A Population Study of Westslope Cutthroat Trout (Oncorhynchus clarki lewisi) in Marvel Lake, Banff National Park, with Implications for Management

by Jenny Earle

A Master's Degree Project submitted to the Faculty of Environmental Design in partial fulfillment of the requirements for the degree of Master of Environmental Design (Environmental Science)

University of Calgary
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A Population Study of Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) in Marvel Lake, Banff National Park, with Implications for Management

by Jenny Earle

June, 1995

In partial fulfillment of the requirements for the degree of Master of Environmental Design (Environmental Science) in the Faculty of Environmental Design, University of Calgary at Calgary, Alberta

Supervisor: Dr. Stephen Herrero

ABSTRACT

A population and management study of the westslope cutthroat trout in Marvel Lake, Banff National Park, was conducted. Information was collected on the population including: a population estimate, growth rates, diet and age structure. Population estimates ranged between 263 and 3435 adults, with a mean estimate of 1700 fish. A spawning survey consisted of a redd count and an estimate of the number and length of spawning fish. Redd counts totalled 91 in 1993 and 142 in 1994. A creel survey was conducted to collect information on fishing pressure and success from anglers, as well as to solicit their opinion concerning the fishing regulations. Fishing pressure, as measured by the creel survey, varied over the two year study period from 407 hours in 1993 to 166 hours in 1994. Lake chemistry measurements were taken to add to the park's baseline database and included temperature, dissolved oxygen, pH and transparency. Zooplankton and benthic invertebrate hauls were used to estimate the quantity and species of organisms present. Management recommendations included catch-and-release only fishing, closure of the logjam and Marvel Creek to fishing, and re-opening of the bay in front of the logjam. Suggested monitoring activities included an ongoing creel survey and spawning survey.

Keywords: westslope cutthroat trout, population study, Marvel Lake, Banff National Park, angling, management

EXECUTIVE SUMMARY

A Population Study of Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) in Marvel Lake, Banff National Park, with Implications for Management

Marvel Lake contains a single species of fish, the westslope cutthroat trout, *Oncorhynchus clarki lewisi*, which was originally introduced into the lake in 1927. This population is unique in that it is in one of the few lakes in Banff National Park that contains a verified pure genetic subspecies of this trout.

As part of a population and management study, a Jolly-Seber multiple mark-recapture method was used to estimate the adult population size. After eight tagging and capture sessions, the population estimates ranged between 263 and 3435 adults, with lower and upper confidence limits ranging between 58 and 1078 and 1845 and 9183, respectively.

Analysis of growth rates, through the use of a Walford plot, yielded an asymptotic maximum size of 566 mm.

Stomachs were collected from angling and trap mortalities, to study the cutthroat diet. The prey items most commonly eaten and those in greatest abundance included organisms of the orders: Cladocera, Amphipoda and Diptera (Chironomidae).

A redd count was conducted during the spawn in both seasons. Observations indicated that spawning commenced at the end of May in the east end of the lake, when the water temperature ranged between 8 and 10°C. Redd counts totalled 91 in 1993 and 142 in 1994. In 1994, the minimum number of spawning fish was 197. The average length of female and male spawners was 461 and 514 mm, respectively. Male trout were estimated to spawn between the ages of three and six, while females were between ages four and six.

A creel survey was used to estimate fishing pressure and success, as well as to solicit angler opinion concerning the angling regulations. In 1993, the lake had a catch limit of one trout, while in 1994, it was catch-and-release only. The total number of hours fished, as estimated by the creel survey, was 407 in 1993 and 166 in 1994. The catch-per-unit effort was 0.49 and 0.68 in 1993 and 1994, respectively. Angler comments ranged widely from requesting reinstatement of the catch limit, to support of the catch-and-release regulations.

Lake chemistry measurements indicated that Marvel is a slightly alkaline, highly transparent lake. It is thermally stratified in the deep water between the months of July and September. Oxygen levels during the summer and fall exceeded percent saturation levels of 80%, to a measured depth of 30 m.

Zooplankton and benthic invertebrate hauls were used to estimate the quantity and species of organisms present. Copepod adults and nauplii were most abundant in the zooplankton hauls. Benthic invertebrates frequently found in dredge samples included: amphipods, chironomids, gastropods, pelecypods and trichopterans.

Management recommendations for Marvel Lake considered the issues of species preservation, recreation, public education, angling regulations and monitoring. Final recommendations included catch-and-release only fishing, closure of the logjam and Marvel Creek, with re-opening of the bay in front of the logjam. Plans for on-going monitoring activities such as a creel survey and spawning survey were outlined.

A Population Study of Westslope Cutthroat Trout (Oncorhynchus clarki lewisi) in Marvel Lake, Banff National Park, with Implications for Management

1.0 INTRODUCTION

Marvel Lake is one of the most popular angling locations in the backcountry of Banff National Park. However, very little information has been gathered on the fisheries resource or fishing pressure there (Pengelly, 1988). It is known that the lake is inhabited by a single species of fish, the westslope cutthroat trout, *Oncorhynchus clarki lewisi,* which was originally introduced into the lake in 1927. There are few native populations of this fish left in North America, due to fish stocking activities, which include introducing competing trout and hybrid cutthroat trout, and natural hybridization with rainbow trout (Nelson and Paetz, 1992). Other perturbations affecting westslope cutthroat populations include overexploitation and habitat degradation or loss (Liknes and Graham, 1988). The population in Marvel Lake is unique in that it is in one of the few lakes in Banff National Park that contains a verified pure genetic subspecies of this trout (McAllister et al., 1981).

1.1 Rationale for the Study

The westslope cutthroat trout was once the dominant trout over a historic range that encompassed southern Alberta, southwestern Saskatchewan, southeastern British Columbia, western Montana, central and northern Idaho, and a small portion of northwestern Wyoming (Liknes and Graham, 1988). In Alberta, it is native to the Bow and South Saskatchewan watersheds and introduced into the Peace, Athabasca, North Saskatchewan and Red Deer River drainages (Nelson and Paetz, 1992). Today however, this dominance has waned and its present status is uncertain (Liknes and Graham, 1988). Liknes and Graham (1988) suggest that protection of the remaining populations is essential because "each population represents an exclusive source of genetic material for increasing diversity of brood stocks used for propagation and reintroductions."

Morphological and biochemical analyses were used by McAllister et al. (1981) to study the purity of some stocks of westslope cutthroat trout in the Bow River system. The fish in Marvel Lake were found to be phenotypically and genotypically pure westslope cutthroat. McAllister et al. (1981) concluded that because the samples from Marvel Lake along with those in Fish Lake (First and Second), Mystic and Lower Twin Lakes, were totally monomorphic[1] at all 32 gene loci[2] examined, they were isolated and locally adapted populations. McAllister et al. (1981) also recommended that the preservation of the genetic diversity inherent in these populations of native westslope cutthroat trout should be the highest priority of management plans.

Parks Canada adheres to the Convention on Biological Diversity, adopted in Rio de Janeiro in 1992. Banff National Park therefore, has an important role to play in protecting this diversity. The recognition of the importance of this role is reflected in the Parks Canada (1994) "Guiding Principles" which state that:

> Protecting ecological integrity[3] ... take[s] precedence in acquiring, managing, and administering heritage places and programs. In every application of policy, this guiding principle is paramount.

Since the population in Marvel Lake contributes to biological diversity, its preservation is a park priority. It has been suggested by parks aquatics staff (Pacas, pers. comm.), that the merit of the stock should be examined not only in a park-wide sense, but in a provincial context. To reduce trends in declining genetic diversity, especially with respect to native trout, throughout the park and province, it has been proposed that the Marvel Lake cutthroat may be used to restore populations both in and outside the park.

Parks Canada's challenge "is to maintain the ecological integrity of the parks while providing opportunities for public enjoyment and education" (Canadian Heritage, 1994). Section 3.2.12 of the policy states that "angling is part of an overall aquatics program involving public education, recreation and ecosystem protection".

The Marvel Lake population has sustained varying amounts of fishing pressure for over 60 years. This study has been designed to collect comprehensive baseline information about the fish population, the lake limnology and the fishery. This information was used to make

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[1]monomorphic: The situation in which all the individuals in a population are the same genetic type or have the same allele (Weaver and Hedrick, 1992)

allele: a particular form of a gene (Weaver and Hedrick, 1992)

[2]loci (locus, sing.): the position of a gene on a chromosome, often used synonomously with the term 'gene' (Weaver and Hedrick, 1992)

[3]ecological integrity, maintenance of: Managing ecosystems in such a way that ecological processes are maintained and genetic, species and ecosystem diversity are assured for the future. (Canadian Heritage, 1994)

recommendations concerning the future of angling at the lake and management options.

In undertaking this study, existing material on Marvel Lake was reviewed. Little detailed information existed concerning the Marvel Lake population. However, a small number of studies have been carried out and a brief review of these follows.

D.S. Rawson (1939) studied the lake as part of a biological survey in Banff National Park. He collected information on the lake's limnology and measured such variables as dissolved oxygen, temperature, pH and transparency. He also took benthic and plankton samples and examined the gut contents of 40 fish.

He reported that the larger fish were in "very poor condition" (i.e. they were underweight). It was suggested that this was due to overpopulation and that a scarcity of food was unlikely a factor. Smaller fish (under 300 mm), were reported to be in "good condition" and "provided good fishing".

In 1988, a spawning survey was conducted at Marvel between May 24 and June 6 (Wiebe and Rennels, 1988). This study concluded that the spawning activity was restricted to a small area of suitable substrates at the lake outflow. It was also suggested that the population was small and was dependent on a low number of spawners.

Also in 1988, a fisheries study was conducted by the Bryant Creek District Warden, which included a creel survey and the results of a September netting session (Pengelly, 1988). This study also concluded that the population was small and recommended regulations which would delay the opening day, reduce the catch and possession limit, prohibit the use of bait and close part of the area in front of the logjam to angling. In subsequent years, all of these regulation changes were implemented.

1.2 Study Objectives

Specifically, the objectives of the study were:

1) To review the relevant sections of the 1994 Parks Canada policy as well as fishery management practices in Canadian mountain national parks. This will illustrate the evolution of park management philosophy towards fishery resources.

2) To estimate fish population characteristics such as population size using a capture-mark-recapture technique; age and size structure; diet and growth rates.

3) To conduct a spawning survey to estimate the duration and timing of the spawn, the amount of spawning habitat and the number of spawners.

4) To estimate angler harvest and success, as well as solicit angler opinion concerning the fishing regulations, by conducting a creel survey.

5) To measure chemical parameters including: dissolved oxygen, water temperature, transparency and pH. This information was collected for baseline limnology purposes and also to estimate if some of the parameters were outside of reported ranges of tolerance for trout.

6) To measure zooplankton and benthic invertebrate prey abundance.

7) To use the above information, such as duration of the spawn, location of spawning areas, population size and creel data to recommend management options which will consider park objectives and user group desires, while maintaining protection of the population as the overall priority.

2.0 DESCRIPTION OF STUDY AREA

Marvel Lake is located in the south end of Banff National Park in the Bryant Creek District (Figure 2.1). Military Grid location is PG 015370 and it lies at a latitude and longitude of 50°52'N/115°33'W. It is shown on the topographical map 82 J/13E (Assiniboine). It is situated at an altitude of 1805m (5885 ft) and has an area of 215 ha (450 acres).

The maximum depth encountered during a 1993 depth sounding was 64 m, in the west end of the lake. The western half of the lake is the deeper, averaging 40 m; while the eastern half varies between 2 and 34 m and averages about 18 m (Rawson, 1939 and Earle and Paczkowski, 1993). Its watershed is Marvel Creek which drains into Bryant Creek.

The lake was stocked yearly, between 1927 and 1930, with trout from the former Spray Lakes hatchery near Canmore. A total of 72,000 trout were stocked. It is thought these were largely fingerlings. Stocking again took place in 1976, when 2,000 fingerlings were planted.

Marvel Lake has historical importance, as the source of fish for Job Lake (Alberta), which has been the main source for stocking cutthroat trout in Alberta since about 1970 (Nelson and Paetz, 1992).

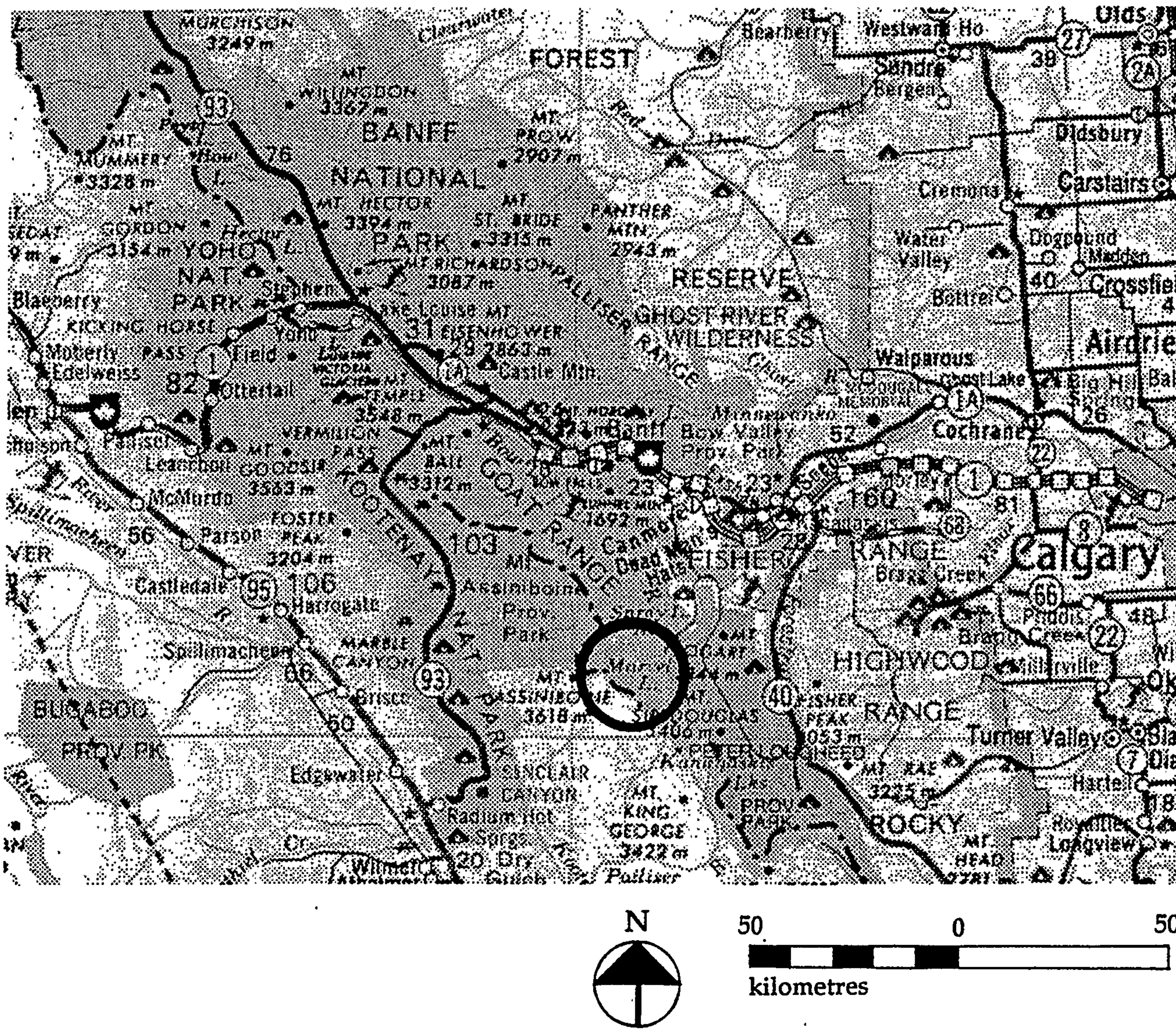

Figure 2.1 Banff National Park and location of Marvel Lake (circled)
Source: Provincial Mapping Section, Land Information Services Division, Edmonton, Alberta.

3.0 A REVIEW OF FISHERY MANAGEMENT PRACTICES IN THE MOUNTAIN NATIONAL PARKS

Fisheries management practices in national parks have changed greatly since 1885 and reflect a fundamental change in the philosophy towards the fishery resource. The recent trend has been towards minimal intervention into the natural system and thus management has relied largely on the use of regulations. This however, has not always been the case.

This chapter provides a review of the sections of the 1994 Parks Canada policy which are relevant to natural resource management in general, and the activity and management of angling specifically. Following this, two management practices, those of stocking and regulations, will be mentionned to illustrate the impact of past management on the fisheries resource and the current direction of management in the national parks. Finally, the status of the joint Aquatic Management plan in the four mountain parks (Banff, Jasper, Kootenay, Yoho), will be discussed.

3.1 Parks policy

The 1988 amendments to the National Parks Act state that the maintenance of ecological integrity must be the first consideration in management planning (Canadian Heritage, 1994). This intention is made clear in the 1994 "Parks Canada Guiding Principles and Operational Policies" document (Canadian Heritage, 1994) some of which was discussed in Section 1.1.

In regards to ecosystem based management, Parks Canada is committed to developing an integrated data base for each national park which will:

> provide, along with research and environmental monitoring, the baseline information required to protect and maintain park ecosystems and contribute to State of the Parks reporting to Parliament (Canadian Heritage, 1994).

The information collected as part of this project, contributes to the Banff National Park data base.

Furthermore, Parks policy (Section 3.2.10) states that:

> A species of plant or animal, which was native to but is no longer present in a park, may be reintroduced after scientific research has shown that reintroduction is likely to succeed and

> that there will be no significant negative effects on the park and neighbouring lands (Canadian Heritage, 1994).

This has direct implications for the present study, since it has been suggested that Marvel Lake stock could be used to restore westslope cutthroat populations in the park.

Parks Canada also seeks to provide "opportunities for public enjoyment and education" (Canadian Heritage, 1994) and to this end, the activity of sport fishing is permitted in national parks but "will be restricted to designated areas" (Section 3.1.4).

Sport fishing can be interpreted as meeting the criteria of an appropriate visitor activity, according to sections 4.1.2 and 4.1.3 of the policy. These sections state that outdoor recreation opportunities "will serve visitors of diverse interests, ages, physical capabilities and skills so that they can understand and experience the park's natural environment" (Section 4.1.2). As well, fishing could be considered as an activity which "promotes the appreciation of a park's purpose and objectives, which respects the integrity of the ecosystem, and which calls for a minimum of built facilities" (Section 4.1.3). Although sport fishing may not currently achieve all these objectives, the potential to do so exists.

In terms of resource management, Section 3.2.12 of the policy states that:

> Where fish populations can sustain some harvest without impairing resources, angling may be permitted in designated areas. Regulations will be conservatively based on continuing stock assessments and will conform to the principle that angling is part of an overall aquatics program involving public education, recreation and ecosystem protection.

Also, "in each national park, an array of representative and unique aquatic ecosystems will be closed to sport fishing" (Section 3.2.12).

The Marvel Lake project is designed in part, to assess whether harvest is a recommended management option. It also examines from the visitors' point of view, the importance of the population and of the opportunity to continue fishing the lake.

The role that Marvel Lake can play in public education, recreation and ecosystem protection is considered in chapter 9.0.

In the next two sections, past and present management practices will be discussed. This will illustrate the impact of previous management actions on the fisheries resource and show how the basic philosophy behind fisheries management in the national parks, has changed in the last 100 years.

3.2 Stocking

Since 1885 when Banff, the first national park in Canada, was established, fishing has been part of the recreational experience available to the park visitor. At this time, and until 1913, unstructured stocking of park waters was carried out by Parks and the Canadian Pacific Railway Company. This was in an attempt to lure visitors with the promise of "many and large fish" (Wiebe, 1990).

Hundreds of lakes, originally barren of fish were stocked. The efforts of hatchery men in "stocking new lakes and preparing for the opening up of new fishing areas" were lauded by individuals such as D.S. Rawson (1940). Faced with the difficulty of bringing fish from the east (Lohnes, 1989) the first hatchery in a Canadian national park was built near Banff in 1913. A second hatchery was built in Waterton Lakes National Park in 1928. Finally in 1942, a third hatchery was built in Jasper National Park.

From 1913 to 1943, the three hatcheries produced 40,000,000 trout in a variety of age classes (Wiebe, 1990). Lake Louise for example, was stocked between 1915 and 1962 with cutthrout and rainbow trout. Numbers of fish stocked varied between 10,000 - 60,000 per year up until 1935. After 1935, the numbers were substantially lower and varied between 24 and 400 per year (Parks Canada, Banff National Park Fish Stocking Records).

The mentality of the time, which basically consisted of getting the <u>maximum production</u> from <u>all</u> the park waters is well illustrated in the following quote:

> [There is an] evident need of a fisheries manager, someone with the training, experience, time and authority to take charge of the area, [...] and in short to farm the waters and produce game fish as efficiently as possible. [...] The hatchery is now and will continue to be a most important unit in the fisheries management of the area (Rawson, 1939).

In 1960, after serious disease problems, the Waterton Lakes hatchery was closed. This was followed by closure of the Banff hatchery in 1969 and of the Jasper facility in 1973, following an outbreak of IPN (infectious pancreatic necrosis) (Lohnes, 1989).

Although limnologists began to question the merits of the massive stocking programs in the early 1960s, it was not until around 1972 that a much reduced stocking program was implemented and lakes originally devoid of fish, were left in their pristine condition (Donald, 1987). In 1979, a new National Parks Policy was introduced which stated that:

> "Controlled sport fishing of naturally regenerating populations of native species will be permitted...subject to the requirement to protect the ecosystems and maintain viable populations of fish..." and that "non native species of plants and animals will not be introduced...and where they exist, efforts will be made to remove them."

In spite of this policy, some stocking occurred in a number of lakes after 1979.

In addition to stocking many species of native fish in park waters, many exotic species were also introduced from other parts of Canada and the United States. These fish were introduced frequently because they were considered "more attractive to anglers" (Solman, et al., 1952). However, their effects on native populations were rarely considered (Wiebe, 1990).

The introduction of eastern brook trout into the Maligne Lake system (in Jasper National Park), was considered by some to be "a high point in the history of Canadian fish culture" (Rawson, 1940). In other Jasper lakes, some of which were originally barren of fish, brown and brook trout were also introduced. In Banff National Park in 1919, 150,000 Atlantic salmon fry were introduced into Lake Minnewanka. Also, in Riding Mountain National Park, Rawson (1940) documented the extensive efforts being made to replace the pike with rainbow trout which was possibly considered a more desirable game fish from the anglers' point of view.

Another "valuable" use of the hatcheries, as described by Solman, et al. (1952), was as a site for experimental hybridization of trout species. Hybrids were created which were "better suited to the environment and the demands of the anglers" (Solman, et al., 1952).

These extensive introductions and stocking operations, which would be frowned upon today, reflected the thinking of the time. That is, that the fishery resource was there for the benefit of the anglers and that management efforts should concentrate on producing the maximum number of fish regardless of the productivity of the individual lakes. Even though for the most part, these intrusive management techniques are no longer implemented, the impacts of past management practices continue to have repercussions to the present day.

3.3 Regulations

Current management in the mountain national parks relies on the use of regulations. These include catch and possession limits, gear restrictions, open seasons and catch-and-release angling. One of the main problems however, with the use of catch and possession limits is that quite often these are 'blanket' limits which apply across a large area (Wiebe, pers. comm.). As Pike (1989), points out, although this may simplify administration, it does not take into account the variability that exists between the resource in an individual lake (or river) and the user pressure on that lake (or river).

Gear restrictions may consist of limiting anglers to the use of artificial lures (including artificial flies) to minimize mortality among released fish. Studies have shown that mortality is lower among fish released from artificial lures than among those released from baited hooks (Wydoski, 1977; Dotson, 1982 and Schill et al, 1986). For this reason, bait bans prohibiting the use of any live or dead natural bait are being implemented more frequently.

Open seasons restrict the time of the year during which park waters may be fished. These may vary from species to species and are designed to afford protection to fish at critical times, such as during the vulnerable spawning period. The open season may be modified depending on changes in the status of a given population. In addition to restricting the open season dates, area closures may also be implemented. These might be used for example, to protect spawning areas from trampling by anglers.

The main goal of catch-and-release management is to eliminate, as nearly as possible, angling-related mortality while still permitting sport fishing. The use of this management tool downplays the importance of fish consumption and trophy fishing and conveys the message that native stocks are valued and this presumably encourages a higher degree of appreciation for the resource (Mayhood, 1991).

Catch-and-release is not however, without its problems. As is indicated by Mayhood (1991), "from the enjoyment point of view, the most obvious problem with catch-and-release is that anglers cannot retain any fish". This may be a difficult adjustment for those who are used to keeping their catch. In addition, compliance with these regulations and their enforcement is problematic. Currently in Banff National Park, both bull trout and cutthroat trout are fished on a catch-and-release basis only.

3.4 Status of Aquatic Management Plan in Rocky Mountain National Parks

A Rocky Mountain District Aquatics Management Plan is currently being produced which will address management issues in Banff, Jasper, Kootenay and Yoho national parks. It is in draft form and undergoing peer review. It is expected to be put forward for public comment shortly thereafter.

This is a general document which discusses management directions and values. It does, however, identify specific threats to aquatic resources.

4.0 FISH POPULATION

4.1 Introduction

An estimate of abundance is central to the management of any species. It is especially important for harvested or potentially harvested species, such as the westslope cutthroat trout in Marvel Lake. For this reason, as part of the population ecology and management study, a mark - recapture design was used to obtain a population estimate.

There are a variety of possible mark-recapture methods and these were considered previous to the start of the study. Each one has a different set of assumptions and is designed for studies of various lengths. The Jolly-Seber method with its associated confidence intervals, was chosen for this study. Unlike the Petersen and Schnabel methods, the Jolly-Seber is designed for open populations - that is ones in which it is not necessary to assume the absence of recruitment and mortality.

Since the violation of one or more of the assumptions can lead to biases in the estimate, these are listed below.

Assumptions of Jolly-Seber method (Krebs, 1989):

1. Every individual has the same probability of being caught in the t th sample, whether it is marked or unmarked.
2. Every marked individual has the same probability of surviving from the t th to the $(t + 1)$ sample.
3. Individuals do not lose their marks, and marks are not overlooked at capture.
4. Sampling time is negligible in relation to intervals between samples.

Further discussion of these assumptions will follow in Section 4.4.1.

The enumeration method, also referred to as the minimum number alive (MNA), was calculated for comparison. According to Krebs et al. (1986) this method may be useful when populations are low and recaptures infrequent. The MNA has been a popular measure of population size, especially for studies of small mammals (Efford, 1992). It has been criticized by some researchers, who state that it is always more biased than the Jolly-Seber (Jolly and Dickson, 1983; Efford, 1992 and Pollock et al., 1990). Jolly and Dickson (1983) recommend the MNA as a lower limit of the Jolly-Seber estimate, but not as a substitute for population size (N), because it has a negative bias which exceeds that of the Jolly-Seber estimate. Others have found that the Jolly-

Seber and MNA population estimate methods yield similar numbers and suggest a combination of the two methods could be used (Zimmermann and Spence, 1992; Galindo-Leal, 1990 and Boyce and Boyce III, 1988).

Information collected as part of the mark-recapture study (e.g. length, weight) was also used to determine age and size structure of the netted population, growth rates, and the length-weight relationship. Where possible, otoliths were collected from trapping and angling mortalities for purposes of age determination. Stomachs were also collected from these fish to examine the cutthroat diet.

4.2 Methods

4.2.1 Population Estimate

The Jolly-Seber model was used to estimate the size of the population. Population estimates were calculated for all sessions, except the first and last, as the Jolly-Seber method precludes estimates at the first and last capture sessions.

For this method, mark-recapture samples are taken on three or more occasions and it is necessary that marks be used which are specific to the sampling time. For each marked individual in the sample it is vital to be able to identify when that individual was last captured. This was accomplished by using individually numbered floy and visible implant (V.I.) tags.

For more details on the Jolly-Seber method, please refer to Krebs (1989); Ricker (1975) and Pollock et al. (1990).

The MNA was calculated by summing the number of animals caught at a particular time, as well as all other animals known to be alive because they were caught both before and after that time (Pollock et al., 1990 and Efford, 1992).

