AN ABSTRACT OF THE THESIS OF

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Title: Age and Growth of Cutthroat Trout, *Salmo clarki clarki* Richardson, in the Rogue River, Oregon

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Abstract approved: ______________________________
Carl E. Bond

A survey of the literature indicates that there are trends in timing of migrations and spawning with latitude for anadromous cutthroat trout. The timings in the Rogue River appear to be in agreement with those trends; downstream migration in April-May and upstream migration in October-November with spawning in February-March. Contrary to findings for other river systems, anadromous cutthroat in the Rogue do not migrate out in large numbers beyond the estuary.

The population in the estuary is mainly composed of first-time migrants (92%), which indicates that mortality is high. Fishing may be a major cause of mortality as the population is vulnerable to angling in the estuary throughout the growing season. The age structure of first-time migrants is relatively simple; age I 20%, age II 75.4% and age III 4.6%. These factors combined with spawning in small tributaries that are sensitive to environmental

fluctuations make the population vulnerable to catastrophic events. Faster growing individuals tend to migrate a year or two earlier than slower growing ones. Within a season, a similar tendency is observed, larger individuals migrate earlier than smaller ones.

Based on spawning marks on scales, only 50% of trout in their second season in the estuary had spawned. Spawning does not occur every year after maturity is reached.

Analysis of strontium:calcium ratios in scales was used to determine the range of the anadromous population. These ratios are higher for trout that have reared in salt water than for those who have reared in fresh water. Anadromous trout appear to be confined to the lower river (up to river km 44.2), whereas potamodromous trout occur throughout the main stem. Length frequency distributions from the lower and the upper river lend support to this conclusion.

Growth of trout in the main stem is similar to that of anadromous trout. Length increment in the first season in the estuary or mainstream decreases with increasing age (size) at first outmigration. Resident trout in the tributaries appear to grow slower than migratory fish do prior to outmigration. This could be explained in terms of faster growing fish developing migratory tendencies, leaving the slower growers behind. The relationship between the different populations cannot be inferred from the present study.

Age and Growth of Cutthroat Trout, *Salmo clarki clarki* Richardson, in the Rogue River, Oregon

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AGE AND GROWTH OF CUTTHROAT TROUT, *SALMO CLARKI CLARKI* RICHARDSON, IN THE ROGUE RIVER, OREGON

INTRODUCTION

The purpose of the present study is to determine life history characteristics of the Rogue River cutthroat trout (*Salmo clarki clarki*), based on information gained from scale reading, related sampling information (length, date and location of capture) and analysis of strontium content relative to calcium in the scales. More specifically the study entails:

1. Age and growth by location.
2. Migration patterns.
3. Age at maturity.

The Rogue River is located in southwestern Oregon. It has a 13,367 km^2 catchment area that extends into the northern part of California. The mainstream is accessible to anadromous fish for 252 km. For further description of the river and its watershed, see Everest (1973).

The data for this study were obtained with the assistance of the Oregon Department of Fish and Wildlife Rogue River Evaluation program. In 1973, the department initiated a long-term study to assess the effect of dam construction at Lost Creek, river km 252, on the anadromous salmonid populations in the Rogue River. The primary species being studied are chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Salmo gairdneri*). The sampling program is thus very much oriented toward these two species, and information on the cutthroat trout was collected incidentally to the sampling program.

Cutthroat trout appear to be relatively scarce in the Rogue. By 1977 however, enough material had been collected to warrant a specific study on this species. Also Lost Creek Dam had been erected and was starting to operate in 1977. This study would thus be an assessment of the cutthroat trout prior to the effects of the dam. The available data were mainly from seining operations in the estuary and the main stem of the river. They consist of size (fork length) of cutthroat captured, date and location of capture, and scale samples from most of the fish (ca 700). These were supplemented with samples from small tributaries, obtained through electrofishing in August 1977 and January 1978.

The information available on coastal cutthroat trout from the literature is rather limited but implies that life history patterns for this subspecies are variable. These will be discussed in the next section, with emphasis on trends with latitude for anadromous fish. Because of this variability, extrapolation of information from studies in other systems to the situation in the Rogue as a basis for management decisions can be dangerous. The Rogue is close to the southern limit of the distribution for coastal cutthroat trout, and specific life-history traits may have evolved in order to maintain a population there. Not until these factors are understood can a sound management program be implemented.

REVIEW OF LITERATURE

The coastal cutthroat trout is native to the west coast of North America, ranging from the Eel River in northern California to Seward in southeastern Alaska (Scott and Crossman, 1973). Anadromy tends to be rather poorly developed (Hoar, 1976) and anadromous fish generally coexist with resident fish, the two being indistinguishable, at least in their juvenile stages. Other populations are entirely confined to freshwater, but may still have distinct migratory stages in their life history. Much has been written on the cutthroat in general, and some on its somewhat unclear taxonomic status, but specific studies dealing with its life history are poorly represented in the literature.

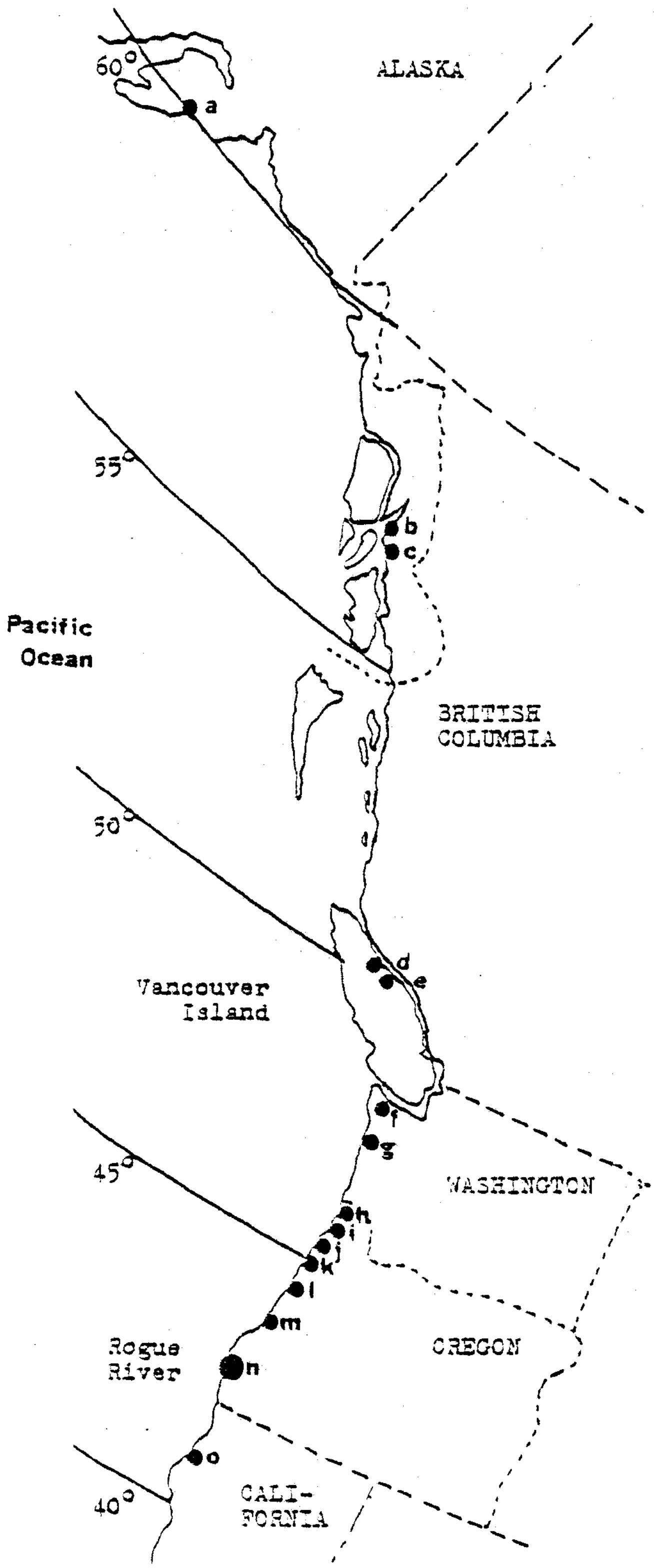
Anadromous Trout

Anadromous cutthroat trout appear generally to have a drawn-out migration pattern and spawning time. They do not appear to make long migrations in the ocean. Haig-Brown (1939) observed that some cutthroat stayed in the estuary of the Campbell River, Vancouver Island, B. C., throughout the summer and even entered freshwater on occasional feeding migrations. He felt that cutthroat would not go much beyond the influence of their home river. Jones (1977) found that cutthroat from Petersburg Creek, Alaska, tended to follow the shoreline in their migrations and tagged specimens were captured in streams up to 70 km from their home stream. Giger (1972) reported 30% straying of hatchery released fish up to 130 km in distance. Other observations indicate that cutthroat generally remain close to shore or in tidewater throughout the summer (De Witt, 1954; Royal, 1972; Sumner, 1972). Cutthroat appear to overwinter in freshwater (Armstrong, 1971; Giger, 1972).

In what follows, an attempt will be made to establish if there are any trends in timing of migrations and spawning with respect to latitude. If observed, trends may be used as a predictor for the present study. The studies (rivers) under consideration will be discussed from south to north. These are shown in Figure 1.

A. Upstream Migration and Time of Spawning

Upstream migration is generally about one month later and spawning about three months earlier in the southern part of the range, compared with Alaska. De Witt (1954) states that searun cutthroat are caught in a number of rivers in northern California in fall and winter, with peak catches after the first fall freshet, usually in September or October. Female cutthroat are found in spawning conditions from September to April, but these could include resident fish. In Oregon (Giger, 1972), catches in the Siuslaw, Alsea and Nestucca estuaries peaked in



a Seward (Northern range)

b Petersburg Creek (Jones, 1977)

c Eva Lake (Armstrong, 1971)

d Campbell River (Haig-Brown, 1939)

e Lymn Creek (Mason, 1974)

f Minter Creek (Royal, 1972)

g Elochoman River (Royal, 1972)

h Kilchis River (Sumner, 1972)

i Wilson River (Sumner, 1972)

j Sand Creek (Sumner, 1962)

k Nestucca River (Giger, 1972)

l Alsea River (Giger, 1972)

m Siuslaw River (Giger, 1972)

n Rogue River (Present study)

o Eel River (Southern range)

Figure 1. Latitude range of coastal cutthroat trout, showing rivers on which anadromous cutthroat studies have been conducted.

August-September, but most fish appeared to move into freshwater in November. Timing of migrations varied among years, but were similar among rivers within a year (in five years of study), suggesting broad climatic and/or marine factors influencing the timing of the runs. Cramer (1940) reported spawning of searun cutthroat in the Alsea River in December to February. Lowry (1965) reported peak upstream movement into three tributaries of Drift Creek, which drains into the Alsea Bay, in December. Sumner (1962) reported peak upstream movement in November in Sand Creek. Sumner (1972) observed spawning cutthroat in a tributary to the Wilson River in January.

In Washington, entrance into freshwater occurs in December in Minter Creek and November in the Elochoman River, where spawning occurs in late December to April. On Vancouver Island, British Columbia, immigration starts in the latter part of August with spawning in February-March in the Campbell River (Haig-Brown, 1939). Spawning time is similar in the Cowichan River (Scott and Crossman, 1973). In Lymn Creek (Vancouver Island), upstream movement was observed from December to March and spawning in the spring (Mason, 1974). The sample size in the latter study however was small, only 13 fish. In southeastern Alaska, peak immigration occurs in September and spawning in May in Eva Lake (Armstrong, 1971). These results compare well with those of Jones (1977) in Petersburg Creek.

B. Spawning Requirements and Freshwater Rearing

In the following sections Roman numerals will be used to designate age, 0-meaning no annulus, I-one annulus, etc.

According to Scott and Crossman (1973), spawning is confined to small gravelly streams. In California, age 0 trout could be found only in streams with minimum summer flows of less than 0.03 m^3/sec (De Witt, 1954). Similarly Sumner (1962) and Lowry (1965) found small tributaries to be very important for spawning cutthroat that left their natal stream at age I. Giger (1972) found that parr would move downstream in spring and some would rear in the estuary throughout the summer, migrating upstream again in fall.

Cutthroat spend variable amount of time in fresh water before their first outmigration. No trends can be detected in length of stay with latitude. Giger (1972) found first-time migrants to be of age group II-V, with age group III comprising over 50%, and age group IV about 25%, in the Siuslaw, Alsea and Nestucca rivers. Sumner (1962) found similar results in Sand Creek, but age group IV was relatively larger than observed by Giger. A comparable result was found in the Kilchis River (Sumner, 1972). In the Campbell River, initial migrants are generally of age II and some of age I (Haig-Brown, 1939). In Alaska, initial migrants in Eva Lake are of age II-IV and mostly III (80%)

(Armstrong, 1971). In Petersburg Creek, the youngest initial migrants are of age III (Jones, 1977).

C. Timing of Seaward Migration

Outmigration is about one month earlier in the south than in the north. Generally kelts move downstream before smolts (Lowry, 1965; Giger, 1972; Royal, 1972). Generally some time is spent in the mainstream and estuary before entering the ocean. Downstream migrations in Oregon appear to be from January to early June. In the Siuslaw, Alsea and Nestucca rivers, most cutthroat had left the estuary by the end of May. Sumner (1972) observed a peak in mid-May in downstream movement in Coal Creek, a tributary to the Kilchis River. In Sand Creek (Sumner, 1962), the downstream run started in March, peaked in early May and ended in mid-June. In Eva Lake, Alaska, outmigration started with ice-breakup and peaked as water temperature reached 6°C, which in 1962-64 was in mid-May to early June (Armstrong, 1971). In Petersburg Creek, Alaska, a similar pattern was observed. Outmigration began in early May and was completed by late August. Peak runs occurred after water temperature reached 6°C, which was in early June to July in different years (Jones, 1977).

D. Ocean Growth

Growth in the ocean for first-time migrants was found to be about 10 cm/season in Giger's (1972) study. However spring growth in fresh water and estuary was on the average 7 cm for age II fish, decreasing slightly with age (and size) at first migration. Growth (in length) declined rapidly for repeat spawners, annual increment being 7 cm for second-time migrants and about 4 cm for third-time migrants. Fish appeared to spawn every year after maturity was reached. Sumner (1962) reported similar ocean growth for Sand Creek cutthroat. In Lymn Creek, Vancouver Island, annual growth appears to be similar to that found in the studies cited above (Mason, 1974). In Eva Lake and Petersburg Creek, Alaska, growth appears to be much slower, about 4 to 6 cm annually (Armstrong, 1971; Jones, 1977).

E. Conclusion

Trends in timings with latitude have been observed. These would be expected because of differences in temperature and photo-period with latitude. In summary, upstream migration appears to be one month later, spawning three months earlier and outmigration one month earlier in the south than in the north. No trends with latitude were observed in age at first outmigration (smolting), but size at first outmigration does not appear to change with latitude. Growth in the ocean is much slower in Alaska than it is in other parts of the range. None of the trends observed can confidently be attributed to latitude. Only a handful of studies have been done and drawn-out timings, inherent problems in the various studies and local conditions may obscure trends if they do exist. Much more work is needed before conclusive results can be obtained.

