Incidence of plastic and other marine debris on the seabed, disposed in rural coastal harbours

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Figure 8. The proportion (%) of different types of plastic debris found at (a) Non-wharf, (b) Wharf, and (c) Low Use sites around Newfoundland, Canada over a 10 year period (2007- 16).

ABSTRACT

Han, V., Morris, C.J., Gregory, R.S., Porter, D., and Sargent, P.S. 2019. Incidence of plastic and other marine debris on the seabed, disposed in rural coastal harbours. Can. Tech. Rep. Fish. Aquat. Sci. 3304: vi + 20 p.

In this ten-year study, we measured debris annually in 17 rural harbours around the Island of Newfoundland, Canada. This survey analyzed 96,412 m^2 of seabed video, categorized into wharf (n=9) non-wharf site (n=3) and low use (n=5) sites. For a standardized average site-survey area of 692 m^2, the average area containing debris was 114 m^2 at wharfs, 45 m^2 at non-wharfs, and 8 m^2 at low-use sites. Debris items were categorized as glass, metal, wood, plastic, paper, rubber, and unidentified. Of the plastic fraction (14%), 29% was household plastic, 25% was single-use plastics, 23% was “fishing-based”; and the remaining 23% was synthetic fabrics and “recreational” plastics (e.g., golf balls). Wharf sites had the greatest proportion of debris on average and the greatest amount of plastic debris. We suggest that more education and awareness could reduce this environmental problem.

RÉSUMÉ

Han, V., Morris, C.J., Gregory, R.S., Porter, D., and P.S. Sargent. 2019. Incidence of plastic and other marine debris on the seabed, disposed in rural coastal harbours. Can. Tech. Rep. Fish. Aquat. Sci. 3304: vi + 20 p.

Dans le cadre de cette étude de dix ans, nous avons mesuré chaque année les débris dans 17 ports en région rurale autour de l'île de Terre-Neuve, au Canada. Ces relevés ont permis d'analyser 96 412 m^2 d'images vidéo du fond marin, classées selon les catégories suivantes : quais (n=9), sites autres que des quais (n=3) et sites à faible utilisation (n=5). Dans une zone de relevé ayant une superficie moyenne normalisée de 692 m^2, la zone moyenne renfermant des débris était de 114 m^2 aux quais, de 45 m^2 aux sites autres que des quais, et de 8 m^2 aux sites à faible utilisation. Les débris ont été classés selon les catégories suivantes : verre, métal, bois, plastique, papier, caoutchouc et débris inconnus. Parmi les plastiques (14 %), 29 % étaient des produits ménagers en plastique, 25 % étaient des plastiques à usage unique, 23 % étaient des plastiques utilisés dans la pêche, et 23 % étaient des tissus synthétiques et des plastiques provenant d'activités récréatives (p. ex. des balles de golf). Les quais avaient la plus grande proportion de débris en moyenne, et la plus grande quantité de débris de plastique. À notre avis, l'augmentation du nombre d'activités d'éducation et de sensibilisation pourrait réduire ce problème environnemental.

1.0 INTRODUCTION

Human population growth and consumption of resources (Ehrlich and Holdren, 1971), the invention and usage of plastic and other synthetic materials (Andrady 2003), and the emergence of a "throwaway society" (Throwaway living, 1955) influenced by consumerism and planned obsolescence of goods, (e.g., single-use and disposable items) (Bulow 1986) have contributed to a growing global waste problem (Hoornweg and Bhada-Tata, 2012; Hoornweg et al., 2013). In 2013, a low estimate of plastic debris in surface waters of the open ocean was 6.6 kilotons (Cozar et al. 2014). A large volume of plastic, along with a wide range of other marine debris, enters the ocean largely from land-based sources (see Barnes et al., 2009; Boucher and Friot, 2017). In addition to plastic by-products entering the marine environment, the problem of marine debris is compounded by continued dumping of garbage into harbours from wharfs located in coastal communities (i.e., point-source; Morris et al., 2016).

Marine pollution has the potential to harm marine environments in many ways. Environmental harm encompasses a wide range of issues, which can include changing the chemical environment (Vollenweider 1992) to directly choking individual animals (Williams et al., 2011). Marine debris can be described as any persistent manufactured or processed solid material that is discarded, disposed, or abandoned in marine and coastal environments (Galgani et al., 2010), and include plastics, wood, metal, glass, rubber, textiles, and paper. There is a wide range of different types of plastic material (see Geyer et al., 2017) that contributes to marine debris (Jambeck et al., 2015) and are known to harm marine fauna (Thompson et al., 2009; Rochman et al., 2012; Williams et al., 2011; Gall and Thompson, 2015). Metal debris can also cause problems in the marine environment by leaching ions into the surrounding environment which

can be toxic or otherwise hazardous to marine life. Other marine debris such as large woody items can pose problems to ocean activities and for navigation as well.

Understanding problems associated with marine debris, including its abundance and origin, is an important step towards improved management and reducing waste in the ocean. We undertook a 10 year study of marine debris annually in 17 harbours surrounded by rural communities on the island of Newfoundland, Canada. The purposes of our study were 1. to evaluate the current state of marine debris on the seabed in Newfoundland harbours, 2. to consider the different types of debris and their frequency of occurrence, and 3. to better understand points-of-entry into the ocean.

2.0 METHODS

We sampled 17 harbours annually each September for 10 years, 2007-2016 (Figure 1). At each harbour site we established three to four 100 m transect lines positioned along the seabed seaward from the shore. These metered transects were repeated at the same locations each year. A GPS was used to identify the starting point of each transect line (±3 m) that was deployed along a compass bearing. Fisheries and Oceans Canada (DFO) scientific scuba divers then collected and analyzed video imagery data along these transect lines at one meter intervals. The location and type of debris along the transect line was recorded. Each meter-long unit of transect represented 2.0 m^2 of surveyed seabed, 1.0 m on either side of the transect line; the average area surveyed per site was 692 m^2. We reported the number of sampled-units (meter of transect line examined) having debris, as a portion of the surveyed area, by site or site-type for comparison; we did not count each item of debris within a survey unit. The date, site location, transect line number, location along transect, and debris type was recorded in a Microsoft Excel spreadsheet.

