Rondeau Cottage Lease Background Report - Literature Review

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Webpage title: Rondeau Cottage Lease Background Report Literature Review

Webpage description: This document is a literature review on the impacts of cottage development and related recreational activities on the natural environment of Rondeau Provincial Park

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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 septics, 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.

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:

- Great lakes shoreline (with a focus on Lake Erie)

- The following SAR and their habitat, Eastern Hognose Snake, Barn Swallow, Chimney Swift, Fowlers Toad, Eastern Foxsnake, Map Turtle, Blanding's Turtle, Prothonotary Warbler, Red Headed Woodpecker, Nodding Pogonia, Five Lined Skink, Common Hoptree, Red Mulberry, Ribbon Snake, Spiny Softshell turtle, SAR fishes
- Rare invertebrates (S1 to S3) known from Rondeau Provincial Park dune, prairie, and savannah ecosystems
- Riparian and littoral habitats and other comparable aquatic ecosystems associated with Rondeau 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)
- Dune and savannah ecosystems and ecotones, including succession and disturbance regimes
- Subsidized, domestic and feral predators
- Introduction and spread of terrestrial invasive species

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 Rondeau Provincial Park community or surrounding landscape is beyond the scope of this review.

RESULTS AND DISCUSSION

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:
    - “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 to 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.

- Few studies have examined impacts of cottage properties, despite the importance of cottages as a shoreline land use along the Great Lakes (Scott and Parker 1996).

- According to Scott and Parker (1996), “Far more cottage properties have been affected by erosion (62% basin wide) than flooding. Erosion impacts were most prominent on the shores of Lake Erie (85% of cottage properties), where shores composed of unconsolidated sand or gravel are highly susceptible to erosion.”

- Water levels in Lake Erie over the past 50 years have been characterized by a period of rising water levels and rapid shoreline development (Meadows *et al*. 2005).

- Historically, Great Lakes nearshore areas have been altered to maintain commercial navigation and protect property threatened by coastal erosion (Meadows *et al*. 2005).

- Development of structures along shorelines that act to prevent natural erosion result in alterations to nearshore processes that transport substrates within littoral communities, and in turn eliminate shoreline migration as Great Lakes water levels change, as well as reducing aquatic habitat diversity (Goforth and Carrnan 2005).

- To protect shoreline property on the Great Lakes from erosion, nearshore areas have been altered (Meadows *et al*. 2005).

- According to Goforth and Carrnan (2005), "Loss of diversity and abundance of prey fish resulting from shoreline development and changes in nearshore habitats may have long-term, cumulative effects on Great Lakes fisheries production due to lost foraging opportunities. Therefore, protection, restoration, and remediation of nearshore habitats and shorelines will likely be necessary to improve the biological integrity of nearshore zones and ensure the sustainability of prey fish resources to support Great Lakes fisheries."

- Urban, industrial, and residential development of shorelines result in ecological stressors that have altered Great Lakes nearshore environments (Goforth and Carman 2009).

- The volume of water within the Great Lakes strongly influences nearshore terrestrial habitats through temperature depression in spring and thermal retention and consequent warming of these same habitats in fall (Ewert *et al*. 2011).

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.

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).

- 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).

- Severe shoreline trampling and soil erosion associated with hiking trails has been implicated in phosphorous enrichment of lakes and streams (Gunn *et al*. 2004).

- 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).

- 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).

- 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.”

- 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 (Dzwairo *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 pm 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 Houlahan 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 (Houlahan 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 Robb *et al*. (2008), "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. 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.

Dune and Savannah Ecosystems and Ecotones

Coastal dunes and savannahs are highly dynamic ecosystems driven by disturbance. However, although disturbance is a key process in these systems, research has shown that many human induced changes have had negative effects on these ecosystems. Globally, these ecosystems attract considerable attention as tourist hotspots. Within the Great Lakes basin, dunes have become fragmented or entirely displaced because of residential and other forms of development. Development pressures continue to rise as seasonal cottages become transformed into year-round residences, resulting in increased impacts (Callaghan 2008).