Resident Trout

The sympatry of anadromous and resident cutthroat has led to some speculation about interaction between the two. Royal (1972) considered that the resident populations possibly maintain the anadromous populations, i.e., some individuals from the resident populations become anadromous. These are indistinguishable in their juvenile stages, and exhibit similar growth when rearing in the same environment. Not until the anadromous individuals migrate to the ocean are the differences in growth observed, and even then there may be no difference. Living space is an important regulatory factor in growth of fishes, but cannot be distinguished from the effect of food availability (Weatherley, 1972). In the Petersburg Creek system (Jones, 1977), no differences could be found in growth of resident and anadromous fish. There the resident fish rear in lakes. In the Willamette River drainage, Dimick and Merryfield (1945) found cutthroat to exhibit two basic life histories. There were those that reared in tributaries all their life, never attained large sizes and spawned in May-June. The other type spawned in February-March, but after rearing in small tributaries for up to two years, the progeny migrated down to the manstream where they could attain 45-50 cm in length. Wyatt (1959) studying resident populations in Lookout Creek and two of its tributaries in the Cascades, Oregon, found a consistent increase in length for all year classes with stream size. For age IV fish the length in September was 13.6, 15.0 and 19.6 cm in the three streams. Spawning took place in April to June.

In Great Central Lake, Vancouver Island, cutthroat apparently rear in small streams for two to three years before migrating to the lake (Narver, 1975). Growth is slow in the tributaries (about 5 cm/year) but rapid in the lake, probably about 15 cm the first year and then gradually decreasing with age. The figures given are only approximations, due to the way date were presented. Similarly rapid growth of cutthroat has been observed in Buttle Lake, Vancouver Island (Scott and Crossman, 1973).

Cutthroat tend to be most abundant in small streams. In British Columbia, Hartman and Gill (1968) found streams with drainages less than 13 km^2 to be predominantly occupied with cutthroat trout, whereas in the larger streams steelhead dominated. However, the gradient of the stream was important also. Streams with drainages less than

120 km^2, with steep gradient and emptying into the ocean, were dominated by steelhead, but similar sized streams in which the lower stretches were low gradient (sluggish water) supported more cutthroat. In streams harboring both species, cutthroat were more confined to the headwaters and small tributaries, and the steelhead to the lower stretches of the main stem.

Wyatt (1959) found cutthroat to be most abundant in streams where summer flow was less than 0.15 m^3/sec. In larger streams rainbow trout (*Salmo gairdneri*) dominated. Resident cutthroat appeared very stationary. In one year 32.2% of marked fish (N=50) remained in the same pool and 64.4% moved less than 200 m. This is further supported by Lowry (1965) who found cutthroat to remain in the same pool in which they were tagged, and many were found to return to the same pool after spawning migration upstream or into small tributaries. Coastal cutthroat appear also to have a home range in lakes, but apparently do not defend territories in the lentic environment (Shepherd, 1973). Miller (1957) concluded that resident cutthroat from Gorge Creek, Alberta, (presumably *Salmo clarki lewisi*) spent their entire life in the same pool (20 m stretch).

Conclusion

Growth of resident cutthroat trout is strongly dependent on the size of the body of water in which they rear.

Growth in lakes and large rivers may equal that observed for anadromous trout in the ocean. Where trout of different life history types coexist, these cannot be distinguished on the basis of morphological characters, and their interrelationship is not known.

MATERIAL AND METHODS

Acquisition of Materials

Four years accumulation of data was available from the Oregon Department of Fish and Wildlife. This was obtained in seining operations, in the estuary and the main stem of the Rogue River. The data included number and length of cutthroat caught, time and location of capture. Scale samples were taken from the majority of the fish. For purposes of analysis, the data were grouped in estuary, lower river (river km 4.8-44.2) and upper river (river km 81-252). A summary of scale samples according to time and location is presented in Table 1. Scales were collected just above the lateral line, behind the posterior insertion of the dorsal fin. The number of scales in a sample ranged from fewer than ten to several hundred.

A limited number of scale samples was available from tributary fish. To supplement these, electrofishing with a pulsating D. C. backpack unit was undertaken during August 1977 and January 1978. Captured cutthroat trout were measured (fork length) and scale samples were taken. Some fish, selected to represent the size range in the catch, were inspected for maturity, and otoliths were taken. Ages were estimated from otoliths for comparison with age results from scale readings. Stream characteristics, such as type of substrate, discharge and water

TABLE 1. NUMBER OF CUTTHROAT TROUT SCALE SAMPLES FROM THE ESTUARY AND THE MAIN STEM OF THE ROGUE RIVER, BY TIME AND LOCATION.

LOCATION	YEAR	JAN-MARCH	APRIL-JUNE	JULY-SEPT	OCT-DEC
Estuary	1974	-	30	39	22
	1975	-	17	56	20
	1976	4	116	126	29
	1977	-	15	2	-
	Total	4	178	223	71
Lower river km 4.8-44.2	1974	-	4	14	-
	1975	7	14	6	10
	1976	19	10	12	3
	1977	4	11	8	1
	Total	30	39	40	14
Upper river km 81-252	1974	-	3	1	1
	1975	7	5	13	-
	1976	6	19	17	-
	1977	3	12	5	1
	Total	16	39	36	2

velocity were estimated. Other species of fish, if present, were recorded. The tributaries that were sampled and number of samples from each are given in Table 2.

Preparation and Interpretation of Scales and Otoliths

Scales for mounting were selected under a low-magnification microscope. Only scales that showed little or no regeneration were selected. When possible five scales from each fish were mounted. Scales from fish larger than 20 cm were mounted on gummed cards with the sculptured (upper) side out. An impression was then made on acetate cards at $100^{\circ}C$ and 350 kg/cm^2 for 3 min. For fish smaller than 20 cm, the scales were mounted on glass slides in 95% sodium silicate and 5% glycerin media.

Scales were read along the medial anterior radius with a microprojector at 80X magnification. Annuli and outer edge of the scale were marked on a paper strip. Two scales were selected for reading. These were read twice independently, with at least one month's interval, by the same reader. A subsample was read by another experienced reader. Scales for which consistent results were not achieved were discarded. Annuli were determined using criteria given by Tesch (1971), which include narrowly spaced circuli followed by widely spaced ones and 'crossing over' of circuli. Spawning checks could not be determined with certainty for resident fish, but were

TABLE 2. TRIBUTARIES SAMPLED IN UPPER ROGUE RIVER DRAINAGE WITH ELECTROSHOCKER.

Creek	Date	Area sampled (m^2)	Ave. width (m)	Amps (A)	Number of cutthroat	Rainbow/ sculpins	Remark
North Fork Big Butte	8/23/77	350	3-4	0.4	10	31/20+	Relatively open channel
Jackass	8/26/77	250	2-2.5	0.5	18	21/19	Trib. to N. Fork Big Butte
----------	1/14/76	-	-	-	12	-	From O.D.F.W.
Rancheria	8/27/77	500	3-4	0.3	20	9/25	Logs and undercut banks
----------	7/25/77	-	-	-	22	-	From O.D.F.W.
Twincheria	8/27/77	250	1.5-2	0.1	30	0/+	Small trib. to Rancheria
Titanic	8/27/77	150	1-1.5	0.2	38	0.0	Small trib. to Rancheria
West Fork Evans	8/22/77	250	3-4	0.5	1	6/+	
----------	5/24/77	-	-	-	9	-	From O.D.F.W.
Rock	8/21/77	200	4-5	0.2	0	37/31	Trib. to West Fork Evans
Cold	8/21/77	100	1-1.5	0.6	0	15/+	Trib. to Rock Creek
Salt	8/21/77	200	1-2	0.6	16	0/11	Above falls, trib. to West Fork Evans

TABLE 2 (cont.) TRIBUTARIES SAMPLED IN UPPER ROGUE RIVER DRAINAGE WITH ELECTROSHOCKER.

Creek	Date	Area sampled (m^2)	Ave. width (m)	Amps (A)	Number of cutthroat	Rainbow/ sculpins	Remark
----------	8/21/77	250	2-3	0.6	0	12/+	Below falls
Jump Off Joe	8/25/77	300	3-3.5	0.6	0	20/25+	Above falls
Quartz	8/17/77	300	0.5-1	0.3	52	0/+	Trib. to Jump Off Joe
Galice	8/19/77	300	4-5	0.2	0	42/10	
TRIBUTARIES SAMPLED IN LOWER DRAINAGE WITH ELECTROSHOCKER**							
Quosatana	1/14/78	1000	6-8		14	0/0	Above falls
Saunders	1/14/78	500	10-12		0	0/0	
Indian	1/14/78	2000	10-12		0	+/+	Fished from mouth to barrier
Edison	1/15/78	500	5-7		3	+/0	
Small trib. to Edison	1/15/78	200	0.7-1		14	24/+	
Lobster	May-June 77	-	-		10	-	Taken in downstream trap

**No ammeter on electroshocker, therefore no amp reading obtained easily identified on scales of cutthroat caught in the estuary as a relative broad zone of undifferentiated matrix.

Scale reading is often called an art. False checks or supernumerary rings are frequently encountered. This is when the reader must often rely on other information, e.g. the time of the year the fish was caught and the appearance of scales of fish caught the previous month. Chuganova (1963) discusses these problems in some detail. Usually these checks are a result of marked changes in environmental conditions, such as food availability, or food preference. Fish may switch from a smaller to a larger food item as they grow, thus causing different growth 'stanzas' within a season. Typically supernumerary rings are evident only in the anterior part of the scale. On the scales from estuary fish, these false checks were quite frequently observed and could be related to smoltification when a rapid increase in length and decrease in condition factor occurs (Wagner, 1974), i.e. the fish does not grow isometrically and it is likely that the same applies for the scales.

Otoliths are considered by many (e.g. Jonsson, 1976) to be more reliable method of age determination than scales. One does not necessarily get more readable otoliths than scales, but while scales tend to be more difficult to interpret from older fish, unreadable otoliths appear to be equally represented in all age (size) groups (Jonsson, 1976). Otoliths do not resorb at starvation or spawning (Simkiss, 1974) and this is understandable in terms of their function as balance organs. Otoliths are a protected structure whereas scales are a protective structure, and random (within season) changes in the environment are more likely to be registered in the scales than in the otoliths.

Otoliths could only be obtained from small fish in the tributaries. They were stored dry in an envelope and read against black background under a microscope in reflected light. The annuli (a long period of slow growth) appears as dark bands, similar to annual rings in trees. From some creeks, the otoliths were hard to interpret and practically useless (e.g. Salt Creek), but in most creeks there could be no doubt about interpreting them. These, together with the existing literature, proved very useful in the beginning of the scale reading, when the reader was developing his skill. For a comprehensive description and discussion on the use of otoliths for age determination see Williams and Bedford (1974).

Backcalculation of Length at Annulus Formation

Backcalculation of growth in fishes from their scales has been used since early this century and a number of methods has been used (Hile, 1970). The most common method is to assume the body-scale relationship to be a straight line through the origin (direct proportion). The most accurate one however, is the use of an empirical relationship, but this has problems associated with it. Scale formation takes place at different lengths on different parts of the body. Thus a variable amount of early life history is recorded on the scales (Clutter and Whitesel, 1956; Cooper, 1970). It is thus necessary to carefully select the location from which one takes samples and to do so consistently. Other complicating factors are resorption of scale margins associated with spawning and loss of neighboring scales (Clutter and Whitesel, 1956).

In the present study, wide variations in scale size at any given body length were found (Figure 2). There is an apparent increase in range with body length. A major cause for this is probably inconsistency in sampling, but other factors, such as those mentioned above, may play a significant role.

The body-scale relationship from the estuary and the mainstream samples are not different, but it varies greatly among individual creeks. If most of the samples are from fish of age I and older, a regression of scale radius on body length gives an intercept with the X-axis (body length) that is negative and numerically high. As more young of the year (age 0) fish are included in the sample, the intercept approaches the origin. This can be explained

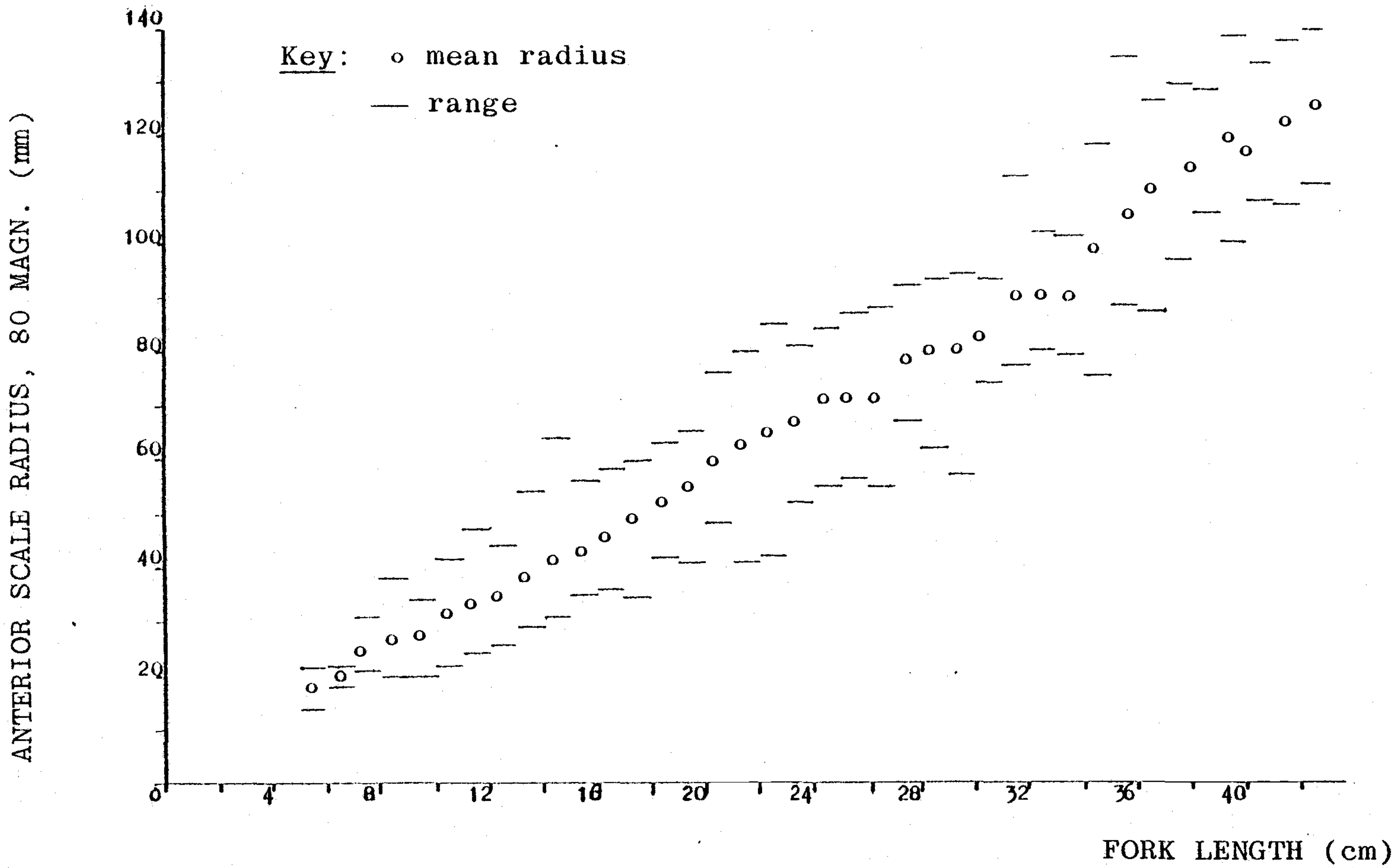


Figure 2. Body-scale relationship of Rogue River cutthroat trout, all samples combined; 1974-1977.

with results obtained by Cooper (1970). He did a careful study on the body-scale relationship in juvenile cutthroat trout, and found the relationship to be curvilinear within the range of his data. In Figure 3, his results are compared to those from Twincheria Creek, a small tributary in the upper Rogue River drainage. If a regression line is drawn through the points in his graph representing the range in which the bulk of samples from Twincheria Creek fall, the resulting X-intercept is similar. If the regression from the Twincheria Creek material is used as a basis for back-calculation of length at annulus formation, up to 50% under-estimation of length at time of first annulus formation can be obtained. Employing the direct-proportion method gives more reasonable results. Furthermore the actual relationship for all samples combined (Figure 2) approaches a straight line through the origin. I therefore decided to employ this method in the present study.

