The Analysis of the Marine Debris in Jeju Island and the Ways to Resolve the Issue

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Abstract

The amount of marine debris in Jeju island is constantly increasing. The marine debris is accumulating in locations such as shores, ports, and sea. Despite the government's, civil organizations', and volunteers' sincere effort to collect the marine waste, the volume of marine debris keeps growing. Surprisingly, most of marine debris comes from inland. The inland trash piled up in landfill travels to the sea by heavy rain, gale, and typhoons. With an increasing number of tourists and small businesses such as restaurants, more trash is generated from the inland which then flows into the sea. The consequence is evident: heavily polluted sea, ports, and shores, and more financial resources to cleanse. It is truly a virtuous cycle which needs to end.

This research paper (1) explores the current status of marine waste in Jeju using three sampled locations, (2) investigates the reasons for ever-growing size of the marine waste, its main source, and types of debris (plastics, glass, fiber, etc), and (3) propose a solution.

The method for the analysis is consisted of (1) data collection, (2) data processing, (3) sampling, (4) analysis, and (5) inference. There are ten different data sets regarding marine waste, inland trash, tourism, weather, and government organization's cleansing effort. The data sets are collected from publicly available sources made by public organizations (refer to citation). It is worth noting that there is a limitation in the data; since different organizations created the data in different years, the years in each data set span differently. This limitation may hinder a fair comparison among data when two or more data are being compared. To work around this limitation as much as possible, I have filtered the years of the data so that the range of years matches as much as possible. The analysis will culminate with a conclusion that addresses major problems found in the analysis; (1) plastic is the main part of marine debris, (2) most of marine waste originates from inland trash, and (3) government organizations' financial resources for waste collection and disposal decreased in recent years. Using the weather's seasonality and pattern regarding downpour and gale, the conclusion proposes a solution as well that addresses these problems.

Introduction

Jeju island is the largest island in Korea, with its area of 1,833.2km^2 and population of 676,810. Due to its distance from the continent, the island has developed its own unique culture and natural environment that is distinguished from other provinces in Korea. Thus, the island has well developed tourism industry.

In terms of economy, Jeju island's main industries are comprised of primary industry, such as agriculture, fishing and livestock farming, and tertiary industry, such as tourism and service. There exists manufacturing industry in Hwabuk Industrial Complex as well. However, its presence is minute compared to the other industries.

My interest in researching and addressing waste issues in Jeju Island was sparked by an experience that left a lasting impact. A friend and I decided to travel to Moseulpo Port, the closest one to my school, to escape from academics. Yet, instead of the beautiful beach we had expected, what greeted us was noxious odor emanating from the ocean waters and a distressing sight – an overwhelming amount of debris floating on the surface. It appeared as though this trash had accumulated at a specific point due to the shifting tides, and it included items such as ramen wrappers, bottles, plastic nets, and more. As residents of Jeju, this stark contrast to our expectations prompted me to take an action. Together with my uncle, I founded a voluntary group called 'hiros.' After each gathering at the port, we diligently cleaned up most of the visible trash. However, every time we returned, the areas we had cleared were once again inundated with new debris. This perpetual cycle left me pondering the root causes of the pollution and its sources. Hence, this research is conducted to find solutions to help protect the environment of Jeju Island.

(1) The Status of Marine Debris

- First, we will investigate marine debris around Jeju island. I will take 3 sample locations of the island, namely Sagyeri, Wiemee, and Gimnyeongri for the investigation. We will find out what kind of waste exists, their number, weight, and etc.

Data

- I will use a monitoring data of marine debris provided by Jeju Special Self-Governing Province
- Source of data: https://www.data.go.kr/data/15110788/fileData.do (public data portal run by Ministry of Public Administration and Security of South Korea)

Data Exploration

Basic

```
##   Year_Measured Measurement_Number     Location Latitude Longitude
## 1          2018                  1 Jeju Sagyeri 33.22264  126.2968
## 2          2018                  2 Jeju Sagyeri 33.22264  126.2968
## 3          2018                  3 Jeju Sagyeri 33.22264  126.2968
## 4          2018                  4 Jeju Sagyeri 33.22264  126.2968
## 5          2018                  5 Jeju Sagyeri 33.22264  126.2968
## 6          2018                  6 Jeju Sagyeri 33.22264  126.2968
##   Waste_Main_Category Waste_Middle_Category Waste_Subcategory Number Weight(kg)
## 1             Plastic                 Film      Film Balloon      0        0.0
## 2             Plastic                 Film      Film Balloon      0        0.0
## 3             Plastic                 Film      Film Balloon      0        0.0
## 4             Plastic                 Film      Film Balloon      0        1.3
## 5             Plastic                 Film      Film Balloon      0        0.8
## 6             Plastic                 Film      Film Balloon      0        0.0
```

This is the head of the data to glimpse.

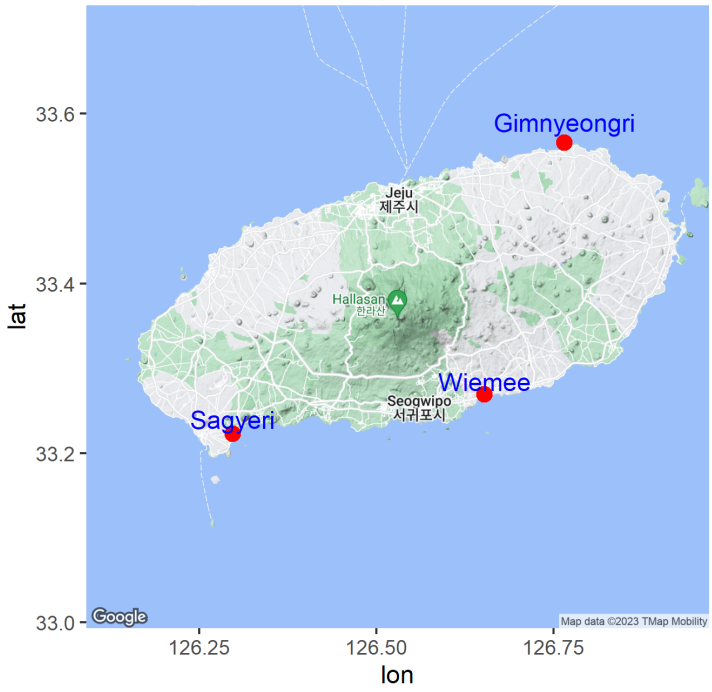
The data is comprised of 3000 rows and 10 variables.

```
## $Year_Measured
## [1] 2018 2019 2020 2021
##
## $Measurement_Number
## [1] 1 2 3 4 5 6
##
## $Location
## [1] "Jeju Sagyeri"     "Jeju Gimnyeongri" "Jeju Wiemee"
##
## $Latitude
## [1] 33.22264 33.56562 33.26946
##
## $Longitude
## [1] 126.2968 126.7650 126.6525
##
## $Waste_Main_Category
## [1] "Plastic"                "Natural Fiber"          "Paper"
## [4] "Glass"                  "Foreign"                "Lumber"
## [7] "Miscellaneous Material" "Metal"                  "Rubber"
##
## $Waste_Middle_Category
##  [1] "Film"
##  [2] "Fiber"
##  [3] "Foam"
##  [4] "Miscellaneous"
##  [5] "Hard Type"
##  [6] "NA"
##  [7] "Plastic"
##  [8] "Drink Bottle, Bottle Cap"
##  [9] "Glass"
## [10] "Medicine Bottle, Medicine Packaging, Syringe"
## [11] "Buoy(Blue Oval)"
## [12] "Buoy(Orange Stick)"
## [13] "Buoy(Blue round stick)"
## [14] "Buoy(Black)"
## [15] "Lighter"
## [16] "Misc Material"
## [17] "Net"
## [18] "Hard Type Misc Buoy"
## [19] "Vinyl Wrap"
## [20] "Hard Type Misc"
## [21] "Misc Plastic"
## [22] "Detergent Container"
##
## $Waste_Subcategory
##  [1] "Film Balloon"
##  [2] "Film Particle"
##  [3] "Film Misc(Disposable Plastic Gloves, etc)"
##  [4] "Vinyl Wrap(Ice cream, Snack bag, etc)"
##  [5] "Plastic Bag"
##  [6] "Clothing, Garment, Gloves, Socks, Blanket(Synthetic Fiber Only)"
##  [7] "Fiber Particle"
##  [8] "Fiber Misc"
##  [9] "Rope(Twisted, For Fishing"
## [10] "Fishing Line"
## [11] "String(String for Wrapping)"
## [12] "Net"
## [13] "Styrofoam Wrap Filling(Shock Absorber for Electronics, etc)"
## [14] "Styrofoam Fish Box"
```

```
## [15] "Styrofoam Food Container(Food Wrapping, Cup Ramen, Lunch Box, Fruit Wrap, etc)"
## [16] "Styrofoam Buoy"
## [17] "Misc Foam(Sponge, Wet Tissue, etc)"
## [18] "Foam Particle"
## [19] "Cigarette Butt"
## [20] "Misc Plastic"
## [21] "Misc Particle"
## [22] "Plastic Buoy"
## [23] "Firecracker, Fireworks Supplies"
## [24] "Wrapping Band(Wide and Hard"
## [25] "Fish Trap, Bait Container for Eels"
## [26] "Syringe"
## [27] "Toys, Dolls, Entertainment Stuff, Office Supplies"
## [28] "Food Container(Pepper Paste, Soy Sauce, etc)"
## [29] "Drink Bottle, Bottle Cap, etc"
## [30] "Chemicals Container for Fish Farming"
## [31] "Detergent Container"
## [32] "Lighter"
## [33] "Pesticide Container, Pesticide"
## [34] "Hard Type Particle"
## [35] "Hard Type Misc"
## [36] "Fake Bait, Fluorescent Paper, Bait Container for Fishing"
## [37] "Disposable Plate, Spoon, Straw, etc"
## [38] "NA"
## [39] "Misc(Disposable Plastic Gloves, etc"
##
## $Number
##  [1]   0   1   2   5   4   6   3  17 111  11   8  10  19  12  55  40  27  15  22
## [20]  16  18   7  86  13  14  26  46 116  64 112 121  31  54  29  56  57  30  48
## [39]   9  20  76  52  21 183  28  51  37  25 396 163 168  73 268 152  94  68  38
## [58]  53  23  63  32  47  39
##
## $`Weight(kg)`
##  [1]  0.0  1.3  0.8  0.4  0.1  0.5  0.3  0.2  7.3  4.8  1.4  3.1 60.0  2.2  4.9
## [16]  1.5  0.6  9.8 12.8  1.7 49.7 10.0 12.5  8.8  2.5 13.4  3.4  7.0  5.4  7.7
## [31]  2.4  0.9  1.0 15.1  5.1 11.7  7.5  1.6  1.1  2.3  4.7  1.8  3.0  3.5  5.8
## [46]  4.4  7.2  6.4  5.0 13.7  4.0  1.2  3.2  6.8  0.7 30.1 15.2  7.4 14.9  1.9
## [61] 75.7 11.3  5.6
```

(1) The data spans from 2018 to 2021.
(2) There are 3 locations around Jeju island the data was gathered. Accordingly, 3 longitudes and latitudes.
(3) The marine debris, or waste, are categorized in 3 levels: main category, middle category, and subcategory.

The 3 Sample Locations



These are the 3 sample locations of Jeju island where the data was collected.

Yearly Trend

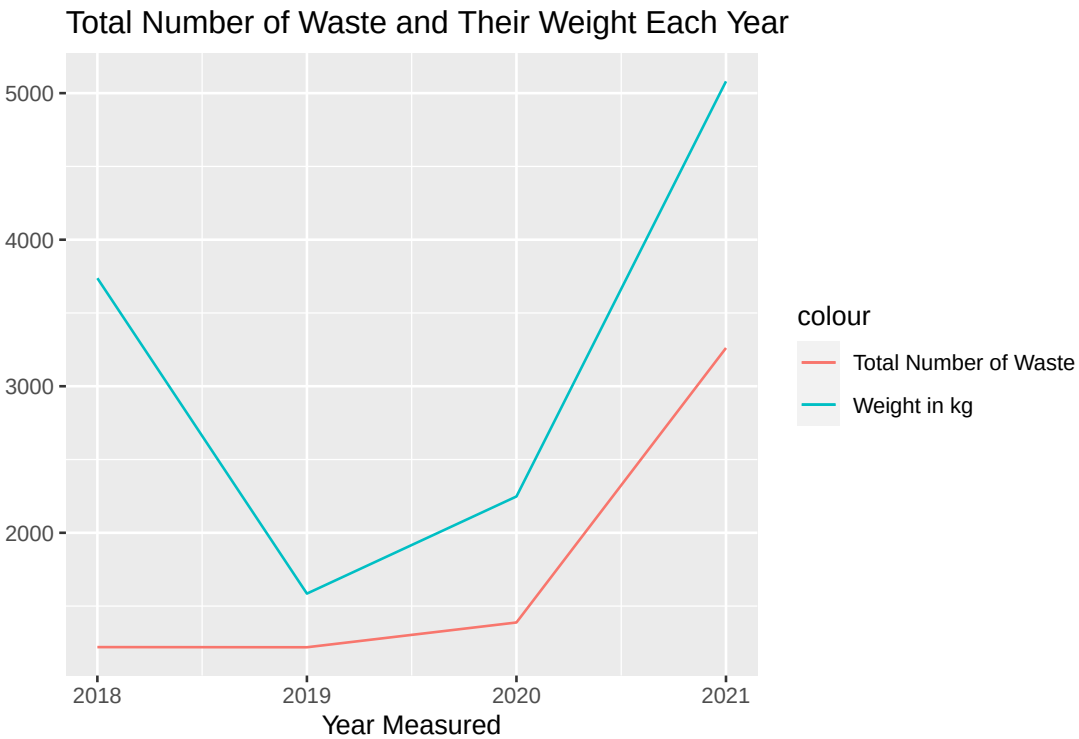


Figure1. Total Number of Waste and Their Weight Each Year

The total number of waste and their weight generally increase as time passes, with 2021 being the highest. In fact, according to Jeju Ilbo, a major newspaper in Jeju island, 70 percent of marine

waste in Jeju actually comes from the wastes littered in the land. These wastes are then flowed into the sea by flood, heavy rain, gale, or typhoon. Hence, to prevent the increase of marine waste, the waste in the land must be reduced and well managed from the beginning.

```
## # A tibble: 4 x 4
##   Year_Measured Mean_Number_of_Waste Mean_Waste Ratio
##           <int>                <dbl>      <dbl> <dbl>
## 1          2018                 1.80       5.51  3.06
## 2          2019                 1.80       2.34  1.30
## 3          2020                 2.05       3.32  1.62
## 4          2021                 3.38       5.26  1.56
```

On a side note, this table shows how many and how much of waste was discarded each time in average, taking the number of waste into account. For example, in 2018, each time when waste was collected, there were about 1.8 number of waste which weighed about 5.51kg.

