UNIVERSITY OF ALBERTA

REPRODUCTIVE ECOLOGY OF BROWN TROUT (*Salmo trutta*) AND BROOK TROUT (*Salvelinus fontinalis*) IN ALBERTA'S UPPER BOW RIVER AND TRIBUTARIES

BY

MICHAEL KERRY BREWIN ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE**.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, a thesis entitled **REPRODUCTIVE EGOLOGY OF OF BROWN TROUT (Salmo trutta) AND BROOK TROUT (Salvelinus fontinalis) IN ALBERTA'S UPPER BOW RIVER AND TRIBUTARIES** submitted by **MICHAEL KERRY BREWIN** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE.**

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ABSTRACT

The reproductive ecology of brown trout (*Salmo trutta*) was examined during a three year study in the upper Bow River system, Alberta. In one tributary, Bill Griffiths Creek, a two-way fish trap was used to capture spawning migrants. Each year the average fork length of the adult brown trout captured was slightly greater than 400 mm. Timing of the spawning migrations was relatively consistent between years. Males generally entered the spawning grounds earlier and stayed longer than females. Peak upstream migration occurred during the last week in October each year. The percent of brown trout returning to spawn in successive years was high in relation to other spawning populations. In 1990, 31.1% and 57.1% of the males and females, respectively, that spawned in Bill Griffiths Creek during 1989 returned to spawn.

The results suggest there are three identifiable life history strategies within the system: annual spawning females; biennial spawning females; and females that delay their first spawn.

The research showed that susceptibility of spawning brown trout to infection by *Saprolegnia* was influenced by sex and fork length. Larger brown trout males were more frequently infected than females or smaller males. Handling and tagging did not correspond with increased infection rates.

Significant differences were detected in tag losses between males (44.3%) and females (15.0%). No differences were detected in fork length distributions between brown trout that lost their tags and those that retained their tags, or between fork length distributions of males and females that lost tags.

The results of redd surveys were related to the number of spawning females captured in the fish trap. Redd surveys were found to provide a reliable method of assessing brown trout spawning activity and to monitor population changes.

Mature male brown trout from two populations in the drainage (Bill Griffiths Creek and Kananaskis River) were found to have a larger adipose fin (as a function of fork length) than females.

The number of brook trout (*Salvelinus fontinalis*) that migrate into Bill Griffiths Creek to spawn was considerably smaller than the brown trout population. Some aspects of the spawning migration of brook trout in Bill Griffiths Creek were also examined.

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1.0 INTRODUCTION

1.1 Background Information

Brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*), two species which are significant to sport fishing in Alberta, represent two of the most successful fish introductions into the province (Nelson and Paetz 1992). Both species have been established in the upper Bow River system in Alberta for over 60 years. Brook trout were introduced into Alberta in the Banff area around 1910 (Vick 1913). The first introduction of brown trout to Alberta occurred in 1924 into the Raven River, part of the Red Deer River system (MacCrimmon and Marshall 1968). A year later they were introduced into the Bow River system when a hatchery truck leaving Banff, Alberta, and destined for eastern Alberta, broke down. Still within the present boundary of Banff National Park, the cargo of brown trout was unloaded into Carrot Creek (Nelson and Paetz 1992).

Simultaneous spawning of the two species frequently occur in tributaries of the Kananaskis (Stelfox 1980) and upper Bow rivers (Stelfox 1979). A major spawning stream for both species within the upper Bow River system originates near the intersection of the Trans-Canada Highway and Highway 1-A immediately west of Canmore, Alberta (Stelfox 1979). This stream, unofficially recognized as Bill Griffiths Creek (23-24-10-5), is believed to provide habitat to western Canada's largest known concentration of spawning brown trout (Alberta Public Lands Division 1990). It was estimated Bill Griffiths Creek contained approximately 2,200 adult brown trout in the 1988 spawning season (Brewin and Stebbins, unpubl. data). Although the number of brook trout in the stream was considerably less, it was still appreciable.

Within the upper Bow River system, many of waterbodies providing suitable habitat for spawning brown trout are side channels that receive surface flow from the Bow River during the spawning season. One of the few exceptions is Bill

Griffiths Creek which is fed entirely by groundwater. Consequently, this stream has a stable flow and is not affected by the changing volumes in the river except near its mouth with the Bow River.

The recreational and economic importance of brown trout and brook trout to sportfishing in the area dictates that the region's fisheries managers have detailed information on the reproductive ecology of both species. For example, both species are vulnerable to angling when they congregate into small headwater streams to spawn. Consequently, knowledge of the timing and location of spawning is critical for fishery managers to institute seasonal angling closures to protect spawning trout and to ensure adequate recruitment of fry into the system. Information on the demographics of the spawning population is also important for effective management. For example, changes in the fork length distribution, or in the ratios of repeat and first time spawners, can provide useful information to help assess whether overharvest may be occurring. It is also important for fishery managers to develop an effective and economical method to monitor changes in spawning populations and to understand whether the method they are using to monitor the population is having detrimental effects on the population.

With these criteria in mind, a research project was designed that would provide the baseline data needed to help manage the brown trout and brook trout sportfisheries in the upper Bow River system.

The spawning populations of brown trout and brook trout in Bill Griffiths Creek were chosen for this study for several reasons. Firstly, previous investigations (Stelfox 1979) suggested that Bill Griffiths Creek contains the largest known concentration of spawning brown trout in the area. Secondly, the spring fed conditions in the stream permit late fall and early winter field research. Thirdly, the stream flows through public land and frequently parallels a major highway; consequently, access to most of the stream is relatively easy.

1.2 Objectives

The objectives of this research were to: i) determine the timing and patterns associated with spawning by brown trout and brook trout in Bill Griffiths Creek; ii) determine the fork length distribution, growth rates, survival rates and size of the brown trout spawning population within the study area; iii) determine the extent that alternate year spawning is practised by brown trout in the upper Bow River system and whether alternate year spawners experience trade-offs (e.g., growth, pre-spawning weight) in relation to annual spawners; iv) determine the distribution of brown trout spawning activity within the side channels and tributaries of the upper Bow River which provide spawning habitat for brown trout; and v) assess the value of redd counts to monitor population trends in the brown trout spawning population. After the first trapping season in 1988, the study was expanded to include research into: vi) the occurrence and possible effects of handling and tagging on infection by *Saprolegnia* spp. among spawning brown trout; vii) determining whether losses of the floy anchor tags used were related to sex or fork length; and viii) determining whether the adipose fin of mature brown trout was sexually dimorphic.

1.3 Study Area

The spawning populations examined during the present study were limited to a 50-60 km reach of the upper Bow River. The location of the study area is shown in Figure 1.1. A map of the study area is provided in Figure 1.2. Although the upper limit of this reach, Bow Falls, is located in Banff National Park (BNP), the majority of the study area is located below the park. The Seebe dam, located at the confluence of the Bow and Kananaskis rivers, represented the lower limit. Paetz (1986) describes the 42 km reach of the upper Bow River between BNP and the Seebe dam as "important coldwater salmonid habitat". Between Bow Falls and the Seebe dam, the gradient of the river is approximately 1.6 m/km. The river, throughout this reach, is interspersed with islands and gravel bars and is extensively braided upstream and downstream of the town of Canmore (Paetz 1986).

The main study stream is a former channel of the Bow River that is fed entirely by groundwater, except when it receives some direct surface flow from the river during abnormally high flood events. It is unofficially called Bill Griffiths Creek. The source of Bill Griffiths Creek is a large beaver pond fed by groundwater inflow that is located southeast of Canmore, Alberta, near the intersection of the Trans-Canada Highway and Highway 1-A. Bill Griffiths Creek is approximately four kilometres long.

The mean monthly discharge of the Bow River at Canmore during the winter (November to April) and June is approximately 40 and 215 m^3/sec, respectively (McGregor 1984). June is typically the month of maximum flows in the river. Being groundfed, the flows in Bill Griffiths Creek are relatively stable throughout the year (pers. obs.). The discharge of Bill Griffiths Creek approximately 400 m from its mouth has been recorded at 2.7 m^3/s during April (unpubl. data).

The sportfish that occur in this reach of the Bow River are: brown trout, brook trout, bull trout (*Salvelinus confluentus*), cutthroat trout (*Oncorhynchus clarki*), rainbow trout (*O. mykiss*), mountain whitefish (*Prosopium williamsoni*) and burbot (*Lota lota*) (Nelson and Paetz 1992). Lake trout (*Salvelinus namaycush*) are also occasionally captured in the upper Bow River and tributaries (see Section 2.0). Non-sportfish that occur in the area include: longnose dace (*Rhinichthys cataractae*), brook stickleback (*Culaea inconstans*), lake chub (*Couesius plumbeus*), white suckers (*Catostomus commersoni*) and longnose suckers (*C. catostomus*) (Nelson and Paetz 1992).

The mainstream of the river as well as several of the other spawning streams examined, including Bill Griffiths Creek in its entirety, flow through Canmore Flats Natural Area (elev. 1295-1310 masl). The Natural Area is located approximately 2 km downstream (southeast) of the town of Canmore's downtown core. The Natural Area lies in the floodplain of the Bow River in a region described as the Rocky Mountain Montane Natural Region (Braidwood 1991).

The surficial geology of the Natural Area is described as overlain by post-glacial deposits, primarily alluvial silts and gravels (Edwards 1979). Gravel bars on the floodplain are covered by a thin veneer of alluvial silt. The underlying bedrock is primarily Mississippian limestone and shales, and Devonian dolomite and sandstone. The ratio of silt to gravel in the floodplain downstream of Canmore is likely greater than in the well drained soils upstream of Canmore (Timoney 1990). Floodplains soils in the Canmore area have been described as being predominately poorly drained Rego-Gleysols and moderately drained Cumulic Regosols (Knapik 1974 in Braidwood 1991).

The braided floodplain of this reach of the river supports a rich variety of shrub and graminoid (grass-like) communities. Soil moisture, soil texture and the flooding regime appear to be the three primary factors determining the composition of the vegetation communities (Timoney 1990). The dominant vegetation type in the Natural Area is a mature white spruce/rye grass-sedge forest on mesic to hygric silty and sandy alluvium (Timoney 1990). The understorey varies according to site conditions but generally the composition can be characterized as being either willow/sedge or bearberry/wolfwillow/rose/rye grass/sedge (Braidwood 1991). The floodplain also supports a dynamic vegetation complex of willow, wolf willow and graminoid meadows within a subhygric to hygric moisture regime (Braidwood 1991). Balsam poplar and poplar-aspen-white spruce forests also occur in the area (Braidwood 1991). The creek bed community of Bill Griffiths Creek is dominated by *Agrostis stolonifera*, *Cratoneuron commutatum*, *Potamogeton pectinnatus* and a filamentous green alga (cf. *Microspora*) (Timoney 1990).

Bill Griffiths Creek contains the largest known concentration of spawning brown trout in Alberta (Alberta Public Lands Division 1990). The importance of Bill Griffiths Creek as a spawning stream for both brook trout and brown trout is largely due to two primary factors: i) abundant groundwater upwellings feed the stream and provide a relatively stable temperature and flow regime; and ii) the streambed is composed of glaciofluvial gravels that are ideal for redd construction and aeration of incubating eggs (Timoney 1990).

Although Paetz (1986) indicated the mainstem of the river throughout this reach supports a regionally important sportfishery with moderate angling pressure, he also indicates regulated flows by hydroelectric dams create unstable aquatic habitat that limit fish and invertebrate production. Releases from hydroelectric plants upstream of Canmore cause the volume of flow in the river at Canmore to increase or decrease by a factor of two, or more, during a

24 hour period during the brook and brown trout spawning season (Brewin and Stebbins 1991).

The fluctuating flows caused by hydroelectric releases may also be detrimental to the reproductive success of brown trout and brook trout that spawn in the side channels of the Bow River throughout this reach (Paetz 1986). Dewatering in the side channels during low flows is thought to contribute to freezing and suffocation of incubating eggs. Several of the potential spawning streams examined during this study are side channels of the Bow River that receive either intermittent or variable surface flows from the Bow River throughout the fall and winter when spawning and egg incubation occurs. The variable, and sometimes intermittent, surface flow from the river into these channels is dependent on releases from hydroelectric plants upstream. Bill Griffiths Creek is one of the few potential spawning streams in the area that is not affected by fluctuating flows during spawning and incubation periods.

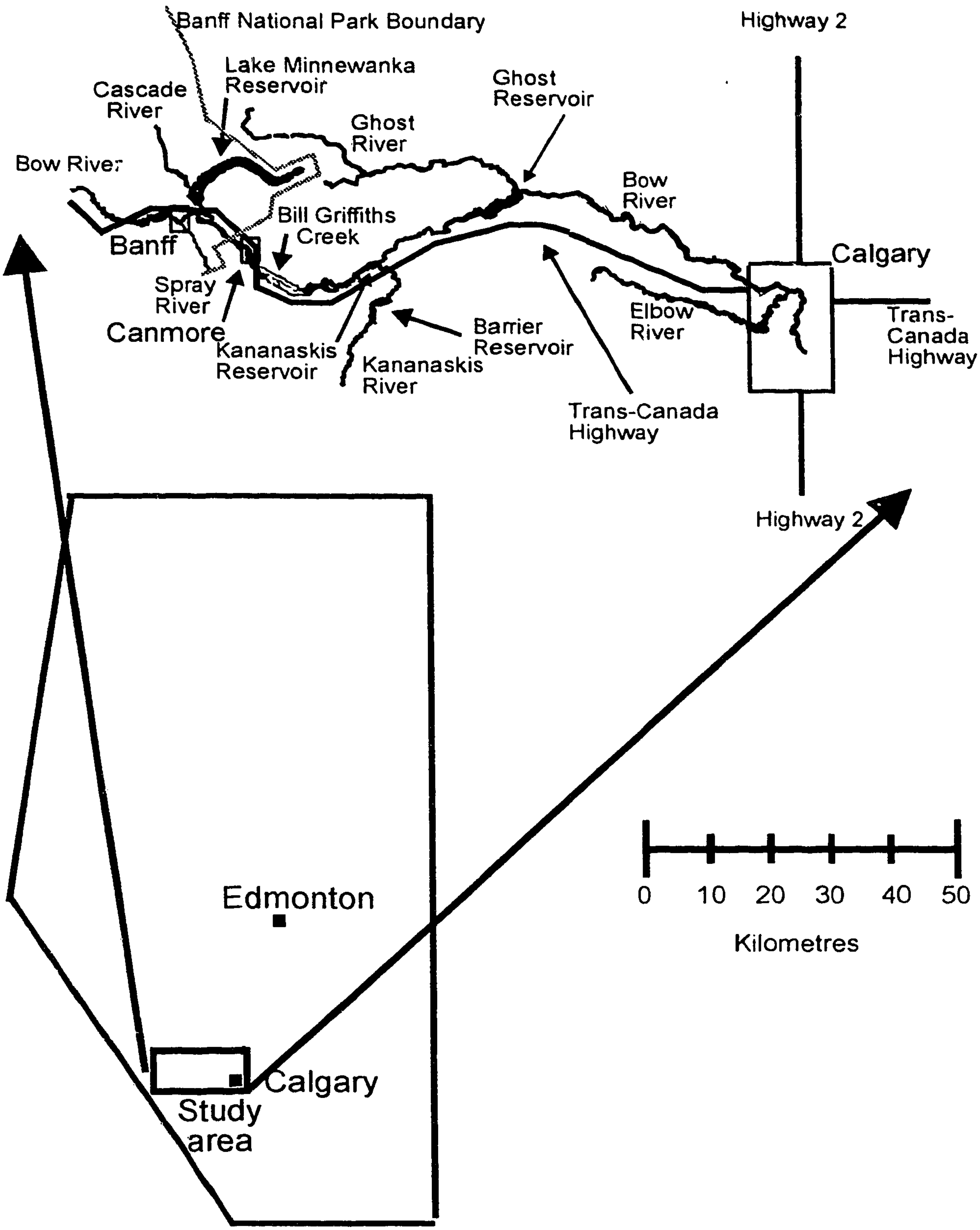

Figure 1.1: Location of study area.

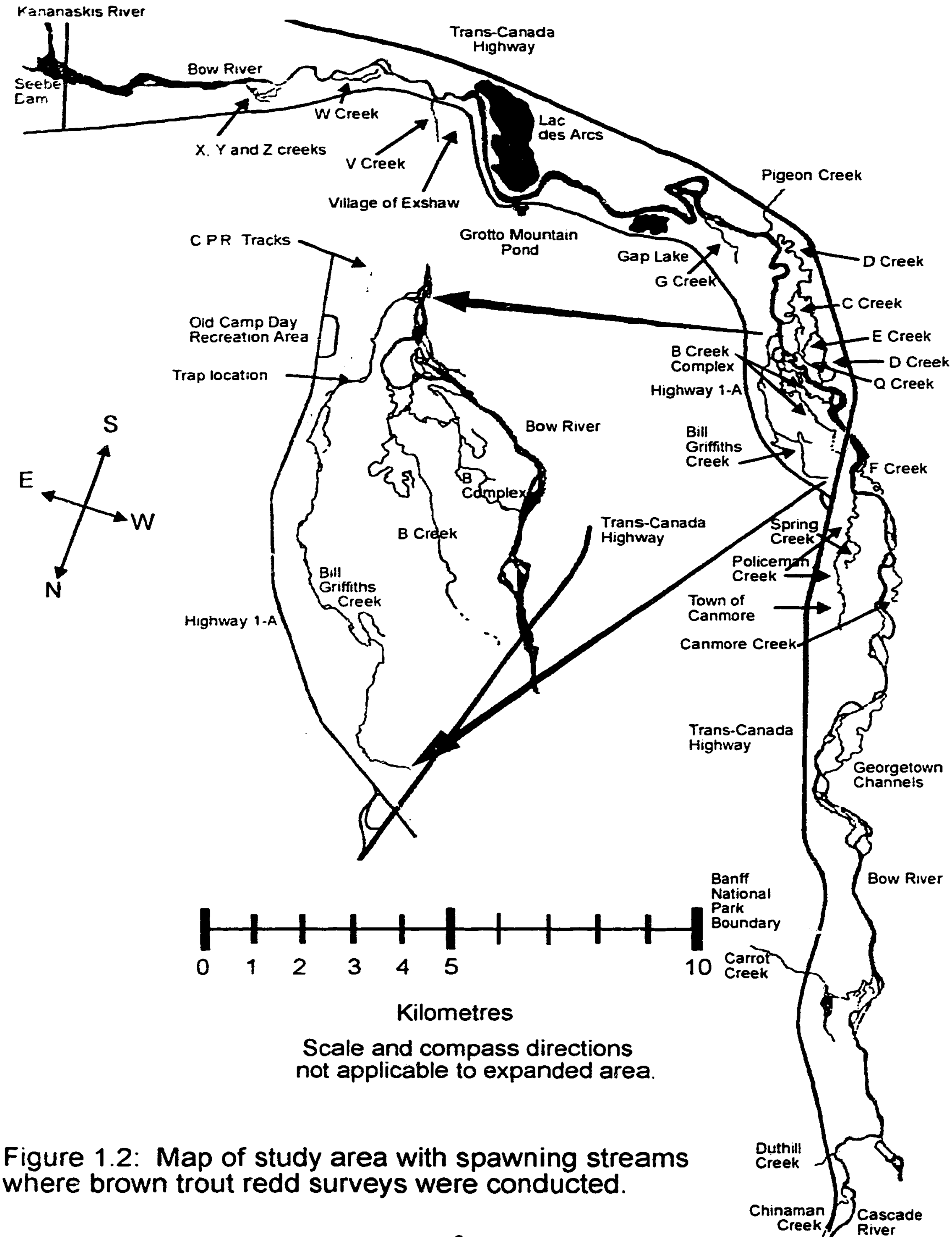

Figure 1.2: Map of study area with spawning streams where brown trout redd surveys were conducted.

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2.0 THE SPAWNING MIGRATION OF BROWN TROUT (*Salmo trutta*), AND BROOK TROUT (*Salvelinus fontinalis*), IN BILL GRIFFITHS CREEK, A TRIBUTARY OF THE UPPER BOW RIVER, ALBERTA

2.1 Abstract

A two way fish trap was used to describe the demographics and spawning migrations of a population of brown trout spawning in Bill Griffiths Creek, a tributary of the upper Bow River, Alberta, during 1988, 1989 and 1990. To a lesser extent, the brook trout spawning population migrating into the stream was also examined.

Brown trout were the dominant species in number and size. During the three years, 3,784 individual brown trout were captured and handled 5,686 times. Excluding 1988, 566 individual brook trout were captured 623 times. The average fork lengths of adult brown trout and brook trout were slightly greater than 400 mm and 200 mm, respectively. Annual growth rates among male brown trout were significantly greater than among females.

The timing of the brown trout spawning migration was relatively consistent during all three years. The spawning migration generally began during the first week of October and peaked during the last week of October each year. In contrast, the upstream migration of brook trout appeared to begin before September 1 and peaked about the same time as brown trout. Male brown trout typically entered the spawning grounds earlier and stayed longer than females. Sexual condition affected how long brown trout females spent on the spawning grounds; females that were ripe when migrating upstream spent less time on the grounds than mature females. Almost all male brown trout migrating upstream were ripe; too few upstream migrating males that were not ripe were captured to determine the effect of sexual condition during upstream migration on their duration of stay. Fork length

did not affect the timing of the upstream migration for either sex. However, shorter males frequently spent less time on the spawning grounds than larger males.

The date annual spawning brown trout migrated upstream was correlated with the date they returned in subsequent years. The percentage of brown trout returning to spawn in successive years was high in relation to published values from other spawning populations. In 1990, 31.1% and 57.1% of the male and female brown trout, respectively, returned after spawning in Bill Griffiths Creek during 1989.

2.2 Introduction

Brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) were both introduced to Alberta, the former in 1924 (Nelson and Paetz 1992) and the latter around 1910 (Vick 1913; Whitehouse 1919). Since their introductions both species have become significant sportfish in the province. In the upper Bow River upstream of the Seebe Dam to Bow Falls, naturalized brown trout and brook trout populations have coexisted for more than 60 years. In this reach of the Bow River where self-reproducing populations of the native cutthroat trout (*Oncorhynchus clarki*) and bull trout (*Salvelinus confluentus*) are thought to have been essentially extirpated, brown trout, brook trout and mountain whitefish (*Prosopium williamsoni*) are the three principal sportfish species (J. Stelfox, Alberta Fish and Wildlife Division, pers. comm.).

Much has been written on the reproductive ecology of brown trout and brook trout (e.g., Greeley 1932; Smith 1941; Stuart 1953; Reiser and Wesche 1977; Witzel and MacCrimmon 1984; Miles 1985; Scholl et. al 1984; Harvey 1991). Both species migrate to headwater streams in the fall to spawn. In some systems, spawning populations of both species are known to migrate into the same streams and spawn simultaneously. In streams where simultaneous spawning occurs, competition between species for preferred spawning sites is reduced through selection of spawning sites based on interspecific preferences for cover, stream depth, distance from shore and current velocity (Reiser and Wesche 1977; Witzel and MacCrimmon 1984).

As is typical for most stream spawning salmonids, the spawning migrations of brown trout and brook trout are characterized by males entering the spawning grounds one to two weeks before the females. Arriving earlier allows males to establish themselves in the dominance hierarchy, and thereby, increase their potential mating opportunities.

Males generally stay on the spawning grounds longer than females and attempt to mate with as many females as possible while on the spawning grounds.

Although the timing of the spawning migrations of brown trout and brook trout in the upper Bow River system likely would not differ greatly from other drainages where their spawning migrations have been described, for management purposes it is often necessary to be aware of subtle differences in the timing of spawning migrations within a specific area. Adults may be spread throughout an entire drainage basin during most of the year, but during spawning they congregate into tributary streams to spawn. Capturing adults migrating through spawning streams can allow important demographic information on populations to be collected more efficiently and more economically than during the rest of the year.

Within the upper Bow River system, many waterbodies with suitable habitat for spawning brown trout are side channels that receive surface flow from the Bow River. One exception is Bill Griffiths Creek; it is fed entirely by groundwater. Consequently, it has a stable flow and is not affected by the changing volumes in the river. It has been suggested Bill Griffiths Creek, previously called "A Creek" (Stelfox 1979), may be the most important spawning stream in the system (Stelfox 1979; Alberta Public Lands Division 1990).

The current study involved capturing brown trout and brook trout during their spawning migrations from the upper Bow River in and out of Bill Griffiths Creek. The study was performed during the 1988, 1989 and 1990 fall spawning seasons. The purpose of the research was to describe: i) the demography of the brown trout and brook trout spawning populations; ii) the timing of the brown trout and brook trout spawning migrations; and iii) how fork length, sex, and/or sexual condition affect the timing of the brown trout spawning migration.

2.3 Methods

2.3.1 Trapping

A two-way fish trap was installed and maintained in Bill Griffiths Creek during the brown trout and brook trout spawning seasons in 1988, 1989 and 1990. The trap, in the same location all three years, was approximately 0.8 km upstream from the confluence of Bill Griffiths Creek and the Bow River. Because Bill Griffiths Creek has no other direct connection with the Bow River, the two-way trap captured all fish entering and leaving the stream reach above the trap.

The length of the trapping periods varied during each of the three years. In 1988, the trapping season was from October 15 to November 27; in 1989, from September 1 to December 20; and in 1990, from September 23 to December 4.

The trap was anchored and reinforced with 2 m steel fence posts. The fencing material used was 12.5 mm X 20 mm plastic vexar. The base of the vexar was held down with stream gravel. The spacing of the vexar ensured the capture of all fish with fork lengths in excess of 150-175 cm; however, in 1988 it was necessary to construct one wing at each end of the trap with 25 mm "chicken mesh" and some fish under 225 mm were able to escape. The fence crossed the stream at approximately a 45^0 angle. The entrances into the trap were v-shaped and each entrance had a funnel-like opening which directed fish into holding areas that had water volumes in excess of 5 cu. m.

2.3.2 Processing live fish

All fish caught during the night were processed the next morning after a thorough check of the trap. The trap was again checked prior to sunset and any captured fish were immediately processed. Separate holding areas allowed a distinction between upstream and downstream migrants. Fish were dip-netted individually from the holding area and weighed to the nearest ten grams on a top loading spring scale while in the dip-net. Fish were then transferred into a basin of stream water. A foam mat was placed under the work area to prevent injury to mishandled fish.

The fork length of each fish was determined to the nearest millimetre by placing the fish on a meter board. All fork length measurements were recorded with the mouth of the fish closed. If fish were captured more than once during a single spawning season their average fork length was calculated and used in any analyses. This was necessary because fish frequently exhibited some variability in their fork lengths (±5 mm) between capture dates during the same spawning season.

Sexing mature fish was performed by either the removal of gametes during the check of an individual's sexual condition or by the presence of a kype, an anterior protrusion of the lower jaw, on mature males. Fish whose sex could not be determined using external methods were recorded as immature. However, in 1988, no distinction was made for immature trout.

Records were also kept on the sexual and general condition of each fish. Sexual conditions (immature, mature, ripe or spent) were determined by gently stroking the ventral surface of fish posteriorly towards their vent. This caused the protrusion of the urogenital papilla on mature females or stimulated the release of gametes (eggs or milt) from ripe fish. Mature fish were individuals that were not ripe or spent but could be sexed externally and were expected to spawn that season. Post-spawning females that exhibited a sunken body cavity or underside were classified as spent. Spent males were those that milt could not be extracted from when they were captured migrating downstream. Records of physical conditions included unusual marks, angling injuries and the infection of *Saprolegnia*, a secondary fungal pathogen commonly implicated in the diseases of teleost fish and eggs (Hoffman 1969).

All untagged brown trout were tagged with individually numbered floy anchor tags (Dell 1968). The applicator and method of tagging are described in Thorson (1967). The adipose fin of each brown trout handled in 1989 and 1990 was removed with scissors to allow identification of fish that had lost their tag.

Captured brook trout were similarly processed, but they were not tagged. The chicken mesh used to construct the wings of the trap in 1988 did not efficiently capture fish under 225 mm; consequently, some brook trout under 225 mm avoided capture and complete records of the brook trout captured in 1988 were not kept. During 1989 and 1990, instead of tags, a series of fin clips was used that was changed every 5 days. Either a dorsal, ventral, or caudal fin, or combination of fins, was clipped to distinguish the five day period when individual brook trout were captured (e.g.: right pelvic - November 4-8, 1990; right pectoral - November 9-13, 1990).

Immediately after processing, all trout were released in the direction of their migration before capture. Trapping and handing fish on their spawning migration, however, often caused fish migrating upstream to become disoriented after being released. Consequently, fish that returned downstream within three days of being released upstream were released back upstream if it was obvious they were not spent. Processing these fish involved examining their tag or clipped fins to determine when they had last been captured. Records, however, were not kept of these fish.

2.3.3 Miscellaneous

In addition to the data collected on fish captured migrating through Bill Griffiths Creek, records were also kept on other factors, such as: whether fish were captured during the day or night; and general weather conditions.

The trap was monitored 24 hours a day to prevent vandalism or theft of fish. This was accomplished by setting up a holiday trailer in the Old Camp Day Use Recreation Area which was located within approximately 300 m of the trap.

To process fish in all weather conditions, a 3.5 m X 5.0 m tent equipped with a wood stove was erected near the trap site. Although fish were never processed inside, the tent kept equipment dry and thawed and was useful for storing equipment. During freezing ambient conditions tagging equipment was emersed in warm water to prevent freezing.

2.3.4 Sampling Problems

Common mergansers (*Mergus merganser*) began preying and harassing fish in the trap near September 24, 1989. The problem lasted for approximately ten days. During this time the remains of three brook trout, one brown trout and one lake trout (*Salvelinus namaycush*) were found. A scarecrow was constructed near the trap, streamers were tied above and around the trap. Spring-loaded mouse traps connected to a string line were also set to scare the mergansers. After several mornings of continued merganser presence, a damage permit was acquired from Alberta Fish and Wildlife Division. After one merganser was destroyed, they were no longer a problem and only needed to be scared by firing a shotgun into the air. No problems with mergansers were experienced in 1988 or 1990.

Although records were kept on the tag number, sex, weight, fork length, sexual and physical conditions of each fish captured, there are instances where data are missing on a few fish. This is usually the result of illegible field notes or human error. With the large sample sizes obtained during this study the omissions were not a problem. However, it may cause some confusion to the reader. For instance, the fork lengths are missing on three of the 1347 individual brown trout captured in 1989; therefore, these three fish were excluded from calculations requiring fork lengths but they were included where fork lengths were not necessary.

One entire day of data are missing from 1990. This occurred as a result of a break and entry into the housing accommodations set up in "Old Camp Day Use Recreation Area". Among the articles stolen were all the field notes from September 23 to October 29, 1990. However, all data up to October 28 on the physical measurements from live fish, except for adipose fin measurements, had been transcribed into computer files. As a result, only the data from October 29 was not recoverable.

The data from 1989 and 1990 is more complete than 1988 because longer trapping periods were employed. Consequently, in some instances 1988 data were excluded from the analysis (e.g., describing migratory trends). In some instances 1990 data were also excluded from the analysis due to the loss of data for October 29, 1990 and the inability to check computer files from September 23 to October 28, 1990, with data sheets from the field.

2.4 Results

2.4.1 Fork length frequency distributions

Brown trout clearly dominated the capture of migrants into Bill Griffiths Creek during the three spawning seasons. Including brown trout captured during their upstream and downstream migration, 3,784 brown trout were captured and handled 5,686 times during the three years. Excluding 1988, 623 brook trout were handled. The three years of trapping also resulted in handling three lake trout, one cutthroat trout, one rainbow trout (*Oncorhynchus mykiss*) and one white sucker (*Catostomus commersoni*). The fork lengths of the cutthroat trout, white sucker and one lake trout were 306 mm, 393 mm and 231 mm, respectively. Records for a rainbow trout and two lake trout captured in 1990 were not transcribed into computer files before the data was lost during a break and enter; however, the fork lengths of these fish were between 180 mm and 270 mm. Approximately 250-300 mountain whitefish were handled; their fork lengths ranged between 160 and 250 mm.

Because some individuals were captured migrating both upstream and downstream, the number of fish handled does not correspond with the number of individual fish captured each year. Table 2.1 provides the number of individual brown trout and brook trout captured each spawning season and provides fork length comparisons between sexes and species. Brown trout were the most numerous species. Adult brown trout were also generally longer than adult brook trout.

The chicken mesh used on the wings of the trap in 1988 likely resulted in some fish under 225 mm passing through the trap undetected. Consequently, fork length comparisons using the 1988 results with brook trout, immature brown trout or male brown trout could not be made. In addition, a significant number of spawning migrants may have entered Bill Griffiths Creek before the trap was installed, or may have left after it was removed in 1988.

Therefore, the number of brook trout captured in 1989 (n = 382) compared to 1988 (n<35) does not necessarily indicate an increase in the size of the brook trout population between 1988 and 1989, but rather an increased trapping efficiency and a longer trapping season in 1989. Similar arguments also explain the increase in brown trout numbers from 1,040 to 1,347 fish between 1988 and 1989.

Comparisons can, however, be made between the size of the spawning populations between 1989 and 1990 because the longer trapping periods employed those years resulted in capturing a larger percentage of the spawning population. Also, the trap construction in 1989 and 1990 did not change. The spawning brook trout population experienced a marked decline from 1989 to 1990. In contrast, the brown trout population increased slightly but remained relatively stable. In 1989 and 1990, 1,290 and 1,389 brown trout (respectively) were captured migrating upstream from September 23 to December 4. The increase was attributed to an additional 55 male, 23 female and 21 immature brown trout being captured in 1990.

With the exception of fewer brown trout males under 225 mm being captured in Bill Griffiths Creek during 1988, the fork length frequency distributions were relatively similar between all three years (Figure 2.1).

Several observations are apparent in the brown trout length frequency distributions when comparisons are made between sexes (Figure 2.1). Both sexes display similar peak distributions and have similar maximum fork lengths. However, relatively few females under 300 mm were captured and males dominated the distribution under 300 mm. Immature brown trout were prevalent under 300 mm but none were captured in excess of 350 mm.

The fork length frequency distributions for the brook trout captured during the 1989 and 1990 spawning seasons are shown in Figure 2.2. Brook trout (Table 2.1 and Figure 2.2) were generally considerably smaller than brown trout (Table 2.1 and Figure 2.1).

Table 2.1: Fork length (FL) distributions among individual brown trout and brook trout captured on spawning migrations through Bill Griffiths Creek during 1988, 1989 and 1990.

	Sample size	Mean FL (mm)	Standard deviation	Maximum FL (mm)	Minimum FL (mm)
Brook trout (September 1 through to December 20, 1989)					
Males	216	189.06	24.28	293	142
Females	163	219.94	30.20	323	167
Immatures	3	173.67	15.80	196	162
Brook trout (September 23 through to December 4, 1990)					
Males	108	198.55	30.56	274	151
Females	71	227.20	33.02	362	170
Immatures	5	177.60	15.42	195	154
Brown trout (October 15 through to November 27, 1988)					
Males	422	403.93	81.50	634	155
Females	618	410.72	53.87	637	222
Brown trout (September 1 through to December 20, 1989)					
Males	557	393.50	92.66	677	170
Females	748	421.56	59.75	657	268
Immatures	39	209.33	40.50	308	153
Brown trout (September 23 through to December 4, 1990)					
Males	590	404.92	89.97	663	160
Females	756	432.08	60.66	645	277
Immatures	51	225.53	43.28	339	119

2.4.2 Repeat spawning among brown trout

The percentage of brown trout returning to spawn in Bill Griffiths Creek in subsequent years differed between sexes. Among 751 females captured during 1989, 429 (171 + 196 + 62), or 57.1%, returned in 1990 (Table 2.2). In contrast, only 173 (25 + 74 + 74), or 31.1%, of 557 males from 1989 returned to spawn in 1990 (Table 2.2).

Removing the adipose fin of captured brown trout in 1989 permitted identification of fish in 1990 that lost their tag. Brown trout tagged during 1988 were not permanently marked; consequently, the total number of brown trout from 1988 returning to spawn in subsequent years could not be determined. However, based on returns of fish with 1988 tags, at least 32 male (7.5%) and 194 female (31.4%) brown trout that spawned in Bill Griffiths Creek in 1988 survived and returned to spawn in 1990 (Table 2.2).

Table 2.2: Number of brown trout captured in 1988, 1989 and 1990 that returned to spawn in Bill Griffiths Creek (BGC) after being captured in a previous spawning season.