Strontium Analysis

It became evident as the scales were read that it would be difficult, if not impossible, to characterize fish from different parts of the mainstem and estuary, based on growth characteristics. Some other means had to be found to determine how far upstream anadromous trout migrate.

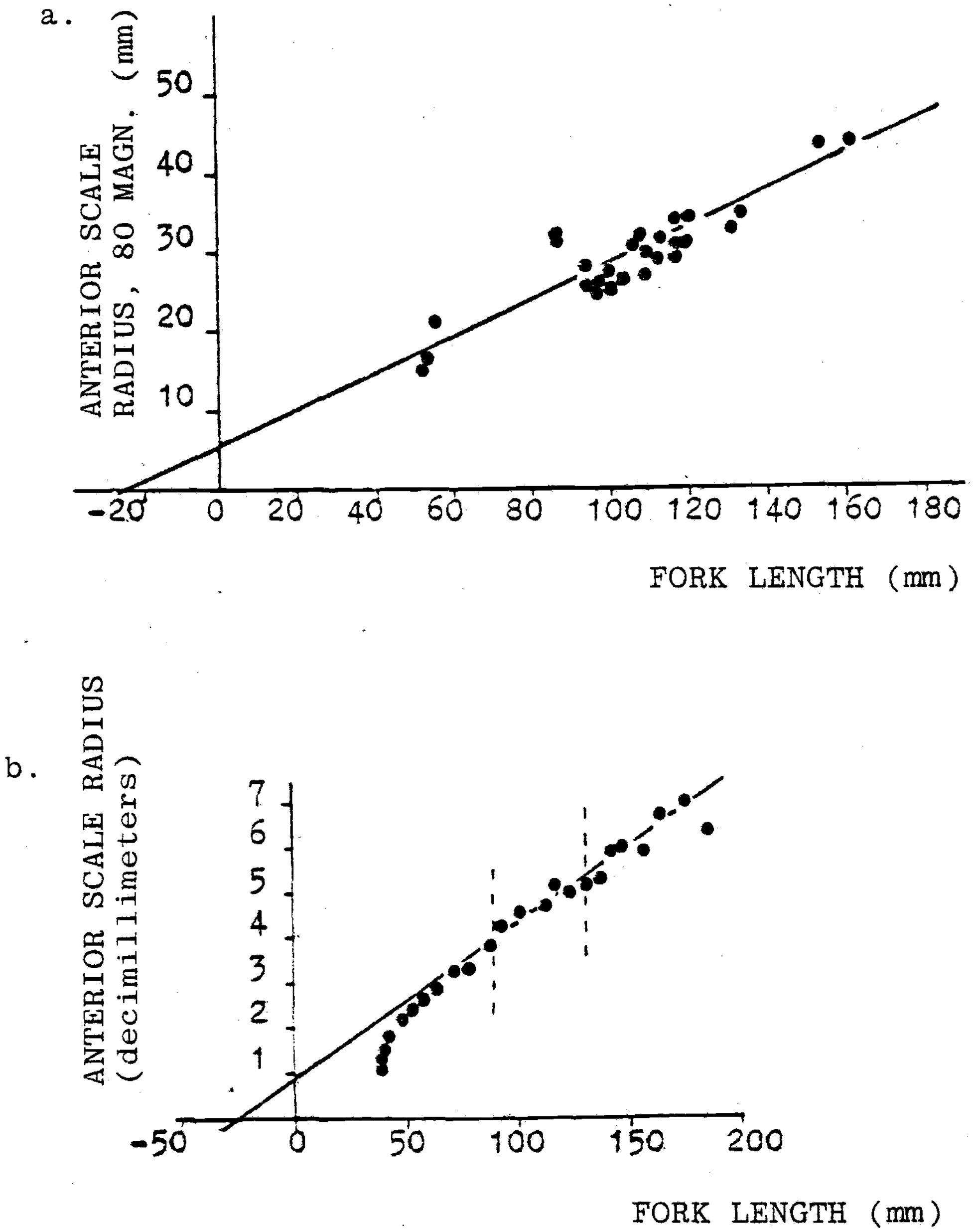


Figure 3. a. Body-scale relationship of cutthroat trout from Twincheria Creek, compared with that through the same range on

b. Cooper's body-scale relationship (1970) of cutthroat trout from Chef Creek, Vancouver Island (Cooper, 1970).

Bagenal et al. (1973) showed that there were marked differences in the strontium (Sr) content in scales from searun and resident brown trout (Salmo trutta). The former had more than 300 μg Sr/g of scale material and the latter less than 200 μg Sr/g of scale material. Even after a period of 67 days in fresh water, the strontium content in the scales of searun trout was still above 300 μg Sr/g of scale material. Analysis of strontium content in scale from other species, freshwater and marine, gave results consistent with those found for brown trout.

Strontium possesses similar chemical properties to calcium (Ca), (both are alkaline earth metals), and tends to replace it in organic structures. Ca is generally much more abundant in seawater than in freshwater, but the ratio Sr:Ca is much higher in the oceans than in freshwater. Thus in the oceans the ratio is 20:1000 (8 mg/l vs 400 mg/l; Hill, 1963), but in freshwater it is much lower. Hutchinson (1957) gives some data on Ca and Sr concentration in fresh water. These are rather variable and unfortunately not from the same water masses. However if the extremes of his values are taken (highest Sr and lowest Ca), the ratio Sr:Ca is not higher than 3:1000 (0.99 mg/l vs 36 mg/l) and is presumably several times lower. Sr concentrations tend to increase with Ca concentration, but the ratio Sr:Ca decreases systematically with increasing Ca concentrations (Hutchinson, 1957).

Studies have shown that there is little discrimination in the relative uptake of Ca and Sr through the gill surfaces in fish. Furthermore, the gills appear to be the major avenue for uptake of Ca (Simkiss, 1974). That differences in Sr:Ca ratio in scales of fish do reflect the media in which they have reared seems a safe assumption.

Rather than analyzing only Sr content, I decided to analyze Ca concentrations as well. The ratio of these two elements can then be used to compare known freshwater fish and anadromous fish (from the estuary). The results form the basis of discrimination between resident and anadromous fish caught in the main stem of the Rogue. By using a ratio, much work in quantitatively weighing scales and measuring chemicals added to the samples is eliminated and should render the method more accurate.

Most scale samples from the estuary and all scale samples from each tributary had to be pooled as not enough scales were available from individual fish. Only scales from first time migrants taken at the same time and location in the estuary were pooled. Two to 17 mg of scales (these were not weighed) were put into 10 ml glass (pyrex) beakers and 1 ml concentrated nitric acid added. The sample was then digested on a 250°C hot plate for approximately 15-20 min until about half of the volume had evaporated. The beakers were then taken off the hot plate and 1 ml of 10,000 ppm lanthanum solution added. The lanthanum suppresses chemical interferences from Si, Al and P. From this solution a subsample was analayzed for Sr in a Perkin-Elmer 306 atomic absorption spectrophotometer. Another subsample was diluted 500X with 10,000 ppm Lanthanum solution and analyzed for Ca. A total of 132 samples was analayzed.

After all samples had been run, problems with the procedure became evident. During the test runs, when the method was developed, similar amounts of scales had been used and the results found to be reproducible. Large differences were also found between samples from known resident fish and known estuary fish. However, using the wide range of sample sizes (2-17 mg) yielded results that were highly dependent upon weight of scale material used.

To investigate further the magnitude of errors involved, and the possibility of applying a correction factor to the experimental values, a large homogeneous sample of scales from resident cutthroat was obtained from Salmon Creek, Willamette River drainage, Oregon. This was then divided into 14 samples of different sizes, each accurately weighed prior to analysis of Sr and Ca. The Ca analysis was found to be consistent (Figure 4), whereas the relative amount of Sr was not. The relationship between Sr and Ca, which ought to be directly proportional, could best be described by a second degree equation,

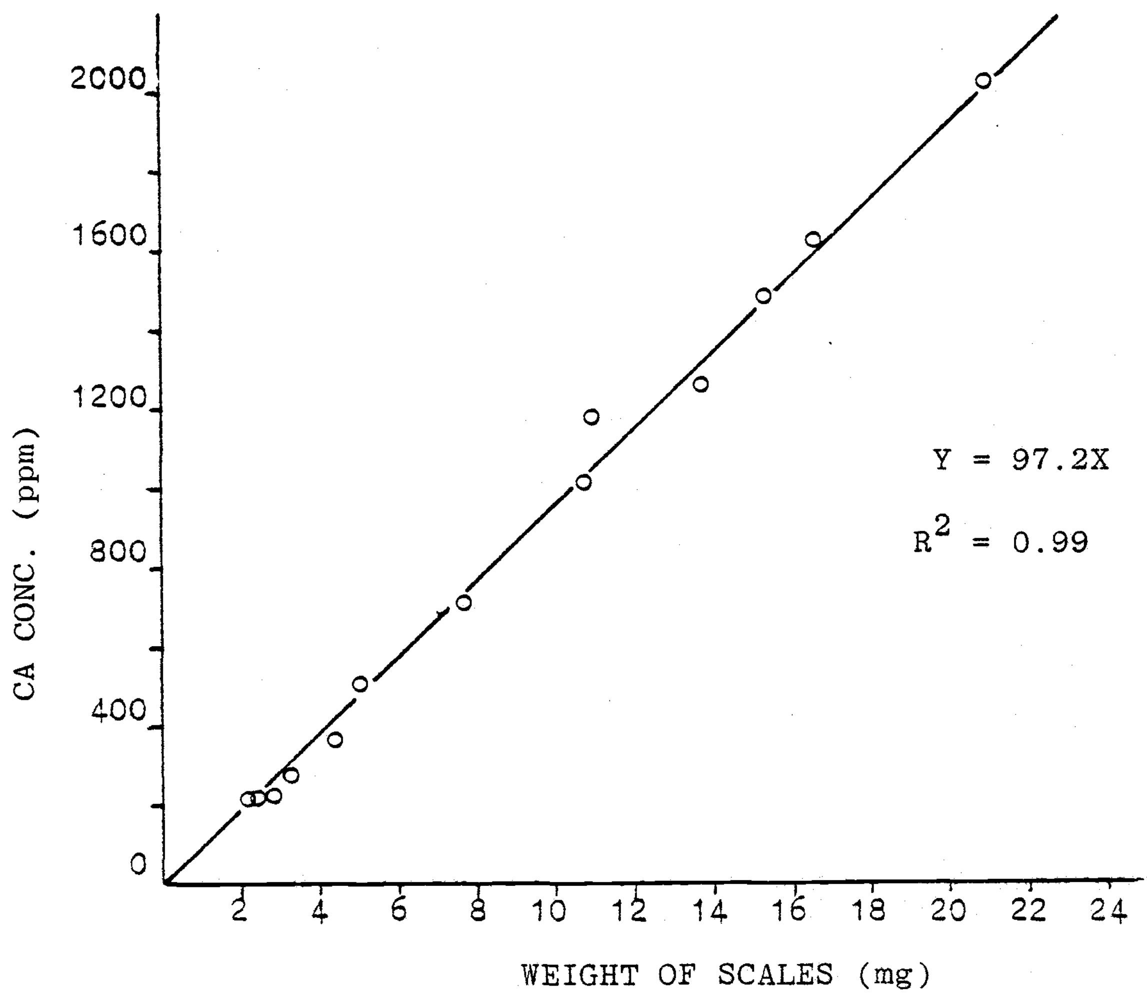


Figure 4. Relationship between Ca concentration and weight of scales of resident cutthroat trout from Salmon Creek, Willamette River drainage, Oregon.

$$Y = b_o + b_1X + b_2X^2$$

where $Y = \log (Sr)$

and $X = (Ca)$.

This was fitted over the range of 200 ppm Ca to 2000 ppm Ca. This relationship (Figure 5) indicates that Sr is precipitating out of the solution (Hanson, pers. comm.). However, between Ca values of 450-1350 ppm the relationship is approximately linear, the maximum deviation from a straight line being 5% in opposite directions at these lower and upper limits. All samples outside this range were excluded from the analysis, leaving 11 data points from known resident fish, 20 from upper river fish, eight from lower river fish and 38 from the estuary.

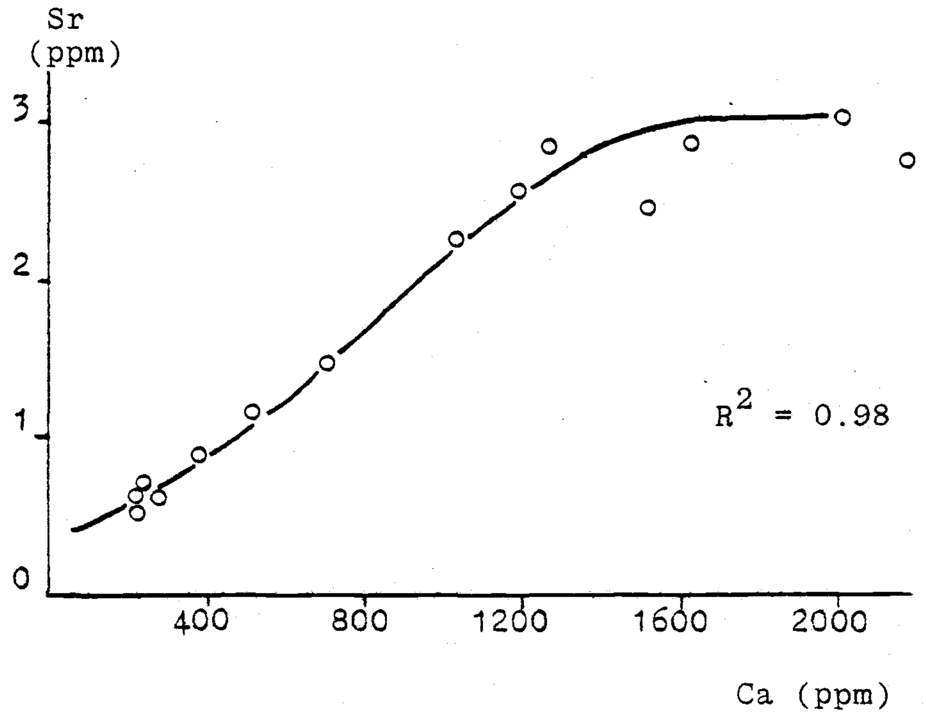


Figure 5. Relationship between experimental values of Sr and Ca from a homogeneous scale sample of resident cutthroat trout, from Salmon Creek, Willimatte River drainage, Oregon.

