COST-EFFECTIVE COMBINATION OF MEASURES TO REDUCE THE LOADS OF PLASTIC MARINE LITTER IN URBAN AREAS:

CASE TURKU REGION

Prepared by Liisa Saikkonen

Introduction

Marine litter is globally a problem, but the impacts of marine litter on Baltic Sea ecosystems and ecosystem services are not yet well understood. Therefore the severity of marine litter problem in the Baltic Sea region, as well as the benefits of marine litter reduction are hard to assess and to take into account in marine conservation planning [1,2]. Marine littering is a problem in urban coastal areas, and especially in those with recreational areas, marinas and ports. Densely populated coastal areas are one of the main sources of overall marine littering, and at the same time marine litter causes considerable damages to the coastal communities. Therefore it is vitally important to assess the applicability of litter reduction measures in urban coastal areas.

The objective of this study is to define a cost-effective combination of marine litter reduction measures to reduce the loads of plastic marine litter in Turku area. Turku is a city on the southwest coast of Finland, with approximately 189 000 inhabitants and a long coastline. The river Aura divides the city center into two parts which are connected by several bridges. The whole river is 70km long with a catchment area of 874 km^2, in average 50 m wide, and rather shallow (2 -2.5 m deep in the city center). Also a port and several marinas are located in the city or its vicinity. The riverside of Turku and several parks close to the river are popular recreational spots among the locals. Turku also attracts a lot of coastal tourism especially in summer, and hosts several summer festivals that take place close to the river or coast. The marine litter data that this study is based on, was collected by beach litter surveys on Ruissalo beach in Turku. It is a popular beach located 3 km from Turku center, and it is also a destination of marine litter from nearby shipping routes and urban runoff including stormwater and river runoff.

Recent assessments have suggested that most plastic litter comes from land, and rivers act as important gateways for litter transport [3, 4]. Therefore we focus on land-based urban litter sources, and the measures to reduce litter from these sources. We limit the study to macroplastic items (>2.5cm) including cigarette remains, because the analysis is based on recognizable litter items found during beach litter surveys on Ruissalo beach between 2012-2017[1]. Also litter found on beaches has often been used as an indicator of overall marine litter [5]. Although recent public concern and media attention has been devoted mainly to microplastic debris, macroplastic litter itself also poses a threat to marine environment, and has the potential to degrade into microplastic litter.

The Marine Strategy Framework Directive (MSFD) requires EU Member States to ensure that, by 2020, the good environmental status (GES) of EU's marine waters will be achieved. The GES is described by a list of 11 descriptors, and the descriptor related to marine litter states that in GES properties and quantities of marine litter do not cause harm to the coastal and marine environment. However, such threshold quantities have not been explicitly defined for Baltic Sea. The aspirational target proposed by the EU commission in the *Circular Economy Package* is to reduce by 30% the amount of beach litter and fishing gear lost at sea by 2020 (compared to 2015) [6]. This reduction target of 30% is set on ten most common litter types of the given sea area [7]. Also the new environmental goals of not yet officially confirmed Finnish marine strategy state that by 2024 the amount of plastic litter should be reduced by 30% compared to the amount of 2015, and that the abundance of cigarette remains found on urban beaches should be reduced drastically [8]. Finally in May 2018 European commission proposed a new directive to reduce the impacts of the ten most common single use plastic products [19]. In our cost-effectiveness study for Turku region, we use the target of -30% for most common macro plastic litter types, and try to define a set of measures that can reach this target cost-effectively. Given the fact that the litter reduction constraint used in this study is based on such a crude target of 30%, the

[1] The method of beach litter survey is explained in more detail in Marlin Beach litter measurement method description [18].

model framework is developed bearing in mind that in the future the reduction targets for marine litter as well as the impacts and costs related to reduction measures may be defined in more detail.