1988 Males	1988 Females	1989 Males	1989 Females	1989 Immat	1990 Males	1990 Females	1990 Immat
Number of individual brown trout captured migrating through BGC							
422	618	557	751	39	590	756	51
Tagged brown trout from 1988 returning to spawn in BGC							
		66	270	0	32	194	0
(also captured in 1989)					(25)	(171)	
(not captured in 1989)					(7)	(23)	
Tagged brown trout previously only captured in 1989 that returned to spawn in BGC							
					74	196	0
Brown trout returning to spawn in BGC that lost their 1989 tag before migrating upstream							
					74	62	0

2.4.3 Growth rates of brown trout

An analysis of covariance (ANCOVA) (Snedecor and Cochran 1989) determined differences existed in annual growth between males [$\log_{10}$(growth) = 5.46 - (1.50 X $\log_{10}$(1988 fork length))] and females [$\log_{10}$(growth) = 5.00 - (1.42 X $\log_{10}$(1988 fork length))] that spawned in 1988 and returned to spawn in 1989 (Table 2.3). Similarly, differences also existed in annual growth between males [$\log_{10}$(growth) = 5.67 - (1.58 X $\log_{10}$(1989 fork length))] and females [$\log_{10}$(growth) = 5.40 - (1.55 X $\log_{10}$(1989 fork length))] that spawned in 1989 and returned in 1990 (Table 2.3).

Repeat spawning males had faster annual growth rates than repeat spawning females. Figure 2.3a shows the mean annual growth at different fork length intervals for males and females that spawned in 1988 and returned to spawn in 1989. Similarly, Figure 2.3b shows the mean annual growth at different fork length intervals for males and females that spawned in 1989 and returned to spawn in 1990.

Table 2.3 Test statistics for analyses of covariance testing for differences between the linear relationships of fork length and annual growth for repeat spawning male and female brown trout returning to spawn in 1989 and 1990.

Fork length in 1988 and growth from 1988 to 1989 for males (n = 67) and females (n = 261) returning to spawn in Bill Griffiths Creek during 1989.

Residual variance	Slopes of Linear regressions	Adjusted intercepts
F = 0.527 (NS)	t = 0.126 (NS)	t = 5.546 (***)

Fork length in 1989 and growth from 1989 to 1990 for males (n = 95) and females (n = 358) returning to spawn in Bill Griffiths Creek during 1990.

Residual variance	Slopes of Linear regressions	Adjusted intercepts
F = 0.538 (NS)	t = 0.097 (NS)	t = 6.508 (***)

NS - differences not significant (P>0.05)
*** - differences highly significant (P<0.001)

2.4.4 Timing of spawning migrations

The number of brown trout and brook trout captured daily migrating upstream during the 1989 trapping period are illustrated in Figure 2.4. The figure suggests the spawning migration of brook trout into Bill Griffiths Creek may have begun prior to when the trap was installed in 1989. In contrast, a disproportionately small number of brown trout migrated into the stream during the first few weeks of trapping. Brook trout also exhibited a more gradual migration into the stream than brown trout. However, the upstream migrations of both species began declining at, or near, the same time. The sudden decrease by brook trout and to a lesser extent by brown trout between September 26 and October 2 was due to predation and/or harassment of trout before they entered the trap by mergansers. Comparisons between upstream migrations of brown trout and brook trout in 1988 and 1990 were not made because the trap was installed later in those years and a larger portion of the brook trout spawning populations were likely missed.

Figure 2.5 illustrates the patterns of the upstream and downstream migrations of brown trout in Bill Griffiths Creek for 1988, 1989 and 1990. The graphs demonstrate clear, distinct trends for both the upstream and downstream migrations each year. The timing of the spawning migration was also similar between years. Except for a small amount of movement into the stream in September, upstream migrations began in early October. Upstream migrations peaked in late October each year. Except for a small number of fish that arrived late, upstream migrations were generally over by early December. Downstream migrations began in the last half of October and peaked about a month later. Movement out of the stream was greatly reduced by mid December.

Differences between the number of upstream and downstream migrants were not caused by mortalities on the spawning grounds. The combined number of brown trout mortalities observed on the spawning grounds for all three years was 16. During the three years of research, the most mortalities were encountered in 1989 when nine dead brown trout were observed. Eight of these mortalities were found in Bill Griffiths Creek and one was found in another nearby spawning stream. Of the eight mortalities found in Bill Griffiths

Creek in 1989, the suspected causes of death were: 1 fish - natural predation (common mergansers); 1 fish - handling (died in the holding basin before being handled); 2 fish - unknown (but found within 3 days of handling); 4 fish - pathogenic (extensive *Saprolegnia* infection). The single dead fish found in a nearby spawning stream during 1989 was heavily infected with *Saprolegnia*.

Timing of the upstream migrations was similar between each of the three years (Figure 2.6). A 5-point running average was used to smooth the data in Figure 2.6.

2.4.5 Influence of sex and sexual condition on timing of migration

Figure 2.7 shows the upstream movement of brown trout into Bill Griffiths Creek during 1989 and 1990. Movement into the stream by males began approximately 10 days earlier than females each year. Each sex exhibited a different peak period for migrating into the stream. If a sudden change in the number of fish of one sex moving upstream occurred, then a similar change was generally also exhibited by the other sex as well. Immatures moved in throughout the spawning season and did not display a period of peak movement.

Figure 2.8 shows the downstream migrations of male and female brown trout from Bill Griffiths Creek during the 1989 and 1990 spawning seasons. The graphs show distinct patterns during the downstream migrations. In contrast to the upstream migrations, the timing of the downstream migrations were similar for both males and females.

As expected, reproductive status influenced the upstream and downstream migrations of females. Approximately 1/3 of the females were ripe during their upstream migration each year. Almost all females exiting the stream were spent. In 1988, all but seven females were spent when exiting the stream; one was known to migrate back upstream before the trap was removed on November 27. In 1989, all but one recaptured female was not spent when leaving the stream. This individual was still mature; however, she returned upstream in a ripe condition three weeks later, then spent six days upstream and was spent when recaptured during her second downstream migration in 1989. In 1990, six females were not yet spent when captured exiting the stream; three of these females were recaptured later in 1990 when they returned back upstream to spawn.

In contrast to females, relatively few males were not ripe when they entered the spawning grounds. Just slightly more than 2% of the males migrating upstream in all three years were not ripe when they were captured. Most non-ripe males were captured either early (i.e., before October 20) or late (i.e., after December 1) in the spawning season.

Reproductive status also influenced the downstream migrations differently between sexes. For example, in 1989 only one female moving downstream was not spent, but 53% of the males were still ripe. Ripe males were also prominent throughout the 1988 and 1990 downstream migrations.

2.4.6 Effect of fork length on timing of upstream migration

A one-way analysis of variance (ANOVA) (Cody and Smith 1991) determined there were no significant differences between mean fork lengths for different time intervals in 1989 that males ($0.75>P>0.5$) and females ($0.1>P>0.05$) migrated upstream. Figure 2.9 illustrates the relationship between mean fork length and timing of upstream migration during 1989. At the start and end of the spawning season, the time intervals were extended to provide adequate sample sizes; otherwise mean fork lengths were calculated for weekly time intervals. Because females generally enter the stream later than males, it was necessary to extend the time interval for females an extra week at the start of the spawning season to obtain an adequate sample size. The smallest sample size used in the analyses was 34 fish.

2.4.7 Relationship between previous spawning and timing of upstream migration

The dates that individuals were captured migrating upstream one year was generally correlated with the date(s) they were captured in subsequent spawning seasons (Table 2.4). For individuals captured only in 1989 and 1990, the dates of upstream capture were strongly correlated ($r = 0.7417$); 55.01% of the variance ($r^2 \times 100$) in the date they were captured in 1990 was attributed to the date they had been captured in 1989. The small number of males ($n = 6$) from 1988 that were recaptured in 1990 may have contributed to the non-significance of correlations for returning males. The non-significant correlation coefficient ($r = 0.3112$, $n = 18$) for alternate year spawners indicates that the date they migrated upstream during their last spawning season does not relate to the date they migrated upstream in subsequent spawning seasons. (Note: The data for females in Table 2.4 is also reported in Section 4.4 of this thesis).

2.4.8 Relationship between upstream migration and time of day when captured

Although spawning activity was frequently observed during daylight, almost the entire movement of brown trout into Bill Griffiths Creek occurred at night. For example, in 1989, the year with the most complete records, 1,315, or 98.8%, of the 1,331 brown trout captured migrating into the stream during the spawning season were captured during the night (dusk to approximately 8:00 AM).

The behaviour of the majority of fish captured during daylight hours may have be altered by stress. Of the 16 fish captured migrating upstream in 1989 during the day, 14 were known to be either infected with *Saprolegnia*, a secondary fungal pathogen, when they migrated upstream or to become infected while on the spawning grounds. Therefore, either a primary stressing agent which led to the infection, or the infection itself, may have led to unusual behaviour that resulted in the capture of 14 of the brown trout captured during daylight.

Table 2.4 Correlation values comparing dates of upstream migrations between individuals that returned to spawn in subsequent spawning seasons.

Relationship of capture dates	Sample size	Correlation coefficient (r)	Significance	r^2
Correlations between upstream migration in 1989 and 1990 for individuals captured in 1989 and 1990 but not 1988:				
Females	346	0.6952	***	0.4833
Males	86	0.7569	***	0.5729
Total	432	0.7417	***	0.5501
Correlations between upstream migration in 1988 and 1989 for individuals captured all three years:				
Females	121	0.3109	**	0.0967
Males	6	0.4669	NS	
Total	127	0.2996	**	0.0898
Correlations between upstream migration in 1988 and 1990 for individuals captured all three years:				
Females	121	0.2238	**	0.0501
Males	6	0.5051	NS	
Total	127	0.2216	*	0.0491
Correlations between upstream migration in 1988 and 1990 for individuals captured in 1988 and 1990 but not 1989:				
Females	16	0.2431	NS	
Males	2	not calculated		
Total	18	0.3012	NS	

2.4.9 Influence of sex and sexual condition on duration of stay on the spawning grounds

During each year some brown trout were captured several times in the upstream and downstream traps. Generally, these individuals were males. But some females also migrated into the stream, then moved downstream below the trap and returned back upstream during the same spawning season

(Section 2.4.5). Some males were captured moving upstream and downstream several times during a single spawning season. For example, one male was caught eight times, and another seven times, during 1989. When individuals were captured several times during the same spawning season, their duration of stay on the spawning grounds was calculated by using the date of their first upstream and last downstream capture.

Only a small portion of the upstream brook trout migrants were also captured migrating from the stream. For example, in 1989 barely one sixth of the upstream migrants were recaptured migrating downstream. Since brook trout were not individually marked, the duration of time brook trout spent on the spawning grounds could not be calculated.

Sex influenced the length of time brown trout spent on the spawning grounds (Figure 2.10). Males spent an average of approximately eleven days more on the spawning grounds than females. Males also displayed greater variability in the amount of time they spent on the spawning grounds. In comparison to sexually mature fish, very few immature fish that migrated upstream returned downstream (Figure 2.10).

Nearly half of the adult brown trout that migrated upstream remained above the trap until after the traps were removed. Consequently, the actual durations of many post-spawning fish could not be determined. However, it is known that many stayed longer than the longest recorded duration of 73 days for recaptured brown trout. For example, of five fish caught migrating upstream on September 27, 1989, only one was captured on its downstream migration. Although it is possible the other four were recaptured as any of the several fish that migrated downstream after losing their tags, it is also possible they were still upstream when the trap was removed. If they were still upstream when the trap was removed, then they would have spent 84 days or more upstream.

Although not shown, similar trends in the duration of time spent on the spawning grounds between male and female brown trout were also observed in 1988 and 1990. The major differences observed between 1989 and the other two years were in the longest durations spent. These differences resulted from the shorter trapping periods in 1988 and 1990.

The duration of stay spent on the spawning grounds by females was affected by their reproductive state when they entered the spawning grounds (Figure 2.11). Mature females generally spent 10-14 more days on the spawning grounds than ripe females which were ready to spawn when they were captured migrating upstream.

The number of males captured migrating upstream that were not ripe was too small to determine whether the duration of time spent on the spawning grounds by males was affected by their reproductive status when they entered the spawning grounds (Figure 2.11). For example, in 1989 only four males recaptured on their downstream migration were not ripe when they entered the spawning grounds.

<u>2.4.10 Influence of fork length on duration of stay</u>

Figure 2.12 illustrates the relationship between the mean fork length of recaptured brown trout and duration of time spent on the spawning grounds in 1989. The absence of any trends exhibited by females in the figure suggests that fork length does not influence their duration of stay on the spawning grounds. A one-way ANOVA (Cody and Smith 1991) confirmed there were no differences among the mean fork lengths of females ($0.5>P>0.25$) spending different durations of stay on the spawning grounds.

Figure 2.12 suggests that males spending the shortest durations generally had shorter fork lengths than males staying longer, and that as the duration of time spent increases the mean fork length also gradually increases, then stabilizes. However, a one-way ANOVA (Cody and Smith

1991) determined there was no significant relationship between fork length and duration of time spent on the spawning grounds when all recaptured males were included in the analysis (0.5>P>0.25).

In a concurrent study (Section 5.0), infection by *Saprolegnia* was evident among approximately 1/3 of the recaptured males. The results of the *Saprolegnia* study revealed that longer males are more susceptible to infection and that the infection may reduce the duration of stay on the spawning grounds (Section 5.4). Consequently, the inclusion in the analysis of males that became infected may distort the actual relationship between fork length and duration of time spent on the spawning grounds.

When the infected males in 1989 are excluded, as shown in Figure 2.13, a one-way ANOVA (Cody and Smith 1991) determined significant differences existed in the mean fork lengths between males spending different durations of stay on the spawning grounds (0.05>P>0.025). A Newman-Kuels method (Prepas 1984) determined the mean fork length of males spending ten days, or less, was significantly shorter, at the five percent level, than males with longer durations.

Similar analyses were conducted on males whose durations of stay in 1990 were known. The relationship between fork length and duration of stay for all males and infected males is shown in Figure 2.14. A one-way ANOVA (Cody and Smith 1991) determined significant differences existed in the mean fork lengths of males that spent different durations of stay on the spawning grounds when all males, including those infected, were included in the analysis (0.01>P>0.005). The mean fork lengths between males that spent four to ten days and 31 to 40 days were found to be significantly different at the five percent level (Newman-Kuels method, Prepas 1984).

Similar to the 1989 results, when recaptured males that became infected with *Saprolegnia* in 1990 were excluded, a one-way ANOVA (Cody and Smith 1991) determined significant differences existed in the relationship between mean fork length and duration of stay (0.005>P>0.001). A Newman-Kuels method (Prepas 1984) was used to determine the mean fork lengths of males that spent less than 20 days (four to ten days and eleven to twenty days) on the spawning grounds were significantly shorter, at the five percent level, than males that stayed longer.

As indicated earlier (Section 2.4.9), several males were recaptured in the both the upstream and downstream trap several times during the same spawning season. Males that returned to the spawning grounds several times during the same season were generally shorter than the average.

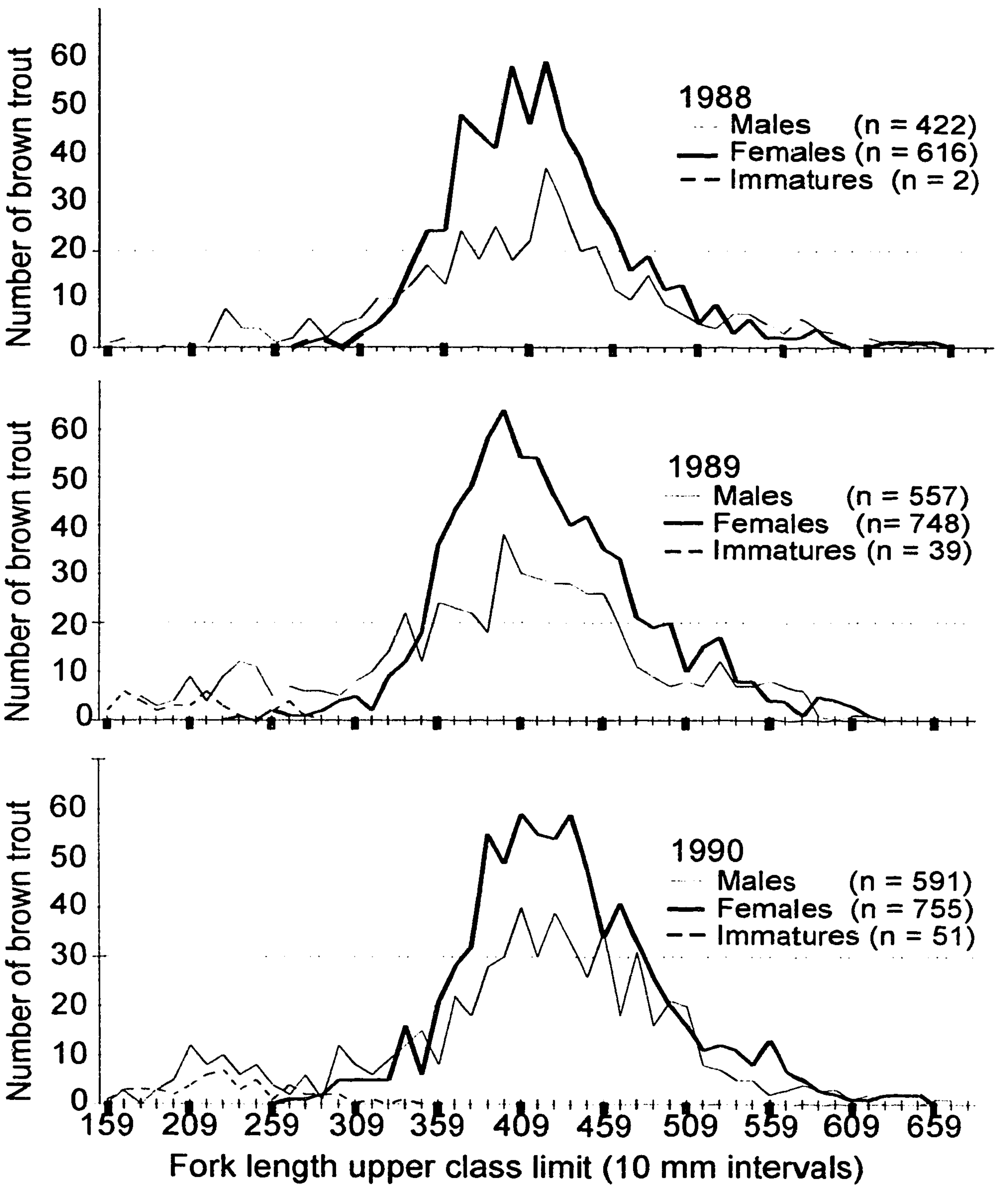

Figure 2.1: Fork length frequency distributions for brown trout captured during the 1988, 1989 and 1990 spawning seasons in Bill Griffiths Creek.

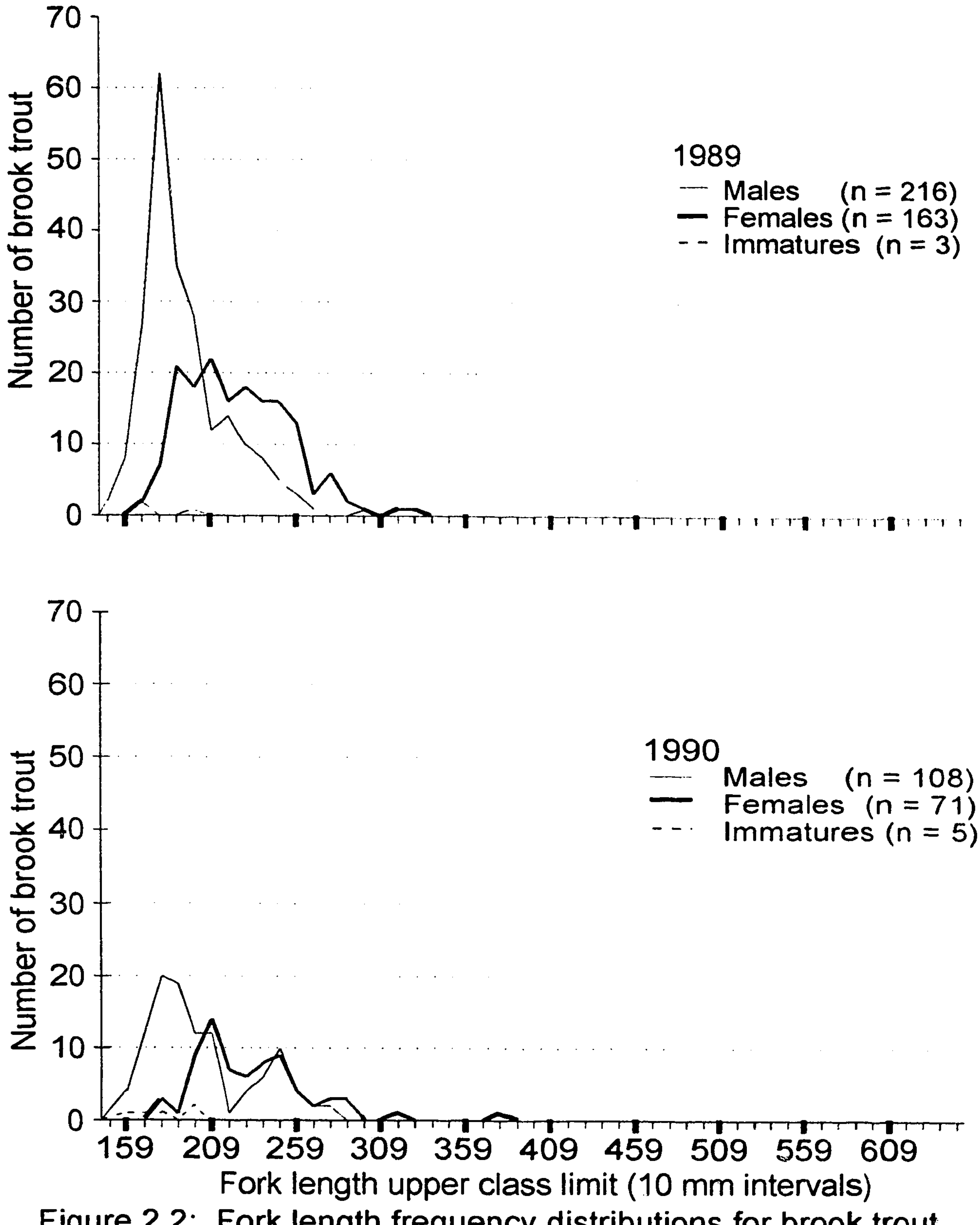

Figure 2.2: Fork length frequency distributions for brook trout captured during the 1989 and 1990 spawning seasons in Bill Griffiths Creek.

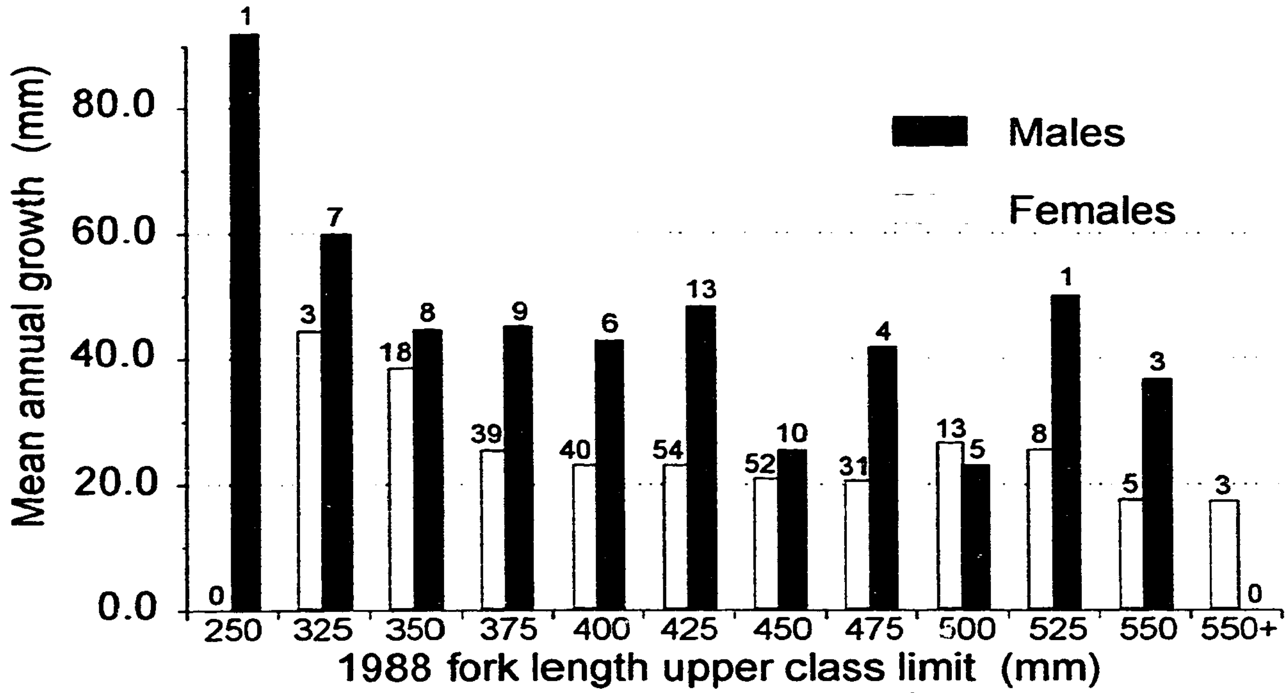

Figure 2.3a: Mean annual growth rates of male and female brown trout returning to spawn in Bill Griffiths Creek during 1989 (sample size above bars).

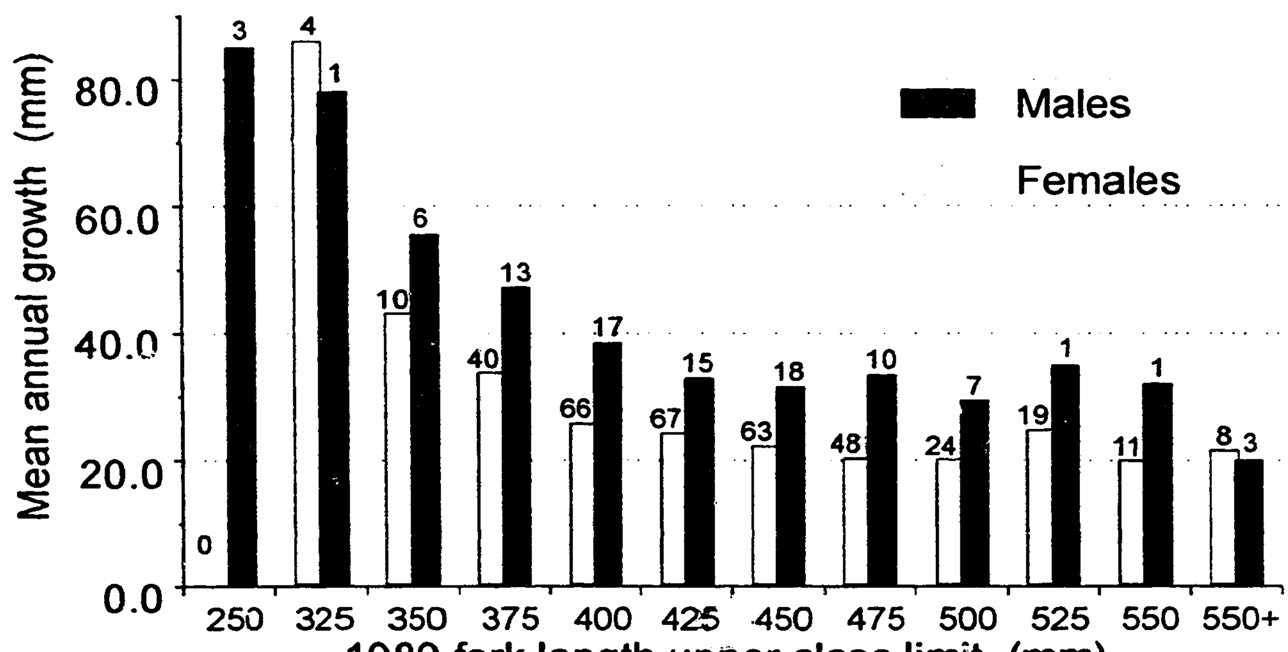

Figure 2.3b: Mean annual growth rates of male and female brown trout returning to spawn in Bill Griffiths Creek during 1990 (sample size above bars).

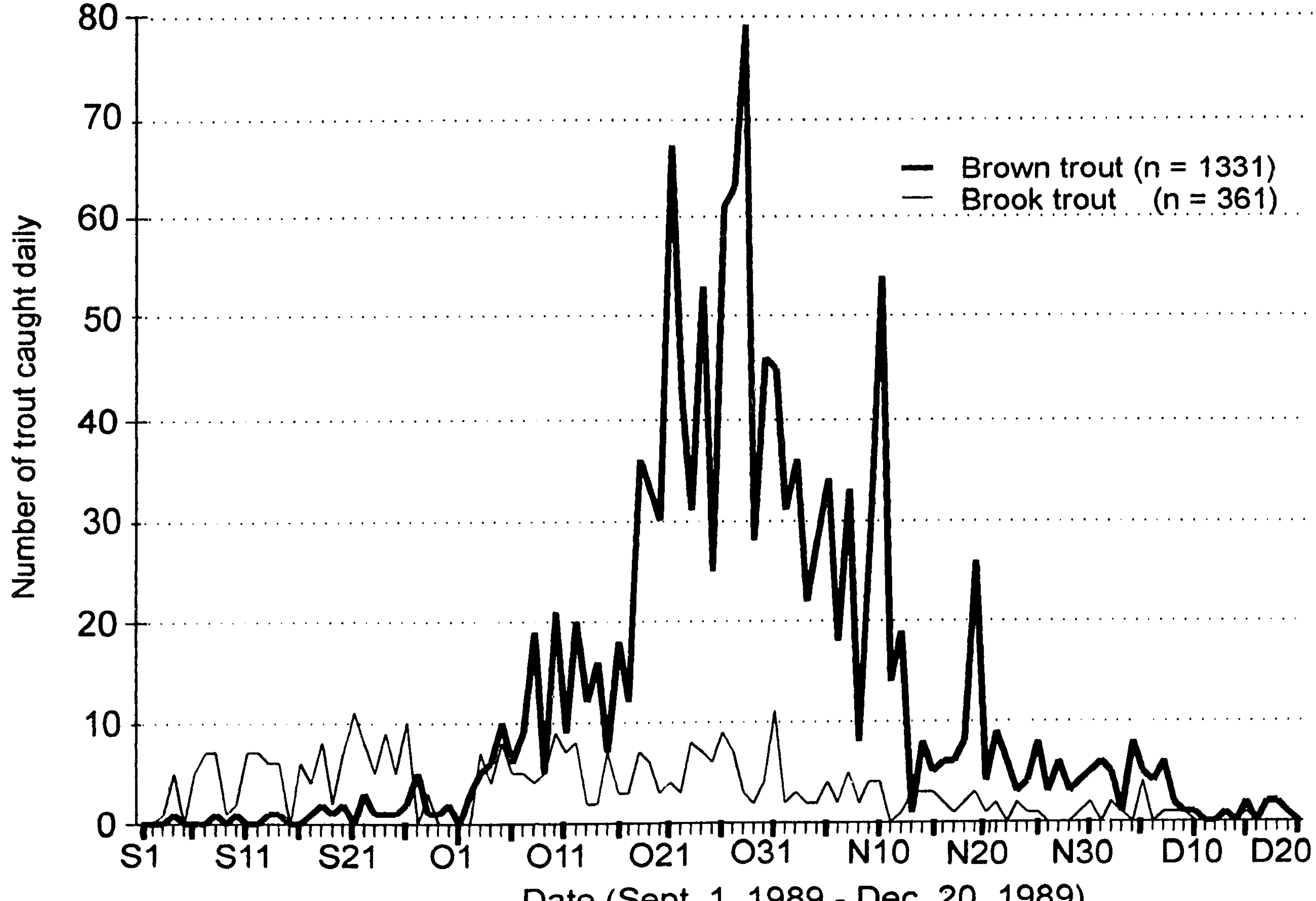

Figure 2.4: Daily migration of brown trout and brook trout into Bill Griffiths Creek during the 1989 spawning season.

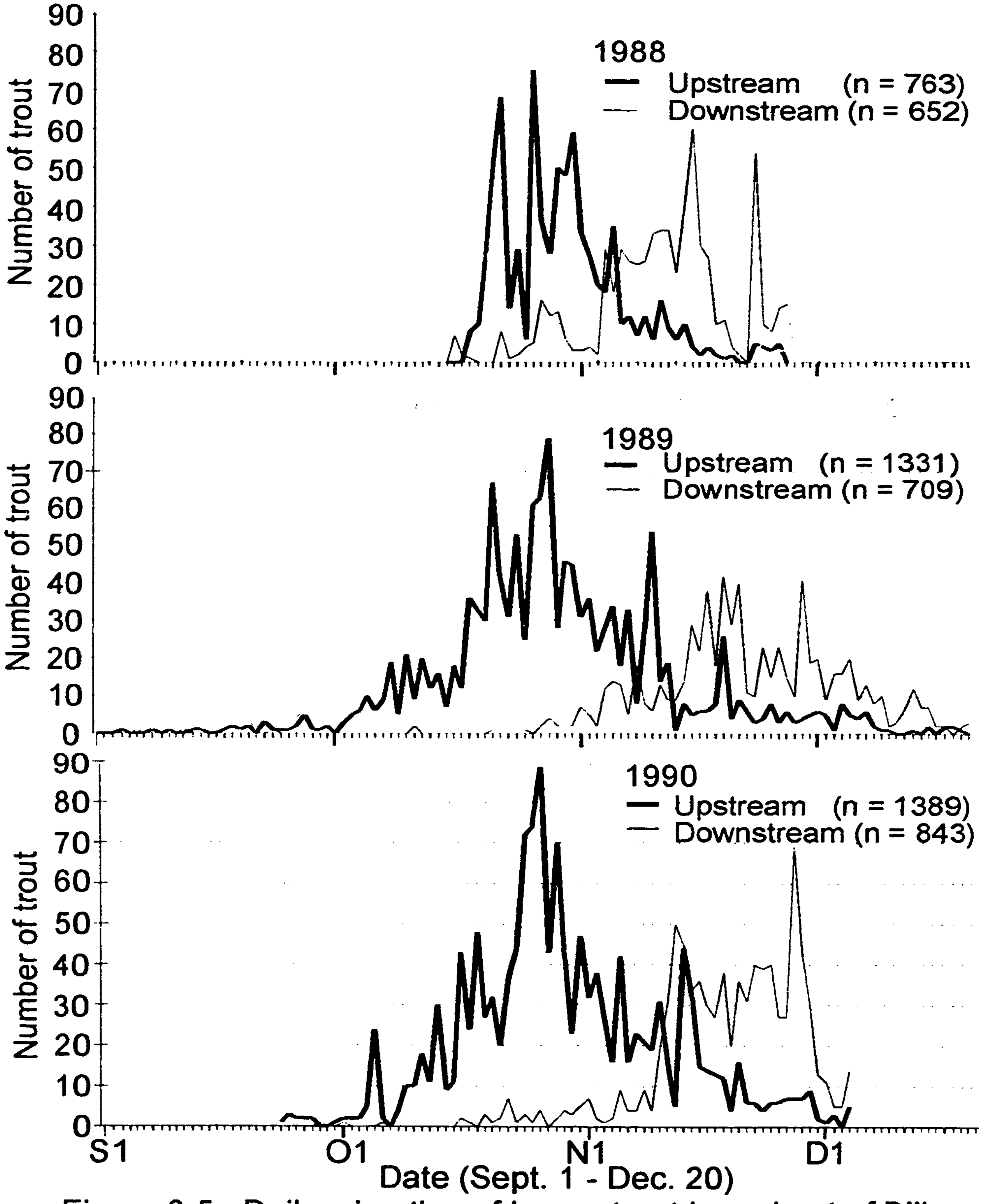

Figure 2.5: Daily migration of brown trout in and out of Bill Griffiths Creek during the 1988, 1989 and 1990 spawning seasons. (Full moon indicated by)

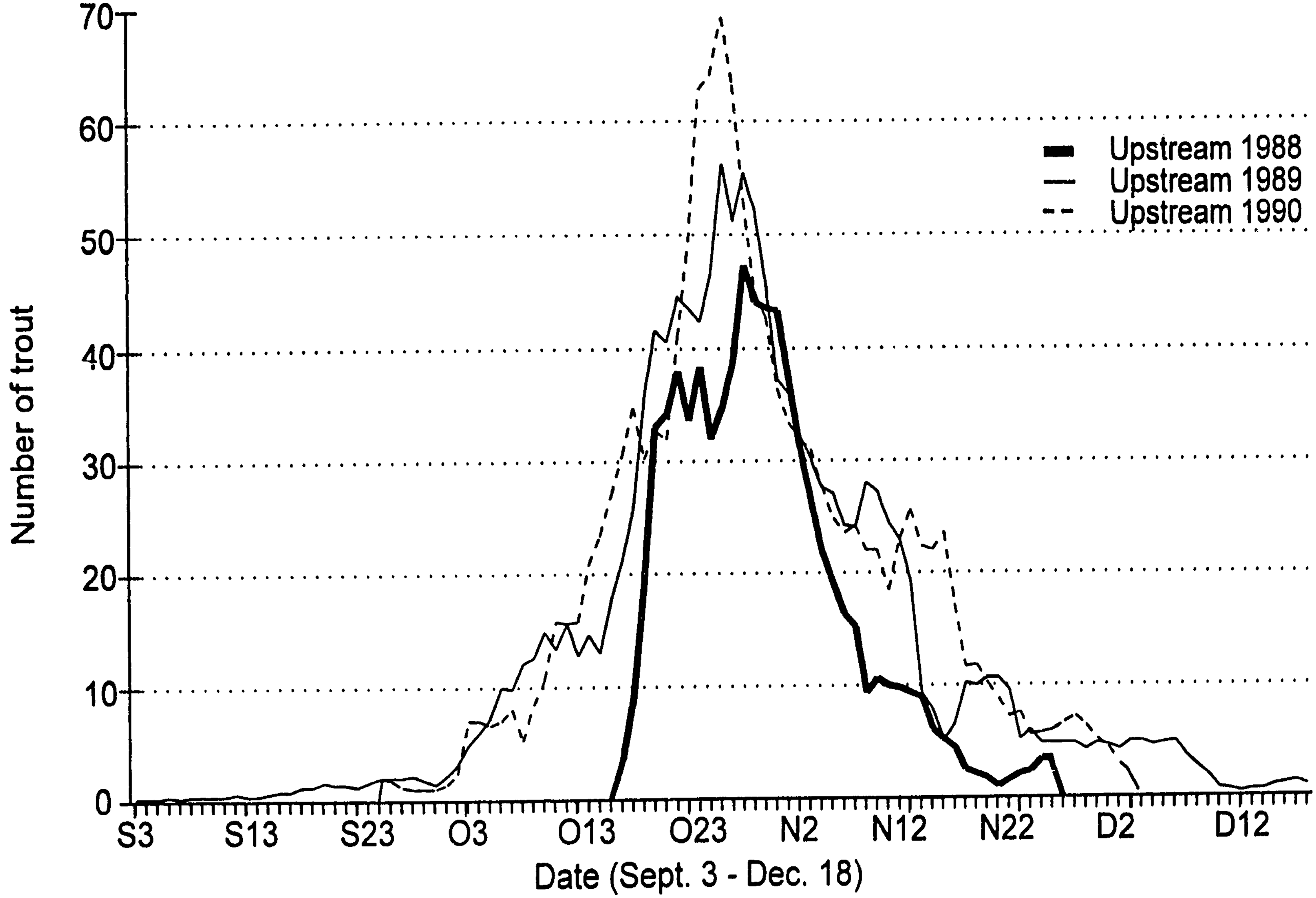

Figure 2.6: Upstream migration of brown trout into Bill Griffiths Creek during the 1988, 1989 and 1990 spawning seasons (data smoothed with a five-point running average).

