water

MDPI

Editorial

River and Lake Ice Processes—Impacts of Freshwater Ice on Aquatic Ecosystems in a Changing Globe

Karl-Erich Lindenschmidt *,†, Helen M. Baulch † and Emily Cavaliere

Global Institute for Water Security, 11 Innovation Blvd., Saskatoon, SK S7N 3H5, Canada; helen.baulch@usask.ca (H.M.B.); emily.cavaliere@usask.ca (E.C.)

* Correspondence: karl-erich.lindenschmidt@usask.ca; Tel.: +1-306-966-6174

† These authors contributed equally to this work.

Received: 29 September 2018; Accepted: 31 October 2018; Published: 6 November 2018

check for updates

Abstract: This special issue focuses on the effects of ice cover on surface water bodies, specifically rivers and lakes. Background information on the motivation of addressing this topic is first introduced with some selected references highlighting key points in this research field. A summary and synthesis of the eleven contributions is then provided, focusing on three aspects that provide the structure of the special issue: Physical processes, water quality, and sustainability. We have placed these contributions in the broader context of the field and identified selected knowledge gaps which impede our ability both to understand current conditions, and to understand the likely consequences of changing winters to the diversity of freshwater ecosystems subject to seasonal ice cover.

Keywords: aquatic ecosystems; field sampling; ice regime; modelling; northern lakes and rivers; water quality

1. Introduction

Most freshwater aquatic ecosystems have focused on open-water conditions, during spring, summer, and autumn. Studies in winter during ice-covered conditions are relatively sparse in many regions [1] due to the logistical challenges, issues of safety, and the historic assumption made by some that these ecosystems are biologically inactive during winter. Despite this, there is growing evidence that the winter period is not quiescent [2,3]—and indeed, many researchers have known this for decades, helping to build a year-round perspective of lakes and rivers in some regions [4].

Instead of winter being a quiescent period, it can be a period of rapid change. In some ecosystems, large under-ice blooms may occur [5,6] while in others anoxia is common, governed in large part by ice-cover duration [7,8]. Key biogeochemical processes continue through winter, and, as such, this can lead to significant greenhouse gas fluxes at ice out [9], and can alter the speciation and concentration of nutrients through winter and early spring [10–14]. Ice conditions can have strong impacts on the physical environment of lakes and rivers, impacting light, temperature, and mixing, and strongly influencing sediment transport. As such, ice can have both direct, and indirect effects on the flora, fauna, and water quality of freshwater systems [2,3,6]. High spatial variability in physical and chemical conditions is the norm. Within lakes vertical zonation, with regions of high and low light, and high and low oxygen can impact biota and geochemistry [2]. Horizontal patchiness in light is influenced by snow and ice conditions. Within rivers, the light environment changes in winter, but ice-induced changes in flow and habitat have received greater study due to the marked impacts on biotic communities. Variability within rivers may even be more extreme than lakes, with frazil ice, anchor ice, and surface ice affecting different aspects of the ecosystem, altering the habitat for fish, macrophytes, and invertebrates [15–17].

We still lack a complete understanding of how winter conditions affect aquatic ecosystems. While this is an important challenge, given the millions of lakes and rivers which are subject to ice cover, this also represents a vast challenge, given the multitude of factors that differ including geomorphology, morphometry, hydrology, trophic status, anoxia risk, carbon concentrations, and of course, the constituent biotic communities. Winter conditions set the stage for biological succession, and seasonal trajectories of change in water quality. As such, changes such as earlier ice-off may affect the duration and magnitude of the spring bloom in lakes [18], and changing winters may alter summer blooms [19,20]. In rivers, shorter ice periods may mean changes in anoxia risk, as many rivers show similar progressive declines in oxygen through winter to lakes [21,22]. However, changes in breakup intensity may represent the greatest impact of changing winter conditions on river ecosystems [23] due to the effects on channel morphology, along with direct impacts on sediment transport, water chemistry, and biota.

Observations of rapid declines in the duration of ice cover for lakes and rivers, (e.g., [24,25]) and evidence of changing timing and risk associated with ice-jam floods [26], combined with concern about implications of declining ice cover for water quality and biota (e.g., [3,27]), create a sense of urgency for winter aquatic research. This is because without an understanding of current conditions and processes governing winter and ice conditions, and with a limited understanding of how winter changes influence the open water season, we cannot effectively predict climate-related changes in seasonally ice-covered lakes and rivers. Likewise, without developing and applying modelling tools to understand physical processes and to anticipate how these processes will change, we cannot predict resultant changes in ecosystems, or risks to ecosystem services. This Special Issue provides a venue to report new findings in field-based and modelling research to highlight the importance of the ice regime within rivers and lakes, building a stronger understanding of current conditions, and ultimately helping to frame our understanding of future change.

