CUTTHROAT TROUT SPAWNING ACTIVITIES ON BEAR LAKE, 1975-1989

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INTRODUCTION

Project Background

The Bear Lake Cutthroat (*Oncorhynchus clarki utah*) Enhancement Project was initiated in 1973 with two main objectives; 1) to determine if the native Bear Lake cutthroat trout still existed in a pure, morphologically distinct form and, 2) if the native cutthroat trout existed, develop methodologies to enhance the population. An important aspect of this latter objective was the operation and maintenance of cutthroat trout spawning traps on the primary tributaries to collect spawn for artificial propagation. Artificial propagation was necessary because flows in the tributaries were either partially or entirely diverted for irrigation purposes during late summer, severely impacting potential natural recruitment to the lake.

A trap has been installed and operated by Utah Division of Wildlife Resources personnel on Swan Creek (Figure 1) annually since 1973. The present site is 30 m upstream from the historic trap site utilized from 1939 to 1953. The trap was originally covered by a metal framework and canvas tent. Improvements to the trap were made in 1978 with the construction of a wood building over the holding pens, and in 1981 with the installation of power.

The Idaho Fish and Game Department has installed and operated a temporary weir and trap on St. Charles Creek annually since 1975. Fish from St. Charles Creek were transported to the

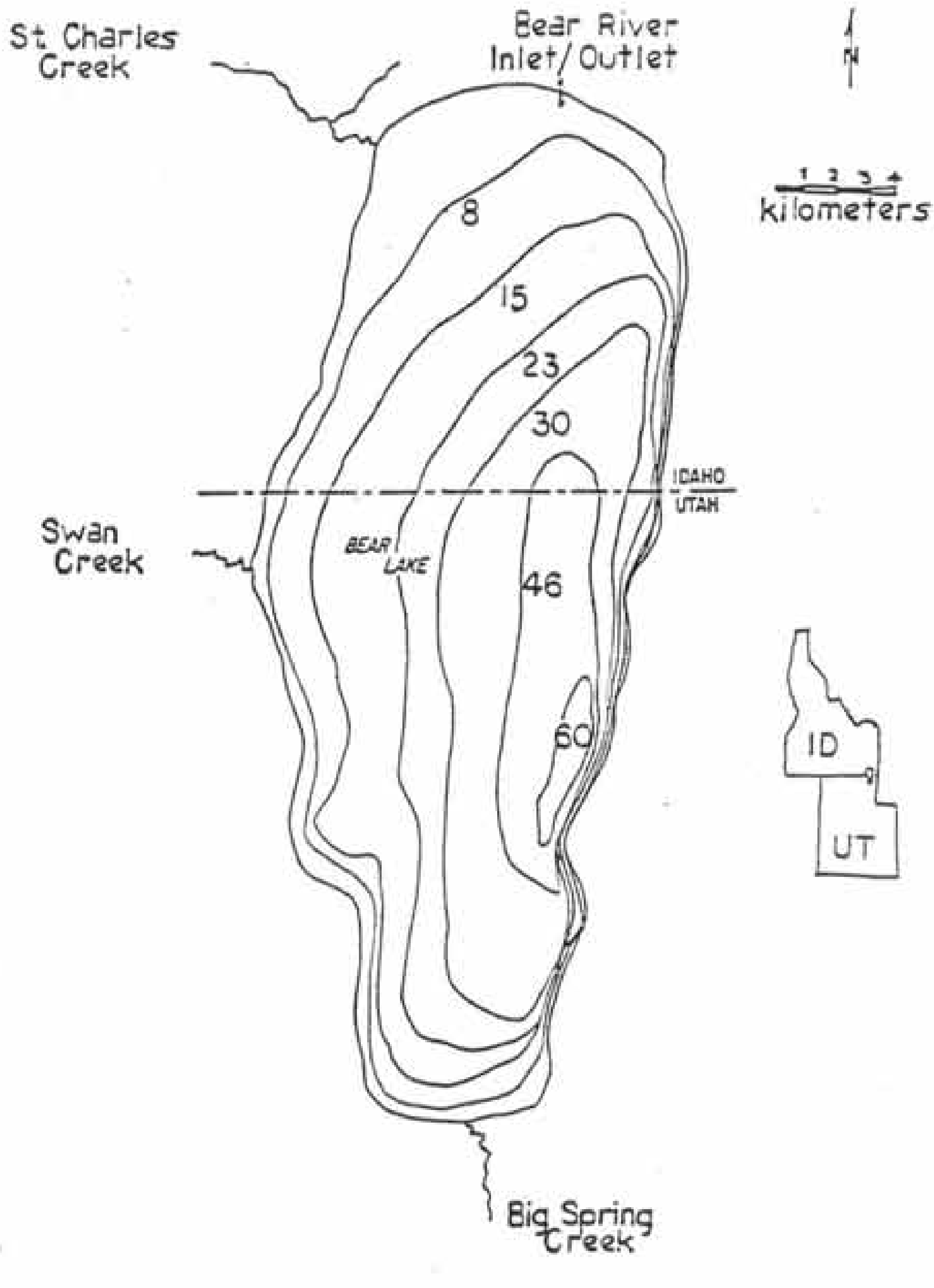


Figure 1. Map of Bear Lake showing major tributaries.

Swan Creek trap for holding until spawning because of lack of holding facilities and security at the temporary trap.

Except for 1989, the St. Charles Creek trap has been located on the property of Mr. Wayne Transtrum in the vicinity of the historic trap site (Figure 2). Slight upstream or downstream yearly variations in actual trap site were dictated by anticipated runoff and lake levels. In 1989, the trap was moved downstream below the high water elevation of the lake because of extremely low lake levels. Under low lake level conditions, St. Charles Creek flows for a considerable distance over mud flats prior to reaching the lake. The mouth of the stream is braided and very shallow in these conditions.

A temporary weir and trap has been installed and maintained by the Utah Division of Wildlife Resources on Big Spring Creek at the south end of Bear Lake (see Figure 1) since 1987. Nielson (1986) noted that runs of spawning cutthroat trout were apparently increasing in this tributary possibly as the result of straying by unimprinted cultured fish. The trap was located approximately 1 km upstream from the mouth, inside the fenced boundaries of Rendezvous Beach State Park for increased security. Fish captured in Big Spring Creek were transported to the Swan Creek trap and held until spawning.

Historical Background

Spawning traps were established on Swan and St. Charles creeks in 1939. The traps were run as part of a U. S. Bureau of

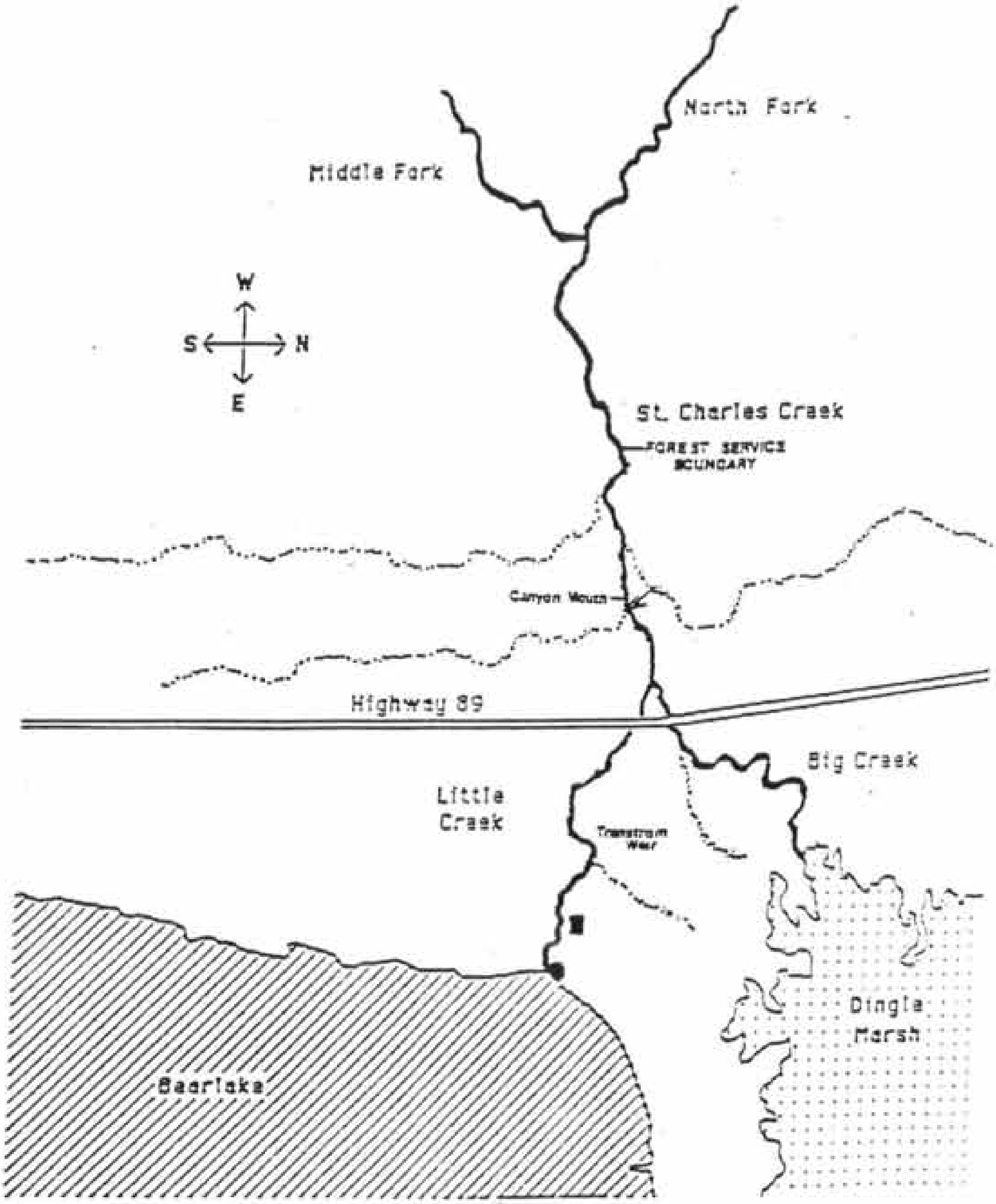


Figure 2. Map showing the location of the 1975-1988 (■) and 1989 (●) St. Charles Creek (Little Creek) trap sites.

Fisheries project, in cooperation with the states of Utah and Idaho, under the direction of Dr. Stillman Wright. Operation of the traps from 1939 to 1943 typically commenced about mid-March and ran through mid-June (S. Wright, 1942, unpub. memo).

Egg collection totals for the two traps in 1939 were 900,000 and 200,000 for Swan and St. Charles creeks, respectively. Low lake levels in the early 1940's impacted egg collection efforts, especially at St. Charles Creek. Totals for 1940 were 662,000 and 38,000 from Swan and St. Charles creeks, respectively. The St. Charles Creek trap was apparently not operated between 1941 and 1946. Egg collection at the Swan Creek trap totaled 788,000 in 1941, 505,000 in 1942, and 117,000 in 1943.

The trapping records are incomplete for subsequent years, but egg totals apparently continued to decline. Egg collection was discontinued at Swan Creek in 1954. Only 40,000 eggs were collected from Swan Creek during that year. Trapping continued on St. Charles Creek until 1960. A total of 152,160 eggs were collected at that time.

Resumed trapping efforts at Swan Creek in 1973 and 1974 yielded 439,896 and 357,845 cutthroat trout eggs, respectively (Nielson and Archer 1977). A total of 140 fish, 115 females and 25 males, were spawned in 1973. In 1974, 141 females and 95 males were spawned. Average total length of spawned fish in 1974 was 447 mm and 386 mm for females and males, respectively. Length data were not collected in 1973.

METHODS

Trap Installation and Operation

The Swan Creek trap required annual cleaning, and installation of a weir and water regulation structure to become operational. Trapping typically commenced in the first half of April to insure capture of all spawners (Table 1). The St. Charles Creek temporary weir and trap were erected approximately 1 May each year except for 1975 and 1987-1989. Because of the later installation time of this trap, a significant number of early migrants were probably missed. Twenty percent of all spawners entering the St. Charles Creek trap were released upstream unspawned to insure the perpetuation of this run.

Trapping activities continued until the latter part of June in most years. Earlier cessation dates of trapping occurred in 1981 due to low flows, and in 1982 because of inundation of both traps during extremely high flows. The St. Charles Creek trap was also shut down early in 1986 because of high flows. Every other bar in the weir at Swan Creek was removed during 1982-1986 because of high flows.

Swan Creek and portions of St. Charles and Big Spring creeks were closed to fishing during the spring to protect spawning cutthroat trout. The area of the lake immediately adjacent to the mouths of Swan and St. Charles creeks was also closed to fishing during the spawning runs. Other species entering the

Table 1. Trapping dates for the three Bear Lake cutthroat trout spawning traps, 1975-1989.

Year	Trapping Season Begin/End		
	St. Charles Creek	Swan Creek	Big Spring Creek
1973		3/1 - 6/18	
1974		3/9 - 6/18	
1975	4/4 - 6/19	4/3 - 6/24	
1976	5/1 - 6/15	4/2 - 6/29	
1977	5/1 - 6/15	4/16 - 6/21	
1978	5/9 - 6/16	4/4 - 6/19	
1979	5/3 - 6/11	4/16 - 6/27	
1980	5/1 - 6/20	4/19 - 6/21	
1981	4/30 - 6/6	4/6 - 6/10	
1982	5/3 - 6/8	4/6 - 6/16	
1983	5/2 - 6/20	4/20 - 6/20	
1984	5/7 - 6/15	4/26 - 6/20	
1985	4/30 - 6/18	4/22 - 6/19	
1986	4/29 - 6/1	4/22 - 6/25	
1987	4/14 - 6/12	4/15 - 6/17	4/24 - 6/17
1988	4/7 - 6/22	4/16 - 6/29	4/20 - 6/14
1989	4/11 - 6/16	4/11 - 6/28	4/24 - 6/15

traps such as Utah sucker (Catostomus ardens), Utah chub (Gila atraria), and carp (Cyprinus carpio) were destroyed during the early years of the project. More recently, they have been released upstream so their natural migration patterns would continue. Rainbow trout (Oncorhynchus mykiss) were stripped and released upstream prior to 1986. Since that time all rainbow trout entering the traps have been sacrificed to avoid any potential hybridization with cutthroat trout.

Cutthroat trout fingerlings raised at the Mantua Hatchery have been exposed to a constant concentration of morpholine for possible imprinting since 1984. Morpholine drip stations were established at the Swan Creek trap 1987-1989 and at the St. Charles Creek trap in 1987 and 1988. The drip station at the Swan Creek trap utilized a 120 liter plastic carboy filled with a stock solution of morpholine and water. Delivery to the stream was accomplished using a peristaltic chemical pump. A 20 liter plastic carboy filled with stock solution was used at St. Charles Creek. Gravity flow was used to deliver the solution to the stream. Concentrations of morpholine in the stock solutions, drip rates and final concentrations were calculated using the methods of Scholz et al. (1975).

Spawning

After sufficient numbers of spawners were captured, spawning occurred on a weekly basis. Broodfish were selected according to a specific set of criteria to avoid including rainbow trout x cutthroat trout hybrids and Yellowstone type cutthroat trout in the spawning stock. Fish selected for spawning had distinctive round spots concentrated posteriorally above the lateral line with very few spots on the head. Cutthroat trout males used in spawning were typically the largest individuals and highly colored with rose-orange hues. Females had a drab gray-brown cast, often with a yellow spot located on the ventral portion of the body. Size was not used as criteria for females. Neither sex exhibited the typical crimson maxillary slash (Nielson 1978). Further separation of Bear Lake and Yellowstone cutthroat trout was also possible by egg color. Bear Lake cutthroat trout eggs were pale yellow, whereas eggs from Yellowstone type cutthroat trout were blood red. These morphological criteria have been substantiated by electrophoresis (Martin 1983, unpub. data).

On spawning days, the fish were anesthetized with tricaine methane sulfonate (MS-222) to facilitate handling then tagged with a numbered tag prior to spawning. Because of observed tag loss in the trap and on repeat spawners, several different tag types were used throughout the project; spaghetti, clinch, and lock-on, all manufactured by Floy Tag of Seattle, WA. Total lengths were recorded for each fish along with tag number, sex and tributary ascended. Weight prior to spawning was taken on all fish from 1975 through 1980.

Each fish was examined under an ultraviolet light to detect fluorescent grit marks to determine hatchery stock and age-class composition of the run. Methods for examination were described by Nielson (1990). Prior to 1982, only cutthroat trout in size classes corresponding to stocked groups of fish were examined. Beginning in 1982, all fish were examined except those released upstream at St. Charles Creek.

