

Introduction

- By building dams beavers modify aquatic habitats
- These habitat modifications influence aquatic organisms
- Freshwater habitats provide important rearing habitats for juvenile salmon and spawning grounds for returning adults
- Dams can block fish movements and cause sedimentation
- Beavers and salmon have co-evolved for millennia
- Positive interactions generally outweigh the negative

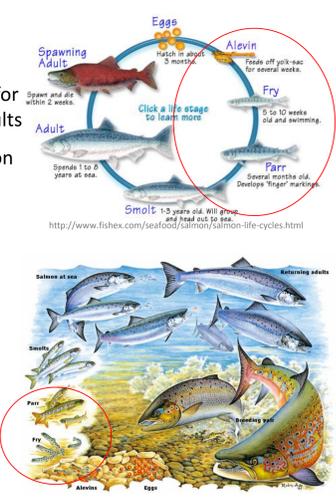


Table 2 Citation of positive impacts of beaver activity on fish populations and the percentage of citations based on quantitative analysis or speculation. Different impacts are expressed as the number of times they are cited in 108 literature sources and as a percentage of the total number of citations.

Positive impact	Number	% of total citations	Data driven (%)	Speculative (%)
Enhanced habitat availability/complexity	19	10.3	52.6	47.4
Enhanced overwintering habitat	17	9.2	64.7	35.3
Enhanced rearing habitat	16	8.7	31.2	68.8
Provision of cover	5	2.7	20.0	80.0
Enhanced diversity/species richness	8	4.2	87.5	12.5
Enhanced abundance/productivity	50	27.2	58.0	42.0
Provision of habitat under low flows	11	6.0	27.3	72.7
Provision of high flow refuge	3	1.6	0	100
Provision of temperature refuge	13	7.1	53.8	46.2
Enhanced water quality	2	1.1	0	100
Sediment trap	3	1.6	0	100
Enhanced invertebrate productivity	16	8.7	56.3	43.8
Enhanced growth rates	16	8.7	62.5	37.5
Enhanced fish condition	1	0.5	100	0
Provision of feeding areas	4	2.2	25.0	75.0
Total	184	100	51.1	48.9

Table 3 Citation of negative impacts of beaver activity on fish populations and the percentage of citations based on quantitative analysis or speculation. Different impacts are expressed as the number of times they are cited in 108 literature sources and as a percentage of the total number of citations.

Negative impact	Number	% of total citations	Data driven (%)	Speculative (%)
Barriers to fish movement	51	42.9	21.6	78.4
Reduced spawning habitat	20	16.8	40.0	60.0
Altered temperature regime	11	9.2	9.1	90.9
Reduced oxygen levels	12	10.1	50.0	50.0
Reduced habitat quality	2	1.7	0	100
Altered flow regimes	4	3.4	75.0	25.0
Loss of cover	5	4.2	0	100
Reduced productivity	3	2.6	33.3	66.7
Retarded growth	2	1.7	50.0	50.0
Stagnation of beaver settlements	1	0.8	100	0
Reduced water quality	1	0.8	100	0
Total	119	100	28.6	71.4

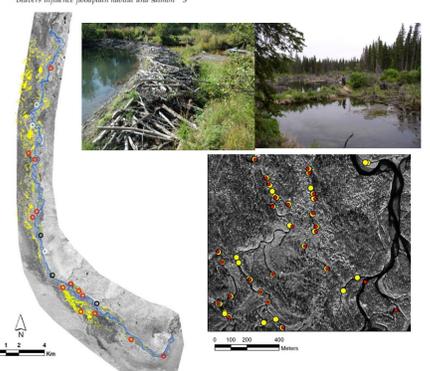
Collen & Gibson 2001

Concerns

- Dams block the movement of spawning adult salmon
- Dams reduce the quality of spawning habitat
- Dams block the use of upstream habitats
- Dammed habitats may not provide good rearing habitat

Naiman et al. 1988; Pollock et al. 1995; Collen & Gibson 2001; Rosell et al. 2005

C. canadensis in Alaska vs. *C. fiber* in Norway



- Alaska research occurred on a large river in the Yukon Delta National Wildlife Refuge, with little human land use
- Norway research occurred in heavily populated areas with a significant land uses, on smaller tributaries
- More dams in Alaska river floodplains
 - 450 dams in 20 km of river floodplain (Malison et al. 2014)
 - 2015 survey of 52.5 km of Stjørdalselva: 9 dams (Halley & Svartaas 2015)
- More bank burrows in Norway and more lodges in Alaska
- Larger, more stable dams in Alaska (lower gradient areas)