RESULTS AND DISCUSSION

Distinction Between Anadromous and Resident Populations

In this section, the three potential life history types of the cutthroat in the Rogue River will be examined and characterized. They are:

1. Anadromous trout, which has variable rearing periods in freshwater as juveniles before migration to salt water.

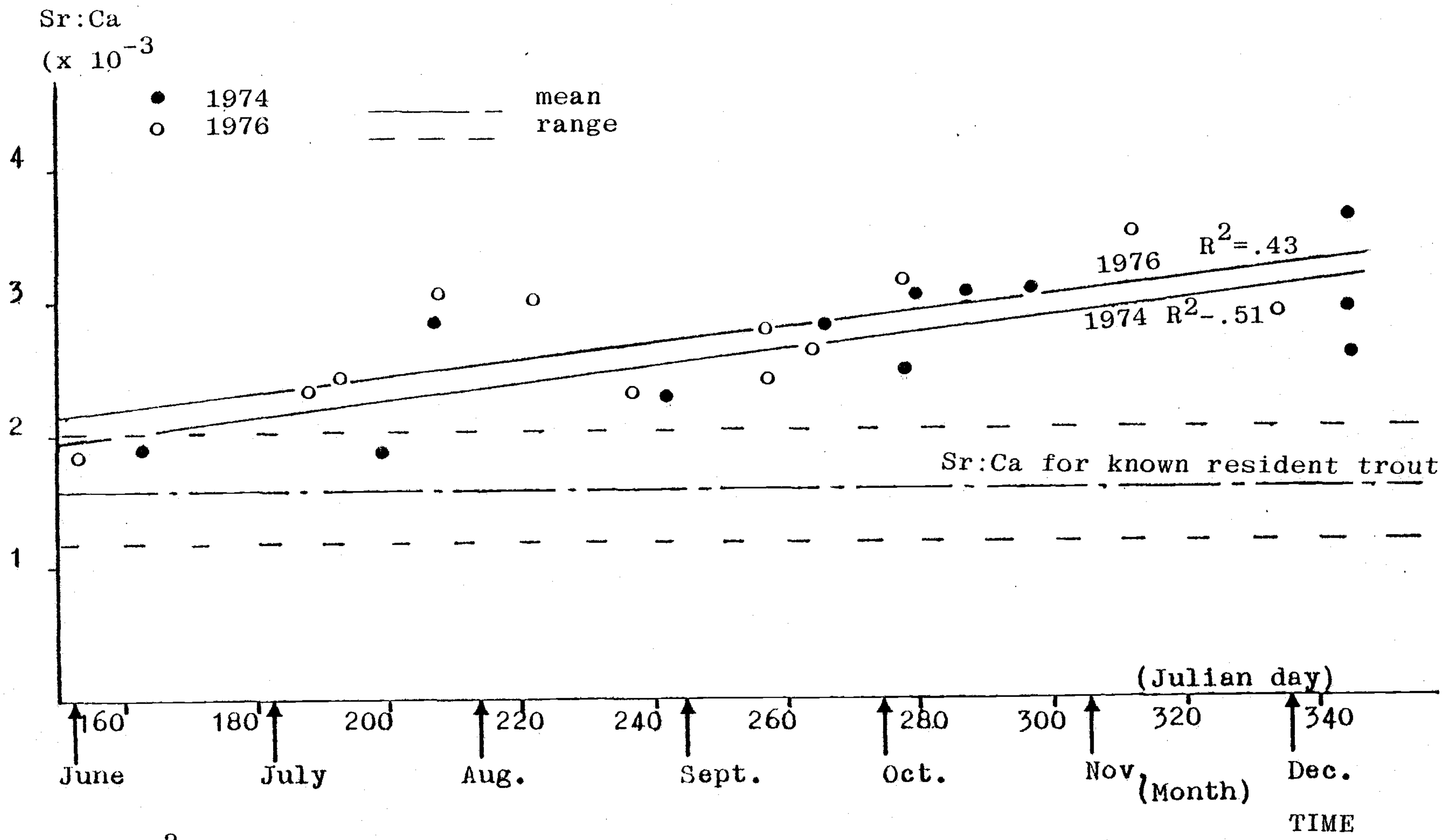
2. Potamodromous trout, which rears in small tributaries before migrating to the main stem of the river.

3. Resident trout, which completes it's whole life cycle in small tributaries.

There is evidence that anadromous and resident trout are present in the Rogue. Cutthroat are captured in the estuary each year, and cutthroat populations are found above impassable falls in small tributaries. To determine if there is a potamodromous population, strontium analysis was used.

A. Strontium Analysis

The results from known resident fish and first-time migrants captured in the estuary are shown in Figure 6. There are differences between the two groups. The Sr:Ca ratio increases with time in the estuary, indicating that the trout in the estuary rear there in the summer. Scales



74: R^2 = .51

76: R^2 = .43

Figure 6. Changes with time of Sr:Ca ratio in scales of first-time migrants of cutthroat trout in the Rogue River estuary. The horizontal lines show the mean and range of Sr:Ca ratio found in scales from resident cutthroat trout from tributaries in the upper Rogue River drainage.

from six trout in their second season in the estuary in 1976 were analyzed. The Sr:Ca ratio for these is generally just below the regression line for first-time migrants, but above the values obtained for resident fish.

Eight samples from the lower river were analyzed: six of these showed low Sr:Ca ratios ($1.10 - 1.58 \times 10^{-3}$; mean 1.42×10^{-3}) and are considered to be a part of a potamodromous population, whereas two showed high ratios (2.52 and 2.97×10^{-3}), and are considered to be anadromous. The anadromous fish were from river km 44.2 and 5.6 respectively, while the fish considered to rear in the main stem were from river km 5.6 - 16.1. All of these trout were large and taken at a time of year when spawning should have been completed. However only the two trout considered to be searun showed definite spawning checks on their scales.

Twenty samples from the upper river were analyzed for Sr:Ca ratio. The length of fish sampled ranged from 16 - 44 cm, and showed up to 17 cm length increment in one season. Samples came from fish caught in all seasons of the year and from river km 104 - 252. It is thus considered to be a representative sample, although sampling was biased towards larger fish. Because the Sr:Ca ratio ranged from 0.94 to 1.70×10^{-3} (mean 1.22×10^{-3}), I concluded that only rarely, if at all, do anadromous trout migrate above river km 104. Exceptions can be found.

Newcomb (1943) reported that one cutthroat, marked at the river mouth in August 1930, was recaptured at river km 175 in November of the same year.

The Sr:Ca ratio from a sample from Edison Creek was high (2.52×10^{-3}), indicating that at least some of the fish included had spent some time in the estuary. Edison Creek drains into the Rogue River just above the estuary. A short period of rapid growth could be identified from their scales.

B. Length-frequency Distribution

Length-frequency distributions from the lower river and the upper river are different (Figure 7). In the lower river there are three peaks which correspond to lengths at first entrance to the estuary (14-15 cm), length at end of first growing season in the estuary (27-31 cm) and length at end of second growing season in the estuary (35-43 cm). As the trout in the main stem appear to grow equally well in the main stem and the estuary, these peaks indicate a superposition of anadromous trout upon potamodromous trout. In the upper river, the distribution is indicative of an homogeneous population. The observed peaks in the lower river may to some extent reflect a sampling problem. Relatively more trout were caught outside the growing season in the lower river than in the upper river (Table 1).

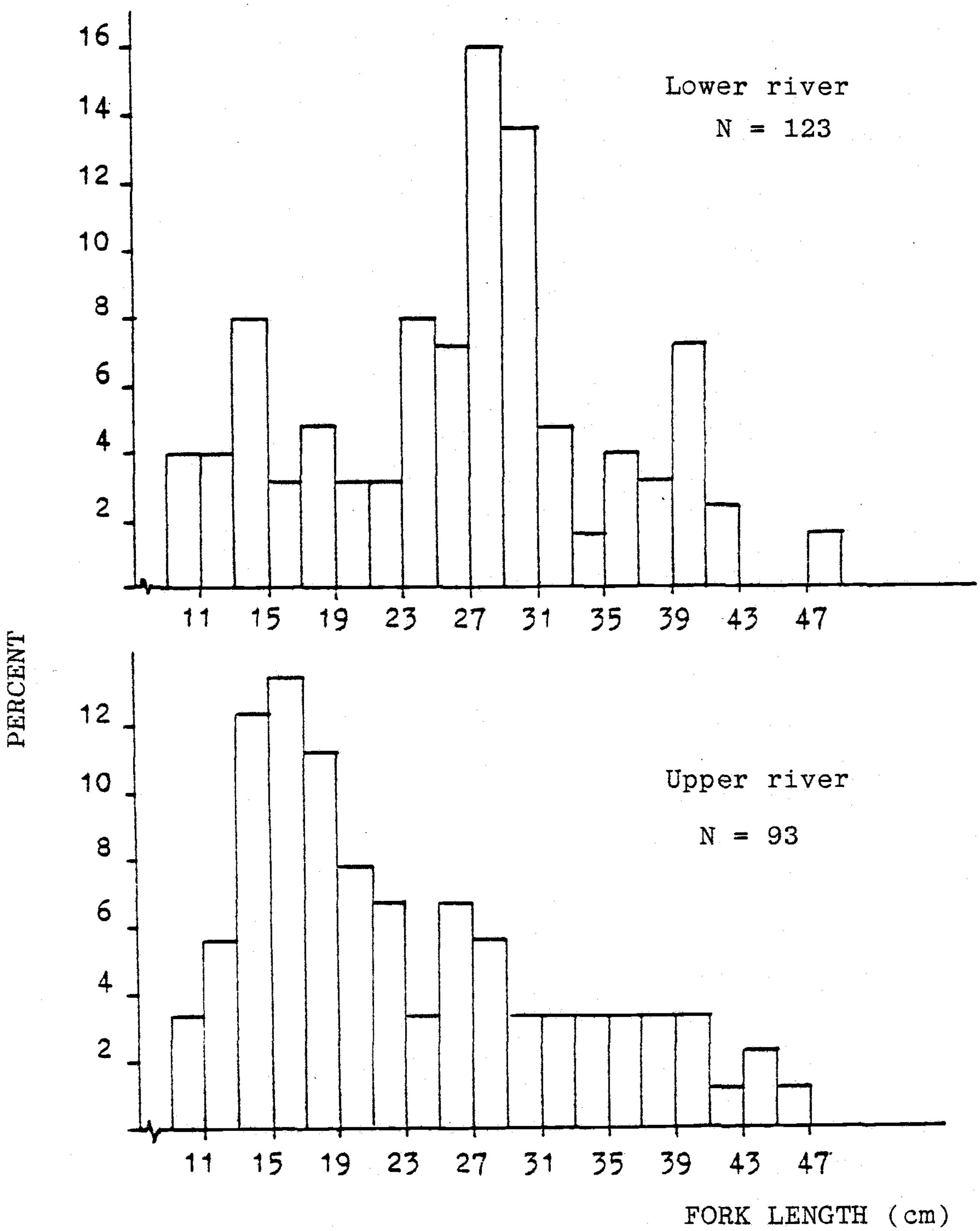


Figure 7. Length-frequency distribution for cutthroat caught in main stem of the Rogue River, 1974-1977. Based on data from trout of which scale samples were available.

C. Backcalculation of Lengths

From the backcalculated lengths at annulus formation (Appendix I), there appear to be differences in growth in first year of life between trout from the upper river and those from the lower river and estuary. A one-way analysis of variance was used to establish whether the observed differences in mean lengths were significant. The method of least significant differences, which uses pair-wise comparisons, was then used to determine which mean lengths were different.

Backcalculated lengths at first annulus formation for age I and for age II first-time migrants were higher in the lower river and estuary than in the upper river. The differences were significant at $p<0.05$ and $p<0.1$ for the age I and age II fish respectively. No dependence on location was found in backcalculated lengths at second annulus formation for age II first-time migrants. The differences could be due to temperature differences in the lower and the upper drainage, causing the eggs to hatch earlier in the lower drainage. These results support the potential existence of different populations obtained from analysis of Sr and Ca.

D. Summary

The results from three independent methods all indicate that the life history of upper river trout is different from the trout found in the lower river and estuary. Length-frequency distributions (Figure 7) and analysis of Sr:Ca ratios in scales indicate that trout in the lower river have two different life history types, anadromy and potamodromy. Trout caught in the upper river appear to be exclusively potamodromous. No inferences are made on life history types from tributaries.

Age and Growth Characteristics

A. Scale Reading

Not all scales could be interpreted. A summary of interpretable samples is given in Table 3.

TABLE 3. PERCENTAGE OF READABLE SCALE SAMPLES OF CUTTHROAT TROUT FROM THE MAIN STEM AND ESTUARY OF THE ROGUE RIVER, 1974-1977.

Location	Percentage of readable scales
Estuary	80
Lower river	87
Upper river	86
Weighted average	82

Scales from trout from tributaries were generally easy to interpret. These fish were usually young (Age 0-II) and reading was aided by otolith comparisons. In Quosatana Creek, however, neither scales or otoliths were interpretable, probably because of extremely slow growth.

There are two main reasons for unreadable scales:

1. Regeneration is very common, in particular in early life, when the trout is still inhabiting small streams. Cooper (1970) found regeneration of scales from cutthroat in a small creek to relate to age rather than length of fish. His data show that regeneration is approximately 50% per year. Thus an age III fish 80 - 90% of the scales are regenerated. Sumner (1972) states that the first annulus is often hard to interpret, and Wyatt (1959) was unable to interpret 19% of his scale samples, in spite of large numbers of scales from each fish. Many of the scale samples from estuary fish were very small, 10 - 20 scales, and often these did not contain one readable scale. Probably relatively more fish of age III at first migration had to be rejected than those from younger fish, because of regeneration.

Slow growing fish may not form scales until after their first winter. This has been observed for Yellowstone cutthroat trout (Salmo clarki lewisi) (Brown and Bailey, 1952; Laakso, 1955), and can lead to an underestimation of age. This is not the case in the present study, since otolith interpretations were generally in good agreement with those for scales.

