Assessing and Mitigating Plastic Pollution in Lake Huron

Prepared for

The Lake Huron Centre for Coastal Conservation

By

Hydra Horizons Consulting

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Photo Credit: Water Canada (www.watercanada.net)

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DISCLAIMER

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EXECUTIVE SUMMARY

The emerging issue of Great Lakes plastic pollution is a threat to the ecological and economic health and stability of the Great Lakes. Plastic debris has the capacity to adversely affect aquatic environments in a variety of ways that directly affects socio-economic and environmental interests. It is a problem on local shorelines that directly affects both municipalities and the general public.

Information on the extent of the issue in marine environments is well documented and researched, while freshwater environments have received little attention. Current research on Lake Superior, Lake Huron, and Lake Erie proposes that plastic concentrations observed exceed data collected in the Great Pacific Garbage Patch. Recognized as a significant resource for both American and Canadian interests, the health of the Great Lakes is important for a variety of social, economic, and environmental factors.

This report has been compiled through researching and summarizing available information on plastic pollution in the Great Lakes. Realizing a lack of information and research dedicated to freshwater plastic pollution, findings have been compared against documented plastic pollution occurrences in oceans. The potential impacts on aquatic and terrestrial wildlife have been considered through literature research and communication with different academic researchers. Ideas have been proposed to best engage municipalities and the public along with best practices towards addressing freshwater plastic pollution.

Further research is imperative in understanding the full extent of plastic pollution in the Great Lakes. Current scientific research on plastic pollution in freshwater systems is limited. While the extensive collection of available literature on plastic pollution in oceans can be used to as comparable framework, it is important for future researchers to address the freshwater knowledge gaps. This includes the specific effects and extent of the problem in freshwater ecosystems. Within Lake Huron, it is necessary to determine the sources of microplastic pollution, the specific effects on aquatic and terrestrial wildlife, and the chemical effects of plastic in the freshwater environment.

Photo Credit: Lake Huron Centre for Coastal Conservation
(www.facebook.com/coastalcentre)

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1 Introduction

In the Great Lakes, recent research has shown comparable or even higher plastic concentrations than that of the Great Pacific Garbage Patch. According to Dr. Rios-Mendoza at the University of Wisconsin, "We have this problem in our oceans, but this will be our first time looking for it in fresh water"[1]. The durability and light weight of plastic allows access into pristine environments by both natural and anthropogenic forces, ensuring its presence in the environment for centuries to come. It is a non-renewable resource that degrades the land, water, human health, and sustainable economies[2].

World plastic production has increased 25-fold over the past 40 years with less than 5% of that material recovered at the end of its useful lifecycle[3]. From the period of 2000 to 2010, the amount of plastic produced is reportedly higher than that produced during the entire last century[4]. This has caused rapid accumulation of plastics in the environment, comprising up to 80% of the municipal waste stream[3]. Considering that global plastic consumption worldwide was estimated at 260 million tons in 2008 and is expected to increase to 297.5 million tons by 2015[5], it is important to gain an understanding of the full range of its influence on the environment.

With more than 40 million people living around the world's largest freshwater ecosystem, accumulation of plastic debris has the potential to transpire into a serious ecosystem health concern for the Great Lakes[6]. Looking specifically at Lake Huron, it contains more than 30,000 islands and is considered the fifth largest freshwater lake in the world. Plastic pollution in the water leads to issues concerning chemical contamination, the safety of wildlife and human health. However, having the longest shoreline of all the Great Lakes presents plenty of opportunity for plastic debris to find itself awash on shorelines, impacting the beaches of Lake Huron as well[7].

To date, scientific literature on plastic pollution in freshwater environments is limited. However, recent research in three of the Great Lakes, including Lake Huron, suggests alarming concentrations of plastic in excess of samples from the infamous Great Pacific Garbage Patch[8]. Such plastic pollution will have substantial social, economic, human health and environmental implications for the Great Lakes region in the years to come. This includes a reduced aesthetic value, entanglement of wildlife in debris, and potential for chemical contamination within the freshwater environment. Many of these impacts will affect local communities and governments. While the responsibility for environment and public health is shared by several levels of government, the municipalities need to be the focus of governmental work. Being the level in direct contact with the public, municipalities are able to effectively promote stewardship and sustainability within local communities.

Figure 1. Map of Lake Huron within the Great Lakes Basin

Source: Google Earth

2 Scope and Objectives

This report is intended as a comprehensive, educational tool created for the Lake Huron Centre for Coastal Conservation to inform and engage members of the Lake Huron community about plastic pollution. The report examines the impacts of all types of plastic pollution including macro-plastics, resin pellets and micro-plastics on Lake Huron's shoreline. In addition to highlighting wildlife, chemical, social, and economic impacts, an investigation into the source of plastic is presented. The current awareness levels of both beach users and municipalities are evaluated in order to recommend effective ways for these stakeholders to help address plastic pollution. While this report is focused on Lake Huron, the information it provides can be related to all Great Lakes. Through examination of current scientific research on the topic, performing interviews and exploring successfully implemented outreach programs, this report provides a review of available information regarding plastic pollution in Lake Huron and a basis for outreach strategy development on the issue.

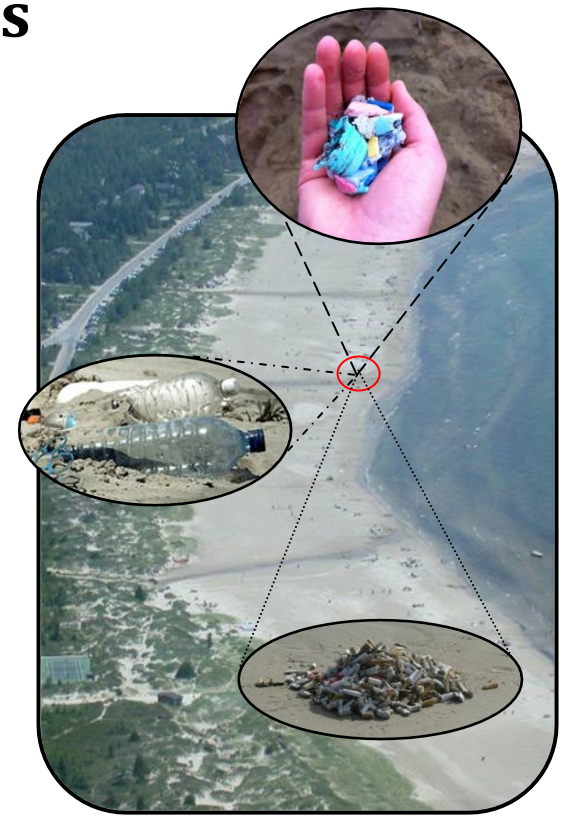


Photo Credits: Mariam Goldstein (www.seaplexscience.com)
epSos.de (www.flickr.com/photos/epsos);
Lake Huron Centre for Coastal Conservation
(www.facebook.com/coastalcentre)

The objectives of this report are:

a) To compile available information on plastic pollution in the Great Lakes including:
- Published research specifically studying the Great Lakes region
- Sources of plastic pollution
- Impacts (chemical, wildlife, social/economic)
- Comparisons to ocean plastic pollution where appropriate

b) To identify knowledge gaps to direct future research topics

c) To recommend actions that increase awareness and engagement of municipalities and the public

d) To recommend ways the public and municipalities may play a role in reducing further plastic pollution in Lake Huron

3 Types and Sources of Plastic

The sources of plastic pollution in the oceans have been recognized, studied and documented since the 1970s[9]. While significant efforts to reduce pollution on local to international scales have been made over the last 40 years, many of the same polluting activities persist to this day. In addition, new sources have come to light in recent years as our society continues to innovate the way in which we consume plastic. Many sources of plastic pollution in the ocean are common to freshwater systems as well. In Lake Huron, sources of plastic pollution vary with the type of plastic.

3.1 Macroplastics

Macroplastics are plastic debris larger than 5mm in diameter.

Photo Credit: 5gyres (www.sustainableguernsey.info)

Macroplastics are larger pieces of plastic that include food packaging, fishing-related debris, smoking-related debris, plastic bags, etc. This debris is not just found at the surface and on shorelines, but is also accumulating throughout the water column and on lake and seabeds[10].

The most recognizable and consistent source of macroplastic pollution on Lake Huron shorelines is land-based littering of beaches. This is most apparent during the summer months when shoreline use is at its peak. During these high volume times, plastics may also be unintentionally littered if waste receptacles overflow or are inadequately covered. Additionally, it is possible for plastic litter inland from the shore to be carried via wind, rain and snowmelt into pathways that eventually transport it to Lake Huron. These pathways include streams, rivers and municipal storm water drainage systems[9].

Open-water sources of pollution are also likely. Recreational boaters and the shipping industry may intentionally or accidentally litter plastic into the water. From here, the plastic may stay in the open water or may eventually wash up on the shoreline.

Lake Huron also supports an active $27 million Ontario commercial fishing industry[11] and provides a $4.6 million American commercial fishing industry[12]. According to the 2010 Great Canadian Shoreline Cleanup Data Report for Lake Huron, plastic fishing-related litter such as floating buoys, containers, plastic films and sheets, fishing line and fishing nets are consistently found along the shorelines of Lake Huron[13], with probably more remaining in the lake. Plastic pollution in the form of fishing gear may be inadvertently lost during operations of the commercial fishing industry or may be intentionally discarded[14].

3.2 Plastic Pellets

Plastic pellets or "nurdles," are small granules with a diameter of 1-5 mm[15].

Plastic pellets are small granules varying in shapes and colours[15] that are used as the industrial raw material to be melted down to form various final plastic products.[16] Plastic pellets have been a long-time recognized pollution issue in ocean environments, especially in the Pacific and Atlantic Oceans. Several studies throughout the world have documented pellets in the open oceans, in coastal surface waters, on beaches, and in sediments since the 1970s[17]. Concentrations along beaches tend to be higher in areas near plastic producing and/or processing facilities[9]. This trend has been observed for Lake Huron as well (see section 7). However, many studies have also reported pellet pollution along the shores of mid-ocean islands with no local plastic industry[18]. The ability for plastic pellets to be transported great distances by wind and water currents, along with their environmental persistence and global distribution makes it difficult to pinpoint the specific origins of plastic pellets[19].

Photo Credit: Ken Costello
(www.chemistryland.com)

Pellets enter aquatic environments through accidental spillage that can occur during any step of the plastic industry's operations. This includes spills during production, transport (via truck, rail or ship), and processing[20](Figure 1). Direct spills of pellets into the water happen during operations at ports or cargo shipping[15]. Pellets spilled inland can be carried by rain into rivers with strong enough flows to transport it to the river outlet[20]. They can also be carried into stormwater drains, and eventually be discharged into the aquatic environment[15].

In recent years, recurring incidences involving significant quantities of plastic pellets washing up along Lake Huron's shoreline have taken place. The most recent event occurred in 2010 along the beaches from Port Franks to Kincardine. Interestingly, analysis of the pellets from the 2010 event determined that the pellets were of a substandard quality and had not been manufactured in North America for at least the last two decades (P. Corcoran, personal communication). Additionally, comparison of the pellets from the 2010 event with pellets collected in 2008 by Dr. Patricia Corcoran for a study of Lake Huron beaches (see section 7), revealed very little similarity. This suggests that pellet pollution is likely coming from a series of different spills opposed to re-distribution of buried pellets from storms[9].

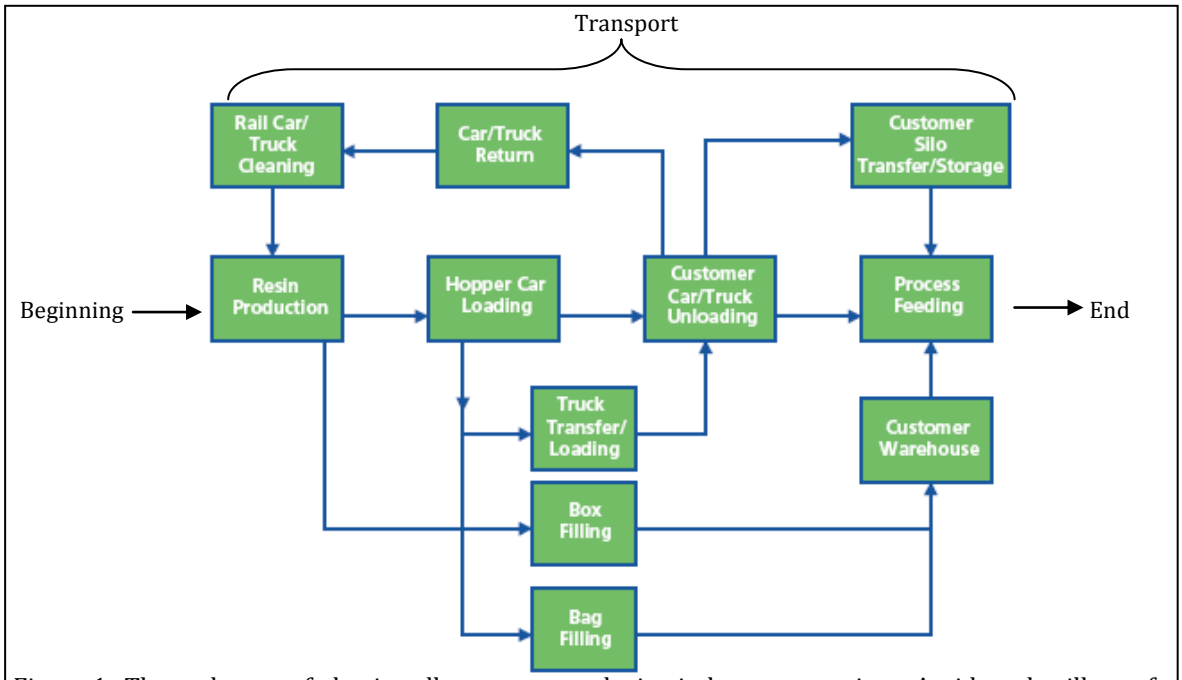


Figure 1. The pathways of plastic pellet movement during industry operations. Accidental spillage of pellets into the environment can occur at any step.
(Source: Operation Clean Sweep, www.opcleansweep.org)

Along Lake Huron, manufacturing facilities that produce plastic resin pellets are located in the industrial area known as "Chemical Valley" in Sarnia, Ontario. This area could potentially be a release source of pellets into the lake, although it is unlikely as Chemical Valley is located along the St. Clair River where water flows south away from Lake Huron. It is most likely that plastic pellets are released into Lake Huron through spillage during transport to processing facilities located north of Sarnia. According to the Ministry of the Environment, pellets have never been shipped across Lake Huron and transport occurs primarily by rail (P. Corcoran, personal communication). The main activities prone to spilling include car unloading, during which a valve is connected to a conveyance suction hose[21]. Spills can result from improper hook-up of the system, possible connection breakage during unloading, dealing with clogged hoses or surges in unloading lines, and seal breakages on the railcar[15]. Valves are frequently not closed and outlet caps not secured after loading and unloading[21, 22]. Cleaning of the rail cars is also prone to spilling if proper maintenance procedures are not employed, such as stormwater runoff containment systems, recovery of all pellets from wash water and proper waste disposal[15,21].

