Relationships Between Aggregate Extraction, Groundwater and Salmonid Populations in a Southern Ontario Trout Stream.

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Abstract

Extraction of sand and gravel resources often takes place below the water table. This practice can alter local groundwater patterns, flow and temperature. Concerns are often expressed that altered groundwater flux can then affect nearby fish habitat, particularly in sensitive coldwater streams. There are currently five active aggregate operations in the upper Mill Creek watershed located in southern Ontario. Dufferin Aggregates began extraction below the water table on lands adjacent to Mill Creek in 1995. Intensive environmental monitoring at the site includes climate, detailed hydrogeology, surface water flow and fisheries in Mill Creek. Brown trout (*Salmo trutta)* population estimates are available for the period 1989 to 2001. Annual redd counts have been undertaken as a measure of spawning activity from 1983 to 2001. As predicted for the license application, groundwater patterns have been altered by extraction below the water table. Monitoring of the fisheries has shown substantial natural variability in the trout populations and spawning activity. Redd numbers in one 600m reach of the creek ranged between 10 and 80 during the 19 year monitoring period. The number of redds increased markedly during the late 1980s in response to stream restoration and rehabilitation efforts, and have remained high. Similarly, brown trout populations responded favourably to habitat restoration, with the estimated number of trout increasing from approximately 175 adult fish/ha in 1989, to over 800 adult fish/ha in 2000 for one reach studied. Data will be presented for a stream reach for both adults and young of the year. The total number of brown trout has remained high for the seven years since below-water table extraction began at the site. Thus, intensive monitoring has demonstrated that although groundwater patterns have been altered, aggregate extraction below the water table at this site has not affected the adjacent trout population.

Introduction

Concern for the protection of both groundwater and surface water has reached new levels in the past few years due to record low levels of precipitation, serious incidents of drinking water contamination in Ontario, growing demands on the finite water supply and increased enforcement for the protection of fisheries habitat by the federal Department of Fisheries and Oceans (DFO).

Open pit mines and extraction of aggregates below the water table can impact groundwater patterns, flow, temperature and quality (Streetly 1998; Jansen et al. 1999). Some advances have been made to mitigate the potential effects of various activities including open pit mining on groundwater (Blackport et. al. 1995). However, the interaction between groundwater and fish productivity is loosely understood (Imhoff 2001). To ensure compliance with the Fisheries Act, extensive monitoring of groundwater, surface water and fisheries resources is being required as part of many aggregate licenses.

Study Area

The Mill Creek property is owned by the University of Guelph and encompasses approximately 189 ha in the Township of Puslinch, (Lat. 43 26.61N; Long. 80 11.08W) near Guelph, Ont. The aggregate extraction is operated by Dufferin Aggregates. Extraction below the water table began in 1995, and will eventually create a number of lakes and ponds covering about 96 ha of the property. In addition to Dufferin Aggregates there are at least four other extraction operations on both sides of the creek.

The northwest corner of the property is traversed by Mill Creek. The closest point of extraction is approximately 250m from the creek. Various reaches of the creek have been delineated for monitoring purposes. However, only data from the University reach (approximately 660m in length) are reported in this paper.

Mill Creek was originally a native brook trout (*Salvelinus fontinalis*) stream but habitat gradually deteriorated as result of watershed development (eg. agriculture, land clearing, construction of Highway 401 etc.). Brown trout (*Salmo trutta*) were stocked in the watershed beginning in the 1940's. Brown trout are able to tolerate warmer water temperatures and generally grow faster and to a larger size than brook trout. Therefore, they are often able to out-compete the native brook trout (Faush and White 1981).

Materials and Methods

Surface Water Flow Monitoring

Water levels are continuously recorded at two monitoring locations in Mill Creek within the study area. Stations SW1 and SW2 are at the upper and lower ends of the study area, respectively. Water levels and mid-stream temperature are recorded every 30 minutes. Water level data are converted to flow (L/s) using rating curves developed from 1993 to 1998.

Groundwater Monitoring

Groundwater monitoring has been ongoing at the property since November, 1986, and now includes approximately 50 monitoring locations. There are four different types of groundwater monitoring stations with the frequency of measurements ranging from daily to monthly. Shallow, in-stream drive points (mini-piezometers) are used to measure the vertical hydraulic gradient of groundwater within the stream bed. A positive gradient indicates groundwater discharge conditions, while a negative gradient indicates recharge conditions. Groundwater flux (L/s) is also estimated for specific reaches using data collected at the in-stream drive points.