Although the majority of fish tagged were captured with a trap net and a vexar trap, a few fish were recaptured through angling. All fish were measured (fork length), to the nearest millimetre with a measuring board. Weight, in grams, was measured with an electronic balance to the nearest gram and occasionally a spring scale (in the event of balance malfunction), to the nearest 10 grams. Maturity was assessed by pressing on the abdomen from the area below the pectoral fin towards the anus, to examine for the release of eggs or milt during the spawn. If roe and milt ran with slight pressure, fish were classified as ripe. If eggs and milt did not run freely but some residual eggs and sperm were left, then the fish were classified as spent. Spent condition was more easily determined in females as the eggs changed colour from an orange/pink to a pale pink almost transparent colour and egg shape changed from completely round to deformed. Classification of spent males was more subjective.

During the non-spawning period, maturity could only be determined by dissection. Fish were defined as "maturing" if the gonads were not well developed but were identifiable as male or female. Immature individuals were those with very small gonads which were not identifiable as male or female to the unaided eye. Since examination was only done in the field and not in the lab, fish were classified as "unknown" if the gonads were not visually identifiable as ovaries or testes.

Maturity was recorded as a number as is shown in Table 4.1. A discussion of trapping methods follows.

Table 4.1. Codes used to classify fish maturity

Female	Condition	Male
1	immature	6
2	maturing	7
3	mature	8
4	ripe	9
5	spent	10
un	unknown	un

Two types of live traps were used to capture fish: a trap net (used in the lake) and a vexar trap (used on Marvel Creek). Trap net locations for both years are shown in Figure 4.1.

Trap netting was divided into four main sessions in each of the two field seasons. In 1993, the session dates were: June 2 - June 29; June 30 - July 12; September 23 - October 2 and October 3 - October 11, 1993. In 1994, the session dates were: June 3 - June 11; June 12 - June 23; September 12 - September 18 and September 19 - September 25, 1994. These dates were used for several reasons. It was intended that trapping commence at the start of the spawn in both years. It was also desired by Banff National Park that as little trapping as possible occur during the mid-summer period, when the lake and area was busiest with tourists. Finally, in the summer and fall of 1994, the trapping equipment was being used in other projects throughout the mountain parks and some session dates were dependent on trap availability.

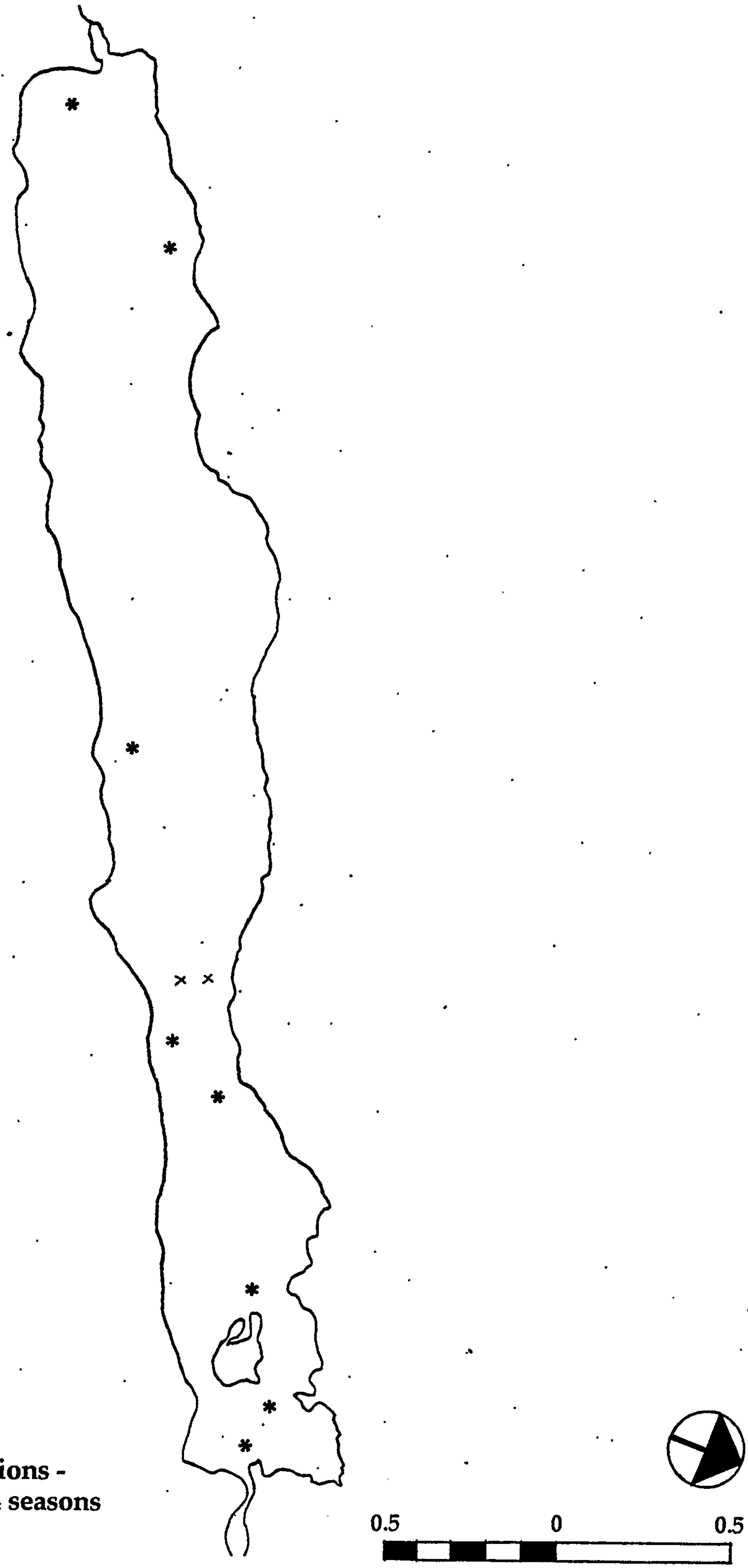

Figure 4.1 Trap net locations -
1993 and 1994 seasons

Before setting the net, the sediment bottom was examined for debris such as large rocks or logs which might have snagged the net, causing tears or preventing it from being fully stretched when the anchor was pulled. In general, the trap net was set so that the box sat in approximately 8-12 ft of water, with most or all of the main line played out. The lid section of the net was used to ensure that fish could not escape over the wings or the mouth of the trap if these were in deep enough water to be fully submerged.

Once the net was in the water, the angle of the wings was adjusted so that these were roughly at a 45° angle between the main line and the trap mouth. The net was stretched tight by pulling on the buoy of the main anchor from an outboard motor boat.

The vexar net (one in. mesh, 100 ft roll) was set on Marvel Creek during the spawn. The net was located approximately 100m downstream of the falls at the Marvel Lake outlet. In 1993, the trap session extended from June 17 - June 28. In 1994, trapping occurred between June 2 and June 18. Because the importance of this area for spawning was not fully realized until mid-June of the first season, the catch dates between the two seasons differ considerably.

Metal posts were driven into the sediment at intervals of roughly four feet in a line extending from one shore to the other. A few metres from each shore posts were driven into a V-configuration. The area inside the V, was used as the catchment area. The netting was then rolled out and attached to the posts with pieces of wire. Approximately one foot of netting was placed on the substrate and anchored with rocks. Two versions of the trap were used. In 1993, funnels were cut and sewn into the netting in each of the upstream and downstream catchment areas. In 1994, this design was modified to an incline plane trap in which the section of netting facing either upstream or downstream was pushed under the water and anchored with rocks or rope. Enough netting was secured underwater to permit fish to enter the catchment, but discourage them from leaving it.

Fallen trees or rocks piled at the upstream end of both catchment areas were used to slow down the flow within the catchment and provide areas for fish to rest from the current. The net was cleaned daily to prevent accumulations of debris from putting undue stress on the netting and causing it to buckle.

In the second week of June in the 1994 season, heavy rains caused the vexar trap to be washed out. It was completely taken out and reset the same day.

To individually identify fish, two types of tags were used. Fluorescent orange Floy anchor tags (Floy Tag and Manufacturing Co., Seattle, model #600FD68B) were printed in black with a number on one side and "Banff National Park" on the other. Visible implant (V.I.) tags (Northwest Marine Technology, Seattle) were red with a black letter and number code.

Floy tags were inserted at a 45° angle on one side of the dorsal fin using a tagging gun and needle. Fish caught in Mårvel Creek were tagged on the right side of the dorsal, while fish caught in Marvel Lake were tagged on the left side. Only fish greater than 25 cm in length were floy tagged. The adipose fin of these fish was cut to check for tag losses.

Visible implant tags were inserted in the postorbital adipose tissue using a tagging needle. A finger was then used to gently push the tag further down to secure its placement. All fish were anaesthetized using 2-phenoxy-ethanol prior to tagging. Only fish greater than 15 cm in length and caught after September 24, 1993 were V.I. tagged. A fin clip on all V.I. tagged fish was used to check for tag losses. This clip varied between right and left pelvic and upper and lower caudal depending on the session.

In the 1994 season, tag wounds were observed on some of the smaller floy tagged fish. For this reason, during the fall trapping sessions, larger fish (up to 45 cm) were V.I. tagged. Fish greater than 45 cm in length were not V.I. tagged as it was felt that the membrane tissue was too opaque and impaired the legibility of the tag.

4.2.2 Age/Size Structure

Otoliths were used to age the cutthroat trout from Marvel Lake. They were collected from both angler caught fish as well as trap mortalities. Due to escapement through the net mesh, no one year old fish were captured. The results of otolith ageing in conjunction with length measurements, permits such population and life history parameters as stock composition, age at maturity and life span to be estimated.

In the field, otoliths were collected using two methods. The first involved splitting the head into two halves by making a downward cut from the base of the skull on the top of the head towards the mouth. The two otoliths were then collected from the cavities on each side of the head. The second method described in Mackay et al., (1990) involved cutting through all the gill arches and the isthmus while holding the fish upside down, thus exposing the roof of the mouth. The parasphenoid bone (the roof of the mouth) was then cut with pliers where the first gill arch joins the roof of the mouth. Then while holding the head of the fish, the backbone was snapped downward where the cut was made. This exposed the otoliths in the roof of the mouth, where they were removed with forceps. Otoliths were stored in vials containing a 90% glycerol/10% alcohol mixture.

The primary reference used for techniques of otolith ageing was Mackay et al., (1990). Jim Stelfox of Fish and Wildlife Services in Calgary also provided some guidance. Two techniques were experimented with to determine which one provided the best results.

Initially, some otoliths were split through the focus with either a fingernail or a scalpel blade. They were then mounted in adhesive on a slide with the cross-section facing up. This face was ground until rings were clearly visible and then toasted to bring the rings out more clearly. The problem encountered with this method was that too frequently the otoliths shattered when split and thus a number of otoliths were lost.

The primary method used involved mounting an otolith whole in the adhesive on a slide. The side of the otolith with the groove was initially ground until the groove was no longer visible and rings were detected. The otolith was then mounted on the other side and ground until rings were clearly visible. All of the larger, thicker otoliths were ground on both sides. Some of the smaller otoliths were only ground on one side. Otoliths were then toasted to emphasize the rings.

Otoliths were read using a dissecting microscope and a light microscope. All otoliths were aged twice to check for consistency. Where discrepancies could not be reconciled, the otolith was dropped from consideration.

The results from the subsample of otolith ages were used in conjunction with the computer modelling program - MIX 3.1a - (copyrighted and distributed by Ichthus Data Systems, 59 Arkell St. Hamilton, Ontario L8S 1N6) to fit the size frequency distribution from the netted population sample with component age curves. This program is interactive and uses the method of maximum-likelihood estimation for grouped data, to fit mixture distributions. Initial inputs for the number of components (age classes), their proportions, means and standard deviations are needed. A more detailed explanation of the program can be found in the User's Guide to Program Mix (Ichthus Data Systems, 1988). The precursor to this program was developed by Macdonald and Pitcher (1979), for the analysis of fisheries length-frequency data.

This program was used to fit the 1993 and 1994 data separately. However, because of low numbers in the age five and six groups, which resulted in undefined peaks in the length frequency histogram, all ages above age four were combined and were fitted as one group on the histogram. This helped to improve the fit for the first three components. Therefore, it should be noted that the mean and standard deviation of the last component group has little biological significance.

As the frequencies of some of the shortest and longest length classes often had counts less than five, these were combined with other length classes to avoid the flattening out of the curve at both ends. For the 1993 data, all fish under 99mm in length were combined into one length class, this included fish from the 70-99mm classes. In addition, fish ranging from 559 to 629mm were combined into the final length group. Similarly, for the 1994 data, all fish under 149mm were combined into the smallest class. Fish from 569 to 589mm were combined into the final length class.

As is shown in the results section, the standard deviations were kept fixed in the 1993 analysis and the proportions were kept fixed in the 1994 analysis. The MIX program allows all, none or some of the parameters to remain fixed throughout the analyses. Through a combination of visual and numerical analyses, it was decided that keeping these parameters fixed gave the optimal fit.

4.2.3 Growth Rates

Fish growth was examined through the use of a Walford plot. A Walford plot is the relationship of the length at age t (lngt), to the length the following year (lngt1). A straight line is fitted to the data using a least squares linear regression. This plot allows the calculation of two parameters related to growth rate: the asymptotic or theoretical maximum size (L_∞) and the growth rate constant (k) which is the rate at which a particular population grows toward the maximum size for that population (Mackay et al., 1990).

For the most part, fish were only used in the calculations if one year had passed between the time of first capture and the time of recapture. In a few cases however, fish a week or two shy of a full year were also included. In these cases, an estimate was made of the full year growth.

An analysis of covariance (ANCOVA), was performed using the statistical package Mystat, to test for differences between growth rates of males and females. This was done to determine if all fish could be combined into one plot.

4.2.4 Length-Weight Relationship

The length-weight relationship can be mathematically described using regression techniques. The regression equation may then be used to predict weight values, given lengths of fish (Mackay et al., 1990).

An analysis of covariance (ANCOVA) was performed to test for significant differences between the male and female regression lines, before deciding if the data could be combined.

4.2.5 Diet

Although a detailed diet study was not part of this project, stomachs were collected from some of the angler caught fish (1993) and trapping mortalities, in an effort to determine the primary prey items in the cutthroat diet. It should be noted that the diet may vary considerably depending on the size of fish and the time of year. For this reason, it should not be assumed that the results of these analyses can be applied to other size classes.

The principal references used in determining the methodology were Bowen (1983) and Hyslop (1980).

Stomachs were preserved in the field in a 4% solution of formalin. In the lab, stomachs were initially soaked in several changes of water to remove excess formalin. The stomachs were then slit lengthwise with fine scissors and the contents were washed into a sieve with a 100μm mesh.

If the contents were dense, then a subsample was taken. Usually, all the macroinvertebrates were picked out and enumerated for the entire sample. The remaining organisms were then suspended in 50 ml of water and mixed with a magnetic stirrer. The subsample was taken with a pipette and placed in a counting cell. To estimate the total number of organisms in a 50 ml sample, the number identified in the subsample was multiplied by 50 ml and divided by the subsample volume. If the contents were not dense, all organisms were counted for a more accurate estimate. Whole stomach counts were done for all but three of the stomachs. When enumeration was complete, the samples were preserved in a 70% ethanol solution.

Identifications were done with a dissecting scope at 12x and 25x magnification. The references used in the identifications were Clifford (1991), Pennak (1989) and Ward and Whipple (1966).

Due to the problems associated with identifying partly digested prey, the following were used as guidelines: 1) Cladocerans and amphipods were counted as one organism if at least a head capsule (usually with an eye) was seen. Therefore a free floating leg or antenna was not counted as an individual. 2) A chironomid was identified by either a head capsule or an entire organism. 3) Other insects were identified by either the entire organism or in some cases by a section of body segments. 4) If an insect could not be identified to Order, it was classified as Insecta (Unidentified).

The results of content analysis were combined over the two years and were divided into two categories: 1) Fish greater than 25 cm fork length. These were caught during the summer, with the exception of two fish caught near the end of April. 2) Fish less than 25 cm. These were caught in the fall.

For each of the two groups, results were presented as frequency of occurrence and percent composition by number.

It should be noted that several of the stomachs were collected from fish which had died overnight in the Vexar trap. Partial evacuation of stomach contents likely occurred in these fish and thus by morning, stomachs were partially empty. In some cases, the stomachs were entirely empty. These stomachs were not considered in the calculations.

4.3 Results

4.3.1 Population Estimate

The trapping effort and performance is shown in Table 4.2. Trapping totals include all recaptured fish.

Table 4.2 Lake and Creek Trapping Results for 1993 and 1994

	Lake		Creek		Total
	1993	1994	1993	1994	
Number of trap nights	53	31	9	11	104
Number of fish caught A=adult J=juvenile	A=283 J=860 Total=1143	A=290 J=221 Total=511	A=6 J=55 Total=61	A=100 J=3 Total=103	A=679 J=1139 Total=1888
Trapping mortalities	A=1 J=11 Total=12	A=3 J=3 Total=6	A=0 J=28 Total=28	A=15 J=0 Total=15	A=19 J=42 Total=61

Note: Totals of adults and juveniles do not add up to 1888. This is due to the fact that length data was not available for all fish caught.

The fish in Table 4.2 were classified as either adult or juvenile. The criteria used to classify fish was the maturity and the length. Since only fish caught during the spawn could be accurately identified as male or female, the length of fish was used to estimate maturity at other times of the year. A cut-off length of 25cm for adults was chosen because: 1) this was the smallest size of fish that could be floy tagged (due to the size of the tags) and 2) this was the smallest size of fish which was determined to be ripe or mature, either during the spawn or by dissection of trap or angler mortalities.

The number of recaptures is shown in Table 4.3. These numbers also include angling recaptures, which totalled five in 1993 and nine in 1994.

Table 4.3 Floy and Visible implant tag recaptures

	1993	1994	Combined
Adult	11	44	55
Juvenile	22	11	33
Tag Losses	2	6	8

In each of 1993 and 1994, three of the juvenile recaptures were V.I. tagged fish. Where possible, the tag return information was used to calculate growth rates.

In 1993, two fish were captured with a clipped adipose but no floy tag. These were both counted as tag losses. In neither case was a tag wound evident. In 1994, six tag losses were recorded. The size profile of fish caught with tag losses was calculated. The mean length was 439 mm (range = 281-523 mm; std deviation = 76.9; N=7).

The number of tag losses in the adult population was estimated from the subsample of recaptured fish with tag losses. A total of 8/63 fish or 13% of those recaptured had lost their floy tag. Applied to the entire population of floy tagged fish, an estimated tag loss of 13% would result in 87 tag losses out of 666 fish (this total does not include 13 adult fish which were V.I. tagged). If 87 fish with tag losses had been recaptured, this would no doubt have had a significant effect on the population estimates and their precision. However, because all floy tagged fish had a clipped adipose, it is concluded with 100% accuracy that only 8 tag losses occurred within the recaptured population.

The sex of fish was examined to determine whether there was a sex-specific difference in the loss of tags. The results were: two males, two females and four unknown. The sample size was too small to test for differences statistically.

No V.I. tag losses or wounds were observed. However, tag wounds were observed on several of the floy tagged fish which were recaptured. The length data of fish with tag wounds was examined. The mean length of fish was 353 mm (range = 305-411 mm; std deviation = 42.7; N=6). Although no fungal infection was evident, in all cases the tag insertion point had widened, resulting in an open sore. In one case, the tag had shifted position and was close to falling out. The length of time before recapture varied from a few days to just over 1 year.

Tag fading was also observed of both floy and V.I. tags. The floy tags faded to a pale pink colour, however the tag numbers were still clear. The V.I. tags faded in colour to a pale red and although the numbers were legible they were also faded. If the study duration was to exceed 2 years, it is felt that the V.I. tags may have posed some legibility problems.

The results of the Jolly-Seber population estimates, as well as the 95% confidence limits and MNA estimates are shown in Table 4.4. The population estimate is for the number of adults only. The raw data used in these calculations is given in Appendix A.

Table 4.4 Jolly-Seber and MNA population estimates

Sample	Time period	Jolly-Seber estimates	95% Confidence limits	MNA estimates
1	June 2-29/93	-	-	654
2	June 30-July 12	3435	L=1029 U=9183	675
3	Sept. 23-Oct. 2	1208	L=280 U=4927	677
4	Oct. 3-11	1194	L=322 U=3732	675
5	June 3-11/94	3101	L=1078 U=7166	672
6	June 12-23	1002	L=259 U=3987	678
7	Sept. 12-18	263	L=58 U=1845	679
8	Sept. 19-25	-	-	680

Note: In the confidence limit column, L= lower limit; U= upper limit

The Jolly-Seber population estimates ranged between 263 and 3435 adults, with lower and upper confidence intervals ranging between 58 and 1078 and 1845 and 9183, respectively. The average population size was 1700 adults and the median estimate was 1201 fish.

The enumeration or MNA method yielded a mean population estimate of 674 and a median estimate of 676 fish.

4.3.2 Age/Size Structure

The results of otolith aging are shown in Figure 4.2. This figure illustrates the overlap in lengths at the various age categories. The oldest fish aged was six years old.

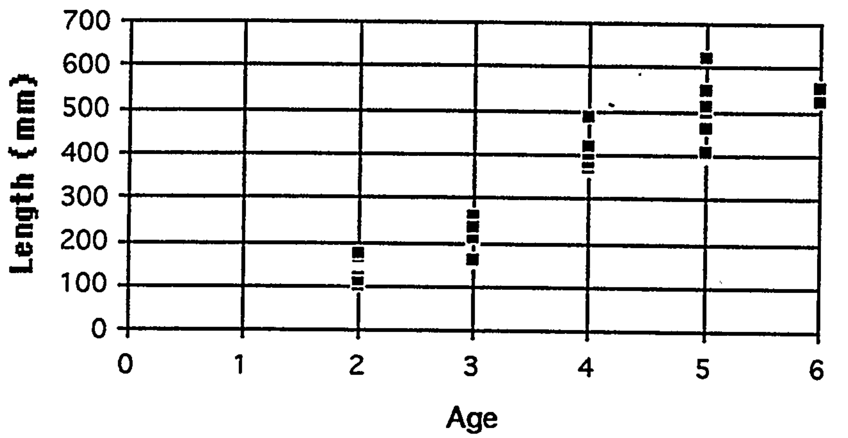

Figure 4.2 Length at age as determined by otolith aging (N=67)

The unfitted histograms for the 1993 and 1994 netting results are given in Figures 4.3 and 4.4.

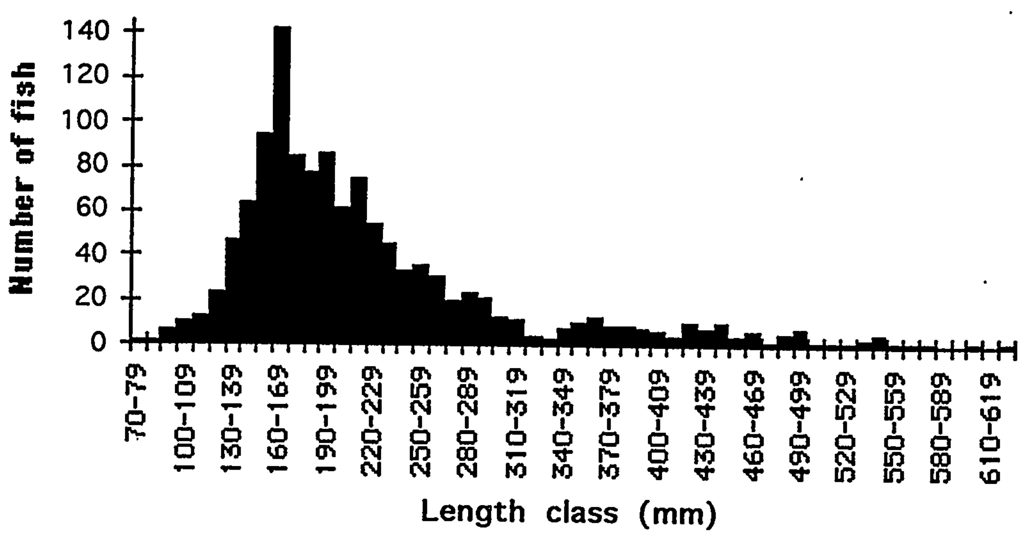

Figure 4.3. Length frequency histogram for 1993 data (N=1216)

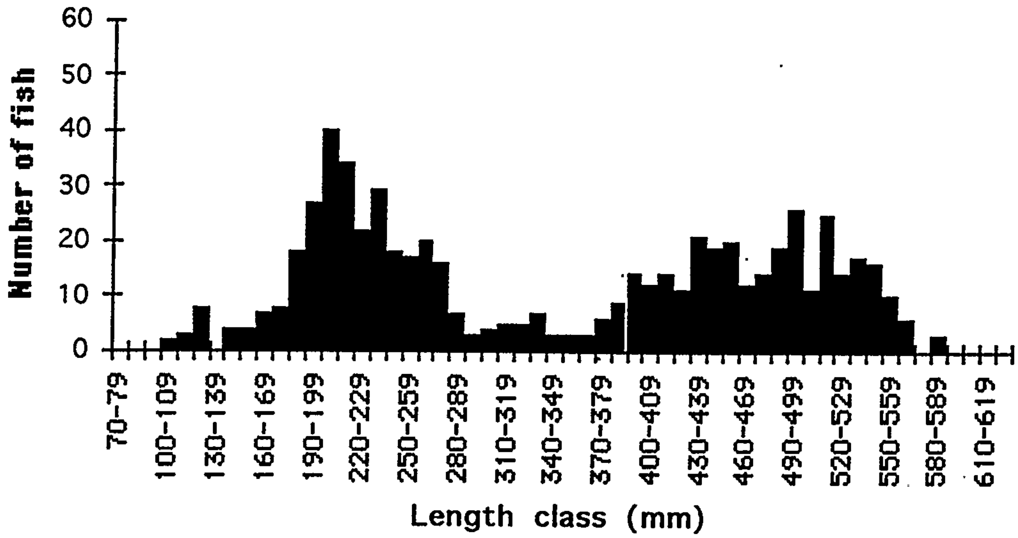

Figure 4.4. Length frequency histogram for 1994 data (N=616)

The fitted histograms are shown in Figures 4.5 and 4.6. As was previously mentionned, the last component includes fish of ages five and older. The triangles mark the mean of each component. Following each graph is a table containing the estimated parameters - proportions, means and standard deviations.

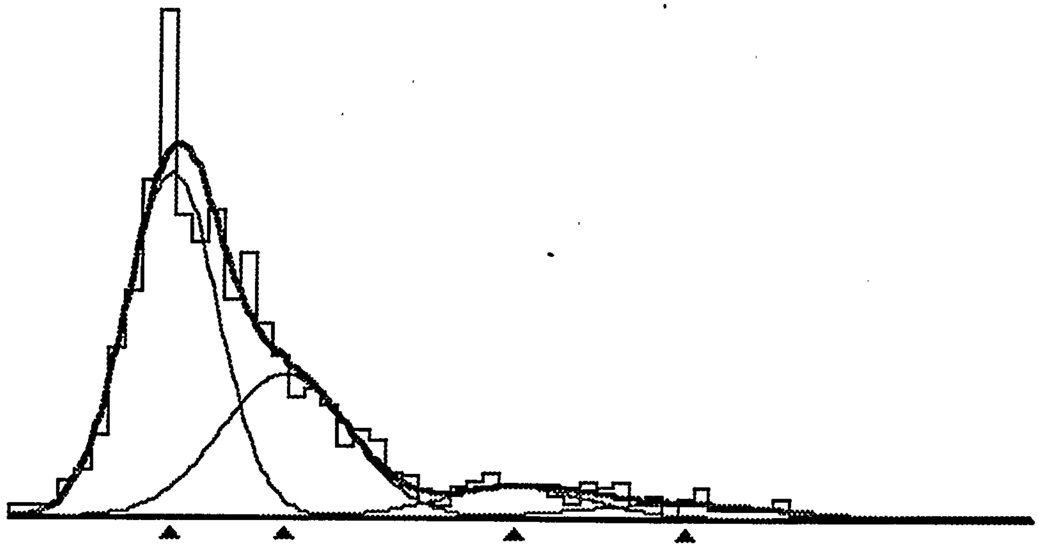

Figure 4.5 Fitted histogram of length frequency data from 1993 (N=1216)

Table 4.5 Parameters associated with components in Figure 4.5 (standard errors are given in brackets)

Component	Age Class	Proportion	Mean	Standard Deviation
1	2	.55605 (.02889)	167.3263 (1.6609)	28.00 (fixed)
2	3	.31896 (.02689)	237.4617 (4.7394)	39.00 (fixed)
3	4	.07618 (.01271)	379.6992 (11.4478)	45.00 (fixed)
4	5 and up	.04880 (.01292)	485.0687 (17.0857)	60.00 (fixed)

In the above table the "fixed" refers to the fact that the standard deviations were kept fixed in the fitted mixture. The same is true of the proportions in the following table.