The dry pan method was used in spawning. Five to ten females were spawned into a net covered pan. The eggs were then transferred to a bucket and fertilized with 3 or 4 selected males. Sperm diluent was added to the bucket to increase sperm motility and egg fertilization. The diluent has been used annually since 1980. Before transportation to the hatchery the eggs were water hardened and disinfected. All spawned fish were allowed to recover from the anesthetic prior to release downstream at the Swan Creek trap.

Hand stripping of broodstock was used in all years except 1980 when compressed air was used. Greater mortality of brood fish resulted from the compressed air technique due to the inability of the fish to vent the air and hemorrhaging of internal organs.

Captive Broodstock Replacement

A captive broodstock has been maintained at the J. Perry Egan Hatchery in Bicknell, Utah since 1973 to supplement the number of eggs taken from the wild. Development of the broodstock began in 1973 when 10,000 eggs were sent to the hatchery from the Swan Creek trap. An additional 10,000 eggs were sent each year through 1977, except 1975. However since

Egan Hatchery is in the Colorado River drainage, disease protocol established by the Colorado River Wildlife Council prevented the hatchery from receiving eggs from non-certified sources after that time.

The required disease protocol was satisfied by 100% lethal sampling of the selected parent stock. Four females and eight males from each tributary were selected and spawned as family groups. Eggs from the broodstock were quarantined at the Fisheries Experiment Station as family groups until the required disease inspections on the parents were completed. After hatching, the fish were raised to fingerling size, then transported to the Egan Hatchery for rearing. Broodstock replacement was done using this method in 1979, 1983, 1987, and 1989. Nine females and twenty-seven males were used for broodstock replacement parents in 1989 in an effort to increase genetic diversity. Broodstock replacement parents were typically selected from different dates in the run to further enhance diversity.

Data Analysis

Original raw data from the trapping operations were coded and entered onto the project's microcomputer. The data were entered into the Paradox database management system (ANSA 1987) and checked a minimum of three times for accuracy. Data summaries and analyses were accomplished using the Number Cruncher Statistical System (Hintze 1987). Unless otherwise noted, all analyses are significant at α .05.

The original data sheets from the 1976 trapping operations had been misplaced and the only data available from that year were a listing of the tag numbers, total lengths, sex, and capture location. Data on repeat spawners and the disposition of captured fish were not available for 1976. For this reason, most of the summaries for the 1976 data were taken from the original annual report (Nielson and Archer 1977). All other years were re-summarized because of minor errors in the initial summaries. Therefore, the summaries presented in this report may not exactly correspond with previous annual reports.

Egg totals for the traps were calculated by summing the total lengths (or weights) of spawned females from each trap and dividing by the summation of all spawned females total lengths (or weights). This ratio was then multiplied by the number of eggs collected to get the totals for each trap.

RESULTS

A total of 6990 cutthroat trout were tagged at Bear Lake between 1975 and 1989 (Table 2). The tagging totals consisted of 4181 females, 2774 males, and 35 immatures. Some of the fish released upstream at St. Charles Creek between 1983 and 1986, and all fish released since 1987 were tagged and included in the totals. Data from untagged cutthroat trout released upstream were not included in any of the summaries.

Cutthroat trout trapping operations at Bear Lake have yielded over 11 million eggs during the project (Table 3). The total number of eggs collected annually has varied between 225,210 in 1982 and 1,204,944 in 1975. Egg eye-up was typically in excess of 85% (R. Roubidoux, UDWR, pers. comm. 1990).

Variations in environmental conditions probably accounted for the wide range in the number of eggs collected. Drought conditions and low stream flows in 1977, 1981, and 1987 through 1989 impeded upstream migration by cutthroat trout and subsequently reduced the number of eggs collected. Dewatering of St. Charles and Big Spring creeks occurred throughout most of the 1988 and 1989 trapping seasons. Conversely, high flows during the period from 1982 through 1986 severely impacted trapping efficiency at Swan and St. Charles creeks.

Although stream flows were not excessive in 1980, the efficiency of the Swan Creek trap was influenced by high lake

Table 2. Summary of Bear Lake cutthroat trout trapping operations, 1975-1989.

YEAR	NO. ♀ TAGGED	MEAN TL ♀	STD DEV ♀	NO. ♂ TAGGED	MEAN TL ♂	STD DEV ♂	NO. IMM. TAGGED	MEAN TL IMM.	STD DEV IMM.
St. Charles									
1975	253	613	62.8	99	623	77.0	0		
1976	260	569	70.6	129	619	88.7	0		
1977	85	541	85.0	67	504	97.0	0		
1978	154	571	69.7	89	619	83.9	2	493	---
1979	144	570	58.3	98	623	69.2	1	412	---
1980	202	597	60.6	102	637	92.6	0		
1981	81	594	66.8	62	588	93.3	0		
1982	33	562	54.0	36	580	76.8	0		
1983	105	558	63.1	70	605	70.1	0		
1984	94	594	56.2	52	598	71.3	0		
1985	113	544	58.9	60	562	71.2	0		
1986	44	548	57.1	26	546	72.5	0		
1987	160	552	53.7	73	566	76.8	1	484	---
1988	170	565	58.2	115	572	74.3	0		
1989	141	563	51.5	107	564	64.5	0		

Table 2. Continued.

YEAR	NO. ♀ TAGGED	MEAN TL ♀	STD DEV ♀	NO. ♂ TAGGED	MEAN TL ♂	STD DEV ♂	NO. IMM. TAGGED	MEAN TL IMM.	STD DEV IMM.
<u>Swan</u>									
1975	55	581	64.4	10	557	114.1	0		
1976	58	538	83.5	31	548	111.5	0		
1977	82	504	85.2	119	467	91.5	0		
1978	212	533	58.7	185	554	74.5	18	390	31.2
1979	168	544	65.5	116	588	80.8	2	381	---
1980	60	537	61.0	39	534	91.5	1	407	---
1981	168	520	69.9	154	504	79.7	0		
1982	72	536	54.4	88	553	61.0	0		
1983	116	547	52.2	85	582	79.9	0		
1984	147	563	71.0	85	573	96.7	1	330	---
1985	160	554	73.0	116	534	87.9	3	438	34.7
1986	118	520	63.5	40	499	68.3	2	412	---
1987	210	530	61.5	108	497	100.8	2	414	---
1988	183	529	64.6	151	513	96.3	0		
1989	235	530	69.7	210	510	95.3	1	395	---
<u>Big Spring</u>									
1987	76	564	60.1	37	568	60.3	1	456	---
1988	19	545	41.6	12	529	46.4	0		
1989	3	508	24.9	3	607	62.0	0		

Table 2. Continued.

YEAR	NO. ♀ TAGGED	MEAN TL ♀	STD DEV ♀	NO. ♂ TAGGED	MEAN TL ♂	STD DEV ♂	NO. IMM. TAGGED	MEAN TL IMM.	STD DEV IMM.
Total Combined									
1975	308	607	67.1	109	617	82.7	0		
1976	318	563	74.0	160	605	97.3	0		
1977	167	523	86.8	186	480	94.9	0		
1978	366	549	66.1	274	575	83.3	20	400	50.5
1979	312	556	63.5	214	604	77.5	3	391	18.7
1980	262	583	65.6	141	608	102.8	1	407	---
1981	249	544	77.2	216	528	91.9	0		
1982	105	544	55.4	124	560	66.8	0		
1983	221	552	57.8	155	592	76.2	0		
1984	241	575	67.2	137	582	88.5	1	330	---
1985	273	550	67.6	176	544	83.4	3	438	34.6
1986	162	528	62.9	66	517	73.2	2	412	---
1987	446	544	60.0	218	532	93.8	4	442	43.1
1988	372	546	63.0	278	538	90.6	0		
1989	379	542	65.2	320	529	89.8	1	395	---
TOTAL	4181	---	----	2774	---	----	35	---	----

Table 3. Summary of Bear Lake cutthroat trout egg collection, 1975-1989.

YEAR	ST. CHARLES	SWAN	BIG SPRING	TOTAL NO.	TOTAL OZ.	#/OZ.
1975	975,093	229,851	------	1,204,944	5053	239
1976[a]	721,592	191,914	------	913,506	3288	278
1977	264,201	213,408	------	477,609	1730	276
1978	533,114	647,300	------	1,180,414	4449	265
1979	443,124	498,312	------	941,436	3605	261
1980[b]	707,933	197,532	------	905,465	4022	225
1981	292,986	377,550	------	670,536	2738	245
1982[c]	66,827	158,383	------	225,210	968	233
1983[c]	215,843	270,039	------	485,882	2231	218
1984[c]	266,249	422,547	------	688,796	3352	206
1985[c]	321,297	510,843	------	832,140	3624	230
1986[c]	108,561	271,135	------	379,696	1677	226
1987	339,887	477,156	207,488	1,024,531	4561	225
1988	400,900	423,246	43,336	867,482	4091	212
1989	377,222	614,395	9094	1,000,711	4645	215
TOTAL	6,034,829	5,503,611	259,918	11,798,358	50,034	236

a - totals from original summaries. See text for explanation.

b - Swan Creek and St. Charles eggs were kept separate at the time of collection. Totals represent actual measured values.

c - Ineffective trapping due to high flows.

levels at that time. Lake water backed up into the trap to a depth of approximately 1 m (Nielson and Johnson 1981). Trapping efficiency was reduced because fish could swim out of the trap or bypass the weir.

Numbers of repeat spawning Bear Lake cutthroat trout were low throughout the project (Table 4). A total of 212 cutthroat trout, 164 females and 48 males, were recaptured in the traps. Fish with obvious scars indicative of tag loss were included in these totals. The majority of repeat spawners returned to the same trap where they were originally tagged and usually the same week as the initial capture. Only 11 cutthroat trout returned multiple years during the period from 1977 through 1989.

Table 4. Summary of Bear Lake cutthroat trout repeat spawners, 1975-1989[a]. Data includes fish with lost tags.

YEAR	NO. ♀ RETURNED	MEAN TL ♀	STD DEV ♀	NO. ♂ RETURNED	MEAN TL ♂	STD DEV ♂
St. Charles						
1975	0			0		
1977	5	660	15.8	0		
1978	0			1	601	---
1979	5	615	37.4	0		
1980	21	622	48.0	3	640	54.6
1981	20	635	41.3	2	482	---
1982	1	565	---	0		
1983	2	678	---	0		
1984	3	659	46.4	1	645	---
1985	1	514	---	0		
1986	2	630	---	0		
1987	1	650	---	0		
1988	1	661	---	0		
1989	15	621	42.5	2	614	---
Swan						
1975	2	585	---	0		
1977	5	634	99.6	0		
1978	3	546	20.1	2	543	---
1979	6	581	41.4	2	619	---
1980	18	590	42.7	3	605	11.8
1981	9	636	69.3	2	490	---
1982	1	556	---	5	500	46.5
1983	6	594	60.6	4	588	55.9
1984	15	623	46.9	6	520	44.9
1985	10	614	50.3	0		
1986	4	626	71.6	2	587	---
1987	2	597	---	0		
1988	2	584	---	0		
1989	7	605	55.4	8	549	52.5

a - 1976 data not available. See text for explanation.

Table 4. Continued.

YEAR	NO. ♀ RETURNED	MEAN TL ♀	STD DEV ♀	NO. ♂ RETURNED	MEAN TL ♂	STD DEV ♂
<u>Big Spring</u>						
1987	1	601	---	1	585	---
1988	0			0		
1989	0			0		
<u>Total Combined</u>						
1975	2	585	---	0		
1977	10	647	68.6	0		
1978	3	546	20.1	3	562	36.3
1979	11	597	41.6	2	619	---
1980	39	607	47.9	6	623	40.3
1981	29	636	50.3	4	486	8.3
1982	2	561	---	5	500	46.5
1983	8	615	64.1	4	588	55.9
1984	18	629	47.5	7	538	62.5
1985	11	605	56.5	6	628	55.5
1986	2	587	---	0		
1987	4	611	51.8	1	585	---
1988	3	609	98.3	0		
1989	22	616	46.2	10	562	56.4
TOTAL	164	---	---	48	---	---

DISCUSSION

Influence of Flow

Tributary flows varied widely throughout the course of the study. Droughts occurred in 1977, 1981, and 1987 through 1989. Flooding occurred from 1982 through 1986. Flows in Swan Creek (Bear Lake Regional Commission 1983) varied from approximately 5 cfs during the 1981 trapping season to greater than 200 cfs in 1982 (Figure 3). Observations in 1986 indicated that flows in Swan Creek were even higher at that time but no measurements were taken.

Ineffective trapping occurred during both drought and flood periods. For example, during June 1986 water depths inside the St. Charles Creek trap were approximately 1.5 m, nearly the height of the weir. Cutthroat trout were observed jumping over the weir at that time.

Fish were also able to bypass the Swan Creek trap during periods of high flows when every other bar was removed from the weir. Electroshocking in Swan Creek in fall 1986 revealed unmarked cutthroat trout fingerlings upstream from the trap. No adult resident cutthroat trout have been observed in Swan Creek indicating that these fingerlings were natural recruits from spawners which had bypassed the trap.

Despite differences in trap efficiencies with flow, a trend in numbers captured was evident (Figure 4). Cutthroat trout catches have increased in Swan Creek during the study and

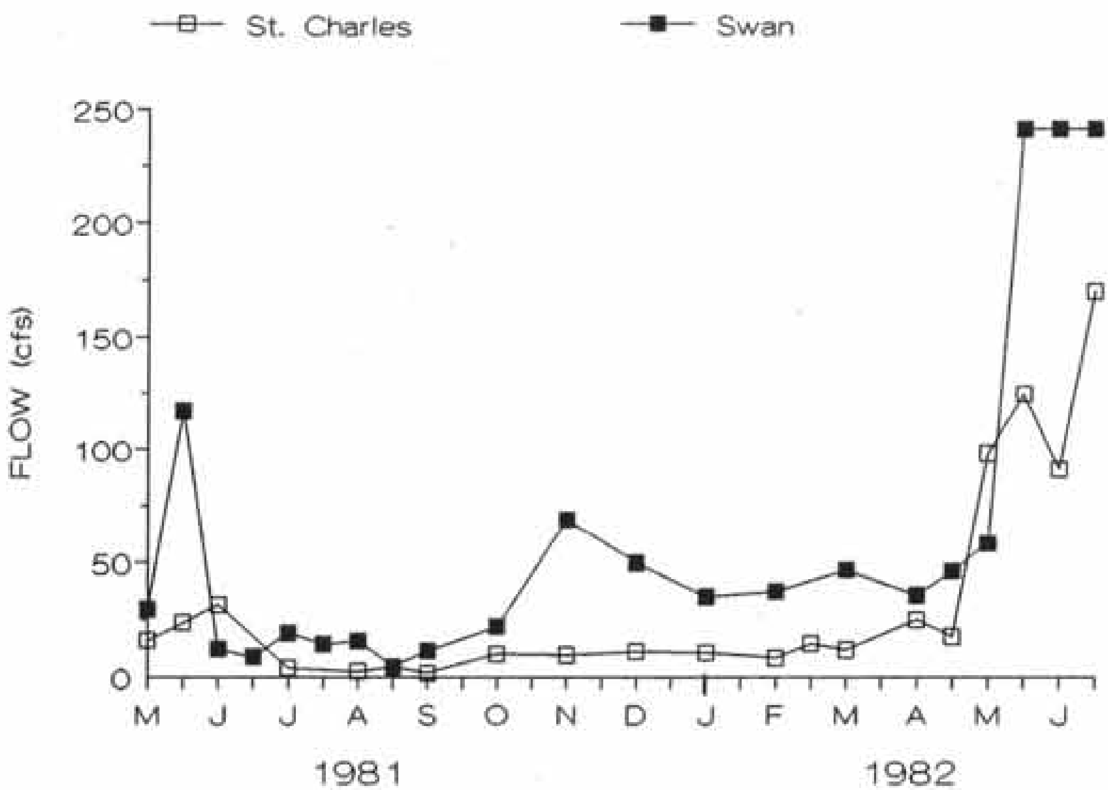


Figure 3. Flows (cfs) in Swan and St. Charles creeks in 1981 and 1982. Data from Bear Lake Regional Commission (1983).

