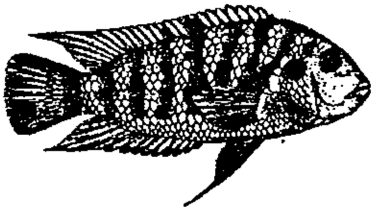
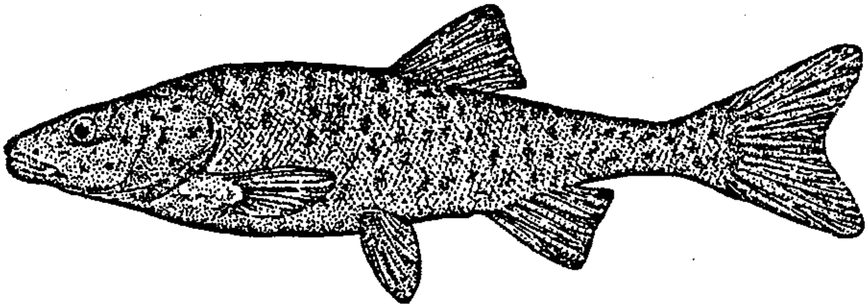
Status and Life History of Pahranagat River Fishes





National Fishery Research Center
Seattle, Washington

Nevada Department of Wildlife
Reno, Nevada

STATUS AND LIFE HISTORY

PAHRANAGAT RIVER FISHES

Completion Report (1990)

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PROLOGUE

From summer, 1986 through summer, 1989, the National Fishery Research Center - Seattle and the Nevada Department of Wildlife conducted a cooperative study on Pahranagat River fish populations. The study was aimed at generating information useful for the development of a management strategy leading to enhancement of Pahranagat River system native fishes. This report, which is divided into three sections, details the findings of the cooperative study.

Titled "Ichthyofauna Survey" Section I gives a comprehensive account of the distribution and relative abundance of fishes in the Pahranagat River system. Section II focuses on the biology of fishes along a relatively short stream reach (Ash Springs pool and 4.5 km of its immediate outflow) which harbors two of the river's endangered species (Pahranagat roundtail chub and White River springfish). Seasonal abundance, distribution, and habitat use are quantified over a three year period. In addition, the section includes an indepth account of Pahranagat roundtail chub life history. Section III addresses interspecific interactions including competition for space and food, and predation.

ACKNOWLEDGEMENTS

We express our appreciation to the people of the Pahranagat Valley for their cooperation. We especially thank Mr. and Mrs. Edwin Higbee for their insight and information of fishes of the Pahranagat River system and for tolerating our continued presence on their ranch. The Hunt family is also deserving of special thanks for permitting access to Ash Springs whenever it was reuired.

Special thanks is also given to Tom Strekal for his extremely helpful review of the manuscript. Stephanie Byers ran the larval predation experiments, helped with graphics, and worked long hours helping to put the report together. Pete Rissler helped with the graphics and assisted in the statistical analysis. Dana Winkelman assisted in the first year of the study and Jim Call helped pick the drift samples.

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PART I
ICHTHYOFAUNA SURVEY

Abstract. An ichthyofauna survey was conducted on the Pahranagat River from the summer of 1986 to the summer of 1987. Pahranagat roundtail chub (*Gila robusta jordani*) were more numerous and had a broader distribution than had previously been believed. Up to 260 adults (> 100 mm FL) were counted in the winter of 1986/1987 spread over a 12 kilometer stream reach. In the spring of 1987, speckled dace (*Rhinichthys osculus*) were the most numerous and widespread of native fishes, with an estimated 60,000 adults occurring in those strata for which estimates could be made. Hiko White River springfish were the least abundant, with approximately 181. A unique form of *Rhinichthys*, thought to be extinct, was discovered in two springs on the Pahranagat National Wildlife Refuge; they appear to be in precariously low numbers. Of the introduced fishes counted, shortfin mollies (*Poecilia mexicana*) were the most numerous, with over 400,000 occurring in the summer of 1986, followed by convict cichlids (*Cichlasoma nigrofasciatum*), with over 250,000 in the same season. Both are thermophilic and restricted to warm headwaters.

INTRODUCTION

In the recent past, two fishes of the Pahranagat River system have become extinct: desert sucker (*Catostomus clarki*; Deacon [1], fieldnotes 1978) and Pahranagat spinedace (*Lepidomeda altivelis*; La Rivers 1962, Minckley and Deacon 1968). Four endemics persist: Pahranagat roundtail chub (*Gila robusta jordani*); White River springfish (*Crenichthys baileyi baileyi*); Hiko White River springfish (*Crenichthys baileyi grandis*); and Pahranagat speckled dace (*Rhinichthys osculus velifer*). All but speckled dace have been federally listed as endangered (U.S. Fish and Wildlife Service 1984), and the dace has been considered for listing. The demise of Pahranagat River fishes is attributed to habitat destruction and the introduction of exotic fishes.

An 1891 survey of fishes of the Pahranagat Valley indicated springfish predominated the source pools at Crystal, Ash, and Hiko Springs (Gilbert 1893). They now exist in precariously low numbers in their native habitats, presumably due to displacement by exotics: convict cichlid (*Cichlasoma nigrofasciatum*), shortfin molly (*Poecilia mexicana*), and mosquitofish (*Gambusia affinis*).

Roundtail chub was first collected from Crystal Springs in 1938 by Miller and Hubbs (1960), but the species was described by Tanner (1950) who collected them in the outflow of Hiko Spring. It is now extirpated in these habitats. Hardy (1982) reported the adult population to have been represented by 37 to 45 individuals from January 1979 to September 1981, which were confined to a single microhabitat (large pool) in the lower reaches of Ash Springs outflow.

An objective of our first year of study was to update the status of native and introduced Pahranagat River fishes. Seasonal distribution and abundance were determined for selected stream reaches. This information is important for native fish management and exotic fish control.

METHODS

Prior to the ichthyofauna survey, land ownership of parcels abutting the river was determined and permission to access was acquired (Appendix A). From August 5 through August 9, 1986, virtually the entire Pahranagat River was walked to delineate stream habitats. Quantitative and qualitative observations were made to characterize each habitat type. Based on physical and biological differences, the river system was divided into nine strata (Figure 1.1). In addition, eight springs isolated from the river, but within its immediate drainage basin, were surveyed and characterized.

Because of the diversity of habitats within the Pahranagat River system, a variety of sampling techniques were used to determine relative abundance and distribution of fishes. Where visibility permitted, estimates were made by snorkel counts which consisted of counting fishes in representative transects within a stratum and then expanding the data (at least 2% of each stratum was sampled). To enumerate Pahranagat roundtail chub, entire areas inhabited by chub were snorkeled and direct counts were made of adults and juveniles.

In strata or reaches with low flow, good water clarity and few obstructions, counts were made from the banks. Again, representative transects within a stratum

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[1] Dr. James Deacon, Department of Biology, University of Nevada, Las Vegas, NV. 89154.

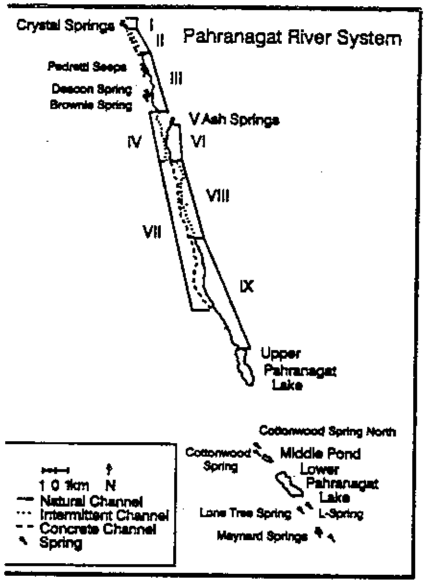

Fig. 1.1. Map of the Pahranagat River system show- nine strata and isolated springs.

re selected and the data expanded to represent the ire stratum. When fish were counted either from the ık or by snorkeling, a second count was made and an ırage was computed for the stratum total.

When estimates were made by mark and recapture, ›resentative transects were isolated with 4.5 mm sh block nets or existing barriers. Fish were captured h standard minnow traps, given a caudal clip, and ›ased for recapture. Estimates were made by using ıation 3-7 in Ricker (1975). Transect estimates were ›anded for the entire stratum.

Conditions prohibited population estimates in eral strata. In these we employed seines, minnow ›s, and visual observation to determine species com- ition and to make a subjective evaluation of relative ındance. The method of sampling, estimating ›ulation number or subjectively evaluating relative cies abundance is addressed in description of strata l isolated springs, below.

The ichthyofauna survey was conducted seasonally n the summer of 1986 to the spring of 1987. Only ingfish, mollies, mosquitofish, and cichlids 25 mm al Length (TL) and longer and speckled dace 35 mm Fork Length (FL) and longer were used in the estimates.

DESCRIPTION OF STRATA METHODS OF SAMPLING AND ENUMERATION

Stratum I (Crystal Springs System)

Stratum I originates from several springs and seeps which discharge into two headwater pools. Cumulative discharge is 0.31 m^3/s. The more substantial southwestern spring pool has two exit channels, one of which conveys water intermittently, because of irrigation diversions and thus offers little habitat. The main channel, and what appears to have been the historic river course, has perennial flow and abundant fish life. Its width ranges from 10 to 30 m and extends approximately 900 meters before discharging into Stewart Channel (Stratum II). Maximum water depth is about 1.5 m. The reach is characterized by dense aquatic vegetation and silt substrate. Tables 1.1 and 1.2 summarize the physical and biological conditions for each stratum.

In the summer of 1986, population estimates were made by mark and recapture. Fish were captured with standard minnow traps, given caudal fin clips, and released for recapture. Only fishes 25 mm FL and greater were included in the estimate. Separate estimates were made for each of the two spring pools. A 10-m-long transect sequestered by 4.5 mm mesh block nets was used to represent the upper 530 m of the outflow. In the lower 370 m, estimates were made by snorkeling one meter wide transects at 20 m intervals. To hold direction while snorkeling a string was drawn across the transect and a meter stick was used to gauge transect width.

Stratum II (Stewart Channel)

Stewart Channel is a 2 km long concrete-lined irrigation ditch with five diversion boxes and seven concrete-lined side channels (four to the east and three to the west). Stream cover is minimal and consists of several scattered willow and Russian olive trees. The channel flows rather swiftly with velocities to 2.5 m/s and, consequently, has little value as fish habitat. Localized pockets of fishes occur at the diversion boxes where water velocities are greatly reduced. They also occur in the slower moving side channels.

Estimates were made by establishing 10 m long transects at three equally spaced intervals along the main channel and each of seven side channels, and by making counts from the bank. Transect averages were expanded to estimate the number of fish in each channel, and then channel estimates summed. Because fish tended to congregate at diversion boxes, snorkel counts (average of two) were made at each of these and added to the total.

Table 1.1. Quantitative physical habitat descriptions of nine strata along the Pahranagat River from July, 1986 to June, 1987.

	Strata	Length (km)	Volume (m^3/sec)	Temperature (°C)	DO (mg/l)
I.	Crystal Springs				
	Source Pool	0.1	0.31	26 - 28	1.3 - 6.4
	East Outflow	0.9	0.06 - 0.31	19 - 30	6.5 - 15.7
	South Outflow	0.2	0.00 - 0.25	25 - 28	3.6 - 5.9
II.	Stewart Channels				
	Main Channel	2.0	0.00 - 0.31	19 - 28	7.1 - 8.3
	Side Channels	1.7	Variable	7 - 29	5.2 - 20 +
III.	Gunther Ranch	5.8	0.00 - 0.31	8 - 31	3.5 - 11.3
IV.	Burns Ditch	4.1	Variable	5 - 29	6.2 - 12.0
V.	Ash Springs	0.4	0.56	31 - 36	1.8 - 5.1
VI.	Ash Outflow				
	Main Outflow	4.5	0.56 - 0.87	18 - 32	5.0 - 7.6
	Crystal Fork	0.2	0.00 - 0.31	5 - 24	1.1 - 10.7
VII.	Highland Ditch	14.2	Variable	18 - 31	6.1 - 7.8
VIII.	East Ditch	5.6	Variable	18 - 28	0.7 - 13.8
IX.	Alamo Reach	10.8	Variable	6 - 29	3.3 - 15.3

Stratum III (William's and Gunther Ranch)

Approximately 5.8 kilometers in length, this stratum consists of slow moving, shallow water punctuated by intermittent pools. Portions had previously been channelized but most appear to have been undisturbed for several years. Much of the channel is bordered by a thick riparian corridor of cottonwood, willow, and ash trees (Table 1.2). These have contributed substantial allochthonous debris and deadfalls. The channel bottom consists primarily of clay and silt. Flow is periodically interrupted by agricultural diversions; these do not, however, cause desiccation of the entire reach.

Estimates were made by snorkeling 10-m-long transects at 500 m intervals, and expanding the estimates for the entire stratum.

Stratum IV (Burn's Ditch)

This stratum is an earthen irrigation ditch supplying water to the north end of the Burn's Ranch, the last field irrigated exclusively by Crystal Springs water. It has an average width of 1 m and extends 5.8 km before joining Ash Springs outflow (stratum VI). During the survey, the ditch contained water in its upper 4.1 km. There is a sparse riparian corridor consisting primarily of arrow bush and willows.

Population size was estimated with bank counts of 10 m transects at 500 m intervals; the data were expanded for the entire stratum.

Stratum V (Ash Springs)

Ash Springs is a recreational site consisting of a large convoluted pool with water depth ranging from 0.5 to 2.0 meters. Springs within the pool collectively discharge at 0.56 m^3/s. The bottom is sand and silt. Submergent vegetation and algae mats are locally dense. Banks are sparsely vegetated with cottonwood and ash trees.

Estimates were made by snorkel-counting fishes within 1 m wide transects at 20 m intervals across the width of the pool. To hold direction while snorkeling a string was drawn across the pool; a hand-held meter stick was used to gauge width. The average of two counts at each transect was expanded to estimate total pool population.

Table 1.2. Qualitative habitat descriptions of nine strata along the Pahranagat River system.

	Strata	Channel Type	Habitat Type	Dominant Substrate	Aquatic Veg.	Emergent Veg.	Riparian Corridor	Livestock Use
I.	Crystal Springs							
	Source Pools	Earth	Pool	Silt	Abundant	Sparse	Sparse	Moderate
	East Outflow	Earth	Glide/Pool	Silt	Abundant	Common	Sparse	Moderate
	South Outflow	Earth	Glide/Pool	Silt	Common	Sparse	Common	Light
II.	Stewart Channels							
	Main Channel	Concrete	Chute	Concrete	Absent	Absent	Absent	Light
	Side Channels	Concrete	Glide	Concrete	Sparse	Sparse	Absent	Heavy
III.	Gunther Ranch	Earth	Glide/Pool	Silt/Clay	Variable	Sparse	Variable	Heavy
IV.	Burns Ditch	Earth	Riffle/Glide	Sand/Silt	Variable	Sparse	Sparse	Heavy
V.	Ash Springs	Earth	Pool	Sand/Silt	Variable	Sparse	Sparse	Light
VI.	Ash Outflow							
	Main Outflow	Earth	Riffle/Glide	Variable	Variable	Sparse	Abundant	Moderate
	Crystal Fork	Earth	Glide/Pool	Silt/Organic	Sparse	Absent	Abundant	Light
VII.	Highland Channel	Concrete	Chute/Glide	Concrete	Sparse	Absent	Absent	Light
VIII.	East Ditch	Earth	Glide/Pool	Sand/Silt	Variable	Sparse	Variable	Heavy
IX.	Alamo Reach	Earth	Glide/Pool	Silt/Organic	Sparse	Sparse	Variable	Heavy

Stratum VI (Ash Springs Outflow)

Stratum VI begins at the outflow of Ash Springs pool and extends approximately 4500 m before discharging into the Highland Channel (stratum VII). In stratum VI, the river flows in what appears to be its historic river channel. Substrate varies according to reach and is comprised of gravel sand, silt, and clay. A dense riparian corridor of ash and willows borders most of the stream.

To determine the number of Pahranagat roundtail chub the entire stratum was snorkeled. Estimates of cohabiting species were made by snorkel-counting fishes in 10 m long transects at 500 m intervals and expanding the data.

Stratum VII (Highland Channel)

Stratum VII is the primary irrigation channel downstream from Ash Springs. This concrete channel is 14.2 km in length with eighteen diversion boxes between its origin and Richardville Road. The majority of fish are relegated to diversion boxes or other areas of relief from high water velocity.

To determine number of chub the entire channel was snorkeled while floating downstream. To estimate population number of other fishes 10-m-long transects were snorkeled at 500 m intervals, and the data were expanded.

Stratum VIII (East Ditch)

Approximately 5.6 km in length, stratum VIII originates at the point of diversion of Ash Springs Outflow (stratum VI) into Highland Channel (stratum VII). During the irrigation season, March 15 to October 15 (Lincoln County Conservation District 1980), leakage from stratum VII supplies a small quantity of water to the upper 750 meters of stratum VIII; downstream intermittent pools are maintained by irrigation runoff and seepage. From about October 16 to March 15, water is conveyed along its entire length. A riparian corridor of willow and ash trees is locally dense. The bottom substrate is comprised primarily of sand and silt.

Stratum IX (Alamo Reach)

During the irrigation season, water in stratum IX originates from agricultural runoff and seepage. From October 16 to March 16 it receives flow from strata VII and VIII, and conveys virtually the entire river flow.

Table 1.3. Quantitative and qualitative descriptions of eight isolated springs in the Pahranagat River drainage.

