town of Koosharem was incorporated, the pioneer population of the valley had grown to only 550 persons.

The very name "Grass Valley" suggests that an abundance of grass greeted the first settlers, but the type of grass in question is uncertain. Possibly, Great Basin wildrye (Elymus cinereus) was common here as it was on many dry bottomlands of the Intermountain west (Cronquist and others 1977), or perhaps it was bluebunch wheatgrass (Agropyron spicatum). The work of Christensen (1963) documents wheatgrass dominated grassland associations as far south as Sevier County. Neither of these grasses is common any longer, though trace amounts of wildrye have been reported along Otter Creek[5/] and the Otter Creek AHMP indicates that wheatgrass is still a component of the range vegetation, though present in only trace quantities. Whatever the grass that inspired the naming of Grass Valley, its abundance undoubtedly provided good forage for livestock moving in with the early settlers.

[5/] Young, D. 1980. Personal communication. USDI, Bureau of Land Management, Sevier River Research Area, Richfield, Utah.

During this early period of expansion into and settlement of the West, grazing was not officially regulated and use levels were left to the stockman's discretion. As a result, overgrazing of western rangelands became a serious problem. In order to ameliorate the problem of deteriorating range conditions, Congress, in 1934, passed the Taylor Grazing Act which created the Grazing Service of the Department of the Interior to regulate grazing on public lands; in 1946 the Grazing Service was combined with the General Land Office, and the BLM was born.

The South Narrows Allotment, with which this report is chiefly concerned, was originally part of one of two divisions of the Parker Mountain Unit as established by the Grazing Service. E. Merril Bagley became a livestock operator in Grass Valley at this time, and remains a principal operator on the South Narrows Allotment to this day. The original division boundaries were readjudicated in 1958, and established a new division called the Koosharem Division, which comprised eight grazing allotments; one of which was the South Narrows Allotment.

Initially, grazing use in the Parker Mountain unit was set at 5832 animal unit months (AUM's). On the basis of a 1956 range survey, use for this area was reduced by 33 percent in 1960 to 3840 AUM's; the South Narrows Allotment was allocated 805 of these, for use either by cattle or sheep. Adjudicated use was further reduced in 1968 to 706 AUM's when one of the permittees converted some sheep AUM's to cattle[6/].

Historically, the South Narrows Allotment has been managed under a continuous grazing system, which allows for season-long use of preferred areas and preferred vegetation. As a result, range conditions declined to the point where, in 1968, the BLM considered initiating a two-pasture deferred system to alternately rest each pasture early in the season, and to limit utilization to 35 percent on spring range and 75 percent on winter range (USDI 1968). This system was not implemented, but, as of 1977, the overall range trend has apparently remained stable.[7/] The vegetation trend in the riparian zone is less clear, but concern over this area and a desire to improve fish and wildlife habitat have led the BLM to propose the strategies contained in the Otter Creek AHMP.

Present and Future Trends

In order to improve conditions for wildlife and fish, experimental manipulation of grazing in the riparian zone has been proposed for the Otter Creek AHMA. Three fenced livestock exclosures have been constructed along selected reaches of Otter Creek, which have been designated as the lower, middle, and upper exclosures (Figure 3). The lower exclosure will receive complete rest, allowing study of riparian rehabilitation

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6/ Because the allotment is more suitable for sheep than cattle, conversion is done on the basis of 8.75 to one in the case of conversion to cattle, and one to 5 in the case of conversion to sheep (USDI 1968).

7/ Likens, John. 1978. 1977 range trend evaluation. (Unpublished, USDI, BLM Memo 4115, U-503, Richfield, Utah.)

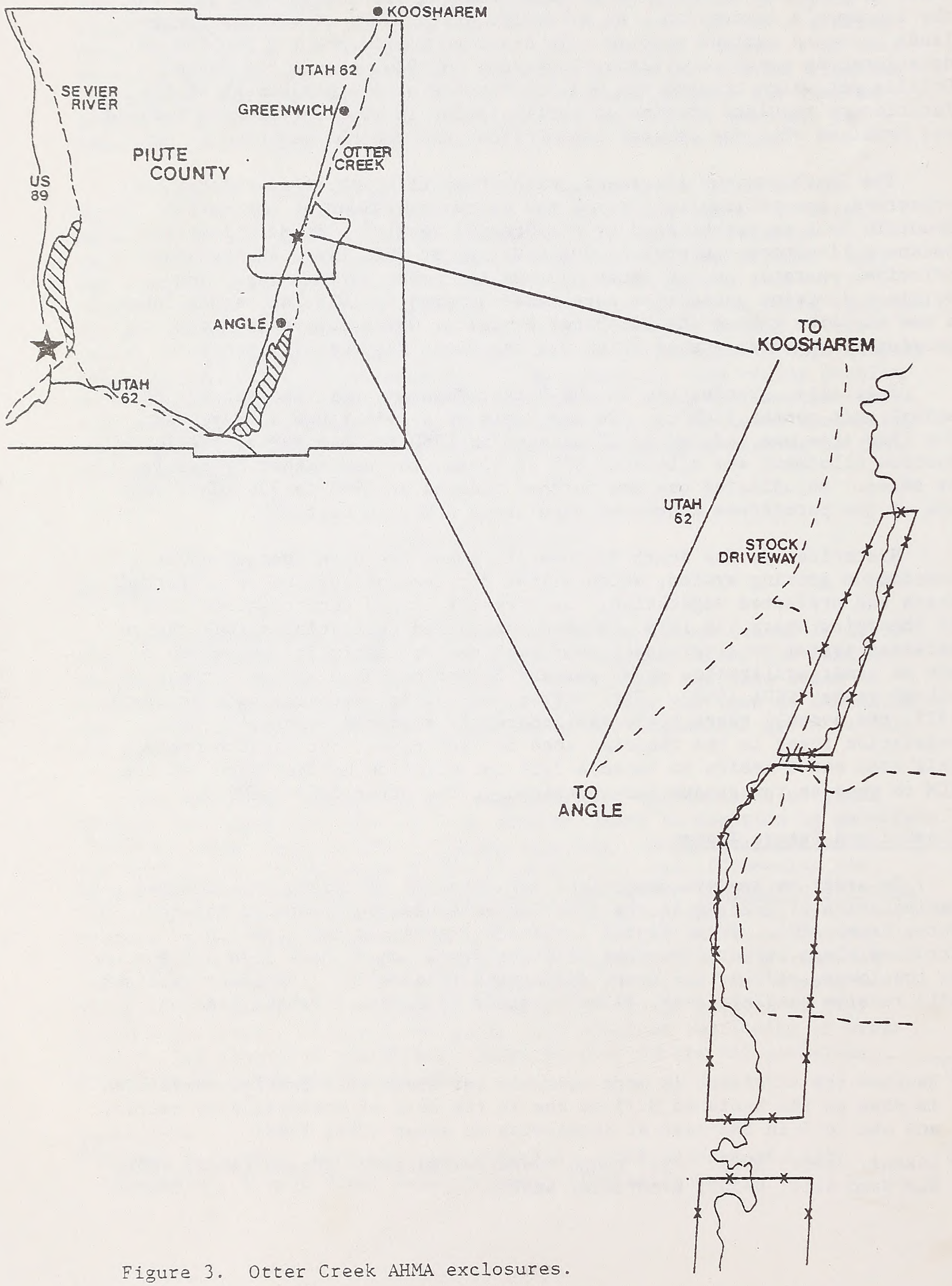


Figure 3. Otter Creek AHMA exclosures.

under this system, and the two upstream pastures (the middle and upper exclosures) will be grazed during alternate years under a modified rest-rotation system. The remainder of the South Narrows Allotment will continue under the current management system at 706 dual AUM's, which is well below the estimated (USDI 1968) 847 AUM's of available forage.

Table 1 summarizes management from 1975 on the South Narrows Allotment and the AHMA and predicts some parameters for 1980 based on the Otter Creek Habitat Management Proposal.

METHODS

General

Ongoing studies are presently being conducted on a total of 15 study sites, 11 in Idaho and two each in Nevada and Utah. These sites are generally in meadow environments on National Forest lands or lower elevation sagebrush type meadows on Bureau of Land Management lands. The purpose of these studies is to refine techniques for monitoring and assessing the impacts of domestic livestock grazing on riparian and aquatic ecosystems and to allow recommendations for improved management.

The basic design of each study area is to stratify 1810 feet of stream by dividing it into 181 transects placed at 10-foot intervals along the stream. The study area is then subdivided into three 600-foot sections, with the middle section fenced to provide an area for manipulation and the up- and downstream sections serving as controls. Livestock are then either introduced to or excluded from the treatment area depending on the study site. Annual monitoring of each section then provides information on each relative to the others over the course of several seasons of use.

On Otter Creek this design has been modified for consistency with the Otter Creek AHMP. The BLM has constructed three livestock exclosures along Otter Creek to allow for manipulation of grazing in the riparian zone. The exclosure farthest downstream (the lower exclosure) has been designated as the non-grazed or treatment area and includes transects 1 through 61 at its upper end. The middle exclosure, which is not part of this study, and the exclosure upstream, which is included, will be grazed during alternate years. Since continuous grazing is the current grazing system on the South Narrows Allotment and since this pasture will henceforth be rested every other year under a modified rest-rotation system, it is not a completely unmanipulated section; it will, however, serve as a control and contains transects 61 through 122 at its upstream end. Immediately above the upper exlcosure are transects 123 through 184 in the unfenced and unmanipulated section. Figure 3 shows the locations of the exclosures along Otter Creek and Figure 4 gives a schematic illustration of the locations of the transects.

Table 1. South Narrows Allotment and Otter Creek aquatic habitat management area grazing management: 1975-1985.

