# Importance of riparian zone management for freshwater fish and fish habitat protection: analysis and recommendations in Nova Scotia, Canada

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# Table of Contents

# List of Figures & Tables

## List of Abbreviations

| | |
|---|---|
| AWCTRT | Alberta Westslope Cutthroat Trout Recovery Team |
| BCFLNRORD | British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development |
| BMZ | biodiversity management zone |
| COSEWIC | Committee on the Status of Endangered Wildlife in Canada |
| DEM | digital elevation model |
| DFO | Fisheries and Oceans Canada |
| DU | designatable unit |
| EFP | environmental farm plan |
| ESA | Ecologically Significant Area |
| FFHPP | Fish and Fish Habitat Protection Program |
| FSC | Forest Stewardship Council |
| HADD | harmful alteration, disruption, or destruction |
| HCVF | High Conservation Value Forest |
| HRM | Halifax Regional Municipality |
| LiDAR | light detection and ranging |
| MEZ | machine exclusion zone |
| MODG | Municipality of the District of Guysborough |
| NSDNRR | Nova Scotia Department of Natural Resources and Renewables |
| NSEFPP | Nova Scotia Environmental Farm Plan Program |
| *RAR* | *Riparian Areas Regulation* |
| *SARA* | *Species at Risk Act* |
| SMZ | special management zone |
| SPEA | streamside protection and enhancement area |
| WAM | wet areas mapping |
| WUA | work, undertaking, or activity |
| ZOS | zone of sensitivity |

# Abstract

Collison, B. R., and Gromack, A. G. 2022. Importance of riparian zone management for freshwater fish and fish habitat protection: analysis and recommendations in Nova Scotia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3475: viii + 71 p.

Watercourses and adjacent terrestrial surroundings are highly interconnected, forming the ‘riparian zone,’ a hotspot for biodiversity and a unique environment that provides fundamental services for freshwater and diadromous fish species, such as food web linkages and thermal refugia. Here, we compile information on riparian ‘buffers’ applied in different jurisdictions across North America, and describe the role of Fisheries and Oceans Canada (DFO) in riparian management across the country. DFO’s current role is evidenced through the identification of riparian critical habitat for species protected under the *Species at Risk Act* and convictions under the *Fisheries Act* caused by activities that destroyed or degraded riparian fish habitat. In order to develop or enhance potential riparian management measures for fish or fish habitat protection, many region-specific parameters need to be understood including existing riparian regulatory requirements, land ownership, Indigenous knowledge, and cumulative effects of riparian disturbance. Riparian management recommendations are made, and options are brought forward, that reflect science advice for what is required for fish and fish habitat protection, while also attempting to balance these external factors. The literature review, policy analyses, and recommendations for moving forward may act as a preliminary framework for including riparian management measures in Ecologically Significant Area case studies or candidates, regulatory review of activities in accordance with the fish and fish habitat protection provisions under the *Fisheries Act*, aquatic species at risk critical habitat identification, and other DFO programs across Nova Scotia and the rest of Canada.

# Résumé

Collison, B. R., and Gromack, A. G. 2022. Importance of riparian zone management for freshwater fish and fish habitat protection: analysis and recommendations in Nova Scotia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3475: viii + 71 p.

Les cours d'eau et les milieux terrestres adjacents sont fortement interconnectés et forment ce qu'on appelle « la zone riveraine », un point chaud pour la biodiversité et un environnement unique qui fournit des fonctions fondamentales aux espèces de poissons d'eau douce et diadromes, comme des liens dans le réseau trophique et des refuges thermiques. Nous avons compilé ici des renseignements sur les bandes riveraines dans différents territoires en Amérique du Nord, et décrivons le rôle de Pêches et Océans Canada (MPO) dans la gestion des zones riveraines dans tout le pays. Le rôle actuel du MPO est mis en évidence par la désignation de l'habitat essentiel riverain pour les espèces protégées en vertu de la *Loi sur les espèces en péril* et par les condamnations en vertu de la *Loi sur les pêches* découlant d'activités qui ont détruit ou dégradé l'habitat riverain du poisson. Afin d'élaborer ou d'améliorer les mesures potentielles de gestion riveraine aux fins de la protection du poisson ou de son habitat, il faut comprendre de nombreux paramètres propres aux régions, notamment les exigences réglementaires existantes concernant les zones riveraines, la propriété foncière, l'histoire et le patrimoine culturels autochtones et les effets cumulatifs des perturbations riveraines. On formule des recommandations sur la gestion des zones riveraines, et on propose différentes options qui reflètent les avis scientifiques sur ce qui est nécessaire pour assurer la protection du poisson et de son habitat, tout en essayant d'équilibrer ces facteurs externes. L'analyse documentaire, les analyses stratégiques et les recommandations pour l'avenir peuvent servir de cadre préliminaire pour l'inclusion de mesures de gestion des zones riveraines dans les études de cas de zones d'importance écologique ou les zones candidates, l'examen réglementaire des activités conformément aux dispositions de protection du poisson et de son habitat en vertu de la *Loi sur les pêches*, la désignation de l'habitat essentiel des espèces aquatiques en péril et d'autres programmes du MPO en Nouvelle-Écosse et dans le reste du Canada.

# 1. Introduction

Human land-use practices within areas around streams and rivers play a critical role in determining the overall health, function, and biodiversity of the aquatic environment (Albertson et al. 2018; Kanno & Beazley 2004; Stoffyn-Egli & Duinker 2013). The transitional zone between aquatic and terrestrial habitats is known as the riparian zone, defined as “the area located between a waterbody’s high water mark and the upland area” (Caskenette et al. 2020). Riparian zones vary greatly in size and connectivity, depending on landscape features, evolutionary history, climate influences and other biophysical attributes of terrestrial and aquatic ecosystem interactions in different parts of the world (Figure 1; Schilling et al. 2017; Zaharescu et al. 2017; Wang et al. 2020; Lan & Rui-Hong 2020).

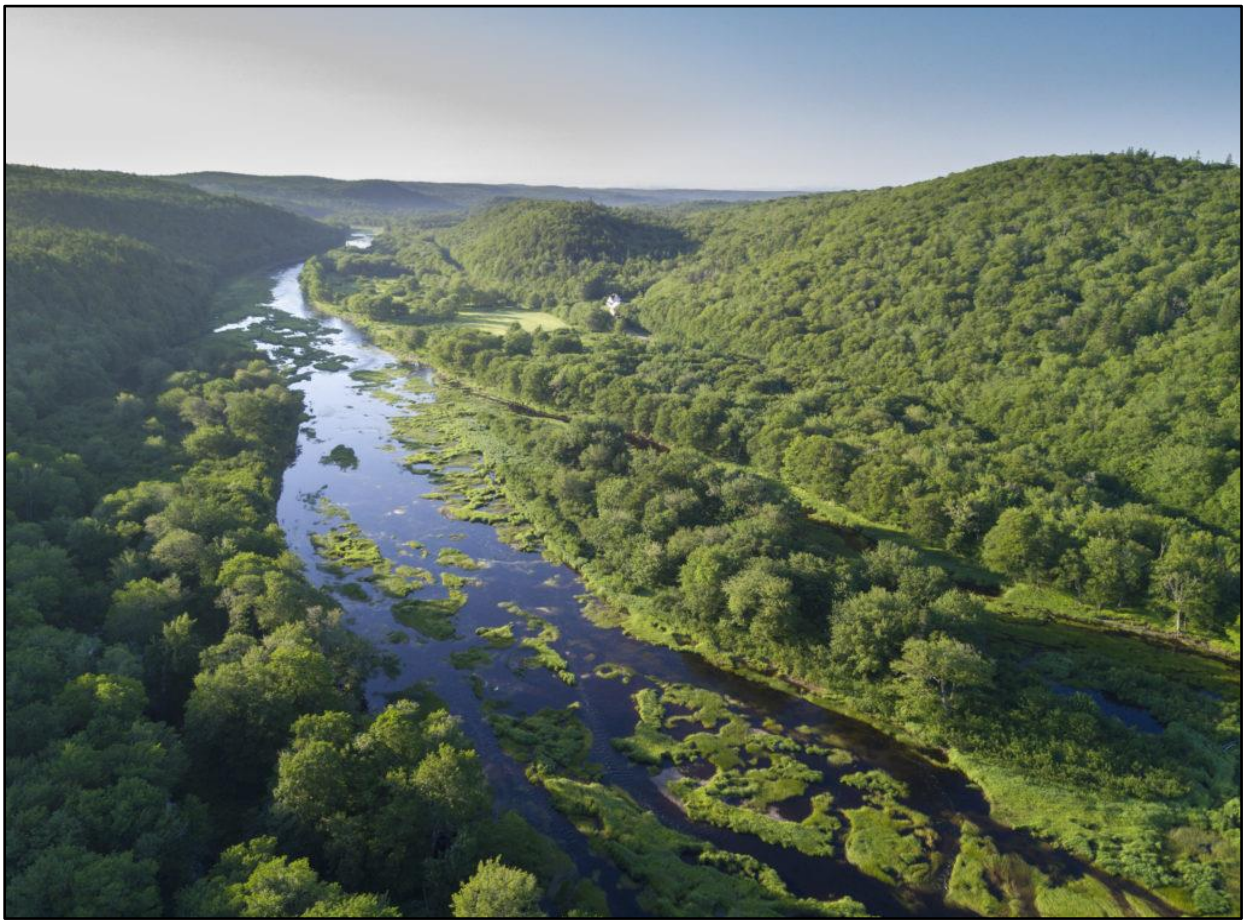

***Figure 1****: Riparian habitat / zone example – St. Mary's River, Nova Scotia, Canada (Nova Scotia Nature Trust 2021)*

The quality of aquatic habitat for fish species is strongly correlated to the condition of riparian habitat, and what activities or disturbances have occurred in those sensitive intermediate areas (Pusey & Arthington 2003; Caskenette et al. 2020; DFO 2020a). Riparian habitat is defined by DFO (2020a) as “features outside the aquatic ecosystem, which support the establishment and maintenance of deep and shallow pool features, supply food for migrating and juvenile fish of many species, and influence water

temperature." Riparian zones and riparian habitat are included within the definition of 'fish habitat' under ss. 2(1) of the Canadian *Fisheries Act* (1985) as "water frequented by fish and *any other areas on which fish depend directly or indirectly to carry out their life processes*, including spawning grounds and nursery, rearing, food supply and migration areas." Many Canadian jurisdictions have recognized the influence that human activities within riparian zones have on watercourses and the species within and therefore have developed regulations, best management practices, or guidelines related to riparian zones (Stoffyn-Egli & Duinker 2013). However, policies for riparian habitat management are variable in different parts of the country. In particular, there is variation in what is considered the appropriate riparian zone 'buffer' distance for mitigating terrestrial land-use impacts on watercourses that support fish and fish habitat (Stoffyn-Egli & Duinker 2013; Gene et al. 2019; Caskenette et al. 2021; Singh et al. 2021). The application of riparian policies can be enforced by various governing bodies, where jurisdictions often overlap between federal, provincial, and municipal authorities. Land ownership near waterbodies is also a critical consideration that influences how riparian zones are managed.

Intact, vegetated, riparian zones have a direct role in regulating the physical, chemical, and biological conditions of aquatic ecosystems, critical for resident and migrating fish (Riis et al. 2020; Hanna et al. 2020). Riparian habitat management is particularly important for species of socio-economic importance and for the conservation, protection, and recovery of many aquatic species at risk (DFO 2020a). For example, Brook Trout (*Salvelinus fontinalis*) are one of the most popular angled species in Nova Scotia, stocked in waterbodies across the province since the early 1900s (Lehnert et al. 2020). Like other salmonids, Brook Trout have a narrow range of tolerable water temperatures to properly carry out their life processes, and warming river systems caused by climate change are putting strain on this species (Kurylyk et al. 2015; Wilbur et al. 2020). Jones et al. (2006) found that 63% of stream segments in a large forested watershed could maintain stream temperatures required for juvenile Brook Trout with a 30 m wide riparian buffer, but only 9% of those streams kept such temperatures when the buffer width was reduced to 15 m. Brook Trout heavily rely on cold-water refugia in the summer months, and actively seek out these areas (e.g. intact riparian cover, groundwater upwelling, etc.) with even higher intensity than another important species in the province, Atlantic Salmon (Kurylyk et al. 2015; Wilbur et al. 2020).

The Southern Upland Atlantic Salmon designatable unit was most recently assessed by COSEWIC (2010) as Endangered and is currently under consideration for addition to Schedule 1 of the *Species at Risk Act* (2002; *SARA*). DFO identified habitat characteristics that are critical for Southern Upland Atlantic Salmon, with "1) water depth and velocity, 2) substrate composition, 3) the presence of cover, 4) water temperature, and 5) water quality" being the five major habitat components required for egg incubation, emergence, and juvenile development (Bowlby et al. 2014). Adult salmon and other cold water salmonid species require these same habitat components for rearing, spawning, overwintering, migrating, thermal refuge, and other life history requirements (Bowlby et al. 2014). Land-based human activities in the riparian zone can influence all of these habitat characteristics required for healthy fish populations, and remain a large threat to the Southern Upland Atlantic Salmon (Bowlby et al. 2014). Studies on Atlantic Salmon

have shown reduced population densities when present in watersheds that have been subject to large-scale timber harvesting (Deschenes et al. 2007), and substantial beneficial changes to water chemistry for Atlantic Salmon are observed when riparian buffer widths along fish-bearing watercourses are increased from 20 to 30 m (Vaidya et al. 2008).

This report consolidates and summarizes scientific and grey literature to explain what research suggests as adequate riparian zone management to sufficiently protect fish and fish habitat (Section 2). DFO has established precedence in riparian management across Canada through protected critical habitat that includes riparian areas for aquatic species at risk, and legal convictions caused by riparian destruction made under the *Fisheries Act* and *SARA* (Section 3). We compare current regulations and guidelines for riparian zone management in Nova Scotia through policy analyses (Section 4), and offer predictions for how riparian management may change with the implementation of provincial initiatives in-progress, such as the Lahey (2018) report recommendations or the provincial *Biodiversity Act* (Section 5). This report outlines a series of considerations for determining appropriate riparian management measures (Section 6), followed by options for riparian management and recommendations for Nova Scotia's fish-bearing freshwater environments, specifically for: 1) high protection or 'sensitive' areas; 2) broader watersheds; and 3) how those may differ on Crown or private land (Section 7). These recommendations may be applied at different scales, either provincially or in specific areas (e.g. critical habitat for aquatic species at risk and Ecologically Significant Area (ESA) designations under the *Fisheries Act* [s. 35.2]). Riparian zone management is complex from science and policy perspectives; as such, the objective of this report is to provide a comprehensive analysis of considerations for riparian management, alongside recommendations for informing fish and fish habitat conservation tools in Nova Scotia and the rest of Canada.

# 2. Riparian Management to Protect Fish and Fish Habitat

## *2.1. Ecosystem Functions Supported by Riparian Zones*

There is a strong connection between aquatic and riparian habitats that are reflected in unique ecosystem processes (DFO 2020a). There are seven main biophysical processes (i.e. erosion, filtration, infiltration, isolation, meandering, shading, and subsidization) occurring in riparian habitats that support, maintain, and protect aquatic ecosystems (Figure 2; DFO, 2020a) as described in Table 1.

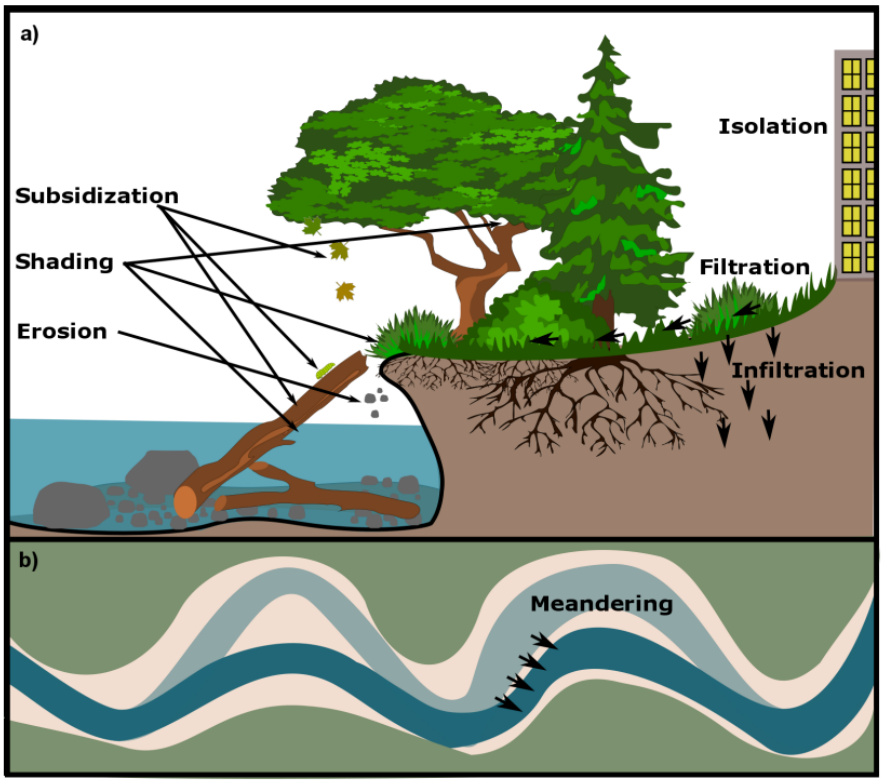


***Figure 2**: The seven main biophysical processes by which features in the riparian zone maintain aquatic features from two different perspectives, (a) cross-sectional, and (b) aerial (DFO 2020a)*

***Table 1**: Descriptions for each of the seven biophysical processes occurring in the riparian zone that support aquatic features and their description. These processes are dynamic and occur within a range of natural of variation that needs to be considered when defining riparian areas (DFO 2020a)*

| Process | Description |
|---|---|
| Erosion | The wearing of soil from terrestrial sources by wind, water or gravity. When erosion is occurring within a natural range of variation, it controls sedimentation and siltation; supporting aquatic attributes such as aquatic vegetation and interstitial spaces. |
| Filtration | Removal of matter, light or sound from air or water. Filtration prevents contaminants and excess nutrients in surface and subsurface water in the riparian zone from entering a waterbody. |
| Infiltration | Entry of surface water into soil. Riparian vegetation provides shading and structure that prevents evaporation, runoff, and allows surface water in the riparian zone to infiltrate into the water table. |
| Isolation | Spatial distancing of a place or thing from a disturbance. The intensity of noise and light decreases the farther away from the source. Therefore, the riparian zone isolates the water body from noise and light pollution that can affect the acoustic and photic environment, as well as other forms of human disturbance. |
| Meandering | Back and forth movement of a stream or river, changing shape as it flows across a floodplain or valley eroding and depositing sediments on alternating banks. Natural levels of meandering by a river or stream creates habitat features such as cover, backwater, and shoals. |

| | |
|---|---|
| Shading | Regulation of the amount of light admitted onto a surface. Shading in the aquatic habitat by vegetation, large woody debris (LWD), and undercut banks provides cover and maintains the photic environment. Shading by riparian vegetation maintains natural variation in temperature of water in the aquatic habitat. |
| Subsidization | Transfer of energy, food, and structural components from the terrestrial zone to the aquatic habitat. Riparian features provide food for mussels (e.g., organic matter) and fishes (e.g., terrestrial insects, nutrients and organic matter that support aquatic invertebrates). Coarse sediment, such as gravel and boulders from banks and beaches, in the riparian zone is transferred into waterbodies as a result of erosion processes and meandering. The subsidization of wood, also termed wood recruitment, is the addition of wood into waterbodies from the associated riparian trees as a result of the mortality of individual trees, disturbances affecting multiple trees or meandering of a river or stream. |

The continuous interactions between aquatic species habitat and the surrounding terrestrial environment highlights the potential cascade effect that human activities in a riparian area can directly or indirectly have on aquatic systems and the species that occupy them (Albertson et al. 2018; Harris et al. 2019; Caskenette et al. 2020). The seven riparian zone biophysical processes that support aquatic species habitat (Figure 2; Table 1) all have the potential to be disrupted to some extent by land-based activities. This is shown through a pathway of effects diagram for riparian works, undertakings, or activities (WUAs), used to communicate potential effects of development proposals on fish and fish habitat (Figure 3).

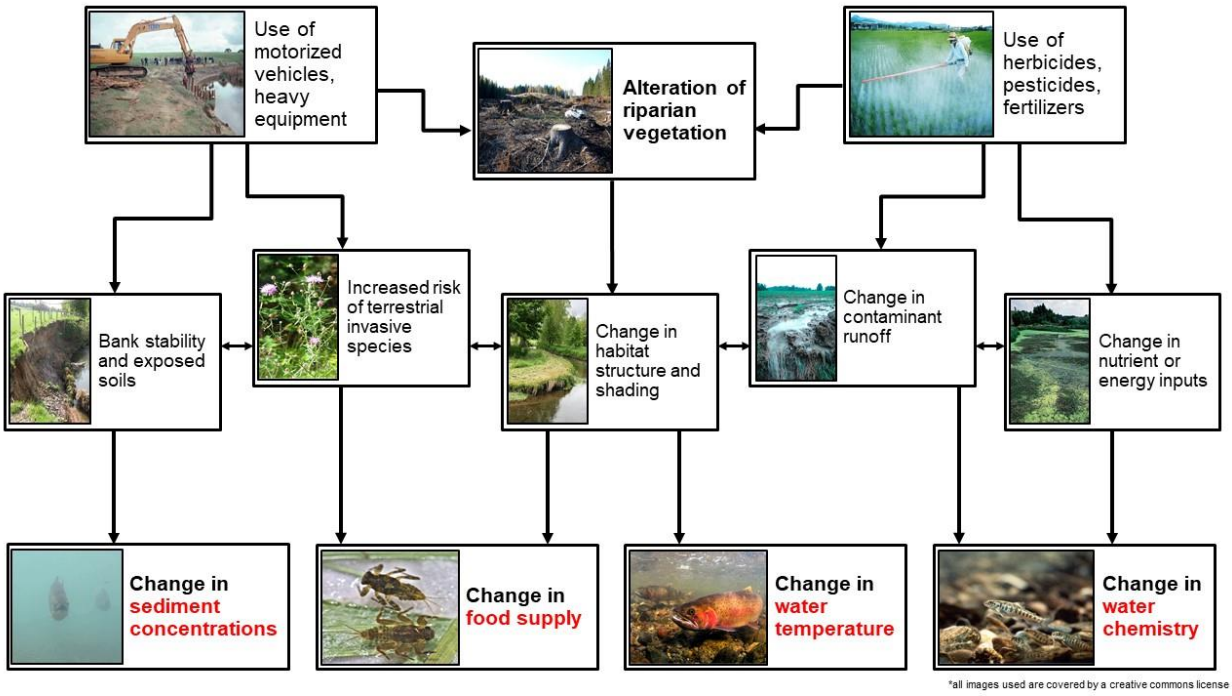


***Figure 3**: Pathway of effects diagram for riparian WUAs (adapted from DFO 2010; DFO 2021b)*

A significant amount of scientific research has been done to determine the appropriate riparian management techniques necessary to sufficiently protect aquatic

ecosystems in a way that allows fish and fish habitat to persist and thrive (DFO 2020; Cole et al. 2020; Albertson et al. 2018; Smokorowski & Pratt 2007; Stoffyn-Egli & Duinker 2013). Despite the influx of published research on this topic in recent years, the management of riparian habitat through fixed or adaptive riparian edge buffers for restricting human land-use activities varies greatly between jurisdictions (Kuglerová et al. 2020; Stoffyn-Egli & Duinker 2013). While most regions in North America have acknowledged the need to protect aquatic environments through riparian management measures, studies have found that many current guidelines or regulations may not be sufficient for adequately protecting fish and fish habitat (Hawes & Smith 2005; Stoffyn-Egli & Duinker 2013; Sibley & Gordon 2010). In particular, existing requirements for relatively narrow, fixed-width riparian buffers that apply to large spatial scales often originate from administratively-simple decision making (Richardson et al. 2012). The dependence on riparian management guidelines that stay constant across site-specific and landscape level variations stems from a historical lack of scientific testing or effectiveness monitoring of deployed riparian management techniques (Tiwari et al. 2016; Richardson et al. 2012).

### *2.2. Fixed-width Riparian Buffer Zones*

Regulatory frameworks and best management guidelines in many regions rely on fixed-width riparian buffer zones around watercourses to mitigate land-use impacts on aquatic ecosystems (Tiwari et al. 2016; Richardson et al. 2012; de Sosa et al. 2017). The concept of preserving riparian habitats originated in the 1950s – 1970s, as the forestry industry was becoming more widespread and mechanized throughout North America and forest research had demonstrated that incorporating a watercourse 'buffer' was mostly sufficient to reach environmental objectives (Richardson et al. 2012). Environmental policy-makers at that time believed that any protection was better than nothing, and implemented fixed-width riparian buffer regulations as a simple measure to reduce freshwater degradation from a rapidly evolving forestry sector (Richardson et al. 2012). While this method was relatively uncomplicated to introduce and enforce, it has been criticized for ignoring the heterogeneity of the landscape or adapting to site-specific conditions (Tiwari et al. 2016). However, the fixed-width buffer model may endure into the future as an easy-to-implement regulatory tool with minimal funding, time, and fieldwork required on a case-by-case basis (Stoffyn-Egli & Duinker 2013; Cole et al. 2020; Chapman et al. 2020).

Lee et al. (2004) quantitatively reviewed riparian buffer guidelines for timber harvesting in Canada and the United States. Although other human activities are also regulated in the riparian zone, forestry often has the most comprehensive set of guidelines to abide by. They found that 80% of provinces, territories, and states allow selective harvest (following specific management measures) within riparian buffers, and regulated widths depended on a variety of factors, such as waterbody type, size, shoreline slope, and fish presence (Table 2; Lee et al. 2004).

***Table 2**: The mean (std. err.) buffer widths (metres) of waterbody classes summarized for Canadian provinces and territories, and American states combined, and separately for each country.* *Statistical significance was tested for width differences between Canada and the United States for each waterbody class using ANOVA (d. f. = 1, post hoc Turkey Kramer HSD test, d. f. = 1, $p < 0.05$) (Lee et al. 2004).*

| Waterbody class | Combined (n=60) | Canada (n=12) | United States (n=48) |
|---|---|---|---|
| Large permanent streams | 28.1 (*2.7*) | 43.8 (*9.1*) | 24.2 (*2.3*) |
| Small permanent streams | 21.8 (*1.7*) | 29.6 (*4.9*) | 19.9 (*1.7*) |
| Intermittent streams | 15.1 (*1.7*) | 13.8* (*3.2*) | 15.5* (*2.0*) |
| Large lakes | 29.0 (*3.2*) | 54.6 (*11.4*) | 22.7 (*2.1*) |
| Small lakes | 27.6 (*3.0*) | 47.1 (*10.9*) | 22.9 (*2.1*) |

** not a significant difference between Canada and the United States*

The regulated 20 m buffer (watercourses > 50 cm wide) and 5 m buffer (watercourses < 50 cm wide) with allowable selective harvest, outlined in the Nova Scotia *Wildlife Habitat and Watercourses Protection Regulations* (2002), are smaller than the average buffer widths for Canadian jurisdictions, but are more closely reflective of guidelines in the United States (Lee et al. 2004). Other than the 50 cm threshold, Nova Scotia's guidelines do not account for the waterbody class when conducting forestry operations. This is particularly noticeable for large lakes (defined by Lee et al. (2004) as a standing waterbody with a surface area of > 4 hectares) and large permanent streams (defined by Lee et al. (2004) as a > 5 m wide watercourse with a defined bank, year-round flows, and a drainage basin of > 50 $km^2$), where the average riparian buffer in all Canadian jurisdictions is more than twice the width of what is required in Nova Scotia (~55 m and ~44 m, respectively). The only waterbody class buffer width without a statistically significant difference between Canada (13.8 m) and the United States (15.5 m) was an intermittent stream, defined in the study as a "permanent watercourse with a defined bank of any width but no year-round flows" (Lee et al. 2004). These buffers were consistently smaller than other waterbody classes, with waterbodies of the same size but year-round flows (small permanent streams) receiving buffers more than twice as wide on average in Canada (29.6 m; Lee et al. 2004).

