COMMERCIAL IN CONFIDENCE

FINAL REPORT

Measuring environmental costs from litter and illegal dumping

Prepared for
New South Wales Environment Protection Authority, Sustainability Victoria, and Queensland Department of Environment and Science

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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Executive summary

Litter and illegal dumping impose significant financial, environmental and social costs on the community. This includes environmental and human health costs, clean-up costs, and losses in recreational, commercial and amenity values.

The focus of this paper is on the environmental costs of litter and illegal dumping in three specific environments: marine, inland waterways and terrestrial. Separate work is concurrently analysing the amenity and clean-up costs of litter and illegal dumping. Used together these studies aim to provide a more holistic understanding of the total cost of litter and illegal dumping.

The costs from litter and illegal dumping vary by debris type and the location the litter or illegal dumping occurs. It is important to identify which types of costs are incurred from litter and illegal dumping to ensure that all relevant costs are included, while avoiding double-counting. For example, litter in urban areas which is readily picked up will generally impose a clean-up cost and minimal environmental, human health and amenity costs. The difficulty lies in determining 'what happens next' after a piece of debris is littered or illegally dumped. Possible pathways include:

- debris is cleaned-up immediately
- debris remains in the environment for a short period of time before being cleaned-up
- debris remains in the environment, either in-situ or is transported to new environments and continues a process of either breaking-down (e.g. paper) or breaking-up (e.g. plastic).

The environmental impacts from litter and illegal dumping are therefore determined by debris type, 'what happens next' which encompasses the receiving environment and the duration which debris remains in that environment.

Table 1 outlines the likely inter-relationships between the environmental costs, human health impacts, recreational use value, clean-up costs and amenity costs. The total economic cost of litter and illegal dumping comprises an interplay between these cost categories. The blue shaded cells outline which impacts/costs are caused by which debris type in each of the three environments. For example, the predominant two impacts of micro-plastic in the marine environment are environmental and human health impacts.

The focus of this paper is on the environmental impacts of debris, and also encompasses human health impacts caused by debris remaining in the environment (e.g. human ingestion of microplastics). In addition, lost recreational use value is also discussed in relation to dog faeces which pollutes inland waterways and marine environments.

1 Predominant impact categories for environment and debris types

Environment/ Debris type	Environmental impact	Human health impact	Recreational use value	Clean up cost	Amenity costs
MARINE ENVIRONMENT (Predominantly coastline)					
Littered items					
Macro-plastic					
Micro-plastics					
Glass					
Paper/cardboard					
Cigarettes					
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					
INLAND WATERWAYS					
Littered items					
Macroplastic					
Microplastic					
Glass					
Paper/cardboard					
Cigarettes					
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					
TERRESTRIAL					
Littered items					
Macroplastic					
Microplastic					
Glass					
Paper/cardboard					
Cigarettes					
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					

Source: CIE.

Evidence to identify and value environmental impacts

The process of identifying and valuing environmental impacts of litter/illegal dumping involves the following steps:

- gather evidence on material types being present in the environment
- identify potential impacts from debris that is littered or illegally dumped
- gather evidence on incidence of impacts, requiring:
  - concentration levels in the natural environment are sufficient for impact to occur
  - establishing cause and effect relationships to final outcomes
- assess whether the impacts are at the population level
- attribute population level impacts to littered or illegally dumped debris (where debris is a contributing factor to a broader impact)
- use available economic values to estimate environmental cost for population level impacts (chart 2).

Population-level impacts can be defined in geographic, local population or total population terms. The key distinction being that threats to a population can impact the broader group, rather than just specific individuals. The population should be defined with reference to the scale of the impact and the migratory nature of the species, such that:

- the local population should be defined in the case of localised impacts for species which are non-migratory
- the total population should be defined in the case of global impacts and/or if the species is migratory.

Furthermore, consideration should be given to whether a species is endangered or vulnerable. For example, localised impacts may still impose population-level impacts for a migratory species if it is also a threatened species.

For the purposes of this study, we have identified 20 species in the marine environment (see discussion in Chapter 3) for which threats (e.g. litter and illegal dumping) can lead to population-level impacts due to their current endangered or vulnerable status.

A comprehensive literature review of the environmental impacts of litter and illegal dumping in each of the three key environments was conducted. This report outlines the evidence and data gathered from the literature review for each step listed in table 2.

2 Steps to identify and value environmental impacts of litter/illegally dumped debris

Step	Evidence and data requirements
Evidence of material in environment	▪ Data on the quantity of debris entering the environment per year (the flow), and/or currently in the environment (the stock), for each type of debris type littered or illegally dumped
Identify potential impacts from debris	▪ Potential impacts differ by type of debris and receiving environment and include entangelment, ingestion, chemical contamination, migration of non-native species, human health impacts
Gather evidence on incidence of impacts	▪ Incidence data at the individual level is required rather than incidence at the species level ▪ Impact should reflect incidence in the natural environment, rather than laboratory conditions, such that concentration levels in the natural environment are sufficient for impact to occur. ▪ Incidence data must be based on final outcomes in order to value impacts ▪ A cause-and-effect relationship must be established for each impact
Identify population level impacts	▪ Impacts can cause individual-level impacts or population-level impacts ▪ Identification of population-level impacts is required for economic valuation in most cases ▪ There is relatively less information on population-level impacts available as it is difficult to determine impacts at this scale
Attribute population level impacts to debris	▪ Debris can either cause an impact in and of itself, or it can contribute to a broader impact ▪ Attribution is required when debris contributes to a broader impact
Apply economic values to population level impacts	▪ Economic values are available for willingness to pay to: – avoid extinction of a threatened and endangered species – to achieve a change of a species- status

Data source: CIE.

The impact types and severity of impacts differ across the three environments. These differences are due to the type, volume and duration which the debris is in the environment and also the nature of the environment and organisms which inhabit it. Chart 3 outlines the key impacts for each of the three environments: Key impacts identified are:

- marine environment — entanglement, ingestion, chemical contamination, non-native species and human health impacts
- inland waterways — entanglement, ingestion, chemical contamination and stormwater pollution
- terrestrial environment — invasive weeds, invasive pests, chemical contamination, human health impacts and fire risk.

There are gaps in the valuation of environmental impacts from litter and illegal dumping driven by a lack of information on one or more of the following:

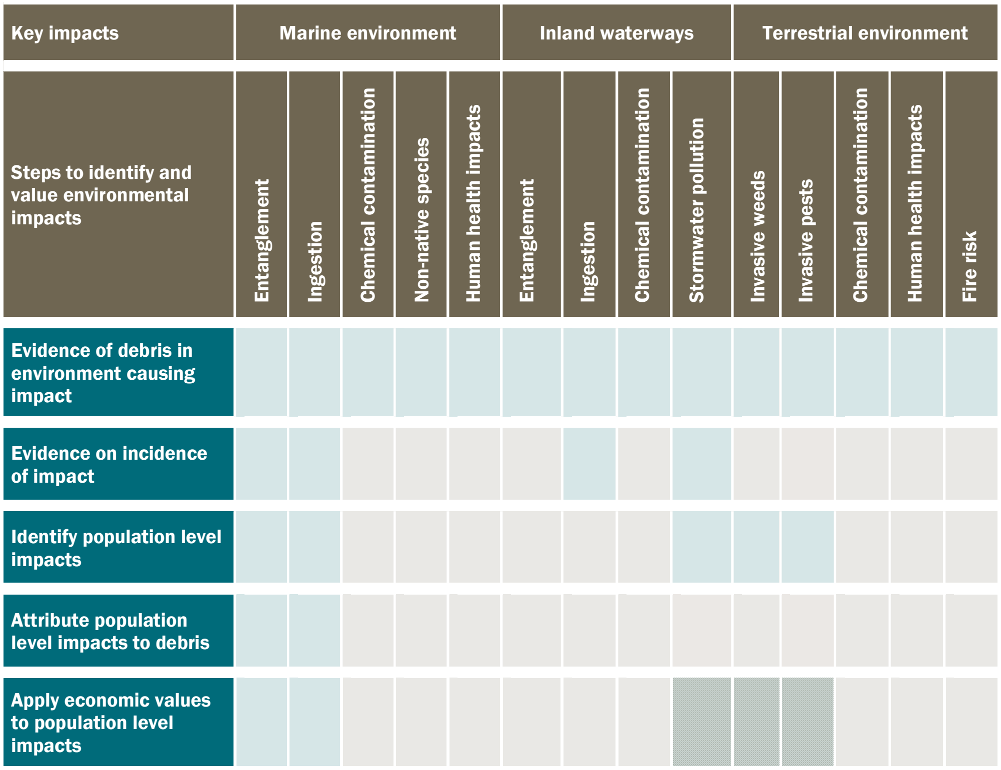
- biophysical changes caused by litter and illegal dumping
- final environmental outcomes from the biophysical changes, and
- the value community places on avoiding the identified biophysical outcomes.

Chart 3 outlines where evidence is available (blue cells) and where gaps remain (grey cells) for each identified potential impact in the three environments.