"Mean_Number_of_Waste": The average number of waste each time collected
"Mean_Waste": The average weight of waste each time collected
"Ratio": The average weight of waste for each number of waste (mathematically, "Mean_Waste" divided by "Mean_Number_of_Waste")

Looking at the "Ratio," in 2018, each waste weighed about 3kg which was the heaviest among all of the years measured. Therefore, in 2018, they littered more waste relative to how often they discarded.

The top 3 Sources of Marine Waste

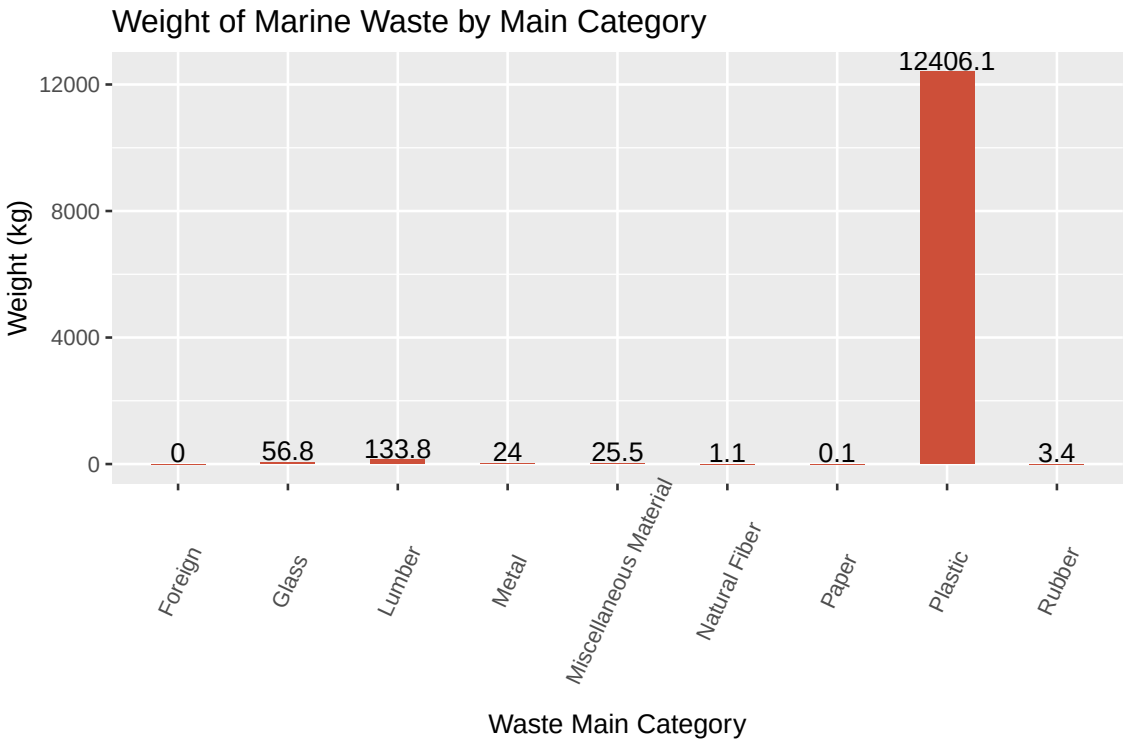


Figure2. Weight of Marine Waste by Main Category

Plastic is the biggest problem in marine pollution, absolutely dominating other kinds of waste in terms of weight. Lumber and glass follow. It would be very helpful for the ocean if people use more of environment-friendly alternative materials that can reduce the use of plastic, such as a recyclable paper straw.

Which location was the most polluted?

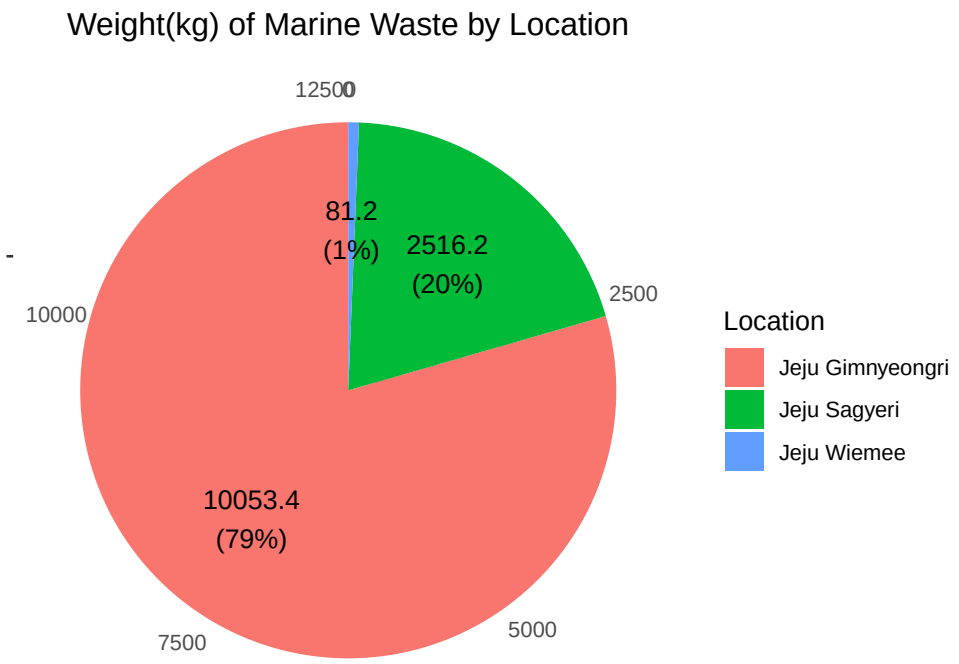


Figure3. Weight(kg) of Marine Waste by Location

With 10,053.4kg of waste, Gimnyeongri of Jeju island seems to be the mostly polluted area.

```
## # A tibble: 3 x 4
##   Location         Total_Number_of_Waste Weight_kg  Ratio
##   <chr>                            <int>     <dbl>  <dbl>
## 1 Jeju Gimnyeongri                  4353   10053.  2.31
## 2 Jeju Sagyeri                       749    2516.  3.36
## 3 Jeju Wiemee                       1986      81.2 0.0409
```

However, when taking the total number of waste into account to produce "Ratio," which is "Weight_kg" divided by "Total_Number_of_Waste," Sagyeri has the highest potential of becoming the most polluted area. In absolute terms, Gimnyeongri is mostly polluted with 10,053kg of waste, but looking at the weight relative to each number of waste, Sagyeri has the highest ratio, which says each number of waste represents about 3.36kg, the heaviest among all. If this trend continues, Sagyeri will be more polluted than Gimnyeongri some day.

```
## # A tibble: 9 x 3
## # Groups:   Location [3]
```

```
##   Location         Year_Measured Number_of_Rows
##   <chr>                    <int>          <int>
## 1 Jeju Gimnyeongri          2018            336
## 2 Jeju Gimnyeongri          2019            336
## 3 Jeju Gimnyeongri          2020            336
## 4 Jeju Gimnyeongri          2021            336
## 5 Jeju Sagyeri              2018            342
## 6 Jeju Sagyeri              2019            342
## 7 Jeju Sagyeri              2020            342
## 8 Jeju Sagyeri              2021            342
## 9 Jeju Wiemee               2021            288
```

One thing to highlight is that the data for Wiemee has been collected only for 1 year (2021) while the other places has collected for 4 years (2018 through 2021). Therefore, Wiemee appears to be the cleanest area but that is simply because it has very small presence. For a fair comparison, Wiemee also needs year 2018 through 2021.

(2) More Locations to Examine

- The 3 locations above can hardly represent Jeju island's marine pollution status well. Hence, I will examine purification of marine waste data from all ports in Jeju island to strengthen my investigation.
  - I will use the status of purification of marine waste data provided by Korea Marine Environment Management Corporation
  - Source of data: https://www.data.go.kr/data/15044296/fileData.do (public data portal run by Ministry of Public Administration and Security of South Korea)
- I will also evaluate their purification effort

Data Exploration

Basic

```
##   Year    Jeju_Ports Collection_Planned(kg) Collection_Actual(kg)
## 1 2012     Jeju Port                115000                172100
## 2 2012 Seoguipo Port                118000                199100
## 3 2012   Chooja Port                 55000                120600
## 4 2014   Hanlim Port                172000                202870
## 5 2014  Sungsan Port                 24000                 38440
## 6 2015   Chooja Port                 34000                 55440
##   Area_Purification_Planned(hectare) Area_Purification_Actual(hectare)
## 1                              34.40                             34.40
## 2                              13.90                             13.90
## 3                              12.10                             12.10
## 4                              30.61                             30.61
## 5                              38.70                             38.70
## 6                              12.00                             12.00
##        Start        End
## 1 2012-05-09 2012-07-19
## 2 2012-05-09 2012-07-19
## 3 2012-11-26 2012-02-04
```

```
## 4 2015-02-23 2014-04-23
## 5 2015-01-26 2014-03-26
## 6 2015-09-07 2015-11-05
```

The head of data where,
"Collection_Planned(kg)": The amount of marine waste in kg they planned to collect.
"Collection_Actual(kg)": The actual amount they collected.
"Area_Purification_Planned(hectare)": The area in hectare of the ocean they planned to cleanse.
"Area_Purification_Actual(hectare)": The actual area they cleansed.

The data is comprised of 16 rows and 8 variables.

```
## $Year
## [1] 2012 2014 2015 2018 2019 2020
##
## $Jeju_Ports
## [1] "Jeju Port"        "Seoguipo Port"    "Chooja Port"      "Hanlim Port"
## [5] "Sungsan Port"     "Moonsum Area"     "Hanlim Port Area" "Aewol Port"
##
## $`Collection_Planned(kg)`
##  [1] 115000 118000  55000 172000  24000  34000  64000  61000 115820 108210
## [11]  45840 176300   2210  25200  96400  20000
##
## $`Collection_Actual(kg)`
##  [1] 172100 199100 120600 202870  38440  55440 222120  74120 115820 108300
## [11]  45840 174960   2210  30980  65890  27730
##
## $`Area_Purification_Planned(hectare)`
##  [1] 34.40 13.90 12.10 30.61 38.70 12.00 15.80  9.20 31.00 29.30 16.80 70.00
## [13] 30.80 24.40 30.00
##
## $`Area_Purification_Actual(hectare)`
##  [1] 34.40 13.90 12.10 30.61 38.70 12.00 15.80  9.20 30.80 31.10 26.30 16.80
## [13] 70.42 21.50 23.50 30.00
##
## $Start
##  [1] "2012-05-09" "2012-11-26" "2015-02-23" "2015-01-26" "2015-09-07"
##  [6] "2015-10-26" "2018-06-19" "2018-08-10" "2018-10-18" "2019-06-03"
## [11] "2019-10-30" "2020-03-31" "2020-11-27"
##
## $End
##  [1] "2012-07-19" "2012-02-04" "2014-04-23" "2014-03-26" "2015-11-05"
##  [6] "2015-12-09" "2018-08-17" "2017-11-07" "2018-12-26" "2019-08-01"
## [11] "2019-12-31" "2020-05-29" "2020-12-23"
```

1. The data spans from year 2012 to 2020 but there are a few missing years (2013, 2016, 2017). It seems they did not perform waste collection in those years.
2. Looking at the values in Collection_Actual(kg), there are much more waste than we saw from the 3 locations above being collected.

How many ports are there?

```
## [1] 8
```

```
## [1] "Jeju Port"        "Seoguipo Port"    "Chooja Port"      "Hanlim Port"
## [5] "Sungsan Port"     "Moonsum Area"     "Hanlim Port Area" "Aewol Port"
```

Yearly amount of marine waste collected

```
## # A tibble: 16 x 5
## # Groups:   Year [6]
##     Year Jeju_Ports       Weight_kg Area_hectare   Ratio
##    <int> <chr>               <dbl>        <dbl>   <dbl>
##  1  2012 Chooja Port         120600         12.1  9967.
##  2  2012 Jeju Port           172100         34.4  5003.
##  3  2012 Seoguipo Port       199100         13.9 14324.
##  4  2014 Hanlim Port         202870         30.6  6628.
##  5  2014 Sungsan Port         38440         38.7   993.
##  6  2015 Chooja Port          55440         12    4620
##  7  2015 Jeju Port            74120          9.2  8057.
##  8  2015 Seoguipo Port       222120         15.8 14058.
##  9  2018 Chooja Port          45840         26.3  1743.
## 10  2018 Hanlim Port         115820         30.8  3760.
## 11  2018 Jeju Port           108300         31.1  3482.
## 12  2018 Seoguipo Port       174960         16.8 10414.
## 13  2019 Hanlim Port Area     30980         21.5  1441.
## 14  2019 Moonsum Area          2210         70.4    31.4
## 15  2020 Aewol Port           27730         30     924.
## 16  2020 Jeju Port            65890         23.5  2804.
```

It looks like they collect marine debris in these various ports in turn, once a few years. Particularly, they've routinely collected marine debris from Chooja, Jeju, and Seoguipo ports every 3 years.