What's being done?

Operation Clean Sweep

www.cleansweep.org
www.plastics.ca/ocs

OCS is a recently revitalized international program designed to prevent plastic pellet loss and reduce marine pellet pollution. The goal of the program is to achieve zero pellet loss through good housekeeping and pellet containment practices in all segments of the plastic industry, from resin producers, transporters, bulk terminal operators and processors. The program provides the tools and resources needed and calls upon companies to take the pledge! [22]

3.3 Microplastics

Microplastics are plastic debris smaller than 5mm in diameter[23].

Examples of microplastics include industrial broken fragments, polystyrene pieces, cosmetic product residues, and synthetic textile fibres[18]. Microplastics have recently emerged as a possible significant pollution issue in the Great Lakes following preliminary findings by Dr. Sherri Mason. Large amounts of microplastics have been identified in water samples taken from 3 lakes, including Lake Huron (see section 7). Possible sources of microplastics stem from either physical breakdown of macroplastics present in the freshwater environment or their introduction inland via runoff or wastewater drainage[18].

Photo Credit: 5gyres
(www.newswatch.nationalgeographic.com)

One known source of microplastics is the breakdown of larger pieces of plastic into smaller and smaller pieces through mechanical and chemical weathering. Chemical reactions with sunlight (see section 4) significantly weakens the surface of the plastic, making it increasingly susceptible to cracking and fragmentation from temperature changes, sand abrasion, waves and turbulence[18,20,24,25]. While this breakdown can occur in the water, on the surface of the water or on the beach, it most likely occurs on the beach because of high temperatures and sun exposure[25].

Photo Credit: PlasticIsn'tNice
(www./plasticisntnice.blogspot.ca/2010_09_01_archive.html)

Microplastic particles have been used as a medium in air blasting technology to strip paint and to clean machinery, engines and boat hulls since the 1990s[26,27]. To utilize this technology, a boat containment area that is completely enclosed to trap the media is supposed to be used. However poor containment, poor handling, improper cleaning, and high winds or rain could lead to release into the freshwater environment[28].

Photo Credit: Roger Marshall
(www.sailmagazine.com)

Micron-sized plastic beads can be found in a number of consumer items including toothpaste, deodorants, body washes, hand cleansers, and a number of cosmetic products like face exfoliates and eye shadow[26,29,30]. These particles can come in a wide range of sizes, with reports in the scientific literature of sizes from 1000 μm to as small as 4 µm[26,29,31]. Numerous studies claim that these microplastics enter marine environments by passing through wastewater treatment systems unfiltered due to their small size[18,29], though very few have actually tested this proposition.

Did you know?

Several major brands such as:

Ambi, Aveeno, Axe, Balea, the Body Shop, Clean and Clear, Clearasil, Clinique, Colgate, Crest, Dove, Garnier, L'Oreal, Maybelline, Neutrogena, Nivea, Olay, Phisoderm and Pond's

have products with microplastics!

Products:

A list of products with microplastics was recently compiled (2013) by Dutch NGO, the North Sea Foundation
Visit:www.noordzee.nl/campagnes/product

Pressure for corporate responsibility:

Unilever, the third largest consumer goods company in the world, has already agreed to phase out microplastics in their products by 2015, following pressure from the 'Beat the Micro Bead' campaign launched in summer 2012!
Visit: plasticsoupfoundation.org

Beth Terry (www.myplasticfreelife.com);
Beaut.ie (www.beaut.ie/blog/2011);
Drugstore.com Inc. (www.drugstore.com);
L'Oreal Paris (www.lorealparis.com)

Microplastics in the form of fibres (as small as 1 µm in diameter)[32] can also originate from consumer sources, specifically from synthetic fibres that shed during laundry[33]. Only recently, after the publication of a study by Browne and colleagues in 2011, has this source of microplastic pollution been verified. The study found that all 18 oceanic shorelines sampled on 6 different continents were polluted with microplastics. Eighty percent of the microplastic pollution was polyester or acrylic fibres, with matching proportions to those found in clothing. Experiments with laundry wastewater from washing shirts, blankets and fleeces revealed that a single garment can shed over 1900 fibres per wash[33].

Tip: Buy clothing made of **natural fibres like cotton, linen, wool & satin** as they do not shed material.

Further, Browne *et al.* examined wastewater effluent from two tertiary wastewater treatment plants in Australia and found an average of one micro-plastic fibre per liter of effluent. Since this study has been published, wastewater as an entry pathway to water bodies for microplastics in consumer products has become a hot topic in the media and inspired some further research. For example , a Dutch study published the following year by Leslie et al., found microplastics in concentrations of 20 particles/litre of effluent from a wastewater treatment plant in the Netherlands[34].

In Ontario, no municipalities measure plastics in their effluent because it is not required by the Ministry of the Environment, so it is not known whether microplastics are passing through local waste-water treatment facilities and

entering Lake Huron. John Braam, London's city engineer, was used a local expert for his opinions on the treatment of water and wastewater and his impressions on if plastic is an issue. He is confident that conventional wastewater facilities capture most microplastics either through membrane filtration or from solids settling out. In terms of smaller microplastic fibres, these fibres often adhere to organic materials that get settled out throughout the process (J. Braam, personal communication). Even if microplastics are fully being filtered out, waste-water can still be a source of microplastic pollution in Lake Huron in two ways.

First, wastewater is not always treated before lake discharge. During wet weather like heavy precipitation events or spring snowmelt, bypass and combined sewer overflow events occur. Bypass occurs when there is too much sewage flowing to a treatment facility and it becomes overloaded. Combined sewer overflows occur when the flow in a combined sewer (an old system that transports sewage and stormwater together in the same pipe) exceeds the system capacity. In both cases, waste-water is directly discharged into Lake Huron[35], along with any microplastics it contains. In 2006, it was estimated by the Ministry of the Environment that over 1.3 billion litres of untreated waste-water were discharged into Lake Huron from bypasses alone[35]. Thus there is ample opportunity on a yearly basis for these consumer microplastics to enter Lake Huron from wastewater.

Secondly as mentioned above, micro-plastic fibres tend to adhere to organic materials that settle out in the waste-water treatment process and become known as sewage sludge. Since the 1970's Ontario has successfully used treated sewage sludge or "biosolids" as a crop fertilizer[36]. Today, over 300 000 tonnes a year are spread across Ontario agricultural fields[37]. It has been shown that microplastic fibres can contaminate soils where this land application is used[38]. Therefore it is possible for microplastics to be carried by agricultural runoff into Lake Huron. This potential source has only recently been suggested by Dutch researchers[39]. According to Dr. Heather Leslie, project coordinator for the 2013 CLEANSEA project (the first European Union framework program research project about marine plastic pollution), research has already indicated that this is a source of microplastics in the environment for the European Union[40].

Table 1. Summary of known and potential sources of plastic in Lake Huron.

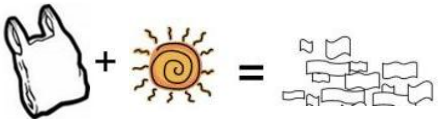
Macroplastics	Plastic Pellets	Microplastics
▪Land-based littering ·direct on the beach ·inland & carried into waterways ▪Marine-based littering ·recreational boaters ·shipping industry ·fishing industry	▪Spills from plastic industry operations ·rail transport ·ex. improper unloading hook up, clogged hoses, unsecured outlet caps on railcars	▪Weathering of macroplastics ▪Air blasting for painting & cleaning boats/engines ▪Exfoliating beads in consumer products ▪Shedding of synthetic fibers during laundry ▪Bypass & combined sewer overflow events ▪Agricultural biosolids

4 Chemical Contamination from Plastic Pollution

Plastic exposure to atmospheric conditions has long-term impacts on the environment. The erosion of plastics due to their contact with oxygen and subjection to solar radiation makes them one of the main sources of chemical contaminants on Earth. Plastics are defined as synthetic macromolecules (polymers) derived from petroleum[18]. There are several chemicals added to plastic that alter their physical properties to make them suitable for different commercial products[41]. The main types of plastic found on the beaches of Lake Huron were made of polyethylene (PE) and polypropylene (PP)[42]. Plastic debris found in water and on beaches can transfer and import chemicals into the environment in many ways, including chemical degradation, contaminant adsorption, and monomers and additives leaching from the surface of plastic[25].

4.1 Photochemical Degradation of Plastic

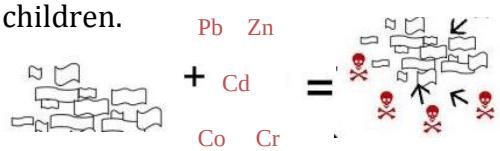
Photochemical degradation of plastic is the reduction of the molecular weight of the polymer by breaking it down into smaller molecules by the action of solar radiation. It initiates when plastics are exposed to UV-B radiation (290-400 nm)[43], which enhances radical breaking of the carbon bonds in the polymer. When plastic breaks down it produces smaller fragments. The successive breakdown of plastic may introduce microplastics into the environment[44]. The degradation of the plastic occurs in water and on the beach. However, the higher temperature on land compared to water accelerates the chemical degradation of pellets on the beach. The lack of UV-B penetrating water surface also lowers the rate of chemical degradation of submerged plastic[44]. Most chemical degradation occurs on land and research completed regarding plastics on ocean beaches is applicable to plastics found on freshwater beaches.



4.2 Plastics as Contaminant Carriers

The effects of solar radiation on plastics is not limited to photochemical degradation, as it also speeds up the oxidation on the plastic molecules and alters its chemical structure. The modification occurs on the surface of plastic and establishes new properties that result in the tendency of plastic to bind to trace metal ions including chromium, zinc, cobalt, cadmium and lead. This was proved by a study that analysed PE pellet samples taken from South-west England in May 2011[45]. Although the concentrations of these metals were low in the PE samples, it demonstrates the possibility of metal transport on the surface of plastic. In turn, this allows plastics to serve as indicators of metal contamination and increases the accessibility of these metals to organisms. Most of these metals are heavy metals and their bioaccumulation in food chain can lead to complicated health hazards in humans. For example, exposure of lead is known to cause can neurological damage in children.

Photo Credit: Sierra Club (delaware.sierraclub.org)



Furthermore, plastic pellets can adsorb persistent organic pollutants (POPs) such as chlorinated agricultural pesticides like DDT, polychlorinated biphenyls (PCBs)[46], polyaromatic hydrocarbons (PAHs) formed during incomplete combustion of fossil fuels, and other organic substances produced through various anthropogenic activities[47] (Figure 2). Generally, PE, which is the main type of plastic used in commercial production, has a greater tendency to accumulate organic pollutants than other types of plastics[47]. The problem is further exacerbated with microplastics because degradation of plastic increases its surface area, allowing greater amounts of contaminants to be adsorbed and their smaller size means a wider range of organisms can ingest them[4]. This is especially an issue when it comes to PCBs since they are present in high concentrations in the Great Lakes.

4.3 Chemical Leachate from Plastic

During production, plastic additives known as plasticizers are incorporated into plastic products for the purpose of life extension or chemical property changes. When incomplete polymerization occurs during plastic formation, additives can later separate from the main plastic matrix and leach from the plastics into the environment (Figure 2). The amount of leaching depends on the polymer type and pore size, the additive size and properties and the environment conditions[18]. Leaching of additive chemicals from plastic is an environmental concern because some additives are hazardous to wildlife[18].

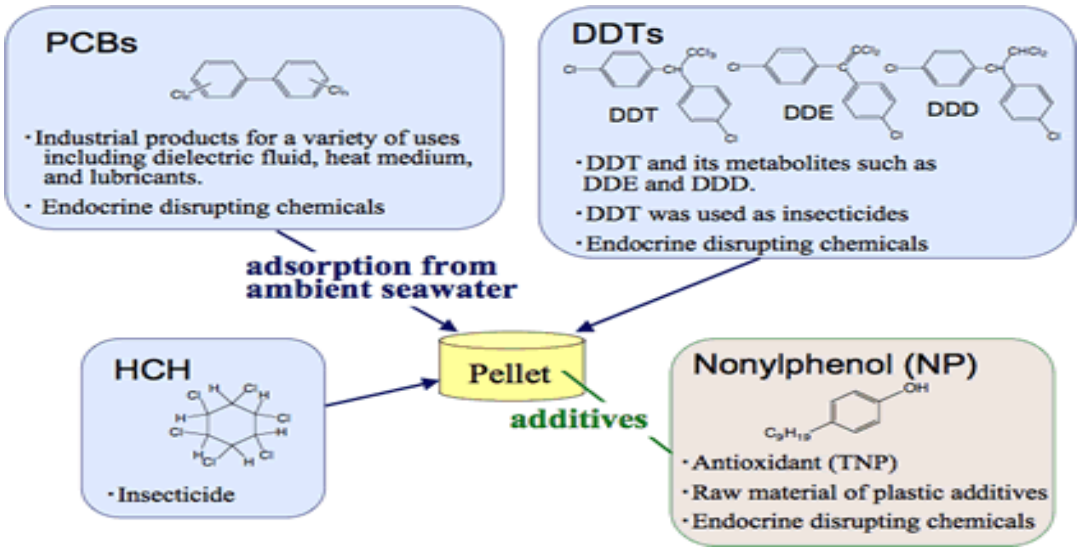


Figure 2. Common chemical pollutants that adsorb to or leach from plastic pellets.
(Source: Living Ocean Society, www.livingoceanssociety.blogspot.ca)

4.4 The Impact of Plastic on Sand Permeability

The presence of plastic on beaches changes the physical properties of the beach. This leads to the alteration of water movement and heat transfer, thus the disturbance of habitat. The smooth surfaces of small plastic fragments can decrease the friction between sand grains. This may contribute to increasing the permeability of the beach sand[47].

