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Trash on Arctic beach: Coastal pollution along Calypsostranda, Bellsund, Svalbard

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Abstract: Beach pollution is one of the most common hazards in present-day anthropogenic environments. Even in the remote Svalbard Archipelago, pollution impacts the beach system and can pose environmental threats. The significant increase in human activity observed in Svalbard over the last 20–30 years has resulted in a visible change in the amount of coastal pollution. A 5 km long transect of modern beach developed along Calypsostranda (Recherchefjorden, Bellsund) was surveyed in the summer of 2015 in order to characterize the beach pollution. During the survey 296 pieces of trash were found on beach surface. 82% of found trash was plastic, followed by glass (8%), and metal (5%). The comparison with previous pollution survey showed the significant increase of plastic waste in local beach environment. Similar problem has been recently recorded in other parts of Svalbard suggesting an urgent need for coastal pollution monitoring.

Key words: Arctic, Spitsbergen, beach pollution, plastic trash, human impact.

Introduction

Climate change resulting from anthropogenic pressure is causing rapid warming and associated melting of ice and thawing of permafrost in the Arctic (IPCC 2015). The Arctic is increasingly becoming an area of interaction of scientific, political, economic and ecological interest. The economic opportunities leading to increase human activity in the Polar Regions come with high risks for the Arctic's ecosystems. Arctic region is inhabited by about 4 million people (Bogoyavlenskiy and Siggner 2004; Duhaime *et al*. 2004) with the vast majority of human activity concentrated along the coast. The last report on the state of the coast of the Arctic highlighted the role of the coastal zone, which is consider to be the place where serious environmental changes have a direct impact on the Arctic communities (Forbes 2011). Intensified coastal hazards (*e.g.*, storms, erosion, flooding) directly threaten the communities living in the Arctic coastal zone, hindering planning of new infrastructure (*e.g.*, Andrew 2014; Jaskólski *et al.* 2018).

Previous Arctic coastal hazard studies have focused on climate change induced processes such as coastal erosion, sea level rise, storm intensity activity, and the disappearance of sea ice (*e.g.*, Reimnitz and Maurer 1979; Kobayashi 1985; Héquette *et al.* 1995; Kobayashi *et al.* 1999; Leont'yev 2003; Prno *et al.* 2011; Overeem *et al.* 2011; Lantuit *et al.* 2012; Ravens *et al.* 2012; Vermaire *et al.* 2013; Overduin *et al.* 2014). Surprisingly, little attention has been given to the direct impact of human activity on Arctic coastal system coasts, as well as to the question of how human presence can alter the fragile Arctic environment, especially in the case of waste management from tourism and fishing activities. At present, Arctic beaches are full of a variety of waste materials, from fishing nets to industrial trash like machine elements and construction rubble (*e.g.*, IPCC 2015; Jaskólski *et al.* 2017; Węsławski and Kotwicki 2018). The aquatic pollution goes back to the beginning of the history of human civilization. But since the widespread development and use of plastic, which is the largest part of waste and causes visible environmental pollution, the problem received attention from the government and scientist (Islam and Tunaka 2004).

According to the Governor of Svalbard, Environmental Protection Fund Reports, and local Svalbard press, the plastic pollution at Svalbard is a significant threat for the environment, especially for Svalbard fauna (Sysselmannen 2012a; Stange 2015; Icepeople 2016a, 2016b). During yearly clean up initiative the Svalbard inhabitants are collecting averagely *ca.* ~90 m^3 of waste (Oceanwide Expedition 2016; Icepeople 2017a, 2017b, 2017c), only in the period 2000–2015 about 1593 m^3 of trash have been removed from beaches (Palm 2015; Icepeople 2015a, 2015b).

The aim of this study is to characterize the current state of beach pollution developed along Calypsostranda in Bellsund and to compare the degree of beach pollution with the results of the first survey carried out in 1993 (Czubla 1994).