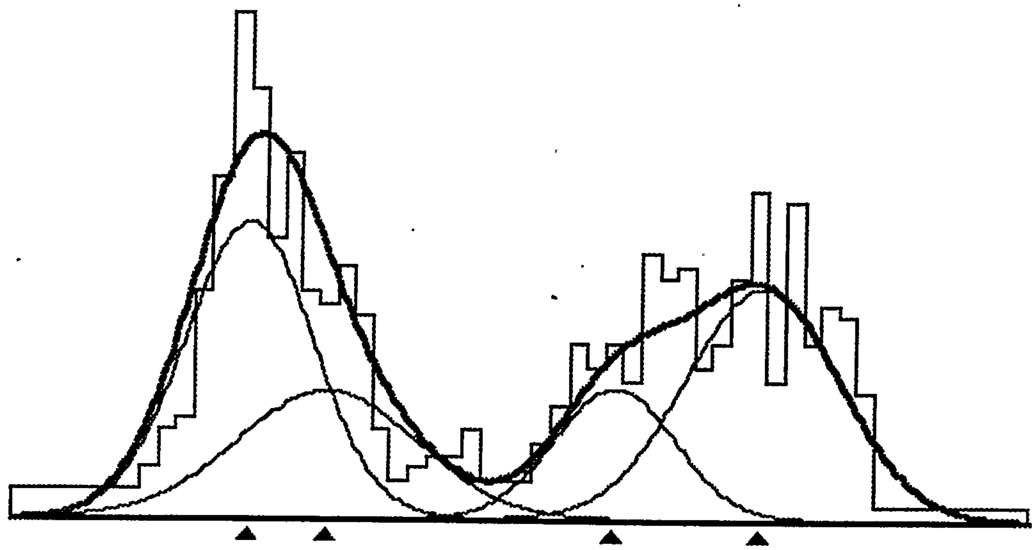

Figure 4.6 Fitted histogram of length frequency data from 1994 (N=616)

Table 4.6 Parameters associated with components in Figure 4.6 (standard errors are given in brackets)

Component	Age Class	Proportion	Mean	Standard Deviation
1	2	.33725 (fixed)	209.099 (3.4780)	35.5073 (2.7599)
2	3	.20540 (fixed)	253.2719 (6.9013)	50.0875 (4.8092)
3	4	.14054 (fixed)	414.5395 (5.8460)	33.3908 (5.1941)
4	5 and up	.31681 (fixed)	495.9456 (3.8982)	42.6657 (3.1377)

4.3.3 Growth Rates

The results of the analysis of covariance showed that there was no significant difference in the growth rates according to sex (F=1.373; df=1,8; alpha=0.05; p=0.275). For this reason, all data was combined in the Walford plot, which is shown in Figure 4.7.

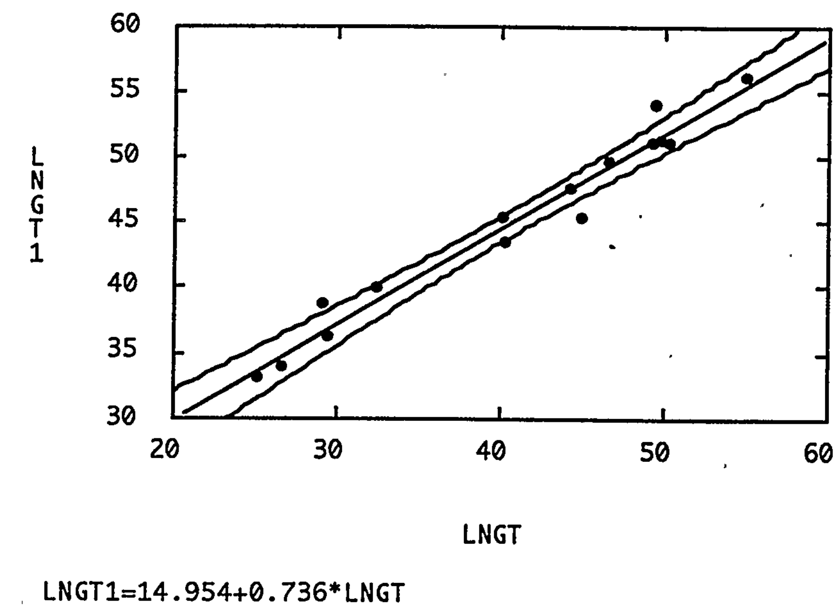

Figure 4.7 Walford plot - regression line with 95% confidence intervals, where lngt is the length at age t and lngt1 is the length the following year (N=15; r=0.983; F=370.17; df=1,13; p=0).

The asymptotic size, L∞, is calculated as: L∞ = y intercept/(1-slope); and has a value of 56.6cm.

The growth rate constant is calculated as: k = -ln(slope); and has a value of 0.31.

4.3.4 Length-Weight Relationship

The results of the ANCOVA showed that there was no significant difference between the male and female length-weight regression lines (F=0.949; df=1,240; alpha=0.05; p=0.331). For this reason, all data was combined into one length-weight regression, shown in Figure 4.8.

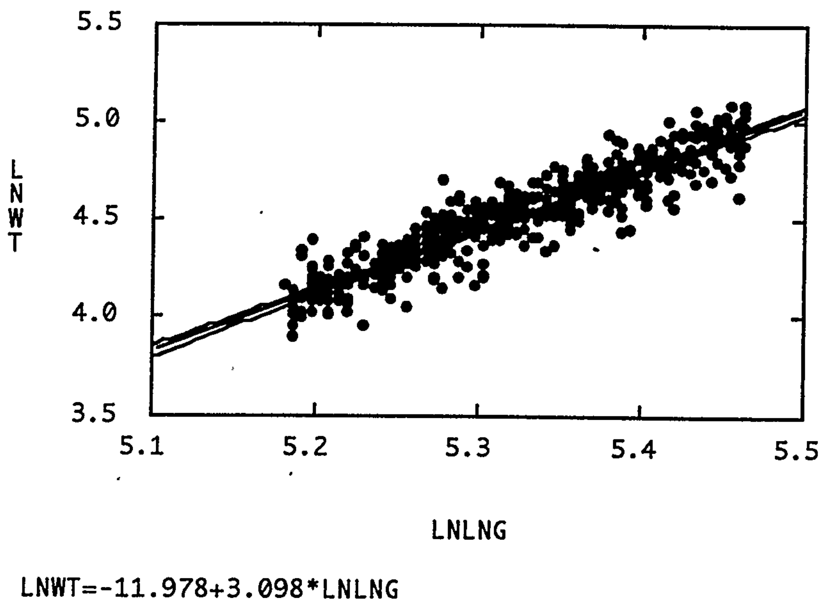

Figure 4.8. Scatter plot of lnlength vs. lnweight with regression line and 95% confidence intervals (N=1718; r=0.995; F=182658; df=1,1716; p=0).

The version of Mystat used was not able to include all the data points on the graph, therefore the equation below the graph is not accurate. A regression analysis was performed separately on all the data and the correct equation was found to be: LNWT=-12.481 + 3.195*LNLNG.

4.3.5 Diet

Results are presented as frequency of occurrence (Tables 4.7 and 4.8) and as percent composition by number (Tables 4.9 and 4.10).

Table 4.7 Frequency of occurrence of prey items, fish >25 cm collected during the summer months between August 1, 1993 and August 20, 1994 with two fish collected April 19, 1994 (N=21)

Order	Frequency of Occurrence	Order	Frequency of Occurrence
Cladocera (water fleas)	57.1 %	Plecoptera (stoneflies)	19 %
Amphipoda (scuds)	40 %	Fish eggs	19 %
Diptera Chironomidae (midges)	33.3 %	Copepoda Calanoida (copepods)	9.5 %
Insecta Unidentified	33.3 %	Plant material	9.5 %
Trichoptera (caddisflies)	28.6 %	Coleoptera (beetles)	4.8 %
Ephemeroptera (mayflies)	19 %	Fish	4.8 %

Common names are given in brackets below the scientific names. Also please note that Insecta is actually a class not an order.

Table 4.8 Frequency of occurrence of prey items, fish <25 cm collected in the fall months between October 8, 1993 and September 25, 1994 (N=4)

Order	Frequency of Occurrence
Cladocera (water fleas)	75 %
Amphipoda (scuds)	50 %
Insecta Unidentified	50 %
Copepoda Calanoida (copepods)	25 %
Trichoptera (caddisflies)	25 %

Results of percent composition by number calculations are given below.

Table 4.9 Percent composition by number of prey items, fish >25 cm collected during the summer months between August 1, 1993 and August 20, 1994 with two fish collected April 19, 1994 (N=21)

Order	Percent Comp. by Number	Order	Percent Comp. by Number
Cladocera (water fleas)	85.3%	Plecoptera (stoneflies)	0.43%
Amphipoda (scuds)	8.8%	Fish eggs	0.18%
Diptera Chironomidae (midges)	0.71%	Copepoda Calanoida (copepods)	1.1%
Insecta Unidentified	2.3%	Coleoptera (beetles)	0.02%
Trichoptera (caddisflies)	0.8%	Fish	0.02%
Ephemeroptera (mayflies)	0.29%		

Table 4.10 Percent composition by number of prey items, fish <25 cm collected in the fall months between October 8, 1993 and September 25, 1994 (N=4)

Order	Percent Comp. by Number
Cladocera (water fleas)	5.3%
Amphipoda (scuds)	87.2%
Insecta Unidentified	2.3%
Copepoda Calanoida (copepods)	0.75%
Trichoptera (caddisflies)	4.5%

4.4 Discussion

4.4.1 Population Estimate

An attempt was made to spread out the trapping effort around the lake. However, due to the nature of the trap net, it worked best when set in 8-12 feet of water. Mortalities in the trap net, especially of adult fish, were low over both seasons. All size classes except the smallest (<100 mm) were represented in the trap net catch.

The vexar trap which was set in one location only, was responsible for higher mortalities of both adults and juveniles. In May and June, the water level and current were higher down the creek than later in the summer. Although an attempt was made to slow down the flow by building up rocks in front of the catchment area, adults still did occasionally get swept to the downstream end of the net and could not right themselves to face the current. The adult mortalities were higher in 1994 since more fish were handled in this season. Juvenile mortalities, largely fish that become lodged in the plastic netting, were reduced from 28 to zero in 1994, when the size of mesh was changed (larger size by 1/2 inch in 1994). As with the trap net, the smallest size class of fish (< 100 mm) was not represented in the catch.

The performance of the tags used is discussed below.

The problems associated with both Floy tags and visible implant tags have been documented by many authors (Mourning et al. 1994; Kincaid and Calkins, 1992; Waldman et al. 1991; Ebner and Copes, 1982 and Muoneke, 1992). Floy tags have several advantages as they are quickly and easily applied, are durable and are easily noted by anglers. This is important where angler returns of tags are needed, such as in this study. Studies have also shown that they have drawbacks because the tags tend to vibrate or spin as the fish swims (Muoneke, 1992). This can create an open wound that may become infected and could eventually result in tag loss or death of the fish (Carline and Brynildson, 1972) as I also observed in this study.

Mourning et al. (1994) compared visible implant tags and Floy anchor tags on hatchery rainbow trout. Although they found that early shedding was a problem with V.I. tags, they also observed that Floy tags worked loose gradually over the 120 day study period. Early Floy tag loss may also occur and is thought to be caused primarily by a failure to lock the T-bar anchor behind the pterygiophores (Ebener and Copes, 1982 and Mourning et al. 1994). The study of Mourning et al. (1994) also concluded that fish with Floy tags had significantly lower growth rates than those with V.I. tags. This however, was not tested for in the Marvel Lake study, but would be an important consideration for future studies.

Mourning et al. (1994) and Kincaid and Calkins (1992) recorded that a small percentage of V.I. tags became completely unreadable over the study period (120 days and 123 days respectively), because of silver pigment in the overlying tissue. Although readability of V.I. tags was previously mentioned as a problem, this was primarily due to tag fading and not silver pigmentation.

Other studies have recorded open sores resulting from the use of Floy tags (Mourning et al. 1994; Carline and Brynildson, 1972 and Muoneke, 1992). The Mourning et al. (1994) study concluded that 98% of the Floy tags caused at least slight injury (defined as a wound 1-3 mm in diameter at the insertion point). It was because of the wounds observed on fish in the present study, that V.I. tags were used on fish up to 450 mm in size, later in the tagging season. Although only small, uninfected Floy tag wounds were recorded in some other studies (Rawstron, 1973 and Tranquilli and Childers, 1982), I would not recommend the use of Floy tags for long term studies (greater than 2 years).

Finally, several scientific papers were consulted when trying to determine the best methods of interpreting and reporting the results of the population estimates (Reimchen, 1990; Sullivan et al., 1993; Galindo-Leal, 1990; Zimmermann and Spence, 1992; Boyce and Boyce III, 1988 and Efford, 1992). Some of these (Reimchen, 1990 and Sullivan et al., 1993) reported Jolly-Seber population estimates as ranges and averaged the estimates over several years. I reported an average of 1700 adults when all Jolly-Seber estimates were used in the calculations and an average MNA estimate of 674. However, the Jolly-Seber confidence limits ranged widely as is shown in Table 4.4.

There is no way to avoid the fact that in some sessions (3/6, or 50%), the number of recaptures was small, i.e. less than seven. Seber (1982) suggested that for seven or more recaptures one can be 95% confident that the bias of N (sample size) is negligible. Otherwise, he recommends using a modified estimate of $m+1/n+1$ (where m = the number of marked animals caught and n = the total number of animals caught) to reduce bias for small sample size. This modified estimate was used in the calculations.

In spite of this, the confidence limits are still wide, because the number of recaptures compared to the total number of fish caught was low. Each Jolly-Seber estimate is equally valid since they all have a 5% chance of error - that is that the true population size lies outside the lower and upper confidence limits and a 95% chance that the true population size falls between the lower and upper confidence limits. The estimates, with the confidence intervals of Table 4.4 are the best estimates which can be derived given the data.

In order to consider the likelihood of bias in the estimate, possible violation of the four assumptions laid out in Section 4.1 will be reviewed.

Assumption 1. Every individual has the same probability of being caught in the t th sample, whether it is marked or unmarked.

This assumption is based on the idea that a random sample is taken from the population. As Jolly and Dickson (1983) point out "the most satisfactory solution to the problem [of nonrandomness] would be a practical one aimed at eliminating causes of unequal catchability in the field." To this end, the trap net was moved around the lake over the two year study period and therefore it was set in a variety of habitats and water depths.

Several tests of equal catchability exist (see Krebs, 1989 and Seber, 1982) and these were examined for their applicability to the data. None of the tests were found to be satisfactory given the open population requirement and the desire to test for equal catchability between marked and unmarked individuals. What can be estimated is the effect of unequal catchability on estimates for an open population. Carothers (1973) showed that for a population composed of two subpopulations with unequal catchabilities, the bias in population size (N) is negative. Therefore, the Jolly-Seber consistently underestimates the population size. Carothers also confirmed these results for small populations from simulated data using Seber's correction, which was also applied to the Marvel Lake data.

Jolly and Dickson (1983) showed that under conditions of both equal and unequal catchability, the MNA, as an estimate of N, has a greater negative bias than that of the Jolly-Seber estimate. Therefore, according to these studies, if unequal catchability is occurring, it is resulting in a negative bias in both the Jolly-Seber and MNA population estimates.

Assumption 2. Every marked individual has the same probability of surviving from the t th to the $(t + 1)$ sample.

In the first field season, a take limit of one fish existed. This added an angler mortality factor to the natural mortality factor. Since anglers very often fish selectively for large fish, it may have been the case that large versus medium or small marked adults experienced a higher mortality. Although this may have happened, it was also my experience that anglers preferred to catch and keep untagged fish, as these had not been previously handled. This differential angler-caused mortality would have largely disappeared in the second season since there was a no possession regulation.

Assumption 3. Individuals do not lose their marks, and marks are not overlooked at capture.

The observed tag losses were 8/63, or 13% over the two year study. This information was lost in terms of the population estimate, and resulted in a lower precision of estimates. However, because of adipose clips on all tagged fish, the tag loss component was accounted for and could be measured.

Marks were not overlooked at capture during any of the netting sessions. However, on a few occasions, anglers may have seen a tag but either forgot to fill out a creel card or did so with an invalid number. It is not believed that this type of error occurred often.

Assumption 4. Sampling time is negligible in relation to intervals between samples.

The time interval between samples varied as is permitted with the Jolly-Seber method. It was suggested (Brewin, pers. comm.) that an interval of at least seven to ten days was necessary to permit natural recirculation of fish following handling. This time interval was used between four of the sampling periods. There was an interval of approximately two and a half months between the second and third sample period. The interval between the fourth and fifth sample was seven and a half months. That between the sixth and seventh samples was close to three months.

In summary, all population estimate methods carry with them a number of assumptions which should not be violated. In the natural world however, it is impossible to fully meet all of these assumptions. The result is estimates which will be negatively or positively biased. However, the magnitude of this bias is hard to estimate.

In spite of its biases, Pollock et al. (1990) recommend the Jolly-Seber as one of the best population estimators for open populations. Even though the estimates and confidence limits varied widely, each estimate has the same risk of error. Although the MNA estimates are more precise, they only provide information concerning the minimum number in the population and are useful as a lower limit to the Jolly-Seber estimate (Jolly and Dickson, 1983).

4.4.2 Age/Size Structure

Given only two years of data, it was not possible to determine whether year-class fluctuations occur in the population.

In both 1993 and 1994, the first component, comprised of two year old fish, was the most dominant in numbers, representing 56% and 34% of the overall catch in 1993 and 1994, respectively. In 1993, the proportion of each class declined from age two to the combined age five and older class. In 1994 however, the proportion of age five and older fish exceeded that of the age three and four fish. It is thought that the explanation for this difference may lie in the different sampling dates between the two years. A larger number of age five and older fish were caught in 1994 because of the trapping on Marvel Creek which occurred two weeks earlier in 1994 and caught a higher proportion of spawning fish than had been captured in 1993.

The 1994 length-frequency histogram did not show as obvious year class peaks (at least in the first three age classes) as the 1993 data did. This is partly due to the smaller sample size in 1994 and the more severe overlapping lengths at age, which made fitting curves difficult.

It would be interesting to examine in the next few years the effect of catch-and-release fishing on the population age structure. Theoretically, one would expect to see an increase in the proportions of older fish with potential effects, such as higher mortality of the younger year classes.

In terms of life span, cutthroat trout have been reported to live to a maximum of ten years, but four to seven is more common (Scott and Crossman, 1973). In Marvel Lake, the oldest fish caught was six years old.

4.4.3 Growth Rates

The asymptotic maximum size provides information about the growth conditions in the lake (Post, pers. comm.). According to Mackay et al., (1990) it indicates whether the population is stunted. In this case, "stunted refers to populations of fish that do not have the potential to reach the normal maximum size for the species. It distinguishes between populations which are not capable of producing large fish (stunted) and those which never achieve their L_∞ because of a short life span" (Mackay et al., 1990).

The L_∞ value as calculated for Marvel Lake was 566 mm. This size was attained or exceeded by nine fish in the netted samples. Due to the short life span of this trout (oldest estimated age was six), I would suggest that most fish do not achieve the asymptotic maximum size, rather because they do not live long enough and not because individuals in the population do not have the potential to reach that size.

Although growth and potential maximum size will vary from stock to stock, the usual maximum length in most localities in Alberta is 320 mm (Nelson and Paetz, 1992). Bulkley (1961), reported total lengths of Yellowstone cutthroats from Yellowstone Lake, of 444 mm at age six, and 485 mm at age seven, the maximum age reported. The high growth rates in Marvel Lake, in comparison, may be due to the abundance of invertebrate foods (see Section 8.0) or may be related to the number of fish utilizing these resources.

The growth rate constant of 0.31, can be used to compare the growth of the current population to that in the future. If, for example, stunting were to occur in the future, perhaps due to overcrowding following the cessation of harvest, this would be reflected in a lower growth rate constant.

4.4.4 Length-Weight Relationship

The length-weight regression equation will be useful for making comparisons between the 1993/94 data and data from future studies. The two equations could be compared using analysis of covariance to determine if they show a statistically significant difference. Such differences could be the result of changes in prey abundance or in the density of the fish population.

4.4.5 Diet

Cutthroat are known to exploit surface, mid-water and benthic food sources. One study in British Columbia (Andrusak and Northcote, 1970) showed that cutthroat fed heavily on zooplankton in late spring, but predominantly on bottom organisms in summer and fall, especially caddis larvae. They also indicated that the change in diet likely reflected seasonal changes in the spatial distribution of the fish, rather than changes in the abundance or distribution of the food items.

Liknes and Graham (1988) reviewed the life history of westslope cutthroat trout in Montana. They described cutthroats as opportunistic feeders that are not highly piscivorous. They found that dipterans and ephemeropterans were the most important dietary components, along with trichopterans for larger fish (>110 mm). Winged insects were not found to be important in the diets of smaller fish but became prominent as the fish increased in size.

Rawson (1939) had collected information on stomach contents from 40 Marvel Lake specimens. He concluded the following: "The small ones (16 -

24 cm), had eaten chiefly (75%) Gammarus, the remainder being mostly caddis pupae and mayfly nymphs with grasshoppers and other insect fragments. Those of middle size had eaten amphipods and caddis in the shallower water and others in the deeper water had taken mostly copepods (90%) and chironomids. The larger fish had eaten caddis (60%) and amphipods (25 - 40%), also miscellaneous insect fragments." It is believed that these fish were collected in early September.

Results of my analysis showed that for fish >250 mm in length, cladocerans, amphipods, chironomids and trichopterans were the most abundant food items in both the number of individuals who had eaten these items (frequency of occurrence) and the average quantity per individual.

For fish <250 mm, cladocerans and amphipods were found most often in the stomachs and these were also the most abundant items in terms of numbers. The sample size for the smaller fish was quite small however (N=4), and this may have skewed the results. In fact, it is known that the high percent composition by number results for amphipods (Table 4.10) was influenced by one fish, which had consumed the bulk of the amphipods.

It is not unusual for cladocerans to make up a high percentage by number of prey items, as was the case for the larger fish. Pennak, (1989) stated that cladocerans are of great importance in the diets of both young and adult fish. A number of studies of stomach contents of young fish show from 1 to 95% Cladocera by volume, and very few studies show less than 10% (Pennak, 1989).

However, it should be noted that frequency occurrence and numerical estimates tend to overemphasize the importance of small prey items taken in large numbers, such as the Cladocera (Hyslop, 1980). Although cladocerans made up 85% of the percent composition by number, this does not necessarily mean that they are of greater nutritional importance, than for example, the amphipods or some orders of insects.

The moderately high frequency occurrence values for cladocerans, amphipods and chironomids indicate that these items are taken by a large proportion of the trout population. In other words, it shows the homogeneity of feeding within the population.

Other items which were part of the diet of a smaller proportion of fish, included fish eggs, copepods, fish and other insects, including trichopterans, ephemeropterans, plecopterans and coleopterans. Plant material was also found in two of the stomachs as was noted in Table 4.7. This information could not be incorporated into the percent composition by number graph, since it could not be broken down into discrete units.

In summary, a variety of food items are available to the fish, including both zooplankton and benthic organisms. Items most commonly eaten and those in greatest abundance included cladocerans, amphipods and a variety of insects, primarily chironomids.

5.0 SPAWNING SURVEY

5.1 Introduction

As part of this study, a spawning survey was conducted in the 1993 and 1994 field seasons. A previous survey in 1988 conducted between May 24 and June 6 (Wiebe and Rennels) concluded that the only area with suitable substrates and water flow for spawning was found in the outlet of Marvel Lake, in and near the logjam. According to this study, "the search of the outflow creek from Terrapin Lake and Marvel Creek showed no evidence of spawning." A maximum number of 48 spawners was estimated in this study and spawners were observed digging redds on top of existing redds, thereby displacing eggs (Wiebe and Rennels, 1988). It was hypothesized at that time that the lack of spawning habitat was the primary factor limiting the increase of the population.

My results indicated that spawning continues until mid-June, and commences approximately one week later in the inlet creek. It is therefore possible that the 1988 study ended too early to detect spawning in areas other than the logjam. The 1993/1994 study also showed that other areas around the lake, as well as below both sets of falls on Marvel Creek, are used by cutthroat for spawning.

5.2 Methods

Redd counts were conducted during the period from May 26-June 16, 1993 and from June 1-June 22, 1994. Since the timing of spawning is correlated with water temperature, temperature measurements were recorded with a pocket thermometer. The areas searched for redds included: 1) the outlet of Marvel Lake, in and near the logjam; 2) Marvel Creek from below the first set of falls to just below the second set of falls (a distance of less than one km); 3) the inflow to Marvel Lake from Terrapin Lake; and 4) the shoreline of Marvel Lake, including two inlet creeks at the west end.

A redd was identified as a depression in the substrate, with guidelines for mean length varying approximately in size from 0.6 to 1.0 m and from 0.32 to 0.45 m in mean width (Shepard et al., 1984). This was usually an area of gravel cleaned free of silt and algae. Since the four areas were surveyed continually, newly created depressions or newly cleaned areas were evident. The Marvel Creek section was surveyed by two individuals who walked upstream on opposite sides and recorded the number and location of redds in a field notebook. Snorkel surveys were conducted on June 13 and June 25, 1993 and on June 10, 1994 in the areas of the logjam and downstream on

Marvel Creek, to just below the second set of falls. Surveying occurred on these dates due to availability of equipment and personnel, as well as good weather conditions.

To determine the timing of fry emergence, the four areas were examined for the presence of fry starting in early July and continuing into August. Since no redds were observed in the two inlet creeks at the west end of the lake these areas were surveyed in early to late July for the presence of newly emerged fry, which could indicate the presence of spawning.

5.3 Results

5.3.1 Duration of Spawn

During the 1993 season, the spawning period extended from the end of May until approximately the 16th of June. Although surveys did not start until June 1 in 1994, the presence of excavated and cleaned areas of gravel, indicated that spawning had likely been occurring for at least a few days. Spawning commenced approximately one week later in the inflow creek in both years. This was correlated to the temperature difference between the east and west ends of the lake.

5.3.2 Water Temperature

In 1993, the water temperature in the logjam area, ranged from a low of 8.0°C to a high of 10°C (mean=9.1°C, n=11). In 1994, temperatures ranged from 8.5 to 9.5°C (mean=8.8°C, n=9) around the east end of the lake. Temperatures at Terrapin creek were lower during the same period and ranged from 5.5 to 6.0°C (mean=5.8°C ,n=2) in 1993 and from 5.5 to 7.1°C (mean=6.3°C, n=2) in 1994. By June 20 in 1993, the temperature had reached 10°C . On June 21, 1994 the temperature was 8.5°C at the mouth of the creek.

5.3.3 Redd Count

Area 1
In 1993, 19 redds were identified in the outlet of Marvel Lake, in and near the logjam. On five of these redds, fish were observed actively spawning on several occasions throughout the survey period.

In 1994, 29 redds were identified in the logjam area. Fish were observed every few days over at least 12 of these redds.

Area 2
The 1993 survey of the Marvel Creek section resulted in a count of 63 redds. As the majority of this area was quite open, fish were observed spawning during the daylight hours, on only two of the redds.

During the June 4 redd count in 1994 on Marvel Creek, a total of 71 redds were counted and six fish were observed. When this count was repeated on June 22 and double checked on July 7, the total count was 105 redds. In some cases, large areas of cleared gravel were found and it was difficult to individually identify redds.

