A BRIEF INVESTIGATION OF ARCTIC GRAYLING (*Thymallus arcticus*) AND AQUATIC INVERTEBRATES IN THE MINTO CREEK DRAINAGE, MAYO, YUKON TERRITORY: AN AREA SUBJECTED TO PLACER MINING

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PREFACE

This report is the third in a series which describes studies on the effects of placer mining sediments upon Arctic grayling (*Thymallus arcticus*). The previous reports delineated the effects of short and long-term exposures to placer mining sediment on survival and certain physiological and behavioural responses of Arctic grayling. This report presents the results of a preliminary study on the distribution of fish in the Minto Creek drainage, Mayo, an area subjected to placer mining. Collectively, these studies provide some initial information on the effects of placer mining on this species of fish.

A longer-term program of more comprehensive studies on the effects of placer mining sediments on various stages in the life cycle of Arctic grayling and their habitat is desirable. However, it is hoped that the present information will be useful for the sensitive management of cold-zone aquatic resources. Knowledge of cold-zone ecology is limited, and accordingly, the authors urge caution in the interpretation and application of these research findings.

The Department of Fisheries and Oceans Salmon Habitat Section (Fisheries Research Branch) and Habitat Management Division (Field Services Branch) together with D. McLeay and Associates Ltd. and Norecol Environmental Consultants Ltd., carried out this cooperative program.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Birtwell, I. K., G. F. Hartman, B. Anderson, D. J. McLeay, and J. G. Malick. 1984. A brief investigation of Arctic grayling (Thymallus arcticus) and aquatic invertebrates in the Minto Creek drainage, Mayo, Yukon Territory: An area subjected to placer mining. Can. Tech. Rep. Fish. Aquat. Sci. 1287: 57 p.

The distribution and abundance of fish in the Minto Creek drainage, Mayo, Yukon Territory, was investigated between August 6 and 10, 1982. The study was carried out to obtain preliminary information on the effects of placer mining on the distribution, feeding and condition of Arctic grayling (Thymallus arcticus).

In Minto Lake, northern pike (Esox lucius), lake whitefish (Coregonus clupeaformis), slimy sculpin (Cottus cognatus) and burbot (Lota lota) were captured by beach seine. In Minto Creek and its main tributary streams, Arctic grayling predominated in pole seine catches in addition to slimy sculpin, burbot and longnose suckers (Catostomus catostomus).

Underyearling Arctic grayling were abundant in the clear waters of Minto Creek above the confluence with Highet Creek - a tributary stream subjected to active placer mining. Only one underyearling fish was captured from two sites in Highet Creek during active placer mining, whereas in the clear unmined tributary creeks (Bennett, Roaring Fork and Mud) higher numbers of underyearling Arctic grayling were captured with less sampling effort. The the numbers of grayling captured increased with progression down the drainage.

Significantly higher condition factors were recorded for underyearling Arctic grayling in the clear tributary creeks compared with those in Minto Creek. The population of fish we captured was comprised of individuals aged 0+, 1+, 2+, 3+, 4+ and 5+ years. Underyearlings were the dominant age group. This age class was most frequently captured in clear waters of the drainage. Older grayling were found primarily in the lower sections of the drainage in both turbid and clear waters.

The highest density but lowest number of taxa of invertebrate drift organisms occurred in Highet Creek, and was dominated by chironomid larvae. The greatest number of taxa in invertebrate drift samples occurred at sites that were not affected by placer mining.

Arctic grayling in unmined tributaries to Minto Creek and in Minto Creek, upstream of the mined tributary, had consumed the greatest number and diversity of prey items, relying primarily on dipteran, ephemeropteran and trichopteran larvae. Arctic grayling in Highet Creek consumed few prey items, mainly dipterans. Older fish in the study area had a more varied diet and consumed more terrestrial invertebrates and trichopteran larvae.

The diet of underyearling Arctic grayling reflected the reliance on invertebrate drift, and, in particular, the role of chironomid larvae. The scarcity of fish in the turbid tributary stream being mined (which had the greatest density of chironomid larvae - the most frequently occurring prey item in age 0+ fish) implies that factors other than food were responsible for the observed distribution.

The gill histology for 69% of underyearling Arctic grayling sampled from the Minto Creek drainage was normal. Although a greater frequency of slight hypertrophy and hyperplasia of the lamellar epithelium was noted for age 0+ fish from Highet Creek, the significance of this result is not known. However, the very marked histopathologies noted for gills from older grayling from Minto Creek is of concern. The present results suggest that these histopathologies were related to elevated suspended sediment levels (in the absence of parasitic infections which can induce the same response). However further studies are required before the relevance of these findings can be ascertained.

It is concluded that a major part of the Minto Creek drainage is used by Arctic grayling but placer mining activities tend to confine underyearlings to the less turbid waters. Despite the presence of relatively high densities of prey (chironomid larvae) for underyearling Arctic grayling in the placer-mined Highet Creek, grayling were scarce, only using this tributary as suspended sediment levels decreased in response to a reduction of placer mining activities.

Key words: Placer mining, Yukon Territory, Arctic grayling, distribution, diet, histopathology.

RÉSUMÉ

Birtwell, I. K., G. F. Hartman, B. Anderson, D. J. McLeay, and J. G. Malick. 1984. A brief investigation of Arctic grayling (Thymallus arcticus) and aquatic invertebrates in the Minto Creek drainage, Mayo, Yukon Territory: An area subjected to placer mining. Can. Tech. Rep. Fish. Aquat. Sci. 1287: 57 p.

Du 6 au 10 août 1982, nous avons étudié la répartition et l'abondance du poisson dans le bassin versant du ruisseau Minto à Mayo (Territoire du Yukon). L'étude a été effectuée dans le but d'obtenir des données préliminaires sur les effets de l'exploitation de placers sur la répartition, l'alimentation et l'état de l'ombre de l'Arctique (Thymallus arcticus).

Des spécimens de grand brochet (Esox lucius), de corégone de lac (Coregonus clupeaformis), de chabot visqueux (Cottus cognatus) et de lotte (Lota lota) ont été capturés à la seine de rivage dans le lac Minto. Les prises par seine à perche effectuées dans le ruisseau Minto et ses principaux affluents étaient surtout composées d'ombres de l'Arctique, mais on y trouvait aussi des chabots visqueux, des lottes et des meuniers rouges (Catostomus catostomus).

Les ombres de l'Arctique de moins d'un an étaient abondants dans les eaux limpides du ruisseau Minto, en amont du point de confluence avec le ruisseau Highet, un affluent soumis à l'exploitation minière; un nombre plus élevé d'ombres de l'Arctique de moins d'un an ont été capturés, avec un effort d'échantillonnage moindre, dans les affluents à eaux limpides (Bennett, Roaring Fork et Mud) où aucun placer n'était exploité. Le nombre d'ombres capturés augmentait à mesure que l'on se déplaçait vers l'aval.

Dans les affluents à eaux limpides, les ombres de l'Arctique de moins d'un an présentaient un facteur de condition significativement plus élevé que ceux notés pour les poissons du ruisseau Minto. La population de poissons capturés comprenait des individus âgés de 0+, 1+, 2+, 3+, 4+ et 5+ ans. Les individus de moins d'un an formaient le groupe d'âge dominant. Les spécimens de cette classe d'âge étaient plus fréquemment capturés dans les eaux limpides. Les ombres plus vieux se trouvaient surtout dans les parties aval du bassin versant, tant dans les eaux troubles que limpides.

La densité la plus élevée, mais le nombre de taxons le plus petit, d'invertébrés en dérive a été notée dans le ruisseau Highet; les larves de chironomidés dominaient. Le nombre le plus important de taxons d'invertébrés en dérive a été noté dans les endroits non perturbés par l'exploitation de placers.

Les ombres de l'Artique des affluents non exploités du ruisseau Minto, de même que du ruisseau Minto en amont de l'affluent exploité, étaient ceux qui avaient consommé des proies dont la quantité et la diversité étaient les plus élevées; ces proies étaient surtout des larves de diptères, d'éphéméroptères et de trichoptères. Les ombres du ruisseau Highet avaient une alimentation peu diversifiée surtout composée de diptères. Celle des poissons plus âgés de la zone étudiée était plus variée; ils consommaient plus d'invertébrés terrestres et de larves de trichoptères.

Le régime alimentaire des ombres de moins d'un an indiquait que ceux-ci dépendaient des invertébrés en dérive, surtout des larves de chironomidés. Le poisson était rare dans l'effluent à eaux troubles faisant l'objet d'une exploitation minière, et où les larves de chironomidés, la proie la plus fréquente chez les poissons d'âge 0+, présentaient la densité la plus élevée. Ce fait indique que des facteurs autres que la disponibilité de la nourriture régissent la répartition observée.

Les paramètres histologiques des branchies de 69% des ombres de l'Arctique de moins d'un an capturés dans le bassin du ruisseau Minto étaient normaux. Une fréquence plue élevée de légères hypertrophies et hyperplasies de l'epithélium lamellaire a été notée chez les poissons d'âge 0+ du ruisseau Highet, mais la signification de ce phénomène n'est pas connue. Les symptômes histopathologiques très marqués des branchies des ombres plus vieux du ruisseau Minto sont cependant source de préoccupations. Nos rétultats indiquent que ce phénomène est lié aux teneurs élevées en sédiments en suspension (en l'absence d'infection parasitaire pouvant provoquer la même réaction). Il faudra cependant effectuer d'autres études pour pouvoir déterminer la significance de ces résultats.

Nous concluons qu'une partie importante du bassin du ruisseau Minto est habitée par l'ombre de l'Arctique, mais que l'exploitation de placers tend à confiner les poissons de moins d'un an aux eaux moins troubles. En dépit de densités relativement élevées de proies (larves de chironomidés) pour les ombres de moins d'un an dans le ruisseau Highet, où des placers sont exploités, ces poissons y étaient rares; ils n'utilisaient cet affluent que lorsque les teneurs en sédiments en suspension diminuaient suite à une baisse de l'activité minière.

Mots clés: exploitation de placers, Territoire du Yukon, ombre de l'Arctique, répartition, régime alimentaire, histopathologie

INTRODUCTION

Placer mining in Yukon Territory is considered to be a viable industrial activity, with much historical and current economical justification for its continuance (Interdepartmental Committee on Placer Mining 1983a). However, the preservation of fish and their supporting habitat continues to be of concern to the Department of Fisheries and Oceans whose mandate it is to manage these resources. A potential conflict is apparent between the need to manage these renewable resources and the requirements to disrupt fish habitat during the extraction of non-renewable gold resources by placer mining. In attempting to resolve this conflict the Departments of Fisheries and Oceans, Indian Affairs and Northern Development, and Environment Canada have proposed guidelines for the management of water in Yukon placer mining operations. These guidelines are currently under public and private review (Interdepartmental Committee on Placer Mining 1983a, b, c).

The proposed guidelines seek to allow placer mining operations to occur in a controlled manner such that the fisheries resources and supporting habitat in Yukon are protected. To facilitate this position a "priority protection schedule" has been developed in accordance with the Department's habitat management policy which strives to maintain the productive capacity of habitats supporting Canada's fish resources. Thus, valuable fish and their habitats receive maximum protection with stringent requirements for the placer mining industry, while areas judged to be currently of lower significance, e.g., those areas previously designated for placer mining, are subject to less stringent requirements.

It has been proposed that there should be no sediment discharge (due to placer mining) to the most important fish habitat areas, and, in previously designated placer mining areas, sediment discharges should not exceed 100 $mg \cdot L^{-1}$ if flowing to fish habitat of lower quality (Interdepartmental Committee on Placer Mining 1983a, b). The rationale for these proposed guidelines is based upon an assessment of information of the effects of placer mining on fish and their habitat, and in particular upon the results of studies on the effects of sediment on salmon and stream habitat (Interdepartmental Committee on Placer Mining 1983b). Inherent in this approach to protect sensitive and economically important fish such as salmon, trout and Arctic grayling (i.e. salmonid fish species) is the protection of other organisms. However, our knowledge of cold-zone ecology (e.g., in Yukon) is very limited and few studies have been carried out to determine the effects of placer mining activities on fish.

Our recent laboratory research has focussed upon the short and long term effects of placer mining sediment upon Arctic grayling, Thymallus arcticus (McLeay et al. 1983, 1984), while field studies have concentrated upon fish distribution, diet and suspended sediment levels (W. Knapp, unpublished MS, Mathers et al. 1981, Pendray 1983a,b). In recognition of the paucity of information specifically related to the effects of placer mining activities on Arctic grayling and their habitat under field conditions we undertook this preliminary field study during August 6-10, 1982 in order to provide some baseline information from which a more detailed research program would be developed. The main components of the study examined the distribution, age, condition, diet and gill histology of Arctic grayling together with a limited investigation of invertebrate drift in the Minto Creek drainage, an area subjected to placer mining.