Scientific evidence supports the notion that intermittent, headwater streams are critical for fish and fish habitat in downstream receiving waters, contributing cold water plumes, food supplies, sediment and eutrophication control, and many other supporting functions (Labbe & Fausch 2000; Alexander et al. 2007; Meyer et al. 2007; Ebersole et al. 2015; Colvin et al. 2019; Kukuła & Bylak 2022). If left undisturbed, intermittent streams can represent thermal anomalies and refuges for cold-water species threatened by climate change (Wigington et al. 2006; Isaak et al. 2016; Vander Vorste et al. 2020; Moidu et al. 2021; Macnaughton et al. 2021). These habitats can also be used by fish to seasonally escape other downstream stressors such as aquatic invasive species or predation, and reach areas where environmental conditions are immediately more optimal (Colvin et al. 2019; Macnaughton et al. 2021). Therefore, it is concerning from an ecological perspective that intermittent streams receive less riparian protection than other waterbody classes in most jurisdictions across Canada and the United States (Lee et al. 2004).

Although Nova Scotia's guidelines have not changed since Lee et al. (2004) conducted their analyses, other provinces, territories, and states have updated their riparian management measures for timber harvesting; as such, these calculated averages may have shifted over time. Furthermore, when guidelines are developed (including

regulations), consultation is often required with industries, Indigenous peoples, non-governmental organizations, the public, and other stakeholders, all of whom have the potential to influence what the final guidelines are, regardless of what scientific advice was used to formulate the original management measures.

To support the jurisdictional scan conducted by Lee et al. (2004) with a sample of recent literature, we performed a scoping literature review of scientific and grey sources published since 2004 using Google Scholar. To stay consistent with the geographic scope of Lee et al. (2004), studies that were done in Canadian or American jurisdictions were reviewed. Studies that did not recommend a quantifiable riparian buffer width (or range of widths) for adequate protection of aquatic ecosystems, freshwater quality, or fish and fish habitat, were excluded from the review. Research that studied parameters that could be encompassed in the definition of "fish" or "fish habitat" under ss. 2(1) of the *Fisheries Act* were summarized in the review, including aquatic habitat, aquatic biodiversity, freshwater species, macroinvertebrates, thermal tolerance, aquatic biomass, and any other parameters included within Table 3. We acknowledge that limitations exist with the literature review methodology including a scaled geographic and temporal scope, a non-exhaustive literature search, and a subjective screening of articles based on buffer width recommendations. Table 3 provides a sample of scientific and grey literature with recommended fixed-width riparian buffer sizes that are likely adequate for protecting fish and fish habitat.

***Table 3**: Literature review summary of recommended fixed-width riparian buffer sizes to protect fish and fish habitat*

| Recommended Riparian Buffer Size(s) | Jurisdiction(s) | Parameters Studied | Source |
|---|---|---|---|
| **30 – 40 m** (adjacent to clearcuts); **≥ 100 m** for large lakes and rivers | Nova Scotia, Canada | riparian and aquatic biodiversity, ecosystem services, recreational value, species at risk and fish habitat | Hunter & Van Damme 2018 |
| **50 m** | Nova Scotia, Canada | shading and temperature thresholds, forest litter supply for invertebrates, reduced artificial sedimentation, coarse woody debris, fish refugia, bank stabilization, terrestrial wildlife | Stoffyn-Egli & Duinker 2013 |
| **20 – 30 m** | Nova Scotia, Canada | riffle-pool stream morphology, water quality, stream temperature, nutrient filtering, bank stability, aquatic habitat | Rideout 2012 |
| **≥ 20 m** | New Brunswick, Canada | fish, fish habitat, temperature thresholds, woody debris abundance, bank stability and erosion, cumulative effects | Cunjak et al. 2004 |
| **30 – 75 m** | Ontario, Canada | aquatic habitat, coarse woody debris, stream temperature moderation, water quality, sedimentation | Henshaw & Ursic 2012 |

| | | | |
|---|---|---|---|
| **30 m** | New Brunswick, Canada; Maine, USA | fish, spawning habitat, water temperature, thermal survival threshold | Figary et al. 2021 |
| **≥ 30 m** | Prince Edward Island, Ontario, Canada; Iowa, North Carolina, Connecticut, Nebraska, Maryland, etc., USA | fish assemblage and communities, reproductive success, thermal tolerance, species richness, fine sedimentation, bank stability, macroinvertebrate density, coarse woody debris | Sweeney & Newbold 2014 |
| **15 – 50 m** | Connecticut, USA | stream shading, stream temperature, litter and debris input | Hawes & Smith 2005 |
| **30 m** | South Carolina, Arkansas, Florida, Mississippi, Virginia, etc., USA | Many states in the USA; aquatic wildlife, fish habitat, macroinvertebrates abundance, water quality, pollution reduction | Warrington et al. 2017 |
| **30 – 46 m**; **46 – 90 m** for SAR fish-bearing streams | Montana, USA | fish, aquatic habitat, stream temperature, riparian vegetation, woody debris, bank stabilization, sedimentation | Ellis 2008 |
| **15 – 100 m** | Washington, USA | fish, water quality, sedimentation, contamination, riparian corridor microclimate, stream temperature, invertebrate prey, litter-detritus input | Kubo et al. 2019 |
| **≥ 30 m** | Georgia, USA | stream temperature, riffle embeddedness, water quality, sedimentation | Jones et al. 2006 |
| **≥ 30 m** | New Hampshire, USA | fish habitat, aquatic macroinvertebrates, sedimentation, water temperature, organic matter inputs, bank stabilization | Flanagan et al. 2017 |

There were some trends observed across the literature sample with regards to recommended buffer widths (Table 3). It is important to consider what ecological functions or habitat components to which each parameter contributes, is influenced by, and where within the riparian zone is the most sensitive to disturbance (Rideout, 2012). To preserve water quality, a smaller buffer range (15 – 20 m) was recommended compared to what was recommended for maintaining stream temperature, shading and microclimate (20 – 30 m, Kubo et al. 2019; Rideout 2012; Cunjak et al. 2004; Figary et al. 2021; Warrington et al. 2017). Similarly, coarse woody debris recruitment and bank stability required a smaller buffer range (20 – 30 m) than what was typically recommended for maintaining benthic invertebrate diversity or density (≥ 30 m; Henshaw & Ursic 2012; Sweeney & Newbold 2014; Ellis 2008). We hypothesize this may be because coarse woody debris recruitment and bank stability are most influenced by the area immediately upland from the high water mark; conversely, the life history of benthic invertebrates is more motile and relies on habitats elsewhere than just near the watercourse edge. Specific riparian buffer size recommendations for protecting fish and/or fish habitat (when available) were

often larger compared to when each parameter used to make the recommendation was considered individually (e.g. macroinvertebrates, sedimentation, temperature, etc.). This finding is also supported by the analysis done by Lee et al. (2004), where riparian buffer widths are larger for large streams in provinces, territories, and states with guidelines that take fish into account (Figure 4). Lee et al. (2004) classified these jurisdictions into broad geographical regions to examine spatial trends through statistical analyses; Appendix C contains the full list of provinces, territories, and states in each region (Boreal, Rocky / Intermountain, Pacific, Northeast, Midwest, Southeast). Nova Scotia's buffer widths are not informed by fish presence (i.e. 'no guideline'), and Lee et al. (2004) classified the province in the 'Northeast' region alongside the other Maritime provinces and 13 states (Figure 4).

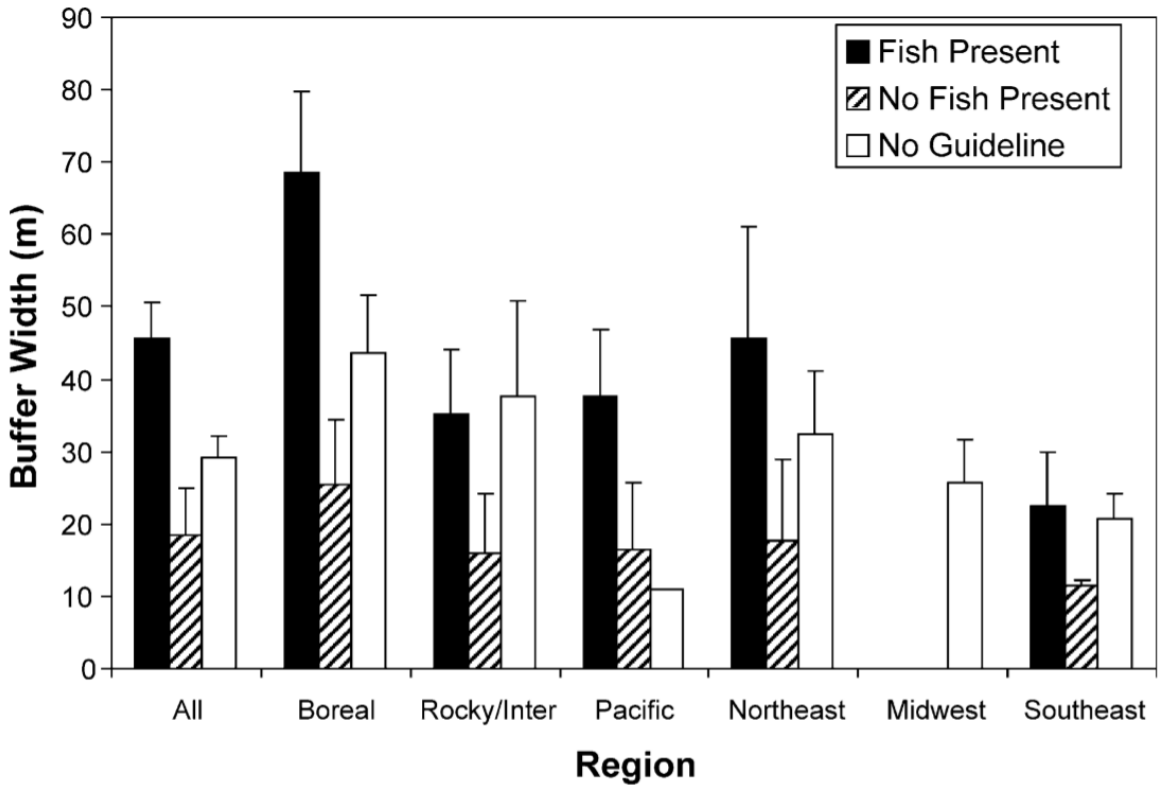


***Figure 4****: Mean buffer widths for timber harvest activities along large permanent streams with fish (first bar) and without fish (second bar) for jurisdictions with fish-related guidelines, and jurisdictions without fish guidelines (third bar).* Standard error shown with error bars. *(Lee et al. 2004)*

While this is a secondary finding not included in Table 3, a consistent finding among studies was larger recommended riparian buffer sizes for protecting terrestrial/riparian species, providing movement corridors between patches of unsuitable habitat (Lee et al. 2004; Stoffyn-Egli & Duinker 2013; Hunter & Van Damme 2018).

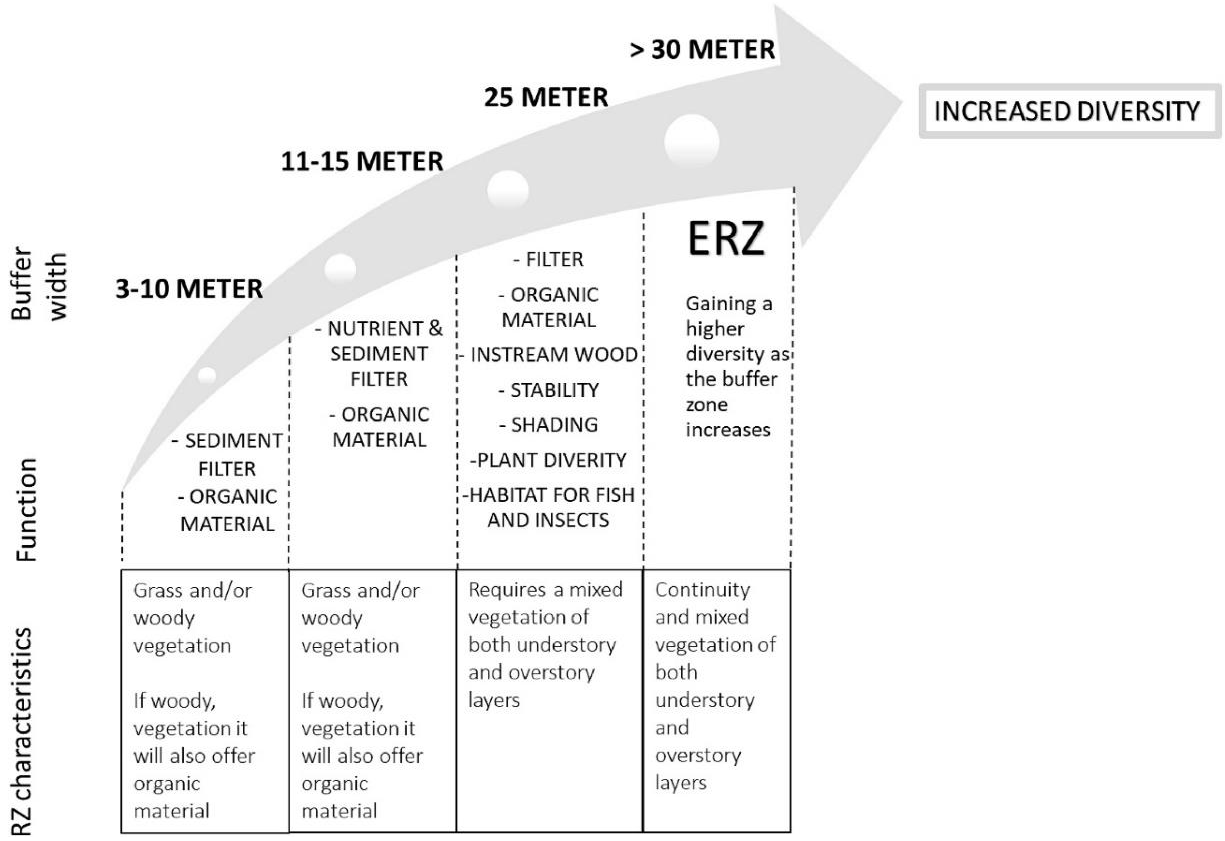


***Figure 5****: Conceptual diagram to represent ecological benefits with increased riparian buffer sizes, with >30 m typically representing the ERZ or 'ecologically functional riparian zone' (Lind et al. 2019)*

Overall, greater ecological and environmental benefits, including the protection of fish and fish habitat, are highly correlated with increasing buffer sizes along all watercourse classes (Figure 5; Smokorowski & Pratt 2007; Stoffyn-Egli & Duinker 2013; Hunter & Van Damme 2018; Albertson et al. 2018; Cole et al. 2020). While larger riparian buffer zones would likely provide greater protection to fish and fish habitat, enforcing these and gaining widespread adoption may be more difficult, depending on the jurisdiction (Richardson et al. 2012; Tiwari et al. 2016).

### *2.3. Variable-width Riparian Buffer Zones*

In order to establish variable-width riparian buffers that are successful at tempering negative impacts on aquatic systems as a result of terrestrial activities, site-specific approaches rely on expert knowledge, accurate scientific data and Indigenous knowledge. While many studies have achieved ecological objectives using this technique, the complexity and variability of riparian and aquatic habitats across the landscape can make variable-width riparian buffer zone designation difficult (Cole et al. 2020; Wilhere & Quinn 2018; Richardson et al. 2012). Natural aquatic and riparian habitats are not spatially consistent, so variable-width buffer zones represent a more tailored management approach that can be altered to achieve different objectives across time and space (Olson et al. 2017). It is beneficial to have one or more specific management objectives (e.g. target species recovery, improved water quality) in mind prior to

delineating a variable-width riparian buffer (Stutter et al. 2021). Ecological response monitoring of the aquatic system can then be used to inform future decision making, depending on the management context (Sergeant et al. 2012; Hansen et al. 2015). An 'accepted' scientific standard for compiling data and designating dynamic riparian buffer zones does not exist, but uses a variety or combination of approaches, depending on the management objectives and geographic scale of application, along with biotic and abiotic features of the region of interest (Figure 6; Kubo et al. 2019; Olson et al. 2017; Stutter et al. 2021; Richardson et al. 2012; Cole et al. 2020).

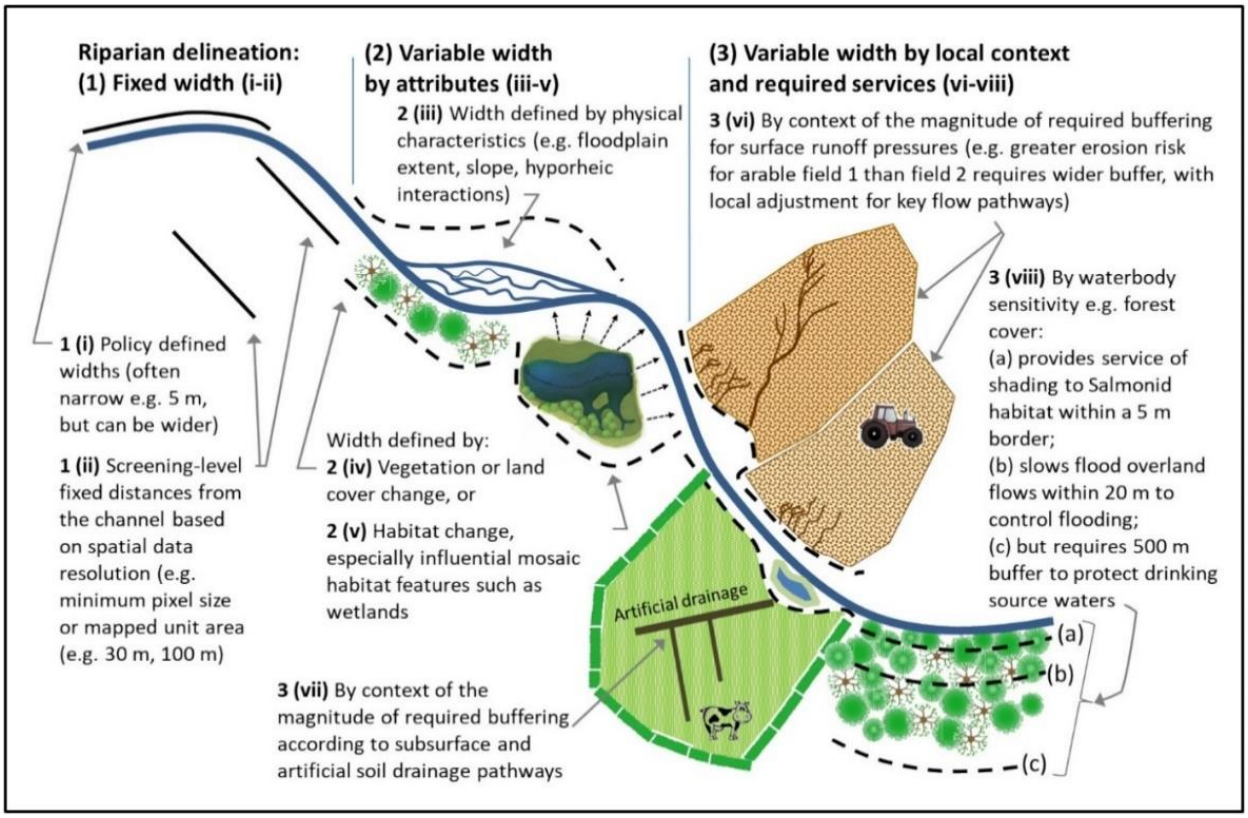


***Figure 6****: An example comparison of riparian buffer width delineation models with increasing complexity in an agriculture-dominated landscape (Stutter et al. 2017)*

DFO does not have a detailed standardized approach for identifying appropriate riparian buffer guidelines to protect fish and fish habitat (Caskenette et al. 2020). However, there is consensus that riparian zones are essential for aquatic species and variable-width buffer zones offer greater benefits to critical habitat for species at risk (DFO 2020a):

> "Literature regarding the widths of riparian habitat required for the biophysical processes [that support aquatic habitat features (Section 2.1.)] was reviewed and showed that increasing width protected a greater number of processes. However, in this guidance specific widths of riparian zone for the different processes were not recommended due to species-specific habitat requirements and regional differences in underlying factors such as geomorphology, slopes, land use practices, and site potential vegetation height. When determining riparian critical

habitat width, reference should be made to regional and species-specific guidance as appropriate."

To implement variable-width riparian buffers in heterogeneous environments, site specific characteristics that influence the seven biophysical riparian habitat processes (i.e. erosion, filtration, infiltration, isolation, meandering, shading, and subsidization) should be considered (DFO 2020a). Satellite imagery can be used as a starting point for understanding macro-scale landscape and aquatic variability to help inform frequency of data collection across a large area (Macfarlane et al. 2017). Some potential immediate characteristics that could be compiled at each site include watercourse width and depth, riparian edge slope, aspect, soil type, vegetation type, canopy cover/shading, water temperature, quality/quantity of food supply (e.g. for target species), substrate, water velocity, dissolved oxygen, channel morphology, pool and riffle habitat, spawning site identification, aquatic and riparian flora and fauna biodiversity, connectivity, and state of the upland area, among many others (Caskenette et al. 2020; DFO 2020; Lind et al. 2019; Kubo et al. 2019; Wilhere & Quinn 2018). Other parameters that should be considered include Indigenous knowledge, historical land-use activities, and future resilience to climate change impacts.

It can be a significant undertaking to fully implement a variable-width riparian buffer system across a large area (such as a watershed), requiring funds, collaboration, and time. Further, landscape-level conservation planning lags behind resource extraction and the encroachment of human activities on riparian-aquatic environments in many jurisdictions (Richardson et al. 2012); sensitive ecosystems can be compromised in the meantime. This goes back to the reason why fixed-width riparian buffer zones were implemented in the first place, as a relatively simple tool that can function sufficiently to protect fish and fish habitat in some areas, but may not accomplish the same objectives elsewhere. It is possible that a combination of fixed and variable-width riparian buffer zones, based on easy-to-understand land-use parameters, can be used to gain implementation and enforcement while also capturing greater heterogeneity across riparian and aquatic habitats.

The alongshore connectivity of a riparian buffer zone is just as important as riparian buffer width (Brumberg et al. 2021; DeWalle 2010). Although riparian habitats in human-dominated landscapes are often discontinuous, the immediate aquatic environment is only a small subset of a larger continuous hydrologic ecosystem (Alexander et al. 2015). As such, riparian human activities or land-use changes that positively or negatively affect aquatic habitats in one or more locations will spill-over into the downstream environment (Alexander et al. 2015). Riparian connectivity should be a priority to mitigate effects of human land-use activities on downstream fish and fish habitat (Fritz et al. 2018).

### *2.4. Activities Permitted in Riparian Buffer Zones*

Studies show that simulating natural disturbances in riparian zones can be effective at maintaining habitat heterogeneity (Penaluna et al. 2018; Sibley et al. 2012; Moore & Richardson 2012). The widespread usage of regulated riparian forest buffers can result in consistent set-width reserve 'ribbons' around watercourses (Kreutzweiser et al. 2012). These unnatural landscape patterns can immediately protect aquatic habitat from anthropogenic disturbance (e.g. logging, agriculture), but longer-term biodiversity

and ecosystem resilience benefits may actually result from disturbance and succession within the riparian zone (Kreutzweiser et al. 2012; Musetta-Lambert et al. 2017). It may be beneficial to allow human influences in the extended riparian zone to more closely mimic the natural disturbance regime in the biotic environment, acting as a 'renewal' of the ecosystem (Penaluna et al. 2018). The simulation of wildfires by forest selective harvesting has been practiced for decades, but there is little scientific consensus if riparian selective harvest offers the same ecological functionality as natural wildfires. Studies have demonstrated that if done properly, riparian selective harvest can increase macroinvertebrate diversity, leaf litter composition (Musetta-Lambert et al. 2017), and primary productivity (Richardson & Béraud 2014).

However, current human disturbance is often intense and frequent, rarely emulating natural recurring regimes like landslides or forest fires (Penaluna et al. 2018). Human population growth and encroachment on the habitat of wildlife species has outpaced natural selection and evolution, thus anthropogenic disturbances have been detrimental to some wildlife populations. For example, Maturana et al. (2014) found that consistent deposition of fine sediment into salmonid spawning habitat from forestry roads resulted in greater embryo mortality compared to an equivalent amount of sediment entering the same aquatic system from a naturally-occurring landslide. Klenk et al. (2009) also argue that attempting to emulate natural disturbance through a historical construct of what is 'natural' is likely to be ineffective, diverging from the intended result. In light of shifting baseline syndrome altering what humans currently deem as 'pristine' or 'intact' riparian habitat, it may be very difficult to replicate historical disturbance events that many aquatic species evolved with such as beaver dams, debris flows, or flooding (Figure 7; Klenk et al. 2009; Soga & Gaston 2018; Jones et al. 2020).

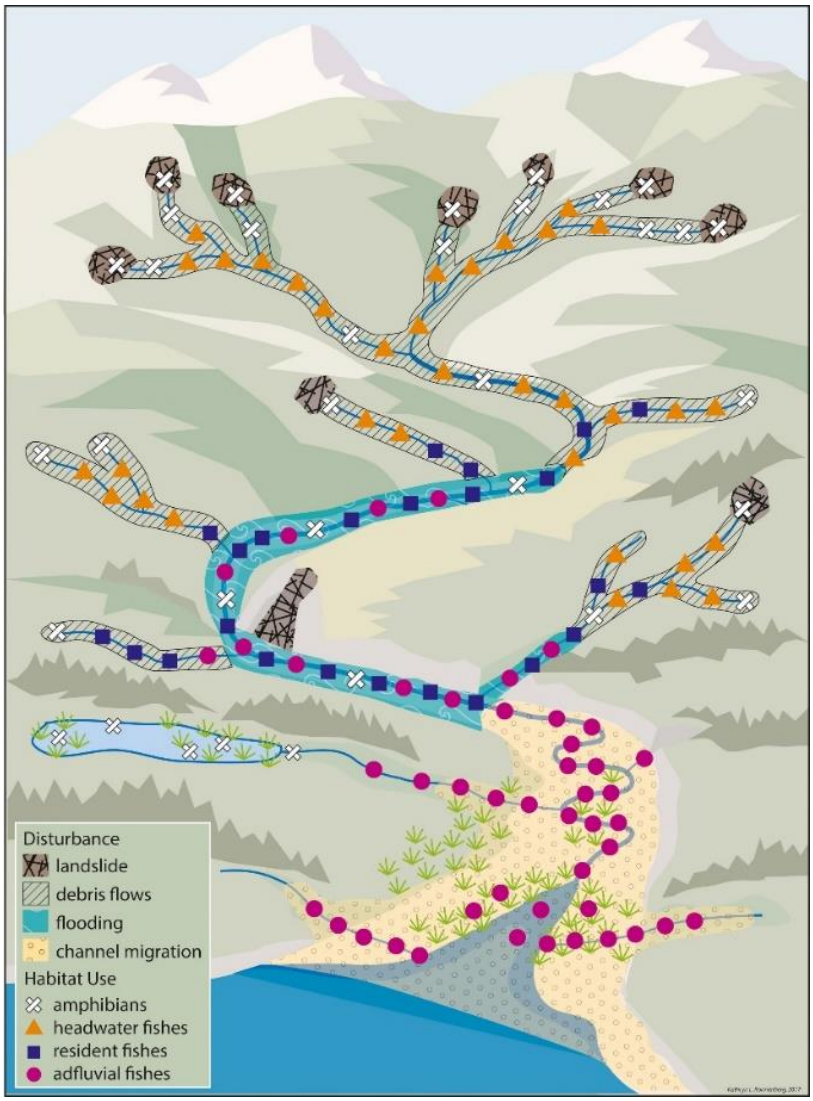


***Figure 7****: Example of natural disturbances that occur within a fish-bearing river system (Penaluna et al. 2018)*

Other studies have investigated if wider (than required by regulation) riparian buffer zones with permitted selective logging in forest environments offers equivalent ecological benefits as more narrow buffer 'reserve' zones. Generally, ecological assets between the two methods do not differ significantly, although economic gain may vary depending on site-specific context and application of each system type (Berrigan et al. 2020; Oldén et al. 2019; Sonesson et al. 2020; Roon et al. 2021). However, the edge effect (i.e. the altered ecological processes at habitat or landscape edges causing differences in biotic community structure, composition, and function near an edge compared to further away from the edge; Braithwaite & Mallik 2012) of narrow width riparian buffer zones are often more severe, increasing undesirable effects such as windthrow blowdown (Figure 8) and microclimate disruption (Pollock & Kennard 1998; Mäenpää et al. 2020; Beese et al. 2019; Braithwaite & Mallik 2012; Wasser & Chasmer 2012). The presence of cover and water temperature regulation are critical riparian components for fish and fish habitat. Depending on what variables are being studied and the surrounding environment, the

edge effect can drastically reduce the effective size and intended objective of a regulated riparian buffer zone to protect fish and fish habitat, particularly when high contrast narrow-width reserve buffers are applied along sharp edges of human disturbance, such as clearcut patches, agriculture fields, or urban developments (Braithwaite & Mallik 2012; Wasser & Chasmer 2012).