Spring	Temperature (°C)	DO (mg/l)	Bottom Substrate	Aquatic Vegetation	Emergent Vegetation
Pedretti	16 - 19	2.3 - 4.9	Silt/Organic	Abundant	Abundant
Deacon	15 - 22	3.4 - 12.3	Silt/Sand	Common	Common
Brownie	7 - 20	4.5 - 8.6	Silt/Organic	Sparse	Sparse
Cottonwood	13 - 19	1.7 - 8.9	Silt/Organic	Common	Abundant
Cottonwood North	5 - 17	3.1 - 6.1	Silt/Clay	Common	Common
Lone Tree	10 - 16	4.0 - 7.7	Silt/Organic	Sparse	Abundant
L Spring	3 - 18	2.7 - 14.2	Silt/Organic	Abundant	Common
Maynard					
Pool 1	11 - 20	3.6 - 9.8	Silt/Organic	Sparse	Sparse
Outflow 1	10 - 19	3.6 - 8.7	Silt/Organic	Common	Abundant
Pool 2	12 - 20	1.8 - 5.8	Silt/Organic	Sparse	Abundant
Outflow 2	12 - 20	1.6 - 5.9	Silt/Organic	Common	Abundant
East Pool	5 - 13	5.0 - 12.5	Silt/Organic	Abundant	Common

Approximately 10.8 m in length, stratum IX discharges into Upper Pahranagat Lake. The channel has ash, cottonwood, and willow trees scattered along its banks. There is a metal fish barrier approximately 2.2 km upstream of the lake; it was installed in about 1969 to prevent largemouth bass from invading the river and preying upon native fishes (Don King[2], Pers. Com.).

Minnow trapping, seining, and visual observation from the banks were used to make a subjective evaluation of species composition and relative abundance.

DESCRIPTION OF ISOLATED SPRINGS

Pedretti Seeps

Pedretti Seeps is located on the Gunther Ranch 3.5 km southeast of Crystal Springs (Figure 1.1). It consists of a series of seeps merging to form a small stream which terminates at a marsh. The entire system is clogged with submergent and emergent vegetation (Table 1.3). The bottom substrate is comprised primarily of organic mud.

Determinations of species composition and relative abundance were made by visual observation from the banks and minnow trapping.

Deacon Spring

Deacon Spring is located on the Gunther Ranch 5.2 km southeast of Crystal Springs (Figure 1.1). It flows into a small pool which discharges into a small stream. Depending on irrigation demands the stream may be diverted to an irrigation ditch or to a small marsh. Submergent vegetation is common in the spring pool and outflow stream. Bottom substrate in the spring pool consists of sand with organic debris; gravel and sand predominated in the stream.

A determination of species composition and a subjective evaluation of relative abundance were made by visual observation from the banks.

Brownie Spring

Located on the Gunther Ranch 0.6 km south of Deacon Spring, Brownie Spring consists of a shallow, mud bottom pool with a small outflow stream. Depending upon irrigation demand the stream is diverted to an irrigation ditch or discharges into a marsh. This spring system receives heavy livestock use and appears to provide minimal fish habitat.

---

[2] Don King, Former Project Leader, Fisheries Assistance, USFWS, Reno, NV. 89502.

Cottonwood Spring

Cottonwood Spring is located within the Pahranagat National Wildlife Refuge 1.7 km south of the refuge headquarters. As its name implies cottonwood trees are present. The spring pool is choked with emergent vegetation and has little open water. The pool bottom consists of silt laden with organic debris. It is fenced to prevent access to cattle, but a channel has been dredged from the pool and beyond the fence to accommodate livestock.

Cottonwood Spring North

Located several hundred meters north of Cottonwood Spring, Cottonwood Spring North consists of a narrow trenched stream channel approximately 100 m in length which discharges into a marsh. Water depth ranges from 5 to 70 centimeters. Emergent and submergent vegetation is locally abundant.

Species composition and relative abundance were determined by observation from the bank and intensive minnow trapping.

Lone Tree Spring

Lone Tree Spring is located within the Pahranagat National Wildlife Refuge 8.9 km southwest of the refuge headquarters. The spring discharges into a small, shallow pool overgrown with emergent vegetation. The bottom consists of silt and organic debris.

L Spring

Located within the Pahranagat National Wildlife Refuge 9.1 km southwest of the refuge headquarters, L Spring had previously been trenched into a "L" shape. The channel is approximately 4 to 5 m in width and about 20 m long. Pool depth is about 70 cm. The pool bottom is comprised of silt. Emergent vegetation is not abundant, while submergent vegetation is seasonally abundant in the southern-most reach.

Species composition and relative abundance were determined by visual observation from the bank and by intensive minnow trapping.

Maynard Springs

Two spring pools are located at the southern boundary of Pahranagat National Wildlife Refuge on the west side of Highway 93 and approximately 11.5 km southwest of the refuge headquarters. The springs are within the bounds of the recently extirpated Maynard Lake. They have depths up to 1 m and bottoms consisting of silt and organic debris. An outflow stream from each discharges into a common marsh choked with cattails.

Species composition and relative species abundance were determined by observation from the bank and by intensive minnow trapping.

RELATIVE ABUNDANCE AND DISTRIBUTION

Pahranagat Roundtail Chub
(Gila robusta jordani)

Pahranagat roundtail chub was found in approximately 12 km of stream including Ash Springs (stratum V), Ash Springs outflow (stratum VI), and the upper reaches of both the Highland Channel and East Ditch (strata VII and VIII; Figure 1.2a).

The number of adults (> 100 mm FL) ranged from 150 in the fall to 260 in the winter (Table 1.4). Juvenile (25 to 100 mm FL) counts ranged from 24 individuals in the winter to 337 in the summer. Most occurred in the Ash Spring outflow (stratum VI). This reach was the least disturbed in the Pahranagat River, and apparently offered the highest quality chub habitat. Relatively few were found in adjacent strata (V, VII, and VIII).

White River Springfish
(Crenichthys baileyi baileyi)

Hardy (1982) reported *C. b. baileyi* as largely relegated to Ash Springs pool with infrequent occurrences in the outflow. Similarly, we found them primarily in the spring pool (Figure 1.2b). In the spring of 1987, however, several were found as far as 100 m downstream from the spring pool. Presumably they were flushed on February 27 and 28, 1987, from Ash Springs pool when its drain valve was opened.

Estimates of adults (>25 mm TL) ranged from 1,057 in the fall 1986 to 1,705 in the spring 1987. We considered our winter estimate unreliable; hence, it does not appear in Table 1.4.

Hiko White River Springfish
(Crenichthys baileyi grandis)

This species is restricted to the headwater pools at Crystal Springs, stratum I (Figure 1.2b). To avoid excessive handling, mark and recapture estimates were only attempted in the summer 1986 and spring 1987.

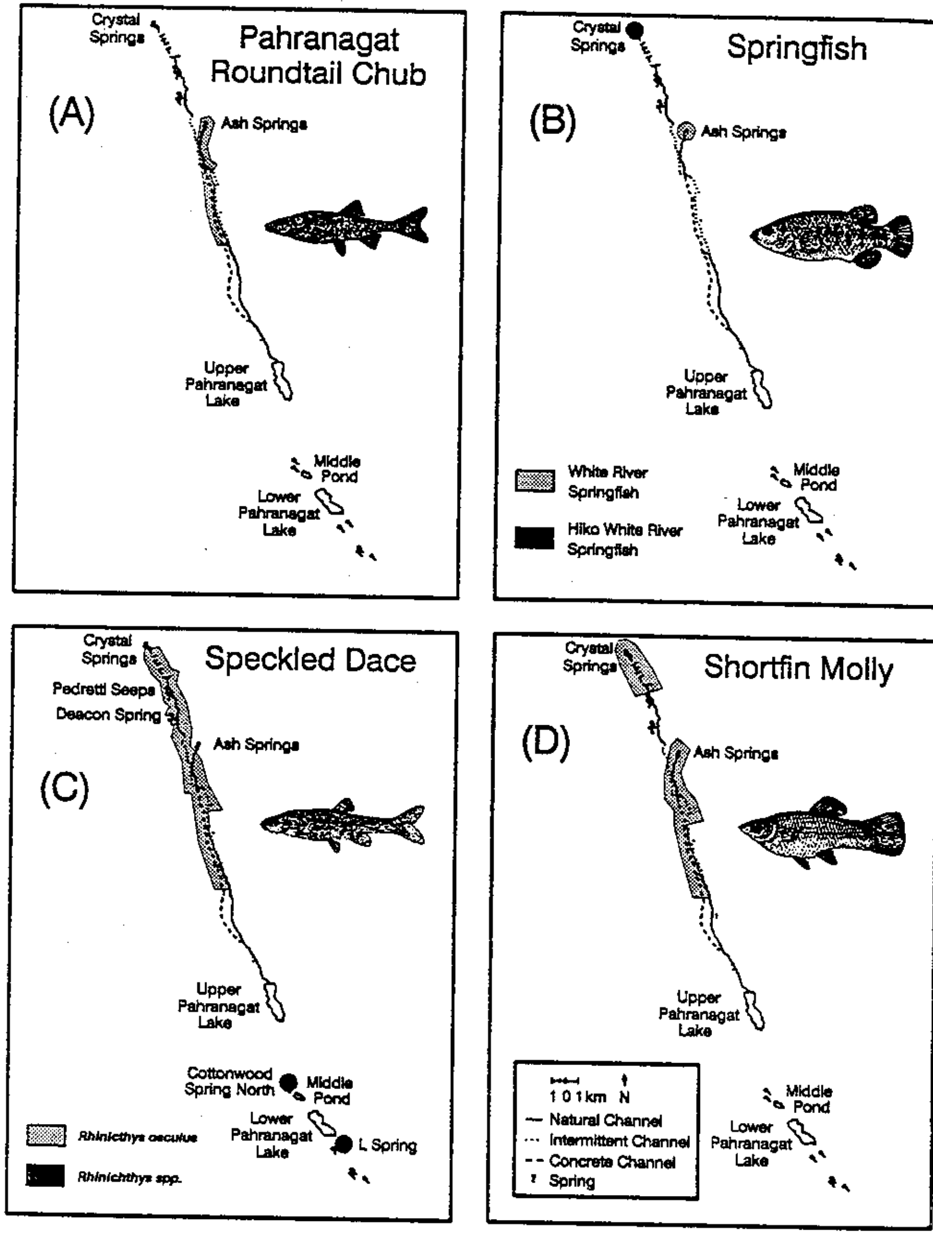

Fig. 1.2. Distribution of (A) Pahranagat roundtail chub, (B) White River and Hiko White River springfish, (C) speckled dace, and (D) shortfin molly in the Pahranagat River system.

Table 1.4. Population estimates of fish occurring in nine strata of the Pahranagat River system from fall, 1986 to spring, 1987. Subjective estimates are given as (A) abundant, (C) common, and (R) rare. N/E denotes no estimate.

Strata	Roundtail Chub Adult	Roundtail Chub Juvenile	Spring-fish	Speckled Dace	Molly	Mosquito-fish	Convict Cichlid	Carp	Bullhead
I. Crystal Springs									
Summer			265		A	R	A	R	
Fall	Not Sampled								
Winter	Not Sampled								
Spring			181	275	51,048	R	28,568	R	
II. Stewart Channels									
Summer				743	2,555	8,129	101		
Fall				390	4,240	5,190			
Winter				265	784	327			
Spring				1,380	245	350	50		
III. Gunther Ranch									
Summer				6,590	6,790	4,395	2,210		
Fall				1,540	165	3,420			
Winter				4,700	200	10,600			
Spring				41,015	1,075	1,285			
IV. Burns Ditch									
Summer				C		A			
Fall									
Winter									
Spring									
V. Ash Springs									
Summer	4	13	1,425		44,772	5,196	4,537	R	
Fall	6	16	1,057		31,491	2,317	2,141	R	
Winter	12	2	N/E		17,119	3,465	905	R	
Spring			1,705		21,890	561	1,328	R	

(Continued)

The summer 1986 adult estimate was 265 (+/- 15); it dropped to 181 (+/- 6) by spring 1987 (Table 1.4).

Because of recent declines, the Nevada Department of Wildlife (NDOW) has successfully established a *C. b. grandis* refugium in Blue Link Spring, Mineral County, Nevada, and, along with Dr. James Deacon (University of Nevada, Las Vegas), has reestablished a reproductive population in Hiko Spring, 7.5 km northeast of Crystal Springs (Baugh et al., 1980).

White River Speckled Dace
(Rhinichthys osculus velifer)

Specked dace was found in seven of nine strata and two isolated springs (Figure 1.2c). Seasonal estimates of adults (>35 mm FL) were variable; the greatest number generally occurred the in spring (Table 1.4). Dramatic seasonal fluctuations in population number are attributed to the species ability to proliferate under favorable conditions.

In the river, larvae were found in the fall, winter and spring indicating that reproduction occurs throughout most of the year, if not year round. Judging from the relative abundance of larvae and juveniles in winter, peak reproduction occurs in the fall and winter. The relatively high estimates for spring were probably fall and winter recruits reaching 35 mm FL by spring.

Two springs, Deacon Spring and Pedretti Seep, harbored reproductive populations of *R. o. velifer*. Numerical estimates were not made, but seasonal qualitative estimates suggested numbers declined in fall and winter in Deacon Spring, but remained relatively constant in Pedretti Seeps (Table 1.5).

Table 1.4. *(Continued)*

Strata	Roundtail Chub Adult	Roundtail Chub Juvenile	Spring-fish	Speckled Dace	Molly	Mosquito-fish	Convict Cichlid	Carp	Bullhead
VI. Ash Springs Outflow									
Summer	206	296		4,475	72,945	7,765	27,725	R	
Fall	129	117		2,950	22,200	8,365	17,000	R	
Winter	243	22		375	19,525	4,875	10,725	R	
Spring	237	31		6,050	26,350	10,700	23,000	R	
VII. Highland Channel									
Summer	3	6		2,758	239	R	314		
Fall	15	35		2,720	178	R	173		
Winter	5			54	367	R	R		
Spring	16			300	R	R	R		
VIII. East Ditch									
Summer	1	22		C	C	A	C	C	
Fall	Not Sampled								
Winter				R	R	A		C	
Spring		62		A	C	A	C	C	
IX. Alamo Reach									
Summer						A		C	C
Fall	Not Sampled								
Winter	Not Sampled								
Spring	Not Sampled								

Unidentified Speckled Dace
(Rhinichthys sp.)

A unique form of *Rhinichthys*, perhaps an undescribed species thought to have been extinct (Deacon and Pedretti[3], pers. com.), was found in Cottonwood North and L Springs, both are within the Pahranagat National Wildlife Refuge (Figure 1.2c). Quantitative estimates were not made, but minnow trapping and visual observation suggested that both populations were at a precariously low number (Table 1.5).

Shortfin Molly
(Poecilia mexicana)

Shortfin molly predominated strata V and VI in all seasons, and stratum III in the summer (Table 1.4, Figure 1.2d). Although there was substantial seasonal fluctuation, numbers remained high year round in strata V and VI. Shortfin molly was predominant in areas historically dominated by springfish (strata I and V).

Sailfin Molly
(Poecilia latipinna)

Only one sailfin molly was found, and it was trapped from Ash Springs in the fall of 1986 during a capture of exotic fishes for food habit analysis.

Mosquitofish
(Gambusia affinis)

Mosquitofish is the most widely distributed of Pahranagat River fishes; it occurred in every stratum (Fig-

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[3] Dr. James Deacon and John Pedretti, Department of Biology, University of Nevada, Las Vegas, NV. 89154.

Table 1.5. Relative abundance of fishes in eight isolated springs of the Pahranagat River drainage. Estimates are given as (A) abundant, (C) common, and (R) rare.

Spring	Speckled Dace	*Rhinichthys* sp.	Mosquitofish	Carp
Pedretti Seeps				
Summer	C		A	
Fall	C		A	
Winter	C		A	
Spring	C		A	
Deacon Spring				
Summer	C			
Fall	R			
Winter	R			
Spring	R			
Brownie Spring				
Summer				
Fall				
Winter				
Spring				
Cottonwood Spring				
Summer			A	
Fall			A	
Winter			C	
Spring			A	
Cottonwood Spring North				
Summer	Not Sampled			
Fall	Not Sampled			
Winter		R	A	
Spring		R	A	
Lone Tree Spring				
Summer			A	
Fall			A	
Winter			C	
Spring			A	
L Spring				
Summer	Not Sampled			
Fall	Not Sampled			
Winter		R	A	
Spring		R	A	
Maynard Spring				
Summer			A	R
Fall			A	R
Winter			A	R
Spring			A	R

ure 1.3a). It was probably the most numerous fish in the Pahranagat River system, predominating the cooler and more intermittent stream reaches (strata II, III, VIII, and IX); however, numerical estimates could not be made throughout its range.

Mosquitofish occurred in six isolated cool-water springs, including two which harbored a unique form of speckled dace (Cottonwood North and L Springs). Visual observation suggested large populations were maintained throughout the year in both springs (Table 1.5).

Convict Cichlid
(*Cichlasoma nigrofasciatum*)

Convict cichlid like shortfin molly is thermophilic in behavior, and hence had similar patterns of distribution (Figure 1.3b). It was found in seven strata, but were only in abundance near the headwaters of Crystal and Ash Springs (strata I, V, and VI; Table 1.4). In strata II and VII where the stream is conveyed in concrete ditches, convict cichlid was sparsely represented.

Cichlid numbers declined in winter and they were not found in strata II, III, and VIII. We attribute this seasonal reduction and apparent localized extirpation to a drop in water temperature. This species was not found in habitats where water temperature was below 16 °C. We witnessed what appeared to be complete cichlid mortality in stratum II following a period of reduced flow and cool atmospheric temperatures.

Carp
(*Cyprinus carpio*)

Carp was widespread throughout the Pahranagat Valley (Figure 1.3c), but it was rare in most of the strata (Table 1.4). The greatest carp abundances were in strata VIII and IX. It was also abundant in the lakes on the Pahranagat National Wildlife Refuge (Appendix B) and present in Maynard Springs.

Black Bullhead
(*Ictalurus melas*)

In the Pahranagat River, black bullhead occurred only in stratum IX, both upstream and downstream of the fish barrier 2 km north of Upper Pahranagat Lake (Figure 1.3d). It was also abundant in Upper Pahranagat Lake (Appendix B).

