



Algonquin Cottage Lease Background Report
Literature Review
Ontario Ministry of Natural Resources

January 2013



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ENVIRONMENTAL SOLUTIONS INC.



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SUBJECT: Literature review for Algonquin Cottage Lease Background Reports

Dear Ms. Hartley:

RiverStone Environmental Solutions Inc. is pleased to provide you with the attached report.

Please contact us if there are any questions regarding the report, or if further information is required.

Best regards,

RiverStone Environmental Solutions Inc.

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1 BACKGROUND

Waterfront property is one of the most sought after recreational resources in Canada. While highly valued for its recreational opportunities the lands in proximity to the water-land interface are also one of the most productive and important ecological zones. These interface zones are often referred to as riparian when in the context of the terrestrial and littoral when referring to the nearshore habitat. The ecological impacts of shoreline development and cottage activities on the natural environment have been the focus of much research. Often the activities being studied are the more obvious ones, for example land clearing, erosion, nutrient impacts from septic, and road impacts. Typical cottage activities often include many passive uses that may also have impacts. Some examples include angling, shoreline tidying, birdhouse installation, landscaping, garbage accumulation, boating, etc. RiverStone has reviewed both the primary and grey literature in this context to provide a comprehensive body of material describing the impacts of cottage development and related recreational activities on the natural environment. Guidance for the main groupings of natural features and functions considered were taken from this project's terms of reference, with additional material included when deemed relevant.

2 METHODS

RiverStone staff acquired a collection of literary sources by searching online databases for primary scientific and grey literature. Our searches included the following online databases:

- Web of Science
- Scholars Portal
- Scopus
- ScienceDirect
- Environment Index
- ISI Proceedings
- Conference Papers Index
- BIOSYS Previews
- Dissertation Abstracts International
- Canadian Research Index

As per the terms of reference, this literature review was completed by conducting keyword and topical searches for the following:

- Inland coldwater lakes
- Lake trout and brook trout populations and habitat (including effects of access)
- Riparian and littoral habitats and other comparable aquatic ecosystems associated with Algonquin Provincial Park.
- Surface and groundwater quality, quantity and flow
- Terrestrial vegetation
- Wildlife populations and habitat
- Habitat connectivity
- Effects of human disturbance on Ontario wildlife behaviour, survival and mortality (including bird feeding and bird boxes, linear corridors)
- Subsidized, domestic and feral predators
- Introduction and spread of terrestrial invasive species
- Ecological effects of water level management to maintain recreational uses

As many of the above topics are broad in scope, we further screened search results to extract those references with a primary focus on Ontario or North America. However, research conducted outside of North America was referenced when necessary to obtain sufficient coverage of a topic. The most relevant resources were reviewed and included in the following results and discussion. When specific papers or authors were found to be highly cited within a given topic, additional searches were conducted using the Cited Reference Search within the Web of Science to locate further resources associated with a given topic. Finally, materials made available through the MNR or other agencies were also included in this review.

The intent of the following review is to provide a summary of the current knowledge of the topics outlined above in the context of recreational cottage use and associated activities. As such, a formal assessment of the impacts of a given topic on the Algonquin Provincial Park community or surrounding landscape is beyond the scope of this review.

3 RESULTS AND DISCUSSION

3.1 Inland Coldwater Lakes, Lake Trout, and Brook Trout

The inland coldwater lakes in Algonquin Park provide ideal habitat for lake trout (*Salvelinus namaycush*) and brook trout (*Salvelinus fontinalis*). Critical to both species are cold water temperatures, less than 20 °C for brook trout (Scott and Crossman 1973) and less than 10 °C for lake trout (Evans 2006) and water that has at least 5 (Mills 1971) and 7 (MOE et al. 2010) parts per million of dissolved oxygen for each species respectively. In the middle of summer as water temperatures rise, this combination can become difficult to find. The increased potential for nutrient loading from cottage development, specifically resulting from septic systems, forest clearing, and increased soil erosion can compromise this cold, deep, well-oxygenated habitat. Lake trout and brook trout also have specific and often area-limited habitat requirements for spawning. Finally, lake and brook trout populations may experience higher mortality rates due to human exploitation and under certain conditions, catch-and-release angling activities.

- According to Webb (2008), “There are no generally recognized common measures of the impacts of human development for aquatic systems.”
- According to a Ontario Government report (MOE et al. 2010), “The lake trout, *Salvelinus namaycush*, is found in about 2,200 lakes in Ontario, most of which are on or near the Precambrian Shield. These lakes are noted for their relatively pristine water quality: they generally have high clarity, low levels of dissolved solids, organic carbon and phosphorus, high concentrations of dissolved oxygen, cool temperatures in bottom waters year round and relatively stable water levels. Self-sustaining populations of lake trout are found in these lakes because they provide the specific, narrow environmental conditions required by this species.”
- Lake trout required high levels of dissolved oxygen in the hypolimnion to survive the summer; however, when shoreline development results in nutrient enrichment algae production and decomposition depletes the oxygen in the deep waters of the lake (MOE et al. 2010).
- The Ministry of Natural Resources has developed a criterion of 7 mg of dissolved oxygen/L for the protection of lake trout habitat (MOE et al. 2010).
- Phosphorous loadings from anthropogenic sources can result in loss of late summer habitats for Lake Trout (MOE et al. 2010).

- Both Lake trout and the lakes they inhabit are vulnerable to human activities that result in increased phosphorus inputs (e.g., cottage septic systems), acidification, species introductions, and habitat destruction (OMNR 2007b).
- Reports prepared by the MNR indicate that “...over time, the development and/or creation of new access to lake trout lakes tends to result in habitat degradation, diminished lake trout populations, and a lower quality fishing experience.” (OMNR 2007b).
- Lakes supporting lake trout have been described as, “cold, clear, deep, and dilute lakes” that appear as “swimming pools carved out of granite” (Gunn et al. 2004).
- While well adapted to harsh conditions associated with many northern lakes, Lake trout are quite poorly adapted to deal with many phenomena that are commonly associated with modern human development commonly found in southern areas of Canada (Gunn et al. 2004).
- Lewin et al. (2006) states, “Although the main threats to fish often are localized outside recreational fisheries, there is growing evidence that angling and angling associated activities can lead to a decline of fish populations and affect aquatic ecosystems in various ways provided that the degree of the fishing mortality is high and the selective exploitation is intensive.”
- Freshwater fish stocks are facing threats from anthropogenic stress including, exotic species invasions, adjacent land uses, pollution, habitat loss and alteration and water level regulation (Lewin et al. 2006).
- Direct impacts of human activities on lake and brook trout include alterations to the natural age and size structure, and loss of genetic variability. Indirect impacts caused by humans on these two species include changes in trophic cascades, habitat modifications, wildlife disturbance, nutrient inputs, and loss of fishing gear (Lewin et al. 2006).
- Environmental influences including both season and weather conditions, the type and location of the water body and the target species’ ecology all influence the exploitation rates in recreational fisheries (Lewin et al. 2006).
- Post et al. (2002) documented Canadian examples of recreational fishing that led to the collapse of lake trout populations (as cited in Lewin et al. 2006).
- Mortality from fishing can be high for sought after fish species (e.g. lake and brook trout) and within these species, larger size classes are positively selected that may in turn result in reduced genetic variability thereby reducing the long-term fitness of the population (Lewin et al. 2006).
- According to Lewin et al. (2006), “Changes in the abundance of top predators control a cascade of trophic interactions that regulate zooplankton community structure, algal dynamics, and nutrient cycles in marine and freshwater ecosystems.”
- According to Pazzia et al. (2002), “The majority of species introductions that have occurred in lake trout lakes have been unintentional, mainly from bait bucket dumping, while others have clearly been deliberate attempts to enhance the growth of lake trout. Nevertheless, the consequences of altering food web structure and the intensity of the species interactions are still poorly understood and warrant strict regulations and guidelines to prohibit transfer of fish from one water body to another.”
- Results of a study completed by Pazzia et al. (2002) indicate that a shift in foraging behaviour by lake trout from fish to invertebrates has a high energetic cost, as invertebrates tend to be less digestible prey than fish and more energy must be allocated to foraging to achieve a given growth rate.

- Lake trout appear incapable of overcoming stressors associated with introductions of warm water and cool water competitors; stocking of domesticated trout; increasing access, exploitation, and habitat disruption by humans; climate warming; inputs of nutrients and toxic contaminants; and hydroelectric development (Gunn et al. 2004).
- A single individual walking across salmonid-spawning habitats during the period before the hatching can kill up to 43% of eggs and fry while as little as one additional crossing of the same area can kill up to 96% (Roberts and White, 1992 as cited in Lewin et al. 2006).
- Motorized boat traffic in rivers and lakes contribute inorganic and organic compounds into the water and into the air near the surface, which are toxic to zooplankton and fishes (Lewin et al. 2006).
- Lake trout are of considerable value as they are a biological indicator of a healthy aquatic environment. Stresses on lake trout caused by deteriorating water quality are observable long before conditions such as the appearance of algae blooms and excessive aquatic plant growth become objectionable to humans (OMNR 1993).
- According to the OMNR (1993), the primary threats to lake trout habitat include
 - “...direct disturbance of spawning grounds, by such activities as dredging, infilling and the removing of substrate material for piers and retaining wall construction;
 - artificial manipulation of water levels resulting in either drowning or exposing spawning grounds, warming water temperature profiles and increasing nutrient silt loading;
 - increased silt loading to lakes resulting in a great accumulation of inorganic sediment...”
- According to Evans et al. (1991), “Loss of spawning and early rearing habitat due to shoreline modifications, substrate extraction, disposal of dredged materials, and water level fluctuations are the most serious nearshore effects.”
- Degradation of lake trout in Ontario can be attributed to excessive harvest, conflicts among user groups, and loss of habitat through human activities and shoreline development (OMNR 1993).
- According to OMNR (1993), “Nutrient enrichment of the lake water stimulates the growth of algae and other aquatic plants which eventually decompose using up oxygen in the process. The optimal and usable lake trout habitat decreases proportionately as the percentage of total lake volume with high' temperature and low oxygen level increases.”
- Dredging and filling in the littoral zone results in the re-suspension of nutrients from the lake's sediments and an cause physical damage to spawning and nursery areas for Lake Trout (OMNR 1993).
- According to Gunn et al. (2004), human impacts on lake trout may include, “...shoreline wildfire, logging or permanent deforestation, shoreline restructuring, nutrient enrichment, acidification, persistent contaminants, increased angling pressure, increased water residence time and ultraviolet light penetration...exotic zooplankton and fish species, and changes in water level caused by dam construction and beaver trapping.” Increasingly many forms of disturbance act in harmony, resulting in diagnosis of population declines in lake trout difficult to assess (Gunn et al. 2004).
- Regulation of adjacent lands uses will minimize soil erosion and reduce the rate of nutrient input, the two primary causes of lake trout degradation (OMNR 1993).