We start by listing the most common litter types found during the beach litter surveys in Ruissalo, and then the probable land-based sources for these litter types. The litter types are linked by probabilities to each litter source using a scoring method defined by Tudor and Williams [13]. Next, with the help of authorities from the municipality, we define the most relevant/viable measures to decrease litter from these sources. Based on the literature and other available data resources, and by consulting the local authorities and other stakeholders, we determine cost and impact probability distributions for the litter reduction measures. The chosen measures are linked to HELCOM national actions [11] and therefore they can also easily be linked with those measures defined in other documents of the BLASTIC project.

Finally we employ the measure cost and impact data in an optimization model to choose the set of measures that reaches the litter reduction target with the lowest costs. The optimization procedure follows closely the one applied by Oinonen et al. [9,10] to study the cost effectiveness of national measures for achieving GES in Finnish marine waters. However our optimization framework is designed to take better into account the characteristics of marine litter such as multiple litter sources and joint measure impacts resulting from the stages of marine litter pathways. Jointness of impacts implies that an impact of one measure can be affected by the implementation of other measures. For comparison we also calculate the results assuming that the impacts are non-joint, so that the impact of one measure is not affected by implementation of other measures. By comparing the results we are able to assess how the neglect of joint impacts in the analysis can result in suboptimal litter reduction policies.

Marine litter types, sources, and pathways

Three surveys were conducted annually for six years (2012-2017) on Ruissalo beach, meaning that the analysis is based on 18 beach litter surveys. The twelve most common litter types found on Ruissalo beach in Turku are listed in Table 1. This list includes the ten most common recognizable litter types and the two types which include unrecognizable plastic, glass, and ceramic pieces. The sources for unrecognizable litter items are difficult to define and therefore it is also difficult to come up with measures to decrease them. For this reason, unrecognizable litter items are not included in the analysis. Further, this study is focused on plastic litter and therefore the non-plastic litter types are excluded from the study. Table 1 reveals that cigarette remains (L2) is the most common recognizable litter type found on Ruissalo beach and that 16.9% of all litter items are cigarette remains. Other common plastic litter types are related to food and drink packaging (L3, L5, and L8) and their total share is 18% of all litter. Plastic strapping, and packaging and insulation material (L9 and L10) form the third largest marine litter bundle (5%), and it can often be associated with construction industry. Finally plastic bags of all kinds cover 1.5% of all litter found in Ruissalo.

Table 1. The twelve most common types of litter found in Ruissalo beach Turku (20m x 100m), including the 10 most common recognizable litter types (in bold are the recognizable plastic litter types).

Litter type			**Total items 2012-2017**	**Percentage of all litter**	**Annual average (3 surveys/year)**
L1	Plastic	other, unrecognizable	2675	28.0%	446
L2	**Plastic**	**cigarette remains**	**1615**	**16.9%**	**269**
L3	**Plastic**	**bottle caps and lids**	**945**	**9.9%**	**158**
L4	Wood	processed timber and pallet crates	445	4.7%	74

L5	**Plastic**	**Knives, forks, spoons, straws, stirrers, (cutlery)**	**428**	**4.5%**	**71**
L6	Metal	bottle caps, lids and ring-pulls	355	3.8%	59
L7	Glass and ceramics	fragments, unrecognizable	348	3.7%	58
L8	**Plastic**	**food containers, candy wrappers**	**343**	**3.6%**	**57**
L9	**Plastic**	**strapping**	**334**	**3.5%**	**56**
L10	**Foam plastic**	**insulation and packaging**	**142**	**1.5%**	**24**
L11	Paper	cardboard boxes and fragments	139	1.5%	23
L12	**Plastic**	**bags (opaque and clear)**	**138**	**1.5%**	**23**
Of all litter			**7907/9545**	**82.8%**	**1318/1591**

The plastic litter types are linked to sources which are listed in Table 2. In this study we focus only on the land-based sources and thus all sea-based sources are excluded from the analysis. Tourism and recreation (S1) includes littering in Ruissalo beach and its vicinity that can be linked to tourism and recreation. Urban runoff including runoff from rivers and stormwater (S2) contains all litter that is drifted to the beach by urban, storm or river runoff. Third land-based source is construction industry (S3), and the last source is related to intentional fly tipping/illegal dumping (S6) due to for example insufficient or inconvenient waste management opportunities. Tourism and recreation (S1), and urban runoff including stormwater and river runoff (S2) are expected to be the main sources of all litter in Ruissalo, with shares of 40.3% and 23.3% of all litter respectively.