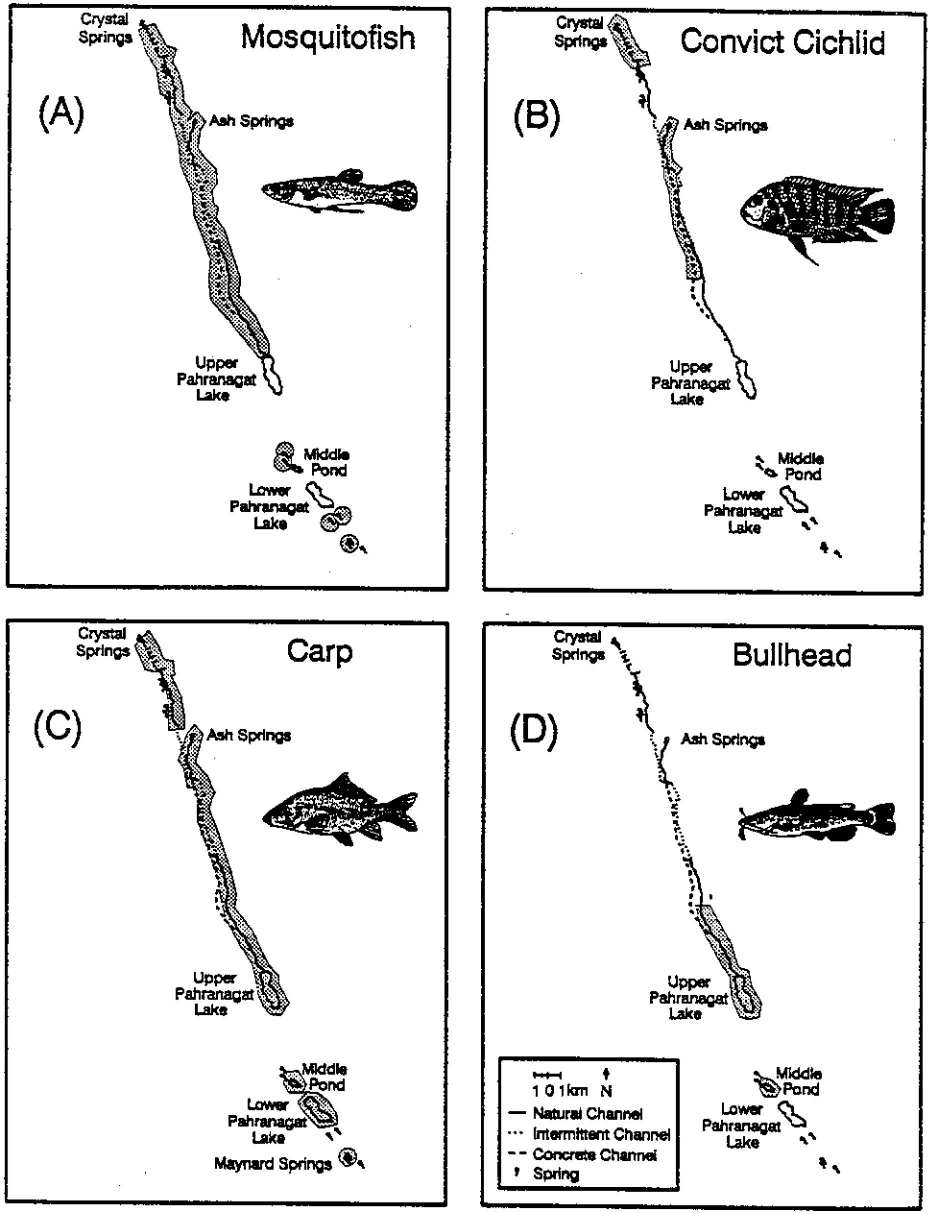

Fig. 1.3. Distribution of (A) mosquitofish, (B) convict cichlids, (C) carp, and (D) bullhead in the Pahranagat River system.

PART II

BIOLOGICAL PERSPECTIVE OF FISHES OCCURRING IN ASH SPRINGS POOL AND ASH SPRINGS OUTFLOW

Abstract. Seasonal abundance and distribution of fish populations in Ash Springs and 4.5 km of its immediate outflow were monitored from fall, 1986 to summer, 1989. Populations were generally highest in the spring and summer and lowest in the winter. There were no definitive seasonal trends in relative abundance of Pahranagat roundtail chub (*Gila robusta jordani*). There were seasonal distribution shifts in adult convict cichlid (*Cichlasoma nigrofasciatum*) and Pahranagat roundtail chub populations. Cool temperatures (20 ° C) caused a slight wintertime reduction in convict cichlid range while warm temperatures (31 ° C) caused many larger chub (>175 mm FL) to move downstream. In the summer, adult chub inhabited significantly ($p < 0.001$) deeper and slower water than in spring and winter; mean summertime active metabolism was about 75% of winter. Drift feeding was the primary mode of chub foraging; the rate was higher in winter (4.3 strikes/minute) than summer (1.3 strikes/minute) and was correlated with temperature.

In 1988, Pahranagat roundtail chub spawned from late January to mid May. Water depth of spawning sites ranged from 0.58 to 1.04 m, and near bed velocity ranged from 0.08 to 0.38 m/s. They broadcast eggs over gravel substrate in water temperature ranging from 17.0 to 24.5 ° C and dissolved oxygen ranging from 6.3 to 8.3 mg/L. Most larvae move between 1800 to 2400 hrs. Peak larvae emergence and emigration occurred on February 11, with an estimated 1232 passing the sampling station.

INTRODUCTION

The Pahranagat River has been drastically altered to provide irrigation water to bench land farms, and this has resulted in a dramatic reduction of habitat quality for native fishes. Much of the stream is dewatered during the irrigation season, and concrete channels replaced sections of the natural river. Only the 4.5 km channel downstream from Ash Springs (less than 10% of the natural stream channel) has perennial flow. This reach is refuge to the endangered Pahranagat roundtail chub (Hardy 1982), and it is here our research efforts were focused.

It was more difficult to define which environmental conditions were limiting for roundtail chub than for the two listed springfish in the Pahranagat River system. The chub has evolved around specific stream hydraulics and water temperatures for each life history stage; it has been demonstrated that springfish, however, will proliferate in a pool with suitable water temperature and chemistry and without exotic fishes (Mike Sevon [4], pers. com.). Thus, our research on Pahranagat River fishes emphasized roundtail chub.

Seasonal population number and distribution were monitored over a three year period for all fishes in Ash Springs pool and the Ash Springs outflow. Study objectives were to determine relative population stability and seasonal movement. This information may assist the fishery manager in developing plans to control exotic fishes; 1) if seasonal die-back of the thermophilic shortfin molly and convict cichlid occurs during the cool winter months, application of pesticide need only be made in Ash Spring and its immediate outflow 2) knowledge of seasonal distribution of chub may aid the manager in selecting a time for chemical treatment which would least jeopardize the chub population.

Seasonal habitat use was investigated for native and exotic fishes to determine habitat requirements and spatial and temporal interactions among species. The foraging behavior of roundtail chub was investigated to gain further insight into its hydraulic requirements. A preliminary study indicated to us that the chub was quite selective of stream habitat in which it foraged. In addition, we investigated Hardy's (1982) hypothesis that winter food abundance limited the population number.

Lastly, we investigated basic life history patterns among fishes with emphasis on the chub in Ash Springs and Ash Springs outflow.

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[4] Mike Sevon, Nevada Department of Wildlife, Fallon, Nevada, 89406.

STUDY AREA

The Pahranagat River drainage in Lincoln County, Nevada is situated at the southern edge of the Great Basin. Average annual precipitation is 22 cm, mostly in the form of rainfall. Predominant native vegetation includes pinyon and junipers in the mountains and greasewood and sage at lower elevations. The Pahranagat River drainage has had a long history of agricultural use. The Pahranagat Paiutes used the outflow of Crystal Spring for crop irrigation in the 1850's (Courtnay et. al. 1985). In the 1860's, the drainage was grazed heavily by livestock followed by the cultivation of row crops and orchards by Mormon settlers at the turn of the century. By the 1940's the primary form of agriculture reverted to livestock production with some feed crops raised and pasture irrigated (USDA 1940), which has continued to today.

The primary water sources for the Pahranagat River are two thermal springs, Crystal and Ash. Situated approximately 1165 m above sea level Crystal Spring discharges at 0.31 m^3/s and marks the river's beginning. Its discharge flows south about 10 km and joins the outflow of Ash Spring which contributes an additional 0.56 m^3/s. The combined flows travel another 21 km and discharge into Upper Pahranagat Lake at 1025 m above sea level. To accommodate irrigation needs, earthen and concrete conveyance channels have been constructed and most of the river bed is either dry during the irrigation season or has been obliterated through land leveling. Only about 20 km of the river channel remains and most of this has been rechanneled. A single relatively undisturbed reach (Ash Springs outflow), 4.5 km in length persists. It has a thick riparian corridor of ash, cottonwood, and willow, and is probably representative of the historic riparian corridor.

Prior to water diversion, the Pahranagat River flowed approximately 60 km, traversed marshlands and eventually discharged into Maynard Lake, the river's terminus. Maynard Lake dried in the 1960's (Dr. James Deacon[5], pers. com.) and the river now discharges into a series of three manmade lakes on Pahranagat National Wildlife Refuge (PNWR). These lakes receive most of the river's flow outside the irrigation season (October 16 through March 14), and receives a limited flow of agriculture return water during the irrigation season. Encompassing 2177 hectares, PNWR is managed for waterfowl.

The Pahranagat River is a relic of the pluvial White River. Physiographic evidence suggests that the White River originated in the eastern slopes of the White Mountains in Central Nevada, traveled south approximately 325 km and discharged into the Virgin River and thence the Colorado River (Hubbs and Miller 1948). The White River is now represented by perennial springs occurring intermittently along its historic course. The endemic ichthyofauna of the Pahranagat River and other relic springs systems of the White River drainage gives zoogeographic testimony to its historic link to the Colorado River (Gilbert 1893; Hubbs and Miller 1948): roundtail chub (*Gila robusta*), spinedace (*Lepidomeda*), and desert sucker (*Catostomus clarki*) are common to both. There are, however, two genera (*Moapa* and *Crenichthys*) unique to the White River drainage, suggesting some degree of isolation. Hubbs and Miller (1948) speculated that the swift water of the Colorado River or a physical barrier near the White River's terminus restricted fish passage.

GENERAL MATERIALS AND METHODS

Seasonal Abundance and Distribution

Adult population number was estimated seasonally from the fall of 1986 through the summer of 1989. In Ash Springs estimates were made by snorkel-counting fishes within a 1.0 m wide transect at 20.0 m intervals across the width of the pool. To hold direction while snorkeling a string was drawn across the pool, and a meter stick was used to gauge transect width. The average of two counts at each transect was multiplied by 20 to represent a 20 m pool length, and these were summed to estimate total pool population. Estimates in Ash Springs outflow were made by snorkel-counting fishes in 10.0 m long transects at 500 m intervals, and expanding the data. Determination of the seasonal number of Pahranagat roundtail chub differed from the aforementioned procedures; direct counts were made by snorkeling the entire Ash Springs pool and outflow. The chub count required two days and it was assumed that fishes were not transient during this period. Only adults (> 100 mm FL) and juveniles (25 mm to 100 mm FL) were counted.

To quantify seasonal distribution, relative abundance of fishes in Ash Springs pool was contrasted with Ash Springs outflow. Further, Ash Springs outflow (Stratum VI, Section I) was divided into three substrata (Figure 2.1) based on differing physical characteristics (Table 2.1).

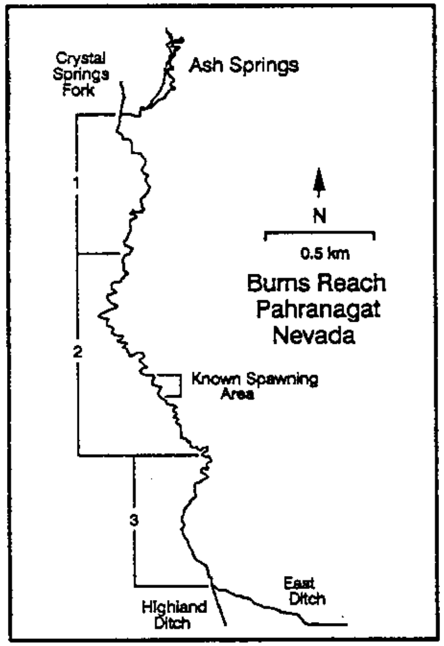

Fig. 2.1. Three selected substrata of the Ash Springs outflow.

Water temperature and dissolved oxygen were monitored to assess their influence on species distribution. Measurements were taken with a YSI model 57 dissolved oxygen and temperature meter, and consisted of spot samples taken each season over three years. To determine daily temperature and dissolved oxygen fluctuations during extremes, diel monitoring was performed in the summer of 1986 and winter 1988.

Habitat Use

We snorkeled upstream at nine selected 100 m stream reaches until an individual or a group of chub was encountered, and made depth and flow measurements for each fish; care was taken to collect data only on fish undisturbed by our presence. Depth and velocity measurements were taken with a Marsh-McBirney model 201D water current meter mounted on a calibrated wading rod. Individual fish size was estimated with the wading rod. The five parameters used to define habitat were as follows:

1. Total depth- distance from stream surface to bottom and traversing the plane of object fish.
2. Focal point depth- distance from object fish to stream bottom.
3. Mean velocity- mean water column velocity.
4. Focal point velocity- velocity at site of object fish.
5. Relative depth- focal point depth as a percent of total depth.

BIOLOGY OF FISHES

Pahranagat Roundtail Chub
(Gila robusta jordani)

Roundtail chub (*Gila robusta*) is known from small and large tributaries of the Colorado River (Lee et al. 1980). The exception is the Pahranagat roundtail chub (*Gila robusta jordani*). Endemic to the Pahranagat River, the population has been isolated from the Colorado since pluvial times (10,000 years).

Table 2.1. Physical description of three selected substrata of the Ash Springs outflow.

Substratum	Location	Length (km)	Shade (% cover)	Substrate (%)	Gradient
1	Confluence of Crystal and Ash Springs outflows to 1.4 km downstream	1.4	90	50 % sand 50 % silt	Low
2	1.4 to 3.4 km	2.0	80	25 % cobble 50 % gravel 25 % sand	Moderate to High
3	3.4 km to Highland Channel	1.1	60	75 % sand 25 % silt	Low

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[5] Dr. James Deacon, Department of Biology, University of Nevada, Las Vegas, NV. 89154.

The Pahranagat roundtail chub is close to extinction. Because of its relative scarcity little information had been generated as to its habitat requirements and life history patterns. Hardy (1982) estimated only 37 to 45 adults remaining and these inhabited a single large pool in the lower reaches of the Ash Springs outflow.

Members of the *Gila robusta* complex are omnivorous (Minckley 1973). Hardy (1982) hypothesized that Pahranagat roundtail chub is similar to what Vanicek and Kramer (1969) found in the Colorado chub (*Gila robusta robusta*) and Greger (1982) found in the Virgin River chub (*Gila robusta seminuda*): adults feed primarily on invertebrates and vegetative matter while juveniles are insectivorous. Hardy (1982) found adult roundtail chub relegated to a single large pool in the lower reach of Ash Springs outflow. He speculated that Pahranagat roundtail chub spawns in February and March. Little else was known of Pahranagat roundtail chub biology.

Seasonal Abundance and Distribution

Few chub occurred in Ash Springs pool. Number of adults in Ash Springs outflow, however, ranged from 129 in the fall of 1986 to 252 in the summer of 1987 (Figure 2.2). There was no definitive seasonal pattern, but the fall counts were generally lowest and the summer highest. Counts were lowest during the second year of the study. Juveniles were most abundant in the spring and summer with the greatest number (411) occurring in the summer of 1988, bringing the total chub count to 594.

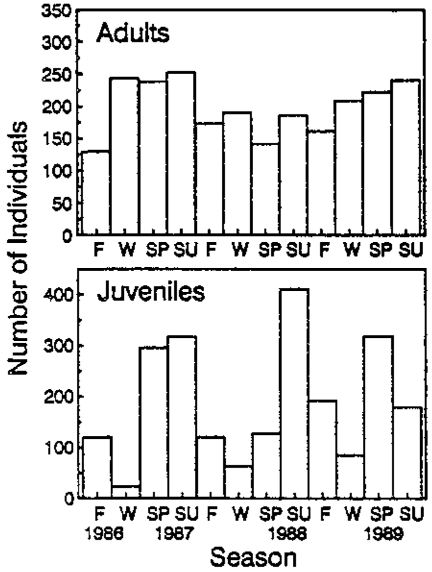

Fig. 2.2. Number of adult and juvenile Pahranagat roundtail chub in the Ash Springs outflow from fall, 1986 to summer, 1989.

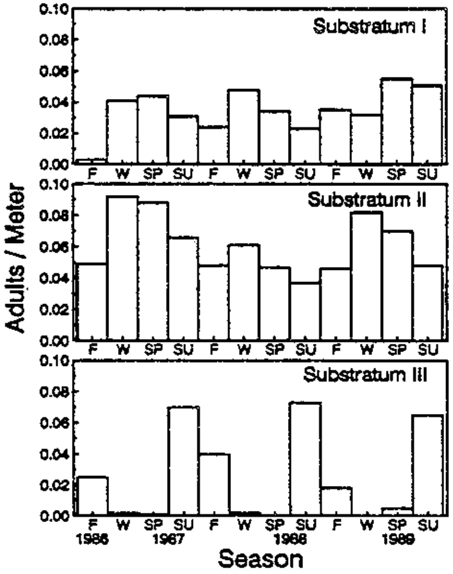

Fig. 2.3. Seasonal densities of adult Pahranagat roundtail chub in three selected substrata of the Ash Springs outflow from fall, 1986 to summer, 1989.

There was a marked change in adult seasonal distribution. Chub density was greatest in substratum II in the fall, winter, and spring (Figure 2.3). During the summer, substratum III generally had the greatest density of adults, with large fish concentrated in two large and deep pools in its lower reaches. Substratum III was virtually devoid of chub in the winter and spring. This obvious summer shift to substratum III appeared to be temperature related, with many of the larger adults moving downstream to slightly cooler water. Figure 2.4 illustrates the summer temperatures and dissolved oxygen concentrations Pahranagat roundtail chub were subjected to over a 24-hour period at two stations along the study reach. Measurements were taken at 4 hour intervals on August 26 and 27, 1986. The upper station marked the upper reach of substratum I while the lower station marked the lower reach of substratum III.