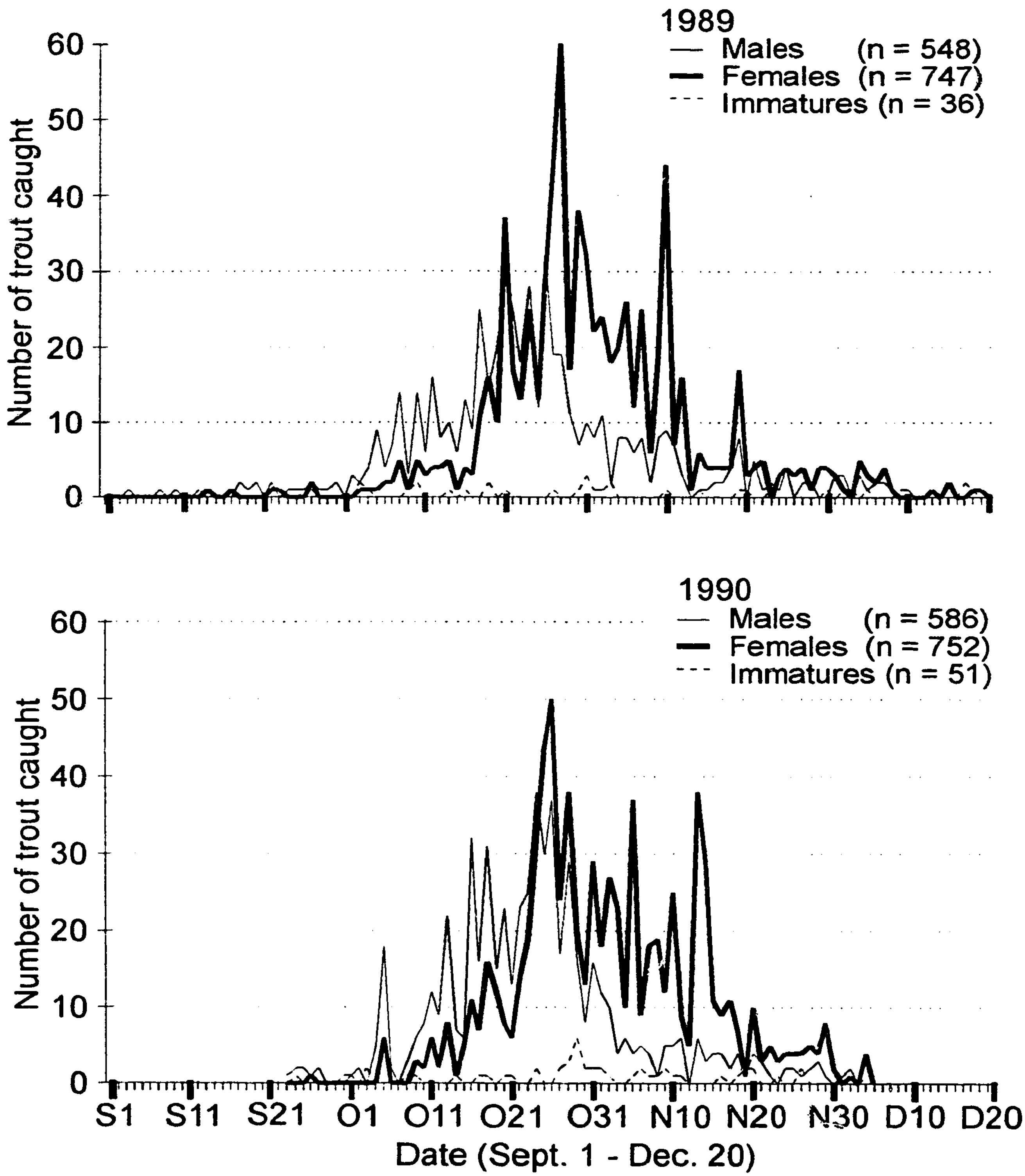

Figure 2.7: Comparison between sexes of upstream migration by brown trout into Bill Griffiths Creek in 1989 and 1990.

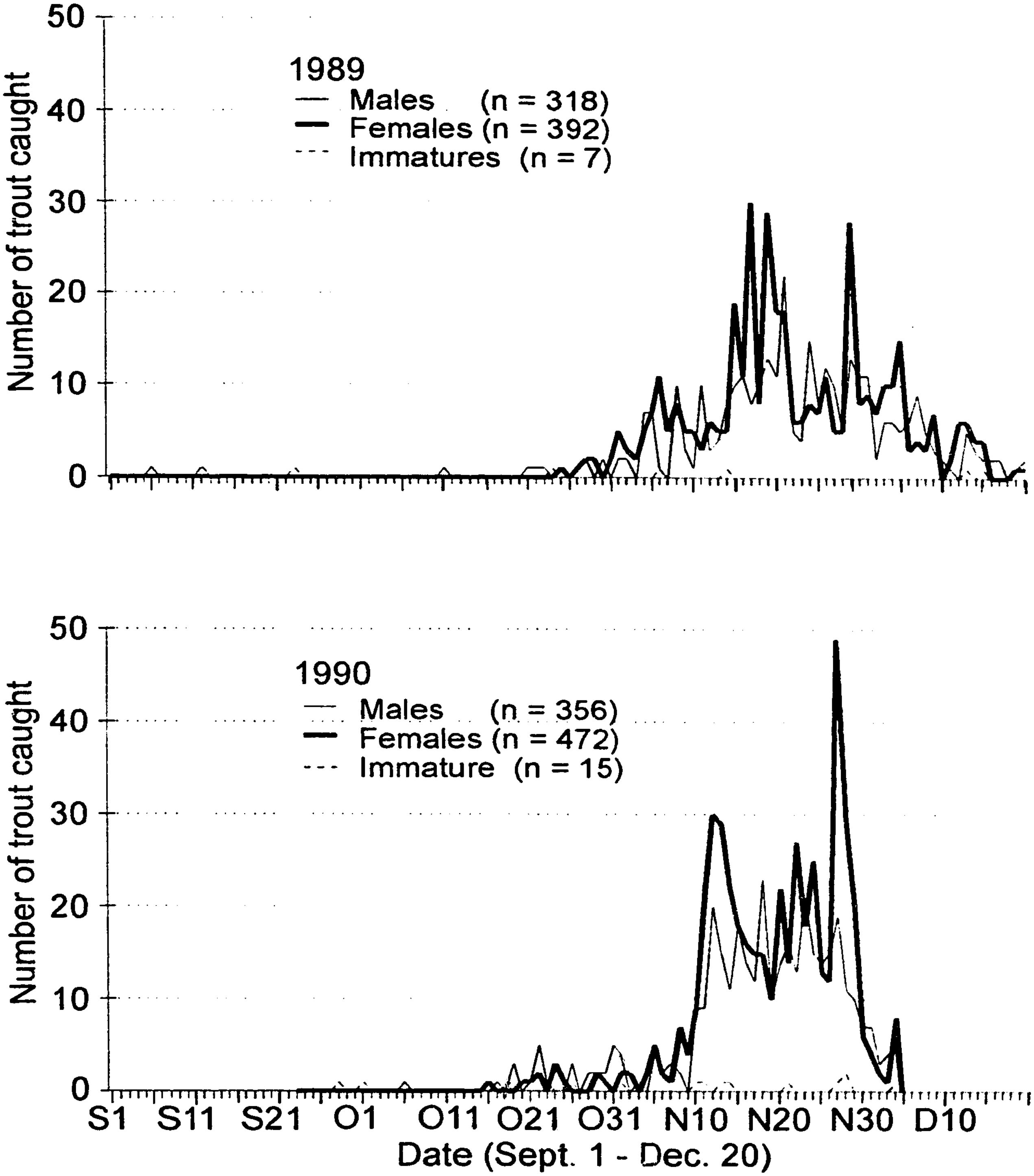

Figure 2.8: Comparison between sexes of downstream migration by brown trout out of Bill Griffiths Creek during 1989 and 1990.

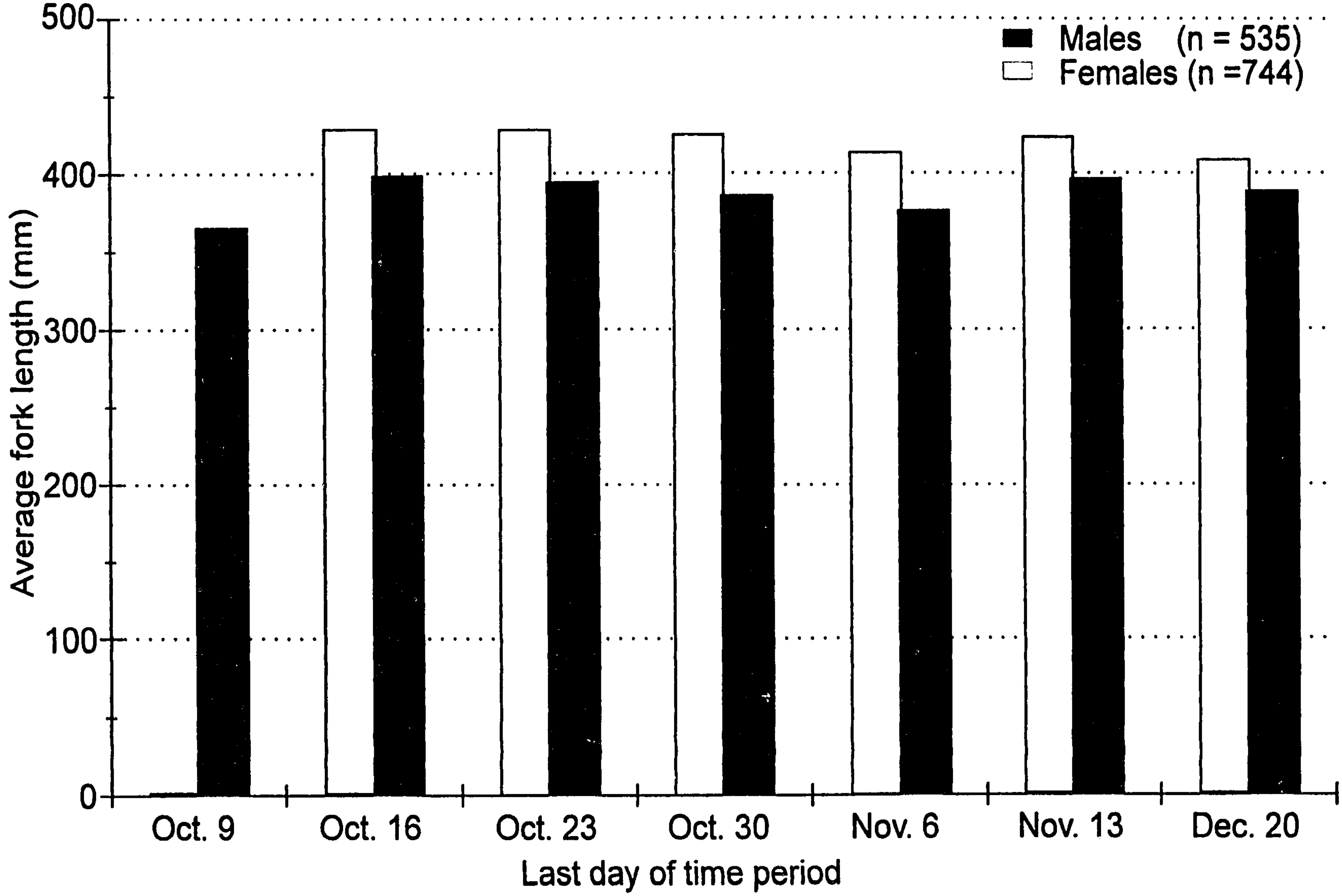

Figure 2.9: Mean fork lengths of male and female brown trout migrating into Bill Griffiths Creek during different time periods throughout the 1989 spawning season.

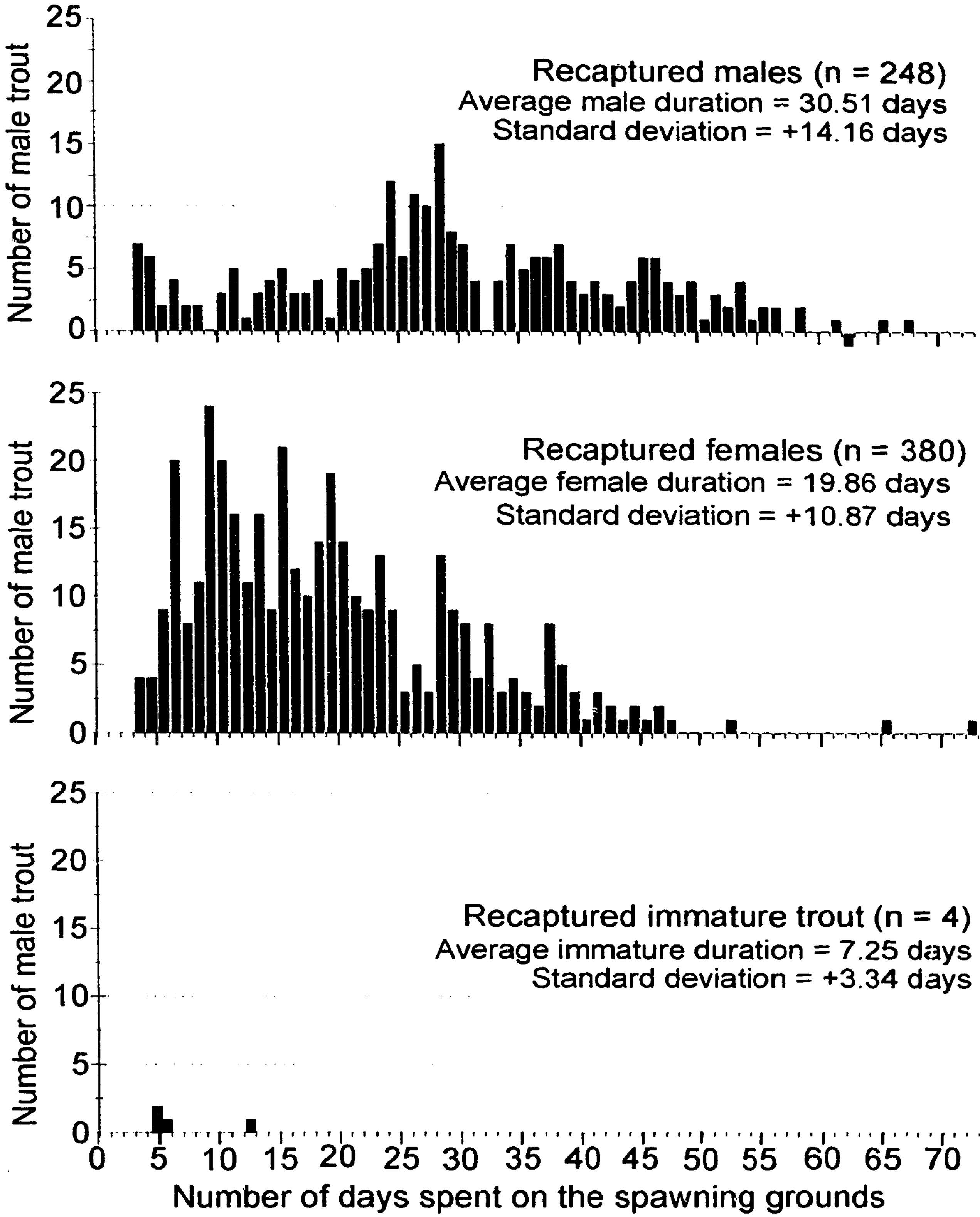

Figure 2.10: Duration of time spent on the spawning grounds by brown trout in Bill Griffiths Creek during the 1989 spawning season.

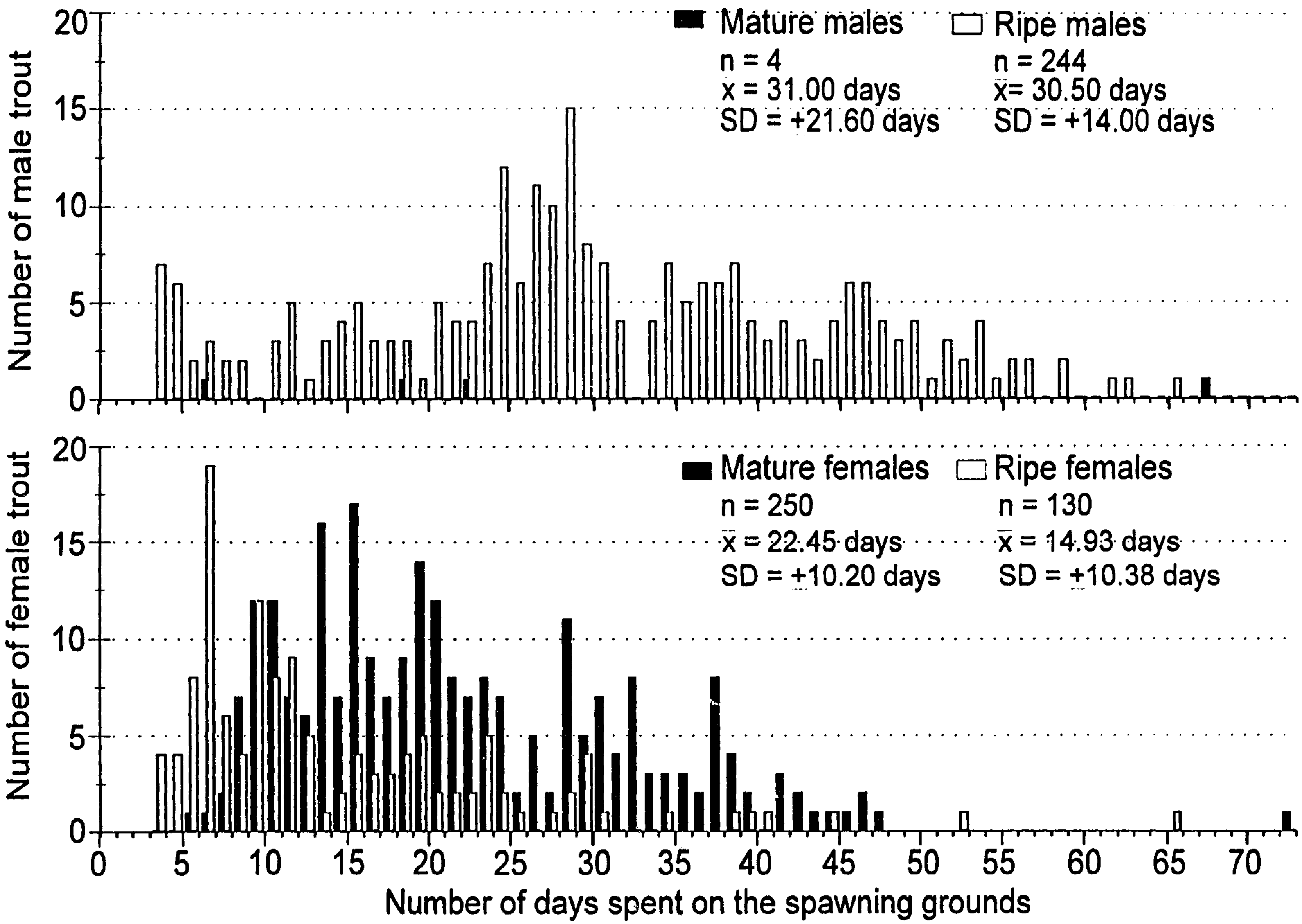

Figure 2.11: Effect of reproductive status on the duration of stay on the spawning grounds by brown trout during 1989 in Bill Griffiths Creek.

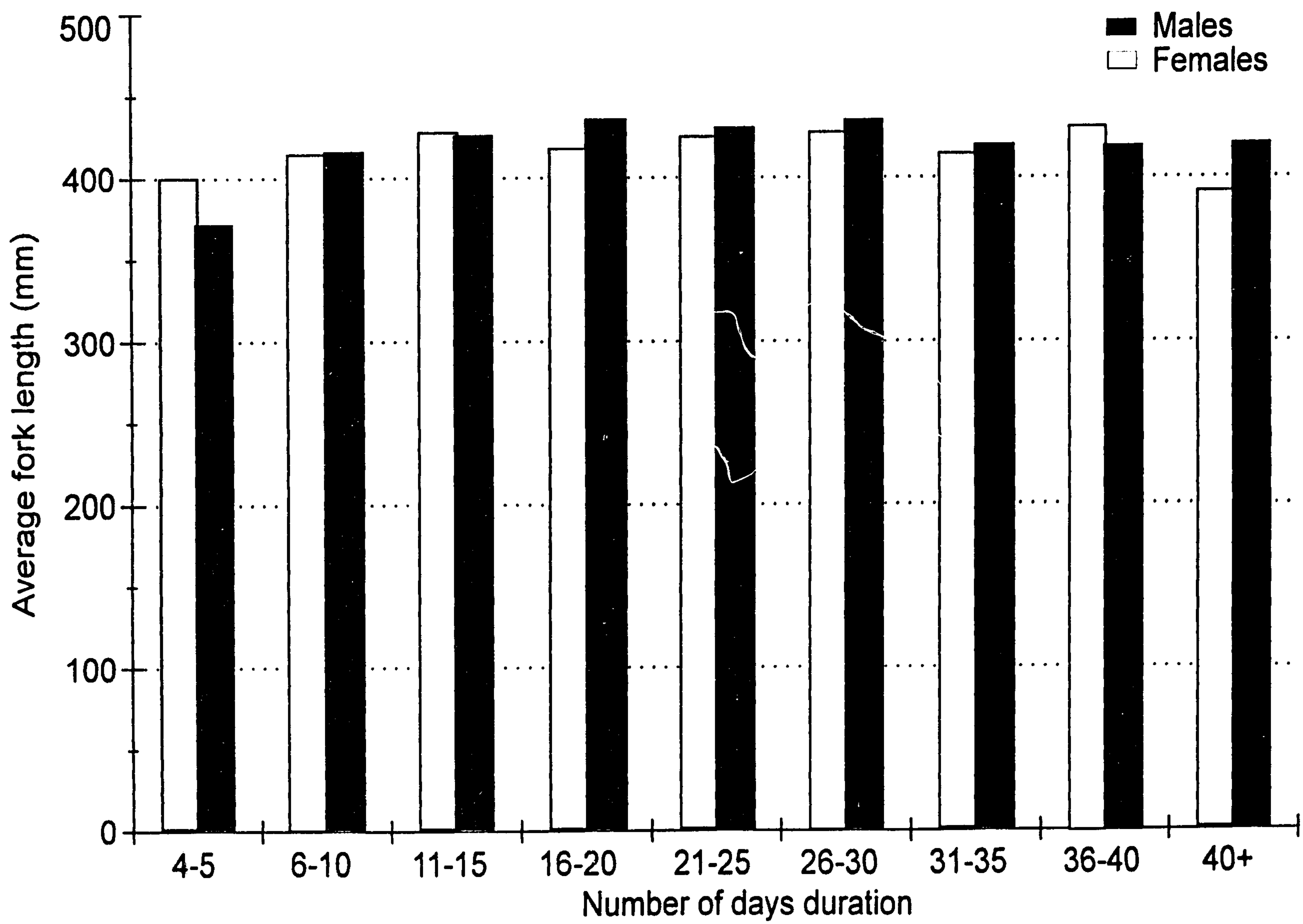

Figure 2.12: Relationship of fork length and duration of stay spent on the spawning grounds by male and female brown trout in Bill Griffiths Creek during 1989.

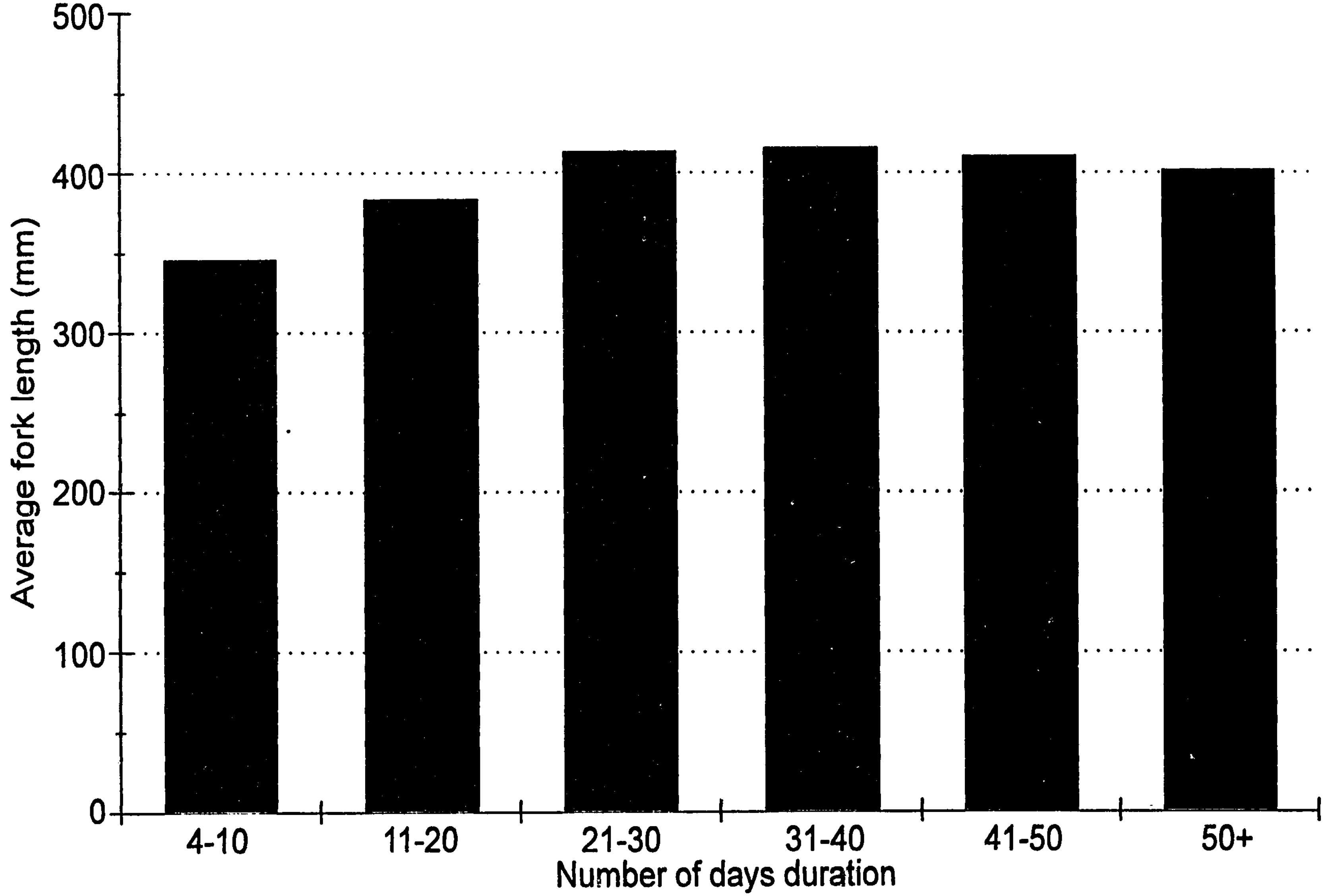

Figure 2.13: Relationship of fork length and duration of stay on the spawning grounds during 1989 in Bill Griffiths Creek by male brown trout that were not visibly infected with *Saprolegnia*.

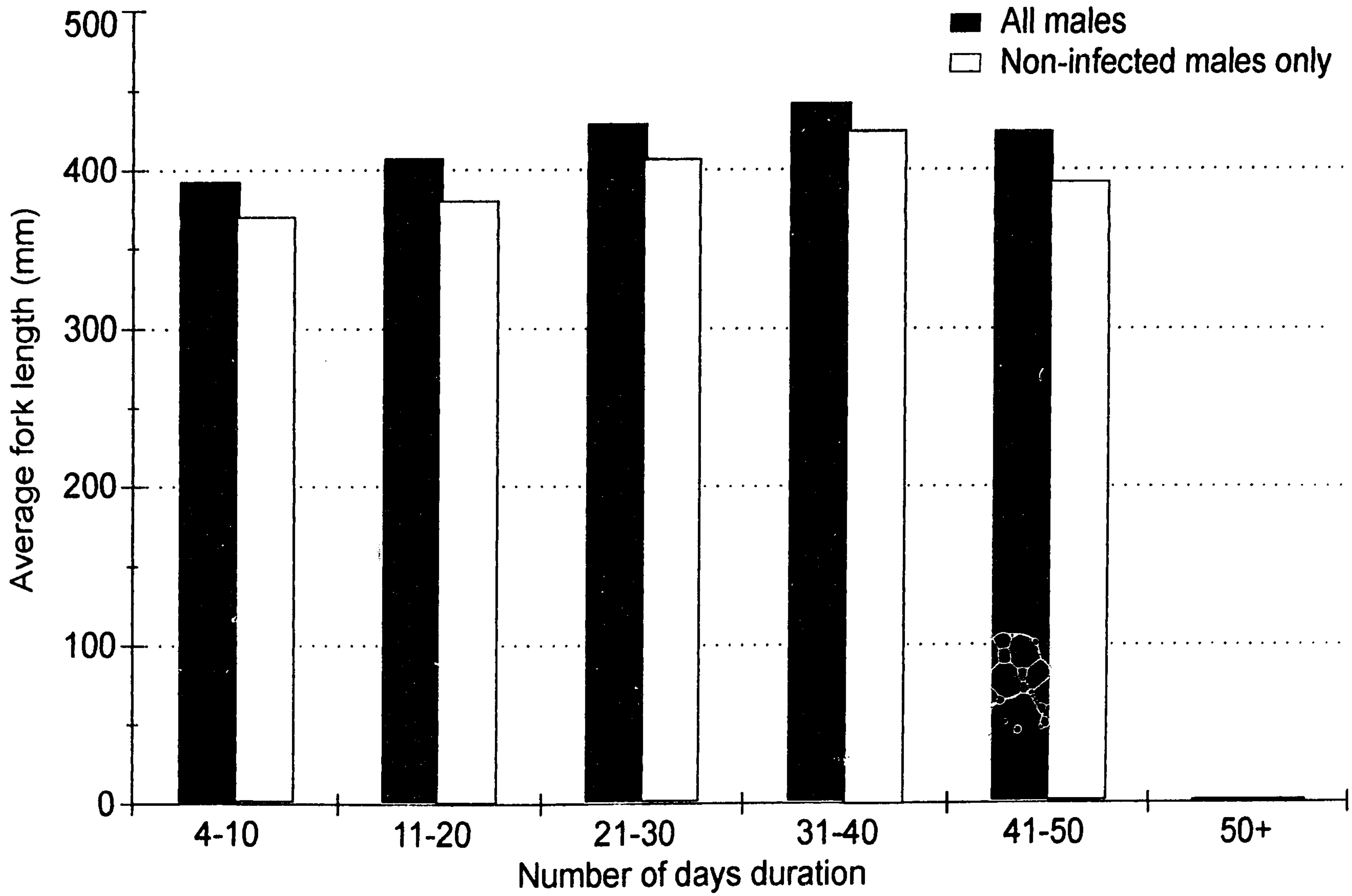

Figure 2.14: Relationship of fork length and duration of stay spent on the spawning grounds in Bill Griffiths Creek during 1990 by all males and males visibly infected with *Saprolegnia*.

2.5 Discussion

As expected, the movement of fish into Bill Griffiths Creek was dominated by fall spawning trout. With the exception of 200-300 immature mountain whitefish, only six fish that were not either brown trout or brook trout were captured during the three years of trapping. Interestingly, no bull trout which are also fall spawners and are native to the watershed, were captured. The springfed conditions in Bill Griffiths Creek would likely also provide optimal spawning habitat for bull trout. Although bull trout spawning may be occurring in other streams in the upper Bow River system that are predominantly fed by groundwater inflow, the failure to capture bull trout in Bill Griffiths Creek during 1988, 1989 or 1990 supports the hypothesis that it is unlikely that a self-sustaining bull trout population still exists in the upper Bow River below Bow Falls (J. Stelfox, pers. comm.).

Large populations of brown trout, and to a lesser extent brook trout, migrated into Bill Griffiths Creek from the upper Bow River to spawn each fall. Although brook trout begin their migration at least one month earlier than brown trout, the latter clearly dominate the spawning run both in number, and in fork length. The number of spawning brook trout migrants declined markedly between 1989 and 1990. In contrast, while the number of immature brown trout migrating through the stream increased slightly from 1989 to 1990, the adult brown trout population remained relatively stable.

The fork length distributions for brook trout suggest the decline in the size of the spawning population from 1989 to 1990 was largely due to a much smaller number of fish centred between 150 and 210 mm being recruited into the spawning population in 1990. This study did not attempt to determine what factors may have led to the decline in size of the brook trout spawning population.

The proportion of immatures that migrated upstream and were recaptured exiting the stream was considerably less than for sexually mature fish. Three possible explanations exist. Immatures do not migrate into the stream to reproduce but rather to establish foraging territories; therefore, they may become resident or remain to prey on fish eggs. Alternatively, because Bill Griffiths Creek is entirely spring fed and likely provides warmer, less severe overwintering conditions than the Bow River, they may migrate into the stream to take advantage of more favourable overwintering habitat. Another possible alternative is that being smaller, immature fish may fall prey to larger adults or to other predators such as common mergansers.

Similar explanations could also explain why the downstream migration of brook trout in Bill Griffiths Creek in 1989 was barely 1/6 of the upstream migration. In one instance during 1990, a male brown trout in excess of 400 mm had a 200 mm brook trout in its mouth when it was captured (pers. obs.).

The fork length distributions for male and female brown trout in the upper Bow River were similar to the schematic representation of many populations and species of spawning salmonids. Generally, females display a distribution that is approximately normal as opposed to males which exhibit a bimodal distribution (Gross 1984).

The bimodal distribution among males is caused by the presence two types of males - "jacks" and larger, antagonistic males (Gross 1985). Jacks are small, precociously mature males that spawn at a small size (Gross 1984). The smaller jacks are younger than the larger, antagonistic males which control the dominance hierarchy on the spawning grounds. The alternative life histories of both male types are selected for (Gross 1984). Larger males with kypes are specialized for fighting while jacks are specialized at sneaking. The specialization of each type is used to gain proximity to spawning females and to increase potential mating opportunities. Despite size disadvantages encountered by jacks, both types of males experience relatively similar reproductive fitness (Gross 1985).