GRAZING PARAMETER		YEAR[1/]										
		1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Allotment Acreage		12,588	12,588	12,588	12,588	12,588	12,588	12,588	12,588	12,588	12,588	12,588
Overall Grazing Management System		AWC[2/]	AWC	AWC	AWC	AWC	AWC	AWC	AWC	AWC	AWC	AWC
Grazing Season	Cattle	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30	12/1-3/10 5/16-6/30
	Sheep	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31	1/16 - 3/31
Permitted Use Intensity (AUM's)	Cattle	281	281	281	281	281	281	281	281	281	281	281
	Sheep	425	425	425	425	425	425	425	425	425	425	425
Range[3/] Vegetation Use	Overall	ND	ND	ND	ND	ND						
	Upper Exclosure	N/A	N/A	N/A	N/A	52.5[4/]						
Riparian Vegetation Use	Lower Exclosure	N/A	N/A	N/A	N/A	0						
	Upper Exclosure	N/A	N/A	N/A	N/A	0						
	Outside Exclosure	N/A	N/A	N/A	N/A	0						

1/ 1980-1985 proposed

2/ Allotment-wide continuous

3/ No utilization data except 1979. 1968 Plan called for 75% on winter range

4/ Cattle removed 2/8/79. Davis, Vernon C. 1979. South Narrows Allotment, utilization north exclosure. (Unpublished, USDI BLM Memo. 4115, U-503, Richfield, Utah).

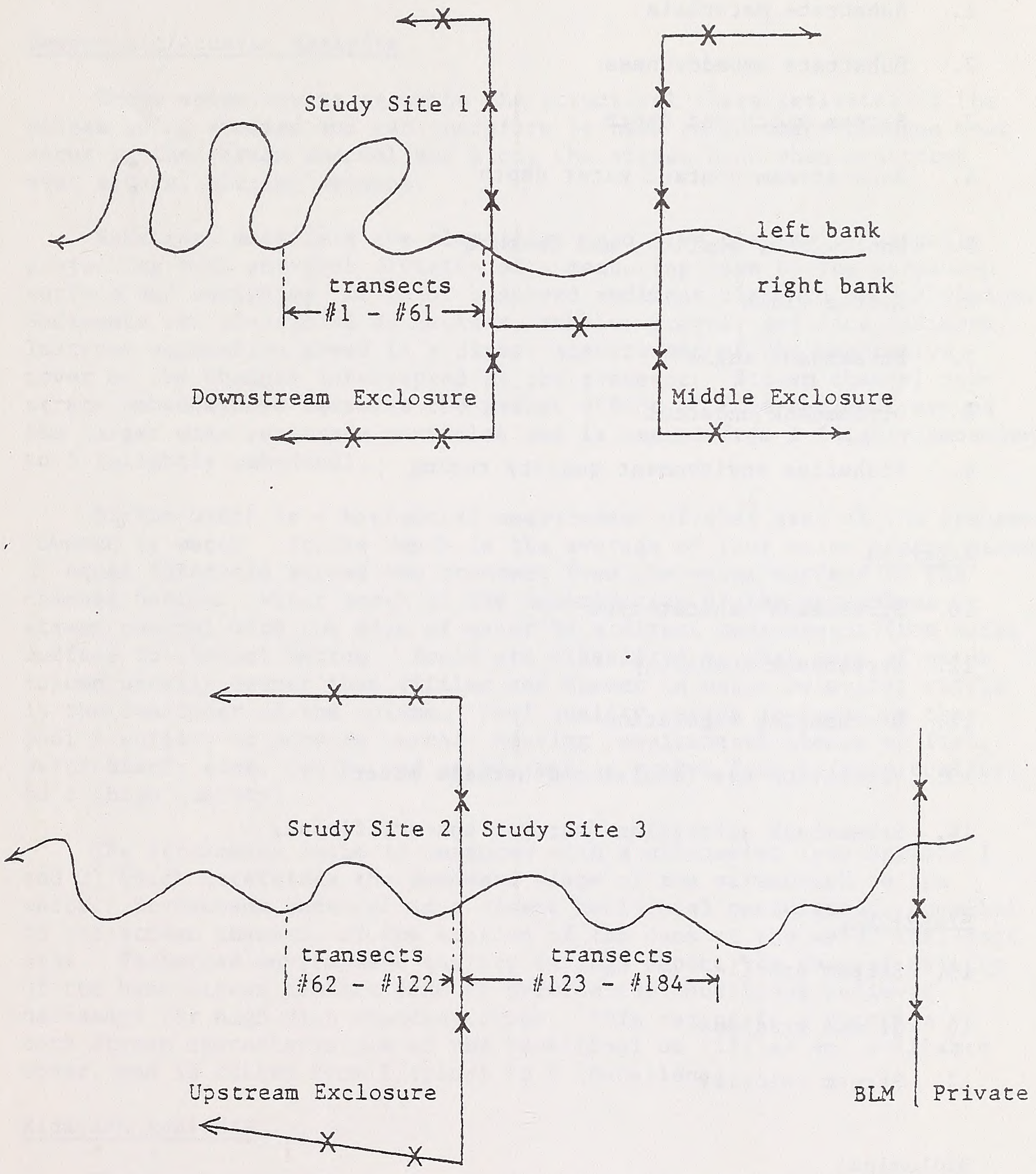


Figure 4. Schematic Representation of Otter Creek Exclosures (adapted from Otter Creek AHMP).

The data collected fall into four basic categories: 1) geomorphic/aquatic, 2) riparian or streamside, 3) hydrologic, and 4) biological, and include the following:

Geomorphic/Aquatic

1. Substrate materials
2. Substrate embeddedness
3. Stream width and depth
4. Bank-stream contact water depth
5. Pool width, quality, and feature
6. Riffle width
7. Streambank angle
8. Streambank undercut
9. Fisheries environment quality rating

Riparian

10. Streamside habitat type
11. Streambank stability
12. Overhanging vegetation
13. Vegetation use (ocular and herbage meter)
14. Streambank alteration (natural and artificial)

Hydrologic

15. Stream profile
16. Stream gradient
17. Stream velocity

Biological

18. Fish species composition, number, and biomass

A brief description of the procedures used in this study follows. More detailed descriptions can be found in Morris and others (1976), Neal and others (1976), Platts (1974), Platts (1976), and Ray and Megahan (1978).

Geomorphic/Aquatic Analysis

These measurements describe the structural characteristics of the stream being studied and can therefore be used to document changes that occur in the stream channel and along the stream bank when monitored over several grazing seasons.

Substrate materials are classified into five classes by visually projecting each one-foot division of a measuring tape to the streambed surface and assigning the major observed sediment class to each division. Sediments are classified as boulder, rubble, gravel, and fine sediment. Instream vegetative cover is a direct measurement of the vegetative cover on the channel intercepted by the transect. Stream channel substrate embeddedness measures the gasket effect of fine sediment around the larger size substrate particles and is ranked from 1 (highly embedded) to 5 (slightly embedded).

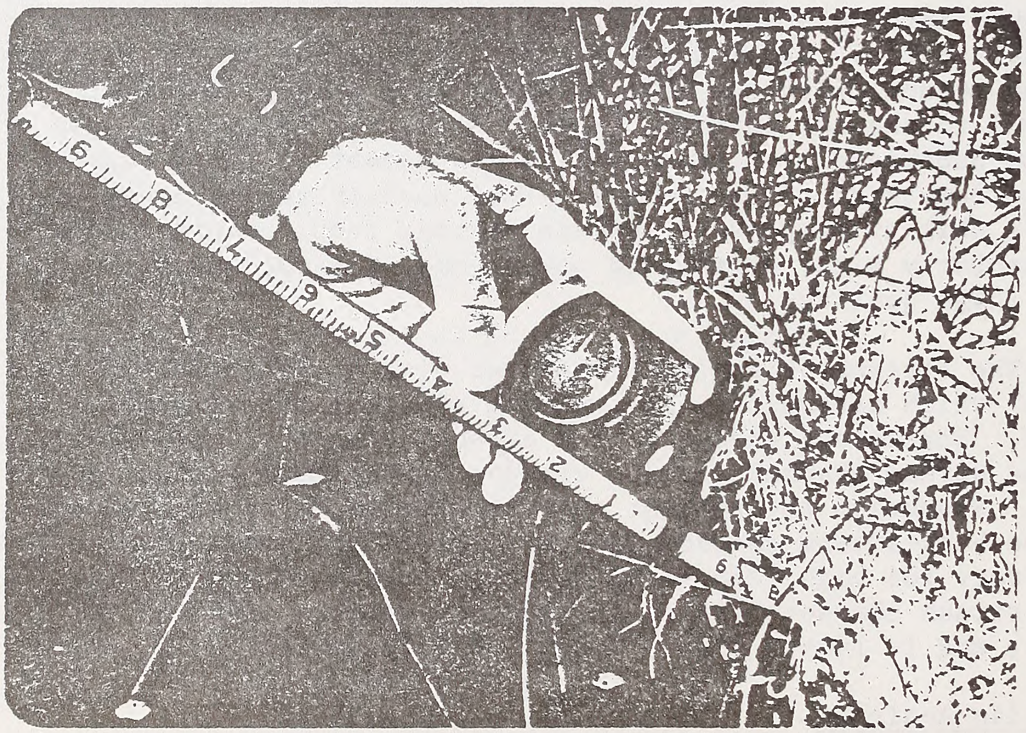
Stream width is a horizontal measurement of that area of the transect covered by water. Stream depth is the average of four water depths measured at equal intervals across the transect from the water surface to the channel bottom. Water depth at the intersection of the streambank or stream channel with the edge of water is a direct measurement from water surface to channel bottom. Pools are classified as that area of water column usually deeper than riffles and slower in water velocity; riffle is the remainder of the column. Pool quality rating is based on the pool's ability to provide certain rearing requirements needed by fish, particularly size, depth, and cover, and is ranked from 1 (poor quality) to 5 (high quality).