Positive Interactions Outweigh Negative Interactions

- Slower current velocities, increased food, more cover
- Increased nutrients, temperature refugia
- Important rearing habitat (Bryant 1983, Grasse 1979, Hagglund & Sjoberg 1999, Leidholt Bruner et al 1992, Malison et al 2014, Smith & Mather 2013, Dittbrener et al. 2022)
- Higher growth rates (Bustard & Narver 1975, Malison et al. 2015, Swales & Levings 1989, Sigourney et al. 2006, Needham et al. 2021)
- Increased production (Bouwes et al. 2016, Nickelson, Rodgers et al 1992, Pollock et al. 2004)
- Increased species richness (Snodgrass & Meffe 1998)
- Important winter rearing habitat (Bustard & Narver 1975, Chisholm et al 1987, Cunjak 1996, Jakober et al 1998, Lindstrom & Hubert 2004, Miller & Sadro 2003, Nickelson et al 1992ab)
- High invertebrate productivity (France 1997)
- Dams are generally not impassable, though movement may be altered or decline (Taylor et al. 2010, Bouwes et al. 2016, Bylak & Kukula 2018, Bylak et al. 2014, Lokteff et al. 2013, Malison & Halley 2020, Parker & Roennig 2007, Cutting et al. 2018, Virbickas et al. 2015, Schlosser & Kallemeyn 2000, Puttock et al. 2017, Malison et al. 2015, Wathen et al. 2018, Mitchell & Cunjak 2007, Pollock et al. 2022)
- Winter fish kills can occur (Fox & Keast 1990), low oxygen (Snodgrass & Meffe 1998), and inundated spawning sites (Knudsen 1962, Swanston 1991, Halley & Lamberg 2001, Muller-Schwarze & Sun 2010)

Norway Case Study

- Determine how beavers influence the habitat use, distribution, growth, density, and movement of juvenile salmonids

Study Area – Stjørdalselva and Orkla

Study Design: Pairs of sites: One with and one without beaver dams

Figure A: Species composition of juvenile fish at study sites, B&C) total density of juvenile trout and salmon in sites with (B1-3) and without (C1-3) beaver dams, D) mean percent of juvenile fish that crossed dams, approached dams or did not move, and E) mean percent of fish that exhibited different movement patterns.

River Ecology

- Naturally functioning rivers are critical to support species diversity
- Flooding and intact riparian areas are critical for supporting biodiversity

River Floodplains

Figure 4: Average daily discharge of the Middle Fork Flathead River for two years (USGS gauging station #135500).

Figures A-D: Inundated areas (darker blue = deeper) at increasing flow levels (A: 800, B: 7900, C: 11,500, and D: 20,000 cfs), E) biodiversity supported in river floodplains, F) discharge over the year, and G-H) images of river floodplain habitat.

Considerations

- Beaver dams vary in structure based on location and site characteristics, which can influence fish passage
 - Many dams flood and/or break often (Fig. A)
 - Dams can prevent movement and/or cause mortality (Fig. B)
 - Fish passage past dams will vary by species, life stage, season, and site characteristics
 - How much of the area can be reached by fish? Much of the beaver influence in Norway occurs where salmon can't reach (e.g. past waterfalls; Fig. C), which reduces potential beaver-fish conflicts
 - Use of beaver ponds varies by fish species
 - How large is the system being dammed? Interactions will differ between large rivers and small streams
 - What are the other land use impacts and what is the likely influence of beavers compared to other uses? In Norway much of the beaver activity occurs near/within other heavy land uses (Fig. D)
 - Beavers can help reconnect rivers to their floodplains, raising the water table, supporting/reconnecting riparian zones and supported linked aquatic-terrestrial foodwebs (Fig. E).
- Figures A-E:** A) A beaver dam that repeatedly breaks during rain events in Norway, B) a dead adult sea trout that landed on an island when trying to jump a beaver dam, C) a waterfall in Norway that salmon cannot pass, D) typical land use patterns where beavers build dams, E) diagram depicting aquatic-terrestrial linkages that are present between rivers and riparian zones (Baxter et al. 2010).