- Brook trout population losses occur through factors such as species introductions, climate change, and land use practices (Ridgway 2008).
- According to OMNR (2007a), “Brook trout have stringent habitat requirements with water temperature being a key factor in determining brook trout habitat. A year-round supply of clean, cold, well oxygenated water, as well as adequate cover, are all habitat necessities. Streams with cool, quiet pools between runs of fast water or rapids are typical as are small lakes and ponds.”
- Lake trout are well adapted to life in oligotrophic lakes; however, this species slow growth, late maturity, low reproductive potential and slow replacement rate make it susceptible to a variety of stresses (OMNR 2006).
- In Algonquin Park, 148 lakes are managed for lake trout by the MNR and are stocked to support recreational angling opportunities (OMNR 2006).
- According to OMNR (2006), “Lake trout, and lake trout lakes, are particularly vulnerable to the impacts of human activities, including exploitation, enrichment from cottage septic systems, acidification, species introductions, and habitat destruction. Because of their high sensitivity to disturbance, special protection is required for these lakes and their lake trout populations.”
- Borwick et al. (2006) found that small-scale habitat features and differences between lake surface and substrate temperatures were important factors for habitat use by brook trout in lakes.
- Young of the year brook trout in lakes are commonly associated with groundwater seeps and streams at the lake margin in Algonquin Park (Borwick et al. 2006). This habitat appears to be essential to the life history of this species in the park.
- Results from Borwick et al. (2006) indicate that “Many of the streams and seeps that serve as YOY brook trout habitat in the Algonquin Park region of central Ontario do not appear on provincial map systems (e.g., OBM). This makes the protection of this unmapped habitat difficult.”
- As stated by Gunn et al. (2004), “The potential for erosion is high during and after construction of roads, culverts, and bridges because these structures require extensive disturbance to vegetation and soils, including excavation, filling, and compaction for ditches, roadbeds, and embankments, and creation of artificial drainage channels. Poor road layout and maintenance and inappropriate selection of crossing structures can potentially degrade fish habitat. Habitat degradation may be caused by physical disruption or burial of stream channels and lakeshores, by sedimentation, or by introduction of hanging culverts or other structures that limit fish movement or migration.”
- Evans et al. (1991) found that adult lake trout are most vulnerable to human exploitation when compared to all possible anthropogenic stressors.
- Introduction of new access to lakes through roads, leads to increased exploitation of fish populations and in some cases, cottage development (Gunn et al. 2004).
- In a study by Morbey et al. (2006), large lake trout were found to become more vulnerable to anglers than smaller lake trout as these large individuals had a tendency to concentrate activities inshore bringing them into closer proximity to human harvest.
- Lake trout have been found to be highly plastic in their use of spawning habitats and have been shown to select new sites when previous spawning habitat was destroyed (Gunn et al. 2004).
- In lake trout spawning shoals, depletion of oxygen levels in interstitial water associated with the substrate, in response to the decomposition of organic material, is a primary concern where excessive nutrient inputs occur (Evans et al. 1991). Low dissolved oxygen concentrations are related

to retarded development, delays in hatching, and have been linked to malformation of embryos (Evans et al. 1991).

- Chemical spills, siltation resulting from construction of new roads or nearby dredging and filling operations, and degradation of organic material all have the potential to reduce egg survival in lake trout (Evans et al. 1991).
- According to Evans et al. (1991), “Oxygen depletion in the hypolimnion during summer, would be expected to force young trout into shallower depths, where they would be more vulnerable to predation and/or cannibalism.”
- Modifications to shoreline structure may affect water quality, in turn reducing oxygen in the hypolimnion thereby, reducing the preferred habitat available to lake trout in the lake; however, there is little evidence that modifications to substrates and physical habitat have serious implications for survival and growth of lake trout after they have reached the juvenile stage (Evans et al. 1991).
- Evans et al. (1991) states, “Shoreline modifications, including infilling of bays, the construction of solid berms and jetties, or the formation of new water bodies by excavation or partial closure, changes in the types of material which form the shoreline involving the use of coarse materials, blocks or pilings to protect shorelines, and placement of sand over other types of substrate to create beach areas can significantly affect the well-being of lake trout populations.”
- When eutrophication results in increased algal production during summer months, lake trout habitat can be negatively affected as thermal stratification at that time of year reduces the available habitat for this cold-water species and, when coupled with nutrient loading and algal blooms, can result in the depletion of hypolimnetic oxygen (Evans et al. 1991).
- According to Risley and Zydlewski (2010) and the references therein, “The actual hooking mortality rate is dependent upon many factors, including the lengths of time for which fish are played and held out of water (Schisler and Bergersen 1996; Cooke and Suski 2005). During the time played, a fish experiences a combination of aerobic and anaerobic exercise resulting in depletion of energy stores, accumulation of lactate, acid–base changes, and osmoregulatory disturbances (Wood 1991). Elevated metabolic rates reduce the ability of the fish to respond to other stressors, such as air exposure, or to engage in predator avoidance (Priede 1985).”
- While not specific to lake or brook trout, Boyd et al. (2010), documented increased mortality of catch-and-release rainbow trout in the evenings when compared to mornings when daily water temperatures reached or exceeded 23 °C. Given the similar propensity for cool water temperatures between lake and brook trout, and rainbow trout, it is likely that similar diurnal pattern in mortality rates.

Brook trout and lake trout require cold well-oxygenated habitat during the warm summer months. Algonquin Park contains a large number of lakes that meet the criteria and that support both species. The most significant threat to these species is the loss of the cold, well-oxygenated, deep-water habitat that is critical through the summer months. Research has shown that the key factor in the decline of summer trout habitat is increased nutrient loading, specifically phosphorus. An increased phosphorus load to a lake is in part attributable to nearshore development. The key anthropogenic phosphorus contributions originate from shoreline development, use of and poor maintenance or function of septic systems, forest and riparian vegetation clearing, and soil erosion. A second more global impact on summer habitat for these trout is thermal pressure based on predictions made around climate change. This predicted impact will require a universal change in human behaviour to address. The potential for thermal pressure combined with local stresses caused by development related phosphorus loading is a

key consideration because dissolved oxygen concentrations are negatively correlated to water temperature. Other negative impacts on these trout species that are attributable to cottage activities have been reported. These include increased angling hours, resulting in both selective pressure and habitat disturbance, habitat loss due to shoreline modifications, physical disturbance of spawning beds, and increased sedimentation in spawning habitat due to land clearing and soil disturbance.

3.2 Riparian and Littoral Habitats

While highly valued for its recreational opportunities the land in proximity to the water-land interface is also one of the most productive and important ecological zones. These interface zones are often referred to as riparian when in the context of the terrestrial and as littoral when referring to the nearshore aquatic habitat. The riparian and littoral areas are the most intensively developed and used in the context of cottage development and associated recreational activities. Due to the ecological importance of the riparian and littoral zones, and the increasing pressure for additional development on waterfront properties, the ecological impacts of shoreline development and activities have been the focus of many studies. The type of shoreline development or cottage activity assessed for impacts range from land clearing and shoreline-erosion control to angling and boating activities. The findings of some of these studies have been included in this section.

- Because they are a transitional area between land and water, shorelines provide a high amenity value for both active and passive recreational activities, including cottage based recreation (Scott and Parker 1996).
- According to Luke et al. (2007), “The importance of riparian areas in many forested systems outweighs their relatively small proportion of the land base, because their physical location means that they can function as both a hydrological link and hydrological barrier between upslope areas and the [waterbody].”
- Human populations are increasing across North America with added strain on aquatic communities as human development is concentrated around freshwaters (Francis and Schindler 2009).
- Human development is commonly concentrated near shorelines and as such, anthropogenic effects are magnified in aquatic ecosystems through habitat alteration, and cumulative effects from pollution and eutrophication (Francis and Schindler 2009).
- According to Scott and Parker (1996), “...some Ontario municipalities had subjected cottage developments to review and approval under the 1946 Planning Act, [however,] province wide regulation of cottage development was not instituted until new subdivision controls were implemented under the Planning Act in 1970. Consequently, many early cottage developments occurred in shoreline areas that are susceptible to shoreline hazards (Kreutzwiser 1978).”
- Riparian and littoral areas are thought to be some of the most diverse and complex communities on earth due to the presence of a land and water interface (Newbrey et al. 2005).
- Nearshore areas are particularly susceptible to anthropogenic stressors because they serve as an interface between terrestrial and open-water environments (Goforth and Carrnan 2005).
- Shorelands are affected by both terrestrial and aquatic activities and as such, are subject to more rapid changes than either terrestrial or aquatic ecosystems (Elias and Meyer 2003).
- Shorelines are some of the most dynamic places on earth, where flooding, erosion, and low water levels threaten both cottage property and the associated recreational activities (Scott and Parker 1996).

- Littoral communities are driven by multi-scale environmental factors associated with surrounding or adjacent landscapes (Goforth and Carman 2009).
- Undeveloped shorelines have been found to have greater species evenness than their developed counterparts (Traut and Hostetler 2004).
- As discussed in Lewin et al. (2006) “The removal of the aquatic plants and shoreline vegetation can affect phytoplankton development, invertebrates, fishes and birds (Brooker and Edwards, 1975; Sukopp and Markstein, 1981), enhance erosion processes (Williams and Moss, 2001 and literature therein), and can change nutrient fluxes (Liddle and Scorgie,1980).”
- The alteration of riparian and littoral areas can adversely alter water quality, habitat structure, and species assemblages (Newbrey et al. 2005).
- Disturbance to riparian and littoral communities can occur through shade loss, physical disturbance, or changes to forest litter inputs, particularly along streams (Gunn et al. 2004).
- Anglers can cause negative impacts on littoral habitats if they create paths to gain access to the water and walk parallel to the shoreline. Medium or heavy use of pathways and shores can change or destroy the natural plant communities of freshwater littoral habitats (Lewin et al. 2006).
- Francis and Schindler (2009) state that, “Extensive research in stream ecosystems has highlighted the importance of linkages between riparian vegetation and aquatic food webs as terrestrial invertebrates are a substantial source of energy for stream fishes. This study expands this concept to lake ecosystems, demonstrating that lakeshore riparian habitat performs the same function as streamside riparian habitat, namely in supporting the delivery of terrestrial insects to surface waters where they are consumed by fishes.”
- Predation of terrestrial insects by trout has been shown to decline with shoreline development and trout in undeveloped lakes were found to have a greater percentage of their gut full of food than those trout found in developed lakes (Francis and Schindler 2009). They also found that “Shoreline development was associated with reduced quantities of terrestrial insects in fish diets on annual and seasonal scales.”
- Changes in nearshore substrate structure will result in changes to the nearshore community (Goforth and Carrnan 2005).
- Shoreline modifications may act to enhance colonization success of invasive species through the alteration of nearshore substrate dynamics (Meadows et al. 2005).
- According to Barling and Moore (1994), “Riparian vegetation creates a greater diversity of food sources for in-stream fauna by providing organic matter input to the stream as well as attracting insects to the riparian zone, which then fall into the stream. Trees and large branches that fall into a stream also contribute to the stream structure by increasing the resistance to flow and providing shelter for in-stream fauna.”
- Goforth and Carrnan (2005) documented significantly lower densities of zooplankton and shallow water fish species adjacent to developed versus undeveloped shorelines. According to Goforth and Carrnan (2005), “As food sources are converted over time, the ability of nearshore ecosystems to support prey fish and invertebrates may become diminished, reducing foraging opportunities for piscivores that have great value as recreational and commercial fisheries.”
- Riparian vegetation is thought to function as habitat for both terrestrial and aquatic species, has the potential to function as both a sanctuary as well as a corridor for movement (Barling and Moore 1994).

