AN ABSTRACT OF THE THESIS OF

ROY A. STEIN, Jr. for the MASTER OF SCIENCE
(Name of Student) (Degree)

in FISHERIES presented on May 6, 1971
(Major) (Date)

Title: SOCIAL INTERACTION BETWEEN JUVENILE COHO AND FALL CHINOOK SALMON IN SIXES RIVER, OREGON

Abstract approved: Redacted for Privacy
James D. Hall

The nature of the interaction between juvenile coho salmon, Oncorhynchus kisutch (Walbaum), and fall chinook salmon, O. tshawytscha (Walbaum), was studied in Sixes River, Oregon. Seining, snorkeling, and tagging were used to determine distribution and patterns of growth of these two species in the stream environment. Experiments conducted in flowing-water observation troughs that provided volitional residence were designed to examine the outcome of agonistic behavior between these two species.

Both species were distributed throughout the entire river system in early spring. During this period, underwater surveys in the main river and selected tributaries indicated that both species preferred the same habitat. As temperatures increased during the late spring, coho disappeared from the main river, but continued to occupy cool tributaries. Fall chinook, on the other hand, were found primarily in the main river until early summer, when they

moved to the estuary. Relatively few individuals remained in the tributaries.

Experiments conducted in the troughs revealed that agonistic behavior, including nipping, chasing, lateral display, submission, and fleeing, occurred between juvenile coho and fall chinook. When the two species were together in the troughs and in cool tributary streams, coho grew faster than chinook. When isolated in troughs, both grew at similar rates. Coho tolerated fewer individuals per unit area than did chinook, and occupied positions of dominance near the source of incoming food at the upstream end of the troughs.

Coho had brighter fin and body colors, greater fin development, deeper bodies, and were heavier than fall chinook of the same length. Coloration and morphology appeared to be important factors influencing the "apparent" size and presumably the social status of both species.

Juvenile coho, with extensive development of fins and coloration and intense territorial behavior, are hypothesized to be adapted to small, cool tributary streams. Fall chinook, on the other hand, with conservative development of fins and coloration and related behavior patterns, appear to be adapted to conditions in the main river and estuary.

Social Interaction Between Juvenile Coho and Fall Chinook Salmon in Sixes River, Oregon

by

Roy A. Stein, Jr.

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1971

APPROVED:

Redacted for Privacy

Associate Professor of Fisheries
in charge of major

Redacted for Privacy

Head of Department of Fisheries and Wildlife

Redacted for Privacy

Dean of Graduate School

Date thesis is presented May 6, 1971

Typed by Velda D. Mullins for Roy A. Stein, Jr.

ACKNOWLEDGMENTS

Thanks are due to many people who aided me in this endeavor. The Fish Commmission of Oregon provided me with financial assistance in addition to personnel and equipment. Individuals in that organization who were particularly helpful include Mr. Richard Roll and Mr. Reese Bender. I am grateful to Miss Deborah Browning who aided in typing the final draft and whose quick wit often buoyed my spirits. Thanks are due Dr. John D. McIntyre and Dr. John A. Weins who reviewed the manuscript. Deepest appreciation is extended to Mrs. Sandra Reimers for her patience and endurance during my stay in Port Orford. To my major Professor, Dr. James D. Hall, who contributed many valuable suggestions during the course of this study and who tirelessly aided in preparing and editing the final draft, I extend my heartfelt thanks. To Mr. Paul E. Reimers of the Fish Commission of Oregon, who suggested this problem and worked very closely with me until its completion, I am very grateful. His seemingly boundless energy and enthusiasm made this project an exciting learning experience. And finally I thank Miss Jean Prindle, without whose assistance and constant encouragement this project would not have been completed. Her patience and understanding throughout this study has made this task a pleasant one indeed.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF THE STUDY AREA	3
Sixes River	3
Crystal Creek	3
METHODS	7
Natural Populations	7
Experimental Populations	8
Color Patterns and Morphology	10
RESULTS	12
Distribution	12
Growth	20
Agonistic Behavior	26
Color Patterns and Morphology	33
DISCUSSION	40
LITERATURE CITED	48

LIST OF TABLES

Table		Page
1	Peak spawning and predicted timing of emergence of coho and fall chinook salmon in Sixes River	15
2	Fish observed while snorkeling in Sixes River during 1970-1971	18
3	Mean size of fish at the outset and termination of experiments conducted in the observation troughs	22
4	Production in gm/m^2 of underyearling coho and fall chinook salmon that remained in the observation troughs until termination of the experiment	26

LIST OF FIGURES

Figure		Page
1	Map of Sixes River showing temperature stations	4
2	Map of Crystal Creek showing areas sampled	5
3	Composite spawning distribution of adult coho and fall chinook salmon in Sixes River	13
4	Composite of spring and summer distribution of underyearling coho and fall chinook salmon in Sixes River	14
5	Weekly maximum temperatures of Sixes River and selected tributaries during the summer of 1970	16
6	Average fork length of juvenile coho and fall chinook salmon seined from Crystal Creek, stations 1-5	21
7	Growth of underyearling coho and fall chinook salmon in the observation troughs	25
8	Growth of tagged juvenile coho and fall chinook salmon in Crystal Creek from July 20 to August 8, 1970	26
9	Growth of underyearling fall chinook salmon planted in Swamp Creek, Sixes River from March 31 to June 2, 1970	27
10	Relationship between number of underyearling coho and fall chinook salmon present in the riffle and pool in the observation troughs during the period June 3 to June 23, 1970	30

Figure		Page
11	Relationship between number of underyearling coho and fall chinook salmon present in the riffle and pool in the observation troughs during the period May 12 to May 25, 1970	31
12	Relationship between height of the dorsal fin and fork length of juvenile coho and fall chinook salmon in Sixes River	34
13	Diagrammatic sketch of the dorsal and anal fins of recently emerged and two-week-old fry of coho and fall chinook salmon in Sixes River	36
14	Relationship between height of the anal fin and fork length of juvenile coho and fall chinook salmon in Sixes River	37
15	Relationship between body depth and fork length of juvenile coho and fall chinook salmon in Sixes River	39

SOCIAL INTERACTION BETWEEN JUVENILE COHO AND FALL CHINOOK SALMON IN SIXES RIVER, OREGON

INTRODUCTION

Coho salmon, *Oncorhynchus kisutch* (Walbaum), and fall chinook salmon, *O. tshawytscha* (Walbaum), occur together in many of the coastal streams of the Pacific Northwest. In Sixes River, on the south coast of Oregon, the timing and location of spawning of these two species overlap; as a consequence, juveniles are found together. Food and space are probably in short supply in the freshwater environment (Chapman, 1966); thus coho and fall chinook may interact because their ecological requirements are similar. Preliminary studies of each species have suggested that territoriality and agonistic behavior may function in the regulation of population numbers relative to available food and space (Chapman, 1962; Reimers, 1968). Thus, this study was designed to examine the nature of the interaction between juvenile coho and fall chinook salmon. Specifically, the objectives of this study were twofold: 1) to examine the habitat preferences and interaction between coho and fall chinook salmon in Sixes River, and 2) to determine the outcome of any social interaction in terms of growth and displacement. The main portion of this investigation was conducted during the spring and summer of 1970.

Interspecific interaction between juvenile salmonids has been examined in some detail. Most recently, Lister and Genoe (1970) suggest that because of size-related differences in habitat selection, underyearling coho and fall chinook salmon do not interact in the Big Qualicum River, British Columbia. They found that fall chinook emerged first, grew at a faster rate, and subsequently moved into water of high velocity before coho. Differences in habitat selection prevented behavioral interaction and persisted until downstream migration of chinook, two to three months after emergence. Hartman (1965) showed that juvenile coho salmon and steelhead trout, *Salmo gairdneri* Richardson, segregate in nature. In sympatry, coho were found mainly in pools and trout primarily on riffles; in allopatry, they were distributed uniformly in both pool and riffle habitats. Interspecific competition between juvenile cutthroat trout, *S. clarki clarki* Richardson, and coho salmon resulted in a reduction of individual rates of growth when the two species were combined in an experimental stream section. However, each species apparently utilized a slightly different portion of the environment, resulting in an increase in total production beyond that of either alone (McIntyre, 1970).

DESCRIPTION OF THE STUDY AREA

Sixes River

Sixes River is a short coastal river located 8 km north of Port Orford, Oregon (Figure 1). The river begins in the Coast Range and drains an area of approximately 340 km^2. Mean daily discharge in 1968 varied from 0.5m^3/sec in the summer to over 200 m^3/sec in the winter (U. S. Geological Survey, 1968). The upper watershed, once extensively logged, now consists of second-growth Douglas fir combined with mixed deciduous species. At present, this area is primarily used as pasture for cattle and sheep. Most of the tributaries remain below 20 C throughout the summer, while temperatures in the main river commonly exceed 25 C. Approximately 2,500 adult salmon spawn in this system each year, of which 90% are fall chinook and 10% are coho (Fish Commission of Oregon, 1968). Other salmonids that spawn in the Sixes system include cutthroat and steelhead trout.

Crystal Creek

Studies of natural populations were concentrated in Crystal Creek, a tributary that flows into Sixes River 6 km inland from the mouth (Figure 2). It drains an area of about 4 km^2. A low

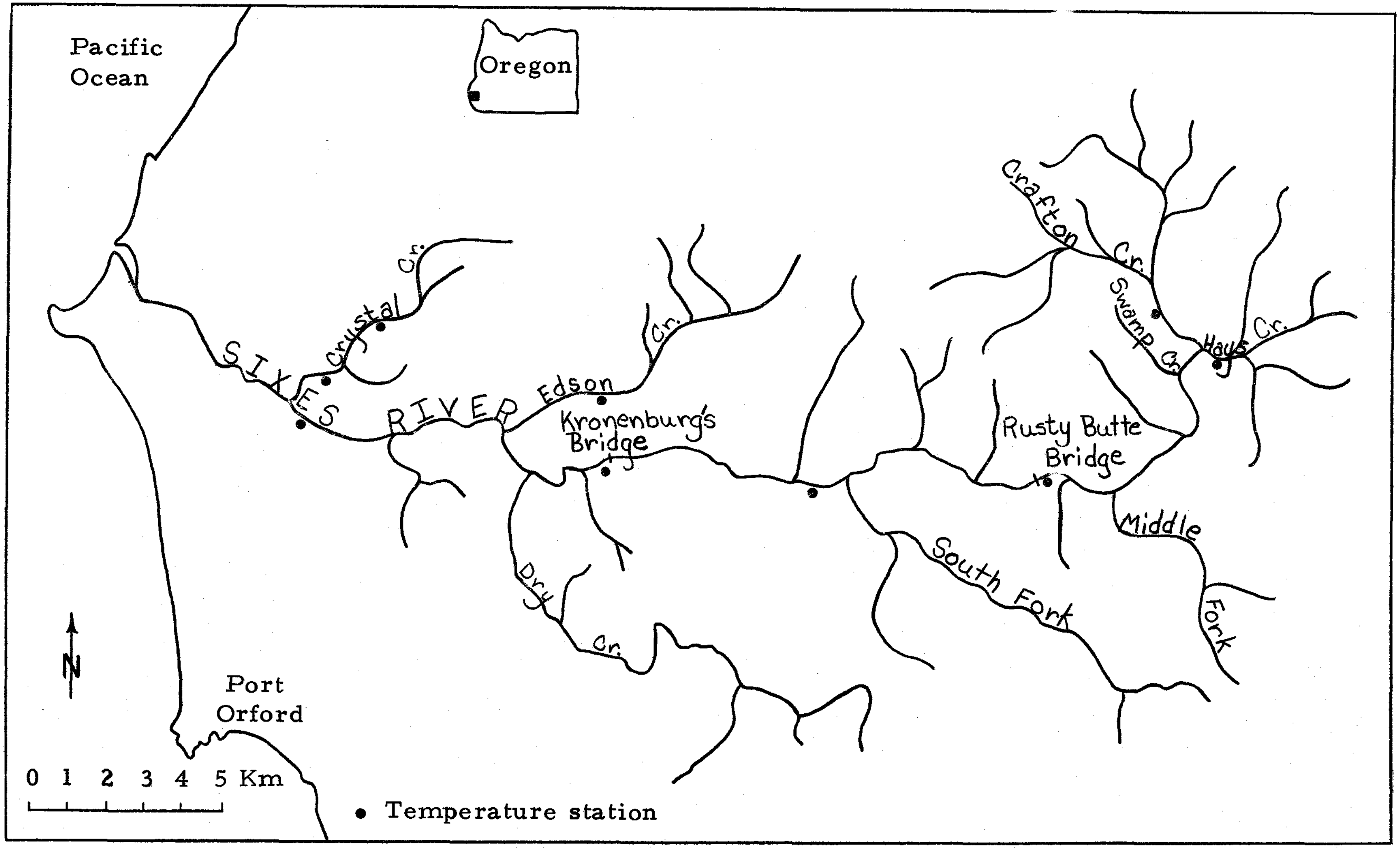

Figure 1. Map of Sixes River showing temperature stations.