The harbour sites surveyed in this study were located along the southeast, north, and northwest coast of Newfoundland, Canada (Figure 1), and were divided into three categories including; wharf sites, non-wharf sites, and low use sites. Most of the harbours were fishing ports. Wharf sites were surveyed directly adjacent to an active wharf in a community, which were often being used by the fishing industry and recreational boaters. The non-wharf sites were located at least several hundred meters away from an active wharf, but within an active harbour in a community. We did not survey wharf and non-wharf sites within the same harbour. Low use sites included locations with no people living in the adjacent area, and also a national park (Terra Nova National Park). With the exception of two sites, harbours were sheltered from extreme currents or sea state conditions. All of our sites were located in rural areas, and not located in close proximity to urban areas that might represent an external source of marine debris. It is likely that the vast majority of anthropogenic marine debris identified in this study, which surveyed seabed's, entered the marine environment locally.

Observed debris was categorized, by material type, plastic type, size, or other (Table 1). The material type included items that were unidentified, rubber/latex, plastic, glass, metal, wood, and paper. The plastic type was divided to include fabrics (e.g., synthetic fabrics like polyester), recreational (e.g., golf balls), household (e.g., vinyl siding), single-use (e.g., plastic bags and bottles), and fishing-based plastics (any plastic that is related to the fishing industry, e.g., abandoned fishing nets). Size categories were identified qualitatively as large, medium, or small. Large items included objects approximately one square meter in size, such as tires, while small debris consisted of items similar to or smaller than bottles, and medium debris included anything in between. The "other" category included biodegradable and potentially hazardous materials. Biodegradables included things that could break down into smaller pieces of materials such as

wood and paper. Potentially hazardous materials included items such as plastic, batteries, and metal.

3.0 RESULTS

We surveyed 96,412 m^2 of seabed at 17 harbours over the 10 years of this study. The surveyed area containing debris was ~10% of the total surveyed area. At individual sites the percentage of surveyed area having debris ranged from 1 to 35%. Debris consisted of: glass (28%), metal (21%), wood fiber material (18%), plastic (14%), rubber/latex (3%) and unidentified debris (12%; consisting of often broken-down and not visually identifiable items). Plastics constituted 14% of the total debris observed; of the plastics, 29% was household use, 25% single-use plastics, 23% fishing-based, 19% synthetic fabrics, and 4% was recreational-use plastics (Figure 2).

Wharf sites had the most marine debris, while low-use sites had the least (Figure 3). A large proportion of debris was found at wharf sites each year, but the proportion was more varied among years compared to non-wharf and low use sites (Figure 4). For a standardized average survey area of 692 m^2 per site, the average area containing debris was 114 m^2 at wharfs, 45 m^2 at non-wharfs, and 8 m^2 at low-use sites. In 2012, ~25% of total wharf site transect area had debris present, but the percentage of declined afterwards. The proportion of debris fluctuated greatly among non-wharf sites, with the maximum coverage being around 12%. The proportion of debris at low use sites was low and relatively stable over time and typically < 2%.

Small- sized items comprised 84.2% of the total marine debris observed. The percentage of sampled units with large and medium-sized items was very similar, 7.5% and 8.2% respectively. Distribution of large and medium items was also similar over time. However, we observed a

significant increase in small items over the duration of our survey (Figure 5). Medium and large items decreased slightly from 2011 to 2016.

The increasing occurrence of marine debris over time was significant only at wharf sites (Figure 6). Occurrences of plastic, wood, and glass were variable over time at non-wharf sites and wharf sites, while paper and rubber/latex were relatively similar across years, but also occurred less frequently than other materials. The proportion of plastics increased over time. Low use areas had less debris and little variability in debris proportions over time.

Most of the debris observed at wharf and non-wharf sites was glass (4.2% and 2.9% respectively), while the least prevalent material was paper (Figure 7). Indeed, metals and plastics occurred more often at wharf sites than other sites. The amount of paper, metal, and rubber/latex debris was relatively stable over time, while, glass and wood were more variable. Compared to non-wharf and wharf sites, low use sites were found to have little debris, as we expected.

Wharf sites had consistently more fishing-based plastics than non-wharf sites and low use sites, as well as fabrics and household plastics (Figure 8). Plastic bottles comprised 60% of single use plastics at wharf sites, 75% at non-wharf sites, and 0% at the low use sites. Clean-area sites have a low percentage (around 0.01%) of either category of plastic debris. The most prevalent plastic type at low use sites was recreational plastics (0.03%).

In our study, hazardous items made up 7.2% of the total transect area while biodegradable items included an average of 2.9% of the total transect area. In non-wharf sites, 1.1% was covered by biodegradable items and 1.4% was hazardous. Low use areas had significantly less, 0.5% and 0.4% coverage by biodegradable and hazardous debris, respectively.

4.0 DISCUSSION

Ocean dumping is an ongoing problem in Newfoundland harbours, the type of marine debris including plastics and other items that are harmful to the ocean, and wharf sites in particular, are a point source for marine pollution. While other sources of marine contamination exist, the problem identified here can be remedied using existing waste collection services and compliance with existing regulations. Clearly there was less discarding at low-use sites sampled in our study, compared to more active harbour sites and wharf structures. Furthermore, Morris et al (2016) showed that the occurrence of seabed debris was highest in close proximity to wharf sites (within a few meters), suggesting that direct dumping at wharf-side was a likely contributor. This suggests that it is a problem associated with human behaviour which might be addressed with increased education and societal awareness regarding waste management issues. This is particularly important in rural coastal communities, where fishing is a major industry and people depend on the resources affected by harmful marine debris.