Dune Ecosystems

- The dune ecosystems along the north shore of Lake Erie are highly dynamic. Under natural conditions, winter storms sculpt new dune faces and alter beaches and vegetation structure on an annual basis. During the summer, fluctuations in water level can greatly affect the shape and area of beach available for wildlife to use. High winds can create waves large enough to have powerful erosive impacts on standing dunes (Boenke 2011).

- The sand spit formation at Rondeau is dynamically maintained by Lake Erie storms, fluctuating water levels, and littoral drift processes (COSEWIC 2010a).

- Recent publications focused on Rondeau Provincial Park indicate that "…the proportion of disturbed dune area resulting from cottage leasehold access versus public access has declined from 95% of all disturbed area (12 ha) in 1955 to 82% in 2006 (6 ha) and over a 50% decline in total area during that time period" (Dobbyn and Pasma 2012). These reductions in leasehold related impacts to the dune ecosystem are attributed to management changes and adherence of leaseholders to conditions. Continued disturbance to dune systems by individuals at select cottage lots continues to result in significant impacts to the ecosystem (Brinker *et al*. 2012).

- In Rondeau, the bulldozing of the east beach to create clear views of the lake for cottagers and remove accumulated sand resulted in the destruction of dune profiles (Brinker *et al*. 2012).

- Regarding cottage impacts on the communities within Rondeau, Bjorgan (2011) stated, “The ecosystems in which the cottages are located are among the rarest in Ontario and in North America. The pressures that have caused the decline in numbers and health of the species and habitats of this area are largely driven by development and the associated human footprint and activities. As long as development human activity continues to be dominant in these habitats, the health of the ecosystem and the species that depend on it will decline. Removing or significantly reducing the footprint of the occupants and engaging in active management to maintain the remaining integrity of the ecosystem and restore degraded areas is the best way to ensure that these habitats and the species that call them home will continue to be in Ontario.”

- Anthropogenic impacts on dune communities include decreased vegetative cover and species richness, reduced above ground biomass, and mean height of colonizing foredune vegetation (Bonanno *et al*. 1998).

- Dune vegetation has been shown to be reduced after as few as 300 trampling passes (Bonanno *et al*. 1998).

- In instances when foredune structure is destabilized, the vegetation community associated with the barrier dune may also experience negative impacts as the foredune provides shelter and contributes to growing conditions of the barrier interior (Bonanno *et al*. 1998).

- Dune vegetation is a dichotomy in that these species are well adapted to severe growing conditions of the dune and beach environments but are highly vulnerable to anthropogenic disturbance (Bonanno *et al*. 1998).

- In instances where sand and colonizing vegetation is disturbed on the lakeward side of the barrier dune, stabilization of the substrates was delayed as sand movement remained at high levels (Bonanno *et al*. 1998).

- According to Bonanno *et al*. (1998), impacts to dune ecosystems from recreation activities are ongoing and show no sign of cessation.

- Tolerance of dune ecosystems to human influences is driven by species composition, the intensity of human impacts, and the nature of the substrate (Bowles and Maun 1982).

- Burden & Randerson (1972) found sand dunes to be among the most fragile natural systems (as cited in Bowles and Maun 1982).

- Bowles and Maun (1982) found that paths in health-grassland communities became visible after as few as 50 passages by humans.

- It has been suggested that plants become bruised through trampling, became water-stressed and show increased susceptibility to frost damage (Bowles and Maun 1982).

- Bowles and Maun (1982) found that most savannah species which showed rapid recovery after isolated trampling events but were seriously impacted by prolonged exposure to trampling pressure.

- According to Callaghan (2008), “Human impacts on coastal dunes, including those of development, overuse, invasive species and pollution, can drastically change the appearance and function of the shoreline landscape.”

- In a recent paper by Callaghan (2008), the author stated that “Cottage development can present several problems with regard to coastal dunes. Firstly, many cottages are accompanied by turf lawns that may extend into the foredune system. As a result of owner upkeep, lawns are typically stable in structure. Coastal dunes, on the other hand, are unstable by nature. As dunes migrate in response to shoreline activity, large volumes of sand may be deposited landward onto lawns or vertically so as to block scenic lake views. So too is the situation when other permanent structures, such as paved roads, driveways or parking lots, are placed within the foredune zone, resulting in large volumes of sand drifting over these secure surfaces."