2. Contributions and Current State of Knowledge

2.1. Physical Processes and Ice Phenology

Lakes and rivers are already experiencing decreased ice-cover duration in many regions [24,28,29], with the largest impact of climate change on ice-cover duration expected to be a much earlier spring melt, up to four-weeks earlier by 2050 [30,31]. Work by Hewitt et al. [32] presented here compares long-term breakup and freezeup records over nine lakes in Wisconsin USA, and Ontario, Canada. They demonstrate that over 35 years, there has been a shift to loss of ice cover five days earlier in spring, and freeze up eight days later, associated with warmer fall, winter, and spring temperatures. By 2070, they predict much more dramatic changes may occur, but these changes will be strongly impacted by the degree of warming observed, with the warmest scenario suggesting breakup could be 43 days earlier. Dramatic decreases in ice-cover duration could have negative impacts on aquatic ecosystems that are already vulnerable to regime shifts [33]. However, there are many unknowns about changes during winter, and how winter duration will affect aquatic ecosystems.

A precursor for understanding change within ice-covered rivers is characterization of its flow and ice regime. Alfredsen [34] investigated the effects of ice on the flow conditions of rivers in relation to their hydrological variability during winter. He used the index of hydrological alteration (IHA) to characterize the interaction between the rivers' flow and ice regimes. Ice processes considered in the IHA include frazil and anchor ice formation and the formation and breakup of ice covers. The modelling tool introduced by Lindenschmidt [35] also includes the process of ice jamming, an important process leading to flooding in many communities along northern rivers. The tool has been successfully implemented to simulate flood hazard and risk induced by ice-jam flooding [36,37], climate change [38], and ice-jam flood forecasting [39]. Zhang et al. [40] introduced a novel space-borne remote sensing method for determining ice volume that breaks up along a river that forms an ice jam. The ice volume constituting an ice jam can be a very sensitive parameter for the accuracy of backwater levels induced from jams [41]. An interesting approach to predict ice-cover failure is presented by Zhang et al. [42] who used an extension of the smooth particle hydrodynamics method, which is based on a simplified finite difference interpolation scheme.

The physical processes of greatest interest in lakes tend to center around dynamics of temperature, light, and mixing. Temperature, light, and mixing tend to be reduced with the onset of ice cover in lentic systems. As the ice forms, the denser, warmer water in the water column sinks and is further heated by the sediments [43], while the colder, less dense water stays near the surface as the ice forms [44]. Snow accumulation on the surface of ice-covered lakes, reservoirs, and ponds decreases light penetration [44], hence snowfall, blowing snow, and snowmelt can alter light inputs over winter [44,45]. When light penetration increases, due to melting of snow and ice, water below the ice–water interface warms, causing mixing [2,45], and altering the light environment for phytoplankton. The type of ice can also alter the light environment, with more opaque, or white ice blocking much of the light while black or crystal ice can be nearly transparent [4,46]. Changes in ice and snow through the season have a critical impact on rates of primary productivity, and the biomass of phytoplankton under ice [45]. Although low temperatures decrease microbial activity [47], important under-ice blooms can occur when light conditions are suitable (e.g., see [2,6]).

2.2. Water Quality

Changes in winter oxygen represent one of the most significant areas of scientific interest, and the longest-studied aspects of winter limnology, in part due to risk of winter fish kills. Within rivers and lakes, dissolved oxygen depletion can occur due to continued respiration, coupled with often low primary productivity, and the prevention of reaeration due to ice cover [28,48]. Oxygen depletion can be exacerbated due to municipal and industrial emissions, exfiltration of oxygen-depleted groundwater, and can be strongly influenced by the light environment, and connectivity of river–lake networks [16,22,49–51].

Akomeah et al. [52] and Terry et al. [53] both used surface water quality models to investigate the water quality of ice-covered water bodies, the former concentrating on a river and the latter on a lake within the Qu'Appelle river–lake system on the Canadian Prairies. Both studies are initial steps in larger projects to investigate the dynamics of dissolved oxygen concentrations and sediment oxygen demand during the winter seasons. The strain on oxygen concentrations increases as the ice cover persists longer at the end of the winter season—consistent with work suggesting that shorter periods of ice cover will lead to reduced anoxia risk, particularly in shallow ecosystems [22,26]. While aerobic respiration, particularly benthic respiration, are considered the dominant drivers of anoxia risk, there is growing interest in the role of methanotrophy [54] and nitrification [10] in mediating differences among lakes in their trajectories of oxygen decline.