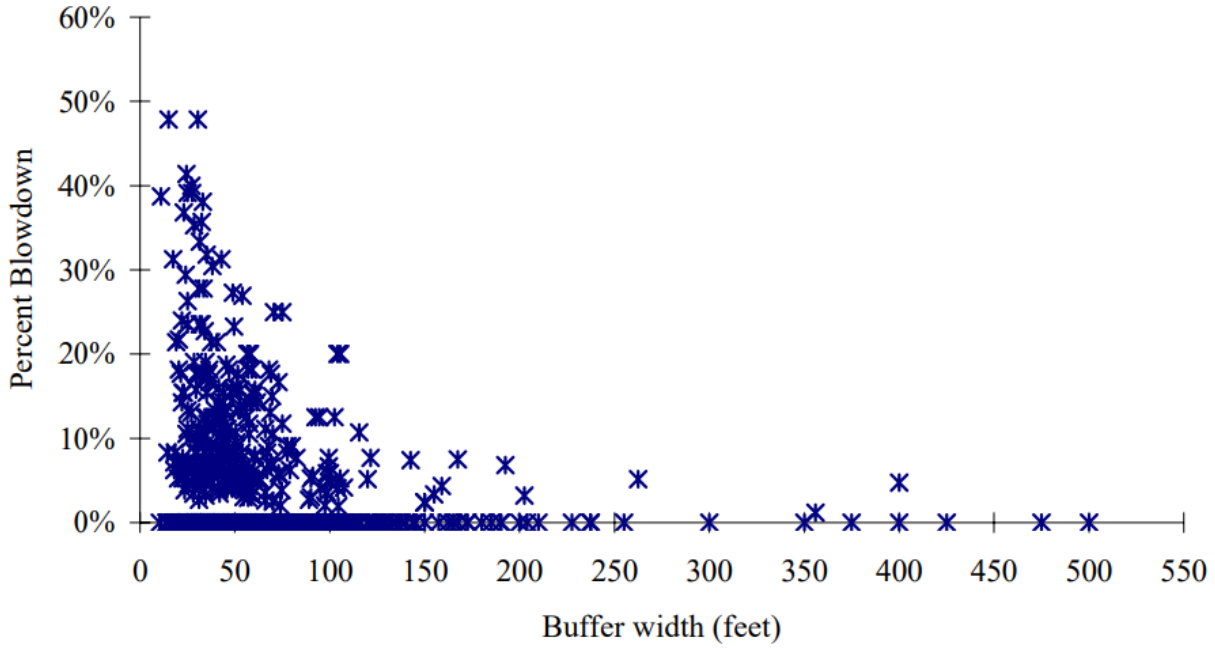


***Figure 8**: The effect of riparian buffer width (in feet) on percent of tree blowdown within the buffer zone (Pollock & Kennard 1998)*

Follow up monitoring and adaptive management to validate whether or not fixed-width, variable-width, or combination of both riparian buffer methods are succeeding to fulfil management objectives is critical (Capon & Pettit 2018). However, the interpretation of cause and effect relationships from monitoring studies in the aquatic and riparian environment becomes more challenging with increased permitted activities (e.g. pesticide application, operation of motorized vehicles, selective harvesting, stream restoration) due to the responsibility to control for different human-influenced variables.

### *2.5. Climate Change*

Climate change has already, and will continue to have, significant effects on fish and fish habitat throughout Canada, depending on locations and species of interest (Poesch et al. 2016; Pandit et al. 2017; Sumaila et al. 2020). However, there is increasing research being done to model climate change resilience across Canada and better understand the adaptability of aquatic species to future climate change scenarios. Freshwater climate change resilience has been modelled for the Acadian-Appalachian bioregion by the Nature Conservancy of Canada, using spatial data metrics such slope gradient, surface temperature, riparian intactness, aquatic connectivity, and impervious surface cover (Figure 9; Noseworthy & Nussey 2020).

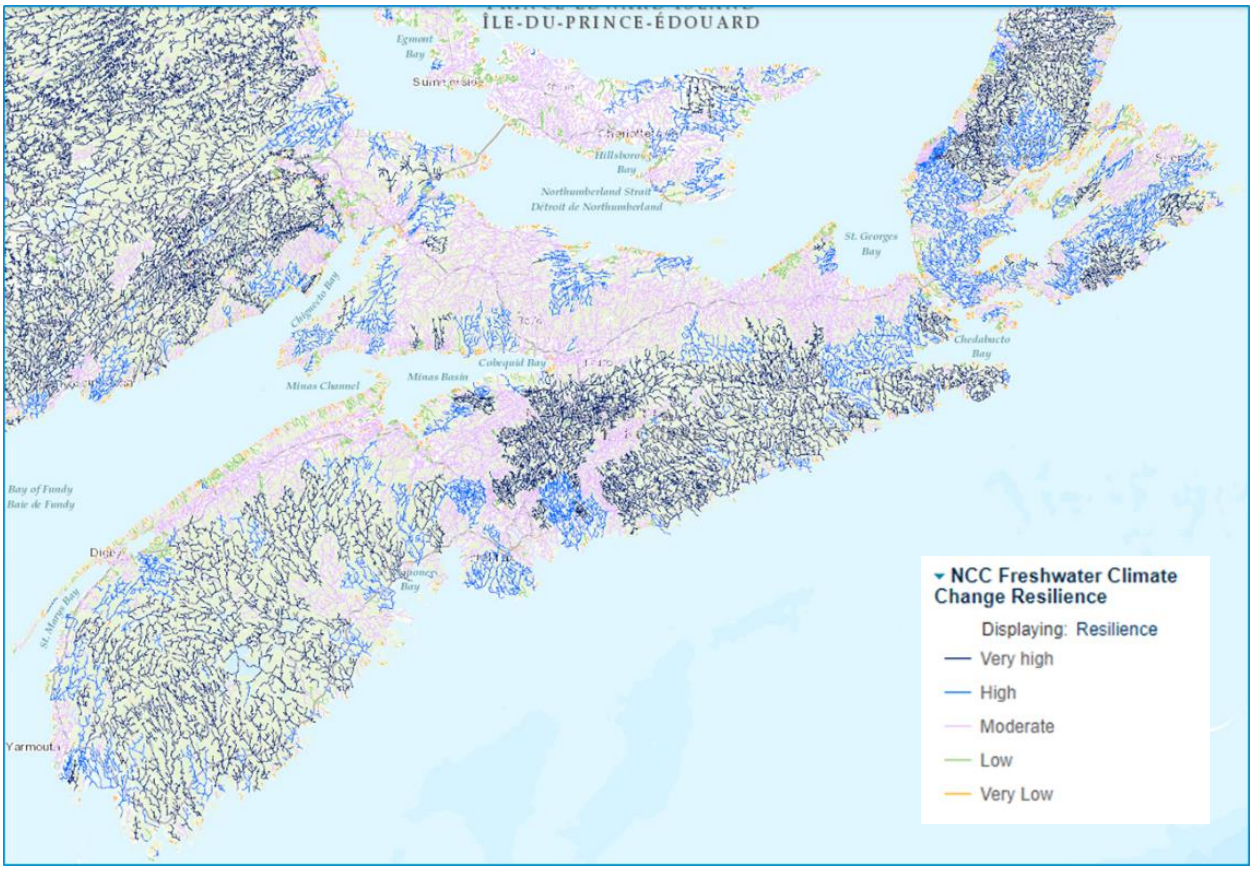


***Figure 9****: Freshwater resilience to climate change for the Northern Appalachian-Acadian region of Canada - 1:50,000 scale (Noseworthy & Nussey 2020)*

Integrating climate change impacts into future considerations is critical for the long-term success of conservation and species at risk recovery planning, especially in the context of riparian restoration (Seavy et al. 2009; Perry et al. 2015). When intact, riparian zones can be some of the most resilient and adaptable ecosystems to climate change impacts such as increased temperature, less seasonal runoff, altered groundwater supplies, and more dynamic winter ice conditions (Bowler et al. 2012; Nilsson et al. 2013; Capon et al. 2013; Johnson & Almlöf 2016). The destruction or degradation of riparian habitat would result in aquatic systems and species that are inherently more vulnerable to climate stressors, underscoring the importance of proper management and protection of these sensitive transitional zones. Many, if not all, freshwater species at risk recovery documents cite climate change as a major or minor threat that may impede future species recovery (Woo-Durand et al. 2020).

## 3. DFO's Role: Riparian Management in Canada

Changes in federal government and political agendas in past decades caused amendments to the *Fisheries Act*, on more than one occasion, that influenced nationally how fish and fish habitat were legally protected (Government of Canada 2019). The "modernized" *Fisheries Act* was enacted in 2019, reinstating previously lost protections by "providing comprehensive protection for all fish and fish habitat" (Government of

Canada 2019), with several DFO programs building on these provisions to include riparian habitat within their scope of protection. The Fish and Fish Habitat Protection Program (FFHPP) administers and ensures compliance of development projects with the fish and fish habitat protection provisions of the *Fisheries Act* and relevant provisions of *SARA*. The program reviews WUAs that may impact fish and fish habitat. However, because developments occur within different provincial and territorial jurisdictions, the approach for reviewing WUAs varies across the country, often through working relationships with other government departments and their applicable laws and policies (further detailed in Section 4). Although Nova Scotia is our target scope of analysis and recommendations, we offer greater context through a comparison of FFHPP's approach to riparian management in Nova Scotia with the other Maritime provinces (New Brunswick and Prince Edward Island) in Canada.

### *3.1. Riparian Management in the Maritime Provinces – DFO FFHPP*

The provincial governments in New Brunswick, Prince Edward Island (PEI), and Nova Scotia act as a first point of contact for proposed WUAs in or near water. Through this 'one-window' approach, projects that require a specific FFHPP review are triaged by the provincial government agency (Government of New Brunswick 2021; Government of PEI 2021; Province of Nova Scotia 2020a). If a project-specific review by FFHPP is required (i.e., if there are potential impacts to fish or fish habitat), FFHPP will determine if the WUA will impact an aquatic species at risk, result in the death of fish and/or HADD of fish habitat, and will determine if the proponent will be required to submit an application for authorization under the *Fisheries Act* and/or *SARA* in order to proceed. If authorized, the authorization will include terms and conditions that must be followed to avoid, mitigate, offset and monitor the impacts to fish and fish habitat resulting from the project WUAs. In most cases, DFO does not receive or review project proposals for standalone riparian disturbance; if in-water WUAs are occurring that have a riparian component, then FFHPP may consider those impacts in the review. If FFHPP deems that the proposed WUA impacts will be negligible or limited, it is more common that a letter of advice is sent to the proponent that outlines the appropriate measures required to avoid causing a HADD; in these cases no *Fisheries Act* authorization would be required. For reference, there were 1,272 letters of advice sent by DFO to proponents for proposed WUAs across Canada in 2016-17, compared to 108 *Fisheries Act* authorizations issued (DFO 2018a). If a proposed WUA falls into a 'standards and codes of practice' category the proponent then follows the provided codes of practice and submits a notification form to FFHPP and authorization will also likely not be required (DFO 2020j; DFO 2021a). An example of this would be a beaver dam removal or culvert maintenance, where each set of guidelines have a specific section addressing 'protection of the riparian zone' (DFO 2021a).

Project proponents are encouraged to avoid causing a HADD and FFHPP suggests various measures to avoid impacts to fish and fish habitat. National guidance for proactive riparian management measures that proponents can follow to comply with the *Fisheries Act* and *SARA*, include "maintaining an undisturbed vegetated buffer zone between areas of on-land activity and the high water mark of any water body; using existing trails, roads or cut lines wherever possible; avoiding tree removal; using methods to prevent soil compaction, such as swamp mats or pads; and limiting the impacts to stream or shoreline banks" (DFO 2019h).

The difference in the regulatory review process conducted by FFHPP between DFO Gulf (includes New Brunswick and PEI) and DFO Maritimes (Nova Scotia) regions with respect to riparian zone management is due to the corresponding differences in provincial legislation. In New Brunswick and PEI, riparian zones are included within the provincial regulations for watercourse, wetland, and buffer zone alterations that require a permit to conduct activities in these areas (Government of New Brunswick 2012; Government of PEI 2016). The New Brunswick *Watercourse and Wetland Alteration Regulation* (s. 40 of the *Clean Water Act*, 1989) enable the province to mandate permits for 'alterations,' defined in s. 1(d) to include "any deposit or removal of sand, gravel, rock, topsoil, organic matter or other material into or from a watercourse or wetland or within 30 metres of a wetland or the bank of a watercourse." Similarly, PEI 's *Watercourse and Wetland Protection Regulations* (s. 25 of the *Environmental Protection Act*, 1988) state that "no person shall, without a license or a Buffer Zone Activity Permit, and other than in accordance with the conditions thereof, engage in or cause or permit the engaging in of any of the following activities [drain, pump, dredge, excavate, remove soil, water, mud, sand, gravel, dump or infill, construct or place structures, operate a motor vehicle, disturb or alter vegetation in any manner, etc.] within 15 metres of a watercourse boundary or wetland boundary." A provincial permit is required for forestry or agricultural operations in New Brunswick or PEI to selectively harvest or cultivate agricultural crops within the 30 m or 15 m buffer zone, respectively. If a permit is granted, the proponent must work with the province to demonstrate how potential impacts to aquatic habitats from riparian disturbance in the buffer zone will be mitigated to stay in compliance with provincial and federal (*Fisheries Act* and *SARA*) laws (Government of New Brunswick 2012; Government of PEI 2016).

FFHPP Gulf region is not involved with every watercourse or wetland alteration permit application, as these are first assessed at the provincial level on a case-by-case basis. Forestry and agricultural proponents may leave the regulated riparian buffer zone intact to avoid going through the provincial watercourse and buffer zone alteration permitting process and ensure compliance with the *Fisheries Act* and *SARA*. If a permit is sought to disturb the riparian zone through these activities, the applicable province will lead the decision-making process and these activities are rarely reviewed by FFHPP unless clear impacts to fish, fish habitat, or aquatic species at risk are expected. However, where a HADD or implications for species at risk are identified, permit applications are triaged to FFHPP for review (Government of New Brunswick 2012; Government of PEI 2016). The buffer zone requirements included in the *Watercourse and Wetland Alteration Regulation* (NB) and *Watercourse and Wetland Protection Regulations* (PEI) were established to help preserve habitat for aquatic species. However, all watercourse and wetland alteration permits issued by the provinces are also sent as a 'notification' to DFO for the department to track cumulative effects and prepare auditing programs (Government of New Brunswick 2012; Government of PEI 2016).

Unlike New Brunswick and PEI, the Nova Scotia *Environment Act*, does not have accompanying regulations that include riparian zones as part of the watercourse alteration permit application, assessment, or triaging process. The Nova Scotia Watercourse Alterations Standard has best management practices for riparian zones, but no legally-binding requirements (Province of Nova Scotia 2015). Thus, HADDs or

potential impacts on species at risk are identified from in-water activities, wetlands and saltmarshes, but riparian zone alterations are not considered in the decision-making process for triaging permit applications to FFHPP Maritimes Region. Riparian habitat impacts can be captured by FFHPP in Nova Scotia if the watercourse alteration proponent submits a review request directly to DFO (DFO 2020j). Although FFHPP also receives all provincially-issued watercourse alteration permits, this current riparian regulatory gap in Nova Scotia may cause riparian habitat alterations to be unreported or underreported in DFO Maritimes Region, which impacts the ability to track the associated cumulative effects on fish and fish habitat. Many other provinces and territories also use a 'triaging' approach to send development proposals to FFHPP that could have impacts to fish and fish habitat; the reliance on contrasting provincial regulations and guidelines to begin this process likely results in inconsistencies for how riparian habitat impacts are assessed by DFO across the country.

### *3.2. Critical Habitat for Freshwater Species at Risk*

DFO is responsible for managing aquatic species listed under Schedule 1 of *SARA* in all Canadian waters with the exception of those individuals found in waters managed by the Parks Canada Agency (DFO 2020e). Recovery planning for aquatic species at risk is a comprehensive process, informed by science advice, socio-economic considerations, internal and external consultation, legal advice, DFO policies, and a variety of other factors (DFO 2020e). Part of the recovery planning process for Schedule 1 listed threatened and endangered species is the identification of critical habitat, defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species" (*SARA*, ss. 2(1)). When critical habitat is identified, it must include a description of the biophysical features and attributes which provide the functional capacity of the habitat to support an essential life process (e.g., spawning, feeding, over-wintering). For example, riparian zones may be identified as features of critical habitat that are outside the aquatic environment but are important to features within the aquatic environment, such as supporting the establishment and maintenance of pool features, supplying food for fish of many species and influencing water temperatures (DFO, 2020a).

Recovery potential assessments and recovery strategies published by DFO for at-risk freshwater fish species showed a typical range of recommended riparian critical habitat widths from 5 – 30 m, with extensions larger than 30 m under some circumstances (DFO 2020a). The absence of riparian critical habitat identification for many aquatic species at risk suggests there is species-specific uncertainty regarding the extent to which riparian zones should be protected (DFO 2020a; Caskenette et al. 2021). There also may be regulatory uncertainty about the inclusion of critical habitat in the riparian zone in some jurisdictions where this practice has not occurred to date (Caskenette et al. 2021). Currently, there are eleven species at risk with riparian critical habitat identified (Table 4). Generally, the riparian critical habitat zone begins at the ordinary high water or bankfull mark, and extends laterally away from the watercourse to a certain distance, representing a total width.

The Nooksack Dace was a significant species in terms of establishing DFO's jurisdiction and authority to manage riparian habitat, included within the definition of "fish

habitat" under the *Fisheries Act*. The minnow species was listed as 'Endangered' on Schedule 1 of *SARA* in 2003, with its historical range reduced to only four streams across British Columbia's lower mainland (DFO 2020g). In what was referred to as a 'precedent-setting' court case, the Federal Court judge found that the Minister of Fisheries and Oceans acted contrary to *SARA* (ss. 41(1)(c)) for failing to identify critical habitat for the Nooksack Dace, part of which included riparian buffer zones. The lawsuit [Environmental Defence Canada v. Canada (Fisheries and Oceans) 2009 FC 878] was launched by a group of environmental organizations after maps and descriptions of critical habitat were removed from the species' recovery strategy prior to publication. Arguments for the inclusion of riparian critical habitat in the recovery strategy stated that a "failure to maintain an adequate riparian reserve as part of critical habitat would be highly likely to cause population-level impacts" and "in the case of the Nooksack Dace, while the dace is not located up in the trees of the riparian buffer zone, it depends on this biological component of habitat to survive and to recover" [Environmental Defence Canada v. Canada (Fisheries and Oceans) 2009 FC 878]. A statement within an email from the Minister of Fisheries and Oceans to the Nooksack Dace recovery biologists offers some context: "we would like to proceed cautiously with the identification of critical habitat, while still recognizing that we have a legal obligation to do so, given that we may be setting a precedent where we are uncertain as to the potential impacts of doing so" [Environmental Defence Canada v. Canada (Fisheries and Oceans) 2009 FC 878]. The recovery strategy for the species was published the following year with identified critical habitat, including riparian buffers along stream lengths ranging from 10 – 30 m for the first time in DFO's history (Pearson et al. 2008).

Currently, there are eleven species at risk with riparian critical habitat, located in DFO's Pacific (5), Ontario & Prairie (5), and Quebec (1) regions (Table 4). The methodologies used to define riparian critical habitat varied among species, with a few processes that were replicated for species with similar habitat niches or locations.

***Table 4**: Riparian critical habitat width for threatened and endangered freshwater fish species in Canada and method used to identify and establish critical habitat*

| **Species, Province (DFO Region)** | **Riparian Critical Habitat Width** | **Method used to Define Riparian Critical Habitat** |
|---|---|---|
| **Nooksack Dace**<br><br>British Columbia (Pacific) | **10 – 30 m** (137.6 hectares) | "Critical habitat includes all riparian areas on both stream banks for the entire length of the identified aquatic reaches. Widths of riparian critical habitat for Nooksack Dace were assessed using a spatially referenced methodology adapted directly from and consistent with the British Columbia *Riparian Areas Regulation* (RAR) (*Riparian Areas Protection Act*, S.B.C. 1997, c. 21). The RAR was developed to protect 'salmonids, game fish, and regionally significant fish' from the impacts of land development. In the absence of data on riparian habitat needs for a SARA-listed species, this is a reasonable standard to apply in the identification of critical habitat because it represents a benchmark and standard methodology to which both federal and provincial agencies responsible for management of species at risk have already agreed. The identified width of the riparian critical habitat for each reach is equal to the widest zone of sensitivity (ZOS) calculated for each of five riparian features and functions: large woody debris supply for fish habitat and maintenance of channel morphology; localized bank stability; channel movement; shade; and, |

| | | |
|---|---|---|
| | | insect and debris fall. The ZOS values are calculated using methods consistent with those used under the RAR. The width of existing riparian vegetation and areas where riparian width is restricted by permanent structures (for example, roads, buildings, yards) were also assessed. Further details of methods and an assessment of existing riparian vegetation in these areas can be found in Pearson (2008)." – DFO 2020g, Pearson 2008 |
| **Salish Sucker**<br><br>British Columbia (Pacific) | **5 – 30 m** (818.1 hectares) | Same methods as Nooksack Dace – DFO 2020f, Pearson 2008 |
| **Sticklebacks** – Misty Lake<br><br>British Columbia (Pacific) | **15 – 30 m** | "Hatfield (2009) suggested including a riparian buffer of 15 to 30 meters surrounding the entire lake, the length of the inlet stream extending up to the extent currently known to be occupied by the stream form of Misty Lake Stickleback, the outlet stream extending down to the extent currently known to be occupied by Misty Lake Stickleback, and the swampy transition zones between the lake and other watercourses in the watershed. This designation was consistent with the *British Columbia Riparian Areas Regulation* (RAR). A 15 meter riparian buffer is important for bank stability, woody debris supply, and for food and nutrient input from litter fall and insect drop into the lake and streams. The larger 30 meter riparian buffer is suggested for areas where shade provides a specific function to the habitat, which is true for the inlet and outlet stream populations. Shade is not as important for the lake due to its large surface area which results in most of the lake receiving sunlight regardless if the riparian buffer is 15 meters or 30 meters… The specific types of riparian vegetation necessary to provide these functions are uncertain but the presence of such vegetation is essential. Also, while the riparian areas are not necessarily considered 'no-go' zones, it is essential that they be managed to conserve the attributes to ensure functionality of the critical habitat is not compromised." – DFO 2018b, Hatfield 2009 |
| **Stickleback Species Pairs** – Paxton Lake, Enos Lake, Vananda Creek<br><br>British Columbia (Pacific) | **15 – 30 m** | Same methods used as Misty Lake Sticklebacks<br><br>"A detailed geotechnical assessment has been completed for Crown land in the Priest, Spectacle, and Emily watersheds under the B.C. Ministry of Forests and Range Identified Wildlife Habitat Area program. The concerns described above with respect to sediment inputs from logging on riparian crown land, particularly in the context of the irreversibility of a hybridization event, resulted in the inclusion of 90 m riparian buffers on lakes, 50 m buffers on primary tributaries, and 30 m buffers on secondary tributaries. These recommended buffer widths under the WHA are wider than those normally recommended under the provincial Riparian Areas Regulations (RAR), but it should be noted that recommended buffer widths under the RAR are intended to afford protection to normal populations of fishes, particularly salmonids, that are not at risk of extinction through hybridization. The potential sensitivity of stickleback species pairs to hybridization through sediment inputs and other disturbances, the irreversibility of these impacts, and their status as an endangered species indicate that RAR buffer widths (15 – 30 m) should be viewed as a minimum requirement for species protection." – DFO 2019c, Hatfield 2009 |
| **Vancouver Lamprey**<br><br>British Columbia (Pacific) | **15 – 30 m** | "In order to define the width of riparian components of critical habitat the *British Columbia Riparian Areas Regulation* (B.C. Reg. 376/2004) methods were applied to a sub-set of in-flowing streams and two lacustrine areas where extremely small ammocoetes were found (inferring either spawning locations, or close proximity to spawning locations). Riparian critical habitat areas resulting from the RAR analysis range in width, depending on site characteristics. Critical Habitat was identified based on best available science and includes tributary deltas and surrounding nearshore lake habitat, stream habitat, pelagic lake habitat, and riparian habitat features." – DFO 2019b, MacConnachie & Wade 2016 |

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| **Westslope Cutthroat Trout** – Saskatchewan Nelson Rivers<br><br>Alberta (Ontario & Prairie) | **30 m** | "The definition of riparian critical habitat was informed by DFO (2009) and scientific information related to riparian buffers. Critical habitat includes all riparian areas on both stream banks for the entire length of the stream segments and all banks of waterbodies identified as critical habitat. The width of the riparian area required to protect the attributes of critical habitat for Westslope Cutthroat Trout has not been quantified, however the riparian area must be sufficient to maintain clean, cold water, sediment and silt free substrates, and provide food (invertebrates) and woody debris into the aquatic environment. In order to determine the width of the riparian area, DFO, PCA, AEP, and Alberta Agriculture and Forestry (AAF) used benchmarks of the terrestrial components that effectively protect key biophysical features that influence water temperature, water flow, sediment, cover and food supply in the waterbody. In the absence of quantitative data specifically identified for Westslope Cutthroat Trout, this seems to be a reasonable approach, until definitive standards are known. Where the attributes for riparian habitat, are encountered within areas designated as aquatic critical habitat, the width of the riparian area within the areas designated as critical habitat are continuous and extend horizontally from the high water mark to a width of 30 meters on both banks of the waterbody for the entire geospatial area." – DFO 2019e, DFO 2009 |
| **Bull Trout** – Saskatchewan Nelson Rivers<br><br>Alberta (Ontario & Prairie) | **30 m** | Same methods as Westslope Cutthroat Trout – DFO 2020b, DFO 2009 |
| **Rainbow Trout** – Athabasca River<br><br>Alberta (Ontario & Prairie) | **30 – 100 m** in areas of groundwater discharge | "Critical habitat for aquatic species may include riparian areas on both stream banks for the entire length of the stream segments identified as critical habitat. Riparian areas and instream structures contribute to stream complexity, creation of refugia, stabilization of stream banks, maintenance of colder stream temperatures by reducing insolation, and are a source of terrestrial invertebrates. Using a reasonable and precautionary approach, a width of 30 m from the high water mark on both stream banks and areas of groundwater recharge outside of the 30 m buffer and within 100 m of the high water mark are included in Athabasca Rainbow Trout critical habitat" – DFO 2020c, DFO 2020h |
| **Redside Dace**<br><br>Ontario (Ontario & Prairie) | **meander belt + 30 m** | "Redside Dace seek overhanging riparian vegetation such as grasses, forbs, and small shrubs as well as undercut banks and in-stream structure such as boulders and large woody debris which are, a source of cover and food. The headwaters of streams and presence of a meander belt (including the riparian zone) are also important features that help maintain riffle-pool morphology and suitable baseflow as well as provide coarse sediment for spawning, cover, and terrestrial insects for feeding. For these reasons, the Ontario habitat regulation for the species under the *Endangered Species Act* 2007 (O.Reg 242/08) includes a minimum of 30 m of vegetated area adjacent to the stream's meander belt to ensure that riparian habitat can provide these ecosystem functions to support Redside Dace populations." – DFO 2019a<br><br>"Riparian habitat that is a minimum of 30 m from the meander belt (measured horizontally) is considered an important habitat element [for identification of critical habitat]. This is consistent with science-based guidelines recently developed for guiding habitat rehabilitation in Great Lakes Areas of Concern which recommend a minimum of 30 metres of naturally vegetated adjacent lands on both sides of the stream. The inclusion of the meander belt width and associated riparian habitat recognizes the naturally dynamic nature of riverine systems and the importance of riparian areas to highly sensitive stream ecosystems. Watercourses move and change over time within the meander belt. |

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| | | Therefore, defining riparian habitat from the edge of the meander belt will provide habitat for Redside Dace over the long-term as opposed to simply based on the current observed conditions." – Redside Dace Recovery Team [RDRT] 2010 |
| **Silver Shiner**<br><br>Ontario (Ontario & Prairie) | **meander belt + 30 m** | Same methods as Redside Dace – DFO 2020d |
| **Striped Bass** – St. Lawrence River<br><br>Quebec (Quebec) | **intertidal riparian zone** (290 $km^2$ total) | "Critical habitat was defined by combining two types of information presented in the science advisory report (DFO 2017): potential habitats defined for larvae and young-of-the-year, and annual recruitment monitoring. These habitats correspond to the intertidal and riparian zones between 0 and 5 metres deep, within a large geographically delineated area. The critical habitat was identified as the area – within this area of potential habitats – where young of-the-year were caught during 2013–2015 recruitment monitoring (excluding the geographic sites farthest upstream and downstream). The critical habitat includes Anse Sainte-Anne (at La Pocatière). This area was designated critical for juveniles between September and October in the previous recovery strategy." – DFO 2017, DFO 2019d |

In conjunction with the identification of critical habitat, examples of 'activities likely to result in the destruction of critical habitat' are required to be included in recovery strategies and/or action plans for threatened or endangered species listed under *SARA*. Examples of activity effect pathways described in published recovery strategies or action plans that could result in riparian critical habitat destruction and subsequent impacts on aquatic species at risk (Table 4) include:

- Drainage maintenance works associated with the removal of riparian vegetation for stream access (DFO 2020f; DFO 2020g).
- Land use or work in or around critical habitat with excessive riparian vegetation removal, nutrient loading, or improper sediment and erosion control (DFO 2020g; DFO 2019b; DFO 2020d).
- Livestock access to streams that damages riparian habitat through trampling or causing erosion that increases sediment deposition (DFO 2020f).
- Over-application of fertilizer or pesticides (DFO 2020d).
- Non-point source pollution and changes in water quality from land use practices such as road construction, poorly maintained roads, stream crossings, and transmission routes (DFO 2018b; DFO 2019c).
- Release of contaminants into aquatic habitats, including from surface runoff and land-based recreational activities and/or spills from oil and gas exploration or ship and pipeline transportation (DFO 2019b; DFO 2019d; DFO 2020c).
- Mechanical forest removal and loss due to high-intensity fire (DFO 2019e; DFO 2020b; DFO 2020c).
- Linear disturbance (road or trail construction and maintenance or lack of maintenance), urbanization, mining, grazing, pipeline construction, railways, high intensity or frequent off-road vehicle use, recreational access (DFO 2019e; DFO 2020b; DFO 2020c).
- Dams or reservoir creation (DFO 2019e; DFO 2020b; DFO 2020c; DFO 2020d).