- Where cottage properties are located in dunes, multiple access points are often created as individual users establish their own paths through dunes to the beach. These paths can lead to destabilization of the dune structure leading to blowouts (Callaghan 2008).

- When blowouts in dune ecosystems as a result of human activities associated with anthropogenic structures, revegetation and restoration of these areas is often prevented by ongoing use of these areas by humans (Callaghan 2008).

- Heavy use of pathways in dune systems equivalent to a single person visiting the beach twice daily results in the reduction of vegetation cover into the following years (Bowles and Maun 1982, Callaghan 2008). As such recreational beach use in dune ecosystems are known to disrupt beach dynamics through the physical removal of vegetation for (Callaghan 2008).

- Contamination of dune soils can occur through seepage from failed septic systems in homes and cottages. This seepage contributes to increase in the organic content of the natural sandy soils (Callaghan 2008). While this may appear to be a positive effect, the increased organic content allows for a corresponding increase in water retention that favours non-native species (Callaghan 2008).

- Private landowners in dune ecosystems have been known to mechanically alter dunes through bulldozing and removal of vegetation for the purposes of increasing the aesthetic value of the community (Callaghan 2008).

- While considerable focus has been placed on the identification of anthropogenic impacts to dune plant communities, little is understood regarding the relationship between plant community composition and the shoreline erosion processes (Ciccarelli *et al*. 2012).

- Dunes are threatened by development of cottages and residences and in some areas, relict dunes continue to be lost to arable fields (Joint Nature Conservation Committee 2004).

- Native dune vegetation is known to protect human developments through soil stabilization; these species are thought to be key to mediating the negative impacts of global climate change, including rising water levels, severe storms, and greater erosion (Emery and Rudgers 2010).

- Pedestrian traffic and recreational activities result in soil compression, as well as a decrease in the infiltration and percolation ratio which causes increased overland flow and erosion in ecosystems associated with sandy soils (Kutiel *et al*. 1999).

- Previous studies have documented a negative correlation between the intensity of recreation activities in dune ecosystems and plant cover, plant height, species richness and species diversity (Kutiel *et al*. 1999).

- Stabilised sand dunes with climax vegetation communities are more susceptible to disturbance when compared to shifting and semi-stabilised sand dunes (Kutiel *et al*. 1999).

- Human recreational reduces leaf litter and organic matter in the upper layer of the soil (Kutiel *et al*. 1999).

- Shoreline stabilization structures act to reduce bluff recession in coastal dune systems; however, over time, these structures may lead to reductions or complete elimination of beaches and barrier systems, and the loss of shoreline and riparian sand substrates (Meadows *et al*. 2005).

- Urbanization and infrastructural development are associated with habitat loss and fragmentation and changes in disturbance dynamics (e.g. erosion and fire) in dune and savannah ecosystems (*Newton et al. 2011*).

- Dune protective measures can include limiting tourist access to highly sensitive areas, fencing, planting dune grass, building boardwalks to access beaches, and use of signs and sand carpets to direct users (P. Lane and Associates Limited 1990).

- Another obvious negative impact of human interaction in dune systems is related to the attempts to stop or slow down the rate of shoreline recession. Attempts to halt shoreline recession result in imbalances in the rate of the sediment supply that maintains the beach and the dune systems (P. Lane and Associates Limited 1990).

- The low-lying, unconsolidated nature of beach and dune areas are known to be vulnerable to both flooding and erosion impacts (Scott and Parker 1996).

Savannah Ecosystems

- Savannah communities rely on specific disturbances regimes (Tagliavia 2002).

- Historically, both anthropogenic and natural fires maintained the characteristic species composition of savannah communities in Ontario; however, the increase in detrimental disturbances such as extensive herbivory by white-tailed deer (Odocoileus virginianus) and the suppression of fires have altered the effects of disturbance regimes (Tagliavia 2002).