An extensive examination of the effects of ice covers on river ecology is provided by Prowse [16,17] with a review on the effects of ice-cover breakup on riverine aquatic systems provided by Scrimgeour et al. [55]. Recent literature also focuses on nutrient dynamics in the water column [56] and dissolved oxygen in the river bed sediments [57] of frozen-over rivers. In addition, there has been significant interest, and progress in the ecology of ice-covered rivers and effects of ice on fish behavior and habitat (e.g., [58–61]).

Within lakes, impacts of ice phenology (ice duration due to the timing of ice-on and ice-off dates) can impact the following spring and summer seasons' water quality, as indicated by the work presented by Warner et al. [62] in this special issue. These trends are consistent with work in Sweden [63] and Lake Erie [18] showing increased diatom biomass with shorter or no-ice cover years. This area of understanding winter impacts on the spring bloom, and on summer water quality is a key area where more work is required to understand different responses across lakes, and to characterize interactions between physical, chemical, and biotic drivers of change.

Winter changes span many more variables. Turcotte and Morse [64] studied the impact of ice breakup on peaks in specific conductivity and turbidity using a conceptual model, the winter environment continuum, to help relate the winter conditions in headwater streams to the water quality state along the river network during the winter. This linking of physical and chemical change is a key area for additional work across lentic and lotic environments. Physical effects of freeze-out may have important impacts upon solute chemistry, particularly in shallow ecosystems [65–67]. Low temperature will affect microbial processes, with impacts on , oxygen and biogeochemical processes [8,11,12,47]. More broadly, the full integration of lakes and their watersheds, necessary to understand likely effects of climatic change represents a vast challenge—as illustrated by the work presented here.

The potential impact of changing ice phenology on a river's future (2050s and 2080s) water quality was modelled by Hosseini et al. [68]. They found that thin ice and shorter ice periods may lead to a decrease in winter nutrient concentrations in the winter, but this could be offset by increased flow if more water is passed through the river system to meet increased water demand. Warner et al. [62] also found that changes in the ice-off dates can have marked effects on the thermal regimes, mixing depths and length of turnover in the spring, which may further influence spring and summer water quality and algal species succession. These changes have already been observed in some areas of the world, including in Lake Erie, and Sweden [18,63,69], and in some cases, resulting in increased spring bloom diatom biomass causing water quality problems for local municipalities [63]. Warner et al. have provided important insights that will help build an understanding of the different responses we might anticipate across lakes of different regions, building on some of our knowledge of different physical responses, for example among lakes with varied mean depths [32]. Parks et al. [70,71] also found that river ice in the arctic is lessening due to regional climate warming, as are other components of the cryosphere such as permafrost, glacier ice, and sea ice.

2.3. Sustainability

Rokaya et al. [71] have criticized how little attention has been given to questions of sustainability within ice research. They noted that there is limited cross-disciplinary collaboration and integration of social sciences despite the massive socio-economic consequences of ice-jam flooding. They provide a scheme to sustainably manage a regulated river system to both (i) mitigate ice-jam flood risk at communities and (ii) promote ice-jam flooding to help replenish moisture and sediment supply of an inland delta's aquatic and terrestrial ecosystem [71]. We are fortunate to have a paper in this issue that delves, on a conceptual level, on the management of ice-jam floods to better sustain socio-economic and socio-ecological systems [72]. They provide a framework for such a management strategy that calls for a more interdisciplinary approach to ice management, which integrates social, economic, and ecological perspectives.

This need for a more interdisciplinary approach within ice science holds more broadly. Ultimately, the ice-cover period, and climate-related changes in the ice-cover period is strongly linked to ecosystem services provided by freshwater. Communities depend upon seasonally ice-covered rivers and lakes for necessities like water, fish, and transportation, and for recreational opportunities. While some of the effects of ice cover on ecology, ecosystem services, and economics have been known for decades (e.g., anoxia risk, fish kills, and ice-jam floods), there is growing awareness of broader effects of changing winters and associated risks and opportunities. More communities are grappling with transportation challenges associated with threats to ice roads, while others may see opportunities to increase transport via barge, or the need to grapple with the high cost of building all weather roads [73] and there is growing awareness of the impacts of ice, and changing ice on industries such as hydroelectric power generation [74]. Changing ice cover may have important economic consequences in some areas [73], and effects on fisheries may have profound cultural impacts, particularly in Indigenous communities. More work is required to better understand how loss of ice will impact people and communities, and support building the adaptive capacity required to respond to changing freshwater ice [75].