- Many species of piscivorous birds are dependent on littoral zone fishes as forage and riparian areas for nesting, and are negatively influenced by loss of habitat caused by human alterations and disturbance (Newbrey et al. 2005). Undeveloped shorelines are associated with higher amounts of emergent macrophytes, large emergent rocks, and fallen trees than developed shorelines. As well, these areas have been found to have higher water-bird diversity and species abundances compared to developed shorelines (Newbrey et al. 2005). According to Newbrey et al. (2005), “Loss or fragmentation of plant cover along shorelines due to human alterations deprives birds and other organisms of food and shelter and also reduces and fragments available foraging and nesting habitat.”
- Clearing of aquatic and terrestrial vegetation in nearshore areas by property owners is a common practice to improve lake views and utility of these areas for recreational activities (Traut and Hostetler 2004). According to Traut and Hostetler (2004), “Littoral zones along developed shorelines [are] characterized by a very patchy habitat structure, with distinct clumps of low and tall [emergent vegetation] and large areas devoid of aquatic vegetation. Onshore habitat in developed areas [are] characterized by significant lawn coverage with very sparse, intermittent understory and shrub layers.”
- Shoreline development is associated with a suite of changes to lake habitat structure and ecosystem function, including riparian deforestation and the loss of both coarse woody debris and emergent vegetation from littoral zones (Francis and Schindler 2009).
- According to Liddle and Scorgie (1980), “...the destruction of aquatic vegetation indirectly affects associated populations of invertebrates as well as vertebrates, [however] direct human disturbance appears to be more important in its effects on wildfowl populations.”
- Cumulative removal of coarse woody debris and vegetation overtime is primarily responsible for the fragmentation and degradation of littoral communities in lakes (Woodford and Meyer 2003).
- Previous work has shown that littoral zones contain high proportions of fish relative to other aquatic communities, with abundance being attributed to the complexity of fine scale habitats that exist within this zone. Reductions of the structural complexity of these areas results in a corresponding reduction in fish (Taillon and Fox 2004). Taillon and Fox (2004) documented a positive correlation between fish production and species richness in littoral habitats and the abundance of submerged macrophytes; this vegetation is often removed by humans to improve recreational opportunities.
- In a study by Goforth and Carman (2009), anthropogenic land uses and the number of shoreline structures within landscape contexts proved to be poor explanatory variables in relation to the variation in mean nearshore total fish catch per unit effort.
- Shoreline modification that does not reduce the abundance of nearshore macrophytes or the complexity of habitat will not have a detectable effect on overall fish species diversity (Taillon and Fox 2004)
- Decreases in spatial aggregation by fish has been linked to shoreline development (Scheuerell and Schindler 2004)
- A study completed by Brazner (1997) found that “There were more fish, more fish species, and more species with strong site affinities at wetland and undeveloped sites than beach and developed sites. This suggests that wetland and undeveloped sites have a greater overall value to fishes than do beach and developed sites. However, beach and developed sites were important to certain species ...”

- Changes in the littoral zone and riparian habitats have been shown to negatively affect green frog populations (Woodford and Meyer 2003).
- Riparian and littoral areas of inland lakes are critical habitat for wildlife (Elias and Meyer 2003).
- Shallow water communities in undeveloped areas have higher percentages of both floating and submerged aquatic vegetation compared to developed shorelines (Elias and Meyer 2003).
- According to Liddle and Scorgie (1980), “The power required to drive a boat must be dissipated in the surrounding water, which in turn directs it on the beds and banks of water bodies, in some cases, causing severe erosion...”.
- Wash from waves striking moored boats may result in the clearing of vegetation from areas surrounding the anchor (Liddle and Scorgie 1980).
- Damage to aquatic vegetation can occur when boats run into them at right angles to the shoreline, and by boats turning, in both cases, the results are isolated patches of plants. (Liddle and Scorgie 1980).
- Boat propellers have been shown to remove approximately 10 cm from the top of submergent macrophytes (Liddle and Scorgie 1980).
- Docking structures are routinely constructed of lumber that has been treated to resist deterioration. Pentachlorophenol (PCP) is the most common oil-borne preservative used industrially for the long-term protection of wood against attack and destruction by fungi and insects. It has been used in Canada for almost half a century (Morris and Wang 2006). Pentachlorophenol is used primarily to treat electrical utility poles, marine piles, lumber, timber, and plywood (CAREX Canada 2010).
- Salmonids appear to be the fish family most sensitive to PCP exposure, particularly in elevated temperatures and lower-pH environments. Experimental studies using Rainbow Trout, Sockeye Salmon, and showed a decrease in reproductive rates (reduced oocyte viability), inhibited growth (reduced by 11–19% in 20–38 days), and increased mortality (100% mortality with exposure from fertilization to yolk-sac absorption) (Eisler 1989). These effects occurred at concentrations ranging from 0.0035–22.0 µg/L. Largemouth Bass also showed a decline in feeding activity, a reduction in food conversion efficiency, and increased mortality (LC50 = 54 µg/L in 120 days). Similarly, Bluegill and Fathead minnows demonstrated negative effects of exposure, including reductions in growth and increases in mortality at concentrations ranging from 48 µg/L to 300–432 µg/L (Eisler 1989).
- To maintain or restore riparian and littoral communities, Elias and Meyer (2003) recommend the following:
 - “increasing the amount of cover in the canopy, subcanopy, and especially the understory, or shrub, layers;
 - increasing the amount the shoreline frontage overhung by trees and (especially) shrubs;
 - increasing the amount of coarse woody debris in the terrestrial buffer zone, along the shoreline, and in the shallow water area; and
 - converting portions of mowed lawn to native plant species.”
- Goforth and Carrnan (2005), stated “Understanding nearshore community responses to shoreline features that drive nearshore substrate composition, distribution, and stability will contribute greatly a manager’s ability to make informed decisions about shoreline development and other activities that may affect these ecosystems.”

- Unaltered riparian vegetation communities are capable of reducing elevated soil water nutrient loads, particularly nitrogen suggesting that maintenance of vegetated buffers in riparian communities have the potential to mitigate impacts of inland activities on water quality (Hazlett et al. 2008).
- Sediment retention by riparian buffers is an effective means for preserving spawning sites for fish and habitats of other aquatic animals. Additionally, riparian vegetation acts to stabilize shorelines while minimizing erosion (Hickey and Doran 2004).
- Results of a study completed by Scheuerell and Schindler (2004) suggests that the cumulative effects of shoreline development and lake morphometry are more important in predicting the spatial distribution of fish than the actual fish species assemblage in lakes.

The recreational and ecological value associated with the land-water interface that includes both the riparian and littoral zones is not in question. The historic development and recreational use combined with the increasing pressure for added development on these lands, requires that land use planners understand the ecological impacts that occur as a result. The literature reviewed suggests that both the terrestrial and aquatic flora and fauna are impacted by shoreline development. The results of the studies/papers included in this section suggest that the removal and alteration of shoreline vegetation negatively affects a whole range of species both terrestrial and aquatic. These include birds, amphibians, zooplankton, invertebrates, and fish. The negative impacts commonly result from the loss of organic materials that provide structural habitat diversity and food sources in the form of coarse organic materials. Unaltered riparian vegetation also reduces nutrient and sediment loads to the downstream waterbodies. This vegetation is important in protecting both the physical habitat from sedimentation and in maintaining water quality. In the littoral zone, aquatic vegetation and woody materials are removed or altered to improve recreational opportunities such as boating and swimming. The removal of this material results in reduced structural diversity and habitat fragmentation, in turn leading to a reduction in fish and aquatic invertebrates.

3.3 Surface and Groundwater Quality, Quantity, and Flow

The quantity and quality of surface and groundwater is a concern of the commons. Negative impacts on this resource affect everything from the humans that depend on the water for drinking right down to the phytoplankton that inhabit the lakes. Surface water and groundwater are very closely linked, so much so that impacts on one will eventually affect the other. There are numerous natural factors, such as weather patterns and geography, as well as human activities that affect the quality of and the interactions between the ground and surface waters. Human activities have a broad range of effects on water including changing the distribution, quantity, flow, and chemical characteristics. The literature described in this section relates to the impacts of cottage development and recreational activities on these features.

- According to Houlahan and Findlay (2001), “There is convincing evidence that watersheds dominated by agriculture and/or human settlement have significantly higher river, stream and lake nutrient levels.”
- Housing in densities as low as 4 units/ hectare can have a significant impact upon water quality as these developments have been shown to export 5–10 times the amount of phosphorous compared to undeveloped forest communities (Woodard and Rock 1995).
- According to the World Health Organization (2006), “The term ‘greywater’ refers to untreated household wastewater, which has not been contaminated by toilet waste. It includes the water from bathtubs, showers, hand basins, laundry tubs, floor wastes and washing machines. It does not include

waste from kitchen sinks, garbage disposal units or dishwashers... Domestic wastewater, or “sewage”, can be divided into two categories: blackwater which originates from toilets and kitchens has gross faecal coliform contamination and generally has high concentrations of organic matter; and greywater which originates from bathrooms and laundries and constitutes the largest flow of wastewater... detergents, hair, lint, body oils, dirt, grease, fats, chemicals (from soaps, shampoos, cosmetics) and urine 1 . The most significant pollutant of greywater is laundry detergent, particularly those high in sodium and phosphorus. Greywater also contains bacteria, parasites and viruses washed from the body and clothes... Chemical contamination found in bathroom greywater originates from shampoo, hair dyes, toothpaste and cleaning chemicals. Laundry water contains higher chemical concentrations from soap powders and soiled clothes (sodium, phosphate, boron, ammonia, nitrogen), and is high in suspended solids, lint, turbidity and oxygen demand and if applied to untreated land could lead to environmental damage, as well as posing a threat to public health... Greywater contains significant amounts of nutrients... particularly nitrogen and phosphorus. An average volume of greywater (356 L per day) will produce approximately 45 g of nitrogen and 3 g of phosphorus per day.”

- For management purposes, the 300 m distance from the shoreline of the lake or any inflowing stream of the lake will continue to be used as the primary influence area. This 300 m zone is immediately adjacent to the lake and is therefore considered sensitive in terms of lake water quality protection (MOE et al. 2010).
- The Ontario Ministry of the Environment has recognized that the degree of retention may vary with soil type and grain size, and has consistently held the position that all of the Phosphorous deposited in septic systems will eventually migrate to lake ecosystems. This reflects the predominance of thin, organic or sandy soils and tills on the Precambrian Shield, the fractured nature of the bedrock, and the predominance of aging septic systems that were designed for hydraulic purposes (i.e., to ensure fast infiltration) rather than for nutrient retention (MOE et al. 2010).
- It has been postulated that wetlands and river channels may have the potential for phosphorus retention; however, to date, evidence does not support this idea on a long-term basis (MOE et al. 2010).
- Preservation of aquatic vegetation and retaining shoreline woodlots help to reduce phosphorus loadings (MOE et al. 2010).
- Disturbances to vegetation and the natural soil cover caused by the construction of buildings, roads, and sewage disposal systems create unprotected soil, which erodes into the lake carrying soil bound nutrients. Additionally, septic tank systems dispense nutrients into the soil which will reach the lake- once the nutrient adsorption capacity of the soil is surpassed (OMNR 1993).
- Phosphorus is considered to be the limiting nutrient for primary production in most lakes located on the Canadian Shield due to its scarcity in bedrock and overburden and the efficient retention by upland forests and wetlands (Gunn et al. 2004).
- Severe shoreline trampling and soil erosion associated with hiking trails has been implicated in phosphorous enrichment of lakes and streams (Gunn et al. 2004).
- Elevated phosphorous inputs into Shield lakes, from cottage septic systems have been associated with algal blooms, hypolimnetic oxygen depletion, fouling of spawning habitat, and impaired visual aesthetics (Gunn et al. 2004).
- Phosphorous input from cottage septic systems can be equal to or greater than all other sources. Minor increases in the nutrient supply have been linked to significant loss of lake trout habitat,

especially in mid- to late summer when habitat is already restricted by thermal stratification and unsuitable surface temperatures (Evans et al. 1991).

