Section 10

RIPARIAN AREA FUNCTION & MANAGEMENT IN LAKES

An annotated bibliography

Compiled for the
Region II FRPA Riparian Management Science & Technical Committee

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SUMMARY

Organic matter. Coarse woody debris (CWD) is thought to be important as cover for fish in the littoral zone of lakes. Development along the shoreline of lakes was negatively correlated with the density of CWD in lakes (Christensen et al. 1996). France et al. (1996) found that losses of leaf litter due to riparian clear cutting along lakes could result in substantial losses of dissolved organic carbon and total phosphorus to these lakes.

Sediments. Logging roads are thought to present the greatest potential for increases in sedimentation of lakes. However, Gunn and Sein (2000) found that experimental loss of lake trout *Salvelinus namaycush* spawning habitat did not result in changes in recruitment of this species over a nine-year time span. Increased access that logging roads provided to anglers presented the greatest threat to lake trout production.

Nutrients. Total phosphorus loading in lakes after forest harvesting depended primarily on their location in the watershed, the amount of groundwater flow influence, and the proximity of lakes to wetland areas. Post-harvest phosphorus loading was greatest in area of high groundwater recharge and close proximity to wetlands (Devito et al. 2000). The dynamics of interactions between lakes, their surrounding soils and groundwater, and riparian management activities along lake shores continues to be poorly understood (Devito et al. 2000, Evans et al. 2000, Prepas et al. 2000, Steedman 2000). Zooplankton biomass in Canadian boreal shield lakes was relatively unaffected by riparian harvesting as compared with those impacted by wild fire (Patoine et al. 2000). Conversely, increases in algal biomass were observed in lakes with riparian harvest as compared to reference lakes (Planas et al. 2000). Response of fish populations to riparian harvesting was variable, with no significant changes in catch rates over time of some species, but potentially significant changes in recruitment rates of other species (St. Onge and Magnan 2000, Steedman 2003).

Water. Harvest activities in the riparian area surrounding lakes could change the amount of wind a lake receives, thereby changing the thermal dynamics of the lake. Changes in timing, duration,

and depth of thermal stratification could influence the production of lacustrine fish populations. France (1997) found evidence of thermocline deepening in Canadian lakes with riparian harvesting, thereby lessening the amount of available habitat for cold stenotherms such as lake trout. Scully et al. (2000) also found changes in the mixing regime of lakes logged during the late 19th century were reflected in the change in sedimentation rates in lake cores. Changes in mixing regime also appear to have affected the composition and abundance of bacterial populations in lakes. Steedman and Kushneriuk (2000) found that thermal habitat volume for lake trout was not significantly reduced by riparian harvesting, but water clarity did decrease in all study lakes. A buffer strip along one of the lakes did not prevent a decline in thermocline depth or water clarity.

References were primarily determined from online databases available to Alaska state government (http://www.library.state.ak.us/index/index.html). Databases used in the search were: Fish and Fisheries Worldwide, Arctic and Antarctic Regions, Wildlife and Ecology Studies Worldwide, Water Resources Abstracts, BasicBIOSIS, Aquatic Science and Technology Abstracts, and GEOBASE. The single best source for information of this type on lakes was drawn from a year 2000 supplement (S2) to the Canadian Journal of Fisheries and Aquatic Sciences on impacts of major watershed perturbations on aquatic ecosystems. When possible and available, PDF files of articles were also compiled; these references are noted with an asterisk following the citation.

REFERENCES

Christensen D.L., B.R. Herwig, D.E. Schindler, and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications 6(4):1143-1149.

Coarse woody debris (CWD) is a critical input from forested watersheds into aquatic ecosystems. Human activities often reduce the abundance of CWD in fluvial systems, but little is known about human impacts on CWD in lakes. We surveyed 16 north temperate lakes to assess relationships among CWD, riparian vegetation, and shoreline residential development. We found strong positive correlation between CWD density and riparian tree density (r^2=0.78), and strong negative correlation between CWD density and shoreline cabin density (r^2=0.71) at the whole-lake scale. At finer spatial scales (e.g., between sampling plots), correlations between CWD and riparian vegetation was also negatively influenced by the extent of cabin development. Overall, there was significantly more CWD in undeveloped lakes (mean of 555 logs/km of shoreline) than in developed lakes. Within developed lakes, CWD density differed between forested sites (mean of 379 logs/km of shoreline) and cabin-occupied sites (mean of 57 logs/km of shoreline). These losses of CWD will affect littoral communities in developed north temperate lakes for about two centuries. Because CWD is important littoral habitat for many aquatic organisms, zoning and lake management should aim to minimize further reductions of aquatic CWD and woody vegetation from lakeshore residences.