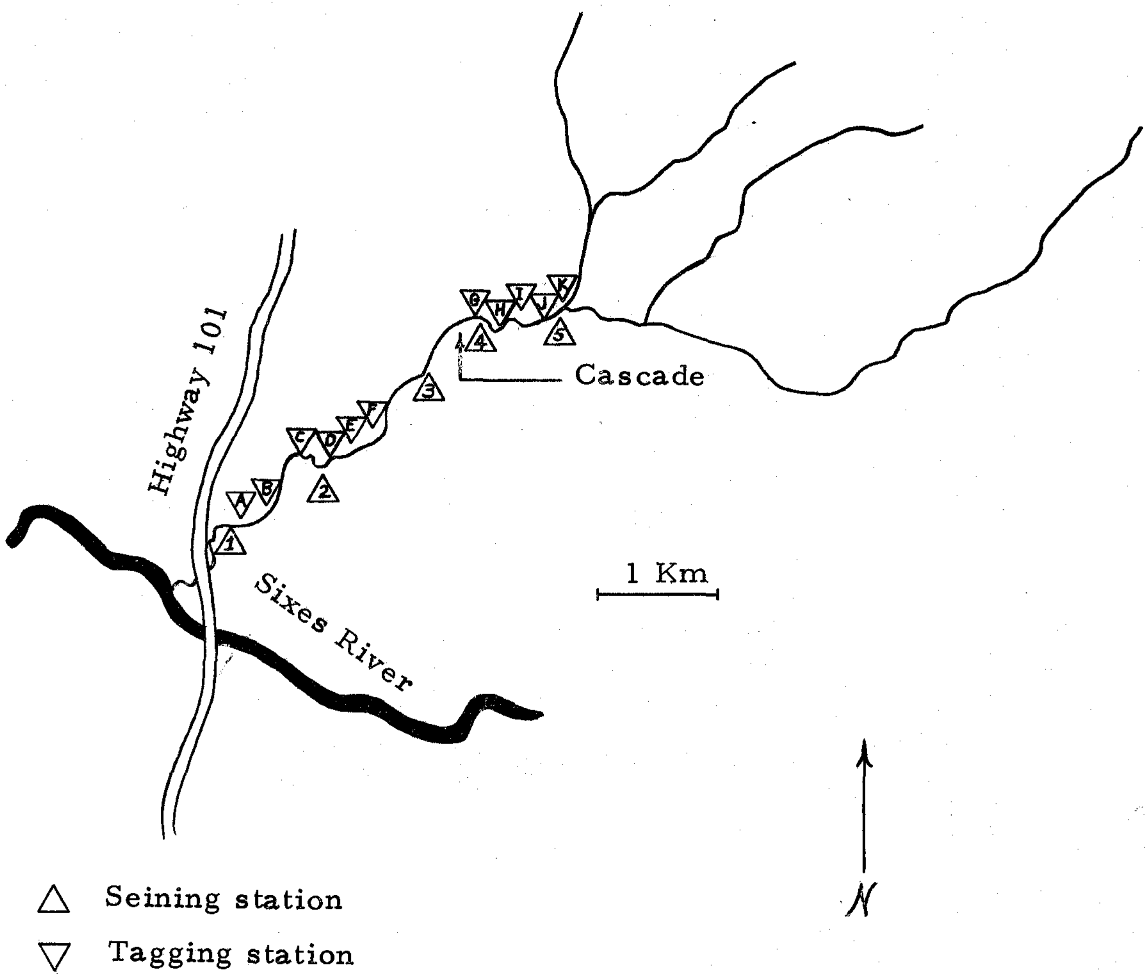

Figure 2. Map of Crystal Creek showing areas sampled.

flow of 0.03 m^3/sec was recorded during the summer of 1970. Crystal Creek is divided into two distinct areas by a cascade: a densely shaded upper section characterized by cool temperatures in summer, and an exposed lower valley where stream temperatures often exceed 20 C (Figure 5). Total number of adult salmon spawning in Crystal Creek is unknown, but counts of spawning fish indicate that coho comprise about 25% of the total population (Fish Commission of Oregon, 1968). However, these survey units were mainly designed for counts of spawning fall chinook. Thus upper spawning areas, where coho predominate, were not included.

METHODS

Natural Populations

Seining stations were established on the main river and selected tributaries to determine distribution and patterns of growth. At 3-week intervals from March to June, fish were seined, anesthesized with tricaine methane sulfonate (MS 222), measured to 0.1 cm fork length, and returned to the stream. Because of the variability in areas sampled, several types of seines were used to capture fish. For small areas, straight seines 2 m, 4 m, and 9 m, all 1.5 m in depth with a stretched mesh of 0.5 cm, were used. For larger areas, an 18 m bag seine 3 m in depth, with a mesh size of 1.25 cm in the bag and 2.5 cm in the wings, was used. To examine the microhabitat distribution of juvenile coho and chinook in the stream, I also conducted underwater surveys using snorkel gear. Observations were made periodically during the spring and summer while moving slowly upstream along the shore.

To determine if small size of tributary streams might influence the growth rate of chinook, an experimental population was planted in Swamp Creek, a small headwater tributary of Sixes River (Figure 1). Although some cutthroat trout were present, coho were absent from the stream. Approximately 2, 500 chinook, incubated at Elk River Salmon Hatchery until absorption of the yolk sac, were stocked in Swamp Creek in April. This experimental population was sampled periodically to determine rate of growth during late spring and early summer.

Eleven tagging stations were established along Crystal Creek, from the mouth to above the cascade (Figure 2). At each station fish were seined, anesthetized, blotted to remove excess water, weighed to the nearest 0. 1 g, and measured to the nearest 0. 05 cm fork length. Fish were then tagged with numbered streamer tags (Pyle, 1965), allowed to recover from the anesthetic, and released at the upstream end of the area in which they were captured. Fish were recaptured, weighed, measured, and released at 3-week intervals for the remainder of the summer.

Data on stream temperature were gathered with Partlow thermographs and Taylor maximum-minimum thermometers placed at strategic locations in the river system (Figure 1).

Experimental Populations

Studies of experimental populations were conducted in observation troughs as described by Reimers (1970). Each system was divided into a riffle and a pool that were visible through plexiglass windows large enough to provide a complete view of fish activity. Water from a natural stream flowed over the riffle, through the pool, and exited into a downstream trap at a rate of about 110 liters/minute. During the experimental period, temperatures in the troughs ranged from 9 to 12 C. Various experiments were conducted in the troughs by using different sizes and proportions of coho and fall chinook.

At the outset of each experiment, individual fish seined from tributaries of Sixes River were weighed to the nearest 0.001 g. All fish that moved downstream into the traps during the first two days of the experiments were replanted in the troughs. When possible, daily observations of the number of each species of fish in the riffle, pool, and trap were recorded. Behavioral observations were also made during this period. When downstream movement had ceased for at least 5 days, experiments were concluded. At the termination of each experiment, fish were weighed to the nearest 0.001 g, and measured to the nearest 0.05 cm fork length.

Instantaneous rates of growth (Ricker, 1958, p. 31) were calculated for experimental fish on a daily basis from changes in body weight. Since experimental fish were not individually marked, the initial size was estimated from the arithmetic mean weight of all fish originally planted. Production was calculated by summing individual weight gains of all fish remaining in the troughs until termination of the experiment. Since fish that moved downstream were not included, values obtained in this fashion do not reflect true production, or total elaboration of fish flesh in the system.

Some experiments were started by planting eyed eggs, previously incubated at Elk River Salmon Hatchery, in the gravel of the observation troughs as described by Reimers (1970). Since the period of embryological development is longer for chinook than for coho, adult chinook were captured and spawned before coho. This procedure permitted fry of both species to emerge at similar times. As in other experiments, volitional residence was allowed, but downstream migrants were not replanted.

Color Patterns and Morphology

To examine more closely the differences between coho and fall chinook, their fin colors and morphology were also studied. These patterns were described by observing fish in the troughs and in the stream with snorkel gear. Wild fish captured in Sixes River were examined in the laboratory with the aid of a binocular microscope. They were anesthetized in MS 222 to relax their chromatophores and viewed against backgrounds of various colors to discern coloration of body and fins.

Measurements of fin and body morphology were made on specimens collected in Sixes River and preserved from 1964 to 1967. Measurements included fork length, body depth, length of the leading edge of the dorsal and anal fins (height of the fins), and length of the pelvic fins (Hubbs and Lagler, 1964). Fork length was recorded to the nearest 0.1 cm; all other measurements were recorded to the nearest 0.01 cm.

Length-weight relationships for the two species were obtained from wild fish captured in the tributaries of Sixes River. Immediately after capture, they were transported live to the laboratory, anesthetized in MS 222, measured to the nearest 0.05 cm fork length, blotted to remove excess water, and weighed to the nearest 0.001 g.

RESULTS

Distribution

Timing and location of spawning coho and fall chinook salmon in Sixes River overlapped (Figure 3). Coho were usually found in the upper areas; chinook spawned in the upper main river and in lower sections of the tributaries. Times of emergence were calculated from peak counts of spawning fish and incubation requirements of each species. Timing of emergence was found to be similar for the two species, although peak emergence of coho occurred about 2 weeks prior to peak emergence of chinook Table 1). As a result of similarity in both spawning time and location, newly emerged coho and fall chinook were found together (Figure 4). Overlap was evident throughout the river system during April and May; both species occurred in the spawning tributaries and in the main river.

Distribution of juveniles in the early spring was related to distribution of spawning adults; juveniles of each species were found downstream from spawning sites. As temperatures

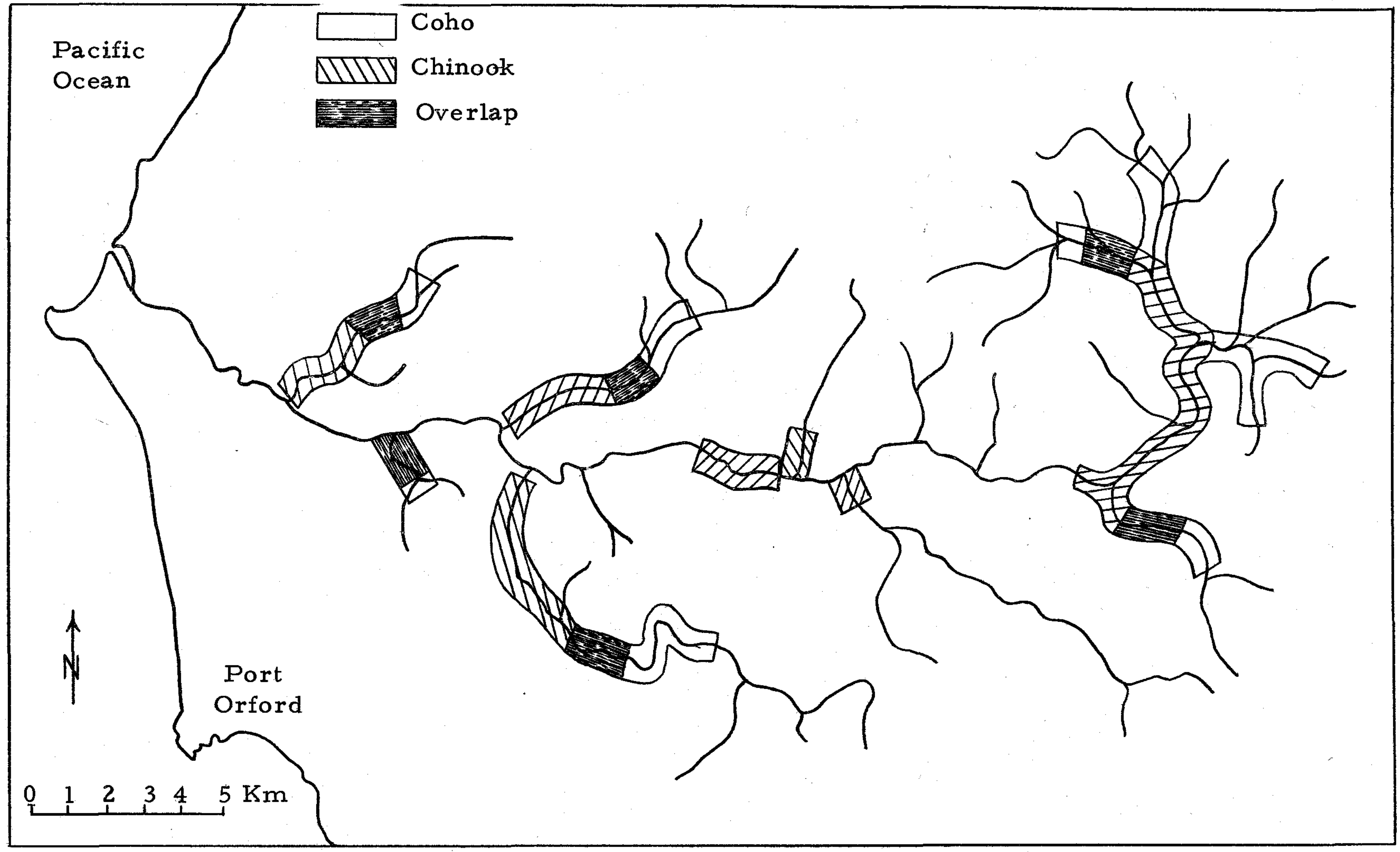

Figure 3. Composite spawning distribution of adult coho and fall chinook salmon in Sixes River. (Summarized from spawning ground surveys, Fish Commission of Oregon, 1964-1970)