MATERIALS AND METHODS

STUDY LOCATION AND SAMPLING SITES

The Minto Creek drainage (Fig. 1) close to Mayo, was chosen after an aerial and ground reconnaissance of numerous creeks in central Yukon on June 26, 27, 1982. Its accessibility, relatively small size, fish presence, and operational placer mining activities were features which supported the selection.

Minto Creek flows eastward into the Mayo River through an upland part of the Yukon Plateau between the Stewart and McQuesten Rivers. The creek drains Minto Lake and flows approximately 16 km before entering the Mayo River at the north end of Wareham Lake. The gradient of Minto Creek is relatively low (1.5 $m \cdot km^{-1}$) especially between Minto Lake and the junction with Highet Creek (an area in which there were numerous beaver dams).

A number of small creeks flow into Minto Creek. The more significant of these are Highet, Bennett, Roaring Fork and Mud Creeks. At the time of our study only the middle third of Highet Creek, a relatively high gradient stream (90 $m \cdot km^{-1}$) was being mined.

Thirteen representative 200 ft (61 m) sections of Minto Creek and its main tributary streams were chosen for sampling. Two of the sites were in Minto Creek above its junction with Highet Creek; two sites were within Highet Creek; one site was located in each of Bennett, Roaring Fork and Mud Creeks; and the others were along Minto Creek, as shown in Figure 1. At each of the main sampling sites we recorded the nature of the stream bed, its average width, percentage pool, riffle and glide, and the percentage of overhanging vegetation and undercutting of the banks. This information is presented in Table 1.

Invertebrate drift samples were collected at four locations, two of which were also used for fish capture. These sites were 'Minto Creek above Highet Creek', 'Highet Creek', 'Minto Creek above Bennett Creek', and 'Bennett Creek' (Figure 1).

FISH CAPTURE

Electroshocking was ineffective for the capture of small Arctic grayling, whereas a pole seine proved successful at all sampling locations except Minto Lake. At this site, a 10-m beach seine was deployed three times by wading from shore. We endeavoured to sample with equal effort at each of the 61-m sampling sections, and accordingly replicated seining 16 to 19 times per section. At each of the main sampling sites the fish were identified and enumerated. The length of each Arctic grayling was determined. Where large samples were collected, a random sub-sample was then measured. Similarly, depending upon the sample size, the whole sample or a sub-sample of Arctic grayling was weighed. Scale samples were taken from a wide size range of fish (n = 40) to examine the age structure of the population within the drainage. The condition factor (K) of underyearling grayling was determined as follows: $K = cW \cdot L^{-3}$ where c is a constant (100) W is the weight (g) and L the fork length (cm) (Carlander 1969).

ANALYSIS OF STOMACH CONTENTS

Whole samples of small fish (<80 mm) together with the stomachs of larger specimens were preserved in the field using buffered 10% formalin or Bouin's fixative, in the field. A total of 150 Arctic grayling were preserved for analysis.

In the laboratory the stomach contents of each fish were placed in separate vials containing a 10% formalin solution. Subsequent analysis involved the measurement of the settled volume for each stomach contents after a settling time of 0.25 h, and a microscopic examination to determine the composition of the diet.

HISTOLOGICAL EXAMINATION

Samples of whole small fish (<80mm) and the dissected gills from larger Arctic grayling were preserved in Bouin's fixative. Each sample of gill tissue was transferred to 70% ethyl alcohol after a two-week storage in the fixative. Following a 24-h immersion in the alcohol, these tissues were transferred to, and stored in, a 10% formalin solution.

All gill samples were wax-embedded, sectioned (6 μm) and stained (haematoxylin and eosin) according to standard practice. Each prepared gill tissue was then examined for histopathologies. For each specimen, a number of pathomorphological changes involving the gill filaments and lamellae were rated on a scale of 0 (normal) to 4+ (extreme pathology). The gills were examined and noted for the presence and extent of cellular hyperplasia (abnormal increase in cell number), cellular hypertrophy (swelling and increase in cell size), clubbing (thickening of the distal ends of secondary lamellae), debris between filaments/lamellae, and intra/extracellular parasites. Each specimen was coded and examined without knowledge of the sampling site or age of fish to prevent biases from influencing the ratings that were assigned.

INVERTEBRATE DRIFT

Invertebrate drift samples were collected at the four sites identified as 'Minto Creek above Highet Creek', 'Highet Creek', 'Minto Creek above Bennett Creek', and 'Bennett Creek'. A modified 200 μm Mundie sampler (Mundie 1971) was used. Each site was sampled overnight on two successive occasions, for a period of between 14.9 and 17.3 h. Upon removal of each sample, it was preserved in a 10% formalin solution. The samples were sorted to remove detritus and depending upon the sample size, the whole sample or a portion (0.25 or 0.125) was examined microscopically. Identification and enumeration was then carried out in relation to the prey items in the stomachs of Arctic grayling captured, in order to determine the relative importance of various prey groups in the Minto Creek drainage, and their variation between sampling locations.

WATER

At the time of fish capture, water samples were collected at all sites downstream of the junction of Highet and Minto Creeks for residue analysis. Water samples were collected at hourly intervals from Highet Creek and 'Minto Creek above Highet Creek' by use of an automated serial pump sampler (ISCO). All samples were analyzed for non-filterable residue, total fixed residue, total residue concentrations and turbidity according to standard procedures employed by Environment Canada and the Department of Fisheries and Oceans laboratories (Anon. 1979).

The temperature of Minto Lake, Minto Creek and tributary streams was determined by thermometer at frequent but irregular intervals.

Water velocities were determined in the stream sections used to capture fish and collect invertebrate drift samples. Between five and seven determinations were made at each location using a floating marker and timing its travel over a fixed distance.

RESULTS

WATER

Residues and turbidity

Minto Creek waters above the junction with Highet Creek were typically of high clarity. At the sites chosen for fish capture, turbidity values were between 0.8 and 1.3 Formazin Turbidity Units (FTU) the lowest recorded at any of the sampling sites (Table 2). Turbidity values ranged between 3.5 and 23.0 (FTU) at sites in Minto Creek downstream of the junction with Highet Creek, while values for the unmined tributary creeks, Bennett, Roaring Fork and Mud, were 1.6, 3.0 and 2.0 respectively. In Highet Creek, turbidity values were variable and ranged from 4.6 to 395 (FTU) no doubt reflecting the variability of placer mining activities and associated sediment releases.

Similar differences in water quality between the creek being mined and Minto Creek or other tributary creeks were evident for the concentration of non-filterable residue (suspended solids) total fixed residues (the ash-weight after ignition at 550°C), and total residue (which includes dissolved solids). These results are presented in Table 2.

Velocities

Water velocity data for the sampling sites are presented in Table 3. Velocities ranged from 0.48 to 0.89 $m \cdot s^{-1}$ at the fish capture sites in Minto Creek and between 0.59 and 0.97 $m \cdot s^{-1}$ in the tributary creeks. In the drift sampling locations, water velocities were 1.02 $m \cdot s^{-1}$ in 'Minto Creek above Highet Creek', and 0.83 $m \cdot s^{-1}$ in 'Minto Creek above Bennett Creek': in the tributary streams the velocities were 0.88 $m \cdot s^{-1}$ in Highet Creek and

$0.62\ m \cdot s^{-1}$ in Bennett Creek.

Temperature

The water temperatures recorded are shown in Table 4. Surface water in Minto Lake was 16°C, higher than Minto Creek waters which in turn were generally higher than temperatures for the tributary streams of Highet, Bennett, Roaring Fork and Mud Creeks.

The temperature recordings listed in Table 4 do not reflect the maximum range that may have occurred in the Minto Creek drainage between August 6 and 10, 1982. Recordings were not made overnight when cooler temperatures may have occurred, nor was there any attempt to record the maximum temperature at a sampling site.

FISH

Distribution and abundance

The number and species of fish that were captured during this survey are presented in Table 5 together with information on the condition factor for 0+ Arctic grayling and the approximate age structure for this species in Minto Creek and tributary streams.

Six species of fish were captured. Northern pike (Esox lucius) and lake whitefish (Coregonus clupeaformis) were only caught in Minto Lake, whereas Arctic grayling were only captured in the stream habitats. Slimy sculpins (Cottus cognatus) longnose suckers (Catostomus catostomus) and burbot (Lota lota) were caught at the lake and stream sampling sites.

The fish populations in Minto Creek were dominated by Arctic grayling, which were in highest numbers in the clear waters upstream of the junction with the turbid Highet Creek (Figure 2, Table 5). All the relatively cooler tributary creeks also supported populations of Arctic grayling. Highet Creek was sampled to examine fish distribution and abundance and water quality on two occasions: (series #1) during reduced placer mining activity, and again when the major placer mining operation closed down (series #2). The relative residue and turbidity values in Highet Creek reflect these activity changes (Table 2). Fewer fish were caught in the lowermost section of Highet Creek during the phasedown of mining than during the succeeding period of reduced mining activity (series #2, Table 5).

At the junction of turbid Highet Creek with clear Minto Creek, a limited sampling effort produced more Arctic grayling in the clear waters, fewer at the interface and none in the sediment-laden Highet Creek. Similarly, where a clear unnamed creek entered the now turbid waters of Minto Creek below the Highet Creek junction, three Arctic grayling were captured in one seine set, whereas in the same vicinity 18 seine sets above this site did not capture any fish, and 19 seine sets below this site only captured six Arctic grayling and one slimy sculpin (Table 5). Higher numbers of fish were captured (for equivalent sampling effort) in tributaries of Minto Creek as sampling progressed downstream from Highet Creek to Mud Creek.

Age structure and condition

The approximate age structure of the Arctic grayling captured from the Minto Creek drainage is shown in Figure 3. The catches were dominated by underyearlings with fewer numbers of older fish to age 5+. A trend of increasing numbers of age classes with progression downstream in the drainage to the junction of Minto Creek with the Mayo River is apparent; however a similar trend in the numbers of Arctic grayling captured at each site was not evident.

The overall mean condition factor for underyearling Arctic grayling in the Minto Creek drainage (n = 107) during Aug 6 - 10, 1982 was 0.87±0.07 and the equation describing the weight-length regression line for this age group is: log weight (g) = 3.054 log length (mm) - 11.883 ($R^2$0.974). The mean (±S.D.) condition factor for 0+ Arctic grayling (n = 39) in Minto Creek above the junction with Highet Creek was 0.84±0.04, 0.84±0.05 for Arctic grayling in Minto Creek below the junction with Highet Creek (n = 24) and 0.09±0.08 for Arctic grayling from Bennett, Roaring Fork and Mud Creeks (n = 44). Application of ANOVA and Newman - Keul's Test revealed that the condition factors for the fish in the tributary creeks were significantly larger and different ($p < 0.05$) from those comprising the other two data groups which formed one homogeneous data subset. Other condition factor information for underyearling Arctic grayling is presented in Table 5. In addition, there is a trend of increasing condition factors with decreasing water temperatures (refer to Tables 4 and 5).

Gill histopathology

The histological findings for each of the 55 gill tissues examined are presented in Table 19.

The appearance of the gill tissue of the underyearling Arctic grayling from Minto Creek just upstream of Highet Creek was normal and typical of healthy salmonid fish (Morgan and Tovell 1969; Ribelin and Migaki 1975). Gill filaments were covered by a stratified epithelium, whereas the secondary lamellae consisted of leaf-like structures, with blood capillaries covered by a single layer of squamous or somewhat cuboidal epithelial cells. Slight hypertrophy and hyperplasia of the lamellar epithelium was noted for only one of the eleven fish sampled from this site (Table 19). No clubbing of the distal ends of lamellae was evident for any fish examined.

Gill tissues from underyearling Arctic grayling taken from Minto Creek just below Bennett Creek (approximately 1.5 km below the point of entry of Highet Creek) were similar to those captured upstream. No histopathologies were evident for six of the eight gills examined. Two tissues showed slight-to-moderate hypertrophy and hyperplasia of lamellar epithelium. The appearance of gill tissue collected from the two juvenile grayling (age 1^+) taken at this site was also characteristic of that from healthy fish. In contrast to this, the gills of each of the three older grayling (age 3^+ and 4^+) captured at this location showed a very marked hypertrophy and hyperplasia of the lamellae (Table 19), associated with mononuclear infiltration of the interlamellar spaces. Lamellar fusion was frequently observed. Some clubbing of the distal ends of unfused lamellae was noted.