- Deer grazing has be linked to the decline of many native species and favoured the expansion of exotic ones in many parks where oak savannahs occur (Tagliavia 2002).

- In savannah communities, the rate of recovery is dependent on the extent, intensity and frequency of the disturbances affecting it (Tagliavia 2002).

- Theory predicts that diversity will be greatest at an intermediate level of disturbance (Tagliavia 2002).

- Savannah ecosystems are constantly in a state of change. High levels of disturbance limit communities to only a few pioneer species, as the ongoing disturbance continually sets succession back. When the disturbance is moderate, both early and late successional species are able to colonize and survive together, maintaining the community in a non-equilibrium state (Tagliavia 2002).

- Disturbances can also be synergistic or additive in nature with each acting to change the community in subtle but different ways (Tagliavia 2002).

- It has been hypothesized that the elimination of an ecosystem stressor, or inappropriate disturbance may reverse degradation within the system; however, if a threshold within the system has been passed, recovery is unlikely as remaining individuals and species are incapable of restoring the system without additional intervention (Tagliavia 2002).

The amount of empirical evidence demonstrating that dune and savannah ecosystems are (1) highly susceptible to adverse anthropogenic disturbance and (2) dependent upon intermittent, large-scale disturbance (e.g., wind, fire) is considerable. From a conservation perspective, these two ecosystems are of elevated concern because there are few areas in Ontario where the natural disturbances necessary to maintain them is allowed to occur. For example, because the majority of the shorelines along the Great Lakes have been settled by humans, there are few locations where sandspits and dunes are permitted to change substantially through weather events (i.e., shoreline modification to protect private property is usually given high priority). Similarly, the intermittent fires necessary to maintain savannahs are either quickly suppressed or have to be carefully controlled because of property and human safety concerns.

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 re- colonization 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 toTewksbury *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 Houlahan 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 Houlahan 1997).

- A study by Findlay and Houlahan (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 impact wildlife through mortality effects, habitat loss and fragmentation, alterations to community composition, and in some cases, reducing reproductive success (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.

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).

- 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).

- 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).

- 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).

- 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.

- Linear habitats may act as dispersal corridors and invasion routs into the communities that they intersect (Maheu-Giroux and Blois 2005).

- The highly connected nature of road networks facilitates the dispersal of invasive plants with some species expanding beyond road verges to colonize neighbouring 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 (Birdsall *et al*. 2012, Meunier and Lavoie 2012).

- In eastern Canada, smooth bedstraw has recently invaded many abandoned agricultural fields. Density of smooth bedstraw in abandoned agricultural fields significantly increases within 125 m of roads allowing this species to outcompete other plant species, thereby rendering plant diversity in these fields at risk (Meunier and Lavoie 2012).

- Where invasive species are abundant it has been recommended that shrubs be planted as competition along road verges (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*.

- Cottage leasehold properties in Rondeau have a higher proportion of alien and invasive tree species such as Black Locust (*Robinia pseudoacacia*), White Mulberry (*Morus alba*), Tree-of-heaven (*Ailanthus altissima*), Manitoba Maple (*Acer negundo*), Norway Maple (*Acer platanoides*), European White Poplar (*Populus* alba), Scots Pine (*Pinus sylvestris*), and to a lesser extent, Catalpa (*Catalpa bignonioides*) than are found in the remaining portions of the park (Brinker *et al*. 2012).

- In Rondeau Provincial Park, the number of invasive species associated with the treed sand dune communities are such that they may compromise the integrity of the natural vegetation types in the remaining portions of the park (Brinker *et al*. 2012).

- 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.

- 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).

- In Rondeau Provincial Park, many exotic plants that originated on leased land, including Japanese Barberry, Black Locust, and Tree of Heaven now occupy many of the park's natural areas (Bjorgan 2011).

- According to Bjorgan (2011), "Planting of exotic species by cottagers on and off lease has resulted in the spread of invasive species into the dune ecosystem and throughout the park."