3. Conclusions

Winter ice cover is changing rapidly, and with it, many changes within lentic and lotic ecosystems will result, impacting key ecosystem services, and more broadly, affecting sustainability of key resources, livelihoods, and traditional practices. Climate change effects must be viewed through a regional lens, understanding the specific types of changes in precipitation, temperature, wind, and other variables that may occur, and building an understanding of how that will affect the ecosystems in a region. To help build the necessary local–regional–global understanding, synthetic work to understand differences across watersheds, across lakes, across rivers, and across regions such as those already presented here [32,62,64] and elsewhere [3,9] is very valuable—identifying common responses of ecosystems through winter, and differences across regions, and across types of lakes and rivers. This type of comparative approach will help to build a more diverse, regionally-informed understanding of physical, hydrological, hydraulic, biogeochemical, and ecological change, particularly when coupled with work to inform process-based understanding of changes through winter (e.g., [10,12]), and to integrate our growing understanding of winter changes into model-based frameworks (e.g., [76–78]).

As we work to anticipate future climatic changes, and effects upon aquatic ecosystems, much of our work has focused on understanding changes within the ice-free season, yet the ice cover and ice-free season must be understood jointly. Despite a rapid growth of interest in this area, key gaps remain. Building the scientific basis to assemble and integrate an understanding of physical, biogeochemical, ecological, and socio-economic change across regions is a vast challenge that will take decades of integrative research to address. Where possible, this represents work that should progress in tandem with community-based approaches to foster climate adaptation.

Author Contributions: K.-E.L. developed the idea for the special issue and introductory manuscript. K.-E.L. and H.M.B. wrote much of the text, with major contributions from E.C.

Funding: Funding sources for this work include the University of Saskatchewan's School of Environment and Sustainability and Global Institute for Water Security and a NSERC Discovery Grant to H.M.B.

Acknowledgments: We thank all authors for their contributions to this special issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Powers, S.M.; Hampton, S.E. Winter Limnology as a New Frontier. *Limnol. Oceanogr. Bull.* **2016**, *25*, 103–108. [CrossRef]
2. Bertilsson, S.; Burgin, A.; Carey, C.C.; Fey, S.B.; Grossart, H.-P.; Grubisic, L.M.; Jones, I.D.; Kirillin, G.; Lennon, J.T.; Shade, A.; et al. The under-ice microbiome of seasonally frozen lakes. *Limnol. Oceanogr.* **2013**, *58*, 1998–2012. [CrossRef]
3. Hampton, S.E.; Galloway, A.W.E.; Powers, S.M.; Ozersky, T.; Woo, K.H.; Batt, R.D.; Labou, S.G.; O'Reilly, C.M.; Sharma, S.; Lottig, N.R.; et al. Ecology under lake ice. *Ecol. Lett.* **2017**, *20*, 98–111. [CrossRef] [PubMed]
4. Schindler, D.W.; Welch, H.E.; Kalff, J.; Brunskill, G.J.; Kritsch, N. Physical and Chemical Limnology of Char Lake, Cornwallis Island (75° N Lat.). *J. Fish. Res. Board Can.* **1974**, *31*, 585–607. [CrossRef]
5. Vehmaa, A.; Salonen, K. Development of phytoplankton in Lake Paajarvi (Finland) during under-ice convective mixing period. *Aquat. Ecol.* **2009**, *43*, 693–705. [CrossRef]
6. Katz, S.L.; Izmest'eva, L.R.; Hampton, S.E.; Ozersky, T.; Shchapov, K.; Moore, M.V.; Shimaraeva, S.V.; Silow, E.A.; Izmest'eva, L.R.; Hampton, S.E.; et al. The "Melosira years" of Lake Baikal: Winter environmental conditions at ice onset predict under-ice algal blooms in spring. *Limnol. Oceanogr.* **2015**, *60*, 1950–1964. [CrossRef]
7. Meding, M.E.; Jackson, L.J. Biological implications of empirical models of winter oxygen depletion. *Can. J. Fish. Aquat. Sci.* **2001**, *58*, 1727–1736. [CrossRef]
8. Barica, J.; Mathias, J.A. Oxygen Depletion and Winterkill Risk in Small Prairie Lakes under Extended Ice Cover. *J. Fish. Res. Board Can.* **1979**, *36*, 980–986. [CrossRef]