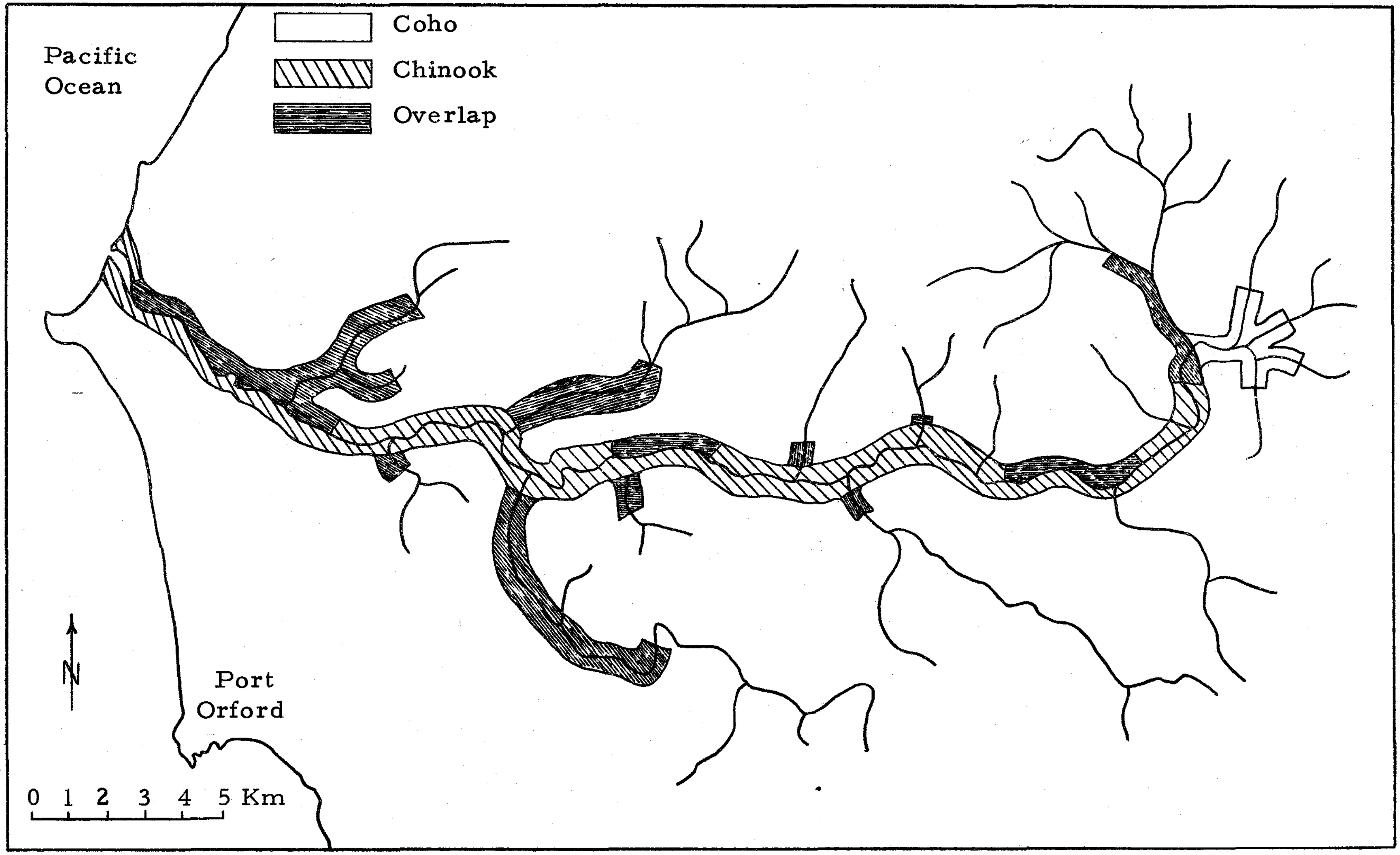

Figure 4. Composite of spring and summer distribution of juvenile coho and fall chinook salmon in Sixes River. Spring distribution is diagrammed on the north side of the river; summer distribution is diagrammed on the south side of the river. (Summarized from seining data, Fish Commission of Oregon, 1964-1970)

Table 1. Peak spawning and predicted timing of emergence of coho and fall chinook salmon in Sixes River. Based on counts of spawning fish and on an average water temperature of 8 C.

	Spawning period		Emergence period	
	Approximate peak	Range	Approximate peak	Range
Coho	Late Dec.	Mid-Nov. to Late Jan.	Early April	Early Mar. to Mid-May
Chinook	Early Dec.	Mid-Nov. to Late Jan.	Late April	Mid-Mar. to Early June

increased in the summer (Figure 5), coho were no longer found in the main river (Figure 4). However, they were still abundant in the cool tributary streams. Chinook were present in the main river as well as the tributary streams.

Comparison of the distributions of juvenile coho between Hays and Crafton creeks may demonstrate the effect of temperature in influencing distribution of this species. Most of the watershed of Crafton Creek has been logged and the

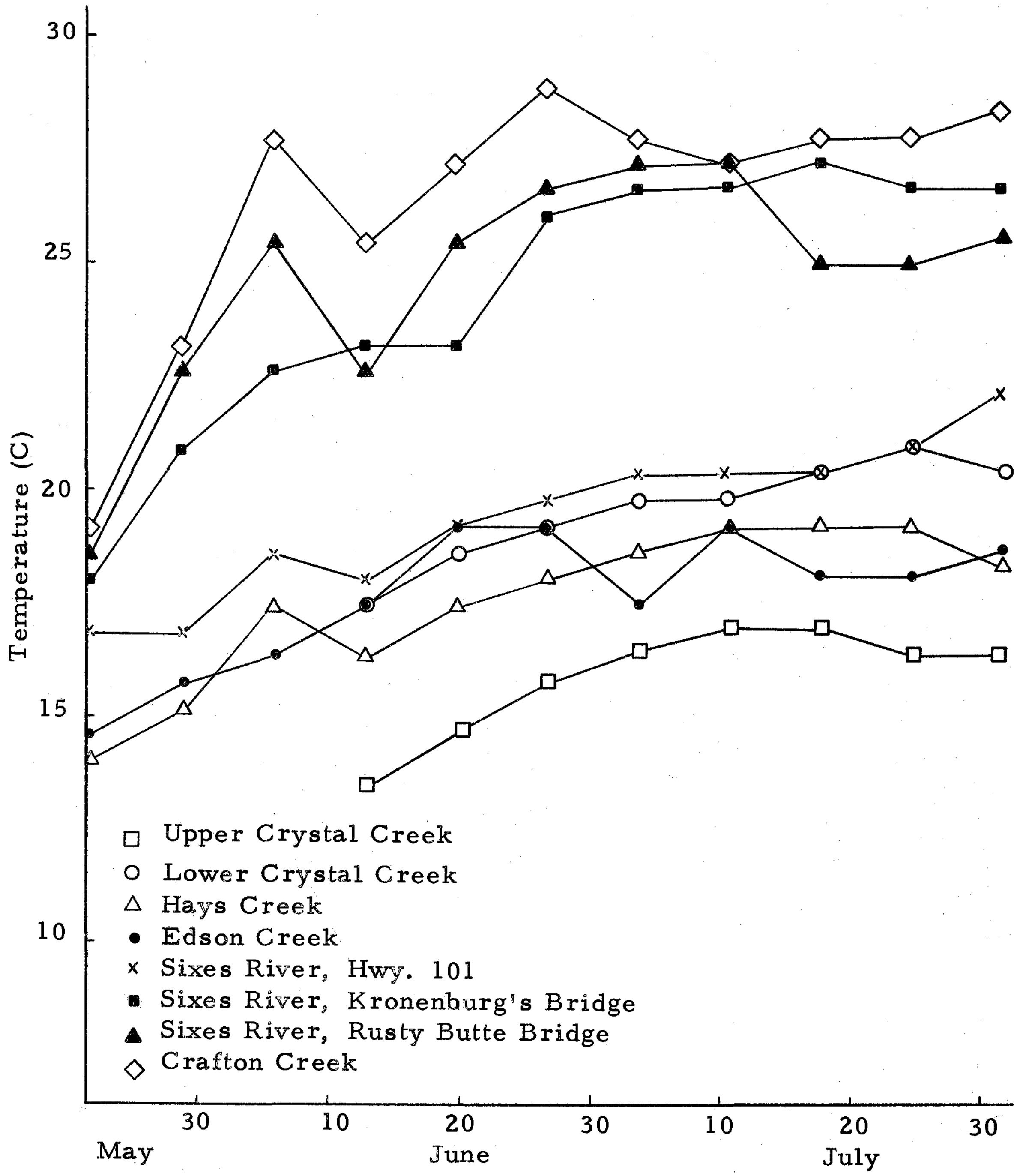

Figure 5. Weekly maximum temperatures of Sixes River and selected tributaries during the summer of 1970.

lower section recently sprayed with a defoliant. As a result, the stream has little shade and is considerably warmer than Hays Creek (Figure 5). Although spawning and emergence of coho occurred in Crafton Creek, no juveniles were present after May. In contrast, coho that emerged in Hays Creek remained throughout the summer (Figure 4).

While snorkeling in Crystal Creek and the main river, I observed that coho and chinook had similar habitat preferences in early spring (Table 2). During this time, recently emerged individuals of both species were observed in close association in backwater eddies near shore. Fish were distributed throughout the water column, actively feeding on drifting organisms. From these preliminary observations, coho and chinook appeared to be utilizing only a small portion of the stream in early spring.

Later in summer, individuals of both species were found together near the downstream end of riffles. Individuals were likewise distributed throughout the water column actively feeding. To supplement these observations and determine their habitat preference, a group of coho was released in Sixes River in September.

Table 2. Fish observed in Sixes River while snorkeling during 1970-1971.

Date	Station	Time period	Juveniles	
			Coho	Chinook
7/16/70	Sixes R. below Edson Cr.	1300-1500	0	15
7/16/70	Sixes R. below Dry Cr.	1500-1700	0	1
7/21/70	Sixes R. main stem	1300-1500	0	4
8/25/70	Sixes R. Crystal Cr.			
	Station 1	1000-1030	4	9
	Station 2	1100-1130	1	5
	Station 3	1300-1330	4	26
	Station 4	1400-1430	8	12
	Station 5	1500-1530	16	0
9/1/70	Sixes R. Crystal Cr.			
	Station 1	1000-1030	-	-
	Station 2	1100-1130	3	2
	Station 3	1300-1330	4	13
	Station 4	1400-1430	4	10
	Station 5	1500-1530	-	-
9/6/70	Sixes R. above Hwy. 101	0900-1000	0	8
9/6/70	Sixes R. below Kronenburg's bridge	1030-1130	0	0

Continued

Table 2--Continued.

