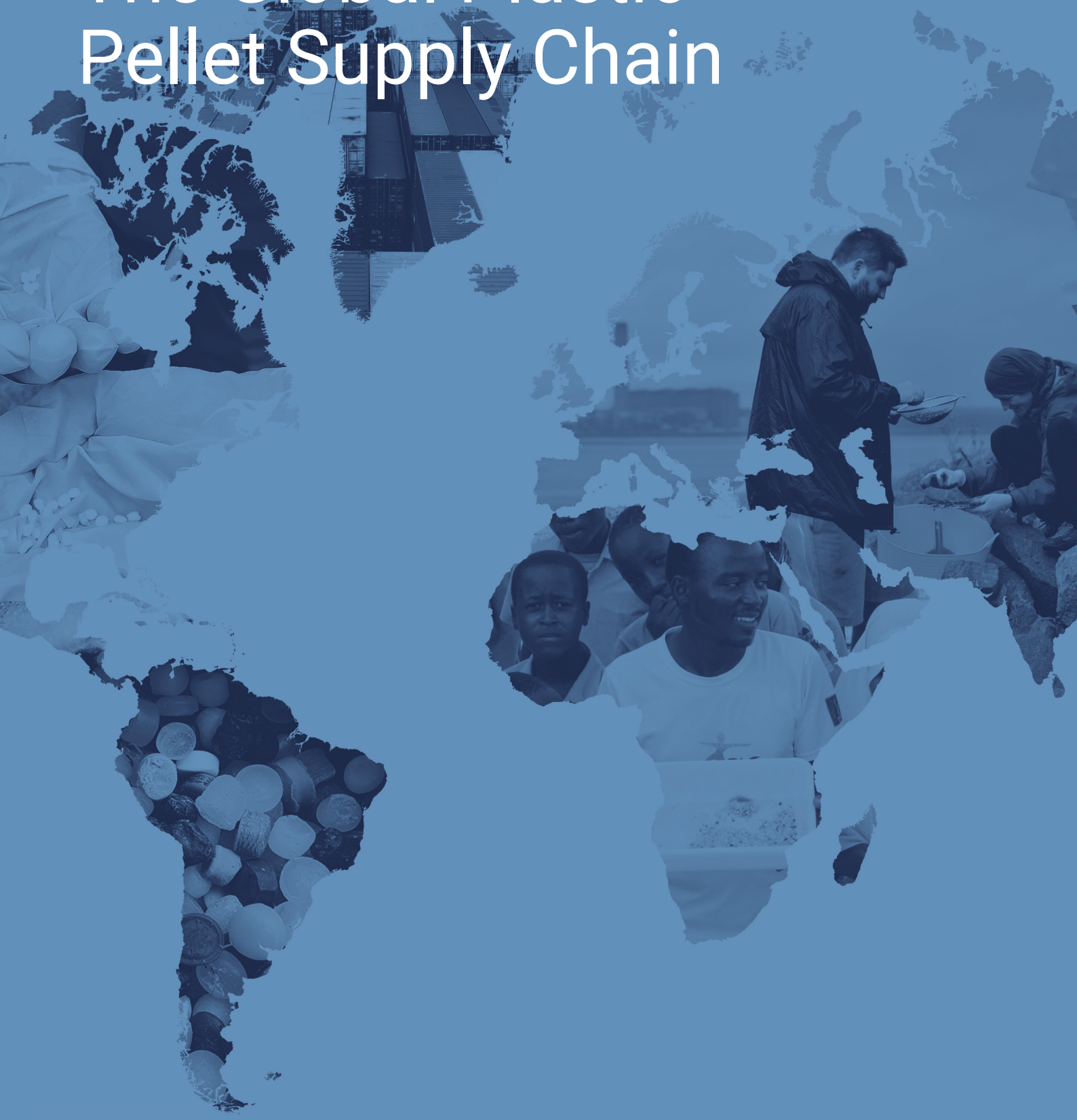
Mapping The Global Plastic Pellet Supply Chain



Fidra

ORACLE Environmental Experts

Fidra is a Scottish registered charity and SCIO no.SC043895

Above: Plastic Pellet Pollution on River Itchen/Chessel Bay, Southampton UK ©Joshua Doran (Oracle Environmental Experts Ltd)

Mapping The Global Plastic Pellet Supply Chain

Prepared for Fidra
by Oracle Environmental Experts Ltd

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Key Findings: **The Scale of the Problem**

- **Based on the current size of the global plastics industry, between 2.2 and 22.4 trillion plastic pellets (commonly called nurdles) are released to the environment across the world annually.** The largest contributions to this pellet loss are from Europe and the Asia Pacific regions. Assuming pellet loss continues at that rate, it is estimated that **between 450,000 and 4.5 million tonnes (Mt) of pellets will have been released to the environment between 2021 and 2030.**

- There is **clear evidence of plastic pellet pollution in regions of the world where there is also a high concentration of plastic manufacturers and converters.**

- **Plastic pellets are ubiquitous in the environment, this has direct and indirect impacts on the environment, health and communities.** In addition to adding to the plastic burden in our environment pellets can transport and release toxic chemicals, and their impact will be cumulative given their persistence. **A larger number of pellets in the environment will lead to a higher load of toxic chemicals being released into the environment.**

- 390 Mt of plastics were produced globally in 2021, predominantly in the form of plastic pellets. Plastic production is forecast to grow to over 1,200 Mt by 2060. Nurdle hunts promoted by Fidra and other organisations, have identified the **widespread and persistent presence of plastic pellets in the environment.**

- **Remote locations which have no plastics industry are also being impacted by pellet pollution.** Once pellets are released to the environment, it is often not possible to identify their source given their mobility, persistence and abundance, and pellets released to the marine environment can be distributed widely.

- Both virgin and recycled plastic pellet loss is occurring with sites of acute and chronic pollution identified. **Pellets made with recycled plastic are more toxic than virgin plastic and predicted increases in recycling of plastics may present increased toxicity risks.**

- Most pellet pollution sites are hard to attribute to specific sources due to a lack of mandatory reporting by industry and the mobility of pellets. Following a review of available literature and citizen science data, examples of acute pellet pollution (e.g. from shipping incidents) and chronic pellet pollution (e.g. plastics industry sources such as producers, converters and recyclers) have been identified across the globe. The true number of pellets lost to the environment is unknown as the majority of these sources have no estimate of the quantity of pellets lost.
- Acute losses from shipping incidents result in the release of billions of plastic pellets into the environment. Pellets may be packaged and stored in plastic bags and containers which degrade over time, resulting in on-going release for many years or decades if they are not recovered.
- Chronic losses of pellets from production, manufacturing, recycling sites and transport is a major issue which requires significant industry engagement and regulatory action to address.
- The loss of plastic pellets to the environment is preventable if a supply chain approach is taken by the plastic industry with the implementation of appropriate standards for pellet handling with associated independent auditing and monitoring, and with improvements to the global transport of pellets by ship, road and rail.

Plastics Production & Recycling

- **A lack of transparency by industry to share the data they hold is likely to result in an underestimation of the scale and location of the industry by this report.**
- **In 2021, China accounted for 32% of world plastics production,** with Europe and the United States (US) accounting for 33% when combined.
- High concentrations of plastic producers have been identified in Northern Europe, the Gulf Coast of the US and Southern China.
- **Europe has the largest concentration of plastic recycling facilities** with over 1,400 plastics recycling plants, equalling 54% of the world's recycling facilities identified.
- Concentrations of plastic recyclers have been identified in Northern Europe, Turkey, India, the East Coast of the US and Southern China.

Plastics Imports & Exports

The largest primary plastic imports and exports occur within Europe (37% of the global market) and the Asia Pacific Region (34% of the global market).

In 2021 the global export trade value of plastics in primary forms, likely to be plastic pellets, flakes and powders, was over USD185 billion.

The Top 5 countries for primary plastics exports in order of trade value are;

1. United States
2. Saudi Arabia
3. Korean Republic
4. Germany
5. Singapore

The Top 5 countries for plastics imports in order of trade value are;

1. China
2. Germany
3. United States
4. Turkey
5. Italy

Transport

- **Shipping is the major global transport method for the distribution of virgin and recycled plastics around the world,** most of which is in the form of pellets, flakes and powders. Key US to Europe shipping routes are from New Orleans to Antwerp in the Netherlands, via Le Havre in France, and Philadelphia to Zeebrugge in Belgium. Key shipping routes from the Middle East to China transport millions of tonnes of primary plastics annually and four acute spills of pellets have been identified along the route.
- **Within the study regions, primary freight transport varies between shipping, road and rail.** In the US and Canada, large amounts of plastics are transported by road and rail via an established intermodal transport network. Whereas, in the European Union in 2021, 67.9% of freight was transported via maritime shipping, 24.6% by road and 5.4% by rail.
- Since 2014, China has accounted for more than 50% of the container port traffic in the East Asia Pacific region and in 2021 accounted for 31% of global container port traffic.

Socio-economic & Environmental Impacts

- **Many countries where tourism is a key part of their economy are at increased risk from ship-sourced pellet spill incidents based on current global shipping routes.** In the Asia Pacific Region these include the Maldives, Sri Lanka, Vietnam and Thailand. Whilst in Central and South America countries in the Caribbean such as Antigua and Barbuda and Jamaica are at risk from chronic and acute pellet sources.
- **Acute ship-sourced pellet spills have occurred at major ports and along key shipping routes.** These incidents have caused significant socio-economic impact on communities and raised human health and environmental concerns. These incidents have affected countries who are not primary plastic producers, such as Sri Lanka.
- Environmentally sensitive sites are often closely linked to the tourism industry, for example, the manatee populations in Florida and the coral reef ecosystems in the Maldives. These areas would face considerable environmental and subsequent economic impact from plastic pellet pollution in the event of an acute spill from the global maritime transport of pellets, or chronic loss from nearby producers and manufacturers.
- **Primary plastic production is occurring within close proximity to environmentally sensitive and protected areas,** e.g. Texas Gulf Coast and Northern Europe, where a large acute spill and cumulative chronic pollution would have a negative impact on marine organisms and habitats, which are already under strain from climate change and habitat destruction.
- As a result of an acute loss, there are economic consequences to a country's resources and companies finances and insurance to pay for the clean up.
- Fishing is known to be impacted following acute pellet spills, however limited data has been found quantifying the impacts on fishing industry from pellet pollution.
- Health impacts of pellet pollution are still being uncovered. These impacts are difficult to quantify but are a concern due to the toxic biological and chemical contaminants on and in pellets and their contribution to microplastic in food chains.
- Social impacts of pellet pollution are wide ranging, site specific and include changes to access, enjoyment, local traditions and as well as limiting space for local coastal activities for both leisure and livelihoods (such as drying fish for market).

Forecasting & Actions to Reduce Pellet Pollution

- The **production and use of plastics could triple by 2060,** with the largest increases expected in Sub-Saharan Africa and Asia Pacific, particularly in India, given their predicted strong economic growth.
- The global trade value of exports of primary forms of ethylene could reach over USD 40 billion by 2030, an increase of around USD 10 billion from the amount produced in 2021.
- **Given the predicted increase in the scale of the plastics industry, the risk of continued acute and chronic pellet loss is also expected to increase if no action is taken to improve the storage, handling, transport and response to pellet spills.** The data and findings of this report provide further evidence that the global plastic pellet supply chain is a current and growing threat to our environment, the economy, health and communities. There is already ongoing impact, and potentially larger future risks to vulnerable species, protected areas, fisheries and aquaculture, tourism and communities if urgent action is not taken to stop pellet loss.
- To address the problem of global plastic pellet pollution, the risk of further losses at source must be reduced through the introduction of international standards on improved pellet handling and transport with associated independent auditing, monitoring and enforcement. These measures should be supported by legislation introduced on a global scale to ensure uptake of the relevant standards and certification and commit to zero pellet loss.
- Additional measures should be taken to improve the global transport of plastic pellets and this study fully supports the proposals from the International Maritime Organisation (IMO) to classify plastic pellets as harmful to ensure improvements are made to the labelling and stowage of pellets when transported by ship, with protocol and compensation in place in the event of a spill. Similar improvements would likely need to be adopted when pellets are transported by road and rail.
- Mandatory improvements are needed across the plastics supply chain to prevent pellet loss. Whilst plastic pellets continue to be released to the environment in their trillions annually, the positive outcomes of any clean-up completed will be weakened, and there will be continued harm to the environment and to health.

Foreword

This report has been prepared for Fidra (an SCIO and Scottish Registered Charity SC043895; www.fidra.org.uk) an environmental charity focussed on preventing pollution and supporting sustainable practices by engaging the public, industry and governments in solutions to environmental issues which catalyse change.

The Global Plastic Supply Chain Mapping Report is part of Fidra's project to prevent plastic pellet pollution. The project is focused on supporting solutions to end plastic pellet pollution across the world by facilitating information exchange with non-governmental organisations (NGOs). Fidra support measures to prevent pellet loss such as increased legislation, mandatory standards, the implementation of a Global Plastic Treaty, amongst other solutions, to be developed and implemented by supporting NGOs at a national, regional and international scale (https://hub.nurdlehunt.org/)

This report, and the associated research, has been completed by Oracle Environmental Experts (OEE) for Fidra. OEE are an independent environmental consultancy specialising in the assessment and mitigation of environmental impacts, risks and liabilities associated with pollution incidents and contaminated land. OEE have completed extensive research into the impacts of the many forms of microplastics within in the environment, as well as the development, and implementation of tools and techniques to prevent, and recover micro and macro-plastics from acute and chronic losses.

This report would not be possible without Great Nurdle Hunt data collected by volunteers and organisations around the world working to address plastic pollution. The Great Nurdle Hunt is a community science initiative organised by Fidra where volunteers log their plastic pellet finds at www.nurdlehunt.org.uk. The authors would like to thank all those who have supported the Great Nurdle Hunt and Break Free From Plastic members for sharing their insights in the development of this report.

1.0 Introduction

1.1 Most plastic is produced at petrochemicals sites in the form of plastic pellets (also commonly referred to as nurdles) which are the industrial feedstock of the global plastic supply chain[1]. Plastic pellets are typically 1 to 5 mm in diameter and are packaged at a variety of scales from either 25 kg bags, bulk bags containing 500 to 1000 kg up to containers and silo trucks holding in excess of 20 tonnes of material[2]. A single 25 kg bag can contain over 1 million individual plastic pellets[2]. The majority of plastic pellets are currently classified as non-hazardous for transport purposes. Pellets can be made of a virgin fossil fuel based plastic, bio-based plastic, recycled plastics or a combination. Plastic may also be produced and transported in the form of flakes and powders which share with pellets many of the same issues and solutions discussed in this report. Plastic pellets, flakes and powders are often referred to collectively as primary plastic forms (Figure 1).

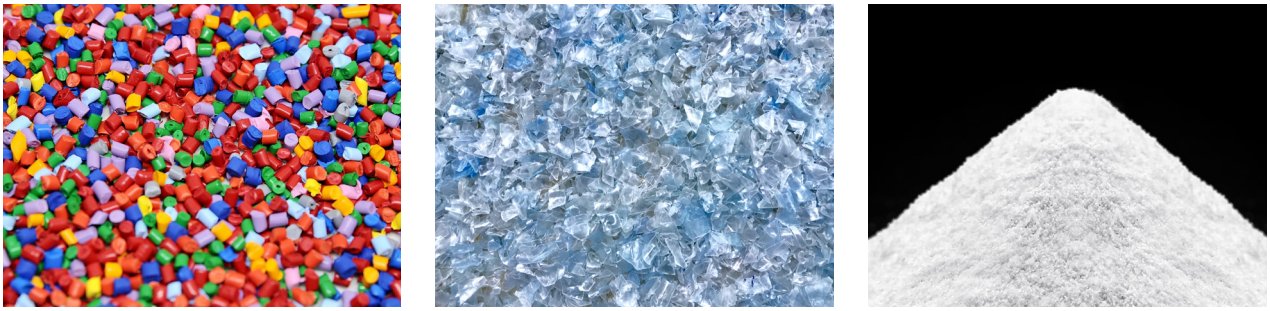

Figure 1: From left to right, plastic pellets, plastic flakes and plastic powders (image credit: Shutterstock)

1.2 **Plastic pellets are known to enter the environment during their production, transport and conversion into other materials and products**[3; 4; 5]. Plastic pellets are handled, stored and transported multiple times between production and conversion, and at each step mismanagement can cause them to spill into the environment[6; 7] representing an often unrecoverable loss of resources. These losses are classified as either chronic loss, which is commonly the continual losses from industry, and the acute loss, which result from specific incidents such as losses during rail transport or shipping[8]. As a result, there can be chronic pollution sites where there is a continual loss into the environment leading to large accumulations of pellets within a particular area. However, there is also the chronic loss of small quantities of pellets along all stages of the supply chain that are dispersed along its journey. While chronic loss from production, processing and intermediary facilities contributes more pellets to the environment overall, an acute loss can result in a high number of pellets entering the environment in one location at one time with immediate as well as long term impacts in the immediate vicinity and beyond[6].

1.3 **Once in the environment plastic pellets are a persistent microplastic pollutant**[9; 10]. Impacts on human health and the environment continue to be identified from this microplastic pollution[11; 12]. Plastic pellets are the second biggest microplastic pollutant identified by research[4; 13]. Plastics are made up of a cocktail of chemicals containing additives, contaminants as well environmental pollutants sorbed onto the plastics' surface such as flame retardants. The combination of chemicals can be detrimental to the surrounding water quality and can have knock on negative impacts to human health[14; 15]. Once in the environment, these pellets can adsorb carcinogenic chemicals in seawater such as Polychlorinated biphenyl (PCB) and Dichlorodiphenyldichloroethylene (DDE) and concentrate other harmful chemicals to their surface[16]. Research has shown plastic pellets have been ingested by a variety of species[17; 18] from remote regions of the Andean mountains[19] to fish farmed in marine pens[20].

1.4 **There are currently no global mandatory requirements to prevent losses of plastic pellets, flakes and powders to the environment.** Voluntary efforts by industry to limit plastic pellet loss, such as Operation Clean Sweep (OCS), have been in place for decades, however, they have currently been ineffective in stopping global plastic pellet loss[6]. The volumes and sources of pellet loss have been poorly documented by industry, but various attempts have been made to estimate and quantify loss by others[3; 8]. However, the lack of transparency across the industry has resulted in significant knowledge gaps and therefore the scale of pellet loss and the awareness of the consequences of mismanagement is widely unknown. The aim of this report is to collate available data of the current global scale of the plastics industry including: importers, exporters,

transport distribution, converters, masterbatchers and to report on the known extent of plastic pellet pollution arising from acute and chronic sources around the world. The report highlights data accessibility and data gaps, aids understanding on the scale of the industry across regions and identifies the associated losses, where possible.

1.5 **There is currently no global mandatory requirements for governments or industry to report known losses of plastic pellets, flakes and powders to the environment.** Therefore, the data presented in this report is incomplete and is likely to provide an underestimate of the full scale of the risks posed by plastic pellet pollution. Given the scale of the industry and variation in the availability of data between countries and regions, data gaps have been highlighted when identified. For the review, the global data has been split into the following regions:

- North America
- Central & South America
- Europe
- Africa & Middle East
- Asia Pacific

2.0 Global Data Exploration

2.1 Data

2.1.1 The datasets used in this review of the global plastic supply chain and the extent of plastic pellet pollution, along with the methodology used in the assessment, are detailed in Appendix A. With no mandatory labelling of pellets in transport and no mandatory reporting of pellet loss, the scale of the issue has been inferred from previous studies of pellet loss at national and regional scale and extrapolated based on World Bank WITS database[21] to assess global imports and exports of plastics in primary forms by country based on the trade value. Plastic in primary forms includes pellets, flakes and powders. Industry transparency has also been a barrier to accessing information on the scale and location of the plastic industry. Locations of pellet pollution have been sourced from Fidra's Great Nurdle Hunt and the Nurdle Patrol with thanks to volunteers for this data.

2.1.2 Data extracted from the World Bank WITS database[21] was used to assess global imports and exports of plastics in primary forms by country based on the trade value. The primary plastic forms data extracted for this study were based on the WITS Harmonised System (HS) codes relating to Ethylene, Propylene, Styrene and Vinyl-chloride polymers in their primary forms. The available HS codes were reviewed and of those relating to these polymers in their primary forms 19 were identified (Table 1).

Table 1: Harmonised system (HS) codes for polymers in their primary forms[21]

HS Code	Description
390110	Ethylene polymers; in primary forms, polyethylene having a specific gravity of less than 0.94
390130	Ethylene polymers; in primary forms, ethylene-vinyl acetate copolymers
390210	Propylene, other olefin polymers; polypropylene in primary forms
390230	Propylene, other olefin polymers; propylene copolymers in primary forms
390311	Styrene polymers; expansible polystyrene, in primary forms
390320	Styrene polymers; styrene-acrylonitrile (SAN) copolymers, in primary forms
390390	Styrene polymers; in primary forms, n.e.s. in heading no. 3903
390421	Vinyl chloride, other halogenated olefin polymers; non-plasticised polyvinyl chloride, in primary forms, mixed with other substances
390430	Vinyl chloride, other halogenated olefin polymers; vinyl chloride-vinyl acetate copolymers, in primary forms
390450	Vinyl chloride, other halogenated olefin polymers; vinylidene chloride polymers, in primary forms
390120	Ethylene polymers; in primary forms, polyethylene having a specific gravity of 0.94 or more
390190	Ethylene polymers; in primary forms, n.e.s. in heading no. 3901
390220	Propylene, other olefin polymers; polyisobutylene in primary forms
390290	Propylene, other olefin polymers; n.e.s. in heading no. 3902, in primary forms
390319	Styrene polymers; (other than expansible polystyrene), in primary form
390330	Styrene polymers; acrylonitrile-butadiene-styrene (ABS) copolymers, in primary forms
390410	Vinyl chloride, other halogenated olefin polymers; polyvinyl chloride (not mixed with any other substances), in primary forms
390422	Vinyl chloride, other halogenated olefin polymers; plasticised polyvinyl chloride, in primary forms, mixed with other substances
390440	Vinyl chloride, other halogenated olefin polymers; vinyl chloride copolymers, in primary forms n.e.s. in heading no. 3904

2.1.3 Data has been extracted from the WITS database for the most recent available year, 2021, and is based on trade value due to plastic mass data being unavailable for some countries. Figure 2 shows that China was by far the largest importer of primary plastics in 2021 with over three times the imports when compared to the next largest importer, Germany.

2.2 Plastic importers and exporters

2.2.3 The **largest importer of primary plastics in 2021 was China** followed by Germany and the US (Figure 2). The **largest exporter of primary plastics in 2021, was the US,** closely followed by Saudi Arabia and South Korea (Figure 3).

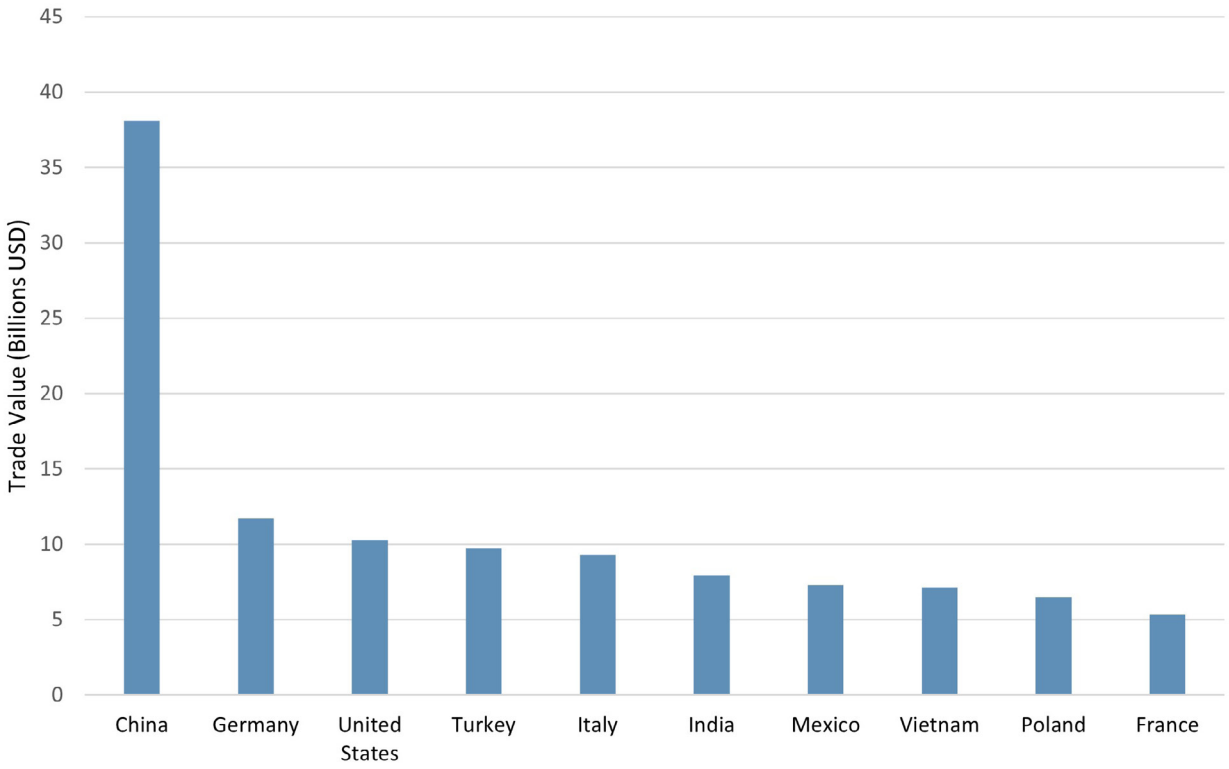

Figure 2: Top 10 importers of plastics in primary forms (based on trade values from 2021)[21]

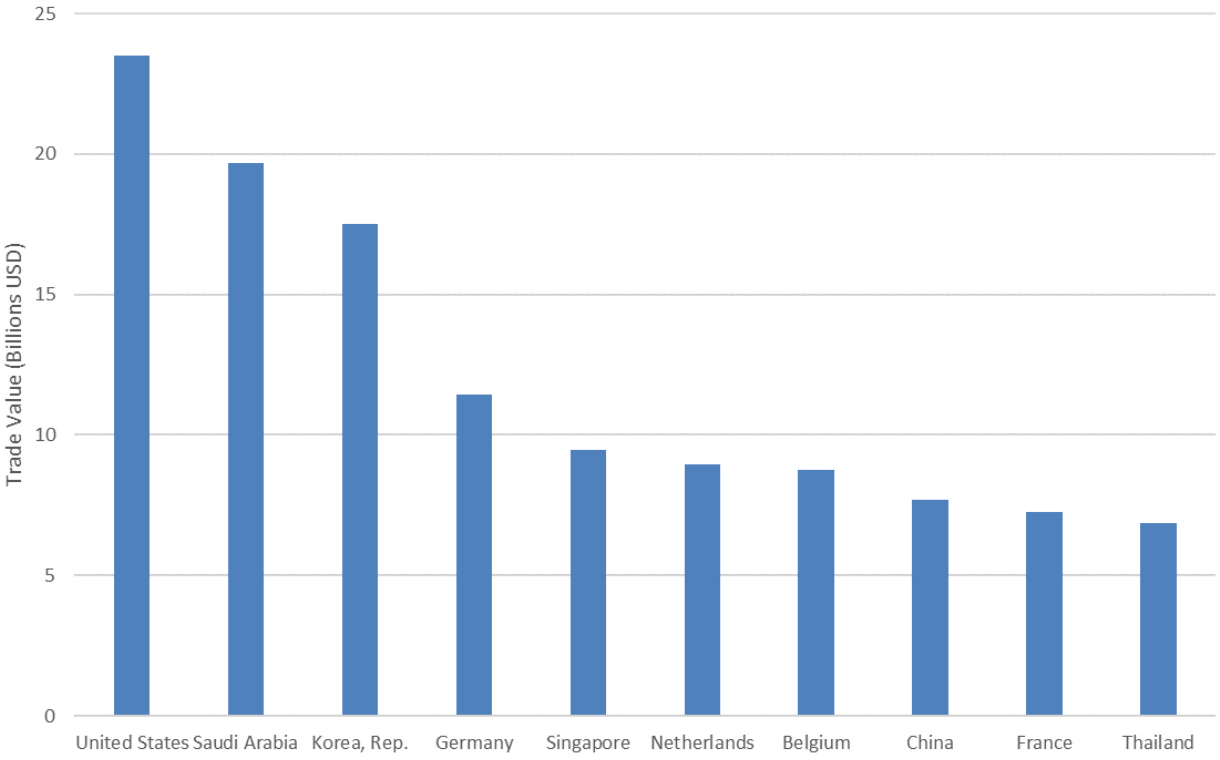

Figure 3: Top 10 exporters of plastics in primary forms (based on trade values from 2021)[21]

2.2.4 **Europe and the Asia Pacific regions account for the majority of primary plastic trade.** Figure 4 shows the global regional share of imports and exports of plastics in primary forms.