Study area

An inventory of beach pollution was completed along the Calypsostranda (Recherchefjorden, Bellsund), in the vicinity of the Maria Curie-Skłodowska University Polar Station (UMCS Polar Station) – at Calypsobyen which is located in South Spitsbergen National Park (Fig. 1A). The park was opened in 1973 and includes Wedel Jarlsberg Land, Torell Land and Sørkapp Land and aims

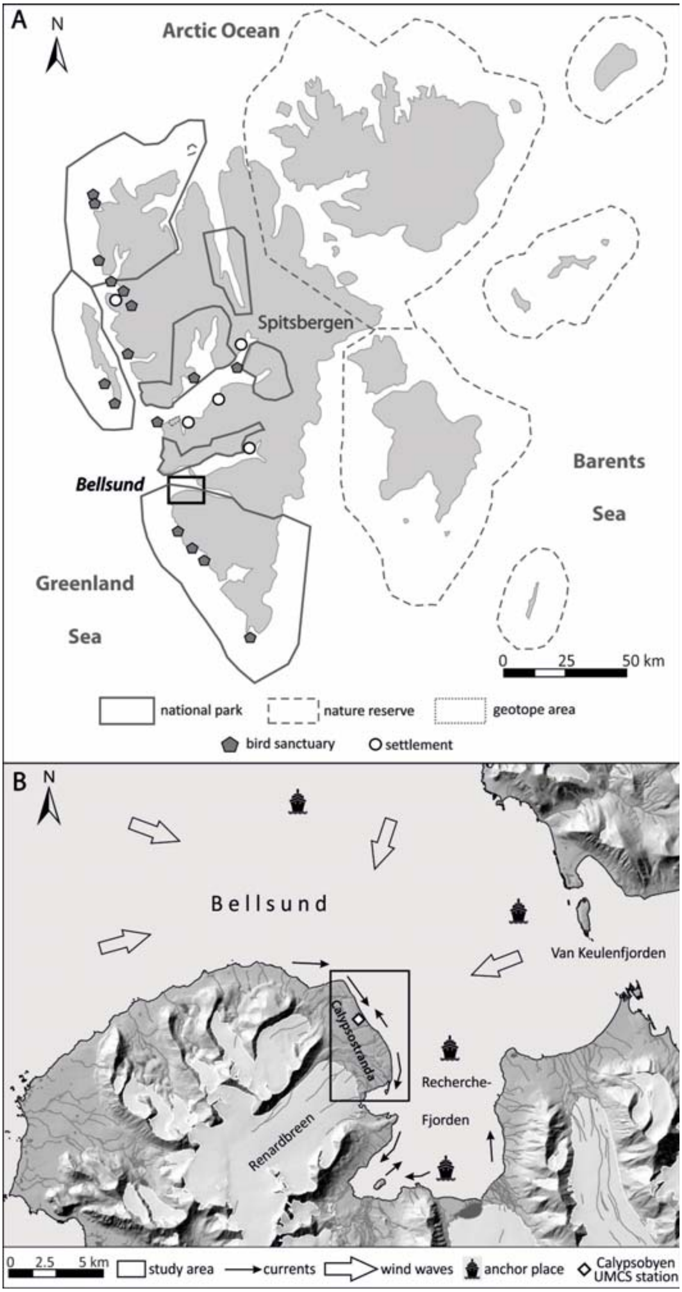

Fig. 1. Protected areas and national parks on the Svalbard archipelago (**A**) after Lier *et al.* (2010) and location of the study area (**B**) at Calypsostranda, Southern Bellsund, based on Zagórski *et al.* (2013) as well as shapefile and DEM from Norsk Polarinstitutt (Digital Elevation Model available at npolar.no).

to protect plant and animal life (Lier *et al*. 2010). It is a part of network of seven national parks, six nature reserves, 15 bird sanctuaries, and one geotope protection area that are functioning in Svalbard archipelago (Fig. 1A). The total protected areas at Svalbard amounts to about 39 800 km² of land and 78 000 km² of territorial waters (Lier *et al*. 2010). The area around UMCS Polar Station and the Station itself are popular tourist destinations. According to Governor's Office, the Bellsund region was visited around 1642 times by various touristic and scientific groups in just a single year of 2015 (Sysselmannen 2015). Currently, the beach is cleaned every summer by UMCS Scientific Expeditions, but the amount of trash is increasing every season (Head of CALYPSO station – personal communication).