The streambank angle is measured with a clinometer (photographs 1 and 2) which determines the downward slope of the streambank to the water. Streambank undercut is a direct horizontal measurement, parallel to the stream channel, of the erosion of the bank at the water influence area. Fisheries environment quality ratings depict the general ability of the bank-stream contact zone to provide the conditions believed necessary for high fish standing crops. This rating is a function of both stream characteristics at the bank (pool or riffle) and available cover, and is ranked from 1 (poor) to 5 (excellent).

Riparian Analysis

These measurements attempt to describe the riparian interface between the aquatic and terrestrial ecosystems. Annual monitoring of these data after the grazing season illustrates changes in many critical fishery habitat parameters.

Photograph 1. Measurement of bank angle with an undercut bank. Angle is approximately 45°.



Photograph 2. Close up view of clinometer for measuring bank angle. Such banks with undercuts are an important source of cover.

Streambank alteration assessment quantifies the natural and artificial changes occurring to the streambank and is rated as percent alteration. Streamside cover categorizes the dominant vegetation as tree, brush, grass, or exposed (numerically ranked 1 to 4). Streamside cover stability rates the ability of the streambanks to resist erosion, with 1 being poor and 5 indicating high stability. Vegetative overhang (photographs 3 and 4) directly measures the length of the vegetation overhanging the water column within 12 inches of the water surface. Habitat rating is based on the belief that sand banks are of least importance to fish, while brush-sod banks are of the greatest value. Intermediate types are ranked accordingly by dominant and subdominant characters. Measurement of vegetation use is done both by ocular assessment and with a herbage meter.

Geomorphic/Aquatic measurements and the riparian measurements are analyzed statistically to determine means, variance, standard deviation, standard error, 95 percent confidence intervals, and F-values for each variable in each study site.

Herbage

In order to provide a quantitative complement to an ocular vegetation use assessment, a Neal Electronics Model 18-2000 herbage meter is used to measure standing vegetation. These readings are taken at approximately every fourth transect, and linear regression analysis against clipped plots provides a quantitative measure of forage biomass and use.

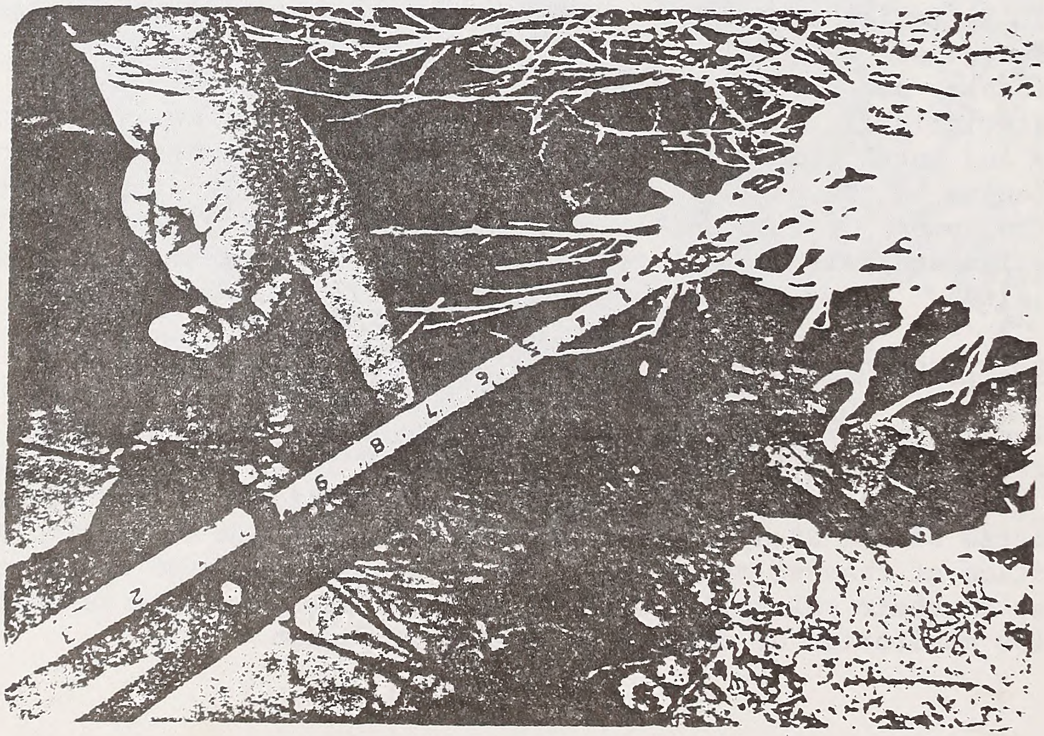
Electrofishing

Fish populations are sampled with battery powered, portable, backpack mounted electrofishers or with gasoline powered, motor energized units (photographs 5 and 6) and electrofishing is performed using a depletion model. Salmonids are counted, measured, and weighed, while non-salmonids are counted and weighed as a group. All are handled as carefully as practicable, and promptly returned to the stream alive. The data are then statistically analyzed to determine mean lengths, weights, standing crops, and total biomass for each fish species, with the exception of mean length in the case of non-salmonids. The biomass data, together with the number of fish obtained in the depletion model, is used in a regression analysis to estimate the resident fish populations of each study site.

Hydraulic Geometry

Ten transects in the central section of each 600-foot stream reach are used for hydraulic geometry measurement. The data obtained here allow us to generate a channel cross-section map. Periodic measurements over the course of the study show quantitative changes due to erosion and deposition of channel materials. The stakes are surveyed to detect changes in their relative positions, and the water surface is surveyed to allow monitoring of changes in channel gradient.

Photograph 3. Measurement of vegetative overhang, an important source of fish cover.



Photograph 4. Close-up of vegetative overhang measurement. This shrub overhangs the stream approximately 1.5 inches, providing good protective cover.

Photograph 5. Electrofishing Otter Creek with a motor-energized Coffelt electrofisher. Alternating current passes between the two electrodes, one of which is held by each member of the team.

Photograph 6. Collected fish are captured in the nets fixed to the ends of the electrodes.

RESULTS

Geomorphic/Aquatic and Riparian Analysis

Results of the first year analysis of stream geomorphology on Otter Creek are given in Table 2. Site 1 was ungrazed in 1979, while sites 2 and 3 were both grazed. Site 2 is grazed on a rest-rotation basis. Initial results of the analysis are highly variable, and show no consistent trends in sites or parameters for the study area. Statistical F-tests made on the data indicate that the sites are inherently different, so further changes in the study sites with time can be largely attributed to grazing or non-grazing.

Herbage Analysis

Application of electronic capacitance herbage meters to the livestock-fishery studies was first done in 1979. The regression analysis results for clipped plots on Otter Creek are presented in Figure 5, derived herbage statistics in Table 3, and site specific comparisons in Table 4.

The calibration curve clearly indicates that wet weights are highly correlated with herbage meter readings for the study area ($r^2 = 0.91$). Sites 2 and 3 have similar production levels (Table 4) since both were grazed in 1979. No herbage analysis was done on the ungrazed Site 1 in 1979, but it will be sampled in 1980 to allow a more complete description of the study site.

Electrofishing

Fish species collected in the Otter Creek study site are listed in Table 5 with their total and average length and weight. Figure 6 is a length frequency diagram for the rainbow and brown trout collected in the study area. Table 6 is a summary of standing crop-biomass data for the game fish collected, and Figure 7 is a graphic representation of that data.

The majority of the brown trout sampled were large fish, with an average length of 11.1 in. (283.2 mm) and an average weight of 9.7 oz. (276.4 gm). Brown trout dominated the fish population in Sites 2 and 3, with these fish averaging more numerous and larger than rainbow trout (Table 6 and Figure 7). In Site 1, however, several smaller rainbow trout (in the 2-3 inch range) were collected so this fish dominated the standing crop, but not the biomass in that site. One Utah chub was collected in Site 3; it was 1.4 in. (35 mm) long and weighed 0.02 oz. (0.5 gm).

Hydraulic Geometry

Stream channel cross section plots for selected transects on Otter Creek are shown in Figure 8 for Site 1, Figure 9 for Site 2 and Figure 10 for Site 3. Velocity readings taken from these same transects are listed in Table 7.

The cross section plots show sloping banks and some areas of exposed bottom in Sites 1 and 2, and a deeper, generally more defined stream channel in Site 3. The greater depth and higher percentage of pools in Site 3 is substantiated by the lower mean velocity for transects at that site.

Table 2. 1979 stream geomorphic/aquatic and riparian analysis means for Otter Creek with their 95% confidence intervals. Asterisk (*) denotes that there are significant differences between sites 1, 2 and 3.