We observed debris on the seabed at several different harbour locations with differing amounts of human activity, and found that the overall proportion of transect units with marine debris varied from 1% to 35% across all sites. Small debris significantly exceeded the occurrence of medium and large debris and had much greater variability over time during our 10-year investigation. We consider it likely that the lower variability of large and medium items occurs because they are heavier and, therefore, less likely to be moved by ocean currents once they are dumped on the seabed (e.g., household appliances, tires), at least until they breakdown. According to Law (2017), one of the reasons why particle size distribution is so dynamic is because plastics of variable size continually enter, and even leave, ecosystems. This may typify results of studies which report that the average size of plastic particles in the environment is

decreasing, as microplastic abundance is increasing (e.g., Barnes et al., 2009). In this study we examined debris that had sunk to the seabed, located primarily in sheltered harbours in a rural region where the external contributions of marine debris is probably very low compared to local sourcing of marine debris. In contrast, the conditions and debris that one might expect to find on beaches for example, might include more easily transported debris and could include different and more dynamic oceanographic conditions.

The debris we identified in rural Newfoundland is likely different from that in urban and more industrial areas. Today, fewer than 200,000 people live in some 600 rural communities of Newfoundland, distributed primarily along the coastline. Furthermore, we focused on items on the seabed and observed occurrences of garbage items near wharf sites that clearly identify a continuing, but preventable, problem of ocean dumping. During our study, we regularly observed textiles, intact vehicle tires, and other large plastic items, all of which will ultimately fragment into smaller pieces. While dumping likely occurs in urban areas as well, the scale of activity, waste management systems, and enforcement, are perhaps important differences affecting the type, volume and disposal of urban as compared to rural debris. We did not measure such differences, as it was beyond the scope of our project. A large portion of plastic from urban areas enters the ocean initially as very small particles from household and industrial use, including examples such as, by-products from textiles transported to the ocean in domestic wash-water and small pieces of vehicle tires eroded during use on our roadways that eventually are transported to the ocean (Napper and Thompson 2016; Bucher and Friot 2017). Microplastics are light and most float near the ocean surface, but some studies have shown that over time they can become negatively buoyant and sink through the ocean layers ultimately to the seabed, including the deep sea (Woodall et al., 2014). Some marine debris will occur through accidental and indirect means;

however, reducing illegal ocean-dumping can be targeted specifically through better education and awareness.

Relatively high amounts of marine debris were recorded at our wharf sites, compared to our non-wharf and low use areas. We also observed an increasing trend in marine debris occurrences during the years of this study. Morris et al (2016) showed that a majority of the debris along transect lines near wharf sites was located in closer proximity to the wharf itself. The rationale "to dump", despite the fact it is illegal, could involve a cost-benefit trade-off such as a time-savings or financial incentive to perpetrators compared to transporting the garbage to a landfill. Perhaps the cost or services provided to collect garbage from these rural areas, and its disposal in distant centralized landfills, could impact decisions to dump which in turn could reduce the problem of marine debris.

Direct intentional dumping of debris and garbage into the ocean is not as accepted, and probably occurs less, today than historically. However, the nature of the marine debris has changed with the usage of synthetic materials – such as plastic. We suggest it is important to recognize that direct ocean dumping continues to occur at present, and the impact is worsened by the inclusion of increasing portions of plastics in this material. Dumping can be reduced with education targeted to increase public awareness about long term consequences of such practices.