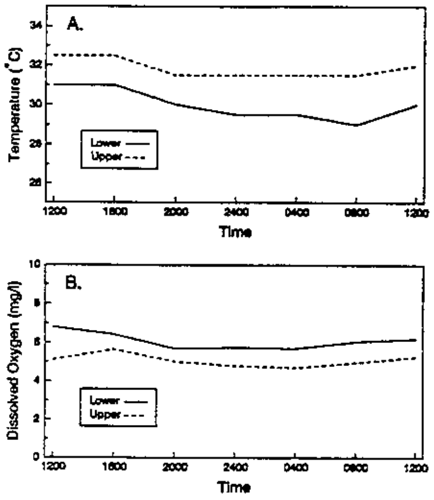

Fig. 2.4. Diel temperatures (A) and dissolved oxygen (B) taken in the upper reaches (substratum 1) and the lower reaches (substratum 3) of the Ash Springs outflow.

Warm temperatures at both stations are probably stressful for Pahranagat roundtail chub; however, the lower station (with a range of 29.0 to 31.0 °C) appeared somewhat more tolerable than the upper station (with a range of 31.5 to 32.5 °C). In the Moapa River system roundtail chub had access to areas with annual temperatures ranging from 14.0 to 31.0 °C; they occurred in areas with temperatures of 15.0 to 30.0 °C, but were most frequently captured where temperatures were 16.0 to 27.5 °C (Deacon and Bradely 1972; Cross 1978). Schumann (1978) estimated juvenile Moapa River and Virgin River roundtail chub to have a temperature optimum of 23.0 °C.

Results of the aforementioned studies suggest that the fall and winter seasons offer the best chub temperatures in the Ash Spring outflow. Daytime temperatures taken at the upper and lower reaches of the Ash Springs outflow ranged seasonably as follows:

summer:	29.2 - 32.2 °C
fall:	22.8 - 25.7 °C
winter:	18.0 - 26.1 °C
spring:	26.2 - 28.2 °C

Hardy (1982) also concluded that warm temperature was stressful for Pahranagat roundtail chub and affected distribution. Hardy suggested, however, that the adult population was confined to a single pool in the lower reaches of our substratum III and, except for spawning, did not display a seasonal movement pattern. We suspect that Hardy (1982) accounted for fewer adult chub than did we because he was unfamiliar with the seasonal movement pattern of adults. In the summer the larger chub moved downstream to slightly cooler water. However, resource constraints (food and space) relegated many adults to occupy habitat further upstream. Substratum II apparently provided the best chub habitat, and except for summer, most adults occurred there.

There was no consistent pattern in seasonal distribution in substratum I. We attribute this inpart to an intermittent occurrence of enhanced foraging opportunity in cool water from the inflow of Crystal Springs. We found periods when thousands of ostracods and other invertebrates were carried into substratum I during the winter months. In the summer there were occasional pockets of cool water caused by irrigation runoff from the adjacent pasture; fish would congregate in these areas, and forage on drift carried by the runoff.

Habitat Use

Adult (>100 mm) and juvenile chub (25 to 100 mm)typically inhabited pools below a riffle, but adults were found in deeper pools, closer to the stream bottom, and in faster water. Larvae (<25 mm)occurred in slack water, near the water surface, and along the stream's edge. For all seasons combined, adults occurred in mean water column depths ranging from 0.4 to 1.4 m with a mean of 0.8 m (Table 2.5). Adult focal point depth ranged from 0.0 to 0.4 m, and a mean of 0.1 m. Relative depth suggested adults were in close proximity to the bottom, most within the lower 20% of the water column, while larvae were generally closer to the surface (in the upper 80 to 100% of the water column). Adults occurred in mean water velocities ranging from 0.00 to 0.80 m/s with a mean of 0.32 m/s. Adult focal point velocity ranged from 0.00 to 0.50 m/s and a mean of 0.18 m/s.

To determine if habitat use was significantly different among the three life stages analysis of variance was employed; there was a significant difference ($p<0.001$) for each of the five habitat parameters tested. This apparent division in habitat segregation supports Moyle and Vondracek's (1985) contention that, in stream fish assemblages with low diversity, juveniles and larvae function ecologically as separate

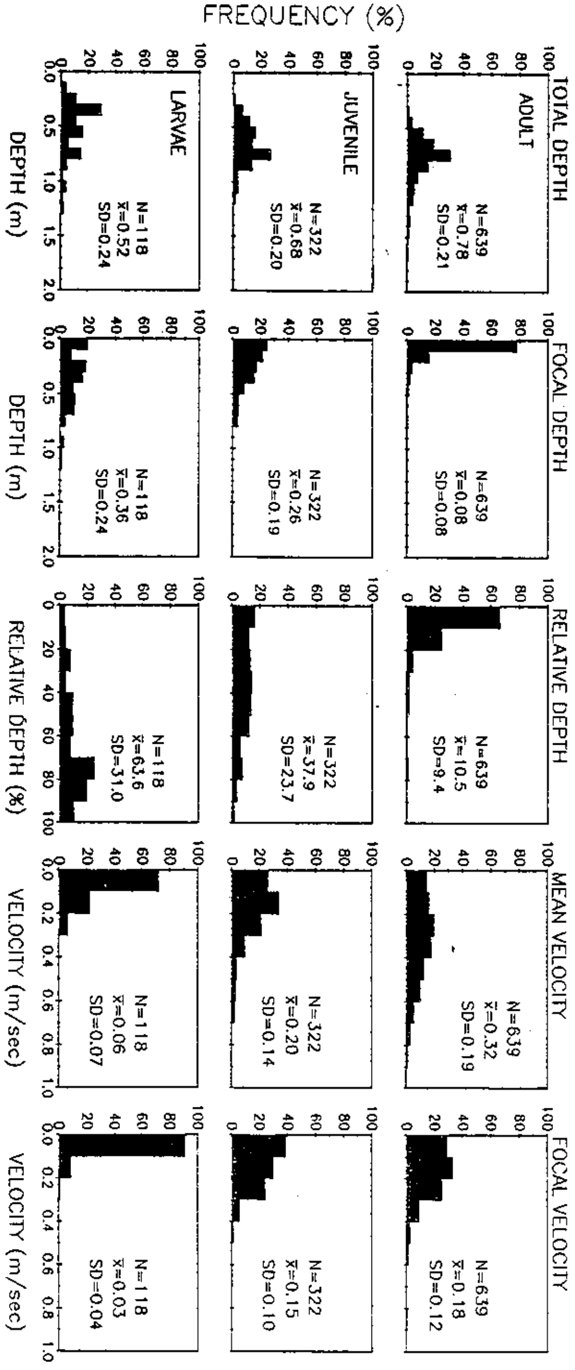

Fig. 2.5. Habitat use in terms of spatial relationship for three life stages of Pahranagat roundtail chub in the Ash Springs outflow.

Table 2.2. Habitat preference of adult Pahranagat roundtail chub in the Ash Springs outflow from fall, 1986 to summer, 1989.

Season	Size (mm)	Total Depth (m)	Focal Depth (m)	Relative Depth (%)	Mean Stream Velocity (m/sec)	Focal Velocity (m/sec)
Summer						
Mean	161	0.82	0.11	12.9	0.25	0.14
SD	29	0.26	0.11	12.1	0.18	0.10
Fall						
Mean	157	0.84	0.08	10.1	0.32	0.18
SD	28	0.20	0.06	7.8	0.18	0.11
Winter						
Mean	158	0.73	0.07	9.1	0.37	0.19
SD	34	0.14	0.05	7.0	0.20	0.11
Spring						
Mean	151	0.73	0.07	9.2	0.36	0.20
SD	27	0.17	0.07	8.1	0.19	0.13

species. This concept is important for future habitat acquisition, development and management.

Adult habitat use was quantified seasonally from the fall of 1986 through the summer of 1989. Adults occupied significantly ($p < 0.001$) deeper and slower water in the summer than in spring and winter (Table 2.2). This shift to lower velocity is partially attributed to reduced summer flow but it may in part be a behavioral response to increase metabolic demands of warmer water. Correlative to inhabiting slower water velocity in the summer there was an apparent reduction in active metabolism. We monitored this by counting tail beats of adults seasonally from the fall of 1988 to the summer of 1989. This method has been proven to give a reasonably accurate account of energy expended due to active metabolism (Soofiani and Hawkins 1985). The mean summer tail beats were only 75% of winter (Table 2.3).

Habitat shift due to energetic demands has been documented for steelhead trout (Smith and Li 1983). Contrary to our findings, however, steelhead trout moved into faster water during low flow and high temperatures. These diametrically opposite responses to increased temperature may be the result of grossly different basal metabolic requirements. Smith and Li speculated that steelhead trout moved into faster water to encounter more prey, and thus meet requirements of an elevated basal metabolic demand, but sufficient forage must be secured to satisfy the increased demands of their increased active metabolism as well. Cyprinids as a group have a basal rate substantially lower than salmonids (Alley 1977; Brett and Groves 1979); hence, they may move into slower water to reduce energy expenditure and become more selective in their foraging.

Foraging

We observed Pahranagat roundtail chub foraging behavior at nine selected stations along the Burn's reach. Visual observations were made using mask and snorkel. Foraging activity was classified into three categories: drift feeding (striking at potential food items in the water column), pecking at substrate (ap-

Table 2.3. Relative seasonal energy expenditure in terms of tail beats per minute for adult Pahranagat roundtail chub in the Ash Springs outflow from fall, 1988 to summer, 1989.

Season	Number	Tail Beats/Minute	
		Mean	SD
Summer	149	85.4	25.9
Fall	32	90.5	37.3
Winter	47	113.8	32.2
Spring	31	97.0	30.9
Total	259	92.2	31.2

parent indiscriminate bites at the surface of branches or substrate), and piscivory (striking at fish).

To quantify the mechanics of drift feeding behavior, the primary method of chub foraging, the following parameters were measured:

1. distance object fish traveled to strike at prey
2. direction object fish traveled in relationship to stream flow to strike at prey
3. water velocity object fish traveled from to strikeat prey
4. water velocity at focal point of object fish strike
5. water depth object fish traveled from to strike at prey
6. water depth at terminus of strike.

Measurements were made by marking the object fish's focal starting and ending point with numbered nails. Focal depth starting and striking points were taken with a calibrated wading rod at the time nails were placed. Water velocities at focal starting and striking points were taken with a Marsh-McBirney model 201D water current meter.

Foraging rate was quantified by observing the feeding rate of an individual for 30 seconds and enumerating strikes at prey items and pecks at the substrate. The influence of relative drift abundance on foraging rate was determined by placing a 200 micron mesh net (48 cm wide and 23 cm deep) immediately upstream of foraging chub and immediately after their foraging rates had been quantified. The net was set for five minutes. Water volume screened was estimated by multiplying velocity entering the net by area of its mouth. Mean water velocity was measured by placing the probe of a Marsh-McBirney model 201D water current meter at two equally spaced points within the net mouth. Drift abundance per unit volume over time was expanded to stream flow.

Foraging Behavior

Roundtail chub distribution was patchy, suggesting specificity in foraging habitat. Chub typically congregated in pools fed by a chute. Fallen trees or branches were common to these selected areas (drift stations), and served to increase water turbulence. We hypothesize that the distinctive hydraulic conditions to which they were attracted enhanced prey encounter rate while allowing for minimal energy expenditure. Similarly, Smith and Li (1983) suggested steelhead habitat selection was directed by energetic advantage.

While foraging from a drift station, chub typically held near the stream bottom and oriented into the current. Vertical strike direction was most frequently upward with a mean attack angle of 14.4 degrees (Figure 2.6a). Horizontal strike direction was more random, but strikes directly into the stream current (0 degrees) occurred most frequently (Figure 2.6b). Strike distance ranged from 0.05 to 0.82 m with a mean of 0.18 m (Figure 2.6c). Chub generally entered slightly faster water velocities when striking at a food item (Figure 2.6d).

Foraging Rate

Piscivory was the least frequent method of foraging; only one chub was observed to successfully consume another fish (mosquitofish). More common but still infrequent was pecking; we observed an average of 0.2 peck/min per adult fish for all seasons combined (Table 2.4). Drift feeding was the primary mode of foraging, with a mean of 3.1 strikes/min per adult for all seasons combined. Strike rates differed significantly ($p < 0.001$) for the three life stages with larvae having the greatest mean rate (12.5 strikes/min), followed by juveniles (8.8 strikes/min) and adults (3.1 strikes/min).

There were significant differences ($p < 0.001$) within seasonal rate of adult drift feeding. The highest frequency (4.3 strikes/min) occurred in the winter while the lowest in the summer (1.3 strikes/min). Associated with the lower summer strike rates was a reduced amount of summer drift (Table 2.5). We hypothesize summer to be a period of austerity for adults, characterized by high metabolic demands and low drift availability.

Drift feeding rate was not correlated with relative drift abundance for two size classes of adults (Figure 2.7). There was, however, a correlation between drift rate and water temperature for adults 175 -250 mm FL (Figure 2.8). Under the metabolic demands of warm water temperature, large chub may be more selective, opting for bigger and energetically more efficient prey items. During the cooler winter season smaller prey items require less active metabolic energy to retrieve.

Reproduction

In December 1986, we began snorkeling the Ash Spring outflow at least once a week to locate spawning chub and quantify their spawning behavior and habitat requirements. Once spawning chub were located measurements of selected habitat were quantified; these measurements included:

1. Water depth- taken where eggs were deposited
2. Mean water column velocity- taken where eggs were deposited
3. Nearbed velocity- taken where eggs were deposited
4. Water temperature
5. Dissolved oxygen.

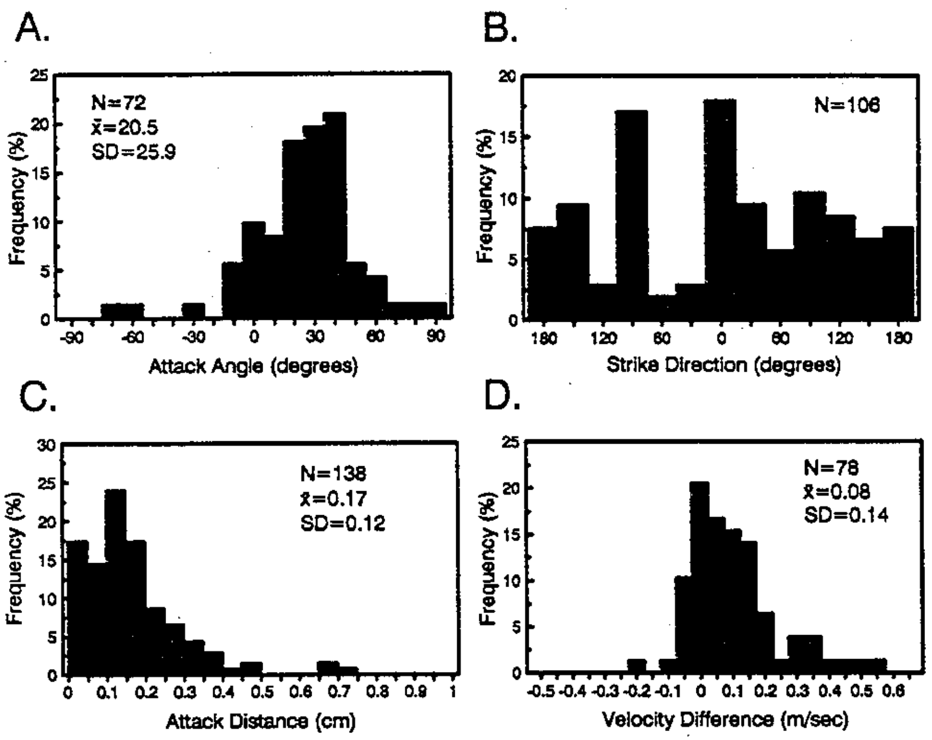

Fig. 2.6. Mechanics of Pahranagat roundtail chub drift feeding in the Ash Springs outflow: (A) vertical attack angle, (B) horizontal strike direction, (C) total distance traveled during the strike, and (D) velocity difference between the point of origin and the destination of the strike.

Water velocity was measured with a Marsh-McBirney model 201D flow meter mounted on a calibrated wading rod which was used to measure water depth. Dissolved oxygen and temperature was measured with a YSI model 57 dissolved oxygen meter. Spawning areas were monitored for three seasons (1987 through 1989). The most intensive observations were made in 1988; each site was visited at three-day intervals and observations made in the morning, noon, and late afternoon. These frequent visits were an attempt to quantify the time of peak spawning activity; it is probable, however, that most spawning occurred at night.

In 1988, larvae emergence and emigration were monitored throughout the spawning season. This was accomplished by setting a drift net downstream of the reproductive areas and approximately 1,400 m upstream of the Highland Channel. The net was 0.5-mm mesh, had a rectangular mouth 43.2 cm deep and 30.5 cm wide, and was 115 cm long; the collection bucket was 3.8 cm wide and 10.2 cm long and lined with 0.5-mm mesh plastic screen. To prevent damage to the larvae, nets were only fished for five-minute periods. Time of day when emigration occurred was determined by conducting weekly diels with nets set for five minutes at four-hour intervals. To quantify larvae passing the sampling station, nets were fished from 1800 to 2400 hrs, four times per hour at three day intervals; the number of larvae entering the net per unit water volume

Table 2.4. Seasonal feeding rates of larval, juvenile, and adult Pahranagat roundtail chub in the Ash Springs outflow from fall, 1986 to summer, 1989.

Season	N	Strikes (strikes/min.) Mean	SD	Pecks (pecks/min) Mean	SD
Larvae					
Spring	61	12.5	6.0	N/A	N/A
Juvenile					
Summer	144	8.5	5.5	0.1	0.6
Fall	56	6.7	4.9	0.1	0.4
Winter	25	6.8	4.3	0.0	0.0
Spring	83	12.1	6.8	0.2	1.1
Total	308	8.8	6.0	0.1	0.7
Adult					
Summer	167	1.3	1.9	0.1	0.3
Fall	116	2.5	2.9	0.1	0.2
Winter	135	4.3	3.9	0.2	0.8
Spring	139	3.2	3.4	0.2	0.9
Total	557	3.1	3.4	0.2	0.8

was expanded for total stream flow. Water velocity entering the net was determined by placing the probe of a Marsh-McBirney model 201D water current meter at the center of the net's mouth. Chub larvae were identified through a process of elimination. Only two other cyprinids, carp and speckled dace, occur in the Pahranagat River besides chub. Carp larvae were eliminated by their small size (only 5 mm TL), and we developed a facility for identifying speckled dace by studying larvae captured in isolated springs. Presumed chub larvae were 9 mm TL, 2 mm larger than dace larvae, and had substantially fewer chromatophores. Captured larvae were placed in a shallow plastic container, identified as to species, and then released downstream from the netting station.