Gills of the five underyearling and two juvenile grayling captured from Minto Creek just downstream of the junction with Roaring Fork Creek (approximately 4 km below the entry of Highet Creek) were normal in appearance, with only one underyearling fish showing evidence of very slight cellular hypertrophy and hyperplasia. The appearance of gill tissue from one of the two older grayling (age 3^+) captured at this site was also unremarkable; whereas very marked histopathologies (hypertrophy, hyperplasia, clubbing) were evident for the second fish of the same age (Table 19).

Gills examined from four underyearling grayling captured from Minto Creek at points further downstream (4 km below Roaring Fork Creek; 1.5 km above Mayo River) appeared normal or with only a very slight degree of hypertrophy and/or hyperplasia. However, gills from each of the five older grayling (age 2^+ to 5^+) taken from lower Minto Creek (4 km below Roaring Fork Creek) again showed significant and severe gill lesions similar to those reported for other adult fish caught upstream of this point (Table 2). Slight-to-marked cellular hypertrophy and hyperplasia were also noted for the two juvenile Arctic grayling (age 1^+ years) caught at this site.

Histopathologies for gills taken from each of the nine underyearling Arctic grayling captured from upper or lower Highet Creek were absent (three fish) or only slight (six fish) (Table 19). The gill histology for the single underyearling fish examined from Mud Creek (another tributary of Minto Creek) was normal.

The frequency with which hypertrophy and hyperplasia of the gill lamellar epithelium was noted for underyearling or juvenile grayling (combined data) collected from Highet Creek versus Minto Creek and below its confluence with Highet Creek is shown in Table 20. The data suggest a greater frequency of slight gill histopathologies for immature grayling captured directly from Highet Creek compared with those taken from Minto Creek, upstream or downstream of its confluence with Highet Creek.

Sediment was occasionally noted between the gill filaments of one or more fish examined from each site. However, the extent of this debris, if evident, was only slight (Table 19). The frequency with which debris was observed in the gills of specimens taken from Minto Creek upstream of Highet Creek was as great as that for fish taken directly from Highet Creek. Slight-to-moderate numbers of extracellular gill parasites were recorded for 16 of the 55 tissues examined. Gill parasites were not observed in the remaining 39 specimens (Table 19). Parasites noted were elongate (approximately 50 μm) multicellular organisms with cuticular hooks in their distal end. These parasites were tentatively identified as monogenetic trematodes.

The percentage of fish gills from each site for which slight-to-moderate numbers of parasites were observed is recorded in Table 21. These results indicate the presence of gill parasites for Arctic grayling collected from Minto Creek at sites both above and below the Highet Creek tributary, as well as within Highet Creek. The frequency with which moderate numbers of gill parasites were observed in these fish groups was greatest for fish taken directly from Highet Creek. The frequency with which slight parasitic infection of the gills occurred in fish from Minto Creek was highest in those grayling taken upstream of Highet Creek (Table 21). Overall, ectoparasites were noted for only nine (23%) of the thirty-nine gill tissues from underyearling grayling and one (10%) of the ten tissues from older fish.

None of the six gills from juvenile (age 1^+) grayling showed any signs of extracellular parasitic infection.

Diet

The results of stomach contents analysis for Arctic grayling captured in the Minto Creek drainage are presented in Tables 6 to 18. Most of the information is for underyearling fish but data are also presented for age classes 1^+ to 5^+ for comparison.

Dipteran larvae were the most important components in the diet of underyearling Arctic grayling. Chironomidae and Simuliidae were the primary dipteran components in grayling diets in Minto Creek above the junction with Highet Creek, but other organisms were also present in significant proportions including zooplankton (probably from Minto Lake and upstream beaver ponds) terrestrial invertebrates and ephemeropteran, plecopteran and trichopteran larvae (Tables 6 and 7).

The diet of fish from Minto Creek contrasts markedly with that of the Arctic grayling from Highet Creek (Tables 8 and 9). The stomach contents of the single fish captured from 'Upper Highet Creek' just downstream of the major placer mining activity, consisted primarily of chironomid larvae. Likewise fish captured later, on August 9, 1982 (series #2) when most placer mining activities had stopped, also had a diet primarily comprised of chironomids (Table 9). However, stomach contents in all these fish were mostly digested, inferring that feeding had occurred 'some time' prior to capture. In contrast, fish examined from other locations did not have stomach contents which were as well digested, inferring 'recent' feeding activity.

In Bennett Creek, the diet of underyearling Arctic grayling (Table 10) differed substantially from that of fish from Highet Creek, and dipteran larvae were not a significant component. <u>Baetis</u> sp. larvae made up a large part of the diet, and in one fish only terrestrial insects had been consumed.

In 'Minto Creek below Bennett Creek', the diet of underyearling Arctic grayling (Table 11) was relatively diverse, though fewer dietary components were consumed than in the region upstream of the junction with Highet Creek. Ephemeropteran and dipteran larvae again predominated in the diet. Juvenile (1^+) and older (3^+, 4^+) Arctic grayling at this site consumed fewer dipteran larvae than the underyearlings and they also had a more diversified diet (Table 12). The high proportion of detritus in the fish stomachs was considered to be from the cases of caddisfly larvae.

Table 13 lists the stomach contents of underyearling, age 3^+ and 4^+ Arctic grayling captured from Roaring Fork Creek. Unfortunately we did not make a distinction between the diet of the different age classes of Arctic grayling. However, it is evident from the 'settled volume' information that the larger fish had consumed primarily trichopteran, ephemeropteran and dipteran larvae. In contrast to the diet of 0^+ fish from Highet Creek, but similar to the diet of fish in Bennett Creek, dipteran larvae were of less significance than other components such as emphemeropteran larvae. At this location, we found the only evidence of a piscivorous diet amongst the 150 fish examined: one small sculpin had been eaten.

In 'Minto Creek below Roaring Fork Creek' (Table 14) the diet of 0^+

Arctic grayling consisted primarily of ephemeropteran and dipteran larvae.

The diet of 0^+ and 1^+ Arctic grayling in Mud Creek was similar to the diet of this species collected from the other clear tributary creeks in the Minto Creek drainage (Table 15). Their diet was relatively diverse but dominated by ephemeropteran, trichopteran and dipteran larvae.

Downstream of the junction with Mud Creek, underyearling Arctic grayling at the 'Lower Minto Creek' sampling site fed primarily upon ephemeropteran and dipteran larvae (Table 16) whereas older fish (1^+ to 5^+) consumed very few dipteran larvae (Table 17). The diet of the older fish was mostly of ephemeropteran larvae and to a lesser extent, trichopteran larvae. Terrestrial invertebrates were also prominent in the diet of these older fish at this location.

At the lowest downstream sampling site in the Minto Creek drainage ('Minto Creek above Mayo River') as at other sites along Minto Creek, the diet of underyearling Arctic grayling contained a significant quantity of ephemeropteran larvae, whereas dipteran larvae were less conspicuous. However, this difference may be of little significance in view of the very small sample examined: only two Arctic grayling were captured (Table 18).

Plecopteran larvae featured significantly in the diet of Arctic grayling taken upstream of the junction with turbid Highet Creek. They were recorded in the diet of one fish from Highet Creek and also in fish from the tributary creeks. However, for approximately 6 km, downstream from the junction with Highet Creek, stonefly larvae were absent from the diet of Arctic grayling in Minto Creek even though they were collected in drift samples downstream of Highet Creek.

Overall there was a trend of decreasing numbers of dietary constituents in 0^+ Arctic grayling between sites upstream and downstream of Highet Creek where sediments from placer mining entering Minto Creek caused increased turbidity and suspended solids and reduced the heterogeneity of benthic habitats. Contrasting with this trend was an increase in the number of dietary components in underyearling Arctic grayling taken in clear-water areas of the drainage. Fish collected from Highet Creek had the least diverse feeding habits as opposed to those from Mud Creek that consumed the greatest diversity of dietary items. Dipteran, ephemeropteran and trichopteran larvae were the major dietary components of the 0^+ fish, but older Arctic grayling had a more diversified diet and consumed more terrestrial invertebrates and trichopteran larvae.

INVERTEBRATE DRIFT

A summary of the drift sampling information is provided in Tables 22 and 23. The volume of water sampled at each site differed in relation to the duration of sampling and stream flow. To facilitate comparisons between sampling sites, information is provided on the number of identified taxonomic groups per sample, and on the density of organisms (Table 22).

Above its junction with Highet Creek, the number of organisms$\cdot m^{-3}$ in each sample from Minto Creek ranged between 7 and 9.3. Below the junction, the range was between 6 and 6.6 organisms$\cdot m^{-3}$. The highest density of organisms occurred in Highet Creek and there was little difference in the range (11.7 - 12 organisms$\cdot m^{-3}$). In contrast to these relatively high densities, the number of organisms$\cdot m^{-3}$ in Bennett Creek (an unmined tributary) was substantially lower and ranged between 2 and 3.4. Although the highest density of organisms was recorded in Highet Creek, the diversity of the identified taxonomic groups was relatively low - between 8 and 11 per sample. The greatest diversity (14-15 taxa per sample) was recorded in samples collected from Minto Creek above the confluence with Highet Creek.

The composition of the invertebrate drift samples is summarized in Table 23. Water mites were most abundant in the clear waters of Bennett Creek. Dipterans were abundant in all locations and in all samples. Fewer dipteran groups were represented in Highet Creek, but chironomid larvae were dominant in the samples. Simuliidae larvae were absent from the samples collected from Highet Creek, and differed in densities between the other sampling locations. The difference in the abundance of chironomids between the tributary creek being mined and unmined Bennett Creek is marked. Greater than fifteen times more dipterans$\cdot m^{-3}$ were present in turbid Highet Creek (Table 23). Contrasting with this situation is the abundance of ephemeropterans. Only *Baetis* sp. were found in Highet Creek whereas in Bennett Creek *Ephemerella* sp. and *Rithrogena* sp. were also collected. The density of ephemeropterans in Highet Creek was about half that found in samples from Bennett Creek.

Plecopterans were most abundant in Minto Creek downstream of the confluence with Highet Creek. Nemouridae were represented in one sample from Highet Creek and Chloroperlidae were present in Bennett Creek. Neither Nemouridae nor Perlidae representatives were found in Bennett Creek.

Trichopterans were found at all sampling sites, but in lowest numbers in the unmined Bennett Creek. *Rhyacophila* sp. were only recorded in Bennett Creek.

There was a mixed terrestrial component in the drift samples from each sampling site.

Zooplankters were numerous in the Minto Creek samples, perhaps reflecting the upstream lake and beaver pond input. Zooplankters (copepods) were present, but less numerous in samples collected from Bennett Creek. The origin of these organisms is not readily explained.

DISCUSSION

The results reveal an uneven fish distribution pattern in the Minto Creek drainage. The dominant species, Arctic grayling, was represented by all age classes up to 5^+ years, but the 0^+ age group was dominant. There appeared to be a general spatial separation of the age classes. The older fish were captured primarily in Minto Creek waters and 0^+ fish were also found in the tributary creeks. Condition factors for the 0^+ Arctic grayling were normal (Reed and McCann 1971; McLeay et al. 1983, 1984) despite differences in their diet, physical habitat and water conditions between sampling sites. The older fish had gill histopathologies but most underyearlings did not. However, the differences in the distribution and abundance of grayling within the drainage area tend to reflect the effects of placer mining operations, which prevented full utilization of the area, and modified the composition and abundance of their food. These results are generally consistent with the findings of other studies on the effects of placer mining on Arctic grayling and their habitat, details of which will be discussed below.

DISTRIBUTION AND ABUNDANCE

Despite the presence of Arctic grayling in many Yukon streams their biology has yet to be adequately described. Pendray's (1983a,b) investigation of grayling in the Yukon River basin provide some recent information on their biology. He speculates on the possibility of a river-spawning population and the subsequent movement of fish into tributary streams of the South McQuesten River. Such a behavioural trait is not consistent with the general opinion that Arctic grayling generally spawn in tributary creeks which are also suitable rearing areas for juveniles (Craig and Poulin 1975). The life cycle of Arctic grayling in the Minto Creek drainage is not known, but it is probable that spawning occurrs in Minto Creek and/or its tributary streams. During a reconnaissance of potential study sites in June 1982, very small underyearling grayling were found just upstream of the junction with Highet Creek. The indication is that these fry probably originated from eggs deposited in the creek waters and not from grayling that may have spawned downstream in the Mayo River. It appears very unlikely that such small grayling would migrate upstream during the high spring run-off period. Pendray (1983b) speculates that such migrations of underyearlings could take place, thus accounting for their presence in Haggart Creek, upstream of its junction with the South McQuesten River. Irrespective of the manner by which grayling came to occupy the Minto Creek drainage, it is apparent that adults of spawning age (>5+ years) were not present in the areas we sampled. Notwithstanding the obvious selectivity of the capture method, the level of effort expended at the sampling sites was high, and a variety of habitats were sampled. Craig and Poulin (1975) and Pendray (1983b) found that only Arctic grayling older than 5+ years were in spawning condition in Yukon Territory and Alaska, but in northern British Columbia sexual maturation can occur at age 4 years, (Stuart and Chislett 1979; cited in Pendray 1983b). Thus during August 1982, those areas of the Minto Creek we sampled were being used by Arctic grayling for rearing, and were occupied primarily by 0+ fish.

