

FRESHWATER BIOLOGY OF THOMPSON RIVER
STEELHEAD (SALMO GAIRDNERI) AS DETERMINED
BY RADIO TELEMETRY

by

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ABSTRACT

Radio telemetry, in combination with an intensive angler survey, was used to determine biology of late summer run steelhead (Salmo gairdneri) in the Thompson River.

Twenty-eight Thompson steelhead were radio tagged in the fall of 1977 near Spences Bridge and fifteen were monitored to the completion of spawning in the spring of 1978.

The mainstem Thompson, (downstream of Kamloops Lake) Bonaparte and Deadman Rivers and Nuaitch Creek, (a tributary of the Nicola River) were identified as spawning areas by radio telemetry techniques. The Nicola River and tributaries, downstream of Nicola Lake, were also verified as spawning grounds for Thompson River steelhead.

Three radio tagged steelhead migrated into the Bonaparte River where they encountered an impassable 6.1 metre falls approximately 2 km from the confluence. There appears to be an excellent opportunity to naturally enhance salmonid runs in the Bonaparte River by providing passage of fish over these falls. Approximately 120 km of spawning and rearing habitat is available above this natural obstruction.

Biological information was collected from adult steelhead during the 1976/77 Thompson River sport fishery and by the

operation of an enumeration fence on the Deadman River in 1984. Scale analysis indicated Thompson steelhead return most frequently at ages 5 and 6.

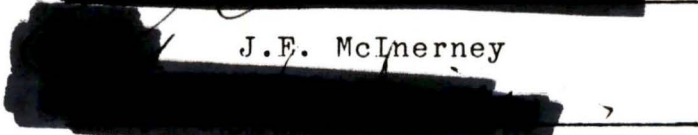
Juvenile Thompson steelhead spent less time (2 years) in freshwater than other steelhead stocks in British Columbia and Alaska and about the same duration as other stocks from Northwestern United States. Ocean phase duration is about the same as most other stocks with minor exceptions.

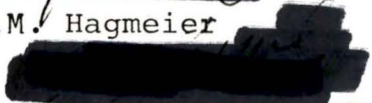
Smolts lengths were back-calculated from adult scale using the Fraser-Lee proportional method. Back-calculations indicated Thompson fish smolt at a mean size similar to other streams reported in the literature.

Adult Thompson steelhead appeared to return at greater average length, weight and fecundity than most other stocks of steelhead in North America.

EXAMINERS:


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Thanks go to Brenda Ressler and Susan Engemoen who typed the manuscript.

DEDICATION

To Family

Introduction

Steelhead trout (Salmo gairdneri) are the anadromous form of rainbow trout recognized by anglers in the Pacific Northwest for their beauty and angling qualities.

The historic geographic range of steelhead trout extended from the southerly streams of California to those of the Gulf of Alaska, and included the headwaters of larger rivers. Sutherland (1973) reports their present distribution as ranging no farther than central or northern California to Kodiak Island, Alaska. Steelhead are virtually extinct in streams south of San Louis Obispo County, California. Steelhead populations have been decimated by water development and diversion projects south of this point (Shapovalov, 1967). Sutherland (1973) states that the oceanic distribution of steelhead trout includes the entire North Pacific Ocean, north of about latitude 42° North and their abundance is greatest in the Gulf of Alaska and eastern North Pacific. The abundance of steelhead decreases to the west and is lowest in the western North Pacific and the western Aleutian Island area. Steelhead have not been identified in the coastal streams of Asia, although steelhead originating from North American waters have been reported by Japanese research vessels at 43° North latitude and 179° East longitude. Adipose clipped hatchery steelhead with coded wire tags were captured along with wild steelhead at this location. The tagged steelhead originated from hatcheries in Oregon, Washington, Idaho,

and British Columbia (Pearcy and Masuda, 1982). Electrophoretic studies of enzymes have also identified steelhead caught in gillnets across the Subarctic Pacific to 165° East longitude near the Asian coast (Pearcy and Masuda, 1982).

A closely related anadromous species, (Salmo mykiss) inhabits Asian rivers which enter the sea of Okhotsk, and are restricted to waters of the western Pacific to about 170° East longitude (Okazaki in Pearcy and Masuda, 1982). Taxonomists are still trying to resolve the relationship between (S. mykiss) and (S. gairdneri). Both have similar life histories but thus far steelhead have not been identified in rivers of the far east.

Steelhead are generally categorized as summer run (entering and migrating upstream during falling stream levels, having immature gonads, and spawning the following season) or winter run fish (entering and migrating upstream during rising stream levels, nearly mature gonads, and spawning within the same season) (Withler, 1972). Shapovalov and Taft (1954) state that steelhead probably enter larger rivers such as the Sacramento, Eel, Klamath, and Columbia at all times of the year. Steelhead generally do not feed in fresh water but remain in excellent condition until spawning. Summer and winter steelhead generally spawn (during the same period), from January through June (Withler, 1972). Unlike the Pacific salmons (Genus

Oncorhynchus) which perish after the first spawning, steelhead can return to spawn for a second and third time. In the Cheakamus River, located in southern British Columbia, Withler (1966) found 31.3% of all winter steelhead captured during 1954, 1955 and 1957 were returning to spawn for a second or third time. Jones (1976) investigating the steelhead life history in Petersburg Creek Alaska found 30.5% of the run showed one or more spawning checks. Everest (1973) found 24% of wild steelhead returned to spawn two or more times in the Rouge River located on the coast of Oregon.

Several investigators have shown that wild steelhead spend highly variable amounts of time in fresh and salt water. Withler (1966) found juvenile steelhead spent from 1 to 4 years in the fresh waters of the Coquitlam, Alouette, Chehalis, Chilliwack, Cheakamus, Capilano, Seymour, and Coquihalla rivers of southern British Columbia. Adults from these streams spent from 1 to 4 years in salt water. Shapovalov and Taft, 1954 (Waddell Creek, California); Narver, 1969 (Babine River, British Columbia); Everest, 1973 (Rouge River, Oregon); Whately, 1977 (Kispiox River, Northern British Columbia); Johnson, 1978 (Snow Creek, Washington); and Slaney, (per.com.) (Keogh River, British Columbia) all found similar variability. Jones, (1976) (Petersburg Creek, Alaska) and Whately (1977) found 5 year old juveniles in fresh water, although these represented

less than 1% of the population. Shapovalov and Taft (1954) noted that steelhead are capable of spawning before their first journey to the sea, and may even remain in freshwater for their entire lives.

Females select a spawning site generally at the head of a riffle or the tail of a pool. Eggs are fertilized by the male as the female deposits them into the redd. Incubation takes from 6-8 weeks depending primarily on water temperature. Once out of the substrate fry inhabit areas of gravel bottom (1-10 cm diameter) and at a mean water depth of 30 cm with no overhead cover. Aged 1+ fish reside over large gravel and cobble (5-10 cm diameter) at a mean depth of 53 cm and in areas of heavy surface cover (Pearlstone, 1976).

Bustard and Narver (1975) found that winter habitat related to water temperature and velocity. During winter months generally November to March 1+ steelhead were found in depths greater than 45 cm and 45% of age 0+ steelhead were observed in water less than 15 cm deep. As water temperatures decreased from 9° to 2°C juvenile steelhead moved closer to submerged cover such as logs and tree roots. Increasing velocities in which steelhead occurred were positively correlated with rising temperatures above 4°C.

Smolting involves the transformation from a cryptic-coloured, bottom-dwelling freshwater parr into a silvery,

pelagic smolt physiologically adapted to the marine environment (Hoar, 1963). Shapovalov and Taft (1954) found juvenile steelhead moving seaward at all times of year, but the largest numbers migrate in the spring and summer, with secondary movements in the late fall or early winter. Everest (1973) working on the Rogue River with summer steelhead reported peak out-migration about May 1. In Snow Creek Washington peak movement occurred in May when 80% of the smolts migrated (Johnson, 1978). Jones (1976) reported peak seaward-migration in Petersburg Creek Alaska as mid June, somewhat later than the more southerly streams.

Factors that influence the time of smolt migration are size of fish, flow, temperature, chemical factors such as oxygen, photoperiod and food (Shapovalov and Taft, 1954). Fessler (1969) indicated the parr-smolt transformation is markedly size dependent and seasonal in occurrence.

The Thompson River, a major tributary of the Fraser system, has historically supported one of the largest runs of late summer steelhead in British Columbia and an associated sport fishery. However, all is not well. Catch statistics (Steelhead Harvest Analysis) and experienced anglers indicate that a progressive decline in fish numbers commenced in the 1960's. Reasons, while speculative, may include habitat degradation such as forest fires and clear cut logging of headwater basins, excessive water withdrawal from rearing streams, trapping in unscreened irrigation

channels, obstructions to adult migration, and industrial effluents including pulp and sewage wastes. Thompson River steelhead run a gauntlet of commercial fisheries including those on the high seas, in the Straits of Juan de Fuca and Georgia, and in the Fraser River. An intensive native sustenance fishery combined with sport fisheries on both the Thompson and Fraser rivers also contribute to adult mortality.

Basic biological information concerning Thompson River steelhead was not available, so this study was initiated to obtain the baseline data necessary for planning and implementation of enhancement strategies including:

- 1) Determination of the time of entry, distribution, movement, and spawning locations of adult Thompson River steelhead using radio telemetry.
- 2) Determination of age composition, length and weight distributions, sex ratio, and fecundity of Thompson River steelhead.
- 3) Identification of obstructions to migrating adult steelhead.

Successful management and enhancement of Thompson River steelhead will depend on a basic understanding of the foregoing biological and ecological requirements.

MATERIALS & METHODS

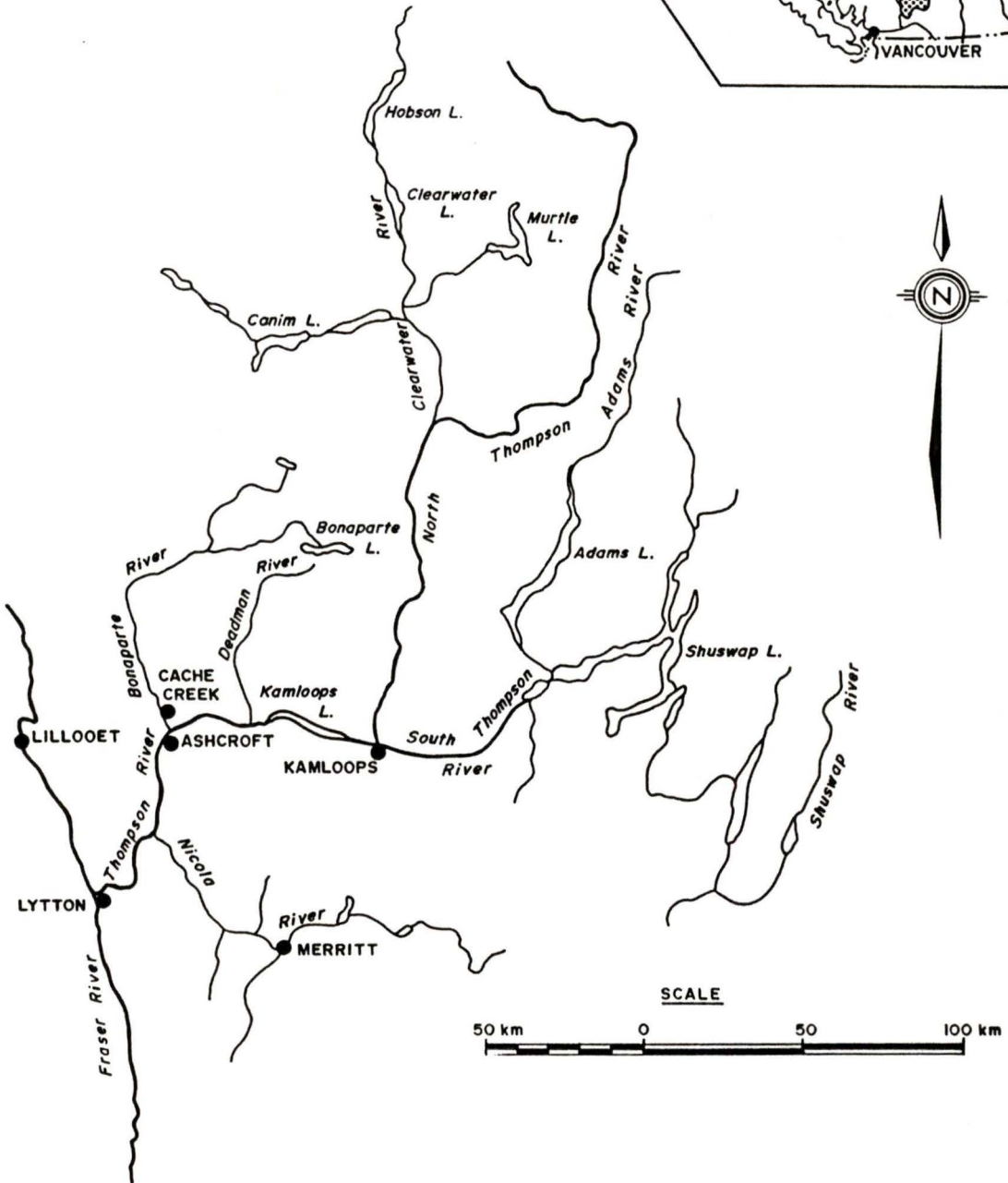
Description of Watershed

The Thompson River, a tributary entering the Fraser River at Lytton has two branches; the North Thompson originating in the Cariboo district, and the South Thompson in the Shuswap district. The two branches meet at Kamloops to form the main Thompson which flows southwest through the interior dry belt where the mean annual rainfall at Kamloops airport is 28 cm/year. Temperatures at Kamloops range from an extreme of 42°C in summer to -34°C in winter.

Major tributaries downstream of Kamloops include the Deadman, Bonaparte, and Nicola rivers. These rivers are 64, 122 and 138 km in length and have drainage areas of 1,160, 5,000, and 7,660 km² respectively (Figure 1).

Primary commercial activity in the Thompson watershed includes growing forage crops such as alfalfa, cattle ranching, logging, and mining. In addition, water quality is impacted by urban and industrial development. Kamloops, the largest urban area with 80,000 inhabitants, discharges 20,700 m³/day of tertiary sewage effluent, and 181,920 m³/day of pulpmill effluent to the Thompson River. Ashcroft, with a population of 2,000 contributes 1,728 m³/day of primary treated effluent. Merritt has an area population of 12,000 and contributes 2,600 m³/day of sewage following secondary treatment to the Nicola River. Cache

Figure 1 Thompson River, tributaries and study site.
Inset map shows location of Thompson River
drainage in British Columbia.



Creek also contributes 725 m³/day of secondary sewage effluent.

Freshets associated with snow melt begin in the Thompson watershed in early April with peaks in mid June. Maximum and minimum flows in the Thompson range from 4,130 m³/s to 115 m³/s . The mean is 750 m³/s.

River Temperature and Discharge

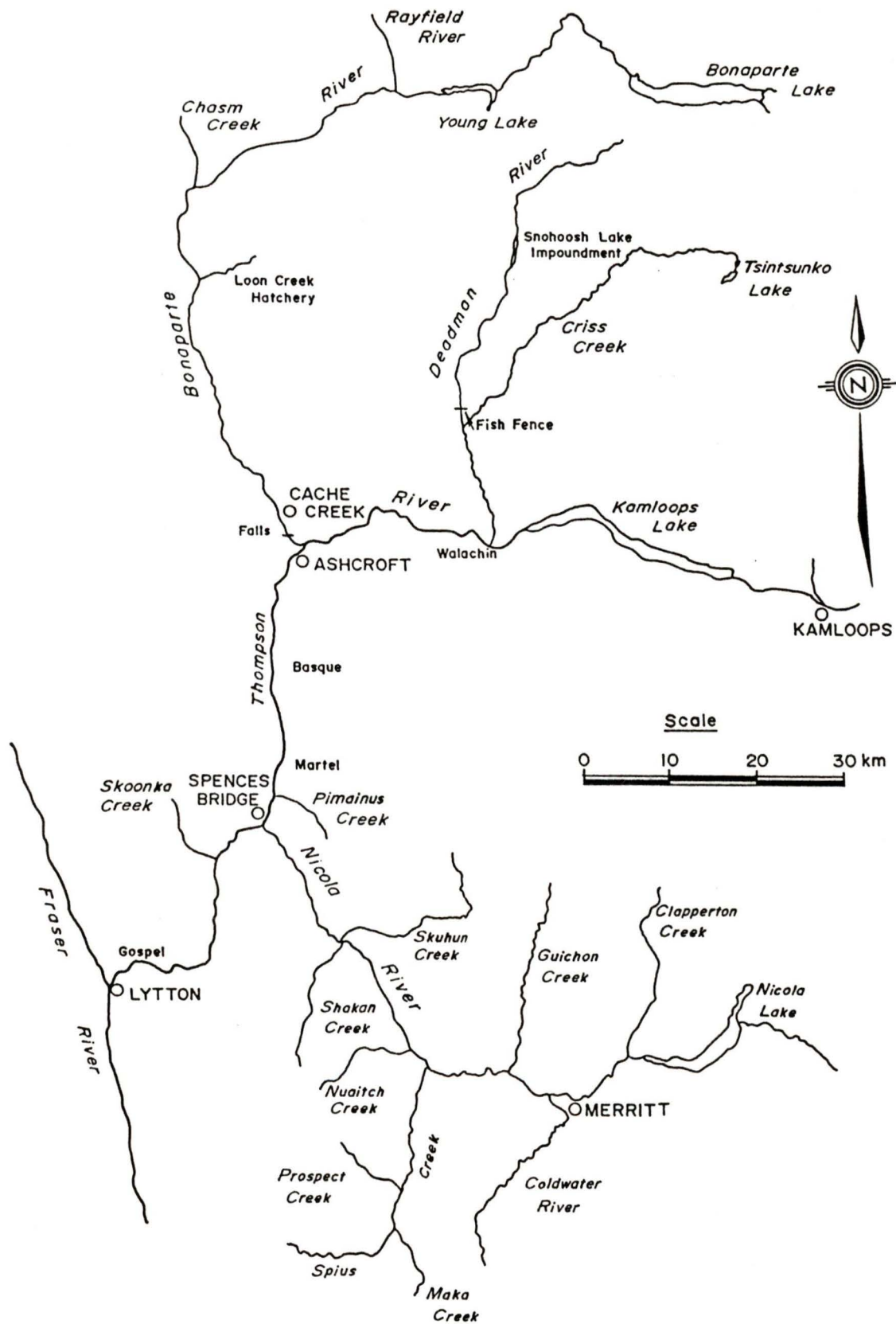
Water temperature (Waste Management Branch, Kamloops) and discharge (Water Survey of Canada) data were recorded on the Thompson River at Walachin, 70 km upstream of Spences Bridge (Figure 2).

Temperature data on the Nicola River were recorded near the Thompson confluence using Fisher brand hand thermometers. Only occasional temperature information was recorded on Bonaparte and Deadman Rivers. Most data, averaged on a bimonthly basis, was extracted from the Water Survey of Canada (1962-1976). Discharge volumes (Water Survey of Canada) were also available for the three main tributaries.

Fish Species

Steelhead and resident rainbow trout (Salmo gairdneri) are the two most important recreational species in the Thompson River. Other salmonids inhabiting the study area include chinook (Oncorhynchus tshawytscha), coho (O. kisutch), sockeye (O. nerka), and pink salmon (O. gorbuscha), Dolly Varden (Salvelinus malma), brook trout (S. fontinalis) and

Figure 2 Detailed map of the study site.



mountain whitefish (Prosopium williamsoni). Other numerous species include largescale suckers (Catostomus macrocheilus), longnose dace (Rhinichthys cataractae), prickly sculpin (Cottus asper), northern squawfish (Ptchocheilus oregonensis) and red sided shiner (Richardsonius balteatus).

Radio Telemetry

Underwater biotelemetry encompasses the instrumentation and application of the technique of remote signaling by means of ultrasonic or radio signals from a transmitter implanted in a fish to a land or boat based receiver. Ultrasonic telemetry requires an underwater receiving unit or hydrophone which restricts the researcher to boat or fixed location receiving station, whereas radio signals can be detected with a receiver and antennae mounted on a land vehicle, boat, airplane, or at a fixed station. Radio telemetry was selected for this program as the most convenient methodology since surveys could be conducted from a vehicle using roads which parallel the rivers. Fifty megahertz radio signals were selected as they are influenced less by changes in water temperature, turbulence, weeds, ice, depth or algae growth, than higher frequency signals (Winter 1976).

An (AVM) model LA 12 portable receiver manufactured in Illinois with 12 pre-set frequency channels 25 kilohertz apart facilitated use of thirty-six transmitters. AVM

model SMI radio transmitters were selected for this program. They operate on a 1.35 volt mercury battery with a life expectancy of approximately one year. Each unit transmitted between 50.250-50.525 megahertz with each transmitter individually identifiable by frequency and pulse rate. If for example two fish were being monitored in close proximity each fish could be identified by receiver channel; however, if both fish were monitored on the same channel the fish could be separated by frequency firstly and secondly by differing pulse rates measured with a stop watch. AVM transmitters weigh 12.5 grams, measure 3.0 x 6.5 cm and are padlock shaped. A second group of radio tags purchased from Wildlife Materials also manufactured in Illinois were cylindrical in shape 1.5 x 5.5 cm and weighed 15 grams.

Conventional three element directional Yagi antennae supplied by AVM were used on both land and water tracking vehicles with the three elements above the sides of the truck and boat to minimize static interference. A small directional loop antennae was used to locate transmitters as precisely as possible at close range. The maximum range of the loop antenna was 0.4 km. The larger yagi antennae was effective to 1.6 km.

Capture and Tagging

Experienced Thompson River fishermen speculate that there are three major peaks of migrating adult steelhead in the

Spences Bridge area. The earliest migrants arrive in early October peaking by the first week in November. Anglers describe the second run as being comprised of smaller fish whose numbers peak in the first week of December. Another small group of migrants also enters the Thompson River in March and April. On the basis of this anecdotal information an attempt was made to intercept steelhead by angling in the lower reaches of the Thompson River, downstream of Spences Bridge. Initial plans to begin radio tagging in early October were delayed as the transmitters did not arrive until mid October. The first fish was tagged October 18, 1977.

Members of the Steelhead Society of British Columbia cooperated in the capture of twenty-eight adult steelhead. Each fish was usually played about ten to fifteen minutes until it could be handled. Two people were required to tag each fish, one to hold the fish by the caudal peduncle using a wool glove, the other to insert the radio tag by hand into the esophagus. A stainless steel probe was then fitted over the loop of the tag and it was gently pushed into the pyloric stomach. Fish were also tagged externally with numbered Floy spaghetti tags before release. After initially observing downstream movement after tagging, steelhead were held in plastic coated wire tubes (20 x 92 cm) in the river for up to 24 hours to allow recovery.

Tracking

Tracking of tagged fish involved both land and water vehicles. Tracking by land proved to be difficult because of interference from passing vehicles, railway locomotives, and from the tracking vehicle itself. A clear signal was audible only when the vehicles engine was turned off. Noise reducing capacitors were ineffective. By driving along the river and parking off the highway every 1.6 km with the engine off, land tracking was possible but time consuming. Boat tracking involved similar problems. The procedure followed was to travel approximately 1.0 km, turn the engine off and listen for signals. Once a fish was located the pulse rate, location and date were recorded. For pinpointing a tagged fish as precisely as possible a 6 x 12 cm rectangular antennae with an effective range of 150 metres was used. If this produced too strong a signal, a paper clip with a range of 10 metres was used. Exact distances moved by each fish on specific days were difficult to estimate since individual fish were not always located on a successive days. For example, if a fish was located October 15 and next located on October 17 distance travelled was given as the total over the two days. A directional Yagi antennae, two receivers, and a Rustract recorder supplied by AVM was set up at the outlet of Kamloops Lake. Any upstream movements of fish past this

tracking station were recorded.

Radio tracking coincided with the Thompson River sport fishery. Since steelhead were tagged downstream of the major fishing grounds a \$100.00 reward was offered as an incentive for fishermen to report and release radio-tagged steelhead. Fishermen recognized radio tagged steelhead by their individually numbered, blaze orange Floy spaghetti tags. Anglers were instructed to clip off the external marker and return it to the nearest Fish & Wildlife office. If a tagged fish was killed only \$25.00 was offered as a reward for return of the radio tag and information on catch location.

Life History and Biological Sampling

Biological data were obtained from adult Thompson River steelhead by examining angled fish, and by trapping migrating adults in the Deadman River.