9. Denfeld, B.A.; Baulch, H.M.; Giorgio, P.A.; Hampton, S.E.; Karlsson, J. A synthesis of carbon dioxide and methane dynamics during the ice-covered period of northern lakes. *Limnol. Oceanogr. Lett.* **2018**, *3*, 117–131. [CrossRef]
10. Powers, S.M.; Baulch, H.M.; Hampton, S.E.; Labou, S.G.; Lottig, N.R.; Stanley, E.H. Nitrification contributes to winter oxygen depletion in seasonally frozen forested lakes. *Biogeochemistry* **2017**, *136*, 119–129. [CrossRef]
11. Powers, S.M.; Labou, S.G.; Baulch, H.M.; Hunt, R.J.; Lottig, N.R.; Hampton, S.E.; Stanley, E.H. Ice duration drives winter nitrate accumulation in north temperate lakes. *Limnol. Oceanogr. Lett.* **2017**, 177–186. [CrossRef]
12. Cavaliere, E.; Baulch, H.M. Denitrification under lake ice. *Biogeochem. Lett.* **2018**, *137*, 285–295. [CrossRef]
13. Orihel, D.M.; Baulch, H.M.; Casson, N.J.; North, R.L.; Parsons, C.T.; Seckar, D.C.M.; Venkiteswaran, J.J. Internal phosphorus loading in Canadian fresh waters: A critical review and data analysis. *Can. J. Fish. Aquat. Sci.* **2017**, *74*, 2005–2029. [CrossRef]
14. Palacin-Lizarbe, C.; Camarero, L.; Catalan, J. Denitrification Temperature Dependence in Remote, Cold and N-Poor Lake Sediments. *Water Resour. Res.* **2018**, *2*. [CrossRef]
15. Linnansaari, T.; Alfredsen, K.; Stickler, M.; Arnekleiv, J.V.; Harby, A.; Cunjak, R.A. Does ice matter? Site fidelity and movements by Atlantic salmon (Salmo salar L.) parr duirng winter in a substrate enhanced river reach. *River Res. Appl.* **2009**, *25*, 773–787. [CrossRef]
16. Prowse, T.D. River-ice ecology. I.: Hydrologic, geomorphic, and water-quality aspects. *J. Cold Reg. Eng.* **2001**, *15*, 1–16. [CrossRef]
17. Prowse, T.D. River-ice ecology. II. Biological aspects. *J. Cold Reg. Eng.* **2001**, *15*, 17–33. [CrossRef]
18. Twiss, M.R.; McKay, R.M.L.; Bourbonniere, R.A.; Bullerjahn, G.S.; Carrick, H.J.; Smith, R.E.H.; Winter, J.G.; D'souza, N.A.; Furey, P.C.; Lashaway, A.R.; et al. Diatoms abound in ice-covered Lake Erie: An investigation of offshore winter limnology in Lake Erie over the period 2007 to 2010. *J. Gt. Lakes Res.* **2012**, *38*, 18–30. [CrossRef]
19. Weyhenmeyer, G.A. Rates of change in physical and chemical lake variables—Are they comparable between large and small lakes? *Hydrobiologia* **2008**, *599*, 105–110. [CrossRef]
20. Reavie, E.D.; Cai, M.; Twiss, M.R.; Carrick, H.J.; Davis, T.W.; Johengen, T.H.; Gossiaux, D.; Smith, D.E.; Palladino, D.; Burtner, A.; et al. Winter-spring diatom production in Lake Erie is an important driver of summer hypoxia. *J. Gt. Lakes Res.* **2016**, *42*, 608–618. [CrossRef]
21. Prowse, T.D. Environmental significance of ice to streamflow in cold regions. *Freshw. Biol.* **1994**, *32*, 241–259. [CrossRef]
22. Chambers, P.A.; Scrimgeour, G.J.; Pietroniro, A.; Culp, J.M.; Loughran, I. Oxygen modelling under river ice covers. In Proceedings of the Workshop on Environmental Aspects of River Ice; Prowse, T.D., Ed.; NHRI Symposium: Saskatoon, SK, Canada, 1993; pp. 235–260.
23. Prowse, T.D.; Beltaos, S. Climatic control of river-ice hydrology: A review. *Hydrol. Process.* **2002**, *16*, 805–822. [CrossRef]
24. Magnuson, J.J.; Robertson, D.M.; Benson, B.J.; Wynne, R.H.; Livingstone, D.M.; Arai, T.; Assel, R.A.; Barry, R.G.; Card, V.; Kuusisto, E.; et al. Historical trends in lake and river ice cover in the Northern Hemisphere. *Science* **2000**, *289*, 1743–1746. [CrossRef] [PubMed]
25. Sharma, S.; Magnuson, J.J.; Batt, R.D.; Winslow, L.A.; Korhonen, J.; Aono, Y. Direct observations of ice seasonality reveal changes in climate over the past 320–570 years. *Sci. Rep.* **2016**, *6*, 25061. [CrossRef] [PubMed]
26. Rokaya, P.; Budhathoki, S.; Lindenschmidt, K.-E. Trends in the Timing and Magnitude of Ice-Jam Floods in Canada. *Sci. Rep.* **2018**, *8*, 5834. [CrossRef] [PubMed]
27. Hampton, S.E.; Moore, M.V.; Ozersky, T.; Stanley, E.H.; Polashenski, C.M.; Galloway, A.W.E. Heating up a cold subject: Prospects for under-ice plankton research in lakes. *J. Plankton Res.* **2015**, *37*, 277–284. [CrossRef]
28. Fang, X.; Stefan, H.G. Simulations of climate effects on water temperature, dissolved oxygen, and ice and snow covers in lakes of the contiguous United States under past and future climate scenarios. *Limnol. Oceanogr.* **2009**, *54*, 2359–2370. [CrossRef]
29. Magee, M.R.; Wu, C.H. Effects of changing climate on ice cover in three morphometrically different lakes. *Hydrol. Process.* **2017**, *31*, 308–323. [CrossRef]
30. Butcher, J.B.; Nover, D.; Johnson, T.E.; Clark, C.M. Sensitivity of lake thermal and mixing dynamics to climate change. *Clim. Chang.* **2015**, *129*, 295–305. [CrossRef]