2. Increase in length per year becomes less after about the third year, or after the first season in salt water or main stem, so that annuli may be hard to separate. Resorption associated with spawning may also exceed a whole year's increment on the scales.

B. Classification of Growth Patterns

Generally, periods of rapid growth can be detected on scales as a zone of relatively large width between circuli (Tesch, 1971). Rapid growth occurs when the habitat is spacious relative to the size of the fish and food supply is abundant (Weatherley, 1972).

Trout from the main stem and estuary generally grow slowly for one to three years. Thereafter the annual length increases markedly for one season, declining thereafter as fish grow older. The slow growth period is similar to that observed for trout sampled from tributaries. The season of rapid growth is generally in agreement for length increments observed for trout caught in the main stem or the estuary. On the basis of this pattern the results from back-calculation of lengths have been summarized as first time migrants, which may be of age I, II or III; and then in terms of numbers of years after first migration to the river, regardless of whether spawning checks could be identified.

C. Back-calculation of Growth

The back-calculated lengths at annulus formation are given in Appendix I. Trout in their second season after first migration appear to be much more common in the main stem than in the estuary. This is to a large extent an artifact of the presentation, as many of the samples are from early winter, when growth had ceased but the fish were still first-time migrants.

The lengths at annulus formation are very similar for trout from the estuary and main stem for first-time migrants and those taken in their second season on the main stem or estuary. This similarity is not evident for back-calculated lengths at first annulus formation. Length increment in the first season in the estuary or main stem decreases with increasing age (size) at first outmigration (Appendix I). Similar results were found by Giger (1972) for searun cutthroat in the Alsea, Siuslaw, and Nestucca rivers.

Trout caught in the upper river tributaries generally show slower growth than the fish caught in the main stem of the upper river prior to outmigration. This does not exclude the possibility that the migratory fish came from these tributaries, as faster growing fish appear to migrate out at an earlier age than slower growing ones. Growth is different for the two samples from Rancheria Creek. As they were taken the same year, this may indicate that the cutthroat trout is very stationary. Similar observations have been made by other researchers (Lowry, 1965; Miller, 1959; Wyatt, 1959).

In the estuary and main stem, first-time migrants may form annuli from early April to May. Trout which have been more than one season in the estuary or main stem form annuli later. Spawned out trout may not start to register growth on their scales until two months later.

Growth in the estuary is linear for first-time migrants until October (Figures 8, 9 and 10). The limited data from the main stem indicates that growth conditions there are similar to those in the estuary (Figure 11). Tapering-off of growth may be related to declining water temperatures and/or onset of maturity. Growth started about one month later in 1974 (Figure 8) than in 1976 (Figure 10), but growth rate was approximately the same. This agrees well with the results for the Sr:Ca ratio observed for these two years (Figure 6), where about one month separates the two lines of similar slope. Length-frequency distributions by month verify the accuracy of back-calculation of plus growth (Figures 12, 13 and 14), the mode of the distributions moving about 2 - 3 cm each month.

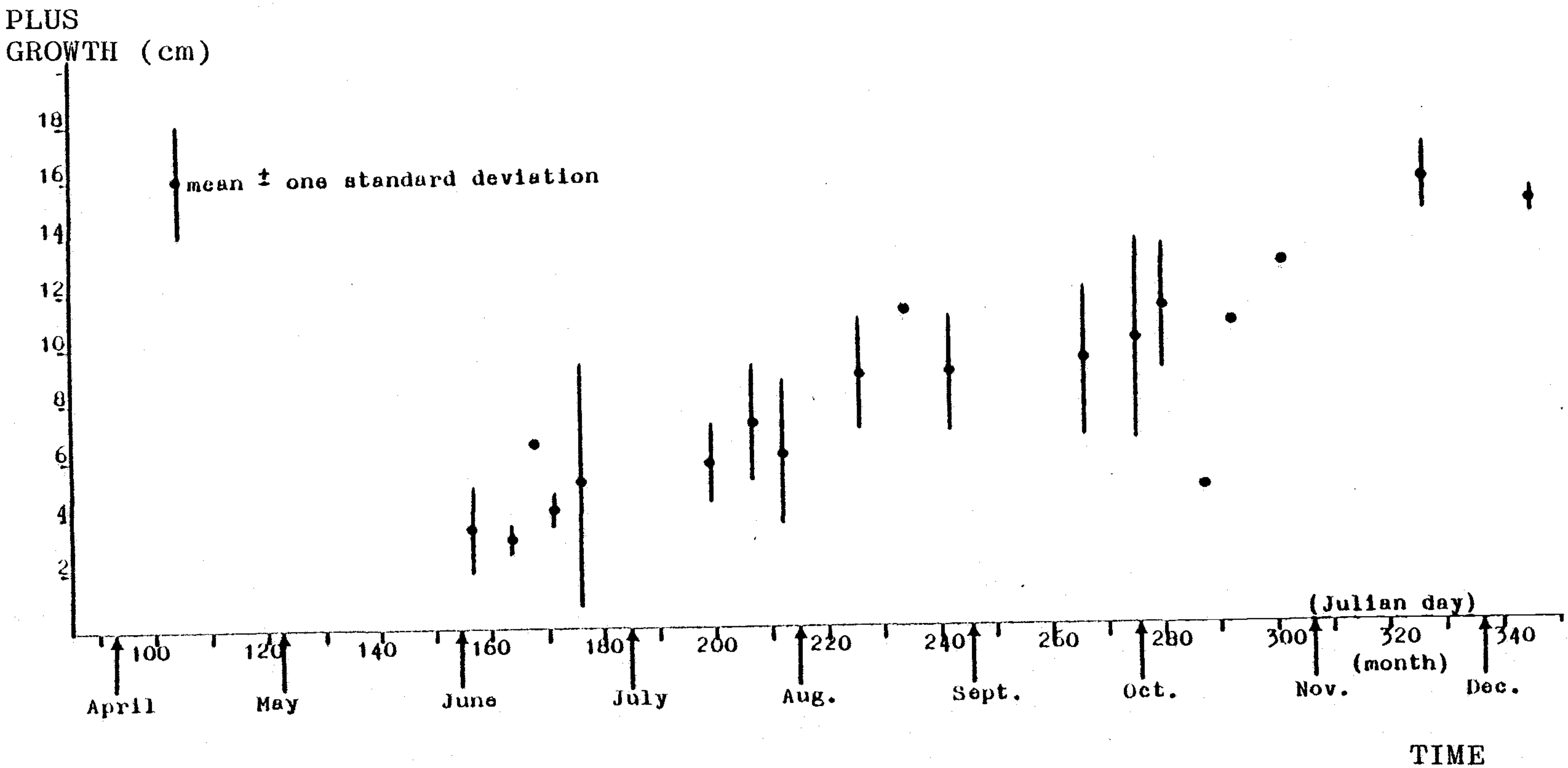


Figure 8. Plus growth, back-calculated from scales of cutthroat trout in their first season in the Rogue River estuary, 1974.

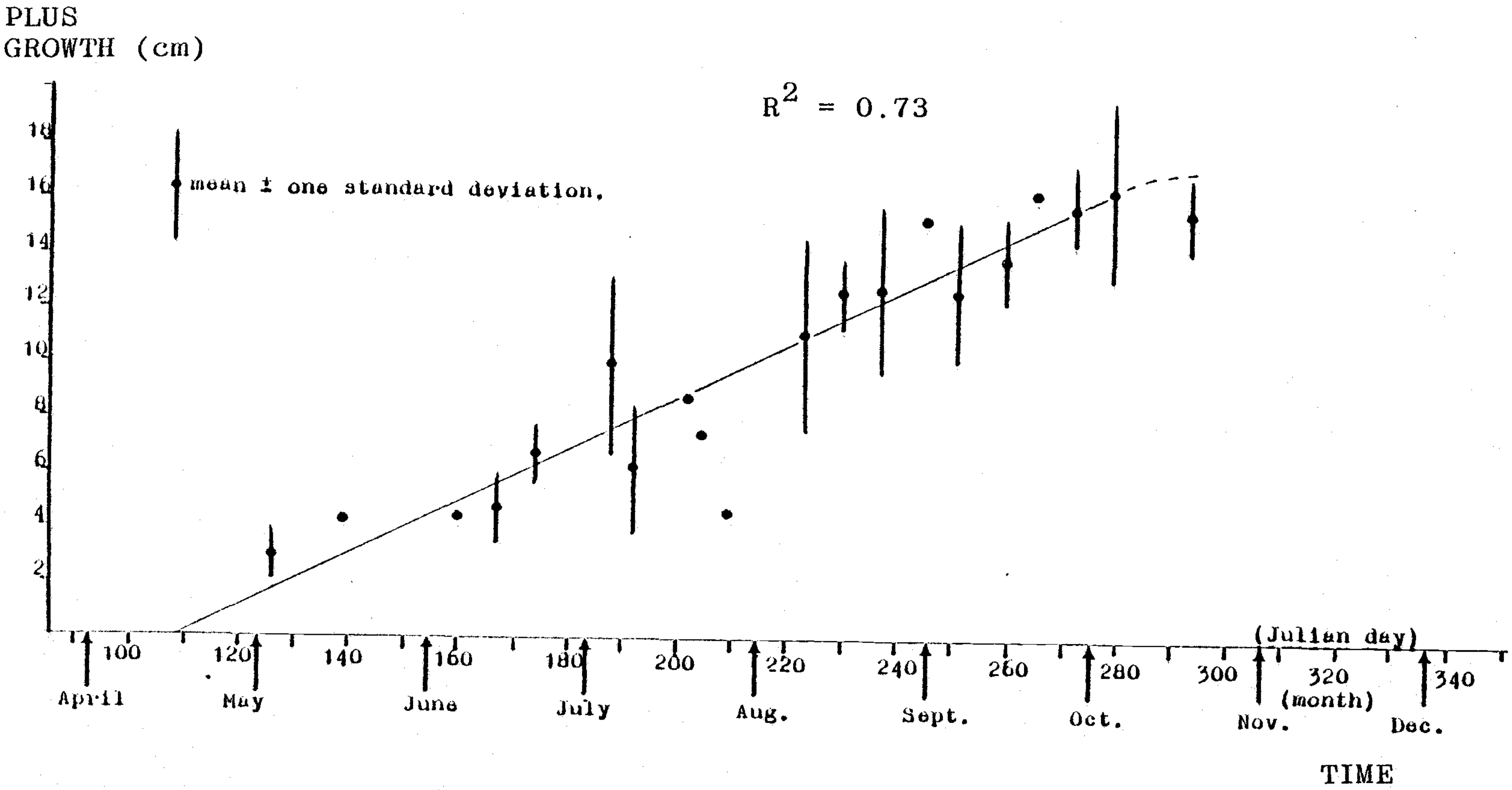


Figure 9. Plus growth, back-calculated from scales of cutthroat trout in their first season in the Rogue River estuary, 1975.

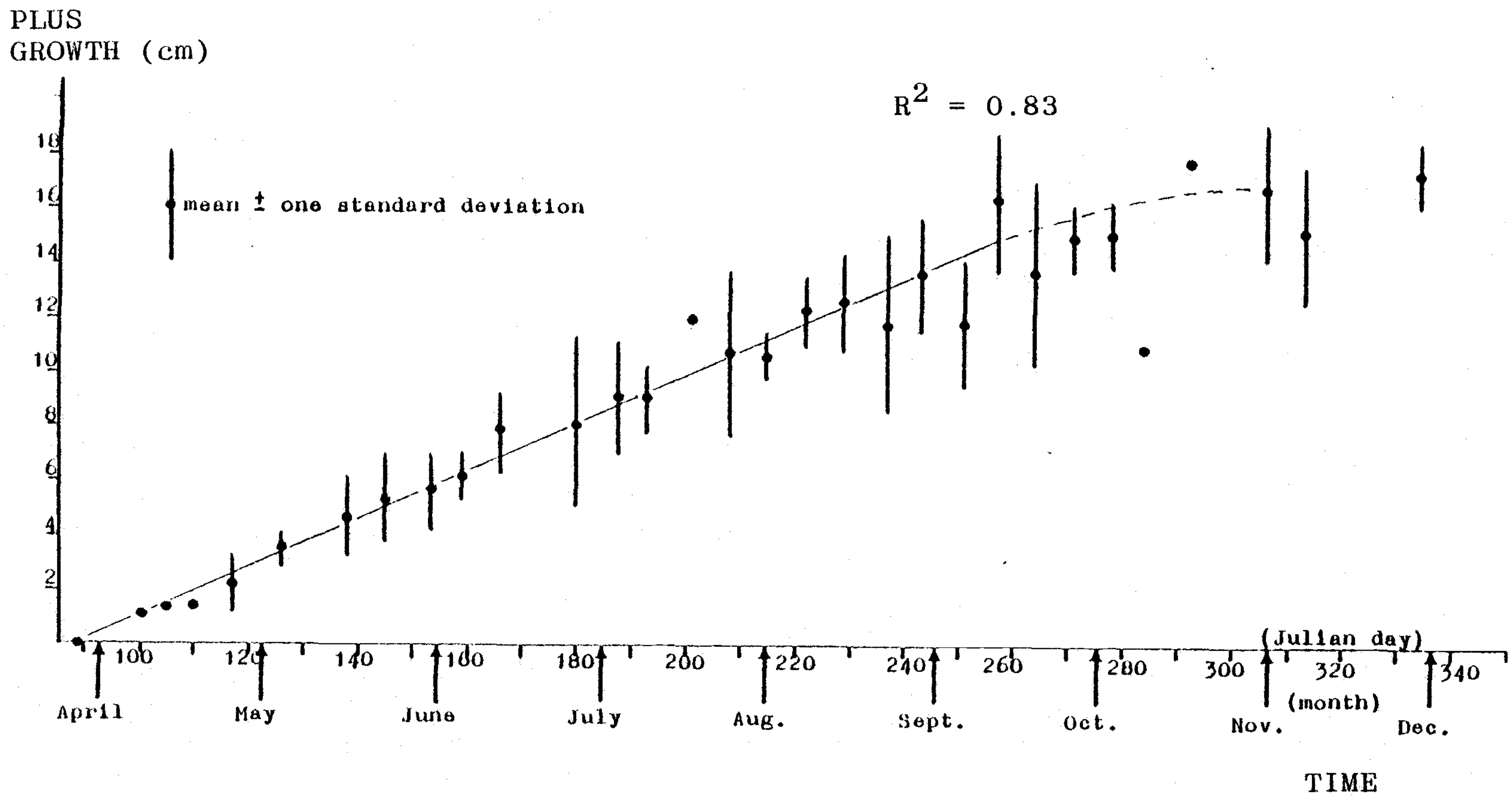


Figure 10. Plus growth, back-calculated from scales of cutthroat trout in their first season in the Rogue River estuary, 1976.