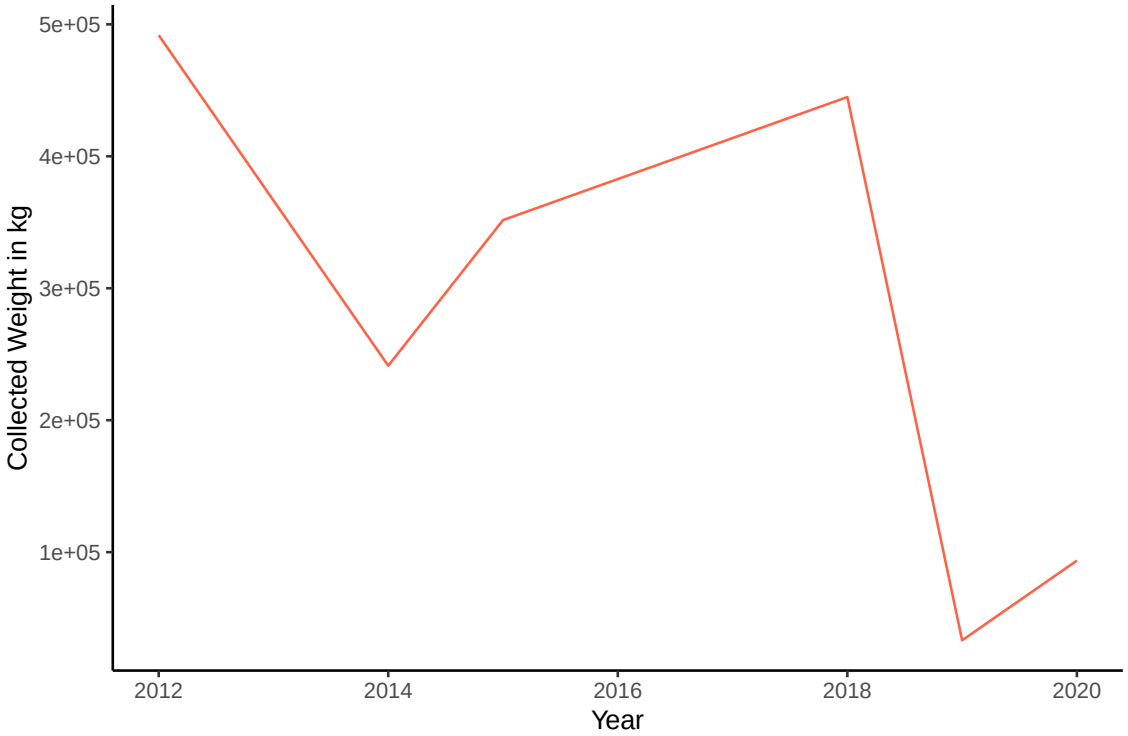


Figure4. The Amount of Marine−Waste Collected

The amount of marine waste they collect has severely decreased in recent years.

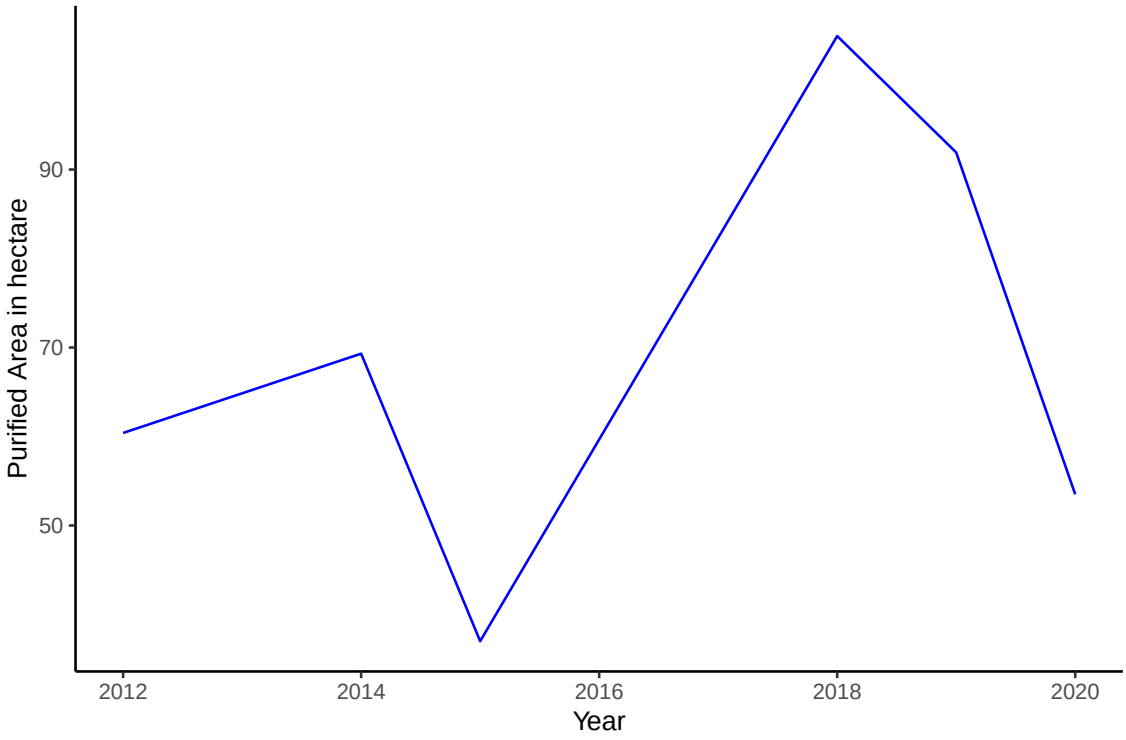


Figure5. The Area Purified

The area they purified decreased in recent years as well.

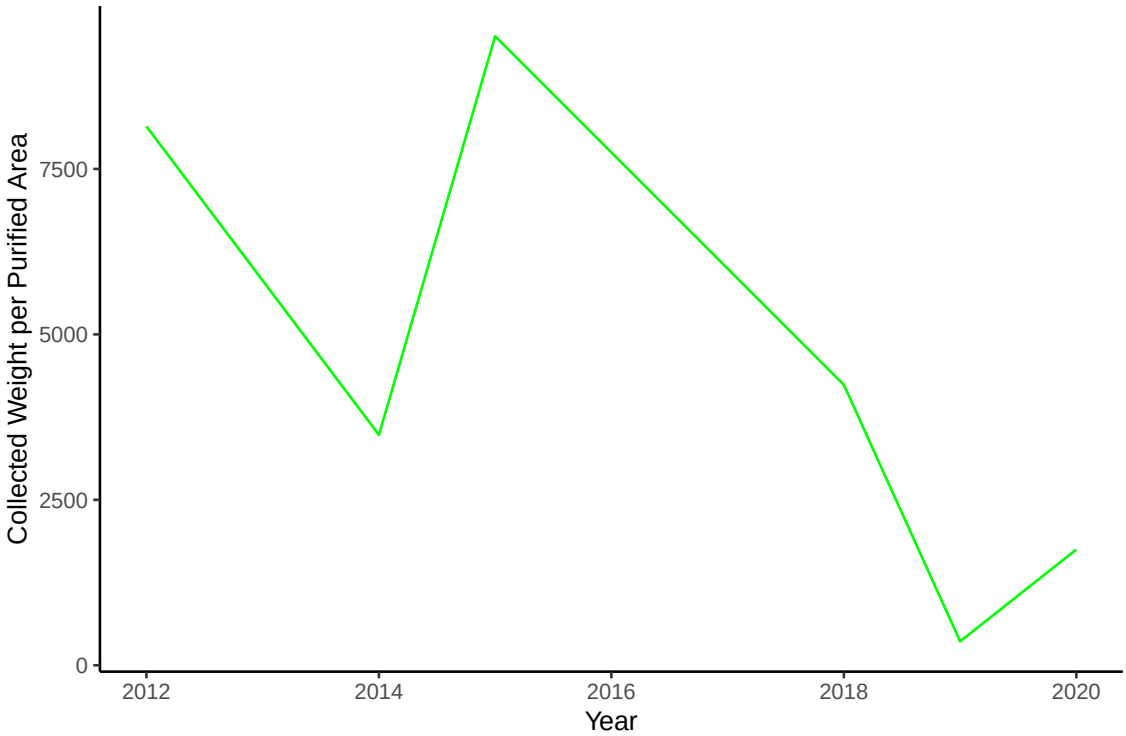


Figure6. The Amount of Marine−Waste Collected per Purified Area

The amount of waste collected in each purified area decreased accordingly.

Evaluating Marine-Cleansing Effort

Plan vs Actual

- Every year for each port, they set a goal of how much of marine waste Korea Marine Environment Management Corporation will collect and of how many hectare they will cleanse. I will find out how well the actual cleansing effort satisfies the plan.

```
##    Year       Jeju_Ports Planned_Weight_kg Actual_Weight_kg
## 1  2012      Chooja Port             55000           120600
## 2  2012        Jeju Port            115000           172100
## 3  2012    Seoguipo Port            118000           199100
## 4  2014      Hanlim Port            172000           202870
## 5  2014     Sungsan Port             24000            38440
## 6  2015      Chooja Port             34000            55440
## 7  2015        Jeju Port             61000            74120
## 8  2015    Seoguipo Port             64000           222120
## 9  2018      Chooja Port             45840            45840
## 10 2018      Hanlim Port            115820           115820
## 11 2018        Jeju Port            108210           108300
## 12 2018    Seoguipo Port            176300           174960
## 13 2019 Hanlim Port Area             25200            30980
## 14 2019     Moonsum Area              2210             2210
## 15 2020       Aewol Port             20000            27730
## 16 2020        Jeju Port             96400            65890
##    Achieved_Weight_rate Planned_Area_hectare Actual_Area_hectare
## 1             2.1927273                12.10               12.10
## 2             1.4965217                34.40               34.40
## 3             1.6872881                13.90               13.90
## 4             1.1794767                30.61               30.61
## 5             1.6016667                38.70               38.70
## 6             1.6305882                12.00               12.00
## 7             1.2150820                 9.20                9.20
## 8             3.4706250                15.80               15.80
## 9             1.0000000                29.30               26.30
## 10            1.0000000                31.00               30.80
## 11            1.0008317                31.00               31.10
## 12            0.9923993                16.80               16.80
## 13            1.2293651                30.80               21.50
## 14            1.0000000                70.00               70.42
## 15            1.3865000                30.00               30.00
## 16            0.6835062                24.40               23.50
##    Achieved_Area_rate
## 1           1.0000000
## 2           1.0000000
## 3           1.0000000
## 4           1.0000000
## 5           1.0000000
## 6           1.0000000
## 7           1.0000000
## 8           1.0000000
## 9           0.8976109
## 10          0.9935484
## 11          1.0032258
## 12          1.0000000
## 13          0.6980519
## 14          1.0060000
## 15          1.0000000
## 16          0.9631148
```

“Planned_Weight_kg”: The goal of marine waste in kg they set to collect
“Actual_Weight_kg”: The actual amount of marine waste they collected.
“Achieved_Weight_rate”: The rate they achieved (Actual_Weight_kg divided by Planned_Weight_kg) with 1 being 100%. For example, for the 1st row, Chooja Port achieved 220% of planned weight in kg in 2012 as their goal was 55000kg and actual collection was 120600kg.

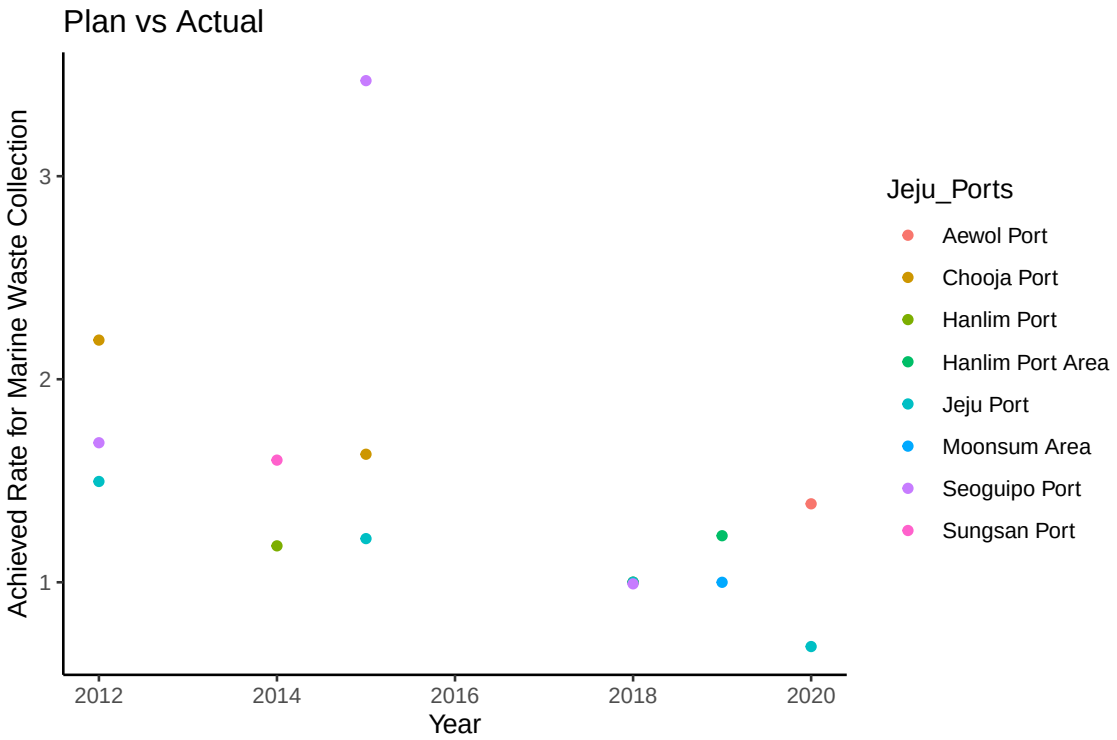


Figure7. Plan vs Actual in terms of Marine−Waste Collection

Most ports every year achieved somewhere between 100% and 350% of what they planned except Jeju port in 2020 which is about 70%.