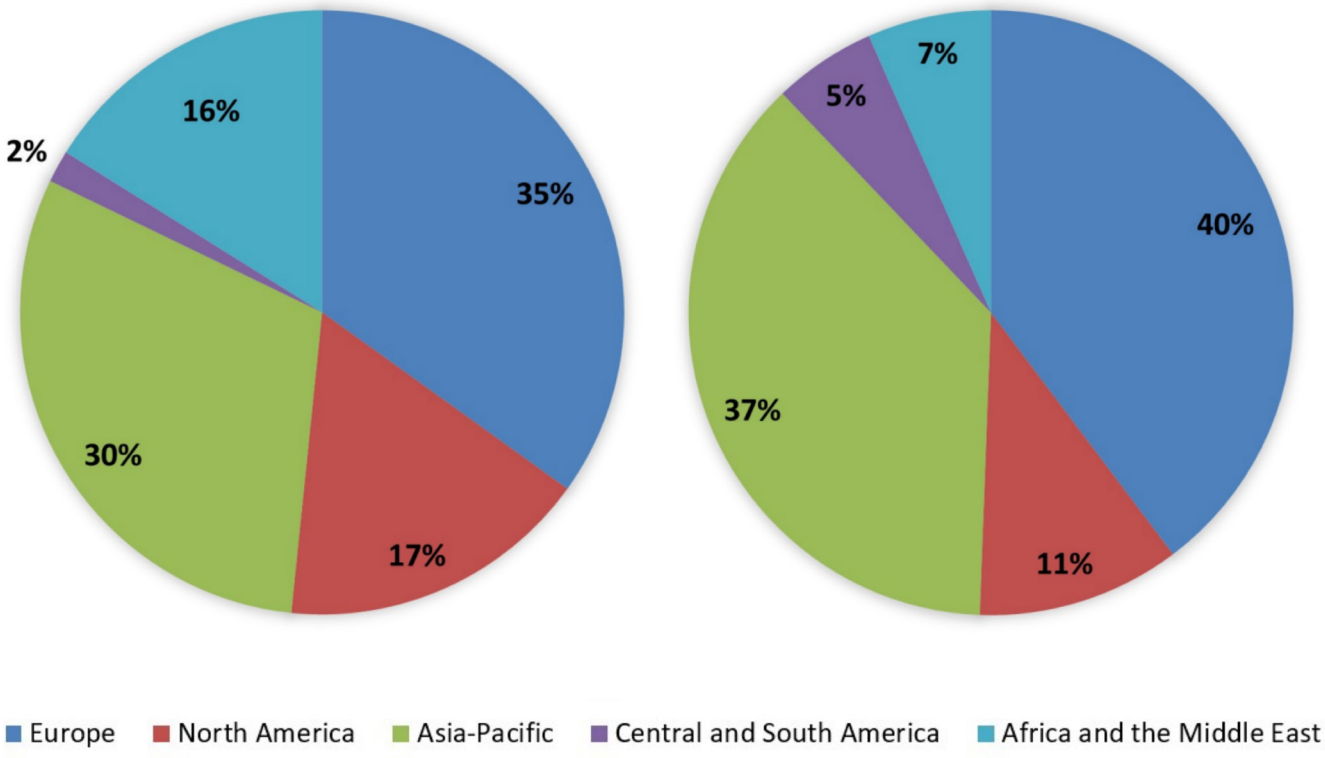

Figure 4: Regional share of global primary plastic exports (left) and imports (right)[21]

2.2.5 **Available data indicates increasing exports of primary plastics, confirming an increase in production.** In order to assess the global trend in the imports and exports of primary plastics, HS code 390110 (Table 1) and the longer-term dataset extracted from the WITS database[21] (1992-2021) was combined (Figure 5). Whilst trade values are variable, the R-squared value indicates that there is an increase in the exports of primary plastics over time and therefore, by inference, an increase in production. Extrapolation of this data suggests that world exports of primary forms of ethylene could reach over USD 40 billion by 2030, an increase of around USD 10 billion from the amount produced in 2021.

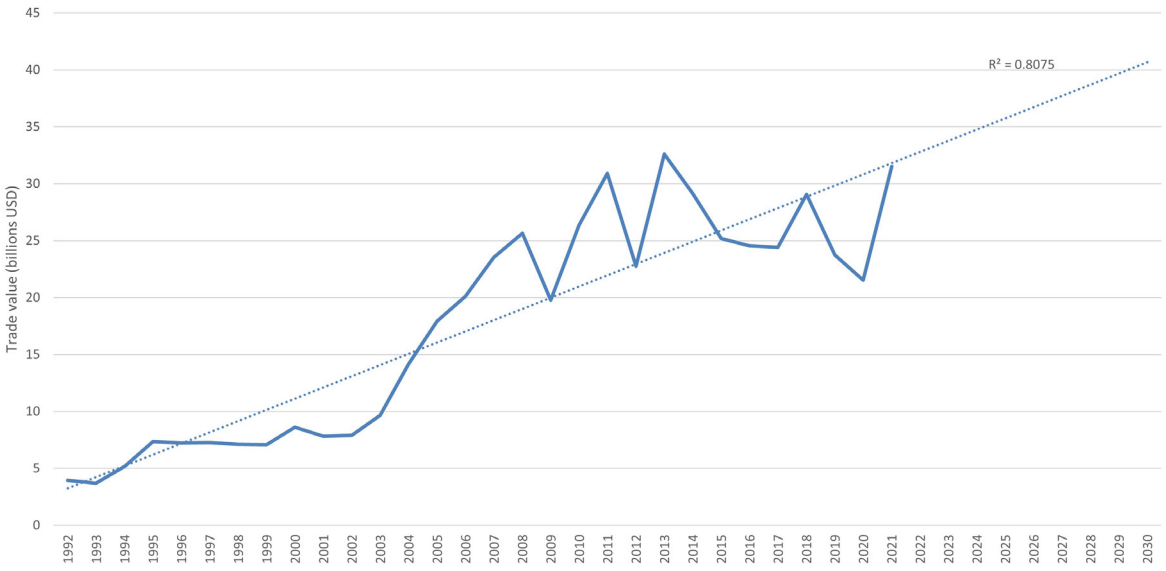

Figure 5: Growth trend of world exports of ethylene polymers in primary forms, based on projected growth of polyethylene having a specific gravity of less than 0.94

2.3 Global shipping

2.3.1 The research undertaken has identified the **annual global transport of millions of tonnes of primary plastics between nations.** Where no viable land transport route exists, maritime shipping is the primary pathway for the movement of this material.

2.3.2 Statistics for global container port traffic have been obtained from the United Nations Conference on Trade and Development (UNCTAD) statistics database[22]. The dataset includes data for individual nations and regional totals which measures the movement of containers in twenty-foot equivalent units (TEU) through ports. A 20-foot-long shipping container is the smallest typically shipped internationally (individual containers may be counted multiple times as they pass through ports).

2.3.3 Since 2000, **a clear upward trend in overall global container port traffic is evident** in global shipping volumes of all trade both regionally and across the world (Figure 6). This trend appears to be primarily driven by a consistent growth in the East Asia and Pacific region. Further interrogation of the data shows that since 2014, China has accounted for more than 50% of the container port traffic in the East Asia Pacific region and in 2021 accounted for 31% of global container port traffic.

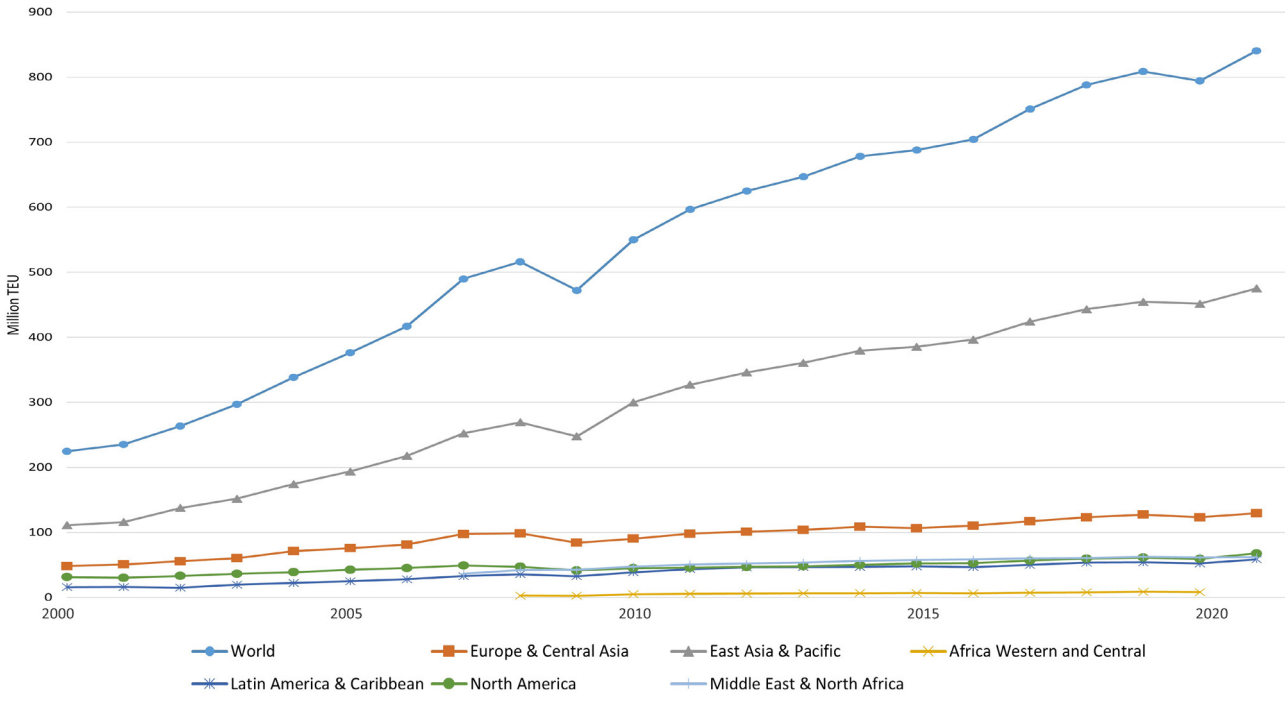

Figure 6: Regional and global shipping container transport volumes[22]

2.3.4 The WITS database[21] was also used to identify major trade in primary plastics between nations. **In 2021 China was the world's largest importer of primary plastics** with the largest imported polymer being propylene (e.g. HS 390210). The **largest exporter to China of propylene polymers in 2021 was South Korea (800,000 tonnes) followed by United Arab Emirates (UAE; 386,000 tonnes) and Saudi Arabia (366,000 tonnes).**

2.3.5 The major container shipping routes were assessed to determine the main trade routes between the plastics exporters and importers. In this study, shipping routes have been explored to identify potential risks posed during maritime transport of plastic pellets to sensitive areas close to the shipping routes such as environmentally protected areas, tourist hotspots and key fishing grounds.

2.3.6 Figure 7 highlights that **a spill of plastic pellets along shipping routes has the potential to negatively impact several nations that are heavily reliant on tourism.** Known acute spills of plastic pellets that occurred in Dubai[23], Sri Lanka[24] and Hong Kong[8] are also shown, highlighting their proximity to these major shipping routes. A review of shipping routes identified that ships call at multiple ports along the route leading to the potential for the loss of plastic pellets during loading and unloading of other containers in ports which are not the ultimate destination of the material.

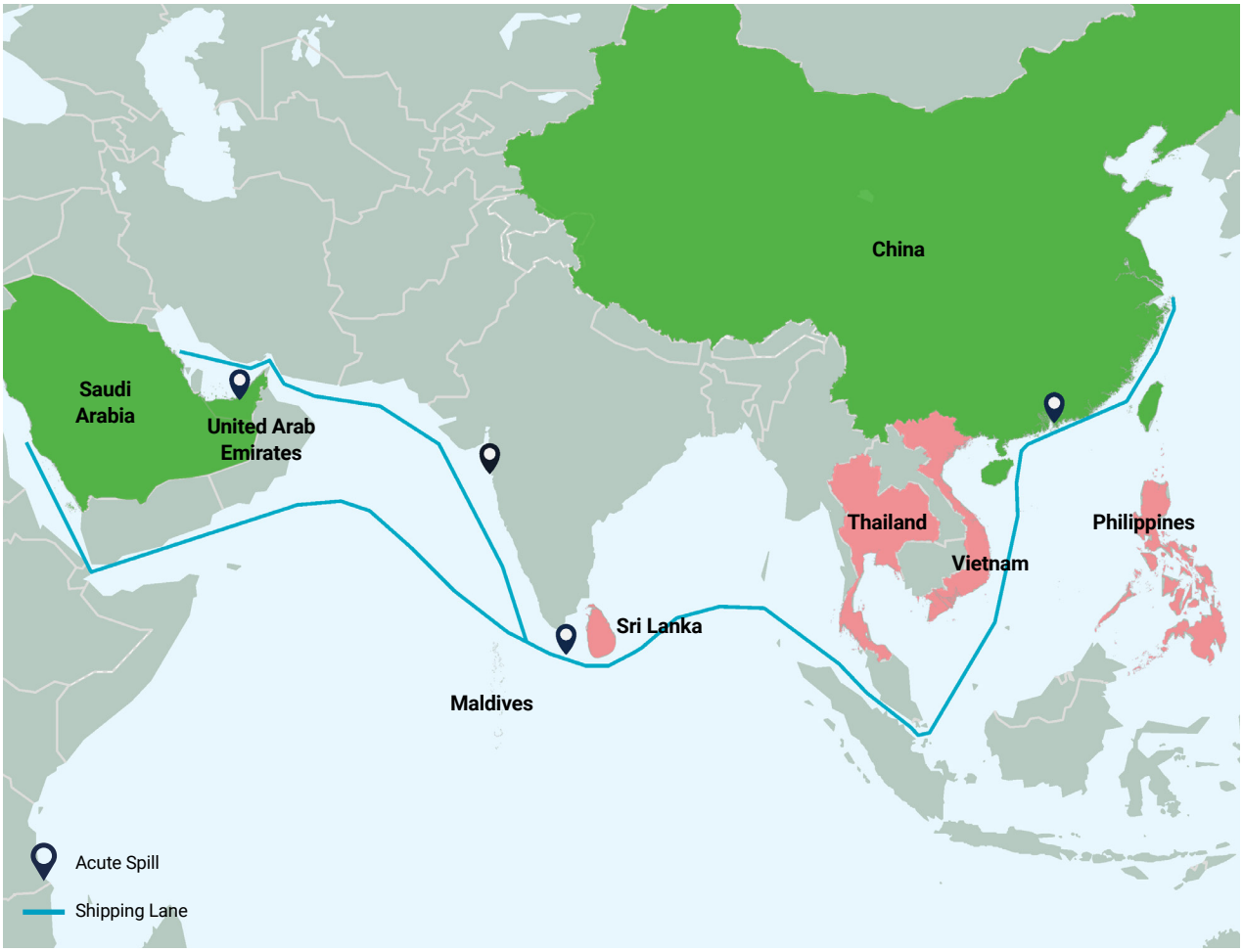

Figure 7: A closer look at the primary shipping routes between Saudi Arabia, United Arab Emirates and China. Acute spills of pellets in Hong Kong (2012), Sri Lanka (2021), Dubai (2023) and Mumbai (2023) are shown (black markers) along this key shipping route (blue line). Countries whose GDP has a high percentage of tourism shown in pink.

2.3.7 A primary shipping route between Europe, Saudi Arabia and China and has already experienced acute spills from maritime incidents (Figure 7). **Acute spills pose a risk to the environment and national economies dependent on tourism. Shipping routes between Saudi Arabia and China pass through countries where tourism is a major industry based on contribution to gross domestic product** (GDP[25]), for example tourism accounts for more than 25% of GDP in the Maldives and more than 10% in Sri Lanka (Figure 7).

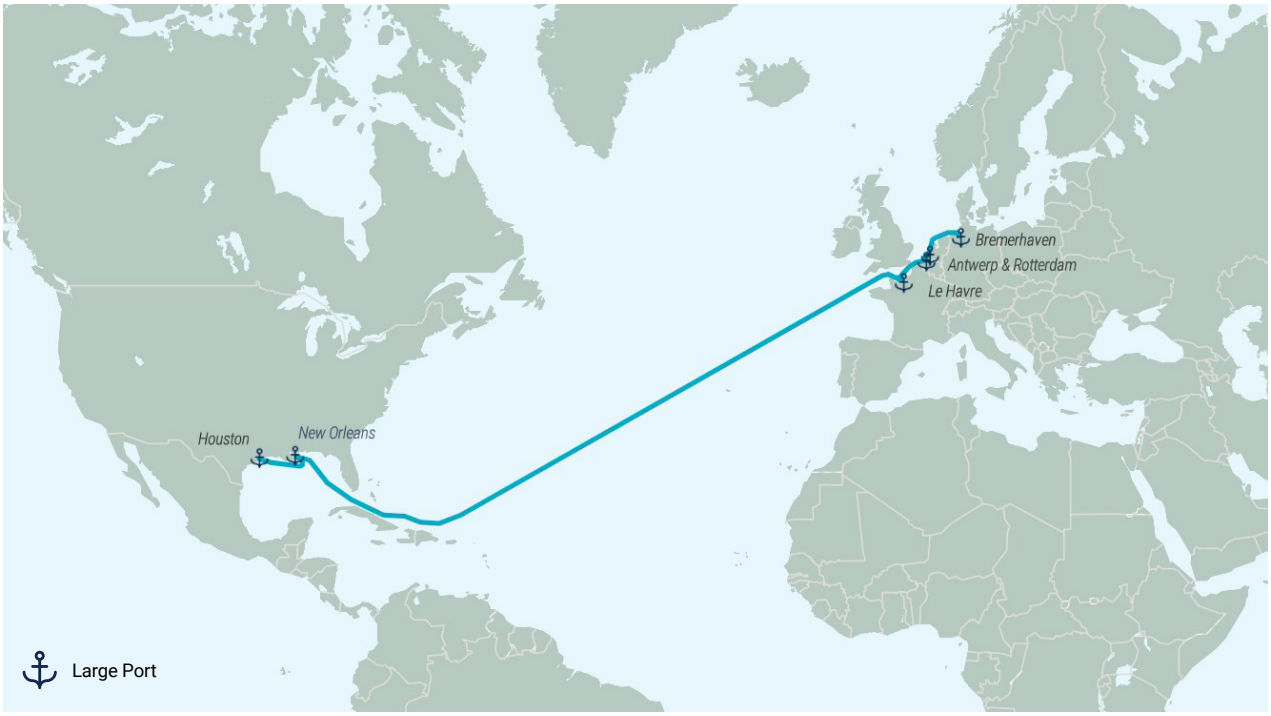

Figure 8: The primary shipping route between the Gulf of Mexico and Northern European Ports[26]

2.3.8 **Major trade was also identified between North America and Europe.** Figure 8 shows the shipping route between Europe and North and Central America and highlights the risk to ecologically sensitive areas in the Caribbean Sea and Gulf of Mexico and Northern Europe, as well as countries whose economies depend on tourism. Research has shown that Belgium is the largest importer of primary plastics from the US at 550,000 tonnes in 2021.

2.4 Plastic producers, converters, masterbatchers and recyclers

2.4.1 Where multinational companies listed their facilities worldwide there were no significant barriers to identifying locations of plastic production and manufacture sites, however not all producers and manufacturers were multinational. Challenges arose when locating smaller companies that may only operate a single facility, or small number of facilities. A live polymer trade database was identified which showed the location of polymer manufacturers worldwide (Appendix A). The authors were not permitted to use the data from the database for the purposes of this report to highlight the locations of the manufacturers. **This demonstrates a lack of transparency by industry to share the data they hold. The barriers identified during data collection are likely to result in an underestimation of the scale and location of the industry by this report.** For example, it is estimated that China was responsible for 52% of global plastic production[27] and was the largest importer of plastics in primary forms in 2021 (Figure 2). However, it was only possible to identify a relatively small number of sites within China.

2.4.2 Information on businesses and facilities involved in the plastics industry was obtained for the US and United Kingdom (UK) based on industry activity codes (e.g. Table 6, Appendix A). This yielded over 5,800 locations within the UK and over 1,200 locations in the US. It was identified that similar information is available from trade directories, but at a significant cost. A trade database was utilised to identify the location of over 2,600 plastic recycling plants worldwide.

2.4.3 The classification of industries using code systems was identified in other countries however data accessibility was often limited to searching for an individual known business, e.g. Canada, or only providing industry wide statistics, e.g. China. Industry classification systems are often linked to taxation and business registration systems within countries, e.g. Companies House in the UK and a lack of understanding of these in specific nations coupled with language barriers made utilising them more widely challenging.

2.4.5 Figure 9 shows the locations of plastic producers, manufacturers and recyclers obtained during this study. **It is accepted that this is unlikely to represent the complete global distribution of this part of the plastics supply chain given the challenges of data access and transparency.**

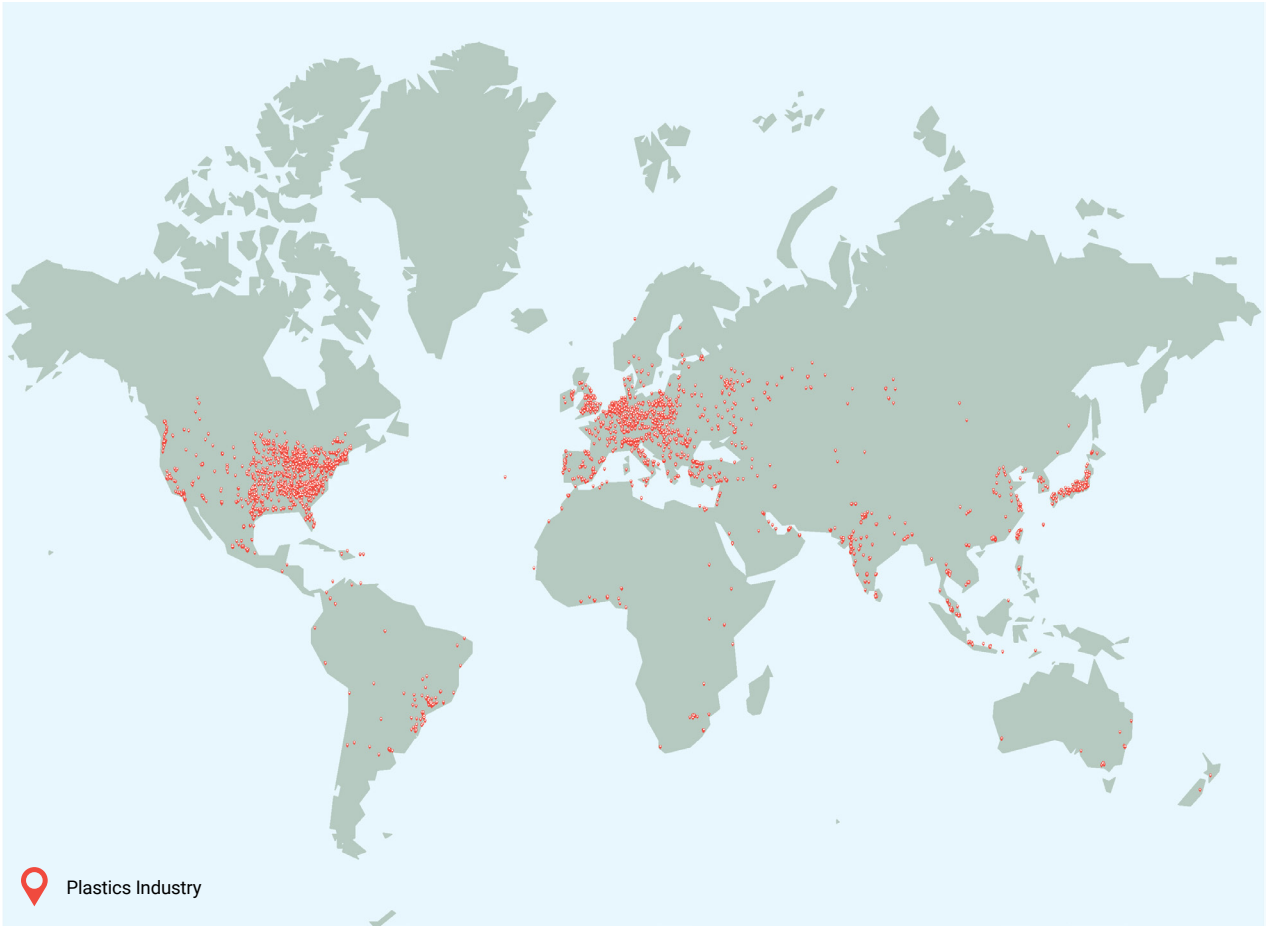

Figure 9: Locations of identified facilities involved in the plastics industry including plastic producers, manufacturers and recyclers (Note: it was not possible to identify all sites due to data access limitations)

2.5 Inland distribution centres

2.5.1 **Inland freight distribution centres or dry ports, of varying scale, are potential acute and chronic sources of pellet pollution as inadequate packaging may become damaged during handling.** These sites are essentially inland ports for container traffic, transferring containers between rail and road for either import or export purposes[28]. Additionally, a large number of container ports offer a 'stripping and stuffing' service where goods are removed from shipping containers and put directly into trucks or repackaged[29] and there is an increased risk of pellet loss during this activity.

2.5.2 In the US, a dataset showing the location of large inland intermodal distribution hubs was identified, however, similar datasets for other regions could not be identified. A large number of inland container or 'dry' ports operate around the world and a number of these have been identified manually using web searches. Figure 10 provides an example of one of the dry ports identified in the US and Figure 19 shows the locations of the marine and dry ports identified in this study across the Africa and Middle East region. It has been difficult to identify inland distribution centre across South America and the Asia Pacific Region in particular, and for more detailed investigation of these sites, the locations of these facilities would need to be identified on a local or country level as required.