Repeat spawning brown trout females exhibited slower growth rates than repeat spawning males. Jonsson (1989) also reported repeat spawning brown trout females experienced slower growth rates than males. Because energetic costs associated with producing eggs are greater than producing sperm, the higher costs of reproduction among females may contribute to slower growth among females than males.

The percentage of female brown trout that returned to spawn in subsequent years was approximately two fold larger than the percentage of males. Greater natural mortality among males have been reported in other post-spawning brown trout populations (Alm 1950; Munro and Balmain 1956; Davies and Sloane 1987; Maisse et al. 1987; Maisse and Bagliniere 1990). One factor that may contribute to higher post-spawning mortalities among males in the upper Bow River system could be the increased incidence of *Saprolegnia* infection among large males. Higher infection rates of *Saprolegnia* among males, and especially larger males, in Bill Griffiths Creek have been reported (Section 5.0).

The large differences in the number of upstream and downstream brown trout migrants captured each year was not caused by large mortalities of fish on the spawning grounds but rather because a large number of post-spawning fish remained on the spawning grounds. Similar occurrences have been documented elsewhere for brown trout. For example, in Kirk Burn, a brown trout spawning stream and tributary of the River Tweed in Scotland, only 9% of the post-spawning brown trout population were recaptured on their downstream migration. It was believed the others remained in the spawning stream until January or February, well after the end of the spawning season (Campbell 1977).

The delayed downstream migration of post-spawners from

Bill Griffiths Creek may be partially due to more favourable overwintering conditions for the spawning population in it than in the Bow River. Daily stream temperatures in Bill Griffiths Creek generally average 3-5° C throughout most of the winter while the temperature regime of the mainstem of the river is approximately 3° C colder (unpubl. data, Alberta Fish and Wildlife Division). Bill Griffiths Creek, being entirely fed by groundwater, has stable flows throughout the winter which may also be more favourable to overwintering trout than the fluctuating river volumes in the Bow River. Releases from hydroelectric plants upstream of Canmore cause the volume of flow in the river at Canmore to increase or decrease by a factor of two, or more, during a 24 hour period during the brook trout and brown trout spawning season (Brewin and Stebbins 1991).

The timing of the brown trout spawning migrations into Bill Griffiths Creek was consistent during all three years. The peak period of upstream migration occurred during the last week in October each year. Similar to other brown trout spawning migrations which have been described (e.g., Munro and Balmain 1956; Libosvarsky 1974; Davies and Sloane 1987), males generally migrate onto the spawning grounds earlier and stay longer than females. It is thought males arrive earlier to establish a dominance hierarchy on the spawning grounds and increase potential mating opportunities.

Almost all brown trout migrating through Bill Griffiths Creek were captured at night. The results suggest the majority of fish moving during the day may have been influenced by stress as most fish captured during the day were affected with *Saprolegnia* or became infected later. Although brown trout have been reported to move during all times of the day, they generally only move during daylight hours when the water is turbid (Munro and Balmain 1956). Although discharges from hydroelectric plants cause large fluctuations in the Bow River, turbid conditions were never observed during any of the spawning seasons in the mainstem of the river or Bill Griffiths Creek (pers. obs.). Reports of brown trout (Schrader and Griswold 1992; Heggenes et al., in press; Griffith and Smith, in press) and other salmonids (e.g., Atlantic salmon, Rimmer et al. 1983; rainbow trout, Campbell and Neuner 1985; cutthroat trout, Schrader and Griswold 1992; and chinook salmon, Emmett and Convey 1990) indicate salmonids at various life history stages generally become nocturnal when water temperatures drop below 8° C.

Brown trout males generally spent more time and displayed greater variability in the length of their duration of stay on the spawning grounds than females. These results were similar to Campbell (1977), who reported females spent less time on the spawning grounds and were known to return downstream in three days. In contrast, the durations of males averaged 145 days (Campbell 1977).

The duration of time female brown trout spent on the spawning grounds in Bill Griffiths Creek was not related to fork length. This is in contrast to coho salmon females (*Oncorhynchus kisutch*) which guard their redds after spawning to prevent their eggs from being disturbed by females that arrive later and attempt to select the same spawning site (van den Berghe and Gross 1986, 1989). Larger coho salmon females reportedly spend more time guarding their redds after spawning than smaller females (van den Berghe and Gross 1986).

The contrasting results between coho salmon and brown trout may be attributed to the different life history strategies practised by the two species. Coho salmon are semelparous and produce all their offspring in a single reproductive event; in contrast, brown trout are iteroparous and can reproduce several times in a lifetime. Consequently, the investment a female coho salmon puts into redd guarding to prevent later spawning females from digging up her eggs during redd construction likely increases her potential reproductive fitness. It has been suggested the positive relationship between body size and redd guarding may be because larger females have greater energy reserves and can guard their nest longer before dying (van den Berghe and Gross 1989). Because brown trout can survive spawning to reproduce again, it would not be advantageous for them to guard their nests until they deplete their energy reserves and compromise their own survival.

The duration of time spent on the spawning grounds by female brown trout was not related to fork length. However, when males that became infected with *Saprolegnia* were excluded, the data suggests that shorter males generally spend less time on the spawning grounds than larger males.

Among spawning salmonids, smaller "jacks" typically spend less time on the spawning grounds than the larger dominant males (Gross 1985). Shorter durations spent by smaller males may be due to conflicts with larger, dominant males on the spawning grounds. Smaller males are likely more prone to injury, because of their size disadvantage. Consequently, to avoid injury, smaller males may spend less time on the spawning grounds than large males.

The results of the present investigation revealed many of the migrating adult brown trout remained in the stream at least until after November 27, December 20 and December 4 in 1988, 1989 and 1990, respectively. The results also suggest a large segment of the spawning population may overwinter in Bill Griffiths Creek.

Subsequent research during the winter of 1992-93, however, suggests the number of spawning brown trout in Bill Griffiths Creek declines abruptly in late November and most spawning adults leave the stream by December 23 (Brewin, In prep.). Snorkel, bank and electrofishing surveys used to estimate the abundance of overwintering adult brown suggest that only a small population, in relation to the spawning population, overwinters in Bill Griffiths Creek (Brewin, In prep.). Although no attempt was made during the subsequent study to assess whether the size of the spawning populations in 1990 and 1992 were comparable, it was not suspected that any drastic changes in population size had occurred.

The subsequent research suggests that the design of the fish trap used during the present investigation may have been restricting the downstream movement of some post-spawning brown trout. Another factor that suggests the trap may have been inhibiting the downstream migration of fish, was the frequency that large numbers (n = 30+) of brown trout were observed in a pool immediately upstream of the trap location. Consequently, the longer duration of time spent on the spawning grounds by some fish may have been due to the presence of the trap.

However, the extent that the trap may have delayed the downstream migration of some fish is not known. While it is possible that the majority of the fish whose durations are known stayed longer because of the trap, it is also possible the presence of the trap had little effect on fish whose durations of stay were known. For example, the majority of fish whose downstream migration was delayed may have remained above the trap location until after the trap was removed. Consequently, fish whose downstream migration was delayed may have been excluded from the analysis because they were never captured. Therefore, until the extent that the design of the trap delayed the downstream migration of post-spawning brown trout can be assessed, the results of the present study concerning the timing of the downstream migration and duration of time spent on the spawning grounds should not be discounted.

The percentage of females returning to spawn in successive years (1989 and 1990) indicates that post-spawning survival rates among female brown trout (57.1%) that spawn in Bill Griffiths Creek were high compared to published values from other brown trout spawning populations. Furthermore, although males in the Bill Griffiths Creek spawning population experienced a lower survival rate (31.1%) than females, survival among males also appears high compared to published values from other populations. Scholl et al. (1984) studied a brown trout spawning population in the Brule River, Wisconsin, a tributary of Lake Superior. They reported that theoretically 11% of the spawning population should return to spawn in subsequent years; however, they found only 4.2% returned in subsequent years. The difference between the actual and theoretical values were attributed to repeat spawners either losing their tags or avoiding recapture when they returned to spawn. Harvey (1991) studied a brown trout spawning population in the Sioux River, Wisconsin, which is also a tributary of Lake Superior and also reported only 4% returned to spawn in subsequent years. Munro and Balmain (1956) studied the major brown trout spawning tributaries of Loch Leven, Scotland and reported 6.9-7.1% of the population returned to spawn in subsequent years. Stuart (1957), who studied brown trout spawning populations in tributaries of three Scottish lakes, reported 19.5-36.9% of males and 22.6-34.3% of females returned to spawn after being captured the previous year. Tilzey (1977) examined spawning brown trout in tributaries of Lake Eucumbene, Australia, and reported repeat spawning occurred among 25.7% and 10.6% of marked brown trout after one and two years, respectively.

Among published sources that were reviewed, only Davies and Sloane (1987) reported survival rates higher than those observed for repeat spawners in Bill Griffiths Creek. They studied brown trout spawning in the major spawning canal of Great Lake, Tasmania, and reported 68% and 53% of the females and males, respectively, had spawned previously.

The factors contributing to the high survival rates among brown trout spawning in Bill Griffiths Creek are unclear. Similarly, the factors contributing to the drastic decline between 1989 and 1990 in the size of the brook trout population migrating into Bill Griffiths Creek to spawn are also unclear. However, after the results of a 12 month creel census on the upper Bow River managed by Alberta Fish and Wildlife Division are completed, more information will be available on the angler effort and harvest for the brown trout sportfishery in this reach of the upper Bow River.

The results from the present investigation and the from the creel census and other studies (i.e., Brewin, In prep.) should provide fishery managers with the information necessary to make knowledgable management decisions that will lead to the long-term success of the brown trout and brook trout sportfisheries in the upper Bow River system. For example, the results from 1988 and 1989 describing the timing of the spawning migrations of brown trout have been used to change angling regulations. The results indicated the angling closure (October 1 to November 15; Alberta Fish and Wildlife 1989) to protect spawning trout from angler harvest needed to be extended to more closely reflect the brown trout spawning season. Consequently, the angling regulations were changed in 1990. The angling closure now extends from October 1 to December 15 (Alberta Fish and Wildlife 1990).

The information collected on the Bill Griffiths Creek will also provide baseline data that could be used to assess whether future changes to the regulations are necessary. For example, if future studies are conducted and detect changes in either the fork length distribution of the spawning population, or the percentage of repeat spawners within the spawning population, then changes to the current regulations may warrant consideration.

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3.0 ASSESSMENT OF BROWN TROUT (*Salmo trutta*) SPAWNING ACTIVITY IN THE UPPER BOW RIVER SYSTEM

3.1 Abstract

Redd surveys and a two-way fish trap were used to monitor population changes and assess the spawning activity of brown trout in the upper Bow River system during 1988, 1989 and 1990. The method used in 1988 to estimate the number of redds in areas where redd superimposition occurred underestimated the actual number of redds constructed during the spawning season. The method used in 1989 and 1990 was altered and differences between the number of redds observed and the number of spawning females known to be on the spawning grounds in Bill Griffiths Creek during 1989 and 1990 were small. As a result, redd surveys were considered to be a reliable method to assess brown trout spawning activity and to monitor population changes in the upper Bow River system.

3.2 Introduction

Fisheries managers require a method of obtaining qualitative and quantitative information to assess salmonid spawning activity. Such a method would provide a relatively quick and inexpensive technique to estimate the approximate number of spawning females within a population and to monitor population fluctuations between spawning seasons.

Observations of redds, nest-like depressions constructed in the stream gravel by spawning females into which they deposit their eggs, have been used to assess the spawning activity and distribution of several salmonid species. Beard and Carline (1991) reported Hobbs (1937) was one of the first researchers to relate the number of observed redds to the distribution and density of spawning brown trout, *Salmo trutta*. Other researchers have also used redd observations from the ground to assess the spawning distribution and abundance of bull trout (*Salvelinus confluentus*) (Fraley et al. 1981), chinook salmon (*Oncorhynchus tshawytscha*) (Bjornn 1978), brook trout (*Salvelinus fontinalis*) (Benson 1953) and brown trout (Benson 1953; Beard 1990; Beard and Carline 1991). In addition to ground observations, aerial redd surveys have also been used to assess the spawning activity of salmonids. For example, aerial surveys have been used for sockeye salmon (*Oncorhynchus nerka*) in Alaska (Eicher 1953) and both Atlantic salmon (*Salmo salar*) and brown trout in Norway (Heggberget et al. 1986).

Although ground surveys are more time consuming, they may be preferable to aerial surveys in certain conditions. They allow personnel familiar with a species' preferred spawning locations, and the distinctive silt- and algal-free appearance of a redd, to more accurately assess spawning activity. Ground surveys may also be preferable in systems where fluctuating water levels frequently occur (i.e., systems with hydroelectric plants). Fluctuating water levels create areas that are periodically exposed to the air.

During low flows areas exposed to the air may become bleached by the sun; consequently, these areas may resemble redds when water levels rise and they are covered by water. Ground surveys can also be preferable along streams with overhanging tree cover and when overlapping redds occur. Overhanging cover is a primary element for salmonid habitat (Boussu 1954) and is thought to be an important component of brown trout spawning habitat (Stuart 1953; Reiser and Wesche 1977; Witzel and MacCrimmon 1983). Overlapping redds, or communal redds as they are often called, frequently occur in streams providing optimal brown trout spawning habitat (Reiser and Wesche 1977; Witzel and MacCrimmon 1983).

The objective of the present study was to evaluate the potential use of redd surveys to assess the spawning activity of brown trout within a 50-60 km reach of the upper Bow River system, Alberta. A ground survey was chosen because several spawning streams within the system experience fluctuating volumes as a result of variable flows in the upper Bow River from hydroelectric plant discharges.

3.3 Methods

Redd surveys were conducted near the end of the spawning seasons in 1988, 1989 and 1990 along side channels and tributaries of the upper Bow River thought to contain suitable conditions for brown trout spawning (Figure 3.1). The surveys were limited to side channels or tributaries along a 50-60 km reach of the upper Bow River system. The lower limit was the Seebe Dam located at the confluence of the Bow and Kananaskis rivers. Bow Falls, located within the town of Banff, was the upper limit.

Hereafter, side channels and tributaries are collectively referred to as spawning streams. Individually, spawning streams are referred to by their given names when known; otherwise, they were assigned letters. Legal descriptions of each spawning stream and the dates that the surveys were conducted along each stream are provided in Table 3.1.

A two-way fish trap was installed in Bill Griffiths Creek to capture and enumerate brown trout migrating in and out of the stream during the 1988, 1989 and 1990 spawning seasons. The trap, in the same location each year, was located approximately 0.8 km upstream from the confluence of Bill Griffiths Creek with the Bow River. The number of females known to have migrated upstream through the trap was related to the number of brown trout redds observed upstream of the trap during each spawning season.

The timing of redd surveys was determined from trapping results that indicated when the upstream migration of spawning females was nearing completion. Factors influencing the timing and order that streams were surveyed were: the long range weather forecast; and information concerning streams most likely to develop ice conditions. Some spawning streams receiving surface flow from the Bow River and likely to develop surface ice were surveyed twice in the same year. An early survey was conducted to insure all spawning streams chosen for the study were surveyed before freezing occurred.

If weather conditions remained favourable, these streams were re-surveyed to insure that redds constructed later in the season were included and to permit a more accurate assessment of the spawning activity in the stream for the season. Only the results from the last survey of the season for each year are presented.

Redd surveys involved walking each spawning stream and mapping the approximate location of all observed brown trout redds. Redds were identified by their location within the stream, their distinctive shape and size, a clean silt- and algal-free appearance and literature descriptions (Reiser and Wesche 1977; Ottaway et al. 1981; Witzel and MacCrimmon 1983; Shirvell and Dungey 1983; Crisp and Carling 1989). The presence and behaviour of brown trout was also used to assist with the identification of redds.

Brook trout are known to spawn simultaneously in several of the same streams as brown trout in the upper Bow River system (Stelfox 1979). However, through selection of preferred spawning habitat, they separate ecologically (Stelfox 1979; Stebbins, Department of Biological Sciences, University of Lethbridge, unpublished data). Disturbances in the gravel subtrate that resembled the appearance of redds were not included in the survey results if they were not located in areas of preferred brown trout spawning habitat described in the literature or if they were not observed with actively spawning brown trout. Occasional notes on brook trout spawning activity were recorded but no attempt was made to map or count the brook trout redds observed during the surveys.

Bull trout, a species native to the upper Bow River, are also fall spawners known to spawn in streams with groundwater inflow. However, no bull trout were captured migrating into Bill Griffiths Creek during 1988, 1989 or 1990 (Section 2.0). It is also doubtful whether a self-sustaining bull trout population still exists in the upper

Bow River between Bow Falls and the Seebe dam (J. Stelfox, Alberta Fish and Wildlife Division, pers. comm.). It is, therefore, unlikely bull trout redds, if they did exist, occurred in sufficient numbers to significantly affect the results of the brown trout redd survey.

Determining the number of individual brown trout redds within a communal area relied on the investigator's interpretation. In 1988, when overlapping redds were encountered, the minimum number of redds necessary to alter the area was visually estimated. The number of redds observed in some communal areas during the course of the spawning season indicated this technique resulted in underestimating the actual number of redds constructed in the area during the 1988 spawning season. In subsequent years, the number of redds in communal areas was also determined by visually estimating the number of redds necessary to alter the disturbed area. But if several nest-like depressions were clustered within an area equivalent to the estimated size of a single redd, then the number of additional nest-like depressions was added to the estimate.

Periodic surveys of Bill Griffiths Creek provided some prior knowledge of redds that became indistinguishable as later spawning females constructed redds that were superimposed on redds built earlier in the season. Periodic observations of spawning activity in communal areas in Bill Griffiths Creek were also valuable to estimate the number of redds in communal spawning areas found in other streams. This estimate was made by comparing the number of redds in communal areas in Bill Griffiths Creek where the disturbance of the substrate was comparable to communal spawning areas observed in the other spawning streams. Care was taken to avoid overestimating the number of individual redds in communal areas; consequently, in communal areas conservative estimates were recorded in favour of generous estimates.

In 1988, the surveys only included spawning streams located below Banff National Park. Surveys in 1988 were conducted between November 11 and November 24 and included five groundfed tributaries of the upper Bow River with insufficient flow to support brown trout spawning. Unsuitable spawning conditions resulted in these streams being removed from subsequent surveys in 1989 and 1990.

In 1989, the surveys were conducted between November 11 and December 4. Streams inside Banff National Park, Carrot Creek, Duthill Creek and Chinaman Creek, were added to the survey in 1989.

In 1990, the surveys were conducted between November 21 and December 6. Except for two streams that developed early ice conditions (B Complex - surface ice; Georgetown Channels - surface and anchor ice), the same streams surveyed in 1989 were surveyed in 1990.

Table 3.1: Dates brown trout redd surveys were conducted along spawning streams in the upper Bow River system during 1988, 1989 and 1990.

Spawning stream (Legal description)	1988	1989	1990
Bill Griffiths Creek (23-24-10-5)			
above trap	Nov 20,23,24	Nov 26,27	Nov 28,Dec 3
below trap		Nov 24	Nov 28,29
Policeman Creek (28-24-10-5)			
upper Policeman Cr.	NS	Nov.21	Nov.25
lower Policeman Cr.	Nov.18	Nov.20	Nov.24
Spring Creek (28-24-10-5)	NS	Nov.20	Nov.23
B Creek Complex (23-24-10-5)			
B Creek	Dec.11**	Dec.3	Nov.28
B Complex	Dec.11**	Dec.3	Nov.28
Canmore Creek (29-24-10-5)	Nov.20	Dec.1	Nov.23
Georgetown Channels (7-25-10-5)	Nov.24	Dec.4	Nov.28
Grotto Mountain Pond Outlet (21-24-9-5)	Nov.23	NR	NR
Chinaman Creek (4-[illegible]-5)	NS	Dec.2	Nov.30
Duthie Creek (4-26-11-5)	NS	Dec.2	Nov.30
Carrot Creek (23-25-11-5)	NS	Nov.19	Dec.6
C Creek (14-24-10-5)	Nov.19	Nov.25	Dec.1
D Creek (23-24-10-5)	Nov.22*	Nov.25,26	Dec.1,2
E Creek (14-24-10-5)	Nov.22	Nov.25	Dec.1
F Creek (21-24-10-5)	Nov.20	Nov.15	Dec.4
G Creek (18-24-9-5)	Nov.19	NR	NR
Q Creek (23-24-10-5)	NS	Nov.26	Dec.1
V Creek (23-24-9-5)	Nov.23	NS	NS
W Creek (23-24-9-5)	Nov.23	NS	NS
X, Y and Z creeks (25-24-9-5)	Nov.23	NS	NS

NR: Date of survey not recorded NS: Not surveyed
* : Not completely surveyed
**: Surveyed by Alberta Fish and Wildlife Division

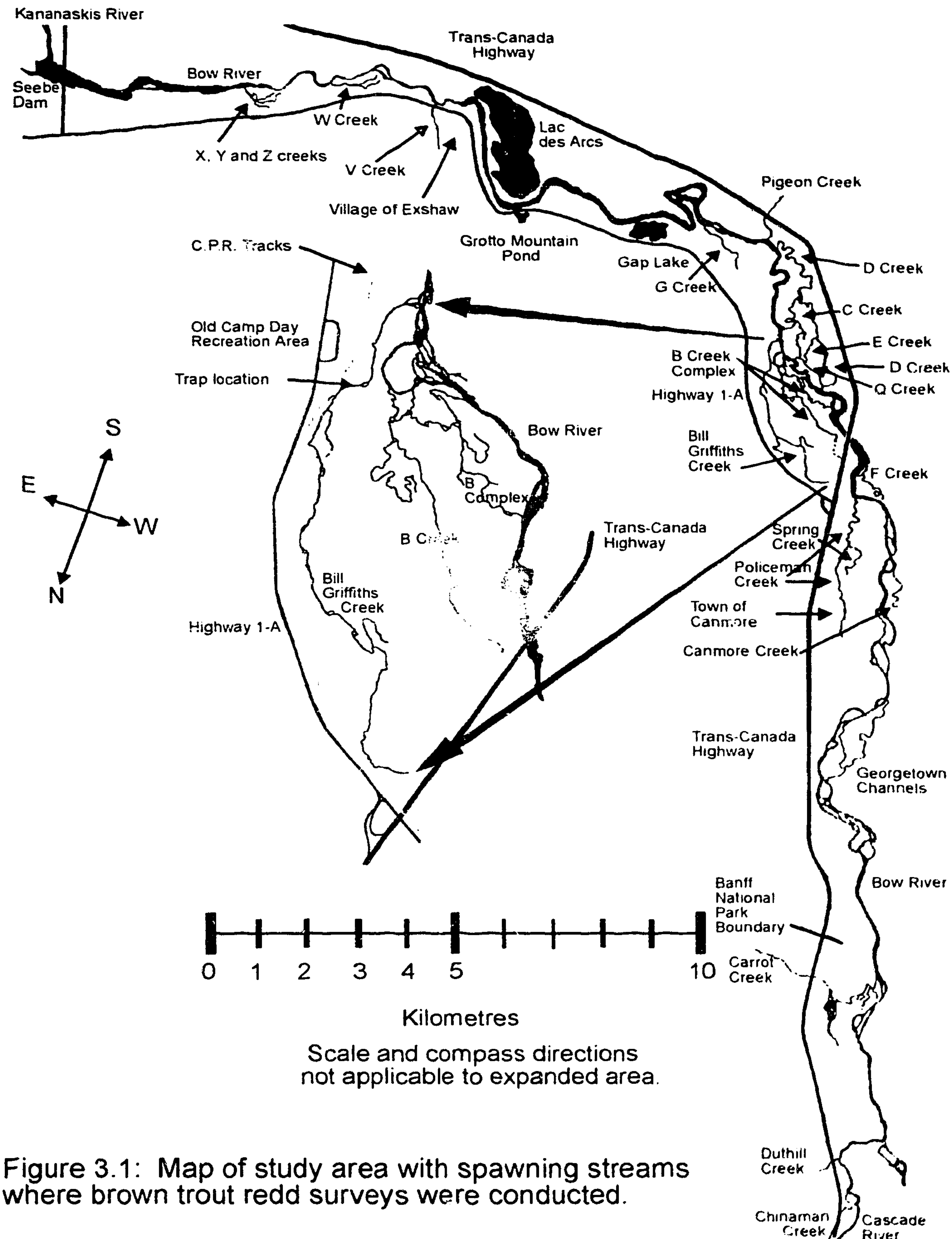

Figure 3.1: Map of study area with spawning streams where brown trout redd surveys were conducted.

3.4 Results

The number of redds observed in 1988 was lower than in 1989 and 1990. Periodic surveys of communal areas in Bill Griffiths Creek in 1988 and early 1989 indicated that the method used to assess communal areas needed to be refined to obtain an accurate appraisal of the number of redds constructed in communal areas during the course of the spawning season. Differences in redds surveys between streams in 1988 and the other two years can largely be attributed to changing the method used to assess communal areas after the 1988 spawning season. However, other reasons contributing to differences between the 1988 survey and subsequent surveys were: an incomplete survey of D Creek in 1988; a failure to survey upper Policeman Creek and streams inside Banff National Park in 1988; and surveys in 1988 were generally conducted earlier in the spawning season than in 1989 and 1990.

The number of redds observed in Bill Griffiths Creek above the trap during 1989 was similar to the number of spawning females known to be above the trap (Table 3.2); consequently, in 1989 the number of females per redd was virtually one female per redd. Although the technique used to identify redds in communal areas was similar in both 1989 and 1990, the ratio of females per redd increased slightly in 1990. The differences in the ratio of females per redd between 1989 and 1990 was due to a 3.8% increase in the number of females captured, and an 8.5% decrease in the number of redds observed, in 1990 (Table 3.2). The conservative method used in 1988 to estimate the number of redds in communal areas resulted in a higher ratio between the number of redds observed and the number of females captured than the refined method used in 1989 and 1990 (Table 3.2).

The results of the redd surveys for 1988, 1989 and 1990 are presented in Table 3.3. Comparisons between the 1989 and

1990 results indicate the differences in the number of redds observed in individual streams were generally small. Excluding Spring and E creeks where less than ten redds were observed in any year, the largest differences between 1989 and 1990 were observed in upper (+111.4%) and lower (-39.9%) Policeman Creek. However, as a single unit, the differences in Policeman Creek between years were not large (+10.2%).

The increase in number of spawning females captured on their spawning migration through Bill Griffiths Creek between 1989 and 1990 was small (3.8%, Table 3.2). The 1988 results were not compared because the trap that year was not installed until October 15 and it was suspected the trapping results did not represent the entire 1988 brown trout spawning population (Section 2.0).

A paired t-test (Prepas 1984) determined the results for the ten spawning streams that were surveyed in both 1989 and 1990 were not statistically different between years ($0.9>P>0.5$). The ten streams included in the analysis are identified in Table 3.3.

Table 3.2: Comparison of brown trout females captured and number of redds observed in Bill Griffiths Creek during the 1988, 1989 and 1990 spawning seasons.

Year	No. of females captured	Redds Observed	Ratio of females captured to redds observed
1988	609	430	1.42 : 1.0
1989	710	696	1.02 : 1.0
1990	737	637	1.16 : 1.0

Table 3.3: Results of 1988, 1989 and 1990 brown trout redd surveys from spawning streams in the upper Bow River system.

Stream	No. of redds in 1988 (% of total)	No. of redds in 1989 (% of total)	No. of redds in 1990 (% of total)	% difference between 89 & 90
Bill Griffiths Creek				
above trap	430(44.6)	696(41.4)	637(42.0)	-8.5%
below trap	147(15.3)	156(9.3)	190(12.5)	21.8%
Total*	577	852	827	-2.9%
Policeman Creek				
upper	+	35(2.1)	74(4.9)	111.4%
lower	102(10.6)	138(8.2)	83(5.5)	39.9%
Spring Creek	+	3(0.2)	1(0.1)	-66.7%
Total*	102	176	158	-10.2%
B Creek Complex				
B Creek*		43(2.6)	58(3.8)	34.8%
B Complex		97(5.8)	++8(0.5)	N/A
Total	81(8.4)	140	66	N/A
Canmore Creek*	30(3.1)	39(2.3)	38(2.5)	2.6%
Georgetown Channels	23(2.4)	55(3.3)	++	N/A
Grotto Mountain Pond Outlet	0	0	0	N/A
Chinaman Creek*	+	47(2.8)	36(2.4)	-23.4%
Duthill Creek	+	0	0	N/A
Carrot Creek*	+	122(7.3)	124(8.2)	1.6%
C Creek*	103(10.7)	95(5.6)	102(6.7)	7.4%
D Creek*	++32(3.3)	134(8.0)	145(9.6)	8.2%
E Creek*	5(0.5)	5(0.3)	8(0.5)	60.0%
F Creek*	11(1.1)	14(0.8)	12(0.8)	-14.3%
G Creek	0	0	0	N/A
Q Creek	+	3(0.2)	++	N/A
V Creek	0	+	+	N/A
W Creek	0	+	+	N/A
X Creek	0	+	+	N/A
Y Creek	0	+	+	N/A
Z Creek	0	+	+	N/A
Total	964(100)	1682(100)	1516(100)	

+ - not surveyed
++ - partially surveyed
N/A - not applicable
* - included in paired t-test to test for differences in annual redd survey results between all streams surveyed in both 1989 and 1990.

3.5 Discussion

The redd surveys provided a relatively accurate method of estimating brown trout spawning activity. However, assessing areas with communal redds relied on a subjective interpretation. Even with the refined method of estimating the number of individual redds in communal areas, it was felt that the technique may have resulted in underestimating the actual number of individual redds in some of the larger communal redd areas. This may have contributed to the increase in the number of females per redd ratio observed in Bill Griffiths Creek in 1990.

Of the 21 streams surveyed, Bill Griffiths Creek in particular, had a large proportion of communal redds. Frequently, redds in communal areas that were constructed early in the season were indistinguishable during the final survey. Knowing the specific sites where redds were constructed earlier in the season was valuable in estimating the number of individual redds present.

Although the number of observed redds and of spawning females above the trap in 1990 did not result in a 1:1 relationship, the results do not indicate that the method of assessing redds in 1990 was inaccurate. At the time of the redd survey, the number of actively spawning fish was considerably reduced from the peak activity observed in early November; however, some spawning activity was occasionally observed during the surveys. If a small number of fish still had to construct redds, then a 1:1 relationship would not be expected.

The method of assessing redds in 1989 and 1990 was found to provide a reliable method to assess brown trout spawning activity and to monitor population trends. This conclusion is supported by a small change in the number of spawning females captured in Bill Griffiths Creek between 1989 and 1990 which corresponded to non-significant differences in the number of redds between 1989 and 1990 when the results from the ten spawning streams surveyed in both years were examined.

Although the number of females migrating into spawning streams other than Bill Griffiths Creek was not known, if significant changes in spawning populations of female brown trout had occurred in the other streams, then similar changes would also have been expected to occur in Bill Griffiths Creek. The migratory spawning populations from all of the spawning streams likely intermix and become part of a combined population during non-spawning periods. Therefore, migratory spawning populations from all the spawning streams likely experience similar competition pressures and survival rates during non-spawning periods of the year. The recorded changes between 1989 and 1990 in the number of females captured in Bill Griffiths Creek from September 23 through to December 4 (+0.41 %, unpublished data) and in the total number of redds observed in all streams (excluding streams not surveyed in 1990 due to ice conditions) (-1.24 %) both demonstrate minor changes in the size of the spawning population between 1989 and 1990.

Although an estimate of the resident population of brown trout in Bill Griffiths Creek was not obtained, the number of resident females was not considered large enough to seriously affect the ratio between the number of known females and observed redds for four reasons. 1) Typically, the majority of brown trout resident to spawning streams are males (Campbell 1977; Bagliniere et al. 1987; Maisse et al. 1987). 2) Data collected by Alberta Fish and Wildlife Division (F&W) indicate the summer temperature regime of this entirely groundfed stream is substantially cooler than the Bow River. Mature brown trout females experience a high cost of reproduction. Therefore, they would likely select warmer, more productive summer habitats provided in the Bow River. 3) Mid-summer electrofishing by F&W in 1989 indicated Bill Griffiths Creek does not support a large summer population of mature brown trout. Only three of 126 captured brown trout were in excess of 15 cm (J. Stelfox, pers. comm.) and were likely to spawn in the fall. 4) During 1989 only four of the 34 brown trout captured exclusively on their downstream migration were females (unpublished data). Brown trout captured only on their downstream migration had to have been upstream prior to the installation of the trap. These four arguments suggest the resident population of adult brown trout in Bill Griffiths Creek during the summer is small and that females are a minority.

The stream that experienced the largest changes in the number of redds between 1989 and 1990 was Policeman Creek. As a single unit the differences in Policeman Creek were not large, but the differences were relatively large when the stream was divided into an upper and lower reach; upper Policeman Creek was defined as the reach upstream of its confluence with Spring Creek. Two factors help explain the increase in spawning activity observed during 1990 in the upper section. 1) In 1989 a beaver dam located at the confluence of the two creeks may have partially obstructed further upstream migration. Beaver dams are known to inhibit the upstream migrations of spawning trout (Cook 1940; Knudsen 1962). 2) During the 1989 spawning season, silt-laden water was pumped from a construction site into Spring Creek which also affected lower Policeman Creek. Increased concentrations of silt reduces the permeability of the spawning substrate (Cordone and Kelley 1961; McNeil and Ahnell 1964). Brown trout are known to select redd sites in areas of the stream exhibiting maximum permeability (Stuart 1954). Being groundfed, neither Spring Creek nor Policeman Creek experience an annual summer high flow event to flush silt accumulations; consequently, brown trout may have migrated further upstream into upper Policeman Creek in 1990 to avoid spawning in stream reaches where silt accumulations were evident. The heavy concentration of redds immediately below the beaver dam in 1989 and fewer redds in the same area in 1990 suggest the removal of the dam, the increased silt accumulations, or some combination of the two factors, may have caused the shift of spawning activity from lower to upper Policeman Creek.

The number of brown trout females per redd (1.02 and 1.16 in 1989 and 1990, respectively, average 1.09) recorded in Bill Griffiths Creek above the trap location indicate the ratio between adult brown trout females and redds is similar to the ratio reported for chinook salmon. Bjornn (1978), who captured chinook salmon migrating into the Lemhi River, Idaho to spawn, performed redd surveys from the ground and reported that the number of spawning females per redd averaged 1.07 (range 0.85-1.41 females per redd) during a ten year period (1965-1974).

The number of females per redd observed in Bill Griffiths Creek, however, was substantially different than has been reported elsewhere for brown trout. Beard (1990) and Beard and Carline (1991) reported the ratio of mature females to redds in Spring Creek, Pennsylvania, was 2.1 to 61.3 females per redd.

There are a number of factors, however, between the experimental designs of the present study and the Pennsylvania study that contribute to the discrepancies between studies. Beard (1990) and Beard and Carline (1991) related a population estimate obtained from electrofishing surveys conducted in July and August to the number of ripe females captured during a single electrofishing pass in late October to determine the number of mature females on the spawning grounds. Their redd surveys were conducted from the ground towards the end of the spawning season in November. Consequently, immigration, emigration and mortality between the electrofishing and redd surveys may have affected the number of females per redd reported by Beard (1990) and Beard and Carline (1991). The Pennsylvania study also did not attempt to assess the actual number of redds in areas where redd superimposition was obvious. Beard (1990) and Beard and Carline (1991) also suggested that a large number of the females found in the stream in July and August may not have spawned.

In the present study the number of spawning brown trout moving into Bill Griffiths Creek were enumerated in order to determine the number of spawning females that were present; consequently, it was possible to relate the number of spawning females to the number of redds observed. Thus, some of potential errors in determining the number of females per redd that were encountered by Beard (1990) and Beard and Carline (1991) were eliminated. The present study also estimated the number of redds constructed in areas where redd superimposition occurred.

Redd surveys conducted from the ground were determined to provide a reliable method of assessing the spawning activity of brown trout and to monitor population trends between years in the upper Bow River system. The level of accuracy of assessing the spawning activity in areas where superimposition of redds occurs, however, is likely affected by the experience of the investigator and the frequency that communal spawning areas are examined during the spawning season. It is recommended that periodic navigations of spawning streams be conducted throughout the spawning season, if a reliable assessment of spawning activity within communal areas is desired. It is also recommended that where communal spawning activity is frequent that the same investigator be used from year to year to assess the same streams, or stream reaches if it is desirable to collect data that can be used to compare results between years.