Area 3
In the inflow to Marvel Lake from Terrapin Lake a total of six redds were observed in 1993. This comprised two redds in the northern-most creek and four in the south creek. Fish were observed on one of the redds in the south creek. These creeks were surveyed again on June 20, and no new redds were observed.

On June 4, 1994, three redds and two fish were observed in the north creek. In the south creek one redd was observed but no fish were seen. On June 12, three redds were again counted in the north creek and no fish were observed. Five redds and one fish were seen in the south creek. In both creeks, depressions characteristic of redds were not as evident as they were in the logjam and Marvel creek.

Area 4
Although no redds were observed along the Marvel lake shoreline or in either of the two inlet creeks surveyed in either 1993 or 1994, it is thought that the inlet creek at the far end of the lake on the north shore, may be used by spawning adults. This is based on observations of fry in July within a week or so of fry emergence. At this time, groups of fry were observed along the shoreline and under fallen logs at the mouth of the inlet.

Table 5.1. compares the redd counts in the four areas surveyed over the two year study period.

Table 5.1. Number of Redds Observed

Area	1993	1994
Logjam	22	29
Marvel Creek	63	105
Inflow from Terrapin Lake	6	8
Marvel shoreline	0	0
Total	91	142

5.3.4 Snorkel Survey

Redd surveys on foot were supplemented by snorkel surveys in the logjam area, as well as in Marvel Creek. This aided in identifying areas of major concentrations of redds and spawning fish. No new redds were identified during the June 13, 1993 snorkel survey. The June 25 survey showed no new redds in the Marvel Creek section. In the same survey, three additional redds were identified in the front section of the logjam. These had not been previously identified due to the difficulties of accessing the front of the logjam by foot and seeing beneath the logs from a boat.

In both years, adults were observed while snorkeling in the pool below the first falls and in the side channel pool. Several adults were also seen down Marvel Creek in the deeper areas and undercut banks upstream of the riffle where the concentration of small islands is located.

5.3.5 Number and Length of Spawners

The numbers and lengths of spawning fish (ripe and spent) were compiled for males and females from both seasons. These are shown in Figures 5.1 and 5.2.

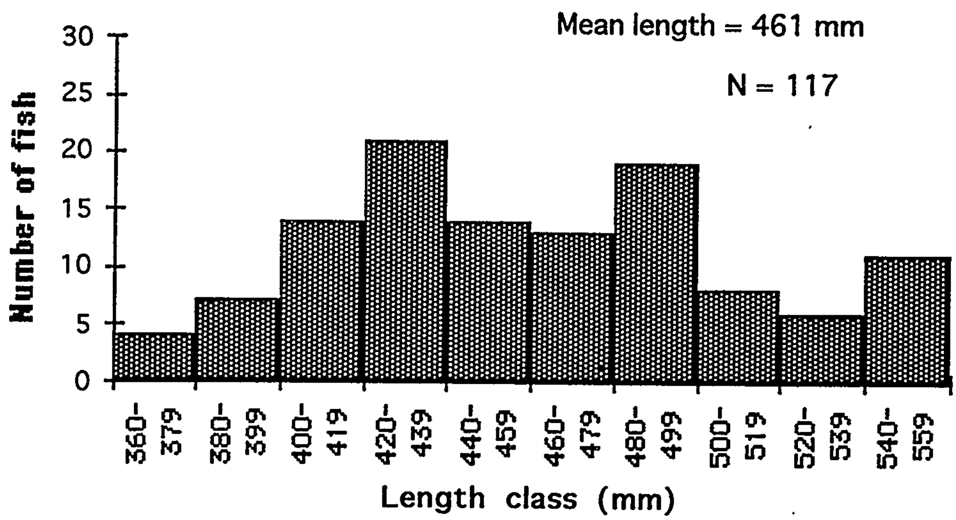

Figure 5.1 Length of female spawners-1993 and 1994

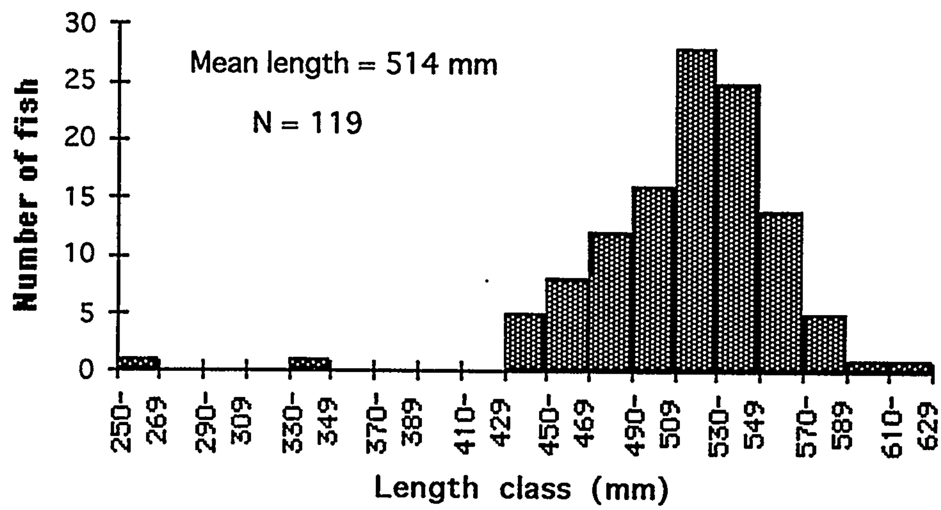

Figure 5.2 Length of male spawners-1993 and 1994

The breakdown of the number of spawners for each season is shown in Table 5.2.

Table 5.2. Number of spawners per year

Number of Spawners		
Sex	1993	1994
Female	20	97
Male	19	100
Total	39	197

The lengths of fish of unknown sex, which were caught during the spawning season and were greater than 250 mm in length, are shown in Figure 5.3.

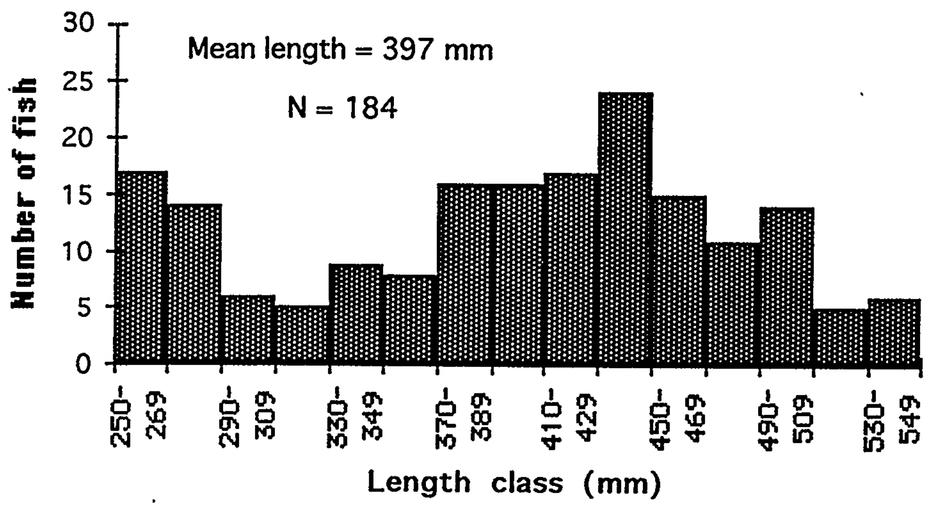

Figure 5.3. Length of possible spawners - sex unknown, 1993 and 1994

Results of otolith ageing suggest that female trout in Marvel Lake are spawning at age four to six. Male trout are spawning at age three to six. The minimum length of male spawners was in the 250-269 mm range. However, ripe fish of that small size were rare. For females, the minimum length was in the 360-379 mm range. If this minimum length is applied as a cut-off point to the fish of unknown sex in Figure 5.3, then an estimate of an additional 35 and 93 potential spawners results, in 1993 and 1994 respectively. This could raise the number of spawners in each year to a total of 74 in 1993 and 290 in 1994. However, the exact number is unknown.

5.3.6 Fry Survey

As early as July 17 in 1993 and July 25 in 1994, fry were observed in the logjam area as well as in Marvel Creek. At the inlet creek from Terrapin Lake, fry were observed in an August 8 survey in 1993. On July 25, 1994, one fry was seen. In an August 8 survey, several groups of five to ten fry were observed. In general, it was estimated that the fry in the inlet were smaller (approximately less than 1 cm versus 1.5 cm) than those in the logjam or Marvel Creek, at the same point in time. This would make sense since the mean temperatures in the inlet creek were 2-3°C lower than those in the logjam in Marvel Creek in early June and indicate that spawning is occurring later in the inlet.

Most frequently the fry were seen in undercut banks, under submerged logs and in areas of silt or mud substrate overlaid with gravel and pebbles and occasionally twigs. Areas of emergent vegetation were also preferred habitat for fry, as was the logjam which also provided good rearing habitat for juvenile fish.

At the inlet creek, fry were observed in both the north and south creeks, as well as in the gravel areas along the shore north of the creeks especially under submerged logs.

In early to mid-August of both years, the mossy inlet at the far end of the lake on the north shore was surveyed. Although no redds had been identified in May or June, fry were seen at the mouth of the inlet over gravel/rubble substrate and under submerged logs along the lake shoreline. This may indicate that spawning was taking place in this inlet creek. However, it would depend on the timing of fry emergence from known spawning areas, such as the Terrapin inlet, as well as the timing of larval movements such as sustained swimming. Therefore, it is possible that the fry observed may have migrated to the inlet from another spawning area.

As early as mid- to the third week of September in both seasons, ice was forming on small pools cut off from the main channel, especially in the logjam. Partly because emergent vegetation was often associated with these shoreline pools, fry were frequently seen in these areas. However, by mid-October, some of these pools were frozen solid, resulting in fry mortality. Numbers of fry observed in these pools ranged between 40-50 total.

5.4 Discussion

5.4.1 Water Temperature

Scott and Crossman (1979) and Carl and Stelfox (1989) reported that cutthroat usually spawn when the water temperature is at or near 10°C. In this survey the average temperatures were between 8.8 and 9.1°C in the east end of the lake during the spawning period. While spawning in Marvel Lake may have commenced at a lower temperature, it reached 9.5-10°C at some point during the spawn in both years.

5.4.2 Redd Count

The redd counts in areas 1, 3 and 4 were similar in both years. However, 42 more redds were counted in the Marvel Creek section in 1994 than in 1993. The potential of this creek for spawning was not initially recognized in 1993. As a result, this area was surveyed at least one week after spawning began. Some redds may therefore have been missed. It is also thought that the researcher's increased familiarity with the creek in the second season eased the identification of individual redds.

Overall, observations of the amount of suitable spawning area available, suggest that this may become a limiting factor should the population increase substantially- for example, to another 50 or more spawning pairs.

Presently, I would estimate that the logjam is at or near capacity in terms of the number of redds it can accommodate. Probably 95% of the spawning habitat (areas with suitable substrates and water flow) is currently used by spawning fish. The remaining 5% area exists in the front of the logjam under the first few logs and appeared underused by fish.

I would estimate that 85% of the suitable spawning habitat in Marvel Creek above the second falls, is currently used. Unused or underused areas exist in a side channel 100m downstream of the falls; in the main channel before the bend and just above the second falls.

In addition to the above mentionned areas, other sections of marginal habitat exist. This may include patches of substrate with a higher silt content or areas with lower water flows - some of which may be exposed by mid- to late summer, potentially endangering egg viability.

While a maximum of three redds and no fish were observed below the second falls, some suitable unused substrate is located downstream of these falls. This area however, is limited to a length of approximately 50-80 m downstream of the falls, due to the presence of unnegotiable falls (at least in the upstream direction), further downstream. Due to the presence of two side channels, with lower flows and a "step-ladder" design, it is thought that fish can move upstream from below the second falls and back to the lake.

The inlet creek from Terrapin Lake, currently supports a small number of redds (six to eight). Given that this inlet is fairly narrow and that flows conducive to spawning are only found in a short section of stream, it is estimated that 90-95% of the available habitat is currently used.

The presence of fry at the inlet at the far end of Marvel on the north shore, may indicate that this inlet was used for spawning in spite of the fact that no redds were identified. However, it is also possible that fry migrated to this location from the inlet creek from Terrapin Lake. Although the inlet itself was characterized by a mud/silt substrate overlaid with moss, the substrate at the inlet mouth was composed of gravel/rubble which was of suitable size for spawning. Since neither redds nor spawning fish were observed in this creek, it is unknown whether this area is used for spawning. If spawning is occurring, it is not known to what extent.

5.4.3 Number and Length of Spawners

It is believed that the number of spawners in 1993 was greatly underestimated. This was due largely to the fact that the Vexar creek trap was installed more than two weeks later in the 1993 season than in 1994. By this time it was likely that the majority of the fish had already spawned and had started to return upstream to the lake. As well, in both years, a number of fish of unknown sex, many of which were believed to be mature, were noted but their contribution in terms of number of spawners could not be exactly determined. It is therefore thought that the 1994 numbers are more representative of the actual situation.

Due to the short duration of the 1988 spawning survey, it is not possible to compare the results from this and the 1993/94 study, to determine what changes, if any, have occurred in the number of spawners or the amount of spawning habitat. From the present study, areas of unused spawning habitat have been identified, which could support an unspecified number of additional spawners.

The phenomenon of alternate year spawning was not tested for in this study. Insufficient numbers of adults were tagged during the spawn in 1993 to detect the probability of this occurrence.

The average reported age at first spawning for cutthroat trout is two to four years (Nelson and Paetz, 1992; Scott and Crossman, 1973). However, this is variable and will depend on factors such as population density, system productivity and length of the growing season (Post, pers. comm.). Fish in some populations may mature as late as age five or six (Scott and Crossman, 1973; Liknes and Graham, 1988). Trout in Marvel Lake spawned between the ages of four to six for females and three to six for males. It is not known whether the older fish were first-time or repeat spawners.

The average length of mature fish is high when compared to populations in other areas in the province. Nelson and Paetz (1992) reported that the maximum length in most localities in Alberta is 320 mm. They also state that in some areas, such as the Ram River drainage, they may exceed 500 mm. In Marvel Lake, this could indicate that exploitation is low (Post, pers. comm.) and may also reflect the abundance of invertebrate foods. On the other hand, it could also indicate that exploitation is high enough to prevent stunting (Post, pers. comm.). Growth rates and food supply are discussed in Section 4. Fishing pressure is discussed in Section 6.0.

5.4.4 Fry Survey

While fry were observed in the inlet creek at the west end on the north shore, it cannot be concluded with certainty that this indicates the presence of spawning in this creek. The potential mobility of fry within one to two weeks of emergence from the gravel suggests that fry could have migrated from another area. While no attempt was made to estimate numbers of fry, potential factors contributing to fry mortality were observed and are discussed.

Stomachs which were collected from both juveniles and mature fish, were analyzed for the presence of eggs and fry. Out of 16 stomachs, collected during the spawn, four (or 25%), contained a small number of eggs (from one to four). It should be noted that some of the stomachs had been evacuated prior to the fishs' death and these may have also contained some eggs.

Mortality rates in fishes are generally highest during the embryonic and larval periods of development and survival of salmonid eggs to the fry phase is commonly less than 15% (Godin, 1981). High mortalities of fry, and likely eggs, are due to bird and fish predators (Godin, 1981). If 25% of the juveniles and mature fish are consuming eggs (assuming population numbers of 1000 fish), then eggs in the order of the tens of thousands could potentially be eaten over a period of three weeks (possible length of spawn) (Post, pers. comm.). Assuming that the average fecundity reported in Alberta is 1100 eggs per female, cannibalism of these numbers of eggs could result in substantial egg mortality. No fry were identified in any of the stomachs.

Another cause of fry mortality was stranding of fry in pools and in parts of the slow bay down the creek, where lowered water levels occurred in late summer. In the logjam, at least four pools were isolated from the main channel and when observed, these contained roughly 10-15 fry each. These pools were shallow enough that they froze solid in October, resulting in the deaths of the fry present.

Water levels and therefore fry mortalities will vary, especially down the creek. The summer of 1994 was unusually hot and the dropping water levels left portions of the creek dry. Where this occurred in slow bays and side channels, it is reasonable to assume that fry mortality resulted. No numerical estimates however, were made.

5.5 Conclusion

The minimum number of spawners was estimated to be 197 (male and female combined) in 1994. Habitat being used for spawning includes Marvel creek, the logjam, the inlet creek and potentially one other inlet creek along the north shore. With the current fishing restrictions in place, I estimate that the number of spawners will increase to numbers which will eventually be limited in part, by the amount of spawning habitat still available. I strongly recommend that the creek closure remain in effect, to protect the largest area of spawning habitat, as well as the incubating eggs from trampling by angler wading, later in the season.

6.0 CREEL SURVEY

6.1 Introduction

Implicit in managing a fishery is balancing the desires of anglers with the need to protect a particular population or species. For the management of a harvested population, it is also necessary to have an idea of the population size, fishing pressure and angler success.

Creel survey cards were used as part of the Marvel Lake study to collect a variety of information from anglers. This included such information as 1) fishing effort; 2) number of fish caught; 3) number of fish kept (1993); 4) length of fish kept (1993); 5) tag returns and 6) visitor comments.

The catch and possession limit for Marvel Lake was one trout in 1993. In 1994, the lake was catch and release only. The open season in both years was July 7 to October 31.

6.2 Methods

The setup for the creel survey at Marvel Lake consisted of a creel box containing survey cards and pencils and an explanatory sign placed beside the box. These were located in the lake shore meadow at the point where the two trails accessing the east end of the lake exit the trees. A sample creel card is given in Figure 6.1.

Completed cards were collected regularly -- usually once during the week and on weekends. In addition, project personnel were present on the water and at the meadow to collect supplementary information. For example in 1993, otoliths and stomachs were collected from some of the angler kept fish. Stomachs were preserved in a 4% formalin solution and otoliths were kept in a 90% alcohol/10% glycerol solution. These results are presented separately.

Where possible, results from both years were combined.

It should be noted that since the survey was voluntary, and it can be assumed that compliance was not 100%, it did not provide data on total angler effort, catch and harvest. Rather it provided trend and other information about a sample of the population which will be useful in managing the fishery (Hills and Stelfox, 1991).

Warden Service
Banff National Park

Warden Service
Banff National Park

VOLUNTARY ANGLER REPORT

MARVEL LAKE STUDY

Date: ______________
Day / Month / Year

Permanent Residence ______________________

1. How many hours did you fish today? ______________

2. How many fish did you catch? ______________

3. How many fish did you keep? (Max = 1) ______________

4. What length was the fish that you kept?

20-29cm (8-12")	30-39cm (12-16")	40-49cm (16-20")	50+cm (20+")

Please check appropriate box

5. Was the fish that you kept tagged?
If so, what was the number? ______________

5. How many days this trip will you fish the area? ______________

6. Comments/Suggestions...

Environment Canada
Canadian Parks Service

Environnement Canada
Service canadien des parcs

Figure 6.1 Sample creel card from 1993

6.3 Results

6.3.1 Fishing Pressure

Table 6.1 summarizes and compares some of the creel data from the 1993 and 1994 seasons.

Table 6.1. Summary of Creel Card Statistics

Variable	1993	1994
Total number of cards	61	37
Total number of anglers	97	44
Total hours fished	407	166.25
Average hours fished per angler	4.2	3.8
Total number of fish caught	201	113
Total number kept	38	n/a
Percent of fish released	81 %	n/a
Hooking mortalities reported	0	3
Catch per unit effort (# of fish/angler hour)	0.49	0.68

Note: The catch-per-unit effort (CPUE) is a measure of the angler success rate and is also an index of stock density (Ricker, 1975).

The monthly distribution of angler hours is shown in Figure 6.2.

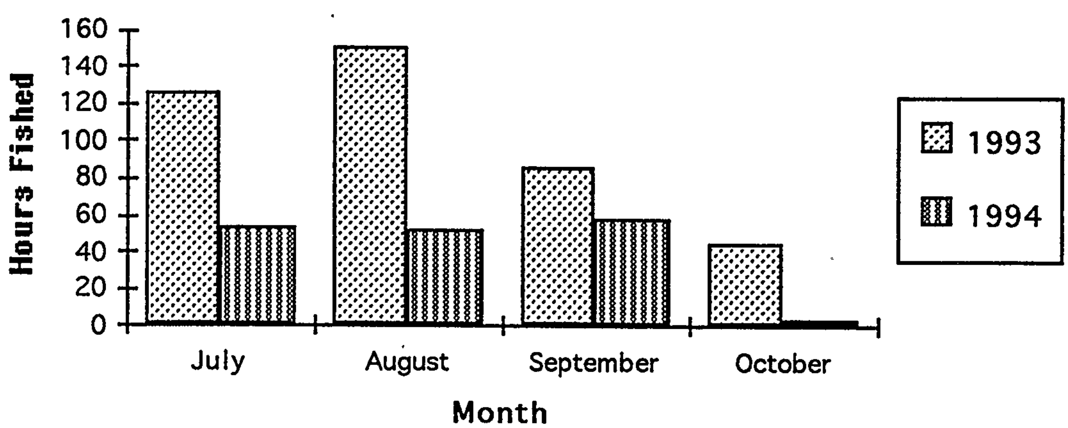

Figure 6.2 Monthly distribution of angler hours - 1993 and 1994 Season

6.3.2 Length of Angler Kept Fish (1993)

As illustrated in Figure 6.3, the length of fish kept (1993 only) was divided into four size categories. Length data were not obtained for two of the angler kept fish.

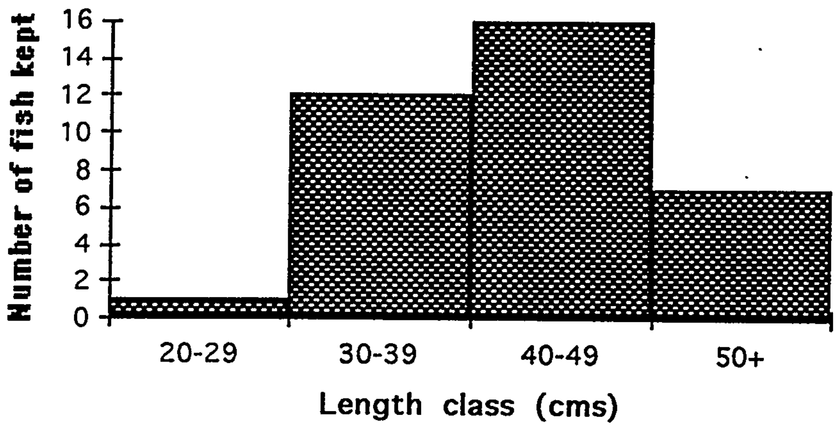

Figure 6.3 Length of angler kept fish - 1993 (N=36)

6.3.3 Tag Returns

Information on the number of tagged fish caught was also obtained through the creel survey. According to the survey, five tagged fish were caught in 1993. In 1994, the survey showed the recapture of nine tagged fish.

6.3.4 Angler Location

When possible, information was collected on the angling location. Locations were divided into five categories, each was given a number as in Figure 6.4. This information is summarized in Figure 6.5.

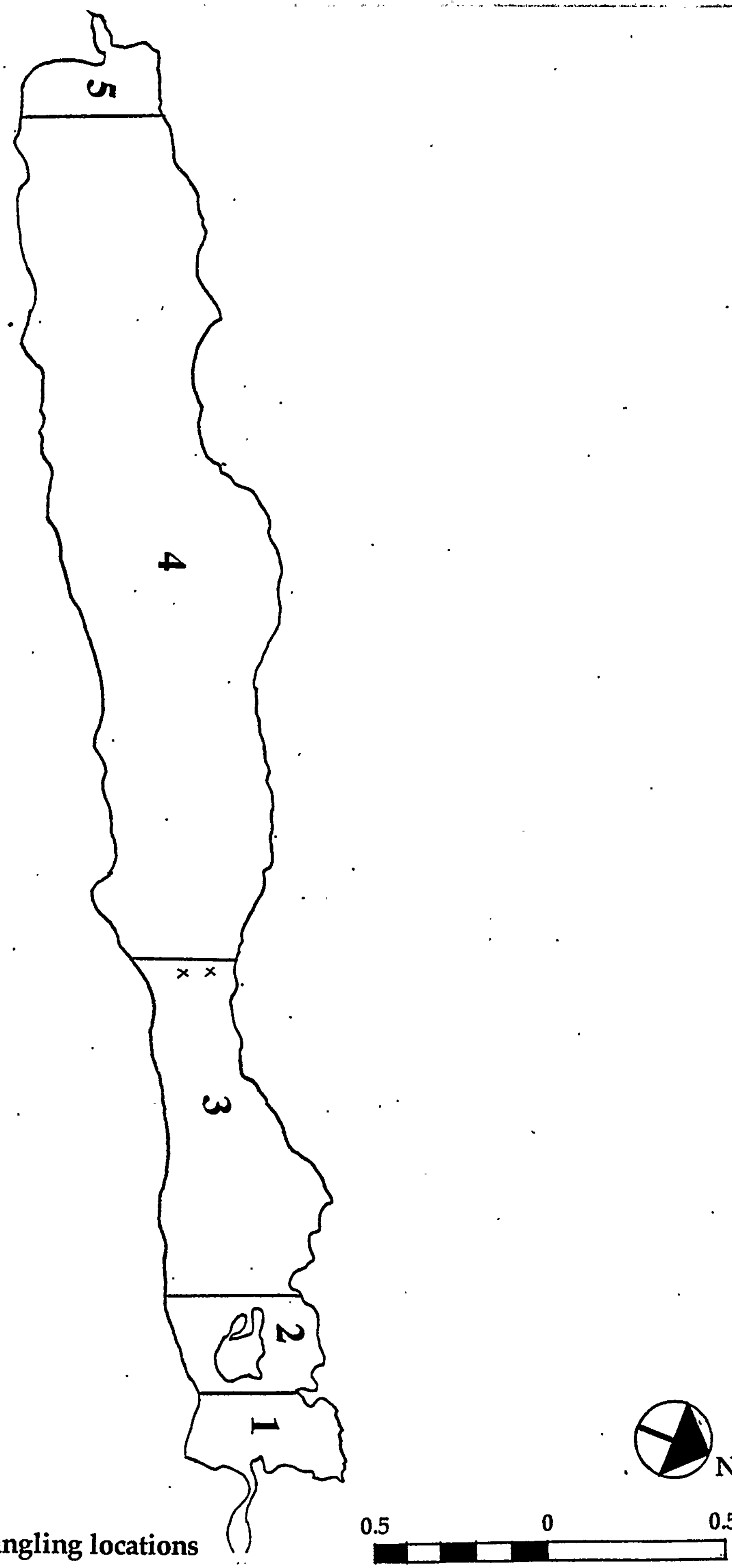

Figure 6.4 Marvel Lake angling locations

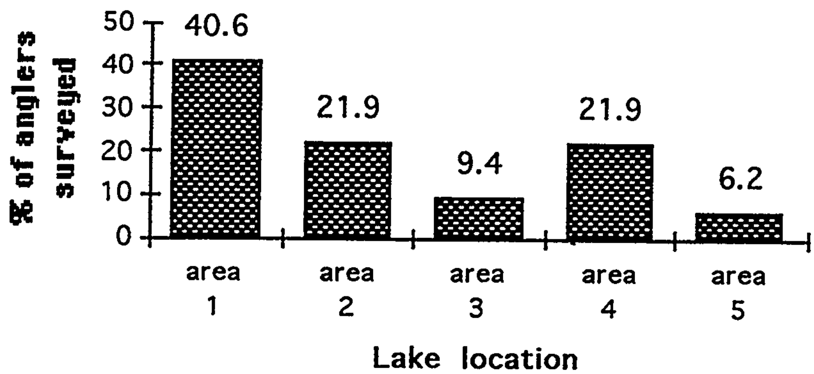

Figure 6.5 Angler use of five angling areas on Marvel Lake - 1993 and 1994 (N=32)

6.3.5 Angler Residence

A blank requesting the permanent residence of the angler was included at the beginning of the survey card. The information obtained is summarized in Table 6.2.

