Ecological Development of the Wolf Point Creek Watershed; A 25-Year Colonization Record from 1977 to 2001

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Abstract. In this paper, we document the colonization of invertebrate taxa and salmonids from 1977 to 2001 in Wolf Point Creek, Muir Inlet. Wolf Point Creek is a short stream flowing from a lake formed from the melting of Muir Remnant. The first colonizers were Chironomidae (non-biting midges) followed by mayflies and stoneflies. Later colonizers include worms, mollusks, the freshwater shrimp and water mites with these non-insect taxa having taken at least 20 years to colonize the stream. Some of the early invertebrate colonizers of the stream, notably some non-biting midge taxa and harpacticoid copepods, are no longer collected. Dolly Varden charr were the first salmonid to colonize the stream in 1987 followed by approximately 100 pink salmon in 1989. In 1997, pink salmon spawner densities exceeded 10,000 fish. However, despite these densities, nutrient subsidies from the decay of post-spawning Pacific salmon were not evident in macroinvertebrate or juvenile fish food webs in Wolf Point Creek. However, the effects of redd digging by these salmon create disturbed patches in the stream where abundance and diversity of macroinvertebrates are reduced, thereby influencing successional patterns.

Introduction

Whereas Engstrom and others (2000) studied 33 lakes of differing ages in Glacier Bay to infer development of the lake environment, environmental conditions must remain constant for the chronosequence approach to correctly represent historical development (Matthews, 1992). Climate change or other potential confounding variables may introduce non-linearities (Kaufmann, 2002) and thus direct observation is necessary to accurately determine succession sequences (Matthews, 1992). We have made almost continuous observations of Wolf Point Creek in Muir Inlet from 1977 and here we summarize the 25-year period from 1977 to 2001. Our aim has been to document the year in which macroinvertebrate taxa and fish species first colonized the stream and document if any taxa have become extinct. We are interested in the environmental and biotic variables driving colonization processes that are important in community assemblages.

Study Site

The mouth of Wolf Point Creek was uncovered by ice in approximately the mid-1940s and the lake, which feeds the stream, emerged in the early 1970s (fig. 1). With the melting of the remnant ice, the lake (unofficial name Lawrence Lake) gradually increased to its present day size of approximately 1.45 km^2 with a maximum depth of 35 m. The stream is between 1.8 and 2.0 km in length, 6 to 10 m wide and flows over glacial moraine, till and outwash deposits. Below the lake, a series of falls more than 30 m high exist that creates a barrier to fish migration. In 1977, the lower floodplain was essentially barren with a few mats of mountain aven (*Dryas spp.)*, but isolated clumps (typically prostrate) of alder (*Alnus crispa)* and cottonwoods (*Salix spp.*) were evident on upper terraces, where mats of *Dryas* were almost continuous. Lower terraces were dominated by alder and willow in 2001 with riparian trees exceeding 4 m in height.

Methods

Macroinvertebrates have been collected yearly from 1977 (except 1984, 1985 and 1987) from a representative sampling station along Wolf Point Creek, typically using 10 replicate Surber samples with a 330-µm mesh net. However, samples collected from 1977 through 1983 were by lifting and cleaning individual stones from the streambed. Although macroinvertebrates have been collected in other months, one set of samples has always been collected in August/early September to minimize the potential effect of seasonal variation on interpreting colonization and succession patterns. Macroinvertebrates were sorted from detritus and inorganic matter and identified in the laboratory. Water temperature was initially recorded with hand held thermometers, but Gemini dataloggers have been employed since 1992 recording temperature every 2 hr. Water samples were collected and tested in the laboratory for turbidity.