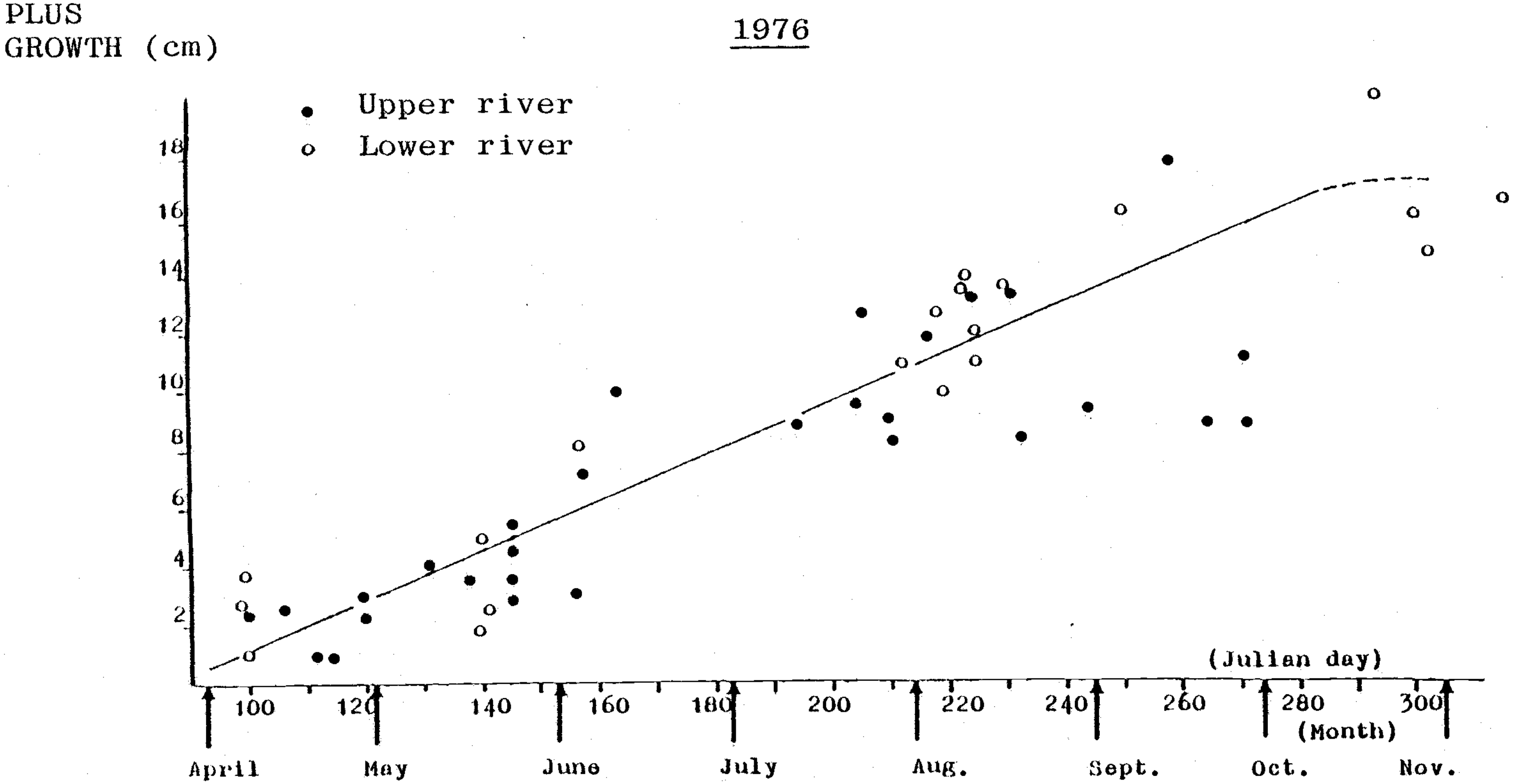


Figure 11. Plus growth, back-calculated from scales of cutthroat trout in their first season in the Rogue River main stem, compared with that in the estuary in 1976.

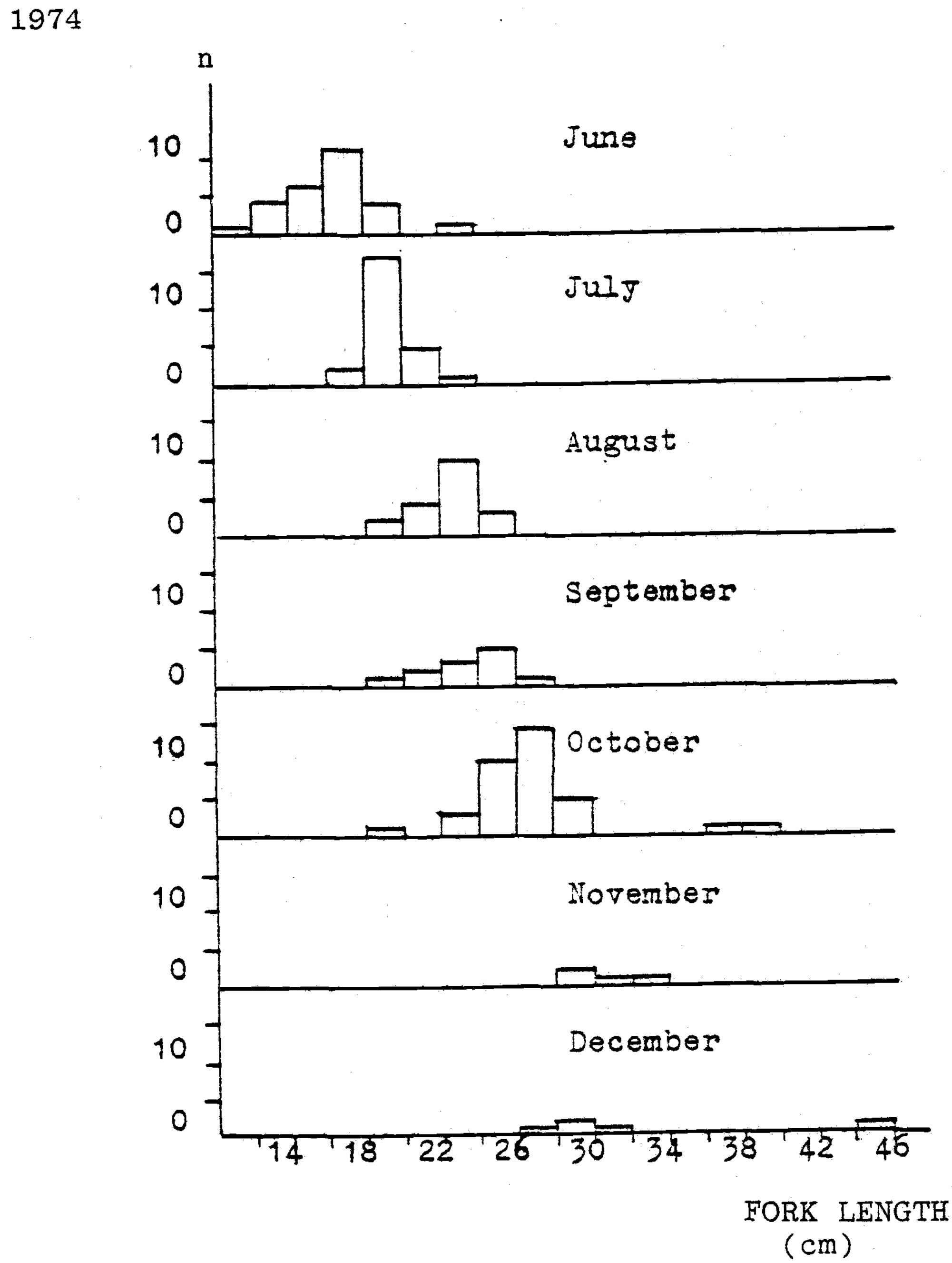


Figure 12. Length-frequency distribution of cutthroat caught in the estuary by month in 1974 (based on original seining data).

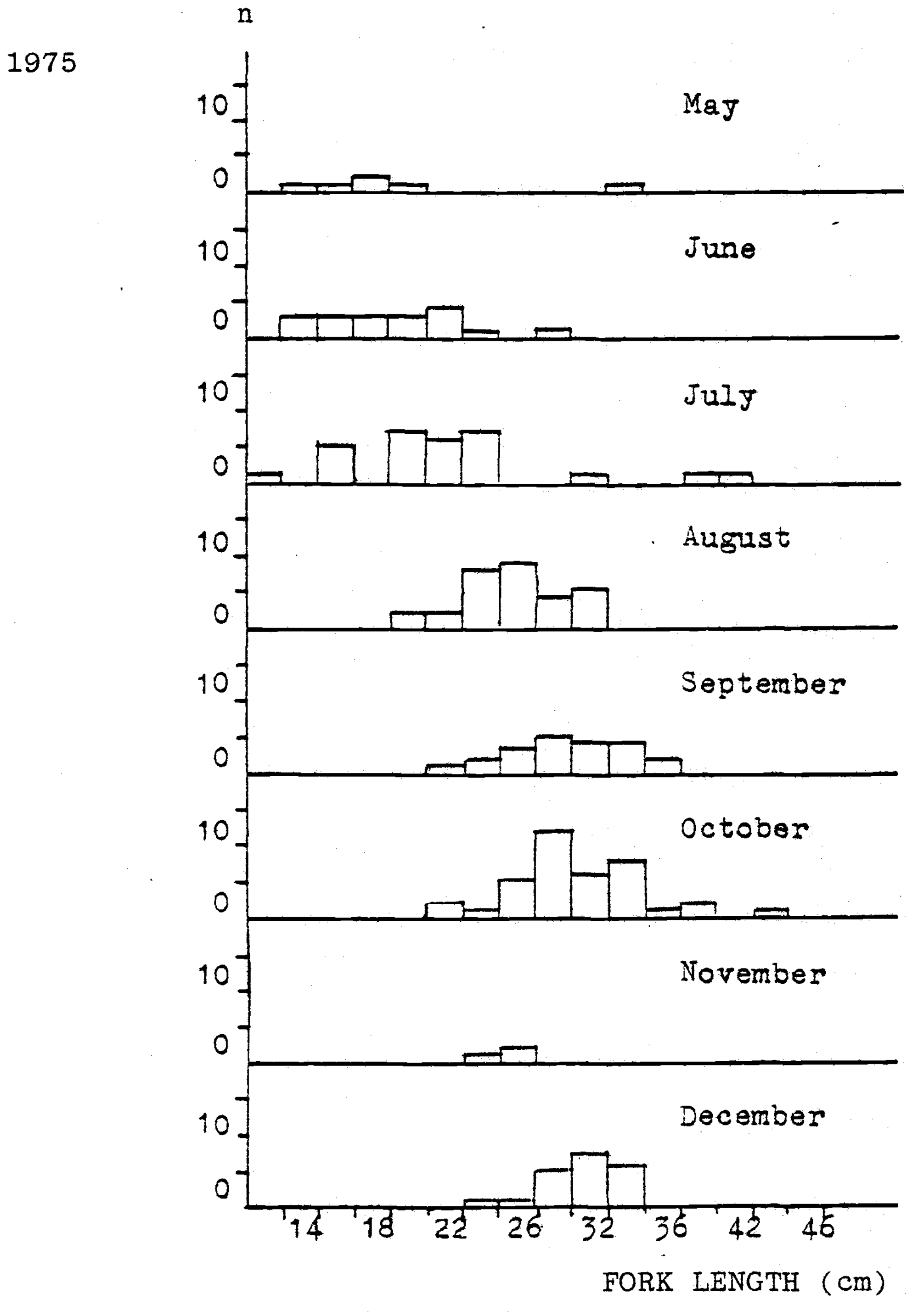


Figure 13. Length-frequency distribution of cutthroat caught in the estuary by month in 1975 (based on original seining data).

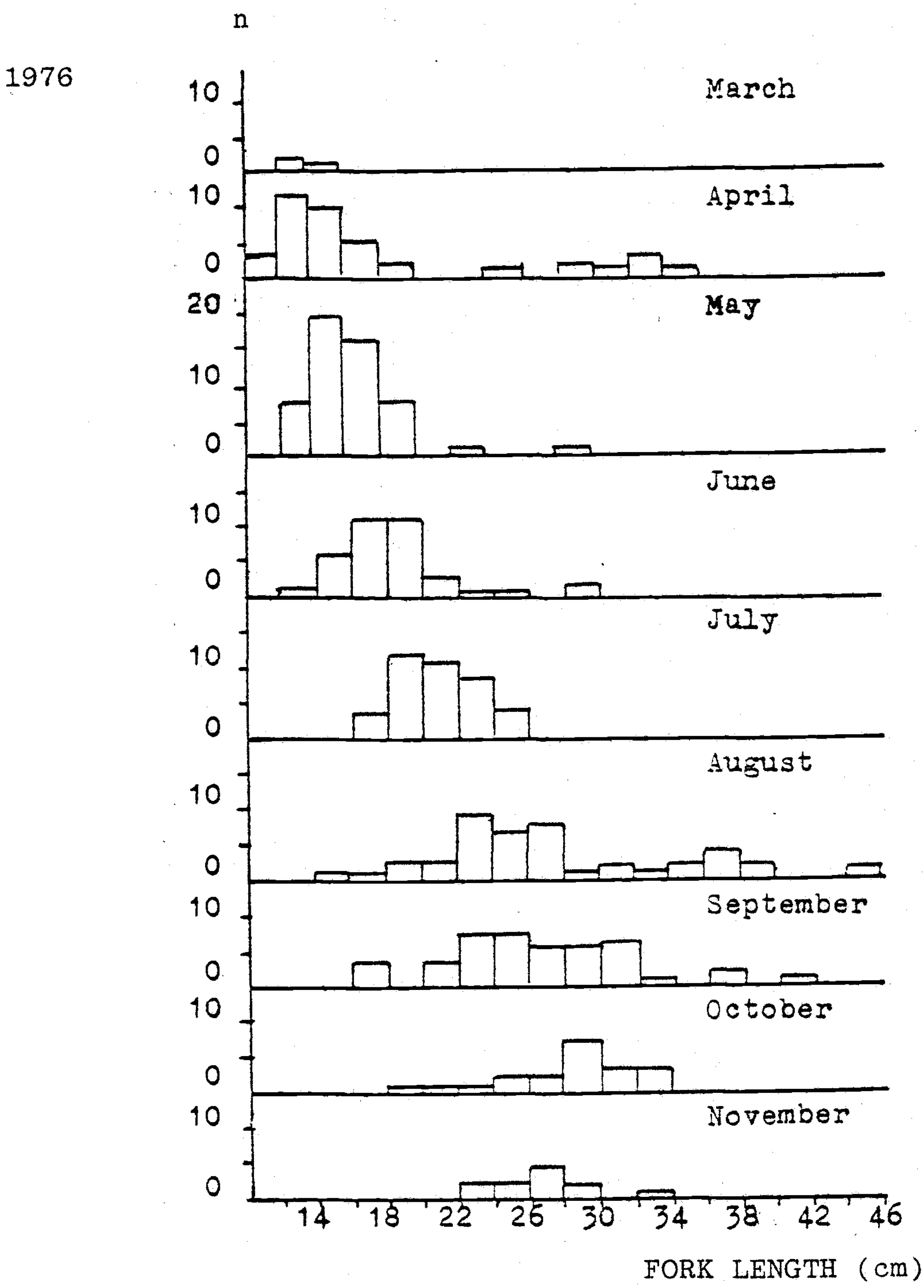


Figure 14. Length-frequency distribution of cutthroat caught in the estuary by month in 1976 (based on original seining data).