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FIGURES

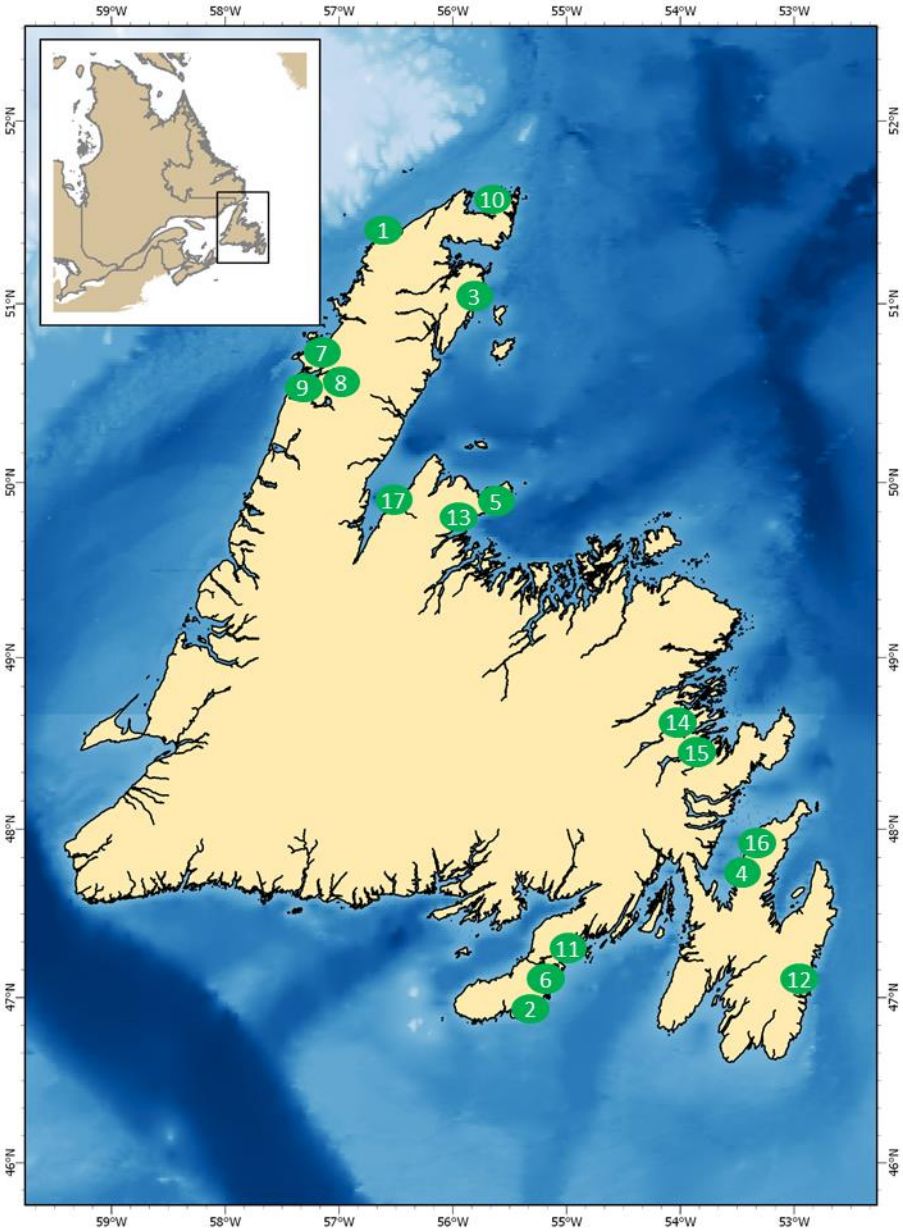
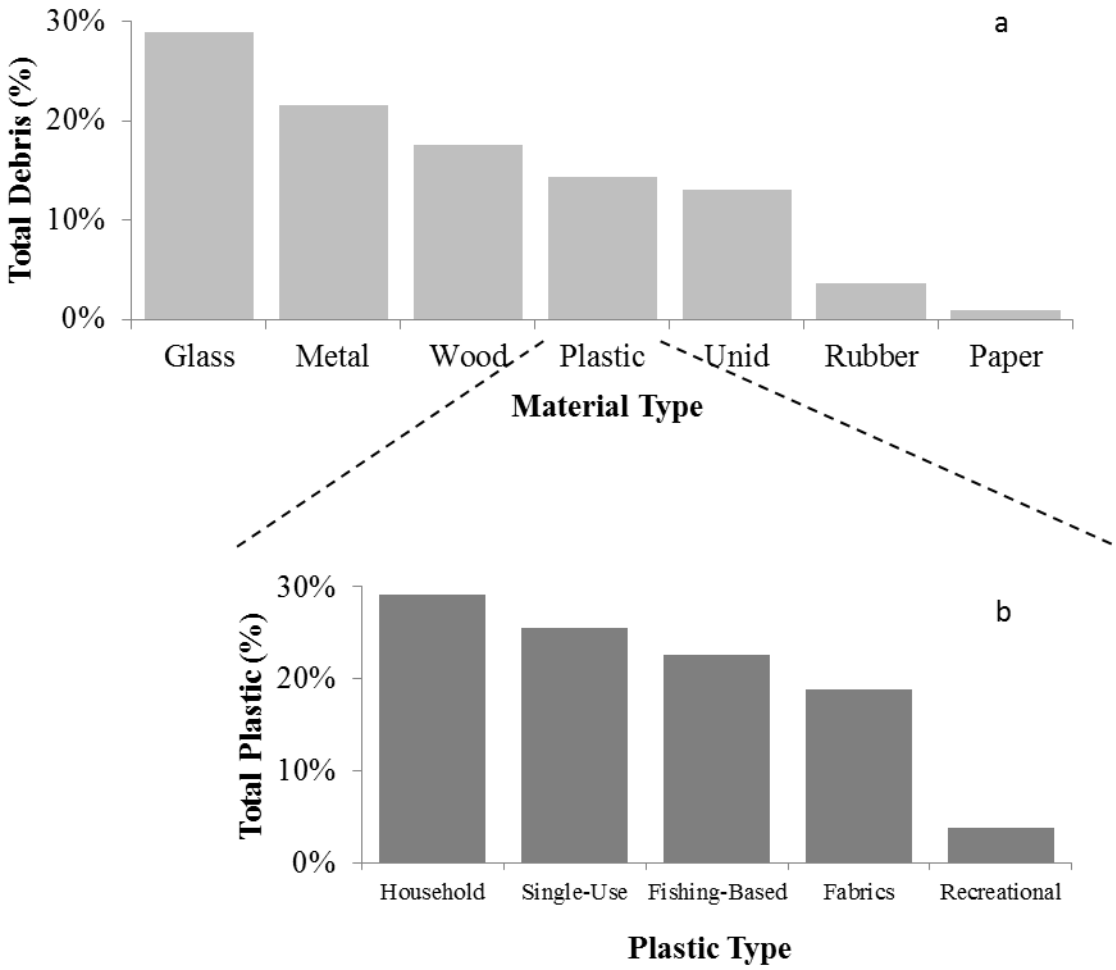


Figure 1. Map of Newfoundland, Canada showing the distribution of survey site locations. Approximate location of survey sites are numbered and correspond with Figure 3 and Table 2.