The survey covered a 5 km long section of gravel-dominated beach system between Renardodden and the Josephbukta (Fig. 2) located in the position of the previous survey, completed in 1993. The local tidal range is ~1.7 m, the dominant wind direction is E and NW (Fig. 1B). Southern Bellsund is characterized by an unstable configuration of ocean currents (Zagórski *et al*. 2013). Local longshore drift is dependent on wave activity, and the diagonal approach of oceanic waves is responsible for the development of local currents of longitudinal directions, NNW–SSE along the shore of Calypsostranda (Zagórski *et al*. 2013). The complexity of ocean current flows is also associated with fjord morphology (Zagórski *et al*. 2013). Short waves from NE developing in Van Mijenfjorden are responsible for undercutting the cliffs of Skilvika. In the vicinity of the cliffed coast of Skilvika, the ocean currents splits, with the stronger (high wave energy) current, consistent with the dominant wind direction, flowing westwards and the counter (weak wave energy) current, flowing eastwards along the eastern coast of Skilvika towards the Renardodden. Around the cape a counter current crashes with a strong SE-NW current flowing along the Calypsostranda associated with short and high waves coming from the Van Keulenfjorden (Zagórski *et al*. 2013). As a result Renardodden is systematically prograding (Zagórski 2011), and developing beach system is fed also by trash pollution. The influence of warm West Spitsbergen Current and operation of long-fetch waves developed in Greenland Sea determinate that the western, open coasts of Spitsbergen are predominantly ice free. But it should be noted that any time of the year, Bellsund can be filled with drifting ice, transported by ocean currents. In case of such situation, the ice floes, growlers pushed by tidal currents fill even the most distant sectors of Bellsund fjords (Zagórski *et al*. 2013).

According to Zagórski (2011), between 1936 and 2007, the northern part of analyzed coast was characterized by coastal progradation *ca*. 20–30 m, whereas the southern part of coast (from Renardbreen outwash plain to Josephbukta) has been eroded by up to 60 m. The transport of coastal sediments is controlled by alongshore current from the entrance of Recherchefjorden towards the inner part of the fjord (Zagórski 2011). Beach forming material is delivered form three

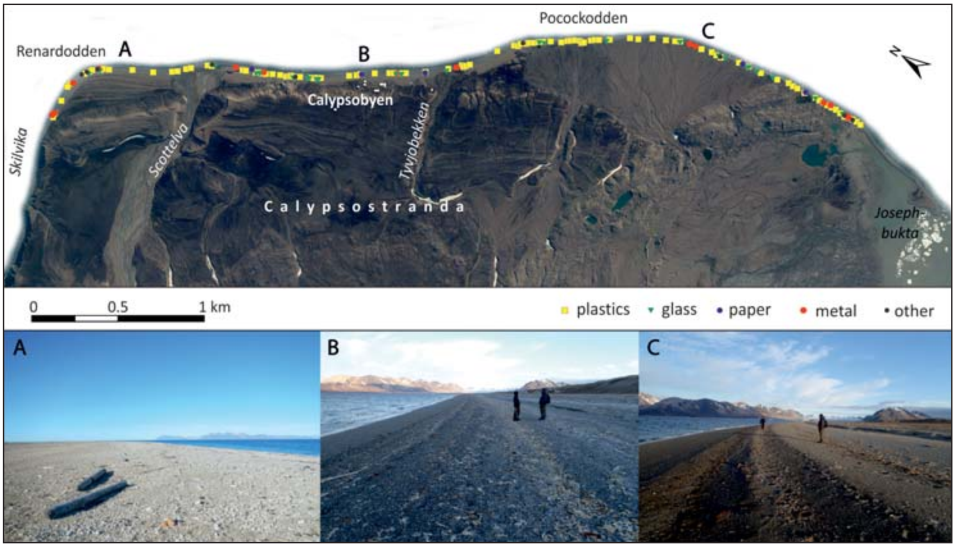

Fig. 2. Distribution of pollutions along Calypsostranda beach, based on air photo from 2011 – Norwegian Polar Institute. Inset photos: studied beach system at Renardodden (**A**), in the vicinity of UMCS polar station (**B**), and in Josephbukta (**C**); all photos taken in 2015 by M. Strzelecki.

main sources (see Fig. 2 for locations): (i) coastal erosion of Skilvika coast, Renardodden and terminal moraine of the Renardbreen, (ii) fluvial transport from catchments of Scottelva, Tyvjobekken and local ephemeral streams, and (iii) storm reworking of nearshore sediments.