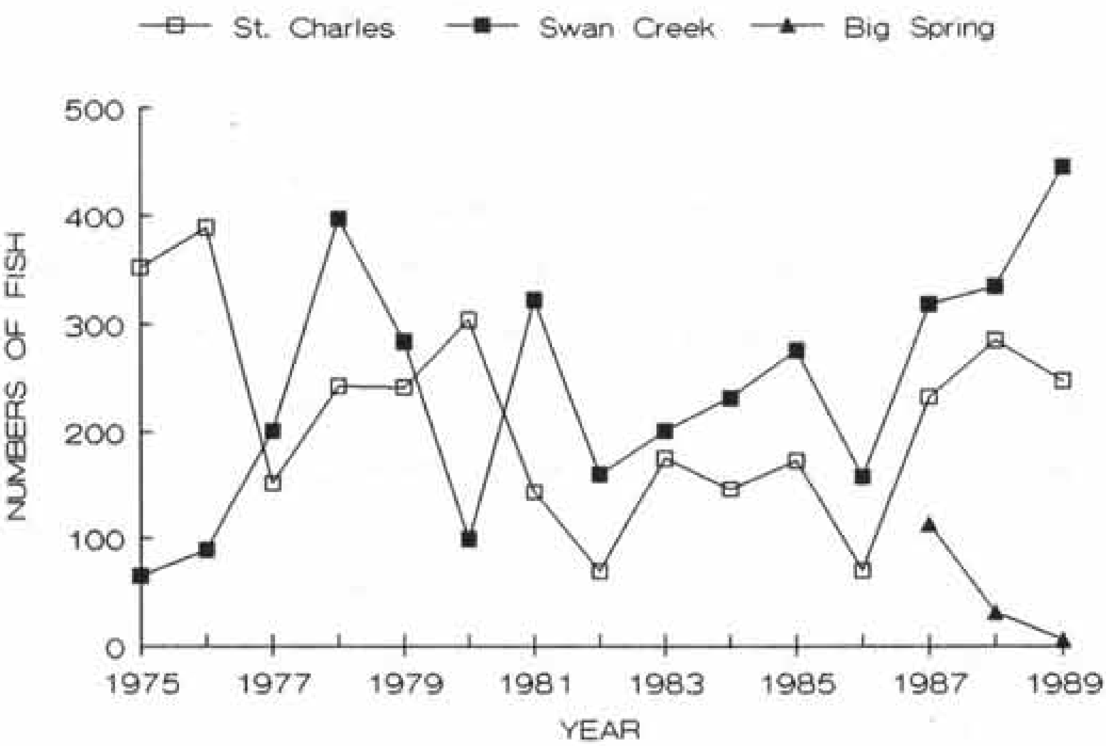


Figure 4. Number of Bear Lake cutthroat trout captured by year at the spawning traps, 1975-1989.

declined at St. Charles Creek. The reasons for the decline in St. Charles Creek are unclear but may be related to changes in the habitat or a reduction in the overall efficiency of the trap structure.

Changes to the habitat or water quality of St. Charles Creek may have occurred as a result of improvements to the irrigation diversion located on Transtrum's property (see Figure 2) in fall 1978. These improvements allowed less water leakage through the structure and better regulation of the downstream flow. The new structure may also have impeded upstream migration of the cutthroat trout released from the trap (20% of the total run), especially during periods of low flows.

Reduced efficiency of the trap structure may also have accounted for the trend in St. Charles Creek. Mean total length of spawning cutthroat trout has declined during the study and distances between the bars on the weir appeared to be sufficient to allow passage of smaller cutthroat trout. Therefore, a greater percentage of the run may have escaped the trap.

Conversely, improved efficiency of the Swan Creek trap operation may account for some of the overall increase in the numbers of fish caught at that trap. The four-fold increase in the number of cutthroat trout captured at the Swan Creek trap, however, probably indicates an enhancement of the population.

Large quantities of gravel were transported downstream and deposited below the Swan Creek trap during the flood period 1982-1986. As a result of this deposition, significant spawning activities have been observed below the trap during 1987-1989.

Timing of the Spawning Run

Gresswell (1985) noted that the greatest catches of Yellowstone cutthroat trout occurred during periods of decreasing streamflow and increasing temperatures. In Bear Lake, cutthroat trout catches were greatest during the period of highest runoff.

The peak of the run typically occurred during the latter half of May or the first part of June (Figure 5). Immature cutthroat trout captured were not included in the figure because immatures were not always tagged. An interesting aspect to the timing of the run through time is the apparent shift in the St. Charles run from a late to an early run. Overall the run has extended in duration. Since 1986, the run has begun earlier than the historic run and continued for 1-2 weeks longer. The increase in duration of the run may be a reflection of an overall increase in the population.

Between Year Variation in Mean Total Length

The average size of cutthroat trout in both tributaries declined during the study (Figure 6). Decline in mean total lengths were especially apparent since 1979. Significant decreases in mean total length were determined for St. Charles males (r^2=0.68, $p<.05$). Regression coefficients were significant only when the 1977 data were excluded from the analyses. The low stream flows in 1977 apparently excluded larger fish from the

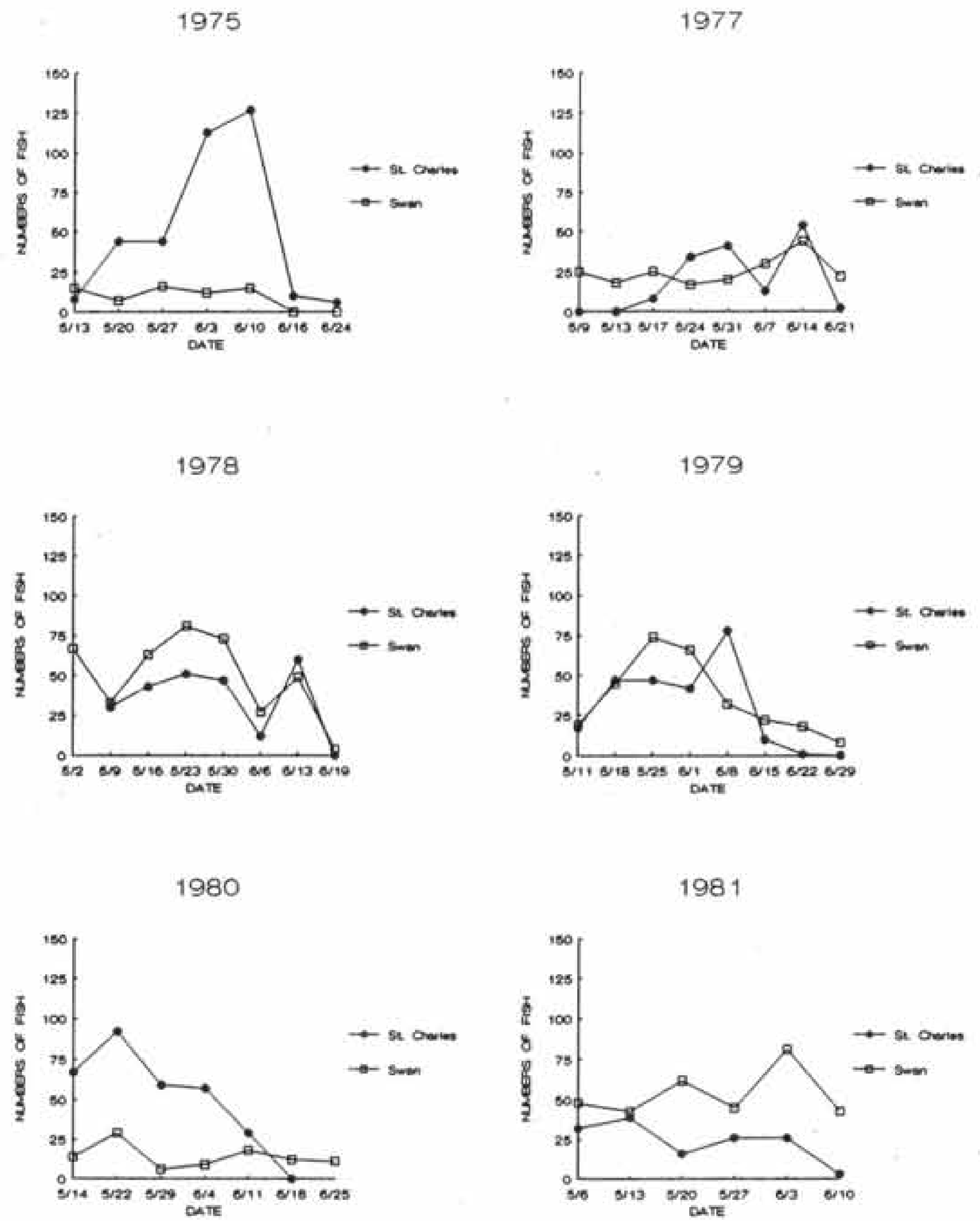


Figure 5. Number of Bear Lake cutthroat trout captured by week at the spawning traps. Repeat spawners and immatures are not included in the figure.

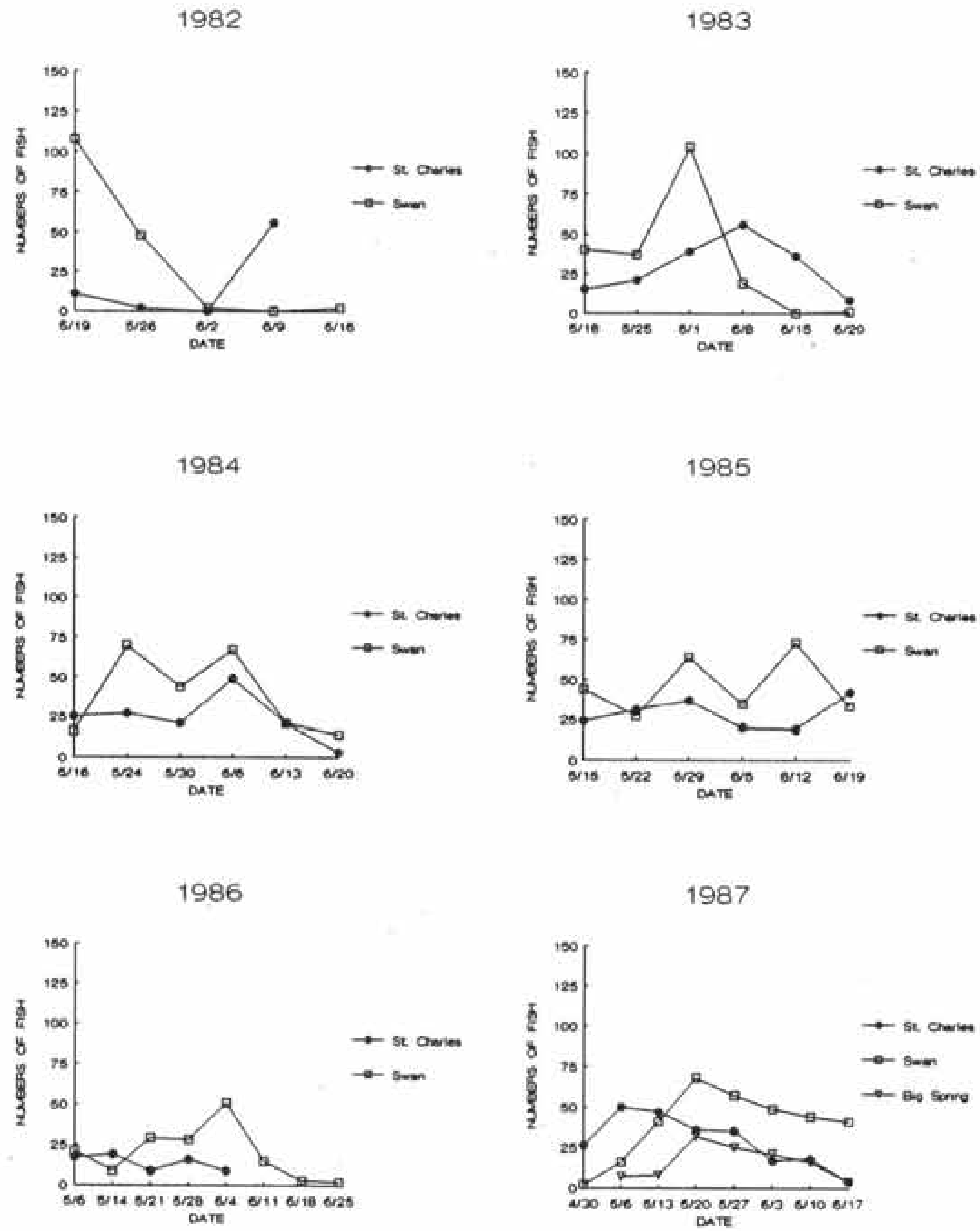
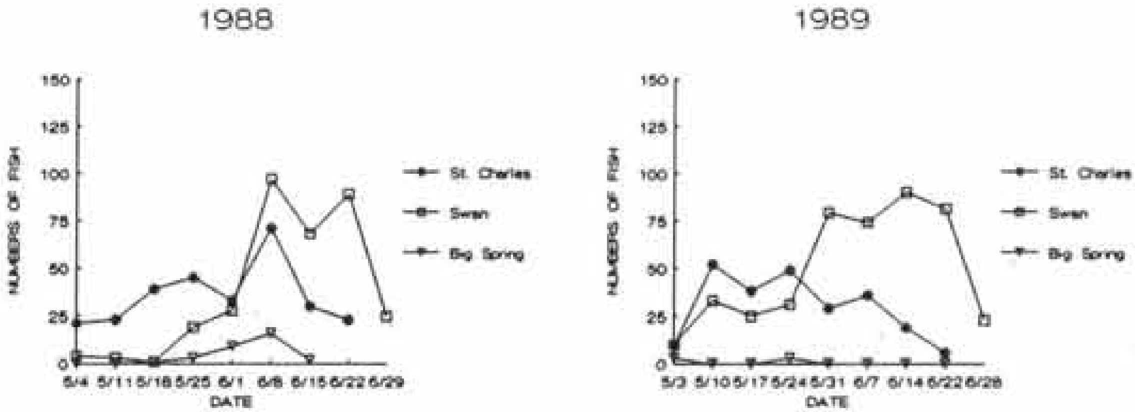


Figure 5. Continued.



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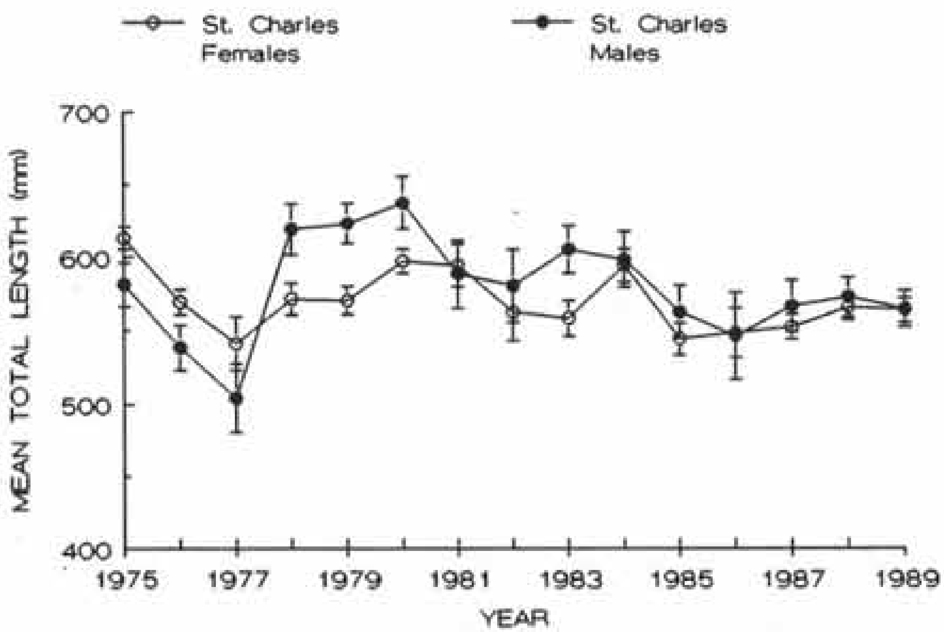


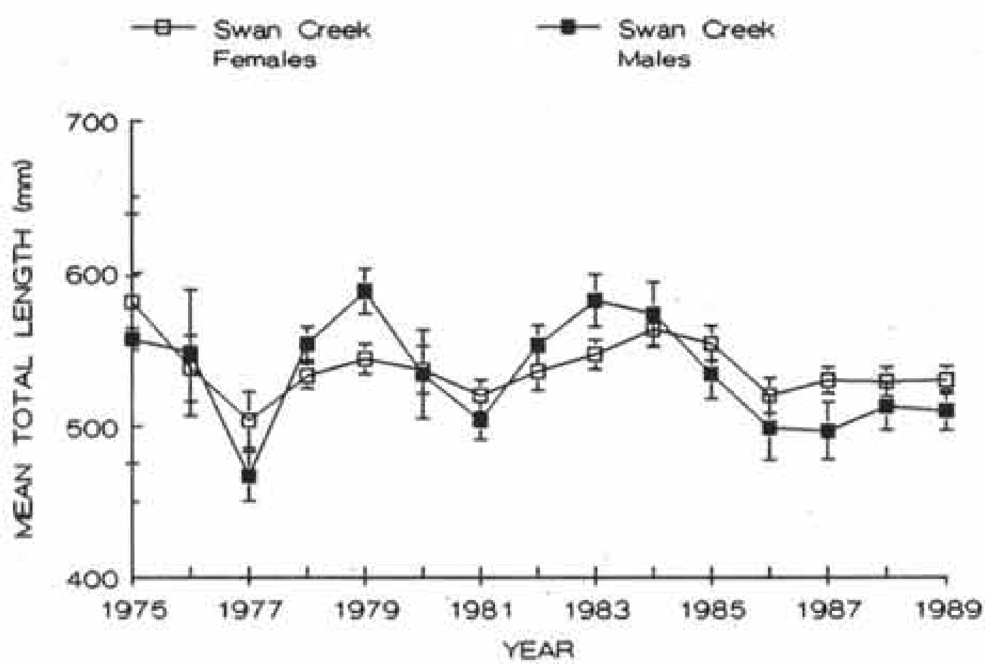


Figure 6. Mean total length with 95% confidence limits for males and females captured in the Bear Lake spawning traps, 1975-1989.

tributaries and the data, therefore, were considered to be an outlier. Significant declines in the mean total length of Swan Creek males, and St. Charles females were also identified by the analysis ($p<.05$), however, the regression coefficients were indicative of high variability (r^2=0.31 and 0.29, respectively) and the significant p value may be an artifact of the data. No change in the mean total length of Swan Creek females was determined by the regression analysis.