31. Beltaos, S.; Prowse, T. River-ice hydrology in a shrinking cryosphere. *Hydrol. Process.* **2009**, *23*, 122–144. [CrossRef]
32. Hewitt, A.; Lopez, L.S.; Gaibisels, K.M.; Murdoch, A.; Higgins, S.N.; Magnuson, J.J.; Paterson, A.M.; Rusak, J.A.; Yao, H.; Sharma, S. Historical Trends, Drivers, and Future Projections of Ice Phenology in Small North Temperate Lakes in the Laurentian Great Lakes Region. *Water* **2018**, *10*, 70. [CrossRef]
33. Scheffer, M.; Hosper, S.H.; Meijer, M.L.; Moss, B.; Jeppesen, E. Alternative equilibria in shallow lakes. *Trends Ecol. Evol.* **1993**, *8*, 275–279. [CrossRef]
34. Alfredsen, K. An Assessment of Ice Effects on Indices for Hydrological Alteration in Flow Regimes. *Water* **2017**, *9*, 914. [CrossRef]
35. Lindenschmidt, K.-E. RIVICE—A Non-Proprietary, Open-Source, One-Dimensional River-Ice Model. *Water* **2017**, *9*, 314. [CrossRef]
36. Lindenschmidt, K.-E.; Das, A.; Rokaya, P.; Chun, K.P.; Chu, T. Ice jam flood hazard assessment and mapping of the Peace River at the Town of Peace River. In Proceedings of the CRIPE 18th Workshop on the Hydraulics of Ice Covered Rivers, Quebec City, QC, Canada, 18–20 August 2015.
37. Lindenschmidt, K.-E.; Das, A.; Rokaya, P.; Chu, T. Ice jam flood risk assessment and mapping. *Hydrol. Process.* **2016**, *30*, 3754–3769. [CrossRef]
38. Das, A.; Rokaya, P.; Lindenschmidt, K.-E. Impacts of climate change on ice-jam flooding along a northern river, Canada. *Clim. Chang.* **2018**, submitted.
39. Lindenschmidt, K.-E.; Rokaya, P.; Das, A.; Li, Z.; Richard, D. A novel stochastic modelling approach for operational real-time ice-jam flood forecasting. *J. Hydrol.* **2018**, submitted.
40. Zhang, F.; Mosaffa, M.; Chu, T.; Lindenschmidt, K.-E. Using Remote Sensing Data to Parameterize Ice Jam Modeling for a Northern Inland Delta. *Water* **2017**, *9*, 306. [CrossRef]
41. Lindenschmidt, K.-E. Using stage frequency distributions as objective functions for model calibration and global sensitivity analyses. *Environ. Model. Softw.* **2017**, *92*, 169–175. [CrossRef]
42. Zhang, N.; Zheng, X.; Ma, Q. Updated Smoothed Particle Hydrodynamics for Simulating Bending and Compression Failure Progress of Ice. *Water* **2017**, *9*, 882. [CrossRef]
43. Bengtsson, L. Ice-covered lakes: Environment and climate-required research. *Hydrol. Process.* **2011**, *25*, 2767–2769. [CrossRef]
44. Catalan, J. Evolution of dissolved and particulate matter during the ice-covered period in a deep, high-mountain lake. *Can. J. Fish. Aquat. Sci.* **1992**, *49*, 945–955. [CrossRef]
45. Pernica, P.; North, R.L.; Baulch, H.M. In the cold light of day: The potential importance of under-ice convective mixed layers to primary producers. *Inland Waters* **2017**, *7*, 138–150. [CrossRef]
46. Petrov, M.P.; Terzhevik, A.Y.; Palshin, N.I.; Zdorovennov, R.E.; Zdorovennova, G.E. Absorption of Solar Radiation by Snow-and-Ice Cover of Lakes. *Water Resour.* **2005**, *32*, 546–554. [CrossRef]
47. Søndergaard, M.; Bjerring, R.; Jeppesen, E. Persistent internal phosphorus loading during summer in shallow eutrophic lakes. *Hydrobiologia* **2013**, *710*, 95–107. [CrossRef]
48. McBean, E.; Farquhar, G.; Kouwen, N.; Dubek, O. Predictions of ice-cover development in streams and its effect on dissolved oxygen modelling. *Can. J. Civ. Eng.* **1979**, *6*, 197–207. [CrossRef]
49. Wharton, R.A.; Simmons, G.M.; McKay, C.P. Perennially ice-covered Lake Hoare, Antarctica: Physical environment, biology and sedimentation. *Hydrobiologia* **1989**, *172*, 305–320. [CrossRef] [PubMed]
50. Jakkila, J.; Lepparanta, M.; Kawamura, T.; Shirasawa, K.; Salonen, K. Radiation transfer and heat budget during the ice season in Lake Paajarvi, Finland. *Aquat. Ecol.* **2009**, *43*, 681–692. [CrossRef]
51. Mackinnon, B.D.; Sagin, J.; Baulch, H.M.; Lindenschmidt, K.-E.; Jardine, T.D. Influence of hydrological connectivity on winter limnology in floodplain lakes of the Saskatchewan River Delta, Saskatchewan. *Can. J. Fish. Aquat. Sci.* **2016**, *73*, 140–152. [CrossRef]
52. Akomeah, E.; Lindenschmidt, K.E. Seasonal variation in sediment oxygen demand in a Northern chained River-lake system. *Water* **2017**, *9*, 254. [CrossRef]
53. Terry, J.A.; Sadeghian, A.; Lindenschmidt, K.E. Modelling dissolved oxygen/sediment oxygen demand under ice in a shallow eutrophic prairie reservoir. *Water* **2017**, *9*, 131. [CrossRef]
54. Denfeld, B.A.; Canelhas, M.R.; Weyhenmeyer, G.A.; Bertilsson, S.; Eiler, A.; Bastviken, D. Constraints on methane oxidation in ice-covered boreal lakes. *J. Geophys. Res. Biogeosci.* **2016**, *121*, 1924–1933. [CrossRef]