Table 2. The sources of litter (land-based sources in bold)

	Source	**Share of total**
S1	**Tourism and recreation**	**40.3%**
S2	**Urban runoff including stormwater and river runoff**	**23.3%**
S3	**Construction**	**5.5%**
S4	Shipping and harbours	22.1%
S5	Fishing and aquaculture	6.9%
S6	**Fly tipping/illegal dumping**	**1.9%**

We categorize the percentage litter reduction measures into four categories based on the stages of the litter pathway that the measures are targeted to (Figure 1.). The first category **M1** includes measures that target litter production (e.g. awareness and education, and bans on plastic bags). Second category **M2** includes measures that improve waste management and thus prevent litter entering the environment (e.g. improved waste management and litter collection systems). The third category **M3** contains measures that prevent litter that is in land environment from entering the waterways (e.g. improvements on sewerage systems). Some litter, such as litter items fly-tipped/dumped directly to the sea, may skip the third stage. Finally the fourth category **M4** includes measures targeted to reduce litter that is already in the waterways and marine environment (e.g. marine litter collection devices).

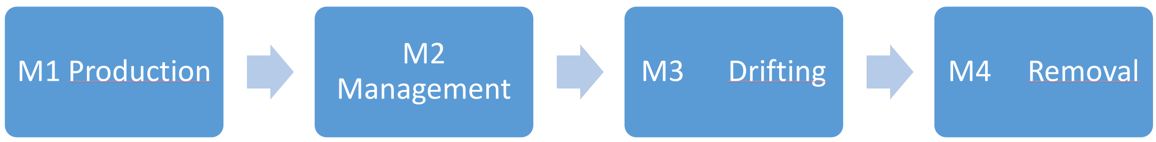

Figure 1. Stages of a litter pathway

In the optimization model it is assumed that measures that take place at the earlier stages of the litter pathway affect the absolute impact of measures on the later stages. This interaction of the marine litter reduction measures results in joint measure impacts. We assume that the impacts of measures within one stage category are additive, meaning that the use of one measure does not affect the impact of other measures within the same category. However, the additive impact of applied measures in each category affects the impact of available measures in the next stage. This is intuitive, since a decreased amount of litter entering a stage of the litter pathway, decreases the absolute impact of the relative percentage measures in this stage.

Measures and computations

We include ten marine litter reduction measures in our analysis which are presented in Table 3, so that each litter type, source and stage is affected by at least one measure. Further, these measures are chosen based on their applicability, efficiency, and availability of data. Therefore it is likely, that the selection of measures does not capture all possible or very detailed litter reduction measures. Thus this analysis should be regarded as a pilot framework to study the cost-effectiveness of litter reduction measures and their combinations. Also the probability distributions of measure costs and impacts that this study is based on should be regarded as approximates. More accurate and case specific background data is required to use the results of this kind of study in the design of a detailed litter reduction policy. However the analysis framework provides a valid method to assess the cost effectiveness of marine litter reduction measures when their joint effects and source variation are taken into account. For comparison we also calculate the results assuming that the impacts are non-joint, so that the impact of a measure is not affected by implementation of other measures.

In Table 3 the first numeral of a litter reduction measure (for example 1 in M1.2) is a reference to the litter pathway stage where the measure has an impact. The second column marks the linkages to the national actions defined in the HELCOM marine litter action plan [11]. The third and fourth columns list the sources and litter types that the measures affect. Last column presents the expected annual costs of the measures in 1000€. These costs are drawn from the measure cost probability distributions. The main sources for measure cost and impact data in addition to expert opinions are given below Table 3. Some of these measures are already implemented to some degree or their implementation is confirmed. However their costs or impacts have not yet materialized.