Craig and Poulin (1975) considered that scale readings tended to underestimate the age of older grayling. However, their age class separations, based on scale and otolith readings were consistent with our findings.

Vincent (1962) in his comprehensive review of the 'biogeographical' and ecological factors contributing to the decline of Arctic grayling in Michigan and Montana described the habitat requirements of these fish. He concluded that Arctic grayling have a relatively narrow "ecological amplitude" which limits their distribution. They often have irregular distribution patterns, and adjacent streams may not support a population. The habitat occupied by Arctic grayling in Minto Creek and its tributaries fits the general descriptions provided by Vincent (1962). These fish, in streams, are frequently found in water depths less than 1.4 m with velocities generally between 0.3 and 0.7 $m \cdot s^{-1}$, but up to 1.5 $m \cdot s^{-1}$. In Minto Creek, surface water velocities were within these ranges (Table 3).

Little information on the temperature requirements of Arctic grayling is available. Vincent (1962) describes the avoidance of high temperatures in summer time, while Knapp (unpublished MS) records the exit of fish from creeks with temperatures declining from 13 to 3°C. In our study water temperatures differed between sampling sites (Table 4) and ranged between those which were considered to be stressful (Vincent 1962) and those which were thought to elicit a downstream migration response (Knapp unpublished information).

Stream substrate conditions varied widely in the Minto Creek drainage (Table 1) but in the areas where most underyearling grayling were caught (above the Highet Creek confluence) stream conditions closely approached those described by Vincent (1962); namely, a substrate comprised of coarse sand and fine gravel. It is evident from Table 1 that such substrate conditions were not always present in the study area, and that the influx of fine sediment due to placer mining profoundly affected the stream bed of Highet Creek and downstream areas of Minto Creek. Other features of the habitat at the sampling sites are described in Table 1. Such features as the percentage of pool, riffle and glide, overhanging vegetation and undercutting of banks differed between sampling locations yet variations in these features could not, in this work, be related to the recorded grayling distribution and abundance.

Although high-latitude Arctic grayling are considered to be adapted to turbid melt waters (Vincent 1962) most grayling streams carry little silt (Bissell 1890; Henshall 1907; Ward 1951; Wojcik 1955; cited in Vincent 1962) and, when muddy water is common during part of the year, grayling are reported to migrate into clear tributaries (Vincent 1962). According to Elrod (1931) Arctic grayling are seldom abundant in main Arctic rivers which are usually 'muddy', but may be very abundant in small clear tributaries. Such broad generalizations coupled with information from the other studies on the effects of suspended sediment on fish assist in the explanation of the Arctic grayling distribution pattern we recorded in the Minto Creek drainage.

Research on the distribution of fish in relation to placer mining is quite limited; however the results of previous studies are very similar to those obtained here. Knapp (unpublished information) in 1974 and 1975 investigated populations of fish in a number of Yukon creeks on which there was active placer mining. In general he found fewer and less diverse populations in streams subjected to the most active placer mining with variable suspended sediment levels to 10,000 $mg \cdot L^{-1}$ (Hunker, Bonanza and Dominion Creeks). However, in Sulphur Creek, where placer miners employed tailings ponds upstream of beaver dams, downstream fish populations were more diverse and abundant with a larger proportion of Arctic grayling (all age classes) and whitefish. Suspended sediment levels in Sulphur Creek contrasted with those in the other creeks and were less than 100 $mg \cdot L^{-1}$ where fish were captured. Knapp also recorded differing fish migration for Sulphur and Bonanza Creeks during the summer ice-free period. In the less turbid Sulphur Creek, both upstream and downstream movements of whitefish and Arctic grayling were recorded, whereas in the highly turbid Bonanza Creek both these species exhibited a general downstream movement which may have been a consequence of displacement due to high suspended sediment levels. Pendray (1983b) recorded an interesting and similar distribution pattern in Haggart Creek (placer mined) and one of its clear water tributaries (Lynx Creek). Few Arctic grayling were recorded in the turbid waters of Haggart Creek but unusually high numbers were captured in Lynx Creek. No age 0+ grayling were found in Haggart Creek until 0.5 km from its confluence with the South McQuesten River. While Pendray considers the presence of 0+ fish in this location to be related to upstream migration, the possibility of downstream displacement cannot be entirely eliminated. Furthermore, the high numbers of grayling recorded in the clear tributary (Lynx Creek), may again be a consequence of displacement due to excessive sediment generated by active placer mining upstream of the confluence, on Haggart Creek. Pendray, however, views this explanation as too simplistic, since creeks in other areas, with seemingly good grayling habitat (i.e., Davidson Creek) do not always contain rearing populations of grayling. It is difficult to make such a comparison between areas and especially between mined and unmined watersheds. However, Pendray's observations are quite consistent with Vincent's (1962) assessments. Vincent states that Arctic grayling have a sporadic and irregular distribution and that adjacent streams may not support a population.

Within an area subject to placer mining elevated suspended sediment levels may well affect the behaviour of underyearling Arctic grayling causing a downstream displacement, possibly to less turbid waters. During laboratory experiments McLeay et al. (1984) determined that the introduction of suspended sediment $\geqslant 300$ $mg \cdot L^{-1}$ resulted in a downstream displacement of the fish in test streams. Similarly, in the Minto Creek drainage, very few underyearling grayling were caught in turbid waters. These fish were most abundant in clear unmined waters of Minto Creek, above the confluence with Highet Creek which was mined. In another study, Mathers et al. (1981) recorded similar results during a comparative biological study of seven streams in Yukon which were being mined. These authors were unable to capture underyearling Arctic grayling in most of the streams being actively mined. While the overall effect of suspended sediment on the behaviour of salmonids is, as yet, unclear (McLeay et al. 1984) there appears to be some evidence from both field and laboratory research that reveals a displacement or avoidance of turbid waters by underyearling Arctic grayling. Such a response would be of adaptive significance possibly enhancing the opportunity to find more favourable (less stressful) conditions. McLeay et al. (1983) determined that whereas underyearling Arctic grayling can survive short-term (4-day) exposure to very high suspended sediment levels ($\leqslant 250{,}000$ $mg \cdot L^{-1}$) such conditions were stressful to the fish. Elevated and/or more varied blood sugar levels and depressed leucocrit levels were noted at sediment strengths as low as 50 $mg \cdot L^{-1}$.

Our fish distribution information for Minto Creek implies that older Arctic grayling (>0+) may tolerate elevated suspended sediment levels better than underyearlings. The absence or scarcity of underyearling fish in turbid waters in the Minto Creek drainage, and in the turbid creeks studied by Knapp (unpublished information), Mathers et al. (1981) and Pendray (1983b), reveals a similar trend. Consistent with our findings, these authors also recorded the presence of older Arctic grayling in turbid waters. Similar findings regarding only juvenile and adult grayling led Mathers et al. (1981) to state that suspended sediment levels (to 4453 $mg \cdot L^{-1}$) did not have an obvious effect on the distribution of grayling; however, like Knapp (unpublished information) these authors noted the presence of adults and underyearlings in Sulphur Creek where suspended sediment levels were about 100 $mg \cdot L^{-1}$. Grayling fry were absent from Clear, Johnson and Duncan Creeks which were being actively placer mined. Thus these findings are similar to our own and those of Pendray (1983b). They imply that elevated suspended sediment levels do affect the distribution of underyearling Arctic grayling. Furthermore, the presence of older Arctic grayling (>0+) in turbid waters does not necessarily indicate that such conditions are acceptable for aquatic life, and it is quite possible that all age classes of fish captured in waters containing high suspended concentrations are under stress. McLeay et al. (1983) held underyearling Arctic grayling in cages for 4-5 days in clear ($\leqslant 34\ mg \cdot L^{-1}$) and turbid ($\leqslant 1210\ mg \cdot L^{-1}$) waters of Minto and Highet Creek respectively. Survival of the fish was greatest in clear Minto Creek and a biochemical examination revealed that those fish in Highet Creek were stressed (elevated plasma glucose levels).

During the reduction of placer mining activities and a corresponding reduction in suspended sediment levels in Highet Creek, we collected underyearling fish in an area where previously none were captured. In light of the foregoing comments it is probable that these fish moved into Highet Creek as a consequence of the decreased sediment concentrations (NFR) which changed from 318 $mg \cdot L^{-1}$ to <20 $mg \cdot L^{-1}$, and turbidities from 395 to 20 F.T.U's at the time of fishing (see results for series 1 and 2, Table 2).

DIET AND INVERTEBRATE DRIFT

Nuttall and Bielby (1973) carried out a survey of macroinvertebrates in rivers receiving china-clay wastes and found that these rivers supported a sparse population of few species. This poor incidence of macroinvertebrates was associated with the deposition of fine inert solids rather than turbidity or abrasion caused by particles in suspension. Furthermore, the typical river fauna was replaced by burrowing or tube building organisms. Increased densities of Tubificidae, Naididae and Chironomidae were correlated with increased silt deposition. Similar results have been found in other investigations, some of which have been summarized by the Interdepartmental Committee on Placer Mining (1983b).

In relation to placer mining, Mathers et al. (1981) examined the seasonal changes in benthic invertebrates in a number of Yukon streams. For example, the number of invertebrates at upstream and downstream sampling sites in Johnson Creek was similar prior to the commencement of placer mining, but fewer invertebrates were found downstream after mining had begun. This impoverished fauna may have been associated with increased sedimentation in the creek (Mathers et al. 1981) and the response of the benthic community to increased suspended solids. Gammmon (1970) reported that insect drift in a cold freshwater stream was increased by 25% with an increase of 19 $mg \cdot L^{-1}$ suspended solids above normal, and by 90% with an increase of 105 $mg \cdot L^{-1}$ suspended solids. Similarly, Rosenberg and Snow (1975) found that 10 to 500 $mg \cdot L^{-1}$ suspended solids increased insect drift in streams. Clearly, such an effect would eventually lead to an impoverished stream benthic community unless there was a continuous input from upstream, undisturbed areas. In contrast, on Thistle Creek (Mathers et al. 1981), the use of settling ponds and the recycling of water during placer mining efficiently reduced suspended solids (<5-56 $mg \cdot L^{-1}$) and there was no decline in the downstream benthic community between May and September. Hardy Associates Ltd. (1981) assessed the rate and degree of natural fish and wildlife habitat recovery in placer mined areas in Yukon. They concluded that approximately 5 years after mining the benthic communities of wide valleys had recovered whereas narrow valley streams did not return to "control" diversities and the benthic fauna were dominated by sediment tolerant organisms.

In the Minto Creek drainage, the highest density, but lowest diversity of invertebrate drift occurred in the placer-mined Highet Creek. While the reduced diversity of organisms is consistent with the findings of others (e.g. Mathers et al. 1981) the high density of drift organisms may well reflect the response of that community to increased sedimentation, as detected by Gammon (1970) and Rosenberg and Snow (1975). In agreement with Mathers et al. (1981) the clear, less sediment-laden waters in the Minto Creek drainage contained the most diverse drift fauna, albeit at a low density (Bennett Creek, Tables 22 and 23). During the time of our study placer mining along Highet Creek was confined to the middle third of the creek, and the contribution of aquatic organisms from upstream areas cannot be ignored. However, in the absence of mining, an invertebrate drift similar to that recorded in Bennett Creek would be expected.

The abundance of chironomid larvae in Highet Creek drift samples is of significance in relation to the diet of underyearling grayling. Despite the relatively high density of food organisms (primarily chironomid larvae) in Highet Creek, exceptionally few fish were present to exploit this food resource.

Throughout the Minto Creek drainage the diet of Arctic grayling was similar to that recorded for other cold-water streams. Diptera normally feature very highly in the diet of both underyearling and older grayling. Vincent (1962) states that chironomid larvae are especially important dietary components which are heavily utilized by young Arctic grayling, and that these fish start ingesting food at one week old. If chironomid larvae are not available in the first four weeks, there are critical implications for these underyearlings.