D. Summary

Of the scale samples from the estuary and main stem, 18% had to be rejected because of extensive regeneration or crowding of annuli at the margin of the scale. First-time migrants appear to grow equally well in the estuary and main stem of the river and commonly grow 14 - 18 cm in one season. Length increment in the first season in the main stem or estuary is related to age (size) at outmigration. Younger (smaller) trout grow more rapidly than older (larger) ones. Growth begins in early April to May, and is linear into October, when declining temperatures and/or onset of maturity slows it down. Trout in the tributaries grow slower than migratory fish in their early life. Observed differences in growth from two different samples from Rancheria Creek indicates that the tributary trout are very stationary.

Migration Patterns

A. Age and Length of First-time Migrants

It is difficult to give lengths of fish at time of outmigration. In the estuary, the data from 1976 are the most complete. Fish 12 - 16 cm are most common in April. Most of these have some spring growth upon capture, but where that growth took place cannot be determined. Giger (1972) found that a 5 cm cutthroat trout could adapt completely to full-strength seawater. Even though this may be true, larger trout apparently migrate to the estuary earlier in the season than do smaller ones. Average length at first annulus formation for age I trout dropped from 9.5 cm in the early part of the season in 1976 to 8.7 cm later. Similarly the average length at second annulus formation for age II trout dropped from 12.2 cm (April-May) to 11.8 cm (June-early July). A similar tendency is marked between years (Appendix I). Faster growing fish migrate a year or two earlier than slower growing ones. Giger (1972) and Sumner (1962) reported the same phenomenon for other rivers in Oregon. Age composition of first-time migrants is given in Table 4.

TABLE 4. AGE COMPOSITION OF FIRST-TIME MIGRANTS OF CUTTHROAT TROUT IN THE ROGUE RIVER BY LOCATION.

Location	Year	Age I (%)	Age II (%)	Age III (%)	No. of trout in sample
Estuary	1974	15.0	71.7	13.3	60
-------	1975	9.9	85.9	4.2	71
-------	1976	23.4	74.2	2.4	205
-------	1977	46.1	53.9	-	13
-------	74-77	20.0	75.4	4.6	349
Lower river	74-77	34.6	59.6	5.8	52
Upper river	74-77	28.6	60.7	10.7	56

B. Timings of Migrations

From the literature it seems that cutthroat trout in the ocean rear close to the shore and may occasionally enter the estuary throughout the summer. A distinct seward migration is normally observed. In the Rogue no such outmigration from the estuary is present. Trout appear to migrate to the estuary in April-May, in accordance with latitude trends observed in the literature. The population then appears to be fairly stationary as the number caught each month throughout the growing season is similar (Figures 12-14). Furthermore J. T. Martin, (personal communication, January 1978, Oregon Department of Fish and Wildlife, Corvallis) noted an increasing percentage of recaptured cutthroat in estuary seining as the season progressed.

The Rogue has a large run of 'half-pounders', which are steelhead which return to the river after one season in the ocean (Everest, 1973). These may occupy the inshore regions where cutthroat normally rear. Possibly the estuary rearing of cutthroat has evolved to avoid competition with steelhead in the ocean (Martin, personal communication).

The decline in numbers caught in the estuary in November could be due to upstream migration and/or heavy fishing mortality. Based on the latitude trends observed in the literature, upstream migration would be expected in October-November.

C. Summary

Migration to the estuary appear to be in April-May and upstream migration into freshwater in November.. This is what could be expected from latitude trends in the literature. First-time migrants are of age I-III, age group II dominating. Faster growing fish migrate earlier to the estuary within as well as between seasons than slower growing ones. Anadromous trout appear to rear in the estuary throughout the summer, as there is no indication of a massive seaward migration.

Age at Maturity

A. Estuary Trout

Age at maturity could be interpreted from scales on anadromous fish, but only by inspection of gonads for freshwater fish. This may be due to physiological stress associated with adaptation to different osmoregulation. Some fish do not spawn every year after first spawning. Of 27 trout in their second season in the estuary, only 14 appeared to have spawned the previous spring. One trout (34.3 cm) caught in the estuary in August, 1977, was inspected for maturity. It was an immature male, but scale reading showed that it was in its second season in the estuary and had spawned the previous spring. These results contrast with those of Sumner (1962). Three (2.5%) of 122 specimens examined in Sand Creek did not show a spawning check on the scales at the first of two or more sea annuli. However, after maturity was reached, spawning occurred every year. Giger's (1972) results from the Siuslaw, Alsea and Nestucca rivers indicate that all searun trout spawn after their first season in the ocean and every year thereafter. Jones (1977) studying anadromous cutthroat in Petersburg Creek, southeastern Alaska, found by inspecting gonadal development that only 50% of trout returning upstream in the fall were maturing.

Spawning time appears to be in February-March. Of 12 trout (26.7-30.4 cm) caught at river km 8.4 in mid-February in 1976, none showed spawning checks at scale margins, whereas a 35 cm trout caught in mid-March in 1977 had already spawned. From a rough correlation of spawning season with latitude, as reported in various studies, spawning would be expected to take place in January-March.

Some trout, especially males, may spawn prior to first full season in the estuary. In Edison Creek age I fish were immature and the sex ratios equal, but of age II fish, three out of four males were maturing and the only female in this age group was immature. The Sr:Ca ratio in the scales of these fish indicates that they had spent some time in the estuary and a short period of rapid growth observed in the scales lends support to this observation. A similar suggestion was advanced by Gibor (1972) for the Alsea river.

A preponderance of females in anadromous trouts has often been noted and the reverse condition for their non-migratory counterparts. For a good review of the literature on this subject, see Campbell (1977). He observed resident brown trout males spawning with anadromous females. Sumner (1972) found the male:female ratio of upstream migrants in Sand Creek to be 1:1.8. There may be a substantial interbreeding between anadromous and resident populations where they co-exist.

B. Upper Drainage Trout

Gonadal development was determined by inspection on some trout from the upper drainage tributaries. Results are given in Table 5.

For only one creek, Twincheria Creek, were individuals found maturing at age I, whereas in Rancheria Creek the youngest maturing trout were of age III for both sexes. Normally, however, over 50% of age II individuals had secondary gonadal development. These fish may not spawn every year after maturity is reached, as indicated by an age VIII male from Quartz Creek (age determined from otoliths), which had immature gonads. Sex ratios are

TABLE 5. SUMMARY OF STAGE OF GONADAL DEVELOPMENT IN CUTTHROAT TROUT FROM UPPER ROGUE RIVER DRAINAGE TRIBUTARIES.

	Immature		Maturing	
Age	Males	Females	Males	Females
I	12	24	2	1
II	5	7	7	6
III	3	1	8	2
IV+	1	-	3	3

heavily in favor of females at age I, but by age III the situation is reversed. This is a small sample size, but it indicates that males are longer lived than females or that there may exist a similar relationship between resident and potamodromous trout, as indicated above for anadromous and resident trout. However, Dimick and Merryfield (1945) report spawning time to be different for the potamodromous and resident life history types in the Willamette River drainage.

C. Summary

Based on spawning marks on scales, less than 50% of trout in their second season in the estuary had spawned the previous spring. Spawning time appears to be in February to March. Some trout may spend a short period in the estuary and spawn the following spring. Trout spawning after one season in the estuary may not spawn again the following year.

In the upper drainage tributaries, youngest maturing trout were of age I. Males appear to be longer lived than females. Alternative-year spawners occur in both these populations.

V. CONCLUSIONS AND RECOMMENDATIONS

In the present study three major life history types have been identified. These are resident trout in small tributaries, potamodromous trout that occur throughout the main stem of the river and anadromous trout that are confined to the lower drainage. The relationship between these populations could not be assessed.

An extensive tagging program to gain understanding of relationships is infeasible as cutthroat are relatively scarce in the Rogue. Strontium analysis of scales could provide information on migration patterns of anadromous trout, but more consistent sampling must be done with regard to time and location if an accurate assessment is to be made. The method of Sr analysis described by Bagenal *et al*. (1973) is recommended. It is several times more expensive than the method used in the present study, but requires much less scale material and is more sensitive because a graphite furnace is used in combination with atomic absorption spectrophotometer.

The status of a fish population can be inferred from its age structure. Of the trout caught in the estuary, 92% were first-time migrants. These fish are vulnerable to angling throughout the growing season as they rear in the estuary. The relative small fraction of the population in their second or third season in the estuary indicates that stricter angling regulations than are now enforced are needed to protect the population. Furthermore, the relatively simple age structure of first-time migrants (75% of age II) makes the population vulnerable to catastrophic events. This is especially true as spawning is confined to small tributaries, which are more affected by changes in the environment than larger streams. The vulnerability of anadromous cutthroat trout in the Rogue is reflected in the large fluctuations in numbers caught in the estuary. In 1976 almost 300 trout were captured in the regular seining program, whereas in 1977 fewer than 20 were caught with only slightly less effort.

Hatchery production is often used to augment (or replace) natural production of salmonids. The cutthroat trout in the Rogue is of little economic importance however, and a hatchery program is not recommended. Selection pressures in a hatchery pond are widely different from those in nature. A superposition of hatchery fish upon the existing wild stock may in the long run reduce successful natural recruitment. Efforts should rather be directed to protection of small tributaries where cutthroat spawn and rear in early life. This may be the most crucial stage in their life history. To do this a survey must be undertaken to identify such streams.

The present study is an assessment of the cutthroat trout <u>prior</u> to the operation of Lost Creek dam. Predictions as to what effect the dam may have are speculative. The operation of the dam might not affect early life history of the cutthroat trout as this occurs in small tributaries. In the mainstem both growth and survival could be affected by changes in flow and temperature. The data available for this study are inadequate to estimate survival, but back-calculation of growth has been done from scales. It has its shortcomings. Most of the material is from the estuary and the lack of consistency as to location on body from where scales have been taken decreases the validity of back-calculated lengths. An obvious remedy is a more consistent sampling program which may be difficult to achieve in practice.

BIBLIOGRAPHY

Armstrong, R. H. 1971. Age, food and migration of searun cutthroat trout, Salmo clarki, at Eva Lake, Southeast Alaska. Trans. Amer. Fish. Soc. 100:302-306.

Bagenal, T. B., the late F. J. H. Mackereth and J. Heron. 1973. The distinction between brown trout and sea trout by the strontium content of their scales. J. Fish. Biol. 5:555-557.

Brown, C. J. D., and J. E. Bailey. 1952. Time and pattern of scale formation in Yellowstone cutthroat trout, Salmo clarkii lewisi. Amer. Micros. Soc. Trans. 71:120-124.

Campbell, J. S. 1977. Spawning characteristics of brown trout and sea trout Salmo trutta L. in Kirk Burn, River Tweed, Scotland. J. Fish. Biol. 11:217-229.

Chugunova, N. I. 1963. Age and growth studies in fish. (Transl.) National Science Foundation: Washington. 132 p.

Clutter, R. J. and L. E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Inter. Pac. Salmon Fish. Comm., Bull. IX. 159 p.

Cooper, E. L. 1970. Growth of cutthroat trout (Salmo clarki) in Chef Creek, Vancouver Island, British Columbia. J. Fish. Res. Board Can. 27(11):2063-2070.

Cramer, F. K. 1940. Notes on the natural spawning of cutthroat trout (Salmo clarkii clarkii) in Oregon. Proc. 6th Pacif. Sc. Cong. 3:335-339.

De Witt, J. W. Jr. 1954. A survey of the coast cutthroat trout, Salmo clarki clarki Richardson in California. Calif. Fish and Game 40:329-335.

Dimick, R. E. and F. Merryfield. 1945. Fishes of the Willamette River system in relation to pollution. Oregon State College, Eng. Expt. Sta. Bull. 20. 58 p.

Everest, F. H. 1973. Ecology and management of summer steelhead in the Rogue River. Oregon State Game Comm. Fish. Res. Rep. No. 7. 48 p.

Giger, R. D. 1972. Ecology and management of coastal cutthroat trout in Oregon. Oregon State Game Comm. Fish. Res. Rep. No. 6. 61 p.

Haig-Brown, R. L. 1939. The Western angler. Vol. I. The Derrydale Press: N. Y. 200 p.

Hartman, G. F. and C. A. Gill. 1968. Distributions of juvenile steelhead and cutthroat trout (_Salmo gairdneri_ and _S. clarki clarki_) within streams in southwestern British Columbia. J. Fish. Res. Board Can. 25:33-48.

Hile, R. 1970. Body-scale relation and calculation of growth in fishes. Trans. Amer. Fish. Soc. 99(3): 468-474.

Hill, M. N. (Ed.) 1963. The sea. Vol. 2. John Wiley: N. Y. 554 p.

Hoar, W. S. 1976. Smolt transformation: Evolution, behavior, and physiology. J. Fish. Res. Board Can. 33:1233-1252.

Hutchinson, G. E. 1957. A treatise on limnology. Vol. 1. John Wiley: N. Y. 1015 p.

Jones, D. E. 1977. Life history of sea-run cutthroat trout in Southeast Alaska. Alaska Dept. Fish and Game, Anadromous Fish Studies. Compl. Rep. Proj. AFS-42, 18:78-105.

Jonsson, B. 1976. Comparison of scales and otoliths for age determination in brown trout, _Salmo trutta_ L. Norw. J. Zool. 24:295-301.

Laakso, M. 1955. Variability in scales of cutthroat trout in mountain lakes. Utah Academy Proc. 32:81-87.

Lowry, G. R. 1965. Movement of cutthroat trout, _Salmo clarkii clarkii_ (Richardson) in three Oregon coastal streams. Trans. Amer. Fish. Soc. 94:334-338.

Mason, J. C. 1974. Movements of fish populations in Lymn Creek, Vancouver Island: A summary from weir operations during 1971 and 1972, including comments on species life histories. Fish. Mar. Serv. Res. Dev. Tech. Rep. 483: 35 p.

Miller, R. B. 1957. Permanence and size of home territory in stream-dwelling cutthroat trout. J. Fish. Res. Board Can. 14:687-691.

Narver, D. W. 1975. Notes on the ecology of cutthroat trout (Salmo clarki) in Great Central Lake, Vancouver Island, British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rep. 567: 20 p.

Newcomb, H. R. 1943. A second preliminary report of investigations made on Rogue River and its tributaries. Report prepared for the Oregon State Game Commission. Manuscript. 76 p.

Royal, L. A. 1972. An examination of the anadromous trout program of the Washington State Game Dept. Rept. Dept. Game, Washington, Oct. 1972. 176 p.