Table 3. Measures to reduce marine litter in Turku region

Litter reduction measure	HELCOM National Actions	Sources (S)	Plastic Litter types (L)	Expected Annual Cost (1000 €)
M1.1 Marine litter education campaigns[a] (Increasing the budget for marine litter education)	NE1, NE5	S1,S2,S3,S6	L2,L3,L5,L8,L12	83
M1.2 Reduce use of plastic bags[b] *	NL7	S1, S2	L12	31
M1.3 Reduce use of plastic food packaging and cutlery[b]	NL2	S1, S2	L3,L5, L8	32
M2.1 Improve waste management in public areas along Aurajoki[a] (Increase the budget of coastal waste management)	NL8, NL9	S2	L2,L3,L5,L8,L12	300
M2.2 Improve waste management in public areas of non-coastal Turku[a] (Increase the budget of general waste management)	NL8, NL9	S2	L2,L3,L5,L8,L12	585
M2.3 Improve waste management in Ruissalo recreational area[a,b]	NL8, NL9	S1	L2,L3,L5,L8,L12	32
M2.4 Reduce fly tipping/illegal dumping by enabling more accessible/cheaper waste management options for large litter items/quantities[c]	NL2	S3, S6	L9,L10	39
M3.1 Improve the outlet efficiency of Kakolanmäki wastewater treatment plant. This measure likely reduces marine litter resulting from urban runoff and combined sewer overflows.[d]* (planned)	NL3	S2,S3,S6	L2,L3,L5,L8,L9,L10, L12	875
M3.2 Outsource the repair and maintenance work of Kakolanmäki wastewater treatment plant and central sewerage system. This can reduce marine litter resulting from urban runoff and combined sewer overflows.[d]* (starting from 2018)	NL3	S2,S3,S6	L2,L3,L5,L8,L9,L10, L12	483
M4.1 Installment of floating debris interception devices in marine litter hot spot areas in Aurajoki and Ruissalo during high season[e]	NL11	S1,S2	L2,L3,L5,L8,L12	27

Main sources for the measure cost and impact data in addition to expert opinions:

a) [12], **b)** [10]

c) Lounais-Suomen Jätehuolto (Local waste management operator), https://www.lsjh.fi/

d) Turun Seudun Puhdistamo (Local waste water treatment operator), www.turunseudunpuhdistamo.fi

e) Seabin floating debris interception device producer, http://seabinproject.com

Following sources relate to most measures:

1) City of Turku, financial statement, budget and strategy, https://www.turku.fi/talous-ja-strategia/

2) Association of Finnish Local and Regional Authorities, https://www.kuntaliitto.fi

3) HILMA - database of public procurement announcements, https://www.hankintailmoitukset.fi

***) These measures are already implemented to some degree or their implementation is confirmed. However their costs or impacts have not yet materialized.**

The independent expected litter reduction impacts of the ten litter reduction measures are presented in Table 4. These impacts are based on an assumption of non-jointness, so that measures in the previous stages of the litter pathway are not applied and thus the impact of a given measure is not affected by other measures. The independent expected litter reduction impacts are drawn from the impact probability distributions and litter source probability scores. These expected impacts are presented as percentage decrease in the amount of given litter type for each measure.