- Eschtruth and Battles (2009) found that White-tailed Deer herbivory played an important role in contributing to the invasion of two plant species.

- According to Dobbyn and Pasma (2012), 224 of the 916 plant species (24.5%) found in the park are considered non-native to Ontario (alien) and a further four species are native to Ontario but not to the park itself.

- Herbivory is thought to be more important in determining the size of individual plants than in the number of plants likely to establish (Eschtruth and Battles 2009).

- Alteration of disturbance regimes has modified the plant community in Rondeau Provincial Park (Tagliavia 2002).

- Over the last 20 years, White-tailed Deer in many parts of Ontario have been described as invasive species due to dramatic increases in their numbers and the drastic impacts that increased herbivory by these animals can have on native communities (Tagliavia 2002).

- In Point Pelee National Park, non-native species richness and cover is an indicator of past plant community disturbance and degradation originating from human recreation activities (Tagliavia 2002).

- Garlic mustard is currently being suppressed in Rondeau by the large deer population which feed on this species (Kothbauer 1992).

- When compared to other dune and savannah ecosystems in Ontario, Rondeau was found to have both the greatest species and non-native species richness (Tagliavia 2002).

- Management of invasive species in Rondeau Provincial Park is complicated by the large contingent of cottage residents and recreational users (Meloche and Murphy 2002).

- Tree-of-Heaven (*Ailanthus altissima*) is an invasive species that is threatening the integrity of Rondeau Provincial Park and is assumed to have spread from a cottage garden (Meloche and Murphy 2002).

- According to the Rondeau Park Vegetation Management Plan (Ontario Parks 2001), "…To the east of Lakeshore Road the natural communities have been greatly altered by cottage development, however, in some areas where cottages or other disturbances have been removed, tallgrass species such as Indian Grass, and Big Bluestem Grass have become re-established."

- In Rondeau, Phragmites (also known as Common Reed) has become well established on the barrier beach (Ontario Parks 2001).

- According to the Rondeau Park Vegetation Management Plan (Ontario Parks 2001), "Leaseholders will be encouraged to replace all exotic species with native species appropriate to the location of their leasehold...and invasive species will be removed."

- Species commonly associated with urban lawns, such as Canada bluegrass (*Poa compressa*), dandelions (*Taraxacum officinale*), and clover (*Trifolium spp*) have invaded coastal dune ecosystems as a result of cottage and residential development (Callaghan 2008).

- 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).

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.

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 supress 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 raccoons 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.

- Domestic pets could be also be classified 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 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 of 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).

- Herbivores can become a subsidized predator if they are released from predation risk by the removal of large predators in developed areas. The increased herbivory by deer can have a major effect on plant diversity (Hanson *et al*. 2005).

- Outcomes of deer herbivory in the parks include local extirpation of native species, loss of the shrub layer, increased graminoid cover, and, in Rondeau, apparently an alteration of forest structure with the development of a more open forest and lower density of trees (Hynes 2002).

- Currently, the prevailing view within the primary literature is that the effects of deer are greatest when they are present in landscapes that have no apex predators (Hurley 2007).

- White tailed deer are known to preferentially forage on some threatened and endangered plants, including American Ginseng in some locations (McGraw and Furedi 2005, as cited in Hanson *et al*. 2005).

- Subsidized predators can also enhance the spread of invasive species. Garlic mustard is a non-native species that invades forest understories, displacing native species through competition (Hurley 2007). Deer can enhance these effects, as they are known to browse preferentially on native species (Hurley 2007).

- Deer have been found to be responsible in delaying sapling recruitment of Sugar Maple by preferentially consuming this species and in turn, promoting growth of American Beech through browse avoidance behaviour (Hurley 2007).

- Deer densities in Rondeau increased significantly between 1974 and 1991 after deer were granted protective status in Ontario Provincial Parks (Tanentzap *et al*. 2011).

- Tanentzap *et al*. (2011) documented increased tree recruitment during a period of deer herd reductions thereby providing evidence for deer as a principal hindrance to forest regeneration.

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) deer populations may benefit from social implications of close contact with human development.

