10-28-2009

Appendices 1-4 to Direct and Terrestrial Vegetation-mediated Effects of Environmental Change on Aquatic Ecosystem Processes

Becky A. Ball

John S. Kominoski

Heather E. Adams

Stuart E. Jones

Evan S. Kane

See next page for additional authors

Authors
Becky A. Ball, John S. Kominoski, Heather E. Adams, Stuart E. Jones, Evan S. Kane, Terrance D. Loecke, Wendy M. Mahaney, Jason P. Martina, Chelse M. Prather, Todd M.P. Robinson, and Christopher T. Solomon

Appendix

Appendix 1. Shifts in terrestrial vegetation (TVS) resulting from environmental change drivers are a global phenomena. Below we list a selection of the documented examples in the literature. Several of these examples are discussed in detail in the text and appendices.

Environmental Change Driver	TVS	Geographic Region	Select references
Agricultural abandonment	Cropland → Grassland	American midwest	Pickett 1982 Inouye 1987
Forest harvesting	Spread of red alder	Pacific northwest	Kennedy and Spies 2004
Dam building	Loss of riparian vegetation (pioneer spp → late successional spp)	African savannah	Hughes 1990 Nilsson 2000
Agriculture	Grassland →Tree plantation	South America	Nosetto et al. 2008
Overgrazing, fire suppression (also climate change)	Woody encroachment	American southwest	Van Auken 2000
Fire suppression, climate change	Decline of aspen	Canadian boreal forests	Rehfeldt et al. 2009
Climate warming	Spread of loblolly pine	Northern U.S.	Iverson and Prasad 1998, 2001
Climate warming	Spruce → Deciduous	Boreal forests	Rupp e tal. 2000 McLean et al. 1999
Climate warming	Tussock → Woody species	Arctic	Chapin et al. 1995 Shaver et al. 2000
Desertification (climate, land overuse)	Salt cedar invasions	American southwest	Wilcox 2006
Climate warming, introduced pathogens	Decline in conifers	Western U.S.	Turner et al. 2008 van Mantgem et al. 2009
Introduced pathogens	Decline in American chestnut	Eastern U.S.	Vandermast and Van Lear 2002 Ellison et al. 2005
Introduced pathogens	Decline in eastern hemlock	Eastern U.S.	Orwig et al. 2002 Ellison et al. 2005
Acid deposition	Decline in red spruce and sugar maple	New England, U.S.	DeHayes et al. 1999 Driscoll et al. 2003
Nitrogen deposition	Decline in species diversity	Europe	Bobbink et al. 1998

Appendix 2. In tundra ecosystems, increased air temperature due to climate warming has direct effects on aquatic processes that provide key ecosystem services. In addition, climate warming is driving encroachment of woody shrubs (such as willow and birch) into tussock grasslands. This shift in terrestrial vegetation structure (TVS) will indirectly influence aquatic processes. Using these, we make predictions about the sum effect of the direct and TVS-mediated effects. Signs refer to a positive (+), negative (-), or neutral (0) effect of the driver on the described aquatic ecosystem process.

Aquatic Process	**Direct**	**TVS-Mediated**	**Sum**	**Implications**
Carbon dynamics / Organic matter processing	- due to increased respiration[1]	- C release to streams due to low DOC production[2] and increased C storage[3]	+/-	Changes in vegetation composition and flowpaths may override the direct effects of warming
Nutrient dynamics	+ or -, depending on changes in precipitation, permafrost depth, and mixing cycles	+ terrestrial nutrient mineralization[4], or - due to nutrient storage in low-quality plant material	+	Fertilization of streams and lakes[5]
Hydrology	- due to evaporation[4]	- surface runoff due to recession of permafrost and increased transpiration[4]	-	Ponds and lakes may decrease in dis-continuous permafrost, or increase in continuous permafrost[6]

[1]Shaver et al. 2000. *BioScience* 50: 871-882.
[2]Judd & Kling. 2002. *Biogeochemistry* 60: 213-234.
[3]Sturm et al. 2001. *Nature* 411: 546-547.
[4]Chapin et al. 1995. *Ecology* 76: 694-711.
[5]summarized by Benstead et al. 2005. *Freshwater Biology* 50: 277-290.
[6]Smith et al. 2005. *Science* 308: 1429.

Appendix 3. Damming of rivers in African savannah ecosystems has direct effects on aquatic processes that provide key ecosystem services. In addition, damming causes the replacement of late successional riparian vegetation with pioneer species. This shift in terrestrial vegetation structure (TVS) will indirectly influence aquatic processes. Using these, we make predictions about the sum effect of the direct and TVS-mediated effects. Signs refer to a positive (+), negative (-), or neutral (0) effect of the driver on the described aquatic ecosystem process.

Aquatic Process	**Direct**	**TVS-Mediated**	**Sum**	**Implications**
Carbon dynamics / Organic matter processing	- woody debris distribution due to lack of flooding[1]	Altered litter inputs due to vegeatation shift, e.g. grasses to evergreens[2]	+/-	Influence on C processing will depend on the nature of the vegetation shift
Nutrient dynamics	- nutrient delivery due to lower flood peaks[3] - nutrient processing rates[3]	Altered litter inputs due to vegeatation shift, e.g. grasses to evergreens[2]	+/-	Negative direct effects may be attenuated or exacerbated by litter quality of late succession species
Hydrology	- flow downstream (extended drought)[3] - contact with soil due to altered flow regime[3]	0	-	Water regulation by damming likely to dominate hydrology

[1]Pettit & Naiman. 2005. *Oecologia* 145: 434-444.
[2]O'Connor. 2001. *Journal of Applied Ecology* 38: 1314-1325.
[3]Pinay et al. 2002. *Environmental Management* 30: 481-491.