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4.0 THE OCCURRENCE AND TRADE-OFFS ASSOCIATED WITH ALTERNATE YEAR SPAWNING AMONG BROWN TROUT (*Salmo trutta*) IN THE UPPER BOW RIVER SYSTEM

4.1 Abstract

The life history strategies practised by female brown trout in a tributary of the upper Bow River system, Alberta, were studied during three successive spawning seasons. The results suggest that within the system there are three identifiable life history strategies: females that delay when they first spawn; females that spawn annually; and females that spawn biennially. Per unit fork length, the post-spawning weights in 1988 of biennial spawners which skipped spawning in 1989 were lighter than annual spawning females that returned to spawn in 1989. Similarly, in 1990 when biennial spawners returned to spawn, their post-spawning weights were significantly lighter than females that spawned annually from 1988 to 1990. Biennial growth rates experienced by biennial and annual spawning females as a function of fork length were not significantly different. There were no significant differences per unit fork length in the pre-spawning weights and weight loss during spawning among biennial spawners or annual spawners. However, significant differences were found in the pre-spawning weights between first-time spawners and both annual and biennial spawners. It is speculated that poorer post-spawning body condition as a result of the lighter weight contributes to physiological stress. This may influence biennial spawners to sacrifice spawning in alternate years and to divert energy away from reproduction to enhance their own survival and increase their opportunities to spawn in the future.

4.2 Introduction

Not all salmonids are semelparous and produce all their offspring in a single reproductive event. Some salmonids such as brown trout (*Salmo trutta*) and Atlantic salmon (*S. salar*) are iteroparous and can reproduce several times during their lifetime (Hoar and Randall 1977). Iteropary provides flexibility in the life history strategy that individual fish within a population may follow.

Once having spawned in a stream, adult brown return to the same stream to reproduce in subsequent years (Stuart 1957; Tilzey 1977; Scholl et al. 1984; Geiger et al. 1986). However, it is not known to what extent annual spawning occurs within a population. It is known that not all brown trout spawn annually after reaching maturity (Stuart 1953).

Allocating energetic costs to reproduction can result in decreased somatic growth (Glebe and Leggett 1981a; Reznick 1983) and increased mortality (Glebe and Leggett 1981a). Therefore, brown trout spawning in alternate years could experience greater survival and growth rates than individuals spawning annually.

As a result of increased growth, females may experience an advantage of increased potential fecundity. The fecundity of brown trout - defined as the number of ripening eggs produced by a female (Bagenal 1978) - is positively correlated with body size (Nicholls 1958; Hardy 1967). The expected fecundity of a female brown trout (i.e., number of eggs produced) is approximately equal to the square of her fork length in centimetres (Hardy 1967).

When the amount of energy allocated to reproduction is decreased, the growth or physical body condition of an individual may improve. Increased body condition can increase the probability of survival and the potential for future reproduction of an individual (Begon et al. 1986). Consequently, female brown trout that do not spawn annually may grow faster, live longer and produce more eggs when they do spawn than females spawning annually.

The purpose of this study was to determine: 1) the extent that biennial and annual spawning occurs among female brown trout in the upper Bow River system, Alberta; 2) whether females which delay when they first spawn experience different post- and pre-spawning body weights than females with similar fork lengths began spawning at an earlier age; and 3) whether biennial spawners, if present, experience measurable differences in growth or weight as a function of fork length. The parameters that were measured and compared between biennial, annual and first-time spawners included: amount of growth between 1988 and 1990; pre-spawning weight in 1990; weight loss during spawning in 1990; post-spawning weight in 1988 and post-spawning weight in 1990.

4.3 Methods

This study was conducted as one of several concurrent studies that data were gathered from the same fish simultaneously. The methods employed in the field for this study are described in Section 2.0. Only methods not previously described in Section 2.0 and that are specific to this study are described in this section.

Numbered floy anchor tags were used to identify individual brown trout; thus, permitting identification in 1990 of annual, biennial and first-time spawners. In some instances the absence/presence of the adipose fin, and the monofilament from floy anchor tags that had been lost, were also used to identify some repeat spawning females that lost their tags. Females that lost their tags but could not be positively grouped into one of five categories were not included in the analyses.

Brown trout females captured in 1990 were divided into five groups. The groups were: annual spawners captured in 1988, 1989 and 1990; annual spawners captured only in 1989 and 1990; biennial spawners captured only in 1988 and 1990; females captured only in 1990 with fork lengths less than 450 mm; and females captured only in 1990 with fork lengths greater than or equal to 450 mm.

It was necessary to divide fish captured only in 1990 into two groups: those less than 450 mm and those fish greater than or equal to 450 mm. An age-fork length relationship for brown trout in the upper Bow River system was determined from data supplied by Alberta Fish and Wildlife Division. The age:fork length relationship suggested that brown trout 450 mm or longer could be seven years of age or older. Therefore, females captured only in 1990 that were in excess of 450 mm could potentially have been: a) first-time spawners; b) tri-ennial spawners that spawned in 1987 at three or four years of age and returned to Bill Griffiths Creek in 1990 to spawn; or c) females that spawned in 1988 but were not captured.

Direct determinations of the fecundity (number of eggs produced by an individual female) of fish requires sacrificing the individual, removing the ovaries and counting the number of eggs (Pope et al. 1961). Sacrificing a large number of pre-spawning females to obtain direct measurements of fecundity was not desirable in this study. Instead, indirect measurements of fecundity were employed to determine if differences per unit fork length occur between females among the five groupings.

Pre-spawning weight and weight loss during spawning were used to obtain indirect measurements of fecundity. Pre-spawning weight was determined by the individual weight (to the nearest 10 gm) of females on their upstream migration. Weight loss during spawning was calculated by subtracting a spent individual's weight on its downstream migration from its pre-spawning weight.

Post-spawning weight was used as an indirect measurement of an individual's post-spawning body condition. Post-spawning weight was obtained by recording the weight of spent females captured on their downstream migration out of Bill Griffiths Creek.

The measured parameters - growth from 1988 to 1990, 1990 pre-spawning weight, weight loss during spawning in 1990, 1990 post-spawning weight and 1988 post-spawning weight - were related to an individual's corresponding fork length. For each parameter, a linear relationship using fork length as the dependent variable was calculated for each group. When necessary, data was transformed logarithmically to the base ten to obtain a linear relationship. Statistical differences between groups were determined using an analysis of covariance (ANCOVA) (Snedecor and Cochran 1989).

Correlation coefficients (Snedecor and Cochran 1989) were calculated to determine the relationship between the dates that repeat spawning females entered the stream. Correlation coefficients were calculated for the dates that: biennial spawners entered the spawning grounds in 1988 and 1990; annual spawners captured only 1989 and 1990 entered the spawning grounds; annual spawners captured all three years entered the spawning grounds in 1988 and 1989; and annual spawners captured all three years entered the spawning grounds in 1988 and 1990.

Some post-spawning brown trout in 1990 were sacrificed because several fork length intervals in the age:fork length relationship for brown trout in the upper Bow River were poorly represented. The otoliths of sacrificed fish were removed and used for aging. The sacrificed fish included one female captured in three successive spawning seasons and four females captured for the first time in 1990. The age:fork length relationship of each sacrificed female was compared to their expected age based on the age:fork length relationship for brown trout in the upper Bow River system.

It was necessary to ensure stream fidelity was being practised by brown trout within the upper Bow River system even though brown trout are known to return to the same stream when repeat spawning (Stuart 1957; Tilzey 1977; Scholl et al. 1984; Geiger et al. 1986). While conducting a survey of brown trout redds on all the spawning streams in the system (Section 3.0), all observed fish were visually checked for the presence of floy anchor tags applied to brown trout migrating through Bill Griffiths Creek during 1988, 1989 or 1990.

4.4 Results

During redd surveys conducted along streams other than Bill Griffiths Creek in 1989 and 1990, 159 and 62 brown trout (respectively) were observed and visually checked for tags. No brown trout with floy anchor tags applied to fish spawning in Bill Griffiths Creek were observed in any of the other spawning streams.

Dates that annual spawning females were captured migrating upstream one year was correlated with the date(s) they were recaptured in subsequent spawning seasons (Table 4.1). For annual spawners captured only in 1989 and 1990, the dates of upstream capture were strongly correlated; consequently, 48.3% (r^2 X 100) of the variance in the date annual spawners were recaptured in 1990 was attributed to the date they were captured in 1989. Similarly, females captured all three years also displayed significant correlations in the dates they were captured between years. The non-significant correlation coefficient for biennial spawners indicates the date individuals migrated upstream in their last spawning season does not relate to the date they returned in subsequent spawning seasons.

No differences between the five groups of females were observed in the linear regression relationships of fork length and weight loss during spawning in 1990. The test statistics for the ANCOVAs that determined whether statistical differences existed between groups of females in the linear regression relationships of fork length and weight loss during spawning are provided in Table 4.2. The linear regressions of fork length and weight loss during spawning are illustrated in Figure 4.1. Individual data points illustrating the relationship between fork length and weight loss during spawning for each of the five groups of females are provided in Appendix I (Figure AI-1).

Differences in the linear relationships of fork length and pre-spawning weight were detected between some of the groups of females (Table 4.3). However, no significant differences in the relationships between pre-spawning weight and fork length were detected between biennial or annual spawning females. Also, no significant differences were detected between annual spawning females captured during 1988, 1989 and 1990 and females captured in 1989 and 1990. The linear regressions illustrating the relationships between fork length and pre-spawning weight for the different groups of females (Figure 4.2), and the ANCOVA (Table 4.3), indicate females captured only in 1990 that were longer than 450 mm had heavier pre-spawning weights than other females with similar fork lengths known to have spawned during two or more of the last three years.

Table 4.1: Correlation coefficients comparing dates of upstream migrations between females that returned to spawn in subsequent spawning seasons.

Sample size	Correlation coefficient (r)	Significance level	r^2
Correlations between upstream migrations in 1989 and 1990 for annual spawners captured in 1989 and 1990 but not 1988:			
346	0.6952	***	0.4833
Correlations between upstream migrations in 1988 and 1989 for annual spawners captured in each of the three years:			
121	0.3109	**	0.0967
Correlations between upstream migrations in 1988 and 1990 for annual spawners captured in each of the three years:			
121	0.2238	**	0.0501
Correlations between upstream migrations in 1988 and 1990 for biennial spawners captured only in 1988 and 1990:			
16	0.2431	NS	

NS - not significant; * - $0.01 < P \leq 0.05$
** - $0.001 < P \leq 0.01$ *** - $P \leq 0.001$

Table 4.2: Test statistics for analyses of covariance determining differences for linear regressions relationships of fork length and weight loss during spawning between groups of female brown trout.

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)	89-90
Spawning frequency	biennial	1st time	annual	1st time	annual
Sample size	15	20	83	172	135

F values: testing residual variances between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.611(NS)			
88-89-90	0.714(NS)	0.443(NS)		
90(<450 mm)	0.575(NS)	0.357(NS)	0.806(NS)	
89-90	0.696(NS)	0.432(NS)	0.975(NS)	0.826(NS)

t values: testing slopes between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.198(NS)			
88-89-90	1.502(NS)	0.312(NS)		
90(<450 mm)	0.795(NS)	0.313(NS)	1.023(NS)	
89-90	0.791(NS)	0.439(NS)	1.287(NS)	0.182(NS)

t values: testing adjusted intercepts between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	0.844(NS)			
88-89-90	0.146(NS)	0.538(NS)		
90(<450 mm)	0.437(NS)	0.134(NS)	1.664(NS)	
89-90	0.458(NS)	1.239(NS)	0.401(NS)	1.881(NS)

NS - not significant; * - $0.01 < P \leq 0.05$
** - $0.001 < P \leq 0.01$ *** - $P \leq 0.001$

Table 4.3: Test statistics for analyses of covariance determining differences for linear regressions relationships of fork length and pre-spawning weight between groups of female brown trout.

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)	89-90
Spawning frequency	biennial	1st time	annual	1st time	annual
Sample size	26	29	169	262	241

F values: testing residual variances between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.089(NS)			
88-89-90	1.173(NS)	1.077(NS)		
90(<450 mm)	1.009(NS)	0.927(NS)	1.162(NS)	
89-90	1.092(NS)	1.003(NS)	0.931(NS)	0.924(NS)

t values: testing slopes between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.387(NS)			
88-89-90	1.788(NS)	3.430(***)		
90(<450 mm)	2.335(*)	3.859(***)	1.010(NS)	
89-90	1.670(NS)	3.336(***)	0.298(NS)	1.558(NS)

t values: testing adjusted intercepts between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.995(NS)			
88-89-90	0.550(NS)	---		
90(<450 mm)	---	---	0.981(NS)	
89-90	0.673(NS)	---	0.159(NS)	1.777(NS)

NS - not significant
* - $0.01 < P \leq 0.05$
** - $0.001 < P \leq 0.01$
*** - $P \leq 0.001$

Because differences were detected between biennial spawners and females captured for the first time in 1990 that were less than 450 mm (Table 4.3), Figure 4.2 also illustrates first-time spawners had heavier pre-spawning weights than biennial spawners with similar fork lengths. Significant differences were also found in the slopes of the linear regressions between both groups of females captured spawning for the first time in 1990 (Table 4.3). Individual data points are plotted in Figure AI-2 (Appendix I) to illustrate the relationship between fork length and pre-spawning weight for females in each of the five groups that were examined.

Differences in the linear relationships of fork length and post-spawning weight in 1990 were detected between some the groups of females (Table 4.4). The linear regressions illustrating the relationships between fork length and post-spawning weight for the different groups of females captured in 1990 (Figure 4.3), and the ANCOVAs (Table 4.4), indicate that larger females ($\geq$450 mm) spawning for the first time in 1990 had heavier post-spawning weights per unit fork length than biennial spawners and both groups of annual spawners. Individual data points illustrating the relationship between fork length and post-spawning weight for females in each of the five groups that were examined are plotted in Figure AI-3 (Appendix I).

Biennial spawning females shorter than 544 mm had significantly lighter post-spawning weights than annual spawning females with similar fork lengths that spawned all three years (Figure 4.3 and Table 4.4). The linear regression relationships between annual spawners captured all three years and biennial spawners intersect at the point where $\log_{10}$ of the fork length (544 mm) is 2.7355 (Figure 4.3).

The opposite relationship applies to fish greater than 544 mm. However, the relationship of females greater than

Table 4.4: Test statistics for analyses of covariance determining differences for linear regressions relationships of fork length and post-spawning weight in 1990 between groups of brown trout.

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)	89-90
Spawning frequency	biennial	1st time	annual	1st time	annual
Sample size	15	20	83	172	135

F values: testing residual variances between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.161(NS)			
88-89-90	1.567(NS)	1.349(NS)		
90(<450 mm)	0.308(NS)	0.265(NS)	0.197(NS)	
89-90	1.134(NS)	0.977(NS)	0.724(NS)	0.272(NS)

t values: testing slopes between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	1.744(NS)			
88-89-90	1.875(NS)	4.195(***)		
90(<450 mm)	0.724(NS)	1.903(NS)	0.398(NS)	
89-90	1.594(NS)	3.780(***)	0.339(NS)	0.295(NS)

t values: testing adjusted intercepts between groups

Years captured	88-90	90(≥450 mm)	88-89-90	90(<450 mm)
90(≥450 mm)	2.638(*)			
88-89-90	2.731(**)	---		
90(<450 mm)	0.615(NS)	0.134(NS)	1.489(NS)	
89-90	1.923(NS)	---	1.302(NS)	1.354(NS)

NS - not significant; * - $0.01 < P \leq 0.05$
** - $0.001 < P \leq 0.01$ *** - $P \leq 0.001$

544 mm is of little consequence to this study because only one biennial spawning female in excess of 544 mm was captured and there appears to be a scarcity of large biennial spawners within the population.

The expected age based on the age:fork length relationship for brown trout in the upper Bow River and age determined from otoliths of each sacrificed fish are provided in Table 4.5. The results indicate all but one of the four sacrificed females that were captured spawning for the first time in 1990 had growth rates that were faster than expected. The growth rate of the sacrificed female that spawned in three consecutive years was slower than average.

Biennial spawning females exhibited slightly faster biennial growth rates than annual spawners (Figure 4.4). However, the differences were not significant (Table 4.6).

Table 4.5: Age and fork length relationships for females sacrificed in 1990.

Tag No.	Spawning frequency	Expected age*	Age determined from otoliths	Fork length
1299	1	6+	10+	439 mm
1839	2	6+	6+	429 mm
2641	2	6+	5+	433 mm
3654	2	7+	6+	458 mm
3837	2	9+	4+	540 mm
3891	2	6+	3+	424 mm

* Expected age based on the age:fork length relationship for brown trout in the upper Bow River system (unpubl. data, Alberta fish and Wildlife Division files).
1 Captured during 1988, 1989 and 1990.
2 Captured only during 1990.

Table 4.6: Test statistics for the analyses of covariance determining differences for linear regressions of 1990 fork length and growth since 1988 between annual and biennial spawning female brown trout.

Residual variance (step 1)	Slopes of Linear Regressions (step 2)	Adjusted intercept (step 3)
P>>0.75	0.4>P>0.2	0.4>P>0.2

Significant differences were detected in the fork length in 1988:post-spawning weight in 1988 relationships between annual spawning females captured all three years and biennial spawning females (Table 4.7). An ANCOVA indicated that neither the residual variances nor the slopes between the linear regressions were different, but that the adjusted intercepts were different. Plotting the linear regressions indicated the lines intersected where the $\log_{10}$ of the fork length was equal to 2.685 (Figure 4.5). Consequently, post-spawning body weights in 1988 of biennial spawning females with fork lengths less than 484 mm were significantly lighter than annually spawning females less than 484 mm.

The sample size of spawning females greater than 484 mm was small and only included one biennial spawner and ten annual spawning females (Figure 4.5). Figure 4.6 shows the linear regressions and plotted data points when females greater than 484 mm are excluded from the sample set. Based on the equations for the linear regressions ($y = a + bx$) displayed in Figure 4.6, the calculated 1988 post-spawning weights of biennial and annual spawning females with fork lengths of 427 mm were 331.0 g and 351.5 g, respectively (difference = 20.5 g). Similarly, the 1988 post-spawning weights of biennial and annual spawning females with fork lengths of 483 mm were 971.6 g and 1019.9 g, respectively (difference = 48.3 g). Consequently, the linear relationships indicate the 1988 post-spawning weights of biennial spawners were 5 to 6 percent lighter than annual spawners with similar fork lengths.

Table 4.7: Test statistics for the analyses of covariance determining differences for linear regressions of fork length and post-spawning weight in 1988 between all annual and biennial spawning female brown trout.

Residual variance (step 1)	Slopes of Linear Regressions (step 2)	Adjusted intercept (step 3)
$P>0.75$	$0.01>P>0.05$	$0.02>P>0.01$

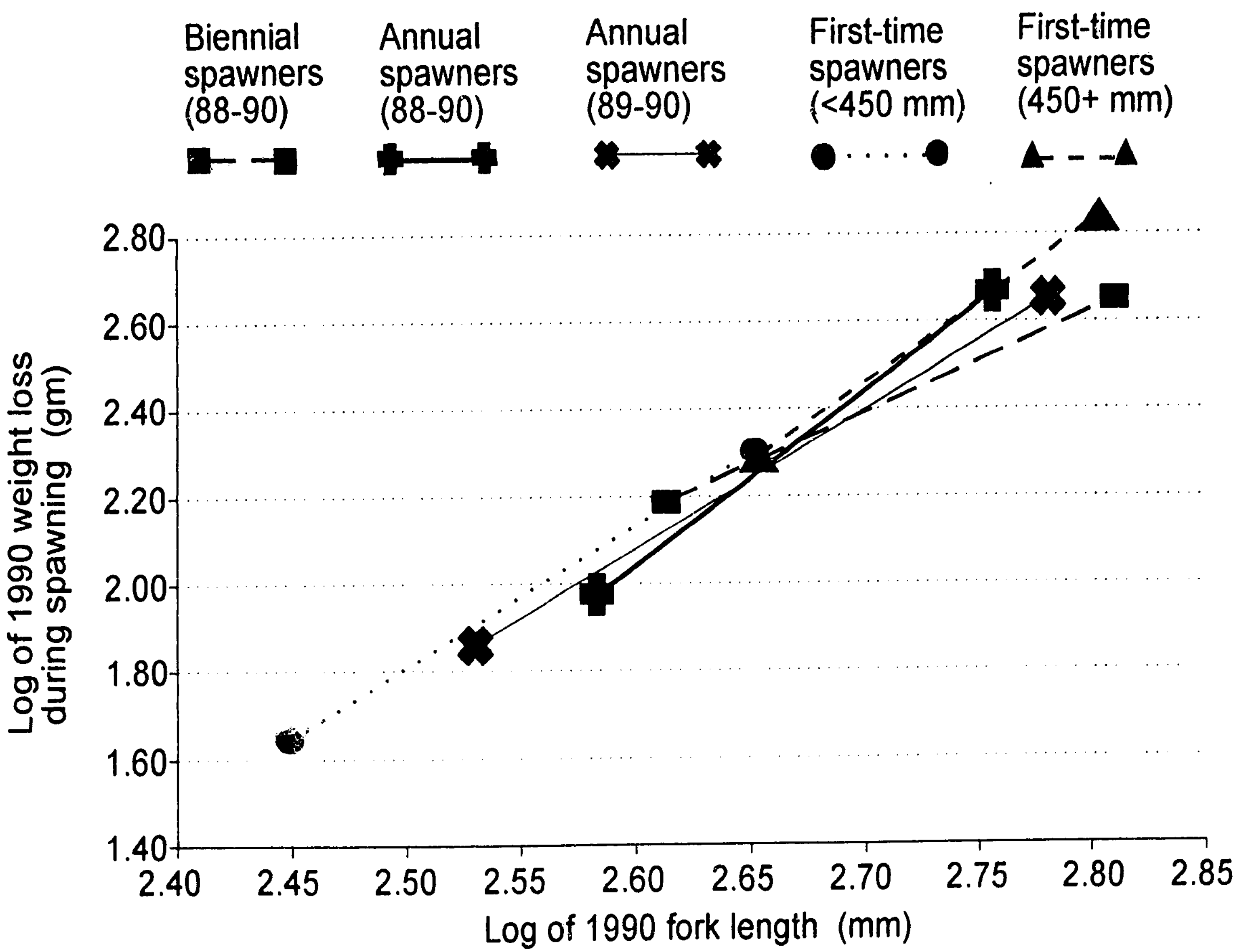

Figure 4.1: Comparison of linear regressions of fork length and weight loss during spawning between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.

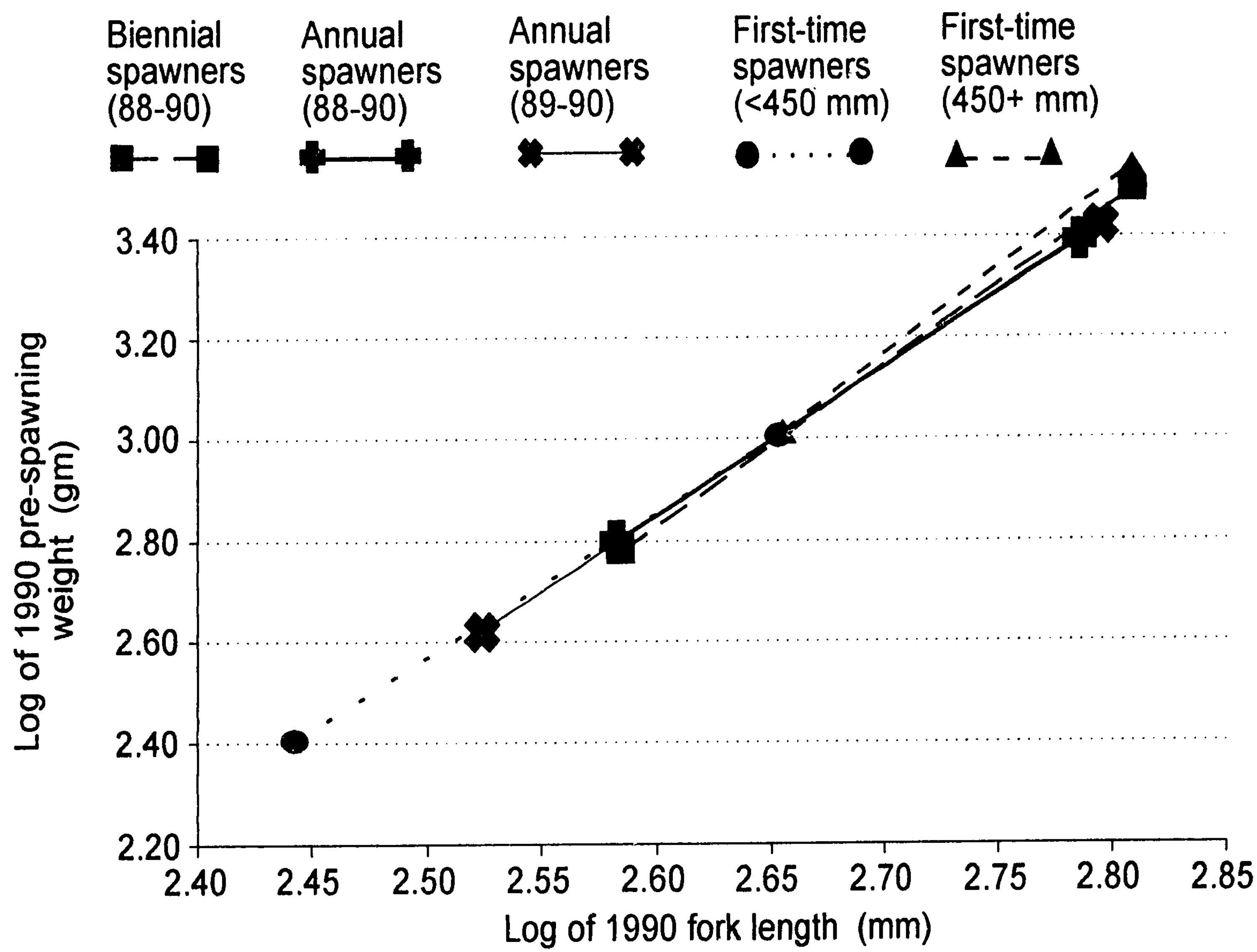

Figure 4.2: Comparison of linear regressions of fork length and pre-spawning weight between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.

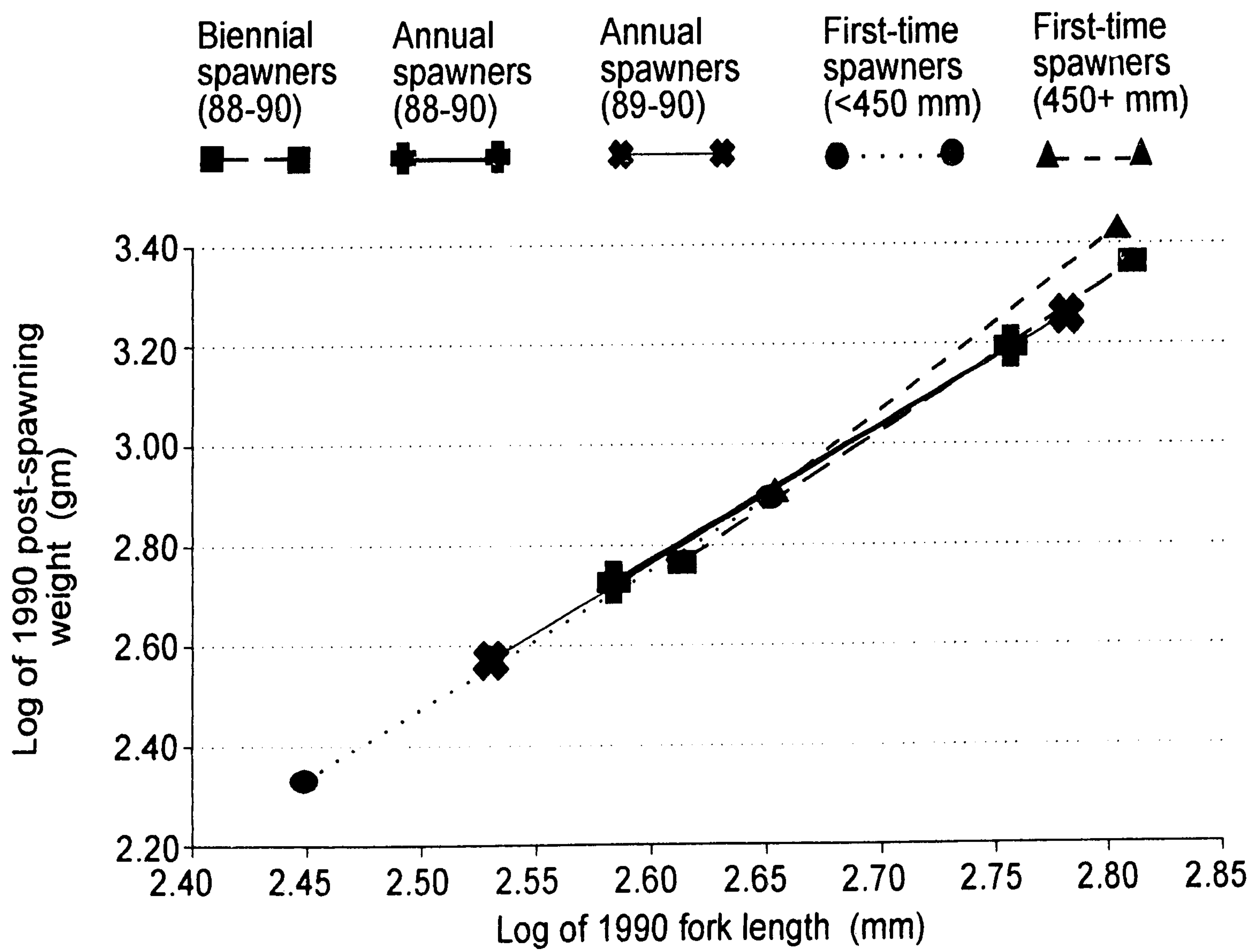

Figure 4.3: Comparison of linear regressions of fork length and post-spawning weight between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.

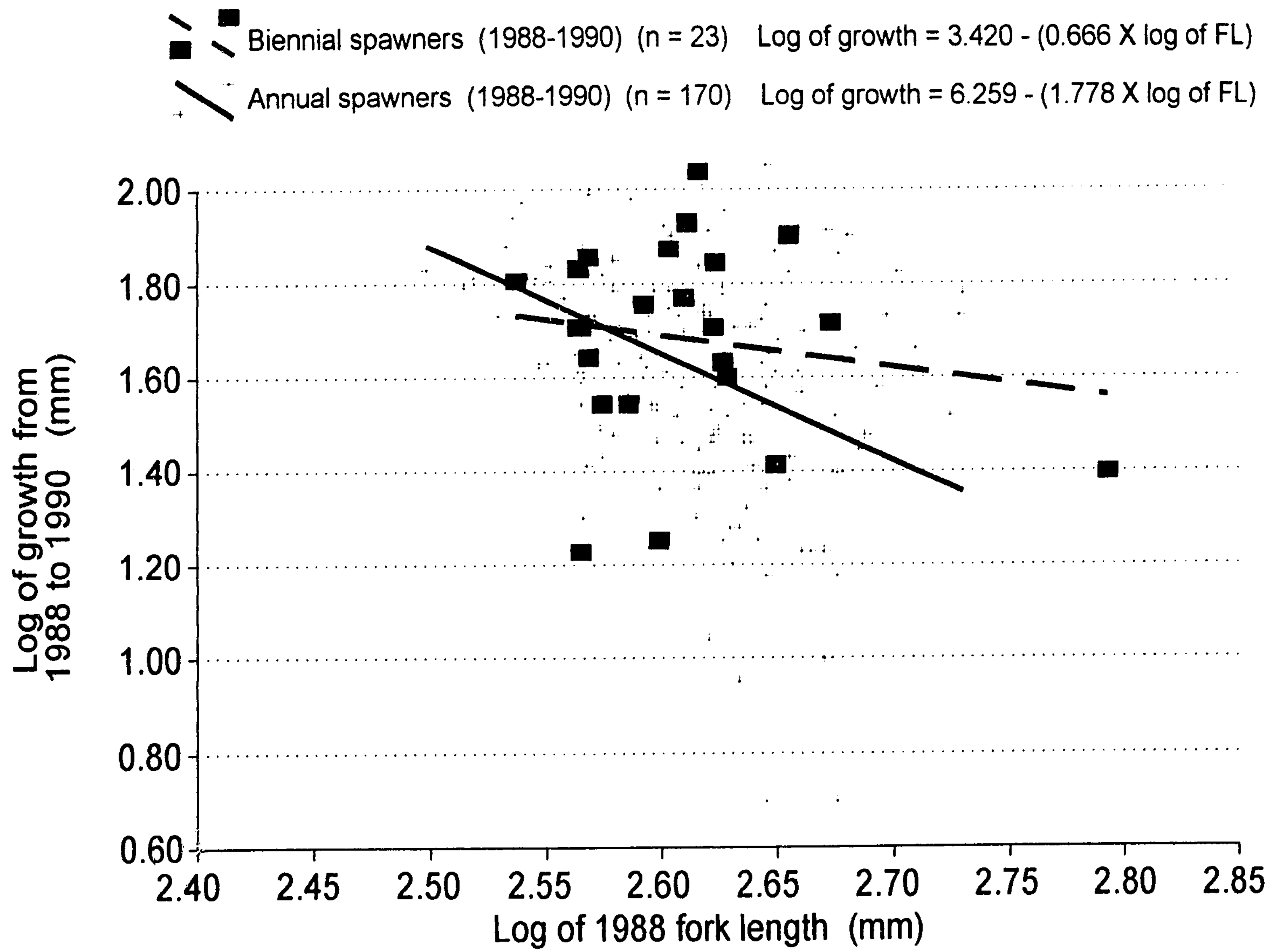

Figure 4.4: Comparison of linear regressions of fork length in 1988 and growth since 1988 between biennial and annual spawning female brown trout that returned to spawn in 1990.

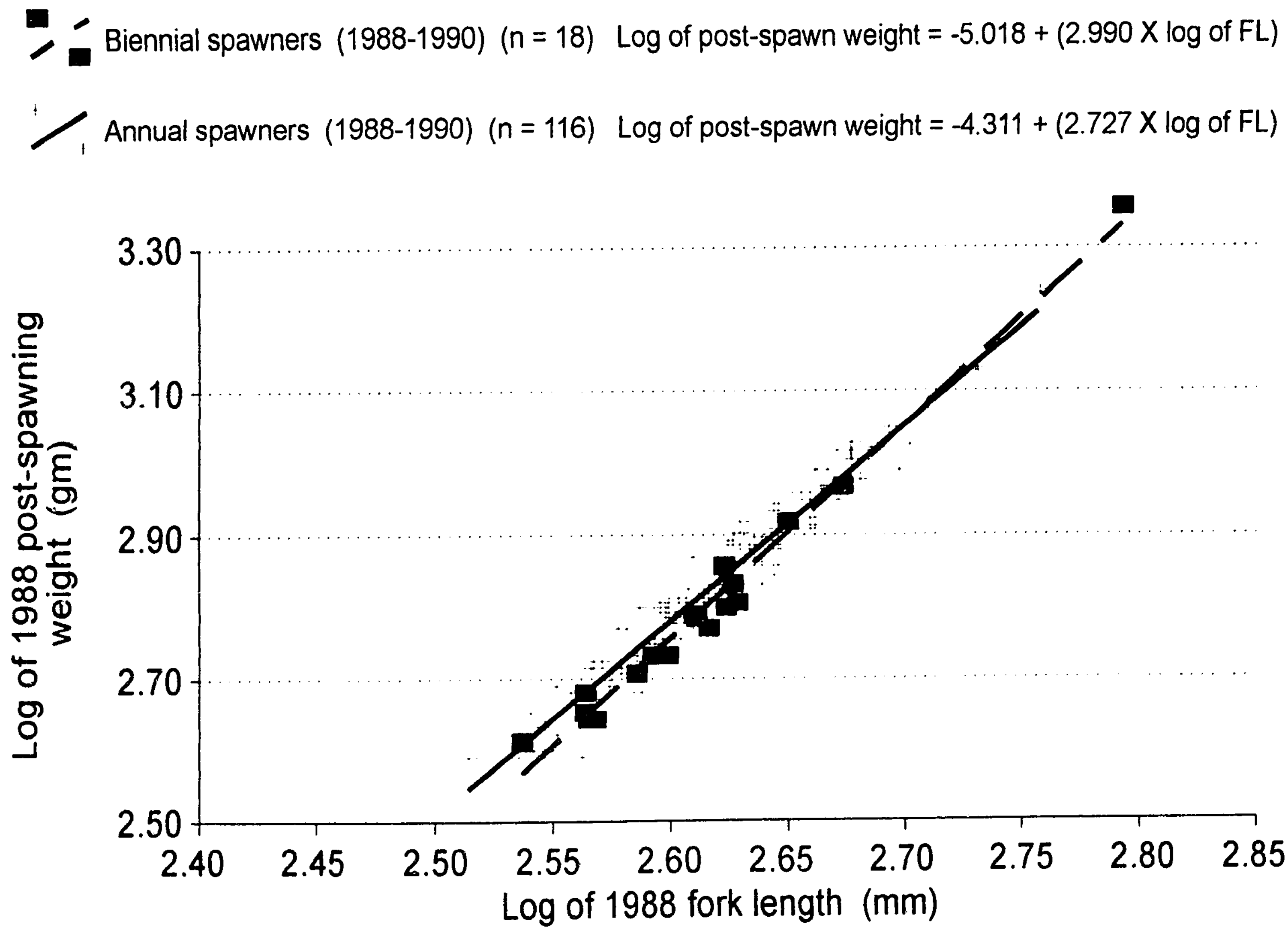

Figure 4.5: Comparison of linear regressions of fork length in 1988 and post-spawning weight in 1988 between all biennial and annual spawning female brown trout captured in both 1988 and 1990.