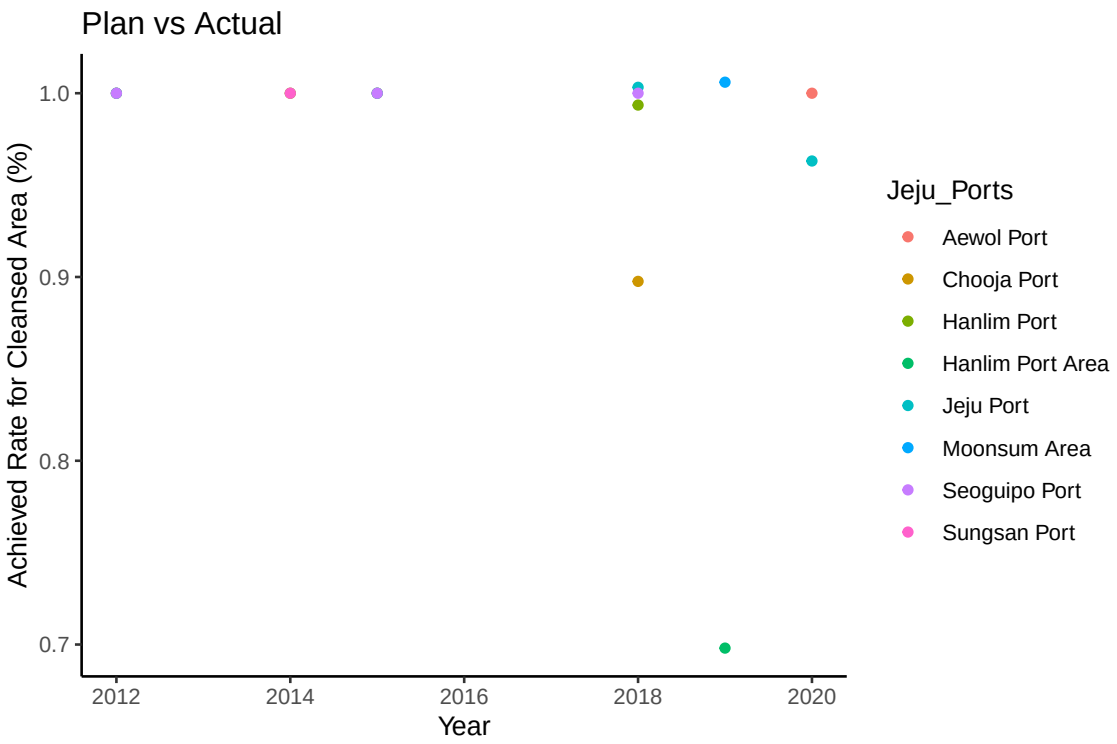


Figure8. Plan vs Actual in terms of Area Cleansed

For this 2nd plot, which represents the area in hectare cleansed, most of the ports achieved 100% of their plan except Chooja and Hanlim ports in 2018 and 2019 respectively (90% and 70%).

```
##   Year Planned_Weight_kg Actual_Weight_kg Achieved_Weight_rate
## 1 2012            288000           491800            1.7076389
## 2 2014            196000           241310            1.2311735
## 3 2015            159000           351680            2.2118239
## 4 2018            446170           444920            0.9971984
## 5 2019             27410            33190            1.2108719
## 6 2020            116400            93620            0.8042955
##   Planned_Area_hectare Actual_Area_hectare Achieved_Area_rate
## 1                60.40                60.40          1.0000000
## 2                69.31                69.31          1.0000000
## 3                37.00                37.00          1.0000000
## 4               108.10               105.00          0.9713228
## 5               100.80                91.92          0.9119048
## 6                54.40                53.50          0.9834559
```

Now, instead of comparing the cleansing effort for each port individually, all of the ports' waste collection and cleansing plans are summed up to entirely compare against that of actuals each year.

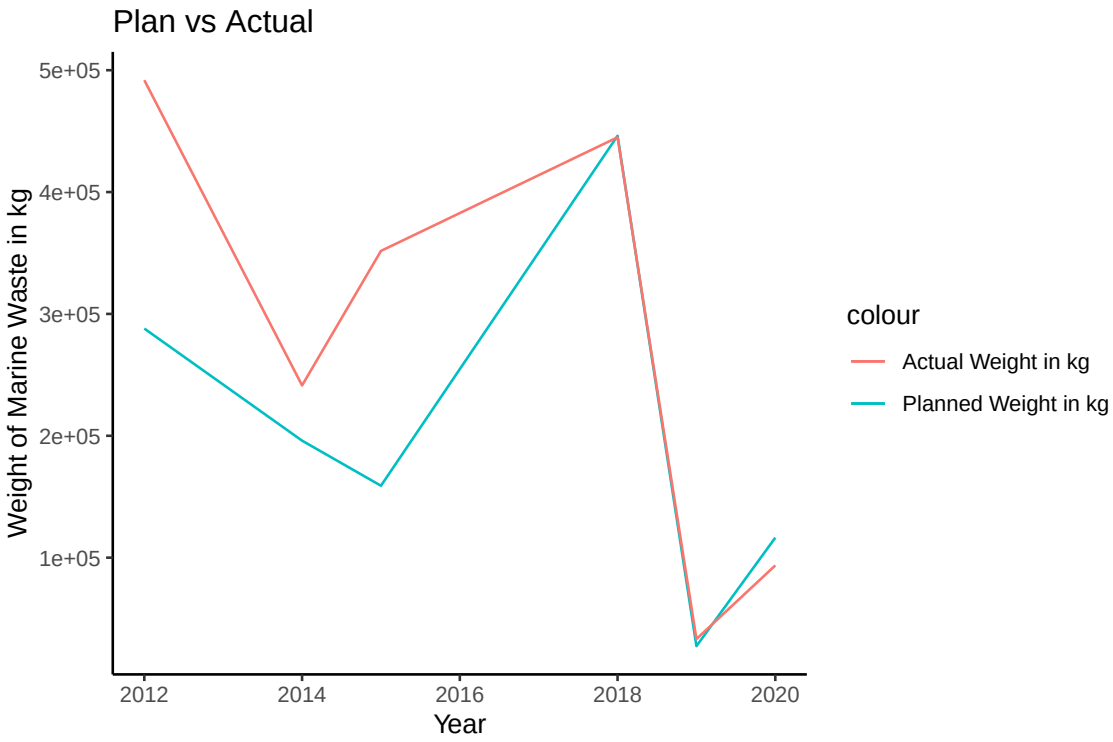


Figure9. Plan vs Actual (Weight of Marine Waste)

For this 1st graph, the planned-weight line is far below the actual-weight line until 2018, meaning the Korea Marine Environment Management Corporation collected more marine waste than the goal they set (achieving more than 100 percent of the goal). For the rest years, the 2 lines are quite close together, meaning the goal is being met quite closely (achieving about 100 percent of the goal).

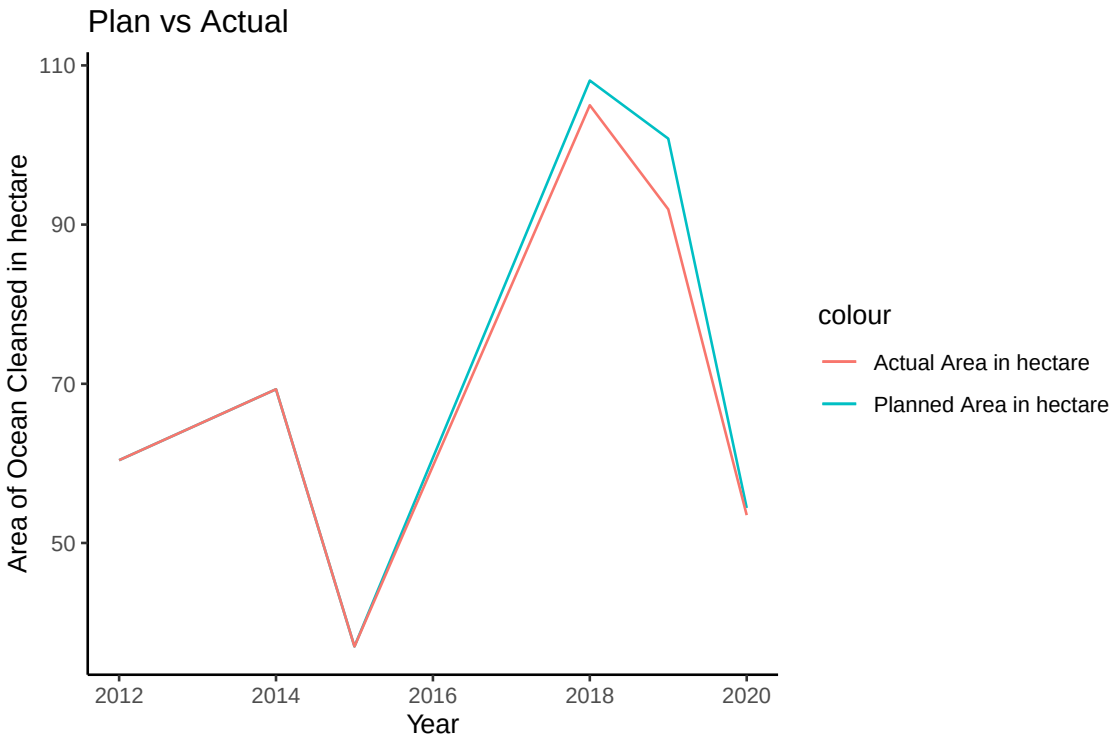


Figure10. Plan vs Actual (Area Cleansed)

For this 2nd graph, the planned-area and the actual-area lines are very close together. So, on the surface, the cleansing effort seems to be quite successful in meeting the goal.

However, I am not very convinced that they are doing a great job because "Figure4. The Amount of Marine-Waste Collected" shows that the amount of collection and the area of purification have severely decreased in recent years (since 2018). It seems like they have lowered their goal standard, collect less amount, and then claim they successfully achieved the goal. The meaning of achieving 100 percent or more of the plan fades away when the goal standard is severely lowered.

Did people actually discarded less amount of waste in 2019 and 2020?

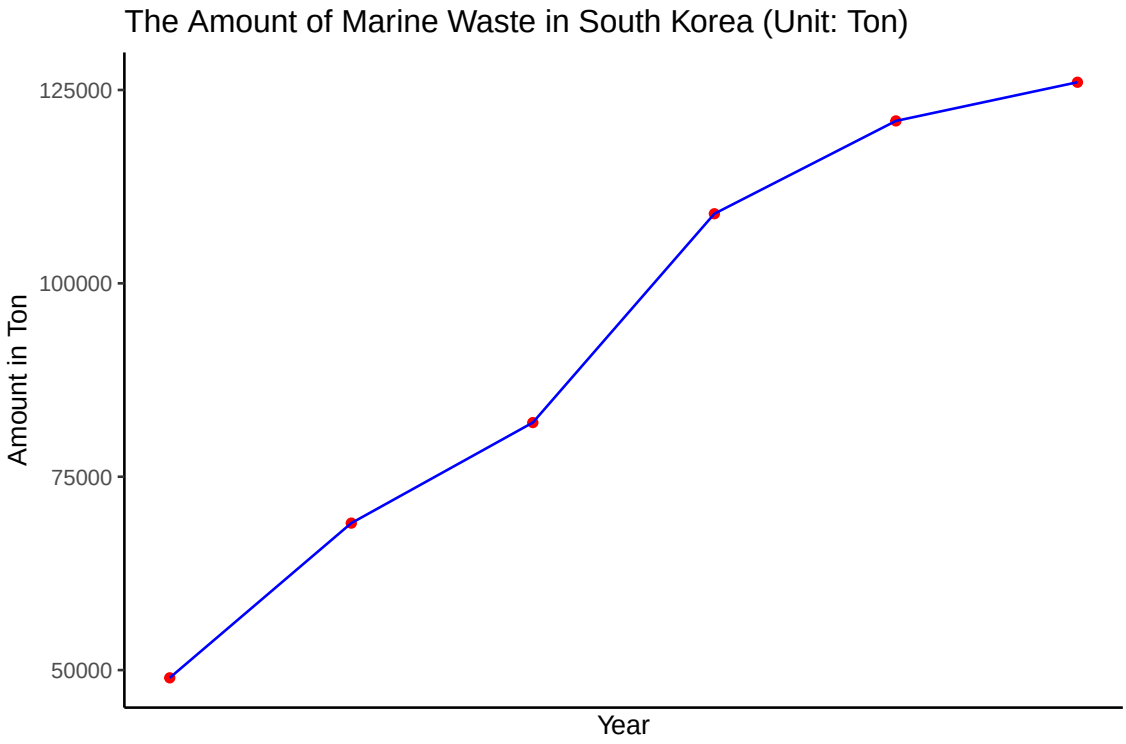


Figure11. The Amount of Marine Waste in South Korea (Unit: Ton)

(Source: Marine Environment Information Portal)

As you can see from "Figure11. The Amount of Marine Waste in South Korea (Unit: Ton)," the annual marine-waste amount rather has increased every year, beginning with 49,000 tons in 2013 to 126,000 tons in 2022. According to the Ministry of Oceans and Fisheries, Jeju island's marine waste accounts for 20 percent of the total marine waste in Korea which is the highest among all. Therefore, it is hard to believe that the marine waste in Jeju island has decreased in 2019 and 2020.

Then why did the amount of waste collection severely decreased in 2019 and 2020? I conducted research and found out that their budget for marine waste collection has significantly decreased. According to Jeju Ilbo, a major newspaper in Jeju, their budget for marine-waste collection in 2015, 2016, 2017, and 2018 were, in USD, 2.5M, 3.5M, 6.1M, and 6.4M, respectively.

However, in 2019, the budget decreased to 4.2M. With the significant decrease in budget, I believe it would have been difficult for the organization to pull sufficient labor and equipment to collect the ever-increasing marine waste. This is a critical problem.

(3) Sea-Water-Quality Analysis

- I will use a measurement data of marine environment provided by Jeju Special Self-Governing Province
- Source of data: https://www.data.go.kr/data/15110786/fileData.do (public data portal run by Ministry of Public Administration and Security of South Korea)
- I will examine the sea-water quality of each port in Jeju and compare them with the analysis result of marine waste in section (2), "More Locations to Examine," above. In order to do this, I will clean sea-water-quality data to be as close as to the port data I used in section (2). Excluding the years that the port data does not have would be an example.