Increasing the permeability of beach sand means more water can flow through more layers of sand (Figure 3). The water flowing into the beach sand carries oxygen and organic matter that are consumed by organisms living in interstitial spaces. However, the loss of great volumes of water from the surface sand layers means a potential decline in oxygen and organic matter content within the sand particles, affecting the metabolic activities of organisms. In addition, plastic fragments have higher thermal insulation than sand granules, which may reduce the surface temperature of the beach[47]. The alteration in surface temperature of the beach can have an impact on beach organisms that are temperature dependent for sex-determination. Further research is necessary to examine the response of organisms to these changes of physical beach properties.

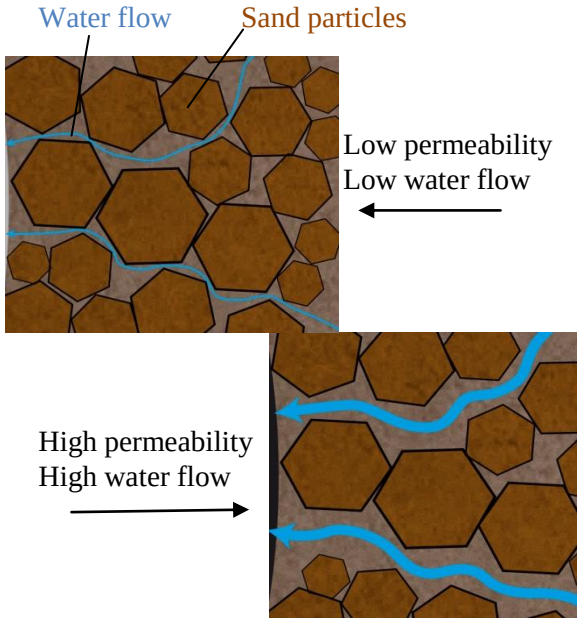


Figure 3. Water movement through various sand permeability.

Photo Credits: DARCY , (www.darcyflow.com)

Photo Credits:
Valeria Hidalgo-Ruz/Universidad Católica del Norte, Chile (www.sciguru.com);
Instagram – sailoursea (www.instagram.com)

5 Wildlife Effects

To date, research regarding the harmful effects of plastic pollution on wildlife has primarily been restricted to marine ecosystems. This topic has just begun to receive attention from the science community, resulting in minimal research focusing on the effects of plastic pollution in freshwater ecosystems. In order to provide some perspective of the ill effects of plastic pollution on wildlife of Lake Huron, published scientific research and documented accounts of the effects of plastic pollution on marine wildlife will be used for comparison. The primary ways in which plastic harms wildlife within aquatic ecosystems is by entanglement and ingestion along with the destruction and smothering of the ecosystem floor, and accumulation of toxins associated with plastics[48].

5.1 Entanglement

Entanglement encompasses the encircling, ensnaring, or an organism becoming trapped within a plastic object (bottles, food container, etc.). These occurrences are either due to chance or the natural behavior of the animal, for example, curiosity or seeking food or shelter[49]. Fish and crustaceans often utilize marine debris as shelter, but often become trapped within these objects[49]. Seabirds and waterfowl also become entangled in plastics when they are used to build nests[49]. Fledglings are particularly vulnerable in this case.

Rainbow trout entangled in plastic zip tie.
Photo Credit: Jim Bodenstab, 5Gyres Newsletter (www.lolako.com)

Photo Credit: Wallpapers Arena (www.hdwallpapersarena.com); Fetch my Flying Monkeys (www.fetchmyflyingmonkeys.com)

There is also the issue of 'ghost fishing'. This occurs when abandoned fishing equipment is left to drift with the current while fish and other wildlife are continually caught[49]. The entangled wildlife also attract other animals such as birds and mammals that feed on fish. These predators subsequently, can become entangled as well[49]. Once entangled, animals struggle to free themselves, often leading to self-inflicted wounds. On the rare occurrence, an

entangled animal is able to free itself, but infections often result in the loss of a limb. The majority of these instances however, lead to death by way of strangulation, suffocation, or the impairment of an animal's ability to swim, which could lead to drowning[49].

5.2 Ingestion

Ingestion occurs when an animal swallows plastic debris. This usually takes place when animals mistake plastics for components of its usual diet. Often, small plastic particles are mistaken by fish and birds as planktonic organisms[10]. Other larger pieces of plastics such as pellets, are mistaken for fish roe or crustaceans and are consumed by birds[50]. A popular case to illustrate these effects would be that of Midway Atoll's Laysan albatross in the Pacific Ocean[50]. The state of the colony has been well documented over the past several years in order to illustrate the negative ecological effects of plastic debris on wildlife. These birds have a tendency to feed their young plastic debris mistaken for food.

When ingested, plastics can lead to starvation and malnutrition. Unable to pass through the digestive system, plastics often block digestion and remain in the internal organs of animals[50]. This leads to animals experiencing a state of satiety, discouraging them from continuing to feed. Often, these animals starve to death or become malnourished to the point that makes them susceptible to predation[50]. Sharper pieces of plastic may also damage an animal's digestive tract or stomach, which may lead to infection and subsequent death. Other swallowed items may block air passages and cause an animal to suffocate[48].

First-Hand Accounts

Dr. Eva Pip, an aquatic toxicologist at the University of Winnipeg who is currently researching the effects of plastic pollution on freshwater lakes in Canada, has witnessed firsthand the following accounts on lakes she has been studying:

- Gulls ingesting plastic grocery bags, tampon applicators, plastic food wrap, sharp fragments of bait containers, band aids, plastic bottle tops, small plastic and foam pieces cast up on beaches
- Fish with plastic pieces in their stomachs
- Entanglement of waterfowl and muskrats in sunken abandoned fishnets
- Crayfish unable to exit bottles
- 6-pack plastic rings around legs and necks of waterfowl
- Fishing line entanglement of waterfowl and turtles
- Deer entangled in baling twine that was disposed of in the water when the deer came to drink
- Discarded electronics cables looped around legs of geese
- Geese with their necks choked by plastic rings from broken containers

A decaying Laysan albatross.

Photo Credit: AMERICAblog (www.americablog.com)

Photo Credit: *Algalita Marine Research Foundation* (www.underwatertimes.com)

Photo Credit: *Axis of Logic* (www.axisoflogic.com/)

Fish with ingested plastic.

Fish that ingest plastic also face additional challenges. When ingested, plastics can alter a fish's ability to control its buoyancy via its swim bladder[51]. Without this ability, a fish is not able to search for food or seek shelter as effectively, which increases its susceptibility to predation.

Ingestion can also expose organisms to harmful chemicals that are either leached from the plastic or adsorbed onto it (Figure 4). For example, commonly used additives such as polybrominated diphenyl ethers, phthalates and bisphenol A are known endocrine disruptors in aquatic invertebrates and fish[18]. These chemicals can be absorbed by organisms, where they can then disrupt the production and function of natural hormones causing reproductive issues and genotoxic damage[18]. Leached additives in water and sediments can also be absorbed by freshwater phyto- and zooplankton[48].

Most persistent organic pollutants (POPs) that can be adsorbed by plastic are highly toxic and are known to cause reproductive problems, mutagenesis, and carcinogenesis in wildlife[4,18]. Currently, it is not known for certain whether adsorbed chemicals on plastic can be transferred from the plastic to the organism when the plastic is consumed, however evidence is beginning to surface to support the proposition that POPs can be transferred in this manner. Results obtained from field experiments where seabirds were fed polyethylene pellets contaminated with polychlorinated biphenyl (PCBs) found that the PCBs were secreted from the birds' preen gland. This suggests that the contaminated pellets delivered PCBs to the biological tissue of the seabird[48.] Further research should investigate the mechanism of chemical release from plastics to living organisms, though one author suggests that acidic gastric conditions may enhance desorption of some of these chemicals as well as metals[47].

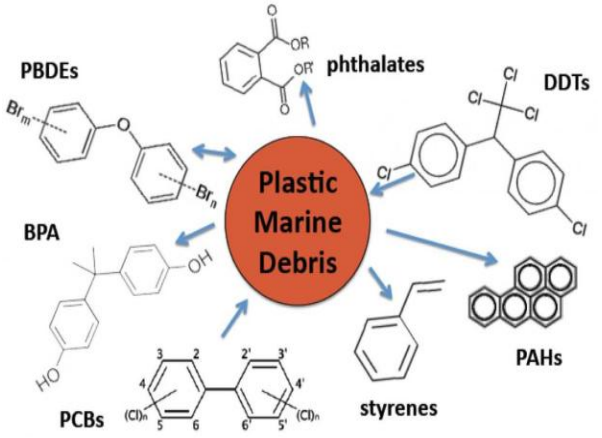


Figure 4. Common chemicals associated with plastic debris that are known to have toxic effects on organisms. Arrows pointing in are adsorbed chemicals and arrows pointing out are leached chemicals.

Source: The Global Journal Project, (vantage.thegjp.org)

Photo Credit: Save Trestles
(www.savetrestles.soup.io/tag/Plastics)

5.3 Bioaccumulation

Once in the food chain, plastics like any other substance can accumulate in higher concentrations as it moves up the food chain. Stomachs of large birds of prey have been found to contain high concentrations of plastic through the consumption of smaller aquatic birds and fish that previously ingested plastics[48]. Another more recent concern that has developed is from the threat of microplastics. Researchers are currently concerned with the prospect that zooplankton, may take up microplastics, transferring plastic from a lower trophic level up to a higher level, increasing bioaccumulation[18]. Chemical bioaccumulation also poses a threat as many leached additives and adsorbed chemicals are known to bioaccumulate in organisms[4].

5.4 Smothering of Lakebed

Due to its composition, most plastics float, but that does not mean lakebeds are immune to the negative effects of discarded plastics. Fishing nets can drag across the lake bottom upwelling sediment and organisms as well as destroying habitat, and plastic sheets can cover large areas. If coverage is ample, photosynthetic organisms that rely on sunlight for production are highly at risk. Such freshwater plants of concern are macrophytes, which are already limited in the area in which they can grow. Animals such as waterfowl and other aquatic birds that feed on these plants directly would face challenges in finding sufficient sources of food[52]. Due to many plastics being impermeable, large pieces may inhibit the oxygen exchange between water and sediments, consequently hindering bottom-dwelling organisms and their ability to breathe[48].

Did you know?

The Ontario Ministry of Natural Resources identifies hundreds of species on their Species at Risk in Ontario (SARO) list. Several of these species are at additional risk due to their reliance on Great Lakes shorelines as habitat and feeding grounds, and the threats to the shorelines posed by plastic pollution. Therefore it is even more important to consider how plastics are affecting wildlife in these delicate ecosystems, including Lake Huron.

Examples of SAR in Lake Huron area:
-Bald eagle
-Snapping turtle
-Shortjaw Cisco fish

Ontario

See Appendix III.

6 Social and Economic Impact

The Great Lakes form the largest group of freshwater lakes on Earth containing approximately 21% of the world's surface fresh water[53]. They provide drinking water for more than 40 million people and support commercial, tribal and sport fisheries valued at more than $7 billion annually[7]. A 2011 report claims that the Great Lakes directly provide more than 1.5 million jobs generating more than $62 billion in wages[54]. This relates specifically to the numerous recreational opportunities offered by the watershed making them an ideal area for businesses to be located. There is also a large university presence in the area contributing 32% of Canada's graduates, along with almost 40% of Fortune 500 companies located in the Great Lakes region[55]. With such a large influence on both Canada and the United States, the Great Lakes region is fundamental for the social and economic well-being of local communities. Several impacts are discussed below.

6.1 Clean-up costs

With litter and debris constantly washing up on the Great Lakes shorelines, this incurs additional costs for clean up along with implementing strategies for pollution reduction. A study that took place on coastal communities on the United States west coast concluded that communities were spending an average of $13 per resident to annually to combat trash on their coastline[55]. This resulted in excess of $520M spent to clean up debris. The spending of over half a billion dollars annually represents a direct economic loss to these communities. There are also preventative controls that can be implemented to capture debris before it enters aquatic environments. Structural devices can be installed to remove debris and can include mesh screens and debris conduits that can significantly reduce land-based litter from reaching waterways. Preventative structural controls will have expenses for implementation and maintenance, but will reduce the future costs associated with other plastic pollution concerns.

Photo Credit: River Link (www.epa.gov)

Mesh net trash trap infrastructure designed to catch debris in storm water discharge.

What's being done?

GREAT CANADIAN Shoreline Cleanup

The Great Canadian Shoreline Cleanup is a program that allows people to take action against pollution by coordinating or participating in organized, voluntary shoreline clean-up events. Take action by getting involved in local clean-ups around Lake Huron.

http://www.shorelinecleanup.ca

6.2 Aesthetics

Clean beaches, free of debris, are a thing of the past. This is apparent worldwide, even on beaches free from human activity[21]. Plastic debris can impact the aesthetic value of these regions, adversely affecting tourism along with recreational activities carried out in these areas. This involves the negative implications of debris including lost tourist days, damage to tourism and leisure infrastructure, damage to recreational fishing, and the local, national, and international image of the area[21]. Floating debris also has the capacity to impact swimmers, while sunken debris is an aesthetic and safety concern for divers. Debris becomes especially evident after large rain events where storm drain systems discharge water directly into surrounding water bodies without treatment. This can result in beach avoidance because of displeasing aesthetics of the environment along with potential physical health risks for beachgoers[56]. Plastic debris on the beach is not attractive for tourism or local recreational users.

Photo Credit: Marine Apps
(i-marineapps.blogspot.ca)

VS.

Photo Credit: LHCCC
(www.facebook.com/coastalcentre)

6.3 Human Health and Safety

Recently, Klecka *et al*. (2010) reviewed and summarized studies of emerging contaminants in the Great Lakes Basin from 1997-2008[56]. Among the contaminants of interest were plasticizers known to leach from plastic debris into water such as bisphenol A and phthalates[57]. Much has been learned about possible adverse toxicological effects of these types of chemicals on human health in recent years from human biomonitoring studies and studies on laboratory animals[4].For example, human exposure to bisphenol A (BPA) has been associated with increased risks of cardiovascular disease, diabetes as well as disruption of hormone levels[18] and could possibly pose developmental and reproductive human health risks[58].