A decline in the mean total length of spawned females during the project was evident for both traps, excluding the 1977 data. The data were again highly variable with r^2 values less than 0.40. A decrease in the average size of spawned females from the Swan Creek trap was apparent despite no change in the overall size of the females captured in that tributary. This indicates that the larger fish ascending the stream were not maturing prior to the discontinuation of spawning operations. The reason for the lack of maturation by the larger females in Swan Creek is unclear and requires further investigation.

T-tests (Hintze 1987) determined that, except for 1985, St. Charles Creek fish of both sexes were significantly larger than Swan Creek males and females, respectively. In 1985, there were no significant differences between females from the two traps. Male cutthroat trout from St. Charles Creek were significantly larger than Swan Creek males that year, however.

Males were significantly larger than females at the St. Charles Creek trap five years during the study (Table 5).

Table 5. Results of t-tests between sexes by trap for the study period. Significantly larger fish (α .05) are indicated by asterisk.

<table>
<tr><th rowspan="2">Year</th><th colspan="2">St. Charles Creek</th><th colspan="2">Swan Creek</th></tr>
<tr><th>Females</th><th>Males</th><th>Females</th><th>Males</th></tr>
<tr><td>1975</td><td colspan="2">NSD</td><td colspan="2">NSD</td></tr>
<tr><td>1976</td><td></td><td>*</td><td colspan="2">NSD</td></tr>
<tr><td>1977</td><td>*</td><td></td><td>*</td><td></td></tr>
<tr><td>1978</td><td></td><td>*</td><td></td><td>*</td></tr>
<tr><td>1979</td><td></td><td>*</td><td></td><td>*</td></tr>
<tr><td>1980</td><td></td><td>*</td><td colspan="2">NSD</td></tr>
<tr><td>1981</td><td colspan="2">NSD</td><td>*</td><td></td></tr>
<tr><td>1982</td><td colspan="2">NSD</td><td colspan="2">NSD</td></tr>
<tr><td>1983</td><td></td><td>*</td><td></td><td>*</td></tr>
<tr><td>1984</td><td colspan="2">NSD</td><td colspan="2">NSD</td></tr>
<tr><td>1985</td><td colspan="2">NSD</td><td>*</td><td></td></tr>
<tr><td>1986</td><td colspan="2">NSD</td><td colspan="2">NSD</td></tr>
<tr><td>1987</td><td colspan="2">NSD</td><td>*</td><td></td></tr>
<tr><td>1988</td><td colspan="2">NSD</td><td>*</td><td></td></tr>
<tr><td>1989</td><td colspan="2">NSD</td><td>*</td><td></td></tr>
</table>

NSD - indicates no significant differences between sexes.

Females were significantly larger than males only one year. The remaining years there were no significant differences. In Swan Creek females were usually larger, with males significantly larger only three years during the study.

Except for 1975 and 1976, instances of no significant differences between the sexes coincided with unusual water flows, either drought or flooding. Males appeared to be more responsive to changes in environmental conditions than females. Average size of males increased during periods of flooding and decreased during drought.

Within Year Variation in Mean Total Length

Mean total length of cutthroat trout captured at the spawning traps typically showed a pattern of a significant increase between the first and second weeks, no change the following 2-3 weeks, and then declining during the last portion of the run (Figure 7). Data from repeat spawners and immatures captured in the traps were included in these analyses. Gresswell (1985) reported a similar pattern in Yellowstone cutthroat trout of larger fish entering the traps early in the run. However, he did not observe the initial significant increase in total length noted for the Bear Lake run.

No intra-year differences in mean total lengths were determined during several years. These periods were usually associated with flood events and occurred more frequently at the St. Charles Creek trap. It is possible that the smaller and

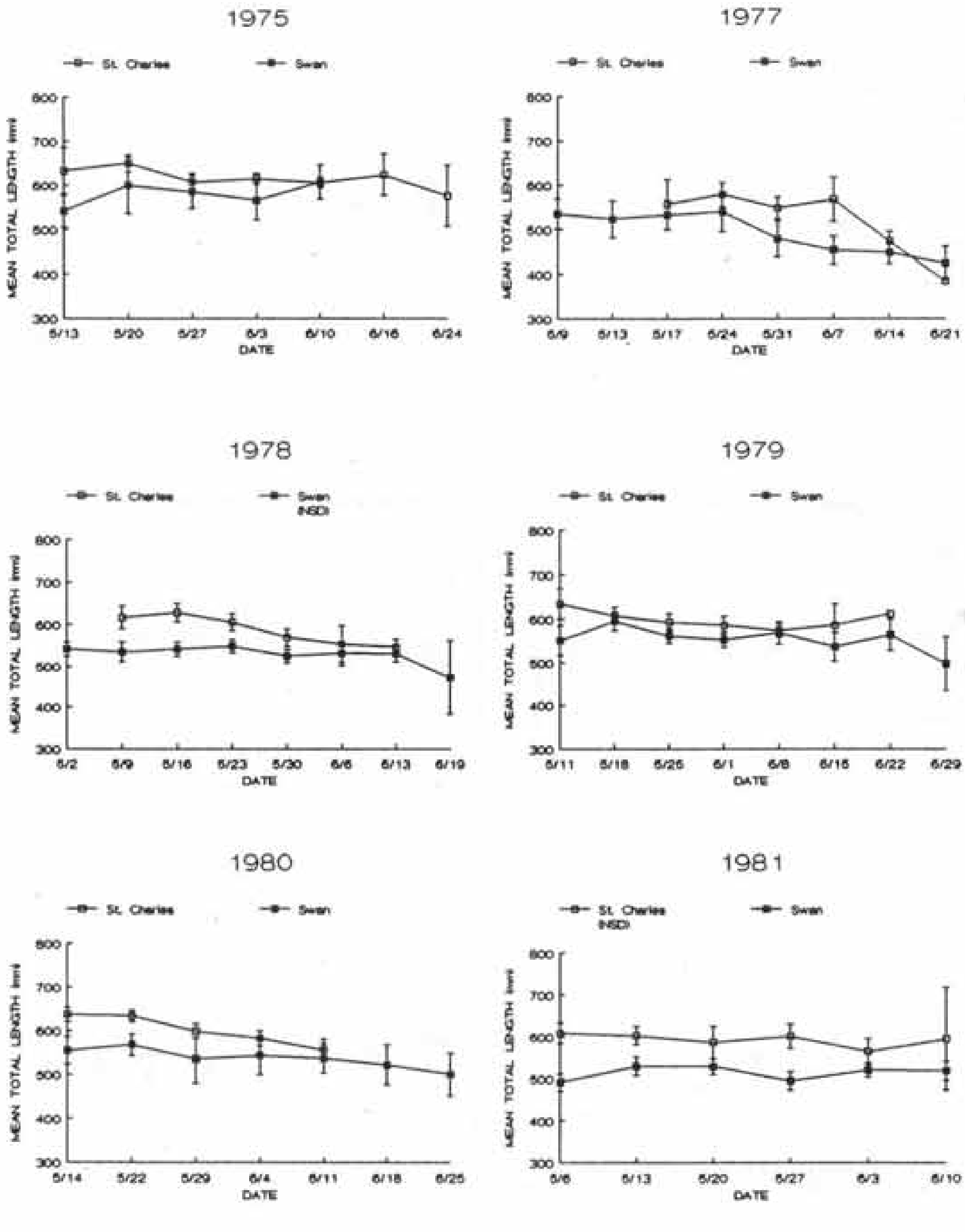
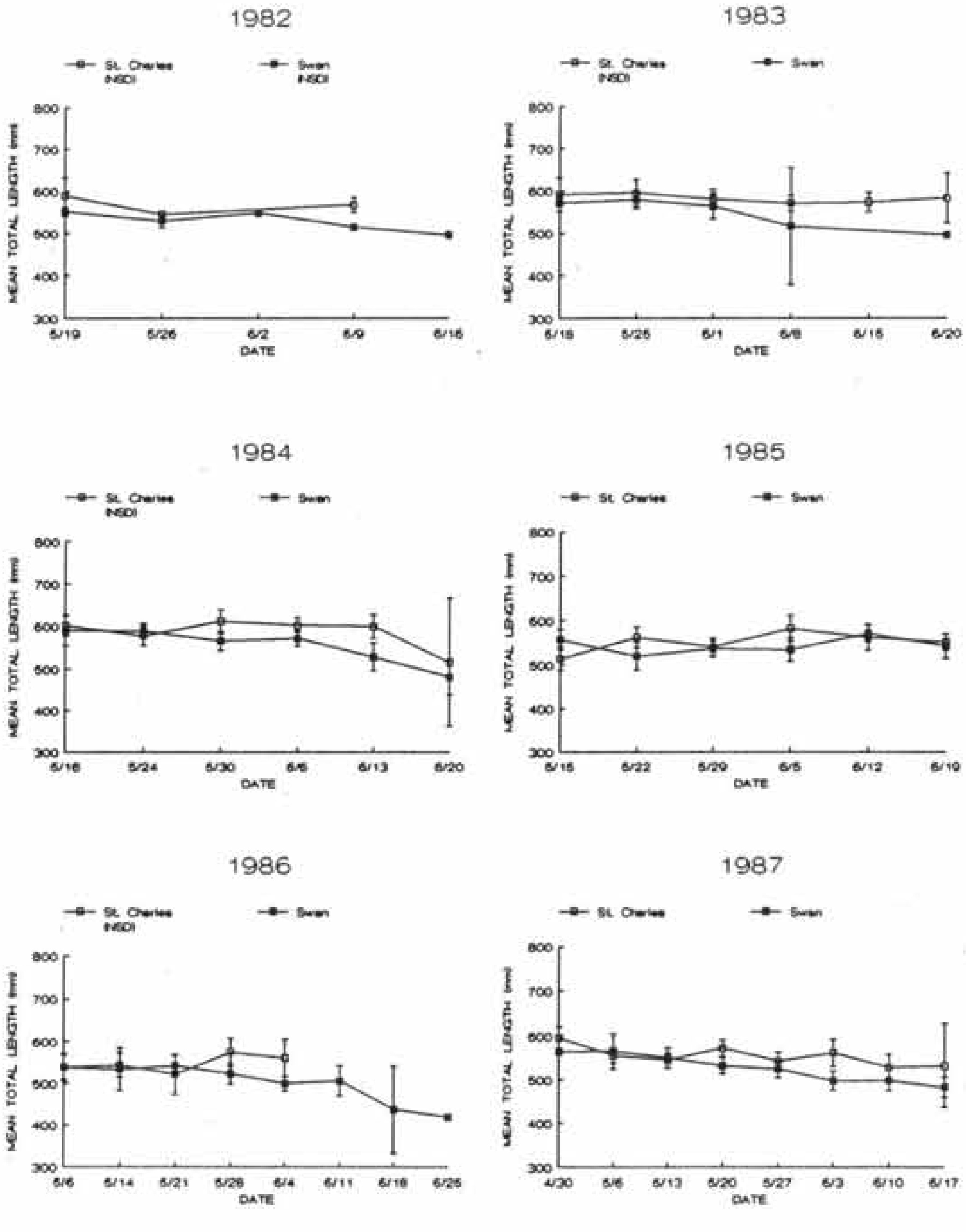


Figure 7. Mean total length with 95% confidence limits by date for the Bear Lake spawning traps. NSD indicates no significant differences between dates.



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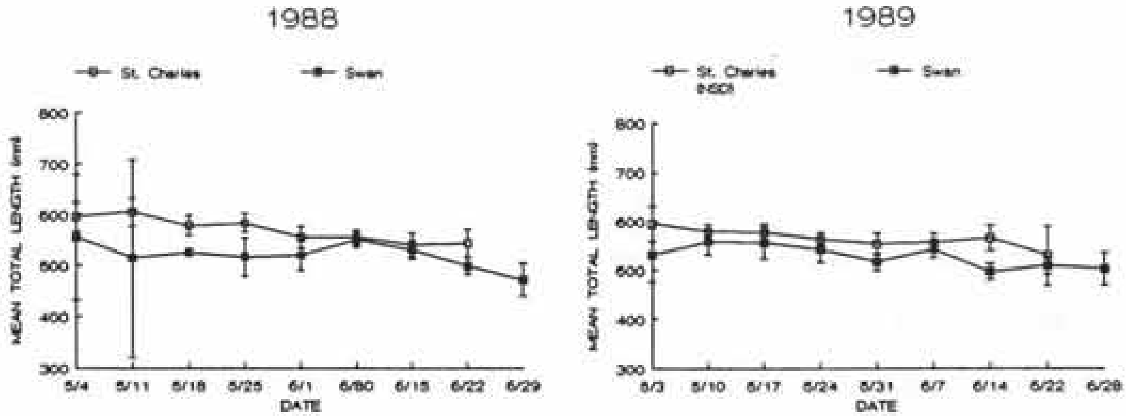

Figure 7. Continued.

larger fish were either excluded from the trap or were able to escape during these periods.

The observed pattern of smaller fish entering the traps early and late in the spawning runs coupled with the increased duration of the runs during the project led to the development of the following hypotheses:

> H_o: There is no significant decrease in mean total length of spawners when comparing similar time periods of the spawning run.
>
> H_a: There is a significant decrease in mean total length of spawners when comparing similar time periods of the spawning run.

The hypotheses were tested using one-way analysis of variance (Hintze 1987) of total lengths of all fish captured versus year for the trapping period from approximately 10 May through 20 June ($F_{10,5248}=68.34$, $p<.001$). Data from the 1981 through 1983 spawning runs were not included in the analysis because of the limited duration of the runs those years. The 1976 data were also not included because no tagging date information was available for that year. Multiple comparisons of the means from the analysis revealed that, except for 1977 and 1984, mean total lengths from the more recent spawning runs were significantly smaller than the earlier runs rejecting the null hypothesis.

