Anthropogenic Marine Litter on the Coasts of Primorsky Krai: 12-year analysis

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Abstract. The growing pollution of coastal-marine areas with litter, mainly plastic, is of concern to both the public and the scientific community around the world. The amount of waste in various, even hard-to-reach, coastal areas is increasing annually, as evidenced by the numerous activities carried out regularly within the framework of diverse environmental projects. The unique geographical position of Primorsky Krai makes its coastline attractive for almost all types of marine recreation and, as a result, does not leave aside the growing problem of anthropogenic impact. The 12-year cycle of studies carried out on the coasts of the Primorsky Krai, differing both in physical-geographical and socio-economic conditions, reveals a predominantly "recreational type" of coastal pollution and suggests that there were no statistically significant changes in the total amount of collected waste on the coasts (taking into account the annually increasing cleaning efforts). At the same time, the studies demonstrate the value of the data obtained as a serious basis for the formation of a unified methodology for monitoring marine litter in the coastal zone - the most important methodological stage on the way to solving the problem of pollution of the coasts of not only Primorsky Krai, but also other regions with anthropogenic litter.

1. Introduction

Marine litter is defined in international literature as any manufactured or processed resistant solid material, directly or indirectly, intentionally or unintentionally, left in the marine environment [1, 2]. Marine litter pollution, mainly with plastic, has become global, fueled by the rapid growth in global production of resins and fibers from 2 million in 1950 to 380 million tons in 2015, the known resistance of plastics and improper waste management. As of 2015, 6,300 million tons of plastic waste were generated, of which 9% were recycled, 12% incinerated, the remaining 79% ended their life cycle in landfills or in the environment [3].

Thus, today marine litter is present everywhere: on land, on the surface of the seas and deep in the oceans [4], in remote and sparsely populated regions around the world, including arctic territories [5] and mountainous areas [6].

The notable impact of plastic pollution on marine organisms is associated with the entanglement of animals in discarded or lost fishing gear and ropes. Many marine organisms mistake litter, especially those fragmented in the marine environment, for food. Plastic accumulates in their stomachs and causes death, both directly and indirectly, affecting habitat, nutrition, physical fitness, reproductive characteristics, causing hormonal disturbances [7]. The number of species affected by entanglement or
ingestion of plastic waste has doubled since 1997, from 267 to 557 species among all wildlife groups, including sea turtles, mammals, birds [8]. Plastic poses a threat to humans: hazardous chemical compounds are formed during the extraction and production of raw materials, when using plastic products, people swallow and (or) inhale a large number of microplastics particles and hundreds of toxic substances. Having been discarded plastic becomes waste, polluting the environment [9]. Plastic particles were found even in tap water [10].

Litter in the sea is also dangerous for navigation [11]. Waste on the coasts depreciates the aesthetic value of such areas and poses a direct threat to safety of life, which scares off visitors and can cause economic losses to municipalities [12].

Surface runoff, including river runoff and recreation, are important sources of marine litter in coastal regions [13]. However, understanding the principles of marine litter distribution is challenging as it is influenced by the litter's own physical characteristics - density, size, and wind-wave parameters of the environment.

Continuous monitoring of coastal litter is a tool for identifying sources of pollution, assessing coastal pressures, identifying most vulnerable areas ("hot spots"), and planning effective intervention strategies.

The purpose of the 12-year series of monitoring studies on the coasts of Primorsky Krai was to collect data for the development of a methodology for further research and implementation of continuous monitoring of the coasts on its basis. For the purpose, the composition, quantity and distribution of marine litter on the coast of the region were evaluated.

2. Topicality, Material and Methods

2.1. Study area
This study was carried out on the coasts of the Primorsky Krai, including the territories of the Peter the Great Gulf (the coast of the Vladivostok urban district, the Nakhodkinsky urban district, the Khasansky district) and the northeastern territories of the Krai (the coasts of the gulfs and bays of the Terneisky, Dalnegorsky, Olginsky districts) (fig. 1).

A pilot study was carried out on the coast of Emar Bay in 2007 and was timed to coincide with the annual coastal clean-up campaign, which covered more than 150 countries around the world, and traditionally held in late September. Since then, in the Primorsky Krai, International Coastal Cleanup events have been held regularly, attracting more and more new participants and contributing to raising the public environmental awareness.

In addition, monitoring studies are being carried out to identify the sources of waste supply to the coastline and such pollution behavior. Within these 12 years, the organizers have tried to expand the geography of the study to the coastal zones of most municipal districts of Primorsky Krai, thus covering 68 coastal areas.

The sites for permanent monitoring studies were selected based on the following:
1. Physical and geographical conditions:
   – coast of southern Primorye (example: Khasansky district);
   – coast of northeastern Primorye (examples: Dalnegorskiy, Terneiskiy, Olginskiy districts).
2. Accessibility of the coast:
   – completely or mainly from a watercraft (examples: Sibiryakov Island, Cape Four Rocks);
   – from the shore (examples: Baklan, Shchitovaya, Plastun bays);
   – city beaches or beaches of large settlements (examples: Fedorov bay, Lazurnaya bay – Vladivostok;
   – Nakhodka.
3. Availability of tenants:
rented beaches (implies daily cleaning during the main recreation period – July-August); run by the municipality (cleanups are rare or absent).