- Curry and Devito (1996) stated that “Other development activities within a catchment such as creation of reservoirs, removal of aggregate materials, and the construction of roads and human residences may alter groundwater recharge and impact spawning and incubation habitats. Development can also affect groundwater quality. Curry et al. (1993) observed road salt contamination of the groundwater in brook trout spawning and incubation habitats. Nutrients can also be introduced to groundwater discharging in the nearshore zone from human septic systems (Lee 1972) and agriculture (Peterjohn and Correll 1984). Protection from these activities will also require the recognition of the hydrological characteristics of spawning and incubation habitats.”
- According to Wehrly et al. (2012) there is growing evidence for a negative relationship between lakeshore development and water quality.
- Alteration to the vegetative structure of shorelines and littoral communities can affect water quality (Rosenberger et al. 2008).
- Cyanobacteria levels have been found to increase in areas of high development in late summer; however, a corresponding increase has not been observed in undeveloped lakes (Rosenberger et al. 2008).
- Nutrients from shoreline septic systems likely enter lakes and streams as groundwater flow before being intercepted by periphyton. Thus, for nutrient enrichment of littoral origin, littoral variables may be particularly valuable indicators relative to pelagic ones (Rosenberger et al. 2008).
- According to Rosenberger et al. (2008), “Periphyton biomass [is] higher at developed sites ... even though water column nutrient levels... were extremely low and in many cases below standard detection limits, suggesting that periphyton in the littoral zone of... oligotrophic lakes quickly incorporate nutrients near shoreline development.”
- Algal biomass at developed sites indicate that these area receive increased nutrients, likely derived from sewage or runoff (Rosenberger et al. 2008).
- Previous studies have examined relationships between land use patterns and water quality associated with Great Lakes coastal wetlands at both regional and local scales (Morrice et al. 2008).
- Results of a study completed by Hall and Smol (1996), indicate that “61% of the lakes showed no significant changes in diatom-inferred pH since preindustrial times and 78% showed no significant Total phosphorous changes.”
- Watershed lands use practices are known to influence the physical-chemical conditions of receiving waterbodies (Morrice et al. 2008).
- In addition to agriculture, point source discharges, activities related to urban and residential development, and atmospheric deposition can be significant sources of nutrients and other chemicals that impact water quality (Morrice et al. 2008).
- According to De Sousa et al. (2008) “Forest clearing, shore erosion, discharge of domestic waste and fertilizers, and harvesting of submerged wood and macrophytes may increase nutrient availability but reduce habitat diversity through loss of woody debris and accumulation of fine particles transported from the disturbed watershed.” Nutrient enrichment of lakes is likely to favour benthic production over pelagic production as phosphorous entering the lake first encounters the littoral zone where it is quickly taken up by periphyton (De Sousa et al. 2008).

- Non-point pollution associated with urbanization and yard and garden runoff can provide high nutrient loads to streams and wetlands that can impact fish habitat (Seilheimer et al. 2007). Degraded water quality and high algal biomass that result from these urban inputs cause the loss of the submerged plant species that are vital habitat for fish and other biota (Seilheimer et al. 2007).
- Potential ecological implications of intensive shoreline development include erosion of shorelines and inadequate protection of water quality (Elias and Meyer 2003).
- Water quality is known to impact property values, the attitudes of lakeshore homeowners, and incidence of recreational activities (Schnaiberg et al. 2002).
- South-central Ontario contains lakes in which water quality is declining is due to anthropogenic activities, such as nutrient inputs derived from recreation and tourism industries, and acid rain. Management of water quality in this region includes maintaining optimal habitat for coldwater fish species and low levels of phosphorus (Quinlan and Smol 2002).
- According to Clerk et al. (2000), “Relatively little is known of how past changes in human activities and land use have altered water quality and limnological conditions in Ontario lakes, even though this information may be important for future lake management.”
- Deterioration of water quality in the Muskoka-Haliburton lakes can be partially attributed to the release of nitrogen and phosphorous laden domestic waste by cottages and resorts (Dillon et al 1991 as cited in (Wilkinson et al. 1999).
- According to Dillon et al. (1991), “Septic tanks have a poor ability to retain phosphorus, and function merely to retard the rate at which nutrients migrate into water bodies.” (as cited in (Wilkinson et al. 1999).
- In a case study completed in Zimbabwe, pit latrines were found to impact groundwater quality up to 25 m away (Dzwauro et al. 2006). This same study concluded that in areas of shallow water table pit latrines resulted in increases in total faecal coliform counts and acted as point sources of both ammonium and nitrates.
- The Ontario Ministry of the Environment (MOE) recognizes the possibility that excessive recreational use of freshwater lakes can lead to an undesirable lowering of water quality (Hendry and Toth 1982).
- Historically, studies detected low densities of fecal indicator bacteria in lakes thereby concluding that septic tank-tile field were insufficient in processing waste to reduce bacterial levels to Ontario Water Management Objective levels (Hendry and Toth 1982).
- According to Drexler and Bedford (2002), “...nutrient loading in the form of N, P, and K reaches wetlands via ground water, surface flow, overland flow, precipitation, and/or dry deposition. It has been linked to decreases in plant diversity in peatlands, wet meadows, riparian areas, and swamps...”
- Vegetative filter strips or buffers, have become an important best management practice to control pollutant transport by stormwater runoff, with numerous studies advocating their effectiveness (Gharabaghi et al. 2006).
- According to Hazlett et al. (2008), “...the slope of the surrounding terrestrial catchment determines the width of a stream or lake buffer zone, with steeper slopes requiring wider buffers. In terms of nutrient loadings, the assumption is that steep slopes are briefly saturated, have increased flow rates to the aquatic system, provide less opportunity for reaction of percolating water with soil and vegetation, and therefore, have little ability to mediate water quality. Conversely, shallow slopes are

saturated longer, have lower flow rates, have longer water residence times, and have a greater ability to alter soil water quality prior to transfer to lakes and streams.”

- The efficiency of a vegetated buffer in removing sediment is a function of width, vegetation type within the buffer, flow rate and the characteristics of the sediment. Dense vegetation and wider buffers, generally, have been shown to be more efficient in the trapping of different pollutants (Hickey and Doran 2004, Gharabaghi et al. 2006).
- In a study conducted by Gharabaghi et al. (2006), demonstrated that the first 5 m of a vegetated buffer are responsible for the removal of more than 95% of sediments larger than 40 µm in diameter. However, this same study found that the remaining 5% of the sediment was very difficult to filter using vegetation alone.
- Woodard and Rock (1995) documented that 15 m vegetated buffers were able to reduce phosphorous concentrations to within control values; however, total suspended solids were not visibly reduced. The authors concluded that additional buffer width was required in areas with slopes greater than 12% to reduce the speed of overland flow and increase buffer efficacy.
- Riparian communities are characterized by vegetation, soils, and hydrology that differ from adjacent upslope forests. As such, riparian zone processes strongly influence the movement of water and nutrients from terrestrial to aquatic ecosystems (Hazlett et al. 2008).
- As stated in Hazlett et al. (2008), “Within the aquatic system, N, P, and dissolved organic carbon (DOC) are primary influences on productivity, nutrient cycling, and light dynamics (Putz et al. 2003).”
- According to Hazlett et al. (2008), “The functional capacity of a particular riparian ecotone and its regulatory influence on the productivity of aquatic systems is dependent on numerous factors, such as width, slope, vegetation composition, organic matter and soil nutrient content, watershed area and gradient, soil texture and chemistry, depth to bedrock, and soil depth.”
- Results of (Hazlett et al. 2008) indicate that both vegetation characteristics and variable buffer widths in response to differences in onshore slopes influence buffer efficacy.
- As stated in Hickey and Doran (2004), “Buffer strips along shorelines are a central component of most non-point source pollution programs in North America. Vegetated buffer strips can mitigate the effects of agricultural and forestry activities by acting as a physical barrier to sediment, nutrients and pesticides being carried into streams (Barling and Moore 1994; Cooper 1990). Buffer strips may also reduce the flux of soluble nutrients by uptake into growing plants or by supporting environmental conditions that favour chemical transformations such as denitrification (Haycock and Pinay 1993; Cooper and Gilliam 1987).”
- While most studies support the idea that riparian buffers are effective in removing phosphorous from stormwater and surface water runoff, the majority of these studies follow phosphorus removal over too short a time span to draw conclusions about the long-term potential for phosphorus removal (Hickey and Doran 2004).
- Hickey and Doran (2004) suggests that while “Wide buffer strips (30-100 m) provide the best protection from non-point source pollution...few studies have focussed on buffer strips within the 1- to 10-m size range...”
- In a study conducted by Hendry and Leggatt (1982), levels of fecal indicator bacteria in lakes containing cottage development were ten times higher after rainfall events than in adjacent

undeveloped lakes. This elevated concentration was found to persist for 2-3 days and was linked to the presence of septic tank tile fields.

- According to Hendry and Toth (1982), “It is unclear if the bacteriological water quality of small freshwater lakes is greatly affected by moderate shoreline cottage development or other recreational activities. Several studies of the recreational use of lake and river watersheds in the United States have reached differing conclusions.”
- The ability of riparian forest vegetation to trap sediment depends upon variables such as soil type, vegetation cover, slope, accumulation of organic matter, and geographic location. As vegetation in these communities become more established, increased plant abundance and species diversity, soil porosity and soil infiltration rates result in an increase in the efficacy of the buffer to protect and enhance water quality (Luke et al. 2007).
- Water quality suffers when riparian communities are altered to result in restriction of overland flow to localized areas of saturated soils, impermeable surfaces such as bedrock or roads, or areas where soils have been compacted through anthropogenic development (Luke et al. 2007).
- Water quality has been found to improve after the implementation of septic tank cleanup programs, suggesting these developments are likely sources of bacteriological contamination in waterbodies (Hendry and Toth 1982).
- Results of a study conducted by Houlihan and Findlay (2001) indicate that, “Potassium and maximum nitrate levels [in waterbodies, are] positively correlated with surrounding road density at 2000 and 500 metres, respectively. There is evidence that increased potassium levels are found downstream of road salt applications because the sodium found in road salts displaces potassium in the soils allowing the displaced potassium to runoff to downstream water-bodies.”
- Impacts of sediment and water nutrient loading can be detected at distances up to 4000 m away from the point source (Houlihan and Findlay 2001), suggesting that buffers of 30-120 m are far narrower than that required to mitigate negative effects.
- Tile beds are known to result in localized phosphorous enrichment of soils (Robertson 2006).
- In situations where phosphorous is highly retained in sediment, mobility of phosphorous in groundwater is limited under normal water table conditions. However, phosphorous found in sediments appears to become remobilized during high water table events, including those experienced during major rainfall events or spring snowmelt conditions. Remobilization of phosphorous under these conditions has the potential to result in elevated concentrations of phosphorous to be released into overland flows towards adjacent waterbodies (Robertson 2006).
- According to Robertson (2003), “The apparent widespread occurrence of acidic conditions in septic system plumes on noncalcareous sediments and the resulting [phosphorous] attenuation suggest that noncalcareous terrain may be much less vulnerable to [phosphorous] loading from septic systems than is similar calcareous terrain.
- A study completed by Moll et al. (1999) concluded that “Human and veterinary pharmaceutical compounds are a source of increasing environmental concern because the compounds are used in large quantities and the physical and chemical properties of the compounds make them likely to be transported into hydrologic systems.”

There is growing evidence that lakeshore development has a negative impact on water quality. Research has demonstrated that in some cases, impacts can occur up to 4 km from the point source.

