*Extension Note*

**BC Journal of Ecosystems and Management**

# Further evidence of size gradients in Arctic grayling (*Thymallus arcticus*) along stream length

**Dominic (Nick) Baccante[1]**

## Abstract

Previous work in Alaska indicates that the distribution of Arctic grayling (*Thymallus arcticus*) along streams is influenced by fish size. Larger fish are usually found in the upstream reaches, and the mean size gradually decreases further downstream, closer to the stream mouth. One of the hypotheses supporting this observation is that larger fish have a feeding advantage because they have first access to drifting prey. This mechanism is also believed to occur within pools. This extension note provides further evidence supporting the size gradient of Arctic grayling in streams. I use data from two rivers in northern British Columbia and one river in Alberta to show similar patterns of size distribution. I quantify these relationships and encourage other researchers who work on Arctic grayling populations in rivers to document what may be a characteristic of this species across its range. These observations should be of interest to anyone who works on Arctic grayling in streams, and I encourage investigators to look for similar patterns in their areas of study. This segregation of Arctic grayling based on size may have management implications through the use of size-based fisheries regulations.

**KEYWORDS:** *Arctic grayling; distribution; fish-size gradient; stream length;* Thymallus arcticus.

### Contact Information

1 Section Head, B.C. Ministry of the Environment, Fish and Wildlife Section, 10003–110th Avenue, Room 400, Fort St. John, BC V1J 6M7. Email: Nick.Baccante@gov.bc.ca



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## Introduction

Published information on size gradients of salmonids in streams is very scarce. The occurrence of larger fish upstream has been reported for Arctic grayling (*Thymallus arcticus*) in Alaskan streams (Tack 1974; Hughes and Reynolds 1994) and brown trout (*Salmo trutta*) in New Zealand streams (Jellyman and Graynoth 1994). The size gradient of Arctic grayling along stream length has been well documented in two Alaskan rivers, the Chena and Goodpaster (Hughes and Reynolds 1994; Hughes 1999). In both papers, the authors show that the mean size of Arctic grayling increases significantly as we move upstream from the river mouth. In the Goodpaster River, the mean length of Arctic grayling increased by 180 mm over a distance of about 175 km from its mouth, and in the Chena River the mean size increased 135 mm over a distance of about 230 km (Hughes 1999). These size differences are relatively substantial given that Arctic grayling rarely reach a length of greater than 400 mm over their life span (Scott and Crossman 1973; McPhail 2007). Along with mean size increases, Hughes and Reynolds (1994) also reported that minimum and maximum length increases upstream.

Hughes (1999) offered two movement-based hypotheses to explain the size gradients of Arctic grayling in the Alaskan streams—"age-phased recruitment" and "growth-dependent movement." The first is based on the possibility that young fish recruit to downstream reaches but eventually move upstream as they become older and grow larger. The second hypothesis predicts that fast-growing fish move upstream and slow-growing fish go downstream. He also offers a third, movement-independent hypothesis whereby the upstream distribution of larger fish is caused by whole-stream gradients in growth and mortality affecting the sedentary population. His analyses and models convinced him that the age-phased recruitment and growth-dependent movements are likely responsible for the size gradients in Arctic grayling river populations.

The purpose of this extension note is to provide further evidence of size gradients in Arctic grayling river populations.

*This extension note provides further evidence that the mean size of Arctic grayling increases significantly as we move upstream from the river mouth.*

## Methods

Data used here were obtained from a variety of sources. The data set for the Burnt River in British Columbia was collected as part of our ongoing long-term studies on Arctic grayling in this system. Data sets for the Chena and Goodpaster rivers in Alaska were obtained from Nicholas Hughes, University of Alaska, Fairbanks. The Kakwa River data set was provided by Travis Ripley, who at the time was with the Alberta Conservation Association in Grande Prairie, Alberta. Lastly, the Table River grayling data set was provided by Brian Blackman with the Peace-Williston Fish and Wildlife Compensation Program in Prince George, B.C.

At each of these locations, size data on Arctic grayling were collected using different methods and for different objectives; in all cases, however, the mean size of the fish was reported at river distances measured upstream from the mouth. Streams were divided into reaches and the distance was measured from the mid-points of these reaches to the river mouth.