Table 6.2. Permanent Residence of Surveyed Anglers - 1993 and 1994 (N=98)

Permanent Residence	% of Respondents
Calgary	64
Banff/Canmore	23.3
Edmonton	3.9
Other Alberta	2.0
British Columbia	4.8
UnitedStates (Washington, California)	2.0

6.3.6 Length of Fishing Trip

One of the questions asked about the length of the fishing trip in the area. When this question was answered, 72% of respondents said they fished the area for one day, 27% fished it for two days and 1% fished the area for 3 days (N=81, 1993 and 1994 combined data).

6.3.7 Angler Comments

The last question on the creel card asked the anglers to write down any comments or suggestions they had. A total of 19 cards (1993 and 1994) contained relevant comments. Six of these simply complemented the area's beauty and/or the quality of fishing. The comments on the remaining cards are summarized below:

One card suggested the introduction of bull trout.

One (1993) simply stated: Continue to preserve this lake. The 1 limit is ok.

One of the 1993 cards suggested making the lake catch and release. In 1994, following the implementation of this regulation change, one angler recommended that the lake should also be fly fishing only. This was following the death of a fish he had caught using a spin rod and lure.

One card recommended that the limit be raised again to two fish.

Three cards questioned the closure of the logjam area and one suggested that the success rate in other areas on the lake was very low with this area closed. One card commented that the success rate in general was low.

On two of the cards, disapproval of the tagging program was expressed. The reasons for this unhappiness were not elaborated upon. It is thought that both of these cards were filled out by the same person.

Two of the cards suggested that a stricter surveillance of the zero possession regulation (1994) was needed, as well as more wardens to stop poaching.

In addition to the above, I talked with many anglers and the following is a summary of the most frequently mentioned comments and suggestions.

In general, repeat anglers commented on how the average size of fish caught has decreased over the years (last 10-15 years). Most of those I talked to were supportive of the decreased limit of 1 fish (1993). One angler stated that he would rather see the lake closed for a few years as a precaution and then re-opened when stocks were sufficiently large that angling could continue.

When I explained the nature of this study, several anglers (and some non-anglers) expressed satisfaction with the idea of research in progress in the fishery field and stated that such projects were very worthwhile in the national parks.

6.4 Discussion

6.4.1 Fishing Pressure

It is difficult to draw conclusions concerning long-term trends in fishing pressure since no extensive data exists for comparison. However, the log book in the Bryant Creek Warden cabin contains an account of the Opening Day activity, as recorded by the district warden. This is presented in Table 6.3.

Table 6.3 Comparison of Opening Day at Marvel Lake 1987-1994

Year	Comments	Catch Limit	Other
1987	100 anglers	5	opening day July 1, closure on logjam itself and Marvel creek to Bryant creek
1988	65 anglers, estimate 100 fish kept and 100 released	5	
1989	85 anglers, 110 fish caught	5	
1990	20 anglers	2	
1991	81 anglers, 188 caught, 62 kept	2	closure markers installed in bay in front of logjam
1992	14 anglers	1	opening day changed to July 7, catch limit decreased
1993	15 anglers, 4 fish kept	1	
1994	2 anglers	0	catch and release only

As seen from Table 6.3, the number of anglers on opening day has generally declined over the past eight years. It is believed that the primary reason for this decline is the decreased catch limit and the increasing restrictions (i.e. closure of logjam area to fishing and delayed opening day).

As a backcountry lake, Marvel is approximately 14 km distant from either the Mt. Shark or Canyon Dam parking lots. Furthermore, accessing the trailhead requires a drive of approximately 45 minutes from the town of Canmore. Reaching the lake is therefore a commitment of both time and energy. The Bryant Creek area remains very popular with backpackers (primarily as a route to Mt. Assiniboine Provincial Park), and is increasing in popularity with mountain bikers. However, it would appear that anglers are less willing to make the trip when they cannot take any fish home.

These results, combined with those of Figure 6.2, may be taken as an indication of the importance of catch and keep, or consumptive fishing, to much of the angling population.

Fishing pressure was considerably lower in 1994 following the closure of the lake to catch and keep fishing. In some months, the number of hours fished in 1994 was less than half of those fished in 1993. Some external factors such as the weather, can be ruled out to explain the difference between 1993 and 1994 statistics. The summer of 1993 was consistently cold and wet, while that of 1994 was warm and dry.

This apparent emphasis on catch and keep angling seems to contradict the 1993 results, which indicated that 81% of the fish caught were released. Many studies of angler motivations have shown that the fishing experience involves more than simply catching fish (Gauthier, 1988; Fedler and Ditton, 1986; Driver and Cooksey, 1977). Often in these studies, catching and keeping fish is rated to be of low importance vis-a-vis other motivations. In spite of this, some researchers have stressed that the importance to anglers of retaining fish should not be underestimated (Matlock et al., 1988; Radonski, 1984). Radonski (1984) for example stated:

> We have seen in the past, when people are denied the opportunity to keep any portion of their catch..., fishing pressure dropped off 80% in most every case. So I would say that's a pretty substantial figure, and fish are important.

He also pointed out (1984) that people may tell you they will continue to fish but actually may reduce their fishing participation when they no longer have the opportunity to go fishing and keep something (Fedler and Ditton, 1994).

Fedler and Ditton (1994) suggest that some of the confusion in interpreting angler motivations may be the result of generalization of conclusions. They state that "motivation results for angler subpopulation groups are frequently extended or extrapolated by managers and researchers to the entire angler population or those in other contexts."

In the Marvel Lake case, it is possible that anglers keeping their catch (1993) did not fill out survey cards and thus the number of fish kept was underestimated. It may also be the case that some anglers concerned with increasing regulations claimed to be solely interested in catch and release. In this way they may hope to forestall future restrictions.

I concur that there are other aspects important in the fishing experience, such as enjoying the outdoors and relaxation. However, I also think that retaining or having the option to retain fish is more important to Marvel Lake anglers than what was indicated by the 1993 release rate statistic of 81%.

The CPUE of 0.49 (1993) increased to 0.68 in 1994. This is thought to be quite high for an alpine lake, especially for one which is not maintained by stocking and an indication of good fishing success. Potential sources of error in the CPUE are discussed in Section 6.5.

Three hooking mortalities were reported in 1994. These usually occurred when fish swallowed a lure which an angler may subsequently have attempted to remove. In addition to the reported mortalities there were likely other unreported mortalities. These could have occurred for example, if a fish died after being released and therefore the angler was unaware of its death. This illustrates the fact that although catch and release has a low impact on the population, it is not a no impact option. Since studies have indicated no significant differences in trout mortalities because of hook types (Schill et al., 1986; Dotson, 1982) it is not recommended that additional gear restrictions be imposed at this time.

6.4.2 Length of Angler Kept Fish

Almost half (44.4%) of the fish kept in 1993, were measured by anglers to have been between 400-490 mm in length. Close to 20% were said to have been >500 mm. It should be noted that Figure 6.3 only represents the lengths of kept fish and does not take into account lengths of released fish. It is to be expected that most anglers will only keep fish which are either of trophy or edible size. Although fish in the 200 to 290 mm class are of edible size, they may have been released more often or were possibly under-represented in the catch.

6.4.3 Tag Returns

The information from tag returns was used in the calculation of the population estimate. When a length measurement accompanied the tag return, this was used to calculate growth rates (provided one year had elapsed between tagging and recapture). On occasion, information on tagged fish was lost when an angler did not record or could not remember the tag number.

6.4.4 Angler Location

The majority of anglers, (62.5%) fished between the far side of the island and the bay in front of the logjam (locations 1 and 2). The pressure on these two areas was highest most likely because of the ease of access. Most anglers start their day at the lake shore meadow. For those without a boat or float tube or those with only a few hours to spend, staying in locations one and two is an obvious choice. Accessing the far end (location 5) is more time consuming, as it necessitates an extra hour and a half or more of hiking. Location four was popular with 21.9% of surveyed anglers. Examination of survey cards indicated that this area was largely frequented by groups of repeat anglers for whom this was a "favourite spot". Although no CPUE information was collected on each lake location specifically, I estimate from talking to anglers and examination of creel cards, that the success rate at the far end of the lake is currently as high or higher than that at the east end.

6.4.5 Angler Residence and Length of Fishing Trip

Marvel Lake is frequented almost entirely (87.3%) by local (Calgary and Canmore/Banff) anglers. In fact, very few anglers surveyed (6.8%), were from out of province or country. Perhaps it is due to the fact that Marvel is popular with locals that 72% of respondents fished the area for one day. Although Marvel is a backcountry lake, trail improvements and the increase in use of mountain bikes have augmented the amount of day traffic going to and from the lake.

6.4.6 Angler Comments

Some interesting and varied comments were received from anglers. In response to comment one, I would not recommend the introduction of bull trout, as this species is not native to Marvel Lake. Although cutthroat were originally introduced to Marvel and have a self-maintaining population, the introduction occurred at a time when park management philosophies were quite different from the present day. The added introduction of bull trout to an originally fishless lake is against current park management policy.

A few comments indicated the interest many anglers have personally shown in maintaining the cutthroat population. At the same time, these comments also indicate the desire to continue angling this lake.

With respect to the logjam closure and the angling success rate; it is not thought with a CPUE of 0.68 fish per angler hour, that logjam accessible fishing is required to increase the success rate. While Alberta Fish and Wildlife tries to maintain certain standards for CPUE (Hills and Stelfox, 1991) the Parks Canada objectives are less geared towards providing high catch rates and large fish. Also of a practical concern, is the safety hazard that logjam accessible angling could present, as portions of this area are unstable. As well, due to the nature of the logjam, it is very easy to snag lures and fish, either accidentally or on purpose, in this area. This is evident in the amount of fishing line and lures already visible between the logs.

In addition, observations have shown that large numbers of maturing trout move into the logjam area when the spawn is over. Opening this area to fishing has the potential to result in a decline in the numbers of young trout, which would have detrimental effects in the future. Recommended regulations are outlined in Section 9.5.

I spoke with the angler who expressed discontent with the tagging study. He is a repeat angler from Canmore and this card was filled out early in the 1993 season. I attempted to explain to him the importance of the population itself, as well as the study and hence the need for gathering information. He was however, reluctant to listen and I remain unconvinced that his ideas have changed.

The suggestions of stricter surveillance were of some concern and lead me to believe that infractions were observed. Prior to the opening of the 1994 season, a group of anglers was caught fishing in the bay area. It is thought that this was not the only infraction which took place during the season. While stricter surveillance of the regulations may be needed, district wardens have a large area to cover and are generally alone during their backcountry shifts. Increased monitoring of the lake may therefore be impractical.

In general, most anglers were either concerned about the population's status, supportive of the project and/or interested in the results.

6.5 Sources of Error

In an attempt to cut down on the number of anglers choosing not to fill out a survey card, I spoke to as many people as possible and explained the nature of the study being carried out and the importance of angler cooperation. In spite of this it is unrealistic to believe that 100% compliance was achieved.

I do not believe the problem of multiple access routes was a serious one at Marvel Lake. The majority of anglers take one of the two trails that lead to the meadow and then depart from this point. I did once however, meet up with a group of anglers who had continued on the Wonder Pass trail to the far end of the lake, without stopping by the meadow. They were therefore unaware of the survey being conducted.

As was shown in Figure 6.5, only 6.2% of the anglers surveyed, fished the far end of the lake. In my experience, information gained through foot and boat surveys of the lake, showed that this was the only group of anglers likely to continue to the far end without stopping at the meadow. Given the size of this group relative to the others and the frequent (usually twice a week) surveys of the west end, I would estimate that the loss of information was minimal (not more than a few anglers per season).

A few times I encountered anglers who were under the impression they were only requested to fill out a survey card if they had caught some fish. This would have resulted in an overestimation of the CPUE but to what degree is unknown.

I am also aware of the fact that several times one survey card was filled out for a group of people. This may have resulted in an error in the CPUE calculation. This would be overestimated if the number of angler hours was underestimated i.e. a card actually filled out for two people represents, for example, not ten hours of fishing rather (10 *2) twenty hours of fishing.

Additional error in the total number of hours fished and in the CPUE, may have resulted from inaccurate reporting of the number of hours fished. This relies on the memory of the individual and may represent the total hours spent at the lake and not necessarily the total number of hours actually spent fishing. If it is assumed that similar type errors occurred in both seasons, then the CPUE still provides accurate trend information about the fishery.

In regards to the population estimate, some data was lost due to the fact that a couple of times anglers reported capture and release of a tagged fish for which no tag number was recorded.

6.6 Conclusion

In summary, the popularity of Marvel Lake with anglers has declined over the last several years. I think that this is due in large part to the increasing restrictions. The CPUE of 0.68 (1994), is thought to be high for an alpine lake which is not maintained by stocking. I do not suggest that the logjam or Marvel Creek be opened to fishing. However, if the lake remains catch and release, I would recommend re-opening the bay in front of the logjam to angling (see Section 9.5 for more details).

7.0 CHEMICAL CONDITIONS

7.1 Introduction

Water chemistry data were collected at five stations in each of the two years, between the months of June and October. The parameters measured were examined specifically in terms of their possible effects on individual trout, especially negative effects which could have an impact on the growth of the population. This information will also serve as a baseline against which future conditions can be evaluated. The only other chemistry data existing for Marvel Lake consists of observations collected in 1936 by D.S. Rawson (Rawson, 1939).

7.2 Methods

Chemistry stations were established using criteria suggested by the Ministry of Natural Resources, Fisheries Branch guidelines (MNR, 1987). The location of each station is shown in Figure 7.1.

For each station the following data were recorded:

1) Water surface condition - This was classified as: a) calm - glass-like appearance of water ; b) rippled - lightly ruffled, less than two cm rise in the undulations; c) wavy - ruffled, less than five cm rise ; and d) rough - waves greater than five cm in height. If conditions were rough, chemistry tests were not performed. (MNR, 1987)

2) Cloud cover - This was given as a percentage of the total sky visible. A clear sky is indicated as 0%.

3) Time - Measurements were taken during the mid-day hours, i.e. between 1130 and 1400 where possible.

4) pH - This was measured with an electronic pH metre in 1993. Before a measurement was taken the instrument was calibrated with standard solutions of pH 4, 7, and 10. In 1994, measurements were taken with a Hach kit.

5) Secchi disc depth - This is a measure of transparency which describes the extent of light penetration into the water. To obtain a reading, the disc was first lowered into the water on the shady side of the boat and the depth at which the disc disappeared from view was recorded. The disc

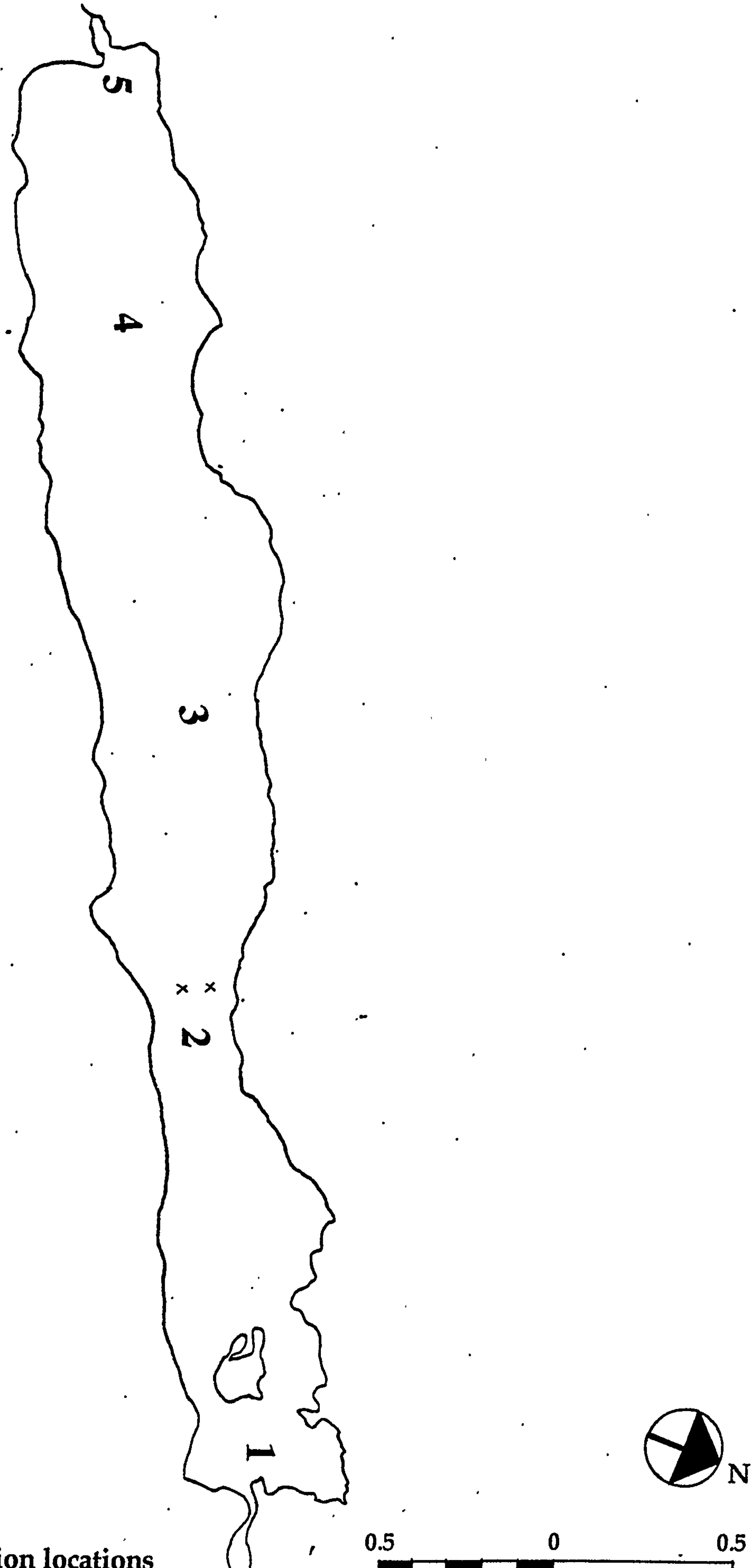

Figure 7.1 Chemistry station locations

was then raised and the depth at which it reappeared was recorded. The secchi depth was calculated as the mean of these two readings. If the lake bottom was contacted during the descent then the station depth was recorded as the secchi depth.

6) Air temperature - This was recorded prior to any measurements being taken. The air temperature was necessary to calibrate the oxygen metre.

7) Water temperature - This was taken with a YSI Water Quality Instrument temperature and oxygen metre, with a Series 5700 probe. For both water temperature and dissolved oxygen, measurements were taken every metre when the station depth was less than 10 m. When station depth was greater than 10 m, measurements were taken every 2 m. In 1993, measurements were taken to a depth of 14 m. In 1994, a new and longer cable permitted measurements to be taken to a depth of 30 m.

8) Dissolved oxygen - This was also taken with a YSI Water Quality Instrument. The oxygen metre was calibrated at each station by first taking the air temperature. Then using multiplication factors provided with the instrument and the lake elevation (5900 ft or 1770 m), it was calibrated to the saturation value of oxygen in air.

7.3 Results

7.3.1 Sampling Conditions, pH and Transparency

The results from each station over the two year sampling period of four months each, are presented in Tables 7.1 to 7.5.

Table 7.1 Sampling conditions, pH and transparency - Station 1

Date	Water surface condition	Cloud cover	Time	pH	Secchi depth (m)	Air temp (°C)
July 19, 1993	calm	5 %	9:50	8.3	>3.9	15
August7	rippled	100%	13:50	8.3	>3.9	14.4
September 17	rippled	100%	18.30	8.3	>3.9	11
October 12	calm	0%	12:30	8.3	>3.9	-
June 21, 1994	rippled	0%	12.00	-	>3.9	27
July 27	rippled	5%	13.35	8.5	>3.9	25.1
August 19	calm	0%	12.35	8.5	>3.9	21.2
Sep 15	wavy	50%	15.05	8.5	>3.9	11.1

Note: Station depth was 3.9 m.

Table 7.2 Sampling conditions, pH and transparency - Station 2

Date	Water surface condition	Cloud cover	Time	pH	Secchi depth (m)	Air temp (°C)
July 19, 1993	rippled	10%	10:50	8.4	>3.0	15
August 8	rippled	30%	11:30	8.4	>3.0	14.2
September 17	rippled	100%	20:10	8.4	>3.0	4.8
October 12	rippled	0%	13:55	8.4	>3.0	-
June 21, 1994	rippled	5%	15.30	-	>3.0	16.3
July 27	calm	0%	10.45	8.5	>3.0	25.5
August 19	calm	0%	12.10	8.5	>3.0	20.8
Sep 15	wavy	50%	14.40	8.5	>3.0	13.7

Note: Station depth was 3.0 m.

Table 7.3 Sampling conditions, pH and transparency - Station 3

Date	Water surface condition	Cloud cover	Time	pH	Secchi depth (m)	Air temp (°C)
July 31, 1993	wavy	40%	12:45	8.2	13.7	17.4
August 8	rippled	60%	12:00	8.2	17.5	13.9
September 17	rippled	100%	19:00	8.2	18.0	11.0
October 12	wavy	40%	14:40	8.2	-	-
June 21, 1994	rippled	0%	13.24	-	18.0	20.8
July 25	calm	0%	10.20	8.5	18.0	23.1
August 19	calm	0%	9.50	8.5	18.8	10.5
Sep 15	rippled	90%	9.55	8.5	18.5	8.8

Note: Station depth is approximately 64 m.

Table 7.4 Sampling conditions, pH and transparency - Station 4

Date	Water surface condition	Cloud cover	Time	pH	Secchi depth (m)	Air temp (°C)
July 19, 1993	calm	40%	11:20	8.3	19.4	16.8
August 8	rippled	80%	13:00	8.3	19.6	14.5
September 17	rippled	100%	19:25	8.3	19.2	6.8
October 12	wavy	70%	15:10	8.3	19.0	-
June 21, 1994	rippled	5%	14.50	-	19.5	16.1
July 25	calm	0%	11.25	8.5	20.5	19.9
August 19	calm	0%	10.40	8.5	18.8	13.2
Sep 15	rippled	90%	10.50	8.5	19.0	7.6

Note: Station depth is approximately 54 m.

Table 7.5 Sampling conditions, pH and transparency - Station 5

Date	Water surface condition	Cloud cover	Time	pH	Secchi depth (m)	Air temp (°C)
July 19, 1993	rippled	70%	12:15	8.3	>4.2	11.5
August 8	rippled	90%	14:25	8.3	>4.2	16.5
September 17	rippled	100%	19:45	8.3	>4.2	5.2
October 12	rippled	95%	15:35	8.3	>4.2	-
June 21, 1994	rippled	0%	14.30	-	>4.2	16.1
July 25	calm	0%	12.15	8.5	>4.2	23.5
August 19	calm	0%	11.35	8.5	>4.2	15.5
Sep 15	rippled	60%	11.20	8.5	>4.2	14.2

Note: Station depth was 4.2 m.

7.3.2 Water Temperature

Water temperature curves for the five stations, over the two field seasons, are shown in Figures 7.2 to 7.5. For the July/August graphs, an average of the temperature values at each depth was used.

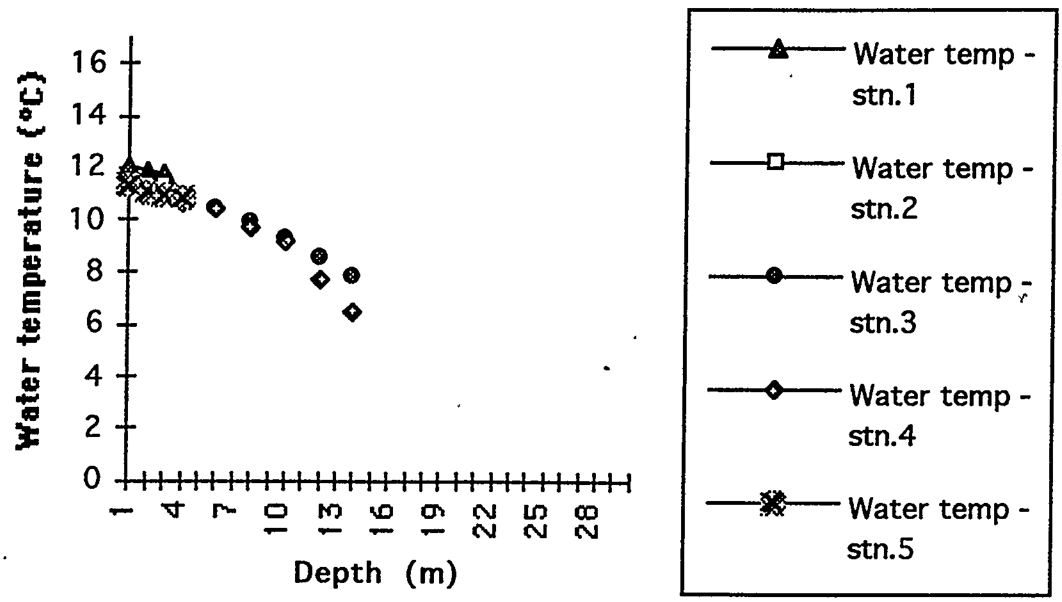

Figure 7.2 Temperature curves for five stations - July/August, 1993

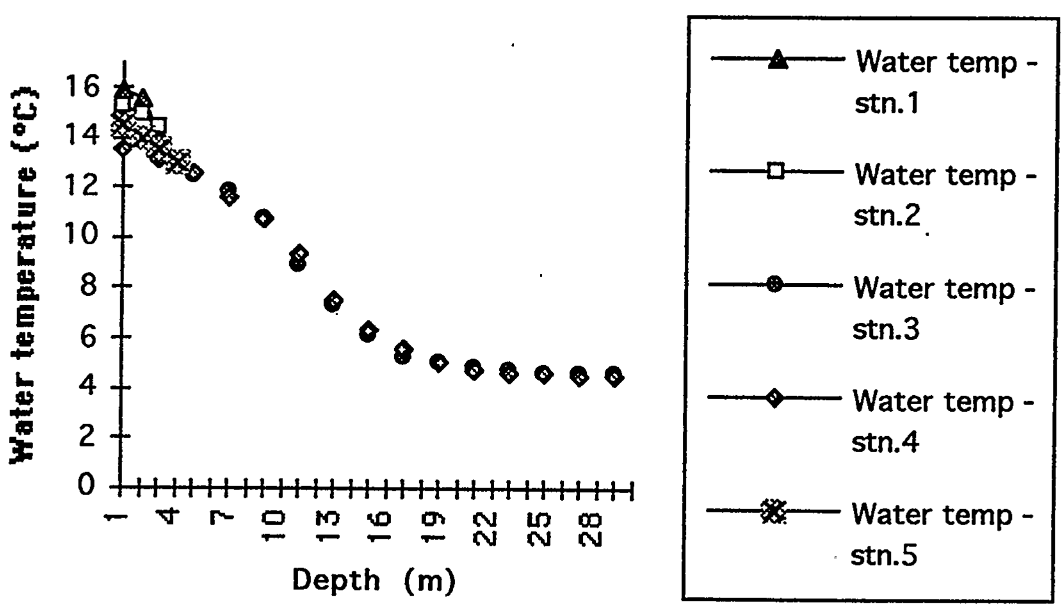

Figure 7.3 Temperature curves for five stations - July/August, 1994

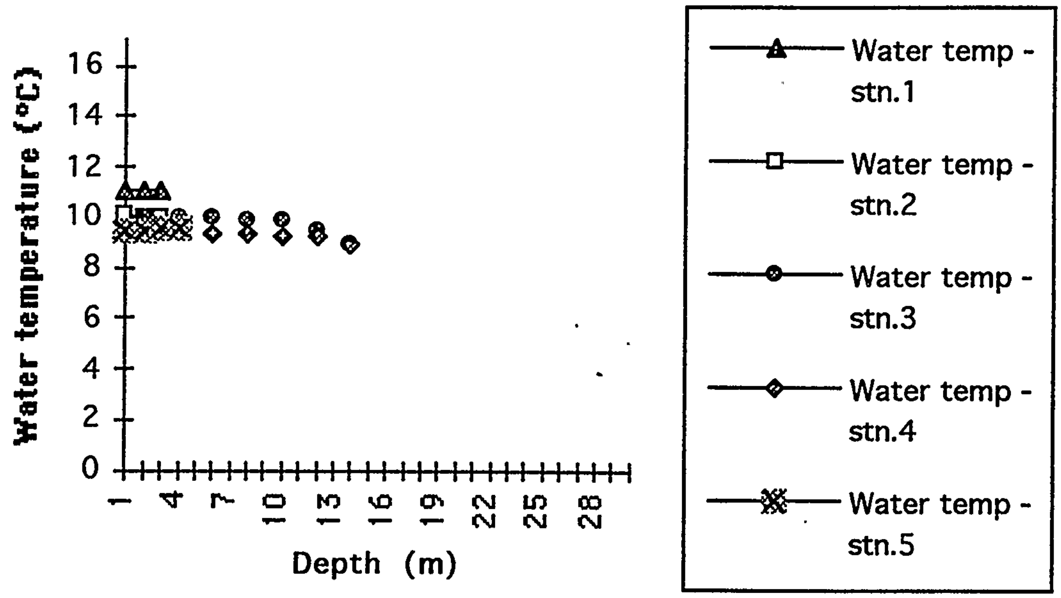

Figure 7.4 Temperature curves for five stations - September, 1993

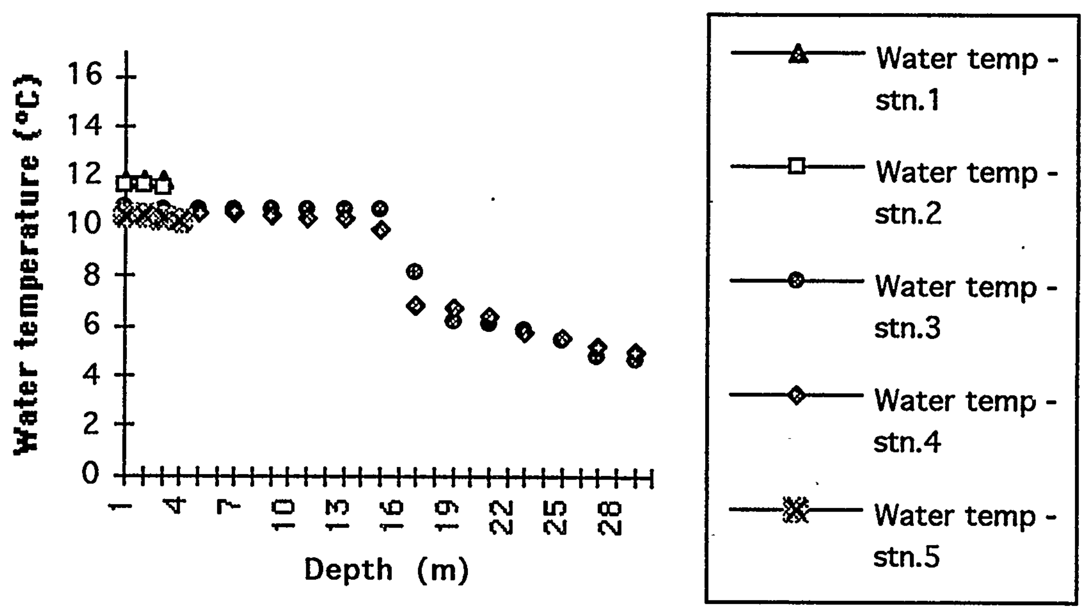

Figure 7.5 Temperature curves for five stations - September, 1994

A summary of the maximum and minimum temperatures for both years combined and between the months of July and September, is shown in Table 7.6.