Increased nutrient loads to both ground and surface water, as a result of shoreline development has been well documented. Water chemistry changes result from soil disturbance and erosion, and road construction and maintenance. Based on the literature, lakes on the Canadian Shield are very sensitive to increased phosphorus. Primitive treatment of sewage, including greywater pits and pit privies, has been shown to have impacts on water quality. Other nutrients and chemicals that have been recognized as having negative impacts on surface and ground water include pharmaceuticals, salts, and nitrogen. Vegetated buffer strips have long been proposed and implemented as a method for mitigating the impacts of shoreline development and site alteration on water quality. While the efficacy of these buffers is all but taken for granted at this point, the size of the buffers necessary to achieve acceptable reductions in anthropogenic impacts is actively debated. Determining appropriate buffer sizes is difficult because the function of buffers is directly related to variables that are highly site specific.

3.4 Water Level Management

Water levels are managed for a number of reasons including production of hydroelectric power, navigation, recreational opportunities, and flood control. Fluctuations in water levels whether caused by humans or wildlife such as beavers have the greatest potential for impact on shallow water or gradual shorelines. The species most immediately impacted by changing water levels are those that are immobile, such as plants or species whose critical habitat is limited by availability and water depths (e.g., fish that spawn on shoals). Also to be considered is the timing and duration of water level changes as different species may depend on habitats associated with specific water levels at various times within a year. Decisions concerning the control of water levels can be complicated as stakeholders can be affected differently and decisions should consider the ecological impacts of the timing, duration, and quantity of drawdowns.

- As stated in Webb (2008), “Water regulation is practiced in many inland lakes and on the Great Lakes (Hudon et al. 2006), and water levels are forecast to decline as a result of climate change (Lofgren et al. 2002, Lofren 2004).”
- As cited in Slivitzky (2002), “Minc (1997) examines the vegetative responses in Michigan coastal wetlands and marshes to interannual fluctuations in Great Lakes levels. Minc (1997) found year-to-year continuity is low (<50%) in Great Lakes marshes, possibly reflecting the continual stress and response of wetlands systems. Minc (1997) also found indicator species of marsh types are generally stable, but experience a shift in abundance and in relative dominance in response to lake level changes. Widely fluctuating water levels are suspected to have impact the distribution and abundance of many species which in turn affects the overall biological production of affected ecosystems (Kothbauer 1992).”
- As stated by Curry et al. (1994), “Many rivers and their watersheds are important to recreation, resource development, and energy production. However, these multiple uses of natural resources are not always compatible.”
- According to Nilsson and Berggren (2000), “Riparian areas are particularly sensitive to variation in the hydrological cycle and serve as good indicators of the environmental change that is caused by dam operations.”
- As cited in Slivitzky (2002), “Wilcox & Meeker (1991) investigate the effects of water level regulation on aquatic macrophyte communities by comparing two regulated lakes in northern Minnesota with a nearby unregulated lake. The unregulated lake supported structurally diverse plant communities at all depths. In the lake with reduced fluctuations, only four taxa were present along transects that were never dewatered; all were erect aquatics that extended through the entire water

column. In the lake with increased fluctuations, rosette and mat-forming species dominated transects where drawdown occurred in early winter and disturbances resulted from ice formation in the sediments.”

- As cited in in Slivitzky (2002), “Dickerson (1995a-e), in a series of Technical Notes, reports that changing water levels or other operations at U.S. Army Corps of Engineers (USACE) reservoirs may impact critical habitat parameters for turtle species (i.e., mud, musk, snapping, softshell, terrestrial, and wetland turtles). These turtle species and habitats have been identified by resource managers as potentially impacted by USACE reservoir or other water-control projects. Life-history summaries and habitat requirement descriptions are provided for each potentially-impacted turtle species. Current state and/or Federal legal protection status is summarized for each turtle species, as is the distribution of USACE Districts and reservoir projects potentially impacted by specific turtle species conservation issues. This work has been accomplished as part of the “Reservoir Operations—Impacts on Habitats of Target Species” study initiated in FY98 under the Ecosystem Management and Restoration Research Program (EMRRP) (Dickerson et al., 1999).”
- Water control structures affect riparian communities upstream by raising water levels and modifying water level fluctuations and downstream by altering flow regimes (Nilsson and Berggren 2000). Additionally, water control structures can obstruct migration pathways for fish, and trap waterborne sediment (Nilsson and Berggren 2000).
- As cited in in Slivitzky (2002), “Bellrose & Low (1943) report on the influence of flood and low water levels on muskrat survival. Too little water, like too much water, resulted in the muskrats attempting to relocate to more favorable habitats. This movement was sometimes within the area but more often to adjacent areas with much stress on the affected populations.”
- Increased stress associated with development is expected to occur at the same time as potential stresses from water level changes as water level management is often conducted with human use of areas in mind (Webb 2008).
- As cited in in Slivitzky (2002), “Kallemeyn et al. (1988) examine a single hydropower facility and two small regulatory dams located outside Voyageurs National Park that regulate water levels in the four large lakes, which compose 96% of the park’s water area. The present water management program utilizes greater-than-natural fluctuations on the second reservoir. Additionally, the regulated lake levels differ from natural levels by usually peaking later, remaining relatively stable throughout the summer rather than slowly declining and, on one reservoir, by declining 1.8 m rather than 0.6 m over the winter. This regularly system was found to have an adverse effect on northern pike, common loon, red-necked grebe, beaver, and muskrat populations of the littoral zone and adjacent wetlands of the park. An alternative water management program is presented that would meet the biological requirements of these species by resorting to more natural lake-level fluctuations. It is hypothesized that it would also have a positive effect on the other members of the aquatic community.”
- In Ontario, water level management has historically led to water level changes of up to 3.5 m, changes in plant communities, varying the area of aquatic beds, and modifications to the composition of plant and animal assemblages (Webb 2008).
- Dams can negatively impact fish spawning and habitat, nesting habitat for waterfowl, muskrat, beaver, and other animals (Kothbauer 1992).
- Slow rates of change in water levels are less likely to have dramatic effects than are rapid changes; however, small changes can have catastrophic effects if they exceed the threshold tolerance of a given ecosystem (Slivitzky 2002).

- According to Slivitzky (2002), “Hudon (1997) shows a strong negative relationship between seasonal water level and the percentage of emergent plant cover in Lake Saint-Pierre on the lower St. Lawrence River. At low water levels, the lake becomes a large marshland that could support a high plant biomass, whereas at high water levels the lake shifts to a vast, open-water body with a lower predicted plant biomass.”
- As cited in in Slivitzky (2002), “It was found that fluctuations in water levels are important to maintain the extent of coastal marshes. The smaller the fluctuation in water levels, the smaller the extent of wetlands (Wilcox *et al.*, 1992, Wilcox, 1995, Wilcox and Meeker, 1992).”
- Barr (1986) as cited in Kothbauer (1992) found that common loons are adapted to the natural rhythm of annual water level changes with high water levels during the spring thaw, followed by gradually declining levels throughout the nesting season. As such, nest-site selection by loons during the spring results in sites being selected that are rarely flooded or stranded far from water. Water level management through dams and weirs can disrupt this process.
- There is little likelihood that minor changes in water level will have significant impact on the availability of thermal habitat for adult lake trout. Permanent minor changes in water level not unlike those caused by beaver dams do not result in significant negative impacts on lake trout (Evans *et al.* 1991).
- One of the most pronounced impacts of water level management is on the temperature regimes in lakes. Management of water levels can result in a deepening of the location of the thermocline and a lengthening of the stratified period in the lakes. Although the center of the thermocline is deeper on average, the temperature gradient through the metalimnion is steeper. A deeper thermocline with a steeper metalimnion gradient will exacerbate the hypolimnetic oxygen depletion problem in coldwater lakes (Slivitzky 2002).
- According to Slivitzky (2002), documented degradation from poorly planned water level management include: “1) fragmentation, partial filling and dyking of habitats; 2) toxic substances in water and sediments; 3) invasion by exotic species; 4) pollution, nutrient enrichment and other changes in the physical and chemical characteristics of a local environment; and 5) decrease in average area.”
- When managed for electrical production, river discharges produced in a ‘peaking’ system typically have been shown to have adverse effects on fish populations (Curry *et al.* 1994). This is likely driven by the large reductions in water depth throughout the peaking cycle, followed by the relatively short term intense flushing of the system.
- Water level regulation can result in decreases in the availability of suitable spawning and nursery habitat if changes are large enough in scale and duration (Evans *et al.* 1991).
- Biological effects of water level fluctuations in both lakes and rivers are greatest in shallow water, where even small changes in water levels can result in the conversion of a standing-water environment to an environment in which sediments are exposed to the air, or vice versa (Slivitzky 2002).
- According to Evans *et al.* (1991), “Water level fluctuations may also indirectly affect lake trout populations. Winter draw-downs, for example, may also eliminate production of lake herring and lake whitefish, depending on the depth at which they spawn. The lake herring, in particular, is an important prey for lake trout, in lakes where they co-exist. The loss of any prey species quite likely would result in a lower lake trout production.”

- Flow regulation is thought to affect fish species that are restricted to shallow shoreline microhabitats. In impacted areas, species composition is predicted to be dominated by habitat generalists (Slivitzky 2002).
- Management of water levels that do not ensure spawning areas are maintained at sufficient depths and flow rates to ensure access to, and the function of, these areas will result in negative impacts on species (Curry et al. 1994).
- Regulated lake levels have been found to have an adverse effects on northern pike, common loon, red-necked grebe, beaver, and muskrat populations of littoral zones and wetlands (Slivitzky 2002).
- Major changes in water level or water flow regimes may influence not only spawning and nursery habitats, but also the thermal habitats of juvenile and adult fish (Evans et al. 1991).
- Declining water levels may cause contaminated sediments to become re-suspended and represents a potentially long-term environmental remediation problem (Slivitzky 2002).
- Results of a study conducted by Webb (2008), suggest that changes in water levels have a negative impact on marsh fish assemblages.
- According to Curry et al. (1994), “The presence of groundwater in the spawning and incubation habitat of brook trout appears to be critical for reproductive success (Curry et al., 1991; Fraser, 1985; Gunn, 1986). Groundwater may mitigate the effects of de-watering events (Brick, 1986), but the effects of regulated river discharge on spawning brook trout adults and the groundwater environment of incubating embryos have never been described.”

The effects of water level management on ecosystems can be substantial. Potential impacts include changes in water quality both upstream and downstream of water control structures, changes in riparian, littoral and wetland communities and habitats, and in both plant and animal assemblages. Changes in water levels can aggravate shoreline erosion and facilitate changes in the thermal regime of lakes and rivers. The effects of water level management are exacerbated when the frequency and extent of fluctuations in water level are increased. Additionally, communities that experience fluctuating water levels resulting from water level management are more likely to be comprised of species that are generalists. Therefore, care should be taken in the development of water level management programs to ensure that alterations to natural water levels do not result in negative impacts on the local ecosystem.

3.5 Habitat Connectivity

In the 1990s, increases in metapopulation research and theory led to predictions surrounding the dynamics of populations in fragmented landscapes. In response to this research, management actions sought to conserve these populations in the face of continuing habitat destruction primarily using corridors and other means for maintaining or increasing connectivity between habitats. This approach has stirred up a debate over whether increasing connectivity in fragmented habitats, mainly by maintenance or creation of dispersal corridors, is appropriate for conservation of metapopulations in nature. Key concerns included what is a fragmented landscape, how do habitats become fragmented, when does fragmentation matter, what limits or enhances connectivity, and what are the implications for managed connectivity.