Table 4. Expected litter reduction impacts of each measure on each litter type assuming that the impacts are nonjoint and when litter source probabilities are taken into account

	L2 -%	**L3 -%**	**L5 -%**	**L8 -%**	**L9 -%**	**L10 -%**	**L12 -%**
M1.1	15.6	17.6	18.3	19.3	1.9	5.4	16.8
M1.2	0.0	0.0	0.0	0.0	0.0	0.0	23.8
M1.3	0.0	9.4	24.1	25.4	0.0	0.0	0.0
M2.1	2.0	5.9	2.4	2.5	1.0	2.5	9.3
M2.2	2.0	4.7	1.9	1.9	0.8	1.9	6.9
M2.3	10.4	7.6	12.2	12.8	0.0	0.0	3.1
M2.4	0.0	0.0	0.0	0.0	1.3	4.9	0.0
M3.1	3.8	6.8	2.3	2.4	2.1	6.4	10.8
M3.2	2.4	5.6	1.8	1.9	1.7	5.1	8.9
M4.1	11.0	15.3	16.5	17.3	0.1	0.3	12.8

To define the optimal sets of measures, we first calculate the expected cost and litter reductions by litter type for each combination of measures (2^{10}=1024). Then we pick the combinations that are expected to meet the reduction goals, and from these choose the combination of measures that can be applied with the lowest expected costs. For litter types L9 and L10 (strapping, and insulation and packaging) more than 50% of litter items are from sea-based sources and thus we do not set goals for these litter types. We also calculate the probabilities that the reduction of cigarette remains for optimal sets of measures for 30% litter reduction target is equal or greater than 20%,30% or 40%. This way we are able to assess the risks related to the chosen sets of measures, and to study the impact of litter reduction measures on cigarette remains, which is not only most abundant, but also regarded as one of the most harmful litter types [14].

Results

The results of optimization (aka expected cost minimization given the litter reduction goal) are provided in Table 5. The joint results represent an assumption that the applied measures in the previous stages of the litter pathway affect the measure impacts. The non-joint results are based on an assumption that the impact of a measure is not affected by any other measures. The first columns of both assumptions describe the outcome when 30% reduction goal is applied for all recognizable plastic litter types except for L9 and L10, and the following columns are the outcomes when the reduction goal of 30% is deviated by -10% (20%) or +10% (40%).

Table 5. Optimal sets of measures.

(Sets of measures that meet the litter reduction goals with the lowest expected costs)

Measure	30% Joint	20% Joint	40% Joint	30% Nonjoint	20% Nonjoint	40% Nonjoint
Est. costs	173K€	110K€	2384€	142K€	90K€	924K€
M1.1	x	x	x	x	-	x
M1.2	x	-	-	-	x	-
M1.3	-	-	-	-	-	-
M2.1	-	-	x	-	-	x
M2.2	-	-	x	-	-	-
M2.3	x	-	x	x	x	x
M2.4	-	-	-	-	-	-
M3.1	-	-	x	-	-	-
M3.2	-	-	x	-	-	x
M4.1	x	x	x	x	x	x

The measure M4.1 (floating debris interception device) is applied in all sets of measures, and the measures M1.1 (Marine litter education campaigns) and M2.3 (Improved waste management in Ruissalo) in all sets of measures, except for 20% non-joint and 20% joint reduction goals respectively. It has to be noted that this analysis applies litter found on Ruissalo beach as an indicator of overall marine litter, and therefore it likely emphasizes litter reduction measures that take place in Ruissalo or its vicinity, such as the measures M2.3 and M4.1. However, the impacts of these measures on total marine litter are likely less significant. The optimal set of measures for 30% reduction goal include measures M1.1, M2.3 and M4.1 for both assumptions of jointness, and also M1.2 (Reduce use of plastic bags) when joint impacts are assumed.

The results of Table 5 show that the underlying assumptions on the joint impacts of litter reduction measures have a significant effect on the outcome of optimal measure selection. Also the expected minimum costs vary significantly between different litter reduction goals and assumptions on joint impacts of measures. For example assuming that there are joint impacts, the cost to reduce litter by 20% is 110K€, whereas when the goal is increased to 40% the cost is 2384K€. However, the cost to reduce litter by 40% assuming non-joint impacts is only 924K€, due to fewer applied measures than for joint impacts. For 20% reduction goal and non-joint impacts, the optimal measure set includes three measures, whereas for joint impacts the optimal measure set contains only two measures. However these two measures are in total expected to be more expensive than the three measures for non-joint impacts.