An intensive creel census was conducted during the Thompson River steelhead season from October through March 31 in 1976 and 1977. Anglers' catches were sampled opportunistically, and, if cooperative, the following information was obtained from each steelhead: fork length (cm), (tip of nose to fork of tail) weight (kg), (Chatillon Model 30 Scale), sex and scale samples. Scales were placed in envelopes noting length, weight, catch location, date and any other relevant data such as dressed or round weight.

Similar information was collected from adult Deadman River steelhead using a fish fence, located 28 km upstream of the Deadman-Thompson confluence. This fish fence was operated in the spring (April, May) of 1984 to obtain biological data from all migratory steelhead. Fish were dip netted from the live trap using fine mesh nets. They were weighed in the net (deducting net weight from the total to obtain fish weight). Individual fish were then placed in a hammock style measuring box to support ripe ovaries and sampled for scales and length before release.

Approximately twenty scales were taken from each steelhead at least three scale rows above the lateral line in the area lying between the dorsal fin and the anal fin (Narver and Withler, 1971). Scales were placed in envelopes. Later they were soaked in warm water, rubbed between fingers to clean and five scales which showed no regeneration were mounted on gummed prepared scale booklets with the circuli ridges facing up. The mounted samples were then imprinted on heated cellulose acetate slides and examined with a twenty-two to fifty-eight magnification Bell and Howell micro-fiche projector. Ages were interpreted using conventional methods by two Fish and Wildlife Branch staff members and compared for consensus (Narver and Withler, 1971).

After determining the age of each steelhead, scales were assigned a numerical notation with a decimal point

separating fresh and salt water age. For example a fish assigned the notation 2.2+ spent two winters in freshwater and two winters in saltwater before returning in the fall of its 5th year which was spent maturing in fresh water. An "S" represents a repeat spawner and a entire year in the life of the fish while "+" notation indicates growth after the formation of either the last freshwater or salt water annulus. A steelhead assigned to age 2+.2 spent two winters in freshwater and some additional undetermined time in freshwater before smolting and spending two winters in the ocean. A fish assigned to notation 2.2S1+ spent two winters in freshwater, two in salt before returning to spawn in the 5th year. This fish then migrated back to the ocean spending one summer and winter there before migrating back into freshwater in its 7th year. Summer steelhead, including Thompson fish, spend approximately 7 or 8 months in freshwater before spawning. Circuli are reabsorbed during this period including part of one winter a summer and a portion of the previous winter. The "S" designation recognizes that portion of a fishes scale that is reabsorbed.

Juvenile rainbow trout were sampled in September from areas known to be used by spawning steelhead including Deadman, Bonaparte, and Nicola Rivers, Guichon, Spius, Maka, Nuaitch and Shackan Creeks, with a Smith-Root Type VII electroshocker. Trout were anesthetized (MS 222) and sampled for

length and scales. Scales were removed from the area described above and pressed between microscope slides.

Juvenile steelhead and resident trout co-exist in the Thompson drainage and at this time there is no certain method to separate residents from anadromous trout. However, from qualitative observations it was estimated that anadromous trout constitute a large majority of the trout population, probably greater than 90%.

Scales were interpreted using a Bell and Howell micro-fiche projector at 57 X. All scale measurements were taken from the focus to the anterior scale radius at a forty-five degree angle.

The length at which smolts leave the Thompson River on their ocean migration was estimated by back-calculation using the proportional Fraser-Lee formula. In order to use the Fraser-Lee formula several assumptions, described by Ricker (1968), had to be met:

- 1) The relationship between fish length and scale (or otolith or other bony structure) is rectilinear but not directly proportional. Graphically, the line cuts the Y-axis at some intercept, c .
- 2) The intercept, c is not necessarily the length at which scales first develop. The mathematical value does not need to fit any biological measurement.

3) The line is described by the mathematical formula:

$$L_n - c = (S_n(L - C))/S.$$

where L_n = length of fish when annulus 'n' was formed

L = length at capture.

S_n = radius of annulus 'n'.

S = total scale radius.

4) Scales are removed from the same location.

5) Measurement from focus to scale margin is done consistently along the same axis.

6) Annuli represent annual marks which are laid down at the same time each year between the end of one growing season and the start of next.

Body lengths and scale radii were plotted for juvenile and adult fish excluding fry of the year (0+). Fry were excluded because scale growth rate during this period exceeds body growth rate and their inclusion would result in a curvilinear relationship (Lewynsky et al., 1986). Thompson River adults captured in the Deadman River in the spring of 1984 were also excluded from the sample as scale reabsorption was evident and probably occurred because of a long pre-spawning period (eight months) in freshwater. Ricker (1968) states that the greatest difficulty with employing proportional calculations lies in failure to comply with assumption number one. After examining residuals from the body length and scale radius plot a pattern was observed which indicated a curvilinear

relationship. Logarithmic transformation produced a curve that appeared linear and after examining a random pattern of residuals, was verified as linear. The Fraser-Lee formula required further modification to take logarithmic transformations into account:

$$\ln(L_n) = \left[\frac{([\ln(S_n) * (\ln(L) - c)])}{\ln(s)} \right] + C$$

where 'c' is the intercept from the transformed regression.

The estimated back-calculated smolt length would therefore be the exponential of the above result.

Fecundity

Between 1979 and 1983, thirty-six pairs of ovaries were collected from anglers' catches and preserved in 10% formalin. (Samples were difficult to obtain as "roe" is a preferred bait of Thompson River anglers).

Ovaries were prepared for counting by boiling in a thirty percent formalin solution for approximately one half hour until the membranous tissue was broken down and the eggs hardened. Some of the eggs had to be separated from the membranous material but the large majority fell away as they were boiled. Eggs were then drained through a small mesh screen, thoroughly rinsed with freshwater and counted manually.

Data were stored and analysed using a Digital Professional

350 computer employing a N.P.L. data management and
S.P.S.S. statistical software.

Results

Radio Tagging

Twenty five adult steelhead were radio tagged between October 18th, and November 13th, 1977. An additional three fish were tagged, two in the Walachin area in mid February and one near Spences Bridge in early April, 1978.

Tagged fish included 17(60.7%) males and 11(39.3%) females a (1.5:1 male to female ratio) ranging between an estimated 4.6 - 9.1 kg. Of the 28 tagged steelhead, 3(10.7%) were recaptured (one was killed and two were released), 4(14.3%) were lost shortly after tagging (tag malfunction was suspected) and 3(10.7%) were tracked for a short period of time and then disappeared. Five (17.9%) tags remained in the same location for eight months and were considered to have been regurgitated. The remaining 15(53.6%) were monitored throughout the spawning cycle. Eight (28.6%) fish spawned in the Thompson River and 7(25%) migrated to Deadman, Bonaparte, and Nicola Rivers (Table 1).

Migration Behavior

The majority of steelhead were tagged approximately 25 km upstream of the Thompson-Fraser confluence. These fish exhibited variable behavior, some moving upstream immediately after tagging, and others moving downstream. In other cases steelhead maintained position near the tagging site and resumed either upstream or downstream migration some days later.

Table I - Summary of radio tagged steelhead including estimated weight (kg.), sex female (F) male (M), tagging date and fate of each fish.

Fish No.	Estimated Weight (kg.)	Sex	Date Tagged	Fate
1	7.3	F	18/10/77	TS
2	7.7	M	18/10/77	TR
3	7.7	M	18/10/77	TR
4	7.3	F	19/10/77	TD
5	6.8	M	19/10/77	TS
6	7.3	M	21/10/77	TS
7	6.8	F	22/10/77	TS
8	5.9	F	25/10/77	TR
9	6.8	M	26/10/77	TD
10	4.6	M	27/10/77	TS
11	7.3	F	27/10/77	TS
12	7.7	M	28/10/77	TR
13	6.8	M	29/10/77	AK
14	5.0	M	01/11/77	TS
15	7.3	M	05/11/77	TS
16	9.1	M	05/11/77	TD
17	7.7	F	05/11/77	TM
18	6.4	F	05/11/77	TM
19	7.3	M	06/11/77	TS
20	8.2	M	06/11/77	TR
21	5.9	M	08/11/77	TS
22	5.9	F	09/11/77	TS
23	6.8	F	09/11/77	TM
24	6.8	F	10/11/77	TS
25	6.8	M	13/11/77	TM
26	5.5	M	12/02/78	TS
27	6.8	M	20/02/78	TS
28	5.5	F	04/04/78	TS

TS - Tracked to Spawning
 TR - Tag Regurgitated
 TM - Tag Malfunction

AK - Angler Kill
 TD - Tracked for Short
 Period & Disappeared
 (Details appendix I)

An example of a tagged fish maintaining position near the tagging site and then continuing upstream movements was as follows. Fish #6 was tagged October 21st, 1977, 11.7 km south of Spences Bridge when the Thompson River temperature was 10°C. After tagging, the fish maintained station near the tagging site for five days and then migrated 3.0 km upstream in one day where it held position for 31 days. On December 1st, 1977, it migrated upstream another 5 km and held position for 15 days, before migrating an additional 0.2 km upstream. Twenty days later on January 4th, 1978, the fish moved 3.0 km upstream to the Spences Bridge area where the water temperature was 2.5°C. On January 18th, 1978, it moved a further 3.5 km upstream to the confluence of the Nicola and Thompson Rivers. By now the water temperature was 1°C and the fish maintained station until April 12th, 1978, when it entered the Nicola River under clearing and falling water conditions at a temperature of 4.5°C (for details on Nicola River migration see Appendix 1).

Seven tagged steelhead migrated downstream either immediately after tagging or two to three days later. Of these seven fish five (fish # 11, 12, 15, 26, and 28) continued upstream migration at a later date (Appendix 1). For example fish #12 tagged October 28th, 1977, 11.7 km downstream of Spences Bridge, went missing immediately after tagging but was located 4 km downstream on October

31st, 1977. Three days later it migrated back to the tagging area, and then went missing for 19 days before it was re-located approximately 4 km upstream, where it was considered to have regurgitated the radio tag.

Details of the two downstream migrants that did not move upstream again are as follows. Fish #1 migrated downstream 3.2 km 3 days after tagging and spawned in that area 7 months later. Fish #4 was tagged October 18th, 1977, 11.7 km downstream of Spences Bridge and located 1.5 km downstream 5 days later on October 23rd, 1977. It was never located again.

Fish held in live pens for a period of twelve to twenty-four hours after tagging maintained position or continued upstream migration. Examples of this behavior was exhibited by radio tagged fish in the Walachin area. Fish #26 a 5.4 kg fish was angled, tagged and held 3.5 hours before release. This fish was monitored the following day 1.6 km downstream. Fish #27 a 6.8 kg fish angled in the same manner, was held 18 hours and released. The latter fish maintained position for 50 days before migrating upstream to spawn.

The longest fall and winter upstream movement of a radio tagged fish was 38.2 km. Fish #7 a 6.8 kg steelhead was captured October 22nd, 1977, 11.7 km south of Spences Bridge and maintained station there for five days before migrating 5 km over a 3 day period. Fish #7 held position

for 12 days before moving 5.0 km upstream. Four days after it arrived at this position, the fish was recaptured and released. Fifteen days after it had been captured for the second time the steelhead migrated 3.5 km upstream. This fish continued a steady upstream migration until January 19th, 1978, when it had travelled 38.2 km in 88 days (.43 km/day) from the original capture site (Appendix 1).

Recaptured Radio Tagged Fish

Three (10.7%) of radio tagged fish were recaptured. Fish #7 was discussed previously. Fish #13 was angled and tagged October 31st, 1977, 8.1 km south of Spences Bridge on the west side of the river. This fish was recaptured 12 days later in the same area on the east side of the river. The fish was killed and the radio tag returned to the Fish and Wildlife Branch. Fish #16 was angled on the west side of the river November 5th, 1977, 11.7 km south of Spences Bridge. Eight days later on November 13th, the fish was recaptured on the east side of the river, the spaghetti tag removed and the fish released. At this time there was no exterior identification or spaghetti tag, and there was angling pressure in the area. Fish #16 was probably recaptured and killed with the absence of an external Floy tag.

All anglers who captured tagged fish, commented that the fish were in good condition with no apparent fungal growths or exterior damage. Anglers did comment that the spaghetti

tag was very loose and when they attempted to cut the tag it merely fell out of the fish. They also observed that a circular hole had developed, larger than the diameter of each spaghetti tag and commented that it appeared some erosion had occurred. The only radio tagged fish observed spawning did not have an external tag.

Winter Holding and Spring Migration of Radio Tagged

Steelhead

The majority of radio tagged steelhead overwintered in the Thompson River near Spences Bridge (Figure 3). The most northerly area that a radio tagged fish over wintered was near Walachin and the most southerly was Botanie Creek (Figure 3). Angling throughout the winter months also indicated that steelhead overwinter between Lytton and Kamloops Lake. Steelhead were also angled at the Thompson-Fraser confluence throughout March and April. There was no evidence that adult steelhead overwintered in lower Thompson tributaries.

Spring Migration

All radio tagged fish terminated upstream migration by January 19th, 1978, (Table II). At this time temperature and flows approached the minimum for the year (Figure 4). Radio tagged steelhead generally remained stationary until March 15th, 1978.

One radio tagged fish migrated from the Walachin area to the mouth of Deadman River on March 15th, 1978. Tagged

Figure 3 Distribution of adult steelhead as determined by radio tagging in the winter of 1977/78. Overwintering distribution of fish #19 and #28 were unknown.

▲ Indicates wintering fish. (Defined as an extended period without either upstream or downstream movement).

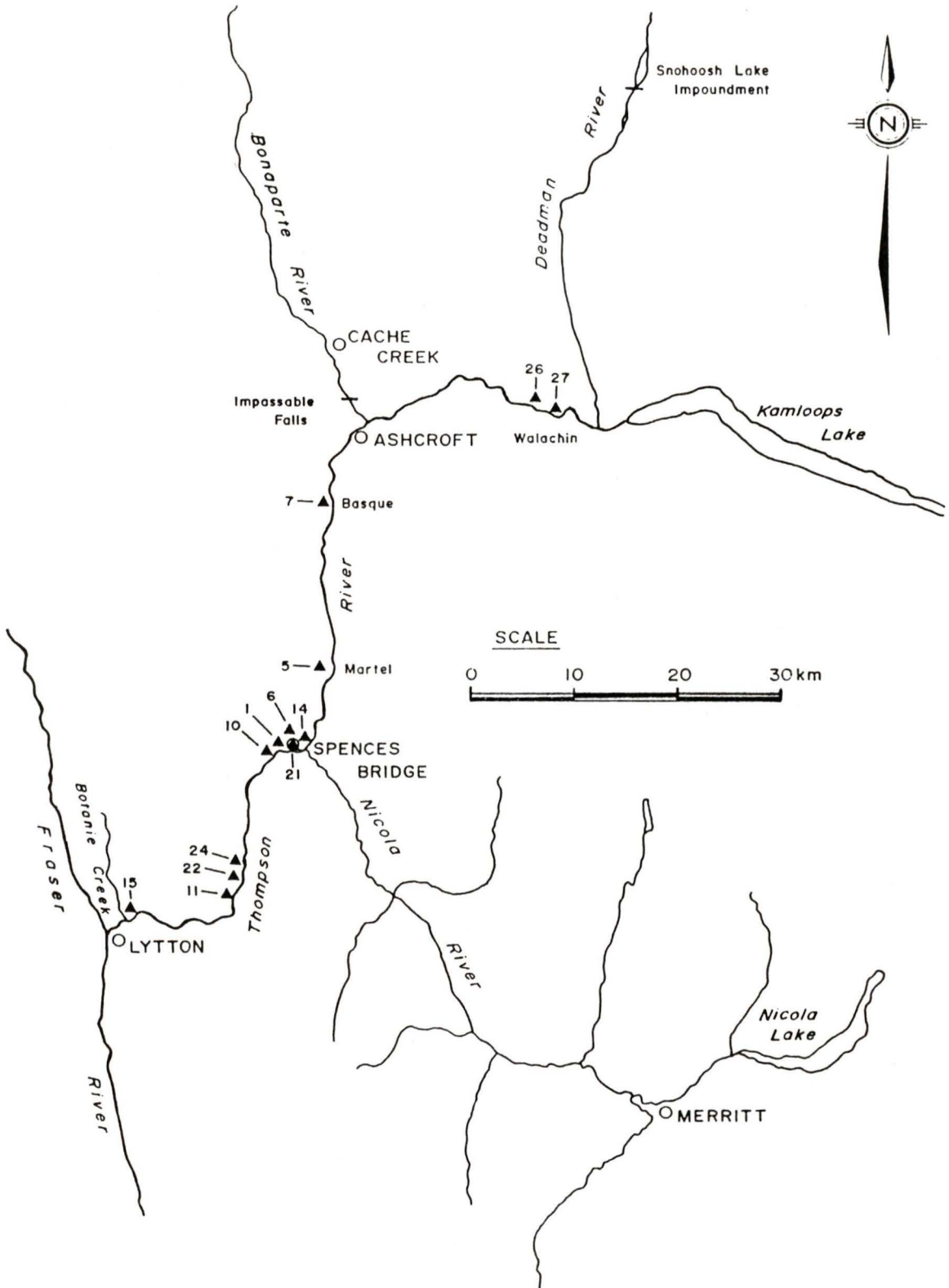


Table II - Summary of temporal migration patterns (winter termination and spring commencement) for 7 radio tagged steelhead which migrated out of the mainstem Thompson to spawn in Deadman (D), Bonaparte (B) and Nicola (N) Rivers.

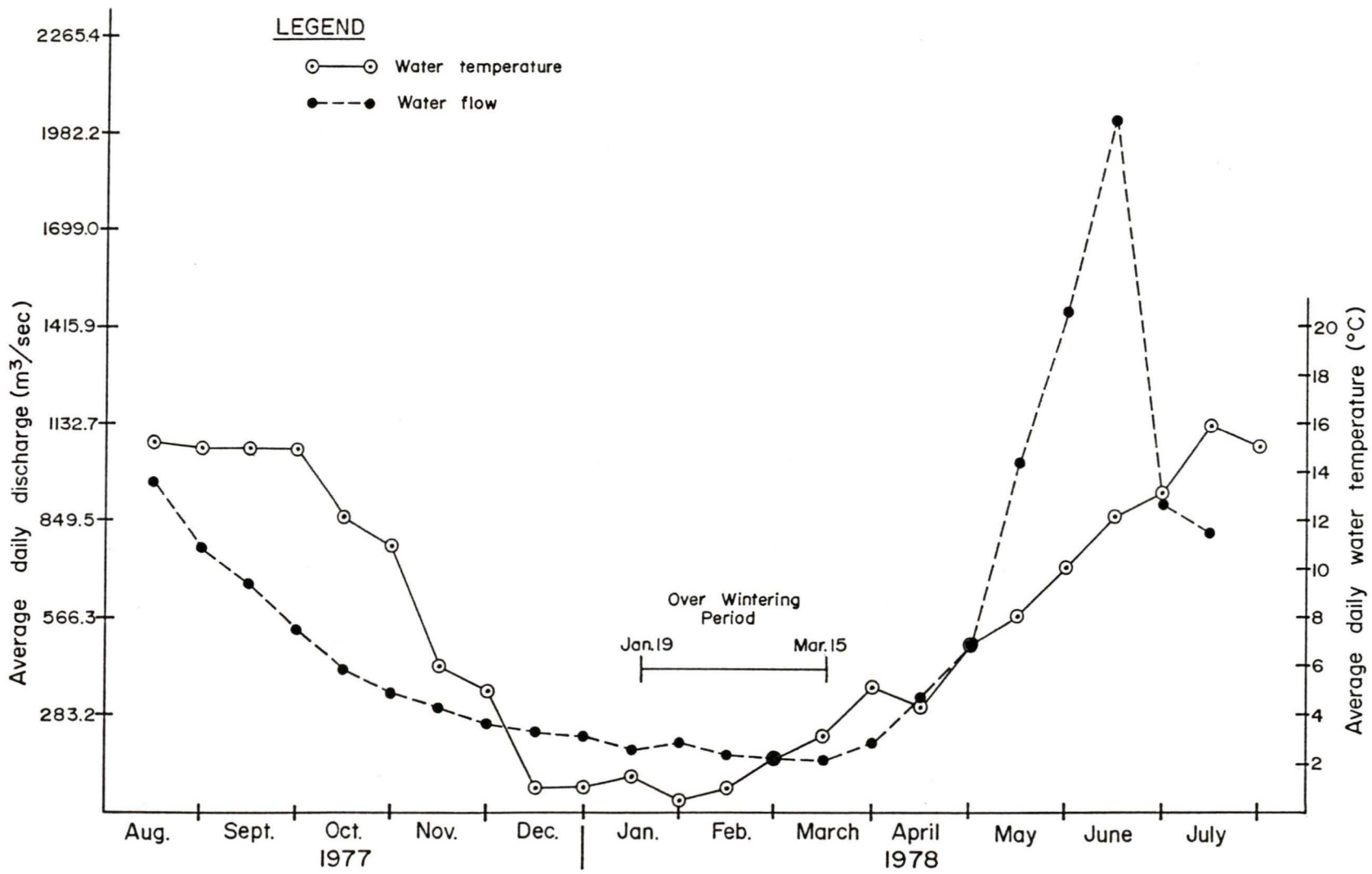
Fish	Sex	Date Tagged	Termination of Winter Migration	Commencement Spring Migration	Spawning Dates ¹
6	M	21/10/77	Jan. 18/78	13/04/78	26/05/78 (N)
7	F	22/10/77	Jan. 19/78	27/04/78	17/05/78 (B)
15	M	05/11/77	N.A.	15/03/78	17/05/78 (B)
19	M	06/11/77	N.A.	N.A.	17/05/78 (B)
21	M	08/11/77	Dec. 15/77	17/04/78	29/05/78 (D)
26	M	26/02/78	N.A. ²	10/05/78	28/05/78 (D)
27	M	20/02/78	N.A. ²	15/03/78	20/05/78 (D)

¹Spawning dates are given as the termination of reproductive activity.

²Fish were tagged in the Walachin area February 12 and 20, 1978 respectively. These fish were believed to have terminated upstream migration prior to the time of capture.

N.A. - Not Available.

Figure 4 Water flow (m^3/s) and temperature ($^{\circ}\text{C}$) in Thompson River for fall, winter, and spring 1977/78.



fish in the lower Thompson River began upstream movements on March 15th, April 13th, 17th, 27th, and May 10th, 1978 (Table II).

Water temperature and discharge rates showed a persistent increase during this period in the Thompson, Deadman, Bonaparte and Nicola rivers (Figure #4, 5, 6, 7).

Deadman River Spring Migration

Three radio tagged steelhead entered Deadman River in early May and migrated to the area downstream of Snohoosh Lake to spawn (Figure 8). Two of these three steelhead were tagged in February 1978 near Walachin, the other was tagged near Spences Bridge in early November 1977. An impoundment on Snohoosh Lake is the limit of anadromous migration in the Deadman River.

Fish #21 a 6.9 kg male, overwintered in the Spences Bridge area until April 17th, 1978. Then migrated upstream 67 km in 21 days (3.2 km/day), entered the Deadman River May 2, 1978, migrated another 47 km in 20 days (2.4 km/day), and spawned on May 27th, 1978. Fish #26, a 5.5 kg male, tagged near Walachin on February 12th, 1978 held position until May 4th, 1978, when migration in to the Deadman river took place. It then migrated 41 km up Deadman River in 13 days (3.2 km/day), and spawned.

Fish #27, a 6.8 kg male tagged February 20th, 1978, at Walachin, held in that location until March 15th, 1978, when migrated in to the Deadman River. Fish #27 then

Figure 5 Water flow (m^3/s) and temperature ($^{\circ}C$) in the Deadman River for fall, winter and spring 1977/78. The duration of ice cover and immigration, spawning and emigration of radio tagged steelhead is noted.