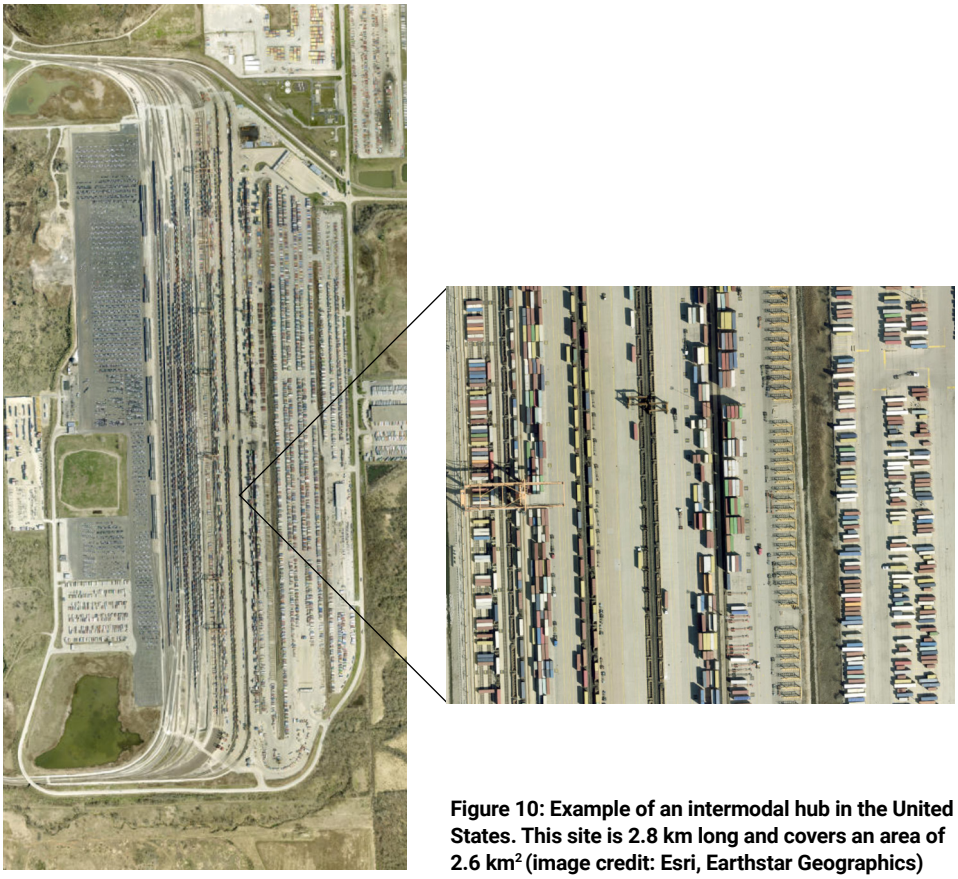

Figure 10: Example of an intermodal hub in the United States. This site is 2.8 km long and covers an area of 2.6 km^2 (image credit: Esri, Earthstar Geographics)

2.6 Plastic pellet pollution

2.6.1 Scale of the problem

2.6.1.1 The top 5 countries for imports and exports of plastics in their primary forms are China (11.62%), United States (8.57%), Germany (5.88%), Saudi Arabia (5.20%) and the Republic of Korea (4.73%) based on the WITS data. Regionally, **Europe had the largest share of the plastics industry (37.54%) and therefore is at greatest risk from pellet loss.** Using the WITS data and the estimates of pellet loss from Eunomia for Europe[30], the potential pellet loss for the other regions across the globe has been extrapolated based on their share of the plastics market. The estimated ranges of pellet loss for the five subject global regions are highlighted in **Table 2.**

Table 2: Estimates of annual plastic Pellet loss across the world based on share of global plastics industry

Region	Imports & Exports Value (Billions USD)	Percentage Market Share Based on Imports & Exports	Estimated Minimum Quantity of Plastic Pellets Lost (tonnes)	Estimated Minimum Quantity of Plastic Pellets Lost (in billions of pellets)	Estimated Maximum Quantity of Plastic Pellets Lost (tonnes)	Estimated Maximum Quantity of Plastic Pellets Lost (in billions of pellets)
Europe	148.01	37.54%	16888	844	167431	8372
Asia Pacific	134.16	34.03%	15308	765	151764	7588
North America	53.68	13.62%	6125	306	60724	3036
Africa & Middle East	43.73	11.09%	4990	249	49468	2473
Central & S. America	14.66	3.72%	1673	84	16584	829
Global	394.24	100%	44983	2249	445970	22298

Notes: Estimate of pellet loss based on pellet mass of 0.02 g

2.6.1.2 These calculations indicate that between 2.2 and 22.4 trillion plastic pellets could be released to the environment annually across the world based on recent estimates of pellet loss, with the largest contributions coming from Europe and the Asia Pacific regions (Figure 11). This estimate of annual pellet loss is consistent with estimates from others such as The Pew Charitable Trusts[31] who reported that there were around 10 trillion plastic pellets released to the ocean environment in 2016.

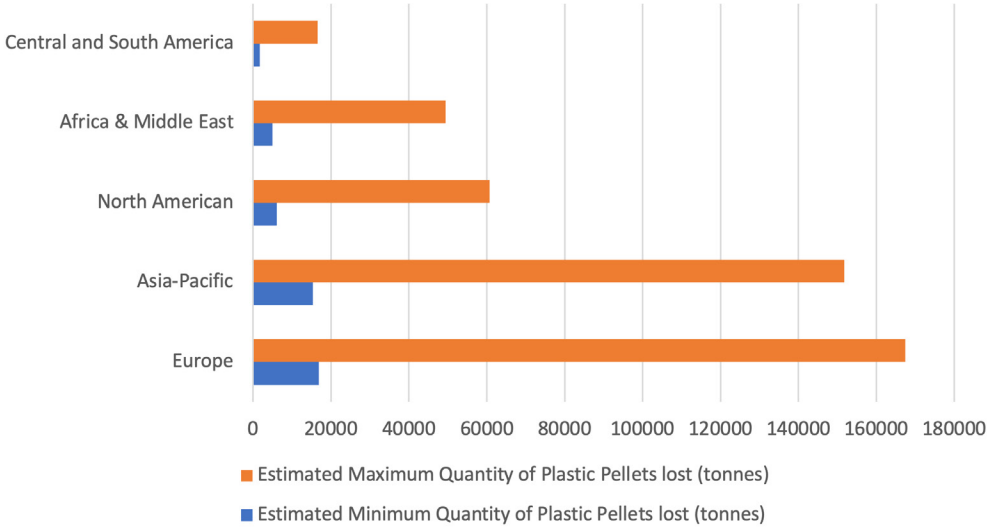

Figure 11: Estimated regional annual plastic pellet loss (tonnes)

2.6.1.3 Plastic pellets are known to be persistent in the environment and release toxic chemicals as they slowly degrade over decades and centuries[14; 18]. It is therefore important to consider the cumulative effect of pellet releases over time. A larger number of pellets in the environment will lead to a higher annual load of toxic chemicals being released and the effects of this will not be reversed easily. Figure 12 shows the potential global cumulative pellet loss between 2021 and 2030 with 450,000 to 4.5 Mt of pellets, extrapolating the above estimates of pellet loss, conservatively assuming the rate of pellet loss remains the same. These cumulative global losses equate to equivalent of 18,000 – 178,000 40ft containers of pellets being lost up to 2030. There is the potential for these numbers to be even higher, given that annual global plastics production in 2021 alone was 390 Mt[27] and the minimum cumulative losses up to 2030 of 450,000 tonnes equates to only 0.1% of global annual production.

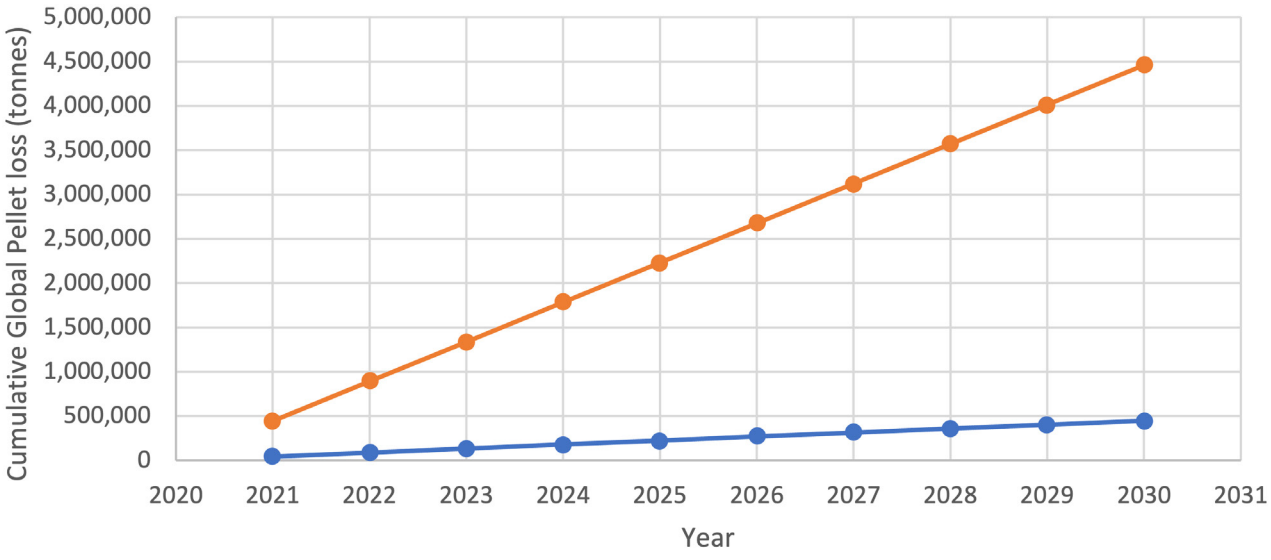

Figure 12: Potential cumulative global pellet loss to 2030 (where blue represents minimum estimates and orange represents maximum estimates of pellet loss in tonnes)

2.6.1.4 Eunomia also considered the stage of the supply chain from which plastics pellets were most likely to be lost within Europe and their conclusions are summarised in Table 3[30]. The data shows that the largest volumes of pellets lost are predicted to be from intermediary facilities, such as transport depots and rail yards with producers and processors also making a significant contribution. It is also predicted that shipping is responsible for the smallest fraction of pellet loss however acute losses from shipping can have immediate and long term environmental and socioeconomic and health impacts (Acute Case Study).

Table 3: Estimates of Annual plastic pellet loss from European industries (tonnes)[30]

Part of plastic pellet supply chain	Material handled (tonnes)	Quantity lost (tonnes)
Producers	58,000,000 – 70,565,000	5,800 – 28,226
Recyclers	6,896,340 – 7,662,600	690 – 3,065
Intermediary Facilities	52,925,399 – 265,026,636	5,293 – 106,011
Processors	48,563,380 – 66,776,366	4,856 – 26,711
Offsite Waste Management	1,079,950 – 7,984,111	108 – 3,194
Shipping	10,082,674	141 – 225
	Total:	16,888 – 167,432

2.6.2 Acute and chronic plastic pellets pollution sites

2.6.2.1 Available information on sites of chronic and acute plastic pellet pollution across the globe have been reviewed (Figure 13), and details of these are presented in Appendix D and Appendix E. This does not include the chronic loss of pellets that occurs along all stages of the global plastic supply chain, and only focuses on reported chronic pollution sites. A total of 41 sites of acute plastic pellet pollution have been identified globally between 1995 and 2023, with 15 of those incidents occurring directly into the marine environment and the remainder having occurred on land. A total of 37 sites of continual chronic pellet pollution have been identified as those with consistently high volumes of pellets (1000+) between 2005 and 2023, with 6 of those sites directly inputting pellets into the marine environment and the remainder occurring on land. As there is no mandatory reporting of acute or chronic pellet losses and much of the location data has been collected by volunteers finding pollution sites on land, the number of chronic and acute pellet pollution sites reported are an underestimate of sites impacted and an underestimate of pellets in the environment. As pellets can disperse it should be noted that not all chronic pellet loss leads to specific chronic pollution sites or a high accumulation of pellets in one location, with diffuse and marine pollution also leading to environment impacts remote from the point of loss. Known chronic and acute pellet pollution sites only account for a fraction of pellet pollution in the environment. Other pellets finds (such as those from the Great Nurdle Hunt) that cannot definitively be attributed to either a chronic or acute loss at this time are discussed in Section 2.6.3 'Plastic Pellet Pollution Distribution' and this too is an underestimate of sites affected and number of pellets in the environment.

Figure 13: Identified locations of acute and chronic pellet losses (blue = acute; orange = chronic)

2.6.2.2 Figure 13 shows a lack of verified losses, both acute and chronic, in three of the study regions – Africa & Middle East, Asia Pacific and Central & South America. Given the information known about the scale of the industry in these regions, particularly in the Asia Pacific region, more chronic and acute losses would be expected to be identified in these regions. It is considered likely that the reason for the lack of identified chronic and acute losses in these regions is predominantly due to a lack of reporting which is driven by a lack of industry transparency and insufficient regulation as there is no requirement to report pellet loss incidents. In addition, there are also limitations in obtaining the data due to the authors' language barriers, restricting the data largely to English speaking nations, therefore the full extent of pellet pollution within these regions is largely unknown.

2.6.2.3 Of the reported sites of chronic and acute pellet pollution identified, only 22 of the incidents provided an estimate of the quantity of pellets lost. It is therefore not possible to accurately estimate the quantity of pellets that have been lost to the environment at these sites, however, **based on the reported estimates alone, the quantity of pellets lost is in excess of 624 billion pellets from 1995 to date from the 78 known chronic and acute pollution sites.** According to the available data on major chronic and acute pollution sites, the greatest number of pellets found in the environment are associated with acute spills, however previous studies identified chronic sources as making the biggest contribution of pellets to the environment. This difference in findings is likely due to a range of factors including: not all chronic pollution sites being known; chronic loss of pellets along the supply chain dispersing over time impacting a wider area, not only industrial areas which has not been identified; the lack of reporting; the lack of available quantitative data and a lack of long term studies on pellet losses from chronic sources.

2.6.2.4 **The reporting of both acute and chronic sources of plastic pellets has shown a general increase since 2005,** as illustrated in Figure 14. This is likely to be associated with increased awareness of plastic pellet pollution and subsequent volunteer initiatives such as Fidra's Great Nurdle Hunt and Nurdle Patrol, but also likely to be associated with the continued growth of the global plastics industry.

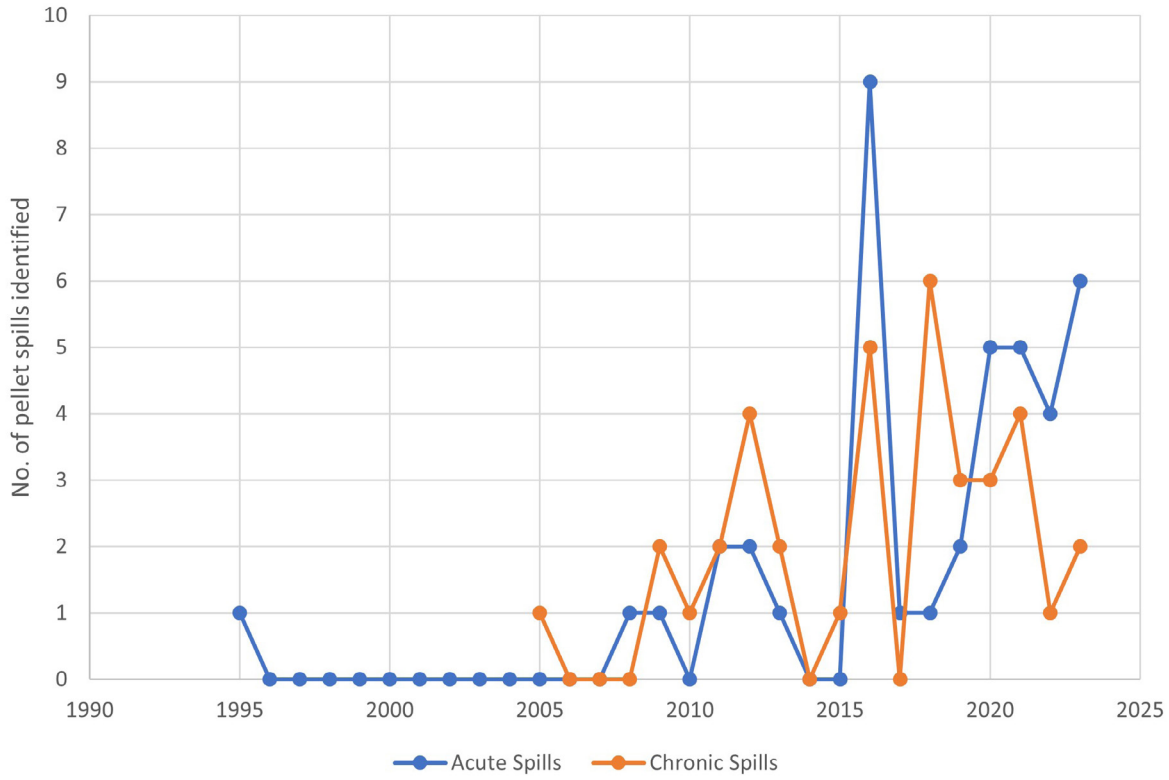

Figure 14: Number of acute and chronic spills identified over time (years)

2.6.2.5 Once released to the environment, it is often not possible to attribute plastic pellets to a particular source given their mobility, persistence and abundance[5]. In particular, owing to their density often being lighter than water, pellets can be distributed widely as a result of ocean currents and wind drift[32; 33]. Schuman and others found that following an acute spill of around 49 tonnes or 2.45 billion plastic pellets into Durban Harbour in South Africa in 2017, plastic pellets remained in specific sections of the coast for long periods, and sporadic wind events were required to move them into new coastal areas[33]. Following the incident, plastic pellets were found to have extended over 2000 km of the South African coastline in a period of 8 weeks. Despite extensive efforts to collect the plastic pellets, some 9 months after the incident, less than 20% of the pellets had been recovered. This research highlighted the connectivity of different ocean regions, and in particular that **when plastic pellets are released to the marine environment it is not just a localised impact but pellets can be dispersed over thousands of kilometres.** Case studies of an acute pellet loss incident (Hong Kong, 2012) and chronic pellet pollution (Chessel Bay, Southampton, UK) are presented in Appendix D. Both these case studies highlight the **multilayered impacts that are caused by chronic and acute pellet losses which are likely to occur to any region in the near future, if not already.**

2.6.3 Plastic pellet pollution distribution

2.6.3.1 Data on the distribution of plastic pellets from citizen science projects across the globe from counts recorded by Fidra and Nurdle Patrol have been reviewed[34; 35]. Due to the nature of citizen science initiatives and the focus of these projects on coastal areas, the pellet pollution distribution is an underestimate of sites affected and does not fully represent pellets in the environment with no data presented on pellets in the marine environment. However, these citizen science projects have identified a large number of pellet pollution sites. Figure 15 shows plastic pellet pollution data highlighting that **large numbers of pellets have been identified in North America and Northern Europe, with far fewer in South America, Africa and the Asia Pacific regions. Given the scale of the plastics industry in the Asia Pacific region, particularly China, South Korea and Singapore, more reports of pellets would be expected in these areas** as discussed below. However, it is considered likely that the lack of recorded pellets in this region is related to a much smaller number of nurdle hunts being carried out rather than there being fewer pellets present. There may also be a lower awareness of plastic pellets in some regions, and it is also recognised that industry and political administrations may inhibit engagement in activities such as nurdle hunts.

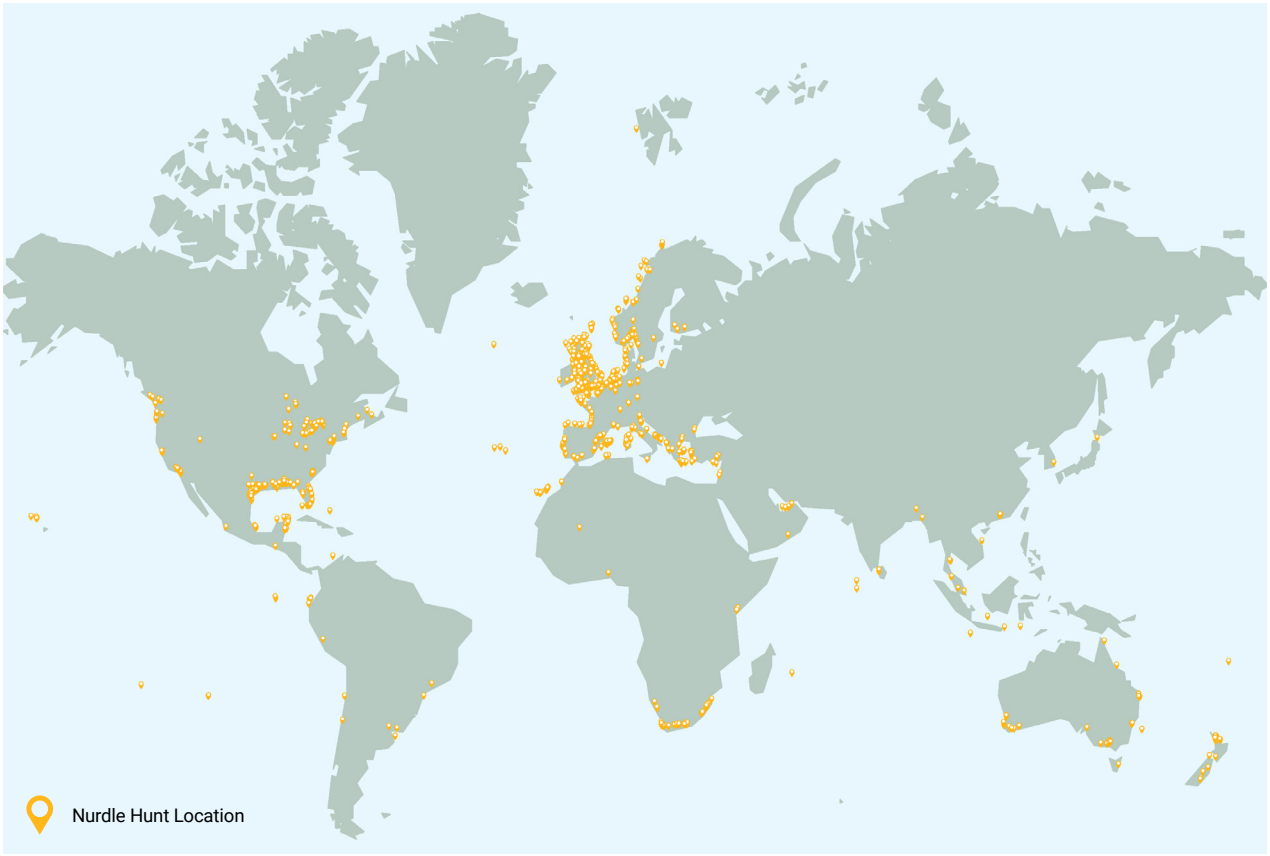

Figure 15: Global distribution of pellets found in the environment through citizen science programmes[34, 35]

3.0 Regional Data Exploration

3.1 Regional Summary

3.1.1 This report has identified that the plastics industry is truly global but there are large variations in the available data for each region, in particular in relation to the reporting of acute and chronic pellet losses and citizen science data. Fidra established the Great Nurdle Hunt in 2013 but only expanded this globally in 2019 and Nurdle Patrol started collecting data on nurdle pollution in 2018. Despite the short timeframe the citizen science projects have already generated a large amount of data about the distribution of pellet pollution in the regions where they have been most active.

3.1.2 Even in regions where a greater number of reports of pellet pollution are available, such as Europe, it is still considered that pellet pollution is grossly under reported based on the scale of the industry. This is driven by a lack of relevant legislation and industry transparency regarding losses. In regions where less data is available, primary drivers for this are likely to again be a lack of legislation and industry transparency, alongside a lack of awareness of the severity of the pellet pollution issue, and the personal risks associated with reporting pollution to relevant authorities or polluters[36].

3.1.3 Key information relating to the five regions targeted in this report has been extracted in relation to primary and recycled plastic production and transport, and where relevant, protected areas, tourism and pellet loss, to explore the magnitude of risk from plastic pellet pollution in each region.

3.2 North America

3.2.1 **North America is a major producer, importer and exporter of primary plastics.** In 2021, North America (US, Canada & Mexico) accounted for 17% of world trade exports of primary plastics and 11% of imports[21]. It is estimated that North America accounted for 18% of global plastics production in 2021 with no change from the same estimate made in 2017[27]. The US was the world's largest exporter of plastics in primary forms (Table 1) in 2021[21] with over 12,500 facilities involved in the plastic industry employing almost 1 million people[37]. Canada was the 11th largest importer and exporter of plastics in primary forms in 2021[21] with over 2,500 facilities involved in the plastics industry[38]. Over 290 plastic recycling plants have been identified in North America[39] with at least 195 present in the US. In 2021, North America accounted for 16% of global import trade in plastics manufacturing wastes[21].

3.2.2 **Rail, road and maritime transport of pellets present an acute pellet loss risk in North America.** Four of the global top 50 container ports by cargo volume are located in North America[40] and 30 large ports as defined by the World Ports Index[41]. A large intermodal transport network exists in North America with freight moved between sea, road, rail and air. The US has almost 140,000 miles of freight railway line with each freight train carrying an average 4,089 tonnes[42]. In Canada there are 20,000 miles of rail track with 14 intermodal terminals[43]. In 2022, the US reported 1,182 train derailments, an average of 3 per day[44] and this report has identified nine pellet loss incidents involving the rail network in North America, with five of these relating to train derailments. The primary transport method for US freight is by truck accounting for around 65% of movements in 2017 with rail accounting for around 8%[45]. The distribution of freight between the transport types is predicted to remain broadly similar but the overall freight volume is predicted to increase from 19,786 Mt in 2017 to 28,890 Mt by 2050[45]. A total of two acute pellet loss incidents during road transport have been identified in North America with one of these relating to the loss of 13 tonnes of plastic pellets.

3.2.3 **Chronic pellet loss is observed in proximity to plastic industry sites in North America.** A strong correlation was observed between the locations of plastic pellets identified through citizen science projects[34; 35] and the concentrations of the plastics industry, producers, converters and recyclers, in North America, as shown in Figure 16. Across North America 7,963 hunts have found pellets in the environment.

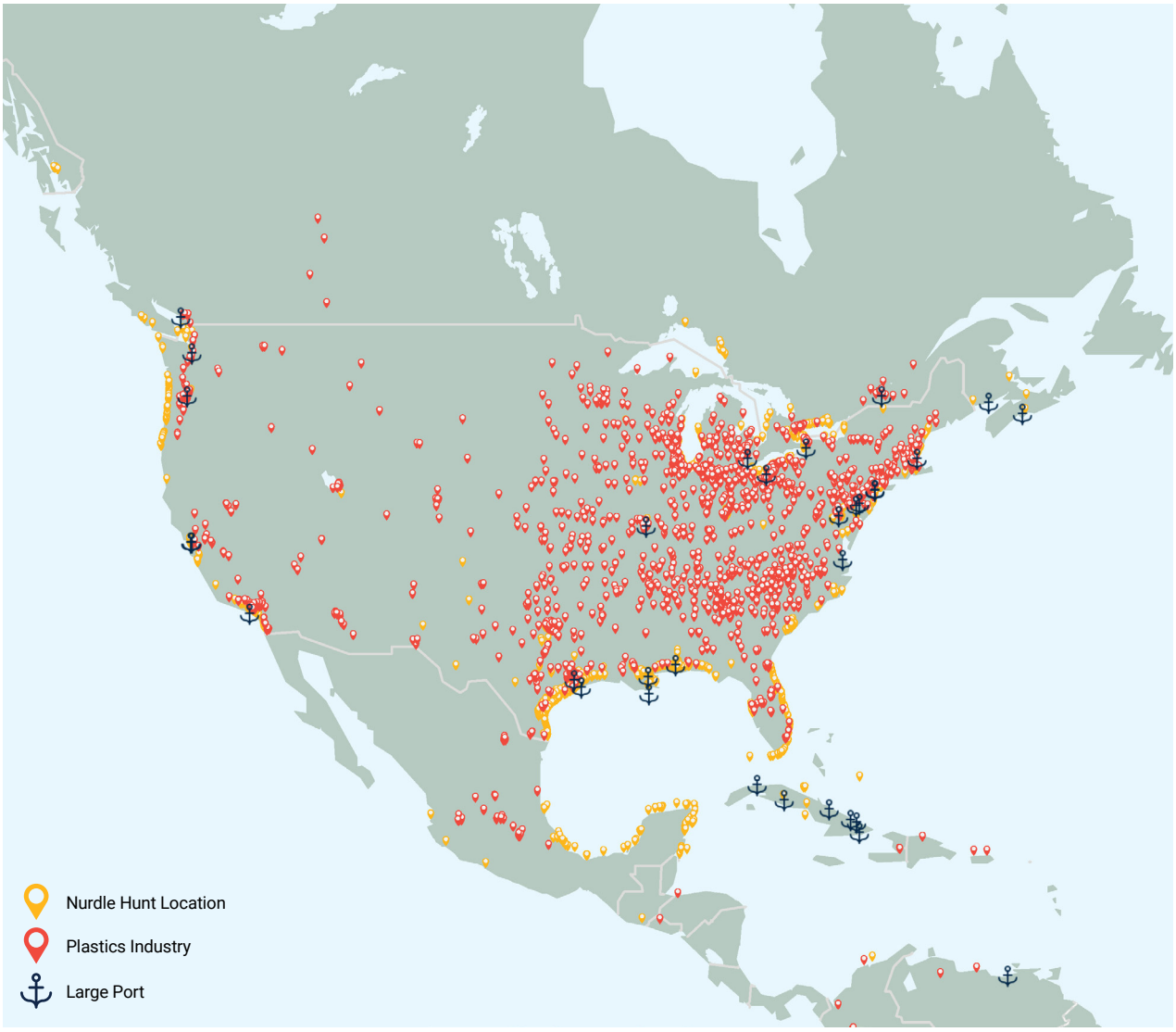

Figure 16: Map of North America plastics industry producers, converters and recyclers (red), large ports, and locations of positive nurdle hunts (orange)

3.2.4 **Protected areas in North America suffer from pellet pollution and are at risk from further pollution due to their proximity to the plastics industry.** The plastics industry also has a presence in very close proximity to designated protected areas within North America, one key example is the Gulf of Mexico (Figure 17). The waters surrounding Florida are well known for their manatee populations and vital sea grass habitats which could be affected by the pellet pollution. In total, the Gulf encompasses over five million acres (about half of the US total) of coastal wetlands that serve as an essential habitat for numerous fish and wildlife species, including migrating waterfowl seabirds and wading birds. Within the area shown a total of 135 facilities involved in the plastics industry have been identified, these include producers, recyclers and manufacturers. The same area contains 2,087 individual protected areas covering over 112,000 km2. This report has identified a total 6,117 positive nurdle hunt reports within the area shown with 1,378 (22.5%) of the positive hunts within 61 protected areas. The data clearly shows that the presence of plastics industry within close proximity to protected areas (Appendix D Case Studies) pose a high risk of plastic pellets being released into protected areas with over one fifth of positive nurdle hunts occurring in protected areas.