- Shoreline development activities such as dewatering, encroachment, dykes, retaining walls, riprap, ports, roads, docks (DFO 2019d).
- Backfilling or offloading of dredged material (DFO 2019d).

Once a species' critical habitat has been identified in a recovery strategy or action plan, DFO must ensure that the critical habitat is legally protected. This protection is typically achieved through an order under ss. 58(4) of *SARA* which triggers the prohibition against the destruction of critical habitat (*SARA,* s. 58(1)). Critical habitat orders for aquatic species at risk apply to the identified critical habitat on both Crown and private land. Where a proposed activity could result in the destruction of critical habitat, it may be allowed to occur, in accordance with ss. 73(1) of *SARA*, where "the competent Minister may enter into an agreement with a person, or issue a permit to a person, authorizing the person to engage in an activity affecting a listed wildlife species, any part of its critical habitat or the residences of its individuals" as long as a number of conditions are met.

When a WUA is proposed that may impact fish habitat, including critical habitat, FFHPP conducts a regulatory review of the proposed WUA under both the *Fisheries Act* and *SARA*. While there is no critical habitat identified in riparian zones within DFO Maritimes Region, there are species at risk with riparian critical habitat in other DFO regions (Pacific, Ontario & Prairie, Quebec; Table 4). In these regions, proposed WUAs in riparian critical habitat have been reviewed on a case-by-case basis. Each project is evaluated based on the biophysical features and attributes of the riparian critical habitat needed to support the functions necessary for species' life-cycle processes at the location of interest, and how those functions, features and attributes would be affected by the proposed WUA. If the impacts to the functions, features, and attributes of critical habitat from the proposed WUA would not result in its destruction, a *SARA* permit or *Fisheries Act* authorization is not required. In many cases, FFHPP works with applicants to mitigate or avoid impacts to critical habitat from the proposed WUAs such that the WUA is not considered to be destruction. The best solution for FFHPP is a situation where the impact to a species is limited or avoided, with all aspects of the activity being considered. However, if a WUA does impact critical habitat in a manner that results in destruction, a permit can only be issued if the ss. 73(3) *SARA* preconditions can be met. For example, if the WUA will jeopardize the survival or recovery of the species, even after all appropriate mitigation measures are put in place, then the proposed WUA would not meet the ss. 73(3)(c) precondition for issuance of a *SARA* permit. While a critical habitat order (that includes a riparian buffer) is in the process of being put into force, DFO can proactively work with landowners, industries, governments, municipalities, Indigenous peoples, and others that manage existing WUAs or public infrastructure in the buffer zone to strive for compliance with the *Fisheries Act* and *SARA*.

In areas of riparian critical habitat with a heavy natural resource extraction presence, engagement with provinces and industries has occurred to make them aware of where riparian critical habitat exists to promote compliance with *SARA*; FFHPP review to determine if a *SARA* permit is required or can be issued may still occur where forestry operations (WUAs) encroach on the functions, features and attributes provided by riparian critical habitat. An example is demonstrated through Alberta's efforts to protect the Westslope Cutthrout Trout (*Oncorhynchus clarkii lewisi*; 'threatened' under Alberta's *Wildlife Act* (2000) and 'threatened' under *SARA;* Alberta Westslope Cutthroat Trout

Recovery Team [AWCTRT] 2013; DFO 2019e). Strategies and approaches for species recovery include education and outreach, in which "educating anglers, the general public, industry, and governments is essential to gain acceptance of, and compliance with, the overall recovery strategy. Support can be gained through increased awareness of the Westslope Cutthroat Trout and through involvement in stewardship programs" (AWCTRT 2013; DFO 2019e). Riparian critical habitat for the Westslope Cutthroat Trout covers many kilometers of upper tributaries throughout Alberta's eastern slopes of the Rocky Mountains, where riparian habitat rehabilitation (planting, slope stabilization, etc.) has occurred in some areas (DFO 2019e); organizations and industries have been made aware of the protective provisions of the critical habitat. The recovery strategy indicates that information exchange with industry was an essential part of the species recovery planning, including "conferences or meetings with the Canadian Association of Petroleum Producers (CAPP) and forestry" (AWCTRT 2013; DFO 2019e).

For species at risk with riparian critical habitat in British Columbia, DFO Pacific region recovery planners used existing provincial legislation as a model for riparian protection. The *British Columbia Riparian Areas Protection Regulation* (*Riparian Areas Protection Act*, 1997) was created to address fish and aquatic habitat protection (British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development [BCFLNRORD] 2019). This regulation is "based on current science regarding fish habitat, while recognizing the challenges in achieving science-based standards in an urban environment" (BCFLNRORD 2019). There are two different assessment methods to determine the appropriate streamside protection and enhancement area (SPEA) that acts as a riparian reserve buffer between the aquatic environment and proposed human activities (BCFLNRORD 2019). A simple assessment sets out SPEA widths based on stream characteristics: streamside vegetation status, nature of stream flows, and fish-bearing status (BCFLNRORD 2019). The simple assessment default SPEA width is 30 m for permanent, fish-bearing watercourses but may be reduced to a minimum of 15 m for non-permanent, discontinuous riparian vegetation, or non-fish bearing waterbodies (BCFLNRORD 2019).

A detailed assessment addresses 5 parameters: large woody debris, area required for localized bank stability, area for channel movement, shade, and litter fall or insect drop (BCFLNRORD 2019). Zones of sensitivity are determined for each parameter using the site potential riparian vegetation type and channel width (LC = low ground cover (grass/sedge/rock), SH = deciduous or coniferous shrubs, TR = deciduous or coniferous trees), shown below in Figure 10. The widest zone of sensitivity becomes the SPEA, with extra buffer width added that protect the SPEA from edge effect factors including windthrow, slope stability, erosion control, etc. (BCFLNRORD 2019). BCFLNRORD (2019) provides the full methodology, and DFO applied a modified version of this system to identify riparian critical habitat for several Pacific region species at risk (described in Table 4). The *Riparian Areas Protection Regulation* buffer methodology was backed by fisheries science advice but also developed with natural resource operations (specifically forestry) in mind (BCFLNRORD 2019). The detailed assessment method usually requires industry professionals to visit the field and delineate site-specific buffers; however, the simple assessment default of 30 m for permanent, fish-bearing watercourses could be applied if more practical.

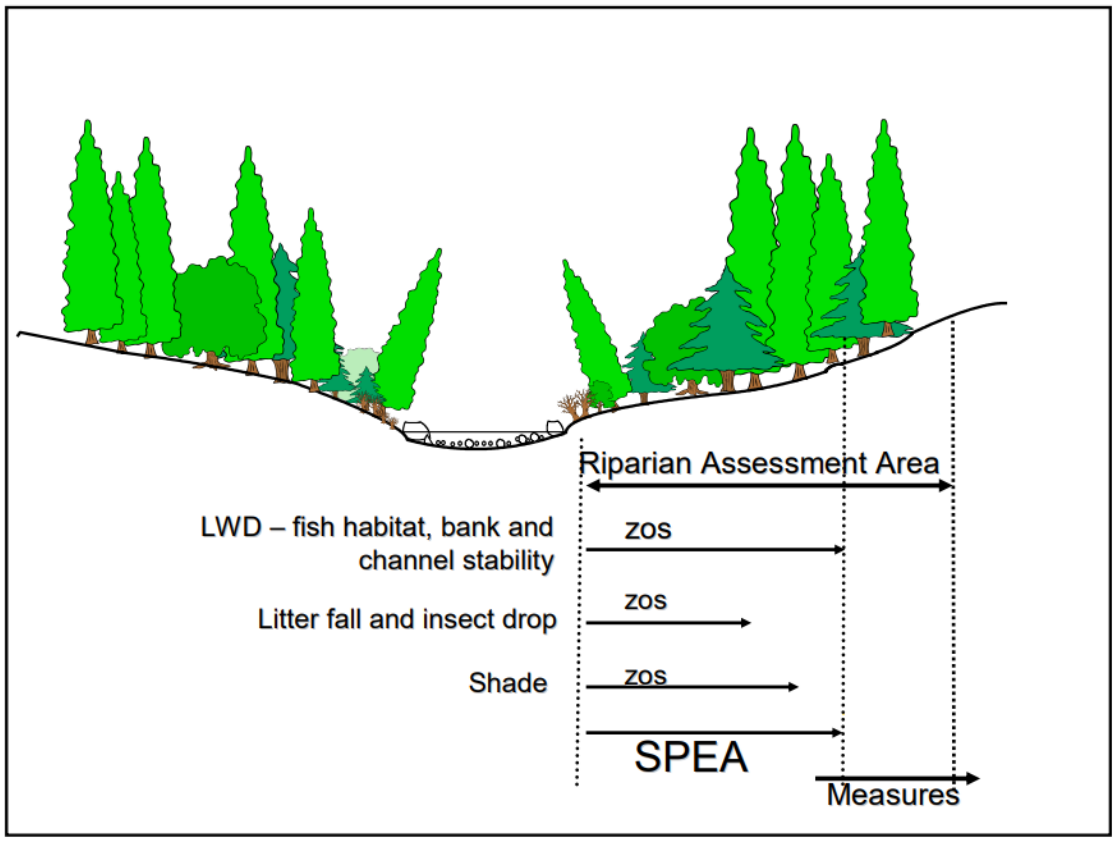


***Figure 10**: Conceptual diagram of the detailed assessment procedure to identify zones of sensitivity (ZOS), stream protection and enhancement area (SPEA), and measures of protection riparian buffer widths (BCFLNRORD 2019)*

### *3.3. Riparian Fisheries Act or Species at Risk Act Convictions*

The jurisdiction of DFO for regulating activities in the riparian zone has been tested in court at various levels. When activities occur that result in the destruction of critical habitat for an aquatic species at risk and a *SARA* permit has not been issued, charges can be imposed under ss. 97(1) of *SARA* in association with ss. 58(1), where "no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species." There has been one conviction for the destruction of critical habitat of an aquatic species at risk since the enactment of *SARA* (Government of Canada 2018). Landowners unknowingly destroyed critical habitat for the endangered Spotted Gar by shoreline dredging along the riparian zone of Lake Erie, resulting in fines under ss. 97(1) totaling $7,000 (Government of Canada 2018). The majority of the fine amount ($6,000) was directed to the Environmental Damages Fund, allocated to recovery efforts to benefit the Spotted Gar (Government of Canada 2018).

Section 35(1) of the *Fisheries Act* states that "no person shall carry on any work, undertaking or activity that results in the harmful alteration, disruption or destruction [HADD] of fish habitat." FFHPP authorizations can be obtained that allow proponents to cause a HADD to fish or fish habitat with appropriate mitigation or offsetting measures. Like *SARA* permits, if an authorization is not obtained prior to WUAs that impact fish or

fish habitat, convictions can occur under ss. 35(1) where financial penalties are imposed from ss. 40(1) or s. 79.2 to the parties liable for violating the *Fisheries Act*. A summary of examples for *Fisheries Act* or *SARA* convictions related to riparian zone activities is shown in Table 5; by no means is this an exhaustive list but is intended provide a brief overview of some riparian activities that resulted in convictions under Canadian law.

***Table 5****: Case law examples of Fisheries Act or Species at Risk Act convictions that were fully or partially caused by the destruction or degradation of riparian habitat*

| Conviction | Description | Case (DFO region) |
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| ss. 35(1) of the *Fisheries Act*; **$100** fine under ss. 40(1) and a **$900** order payable under ss. 79.2(f) for habitat restoration and remediation in Bertrand Creek. | Excavating **riparian** vegetation in and around Howes Creek – HADD to fish habitat for the Nooksack Dace (prior to *SARA* critical habitat order) | R. v. Grewal and Mallhi 2011 BCPC 205 (Pacific) |
| ss. 35(1) and ss. 36(3) of the *Fisheries Act*; **$4,500** fine under ss. 40(1) and an **$40,500** order payable under ss. 79.2(e) to the Kennisis Lake Cottage Owners Association. | Destruction of **riparian** and in-water fish habitat for the placement of boulders and construction of a large concrete seaplane ramp. | R. v. Montgomery 2014 ONSC 2775 (Ontario & Prairie) |
| ss. 35(1) of the *Fisheries Act*; three different defendants (Gwaii Wood Products Ltd., Howe Sound Forest Products Ltd., and Crosby Contracting Ltd.). Fines under ss. 40(1) totaled **$600,000** and orders payable under ss. 79.2(f) to the Receiver General of Canada for DFO, for the purposes of promoting proper management and control of fisheries or fish habitat or the conservation and protection of fish or fish habitat on Haida Gwaii totaled **$1,600,000**. | Forestry activities and road construction that destroyed **riparian** vegetation along 2.5 km of eight different fish-bearing tributaries and wetlands. Species impacted included Coho Salmon, Dolly Varden char, stickleback and sculpin. | R. v. Gwaii Wood Products Ltd. et al. 2017 BCPC 6 (Pacific) |
| ss. 35(1) of the *Fisheries Act*; **$20,000 fine** under ss. 40(1) and **$55,000** order under ss. 79.2(f) for the restoration of fish habitat in question in this case. | Drilling, blasting, and stockpiling of granite rock in the intertidal **riparian** zone of Wainwright Basin. Destroyed 352 $m^2$ of known habitat for juvenile Pacific Salmon. | R. v. Basso 2001 BCSC 801 (Pacific) |
| ss. 35(1) of the *Fisheries Act*; **$55,000** fine under ss. 40(1) and **$26,540** order payable under ss. 79.2(f) to Fraser Valley Conservancy for the restoration of fish habitat in question in this case. | HADD was created by the "cutting down of a number of trees, the removal of shade from the creek and the currying of adjacent vegetation" in the **riparian** zone along Windebank Creek, thereby altering fish habitat to a "degree that was more than trivial or minimal." | R. v. Larsen 2015 BCSC 1334 (Pacific) |
| ss. 35(1) of the *Fisheries Act;* **$1,000** fine under ss. 40(1) and **$29,000** order payable under ss. 79.2(f) for the restoration of fish habitat in question in this case. | **Riparian** land clearing, removed trees and vegetation and filled in a fish-bearing stream section with material; impaired ~8000 $m^2$ of fish habitat. | R. v. Brown 2010 BCCA 225 (Pacific) |
| ss. 35(1) of the *Fisheries Act;* fines under ss. 40(1) totaled **$70,000**. | Land clearing and grubbing of **riparian** vegetation along the banks of South Thompson River and McGregor Creek. | R v. Rhodes et al 2007 BCPC 1 (Pacific) |

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| ss. 35(1) of the *Fisheries Act*; fines under ss. 40(1) totaled **$4,000** and a **$40,000** order payable to a fish habitat conservation trust fund under ss. 79.2(f). | Destroyed **riparian** vegetation to create artificial berms with large machinery along the banks of Big Creek, causing HADDs to Rainbow and Bull trout. | R. v. Sapp 2005 BCPC 166 (Pacific) |
| ss. 35(1) of the *Fisheries Act*; fines under ss. 40(1) totaled **$20,000** and a **$120,000** order payable to the British Columbia Conservation Foundation for fish habitat conservation in the Thompson River Watershed under ss. 79.2(e). Further **$85,000** paid to DFO for site remediation. | The complete destruction of dense foreshore and **riparian** vegetation along 4,200 $m^2$ of Kamloops Lake shoreline. Caused HADDs to fish habitat migration routes for 5 species of Pacific Salmon. | R. v. Northland Properties Corporation 2015 BCSC 1571 (Pacific) |
| ss. 58(1b) of the *Species at Risk Act*; fines under ss. 97(1) totaled **$7,000**. | Shoreline dredging adjacent to their property along the **riparian** zone of Lake Erie. Destruction of critical habitat for the Spotted Gar. | Government of Canada 2018 (Ontario & Prairie) |
| ss. 35(1) of the *Fisheries Act*, fines under ss. 40(6) totaled **$50,000**.<br>ss. 32(1) of the *Species at Risk Act*, fines totaled **$20,000** with $14,000 being credited to the Environmental Damages Fund pursuant to ss. 105(k). | The operation of motorbikes, degrading several **riparian** and in-stream areas of Racehorse Creek during a motorbike race, resulting in a HADD to fish and fish habitat for the threatened Westslope Cutthroat Trout. | R v French 2019 ABPC 149 (Ontario & Prairie) |

The penalties associated with *Fisheries Act* and *SARA* violations range greatly depending on the scope and severity of the action that caused conviction. Total fine amounts per conviction ranged from $1,000 (R. v. Grewal and Mallhi 2011 BCPC 205) to $2.2 million (R. v. Gwaii Wood Products Ltd. et al. 2017 BCPC 6), showing the ability of the courts to assign penalties that they deem fit based on the evidence provided. A common trend among cases was the allocation of financial penalties to causes that benefit fish or fish habitat. Most often, the majority of fine amounts were laid as court orders under s. 79.2 of the *Fisheries Act* directed to fish conservation initiatives or payments for the remediation of sites that were degraded or destroyed by the activity that caused the conviction.

### *3.4. Ecologically Significant Areas*

The goal of ESA establishment is “to manage fish and fish habitat that is sensitive, highly productive, rare or unique in accordance with management objectives established for their conservation and protection” (DFO 2019f). These new provisions under the *Fisheries Act* allow the Governor in Council to make regulations that prohibit or require FFHPP authorization for certain WUAs within ESAs (DFO 2019f). Currently, there are no ESAs established in Canada, however DFO staff are working to develop a National Framework for ESA Identification, Establishment and Management. Various case studies are being explored to support development and test components of the ESA Framework, including the process for identifying candidate ESA sites. While ESAs are a relatively new provision within the *Fisheries Act* specifically meant to protect fish and fish habitat (including riparian habitat), they also can offer incidental protection to terrestrial species including amphibians, reptiles, birds, mammals, plants, invertebrates, and microorganisms (Harris et al. 2019; Lind et al. 2019; Hanna et al. 2020; Olson et al. 2007; Singh et al. 2021). ESAs may contribute to broader biodiversity goals and Government of

Canada targets for freshwater, marine, and terrestrial protection (e.g., 25% by 2025 working towards 30% by 2030).

Engagement on ESAs is in early stages where external groups are being made aware of the ESA provisions in the *Fisheries Act* and DFO is seeking input on early concepts for the National ESA Framework. It is likely that riparian zone management will be a priority for offering protection to sensitive, highly productive, rare or unique fish and fish habitat, depending on the conservation objectives set for ESA candidates. Where *SARA*-listed species at risk presence and identified ESAs overlap, there may be synergistic riparian management measures that offer fish or fish habitat conservation under both mandates (*Fisheries Act* and *SARA*). ESAs can also afford protection to non-listed species that have been assessed as at-risk by COSEWIC (special concern, threatened, or endangered) that depend on the riparian zone.

# 4. Current Riparian Management in Nova Scotia

The most common human activities that encroach on riparian habitats in Nova Scotia are forestry, agriculture, and residential or industrial development (Stoffyn-Egli & Duinker 2013; Rideout 2012). Outlined below are applicable current provincial or municipal legislation, policies, or guidelines that manage these activities.

## *4.1. Provincial and Municipal Legislation, Bylaws, and Guidelines*

The forestry sector is subject to both the provincial *Forests Act* (1989) and *Crown Lands Act* (1989). In Nova Scotia, forestry activities are subject to the most specific regulations for riparian zone management, found in the *Wildlife Habitat and Watercourses Protection Regulations*, made under s. 40 of the *Forests Act*. Riparian zones are referred to in s. 6 of the regulations as special management zones (SMZs) in which a 20 metre (m) selective harvest buffer must be maintained around all watercourses with an average width of 50 centimeters (cm) or greater. Under the selective harvesting requirements (ss. 6(3)) it is not permitted to reduce the total basal area (tree stem diameter at chest height) of living trees to less than 20 $m^2$ per hectare, or create an opening in the dominant tree canopy larger than 15 m at its greatest dimension. If the SMZ has a slope gradient greater than 20%, then the SMZ width increases by 1 m for each additional 2% of slope to a maximum of 60 m in width (ss. 6(2)).

The regulations also define a machine exclusion zone (MEZ) within 7 m of the watercourse in which no vehicles are permitted. However, selective harvest can occur in the MEZ (ss. 6(3a)) as long as the forestry operations do not conduct any activities that would result in sediment being deposited in the watercourse (s. 8). The riparian buffer is decreased to 5 m for all watercourses with an average width of less than 50 cm; this buffer only prohibits vehicle access and still allows selective harvest up to the watercourse edge. The watercourse buffer requirements apply on both Crown and private land across the province.

A Crown Land License must be obtained prior to logging on Crown land, where proposed timber harvest plans and prescriptions are submitted to the Nova Scotia Department of Natural Resources and Renewables (NSDNRR; formerly Lands and Forestry), conforming to the Code of Forest Practice guidelines in order to get approval

(Province of Nova Scotia 2012). While the *Crown Lands Act* (ss.25(2)) reinforces that the Minister shall implement protective measures in 'forest-management planning' on provincial land, s. 24 also offers the ability of the Minister to set aside 'special areas' for (c) "the protection and regulation of the flow of water within the lands so reserved and set apart," and (e) "the protection, management and conservation of wildlife and wildlife habitats." It is not known to what extent these protective measures have been implemented in Nova Scotia, with the newly assented *Biodiversity Act* aimed at fulfilling some of these provisions originating in the *Crown Lands Act*.

The agriculture sector does not have legislated regulations for riparian buffer requirements, but the Nova Scotia Environmental Farm Plan Program (NSEFPP), a voluntary, government-funded, educational program delivered by the Federation of Agriculture, recommends that a 5 m buffer is maintained between watercourses and farmland (pastures, crops, etc.) (NSEFPP 2020). The NSEFPP recommends that land clearing activities on farms for building farm-related infrastructure follows the same 20 m riparian buffer required for forestry activities (NSEFPP 2020). In Nova Scotia, 80% of farms have been assessed under the NSEFPP (Rideout 2012), with 63% stating that an environmental farm plan (EFP) has been developed for their agriculture land (Statistics Canada 2017). The Department of Agriculture recommends that a 50 m buffer is retained between lakes, rivers and brooks and manure storage facilities, with a reduction to 20 m for intermittent streams, ditches, or wetlands (Province of Nova Scotia 2006). These buffers become more complex within municipal drinking water supply areas, where further guidance is provided for additional activities such as fertilizer, pesticide, and compost application (detailed in Appendix A; Province of Nova Scotia 2017a). As well, many municipal bylaws require watercourse setbacks between 30 and 100 m related to agriculture and livestock-related buildings (Municipality of Cumberland 2018; Region of Queens Municipality 2009; Municipality of the County of Kings 2020). However, the implementation and enforcement of these bylaws is inconsistent, and they do not apply to row crops, where no riparian buffers are required (Rideout 2012).

For residential development, the only provincial regulation that provides specific riparian buffer requirements from freshwater bodies is the *On-site Sewage Disposal Systems Regulations* (s. 66, s. 110, and ss. 122A(3) of the *Environment Act*, 1995). These regulations require a septic system to be setback 30.5 m from all watercourses and wetlands; however, this buffer only applies to the septic system installation and not any other activities on the residential property. While not a regulation, the provincial *Wetland Conservation Policy* recommends the use of buffers between developments and wetlands, similar to what is required for forestry operations (Province of Nova Scotia, 2019). The remainder of residential development setback requirements are enacted at a municipal level through bylaws, using the power provided by the *Municipal Government Act* (1998). Riparian buffers vary among municipalities and land-use activities, but generally range from 4.5 to 30.5 m in width (Rideout 2012). Using the Municipality of the District of Guysborough (MODG) as an example for residential development, they require a 10 m buffer from the normal high water mark of any watercourse or ocean where no building is allowed, with the exception of a boathouse (MODG 2013). Halifax Regional Municipality (HRM) bylaws adopt the same watercourse setbacks as the provincial *Wildlife Habitat and Watercourses Protection Regulations*, except that no vegetation

removal is allowed within the 20 m buffer for development activities without a permit (HRM 2000). The HRM 'Green Network Plan' was introduced in 2018, with an objective (4.1.3.3.) to increase riparian buffer zones from 20 to 30 m for all watercourses greater than 50 cm wide and from 30.5 to 100 m for all drinking water supply areas (HRM 2018); The HRM (2000) bylaws have not been amended yet to reflect these objectives.