- Both empirical and modeling based studies of populations at a landscape scale have demonstrated that spatial pattern of habitat is a key determinant in the persistence of natural populations (Opdam et al. 2003).

- It is the spatial structure of the non-habitat patches in the landscape, in which the habitat patches are embedded that affects the ability of dispersing individuals to disperse or migrate to habitat patches within the landscape (Opdam et al. 2003).
- Opdam et al. (2003) stated that "...habitat quality, the amount and configuration of habitat and the permeability of the landscape..." are the primary concerns when assessing the likelihood that a species will persist.
- According to Opdam et al. (2003), "For a species to survive in a habitat network, two conditions have to be fulfilled: the dispersal stream across the landscape balances local extinction and recolonization rates, and the total network is large enough to minimise the chance that all local populations go extinct."
- Fragmentation of habitat can have significant effects on the dynamics of resident populations, independent of the amount or quality of the habitat (Fahrig 1998).
- Movement within a given landscape will vary among individuals and species as well as the direction and distance of the movement (Belisle 2005).
- Movement of individuals within a landscape are of great importance for ongoing population viability, stability, and gene flow (Belisle 2005).
- Different species perceive the landscape at different scales and in turn, the impacts of human induced disturbances and alterations to the landscape will affect species differently (Milne and Bennett 2007). Therefore, selecting conservation of habitat or determining the ecological value of a given landscape on the basis of a single taxa is fraught with errors (Milne and Bennett 2007).
- In southern Ontario, historical transitions from forest to agricultural fields, are now being repeated as agricultural landscapes are being converted from mixed farming to cultural grasslands and savannahs, as well as from agricultural land uses to residential development (Milne and Bennett 2007).
- Previous studies have shown a correlation between habitat area and isolation and species numbers, and between the fitness of particular species and habitat fragmentation (Milne and Bennett 2007).
- Landscape connectivity describes the function of a landscape, with those having high connectivity being represented by a continuous pattern of similar habitat types and landscapes with low connectivity describing those with a discontinuous pattern of similar habitat types (Milne and Bennett 2007).
- In a small number of studies, the spatial configuration of a given type of habitat was an indication of population persistence (Harrison and Bruna 1999)
- Despite being considered a key concept, the study of functional connectivity requires dealing with complex phenomena difficult to sample, experiment on, and describe synthetically and as such is a topic that is rarely studied (Belisle 2005).
- Small scale grazing and mowing experiments have shown that the spatial configuration of habitats may impact plant diversity, parasitism, pollination and the population demographics of small mammals (see references in Harrison and Bruna 1999).
- Degree of parasitism on forest tent caterpillars by tachinid flies declined with increased forest fragmentation; resulting in longer outbreaks and increased damage by caterpillars (Harrison and Bruna 1999).

- Changes in food availability near roads may influence territory selection and reproductive success for birds (Bassett-Touchell 2008).
- In the context of habitat connectivity, habitat patches that are considered proximal are those that can easily be reached through regular movements and are within the perceptual range of individuals in neighboring patches, while distant patches have neither of these qualities, although these distance patches may be reachable through rare movement events (Boenke 2011).
- Accurately describing the size of a given patch is species specific with large patches being those which contain sufficient resources for an individual to survive without having to leave the patch and small patches being those that lack those resources (Boenke 2011).
- Because individual organisms perceive their surrounding environment at spatial scales that are influenced by individual perceptive and movement capabilities, then the effects of landscape fragmentation is specific to the scale at which any given organism interacts with its surrounding landscape (Boenke 2011).
- Habitat loss and fragmentation resulting from anthropogenic development are widely known to affect the effectiveness of reserves and biological diversity (Goetz et al. 2009).
- Species declines within fragmented landscapes have been attributed to reductions in food supply, avoidance of edges, and increases in nest predation and parasitism (Turcotte and Desrochers 2005)
- Reductions in pairing success in bird assemblages found in isolated forest patches has been attributed to low connectivity associated with the reduction in forest cover at a landscape scale (Turcotte and Desrochers 2005).
- Because movement is so critical to animal population survival, management of wildlife must consider connectivity within the context of a given landscapes' structure (Eastern Foxsnake Recovery Team 2010).
- Previous works have demonstrated that movement of individuals within a landscape is fundamental to population viability; however, mapping used in planning exercises usually depict resource distribution, not movement patterns (Eastern Foxsnake Recovery Team 2010).
- Identification of patches that function as neighbours to a focal patch depends not only on physical distance but also on the landscape connectivity; distant patches with high connectivity will exert stronger neighbourhood effects than closer patches within a landscape with lower connectivity (Eastern Foxsnake Recovery Team 2010).
- Landscape connectivity is a species specific measure of the probability of movement between all points or resource patches in a landscape (Eastern Foxsnake Recovery Team 2010).
- Decreases in patch size while maintaining constant amounts of habitat (i.e., true fragmentation) has been shown to decrease the probability of population survival (Fahrig 1998).
- Extensive habitat results in ensured population survival and in this case, the spatial arrangement of the habitat becomes unimportant. Furthermore, the more breeding habitat that is present for a species results in smaller distances between individual patches thereby resulting in faster re-colonization should local extinctions occur (Fahrig 2003).
- Habitat fragmentation can result in significant effects on the dynamics of resident populations, that are independent of the quality or quantity of the habitat (Fahrig 1998).
- Fragmentation of communities at a landscape scale results in greater inter-patch distances and a higher ratio of edge to interior habitats (Fahrig 2003).

- While corridors may prevent the losses of large bodied species from fragmented landscapes, no studies to date have demonstrated the ability of corridors to do so (Fahrig 2003).
- When movement distance between patches is small, the effect of habitat fragmentation on population survival is also small no matter what their spatial pattern is (Fahrig 1998, 2003).
- Previous studies have suggested that riparian buffers may serve as corridors for dispersal among larger patches of forest habitat with many reporting the use of corridors by forest-dwelling species (Hickey and Doran 2004).
- According to Fahrig (1998), fragmentation of breeding habitat specifically, only affects population survival under a narrow set of conditions:
 - breeding habitat covers less than 20% of the landscape
 - habitat is not ephemeral
 - probability of an individual moving is lower in breeding habitat than in nonbreeding habitat
 - mortality in non-breeding habitat is higher than in breeding habitat
- Corridors have been proposed as a means to promote dispersal or provide alternative management strategies when planning landscape level conservation initiatives directed at alleviating the effects of habitat fragmentation (Harrison and Bruna 1999).
- Corridors are often suggested as a means for increasing habitat connectivity; however, their use in management and conservation planning has been the result of intuition and not empirical evidence of their efficacy (Tewksbury et al. 2002).
- According to Tewksbury et al. (2002), “Corridors are thought to facilitate movement between connected patches of habitat, thus increasing gene flow, promoting reestablishment of locally extinct populations, and increasing species diversity within otherwise isolated areas.”
- Road construction and forest removal has been shown to have significant impacts on wetland biodiversity (Findlay and Houlihan 1997).
- Roads have been shown to reduce biodiversity on a regional scale by limiting movement between local populations, increasing the amount of edge habitats, increasing mortality, acting as a vector for the introduction of invasive species, and increasing human access to sensitive communities (Findlay and Houlihan 1997).
- A study by Findlay and Houlihan (1997) found that impacts of roads on mammal and herptiles populations could be detected as far as 2 km from the road surface.
- Functional connectivity of a landscape, with respect to animal movement is dependent on how an organism perceives and responds to landscape structure within a hierarchy of spatial scales. It is theorized that organisms will alter their location and use of a landscape to adjust for differential fitness benefits or costs, according to the nature, form, and spatial arrangement of habitat patches and ecotones (Belisle 2005).
- Roads act as barriers to wildlife movement, are a source of mortality, and act as movement corridors for introductions of non-native species. Conversely, areas lacking roads have been shown to have higher levels of native diversity and fewer invasive species than those with roads (Goetz et al. 2009).

- Roads may function to fragment habitat for species, including some species of birds. Yellow rumped warblers (*Dendroica coronata*) have been shown to avoid crossing anthropogenic gaps, including roads (Bélisle and St. Clair 2001 as cited in Bassett-Touchell 2008).
- Bassett-Touchell (2008) documented higher rates of nest predation along paved roads than unpaved roads.
- Roads are thought to influence local abundance of generalist predators through increased food sources such as road-kill and human trash. This is of concern, as most animals that predate nests are generalist predators that opportunistically find nests. Approximately 80% of nest failures are due to nest predation, making this the leading cause of nest failure for songbirds (Bassett-Touchell 2008).
- Roads influence wildlife and ecosystems through mortality from vehicle collisions and road construction, habitat loss, changes in species behaviour (e.g., road avoidance or attraction) and reducing landscape connectivity (Bassett-Touchell 2008).

The ability of individuals to access habitats required to complete all stages of their life history is essential to the perpetuation of wildlife populations. Fragmentation of habitats by human development can result in a segregation of wildlife populations and individuals from key habitats. When the amount of a given species' habitat in a landscape is high, the effects of fragmentation are often low; however, fragmentation effects can be exacerbated when specific habitats are limited. Efforts to increase habitat connectivity are often associated with the use of corridors; however, the efficacy of large-scale corridors is largely untested. Roads limit the movement of animals between local populations, increase the amount of edge habitat, increase mortality, function as a vector for the introduction of exotic species, and provide increased access for humans to sensitive interior communities and species.

3.6 Introduction and Spread of Terrestrial Invasive Species

It has been suggested that invasive plants and animals are second only to habitat loss and degradation in causing native species to become endangered (Reichard and White 2001, Li et al. 2004). New species continue to be introduced into Canada each year. As new species become established, they often compete with native flora and fauna. Invasive species are thought to be responsible for significant ecological damage by outcompeting native species for resources and, through the replacement and alteration of the habitat of native species. Additionally, many species native to Canada are expanding their ranges to include new areas, and some of these species exhibit the same traits that make certain non-native species invasive. Cottages and cottagers can act as vectors for the introduction and spread of terrestrial invasive species.

- Species introductions are occurring at unprecedented rates (Eschtruth and Battles 2009).
- Invasive species can have serious impacts on the ecological integrity of highly valued natural ecosystems, particularly those within protected areas (Meunier and Lavoie 2012).
- Most species used in North American agriculture, forestry, and horticulture are not native to the continent and while most of the plants that have been introduced are not invasive, a small portion of these species escape from cultivation and become pests of natural areas (Reichard and White 2001).
- Establishment of secondary invasive species can be promoted through attempts to control primary invasive species as many control methods result in significant disturbances to the community (French 2012).