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.

- 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).”

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.

Species at Risk (SAR) and Other Species of Conservation Interest

Because Rondeau Provincial Park is located within Ecoregion 7E, it inherently has a high species diversity relative to the rest of Ontario (i.e., due to the latitudinal diversity gradient). This high diversity, and the fact that the northern limit of many species' distributions extends only as far north as southwestern Ontario means that the area where the park is located has a high number of Species at Risk (SAR). The importance of the park for SAR is further increased because the majority of Ecodistrict 7E-1 has been converted to other land uses (e.g., agricultural lands comprise approximately 88% of the land area; Henson and Brodribb 2005). In addition to SAR, Rondeau provides habitat for a number of invertebrates/arthropods that are either currently recognized as provincially rare, or are likely of conservation interest but have yet to be assessed.

SAR—Roads and Human-induced Mortality

- Rondeau has 17.2 km of interior public roads and the speed limits are between 20 km/h and 50 km/h (Farmer 2007, Farmer and Brooks 2012).

- Three reptiles designated Endangered or Threatened, the Eastern Foxsnake, the Eastern Hog-nosed Snake, and Blanding's Turtle are regularly killed by motor vehicles on roads in provincial and national parks, including in Rondeau (COSEWIC 2007a, Farmer 2007, Eastern Foxsnake Recovery Team 2010).

- Four reptiles designated Special Concern, the Eastern Ribbonsnake, Five-lined Skink, Northern Map Turtle, and Snapping Turtle are also regularly killed on roads in Rondeau (COSEWIC 2002, Gillingwater and Brooks 2002, Farmer 2007).

- One amphibian, Fowler's Toad (Endangered), is also found killed on the roads in Rondeau (Farmer 2007).

- Farmer (2007) found that road-killed birds were more often found in areas of high building density and low road density, and that these sites corresponded to the areas of the park that had cottages. He speculated that these areas may be attractive to birds if they contain bird feeders and other deliberately-placed food sources. The Barn Swallow (Threatened) was one of the bird species found road-killed during his study.

- Because roads in southwestern Ontario parks are closer to wetlands than in the surrounding landscape, reptiles and amphibians are more likely to experience higher levels of road mortality in these areas (Farmer 2007).

- The most common source of mortality reported for Eastern Foxsnake is vehicular collisions on roads (COSEWIC 2008).

- Because Fowler's Toads burrow and take shelter along the eastern beech they are inadvertently killed when boats are dragged on shore to the cottages (Bjorgan 2011).

- Intentional killing of snakes by humans has been documented throughout North America and there are numerous accounts of this form of mortality in Ontario (COSEWIC 2007a, 2008).

- As reported in (COSEWIC 2007a), S. Gillingwater interviewed several in-park cottagers who admitted killing Eastern Hog-nosed Snakes and other snake species and two cottage residents stated that they would continue to do so.

SAR—Other Impacts

- The non-native species, Common Reed (*Phragmites australis*), can alter the thermal microenvironment of nests and this in turn could reduce the fitness of at-risk turtles that nest in Rondeau (e.g., Spiny Softshell, Blanding's Turtle, Northern Map Turtle) (Bolton and Brooks 2010).

- Common Reed is considered a serious threat to habitat for Fowler's Toad at Rondeau (COSEWIC 2010a, Green *et al*. 2011) and is also considered a threat to Prothonotary Warbler nesting habitat where it encroaches into the slough forests (COSEWIC 2007c).

- The breeding success of Prothonotary Warblers that nest or would nest in Rondeau is adversely affected by competition for nests with House Wrens (Dobbyn and McCracken 2005, Dobbyn and Pasma 2012). The population of House Wrens in the park is augmented or subsidized by artificial nest boxes.

- Adults and juveniles of several SAR reptiles occurring in Rondeau are preyed upon by subsidized predators and domestic pets (e.g., Eastern Foxsnake, Eastern Hog-nosed Snake, Five-lined Skink, Eastern Ribbonsnake; COSEWIC 2002, 2007a, 2007b, 2008).