Environmental assessments are required to follow the *Environmental Assessment Regulations* (*Environment Act*, s. 49), for any large-scale industrial developments such as mines, highways, wind farms, or pulp and paper mills. There are no widely-applicable riparian buffer requirements for environmental assessments, so riparian habitat is considered and assessed along with fish, fish habitat, and species at risk on a project-specific basis (Rideout 2012). The *Wetland Conservation Policy* has been used in the past to provide rationale during environmental assessment approvals for proponents to abide by at least a 30 m riparian buffer. There may be other niche industries or activities with specific policies or best management practice guidelines for riparian buffer widths in Nova Scotia, but the activities outlined above are likely the most common to occur (Table 6).

***Table 6****: Summary of riparian buffer widths for different types of human activities in Nova Scotia*

| **Activity** | **Regulated or Recommended Riparian Buffer** | **Legal Requirements or Best Management Practice Guidelines** |
|---|---|---|
| Forestry | **20 m**; extends by 1 m for every 2% of slope (for slopes > 20%) to a maximum of **60 m**. Selective harvest is permitted up to the ordinary high water mark as long as no sedimentation is caused. | *Wildlife Habitat and Watercourses Protection Regulations*, under s. 40 of the *Forests Act*, R.S.N.S. 1989, c. 179 |
| Agriculture | 1) **5 m** for farmland (e.g. crops, pastures, etc.)<br>2) **30 – 100 m** for agriculture and livestock-related buildings | 1) Nova Scotia Environmental Farm Plan Program<br>2) Municipal bylaws (inconsistently applied) |
| Residential development | 1) **30.5 m** for septic system installation<br>2) **5 – 20 m** of no building/development allowed<br>3) **5** – **100+ m** for estuary and marine shorelines (proposed regulations are undergoing public consultation) | 1) *On-site Sewage Disposal Systems Regulations*, under s. 66, s. 110, and ss. 122A(3) of the *Environment Act*, S.N.S. 1994-95, c. 1<br>2) Municipal bylaws<br>3) *Coastal Protection Act*, S.N.S. 2019, c. 3 |
| Industrial development | Assessed on a project-specific basis, may range from 0 to several hundred metres | *Environmental Assessment Regulations*, under s. 49 of the *Environment Act*, S.N.S. 1994-95, c. 1 |

### *4.2. Estuarine Environments*

The province enacted the *Coastal Protection Act* (2019) to increase adaptation and resilience capacity of the Nova Scotia coastlines to sea level rise and other climate change impacts (Province of Nova Scotia 2021). Regulations that accompany the legislation recently underwent public consultation, which sought to implement a stricter

set of coastline activity setback requirements than what exist in current municipal bylaws (Province of Nova Scotia 2021). Rather than imposing a fixed-width coastal building setback like most municipality bylaws, the *Coastal Protection Act* proposed that any developments within 100 m of the ordinary high water mark require a 'coastal erosion risk factor assessment' (Province of Nova Scotia 2021). The landowner is required to pay a designated professional to assess the planned development in the context of the site-specific shoreline profile using three categories of factors: 1) erodibility, 2) sea level rise, and 3) slope stability (Province of Nova Scotia 2021). A standardized spreadsheet is used to input site measurements and observations to calculate how far the shoreline is expected to shift over the next 80 years and output the horizontal setback that the landowner must abide by (Province of Nova Scotia 2021). A report is filed by the designated professional to the appropriate municipality, and building permits are accepted or altered to conform to the setback requirement (Province of Nova Scotia 2021). If the proposed *Coastal Protection Act* regulations are well received through public consultation and get inserted into the statute, the coastal development setback distances may vary significantly based on each individual property and building proposal, starting at the minimum municipal requirement (10 – 20 m) and reaching an unknown maximum setback (Province of Nova Scotia 2021). Through these newly proposed regulations, it appears that fish and fish habitat protection will be increased for Nova Scotia's coastlines for the coastal building and development sector. While estuary environments have important habitat for biodiversity-promoting species like eelgrass (Joseph et al. 2013; Namba et al. 2018; Krumhansl et al. 2021) at this point, the recommendations outlined in Section 7 should be used primarily to inform riparian management measures around freshwater ecosystems.

# 5. Potential Future Riparian Management in Nova Scotia

## *5.1. The Lahey Report*

In 2017, the provincial government commissioned an independent review of forestry in Nova Scotia. Dr. William Lahey's report, 'An independent review of forest practices in Nova Scotia,' provides a comprehensive look at how forests are managed in Nova Scotia with recommendations to shift towards a 'triad model of ecological forestry' (Lahey 2018). The triad model contains three elements that, if implemented, could support "ecological well-being and a thriving forestry economy" in Nova Scotia (Lahey 2018):

1) The protection of some forests from all forestry (and other human activities) through the designation of parks, wilderness areas, nature reserves, or private conservation.
2) Forests dedicated to high-production forestry, including clearcutting and other high-production alternatives to clearcutting. This system allows for industry's activities to be more concentrated in certain areas, limiting the impact on the overall landscape.
3) The remainder of forests to be managed through a combination of ecological and production objectives, with contributions to commercial forestry and ecological conservation (i.e. forestry with a 'lighter touch' and less clearcutting).

The report followed with 45 recommendations to achieve the triad model, with the provincial government accepting the "spirit and intent" of these recommendations and agreeing to implement them gradually over time (Province of Nova Scotia 2018). Specific to riparian management, recommendation 25 stated (Lahey 2018):

> "The efficacy and adequacy of a 20 metre riparian zone that is only varied on the basis of slope conditions, currently required by the *Wildlife Habitat and Watercourse Protection Regulations*, should be independently studied with a view to determining (a) if it should be changed and (b) how it should be changed to better address the ecological rationale for riparian buffer zones."

During forestry site inspections, the Lahey Report review team did not find any significant violations to the existing 20 m riparian buffer requirement; however many SMZs appeared to be too narrow from an ecological standpoint, in which the riparian and above-water shaded microclimates would certainly be disrupted (Hunter & Van Damme 2018). They also noted that the visual aesthetics for many clearcuts that defined upland riparian edges were poor (Hunter & Van Damme 2018). As part of the Lahey Report addendum, the review experts concluded that riparian zones, or SMZs, would benefit from modest changes to increase watercourse protection, including (Hunter & Van Damme 2018):

- Where clearcuts are planned near watercourses, the SMZ width on both shorelines should be increased to either 30 m (if the watercourse is so narrow that the forest canopy is unbroken above it) or 40 m for wider watercourses.
- The MEZ should be increased to 10 m and also be a no-cut zone to provide an area to retain large old trees and snags.
- Much wider SMZs (even >100 m) should be established on larger lakes and rivers on a case-by-case basis to account for recreational and aesthetic issues, especially on Crown Lands, or wherever other considerations are relevant, such as habitat for species at risk or in community watersheds.

Hunter and Van Damme (2018) also provide a comparison of Nova Scotia's current forestry regulations for riparian management with mandatory guidelines or legislated regulations in other provinces, offering the ability to learn from different approaches used elsewhere in Canada [Appendix B]. The *Wildlife Habitat and Watercourses Protection Regulations* that currently regulate riparian buffer zone requirements apply to both Crown and private forest land in Nova Scotia (s. 3). Thus, Lahey (2018) makes it clear that the recommended amendments to these regulations to increase riparian habitat protection should apply to both Crown and private land as well. The rationale given was "the ecological reason for doing so – the common public interest in protecting bodies of water and the ecosystems and aquatic and terrestrial life that depend upon them – would apply as much to changes in the regulation to improve their effectiveness as it did to the original decision to make the regulations applicable to private land in the first place" (Lahey 2018).

The new Nova Scotia Silvicultural Guide to the Ecological Matrix that accompanies the Lahey Report identifies specific forest types with aquatic and riparian values important to preserve. As of 2021, prescriptions for timber harvesting are no longer granted in wet coniferous (WC) and wet deciduous (WD) forest stands on Crown lands in the province

due to “high biodiversity values, the probability of impacting species at risk, and the possibility that these sites will not reforest” (McGrath et al., 2021).

### *5.2. The Nova Scotia Biodiversity Act*

The provincial *Biodiversity Act* was first introduced in 2019, then amended in 2021 to remove private land from the scope of the legislation. It came into effect on October 1, 2021 (Dorreen et al. 2021). The purpose of the Act, under s. 2, is “to provide for an integrated framework of legislation that supports the stewardship, conservation, sustainable use and governance of biodiversity in the Province.” The most important piece of the *Biodiversity Act* in the context of riparian habitat management is the ability of the Minister of NSDNRR to designate “biodiversity management zones” (BMZs) defined under ss. 3(b) as “a specified area of land managed, for a period of time, for the purpose of supporting the conservation or sustainable use of specified biodiversity values.” The *Biodiversity Act* does not provide any specific details for how BMZs could be created in riparian habitats to aid with the protection of fish and fish habitat. However, the definition of “biodiversity” under ss. 3(a) includes aquatic ecosystems as a priority. It is likely that where productive, sensitive, and biodiverse aquatic systems are potentially under threat of degradation from human activities, BMZs could be established to 1) extend riparian buffer zones to limit encroachment on watercourses, or 2) restrict activities that are currently permitted within riparian habitats in existing provincial legislation or municipal bylaws. The geographic extent, allowable activities, management objectives, monitoring strategies, time period, and other components would all be specified on a case-by-case basis for a specific BMZ.

Unlike the recommendations made to alter existing forestry riparian zone regulations by Hunter and Van Damme (2018) in the Lahey Report, the *Biodiversity Act* would not automatically apply on both Crown and private land. The *Biodiversity Act* allows BMZs to be established “on any land vested in Her Majesty in right of the Province” (ss. 15(1a)) or “on private land with the consent of the owner of the private land by entering into an agreement with the owner” (ss. 16(1)). The Act also defines “land” to include “land covered by water” (s. 3(l)). Rather than imposing mandatory BMZ-specific regulations for private landowners to follow, the *Biodiversity Act* offers a voluntary opt-in scheme for the owners of private land. Of particular importance is the opportunity for private landowners to be financially compensated for allowing BMZs to be designated on their property (ss. 16(2f)). The method and rate of possible compensation for private landowners is not outlined in the *Biodiversity Act*, and likely will not be known until BMZs have been established on the landscape. The majority of land in Nova Scotia is privately-owned, with only 1.53 million hectares (29%) of Nova Scotia’s total area owned by the provincial or federal governments (NSDNRR 2018). With the *Biodiversity Act* being a relatively new piece of legislation, the acceptance rate to allow BMZs on private property remains to be tested. Strategic BMZ designation in riparian and aquatic habitats on Crown and private land throughout Nova Scotia could be successful at reducing the current land-use activities that threaten fish and fish habitat.

### *5.3. Environmental Goals and Climate Change Reduction Act*

In the newly enacted *Environmental Goals and Climate Change Reduction Act* (2021), the Province of Nova Scotia made some commitments that may have broader

implications for riparian zone management. The provincial government has committed to conserve at least 20% of the total land and water mass by 2030 through protected areas or other 'effective area-based conservation measures,' including Indigenous Protected and Conserved Areas (s. 10a). This will be supported through a 2023 collaborative protected areas strategy which may involve DFO (s. 10b). The Lahey report is emphasized again in the proposed statute, in which the ecological forestry triad model approach will be implemented on all Crown lands by 2023, that "prioritizes the sustainability of ecosystems and biodiversity in the province" (s. 10c). Furthermore, the forest conservation 'triad' of the Lahey report and protected area commitments in this statute also align with Government of Canada conservation targets (25% by 2025 and 30% by 2030) and DFO aquatic protection initiatives like ESAs.

Of particular interest is a new commitment to "develop provincial water quality objectives to guide activities that affect water quality by 2026" (s. 11a). While the *Environmental Goals and Climate Change Reduction Act* does not specifically discuss riparian management, these new commitments may provide greater rationale for riparian protection during discussions with the Province of Nova Scotia.

# 6. Considerations for Determining Riparian Management Measures

Riparian habitat management is important for protecting fish and fish habitat, and there are many different ways that riparian habitat may be managed. Management can include regulations, voluntary best management practices, and other collaborative measures by government departments at all levels including engagement with Indigenous peoples, industry, landowners, and others. A key factor in establishing riparian management measures is identifying the specific area and aquatic species (or groups of species) that are being considered. However, the approach to managing the riparian zone that would be deemed necessary from a scientific perspective to protect fish and fish habitat may differ in comparison to what is practical to implement on the landscape. Aside from ecological considerations and science advice, there are a set of region-specific considerations that should be understood in order to develop riparian management measures to protect fish and fish habitat that are realistic to implement. Some important considerations include land cover, use, and ownership, sensitive areas, climate change, and cumulative effects.

## *6.1. Land Cover, Use, and Ownership*

Land cover, use and ownership are fundamental considerations to understand what industries and activities have altered and will continue to alter riparian zones with the potential to impact aquatic ecosystems and this information should inform the establishment of riparian habitat management measures. Land cover refers to the physical morphology and biology (e.g., forests, wetlands, impervious surface) of the landscape (Lambin et al., 2001). Land use is a description of how humans are using or modifying the land cover (Lambin et al., 2001). Once this is understood, it is beneficial to analyze if and how riparian zones are regulated for all common land use activities identified (Section 3 & 4), as well as to assess if best management practices or other non-regulatory tools exist and are being implemented. Unlike offshore and freshwater areas

(below the high water mark), terrestrial riparian zones can involve a larger number of stakeholders that use and/or manage the physical habitat.

Land ownership is crucial to understand (i.e., where private or Crown land exists) and in what forms (e.g. urban settlements, protected areas, large industrial developments, etc.). It is important to consider the amount of private land compared to Crown land in a given area. Across Canada this is variable, and on two opposite ends of the spectrum are British Columbia, with only ~5% private land (Province of British Columbia 2021), and Nova Scotia with ~70% private land (Province of Nova Scotia 2017b). Allowable activities on private land are often governed by a combination municipal bylaws and provincial regulations, so assessing the adequacy of these policies from a fish and fish habitat protection perspective is essential.

In areas of riparian Crown land, collaboration with provincial and territorial governments could result in the ability to implement more comprehensive riparian management measures (e.g., wider buffer zones, greater riparian connectivity). Applying the same terms on private land may be more complicated due to the greater number of stakeholders involved. However, depending on the landowners, the specific ecological needs or sensitivities of the area, and current or foreseeable activities (e.g., residential development vs. forestry), it could be possible to strengthen existing provincial/territorial or municipal regulations with federal tools on private land (e.g., ESAs, *SARA* critical habitat orders) or voluntary landowner stewardship activities. In jurisdictions where existing riparian habitat regulations may be more reflective of what is deemed adequate scientifically for protecting fish and fish habitat (Appendix B), it is possible that further measures do not need to differ significantly. For example, under the Alberta *Forests Act* (2000) riparian buffer zones are required to be between 30 and 200 m for permanent watercourses with selective harvest only permitted under certain conditions and no machinery allowed within 20 m of the watercourse. All freshwater species at risk with riparian critical habitat in Alberta have a buffer width of 30 m or larger (Table 4), in which DFO modelled the current provincial forestry buffer regulations to slightly enhance species at risk protection without causing drastic changes in forestry practices.

Highlighting local industry practices that go beyond what is legally required by regulations can also provide rationale for improving broad-scale riparian management measures. Port Hawkesbury Paper is a company with certification under the Forest Stewardship Council (FSC) that operates on Crown and private land throughout Nova Scotia (Doucette & Miller 2015). There are 10 principles and 57 criteria that must be followed to gain FSC certification, demonstrating “environmentally sound, socially beneficial and economically prosperous management of forests” (FSC International 2021). Principle 9 states that High Conservation Value Forests (HCVF) must be identified and managed such that the attributes that define such forests are maintained or enhanced over time (FSC International 2021). For example, as part of a Nova Scotia-wide HCVF assessment done by Port Hawkesbury Paper, the St. Mary’s River in Guysborough County was identified as a ‘critical HCV watershed’ due to the presence of species at risk, significant ecosites, old forest, and large landscape-level forests (Doucette & Miller 2015). The watershed has the highest concentration of *SARA*-listed threatened Wood Turtles in Nova Scotia and supports the COSEWIC-assessed endangered population of Southern Upland Atlantic Salmon (Doucette & Miller 2015; COSEWIC 2010). Port Hawkesbury

Paper forest harvest operators have maintained a 200 m non-intensive selective harvest riparian buffer along all main St. Mary's River watercourses; a 100 m no-motorized vehicle buffer along perennial watercourses in April, May, and October; and a 150 m no-motorized vehicle buffer from June to September to help protect Wood Turtle and Atlantic Salmon habitat (Doucette & Miller 2015). As discussed previously (Section 3.3.), court cases that result from deleterious substance deposition (ss. 36(3)), fish habitat destruction (ss. 35(1)), or other *Fisheries Act* and *SARA* charges can potentially tarnish a company's reputation and make forest certification more difficult to obtain or maintain. Therefore, using the forestry industry as an example, companies may wish to implement management measures that offer greater riparian protection to ensure compliance with existing laws and policies, while also striving for certifications that may bolster conservation of the aquatic environment.

### *6.2. Indigenous Knowledge*

Understanding the historical local knowledge of a region would allow for greater interpretation of how the area(s) has changed over time and adds a societal dimension to consider. Indigenous cultural heritage, traditional use, and ecological knowledge information should be taken into account, with particular attention to riparian areas. Areas of Mi'kmaq cultural and/or spiritual significance, traditional use, rights, and title should be a priority consideration for determining riparian management measures. Global, national, and DFO initiatives have brought historical colonial events to the forefront and emphasized a focus on reconciliation with Indigenous peoples (McMillan & Prosper 2016; Noble et al. 2016; Giles et al. 2016; DFO 2019g). Indigenous peoples throughout Canada have a deep connection to the lands and waters along with the wildlife that occupy them (Gunn 2007; Abu et al. 2020). Examples of Indigenous cultural and spiritual significance, traditional use, rights, and title can take many forms, but one situation could be a lake or river reach that local First Nations use for subsistence fishing. Another example could be the presence of Indigenous artifacts that signal historical use by the Mi'kmaq. While largely situation and context dependent, riparian management measures must be developed in partnership with Indigenous peoples and communities that account for their interests and local governance structure over fisheries and natural resources. Where ecological, cultural, spiritual, recreational, and other values overlap, these areas should be treated with the utmost importance, with riparian habitat management techniques that reflect those values.

### *6.3. Sensitive Areas*

Another consideration in the development of riparian management measures is understanding the relative sensitivity of areas. There are likely discrete sensitive areas within larger watersheds or other large waterbodies that play an important role in maintaining fish and fish habitat, depending on the complexity or heterogeneity of the region of interest. Examples of sensitive areas could be known vulnerable stream lengths that fulfill a life history requirement (e.g. spawning) for an aquatic species at risk; a series of high connectivity wetlands with high species richness; or an isolated lake that contains the last self-sufficient population of an endemic fish species. Depending on the threats to riparian habitat, it is important that riparian management measures offer adequate protection for fish and fish habitat in sensitive locations. This may involve extensions of

variable-width riparian buffers to greater distances from watercourses. Habitat restoration efforts may target destroyed or degraded riparian zones around sensitive areas first to offer greater future connectivity to the riparian buffer zone. Where riparian habitat is privately-owned and managed around a sensitive area, it is recommended that engagement occurs with landowners to discuss more protective riparian habitat regulations or best management practices (similar to what may occur in BMZs, regulated by the Nova Scotia *Biodiversity Act*). Terrestrial protected areas (e.g. provincial parks, wilderness areas, nature reserves) already have protection from human impacts in some form or another. A variable-width riparian buffer system could add an extra layer of protection to protected areas where management measures for fish and fish habitat protection would likely be easier to enforce, whether or not sensitive areas are present.

Another way to inform buffer delineation is by the Nova Scotia 'wet areas mapping' (WAM) model, a spatial dataset that may be useful for determining natural water flow and accumulation areas (Province of Nova Scotia 2007). This could be helpful to determine where sensitive riparian areas should be preserved to protect important watercourses or wetlands for fish and fish habitat. The model algorithm was developed by the Atlantic Forest Research Collaborative at the University of New Brunswick, designed to offer more predictive management strategies to improve sustainability in terrestrial and freshwater ecosystem and habitat management (Arp 2019). The WAM product is based on a province-wide 10 x 10 m digital elevation model (DEM) and existing spatial knowledge of water resources to provide a comparison of ground-surface elevation with the above or below-ground water table elevation (Province of Nova Scotia 2007). The result is a 'depth to water' index, in which classes that are a low depth have a greater likelihood of having natural water flows, and thus human activities in these more vulnerable areas are more likely to cause negative impacts to freshwater ecosystems, fish, and fish habitat. The WAM model is currently being used by forest managers for "harvest block layout planning, optimizing trail and road routing to reduce road construction and road maintenance costs, assessing location-specific species suitability for planting, and deciding on field accessibility or operations timing" (Arp 2019). Thus, WAM model could be used to support potential changes to riparian management measures. The WAM model may be evaluated to determine an appropriate 'depth to water' metric that could be used as a variable-width riparian buffer to protect fish and fish habitat. New high resolution LiDAR-based freshwater and landscape digital elevation models have recently became available in Nova Scotia (Province of Nova Scotia 2020b), which should also be investigated for applicability to inform riparian zone management.

### *6.4. Cumulative Effects*

In the context of the FFHPP, DFO defines 'cumulative effects' as "any cumulative harmful impacts on fish and fish habitat that are likely to result from the work, undertaking or activity in combination with other works, undertakings, or activities that have been or are being carried out" (DFO 2019f). Further, DFO states that "the consideration of cumulative effects provides a better understanding of the challenges to the aquatic ecosystem outside of the context of the reviews of specific works, undertakings, or activities. The Department is responsible for collecting the information needed to consider the cumulative effects of a proposed work, undertaking or activity" (DFO 2019f). While the theoretical concept of cumulative effects is rather simple, quantifying many activities

across many locations that impact fish and fish habitat in a continuous system to varying degrees can pose a unique set of challenges (MacDonald 2000; Stelzenmüller et al. 2018; Stelzenmüller et al. 2020; Murray et al. 2020; Kuglerová et al. 2017).

Murray et al. (2020) suggests that two main approaches can be split into four frameworks for assessing cumulative effects (Figure 11). Cumulative effects assessments can "use a top-down approach (starting from the human activity or stressor and identifying all the potential impacts on ecosystem components), a bottom-up approach (starting from the ecosystem component(s) and identifying all potential impacts and stressors) or a combination of the two" (Murray et al. 2020).

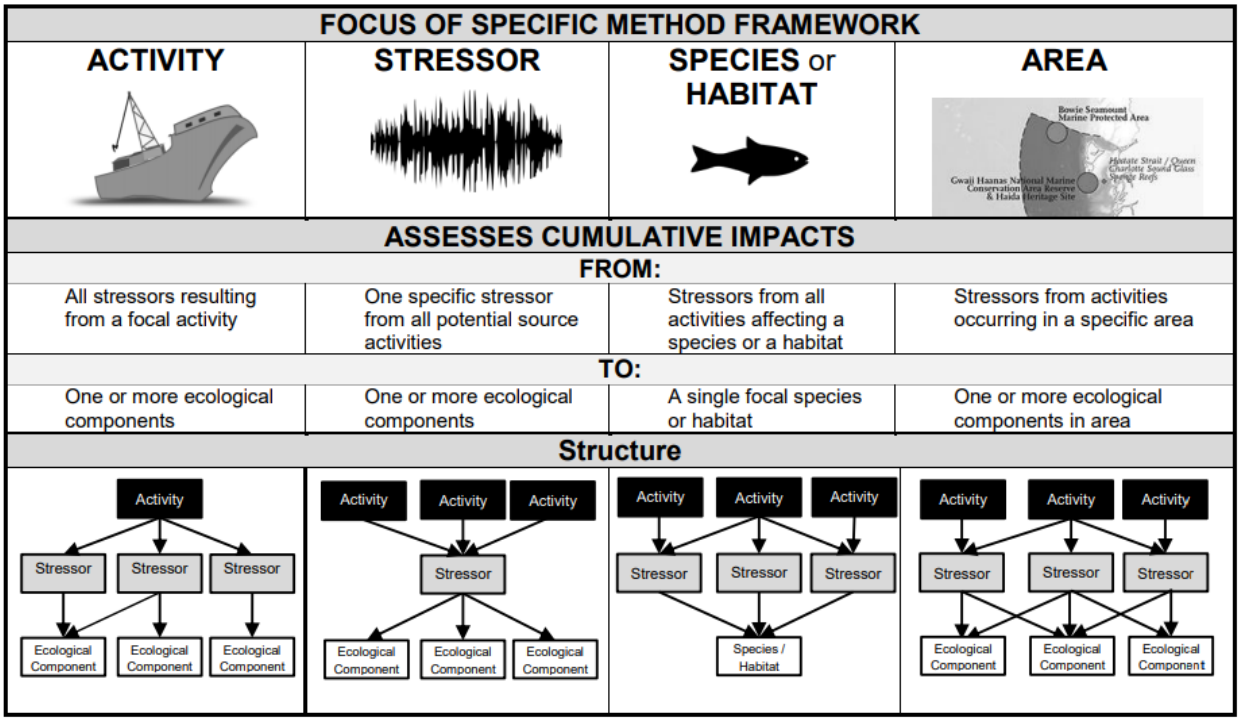


***Figure 11**: proposed Cumulative Effects Assessment strategy for DFO, comprising four types of method frameworks. (Murray et al. 2020)*

In the context of riparian habitat management, a possible avenue to apply this approach could be the integration of a specified spatial-scale (e.g., a watershed) riparian disturbance threshold, depending on the fish or fish habitat protection objectives. It may be appropriate to use an umbrella species, defined as "a species whose conservation is expected to confer protection to a large number of naturally co-occurring species" (Roberge & Angelstam 2004), to determine the watershed-scale riparian disturbance threshold required to limit the risk of cumulative effects fish populations. Other components of the ecosystem that are subject to cumulative effects could be used as well, depending on the desired conservation objective and monitoring strategy (e.g. percentage of impervious surface across a watershed).

However, identifying risk pathways can have high degrees of uncertainty due to spatial-temporal variability of cause and effect relationships (Stelzenmüller et al. 2018; Stelzenmüller et al. 2020). Full data coverage when identifying cumulative effects risks is

rare, so assumptions are made that may cause the accepted level of risk threshold to stray from reality (Stelzenmüller et al. 2018; Stelzenmüller et al. 2020). It is also worth noting that, in scientific literature, cumulative effects on fish or fish habitat are often assessed from a single disturbance-driver perspective (e.g., migration barriers) (Peterson et al. 1992; Fu et al. 2018; Cooper et al. 2017) while DFO (2019f) is taking responsibility for "challenges to the aquatic ecosystem outside of the context of the reviews of specific works, undertakings, or activities." The proposed riparian management regime should attempt to preserve riparian connectivity while promoting heterogeneity and staying below an accepted risk threshold for cumulative riparian impacts on fish and fish habitat. In consideration of the factors discussed above, a combination of fixed and variable riparian buffer widths are recommended to promote habitat connectivity and a lower risk of cumulative effects (Section 7).

# 7. Options and Recommendations for Riparian Management in Nova Scotia

A review of the scientific literature (Section 2), policies in other jurisdictions (Section 3), and the Lahey (2018) report demonstrate that the current riparian buffer requirements for different types of human activities in Nova Scotia are likely not sufficient for the general protection of fish and fish habitat. Therefore, a new system should be proposed that may better reflect the science behind riparian habitat protection alongside other important real-world considerations (Section 6). Riparian management options around priority areas for fish and fish habitat protection in Nova Scotia include:

1. status quo for all WUAs (Section 4); follow the Province of Nova Scotia's lead on recent commitments that are in the process of being implemented, such as the triad model of ecological forestry from the Lahey (2018) report and conservation goals from the *Environmental Goals and Climate Change Reduction Act* (Section 5); or
2. engage with the Province of Nova Scotia, municipalities, Indigenous peoples, industries, and private landowners, to coordinate the addition of a low-impact riparian buffer to offer greater fish protection, and add a selective disturbance buffer beyond the low-impact buffer to model natural disturbance and allow some economic returns in riparian areas.