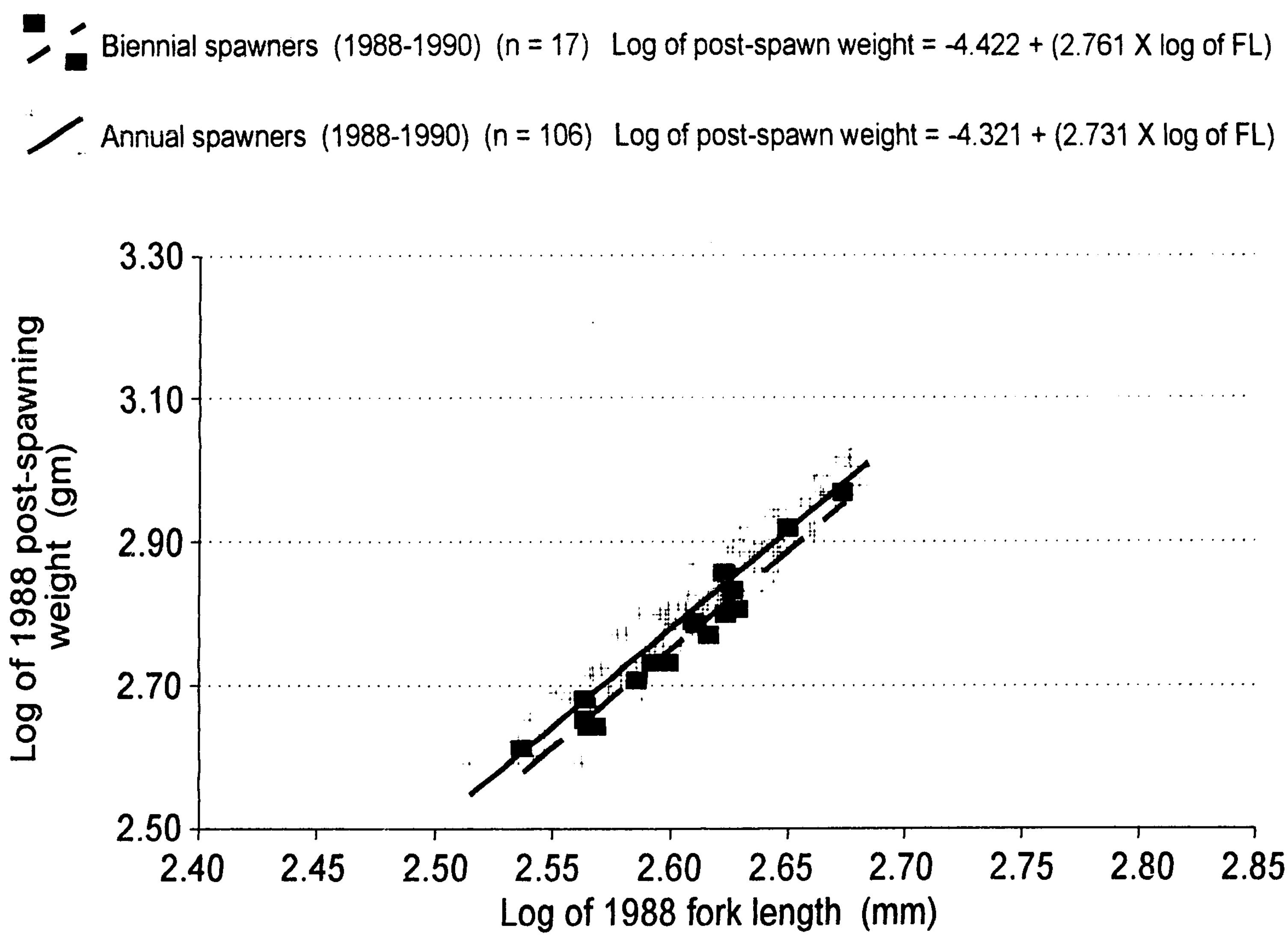

Figure 4.6: Comparison of linear regressions of fork length in 1988 and post-spawning weight in 1988 between biennial and annual spawning brown trout females that were less than 484 mm when captured in 1988.

4.5 Discussion

4.5.1 Occurrence of biennial spawners

The results of the redd surveys indicate the majority of brown trout spawning in the Bow River system practice stream fidelity with respect to reproduction. However, the results do not prove that absolute stream fidelity occurs. The absence of observing tagged brown trout from Bill Griffiths Creek in any of the other spawning streams, and the return in 1990 of 57.1% (Section 2.0) of the female brown trout that spawned in 1989, indicate stream infidelity is rare. These results support reports from Scotland (Stuart 1957), Australia (Tilzey 1977), the United States (Scholl et al. 1984) and Switzerland (Geiger et al. 1986), where repeat spawning brown trout returned back to the same spawning stream in subsequent years.

The capture of some females in three successive years and the capture of some females only in alternate years suggests both biennial and annual spawning females occur in Bill Griffiths Creek. Although it is possible that females captured only in 1988 and 1990 had spawned annually but avoided recapture in 1989, two factors suggest this scenario is unlikely. Firstly, it appears females return to the same reach of stream between years because: i) a high ratio (57.1%) of females from 1989 that spawned above the trap also spawned above the trap in 1990; and ii) a high ratio of females that were not spent when they initially migrated downstream through the trap returned upstream shortly after to spawn (Section 2.0). Secondly, females captured spawning in successive years displayed a significant correlation in the dates between years when they were captured migrating upstream; if females captured in alternate years had spawned in streams other than Bill Griffiths Creek in 1989, or in Bill Griffiths Creek but below the trap, then they also would have been expected to display a significant correlation in the dates they were captured in 1988 and 1990. This, however, did not occur.

4.5.2 Differences between females captured in 1990 only and other groups

Significant differences were detected in the linear regressions of fork length and pre-spawning weight between females <450 mm, and females ≥450 mm, captured only in 1990. This suggests either: i) there were two distinct groups among the females captured only in 1990 (i.e., females spawning for the first time and repeat spawners that skipped spawning in both 1988 and 1989); or ii) the majority of females ≥450 mm captured only in 1990 were spawning for the first time but the relationship between fork length and pre-spawning weight (transformed logarithmically) is not linear throughout the range of fork lengths.

Although it is possible some of the females ≥450 mm captured only in 1990 were biennial spawners that had spawned in 1988 but were not captured or had lost their tag, they likely represented a minority. The most likely scenarios are that females ≥450 mm were either: a) first-time spawners: b) triennial spawners: or c) some combination of a) and b).

The age at first spawning among individual salmonid populations is variable. For example, among Atlantic salmon it has been suggested the age at first spawning is heritable (Schaffer and Elson 1975) or related to growth rates in freshwater (Schiefer 1971 in Schaffer and Elson 1975). The focus of the present study was to determine whether alternate year spawning was occurring within the Bow River system and whether trade-offs were associated with alternate year opposed to annual spawning; consequently, the data necessary to determine whether females captured only in 1990 were, or were not, first-time spawners was not collected. Regardless of whether females ≥450 mm that were captured only in 1990 were spawning for the first-time or were repeat spawners that skipped spawning in both 1988 and 1989, the results indicate females that delay spawning for the first-time, or delay repeat spawning, until a larger length is attained (i.e., ≥450 mm) experience heavier pre- and post-spawning weights per unit fork length than females that spawned in two, or more, of the last three years.

The absence of significant differences in the relationships between fork length and weight loss during spawning suggests indirectly that fecundity is consistent per unit fork length among all five of the examined groups of females. This is in contrast to Jonsson (1985) who directly measured fecundity and found significant heterogeneity in slopes between residents, first-time migrants and repeat spawning migrants. His residents were females that inhabited the spawning stream and migrants were sea-run brown trout returning to the stream only to spawn. Jonsson (1985) reported that repeat spawners had higher fecundity per unit of tip length than first-time spawners. The contrasting results between studies suggests the absence of differences in the present study indicate weight loss during spawning may not provide a reliable indirect measurement of fecundity, or alternatively, differences detected by Jonsson (1985) may have been partially due to environmental differences experienced by the migrants and resident spawners examined by Jonsson (1985).

Diverting energy from reproduction can result in increased somatic growth (Glebe and Leggett 1981a; Reznick 1983). Females ≥450 mm that were only captured in 1990 likely delayed spawning for one or more years; consequently, when they did spawn they were probably longer than cohorts of the same age that spawned in 1988 and/or 1989. Because fecundity is directly related to body size (Nicholls 1958; Hardy 1967), they likely experienced greater fecundity than repeat spawning females of the same age. The limited information on age:fork length relationships from sacrificed fish supports the argument that first-time spawners that delayed spawning experienced faster growth rates than cohorts that began spawning at shorter fork lengths.

Although females captured only in 1990 with fork lengths ≥450 mm did not experience greater weight losses during spawning, they did exhibit heavier post-spawning weights than repeat spawners. Post-spawning mortality rates among American shad (*Alosa sapidissima*) are higher among fish that experience greater depletions of their energy reserves during the spawning experience (Glebe and Leggett 1981a; Glebe and Leggett 1981b). Low frequencies of repeat spawning among American shad are also influenced by higher energy costs associated with spawning (Leggett and Carscadden 1978; Shoubridge and Leggett 1978 in Glebe and Leggett 1981a). Heavier post-spawning weights among brown trout females ≥450 mm that were captured only in 1990 suggest females that delay spawning for the first time, or for more than one year, may experience better post-spawning body condition which may lead to increased survival.

4.5.3 Differences between biennial and annual spawners

The results suggest that delaying spawning for one year likely did not result in increased fecundity for biennial spawners. There were no significant differences among the linear regression relationships for fork length and pre-spawning weight, or for fork length and weight loss during spawning, between annual and biennial spawners.

Furthermore, the lack of statistical differences in growth between annual and biennial spawning females suggests there was no benefit in terms of increased growth by delaying spawning for only one year. Consequently, skipping spawning and diverting energy from reproduction in 1989 likely did not cause biennial spawners to experience increased fecundity as a result of increased body size.

Females that skipped spawning in 1989 had lighter post-spawning body weights per unit fork length in both 1988 and 1990 than females that spawned in three successive years. This, and previous studies involving American shad and Japanese medaka (*Oryzias latipes*), suggests females that skipped spawning in 1989 lacked the physical conditioning after spawning in 1988 to spawn the following year. American shad that consume greater percentages of their energy reserves during spawning also experience reduced survival (Glebe and Leggett 1981b). Among Japanese medaka increased loss of mass during spawning has been correlated with increased sickness and mortalities shortly after spawning (Hirshfield 1980). Consequently, the bodily reserves of females that skipped spawning in 1989 may have been inordinately depleted after spawning in 1988; as a result, they may have sacrificed spawning in 1989 to enhance their survival and increase opportunities to spawn in the future.

By forfeiting spawning in 1989, biennial spawners appear to have diverted energy from reproduction and into body conditioning, thereby increasing their chances for survival. Mortality rates among post-spawning Atlantic salmon are greater among males than females (Jonsson et al. 1990). Concurrent research with this study (Section 2.0) and other studies (Alm 1950; Davies and Sloane 1987; Maisse et al. 1987; Maisse and Bagliniere 1990) have reported mortalities among post-spawning brown trout are also higher among males than females. Although the total energetic costs of spawning between sexes reported for Atlantic salmon are similar, the loss of soma during spawning among males is greater than among females despite females experiencing a higher pre-spawning, mean wet weight gondosomatic index than males (Jonsson et al. 1991). Consequently, Jonsson et al. (1991) speculated that greater post-spawning mortalities among male Atlantic salmon were due to their post-spawning somatic energy reserves being more depleted than those of females.

Similarly, females in the present study that skipped spawning in 1989 may have been approaching the threshold where they lacked the physical conditioning to spawn in 1989 without compromising survival. Consequently, rather than diverting energy into reproduction in 1989, they delayed spawning. This delay may have contributed to increasing their chances of survival and future spawning opportunities.

Interestingly, the biennial spawning females that had significantly lighter post-spawning weights than annual spawners in 1988 also had significantly lighter post-spawning weights in 1990 despite skipping spawning in 1989. The repeated occurrence of significantly lighter post-spawning weights strengthens the argument that biennial spawners skipped spawning because of depleted body reserves after spawning. It also suggests that biennial and annual spawners in the upper Bow River system may be different physiologically and that biennial spawners are unable to spawn in successive years. However, this study did not attempt to examine whether differences in the physiology between annual and biennial spawners are genetic, environmental or pathological.

This study indicates several life history strategies are practised by individuals within the same population. For example, the study illustrates the presence of individuals that delay when they first spawn as well as annual and biennial spawners. The indirect methods used to assess the trade-offs associated with the different life history strategies suggests research to examine the physiology of individuals practising different life history strategies may be warranted. Further research employing direct measures of fecundity and post-spawning energetic reserves would assess the reliability of the indirect measurements employed in this study and help identify some of the potential mechanisms influencing the life history strategy followed by some individuals.

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5.0 THE INCIDENCE OF *Saprolegnia* SPP. INFECTION IN A SPAWNING POPULATION OF BROWN TROUT (*Salmo trutta*) AND THE EFFECTS OF TAGGING AND HANDLING ON ITS OCCURRENCE

5.1 Abstract

Susceptibility to infection by *Saprolegnia* among a population of brown trout migrating through Bill Griffiths Creek, a tributary of the upper Bow River, Alberta, is influenced by the sex and fork length of spawning adults. Larger brown trout males are more frequently infected than females or smaller males. Handling and tagging during spawning, and the presence of floy anchor tags, were not found to cause increased infection rates among larger males which were the portion of the population most susceptible to infection. The duration of time spent on the spawning grounds appears to be reduced as a result of infection by *Saprolegnia*.

5.2 Introduction

Saprolegnia parasitica-diclina complex is the most important species grouping in fish pathology (Roberts 1989). It is commonly implicated in the infection of sexually mature brown trout (White 1975; Richards and Pickering 1978; Pickering and Christie 1980). Although *Saprolegnia* infections are considered secondary to bacterial or viral infections, malnutrition, physical injury and/or physical stress (Roth 1972; Post 1983), they are also thought to cause lethal primary infections on healthy fish (Stuart and Fuller 1968). When infected individuals within a spawning stream are present, it is reasonable to assume that all individuals are exposed to fungal spores in the water. Since many fish do not become infected, it adds support to the theory that the *Saprolegnia parasitica-diclina* complex are opportunistic facultative parasites (Neish 1977).

It has been suggested that *Saprolegnia* infection among spawning brown trout is promoted by the damage inflicted upon females during redd construction and upon males from the abrasions and wounds they sustain during redd defense (White 1975). However, infection on brown trout is also influenced by sexual maturity (Roberts and Shepard 1974; Richards and Pickering 1978; Pickering and Christie 1980) and males are more susceptible than females (White 1975; Richards and Pickering 1978; Pickering and Christie 1980).

A sexual dimorphism exists in the skin of brown trout during spawning whereby males possess fewer mucous secreting goblet cells in their epidermis (Stoklosowa 1966; Pickering 1977). Consequently, males have a reduced layer of mucous over their epidermis compared to females. Since structural differences also coincide with increased susceptibility by males to a variety of skin infections (Pickering and Christie 1980), one function of the mucous coating may be to provide a protective barrier against colonization by parasites, fungi and bacteria. Evidence suggests mucous inhibits the colonization of *Saprolegnia* on brown trout (Wood et al. 1986).

Saprolegniasis on salmonids may be stress related (Neish 1977) as are other infectious diseases caused by opportunistic facultative parasites (Wedemeyer 1970; Wedemeyer and Wood 1974; Snieszko 1974). Handling and/or tagging fish during spawning may increase the stress that they experience. Handling is an acute stress; it is a short-term stimulus removed before the response is complete (Pickering et al. 1982). Tagging is a chronic stress as the tag remains with the fish providing a continuous challenge. Consequently, the stresses associated with handling and tagging fish may increase their susceptibility to infection by *Saprolegnia*.

Acute handling stress is known to increase both the concentration of plasma cortisol and epidermal mucous secreting cells of brown trout (Pickering et al. 1982). Similarly, handled Arctic char (*Salvelinus alpinus*) also experience an increased production of epidermal mucous secreting cells (Pickering and Macey 1977). Therefore, handling brown trout may cause negative and positive effects. Elevated cortisol rates increase the susceptibility of brown trout to *Saprolegnia* infection (Pickering and Duston 1983), while increased concentrations of mucous secreting cells caused by handling may reduce the susceptibility of infection (Pickering and Christie 1980).

There exists little evidence in the literature concerning how tagging effects the incidence of *Saprolegnia* infection. The tagging of Atlantic salmon (*Salmo salar*) parr (age 1+) has caused minor *Saprolegnia* infection around the tag insertion (Roberts et al. 1973). Application of Carlin tags may increase the risk of *Saprolegnia* infection among upstream salmonid migrants (Miles 1985). Research into the haematological effects among juvenile pink salmon (*Oncorhynchus gorbuscha*) revealed the implantation of floy anchor tags was not the major stressing agent encountered; observed changes were a result of capture, handling or confinement after tagging (Cardwell et al. 1971).

The purpose of this study was to determine: which individuals in a population of brown trout spawning in Bill Griffiths Creek, a tributary of the upper Bow River system, Alberta, were most susceptible to infection by *Saprolegnia*; whether handling, handling and tagging, or the presence of a floy anchor tag affects the incidence of *Saprolegnia* infection within the spawning population; and, whether infection by *Saprolegnia* affects the duration of stay on the spawning grounds. Incidental information on brook trout infected with *Saprolegnia* was also collected.

5.3 Methods

This study was conducted as one of several concurrent studies that data were gathered from the same fish simultaneously. The methods employed in the field for this study are described in Section 2.0. Only methods not previously described in Section 2.0 and that are specific to this study are described in this section.

Infected brown trout were identified by the presence of a cotton-like growth on the epidermis of infected fish. *Saprolegnia* samples were collected from live fish by clipping with a portion of an infected fin with scissors and placing the removed portion on an agar plate. Samples were maintained on glucose-peptone agar (Willoughby and Pickering 1977). Identification of the samples to the genus level was determined by Dr. Ted Cook (retired professor, Dept. of Soil Science, University of Alberta).

A chi-square test for homogeneity of samples (Prepas 1984) was used to determine if handling and/or tagging influenced whether larger male brown trout subsequently became infected with *Saprolegnia* while on the spawning grounds.

5.4 Results

The fork length frequency distributions for brown trout captured in 1988, 1989 and 1990, combined (Figure 5.1a), reveals that male and female brown trout spawning in Bill Griffiths Creek displayed similar peak distributions in fork length and had similar maximum fork lengths. However, relatively few females under 300 mm were captured and males were the dominant sex under 300 mm. Immature brown trout were prevalent under 300 mm but did not exceed 350 mm.

Figure 5.1b shows the combined fork length distribution of all individuals known to become infected with *Saprolegnia* during the 1988, 1989 and 1990 spawning seasons, combined, in Bill Griffiths Creek. Infected males outnumbered infected females by greater than a 10:1 ratio.

Figures 5.1a and 5.1b illustrate the incidence of infection is greatest among males in the spawning population. Although females represented 56.1% of the brown trout captured during all three years, they only account for 8.7% of the infected fish captured. The graphs also suggest infection and fork length are related. For example, although similar numbers of each sex above 549 mm were captured, no infected females in excess of 549 mm were captured. Males under 319 mm were common in the total population, but no infected males under 319 mm were ever captured.

Figure 5.2 shows percentages of the males, females and immatures that were captured within each 10 mm fork length interval and were visibly infected with *Saprolegnia*. Figure 5.2 shows larger males were more frequently infected. All males with fork lengths longer than 589 mm became infected with *Saprolegnia*. No males were captured in the 620-629 mm and 640-649 mm fork length intervals.

Although the percentage of females that were visibly infected was smaller, females also displayed a slight increasing trend in the percentage of infected females increased as fork length increased (Figure 5.2). Relatively few infected females were under 300 mm (n = 9). Consequently, although only one female captured in the 290-299 mm fork length interval was infected, the 290-299 mm fork length interval was distorted.

During the three years of field research only one immature brown trout infected with *Saprolegnia* was captured (Figures 5.1b and 5.2). This individual's only site of infection was a large, predator wound.

Among 85 post-spawned brook trout captured during the three years, only one was ever captured that was infected with *Saprolegnia*. It was a female (226 mm) whose site of infection was limited to a large predator wound.

Infection by *Saprolegnia* was not limited to post-spawning individuals. The occurrence of infection among ripe males and females migrating into Bill Griffiths Creek in 1989 were 2.4% and 1.6%, respectively. Among spent individuals exiting the stream in 1989, 22.1% and 0.5% of the males and females, respectively were infected. In 1990, 1.9% of the ripe males and none of the ripe females were infected when they entered Bill Griffiths Creek to spawn, but 44.9% and 3.3% of the spent males and females, respectively, were infected when they exited the stream. Since the trap in 1988 was not installed until October 15, a portion of the upstream spawning migration was not captured and similar analyses of the 1988 data were not attempted.

Increased infection rates among males appears to cause increased mortalities among males. For example, the largest number of observed mortalities occurred in 1989 (see Section 2.4). Among the nine dead fish found in 1989, five were heavily infected with *Saprolegnia* and all five were males. Furthermore, between five and ten of the downstream migrants each year appeared to be severely distressed and near death. These distressed individuals were always large males that were severely infected with *Saprolegnia*.

Neither tagging nor handling increased the occurrence of infection by *Saprolegnia* among brown trout spawning in Bill Griffiths Creek Figure 5.3 illustrates the combined number of males (within 3 standard deviations of the mean fork length of infected males) for each "tag-type" captured during both 1988 and 1989 compared to the combined number of infected males with the same "tag-type". Each "tag-type" is defined in the legend provided with Figure 5.3. No differences were found among different "tag types" between infected males and males within three standard deviations of the mean fork length of infected males (0.9>P>0.5).

To eliminate fish less likely to become infected, the data set used in Figure 5.3 included only males captured in 1988 and 1989 with fork lengths within three standard deviations of the mean fork lengths of infected males. Data from 1990 was excluded because a theft of field data for October 29, 1990 prevented identifying whether some males exiting the stream had been previously handled in 1990. Females, immatures and shorter males were also excluded because they were less prone to infection and their inclusion would bias the results concerning whether tagging or handling influenced subsequent infection.

Some individuals were captured several times during the same spawning season. Although these individuals were handled more often, they seldom become infected. For example, one male (tag #3074) with a fork length of 429 mm was captured eight times between October 31 and December 7, 1989 and never became visibly infected with *Saprolegnia* that year. When this fish returned in late October 1990, it was not infected and had grown to 457 mm, nor was it infected when it migrated downstream after a couple of weeks on the spawning grounds. However, when it returned upstream in late November, *Saprolegnia* colonies were present on its anal and dorsal fins, respectively. Other males were captured up to six times in 1989 and eight times in 1990 without contracting *Saprolegnia*.

Table 5.1 provides the numbers of infected males and females captured each year and the number of infected fish that survived and returned in a subsequent year to spawn. It is noteworthy that some fish that survived after being infected one year became re-infected in a subsequent year.

Figure 5.4 compares dates infected and non-infected males exited the stream in 1989. It suggests infection by *Saprolegnia* may be associated with an earlier migration from the spawning grounds and that almost half of the males leaving the spawning grounds during the peak downstream migration were infected. This data was smoothed using a 5-point running average. All sexually mature males were included in this graph because fork length did not affect the timing of spawning (Section 2.4.6).

Figure 5.5 compares the duration of stay on the spawning grounds during the 1989 spawning season between: non-infected males; males that became infected while on the spawning grounds; and males that were infected when they entered the spawning grounds. The figure shows males that were already infected with *Saprolegnia* when they were captured migrating upstream generally spent the shortest time on the spawning grounds. The mean durations of non-infected males, males that became infected while on the spawning grounds, and males that were infected when captured migrating upstream were 32.0, 29.2 and 10.2 days, respectively. A one-way analysis of variance (ANOVA) (Cody and Smith 1991) determined differences existed in the mean durations of stay between the three groups ($0.005>P>0.001$). A Newman-Kuels method determined the duration spent on the spawning grounds by males that were infected when they entered the spawning grounds was significantly less, at the five percent level, than the durations spent by both non-infected males and males that became infected while on the spawning grounds. However, the number of males that became on the spawning grounds was low (n = 5); consequently, the small sample size may have contributed to the differences that were detected. Although males that became infected while on the spawning grounds spent an average of 2.8 days less spawning than non-infected males, the duration of time spent on the spawning grounds was not significantly different between the two groups.

The data set for Figure 5.5 was limited to males within three standard deviations of the mean fork length of infected males. This eliminated any bias caused by smaller males that were less prone to infection and were found to spend less time on the spawning grounds (see Section 2.4). Similar analyses of the 1988 and 1990 data were not made because of the reduced trapping period in 1988 and the loss of data from October 29, 1990.

Table 5.1: Number of brown trout infected with *Saprolegnia* when captured during the 1988, 1989 and 1990 spawning seasons and the number of infected brown trout in 1988 and 1989 that returned to spawn in a subsequent spawning season.

Spawning season	1988	1989	1990
No. of infected males	68	110	159
No. of infected females	4	6	16
No. of infected immatures	0	0	1
No. of infected males in 1988 that returned in a subsequent spawning season (No. that became re-infected)		5 (1)	2 (1)
No. of infected females in 1988 that returned in a subsequent spawning season (No. that became re-infected)		0 (0)	0 (0)
No. of infected males in 1989 that returned in a subsequent spawning season (No. that became re-infected)			8 (2)
No. of infected females in 1989 that returned in a subsequent spawning season (No. that became re-infected)			2 (0)

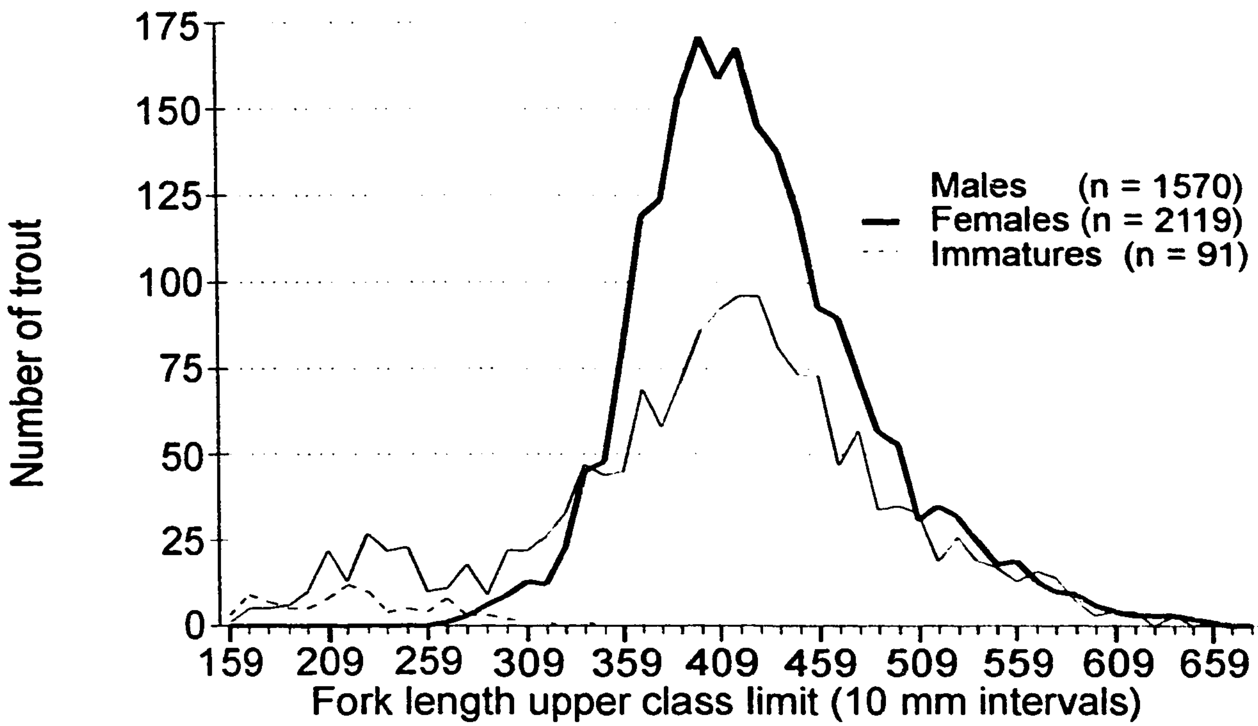

Figure 5.1a: Combined fork length frequency distributions for all brown trout captured during the 1988, 1989 and 1990 spawning seasons in Bill Griffiths Creek.

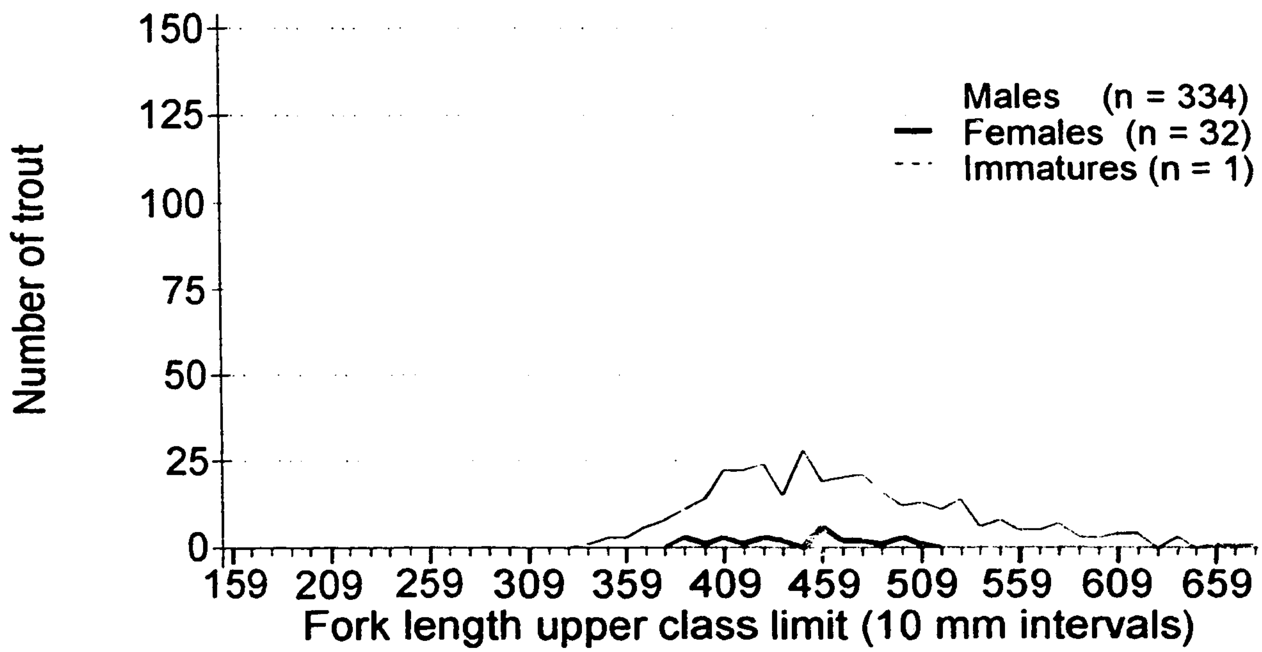

Figure 5.1b: Combined fork length frequency distributions for all brown trout captured during the 1988, 1989 and 1990 spawning

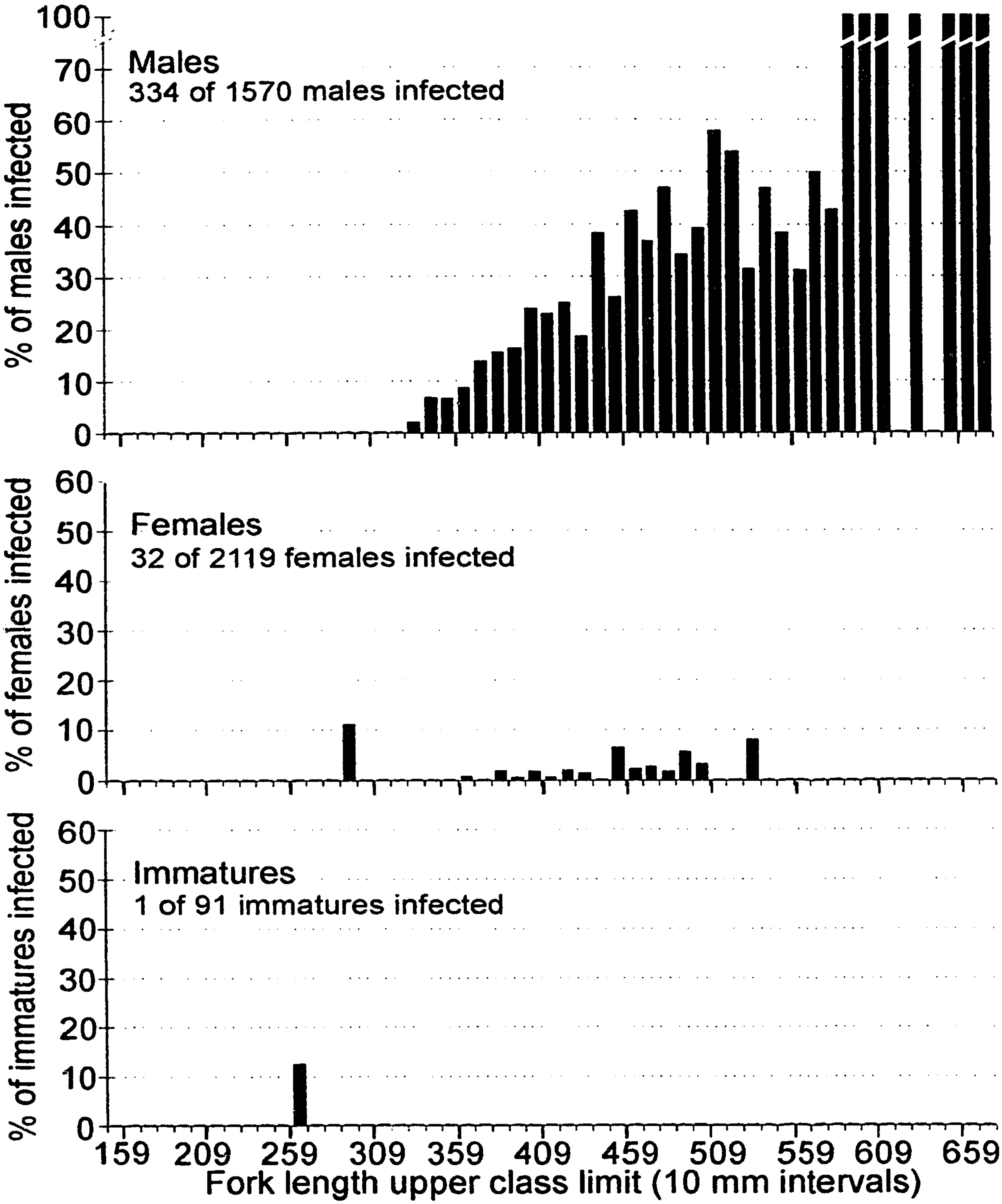

Figure 5.2: Percentage of male, female and immature brown trout within each 10 mm fork length interval captured during

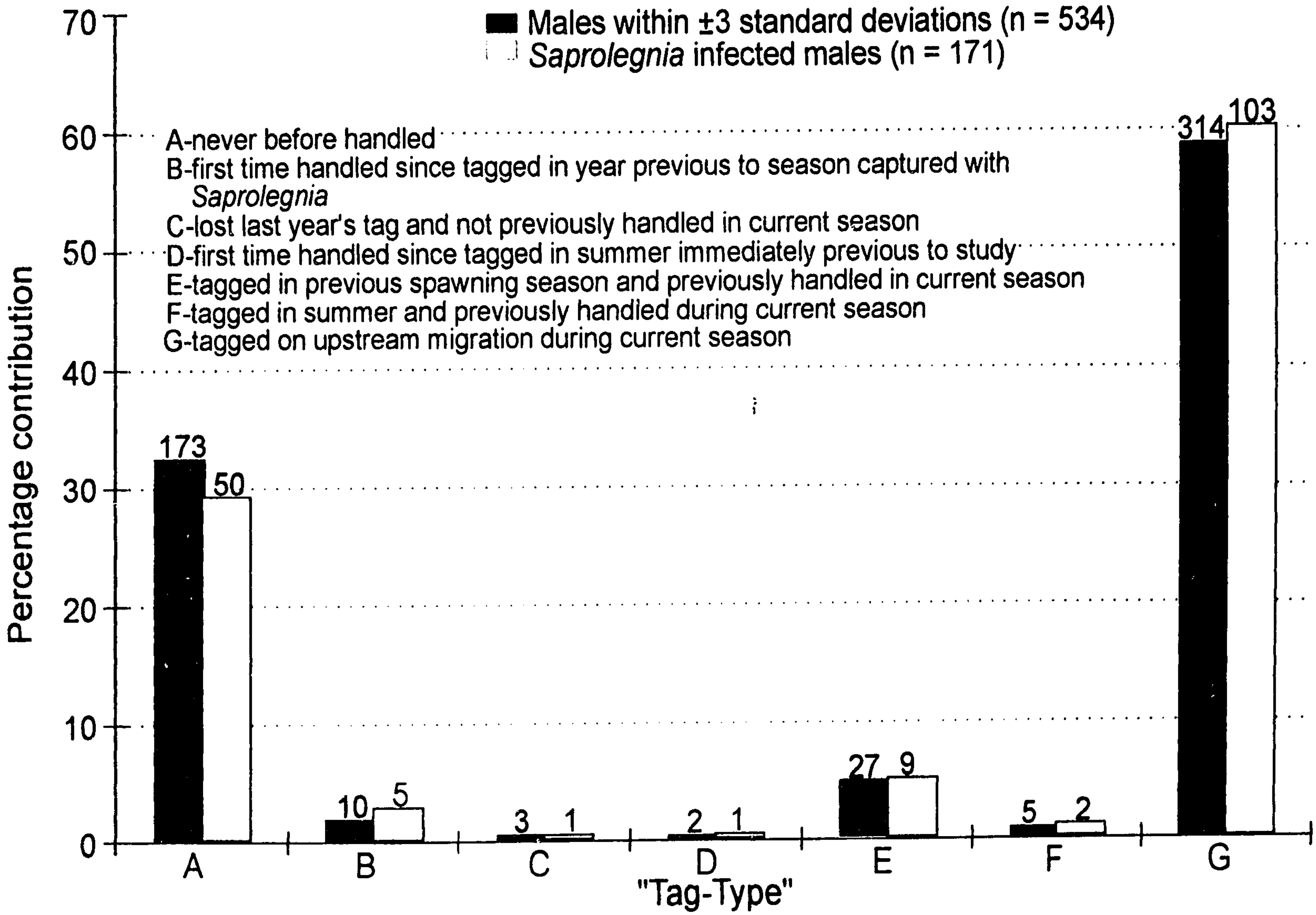

Figure 5.3: Comparison of percentage contribution by each "tag-type" between all post-spawning males in 1988 and 1989 that became infected with *Saprolegnia* and that had fork lengths within three standard deviations of the mean fork length of infected males.