- **Evidence of debris in environment causing impact** — there is sufficient evidence that debris (from either litter or illegal dumping) is causing environmental impacts in the marine, inland waterways and terrestrial environments. This is particularly true of the marine environment for which there is the most information available. The least amount of systematic evidence is available on debris in the terrestrial environment.
- **Evidence on incidence of impact —** there is information available for incidence of entanglement and ingestion in the marine environment, ingestion and stormwater pollution in inland waters.
- **Identify population level impacts —** there is information available to identify population impacts from entanglement and ingestion in the marine environment, and from stormwater pollution in inland waterways which can be linked to litter and illegal dumping. In the terrestrial environment, there is evidence that invasive weeds and invasive pests are causing population level impacts, however there is insufficient information on the incidence in which littered and/or illegally dumped debris is contributing to the broader impact of invasive weeds and pests.
- **Attribute population level impacts to debris —** in many cases debris from litter and illegal dumping is only one contributing factor to an impact, requiring attribution of population level impacts to littered or illegally dumped debris. There is sufficient information available to approximate attribution of entanglement and ingestion impacts in the marine environment to littered and illegally dumped debris. There is insufficient information to attribute the following to litter and illegal dumping:
  – stormwater pollution from dog faeces in inland waterways
  – invasive weeds and pests from illegally dumped green/garden waste in terrestrial environments
- **Apply economic values to population level impacts** — there is sufficient information available in the economic valuation literature to estimate community's willingness-to-pay to avoid entanglement and ingestion impacts to key vulnerable and threatened marine species.

  Whilst there is sufficient information to estimate the total impact of lost recreational use value from stormwater pollution and the environmental cost of invasive weeds and pests, as noted above there is insufficient information to attribute these costs to litter and illegal dumping.

3 Evidence and data gaps at each step to identify and value environmental impacts of litter/illegally dumped debris



Note: Hashed shading shows that an economic value/cost has been estimated for the impact, however there is insufficient information to attribute the impact to litter and/or illegal dumping.

Data source: CIE.

Value of environmental impacts

The following impacts from litter and illegally dumped debris have been valued (table 4):

- Marine environment — impacts from entanglement and ingestion of plastic by marine species
- Inland waterways — lost recreational use value of beaches, baths and lagoons due to stormwater pollution from dog faeces (estimated for Sydney only).[1] Potential range estimated in absence of information on the contribution of littered dog faeces to the broader problem of stormwater pollution.
- Terrestrial environment —contribution to invasive weeds and pests from illegally dumped green waste. Potential range estimated in absence of information on the contribution of illegal dumping to the broader problem of invasive weeds.

1 Recreational use value is distinct from environmental non-use values. However, lost recreational use value is included in this report as it stems from stormwater pollution caused by dog faeces littered in the environment.

4 High-level estimate of environmental cost of litter and illegal dumping

	Australia	Factor to apportion to states	New South Wales	Queensland	Victoria
	$m per year		$m per year	$m per year	$m per year
Litter					
Ingestion of plastics — marine environment	104.4	Population as proxy for amount of litter entering ocean	33.18	21.07	27.15
Stormwater pollution from dog faeces — marine environment			Range $0.9m - $3.7m (Sydney)		
Illegal dumping					
Entanglement derelict fishing gear — marine environment[a]	363.6	Total volume of fisheries and aquaculture production in state-based fisheries	26.64	42.87	9.61
Invasive weeds from illegal dumping of green/garden waste — terrestrial environment	Range $311m - $1.5b	Number of invasive weeds in each state Number of households	Range $140m - $700m	Range $97m - $487m	Range $74m - $370m

[a] Attribution of entanglement impacts to states is based on the volume of fisheries and aquaculture production in 2019/20. Sourced from ABARES, 2021, *Australian fisheries and aquaculture statistics 2020,* https://www.awe.gov.au/abares/research-topics/fisheries/fisheries-and-aquaculture-statistics/production#new-south-wales Accessed 3 December 2021.

Note: A range based on assumptions regarding attribution rates is provided for invasive weeds and stormwater pollution because there is insufficient information on the contribution of litter and illegal dumping to the broader problem of invasive weeds and stormwater pollution, respectively.

Source: CIE

Entanglement impacts in the marine environment

The cost of entanglement of threatened marine species in Australian fishing gear is estimated to be $363.6 million per year (table 5). This estimate is based on the following assumptions:

- 71 per cent of entanglement is due to fishing gear[2] (entanglement due to other debris items (excl. fishing gear) is not included in this cost estimate)
- the incidence rates for entanglement by species outlined in table 5. Authors note the difficulty in distinguishing between entanglements in active fishing gear and derelict fishing gear.[3],[4] The focus of the studies from which the incidence rates are sourced was marine debris including derelict fishing gear. As such it is assumed the incidence

2 Gall, 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179

3 National Oceanic and Atmospheric Administration, 2014, *Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States,* 2014 NOAA Marine Debris Program Report, page 1.

4 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

rates below relate only to derelict fishing gear and not active fishing gear (i.e. bycatch).

- willingness to pay per threatened species outlined in table 5
- 4 per cent of derelict fishing gear originates from Australian fisheries[5], [6]
- mortality rate of 80 per cent[7] for all species except whales for which mortality rates in table A.15 are applied.

5 Estimated cost of fishing gear entanglement for threatened species

Species	Population	Entanglement incidence	Total WTP per species per year	Attribution to Australian fisheries	Total cost attributed to Australian fishing gear
	number	per cent	$ billion per year	per cent	$ million per year
Endangered species					
Loggerhead Turtle	45 000	4.2	0.71	4.0	8.4
Southern Right Whale	3 500	1.4	0.97	4.0	1.1
Blue Whale	17 500	0.0	0.97	4.0	-
Tristan Albatross	11 000	6.6	1.29	4.0	23.9
Northern Royal Albatross	20 000	6.6	1.29	4.0	23.9
Gould's Petrel[a]	2 500	6.6a	1.29	4.0	23.9
Vulnerable species				4.0	-
Leatherback Turtle	35 000	14.1	0.67	4.0	26.7
Hawksbill Turtle	21 500	8.3	0.67	4.0	15.7
Flatback Turtle[b]	20 500	10.7	0.67	4.0	20.2
Green Turtle	87 500	9.0	0.67	4.0	17.1
Wandering Albatross	55 000	6.6	1.23	4.0	22.7
Humpback Whale	60 000	7.2	0.92	4.0	4.2
Antipodean Albatross	25 260	6.6	1.23	4.0	22.7
Gibson's Albatross	40 000	6.6	1.23	4.0	22.7
Southern Royal Albatross	27 000	6.6	1.23	4.0	22.7
Indian Yellow-nosed Albatross	170 000	6.6	1.23	4.0	22.7
Grey Nurse Shark	1 950	NA	0.56	4.0	-
Grey-headed Albatross	90 000	6.6	1.23	4.0	22.7
Blue Petrel[c]	80 000	9.0	1.23	4.0	31.0

5 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

6 Data on incidence of entanglement in active fishing gear in Australia and elsewhere has not been compiled. Nor has the share of entanglements in active versus derelict fishing gear. As such 4 per cent of all entanglements, whether in active or derelict fishing gear are assumed to be attributable to Australia for the species listed.

7 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

Species	Population	Entanglement incidence	Total WTP per species per year	Attribution to Australian fisheries	Total cost attributed to Australian fishing gear
	number	per cent	$ billion per year	per cent	$ million per year
Northern Giant Petrel[c]	7 425	9.0	1.23	4.0	31.0
Total					**363.6**

[a] Rate of entanglement not available for Gould's Petrel. Estimate based on average rate for other petrel and fulmar species.
[b] Rate of entanglement not available for flatback turtle. Estimate based on average rate for other turtle species.
[c] Rate of entanglement not available for Blue Petrel and Northern Giant Petrel. Estimate based on average rate for Leach's storm petrel and white-faced storm petrel.

Note: Entanglement incidence data not available for Grey Nurse Share, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Ingestion impacts in the marine environment

The cost of ingestion of plastic litter from Australia entering the ocean per year is estimated to be $104 million per year. This reflects the impact on threatened species from mortality following plastic ingestion. In particular, two thirds of this estimated cost is due to impacts to Gibson's Albatross. This species predominantly inhabits Australian and New Zealand coastlines, so a higher proportion of the impact (32 per cent) is attributable to Australia. This is in strong contrast to other species for which minimal impact (e.g. 0.003 per cent for a variety of turtle species) is attributable to Australia.

The total cost ranges between $803 and $3 994 dollars per tonne of plastic entering the ocean (approximately between $0.008 and $0.04 per empty 10 gram plastic bottle), depending on the estimated tonnes of plastic litter entering Australian waters per year:

- low estimate of debris — based on estimated 26 150 tonnes of plastic entering the ocean from Australia per year [8]
- high estimate of debris — based on estimated 130 000 tonnes of plastic litter entering Australian waters per year (table 6).

6 Estimated cost of Australia's marine plastic litter for threatened species

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed Australian litter	Cost per tonne of plastic litter per year	
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low debris (t) estimate	$/t/yr high debris (t) estimate
Endangered species							
Loggerhead Turtle	45 000	22	0.71	0.003	0.0	0.1	0.0

8 Based on global estimate of 8 million tonnes of plastics entering ocean (see https://www.marineconservation.org.au/ocean-plastic-pollution) and Australia's share of plastics emitted to the ocean, estimated as 0.003 per cent.