Option two would minimize the edge effect on watercourses and offer the ability to extend riparian buffer zones in areas of high ecological or cultural importance. This option forms the basis of the recommendations for Nova Scotia and is outlined in greater detail below.

**A low-impact riparian buffer begins at the ordinary high water mark and extends outward into the upland habitat around priority areas for fish or fish habitat protection. Priority areas may include federal riparian management measures (e.g., ESAs or species at risk critical habitat) and other riparian habitats located throughout Nova Scotia**. This riparian buffer is intended to limit human disturbance, where high-impact works, undertakings, or activities (WUAs) that could affect fish and fish habitat should be avoided. The low-impact buffer would not apply to existing structures or WUAs, but could be used to help manage newly proposed WUAs (described below).

WUAs that should be avoided in the low-impact riparian buffer zone (initial **30 m**, detailed below) to promote compliance with the *Fisheries Act* and *SARA* would include any activity that could cause unavoidable negative changes to the seven riparian biophysical processes that support aquatic species habitat (Figure 2, Table 1; DFO 2020a). Examples include fertilizer and pesticide application, the removal of merchantable timber, livestock grazing, the use of motorized vehicles, and other activities. High-impact WUAs are similar to items included within the inventory of 'activities likely to destroy' riparian critical habitat for aquatic species at risk recovery strategies (Section 3.2.). The selective disturbance buffer zone could have similar requirements as the low-impact buffer zone, with the exception that vehicle access is permitted and merchantable timber harvesting can occur. The restrictions in the Nova Scotia *Wildlife Habitat and Watercourses Protection Regulations* could be applied to the selective disturbance buffer. Even when timber harvest is not occurring, the *Wildlife Habitat and Watercourses Protection Regulations* (in effect since 2002) still offer existing guidance for landowners to abide by in the selective disturbance buffer layer when conducting any WUAs.

It has been recognized that riparian management measures could be improved to provide greater protection to Nova Scotia's fish-bearing freshwater environments (Lahey 2018; Lee et al. 2004; Stoffyn-Egli & Duinker 2013). Riparian management should consider the broader (watershed) scale; ecologically important or sensitive areas within such watersheds, including existing protected areas; and management differences on Crown and private land. Watersheds with intact riparian zones, a high degree of naturalness, and predicted future resilience to climate change should be given priority for greater levels of riparian protection. Areas with large inhabited floodplains, high biodiversity meander belts, and habitats for species at risk need to also be given priority consideration.

The following riparian management recommendations were developed based on a comprehensive review of relevant riparian management scientific and grey literature, and current or anticipated future riparian buffer regulatory/best management practice regimes in Nova Scotia and other jurisdictions that have been outlined above. Additional considerations include land cover, use and ownership, sensitive areas, future threats of climate change, and cumulative effects. In addition, recommendations were informed by advice and feedback provided by DFO staff from various regions/programs and staff from the Province of Nova Scotia.

**These recommendations may inform future discussions with the Province of Nova Scotia to apply differently at various scales (e.g., at the provincial scale compared to specific areas that require enhanced management) and can also serve as a starting point for other jurisdictions in Canada.**

### *7.1. Crown Land*

The following recommendations are provided for the management of riparian areas on Crown land:

**Broad-scale (watershed) application**:

A cumulative buffer width of **60 m** (Figure 12) is recommended:

- A **30 m** low-impact riparian buffer is recommended along fish-bearing, permanent, perennial or intermittent tributaries and connected waterbodies, including lakes, rivers, wetlands, and any other areas of interest for fish and fish habitat protection (Figure 12).
- To reduce the edge effect outside of the low-impact buffer, a further **30 m** buffer is recommended where selective disturbance is permitted, following the same SMZ restrictions as the Nova Scotia *Wildlife Habitat and Watercourses Protection Regulations*, in which no forestry operator shall:
    - permit the use of a vehicle for forestry operations within 7 m of the low impact buffer;
    - reduce the basal area of living trees to less than 20 $m^2$ per hectare; or
    - create an opening in the dominant tree canopy larger than 15 m at its greatest dimension.
- It is also recommended that cumulative riparian buffers of **100 m** or larger are identified around areas where recreational or aesthetic values are important to preserve, in accordance with the scientific addendum (Hunter & Van Damme 2018) attached to recommendation 25 from the Lahey (2018) report.

**Sensitive Areas (described in Section 6.3.)**:

A cumulative buffer width of **100 m** (Figure 12) is recommended:

- As above, a **30 m** low-impact riparian buffer is recommended;
- It is recommended that the selective disturbance buffer increase to **70 m**, following the same SMZ restrictions described above.

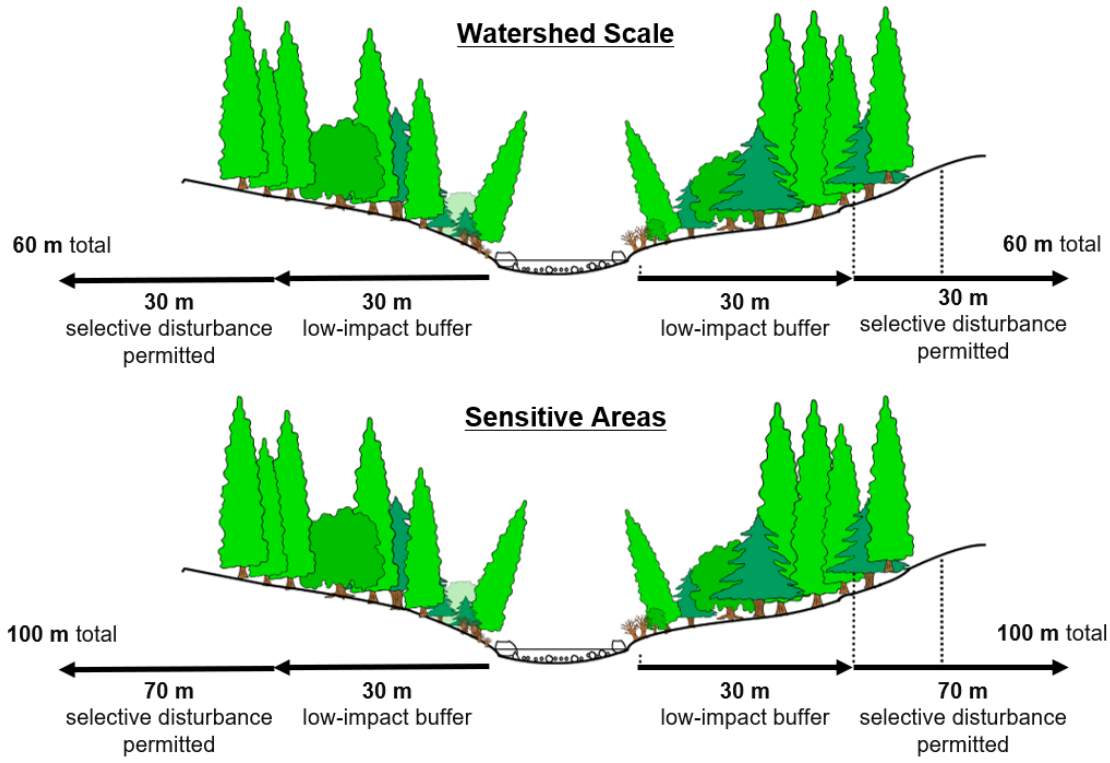


***Figure 12**: Cross section diagram of recommended Crown land riparian management measures*

### *7.2. Private Land*

The selection of an appropriate riparian management approach for private land may differ depending on the location and must be informed through engagement with the Province of Nova Scotia, private landowners, Indigenous peoples, and other stakeholders. The list below provide **options** with varying degrees of riparian habitat protection (Figure 13):

**Broad-scale (watershed) application**:

1) Work with private landowners to promote voluntary best management practices and stewardship activities, but do not impose new riparian management measures on private land; allow riparian buffer zones to continue to be managed by existing provincial legislation and municipal bylaws.
2) For federal riparian management measures (i.e., ESAs or species at risk critical habitat) on private land, mirror the buffer width and prohibitions required by any existing or proposed provincial regulations or municipal bylaws that apply on private land for each accompanying WUA; for example:
    - **20 m** selective harvest for forestry (**30**, **40**, or up to **100 m** in accordance with Lahey report recommendations (Section 5.1.))
    - **10 m** 'no cut' zone, as per the Lahey report recommendations (Section 5.1.).
    - **5 m** for farmland (i.e. crops, pastures); larger buffers (**30, 50, 100 m**) for agriculture storage, livestock, processing facilities (depending on the municipality)
    - **10**, **15**, **20 m** watercourse setback for residential development (depending on the municipality)
    - **10 – 100 m** estuary/marine shoreline building setback, as per the *Coastal Protection Act*
    - Work with private landowners to promote voluntary best management practices and stewardship activities.
3) Apply the recommended Crown land low-impact buffer management measures with a reduced width of **20 m**.
4) Apply the recommended Crown land low-impact buffer width (**30 m**) but allow selective harvest forestry (following the *Wildlife Habitat and Watercourses Protection Regulations*) to occur up to 10 m from the ordinary high water mark or floodplain edge.
5) Apply the same Crown land recommendations (low impact (**30 m**) and selective disturbance (**30 m**) buffer width and management measures) on private land as well.

**Sensitive Areas (described in Section 6.3.)**:

Discussions with private landowners around sensitive areas would inform the options for changes to riparian management in specific sensitive areas. At a minimum, it is desirable to attain a **30 m** low-impact riparian buffer. A selective disturbance buffer may also be implemented outside of the low-impact zone, with the specific width(s) dictated by landowner engagement, ecological requirements, and other regulatory considerations.

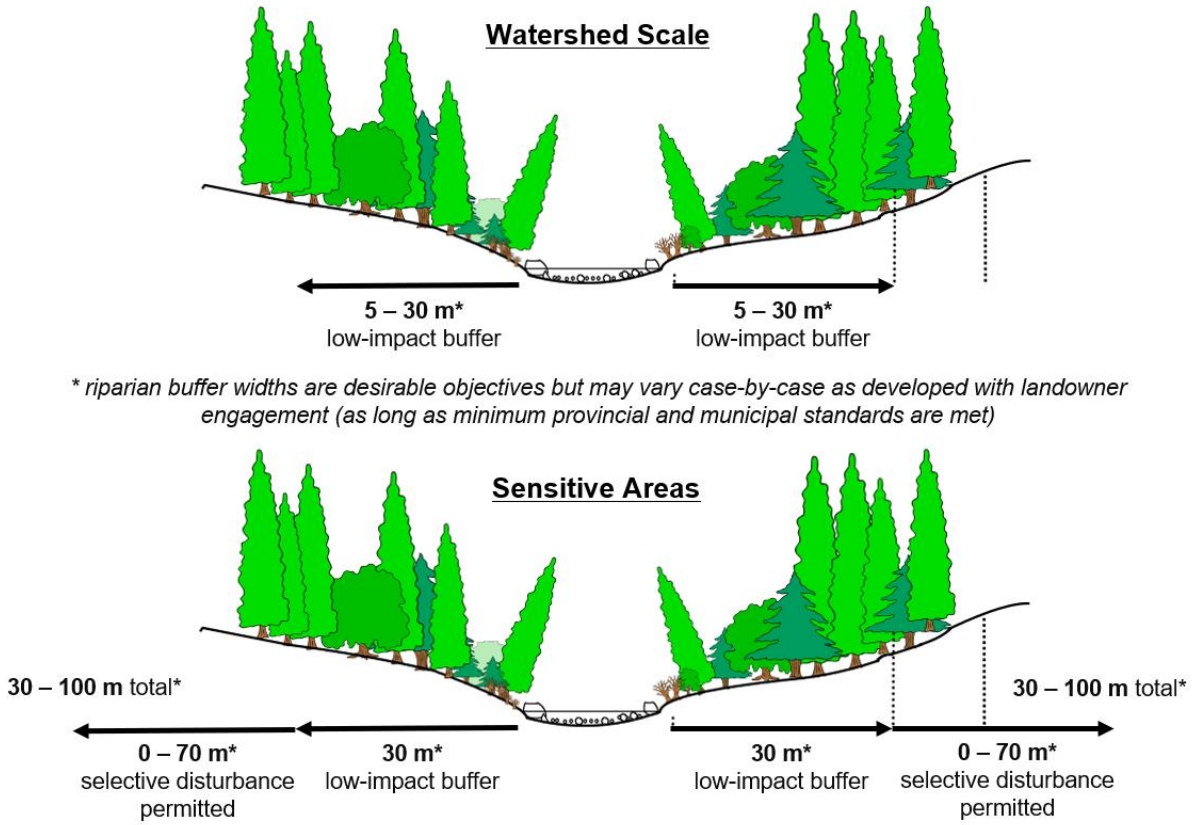


***Figure 13**: Cross section diagram of recommended private land riparian management measures*

***Table 7**: Summary of riparian buffer width recommendations around priority areas for fish or fish habitat protection (including species at risk critical habitat and ESAs)*

| | **Crown land** | **Private land** |
|---|---|---|
| **Watershed Scale** | Low-impact buffer (**30 m**) + **30 m** selective disturbance buffer = **60 m** total | Low-impact buffer (**5 – 30 m**)* |
| **Sensitive Areas** | Low-impact buffer (**30 m**) + **70 m** selective disturbance buffer = **100 m** total | Low-impact buffer (**30 m**)* + **0 – 70 m*** selective disturbance buffer = **30 – 100 m** total* |

* private land riparian buffer size is a desirable objective, but will depend on which recommendation(s) is chosen and will likely vary on a case-by-case basis as developed with landowner engagement.

### *7.3. FFHPP – Province of Nova Scotia Collaboration*

As explored in Section 4.2., the FFHPP regulatory reviews process differs between the DFO Maritimes and Gulf regions due to the associated provincial legislation and triaging process for watercourse alterations. The provincial regulatory gap in Nova Scotia likely causes province-wide riparian management and cumulative effects to be more difficult for DFO to analyze and track over time in the Maritimes Region. It is recommended that DFO Maritimes Region work with the Province of Nova Scotia to

amend the *Activities Designation Regulations* such that riparian alterations are captured in the watercourse/wetland alteration permitting process, using New Brunswick or PEI as an example for choosing a specific buffer size. It is also recommended that DFO engage with the Province of Nova Scotia and municipalities to discuss the above proposed riparian management measures and how they overlap/interact with provincial legislation and municipal land-use bylaws. In most locations, the immediate riparian area along fish-bearing watercourses is overlapping federal and provincial jurisdiction, subject to various pieces of legislation. This requires coordination among levels of government to ensure adequate protection. For example, with possible riparian buffer extensions that allow selective disturbance on Crown land, it is necessary that the province aligns the added federal fish and fish habitat protection objectives with their own priorities.

It is also recommended that DFO engage with the Province of Nova Scotia to identify areas where riparian buffers of >100 m should be identified, particularly for larger lakes or river sections where recreational, aesthetic, or ecological values are important to preserve, in accordance with the addendum (Hunter & Van Damme 2018) attached to recommendation 25 from the Lahey (2018) report. These locations may also present an opportunity to establish BMZs from the *Biodiversity Act* to offer terrestrial and aquatic protection for other species.

### *7.4. Critical Habitat for Freshwater Species at Risk*

Where scientific advice indicates that riparian areas support specific life history functions of a species at risk, DFO should continue identifying riparian areas as critical habitat. The Inner Bay of Fundy population of Atlantic Salmon is listed as Endangered under *SARA*, and it is recommended that any amendments to the identification of critical habitat in the recovery strategy consider the inclusion of riparian habitat. The nine other designatable units (DUs) of the species in eastern Canada are currently under consideration for listing under *SARA.* For the threatened or endangered DUs, the inclusion of riparian habitat should also be considered in the identification of critical habitat if these populations are listed under *SARA*. Water temperature and quality are critical components of Atlantic Salmon habitat, both of which are greatly influenced by land-use activities in the riparian zone (Bowlby et al. 2014). Avoiding or mitigating negative impacts from riparian degradation or destruction would provide ecosystem benefits that not only support the conservation of Atlantic Salmon, but can preserve ecosystem functioning for other freshwater and anadromous species. Other well-known COSEWIC-assessed species in Nova Scotia such as Atlantic Sturgeon (*Acipenser oxyrinchus*; Threatened), Striped Bass (*Morone saxatilis*; Endangered – Bay of Fundy Population), and American Eel (*Anguilla rostrata*; Threatened) would likely benefit from riparian habitat protection by critical habitat protection if listed under *SARA*, using ESAs for key areas, or through other means.

### *7.5. FFHPP Assessment of Cumulative Effects*

DFO “is responsible for collecting the information needed to consider the cumulative effects of a proposed work, undertaking or activity” for a better understanding of a region-specific set of challenges to the aquatic ecosystem (DFO 2019f). Thus, it is also recommended that DFO identifies what data is available and what information needs to be collected in order to conduct species, habitat, or area-based cumulative effects

assessments for the purpose of riparian management (Murray et al. 2020). Assessments of this nature could be helpful for determining what watershed-scale thresholds of shoreline vegetation removal (parallel to the watercourse ordinary high water mark) would be allowable to maintain riparian connectivity sufficient to protect fish and fish habitat. Fishless, intermittent streams must also be considered within a cumulative effects assessment framework due to their high importance as indirect fish habitat. It may be possible to isolate specific vegetation removal thresholds per stream length, stream order, or watershed branch, depending on the area of interest. A cumulative effects assessment also might indicate that very little to no shoreline vegetation removal would be allowable for successful protection of fish and fish habitat in specific areas. DFO Science (Dey et al. 2021) identified immediate research priorities for freshwater fish habitat in Canada, with DFO employees and other freshwater fish experts collaborating to create a list of research questions, if addressed, would significantly advance freshwater fish habitat management across Canada. Six out of the top 10 highest priority research questions included topics revolving around evaluating cumulative effects tipping points, addressing different forms of land-use impacts on fish habitat, and identifying allowable habitat modification thresholds for fish populations across spatial scales (Dey et al. 2021). The study showed that there are knowledge gaps in these areas, but offered direction for researchers and policy makers to topics that would allow the FFHPP provisions of the *Fisheries Act* to be applied to the fullest extent possible (Dey et al. 2021). The proposed low-impact riparian buffer system (Section 7) is intended to address the current cumulative effects uncertainty associated with watershed-scale riparian removal thresholds by using proactive protection wherever possible.

# 8. Conclusion

Riparian zone management is critically important to protect fish and fish habitat, and the federal *Fisheries Act* gives DFO the ability to impose riparian management measures in riparian habitat, included in the definition of ‘fish habitat’ under ss. 2(1) of the Act. DFO’s jurisdiction is demonstrated through protected riparian critical habitat for several *SARA*-listed threatened or endangered freshwater fish species (DFO 2020a); an emphasis in DFO-published documents linking riparian ecology and pathways of effects with fish and fish habitat (DFO 2010; DFO 2019f; DFO 2020a; Caskenette et al. 2020); and numerous *Fisheries Act* charges laid on the grounds of HADDs to fish or fish habitat that were caused by the removal or alteration of riparian habitat (described in Section 3.3.). However, the jurisdictional boundaries of riparian zone management are not discrete lines that can be drawn on a map, but rather context-specific overlapping areas that require communication and collaboration to strive for effective management decision-making, as well as compliance with the federal *Fisheries Act*, *Species at Risk Act*, provincial legislation, and municipal by-laws. A collaborative approach to introducing or revising riparian management measures for the protection of fish and fish habitat (including species at risk and critical habitat) is new in Nova Scotia, but can be accomplished through proactive and frequent discussions with the province, municipalities, private landowners, Indigenous peoples, and other stakeholders. Provincial commitments already in motion, such as the ‘triad model of ecological forestry’ from the Lahey report or ‘biodiversity management zones’ from the *Biodiversity Act*, should be used to align conservation and environmental objectives between federal and

provincial departments. This report provided a background and analysis of factors for DFO Maritimes Region to consider when developing riparian management policies to protect fish and fish habitat, particularly through area-based conservation tools such as species at risk critical habitat or ESAs. The literature review, policy analyses, and subsequent recommendations may act as a preliminary framework for consolidating riparian management into DFO programs across Nova Scotia and the rest of Canada.

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[1] DFO, Integrated Planning, FFHPP

[2] DFO, Regulatory Reviews, FFHPP

[3] DFO, Engagement and Partnerships

[4] DFO, Species at Risk Program

[5] DFO, Fisheries and Ecosystem Science

[6] Province of Nova Scotia, DNRR, Wildlife Division

# References

## *Legal Sources*


Bill 4, *Biodiversity Act,* 3rd Sess, 63rd General Assembly, Nova Scotia, 2021 (assented to April 19, 2021), S.N.S. 2021, c. 3.

*Environmental Goals and Climate Change Reduction Act*, S.N.S. 2021, c. 20

*Clean Water Act*, S.N.B. 1989, c. C-6.1.

*Coastal Protection Act,* S.N.S. 2019, c. 3.

*Crown Lands Act*, R.S.N.S. 1989, c. 114.

*Crown Lands and Forests Act*, S.N.B. 1980, c C-38.1.

*Environment Act*, S.N.S. 1994-95, c. 1.

*Environmental Protection Act*, R.S.P.E.I. 1988, c. E-9.

*Fisheries Act*, R.S.C. 1985, c. F-14.

*Forests Act,* R.S.A. 2000, c. F-22.

*Forests Act*, R.S.N.S. 1989, c. 179.

*Municipal Government Act*, S.N.S. 1998, c. 18.

*Provincial Parks Act*, R.S.N.S. 1989, c. 367.

*Riparian Areas Protection Act*, S.B.C. 1997, c. 21.

*Species at Risk Act*, S.C. 2002, c. 29.

*Wildlife Act*, R.S.A. 2000, c. W-1.

Environmental Defence Canada v. Canada (Fisheries and Oceans), 2009 FC 878 (CanLII), <https://canlii.ca/t/25l43>.

R. v. Basso, 2001 BCSC 801 (CanLII), <https://canlii.ca/t/4x9k>.

R. v. Brown, 2010 BCCA 225 (CanLII), <https://canlii.ca/t/2b29h>.

R v French, 2019 ABPC 149 (CanLII), <https://canlii.ca/t/j15qx>.

R. v. Grewal and Mallhi, 2011 BCPC 205 (CanLII), <https://canlii.ca/t/fmrng>.

R. v. Gwaii Wood Products Ltd. et al, 2017 BCPC 6 (CanLII), <https://canlii.ca/t/glpbf>.

R. v. Larsen, 2015 BCSC 1334 (CanLII), <https://canlii.ca/t/gkff8>.

R. v. Montgomery, 2014 ONSC 2775 (CanLII), <https://canlii.ca/t/g705x>.

R. v. Northland Properties Corporation, 2015 BCSC 1571 (CanLII), <https://canlii.ca/t/gkz78>.

R v. Rhodes et al, 2007 BCPC 1 (CanLII), < https://canlii.ca/t/1q8t6>.

R. v. Sapp, 2005 BCPC 166 (CanLII), <https://canlii.ca/t/1kf28>.

## *Literature Cited*


Alberta Westslope Cutthroat Trout Recovery Team [AWCTRT]. (2013). Alberta Westslope Cutthroat Trout Recovery Plan: 2012 – 2017. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 28. Edmonton, AB. 77pp. https://open.alberta.ca/dataset/c9ab0297-c99a-4478-b9e5-ff8d7b9d2c03/resource/ab4527e8-0643-47ec-842a-efd79a6221b5/download/6246341-2013-alberta-westslope-cutthroat-trout-recovery-plan.pdf.

Albertson, L. K., Ouellet, V., & Daniels, M. D. (2018). Impacts of stream riparian buffer land use on water temperature and food availability for fish. *Journal of Freshwater Ecology*, *33*(1), 195-210. https://doi.org/10.1080/02705060.2017.1422558.

Alexander, L. C., Autrey, B., DeMeester, J., Fritz, K. M., Golden, H. E., Goodrich, D. C., Kepner, W. G., Lane, C. R., LeDuc, S., Leibowitz, S. G., McManus, M. G., Pollard, A. I., Kiperwas, H. R., Ridley, C. E., Schofield, K., Vanderhoof, M. V., & Wigington, P. J. (2015). Connectivity of streams and wetlands to downstream waters: A review and synthesis of the scientific evidence. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/475F. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=296414.

Alexander, R. B., Boyer, E. W., Smith, R. A., Schwarz, G. E., & Moore, R. B. (2007). The role of headwater streams in downstream water quality 1. *Journal of the American Water Resources Association*, *43*(1), 41-59. https://doi.org/10.1111/j.1752-1688.2007.00005.x.

Arp, P. Wet areas mapping technology. *Atlantic Forest Research Collaborative*. https://blogs.unb.ca/afrc-research-highlights/2019/05/wet-areas-mapping.php.

Beese, W. J., Rollerson, T. P., & Peters, C. M. (2019). Quantifying wind damage associated with variable retention harvesting in coastal British Columbia. *Forest Ecology and Management*, *443*, 117-131. https://doi.org/10.1016/j.foreco.2019.04.019.

Berrigan, A., Halme, P., Peura, M., & Oldén, A. (2020). Are wide but selectively logged buffer strips better than narrow ones?. *Scandinavian Journal of Forest Research*, 1-11. https://doi.org/10.1080/02827581.2020.1858957.

Bowler, D. E., Mant, R., Orr, H., Hannah, D. M., & Pullin, A. S. (2012). What are the effects of wooded riparian zones on stream temperature?. *Environmental Evidence*, *1*(1), 1-9. http://dx.doi.org/10.1186/2047-2382-1-3.

Bowlby, H.D., Horsman, T., Mitchell, S.C., and Gibson, A.J.F. (2014). Recovery Potential Assessment for Southern Upland Atlantic Salmon: Habitat Requirements and Availability, Threats to Populations, and Feasibility of Habitat Restoration. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/006. vi + 155 p. https://waves-vagues.dfo-mpo.gc.ca/Library/359664.pdf.

Braithwaite, N. T., & Mallik, A. U. (2012). Edge effects of wildfire and riparian buffers along boreal forest streams. *Journal of Applied Ecology*, *49*(1), 192-201. https://doi.org/10.1111/j.1365-2664.2011.02076.x.

British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development [BCFLNRORD]. (2019). Riparian Areas Protection Regulation technical assessment manual. *Province of British Columbia*. https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/riparian-areas-regulations/rapr_assessment_methods_manual_for_web_11.pdf.

Brumberg, H., Beirne, C., Broadbent, E. N., Almeyda Zambrano, A. M., Almeyda Zambrano, S. L., Quispe Gil, C. A., Lopez, G. B., Eplee, R., & Whitworth, A. (2021). Riparian buffer length is more influential than width on river water quality: A case study in southern Costa Rica. *Journal of Environmental Management*, *286*, 112132. https://doi.org/10.1016/j.jenvman.2021.112132.

Capon, S. J., & Pettit, N. E. (2018). Turquoise is the new green: Restoring and enhancing riparian function in the Anthropocene. *Ecological Management & Restoration*, *19*, 44-53. https://doi.org/10.1111/emr.12326.

Capon, S. J., Chambers, L. E., Mac Nally, R., Naiman, R. J., Davies, P., Marshall, N., Pittock, J., Reid, M., Capon, T., Douglas, M., Catford, J., Baldwin, D. S., Stewardson, M., Roberts, J., Parsons, M., & Williams, S. E. (2013). Riparian ecosystems in the 21st century: hotspots for climate change adaptation?. *Ecosystems*, *16*(3), 359-381. https://doi.org/10.1007/s10021-013-9656-1.