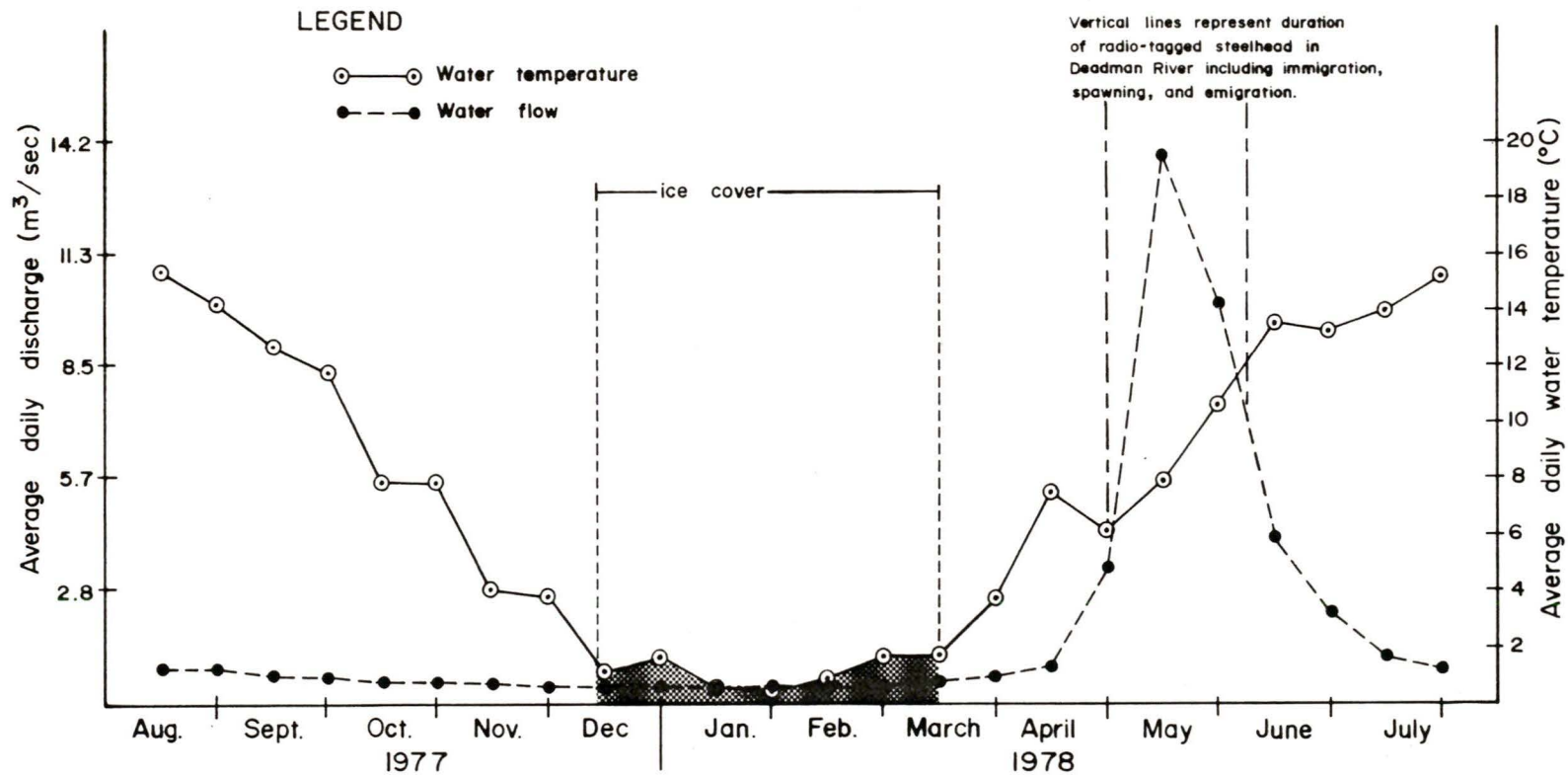


Figure 6 Water flow (m^3/s) and temperature ($^{\circ}C$) in the Bonaparte River for fall, winter and spring 1977/78. The duration of ice cover and one tracking of radio tagged steelhead is noted.

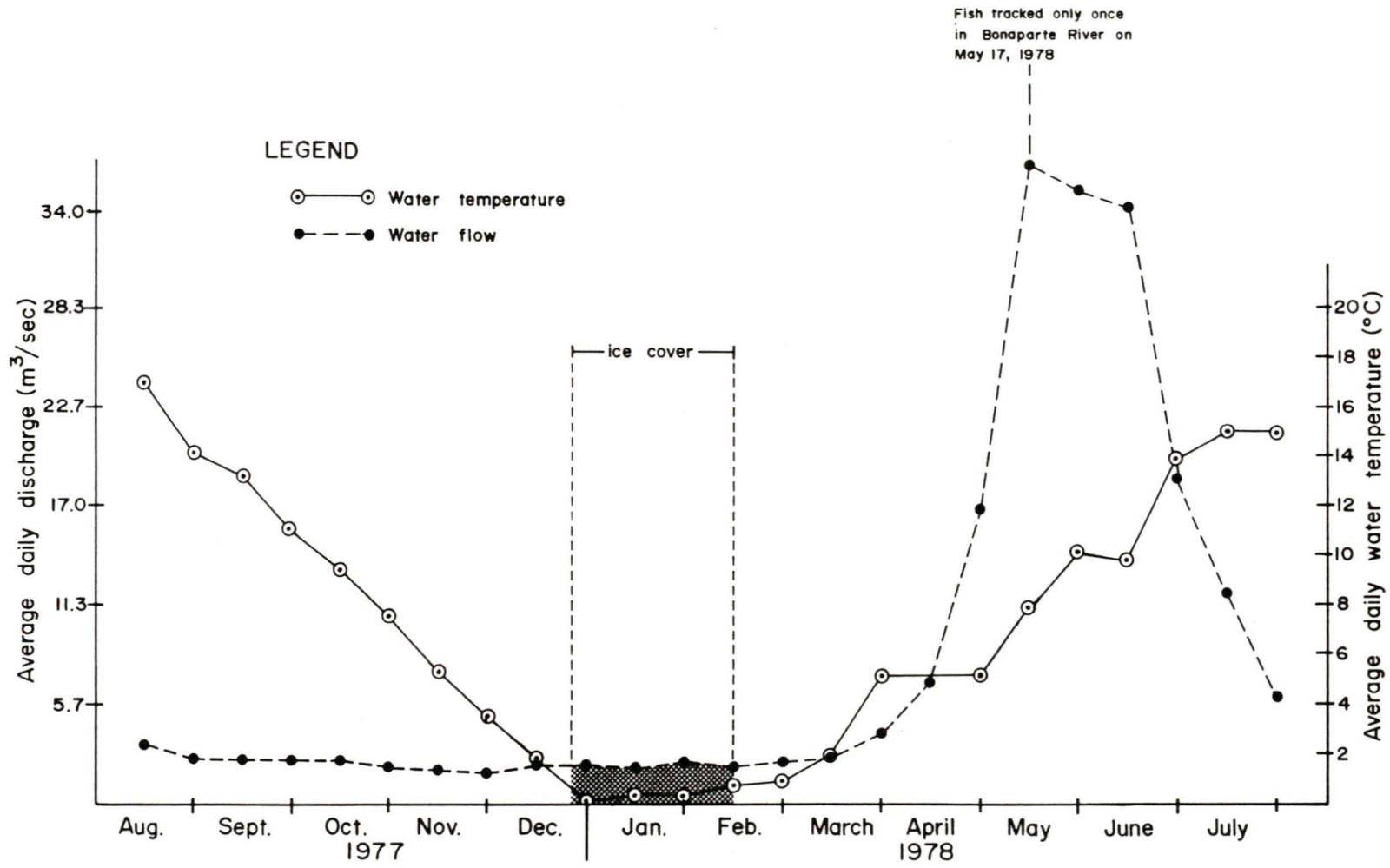


Figure 7 Water flow (m^3/s) and temperature ($^{\circ}\text{C}$) in the Nicola River for fall, winter and spring 1977/78. The duration of ice cover and immigration, spawning and emigration of radio tagged steelhead is noted.

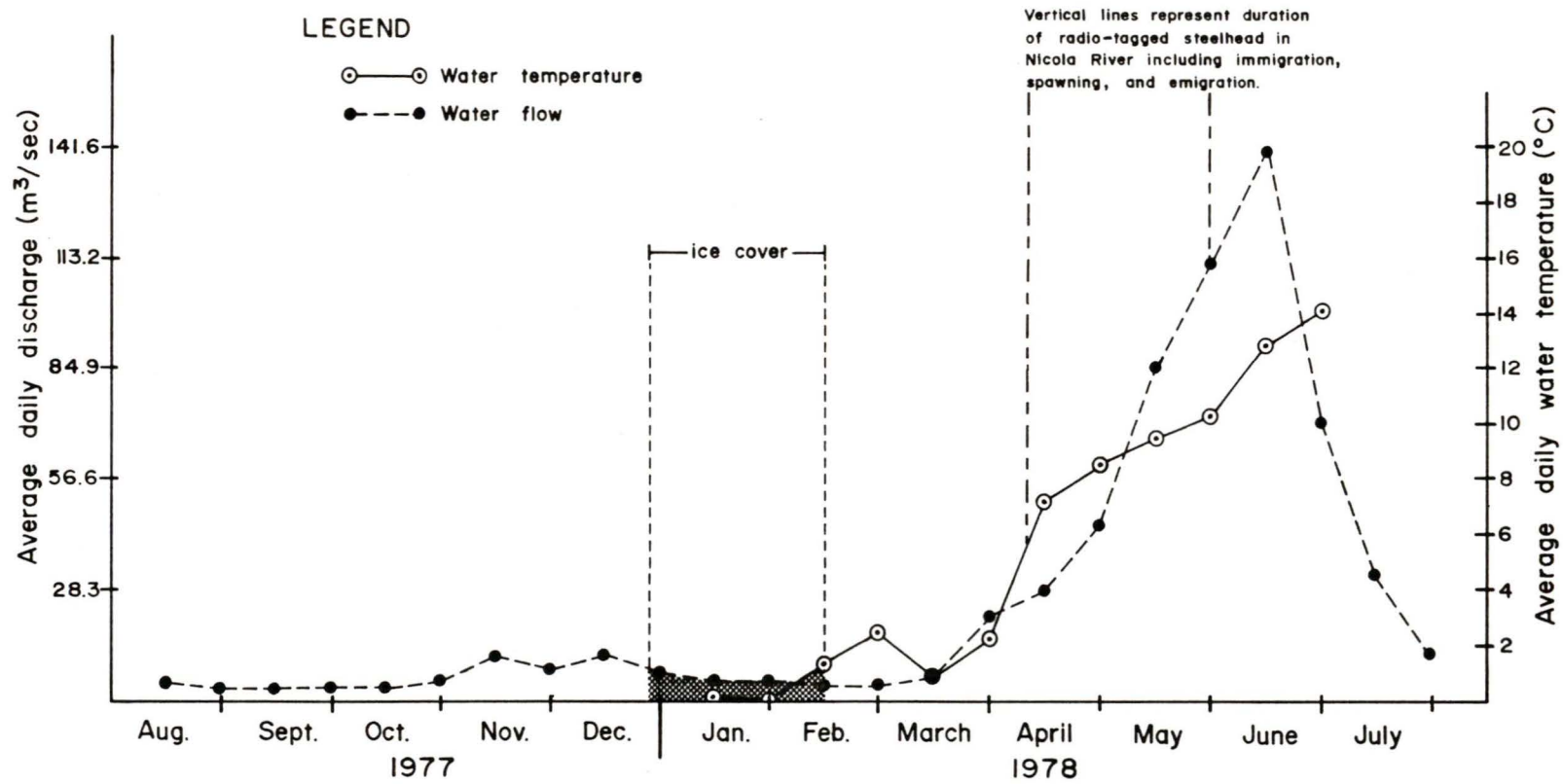
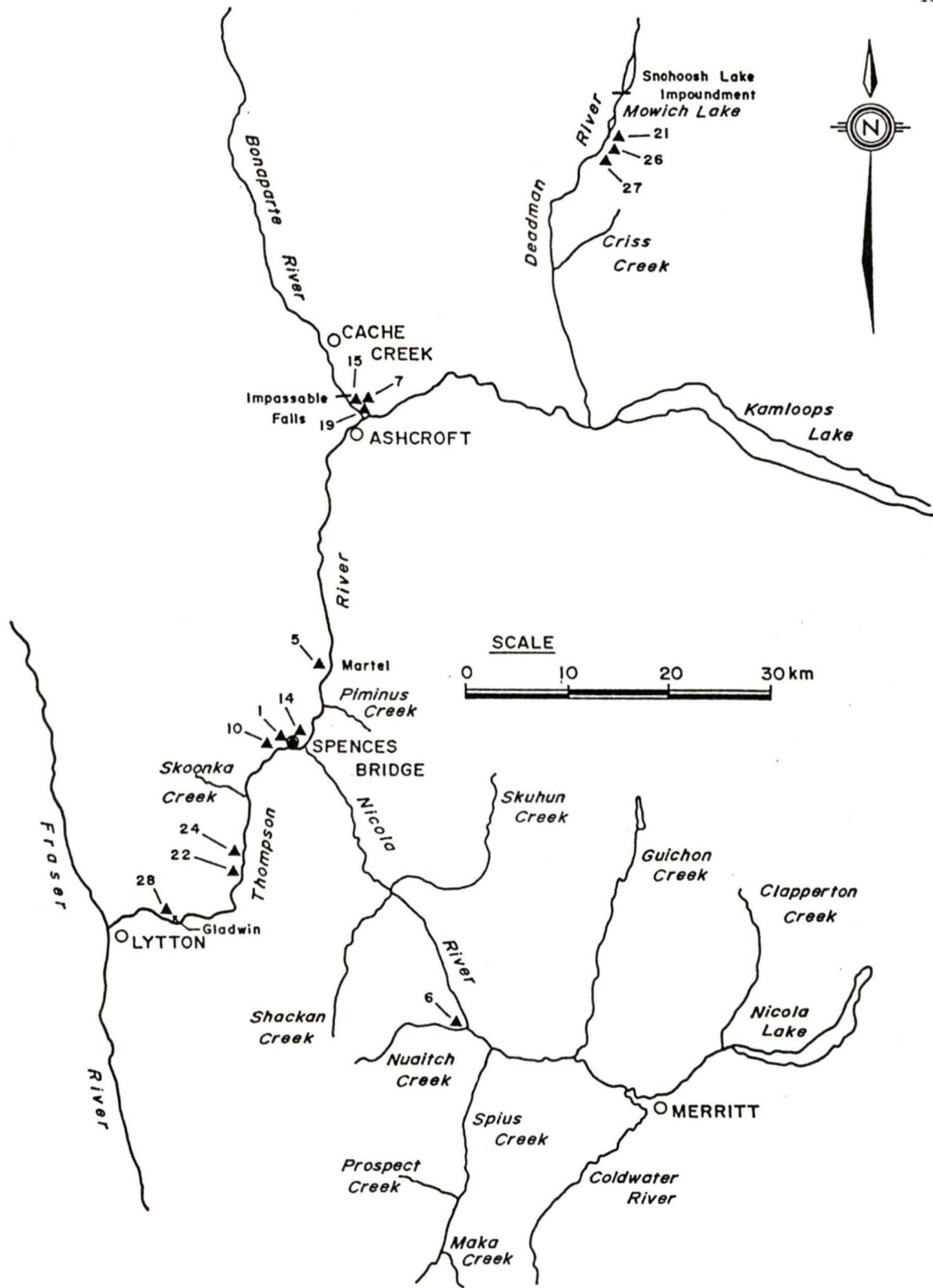


Figure 8 Spawning destination of radio tagged
steelhead.

▲ Indicates spawning location.



migrated 29 km in an undetermined number of days upstream and spawned May 16th, 1978.

Bonaparte River Spring Migration

Three radio tagged fish spawned in the Bonaparte River (Figure 8). Fish #15, a 7.3 kg male was tagged 11.7 km south of Spences Bridge. The fish was next located downstream near Lytton on March 1st, 1978, and then upstream May 17th, directly below the obstruction in the Bonaparte River. Fish #19, tagged November 6th, 1977, was monitored for three days after tagging, disappeared for the winter, and next was located upstream on May 17th, 1978, in the Bonaparte. Since both fish were contacted shortly after tagging but not again until five months later, migration patterns are unknown for the intervening period. However, a possible migration pattern was indicated by seven other tracked fish. These fish first migrated downstream after tagging, but only four or five km. Fish #15 and #19 may have migrated further downstream (15-20 km) near Lytton where access to the river and tracking was difficult. Since tracking was not done on a daily basis, and if subsequent upstream migration to the Bonaparte river occurred rapidly both fish may have gone undetected.

Fish #7 tagged October 22nd, 1977, wintered in the Basque Ranch area 22 km north of Spences Bridge. This fish left the winter holding area April 27th, 1978 and was located in the Bonaparte River May 17th, 1978 (Appendix I).

Nicola River Migration

Fish #6, a 7.3 kg male, was radio tagged October 21st, 1977, 11.7 km south of Spences Bridge. The fish remained in this area for 5 days and then began a slow upstream movement until January 18th, when it reached the mouth of the Nicola River. It held position at this confluence for 84 days before entering the the Nicola River on April 12th. It then travelled 36 km, arriving at the mouth of Nuaitch Creek, 37 days later. River temperature and discharge rates were increasing at this time (Figure 7). Fish #6 entered Nuaitch Creek on May 20th, spawned and disappeared by May 30th, 1978 (for details of tagged steelhead movements see Appendix I).

Steelhead Spawning Locations Verified by Radio Tagging and Visual Siting in the Thompson River and Tributaries.

Radio tagging verified that spawning occurred in two of the three tributaries, Deadman and Bonaparte Rivers, and the mainstem Thompson (Figure 8). One radio tagged fish migrated into the Nicola River system and spawned, in a small tributary, Nuaitch Creek. Eight radio tagged steelhead spawned in the mainstem Thompson river. One radio tagged fish was verified spawning 13.5 km downstream of Spences Bridge. The furthest north a fish was verified spawning was Martel, 11 kms upstream of Spences Bridge. Other radio tagged fish spawned at various locations between these two sites (Figure 8).

Steelhead spawning areas identified in the Thompson drainage by visual siting included, Skuhun, Shakan, Guichon, Spius, Maka, Prospect Creeks, and the Coldwater River in the Nicola drainage and Criss Creek in the Deadman drainage. Streams reported to have steelhead spawning include Clapperton Creek located in the Nicola River system, Pimainus and Skoonka Creeks, tributaries of the Thompson River (Figure 2).

Obstructions to Upstream Migration

Deadman River

Steelhead approximately 26 km up the Deadman River encountered an impassable blockage, in the form of a timber crib irrigation dam probably constructed about 40 years ago. On one occasion 40 adult steelhead were observed attempting to leap over the obstruction in a one hour period. It was difficult to ascertain whether these were repetitive leaps. Several resident and juvenile rainbow trout also attempted to pass the barrier with no success. Subsequent installation of a portable Alaskan steep pass allowed steelhead access to an additional 24 km of spawning and rearing area above this barrier.

Bonaparte River

Steelhead entering the Bonaparte River encountered a natural barrier approximately 2.4 km upstream. A 6.1 meter falls blocks access for anadromous fish to 122 km of otherwise suitable spawning and rearing habitat.

Nicola River

One radio tagged steelhead entered the Nicola River and migrated 37 km upstream to a log jam located 1 km upstream from the mouth of Nuaitch Creek. Only one adult steelhead could be located upstream of this first of four major blockages. Log jams were subsequently removed allowing adults and juvenile steelhead access to additional spawning and rearing areas.

Post-spawning Behavior

Radio tagged steelhead exhibited varying post-spawning behavior. Adults, particularly females, in small streams, ($<2.0 \text{ m}^3/\text{s}$) left the spawning grounds immediately. Some males remained 1-2 days after spawning but, generally, all fish migrated downstream into the larger tributaries after spawning.

Within a day of spawning in the Deadman River ($<14.5 \text{ m}^3/\text{s}$) a male steelhead migrated downstream 2 km. Fish #27 then migrated downstream 10 km in 4 days (average of 2.5 km/day) and disappeared. Another male, fish #26, spawned May 28th, dropped downstream 800 meters, held there for one day and then was relocated 7 days later 23 km downstream (average of 3.3 km/day). Fish #21, also a Deadman River male spawned 47 km from the Thompson confluence migrated downstream in 8 days; (average of 2.5 km/day), and disappeared.

One mainstem male, fish #10, migrated downstream 0.5 km

after spawning and maintained position there for 9 days before disappearing, presumably downriver based on other fishes behaviour.

One radio tagged downstream migrant, Fish #7, was monitored as it approached the confluence of the Thompson-Fraser. Its speed was that of the river (.5 m/sec). Coldwater River, a tributary of the Nicola river is a clear flowing stream greater than $11.5 \text{ m}^3/\text{s}$ during freshet. The majority of non-radio tagged fish in the Coldwater river migrated downstream shortly after spawning as observed by helicopter. Exceptions were males maintaining station near completed redds, for 3-5 days. Adults, in the Coldwater River, have been observed as late as mid July 45 days after peak spawning.

Tag Regurgitation

Five (17.9%) of the twenty-eight radio tagged steelhead probably regurgitated tags, although none of these radio tags were recovered. Tag regurgitation was verified by sending divers into the area of signal strength. If the tag remained stationary after repetitive passes and the area was not typical of steelhead holding water (eg. back-eddie) the radio tag was considered regurgitated.

Four (80%) of the 5 tags regurgitated were by males with a mean weight of 7.4 kg. The smallest fish to regurgitate a tag was a 5.9 kg female and the largest a 8.2 kg male (Table III).

Table III - Radio tags considered regurgitated with reference to sex female (F) male (M) and weight.

Fish No.	Tagging Date	Sex	Weight Kg	Days in Fish
2	18/10/77	M	7.7	33
3	18/10/77	M	7.7	Unknown
8	25/10/77	F	5.9	6
12	28/10/77	M	7.7	7
20	6/11/77	M	<u>8.2</u>	Unknown

$\bar{x} = 7.4$

Life History

Age

Maiden Thompson River steelhead returned most frequently at age 5 and 6. Ten different age classes were identified in 1976 with 2.2+ accounting for 58.8% of the 211 aged fish (Table IV). The next most common age classes were 3.2+ (20.4%), 2+.2+ (12.8%), and 2.3+ (3.3%). Six other age classes completed the distribution, although less than 5% of the population was represented. Four (2%) of the aged fish were repeat spawners (Table IV).

Fourteen age classes were identified in 1977 and of the two hundred fish aged 2.2+ (70%) was the dominant age class, 2+.2+ (11%) and 3.2+ (8%) respectively. Repeat spawners represented 3.5% of the population in four different age classes 2.2S1+, 3.1S1+ and 3.2S1+ (Table IV).

In the Deadman River, in 1984, fifteen age classes were identified (Table V). Again, maiden fish of the designations 2.2+ (63.3%), 2+.2+ (7.0%), and 3.2+ (3.1%) represented the majority of age classes and 2.1+ represented 4.7% of the population. In 1976 and 1977 only 1.4% and 0.5% of the population had the age designation 2.1+.

Repeat spawners represented 7.1% of the 1984 population compared with 2% and 3.5% in 1976 and 1977 respectively. Five age classes were identified including 2.2S+ (4.3%), 2.2S1+ (1.2%), 2+.1S1+ (0.4%), 2+.2S+(0.4%), 3.2S+ (0.4%)

Table IV Age classes of Thompson River steelhead sampled in 1976 and 1977 angler survey including sex female (F), male (M), number (N), and percentage.

Year	AGE COMPOSITION															Total
	Maiden Fish										Repeat Spawners					
	1+.2+	2.1+	2.2+	2.3+	2+.1+	2+.2+	2+.3+	3.1+	3.2+	3.3+	2.2S+	2.2S1+	2+.2S1+	3.1S1+	3.2S1+	
<u>76</u>																
M(N)			45	5		8		1	19	1		1	2			82
%			54.9	6.1		9.8		1.2	23.2	1.2		1.2	2.4			
F(N)		3	79	2	1	19			24				1			129
%		2.3	61.2	1.6	0.8	14.7			18.6				0.8			
Total																
N		3	124	7	1	27		1	43	1		1	3			211
%		1.4	58.8	3.3	0.5	12.8		0.5	20.4	0.5		0.5	1.4			
<u>77</u>																
M(N)	1	5	60	1	1	11		1	5				2			87
%	1.1	5.7	69.0	1.1	1.1	12.6		1.1	5.7				2.2			
F(N)	1	1	80	2	1	11		1	11				2	1	1	113
%	0.9	0.9	70.8	1.8	0.9	9.7		0.9	9.7				1.8	0.9	0.9	
Total																
N	2	6	140	3	2	22		1	16				4	1	1	200
%	1.0	3.0	70.0	1.5	1.0	11		0.5	8.0				2.0	0.5	0.5	

Table V Age classes of Deadman River steelhead sampled in 1984 including sex female (F), male (M), number (N) and percentage.