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed Australian litter	Cost per tonne of plastic litter per year	
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low debris (t) estimate	$/t/yr high debris (t) estimate
Southern Right Whale	3 500	16.67	0.97	0.118	0.1	4.5	0.9
Blue Whale	17 500	16.67	0.97	0.003	0.0	0.1	0.0
Tristan Albatross	11 000	27.7	1.29	0.067	0.1	5.7	1.2
Northern Royal Albatross	20 000	27.7	1.29	0.352	0.8	29.9	6.0
Gould's Petrel	2 500	27.7	1.29	6.882	15.3	584.8	117.6
Vulnerable species							
Leatherback Turtle	35 000	30	0.67	0.003	0.0	0.2	0.0
Hawksbill Turtle	21 500	36	0.67	0.003	0.0	0.2	0.0
Flatback Turtle	20 500	100	0.67	0.003	0.0	0.5	0.1
Green Turtle	87 500	47	0.67	0.003	0.0	0.2	0.0
Wandering Albatross	55 000	27.7	1.23	0.166	0.4	13.4	2.7
Humpback Whale	60 000	16.67	0.92	0.003	0.0	0.1	0.0
Antipodean Albatross	25 260	27.7	1.23	7.583	16.0	612.4	123.1
Gibson's Albatross	40 000	27.7	1.23	32.000	67.5	2584.2	519.6
Southern Royal Albatross	27 000	27.7	1.23	0.317	0.7	25.6	5.2
Indian Yellow-nosed Albatross	170 000	27.7	1.23	0.416	0.9	33.6	6.8
Grey Nurse Shark	1 950	NA	0.56	NA	0.0	0.0	0.0
Grey-headed Albatross	90 000	27.7	1.23	0.326	0.7	26.3	5.3
Blue Petrel	80 000	27.7	1.23	0.576	1.2	46.5	9.3
Northern Giant Petrel	7 425	27.7	1.23	0.317	0.7	25.6	5.2
Total					**104.4**	**3994.2**	**803.0**

Note: Ingestion incidence data was not available for Grey Nurse Shark, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Lost recreational use value due to stormwater pollution

Almost 60 per cent of beaches, baths and lagoons in Greater Sydney are subject to poor water quality from potential sources of faecal contamination following rainfall events (table B.10). Dog faeces are one contributing element of this faecal contamination. Based on results of microbial source-tracking to assess water quality (outlined in table B.11) dog faeces contribute to poor water quality during rainfall events but to a lesser extent compared to sewage inputs. There is insufficient evidence to proportion impact to dog faeces relative to other sewage inputs.

Deloitte Access Economics (2016) estimated there are 36 million visits to Sydney's coastal beaches per year with an average value of $38 per person per visit.[9] This information coupled with estimated days of closure based on average high rainfall events (table B.12) per year is used to estimate the lost recreational use value of $37 million per year due to closure of beaches, baths and lagoons in Greater Sydney due to stormwater pollution.

As noted, there is a lack of evidence on the contribution dog faeces makes to poor water quality following heavy rainfall events. Although a general finding is that sewage inputs play a larger role than dog faces in reducing water quality.[10] In the absence of a sound basis to attribute lost recreation value associated with stormwater pollution to littered dog faeces, table 7 shows indicative estimates under various attribution assumptions (ranging from 2.5 per cent to 10 per cent). These estimates are provided as an order of magnitude based on different attribution assumptions.

7 Estimated lost recreational value from dog faeces in stormwater — Sydney

Item	Unit	Value
Number of visits to Sydney's beaches per year	million	36
Average visits per day (not accounting for seasonal effects)	no.	98630
Average high rainfall events per year (based on daily rainfall > 30mm)	no.	8
Estimated days per closure	Days per closure	2
Total number of closure days per year	Days per year	16
Proportion of beaches, baths, lagoons closed following heavy rainfall events		58
Estimated number of lost visits to Sydney's beach per year		974 309
Value per beach visit	$ per person per visit	38
Estimated total lost recreational use value	$m per year	37.0
Proportion attributable to litter dog faeces	per cent	
Estimated lost recreation use value due to dog faeces		
Based on 2.5 per cent attribution	$m per year	0.9
Based on 5 per cent attribution	$m per year	1.9
Based on 7.5 per cent attribution	$m per year	2.8
Based on 10 per cent attribution	$m per year	3.7

Source: CIE based on various source.

9 Deloitte Access Economics, 2016, *Economic and social value of improved water quality at Sydney's coastal beaches.*

10 University of Technology Sydney, 2020, *Microbial source-tracking to assess water quality in Central Coast Lagoons,* Climate Change Cluster, Faculty of Science, UTS.

Invasive weeds in terrestrial environments

The willingness to pay to control environmental weeds aggregated across NSW, Victoria and Queensland is estimated at around $3.1 billion per year (table 8).

8 Estimated aggregate willingness to pay to control environmental weeds

	Number of invasive garden species	Number of households	Aggregate WTP per species[a]	Annual WTP to reduce area infested by invasive garden species
	No.	Million	$ million	$ billion per year
NSW	6	3.13	233.14	1.40
Victoria	5	2.61	194.67	0.97
Queensland	5	1.98	147.62	0.74
Total			**575.42**	**3.11**

[a] Assumes each household is willing to pay $74.46 to reduce the infestation area for each invasive garden species that is threatening at least one native species in their state.

Source: CIE estimates.

Illegally dumped garden waste contributes to the broader problem of invasive plants. In order to value the environmental impact of illegally dumped garden waste, data is required on its contribution to the broader problem. Currently there is no systematic data on the quantity of illegally dumped green waste, nor the incidence of invasive plants spreading and damaging native species to attribute impact to illegally dumped green waste.

In the absence of a sound basis to attribute the environmental costs associated with escaped garden plants to illegal dumping, table 9 shows indicative estimates under various attribution assumptions. These estimates are provided as an order of magnitude based on different attribution assumptions.

9 Indicative estimates of the costs attributable to illegal dumping under various attribution assumptions

	10% attributed to illegal dumping	20% attributed to illegal dumping	30% attributed to illegal dumping	40% attributed to illegal dumping	50% attributed to illegal dumping
	$ million	$ million	$ million	$ million	$ million
NSW	139.9	279.8	419.6	559.5	699.4
Victoria	97.3	194.7	292.0	389.3	486.7
Queensland	73.8	147.6	221.4	295.2	369.1
Total	**311.0**	**622.1**	**933.1**	**1 244.1**	**1 555.1**

Source: CIE estimates.

Invasive pests in terrestrial environments

With the current yellow crazy ant eradication program is place, the predominant impact category for yellow crazy ants is ‘clean-up cost’. The Wet Tropics Management

Authority (WTMA) estimates the annual cost of the eradication program is $6 million per year for 7 years, equivalent to a present value of $34.6 million.[11]

However, where the eradication program is yet to be effective, or in the absence of an eradication program, there would be costs to industry and environmental impacts. Spring et al. (2019) estimated:

- avoided control costs (e.g. pesticide expenditure, treatment costs) and avoided damages (e.g. crop losses) due to eradication program at $548 million (present value applying 7 per cent discount rate).
- total avoided costs from the eradication program, including the avoided environmental costs, was estimated at $6.1 billion (present value applying 7 per cent discount rate).[12]

Illegal dumping has contributed to the spread of yellow crazy ant and the associated costs. However, there is currently a lack of information to attribute a portion of these costs to the spread caused by illegal dumping (primarily green/garden waste).

Environmental impacts that remain unquantified

There is insufficient information to value the following environmental impacts:

- Marine environment — chemical contamination, non-native species, human health impacts from ingestion of plastic
- Inland waterways — entanglement, ingestion, chemical contamination
- Terrestrial environment — chemical contamination, human health impacts, and fire risk.

Agenda for further research

The gaps in identifying and valuing environmental impacts of litter and illegal dumping can broadly be categorised as one of the following:

- population level impacts are possible however there is insufficient scientific evidence to determine the extent and/or establish cause-and-effect relationships to litter and illegal dumping
- impacts are possible but are most likely localised at an individual-level rather than population-level
- debris from litter and illegal dumping does not currently accumulate in the environment in sufficient quantities to cause potential impacts.

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11 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

12 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

Further research should focus on the first category. Impacts which are likely to fall into this category include chemical contamination from plastics in the marine and inland waterway environments, and human health impacts from ingestion of plastics.

PART I

Main Report

1 Background and introduction

Understanding the environmental costs of litter and illegal dumping

Litter and illegal dumping imposes significant financial, environmental and social costs on the community. The costs of littering and illegal dumping include:

- Direct costs, including the cost of cleaning up littered and illegally dumped material
- Indirect costs, including:
  - reduced amenity due to the presence of littered or illegally dumped material in various environments
  - the environmental costs of litter and illegal dumping, including human health impacts.

However, the scale of these costs is not well understood. To better understand these costs, the Centre for International Economics (CIE) has been engaged to estimate the indirect costs of litter and illegal dumping.

The environmental costs of litter and illegal dumping

Understanding the environmental costs of litter and illegal dumping is an important aspect of this project. The purpose of this component of the project is to:

- estimate the total environmental costs caused by littering and illegal dumping; and
- estimate the marginal environmental cost of an additional unit of material littered or illegally dumped (where possible).

This component of the study forms part of a broader piece of work to understand the full cost (including all financial, social and environmental costs) of litter and illegal dumping.

- As part of the broader project, the CIE is conducting a 'willingness to pay' (WTP) study to estimate the value of amenity impacts from litter and illegal dumping.
- A separate study estimating the direct clean-up costs associated with litter and illegal dumping is being undertaken.

Inter-relationship between costs

The costs from litter and illegal dumping vary by debris type and the location the litter or illegal dumping occurs. It is important to identify which types of costs are incurred from litter and illegal dumping to ensure that all relevant costs are included, while avoiding double-counting. For example, litter in urban areas which is readily picked up will generally impose a clean-up cost and minimal environmental, human health and amenity costs. The difficulty lies in determining 'what happens next' after a piece of debris is littered or illegally dumped. Possible pathways include:

- debris is cleaned-up immediately
- debris remains in the environment for a short period of time before being cleaned-up
- debris remains in the environment, either in-situ or is transported to new environments and continues a process of either breaking-down (e.g. paper) or breaking-up (e.g. plastic).