Fisheries

Trout Population Estimates:

The numbers of young of the year (YOY) and adult trout ($\geq$ 1+) are estimated each year by mark and recapture techniques. Fish are sampled by electroshocking during August or September. Each fish is measured, weighed and fin-clipped prior to release. Recapture runs are completed within one week. Populations are estimated using the Petersen Population Estimate and expressed as the number of fish per hectare. Data are available since 1989 with the exception of 1996 and 2002 when the population surveys were not conducted.

Redd Surveys:

A redd is an obvious nest or disturbance in the substrate where salmonid eggs are deposited. Brown trout redds are typically elongated scars in the stream bed, characterized by a mound of gravel at the downstream end. Brook trout redds are smaller, rounder and less obvious than brown trout redds.

All redds were counted on 2 or 3 occasions during November and December of each year and their locations recorded on large-scale maps within each study reach. The GRCA and MNR conducted spawning surveys between 1983 and 1993. Since 1993, the redd surveys have been conducted by experienced ESG staff.

Results and Discussion

Stream Flow

Stream flow in Mill Creek in the study area in 2001 ranged from 164 to 1880 L/s (Figure 1). Historical monitoring data indicate that the general surface water flow patterns observed in Mill Creek over the 1995-2001 monitoring period are strongly correlated to air temperature and precipitation patterns. Furthermore, the data suggest that the reduced low flows observed in 1999 and 2001 are a product of below normal precipitation and above average temperatures experienced, particularly during summer months. For example, the 7-day low flow of 0.131 m^3/s observed in 1999 occurred in a year with a total annual precipitation of 791.0 mm, which is well below the long-term normal of 917 mm.

Stream Temperatures

Data collected since 1997 show that the maximum summer temperatures in the main channel of Mill Creek exceeded the maximum tolerable temperature for brown trout (26.8°C; Raleigh et al. 1986) in 1999, but and routinely exceed the upper tolerance limit for brook trout of 23.9°C (Raleigh, 1982).

Elevated water temperature in the creek originate upstream of the study area due to on-line ponds and loss of riparian vegetation and are unrelated to gravel extraction activities.

Groundwater

The overall groundwater discharge from the Mill Creek property during the 2001 winter low flow condition was estimated at about 22.2 L/s, which is similar to the baseline (pre-extraction) average of 23.0 L/s.

Average vertical hydraulic gradients from piezometers along Mill Creek for the years 2000 and 2001 are compared to historical averages (1989 – 2001) in Figure 2. The data indicate that groundwater discharge at some in-stream drive points (DP22, DP4, DP21, DP20, DP19, DP18) in recent years is less than the historic average. The reduced flux is due to a combination of effects of multiple aggregate extraction as well as from lower precipitation and higher summer air temperatures in recent years. This decrease in hydraulic gradients translates into a decrease in the ground water discharge to certain reaches of Mill Creek.

Fisheries

Brown Trout Population Estimates

There has been a general trend of increasing young-of-the-year (YOY) brown trout within the Study Area since 1992 (Figure 3).

Similarly, the number of adult trout increased during the early 1990's and has remained relatively constant for the past 5 years. In 2001, the estimated number of adult brown trout in the University of Guelph reach was approximately 710/ha (Figure 3), which was well within recent historical ranges for the past several years.

A statistical analysis of brown trout populations was performed to compare population sizes before commencement of extraction below the water table (pre-operational;1987-94), to populations after extraction below the water table (post-operational; 1995-2001). Young of the year (YOY) and adult (Age $\geq 1^{+}$) brown trout densities were considered. Adult populations were significantly ($p < 0.05$) greater during post-operational years. The average number of adult brown trout increased from approximately 354 per ha during the pre-operational period to 733 per ha during the post-operational period. The average number of YOY ($p > 0.05$) between study periods was not significantly different due to variability of the data.

Redd Surveys

The 55 brown trout redds observed in 2001 was higher than the number counted in 1999 and 2000 (Figure 4) but was within historical ranges observed since 1990.

The number of brown trout redds in the University of Guelph section ranged widely from 9 to 79 during the pre-extraction period from 1983 to 1994 (Figure 4), and from 39 to 60 during the post operational period. The number of redds observed before and after below-water extraction began is not significantly different ($p < 0.05$).

The Grand River Conservation Authority (GRCA) and Ontario Ministry of Natural Resources (OMNR) carried out stream habitat restoration during the mid-1980's. These activities resulted in increased brown trout biomass and spawning activity (Grillmayer 1990; Grillmayer and Baldwin 1990). Prior to the completion of rehabilitation in 1987, the mean number of redds in the University of Guelph station was 14.8 (range 9-22). Following rehabilitation, the mean increased significantly ($p < 0.05$) to 51.3 (range 30-79). These data indicate a positive response to the habitat restoration measures.