An index of adult salmon spawners was estimated by foot counts along the length of the stream during the years of the study and juvenile salmonids were captured using minnow traps baited with salmon eggs and fished for 1.5–2 hr at selected reaches. To investigate the potential effect of redd digging by adult pink salmon females, macroinvertebrates were collected prior, during and subsequent to peak digging times using five replicate Surber samples in both high (1997)

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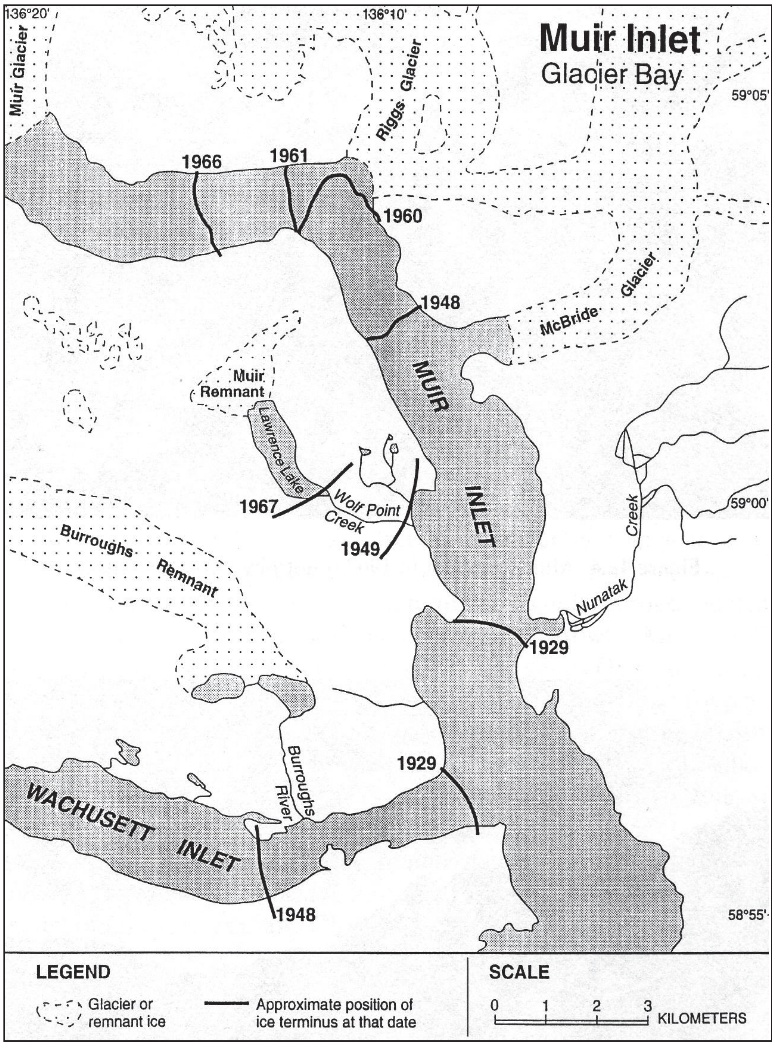

Figure 1. Wolf Point Creek drainage and the location of Lawrence Lake.

and low pink salmon (1996 and 1998) years. Drift samples over 24 hr also were collected in 1997 and 1998, between the end of July and early September downstream of known redds. Marked salmon carcasses also were staked into the streambed in 1997 to observe potential direct utilization by scavenger macroinvertebrates as a food source.

In 1997 and 1998 samples of vegetation, macroinvertebrates and juvenile fish were collected for stable isotope analysis of N^{15} to determine if marine-derived nutrients from salmon carcasses were being incorporated into the food chain. New foliage was taken from riparian willows with forceps and stored in plastic sample bags. Invertebrates were collected from stones (two representative genera [typically collectors and grazers] were used for comparison). Three juvenile coho salmon captured by minnow trapping were sacrificed and dorsal muscle tissue between the skull and dorsal fin removed for analysis. These samples were then analyzed for marine-derived N using the techniques outlined in Milner and others (2000).

Results

Turbidity in Wolf Point Creek decreased from 140 NTU in 1977 to <10 NTU in 2003. With water temperature increasing from a maximum 2°C in August 1977 to 18.5°C in July 2003, the number of degree-days has increased from <500 to 1,945 CTU. The year in which macroinvertebrates (orders, families and some specific genera) and fish first colonized Wolf Point Creek is summarized in figure 2. Macroinvertebrate taxon richness, cumulative taxon richness and cumulative taxa lost all showed a strong significant relationship with water temperature (r^2=0.90, 0.97, and 0.93, respectively; $P < 0.05$) (fig. 3).