Date	Station	Time period	Juvenile	
			Coho	Chinook
9/10/70	Sixes R. above Hwy. 101	0900-1100	3	2
9/10/70	Sixes R. below Kronenburg's bridge	1300-1500	5	0
9/14/70	Sixes R. above Hwy. 101	0900-1100	2	1
9/14/70	Sixes R. below Kronenburg's bridge	1300-1500	3	0
4/3/71	Sixes R. Crystal Cr.	1200-1500	15	17
4/4/71	Sixes R. Crystal Cr.	1000-1230	12	14

They were planted in a pool downstream from chinook, but later moved upstream to occupy areas closely associated with chinook.

Growth

At emergence, fall chinook were larger than coho fry. When the two species were allowed to emerge together in the observation troughs, the chinook fry were approximately 25% heavier than the coho (0.45 vs. 0.35 g). Similar findings were reported by Lister and Genoe (1970) in the Big Qualicum River, British Columbia.

As stream rearing progressed, chinook lost this initial size advantage. After mid-May, chinook were smaller than coho when sampled in Crystal Creek (Figure 6). McGie and Lenarz (1964) found that chinook were also smaller than coho in Crystal Creek in 1963.

In order to test this apparent growth differential and the outcome of social interaction, coho and fall chinook of similar sizes were combined in observation troughs (Table 3). In experiment I, in which eggs were planted,coho emerged 7 days before chinook, an emergence pattern similar to that found initially in the stream environment. Even if coho had grown at the calculated rate for those 7 days, they still would have been smaller than the emerging chinook.

In all experiments where these species were in allopatry, some chinook grew at the same rate as the fastest growing coho.

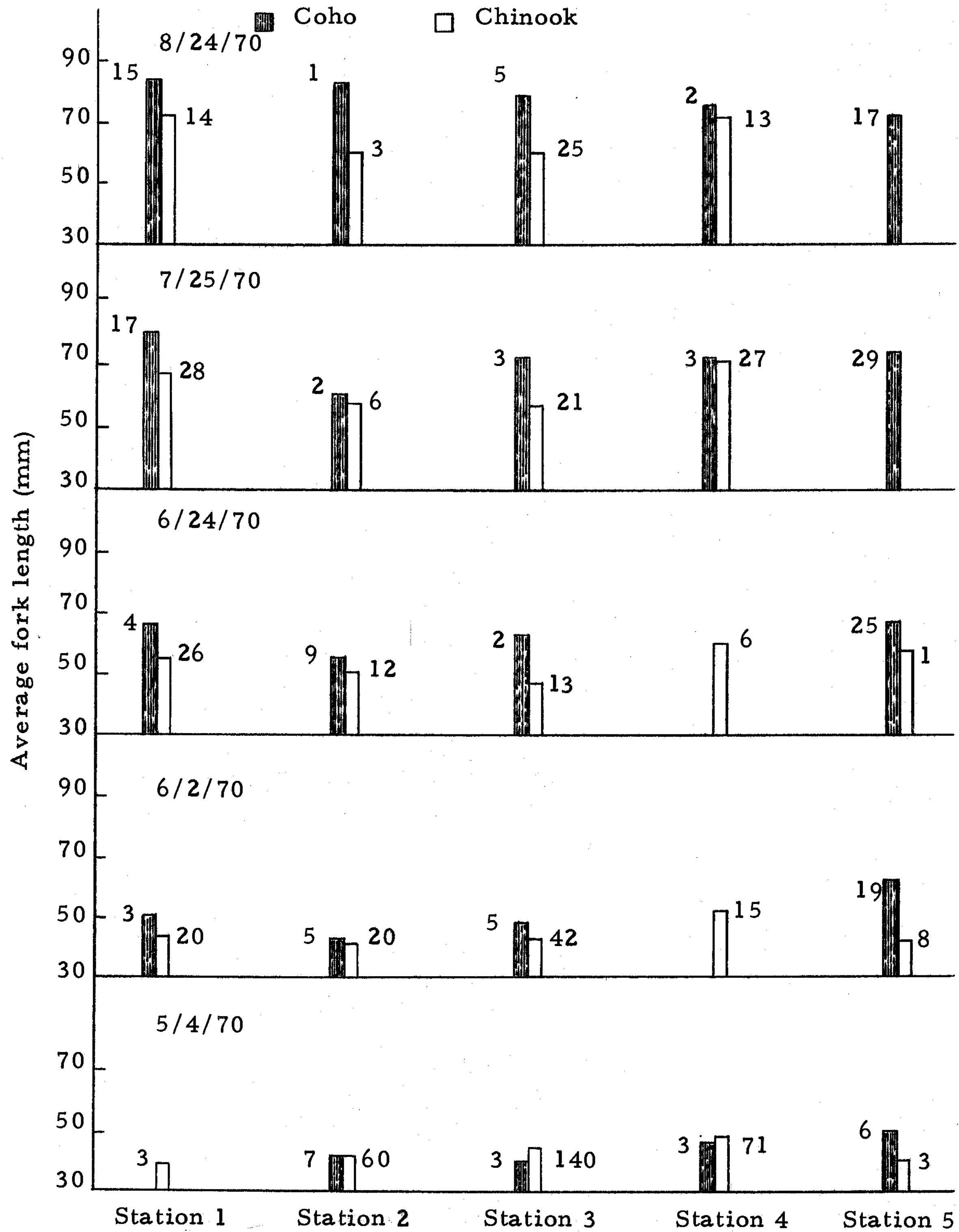

Figure 6. Average fork length of juvenile coho and fall chinook salmon seined from Crystal Creek, Stations 1-5. Sample size is indicated at the top of each bar.

Table 3. Mean size of fish at the outset and termination of experiments conducted in the observation troughs. Ranges of lengths and weights in parentheses.

Trough			Number Planted	Mean Length (centimeters) Planted	Mean Length (centimeters) Termination	Mean Weight (grams) Planted	Mean Weight (grams) Termination
I	1	Coho	600	(Eyed Eggs)	4.55 (4.30-4.80)	.35 (.34-.36)	.91 (.73-1.09)
	2	Chinook	600	↓	4.28 (4.00-4.90)	.47 (.46-.48)	.70 (.50-1.09)
	3	Coho	300	↓	4.60 (4.30-4.90)	.35 (.34-.36)	.92 (.73-1.13)
	3	Chinook	300	↓	4.16 (4.05-4.80)	.47 (.46-.48)	.65 (.52-1.00)
	4	Coho	300		4.75 (4.60-4.90)	.35 (.34-.36)	1.00 (.88-1.12)
	4	Chinook	300		4.16 (4.10-4.30)	.47 (.46-.48)	.60 (.56-.66)
II	1	Coho	41	4.36 (4.00-4.50)	5.10[a/] --	.78 (.58-.85)	1.46 --
	2	Chinook	42	4.40 (4.00-4.50)	4.77 (4.10-5.60)	.72 (.52-.79)	1.06 (.59-1.89)
	3	Coho	20	4.26 (4.00-4.40)	5.10 (4.70-5.60)	.71 (.58-.79)	1.48 (1.09-1.96)
	3	Chinook	20	4.26 (4.00-4.40)	4.57 (4.45-4.70)	.65 (.52-.73)	.92 (.85-1.00)
	4	Coho	20	4.26 (4.00-4.40)	5.62 (5.45-5.80)	.71 (.58-.79)	1.92 (1.67-2.16)
	4	Chinook	20	4.26 (4.00-4.40)	4.45 --	.65 (.52-.73)	.72 --
III	1	Chinook	18	4.10 (3.90-4.35)	4.48 (4.20-5.10)	.58 (.45-.80)	.89 (.68-1.37)
	2	Coho	5	4.08 (3.80-4.30)	4.97 (4.80-5.05)	.61 (.48-.69)	1.22 (1.10-1.35)
	2	Chinook	12	4.13 (3.90-4.40)	[b/]	.60 (.45-.75)	
IV	1	Chinook	44	4.22 (3.90-4.00)	4.54 (4.10-5.45)	.70 (.43-.84)	.89 (.47-1.67)
	2	Coho	22	4.21 (3.90-4.50)	5.05 (4.30-5.95)	.71 (.42-.88)	1.42 (.82-2.26)
	2	Chinook	22	4.34 (3.80-4.60)	4.30 --	.71 (.41-.89)	.67 --

Continued on next page

Table 3 Continued.

		Trough	Number Planted	Mean Length (centimeters) Planted	Mean Length (centimeters) Termination	Mean Weight (grams) Planted	Mean Weight (grams) Termination
	1	Chinook	12	4.09 (4.00-4.20)	4.52 (4.00-4.90)	.59 (.52-.61)	.89 (.66-1.19)
V	2	Coho	4	4.05 (4.00-4.10)	4.62 (4.40-4.80)	.60 (.58-.63)	1.00 (.77-1.12)
		Chinook	8	4.10 (4.00-4.20)	4.32 (4.10-4.70)	.56 (.52-.61)	.70 (.54-1.07)

a/ Near the termination of the experiment, three large coho moved downstream (following a temporary cessation of flow) and jumped out of the trap.

b/ No chinook remained at termination.

Whether combined with chinook or not, coho always grew rapidly. No coho ever lost weight during an experiment, while individual chinook, irrespective of the presence of coho, lost weight in several experiments (Figure 7). Likewise, production of fall chinook was reduced by the presence of coho, while production of coho was unaffected by chinook (Table 4). In allopatric situations, chinook production often exceeded total production in the combination troughs.

Tagged coho grew at a faster rate than tagged chinook in upper Crystal Creek from July 20 to August 8. However, chinook grew faster than coho in the lower section of the creek during this period (Figure 8). These results further demonstrate the ability of coho to grow more rapidly than chinook in cool tributary streams. They further suggest the capacity of chinook to grow more rapidly than coho in warm environments. For the remainder of the summer, coho also grew faster than chinook in upper Crystal Creek, while the reverse was true for lower Crystal Creek.

Fish sampled in Swamp Creek 64 days after planting had grown faster than tagged chinook in Crystal Creek, indicating that in the absence of coho chinook are able to do well in very small tributary streams (Figure 9). These results are comparable since Pyle (1965) has shown that the tag does not influence the growth rate of tagged fish.