Spawning Habitat and Behavior

From 1987 through 1989 spawning was observed at three sites approximately 1,500 to 1,700 m upstream of Highland Channel (Figure 2.1). Congregations of spawners, ranging from about 100 to 300 mm FL, were first observed in mid-January but spawning was not observed until late January. Peak day time spawning occurred during early to mid February. Although congregations persisted through March of each year, no spawning was witnessed after mid February. In May 1988 spawning congregations appeared to have convened again at two of the spawning sites, but no spawning activity was observed. Subsequent larvae sampling indicated that reproduction occurred into May.

Sexes were distinguished by their reproductive behavior which was similar to other cyprinids (Moyle 1976). The persistent and insistent behavior of most fish in the spawning congregation suggested that they were males. The few females received substantial attention in the form of male pursuit. When ready to spawn the female swam down to the graveled bottom were she was attended by two or more males; at times ten or more. There was a violent vibration of the spawning groups lasting from three to six seconds. After the spawning act, the female generally swam up and was harassed and pursued by males until ready to spawn again. It was our impression that females only appeared at the spawning site when prepared to spawn, which probably occurred intermittently over several days.

Eggs were broadcast over gravel substrate and apparently fell into the interstices; they were found by removing pieces of gravel or stirring the gravel which caused them to float into a plankton net. Convict cichlid and speckled dace were observed picking at the spawning beds, presumably in search of eggs.

Spawning occurred in relatively fast water in gravel bottom pools. Water depth of observed spawning activity ranged from 0.58 to 1.04 m. Mean water column velocity ranged from 0.08 to 0.54 m/s while near bed velocity ranged from 0.08 to 0.38 m/s. Water temperature in January and February ranged from 17.0 to 24.5 °C and dissolved oxygen from 6.3 to 8.3 mg/l. In May 1988 water temperature ranged from 24.0 to 29.0 °C and dissolved oxygen from 5.2 to 6.3 mg/l.

Table 2.5. Seasonal abundance (items per minute) of invertebrate drift in three selected substrata of the Ash Springs outflow.

Season	Substratum 1	2	3
Summer	116	55	227
Fall	139	289	233
Winter	880	156	203
Spring	175	126	99

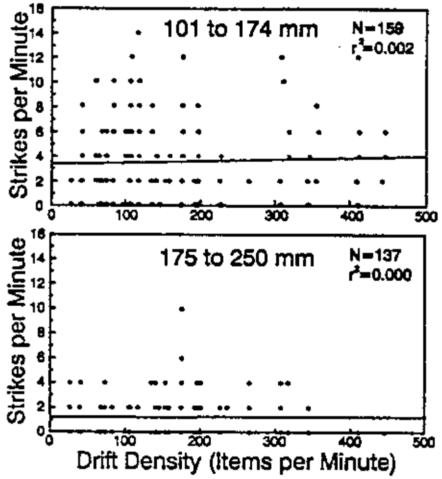

Fig. 2.7. Strike rate versus invertebrate drift abundance for two size classes of adult Pahranagat roundtail chub in the Ash Springs outflow.

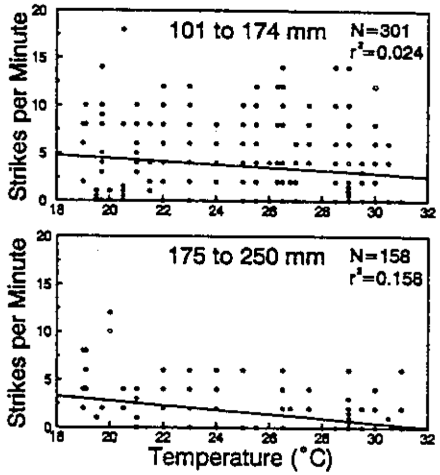

Fig. 2.8. Strike rate versus temperature for two size classes of adult Pahranagat roundtail chub in the Ash Springs outflow.

Larvae Emergence and Emigration

In 1988, larvae sampling began on January 14 immediately after spawning congregation were observed to have formed. Chub larvae were first captured February 11 and peak captures occurred on February 13 with an estimated 1,232 larvae passing the sampling station from 1800 to 2400 hrs (Figure 2.9). Only one larva was captured after March 3 and sampling was curtailed on March 14. Most captures occurred between 1900 and 2000 hrs and none after 2300 hrs (Figure 2.10). Our diel sampling suggested that most if not all larvae moved between 1800 to 2400 hrs; thus our estimates are probably representative of the total number passing our station in a given day.

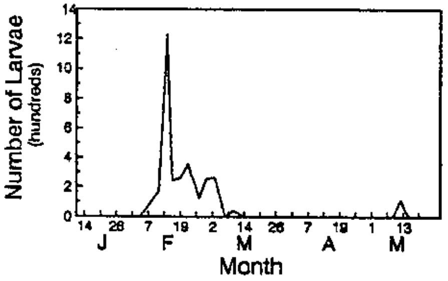

Fig. 2.9. Emigration of swim-up Pahranagat roundtail chub larvae in the Ash Springs outflow from late winter to early spring, 1988.

On May 2, 1988, congregations of chub were found on two of the spawning sites, but no spawning was observed; plankton netting was resumed on May 5 and fished weekly. Larvae were captured on May 12 with an estimated 225 passing our station. None was captured on May 19 and sampling was again terminated on May 26.

White River Springfish
(Crenichthys baileyi baileyi)

The genus *Crenichthys* is unique to the White River system and adjacent drainage. It is represented by two species, Railroad Valley springfish (*Crenichthys nevadae*) and White River springfish (*Crenichthys baileyi*), which is represented by five subspecies (Williams and Wilde 1982). Two subspecies occurred in the Pahranagat River, Hiko White River springfish (*C. b. grandis*) and White River springfish (*C. b. baileyi*). At-

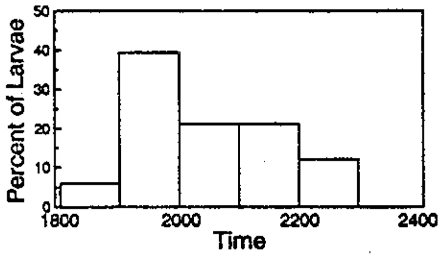

Fig. 2.10. Capture success of Pahranagat roundtail chub larvae in the Ash Springs outflow from 1800 to 2400 hours.

tention was focused on *C. b. baileyi* because it was endemic to the study area. It has been previously documented as localized in distribution. In 1938 it was reported as common in Ash Springs pool to about 12 km downstream; by 1959 it was reported common in Ash Springs pool and in moderate numbers to several km downstream (Miller and Hubbs 1960). By 1981, it was rare in Ash Springs pool (Don Sada[6], pers. com.) and scarce in the Ash Springs outflow (Hardy 1982).

Seasonal Abundance and Distribution

Few springfish were observed in the Ash Springs outflow; no more than three were sighted in any one season in three years of study (Figure 2.11). An individual was observed as far downstream as the lower reach of substratum III. Virtually the entire White River springfish population occurred in Ash Springs pool. Estimates varied considerably over the three year study and ranged from 1,050 in the fall of 1986 to 2,685 in the winter of 1988. Only adults (> 25 mm TL) were counted. There was no apparent seasonal pattern for abundance.

Habitat Use

Adult White River springfish were found in a wide range of total water depths (Figure 2.12), reflective of the wide range of depths available in Ash Springs pool. Focal depth (depth from bottom) and relative depth (percent of total water depth) suggest the majority were closer to the bottom. Juveniles (10 to 25 mm TL) and larvae (< 10 mm TL) generally occurred in shallower water, and were more vertically dispersed than adults. Virtually all springfish occurred in pool habitat at zero velocity. We observed few springfish larvae.

White River Speckled Dace
(Rhinichthys osculus velifer)

Specked dace within the White River drainage were given a common subspecies designation, *R. o. velifer* (La Rivers 1962). They were first collected from the Pahranagat River in 1891 (Gilbert 1893).

In 1981, Hardy (1982) estimated 1500 occurred in the Ash Springs outflow. In the mid-1980's the population appeared sufficiently depressed for endangered species listing consideration.

Seasonal Abundance and Distribution

No speckled dace were observed in Ash Springs pool, but were seasonally abundant in the outflow. There were dramatic shifts in population size with estimates ranging from 10 adults (>35 mm FL) in the winter of 1988 to 6,200 in the summer 1987 (Figure 2.13). Estimates were highest for spring and summer and lowest in winter.

Dace were most abundant in the lower reaches of Ash Springs outflow (Figure 2.14). The greatest densities typically occurred in substratum II. There was no apparent seasonal movement between substrata as was noted for chub.

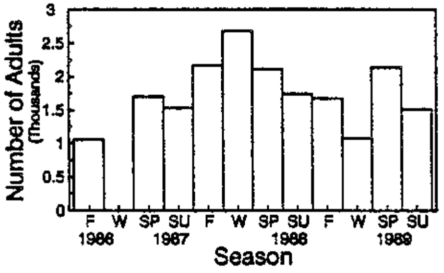

Fig. 2.11. Seasonal fluctuations of adult White River springfish in Ash Springs from fall, 1986 to summer, 1989.

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[6] Don Sada, former USFWS Biologist, Great Basin Complex, Reno, NV. 89502.

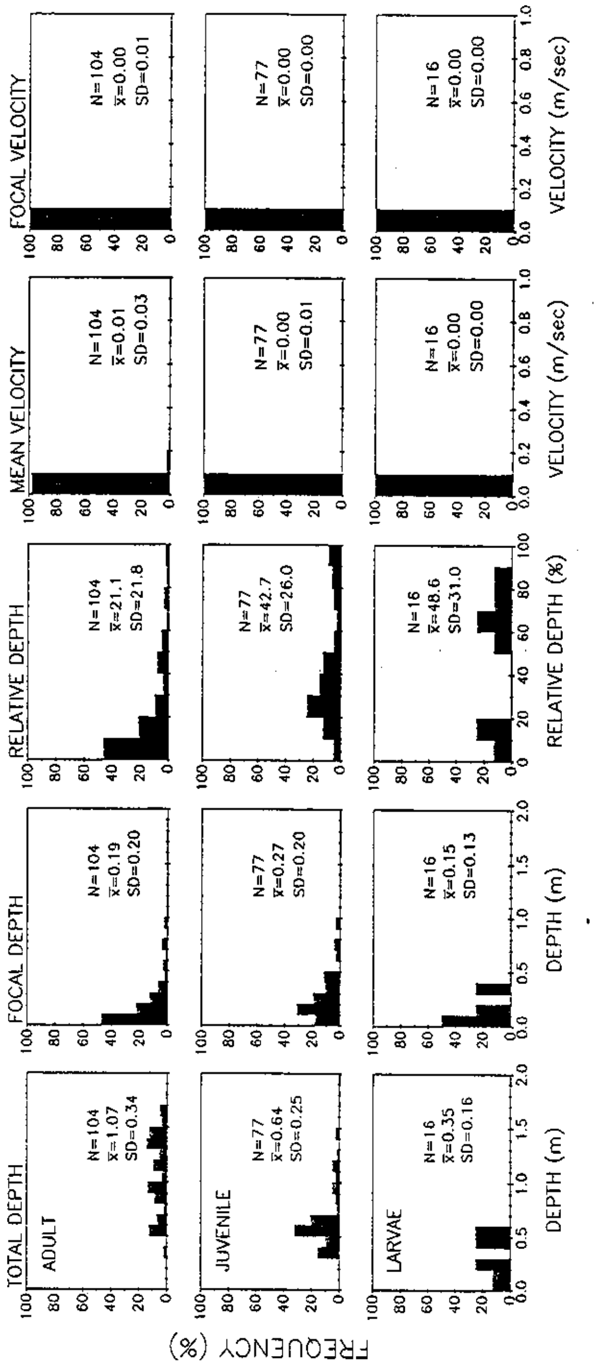

Fig. 2.12. Habitat use in terms of spatial relationship for three life stages of White River springfish in Ash Springs.

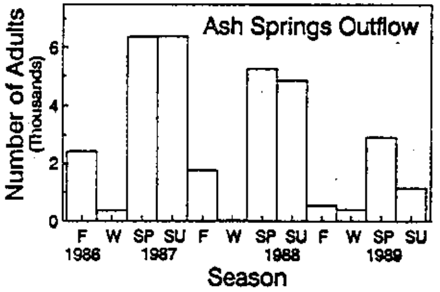

Fig. 2.13. Seasonal fluctuations of adult White River speckled dace in the Ash Springs outflow from all, 1986 to summer, 1989.

Habitat Use

Although speckled dace occupied a wide habitat ariety throughout the Pahranagat River system, we oncentrated on the Ash Springs outflow. There, dults (>35 mm FL) occupied a mean total depth of .60 m, a mean focal depth of 0.15 m, and mean occurence in the water column was 23 % from the bottom Figure 2.15). Mean water column velocity was 0.18 m/s nd focal velocity was 0.12 m/s. Juveniles (15 to 35 mm L) occupied shallower water, higher in the water olumn, and in lower velocities. Larvae (<15 mm FL) vere found in shallow slack water, and occupied a road range of the vertical water column.

Adult dace were somewhat specific in habitat use in he Ash Springs outflow. In the rest of the valley, they sed a broad range of habitats from shallow springs to wift moving water. Perhaps their apparent specificity n the Ash Springs outflow is due to either the resident ish assemblage or a response to warm water temperaures. In any case, its adaptability enabled it to be the nost abundant native fish in the river system.

Shortfin Molly
(Poecilia mexicana)

Endemic to Central America, the shortfin molly has ecome established in several western states (Courenay et al. 1985, Lee et al. 1981). It is popular in the quaria trade, and most introductions are attributed to wner's release of unwanted fish pets. Shortfin molly vas first collected from Ash Springs in 1963 along with ailfin molly and convict cichlid (Deacon et al. 1964).

Since the introductions the *C. b. baileyi* population has declined dramatically (Courtenay et al., 1985). Associated parasitism and negative interactive behavior with exotics were hypothesized as causing their decline.

The apparent negative impact exotic fishes had on Pahranagat White River springfish directed our research effort to determining means of their extirpation from Ash Springs with minimal impact to the native fishes.

To this end, we tested the hypothesis that the thermophilic shortfin molly moves upstream to the warmth of Ash Springs pool (32° C) during the fall and winter when Ash Springs outflow water temperatures falls below 20 °C. If there is a pattern of restrictive seasonal temperatures, localized treatment of a fish pesticide may be a control for shortfin molly.

Seasonal Abundance and Distribution

Estimated number of adults (>25 mm TL) in Ash Springs pool ranged from 7,000 in the winter of 1987 to 40,000 in the spring 1988 (Figure 2.16). In Ash Springs outflow estimates ranged from 11,000 to 28,000 adults. In both areas, high estimates were in the summer while

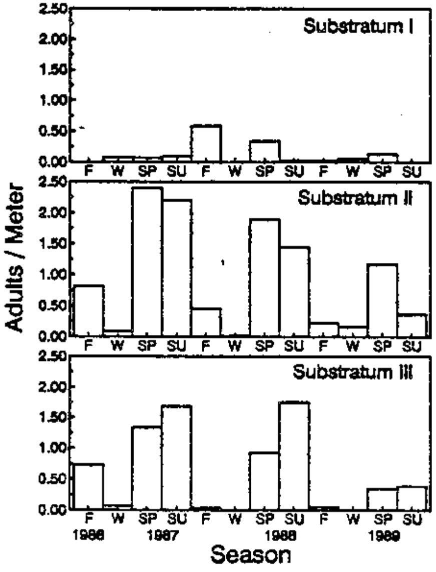

Fig. 2.14. Seasonal densities of adult White River speckled dace in three selected substrata of the Ash Springs outflow from fall, 1986 to summer, 1989.

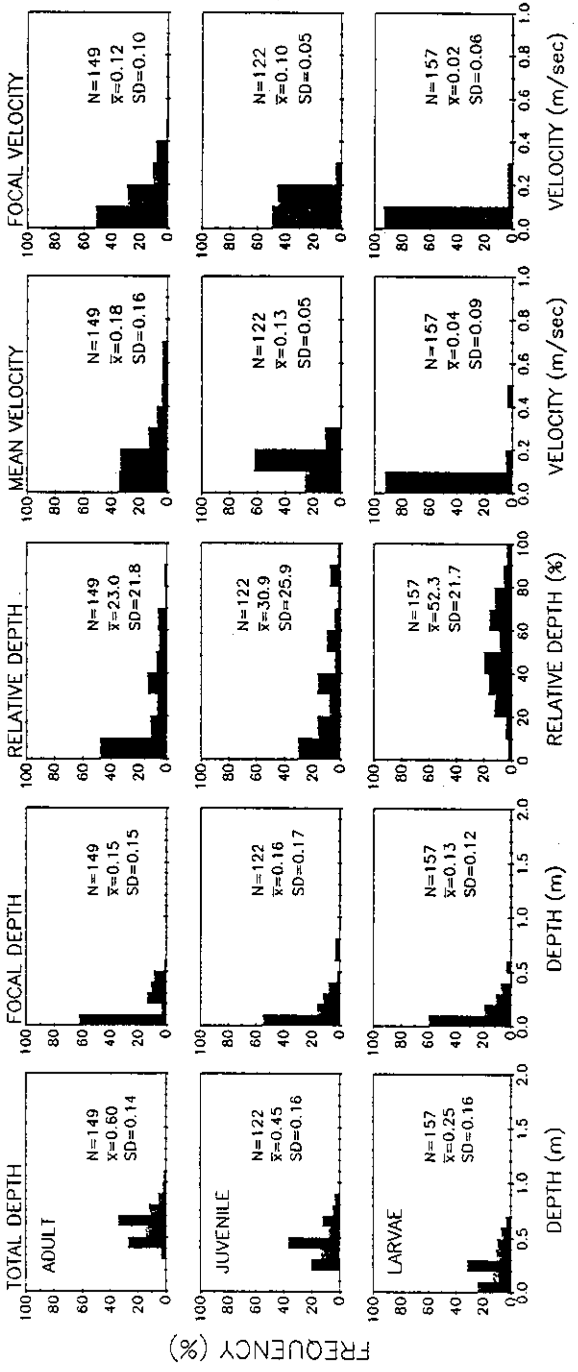

Fig. 2.15. Habitat use in terms of spatial relationship for three life stages of White River speckled dace in the Ash Spring outflow.