Devito, K.J., I.F. Creed, R.L. Rothwell, and E.E. Prepas. 2000. Landscape controls on phosphorus loading to boreal lakes: implications for the potential impacts of forest harvesting. Canadian Journal of Fisheries and Aquatic Sciences 57:1977-1984.*

For 12 low-order lakes in the Western Boreal Forest of Canada, lake position in the groundwater flow system and surface hydrologic connection to wetlands accounted for 57% of the variation in the change in postharvest (1997) relative to preharvest (1996) open-water median total phosphorous concentration ([TP]). Changes in [TP] decreased with calcium and magnesium concentrations, indicating that the largest increases in [TP] are likely to occur in lakes located in areas of groundwater recharge or shallow local discharge. Changes in [TP] increased with the area of wetland connected to the lake, a measure of near-surface hydrologic flushing of TP to the lake. However, the remaining variation (43%) in the TP response of lakes to harvest was not explained by landscape-based criteria. This study illustrates that in landscapes with complex hydrogeology, factors controlling the chemical responses of lakes to disturbance are complex, remain poorly understood, and require further study.

Evans, J.E., E.E. Prepas, K.J. Devito, and B.G. Kotak. 2000. Phosphorus dynamics in shallow subsurface waters in an uncut and cut subcatchment of a lake on the Boreal Plain. . Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 60-72.*

Phosphorus dynamics in shallow subsurface waters (<2.5 m depth) were studied in harvested and unharvested subcatchments of a Boreal Plain lake. The organic soil layer was underlain by discontinuous layers of sand and clay glacial till. Total dissolved P (TDP) concentrations (6–798 mg·L–1) of discrete water samples from mineral layers (0.9–2.5 m deep) generally decreased with depth, were negatively related to Ca (rs < –0.7), and were lower in clay. When the groundwater table rose and saturated the organic layer, TDP concentrations increased in the composite (organic mineral layer) but not in the discrete (mineral layer) water samples, indicating that elevated TDP concentrations originate from the near-surface organic layer. TDP concentrations in composite samples were negatively correlated with water table depth (rs = –0.6) and were positively correlated with transmissivity (rs = 0.7) and dissolved organic C concentration (rs > 0.6). In the riparian buffer zone of the harvested subcatchment, TDP concentrations of composite samples decreased during high runoff, but these values remained higher than concentrations in the unharvested subcatchment. However, surface topography and variable depth to confining clay layers resulted in higher groundwater tables in the harvested subcatchment, especially in the cut area. Mean daily TDP export coefficients were similar between the unharvested (14 mg·m–2) and harvested (12 mg·m–2) subcatchments.

France, R. 1997. Land-water linkages: influences of riparian deforestation on lake thermocline depth and possible consequences for cold stenotherms. Canadian Journal of Fisheries and Aquatic Sciences 54:1299-1305.*

The purpose of the present study was to determine if riparian deforestation would expose lake surfaces to stronger winds and therefore bring about deepening of thermoclines and resulting habitat losses for cold stenotherms such as lake trout *(Salvelinus namaycush)*. Removal of protective riparian trees through wind blowdown and two wildfires was found to triple the overwater windspeeds and produce thermocline deepening in two lakes at the Experimental Lakes Area. A survey of thermal stratification patterns in 63 northwestern Ontario lakes showed that lakes around which riparian trees had been removed a decade before through either clearcutting or by a wildfire were found to have thermocline depths over 2 m deeper per unit fetch length compared with lakes surrounded by mature forests. Riparian tree removal will therefore exacerbate hypolimnion habitat losses for cold stenotherms that have already been documented to be occurring as a result of lake acidification, eutrophication, and climate warming.

France R., H. Culbert, and R. Peters. 1996. Decreased carbon and nutrient input to boreal lakes from particulate organic matter following riparian clear-cutting. Environmental Management 20(4):579-583.

Through estimates of airborne litter input from forested and clear-cut shorelines of Canadian Shield lakes, and laboratory measurements of concentrations released from leaf leachate, it was determined that riparian deforestation resulted in reductions of dissolved organic carbon (DOC) from 17.8 to 0.4 g/m shoreline/yr and of total phosphorus from 2.9 to 0.3 g/m shoreline/yr. Previous predictive models indicate that such reductions may be substantial enough to decrease basic metabolic processes of lake plankton communities by as much as 9% in primary production and 17% in respiration.