Variable	Site 1 Mean	Site 1 Interval	Site 2 Mean	Site 2 Interval	Site 3 Mean	Site 3 Interval	Overall Mean	Overall Interval
Geomorphic/Aquatic								
Stream width (ft)*	11.9	11.1 - 12.7	14.0	13.2 - 14.8	14.5	13.7 - 15.3	13.5	13.0 - 13.9
Stream depth (ft)*	0.72	0.62- 0.81	0.78	0.68- 0.88	0.92	0.82- 1.0	0.80	0.75- 0.86
Riffle (percent)*	46.6	37.8 - 55.3	38.3	29.5 - 47.2	10.0	1.4 - 18.7	31.5	26.4 - 36.5
Pool (percent)*	53.4	44.7 - 62.2	61.7	52.8 - 70.5	89.9	81.3 - 98.6	68.5	63.5 - 73.6
Bank angle (deg.)*	117.9	110 -126	102.7	95 -110	90.0	82 - 98	103.5	99 -108
Bank undercut (ft)	0.20	0.14- 0.26	0.21	0.15- 0.27	0.24	0.17- 0.29	0.22	0.18- 0.25
Bank water depth (ft)*	0.19	0.07- 0.30	0.45	0.30- 0.60	0.96	0.80- 1.10	0.54	0.47- 0.61
Embeddedness*	2.9	2.6 - 3.1	2.9	2.6 - 3.2	1.8	1.5 - 2.0	2.5	2.3 - 2.7
Boulder (percent)*	0	0 - 0.20	0.6	0.40- 0.80	0	0 - 0.30	0.2	0.10- 0.40
Rubble (percent)*	1.8	0 - 6.6	23.7	18.9 - 28.6	9.6	4.9 - 14.4	11.7	8.9 - 14.4
Gravel (percent)*	79.4	72 - 86	39.1	32 - 46	22.3	15 - 29	46.8	43 - 51
Fines (percent)	18.8	N.A.[1/]	36.6	N.A.	68.1	N.A.	41.3	N.A.
Instream cover (ft)*	7.9	6.8 - 9.0	8.9	7.8 - 9.9	12.1	11.0 - 13.2	9.7	9.0 - 10.3
Fisheries rating	2.4	2.2 - 2.7	3.4	3.2 - 3.6	3.9	3.7 - 4.2	3.3	3.1 - 3.4
Riparian								
Bank cover stability*	2.9	2.7 - 3.1	3.4	3.2 - 3.5	3.3	3.1 - 3.5	3.2	3.1 - 3.3
Habitat type*	11.2	10 - 12	13.7	12 - 15	14.2	13 - 15	13.0	12 - 14
Vegetative use (%)*	0	-	0	-	0	-	0	-
Alteration-natural (%)*	43.1	39 - 46	23.0	19 - 26	24.3	21 - 28	30.1	28 - 32
Alteration-artificial (%)*	0	-	0	-	0	-	0	-
Vegetative overhang (ft)*	0.31	0.21- 0.41	0.57	0.47- 0.67	0.27	0.18- 0.37	0.38	0.32- 0.44

1/ N.A. - not available

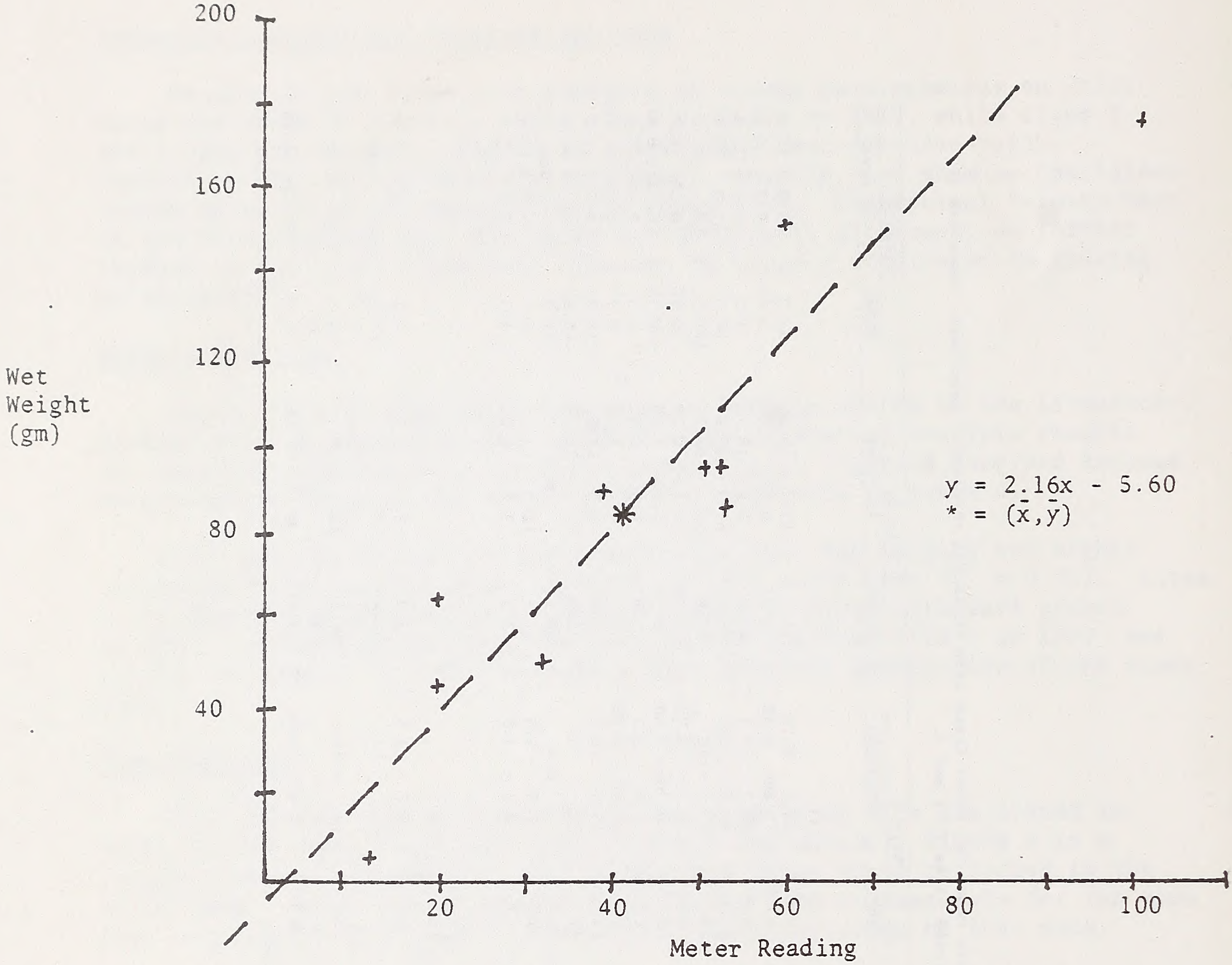


Figure 5. Regression curve of vegetation weight to meter readings for Otter Creek (sampled 10/10/79).

Table 3. Herbage analysis for calibration data. Variables fit the regression equation y = a + bx.

	Variable						
Year	$\bar{x}$	$\bar{y}$	a	b	Avg. Prod. (lb/acre)	r	r^2
1979	41.7	84.5	-5.60	2.16	4055	0.96	0.91

Table 4. 1979 herbage analysis results for grazed and ungrazed sites.

	Variable		
Study Site	Meter Reading	Weight (gm)	Production (lb/acre)
Site 2 (grazed alt. yrs)	39.0	85.1	4085
Site 3 (grazed)	44.9	83.7	4018

Table 5. Results of fish collection on Otter Creek (collected 8/14/79).

	Total No. Collected	Ave. Length (in)	Ave. Length (mm)	Ave. Weight (oz)	Ave. Weight (gm)	Total Length (in)	Total Length (mm)	Total Weight (oz)	Total Weight (gm)
Rainbow Trout (RT)									
Site 1	10	6.4	162.7	4.2	118.9	64.1	1627	41.6	1189
Site 2	6	7.8	199.0	4.3	122.4	47.0	1194	25.7	734
Site 3	5	9.4	237.8	6.8	195.1	46.9	1192	34.2	976
Overall	21	7.5	190.9	4.8	138.1	157.9	4013	101.5	2899
Brown Trout (BN)									
Site 1	6	10.2	260.3	7.4	210.9	61.5	1562	44.3	1266
Site 2	12	11.4	290.8	10.1	289.0	137.3	3487	121.6	3474
Site 3	8	11.4	289.4	10.7	306.6	91.1	2315	85.9	2453
Overall	26	11.1	283.2	9.7	276.4	351.4	8926	251.8	7193

NOTE: One Utah chub was collected in Site 3. It was 1.4 in. (35 mm) in length and weighed 0.02 oz (0.5 gm).

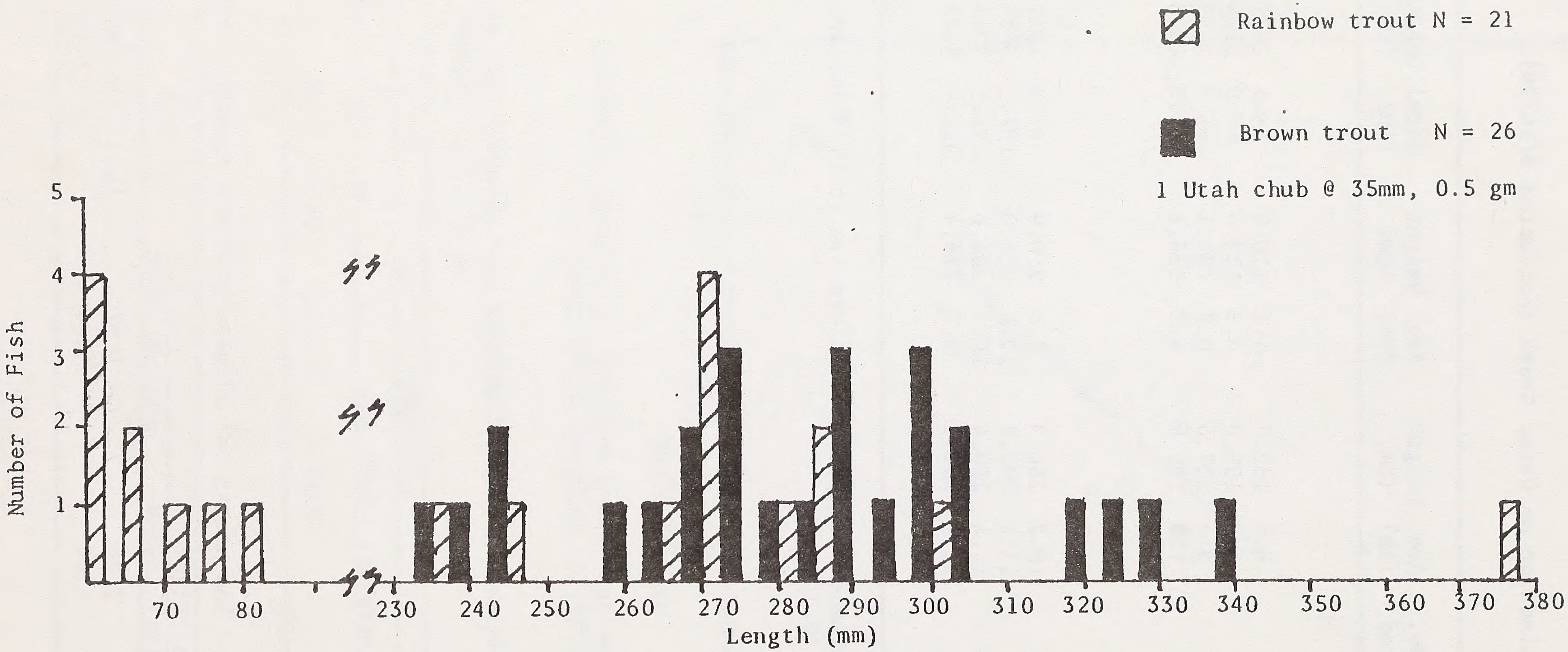


Figure 6. Length frequency diagram for fish collected in Otter Creek, 1979.