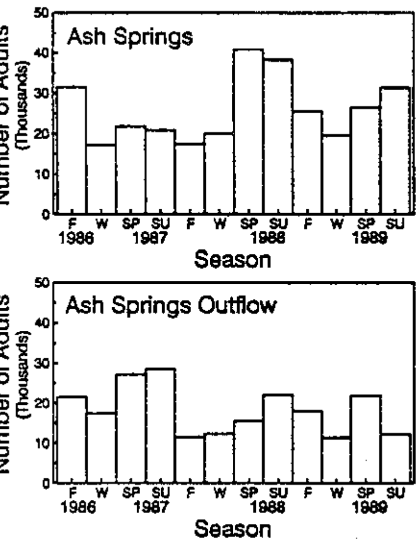

Fig. 2.16. Seasonal fluctuations of adult shortfin olly in Ash Springs and the Ash Springs outflow from ll, 1986 to summer, 1989.

wer estimates generally occurred in the winter. hese data do not suggest a seasonal migration from e Ash Springs outflow into the substantially warmer sh Springs pool during the cooler months. Apparent- , there is a substantial die-back in the winter months roughout their range.

Figure 2.17 indicates that shortfin mollies persisted the lower reaches of Ash Springs outflow (substrata and III) through the cooler winter months. They were ast common in substratum II, the highest gradient each. This reach also supported the highest chub oncentration and was the area in which chub eproduced. Among the substrata there was only a ibtle indication of seasonal movement. In substratum the highest concentration occurred in spring with the umber dropping in summer. Coincidentally, the sum- er number increased each year. No other readily pparent trends were detected.

Habitat Use

Adult mollies did not display selectivity in total ater depth used, but generally occurred lower in the ater column (Figure 2.18). They used low velocity eas and occurred in focal point velocities of 0.10 m/s or less. Juveniles (10 to 25 mm TL) used similar habitat as adults, but tended to occur higher in the water column and in slightly less velocities. Larvae (< 10 mm TL) generally occurred in zero velocity shallow back water and most frequently occupied the mid-water column.

Mosquitofish
(Gambusia affinis)

Mosquitofish have long been used for mosquito abatement and for that purpose they have been spread around the world (Moyle 1976). Extremely adaptable, mosquitofish have established in a broad range of habitat types and physical conditions. First documented from the Pahranagat River in 1959 (Miller and Hubbs 1960), they are now the most wide spread and probably the most abundant fish in the river system (Section I). Because they are spread throughout the system, and difficult to rid by chemical treatment, it is unlikely they can be extirpated from the system. However, it is important to understand their dynamics so native fish can be managed around their existence.

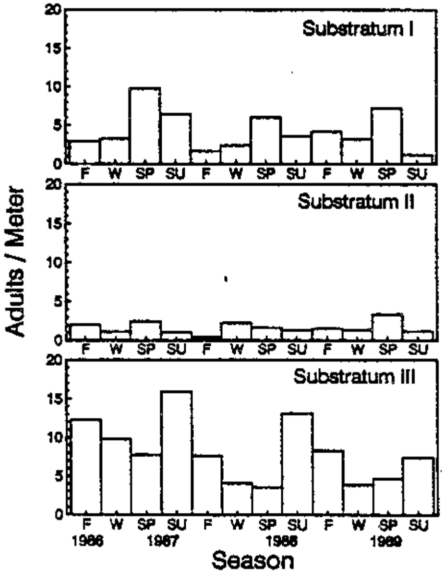

Fig. 2.17. Seasonal densities of shortfin molly in three selected substrata of the Ash Springs outflow from fall, 1986 to summer, 1989.

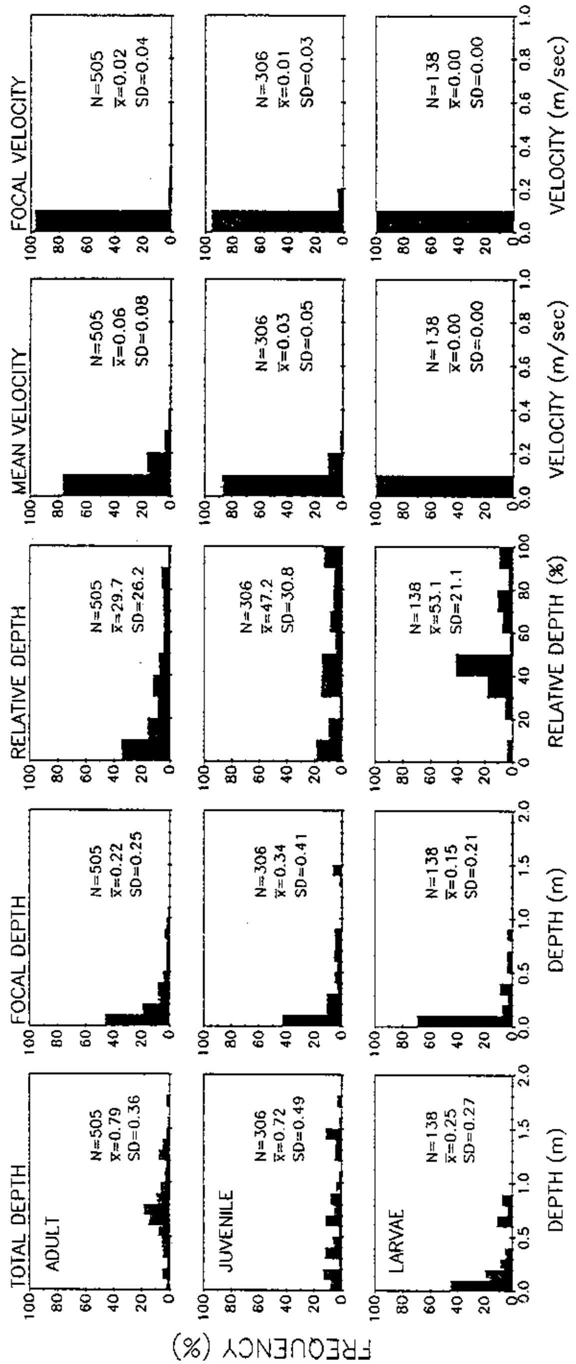

Fig. 2.18. Habitat use in terms of spatial relationship for three life stages of shortfin molly in Ash Springs and Ash Spring outflow.

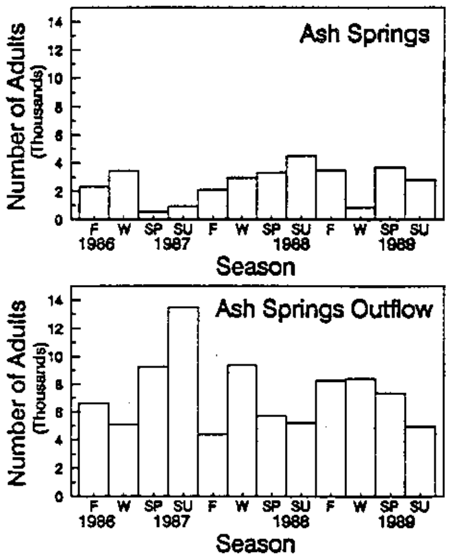

Fig. 2.19. Seasonal fluctuations of adult mosquitofish in Ash Springs and the Ash Springs outflow from fall, 1986 to summer, 1989.

Seasonal Abundance and Distribution

In Ash Springs pool, the estimated population of adults (> 25 mm TL) ranged from 500 to 4,500 over the three year period (Figure 2.19). There were no seasonal patterns of abundance, though the population was generally low in the winter. In Ash Springs outflow estimates ranged from 5,000 to 13,000. Again, there is no seasonal patterns of abundance or indication of movement between the spring pool and outflow.

There is no readily observable pattern of abundance to suggest movement within substrata (Figure 2.20). Like the shortfin molly, the greatest densities occurred in the slower water substrata (I and II).

Habitat Use

Adults occurred in pool or backwater habitat. They were typically near the water surface, 80 % from the bottom or greater (Figure 2.21). Juveniles (10 to 25 mm TL) occurred in similar habitat but in slightly shallower and slower water. Larvae (< 10 mm TL) were in shallow water and tended to distribute equally throughout the water column.

Convict Cichlid
(Cichlasoma nigrofasciatum)

Native to South America, convict cichlid was first collected from Ash Springs in 1963 along with shortfin molly (Deacon 1964). The population subsequently proliferated (Courtenay et al., 1985). Like other South American introductions, its success has been attributed to parental investment (K strategy). Convict cichlids are largely monogamous and parents invest energy by guarding the nest and larvae (Bernstein 1980, Keenleyside 1985). This behavior has given them a reproductive advantage over native fishes that leave their eggs and resulting larvae unguarded (r- strategy) (Stauffer 1985). Shortly after the introduction of these K-strategy fishes into Ash Springs, the White River springfish population plummeted. Similarly, the Hiko White River springfish population declined sharply

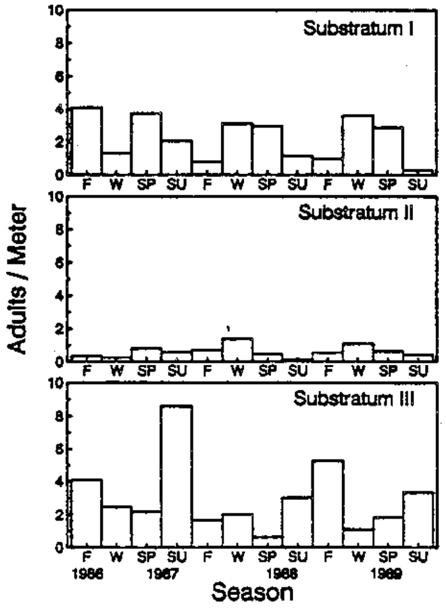

Fig. 2.20. Seasonal densities of adult mosquitofish in three selected substrata of the Ash Springs outflow from fall, 1986 to summer, 1989.

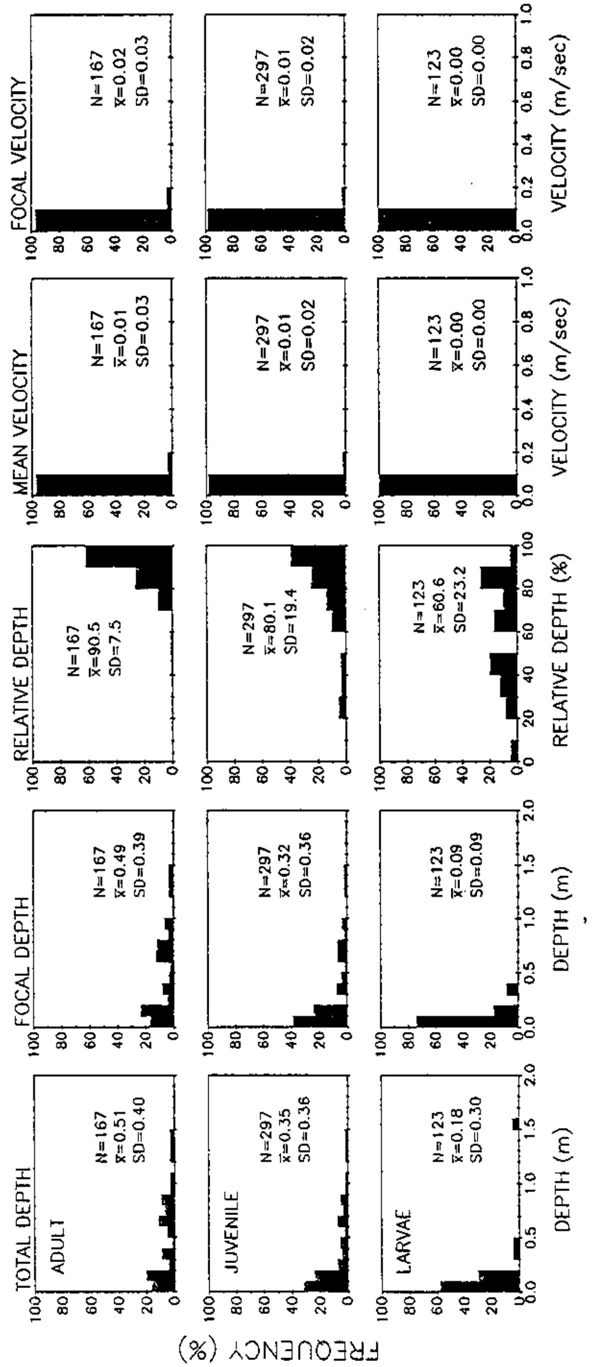

Fig. 2.21. Habitat use in terms of spatial relationship for three life stages of mosquitofish in Ash Springs and the Ash Spring outflow.

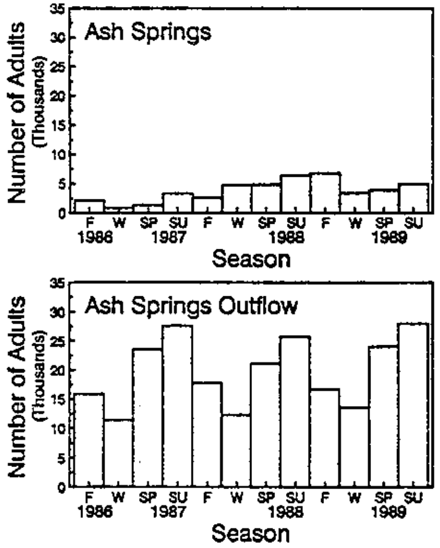

Fig. 2.22. Seasonal fluctuations of adult convict cichlids in Ash Springs and the Ash Springs outflow from fall, 1986 to summer, 1989.

after convict cichlids and shortfin mollies were introduced into Crystal Springs. Hardy (1982) estimated the convict cichlids population in Ash Springs outflow to range from about 1,500 to 4,000 from winter to fall 1981. They are omnivorous and occupy a broad range of habitats.

Seasonal Abundance and Distribution

Estimates of adult convict cichlids (>35 mm TL) in Ash Springs pool ranged from 1,000 to 7,000 while in Ash Springs outflow they ranged from 10,000 to 25,000 (Figure 2.22). Estimates were generally greatest in the summer and lowest in the winter suggesting annual population die backs. There was no ostensible pattern in relative abundance between the spring pool and outflow that suggests seasonal movement between the two.

Seasonal patterns of change were apparent within substrata of Ash Springs outflow. Densities dropped dramatically during the winter in substratum III, and rebounded in the spring and summer (Figure 2.23). The lowest counts in substratum I were in the fall; numbers increased in the winter suggesting upstream movement from substratum III.

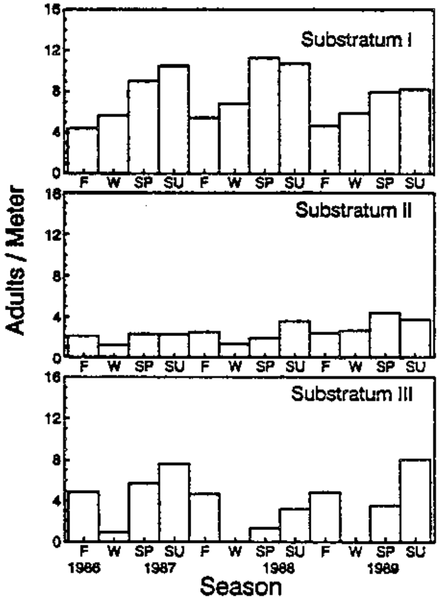

Fig. 2.23. Seasonal densities of adult convict cichlids in three selected substrata of the Ash Springs outflow from fall, 1986 to summer, 1989.

Habitat Use

Adults and juveniles (10 to 35 mm TL) tended to inhabit slow water low in the water column (Figure 2.24). Larvae (<10 mm TL) were found in nests guarded by the presumed parents, in water ranging from several centimeters to over a meter deep. Larvae were always found in close proximity of the bottom.

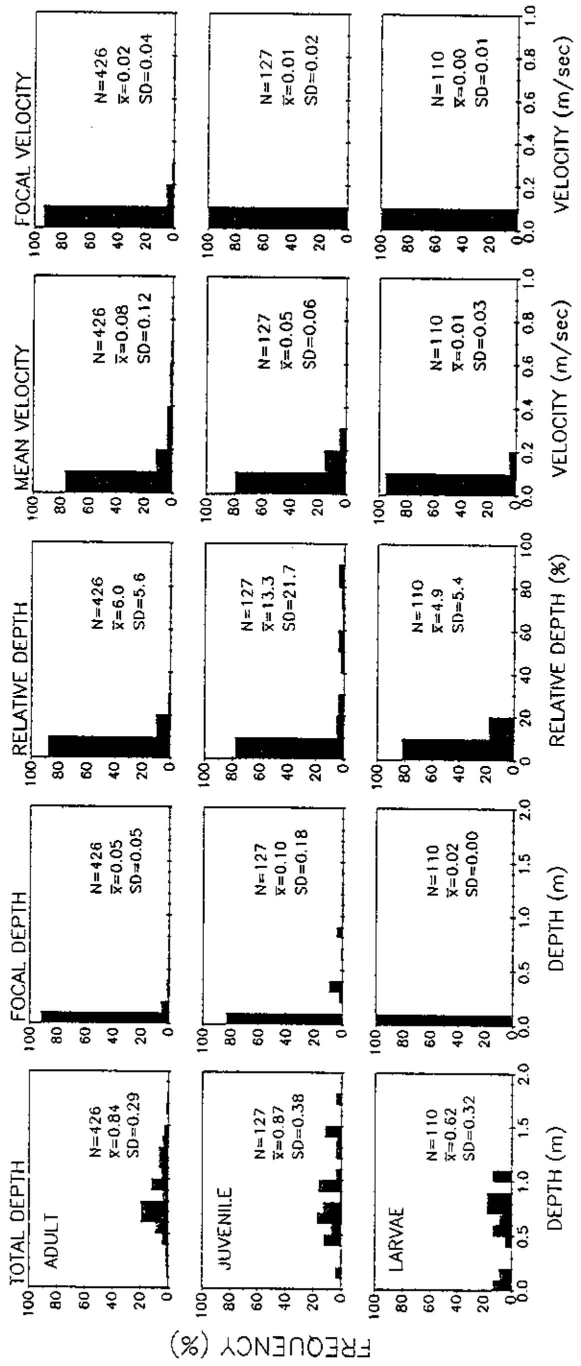

Fig. 2.24. Habitat use in terms of spatial relationship for three life stages of convict cichlid in Ash Springs and the Ash Spring outflow.