What can you do?

Photo Credit: Tensens
(www.tensens.com.au)

Tip: Use proper, secure lids for waste receptacles in order to minimize litter during waste pick-up & strong wind/heavy rain events.

Leached plasticizer chemicals have been detected in Great Lakes surface water and sediment[58]. Thus it is possible that people are exposed to the chemicals via skin contact through swimming in Lake Huron or when leached onto beach sand. However the degree to which chemicals are exposed to the human population by plastics[4] and the extent to which dermal exposure leads adverse human health impacts has yet to be confirmed[4,59].

The human health risk of chemicals leached from or adsorbed to plastics comes more from the food we consume out of Lake Huron. This is due to the potential of these chemicals to bioaccumulate up the food chain (see section 5.3). Leached chemicals like BPA and phthalates can bioaccumulate in aquatic organisms[18], and may be absorbed into human fat cell tissue after ingestion of contaminated fish [55]. Additionally, adsorbed chemicals such as PCBs that are known to bioaccumulate may also pose a threat[59], though it is uncertain if plastic can transfer chemicals to the food chain when ingested[4].

Of specific concern to users of Lake Huron (see section 8) is the possibility of physical pieces of microplastic pollution from the lake entering the drinking water supply. Drinking water treatment plants are well regulated with stringent regulations in terms of biological and chemical limits. They are designed to filter out small pathogens like *Cryptosporidium* that can range between 3 and 8 µm (J. Braam, personal communication). Based on the scientific literature, the majority of microplastics are much larger than this. John Braam (technical expert on water treatment) is certain that London's drinking water facilities filter all particles greater than 2 µm and believes most other treatment facilities, including those in smaller Lake Huron municipalities, can achieve this filtration level as well. As in the wastewater treatment process, particles smaller than 2 µm, if present, will be fibres that tend to adhere to organic material. Thus, these should be removed when the organics settle out. As a result, it is highly unlikely that microplastics are entering the water supply (J. Braams, personal communication).

Photo Credits: Hearst Communications, Inc. (www.thedailygreen.com)

Know your plastics!

It is important to know the various types of plastic to understand your exposure level and risk to adverse effects.

Familiarize yourself by referring to Appendix IV.

7 Existing Studies on Plastics in the Great Lakes

Presently, most research surrounding plastic pollution in aquatic environments is ocean-based, with little knowledge on the extent of the issue in freshwater ecosystems. However, there are two local researchers whose work on plastic pollution issues in the Great Lakes Region is helping to address the freshwater knowledge gap. The research that has been conducted to-date by Dr. Sherri Mason and Dr. Patricia Corcoran is discussed below, along with a summary of identified research gaps.

7.1 Plastic in the water

During the summer of 2012, Dr. Sherri Mason, Department of Chemistry, SUNY Fredonia, New York recorded the plastic content of Lake Huron, Lake Erie and Lake Superior[60]. Based on email correspondence with Dr. Mason in February/March 2013 (see Appendix I), the research has not been published or peer-reviewed, as some interesting findings emerged as the analysis of the chemical composition of particles collected has reportedly delayed submission. However, several news articles have documented some of the preliminary and perhaps surprising findings. Twenty-one open-water samples were collected with a net trailing from the research vessel with the net's mesh a mere 333 micrometres (1/76th of an inch) wide[61]. According to Dr. Mason's research, deposits of plastic were discovered in greater concentrations than any other body of water on Earth[61]. Two of the twenty-one samples contained 450 000 and 600 000 plastic pieces per square kilometer[62], which is nearly twice as much as the highest plastic count ever recorded[63]. More specifically, the number of plastic particles in two samples collected in Lake Erie was three times higher than any sample gathered anywhere in the world[62]. The lowest plastic particle counts were found in Lake Superior[62], with the least-polluted sample containing 600 pieces per square kilometer[64]. Concentrations increased as the researchers travelled south[62] in the direction of the water flow, from Lake Superior through Lake Huron and into Lake Erie and Lake Ontario[62].

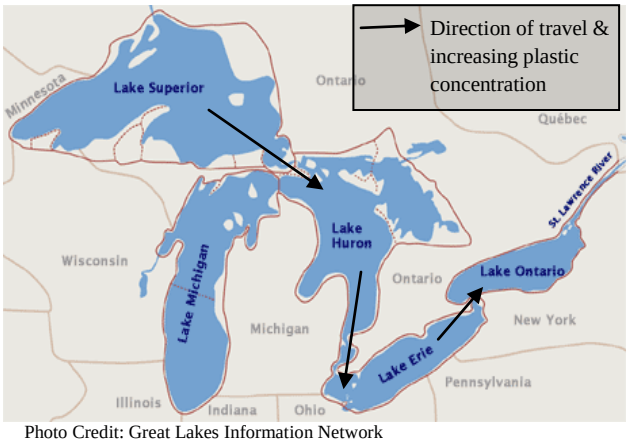


Photo Credit: Great Lakes Information Network (www.great-lakes.net)

Most of the plastics within the samples were very small pieces, referred to as microplastics, ranging from 330 micrometers to 1 millimeter in size[62]. The occurrence of microplastics found in the oceans does not compare to the discovery by Dr. Mason in the lakes and as a result, the plastics are disappearing and could be washing up on beaches or entering the

food chain[62]. The majority of the plastics found were on average smaller in size than those documented in the oceans, therefore the highly polluted Great Lakes samples still contained less plastic by weight than the worst ocean samples[64]. Some plastics discovered within the Great Lakes were tiny beads from personal care products such as exfoliants[63]. It concerns Dr. Mason that microscopic beads from personal care products and additional sources could potentially bypass local wastewater treatment systems, especially during heavy rain falls when sewers overflow and untreated sewage escape[63]. In addition, microscopic beads could possibly be returning through drinking water intakes[63].

Future Work of Sherri Mason

According to email correspondence with Dr. Mason, she will be returning to Lake Erie for additional sampling in May and will be sampling Lake Michigan in August. In addition, she intends to study Lake Ontario in July, where she hypothesizes she will find the highest concentrations of plastic, as this lake is the farthest downstream[64]. Dr. Mason anticipates sampling four municipal wastewater systems in New York State later this year[61]. The uncertainty regarding where microplastics end up requires analysis of different organisms to determine quantifiable data across various parts of the food chain[62]. It presents a severe risk to human health if plastics are getting into the food chain[62]. According to Dr. Mason, the research that is expected to be underway this summer, along with information conducted to date, will provide baseline data. However, there is still a considerable amount of work to be completed and several unanswered questions still exist.

7.2 Plastic on the beaches

Dr. Patricia Corcoran, Department of Earth Sciences, Western University, London, Ontario has completed some initial research which has generally focused on plastic debris on the beaches of Lake Huron. One of Dr. Corcoran's studies examined the distribution, types and physical and chemical degradation processes of plastic particles in the freshwater setting of Lake Huron[42]. Very little to no plastic particles were visually observed along the western and northern shores of Lake Huron during a preliminary survey[6]. However, a thorough exploration conducted along the eastern and southern shorelines of the lake in the fall of 2008 resulted in sampling seven beaches[42].

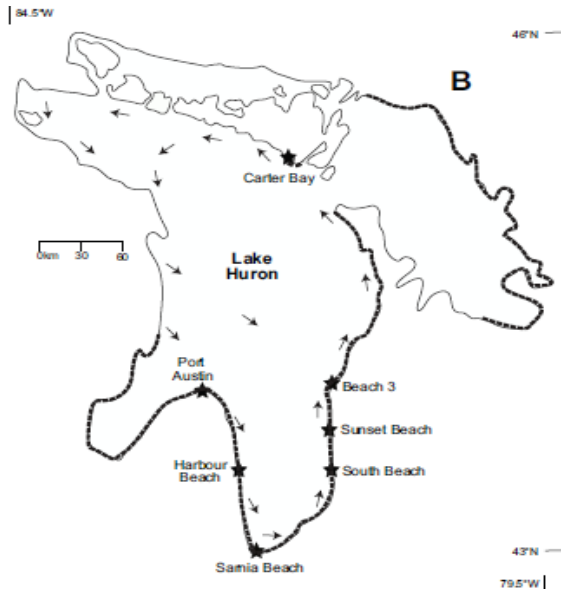


Photo Credit: Zbyszewki and Corcoran, 2011

Using Fourier Transform Infrared Spectroscopy (FTIR), Dr. Corcoran determined the polymer composition of the plastic particles sampled from selected beaches[64]. The majority of the plastic fragments consisted of industrial pellets composed of polypropylene and

polyethylene that are the unprocessed raw materials for plastic manufacturing[65]. The research discovered that the total number of pellets over various sampling locations comprised 94% of plastic debris[42]. Most of the pellets were found in close proximity to an industrial area along the south-eastern portion of Lake Huron, near Sarnia[42]. Similarly, oceans reportedly have the highest concentrations of pellets in close proximity to industrial areas. The abundance of pellets notably decreased northward, which logically follows the flow of water southward towards Sarnia[42]. Laboratory analysis concluded that the predominant type of plastic, polyethylene appears to be much more resistant to chemical weathering than polypropylene which degrades more readily under natural conditions on freshwater beaches[42].

Future Work of Patricia Corcoran

Dr. Corcoran plans on studying the levels of persistent organic pollutants absorbed by the pellets on Lake Huron, which will indicate the threats posed to organisms and animals higher in the food chain in freshwater environments. She intends to study and monitor certain sections of beaches continuously looking to collect data on the frequency of plastic washing up on designated plots of shoreline. She also wants to perform further research through core sampling to understand the amount of plastic found in different sedimentary layers. This would include sampling both lake shorelines and lake beds and would assist understanding the full extent of plastic within the freshwater environment.

7.3 Research Gaps

Scientific research on plastic pollution in freshwater systems is currently in the early stages. While the extensive collection of available literature on plastic pollution in oceans can be used to as comparable framework, it is important for future researchers to address the freshwater knowledge gap to:

a) detect any effects that may be specific to freshwater ecosystems;
b) determine and address sources of plastic to inland lakes;
c) determine the extent of the problem in freshwater environments.

Essentially, further research needs be conducted in all areas of the issue but the immediate topics of concern that local researchers could address for Lake Huron are the following:

▪Sources of microplastic pollution (Examples: testing effluent of waste-water treatment facilities for plastic, investigating bypass and combined sewer overflow incidences, investigating the frequency and distribution of pellet spills during transportation, investigating northern industry upstream of Lake Huron, measuring microplastics in agricultural soil and runoff)

▪Wildlife effects (Examples: studies of effects listed in section 5.0 for freshwater species and birds, studies on native Lake Huron species at risk, investigating the role of microplastics as a vector for chemical contamination in organisms)

▪Chemical effects (Examples: investigating plastic degradation times for freshwater, determining the optimal conditions for chemical adsorption and leaching, examining the effectiveness of biodegradable plastic – do they degrade completely, how do the biodegradation products influence the environment etc.)

8 Public Awareness

There are many studies on reducing plastic pollution on ocean beaches, thus increasing public awareness on the impacts of plastic on marine life. However, public awareness regarding plastic on the beaches of the Great Lakes needs more attention. In an attempt to get feedback on plastic contamination of Lake Huron, a web-based survey was distributed through the Lake Huron Centre for Coastal Conservation's Facebook page. It aimed to collect information on whether Lake Huron users are familiar with the plastic pollution issue and how this may affect their activities on the beach. The survey included 10 questions and was open to the general public on March 11, 2013. Survey results were gathered from 43 beach users. A summary of the results is presented, see Appendix V for complete results.

Just over half of the respondents were familiar with the plastic pollution issue on Lake Huron beaches, with most people getting their information from The Lake Huron Centre for Coastal Conversation. The other main sources of information included newspapers (30.8%), the internet (25.6%) and TV (12.8%). Public awareness is also the result of long-time observations of plastic pollution on the shoreline. Many respondents left comments about observed plastic pieces or pellets washing up along the beach.

The majority of plastic observed on the beaches was water bottles, plastic bags and balloons (88.1%). Other sources were mainly cigarette butts (66.7%) and food containers and wrappers (61.9%). Considering that it takes plastic a long time to breakdown into smaller pieces, the fact that 64.3% of respondents observed broken plastic fragments indicates that plastic pollution has been a long-standing issue in Lake Huron. Additionally, 31% of respondents noted observations of plastic pellets.

Generally, there was no specific information from the respondents on the when they first started noticing plastic on the beaches. However, most respondents confirmed observing them at least in the last 2- 6 years and few said that the presence of plastic trash on the beach has been observed on longer terms. The highest rates of accumulation were observed during warmer seasons, most likely due to increased plastic littering, from more beach visitors. Notably, plastic pellets were observed mainly after winter storms and ice melting.

Respondents were asked to rate the severity to which they believed plastic pollution on the beach or in the water is affecting wildlife on a scale of 1 to 5 (low to high). The majority of respondents were aware that plastic pollution impacts wildlife, with 72% of respondents ranking the severity at 3 or higher (Figure 5).

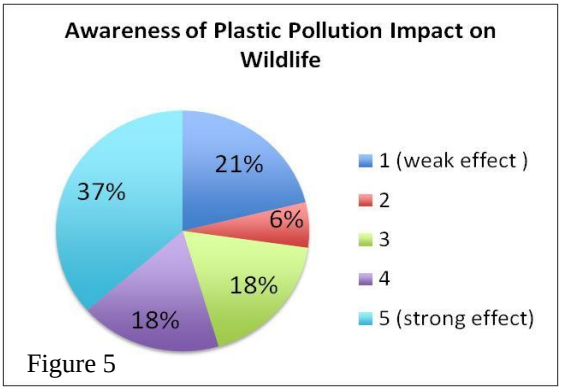


Figure 5

Numerous respondents commented about observing seagulls and shorebirds mistaking plastic for food as well as their entanglement in various types of plastic such as fishing line and beverage container rings.

Respondents were asked whether they believed that plastic pollution could be affecting their health. Beliefs were divided (Figure 6), suggesting that the public is not as informed about this topic or are uncertain about the validity of available information.