The expected reductions by litter type for each optimized set of measures described in Table 5 are given in Table 6. For most litter types the expected litter reductions exceed the reduction goals significantly. In addition to binary measure implementation levels (0 or 1), this is due to the fact that the litter reduction goals have to be met for all litter types, except for L9 and L10, and most measures affect multiple litter types. The last three rows of Table 6 for the litter reduction goal of 30% present the probability that the optimal sets of marine litter reduction measures (M1.1, (M1.2)[2], M2.3, M4.1) reduce cigarette remains (L2) by at least 30%, 20% and 40% respectively.

Table 6. Expected litter reductions by litter type for the sets of cost minimizing measures

Reduction goal/ Litter type	**-30% Joint**	**-20% Joint**	**-40% Joint**	**-30% Nonjoint**	**-20% Nonjoint**	**-40% Nonjoint**
L2	32%	24%	*38%*	37%	21%	41%
L3	35%	30%	49%	41%	23%	52%
L5	40%	32%	45%	47%	29%	51%
L8	42%	33%	47%	49%	30%	54%
L9	2%	2%	6%	2%	0%	5%
L10	6%	6%	18%	6%	0%	13%
L12	49%	27%	52%	33%	40%	51%
P(ΔL2≥30%)	**50%**			**60%**		
P(ΔL2≥20%)	**91%**			**98%**		
P(ΔL2≥40%)	**19%**			**44%**		

For example if we assume that the litter reduction measure impacts are joint and we apply the optimal set of measures expected to meet the reduction target of 30%, the probability that cigarette remains are reduced by at least 30% is 50%. Whereas assuming that the measures are nonjoint, the optimal set of measures that is expected to meet the reduction target of 30%, decreases the cigarette remains by at least 30% with a probability of 60%. These probabilities were calculated by simulating 10 000 litter reduction outcomes for the measure sets (M1.1, M2.3 and M4.1) on cigarette remains, and studying their distributions which are presented as histograms in Figure 2. It is very likely (91% for joint analysis and 98% for nonjoint analysis) that the optimal measure set to reach the expected litter reduction target of 30% reduces cigarette remains by at least 20%, whereas the probability for at least 40% reduction of cigarette remains for joint impacts is only 19% (44% for nonjoint impacts).

[2] Measure M1.2 (reduce the use of plastic bags) is not expected to have any impact on cigarette remains.