Table 7.6 Temperature maxima and minima for July to September, 1993 and 1994

	Temperature (°C)	Date	Station
Maximum surface temp	16.6	July 27, 1994	1
Maximum surface temp -main body of lake	14.5	July 27, 1994	3
Minimum surface temp	9.5	September 17, 1993	5
Minimum surface temp -main body of lake	9.8	September 17, 1993	4
Maximum bottom temp -30m depth	5.0	September 15, 1994	4
Minimum bottom temp -30m depth	4.5	August 19, 1994	4

7.3.3 Dissolved Oxygen

Dissolved oxygen curves for the five stations, over the two field seasons, are shown in Figures 7.6 to 7.10. For the July/August graphs, an average of the dissolved oxygen values at each depth was used.

One set of measurements was taken on April 20, 1994, while ice was still on the lake. These results are shown in Figure 7.6.

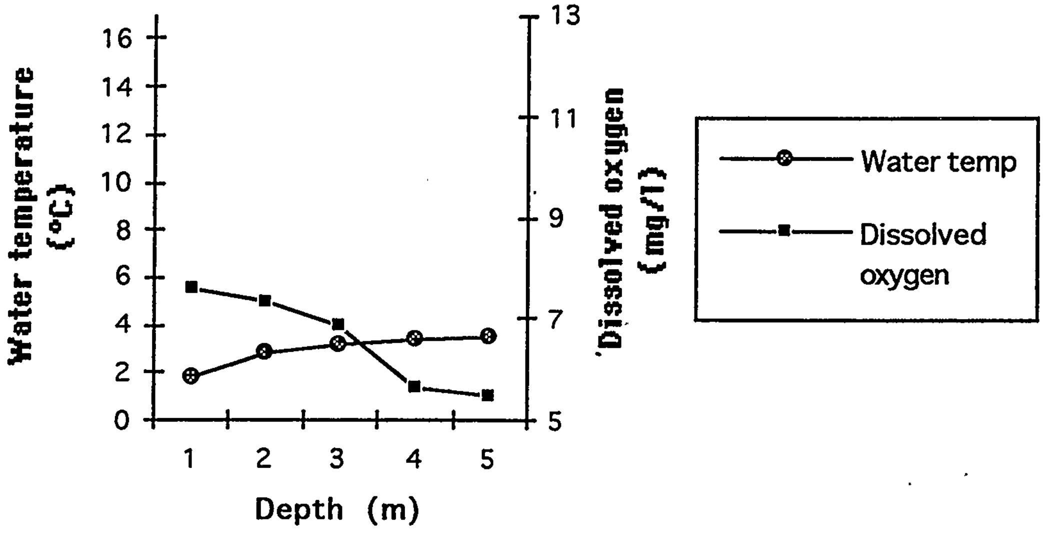

Figure 7.6 Dissolved oxygen and temperature curves for station 1 - April 20, 1994

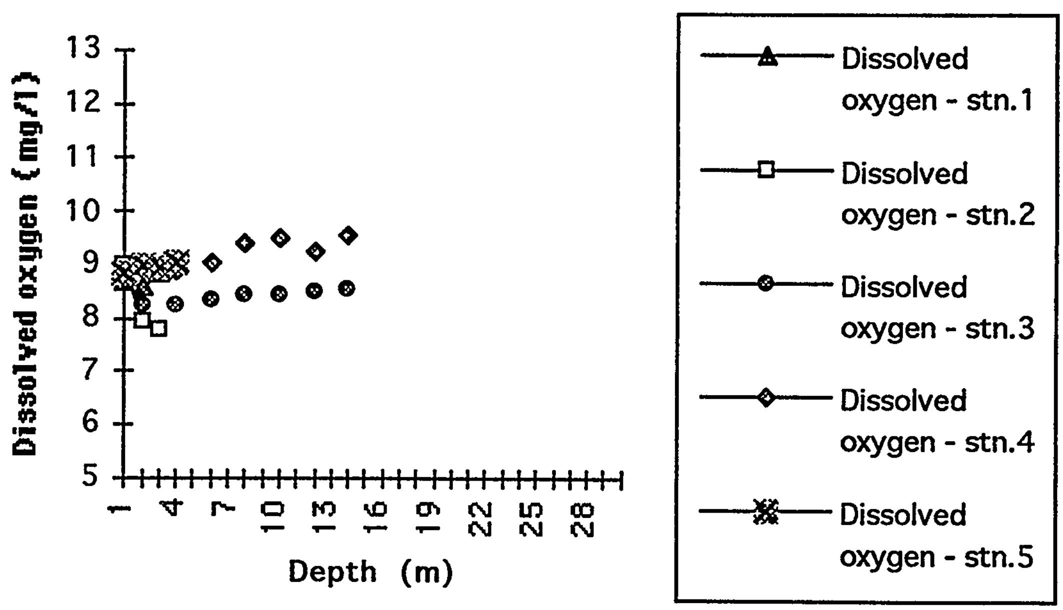

Figure 7.7 Dissolved oxygen curves for five stations - July/August, 1993

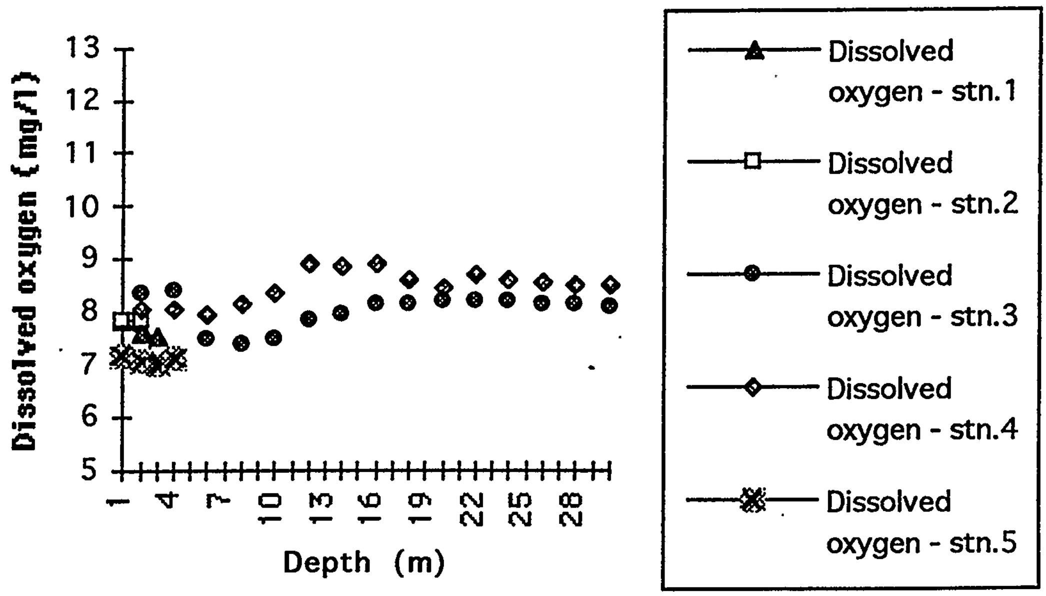

Figure 7.8 Dissolved oxygen curves for five stations - July/August, 1994

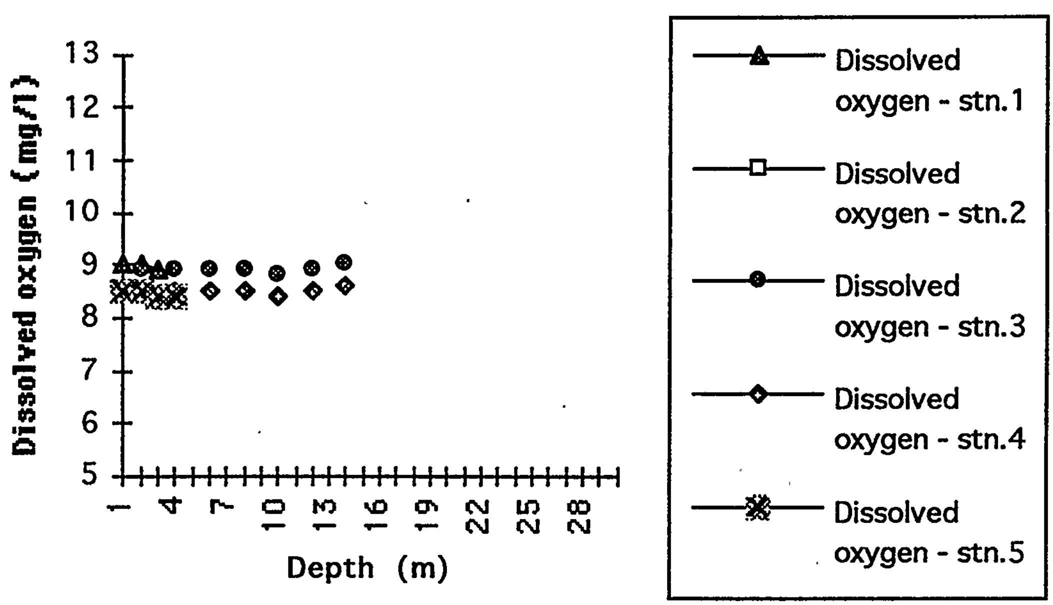

Figure 7.9 Dissolved oxygen curves for five stations - September, 1993

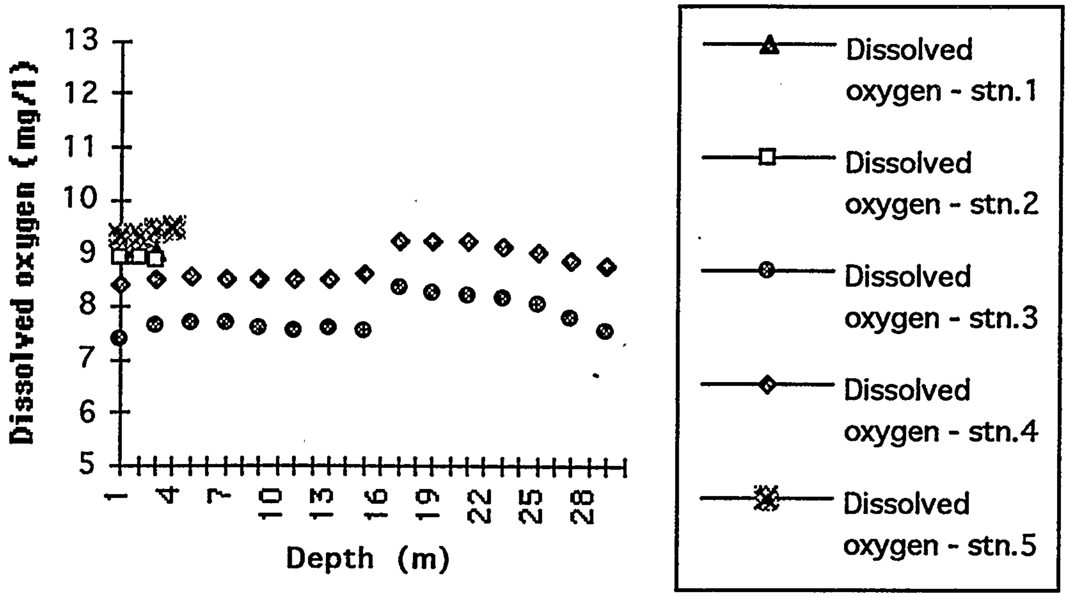

Figure 7.10 Dissolved oxygen curves for five stations - September, 1994

Percent saturation at all stations over the study period, ranged from a low of 80% to a high of just over 100%. In general it was between 85% and 95%. On April 20, 1994, the dissolved oxygen values were at their lowest and reached levels of between 42% and 56% saturation.

7.4 Discussion

7.4.1 pH and Transparency

The pH ranged between 8.2 and 8.5 over the two year study period, indicating that Marvel is a slightly alkaline lake. This pH was comparable to that of 8.0-8.1, recorded by Rawson (1939).

At three of the five stations, the secchi disc depth was greater than the station depth. At the two deepest stations, transparency was high, as was indicated by secchi depths ranging between 13.7 and 20.5 m. Transparency remained high throughout the sampling periods. Rawson (1939) documented a secchi depth of 11 m, however where this was recorded is unknown. He stated that at that time, this secchi depth was "greater than that of any other medium or large lake in the region." Similarly, when compared to the results of Anderson (1974), who surveyed 340 lakes and ponds in and near the Canadian Rocky Mountain national parks, Marvel ranked as one of the lakes with the highest transparency.

7.4.2 Water temperature

Surface temperatures differed between July and September (both years combined), by as much as 7.1°C in sheltered areas, and by as much as 4.7°C in the main body of the lake. In contrast, the bottom temperatures (taken at 30 m), differed by only 0.5°C over the study period, indicating more stable temperatures at deeper depths.

Due to the shallow location of three of the five stations, the temperatures were stable with depth, in each of the sampling periods.

Thermal stratification occurred throughout the months of July to September, in the main body of the lake (stations three and four). The thermocline, defined as the plane of maximum rate of decrease of temperature with respect to depth, is usually accepted as a change of greater than 1°C per metre (Wetzel, 1983). The location of the thermocline is also affected by the lake transparency. Since Marvel's transparency is high, light penetrates deeper than in most other lakes surveyed, and therefore it can be expected that the thermocline will be deeper. In Marvel, the thermocline was located at station three between 10-14 m in July/August, 1994 and between 16-18 m in September, 1994. At station four, the thermocline was located between 10-14m in July/August, 1993 and 1994 and between 16-18 m in September, 1994. The thermocline is likely deeper in September because the lake has absorbed enough solar radiation to warm the 10-14 m depth zone.

7.4.3 Dissolved Oxygen

The solubility of oxygen in water is affected by temperature. The dissolved oxygen concentration increases with a decrease in water temperature, however not necessarily in a linear relationship (Wetzel, 1983). The solubility of oxygen in water is also affected by pressure, hence the lake elevation influences the oxygen concentration (Wetzel, 1983). The elevation was taken into account when measurements were made.

On April 20, 1994, while ice was still on the lake, temperature and dissolved oxygen measurements were taken to represent winter conditions at the lake. Temperature values were lowest at the surface and increased gradually with depth. Despite the low levels of percent saturation, oxygen values at the surface remained above 7.5 mg/l, which was comparable to levels measured across the lake in July through September.

As with the water temperature, dissolved oxygen values varied little with depth (less than 1 mg/l change) in the shallow stations (one, two and five), over the months of July to September.

In the deeper stations, dissolved oxygen levels generally increased with depth and decreasing water temperature, as was expected. The location of greatest change in dissolved oxygen levels (an increase) occurred at the thermocline.

Percent saturation values were high, above 80%, throughout the season and at all stations over both years, with the exception of the April measurements. In a few cases, saturation levels exceeded 100%. This was usually at the surface and may have been the result of turbulence caused by wind action.

7.5 Conclusion

Marvel is a slightly alkaline, highly transparent lake. It is thermally stratified in the deep water between the months of July and September. Over the course of the study, surface water temperatures did not exceed 16.6°C (July, 1994), and were recorded to a low of 2°C (surface) and 4°C (4m depth), in April, 1994. The fish are therefore exposed to a wide range of temperatures over the year. However, these temperatures are not outside of the range of tolerance reported for several trout species (Cherry et al., 1977; Crisp, 1981 and Armour, 1994). Furthermore, results showed that below the thermocline (in July to September), temperatures were less variable than those above the thermocline, changing by less than 2°C over a depth of approximately 13 m. A more temperature stable environment is thus provided for the fish.

Marvel is well oxygenated throughout the summer and fall, with percent saturation levels exceeding 80% to a measured depth of 30 m. One winter sampling session showed percent saturation levels as low as 42%, however, in terms of mg/l, the oxygen levels were comparable to lower summer and fall levels. Therefore, low dissolved oxygen levels are probably not a factor leading or contributing to fish mortality.

8.0 BIOLOGICAL CONDITIONS

8.1 Introduction

A study was made of the quantity and species of zooplankton and benthic invertebrates. The abundance of these organisms will affect the number of fish the lake can sustain, as well as fish growth rates.

8.2 Methods

8.2.1 Zooplankton

Plankton were collected with an unmetered tow net (mesh size 153 μm, mouth diameter 14.2 cm) from a boat. Both horizontal and vertical hauls were taken. The contents of each tow were preserved with 70% ethanol in the field. Locations of hauls from both years, are shown in Figure 8.1. The numbers refer to sample numbers, the details of which are given in Appendix B. Samples were divided into near-shore (littoral) and off-shore (pelagic) zones. For purposes of this study, littoral samples were classified as those up to 5m in depth. Pelagic samples were taken in the open water up to a depth of 20m. Results from the samples of the two seasons were combined.

In the lab, each container was topped up to a volume of 50 ml. The sample was then stirred with a magnetic stirrer and if the contents were dense, a subsample was taken. This subsample was placed in a counting cell and examined under a dissecting microscope. To estimate the total number of organisms in a 50 ml sample, the number identified in the subsample was multiplied by 50 ml and divided by the subsample volume. Individuals were identified to Order.

The average number of organisms per litre of lake water was calculated. The volume of water passing through the tow net (Lind, 1974) was calculated as:

$$\text{Volume } (m^3) = \text{length of tow (m)} * \pi(r)^2$$

where r is the radius of the net opening in metres.

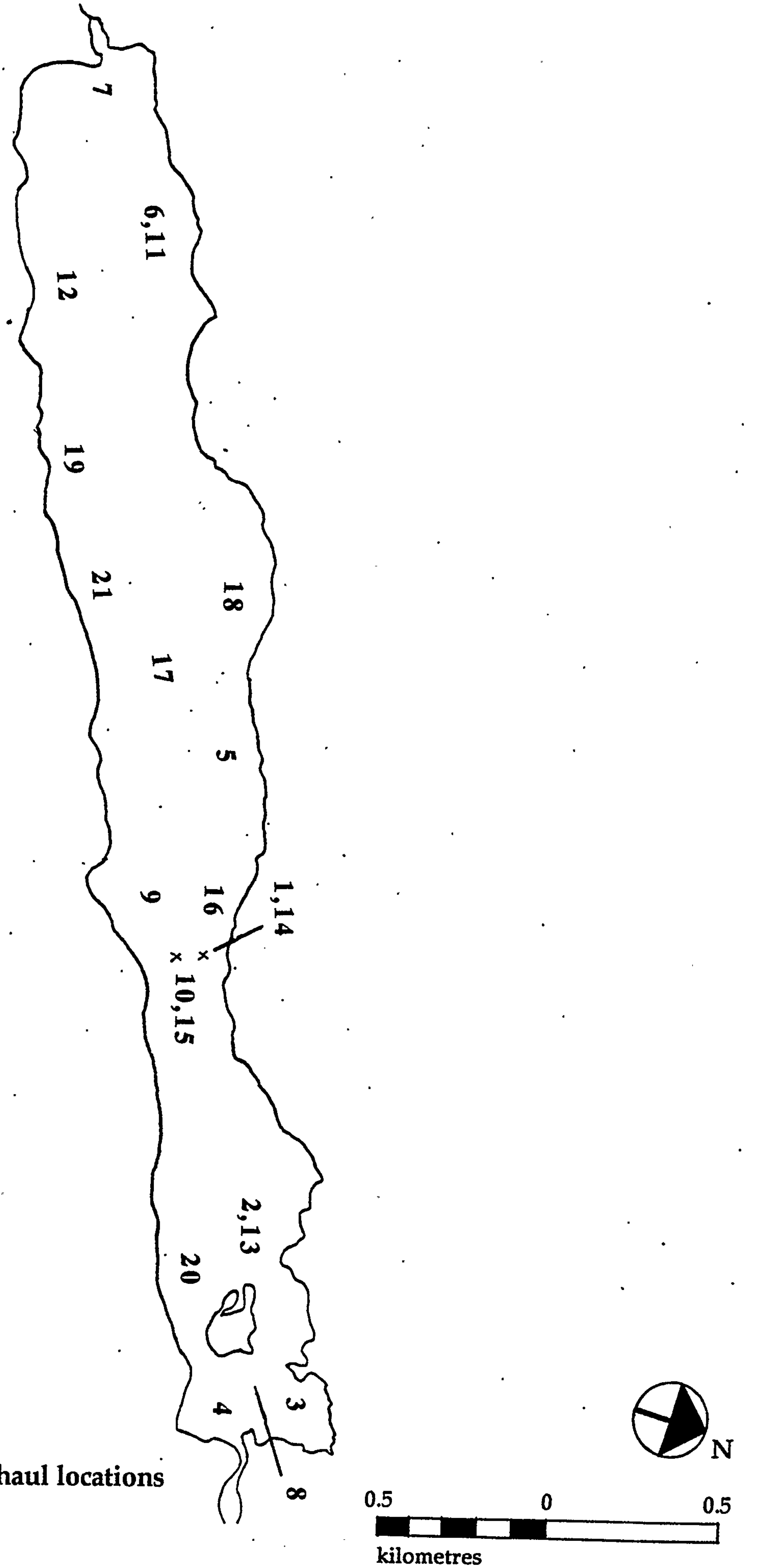

Figure 8.1 Zooplankton haul locations 1993 and 1994

8.2.2 Benthic Invertebrates

Samples were taken at a variety of locations around the lake (Figure 8.2) and an effort was made to sample areas of different substrates. Numbers in the figure refer to sample numbers and details of the hauls from both years, including date, substrate composition and depth are given in Appendix B.

With the exception of several kick samples, all samples were taken with an Ekman grab (dimensions 14 cm)^2. When taking a sample, the substrate composition and depth of sample were recorded. Incidental observations of invertebrates that were not collected in grab samples were also recorded.

Each Ekman sample was sifted through a wire mesh screen (mesh size 1.5 mm). Water was poured over the top of the screen to dissolve the sediment and aid in locating invertebrates. Invertebrates were sorted live and were preserved in a 70% ethanol solution.

In the lab, specimens were identified with a dissecting scope, using between 12 and 50 x magnification. References used in identifications were: Clifford (1991), Pennak (1989) and Ward and Whipple (1966). Assistance and verification of some specimens was provided by Don Iredale, Department of Biology, University of Calgary.

All specimens were identified to Order. Where possible some were keyed to another level such as Family or Genus.

Samples were grouped into depth zones. Results were presented as an average number of organisms per sample, as well as an average number of organisms per square metre.

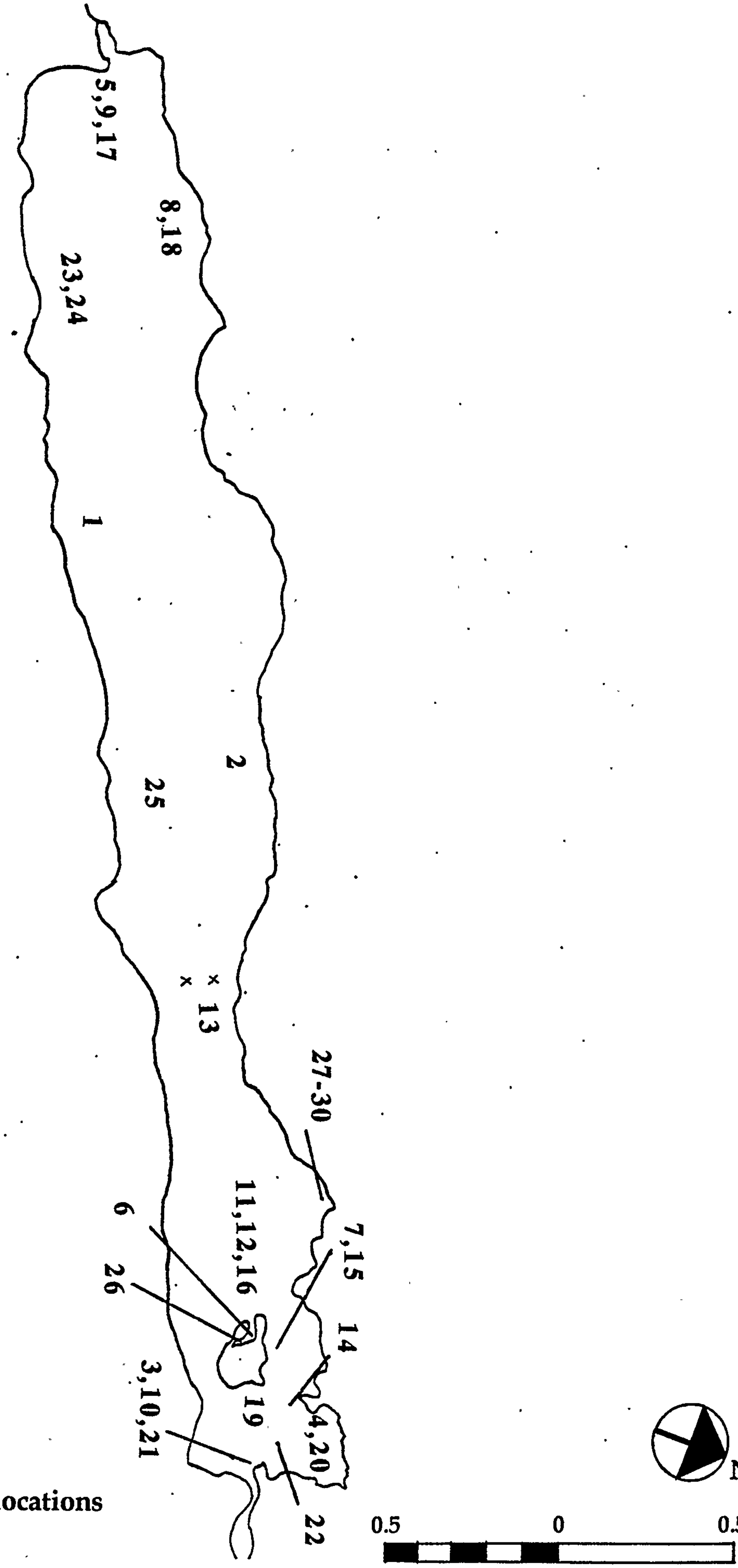

Figure 8.2 Benthic haul locations 1993 and 1994

8.3 Results

8.3.1 Zooplankton

The average number of organisms per litre was calculated for the littoral (N=8) and pelagic zones (N= 10) and the results are shown in Table 8.1.