Methods

In summer 2015, Calypsostranda beach was mapped in order to prepare the inventory of beach pollution. The inventory focused on the determination of dominant type and weight of trash found in modern beach environment. Every piece of trash found between water line and the first storm ridge (also buried in storm ridge), was weighed, photographed, described, and classified. Position of trash were marked usinghand-held GPS with horizontal measurement error ~5 m. The study was designed in order to show contemporary beach pollution and provide a reliable comparison with the results of other Arctic beach pollution surveys, hence the trash inventory was limited to the strip of coast between the swash zone and active storm ridge. All trash pieces were collected between 24th and 25th of August 2015. Firstly, located trash material was photographed using a reference wooden scale frame with the parameter 50×50 cm. Then, the trash material was collected, dried and cleaned, extra care was exercised to prevent breaking any trash piece to small pieces and weighted. For weighing, we used a GDEALER Digital Scale with 5 kg capacity and division of 0.1oz/1g, while for lighter pieces and PCE weighing hook scale with a weight range from 5 to 20 kg for heavier sample pieces. After weighting, the samples were visually sorted by category of the material and potential origin.

Results

179 pieces of garbage were localized during our survey along ~5 km long and 12 m wide beach section (Fig. 2). In addition 117 plastic (fastening) strips (no GPS tracked) were counted, making the total amount of waste 296 units.

The largest group of tracked waste was of plastic origin, accounting for 82% of the analyzed population (Fig. 3). The remaining waste was composed of glass, metal, paper, and others, all together accounting for only 18%. Overall, 117 plastic strips, 63 plastic bottles, and 15 fishing lines/nets were inventoried (Table 1).

Weight of found waste ranged from 0.05 kg to 16 kg. The lightest of rubbish were plastics sticks, bottle tops and pieces of boxes while the heaviest: ropes, fishing nets and containers (Fig. 5). The lightest elements (<0.01 kg) constitute the largest group of pollution (Fig. 4). Group to 0.01 kg, consists of 122 units and was 41% of the population. The second largest group of 55 items (19%) consists of waste between 0.1 kg and 0.5 kg. We have found small number of elements heavier than 0.5 kg: 10 elements in 0.5–1 kg; 3 elements in 1–2 kg; 4 elements (petrol cans) in 2–5 kg; 2 elements (oil cans) in 5–10 kg; and 3 elements (ropes) in the weight group above 10 kg .

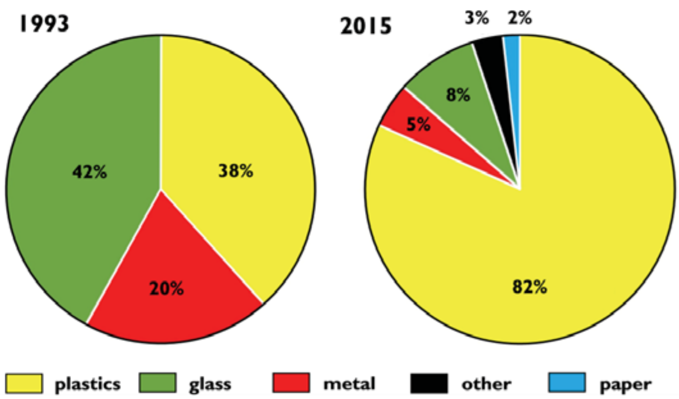

Fig. 3. Percentage (amount) of different types of trash material polluting Calypsostranda in 1993 – 114 pieces in total (Czubla 1994) and in 2015 – 296 pieces in total.

Table 1

Types of localized trashes on study area in 2015. F stands for fishing industry origin.

Material	Type	Amount	Population share [%]	Weight [kg]	Weight share [%]
Plastics	strips (F)	117	39.5	0.82	0.8
	bottles	63	21.3	4.77	4.3
	jerrycans	6	2.0	22.29	20.5
	fishing nets, ropes (F)	15	5.1	33.51	30.7
	foil	6	2.4	0.97	0.9
	pipes	6	1.7	7.79	7.1
	floats (F)	3	1.0	1.07	1.0
	other	26	8.8	8.71	8.0
Glass	bottles	19	6.4	6.43	5.9
	jars	5	1.7	1.06	1.0
	bulbs	1	0.3	0.03	0.0
Metal	cans	11	3.7	2.32	2.1
	buoys (F)	3	1.0	16.59	15.2
Paper	pieces of paper	5	1.7	0.34	0.3
Other	gloves	3	1.0	0.06	0.1
	boots	6	2.0	1.96	1.8
	rag	1	0.3	0.28	0.3