55. Scrimgeour, G.J.; Prowse, T.D.; Culp, J.M.; Chambers, P.A. Ecological Effects of River Ice Break-Up—A Review and Perspective. *Freshw. Biol.* **1994**, *32*, 261–275. [CrossRef]
56. Shakibaeinia, A.; Kashyap, S.; Dibike, Y.B.; Prowse, T.D. An integrated numerical framework for water quality modelling in cold-region rivers: A case of the lower Athabasca River. *Sci. Total Environ.* **2016**, *569–570*, 634–646. [CrossRef] [PubMed]
57. Sharma, K. Factors Affecting Sediment Oxygen Demand of the Athabasca River Sediment under Ice Cover. Ph.D. Thesis, University of Alberta, Edmonton, AB, Canada, 2012.
58. Bergeron, N.E.; Enders, E.C. Fish response to freeze up. In *River Ice Formation*; Beltaos, S., Ed.; Committee on River Ice Processes and Environment: Edmonton, AB, Canada, 2013; ISBN 978-0-9920022-0-6.
59. Brown, R.S.; Duguay, C.R.; Mueller, R.P.; Moulton, L.L.; Doucette, P.I.; Tagestad, J.D. Use of Synthetic Aperture Radar (SAR) to Identify and Characterize Overwintering Areas of Fish in Ice-Covered Arctic Rivers: A Demonstration with Broad Whitefish and Their Habitats in the Sagavanirktok River, Alaska. *Trans. Am. Fish. Soc.* **2010**, *139*, 1711–1722. [CrossRef]
60. Carr, M.; Lacho, C.; Pollock, M.; Watkinson, D.; Lindenschmidt, K.-E. Development of geomorphic typologies for identifying Lake Sturgeon (*Acipenser fulvescens*) habitat in the Saskatchewan River System. *River Syst.* **2015**, *21*, 215–227. [CrossRef]
61. Linnansaari, T.; Cunjak, R.A. Effects of ice on behavior of juvenile Atlantic salmon (*Salmo salar*). *Can. J. Fish. Aquat. Sci.* **2013**, *70*, 1488–1497. [CrossRef]
62. Warner, K.; Fowler, R.; Northington, R.; Malik, H.; McCue, J.; Saros, J. How Does Changing Ice-Out Affect Arctic versus Boreal Lakes? A Comparison Using Two Years with Ice-Out that Differed by More Than Three Weeks. *Water* **2018**, *10*, 78. [CrossRef]
63. Weyhenmeyer, G.A.; Westoo, A.K.; Willen, E. Increasingly ice-free winters and their effects on water quality in Sweden's largest lakes. *Hydrobiologia* **2008**, *599*, 111–118. [CrossRef]
64. Turcotte, B.; Morse, B. The Winter Environmental Continuum of Two Watersheds. *Water* **2017**, *9*, 337. [CrossRef]
65. Schmidt, S.; Moskal, W.; De Mora, S.J.; Howard-Williams, C.; Vincent, W.F. Limnological properties of antarctic ponds during winter freezing. *Antarct. Sci.* **1991**, *3*, 379–388. [CrossRef]
66. Dugan, H.A.; Helmueller, G.; Magnuson, J.J. Ice formation and the risk of chloride toxicity in shallow wetlands and lakes. *Limnol. Oceanogr. Lett.* **2017**, *2*, 150–158. [CrossRef]