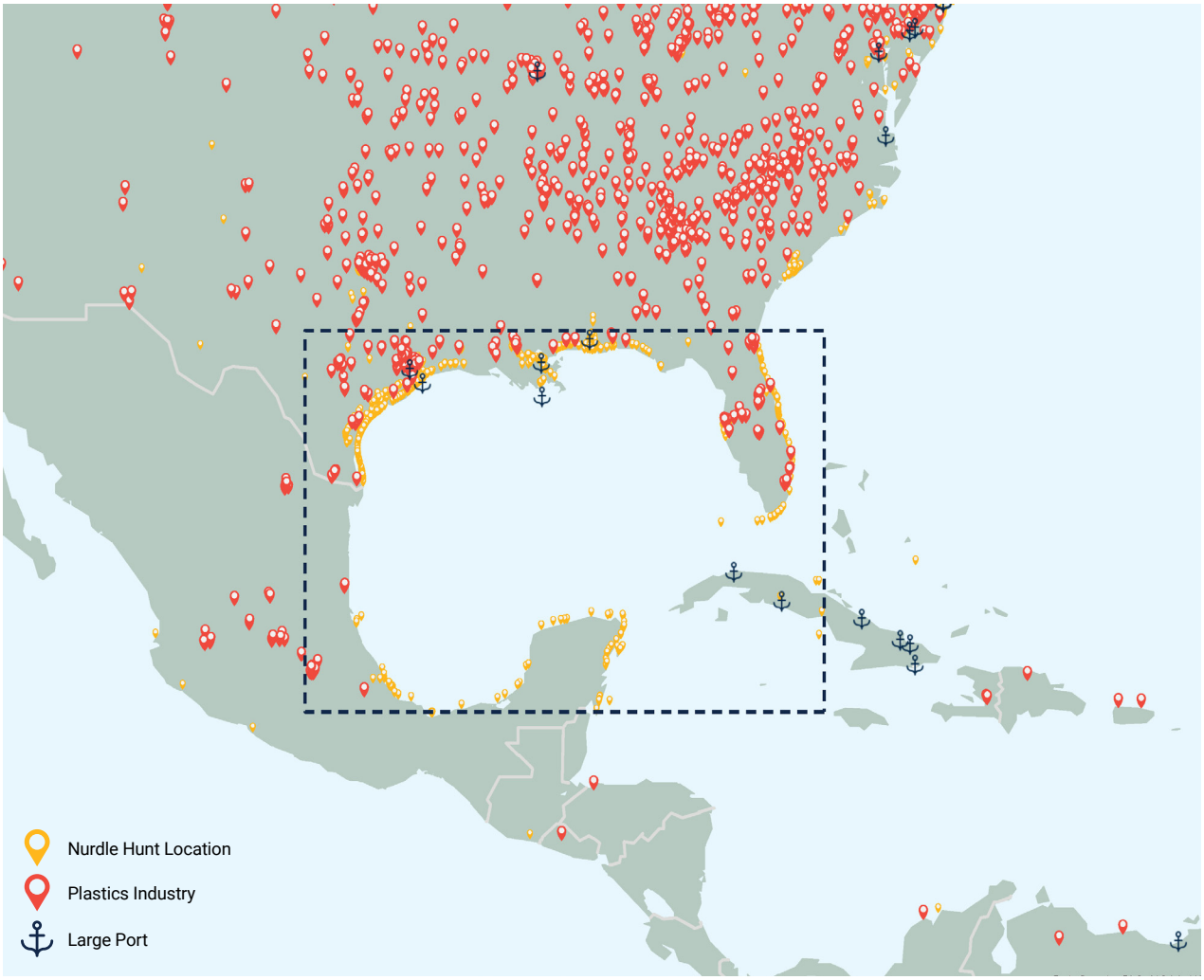

Figure 17: Close up of plastics industry facilities, ports and nurdles identified in the Gulf of Mexico

3.2.5 **The Gulf of Mexico and Caribbean tourism is at risk from chronic and acute pellet loss.** In 2019 (pre Covid-19 pandemic) North America had over 143 million tourist arrivals with the US being the third most popular tourist destination worldwide[25] with the US employing 3.8 million people in the tourism industry in 2020 (down from over 6 million in 2019)[46]. Mexico employed 2 million people in the tourism industry in 2020 with Canada employing 500,000 people[46]. Notwithstanding the scale of the tourism industry in the US and Mexico, the impact from pellet pollution will be greater on those countries whose economies are heavily reliant on tourism. The Gulf of Mexico and surrounding Caribbean waters are also well known for bringing in international travellers for its sport and commercial fishing. For example, a number of countries in the Caribbean are heavily reliant on tourism with it making a major contribution to their GDP, for example Antigua and Barbuda (14.6% of GDP) and Jamaica (9.2% of GDP). These countries generally have little or no contribution to the plastics industry yet could be severely impacted by the loss of pellets along the supply chain. The impact of plastics on tourism in the region is known[47] and this issue has led to action by the UN to mitigate the impact from plastic pollution[48], although there appears to have been limited assessment of the specific impact of plastic pellets on tourism.

3.2.6 **Current legislation and management practices are failing to stop pellet loss.** In the US, since 2010, petrochemical companies have invested over USD 200 billion to expand plastic resin production capacity along the US Gulf Coast[49]. To support this growing market, Union Pacific has invested heavily in the Gulf Coast rail network, adding terminal and rail car switching capacity. Union Pacific and a number of petrochemical companies in the US, including BASF, DuPont, Dow Chemicals, ExxonMobil, INEOS and Lyondell Bassell, have committed to the OCS pledge[50] which is designed to help companies that handle plastic resin share best practices as they work toward achieving zero plastic pellet loss and keep pellets out of the environment. However, the pledge is a voluntary measure with no external monitoring, auditing or mandatory requirements[51]. This study has identified two acute pellet loss incidents involving Union Pacific trains; however, these were both before they joined OCS in August 2022.

3.3 Central and South America

3.3.1 **Central and South America suffers from pellet pollution despite having lower plastic production, import and export compared to other regions.** Data on the Latin American region which includes Central and South America indicates that their share of global plastic production is low (~4% in 2021)[27]. World data identified the region accounted for >2% of exports and 5.5% of primary plastic movement across the region[21]. Despite the regions seemingly small contribution to worldwide production and trade of plastic products, they are undeniably impacted by plastic pollution[52; 53; 54]. Numerous national and local laws have been passed across the Latin America and Caribbean Region since 2016. For example, Antigua and Barbuda was the first country to introduce a ban on plastic bags in 2016[55] and Chile introduced the first South America ban of plastic bags in 2018, before then introducing a single use plastic ban in 2021[54]. Across the region where laws are not in place, action plans to target plastic pollution and marine litter or the use of bio-fences, to capture plastic waste from waterbodies, have become fundamental to tackling plastic pollution[56; 57; 58.]

3.3.2 **Chronic plastic pellet pollution has been identified in the Central and South America Region.** Despite the majority of Central and South American countries having laws associated with managing plastic waste, no country within the region has any regulations in place to monitor or tackle any form of microplastic pollution[59]. The lack of awareness of what constitutes primary plastics, including pellets, could be a reason for this. There is evidence that plastic pellets are being found in the environment across the region[60]. Figure 18 shows the identified plastics industry along with plastic pellets identified by citizen science programs and reflects the limited number of volunteers actively recording pellet pollution in comparison to other regions. A Costa Rican beach was included in the IPEN study exploring plastic pellet chemical contamination; however, no NGO group or volunteers have logged pellet pollution in this location via www.nurdlehunt.org.uk. Peer reviewed literature on the scale of pellet pollution, is limited, but is increasing in the region with research in coastal[61] and riverine environments[62] identifying pellet pollution and subsequently pellet mismanagement. Whilst no known acute pellet spills have been recorded in the region, the region is at risk from acute spills from the major North America to Europe plastic trade route as well as major ports within the region. One study documented chronic pellet losses around Santos Port and plastic factories in Cubatão city[63]. Pellet pollution logged by volunteers highlight the beaches south of Santos Port to have a high concentration of pellet pollution, which is supported by pellets logged through the nurdle hunt portal. In this study **it is estimated that between 1,673 to 16,584 tonnes of plastic pellets could be lost annually in Central and South America Region alone** (Table 2).

3.3.3 **Plastic recycling could be on the rise in Central and South America increasing the risk of toxic plastic pellet pollution.** The plastics industry is highly influential in many countries in the region, due to the opportunity the industry has created for economic growth. For example, The Chilean Plastics Industry Trade Association has successfully lobbied against additional taxes to the industry and have instead pushed for a law focused on Extended Producer Responsibility (EPR) to encourage plastic recycling. In this study, 198 plastic recycling plants were identified in the region, 7% of the global share, with 57% of those identified located in Brazil[15]. This is unsurprising with the Brazilian plastic converting sector generating around USD 23.7 billion in 2021 alone[64]. It is not clear if these recycled plastic pellets, flakes and powders are then being used in the region or being exported to other regions because of limited transparency in the sector[65], further emphasising, the uncertainty in mapping the supply chain in this region. The increase in plastic recycling supported by the industry, will undoubtedly address some short-term circular economy issues the region is facing. However, the associated chemical contamination from the creation of recycled pellets is a major concern which cannot be ignored[60; 65]. The expected increase in production of recycled pellets across the region will lead to more imports and exports of pellets and subsequently increase the risk of chronic and acute pellet spills with unknown impacts to human health and the environment if not understood, monitored and regulated using a supply chain approach to stop pellet pollution.

3.3.4 **There is limited data available on plastic pellets contamination in the region due to lack of mandatory reporting requirements.** Overall, data was difficult to find for the region, with limited accessibility to information due to language barriers as well as limited requirements for industry to share information, therefore limiting the study's understanding of the plastic pellet supply chain in this region. Key data gaps identified in the regional review included identification of the plastics converters and all the recyclers across the region, as well as the absence of reported nurdles as discussed above. Commerce and local industry databases are understood to provide an accurate source of industry data, but are mostly written in Spanish or Portuguese, which limited the authors' ability to access this data.

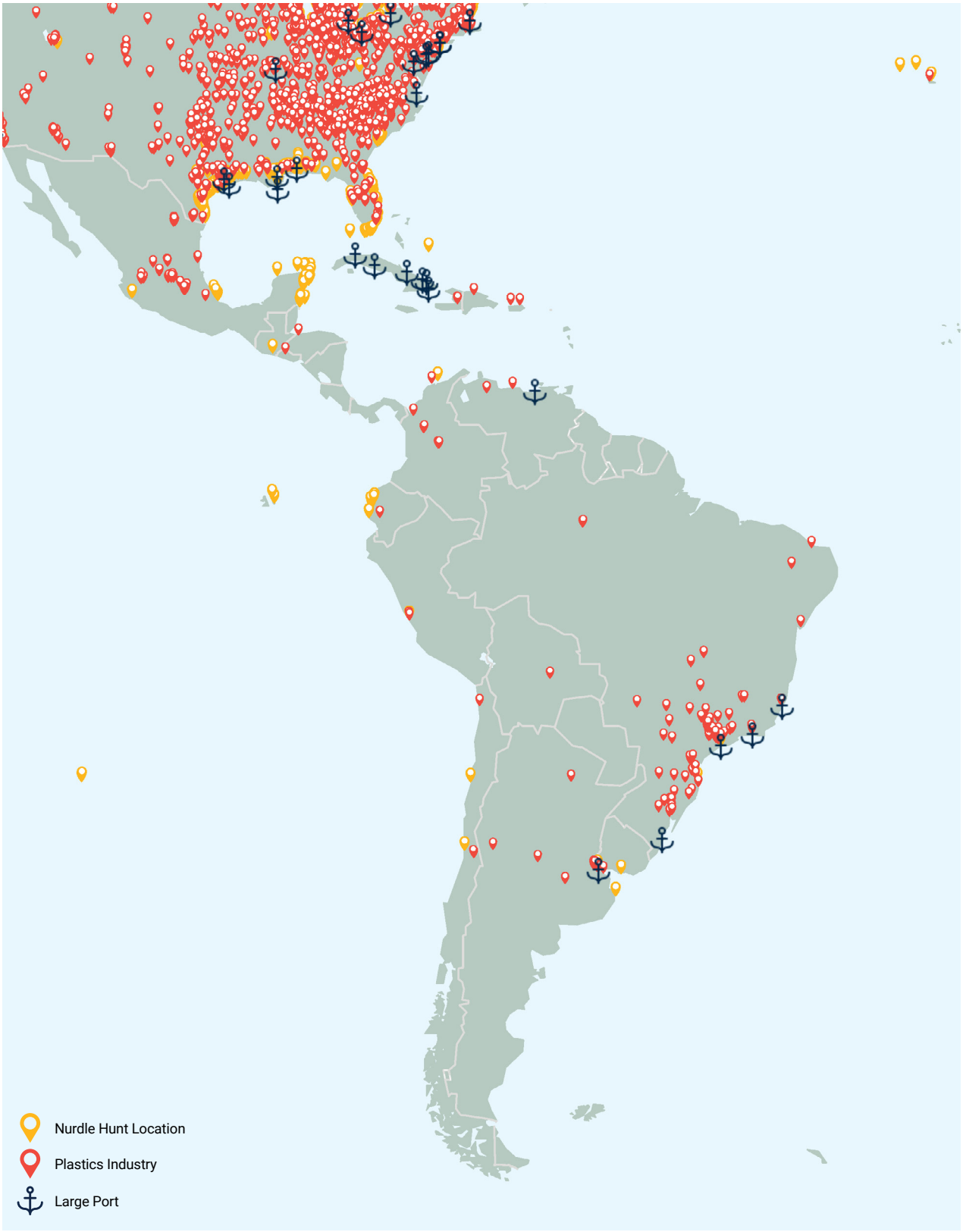

Figure 18: Map of Central and South America plastics industry producers, converters and recyclers (red), large ports, and locations of positive nurdle hunts (orange)

3.4 Europe

3.4.1 **Europe is a major producer, importer and exporter of both primary and recycled plastic pellets.** Europe has the largest share of the global plastics industry based on combined imports and exports of plastics in primary forms at 148 billion USD, according to 2021 trade value, Europe accounted for 40% of world trade imports of primary plastics and 35% of primary plastics exports[21]. The European Union accounted for 15% of global plastic production in 2021 with 52,000 companies in the plastics industry employing more than 1.5 million people[27]. Europe contains four of the World's top 10 exporters of plastics in primary forms and five of the top 10 importers with Germany being the World's second largest importer in 2021 by trade value[21]. Over 1,400 plastics recycling plants have been identified in Europe, which is 54% of the global total identified in this project[39]. Both primary and recycled pellets are known to contain toxic contaminants and additives with particularly high levels found in recycled pellets which is an additional risk factor for European pellet pollution[66].

3.4.2 **Road and maritime transport of pellets are an acute pellet loss risk to European countries.** Europe is home to seven of the World's top 50 container ports by cargo volume handling over 56 million TEU in 2021[40] (refer to Figure 8 which shows the major shipping route between North America and Europe). In the European Union in 2021, 67.9% of freight was maritime, 24.6% was by road and 5.4% was by rail[67], with Germany accounting for 23.8% of goods transported by road in the European Union in 2021[68]. This report has identified 24 sites suffering from acute plastic pellet loss incidents in Europe with half of these occurring during the transport of pellets by road with all road incidents occurring within France where there is mandatory reporting of spills[69]. A number of European countries have larger plastics industries than France based on trade in primary plastics, including Belgium and Germany. It is therefore considered likely that incidents are going unreported given the scale of the plastics industry across Europe, and the lack of reported incidents outside of France.

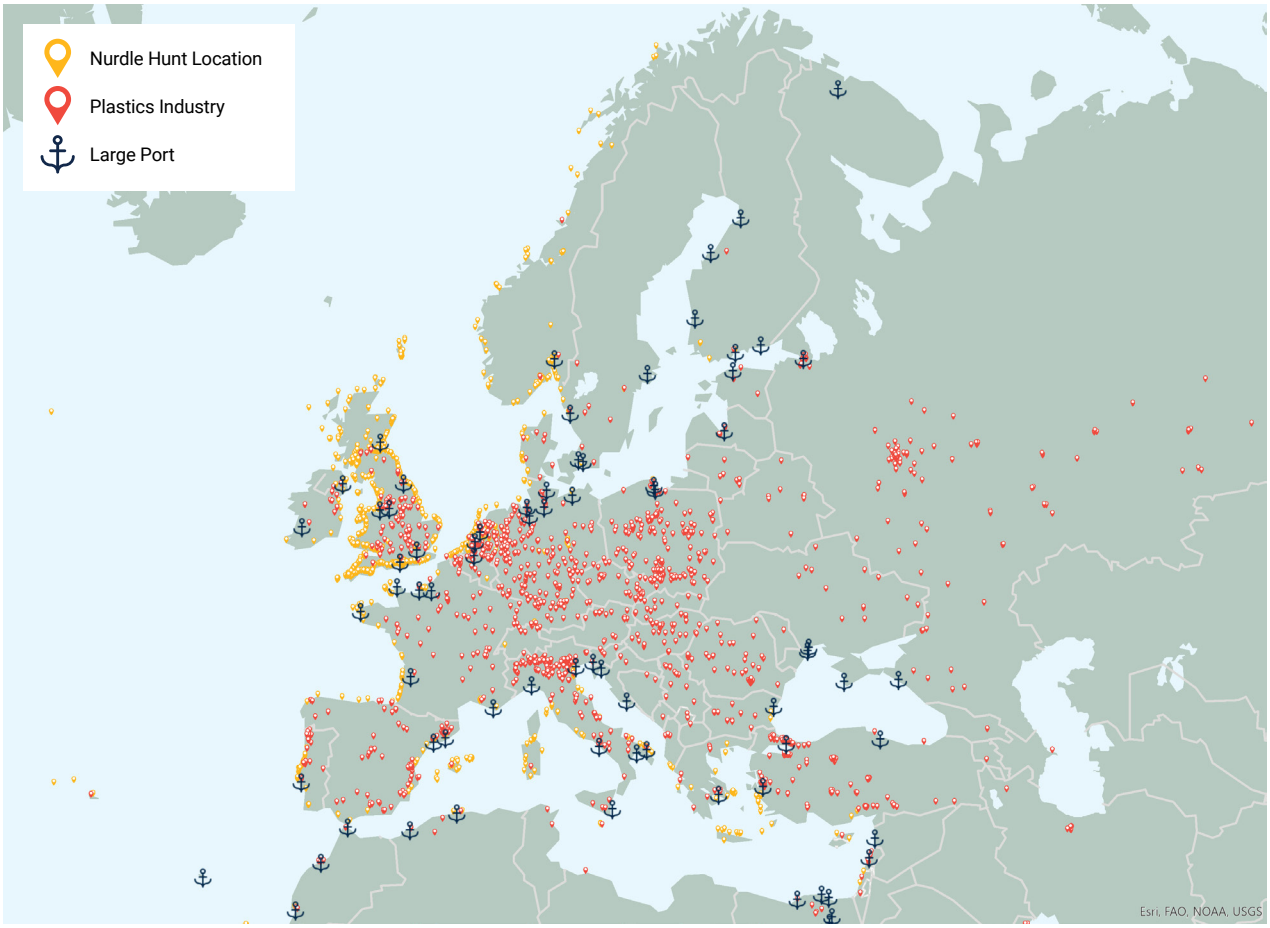

Figure 19: Map of Europe plastics industry producers, converters and recyclers (red), large ports, and locations of positive nurdle hunts (orange)

3.4.3 **Chronic pellet loss has been identified in proximity to plastic industry sites across Europe.** A strong correlation has been observed between the concentration of the plastics industry and the location of pellets identified in the environment (Figure 19), which indicates mismanagement of pellets is occurring near sites where pellets are handled. This report has identified 26 chronic pellet loss sites, with 21 of these attributed to direct losses from industry. The plastics industry near these sites has heavily polluted the local environment with plastic pellets, and it is not always possible to determine whether pellets have been lost from the production, transport or conversion of pellets, however chronic pellet loss on land is the largest known source of pellet pollution[30]. Notable industrial areas with nearby pellet pollution include Grangemouth, Scotland, UK where an INEOS' site produces one-third of the entire UK plastics production, making an estimated 30-35 billion plastic pellets each day[70]; the Feluy industrial zone, Belgium, where Total Petrochemicals produce pellets and is the leading producer of TotalEnergies polymers in Europe, and other companies involved in the handling, transport and logistical management of pellets (e.g. Harry Vos Logistics, Katoen Natie and Feluy Service Center) with pellet pollution noted in the area since 2007[71]; the Westerschelde[72] and Oosterschelde regions of the Netherlands with pellets originating from both production in local cities (e.g. Terneuzen) and transfer in regional ports (e.g. Antwerp and Vlissingen) as well as ports in other countries (e.g. Hull and Felixstowe in England).

3.4.4 As noted above, 52,000 companies are involved in the plastics industry within the European Union alone with over 1,400 recycling plants, therefore it is again considered that the 21 known chronic pellet loss sites is an underestimation of the true scale of the issue. Currently there are 2,664 signatories to the voluntary industry led initiative Operation Clean Sweep (OCS) in Europe. However, this report has identified 49 acute and chronic pellet loss incidents across Europe between 2009 and 2023 which confirms that this voluntary approach is not sufficient, indicating a need for the introduction of mandatory measures to address pellet loss. This was also a conclusion reached by Flora and Fauna International and Plastic Change in their review of plastic pellet pollution in Denmark[73] In this study, the Port of Aalborg and the Port of Aarhus were identified as major transport hubs for import of virgin plastic pellets to the Danish plastics industry. The study highlighted that pellets are transported in containers by truck from the harbours to the plastic converters production sites and that no plastic pellets are handled in bulk in the harbours. The loss of pellets was principally identified to take place when containers are opened and pellets in bulk bags are handled at redistributors or at production sites. Based on field sampling near pellet production sites it was concluded that there was no discernible difference in pellet retention and pellet loss prevention at companies that had or had not signed up to OCS. To address the issue of pellet loss the study recommended that all companies involved in making, using or transporting plastic pellets must follow mandatory guidelines that prevent pellet loss throughout all stages of making plastic products (i.e. throughout the plastic 'supply chain').

3.4.5 **Protected areas in Europe suffer from pellet pollution and are at risk from further pollution due to their proximity to the plastics industry.** A large concentration of the plastics industry in Northern Europe is located within and very close to environmentally protected areas and pellets have been found at a number of these sites. For example, high concentrations of plastic pellets have been identified in Chessel Bay, England, UK, which is a Local Natural Reserve, a Site of Special Scientific Interest (SSSI), part of a Special Protection Area (SPA) protected under European legislation, and an internationally important Ramsar Site (Appendix D).

3.4.6 While some European countries have introduced national legislation in an attempt to minimise pellet loss (e.g. French Anti-Waste Circular Economy Law) given the global nature of the plastics supply chain national action must be supported by global action to ensure that pellet loss from the entire supply chain is prevented (discussed further in Section 4).

3.5 Africa and Middle East

3.5.1 **Africa is an importer and exporter of plastic and production is growing.** The region is estimated to account for 8% of global plastic production in 2021, a growth from 7% in 2017[9] with over 112 plastic recycling plants identified[15], approximately 4% of those identified globally in this report. The Africa & Middle East region accounted for 16% of world trade exports of plastics in primary forms and 17% of imports in 2021 with Saudi Arabia the world's second largest exporter in 2021[21]. In Africa the largest importer of primary plastics was Nigeria, with Egypt the largest exporter[21]. Signatories to OCS in Africa are located in Ghana, Egypt and South Africa although trade data shows plastics activities occurring in many more countries in Africa than this including Nigeria, Morocco, Kenya, Tanzania. The Gulf Petrochemicals and Chemicals Association is a member of OCS in the Middle East[50].

3.5.2 **Maritime transport of pellets present an acute pellet loss risk in Africa.** The region has six of the World's top 50 container ports by cargo volume[40] and 21 large ports as defined by the World Ports Index[41]. Africa has a number of large inland container depots and 'dry ports' for the inland distribution of goods. These are likely to be centres or hubs for onward plastic pellet distribution. A positive correlation is observed between the location of major ports and the concentration of nurdles identified (Figure 20). The region has suffered from acute pellet pollution with large pellet spills having occurred in Durban, South Africa in 2017, Plettenburg South Africa in 2020 and Dubai, UAE in 2023. Despite these incidents, there remains a lack of regulation around the production and transport of plastic pellets across the region which in part could be due to the contribution that the plastics industry makes to national economies. For example, in South Africa, in 2018 the plastics industry contributed more than 2.1% to the overall GDP and a 21.8% contribution to Manufacturing GDP[74]. It is also estimated that there are approximately 1,800 companies employing around 60,000 workers in the sector.

3.5.3 **Chronic pellet pollution is underreported in Africa.** While pellets are found, no sites of chronic pellet pollution have been identified in Africa and Middle East in this study, however, this is expected to be due to under reporting of the issue. Chronic pollution in Africa from the oil and gas industry has been ongoing since the 1950s and 1960s and this is also often under reported yet can have devastating effects on communities, particularly those which rely heavily on fishing and aquaculture. This is despite the presence of regulation and the involvement of large multi-national companies headquartered outside of Africa. One region where chronic oil pollution continues to occur today is the Niger Delta in Nigeria. It is therefore considered likely that the plastics industry, which is currently less regulated than oil and gas in relation to the reporting of spill incidents, is likely to be causing chronic pollution within the region, which is going unreported, yet also has the potential to cause damage to the environment and livelihoods.

3.5.4 **Pellets and other microplastics are impacting health and the environment.** Microplastic pollution across Africa and reported pellet pollution is reported along the coastlines of South Africa, Tunisia, Nigeria, Ghana and on Lake Ziway in Ethiopia[75]. The authors identified that microplastic contamination in Africa can lead to severe environmental consequences including the development of metal toxicity within aquatic and terrestrial organisms, disruptions of the food chain in the ecosystem, and public health risks to humans who consume seafood. These findings were echoed in a review of plastic pollution in Nigeria[76] although the research identified a gap in the knowledge of microplastic distribution in the environment in Nigeria as well as limitations on the biological effects of microplastics on terrestrial and aquatic biota. Recommendations for policy change were proposed by the authors who expressed an urgent need to take action to educate citizens and other stakeholders on the environmental consequences of plastic pollution[76]. Furthermore, they recommended that policies be directed at plastic use reduction, reuse and recycling to mitigate the impact of plastic pollution including taxes on the production and importation of single-use, non-biodegradable plastics. To date, none of the recommendations have been brought forward into regulations in Nigeria.

3.5.5 **Pellet pollution is likely to increase in Africa.** Given the predicted growth of the plastics industry across the region, particularly in Sub-Saharan Africa, the occurrence of plastic pellet pollution is likely to increase without the introduction of regulations to manage their use and handling and transport. The release of plastic pellets has the potential to severely impact sensitive environmental habitats across the region. For example, Africa has 20% of the world's mangroves 74% on the west coast and 26% on the east coast[77]. Once plastic pellets enter a mangrove environment, their removal will be extremely difficult given the difficulty in accessing the mangroves and the associated creek environment, and when pellets deposit on sediments they will become buried within the sediment profile. The removal of pellets from such an environment could also result in long term damage to the mangroves themselves[78].