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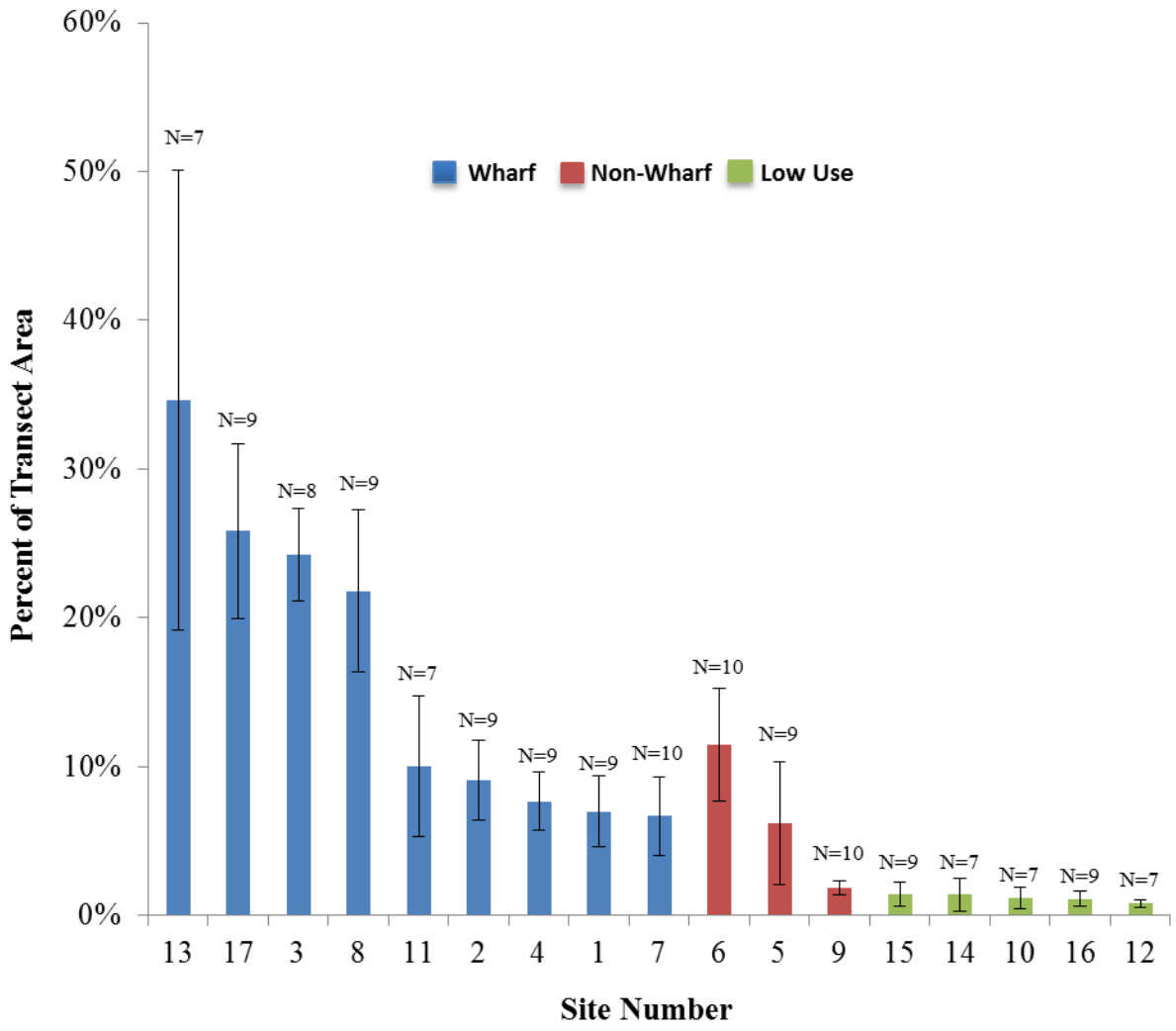

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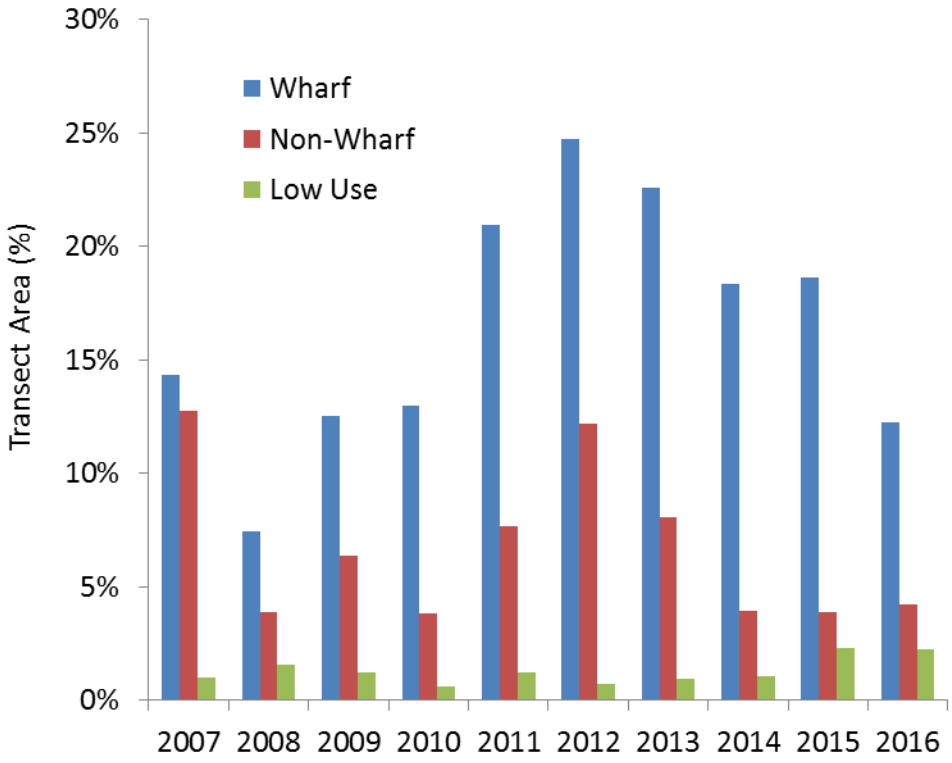