SUMMARY

Continuous monitoring in Mill Creek has shown that stream flow has been markedly affected by climatic conditions in recent years. Stream temperatures in the main channel of Mill Creek continue to reach levels not tolerable to brook trout, and are approaching levels not favourable to

brown trout due to watershed activities unrelated to gravel extraction.

There has been reduced groundwater discharge into Mill Creek at several drive point locations as a result of gravel extraction on both sides of the creek. However, decreased groundwater levels across the site is also strongly related to lower precipitation in recent years.

Spawning surveys conducted for the past 18 years demonstrated a very positive response to stream habitat restoration, and indicate that spawning activity has not been affected by gravel extraction. The monitoring data also clearly show that brown trout population numbers have not been impacted by nearby aggregate extraction activities below the water table.

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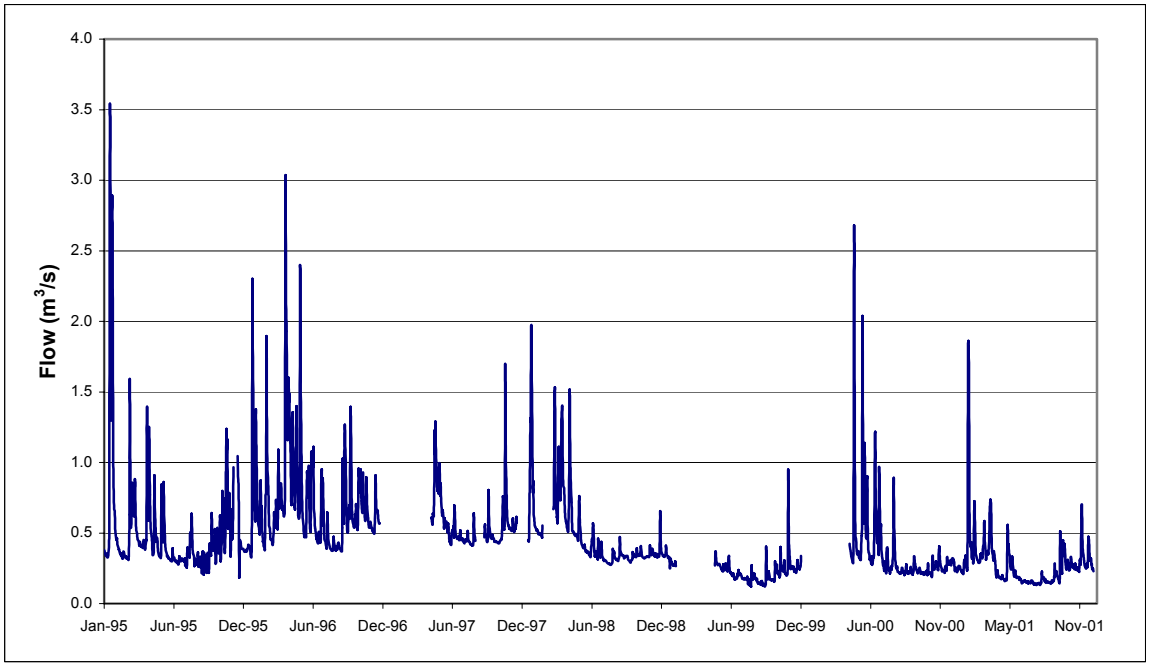


Figure 1. Mill Creek discharge (m^3/s) at surface water monitoring station SW2 (1-day averages)