Table 6. Summary of standing crop/biomass data for Otter Creek game fish.

	Rainbow Trout (RT)	Brown Trout (BN)
<u>Site 1</u>		
No. Collected	10	6
Total Weight	41.6 oz (1189 gm)	44.3 oz (1266 gm)
Area	7140 ft^2 (664 m^2)	7140 ft^2 (664 m^2)
Standing crop [1/]	0.0014 (0.015)	0.0008 (0.009)
Biomass [2/]	0.006 (1.79)	0.006 (1.91)
<u>Site 2</u>		
No. Collected	6	12
Total Weight	25.7 oz (734 gm)	121.6 oz (3474 gm)
Area	8400 ft^2 (781 m^2)	8400 ft^2 (781 m^2)
Standing Crop	0.0007 (0.008)	0.0014 (0.015)
Biomass	0.003 (0.94)	0.014 (4.45)
<u>Site 3</u>		
No. Collected	5	8
Total Weight	34.2 oz (976 gm)	85.9 (2453 gm)
Area	8700 ft^2 (809 m^2)	8700 ft^2 (809 m^2)
Standing Crop	0.0006 (0.006)	0.0009 (0.010)
Biomass	0.004 (1.21)	0.009 (3.03)

[1/] Standing crop = $\frac{\text{Number}}{\text{Area}}$

[2/] Biomass = $\frac{\text{Weight}}{\text{Area}}$

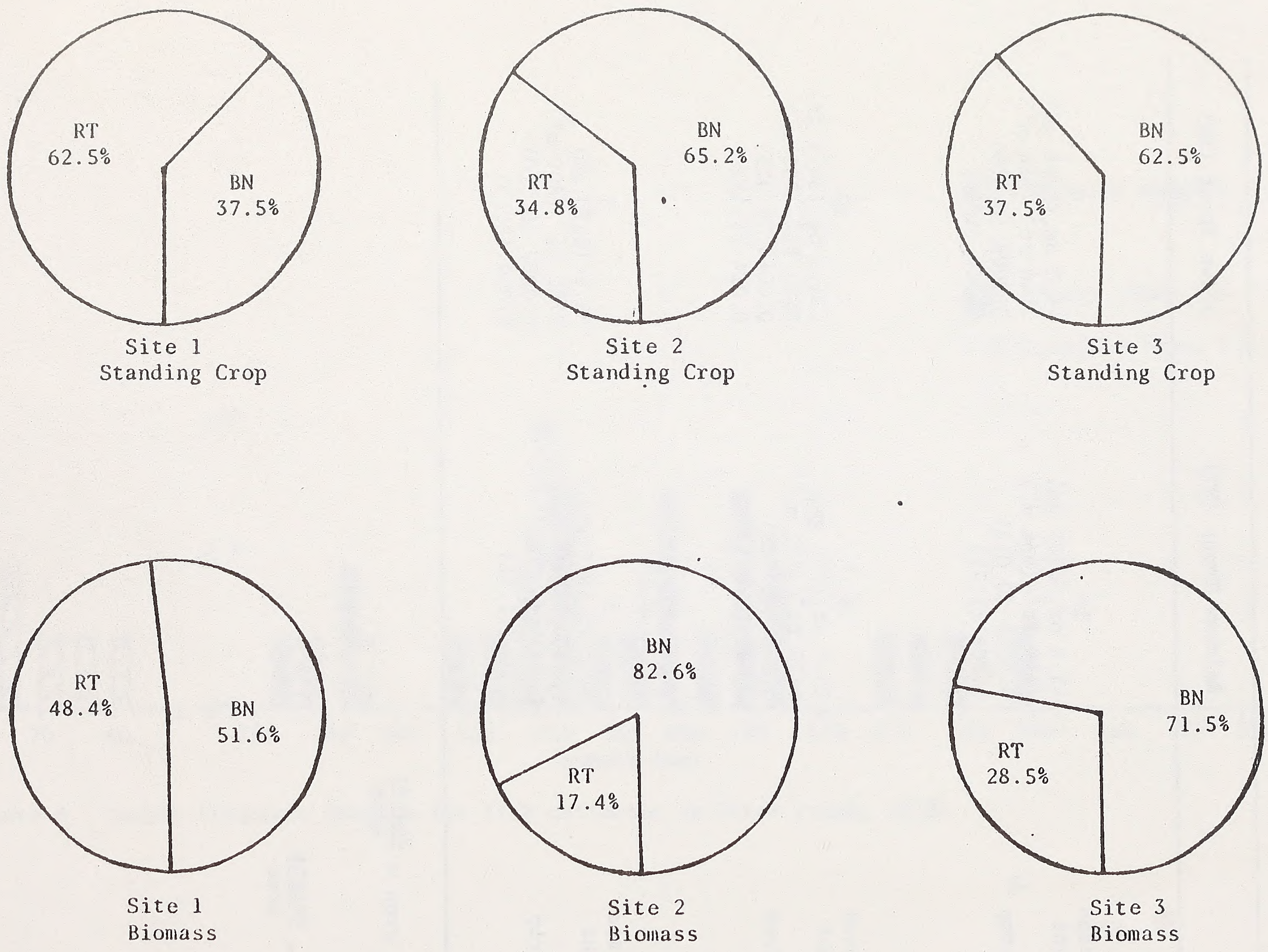


Figure 7. Percentage standing crop and biomass for game fish collected in Sites 1, 2 and 3 in Otter Creek, 1979.

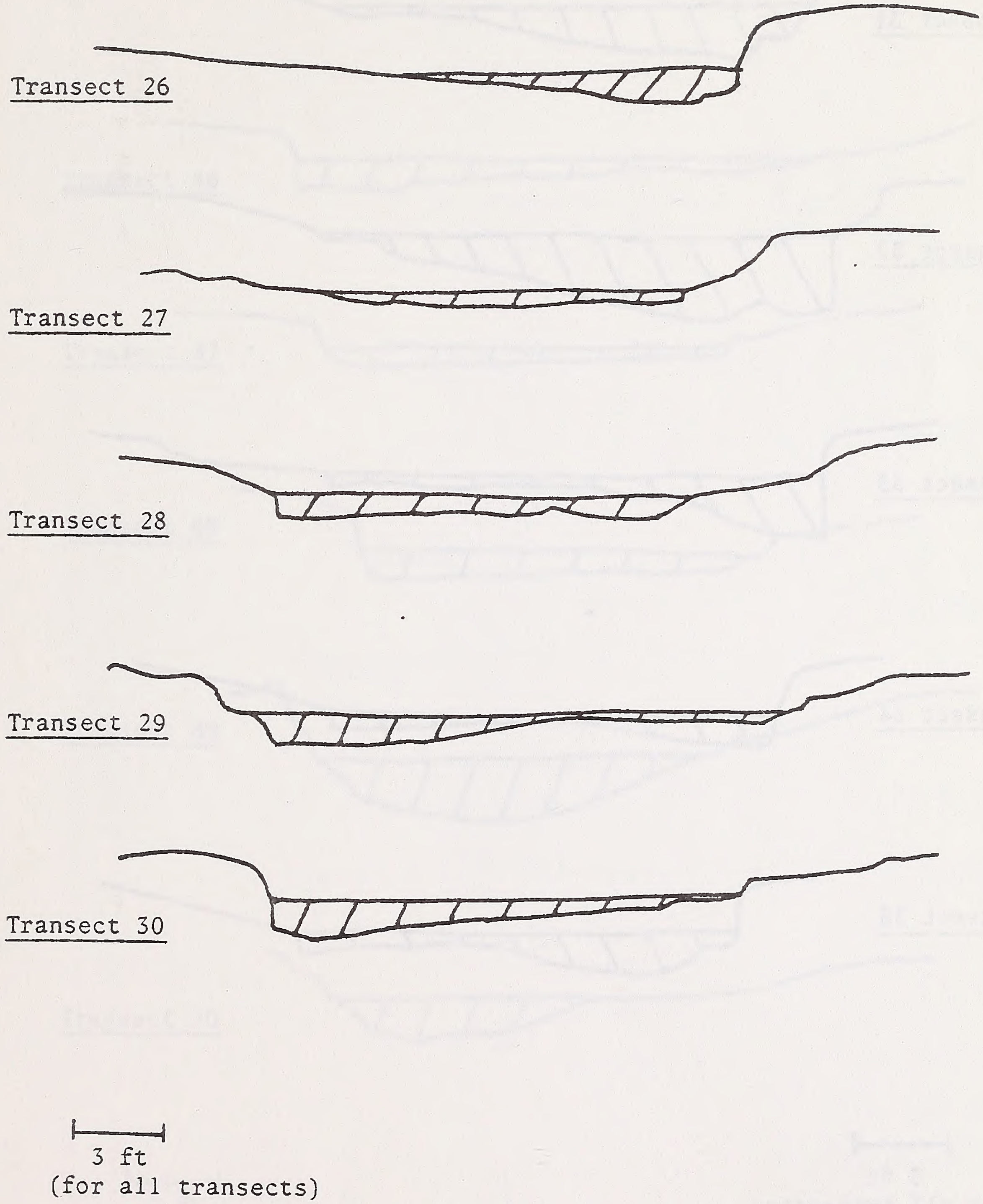


Figure 8. Stream channel cross sections for Site 1, Otter Creek.