Data Exploration

Basic

```
##    MeasurementDate              Port Latitude Longitude         Weather
## 1       2014-02-05     Jeju Port H01 33.52611  126.5400 A Little Cloudy
## 3       2014-02-05     Jeju Port H02 33.52722  126.5306 A Little Cloudy
## 5       2014-02-06 Seoguipo Port H01 33.23639  126.5653 A Little Cloudy
## 7       2014-02-06 Seoguipo Port H02 33.24028  126.5600 A Little Cloudy
## 9       2014-02-06   Hanlim Port H01 33.41556  126.2553 A Little Cloudy
## 11      2014-02-06   Hanlim Port H02 33.41806  126.2597 A Little Cloudy
##    WaterDepth Clarity WaterQualityindex Year YearMonth
## 1          14     6.2                 2 2014   2014-02
## 3           6     3.6                 3 2014   2014-02
## 5           7     6.5                 2 2014   2014-02
## 7           4     3.4                 4 2014   2014-02
## 9           8     7.0                 2 2014   2014-02
## 11          4     4.0                 3 2014   2014-02
```

Water Quality Index (WQI): It classifies the quality of sea water in 5 levels with 1 being excellent and 5 being very poor.

The data is comprised of 60 rows and 11 variables.

```
## $MeasurementDate
##  [1] "2014-02-05" "2014-02-06" "2014-08-13" "2015-02-10" "2015-02-11"
##  [6] "2015-08-20" "2018-02-25" "2018-08-30" "2019-02-27" "2019-02-28"
## [11] "2019-08-13" "2020-02-19" "2020-02-20" "2020-08-19"
##
## $Port
## [1] "Jeju Port H01"     "Jeju Port H02"     "Seoguipo Port H01"
## [4] "Seoguipo Port H02" "Hanlim Port H01"   "Hanlim Port H02"
##
## $Latitude
## [1] 33.52611 33.52722 33.23639 33.24028 33.41556 33.41806
##
## $Longitude
## [1] 126.5400 126.5306 126.5653 126.5600 126.2553 126.2597
##
## $Weather
## [1] "A Little Cloudy" "Sunny"           "Cloudy"
##
## $WaterDepth
##  [1] 14  6  7  4  8 17  2 15  5 20 18 13  3  9
##
```

```
## $Clarity
##  [1]  6.2  3.6  6.5  3.4  7.0  4.0  7.5  2.0  9.0  5.0  6.0  1.5  3.5  5.5  3.0
## [16]  2.5  4.3 10.0  4.5  4.2  2.7  1.6  0.4  1.4  2.1  1.8  7.7  5.7  1.7  4.7
## [31]  2.4  2.3 10.5  3.2  2.8  8.7  2.2  1.2
##
## $WaterQualityindex
## [1] 2 3 4 1
##
## $Year
## [1] "2014" "2015" "2018" "2019" "2020"
##
## $YearMonth
##  [1] "2014-02" "2014-08" "2015-02" "2015-08" "2018-02" "2018-08" "2019-02"
##  [8] "2019-08" "2020-02" "2020-08"
```

Unfortunately, the data does not contain year 2012. And the data only has 3 ports while dfport has 8 ports. I will use the overlapping years and ports from both data.

Jeju Port: Comparing Water Quality Index (WQI) and Marine Waste Collected

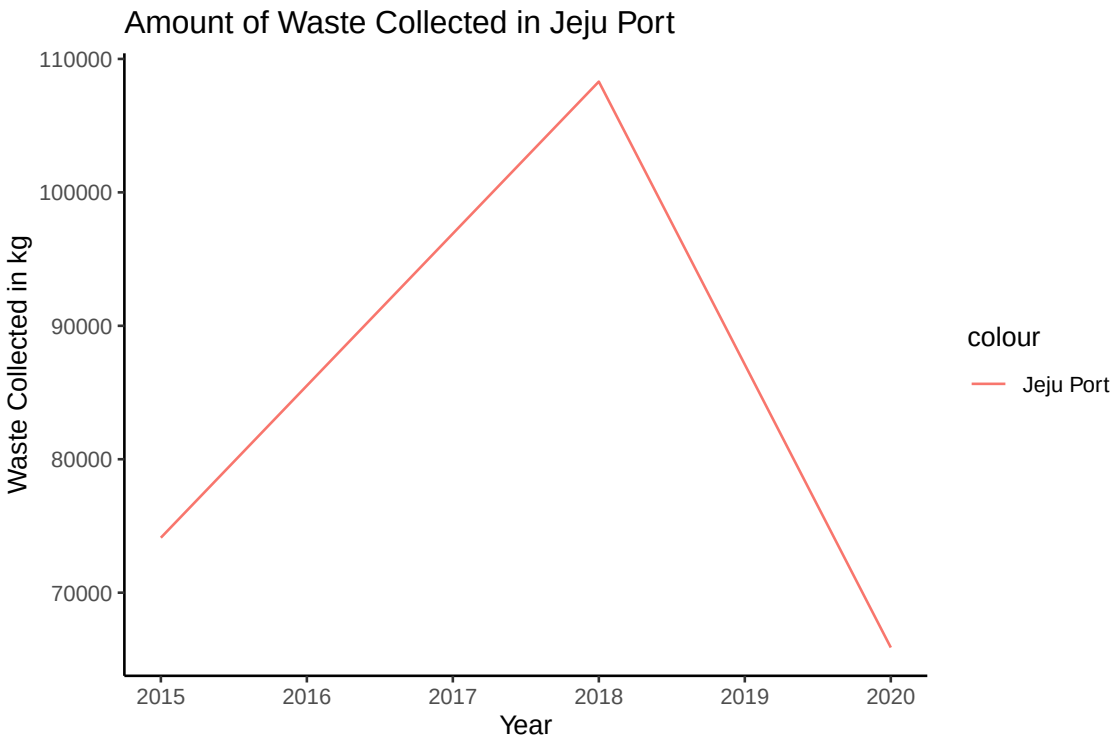


Figure12. Amount of Waste Collected in Jeju Port

The amount of marine waste collected peaked in 2018 followed by decline through 2020.

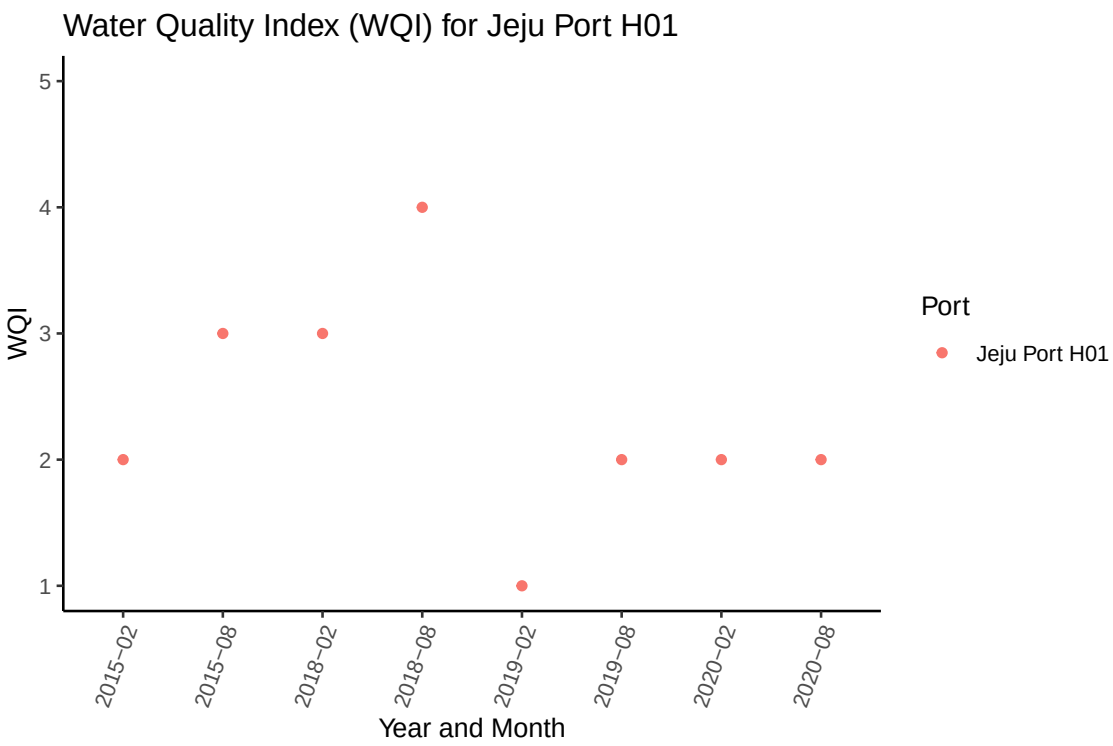


Figure13. WQI for Jeju Port H01

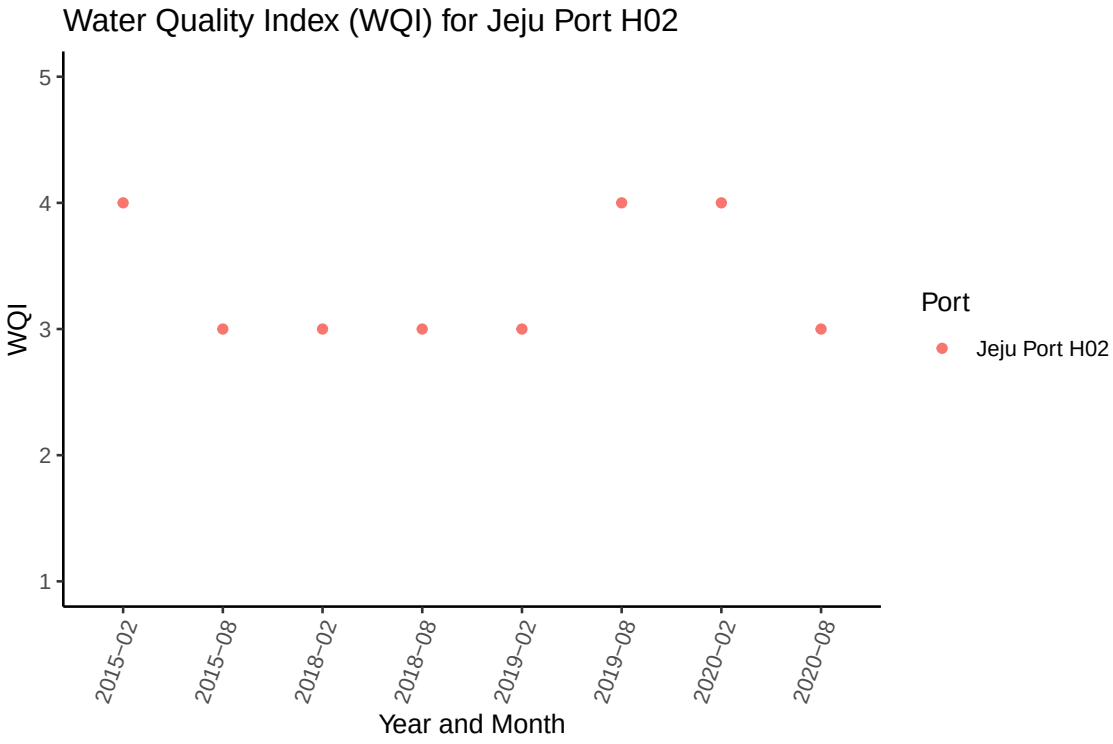


Figure14. WQI for Jeju Port H02

However, the WQI in Jeju Port H01 and H02 in 2018 did not improve. WQI in Jeju Port H01 rather increased from 2 to 4 which is very poor grade, and WQI in Jeju Port H02 stayed the same at 3. 4 and 3 are quite poor grades. In 2019, Jeju port H01 showed the best WQI of 1, and then 2 in the following years. Perhaps the effects of marine-waste collection possibly appear in the later years, or the water is influenced by other factors such as waste water released from a factory nearby. Still, the relationship between the amount of marine waste collected and WQI does not look very strong.

Seoguipo Port: Comparing Water Quality Index (WQI) and Marine Waste Collected

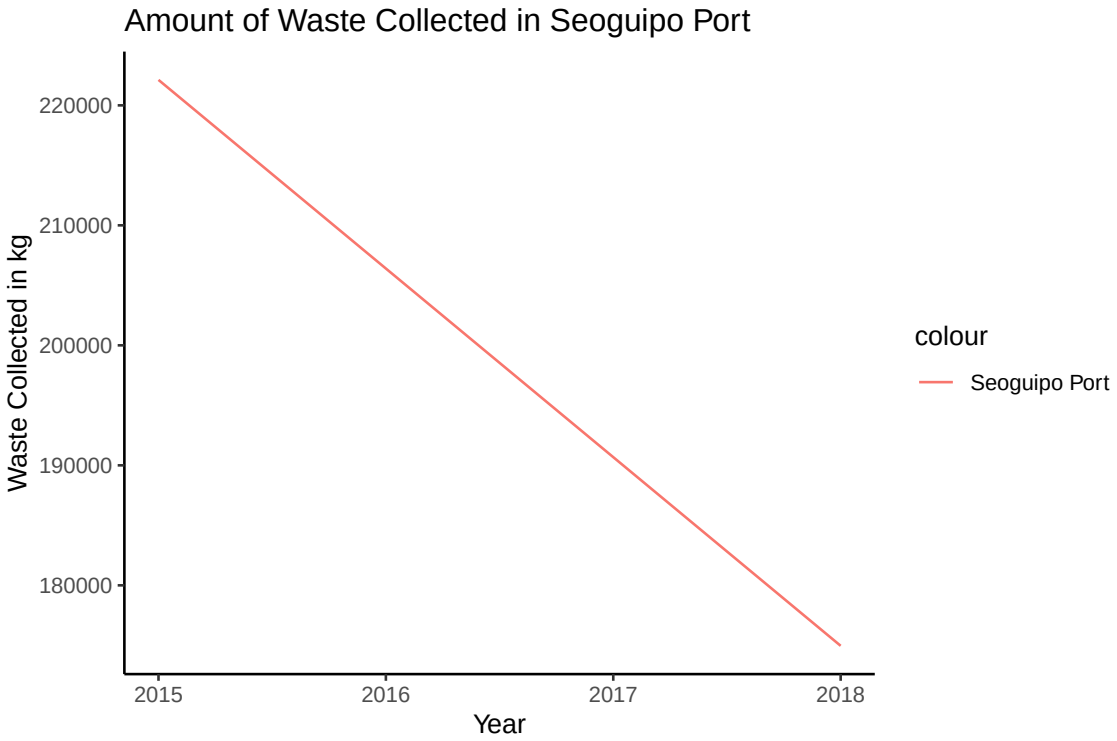


Figure15. Amount of Waste Collected in Seoguipo Port

The collection of marine waste declined from 2015 through 2018.