Gunn, J.M. and R. Sein. 2000. Effects of forestry roads on reproductive habitat and exploitation of lake trout *(Salvelinus namaycush)* in three experimental lakes. Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 97-104.*

This study was designed to test the effects of two potential impacts of forest access roads on lake trout *(Salvelinus namaycush)* lakes in the Boreal Shield ecozone: (i) loss of reproductive habitat through siltation and (ii) increased access and exploitation. During an 9-year study (1991–1999) in Whitepine Lake, access to seven original spawning sites and over 250 alternate spawning sites was progressively removed by covering the substrate with opaque plastic sheeting to simulate siltation. No effects on recruitment of lake trout have yet been detected. Mark–recapture estimates of juvenile (<370 mm fork length) abundance remained high, mean body size did not increase, and emergent alevins continued to be produced from the alternate spawning sites each year. Similar results occurred in a short-term study in Helen Lake. The lack of obvious effects of reproductive habitat loss was in sharp contrast with the rapid and severe effects that fishing pressure exerted on the lake trout population in Michaud Lake where access was improved by construction of a 12-km forest access road. These findings suggest that lake trout can tolerate substantial losses in spawning habitat, but natural populations, particularly in small lakes, must be protected from excessive exploitation.

Patoine, A., B. Pinel-Alloul, E.E. Prepas, and R. Carignan. 2000. Do logging and forest fires influence zooplankton biomass in Canadian Boreal Shield lakes? Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 155-164.*

Zooplankton biomass was assessed in 20 reference lakes, nine logged-watershed lakes, and nine burned watershed lakes during three summers following watershed disturbances by logging or wildfires. Biomass of cladocerans, calanoids, cyclopoids, and rotifers was quantified in the 38 lakes for the first year following disturbances. Limnoplankton biomass in four size fractions was quantified during 3 years following disturbances. One year after disturbances, burned-watershed lakes supported 59% more biomass of the rotifer size fraction of limnoplankton (100–200 mm) than reference lakes, while logged-watershed lakes supported 43% less of calanoid biomass. Two years after disturbances, differences in limnoplankton biomass between burned-watershed lakes and reference lakes were more pronounced than during the first year, while logged-watershed lakes supported levels of limnoplankton biomass no different from those of reference lakes. Three years after disturbances, no significant variations could be detected among the three groups of lakes for any of the limnoplankton size fractions. The proportion of watershed area impacted by logging activities was on average less than half the proportion impacted by wildfires. Nonetheless, both types of disturbances seemed to have opposite effects on the zooplankton biomass during the first year, and the effects did not extend beyond 2 years.

Planas, E.E., M. Desrosiers, S-R. Groulx, S. Paquet, and R. Carignan. 2000. Pelagic and benthic algal responses in eastern Canadian Boreal Shield lakes following harvesting and wildfires. Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 136-145.*

Pelagic and benthic algal biomass and pelagic algal community structure were measured in Boreal Shield lakes impacted by forest harvesting and wildfires (Haute-Mauricie, Québec). Sixteen reference lakes in which the watershed has been unperturbed for at least 40 years, seven harvested lake watersheds (logged in 1995), and nine lake watersheds burnt in 1995 were sampled for 3 years following harvesting or wildfires. From 1996 to 1998, repeated measures ANOVA showed significant effects between treatment and sampling years for pelagic chlorophyll a (Chl a) and biomass, but for 1997–1998 benthic Chl a, repeated-measures ANOVA showed only significant treatment effects. Chl a concentrations increased 1.4- to 3-fold in perturbed lakes as compared with reference lakes. Areal pelagic Chl a (milligrams per square meter) was lower than estimated littoral Chl a in perturbed lakes. The pelagic algal community was dominated by mixotrophic nanoflagellates in reference lakes. Watershed perturbation induced differential changes in pelagic algal communities: mixotrophic nanoflagellates increased in harvested lakes and photoautotrophic diatoms in burnt lakes. Considering only perturbed lakes, algal biomass was proportional to the fraction of the catchment area perturbed divided by the surface area of lakes in the catchment.