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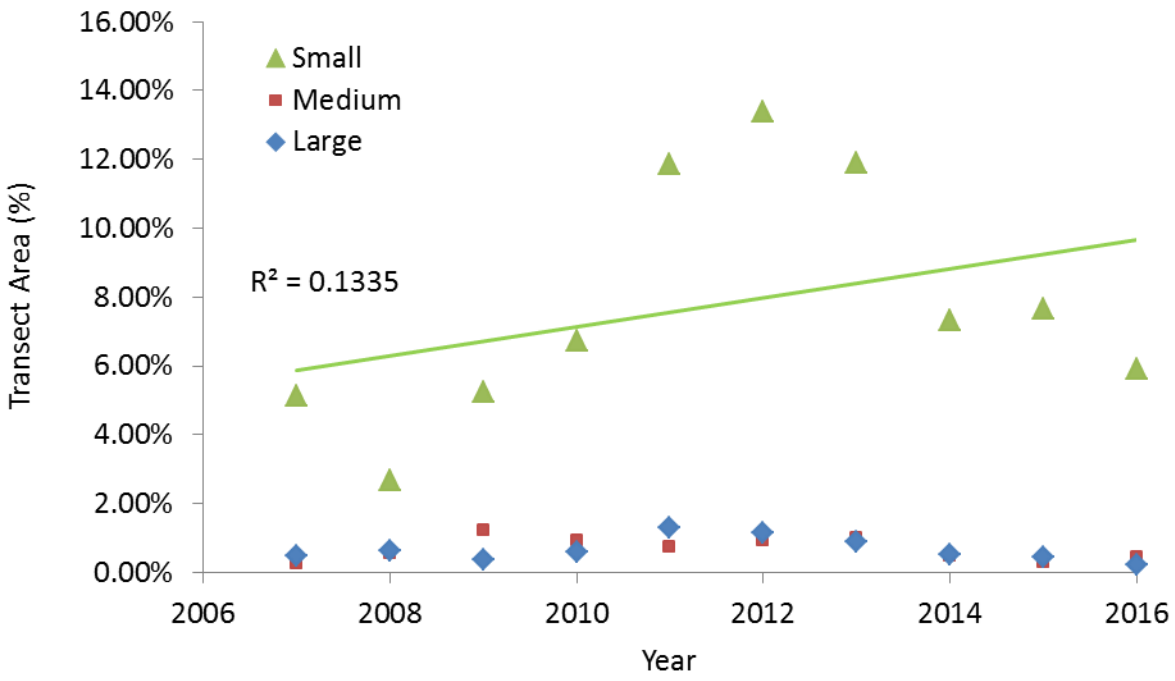

Figure 5. Percentage of large, medium, and small debris observed at different harbour sites around Newfoundland, Canada over a 10 year period (2007- 2016). The linear equation for small debris was y = 0.0042x - 8.3943. The frequency of occurrence for small, medium, and large items was 84.2%, 8.2%, 7.5% respectively.

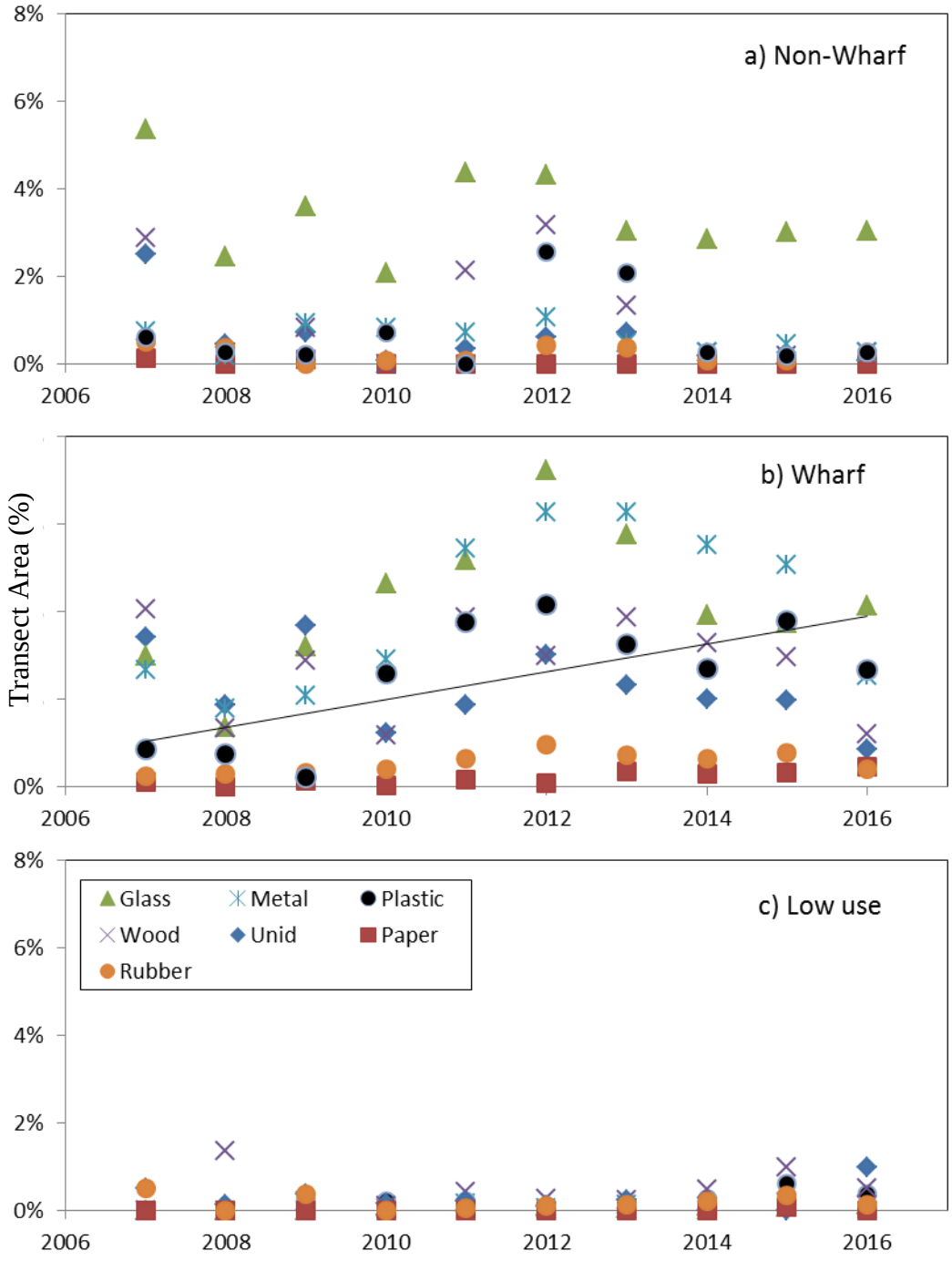

Figure 6. The mean proportion of different types of debris found each year (2007-2016) at (a) Non-Wharf, (b) Wharf, and (c) Low Use sites around Newfoundland, Canada. The equation of the regression line in (b) is fitted to plastic, $y = 0.0032x - 6.3711$, $R^2=0.42$.