Vincent (1962) records that adult Arctic grayling are less restrictive in their diet and that the availability of food items is an important feature. This opinion is supported by the work of Schmidt and O'Brien (1982) who determined that Arctic grayling located and preyed upon species within the visual field, locating all by core body size; an ability which increased with prey size and light intensity. Nagy (1980) also determined that juvenile grayling (age 1+ to 3+) consumed smaller food items, predominantly chironomid larvae, while older fish (age 4+ to 5+) ate mainly trichopteran larvae. These results are supported by Mathers et al. (1981) and, although the diet of underyearling and older Arctic grayling were found to vary seasonally, dipteran larvae predominated in the diet. Typically, older fish (>0+) had a more diversified diet which included ephemeropteran, trichopteran and plecopteran larvae. Underyearlings fed primarily upon dipteran larvae and to a lesser extent ephemeropteran larvae. Mathers et al. (1981) also refer to other studies which have revealed similar trends in the diet of Arctic grayling between age classes and the reflection of benthic communities in the vicinity of the collection site.

The results of stomach contents analysis for Arctic grayling in the Minto Creek drainage parallel the findings mentioned above. The older grayling had a more diverse diet and the underyearlings fed primarily upon chironomid larvae. As in other studies, terrestrial insects were a minor dietary component. That the diet of the grayling differed between sampling locations was most probably a reflection of prey availablility and the prevailing aquatic conditions. That the fewest dietary components were found in fish taken from the placer-mined Highet Creek is in agreement with the findings of Mathers et al. (1981). The diet of fish in unmined tributary streams (e.g. Bennett Creek) reflected the more diverse, though less abundant invertebrate drift.

It is apparent that fish do not constitute a major prey item for Arctic grayling younger than five years old. Only one example of fish predation by grayling was recorded. One sculpin was found in the stomach of a grayling taken from the clear waters of Roaring Fork Creek. Mathers et al. (1981) also record small sculpins in the diet of adult grayling but their occurrence was very low, in contrast to benthic invertebrates.

Despite the differences in the diet of Arctic grayling between sampling locations in the Minto Creek drainage, condition factor analysis on underyearlings revealed that those in the clear tributary streams had statistically greater condition factors than those in both clear and sediment-laden waters of Minto Creek. The significance of this finding is unclear and difficult to explain without a more detailed investigation of the feeding ecology of these fish, their migrations within the drainage area, and the influence of differing water quality conditions at each location. Condition factors for the grayling we caught were within ranges recorded elsewhere. For example, Reed and McCann (1971) recorded values of between 0.77 and 1.09, based upon 1,283 specimens collected from 14 different areas in Alaska. McLeay et al. (1983) recorded values between 0.8 and 1.0, and later between 0.83 and 0.96 (McLeay et al. 1984). In the Minto Creek drainage the mean condition factor for underyearlings was 0.87±0.07 (S.D.) and ranged from 0.77 (Lower Minto Creek) to 0.93 (Bennett and Roaring Fork Creeks).

Underyearling Arctic grayling captured in Highet Creek during placer mining were found to have consumed primarily chironomid larvae, as did others of this age group in other locations. At the time of reduced mining activity (when suspended sediment concentrations were lower) more fish were captured and, although they had consumed chironomids, it was apparent from their digested state that they had not been recently ingested. This situation was not typical. The analysis of stomach contents of other grayling implied recent (continuous?) feeding. Our data indicate that the feeding activity and/or success for underyearling Arctic grayling in the turbid waters of Highet Creek was lower than those in less turbid waters in the area. This opinion is in accordance with, and supported by, the recent results of McLeay et al. (1984) who found that the feeding success of underyearling Arctic grayling under controlled laboratory conditions was reduced at suspended sediment strengths of 100 - 1000 $mg \cdot L^{-1}$. Although the condition factors of these fish did not change due to the sediment strengths tested, the growth rates of the test fish were reduced at 100, 300, and 1,000 $mg \cdot L^{-1}$ suspended sediment (taken from the Highet Creek area) relative to the controls. No effect of these sediment concentrations on the survival of the fish was evident after a six-week exposure period; whereas the general condition and performance of exposed fish were impaired (McLeay et al. 1984).

The effects that McLeay et al. (1984) recorded in relation to the feeding success of Arctic grayling may have direct relevance to the field distribution of these fish and their growth. Sediment strengths of 1000 $mg \cdot L^{-1}$ markedly impaired the feeding performance of underyearlings offered surface, subsurface and benthic drift prey organisms. At 300 and 100 $mg \cdot L^{-1}$ suspended sediment the feeding success of the fish on surface drift was impaired, but not for subsurface and benthic drift. Schmidt and O'Brien (1982) who determined that the reactive distance (in relation to prey attack) for Arctic grayling increased with light intensity (and size of prey) concluded that genetic selection for low light vision may be low, because most of the feeding would be under almost continuous daylight and high light intensities during summer in the Arctic. If this were so, high suspended sediment levels could reduce light transmission below that necessary for prey location. In Highet Creek, where prey items (chironomid larvae) were relatively abundant, the scarcity of fish in this creek and the seemingly lack of recent feeding implies that feeding success was low in this environment: migration or displacement from such turbid areas would be beneficial from a feeding standpoint. Thus, the relative scarcity of underyearling Arctic grayling in placer-mined Highet Creek could be attributed to the elevated suspended sediment levels. Suspended sediment levels greater than 1000 $mg \cdot L^{-1}$, a level which impaired feeding success under controlled laboratory conditions (McLeay et al. 1984) were recorded in Highet Creek during the summer of 1982 (McLeay et al. 1983).

The above deductions may also be applicable to older Arctic grayling, but it is apparent from an examination of stomach contents that the feeding success of these fish was relatively good. In that these older fish were located in the less sediment laden water of Minto Creek (Tables 2 and 5) generally fed upon larger prey, and would have a greater reactive distance than underyearlings (Schmidt and O'Brien 1982) prey location by these grayling was probably less impaired.

GILL HISTOPATHOLOGY

Gill histopathologies have been noted for salmonid fish exposed to high suspended sediment loadings in streams (Herbert et al. 1961) or in the laboratory (Herbert and Merkens 1961; Noggle 1978). Herbert et al. (1961) noted appreciable thickening (hypertrophy and hyperplasia) of gill respiratory epithelium from some brown trout (*Salmo trutta*) taken from streams containing 1,000 - 7,000 $mg \cdot L^{-1}$ of suspended solids; however the gill histology of other fish from the same streams was normal. Herbert and Merkens (1961) reported thickened gill lamellae for some rainbow trout (*Salmo gairdneri*) held in suspensions of diatomaceous earth for 13 days or more; whereas gills of other fish held for more than five months appeared normal. Noggle (1978) also found variable histopathological changes for juvenile steelhead trout (*S. gairdneri*), coho salmon (*Oncorhynchus kisutch*) or chinook salmon (*O. tshawytscha*) held in streams receiving high suspended sediment loadings for up to 4 days. The most common effects noted by Noggle (1978) were epithelial swelling (hypertrophy) and separation of the epithelial layer from the capillary. Smith (1978) was unable to demonstrate gill histopathologies for underyearling chum salmon (*O. keta*) held in high suspensions of inorganic sediment for up to four days. Yet it is well established (Wobeser 1975; Wedemeyer et al. 1979) that exposure of salmonid fish to other aquatic contaminants for periods as brief as one day can cause marked histopathological lesions (hypertrophy, hyperplasia, lamellar fusion). In a recent review of the pertinent literature, Pickral (1981) indicated the variability in results of fish gill tissue damage caused by high concentrations of suspended sediment. This variability in response could well be related to different sediment characteristics, biological and experimental differences. Accordingly more controlled experimentation is necessary to elucidate effects and the relevance of these variables.

The caged fish studies conducted in Highet Creek with underyearling Arctic grayling during August and September 1982 did not show any gill pathologies attributable to 4-day exposures to variable (less than 20 to 1,300 $mg \cdot L^{-1}$) concentrations of suspended solids (McLeay et al. 1983). Concurrent laboratory studies with underyearling grayling also found no changes in gill histology following exposure of fish to very high (up to 100,000 $mg \cdot L^{-1}$) concentrations of suspended inorganic or organic sediments. These findings indicate that, at least for this type of sediment discharged to Highet Creek during placer mining activities, grayling gill histology is unaffected by short-term exposure of fish to these sediments. The effect of more prolonged exposures is unknown but, in consideration of the marked gill lesions noted for adult grayling in the present report, there is reason for concern and the need for more research.

The gill histology for 69% of the underyearling Arctic grayling sampled from the Minto Creek drainage was normal, with slight histopathologies noted for only 28% of those fish examined. No consistent differences in gill histology were apparent for groups of underyearling grayling captured from Minto Creek above or below its confluence with Highet Creek. Although a greater frequency of slight hypertrophy and hyperplasia of the lamellar epithelium was noted for underyearling fish sampled from Highet Creek, the significance of this minor change is not known and is not thought to reflect any severe respiratory impairment attributable to higher suspended sediment loadings within Highet Creek.

The number (0 - 2) of gill tissues from juvenile (1+) grayling captured from each site was too small to permit any interpretations of histopathologies for this year class attributable to capture site. Only one of the six tissues examined from this age class of grayling showed marked lesions.

The relevance of the apparent increase in frequency of gill ectoparasites for grayling captured directly from Highet Creek is not known. Since gill parasites were noted for only five of the nine tissues examined, and since the degree of parasitic infestation for these fish was only slight-to-moderate, the gill parasites present would not pose an immediate threat to the well-being of these fish. The prevalence of gill parasites was not positively correlated with the histopathologies noted. Thus, although monogenetic trematodes can cause extensive gill epithelial hyperplasia in Arctic grayling (Wobeser et al. 1976), the present findings do not suggest that ectoparasites were the cause of the histopathologies observed.

The observation of very marked histopathologies for nine of the ten gill specimens examined from "adult" grayling captured from Minto Creek is of concern. Since no "adult" fish were captured for gill tissue examination from Minto Creek above its confluence with Highet Creek, nor from any tributary creeks or other waters believed to be relatively free from high loadings of suspended sediment, we cannot address the question of differences above and below Highet Creek. Additionally, the prior history of these fish (including residence time in Minto Creek below Highet Creek) is not known. Wobeser et al. (1976) reported severe lamellar hyperplasia for gill tissues of captive Arctic grayling infested with large numbers of monogenetic trematodes. While parasitic infection may have been responsible for the marked hypertrophy and hyperplasia of gill tissues from one age 3+ Arctic grayling captured in Minto Creek below Roaring Fork Creek (Table 19) parasitic infection did not appear to be the cause of marked effects at other sites in the drainage. At both 'Minto Creek below Bennett Creek' (about 1.5 km downstream of the junction with placer mined Highet Creek) and at the 'Lower Minto Creek' sampling site (about 6.0 km downstream) gill clubbing and marked hyperplasia and hypertrophy were recorded for age 3+ fish in the absence of parasitic infestation. The results of the present gill tissue studies with Minto Creek fish suggest that a prolonged exposure of Arctic grayling to waters with high suspended sediment loadings might cause histopathologies. However, without further investigation, the relevance of such findings cannot be established.

GENERAL

The age and spatial distribution of Arctic grayling in the Minto Creek drainage was found to be very similar to those in other areas subjected to placer mining. There was a scarcity of underyearling fish in sediment laden waters, implying their avoidance or displacement from Highet Creek and for at least 1 km below the input of these turbid waters into Minto Creek. Underyearling fish were more numerous in Highet Creek only when suspended sediment levels decreased (318 - $<20\ mg \cdot L^{-1}$) due to a reduction in placer mining despite the relatively high density of preferred prey items (chironomid larvae). As in other studies in placer mining areas, older fish were recorded in the turbid waters of the drainage. They were not in Highet Creek. The results imply that there was incomplete utilization of the waters within the Minto Creek drainage due to placer mining operations. While the diet of Arctic grayling tended to reflect the availability of food items, it is inferred from these studies that the feeding success of underyearling Arctic grayling may have been impaired during exposure to elevated sediment levels in placer mined Highet Creek.

An examination of the gills of underyearling and juvenile Arctic grayling from the Minto Creek drainage determined a normal condition although the frequency of gill ectoparasites for fish captured in Highet Creek was elevated relative to that for fish from Minto Creek or its clear water tributaries. Of more concern, was the histopathologies found in older fish (age 3+, 4+, 5+) captured in Minto Creek downstream of Highet Creek. Marked hyperplasia, hypertrophy and clubbing were recorded, and, although this response may be induced by elevated suspended sediment levels, parasitic infection can induce the same response. Only further research will be able to elucidate the significance of these findings.

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Table 1. Description of the main sampling sites within the Minto Creek drainage, August 6 - 10, 1982.