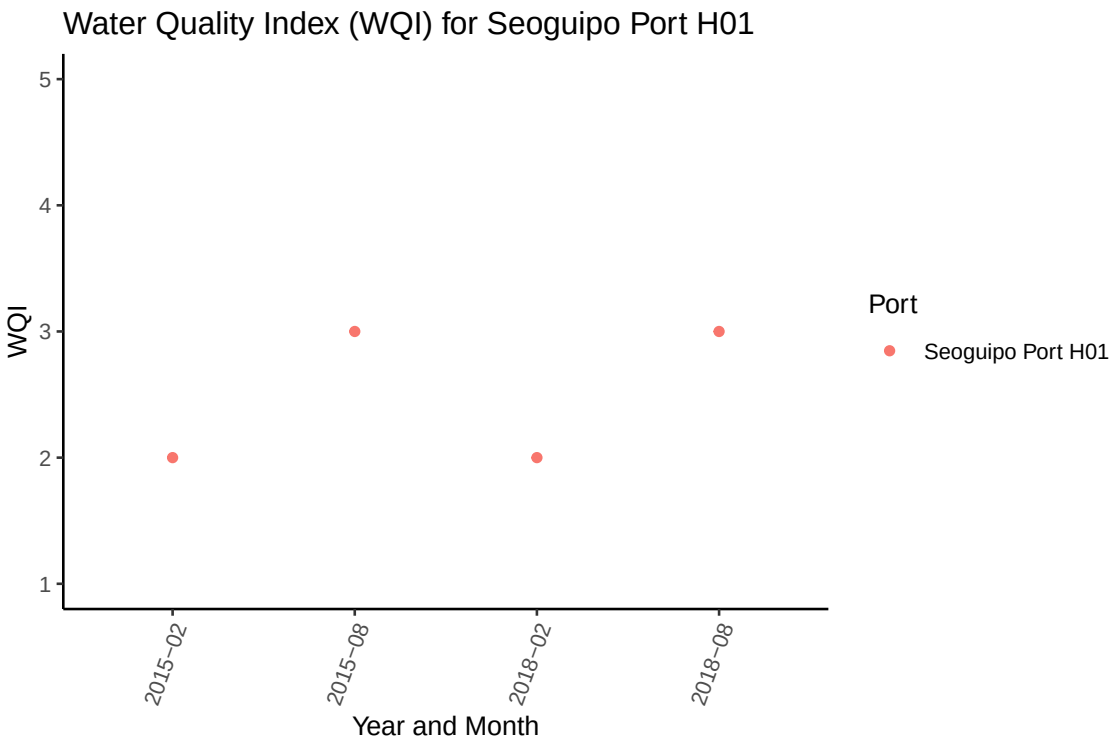


Figure16. WQI for Seoguipo Port H01

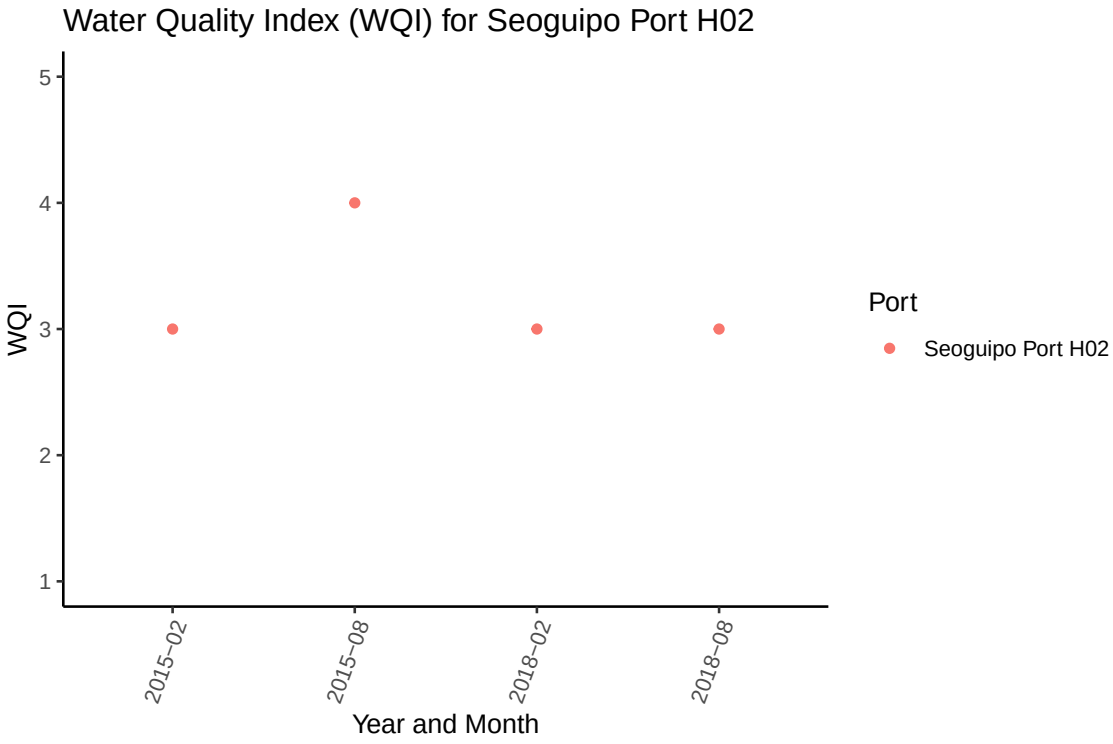


Figure17. WQI for Seoguipo Port H02

WQI for both H01 and H02 generally maintained around 3 throughout all years. It is hard to tell that the amount of marine waste collection and WQI are highly correlated.

Hanlim Port: Comparing Water Quality Index (WQI) and Marine Waste Collected

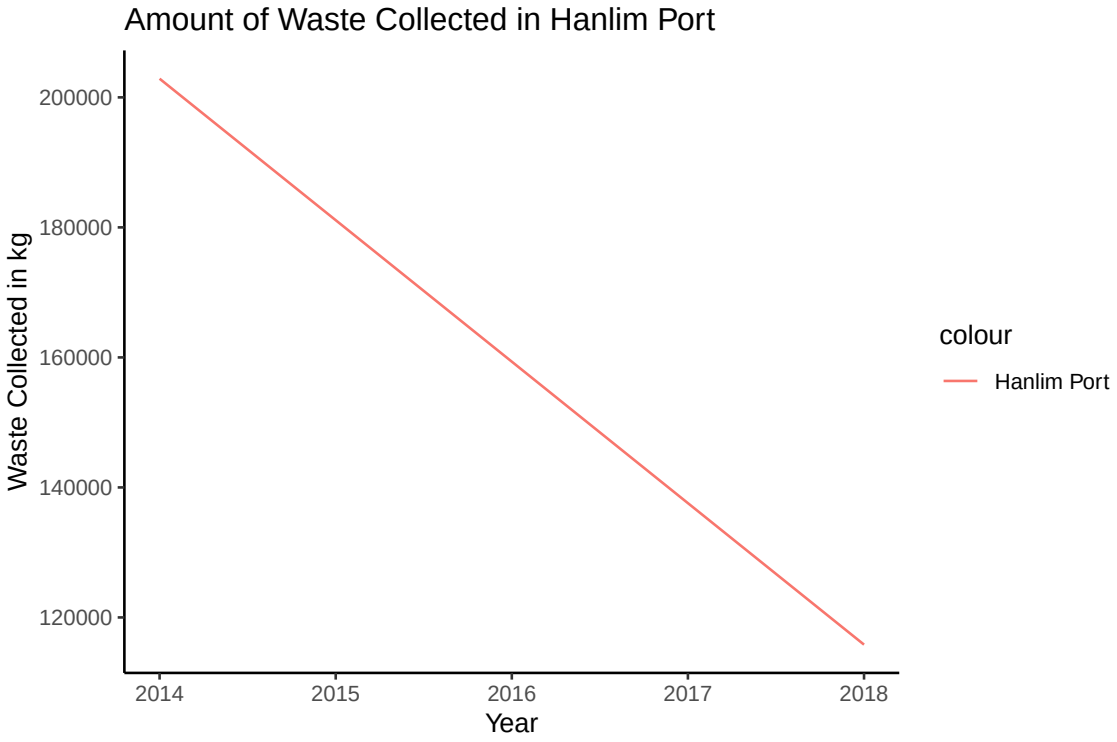


Figure18. Amount of Waste Collected in Hanlim Port

The collection amount in Hanlim port constantly decreased from 2014 through 2018.

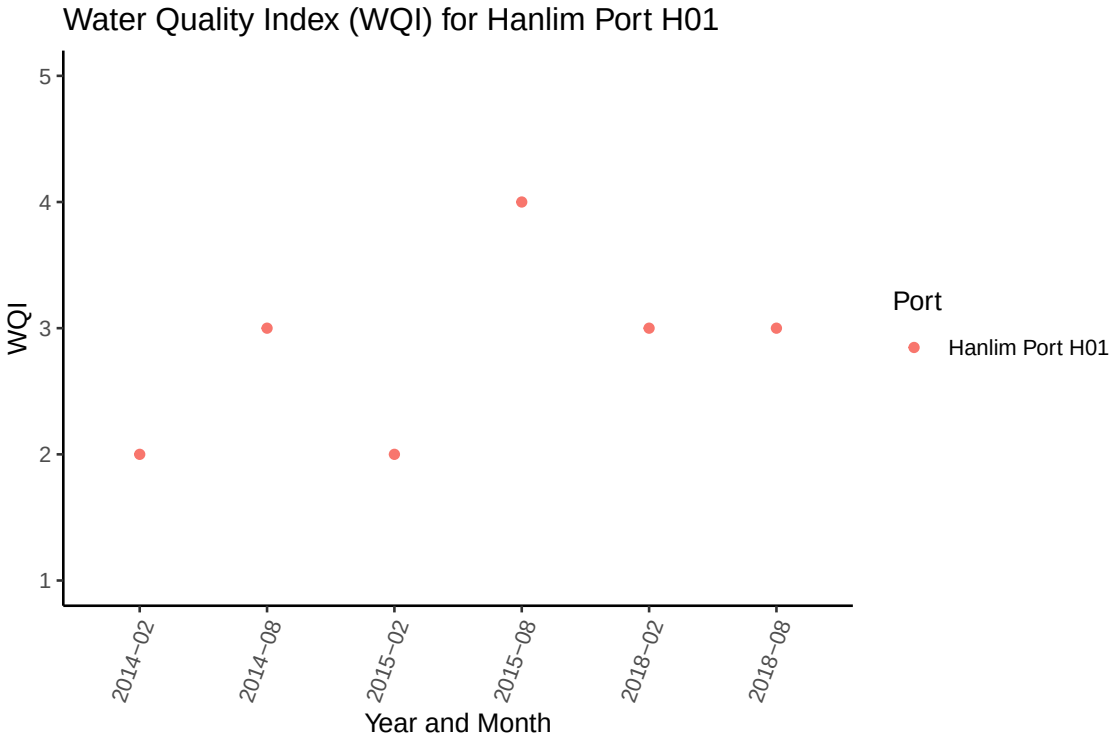


Figure19. WQI for Hanlim Port H01

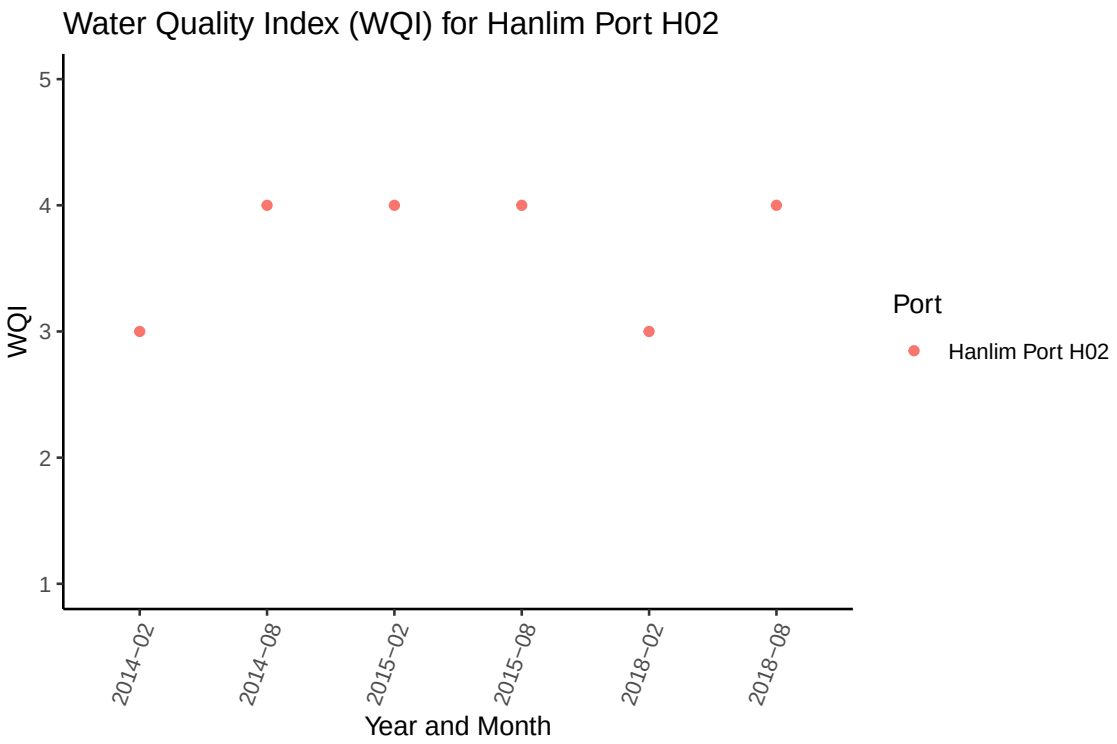


Figure20. WQI for Hanlim Port H02

As the amount of marine waste collected decreases, WQI in Hanlim port H01 went from 2 in 2014 to 4 and then 3 through year 2018. For Hanlim port H02, WQI did not change much, maintaining around 3 and 4.