Table 8.1 Average number of organisms per litre

Order	Average number per litre	
	Littoral	Pelagic
Copepoda - Nauplius	8.5	8.7
Copepoda - Adult	1.3	10.9
Rotifera	0.9	0.42
Cladocera	0.24	0.63
Insecta	0.19	0.063

The results of the hauls showed that the adult copepods were more abundant in the deep water than the nauplii. In shallower, near-shore waters, adults and nauplii were equally abundant.

Horizontal or surface hauls were also used to supplement the information gathered from the vertical hauls. These were not analyzed quantitatively. Similar organisms to those found in the vertical hauls were identified. In addition, chironomid remnants and a plecopteran were found in some of the surface hauls.

In addition to my data, further information on the plankton composition of Marvel Lake was found in Anderson (1974) and Rawson (1939). The organisms which have been identified in these sources, as well as my data, are shown in Table 8.2.

Table 8.2 Plankton species identified in Marvel lake

Order	Family	Genus	Species
Cladocera	Polyphemidae	Polyphemus	pediculus
	Chydoridae	Chydorus	sphaericus
	Bosminidae	Bosmina	
Calanoida Subclass Copepoda	Diaptomidae	Diaptomus	arcticus
		Diaptomus	tyrrelli
		Diaptomus	eiseni
Phylum Rotifera Order Ploima	Brachionidae	Kellicottia	longispina
		Notholca	longispina

8.3.2 Benthic Invertebrates

Composition of the substrate varied widely around the lake, but was generally a combination of silt mixed with sand, gravel or pebbles. The substrate at the foot of slide paths was usually a silt/mud mixture containing twigs and needles.

Due to the gravelly nature of the substrate at the Terrapin inlet to Marvel Lake, sampling with the Ekman was often unsuccessful or difficult. Observations of invertebrates supplemented the dredging hauls. In early August, abundant Trichoptera were seen in the shore areas near the inlet creek.

Similarly, on several occasions, Ekman samples were attempted at various slide paths along the south side of the lake. The substrate, consisted of many medium to large size rocks, as well as branches. These often became jammed in the jaws of the dredge, and prevented successful sampling efforts. However, abundant Trichoptera (generally smaller in size than those caught elsewhere), were observed on rocks at the water's edge.

In late July and early August, a series of kick samples down Marvel Creek, revealed the presence of mayfly nymphs, which were in abundance, as well as adults. Stonefly nymphs were also caught. Emerging adult stoneflys were observed. Other kick samples showed the presence of beetles (Coleoptera). Black fly larvae (Diptera - Simuliidae), were abundant down Marvel Creek in June. They were attached to vegetation and especially noticeable anchored to the vexar posts and netting. A September kick sample in the silt/mud bottom of the bay in the island, revealed abundant trichopterans, as well as a few gastropods.

The results of the Ekman dredge samples are shown in Table 8.3.

Table 8.3 Average number of invertebrates with 90% confidence limits, in Ekman dredge samples for four depth zones

	Depth Zones (m)			
Order	**0-5**	**5.1-10**	**10.1-20**	**>20.1**
Pelecypoda	39.2±26.8	7.5±9.3	2.5±0.8	26±23
Amphipoda	4.4±2.5	1.8±1.0	1±0	0.5±0.8
Trichoptera	0.5±0.3	0.25±0.4	-	0.5±0.8
Diptera Chironomidae	10.2±6.7	-	-	-
Tipulidae	0.06±0.09	-	-	-
Ephemeroptera	0.28±0.2	-	-	0.5±0.8
Gastropoda	0.89±1.0	-	-	-
Megaloptera	0.22±0.4	0.25±0.4	-	-
Hirudinea	0.06±0.09	0.25±0.4	-	-
Plecoptera	0.22±0.4	-	-	-
Oligochaeta	0.170±.27	-	-	-
Copepoda	0.390±.44	-	-	-
Number of samples	18	4	4	4

A more detailed listing of the family, genus or species of organism identified is given in Table 8.4.

Table 8.4 Taxonomic descriptions of benthic organisms

Order	Family	Genus
Amphipoda	Gammaridae	Gammarus
	Talitridae	Hyalella
Cladocera	Polyphemidae	Polyphemus
Coleoptera	Dytiscidae	-
Calanoida Subclass Copepoda	Diaptomidae	Diaptomus
Diptera	Chironomidae	-
	Tipulidae	-
	Simuliidae	-
Ephemeroptera	Siphlonuridae	-
	Leptophlebiidae	-
Gastropoda	Planorbidae	Promenetus
	Lymnaeidae	-
Hirudinea (Pharyngobdellida)	Erpobdellidae	Erpobdella
Megaloptera	Sialidae	Sialis
Pelecypoda	Sphaeriidae	-
Plecoptera	Perlodidae	-
	Chloroperlidae	-
Trichoptera	Limnephilidae	-

The average number of bottom organisms per square metre at various depths was calculated and is shown in Table 8.5. The overall average of all organisms combined was 1169 per square metre. This number was obtained by averaging the values for each of the depth zones.

Table 8.5 Average number of bottom organisms per square mètre at various depths

	Depth zones (m)			
Order	0-5	5.1-10	10.1-20	>20.1
Amphipoda	209.5	85.7	47.6	23.8
Copepoda	18.6	-	-	-
Diptera	490.5	-	-	-
Ephemeroptera	13.3	-	-	23.8
Gastropoda	42.4	-	-	-
Oligochaeta	8.1	-	-	-
Pelecypoda	1866.7	357.1	119	1238
Plecoptera	10.5	-	-	-
Trichoptera	23.8	11.9	-	23.8
Hirudinea	2.7	11.9	-	-
Megaloptera	10.5	11.9	-	-
Diptera (Other)	-	-	-	23.8
Totalnumber	2697	479	167	1333
Numberof samples	18	4	4	4

8.4 Discussion

8.4.1 Zooplankton

A study done by Anderson (1974) examined the plankton communities of 340 lakes and ponds in the Canadian Rocky Mountains. Marvel Lake was one of the lakes studied and Anderson's results showed a maximum number of 8.7 organisms per liter. A brief survey of the results from some of the other lakes studied by Anderson, indicated that Marvel had one of the higher densities, in spite of being one of the largest and deepest lakes. According to the Anderson study, Marvel Lake also ranked high in terms of total number of plankton species (4).

While the species diversity in Marvel Lake may be considered high for an alpine or subalpine lake, when compared to other lake types, it is fairly low. Anderson (1971) suggested this may be the result of "uniform and somewhat inhospitable physical environments that provide few ecological niches". In some alpine and subalpine lakes, he states that low temperatures, very low primary production and short growing seasons may in combination make conditions very difficult and will impose limits on the distribution of certain species.

A discussion of the importance and distribution of the planktonic organisms found in Marvel Lake follows.

Rotifers are ubiquitous freshwater organisms which may reach densities of between 40 and 500 individuals per liter. However, in mountain and large oligotrophic lakes, densities of 20 rotifers per liter or less, are more common (Pennak, 1989). The data from Marvel suggests that rotifer densities are even lower than those put forward by Pennak, however it should be noted that the mesh size used in Marvel was 153μm and a mesh size of 70μm is recommended by Clifford (1991) for rotifer collection.

Although perhaps not of direct food value to fish, rotifers can serve as food to larger cladocerans, many cyclopoid and calanoid copepods, and even very small fish. These organisms in turn act as food sources for medium and large sized fish. In Marvel Lake however, because of their relative sizes, it is more likely that the cladocerans identified are feeding on organic particles such as algae, detritus and bacteria (Clifford, 1991) rather than rotifers. For the same reason, the calanoid copepods in Marvel Lake are likely feeding on minute plant material (Clifford, 1991).

Copepods, along with the Cladocera, are widely distributed in pelagic, benthic and littoral regions of fresh waters (Pennak, 1989). Copepods are an important link in the aquatic food chain. They are on an intermediate trophic level between bacteria, algae and protozoans, on one hand and small and large plankton predators (chiefly fish), on the other. While most copepods feed on plant matter, a few are predacious and some are parasitic (Clifford, 1991). In general, however, copepods are not as important an element in the fish diet as the Cladocera (Pennak, 1989).

A small number of insects were found in the plankton hauls. These most often consisted of insect parts, which may have been floating on the surface and were thereby collected in the surface plankton tows.

8.4.2 Benthic Invertebrates

The Sphaeriidae (Order Pelecypoda), also known as fingernail clams, were in greatest abundance in terms of numbers in the benthic samples at all depths. According to Pennak (1989) they are often found in "great abundance on some lake bottoms more than 30m below the surface." The immature bivalves especially, are active burrowers and have been collected from as deep as 25cm in soft substrates (Pennak, 1989).

The Spaeriidae are found on all bottom types except clay and rock and in favourable conditions, populations of more than 10,000 individuals per square metre can be counted (Pennak, 1989). They are known to be eaten regularly by numerous species of fish, including whitefish, sucker and perch (Pennak, 1989) but in Marvel Lake, they are not known to be part of the cutthroat diet.

Gastropods were frequently found in the benthic samples in the near shore zone. This concurs with the findings of Pennak (1989) who found that the majority of species and individuals inhabit the shallows, especially in water less than three metre deep. This distribution pattern is probably correlated with the abundance of food in this zone. Although many species of fish are known to feed on gastropods, they only form a significant part of the diet for a few fish species such as the suckers, perch, pumpkinseed and whitefish (Pennak, 1989). They are not known to be important in the cutthroat diet.

Chironomids (Order Diptera), were abundant in the shallowest samples, but were not found in the deeper water samples. It is thought that this absence in all other samples, may be due to the escape of some organisms from the dredge and probably from the sieve. This likely also occurred with amphipods and ephemeropterans and may have resulted in an underestimation of their densities. It has been suggested (Anderson and De Henau, 1980) that escape from the dredge by large, active invertebrates does occur and can be important.

Chironomid larvae are found in almost all types of aquatic habitats and some can live in the oxygen-poor substrata of deep lakes (Clifford, 1991). Chironomid larvae can be very important in the aquatic food chain (Clifford, 1991) and indeed this is the case in Marvel Lake, as stomach content analysis has shown.

Amphipod species are common in unpolluted clear waters, require an abundance of dissolved oxygen and tend to be restricted to shallow waters (Pennak, 1989). They may be found in high concentrations, for example, Pennak (1989) collected populations of *Gammarus* from spring brooks rich in rooted vegetation which exceeded 10,000 per square metre. In Marvel Lake, amphipods were found at all depths sampled but were especially abundant in the 0-5m depth zone.

Amphipods are an important part of the Marvel Lake cutthroat diet. The contents of one stomach (498 mm fish), revealed approximately 265 amphipods. According to Pennak (1989) "the planting of amphipods in small western lakes [in the United States], has, in a few instances been at least temporarily successful in augmenting the natural food supply of trout."

Trichopterans were also frequently found in samples throughout the depth range (except the 10.1-20 m range). The family identified is a case builder, as is common with many caddis larvae. Observations and kick samples revealed abundant Trichoptera attached to rocks and woody material which were often not collected in dredge hauls. Cases were often found in the stomachs of cutthroats indicating the importance of trichopterans in the cutthroat diet.

Ephemeropterans were found in two of the depth zones, but are thought to be in greatest abundance in running water; for example, down Marvel Creek, where they are probably an important food item for fish. This abundance, especially in late July and early August, was substantiated by observations and kick samples.

Perhaps because Plecoptera larvae are found mainly in streams and less frequently in lakes (Clifford, 1991) they were not abundant in the lake benthic samples. They were however, common in the kick samples down Marvel Creek and were often quite large when compared to the other invertebrates found. They may be important as food for cutthroats, but since many of the stomachs were from fish caught in the lake, this was not obvious in the results of content analysis.

The average number of bottom organisms per square metre at various depths was 1169. Rawson (1939) calculated an average of 2020 organisms per square metre in Marvel Lake, however over half of the samples were taken in water less than 10 m in depth. The samples were taken on September 9, 1936, however, it is unknown what sieve size was used and therefore the present data and Rawson's data may not be directly compared. He described this number as a "heavy population" and stated that it was "greater in numbers than Herbert or Third Vermillion Lakes".

8.5 Conclusion

The zooplankton in Marvel Lake was dominated by Calanoid copepods, both adults and nauplii. Rotifers were the next most dominant organisms in the plankton hauls and it is thought that their abundance was likely underestimated due to the mesh size used.

In the benthic samples, pelecypods, amphipods and chironomids (Diptera) were the organisms in greatest abundance. Trichopterans and ephemeropterans were common in the hauls in lesser numbers. As mentionned, it is thought that the abundance of amphipods, chironomids and ephemeropterans was underestimated due to the sieve size used and escape from the dredge prior to jaw closing by these active invertebrates.

9.0 MANAGEMENT

The management of any species should begin with the collection of baseline data to estimate such variables as initial population size, distribution, mortality, and growth rates. However, populations are not only limited from within, but by constantly changing external factors as well. These external factors may include environmental conditions, such as temperature and habitat availability. In some cases, harvest may also have a significant effect on population levels. Catastrophic events may also affect the aquatic system directly (e.g. avalanche) or indirectly through effects on the surrounding terrestrial system (e.g. fire). While the effects of such events may be predictable, the timing of the events themselves and the magnitude of their effects are unpredictable.

Therefore, a great deal of information is needed to piece together a preliminary picture of the relationship between a species or population and its environment. The present study has resulted in the collection, compilation and analysis of baseline data for the cutthroat population and the environmental conditions of the lake. Furthermore, it has taken into consideration the potential effects of external factors on the population.

In the future, the information can be used to evaluate the magnitude of changes within the population, as well as in the external environment. Shortly the information will be discussed in the context of management issues. These issues will be identified and then options which address them will be recommended.

9.1 Overview of the System

The complexity of the aquatic ecosystem, and the multitude of factors affecting it, is illustrated in Figure 9.1.

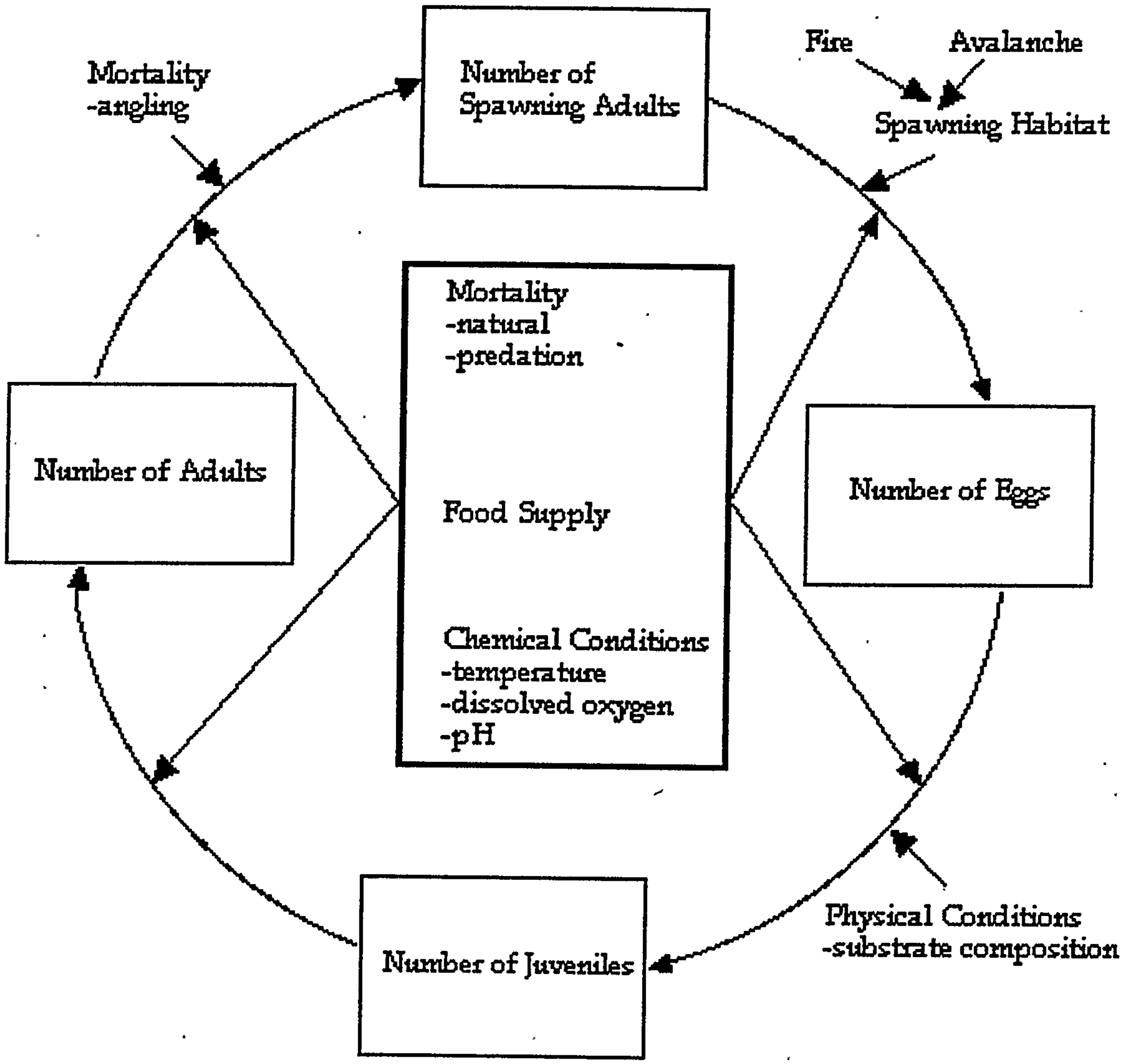

Figure 9.1 Overview of aquatic system components

While some of these parameters can (and have) been measured, the effects of others on the system are unpredictable. Catastrophic events such as avalanches and wildfires may have direct or indirect effects on the aquatic system which may be short or long-term.

For example, avalanche slide paths are visible along both the north and south shorelines. On the north shore, the avalanches have taken down trees and resulted in accumulations of logs in the water at the foot of the slide paths. Although this may provide cover for maturing fish, it has also resulted in sediment loading. The substrate at the foot of the slide paths is generally silt and organic debris. While some of the sediment would have a local effect, a portion of it is likely carried downstream where it may settle in the outlet or down the creek.

The terrain on the south side of the lake is steeper and several paths, the result of rock slides from Marvel Peak, can be seen primarily in the west end of the lake. These rock slides have eroded the shoreline, resulting in a diminished littoral zone, which rapidly slopes down (at a distance of less than one metre from the shoreline) to depths of seven to ten metres.

One of the effects of the sudden increase in depth is to diminish potential shore spawning opportunities in areas where other favourable conditions, such as substrate particle size and aeration of gravels by wind and wave action, exist.

Fires, whether natural or man-caused, can also affect the aquatic environment. Suspended sediments in the water for example, can greatly increase after a fire (Brown and Binkley, 1994). Settling soil particles "reduce porosity of gravel beds, generating anaerobic conditions unsuitable for spawning and blocking emergence of fry from gravel" (Brown and Binkley, 1994). Factors affecting the amount of sediment which reaches the water include the weather and the slope of the terrain.

The water temperature can also be altered by fire. The magnitude of effects would change depending on the time of year and location. For example, a fire along the creek could result in increased water temperatures. If this event were combined with low flows in late summer, the effects could be detrimental to all life history stages of the fish (Brown and Binkley, 1994).

Although these events are naturally occurring, they are unpredictable and highlight the dynamic nature of the system. Therefore while managers should be aware of them, and their potential effects on the population, they cannot be readily accounted for in management planning. The following sections concentrate on issues which can more easily be included and addressed in an aquatics management plan.

9.2 Ecosystem Protection and Species Preservation

Parks Canada policy clearly states that ecosystems must be managed "in such a way that ecological processes are maintained and genetic, species, and ecosystem diversity are assured for the future" (Canadian Heritage, 1994). This would put the importance of ecosystem protection and species preservation above the provision of angling opportunities to park visitors.

9.2.1 Spawning Habitat

In terms of protection of the aquatic system, the maintenance of spawning habitat is essential. As discussed in detail in chapter five, the majority of suitable spawning substrate is located in the logjam area and down Marvel creek. While spawning is known to occur in at least one inlet creek, the number of fish using this area is low.

Since the substrate in front of the logjam is largely overlaid with silt and in sections of Marvel Creek a thin layer of gravel is underlaid with silt, the potential for redd siltation exists. This potential is especially high later in the summer (July), when water levels generally drop. Although fish are not spawning at this time, eggs may still be incubating in the gravel. As was discussed in Section 5.3.6, fry emergence in Marvel Creek and the logjam occurred in mid- to late July. Therefore, in early July a silt load, such as could be caused by anglers walking through the creek, in combination with low flows, could result in increased egg mortality. Furthermore, direct egg mortality could be the result of redd disturbance also caused by angler wading.

Roberts and White (1992), studied the effects of angler wading on the survival of trout eggs and pre-emergent fry. In a multiple wading experiment (a 75 kg person waded twice daily), from the period of egg fertilization to fry emergence, 83% of eggs and pre-emergent fry of cutthroat trout were killed. Mortality from multiple wading varied during other developmental stages from 11 to 72% (eggs and/or fry depending on the treatment).

In single wading experiments, mortality for cutthroat, brown and rainbow trout ranged from 0 to 43% depending on the stage of development. Roberts and White suggest that where spawning habitat is limiting, as is thought to be the case in Marvel Lake, "the benefits of protecting spawners could later be nullified by high-intensity angler wading in incubation areas".

For these reasons, I recommend that the area directly in front of the logjam and down Marvel Creek, at least as far as the second set of falls, remain closed to angling at all times.

9.2.2 Law Enforcement

Another important management issue is that of enforcement of the regulations. While some violations occur out of ignorance, others are committed knowingly. Over the study period, several violations including: fishing out of season, fishing in a closed area and exceeding the possession limit for trout, were observed. In addition, it is likely that some poaching is occurring but the amount is unknown.

Apart from fisheries infractions, other activities, such as illegal camping, especially along shorelines, and improper disposal of garbage could have negative effects on both the aquatic and surrounding terrestrial ecosystems.

In order to ensure the preservation of the population and protection of the local ecosystem, the continued presence of backcountry patrol wardens is necessary.

9.2.3 Ecosystem Role

Fish are only one of a multitude of species in the aquatic and surrounding terrestrial ecosystems. Their presence helps to sustain a variety of animals including loons, bald eagles and grizzly and black bears, all of which were observed during the study period. Apart from serving as a prey source for other species, the trout also act as predators on zooplankton and benthic invertebrate species in the lake. In addition, the natural death of the trout is all part of nutrient cycling in the ecosystem. Bacteria in the water work to decompose dead fish and release such important elements as carbon back into the system.

The fish population therefore plays a role in such ecosystem processes as nutrient cycling, as both a predator and prey.

9.2.4 Role in Maintaining Biodiversity

As discussed in Section 1.1, national parks play a vital role in protecting biodiversity. The fact that the Marvel Lake population differs genetically from cutthroat populations in other Banff National Park lakes (McAllister et al., 1981), highlights the importance of each population as a source of genetic material.

Each of these populations has been isolated from the effects of introgression and have in their 60 or more years of existence, become adapted to the environmental conditions of their particular bodies of water. Furthermore, it has been estimated that only a half dozen lakes in Alberta may contain genetically pure stocks of westslope cutthroat trout (Clyde Park, pers.,comm.). Therefore, protection of the genetic diversity found in the Marvel Lake and other populations is a management priority.

It should however be mentioned, that while the Marvel Lake cutthroat contribute to biodiversity when considered in a regional or provincial context, their presence as an introduced species in Marvel Lake may actually have lowered the biodiversity in the lake ecosystem.

While it might be possible to restore the lake to its 'pre-fish' conditions, I would suggest that drastic measures such as poisoning the lake should not be undertaken due to the importance of the stock in a broader geographic area and its potential use in species restoration efforts.

9.2.5 Species Restoration - Use of Marvel Lake Stock

One of the potential future uses of the Marvel Lake stock is as a source for restoring the species throughout its native range. Marvel Lake was used in the past as the source of fish for Job Lake which has served as the main source for stocking cutthroat trout in Alberta since about 1970 (Nelson and Paetz, 1992).

A detailed examination of this possibility was not one of the objectives of the present work, therefore a comprehensive study would have to be undertaken to determine the effects of an egg take on the population.

9.3 Recreation - Meeting the Needs of Anglers and Other Park Users

Although ecosystem protection takes precedence over human use of park resources, the human component is nonetheless important and needs to be integrated into management planning.

According to the National Parks Act (1930), national parks are "dedicated to the people of Canada for their benefit, education and enjoyment...and shall be maintained and made use of so as to leave them unimpaired for enjoyment of future generations."

With growing pressures on national parks and conflicting views on how they should be managed and on what kind of human activities are appropriate, balancing the need to protect park resources and at the same time to accommodate park visitors has become a delicate issue.

9.3.1 Park Rationale for Angling

As discussed in section three, fishing has been part of the recreational experience available to the park visitor since 1885. From that time, and for many years to follow, the fishery resource was exploited and managed for the benefit of anglers.

Until recently, Parks Canada has used angling's status as a traditional use, to justify its existence. This approach however, is no longer acceptable, as more people question the appropriateness of a potentially consumptive use of our national park resources (P. Wiebe, pers. comm.).

The current park policy (1994), puts angling into a broader context and states that it is "part of an overall aquatics program involving public education, recreation and ecosystem protection" (Canadian Heritage, 1994). This diversity of goals, shifts the emphasis on angling as a purely traditional use to angling as part of an overall park experience.

In referring to the United States national park system, Panek (1994), commented that:

> Management of recreational fisheries in the National Park System will likely continue as long as the activity is supported by the public and the fishing activities leave the resources unimpaired for the enjoyment of future generations. Properly managed and regulated recreational fishing can be entirely compatible with the service's mission.

I believe that this applies equally to the Canadian Parks Service.

9.3.2 Role of Angling in Achieving Park Goals

Although harvest may be permitted where it has been shown that populations can sustain it, in general, the baseline information to assess fish populations, as well as the potential effects of harvest does not exist. Furthermore, harvest regulations would have to be modified based on continuing stock assessments (Canadian Heritage, 1994). Given current constraints on aquatics staff, as well as funds for research, it is unlikely that such a comprehensive approach to management could be sustained.

For this reason, given the emphasis on ecosystem protection, it would appear that in most cases, management will have to rely primarily on catch-and-release to achieve this goal. Especially where populations of native species exist, conservative management would be recommended. Harvest opportunities would more appropriately concentrate on introduced, non-native fish such as brook and brown trout. In this way, the park could still provide recreational opportunities, while emphasizing the protection of "representative and unique aquatic ecosystems" (Canadian Heritage, 1994). The role of angling in public education will be discussed in Section 9.4.

9.3.3 Importance of Marvel Lake to Anglers and Other Park Users

Over the last eight years, fishing pressure has declined at Marvel Lake (section six). Information gathered from creel cards and conversations with anglers, seems to indicate that the increasing restrictions are the main reason for this trend. Although some anglers placed protection above angling opportunities in terms of importance, others clearly were concerned with the chance to keep fish. While catch-and-release fishing would accommodate the first group, it would not meet the needs of the second group.