Year	<u>AGE COMPOSITION</u>															Total
	<u>Maiden Fish</u>						<u>Repeat Spawners</u>									
	1+.2+	2+.1+	2+.2+	2+.3+	2.1+	2.2+	2.3+	3+.1+	3.1+	3.2+	2+.1S1+	2+.2S+	2.2S+	2.2S1+	3.2S+	
<u>84</u>																
M(N)		1	6		5	45	1	1	2	2						63
%		1.4	8.6		7.1	64.3	1.4	1.4	2.9	2.9						
F(N)	1	3	12	1	7	117	3		2	6	1	1	11	3	1	169
%	0.5	1.6	6.5	0.5	3.8	62.9	1.6		1.1	3.2	0.5	0.5	5.9	1.6	0.5	
Total																
N	1	4	18	1	12	162	4	1	4	8	1	1	11	3	1	232
%	0.4	1.6	7.0	0.4	4.7	63.3	1.6	0.4	1.6	3.1	0.4	0.4	4.3	1.2	0.4	

and the regenerative scale $R.2S^+$ (0.4%) (Table V).

In 1976 78.7% of the population had smolted after spending two years and 21.3% after three years in freshwater. In 1977 89.2% of the population spent two years in freshwater before smolting and 9.8% three years (Table VI). Only 2 fish or 1% of the population smolted after one year in freshwater. Deadman River followed the general pattern with 93.5% of the population remaining in freshwater for two years and 6% for 3 years (Table VII).

Maiden fish representing .2+ ocean age class was the most common: 91.9%, 90.0%, and 82.8% in 1976, 1977 and 1984 respectively (Table VIII, IX, X). In 1976 age .3+ fish represented 3.8% and .1+ (2.4%). Other ocean aged fish (5.7%) were repeat spawners (Table VIII). In 1977 .1+ (4.5%) and .3+ (2%) completed the age class for maiden fish. Repeat spawners included 3.5% of the population. Ocean aged fish from the Deadman River were .1+ (8.2%) and .3+ (2.0%). Repeat spawners made up 7.1% of the population.

Size

Mean length of 1976 females was 83.7 cm considerably smaller than males 91.2 cm. Females ranged from 68.6 - 95.3 cm and males 63.5 - 108.0 cm. Mean length of males and females combined was 86.6 cm (Table X). Table X also summarizes the mean length at age for males and females separately and combined. The length frequency distribution

Table VI Freshwater age classes including sex female (F), male (M), number (N), and percentage of Thompson River steelhead sampled in the 1976 and 1977 angler survey.

Year	Sex	FRESHWATER AGE CLASSES			Total	
		1.	2.	3.		
1976	M (N)		61	21	82	
	%		74.4	25.6		
	F (N)		105	24	129	
	%		81.4	18.6		
Total	N		166	45	211	
	%		78.7	21.3		
1977	M (N)	1	75	6	82	
	%	1.2	91.4	7.3		
	F (N)	1	99	13	113	
	%	0.9	88.4	11.6		
	Total	N	2	174	19	193
		%	1.0	89.2	9.8	

Table VII Freshwater age classes including sex female (F), male (M), number (N) and percentage of steelhead sampled in the 1984 Deadman River enumeration fence.

		<u>FRESHWATER AGE CLASSES</u>			
	Sex	1.	2.	3.	Total
	M (N)		58	5	63
	%		92.1	7.9	
	F (N)	1	159	9	168
	%	0.4	94.6	5.0	
Total	N	1	217	14	232
	%	0.4	93.5	6.0	

Table VIII Ocean age classes including sex female (F), male (M), number (N) and percentage of Thompson River steelhead sampled in the 1976 and 1977 angler survey.

<u>OCEAN AGE CLASSES</u>								
Year	Sex	<u>Maiden Fish</u>			<u>Repeat Spawners</u>			Total
		.1+	.2+	.3+	.1S1+	.2S+	.2S1+	
1976	M (N)	1	72	6		1	2	82
	%	1.2	87.8	7.3		1.2	2.4	
	F (N)	4	122	2			1	129
	%	3.1	94.6	1.6			.8	
	Total N	5	194	8		1	3	211
	%	2.4	91.9	3.9		0.6	1.4	
1977	M (N)	7	77	1	1		2	89
	%	7.9	86.5	1.1	1.1		2.2	
	F (N)	2	103	3			4	111
	%	1.8	92.8	3.4			3.6	
	Total N	9	180	4	1		6	200
	%	4.5	90.0	2.0	0.5		3.0	

Table IX Ocean age classes including sex female (F), male (M), number (N), and percentage of steelhead sampled in the 1984 Deadman River enumeration fence.

		<u>OCEAN AGE CLASSES</u>						
		<u>Maiden Fish</u>			<u>Repeat Spawners</u>			
Sex		.1+	.2+	.3+	.1S1+	.2S+	.2S1+	Total
	M (N)	9	60	1				70
	%	12.9	85.7	1.4				
	F (N)	12	152	4	1	14	3	186
	%	6.5	81.7	2.2	0.5	7.5	1.6	
Total	N	21	212	5	1	14	3	256
	%	8.2	82.8	2.0	0.4	5.5	1.2	

Table X Age class, mean length (\bar{x}), range, and total numbers(n) of female (F) and male (M) steelhead sampled from 1976 Thompson River angler survey.

Age	<u>Length (cm) F</u>			<u>Length (cm) M</u>			<u>Length (cm) F and M</u>		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
1+.2+									
2.1+	76.9	70.0-83.8	2				76.9	70.0-83.8	2
2.2+	83.2	68.6-94.5	75	89.4	81.3-99.7	42	85.4	68.6-99.7	117
2.2S+				94.2	94.2	1	94.2	94.2	1
2.2S1+	83.3	91.4-95.5	1	93.4	91.4-95.5	2	90.1	83.3-95.5	3
2.3+	93.0	90.8-95.3	2	97.1	93.5-100.0	5	95.9	90.8-100.0	7
2+.1+	77	77	1				77.0	77.0	1
2+.2+	84.2	71.1-88.9	19	93.2	87.6-101.6	7	86.6	71.1-101.6	26
2+.2S1+									
2+.3+									
3.1+				63.5	63.5	1	63.5	63.5	1
3.1S1+									
3.2+	84.3	73.5-94.0	21	91.7	80.0-101.6	18	87.5	73.5-101.6	39
3.3+				95.3	95.3	1			1
x	83.5	68.6-95.5	121	90.7	63.5	77		63.5-101.6	198
*	83.7	68.6-95.3	160	91.2	63.5-108.0	102	86.6	63.5-108.0	266

* Data include mean length and range of fish that were not aged but for which a length was available.

for Thompson steelhead sampled in the 1976 angler survey is shown in Figure 9. In 1977 mean length for females was 83.9 cm and males 89.4 cm. Females ranged from 66.0 - 105.0 cm and males 66.0 - 112.0 cm. Mean length for both sexes was 86.3 cm (Table XI). Table XI also summarizes the mean length at age for males and females separately and combined. The length frequency distribution for Thompson steelhead sampled in the 1977 angler survey is shown in Figure 10.

Deadman River females had a mean length of 79.7 cm and the males 83.6 cm (Table XII). Females ranged from 62.0 - 91.0 cm and males from 65.0 - 99.0 cm. The mean length for males and females in 1984 was 80.7 cm. Table XII also summarizes the mean length at age for males and females separately and combined. The length frequency distribution for Thompson steelhead sampled in the 1984 enumeration fence is shown in Figure 11. Mean lengths were not significantly different for the three sample years: 1976, 1977, and 1984 ($P > .05$) and two rivers (mainstem Thompson and Deadman).

Greater body length of adult steelhead was positively correlated with longer ocean residence. In all sample years (1976, 1977 and 1984) the greater the number of years spent in the ocean the greater the body length (Tables X, XI, and XII).

Mean female weight in 1976 (Table XIII) was 6.3 kg (range

Figure 9 Length frequency distribution of Thompson
River steelhead captured in the 1976 angler
survey.

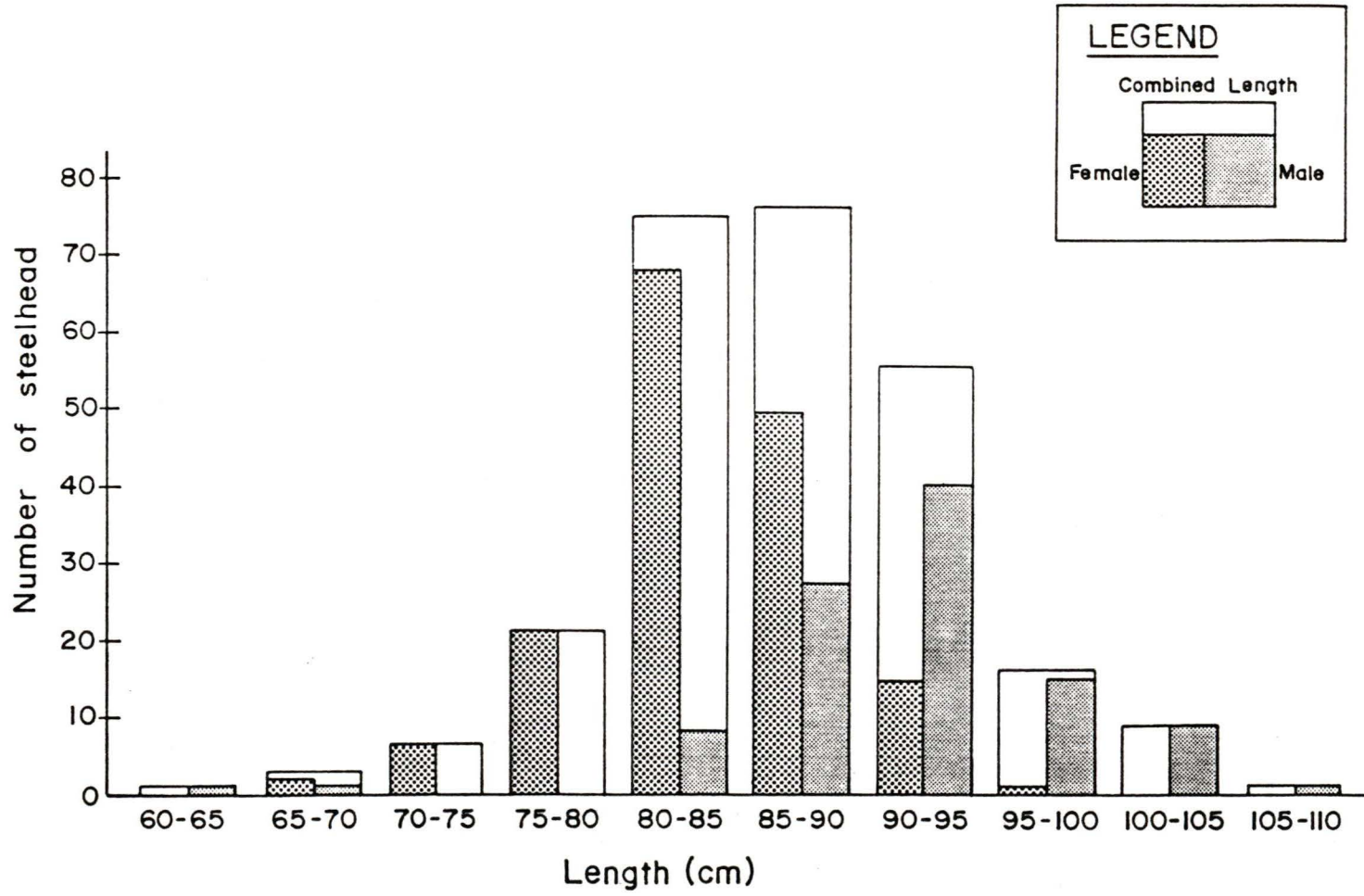


Table XI Age class, mean length (\bar{x}), range, and total numbers(n) of female (F) and male (M) steelhead sampled from 1977 Thompson River angler survey.

Age	<u>Length (cm) F</u>			<u>Length (cm) M</u>			<u>Length (cm) F and M</u>		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
1+.2+	86.0	86.0	1	84.0	84.0	1	85.0	84.0-86.0	2
2.1+	67.0	67.0	1	77.8	68.0-88.0	5	76.0	67.0-88.0	6
2.2+	83.3	74.0-96.0	80	90.0	71.0-105.0	60	86.2	71.0-105.0	140
2.2S+									
2.2S1+	90.5	90.0-91.0	2	93.0	89.0-97.0	2	91.7	89.0-97.0	4
2.3+	97.0	89.0-105.0	2	107.0	107.0	1	100.3	89.0-107.0	3
2+.1+	66.0	66.0	1	76	76.0	1	71.0	66.0-76.0	2
2+.2+	83.9	79.0-90.0	11	89.7	82.0-97.0	11	86.8	79.0-97.0	22
2+.2S1+	86.0	86.0	1				86.0	86.0	1
2+.3+				91.0	91.0	1	91.0	91.0	1
3.1+				79.0	79.0	1	79.0	79.0	1
3.1S1+				97.0	97.0	1	97.0	97.0	1
3.2+	87.0	81.0-94.0	11	89.8	85.0-95.0	5	87.9	81.0-95.0	16
3.2S1	93.0	93.0	1				93.0	93.0	1
x	43.9	66.0-105.0	111	89.2	68.0-107.0	89	86.3	66.0-107.0	200
*	83.9	66.0-105.0	208	89.4	68.0-112.0	164	86.3	66.0-112.0	372

* Data include mean length and range of fish that were not aged but a length was available.

Figure 10 Length frequencies of Thompson River steelhead captured in the 1977 angler survey.

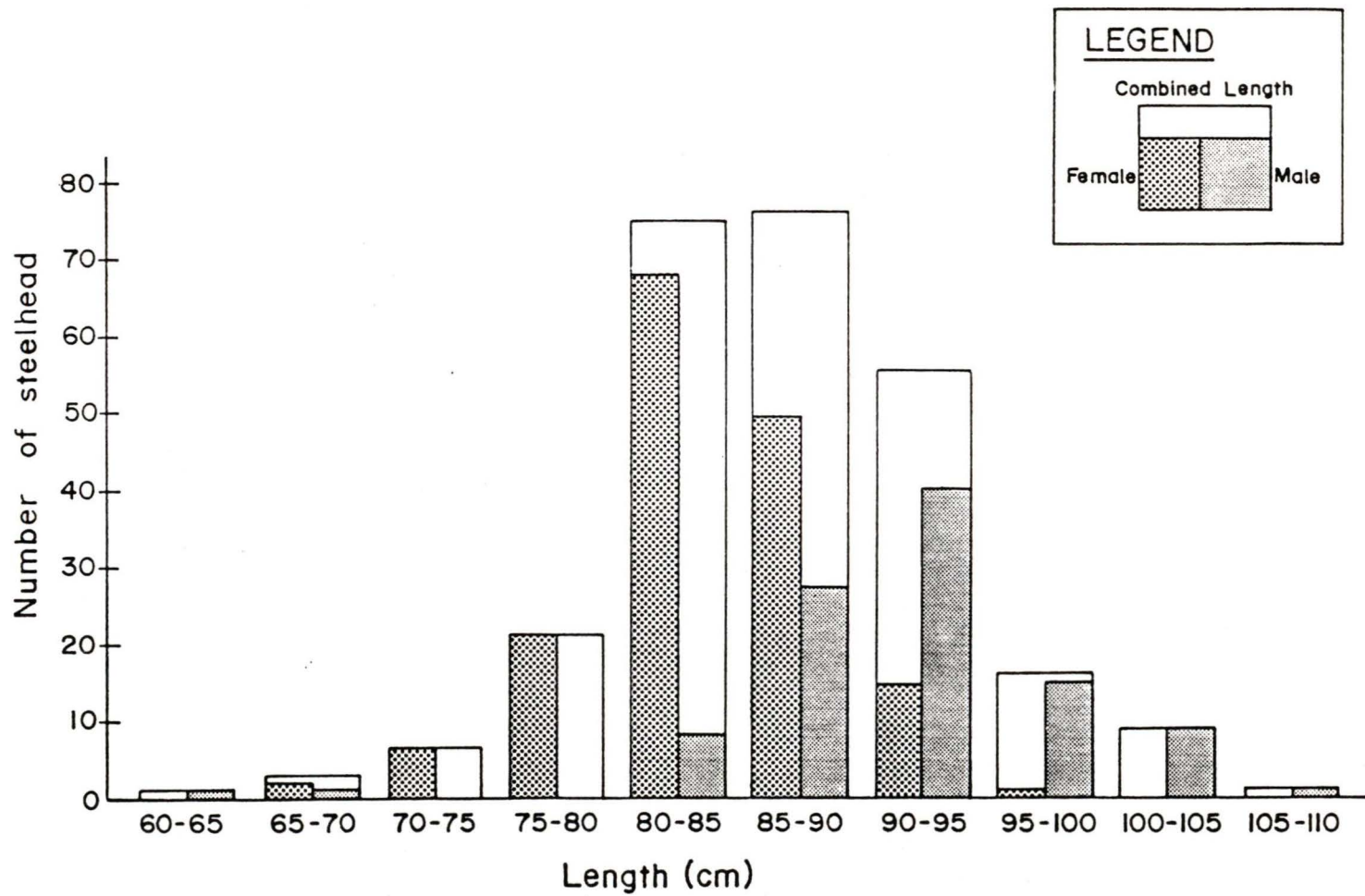


Table XII Age class, mean length (\bar{x}), range, and total numbers(n) of female (F) and male (M) steelhead sampled from Deadman River in 1984.

Age	<u>Length (cm) F</u>			<u>Length (cm) M</u>			<u>Length (cm) F and M</u>		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
1+.2+	78.0	78.0	1	66.5	66.5	1	78.0	78.0	1
2+.1+	65.7	63.5-69.5	3				65.9	63.5-69.5	4
2+.1S1+	82.5	82.5	1				82.5	82.5	1
2+.2+	81.5	70.0-89.0	12	85.5	76.0-91.5	6	82.9	70.0-91.5	18
2+.2S+	80.5	80.5	1				80.5	80.5	1
2+.3+	87.0	87.0	1				87.0	87.0	1
2.1+	71.1	62.0-84.0	7	69.1	65.0-74.0	5	70.3	62.0-84.0	12
2.2+	79.6	68.5-91.0	117	85.4	69.0-96.0	44	81.2	68.5-96.0	162
2.2S+	82.4	77.5-86.5	11				82.4	77.5-86.5	11
2.2S1+	86.3	84.0-90.0	3				86.3	84.0-90.0	3
2.3+	89.3	88.5-90.5	3	96.0	96.0	1	91.0	88.5-96.0	4
3+.1+				70.0	70.0	1	70.0	70.0	1
3.1+	67.0	66.0-68.0	2	72.5	72.0-73.0	2	69.7	66.0-73.0	4
3.2+	81.7	76.0-88.0	6	92.5	86.0-99.0	2	84.4	76.0-99.0	8
3.2S+	85.5	85.0	1				85.5	85.5	1
x	79.6	62.0-91.0	169	83.5	65.0-99.0	63	80.7	62.0-99.0	232
*	79.7	62.0-91.0	187	83.6	65.0-99.0	70.0	80.7	62.0-99.0	257

* Data include mean length and range of fish that were not aged but a length was available.

Figure 11 Length frequencies of Thompson River steelhead captured in the counting fence located on the Deadman River.

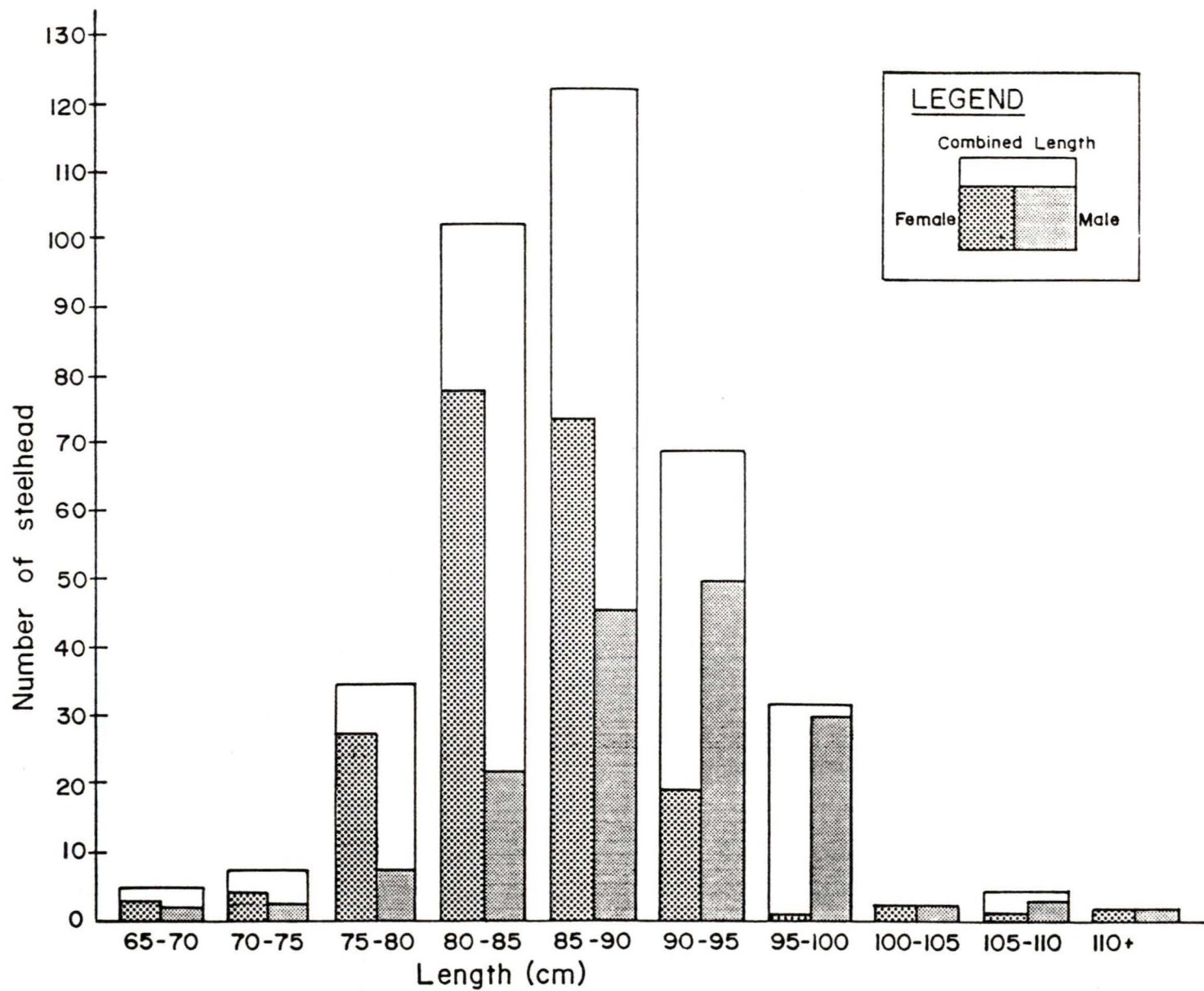


Table XIII Age class, mean weight (\bar{x}), range, and total numbers(n) of female (F) and male (M) steelhead sampled from 1976 Thompson River angler survey.

Age	<u>Weight (Kg) F</u>			<u>Weight (Kg) M</u>			<u>Weight (Kg) F and M</u>		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
2.1+	4.5	3.6-6.2	3				4.5	3.6-6.2	3
2.2+	6.2	4.3-8.9	77	7.8	5.9-10.4	45	6.8	4.3-10.4	122
2.2S+	9.3	9.3	1	9.3	9.3	1	9.3	9.3	2
2.2S1+	5.6	5.6	1	8.5	8.1-9.0	2	7.6	5.6-9.0	3
2.3+	7.2	7.2	1	10.3	9.7-11.1	5	9.4	7.2-11.1	6
2+.1+	5.5	5.5	1				5.5	5.5	1
2+.2+	6.6	5.3-8.7	19	8.4	6.3-9.9	8	7.2	5.3-9.9	27
3.1+				2.6	2.6	1	2.6	2.6	1
3.2+	6.4	5.0-9.0	22	7.9	5.9-10.8	19	7.1	5.0-10.8	41
3.3+				9.6	9.6	1	9.6	9.6	1
x	6.3	3.6-9.3	125	8.0	5.9-11.1	82	7.0	3.6-10.8	207
*	6.3	3.4-9.8	169	8.1	2.6-13.5	107	7.0	2.6-13.5	276

* Data include mean weight and range of fish that were not aged but for which a weight was available.

4.6 - 7.8 kg). Mean weight for males was 8.1 kg (range 2.6 - 13.5 kg). Mean weight for both sexes was 7.0 kg. The predominant combined age class (M + F) is 5 (2.2+) years and the mean weight is 6.8 kg.