According to my WQI analysis, it is hard to establish any strong relationship between the amount of marine waste collected and WQI. Indeed, there are many other factors that affect WQI of sea water around Jeju island such as waste water from factories nearby or oil leakage from oil tanker ships. More data regarding ocean contamination in Jeju and further investigation would be required.

Reaching a Solution

- To devise a solution, I need more evidence and need to make the following assumptions:

Assumption (1): Since 70% of marine debris comes from the land by typhoon, gale, and heavy rain, the debris would not be too heavy. For example, construction waste such as a chunk of bricks and cement would not be appropriate.

Assumption (2): Since Jeju island's main industry is tourism & service, the major source of trash would be from dwellers, tourists, and travel related businesses such as restaurants.

Evidence 1: The increasing amount of inland trash

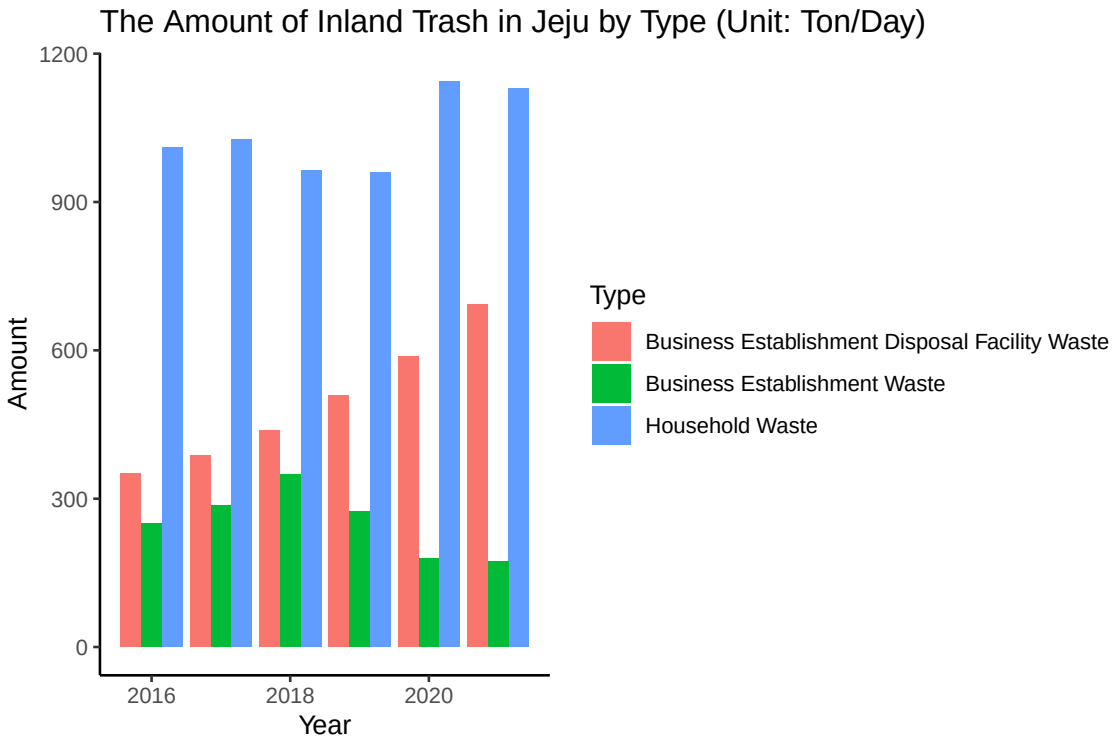


Figure21. The Amount of Inland Trash in Jeju by Type

Daily waste in Jeju inland is increasing. Although business sites' waste decreased since 2019, the daily waste from households and businesse disposal facilities constantly increase over time.

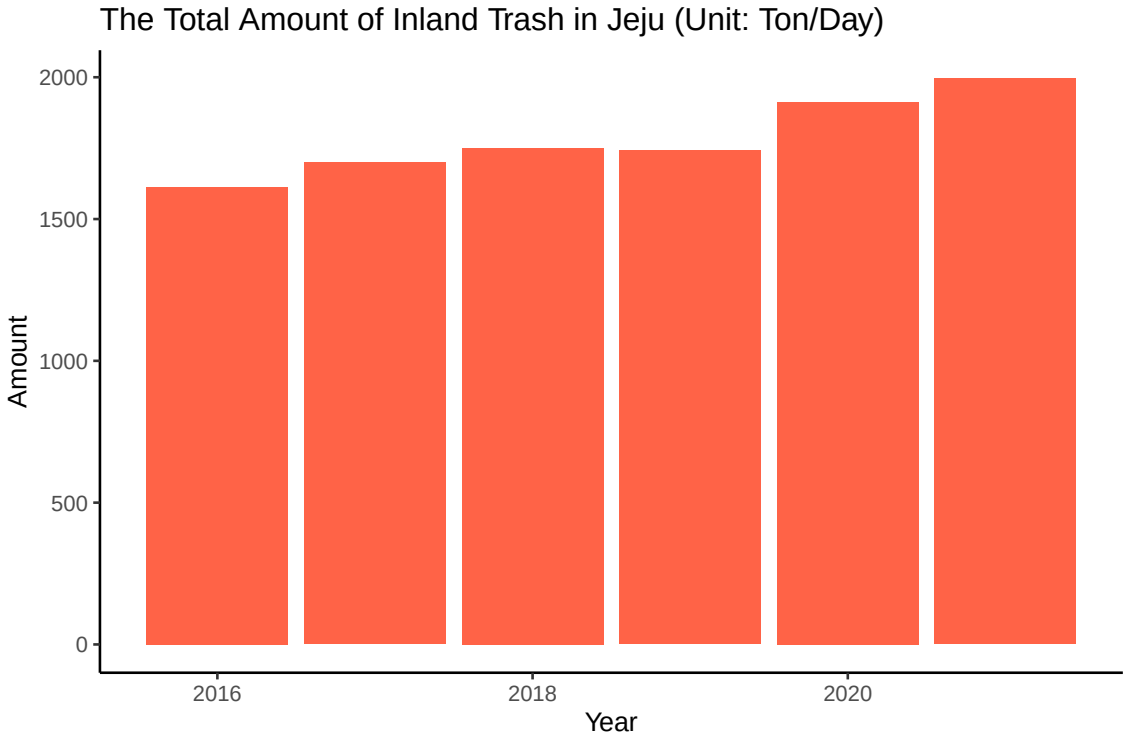


Figure22. The Total Amount of Inland Trash in Jeju (Ton/Day)

When combined altogether, the total daily waste from the inland is constantly increasing.

Evidence 2: The number of tourists are increasing

- The tourists are increasingly visiting Jeju island

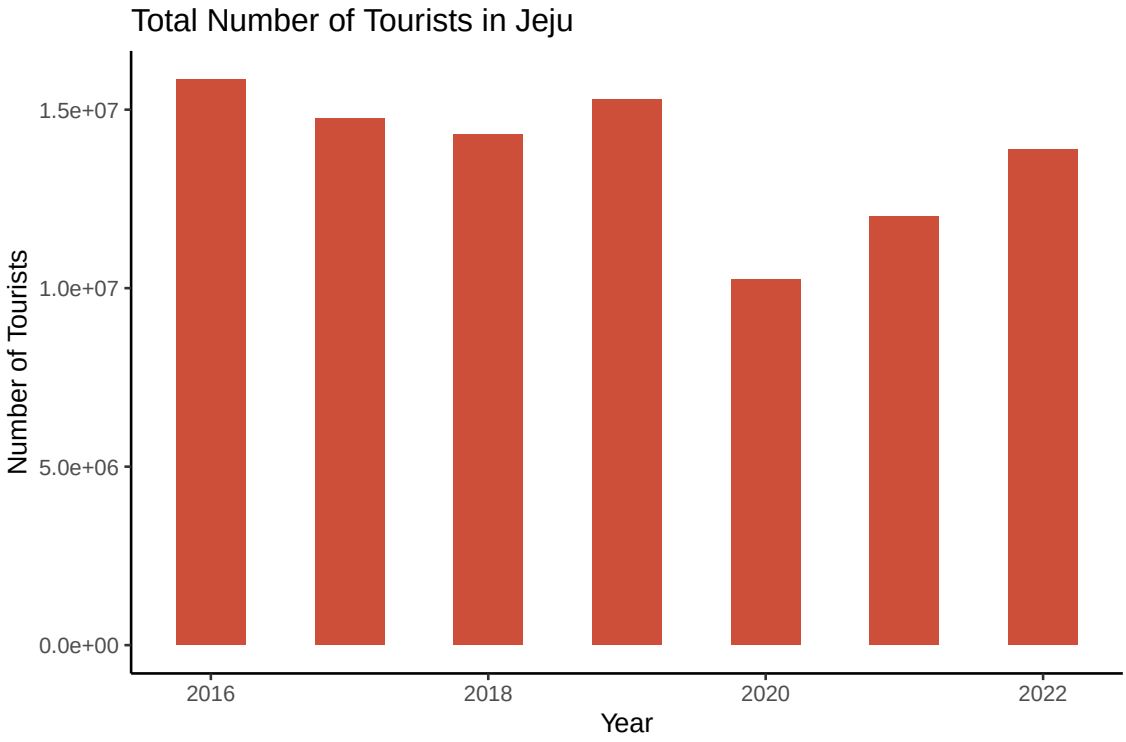


Figure23. Total Number of Tourists in Jeju

Since the tourism was hit by COVID-19, the demand for tourism decreased in 2020. Since then, the total number of tourists are picking up again. It is probable that more waste would be disposed if more tourists are visiting.

Evidence 3: More people are using restaurants

- The number of restaurant users are increasing

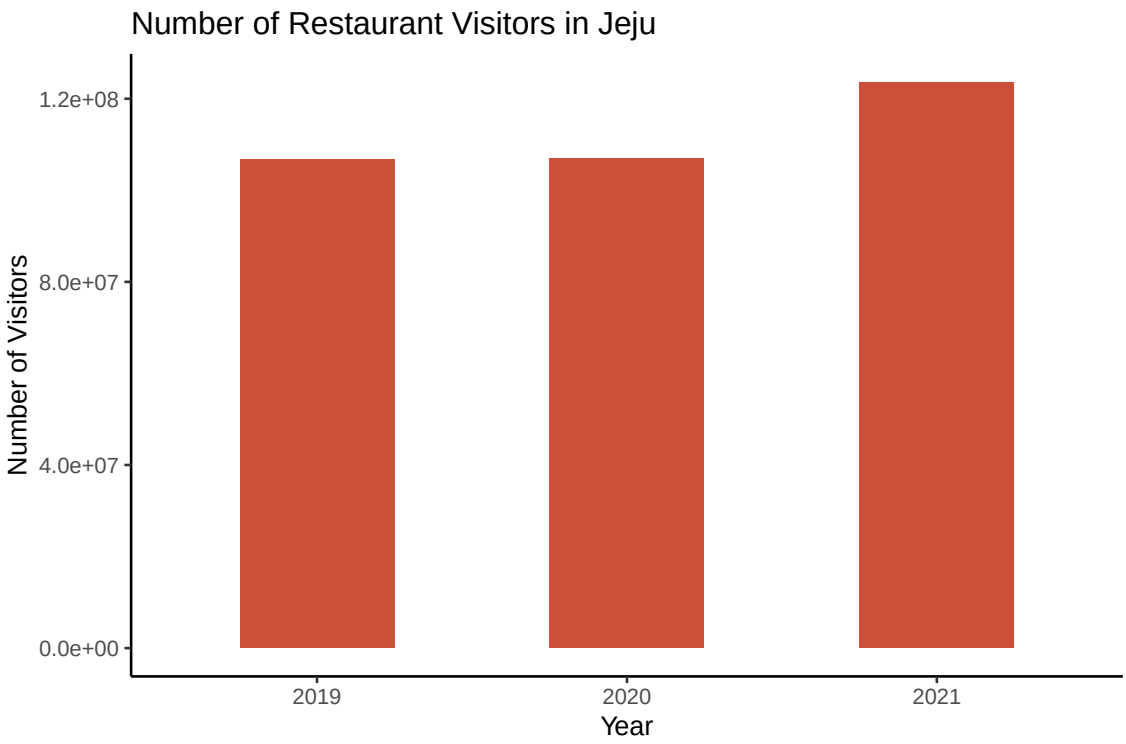


Figure24. Number of Restaurant Visitors in Jeju

More people are visiting restaurants which will lead to more waste.

The 3 evidences above support the amount of inland waste in Jeju is highly probable to increase significantly.

And again, as stated above, 70 percent of the inland waste will go to the sea around Jeju island. Yet, Korea Marine Environment Corporation's budget for marine-waste collection had decreased along with the amount of marine waste they collect. To make matters worse, Jeju special self-government's budget for inland trash disposal has decreased as well.