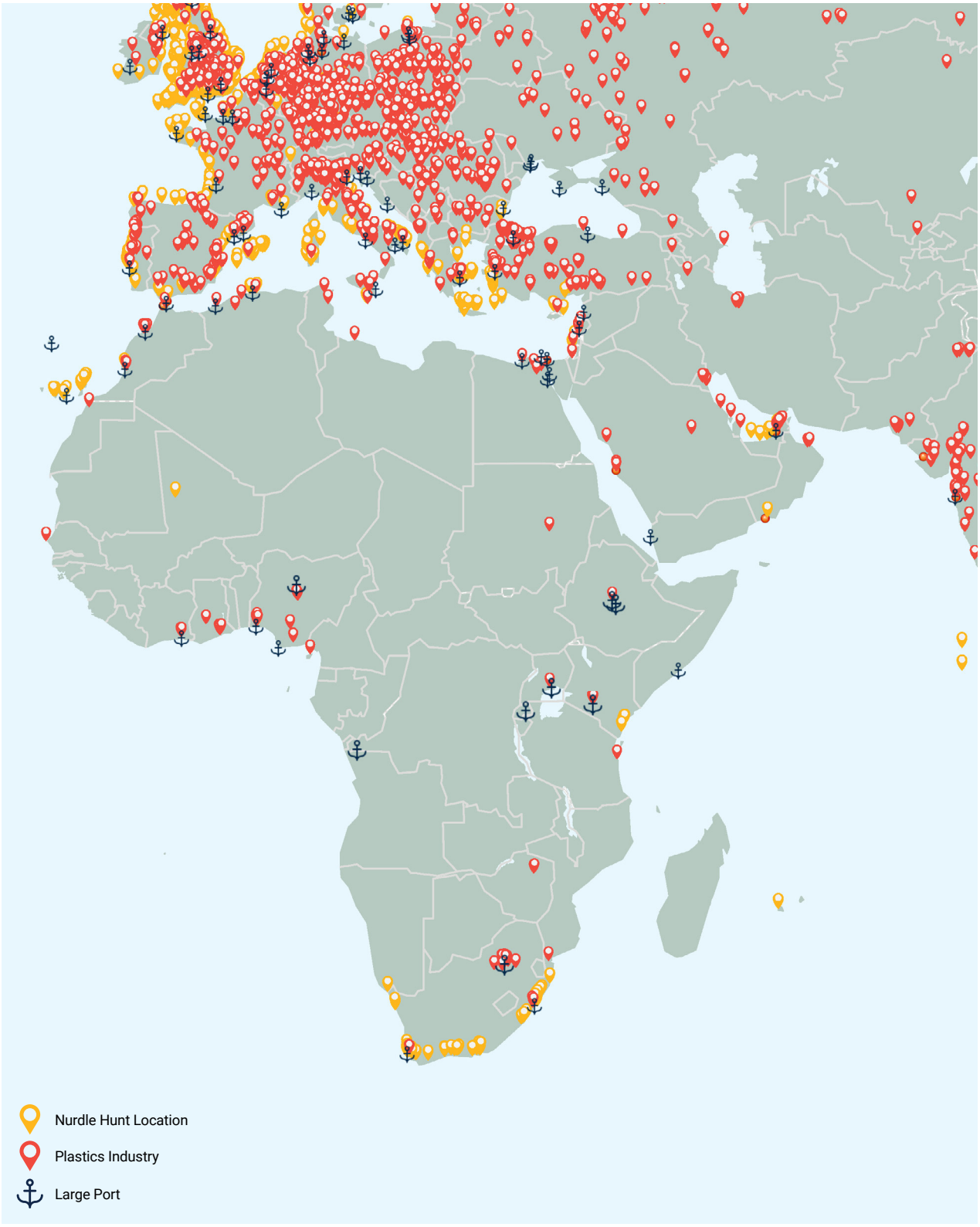

Figure 20: Map of African and Middle East plastics industry producers, converters and recyclers (red), large ports, and locations of positive nurdle hunts (orange)

3.6 Asia Pacific

3.6.1 **The Asia Pacific Region accounts for 52% of global plastic production and is a major importer and of primary plastic.** In 2021 the Asia Pacific region accounted for 31% of primary plastic exports and 37% of primary plastic imports with China identified as the world's largest importer[21]. The region accounted for 52% of global plastic manufacturing with 32% of this attributed to China[27]. The region has over 660 plastic recycling plants[39] and handled 23% of world trade in plastic manufacturing waste in 2021[21].

3.6.2 The region has 31 of the world's top 50 container ports by cargo volume[40] and 40 large ports as defined by the World Ports Index[41]. In 2019 within China over 3 million tom-km of freight by rail and over 262 million TEU of container port traffic[22] out of a regional total of over 475 million TEU.

3.6.3 **Pellet pollution is under reported in the region due to social and political barriers to data gathering.** China is identified as the world's largest importer of primary plastics, accounted for 31% of global container port traffic in 2021 and the world's largest manufacturer of plastic products. Significant plastics industry has also been identified in other countries in the region including South Korea, Singapore and Thailand. The number of nurdle hunts undertaken in this region is markedly lower than for other regions and, given the scale of the industry in this region, this is likely to be a under estimation of the scale of pellet pollution in this region. This study has also only identified two chronic sources of microplastic and pellet pollution in the region, one in China[79] and one in Christchurch, New Zealand[80]. A possible cause of the absence of identifiable chronic sources of pellet in the region is the reported difficulty volunteers face in the collection and reporting of this type of data, with effort sometimes blocked or discouraged by authorities[36].

3.6.4 In Europe, citizen science programmes undertaking nurdle hunts have identified pellets in over 2,489 locations with Europe accounting for around 15% of global plastic production. The Asia Pacific region accounts for more than 50% of global plastic production, therefore it would be expected that a similar increase in positive nurdle hunts would be expected if they were undertaken.

3.6.5 Those hunts that identify pellets do, however, show a positive **correlation between the location of pellet pollution and the plastics industry** (Figure 21). This is consistent with research that has been completed in the region, for example, plastic pellets were found in surface waters and in sediments of the Meycauayan and Tullahan Rivers in Manila, Philippines, and are thought to be associated with the plastics industry in the area, although the source is unconfirmed[81].

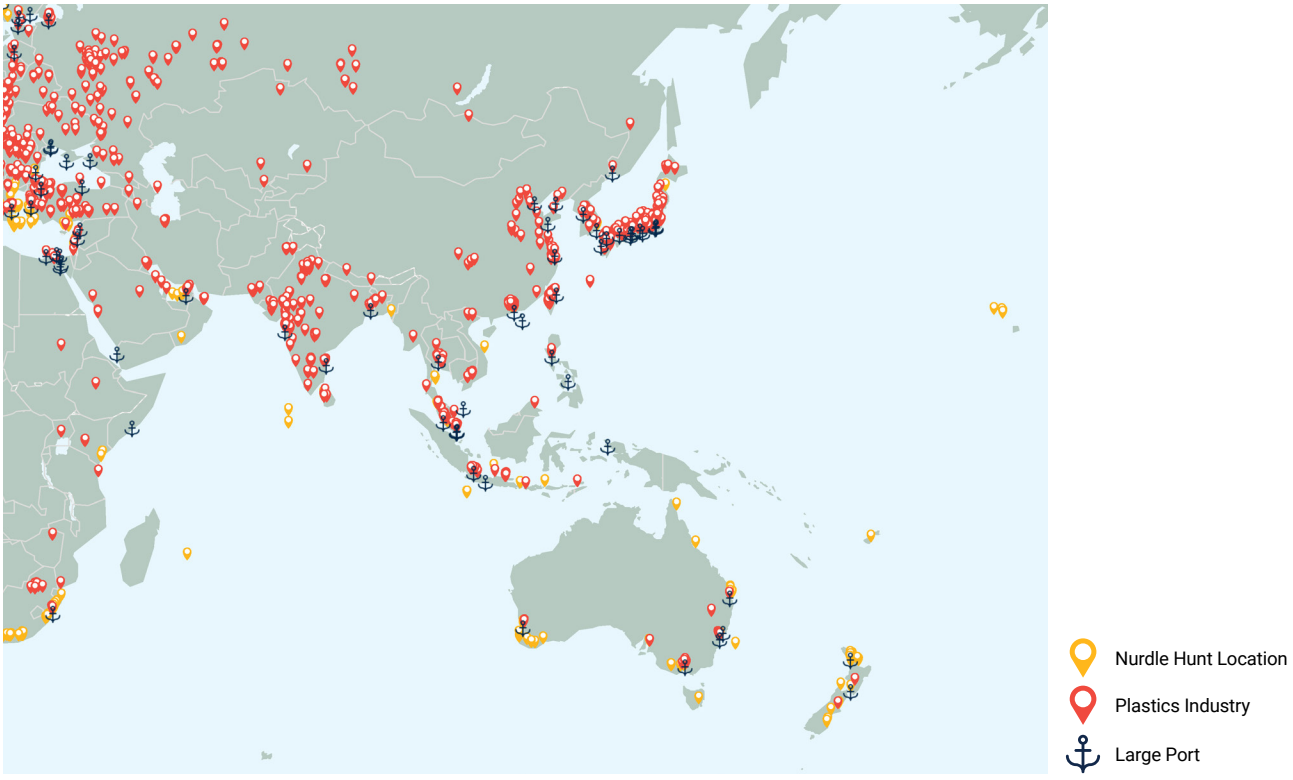

Figure 21: Map Asia Pacific plastics industry producers, converters and recyclers (red), large ports, and locations of positive nurdle hunts (orange)

3.6.6 **Asia Pacific countries suffer from acute pellet loss incidents and are at risk of further spills.** Owing to the major shipping routes through the region (Figure 7), there have been several large acute spill incidents including the X-Press pearl incident, where 87 shipping containers carrying several types of plastic pellets were lost from a container ship which ran aground and caught fire off the coast of Sri Lanka in May 2021. A total of around 1,680 tonnes of plastic pellets were released to the ocean as a result of that incident[24; 82; 83] and the clean-up of the pellets continued for well over a year following the incident. Researchers have identified the influence that ocean currents in the region had on the distribution of plastic pellets following the incident[84], highlighting that as a result of the buoyancy of the pellets and that they float on the water surface, their distribution is directly influenced by winds, waves, and ocean currents. Pellets released to the marine environment can therefore be distributed widely in the world's oceans and be deposited in remote locations.

3.6.7 Other acute spill incidents in the region include the MV Rena which ran aground off the coast of New Zealand in 2011 resulting in the release of 150 tonnes of plastic pellets into the Bay of Plenty, and the loss of containers from a ship near Hong Kong in 2012 (i.e. The Yong Xin Jie) which also resulted in the release of 150 tonnes of pellets to the ocean, near the Ninepin Group Islands (Appendix D). These incidents alone resulted in the release of an estimated 99 billion pellets to the marine environment in the region, with clear and significant impacts on tourism and local economies. However, given the scale of the plastics industry in the Asia Pacific region, the unreported acute and chronic sources of pellet pollution are likely to have a far greater impact on the environment and the health of the people across the region. **This study has estimated that given the scale of the global plastics industry in the Asia Pacific, between 15,308 and 151,764 tonnes of plastic pellets could be lost annually in this region alone** (Table 2).

3.6.8 It is also likely that in the future, the effects of climate change will increase the likelihood of acute spills of pellets from shipping if no measures are introduced to improve their storage during transport, owing to the increased frequency and severity of storm events[85]. In addition, given the scale and predicted growth of the plastics industry, discussed in section 4, and the associated transport routes in the region, there will be an increase in the risk of plastic pellet spills occurring in the future.

3.6.9 As detailed in section 2.2, losses of plastic pellets along the major shipping routes between Europe and the Asia Pacific region have the potential to have severe negative impact on nations that rely heavily on tourism (e.g., The Maldives and Sri Lanka). Following acute pellet spills, receiving appropriate compensation for the resultant damage to the environment and livelihoods is often not a straightforward process. Following the X-Press Pearl incident in 2021, the Sri Lankan government has so far received $7.85 million in compensation from the ship's insurer[86]. The Sri Lankan government has stated that this money has been used for cleanup efforts and to compensate fishers for lost income. However, Sri Lanka's Marine Environment Protection Authority (MEPA) assessed that $6.5 billion was required to compensate for all the damage caused to the coastline and coastal environment by the incident, so the monies received to date fall far short of the necessary compensation[87]. Although some compensation has been received by fishers, there is understood to be an absence of support for the communities who have been unable to use the impacted regions of coastline as a result of the pollution. Experts involved in the assessment of the environmental impact of the X-Press Pearl incident recommended that international shipping laws such as the International Maritime Organization's Hazardous and Noxious Substances (HNS) Convention, be updated to provide an appropriate mechanism for apportionment of liability and appropriate compensation for damages from incidents involving hazardous materials other than oil[86].

3.6.10 **Pellet pollution is a risk to globally important habitat in the Asia Pacific Region.** Pellet pollution in the Asia Pacific region also has the potential to detrimentally impact some of the world's most environmentally sensitive marine and coastal environments. For example, South Asia, Southeast Asia and Asia Pacific contain approximately 46% of the world's mangrove ecosystems, including some of the most biodiverse mangrove forests[88]. The region also has a large number of marine protected areas and coastal protected areas covering a total area of 11,697,141 km^2, approximately 19% of the total marine and coastal area in the region[89] making the region highly vulnerable to both acute and chronic sources of plastic pellets and the associated pollution.

4.0 The Future for Pellet Pollution

4.1 Growth of the plastics industry

4.1.1 UNEP[90] highlight that **over the last 40 years global plastic production has more than quadrupled,** and in 2020 the global plastic market was valued at around $580 billion USD. The OECD estimate that plastics production increased 230-fold from 2 Mt in 1950 to 460 Mt in 2019[91]. In another report which modelled scenarios based on 14 polymer categories, and both primary and secondary (recycled) plastics, the OECD estimate that **under current policies, the use of plastics could almost triple by 2060,** with the largest increases expected in Sub-Saharan Africa and Asia, particularly in India, given their predicted strong economic growth[92].

4.1.2 While recycled (secondary) microplastics (i.e. pellets, flakes and powders) are projected to grow more quickly than primary microplastics, they are predicted to only make up 12% of all plastics by 2060[91]. However, the growth of the recycled plastics industry is important as recycled pellets have been identified to be more toxic than virgin plastic materials, owing to the concentration of toxic chemicals during the recycling process and the creation of new and potentially more toxic compounds during recycling, such as dioxins[66]. There is a predicted growth in the production of bioplastics. Bioplastics refers to polymers made from biological sources of hydrocarbons and the plastic produced shares many of the properties and problems associated with fossil fuels based plastic production including contributing to pellet pollution. Like plastic pellets made from fossil fuel based plastic bioplastic pellets do not breakdown safely in the environment causing the build of plastic and toxic chemicals in the environment[93].

4.1.3 Under the OECDs 'business as usual' scenario for the plastics industry, it is predicted that global annual plastic use will grow from 490 Mt in 2019 to 1,231 Mt by 2060 as illustrated in Figure 22 which also highlights factors influencing that increase in plastics use.

Figure 22: Factors predicted to influence the growth of the plastic industry to 2060 and their respective influence on growth (Mt = Millions of tonnes)[42]

4.1.4 To facilitate the predicted growth of the plastics industry, there will have to be an increase in the growth and development of the global supply chain infrastructure, including increases in shipping and road and rail transport infrastructure, and likely including the construction of new dry ports across all regions.

4.2 Forecasts and risks

4.2.1 Given the predicted growth of the plastics industry and the associated increase in the global plastics supply chain infrastructure, without the introduction of legislative measures to better control the release of plastic pellets, there will clearly be an increase in the risk of release of plastic pellets to the environment. In their review of plastic pellet loss, Eunomia highlighted that pellets can be lost at any point in the plastics supply, and use chain[30]. The review identified that the more pellets are handled within the supply chain, the greater the risk for pellet loss. Eunomia estimated that between 5 and 53 billion pellets (equating to between 105 and 1,054 tonnes) were lost to the UK environment annually[8], and approximately between 16,881 and 167,431 tonnes (equivalent to 848 billion and 8.4 trillion pellets) were annually lost across Europe[30] estimated to be between 16,881 and 167,431 tonnes (equivalent to 848 billion and 8.4 trillion pellets).

4.2.2 This study estimates global annual pellet loss, between 2.2 to 22.4 trillion based on the relative share of the global plastics industry within each region (Table 3). If we assume that the OECD 'business as usual' scenario plays out in the future, then by 2060, we could see triple the above estimated numbers of pellets lost to the environment on an annual basis. However, as indicated by the OECD, given the predicted greater increase in the plastic industry in Sub- Saharan Africa and Asia Pacific (India in particular), there could be a more significant increase in pellet loss within these regions.

4.2.3 The global shipping of plastics will have to increase to facilitate the predicted growth of the industry and there is an obvious increased risk of plastic pellet spills given the increased volume and frequency of plastics shipping. A further worrying aspect in the future of global shipping is the opening of new shipping routes as a result of climate change. Due to the global rise in temperature of the ocean along the Northern Sea Route and the Transpolar Passage, these are likely to become viable alternatives for maritime freight transport[94]. Using the Northern Sea Route for the transport of maritime freight between Northern Europe and Asia could reduce voyage distances relative to routing through the Suez Canal by 37% for Japan, 31% for South Korea, 23% for China and 17% for Taiwan, and would also result in less shipping around Southern Africa. These new shipping routes have been identified as increasing the vulnerability of sensitive Arctic Marine Ecosystems to pollution but the focus to date has been on the potential increased risk of oil spills[95]. Given the predicted growth of the plastics industry, and the high concentration of the industry in Northern Europe, the opening of these new shipping routes is also likely to present an increased risk of plastic pellet contamination in the Arctic.

4.3 Measures to reduce plastic pellet pollution

4.3.1 A supply chain approach

4.3.1.1 To reduce the identified increased risks to the environment and health from plastic pellet pollution in the future, action must be taken along the entire global plastic supply chain[96]. Incorporating certification and independent audits against rigorous standards which is legislated and communicated along the entire supply chain **the supply chain approach could reduce 95% of pellet loss to the environment**[30; 96]. Operation Clean Sweep (OCS) is a voluntary initiative led by the plastic industry to encourage pellet loss prevention. However, there is limited progress and low uptake of this voluntary scheme. Data from the Great Nurdle Hunt confirms the ongoing and the global nature of the plastic pellet pollution. To address this complex supply chain issue, a globally compatible, mandatory and unified approach to minimise pellet loss is needed based on the supply approach (Figure 23)[96]. The measures include the introduction of standards to define minimum requirements for best practice with third party independent auditing and compliance assessments. These measures would need to be adopted and implemented throughout the plastics supply chain with legislation needed to ensure compliance and uptake of robust standards and certification.

Figure 23: The supply chain approach to tackling plastic pellet loss[96]

4.3.2 Standards and regulations

4.3.2.1 Given the global nature of the plastic supply chain, attention must turn to coordinated regulatory measures that take into account pellet handling and pellet loss prevention measures on land and at sea to achieve zero pellet loss[6]. The Fauna & Flora report further highlighted that regulation based on a supply chain approach is urgently needed to ensure that all companies involved in the handling of plastic pellets at every stage of the supply chain can verify that pellet loss prevention measures are being adhered to. Despite the known issues presented by the chronic and acute release of plastic pellets into the environment, there are currently no international or regional regulations which specifically regulate the loss of pellets on industrial sites, or during their transport along the supply chain.

4.3.2.2 Some measures are being introduced specifically aimed at reducing plastic pellet loss. For example, the world's first pellet handling specification (PAS 510:2021) to mitigate the loss of pellets was published in 2021[97]. PAS 510:2021 is a publicly available specification which sets out requirements for the handling and management of plastic pellets, flakes and powders, throughout the supply chain to prevent spills, leaks and losses to the environment. However, these requirements need to be applied across the supply chain with third party verification to be effective within a mandatory supply chain approach.

4.3.2.3 International commitments have been made to tackle pellet pollution by organisations such as OSPAR, a mechanism by which 15 countries across Europe protect the marine environment of the North East Atlantic. OSPAR's Regional Action Plan (RAP) was agreed for the period 2014 to 2021 in order to address marine litter issues[98]. The plan contained 55 Actions which aimed to reduce both land-based and sea-based sources of litter, and Action 52 aimed for zero pellet losses in the environment. Action 52 led to the publication of several reports on pre-production plastic pellets (e.g.[3]) and in 2021, OSPAR adopted Recommendation 2021/06[99] and produced the associated guidelines[100] to reduce the loss of plastic pellets into the marine environment. The guidelines recommended implementation of procedures at each level of the supply chain with a goal to prevent pellet loss and proposed the following hierarchy of measures with international policymakers urged to embed these into their standard and certification-scheme frameworks. The European Union as a signatory to OSPAR has committed to further action on pellets but to date has introduced no new legislation.

4.3.2.4 In 2023 the trade associations Plastics Europe and EUPC launched a certification scheme for plastic pellet handlers in Europe. However, the certification does not follow all the OSPAR recommendations (Figure 24). For example, it does not use a rigorous standard (e.g. PAS 510:2021), as the basis for its scheme, due to insufficient information to address transparency across the supply chain, and therefore it is unable to monitor loss from all stages of the supply chain[101]. There are currently no robust mandatory certification schemes and to date voluntary initiatives have not driven sector wide uptake of measures to address pellet loss. Fidra states that legislation will be needed to ensure all companies meet standards and to ensure certification schemes meet minimum requirements[96].

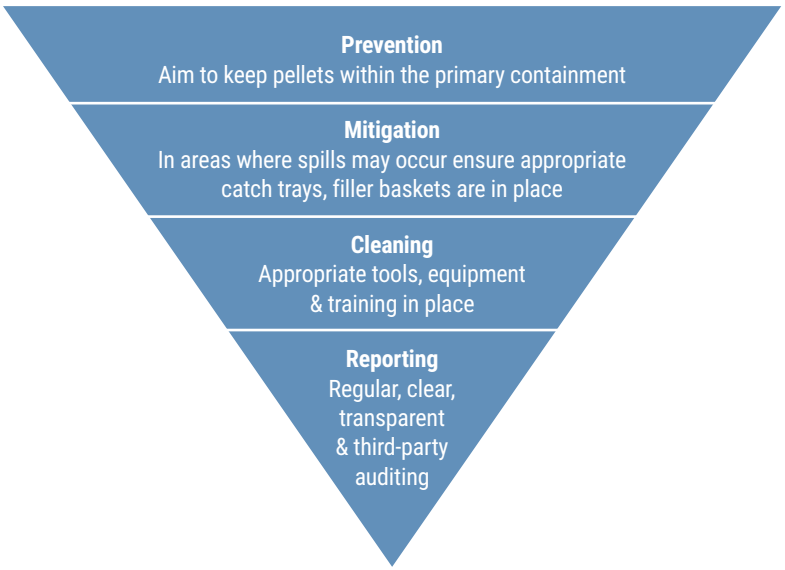

Figure 24: The hierarchy for certification schemes to limit the loss of pellets[100]

4.3.2.6 France were the first country in the world to introduce regulations specifically aimed at preventing pellet loss to the environment. In 2020, France introduced the Anti-Waste Circular Economy Law (the AGEC law, and this includes prevention measures which require sites where plastic pellets are produced, handled and transported, to have appropriate equipment and methods in place to mitigate spills. It also includes mandatory inspections by independent certified bodies and contains obligations linked to producer responsibilities[102]. The success of the measures will be established through the continued assessment and monitoring of pellet pollution in the environment, although the success will be limited if other countries do not adopt similar measures and this was exemplified in 2022 when large amounts of pellets were identified on the beaches of Brittany, France. In December 2022, in Finistère, Brittany, volunteers collected more than 80,000 pellets from a beach in less than an hour and the source of the pellets has not been identified but the Surfrider Foundation, estimated that hundreds of thousands of pellets had impacted the French coast[103]. This incident again highlights the need for global action on plastic pellet loss prevention.

4.3.3 Maritime solutions

4.3.3.1 The IMO are considering the introduction of measures to reduce the environmental risks associated with the shipping of plastic pellets in packaged form. In their Pollution Prevention and Response sub-committee document PPR9/15/1, the IMO presented proposed amendments to the criteria for the identification of harmful substances in package form in order to change the classification of plastic pellets. MARPOL Annex III contains the regulations for the prevention of pollution by harmful substances carried by sea in packaged form. Further to this, the IMO proposed that one measure to reduce the environmental risks associated with the shipping of plastic pellets in packaged form would be to amend the criteria for the identification of harmful substances in MARPOL Annex III to ensure that plastic pellets are identified as a harmful substance.

4.3.3.2 If plastic pellets are identified as a harmful substance and classified as a marine pollutant they would be transported under the entry: “UN 3077 ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S”. This would mean that requirements for transport of plastic pellets by ship would include the following:

- Packages shall be adequate to minimize the hazard to the marine environment, having regard to their specific contents;
- Packages containing a harmful substance shall be durably marked or labelled to indicate that the substance is a harmful substance, in accordance with the relevant provisions of the IMDG Code;
- Each ship carrying harmful substances shall have a special list, manifest or stowage plan setting forth, in accordance with the relevant provisions of the IMDG Code, the harmful substances on board and the location thereof. A copy of one of these documents shall be made available before departure to the person or organization designated by the port State authority; and
- Harmful substances shall be properly stowed and secured to minimize the hazards to the marine environment without impairing the safety of the ship and persons on board (regulation 6 of MARPOL Annex III)[39].

4.3.3.3 These measures would reduce the risk of accidental discharge of plastic pellets as it would raise awareness, set minimum standards for acceptable packaging, and recommend more protected stowage of containers containing plastic pellets. While the focus should remain on prevention in addition globally agreed clean up protocols and compensation regimes are needed to ensure that should an incident occur a rapid and effective response can be launched. This would help limit pollution and ensure communities impacted are compensated and the environment is restored whilst upholding the polluter pays principle (Appendix D Acute Case Study).

4.3.3.4 A review of the impact of the implementation of these measures to prevent pellet loss was provided by CE Delft on behalf of Fauna & Flora International[104]. The review identified that it may take five years or more after approval by IMO to implement the classification of plastic pellets as environmentally hazardous. In addition, it was further noted that the introduction of a new UN number would require large changes in the transport chain, with impacts on both maritime and land transport. Given the extent of plastic pellet pollution identified in this study in all regions of the globe, such measures are clearly needed to ensure that we reduce the impact of pellet loss on the environment and on health in the short, medium and long term.

4.3.4 Preventing Pollution from the Global Plastic Pellet Supply Chain

4.3.4.1 Plastic pellet pollution is already impacting the environment, health, wealth and wellbeing at local, national, and global levels. Virgin, recycled and biobased plastic pellets are a growing risk to our environment, economies and communities worldwide. An ongoing challenge for any solution to pellet pollution is how to ensure global coordination and compatibility across complex international supply chains. The Global Plastic Treaty is currently being negotiated and provides a platform to discuss and agree the implementation of the solutions such as a supply chain approach[105]. It could allow for global uptake of working solutions as they are developed in nations and regions across the world.

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Appendix A:
Data Collection Methodology and Data Sources

A.1 Overview

A.1.1 The following methodology was used to source the data to assist with the mapping of the global plastic pellet supply chain. While this report aims to address plastic pellet pollution it is acknowledged that the identified global supply chain will also include plastics in other forms of feedstock such as powders and flakes.

A.1.2 The Google search engine was used to initially locate datasets and data repositories based on key search terms, e.g., primary plastic manufacturers. The suitability and reliability of the dataset was then assessed along with the usage and licensing requirements. Where a dataset required specific permissions for use these were sought from the data owner/licensor.

A.1.3 The ESRI ArcGIS Online and Living Atlas databases were also searched for suitable datasets.

A.1.4 National government websites were searched for information on the plastics industry within specific countries, for example by identifying businesses with Specific Industry Classification (SIC) codes relating to the plastics industry.

A.1.5 Where existing datasets were not geo-referenced, geo-references were added, and the datasets added to ArcGIS to enable the production of maps and infographics.

A.1.6 In some instances, existing datasets were combined to produce more relevant geo-referenced data. For example, the location of major ports was combined with their annual cargo volumes to identify those ports with the high throughput of cargo.

A.1.7 Datasets available from governments, inter-governmental organisations, trade associations and international financial institutions were prioritised due to their likely higher reliability and accuracy.

A.1.8 A number of datasets required further analysis and interpretation, and the methodology for this is detailed

A.1.9 The report refers to the plastics industry and identifies producers, converters, masterbatchers and recyclers. Definitions of these used in the report are shown below:

Producer – A facility involved in the conversion of raw materials into plastic feedstock, e.g. plastic pellets.

Converter – A facility manufacturing products from plastic feedstock, e.g. plastic pellets, flakes and powders.

Masterbatcher – A company involved in the addition of additives to plastics to impart colour or physical properties.

Recycler – A plant involved in the recycling of waste plastics back into feedstock e.g. plastic pellets. This does not include sites where municipal plastic waste is collected.