- Increased nutritive input through intentional (i.e., fertilization) or unintentional (e.g., septic failure) may result in new opportunities for establishment of exotic species which may not normally be invasive under lower nutrient conditions (French 2012).
- Invasive plant species can reduce the abundance and diversity of native plants by changing both soil biota and chemistry, and can reduce reproductive success of some species of birds (Birdsall et al. 2012).
- According to Bauer (2012), “Alteration of natural disturbance regimes or the introduction of new disturbances may suppress native species, allowing invasive species which are tolerant of these altered conditions to achieve dominance.”
- Species extinctions resulting primarily from competition with invasive species are rare (Bauer 2012).
- Previous work suggests that many native species are superior competitors to invasive species when nutrient levels are low and it is only through alterations in flooding, sedimentation regimes and/or nutrient enrichment that invasive species become dominant (Bauer 2012).
- It has been suggested that “...disruptions of ecosystem processes and properties are the underlying cause of biodiversity loss, and management must focus on restoring these factors to successfully protect and restore native species.” (Bauer 2012).
- Canopy disturbance may play a pivotal role in the invasions of exotic species in ecosystems such as hemlock forests, as canopy is known to exert strong control over many aspects of the understory community in these ecosystems (Eschtruth and Battles 2009).
- Linear habitats may act as dispersal corridors and invasion routes into the communities that they intersect (Maheu-Giroux and Blois 2005).
- Disturbance is a common cause of exotic plant invasions; however, the mechanism by which disturbance facilitates invasion is poorly understood. Eschtruth and Battles (2009), suggest that disturbance may act to reduce competition or create instances of higher resource availability.
- The highly connected nature of road networks facilitates the dispersal of invasive plants with some species expanding beyond road verges to colonize neighboring communities (Birdsall et al. 2012, Meunier and Lavoie 2012).
- Roads have been shown to function as prime habitats and corridors for invasive plant species and therefore, can contribute to the spread and establishment of invasive species inside protected areas (Jodoin et al. 2008, Birdsall et al. 2012, Meunier and Lavoie 2012).
- Large roadside verges and high levels of disturbance associated with roads create conditions suitable for the establishment and growth of many invasive species (Birdsall et al. 2012, Meunier and Lavoie 2012).
- According to Jodoin et al. (2008), “Most roads are bordered by drainage ditches, forming a network of linear wetlands. Because of their spatial configuration, drainage ditches may serve as habitats and corridors facilitating the spread of aquatic invaders into the intersected ecosystems.”
- *Phragmites australis* (common reed) is an emergent macrophyte that is often found in narrow linear wetlands of Eastern Canada; roadside and agricultural ditches are believed to play a key role in the observed invasion patterns (Maheu-Giroux and Blois 2005).

- Results of Wilcox et al. (2003) suggest that natural and anthropogenic disturbances resulted in optimum conditions for the colonization and rapid expansion of the introduced genotype of *Phragmites*.
- Monitoring of invasive plant species should be included in forest restoration efforts. Weed control in disturbed areas and along roadways may represent cost-effective and efficient tactics to limit plant invasion (Birdsall et al. 2012).
- According to Reichard and White (2001), “The majority of woody invasive plants in the United States were introduced for horticultural purposes—one study found that 82% of 235 woody plant species identified as colonizing outside of cultivation had been used in landscaping (Reichard 1997), and an additional 3% were widely distributed for soil erosion control (virtually all of the latter group were also introduced as ornamentals, however).”
- As cited in Li et al. (2004), “Reichard and Campbell (1996) documented that 85% of the 235 invasive woody plants in the United States were originally introduced as ornamental plants, while an additional 14% were introduced as agricultural plants.”
- According to Pejchar and Mooney (2009), it is generally easier to prevent species introductions than to control invasions. As such, it is important to have the knowledge of what species or groups of species are most likely to impact ecosystem services to direct management decisions and direction.
- Changes in competitive interactions between species in response to anthropogenic disturbance can result in native species retreating from highly competitive species or altering their resource usage to minimize competition (Milko 2012).
- According to a recent study by Benson et al. (2012), it may be difficult for coyotes to invade Algonquin Provincial Park as smaller prey, such as deer, are relatively scarce in summer and largely absent in winter in western portions of the park. Additionally, foods such as garbage or the remains of hunted animals are presumably rare relative to adjacent areas.

Anthropogenic activities such as the development of roads and cottages can facilitate the spread and establishment of non-native plants and animals, and the introduced species that are invasive have the potential to alter the communities that they inhabit, often to the detriment of resident species. Access roads that facilitate travel to and from cottages are likely to have the greatest potential to aid in the spread of invasive species. Additionally, increased nutrient input from septic systems may give non-native vegetative species a competitive advantage. Gardening activities have a long history of introducing non-native plants into new communities and thereby facilitating the spread of invasive species or varieties. Additionally, disturbances to the ecological communities where cottaging activities occur may facilitate the expansion of species into new areas, and once established, the altered environments can favour the non-native species. In most cases, non-native species are unlikely to spread through natural processes; instead, the presence of human disturbance plays a pivotal role establishing species that become invasive.

3.7 Subsidized domestic and Feral Predators

Anthropogenic landscapes may provide increased opportunities for generalist predators that are capable of exploiting both anthropogenic and natural resources (Webb et al. 2004). Rather than being randomly distributed, anthropogenic development is usually associated with the borders of national parks and other public lands, rivers, lakes, or coastal areas (Hanson et al. 2005); this development is known to alter the landscape composition to suit human needs. Anthropogenic development produces conditions that support high densities of both generalist and opportunistic predators while at the same

time, supporting low diversity of insectivorous and sensitive avian species (Rodewald et al. 2011). Changes at a landscape scale can create refuges, or areas that are unexploited by top-level predators. These refuges can free lower level predators from predation and produce an increased population size or density of so called meso-predators which in turn can suppress the prey population (DeCesare et al. 2010).

- Predators are a key element in the maintenance of ecosystems and both the presence and persistence of apex predators is important in the continuation of healthy ecosystems (DeCesare et al. 2010).
- The effects of predators at any trophic level may be increased in human-altered landscapes (DeCesare et al. 2010).
- Theory predicts that subsidized predators that are not dependent on a given prey can suppress the population of this prey to very low densities by continuing to take wildlife in habitat patches long after the density of prey is too low to sustain natural predators (Schneider 2001).
- Nests of some species may have increased detectability in areas of human development as these locations are often associated with reduced vegetation structure, corridors that facilitate predator movement, or by reducing the amount of available nesting habitat thereby increasing local nesting density (Phillips 2008).
- Opportunistic nest predation by subsidized predators is a common phenomenon (Phillips 2008).
- Anthropogenic development can produce conditions that lead to the decoupling of interactions between breeding birds and their nest predators, often to the extent that the two are no longer interrelated (Rodewald et al. 2011).
- The potential for predators to have a negative influence on prey populations was low when the fraction of human settlement in the landscape was low (< 20%). When human settlements covered much of the landscape (> 40%) the effect of subsidized predators was found to result in low likelihood of prey persistence (Schneider 2001).
- The presence of human development may be associated with supplemental food resources that attract predators and may increase predation on nearby non-target species (Strickland and Janzen 2010).
- It has been suggested that supplementing predators with food via garbage, bird feeders, and so on may reduce predation levels on prey species; however, other research suggests that such supplemental foods can increase predation on prey as predator density increases in response to the increased food source (Strickland and Janzen 2010).
- Predation may be problematic in human-dominated landscapes where generalist predators have been shown to increase in density and in turn, limit the populations of some prey species (Marchand and Litvaitis 2004)
- Red foxes and racoons are considered subsidized predators for two reasons: these species benefit directly from agricultural landscapes, and they inhabit a region where the natural carnivore community is fractured, thus releasing both foxes and racoons from competition with larger carnivores (Gompper and Vanak 2008).
- Phillips (2008) found that the densities of racoons in Point Pelee National Park, was amongst the highest reported in the literature, and four times higher than the overall average for rural Ontario. This is important because Browne and Hecnar (2007) found that turtle nest predation by racoons ranged from 63% to 100%.

- Results of Phillips (2008) suggest that racoons do not direct foraging efforts specifically towards turtle nests; however, increased density of racoons in a given area can increase the likelihood of a nest being discovered and predated. Furthermore, individual racoons do not appear to demonstrate higher site fidelity to areas where they have depredated nests.
- Strickland and Janzen (2010) found that turtle nests located away from anthropogenic structures had a greater likelihood of being predated than those located adjacent to the same structures. Marchand and Litvaitis (2004) suggested that presence of humans and domestic dogs may have been responsible for the low nest predation rates of turtles that oviposit close to anthropogenic structures.
- Phillips (2008) suggested that alterations to the landscape by humans can contribute to increased rates of turtle nest predation by creating increased opportunities for subsidized predators to locate prey.
- Common ravens (*Corvus corax*) are an exemplary generalist predator whose population growth and persistence has been linked to food subsidies associated with human development (Webb et al. 2004).
- Human population increase has been found to be a significant driver of raven populations as this species is known to forage at anthropogenic sites (Webb et al. 2004).
- Webb et al. (2004) found a positive correlation between nest survival of juvenile ravens and proximity of the nest to the closest human subsidy. In this case, increased survival was linked to the availability of anthropogenic resources to facilitate lower foraging costs and increased food delivery rates that allow both an increase in the health of young and parents but also allows for increased parental vigilance against predators.
- Pets may also function as subsidized predators. Literature suggests that hunger and hunting have become uncoupled in cats, as individuals will routinely hunt even if they are well fed (Adamec 1976, May 1988, as cited in Hawkins et al 1998).
- In the United States, pet cats are responsible for the deaths of millions of birds every year (Hawkins 1998, Hanson et al. 2005).
- Domestic cats (*Felis silvestris catus L.*) are opportunistic predators associated with anthropogenic development. Adjacent to development, cats are sustained by human food supplements to the point where population densities exceed the carrying capacity of the landscape; they have been shown to be important predators in small mammals and birds (Schneider 2001).
- Pet dogs can act as predators in many ecosystems as they have been shown to alter the distribution of deer, and in the Florida Keys, have eliminated Key Deer from some areas (Hanson et al. 2005).
- Pet dogs may actually deter some subsidized predators as reduced nest predation of turtles by racoons have been attributed to the presence of domestic dogs (Marchand and Litvaitis 2004).
- According to Kunkel and Pletscher (2000), “as logging reduces the size of residual forest patches and increases the density of roads, the travel and searching efficiency of large carnivores is enhanced.”
- Wolves have been show to use roads to for travel. It is assumed that use of these corridors increases hunting efficiency for wolves; however, the risk of wolf mortality resulting from human presence on or near roads, likely outweighs any benefits of their use for hunting and travel (Kunkel and Pletscher 2000).

- In a study by Kunkel and Pletscher (2000), locations where moose were killed by wolves were characterized by low road density and that wolf territories were selected to result in the lowest possible road densities.
- James and Stuart-Smith (2000) indicate that, "...linear corridors may provide wolves with increased access into caribou ranges and allow them to travel more quickly through their environment."
- In a study of wolf predation on Caribou, James and Stuart-Smith (2000) documented higher predation risk for prey found close to linear corridors (e.g., roads).
- According to Benson et al. (2012), "Where wolves are protected, wolf presence may actually be positively associated with tertiary roads because wolves use linear features such as roads to facilitate rapid movement across rugged terrain."

Generalist predators that typically increase in numbers in communities modified by humans, especially in areas where large carnivores have been extirpated, are often called subsidized predators (Browne and Hecnar 2007). Predators are said to be subsidized when humans directly or indirectly alter resource availability in such a way that the density of a given predator population is increased beyond levels that would occur without the additional resources (Gompper and Vanak 2008). Predators can be subsidized by human activities associated with cottage development in a number of ways: (1) presence of additional food resources associated with human development; (2) domestic pets owned by cottagers are fed and cared for; and (3) the literature provides some support that wide-ranging carnivores such as wolves, may benefit from the presence of roads or anthropogenic clearings associated with cottage development, in so long as these features are not readily used by humans.