Population Structure

Length-frequency histograms for St. Charles (Figure 8) and Swan Creek (Figure 9) illustrated similar patterns. Females

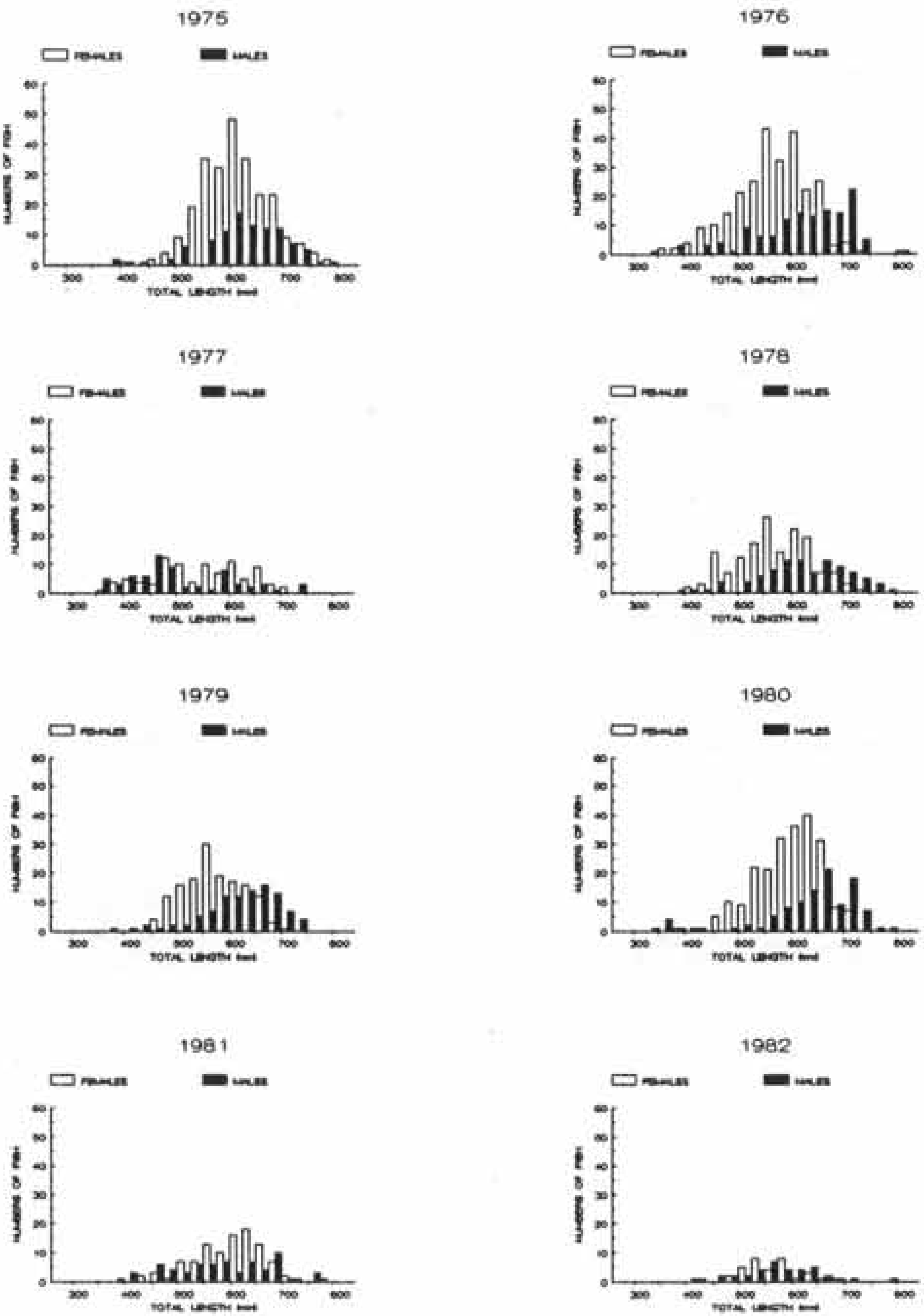

Figure 8. Length-frequency histograms of males and females captured in the St. Charles Creek trap, 1975-1989. Interval width equals 25 mm.

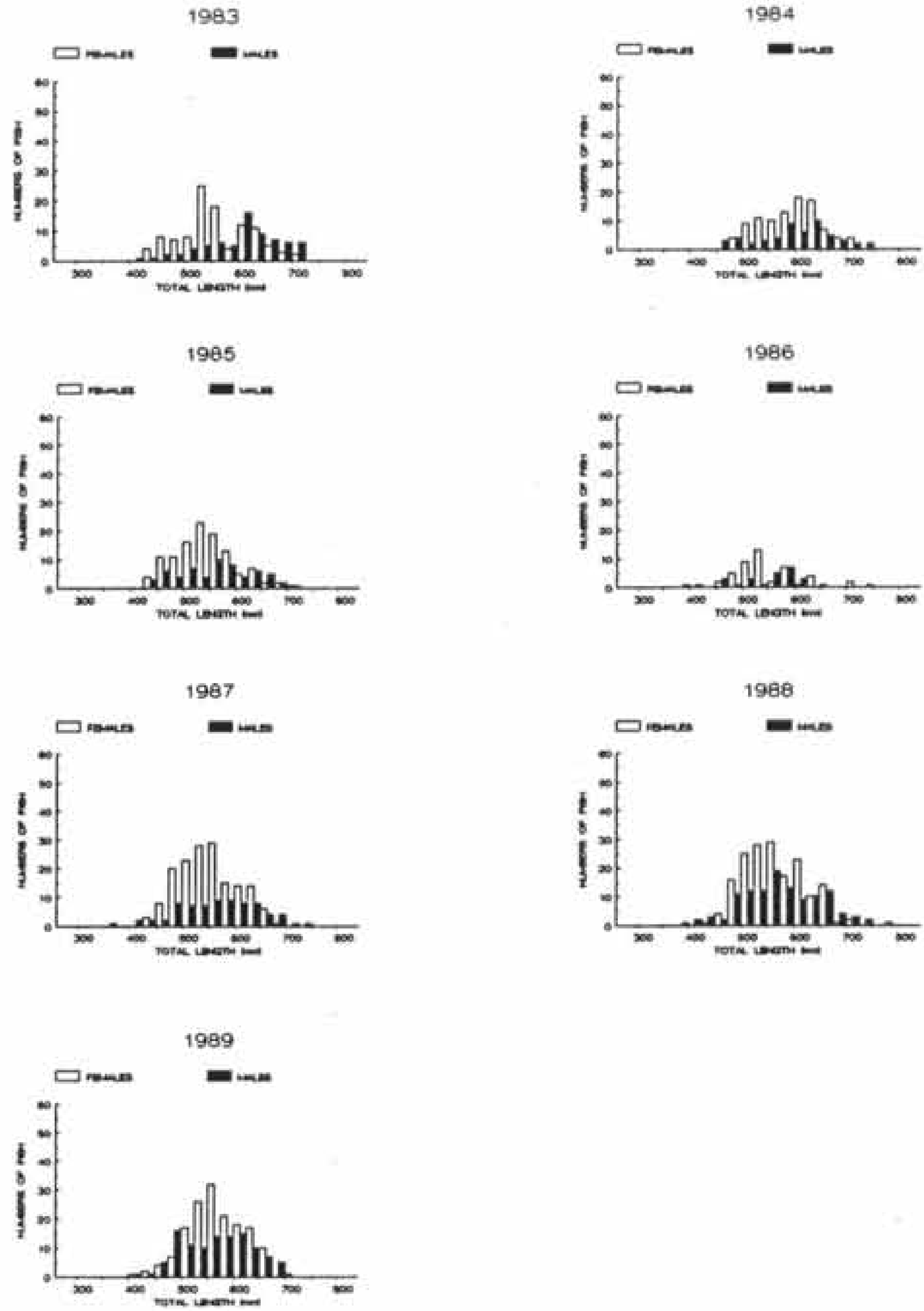

Figure 8. Continued.

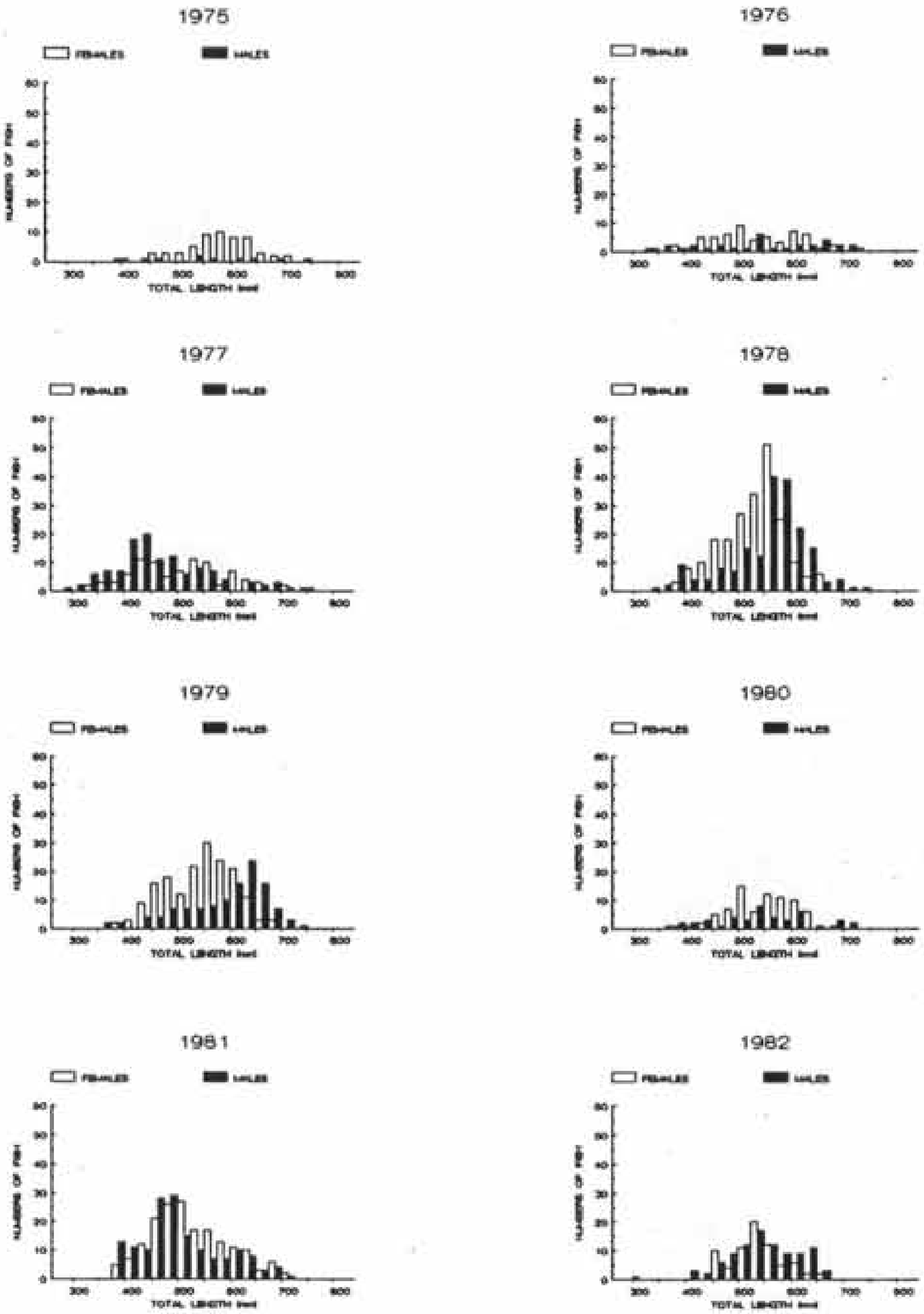

Figure 9. Length-frequency histograms of males and females captured at the Swan Creek spawning trap, 1975-1989. Interval width equals 25 mm.

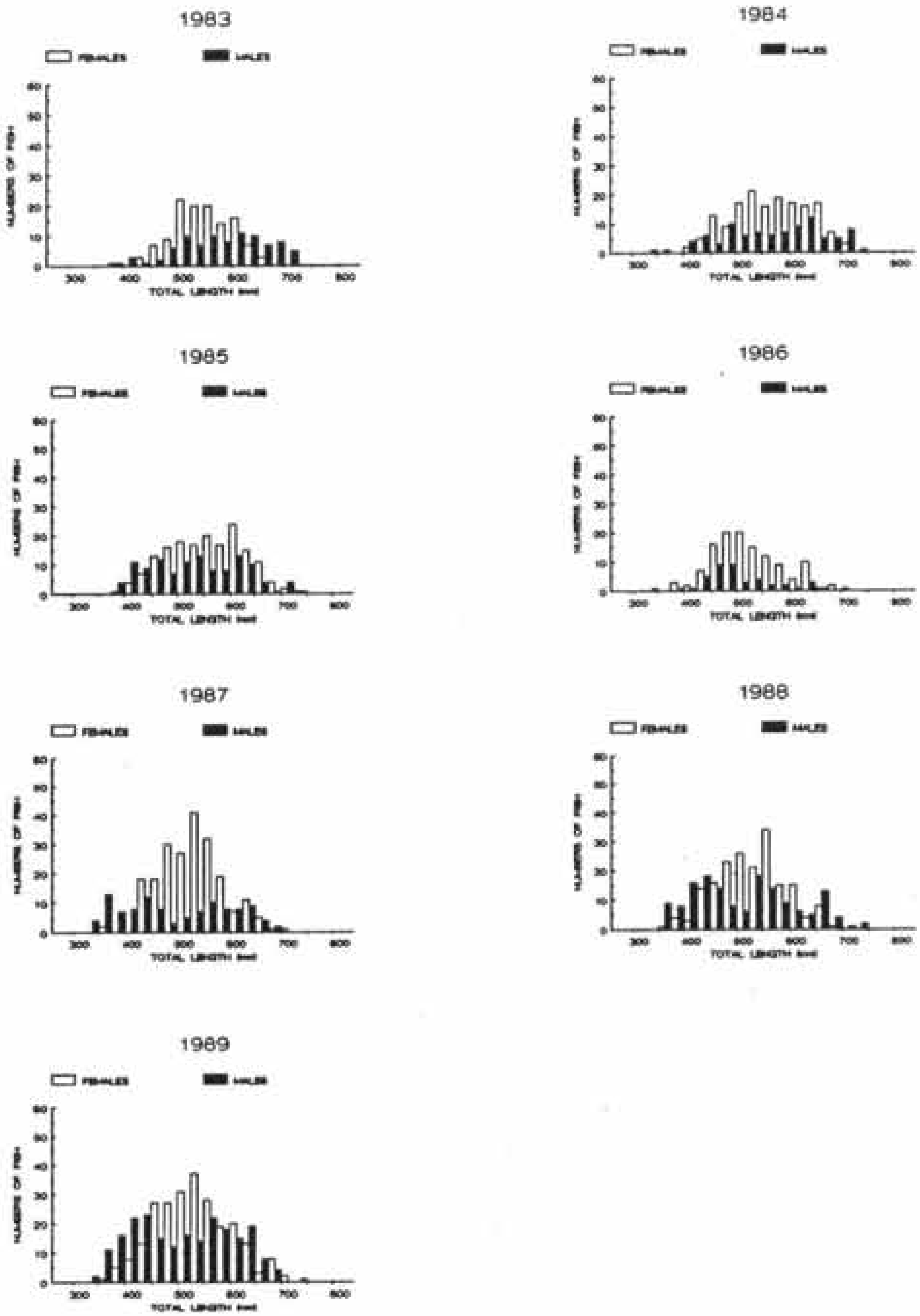

Figure 9. Continued.

were approximately normally distributed throughout the study. Males however, shifted from a skewed-right distribution to a more normal distribution.

Histograms of males and females combined revealed a declining percentage of fish in the larger size classes through time. In St. Charles Creek (Figure 10) the mode decreased from approximately 600 mm TL to 570 mm TL between 1975 and 1989. The mode in Swan Creek (Figure 11) declined from 570 mm TL to 530 mm TL during the same period.

The skewed distribution of fish captured in the 1977 and 1981 runs reflects the low water conditions experienced during those years. However, a similar pattern was not apparent for the drought period from 1987 through 1989. Changes in trap operations, occurrence of spawning below the traps, or overall changes in the population structure likely masked the influence of low water.

<u>Mark and Age Composition</u>

Cutthroat trout examined for marks in the Swan Creek trap revealed a higher percentage of marked fish entering the Swan Creek trap than St. Charles Creek (Figure 12). Because only cutthroat trout in size classes corresponding to stocked fish were examined in 1981, the value for that year is probably inflated. Only three fish were captured in the Big Spring Creek trap in 1989, and the percentage shown in the figure for that year is probably not representative of the population.