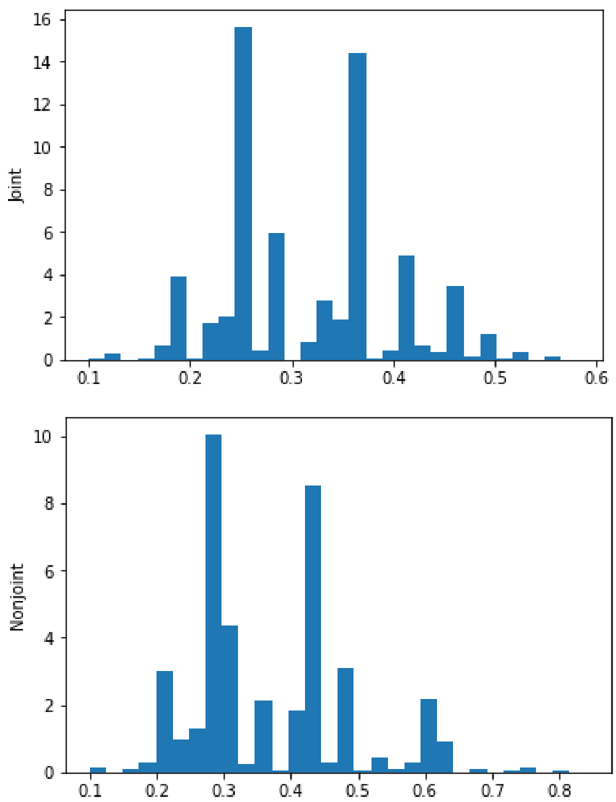

Figure 2. Distributions of simulated reduction outcomes for cigarette remains

Discussion and Conclusions

As already mentioned, this study should be regarded as a pilot framework for cost-effectiveness analysis on marine litter reduction measures, with joint measure impacts and multiple litter sources. The comparison of joint impact and non-joint analyses shows that the pathways of marine litter should be identified carefully for each litter type, before conducting a cost effectiveness analysis of litter reduction measures. If the likely joint impacts of the measures are not taken into account, the estimated reductions are likely exaggerated and suboptimal measures might be chosen.

Also the measure cost and impact distributions used in this study should be regarded as approximates. More accurate and case specific background data is required to use the results of this kind of study in the design of a detailed litter reduction policy design. However the analysis framework provides a sound method for studying the cost effectiveness of marine litter reduction measures when their joint effects and different sources are taken into account. Also the results can be used as ballpark estimates to compare the relative cost effectiveness of litter reduction measures, and to rule out obviously ineffective reduction measures from the more applicable ones.

Based on previous literature, marine litter education or awareness campaigns are among the most effective ways to reduce litter [12, 15]. This is also a result of this study, and is backed up by the fact that such campaigns can reduce litter production at the source and thus the impacts of such campaigns are not affected by litter reduction measures that take place later on the litter pathway. Further, well planned litter education or awareness campaigns can reduce multiple litter types, whereas for example bans or taxes on certain products such as plastic bags or cigarettes can be targeted to reduce certain types of litter [17].

Drink container deposit legislation has proven to be one of the most effective measures to reduce marine plastic litter [16]. Deposit legislation is already implemented in Finland, but still deposit drink containers are a problem in river Aurajoki [20], which is one of the main marine litter waterways of this case study. However drink containers were not one of the most common litter types found during the beach litter surveys of Ruissalo beach that our data is based on and therefore they are not taken into account in the measure optimization. The absence of drink containers in beach litter surveys might be due to the fact, that drink containers have a habit of sinking and therefore they did not reach Ruissalo beach.

According to the results, debris interception devices and improved waste management in Ruissalo are effective measures to reduce plastic marine litter. However, as already stated, the littering and litter reduction that take place in Ruissalo beach, where the beach litter surveys were conducted, is emphasized in this study. If we want to study the measures to reduce overall marine litter, the reduction measures that target Ruissalo beach are likely not as effective as the results imply. Therefore it could be fruitful to study litter sources independently or by excluding the littering that takes place in Ruissalo and its vicinity. Albeit litter found on beaches has often been used as an indicator of overall marine litter, it may overemphasize the given beach and its vicinity as a litter source, especially when assessing the cost effectiveness of marine litter reduction measures.

In future research, cost effectiveness analysis could take better into account the temporal scope of different measures. For example there are possible lags between the implementation of some measures and the realization of their impacts. Also the probabilities that reduction goals are met for certain litter types could maybe be integrated in the analysis as input parameters in the optimization, and not just as ex-post analysis for already defined optimal sets of measures. Furthermore some of the measures, such as those related to sewerage system improvements, likely have impacts beyond marine litter reduction which are not included in our optimization procedure. These impacts should be taken into account in the analysis since their inclusion would affect the measure costs allocated to litter removal.

References

[1] Laamanen, M. (editor). 2016. Suomen merenhoitosuunnitelman toimenpideohjelma 2016–2021 (Programme of measures for the development and implementation of the marine strategy in Finland 2016–2021). Reports of the Ministry of the Environment 5/2016.