Korea Marine Environment Corporation's budget for marine-waste collection

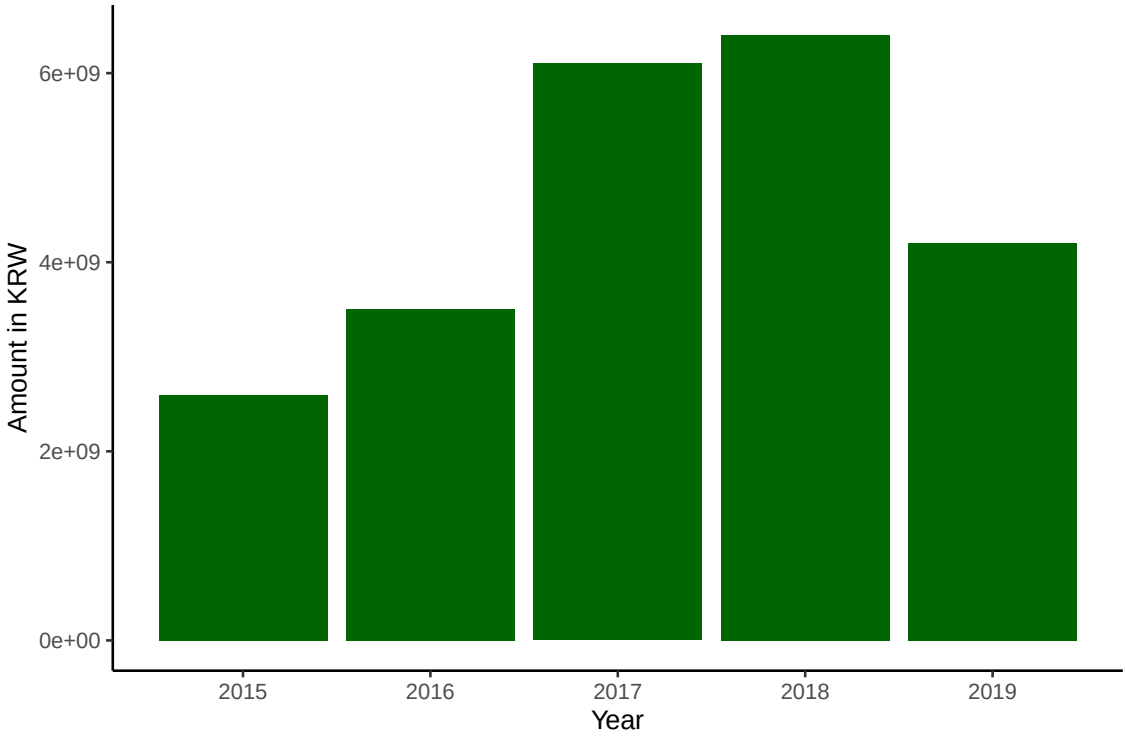


Figure25. Korea Marine Environment Corporation's Budget for Marine−Waste Collection

Jeju special self-government's budget for inland trash disposal

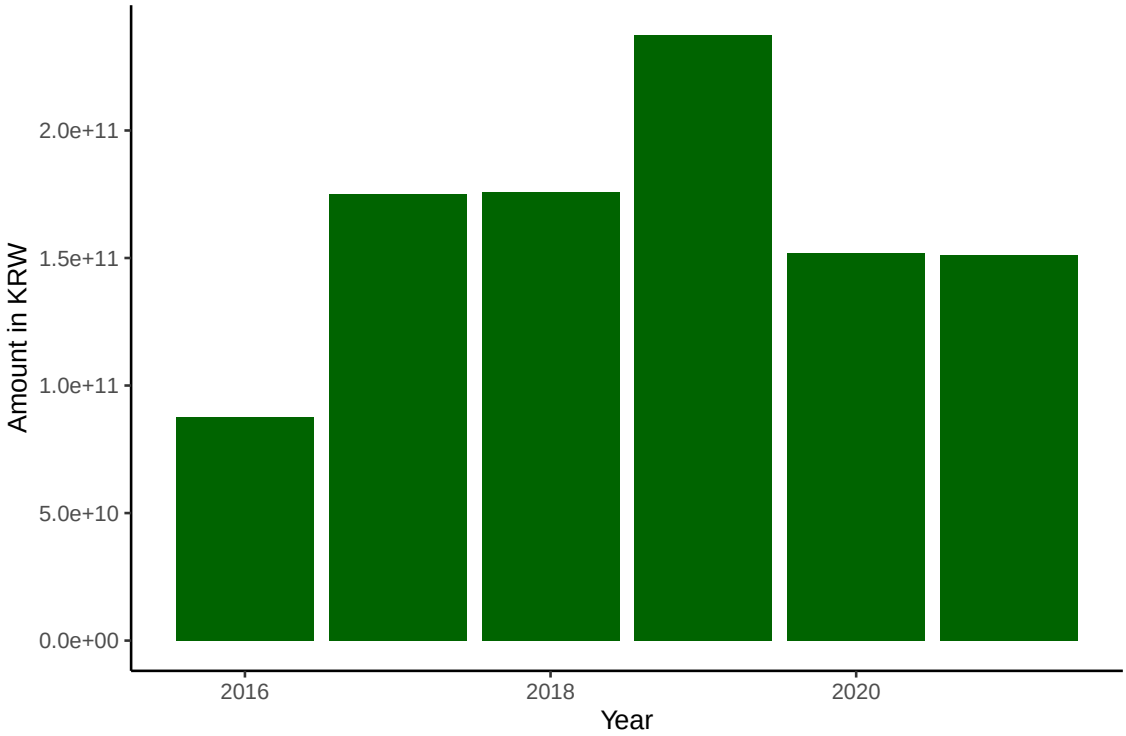


Figure26. Jeju Special Self−Government's Budget for Inland Trash Disposal

Factors to Consider for a Solution

- Factor 1: The main source of marine waste is inland waste.
- Factor 2: The budget for waste collection & process is decreasing

Ultimately, there is an immediate need for a solution that can efficiently manage the inland waste that is not highly costly so that it can work out within the decreasing budget and prevent the waste from traveling down to the sea.

And I believe the key is in understanding the weather's pattern. It is worth stressing again that 70 percent of marine debris comes from the inland trash, carried by downpour, gale, and typhoon to the ocean.

Precipitation in Jeju

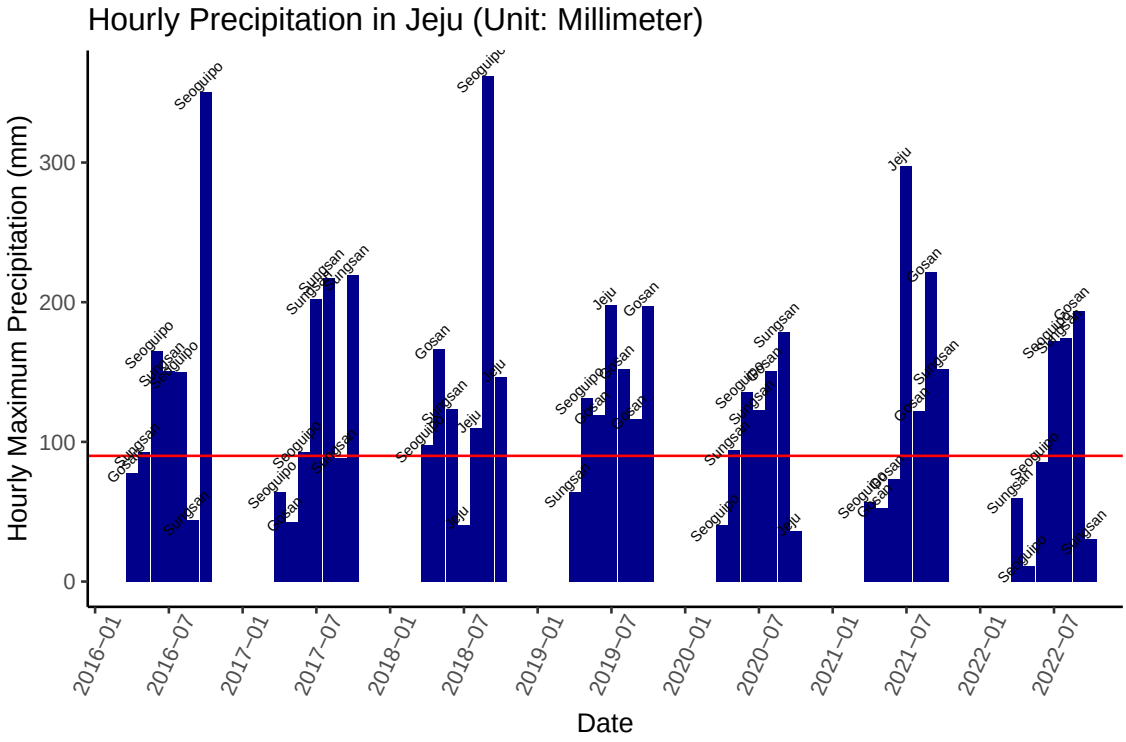


Figure27. Hourly Precipitation in Jeju

This precipitation data originally contains hourly maximum amount of precipitation (in millimeters) for each year and month (the data does not contain information from January to March and from November to December).

Meanwhile, the criteria for downpour warning, according to Korea Meteorological Administration, is when the amount of precipitation for 3 hours is 90mm or more. Thus, I have multiplied the hourly maximum amount of precipitation by 3 to infer 3-hour maximum amount of precipitation.

Looking at the bar plot, any bar above the red line, which represents 90mm, signals warning for downpour or heavy rain.

In general, downpour is expected in June to October. The downpour is expected to occur in all areas: Sungsan, Gosan, Jeju city, and Seoguipo city.

Wind speed in Jeju

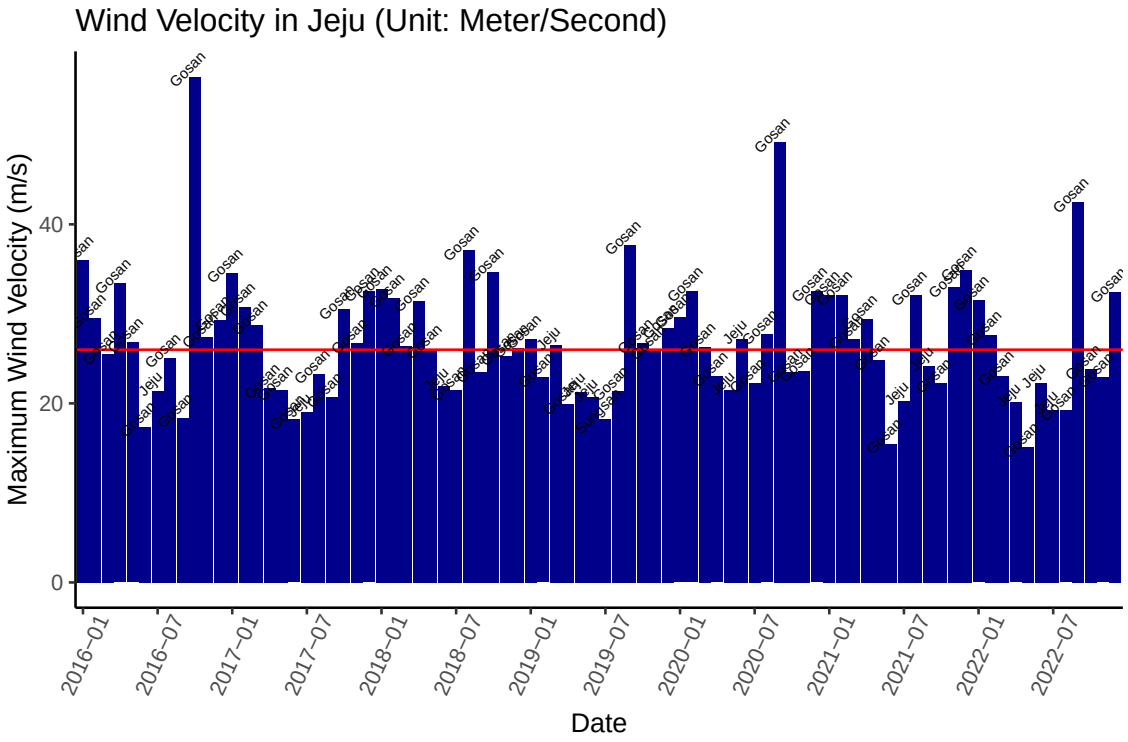


Figure28. Wind Velocity in Jeju

The definition for gale, according to Korea Meteorological Administration, is the winds exceeding a certain speed, leading to risks to human life and property damage, where the certain speed refers to wind velocity of 26 meters/second or above.

Looking at the plot, any bar above the red line represents wind velocity of 26 m/s or above, and they signal gale warning.

In general, gale is expected in September to October, and Gosan is the area in Jeju that is vulnerable to gale. In fact, all of the 16 bars above the red line were formed in Gosan.

(4) Conclusion

With my data analysis and investigation, I have revealed several critical problems associated with marine waste around Jeju island. Specifically,

- plastic is the main source of marine waste.
- 70% of marine waste comes from the land.

- in recent years, there were insufficient financial resources for Korea Marine Environment Management Corporation to cleanse the sea.

In order to devise a cost-efficient trash-management system, I believe we need to prepare in advance in accordance with the weather, namely downpour and gale because the main source of marine waste is inland trash, and the downpour and gale practically carry the inland trash over to the sea.

According to my data analysis, downpour is most expected in June to October throughout all 4 areas, and gale is most expected in September to October in Gosan area. Hence, prior to these seasons, I propose to install a temporary firm sold protection wall and covering around and on top of landfill that can withstand the downpour and gale during the seasons. As this will effectively prevent the trash flying or flowing down to the sea, the need for the budget for marine-waste collection would be much mitigated. Although there will be inital investment to be spent, the required budget for marine-waste collection afterwards would be much reduced.

In addition to these changes, the following actions would further help protect the sea around Jeju:

- to regulate the use of plastic. One example would be making people pay for plastic bags. Currently, plastic bags from small businesses are free of charge; the current government regulation that makes plastic bags not free of charge only applies to large businesses. Yet, too many businesses in Jeju island are small businesses. Hence, the government widen the scope of the regulation to include the small businesses in order to reduce the use of plastic bags. In addition, these small businesses dispose of their waste individually which makes the management of trash difficult. Making a public disposal sites for them would encourage an efficient management for waste collection.

- to promote the recycling of plastic by providing reward such as allowing less taxes for businesses that are associated with recycling, upcycling, or producing alternative materials to plastic that naturally decompose.

- And above all the promotions, regulations, and institutional arrangements, improving people's awareness to not litter any waste, to recycle well, and to protect the environment is important. Therefore, we must invest in educational campaigns to let people know how wrong the current situation is and teach them how they can contribute to protect the sea. Furthermore, disposing of waste in Korea is not simple. Trash must be separated in accordance with each type of trash. And there are specific plastic bags to be used for trash and food waste. People who visit the island, especially foreign tourists, may not know these rules and policies. The effort to let them know and make them notice should be made.

Citation

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Data Citation

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