Site	Substratum	Approximate stream width (m)	Bank overhang (%)	Bank undercut (%)	Stream pool (%)	Stream riffle (%)	Stream glide (%)
Upper Minto Creek	sand and gravel with cobbles to 15 cm	6	50	-	10	20	70
Minto Creek above Highet Creek	sand and gravel with cobbles to 15 cm	4.5	30	<5	20	50	30
Highet Creek	cobbles to 15 cm with sand and mud	2.5	60	20	10	80	10
Upper Highet Creek	sand, gravel and mud with boulders to 30 cm	2.5	10	20	20	70	10
Minto Creek below Highet Creek	sand, gravel and mud with boulders to 100 cm	4.5	20	<10	10	60	30
Minto Creek above Bennett Creek	silt, sand, boulders, to 60 cm	3	50	60	10	70	20
Bennett Creek	cobbles to 20 cm with sand	2	80	<5	20	60	20
Minto Creek below Bennett Creek	sand, silt and clay with cobbles and small boulders to 30 cm	4.5	5-10	<5	25	60	15
Roaring Fork Creek	mainly flat loose stones to 30 cm, with gravel and sand	3.5	20	<5	5	90	5
Minto Creek below Roaring Fork Creek	sand and mud in gravel, cobbles to 15 cm, flat rocks	6	5	25	35	35	30
Lower Minto Creek	gravel and cobble to 20 cm	6	<5	-	30	30	40
Mud Creek	boulders to 100 cm, cobbles and gravel, little sand	2	80	80	10	10	80
Minto Creek above Mayo River	sand, mud, gravel (no large rocks)	12	60	80	40	50	10

Table 2. The number of Arctic grayling and determinations of turbidity (F.T.U), non-filterable residue ($mg \cdot L^{-1}$), total fixed residue ($mg \cdot L^{-1}$) and total residue ($mg \cdot L^{-1}$) at sampling sites in the Minto Creek drainage August 6-10, 1982.

Site	Number of Arctic grayling captured	Turbidity (F.T.U)	Non-filterable residue ($mg \cdot L^{-1}$)	Total fixed residue ($mg \cdot L^{-1}$)	Total residue ($mg \cdot L^{-1}$)
Upper Minto Creek	236	<1	36	246	319
Minto Creek above Highet Creek	71	1	22	101	122
Highet Creek (Series #1)	-	395	318	375	415
Highet Creek (Series #2)	5	20	<20	105	112
Upper Highet Creek (Series #1)	1	5	<20	86	109
Upper Highet Creek (Series #2)	1	20	<20	105	112
Minto Creek above Bennett Creek	-	9	50	140	187
Bennett Creek	6	2	<20	119	146
Minto Creek below Bennett Creek	13	21	20	150	193
Roaring Fork Creek	29	3	<20	89	132
Minto Creek below Roaring Fork Creek	24	10-15	<20-26	128-143	172-199
Lower Minto Creek	9	23	70	196	232
Mud Creek	41	2	<20	139	190
Minto Creek above Mayo River	2	4	<20	140	167

N.B. Samples not collected simultaneously

Table 3. Water velocities recorded at sampling sites within the Minto Creek drainage, August 6-10, 1982.

Site	mean water velocity ($m \cdot s^{-1}$)			
	n[1]	fishing zone	n[1]	drift sampling zone
Upper Minto Creek	7	0.50	-	-
Minto Creek above Highet Creek	6	0.81	6	1.02
Highet Creek	5	0.97	5	0.88
Upper Highet Creek	5	0.63	-	-
Minto Creek below Highet Creek	5	0.81	-	-
Minto Creek above Bennett Creek	5	0.89	5	0.83
Bennett Creek	5	0.73	5	0.62
Minto Creek below Bennett Creek	5	0.81	-	-
Roaring Fork Creek	5	0.59	-	-
Minto Creek below Roaring Fork Creek	5	0.52	-	-
Lower Minto Creek	5	0.80	-	-
Mud Creek	5	0.68	-	-
Minto Creek above Mayo River	5	0.48	-	-

[1] n - number of replicate velocity determinations.

Table 4. Temperatures recorded at sampling sites within the Minto Creek drainage, August 6-10, 1982.

Site	Temperature (°C)		
	mean	range	n
Minto Lake	16.0	-	1
Upper Minto Creek	13.7	13.0-14.5	3
Minto Creek above Highet Creek	13.2	12.0-14.5	5
Highet Creek	8.0	6.0-9.5	4
Upper Highet Creek	9.4	7.5-10.5	4
Minto Creek below Highet Creek	11.7	11.0-12.5	3
Minto Creek above Bennett Creek	12.2	10.5-14.0	6
Bennett Creek	5.3	3.8-7.0	8
Minto Creek below Bennett Creek	11.7	9.5-13.0	5
Roaring Fork Creek	6.2	5.5-7.5	4
Minto Creek below Roaring Fork Creek	10.5	10.0-11.0	2
Lower Minto Creek	13.0		1
Mud Creek	10.5	10.0-11.0	3
Minto Creek above Mayo River	9.0		1

Table 5. Numbers and species of fish, the age structure of Arctic grayling and the condition factor for 0+ fish, captured in Minto Lake, Minto Creek and tributary streams, August 6-10, 1982.

Site	Number of Seines	Species	Number	Condition Factor mean ± S.D.(n)	Age (Years)
Minto Lake	3	Northern pike	6		
		Burbot	12		
		Lake whitefish	2		
		Slimy sculpin	1		
		Total	21		
Upper Minto Creek	16	Arctic grayling	236	0.86±0.03 (n=15)	0+
		Slimy sculpin	40		
		Burbot	1		
		Total	277		
Minto Creek above Highet Creek	16	Arctic grayling	71	0.83±0.05 (n=24)	0+
		Slimy sculpin	8		
		Total	79		
Highet Creek (Series #1)	16	Slimy sculpin	1		
		Burbot	1		
		Total	2		
Highet Creek (Series #2)	16	Arctic grayling	5		0+
Highet Creek, 50 m to junction with Minto Creek (Series #2)	1	Arctic grayling	2		0+
		Burbot	1		
		Total	3		
Upper Highet Creek (Series #1)	16	Arctic grayling	1		0+
Upper Highet Creek (Series #2)	16	Arctic grayling	1		0+

Table 5 (Cont'd)

Site	Number of Seines	Species	Number	Condition Factor mean ± S.D.(n)	Age (Years)
Junction - Highet/Minto Creeks					
Minto Creek	1	Arctic grayling	7		0+
Interface	1	Arctic grayling	3		0+
Highet Creek	1		0		
Minto Creek below Highet Creek	16	Arctic grayling	1	0.88 (n=1)	0+
		Longnose sucker	1		
		Slimy sculpin	1		
		Total	3		
Minto Creek above Bennett Creek	18		0		
Junction, unnamed creek with Minto Creek	1	Arctic grayling	3		0+
Bennett Creek	19	Arctic grayling	6	0.93±0.05 (n=6)	0+
		Slimy sculpin	1		
		Total	7		
Minto Creek below Bennett Creek	19	Arctic grayling	13	0.80±0.03 (n=8)	0+;1+;3+;4+
Roaring Fork Creek	16	Arctic grayling	29	0.93±0.09 (n=15)	0+;3+;4+
		Slimy sculpin	1		
		Total	30		
Minto Creek below Roaring Fork Creek	16	Arctic grayling	24	0.85±0.04 (n=12)	0+;1+
		Slimy sculpin	1		
Minto Creek 30 m below section named above	4	Arctic grayling	1		0+
		Slimy sculpin	1		
		Total	2		

Table 5 (Cont'd)

Site	Number of Seines	Species	Number	Condition Factor mean ± S.D.(n)	Age (Years)
Lower Minto Creek	16	Arctic grayling	9	0.77 (n=1)	0+;1+;2+;3+; 4+;5+
Mud Creek	16	Arctic grayling	41	0.87±0.06 (n=23)	0+;1+
		Slimy sculpin	1		
		Total	42		
Minto Creek above Mayo River	16	Arctic Grayling	2	0.88±0.1 (n=2)	0+
		Longnose sucker	2		
		sculpin	8		
		Total	12		

Table 6. Stomach contents of 20 arctic grayling (age 0^+) from 'Upper Minto Creek' August 8, 1982

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Ostracoda and *Bosmina*	Detritus
<0.2		20		10		50				20				
<0.2			20			70				10				
<0.2		30	20	20		30								
<0.2				10		90								
<0.2			60			40								
<0.2		20		20		55							5	
<0.2						50				50				
<0.2						95							5	
<0.2		20	20	20		20			20					
<0.2				30		70								
<0.2		20				80								
<0.2		10	20	20		50								
<0.2						100								
<0.2		20				70				10				
<0.2								100						
<0.2						100								
<0.2					60	40								
0.2					90	10								
0.3		5		10	70	15								
0.3								100						

MAJOR COMPONENTS:
- Simuliidae
- Chloroperlidae
- *Ephemerella* sp.
- Chironomidae

MINOR COMPONENTS:
- *Baetis* sp.
- Tipulidae
- *Glossosoma* sp.
- Perlidae
- Ostracoda
- *Bosmina* sp.
- Hydroptilidae
- *Paraleptophlebia* sp.
- Ceratopogonidae
- Lymnaeidae

Table 7. Stomach contents of 36 arctic grayling (age 0^+) from 'Minto Creek above Highet Creek' August 6, 1982.

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
<0.2		50	20			30								
<0.2				40		60								
<0.2			40		60	60								
<0.2		30	15	30		25								
<0.2		20				70				10				
<0.2				70		30								
<0.2		20				20				60				
<0.2		20	50			30								
<0.2		10	80			10								
<0.2		30	20			50								
<0.2		10	60			30								
<0.2		5	40			40	10							5
<0.2		35	20			45								
<0.2			50			50								
<0.2		20		10		70								
<0.2		40				60								
<0.2			20	30		40	10							
<0.2			50			40			10					
<0.2		40		30		30								

Table 7. Cont'd

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Coleoptera Adults	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
<0.2						90	10							
0.2		10	25	35		30								
0.2		10		30		30				30				
0.2		20				80								
0.2		25	10	25		20				20				
0.2		10		10		80								
0.2		10	5			85								
0.2			20			80								
0.2		50								50				
0.2		40	50			10								
0.2		10	20			70								
0.2		55	30			15								
0.2		30	40	25		5								
0.2		50		50										
0.2						100								
0.2		30		40		30								
0.2		50		50										

MAJOR COMPONENTS:
- Simuliidae
- Chloroperlidae
- Ephemerella sp.
- Chironomidae

MINOR COMPONENTS:
- Rhyacophila sp.
- Tipulidae
- Coleoptera
- Glossosoma sp.
- Alloperla sp.
- Paraleptophebia sp.
- Perlidae sp.
- Ephemerella sp.

Table 8. Stomach contents of one arctic grayling (age 0^+) from 'Upper Highet Creek' August 7, 1982.

	Stomach Content Composition (%) by Volume												
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
0.4		10			90								

MAJOR COMPONENTS:
Chironomidae

MINOR COMPONENTS
Tipulidae
Ephemerella sp.

Table 9. Stomach contents of seven arctic grayling (age 0^+) from 'Highet Creek' August 9, 1982.

Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Adult	Algae	Detritus
	Stomach Content Composition (%) by Volume													
<0.2						100								
<0.2						100								
0.2		15				80				5				
0.2						90				10				
<0.2			70			30								
<0.2		40				60								
0.2						100								

Most stomach contents digested beyond recognition.

MAJOR COMPONENTS:
Chironomidae

MINOR COMPONENTS:
Tipulidae
Baetis sp.
Nemoura sp.

Table 10. Stomach contents of six arctic grayling (age 0^+) from 'Bennett Creek' August 6, 1982

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Adults	Algae	Detritus
0.2										100				
0.2		90				10								
0.3		60				30				10				
0.6		60				20	20							
0.6		80	10			10								
0.6		75				25								

NOTE: It would appear that a Baetis hatch was occurring.

MAJOR COMPONENTS:
Ameletus sp.
Baetis sp.
Chironomidae

MINOR COMPONENTS:
Simuliidae
Coleoptera
Chloroperlidae

Table 11. Stomach contents of eight arctic grayling (age 0^+) from 'Minto Creek below Bennett Creek' August 6, 1982.

Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
	Stomach Content Composition (%) by Volume													
0.2		45				45			5		5			
0.2		45				45			10					
0.2		40				20						40*		
0.2		60				40								
0.2		60				35	5							
0.2		65				25					10			
0.2		60				10			10	10	10			
0.2						5			20	75				

* One large specimen

MAJOR COMPONENTS:
Ephemerella sp.
Tipulidae
Chironomidae

MINOR COMPONENTS:
Chloroperlidae
Baetis sp.
Dytiscidae

Table 12. Stomach contents of five arctic grayling (age $1^+, 3^+, 4^+$) from 'Minto Creek below Bennett Creek' August 6, 1982.