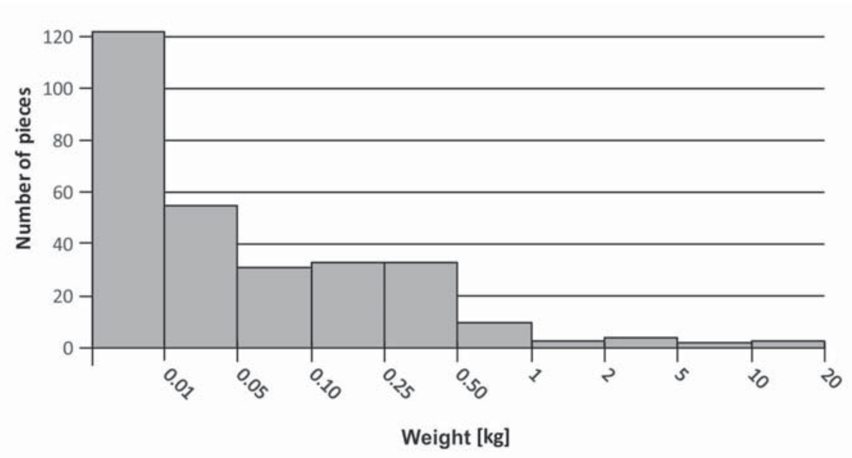

Fig. 4. Weight ranges of trash collected along Calypsostranda in summer 2015.

Fig. 5. Examples of trash found on Calypsostranda (all photos taken by M. Jaskólski in 2015). **A** – oil/petrol can; **B** – plastic container; **C** – hard plastic containers and fragments; **D** – plastic pipe; **E** – fishing nets; **F** – strong plastic foil/tarpaulin; **G** – light plastic bottles and caps; **H** – ropes; **I** – plastic foil.

The waste found along Calypsostranda was classified in two source groups. The first group is local/regional waste from tourism and industrial fishing. The second group represents waste that was most probably generated in remote areas *e.g.*, Europe or Asia, and before redistribution along Calypsotranda by local current circulation (Fig. 1B) was delivered to Svalbard by sea-ice and main ocean currents (West Spitsbergen Current).

Discussion

The worldwide production of plastic, has expanded from the total 1,5 million tons since the beginning of production in 1950, to over 300 million tons in 2013 (Seltenrich 2015; Urbanek *et al*. 2017). According to the World Bank data, each year approximately 1.4 billion tons of trash are generated, 10% of which is plastic (Browne *et al*. 2011; Hoornweg and Bhada-Tata 2012; Seltenrich 2015; Fok *et al*. 2017). Plastic items make also 50–80% of waste that is stranded on beaches, floating on the sea surface, or resting at the seabed (Zarfl and Matthies 2010). It is widely accepted that plastic pollution has a negative impact on the ecological processes. For instance, plastic ingestions by seabirds may reduce their growth and affect dietary efficiency (Provencher *et al*. 2010). Degraded plastics (PCB's, HCH, DDT) have very significant impact on the marine food chain, well documented by accumulation of xenobiotic compounds in all forms of aquatic ecosystem (Islam and Tunaka 2004; Wright *et al*. 2013). This is also the case of high latitude seas and coastal environments. For instance, zooplankton and fish found in almost every part of Arctic Ocean are contaminated with plastic degradation products (Islam and Tunaka 2004; Wright *et al*. 2013), and plastic pollution is thought to be responsible for re-productive failure of the common seal (*Phoca Vitulina*) or higher mortality and defectiveness of fish and bird eggs and embryos (Islam and Tunaka 2004).

Currently, the plastic flux to the Arctic Ocean is estimated to 62,000–105,000 tons per year (Zarfl and Matthies 2010). Most of the recent studies suggest that trash is transported into the Arctic by ocean currents (Barnes and Milner 2005; Tekman *et al*. 2017). Cózar *et al*. (2017) found that the poleward branch of the Thermohaline Circulation transfers floating debris from the North Atlantic to the Greenland and Barents seas, which act as a dead end in this plastic conveyor belt. In our opinion, Svalbard, thanks to its location at the junction of major oceanic and atmospheric fronts in European Arctic, is perfectly situated to investigate the scale and mechanisms of coastal pollution.