The pathway taken after debris is littered or illegally dumped influences which costs are incurred. For example:

- Environmental impacts are likely to be greatest where material persists in the environment for long periods. This implies:
  - environmental costs likely to be greatest where the litter or dumped material is not cleaned up (and therefore no clean-up costs)
  - environmental costs likely to be lowest where the litter or dumped material is cleaned up quickly (i.e. clean-up costs are incurred)
- Littered or illegally dumped material is most likely to be removed from the environment (i.e. clean-up costs are incurred) where:
  - it is clearly visible by many people (i.e. amenity costs are high);
  - the costs of removing it are low, and/or
  - the debris has a significant associated environmental or human health hazard.

Table 1.1 outlines the inter-relationships between environmental costs, human health impacts, recreational use value, clean-up costs and amenity costs. The total economic cost of litter and illegal dumping comprises an interplay between these cost categories. The blue shaded cells outline which impacts/costs are caused by which debris type in each of the three environments. For example, the predominant two impacts of micro-plastic in the marine environment are environmental and human health impacts.

The focus of this paper is on the environmental impacts of debris, and also encompasses human health impacts caused by debris remaining in the environment (e.g. human ingestion of microplastics). In addition, lost recreational use value is also discussed in relation to dog faeces which pollutes inland waterways and marine environments.

1.1 Predominant impact categories for environment and debris types

Environment/ Debris type	Environmental impact	Human health impact	Recreational use value	Clean up cost	Amenity costs
MARINE ENVIRONMENT (Predominantly coastline)					
Littered items					
Macro-plastic					
Micro-plastics					
Glass					
Paper/cardboard					
Cigarettes					

Environment/ Debris type	Environmental impact	Human health impact	Recreational use value	Clean up cost	Amenity costs
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					
INLAND WATERWAYS					
Littered items					
Macroplastic					
Microplastic					
Glass					
Paper/cardboard					
Cigarettes					
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					
TERRESTRIAL					
Littered items					
Macroplastic					
Microplastic					
Glass					
Paper/cardboard					
Cigarettes					
Dog faeces					
Illegally dumped items					
Green waste					
Asbestos					
Other (e.g. household items)					

Source: CIE.

This report

This report sets out the evidence available to identify and quantify the environmental impacts of littering and illegal dumping.

The remainder of the report is set out as follows.

- Chapter 2 sets out the conceptual framework for identifying and quantifying the environmental impacts of littering and illegal dumping.

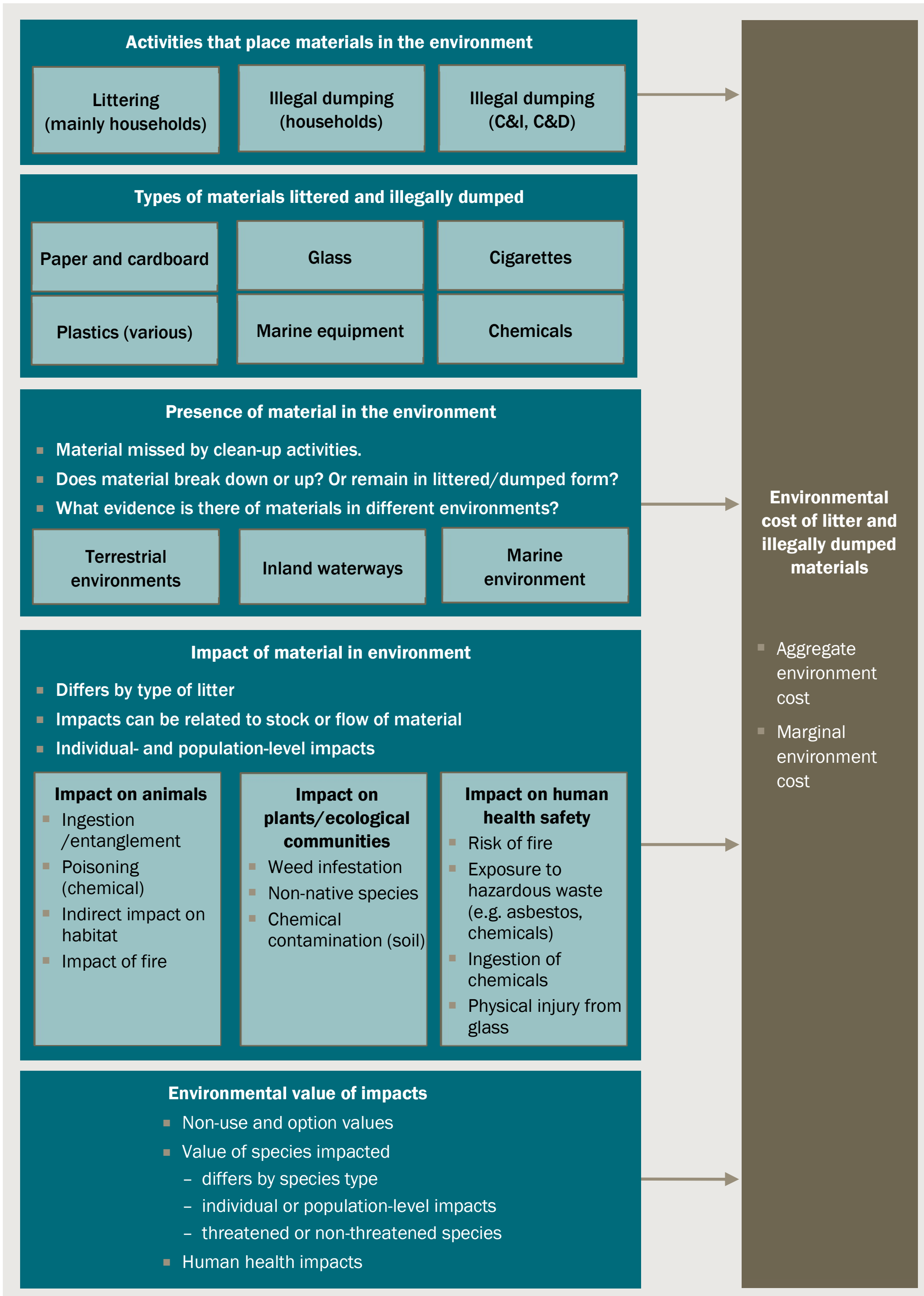
- Chapter 3 discusses major environmental challenges, including key threatening processes, which relate to litter and illegal dumping.
- Chapters 4,5,6 summarises the evidence of material and environmental impacts from material in marine, inland waterways and terrestrial environments.
- Appendix A, B and C includes the literature review of environmental impacts in the marine environment, inland waterways and terrestrial environmental respectively.
- Appendix D outlines evaluation of environmental costs.

2 Conceptual framework and approach

Conceptual framework

The conceptual framework used to identify and value the environmental costs of litter is summarised in chart 2.1. It is based on a chain of logic that links human activities to quantifiable environmental costs.

2.1 Conceptual framework



Data source: CIE.

Activities

The chain of logic starts with human activities: littering and illegal dumping. Although individuals engage in littering, either individuals or businesses can engage in illegal dumping.

In general, the focus of this study is on the impact of materials in the environment, rather than how it got there.

Although the definition of litter is fairly clear, there are some 'grey areas' in relation to the activities that constitute illegal dumping. Nevertheless, littering and illegal dumping are inherently 'activities'. As such, defining the scope in terms of activities is useful in some contexts.

In this regard, the project group agreed on the following scope in terms of activities.

- Littering and illegal dumping by both households and businesses is within the scope of the analysis.
- Illegally discharging liquid waste or emitting gaseous waste from premises is not within the scope of illegal dumping.
- The study should focus on the environmental damage caused by the littered or illegally dumped material. As such, any environmental damage caused by the act of illegal dumping such as environmental damage caused by transporting waste (e.g. driving through bushland to dump material) is out of scope.

The presence of material in an environment

Human activities relating to littering and illegal dumping lead to the presence of material in an environment that may have some environmental impacts. The environmental impacts of materials in the natural environment will depend on a range of factors, including:

- The type of material — different types of material will have different environmental impacts. Some materials break down (e.g. green waste) or break up (e.g. plastics) over time. The environmental impact of materials in the environment may be different when it breaks down or breaks up, compared with its original form. It is therefore important to consider the environmental impacts of material in the environment in both its original form and when it breaks down/up. The type of material can also influence the likelihood that wildlife will interact with the debris. For example, juvenile turtles are attracted to certain plastic types (e.g. balloon litter).
- The volume of material — the environmental impacts will depend on the volume of material in the environment, with the exception of certain materials like asbestos. This matters from several perspectives.
  - The environmental damage caused by some materials/substances depends on the concentration in the environment (i.e. some materials/substances may have limited impact at low concentrations, but may be toxic to animals or humans at higher concentrations).
  - A related issue is whether there is enough material in the environment to have impacts beyond local site-level impacts.

- The length of time the material is in the environment — in general, significant environmental impacts are more likely where materials persist in the environment for longer periods of time.
  - Some proportion of littered and illegally dumped material would be removed from the environment within a reasonably short timeframe. Although there would be associated clean-up costs (and possibly some amenity impacts while the material remains in an environment), the associated environmental impacts are likely to be minimal.
  - This implies that it is the stock of material in an environment that matters for environmental impacts, rather than the flow.
  - That said, there are some circumstances where it is difficult (or too costly) to remove **all** of the littered/dumped material from the environment. Residual material left in the environment could potentially have significant environmental costs, including where:
    - illegal dumping of green waste spreads seeds and leads to an infestation of weeds
    - a site remains contaminated, even after most of the material has been removed (such as chemical contamination or hazardous materials, such as asbestos).
- Receiving environment — environmental impacts will also vary depending on the receiving environment. The receiving environments to be included in the analysis are:
  - Terrestrial environments:
    - Minimal environmental impact on urban environments, such as streetscapes
    - May be significant in bushland
  - Inland aquatic environments (including inland waterways and aquatic environments)
  - Marine environment — this could include:
    - coastal marine environment local to Australia
    - global issues relating to the marine environments (i.e. Australia's contribution to global issues).