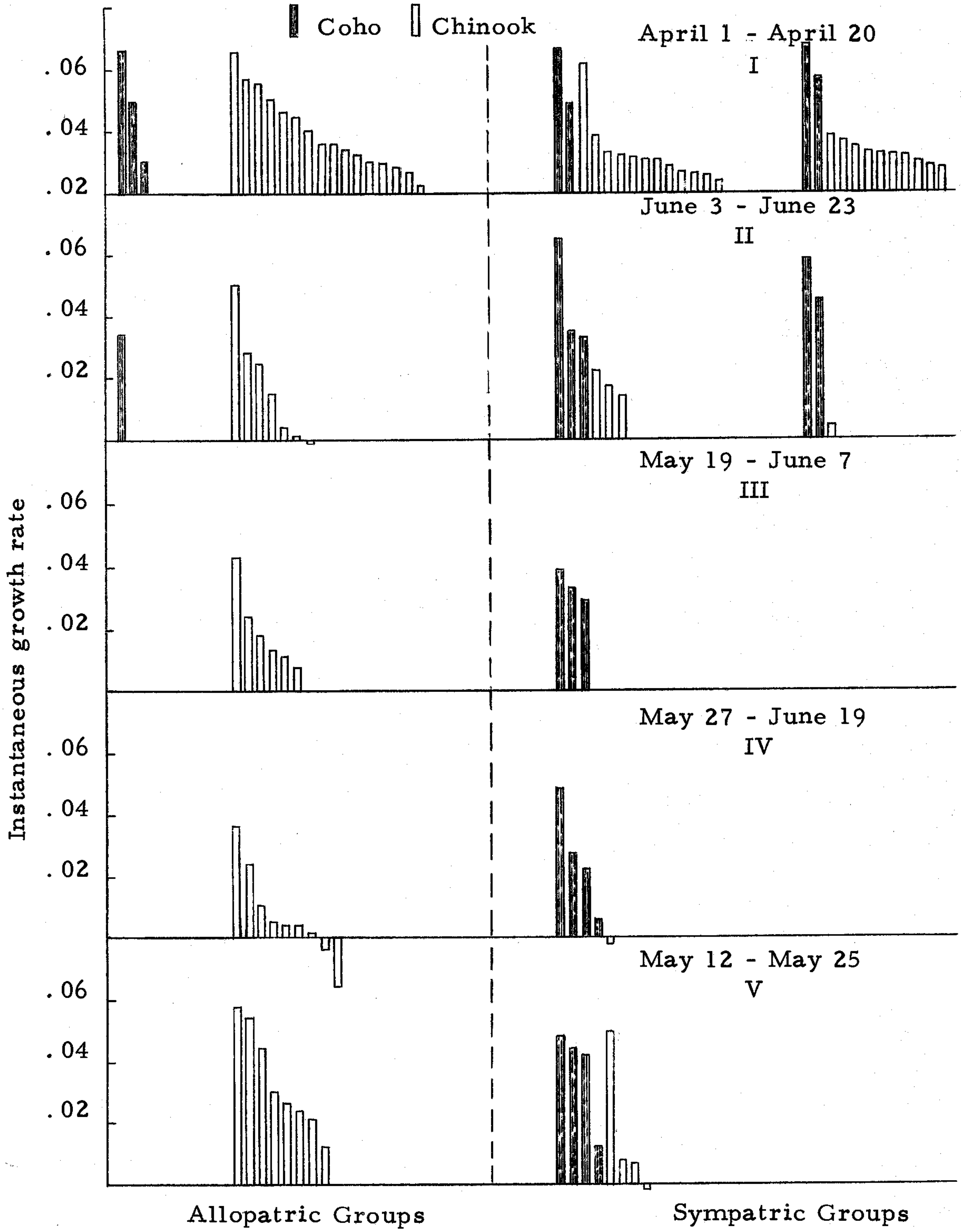

Figure 7. Growth of underyearling coho and fall chinook salmon in the observation troughs. Each vertical bar represents one fish. Experiments I-V are in order of increasing advantage to chinook based on initial size and numbers. See Table 3 for initial conditions.

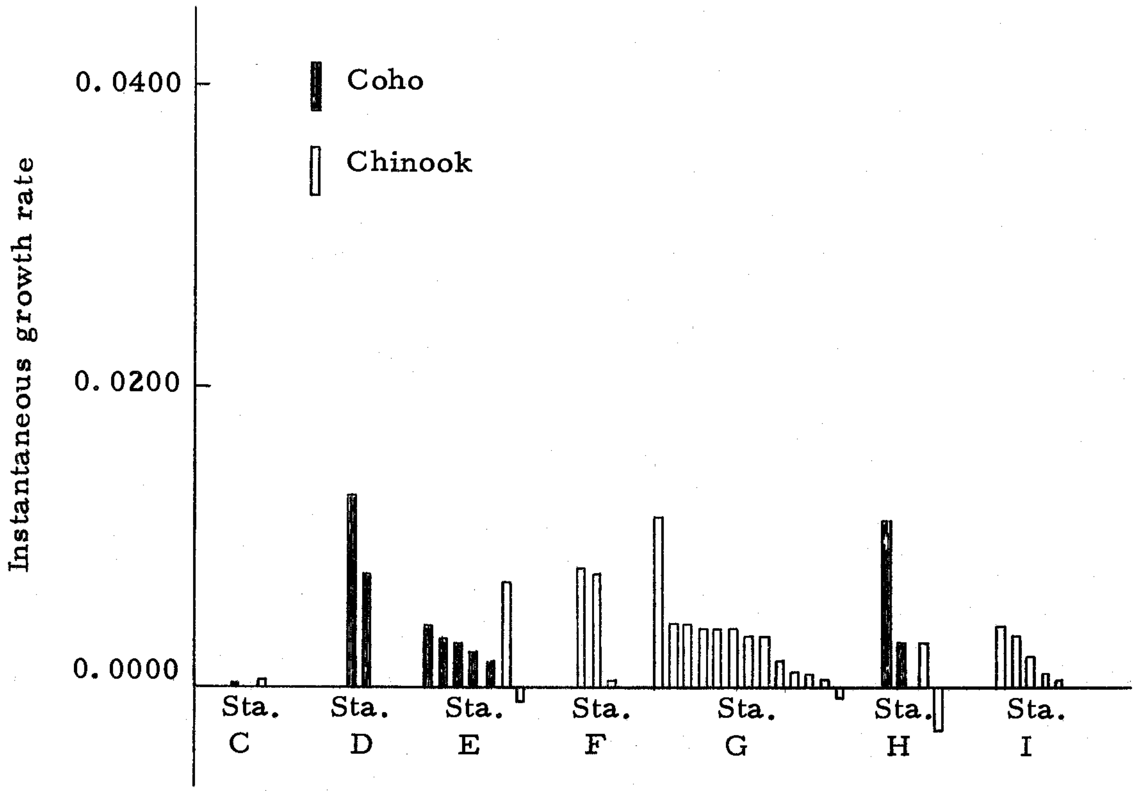

Figure 8. Growth of tagged juvenile coho and fall chinook salmon in Crystal Creek from July 20 to August 8, 1970. Each vertical bar represents one fish.

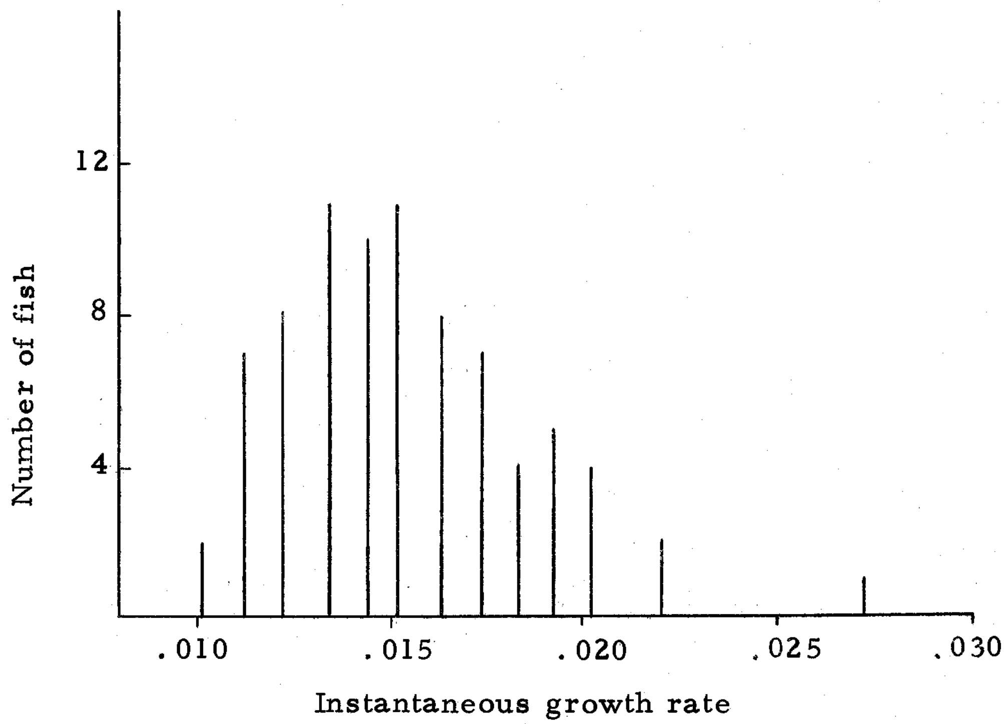

Figure 9. Growth of underyearling fall chinook salmon planted in Swamp Creek, Sixes River from March 31 to June 2, 1970.

Table 4. Production in gm/m^2 of underyearling coho and fall chinook salmon that remained in the observation troughs until termination of the experiment.

Expt.	Time period	Allopatry		Sympatry		Total
		Coho	Chinook	Coho	Chinook	
I	Apr. 2-Apr. 20	0.833	2.492	0.780	1.217	1.997
				0.884	0.863	1.746
II	May 12-May 25	0.464	1.627	1.482	0.476	1.959
				1.584	0.057	1.659
III	May 19-June 7	a/	1.232	1.226	0.000	1.226
IV	May 27-June 19	a/	1.139	1.912	-0.023	1.889
V	June 3-June 23	a/	1.744	1.081	0.458	1.539

a/ No data.

Agonistic Behavior

Patterns of intraspecific agonistic behavior such as those described for coho (Chapman, 1962) and for fall chinook (Reimers, 1968) were observed in the troughs during these experiments. Interspecific agonistic behavior was also observed, including nipping, chasing, lateral display, submission, and fleeing. Shortly after they were planted in the troughs, fry of both species were in close contact with one another near the bottom of the pool in a fright huddle (Mason and Chapman, 1965). Following this initial behavioral response, fish then began interacting with other individuals regardless of species. After a period of intense agonistic behavior that lasted about 10 days, interaction decreased to a low level.

Dominant-subordinate hierarchies were formed in both sympatric and allopatric groups. In every case where coho were combined with chinook, coho occupied positions of dominance at the upstream end of the riffle, where drifting food organisms were first available to fish. When equal numbers of coho and chinook of the same size were combined in the observation troughs (Table 3, Expt. II), more coho than chinook occupied the riffle (Figure 10). Even when only four coho were combined with eight chinook (Table 3, Expt. V), more coho than chinook occupied the upper riffle (Figure 11). When fall chinook were isolated, they were evenly distributed between the riffle and the pool.

In the troughs, chinook appeared to be less territorial than coho, permitting a larger number of individual fish per unit area. In allopatric groups, a larger number of chinook than coho remained in the troughs until termination of an experiment; when they were combined with coho, few chinook remained until termination. Coho did not seem to be adversely affected by the presence of chinook; no difference in number of coho remaining was apparent between sympatric and allopatric groups.

Interspecific interaction between coho and chinook, including lateral display, nipping, and chasing, was observed during

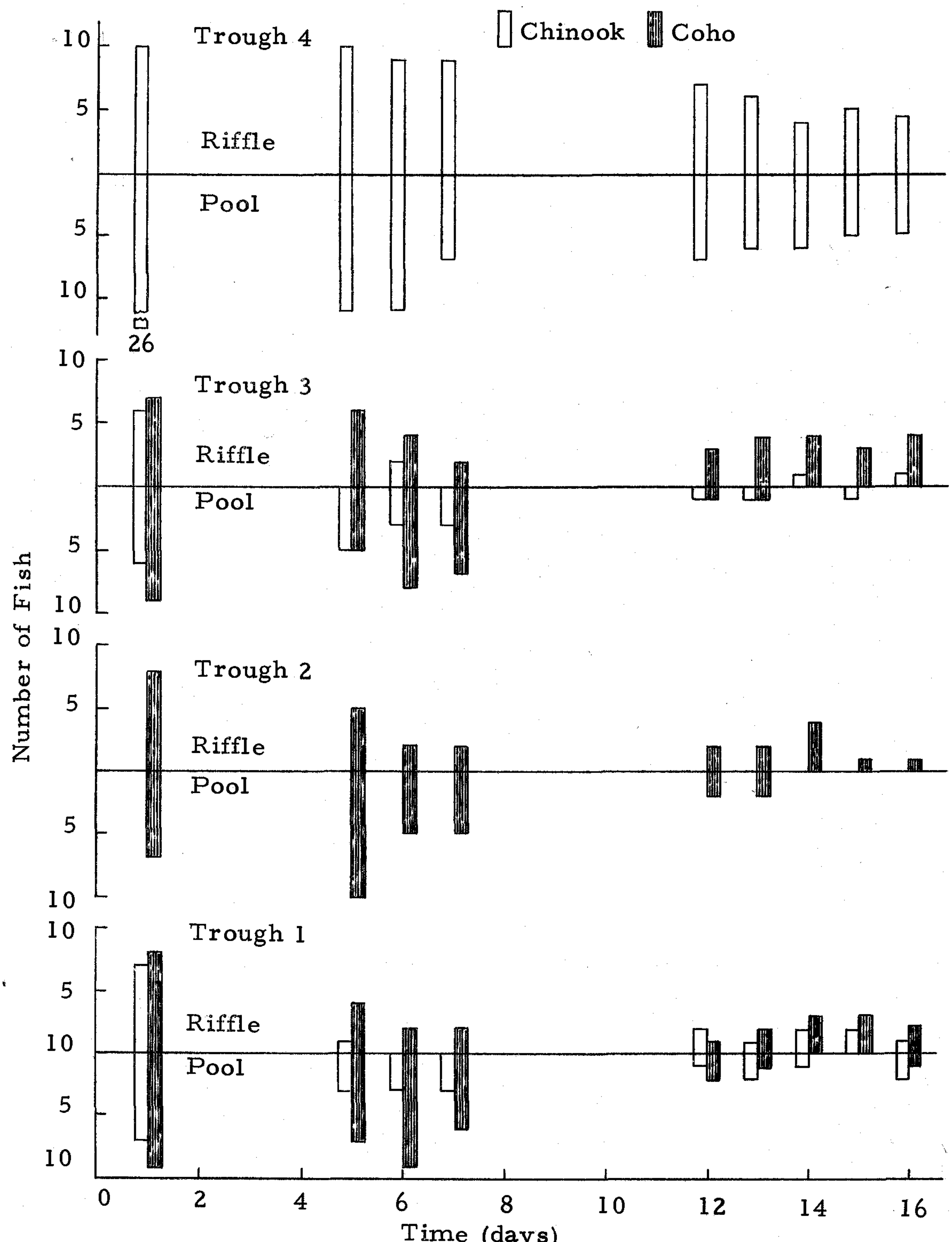

Figure 10. Relationship between the numbers of underyearling coho and fall chinook salmon present in the riffle and pool in the observation troughs during the period June 3 to June 23, 1970. Decline in numbers of fish with time resulted from downstream movement.