	Stomach Content Composition (%) by Volume													
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
0.2		25		20				10	20		5			20
1.0		10				10				50				30
1.0		10				10		15	35	10				20
2.0				10					10					80
2.2				40				10		30				20

MAJOR COMPONENTS:
Limnephilidae
Ephemerella sp.

MINOR COMPONENTS:
Chironomidae
Empididae
Baetis sp.

Table 13. Stomach contents of 36 arctic grayling (age 0^+,3^+,4^+) from 'Roaring Fork Creek' August 7, 1982.

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Sculpin	Detritus
<0.2		30				50				20				
0.2		80	10			10								
0.2		90				10								
<0.2		65		20		15								
<0.2		65	20			15								
<0.2		90				10								
<0.2		90	5			5								
<0.2		80	10			10								
<0.2		50	30			5				15				
0.2		100												
0.2		100												
0.2		100												
0.2		100												
0.3		70	20			10								
0.4		100												
0.4		50				20				20				10
<0.2						100								
<0.2		60				40								
<0.2		15				15				70				
<0.2		60				40								
4.5				30						10		10		50
<0.2		70				30								
<0.2		35		35		30								

Table 13. (cont'd)

Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Sculpin	Detritus
	Stomach Content Composition (%) by Volume													
3.8				30		10				20				40
0.2		10				10				80				
<0.2													100	
1.6		40		30		20								10
1.0		95				5								
0.6		40				10				20		30		
<0.2		50				50								
<0.2		30				70								
<0.2		80				20								
0.2		90				10								
<0.2		40				60								
0.2		35	5			60								
<0.2				20		80								

NOTE: Large amounts of detritus are from caddisfly cases

MAJOR COMPONENTS:
Heptageniidae
Chironomidae
Baetis sp.

MINOR COMPONENTS:
Simuliidae
Nemoura sp.
Ameletus sp.
Rhyacophila sp.
Glossosoma sp.
Limnephilidae
Chloroperlidae

Table 14. Stomach contents of five arctic grayling (age 0^+) from 'Minto Creek below Roaring Fork Creek' August 7, 1982.

Settled Volume (ml)	Stomach Content Composition (%) by Volume													
	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids & Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Adult	Algae	Detritus
0.2		15				15				70*				
0.2		35		15		50								
0.2		60		10		20			10					
0.2		40				50			10					
0.3				20		80								

*A single large terrestrial larva

MAJOR COMPONENTS:
Ephemerella sp.
Chironomidae
Baetis sp.

MINOR COMPONENTS:
Tipulidae
Glossosoma sp.

Table 15. Stomach contents of 14 arctic grayling (age 0^+, 1^+) from 'Mud Creek' August 9, 1982.

	Stomach Content Composition (%) by Volume													
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
0.5		30	5	5		55				5				
0.4		55		5		30				5	5			
0.3	45	20		20		10				5				
0.4		35	10	10		40				5				
0.3		10		45	5	40								
0.5		10	10	20		20				40				
0.3		20		5		75								
0.5		10	5	25		30			30					
0.4		30	5	35		30								
<0.2		40				60								
0.8		30		40		5					20			5
0.8		30		30		10							30	
0.9		30		60		10								
1.2		15		70		15								

MAJOR COMPONENTS:	MINOR COMPONENTS:	
Simuliidae	Ceratopogonidae	Tipulidae
Chironomidae	Hydropsychidae	<u>Glossosoma</u> sp.
<u>Baetis</u> sp.	Nemouridae	<u>Ameletus</u> sp.
<u>Ephemerella</u> sp.	Collembola	
<u>Rhyacophila</u> sp.	Dixidae	

Table 16. Stomach contents of two arctic grayling (age 0^{+}) from 'Lower Minto Creek' August 8, 1982.

	Stomach Content Composition (%) by Volume													
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
0.2		40	10			50								
0.3		30		5		65								

MAJOR COMPONENTS:
Heptageniidae
Chironomidae

MINOR COMPONENTS:
Chloroperlidae
Baetis sp.
Glossosoma sp.

Table 17. Stomach contents of seven arctic grayling (age $1^+, 2^+, 3^+, 4^+, 5^+$) from 'Lower Minto Creek' August 8, 1982.

	Stomach Content Composition (%) by Volume													
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids & Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
1.0		65				5				10				20
1.5		60				5					15			20
0.5		80				10								10
1.6		50				10				10				30
4.0		10		25						25				40
2.2		35		35										30
3.6		10		40						20	10			20

NOTE: A large part of the detritus appears to be from caddisfly cases.

MAJOR COMPONENTS:
<u>Ephemerella</u> sp.
Heptageniidae
Limnephilidae

MINOR COMPONENTS:
Chironomidae
Hydropsychidae

Table 18. Stomach contents of two arctic grayling (age 0^+) from 'Minto Creek above Mayo River' August 10, 1982.

	Stomach Content Composition (%) by Volume													
Settled Volume (ml)	Ephemeroptera Adult	Ephemeroptera Larvae	Plecoptera Larvae	Trichoptera Larvae	Diptera Adult	Diptera Larvae	Coleoptera Larvae	Gastropoda	Arachnids and Coleoptera Adult	Terrestrial Insects	Formicidae Adult	Lepidoptera Larvae	Algae	Detritus
0.2		40	40			20								
0.2		60		30		10								

MAJOR COMPONENTS:
- Chironomidae
- Nemouridae
- *Ephemerella* sp.
- *Baetis* sp.
- *Glossosoma* sp.

Table 19. Gill histopathologies[a] for Arctic grayling collected from Minto Creek, Highet Creek and Mud Creek during the period August 6 - 10, 1982.

Collection site	Life stage/age	Age	Hyperplasia[b]	Hypertrophy[c]	Clubbing[d]	Debris	Parasites[e]
Minto Creek above Highet Creek	underyearling		*	*		*	*
	underyearling					*	*
	underyearling					*	**
	underyearling					*	
	underyearling					*	
	underyearling						*
	underyearling					*	
	underyearling					*	
	underyearling					*	
	underyearling						
	underyearling						
	underyearling						*
Minto Creek below Bennett Creek	underyearling						*
	underyearling						
	underyearling					*	
	underyearling						
	underyearling						**
	underyearling		*	*			
	underyearling						
	underyearling		**	**	*	*	
	juvenile	1+	*	*	*		
	juvenile					*	
			****	****	*	*	
	juvenile	3+, 4+	****	****	*		
	/adult		****	****	*		
Minto Creek below Roaring Fork Creek	underyearling						*
	underyearling						**
	underyearling		*	*		*	
	underyearling						
	underyearling						
	juvenile	1+					
	juvenile						
	juvenile	3+	*	*			
	juvenile		****	****	***		**
Lower Minto Creek	underyearling						
	underyearling		*	*	*	*	
	juvenile	1+	***	***	*	**	
	juvenile		*	*	*		
			****	****	**		
		2+, 3+	****	****	**		
	juvenile		****	****	**		
	/adult	4+, 5+	****	****	**		
			****	****	**		

Table 19 (Cont'd)

Collection site	Life stage/age	Hyperplasia[b]	Hypertrophy[c]	Clubbing[d]	Debris	Parasites[e]
Minto Creek above Mayo River	underyearling				*	
	underyearling	*			*	
Upper Highet Creek	underyearling	*	*		*	*
	underyearling				*	
Lower Highet Creek	underyearling					
	underyearling					
	underyearling	*	*		*	
	underyearling	*	*	*		**
	underyearling	*	*	*	*	**
	underyearling	*	*	*	*	**
	underyearling	*	*	*		**
Mud Creek	underyearling				*	*

[a] Positive values are based on a scale of 1 to 4, where * = slight; ** = moderate; *** = marked; and **** = very marked.
[b] Abnormal increase in cellular number.
[c] Increase in cellular size.
[d] Thickening of distal ends of lamellae.
[e] Tentatively identified as monogenetic trematodes.

Table 20. Frequency of gill histopathologies for underyearling and juvenile Arctic grayling collected from Minto Creek and tributary Creeks between August 6 and 10, 1982.

Site	n	Frequency of Gill Histopathologies (%)		
		none	slight	moderate
Highet Creek	9	33	67	0
Minto Creek above Highet Creek	12	92	8	0
Minto Creek below Bennett Creek	10	70	20	10
Minto Creek below Roaring Fork Creek	7	86	14	0

Table 21. The percentage of Arctic grayling gills from each sampling site in the Minto Creek drainage for which parasites were observed.

Site	Parasite Frequency (%)		
	n	slight	moderate
Minto Creek above Highet Creek	12	33	8
Minto Creek below Bennett Creek	13	8	8
Minto Creek below Roaring Fork Creek	9	11	22
Minto Creek 4 km below Roaring Fork Creek	9	0	0
Highet Creek	9	11	44

Table 22. A summary of drift sampling information obtained August 6 - 10, 1982 in the Minto Creek drainage.

Site	Series	Sampling duration (h)	Water flow ($m \cdot s^{-1}$)	Water volume sampled (m^3)	Number of organisms (m^{-3})	Number of taxa$\cdot$sample^{-1}
Minto Creek above Highet Creek	1	16.50	1.02	196.9	9.26	15
	2	16.00	1.02	190.9	7.00	14
Highet Creek	1	17.00	0.88	175.0	22.65	11
	2	16.00	0.88	164.7	11.94	8
Minto Creek below Bennett Creek	1	17.33	0.83	168.3	5.94	13
	2	14.95	0.83	145.2	6.64	13
Bennett Creek	1	17.33	0.62	125.7	3.33	11
	2	14.95	0.62	108.4	2.02	12

Table 23. The composition of, and invertebrates (·100 m^3) in, drift samples collected from Minto, Highet and Bennett Creeks, between August 6 and 10, 1982.

Taxonomic group		Minto Creek above Highet Creek[a]		Highet Creek		Minto Creek above Bennett Creek[a]		Bennett Creek[b]	
	Series	1	2	1	2	1	2	1	2
ARACHNIDA			4.16						
Acarina		32.64	45.76	20.52	4.56	30.68	24.84	124.00	54.28
ANNELIDA									0.92
COLEOPTERA (terrestrial)			4.16						
DIPTERA									
Chaoboridae		6.12		9.12		2.36			
Chironomidae	adults	193.80	112.32	9.12	19.52	80.24	24.84	5.60	
	larvae	206.04	178.80	984.96	1039.44	214.76	338.20	52.80	46.00
	pupae	95.88	62.40	13.68	14.64	14.16	11.04	4.00	13.80
Dixidae		2.04							
Simuliidae	larvae	183.60	191.36			18.88	11.04	1.60	2.76
Tipulidae		2.04		22.80	9.76	7.08	13.80	3.20	0.92
EPHEMEROPTERA									
Baetidae									
Baetis sp.		95.88	54.08	27.36	13.42	30.68	38.64	24.00	15.64
Ephemerella sp.		8.16	4.16			9.44			3.68
Heptageniidae									
Rhithrogena sp.								1.52	21.16
Leptophlebiidae									
Paraleptophlebia sp.		4.08	8.32						
HEMIPTERA									
Corixidae			2.76						

Table 23. (cont'd).