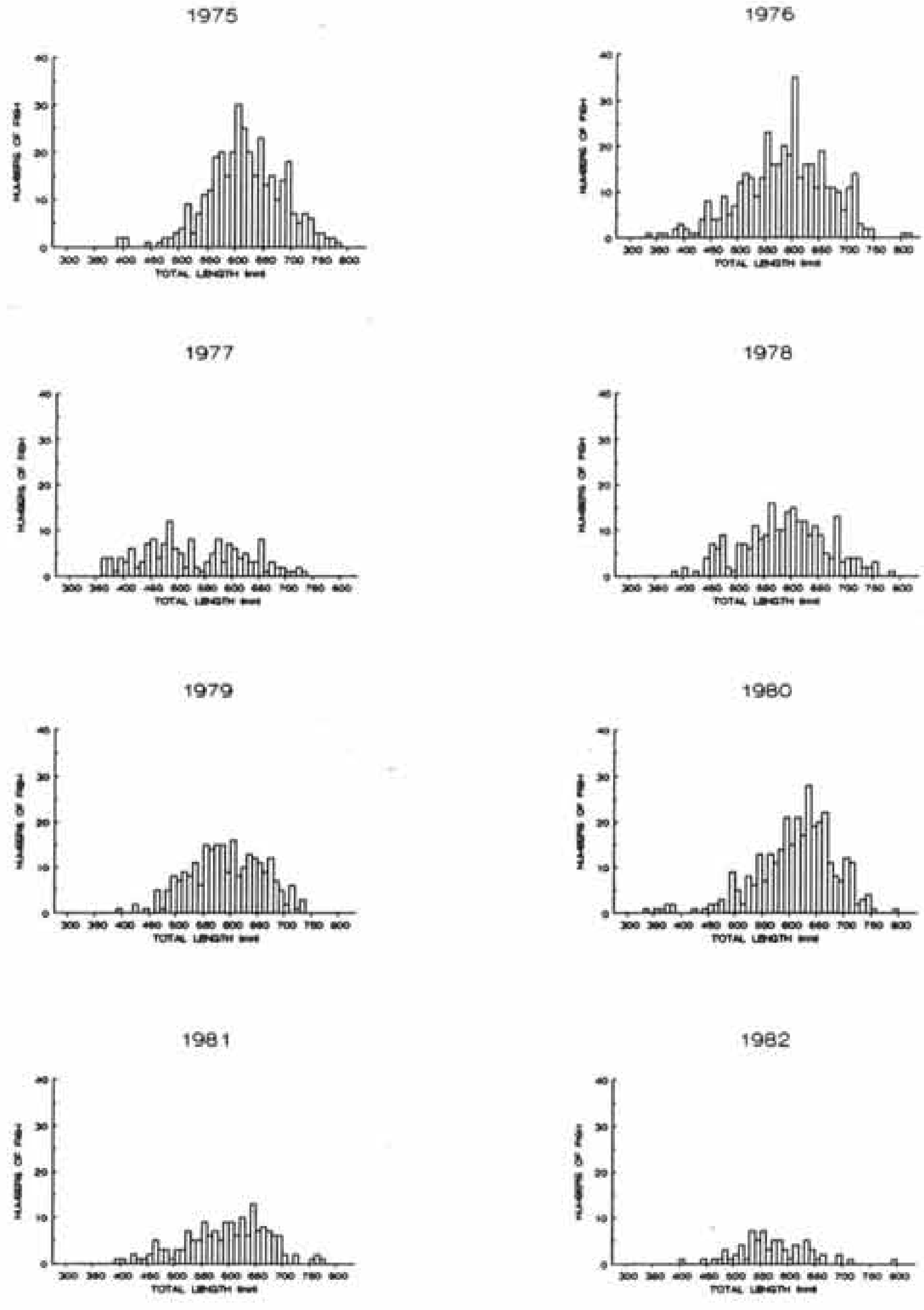

Figure 10. Length-frequency histograms of males and females combined from the St. Charles Creek spawning trap, 1975-1989. Interval width equals 10 mm.

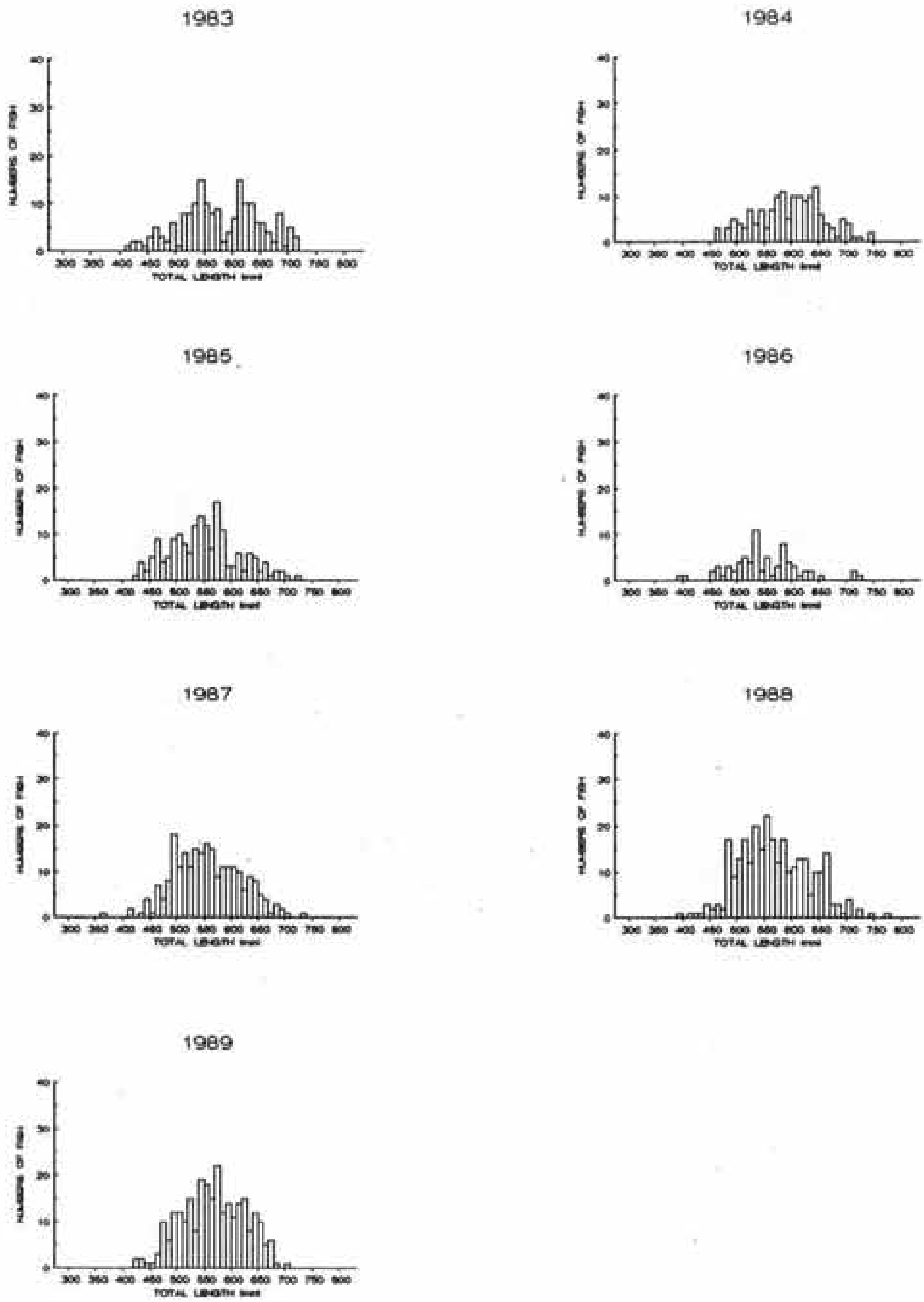

Figure 10. Continued.

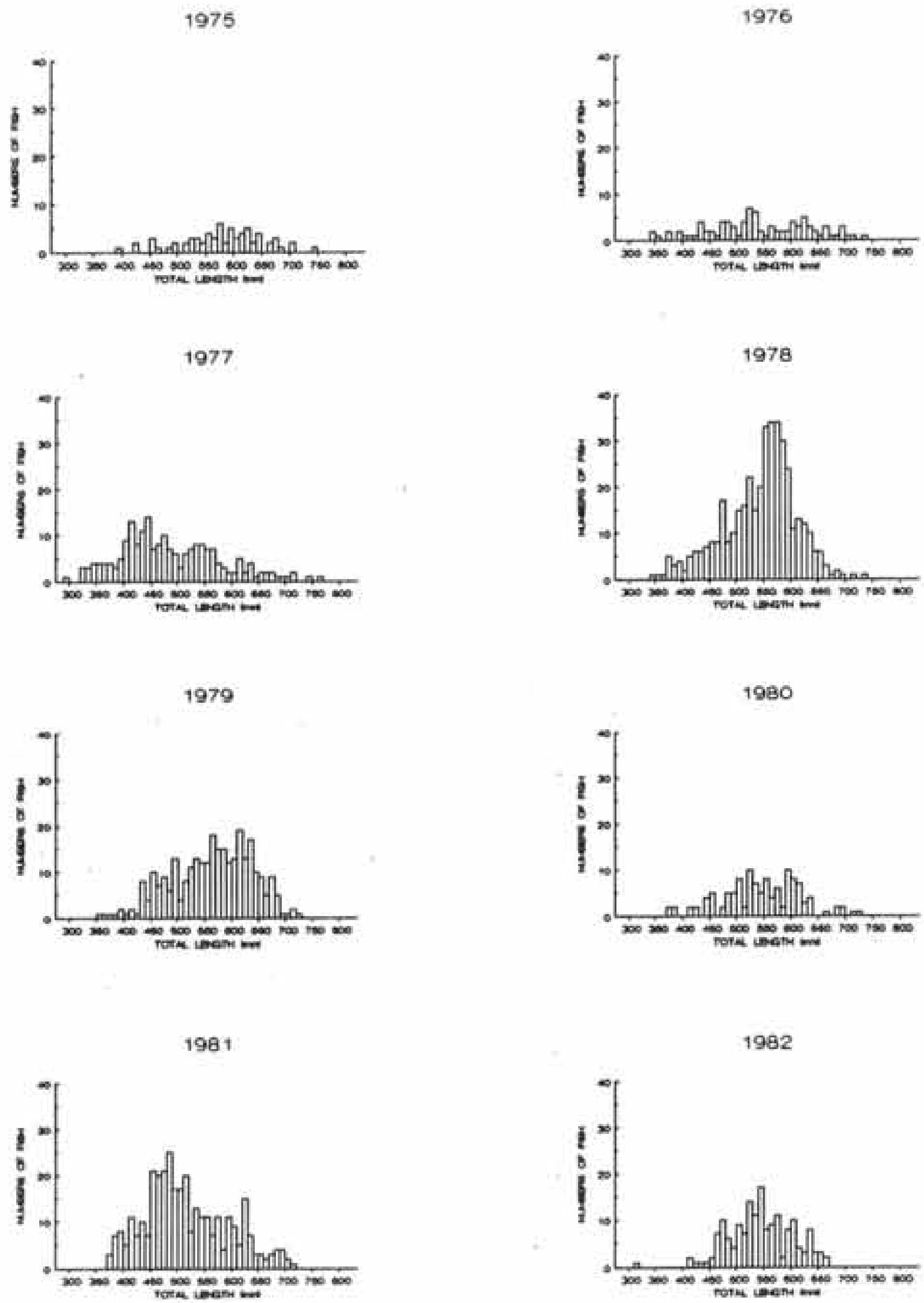

Figure 11. Length-frequency histograms of males and females combined from the Swan Creek spawning trap, 1975-1989. Interval width equals 10 mm.

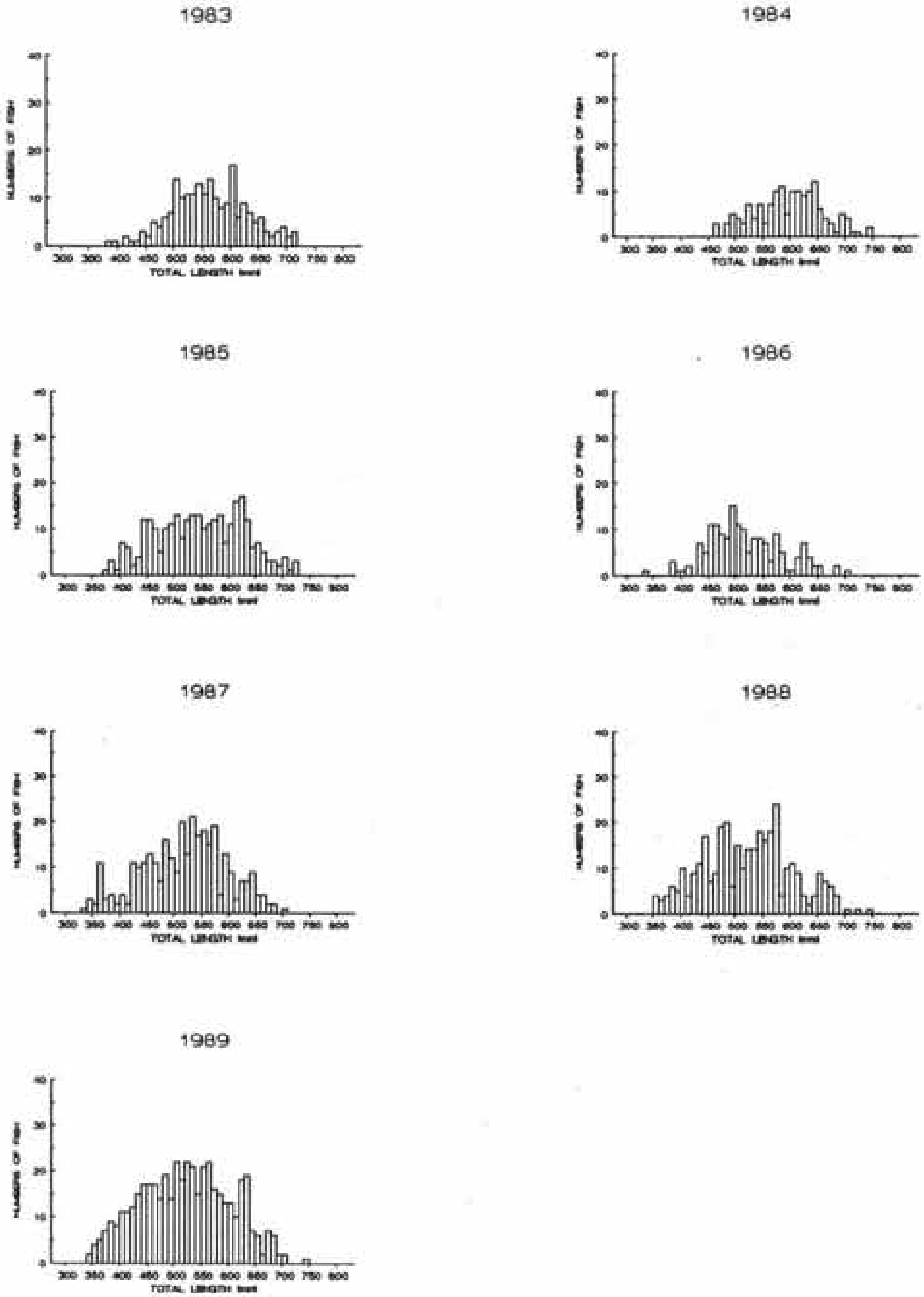

Figure 11. Continued.

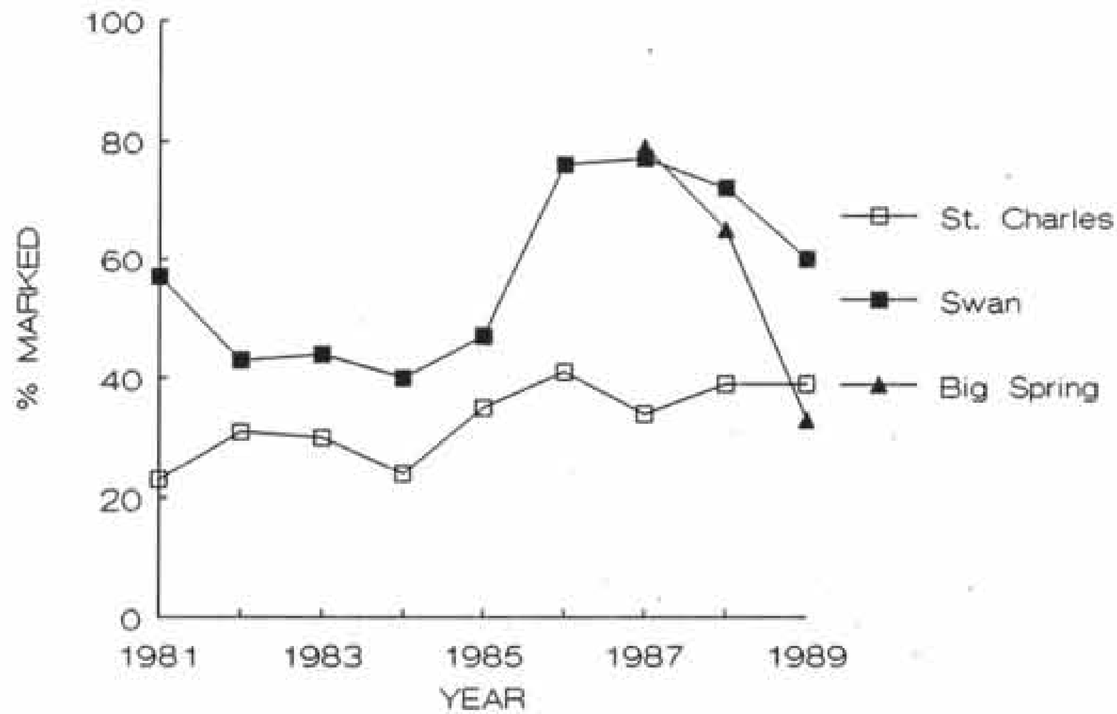

Figure 12. Percentage of examined spawning Bear Lake cutthroat trout which were marked, 1981-1989 (see text for explanation).