- Predation of SAR turtle nests by subsidized predators in Rondeau is well documented (Gillingwater and Brooks 2002, COSEWIC 2005).

- Invasive plant species such as Japanese Barberry (*Berberis thunbergii*) and herbivory by deer may threaten populations of Nodding Pogonia within Rondeau (COSEWIC 2010b)

- Unlike the impacts referenced above for the terrestrial or semi-aquatic SAR that occur in Rondeau, there is no direct evidence of negative impacts on the SAR fish that occur within or adjacent to the park, at least not that could be found in the COSEWIC status reports for the relevant fish species; instead, the sections of this review dealing with impacts of development on riparian and littoral habitats and surface and groundwater quality should be referred to.

Rare Invertebrates (Arthropods) known from Rondeau's dune, prairie, and savannah ecosystems

Although there are several rare species (i.e., S1 to S3) of the insect orders Lepidoptera and Odonata that have been documented within Rondeau (see Dobbyn and Pasma 2012), the majority of these species would not be considered sensitive to disturbance of dune, prairie, or savannah communities. Instead, the taxa most likely affected by activities associated with cottages and cottaging in these ecological communities include moths (via attraction to artificial night lighting; Altermatt *et al*. 2009), hymenopterans, and other arthropods, particularly hemipterans, known to require dune, prairie, or savannah habitat. For example, as summarized in Dobbyn and Pasma (2012), a substantial number (30 of 42) of the savannah-dwelling bee species documented by researchers at York University were new to the University of Guelph's collections. Additionally, Steve Marshall's lab at the University of Guelph has documented a substantial number of insects within Rondeau that specialize in dune, prairie, and savannah communities (e.g., the hairy-necked tiger beetle, *Cicindela hirticollis*, and numerous hemipterans, particularly different species of leafhopper). It should be recognized that the majority of these arthropod taxa have not been assessed by COSEWIC or COSSARO, yet current knowledge suggests that many of them would be considered rare in Ontario, or in some cases SAR. Thus, research demonstrating that development and associated activities can have negative impacts on these taxonomic groups (as opposed to butterflies and odonates) is likely more important for the purposes of this review. In this regard, the following points are relevant:

- Altermatt *et al*. (2009) stated that moths attracted to artificial night lighting can experience the following negative impacts: death by "…direct burning (Nowinszky, 2003), experience a higher risk of predation by bats and other predators (Warren, 1990; Svensson & Rydell, 1998; Rydell, 2006), and exhibit reduced fitness because of distraction from normal mating or feeding behaviors (Frank, 1988, 2006)."

- Concerning the tiger beetle, *Cicindela hirticollis*, Brust *et al*. (2006) stated that "Human-induced changes, including hydrologic alterations, dams, and compaction from human activity, are believed to be the primary cause of the decline. Beach trampling was apparently responsible for the decline of two subspecies (Nagano, 1980; Dunn, 1981). *Cicindela hirticollis gravida* LeConte is extinct over most of its former range in the southern half of California (Nagano, 1980). *Cicindela hirticollis rhodensis* Calder is threatened in much of its former range in New England (Dunn, 1981; Larochelle and Lariviere, 2001) and has disappeared from many historic sites near the Great Lakes."

Summary

Because Rondeau is an island amongst a predominantly agricultural landscape, the park's land is arguably some of the most important real estate for SAR in southwestern Ontario, and this is true for several taxonomic groups—particularly reptiles, birds, plants, and amphibians. Relative to some of the other subtopics discussed in this review, much of the evidence for negative impacts on SAR is from direct examples or studies that occurred within the park. Direct evidence of human-induced mortality (e.g., roadkills, persecution) or mortality resulting from subsidized predators has been documented for many decades. As studies continue on species currently designated at risk, or are initiated for those species not yet assessed by COSEWIC or the province, it is likely that additional, more subtle negative impacts attributable to development in the park will be elucidated. Given the high conservation priority inherently placed on SAR, this component of the impact review is likely one of the most important to consider.

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 Raemsburg 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 Raemsburg 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)

- 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.

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