Caskenette, A. L., Durhack, T. C., & Enders, E. C. (2020). Review of information to guide the identification of Critical Habitat in the riparian zone for listed freshwater fishes and mussels. *DFO Can. Sci. Advis. Sec. Res. Doc*, *49*. https://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2020/20-35/publications.gc.ca/collections/collection_2020/mpo-dfo/fs70-5/Fs70-5-2020-049-eng.pdf.

Caskenette, A., Durhack, T., Hnytka, S., Kovachik, C., & Enders, E. (2021). Evidence of effect of riparian attributes on listed freshwater fishes and mussels and their aquatic critical habitat: a systematic map protocol. *Environmental Evidence*, *10*(1), 1-10. https://doi.org/10.1186/s13750-021-00231-1.

Cole, L. J., Stockan, J., & Helliwell, R. (2020). Managing riparian buffer strips to optimise ecosystem services: A review. *Agriculture, Ecosystems & Environment, 296*, 106891. https://doi.org/10.1016/j.agee.2020.106891.

Colvin, S. A., Sullivan, S. M. P., Shirey, P. D., Colvin, R. W., Winemiller, K. O., Hughes, R. M., ... & Eby, L. (2019). Headwater streams and wetlands are critical for sustaining fish, fisheries, and ecosystem services. *Fisheries*, *44*(2), 73-91. https://doi.org/10.1002/fsh.10229.

COSEWIC. (2010). COSEWIC assessment and status report on the Atlantic Salmon *Salmo salar* (Nunavik population, Labrador population, Northeast Newfoundland population, South Newfoundland population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Lake Ontario population, Gaspé-Southern Gulf of St. Lawrence population, Eastern Cape Breton population, Nova Scotia Southern Upland population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xlvii + 136 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/cosewic/sr_Atlantic_Salmon_2011a_e.pdf.

Cunjak, R. A., Curry, R. A., Scruton, D. A., & Clarke, K. D. (2004). Fish-forestry interactions in freshwaters of Atlantic Canada - Fishes and forestry: worldwide watershed interactions and management. 439-462. *Blackwell Science Publishing*. https://onlinelibrary.wiley.com/doi/pdf/10.1002/9780470995242.

De Sosa, L. L., Glanville, H. C., Marshall, M. R., Abood, S. A., Williams, A. P., & Jones, D. L. (2018). Delineating and mapping riparian areas for ecosystem service assessment. *Ecohydrology*, *11*(2), e1928. https://doi.org/10.1002/eco.1928.

Department of Natural Resources and Renewables [NSDNRR]. (2018). Crown land in Nova Scotia. Province of Nova Scotia. https://novascotia.ca/natr/land/.

Deschenes, J., Rodriguez, M. A., & Berube, R. (2007). Context-dependent responses of juvenile Atlantic salmon (Salmo salar) to forestry activities at multiple scales within a river basin. *Canadian Journal of Fisheries and Aquatic Sciences, 64*, 1069-1079.

DeWalle, D. R. (2010). Modeling stream shade: Riparian buffer height and density as important as buffer width. *Journal of the American Water Resources Association*, *46*(2), 323-333. https://doi.org/10.1111/j.1752-1688.2010.00423.x.

Dey, C. J., Rego, A. I., Bradford, M. J., Clarke, K. D., McKercher, K., Mochnacz, N. J., ... & Koops, M. A. (2021). Research priorities for the management of freshwater fish habitat in Canada. *Canadian Journal of Fisheries and Aquatic Sciences*. https://doi.org/10.1139/cjfas-2021-0002.

DFO [Fisheries and Oceans Canada]. (2009). Recovery potential assessment of pure native Westslope Cutthroat Trout, Alberta population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/050. https://waves-vagues.dfo-mpo.gc.ca/Library/337838.pdf.

DFO. (2010). Vegetation clearing pathway of effects. *Government of Canada*. https://www.dfo-mpo.gc.ca/pnw-ppe/pathways-sequences/vegetation-eng.html.

DFO. (2013). Recovery potential assessment for Southern Upland Atlantic Salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/009. https://waves-vagues.dfo-mpo.gc.ca/Library/348496.pdf.

DFO. (2017). Information in Support of Critical Habitat Identification for Striped Bass (*Morone saxatilis*) of the St. Lawrence River. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/001. https://waves-vagues.dfo-mpo.gc.ca/Library/40597234.pdf.

DFO. (2018a). Annual Report to Parliament on the Administration and Enforcement of the Fisheries Protection and Pollution Prevention Provisions of the *Fisheries Act* – April 1, 2016 to March 31, 2017.: v + 45 p. https://waves-vagues.dfo-mpo.gc.ca/Library/40812212.pdf.

DFO. (2018b). Recovery Strategy for the Misty Lake Sticklebacks (*Gasterosteus aculeatus*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. iv + 41 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-MistyLakeStickleback-v00-2018Apr-Eng.pdf.

DFO. (2019a). Recovery Potential Assessment of Redside Dace (*Clinostomus elongatus*) in Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/012. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2019/2019_012-eng.pdf.

DFO. (2019b). Action Plan for the Vancouver Lamprey (*Entosphenus macrostomus*) in Canada. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. iv + 39 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Ap-LamprioeVancouverLamprey-v00-2019-En.pdf.

DFO. (2019c). Recovery Strategy for Paxton Lake, Enos Lake, and Vananda Creek Stickleback Species Pairs (*Gasterosteus aculeatus*) in Canada. *Species at Risk Act* Recovery

Strategy Series. Fisheries and Oceans Canada, Ottawa. ix + 45 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-SticklebacksEpinoches-v00-2019Aug-Eng.pdf.

DFO. (2019d). Recovery Strategy and Action Plan for the Striped Bass (*Morone saxatilis*), St. Lawrence River population, in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. v + 56p. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/RsAp-StripedBassBarRaye-v01-June2019-Eng1.pdf.

DFO. (2019e). Recovery Strategy and Action Plan for the Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) Alberta population (also known as Saskatchewan-Nelson River populations) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 61 pp + Part 2. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/RsAp-TruiteFardeeOuestWestslopeCutthroatTrout-v00-2019-Eng.pdf.

DFO. (2019f). Fish and fish habitat protection policy statement. *Government of Canada*. https://waves-vagues.dfo-mpo.gc.ca/Library/40971193.pdf.

DFO. (2019g). DFO-Coast Guard reconciliation strategy. *Government of Canada*. https://waves-vagues.dfo-mpo.gc.ca/Library/40947208.pdf.

DFO. (2019h). Measures to protect fish and fish habitat. *Government of Canada*. https://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures-eng.html.

DFO. (2020a). Guidance on the identification of Critical Habitat in the riparian zone for freshwater species at risk. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/040. 26pp. https://waves-vagues.dfo-mpo.gc.ca/Library/40940469.pdf.

DFO. (2020b). Recovery Strategy for the Bull Trout (*Salvelinus confluentus*), Saskatchewan-Nelson Rivers populations, in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. viii + 130 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-BullTroutOmblesTetePlateSaskNelson-v00-2020Sept-Eng.pdf.

DFO. (2020c). Recovery Strategy for the Rainbow Trout (*Oncorhynchus mykiss*) in Canada (Athabasca River populations). *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 90 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-AthabascaRainbowTroutTruiteArc-en-ciel-v00-2020Sept-Eng.pdf.

DFO. (2020d). Recovery Strategy and Action Plan for the Silver Shiner (*Notropis photogenis*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii + 48 p. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rsap-MeneMirroirSilverShinerProp-v00-2021Jan-Eng.pdf.

DFO. (2020e). Species at risk decision making. *Government of Canada*. https://www.dfo-mpo.gc.ca/transparency-transparence/mtb-ctm/2019/binder-cahier-1/1F4-sara-lep-eng.htm.

DFO. (2020f). Recovery Strategy for the Salish Sucker (*Catostomus sp*.) in Canada. 1st amendment. *Species at Risk Act* Recovery Strategy Series, Fisheries and Oceans

Canada, Vancouver. viii + 71 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-MeunierSalishSucker-v01-2020Jun-Eng.pdf.

DFO. (2020g). Recovery Strategy for the Nooksack Dace (*Rhinichthys cataractae* ssp.) in Canada. 1 st amendment. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vii+ 47 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/Rs-NaseuxNooksackDace-v00-feb2020-Eng.pdf.

DFO. (2020h). Information for identification of candidate critical habitat of Athabasca Rainbow Trout (*Oncorhynchus mykiss*). DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/029. https://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2020/2020_029-eng.pdf.

DFO. (2020j). FFHPP Regulatory review process map (FA, SARA, AISR). *Government of Canada*. https://www.dfo-mpo.gc.ca/pnw-ppe/reviews-revues/docs/process-map-plan-processus-eng.pdf.

DFO. (2020k). Permitting under the Species at Risk Act. *Government of Canada*. https://www.dfo-mpo.gc.ca/species-especes/sara-lep/permits-permis/index-eng.html.

DFO. (2021a). Standards and codes of practice. *Government of Canada*. https://www.dfo-mpo.gc.ca/pnw-ppe/practice-practique-eng.html.

DFO. (2021b). Science advice on revisiting Pathways of Effects (PoE) diagrams in support of FFHPP risk assessment. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/053. https://waves-vagues.dfo-mpo.gc.ca/Library/4102963x.pdf.

Dorreen, M., Dobson, S., & Thompson, I. (2021). Nova Scotia's new Biodiversity Act. *Cox & Palmer*. https://coxandpalmerlaw.com/publication/nova-scotias-new-biodiversity-act/.

Doucette, A., & Miller, C. (2015). High conservation value forest assessment update 2015 – 2020 FSC® Certification Period. Port Hawkesbury Paper LP. https://www.porthawkesburypaper.com/documents/PHP_HCVF%20Assessment%20Update%202015-2020%20compressed.pdf.

Ebersole, J. L., Wigington Jr, P. J., Leibowitz, S. G., Comeleo, R. L., & Sickle, J. V. (2015). Predicting the occurrence of cold-water patches at intermittent and ephemeral tributary confluences with warm rivers. *Freshwater Science*, *34*(1), 111-124. https://doi.org/10.1086/678127.

Ellis, J. H. (2008). Scientific recommendations on the size of stream vegetated buffers needed to protect fish and aquatic habitat, part two, the need for stream vegetated buffers: What does the science say? Report to Montana Department of Environmental Quality, EPA/DEQ Wetland Development Grant. Montana Audubon, Helena, MT. 20 pp. https://mtwatersheds.org/app/wp-content/uploads/2017/11/Vegetative-buffers-and-protection-of-aquatic-habitat.pdf.

Figary, S., Detenbeck, N., & O'Donnell, C. (2021). Guiding riparian management in a transboundary watershed through high resolution spatial statistical network models. *Journal of Environmental Management*, *278*, 111585. https://doi.org/10.1016/j.jenvman.2020.111585.

Flanagan, S. E., Patrick, D. A., Leonard, D. J., & Stacey, P. (2017). Buffer Options for the Bay: Exploring the Trends, the Science, and the Options of Buffer Management in the Great Bay Watershed Key Findings from Available Literature. *PREP Reports & Publications*, 380. 52pp. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1382&context=prep.

Forest Stewardship Council International. (2021). *Mission and vision*. https://us.fsc.org/en-us/what-we-do/mission-and-vision.

Fritz, K. M., Schofield, K. A., Alexander, L. C., McManus, M. G., Golden, H. E., Lane, C. R., Kepner, W. G., LeDuc, S. D., DeMeester, J. E., & Pollard, A. I. (2018). Physical and chemical connectivity of streams and riparian wetlands to downstream waters: A synthesis. *Journal of the American Water Resources Association*, *54*(2), 323-345. https://doi.org/10.1111/1752-1688.12632.

Fu, C., Travers-Trolet, M., Velez, L., Grüss, A., Bundy, A., Shannon, L. J., Fulton, E. A., Akoglu, E., Houle, J. E., Coll, M., Verley, P., Heymans, J. J., John, E., & Shin, Y. J. (2018). Risky business: The combined effects of fishing and changes in primary productivity on fish communities. *Ecological Modelling*, *368*, 265-276. https://doi.org/10.1016/j.ecolmodel.2017.12.003.

Gene, S. M., Hoekstra, P. F., Hannam, C., White, M., Truman, C., Hanson, M. L., & Prosser, R. S. (2019). The role of vegetated buffers in agriculture and their regulation across Canada and the United States. *Journal of environmental management*, *243*, 12-21. https://doi.org/10.1016/j.jenvman.2019.05.003.

Government of Canada. (2016). Nooksack dace (*Rhinichthys cataractae ssp*.): critical habitat order SOR/2016-82. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/critical-habitat-descriptions/nooksack-dace-order.html.

Government of Canada. (2018). Destruction of critical habitat for threatened Spotted Gar nets a $7,000 fine. https://www.canada.ca/en/fisheries-oceans/news/2018/11/destruction-of-critical-habitat-for-threatened-spotted-gar-nets-a-7000-fine.html.

Government of Canada. (2019). Introducing Canada's modernized Fisheries Act. https://www.dfo-mpo.gc.ca/campaign-campagne/fisheries-act-loi-sur-les-peches/introduction-eng.html.

Government of Canada. (2021). Species at Risk Act: information note for landowners. https://www.canada.ca/en/environment-climate-change/services/species-risk-education-centre/your-responsibility/landowners.html#toc1.

Government of New Brunswick. (2012). Watercourse and wetland alteration technical guidelines. *Department of Environment and Local Government*. https://www2.gnb.ca/content/dam/gnb/Departments/env/pdf/Water-Eau/WatercourseWetlandAlterationTechnicalGuidelines.pdf.

Government of New Brunswick. (2021). Watercourse alteration and wetland alteration permit*. Department of Environment and Local Government*. https://www2.gnb.ca/content/gnb/en/departments/elg/environment/content/land_waste/content/reference_manual/watercourse_and_wetlandalteration.html.

Government of Prince Edward Island. (2016). Watercourse , wetland and buffer zone activity guidelines. *Department of Environment, Water, and Climate Change*. https://www.princeedwardisland.ca/sites/default/files/publications/watercourse_wetland_and_buffer_zone_activity_guidelines_dec_2016.pdf.

Government of Prince Edward Island. (2021). Apply for a watercourse, wetland and buffer zone activity permit. *Department of Environment, Water, and Climate Change*.

https://www.princeedwardisland.ca/en/service/apply-watercourse-wetland-and-buffer-zone-activity-permit.

Gunn, B. L. (2007). Protecting Indigenous peoples' lands: Making room for the application of Indigenous peoples' laws within the Canadian legal system. *Indigenous Law Journal*, *6*, 31. https://heinonline.org/HOL/LandingPage?handle=hein.journals/ilj6&div=6&id=&page=.

Halifax Regional Municipality. (2000). *Land-Use Bylaw Mainland Area (Edition 209)*. https://www.halifax.ca/sites/default/files/documents/about-the-city/regional-community-planning/HalifaxMainlandLandUseBy-law-Edition209-Eff-21May08-Case22332-TOCLinked.pdf.

Halifax Regional Municipality. (2018). *Halifax Green Network Plan.* https://www.halifax.ca/sites/default/files/documents/about-the-city/regional-community-planning/HGNP-Final%20Report_20180726_updated.pdf.

Hanna, D. E., Raudsepp-Hearne, C., & Bennett, E. M. (2020). Effects of land use, cover, and protection on stream and riparian ecosystem services and biodiversity. *Conservation Biology, 34*(1), 244-255. https://doi.org/10.1111/cobi.13348.

Hansen, B. D., Reich, P., Cavagnaro, T. R., & Lake, P. S. (2015). Challenges in applying scientific evidence to width recommendations for riparian management in agricultural Australia. *Ecological Management & Restoration*, *16*(1), 50-57. https://doi.org/10.1111/emr.12149.

Harris, P., Dykens, T., Wright, T., Dehaan, R., & Westphal, K. (2019). Beneficial management practices for riparian zones in Atlantic Canada. *Island Nature Trust*. https://nsefp.ca/wp-content/uploads/2019/09/BMP-Atlantic-riparian_zones.pdf.

Hatfield, T. (2009). Identification of critical habitat for sympatric Stickleback species pairs and the Misty Lake parapatric Stickleback species pair. DFO Can. Sci. Advis. Rec. Res. Doc. 2009/056. vi + 35 p. https://waves-vagues.dfo-mpo.gc.ca/Library/339093.pdf.

Hawes, E., & Smith, M. (2005). Riparian buffer zones: functions and recommended widths. *Eightmile River Wild and Scenic Study Committee, 15*, 15pp. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.496.8230&rep=rep1&type=pdf.

Henshaw, B., & Ursic, M. 2012. Ecological buffer guideline review. *Beacon Environmental Limited*. https://cvc.ca/wp-content/uploads/2013/08/Ecological-Buffer-Guideline-Review.pdf.

Hunter, M., & Van Damme, L. (2018). *The shores of watercourses (riparian areas) - An independent review of forest practices in Nova Scotia, addendum*. https://novascotia.ca/natr/forestry/forest_review/FP_Addendum.pdf.

Isaak, D. J., Young, M. K., Luce, C. H., Hostetler, S. W., Wenger, S. J., Peterson, E. E., ... & Nagel, D. E. (2016). Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity. *Proceedings of the National Academy of Sciences*, *113*(16), 4374-4379. https://doi.org/10.1073/pnas.1522429113.

Johnson, R. K., & Almlöf, K. (2016). Adapting boreal streams to climate change: effects of riparian vegetation on water temperature and biological assemblages. *Freshwater Science*, *35*(3), 984-997. https://doi.org/10.1086/687837.

Jones, K. L., Poole, G. C., Meyer, J. L., Bumback, W., & Kramer, E. A. (2006). Quantifying expected ecological response to natural resource legislation: a case study of riparian buffers, aquatic habitat, and trout populations. *Ecology and Society*, *11*(2). https://www.jstor.org/stable/26266006.

Jones, L. P., Turvey, S. T., Massimino, D., & Papworth, S. K. (2020). Investigating the implications of shifting baseline syndrome on conservation. *People and Nature*, *2*(4), 1131-1144. https://doi.org/10.1002/pan3.10140.

Joseph, V., Schmidt, A.L., and Gregory, R.S. (2013). Use of eelgrass habitats by fish in eastern Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/138. ii + 12p. https://waves-vagues.dfo-mpo.gc.ca/Library/347914.pdf.

Kanno, Y., & Beazley, K. (2004). Freshwater fish considerations for aquatic conservation systems planning in Nova Scotia. *Proceedings of the Nova Scotian Institute of Science (NSIS)*, *42*(2). https://doi.org/10.15273/pnsis.v42i2.3612.

Klenk, N. L., Bull, G. Q., & MacLellan, J. I. (2009). The “emulation of natural disturbance”(END) management approach in Canadian forestry: A critical evaluation. *The Forestry Chronicle*, *85*(3), 440-445. https://doi.org/10.5558/tfc85440-3.

Kreutzweiser, D. P., Sibley, P. K., Richardson, J. S., & Gordon, A. M. (2012). Introduction and a theoretical basis for using disturbance by forest management activities to sustain aquatic ecosystems. *Freshwater Science*, *31*(1), 224-231.

Krumhansl, K. A., Dowd, M., & Wong, M. C. (2021). Multiple Metrics of Temperature, Light, and Water Motion Drive Gradients in Eelgrass Productivity and Resilience. *Frontiers in Marine Science*, *8*, 48. https://doi.org/10.3389/fmars.2021.597707.

Kubo, J., Thai, M., Higgins, K., & leDoux, B. 2019. *Synthesis of riparian buffer best available science: Informing variable-width buffers in the lower Snoqualmie Valley*. King County Water and Land Resources Division. https://kingcounty.gov/~/media/services/environment/watersheds/snoqualmie-skykomish/snoqualmie-fish-farm-flood/Buffers_Task_Force/Final_Synthesis_of_Riparian-_Buffer_Best_Available_Science_8_1_19.ashx?la=en.

Kuglerová, L., Hasselquist, E. M., Richardson, J. S., Sponseller, R. A., Kreutzweiser, D. P., & Laudon, H. (2017). Management perspectives on Aqua incognita: Connectivity and cumulative effects of small natural and artificial streams in boreal forests. *Hydrological Processes*, *31*(23), 4238-4244. https://doi.org/10.1002/hyp.11281.

Kuglerová, L., Jyväsjärvi, J., Ruffing, C., Muotka, T., Jonsson, A., Andersson, E., & Richardson, J. S. (2020). Cutting edge: A comparison of contemporary practices of riparian buffer retention around small streams in Canada, Finland, and Sweden. *Water Resources Research, 56*(9), e2019WR026381. https://doi.org/10.1029/2019WR026381.

Kukuła, K., & Bylak, A. (2022). Barrier removal and dynamics of intermittent stream habitat regulate persistence and structure of fish community. *Scientific Reports*, *12*(1), 1-14. https://doi.org/10.1038/s41598-022-05636-7.

Kurylyk, B. L., MacQuarrie, K. T., Linnansaari, T., Cunjak, R. A., & Curry, R. A. (2015). Preserving, augmenting, and creating cold-water thermal refugia in rivers: Concepts derived from research on the Miramichi River, New Brunswick (Canada). *Ecohydrology*, *8*(6), 1095-1108. https://doi.org/10.1002/eco.1566.

Labbe, T. R., & Fausch, K. D. (2000). Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. *Ecological Applications*, *10*(6), 1774-1791. https://doi.org/10.1890/1051-0761(2000)010[1774:DOISHR]2.0.CO;2.

Lahey, W. (2018). *An independent review of forest practices in Nova Scotia*. https://novascotia.ca/natr/forestry/Forest_Review/Lahey_FP_Review_Report_ExecSummary.pdf.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., ... & Xu, J. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, *11*(4), 261-269. https://doi.org/10.1016/S0959-3780(01)00007-3.

Lan, D., & Rui-Hong, Y. (2020). New grassland riparian zone delineation method for calculating ecological water demand to guide management goals. *River Research and Applications*, *36*(9), 1838-1851. https://doi.org/10.1002/rra.3707.

Lee, P., Smyth, C., & Boutin, S. (2004). Quantitative review of riparian buffer width guidelines from Canada and the United States. *Journal of Environmental Management*, *70*(2), 165-180. https://doi.org/10.1016/j.jenvman.2003.11.009.

Lehnert, S. J., Baillie, S. M., MacMillan, J., Paterson, I. G., Buhariwalla, C. F., Bradbury, I. R., & Bentzen, P. (2020). Multiple decades of stocking has resulted in limited hatchery introgression in wild brook trout (*Salvelinus fontinalis*) populations of Nova Scotia. *Evolutionary Applications*, *13*(5), 1069-1089. https://doi.org/10.1111/eva.12923.

Lind, L., Hasselquist, E. M., & Laudon, H. (2019). Towards ecologically functional riparian zones: A meta-analysis to develop guidelines for protecting ecosystem functions and biodiversity in agricultural landscapes. *Journal of Environmental Management, 249*, 109391. https://doi.org/10.1016/j.jenvman.2019.109391.

MacDonald, L. H. (2000). Evaluating and managing cumulative effects: process and constraints. *Environmental management*, *26*(3), 299-315. https://doi.org/10.1007/s002670010088.

Macfarlane, W. W., McGinty, C. M., Laub, B. G., & Gifford, S. J. (2017). High-resolution riparian vegetation mapping to prioritize conservation and restoration in an impaired desert river. *Restoration Ecology*, *25*(3), 333-341. https://doi.org/10.1111/rec.12425.

Macnaughton, C. J., Durhack, T. C., Mochnacz, N. J., & Enders, E. C. (2021). Metabolic performance and thermal preference of Westslope cutthroat trout (Oncorhynchus clarkii lewisi) and non-native trout across an ecologically relevant range of temperatures. *Canadian Journal of Fisheries and Aquatic Sciences*, *78*(9), 1247-1256. https://doi.org/10.1139/cjfas-2020-0173.

Mäenpää, H., Peura, M., Halme, P., Siitonen, J., Mönkkönen, M., & Oldén, A. (2020). Windthrow in streamside key habitats: Effects of buffer strip width and selective logging. *Forest Ecology and Management*, *475*, 118405. https://doi.org/10.1016/j.foreco.2020.118405.

Maturana, O., Tonina, D., McKean, J. A., Buffington, J. M., Luce, C. H., & Caamaño, D. (2014). Modeling the effects of pulsed versus chronic sand inputs on salmonid spawning habitat in a low-gradient gravel-bed river. *Earth Surface Processes and Landforms*, *39*(7), 877-889. https://doi.org/10.1002/esp.3491.

McGrath, T., Pulsifer, M., Seymour, R., Doucette, L., Forbes, G., McIntyre, R., Milton, R., Cogan, L., Retallack, M., and Crewe, T. 2021. Nova Scotia Silvicultural Guide for the Ecological Matrix. *Nova Scotia Department of Natural Resources and Renewables*. https://novascotia.ca/ecological-forestry/docs/silvicultural-guide.pdf.

McMillan, L. J., & Prosper, K. (2016). Remobilizing netukulimk: Indigenous cultural and spiritual connections with resource stewardship and fisheries management in Atlantic Canada. *Reviews in fish biology and fisheries*, *26*(4), 629-647. https://doi.org/10.1007/s11160-016-9433-2.

Meyer, J. L., Strayer, D. L., Wallace, J. B., Eggert, S. L., Helfman, G. S., & Leonard, N. E. (2007). The contribution of headwater streams to biodiversity in river networks 1. *Journal of the American Water Resources Association*, *43*(1), 86-103. https://doi.org/10.1111/j.1752-1688.2007.00008.x.

Moidu, H., Obedzinski, M., Carlson, S. M., & Grantham, T. E. (2021). Spatial patterns and sensitivity of intermittent stream drying to climate variability. *Water Resources Research*, *57*(11), e2021WR030314. https://doi.org/10.1029/2021WR030314.

Moore, R. D., & Richardson, J. S. (2012). Natural disturbance and forest management in riparian zones: Comparison of effects at reach, catchment, and landscape scales. *Freshwater Science*, *31*(1), 239-247.

Municipality of Cumberland. (2018). *Land Use By-Law*. https://www.cumberlandcounty.ns.ca/1323-cumberland-land-use-bylaw-with-schedules-2020-web-1/file.html.

Municipality of the County of Kings. (2020). *By-Law 106 – Land Use By-Law*. https://www.countyofkings.ca/upload/All_Uploads/Living/services/planning/lub/bylaw/By-law%20106%20-%20Land%20Use%20By-law.pdf.

Municipality of the District of Guysborough [MODG]. (2013). Official land use revised by-law. http://modg.ca/sites/default/files/pdfs/LAND%20USE%20BYLAW.pdf.

Municipality of the District of St. Mary's. (2020). *Land use and Zoning Bylaw*. https://www.saint-marys.ca/policies-bylaws/600-land-use-by-law/file.html.

Murray, C., Hannah, L., & Locke, A. (2020). A review of cumulative effects research and assessment in Fisheries and Oceans Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3357: vii + 51 p. https://waves-vagues.dfo-mpo.gc.ca/Library/40851576.pdf.

Musetta-Lambert, J., Muto, E., Kreutzweiser, D., & Sibley, P. (2017). Wildfire in boreal forest catchments influences leaf litter subsidies and consumer communities in streams: Implications for riparian management strategies. *Forest Ecology and Management*, *391*, 29-41. https://doi.org/10.1016/j.foreco.2017.01.028.

Namba, M., Lotze, H. K., & Schmidt, A. L. (2018). Large-scale differences in community structure and ecosystem services of eelgrass (Zostera marina) beds across three regions in Eastern Canada. *Estuaries and coasts*, *41*(1), 177-192. https://doi.org/10.1007/s12237-017-0271-9.

Nilsson, C., Jansson, R., Kuglerová, L., Lind, L., & Ström, L. (2013). Boreal riparian vegetation under climate change. *Ecosystems*, *16*(3), 401-410. https://doi.org/10.1007/s10021-012-9622-3.