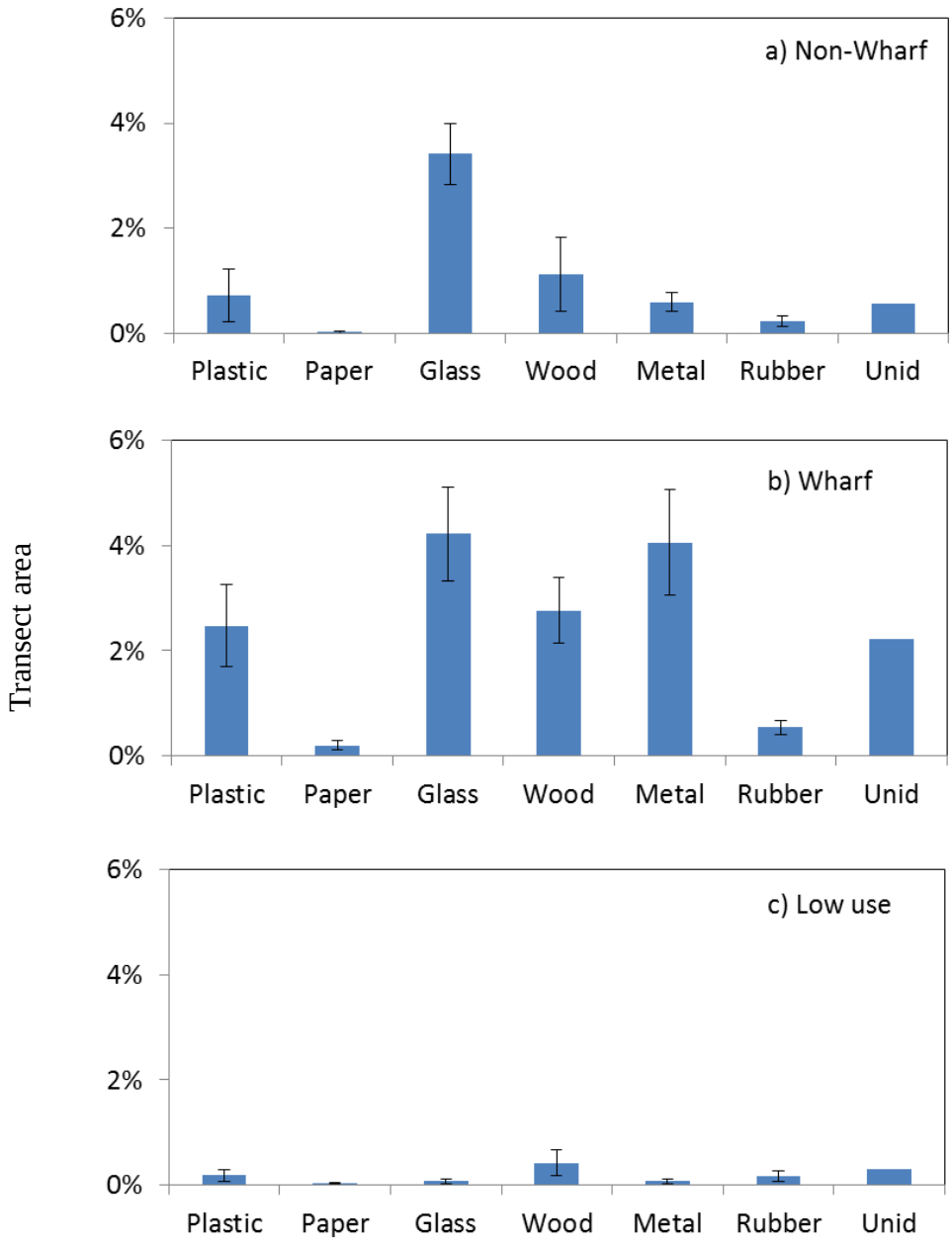

Figure 7. The mean proportion (% ± SE) of debris surveyed at (a) Non-Wharf, (b) Wharf, and (c) Low Use sites, around Newfoundland, Canada over a 10 year period (2007-16).