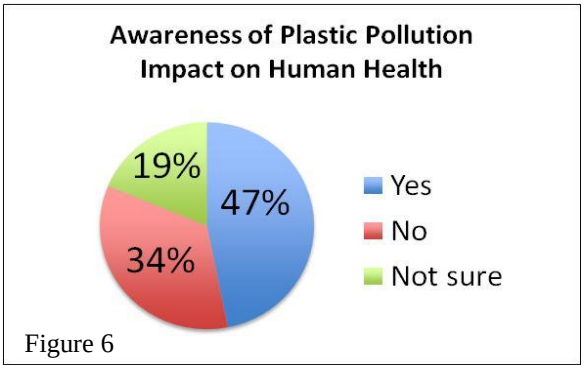


Figure 6

The majority of respondents who did believe their health could be impacted also ranked a high wildlife impact (severity >3), while the majority of respondents who did not believe their health could be impacted also ranked a low wildlife impact (severity > 2). Of specific concern to over half the people who replied yes to the health question was the issue of plastics in drinking water and/or food from Lake Huron (see section 6.3). Another focus that was mentioned multiple times was the impact on respondents' mental health. Feelings of disappointment, stress, sadness and anger were voiced.

Plastic pollution affects people's experience using the beach to different extents. 47% of respondents reported being highly affected (4-5 on a scale of 1-5), while 37% reported their experience being affected minimally (1-2). A notable trend was observed in the responses. Of the 16 people who rated a low effect on their experience, 94% of them had also replied that they did not believe or were unsure if there was a health effect from plastic pollution, and 75% of them were unsure or believed wildlife was affected minimally. On the other hand, of the 20 people whose experiences were highly affected by plastic pollution, the majority of them believed their health and wildlife would be highly impacted (80% and 65% respectively). Therefore, it is important to increase awareness in order to motivate people to improve their Lake Huron experiences.

Almost all of the respondents (81%) reported that they have participated in past beach clean-ups. While many have participated in formal clean-up events, most respondents participate informally by regularly picking up plastic and litter during walks along their respective beaches. Many respondents mentioned the need for garbage and recycling infrastructure on the beach opposed to just the beach entrances/exits. Additionally signage reminding users to dispose of their plastic properly as well as for littering fines should be more frequently posted.

9 Municipality Awareness

Municipality awareness is a vital link to building healthy communities, as recognizing issues allows local governments to effectively establish the needs of the community. Municipal governments are not only in a position to promote awareness, but can also foster collaboration between diverse sectors of the community and create social capital.

With municipal focus along the Lake Huron shoreline primarily on sand dune preservation and invasive species control (phragmites), plastic pollution in Lake Huron has yet to be presented as a forefront issue. According to responses to an e-mail questionnaire sent to various Lake Huron coastal municipality officials, plastic pollution is not considered to be a high priority issue for communities now, nor do they see it becoming one in the future. However, it is unclear if municipalities are aware of the full extent of the problem. The issue of plastic pollution in Lake Huron goes beyond litter found on the beach. With microplastics gaining recent attention in the media and the scientific community, new sources and impacts are continually being identified. It is likely that municipalities will face unanticipated obstacles when addressing plastic pollution in the future.

Generally, municipalities are focused on providing litter-management services such as beachcombing. Additionally all municipalities reported providing garbage receptacles, though public recycling infrastructure is not available on all beaches. Few beach protection outreach programs and initiatives were mentioned. In most cases, responsibility for shoreline cleanups was shared between property owners, volunteer community groups, beach associations and the municipality (e.g. Parks department, Public Works department, etc.). While it is not the sole responsibility of municipalities to provide such programs, their awareness and involvement is an essential part of developing strong community partnerships and a high quality of place for residents and visitors.

Beachcombing machine.

Photo Credit: Derrick Coetzee (www.flickr.com/)

Grand Bend, Ontario, located on Lake Huron.

Photo Credit: Premier Life (www.premierlife.ca)

10 Current Initiatives and Programs

Various initiatives and actions intended to reduce, mitigate, prevent and control the harmful effects of plastic pollution have been carried out across the world. Such actions and initiatives are existing measures with intentions of increasing engagement and awareness. The following subsections outline some relatively new concepts recently put into practice, whereas others such as shoreline cleanups have been in place for years. The examples of initiatives and programs discussed below are applicable to addressing the issue of plastic pollution and could be implemented for Lake Huron with the assistance of the Lake Huron Centre for Coastal Conservation.

10.1 Project AWARE – Dive Against Debris

Project AWARE Foundation consists of a global force of scuba divers in more than 180 countries and territories protecting the ocean planet, with a focus on marine debris as one of the major ocean issues[66]. Moving beyond Project AWARE International Cleanup Day events, the introduction of Dive Against Debris is a year-round data and debris collection effort to decrease the disturbing impacts of debris by removing fragments, recording and reporting the types and amounts online[66]. There is a need of underwater data to paint a true global picture of the plastic pollution issue beneath the surface and to assist with filling in gaps by understanding the impacts that marine debris has on the underwater environment[66]. Data reported by volunteer divers would help determine the extent of the plastic pollution issue in Lake Huron. Subsequently, it would improve infrastructure and policies that prevent and reduce marine debris from entering Lake Huron at a local and regional level.

10.2 Adopt-A-Beach Programs

The California Coastal Commission has implemented an Adopt-A-Beach® program that consists of a year-round, state-wide beach cleanup[67]. Private and/or public groups can take part in the program by volunteering to clean any of California's adoptable beaches by committing to cleaning it at a minimum of three times a year[68]. A school group can achieve their commitment for the program with a one-time annual cleanup[68]. The implementation of such programs promotes feelings of pride and ownership as volunteers begin to care for 'their' beach[68]. At the end of the year, groups are encouraged to re-adopt a beach[67]. The Adopt-A-Beach program consists of a simple process that has been received with great enthusiasm by hundreds of California schools, corporations, service and professional organizations[68]. This style of beach clean-up could be adopted by local schools in the Lake Huron region to promote awareness and education of the issue.

10.3 Contests

The single most effective approach for long term protection and enhancement of the environment is educating young people[68]. The California Coastal Commission encourages the public to consider, visit and care for its coast by holding several contests throughout the year[69]. For example, art and poetry contests present an opportunity for youth to reflect on the spirit and beauty of the ocean and beaches of California, while hoping to motivate a better sense of stewardship for such natural places[69]. If young people care about the coast, they are more likely to be engaged in the conservation and protection of the resources[67]. Again, this could be adopted by the Lake Huron region.

10.4 Lost Fishing Gear Recovery Project

In 2005, the California Lost Fishing Gear Recovery Project was launched to encourage ocean users to report the presence of lost fishing gear[70]. The project hires qualified commercial scuba divers to eliminate gear from near-shore waters in a safe and environmentally profound way[69]. More than 45 tons of fishing gear has been recovered from California's coastal ocean since May 2006[69]. In addition, more than 1,400 pounds of recreational fishing gear, including more than 1 million feet of fishing line has been cleaned off public fishing piers in the state[69]. According to the Great Canadian Shoreline Clean Up Report (2010), 'ocean and waterway activities' debris such as fishing gear was found in significant quantities on some Lake Huron beaches[13]. So it is possible that fishing gear is a significant in-water plastic pollution issue as well. While, this program is not presently feasible or necessary as we do not yet know the extent of the plastic pollution issue in Lake Huron, it could be a future consideration if fishing gear is found to be impacting the lake.

10.5 Marine Debris Tracker Mobile Application

Through a joint effort of the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program and the Southeast Atlantic Marine Debris Initiative (SEA-MDI) out of the University of Georgia College of Engineering, the Marine Debris Tracker mobile application was designed to allow for marine debris found in the water or on the beach to be easily tracked and logged[71]. By recording the location of the debris through GPS and by selecting the type from a list of common debris items, the data is submitted to the Marine Debris Tracker Website as a fast and efficient data collection method[70].This application reaches out to people to have them notice and then pick up debris as a measure to help spread awareness and mitigate the issue[70].One of the main objectives of the application is to educate the public about marine debris and its harmful impacts in a socially appropriate way[70]. LHCCC could encourage people to download and use the free application. This would increase awareness and help build information and monitoring networks for plastic pollution on Lake Huron's shoreline.

11 Recommendations

The Lake Huron Centre for Coastal Conservation, the public and local municipalities will need to work collaboratively in order to effectively mitigate plastic pollution and its adverse impacts in Lake Huron and along its shorelines. Our recommendations to the Lake Huron Centre for Coastal Conservation (LHCCC) on collaborative ways that all three stakeholder groups might help to address this issue are provided in the following section. All recommendations are directed towards LHCCC but also describe how the other two target groups are involved or actions they should take. Recommendations fall under three categories: awareness and education, monitoring investing in appropriate infrastructure.

Awareness and Education

1) Educational workshops
Target: Municipalities

Recommendation (R): Run learning workshops about plastic pollution for municipality officials.

Benefits (B): According to the email questionnaires sent to Lake Huron municipal officials (see section 8), most municipalities are not aware and informed about the issue of plastic pollution. A workshop would be an effective tool to teach local officials about the impacts and give them an understanding of the issue's importance. It could also serve as a platform for providing guidance to municipalities on how to go about dealing with the issue.

2) Youth beach-protectors program
Target: Public

R: Create a youth steward community program for Lake Huron's beaches. This would involve volunteers to perform activities such as creating public displays, reminding people to recycle on the beach, giving directions towards proper disposal areas, doing outreach to tourists regarding impacts of plastic pollution, organizing beach clean ups, emptying additional garbage and recycling infrastructure located on beaches, etc.

B: This would increase awareness among young people and is a direct opportunity for youth to become involved in an emerging issue. Additionally, high school students could obtain their community service hours required for graduation through this program.

3) Plastic pollution campaigns
Target: Public

R: Create a campaign focused on plastic pollution. This could be an all-encompassing on-going campaign or a series of smaller, focused ones. An example of a campaign focus could be lobbying government for a bottle deposit on non-biodegradable plastic bottles. The deposit would promote plastic recycling and prevent littering. Similar to the Ontario beer bottle returns, it has the potential to change the behavior of consumers making them realize the importance of returning plastic bottles. Through placing an associated fee on the plastic bottle, it will entice consumers to return the used bottle in order to receive their deposit. This system has already been implemented in ten U.S. states[21]. The campaign should be well advertised in the media. Adding a regular "plastic pollution" section to LHCCC's community newsletter would be an easy addition. The creation of a video to be shared on the internet should be a main component of any campaign. Community members are encouraged to play an active role in every aspect of the campaign.

B: A campaign would provide an opportunity for public engagement of the issue. It could raise money to fund new community programs that are created for the plastic pollution issue. Lastly, it could foster future collaboration with other advocates and organizations that are interested in this issue such as the Freshwater Institute, Canada Centre for Inland Waters and Living Lake Canada.

4) Develop public/Private Partnerships to reduce plastic waste along the shoreline.
Target: Public

R: Initiate partnerships with shoreline-based industry (food vendors, shops, etc.) in order to reduce plastic waste sold. Items of interest are plastic packaging, plastic cutlery, plastic food containers, and plastic bags. This same engagement approach can be applied to events that take place along the Lake Huron shoreline. Such plastic-free and waste-reduced events have been successful throughout North America and include Vans Warped Tour (throughout the US), Telluride Blue Grass Festival (Colorado), Firefly Music Festival (Delaware), Floydfest Music Festival (Virginia), Salmonstock Music Festival (Alaska), and Pickathon Music Festival (Oregon).

B: Partnerships strengthen community relationships. Additionally, plastic-free shoreline events would help to reduce land-based littering, which is the main source of plastic pollution.

5) Innovate traditional events
Target: Public

R: Innovate traditional events that already take place in the community, such as beach cleanups. For example, since 2009 the Cleveland Museum of Natural History and Cleveland Metroparks have hosted the annual Great Lake Erie Boat Float in Cleveland, Ohio. The event combines a beach cleanup with a boat race using boats that participants build out of post-consumer, recyclable plastic![72] Another example is running a community-wide 'reduce your plastic' challenge. Social media could be an easy advertising and progress tracking medium for these challenges.

B: Spicing up recurring events keeps public interest in them and attracts new people to events.

6) Encourage the avoidance of consumer products containing microplastic
Target: Public

R: Avoiding buying products that contain the words polyethylene (PE), polypropylene (PP), polyethylen terephlatate (PET) or polymethyl methacrylate (PMMA) in their ingredients as they contain plastic[73]. Choose products that do not contain plastic and products that use natural exfoliates such as walnut shells, almonds, grape seeds, sugar, oatmeal and sea salt[74]. Many websites also provide recipes to create your own affordable, homemade cleansers and scrubbers that are plastic-free!

B: If microplastics are not being removed during wastewater treatment or enter the lake during bypass or combined sewer overflows, people may be unknowingly contributing to the plastic pollution issue by using products that contain microplastic. This recommendation applies the precautionary principle.

7) Support campaigns to pressure companies into banning micro beads in their products
Target: Public

R: The public can support campaigns that pressure companies into banning microplastics in their products. Currently, the internet-based campaign called 'Beat the Micro Bead', headed by two Dutch NGOs, Plastic Soup Foundation and North Sea Foundation, is the only campaign of this kind. However it is an international effort and with its initial success getting Unilever to agree to phase out microplastics by 2015, similar campaigns by NGOs in North America may begin to pop up. The public is encouraged to support campaigns that ban microplastics by getting informed and telling others about the issue, avoiding microplastic products, signing online petitions, and promoting campaigns or NGOs working on the issue through social media.

B: This movement is important because it pushes companies to accept corporate responsibility for their environmental impacts and liabilities, promotes the precautionary principle and encourages the integration of an environmental perspective into corporate decision-making and company values[75]. Addressing microplastics is important with respect to Lake Huron because it may prove to be the most significant type of plastic pollution impacting the Great Lakes.

8) Encourage public to use reusable bags
Target: Municipalities and Public

R: As a short-term action, encourage the public to use reusable bags and reuse plastic bags. Also encourage retailers to charge customers for the purchase of plastic or reusable bags if not already doing so. As a long-term action, municipalities need to create a by-law to legally ban one-time-use plastic shopping bags.

B: This is a means to change people's daily habits by eliminating and reducing waste from single-use plastic bags. In terms of the ban, various towns and cities across the world have already enforced single-use shopping bag free zones. For example, the town of Leaf Rapids, Manitoba was the first municipality in North American to ban plastic bags in 2007[76]. The municipal budget showed that this could be an opportunity to save money that the town of Leaf Rapids had been spending to clean up the community[76]. Following the ban, the town is reportedly much cleaner and it is anticipated to be even cleaner than that as time progresses. Residents of the town are taking more pride in the community because they are doing something that is good for the environment[76].