One of the important points to consider, in reference to the catch-and-keep anglers is their reasons for consumptive fishing - is angling part of their overall park experience, or is consumption of fish their primary motive? Parks policy (1994), clearly states that consumption alone does not justify the existence of fishing in a national park setting. Anglers with this as their main goal, would probably be better served outside the context of a national park.

Other user groups utilize Marvel Lake as a destination. Backpackers, for example, camped at one of three locations within 1.5 km of the lake may also wish to fish and keep their catch. In this case, it is my opinion that angling is but a part of a park experience and achieves the goal of recreation, while enhancing appreciation and understanding of the park's natural resources and fostering a sense of stewardship for these resources.

I would recommend a more detailed park-wide angler survey to determine angler attitudes towards the fisheries resource. In the meantime, I would agree that catch-and-keep angling has a role to play in aquatics management, but the locations and species designated for the harvest of fish should be carefully considered. Recommendations specific to Marvel Lake are presented in Section 9.5.

9.4 Education - The Potential Role of Marvel Lake in an Aquatics Program

Parks Canada is committed to providing the public with:

> interesting and enjoyable opportunities to observe and discover each park's natural, cultural, historical and environmental features and processes, as well as the park's resource management issues and practices, both within and outside national parks. (Section 4.2.4)

By helping Canadians to become better informed, Parks Canada hopes to enhance the public's understanding, appreciation and enjoyment of their national parks (Section 4.2.2).

Traditionally in national parks, interpretive programs have focused on the readily visible natural, historical and cultural features of each park. In Banff National Park for example, large mammals such as bears and elk are often observed or sought out by park visitors and are therefore prime candidates for interpretive programs.

Aquatic species, on the other hand, are less visible to the average park visitor. As a result, aquatic ecosystems and the species which inhabit them have been under emphasized in educational efforts.

9.4.1 Non-Consumptive Uses of Aquatic Resources

Non- consumptive uses of aquatic resources have been encouraged in some American national parks such as Yellowstone in Wyoming. Since 1973, the area of Fishing Bridge on the outlet of Yellowstone Lake has been closed to fishing due to overharvest. This area, also important as spawning grounds for cutthroat trout, has become popular with park visitors who can observe spawning cutthroat at close range (Mayhood, 1990). In 1988, the number of visitors at Fishing Bridge reached a record high of 288,928 (National Park Service, 1993).

Similar opportunities, however on a much smaller scale, could be pursued at Marvel Lake. Spawning cutthroat in the logjam can be observed from the logs or even from shore. Also of interpretive potential is the fish jumping the falls at the lake outlet. The lake itself and its surrounding environment also presents opportunities to interpret ecosystem processes such as fires and avalanches. As well, the links between other species, such as loons, goldeneyes and moose, and the aquatic environment could be explored.

I would strongly recommend the presence of a park warden and/or interpretive personnel during the spawn, to increase the visitors' understanding and appreciation of park resources.

However, before such an activity were to be publicized, it would be necessary to assess the numbers of visitors the area could support. Most certainly, Yellowstone type numbers would far exceed the capacity of the area. However, Marvel's status as a backcountry lake would undoubtedly limit the number of potential observers.

9.4.2 Role of Angling in Public Education

Anglers have a unique perspective on the aquatics resource. According to Mayhood, (1990):

> Sport fishing encourages an appreciation and depth of ecological understanding in certain people that just is not evident in other users of the resource. Fly fishermen frequently display a knowledge of aquatic entomology that many professional biologists would envy.

In my experience, I had occasion to speak with a number of anglers and was often impressed with their knowledge of aquatic ecology. Some anglers in addition to being avid conservationists, are also good sources of information concerning long-term fluctuations in the fisheries resource (size of fish caught, success rate). I would therefore suggest that angling has a valuable role to play in educating a portion of the public. Further, I would argue that the continued presence of angling in designated areas, ensures that fish resources remain "visible" and the subject of ongoing research.

Finally, in order to reach that portion of the angling public who are still concerned primarily with a catch-and-keep experience, a more detailed fishing brochure which clearly explains park priorities and stresses angling as part of an overall park experience could prove useful. Perhaps by clearly articulating the primary purpose of national parks, through brochures and park programs, wider public acceptance can be gained for the management shift towards natural regulation of fish populations and hence the increasing use of catch-and-release fishing.

9.4.3 Education of Park Personnel

In order to adequately inform the public, park personnel must have a clear understanding of the reasons behind the management decisions. Often it is the case that the decision-makers are not those who regularly interact with the public. It is these "front-liners" - wardens and interpreters, for example - who must respond to visitor queries and explain the "whys" of management decisions. Effective communication is therefore required, not only between park employees and the public, but also between the various sections of personnel within the park.

9.5 Recommended Regulations

Recommendations for regulations specific to Marvel Lake are outlined below. They are listed in order of priority. In some cases, the recommendations may also apply to fisheries management park-wide.

9.5.1 Catch-and-Release

As of 1994, catch-and-release fishing was implemented on cutthroat and bull trout in Banff National Park. This was a conservative measure designed to protect populations of native fish in the park, about which little is known. While it is possible that harvest limits may be re-instated in designated areas, it appears that a fundamental shift has occurred in management policy away from any consumptive use of the fisheries resource - at least in the case of native fish.

Catch-and-release still provides opportunities for visitors to enjoy, appreciate and increase their understanding of fish and their environment. According to Mayhood (1991):

> The very act of establishing a catch-and-release fishery conveys the message that the stocks are highly valued, that they are too valuable to risk losing, and that it is a special privilege to fish for them. Presumably this encourages a higher degree of appreciation for the resource among anglers, perhaps motivating them to learn more about the ecological relationships of the fishes and environmental threats to them, and making it easier for managers to enlist their support in protecting the stocks and the fisheries.

Many such valuable stocks of native fish, such as that in Marvel Lake, exist in Banff National Park. Although some of these stocks may be capable of supporting a limited harvest, the amount of ongoing stock assessment which would be required to ensure their protection would not realistically be available.

I would therefore recommend a conservative approach consisting of catch-and-release fishing which is more realistic and most accurately reflects the current Parks Policy (1994), which places an overwhelming emphasis on ecosystem protection above use of the resource. The provision of catch-and-release fishing would have to be re-evaluated in the event of future changes in park policy and/or changes in the attitudes of the general public concerning the appropriateness of any type of fishing in the national parks.

9.5.2 Bay in front of Logjam

Currently, fishing in the bay in front of the logjam is restricted to that area beyond the two fishery markers, which have been installed on shore on either side of the bay. I recommend opening this bay to fishing, while keeping the logjam itself closed to angling (See section 9.5.3). The rationale for this is outlined below.

My netting results indicate a decrease in the numbers of adult trout in the logjam and bay, and an increase in the waters on the west side of the island, following spawning. By the end of June, in both years, few adult fish were counted in the logjam.

The bay and outlet area is popular with anglers because it is easily accessible from the main trail and provides shelter, for anglers in float tubes for example, from the winds affecting the west end of the lake.

Also, the current fishery markers pose a law enforcement problem because it tempts people to cast a line within the closed area. Removing the markers would simplify the regulations and visually improve the area of the lake outlet.

9.5.3 Logjam

I recommend keeping a closure on fishing in or off of the logjam for the duration of the angling season. There are several reasons for this suggestion. One of the most important - protection of the spawning habitat, as well as eggs and emergent fry in the logjam - has already been discussed (Section 9.2.1).

In addition, this area is unstable, as the logs are constantly shifting and presents a safety hazard. This would especially be a problem if the logjam were open to fishing since an increased number of people would be encouraged to walk in this area.

Another consideration is aesthetics. Even now, with an area closure, there are fishing line and lures snagged on logs in the shallow water, which are visible from the logjam and shore. I would presume that the amount of "garbage" would only increase if this area were open to fishing.

9.5.4 Marvel Creek

I recommend that Marvel Creek remain closed to fishing. The reasons for this closure were detailed in Section 9.2.1.

9.5.5 Gear and Tackle Restrictions

Currently in Banff National Park a bait ban is in effect. This prohibits the use of any kind of live or dead natural bait. Scientific evidence generally supports this restriction which is designed to minimize mortality among released fish. As Mayhood (1991) summarized: mortality averages 25 percent among fish released from baited hooks, and has exceeded 60 percent in some cases, whereas mortality after release from artificial lures often approaches zero, averages approximately 5 percent and rarely exceeds 10 percent, although individual estimates as high as 42.6 percent have been reported (Wydoski, 1977; Dotson, 1982 and Schill et al., 1986).

Barbless hooks are not mandatory, but were used by the occasional angler interviewed.

Although the question of gear type was not on the creel cards, observations showed a mixture of both fly and spin cast anglers, with the latter appearing to be marginally more popular. No studies were found to support the notion that fly fishing results in significantly lower mortalities of released fish than fishing with a spin rod and artificial lures. From a recreation standpoint, a wider range of people can fish with a spin rod, since it requires less developed skills than fly fishing. Especially in the case of families with young children, a mixture of spin cast and fly fishing would allow young park visitors to enjoy and gain an appreciation for the fisheries resource.

In regards to hooking mortality reported at Marvel Lake, it is known that two of the three mortalities reported in 1994 were caused by artificial lures, with treble hooks. It is possible that additional mortalities occurred and were not reported. Presently, there is no evidence to show that barbed hooks result in significantly higher hooking mortalities than barbless hooks (Mayhood, 1991). Therefore, I would agree with Mayhood (1991), that a barbless hook restriction should not be imposed at this time.

9.5.6 Open Seasons

The current open season on Marvel Lake is July 7 - October 31. If fishing pressure remains as low as it was during the two year study period, and the lake remains catch-and-release, I would suggest that the opening day could be changed to July 1, if the park and/or anglers so desire.

At the present time, there are five lakes which have a July 7 opening day. This date was originally chosen by the park to protect late-spawning fish. All other waterbodies open either July 1 or May 20, with the exception of the Bow River, which is open year round.

Year round fishing is not common in the park probably in part, because no regular backcountry patrols occur throughout the winter. Not only does this present a safety concern, but it also means that fishing in lakes such as Marvel, would be unmonitored. Also, ice fishing generally involves the use of bait to increase success rate (J. Cairns, pers. comm.) and since bait fishing is not permitted in the park, ice fishing is prohibited.

Netting during the spawn showed that the peak movements and spawning activity occurred in early to mid-June. By July 1, very few (if any) trout are spawning or are in the process of migrating to or from a spawning area. Therefore a July 1 season opening would not adversely affect spawning fish, provided other restrictions are in place.

Seasonal closures are commonly used in fisheries management to protect fish during the spawning period. The rationale for this, is to allow mature fish the chance to spawn at least once before exposing them to angling pressure. Furthermore, I would suggest that from experience, ripe fish should be handled as little as possible, to prevent them from prematurely releasing their eggs or milt.

9.5.7 Harvest

If the park decides to re-open the lake to harvest a number of factors would have to be considered, along with the possible implementation of additional regulations.

9.5.7.1 Fishing Pressure and Success

It would be reasonable to assume that the fishing pressure (number of hours fished per season), would increase if harvest of fish was permitted. Although no long-term full season data exists on fishing pressure, the opening day results presented in Table 6.3, indicated a trend of decreasing effort with increasing restrictions and lower catch limits.

The 1993-1994 creel survey data showed a drop in hours fished by more than half from 1993, when a one fish limit existed, to 1994 when the lake was catch-and-release only. Therefore while an increase in pressure can be predicted with a harvest limit in effect; the magnitude of this change is unknown. If a harvest limit is re-instated, I would recommend a thorough creel survey in the first season to determine whether actual levels of exploitation exceed predicted levels. Given my 1993 results, I would estimate that the fishing pressure with a one fish limit, would be at least comparable to the 1993 level of 407 hours fished and would most likely be higher since this number represents a sample of the entire season, in which weather conditions were far from ideal.

Under a harvest scenario, the catch per unit effort or CPUE, which is also an index of stock density, should be monitored for fluctuations which may indicate changes in population levels.

9.5.7.2 Release Rate

Even under a harvest scenario, not all fish caught will be kept. The release rate as estimated from the 1993 creel survey was 81%. However, as discussed in section 6.4.1, this was believed to be an overestimate. A 1988 fisheries survey, conducted largely on opening day, showed that approximately two thirds or 67%, of the fish caught were released. Sizes of released fish were unavailable. It seems reasonable to assume that the likelihood of release may depend on fish size. However, since no information was collected on the sizes of released fish, I could not test this hypothesis. This should also be monitored as part of a creel survey, under a harvest option.

9.5.7.3 Angler Location

Although a detailed study of success rate relative to angling location was not performed, the fishing pressure in different areas of the lake was examined (Figure 6.6). Most of the pressure (62.5%), is on the east end of the lake in the bay in front of the logjam and to just west of the island. An informal survey suggested that the few anglers who do fish the far end of the lake generally have a high success rate. If a considerably higher success rate in the east end is coupled with the higher fishing pressure, then under a harvest scenario it may be more desirable to spread the fishing effort out around the entire lake.

9.5.7.4 Catch Limits

The Marvel Lake cutthroat population has successfully sustained a harvest for approximately 60 years. However, due to the lack of long-term information on fishing pressure and success, as well as population levels, the effect that past harvest has had on the population is unknown.

The factors which may be currently limiting population growth include the number of spawners. As was discussed in section 5.0, the minimum number of spawners was 197 in 1994. While the age at first spawning is not known for certain, it is likely between 3 and 4, which were the minimum estimated ages for ripe fish caught during the spawn. Although there are more than 197 mature fish in the population, the likelihood of some alternate year spawning means that all mature fish do not repeat spawn in consecutive years. Due to the uncertainty surrounding the prevalence of alternate year spawning, as well as the age at first spawning, it was not possible to estimate the recruitment into the spawning stock.

Other factors which may limit population growth in the near future include a lack of spawning substrate. Additional external factors having an effect could include fluctuations in water levels, especially down Marvel Creek. This could result, in dry years, in a portion of redds being out of the water, thereby increasing egg and fry mortality.

Given the insufficient information to estimate sustainable harvest rate, I would recommend a limit of no more than one fish, if harvest is to be permitted.

Other restrictions which could be used include trophy fishing regulations, which would restrict the harvest to the largest fish. Presumably, this would limit the catch to fish which have spawned at least once. If it is assumed for sake of argument, that the majority of fish are spawning by, or at age 4, then trophy catch should be restricted to fish ages 5 and older. From the length/frequency histogram and age fitted histogram (Section 4.2.2), I estimated a minimum harvest size of approximately 450 mm.

Under a harvest scenario, one of the factors which would have to be closely monitored includes angler behaviour in response to a catch-and-keep fishery. As discussed in section 6.0, angler attitudes varied widely from supporting a catch-and-release fishery, to indicating a desire for a higher take limit. In general however, trends in hours fished over the two year study period suggested that less anglers were willing to come to the lake under a catch-and-release restriction. If this trend is true, then it would be reasonable to assume that the fishing pressure would increase in the event of a regulation change permitting harvest.

Also, complaints of poor success rates suggested that some anglers surveyed are unwilling to fish the lake unless the chances of catching a fish increase. Some of these comments were directly related to the bay area closure and so if this area is re-opened, some of these anglers may be persuaded to return to the lake.

Therefore, if a harvest limit is re-instated, the results would have to be carefully monitored, especially the fishing pressure, success and release rate. Ideally, this would occur in conjunction with additional population and age structure studies. An additional trophy regulation could be used to limit the harvest to the largest fish. Furthermore, environmental conditions, especially the amount and quality of spawning substrate would need to be evaluated every few years to detect changes which might have an adverse impact on population levels.

9.6 Monitoring - Its Importance and Recommended Procedures

In the majority of our national parks, little data has been collected on aquatic systems and management decisions are often based on incomplete information. One of the ways to improve management is to carefully evaluate the outcome of previous decisions and learn from them. For this reason, monitoring the effects of management actions is vital - the outcome of every decision is important. Thorough monitoring of one system may provide some generalizations or information that can be applied to other situations.

Parks Canada has acknowledged the role of monitoring in making responsible decisions in management, planning and operating practices, as well as in broadening scientific understanding (Canadian Heritage, 1994).

With this in mind, I have outlined in some detail, potential monitoring activities which could take place at Marvel Lake. These are discussed in order of priority. The information obtained would add to the baseline population and environment information collected through this study.

9.6.1 Spawning Survey

An important environmental condition affecting the potential growth of the population is the quantity and quality of available spawning habitat. The present study has shown that the suitable spawning habitat is close to capacity. To effectively monitor the spawning habitat, a time commitment of several days over a span of approximately two to three weeks in early to mid-June would be required.

A redd count, requiring the work of two individuals familiar with redd identification, could take place in the logjam and down Marvel Creek. Ideally, the entire lake should be surveyed including the inlet from Terrapin Lake, as well as the moss inlet at the west end on the north shore of Marvel. Pending weather conditions, a survey of the entire lake could be completed in two days, provided two people are involved. Counts should be taken more than once to ensure that all redds have been identified. Additional information on the substrate composition should also be recorded and would require minimal effort.

The information collected should be compared to the existing information from this study to examine trends in the amount of spawning habitat. This is an important factor to monitor since the growth of the population will eventually be limited in part, by the amount of available spawning habitat.

Furthermore with a time commitment of a full two to three weeks, a good estimate of the number of spawning fish could be attained. This would involve trapping and tagging fish down the creek and in the logjam area starting as early as the end of May (depending on ice breakup) until mid-June. Information collected could include length, weight and sex of fish. Otoliths should also be collected from any mortalities.

Two people would be necessary for this operation. Further details on methodology can be found in the present study. The procedures should be followed as closely as possible to ensure that the results from various trapping studies can be compared. A complete set of equipment required for additional work already exists at the park.

9.6.2 Creel Survey

The creel box installed for this study is still in place and enough creel cards currently remain to fill the box for another fishing season. On-going information could be collected on fishing pressure and success at the lake. Another valuable use of the cards is as a source of sampling angler opinions and attitudes concerning the current fishing regulations. Further demographic information on the lake angling population could also be collected.

The box is easy to maintain and only requires periodic emptying and replenishing of the cards. During the summer and fall, a district warden is on patrol in the area and therefore additional personnel would not be required to tend the creel box.

As was found in this study, compliance with respect to filling out creel cards, was much higher when project or park personnel were present at the lake. For this reason, it is recommended that intensive creel interviews be conducted on a yearly basis by the aquatics section. This would consist of several sample sessions a year, each comprising a few days (a weekend for example).

By investing the time in short periods of intensive sampling, valuable trend information can be collected. Catch-per-unit effort for example, while being a measure of angler success is also an index of stock density (Ricker, 1975). This represents an indirect measure of population levels.

9.6.3 Population Estimate

If spawning fish were trapped and tagged (as in section 9.6.1), it would be useful to extend the study to include an estimate of the adult population. In addition to the time commitment required during the spawn, additional trapping should take place in the lake. I would recommend trapping at least one and a half to two weeks, so that the net could be moved around the lake. If recaptures are low, another sampling period of similar duration could be performed.

Information collected could include a population estimate, length-weight and length-age relationships (see section 9.6.4), and age structure, which could be studied for example to examine the effects of cessation of harvest. Ideally, trapping should be done within the next one to three years, so that additional information on growth rates, life span, minimum number of repeat spawners and tag retention may be gained by recapture of tagged fish from the 1993/94 study.

While the information would be of biological interest, the excessive effort required for a precise population estimate would make this a less viable option for long-term management purposes. In other words, it would not be realistic to undertake a full scale population estimate on a yearly basis to gain trend information on population levels.

9.6.4 Length-Weight and Length-Age Relationship

The length-weight relationship could easily be determined if additional trapping studies are done. The length-weight regression equations from my study and a future study could be compared using analysis of covariance to see if they are significantly different. If this were to be done, weight measurements would have to be taken at the time of sampling. Statistically significant differences could be an indication of changes in prey abundance or in the density of the fish population. This type of study could be done in conjunction with zooplankton and benthic invertebrate sampling which would estimate densities of these organisms. If they were to be compared with the results of past studies, care would have to be taken to approximate or duplicate the sampling methods.

Changes in growth rates could be examined by the range or average of length at age values. For example, the absence of a harvest might lead to an increase in population numbers which could subsequently result in a decline in growth rates, and thus the average length at a given age would decrease. Comparisons with the Walford plot parameters (section 4.3.3) such as maximum theoretical length attainable and the growth rate constant would also allow data from different years to be contrasted.

9.6.5 Water Chemistry

A detailed set of data concerning chemical conditions at the lake was one of the results of this study. Equipment required to measure dissolved oxygen, temperature, pH and transparency exists or has recently been purchased by the park, so no additional equipment would be necessary to continue monitoring these parameters. A boat would be needed to reach the middle of the lake, however an aluminum boat is already present at Marvel.

The methodology outlined in this study should be followed, including the locations of measurements. In this way, comparison of results is facilitated. Measurements would be taken once a month from May or June until October, every few years. All five chemistry stations can be sampled in one day by one individual, but this is dependent on the weather. Sampling could be the responsibility of the district warden or aquatics staff.

Although this information would be useful for monitoring long-term changes at Marvel Lake, in terms of establishing a benchmark lake for monitoring changes in such variables as temperature or pH, a lake of small to medium size may be a better choice (see section 9.6.6).

9.6.6 Benchmark Systems

To better understand the effects of human activity on ecosystems both in and outside the national parks, Parks Canada will establish and maintain benchmark research areas (Canadian Heritage, 1994). Presumably these areas would be representative ecosystems unaltered by humans. Due to its past stocking and fishing history, as well as its location in a heavy-use area, Marvel Lake would not qualify as an "unaltered ecosystem".

However, the lake would make an excellent case study of an "altered ecosystem" in which the growth and recovery potential of the population, following the cessation of fishing (or at least harvest) could be monitored. This would offer a prime opportunity to study the effects of environment alone in limiting the population growth of a stock in an alpine lake, exposed to sometimes harsh environmental conditions, such as 6-7 months ice cover and generally low productivity. It would also provide useful information pertaining to the resiliency of the stock if it was used in future restoration efforts.

A data set of environmental conditions, which dates back to 1936 with the studies of D.S. Rawson, exists for Marvel Lake. However, the methodologies are often not well described. Ongoing monitoring studies of environmental conditions could be used to track long-term changes in some of these variables, pH for example, which may be indicative of regional or global changes. Marvel would represent a backcountry ecosystem in a heavily used area. In comparison to other backcountry lakes, Marvel is fairly accessible, however I would note that it is one of the largest backcountry lakes and therefore changes in certain environmental conditions, may not be as quickly observed as they would be in smaller lakes.

Changes in temperature, for example a temperature increase, would be more readily observed in a smaller lake. A large lake such as Marvel, would require much larger inputs of heat to make a noticeable difference in average temperatures. Therefore, although a change may eventually be noticed, it would take longer than if a smaller lake was monitored.

10.0 RECOMMENDATIONS

Some of the following recommendations are specific to Marvel Lake and some are applicable to the park as a whole.

<u>Marvel Lake</u>

1.0 Permit catch-and-release fishing only.

2.0 Re-open bay area in front of logjam to fishing, with the exception of the area mentioned in recommendation 3.0.

3.0 Close to fishing the area directly in front of and including the logjam, as well as down Marvel Creek at least as far as the second set of falls, to protect spawning habitat.

4.0 Continue to permit both spin cast and fly fishing. No additional gear or tackle restrictions are suggested at this time.

5.0 Continue backcountry warden patrols of Marvel Lake to deter the violation of regulations.

6.0 Continue creel survey to collect information on fishing pressure, success and hooking mortality, as well as angler opinion concerning regulations.

7.0 Conduct spawning survey (preferably every 2-3 years). Methodology is as outlined in Section 5.0.

8.0 Consider the use of Marvel Lake for fish-viewing. The presence of a park representative during the spawn would be essential.

9.0 Include Marvel Lake in long-term water monitoring program.

10.0 Consider use of Marvel Lake as a case study of an "altered ecosystem". Growth and recovery of population following closure to harvest could be monitored.

General

11.0 Ensure effective communication of regulation changes between fisheries personnel, decision-makers and staff interacting with the public.

12.0 Conduct/Continue angler survey, park-wide, to determine angler desires and attitudes towards the fisheries resource.

13.0 Stress the park's priority of ecosystem protection and the role of fishing as part of an overall park experience in the park fishing brochure.

APPENDIX A

Mark - Recapture data for Cutthroat trout in Marvel Lake - 1993 and 1994

The following is termed a "Method B" table by Krebs (1989).

	Time of capture							
Time of last capture	1	2	3	4	5	6	7	8
1	-	7	1	0	15	3	0	0
2		-	1	1	2	1	0	0
3			-	2	1	0	0	0
4				-	0	4	1	0
5					-	4	3	1
6						-	1	1
7							-	1
Total marked	0	7	2	3	18	12	5	3
Total unmarked	151	86	23	31	223	73	32	11
Total caught	151	93	25	34	241	85	37	14
Total removed	1	4	0	0	15	3	1	0
Total released	150	89	25	34	226	82	36	14

Results of Initial Calculations

Session	Proportion marked	Size of marked population
1	0	0
2	0.085	292
3	0.12	145
4	0.11	131.3
5	0.079	245
6	0.15	150.3
7	0.16	42
8	0.27	-

APPENDIX B

Summary of zooplankton hauls

Sample Number	Date	Location	Type of Haul	Depth (m)
1	July 19/93	shoal area	horizontal	1
2	July 19	w side island	horizontal	1
3	August 2	bay in front meadow	vertical	7
4	August 2	logjam	vertical	5
5	Sept. 13	vegetated slide path, n shore	horizontal	1
6	Sept. 30	mossy inlet	vertical	8.5
7	Sept. 30	Terrapin inlet	vertical	3
8	Oct. 30	n logjam	vertical	4
9	June 23/94	s of shoals	vertical	4
10	June 23	e of shoals	vertical	3
11	July 25	moss inlet	vertical	3
12	July 25	middle of lake, far end near s side falls	vertical	3
13	July 27	w side island	vertical	6
14	July 27	shoal area	vertical	3
15	July 27	east of shoals	vertical	10
16	July 27	w of shoals	vertical	20
17	August 20	middle of lake, 3/4 max. depth	vertical	20
18	August 20	vegetated slide path	vertical	7.5
19	August 20	scree slide path	vertical	7.5
20	August 20	near island s side, far end	vertical	6
21	August 20	scree slide path	vertical	9.5

Summary of Benthic hauls

Sample Number	Date	Location	Substrate	Depth (m)
1	June 16/93	slide path s shore far end of lake	organic debris (twigs and needles)	23.5
2	June 16	slide path n shore far end lake	organic debris (twigs and needles)	22.0
3	July 30	logjam	sand/pebble	1
4	July 30	bay in front meadow	sand/mud	1
5	July 31	Terrapin Creek	gravel/silt	2
6	July 31	island bay	muck/silt	3
7	Sept. 30	bay n of island	muck	5
8	Sept. 30	moss inlet	sand/silt	3.5
9	June 12/94	Terrapin creek	silt/gravel	1
10	June 23	logjam	silt/mud	3
11	June 23	w side island	silt/mud	7
12	June 23	w side island	silt/mud	2
13	June 23	east of shoals	silt/mud	11.0
14	July 9	gravel bar near meadow	sand/pebble/ silt	3
15	July 9	bay n of island	sand/pebble	5
16	July 9	w side island	silt/pebble	10
17	July 25	Terrapin creek	silt/mud	4
18	July 25	moss inlet	silt/pebble	3
19	July 27	e side island	muck	5
20	August 20	bay area, near meadow	sand/silt	12.5
21	August 20	front of logjam	mud/sand/silt	1.5
22	August 20	middle of bay, front of logjam	muck	30
23	August 20	bay at west end of lake, s of Terrapin inlet	sand/silt	12
24	August 20	bay at west end of lake, s of Terrapin inlet	sand/silt/ organic debris (twigs and needles)	10
25	August 20	slide path, far end of lake	mud/organic debris (twigs and needles)	4
26	September 23	island bay	silt/muck with gravel/cobble	1
27	September 23	first slide path, n shore of lake	mud/needles and twigs	7
28	September 23	first slide path, n shore of lake	mud/needles and twigs	3
29	September 23	first slide path, n shore of lake	mud/needles and twigs	12
30	September 23	first slide path, n shore of lake	mud/needles and twigs	23

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