In 1977 mean weight of females (Table XIV) was 6.3 kg (range 3.1 - 11.1 kg). Males had a mean weight of 7.7 kg (range 3.6 - 14.6 kg). The predominant combined age class (M + F) is 5 (2.2+) years and the mean weight is 6.8 kg. Mean weight between years for each sex was not found to be significantly different ($P > 0.05$). As expected fish spending 3 years in ocean had the greatest weight and one year the least.

Steelhead, for the purposes of this study, were sampled at two different time periods. In 1976 and 1977 adults were sampled in the fall during the Thompson sports fishery and in 1984 from Deadman River during the spring spawning migration. Weight loss over the 6-8 month holding period in the Thompson River is expected to be significant, although it has not yet been determined. It must be remembered that the weights of Thompson River steelhead as they ascend tributaries is less than fish that initially entered freshwater as summer run steelhead (Shapovalov and Taft, 1954).

Mean weight for 1984 Deadman females (Table XV) was 5.3 kg and ranged from 2.7 - 8.6 kg. Males had a mean weight of 6.0 kg and ranged from 3.0 - 9.3 kg. Mean weight for both

Table XIV Age class, mean weight (\bar{x}), range, and total number(n) of female (F) and male (M) steelhead sampled from 1977 Thompson River angler survey.

Age	Weight (kg) F			Weight (kg) M			Weight (kg) F and M		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
1+.2+	6.4	6.4	1	7.3	7.3	1	6.8	6.4-7.3	2
2.1+	3.7	3.7	1	7.0	5.5-8.5	2	5.9	3.7-8.5	3
2.2+	6.1	4.5-8.2	68	7.7	4.2-10.7	56	6.8	4.2-10.7	124
2.2S1+	7.6	7.6-7.7	2	7.9	7.3-8.6	2	7.8	7.3-8.6	4
2.3+	9.4	7.7-11.1	2	11.4	11.4	1	10.1	7.7-11.4	3
2+.1+				3.6	3.6	1	3.6	3.6	1
2+.2+	5.9	5.1-6.5	8	7.6	5.1-10.0	9	6.8	5.1-10.0	17
2+.3+				7.5	7.5	1	7.5	7.5	1
3.1+				4.6	4.6	1	4.6	4.6	1
3.1S1+				9.8	9.8	1	9.8	9.8	1
3.2+	7.1	5.9-9.1	8	7.4	5.9-8.5	3	7.2	5.9-9.1	11
3.2S1+	7.5	7.5	1				7.5	7.5	1
x	6.3	3.7-11.1	91	7.6	3.6-11.4	78	6.9	3.6-11.4	169
*	6.3	3.1-11.1	181	7.7	3.6-14.6	146	6.9	3.1-14.6	327

* Data include mean weight and range of fish that were not aged but for which a weight was available.

Table XV Age class, mean weight (\bar{x}), range, and total numbers(n) of female (F) and male (M) steelhead sampled in the 1984 Deadman River enumeration fence.

Age	Weight (kg.) F			Weight (kg.) M			Weight (kg.) F and M		
	\bar{x}	Range	n	\bar{x}	Range	n	\bar{x}	Range	n
1+.2+	5.2	5.2	1				5.2	5.2	1
2+.1+	3.0	2.7-3.2	3	3.0	3.0	1	3.0	2.7-3.2	4
2+.1S1+	5.1	5.1	1				5.1	5.1	1
2+.2+	5.8	3.6-7.3	12	6.1	3.6-7.3	6	6.0	3.6-8.2	18
2+.2S+	6.2	6.2	1				6.2	6.2	1
2+.3+	7.4	7.4	1				7.4	7.4	1
2.1+	4.2	2.7-7.6	7	3.2	2.8-3.6	5	3.8	2.7-7.6	12
2.2+	5.3	3.2-8.6	112	6.4	3.9-9.3	45	5.6	3.2-9.3	157
2.2S+	5.2	3.6-6.6	11				5.2	3.6-6.6	11
2.2S1+	6.6	6.0-7.5	3				6.6	6.0-7.5	3
2.3+	7.0	6.1-7.6	3	9.2	9.2	1	7.3	6.1-9.2	4
3+.1+				3.1	3.1	1	3.1	3.1	1
3.1+	3.3	3.2-3.4	2	3.9	3.8-4.0	2	3.6	3.2-4.0	4
3.2+	5.4	4.7-6.9	5	7.5	6.8-8.2	2	6.0	4.7-8.2	7
3.2S+	7.3	7.3	1				7.3	7.3	1
x	5.3	2.7-8.6	163	6.0	2.8-9.3	63	5.5	2.7-9.3	226
*	5.3	2.7-8.6	181	6.0	2.8-9.3	70	5.5	2.7-9.3	251

* Data include mean weight and range of fish that were not aged but for which a weight was available.

sexes was 5.5 kg and the range 2.7 - 9.3 kg. The dominant combined age class (M & F) is 5 (2.2⁺) years and the mean weight is 5.6 kg.

Sex Ratios

In 1976, 290 adult steelhead were sampled by creel census: 286 were sexed resulting in a male:female sex ratio of 1:1.60. In 1977, 391 fish were sampled, all were identified to sex and the male:female ratio was 1:1.27. The two hundred and fifty-seven steelhead processed through a counting fence on the Deadman River in 1984 had a sex ratio of 1:2.67 male:female.

Fecundity

Histogram analysis verified that the length frequency distribution of 36 Thompson River steelhead followed a normal distribution (Appendix II). The regression of fecundity versus length was found to be linear, after examining the residuals and observing no pattern (Appendix III). The relationship was described by the following equation:

$$F = 283.364(L) - 11872.90 \text{ (+/-}3648 \text{ at } p = 0.05)$$

where F = number of eggs and L = length in cm.

Thompson steelhead fecundity ranged from 5,907 to 18,402 with a mean of 12,614 significantly greater than any race of steelhead sampled to date. Length of sampled steelhead ranged from 68.0 - 105 cm with a mean of 86.5 cm. A coefficient of determination, .65, indicated moderate

variability between females of similar size.

River Temperature and Discharge

Water temperature on the Thompson River during the study period ranged from a low of 0°C to a high of 15°C (Figure 4). At one point in late January shore and anchor ice formed on the Thompson River. The three major tributaries, Deadmans, Bonaparte and Nicola were ice covered for variable periods (Figure 5,6,7) with Deadman covered the longest from mid December to early March (Figure 5,6,7). Only spot temperatures were available for Deadman and Bonaparte (Figure 5 & 6). Temperatures on the Nicola ranged from a low of 0°C to 10.5 C° (Figure 7).

Maximum daily discharge from September to June on the Thompson River was 1,982 m³/s, while the daily minimum approached 142 m³/s. Discharges for the three tributaries are outlined in Figures 5, 6, and 7.

Steelhead migratory biology appeared correlated to water temperature and discharge. When these two parameters were at a minimum for the year (mid January - mid March) movements of radio tagged steelhead terminated. Conversely, as temperature and discharge increased movements were initiated.

Back-Calculated Lengths of Juvenile, Smolt and Adult

Steelhead from Body-Length and Scale-Radius Relationships.

A simple regression of fork length and scale radius, including juveniles (excluding 0⁺), smolts and adult

steelhead, was plotted to determine the intercept 'c' for use in the Fraser-Lee proportionality equation (Figure 12). Underyearling (0^+) fish were omitted because they often display curvilinearity due to scale growth catch-up in the body-length scale-radius relationship (Carlander, 1981; Lewynsky et al; 1986, Ward (In prep.)). Linearity was tested by examining the residual plot of expected vs observed lengths which indicated a curvilinear pattern and the need to transform the data (Figure 13).

Logarithmic transformation produced a curve that appeared linear and after examining a random pattern of residual plots, near linearity was verified (Figures 14 and 15). Lewynsky et al; (1986) showed logarithmic transformation did not improve the coefficients of determination but did stabilize the residual. Similar results were shown in logarithmic transformation of Thompson steelhead: coefficients of determination were 0.97 for raw data and 0.98 for the transformed data. The Fraser-Lee proportion formula was then used to back-calculate lengths for freshwater and ocean ages of Thompson River steelhead.

Back-calculated fork lengths for freshwater age 1 to 3 fish, smolts and ocean age 1 to 3 fish are summarized in Table XVI. No consistent differences between years (1976 and 1977) were evident in the mean length back-calculated for freshwater age 1 and 2 fish. Age 3 fish showed a slight difference between 1976 and 1977 which could be due

Figure 12 Body length-scale radius relationship for juvenile and adult steelhead sampled from the Thompson River (n=672). Numbers indicate frequency greater than one.

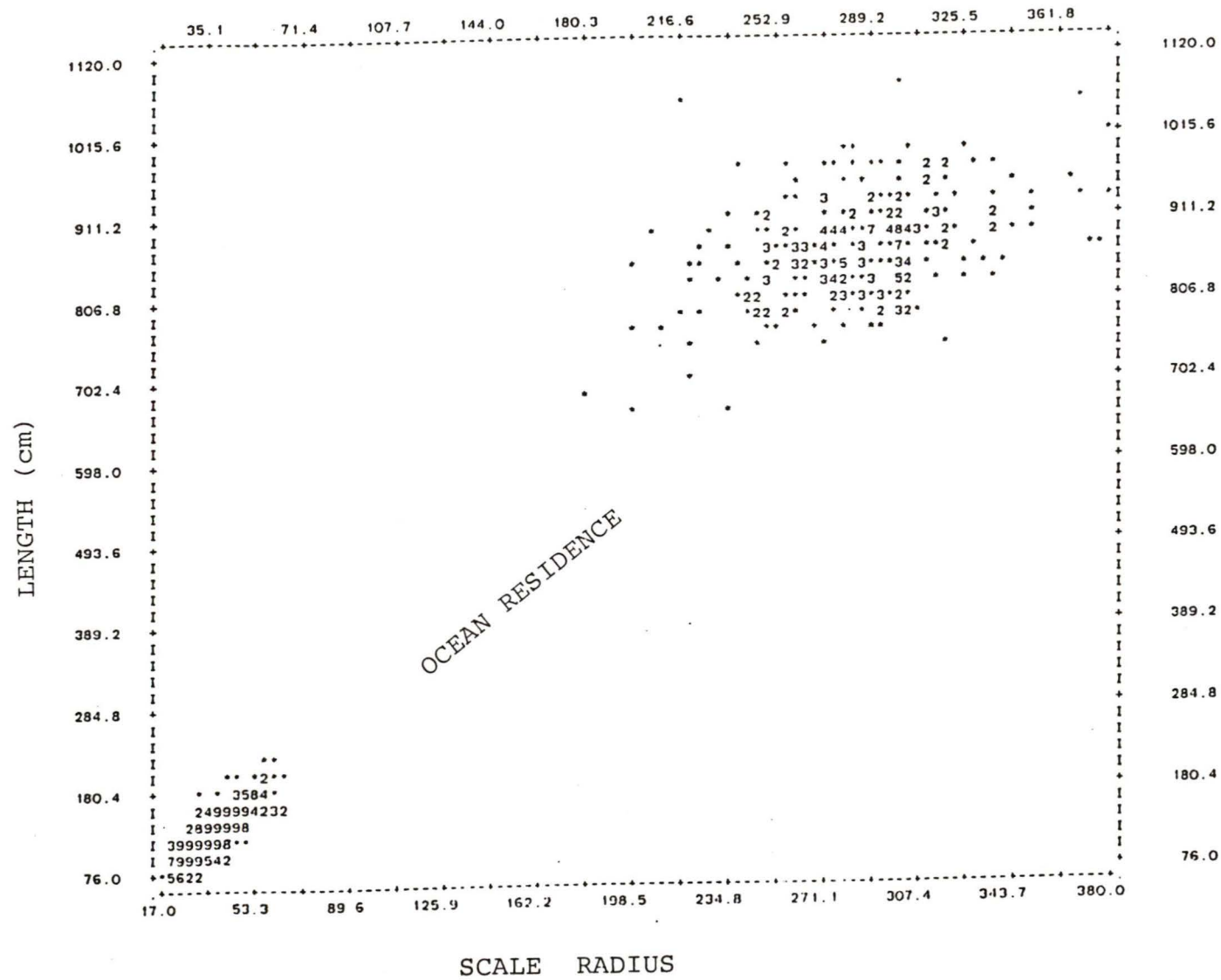


Figure 13 Standardized residual plot of observed and expected lengths.

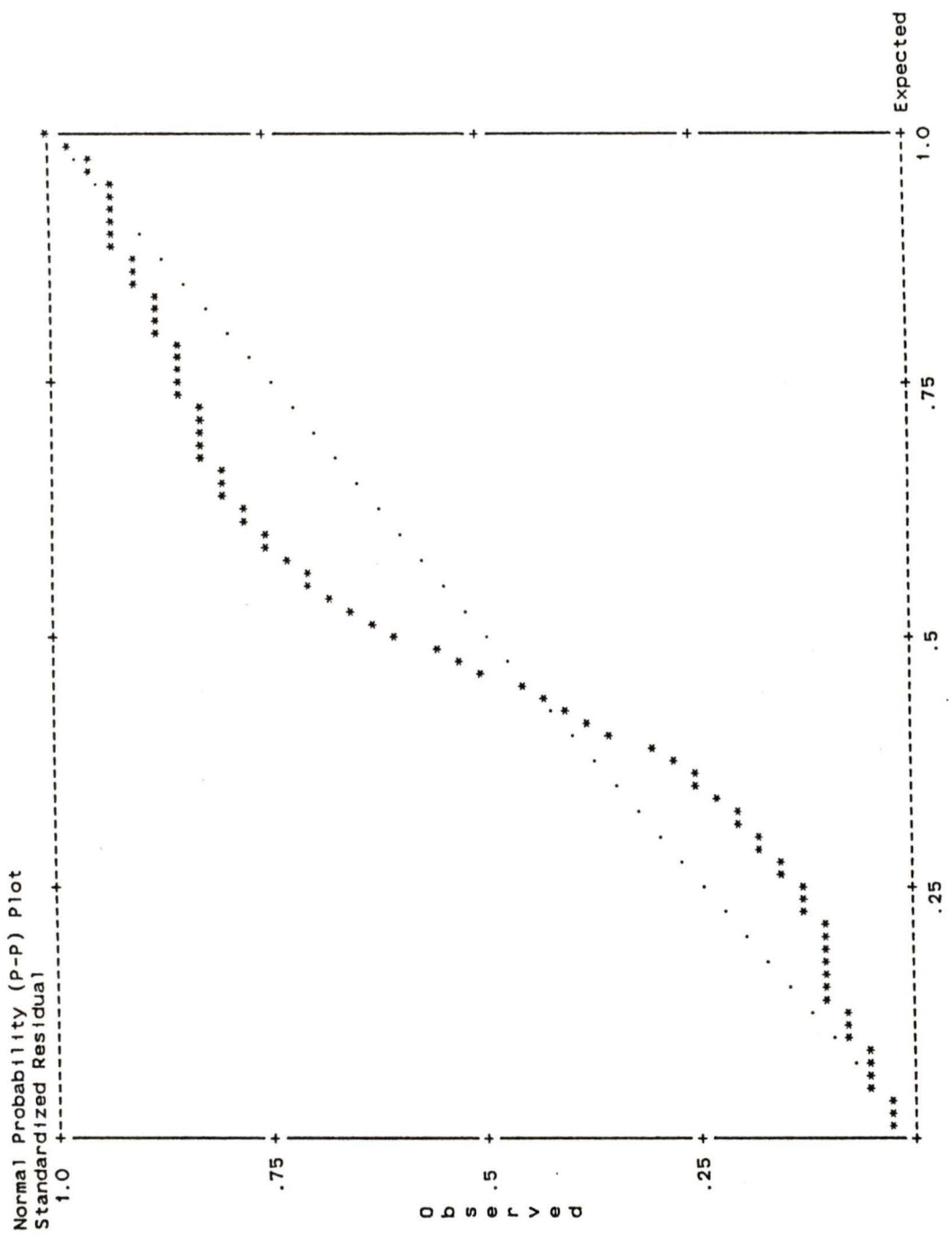


Figure 14 Logarithmic transformed body length-scale
radius relationship for juvenile and adult
steelhead from the Thompson River (n=672).
Numbers indicate frequency greater than one.

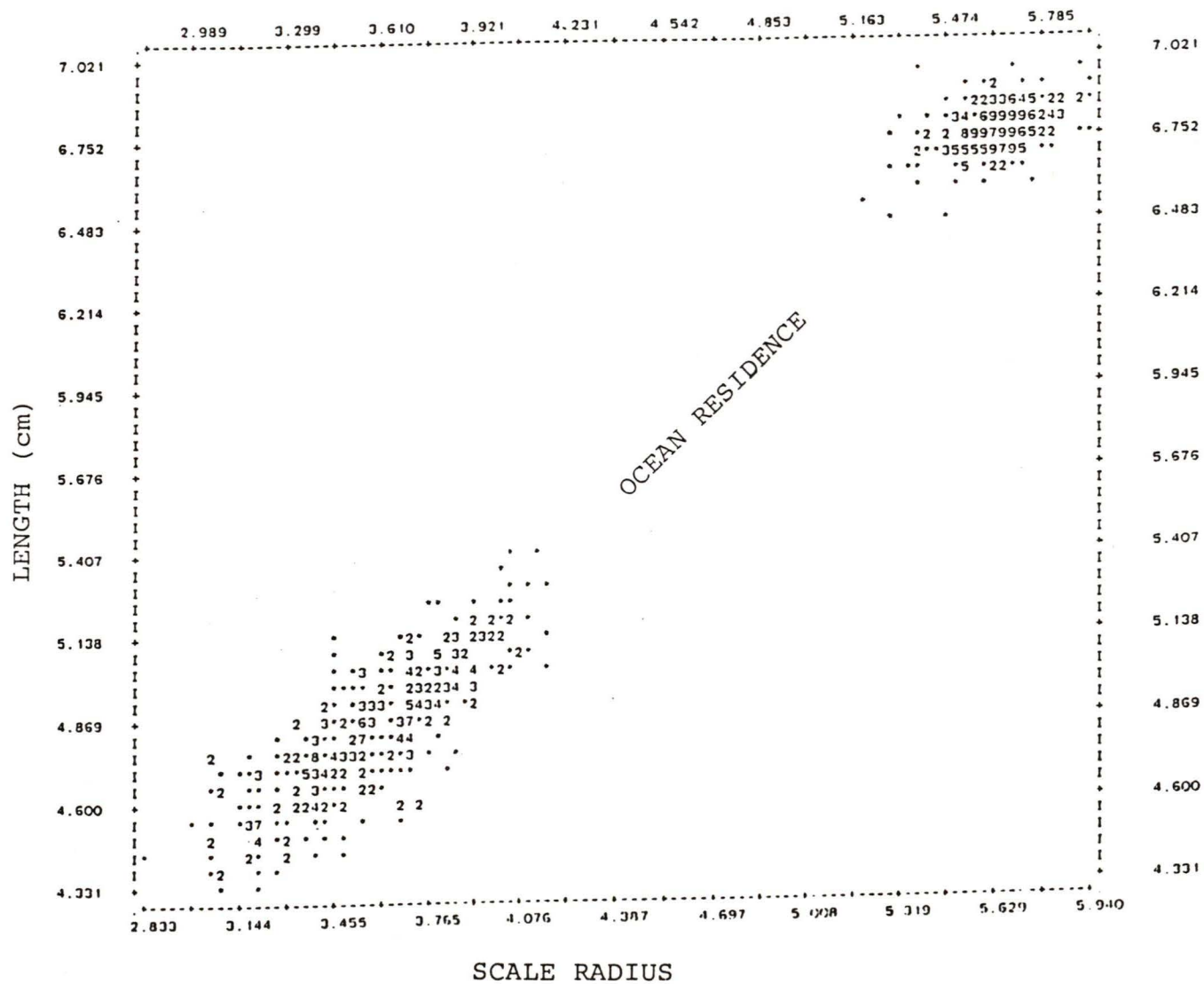


Figure 15 Standardized residual plot of observed and expected length of juvenile and adult Thompson steelhead.

Normal Probability (P-P) Plot
Standardized Residual

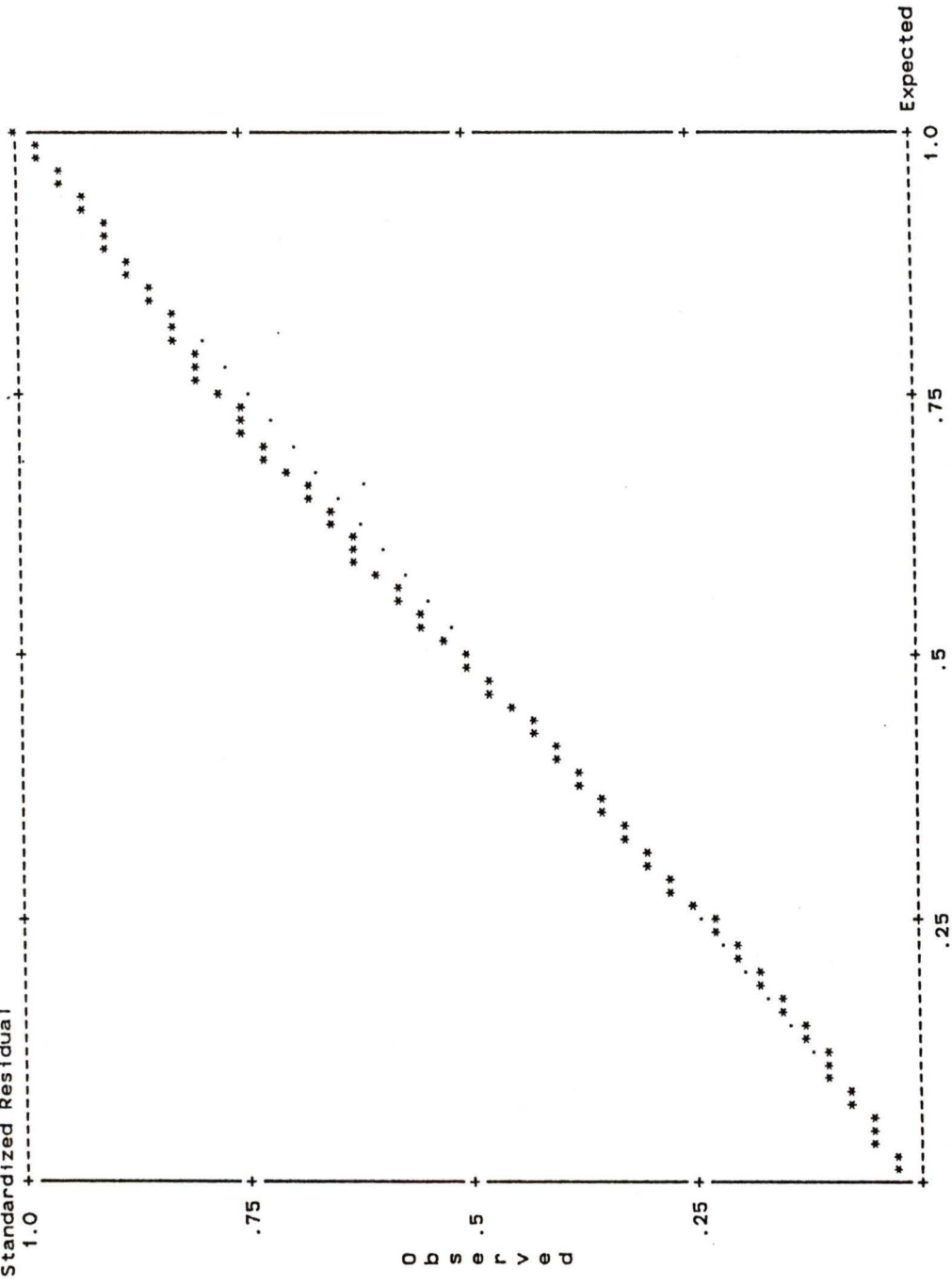


Table XVI Back-calculated fork lengths (mm) and range of juvenile and adult steelhead as determined from scale samples obtained from the 1976 and 1977 sport fishery

<u>JUVENILE BACK-CALCULATIONS (FRESHWATER)</u>											
1976				1977				1976 and 1977 combined			
Age	Mean	Range	n	Age	Mean	Range	n	Age	Mean	Range	n
1.	70.8	37.0-111.2	98	1.	69.0	32.4-111.7	200	1.	69.6	32.4-111.	298
2.	157.8	85.0-271.7	98	2.	154.0	62.0-242.1	198	2.	155.2	62.9-271.7	296
3.	209.6	160.0-276.6	20	3.	183.6	139.3-265.5	20	3.	196.6	139.3-276.6	40
Smolt	182.9	112.1-276.6	97	Smolt	166.0	108.0-265.5	200	Smolt	171.5	108.0-276.6	297

<u>ADULT BACK-CALCULATIONS (OCEAN)</u>											
1976				1977				1976 and 1977 combined			
Age	Mean	Range	n	Age	Mean	Range	n	Age	Mean	Range	n
.1	484.9	384.8-600.	298	.1	485.9	366.6-668.9	200	.1	485.6	366.6-668.9	298
.2	782.9	672.8-898.	697	.2	779.3	619.7-1025.5	191	.2	780.5	619.7-1025.5	288
.3	888.5	827.5-932.1	4	.3	946.6	870.7-1031.9	4	.3	917.5	827.5-1031.9	8

to small sample size.