Monitoring

9) Fish remains collection program
Target: Municipalities and Public

R: Develop a fish remains collection program. This would involve the collection of fish remains to further investigate and research the movement of plastic through the food chain. This information would be easiest to collect during Lake Huron fishing derbies. Stations could also be set up at public boat launches. Specific bags would be provided and marked with the date, species, and location where the remains are coming from. This program could be run by the provincial government, local municipalities, or by a university research group.

B: It is beneficial to gather data regarding the bioaccumulation of plastic within different trophic levels in the aquatic environment to further develop baseline information.

10) Encourage web-based reporting of wildlife being affected by plastic pollution
Target: Public

R: Provide a web-based report recording animal fatalities and mortalities form on LHCCC's website that the public could complete. The report would contain sections for species type, where the animal was found, and the possible cause of the fatality/mortality. In order to encourage public participation, such web-based reports would need to be advertised. This could be done through the Centre's website, the Centre's forms of social media (Facebook, Twitter), coastal signage, and community new letters.

B: This would provide an easy way for the Centre to gather data regarding factors that are negatively impacting shoreline wildlife including plastic pollution. This information can be shared with researchers and authorities as an aid for research, to build a case for further research, and initiation of possible intervention programs to reduce the negative affects recorded.

11) Beach monitoring research program
Target: Municipalities and Public

R: A research team should conduct continuous monitoring surveys of plastic waste on Lake Huron beaches. Municipalities would be encouraged to stay updated with this program.

B: This would prove to be a constant source of data referring to Lake Huron plastic pollution types, location, and frequency. It would serve as baseline information to gain a better understanding of the full extent of plastic pollution in Lake Huron. Informed municipalities would have a better understanding of what impacts are affecting their communities the most and thus could better plan and prepare for them.

Infrastructure

12) Provide recycling infrastructure on the shoreline for the public to utilize
Target: Municipalities

R: Encourage municipalities to provide recycling infrastructure alongside their garbage infrastructure on the shoreline. Waste receptacles should contain some sort of cover system and should be emptied before overflowing occurs (e.g. more often on the weekends during summer).

B: Advantages to this would include providing a location for proper disposal of plastics, lessening the volume of "garbage" in the present waste receptacles which could potential decrease the occurrence of overflow events and subsequent litter on the beach as well as providing a space that could be used to display plastic pollution information/signs (i.e. have signs on the bins themselves).

13) Trash-trap infrastructure
Target: Municipalities

R: Preventative trash-trap infrastructure could prove to be a viable solution for reducing the amount of plastic pollution that enters Lake Huron. For example, the use of collection baskets, release nets and storm drain covers present initiatives that would reduce the amount of land-based litter from entering waterways.

B: During rates of high flow, many collection systems are bypassed allowing debris to flow freely into aquatic environments. This will be a main issue to resolve, as high flow increases the chances of debris being swept into waterways. Trash-trap infrastructure is a feasible solution for the prevention and reduction of plastic debris from entering Lake Huron.

14) Develop signage for public shoreline areas
Target: Municipalities and Public

R: Develop and post various types of signs on public beaches that aim to decrease littering by beach goers. Recommended types of signs include directions/maps locating garbage and recycling bins along the beach, litter fines and enforcement reminders, signs that contain information about plastic pollution and its impacts to educate the public and "warning" signs about plastic pollution effects on wildlife that contain animal imagery.

B: It is important that special effort is made to inform the public and increase awareness while people are actually on the beach. The message will then be fresh in beach goers' minds and there will be increased social pressure to not litter.

15) Designated smoking areas and smoke-free beaches
Target: Municipalities and Public

R: Implement designated smoking areas or entirely smoke-free beaches. Signage would be necessary to inform smokers of the specific rules for each public beach. Signs would also provide direction towards proper waste infrastructure to deal with cigarette butts and other related trash.

B: This would reduce the amount of smoking-related trash found on beaches.

Summary Table of Recommendations

Category	Recommendation	Target (M = municipalities P = public)
Awareness and Education	Educational workshop	M
	Youth beach-protectors program	P
	Plastic pollution campaigns	P
	Public/Private partnerships	P
	Event innovation	P
	Avoid consumer products with microplastics	P
	Support campaigns that pressure banning of microbeads	P
	Reusable bag use/Plastic bag by-law ban	M, P
Monitoring	Fish remains collection program	M, P
	Wildlife reporting	P
	Beach monitoring research	P
Infrastructure	Recycling receptacles on beach	M
	Trash traps	M
	Plastic pollution signage	M, P
	Designated smoking areas/smoke-free beaches	M, P

12 Conclusion

Plastic pollution is an emerging issue in the Great Lakes. Using the extensive research within the marine environment as a comparable framework to forecast Great Lakes issues, it is clear that plastic pollution will have substantial social, economic, human health and environmental implications. Many of these impacts will affect local communities and governments. Based on the aforementioned recommendations, these could be used individually or in combination to generate the most effective response to plastic pollution.

Current research has provided insight towards increasing concerns regarding plastic pollution concentrations within freshwater ecosystems. The pressure of population growth and an increasing consumer market will certainly only add to this accumulation. Public consumption behaviours need to shift away from using plastic and focus on more sustainable, environmentally friendly materials. Taking proactive measures will be required in order to successfully mitigate plastic pollution and its adverse impacts in the Great Lakes Region.

Photo Credit: Lake Huron Centre for Coastal Conservation (www.facebook.com/coastalcentre)

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Appendix I

Dr. Mason Email Correspondence

On Tue, Feb 26, 2013 at 11:56 PM, Emily Payton <epayton2@uwo.ca> wrote:

Good evening Dr. Mason,

I am an Environment and Sustainability Master's student at Western University, Canada and as part of a group project we are working with the Lake Huron Centre For Coastal Conservation on the emerging issue of plastic pollution, with a focus on Lake Huron. A portion of our work with the Lake Huron Centre For Coastal Conservation is to prepare a report which consists of a literature review on research to date. Throughout my research I have come across several news articles regarding your field work that was completed this past summer; however, I am not sure if this has been published yet? In addition, one news article mentioned that you planned on traveling around the region raising awareness about the study and providing alternatives to limit plastic use in our daily lives. If you had an opportunity to do so, how did you present this information and how did the public perceive the results?

Also, news articles have mentioned that you aim to continue your work by sailing Lake Michigan this summer. Is this still the plan? What future work is on the horizon with regards to plastic pollution?

Thanking you in advance for your assistance.

Best Regards, Emily Payton

On 02/27/13, Sherri Mason <Sherri.Mason@fredonia.edu> wrote:

Hi Emily,

We are still working on our manuscript, but hope to have it submitted for peer-review soon. We had some interesting findings arise as we analyzed the chemical composition of our particles that has delayed submission.

I had hoped to do an outreach tour this semester, but as we are still working on the data and manuscript haven't done much. I have spoken to a few local groups (The League of Women's Voters, the American Association of University Women, and the Chautauqua Vegetarian Society, for example) and have a presentation scheduled in Syracuse, NY in April. In general when I do such presentation I use powerpoint with some hands-on visual aids (i.e., bring in actual samples of debris). Throughout my presentations or interviews about this issue, people are mostly just shocked. They don't realize the impact that plastic

is having- they are unaware- especially when it comes to consumer products in which plastic is actually included with the explicit purpose of washing straight down the drain (and therefore out to sea). They are surprised that such products are allowed to exist.
I will be in Lake Erie in May and Lake Michigan in August. I was also just recently contacted and might be able to get some samples in Lake Ontario in July (I hope).

What we have provided between last summer and this upcoming summer is a good baseline, but there is much work still to be done. More intensive open-water sampling campaigns; investigations of seasonal variation; investigations within the St. Lawrence seaway to compare what is in the lakes with what is actually leaving them and heading out to the oceans. We have results to indicate that there is a difference between the lakes and the samples obtain in the oceans- why? What is happening along the way? How is this affecting the animals that rely upon the lakes for survival? We already know that the lakes are harbingers of Persistent, Bioaccumulative and Toxic compounds- how is this affected by plastics? Generally they adsorb these chemicals from the surrounding waters and Bioaccumulate them. Is there preferential adsorption of certain chemicals over others? how long? Do they desorb once ingested? What is the degradation rate for plastics in a freshwater system and is this influenced by the shoreline?

Lots of questions still to answer. Hope this helps.

Take care, Sam

Sherri A. Mason, Ph. D. Associate Professor of Chemistry Sustainability Coordinator, SUNY FACE Center Program Coordinator, Environmental Sciences Event Coordinator, Earth Week 2013
SUNY Fredonia Houghton Hall 220 Fredonia, NY 14063 716.673.3292

On Tue, Mar 5, 2013 at 12:01 PM, Emily Payton <epayton2@uwo.ca> wrote:

Good afternoon Dr. Mason,

I want to thank-you for taking time to reply to my email. Yesterday, our group met with the Lake Huron Centre For Coastal Conservation to update them on our progress with our project thus far. I had informed the Coastal Centre that you are stilling working on your manuscript. Do you anticipate returning to Lake Huron to conduct further sampling in the future?
Could you provide us with any insight as to what you think the Coastal Centre could do for outreach regarding the emerging issue of plastic pollution?
As part of our report, would you please give us permission to include any email correspondence with you as an appendix?
Once again, I want to take this opportunity to thank you for your assistance.

Best Regards, Emily Payton

Subject: Re: Plastic Pollution Research - Great Lakes Date: 03/05/13 06:09 PM
To: Emily Payton epayton2@uwo.ca From: Sherri Mason Sherri.Mason@fredonia.edu

Hi Emily,

Are you familiar with Patricia Corcoran <pcorcor@uwo.ca>? She is another plastics pollution researcher, who might be a closer contact for you and your group. Perhaps you could get her out to do some public awareness events to discuss the issue of plastic pollution? Though she doesn't do open-water sampling, she has done some fantastic work on near-shore sampling along the shores of Lake Huron (among other bodies of water). Beach clean-up events are also another great hands-on way to raise awareness, while collecting useful information for researchers like myself and Patricia. The Adopt-a-Beach program is a good example and contact.

Creating displays of plastic debris collected along the shores along with information about the impact of plastic pollution is another great vehicle for raising awareness.
I hope to continue to conduct surveys of all the Great Lakes every summer, hitting what lakes I can based upon available vessels. So, yes, I do hope to get in Lake Huron again, though it is doubtful for 2013.

You are welcome to include my emails as an appendix. That is fine. I hope this information is helpful. If you have any other questions, please let me know.
Sincerely, Sam

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Appendix II

Endocrine-Disrupting Chemicals

Pollutant	Chemical name/ group	Potential source on plastic	Potential impact on human health
DBP DEHP DINP DEHA	dibutyl phthalate, di(2ethylhexyl) phthalate diisonylphthalate Bis (2-ethylhexyl) adipate	Plasticizers leaching from plastic - used in flexible PVC products	Induce adverse effects in the reproductive system of male rats, liver carcinogenic in mice
BPA	Bisphenol A	Monomer used as lining for most food and beverages cans	Mimic estrogen in binding to the same receptors in the body, can promote breast cancer cell growth
tOP nNP	4-tertoctylphenol 4-nonylphenol	Aps are hydrophobic surfactants used as additive in plastic and can leach out by weathering - used in herbicides and pesticides and can accumulate on the surface of plastic fragments	Toxic towards organisms and can potentially be transferred through the food chain and into humans
CMP	4-chloro-3-methylphenol	Chlorophenols are used as an antiseptic and disinfectant in cosmetics adsorbed on the surface of plastic fragments	Toxic to birds, moderately toxic to invertebrates, and highly toxic to fish

Resorcinol	1.3-benzendiol	In production of resins adhesives used in cosmetics and hair dyes might be adsorbed on the surface of plastic fragments	Causes disruption of the thyroid hormone biosynthesis
Cadmium	Heavy metal	Found in plastic waste and accumulates on the surface of pellets from sewage sludge and application of fertilizers.	Toxic effect on the kidney, bone effects and fractures and human carcinogenic
Copper	Heavy metal	Accumulates on the surface of plastic mainly on smoked cigarettes	Gastrointestinal and renal symptoms
Lead	Heavy metal	Accumulates on the surface of plastic from	Affect brain cells in children
Nickel	Heavy metal	Accumulate on the surface of plastic from	Birth defects and allergy

Appendix III

Lake Huron Species of Concern

Common Name	Taxonomy	Scientific Name	OMNR Status
Bald Eagle	Bird	Haliaeetus *leucocephalus*	Special Concern
Black Tern	Bird	Chlidonias *niger*	Special Concern
Blanding's Turtle	Reptile	Emydoidea *blandingii*	Threatened
Bridle Shiner	Fish	Notropis *bifrentus*	Special Concern
Channel Darter	Fish	Percina *copelandi*	Threatened
Eastern Musk Turtle	Reptile	Sternotherus *odoratus*	Threatened
Grass Pickerel	Fish	Esox americanus *vermiculatus*	Special Concern
Horned Grebe	Bird	Podiceps *auritus*	Special Concern
Kidney Shell	Mollusc	Ptychbranchus *fasciolarus*	Endangered
Lake Chubsucker	Fish	Erimyzon *sucetta*	Threatened
Lake Erie Watersnake	Reptile	Nerodia sipedon *insularum*	Endangered
Lake Sturgeon (Great Lakes population)	Fish	Acipenser *fulvescens*	Threatened
Mapleleaf Mussel	Mollusc	Quadrula *quadrula*	Threatened
Northern Madtom	Fish	Notorus *stigmosus*	Endangered
Northern Map Turtle	Reptile	Graptemys *geographica*	Special Concern
Paddlefish	Fish	Polyodon *spathula*	Extirpated
Piping Plover	Bird	Charadrius *melodus*	Endangered
Pugnose Minnow	Fish	Opsopoedus *emiliae*	Threatened
Pugnose Shiner	Fish	Notropis *anogenus*	Endangered
Queensnake	Reptile	Regina *septemvittata*	Endangered
Rainbow Mussel	Mollusc	Villosa *iris*	Threatened
Rayed Bean	Mollusc	Villosa *fabalis*	Endangered
Round Hickorynut	Mollusc	Obovaria *subrotunda*	Endangered
Round Pigtoe	Mollusc	Pleurobema *sintoxia*	Endangered
Shortjaw Cisco	Fish	Coregonus *reighardi*	Endangered
Silver Chub	Fish	Macrhybopsis *storeriana*	Threatened
Snapping Turtle	Reptile	Chelydra *serpentina*	Special Concern
Snuffbox	Mollusc	Epioblasma *triquetra*	Endangered
Spiny Softshell Turtle	Reptile	Apalone *spinifera*	Threatened
Spotted Sucker	Fish	Minytrema *melanops*	Special Concern
Wavy-rayed Lampmussel	Mollusc	Lampsilis *fasciola*	Threatened