Appendix 4. In the Northern United States, increased air temperature due to climate warming has direct effects on aquatic processes that provide key ecosystem services. In addition, climate warming is driving the replacement of deciduous tree species with coniferous loblolly pines. This shift in terrestrial vegetation structure (TVS) will indirectly influence aquatic processes. Using these, we make predictions about the sum effect of the direct and TVS-mediated effects. Signs refer to a positive (+), negative (-), or neutral (0) effect of the driver on the described aquatic ecosystem process.

Aquatic Process	**Direct**	**TVS-Mediated**	**Sum**	**Implications**
Carbon dynamics / Organic matter processing	- due to increased respiration[1]	+ DOC input[2] - litter input (with altered timing) of lower quality[3]	+/-	Relative influence of loblolly encroachment on stream DOC inputs is uncertain
Nutrient dynamics	+ DIN and nutrient loading, due to faster processing of organic matter[4]	+ DON inputs[3], or - N export to streams due to lower litter N concentrations and decreased soil N mineralization[5]	+/-	Relative influence of loblolly encroachment on stream N inputs is uncertain
Hydrology	- due to evaporation[6]	- runoff due to higher precipitation interception[3], or 0[7]	-	Decreased discharge to streams

[1]Shaver et al. 2000. *BioScience* 50: 871-882.
[2]Kalbitz et al. 2000. *Soil Science* 165: 277-304.
[3]Whiles & Wallace. 1997. *Hydrobiologia* 353: 107-119.
[4]Coûteaux et al. 1995. *Trends in Ecology & Evolution* 10: 63-66.
[5]Ollinger et al. 2002. *Ecology* 83: 339-355.
[6]Schindler. 1997. *Hydrological Processes* 11: 1043-1067.
[7]Dangelo & Webster. 1991. *Freshwater Biology* 26: 335-345.

References

Benstead JP, Deegan LA, Peterson BJ, Huryn AD, Bowden WB, Suberkropp K, Buzby KM, Green AC, Vacca JA. 2005. Responses of a beaded Arctic stream to short-term N and P fertilisation. Freshwater Biology 50: 277-290.

Chapin FS. 1995. New cog in the nitrogen cycle. Nature 377: 199-200.

Coûteaux MM, Bottner P, Berg B. 1995. Litter decomposition, climate and litter quality. Trends in Ecology and Evolution 10: 63-66.

Dangelo DJ, Webster JR. 1991. Phosphorus retention in streams draining pine and hardwood catchments in the southern Appalachian Mountains. Freshwater Biology 26: 335-345.

Inouye RS, Huntly NJ, Tilman D, Tester JR, Stillwell M, Zinnel KC. 1987. Old-field succession on a Minneosta sand plain. Ecology 68: 12-26.

Judd KE, Kling GW. 2002. Production and export of dissolved C in arctic tundra mesocosms: The roles of vegetation and water flow. Biogeochemistry 60: 213-234.

Kalbitz K, Solinger S, Park JH, Michalzik B, Matzner E. 2000. Controls on the dynamics of dissolved organic matter in soils: A review. Soil Science 165: 277-304.

McLean R, Oswood MW, Irons JG, McDowell WH. 1999. The effect of permafrost on stream biogeochemistry: A case study of two streams in the Alaskan (USA) taiga. Biogeochemistry 47: 239-267.

Nosetto MD, Jobbágy EG, Tóth T, Jackson RB. 2008. Regional patterns and controls of ecosystem salinization with grassland afforestation along a rainfall gradient. Global Biogeochemical Cycles 22.

O'Connor TG. 2001. Effect of small catchment dams on downstream vegetation of a seasonal river in semi-arid African savanna. Journal of Applied Ecology 38: 1314-1325.

Ollinger SV, Smith ML, Martin ME, Hallett RA, Goodale CL, Aber JD. 2002. Regional variation in foliar chemistry and N cycling among forests of diverse history and composition. Ecology 83: 339-355.

Pettit N, Naiman R. 2005. Flood-deposited wood debris and its contribution to heterogeneity and regeneration in a semi-arid riparian landscape. Oecologia 145: 434-444.

Pickett STA. 1982. Population-patterns through 20 years of oldfield succession. Vegetatio 49: 45-59.

Pinay G, ClÉMent JC, Naiman RJ. 2002. Basic principles and ecological consequences of changing water regimes on nitrogen cycling in fluvial systems. Environmental Management 30: 481-491.

Rehfeldt GE, Ferguson DE, Crookston NL. 2009. Aspen, climate, and sudden decline in western USA. Forest Ecology and Management 258: 2353-2364.

Schindler DW. 1997. Widespread effects of climatic warming on freshwater ecosystems in North America. Hydrological Processes 11: 1043-1067.

Shaver GR, et al. 2000. Global warming and terrestrial ecosystems: A conceptual framework for analysis. Bioscience 50: 871-882.

Smith LC, Sheng Y, MacDonald GM, Hinzman LD. 2005. Disappearing Arctic lakes. Science 308: 1429-1429.

Sturm M, Racine C, Tape K. 2001. Climate change - Increasing shrub abundance in the Arctic. Nature 411: 546-547.

Turner MG, Raffa KF, Aukema BH, Bentz BJ, Carroll AL, Hicke JA, Romme WH. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. Bioscience 58: 501-517.

van Mantgem PJ, et al. 2009. Widespread increase of tree mortality rates in the western United States. Science 323: 521-524.

Whiles MR, Wallace JB. 1997. Leaf litter decomposition and macroinvertebrate communities in headwater streams draining pine and hardwood catchments. Hydrobiologia 353: 107-119.