Beach pollution along Calypsostranda in 1993 and 2015. — The increase in plastic and general pollution of Arctic coastal environment has been also detected in our case study. In comparison to the state of beach mapped in year 1993 (Czubla 1994), our study indicates that there has been a significant (by 500% in numbers) increase in beach pollution by plastic trash (Fig. 3). We observed that nearly half of the share of glass, and about a quarter of metal pollution has decreased, explained by the increase of plastic in common daily use (~8300 million metric tons of virgin plastics produced to date) and the supersession of more expensive metal and glass by plastic (Geyer *et al*. 2017).

About 2% of trash found in 2015 consisted of paper, so we argue that paper and cardboard are of regional origin as they were not able to resist long transport distances. The surface current circulation pattern also favours regional pollution source from fishing anchorage sites (Fig. 1B). Another indicator for regional pollution, mainly fishery source, is the character of trash typical for fishing industry *e.g*. fishing nets, ropes, floats and buoys. This was also confirmed by Svalbard community observation (Stange 2015; Icepeople 2016a). Similar remarks about the source of beach pollution in northern Svalbard were also made by Bergmann *et al*. (2017). The main berth and anchorage places for fishing vessels in Bellsund are located in the vicinity of our study site, which explains relatively high level of fishing trash pollution along the Calypsostranda beach.

Pollution of Calypsostranda in comparison with other Svalbard sites. — Recently, during the Polarstern Expedition 2016 and The Plastic Project Sv Antigua expedition by the Alfred Wegener Institute in 2016 (Bergmann *et al*. 2017), similar measurements were made as part of a pilot Citizen Science Project about the pollution of the Arctic by humans. In addition to counting and tracing of floating garbage, the expedition participants weighed, counted and classified garbage on the beaches of Spitsbergen. Comparison of our data with the published results (Lutz 2016), showed that the amount of garbage found in our study site was lower than the lowest average detected by Polarstern Expedition (8–43 kg per 100 m). Approximately 109 kg of trash was found along *ca*. 5 km long beach segment (~2.2 kg per 100 m). The smaller then average amount of trash scattered along Calypsostranda could be explained by the distance of the study area from human settlements and limited access to South Spitsbergen National Park, and most of all every-year cleaning of the beach by UMCS polar expeditions members.

How we can reduce the problem of beach pollution in Svalbard. — Given that the study area is located in national park and the biggest pollutant is plastic that has a long period of decay and a very negative impact on the environment, it is necessary to consider the effectiveness of the protective function of the park.

According to the operating regulations relating to persistent, bioaccumulative and toxic substances, waste, waste water and waste management fees in Svalbard (*e.g.*, Chapter III; section 7 waste prohibition against littering, etc. and section 8. clean-up operations) as well the act relating to the protection of the environment in Svalbard (*e.g.*, Section 71; waste) there are legal bases to enforce entities that generate pollution to clean up (Sysselmannen 2012b, 2012c).

It is clear that the main problem is not the lack of regulations, but the deficiency of executives, who should search for sources of pollution and monitor the coast sections particularly vulnerable to pollution. It is necessary to consider the restrictions on anchoring at a short distance from the protected areas as the ~40% of found trash were most probably of local origin. According to the classification of the sensitivity of the coast for potential oil spills (Węsławski *et al*. 1997), Calypsostranda area is very sensitive to such a threat and this could be an additional argument to regulate the operation of certain type of ships in the vicinity.

In the scenario of further tourism growth in Svalbard, it is necessary to tighten restrictions on import of certain packaging materials to the archipelago and improve waste disposal policies in Svalbard towns and research bases. It is also necessary to strengthen the media campaign awareness for tourists visiting Svalbard about the waste management and negative effects of littering. Introduction of pollution fees for residents and visitors may be a new way of funding clean-up actions and information campaigns, which for now seems as the fastest way for limiting amount of litter resident on Svalbard's beaches/coast.

Conclusions

This paper provided a new insight into beach pollution on Svalbard. Based on the results of this survey, we draw the following conclusions: (i) the most common type of pollution found along Calypsostranda beach system in the summer of 2015 was plastic waste of fishing origin; (ii) we observed an almost 500% increase of plastic pollution of local beach system in comparison with 1993 survey by Czubla (1994); (iii) in comparison with the results of Polarstern Expedition in 2016, Calypsostranda is less polluted then other coastal areas of Svalbard; and (iv) there is a need for regular monitoring of coastal pollution and organized clean up actions along Svalbard beaches.

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