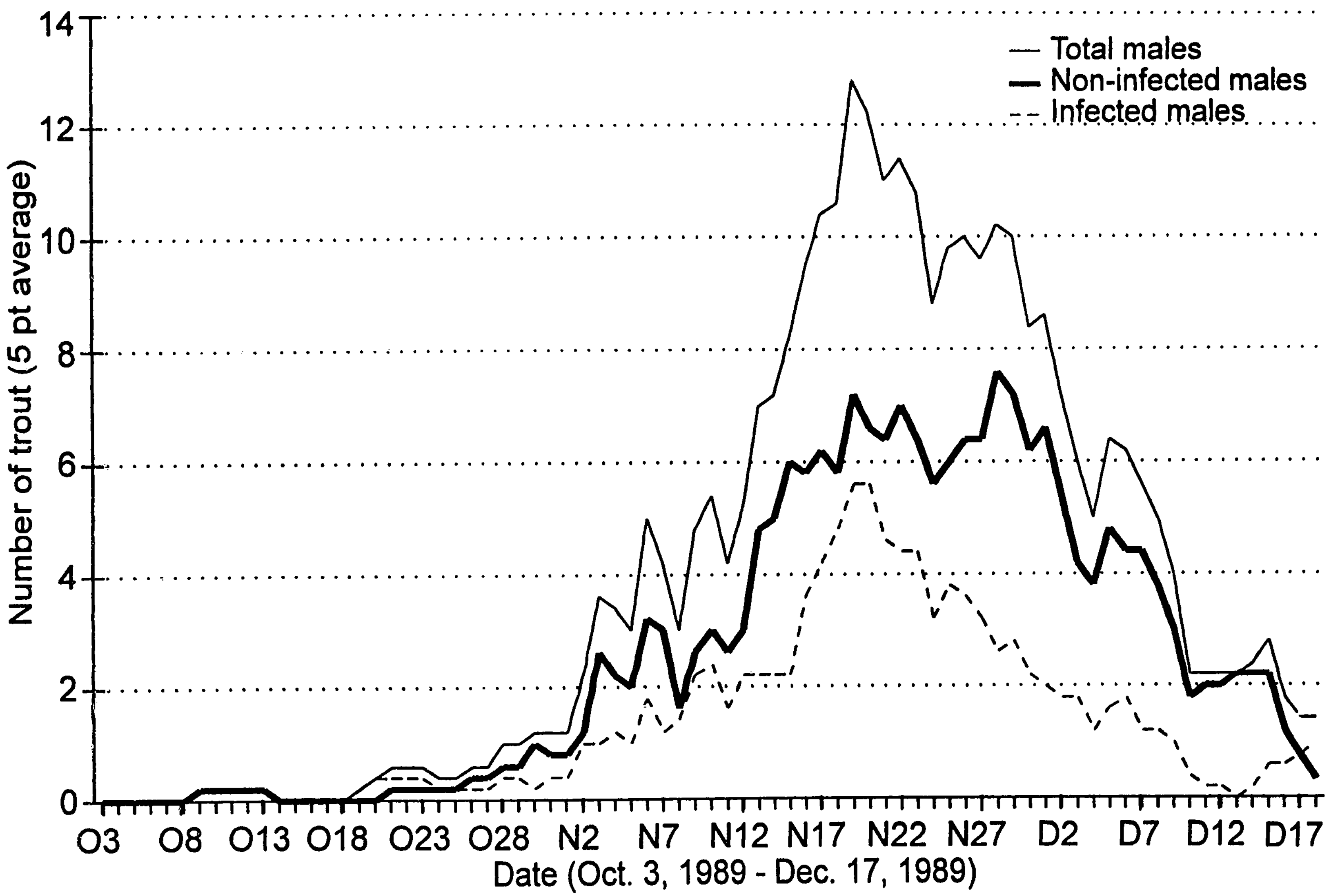

Figure 5.4: Downstream migration of all males, males infected with *Saprolegnia* and non-infected males during the 1989 brown trout spawning season in Bill Griffiths Creek (data smoothed with 5-point running average).

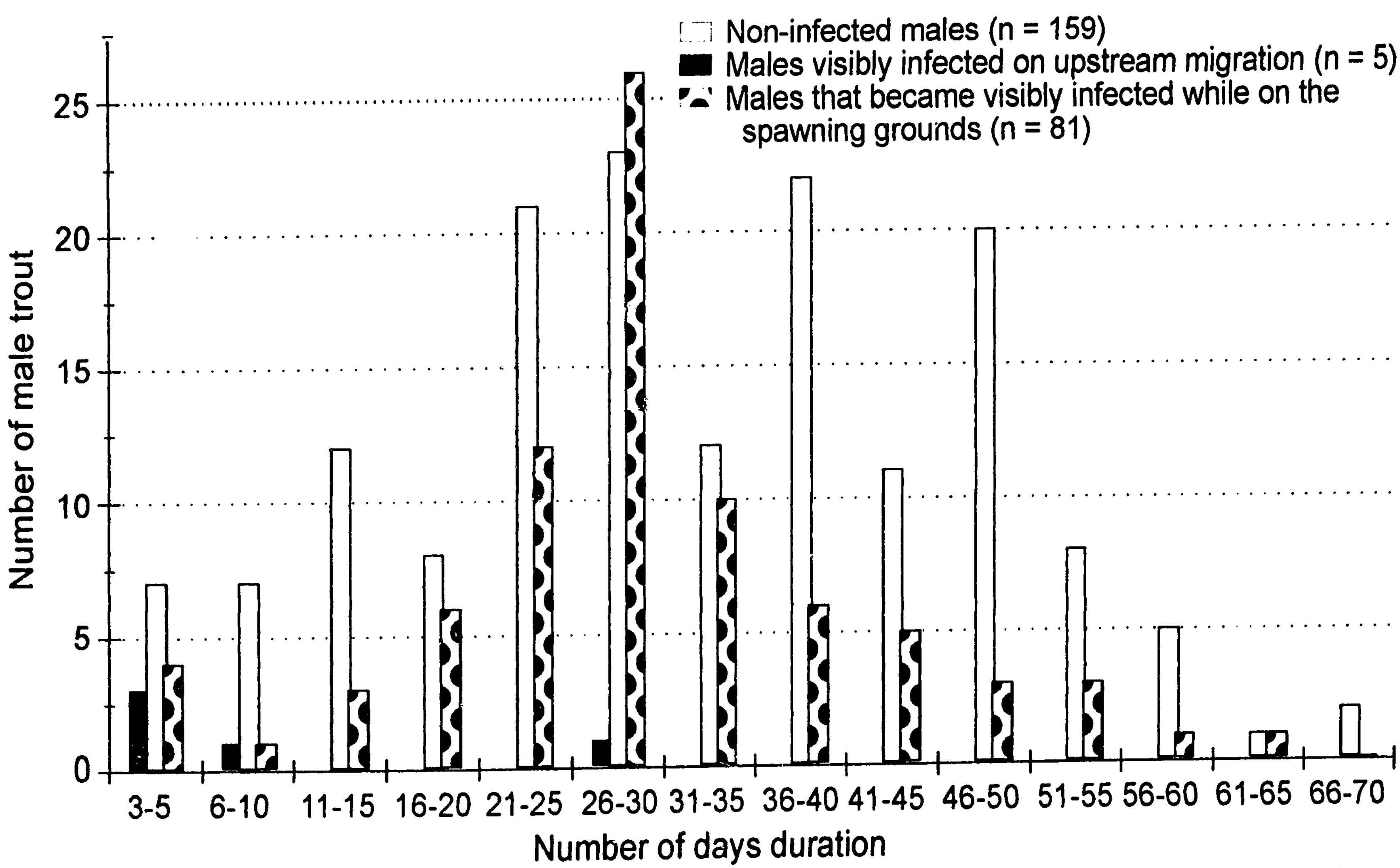

Figure 5.5: Duration of stay on the spawning grounds in Bill Griffiths Creek during 1989 by brown trout visibly infected with *Saprolegnia* when they entered the spawning grounds, that became visibly infected while on the spawning grounds and that were not visibly infected when they left the spawning grounds.

5.5 Discussion

The results indicate that males infected with *Saprolegnia* when they entered the spawning grounds spent less time spawning than males that became infected while on the spawning grounds and than males that were not known to become infected. Although significant differences were not found between the duration of time spent on the spawning grounds between males that became infected while spawning and males that did not become infected, it is possible that infection by *Saprolegnia* reduces the time that males spend on the spawning grounds. However, because the present study did not attempt to determine when individuals contracted the infection while on the spawning grounds, it was not possible to determine how long males spent on the spawning grounds after becoming infected.

The results clearly indicate male brown trout become infected with *Saprolegnia* more frequently than females. These results support earlier findings by White (1975), Richards and Pickering (1978) and Pickering and Christie (1980). The results also indicate that larger males are more susceptible to becoming infected than females.

The influence of increased size may explain why only one brook trout was noticed to be visibly infected with *Saprolegnia*. The average and maximum fork lengths of male brook trout [192.22 cm (unpubl. data) and 293 cm (Section 2.4.1), respectively] and brown trout [400.43 cm (unpubl. data) and 677 cm (Section 2.4.1), respectively] indicate brook trout males were generally substantially shorter than brown trout males.

Infection of brown trout in Bill Griffiths Creek was not limited to ripe individuals. Richards and Pickering (1978) indicated sexual maturity favours the incidence of infection and that males are more susceptible to infection than females. However, they stated the sexual difference was more apparent among ripe fish prior to spawning and may not apply to spent fish. The results from this study confirm sexual differences in the susceptibility of infection were also evident among spent fish leaving Bill Griffiths Creek.

Among iteroparous salmonids, despite a greater cost of gonadal maturation, females frequently experience higher survival rates after spawning than males (Hutton 1925; Jonsson et al. 1990; Le Cren and Kipling 1963). This phenomenon may also be occurring among the brown trout in the Bow River and may be influenced by the higher occurrence of *Saprolegnia* infection among males. Except for three immature fish and one male killed by mergansers, all dead brown trout found in 1989 during redd surveys were infected males. Furthermore, the percentage of female brown trout from 1989 returning to spawn in Bill Griffiths Creek in 1990 was 57.1% compared to 31.1% for males (Section 2.4.2) suggesting that males experience greater mortality rates than females.

Higher rates of infection by *Saprolegnia* among males have been reported by other researchers (White 1975; Richards and Pickering 1978; Pickering and Christie 1980). Male brown trout are also more susceptible to infection by other ectoparasites (Pickering and Christie 1980). It has been suggested that higher rates of infection among males is caused by the abrasions and wounds received during territorial defense of redds (White 1975). However, males experience a decreased concentration of mucous secreting goblet cells in their epidermis as they mature (Stoklosowa 1966; Pickering 1977), which may account for their increased vulnerability.

The external layer of mucous produced by these goblet cells inhibits the establishment of *Saprolegnia* infection by: i) physically removing attached spores as the mucous is continuously renewed (Wood et al. 1988); ii) possessing a morphogen that inhibits mycelium growth without killing the spores (Wood et al. 1988); and iii) containing lymphocytes or neutrophils that attach to the mycelium and lyse it internally (Wood et al. 1986). These methods of control also aid the fish in a continued defense against the fungus after colonies have become established; however, the cellular response of the lymphocytes or neutrophils is less efficient on larger colonies (Willoughby 1989).

Most literature concerning the infection of *Saprolegnia* among salmonids suggests that the infection is generally fatal for the host if left untreated (Hoffman 1969; Willoughby 1971). Frequently the host fish will succumb to death in about three days (Richards and Pickering 1979). However, the results of this study indicate some infected fish survived and returned to spawn the subsequent year. The actual percentages of fish which survived infection were probably higher than shown in Table 5.1, because all surviving fish did not return to Bill Griffiths Creek to spawn in the following spawning season (see Section 4.0) and some brown trout that lost their tag from 1989 returned to spawn in 1990 (see Section 6.0).

Interestingly, several of the fish that survived infection one year became re-infected in the subsequent spawning season. Therefore, after becoming infected once brown trout, or at least some brown trout, may not produce antibodies needed to prevent re-infection. It has been reported such antibodies are produced by Atlantic salmon (Hodkinson and Hunter 1970) but not by rainbow trout (Sohnle and Chusid 1983).

The results indicate handling and tagging brown trout captured on their spawning migration through Bill Griffiths Creek did not correspond with increased rates of infection of *Saprolegnia*. Rather, the number of individuals infected within each "tag-type" was a reflection of the number of individuals within each category. If the stress caused by handling was contributing to increased susceptibility to infection by *Saprolegnia*, then immatures, females, smaller males and especially males captured several times during the same spawning season should have experienced greater rates of infection. This, however, did not occur.

Two possible alternatives may explain why handling had a negligible effect on the subsequent infection of *Saprolegnia*. Either handling did not induce a rise of the plasma cortisol concentration to the level necessary to increase the susceptibility to *Saprolegnia*, or handling induced an increased concentration of mucous secreting cells which inhibited infection. Acute handling stress increases plasma cortisol concentrations (Pickering et al. 1982) which can increase the susceptibility of infection (Pickering and Duston 1983). However, handling also increases the production of mucous secreting epidermal cells (Pickering and Macey 1977; Pickering et al. 1982) which can reduce the susceptibility of infection (Pickering and Christie 1980). Handling benefits may also occur since acute handling stress suppresses the plasma levels of 11-ketotestosterone (Pickering et al. 1987) which may control the structure of the male epidermal structure (Pottinger and Pickering 1985a; Pottinger and Pickering 1985b). Further research is necessary to determine the degree of the physiological effects resulting from handling.

Interestingly, the only noticeable infection on three brown trout captured migrating upstream was on their adipose fin. The adipose fin of these three fish was removed for identification purposes (Section 2.3). When these three fish were recaptured, up to 30 days later, no trace of the infection was recorded (unpubl. data). *Saprolegnia* spp. are commonly implicated as secondary pathogens (Hoffman 1969; Roth 1972; Post 1983), and it is probable that the primary agent causing the original infection on these three fish was still present. Removing infected areas would not have removed their susceptibility to infection. Since they were exposed to other infected individuals on the spawning grounds, then these three fish should have become re-infected especially if handling and tagging was associated with increased susceptibility of infection.

One possibility for the increased number of infected fish in subsequent years may be the slight increase in the number of males captured each year. The increased density of males on the spawning grounds may result in more frequent aggressive acts between adult males. Consequently, spawning males may receive more wounds and abrasions and/or may experience added stress when spawning densities increase.

The present study indicates infection by *Saprolegnia* is strongly influenced by sex and fork length but not by the stress of handling and/or tagging. These results suggest *Saprolegnia* is an opportunistic facultative pathogen infecting individuals whose epidermal structure and physiology are more susceptible to infection. However, while identifying the cultured *Saprolegnia* samples from this study to the genus level, *Lysobacter* sp. were also found in the cultured samples of *Saprolegnia* (T. Cook, pers. comm.). It is possible *Lysobacter* may be the elusive primary agent responsible for subsequent infection by *Saprolegnia* in this system (T., Cook, pers. comm.). *Lysobacter* spp. are gram-negative gliding bacteria noted for the production of extracelluar enzymes which have a role in biodegradation (Christensen and Cook 1978; von Tigerstrom and Boras 1990). However, more research is needed to identify the relationship between *Lysobacter* and infection by *Saprolegnia*.

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6.0 DIFFERENTIAL LOSSES OF FLOY ANCHOR TAGS BETWEEN MALE AND FEMALE BROWN TROUT

6.1 Abstract

Annual losses of floy anchor tags among brown trout, permanently marked by removing the adipose fin, was studied in a population of brown trout returning to spawn in three successive years (1988-1990) in a tributary of the upper Bow River, Alberta. Significant differences were detected in tag losses between males (44.3%) and females (15.0%). No differences were detected in the fork length distributions between brown trout that lost their tags and those brown trout that retained their tags, or between fork length distributions of male and female brown trout that lost their tags. It is speculated that higher tag losses among males was due to biting of tags by other males during conflicts on the spawning grounds.

6.2 Introduction

Fish tagging is frequently employed to gather information concerning fish movements (i.e., Peterson 1896; Armstrong and Blackett 1966) and to make population estimates (i.e., Lawler and Smith 1963; Power and Shooner 1966). The results, however, are only valid if there are either no tag losses, no differential mortality of tagged fish, or these factors are quantifiable. Significant tag losses can occur dependent on the species, size of the fish being studied and the type of tag used (Eschmeyer 1959; Muir 1963; Greenland and Bryan 1974; Kennedy et al. 1982; Dunning et al. 1987). Therefore, it is essential for fisheries researchers to be aware of, and to minimize, problems associated with tag losses.

Floy anchor tags, also known as Dennison tags, are appealing to fisheries researchers for several reasons: i) one person can easily, quickly and uniformly tag fish even with cold, wet hands; ii) the cartridge fed applicator retains the tags in serial order (Thornson 1967; Dell 1968); iii) the implantation of the tag is less of a stressing agent than the capturing and handling of the fish (Cardwell et al. 1971) as the immediate effects of tagging are some bleeding associated with the insertion of the tag and some bruising around the area of insertion (Axford 1974); and, iv) when used on brown trout (*Salmo trutta*) in excess of 18 cm floy anchor tags have been shown to not adversely affect growth or survival rates (O'Grady 1984). Although short and long term effects of using floy anchor tags to mark salmonids are known (Carline and Brynildson 1972; Axford 1974; O'Grady 1984), the limited information available concerning tag losses generally applies to either non-salmonids and/or size related losses (Koshinsky 1972; Greenland and Bryan 1974; Dunning et al. 1987; Waldman et al. 1990). No literature was found reporting different rates of tag losses between sexes.

The present study was initiated while studying the reproductive ecology of brown trout, *Salmo trutta*, in the upper Bow River system, Alberta (Section 2.0). Anchor tags were used to identify individual brown trout during their spawning migration. In order to estimate the ratio of male and female brown trout returning to spawn in subsequent spawning seasons, it was necessary to determine whether tag losses were similar between males and females.

6.3 Methods

A two-way fish trap was used to capture adult brown trout migrating in and out of Bill Griffiths Creek, a tributary of the upper Bow River located near Canmore, Alberta, during the 1988, 1989 and 1990 spawning seasons. Processing fish included tagging all untagged brown trout with individually numbered anchor tags and recording each individual's fork length and sex. The tagging procedure followed Dell (1968); however, fish were not anaesthetized. Processing fish during the 1989 spawning season included removing the adipose fin from all brown trout returning from 1988 with tags, and from all brown trout tagged in 1989 to permit identification of fish that lost their tags. The adipose fin was also removed from all fish tagged for the first time in 1990. Annual tag losses were determined by fish with a clipped adipose fin that returned to spawn in Bill Griffiths Creek in 1990 without a tag from 1989. A detailed description of the procedure used to process fish is described in Section 2.3.

A "chi-square" test of homogeneity of samples (Prepas 1984) determined: whether tag losses were significantly different between sexes; whether males and females which lost their tags had significantly different fork length distributions; and whether there were significant differences in fork length distributions between fish that lost their tags from 1989 and fish that retained their tags.

6.4 Results

Brown trout whose adipose fins were clipped in 1989 that returned to spawn in 1990, did not exhibit noticeable re-growth of the fin. Epidermal tissue appeared to cover the surgical wound and fish with their adipose fin clipped in 1989 were easily distinguished from fish clipped in 1990.

The number of male and female brown trout known to have a clipped adipose fin and anchor tag in 1989 that were re-captured in 1990 on their upstream migration into Bill Griffiths Creek are shown in Table 6.1. Males experienced significantly greater tag losses than females ($P<<0.001$).

Differences in fork length distributions between males and females that lost tags were insignificant ($P = 0.0502$) when only individuals captured on upstream migrations were included (Figure 6.1a). An additional 35 post-spawning brown trout (11 females and 24 males) captured on their exit from the spawning grounds in 1990 also lost their tags; however, some of these 35 fish had lost 1989 tags while others had lost 1990 tags. Differences in fork length distributions between sexes were also insignificant ($P = 0.1007$) when these 35 fish were included with the fish known to have lost their tags when they were captured entering Bill Griffiths Creek.

Differences in fork length distributions (see Figure 6.2) between fish returning to Bill Griffiths Creek that either retained their 1989 tags or lost their 1989 tags were not significant ($P = 0.054$). Therefore, tag losses were not related to the fork length of tagged trout.

Table 6.1: Annual tag losses between male and female brown trout returning to spawn in Bill Griffiths Creek in 1990.

Sex	Number of fish returning in 1990 with a tag and a clipped adipose	Number of fish returning in 1990 without a tag but with a clipped adipose	Percent tag losses
Males	93	74	44.3%
Females	351	62	15.0%

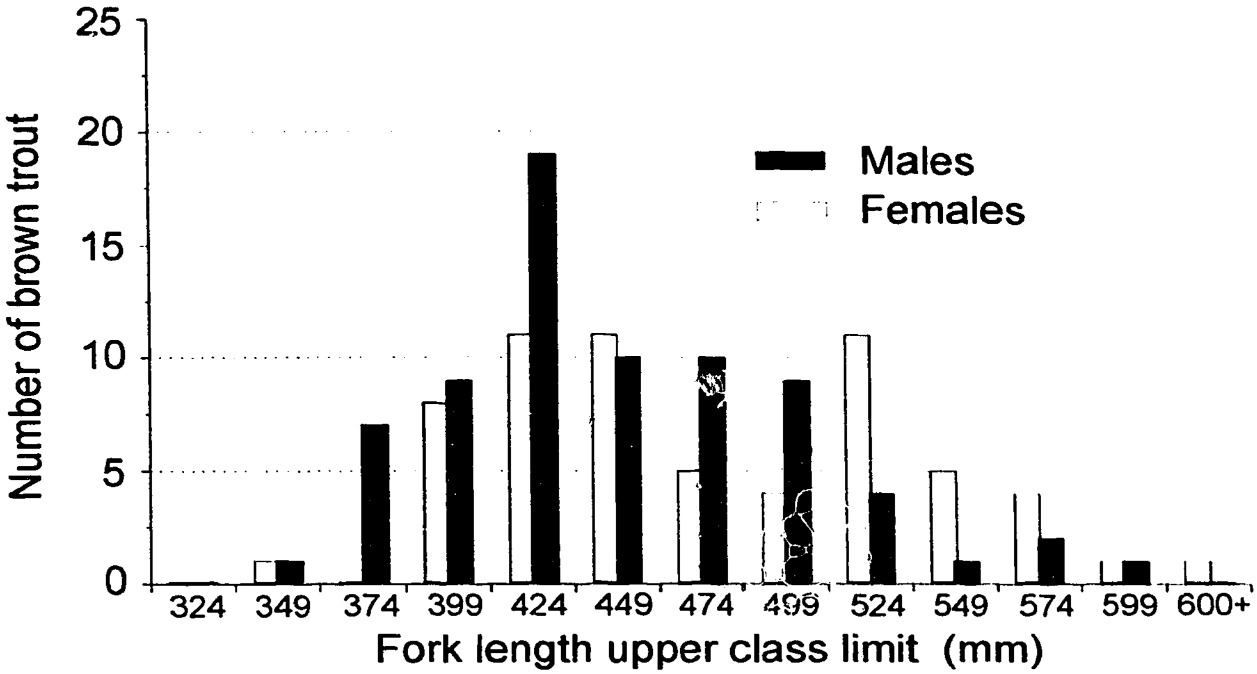

Figure 6.1a: Fork length distributions of male and female brown trout that lost their tags from 1989 before migrating onto the spawning grounds in Bill Griffiths Creek during 1990

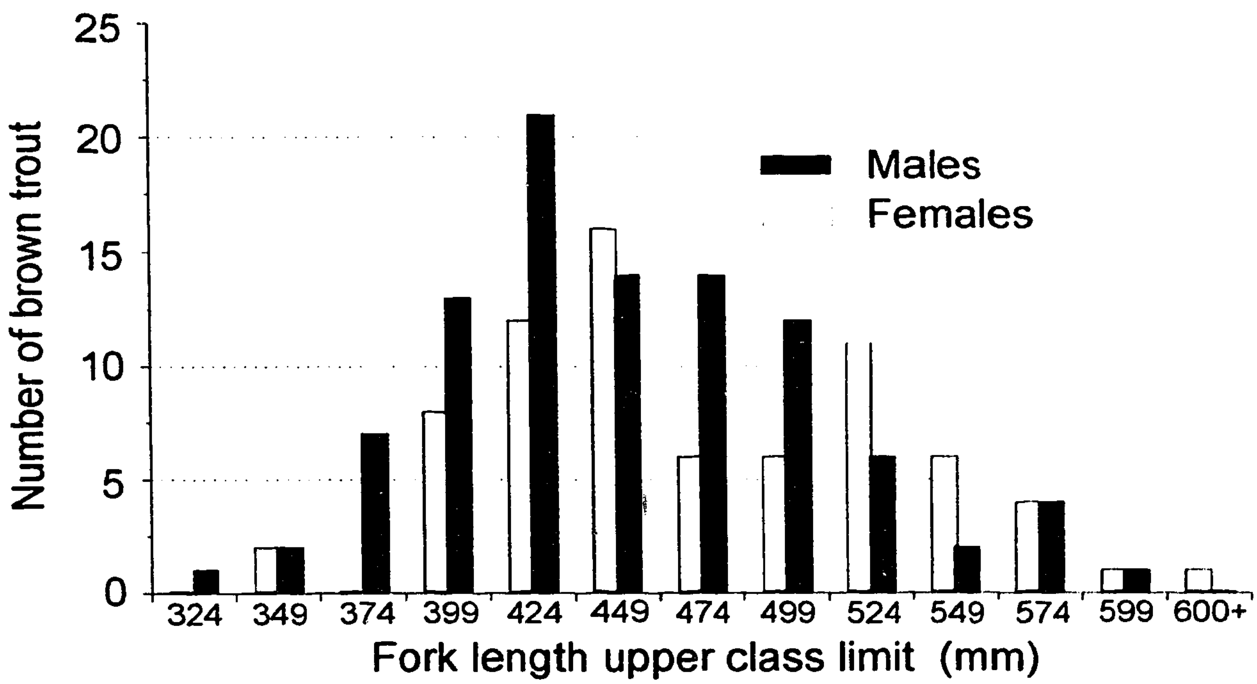

Figure 6.1b: Fork length distributions of male and female brown trout that lost their tags before, and during, the 1990 spawning season.

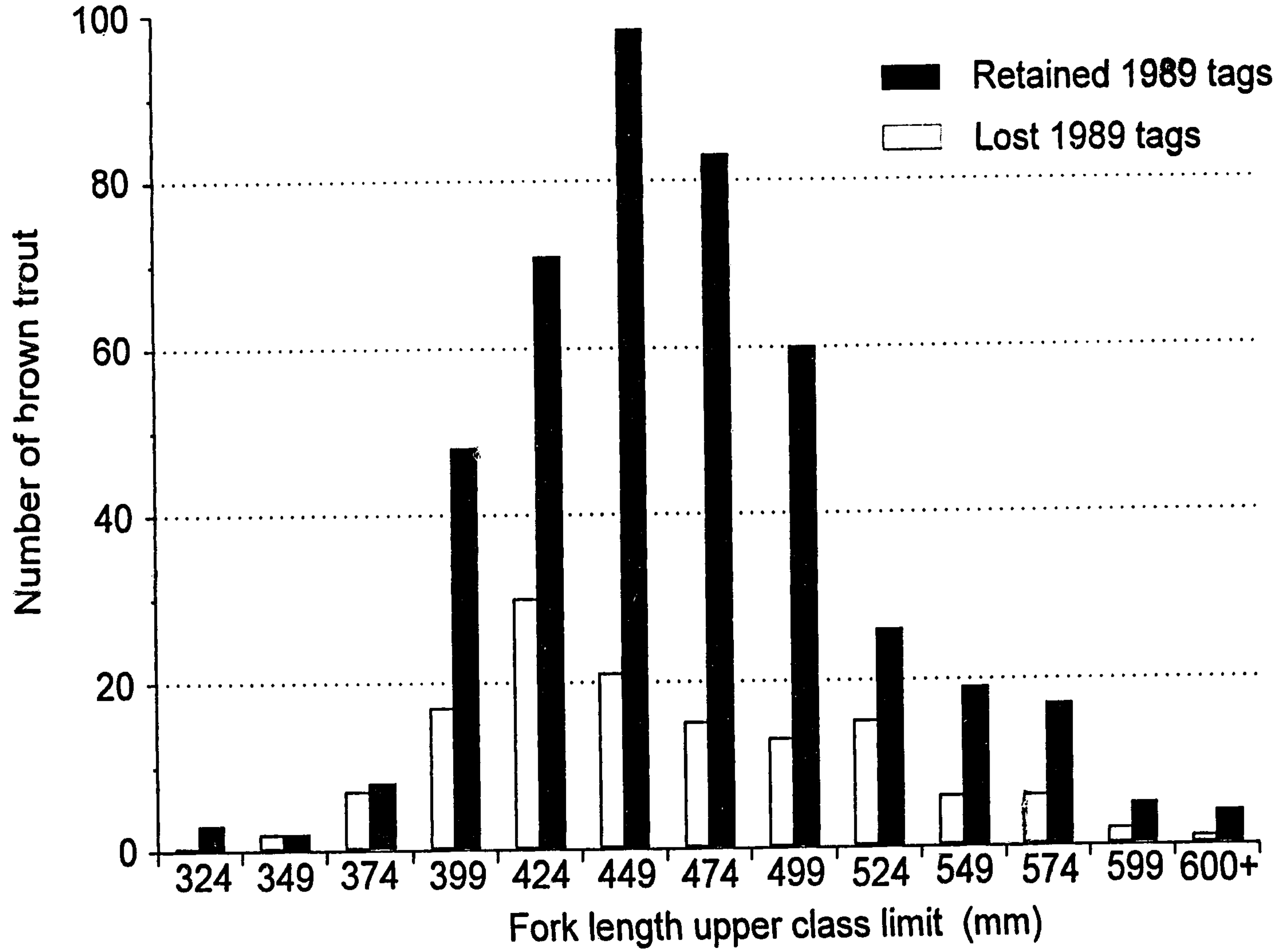

Figure 6.2: Fork length distributions of brown trout that had lost and that had retained their 1989 tags when they returned to spawn in Bill Griffiths Creek in 1990.

6.5 Discussion

The differences in fork length distributions between males and females that lost their tags were insignificant when only fish migrating into the spawning stream were examined, and also when the 35 additional post-spawning fish that lost their tags while spawning were included. The results indicate tag losses were not related to the size of returning brown trout.

The differences in significance levels for fork length distributions between sexes that occurred when fish that lost their tags while on the spawning grounds were included in the analysis may be attributed to high mortality rates among large males. Large males are more susceptible to infection by *Saprolegnia* (Section 5.0). Because infection generally causes death (Willoughby 1971), relatively few large males return to spawn. The addition of post-spawning fish migrating from the spawning grounds in 1990 insured some large infected males were included in the analysis.

Aggressive interactions between males, common during spawning (Greeley 1932; Stuart 1953; Jones and Ball 1954), may explain why males experienced higher tag losses than females. Tagging fish can result in increased predation rates (Lawler and Smith 1963; Armstrong and Blackett 1966). Seagulls have been observed to pick tagged white suckers (*Catostomus commersoni*) and longnose suckers (*C. catostomus*) from the water by their anchor tags (J. Stelfox, Alberta Fish and Wildlife Division, pers. comm.). During conflicts between males on the spawning grounds, a dangling anchor tag may act as a target and may be bitten by other males. If the tag is not completely pulled out, it may become sufficiently loosened so that it eventually falls out.

Anchor tags are useful in fisheries research but this study demonstrates differences in tag losses can be sexually related and must be taken into consideration when sexual differences within a population are being examined.

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7.0 SEXUAL DIMORPHISM IN THE ADIPOSE FIN OF BROWN TROUT

7.1 Abstract

Mature male brown trout, *Salmo trutta*, from two populations in the Bow River drainage, Alberta, were found to have a larger adipose fin (as a function of fork length) than females. The sexual dimorphism was evident during spawning (October - December) at fork lengths greater than approximately 200 mm. However, several months prior to spawning (August) the sexual dimorphism became evident only in specimens over approximately 300 mm. These results indicate the adipose fin can be used to determine the sex of brown trout throughout the year. When used in association with the sexual dimorphism of the anal fin (Gruchy and Vladykov 1968), this information can be used to give a reasonably reliable technique to sex brown trout.

7.2 Introduction

Several sexual dimorphisms are known for brown trout, *Salmo trutta*. Peri-spawning males are often identified by the presence of a kype (an anterior, upwards protrusion of the elongated lower jaw) (Morton 1965). Males also develop distinguishing spawning colours. A sexual dimorphism of the shape of the anal fin is present throughout the year (Gruchy and Vladykov 1968). Although sexual dimorphisms in the epidermis of spawning brown trout (Stoklosowa 1970; Pickering 1977) do not allow the sex of an individual to be determined, they correspond with increased incidence and severity of infestation by ectoparasites among males (Pickering and Christie 1980).

Morphology of the adipose fin has several characteristics that can be used for external sexual identification. Differences in the shape of this fin have been used to sex Atlantic salmon (*Salmo salar*) (Naesje et al. 1988), bull trout (*Salvelinus confluentus*) (McPhail and Murray 1979) and five species of *Oncorhynchus*: pink (*O. gorbuscha*), chinook (*O. tshawytscha*), chum (*O. keta*), coho (*O. kisutch*) and sockeye salmon (*O. nerka*) (Beacham and Murray 1983, 1986). The adipose fin can be used to accurately sex Atlantic salmon during spawning and several months prior to spawning (June and July) (Naesje et al. 1988). However, adipose fin morphology does not permit sexual identification among immature individuals of *Oncorhynchus* spp. (Beacham and Murray 1986). Specimens of bull trout and Dolly Varden (*S. malma*) during the summer also do not possess a sexually dimorphic adipose fin (Haas and McPhail 1991; G. Haas, Department of Zoology, University of British Columbia, personal communication).