3.8 Effects of Human Disturbance on Wildlife Behaviour, Survival, and Mortality

Historically, much of the research into the impacts of humans on wildlife has focused on the role of direct loss of habitat from development and site alteration activities. With recent intensification of human development in previously natural communities, concern has been raised regarding the potential for human activities to cause less tangible impacts on wildlife than the direct loss of habitat. For example, behavioural responses by wildlife to the environments in which they live have evolved over countless generations in response to site-specific conditions. Introduction of human stressors into this environment can result in changes in these evolved behaviours, and often these altered behaviours affect survival and fitness. Therefore, insight into how wildlife responds to anthropogenic activities and the presence of humans is fundamental to better understanding the impacts of human disturbance on wildlife populations.

- Non-motorized recreation activities have been shown to alter the physiology and immediate behaviour of birds including changes in foraging, vigilance, and evasion behaviours (Steven et al. 2011).
- In a recent review by Steven et al. (2011), 88% of papers focused on impacts of recreation on avian species reported negative effects, with most documenting impacts on reproductive success.
- Human disturbances on wildlife vary in duration, intensity, and periodicity all of which can have significant impacts on wildlife. The approach of a human may trigger a short term change in the behaviour or physiological processes in a bird (e.g., flight responses); however, these short term responses can have longer term effects as is the case of breeding birds being flushed from nests leaving eggs or chicks vulnerable to predation (Steven et al. 2011).

- Shoreline anglers can have serious impacts on water birds, as anglers often remain in one location for long periods. During angling activities, humans demonstrate short periods of rapid movements interspersed by long periods of inactivity. This pattern of behaviour is known to impact shoreline birds with the disturbances resulting in higher rates of non-hatching and nest abandonment (Lewin et al. 2006).
- Human disturbances of wildlife caused by recreational activities, can result in changes to species distribution, richness, and abundance in water birds (Lewin et al. 2006).
- According to Liddle and Scorgie (1980), “The physical forces associated with water-based activities originate mainly from boats, and include wash, turbulence, propeller action (cutting effects), direct contact and also disturbance by sight and sound. The effects of other activities such as swimming are insignificant in comparison, except when they are particularly concentrated in space and time.”
- Cunnington and Fahrig (2010) documented changes in amphibian vocalizations in response to increased levels of traffic noise. And while, the results of Cunnington and Fahrig (2012) indicate that these changes in amphibian vocalizations in response to traffic noise appear to compensate for any negative effects this noise may have on an individual’s ability to attract a mate, it is unknown what additional costs these changes may have (e.g., increased predation risk, increased energetic requirements).
- According to (Fahrig and Rytwinski 2009), negative effects of roads on wildlife populations are predicted to occur under four situations:
 - When species are attracted to roads and are unable to avoid individual cars
 - Species with large movement ranges, low reproductive rates and low natural densities
 - Small animals whose populations are not limited by road-affected predators but who avoid habitat near roads
 - Small animals whose populations are not limited by road-affected predators but who avoid habitat near roads
- Summers et al. (2011) found that negative correlations between bird richness and abundance, and roads was not the result of behavioural avoidance of traffic noise but instead likely the result of individual responses to habitat edges or increased road kill mortality rates.
- While wolves appear to avoid roads in the establishment of their territories, in some cases, linear corridors may increase wolf predation efficiency by increasing their search rate and may provide greater access to prey species (James and Stuart-Smith 2000).
- James and Stuart-Smith (2000), found that wolves made greater use of linear corridors for movement than would be expected by chance.
- Whittington et al. (2004) found that wolves traveled on roads, trails, and railway lines 16% of the time and traveled through the forests, rivers, and meadows the other 84% of the time.
- Additionally, Whittington et al. (2004) documented that wolves were “...3.7, 2.7, and 2.6 times more likely to cross low-use trails than high-use roads, high-use trails, and the railway line, respectively.”
- Wolves are thought to avoid the hazards associated with humans rather than the features used by humans (Whittington et al. 2004).

- Moose have been shown to avoid areas close to roads where hunting is permitted and individuals demonstrate strong seasonal avoidance of these areas during times when hunting by humans is permitted (McLoughlin et al. 2011).
- Most studies have documented a negative response by amphibians and reptiles, as well as medium to large mammals to roads. These negative responses are likely best explained by vulnerability to road mortality in these species (Fahrig and Rytwinski 2009).
- Feeding birds is a popular form of recreation for people of all ages, and the benefits of bird feeding to people are numerous; however, risks to birds utilizing feeders include becoming overly dependent on them (Brittingham and Temple 1992).
- Avian dependency on supplemental feeding can be short term, i.e., birds relying on the presence of the feeders may be adversely affected if the feeder is removed or left empty for a prolonged period. Over the long-term, overreliance on supplemental feed may result in reduced survival rates when feeders are not available (Brittingham and Temple 1992).
- Individuals that continuously forage at feeders may be less efficient in seeking natural food sources (Brittingham and Temple 1992).
- According to Brittingham and Temple (1992), “Migratory species may become more dependent on feeders because of unfamiliarity with the wintering area.”
- Aggregations of birds around feeders may attract predators or enhance the spread of diseases (Robb et al. 2008).
- Feeders may function as ecological traps, as they provide inaccurate cues to the quality of habitat based food resources (Robb et al. 2008).
- Supplementation of food resources may allow birds to invest in larger or higher quality eggs as an alternative (or in addition) to investing in increased clutch size (Robb et al. 2008).
- According to Robb et al. (2008), the presence of additional food resources may allow females to spend less time foraging, thereby allowing earlier initiation of incubation, better protection of eggs from predation, and earlier fledging, leading to higher survival rates.
- As stated in Robb et al. (2008), “Disease transmission appears to vary according to the type of feeder used, the number of birds visiting it, and the habitat in which the feeder is located. In a survey of households in Wisconsin, bird mortality was found to be higher around platform feeders (Brittingham and Temple 1986).”
- Colonization of areas by coyotes has been facilitated by human actions that include clearing of forests, as well as the persecution and elimination of wolves. These anthropogenic influences may have also reduced reproductive barriers between wolves and coyotes (Benson et al. 2012).
- According to Benson et al. (2012), “Tertiary roads probably affect wolves and coyotes primarily by providing access for harvest, as these unpaved roads and trails are probably not a significant source of fragmentation or mortality from vehicle collisions.”
- Ungulates may be attracted to roads to avoid predation if human presence creates refugia from predators; however, these areas may be avoided should they present additional risks from the presence of humans (McLoughlin et al. 2011).

The presence of anthropogenic disturbances in communities can have detrimental impacts on individuals from a variety of species. The presence of anthropogenic noise has been shown to impact

vocalization behaviour in some species; disturbances associated with human use of littoral zones has been shown to impact avian species; supplemental feeding can increase wildlife reliance on humans, increase mortality rates, and increase the spread of parasites and disease. Some species have been shown to avoid areas of high human use, while others are drawn to human developments such as roads, often with disastrous consequences. Alternatively, human activities can have positive effects on the reproductive rates of species and facilitate movement of wildlife. Finally, many anthropogenic activities affect wildlife behaviour and survival.

3.9 General Wildlife Populations and Habitat and General Terrestrial Vegetation

The subtopics “Terrestrial Vegetation” and “Wildlife Populations and their Habitats” are inextricably linked to the other subtopics we have evaluated. For example, fragmentation caused by roads will decrease the amount of available habitat for wildlife while at the same time reducing the diversity of terrestrial vegetation and facilitating the spread and establishment of invasive species. Therefore, the following section includes additional information on the impacts of cottages and associated recreational activities on wildlife populations, their habitats, and terrestrial vegetation communities that have not been examined previously in this review.

- Human developments create immense problems for wildlife the world over because they degrade habitat quality (Whittington et al. 2004).
- Ecological impacts of outdoor recreation activities are considered to be a significant threat to the integrity of the ecosystems in which they occur (Marzano and Dandy 2012).
- Direct impacts of recreation on wildlife can include changes in both behaviour and habitat use, both of which can impact foraging and fitness of individuals (Marzano and Dandy 2012).
- Indirect impact of recreation can include soil erosion and compaction, and the potential to introduce pathogens, and exotic species (Marzano and Dandy 2012).
- Cover of trees, shrubs, and ground vegetation decreases with shoreline development. The most significant structural reduction in forest communities is the removal of deadfalls and snags by cottagers (Racey and Euler 1982).
- Cottage development can affect vegetation directly through the planting and removal of species, and indirectly by alterations to the microhabitat and soil characteristics (Racey and Euler 1982).
- Riparian vegetation structure is known to affect breeding bird communities and the alteration of these communities through vegetation removal can result in changes in the bird community as well (Ford and Flaspohler 2010).
- Simplification of vegetation structure as a result of cottage development may be the primary driver of changes in wildlife communities in these areas (Henning and Raembsburg 2009).
- Anthropogenic reductions in vegetation structure can diminish the number of refugia for frogs during the mating season thereby increasing the likelihood of predation (Henning and Raembsburg 2009).
- The most obvious impact of cottage development is the removal and clearing of vegetation to provide access and building locations (Pickering and Hill 2007).
- Damage to vegetation communities from anthropogenic development is not restricted to the initial removal of vegetation as the construction and use of roads often results in changes to hydrology and

soils including erosion, sedimentation, and pollutant runoff in adjacent areas (Pickering and Hill 2007)

- According to Pickering and Hill (2007), "...the impacts of tourism on rare flora including that in protected areas has not been generally recognised as a specific type of threat, even though there is evidence of negative environmental impacts from tourism on these taxa in protected areas."
- According to Taylor and Knight (2003), "...recreation is the second leading cause for the decline of federally threatened and endangered species on public lands..."
- For some species, the presence of humans may result in wildlife avoiding portions of their normal range; this loss of suitable habitat and the associated range shift may reduce the carrying capacity of protected areas for some species (Taylor and Knight 2003).
- Wildlife movement is a fundamental aspect of population viability. Anthropogenic stressors that restrict or limit wildlife movement will have negative impacts on the long term viability of wildlife populations (Taylor et al. 1993).
- Small mammals function as both first and second level consumers and changes in their population sizes are indicative of alterations in trophic structure in the wildlife community. Impacts to small mammal communities by cottage and shoreline development can result in significant declines in these key elements in the community food web (Racey and Euler 1982).
- Food conditioning and human habituation has been found to be a response by some birds to the presence of feeders (Marzano and Dandy 2012). Food conditioning can cause nutrient deficiencies in some wildlife or enable local populations to reach unnaturally high levels (Marzano and Dandy 2012)
- Hatching success in the common loon (*Gavia immer*) decreased as the number of cottages within 150 m of the nest increased (McCarthy and Destefano 2011).
- Common loons are often absent from lakes with high levels of cottage development (McCarthy and Destefano 2011).
- A study conducted by Ford and Flaspohler (2010) found that shrub-nesting birds were more abundant in undeveloped shorelines while canopy-nesting birds were more abundant in developed shoreline areas. In this same study, birds that nested on the ground were found to be equally abundant in both developed and undeveloped shorelines.
- In a study by Obbard et al. (2010), black bears (*Ursus americanus*) were found to limit their use of areas in close proximity to human settlements and developed areas.
- Young black bears have been shown to avoid roads during the spring and summer, but increase their use of road corridors in late summer as berry-producing plants with high nutritive value are producing fruit during this period (Obbard et al. 2010).
- Mech (1989) suggests that wolf populations tend to survive where human population density is low and the density of roads that can be traversed by 2-wheel drive vehicles is less than 0.6 km/km².
- In a study by Mech (1989), human caused mortality of wolves was not detected in large roadless landscapes despite accessibility to the area via hiking trails and canoe.
- Wolf densities have been shown to be negatively associated with road densities, particularly in areas where harvesting wolves is permitted; however, coyotes are often abundant in areas with high road densities and associated human disturbance (Benson et al. 2012).

4 REFERENCES

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