Based on discussions with the project team, the scope of materials in the analysis include/exclude the following specific items:

- Illegal dumping will generally include solid items only, unless liquid waste is stored and then dumped.
- Asbestos is within the scope of this study.
- Derelict fishing gear is within the scope of the study.

Environmental impacts

As a general principle, the project team agreed that the mere presence of material in the environment does not necessarily constitute an environmental impact (although it could have an amenity impact and/or invoke clean-up costs). Dumped or littered material would need to impact on the flora, fauna or the functioning of the ecosystem to be considered an environmental impact.

The types of environmental impacts of dumped material varies across environments, but includes the following:

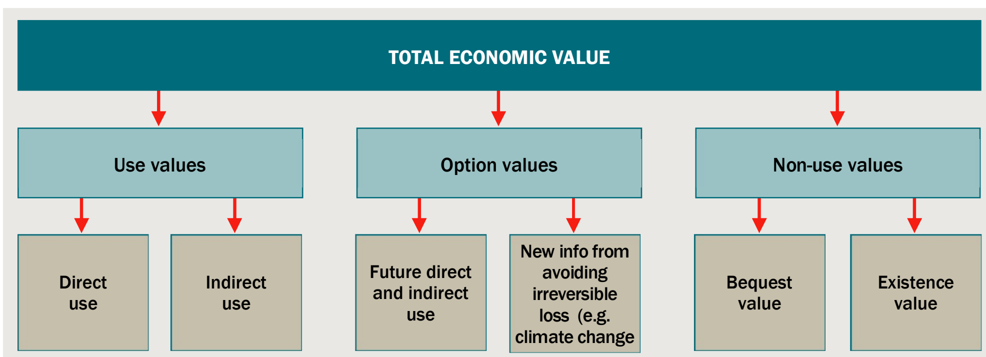
- Impact on animals — the presence of littered and dumped material in an environment could impact on animals through:
  - direct ingestion of littered/dumped material (either in original form or as it breaks down) causes harm to the animal in various ways, including:
    - ingestion of plastic debris can cause marine animals to die of starvation
    - ingestion of toxic material.
  - entanglement in littered or dumped material
  - impact on habitat.
- Degradation of natural environments and ecological communities — littering and illegal dumping can degrade natural environments and ecological communities through:
  - introducing weed and pest species to an environment through dumping of green waste, soils and other materials
  - chemical contamination of an environment
  - suffocation of vegetation and soil degradation (which can also affect wildlife through food availability)
  - increased fire risk.
- Impact on human health/safety via the environment — Some littered or dumped material in terrestrial environments could have an impact on human health and safety (as well as property), in addition to amenity. This could include the following.
  - Human health impacts associated with dumped hazardous materials, such as asbestos or chemical contamination.
  - Safety impacts from littered material, such as broken glass, syringes etc.
  - Any potential human health impacts where contamination accumulates in the food chain.
- Fire risk —- to the extent that littered and illegally dumped material contributes to fire risk, this could impact on animals, ecological communities and human safety as well as damage property. Litter and illegal dumping could potentially contribute to fire risks in various ways, including the following.
  - Littered/dumped material can be an ignition point for fires — examples include lit cigarettes and glass
  - Flammable littered or dumped material can contribute to the fuel load and potentially exacerbate bushfires.
  - Illegal dumping on roads/tracks can limit access to fires/escape from fires.
  - Some types of dumped or littered material can potentially increase the social and environmental cost of a fire — for example, fires involving large quantities of (dumped) tyres can cause thick dark smoke that contains various toxic chemicals, leave behind a residue and/or delay return to properties until clean-up efforts have made area safe..

Valuing environmental impacts

The total economic cost of litter and illegal dumping reflects (chart 2.2):

- use values — this includes the loss of ecosystem services, such as providing food, recreation etc. To avoid double counting the economic value of environmental impacts will exclude impacts that relate to amenity and recreational use values that are covered in the willingness-to-pay (WTP) survey. The WTP survey will capture direct use values (i.e. direct losses of amenity from litter), but not indirect use values, for example:
  - plastics in the ocean could reduce the abundance of some species, which could reduce the amenity of some environments
  - littered dog faeces which pollute stormwater and results in river or beach closures preventing recreational use.
- option values for potential future uses, and
- non-use valuation of the environment, including:
  - existence value
  - bequest value.

2.2 Components of economic value



Data source: CIE

In the economic literature, environmental services are generally valued based on the community's 'willingness to pay'. Approaches to valuing environmental services used in the economic literature are summarised in appendix D.

This study uses the benefit transfer approach, which involves extrapolating the results from pre-existing studies to another similar situation.[13] It is frequently used in policy analysis where the time and cost prohibits primary research. Some of the challenges and pitfalls associated with the benefit transfer approach are summarised in appendix D.

In general, the environmental economics literature focuses on valuing relatively significant environmental impacts, such as:

- population-level impacts on species (rather than impacts on individual animals/plants)

[13] Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 4.

- significant changes in environmental values at particular sites, such as those relating to significant changes in land use (e.g. clearing activity).

Applying the conceptual framework

A key focus of the conceptual framework is establishing causal links between each step in the logic chain from the activity (i.e. littering and illegal dumping), through to the quantifiable environmental impacts. This approach focuses on establishing what are the **actual** environmental impacts from litter and illegal dumping (based on current levels of material in the environment), rather than the **potential** environmental impacts at the conceptual level.

Causal links from activities to material in the environment

In many cases there is a self-evident link between the activity (i.e. littering and illegal dumping) and the presence of material in the environment. The presence of material in the environment is enough to establish that it has been littered or dumped illegally.

However, there are circumstances where it is relevant to consider whether the presence of a material/substance can be linked to littering and illegal dumping.

- Debris in the marine environment may not have come from littering or illegal dumping within Australia.
- The presence of some pollutants may have come from other sources (such as directly discharged (legally) from a facility).

Another point to note is that although the activities (littering and illegal dumping) clearly cause the material to be present in the environment, there will not necessarily be a strong relationship between the volume of material littered/dumped and the amount of material present in the environment. The amount of material present in the environment depends on how rapid the material breaks down or up, and also on the frequency and effectiveness of clean-up activities (including both formal and informal clean-up activities). For example, there is likely to be more material littered (and possibly dumped) in densely populated areas. Clean-up resources are likely to be directed to areas where there is high visibility and/or high levels of litter and dumping and therefore a higher proportion of material in those environments may be removed within a short timeframe. An exception is high quantities of microplastics which may not be targeted by clean-up efforts because either they are not highly visible, and/or may be too costly to clean-up.

Causal links from material in the environment to environmental impacts

Establishing a causal link between littered and illegally dumped material in the environment and the environmental impacts is more complex. Some of the key issues are discussed below.

Establishing cause and effect

There is evidence that debris causes environmental impacts. However, as noted by many authors and scientists in the literature it is often difficult to establish a cause-and-effect relationship, [14] such as in the case of impacts via ingestion where invasive investigation methods are required. For example, Dr Hardesty from CSIRO explained to the Senate Standing Committee on Environment and Communications:

> …that the ability to assign actual cause of death to plastic ingestion is exceptionally small……. the differentiation between causality and correlation is really important and that unless gut perforation or blockage is identified, cause of death can be difficult to identify. [15]

Whilst it is easier to establish cause and effect relationships between debris and entanglement, in many cases it is difficult to identify the type of debris which caused the impact. For example, it is often difficult to distinguish whether wounds on a marine animal are from entanglement in active fishing gear or lost/discarded fishing equipment.[16]

These factors can make it difficult to establish a cause and effect relationship. A causal relationship establishes links along the full impact pathway. However, it is not sufficient to establish links between segments of the impact pathway, as this does not necessarily establish a causal relationship. As noted in the literature, a causal relationship for toxic responses to plastic-associated chemicals can not be implied purely based on causal links between the following two segments of the impact pathway:

- pollutant to or from plastic
- pollutant to harm.[17]

Different correlations between debris and response include:

- causal — debris causes a direct response
- confounded — debris is a confounding factor
- mediator — debris is a mediating factor enabling another factor to cause a response
- incidental — debris is an incidental factor, present but not causing the response (chart 2.3)

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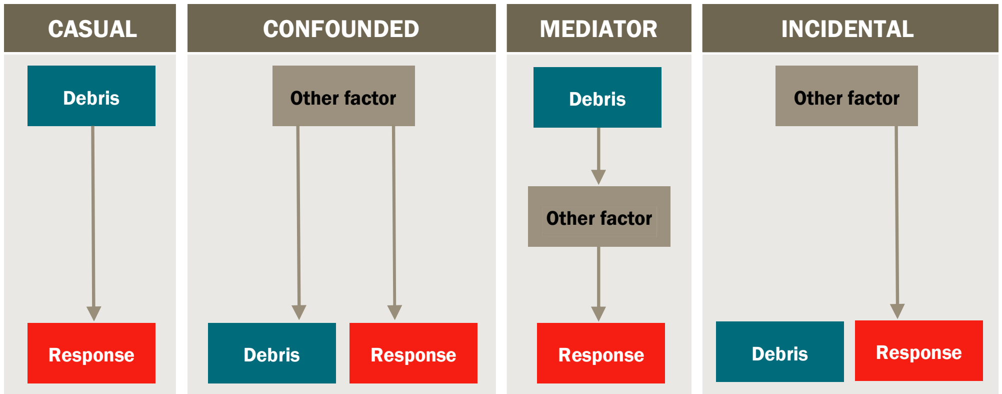
14 Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015*, Deleterious Effects of Litter on Marine Life,* Marine Anthropogenic Litter, pp 75-116.