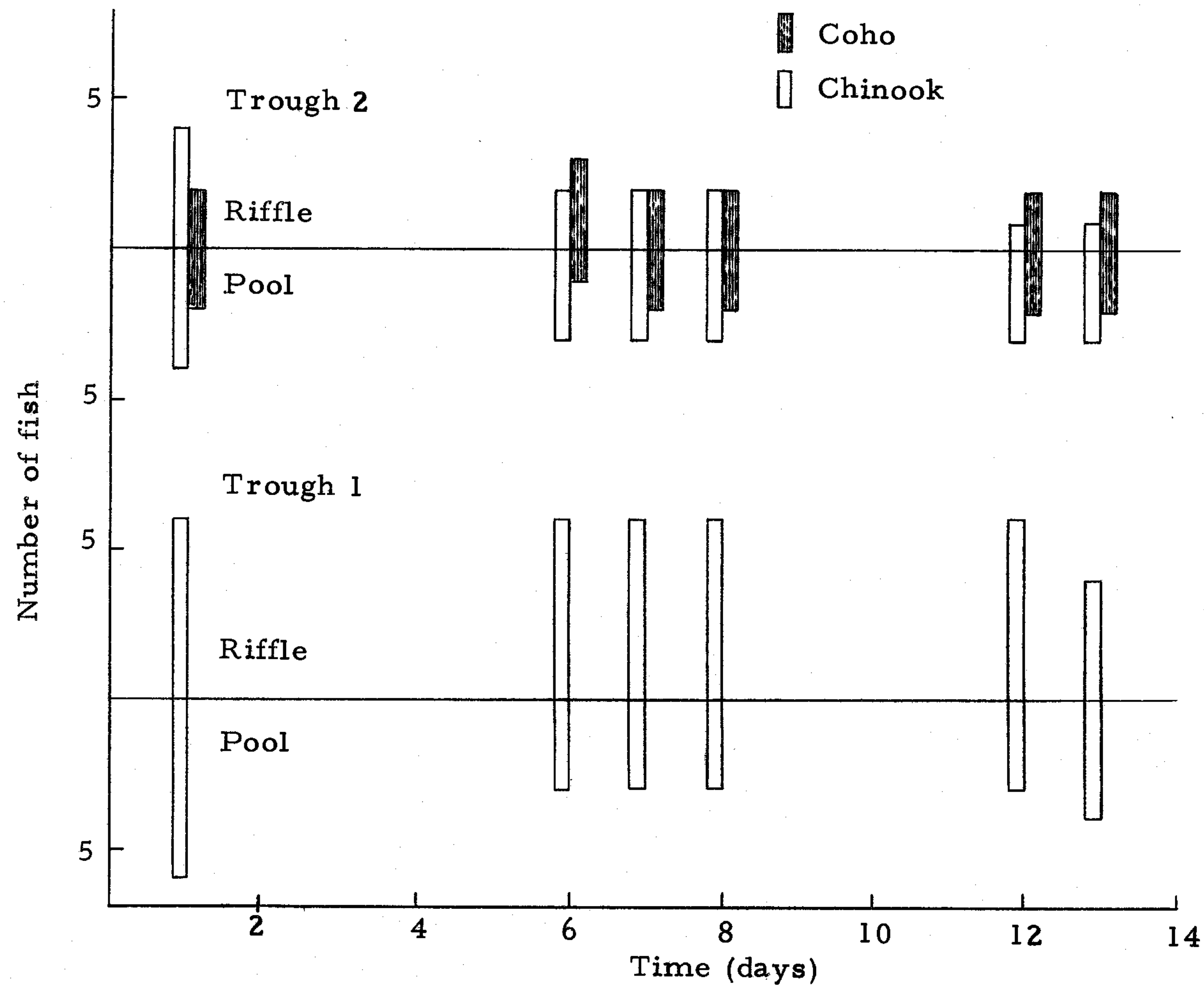

Figure 11. Relationship between the numbers of juvenile coho and fall chinook salmon present in the riffle and pool in the Anvil Creek observation troughs during the period May 12 to May 25, 1970. Decline in numbers of fish with time resulted from downstream movement.

underwater surveys in Crystal Creek in the early spring. In summer, intraspecific interaction was evident in both species, but very little interaction between species was observed even though they occupied similar microhabitats.

Since both species of salmon are sufficiently different in size from either underyearling or yearling trout during the spring, their interaction with juvenile trout was judged to be not significant during this period. This conclusion was based on underwater observations and seining. In the spring, salmon utilized areas in backwater eddies near shore, isolated from yearling trout that were in fast water. By the time trout fry had emerged from the gravel, coho and chinook were large enough to utilize areas of high water velocity, segregating them from recently emerged trout. As the summer progresses, trout may play an increasing role in influencing the relationship between coho and chinook; their size distributions become more similar and both trout and salmon appear to select a similar habitat, near the downstream end of riffles. Similar segregation of sympatric species of salmonids has been reported by many other workers (Everest, 1969; Lister and Genoe, 1970). This mechanism appears to reduce the amount of interaction between salmon and trout in Sixes River.

Color Patterns and Morphology

Juvenile coho were yellow-brown with dark brown backs. Their parr marks were narrow and dark brown but did not contrast sharply with the rest of their body coloration. All fins were prominent and bright orange. In comparison, fall chinook were silvery or light yellow with blue-green or brown backs. Parr marks were wide and black, and contrasted sharply from the rest of the body. The fins were yellow and less prominent than those of the coho. Considerable variability was observed for these general patterns of coloration, and size-related seasonal differences were noted. Both newly emerged and large chinook were more silvery than fish of intermediate size. As observed by Hartman (1965) for coho, general coloration of both species became less vivid near the end of the summer.

Major differences between the two species were found in the dorsal, anal, and pelvic fins, but the caudal and pectoral fins differed only in general coloration as described above.

The height of the dorsal fin of coho was distinctly greater than that of chinook (Figure 12). The relationship between height of the dorsal fin and fork length was linear for chinook but curvilinear for coho. Variation around the line was greater for coho than for chinook. Maximum disparity between the two species occurred

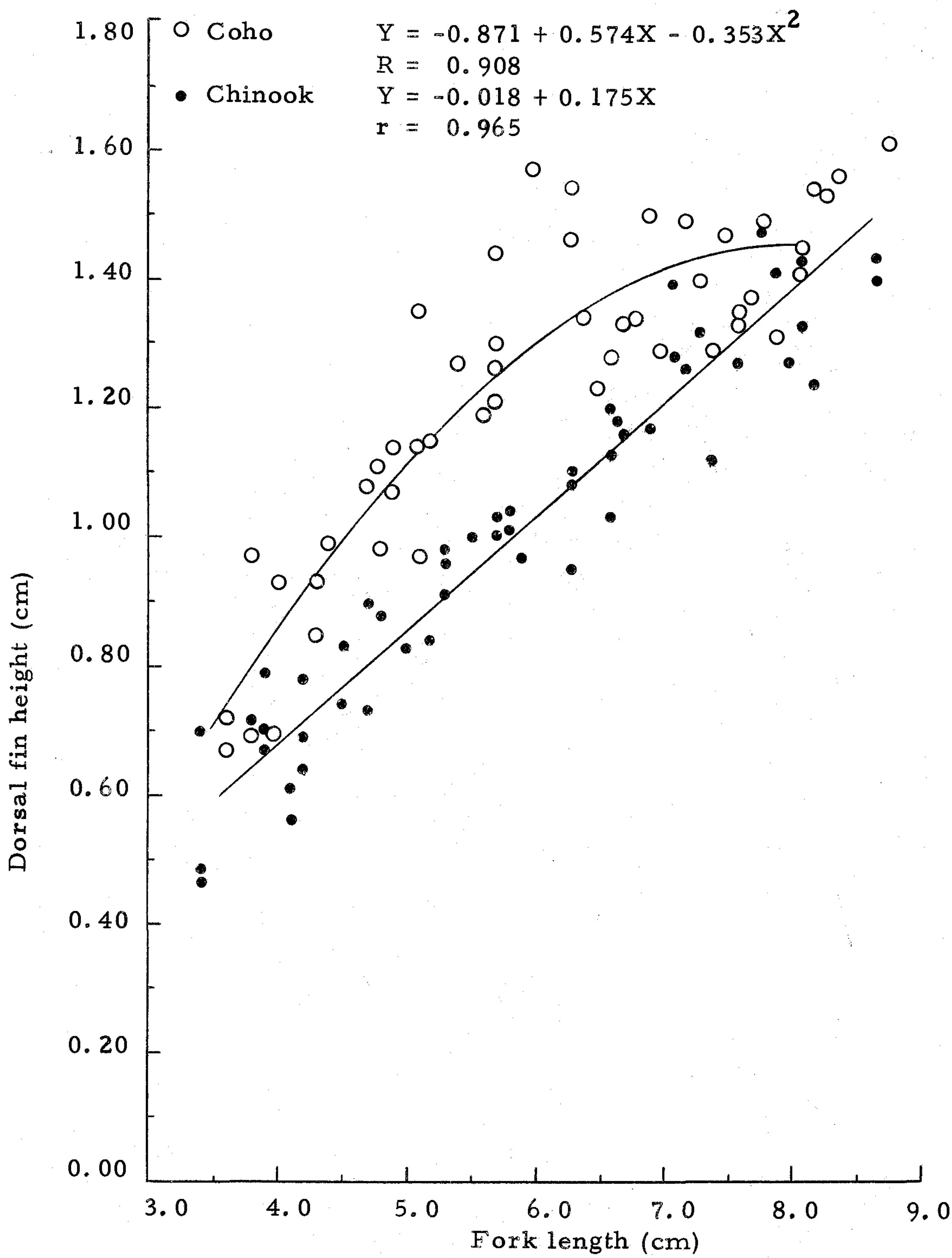

Figure 12. Relationship between height of the dorsal fin and fork length of juvenile coho and fall chinook salmon in Sixes River.

from 5 to 7 cm.

The leading edge of the dorsal fin of coho was white, backed by a black band; the remainder of the fin was orange (Figure 13). Initially, fin colors were not fully developed. At emergence, the leading edge of the dorsal fin was black proximally and white distally. As fish became older, the black pigment appeared to extend distally behind the white band, which had extended proximally to the base of the fin. Development of vivid coloration required approximately 10 days.

The distal portion of the leading edge of the dorsal fin of chinook was white. In contrast to coho, black rather than white coloration developed in the proximal portion of the leading edge of the dorsal fin (Figure 13). Chinook also differed from coho in possessing an orange band behind the white leading edge of the dorsal fin. The remainder of the fin was yellow. The dorsal fin of emergent chinook was nearly transparent and contained only a few scattered chromatophores. As the fish became older, a proximal band of black developed simultaneously with the white and orange distally. Full development of coloration took about 14 days.

The height of the anal fin of coho was much greater than that of fall chinook (Figure 14). The relationship between height of the anal fin and fork length was linear for chinook but curvilinear for coho. Maximum disparity between the species occurred from 5 to 7 cm.