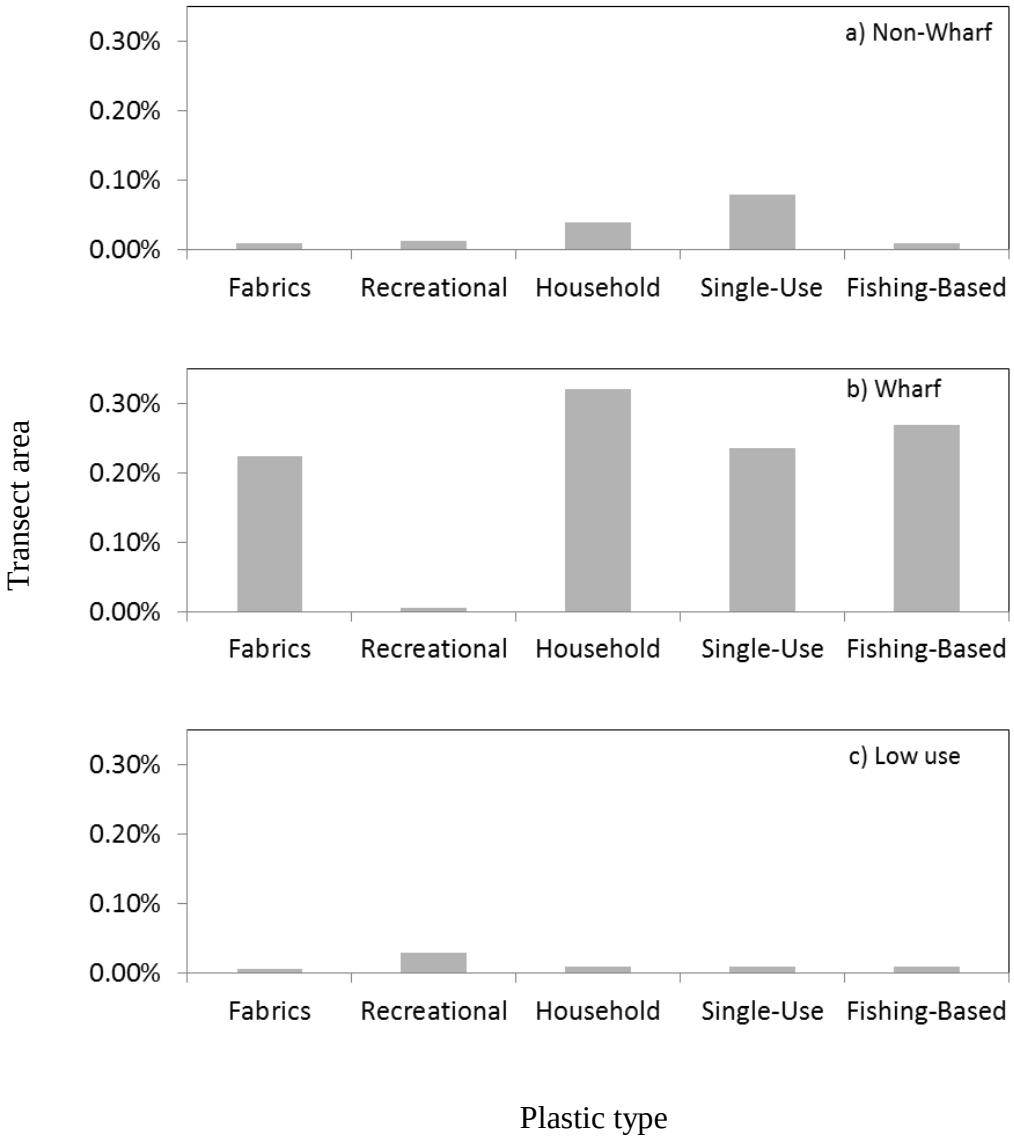

Figure 8. The proportion (%) of different types of plastic debris found at (a) Non-wharf, (b) Wharf, and (c) Low Use sites around Newfoundland, Canada over a 10 year period (2007- 16).

TABLES

Table 1. Categories used to describe debris in our study, as well as examples of common items identified.

	Category	Examples
Material Type	Unidentified	Fragments of unidentified plastics, metals
	Rubber/Latex	Tires, boots, gloves
	Plastic	Bags, bottles, ropes, fishing nets
	Glass	Beer bottles, glass shards, glass jars
	Metal	Household appliances, cans, vehicle parts
	Wood	Wharf timber, logs
	Paper	Cardboard boxes
Plastic Type	Fabrics	Rags, clothing, carpet
	Recreational	Golf balls
	Household	Wire cables, shingles, vinyl siding
	Single-Use	Cutlery, bags, bottles
	Fishing-Based	Gill nets, trawler warps
Size	Large	Washing machine, fridge, stove, fishing debris (e.g., gill nets, traps, etc.)
	Medium	BBQ, logs, bookcase, lawn-chair
	Small	Cans, bottles, plastic bags, wire cables
Other	Biodegradable	Wood and paper
	Hazardous	Metals and plastics

Table 2. Description of various harbour sites that were surveyed 2007-2016. Sites are located in small, rural communities. Diving at some sites was excluded depending on construction activities at the wharf or breakwater at the dive site.

#	Site Type	Active Harbour	Years Excluded	General Site Description
10	Low use	y	2008, 2013, 2016	Unsheltered, 3-7 meters, sandy bottom, limited activity
12	Low use	y	2007, 2015, 2016	Poorly sheltered, largely inactive harbour, sandy bottom, 3-5 meters
14	Low use	n	2007, 2015, 2016	Sheltered 3-7 meters depth, in national park no community adjacent
15	Low use	n	2007	Sheltered 3-7 meters depth, in national park no community adjacent
16	Low use	n	2007	Sheltered 3-7 meters depth, no community or wharves adjacent
5	Non-Wharf	y	2013	Unsheltered, 3-12 meters depth
6	Non-Wharf	y		Sheltered, 3-15 meters depth
9	Non-Wharf	y		Sheltered, large harbour, 3-7 meters depth,
1	Wharf	y	2013	Unsheltered, 3-7 meters depth,
2	Wharf	y	2015	Sheltered, 3-20 meters depth
3	Wharf	n	2007, 2008, 2009	Sheltered, inactive community, sandy bottom, 3 meters depth
4	Wharf	y	2007	Sheltered, 12 meters depth
7	Wharf	y		Sheltered, steep sloping, parallel to shore, 7 meters depth
8	Wharf	y	2016	Sheltered, 10 meters depth
11	Wharf	y	2008, 2014	Sheltered, 3-10 meters
13	Wharf	y	2014, 2015, 2016	Sheltered harbour, 3-7 meters depth
17	Wharf	y	2016	Poorly sheltered, 3-7 meters depth, community adjacent.