The first salmonids to colonize were Dolly Varden charr, as indicated by the first collection of their juvenile fry in 1988. Approximately 100 pink salmon colonized Wolf Point Creek in 1989 following a massive run of pink salmon throughout southeast Alaska during that year. Two years later in 1991, an index of spawning pink salmon was estimated at 1,250, in 1993, 3,600, and by 1997 the index exceeded 10,000 spawners (fig. 4). No evidence indicated that marine derived N was being incorporated into the stream foodweb or the riparian vegetation (Milner and others, 2000), even though macroinvertebrates were observed feeding directly on the salmon carcasses.

Macroinvertebrate abundance in reaches with redds during peak spawning periods in late August 1997 was significantly lower than abundance in August 1996 or 1998 or in the period prior to spawning in 1997. Macroinvertebrate densities were reduced to less than 100/0.1 m^2 from a mean of 480/0.1 m^2 whereas total taxon richness was reduced from 18 to 10. Drift densities of macroinvertebrates were fourfold higher during peak spawning compared to the low salmon run year of 1998.

Discussion

Although water temperature was clearly an important determinant for colonization by some macroinvertebrates, other taxa, notably caddisflies and some chironomids, were related more to the growth of riparian vegetation along the stream and the provision of willow catkins as a food source or alder roots as a substrate (Flory and Milner, 1999). Of particular interest is the time taken for non-insect taxa to colonize the stream, as they lack obvious inter-stream dispersal mechanisms. The first non-insects were Oligochaeta in 1992 followed by snails (Planorbidae) and a gammarid shrimp in 1998. In 1992 maximum water temperature in Wolf Point Creek was 9°C, which would appear well above the threshold for Oligochaeta and thus the delay in colonization