4. Type of coastal ground:
- sand;
- shingle;
- mixed.

No classification was done as to the type of use of the coast, since the climatic characteristic of the Primorsky Territory implies the use of almost the entire coast, excluding the port waters occupied by berthing facilities, for recreational purposes.

Figure 1. Sketch map for marine litter research study in the Primorsky Krai.

2.2. Methodology
Field surveys were conducted on annual basis during the warm season, from May to October. This period includes both the recreational period (July-August) and the months when the coasts are left without regular cleaning by tenants and municipal services.

The studies were carried out in accordance with the Guidelines for Monitoring Litter on Beaches in the Northwest Pacific, proposed by the Ocean Conservancy, a non-profit environmental group, jointly with the United Nations Environment Program (UNEP), to avoid discrepancies in observations. In accordance with this monitoring protocol, all items that can be attributed to marine litter were
collected at each selected coastal area, and analyzed quantitatively according to various categories of their origin. The data obtained were entered into the form for each site (fig. 2).

Since in the Primorsky Krai is still going through the initial stages of implementing the procedure for monitoring marine litter on the coast, the control points were first selected based on the site's accessibility, and the proposed methodology was partially adapted due to the need to identify problem areas in a wide range of the rugged coast of the Primorsky Krai. Furthermore, the monitoring forms to be filled in have undergone a slight change due to the difference in types of common waste in the APR countries in comparison with the Primorsky Krai of the Russian Federation. Also, the organizers of the research decided to divide the collected waste into 4 categories (plastic, glass, metal, and others), each being weighed, in addition to breaking down the waste categories and their quantity. Such approach is dictated by the possibility of their further processing.

The results obtained are entered into a table created in a program for working with Microsoft Excel spreadsheets, which provides the possibility of statistical calculations and other information processing (fig. 3). The completed forms are sent by the national coordinator for the collection of monitoring data to the Ocean Conservancy and duplicated in NOWPAP UNEP, where the global processing and analysis of data from all the participating in the actions countries of the world are carried out.

Figure 2. Blank form for entering data obtained through monitoring activities.
Figure 3. An excerpt of a table with results of monitoring marine litter on Primorsky Krai.

3. Research objective

Therefore, the obtained monitoring data are combined into a common Microsoft Excel table, the functions of which allow automatic statistical processing according to specified conditions.

The results of the research done through the history of waste monitoring makes it possible to draw a number of the following conclusions:

1. Over this 12-year period, 68 sites in various municipal districts of Primorsky Krai were surveyed. The total area of the designated coastal areas throughout the said period of time was 92,850 sq m. The total weight of the marine litter constituent parts collected from this area amounted to 2305.1 kg. The total number of collected constituent parts is 45698 pcs. Thus, the density of garbage in the coastal zone of the Primorsky Territory was 20 g / sq m by weight and 0.5 units of marine litter / sq m by quantity.

2. It was noted that the density of small litter on beaches with mixed ground (sand and shingle), located within the boundaries of large settlements (Fedorov bay in Vladivostok, Plastun bay in Plastun settlement) is higher than on similar sandy beaches (Baklan bay in Slavyanka, the coast of Nakhodka bay in Nakhodka), which is likely to be accounted for by the difficulties in cleaning by tenants or municipalities due to the peculiarity of mixed grounds.

The composition of marine litter in the southern territories of Peter the Great Gulf (the coast of the Khasansky District and the Vladivostok Urban District) and in the open areas of the East Sea / Sea of Japan (Olginsky and Dalnegorsky Districts) in the northeastern part of Primorsky Krai is probably different in accordance with the prevailing types of recreation in these territories: beach recreation in the south, fishing in the northeast.

3. Separation of the collected waste by composition made it possible to determine the proportion of the weight of each type of waste (plastics, glass, metal, others) in the total weight (fig. 4).

At the same time, in terms of quantity, objects made of plastic prevail, which is explained by the lightness of plastic elements in comparison with other categories (fig. 5). Considering the resistance of plastics and its increasing application range, it is not surprising that products made of synthetic materials account for a large share of man-made waste, Primorsky Krai being no exception.

The most common waste constituent parts belong to the recreational source of pollution category.

4. The pollution behavior assessment was carried out for the sites being periodically monitored in order to detect trends in the amount and composition of marine litter. No significant changes in pollution behavior were experience, so the data are not presented here. Certain changes were found at some permanent observation points, such as Fedorov Bay, where a decrease in the amount of construction waste noticed in backcasting of activities on the coast can result from the completion of
residential multi-storey buildings construction work, while a decrease in the density of garbage pollution per square meter in some months - from a lower tourist load beyond the recreational season.

![Figure 4. Morphological composition of the collected marine litter items, kg (2007-2019).](image)

![Figure 5. Most common types of waste, pieces (2007-2019).](image)

4. Conclusions
The research done allowed for identifying a number of priority tasks, the implementation of which is necessary to improve the quality of work performed and to make the best decision, including:

- development of a methodology for monitoring marine litter in the coastal zone of the Primorsky Krai;
- determination of “control points” and conducting series of annual monitoring studies on-site;
- development of new methods for the study of coastal zones in the circumstances of difficult access to some coastal areas and limited resources.
The implementation of these measures is of great importance for assessing the extent of pollution of the coastal zone of Primorsky Krai (and other regions) with anthropogenic litter and planning an effective mitigation strategy.

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