A.2 Primary Plastics Imports and Exports Dataset

A.2.1 This dataset was formed from import and export trade data obtained from the World Bank World Integrated Trade Solution (WITS) (5). The WITS system assigns categories of traded goods with a numeric HS code which is 6 digits long. The database contains data on the imports and exports of these goods between nations with data available from 1992 to 2021. The data can be downloaded in a spreadsheet format for further interpretation. This data has been used across all regions to understand plastic imports and exports.

A.2.2 Plastic pellets are primarily made up of Ethylene, Propylene, Styrene and Vinyl-chloride polymers.

A.2.3 Worldwide import and export data was downloaded for all 19 suitable codes (Table 1) for the year 2021 and

compiled into two spreadsheets: imports and exports. The WITS system presents trade data as trade value (in thousands of USD) and as mass (in kg). There were a number of instances where the traded mass was missing from the dataset for countries with large trade values. The trade value was available for all import and export trades in the dataset and has therefore been used when ranking the countries.

A.2.4 The sum of the import and export trade value for each HS code (Table 1) for all countries with data was calculated. This data was then sorted from largest to smallest to enable a ranking to be applied.

A.3 Plastic Recyclers

A.3.1 A worldwide trade database was identified which showed the location of plastic recycling facilities from ENF Recycling. An extract from the database was purchased which showed the locations of plastic recycling plants where the physical process of turning waste materials back into a usable raw material, e.g., pellets and flakes, is carried out.

A.3.2 The database provided the company details, contact details, physical street address and plant information. The street addresses were geo-coded using Google Earth to convert their locations to a longitude and latitude. These locations were then imported into ArcGIS and plotted on a world map.

A.3.3 Due to usage restrictions the resulting geocoded dataset is not permitted to include the name or contact details of the plant. These can be obtained directly from the ENF Recycling website.

A.3.4 The raw data was also sorted based on country and region to allow the number of recycling plants within each to be calculated.

A.4 Plastic Producers & Manufacturers

A.4.1 A trade portal showing the location and output of plastic production facilities worldwide was identified (PolyGlobe) (40) , however, OEE were not permitted to use the data for this project. A number of other trade databases were also identified, however, OEE were quoted costs in excess of €1,500 for data regarding single countries and €5,000 for regions.

A.4.2 In the UK, companies involved in the plastics industry were identified using their Standard Industry Classification code, codes which included primary forms of plastic were identified (Table 2).

Table 4: Relevant SIC codes that include plastic pellets, flakes and powders

Standard Industry Code (SIC)	Industry
20160	Manufacture of plastics in primary forms
22210	Manufacture of plastic plates, sheets, tubes and profiles
22220	Manufacture of plastic packing goods
22230	Manufacture of builders ware of plastic
22290	Manufacture of other plastic products

A.4.3 The registered office addresses for companies listed under the SIC codes were downloaded from the UK Companies House online system (41). These locations were then geo-coded using Google Earth to generate a longitude and latitude.

A.4.4 A similar industry code system was identified in the US, North American Industry Classification System (NAICS). A US EPA database (42) was identified which provided the location of companies involved in various industries based on their NAICS code. A dataset showing the geo-location of facilities based on the relevant NAICS code was downloaded.

A.4.5 The above approach may also be possible using national government databases in other countries, however, this was outside the scope of the project.

A.4.6 A further approach used a search engine to identify the primary plastic producing companies within each region. If listed, details of the company's production facilities were identified. Activities associated with each facility was then cross checked to verify that polymers were produced at the location. All other locations owned by the companies were excluded.

A.4.7 The location of each facility was identified on satellite imagery using Google Maps based on its street address. This process confirmed that a chemical plant and/or commercial/factory building was present at the street address. The longitude and latitude of each facility was then extracted and stored alongside the company name and facility name.

A.5 Shipping Routes

A.5.1 A generic map of global shipping routes was obtained from the ArcGIS online library based on major routes. Primary plastics trade data was then used to identify large volumes of trade between nations.

A.5.2 The websites of major container shipping companies, (e.g. CMA CGM (6)) were searched to identify major shipping routes between countries where a high volume of primary plastic trade exists. Where relevant routes were identified these were digitised from route maps using Google Earth and ArcGIS.

A.5.3 Appendix D provides a brief presentation of global shipping routes used in the plastics supply chain.

A.6 Acute and Chronic Pellet Loss

A.6.1 To obtain information on reported acute and chronic losses of plastic pellets, the Google search engine and Google Scholar were used by searching key search terms, e.g., "plastic pellet loss" and "nurdle spills". Relevant journals, reports, website articles, and news reports were used to obtain the date, location (as precise as possible, country and region), setting (terrestrial or marine), type (acute or chronic), quantity (tonne and pellet no.) and cause of the loss.

A.6.2 Where the exact date could not be obtained, the date was recorded as the beginning of the known month (i.e., 01/MM/YYYY) or if the month was unknown, the data was recorded as the beginning of the known year (i.e., 01/01/YYYY).

A.6.3 Geo-referenceable locations were geo-coded using Google Earth to convert their locations to a longitude and latitude. These locations were then imported into ArcGIS and plotted on a world map. Where the exact location could not be obtained, the position was taken from the nearest industrial area or best estimates from the described location in the text or from photographs taken.

A.6.4 Further information was provided by Fidra on known pellets losses in Europe obtained largely from an NGO (Surfrider) based in France. Other NGOs of the study regions were also contacted to provide any local knowledge available. Where required, Google Translate was used to translate none English website to obtain information from the respective nations platforms.

A.6.5 The acute and chronic case studies (Appendix D) were determined by relevance in relation to the cause of pellet loss, and available information that could be obtained.

A.6.6 Where the tonnage of volume spilled was provided, an estimate of the number of pellets was calculated by dividing the tonnage by 0.00000002 tonnes (0.02 g per pellet). Conversely, where the number of pellets was provided, an estimated tonnage was calculated by multiplying the number by 0.00000002 tonnes.

A.6.7 A limitation of the research was that it was difficult to find data on certain countries due to accessibility to information due to language barriers.

A.7 Additional data

Other additional information to help infer the impact of pellet pollution across each region was collected including the following where possible:

- Protected areas (e.g. Sites of scientific interest (SSSIs), nature reserves, Marine protected area)
- Species data (e.g. Bird colonies, coral reefs)
- Fishing and Tourism data

A full list of all data available, by region, type, accessibility and the licence agreements associated with the data (if required) can be found in the following tables.

During the sourcing of the data for use in the project, data gaps have been identified across the different regions of interest. Where it has not been possible to source some of the data (e.g. plastic converters) proxy data sources have been used and it may be possible to refine the outputs of the project if alternative data sources can be obtained.

The tables below summarise the data that has been sourced for use in the project.

Table 5: North America data sources and licensing requirements

Data Type	Data Source	Licensing Requirements
Plastic Producers	Location pages of websites of major petro-chemical organisations	None, publicly available information
Plastic Converters	USA – United States Environmental Protection Agency (EPA) TRI Explorer – location of plastic manufacturing companies reporting emissions to the EPA.	Attribution only. Publicly available information.
Plastic Recyclers	ENF Recycling Database (https://www.enfrecycling.com/)	Dataset provided and licensed to OEE. Permitted to share anonymised location data for recyclers. Attribution required.
Major Ports	World Ports Index (https://msi.nga.mil/Publications/WPI)	Attribution only. (https://msi.nga.mil/faq)
Inland Distribution Centres	USA Intermodal Depots - US Department of Transport/Bureau of Transportation Statistics – (https://geo.dot.gov/mapping/rest/services/NTAD/Intermodal_Freight_Facilities_Rail_TOFC_COFC/MapServer/0)	Public use, no sale/resale
Shipping Routes	ESRI shapefile based on CIA "Map of the World Oceans", October 2012. (https://tiles.arcgis.com/tiles/nzS0F0zdNLvs7nc8/arcgis/rest/services/ShipRoutes/MapServer)	http://downloads2.esri.com/ArcGISOnline/docs/tou_summary.pdf
Rail Networks	USA Rail network – US Department of Transport/ Bureau of Transportation Statistics https://geo.dot.gov/mapping/rest/services/NTAD/North_American_Rail_Network_Lines/MapServer/0	Public use, no sale/resale
Protected Areas (e.g. Nature Reserves, SSSIs)	Protected Planet (https://www.protectedplanet.net/en)	Non-commercial use only. https://www.protectedplanet.net/en/legal
Coral Reefs	United Nations Environment Programme (https://data.unep-wcmc.org/datasets/1)	Non-commercial use, no further distribution of downloadable dataset. Publishable if non-downloadable with full attribution. (https://www.unep-wcmc.org/en/general-data-license#data_policy)
Fishing	Organisation for Economic Co-operation and Development (https://data.oecd.org/fish/fish-landings.htm#indicator-chart)	Commercial and non-commercial use within specified terms and attribution. https://www.oecd.org/termsandconditions/
Tourism	UNWTO (https://www.unwto.org/tourism-data/global-and-regional-tourism-performance)	Non-commercial use (https://www.unwto.org/copyright)
Bird Colonies	Birdlife International (http://datazone.birdlife.org/species/requestdis)	Non-commercial use, dataset cannot be shared with third parties.
Pellet Concentration Data	1. Nurdle Patrol (https://nurdlepatrol.org/map) 2. Fidra – The Great Nurdle Hunt Nurdle Map (https://www.nurdlehunt.org.uk/nurdle-finds.html)	1. Attribution only 2. Permission required to access and distribute data
Primary Plastics Imports and Exports	World Bank, World Integrated Trade Solution (WITS) (https://wits.worldbank.org/Default.aspx?lang=en)	Permission required to distribute data. (https://comtrade.un.org/db/help/LicenseAgreement.aspx)
Special Economic Zones	https://www.openzonemap.com/	Free for research purposes. Permission of project use agreed with data owner by OEE.

Table 6: Europe data sources and licensing requirements

Data Type	Data Source	Licensing Requirements
Plastic Producers	Location pages of websites of major petro-chemical organisations	None, publicly available information
Plastic Converters	UK – Companies House SIC data (https://www.gov.uk/government/organisations/companies-house)	Attribution only. Publicly available information.
Plastic Recyclers	ENF Recycling Database (https://www.enfrecycling.com/)	Dataset provided and licensed to OEE. Permitted to share anonymised location data for recyclers. Attribution required.
Major Ports	World Ports Index (https://msi.nga.mil/Publications/WPI)	Attribution only. (https://msi.nga.mil/faq)
Shipping Routes	ESRI shapefile based on CIA "Map of the World Oceans", October 2012. (https://tiles.arcgis.com/tiles/nzS0F0zdNLvs7nc8/arcgis/rest/services/ShipRoutes/MapServer)	http://downloads2.esri.com/ArcGISOnline/docs/tou_summary.pdf
Protected Areas (e.g. Nature Reserves, SSSIs)	Protected Planet (https://www.protectedplanet.net/en)	Non-commercial use only. https://www.protectedplanet.net/en/legal
Coral Reefs	United Nations Environment Programme (https://data.unep-wcmc.org/datasets/1)	Non-commercial use, no further distribution of downloadable dataset. Publishable if non-downloadable with full attribution. (https://www.unep-wcmc.org/en/general-data-license#data_policy)
Fishing	Organisation for Economic Co-operation and Development (https://data.oecd.org/fish/fish-landings.htm#indicator-chart)	Commercial and non-commercial use within specified terms and attribution. https://www.oecd.org/termsandconditions/
Tourism	UNWTO (https://www.unwto.org/tourism-data/global-and-regional-tourism-performance)	Non-commercial use (https://www.unwto.org/copyright)
Bird Colonies	Birdlife International (http://datazone.birdlife.org/species/requestdis)	Non-commercial use, dataset cannot be shared with third parties.
Pellet Concentration Data	Fidra – The Great Nurdle Hunt Nurdle Map (https://www.nurdlehunt.org.uk/nurdle-finds.html)	Permission required to access and distribute data
Primary Plastics Imports and Exports	World Bank, World Integrated Trade Solution (WITS) (https://wits.worldbank.org/Default.aspx?lang=en)	Permission required to distribute data. (https://comtrade.un.org/db/help/LicenseAgreement.aspx)
Special Economic Zones	https://www.openzonemap.com/	Free for research purposes. Permission of project use agreed with data owner by OEE.

Table 7: Asia Pacific data sources and licensing requirements

Data Type	Data Source	Licensing Requirements
Plastic Producers	Location pages of websites of major petro-chemical organisations	None, publicly available information
Plastic Converters	China – National Bureau of Statistics of China; chyxx.com – Top 10 provinces for production of plastic products. Rest of region – The location of plastic recyclers and Special Economic Zones has been used as a proxy for the location of plastic converters in the absence of specific location data.	Attribution only. Publicly available information.
Plastic Recyclers	ENF Recycling Database (https://www.enfrecycling.com/)	Dataset provided and licensed to OEE. Permitted to share anonymised location data for recyclers. Attribution required.
Major Ports	World Ports Index (https://msi.nga.mil/Publications/WPI)	Attribution only. (https://msi.nga.mil/faq)
Shipping Routes	ESRI shapefile based on CIA "Map of the World Oceans", October 2012. (https://tiles.arcgis.com/tiles/nzS0F0zdNLvs7nc8/arcgis/rest/services/ShipRoutes/MapServer)	http://downloads2.esri.com/ArcGISOnline/docs/tou_summary.pdf
Protected Areas (e.g. Nature Reserves, SSSIs)	Protected Planet (https://www.protectedplanet.net/en)	Non-commercial use only. https://www.protectedplanet.net/en/legal
Coral Reefs	United Nations Environment Programme (https://data.unep-wcmc.org/datasets/1)	Non-commercial use, no further distribution of downloadable dataset. Publishable if non-downloadable with full attribution. (https://www.unep-wcmc.org/en/general-data-license#data_policy)
Fishing	Organisation for Economic Co-operation and Development (https://data.oecd.org/fish/fish-landings.htm#indicator-chart)	Commercial and non-commercial use within specified terms and attribution. https://www.oecd.org/termsandconditions/
Tourism	UNWTO (https://www.unwto.org/tourism-data/global-and-regional-tourism-performance)	Non-commercial use (https://www.unwto.org/copyright)
Bird Colonies	Birdlife International (http://datazone.birdlife.org/species/requestdis)	Non-commercial use, dataset cannot be shared with third parties.
Pellet Concentration Data	Fidra – The Great Nurdle Hunt Nurdle Map (https://www.nurdlehunt.org.uk/nurdle-finds.html)	Permission required to access and distribute data
Primary Plastics Imports and Exports	World Bank, World Integrated Trade Solution (WITS) (https://wits.worldbank.org/Default.aspx?lang=en)	Permission required to distribute data. (https://comtrade.un.org/db/help/LicenseAgreement.aspx)
Special Economic Zones	https://www.openzonemap.com/	Free for research purposes. Permission of project use agreed with data owner by OEE.

Table 8: Africa and Middle East data sources and licensing requirements

Data Type	Data Source	Licensing Requirements
Plastic Producers	Location pages of websites of major petro-chemical organisations	None, publicly available information
Plastic Converters	The location of plastic recyclers and Special Economic Zones has been used as a proxy for the location of plastic converters in the absence of specific location data.	Attribution only. Publicly available information.
Plastic Recyclers	ENF Recycling Database (https://www.enfrecycling.com/)	Dataset provided and licensed to OEE. Permitted to share anonymised location data for recyclers. Attribution required.
Major Ports	World Ports Index (https://msi.nga.mil/Publications/WPI)	Attribution only. (https://msi.nga.mil/faq)
Inland Distribution Centres	Africa- Manual internet search for 'dry ports' and 'inland container ports'. Locations were then geo-referenced using Google maps.	None, publicly available information
Shipping Routes	ESRI shapefile based on CIA "Map of the World Oceans", October 2012. (https://tiles.arcgis.com/tiles/nzS0F0zdNLvs7nc8/arcgis/rest/services/ShipRoutes/MapServer)	http://downloads2.esri.com/ArcGISOnline/docs/tou_summary.pdf
Protected Areas (e.g. Nature Reserves, SSSIs)	Protected Planet (https://www.protectedplanet.net/en)	Non-commercial use only. https://www.protectedplanet.net/en/legal
Coral Reefs	United Nations Environment Programme (https://data.unep-wcmc.org/datasets/1)	Non-commercial use, no further distribution of downloadable dataset. Publishable if non-downloadable with full attribution. (https://www.unep-wcmc.org/en/general-data-license#data_policy)
Fishing	Organisation for Economic Co-operation and Development (https://data.oecd.org/fish/fish-landings.htm#indicator-chart)	Commercial and non-commercial use within specified terms and attribution. https://www.oecd.org/termsandconditions/
Tourism	UNWTO (https://www.unwto.org/tourism-data/global-and-regional-tourism-performance)	Non-commercial use (https://www.unwto.org/copyright)
Bird Colonies	Birdlife International (http://datazone.birdlife.org/species/requestdis)	Non-commercial use, dataset cannot be shared with third parties.
Pellet Concentration Data	Fidra – The Great Nurdle Hunt Nurdle Map (https://www.nurdlehunt.org.uk/nurdle-finds.html)	Permission required to access and distribute data
Primary Plastics Imports and Exports	World Bank, World Integrated Trade Solution (WITS) (https://wits.worldbank.org/Default.aspx?lang=en)	Permission required to distribute data. (https://comtrade.un.org/db/help/LicenseAgreement.aspx)
Special Economic Zones	https://www.openzonemap.com/	Free for research purposes. Permission of project use agreed with data owner by OEE.

Table 9: Central & South America data sources and licensing requirements

Data Type	Data Source	Licensing Requirements
Plastic Producers	Location pages of websites of major petro-chemical organisations	None, publicly available information
Plastic Converters	The location of plastic recyclers and Special Economic Zones has been used as a proxy for the location of plastic converters in the absence of specific location data.	N/A
Plastic Recyclers	ENF Recycling Database (https://www.enfrecycling.com/)	Dataset provided and licensed to OEE. Permitted to share anonymised location data for recyclers. Attribution required.
Major Ports	World Ports Index (https://msi.nga.mil/Publications/WPI)	Attribution only. (https://msi.nga.mil/faq)
Shipping Routes	ESRI shapefile based on CIA "Map of the World Oceans", October 2012. (https://tiles.arcgis.com/tiles/nzS0F0zdNLvs7nc8/arcgis/rest/services/ShipRoutes/MapServer)	http://downloads2.esri.com/ArcGISOnline/docs/tou_summary.pdf
Protected Areas (e.g. Nature Reserves, SSSIs)	Protected Planet (https://www.protectedplanet.net/en)	Non-commercial use only. https://www.protectedplanet.net/en/legal
Coral Reefs	United Nations Environment Programme (https://data.unep-wcmc.org/datasets/1)	Non-commercial use, no further distribution of downloadable dataset. Publishable if non-downloadable with full attribution. (https://www.unep-wcmc.org/en/general-data-license#data_policy)
Fishing	Organisation for Economic Co-operation and Development (https://data.oecd.org/fish/fish-landings.htm#indicator-chart)	Commercial and non-commercial use within specified terms and attribution. https://www.oecd.org/termsandconditions/
Tourism	UNWTO (https://www.unwto.org/tourism-data/global-and-regional-tourism-performance)	Non-commercial use (https://www.unwto.org/copyright)
Bird Colonies	Birdlife International (http://datazone.birdlife.org/species/requestdis)	Non-commercial use, dataset cannot be shared with third parties.
Pellet Concentration Data	Fidra – The Great Nurdle Hunt Nurdle Map (https://www.nurdlehunt.org.uk/nurdle-finds.html)	Permission required to access and distribute data
Primary Plastics Imports and Exports	World Bank, World Integrated Trade Solution (WITS) (https://wits.worldbank.org/Default.aspx?lang=en)	Permission required to distribute data. (https://comtrade.un.org/db/help/LicenseAgreement.aspx)
Special Economic Zones	https://www.openzonemap.com/	Free for research purposes. Permission of project use agreed with data owner by OEE.

Appendix B:
Supporting Documentation

The following Appendices include supplementary material to the report or information on how to access supplementary material which can be distributed and used, when referenced appropriately.

The following information packs are available:
A global information pack – including higher resolution figures and social media assets

Regional asset packs

- North America
- Central and South America
- Europe
- Africa and Middle East
- Asia Pacific

These are accessible via https://hub.nurdlehunt.org/resource/oracle-mapping-the-global-plastic-pellet-supply-chain/

Appendix C is a series of two-page reviews for each region including production, transport, recycling activity as well as discussing region specific environmental and socioeconomic factors relating to pellet pollution.

Appendix D provides a closer look at a chronic pellet incident and an acute pellet incident. These are set up to help NGO's replicate case studies of local pellet pollution incidents.

Appendix E provides a summary of all verified pellet pollution incidents (chronic and acute).

This is to be set up as a live database in the future.

To keep up-to-date register your organisation at https://hub.nurdlehunt.org/directory/register/

North America

Production, Transport & Recycling Activity

Activity	Observations
Plastic Production	• North America accounted for 18% of global plastic production in 2021 • 17% of world trade share in primary plastic exports in 2021 • USA was world's largest exporter of plastics in primary forms in 2021
Plastic Manufacturing	• USA has over 12,500 facilities involved in plastics industry employing almost 1 million people
Maritime Freight Transport	• Contains 4 of worlds top 50 ports by container volume and 30 large ports overall • Increasing number of containers shipped each year • Over 67 million TEU of container traffic in North America in 2021
Rail Freight Transport	• Large intermodal transport network in North America. Some terminals are almost 3km in length and cover over 2.5km^2 • Over 140,000 miles of freight railway in USA • 1,182 train derailments in USA in 2022 • Canada – 20,000 miles of railtrack and 14 intermodal terminals • USA – 1,616 million tonnes of freight moved by rail in 2017
Road Freight Transport	• USA – 12,800 million tonnes of freight moved by road in 2017 • USA – Freight tonnages expected to increase by 1.4% annually until 2050
Plastic Recycling	• More than 249 recycling plants • USA has worlds third highest number of recycling plants

Environmental Incidents

It is estimated between 6,125-60,72 tonnes of plastic pellets are lost annually in North America. In addition to widespread pellet pollution identified via citizen science this review has identified 10 acute and 8 chronic pellet losses in US and Canada between 2005 and 2022. 70% of the acute losses occurred during transport by rail with four of these train derailments. One maritime and two road-based losses were also identified.

Six of the identified chronic losses were related to plastics industry production/conversion facilities with two related to ongoing losses in relation to rail transport.

With increased regulation and transparency of all the sectors within the plastic industry across the region, there would be an increase in the amount of reported chronic and acute pollution which would highlight the true extent of the issue.

Environmental Sensitivity

Extensive plastic industry activity is located around the Gulf of Mexico with a number of primary plastic production plants located close to the coast in Texas, USA. The Gulf coast has over 112,000 km2 of protected areas with the area containing around half the US total of coastal wetlands and home to extensive sea grass ecosystems off the coast of Florida, the primary habitat for manatees, a species listed as vulnerable on the IUCN Red List due to their decreasing population[1].

An assessment of the plastic pellet (nurdle) hunt data in the Gulf of Mexico identified that 22.5% of the nurdles found were located within protected areas. Of the acute and chronic losses detailed above, two chronic and four acute spills occurred in Texas with a further two acute spills in Louisiana. Data shows clear impacts along the coastline in close proximity to plastics industry and ports which is leading to pellet pollution within protected areas.

Caribbean Coral reefs account for around 9% of the worlds coral reefs spanning 38 countries[2] with reef-building corals in the region declining by 50% since the late 1970s[3]. Pellet losses in this region could further impact an already fragile, and declining, ecosystem which is under pressure from climate change and rising sea temperatures.

A large number of inland protected areas also exist within North America and are likely crossed by remote sections of road and rail networks where a response to a spill incident may be very challenging.

Socio-Economic Sensitivity

A number of island nations in the Caribbean Sea generate a significant proportion of their GDP from tourism such as Jamaica (9.2% of GDP in 2018) and Antigua and Barbuda (14.6% of GDP in 2019). A spill incident in the Gulf of Mexico could significantly impact their economies if coastal resorts are damaged. The Caribbean coral reefs are also relied upon by tens of millions of people for their livelihoods through activities such as fishing and tourism.

Florida is the second most visited US state by tourists and large numbers of nurdles have already been identified along its coast. The states high reliance on tourism and the surrounding protected areas mean that significant acute pellet loss could be very damaging to the area, both environmentally and economically.

Mexico has a large tourism industry employing around 1 in 10 people in a sector which continues to rebound post-Covid[4]. Nurdle hunt data shows a large number of pellet locations along the Gulf and Caribbean coasts close to the popular Yucatan Peninsular, home to the city of Cancun.

[1] Deutsch, C.J., Self-Sullivan, C. & Mignucci-Giannoni, A. (2008). Trichechus manatus. The IUCN Red List of Threatened Species 2008: e.T22103A9356917. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T22103A9356917.en

[2] Jackson JBC, Donovan MK, Cramer KL, Lam VV (editors). (2014) Status and Trends of Caribbean Coral Reefs: 1970-2012. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland. Available at: https://www.iucn.org/sites/default/files/import/downloads/caribbean_coral_reefs___status_report_1970_2012.pdf [Accessed on 28/07/23]

[3] Cramer, K. L., Jackson, J. B. C., Donovan, M. K., Greenstein, B. J., Korpanty, C. A., Cook, G. M., & Pandolfi, J. M. (2020). Widespread loss of Caribbean acroporid corals was underway before coral bleaching and disease outbreaks. Science Advances, 6(17). https://doi.org/10.1126/sciadv.aax9395

[4] World Travel & Tourism Council. (2022). Mexico. Available at: https://wttc.org/DesktopModules/MVC/FactSheets/pdf/704/161_20220613164803_Mexico2022_.pdf [Accessed on 28/07/23]

Central and South America

Production, Transport & Recycling Activity

Activity	Observations
Plastic Production	• The region contributed 4% of world plastic production in 2021 • The region accounted for 1.72% of world trade exports of plastics in primary forms in 2021 • Brazil was the largest importer and exporter of plastics in primary forms in 2021 in the region. Colombia was the second largest exporter of plastics in primary forms in 2021
Plastic Manufacturing	• The region accounted for 5% of world trade imports of plastics in primary forms in 2021 • Peru was the second largest importer of plastics in primary forms in 2021 in the region after Brazil • The total value of imports and exports in the region in 2021 was 14.6 billion USD
Maritime Freight Transport	• 12 large ports as defined by World Ports Index • 2 of the world's top 50 container ports by cargo volume are present in the region • In 2021, the port of Colón, Panama, handled the highest volume of cargo containers in Latin America and the Caribbean, at approximately 4.92 million TEUs. The port of Santos, in Brazil, followed with 4.44 million TEUs of cargo.
Rail Freight Transport	• In Brazil rail accounted for 15% of freight transport in 2015 • Argentina has the largest rail network in South America at around 47,000 km.
Road Freight Transport	• In Brazil roads accounted 65% of freight transport in 2015
Plastic Recycling	• Over 198 plastic recycling plants (7% of global share based on industry database) • The region dealt with 3% of world trade in plastic manufacturing waste in 2021 • Brazil – 57% of recycling plants identified in the region located in Brazil

Environmental Incidents

Using recorded pellet presence data from Fidra's Great Nurdle Hunt, there is a slight positive correlation between the locations of pellets and the location of the plastics industry across the region, with potential pellet hotspots identified in Brazil, Argentina, Chile and Peru. This suggests there could be chronic pellet pollution issues yet to be fully investigated in the region. It is estimated that between 1,673 to 16,584 tonnes of plastic pellets could be lost annually in this region alone. There is one record of chronic pellet loss in the region, in Brazil, where accumulation zones of pellets in sandy beaches along the eastern coastline within the São Paulo region, the source is unknown and undeclared. There is likely to be further unrecorded chronic loss sites in region due to the presence on plastics industry.

There are no recorded acute spills across Central & South America that have been identified within this review. Whilst some of the region have plastic associations affiliated with Operation Clean Sweep, this is limited to Argentina, Brazil, Chile, Colombia and Guatemala, the majority >70% are not committed to any measures to prevent pellet pollution at source[1]. Overall data was difficult to find for the region, accessibility to information due to authors' language barriers, as well as limited requirements for industry to share information is likely to have limited access therefore the full extent of pellet loss within this region is largely unknown.

Given the information known about the scale of the industry in these regions and the potential for pellet loss to occur during transport, handling and storage, it should be expected that more chronic and acute losses would be identified with clearer transparency and reporting of these incidents. However, there is limited understanding of what plastic pellets are within the region and current legislation is being driven by waste management issues, with a focus on single use plastic in the region.