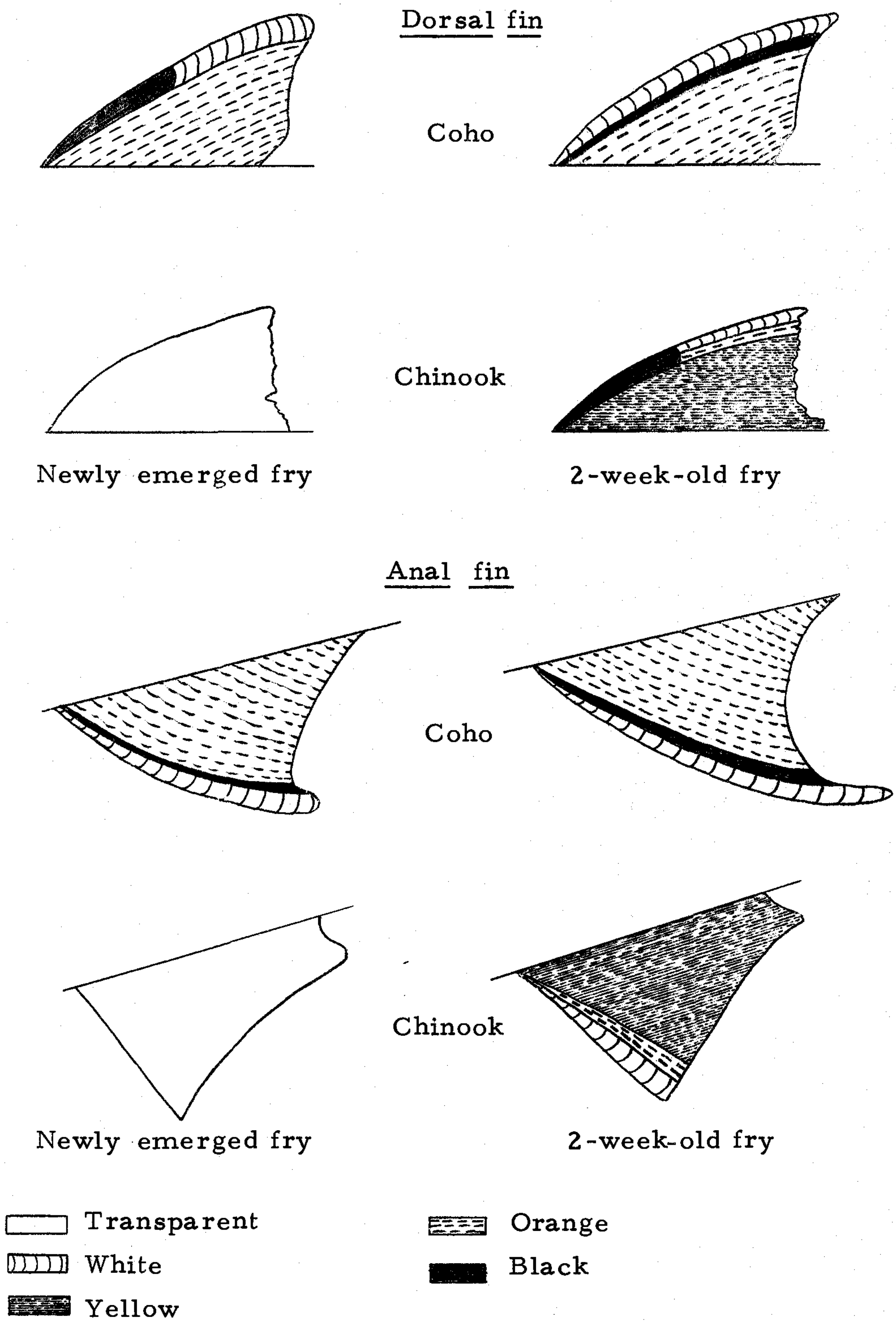

Figure 13. Diagrammatic sketch of the dorsal and anal fins of recently emerged and 2-week-old fry of coho and fall chinook salmon in Sixes River.

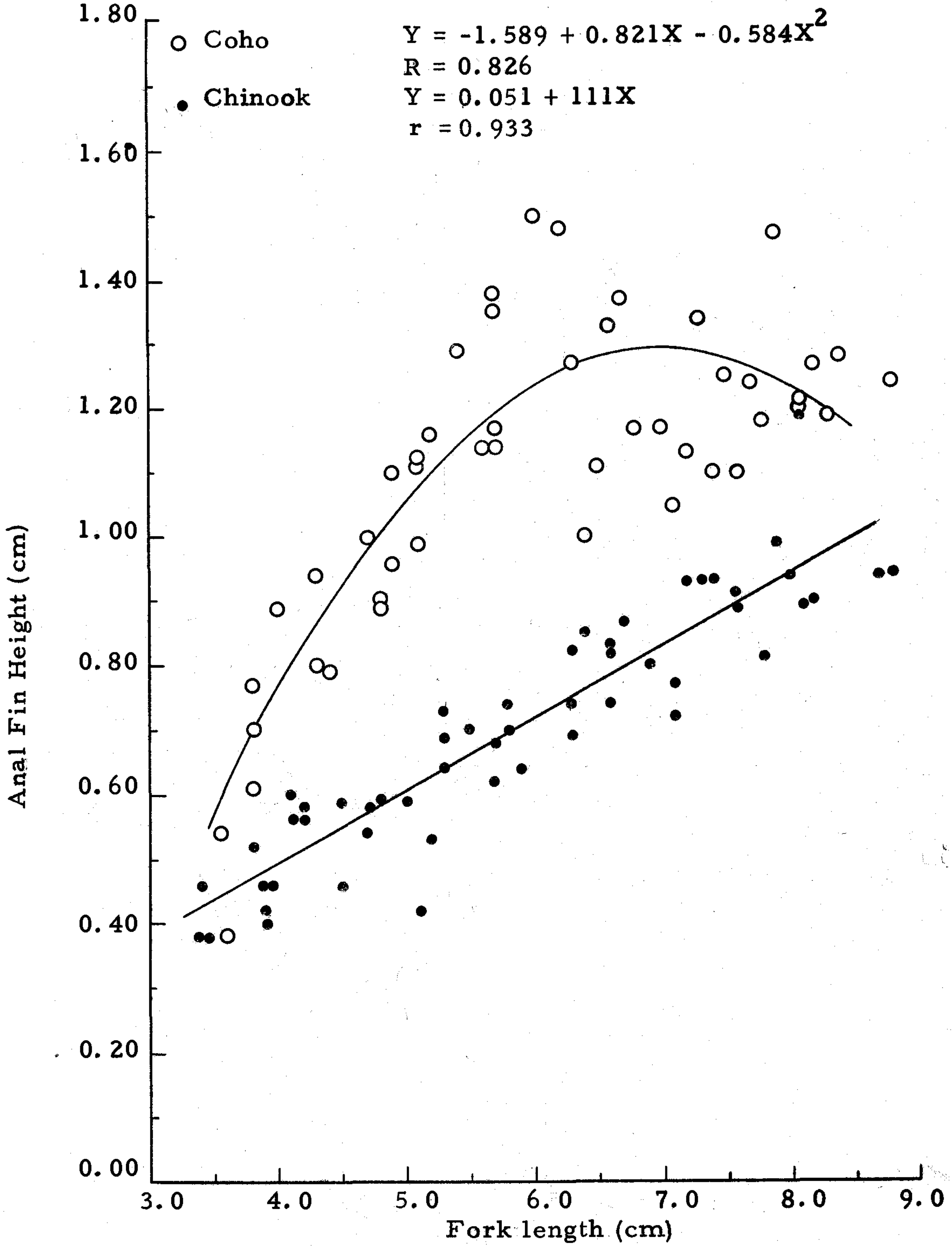

Figure 14. Relationship between height of the anal fin and fork length of juvenile coho and fall chinook salmon in Sixes River.

Color patterns of the anal fin of these two species were similar to those of their dorsal fins (Figure 13). At emergence coho already possessed a band of black pigmentation behind the white leading edge of the fin. Both bands became more prominent in older fish. The remainder of the fin was orange.

The white leading edge of the anal fin of chinook was only faintly visible at emergence but developed rapidly during the first week of stream residence. In contrast to the dorsal fin, the entire leading edge of the anal fin was white. An orange band developed directly behind the white leading edge and graded into pale yellow over the remainder of the fin.

The pelvic fins of coho were only slightly longer than those of chinook. However, color patterns of the fins were quite dissimilar. Pelvic fins of coho were completely orange, but those of chinook had a distinct white leading edge backed by an orange band that graded into pale yellow over the remainder of the fin.

Coho were heavier than chinook of the same length from 3.5 to 6.5 cm but the reverse was true from 6.5 to 7.5 cm. Regressions of the logarithm of weight on the logarithm of length computed for each species yielded the following relationships:

$$\text{coho} \quad W = 0.0057L^{3.329}$$
$$\text{chinook} \quad W = 0.0037L^{3.355}$$

Coho had deeper bodies than chinook. This difference was small but consistent (Figure 15).

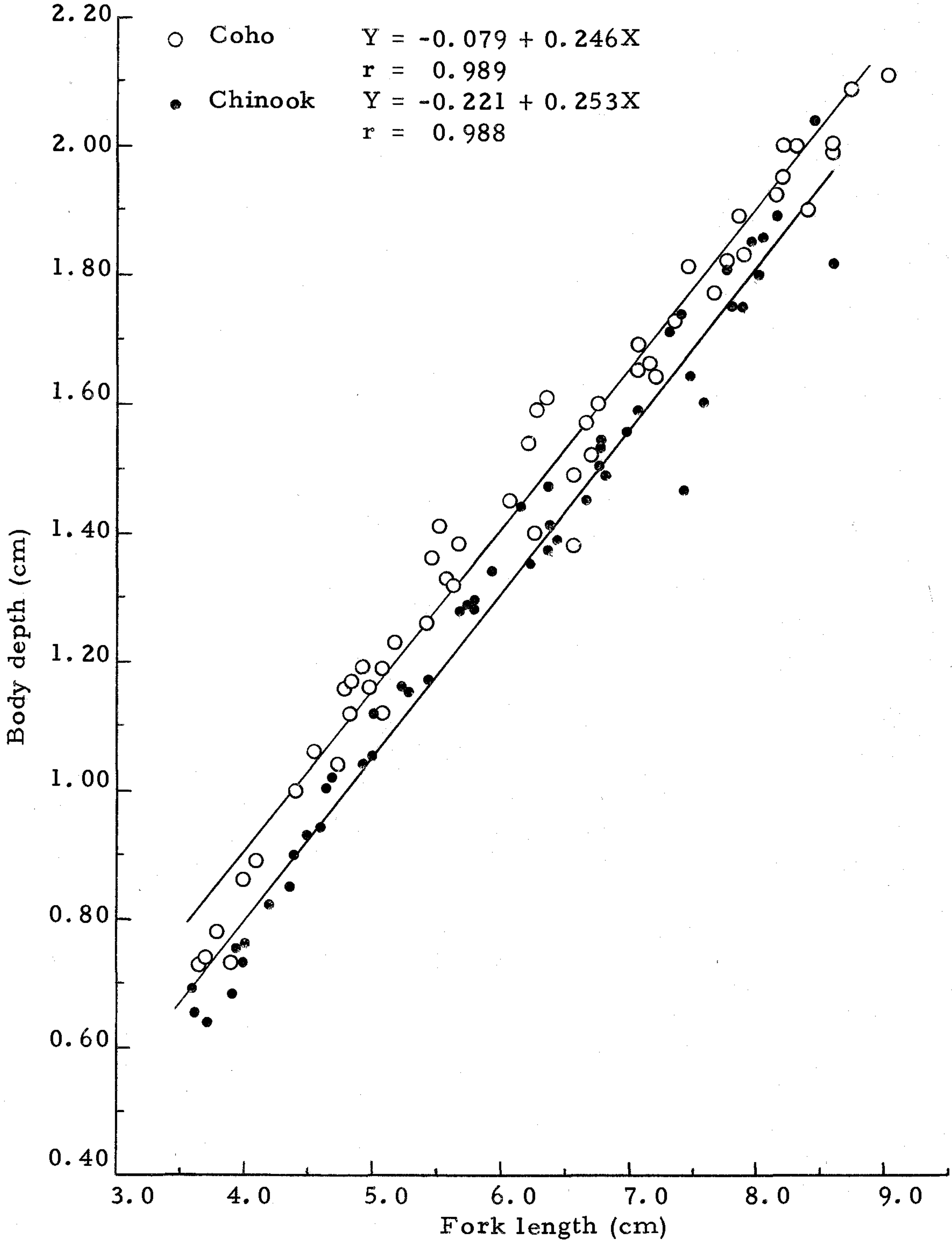

Figure 15. Relationship between body depth and fork length of juvenile coho and fall chinook salmon in Sixes River.