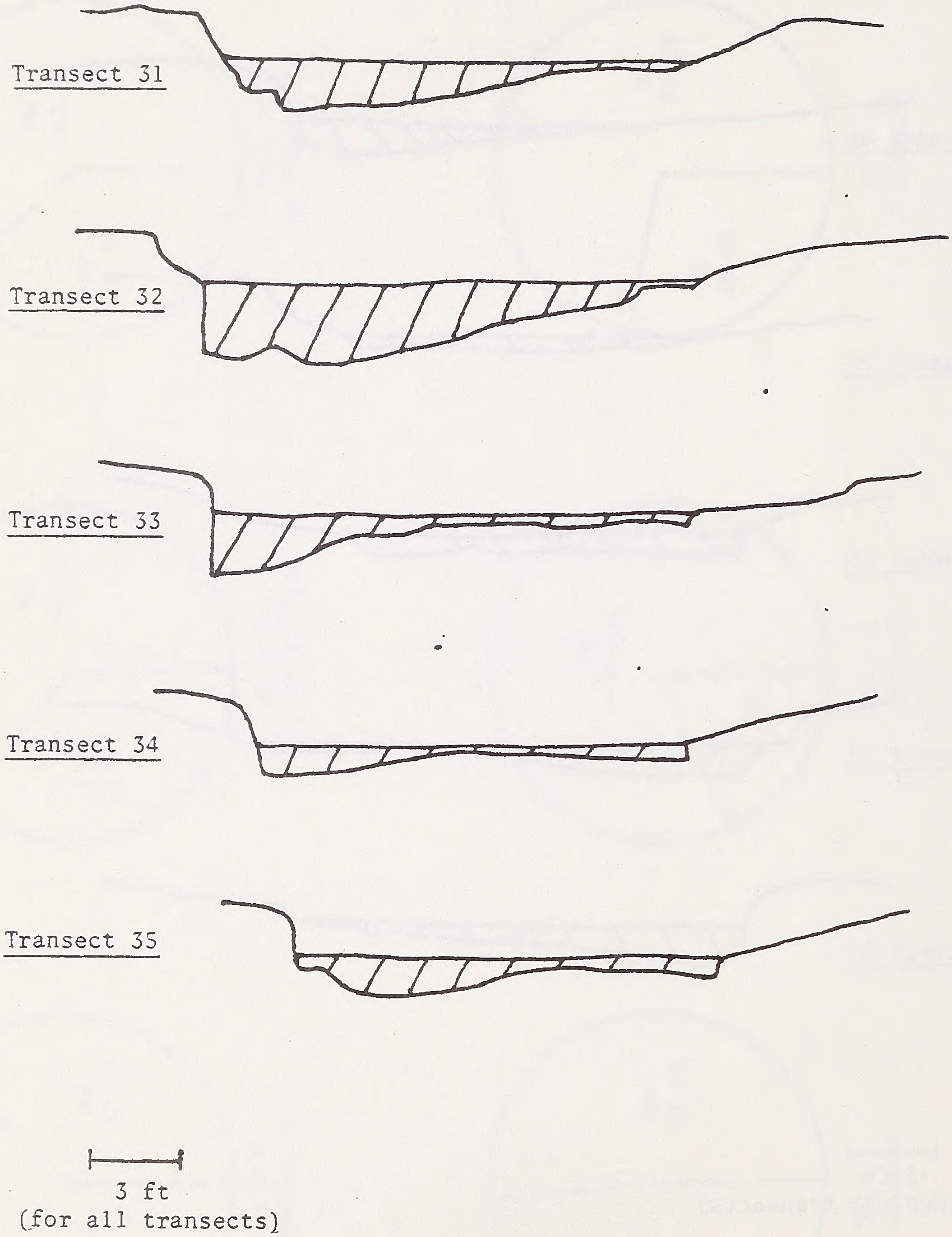


Figure 8. Continued.

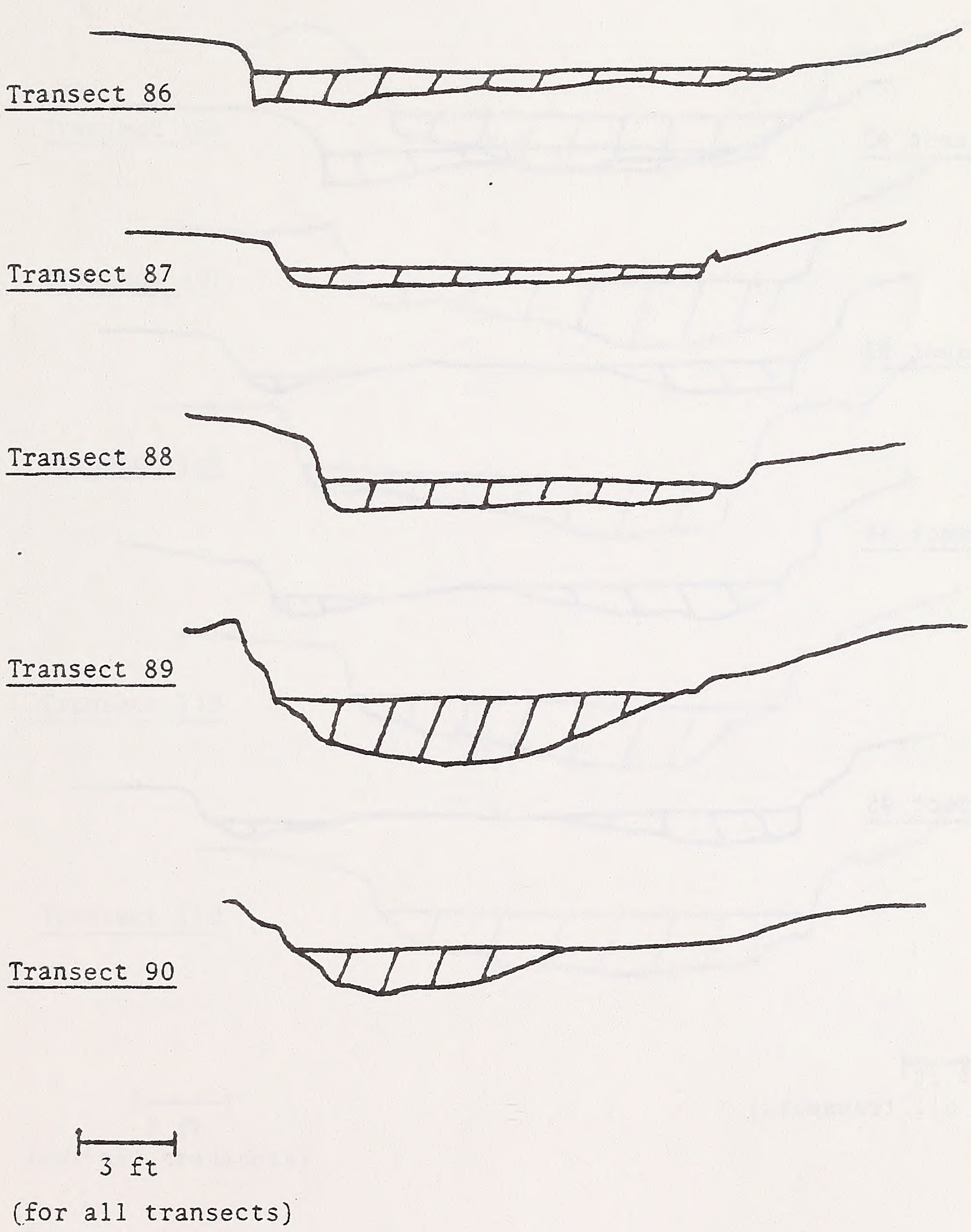


Figure 9. Stream channel cross sections for Site 2, Otter Creek.