15 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

16 Kühn, S. and van Freneker, J.A., 2020, *Quantitative overview of marine debris ingested by marine megafauna*, Marine Pollution Bulletin 151 (2020) 110858.

17 Correspondence/Rebuttal, 2020, The need for attention to confirmation bias and confounding in the field of plastic pollution and wildlife impacts: Comment on "Clinical Pathology of Plastic Ingestion in Marine Birds and Relationships with Blood Chemistry, *Environmental Science and Technology, 2021, 55, 801-804.*

2.3 Examples of types of correlations between debris and response



Data source: Adapted from Correspondence/Rebuttal, 2020, The need for attention to confirmation bias and confounding in the field of plastic pollution and wildlife impacts: Comment on "Clinical Pathology of Plastic Ingestion in Marine Birds and Relationships with Blood Chemistry, *Environmental Science and Technology, 2021, 55, 801-804.*

Evidence of final outcomes caused by plastic debris impacts

An animal's interaction with debris can lead to short or long term non-fatal injuries, or direct lethal or sublethal effects.[18] For example, ingestion can cause direct mortality if an animal's gastrointestinal tract becomes completely blocked or severely damaged. Conversely ingestion of a single piece of debris may cause minimal impact depending on size of debris and type of animal, such as ingestion of small volumes of debris by whales. However, it is widely acknowledged that there are many unknown risks to the welfare of animals, in particular marine animals, related to ingestion of small volumes of debris and microplastic particles. [19]

The final outcome of impacts from litter and dumping material is often not reported in the literature. Given the range of possible outcomes, ranging from non-fatal to fatal, it can be difficult to assign probabilities that a certain final outcome will occur from an animal's interaction with debris. For example, evidence of plastic in an animal's gut does not necessarily indicate a causal effect from plastic, or determine the final outcome. One study found that direct harm or death is reported in 80 per cent of reports of entanglement and in 5 per cent of ingestion reports.[20] Gall et al (2015) reported results of 79 per cent of direct harm or death for cases of entanglement and 4 per cent for cases of ingestion.[21]

CSIRO is conducting research to analyse the relationship between ingestion and mortality, with preliminary results indicating there is a positive relationship. Further

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[18] Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

[19] Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[20] Ibid.

[21] Gall, S.C. and Thompson, R.C., 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179.

research between CSIRO and the University of Tasmania is estimating mortality rates from ingestion.[22]

Individual versus population level impacts

Interaction with debris can cause individual-level or population-level impacts. In the case of plastic marine debris, it is widely acknowledged that there is relatively less knowledge on the population-level impacts compared to individual-level impacts.[23], [24], [25]

Authors in the literature suggest using population averages, rather than affected averages, when assessing the extent of the environmental impacts from litter or illegally dumped material to avoid overestimation of numbers.[26]

- affected average – divides the number of items detected by the number of affected organisms
- population average – divides the number of items by all the individuals in the complete sample, i.e. including individuals with no ingested items.[27]

With respect to marine debris, it is noted that the available data likely underestimates the population wide prevalence of impacts.[28]

Determining population level impacts is difficult because:

- unbiased sampling of populations is not possible for anthropogenic induced impacts that occur in remote locations, including the high seas, and hence are not recorded
- invasive methods are required to determine if a living animal has ingested debris, including post-mortem examinations [29], which are not feasible for most observational studies on wild populations [30]

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22 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

23 Ibid.

24 Ibid.

25 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

26 Kuhn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

27 Ibid.

28 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

29 CBD - Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel— GEF (2012). Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions, Montreal, Technical Series No. 67, 61 pp. referenced in Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

30 Pierce, K.E., Harris, R.J., Larned, L.S., and Pokras, M.A. (2004) Obstruction and starvation associated with plastic ingestion in a northern gannet Morus bassanus and a

- indirect, sub-lethal impacts may be more relevant for understanding population-level impacts but are more difficult to observe. For example, ingestion of plastic may not be directly lethal but may translate into negative effects on average survival and reproductive success across a population where plastics are frequently ingested.[31]
- impact monitoring is often not accompanied by estimates of total population as it would be too resource intensive to produce them.[32]
- techniques used to obtain live sample populations and assess them for ingestion can lead to underestimates. For example, faecal analysis of turtles revealed 10 times more individuals had ingested debris compared to lavage (gastric irrigation) technique of the same population, 19 per cent compared to 1.9 per cent, and necropsy revealed a proportion of 29 per cent.[33]
- observed incidences of any impact may underestimate actual figures, such as entangled species which die at sea prior to detection. For example, one study found that only between 3 and 10 per cent of whale entanglements were witnessed and reported and another reported that only 6 per cent of all killer whale mortality was documented.[34]

Despite these difficulties, there are advances in sampling and assessment of impacts from marine debris. For example, CSIRO has developed a non-invasive method to measure the amount of plastic in a seabird by examining the oil secreted from a seabird's preening gland. This method enables observation at the individual, population and species levels. [35]

Linking environmental impacts to the economic valuation literature

Although not a causal linkage *per se*, for benefit transfers to be accurate it is important that the environmental impacts being valued closely align with the primary studies (see appendix A for further details).

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greater shearwater Puffinus gravis, *Marine Ornithology*, Vol.32, pp.187–189 referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

31 Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, Deleterious Effects of Litter on Marine Life, Marine Anthropogenic Litter, pp. 75-116.

32 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

33 Pierce, K.E., Harris, R.J., Larned, L.S., and Pokras, M.A. (2004) Obstruction and starvation associated with plastic ingestion in a northern gannet Morus bassanus and a greater shearwater Puffinus gravis, *Marine Ornithology*, Vol.32, pp.187–189 referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

34 Cole, T.V., Hartley, D., and Garron, M. (2006) Mortality and Serious Injury Determinations for Baleen Whale Stocks along the Eastern Seaboard of the United States, 2000-2004 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

35 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

Evidence to identify and value environmental impacts

The process of identifying and valuing environmental impacts of litter/illegal dumping involves the following steps:

- gather evidence on material types being present in the environment
- identify potential impacts from debris that is littered or illegally dumped
- gather evidence on incidence of impacts, requiring:
  - concentration levels in the natural environment are sufficient for impact to occur
  - establishing cause and effect relationships to final outcomes
- assess whether the impacts are at the population level
- attribute population level impacts to littered or illegally dumped debris (where debris is a contributing factor to a broader impact)
- use available economic values to estimate environmental cost of population level impacts (chart 2.4).

This process is presented for each environment to summarise the existing evidence base and where gaps exist.

Population-level impacts can be defined in geographic, local population or total population terms. The key distinction being that threats to a population can impact the broader group, rather than just specific individuals. The population should be defined with reference to the scale of the impact and the migratory nature of the species, such that:

- the local population should be defined in the case of localised impacts for species which are non-migratory
- the total population should be defined in the case of global impacts and/or if the species is migratory.

Furthermore, consideration should be given to whether a species is endangered or vulnerable. For example, localised impacts may still impose population-level impacts for a migratory species if it is also a threatened species.

For the purposes of this study, we have identified 20 species in the marine environment (see discussion in Chapter 3) for which threats (e.g. litter and illegal dumping) can lead to population-level impacts due to their current endangered or vulnerable status.

2.4 Steps to identify and value environmental impacts of litter/illegally dumped debris

Step	Evidence and data requirements
Evidence of material in environment	▪ Data on the quantity of debris entering the environment per year (the flow), and/or currently in the environment (the stock), for each type of debris type littered or illegally dumped ▪ Trends on whether the quantity of debris is increasing or decreasing
Identify potential impacts from debris	▪ Potential impacts differ by type of debris and receiving environment and include entangelment, ingestion, chemical contamination, migration of non-native species, human health impacts
Evidence on incidence of impact	▪ Incidence data at the individual level is required rather than incidence at the species level ▪ Impact should reflect incidence in the natural environment, rather than laboratory conditions, such that concentration levels in the natural environment are sufficient for impact to occur. ▪ Incidence data must be based on final outcomes in order to value impacts ▪ A cause-and-effect relationship must be established between the debris and final outcome
Identify population level impacts	▪ Impacts can cause individual-level impacts or population-level impacts ▪ Identification of population level impacts is required for economic valuation in most cases ▪ There is relatively less information on population-level impacts available as it is difficult to determine impacts at this scale
Attribute population level impacts to debris	▪ Debris can either cause an impact in and of itself, or it can contribute to a broader impact ▪ Attribution is required when debris contributes to a broader impact
Apply economic values to population level impacts	▪ Economic values are available for willingness to pay to: – avoid extinction of a threatened and endangered species – to achieve a change of a species- status

Data source: CIE.

3 Contribution to major environmental challenges

The approach to identifying and valuing the environmental impacts of litter and illegal dumping used for this study focuses on **actual** environmental impacts. This chapter reviews the evidence linking litter and illegal dumping to the major environmental challenges facing Australia.

Evidence of contribution to major environmental threats

Depending on the type of material, litter and particularly illegally dumped material can have environmental impacts at the site. However, it is important to understand the extent to which litter and illegal dumping more broadly contributes to the major environmental challenges facing Australia (and NSW, Victoria and Queensland in particular).

Key threatening processes

One indicator that littering and illegal dumping contributes to the major environmental problems facing Australia is listing as a key threatening process under the *Environment Protection and Biodiversity Control Act 1999* (EPBC Act).

Under the EPBC Act (Section 188(4)), a threatening process is eligible to be treated as a key threatening process if:

- it could cause a native species or an ecological community to become eligible for listing in any category, other than conservation dependent; or
- it could cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment; or
- it adversely affects 2 or more listed threatened species (other than conservation dependent species) or 2 or more listed threatened ecological communities.