Scott, W. B., and E. J. Crossman. 1973, Freshwater fishes of Canada, Fish. Res. Board Can. Bull. 184. 966 p.

Shepherd, B. G. 1973. Activity localization in coastal cutthroat trout (Salmo clarki clarki) in a small bog lake. J. Fish. Res. Board Can. 31:1246-1249.

Simkiss, K. 1974. Calcium metabolism of fish in relation to ageing, p. 1-12. In Bagenal, T. B. (ed.). Ageing of fish. Unwin Bros. Ltd.: Old Woking.

Sumner, F. H. 1962. Migration and growth of the coastal cutthroat trout in Tillamook County, Oregon. Trans. Amer. Fish. Soc. 91:77-83.

Sumner, F. H. 1972. A contribution to the life history of the cutthroat trout in Oregon (with emphasis on the coastal subspecies, Salmo clarki clarki Richardson). Oregon State Game Commission. Unpublished manuscript. 113 p.

Tesch, F. W. 1971. Age and growth. p. 98-130. In Ricker, W. E. (ed.). Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications: Oxford.

Wagner, H. H. 1974. Photoperiod and temperature regulation of smolting in steelhead trout (Salmo gairdneri). Can. J. Zool. 52(2):219-234.

Weatherly, A. H. 1972. Growth and ecology of fish populations. Academic Press: N. Y. 293 p.

Williams, T. and B. C. Bedford. 1974. The use of otoliths for age determination. p. 114-123. In Bagenal, T. B. (ed.). Ageing of fish. Unwin Bros. Ltd.: Old Woking.

Wyatt, B. 1959. Observations on the movements and reproduction of the Cascade form of cutthroat trout. Master's Thesis. Oregon State University, Corvallis. 60 p.

APPENDIX

APPENDIX I

Summary of Back-calculation of Lengths at Annulus Formation

The material from the main stem and estuary has been arranged according to how many years have elapsed since first outmigration. Thus the first section in each year is on first-time migrants, the second one on trout in their second season after first outmigration and so on.

l_1, l_2,...l_6 are the back-calculated length at first, second,..., sixth annulus formation. Standard deviations are given in parentheses, where appropriate.

ESTUARY

Season in estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
				1974, N = 63				
1st	I	9.7(1.67)	-	-	-	-	-	9
	II	8.0(1.17)	13.8(1.70)	-	-	-	-	43
	III	6.8(0.78)	11.1(1.33)	15.9(1.88)	-	-	-	8
2nd	III	7.5	13.0	27.3	-	-	-	1
	IV	6.4	12.5	19.1	32.8	-	-	1
4th	IV	11.1	20.2	34.1	43.1	-	-	1
				1975, N = 75				
1st	I	8.4(1.49)	-	-	-	-	-	7
	II	7.4(1.05)	12.8(1.75)	-	-	-	-	61
	III	5.3(0.56)	9.8(0.49)	14.2(0.23)	-	-	-	3
2nd	II	6.8(0.28)	20.3(0.99)	-	-	-	-	2
	III	7.7(1.27)	15.4(1.27)	29.2(2.47)	-	-	-	2
				1976, N = 227				
1st	I	9.3(1.82)	-	-	-	-	-	48
	II	7.2(1.25)	12.1(1.70)	-	-	-	-	152
	III	5.6(0.98)	10.5(0.70)	15.3(1.22)	-	-	-	5
2nd	II	9.7(1.27)	30.2(2.22)	-	-	-	-	6
	III	7.3(1.22)	13.1(1.52)	28.1(2.66)	-	-	-	13
3rd	IV	8.4(1.20)	15.5(1.85)	25.9(4.25)	32.7(4.88)	-	-	3

ESTUARY (continued)

1977, N = 15

Season in estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	I	9.0(1.87)	-	-	-	-	-	6
	II	8.6(1.56)	13.4(1.80)	-	-	-	-	7
2nd	III	6.9(1.7)	12.0(2.33)	29.3(5.1)	-	-	-	2

LOWER RIVER

Season in main stem or estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
		1974, N =12						
1st	I	9.1(0.86)	-	-	-	-	-	4
	II	9.1(0.55)	14.0(2.07)	-	-	-	-	6
	III	5.2	9.4	14.5	-	-	-	1
	V	7.5	15.1	25.7	35.3	40.6	-	1
		1975, N = 32						
1st	I	9.4(0.91)	-	-	-	-	-	7
	II	7.7(1.06)	13.7(1.75)	-	-	-	-	9
2nd	II	7.8(1.20)	19.0(1.84)	-	-	-	-	2
	III	7.9(0.86)	13.4(1.34)	26.9(3.50)	-	-	-	7
	IV	6.2(0.14)	11.1(0.71)	18.2(0.71)	29.5(1.06)	-	-	2
3rd	IV	8.8(0.56)	13.1(0.35)	24.2(0.35)	28.0(0.00)	-	-	2
	V	7.5(1.63)	12.3(2.69)	18.0(0.42)	25.5(3.75)	32.2(1.27)	-	2
4th	V	9.0	15.8	34.1	42.0	48.0	-	1
		1976, N = 41						
1st	I	9.2(1.00)	-	-	-	-	-	6
	II	7.0(1.00)	12.3(2.06)	-	-	-	-	15
	III	7.0(0.92)	13.2(2.54)	19.5(3.18)	-	-	-	2

LOWER RIVER (continued)

1976, N = 41 (continued)

Season in main stem or estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
2nd	II	8.8(2.19)	25.0(8.13)	-	-	-	-	2
	III	7.0(1.38)	13.4(3.34)	28.9(0.81)	-	-	-	9
	IV	5.4(0.52)	11.4(1.74)	17.8(1.97)	27.8(0.40)	-	-	3
3rd	III	8.2(0.90)	21.0(2.60)	29.4(1.07)	-	-	-	4
				1977, N = 20				
1st	I	9.1	-	-	-	-	-	1
	II	7.5	13.2	-	-	-	-	1
2nd	III	6.8(0.77)	11.8(1.74)	27.7(5.62)	-	-	-	6
	IV	8.6	13.5	17.1	35.0	-	-	1
3rd	III	8.2(1.48)	21.3(0.64)	29.1(1.98)	-	-	-	2
	IV	6.6(0.64)	12.5(1.13)	28.7(2.62)	34.1(1.55)	-	-	2
4th	V	6.3(0.94)	11.3(1.45)	28.0(5.03)	36.3(4.83)	40.8(2.46)	-	3
5th	V	6.5	18.5	29.7	36.2	39.5	-	1
	VI	5.5(0.49)	9.8(0.56)	21.0(2.05)	27.8(0.71)	33.8(3.61)	38.2(2.47)	2

UPPER RIVER

1974, N = 5

Season in main stem	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	II	8.0(1.48)	13.4(1.48)	-	-	-	-	2
2nd	II	7.2	19.5	-	-	-	-	1
	III	6.8	12.8	33.0	-	-	-	1
3rd	III	6.5	20.4	28.3	-	-	-	1

1975, N = 17

Season in main stem	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	I	6.4	-	-	-	-	-	1
	II	6.9(0.61)	12.7(1.45)	-	-	-	-	6
	III	5.9(0.35)	11.2(2.54)	17.2(0.92)	-	-	-	2
2nd	III	6.4	10.4	28.9	-	-	-	1
	IV	6.4(0.42)	10.9(1.84)	15.3(3.46)	27.2(1.48)	-	-	2
3rd	IV	7.7	14.2	27.9	33.1	-	-	1
	V	7.1	11.6	16.6	33.3	39.0	-	1
	VI	5.1	8.8	13.3	18.0	27.7	35.8	1
4th	VI	6.7(0.14)	11.5(0.78)	17.7(2.90)	25.2(1.20)	37.8(0.07)	41.8(1.20)	2

UPPER RIVER (continued)

Season in main stem	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
				1976, N = 37				
1st	I	6.8(1.10)	-	-	-	-	-	12
	II	7.2(1.51)	12.9(2.18)	-	-	-	-	14
	III	5.3(0.60)	9.8(1.62)	15.2(1.91)	-	-	-	4
2nd	III	6.5(0.89)	12.7(1.03)	26.9(2.74)	-	-	-	6
5th	VI	8.1	14.3	22.4	29.5	38.8	42.5	1
				1977, N = 19				
1st	I	9.1(1.85)	-	-	-	-	-	3
	II	6.6(1.62)	11.7(1.34)	-	-	-	-	12
2nd	III	8.0(0.95)	14.1(0.81)	31.8(3.39)	-	-	-	3
	IV	8.0	13.3	19.7	36.0	-	-	1

SUMMARY

ESTUARY 1974-1977

Season in estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	I	9.1(1.61)	-	-	-	-	-	70
	II	7.4(1.59)	12.6(1.82)	-	-	-	-	263
	III	6.2(1.03)	10.7(1.12)	15.4(1.57)	-	-	-	16
2nd	II	9.0(1.71)	27.7(4.95)	-	-	-	-	8
	III	7.3(1.16)	13.2(1.68)	28.3(2.68)	-	-	-	18
	IV	6.4	12.5	19.1	32.8	-	-	1
3rd	IV	9.1(1.65)	16.7(2.79)	27.9(5.37)	35.3(6.57)	-	-	4

LOWER RIVER 1974-1977

Season in main stem or estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	I	9.2(0.85)	-	-	-	-	-	18
	II	7.6(1.21)	13.1(2.02)	-	-	-	-	31
	III	6.4(1.25)	11.9(2.83)	17.4(2.90)	-	-	-	3
2nd	II	8.3(1.55)	22.0(5.95)	-	-	-	-	4
	III	7.2(1.14)	13.0(2.44)	27.9(3.50)	-	-	-	22
	IV	6.2(1.38)	11.7(1.29)	17.8(1.41)	29.6(2.78)	-	-	6
3rd	III	8.2(1.13)	21.1(2.04)	29.3(1.70)	-	-	-	6
	IV	7.7(1.13)	12.8(0.78)	26.5(3.01)	31.0(3.63	-	-	4
	V	7.5	12.3	18.0	25.5	32.2	-	2

SUMMARY (continued)

LOWER RIVER 1974-1977 (cont.)

Season in main stem or estuary	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
4th	V	7.1(1.35)	12.9(2.52)	28.8(4.75)	37.2(4.36)	42.2(3.68)	-	5
5th	V	6.6	18.5	29.7	36.2	39.5	-	1

UPPER RIVER 1974-1977

Season in main stem	Age	l_1	l_2	l_3	l_4	l_5	l_6	n
1st	I	7.2(1.49)	-	-	-	-	-	16
	II	7.0(1.43)	12.5(1.78)	-	-	-	-	34
	III	5.5(0.58)	10.4(2.02)	15.9(1.86)	-	-	-	6
2nd	II	7.2	19.5	-	-	-	-	1
	III	7.0(1.03)	12.9(1.33)	29.0(3.64)	-	-	-	11
	IV	6.9(0.97)	11.7(1.90)	16.8(3.51)	30.2(5.16)	-	-	3
3rd	III	6.5	20.4	28.3	-	-	-	1
	IV	7.7	14.2	27.9	33.1	-	-	1
	V	7.1	11.6	16.6	33.3	39.0	-	1
	VI	5.1	8.8	13.3	18.0	27.7	35.8	1
4th	VI	6.7(0.14)	11.5(0.78)	17.7(2.90)	25.2(1.20)	37.8(0.07)	41.8(1.20)	2
5th	VI	8.1	14.3	22.4	29.5	38.8	42.5	1

TRIBUTARIES

Location	Age	l_1	l_2	l_3	l_4	Plus growth	n
North Fork	0	-	-	-	-	5.4(0.07)	2
Big Butte	I	7.8	-	-	-	3.7	1
	II	7.2(0.75)	11.6(0.79)	-	-	4.0(1.39)	4
	III	5.4	9.3	13.8	-	4.0	1
	IV	5.8	11.4	15.5	18.0	2.6	1
	V	4.0	8.1	12.4	15.7(l_5=18.9)	3.1	1
Jackass	0	-	-	-	-	4.6(0.61)	4
8.24.77	I	5.2(0.53)	-	-	-	3.1(0.53)	9
	II	6.6(0.92)	10.0(0.64)	-	-	2.3(0.28)	2
	III	5.2(0.66)	8.6(1.96)	11.5(2.03)	-	2.6(0.29)	3
Jackass	0	-	-	-	-	5.5(0.35)	2
	I	6.3(0.37)	-	-	-	4.2(0.39)	6
	III	6.6(0.07)	11.6(1.20)	14.2(0.42)	-	2.3(1.55)	2
Rancheria	I	6.1(0.96)	-	-	-	3.4(0.74)	15
7.25.77	II	5.8(0.55)	9.7(0.62)	-	-	3.0(1.03)	6
	IV	7.8	11.5	16.2	18.8	3.2	1
Rancheria	I	6.85(0.98)	-	-	-	3.4(0.70)	8
8.26.77	II	6.3(1.16)	10.5(1.84)	-	-	2.6(0.78)	5
	III	6.8(0.98)	10.5(0.99)	13.5(1.68)	-	3.4(0.35)	4
	IV	7.5(0.17)	10.9(0132)	14.8(0.85)	16.9(0.30)	1.6(1.30)	3
Twincheria	0	-	-	-	-	5.3(0.15)	3
	I	6.9(0.86)	-	-	-	3.8(0.52)	20
	II	5.6(1.32)	9.8(2.01)	-	-	3.2(0.98)	6

TRIBUTARIES (continued)

Location	Age	l_1	l_2	l_3	l_4	Plus growth	n
Titanic	0	-	-	-	-	5.7(0.25)	5
	I	5.1(0.59)	-	-	-	3.7(0.73)	20
	II	5.6(1.04)	10.1(0.67)	-	-	2.3(0.63)	8
	III	5.5(0.15)	10.2(1.81)	12.2(1.53)	-	1.9(0.47)	3
	IV	7.1	11.3	13.5	15.3	1.7	1
West Fork	II	6.1(0.77)	10.5(1.41)	-	-	2.7(0.89)	5
Evans	III	5.4(1.20)	9.3(1.06)	15.2(0.49)	-	1.2(0.14)	2
	IV	6.0(0.60)	10.4(1.51)	14.2(0.96)	18.3(0.65)	1.2(0.60)	3
Salt	I	6.4	-	-	-	4.4	1
	II	6.3(0.76)	9.3(1.16)	-	-	3.2(0.82)	14
	III	8.5	12.2	15.5	-	1.0	1
Quartz	0	-	-	-	-	5.0(0.63)	36
	I	6.4(0.90)	-	-	-	4.0(0.99)	10
	II	6.2(2.54)	10.2(4.03)	-	-	3.9(1.06)	2
	III	6.7	10.3	14.3	-	3.9	1
	IV	5.6	10.5	14.2	17.1	3.2	1
Edison	I	6.0(1.02)	-	-	-	4.6(2.12)	13
	II	7.0(1.29)	13.0(1.49)	-	-	3.2(0.84)	4
Lobster	I	8.0(0.50)	-	-	-	-	4
	II	7.8(0187)	11.9(1.27)	-	-	-	6