Noble, M., Duncan, P., Perry, D., Prosper, K., Rose, D., Schnierer, S., Tipa, G., Williams, E., Woods, R., & Pittock, J. (2016). Culturally significant fisheries: keystones for management of freshwater social-ecological systems. *Ecology and Society*, *21*(2). http://dx.doi.org/10.5751/ES-08353-210222.

Noseworthy, J. & Nussey, P. (2020). Freshwater Resilience to Climate Change for the Northern Appalachian–Acadian Region of Canada. *Nature Conservancy of Canada*. Atlantic Regional Office. Fredericton, New Brunswick. https://2c1forest.databasin.org/datasets/c3b6f4176558444a85f0218b4487749c/.

Nova Scotia Environmental Farm Plan [NSEFPP]. (2020). Environmental guide for Nova Scotia Farms. *Canadian Agricultural Partnership*. https://nsefp.ca/wp-content/uploads/2021/01/Env-Guide-for-NS-Farms-v2020_11.pdf.

Nova Scotia Nature Trust. (2021). *St. Mary's River.* https://nsnt.ca/our-work/campaigns-and-projects/project/st-marys-river/.

Oldén, A., Peura, M., Saine, S., Kotiaho, J. S., & Halme, P. (2019). The effect of buffer strip width and selective logging on riparian forest microclimate. *Forest Ecology and Management*, *453*, 117623. https://doi.org/10.1016/j.foreco.2019.117623.

Olson, D. H., Anderson, P. D., Frissell, C. A., Welsh Jr, H. H., & Bradford, D. F. (2007). Biodiversity management approaches for stream–riparian areas: Perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management*, *246*(1), 81-107. https://doi.org/10.1016/j.foreco.2007.03.053.

Olson, D. H., Johnson, S. L., Anderson, P. D., Penaluna, B. E., & Dunham, J. B. (2017). Aquatic-Riparian Systems. In *People, Forests, and Change*, pp. 191-206. Island Press, Washington, DC.

Pandit, S. N., Maitland, B. M., Pandit, L. K., Poesch, M. S., & Enders, E. C. (2017). Climate change risks, extinction debt, and conservation implications for a threatened freshwater fish: Carmine shiner (Notropis percobromus). *Science of the Total Environment*, *598*, 1-11. https://doi.org/10.1016/j.scitotenv.2017.03.228.

Pearson, M. (2008). An assessment of potential critical habitat for Nooksack dace (*Rhinichthys cataractae* ssp.) and Salish sucker (*Catostomus* sp.). DFO Can. Sci. Advis. Sec. Res. Doc. 2007/058. https://waves-vagues.dfo-mpo.gc.ca/Library/333992.pdf.

Pearson, M. P., Hatfield, T., McPhail, J. D., Richardson, J. S., Rosenfeld, J. S., Schreier, H., Schluter, D., Sneep, D. J., Stejpovic, M., Taylor, E. B., & Wood, P. M. (2008). Recovery Strategy for the Nooksack Dace (*Rhinichthys cataractae*) in Canada. *Species at Risk Act* Recovery Strategy Series, Fisheries and Oceans Canada, Vancouver. vi + 29 pp. https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/rs_nooksack_dace_0608_e.pdf.

Penaluna, B. E., Reeves, G. H., Barnett, Z. C., Bisson, P. A., Buffington, J. M., Dolloff, C. A., Filtcroft, R. L., Luce, C. H., Nislow, K. H., Rothlisberger, J. D., & Warren Jr, M. L. (2018). Using natural disturbance and portfolio concepts to guide aquatic–riparian ecosystem management. *Fisheries*, *43*(9), 406-422. https://doi.org/10.1002/fsh.10097.

Perry, L. G., Reynolds, L. V., Beechie, T. J., Collins, M. J., & Shafroth, P. B. (2015). Incorporating climate change projections into riparian restoration planning and design. *Ecohydrology*, *8*(5), 863-879. https://doi.org/10.1002/eco.1645.

Peterson, N. P., Hendry, A. P., & Quinn, T. P. (1992). *Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions* (p. 75). Timber, Fish & Wildlife. https://geo.nwifc.org/CMER/PublicDocs/TFWDocs/TFW_F3_92_001.pdf.

Poesch, M. S., Chavarie, L., Chu, C., Pandit, S. N., & Tonn, W. (2016). Climate change impacts on freshwater fishes: a Canadian perspective. *Fisheries*, *41*(7), 385-391. https://doi.org/10.1080/03632415.2016.1180285.

Pollock, M. M., & Kennard, P. M. (1998). A low-risk strategy for preserving riparian buffers needed to protect and restore salmonid habitat in forested watersheds of Washington State. 10,000 Years Institute, Bainbridge Island, Washington. https://www.researchgate.net/publication/237501883_A_low-risk_strategy_for_preserving_riparian_buffers_needed_to_protect_and_restore_salmonid_habitat_in_forested_watersheds_of_Washington_state.

Pusey, B. J., & Arthington, A. H. (2003). Importance of the riparian zone to the conservation and management of freshwater fish: a review. *Marine and freshwater Research*, *54*(1), 1-16. https://doi.org/10.1071/MF02041.

Province of British Columbia. (2021). Working on the land base. https://www2.gov.bc.ca/gov/content/industry/natural-resource-use.

Province of Nova Scotia. (2006). Manure Management Guidelines. *Department of Agriculture*. https://novascotia.ca/thinkfarm/documents/manureguide_2006lowres.pdf.

Province of Nova Scotia. (2007). Nova Scotia Wet Areas [vector digital shapefile metadata]. *Department of Natural Resources and Renewables*. https://novascotia.ca/natr/forestry/gis/Wam_wtbl_2012.xml#Entity_and_Attribute_Information.

Province of Nova Scotia. (2012*).* Nova Scotia's Code of Forest Practice: A framework for the implementation of sustainable forest management. *Department of Natural Resources and Renewables*. https://novascotia.ca/natr/forestry/reports/Code-of-Forest-Practice.pdf.

Province of Nova Scotia. (2015). Guide to altering watercourses. *Department of Environment and Climate Change*. https://novascotia.ca/nse/watercourse-alteration/docs/NSE-Watercourse-Alteration-Program-May29.pdf.

Province of Nova Scotia. (2017a). A Guide to Agricultural Best Management Practices within Municipal Drinking Water Supply Areas in Nova Scotia. *Department of Agriculture and Department of Environment and Climate Change*. https://www.nsefp.ca/wp-content/uploads/2017/04/Watershed_WEB_Final_2017.pdf.

Province of Nova Scotia. (2017b). Private Land Conservation. *Department of Environment and Climate Change*. https://novascotia.ca/nse/protectedareas/privateconservation.asp.

Province of Nova Scotia. (2018). Government response to the independent review of forest practices in Nova Scotia. *Department of Natural Resources and Renewables*. https://novascotia.ca/natr/forestry/forest_review/Government-Response-to-Independent-Forestry-Report.pdf.

Province of Nova Scotia. (2019). Nova Scotia Wetlands Conservation Policy. *Department of Environment and Climate Change*. https://novascotia.ca/nse/wetland/docs/nova.scotia.wetland.conservation.policy.pdf.

Province of Nova Scotia. (2020a). Watercourse alteration. *Department of Environment and Climate Change.* https://novascotia.ca/nse/watercourse-alteration/.

Province of Nova Scotia. (2020b). New Provincial LiDAR available. https://geonova.novascotia.ca/news-blog/new-provincial-lidar-available.

Province of Nova Scotia. (2021). A detailed guide to proposed Coastal Protection Act regulations. *Department of Environment and Climate Change*. https://novascotia.ca/coast/docs/part-2-detailed-guide-to-proposed-Coastal-Protection-Act-Regulations.pdf.

RDRT (Redside Dace Recovery Team). (2010). Recovery Strategy for Redside Dace (*Clinostomus elongatus*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, ON. vi + 29 p. https://files.ontario.ca/environment-and-energy/species-at-risk/286971.pdf.

Region of Queens Municipality. (2009). *Land Use Bylaw*. https://www.regionofqueens.com/document-library/bylaws/municipal-bylaws/24-bylaw-24-regional-land-use-bylaw/file.

Richardson, J. S., & Béraud, S. (2014). Effects of riparian forest harvest on streams: a meta-analysis. *Journal of Applied Ecology*, *51*(6), 1712-1721. https://doi.org/10.1111/1365-2664.12332.

Richardson, J. S., Naiman, R. J., & Bisson, P. A. (2012). How did fixed-width buffers become standard practice for protecting freshwaters and their riparian areas from forest harvest practices? *Freshwater Science, 31*(1), 232-238.

Rideout, E. (2012). Setbacks and vegetated buffers in Nova Scotia. *Nova Scotia Environment, Canada: Hydrologic Systems Research Group*. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.712.407&rep=rep1&type=pdf.

Riis, T., Kelly-Quinn, M., Aguiar, F. C., Manolaki, P., Bruno, D., Bejarano, M. D., ... & Dufour, S. (2020). Global overview of ecosystem services provided by riparian vegetation. *BioScience*, *70*(6), 501-514. https://doi.org/10.1093/biosci/biaa041.

Roberge, J. M., & Angelstam, P. E. R. (2004). Usefulness of the umbrella species concept as a conservation tool. *Conservation biology*, *18*(1), 76-85. https://doi.org/10.1111/j.1523-1739.2004.00450.x.

Roon, D. A., Dunham, J. B., & Groom, J. D. (2021). Shade, light, and stream temperature responses to riparian thinning in second-growth redwood forests of northern California. *PloS one*, *16*(2), e0246822. https://doi.org/10.1371/journal.pone.0246822.

Schilling, K. E., Jacobson, P. J., & Wolter, C. F. (2018). Using riparian Zone scaling to optimize buffer placement and effectiveness. *Landscape ecology*, *33*(1), 141-156. https://doi.org/10.1007/s10980-017-0589-5.

Seavy, N. E., Gardali, T., Golet, G. H., Griggs, F. T., Howell, C. A., Kelsey, R., Small, S. L., Viers, J. H., & Weigand, J. F. (2009). Why climate change makes riparian restoration more important than ever: recommendations for practice and research. *Ecological Restoration*, *27*(3), 330-338. https://doi.org/10.3368/er.27.3.330.

Sergeant, C. J., Moynahan, B. J., & Johnson, W. F. (2012). Practical advice for implementing long-term ecosystem monitoring. *Journal of Applied Ecology*, *49*(5), 969-973. https://doi.org/10.1111/j.1365-2664.2012.02149.x.

Sibley, P. K., Kreutzweiser, D. P., Naylor, B. J., Richardson, J. S., & Gordon, A. M. (2012). Emulation of natural disturbance (END) for riparian forest management: synthesis and recommendations. *Freshwater Science*, *31*(1), 258-264.

Sibley, P., & Gordon, A. (2010). Managing riparian forests. A decision support system. *Sustainable Forest Management Network*, Edmonton, Alberta. 42pp. https://era.library.ualberta.ca/items/a8ecb3e4-065b-4dea-b286-273fe316c115/view/8543adc1-727d-4f7c-9e38-8a8c06ebc380/SR_2010_Sibley-Gordon_RiparianForest_En.pdf.

Singh, R., Tiwari, A. K., & Singh, G. S. (2021). Managing riparian zones for river health improvement: an integrated approach. *Landscape and Ecological Engineering, 17*, 195-223. https://doi.org/10.1007/s11355-020-00436-5

Smokorowski, K. E., & Pratt, T. C. (2007). Effect of a change in physical structure and cover on fish and fish habitat in freshwater ecosystems–a review and meta-analysis. *Environmental Reviews*, *15*, 15-41. https://doi.org/10.1139/a06-007.

Soga, M., & Gaston, K. J. (2018). Shifting baseline syndrome: causes, consequences, and implications. *Frontiers in Ecology and the Environment*, *16*(4), 222-230. https://doi.org/10.1002/fee.1794.

Sonesson, J., Ring, E., Högbom, L., Lämås, T., Widenfalk, O., Mohtashami, S., & Holmström, H. (2020). Costs and benefits of seven alternatives for riparian forest buffer management. *Scandinavian Journal of Forest Research*, 1-9. https://doi.org/10.1080/02827581.2020.1858955.

Statistics Canada. (2017). Farms with a formal Environmental Farm Plan (EFP), Canada and provinces, 2017. *Government of Canada.* https://www150.statcan.gc.ca/n1/daily-quotidien/190426/t005b-eng.htm.

Stelzenmüller, V., Coll, M., Cormier, R., Mazaris, A. D., Pascual, M., Loiseau, C., Claudet, J., Katsanevakis, S., Gissi, E., Evagelopoulos, A., Rumes, B., Degraer, S., Ojaveer, H., Moller, T., Gimenez, J., Piroddi, C., Markantonatou, V. & Dimitriadis, C. (2020). Operationalizing risk-based cumulative effect assessments in the marine environment. *Science of the Total Environment*, *724*, 138118. https://doi.org/10.1016/j.scitotenv.2020.138118.

Stelzenmüller, V., Coll, M., Mazaris, A. D., Giakoumi, S., Katsanevakis, S., Portman, M. E., Degen, R., Mackelworth, P., Gimpel, A., Albano, P. G., Almpanidou, V., Claudet, J., Essl, F., Evagelopoulos, T., Heymans, J. J., Genov, T., Kark, S., Micheli, F., & Ojaveer, H. (2018). A risk-based approach to cumulative effect assessments for marine management. *Science of the Total Environment*, *612*, 1132-1140. https://doi.org/10.1016/j.scitotenv.2017.08.289.

Stoffyn-Egli, P., & Duinker, P. N. (2013). An ecological approach to riparian-buffer definition, and implications for timber harvests in Nova Scotia, Canada. *Journal of sustainable development*, *6*(12), 111. http://dx.doi.org/10.5539/jsd.v6n12p111.

Stutter, M., Baggaley, N., Ó hUallacháin, D., & Wang, C. (2021). The utility of spatial data to delineate river riparian functions and management zones: a review. *Science of The Total Environment*, *757*, 143982. https://doi.org/10.1016/j.scitotenv.2020.143982.

Sumaila, U. R., Palacios-Abrantes, J., & Cheung, W. (2020). Climate change, shifting threat points, and the management of transboundary fish stocks. *Ecology and Society*, *25*(4). https://doi.org/10.5751/ES-11660-250440.

Sweeney, B. W., & Newbold, J. D. (2014). Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. *Journal of the American Water Resources Association*, *50*(3), 560-584. https://doi.org/10.1111/jawr.12203.

Tiwari, T., Lundström, J., Kuglerová, L., Laudon, H., Öhman, K., & Ågren, A. M. (2016). Cost of riparian buffer zones: A comparison of hydrologically adapted site-specific riparian buffers with traditional fixed widths. *Water Resources Research*, *52*(2), 1056-1069. https://doi.org/10.1002/2015WR018014.

Vaidya, O. C., Smith, T. P., Fernand, H., & Leek, N. R. M. (2008). Forestry best management practices: Evaluation of alternate streamside management zones on stream water quality in Pockwock Lake and Five Mile Lake Watersheds in Central Nova Scotia, Canada. *Environmental monitoring and assessment*, *137*(1), 1-14. https://doi.org/10.1007/s10661-006-9370-y.

Vander Vorste, R., Obedzinski, M., Nossaman Pierce, S., Carlson, S. M., & Grantham, T. E. (2020). Refuges and ecological traps: Extreme drought threatens persistence of an endangered fish in intermittent streams. *Global change biology*, *26*(7), 3834-3845. https://doi.org/10.1111/gcb.15116.

Wang, M., Duan, L., Wang, J., Peng, J., & Zheng, B. (2020). Determining the width of lake riparian buffer zones for improving water quality base on adjustment of land use structure. *Ecological Engineering*, *158*, 106001. https://doi.org/10.1016/j.ecoleng.2020.106001.

Warrington, B. M., Aust, W. M., Barrett, S. M., Ford, W. M., Dolloff, C. A., Schilling, E. B., Wigley, T. B., & Bolding, M. C. (2017) Forestry best management practices relationships with aquatic and riparian fauna: A review. *Forests, 8*(9), 331. https://doi.org/10.3390/f8090331.

Wasser, L. A., & Chasmer, L. E. (2012). Assessing anthropogenic influence and edge effect influence on forested riparian buffer spatial configuration and structure: An example using Lidar remote sensing methods. *AGU Fall Meeting Abstracts* (Vol. 2012, pp. B31A-0403). https://ui.adsabs.harvard.edu/abs/2012AGUFM.B31A0403W/abstract.

Wigington Jr, P. J., Ebersole, J. L., Colvin, M. E., Leibowitz, S. G., Miller, B., Hansen, B., ... & Compton, J. E. (2006). Coho salmon dependence on intermittent streams. *Frontiers in Ecology and the Environment*, *4*(10), 513-518. https://doi.org/10.1890/1540-9295(2006)4[513:CSDOIS]2.0.CO;2.

Wilbur, N. M., O'Sullivan, A. M., MacQuarrie, K. T., Linnansaari, T., & Curry, R. A. (2020). Characterizing physical habitat preferences and thermal refuge occupancy of brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) at high river temperatures. *River Research and Applications*, *36*(5), 769-783. https://doi.org/10.1002/rra.3570.

Wilhere, G. F., & Quinn, T. (2018). How wide is wide enough: Science, values, and law in riparian habitat conservation. *Natural Resources Journal*, *58*, 279-318. https://digitalrepository.unm.edu/nrj/vol58/iss2/13.

Woo-Durand, C., Matte, J. M., Cuddihy, G., McGourdji, C. L., Venter, O., & Grant, J. W. (2020). Increasing importance of climate change and other threats to at-risk species in Canada. *Environmental Reviews*, *28*(4), 449-456. https://doi.org/10.1139/er-2020-0032.

Zaharescu, D. G., Palanca-Soler, A., Hooda, P. S., Tanase, C., Burghelea, C. I., & Lester, R. N. (2017). Riparian vegetation in the alpine connectome: Terrestrial-aquatic and terrestrial-terrestrial interactions. *Science of the Total Environment*, *601*, 247-259. https://doi.org/10.1016/j.scitotenv.2017.05.135.

# Appendix A – Agriculture-related Setback Distances in Nova Scotia Municipal Drinking Water Supply Areas

| Agriculture Activity | Minimum Setback Distance (Meters) | | | |
|---|---|---|---|---|
| | Intake Source[1] | Wellhead | Lake, River, Brook | Ditches |
| **Manure and Compost Application** | 200 | 200 | 20 [2] | 5 |
| **Pasturing Livestock** | 30 | 30/15 [3] | 5 | 5 |
| **Livestock Facilities** [4] (Non-Contained Storage - Solid manure) | 200 | 200 | 100 | 20 |
| **Livestock Facilities** [3] (Fully Contained Storage - Liquid manure) | 200 | 100 | 50 | 20 |
| **Chemical Fertilizer Loading** | 200 | 200 | 200 | 200 |
| **Chemical Fertilizer Application** | 50 | 50 | 10 | 5 |
| **Fuel Storage** | 200 | 200 | 200 | 30 |
| **Pesticide Storage and Handling** | 200 | 200 | 30 | 30 |
| **Pesticide Application** [5] | 200 | 30 | 30 | 5 |

1 The source water body in which an intake structure is located. In the case of a river, beyond 200 m upstream, the setback distance for lakes, rivers, and brooks applies.

2 As per Section 3.2.2, 20m if slope is less than 2%; 50m if slope 2-5%; 100m if slope 5-10%.

3 30m to a dug well and 15m to a drilled well.

4 New Livestock facilities

5 Pesticide application should follow the recommended setback distances in this table or the distances supplied on the label, whichever is higher.

***Figure 14**: Recommended minimum setback distances from water features within the municipal water supply areas for agriculture activities in Nova Scotia. Use the largest setback distance from the applicable regulations and/or guide (Province of Nova Scotia 2017a)*

# Appendix B – Riparian Forestry Guidelines in other Canadian Jurisdictions

***Table 8**: Summary of riparian forestry guidelines in other provinces in Canada (Hunter & Van Damme 2018)*

| Province | Existing riparian regulations, guidelines, or best management practices |
|---|---|
| *British Columbia* | ▪ Results-based approaches to riparian management under the *Forest and Range Practices Act* (FRPA) are designed to provide for increased management flexibility and are informed by existing watershed-scale information and (or) new data from integrated riparian assessments.<br>Under the FRPA, two options are available for riparian system management (Tschaplinski and Pike, 2010):<br>▪ the default prescriptive approach, using fixed width buffers ranging from 0 to 50 m, no-harvest riparian reserve zones, and possibly additional modified riparian management zones 20–100 m (see Forest Planning and Practices Regulation Part 4, Practices Requirements, Division 3 – Riparian Areas).<br>▪ an alternative approach set out in a Forest Stewardship Plan and approved by government, which contains results or strategies that are consistent with government's objectives for riparian areas.<br>Common practice is often to use default prescription since many lack the resources to develop rationale for alternative approaches |
| *Alberta* | ▪ The *Forests Act*, Timber Management Regulation and Timber Harvest Planning and Operating Ground Rules (Section 6.0, Watershed Protection) provide mandatory direction for protection of riparian systems in forest management.<br>▪ Riparian protection areas shall be established as per Standards and Guidelines for Operating Beside Watercourses (Table 2 of the Ground Rules, Section 6.0).<br>▪ Section 6.0.6 – Unless otherwise approved in a Forest Management Plan, variances from the standards must demonstrate that aquatic and terrestrial objectives are met. Any such proposals shall undergo a full review by Alberta as a component of the FMP review and are required to be approved by the Forestry Program Manager.<br>▪ As per the Ground Rules, riparian buffers can range in width from 30 m to 200 m, depending on the riparian value.<br>▪ Since 2011, a Riparian Management Review Committee has been examining the question of how best to manage riparian systems to maintain functions and value (FRI Research 2013).<br>▪ In instances of overlapping land use or activities (e.g., forest harvest operating together with oil and gas exploration), the manner in which riparian lands are managed is directed by the laws, regulations, and standards that are specific to that particular land use or activity. |
| *Saskatchewan* | ▪ In Saskatchewan each major Forest Management Area holder did its own Environmental Impact Assessment and 20-year forest management plan.<br>▪ As a result, each FMA has its own 'custom' standards and guidelines (FMA Standards and Guidelines). |

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| | ▪ Direction on riparian management is provided by the Saskatchewan Environment/DFO Fish Habitat and Protection Guidelines on Road Construction and Stream Crossings (1995), including recommended vegetation buffers for bodies of water and different stream classes.<br>▪ Common practice is to apply the SE/DFO fixed-width buffers (15 – 90 m) to protect riparian values. |
| *Manitoba* | ▪ Forest Management Guidelines for Riparian Areas (2009) are based on a series of keys called the Riparian Management Decision Framework (RMDF).<br>▪ These provide flexibility to accommodate the various resource values and site conditions identified through pre-harvest surveys, recognizing the natural range of variability on the landscape.<br>▪ Management actions are guided by defined zones that include the following:<br>▪ Riparian Area (RA): For operational purposes, the RA will end at the edge of the merchantable forest. No forestry activity will be permitted within the RA.<br>▪ Riparian Management Area (RMA): The forested area adjacent to the RA where forest management activities can be approved. Management may include protection or disturbance through forest management activities.<br>▪ Any proposed activities in the RMA must be approved by Manitoba Conservation's Integrated Resource Management Teams.<br>▪ RMA is further divided into three zone types:<br>▪ Machine-free zone (MFZ) – no operation of machinery is allowed within this approximately 7 m zone, but harvesting is allowed.<br>▪ Management zone (MZ) – prescribed harvesting activities may take place (as described in Table 2 of the Guidelines).<br>▪ Reserve zone (RZ) – no harvest, mechanical, or ground disturbance will take place in the RZ, (width will depend on the feature or function being protected).<br>▪ RZ and MZ, or in some cases only BMPs, may be applied as defined in the Guidelines. |
| *Ontario* | ▪ The 2010 Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales (Section 4.1 – Maintaining Ecological Functions of Aquatic and Wetland Ecosystems and Shoreline Forest Including Habitat Suitability and Productive Capacity) provides mandatory direction on how impacts from forestry activities on riparian systems will be mitigated.<br>▪ Ontario has moved on from the fixed-width buffer approach and permits harvesting in riparian zones, subject to detailed conditions laid out in the guide – riparian harvesting is considered in wood supply calculations for forest management plans.<br>The guide divides riparian systems and standards into two main categories:<br>▪ Standards, guidelines, and best-management practices for lakes and ponds and associated shoreline forest<br>▪ Standards, guidelines, and best-management practices for rivers, streams, and associated shoreline forest<br>The guidelines are very detailed, and allow for a wide range of approaches to the management of riparian systems. |

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|---|---|
| | ▪ They take a risk-based approach to management prescriptions, in that the prescriptions consider the sensitivity of a given riparian system to different types of disturbance. |
| *Quebec* | ▪ The Quebec government is currently conducting a comprehensive review of its forest management regulations to incorporate criteria of sustainable forest management. However, it is not expected that the Regulations on sustainable forest development (RADF) will come into force until 2015.<br>▪ In the interim, riparian management is regulated under the Regulation Respecting Standards of Forest Management for Forests in the Domain of the State, Section II, Protection of Banks, Lakes and Rivers which describes riparian management standards for Quebec Crown lands (Règlement sur les normes d'intervention dans les forêts du domaine public).<br>▪ Riparian forests along the banks of streams, lakes, and wetlands with a shoreline slope inclination of less than 40% receive a 20 m riparian management zone. Selective logging is permissible in this zone, provided a minimum of 500 trees/ha (with diameter of 10 cm measured at 1.3m) is retained.<br>▪ Riparian forests along the banks of streams, lakes, and wetlands with a shoreline slope inclination greater than 40% receive a 20 m riparian reserve zone.<br>▪ There are separate standards for salmon streams, which can receive a 20–100 m riparian buffer, depending on the values identified (e.g., juvenile vs. adult salmon – approximately 115 of thousands of known rivers and streams are classified as salmon streams in the province). See Intégration des territoires et habitats fauniques aux stratégies d'aménagement forestier des UAF 09751 et 02452 – Octobre 2011. |
| *Newfoundland & Labrador* | ▪ Newfoundland and Labrador has a policy recommendation for riparian forest protection that is incorporated as a binding contractual provision in forest management contracts.<br>▪ The 1998 Environmental Protection Guidelines for Ecologically Based Forest Resource Management(Section 1.2, Operations) recommend a 20 m reserve zone around all water bodies greater than 1 m wide. These requirements may be increased at the discretion of the district manager to account for shoreline slope as well as fish and wildlife habitat needs. Where the slope is greater than 30% there shall be a no-harvest buffer of 20 m + (1.5 x % slope).<br>▪ Unspecified additional buffer zone requirements may be imposed when operations are within water supply areas or within 200 m of certain designated salmon streams.<br>▪ Small waterbodies, less than 1 m wide, which do not appear on 1:50,000 scale topographic maps, have no recommended protection for their riparian forests.<br>▪ Reasonable efforts will be made to identify intermittent streams. |

# Appendix C – Jurisdictional Classification of Ecological Regions in Lee et al. (2004)

***Table 9**: Classification of provinces, territories, and states from Canada and the United States into broad ecological regions for riparian buffer width quantitative analysis (Lee et al., 2004)*

| Country | Regions | Jurisdictions |
|---|---|---|
| *Canada* | Boreal | Alberta, Manitoba, Newfoundland, Northwest Territories, Ontario, Quebec, Saskatchewan, Yukon, British Columbia |
| | Northeast | Nova Scotia, New Brunswick, Prince Edward Island |
| | Rocky / Intermountain | Alberta, British Columbia |
| | Pacific | British Columbia |
| *United States* | Boreal | Michigan, Minnesota, Wisconsin, Alaska |
| | Rocky / Intermountain | Colorado, Montana, Utah, Wyoming, Idaho, Nevada, Washington |
| | Midwest | Illinois, Indiana, Iowa, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Texas |
| | Northeast | Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia |
| | Pacific | Alaska, California, Hawaii, Oregon, Washington |
| | Southeast | Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Caroline, South Carolina, Tennessee, Virginia |