The percentages in the figure represent all marks including double-marked fish that had lost the fluorescent pigment mark or did not have a detectable fin-clip but were of the appropriate size to have had one. Nielson (1990) estimated an average of 20% of the double-marked cutthroat trout in the spawning population had lost a grit mark and 10% were missing a fin-clip.

Double marked spawners apparently missing one mark were assigned to a year-class by the biologist at the time of spawning based on total length and external morphological characteristics such as head and fin size. Obviously some error may have occurred using this method, but the number of fish involved was low and the bias incurred was probably negligible.

The relatively high percentage of unmarked fish in the St. Charles Creek run indicates natural recruitment was occurring to the lake from this tributary. The overall importance of natural recruitment to the Bear Lake fishery was not possible to estimate based on the trap returns because imprinting by naturally produced fish may have resulted in a disproportionate rate of return. Straying by hatchery origin cutthroat trout was evidenced by the presence of marked fish in the Big Spring Creek run. Cutthroat trout have not been stocked in the vicinity of Big Spring Creek during the project. The proximity of the Bear River inflow to St. Charles Creek (see Figure 1) increases the likelihood of straying by unimprinted cutthroat trout.

Age composition of the Bear Lake cutthroat trout population was determined from marked fish in the run (Figure 13).

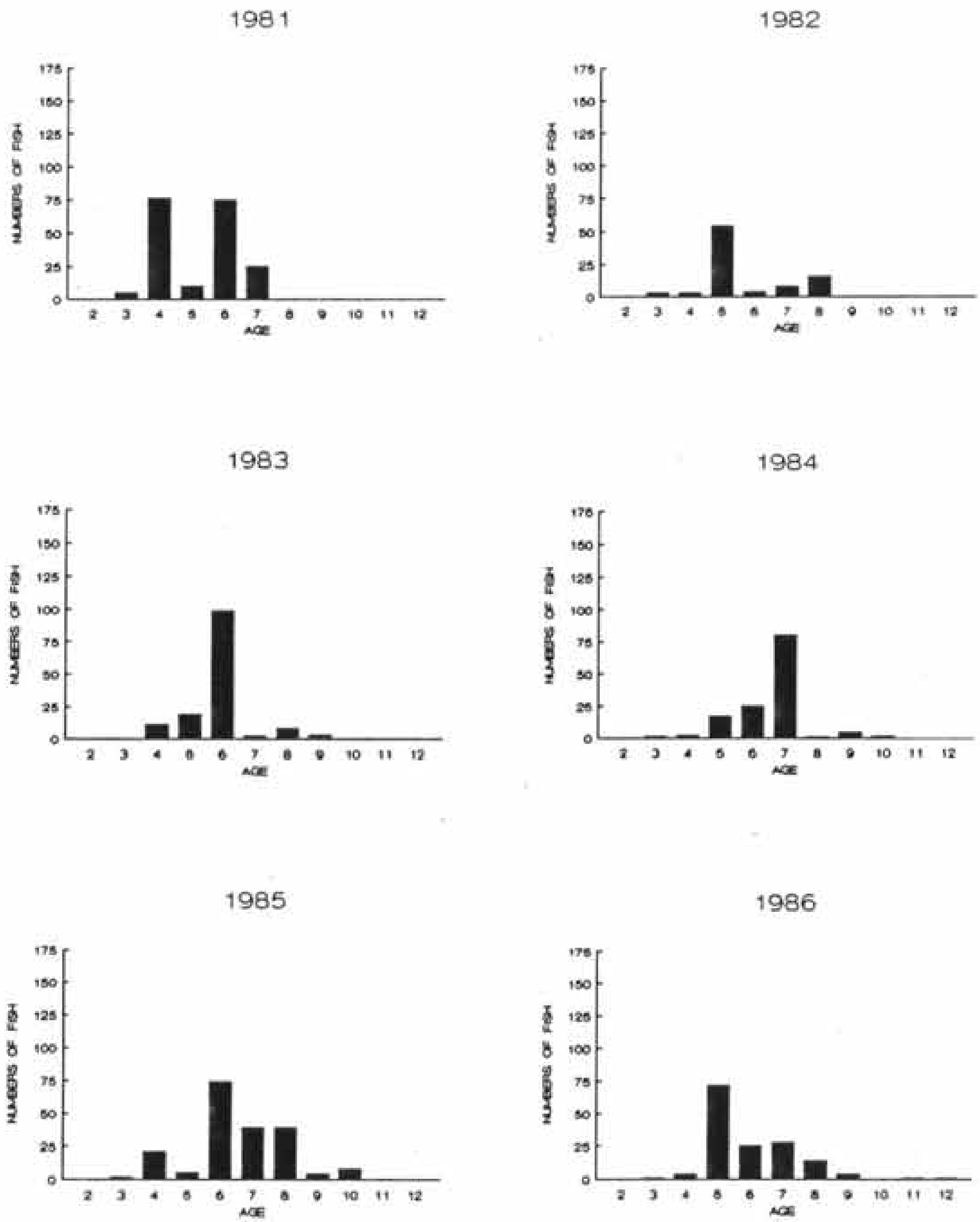

Figure 13. Composition of known age fish in the Bear Lake cutthroat trout spawning population, 1981-1989.

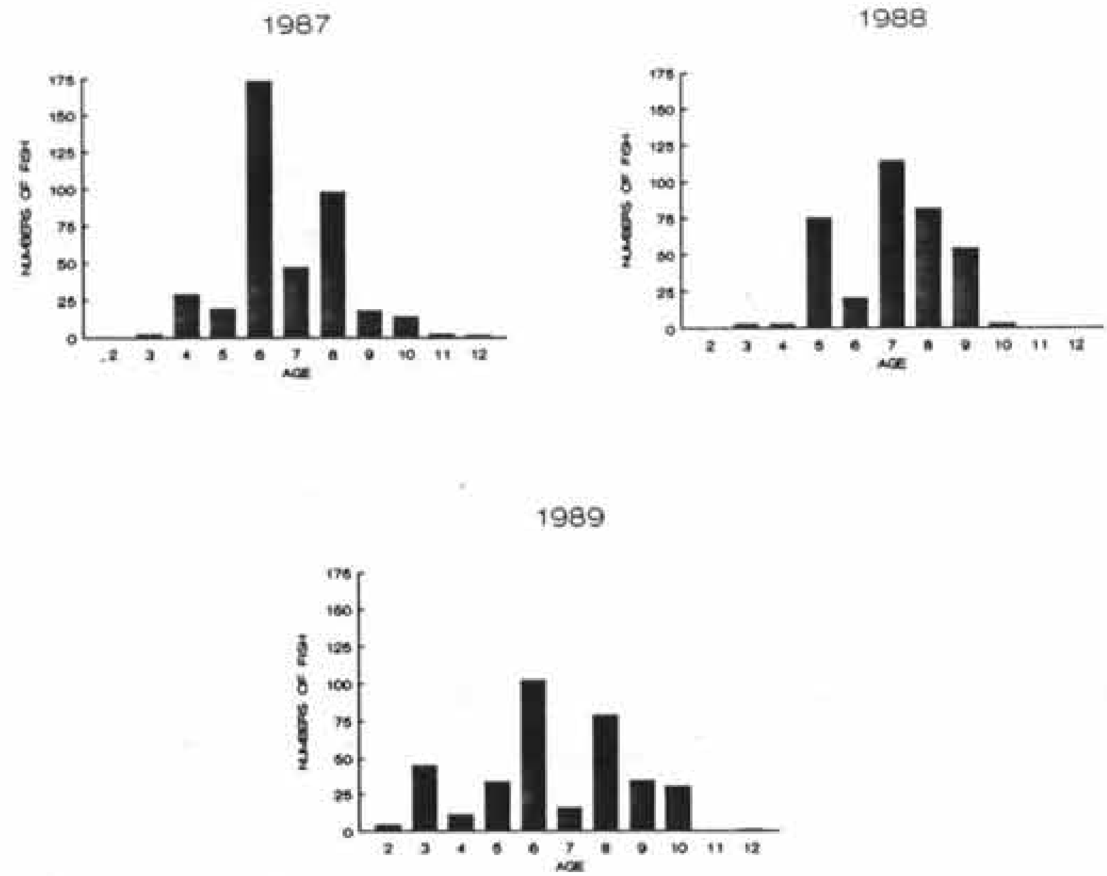

Figure 13. Continued.

Cutthroat trout did not appear to fully recruit to the spawning population until VI+. The minimum observed age in the spawning population was II+ in 1989, and the maximum observed age was XII+. Mean age of Bear Lake cutthroat trout in 1989 was 6.4 years and 40% of the marked spawners were greater than VII+. In contrast, the mean age of cutthroat trout in the 1984 Yellowstone Lake spawning population was 5.3 years, and only 11.2% of the fish in the run were greater than VII+ (Gresswell 1985).

An interesting aspect to the age composition of the Bear Lake spawning run was the wide variation in age at maturity for the same cohort. Fish from the same cohort were observed entering the traps as first-time spawners between the ages of III+ and X+. The largest fish entering the traps on an annual basis were always first-time spawners.

It has been assumed during the Bear Lake project that trap returns have been low, in part, due to a lack of imprinting by stocked fish. For this reason, it was theorized that return of morpholine imprinted fish would skew the distribution of age-classes downward as precocious fish which had previously been unable to locate a spawning tributary entered the traps. Although an increase of younger aged fish was observed in 1989, it is unclear whether this was an impact of the morpholine, a reflection of year class strength, or a result of shifts in the population due to other factors. It will be necessary to continue monitoring of the spawning population to fully determine the impact of morpholine.

Influence of Growth Rate on Maturation

Growth rates may influence age and size at maturation. Thorpe (1987) cited two examples of changes in the population structure of sockeye salmon (Oncorhynchus nerka) as a result of increased juvenile growth rate. In both cases the percentage of precocious males increased in the runs when growth rates of the juveniles increased. Furthermore, Thorpe (1987) stated that conditions existing in fish culture situations; i.e., abundant food and constant temperatures, may result in early maturation.

Growth rates from known age marked fish in the spawning runs were determined. Large intra-year variation in size at a known age existed resulting in r^2 values for the yearly age-growth regressions of less than .60. Combining the 1981-1989 data however reduced the intra-age class variation and increased the r^2 to 0.9 (Figure 14). The linear nature of the growth curve is unique given the span of years examined.

Comparison of the growth curve from the spawning population with the curve generated from gill-netted Bear Lake cutthroat trout (Nielson and Lentsch 1988) revealed that age II+ and III+ fish from the spawning population were approximately 100 mm and 50 mm longer, respectively, than similarly aged cutthroat trout from the gill nets. These data suggest that the fastest growing Bear Lake cutthroat trout mature earliest.

Considerable evidence suggests that growth rates and age at maturity are heritable characteristics for a variety of salmonid species (Thorpe and Morgan 1978, Naevdal 1983, Thorpe 1987,

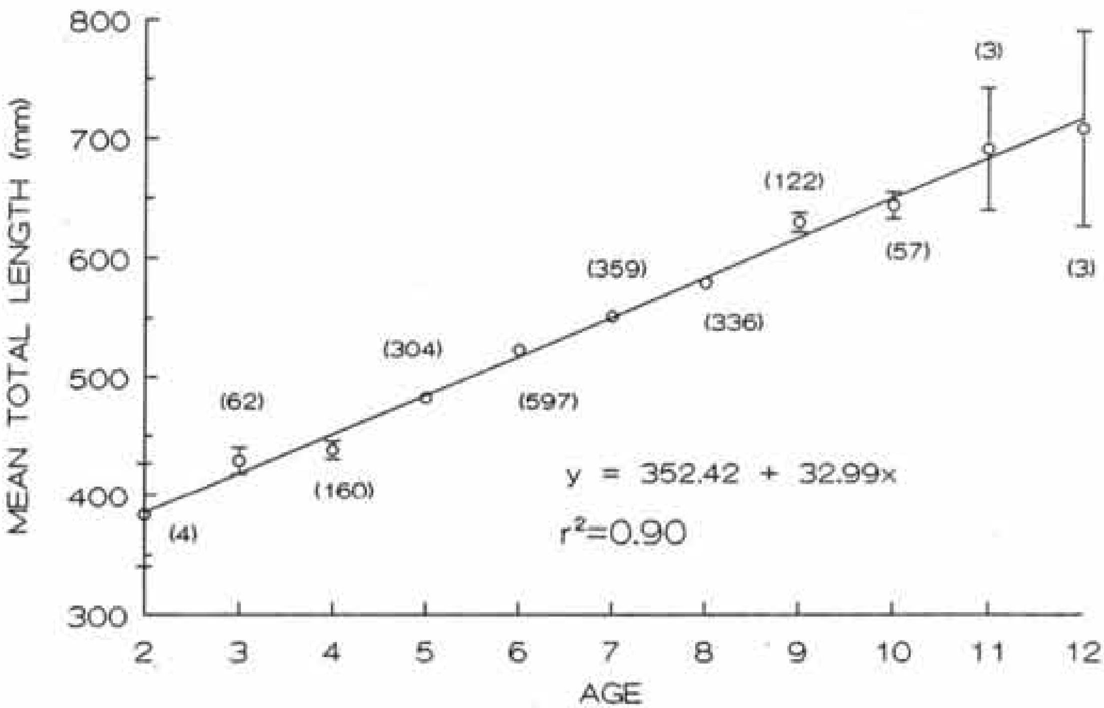

Figure 14. Mean total length with 95% confidence limits for known age Bear Lake cutthroat trout captured in the spawning traps, 1981-1989. Sample size in parentheses.

Gall et al. 1988). The diversity of ages in the Bear Lake cutthroat trout spawning population, the wide variation in age at maturity for the same cohort, and the apparent differences in growth rates within each cohort suggests that these characteristics are heritable in this species also. Thus, increased numbers of smaller fish in the spawning population at Bear Lake may be a reflection of increased diversity within the population.

Two anomalies exist in the growth data that makes further interpretation difficult. Data from known age cutthroat trout were separated by age class and analyzed using one-way analysis of variance (Hintze 1987) by mark group. In general, fish stocked as 225 mm TL catchables were significantly smaller at the same age than fish stocked as 125 mm TL fingerlings (Figure 15). Additionally, fingerlings stocked since 1984 returned to the traps at a smaller mean size than fingerlings stocked prior to 1980. These relationships held true only for fish less than eight years old. Further investigation of the relationship between size at stocking and size at maturity is required.

Egg Size vs. Female Total Length

From 1975 through 1979, the number of eggs per ounce was determined using a Von Bayer trough. The trough was closed at both ends and all eggs placed in the trough were counted (T. Miles, UDWR, pers. comm., 1990). Two different methods were used after 1979. From 1980 through 1984 three ounces of eggs

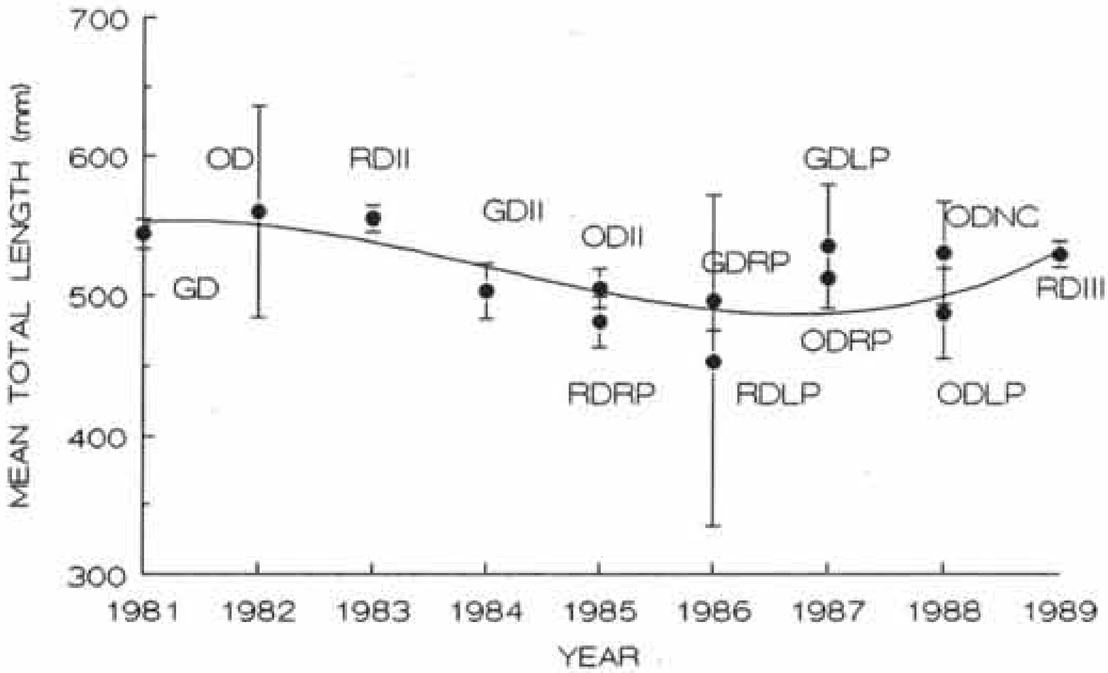

Figure 15. An example of change in total length (with 95% confidence limits) by mark group. All fish are age VI+.

were hand counted on a counting board and the average number extrapolated to the total volume of eggs (California method). From 1985 to the present, an open-ended Von Bayer trough has been used to prevent "packing" of the eggs and ten percent subtracted from the total (Mandis and Harris 1984). According to Miles (pers. comm 1990), the latter two methods provided similar estimates of total eggs.