Back-calculated smolt sizes, for 1976 (182.9 mm) and 1977 (166.0 mm), were not significantly different ($p > 0.05$). Mean length of thirty-three smolts captured in the Deadman River 167.2 mm (per.obs) was only slightly different from the combined smolt lengths of 171.5 cm for 1976 and 1977. No consistent differences were evident in ocean aged 1 and 2 year fish (Table XVI). Differences exhibited in back-calculated ocean aged 3 fish appear to be due to sample size. Only 4 fish of the ocean age 3 were sampled in each of the two years.

Back-calculated adult lengths showed differences between sexes. Males, as expected, were larger for each age class in 1976 and 1977 (Figure 16 & 17). Back-calculated data are consistent with observed lengths obtained from creel sampled adults, males being larger than females for all ocean age classes. Mean adult back-calculated lengths were consistently lower than adult lengths sampled from the sport fishery located at Spences Bridge. This was understandable because measurement of adult scale radius for back-calculation was done from the focus to the termination of each ocean winter. However, Thompson steelhead are a late summer run stock, and they have a spring and the better portion of one summer to feed before returning to be caught in the freshwater sport fishery. For example, a fish spending two complete winters in the

Figure 16 Back-calculated mean fork lengths of 1976
ocean aged male (M) and female (F) Thompson
steelhead.

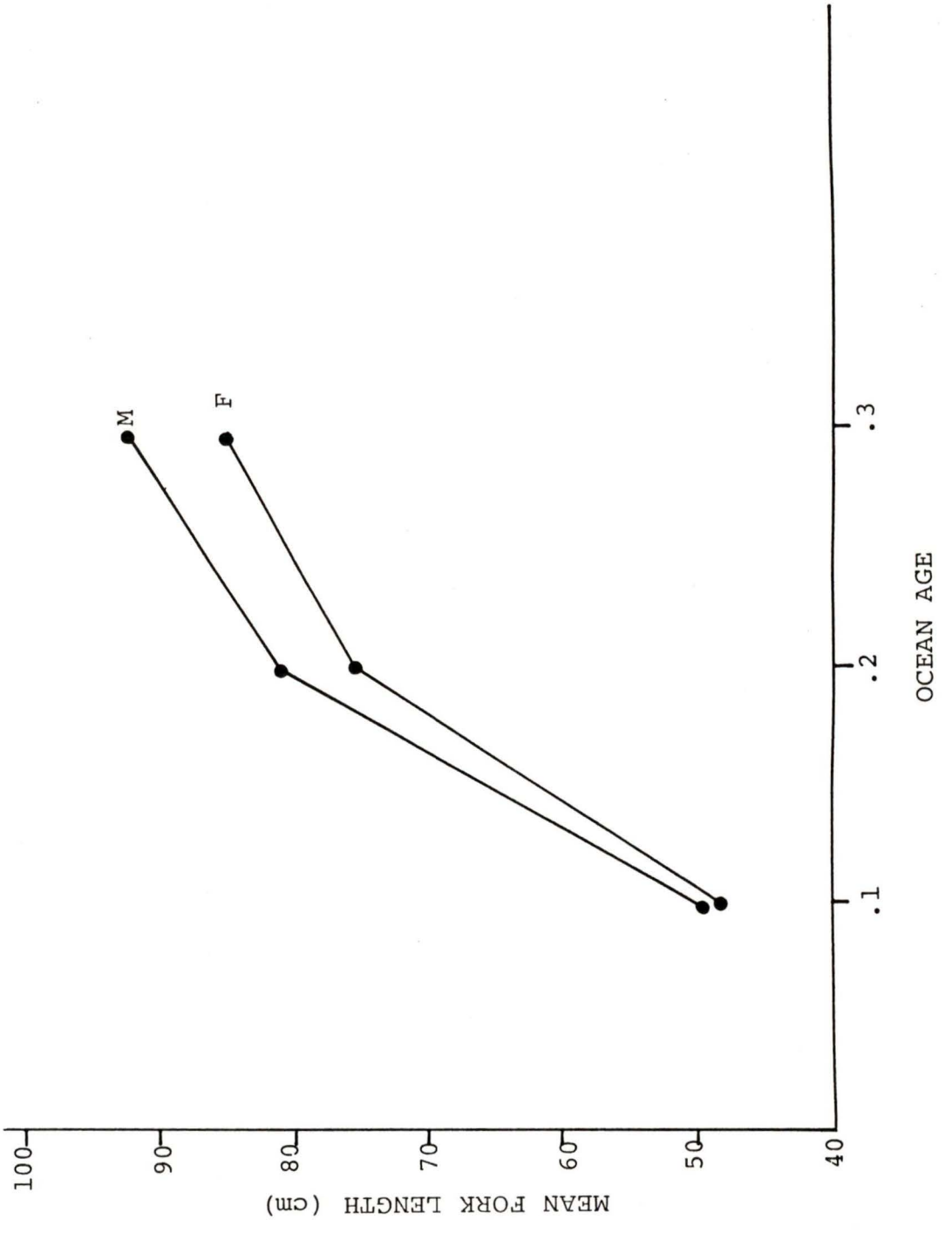
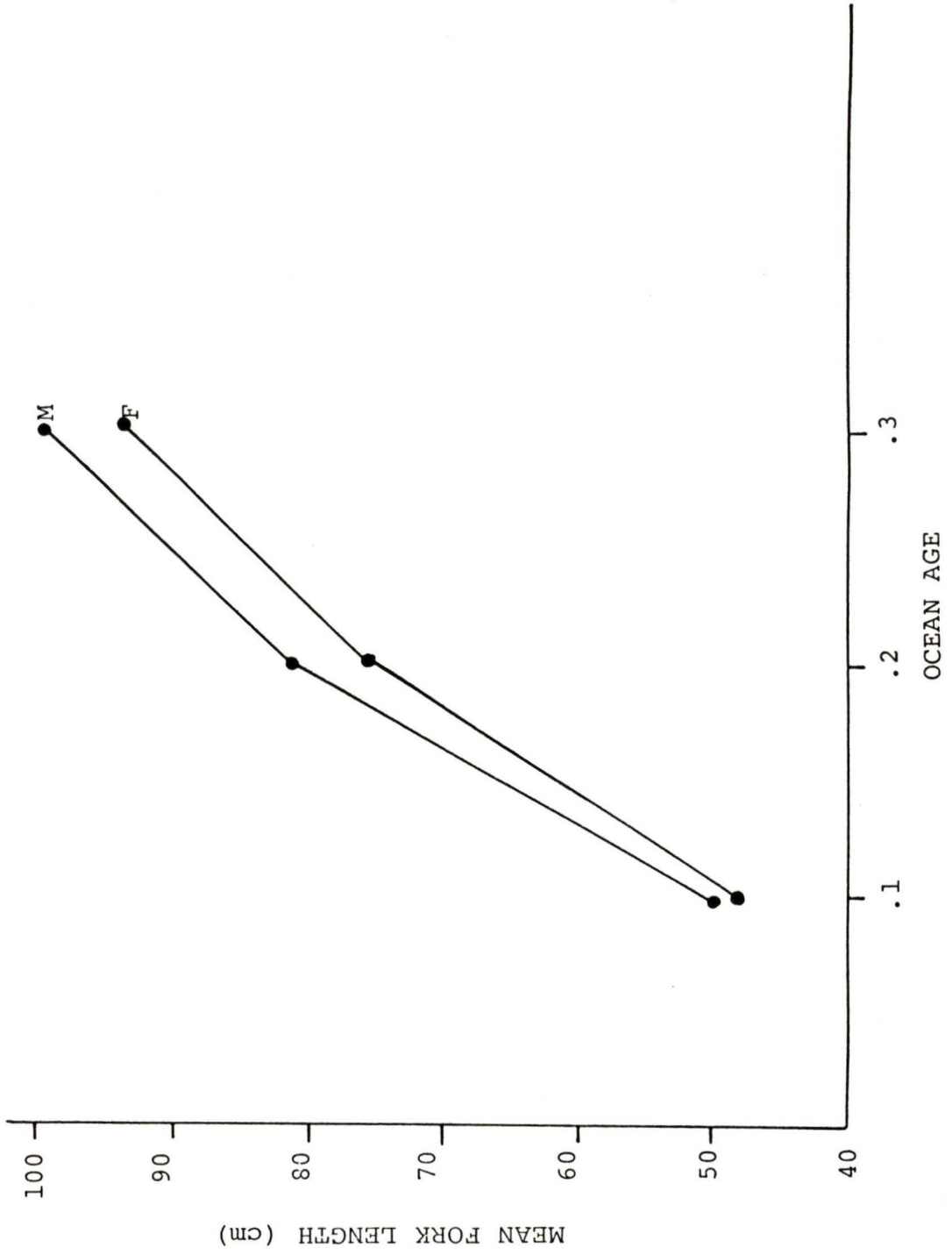


Figure 17 Back-calculated mean fork lengths of 1977
ocean aged male (M) and female (F) Thompson
steelhead.



ocean would only have a back-calculated length to the end of the second winter. Any time spent feeding and growing after the second ocean winter would not be taken into consideration by back-calculation.

Discussion

Radio Tagging and Overwintering

Historical observations suggested that late summer run steelhead immigrated into the Spences Bridge area of the Thompson River and remained stationary until the freshet of the following spring.

Radio tagging results show that this speculation was not entirely correct and that steelhead, after entering the Thompson River, exhibit both upstream and downstream movements and long periods without movement. Spence (1980) and Lough (1980) investigating summer steelhead migration behavior in the Chilcotin and Skeena Rivers respectively observed results similar to those of the present study with radio tagged steelhead. They described fall steelhead migration as sporadic with fish moving upstream and downstream interspersed with position holding. Pettit and Lindland (1979), studying summer steelhead in the Clearwater River in Idaho, also made similar observations. Six of eight radio tagged steelhead were reported to have migrated 20-30 km upstream in the Clearwater River, then downstream from the Clearwater to overwinter in the Snake River, a major tributary of the Columbia River. They did not return to the Clearwater to spawn until freshet the following spring. Burger et al; (1983) studying fall steelhead migration in the Copper River in Alaska and Hooton and Lirette (1985) investigating winter steelhead

migration in the Gold River on Vancouver Island British Columbia found similar behavior. Hooton and Lirette (1985) speculated that radio tag insertion may have interrupted normal upstream migration and initially may cause radio tagged steelhead to remain at the tagging location or to move downstream.

Evidence from the present study, although not conclusive, suggests that stress from handling and radio tagging may have caused initial downstream movement of 7 of 28 fish. Spence (1980) indicated that both upstream and downstream movements monitored after fall tagging continued long after release and appeared to correlate with the onset of winter, declining river temperatures and discharge and not just with the tagging procedure.

Published literature appears to suggest immediate downstream migration can result from the trauma of radio tagging but there is also evidence to suggest that long-term extrinsic factors such as ice build-up, declining water temperature, may individually or in concert affect fall and early winter movements of summer steelhead (Lough 1980, and Spence 1980). Spence (1980) and Pettit (1979) reported 20-30 km late fall and early winter downstream movements in the Chilcotin and Clearwater Rivers respectively. One verified radio tagged Thompson steelhead moved 22 km downstream from the original site. Because of poor access and the original assumption that

fish always migrated upstream, minimal amounts of time were expended tracking fish downstream of the Thompson-Fraser confluence in the present study. More lengthy downstream movements of radio tagged steelhead might explain the disappearance of some tagged individuals.

It was noteworthy that radio tagged Thompson steelhead generally terminated migratory movements during the winter months from mid-January to mid-March as water flows and temperatures both approached seasonal minima (Figure 4). In contrast Lough (1980) and Spence (1980) reported downstream movements throughout the winter months. Such behavior was not observed with Thompson fish. The Skeena and Chilcotin Rivers, studied by the Lough and Spence, are generally ice covered all winter whereas the Thompson is never ice covered. Speculatively, moderate water temperatures and the absence of anchor ice might account for reduced mid-winter movements.

A combination of radio tagging results and information from experienced Thompson River anglers shows that over-wintering occurs throughout the length of the Thompson river from Lytton to Kamloops Lake with concentrations below the Nicola and Deadman Rivers. There appeared to be little or no overwintering in mainstem tributaries.

Spring Migration and Spawning

Radio tagged Thompson steelhead resumed upstream migration in mid-March as water temperatures approached 2.5°C. Lough

(1980) noted migration in the Skeena tributaries began in April and early May as water temperature increased above 2°C. One radio tagged steelhead migrated into the Nicola River on April 12, although steelhead have been verified in the Nicola by angling as early as March 17 (Per. obs). Temperature in the three major tributaries: Deadman, Bonaparte, and Nicola Rivers ranged from 6-12°C during spring upstream movements. Lough (1980) reported temperatures in tributary streams ranging from 4-9°C while Spence (1980) and Winter (1976) reported temperatures from 6-9°C.

Behavioral observations of radio tagged steelhead showed that they entered the major mainstem tributaries, Deadman, Bonaparte, and Nicola Rivers on rising but not peak flows. After entry they avoided peak flood events by using stream margins or continuing movements on dropping stream levels. Hooton and Lirette (1985) reported similar characteristics during peak flows observing lateral movement to the stream margins where velocities were minimal. Lough (1980) reported similar movement patterns and in some cases downstream displacement.

Upstream movement of radio tagged steelhead into the Deadman and Nicola Rivers was primarily nocturnal. Olmstead and Moore (1984) observed similar nocturnal movements (between 1700 h - 0600 h) while operating a fish counting fence on Deadman River. Winter (1976) observed

steelhead entering tributary rivers more frequently during the night and early morning hours.

Migration of tagged fish into smaller spawning tributaries ($<2.0 \text{ m}^3/\text{s}$) of the Nicola River (Shakan, Skuhun and Nuaitch Creek) were mainly dependent on flow (Per. obs.) Steelhead are the only anadromous species that utilize these streams, probably because adequate flows are only available during spring freshet.

One radio tagged male entered Nuaitch Creek, spawned and emigrated within ten days. Everest (1973) observed similar results in the Rogue River, Oregon where steelhead spawned in small streams with flows of $<1.5 \text{ m}^3/\text{s}$. He speculated that spawning was completed in an average of 10 days although females were observed to complete spawning in 4 to 7 days. Spence (1980) noted that many fish spawned over a two week period and that males on average spent nearly three times as long on spawning grounds as females. In the present study one radio tagged male, spawning in the Deadman River, required 4 days to complete spawning. Olmstead and Moore (1984), also working in the Deadman River, estimated an average spawner remained on a redd for 5 days.

Steelhead spawning in the Thompson watershed generally begins in the last week of April, peaks by mid-May and is completed by the first week of June. Radio tagging results indicated spawning peaked in the latter part of May

although bias resulting from small samples and seasonal variability could explain these different results. Lough (1980) and Spence (1980) reported peak spawning in the Skeena and Chilcotin Rivers as occurring 7-10 days later than the Thompson.

Spawning temperatures ranged from 6-12°C in the Thompson, Deadman, Bonaparte, and Nicola Rivers during the period radio tagged fish were in the system. Spot temperatures taken while the one radio tagged steelhead was in Nuaitch Creek were lower (4.8-6°C).

Spence (1980) reported peak spawning took place at temperatures of 6.5-7.5°C while steelhead spawned in the Morice and Zymoetz at temperatures of 5.6-6.7°C (Pinsent and Chudyk, 1973). Everest (1973) reported average temperatures of 7.2°C for Rouge River spawning steelhead.

Post Spawning Behavior

Everest (1973) Spence (1980) and Hooton and Lirette (1985) reported males remained near spawning areas after spawned females had emigrated. Hooton and Lirette associated delayed emigration with promiscuity and observed the presence of males 4.3 weeks after females. Post spawning emigration of radio tagged steelhead from Nicola and Deadman Rivers was so rapid tracking was difficult. One radio tagged male in the Deadman River migrated 47 km downstream into the Thompson River within 9 days and disappeared. Radio tagging results did not indicate males

remained near spawning area after females had emigrated, although untagged males in the Coldwater River remained near spawning areas longer than females. One such male was observed 45 days after peak spawning.

Everest (1973) reported steelhead remaining in tributary streams for a maximum of 18 days after spawning. Spence (1980) reported all female radio tagged steelhead had vacated the spawning area by late May but radio tagged males remained near spawning grounds until June 15th.

Tag Regurgitation

Some Thompson steelhead regurgitated radio tags. Pettit and Lindland (1979), Lough (1980) and Spence (1980) all reported tag regurgitation in summer steelhead. Hooton and Lirette (1985) observed similar problems with winter steelhead as did McCleave et al., (1978) with Atlantic salmon. Other researchers did not hypothesize a sex or weight relationship but 4 of the 5 (80%) radio tagged Thompson river steelhead that regurgitated tags were larger males averaging 7.4 kg. Data are far from conclusive, but suggest that regurgitation may be sex and size related.

Life History

Thompson and Kispiox steelhead generally return from ocean life at greater average length, weight, and fecundity than any other known steelhead race in North America. The majority of Thompson River fish spend 2 years in fresh water before smolting (78.7%, 1976; 89.2%, 1977; 93.5%,

1984) and 2 years in salt water (91.9%, 1976; 90.0%, 1977 and 82.8%, 1984) before returning to spawn in their 5th year. Several investigators have shown that steelhead in Alaska and northern and coastal British Columbia spend 3 or 4 and in rare cases 5 years in fresh water prior to smolting. Researchers in Washington and Oregon have reported results similar to the Thompson. Jones (1976) studying steelhead life history in Petersburg Creek, Alaska reported fish rearing in freshwater for 3 (55.5%) and 4 (37.9%) years prior to smolting. Whately (1977) working on the Skeena in northern British Columbia, Hemus (1974) the Dean River, on the central British Columbia coast, Spence (1978) on the Chilcotin River central Interior of British Columbia, and Withler (1966) on southern British Columbia coastal streams all reported 3 and 4 year smolts. Johnson et al., (1978) working on Snow Creek Washington and Everest (1973) working on the Rouge River Oregon, report results similar to the Thompson for fresh water residence: a large majority of juveniles spend only 2 years in fresh water prior to smolting.

Thompson steelhead returned most frequently after 2 full winters in saltwater (91.9%, 1976; 90.0%, 1977 and 82.8%, 1984). Ocean age 3 was the next most common age class. Researchers in Alaska and British Columbia, found similar results: Jones (1976) Petersburg Creek, Alaska; Whately (1977) Kispiox River, northern B.C.; Hemus (1974) Dean

River, central coast; Spence (1978) Chilcotin River central interior B.C.; Hooton and Hay (1978) Qualicum River, Vancouver Island; and Withler (1966) southern mainland of British Columbia all found that steelhead returned predominantly at ocean age 2 with ocean 3 the next most common group. Whately and Imbleau (1975) studying life histories in the Bulkley-Morice system in northern British Columbia, and Narver and Withler (1971) on Vancouver Island observed a high percentage of 1 ocean year fish.

Johnson (1978) studying Snow Creek, Washington, Shapovolov and Taft (1954) Waddel Creek, California found predominantly saltwater age 1 and 2 year fish. Everest (1973) examining the Rogue River, Oregon reported an exception: he observed 96.6% of maiden fish returning after only 2-4 months at sea.

The Thompson River is one of the most productive steelhead systems in British Columbia yielding 2 year smolts when other systems produce predominantly 3 year smolts. While somewhat speculative the Thompson appears to be as productive as the more southerly rivers including the Rouge and the Klamath. Ocean life history is similar to other British Columbia steelhead streams but differs from the streams in Oregon and California. Steelhead from other streams in British Columbia are predominantly 2 and 3 year ocean fish, whereas steelhead from streams in Oregon and California are usually 1 and 2 year ocean fish.

Repeat Spawning

The interior streams of British Columbia, have a low incidence of repeat spawning compared with coastal streams of Alaska, northern and coastal British Columbia, Washington, Oregon, and California. Repeat spawners on the mainstem Thompson comprise only 2.8% and the Chilcotin 2.2% (Spence 1978). In contrast Petersburg Creek, Alaska has 38.3% (Jones, 1976), the Kispiox River 17.6% (Whately, 1977), the Dean River 17.9% (Hemus, 1974) and Withler, (1966), lower mainland rivers 9.5-36.3% all have significantly higher incidences of repeat spawning. The coastal streams of the Pacific Northwestern United States had similar high incidence of repeat spawning. The reason for the discrepancy may be that maiden Thompson and Chilcotin late summer steelhead migrate through a tremendous gauntlet of commercial, native and sport fisheries where exploitation ranges from 50-80%. Emigrating kelts (including marked fish) have been caught in Fraser River native nets, by sport anglers in Georgia Strait, and by the commercial fleet in Johnstone Strait. The probability of migrating through these fisheries to spawn a second time partially explains the 3% repeat spawning rate.

Length and Weight

Except for Kispiox River fish, Thompson summer steelhead return to spawn at greater lengths and weights than any

other known steelhead stocks in North America. Thompson fish sampled in the 1976 and 1977 creel surveys showed mean lengths of 86.6 and 86.3 cm respectively. The Kispiox River in northern British Columbia is the only documented river with steelhead returning at comparable length and weight at age, (Whately, 1977).

All other stocks return at lower average length and weights including Petersburg Creek, Alaska (Jones, 1976); Chilcoton River central British Columbia (Spence, 1978); mainland coastal streams (Withler, 1966); Snow Creek, Washington, (Johnston, 1980); Rouge River, Oregon (Everest, 1973); and Waddel Creek, California, (Shapovalov and Taft, 1954).

Shapovalov and Taft (1954) have speculated that growth is primarily related to ocean feeding grounds. There is also some evidence to suggest that genetic inheritance plays a role in behavior and feeding habits and consequently the larger average size of Thompson steelhead.

Tsuyuki and Willisroft (1977) tested the swimming stamina differences between genotypically distinct forms of rainbow and steelhead trout. Rainbow and steelhead trout homozygous for liver lactate dehydrogenase alleles $H\alpha^A$ and $H\alpha^B$ were artificially propagated and compared for swimming stamina. The time required to fatigue 50% of rainbow trout with phenotype $H\alpha^A H\alpha^A$ was 2.3 times greater than phenotype $H\alpha^B H\alpha^B$.

Steelhead from the Thompson River of similar phenotypes were tested and significant differences in stamina among the phenotypes were not evident. This was also the case for Vedder River juvenile fish, although the stamina of juvenile steelhead from the Thompson were found to be 3.8 times greater than Vedder fish.

Shapovalov and Taft (1954) may be correct in assuming growth is primarily related to the richness of ocean feeding areas but some consideration should be given to genetic inheritance and the role it plays in feeding behavior.

Sex Ratio

In 1976 and 1977 adult steelhead sex ratios were determined from creel census samples. Caution must be observed in interpreting these results as anglers tend to keep females rather than males in order to obtain roe. Other researchers have observed a similar problem (Narver and Withler, 1971; Whately and Imbleau, 1975; and Lewynsky et al., 1986). However, a less biased but smaller counting fence sample indicated that females were more than twice as abundant as males.

Fecundity

Thompson River steelhead are generally larger and more fecund than other steelhead populations in the Pacific Northwest (Table XVII). Withler (1966) examined steelhead growth in North America and found that average length

Table XVII Comparison of steelhead fecundity from streams throughout North America.

RIVER	SOURCE	MEAN LENGTH (mm)	MEAN FECUNDITY (NO. OF EGGS/INDIVIDUAL)
Scott Cr., Calif. ¹	Rounselfell 1957	590.0	5541
Trinity R., Calif. ¹	Bulkley 1967	571.0	3540
Alsea R., Oregon ¹	Bulkley 1967	649.0	3438
Green R., Wash. ¹	Meigs & Paultzke 1941	-	3128
Qualicum R., B.C. ¹	Peterson & Lyon 1980	719.5	3405
Skeena R., B.C. ¹	Wilkman & Stocker 1980	765.6	7078
Thompson R., B.C.	McGregor 1986	865.0	12614

¹From Wilkman & Stocker 1980

increased with increasing latitude. Even when length is held constant Thompson stocks are still more fecund than all other stocks with the exception of Scott Creek steelhead (Table XVIII).