Prepas, E.E., M. Holst, P. McEachern, D. Millions, M. Serediak, D. Vitt, L. Halsey, T. Prowse, J. Gibson, D. Planas, and B. Pinel-Alloul. 2000. Watershed-lake interactions on the Boreal Plain and the impact of disturbance: fire in the wetlands, logging in the uplands. Final Project Report 2000-44, Sustainable Forest Management Network, University of Alberta, Edmonton. 41 p.

Water quality in lakes on the Boreal Plain was examined pre- and/or post disturbance by fire or logging. Indirect gradient analyses of chemical data from headwater lakes in undisturbed watersheds on the Boreal Plain, indicated a clear separation between those in wetland-dominated watersheds (57 to 100% wetland with variable proportions of bog, fen, swamp and marsh cover) and upland-dominated watersheds (0 to 44% wetland cover). In the former, percentage wetland cover in the watershed was positively correlated with total phosphorus (TP, r2 = 0.78, primarily bog), total nitrogen (TN, r2 = 0.46) and dissolved organic carbon (DOC, r2 = 0.74) concentrations. In undisturbed settings, rich fens appeared to sequester both total phosphorus and total nitrogen. In upland-dominated lakes, the ratio of catchment area to lake volume (CA/LV) was the strongest watershed correlate of total phosphorus concentration (r2 = 0.57) while most limnetic nitrogen and dissolved organic carbon were generated in situ. Color concentration, being highest in wetland lakes, was correlated with isotopically defined effective drainage basin area (eDBA)/LV (r2 = 0.66). Higher Chlorophyceae and Cryptophyta biomasses in wetland- than in upland-dominated systems may coincide with greater NH4 availability.

Eleven headwater lakes in Alberta’s Boreal Plain were monitored for nutrients and phytoplankton, two years before and two years after variable watershed harvesting (harvesting mean 16%, range 0-38%), as part of the Terrestrial and Riparian Organisms, Lakes and Streams (TROLS) program. After harvesting, variations in annual precipitation resulted in lake water residence times that differed by an order of magnitude from one year to the next. During the first post-treatment year, total phosphorus concentrations increased (overall 40%) in most lakes; however response was most consistent in lakes that were shallow, and the water column mixed or weakly thermally stratified. Chlorophyll a, cyanobacteria (Aphanizomenon-Anabaena), and yanotoxins (MCLR) increased after harvesting, primarily in shallow lakes. Post-treatment change in TP concentration was strongly related to weather (greatest response in wet year) and relative drainage basin size (drainage basin area to lake volume, r2 = 0.82, P << 0.01). There was no evidence that buffer strip width (20 m, 100 m, 200 m) influenced lake response. In lakes with relatively large watersheds (catchment area to lake volume ratio ≥ 4) logging in or near rich fens linked with the lake appears to enhance lake TP concentration. These results suggest that activities within the entire watershed should be the focus of catchment-lake interactions.

St-Onge, I. and P. Magnan. 2000. Impact of logging and natural fires on fish communities of Laurentian Shield lakes. . Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 165-174.*

The goal of this study was to determine if natural fires and logging have a significant impact on abundance, growth, and size structure of fish populations in 38 lakes of the Laurentian Shield (Québec, Canada). The watersheds of nine of these lakes underwent logging and nine underwent natural fires, while the 20 remaining lakes were used as references. No significant differences were found among the three lake groups in the catch per unit of effort of the most abundant species: white sucker *(Catostomus commersoni)*, northern pike (Esox lucius), yellow perch *(Perca flavescens)*, lake whitefish *(Coregonus clupeaformis)*, fallfish *(Semotilus corporalis)*, brook trout *(Salvelinus fontinalis)*, walleye *(Stizostedion vitreum)*, and burbot *(Lota lota)*. No significant difference was found among control, burned, and logged lakes in the back-calculated length of yellow perch, for which age determinations were made. However, we found that the proportions of small yellow perch and white sucker were significantly lower in populations of impacted lakes (burned and logged lakes pooled). The influence of logging and fires remained significant when a series of biotic and abiotic variables on watershed and lake characteristics were accounted for in multiple regression analyses. The lower proportion of small fish in impacted lakes could be due to an increase in postemergence mortality or to a shift of individuals to the pelagic zone.