Adapted from Species at Risk in Ontario (SARO) List

Ontario Ministry of Natural Resources. (2013, January 13). *Species at Risk in Ontario (SARO) List*. Retrieved March 20, 2013, from Species at Risk: http://www.mnr.gov.on.ca/en/Business/Species/2ColumnSubPage/276722.html

Appendix IV

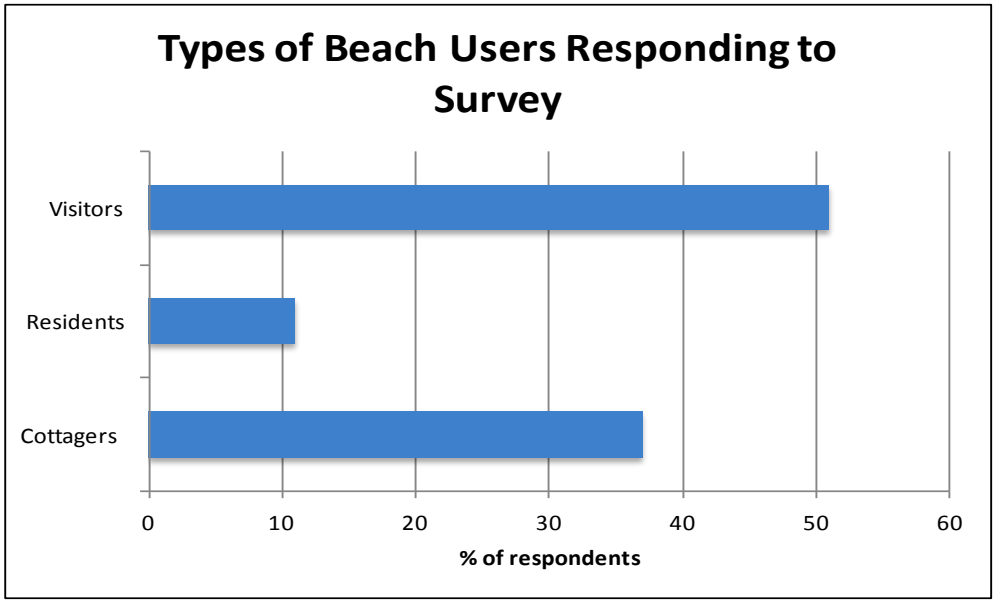
Types of Plastic

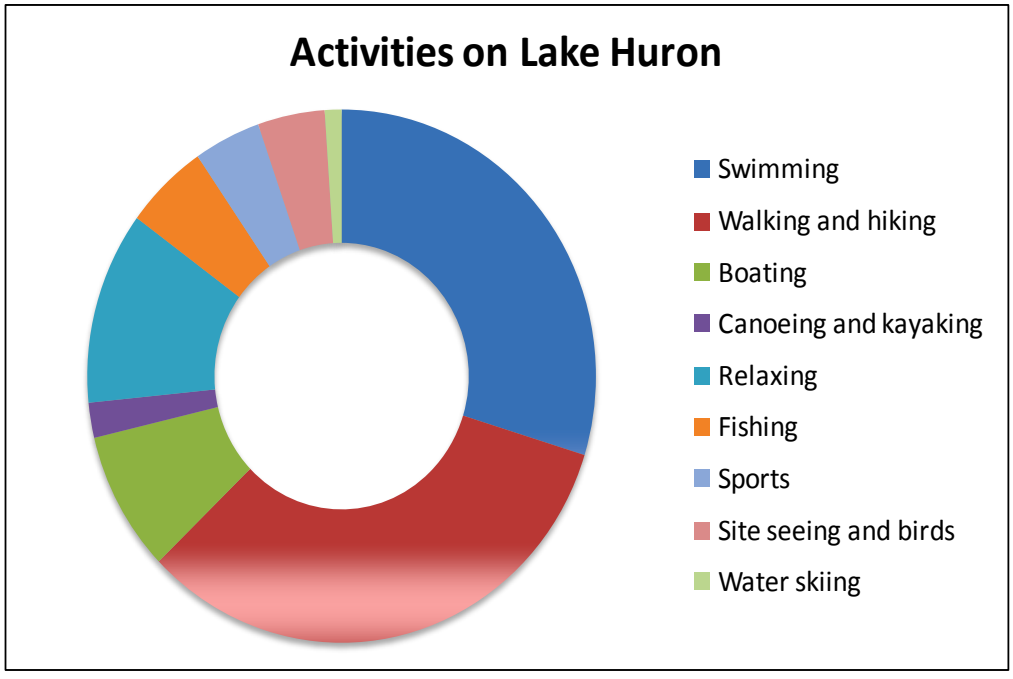
Recycling Number	Type	Examples; Safety for Food & Beverage Use
	Polyethylene terephtalate (PETE or PET)	Includes clear plastic soda and water bottles; generally considered OK to use, but don't reuse
	High density polyethylene (HDPE)	Includes opaque milk jugs, detergent bottles, juice bottles, butter tubs and toiletry bottles; considered OK to use
	Polyvinyl chloride (PVC)	Includes food wrap, cooking oil bottles, and plumbing pipes; do not cook food in these plastics and try to minimize using no. 3 plastics around any type of food (use wax paper instead of plastic wrap and use glass containers in the microwave)
	Low density polyethylene (LDPE)	Includes grocery bags, some food wraps, squeezable bottles, and bread bags; considered OK to use
	Polypropylene (PP)	Includes most yogurt cups, water bottles with a cloudy finish, medicine bottles, ketchup and syrup bottles, and straws; considered OK to use
	Polystyrene/Styrofoam (PS)	Includes disposable foam plates and cups and packing materials; do not cook food in these plastics and avoid using no. 6 plastics around any type of food
	All other plastics not included in the other categories and mixes of plastics 1 through 6 are labeled with a 7	Includes compact discs, computer cases, BPA-containing products, and some baby bottles; do not cook food in no. 7 plastics that aren't PLA and avoid using non-PLA no. 7 plastics around any type of food

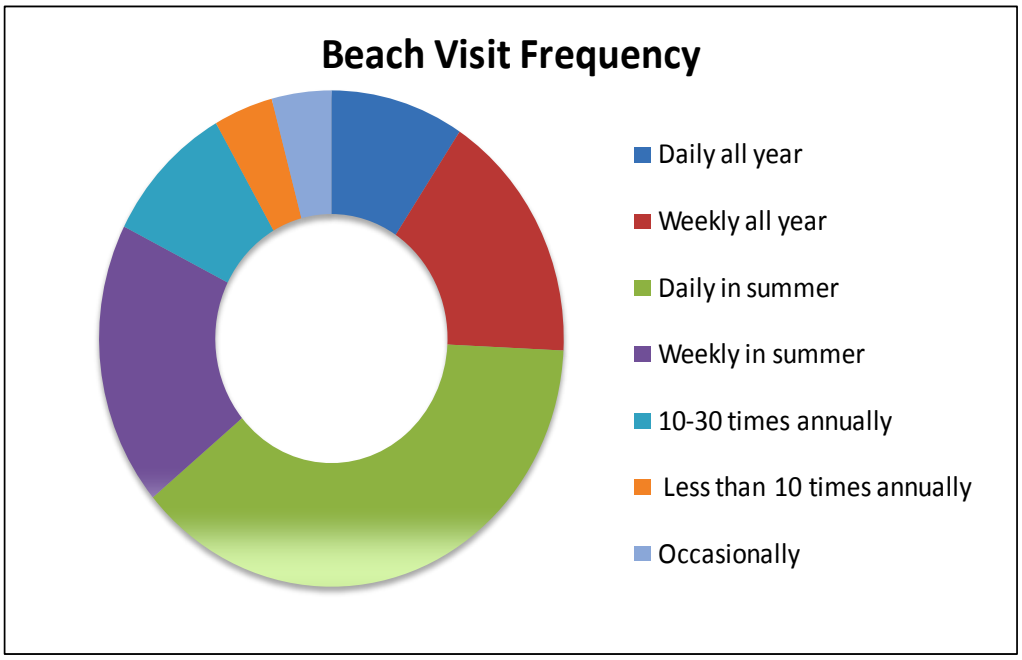
Appendix V

Survey Results

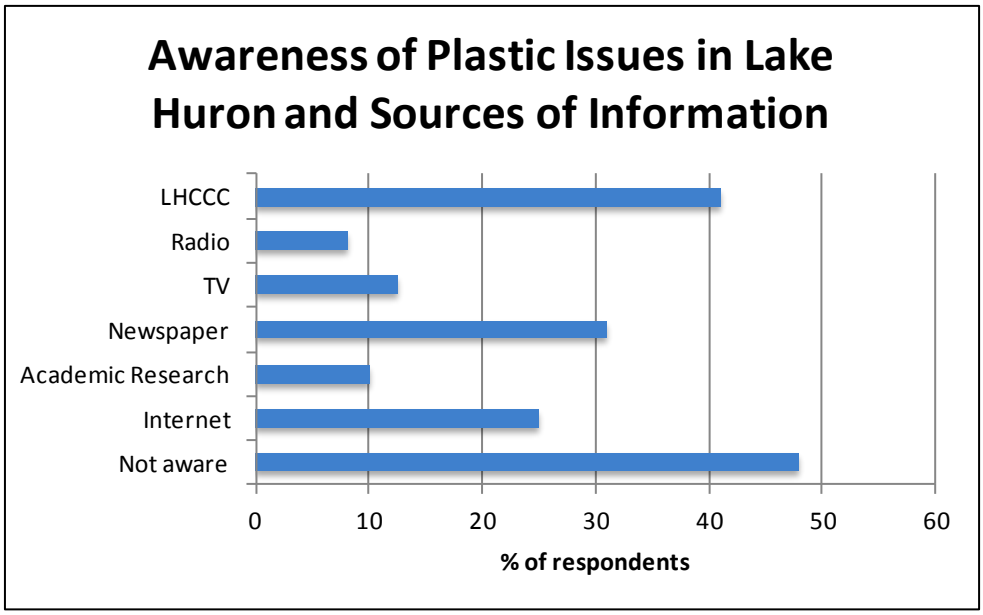
1. How often do you visit Lake Huron? How do you utilize the beach or the water? (Examples: Swimming, walking, site seeing, sports, relaxing, fishing, boating, cottagers etc.)



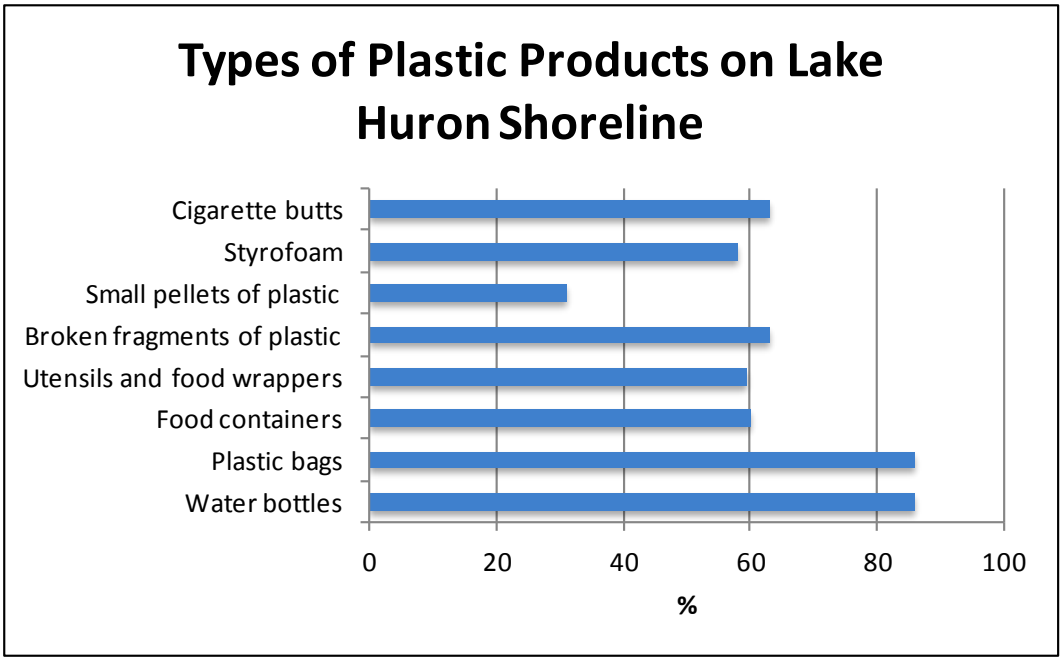




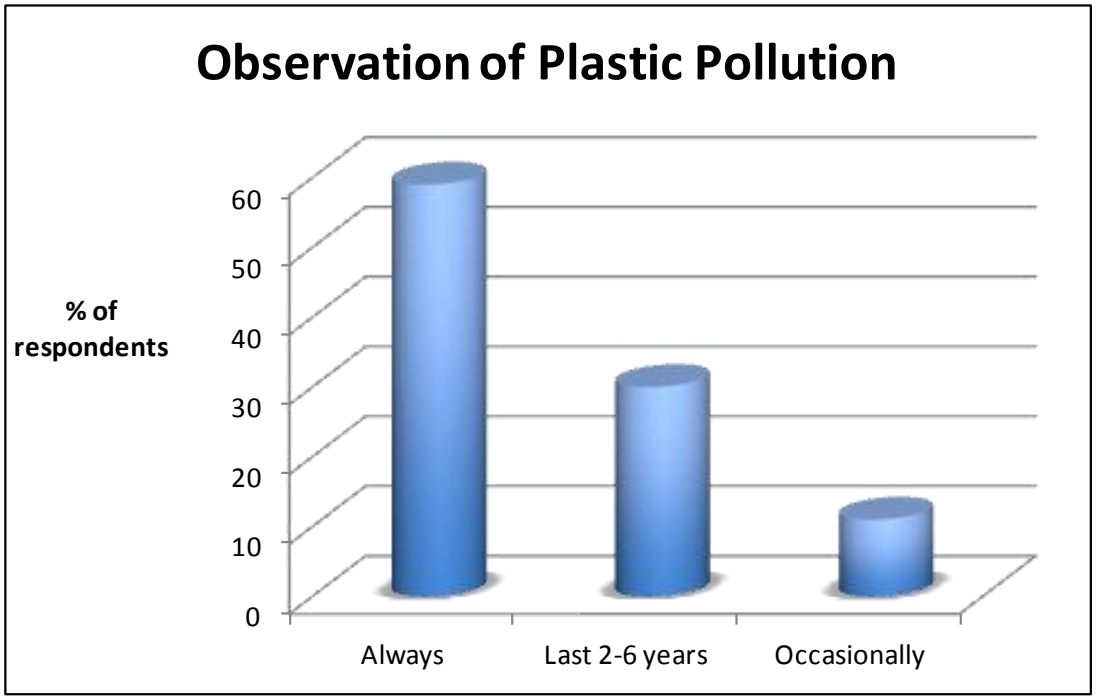
2. Are you familiar with the plastic pollution issue in Lake Huron? If yes, what sources have helped you become informed?