[2] Finnish Ministry of Environment. 2015. Hearing on the proposal on Programme of measures for the development and implementation of the marine strategy in Finland 2016–2021. Available from (in Finnish):
http://www.ymparisto.fi/download/noname/%7B326E0CC1-FAEE-4600-95F1-917B2A6DB00C%7D/101462
(Accessed: 28/05/2018)

[3] United Nations Environmental Programme (UNEP). 2016. Marine plastic debris and microplastics - Global lessons and research to inspire action and guide policy change. United Nations Environment Programme, Nairobi.

[4] Schmidt, C., Krauth, T., Wagner, S. 2017. Export of Plastic Debris by Rivers into the Sea. Environmental Science & Technology 51(21):p. 12246-12253.

[5] Derraik, J.G.B. 2002.The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44(9): p. 842-852.

[6] European Commission. 2018. Our Oceans, Seas and Coasts Descriptor 10: Marine Litter. http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm
(Accessed: 28/05/2018)

[7] Arcadis. 2013. Marine Litter Study to support the establishment of an initial quantitative headline reduction target - SFRA0025.

[8] Finnish Ministry of Environment. 2018. Revision of the indicators and environmental goals of the implementation of the marine strategy in Finland. Available from (in Finnish): http://www.ymparisto.fi/download/noname/%7B268CBEB9-F715-4C51-B4CE-BBD98470C3FF%7D/133918
(Accessed: 28/05/2018)

[9] Oinonen, S., Hyytiäinen, K., Ahlvik, L., Laamanen, M., Lehtoranta, V., Salojärvi, J., Virtanen, J. 2016. Cost-Effective Marine Protection- A Pragmatic Approach. PloS one 11(1).

[10] Oinonen, S., Hyytiäinen, K., Ahlvik, L., Salojärvi, J., Ahtiainen, H., Lehtoranta, V., Virtanen, J., Väisänen, S., Valve, H. 2015. Merenhoitosuunnitelman toimenpideohjelman taustaraportti: Merenhoitosuunnitelman toimenpideohjelman valmistelun tueksi laaditut taloustieteelliset analyysit (Background report on the economic analysis for Programme of measures for the development and implementation of the marine strategy in Finland 2016–2021). Available from (in Finnish): http://www.ymparisto.fi/download/noname/%7BCEBD52F4-09F3-41F6-9054-1BE241976DC4%7D/34447
(Accessed: 28/05/2018)

[11] HELCOM. 2015. Regional Action Plan for Marine Litter in the Baltic Sea.

[12] Willis, K., Maureaud, C., Wilcox, C., Hardesty, B.D. 2018. How successful are waste abatement campaigns and government policies at reducing plastic waste into marine environment. Marine Policy, in Press.

[13] Tudor, D.T. and A.T. Williams. 2004. Development of a 'Matrix Scoring Technique' to determine litter sources at a Bristol Channel beach. Journal of Coastal Conservation 10(1): p. 119–127.

[14] Novotny, T., Lum, K., Smith, E., Wang, V., Barnes, R. 2009. Cigarettes Butts and the Case for an Environmental Policy on Hazardous Cigarette Waste. International Journal of Environmental Research and Public Health 6(5).

[15] Hartley, B., Thompson, R., Pahl, S. 2015. Marine litter education boosts children's understanding and self-reported actions. Marine Pollution Bulletin 90: p. 209-217.

[16] Schuyler, Q., Hardesty, B., Lawson, T.J., Opie, K., Wilcox, C. 2018. Economic incentives reduce plastic inputs to the ocean. Marine Policy, in Press.

[17] Oosterhuis, F., Papyrakis, E., Boteler, B. 2014. Economic instruments and marine litter control. Ocean & Coastal Management 102: p. 47-54.

[18] MARLIN. Beach litter measurement method description. www.hsr.se/sites/default/files/appendix1_measurement_method.pdf
(Accessed: 18/06/2018)

[19] European Commission. 2018. Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the reduction of the impact of certain plastic products on the environment.

[20] Personal communication with senior researcher Outi Setälä concerning BLASTIC litter survey conducted in river Aura during summer 2017. outi.setala@ymparisto.fi .(20/06/2018)