67. Chambers, M.K.; White, D.M.; Lilly, M.R.; Hinzman, L.D.; Hilton, K.M.; Busey, R.C. Exploratory analysis of the winter chemistry of five lakes on the North Slope of Alaska. *J. Am. Water Resour. Assoc.* **2008**, *44*, 316–327. [CrossRef]
68. Hosseini, N.; Johnston, J.; Lindenschmidt, K.-E. Impacts of Climate Change on the Water Quality of a Regulated Prairie River. *Water* **2017**, *9*, 199. [CrossRef]
69. Weyhenmeyer, G.A.; Livingstone, D.M.; Meili, M.; Jensen, O.; Benson, B.; Magnuson, J.J. Large geographical differences in the sensitivity of ice-covered lakes and rivers in the Northern Hemisphere to temperature changes. *Glob. Chang. Biol.* **2011**, *17*, 268–275. [CrossRef]
70. Park, H.; Yoshikawa, Y.; Oshima, K.; Kim, Y.; Ngo-Duc, T.; Kimball, J.S.; Yang, D. Quantification of Warming Climate-Induced Changes in Terrestrial Arctic River Ice Thickness and Phenology. *J. Clim.* **2016**, *29*, 1733–1754. [CrossRef]
71. Park, H.; Yoshikawa, Y.; Yang, D.; Oshima, K. Warming Water in Arctic Terrestrial Rivers under Climate Change. *J. Hydrometeorol.* **2017**, *18*, 1983–1995. [CrossRef]
72. Rokaya, P.; Budhathoki, S.; Lindenschmidt, K.-E. Ice-jam flood research: A scoping review. *Nat. Hazards* **2018**. [CrossRef]
73. Das, A.; Reed, M.; Lindenschmidt, K.-E. Sustainable Ice-Jam Flood Management for Socio-Economic and Socio-Ecological Systems. *Water* **2018**, *10*, 135. [CrossRef]
74. Prowse, T. Introduction: Hydrologic effects of a shrinking cryosphere. *Hydrol. Process.* **2009**, *23*, 1–6. [CrossRef]
75. Prowse, T.; Alfredsen, K.; Beltaos, S.; Bonsal, B.R.; Bowden, W.B.; Duguay, C.R.; Korhola, A.; McNamara, J.; Vincent, W.F.; Vuglinsky, V.; et al. Effects of changes in arctic lake and river ice. *Ambio* **2011**, *40*, 63–74. [CrossRef]
76. Olsson, P.; Folke, C.; Berkes, F. Adaptive comanagement for building resilience in social-ecological systems. *Environ. Manag.* **2004**, *34*, 75–90. [CrossRef] [PubMed]

77. Hosseini, N.; Akomeah, E.; Davies, J.-M.; Baulch, H.; Lindenschmidt, K.-E. Water quality modelling of a prairie river-lake system. *Environ. Sci. Pollut. Res.* **2018**, *25*, 1–15. [CrossRef] [PubMed]
78. Hosseini, N.; Chun, K.P.; Wheater, H.; Lindenschmidt, K.E. Parameter Sensitivity of a Surface Water Quality Model of the Lower South Saskatchewan River—Comparison Between Ice-On and Ice-Off Periods. *Environ. Model. Assess.* **2017**, *22*, 291–307. [CrossRef]