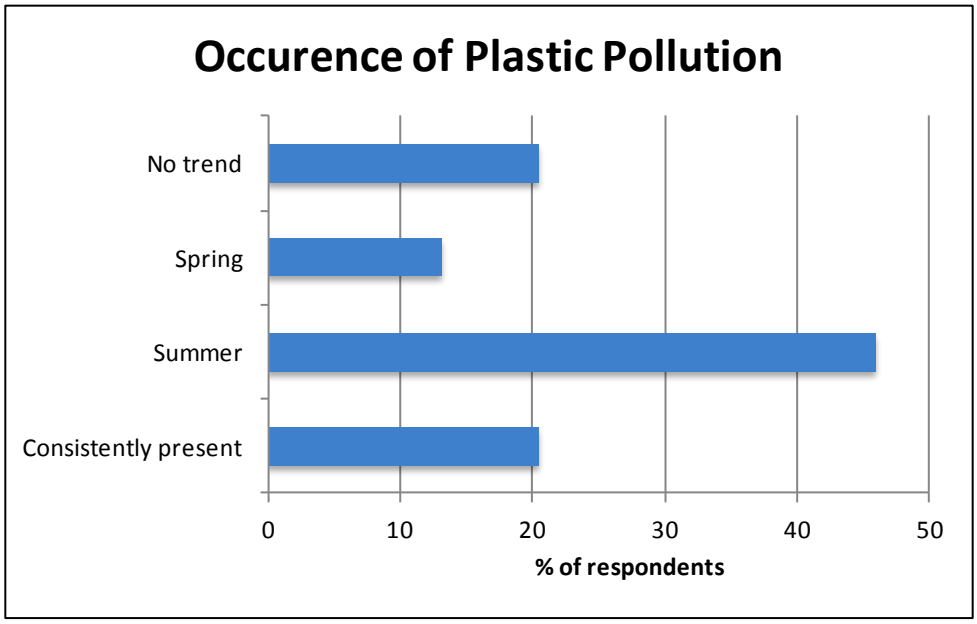
3. Have you noticed plastics on the beach? If yes, tick the types of plastic you see.



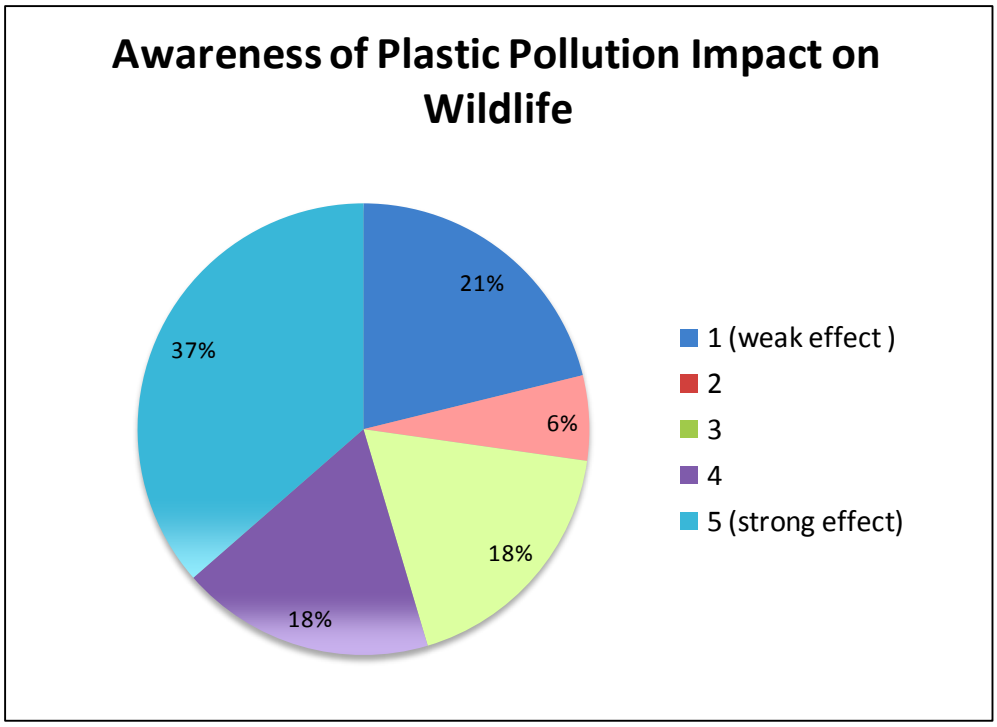
4. When did you start noticing plastic pollution - did you recently notice it or has it always been there?



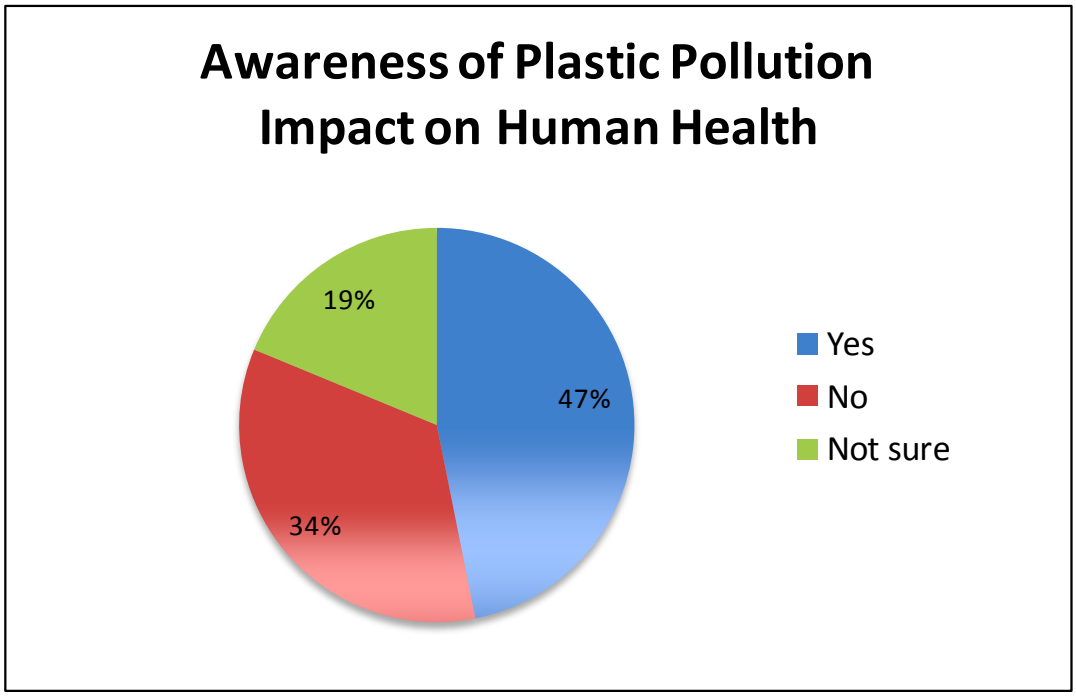
5. Do you see plastic pollution occurring more often at certain times/days/months etc. or is it consistently present?



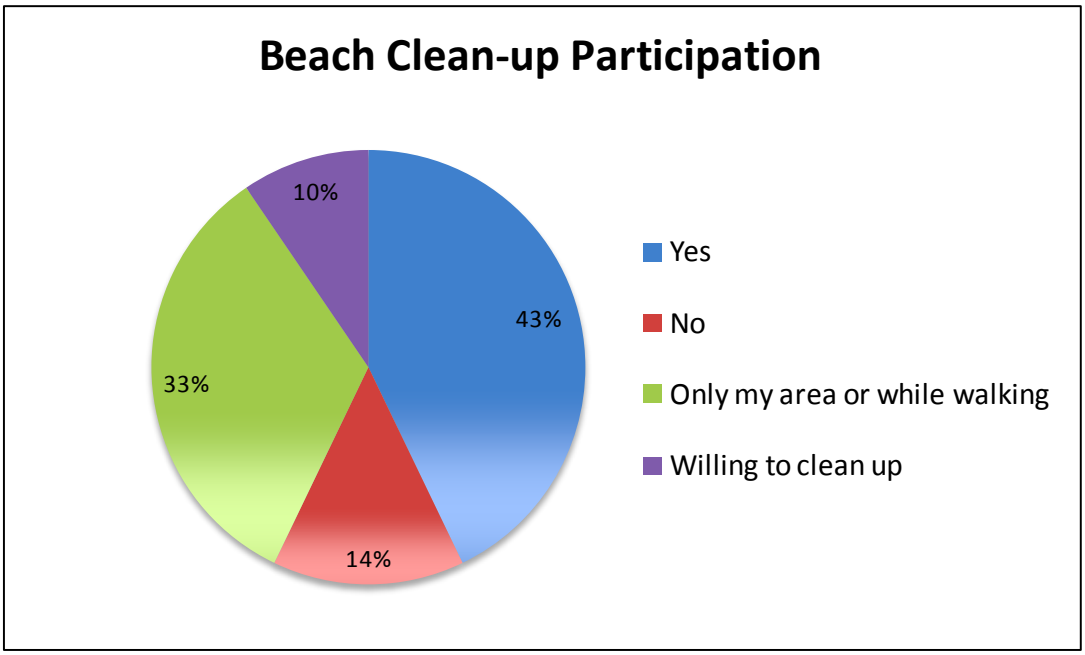
6. Do you think the wildlife are being affected by plastic pollution on the beach or in the lake? If yes, rank the severity to which you believe it is affecting wildlife (1 being low severity and 5 being high severity). Please provide any useful comments on observations you have made (for example, have you seen birds mistaking plastic for food?)



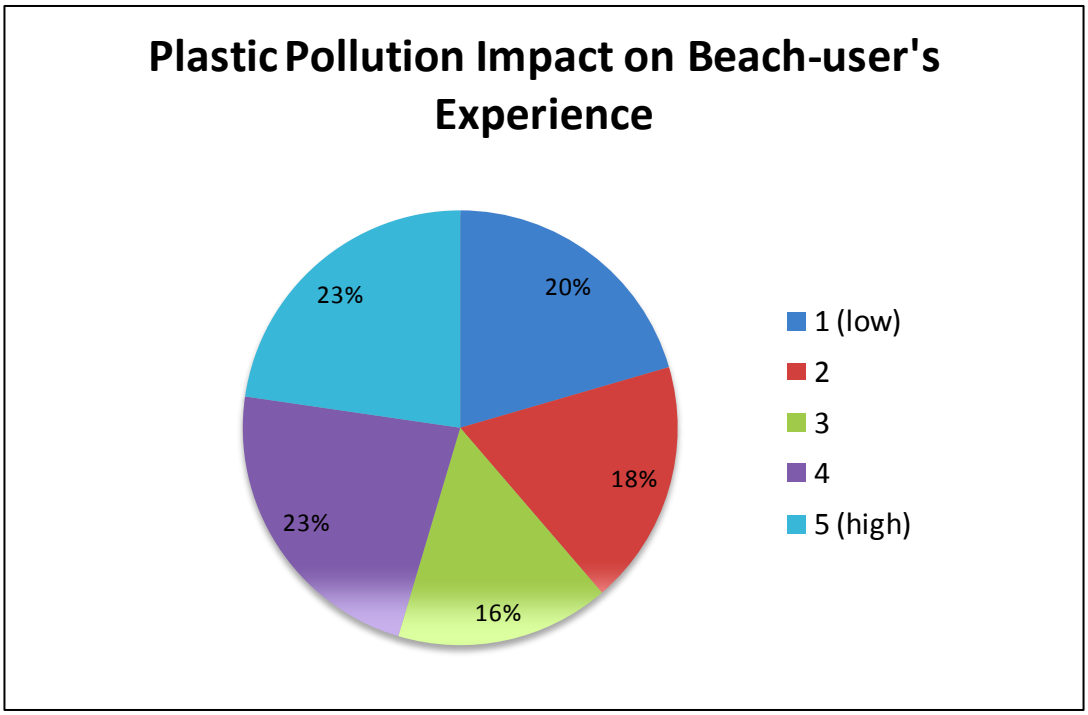
7. Do you believe that plastic pollution could be affecting your health? (Please elaborate briefly if you would like on why or why not?)



8. Have you participated in beach clean-ups in the past? If yes, what motivated you to do that? If no, what would motivate you to get involved?



9. Rank the extent to which plastic pollution on the beach or in the water affects your experience visiting the Lake? (1 being low and 5 being high)



10. Please feel free to share any observations or experiences with plastic pollution in Lake Huron with us! (For example, have you found plastic inside of fish that you caught,

experiences participating in a beach clean-up, any suggestions for engaging others about plastic pollution etc.)

Sample of answers:

- The level of plastic waste on our section of beach seems constant. Each year I think it will improve or get worse but it doesn't - even though we are beside a public beach area (Houston Heights).
- The spring seems to be the time when the snow melts, and the garbage is everywhere.
- So hard. Much washes in from the lake and that is hard to monitor. the beach at Port Franks gets more crowded every year, so the problem is escalating. Extra garbage cans on the beach are ugly and hard to collect from. Often the garbage cans we do have are filled to overflowing. More penalties? More policing? Or just pay to have the beach cleaned up regularly, without letting people know we do that.