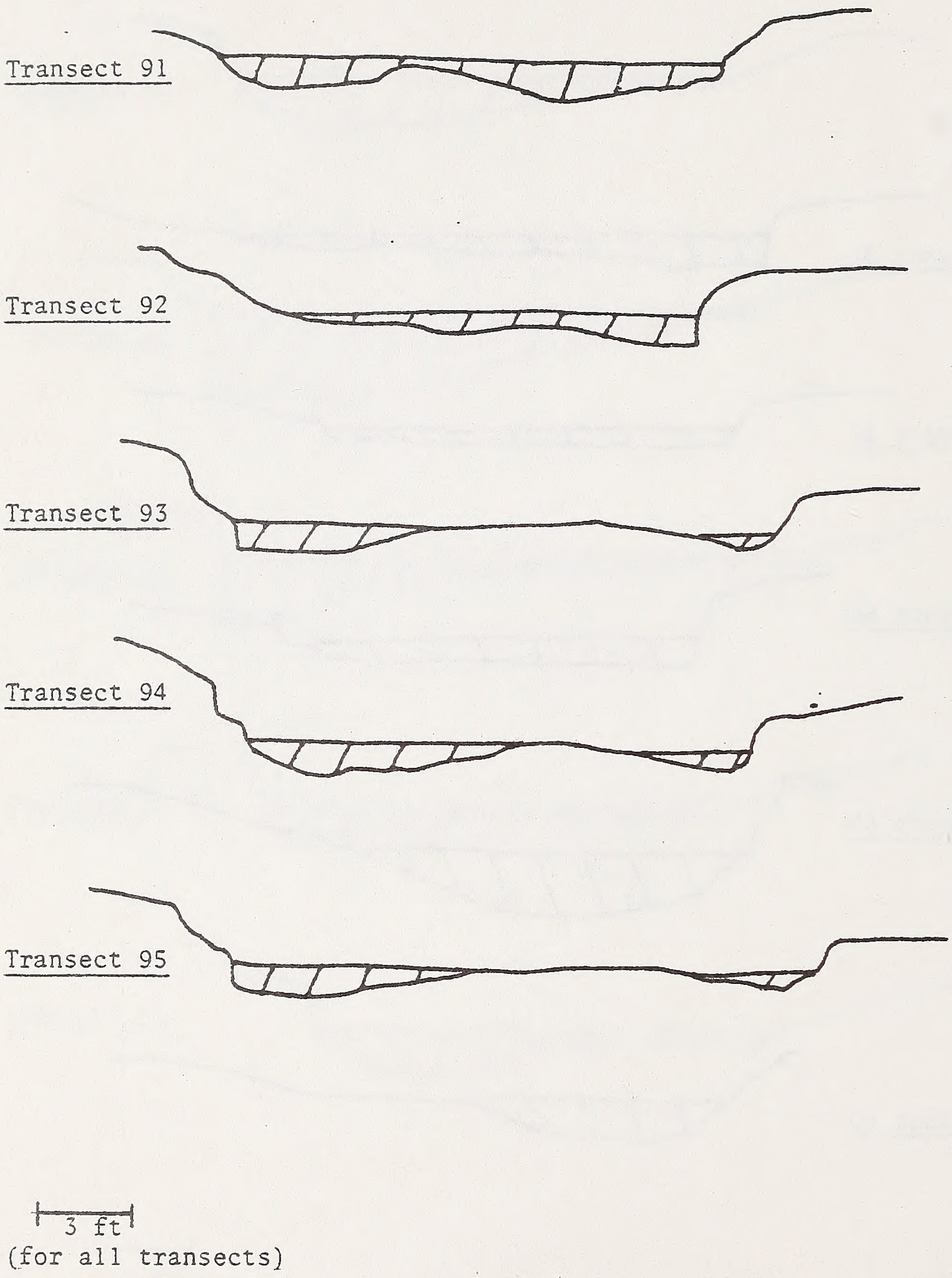


Figure 9. Continued.

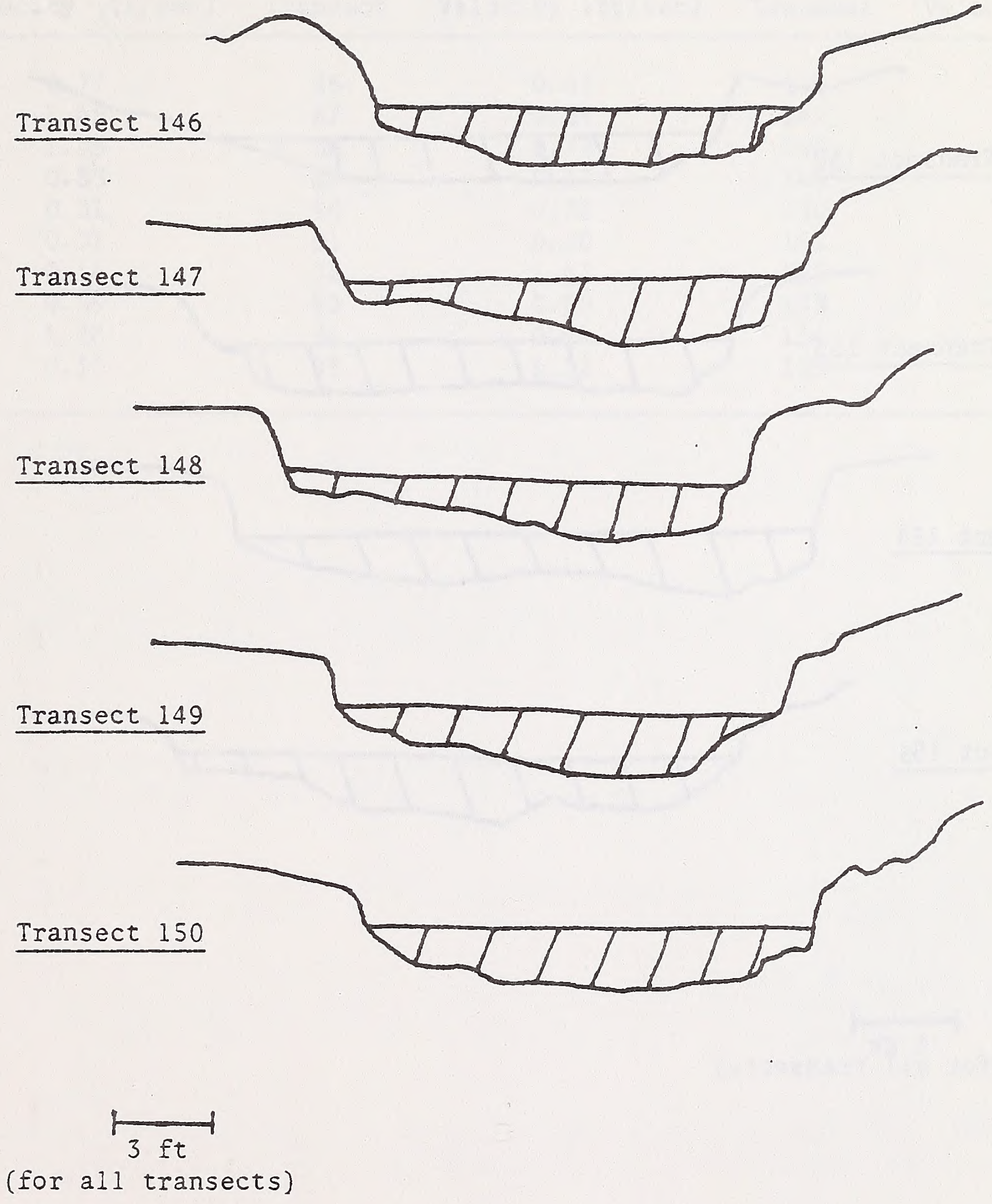


Figure 10. Stream channel cross sections for Site 3, Otter Creek.

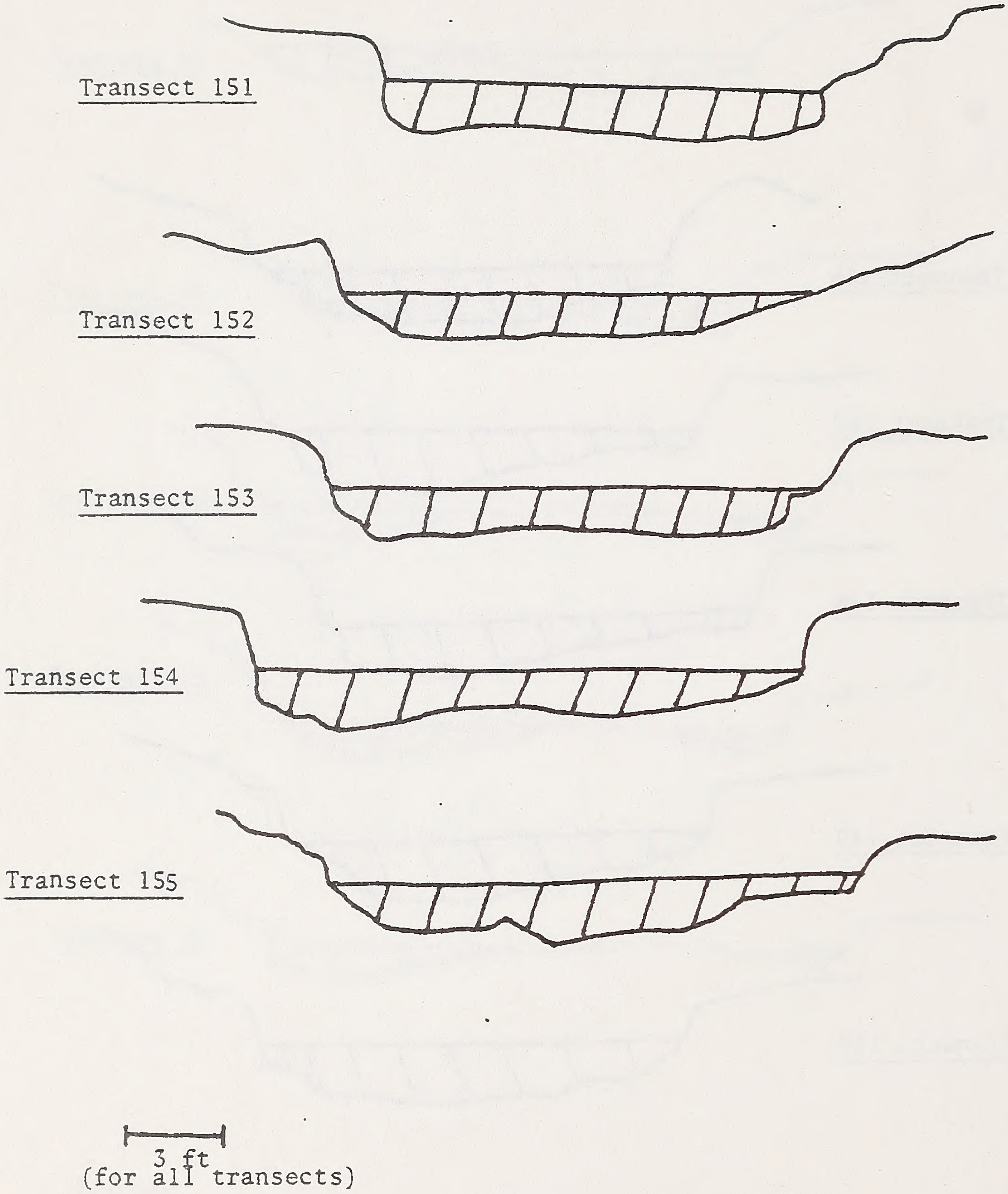


Figure 10. Continued.