Fishery managers and hatchery operators working with brown trout would find it useful to be able to correctly sex individuals. Although the sexual dimorphism of the anal fin is evident throughout the year (Gruchy and Vladykov 1968), correct identification of the sex of brown trout by external characteristics is often difficult during non-spawning periods. This paper describes a new method of using the adipose fin to externally sex brown trout. This method became evident while removing the adipose fin of spawning brown trout for marking purposes. The method was subsequently tested in an adjacent population several months prior to the spawning season.

7.3 Methods

Measurements were taken from 121 male and 169 female brown trout from a spawning population on their migration in Bill Griffiths Creek, during 1989 and 1990, and in a population of brown trout in Barrier Reservoir, Kananaskis River system, three months prior to their spawning season. Bill Griffiths Creek and the Kananaskis River are tributaries of the upper Bow River, Alberta. Populations of brown trout in both systems resulted from a single introduction in 1925 (Nelson and Paetz 1992). The populations became isolated after construction of the dam and filling of Barrier Reservoir in 1947 (Nelson 1965).

A two-way fish trap was used to capture the spawning migrations of brown trout in and out of Bill Griffiths Creek in 1989 and 1990 (see Section 2.0). All mature brown trout were sexed externally using the presence or absence of a kype on the lower jaw. The expulsion of gametes was used to confirm sexual identity and determine the sexual condition of each fish. The fork length of each fish was recorded to the nearest 1.0 mm. After processing, fish were released to continue their spawning migration.

The adipose fin was removed for marking purposes by clipping the entire fin along its base with scissors. The shortest length of the adipose, from the posterior base (insertion) to the posterior tip (Figure 7.1), was measured to the nearest 0.5 mm using vernier callipers with the adipose fin placed on a flat surface. These two locations on the fin were easily identified, were not damaged during fin removal when the cut was made below the posterior base, and provided the most consistent and reliable measurement.

The Barrier Reservoir population was sampled August 21, 1990 with test nets set by Alberta Fish and Wildlife Division. The nets were pulled after 24 h and the fish were placed immediately on ice. All fish were processed on the same day of collection. Fork lengths were recorded to the nearest 1.0 mm, and the sex of each fish was confirmed by an examination of the gonads. The adipose fin was removed with scissors in a manner similar to the live brown trout captured in Bill Griffiths Creek.

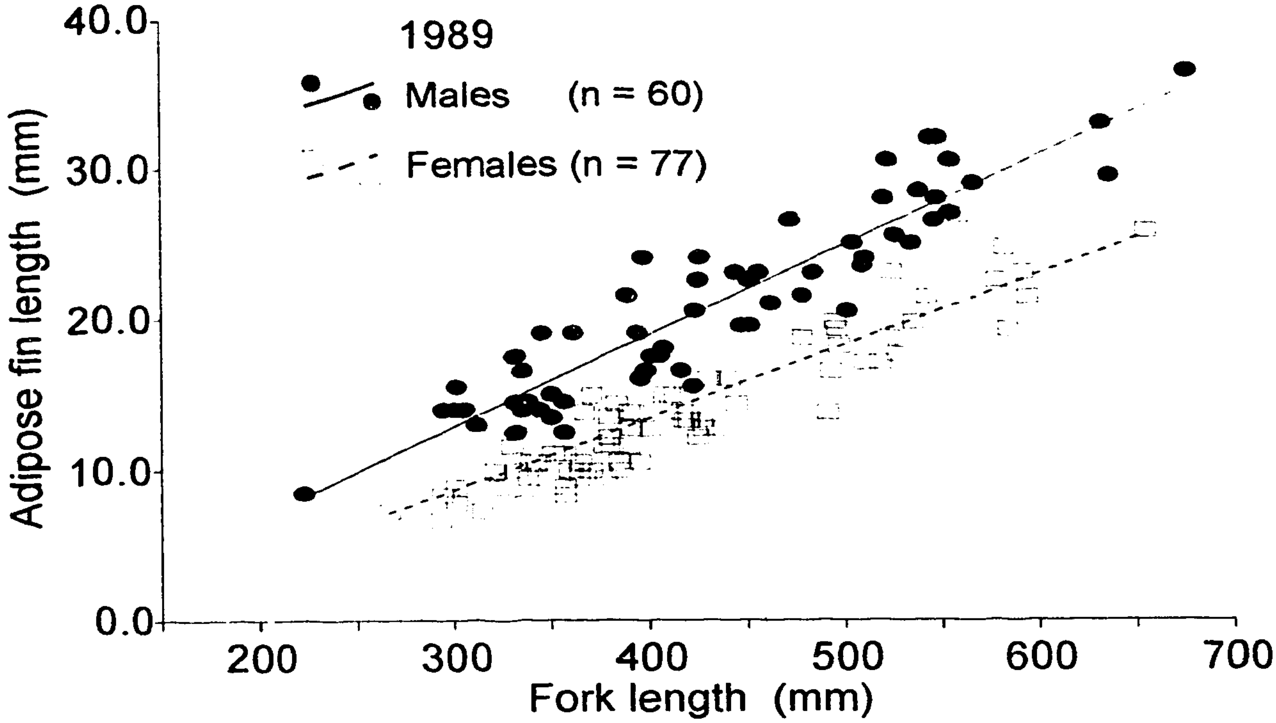
The measurement of the adipose fin, described as the shortest length of the adipose fin, was related to the fork lengths of individuals sampled from each population. An analysis of covariance (ANCOVA) was used to determine whether statistical differences existed in the fork length-adipose fin relationship between sexes for each population.

Figure 7.1: Illustration showing the "shortest length of the adipose fin".

7.4 Results

The fork length-shortest adipose fin length relationships for adult brown trout captured in Bill Griffiths Creek during the 1989 and 1990 spawning seasons are shown in Figure 7.2. The ANCOVA detected significant differences in the residual variances between sexes in 1989 and 1990 ($P<<0.001$ and $0.05>P>0.025$, respectively). Males during both spawning seasons had statistically larger adipose fins than females. Extrapolations of the regressions for brown trout from Bill Griffiths Creek suggest that size differences in the adipose fin become detectable at fork lengths of approximately 200 mm.

The fork length-shortest adipose fin length relationship between non-spawning male and female brown trout from Barrier Reservoir is shown in Figure 7.3. Three months prior to the onset of the spawning season, males were found to have a larger adipose fin than females. The ANCOVA determined differences did not exist between residual variances ($0.75>P>0.50$), but significant differences were detected between the slopes of the regressions ($0.05>P>0.02$). The intersection of the regression lines between sexes from Barrier Reservoir indicated that differences in the reservoir were not detectable until brown trout reached a fork length of approximately 300 mm as opposed to 200 mm in Bill Griffiths Creek.



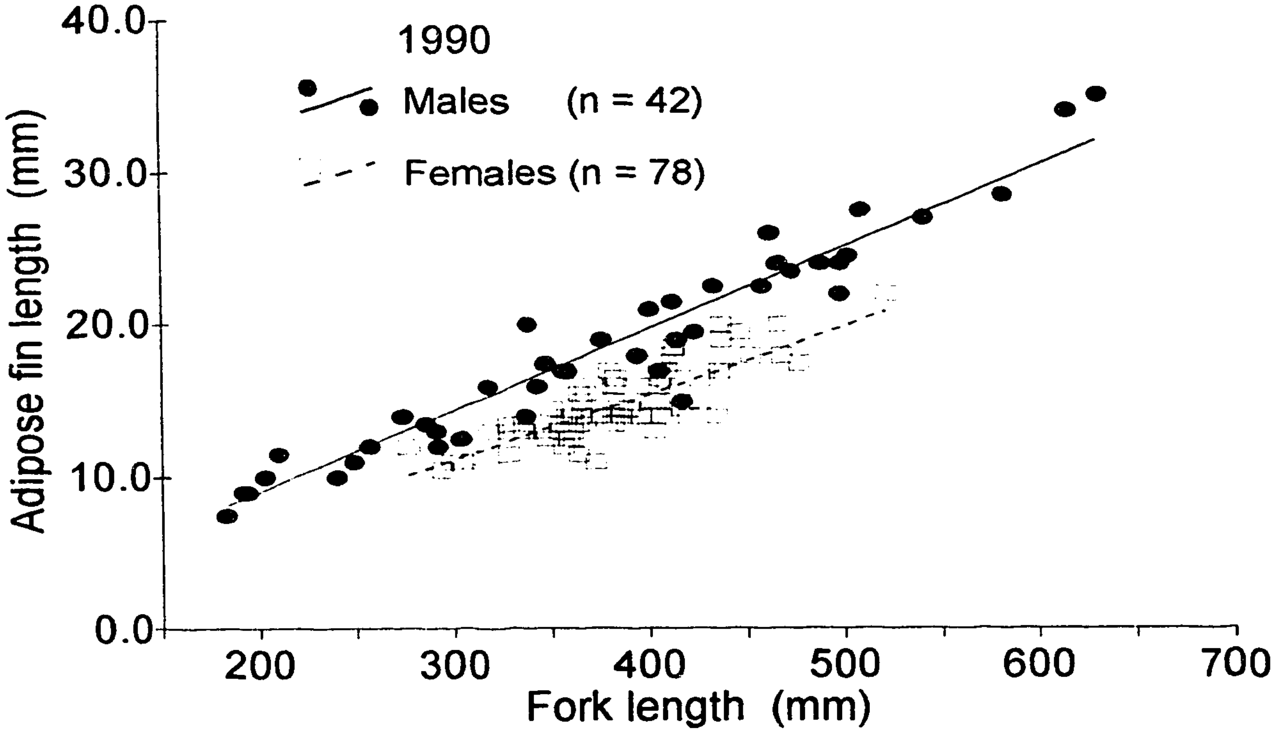


Figure 7.2: Linear regressions of fork length and "shortest length of the adipose fin" for both sexes of brown trout spawning in Bill Griffiths Creek during 1989 and 1990.

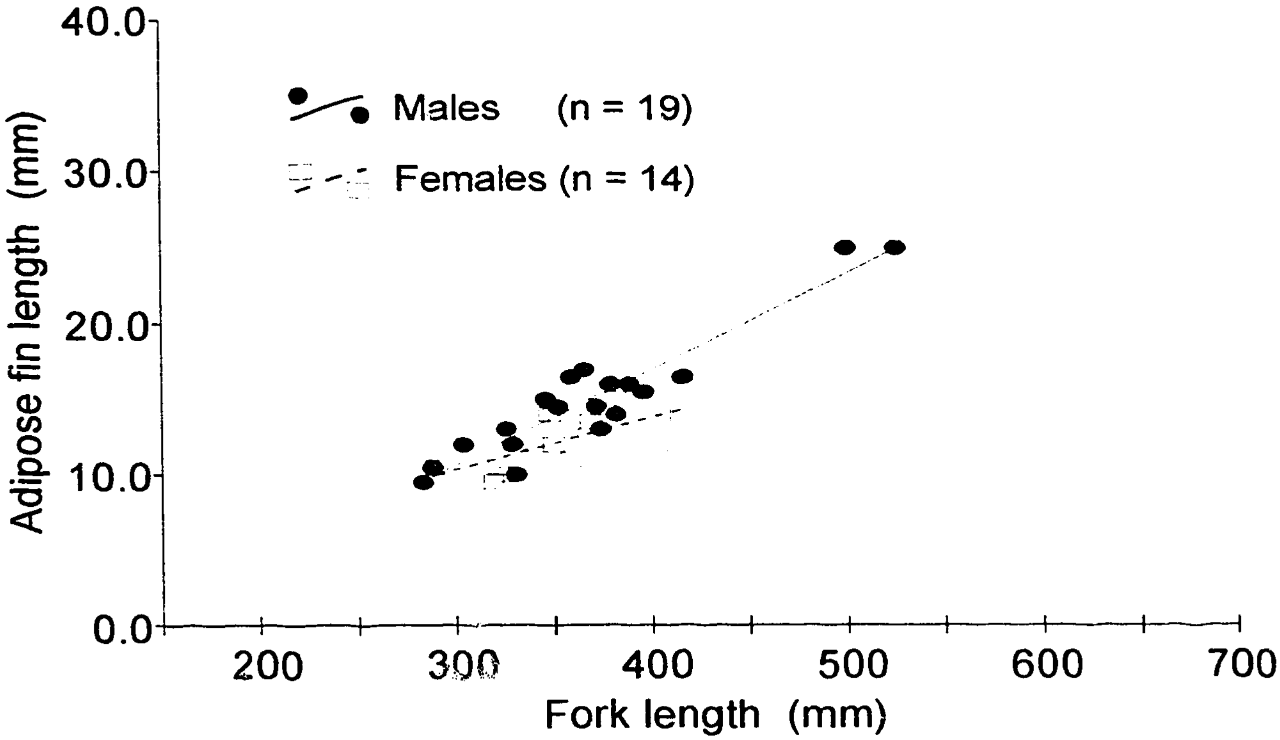


Figure 7.3: Linear regressions of fork length and "shortest length of the adipose fin" for both sexes of brown trout sampled from Barrier Reservoir.

7.5 Discussion

The results indicate that male brown trout have a larger adipose fin than females and that the differences are evident even during non-spawning periods. Similar results have been reported for Atlantic salmon (Naesje et al. 1988).

Beacham and Murray (1986) reported five species of Pacific salmon could be sexed using the adipose fin. However, their method was not successful for sexing immature individuals. They concluded that the larger adipose fin among male Pacific salmon is dependent upon sexual maturity.

Maturity probably also influences this dimorphism among brown trout. Males generally mature a year earlier than females (Alm 1959; Jonsson 1977). Concurrent research conducted in 1989 and 1990 indicated that males with fork lengths of 160-169 mm were sexually mature (Section 2.4). Consequently, the sexual dimorphism may become evident after males reach sexual maturity.

There are three possible explanations for the apparent differences in size of fish that the dimorphism of the adipose fin became evident. Genetic differences may exist between the two populations. However, both populations are the result of a single introduction and have only been isolated for about 50 years (Nelson 1965). Secondly, the smaller sample size from Barrier Reservoir may not have accurately represented the population and the absence of females with longer fork lengths may have distorted the regression relationships. Thirdly, similar to Pacific salmon (Beacham and Murray 1986), the size of the adipose fin of brown trout may be influenced by sexual maturity. Naesje et al. (1988) reported the relative size of the adipose fin of male Atlantic salmon increased during the summer as the spawning season approached. Because male brown trout captured in Barrier Reservoir were sampled several months prior to spawning, their adipose fins likely had not reached their full size.

It may be possible to identify the sex of shorter individuals if a more precise measurement of the surface area or volume of the adipose fin was made. The measurements used by Beacham and Murray (1983, 1986) and the present study may not accurately reflect the overall size of the fin. For example, the actual size or volume of the adipose fin may also be related to its depth, width and/or external shape.

This study revealed that brown trout possess a sexually dimorphic adipose fin. The information may be useful in culling brood stock to reduce maintenance costs related to injury and disease in hatcheries. Male brown trout become aggressive to other males during spawning (Greeley 1932; Stuart 1953). Consequently, identifying and removing males before they become ripe and injure others could decrease the frequency of injuries. Outbreaks of infection of *Saprolegnia* can also cause problems in hatcheries (Scott and O'Bier 1962; Richards and Pickering 1978; Roberts and Shepard 1979). Since brown trout males are more susceptible to infection (White 1975; Richards and Pickering 1978; Pickering and Christie 1980; this thesis, Section 5.4), it may be desirable to isolate or remove them under some circumstances.

Although knowledge of the size of the adipose fin does not guarantee error-free identification of the sex of an individual, familiarity with the sexual dimorphism of both the adipose and anal fins (Gruchy and Vladykov 1968) may allow reasonable separation of the sexes. If size of the adipose fin of male brown trout becomes more pronounced during spawning, as has been described for Atlantic salmon (Naesje et al. 1988), then the accuracy of identifying the sex on an individual using only the adipose fin would change according to the time of year. Further research is needed to determine when the dimorphism becomes apparent, whether additional measurements would permit greater accuracy in sexing fish, and the factors that influence the appearance of the sexual dimorphism.

Fishery managers should establish the relationship between adipose fin length and fork length in their brown trout populations in order to sex unknown individuals. Although the adipose fin alone cannot be used to sex all individuals, increased confidence may be obtained by using the technique in conjunction with differences between sexes in the distal end of the anal fin as described by Gruchy and Vladykov (1968).

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8.0 SUMMARY

Effective management of a sportfishery is dependent on informed decisions by fishery managers. To make such decisions, fishery managers must be familiar with the relevant scientific literature. They must also have sufficient baseline information on the fishery resources that they manage.

The present study provides fishery managers responsible for the upper Bow River system with important information on the local brown trout and brook trout sportfisheries (e.g., timing of spawning; percentage of adults surviving to spawn in successive years; and location and number of redds). It also provides information that can benefit fishery managers and researchers from other areas. For example, the research examined: 1) the reliability of redd counts to monitor population trends; 2) the trade-offs associated with different life history strategies practised by brown trout females; 3) the effects of handling and tagging on the incidence of *Saprolegnia* infection among spawning brown trout; 4) differential annual losses of floy anchor tags between male and female brown trout; and 5) the sexual dimorphism of the adipose fin among brown trout. The results from this research will be useful to fishery biologists studying brown trout, and to some extent other salmonids, throughout their range.

8.1 Redd surveys

Bill Griffiths Creek was thought to provide habitat to the largest brown trout spawning population in the upper Bow River system (J. Stelfox, pers. comm., Alberta Fish and Wildlife Division). Redd surveys conducted as part of this study confirmed that it is the most important known spawning stream in the system.

Although redd counts have been used to monitor population trends and assess the spawning activity of most salmonids (e.g., brown trout - Hobbs 1937, Benson 1953, Heggberget et al. 1986, Beard and Carline 1991; bull trout - Fraley et al. 1981; chinook salmon - Bjornn 1978; sockeye salmon - Eicher 1953; Atlantic salmon - Heggberget et al. 1986), documentation indicating the reliability of redd counts in monitoring population trends is limited. The redd surveys conducted on Bill Griffiths Creek and other brown trout spawning streams in the upper Bow River system were found to be a reliable indicator with which to monitor population trends and to assess spawning activity.

8.2 Migratory patterns and demographics

Of the three fall spawning salmonid species known to select groundfed tributaries of the upper Bow River system to spawn, brown trout was the dominant species migrating into Bill Griffiths Creek. Spawning brook trout migrating into Bill Griffiths Creek were smaller both in terms of number and average fork length. Although abundant groundwater upwellings in the creek likely also provide optimum spawning conditions for bull trout, no spawning bull trout were captured. These results suggest it is unlikely that a self-sustaining population of bull trout still exists in the upper Bow River system between Bow Falls and the Seebe dam. Of these three fall spawning species, only bull trout are native to the area.

The patterns associated with the spawning migrations of brown trout in the upper Bow River system were similar to other published results (e.g., Stuart 1953, 1957; Munro and Balmain 1956; Libosvarsky 1967; 1974, 1976; Campbell 1977; Scholl et. al 1984; Davies and Sloane 1987; Harvey 1991). For example, males generally migrated into Bill Griffiths Creek earlier and stayed longer than females. The size of individuals (i.e., fork length) did not affect the timing of the upstream migration for either sex. Shorter males frequently spent less time on the spawning grounds than larger males.

The percent of spawning brown trout surviving to return to spawn in Bill Griffiths Creek in successive years was high in relation to published values from other spawning brown trout populations (Munro and Balmain 1956; Stuart 1957; Tilzey 1977; Scholl et al. 1984; Davies and Sloane 1987; Harvey 1991). Among the male and female brown trout that spawned in Bill Griffiths Creek during 1989, 31.1% and 57.1%, respectively, returned to spawn in 1990.

Greater natural mortalities among males have been previously reported for several post-spawning brown trout populations (Alm 1950; Munro and Balmain 1956; Davies and Sloane 1987; Maisse et al. 1987; Maisse and Bagliniere 1990). The lower percentage of male brown trout returning to spawn in successive years in Bill Griffiths Creek suggests males in the upper Bow River system also experience higher post-spawning mortalities than females.

Male brown trout experienced greater post-spawning mortalities than females, but males returning to spawn in successive years experienced significantly greater annual growth rates than females. Differences in growth rates suggest that although males experience greater post-spawning mortalities, surviving females experience greater energetic costs associated with reproduction than surviving males.

8.3 Trade-offs associated with alternate year spawning

Among repeat spawning females in the upper Bow River system, no significant differences were detected in growth rates from 1988 to 1990 between biennial and annual spawners. Furthermore, no differences, as a function of fork length, were detected in pre-spawning weights, or weight losses during spawning, between biennial and annual spawning females. Therefore, although annual spawners allocate more energy towards reproduction than biennial spawners, the results from the indirect measurements suggest that when they do spawn, biennial spawners do not experience greater fecundity than cohorts that spawn annually. Among the measured parameters, the only differences detected between annual and biennial spawners were lower post-spawning weights, as a function of fork length, by biennial spawners. Lower post-spawning weights suggest biennial spawners are physiologically stressed after spawning and may forfeit spawning in consecutive years to increase their own chances of survival.

Relatively little literature exists on trade-offs associated with different life history strategies, especially for iteroparous fish practising annual versus biennial reproductive strategies. The results from indirect measurements used to examine the trade-offs associated between different life-history strategies practised by brown trout in the upper Bow River system suggest that more examination of these alternative life-histories strategies is warranted.

8.4 *Saprolegnia* infection among spawning brown trout

One of the factors contributing to higher post-spawning mortalities among male brown trout in the upper Bow River system appears to be infection by *Saprolegnia*. Most literature concerning the infection of *Saprolegnia* among salmonids suggests that if left untreated, the infection is generally fatal (Hoffman 1969; Willoughby 1971). Frequently, the host fish succumbs to death in about three days (Richards and Pickering 1979). Similar to previous studies (White 1975; Richards and Pickering 1978; Pickering and Christie 1980), brown trout males in the upper Bow River system during spawning were more susceptible to infection by this secondary fungal pathogen than females.

Males may be more susceptible than females because of a sexual dimorphism in the skin of brown trout whereby peri-spawning males possess fewer mucous secreting goblet cells in their epidermis (Stoklosowa 1966; Pickering 1977). Consequently, males have a reduced layer of mucous over their epidermis than females. Evidence suggests that mucous inhibits the colonization of *Saprolegnia* on brown trout (Wood et al. 1986).

Saprolegniasis on salmonids may be stress related (Neish 1977) as are other diseases caused by opportunistic facultative parasites (Wedemeyer 1970; Wedemeyer and Wood 1974; Snieszko 1974). Handling and/or tagging fish during spawning may increase the stress they experience. Consequently, if fishery workers need to capture, handle and/or tag brown trout during spawning, it is important to determine whether such activities may increase the susceptibility of infection among captured trout. Handling and tagging during spawning did not influence the susceptibility of infection by *Saprolegnia* among those brown trout in the upper Bow River system that were found most susceptible to infection by *Saprolegnia* (i.e., large males).

8.5 Differences in tag losses between sexes

Marking fish with tags is a method frequently used by fishery workers to monitor seasonal movements and to facilitate estimates of annual survival and mortality rates. To accurately determine survival rates, it is essential to quantify tag losses among the original population. Tag losses can occur depending on the species, size of the fish being studied and the type of tag used (Eschmeyer 1959; Muir 1963; Greenland and Bryan 1974; Kennedy et al. 1982; Dunning et al. 1987). However, the limited information available concerning tag losses generally applies to either non-salmonids and/or size related losses (Koshinsky 1972; Greenland and Bryan 1974; Dunning et al. 1987; Waldman et al. 1990). No information was known to exist reporting differential tag losses between sexes.

Annual rates of tag losses among brown trout males were nearly three-fold greater than among females returning to spawn in Bill Griffiths Creek during successive years. One of the suspected causes of higher tag losses among males was the aggressive behaviour between males while on the spawning grounds. It is speculated that the dangling anchor tag may act as a target and may be bitten by other males during conflicts on the spawning grounds. If the tag is not completely pulled out when bitten, it may become sufficiently loosened and eventually fall out.

8.6 Sexual dimorphism in adipose fin

While clipping the adipose fin of spawning brown trout to provide a permanent mark that would identify fish which lost their tag, it became apparent that spawning brown trout males have a larger adipose fin, as a function of fork length, than females. The dimorphism was also evident in an adjacent population in August several months before the spawning season began. Although this sexual dimorphism had been documented among other salmonid species (*Salmo salar* - Naesje et al. 1988; *Salvelinus confluentus* - McPhail and Murray 1979; and *Oncorhynchus gorbuscha*, *O. tshawytscha*, *O. keta*, *O. kisutch* and *O. nerka* - Beacham and Murray 1983, 1986), it had not been previously described for brown trout.

Differences in the adipose fin between sexes may provide a useful method to sex brown trout during non-spawning periods when used in combination with a sexual dimorphism of the anal fin described by Gruchy and Vladykov (1968).

8.7 Literature cited

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APPENDIX I

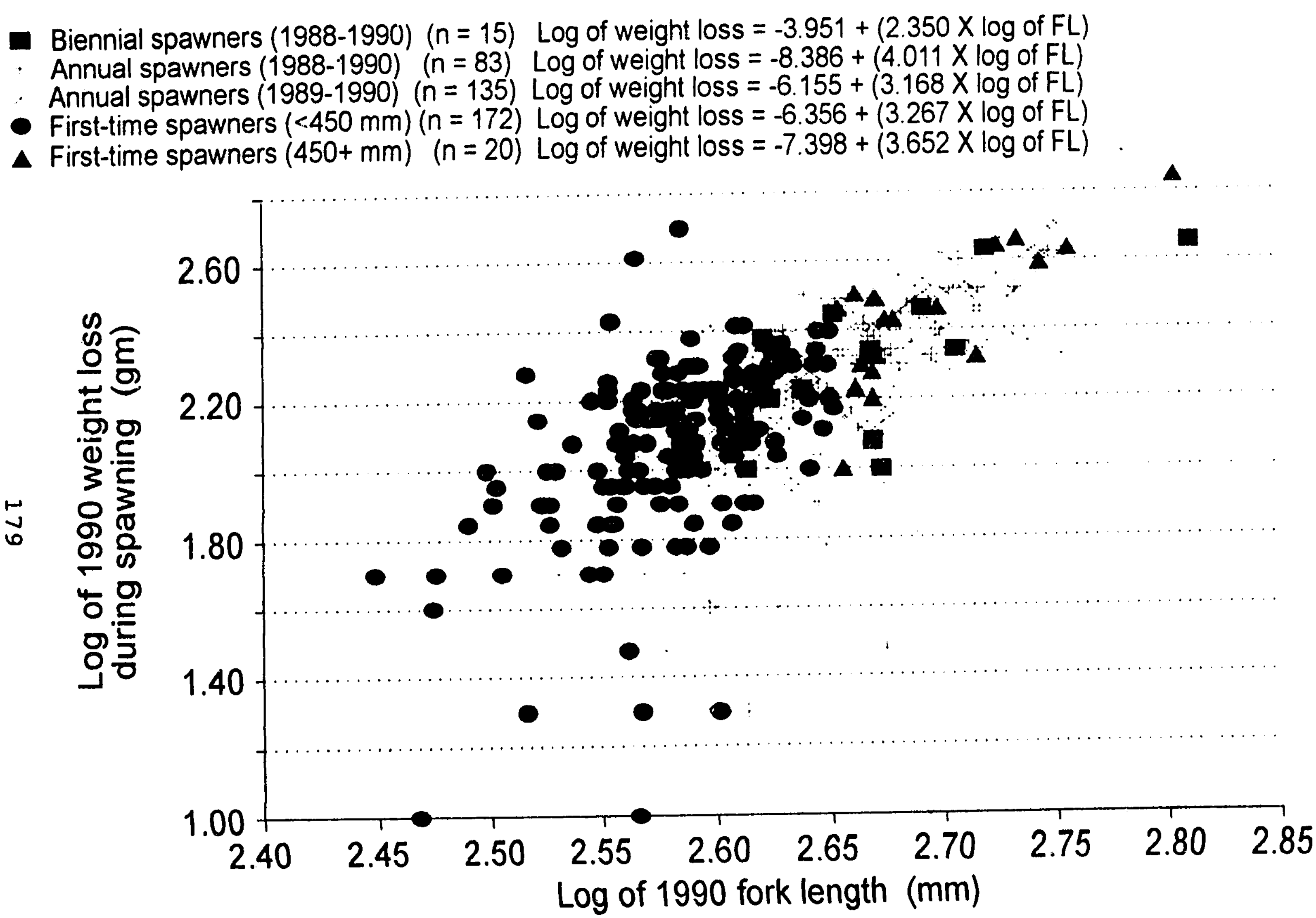

Figure AI-1: Comparison of plotted data points illustrating the relationship of fork length and weight loss during spawning between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.

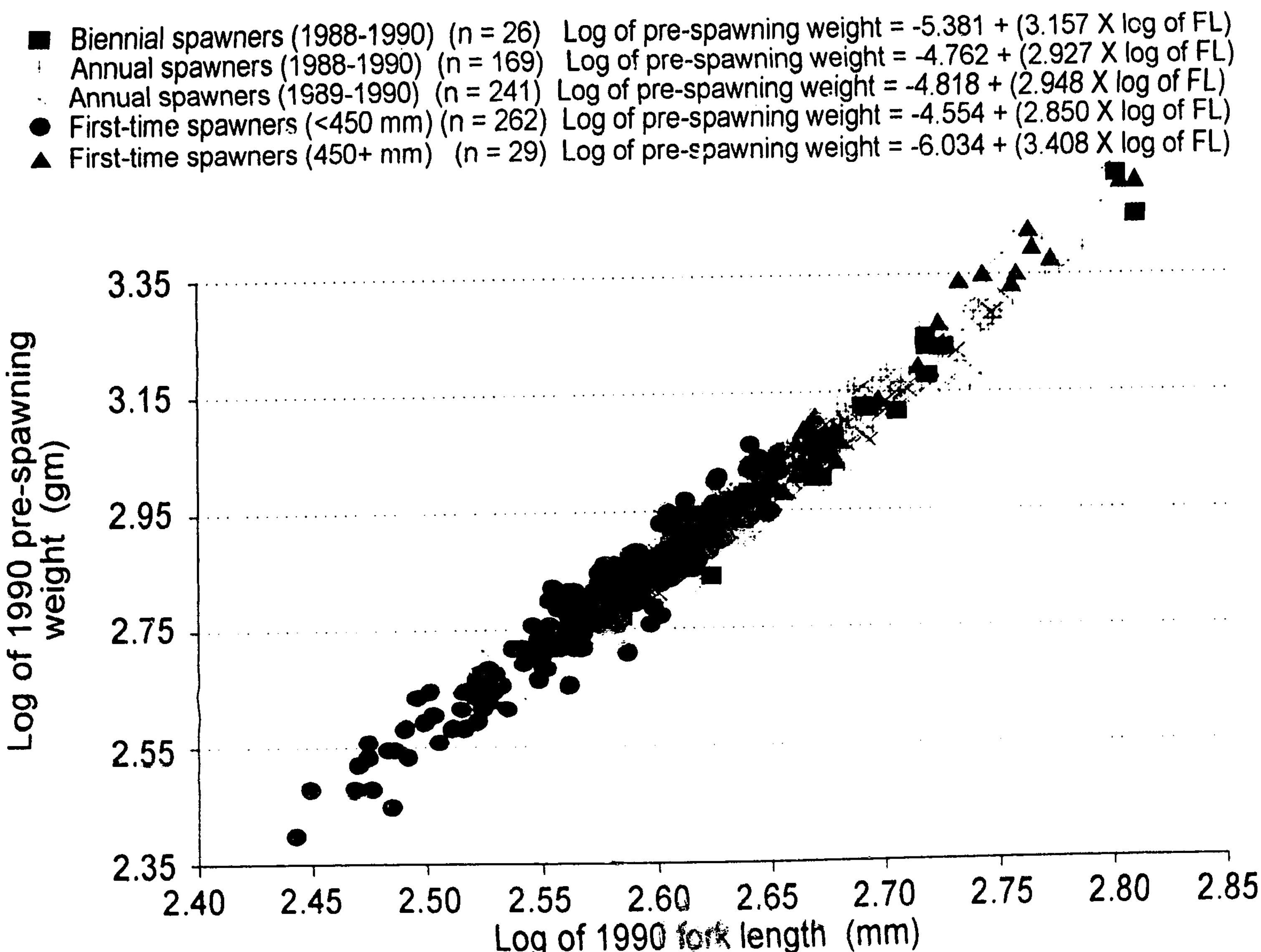

Figure AI-2: Comparison of plotted data points illustrating the relationship of fork length and pre-spawning weight between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.

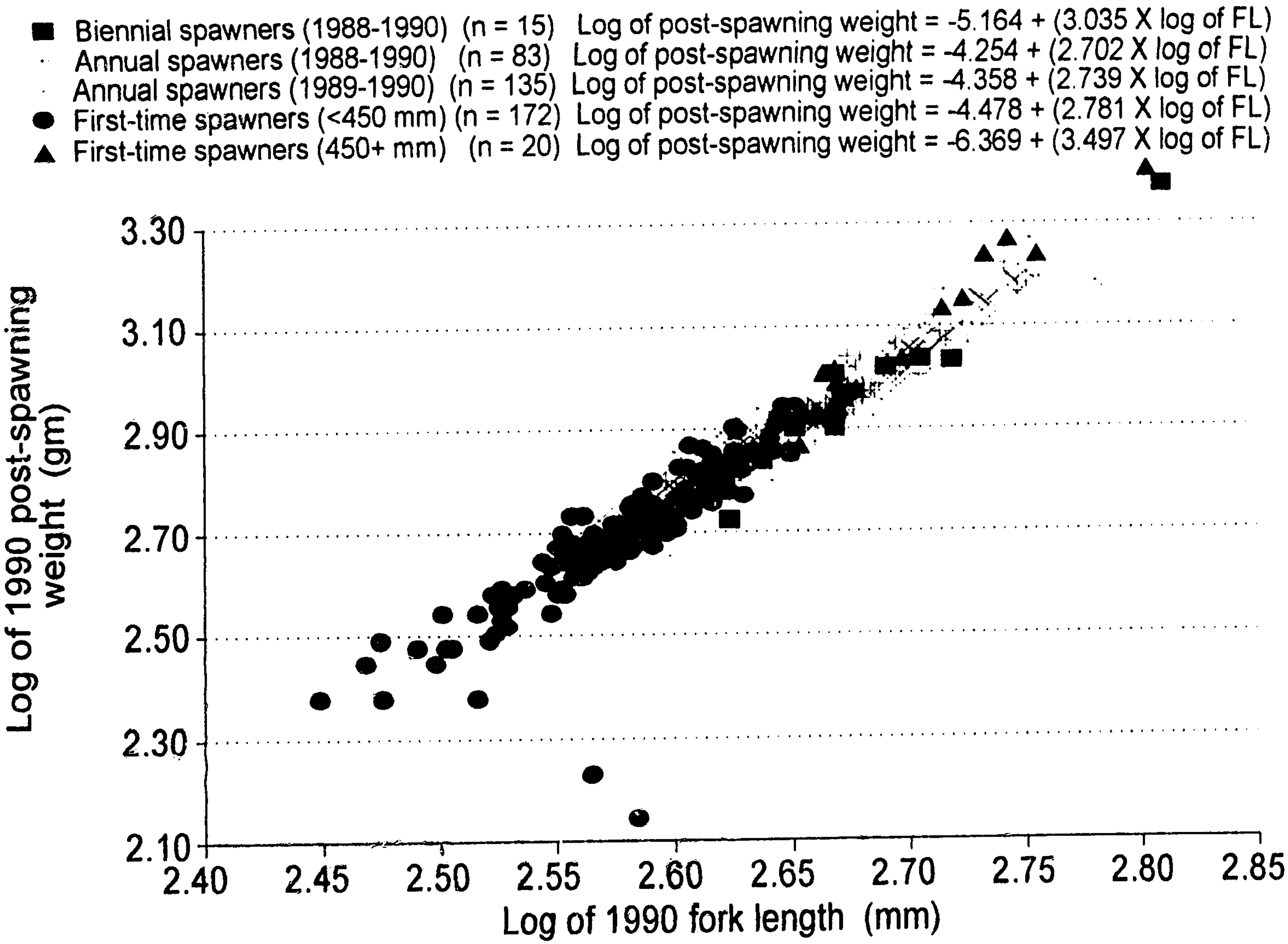

Figure AI-3: Comparison of plotted data points illustrating the relationship of fork length and post-spawning weight between five groups of female brown trout spawning in Bill Griffiths Creek during 1990.