DISCUSSION

Chronological and spatial overlap in freshwater residence resulted in social interaction between juvenile coho and fall chinook salmon in Sixes River, Oregon. Both species are dependent upon a period of freshwater residence for production of returning adults (Salo and Baliff, 1958; Chapman, 1962; Reimers, 1971). Thus, interaction that influences patterns of distribution and growth in fresh water may ultimately influence population levels.

When together in cool tributary streams and observation troughs, coho grew faster than fall chinook. Growth of coho far exceeded that of chinook in sympatric situations; when alone, individuals of both species grew at similar rates. Although this analysis is complicated by the fact that the resulting biomasses were not equal, these biomasses were established through volitional residence. Thus even though biomass may have influenced the observed growth rates, these rates are thought to be representative of those occurring in the natural environment.

Coho did not seem to be influenced by the presence of chinook. However, chinook appeared to be severely affected by coho, as both their rate of growth and their ability to maintain themselves in the troughs were reduced. If growth and residence in fresh water are required for production of returning adults, chinook must be successful in areas other than cool tributary streams occupied by coho.

From studies of coho and fall chinook in the Big Qualicum River, British Columbia, Lister and Genoe (1970) suggested that differences in time of emergence and growth rate of these two species allow for coexistence. From their seining data, they suggested that coho and fall chinook did not interact, due to size-related differences in habitat selection. Fall chinook emerged first, grew faster, and selected areas of progressively higher water velocity before coho reached a size where they could utilize such areas. They suggested that segregation results simply from difference in size; coho and fall chinook of equal length preferred similar habitat types.

In Sixes River, coho and chinook emerged at similar times, selected similar habitat types, and interacted. Owing to nearly complete overlap in timing of emergence, microhabitat segregation based on a size differential did not occur. Both species shared a common habitat preference in the spring. However, distribution of these two species changed as main river temperatures increased. I hypothesize that as temperature increases, coho in the main river are not as successful as fall chinook and consequently move into the cooler tributaries or die.

In my work in troughs, I found similar growth rates for both species in allopatric groups. Lister and Genoe (1970) reported that chinook grew faster than coho, but they did not measure growth rates of individual fish. They assumed that the progressive differences in size between coho and fall chinook resulted from differential rates of growth. Neither tagging nor growth experiments involving individual fish were attempted. In fact, they noted that various factors such as recruitment of emergent fry and emigration of large individuals of both species may have complicated this comparison.

In the Big Qualicum River, chinook emerged before coho, and maintained a size advantage in an environment that permitted microhabitat segregation. Owing to overlap in emergence and high temperatures limiting the amount of suitable habitat in the late spring, microhabitat segregation based on a size differential did not occur in Sixes River. But behavioral differences between chinook and coho, possibly related to temperature, may have led to segregation permitting coexistence.

Both species have evolved physiological, behavioral, and morphological adaptions to specific habitat types. Fall chinook appear to possess a greater physiological tolerance to high temperature than do coho. Examination of the range and native environment of these two species supports this suggestion. Large numbers of chinook are present in the Sacramento River in central California, while coho are nonexistent. High summer temperatures in the tributaries were suggested as an important factor limiting the distribution of coho in this area (Cal. Fish and Game, 1965; Hallock and Fry, 1967). Coho are found in large northern rivers that are cool during the summer, such as the Chignik River in Alaska (R.A. Iverson, Dept. of Fisheries and Wildlife, Oregon State Univ., pers. comm.) and the Big Qualicum River in British Columbia (Lister and Genoe, 1970). Farther south, where summer temperatures are warm, coho do not reside in the main river.

Chinook appear to possess a greater potential than coho for growth at high temperatures. In aquarium experiments, under conditions of maximum food, coho grew faster (35-55 mg/g/day) than fall chinook (45 mg/g/day) at 13 C (T. O. Thatcher, Dept. of Fisheries and Wildlife, Oregon State Univ., unpubl. data). However at 18 C, fall chinook grew much faster (62 mg/g/day) than coho (37 mg/g/day). Although food is not unlimited in the natural environment, these relative differences between coho and chinook may be important in explaining the distribution of these two species in Sixes River.

In addition to these physiological differences, coho and chinook have evolved distinct behavioral adaptations to the freshwater mode of existence that appear to be closely related to their specific patterns of life. In the observation troughs, coho were more aggressive than chinook, tolerating fewer individuals per unit area. Coho spawn in the uppermost tributaries of the river system and reside a full year before entering the ocean. Coho must depend on a territory within the stream that will provide adequate food for an extended period of time. Consequently, they have evolved complex behavioral mechanisms to deal with the problem of distributing juveniles in relation to the available food and space in the stream environment (Chapman, 1966).

Chinook tolerate a greater number of individuals per unit area than do coho. Chinook may have evolved a pattern of behavior that involves small territory size because they reside only three months in fresh water before entering the estuary. During several experiments, some individuals lost weight rather than leave the troughs, suggesting the incomplete nature of this territorial mechanism for distribution with respect to available food. In contrast, all coho remaining in a trough at the termination of an experiment had grown.

Coho and chinook appear to have also evolved morphological adaptations to the freshwater mode of life that are consistent with their length of residence. Coho had brighter colors, greater fin development, deeper bodies, and were heavier than chinook of the same length.

The involvement of color patterns and fin morphology in social behavior has been discussed for a variety of species including the Atlantic salmon, Salmo salar Linnaeus (Keenleyside and Yamamoto, 1962), the tilapia, Tilapia mossambica (Peters) (Neil, 1964), and the Siamese fighting fish, Betta splendens (Regan) (Simpson, 1966). In all these species, bright, vividly colored fish were dominant while pale, light colored fish were submissive. Whether these shades were the cause or the effect of dominance was not determined, but these observations suggest that possession of bright colors is advantageous in social contests.

Furthermore, large fins and vivid coloration of coho may serve to increase the "apparent" size of individual fish. The black band behind the white leading edge on the anal and dorsal fins of coho accentuates their prominence in social display. In chinook, the adjacent orange band offers considerably less contrast with the white leading edge of these fins. Thus, if apparent size is important in determining the outcome of interspecific contests, coho probably enjoy a social advantage over chinook of equal length. Perhaps these morphological adaptations have evolved to allow coho to cope with extended residence in the stream environment.

Since most fall chinook move down to the estuary after about three months of freshwater residence, selection has apparently not favored extensive development of coloration and morphology for social purposes in Sixes River. However, in Alaska, where most chinook spend a full year in fresh water (Meehan and Siniff, 1962), their color and fin development are sufficiently extensive that distinguishing between coho and chinook is difficult without the use of additional characters (Meehan and Vania, 1961).

Due to various physiological, behavioral, and morphological features, coho appear to be adapted to conditions in cool, small streams, while chinook appear to be adapted to rearing conditions in the warm main river and estuary. Consequently, mutual agonistic behavior in the Sixes system may favor coho in cool tributaries and chinook in the main river and estuary. These ideas seem consistent with those of Nilsson (quoted in Hartman, 1965), who suggested that intense interspecific competition in sympatric populations of similar or closely related species forces each species to compete at its "ecological optimum", or under those conditions to which it is best adapted. In this way interspecific interaction promotes segregation. Even though segregation in Sixes River may not be the direct result of territorial conflict, interspecific agonistic behavior may play an important role in the distribution of juvenile coho and fall chinook salmon.

Due to the competitive advantage of coho at low temperatures, early spring may be the critical time for interspecific interaction to affect chinook in Sixes River. During this time, temperatures in the main river are cool, yet coho are found there in relatively low numbers. Thus, owing to their small population at present, coho may not be seriously affecting growth or residence of chinook in the river. However, if large numbers of hatchery fish were planted, increased interaction might result in the replacement of chinook by coho in the main river prior to the time most chinook normally enter the estuary. As temperatures increased in the summer, the main river would no longer be suitable for coho. As a result, this area would contribute little, if any, to the total population of salmon in Sixes River.

Close examination of the distribution and life history of native species should be attempted before planting is encouraged in any river system. Indiscriminate stocking of fish surplus to the needs of hatcheries could lead to unfortunate long-term consequences. Even if smolts were planted so that they moved immediately to the ocean and had little effect on native stocks, competition might be severe between their progeny and native juveniles. Introductions of new species may result in increased population levels, but reduction in desirable native stocks may occur.

LITERATURE CITED

California Fish and Game. 1965. California fish and wildlife plan. Volume III. Supporting data, part B inventory (Salmon-Steelhead and Marine Resources). 679 p.

Chapman, D. W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. J. Fish. Res. Bd. Canada 19:1047-1080.

Everest, F. H. 1969. Habitat selection and spatial interaction of juvenile chinook salmon and steelhead trout in two Idaho streams. Ph. D. Thesis. Univ. Idaho, Moscow, Idaho. 77 p.

Fish Commission of Oregon. 1968. Research and management on wild and hatchery produced salmon and steelhead in Oregon south coastal streams, annual report, July 1, 1967 to June 30, 1968. Clackamas. Processed. 49 p.

Hallock, R. S., and D. H. Fry, Jr. 1967. Five species of salmon, Oncorhynchus, in the Sacramento River, California. Calif. Fish and Game 53:5-22.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (O. kisutch) and steelhead trout (S. gairdneri). J. Fish. Res. Bd. Canada 22:1035-1081.

Hubbs, C. L., and K. F. Lagler. 1964. Fishes of the Great Lakes region. Rev. Ed. Bull. Cranbrook Inst. Sci. 26:1-213.

Keenleyside, M. H. A., and F. T. Yamamoto. 1962. Territorial behaviour of juvenile Atlantic salmon (Salmo salar). Behaviour 19:139-169.

Lister, D. B., and H. S. Genoe. 1970. Stream habitat utilization by cohabitating underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon in the Big Qualicum River, British Columbia. J. Fish. Res. Bd. Canada 27:1215-1224.

Mason, J. C., and D. W. Chapman. 1965. Significance of early emergence, environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. J. Fish. Res. Bd. Canada 22:173-190.

McGie, A. and W. Lenarz. 1964. A study of natural and introduced salmonids in Crystal and Brush Creeks, June-September 1963. Fish Comm. Oregon, Res. Div. Infor. Rep. Processed. 18 p.

Meehan, W. R. and J. S. Vania. 1961. An external characteristic to differentiate between king and silver salmon juveniles in Alaska. Alaska Dept. Fish and Game, Infor. Leaf. No. 1. Processed. 6 p.

________________ and D. B. Siniff. 1962. A study of the downstream migrations of anadronmous fishes in the Taku River, Alaska. Trans. Am. Fish. Soc. 91:399-407.

McIntyre, J. D. 1970. Production and behavioral interactions of salmonids in an experimental stream. Ph. D. Thesis. Oregon St. Univ., Corvallis. 58 p.

Neil, E. H. 1964. An analysis of color changes and social behavior of Tilapia mossambica. Univ. Calif. Publ. Zool. 75:1-58.

Pyle, E. A. 1965. Comparative tests of three types of vinyl tags on growth and swimming performance of brook trout within a hatchery, p. 48-52. In The nutrition of a trout, Cortland, New York. (New York. Conservation Dept. Fisheries Research Bulletin 28. Cortland Hatchery Report No. 33 for the year 1964)

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Can. No. 119. 300 p.

Reimers, P. E. 1968. Social behavior among juvenile fall chinook salmon. J. Fish. Res. Bd. Canada 25:2005-2008.

________________ 1970. Behavior troughs with simulated redds to study recently emerged salmon fry. Fish Comm. Oregon, Res. Rep. 2:96-99.

Reimers, P. E. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Ph. D. Thesis, Oregon St. Univ., Corvallis. 99 p.

Salo, E. and W. Bayliff. 1958. Artificial and natural production of silver salmon, Oncorhynchus kisutch, at Minter Creek, Washington. Wash. Dept. of Fish. Res. Bull. 4: 76p.

Simpson, M. J. A. 1968. The display of the Siamese fighting fish, Betta splendens. Anim. Behav. Monogr. 1(1): 1-73 p.

U. S. Geological Survey. 1968. Water resources data for Oregon. Part 1. Surface water records. 372 p.