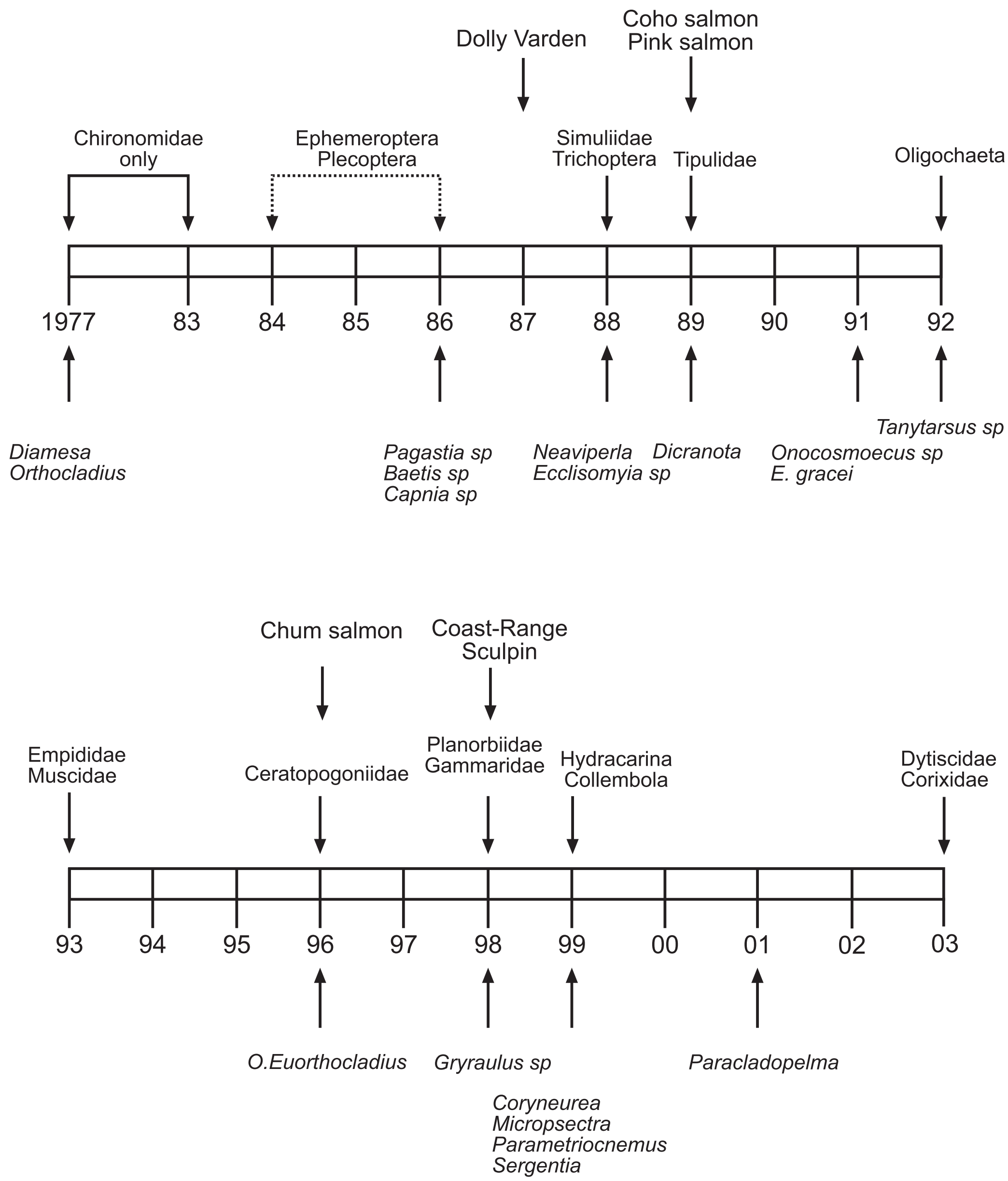

Figure 2. Chronosequence showing the point of first colonization of major taxonomic groups of macroinvertebrates and fish species.

is presumably due to difficulties in crossing land barriers from nearby streams, either across the inlet or across mountain ranges. Non-insects have to employ passive means of colonizing the stream, which probably includes the feet of water birds or resistant stages being ingested and passing through their intestines. The appearance of water beetles (Dysticidae) and water boatmen (Corixidae) in very recent years is associated with an increase in slower flowing habitats, such as pools and backwaters.

One of the most interesting aspects of the colonization and succession sequence documented in Wolf Point Creek concerns the non-biting midges (Chironomidae). Although adult chironomids typically are weak fliers, they are small and light, able to be carried long distances by wind. Hence they often are the first colonizers of newly formed freshwater habitats. Some chironomids can survive and reproduce in harsh conditions and, in the absence of predation or competition, were detected in large numbers (>4,000 m^2) in the stream throughout July and August in the late 1970s. However some of the early colonizing *Diamesa* species (notably *D. sommermanni*) were not collected after 1988 when water temperature reached 7.5°C, indicating they probably are cold stenotherms. Abundance of another early colonizer, a species of the *Diamesa davisi* group decreased after 1978 and larvae were not collected after 1992. Experimental work has indicated that this *Diamesa* is a fugitive species