The average number of eggs per ounce was inversely related to the average size of the spawned females. This relationship has been described as typical for salmonids (Gall 1974).

Post-spawning Survival

Post-spawning survival of Bear Lake cutthroat trout was estimated from angler tag returns using the methods of Brownie et al. (1985). Tag returns were insufficient to generate estimates from the four different models which are possible outputs from the computer program ESTIMATE (Brownie et al. 1985). For this reason, a limited run which assumed constant survival and tag recovery probabilities was the only output possible.

Post-spawning survival was estimated at 50%. Average longevity after spawning was estimated at 1.2 years. The data were not sufficient to estimate survival by sex, but observations indicated that females had a better survival rate than males. During the period from 1977 through 1988, 191 tags from females were returned, whereas, only 67 male tags were returned.

Angler tag returns from the period 1977 through 1988 were used to calculate exploitation rates (Beverton and Holt 1957). Exploitation rates ranged from 0.3-4% with a mean of 2%. These values are probably low because natural post-spawning mortality and angler reporting bias are not considered in the equation. However, even assuming a 200% bias from these sources it is unlikely that fishing mortality contributed substantially to total mortality.

Repeat Spawning

Large, late-maturing fish such as the Bear Lake cutthroat trout should produce more than one brood. Repeat spawning reduces the risk of extinction in highly variable environments (Dillinger 1989). Yet, the incidence of repeat spawning by Bear Lake cutthroat trout averaged less than 3% and never exceeded 7% of the total run (Figure 16). The 1977-1989 data were used in all analyses of repeat spawning because it represented the most complete data set.

Most of the repeat spawners returned to the trap the year following initial capture (Figure 17). The average post-spawning longevity of 1.2 years from the ESTIMATE model appeared to be sufficient to allow a higher percentage of repeat spawning. The percentage of unmarked repeat spawners (Figure 18) versus the percentage of unmarked fish in the total population provided an indication that other factors may have controlled the rate of repeat spawning.

A total of 121 females, 37 males, and 1 immature fish were

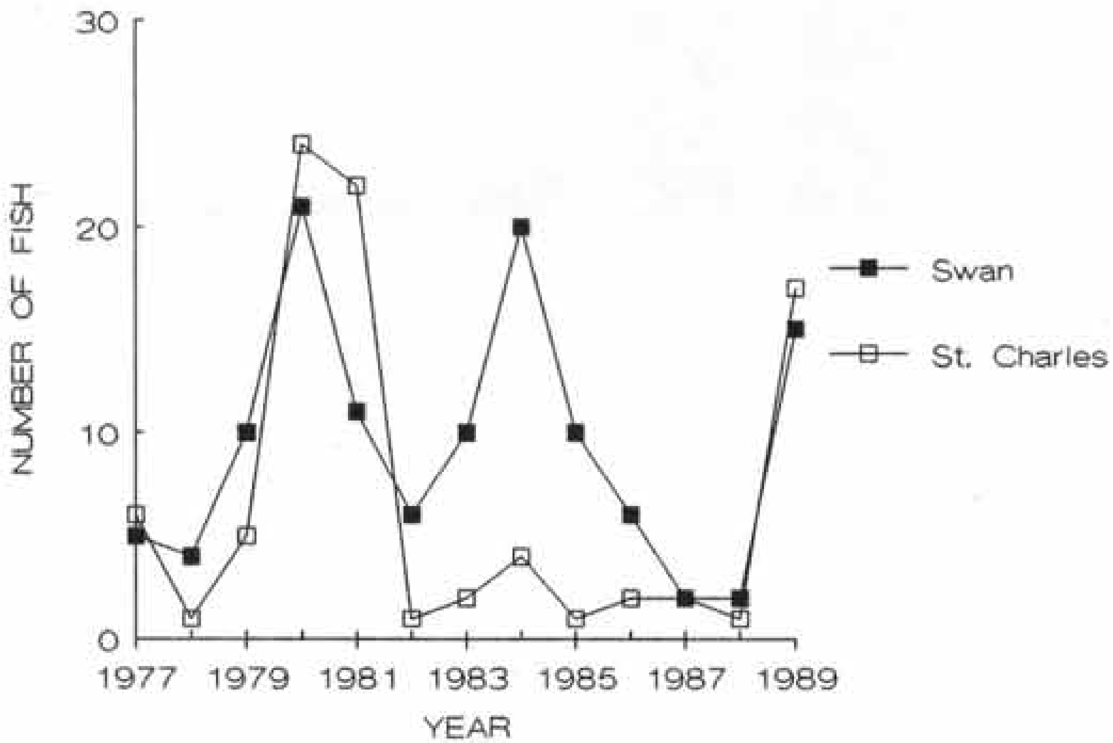

Figure 16. Number of repeat spawning Bear Lake cutthroat trout captured in the spawning traps, 1977-1989.

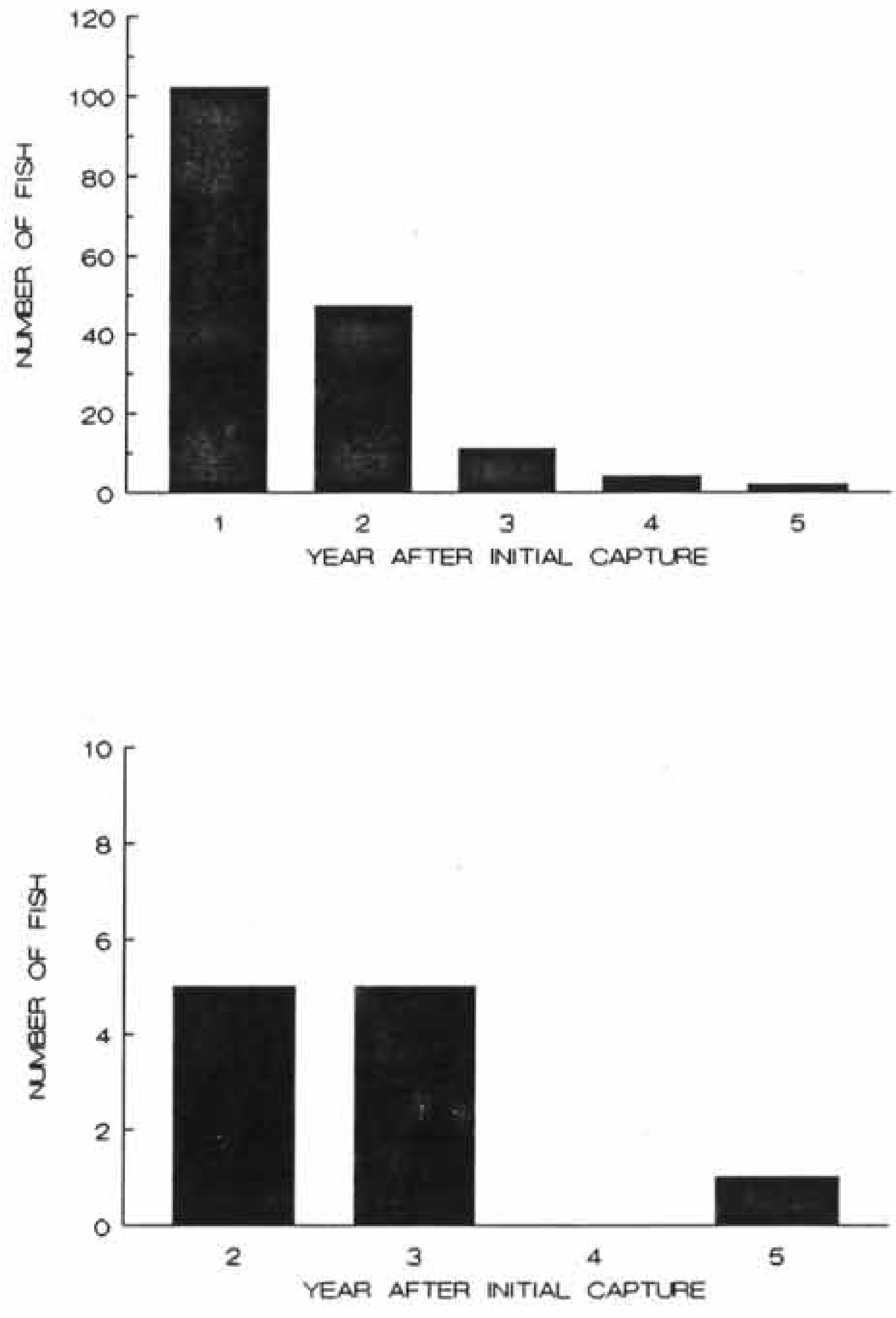

Figure 17. Year returned after initial capture for all repeat spawning Bear Lake cutthroat trout (upper figure) and multiple trap returns (lower figure).

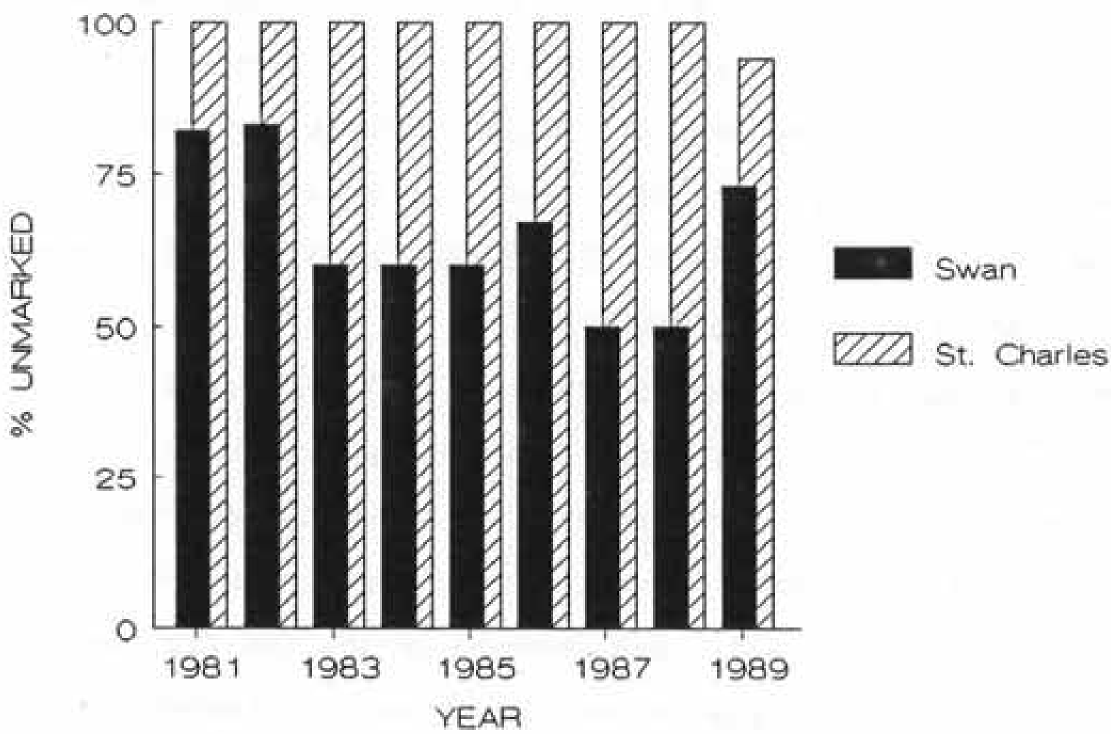

Figure 18. Percent unmarked repeat spawning Bear Lake cutthroat trout, 1981-1989.

used to determine if some characteristics were common to all repeat spawners. Data from initial year of capture were used to determine if trap operations were influencing the rate of return. Fish with obvious scars indicative of a lost tag were counted as repeat spawners, but could not be utilized in the analyses because it was impossible to determine characteristics from the initial capture. Factors evaluated were; sex, trap, whether the fish was marked or unmarked, disposition of fish at time of initial capture, Julian date of initial capture, and number of days held in the trap in initial year. An arbitrary size class designation; <500 mm, 500-599 mm, and >600 mm also was assigned to each fish and used as a factor.

Contingency table analysis (Hintze 1987) was used to determine the inter-relationship between the individual factors and whether or not the fish returned in a subsequent year. Results from the analyses indicated that sex, the number of days held in the trap initially, and whether or not the fish was marked influenced the rate of return. Females returned at a higher percentage than males, at approximately the same ratio as the angler tag returns. Fish held in the traps less than eight days during the initial year of capture were the most likely to return in a subsequent year.

Unmarked fish returned at a higher rate than marked fish, suggesting that most of the repeat spawners were naturally recruited from the tributaries. The increase in the number of repeat spawners in 1989 is consistent with this theory. Sizes of the 1989 returned fish suggest they were produced from spawners which bypassed both traps during the high water years. The relationship between mark and rate of return questions the benefits of morpholine as an attractant.

Cutthroat trout in the 500-599 mm size class were also the most likely to return in subsequent years, but other factors such as age and growth rate may have been the determining factors for this result. Larger fish may have simply been close to the end of their normal lifespan. Whereas, the smaller fish were most likely the fastest growing members of their cohorts and growth rate has been shown to be inversely related to longevity (Dillinger 1989).

Disposition of the fish, that is whether it was spawned, released unspawned, or released upstream at St. Charles was not related to the rate of return. Julian date of initial capture and trap site also did not appear to influence the return rate.

Mann and Mills (1979) stated that one-time spawning fish such as the Atlantic salmon (Salmo salar) can achieve the benefits of multiple spawning by the production of individuals of the same year class which mature at different ages. Thorpe (1987) suggested the threshold level of biochemical indices necessary to trigger maturation vary throughout the population. He further related this variation to the ability of salmonids to occupy a wide variety of geographic and climatic regions.

Evidence presented from other salmonid species suggests that semelparity is common for salmonids. From the low rate of repeat spawning in Bear Lake, the wide diversity of age at maturity for the same cohort, and the fact that the largest fish in the spawning population are always first-time spawners, it can be concluded that the majority of Bear Lake cutthroat trout are one-time spawners. Lahontan cutthroat trout also appear to be semelparous (P. Coffin, NDW, pers. comm., 1990).

However, the influence on return rate of the factors analyzed earlier and the average longevity estimated from the tag returns suggests that a higher rate of repeat spawning could be expected in Bear Lake. Repeat spawning rates for Lahontan cutthroat were two to three times greater than the rate experienced in Bear Lake (P. Coffin, NDW, pers. comm., 1990).

RECOMMENDATIONS

Several aspects of the Bear Lake cutthroat trout spawning run require further investigation and should be undertaken during the next phase of the project:

1. Additional effort is required to more closely estimate post-spawning mortality and angler exploitation. Reward tags should be utilized in the future to provide an estimate of reporting bias from previous years, and hopefully increase the total number of tags returned.

2. Consultation with a geneticist should be done concerning current methods of spawning wild broodstock, including review of the broodstock selection criteria used in the trap and the male to female spawning ratio. The number of parents selected for broodstock replacement needs to be defined for maximizing genetic diversity while still working within the constraints of the culture system to maintain isolated lots of eggs for disease purposes.

3. The use of only wild origin fish as captive broodstock parents should be considered. This would require differential marking of any stocked fish from eggs produced at the J. Perry Egan Hatchery.

4. Further investigation of the apparent relationship between size at stocking and size at maturity should be done. An important aspect of this project would be defining the size of natural recruits.

5. Natal stream imprinting by Bear Lake cutthroat trout appears to occur. Additional work on the timing of juvenile imprinting and refinements to the methodology of artificial imprinting need to be undertaken.

6. Investigate the magnitude of natural reproduction in the tributaries below the traps. Other drainages (e.g. Fish Haven Creek) should be surveyed to determine extent of use by spawning Bear Lake cutthroat trout.

7. The possible influence of weather patterns on daily trap catches should be investigated further by the acquisition of a recording thermometer to monitor diel changes in stream temperature at Swan Creek. Monitoring of flow patterns, minimum and maximum air temperature, and percent cloud cover should also be considered.

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