I plotted and regressed mean fork length of Arctic grayling sampled in each reach against distance upstream from the river mouth. Slopes, intercepts, and correlation coefficients were calculated for each regression. Statistical significance of correlation coefficients was also calculated and reported.

## Results

Plots of mean fork length (millimetres) against distance from mouth (kilometres) show appositive correlation, indicating that fish are larger in upstream reaches in each river (Figure 1). Strong positive correlations exist between these two variables; all correlation coefficients were statistically significant with $n$–2 degrees of freedom (Table 1). The Burnt (71 km) and Table (56 km) rivers are the shortest of this group and have regression slopes of 5.55 and 1.99, respectively. The Goodpaster (200 km),

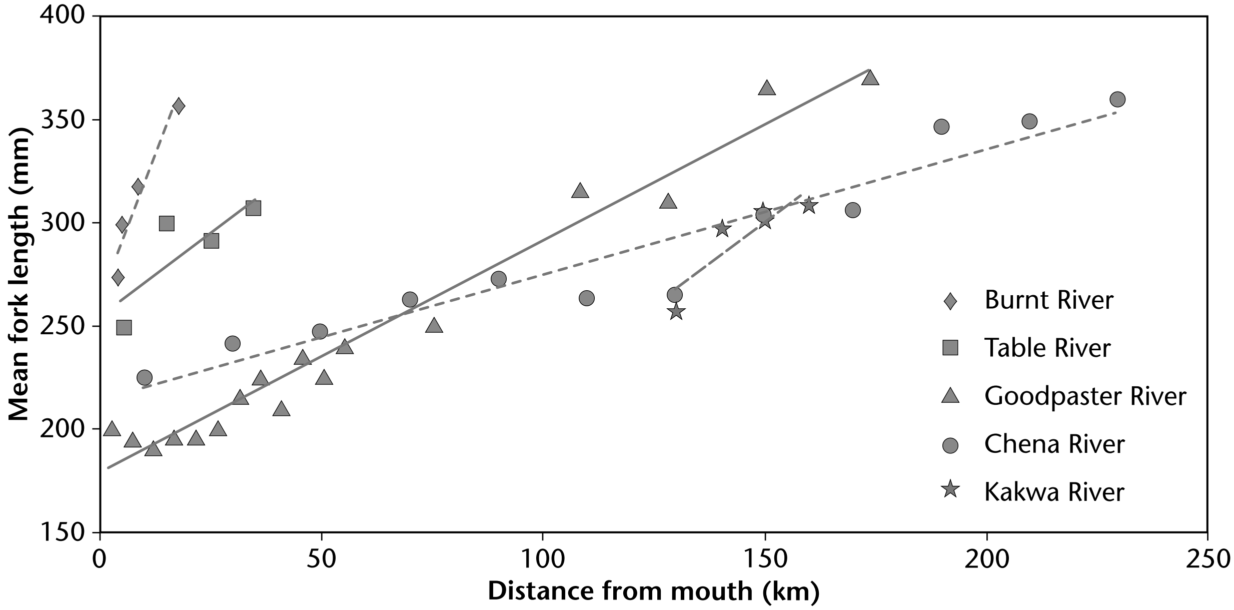


**FIGURE 1.** Changes in mean lengths of Arctic grayling along a distance gradient measured as distance from river mouth. Data shown are for populations in the Burnt and Table rivers (British Columbia), the Kakwa River (Alberta), and the Chena and Goodpaster rivers (Alaska).

**TABLE 1.** Summary of linear regression ($Y = aX + b$), correlation coefficients, and statistical significance from linear regressions between mean fork lengths of Arctic grayling ($Y$) and the distance upstream of the mouth ($X$) in each of the rivers where they were sampled.

| Location | Slope (*a*) | Intercept (*b*) | Correlation coefficient (*r*) | Sample size (*n*) | Significance (*p*) |
|---|---|---|---|---|---|
| Burnt River (British Columbia) | 5.55 | 263.1 | 0.966 | 4 | < .05[a] |
| Table River (British Columbia) | 1.99 | 241.5 | 0.978 | 4 | < .05[a] |
| Kakwa River (Alberta) | 1.75 | 32.3 | 0.961 | 4 | < .05[a] |
| Goodpaster River (Alaska) | 1.13 | 178.1 | 0.984 | 15 | < .01[b] |
| Chena River (Alaska) | 0.61 | 213.5 | 0.960 | 10 | < .01[b] |

[a] Significant at the 95% level.