There are 2 key threatening processes listed under the EPBC Act that are broadly relevant to litter and illegal dumping as follows:

- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris
- Loss and degradation of native plants and animal habitat by invasion of escaped garden plants, including aquatic plants.

Harmful marine debris

'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' (referred to as 'harmful marine debris') was listed as a threatening process under the EPBC Act on 13 August 2003.[36]

For the purpose of the listing under the EPBC Act, harmful marine debris is defined as: land sourced plastic garbage, fishing gear from recreational and commercial fishing abandoned into the sea, and ship sourced, solid non-biodegradable floating materials disposed of at sea. As such, this key threatening process is only partially relevant as some of the items included (e.g. ship sourced) in the definition of marine debris are not within the scope of this study.

A key part of the process for listing key threatening processes is an assessment of nominated items against the listing criteria by the Threatened Species Scientific Committee (TSSC), a process that involves seeking public and expert comment.[37] This assessment forms the basis for the TSSC's advice to the Minister on whether a nominated key threatening process is eligible for listing under the EPBC Act.

The TSSC's assessment of 'harmful marine debris' against the EPBC Act criteria is shown in table 3.1. Note that this assessment was made based on the evidence available in 2003. As such, the assessment may not reflect the current state of scientific knowledge.

3.1 Harmful marine debris — TSSC assessment against EPBC Act criteria

Criteria	TSSC assessment
Could the threatening process cause a native species or an ecological community to become eligible for listing as Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable?	Based on the current research at the time the listing was made, the TSSC found that the threatening process places some marine animals at risk but there was not enough evidence to suggest that this is likely to cause them to become eligible to be listed in another category representing a higher degree of endangerment.
Could the threatening process cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment?	Although the nomination provides data on instances of mortality due to the threatening process, the TSSC considered that there is insufficient data or quantifiable evidence to support the view that the threatening process could at the present time cause a native species or an ecological community to become eligible for listing as Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable.

36 Australian Government website, https://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl, accessed 26 August 2021.

37 The full process is summarised on the Australian Government Environment website, https://www.environment.gov.au/system/files/resources/0a68a7c6-62c8-4417-8f08-aa62e1eedb65/files/nominations-flowchart_1.pdf, accessed 22 September 2021.

Criteria	TSSC assessment
Does the threatening process adversely affect two or more listed threatened species (other than conservation dependent species) or two or more listed threatened ecological communities?	The TSSC considered the threatening process is eligible under this criterion. It is considered that marine debris that are sourced from land based plastics, fishing gear from recreational and commercial fishing and ship sourced, solid non biodegradable materials disposed of at sea does adversely affect two or more listed marine species. It is important to note that this is not the only threat to these species and that the relative magnitude of the threat from marine debris, as defined, is not certain when compared with other processes, such as long-line fishing (which affects albatrosses) and indigenous harvesting of turtles. However, a precautionary approach to the issue leads to the conclusion that, even in the absence of clear scientific evidence that the named species (see table 3.2 below) are affected at the level of populations, it is reasonable to state that these species are adversely affected by the threatening process, especially when its effects are combined with those of other threatening processes.

Source: http://www.environment.gov.au/biodiversity/threatened/key-threatening-processes/harmful-marine-debris, accessed 23 August 2021.

As set out in table 3.1, 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' is listed a threatening process on the basis that it adversely affects two or more listed marine species. At the time of the assessment, the named endangered and vulnerable species assessed as being affected are shown in table 3.2.

3.2 Endangered and vulnerable species

Endangered species (6)	Vulnerable species (14)
▪ Loggerhead Turtle	▪ Leatherback Turtle
▪ Southern Right Whale	▪ Hawksbill Turtle
▪ Blue Whale	▪ Flatback Turtle
▪ Tristan Albatross	▪ Green Turtle
▪ Northern Royal Albatross	▪ Wandering Albatross
▪ Gould's Petrel	▪ Humpback Whale
	▪ Antipodean Albatross
	▪ Gibson's Albatross
	▪ Southern Royal Albatross
	▪ Indian Yellow-nosed Albatross
	▪ Grey Nurse Shark
	▪ Grey-headed Albatross
	▪ Blue Petrel
	▪ Northern Giant Petrel

Source: http://www.environment.gov.au/biodiversity/threatened/key-threatening-processes/harmful-marine-debris, accessed 23 August 2021.

Environmental weeds

Loss and degradation of native plants and animal habitat by invasion of escaped garden plants, including aquatic plants was listed as a key threatening process under the EPBC Act on 8 January 2010.[38]

According to the TSSC assessment, invasive garden plants can be defined as plants that are currently or were historically used in gardens, primarily for ornament or utility, which have escaped or threaten to invade natural and other areas.[39] Dumping of garden waste in bushland is one way that invasive garden plants escape into the natural environment.

- In natural ecosystems, invasive plants impact negatively on the biodiversity of many Australian vegetation types. Conservative estimates of the impact of weed competition (that according to the TSSC assessment are likely to significantly underestimate the problem) are as follows.
  - Weed competition has been identified as the primary cause for the extinction of at least four native plant species.
  - It has also been estimated that a further 57 species were threatened or would become so in the future through competition of weeds.
- Garden and aquarium plants are a significant source of the problem:
  - The gardening industry is the largest importer of introduced plant species, being the source for the introduction of 25 360 or 94 per cent of non-native plant species into Australia.
  - Garden plant introductions are the dominant source of new naturalised plants and weeds in Australia.
    - Of the 2779 introduced plant species now known to be established in the Australian environment, 1831 (or 66 per cent) are escaped garden plant species.
    - Garden plants are also expected to comprise an even greater portion of all naturalised species in the future.
  - Invasive garden plant species — both introduced and native species outside their natural range — are the largest source of environmental weeds (weeds which impact on natural biodiversity), comprising 72 per cent of the 1765 listed environmental weeds.
  - An increasing number of Australian native plants are invading beyond their natural indigenous range, with their spread facilitated by the nursery and garden industry and enthusiastic gardeners.

The TSSC assessed that 'Loss and degradation of native plants and animal habitat by invasion of escaped garden plants, including aquatic plants' to be eligible for listing as a key threatening process under all 3 EPBC Act criteria.

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38 Australian Government website, https://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl, accessed 26 August 2021.

39 Australian Government website, https://www.environment.gov.au/system/files/pages/215ddf2d-5955-4974-b2c3-a7e99c14f5e3/files/garden-plants-listing-advice.pdf, accessed 8 October 2021.

3.3 TSSC assessment against EPBC Act criteria

Criteria	TSSC assessment
Could the threatening process cause a native species or an ecological community to become eligible for listing as Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable?	There are a number of species not listed as threatened under the EPBC Act that are likely to be negatively impacted by escaped garden plants. However, there are currently insufficient quantitative data available to enable assessment of the impacts on most of these species against this criterion. There is however, evidence that the threatening process could cause Troides richmondia (Richmond Birdwing Butterfly) to become eligible for listing as threatened under the EPBC Act. The Committee considered that the threatening process is eligible under this criterion as the process could cause the Richmond Birdwing Butterfly to become eligible for listing as threatened under the EPBC Act.
Could the threatening process cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment?	The Committee considers that the threatening process is eligible under this criterion as the process could cause the Cumberland Plain Woodlands to become eligible for listing as critically endangered, a category which represents a higher degree of endangerment, under the EPBC Act.
Does the threatening process adversely affect two or more listed threatened species (other than conservation dependent species) or two or more listed threatened ecological communities?	The Committee considers that the threatening process is eligible under this criterion as the process is adversely affecting population numbers and geographic distribution of at least three listed threatened species and two listed threatened ecological communities, primarily through competition and habitat degradation. As discussed under 'Threats to Native Species' there are a number of species being impacted upon by this threatening process. The following species, listed as threatened under the EPBC Act, are examples that demonstrate the adverse impacts of escaped garden plants on threatened Australian native species. These species are being affected by escaped garden plants primarily through competition and habitat degradation. • Pimelea spicata (a shrub) • Pterostylis arenicola (Sandhill Greenhood Orchid) • Lasiopetalum pterocarpum (Wing-fruited Lasiopetalum) Additionally, the 'Blue Gum High Forest of the Sydney Basin Bioregion' and 'Littoral Rainforest and Coastal Vine Thickets of Eastern Australia' are examples of ecological communities listed as threatened under the EPBC Act that are adversely impacted by this threatening process.

Source: Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), https://www.environment.gov.au/system/files/pages/215ddf2d-5955-4974-b2c3-a7e99c14f5e3/files/garden-plants-listing-advice.pdf, accessed 26 August 2021.

State of the Environment report

Every 5 years, the Australian Government commissions a panel of independent experts to review the state of the environment (box 3.4).[40] The most recent report relates to the 2011-2016 period and was published in 2017. The forthcoming State of the Environment Report 2021 is due to be published in early 2022.

[40] State of the Environment website, https://soe.environment.gov.au/how-why, accessed 29 September 2021.

3.4 State of the Environment report[41]

The 'State of the Environment' review includes 9 thematic reports which represent biogeographic or conceptual aspects of the Australian environment, including:

- **Atmosphere** — considers changes to Australia's atmosphere, particularly greenhouse gas emissions and climate change as well as ambient air quality.
- **Built environment** — considers the impacts of population and economic growth, and climate change on Australia's urban environments.
- **Heritage** — considers the extent and condition of Australia's rich natural, Indigenous, and cultural heritage, the threats each faces from natural and human processes, and the challenges of management.
- **Biodiversity** — considers the condition of Australia's living resources and highlights the challenges of management in the context of human dependence on biodiversity for ecosystem services.
- **Land** — considers the state of our soil and terrestrial vegetation resources, the pressures they face, and issues and priorities for management.
- **Inland water** — considers the evolving state of surface and groundwater resources in the context of the breaking of a major drought and ongoing water policy reform.
- **Coasts** — considers features of the interface between the ocean and land, the challenges to coasts posed by climate change and ongoing coastal development, and management responses to pressures on our coastlines.
- **Marine environment** — considers the condition of Australia's oceanic habitats, communities and species group; the existing pressures on our marine environments and current management.
- **Antarctic environment** — considers the global importance and evolving state of the Antarctic environment, changes to marine and terrestrial ecosystems resulting from human activity, and the significance of climate change in the region.