PART III

INTERACTIONS BETWEEN NATIVE AND EXOTIC SPECIES

Abstract Spatial overlap among adult native Pahranagat River fishes was greatest between the springfish and shortfin molly, followed by springfish and convict cichlid. The greatest spatial overlap of Pahranagat roundtail chub and exotics occurred at the chub's larval stage, and this was modest. Like springfish, convict cichlids are omnivorous, suggesting that they are a greater competitor for food items then the more herbivorous shortfin mollies. To test the potential for predation on Pahranagat roundtail chub larvae by adult shortfin mollies and convict cichlids, catostomid larvae were used as a model for chub larvae. Results indicated that adult shortfin mollies have the capacity to be a formidable predator: they consumed an average of 8 larvae in a 7.5 hour period as opposed to 2.5 by convict cichlids. The presence of shelter only slightly retarded consumption rate in both species.

INTRODUCTION

Ten fish species inhabit the Pahranagat River. Four species are native (Hiko White River springfish, White River springfish, White River speckled dace, and Pahranagat roundtail chub) and six have been introduced (carp, black bullhead, mosquitofish, shortfin molly, sailfin molly, and convict cichlid). Of the introduced fishes, black bullhead is not sympatric with natives, sailfin molly is extremely rare, and carp is scarce (Section I). Mosquitofish, convict cichlid, and shortfin molly are generally abundant where native Pahranagat River fishes occurred.

The first documented occurrence of mosquitofish in the Pahranagat River was in 1959 (Hubbs and Miller 1960) while the first capture of convict cichlid and shortfin molly was in 1963 (Deacon et al. 1964). Following their introduction there was a sharp decline in native fishes (Courtenay et al;, 1985). The precise mechanism by which exotics impact natives is unclear, but competition, predation, and disease were suspected (Deacon 1979).

In this section we address potential competition for space by comparing interspecific habitat use, and competition for food by comparing food habits. Predation of chub and speckled dace larvae was also addressed.

MATERIALS AND METHODS

Spacial Overlap

Habitat overlap between native and introduced fishes was evaluated by first quantifying focal point velocity and relative depth (described in GENERAL MATERIALS AND METHODS, Section II) for each life stage of native and introduced fishes. The percent of overlap for these parameters was then computed and the resulting product was used to rate relative habitat overlap. The following rating system was devised:

Percent	Rating
81-100	1
61-80	2
41-60	3
21-40	4
0-20	5

Focal velocity and relative depth were selected over other measurements (total depth, Focal depth, and mean water column velocity) because they characterized fish behavior better than habitat availability.

Predation

To test the potential for exotic fish predation on Pahranagat roundtail chub larvae, catostomid larvae were used as a model. Larval catostomids were used because of their availability and their similarity in size, shape, habitat use and behavior to roundtail chub larvae. They were collected from the Truckee River, Nevada in late spring of 1988. Nine to 12 larvae were introduced into each of nine 38 liter tanks: three control tanks without shelter; three test tanks with a single exotic and no shelter; and three test tanks with a single exotic and shelter. Shelters consisted of pvc pipe (25 cm long and 1.5 cm wide) placed vertically in rows of four and five. Exotics were starved 24 hrs prior to the start

Table 3.1. Relative degree of habitat overlap between native and introduced Pahranagat River fishes. Numerical values represent scales ranging from (1) high degree to (5) low degree of overlap.

	Shortfin Molly			Mosquitofish			Convict Cichlid		
	Adult	Juvenile	Larvae	Adult	Juvenile	Larvae	Adult	Juvenile	Larvae
Pahranagat Roundtail Chub									
Adult	5	5	5	5	5	5	4	4	4
Juvenile	4	4	4	5	5	4	5	5	5
Larvae	3	3	3	4	3	3	5	4	5
White River Springfish									
Adult	2	3	2	5	5	4	3	2	2
Juvenile	2	2	3	4	4	3	5	4	5
Larvae	3	3	4	4	4	3	4	4	4
Hiko White River Springfish									
Adult	1	2	4	5	5	4	3	3	3
Juvenile	3	3	3	3	5	4	3	5	4
White River Speckled Dace									
Adult	3	4	5	5	5	5	4	4	4
Juvenile	3	4	5	5	5	4	4	4	5
Larvae	3	2	2	5	4	2	5	4	5

of the experiment. Larvae were introduced into the tanks 8 hrs before the start of the experiment and were separated from the adult exotic fish by a plexiglass partition until the experiment began.

Competition for Food

Because of their endangered status, we could not perform a food habit analysis on Pahranagat roundtail chub or the Pahranagat springfishes; we were forced to rely on food habitat analysis of other subspecies of springfish and roundtail chub to contrast with food items consumed by exotics (shortfin molly and convict cichlid). There was little information on food habits of shortfin molly and convict cichlid, so gut analysis was made of these species. They were collected seasonally in Ash Springs outflow with unbaited minnow traps. Traps were fished a maximum of 30 minutes. Specimens were preserved in 10% formalin and transferred to a 40% isopropyl alcohol solution. The gut contents of at least 15 individuals of each species from each season were examined. Gut contents from the esophagus to anus were examined under a dissecting microscope and percent by volume of each food type in each digestive tract was estimated and placed in one of six categories (0-5%, 6-25%, 26-50%, 51-75%, and 76-90, and 95-100%). The median category value was used to estimate the overall and seasonal mean percent by volume of each food type. A second method used to quantify food habitats was by percent frequency of occurrence; the percent of guts containing a given food type.

RESULTS AND DISCUSSION

Spatial Overlap

Among adults, the greatest spatial overlap between native and introduced fishes was springfish (both subspecies) with shortfin molly followed by springfish with convict cichlid (Table 3.1). Native fish larvae overlapped most with adult mollies (Appendix C).

Like the springfish, mollies and convict cichlids are thermophilic, and are extremely abundant in the areas inhabited by springfish (Section 1). Furthermore, there is strong circumstantial evidence that these species caused the decline of springfish, and are in fact largely responsible for springfish endangered status. Because of the exotics apparent impact, a more comprehensive and separate investigation has been completed on springfish and exotic fishes interactions (in preparation).

Table 3.2. Seasonal mean total length, ratio of gut length to standard length, and mean percent volume of gut content of shortfin molly.

Shortfin Molly	Summer	Fall	Winter	Spring	Total
Number	15	15	15	15	60
Total Length (mm)	46.0	41.3	42.2	42.6	43.0
GL/SL	3.3	3.3	3.2	3.3	3.3
Content Type					
Plant					
Diatom	0.0	0.5	0.0	0.0	0.1
Filamentous Algae	15.8	7.5	1.7	38.6	15.5
Vascular Plant	0.2	0.0	0.0	0.0	< 0.1
Plant Seeds	0.0	0.0	0.0	0.0	0.0
Animal					
Rotifera	0.0	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0	0.0
Crustacea	0.0	0.0	0.0	0.0	0.0
Acarina	0.0	0.0	0.0	0.0	0.0
Insecta	0.0	2.2	0.0	0.0	0.6
Gastrapoda	0.0	0.0	0.0	0.0	0.0
Fish Remains	0.0	0.0	0.0	0.0	0.0
Detritus	43.6	56.8	58.9	48.1	51.8
Inorganic Debris	40.4	33.0	39.4	13.2	31.9

Competition for Food

Of the two thermophilic exotics, shortfin molly appeared more herbivorous than convict cichlid. Detrital matter and filamentous algae comprised a substantial volume of the guts in all seasons Table 3.2), but cichlids had consumed a greater amount and diversity of animal matter (Table 3.3). Although scarcely represented, larval fish remains were found in cichlids in every season. Mollies had ingested large portions of inorganic debris (primarily sand) indicating a propensity to forage at or near the bottom, as their spatial distribution in the water column suggests (Section II). Appendix 4 gives food consumed by shortfin mollies and convict cichlids by frequency of occurrence.

Correlative to the apparent tendency toward shortfin molly herbivory was a mean gut length 3.3 times the mean standard length (Nikolsky 1963). Convict cichlids examined had a mean gut length only 1.3 times the standard length indicative of a more omnivorous diet.

The inference from other subspecies of springfish, roundtail chub and speckled dace (Williams and Williams 1982) as well as work by Hardy (1981) suggest Pahranagat River native fishes, like the convict cichlid, are omnivorous. However, we suspected the greatest competition for food resource to occur between cichlids and the two Pahranagat River springfish. Both are thermophilic and convict cichlid has greater spatial overlap than the other natives.

Predation

Habitat overlap between roundtail chub and exotics occurred primarily during the chub larval stage. We thus tested if shortfin molly and convict cichlid are predatory upon chub larvae. Most speckled dace occurred outside the spatial overlap of shortfin molly and convict cichlid, but larval catostomids used in this experiment were a reasonable substitute.

Judging from food items consumed, mollies did not appear to be as formidable a threat to larvae as convict

Table 3.3. Seasonal mean total length, ratio of gut length to standard length, and mean percent volume of gut content of convict cichlid.

Convict Cichlid	Summer	Fall	Winter	Spring	Total
Number	35	37	27	37	136
Total Length (mm)	51.2	54.9	53.8	53.8	53.4
GL/SL	1.3	1.2	1.1	1.1	1.2
Content Type					
Plant					
Diatom	0.2	3.3	17.2	0.0	5.1
Filamentous Algae	39.5	18.0	29.5	38.1	31.4
Vascular Plant	6.3	1.3	0.3	2.1	2.6
Plant Seeds	0.2	0.1	0.1	0.2	0.2
Animal					
Rotifera	0.0	0.0	0.0	<0.1	<0.1
Nematoda	0.0	0.0	0.1	0.0	<0.1
Crustacea	3.6	6.7	0.4	0.2	2.7
Acarina	0.0	0.2	0.0	0.1	0.1
Insecta	13.5	11.9	2.2	10.8	9.7
Gastrapoda	3.2	0.5	0.1	0.4	1.1
Fish Remains	0.2	3.4	0.1	0.8	1.1
Detritus	32.5	52.6	46.8	46.4	44.4
Inorganic Debris	1.1	2.4	3.4	1.2	2.0

cichlids. However, results of our predation experiment suggested them to be extremely formidable. Without shelter, almost all larvae were consumed within 7.5 hrs (Figure 3.1). The rate of consumption was slightly impeded when shelter was present.

In this experiment cichlids were less effective as predators than shortfin mollies. They generally appeared skittish throughout the experiment which may have inhibited their performance. Regardless, shortfin mollies are probably a greater threat to chub larvae than are cichlids because of their tendency for greater spatial overlap.

Fortunately, chub reproduction occurred in the reach of Ash Springs outflow least populated with exotic fishes (Section 2). Also, peak reproduction occurred in late winter when populations of exotics were depressed and probably in sufficiently cool water that foraging activity was likewise depressed. Thus, we feel exotic fishes have much less of an impact on chub than the two subspecies of Pahranagat River springfish.

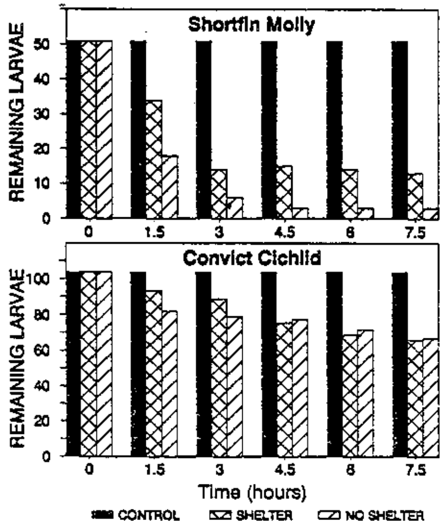

Table 3.1. Rate of catostomid larvae predation by shortfin molly and convict cichlid.

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APPENDIX A

Property Ownership in the Pahranagat Valley

Plot #	Owner Name
1.	Latter Day Saints
2.	Earl Williams, c/o Bryan Hafen
3.	Stewart Brothers, c/o Vern Albright
4.	Marion Burns Trust, James Neal Trustee c/o Edwin Higbee
5.	Nevada National Bank, c/o Scotty Main
6.	Whipple and Bradshaw, c/o Jane Bradshaw
7.	Thomas Steele
8.	Wadsworth, et al., c/o Charles Wadsworth
9.	Bureau of Land Management
10.	Nelma Simmers
11.	Nolan Shumway
12.	Carlos Taylor
13.	Jake Nelson
14.	Charles and Donald Wadsworth
15.	Trustee of Lamb and One Employee Profit Share Plan
16.	James Logan
17.	Isaac Spenser
18.	LeMoine Davis
19.	Ken Wadsworth (Don Anhder)
20.	Bingham and Isom
21.	Russel Lange
22.	Ed Weinstein
23.	Edwin Hartwell and James Spear
24.	Charles Wadsworth
25.	Paul Christian
26.	Micheal Leavitt
27.	Don Farrel Anhder
28.	Garland Neilson
29.	Joe Higbee
30.	Cleo Connel
31.	Higbee Trust
32.	Varlin Higbee
33.	Vaughn Higbee
34.	Edwin Higbee
35.	Conley Newby
36.	Russel Christian
37.	A.M. Simmons
38.	Carl Doerr
39.	Jerry Johnston
40.	Meehan Hall
41.	Eleanor and Floyd Lamb
42.	Varan Frehner
43.	Gun and May Liu
44.	Martin Ross and Doug Barlow
45.	Larry Lytle
46.	CTR Investment
47.	Ed G. Stewart
48.	Daniel Stewart
49.	Shirl and Maxine Brown Trust
50.	Albert Frehner
51.	Leo Stewart
52.	Thomas Seletos
53a.	Donald Denison
53b.	Donald Denison
53c.	Charles Ankenman
53d.	Micheal Steinbach
53e.	Stewart Subdivision, Lincoln County
53f.	Stewart Subdivision, Lincoln County
53g.	Bruce Little and Jim Ward/ Barlow Trust
53i.	Darwin Flanigan
53j.	Ray Odell
54.	Robert Kech
55.	Brent and Michelle Stewart
56.	Lewin Wilkinson
57.	William Warren
58.	Sylvia Thompson
59.	Richard Gardner
60.	Monte Lamb
61.	V.L. Robinson
62.	Elwyn Robinson
63.	Edwin Sharp
64.	Joseph Sharpe

Fig. A.1. Land ownership along the Pahranagat River.

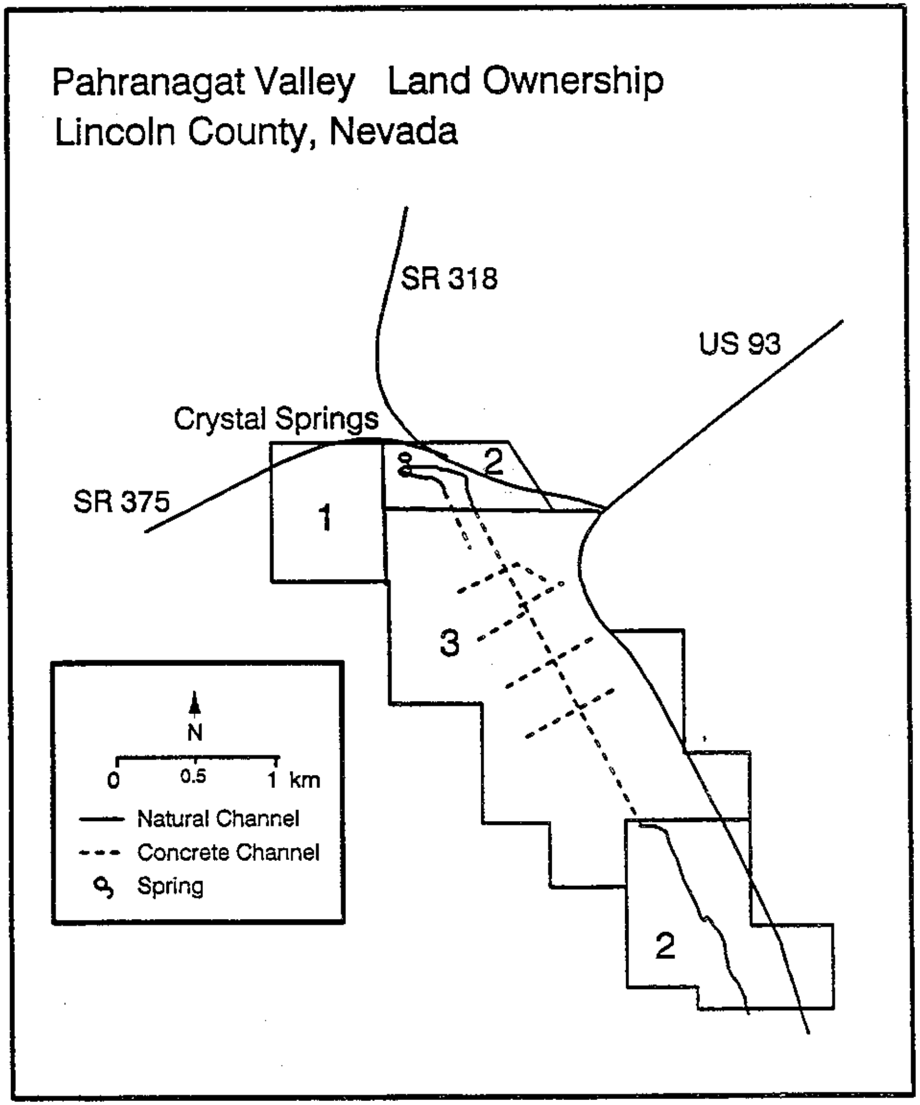


Fig. A.2. Land ownership along the Pahranagat River.