Taxonomic group	Minto Creek above Highet Creek		Highet Creek		Minto Creek above Bennett Creek[a]		Bennett Creek[b]	
Series	1	2	1	2	1	2	1	2
PLECOPTERA								
Chloroperlidae						2.76	6.40	6.44
Nemouridae	6.12	4.16	11.40		37.76	104.88		
Perlidae	2.04							
TRICHOPTERA								
Glossosomatidae								
Glossosoma sp.		4.16	4.56		4.72			
Hydropsychidae								
Hydropsyche sp					2.76			
Limnephilidae	14.28	4.16	2.28	4.88	4.72	22.08	1.60	
Rhyacophilidae								
Rhyacophila sp.								0.92
MISCELLANEOUS TERRESTRIAL	77.52	16.64	68.40	92.72	134.52	74.52	96.00	34.96
TOTAL	930.24	697.40	1174.20	1198.94	592.76	659.64	338.40	201.48

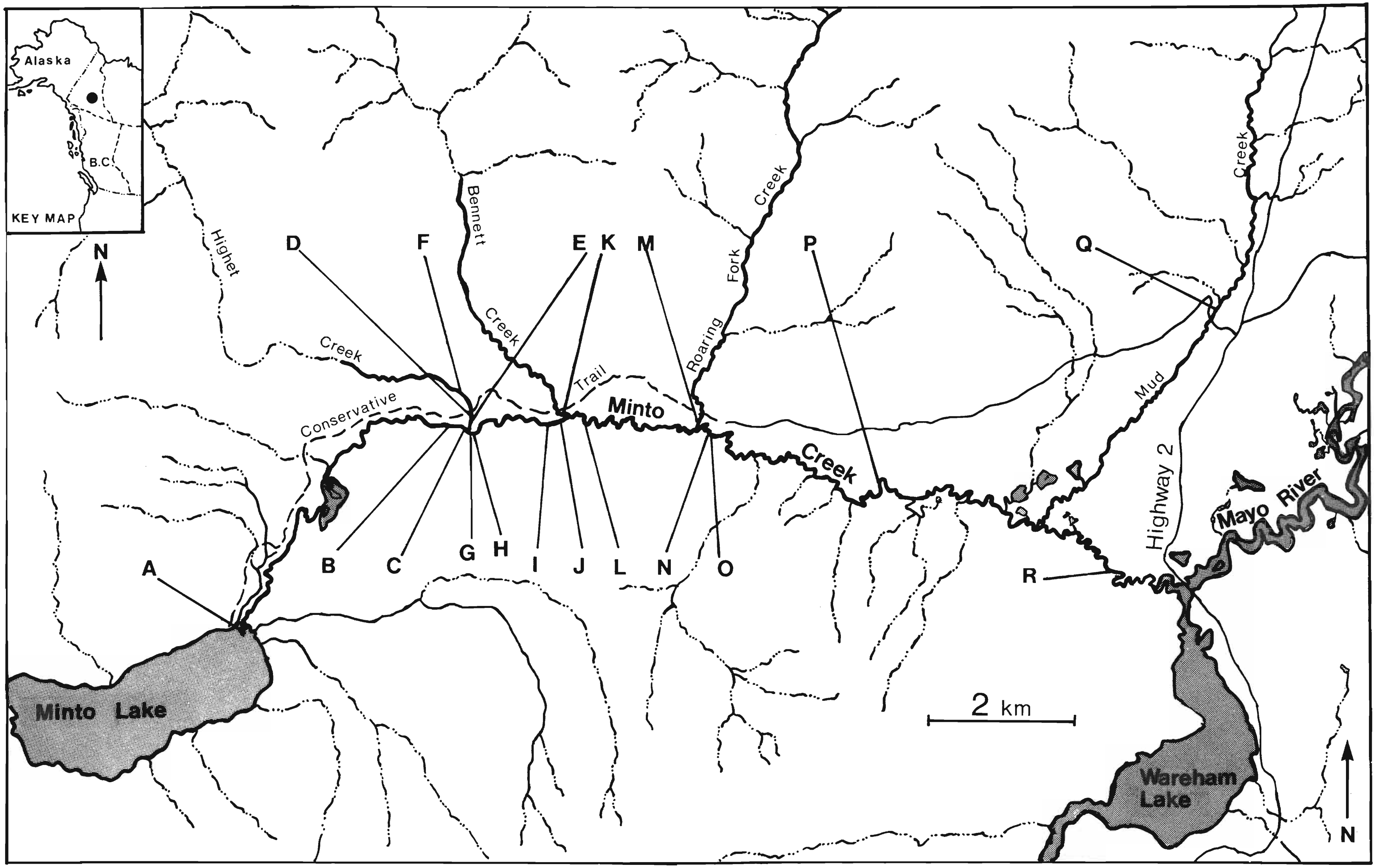
[a]Zooplankters (copepods, cladocerons - *Bosmina* sp., *Polyphemus* sp. predominant) and ostracods numerous but not enumerated.

[b]Zooplankters (copepods) common, but not enumerated.

FIGURES

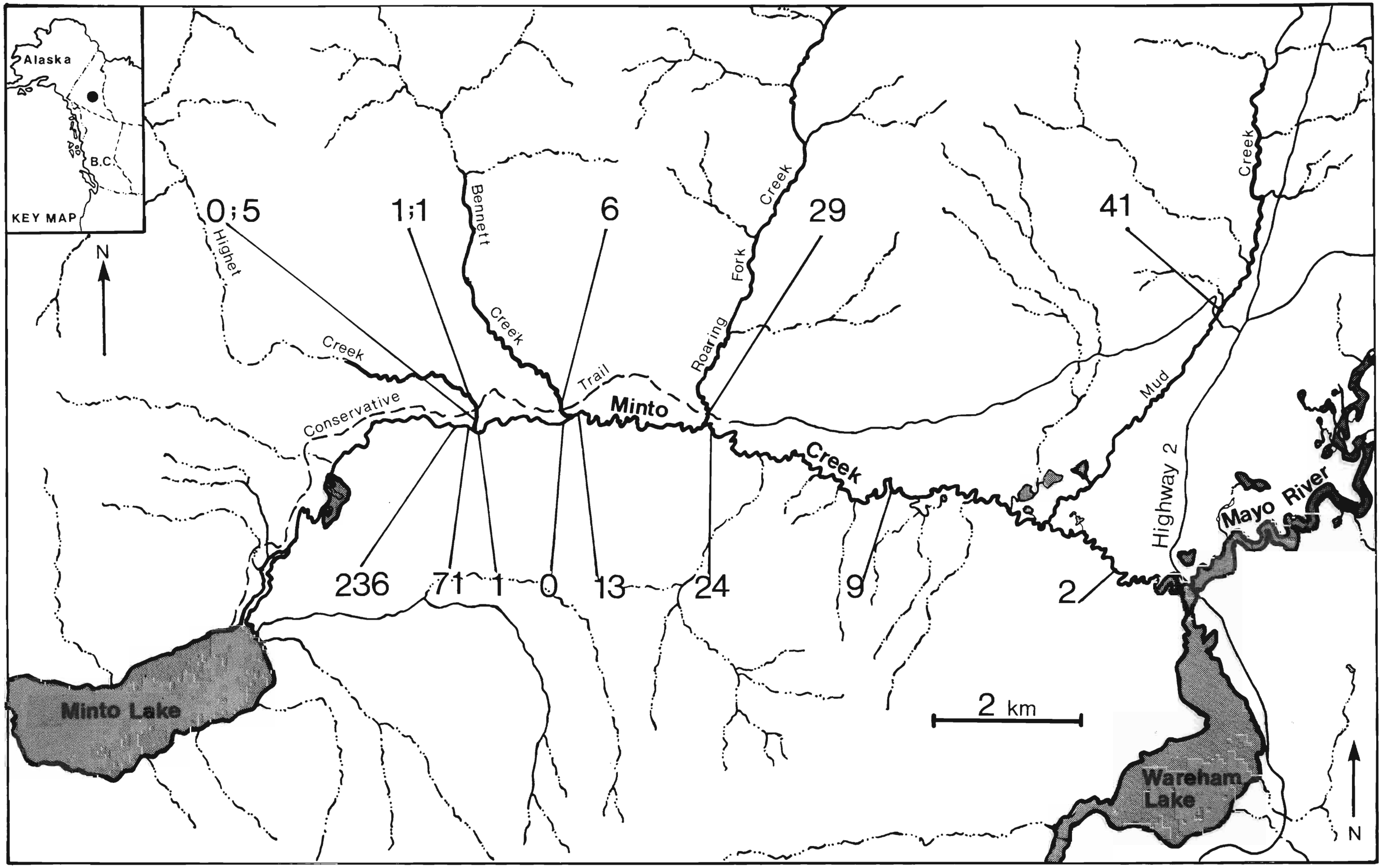
Figure 1. The Minto Creek drainage, Mayo, Yukon Territory, and the location of sampling sites.

KEY:
A. Minto Lake
B. Upper Minto Creek
C. Minto Creek above Highet Creek
D. Highet Creek
E. Highet Creek, 50 m above confluence with Minto Creek
F. Upper Highet Creek
G. Junction - Highet and Minto Creeks
H. Minto Creek below Highet Creek
I. Minto Creek above Bennett Creek
J. Junction, unnamed creek with Minto Creek
K. Bennett Creek
L. Minto Creek below Bennett Creek
M. Roaring Fork Creek
N. Minto Creek below Roaring Fork Creek
O. Minto Creek 30 m below (N)
P. Lower Minto Creek
Q. Mud Creek
R. Minto Creek above Mayo River



Alaska
B.C.
KEY MAP
N
Highet
Creek
Bennett
Creek
Roaring
Fork
Creek
Conservative
Trail
Minto
Creek
Mud
Creek
Highway 2
Mayo River
Minto Lake
Wareham Lake
2 km
N
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R

Fig. 2. Numbers of Arctic grayling captured at the main sampling sites in the Minto Creek drainage (16-19 pole seine sets per site).


Alaska
B.C.
KEY MAP
N
0;5
1;1
6
29
41
Highet
Creek
Bennett
Creek
Roaring
Fork
Creek
Conservative
Trail
Minto
Creek
Mud
Creek
Highway 2
Mayo River
236
71
1
0
13
24
9
2
2 km
Minto Lake
Wareham Lake
N

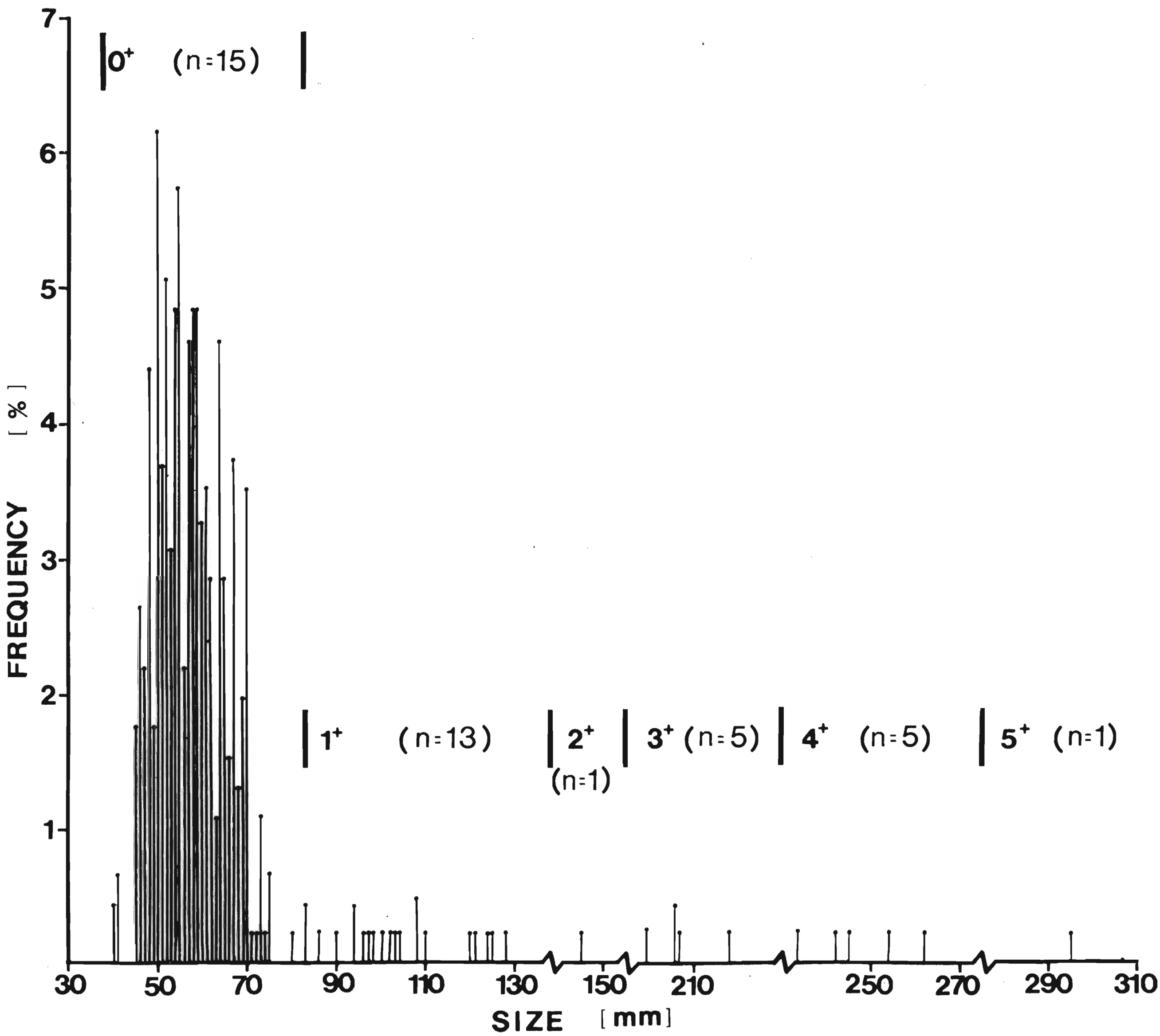


Fig. 3. Size-frequency histogram (n=449) and an age classifcation (n=40) for Arctic grayling captured August 6-10, 1982 in the Minto Creek drainage.