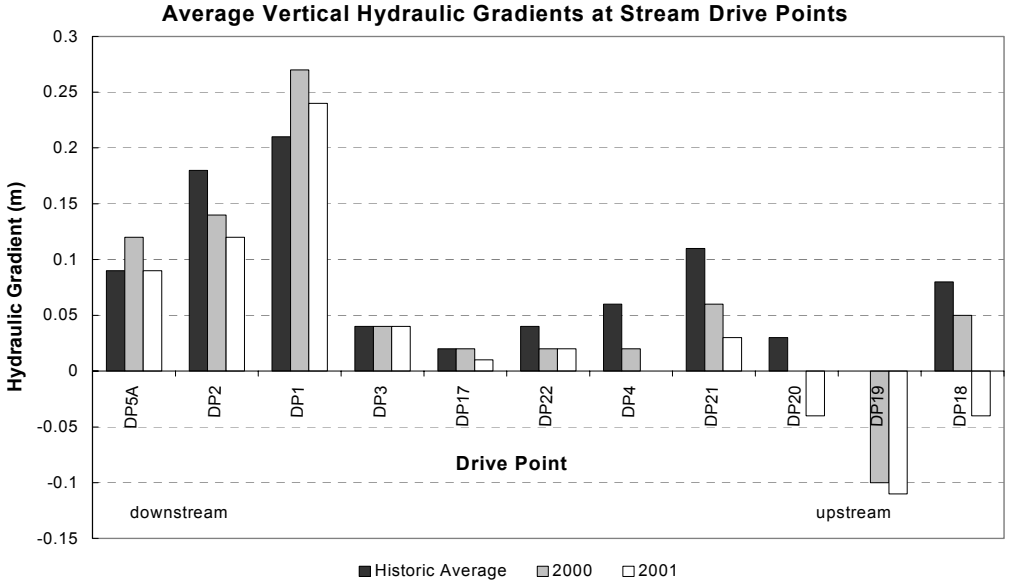


Figure 2. Comparison of drive point vertical hydraulic gradients for 2001 and 2000 to historic averages.

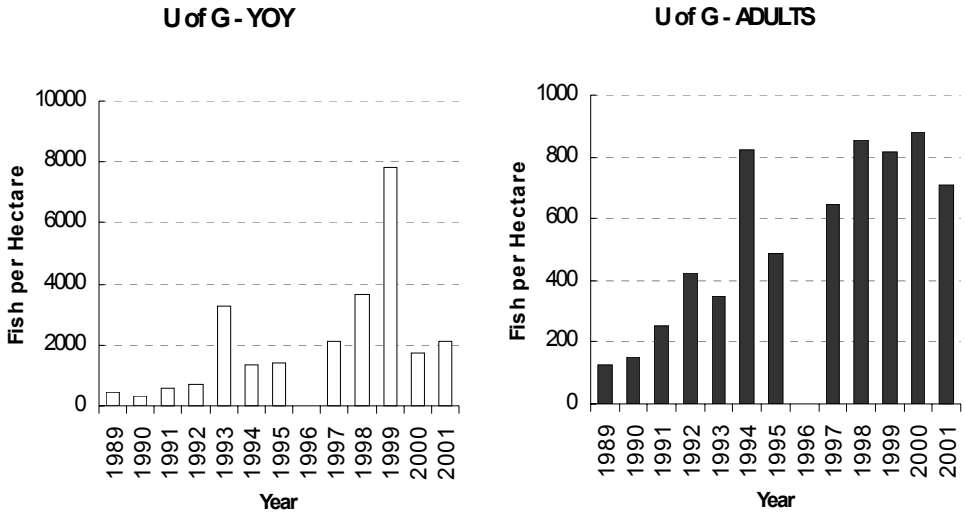


Figure 3. Population estimates of brown trout in the University of Guelph reach; 1989 to 2001

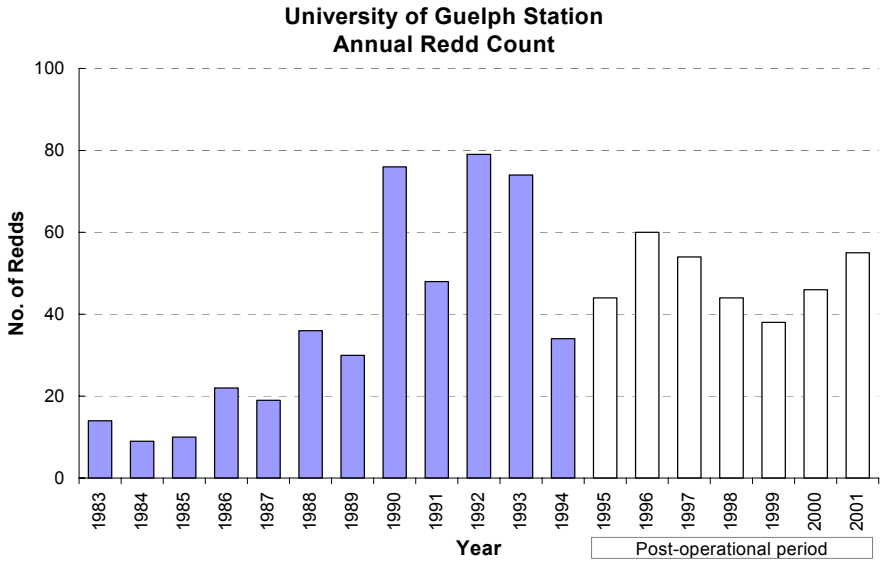


Figure 4. Annual number of brown trout redds in the University of Guelph Station of Mill Creek (1983 to 2001).