Several theories have been proposed concerning fecundity differences, but evidence is lacking as to whether fecundity is innate or a result of environmental influences.

McFadden (1969) and Neave (1948) reported environmental factors, in the freshwater stage, were responsible for fecundity. McFadden (1969) found growth and fecundity of brown trout were related to the productivity of the environment. Mathison and Gunnerod (1968) reported greater fecundity in sockeye salmon to be a function of increased oceanic temperatures.

Conclusive empirical evidence appears to be lacking as to the cause of increased fecundity. Bulkley (1967) may be correct in indicating both environmental and hereditary factors are involved.

Life History - a note of caution

Caution must be observed when interpreting the life history data for 1976 and 1977. Data were obtained opportunistically from angler catches in the Thompson River and these samples may not be representative of the population. Anglers have a tendency to retain females to obtain roe and generally larger adults of both sexes.

Table XVIII Comparison of Pacific Coast steelhead fecundity with length held constant (L = 571 mm).

LOCATION	REGRESSION EQUATION	FECUNDITY
Scott Cr., Calif. ¹	$E = 0.941 \times L^{2.11}(\text{in.})$	4964
Trinity R., Calif. ¹	N.A.	3540
Big Cr., Oregon ¹	$E = -2078 + 90.302L (\text{cm})$	3107
Alsea R., Oregon ¹	$E = -5054 + 130.53L (\text{cm})$	2424
Skeena R., B.C. ¹	$E = -6443 + 17.66 (\text{mm})$	3641
Thompson R., B.C.	$E = -11,873 + 283.36 (\text{mm})$	4307

¹From Wilkman & Stocker 1980

Narver and Withler (1971) expressed a similar caution, explaining that fish of different sizes react differently to various baits and lures, and that larger fish escape more often than smaller fish. Narver and Withler (1971) felt that comparisons among rivers may be valid if data from anglers' catches were used because anglers' catches, while selective, tend to be selective in about the same way from river to river.

Whately and Imbleau (1975) and Lewynsky et al; (1986) also caution against interpreting anglers' catch as unbiased samples. The effect of suggested bias could, for example, result in differential age or growth calculations relevant to management. Methods to reduce potential bias are discussed later in this paper. In the mainstem Thompson River anglers' catches are the only method available, with current technology, to obtain such biological samples.

Back-Calculation

Back-calculation of steelhead smolt lengths provides a means of obtaining information useful for managing and protecting steelhead populations in British Columbia. Sportfishing regulations governing the minimum allowable length in mixed stock sport fisheries (where both juvenile steelhead and resident rainbow trout co-exist) can be based on such information.

Two methods, regression and proportional analysis, have been suggested to describe the relationship between body-

length and scale-radius. Several investigators working in British Columbia have used the regression method including Narver and Withler (1971); Hemus (1974); Whately (1977), and Horncastle (1981). Many of these studies used adult scales to back-calculate smolt or juvenile lengths based on a body-length and scale-radius relationship established from juvenile fish. Ward (In prep) states there are two problems arising from samples containing juvenile fish only. First, he states the relationship of body-length and scale-radius must be established by including adults, smolts and juveniles if one is back-calculating from adult scales. If only juvenile fish are used to establish the relationship, then back-calculation to smaller juvenile sizes may be appropriate, but if back-calculating to smolt and adult size, adult scales must be used in establishing the relationship. Secondly, juvenile samples containing 0+ fish, which are rarely of interest in back-calculation, often display curvilinearity due to initially accelerated scale growth and should be omitted from the regression used to calculate the constant 'c'. Smith (1955) reported rainbow trout (like steelhead) were devoid of scales until an average length of 3.54 cm was reached. During the period when scales are forming, scale growth rate must exceed body growth rate and if these fish are included in the regression, a curvilinear relationship is observed.

Ward (In prep) states there are no studies of which he is aware that have empirical data to substantiate the methodology used in back-calculation. Ward has examined steelhead life histories on a system (Keogh River) where empirical data (marked fish) were present. He was able to observe the Fraser-Lee proportional method and noted empirical and back-calculated results that were within the range of the expected empirical mean.

Carlander (1981) recommends the Fraser-Lee proportional technique. He states the traditional methods corrects for the fact that not all scales on a fish are of the same size and not all fish of the same length in the population have scales of the same size. This reduces variances and possible bias by eliminating large variations between fish. The regression method describes the relationship for an average fish and consequently increases variances and bias.

Carlander (1982) observed variation in the intercept values calculated from body-scale regressions used in Fraser-Lee calculation of growth from scales, but did not believe the methodology was in error. He speculated that variation was not attributable to differences in population but rather was the result of measuring scales at different angles, collecting scales from different areas of the body, different seasons of collection, and samples with poor representation of all sizes. He speculated that any of the

above could produce curvilinearity in the regression equation. Carlander (1981) also noted that if the true body-scale relationship is curvilinear deviations are insignificant.

Potential errors are apparent in the present study because the opportunity to employ Carlander's suggestions for reducing variation and thus curvilinearity was extremely difficult. When sampling adult steelhead from anglers' catches, bias probably occurs because anglers do not select steelhead randomly from the population. Lewynsky et al., (1986) also stated bias could occur when sampling juveniles. For example, since most sampling occurs in summer and fall, back-calculated lengths were based on steelhead that had not smolted in each age group and these fish may be smaller than those that had already emigrated, and therefore constituting a biased sample with poor representation of all sizes.

Scarnecchia (1979) also reported that error can be introduced into interpretation of scale data if scales are not sampled from precisely the same area. Considering the degree of bias reported in back-calculation procedures, the proportional Fraser-Lee method (which utilizes each fishes' scale and length history and a correction factor for scale growth "catch-up" from the transformed body length/scale radius regressions) appears to be a reliable method especially since Ward has provided empirical data

supporting the model for steelhead.

General Overview of Steelhead Interception, Timing and Migration to the Thompson River.

Steelhead are incidentally caught in the Strait of Juan de Fuca, Johnstone Strait, Strait of Georgia, and in the lower Fraser River by commercial net and line fisheries for salmon. Several lines of evidence including protein electrophoresis, coded wire tag returns, run timing, and size of steelhead suggest that some of these steelhead are of Thompson origin. Andrews and McSheffrey (1976) compiled data (1963-72) confirming that a race of large steelhead migrate through the Straits and lower Fraser in September and October.

Oguss and Andrews (1977) further indicated that Thompson River steelhead enter the commercial fishery in the Strait of Juan de Fuca and lower Fraser in late August and early September. Timing and size of these steelhead indicate that a high proportion of the 3,000(+/-500) fish caught annually in the Strait and 1000(+/-200) caught in the lower Fraser River are Thompson stocks. Recent returns of marked steelhead (adipose clipped and coded wire tagged, 1985) confirm that Thompson steelhead migrate through Juan de Fuca from September through October.

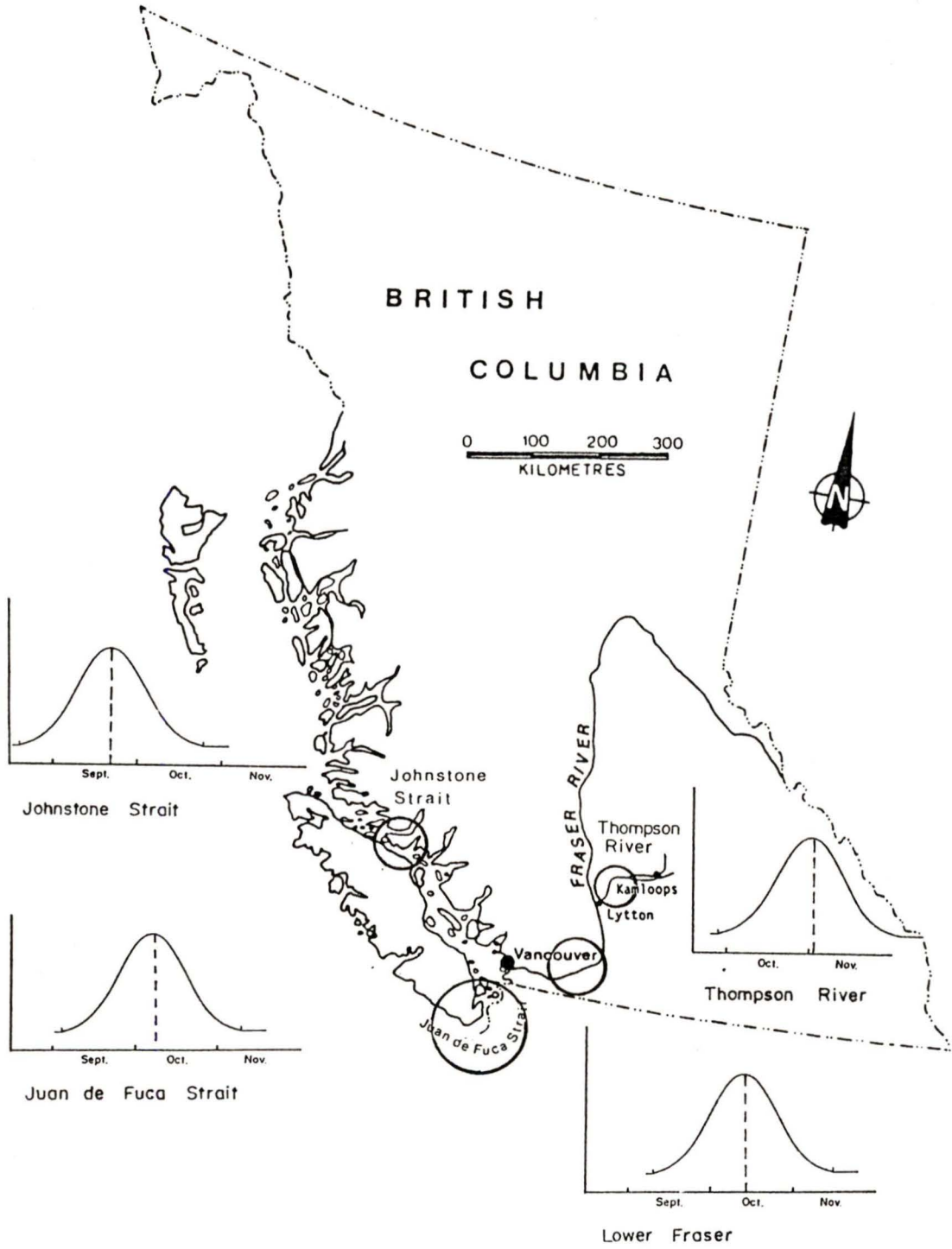
Oguss and Evans (1978) have shown a similar timing for Johnstone Strait. Through stock identification research they estimated the 1978 steelhead catch to be 3,000(+/-500)

fish of which approximately one third were Thompson/Chilco stocks. Oguss and Evans repeated the Fraser River study and again found the large average size of 800(+/-300) steelhead migrating through the Fraser River in September and October were of Thompson origin. Lewynsky and Olmstead (1986) have since refined these numbers and found in one twelve hour opening in early October, on the lower Fraser River, the commercial fleet caught 1,250 steelhead.

Thompson steelhead are also taken in the Fraser River sport fishery. Lewynsky reported 400 steelhead killed in the fall of 1985. Native catches in the Fraser River during the fall of 1985 were approximately 1,800 steelhead in a year of minimal native interception (Lewynsky and Olmstead, 1986).

Evidence from commercial, native, and sport fisheries suggest the majority of Thompson River steelhead enter the Fraser River in late August (at the earliest) and peak in the last week of September and first three weeks of October and diminish by late December (Figure 18). Thompson steelhead then migrate to the Thompson River where sports fishery catch statistics indicate the run peaks in the Spences Bridge area from mid-October to mid-November (Oguss and Evans, 1978), (Schubert, 1983), and (Lewynsky and Olmstead, 1986). Further evidence (see below) suggests that an undetermined portion of this run overwinters in the Fraser River and then migrates into the Thompson River and

Figure 18 Approximate migration timing of Thompson River
steelhead in Johnstone and Juan de Fuca
Straits and Fraser and Thompson Rivers.



other Fraser tributaries (Nahatlatch, Stein, Cayoosh, Seton, Bridge, and Chilcotin Rivers) at undetermined periods. However, the present work suggests that this is probably during March and April as river flows begin to increase and temperatures moderate.

Although the evidence is not conclusive, observations of both the native fishery in the Fraser during March and April and of the sports fishery at the Fraser-Thompson confluence during the same period suggest that an undetermined number of steelhead overwinter in the Fraser. Scales obtained and aged from these fisheries further substantiates the probable overwintering of Thompson fish in the Fraser River since re-absorption of the outer scale margins parallels Thompson scales. The scale characteristics are also similar to known Thompson late summer steelhead. To date, no scales have been observed indicating a "fresh spring run" of steelhead or one that has recently entered freshwater from saltwater. This evidence does not preclude the presence of a spring run of steelhead in the Thompson River but if it exists it must be small.

Many experienced Thompson River steelhead anglers feel that there are three major peaks of steelhead migration into the Spences Bridge area. Anglers theorize that the first steelhead enter the Thompson in October and peak in the Spences Bridge area in late October and the first week in

November. The second group enters at an undetermined time and peaks in the first week of December. This angler speculation has some credence since catch statistics from 1976-82 indicate peak catches of steelhead in late October and early November and the first of December while angler effort remains static (Antifeau, 1976); (Dolighan, 1978-79) and (Caverly, 1981-82). Anglers also speculate that a spring run of fish enter in March and April as discussed previously.

Thompson steelhead have been verified as spawning in the mainstem Thompson and virtually all tributaries downstream of lakes but no fish have been verified spawning above either Nicola or Kamloops Lake. No radio tagged fish were recorded as passing the receiver/recorder at the outlet of Kamloops Lake. Steelhead do migrate through other lake systems on the Bella Coola, Chilcotin, Harrison and Morice River systems.

Management Recommendations

As a result of the present biological study, several management strategies were identified and implemented, they include:

- 1) A 25 cm size limit to protect young rearing juvenile fish.
- 2) A more restrictive angler harvest due to excessive sport kills.
- 3) A spring angling closure on Deadman, Bonaparte and Nicola Rivers.
- 4) A removal of blockages to adult steelhead migration on Deadman River, Criss and Nuaitch Creeks were removed.
- 5) A series of irrigation ditches, which divert young migratory steelhead into alfalfa fields, were screened on Deadman and Nicola Rivers and Criss and Shackan Creeks. Two ditches located on the Nicola River were replaced in favor of pumping stations.
- 6) A moratorium was placed on further water licencing of Nicola River tributaries. Ranchers were encouraged to transfer existing ditch irrigation licences to the Nicola River and upgrade to spray irrigation.
- 7) A key steelhead spawning area in the Deadman River has been stablized by rip rapping, fencing and tree planting.
- 8) A fry colonization project has begun in under recruited areas of the Nicola drainage and upstream of the

Bonaparte River blockage.

Several habitat management and research needs must be addressed in order to rebuild the Thompson steelhead run to historic levels. Proposed habitat recommendations include:

- 1) Continuation of screening projects and replacement of irrigation diversions in the Nicola River. On small streams it would be preferable to transfer all types of water withdrawal to the Nicola River.
- 2) Continuation of habitat restoration on the Deadman River including bank stabilization, fencing and tree planting.
- 3) Continuation of fry stocking programs in the Bonaparte River and eventual removal of the blockage.

Future research needs include:

- 1) An evaluation of commercial and native interception, including determination of peak timing and migration rate of Thompson River steelhead, in Johnstone and Juan de Fuca Straits and the Fraser River.
- 2) Evaluation of juvenile steelhead carrying capacity, in the mainstem Thompson River, for proposed fry stocking programs.

Summary

- 1) Twenty-eight Thompson River steelhead were radio tagged, including 17 males and 11 females. Of the 28 steelhead 3 (11%) were recaptured, 4 (14%) tags malfunctioned, 3 (11%) were tracked for a short period and disappeared, 5 tags (18%) were regurgitated and 15 (54%) were monitored throughout the spawning cycle.
- 2) Fall spawning migrations of Thompson steelhead included both upstream and downstream movements.
- 3) Between mid January and mid March no movements were observed. All tagged fish overwintered in the mainstem Thompson and did not enter spawning tributaries until water temperatures and flows began to increase after winter minima.
- 4) Radio tagging verified that fish tagged in the Thompson River spawned in the Thompson, Deadman, Bonaparte Rivers and in Nuaitch Creek a tributary of the Nicola River. Virtually all major tributaries downstream of Kamloops and Nicola Lakes to Lytton have now been verified as spawning areas for Thompson steelhead by a combination of radio tagging and on site verification.
- 5) Biological information obtained from angler surveys showed that Thompson steelhead returned predominantly in their 5 and 6 year of life after 2+ years in freshwater and 2 or occasionally 3 years of saltwater rearing.

- 6) Biological information obtained from angler surveys also indicated that Thompson steelhead attain greater lengths, weights, and are more fecund at spawning age than the great majority of steelhead stocks in North America.
- 7) Back-calculated fork lengths of steelhead at smolt age, using the Fraser-Lee proportional technique, are within the range of the published literature.

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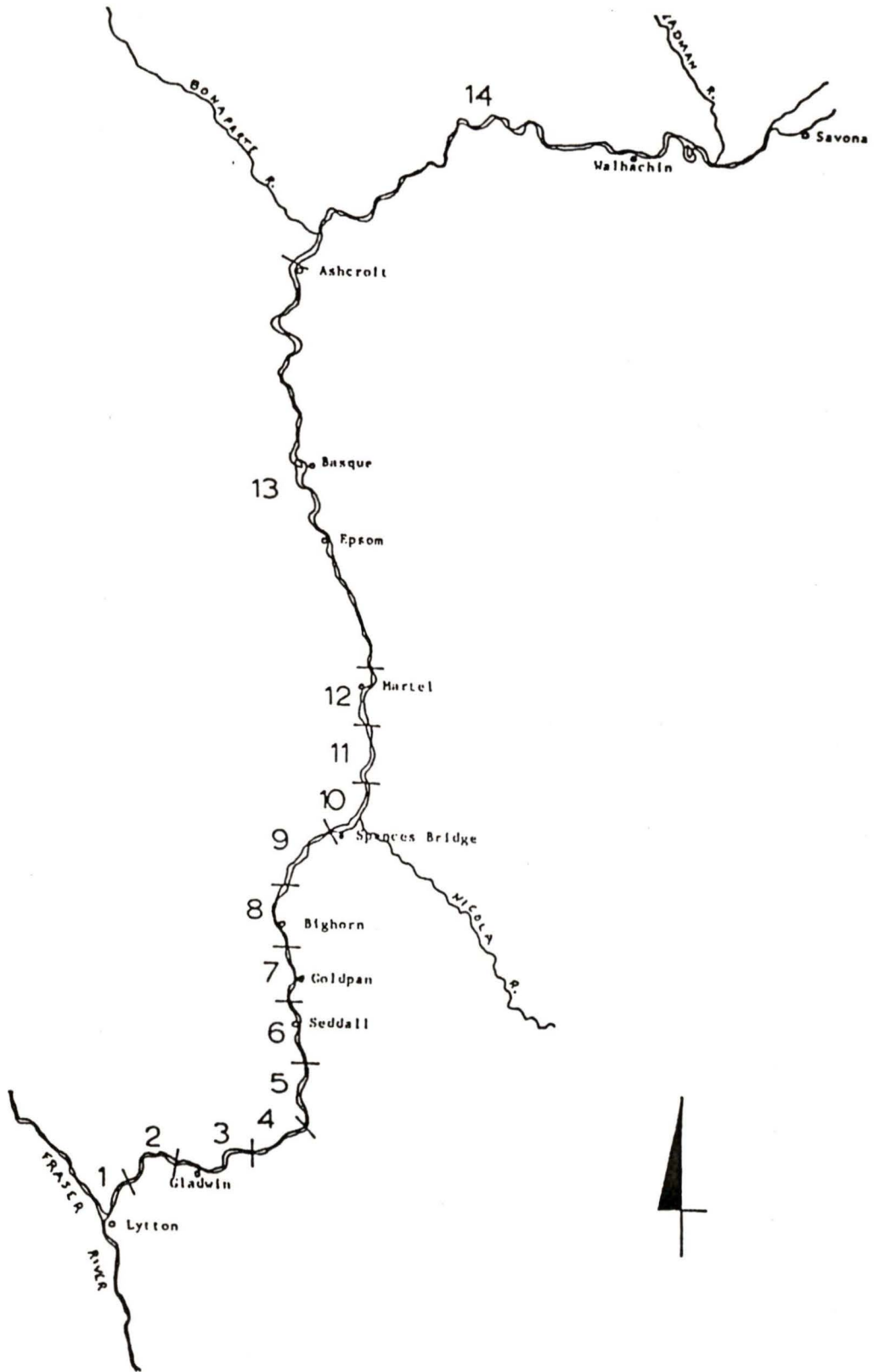
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Appendix I Detailed riverine migration of radio tagged
Thompson River steelhead. Zone map is a key
to Appendix I.



Fish #1 Tagged: October 18, 1977
 Sex: Female
 Weight: 7.3 kg.

Oct. 18 Tagged in zone 10.
 19-22 Holding in zone 10.
 23 Fish migrated downstream approximately 3.2 km to
 zone 9.
 23 Holding in zone 9.

Oct. 23 - Nov. 23
 Holding in zone 9.

Nov. 24 Migrated .5 km downstream in zone 9.

Nov. 25 - May 26, 1978
 Holding in zone 9.

May 28 Fish migrated .5 km downstream and was located in
 a zone 9 back eddie.

Sept. 5 Fish migrated downstream and perished in a back
 eddie. Tag malfunctioned Sept. 5, 1978.

Conclusion: Fish spawned in zone 9 on May 26, 1978. *

*Spawning date are given as the termination of reproductive
 activity.

Fish #2 Tagged: October 18, 1977
 Sex: Male
 Weight: 7.7 kg

Oct. 18 Tagged in zone 10.
 Oct. 19 Holding in zone 10.

Oct. 20 - Sept. 5, 1978

 Holding in zone 10.

Conclusion: Fish considered to have disgorged radio tag.

Fish #3 Tagged: October 18, 1977

 Sex: Male

 Weight: 7.7 kg

Oct. 18 Holding in zone 10.

Oct. 19 - 22

 Holding in zone 10.

24 Fish moved 2.5 km upstream into zone 11.

25 Fish holding in zone 11.

26 Fish moved 3.1 km upstream and is holding in zone
12.

30 Fish holding in zone 12.

31 Fish migrated 5 km downstream to zone 10.

Nov. 1 Fish could not be located.

Mar. 1, 1978

 Fish located downstream in zone 2.

Mar. 2 - Aug. 29

 Fish holding in zone 2.

Conclusion: Although data are not conclusive, fish was considered to have disgorged radio tag in zone 2 because of the uncharacteristic river area or back eddie the fish was holding in.

Fish #4 Tagged: October 18, 1977

Sex: Female

Weight: 7.3 kg

Oct. 18 Tagged in zone 7.

23 Located 1.5 km downstream in zone 6.

24 Did not locate again.

Conclusion: Either the tag malfunctioned or the fish
migrated out of the system.

Fish #5 Tagged: October 19, 1977

Sex: Male

Weight: 6.8 kg

Oct. 19 Holding in zone 7.

23 Holding in zone 7.

24 Moved 2.9 km upstream to zone 8.

Oct. 25 - Dec. 5

Fish went missing.

Dec. 6 Located back in zone 7.

11 Located in zone 8, 2.9 km upstream.

12 Migrated .5 km upstream in zone 8.

15 Located in zone 9 approximately 4 km upstream.

16 Holding at the zone 9.

Dec. 17 - Jan. 18

Fish went missing.

Jan. 19 Located in zone 12 approximately 10 km upstream.

Jan. 20 - Sept. 5, 1978

Holding in zone 12.

Sept. 5 Tag still functioning in zone 12.

Conclusion: Fish considered to have spawned in zone 12
sometime between May 21 - June 7.

Fish #6 Tagged: October 21, 1977

Sex: Male

Weight: 7.3 kg

Oct. 21 Tagged in zone 7.

22 Holding

25 Holding

26 Migrated 3 km upstream to the zone 8.

Oct. 27 - 28

Cannot locate.

30 Located in zone 8.

Oct. 31 - Nov. 30

Holding in zone 8.

Dec. 1 Migrated .5 km upstream in zone 8.

Dec. 16 Moved approximately 200 metres upstream in zone
8.

Dec. 17 - 31

Holding in zone 8.