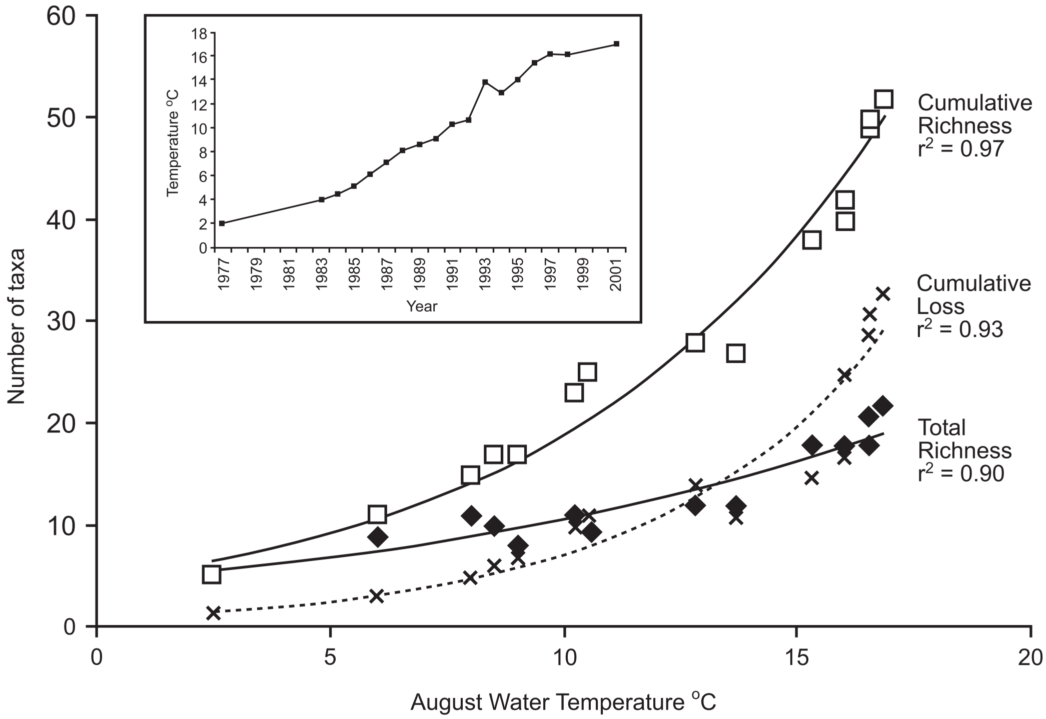

Figure 3. Relationship of macroinvertebrate taxon richness (closed diamonds), cumulative taxon richness (open squares), and cumulative taxa (x's) lost with water temperature.

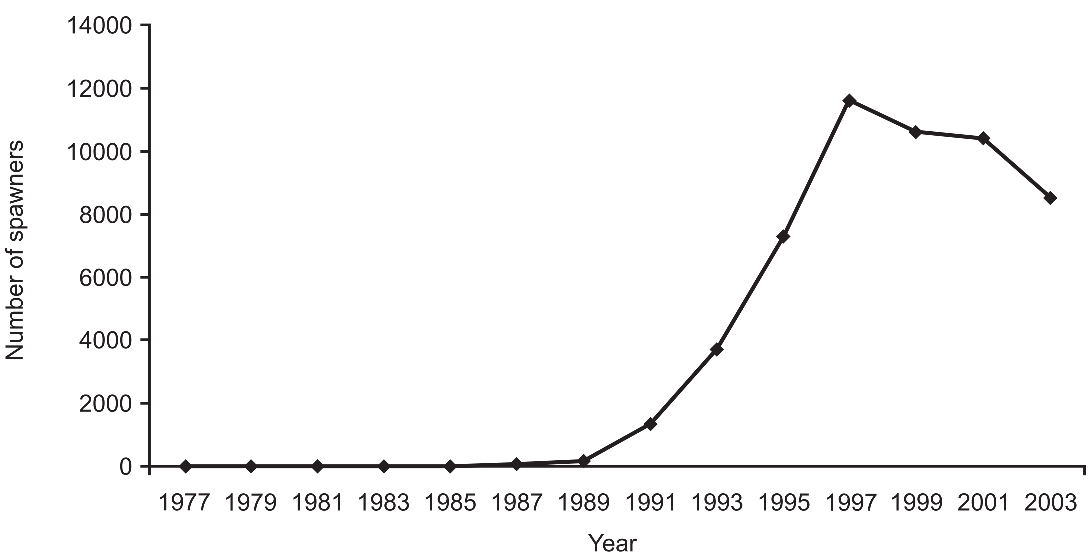

Figure 4. Index of pink salmon spawners in Wolf Point Creek.

(rapid colonizer of disturbed patches and habitats but a poor competitor), but can tolerate warmer temperatures in the absence of competition (Flory and Milner, 1999). However, when competitors are present in relatively large numbers they must seek new habitats to persist. In a separate study of six Glacier Bay streams in May 1997 (Milner and others, 2000) abundances of *Diamesa davisi* and *Pagastia partica* were negatively correlated ($N = 18$, $r^2 = 0.59$, $P<0.05$).