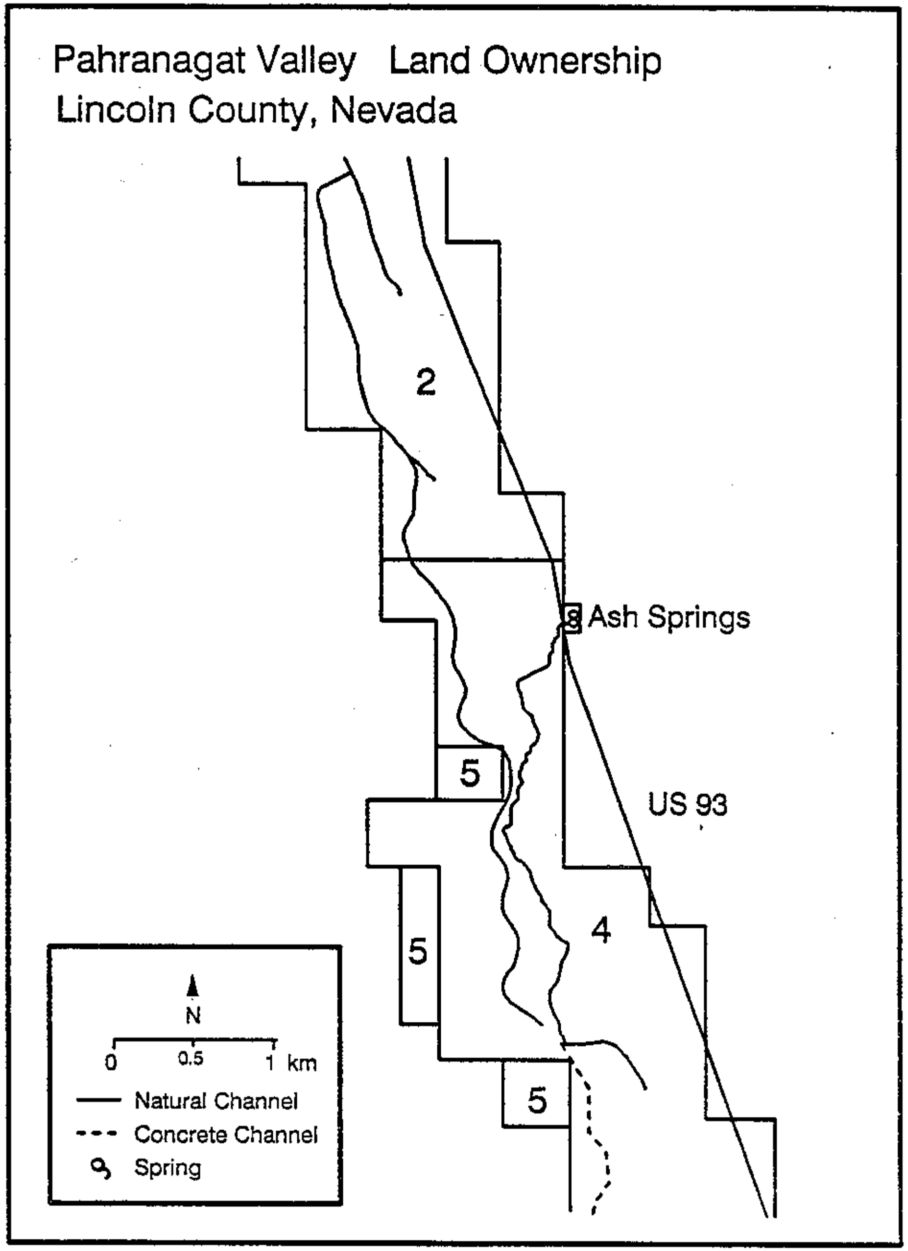


Fig. A.3. Land ownership along the Pahranagat River.

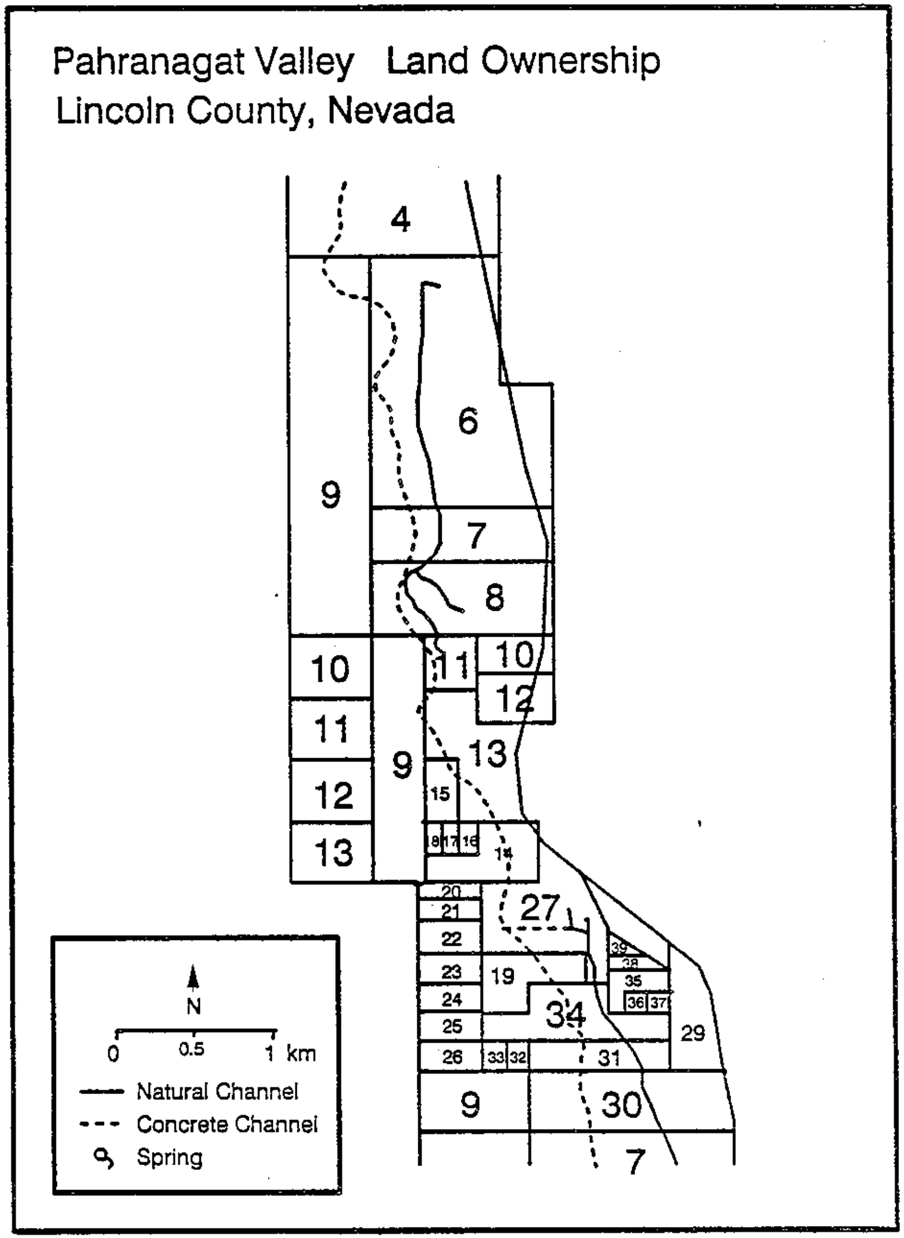
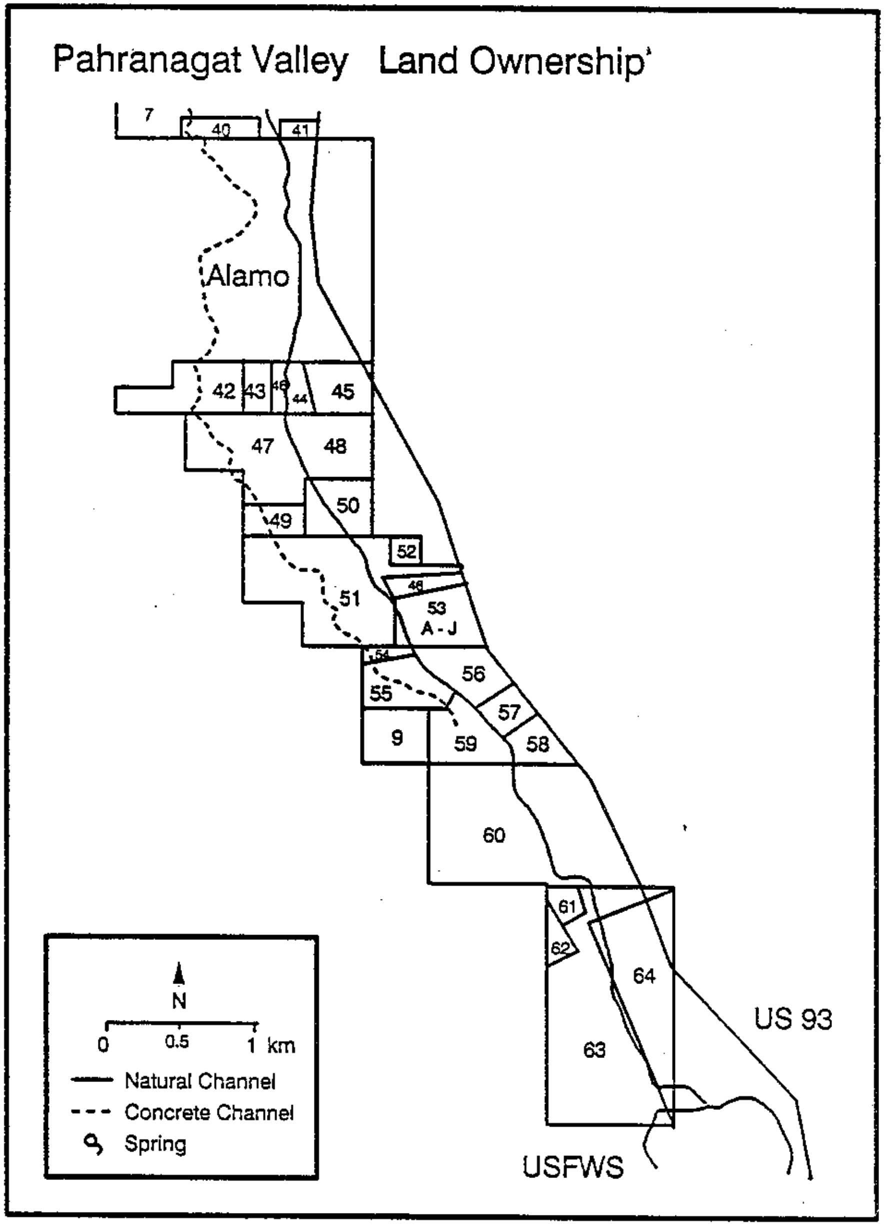


Fig. A.4. Land ownership along the Pahranagat River.



APPENDIX B

Upper Pahranagat Lake Sampling

Three hoop nets were placed near the inflow of the Pahranagat River into the Upper Pahranagat Lake from January 19 to May 6, 1987. The nets, constructed of a 2 cm stretch mesh, had a mouth opening measuring 1 x 2 m with a 30 m lead extending from it. The intent of this sampling was to capture any chub that might leave the lake for spawning purposes. Our efforts resulted in the capture of four fish species, none of which were native to the Pahranagat River system.

Table B.1. Capture success and size of fish in the Upper Pahranagat Lake from the Winter to the Spring, 1987.

Species	Total Catch	Mean Size (mm)	Minimum Size (mm)	Maximum Size (mm)
Largemouth Bass	1	76	N/A	N/A
White Crappie	4	186	176	191
Carp	627	312	64	570
Black Bullhead	902	163	57	270

APPENDIX C

Hiko White River Springfish

The Hiko White River Springfish was outside the area of focus of Part II of our study: Biological Perspective of Fishes Occurring in Ash Springs Pool and Ash SPrings Outflow. However its endangered status warrants at least a brief species account.

Historically Hiko White River springfish occurred in both the Crystal and Hiko Springs systems. Earlier surveys showed that they were abundant in the spring pools and common in the outflows. However, the population in Hiko Spring was extripated by 1967, their demise was attributed to the introduction of largemouth bass (Minkley and Deacon 1968; Deacon 1979). The Crystal Springs population declined in the 1970's following the introduction of shortfin mollies and convict cichlids (Courtenay et al. 1985).

The Nevada Department of Wildlife, in conjunction with the University of Nevada, Las Vegas, successfully reestablished the population in Hiko Spring in 1984 (Baugh et al. 1986). To further insure its existence the Nevada Department of Wildlife also introduced *C. b. grandis*, into Blue Link Spring, Mineral County, Nevada.

Abundance

From 1986 to 1988 annual population estimates were made in the source pools of Crystal Springs by mark and recapture (reference Section 1 for materials and methods). The greatest number (356 +/- 23) occurred in July 1988, and the least in May 1987 (Table C.1). Small numbers of springfish also occurred immediately below the eastern outflow of Crystal Springs pools, however their numbers were not estimated.

Table C.1. Estimated number of Hiko White River Springfish in the source pools of Crystal Springs during three samples from August, 1986 to July, 1988.

Sample Date	Estimated Number	95% Confidence Interval
August, 1986	265	15
May, 1987	181	20
July, 1988	356	23

Habitat Use

Hiko White River springfish were extremely restricted in range, and consequently exposed to limited habitat diversity. Adults (>25 mm) were found in total water depths ranging from 0.2 to 1.3 m with an average of 0.8 m and tended to occur lower in the water column (Figure C.1). Juveniles (10 to 25 mm) were extremely uncommon in Crystal Springs hence we have few observations. This age group occurred in water up to a meter deep but did not exhibit depth preference. Both size classes were found in minimal water velocities. No larvae were found.

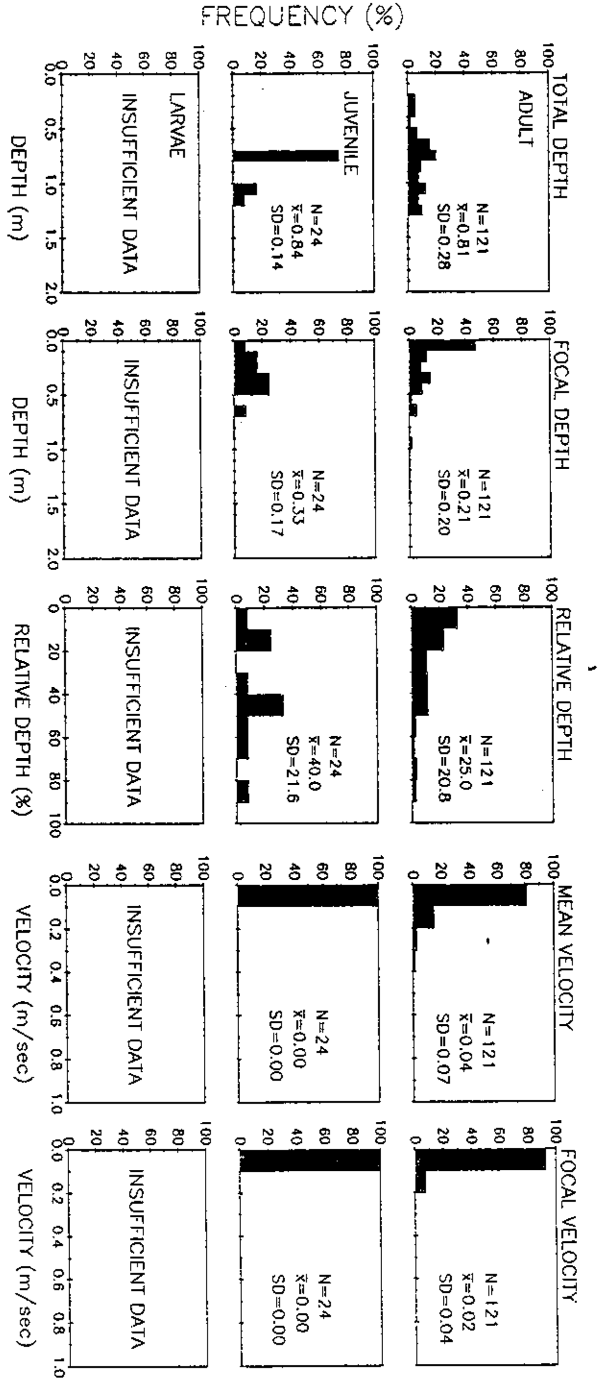


Fig. C.1. Habitat use in terms of spatial relationship for two life stages of Hiko White River springfish.

APPENDIX D

Table D.1. Seasonal percent frequency of occurrence of gut contents of (A) shortfin molly and (B) convict cichlid collected in the Ash Springs outflow, Pahranagat, Nevada.

A. Shortfin Molly

Content Type	Summer	Fall	Winter	Spring
Number	15	15	15	15
Plant				
Diatom	0.0	20.0	0.0	0.0
Filamentous Algae	53.3	66.7	40.0	100.0
Vascular Plant	6.7	0.0	0.0	0.0
Plant Seeds	0.0	0.0	0.0	0.0
Animal				
Rotifera	0.0	0.0	0.0	0.0
Nematoda	0.0	0.0	0.0	0.0
Crustacea	0.0	0.0	0.0	0.0
Acarina	0.0	0.0	0.0	0.0
Insecta	0.0	26.7	0.0	6.7
Gastropoda	0.0	0.0	0.0	0.0
Fish Remains	0.0	0.0	0.0	0.0
Detritus	100.0	100.0	100.0	100.0
Inorganic Debris	100.0	100.0	100.0	80.0

B. Convict Cichlid

Content Type	Summer	Fall	Winter	Spring
Number	35	37	27	37
Plant				
Diatom	8.6	35.1	44.4	0.0
Filamentous Algae	74.3	62.2	77.8	75.7
Vascular Plant	20.0	10.8	3.7	40.5
Plant Seeds	8.6	5.4	3.7	5.4
Animal				
Rotifera	0.0	0.0	0.0	2.7
Nematoda	0.0	0.0	3.7	0.0
Crustacea	20.0	29.7	14.8	5.4
Acarina	0.0	8.1	0.0	2.7
Insecta	85.7	83.8	81.5	81.1
Gastropoda	17.1	5.4	3.7	16.2
Fish Remains	8.6	21.6	3.7	16.2
Detritus	91.4	97.3	96.3	97.3
Inorganic Debris	28.6	51.4	70.4	29.7