[b] Significant at the 99% level.

Chena (260 km), and Kakwa (210 km) rivers have slopes of 1.13, 0.92, and 1.75 (Table 1). All correlation coefficients were statistically significant at the 95% and 99% levels (Table 1).

## Discussion

These data provide further evidence to support Hughes' observations that Arctic grayling in upstream stream reaches are, on average, larger than those downstream. It also supports Tack's (1980) hypothesis that young grayling tend to colonize downstream areas and gradually move upstream as they get larger and older. This is believed to provide feeding advantage for larger fish because they have first access to drifting prey items such as floating insects. This competition for ranked positions in more desirable feeding areas is also thought to be responsible for within-pool distribution patterns not only for Arctic grayling and other salmonids (Newman 1956; Fausch 1984; Hughes and Dill 1990; Hughes 1992); it was also observed by Goto (1989) for river sculpin (*Cottus hangiongengis*).

Personal observations in the Burnt River and other streams in northern British Columbia appear to support the notion that larger grayling have a feeding advantage. Whenever we fished for Arctic grayling in large stream pools, the majority of the first fish we caught tended to be relatively large individuals. Presumably, this indicates some dominant feeding behaviour based on size. This size-influenced feeding behaviour could result in relatively higher vulnerability of larger grayling to angling, which could have management implications. When developing angling regulations for Arctic grayling, managers should determine whether a size-based vulnerability exists and recommend appropriate protective measures.

The dominance of older Arctic grayling was corroborated by Hughes and Reynolds (1994). In a controlled removal experiment within a short (12 km) stream, they found that larger fish were excluding smaller ones from upstream reaches. This larger upstream size gradient for Arctic grayling is ubiquitous in large and small streams in Alaska (N. Hughes, University of Alaska, Fairbanks, pers. comm., June 2001).

The slopes of the regressions shown in Table 1 indicate varying size gradients between streams. One obvious reason for these differences is likely stream length. In a longer river, fish can distribute themselves over larger distances. Hughes (pers. comm., June 2001) believes this to be the case in all Alaskan streams. The data here also support his observations.

Undoubtedly, other factors may contribute to the observed size gradients in Arctic grayling. For example, the Burnt River contains a small waterfall (about 1.5 m) that presents a physical barrier at low flows and is likely a velocity barrier for smaller fish at high flows.

Hughes (1999) showed that Arctic grayling in the upstream reaches of the Chena and Goodpaster rivers were not only larger but also older. Although I do not have age data for the other populations used in this extension note, growth data from other studies in the Burnt, Table, and Kakwa rivers show a normal age–length growth pattern for Arctic grayling. It is therefore safe to assume that the larger fish in these rivers are also older.

Data on all these streams represent summer distributions and do not apply to other times of the year. It may be possible that during winter, size distributions based on ranked feeding advantage is not prevalent because of the reduced feeding associated with lower metabolism and lower food availability.

*When developing angling regulations for Arctic grayling, managers should determine whether a size-based vulnerability exists and recommend appropriate protective measures.*

The results reported here will hopefully encourage others to document what may be a prominent aspect of Arctic grayling populations in streams. Fisheries managers may also want to consider these size-based gradients along their streams when formulating regulations for their angling fisheries.

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# Test Your Knowledge . . .

*Further evidence of size gradients in Arctic grayling (*Thymallus arcticus*) along stream length*

**How well can you recall some of the main messages in the preceding Extension Note?**
**Test your knowledge by answering the following questions. Answers are at the bottom of the page.**

1. Where was this size-based segregation of Arctic grayling first reported?
   A) Streams in Alaska
   B) Streams in northern British Columbia
   C) Streams in northern Alberta

2. What is one hypothesis that explains why larger Arctic grayling are found upstream?

3. What are the names of two rivers in British Columbia reported in this article?

## *ANSWERS*

*1. A*

*2. Larger fish have a feeding advantage because they have first access to drifting prey.*

*3. The Burnt River and the Table River.*