Environmental Sensitivity

There is a large concentration of the plastics industry in the Sao Paulo region of Brazil, and there are also a large number of marine and terrestrial protected areas in this region with 7% designated as protected areas which could be highly sensitive to a nurdle spill incident. Research on the impact of pellet consumption by wildlife is on the rise in the region[3,4,5]. There are environmentally sensitive sites across much of the region's coasts with mangroves extending over large distances of the coasts of Peru, Venezuela, Colombia and Brazil including areas of these countries with large concentrations of the plastics industry. The North of the region may also be at risk from the Americas to Europe trade routes transporting plastic.

Socio-Economic Sensitivity

In 2019, pre-Covid, Brazil was the world's 52nd most popular tourist destination with 6.4 million visitors and accounts for 3.1% of its GDP, 2.1 million jobs. Plastic spill incidents are likely to have localised impacts on those economies with less dependence on tourism, while in other countries that rely more heavily on tourism such as Jamaica (9.2% of GDP in 2018) and Antigua and Barbuda (14.6% of GDP in 2019), the effects of a spill incident could have a significant effect on their national economy.

It was not possible to determine the impacts of pellet pollution on the fishing industry in the region due to lack of data and research on this topic but as demonstrated in the Acute Spill Case Study and other maritime acute spills, these incidents have been known to impact fisheries with as yet unknown and unquantified health impacts. Similarly, accumulations of pellets can limit a community's access and enjoyment of the environment which may impact wellbeing, local traditions and access to coastal space used for local industry.

Whilst the risks to wildlife are often more direct and immediate from pellet spills, there are human health risks associated with plastic pellet pollution (due to the biological and chemical cocktail on pellets and the ability of microplastics to degrade and concentrate up food chains), however, there is a lack of data to determine human health implications specific to this region.

[1] Operation Clean Sweep. International OCS Programs. Available at: https://www.opcleansweep.org/operation-clean-sweep-around-the-world/ [Accessed on: 28/07/23]

[2] Baldi, G., Schauman, S., Texeira, M., Marinaro, S., Martin, O. A., Gandini, P., & Jobbágy, E. G. (2019). Nature representation in South American protected areas: country contrasts and conservation priorities. PeerJ, 7, e7155. https://doi.org/10.7717/peerj.7155

[3] Orona-Návar, C., García-Morales, R., Loge, F. J., Mahlknecht, J., Aguilar-Hernández, I., & Ornelas-Soto, N. (2022). Microplastics in Latin America and the Caribbean: A review on current status and perspectives. Journal of Environmental Management, 309, 114698. https://doi.org/10.1016/j.jenvman.2022.114698

[4] Gamarra-Toledo, V., Plaza, P. I., Peña, Y. A., Bermejo, P. A., López, J., Cano, G. L., Barreto, S., Cáceres-Medina, S., & Lambertucci, S. A. (2023). High incidence of plastic debris in Andean condors from remote areas: Evidence for marine-terrestrial trophic transfer. Environmental Pollution, 317, 120742. https://doi.org/10.1016/j.envpol.2022.120742

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Europe

Production, Transport & Recycling Activity

Activity	Observations
Plastic Production	• Europe has the largest share of the global plastics industry based on combined imports and exports of plastics in primary forms at 148 billion USD according to 2021 trade value. • Accounted for 40% of world trade imports of plastics in primary forms in 2021 • Accounted for 35% of world trade exports of plastics in primary forms in 2021 • 15% of world plastic production in 2021 • 4 of world's top 10 exporters of plastics in primary forms
Plastic Manufacturing	• 5 of world's top 10 importers of plastics in primary forms • More than 1.5 million people employed in plastics industry in European Union across 52,000 companies • Germany is the world's second largest importer and fourth largest exporter of plastics in primary forms in 2021 by trade value
Maritime Freight Transport	• 7 of world's top 50 ship container ports by cargo volume • 55 large ports as defined by World Ports Index • 67.9 % of freight movement was maritime across EU in 2021
Rail Freight Transport	• Rail accounted for only 5.4% of freight transport in 2021 across the EU. • Plastics accounted for less than 7.6 % of goods transported by rail across the EU in 2021 • Germany is by far the largest contributor to rail freight transport in the EU, with 123 billion tonne-km in 2021, representing around 31 % of the total across the EU
Road Freight Transport	• 24.6 % of freight movement was by road across EU in 2021 • In 2021, Germany accounted for 23.8 % of tonnage of goods transported by road in the EU
Plastic Recycling	• Over 1,400 plastics recycling plants (54% of global share based on industry database)

Environmental Incidents

It is estimated 145,150 tonnes of pellets are lost annually to the environment within Europe alone. There is a strong correlation between locations of pellets and concentration of plastic industry within Europe. With increased regulation and transparency of all the sectors within the plastic industry across Europe, there would be an increase in the amount of reported chronic and acute spills within many more countries within the region to highlight the true extent of the issue.

A total of 26 recorded chronic pellet loss sites have been identified across Europe, predominately from France, UK and Nordic regions. Using recorded pellet presence data from Fidra's Great Nurdle Hunt, there is a strong correlation between locations of pellets identified and the concentration of plastic industry within Europe. Extreme examples of these include Chessel Bay in Southampton where ongoing pellet loss has been identified since 2011, as well as Antwerp and Feluy in Belgium which has reported constant, high volumes of pellet loss into the Scheldt River and nearby watercourses respectively.

A total of 24 recorded acute pellet loss sites have been identified across Europe totalling an estimated 10,255.5 tonnes of pellets having been released into the environment since 1995. Of these, 19 have been reported in France. This is likely due to regulations that have been introduced to make it compulsory to report any acute spill of plastic pellets in France along the supply chain.

Nurdles have been identified throughout many of the marine and terrestrial protected areas across Europe particularly in the UK, Belgium and Netherlands where there is a high concentration of plastics industry activity.

Environmental Sensitivity

The European Union's biodiversity information system for Europe confirms that as of 2020 protected areas currently cover 23% of the European (38 EEA countries) terrestrial landscape and around 8% of the marine environment[1]. Europe has over 130,000 protected areas which is more than any other continent in the world.

This review has identified that Europe has the largest share of the global plastics industry based on combined imports and exports of plastics in primary forms and has 54% of the global recycling industry. The examples of acute and chronic plastic pellet pollution identified in this study have highlighted the impact that the plastics industry is having on environmentally protected areas in the region with extensive pellet contamination having been identified in SSSIs, SACs and RAMSAR sites across the region.

Socio-Economic Sensitivity

Four of the world's most popular tourist destinations are in Europe including France (largest number of arrivals worldwide – 90.9 million), Spain (83.5 million – 2nd most popular worldwide), Italy (64.5 million – 6th most popular worldwide) and UK (39.4 million – 10th most popular worldwide). While national economies may not be significantly affected by a large pellet incident in the long term (as most of their GDP is not derived from tourism) pellet incidents could have large scale impacts on local tourism within European countries for example high numbers of pellets have been reported in Cornwall, UK which borders the major US – Europe trade route and may be at risk of future acute spills. It was not possible to determine the impacts of pellet pollution on fishing industry in the region due to lack of data and research on this topic but as demonstrated in the Acute Spill Case Study these incidents have been known to impact fisheries with as yet unknown and unquantified health impacts. Similarly, accumulations of pellets can limit a community's access and enjoyment of the environment which may impact wellbeing, local traditions and access to coastal space used for local industry.

There is a risk associated with the microplastics to human health. Across Europe intentionally added microplastics are in the process of being banned from products because of this recognised risk to both human health and the environment[2]. More data is needed to understand the health impact of ingesting microplastics including pellets. However, microplastics are present in human food, microplastics have been found to contain ~4% of additives and they can adsorb contaminants[3]. A study on the risk associated with wild fish ingestion exposure to human health in this region found that wild fish consumption by adults could lead to 842 microplastic items being consumed annually. In addition to this, there was evidence of neurotoxicity and oxidative damage in fish, although this was yet to be detected in humans[4]. Whilst the risks associated with plastic pellet pollution on human health are likely to be low in comparison to the impact on wildlife there is a lack of evidence to know the true extent pellet pollution will have on human health in this region.

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Africa and Middle East

Production, Transport & Recycling Activity

Activity	Observations
Plastic Production	• Africa and Middle East accounted for 16% of world trade exports of plastic in primary forms in 2021 • Saudi Arabia is the world's second largest exporter of plastics in primary forms in 2021 • The region was responsible for 8% of world plastic productions in 2021 • Egypt is the largest exporter of plastic in primary forms in 2021 in Africa
Plastic Manufacturing	• Africa and Middle East accounted for 7% of world trade imports of plastic in primary forms in 2021 • Nigeria is the largest importer of plastics in primary forms in Africa
Maritime Freight Transport	• Africa and Middle East has 6 of the world's top 50 ship container ports by cargo volume • There are 21 large ports as defined by World Ports Index
Rail Freight Transport	• Freight movements in Africa reached over 170.6 billion ton-km in 2020 • Africa has at least 8 large inland ports and container depots
Road Freight Transport	• African cross-border freight transport market is expected to exhibit a compound annual growth rate of 4.5% showing its increased use in the region
Plastic Recycling	• Over 112 plastic recycling plants (4% of global share based on industry database) • South Africa has the largest number of plastic recycling plants within Africa • The United Arab Emirates (UAE) has 12 recycling plants

Environmental Incidents

It is estimated between 4,990 – 49,468 tonnes of plastic pellets are lost annually in Africa and Middle East. In addition to widespread pellet pollution identified via citizen science three major acute pellet spills have been reported in this region between 2017 and 2023 with all incidents involving the loss of shipping containers being lost overboard. In 2017 near the Port of Durban, South Africa two shipping containers of plastic pellets were lost overboard during a storm and contained an estimated 49 tonnes of material. The incident is estimated to have impacted 2,000 km of coastline with only 23% of the spilled pellets having been recovered. Plastic pellets were also identified on South Africa beaches in the proximity of Plettenberg Bay in 2020 with a loss at sea thought to have occurred in October 2020. Plastic pellets, including sacks filled with pellets, began washing up on beaches close to Dubai, UAE in February 2023. The cause of the pollution is unknown but it is suspected it occurred as a result of a loss overboard from a vessel.

With increased regulation and transparency of all the sectors within the plastic industry across the region, there would be an increase in the amount of reported chronic and acute pollution within many more countries in the region which would highlight the true extent of the issue.

Environmental Sensitivity

Africa has over 178,000 km^2 of coastal protected areas with a large region of the south coast of South Africa designated as a UNESCO Biosphere Reserve. Africa is home to 20% of the world's mangroves, occurring in 34 countries across the continent[1] which are complex and fragile ecosystems. Pellet clean- p in mangroves would be extremely challenging and likely damaging. Inland protected areas are highly variable in Africa and consist of deserts, rainforest and the African Great Lakes. Nigeria is identified as the largest importer of plastics in primary forms in Africa and is already subject to extensive contamination in the Niger Delta from decades of exploration and exploitation by the oil and gas industries. Releases of pellets in this area, and others in Africa already polluted by other industry, will only serve to exacerbate the existing impacts.

Coastal protected areas are located on both the east and west coasts on Saudi Arabia, UAE, Qatar and Oman in close proximity to identified plastics industry and ports. The protected regions include UNESCO Biosphere Reserves, National Parks and Nature Reserves.

Socio-Economic Sensitivity

Within the UAE in 2019, tourism accounted for 11.6% of its GDP and the sector employed over half a million people in 2021. It is reported that the UAE tourism sector is due to recover to near 2019 levels in 2023 with the contribution to GDP from tourism at 9% in 2022[2].

Acute pellet loss incidents, such as that which impacted Dubai beaches in February 2023, have the potential to harm this recovery as they are a highly visible pollutant with the potential to be remobilised and continue to re-emerge long after a spill incident has occurred.

Across Africa, Egypt received 13 million arrivals in 2019 being the most popular destination in Africa due to its beaches and rich coral reefs for scuba diving. South Africa received 10.2 million arrivals in the same year and tourism accounted for 4.7% of total employment. It is reported that tourism will be a major driver for post-Covid economic recovery in South Africa over the next decade with an estimated 800,000 jobs created in this time[3]. Acute pellet loss incidents such as those seen in 2017 and 2020 have the potential to stunt this recovery particularly given the increasing press coverage future incidents are likely to receive as awareness of plastic pellets and their impacts on the environment grows.

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[2] World Travel & Tourism Council. (2023). UAE Travel & Tourism sector set to recover this year, says WTTC. Available at: https://wttc.org/news-article/uae-travel-and-tourism-sector-set-to-recover-this-year-says-wttc [Accessed on 28/07/23]
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Asia Pacific

Production, Transport & Recycling Activity

Activity	Observations
Plastic Production	• Across the region primary plastic export trade worth over 56 billion USD in 2021 • 52% of world plastic production in 2021 was from Asia Pacific region • Asia Pacific accounted for 31% of world trade exports of plastics in primary forms in 2021 • South Korea and Singapore are the world's third and fifth largest exports of plastics in primary forms, respectively
Plastic Manufacturing	• Asia Pacific accounted for 37% of world trade imports of plastic in primary forms in 2021 • The region dealt with 23% of world trade in plastic manufacturing waste in 2021 • China is the world's largest importer of plastics in primary forms in 2021 and responsible for 32% of world plastic manufacturing
Maritime Freight Transport	• Asia Pacific region has 40 large ports as defined by World Ports Index • 31 of world's top 50 container ports by cargo volume • East Asia Pacific has over 475 million 20 foot equivalent (TEU) of shipping container traffic in 2021 • China had over 262 million TEU of shipping container traffic in 2019 • Given the high density of islands within the Asia Pacific region, marine transport is the dominant method of freight transport
Rail Freight Transport	• India recorded around 2.7 trillion ton-km of freight was moved via road transport in 2019. Road freight is the dominant method of freight logistics in India • Asia Pacific road freight transport market is expected to exhibit a compound annual growth rate of 5.8% showing its increased use in the region
Road Freight Transport	• African cross-border freight transport market is expected to exhibit a compound annual growth rate of 4.5% showing its increased use in the region
Plastic Recycling	• More than 660 plastic recycling plants (25% of global share based on industry database)

Environmental Incidents

It is estimated between 15,308 –151,764 tonnes of plastic pellets are lost annually in the Asia Pacific Region. In addition to widespread pellet pollution identified via citizen science this report has identified four acute and two chronic pellet loss incidents in the region. All acute losses are thought to be related to releases from shipping containers with an estimated 1,980+ tonnes of plastic pellets entering the environment.

The X-Press Pearl incident off the coast of Sri Lanka in May 2021 is estimated to have resulted in 1,680 tonnes of plastic pellets being released following a fire onboard the ship. Pellets were quickly identified in large quantities on Sri Lankan beaches. The presence of a fire onboard the ship led to a quantity of pellets being melted, releasing toxic chemicals into the environment. Coastal fishing in the area of the incident was stopped and dead marine life including sea turtles were reported to have been washed up on shorelines.

An estimated 150 tonnes of plastic pellets were released into the environment in July 2012 off the coast of Hong Kong due to poor weather conditions leading to the loss of shipping containers overboard. Knee deep layers of pellets were identified on shorelines of the surrounding islands. Concerns were raised about the safety of seafood caught in the area and the impacts this may have on human health. It is estimated that 105 tonnes of pellets were recovered.

A container ship, the MV Rena, ran aground in poor weather off the North coast of New Zealand in 2011 resulting the loss of an estimated 150 tonnes of plastic pellets to the environment which were washed up on the shoreline. Plastic pellets began to emerge again on affected coastline in 2021 and it is suspected these have been remobilised from the original incident a decade earlier[1].

A chronic loss was identified in Christchurch, New Zealand associated with the plastic industry and also chronic pollution from Chinese recycling plants where microplastics were released in wastewater into the environment or drainage networks.

Given the scale of the plastics industry in this region the incidents identified above are a gross underestimation of the scale of plastic pellet loss to the environment.

Environmental Sensitivity

The Asia Pacific region has several key environmentally sensitive areas, including the Coral Triangle across parts of Indonesia, Malaysia Philippines and Solomon Islands. It is estimated that 120 million people live in the Triangle and rely on the reef for food, income and protection from storms[2]. The region also contains the Great Barrier Reef which covers an area of over 340,000 km^2 and is designated as a World Heritage Site.

The region also contains over 68,000 km^2 of mangroves[3] and plastic pellets entering this type of environment would prove challenging to clean up and likely result in further damage to the mangroves.

Socio-Economic Sensitivity

For many of the island nations across the Asia Pacific Region tourism is a significant share of their GDP. For example, the Maldives and Sri Lanka have GDPs of 25.2% and 10.3% respectively. These two nations both have <0.1% of global import and export value of primary plastics. However, their tourism income could be heavily impacted as a result of a major loss of nurdles on their shoreline from maritime freight transport.

As shown by the acute losses in Sri Lanka and Hong Kong, releases of pellets to the environment can have an impact on fishing, both for subsistence and commercially. Plastic pellets, and the associated toxic chemicals, are ingested by marine life, including fish and marine mammals, and can potentially enter the human food chain. Spills also dent consumer confidence in aquaculture products if there is the perception that they may be contaminated. OECD data shows the region contains the world's top four aquaculture producer by tonnage, these are China, Indonesia, India and Vietnam[4]. This highlights their reliance on the sea and the importance of it being free from plastic pellet pollution.

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Chessel Bay, England

Chronic Plastic Pellet Loss Case Study

Key Facts

Date: First reported in 2011 – Ongoing (2023)
Location: Chessel Bay Nature Reserve Southampton, England, Europe
Cause: Suspected loss from plastic manufacturers
Quantity lost: Unknown
Quantity removed: ~4,680 kg (~234 million microplastic fragments)

Location and habitat

Chessel Bay is an estuarine bay located in Southern England, on the eastern bank of the River Itchen in Southampton[1]. The River Itchen is approximately 45 km long and passes through two cities within the county of Hampshire, Winchester and Southampton[2]. The river is widely used for a range of recreational activities such as sailing and fishing, and there is a variety of industries located in proximity to the river, with the highest density of these being at the river's mouth in Southampton.

Chessel Bay is the only remaining long stretch of undeveloped natural shoreline of the lower Itchen, and at low tide provides feeding and nesting grounds for wading birds and wildfowl such as egrets, oystercatchers, and Brent Geese[1]. This site was designated as a Nature Reserve in 1989[3] and is of national importance due to its natural salt marshes and mud flats classified as a Site of Special Scientific Interest (SSSI). It is also part of the Southampton Water and Solent Marshes Special Protection Area (SPA) protected under European legislation[4], and is an internationally important Ramsar Site[4] (Figure 1).

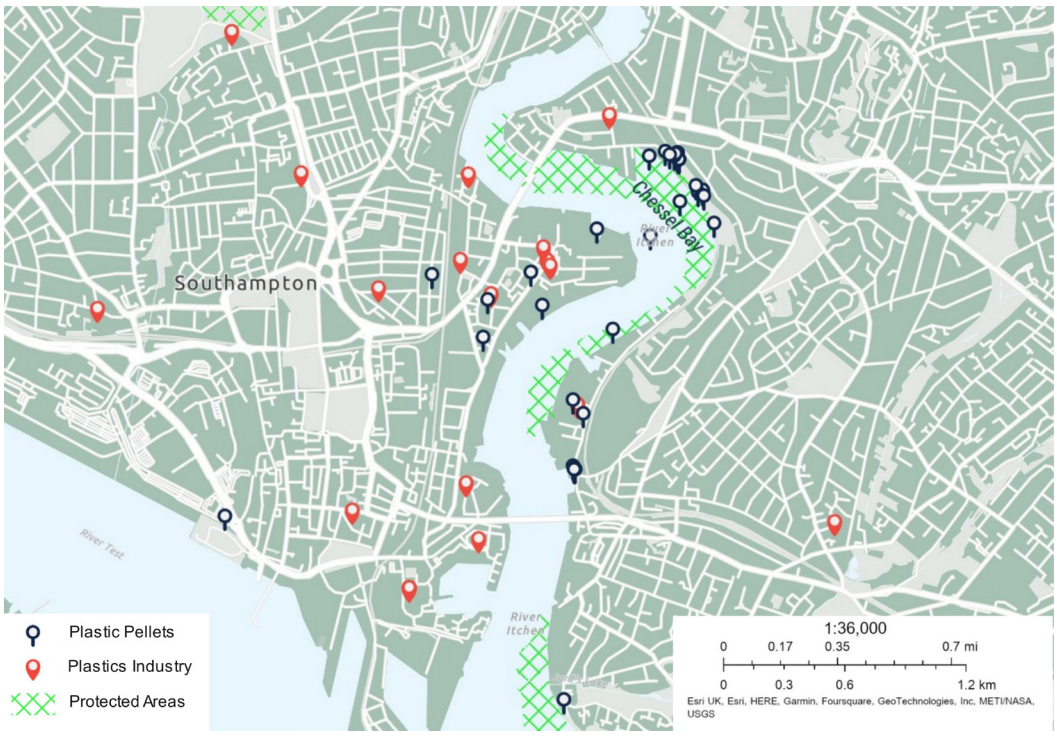

Figure 1: Map of the River Itchen and Chessel Bay illustrating the environmental designation areas, recorded pellets from Fidra Nurdle Hunt data[11], and registered plastic industries within the surrounding area

The nature reserve is adjacent to a residential area and is accessible to the public year-round. The Bay is managed by Southampton City Council and Natural England which allow bi-annual beach cleans to be carried out by local volunteers. The site itself is under environmental pressure from background marine pollution due to the heavy industrial setting, and the effects of climate change and sea level rise reducing the available habitat. The Bay has been subject to management issues, including illegal fly tipping, and large accumulations of general and industrial litter,

Figure 2: Chessel Bay, facing south towards the River Itchen at high tide and nearby marinas and industrial areas[7]

including plastic pellets[1,3,5]. Due to the unique double high water of the Solent that influences the water levels within the Itchen[6], and it being located on an outside bend of a meander in the river, the bay is an accumulation zone for river bound debris. The shoreline substrate is a mixture of shingle beach, dense salt marsh, and natural vegetation debris (Figure 2), meaning the plastic debris and pellets mix into the substrate and are difficult to recover.

Extent of plastic pellet impact

Plastic pellets, along with miscellaneous microplastic fragments and polystyrene, have been recorded in the Bay since 2011 by Southampton Urban Wildlife Centre and Friends of Chessel Bay[8]. A report on the impact from this group illustrated the variety of pellet shapes and colours found indicating multiple sources and varying stages of weathering, which suggests **a chronic release of pellets over a long period of time.** High concentrations of pellets have been seen to accumulate on the upper shoreline (Figure 3).

There are a large number of plastic manufacturers in the area (Figure 1), however, none have taken responsibility for the pellet pollution along the River Itchen. Without transparency within the sector, it is hard to identify who is responsible, making it difficult to make the relevant companies liable for the chronic spill. Mismanagement of pellets during transport, handling and storage can result in pellets reaching the environment through inadequate spill management procedures, therefore leading to direct input into the river from surface runoff, or into surface water drainage which can be exacerbated in windy or rainy conditions as they are easily transported due to the pellets' small size and weight[9].

Figure 3: Photo of the floating material on the water surface downstream from Chessel Bay, showing the volume of plastic pollution from pellets, polystyrene, macroplastics, and microplastic fragments, amongst the natural debris[14]

Pellet pollution was reported to the regulator, the Environment Agency (EA), in 2012, and again in 2019, following further beach cleans, citizen science surveys, and along with collaboration with the charity Surfers Against Sewage (SAS) and the University of Southampton's Marine Conservation Society. These surveys identified that the pellet pollution in the Bay was consistent and identified recent losses due to the lack of discolouration which is seen when plastics are exposed to UV radiation over time. Data was also reported to the Fidra Great Nurdle Hunt, which has 15 recorded entries within the nature reserve of pellet concentrations from 101 to greater than 1000 pellets between 2017 and 2022[11] (Figure 1).

Assessment of the surrounding area and downstream riverbanks also identified thousands of plastic pellets had washed up on beaches between Chessel Bay and within the Royal Victoria Country Park (7 km from Chessel Bay), following high tides and storms in 2019[3].

Response to plastic pellet pollution – Prevention

Across a 2.5 km length of the river, there are nine industrial areas and eight registered plastic manufacturers under Standard Industrial Classification (SIC) code 22290 – 'manufacture of other plastic products', all within 800 m of the water's edge (Figure 1). The EA reported that since the issue was first reported to them in 2012, they had undertaken pollution prevention visits to the manufacturing companies along the Itchen that have had a history where spillages were common. This was to encourage better practices including, the installation of drainage grates, border walls, and spill kits to improve clean up procedures[11]. The EA reported that following repeat visits in 2018, improvement and prevention techniques had been implemented by the relevant companies.

Table 1 Plastic manufacturers surrounding the River Itchen where details on product produced could be identified

Manufacturer	Products Produced	Pellet Pollution	Year & Source
Plastic polythene manufacturer, located in Northam Industrial Estate	Bags and covers, films and sheeting, disposable aprons, shrink and stretch films, refuse sacks, horticulture and agriculture, and bio-compostable plastics.	Pellets were found on the pavement, gutter and drains on public highways surrounding the manufacturer's premises. Pellets covered the company's yard, most of the drains did not have capture traps, and the ones that did were damaged and leaking pellets.	Feb 2020[3]
Plastic polythene manufacturer, located in Millbank Industrial Area	Bags and covers, films and sheeting, disposable aprons, shrink polythene, refuse sacks, agricultural, and specialised (biodegradable, UV resistant, flame-retardant) including in-house reprocessing machinery.	Pellets in the gutters and drains as well as accumulations on the driveway and neighbouring areas.	Feb 2020[3]
Plastic polyethylene manufacturer, located in Spitfire Quay	Lamination, blown film extrusion, flexographic printing, slitting & finishing and food packaging.	Pellets within the drains without any capture traps, and pallets of plastic pellets stored outside near the quayside with pellets scattered across the road.	Feb 2020[3]
Aircraft Seal & Polymer Engineer, located in Mount Pleasant Industrial Estate	Polyurethane, fluorosilicone, natural rubber products, polymer hybrids and blends, polychloroprene, silicone, fluorocarbon and Ethylene Propylene Diene Monomer.	No reported pollution or investigations undertaken.	N/A
Thermoformed plastic packaging manufacturer, located in Millbank Industrial Area	Electronic (packaging for Electro Static Discharge (ESD)-sensitive components), pharmaceutical (blister packs, handling trays, clamshells), medical (packaging for syringes, scalpels, catheters, cannulas and needles), aerospace and nautical, construction (cavity trays, roof tile sealant).	No reported pollution or investigations undertaken.	N/A

Figure 4: Image of the storage and movement of plastic pellets within tonne bags (image credit: Shutterstock)

Inland surveys were undertaken on the western side of the River Itchen in 2020 where a number of the plastic manufacturing facilities are located in a further attempt to identify the source of the plastics[3]. This was again reported to the EA and recorded on the Great Nurdle Hunt database. The world's first pellet handling specification (PAS 510) was published in 2021[12] by British Standards Industry (BSI) to mitigate the loss of pellets from organisations within the plastic supply chain. PAS 510 is a publicly available specification that sets out requirements for the handling and management of plastic pellets, as well as flakes and powders, throughout the supply chain to prevent spills, leaks and losses to the environment. The observations from these surveys are evidence that despite EA intervention, **pellet management guidance is not being followed by plastic industry in the area or is ineffective, leading to continued pellet losses** within close proximity to Chessel Bay (Table 1). Furthermore, none of the plastic manufacturers are listed as signatories for the voluntary Operation Clean Sweep (OCS)[13].

Response to plastic pellet pollution – Clean up

A not-for-profit company 'Nurdle.org' (partnered with cleaning suppliers Karcher) has been involved in trials and clean ups along the shoreline of Chessel Bay. This has been undertaken using specifically designed vacuum equipment in agreement with the EA, Natural England and local authorities to avoid times of migratory birds and nesting seasons. An initial clean up trial was undertaken in August 2021 along with an impact and biodiversity survey. From this, it was concluded that the equipment was effective in the recovery of all types of plastic pollution. The plastic collected was found to cover the ground to such an extent that it restricted the growth of certain grasses, preventing the creation of suitable habitats for wildlife to thrive. Subsequently 'Nurdle.org' reattended throughout January to April 2023 along with SAS, Friends of Chessel Bay, The Final Straw Foundation and other public volunteers to undertake a mass clean up along the nature reserve for five days at a time. They claim to have removed over 234,000,000 pieces of microplastic, cleaning 90% of the pollution in some areas of the nature reserve[5]. **The local industry has been approached to take part in clean up at Chessel Bay, however, to date, they have not been involved.** The EA have since reached out to the relevant parties to begin to form a coalition and stakeholder groups to tackle the pollution[3].