A number of studies in southeast Alaska have demonstrated the incorporation of marine derived nutrients into stream food webs (e.g. Wipfli and others, 1998; 1999). The lack of evidence of incorporation of marine derived nutrients into lotic food webs or riparian vegetation in Wolf Point Creek, despite more than 10,000 fish spawning the previous year, indicates that the stream has not yet developed the ability to retain carcasses. Heavy rains in September and

October will flush the carcasses back to the estuary. This was demonstrated by the experimental release of tagged carcasses in Wolf Point Creek, indicating <10 percent carcass retention after 5 days at relatively low flows. Retention ability is conferred to the stream by marginal habitats, pools and particularly coarse woody debris. Coarse woody debris is a major component of small-forested streams in coastal southeast Alaska. However, only small amounts are present in Wolf Point Creek to date, as terrestrial succession has not yet progressed to a stage where recruitment into the stream of larger trees allows debris to accumulate. We estimate this may take a further 60 to 80 years.

Disturbances by salmon digging redds in odd years may open up patches on the streambed for colonization by fugitive macroinvertebrate species in Wolf Point Creek. The relative abundance of blackflies (Simuliidae) and the chironomid *Cricotopus intersectus* increased during peak spawning. Subsequent increase in potential fugitive taxa following spawning has been observed in another stream study (Minakawa and Gara, 2003) and redd digging may be a mechanism to allow these potentially poor competitors to persist in the benthic community and influence the successional sequence.

Management Implications

This study has interesting implications for the management of streams and rivers, particularly with respect to recovery and restoration from disturbance. There is a long period for non-insect forms to colonize emergent streams due to the difficulties of crossing mountain barriers and thus community assemblage of macroinvertebrates is a long process. Clearly, salmonid colonization of new streams is rapid and Glacier Bay is providing significant habitat for the establishment of new salmon stocks in southeast Alaska. However in young streams, the influx of marine derived nutrients is not utilized due to the lack of large pieces of coarse woody debris. Salmon also have an influence on the geomorphology of the stream through the activity of redd construction.

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References Cited

Engstrom, D.E., Fritz, S.C., Almendinger, J.E., and Juggins, S., 2000, Chemical and biological trends during lake evolution in recently deglaciated terrain: Nature, v. 408, p. 161-166.

Flory, E.A., and Milner, A.M., 1999, Influence of riparian vegetation on invertebrate assemblages in a recently formed stream in Glacier Bay National Park, Alaska: Journal of the North American Benthological Society, v. 18 p. 261-273.

Kaufmann, R., 2002, Glacier foreland colonization—distinguishing between short-term and long-term effects of climate change: Oecologia, v. 130 p. 470-475.

Matthews, J.A., 1992, The ecology of recently-deglaciated terrain—A geoecological approach to glacier forelands and primary succession: Cambridge, Cambridge University Press.

Milner, A.M., Knudsen, E., Soiseth, C., Robertson, A.L., Schell, D., Phillips, I.T., and Magnusson, K., 2000, Stream community development across a 200 year gradient in Glacier Bay National Park, Alaska, USA: Canadian Journal of Fisheries and Aquatic Sciences, v. 57, p. 2319-2335.

Minakawa, N., and Gara, R.I., 2003, Effects of chum salmon redd excavation on benthic communities in a stream in the Pacific Northwest: Transactions of the American Fisheries Society, v. 132, p. 598-604.

Wipfli, M.S., Hudson, J., and Caouette, J., 1998, Influence of salmon carcasses on stream productivity—response of biofilm and benthic macroinvertebrates in southeastern Alaska, U.S.A: Canadian Journal of Fisheries and Aquatic Sciences, v. 55, p. 1503-1511.

Wipfli, M.S., Hudson, J.P., Chaloner, D.T., and Caouette, J.P., 1999, Influence of salmon spawner densities on stream productivity in southeast Alaska: Canadian Journal of Fisheries and Aquatic Sciences, v. 56, p. 1600-1611.

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