Jan. 4 Located 3 km upstream into zone 9.

Jan 5 - 13

Holding in zone 9.

Jan. 18 Located 3.5 km upstream in zone 10 - the
confluence of Nicola and Thompson Rivers.

Jan. 19 - Apr. 11

 Holding in zone 10 at the confluence of the
 Nicola and Thompson Rivers.

Apr. 12 Migrated into the Nicola River.

13 Migrated 3.7 km upstream of the mouth.

14 Migrated 5.4 to the brown house at the fruit
 stand.

16 Migrated to 9.5 km upstream.

17 Holding 9.5 km upstream.

21 Migrated 14.4 km upstream.

22 Migrated 18 km upstream of the mouth.

24 Migrated 18.5 km upstream of the mouth.

25 Migrated 25 km upstream of the mouth.

Apr. 26 Migrated 32 km upstream of the mouth (Dot
 Ranch).

27 Migrated 33.8 km upstream of the mouth.

Apr. 28 - May 1

 Holding.

May 2 Migrated 35.7 km upstream of the mouth.

3 Migrated 36 km upstream of the mouth.

4 Migrated 37 km upstream of the mouth.

5 Holding.

6 Migrated 40 km upstream of the mouth.

May 7 - 18

 Holding 40 km upstream of the mouth, immediately
 upstream of Nuaitch Creek.

May 19 Located in Nuaitch Creek approximately .5 km from the mouth.

May 19 - 26

Holding in Nuaitch Creek.

May 30 Could not locate.

Conclusion: Spawned in Nuaitch Creek May 26, 1978.

Fish #7 Tagged: October 22, 1977

Sex: Female

Weight: 6.8 kg

Oct. 22 Tagged in zone 7.

23-26 Holding in zone 7.

27-28 Cannot locate.

30 Located 5 km upstream in zone 8.

Oct. 31 - Nov. 10

Holding in zone 8.

11 Migrated 5 km upstream to zone 9.

12 Holding in zone 9.

15 Fish recaptured and released on this date. Still holding in zone 9.

16-24 Holding in zone 9.

30 Located 3.5 km upstream in zone 10 at Thompson-Nicola confluence.

Dec. 1 Migrated 3 km upstream to zone 11.

2-6 Holding in zone 11.

9 Located approximately 3 km upstream into zone 12.

- 10 Migrated .5 km upstream in zone 12.
- 11-15 Holding in zone 12.
- 16 Migrated .7 km upstream of zone 12.
- 19 Located 3.3 km upstream of Martel.
- 21 Located 5.9 km upstream of Martel.
- 22 Could not locate. Out of range.
- Jan. 19 Located approximately 15 km upstream of Martel
immediately downstream of the Basque Ranch.
- Jan. 20 - Apr. 25
Holding approximately 15 km upstream of Martel.
- May 3, 1978
Could not locate fish.
- May 17, 1978
Fish located in Bonaparte River 1 km upstream of
the mouth.
- Conclusion: Fish spawned in Bonaparte River on or before
May 17, 1978.
- Fish #8 Tagged: October 25, 1977
Sex: Female
Weight: 5.9 kg
- Oct. 25 Tagged in zone 7.
- 26-29 Holding in zone 7.
- 30 Migrated approximately 5 km upstream to zone 8.
- Oct. 31 - Sept. 5, 1978
Holding in zone 8.
- Conclusion: Fish considered to have disgorged radio tag.

Fish #9 Tagged: October 26, 1977

Sex: Male

Weight: 6.8 kg

Oct. 26 Tagged in zone 7.

30 Migrated to zone 8.

31 Could not locate.

Conclusion: Fish was either recaptured, migrated out of
the system or the tag malfunctioned.

Fish #10 Tagged: October 27, 1977

Sex: Male

Weight: 4.6 kg

Oct. 27 Tagged in zone 9.

28-30 Holding in zone 9.

31 Migrated 4 km upstream to zone 10.

Nov. 1 - May 24

Holding in zone 10.

May 25 Dropped downstream .5 km.

28-31 Holding in zone 9.

June 5 Cannot locate fish.

Conclusion: Spawned May 25, 1978 in zone 10.

Fish #11 Tagged: October 27, 1977

Sex: Female

Weight: 7.3 kg

Oct. 27 Tagged in zone 9.

Oct. 28 - Jan. 3

Could not locate.

Jan. 24 Fish located in zone 5, 13 km downstream of original tagging location.

Jan. 25 - Feb. 7

 Holding in zone 5.

Feb. 8 Migrated 4 km upstream to zone 6.

Feb. 9 - Apr. 3

 Holding in zone 6.

 4-11 Could not locate.

Apr. 12 Located in zone 10 approximately 15 km upstream near the Nicola River confluence.

Apr. 13 - June 11

 Holding in zone 10.

June 12 Fish could not be located.

Conclusion: Fish considered to have spawned in zone 10 sometime between May 21 - June 11 based on other mainstem spawners.

Fish #12 Tagged: October 28, 1977

 Sex: Male

 Weight: 7.7 kg

Oct. 28 Tagged in zone 7.

 29-30 Could not locate.

 31 Located approximately 4 km downstream in zone 6.

Nov. 1-2 Holding in zone 6.

Nov. 3 Migrated 4 km upstream to zone 7.

Nov. 4 - 21

 Could not locate.

Nov. 22 Located approximately 4 km upstream in zone 8.

Nov. 22 - Sept. 5

 Holding in zone 8.

Conclusion: Fish considered to have disgored radio tag.

Fish #13 Tagged: October 31, 1977

 Sex: Male

 Weight: 6.8 kg

Oct. 31 Tagged in zone 8.

Nov. 1 - 12

 Holding in zone 8.

Nov. 13 Fish caught and killed .5 km upstream of tagging area.

Fish #14 Tagged: November 1, 1977

 Sex: Male

 Weight: 5.0 kg

Nov. 1 Tagged in zone 7.

 2-3 Holding in zone 7.

 4-13 Could not locate.

 14 Located 13 km upstream in zone 10.

Nov. 15 - June 9, 1978

 Holding in zone 10.

 10 Cannot locate.

Conclusion: Fish considered to have spawned in zone 10
 sometime between May 21 - June 9.

Fish #15 Tagged: November 5, 1977

Sex: Male

Weight: 7.3 kg

Nov. 5 Tagged in zone 7.

Nov. 6 - Feb. 28

Cannot locate fish.

Mar. 1, 1978

Located in zone 2 for the first time since
November 5, 1977.

Mar. 15 Cannot locate.

Apr. 17 Cannot locate.

May 17 Located in the Bonaparte River near the
obstruction.

Conclusion: Fish spawned in the Bonaparte River on or
before May 17, 1978.

Fish #16 Tagged: November 5, 1977

Sex: Male

Weight: 9.1 kg

Nov. 5 Tagged in zone 7.

6-12 Holding in zone 7.

13 Fish caught and released on this date. Fish
maintained position in zone 7. External
spaghetti tag was removed at this time.

13-29 Holding in zone 7.

30 Migrated 1 km upstream to Goldpan Park.

Dec. 1 - 9

 Holding in zone 7 at Goldpan Park.

10 Cannot locate.

Conclusion: Fish could have migrated out of the system,
 but I believe that it was angled and killed
 with the absence of the external mark.

Fish #17 Tagged: November 5, 1977

 Sex: Female

 Weight: 7.7 kg

Nov. 5 Tagged in zone 7.

6 Cannot locate fish.

Conclusion: Fish either migrated out of the system, was
 recaptured and killed or the tag
 malfunctioned.

Fish #18 Tagged: November 5, 1977

 Sex: Female

 Weight: 6.4 kg

Nov. 5 Fish tagged in zone 7.

7 Cannot locate fish.

Conclusion: Fish either migrated out of the system, was
 recaptured and killed or the tag
 malfunctioned.

Fish #19 Tagged: November 6, 1977

 Sex: Male

 Weight: 7.3 kg

Nov. 6 Tagged in zone 7.

7-9 Holding in zone 7.

Nov. 10 - May 16

Cannot locate fish.

May 17, 1978

Located approximately 1 km downstream of
Bonaparte obstruction.

Conclusion: Fish spawned in Bonaparte River, on or before
May 17, 1978.

Fish #20 Tagged: November 6, 1977

Sex: Male

Weight: 8.2 kg

Nov. 6 Tagged in zone 7.

7-15 Could not locate.

16 Located approximately 10 km upstream in zone 10.

Nov. 17 - Sept. 5, 1978

Holding in zone 10.

Conclusion: Fish considered to have disgorged radio tag.

Fish #21 Tagged: November 8, 1977

Sex: Male

Weight: 5.9 kg

Nov. 8 Tagged in zone 5.

12 Located approximately 7 km upstream in zone 7.

13 Located 5 km upstream in zone 8.

13-15 Holding in zone 8.

16 Located .5 km upstream in zone 8.

- 17-22 Cannot locate.
- 22 Located 7 km upstream in zone 9.
- 23-30 Migrated in zone 10.
- Dec. 1 - 14
- Holding in zone 10.
- 14 Migrated .5 km upstream in zone 10.
- Dec. 15 - Jan. 17, 1978
- Holding in zone 10.
- 18 Migrated .5 km upstream to the mouth of the
 Nicola River in zone 10.
- Jan. 19 - Feb. 3
- Holding at the mouth of the Nicola River in zone
 10.
- 4 Dropped downstream .5 km in zone 10.
- Feb. 5 - Apr. 16
- Holding in zone 10.
- Apr. 17 (am)
- Holding in zone 10.
- Apr. 17 (pm)
- Migrated approximately 5 km upstream into zone
 11.
- 18 Migrated 2 km upstream to zone 12 (Martel)
- 19 Migrated 3.6 km upstream of Martel.
- 20-25 Cannot locate.
- 26 Located .8 km upstream of Bonaparte River.
- 28 Located 8 km upriver from Walachin.

- 29 Holding 8 km upriver from Walachin.
- 30 Located .8 km downriver from C.N. Railway Bridge immediately downstream from Thompson-Deadman confluence.
- May 1 Located at the Thompson Deadman confluence.
- 2 Located 30 m upstream in Deadman River.
- 3 Dropped back into the Thompson River.
- May 3 - 18
- Holding at the Thompson-Deadman confluence.
- 19 Located 2 km upstream in Deadmans River.
- 20 Located 7 km upstream from mouth.
- 23 Located at the Indian Village approximately 17 km upstream of the mouth of Deadman.
- 25 Holding below the cement dam at the Indian Village approximately 23 km from the mouth.
- 26 Holding.
- 29 Located near the Phillipe pasture. 47 km from the mouth and 3 km downstream from the Mowich Lake.
- June 6 Located downstream at Indian Village 17 km from mouth.
- 9 Could not locate.

Conclusion: Fish spawned May 29, 1978 in Deadmans River 47 km from the mouth.

Fish #22 Tagged: November 9, 1977

Sex: Female

Weight: 5.9 kg

Nov. 9 Tagged in zone 5.

10-15 Cannot locate.

16 Located approximately 6 km upstream in zone 7.

Nov. 17 - Dec. 5

Cannot locate.

Dec. 6 Located in zone 6 approximately 1.5 km
downstream.

Dec. 7 - June 23, 1978

Holding in zone 6.

June 26 Cannot locate.

Conclusion: Fish considered to have spawned in zone 6
between May 21 - June 7.

Fish #23 Tagged: November 9, 1977

Sex: Female

Weight: 6.8 kg

Nov. 9 Tagged in zone 9.

9 Could not locate 5 minutes after tagging.

Conclusion: Tag malfunction.

Fish #24 Tagged: November 10, 1977

Sex: Female

Weight: 6.8 kg

Nov. 10 Tagged in zone 7 near Goldpan Park.

11 Holding in zone 7.

12 Migrated 1.5 km upstream to zone 8.

13-17 Holding in zone 8.

Nov. 18 - Dec. 20
Cannot locate.

Dec. 21 Located approximately 6 km downstream in zone 7.

Dec. 20 - May 26
Holding in zone 7.

May 27 Dropped downstream 30 metres.

June 2 Cannot locate.

Conclusion: Fish spawned on May 26, 1978 in zone 7.

Fish #25 Tagged: November 13, 1977
Sex: Male
Weight: 6.8 kg

Nov. 13 Tagged in zone 9.
13 Could not locate fish 5 minutes after tagging.

Conclusion: Tag malfunction.

Fish #26 Tagged: February 12, 1978
Sex: Male
Weight: 5.5 kg

Feb. 12 Fish tagged in the Walachin area.
20 Located 1.6 km downstream from tagging location.

Feb. 21 - May 4
Holding 1.6 km downstream from tagging location.

May 5 Migrated .5 km upstream.
7 Holding.
8-10 Cannot locate.

- 11 Located at the mouth of Deadmans River.
- 12 Migrated 1 km upstream in Deadmans River.
- 13 Holding 1 km upstream.
- 14 Trans-Canada Highway bridge 3.5 km upstream from mouth.
- 15 Deadman Canyon 5 km upstream from mouth.
- 16 Located 6 km upstream from mouth.
- 17 Located 10 km upstream from mouth.
- 19 Located 13 km upstream from mouth.
- 20 Located 29 km upstream at Allan Ranch.
- 21-22 Holding.
- 26 Located 40 km upstream at the Dockstader Ranch.
- 28 Located 41 km upstream.
- 29 Dropped downstream .8 km.
- June 5 Cannot locate.
- 6 Located at the Indian Village 17 km from the mouth.
- 9 Gone from Deadman.
- Conclusion: Fish spawned May 28, 1978 in the Deadman River
41 km from the mouth.
- Fish #27 Tagged: February 20, 1978
- Sex: Male
- Weight: 6.8 kg
- Feb. 20 Tagged in the Walachin area.
- Feb. 21 - March 7
- Holding in area of tagging.

- 15 Cannot locate.
- Apr. 13 Thompson, Deadman confluence.
- Apr. 14-30
- Cannot locate.
- 30 8.5 km upstream from the mouth.
- May 1 Holding 8.5 km upstream from the mouth.
- 2 Located 10 km upstream from the mouth.
- 6 Located 17 km from mouth Indian Village.
- 7 Located 21 km upstream.
- 9 Located at the Massey obstruction 26 km upstream from mouth.
- 10-11 Holding at Massey's obstruction.
- 12 Located 29 km upstream (fish has moved passed obstruction).
- 13-14 Holding.
- 15 Located 32 km from mouth.
- 16 Located 39 km upstream at McAvany house.
- 17-19 Holding.
- 20 Fish has dropped downstream 2 km.
- 22 Dropped downstream 6 km Hihum Lake turnoff (33 km).
- 26 Located 27 km from the mouth (Craig dam).
- Conclusion: Fish spawned May 16, 1978 in the Deadman River 39 km from the mouth.

Fish #28 Tagged: April 4, 1978

Sex: Female

Weight: 5.5 kg

Apr. 4 Holding zone 10.

5 Migrated .5 km downstream in zone 10.

10 Cannot locate.

11 Located approximately 20 km downstream in zone
5.

12:00 am Migrated upstream 7.4 km in zone 7 (Goldpan
Park).

12:00 pm Located in zone 8. Migrated 1.9 km in 1 hour.

13 Holding.

14 Migrated approximately 11 km upstream in a 24
hour period to the confluence of the Nicola River
in zone 10.

15-17 Cannot locate.

18 Located 24 km downstream from previous location
in zone 3.

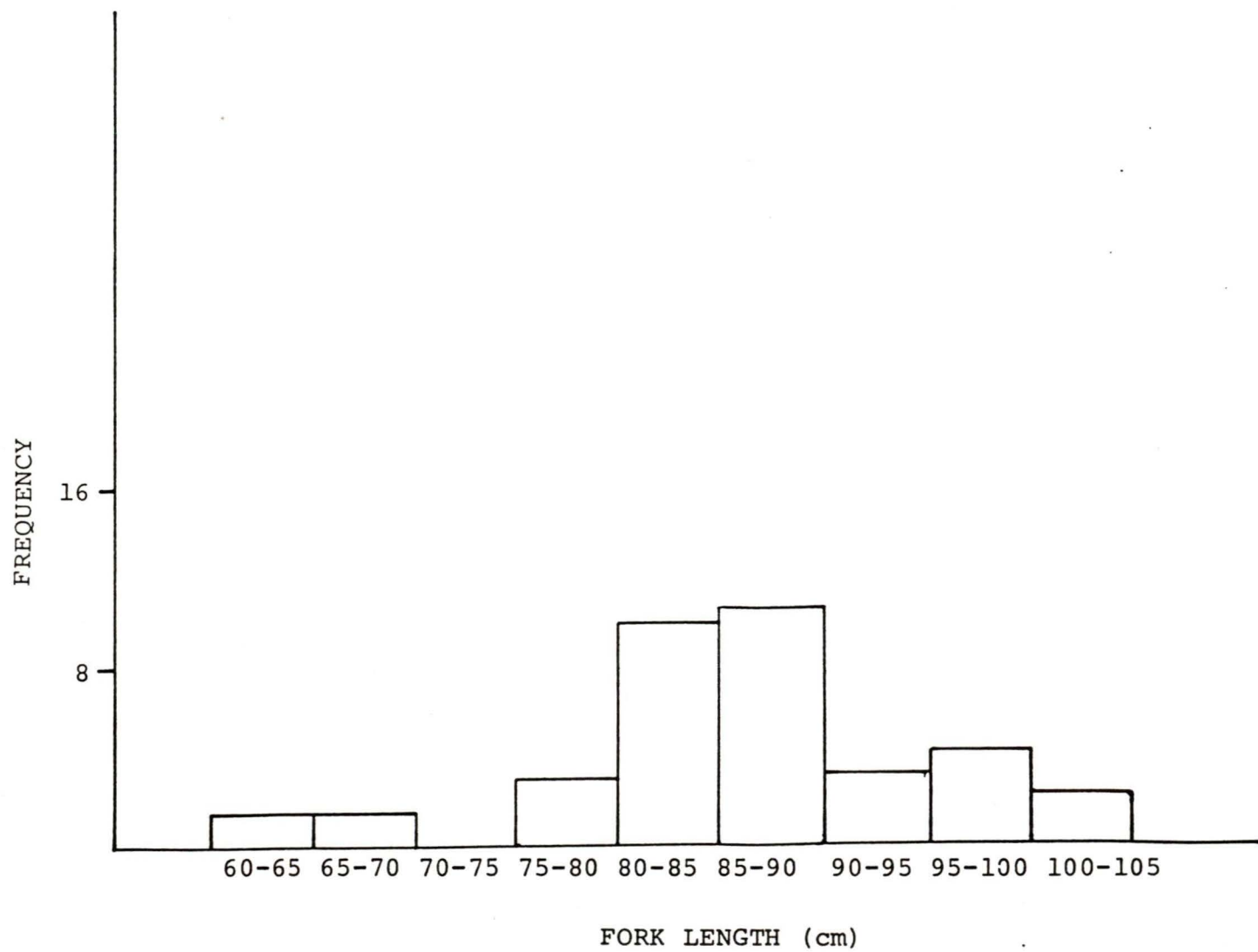
Apr. 19 - June 1

Holding in zone 3.

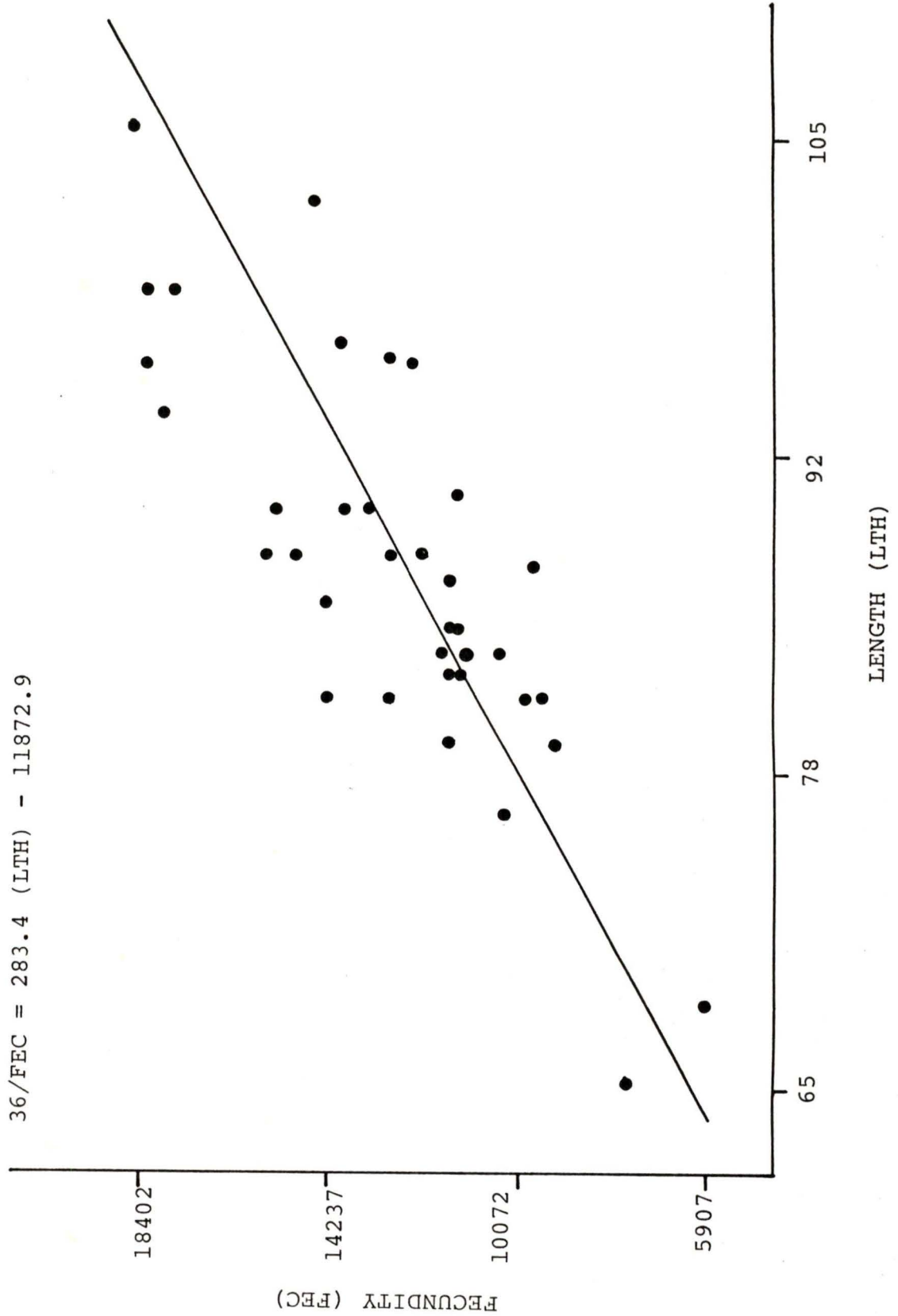
2 Cannot locate.

Conclusion: Fish considered to have spawned in zone 3
sometime before June 2.

Appendix II Normal length distribution of 36 female
steelhead sampled from anglers catches.



Appendix III Regression of fecundity versus length for 36
steelhead sampled from anglers catches.



Appendix IV List of companies currently manufacturing
radio telemetry equipment.

- 1) AVM Instrument Company
810 Dennison Dr.
Champaign, Illinois USA
61820 217-356-1512

- 2) Custom Electronics
2009 Silver CT.W.
Urbana, Illinois USA
61801 217-344-3460

- 3) Lotek Engineering Inc.
34 Berczy Street
Aurora, Ontario Canada
L4G 4J9 416-727-0181

- 4) Smith-Root, Incorporated
14014 N.E. Salmon Creek Avenue
Vancouver, Washington USA
98665 206-573-0202

- 5) Telonics, Inc.
932 East Impala Avenue
Mesa, Arizona USA
85204 602-892-4444

- 6) Wildlife Materials, Inc.
R.R. 1, Giant City Road
Carbondale, Illinois USA
62901 618-549-6330

VITA

Surname: McGregor Given Names: Ian Angus

Place of Birth: Kamloops, B.C.

Date of Birth: April 24, 1952

Educational Institutions Attended with dates of Entering and Leaving:

University of Victoria, Victoria, B.C. 1974 to 1977

University of Victoria, Victoria, B.C. 1981 to 1986

_____ to _____

Degrees, Diplomas, Etc., Awarded, with Dates and Names of Institutions:

B.Sc. 1977 University of Victoria

Honours and Awards:

Publications:

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Title of Thesis

FRESHWATER BIOLOGY OF THOMPSON RIVER

STEELHEAD (*Salmo gairdneri*) AS DETERMINED

BY RADIO TELEMETRY

Author



Ian A. McGregor