Table 7. Mean velocity readings for selected hydrology transects on Otter Creek (collected 10/12/79).

Site 1 Transect	Mean Velocity (ft/sec)	Site 2 Transect	Mean Velocity (ft/sec)	Site 3 Transect	Mean Velocity (ft/sec)
26	0.77	86	0.63	146	0.36
27	1.49	87	0.89	147	0.29
28	1.36	88	0.73	148	0.33
29	0.83	89	0.17	149	0.33
30	0.31	90	0.78	150	0.23
31	0.31	91	0.60	151	0.33
32	0.14	92	1.43	152	0.32
33	0.39	93	0.96	153	0.39
34	1.28	94	0.94	154	0.28
35	0.57	95	1.52	155	0.13

DISCUSSION

Initial results show much variability between the grazed and ungrazed sites on Otter Creek. Further data are necessary, however, to draw valid conclusions. This study was designed for a time-trend analysis and additional data acquired in the next few years will make the conclusions more definite and valid.

PUBLICATIONS CITED

Bailey, Robert G.
1978. Description of the ecoregions of the United States. USDA For. Serv., Intermtn. Reg., Ogden, Utah, 77 p.

Christensen, Earl M.
1963. The foothill bunchgrass vegetation of central Utah. Ecology 44(1):156-158

Christensen, Earl M. and Hyrum B. Johnson
1964. Presettlement vegetation and vegetational change in three valleys in central Utah. Brigham Young University Science Bulletin, Biol. Serv., Vol. 4, No. 4., BYU, Provo, Utah.

Duff, Don A.
1978. Riparian habitat recovery on Big Creek, Rich County, Utah - a summary of 8 years of study. In: O.B. Cope (ed.) Proc. For. Grazing Riparian/Stream Ecosystems, Trout Unlimited, Inc., Denver, Colo.

Hormay, August L.
1970. Principles of rest-rotation grazing and multiple-use land management. USDA For. Serv., Training Text 4(2200), 26 p.

Leopold, A. S.
1975. Ecosystem deterioration under multiple-use. Wild Trout Manage. Sym., Trout Unlimited, Inc. p. 96-98.

Meehan, William R. and William S. Platts
1978. Livestock grazing and the aquatic environment. J. Soil and Water Cons. 33(6):274-278.

Minshall, G. W.
1967. The role of allochthonous detritus in the trophic structure of a woodland spring brook community. Ecology 48(1):139-149.

Morris, Meredith J., Kendall L. Johnson, and Donald L. Neal
1976. Sampling shrubranges with an electronic capacitance instrument. J. Range Manage. 29(1):78-81.

Neal, Donald L. Pat O. Currie, and Meredith J. Morris
1976. Sampling herbaceous native vegetation with an electronic capacitance instrument. J. Range Manage. 29(1):72-77.

Platts, William S..
1974. Geomorphic and aquatic conditions influencing salmonids and stream classification with application to ecosystem classification. USDA For. Serv., Surface Environ. and Min. Proj., Billings, MT, 200 p.

Platts, William S.
1976. Validity in the use of aquatic methodologies to document stream environments for evaluating fishery conditions. Instream Flow Needs Proc., Vol. 2, p. 267-284. Am. Fish Soc., Bethesda, Md.

Platts, William S.
1978. Livestock interactions with fish and aquatic environments: problems in evaluation. 43d No. Am. and Nat'l. Res. Conf., Wildl. Manage. Inst., Wash., D.C., p. 498-504.

Platts, William S.
1980. Streamside management to protect bank-channel stability and aquatic life. (In press) USDA For. Serv. Intermtn. For. and Range Exp. Stn., Ogden, Utah

Ray, Gary A. and Walter F. Megahan
1978. Measuring cross sections using a sag tape: a generalized procedure. USDA For. Serv. Gen. Tech. Rpt. INT-47, USDA For. Serv. Intermtn. For. and Range Exp. Stn., Ogden, Utah, 12 p.

Stoddart, L. A.
1941. The Palouse grassland association in northern Utah. Ecology 22(2):158-163.

Stoddart, Lawrence A. and Arthur D. Smith
1955. Range Management. McGraw-Hill, New York, N.Y., 433 pp.

United States Department of Agriculture
1936. The western range. Letter from the Secretary of Agriculture. USDA, Senate Document 199 620 p.

USDI, Bureau of Land Management
1979. Randolph planning unit grazing management final environmental statement. USDI Bur. Land Manage., Salt Lake City, Utah.

SELECTED REFERENCES

Armour, Carl L.
1977. Effects of deteriorated range streams on trout. USDI Bur. Land Manage., Idaho State Office, Boise, Idaho

Berry, Charles R., Jr.
1978. Impact of sagebrush management on riparian stream habitat. Utah. Coop. Fish Res. Unit. (Presented at Sagebrush Ecosys. Sym., Utah State Univ., Logan, Utah.)

Bidwell, R. G. S.
1974. Plant physiology. MacMillian Publishing Co., Inc., New York, New York, 643 p.

Branson, F. A., R. F. Miller, and I. S. McQueen
1967. Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. J. Range Manage. 20(5):287-296.

Christensen, Earl L. and Stanley L. Welsh
1963. Presettlement vegetation of the valleys of western Summit and Wasatch counties, Utah. Proc. Utah Acad. Sci., Arts, and Letters, Vol. 40, Pt. 2, p. 163-174.

Council for Agricultural Science and Technology
1974. Livestock grazing on federal lands in the 11 western states. J. Range Manage. 27(3):174-181.

Cronquist, A., A. H. Holmgren, N. H. Holmgren, J. L. Reveal, and P. K. Holmgren
1977. Intermountain flora. Vol. 6. Columbia Univ. Press, New York, 584 p.

Currie, P. O., M. J. Morris, and D. L. Neal
1973. Uses and capacities of electronic capacitance instruments for estimating standing herbage, Part 2, sown ranges. J. Br. Grassld. Soc. 28:155 160.

Dix, Ralph L.
1964. A history of biotic and climatic changes within the north american grassland. In: Grazing in Terrestrial and Marine Environments, Blackwell's Sci. Pub., Adlard & Son, Ltd., Dorking, England

Egglor, Willis A.
1941. Primary succession on volcanic deposits in southern Idaho. Ecol. Monogr. 11(3):277-298.

Garrison, George A., Ardell J. Bjugstad, Don A. Duncan, Mort E. Lewis, and Dixie R. Smith
1977. Vegetation and environmental features of forest and range ecosystems. USDA For. Serv., Agric. Handb. 475, 68 p.

Harris, Grant A.
1977. Changing philosophies of rangeland management in the United States. J. Range Manage. 30(1):75-78.

Hitchcock, A. J.
1935. Manual of the grasses of the United States. USDA, Misc. Publ. 200, 1040 p.

Hunt, Charles B.
1967. Physiography of the United States. W.H. Freeman & Co., San Francisco and London, 480 p.

Jameson, Donald A.
1965. Phenology of the grasses of the northern Arizona pinyon-juniper type. USDA For. Serv. Res. Note RM-47, USDA For. Serv., Rocky Mtn. For. and Range Exp. Stn., Fort Collins, Colo.

Kothman, M. M.
1974. Grazing management terminology. J. Range Manage. 27(4)326:327.

Kuchler, A. W.
1964. Potential natural vegetation of the conterminous United States. (map and manual) Amer. geog. Soc. Spec. Pub. 36, 116 p. map scale 1:3, 168,000.

Kuchler, A. W.
1966. Potential natural vegetation (map). USDI Geol. Surv. Natl. Atlas, Veg.; map scale 1:7 500,000.

Long, Robert W.
1974. Future of rangelands in the United States. J. Range Manage. 27(4);253-255.

Mirov, N. T.
1967. The genus Pinus. The Ronald Press Co., New York, 602 p.

Platts, William S.
1980. Effects of sheep grazing on a riparian-stream environment. (Manuscript proposed for publ. J. Soil and Water Cons.)

Snedecor, George W. and William G. Cochran
1967. Statistical Methods. Iowa State Univ. Press, Ames, Iowa, 6th Ed., 593 p.

Thomas, Jack Ward, Chris Maser, and Jon E. Rodiek
1978. Riparian zones in managed rangelands - their importance to wildlife. In: O.B. Cope (ed.), Proc. For. Grazing Riparian/Stream Ecosystems, p. 21-31, Trout Unlimited, Inc., Denver, Colo.

Thornbury, William D.
1965. Regional geomorphology of the United States. John Wiley & Sons, Inc.: New York, London, Sydney, 609 pp.

Vale, Thomas R.
1975. Presettlement vegetation in the sagebrush-grass area of the Intermountain west. J. Range Manage. 28(1):32-36.

Valentine, John F.
1971. Range development and improvements. Brigham Young University Press, Provo, Utah, 516 p.

Varies, Kimery C. and Philip L. Sims
1977. The plant information network. USDI, Fish and Wildlife Serv., Office of Biological Services, FWS/OBS-77/38. (In cooperation with U.S. Environmental Protection Agency.)