Figure 5: Use of vacuum recovery equipment to remove plastic pollution from an intertidal section of the River Itchen, downstream from Chessel Bay, that has also been impacted by the chronic pellet pollution[14]

Current research at the University of Southampton[15] has also been conducted in the Bay to understand a) what, if any, positive and negative impacts the clean up has on the Nature Reserve and b) if there is an increased input of pellets identified following the clean up works. This can determine if they are 'fresh' virgin pellets potentially from ongoing losses from the plastic manufacturers, or if it is residual background legacy pollution being re-mobilised from the surrounding areas.

In recent years, the pellet pollution and clean up efforts at Chessel Bay have received media attention[7,9,16]. Despite this, the unknown **perpetrators of pellet mismanagement have not been held to account.** The chronic accumulation of pellet pollution is unlikely to be stopped without regulatory measures and sanctions in place to hold those accountable. **The reliance on NGO's and community volunteers to clean up the Bay contravenes the 'polluter pays principle' of the UK Government[17] and is not a viable management plan.** In the absence of data on the source of the pellets, any outcomes of research on the impacts of pellet pollution to Chessel Bay and the surrounding area is likely to provide further evidence to support the application of the precautionary principle to stop pellet pollution.

Summary & Conclusions

- There is sufficient evidence to infer that the **pellet pollution at Chessel Bay is chronic**, and is potentially from the local plastic manufacturing industry based on the series of incidences of logged nurdles between 2011 to 2023. However, the exact source is still unknown due to a lack of reporting and transparency from the industry.
- The **pellet pollution is having an impact on nationally important habitats and the seascape,** however the environmental, chemical and health risks associated with this are unclear.
- Regulators and governing authorities are aware of the chronic pollution in this area. However, **attempts to enforce prevention measures have been voluntary and ineffective based on the ongoing pollution.**
- Despite media attention, academic research and community group efforts, the lack of industry transparency has meant it is unclear what prevention and mitigation measures are in place to stop pellet loss at source.
- **Industry have not met the costs of clean up to date.** The prevention and polluter pays principle[16] are not being adhered to in preventing pellets from impacting the environment nor in the clean up of pellets lost. Mandatory measures are needed to ensure zero pellet loss in the first instance, and where there is evidence of chronic pollution the cost of clean up efforts are met by polluters.
- None of the plastic manufacturers within an 800 m radius of the River Itchen are registered as signatories to the voluntary OCS scheme. Nationally, out of the 5851 registered plastic manufacturers in the United Kingdom, only 185 are registered signatories of OCS. **Without mandatory standards (such as PAS510:2021)[12] verified by third parties, chronic pellet loss is likely to continue resulting in severe pollution.**

Chronic pellet pollution sites around the world

- Similar **chronic pellet pollution sites have been identified worldwide** such as Limekilns in Scotland, Antwerp in Belgium and Corpus Christi & Point Comfort in the US where there is a large concentration of plastic manufacturers, commonly near a river or shoreline, that are contributing to severe pellet pollution. Due to the lack of industry reporting on pellet losses and volunteers being unable to undertake surveys in some regions, there is underreporting of chronic pellet pollution sites across the globe. **Further sites will be at risk if the plastic industry expands further.**
- With the identification and recorded quantity of pellets associated with chronic losses being underreported, it is hard to quantify the current extent of the chronic issue. In 2018 it was estimated that the loss from chronic spills in Europe is ~145,150 tonnes annually, which is equivalent to 7.3 billion pellets lost[18]. To add to this issue, plastic production is expected to triple 2060[19] and if there is no change in behaviours towards pellet loss this could result in severe quantities being lost each year.
- Current voluntary efforts to address pellet loss are insufficient resulting in ongoing pollution from industry and chronic accumulations of pellets, many in environmentally sensitive locations. This is evidenced by the correlation of pellet finds and plastic industry locations highlighting the ongoing chronic pollution around these sites. Pellet loss is preventable with a legislated mandatory supply chain approach, where all actors in the process are required to meet rigorous standards that are externally verified and communicated along the supply chain. This can be supported by strong enforcement and compliance should actors in the supply chain fail to follow through with preventative measures, ensuring the costs of clean up are met polluters. **Implementing a mandatory supply chain approach should be the first step in stopping chronic pellet loss, to turn the tap off from the source.**

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Hong Kong

Acute Plastic Pellet Loss Case Study

Key Facts

Incident Date: 24 July 2012
Location: Hong Kong islands, China, Asia Pacific
Cause: 6 containers of polypropylene pellet lost overboard during a storm
Quantity lost: 150 tonnes (~7.5 billion pellets)
Quantity removed: ~105 tonnes (~5.25 billion pellets)

Incident summary

Between 20 and 24 July 2012, originating over the western North Pacific northeast of the Philippines, the category 4 Typhoon Vicente swept across Hong Kong, China and Vietnam[1]. This was the culmination of three tropical storms which rapidly strengthened near the coast of Hong Kong[2].

As the storm passed southwest of Hong Kong on the evening on 23 July 2012, the 128m long container ship Yong Xin Jie 1[3], owned by China Petroleum and Chemical Corp (SINOPEC), was traveling east to moor in the open waters of Ninepin Group islands, approximately 2 km off the coast of Hong Kong. Due to the high winds and sea conditions, a total of seven 40-foot-long cast steel containers were lost overboard, six of these contained polypropylene pre-production plastic pellets. Each container was thought to carry ~1,000 bags (25 kg each) resulting in **150 tonnes (an estimated 7.5 billion pellets) being lost to the marine environment[4].** According to the Marine Department and the Food and Environmental Hygiene Department (FEHD), five of the containers were recovered. However, four were completely damaged, and most of the pellets had been released into the sea. The incident was not released to the public at the time[4].

Extent of plastic pellet impact

On 25 July 2012, Plastic Free Seas (PFS), a Hong Kong-based environmental charity, found plastic pellets on Hong Kong's Lantau Island and notified the government[5]. A deep layer of pellets covering the length of the beach and 30 SINOPEC branded plastic bags containing pellets were found (Figure 1). Cleanup was undertaken by PFS on 26 July 2012 with over five tonnes of loose pellets removed and a further 170 branded bags were identified in varying conditions, some being damaged and completely empty[5].

Figure 1: SINOPEC bags recovered from the beach by Plastic Free Seas and other NGOs and individuals[5]

Figure 2: Location of Yong Xin Jie container loss and extent of Hong Kong Administrative Areas

Six days later, more pellets were found in some areas of Hong Kong's southern island's, Beaufort Island and Lamma Island, with further impact to the Chi Ma Wan peninsula. Mui Wo on Lantau Island was seen to be knee-deep with pellets in some areas[5]. The scale of the spilled pellets is likely to be underreported due to the geographical spread of Hong Kong's 250 islands[6] and 1189 km of coastline[7] (Figure 2).

Response to plastic pellet pollution – Clean-up

Thousands of citizens and non-governmental groups (NGOs)[5,8,9] were involved in the cleanup efforts across Hong Kong after the pellet spill. The government and SINOPEC were heavily criticized by the public and NGOs for their lack of responsibility, slow response to the incident and for the delay in announcing the spill to the public. Although SINOPEC were responsible for the cargo, it had not admitted liability and China Shipping Container Lines reportedly leased the cargo vessel, however, they did state SINOPEC would "pay for the necessary costs and expenses"[10]. Seventeen days after the spillage, SINOPEC initially set aside 1.28 million USD to help with the cleanup effort and sent staff to join local volunteers in picking up pellets by hand[11]. In addition to this, a comprehensive cleanup strategy[5] was agreed between the government's Marine Department, Environmental Protection Department (EPD), FEHD, NGOs and SINOPEC.

Figure 3: SINOPEC bags filled with plastic pellets piled up on the shoreline, floating and sunken near the shore. Concentrations of white plastic pellets are visible on the strandline and on rocks on the shore. A washed-up damaged container is visible too[5]

This led to a widescale clean-up operation covered by the media and promoted on social media, resulting in over 1000 resourceful volunteers participating in removing pellets from the beaches of Tung o Wan (East Lamma)[5]. During the clean-up, some plastic bags were seen to float, but others were seen sinking to the seabed (Figure 3). The scale of lost pellets had the potential to affect marine ecosystems including coral reefs and IUCN Vulnerable Finless porpoises *Neophocaena sp.*[12] that hunt nearby[13,14].

In the following days, smaller volumes of pellets were found on the Special Administrative (SA) mainland China by Macau, on Hac Sa and Zhuwan Beach approximately 80 km west of the container loss. The Port Authority, the EPB, and Macau Cleaning Specialty Co. Ltd conducted clean ups in the area and organised ships to patrol the beaches for floating particles to tackle the pellet pollution[15].

In Hong Kong, in response to the public's criticism of the government's slow response, the Secretary for Food and Health defended the government's actions stating that they were also responsible for clearing fallen trees and debris following the typhoon. Consequently, this took people away from responding to the plastic incident[16]. They stated lessons needed to be learned from the incident, including response time and making the public aware[17]. Issues began to arise with recycling the recovered pellets due to the mixed material obtained contaminated with sand and other waste[17]. Further to this, NGOs noted the interspersal of pellets with other marine debris including household items, which highlighted the scale of the background plastic pollution problem in the area[18] (Figure 4).

Figure 4: Plastic polypropylene pellets spread across the surface of the beach along with varying macroplastic pollution, such as domestic plastic bottles and other unidentifiable plastics[8]

Environmental, social and economic affects

Health and access

The government advised public swimmers to contact beach lifeguards, or their Environmental Protection Hotline if they found pellets on the beach[16], and due to the unknown health impact at the time, the **government advised caution when bringing children to the beach[19].** This was in parallel while the EPD continued to monitor the water quality and for any "ecological changes"[16].

Toxicity

From the start, SINOPEC stated that the pellets were not toxic or hazardous on their own[20]. However, research had identified **plastic pellets are able to adsorb toxins and other chemicals within the surrounding waters,** which could then lead to further contamination of the environment and risk to human health[21,22]. An associate professor[13] and other researchers,[23,24] have stated that the pellets may have already been exposed to plasticizers or flame retardants to give them certain characteristics that could be toxic to marine life over many years as the pellets degrade. Another study highlighted that just 6 days was sufficient for the microplastic particles to adsorb carcinogenic chemicals in seawater, such as Polychlorinated biphenyl (PCB) and Dichlorodiphenyldichloroethylene (DDE)[12]. The ingestion of these pollutants could result in accumulation within food webs and could result in ingestion into human consumption[25], thus **sparking concerns about the safety of consuming locally produced seafood in the waters surrounding Hong Kong.**

Fishing

Fishers reported appetite loss in farmed fish due to their stomachs being occupied by the microplastic pellets or blocking their digestive systems[26].The Hong Kong Fisheries Federation received reports from fishers of a small amount of abnormal dead fish were found in south Hong Kong, and it was confirmed these fish had ingested plastic pellets[4]. The white, transparent pellets spilled are similar to fish eggs and small fish ingest them by mistake[27]. Despite reported fish mortalities, the Hong Kong government made a statement, saying the fishing industry of the bay would not be strongly impacted by the plastic contamination, and would not have a negative impact on the quality of the fish[28]. However, this event was later credited **to the crash in fishery stocks, impacting the natural food resource and warnings were issued** that the 'fish had eaten the gelatinous particles, and (the public) should not eat them and any **fish showing signs of being affected should not be sold'**[17].

Protected areas and species

Within the Hong Kong and the SA China region, there are 103 National designations including the Terrestrial and Inland Waters Protected Areas (Figure 5), and one International designated Ramsar Site Marine Protected Area (Mai Po Marsher & Inner Deep Bay to the north)[28]. Sham Wan on Lamma Island is a spawning area for IUCN Red List Endangered green sea turtles, *Chelonia mydas*[29], where tourists are prohibited during the spawning season. The pellet spill occurred during the turtles' spawning months meaning hatchlings were likely exposed to large quantities of pellets from birth, potentially ingesting them. Additionally, Sham Wan, Tung O Wan of Lamma, Po Toi, Beaufort Island and South Ninepin Island have **coral reef sites**[30]**, that were likely not only impacted by the typhoon itself, but at risk from plastic pellets and covering the corals and the introduction of potential toxins and pathogens into the environment.**

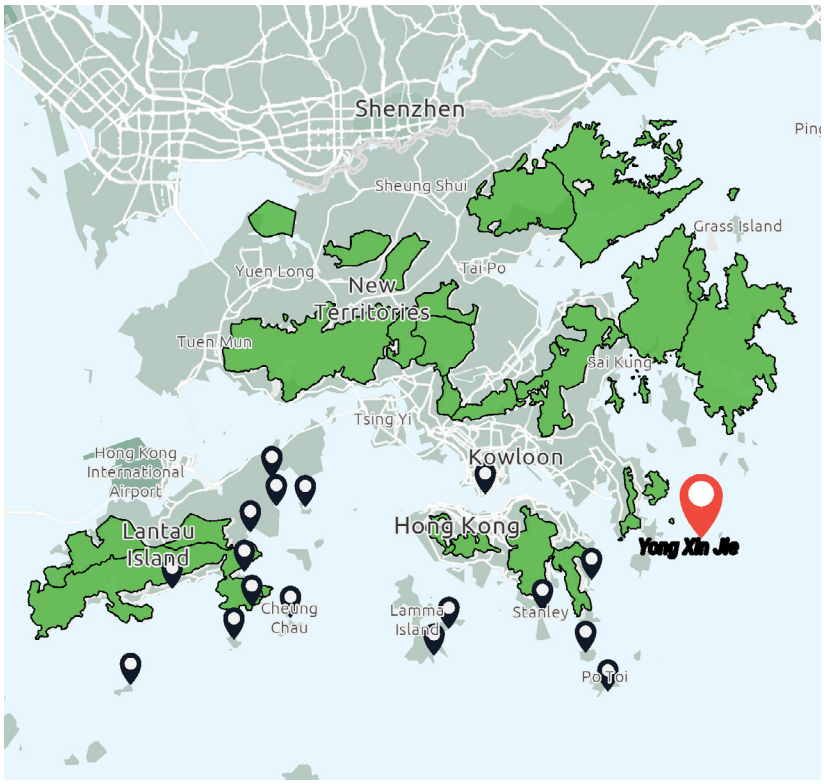

Figure 5: Location of Yong Xin Jie container loss, environmental designated areas (green) and recorded pellets (black markers) identified following the incident

Legacy pollution

Due to the dynamic nature of the three dominant ocean currents in the Hong Kong area[7], **pellets were found newly deposited on beaches months after the container spill event.** Six months after the incident plastic pellets were found at Ngong Chong Beach on Po Toi Island and six years later in 2019, mounds of pellets were still found on some of the Hong Kong islands[31]. It is unclear if the pellets found are legacy pollution from the 2012 incident (e.g. sunken bags releasing pellets over time), new acute or chronic spills due to mismanagement within the supply chain.

The Hong Kong government reported that 70% of the pellets had been recovered totalling an estimated 105 tonnes (~5.25 billion pellets). As a result of the incident, funding of a two-year Coastal Watch programme was initiated to promote marine conservation and protect Hong Hong's ecologically valuable habitats[6]. This promoted the development of the first inter-Departmental Working Group on Marine Environmental Management 'Clean Shorelines', comprising of nine government departments with a focus on marine plastic pollution[5].

Lack of regulation and compensation

The areas impacted by the acute incidents not only have to deal with the potential damage to the environment, community space and livelihoods but also the financial fallout associated with it. The International Maritime Organisation (IMO) have put in place measures to ensure strict liability to those affected by an oil spill as a result of oil spills leading back to the Amoco Cadiz spill in 1978[32], and since 2003 it has been possible to hold multiple entities liable, including the individuals who hire a ship, not just the ship owner. However, **there are no specific regulations in place to address the consequences of container loss and therefore enforcing compensation for damage made to both a community impacted, or the environment is difficult[33].** Hong Kong did announce almost two years after the event a private deal had been struck to cover costs associated with the clean-up of the spill[34]. Due to the confidentiality clause in the agreement it is unclear, the type of compensation received (e.g. equipment, resources, financial). Further to this it was not disclosed who was compensated, how local communities could apply for this, if the compensation supported the local economy, or if compensation would only be for clean-up.

Overall, despite the long term negative impact of the acute spill on Hong Kong's government resources, the public perception of the government, and the increase in container traffic on the route where the spill occurred in 2012, there has been no additional regulation or spill protocols that have been put in place that is accessible to the public following the incident. Further measures need to be in place to ensure if acute pellet incidents do occur, the countries and communities most likely to be affected will be sufficiently protected from the associated impacts and will also be appropriately compensated.

Summary & Conclusions

- The **plastic pellet spill had significant impacts on the fauna and flora of the surrounding Hong Kong islands, the health of local communities, and financial losses to fisheries and businesses** including the polluter SINOPEC. The true extent and impacts of the spill is likely to have been underreported based on the remoteness of some of the island communities, and low value placed on plastics.
- The 2012 Hong Kong incident was caused by a severe storm event that was rare at the time, however, **with ever-increasing sea temperature and climate change these storm events are likely to become more frequent and have greater intensity[35].**
- Classification of pellets by the IMO as environmentally hazardous would have allowed more accurate and timely information on the containers lost which could have helped improve response. Safer stowage may also prevent containers with pellets from being lost in the future and secure packaging may also aid in pellet recovery in the event of containers being lost overboard.

Acute pellet pollution sites around the world

- 41 acute pellet losses have been identified in this study globally to date, with 34 of these occurring after the Hong Kong incident. The largest from a container ship was the fire on the X-Press Pearl off the west coast of Sri Lanka which resulted in the release of 1,680 tonnes of pellets into the environment. This value is likely underreported but similar impacts to those listed here could be found at other acute pellet loss sites.
- Local NGOs are vital in spreading awareness of these issues to the general public and being custodians of the environment. However, **dedicated national and international spill response is needed, particularly near major ports, shipping routes and nations that are at risk of these pollution events.**

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Mapping The Global Plastic Pellet Supply Chain

Appendix E: List of Chronic Sites of Pellet Pollution

Date	Location	Country	Region	Setting	Pellets Lost (tonnes)	Cause
Jan 05	Vernon, California	USA	North America	Terrestrial	–	Transport – Rail and trans shipment
Oct 09	Metro Poly Corp of San Leandro, San Francisco	USA	North America	Terrestrial	–	Transport – Rail docking area and industry
Dec 15	Tujunga Wash, Los Angeles River, California	USA	North America	Terrestrial	–	Industry – Plastic producers
Jan 16	Vancouver, Gulf, San Juan Islands and Sunshine Coast	Canada/USA	North America	Terrestrial	–	Industry – Plastic producers
Jan 16	Cox Creek and Lavaca Bay, Point Comfort, Texas	USA	North America	Terrestrial	–	Industry – Plastic producers, Formosa Plastics
Sep 18	North Padre Island, Corpus Christi, Texas	USA	North America	Terrestrial	–	Industry – Plastic producers
Jul 19	Sullivan's Island, Port of Charleston, South Carolina	USA	North America	Marine	–	Industry – Plastic related industies loss
Dec 20	Great Lakes, Ontario/Michigan Border	Canada/USA	North America	Terrestrial	–	Industry – Plastic related industies loss
Nov 16	Santos, São Paulo state	Brazil	Central America	Marine	–	Unknown
May 09	Le Havre	France	Europe	Terrestrial	–	Transport – Nearby port
Nov 10	Grand Canal du Havre	France	Europe	Terrestrial	–	Industry – Plastic producers
Jan 11	Chessel Bay, Southampton	England	Europe	Marine	–	Industry – Plastic producers
Aug 11	1 Rue Louis Blanc, 40100, Dax	France	Europe	Terrestrial	–	Industry – Plastic producers
Sep 12	Zone Industrielle de la Gare BP14, Cany-Barville	France	Europe	Terrestrial	–	Industry – Plastic producers, Polytechs
Oct 12	Avenue des Canadiens, 76860 Ouville-la-Rivière	France	Europe	Terrestrial	–	Industry – Plastic producers
Oct 12	Feluy Service Center, Ecaussinnes	Belgium	Europe	Terrestrial	–	Industry – Plastic producers
Oct 12	53 Rue Jean Jaures 76290, Montivilliers	France	Europe	Terrestrial	–	Industry – Plastic producers
Jan 13	Stenungsund	Sweden	Europe	Marine	0.72	Industry – Plastic producers
Feb 13	Chemin du Gord, 76120 Le Grand-Quevilly	France	Europe	Terrestrial	–	Industry – Plastic producers, GREIF
Jun 16	Katoen Natie Gonfreville	France	Europe	Terrestrial	–	Industry – Storage and logistics, TOTAL
Aug 16	Rue Marius Sire, 80420 Ville-le-Marclet, Nievre River	France	Europe	Terrestrial	–	Industry – Plastic producers
Apr 18	Boucles de la Seine Normande	France	Europe	Terrestrial	<1	Unknown
May 18	Vitasheet Group, Thyrasvej 12, Tistrup	Denmark	Europe	Terrestrial	<1	Industry – Plastic producers, waste/leaks
May 18	Emtelle production site	Denmark	Europe	Terrestrial	<1	Industry – Plastic producers
May 18	Fife, Grangemouth, Barra and Collieston	Scotland	Europe	Terrestrial	–	Industry – Plastic producers, since 1950s
Oct 18	La Pineda beach and Balearic islands, Tarragona	Spain	Europe	Marine	1.80	Industry – Plastic producers
Feb 19	Lillebonne Port Jerome, Riviere due Commerce	France	Europe	Terrestrial	–	Industry – Plastic producers, EXXON
Jul 19	Antwerp	Belgium	Europe	Marine	–	Industry – Plastic producers
Jan-20	The Londonhaven, Rotterdam Port	Netherlands	Europe	Terrestrial	–	Industry – Plastic producers
Jan 20	Chemelot, Limburg	Netherlands	Europe	Terrestrial	–	Industry – Plastic producers
Nov 21	Terneuzen, Westerschelde	Netherlands	Europe	Terrestrial	–	Industry – PE and PP producers, Sewage overflow
Nov 21	Roompotstrand, Westerschelde	Netherlands	Europe	Terrestrial	–	Potential transport overseas from UK producers
Nov 21	Kanaal Gent-Terneuzen, Westerschelde	Netherlands	Europe	Terrestrial	–	Industry and transport – Vlaeynatie
Feb 23	DeLisle, Lillebonne	France	Europe	Terrestrial	–	Tank washing, release of powders
May 23	Unknown plastic recyclers	UK	Europe	Terrestrial	–	Recyclers
Jul 21	Plastics industry, Avon-Heathcote Estuary, Christchurch	New Zealand	Asia Pacific	Terrestrial	–	Local plastics industry in Christchurch
Sep 22	Unknown plastic recyclers	China	Asia Pacific	Terrestrial	–	Recyclers

Mapping The Global Plastic Pellet Supply Chain

Appendix E: List of Acute Sites of Pellet Pollution

Date	Location	Country	Region	Setting	Pellets Lost (tonnes)	Cause
Jan 08	Lake Superior, Cavers Cove near Rossport, Ontario	Canada	North America	Terrestrial	–	Transport – Train derailed – 14 carriages
Aug 09	Near Algoa, Texas	USA	North America	Terrestrial	–	Transport – Train derailed – 12 carriages
Apr 13	Wheeling & Lake Erie Railroad Gambrinus Yard, Canton, Ohio	USA	North America	Terrestrial	–	Storage – Rail Yard – 2 carriages tipped
Mar 18	Pocono Creek, Route 80 near Tannersville, Pennsylvania	USA	North America	Terrestrial	13	Transport – Road Freight tractor-trailer crash
Aug 20	Mississippi River, near New Orleans	USA	North America	Marine	15	Transport – CMA CCM Bianca – Container loss
Sep 20	Rosemar Road, Intersection 46 Street, West Virginia	USA	North America	Terrestrial	–	Transport – Road transport spill
Jan 21	Jackson County, Texas	USA	North America	Terrestrial	–	Transport – Train collision, Formosa Plastics Corp.
Sep 21	Raceland, Lousiana	USA	North America	Terrestrial	–	Transport – Train collision
Nov 21	Carlisle, Iowa	USA	North America	Terrestrial	–	Transport – Train derailment
May 22	Guy's Run Creek and Allegheny River junction, Pittsburg	USA	North America	Terrestrial	5	Transport – Train derailment
Oct 95	BASF Wilton, Teesside, Middlesbrough	England	Europe	Terrestrial	10,000	Industry – Factory fire
Dec 11	Gonfreville	France	Europe	Terrestrial	–	Transport – Road transport spill
May 12	De Rijke	France	Europe	Terrestrial	–	Industry – Plastic producers, storage
Feb 16	Wimille A16, Denacre and the Wimereux river	France	Europe	Terrestrial	8	Transport – Road transport spill
Jun 16	Le Havre to Port Jerome	France	Europe	Terrestrial	–	Transport – Road transport spill
Jul 16	Myennes toll, A77	France	Europe	Terrestrial	25	Transport – Road fire, 1 trailer loss
Sep 16	A61, Gardouch, Haute-Garonne	France	Europe	Terrestrial	–	Transport – Road transport spill
Oct 16	D82 Romagnieu	France	Europe	Terrestrial	–	Transport – Road transport spill
Oct 16	Beaumont-en-Verdunois in the Meuse	France	Europe	Terrestrial	–	Transport – Road transport spill
Nov 16	A10, near Massy and Wissous	France	Europe	Terrestrial	25	Transport – Road transport fire and spill
Dec 16	A85, near Blere exit	France	Europe	Terrestrial	–	Transport – Road transport spill
Dec 16	N10 near Barbezieux	France	Europe	Terrestrial	–	Transport – Road transport fire and spill
Jan 19	Schiermonnikoog island, North Sea	Netherlands	Europe	Marine	11	Transport – MCS Zoe – 345 containers lost
Nov 19	La Rocquennerie, La Gacilly	France	Europe	Terrestrial	28	Transport – Fell from road transport
Feb 20	German and Dutch waters of the North Sea	Sweden/Norway	Europe	Marine	13	Transport – MV Trans Carrier, damaged container
Oct 20	A29 near Yvetot (Seine-Maritime)	France	Europe	Terrestrial	20	Transport – Road transport fire and spill
Apr 21	Isola of Sant'Andrea, Brindisi	Italy	Europe	Terrestrial	–	Industry – Brindisi petrochemical plant
Nov 22	South Finistère coast	France	Europe	Marine	–	Unknown – Potential container loss
Dec 22	Les Granges in Les Sables-d'Olonne (Vendée)	France	Europe	Marine	–	Unknown – Potential container loss
Dec 22	Tréguenec and La Torche beach	France	Europe	Marine	–	Unknown
Jan 23	Loire-Atlantique and Vendée	France	Europe	Marine	125	Transport – 5 containers lost overboard
Feb 23	Saint-Jouin-Bruneval, near Le Havre	France	Europe	Marine	–	Unknown – Potential poorly closed container
Mar 23	PMG Plastiques Mitry Grandjouan factory, Froissy, Oise	France	Europe	Terrestrial	–	Industry – Factory fire
Apr 23	Kimmeridge Bay, Dorset	England	Europe	Marine	–	Unknown – Potential container loss
Oct 17	Near Port of Durban	South Africa	Africa & Middle East	Marine	49	Transport – MCS Susanna – 2 containers lost
Aug 20	Plettenburg Bay (Eastern Cape)	South Africa	Africa & Middle East	Marine	175	Transport – Container loss overboard
Feb 23	Sunset Beach, Dubai	UAE	Africa & Middle East	Marine	–	Transport – Container loss overboard
Oct 11	Near Tauranga – Tairua Beach and Bay of Plenty	New Zealand	Asia Pacific	Marine	150	Transport – MV Rena Container ship
Jul 12	South Hong Kong towards Ninepin Group	Hong Kong	Asia Pacific	Marine	150	Transport – 5 Containers loss at sea
Jun 21	Near Colombo	Sri Lanka	Asia Pacific	Marine	1,680	Transport – X-Press Pearl Fire onboard a container ship
Jul 23	Aksa beach, Versova and Juhu, Mumbai and Palghar beaches	India	Asia Pacific	Marine	–	Transport – Hanwha TotalEnergies sacks

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