Scully, N.M., P.R. Leavitt, and S.R. Carpenter. 2000. Century-long effects of forest harvest on the physical structure and autotrophic community of a small temperate lake. Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 50-59.*

The effects of forest clearcut and regrowth on a small (8.1 ha) stained lake were studied using a 200-year record of fossil carotenoids and chlorophylls. Comparison of high-resolution cores recovered from exposed, sheltered, and reference lake basins showed that annual laminations of sediments ceased concomitant with logging (ca. 1870–1890), indicating a fundamental change in the lake mixing regime. Biological responses to forest harvest included elimination of deepwater populations of anaerobic photosynthetic bacteria and reduced abundance of metalimnetic chrysophytes. Photosynthetic bacteria remained absent for over 100 years, while sediment laminae and chrysophytes have only returned since around 1970. In contrast, populations of epilimnetic phytoplankton (cyanobacteria, chlorophytes, cryptophytes) were unaffected by the clearcut. Analysis of sediment profiles did not reveal evidence of eutrophication or of increased flux of organic matter following watershed disturbance. Instead, fossil records were most consistent with increased wind stress, leading to deeper water column mixing in fall and reduction in deepwater anoxia, the main factor promoting sediment laminations and populations of photosynthetic bacteria. Such century-long disturbance may be common in small, stratified boreal lakes that lack physical shelter due to landforms.

Steedman, R.J. 2000. Effects of experimental clearcut logging on water quality in three small boreal forest lake trout *(Salvelinus namaycush)* lakes. Canadian Journal of Fisheries and Aquatic Sciences 57: 92-96.*

Water quality was monitored in three 30-ha stratified headwater Precambrian Shield lakes for 5 years before and 3 years after moderate to extensive catchment deforestation. These lakes, which had water renewal times of about a decade, showed only minor changes in water quality by the third year after logging. Water quality response in a lake with moderate deforestation and intact shoreline forest was similar to that in two lakes with extensive upland and shoreline deforestation. By the second and third years after logging, May-September average volume-weighted concentrations of dissolved organic carbon, chlorophyll, total nitrogen, K^+, Cl^-, and Si had all increased, generally by about 10-40% over predisturbance levels, while Ca2+ and Mg2+ had declined by 10-25%. Dry weather the first year after logging was associated with temporary declines of 10-20% in dissolved organic carbon and chlorophyll.

Steedman, R.J. 2003. Littoral fish response to experimental logging around small boreal shield lakes. North American Journal of Fisheries Management 23: 392-403.*

Littoral minnow trap catch in three small (26-39-ha), dimictic, oligotrophic headwater lakes in northwestern Ontario, Canada, was monitored for years before and after moderate to extensive watershed and shoreline clear-cutting. An abundant and diverse littoral fish community, dominated by Cyprinidae, persisted in the study lakes 5 years after logging, suggesting that logging impacts were small, compensatory, or delayed. The species richness of the catch among lakes ranged from 6 to 10 species and was constant within lakes. Although catch and average fish size varied significantly over the 10-year study, changes were not clearly linked with logging impacts. In the postlogging period, total catch was 17% less in the moderately disturbed lake (45% of watershed logged, with shoreline buffer strips) and 2-27% less in the two intensively disturbed lakes (75% of watershed and 60% of shoreline logged) than in the prelogging period. However, total catch began to decline 1-2 years before the experimental logging treatments in all cases. A similar pattern of reduced catch was evident for most of the abundant littoral fish species individually, although each lake had at least one relatively uncommon species that increased in abundance during the postlogging period. Average fish size in the moderately disturbed lake was 1-7% smaller in the postlogging period. In the extensively disturbed lakes, average size of the most abundant species increased by 1%; other species showed various responses, ranging from an 11% increase to an 11% decrease. Removal of approximately 23,000 fish from two of the lakes in the last year of the study did not produce an immediate reduction in total catch.

Steedman, R.J. and R.J. Kushneriuk. 2000. Effects of experimental clearcut logging on thermal stratification, dissolved oxygen, and lake trout *(Salvelinus namaycush)* habitat volume in three small boreal forest lakes Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl. 2): 82-91.*

Clearcut logging around three 30- to 40-ha dimictic northwestern Ontario lakes was associated with increases of 5% or less in midlake wind speed and no measurable changes in spring and fall circulation efficiency or duration of stratification. Water clarity, indexed as the depth at which photosynthetically active radiation was 1% of surface intensity, declined by 25% after 3 years. Late-summer thermoclines were about 1 m shallower in two lakes after logging, but it was not possible to exclude weather as a factor. None of the lakes showed significant declines in lake trout *(Salvelinus namaycush)* habitat volume. A forested shoreline buffer strip around one of the lakes prevented increases in midlake wind speed but did not prevent declines in water clarity and thermocline depth.