Each thematic assessment follows a common format, which includes identifying:[42]

- Drivers — the underlying natural and human-caused forces that exert pressures on the environment.
- Pressures — factors that arise from the drivers of environmental change that directly affect the environment
- State and trends — describes the current condition and trends of the environment.
- Management effectiveness — identifies management responses to the pressure and assesses the effectiveness
- Resilience — examines the ability of the environment to withstand ore recover from a shock or disturbance.
- Risk — identifies and assesses the residual risk
- Outlook — the long-term outlook is assessed.

The State of the Environment identifies the key pressures facing the Australian environment. Among these key pressures are some that are relevant to litter and illegal dumping.

- Marine debris is identified as a pressure in several thematic reports, including: *Biodiversity*, *Marine environment* and *Coast*. The Biodiversity thematic report notes that marine debris and ingestion of plastics by marine animals is perhaps the largest pollution issue of concern for biodiversity in Australia that has risen in prominence during the past 5 years.[43] The identified impacts on the environment are as follows.
  - Entanglement of marine animals in debris can cause restricted mobility, drowning, starvation, smothering, wounding and amputation of limbs—all of which can result in death. Ghost nets (i.e. fishing nets that drift through the ocean for years or decades) were identified as one of the major threats to marine wildlife through entanglement. Furthermore, of the ghost nets removed from beaches and estuaries (more than 13 000) only 4 per cent of those that could be identified originated from Australian fisheries (although only around 50 per cent could be identified).[44]
  - Ingestion of floating plastics by marine animals was also identified. Plastics are resistant to breakdown, and thus persist and accumulate in the marine environment. Ingested plastics remain in the stomach of marine animals and accumulate, eventually causing starvation.[45]
  - Plastics are also identified a potential source of toxic chemicals.[46]
    - These chemicals leach out of ingested plastics and transferred into the blood and tissues. These chemicals may cause sublethal health effects in wildlife, even at very low contamination levels.
    - Microplastics have also been linked to the degradation of molecular, cellular, physiological and, ultimately, ecological processes within the marine environment.
  - The Coast thematic report notes that little scientific evidence exists to assess the pressure of coastal marine debris (human litter in the coastal zone) in Australia. Most studies focus on distribution or exposure, and do not consider impacts or risk to the environment. [47]

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41 State of the Environment website, https://soe.environment.gov.au/how-why/how-report-written#SoE_2016_framework, accessed 29 September 2021.

42 State of the Environment website, https://soe.environment.gov.au/how-why/how-report-written, accessed 29 September 2021.

43 Cresswell, I. and Murphy, H. "Biodiversity", *Australia State of the Environment Report 2016*, pp. 19-20.

44 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

45 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

46 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

47 Clark, G.F. and Johnston, E.L. 2017, "Coasts", *Australia State of the Environment 2016*, pp. 31-33.

- The impacts of marine debris were assessed as follows.
  - The impacts on the marine environment were assessed as high (the current environmental impacts from this pressure are significantly affecting the values of the region, and projections indicate serious environmental degradation in the marine environment within 50 years if the pressure is not addressed), with a deteriorating trend.[48]
  - In the coastal environment, marine debris is assessed as high impact (imposes moderate pressure on the state of habitats, species/taxa groups; or physical, biogeochemical, biological or ecological processes), with a deteriorating trend.[49]
- Weeds are identified as a pressure on the land environment.
  - The Land thematic report notes that weeds continue to have a negative impact on the natural environment, through impacts on biodiversity, ecosystem function and environmental health, and promotion of bushfires.[50] Although not a key focus of the report, it nevertheless notes that an enormous number of species have been introduced for recreational gardening (as well as agriculture).[51] Dumping of green waste from gardens has the potential to spread these weeds.
  - Invasive plant species (i.e. weeds) are assessed as having high impact (current and expected impacts are widespread, and may irreversibly affect land environmental values) with a deteriorating trend.[52]
- There were no other pressures identified in the various thematic reports relating to litter or illegal dumping, including the *Land* and *Inland water* thematic reports. This could mean that litter and illegal dumping are not a major environmental pressure in these environments at the present time, or alternatively there is a lack of scientific evidence collated to date on the impacts.

Implications for valuing the environmental impacts

The findings from reviewing the above material have several implications for valuing the environmental impacts of litter.

- Litter and illegal dumping contribute to the following key environmental challenges.
  - Plastics in the marine environment has been identified as impacting on at least 20 threatened or endangered species.
    - Littered (and potentially illegally dumped) plastics contribute to this problem mainly through ingestion.
    - Entanglement has also been identified as a significant issue for some species.

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48 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

49 Clark, G.F. and Johnston, E.L. 2017, "Coasts", *Australia State of the Environment 2016*, p. 51.

50 Metcalfe, D.J. and Bui, E.N. 2017, "Land", *Australia State of the Environment 2016*, p. 29.

51 Metcalfe, D.J. and Bui, E.N. 2017, "Land", *Australia State of the Environment 2016*, p. 3.

52 Metcalfe, D.J. and Bui, E.N. 2017, "Land", *Australia State of the Environment 2016*, p. 36.

   … Microplastics have been identified as an emerging concern. However, the ecological effects of microplastics are largely unknown. Potential pathways of impact include blockage of digestive tracts and the transfer of organic toxins through food webs.
  – Dumped garden waste can contribute to the spread of environmental weeds, which can impact negatively on the biodiversity of many Australian vegetation types.
- Litter and illegal dumping have **not** been identified as either:
  – a key threatening process for any other species or ecological communities; or
  – a key environmental pressure on other environments, including inland waterways or terrestrial environments.
- This suggests that any other environmental costs (over and above any amenity and clean-up costs) are at the site or individual animal level, rather than having a significant impact on populations or major changes in environmental values at a major site.
  – This may reflect a combination of:
    … the amount of material either littered or dumped is not sufficiently large to have broader environmental impacts; and/or
    … existing clean-up activities are effective at preventing significant environmental impacts from litter and illegal dumping.
  – Alternatively, it could reflect a lack of scientific information on the actual impacts of litter and illegal dumping.
- There is sufficient information available to value the environmental impacts at the site or individual animal level.
  – There is no data on the number of illegal dumping sites that are likely to be affected.
  – Economic studies valuing environmental impacts are generally at the population level, rather than the individual animal or small site level.

4 Impacts on marine environments

Marine debris includes "*any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment*".[53]

Various types of littered or dumped debris could potentially have detrimental impacts on the marine environment. There is a current focus on the impacts of plastics in the marine environment. This is driven by the:

- persistence of plastics within the ocean with effects on wildlife and potentially humans.[54] It is considered that plastics break up over time into micro-plastics and do not decompose.[55]
- prevalence of plastics, it is estimated that 60-80 per cent of marine debris is comprised of plastic,[56]
- most of the data on impacts on marine wildlife is from plastic marine debris,[57] and
- a finding that 80 per cent of the impacts were associated with plastic debris, while paper, glass and metal together accounted for less than 2 per cent.[58]

The key impacts from marine debris are entanglement, ingestion, chemical contamination, migration of non-native species and human health impacts. Chart 4.1 outlines the evidence base for these five identified impacts (blue shading represents information available for each valuation step). Based on the available evidence, an economic value can be placed on ingestion and entanglement impacts. There is insufficient evidence to value the other identified impacts.

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53 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica, page 7.

54 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

55 APEC, 2020, *Update of 2009 APEC Report on Economic Costs of Marine Debris to APEC Economics.*

56 Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

57 Kühn, S. and van Freneker, J.A., 2020, *Quantitative overview of marine debris ingested by marine megafauna*, Marine Pollution Bulletin 151 (2020) 110858.

58 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

4.1 Steps to identify and value environmental impacts from litter/illegally dumped debris — marine environment

Steps /impact categories	Entanglement	Ingestion	Chemical contamination	Non-native species	Human health
Evidence of debris in environment causing impact					
Evidence on incidence of impact					
Identify population level impacts					
Attribute population level impacts to debris					
Apply economic values to population level impacts					

Data source: CIE.

This chapter summaries the information on:

- evidence of material in the marine environment
- environmental impacts
- valuation of environmental impacts.

More detailed information regarding impacts in the marine environment is available in Appendix A.

Evidence of material in the marine environment

Littered or illegally dumped debris can enter the marine environment from land-based sources or sea/ocean-based sources.

Land based marine debris

The Ocean Conservancy (2015) investigated the key sources of plastic leakage into the ocean and found at least 80 per cent of ocean plastic comes from land-based sources.[59] Sources of land-based marine pollution are urban residential, manufacturing and industrial sites, commercial services, roads, landfill, sewerage, recreational uses (e.g. beach users) and agricultural activities.[60]

59 Ocean Conservancy, 2015, *Stemming the Tide: Land-based strategies for a plastic-free ocean.*

60 Queensland Department of Environment and Science, *Litter and illegal dumping: Sources,* https://wetlandinfo.des.qld.gov.au/wetlands/management/pressures/litter-illegal-dumping/sources/, Accessed 10 November 2021.

Debris moves through the environment via air, water, mechanical and biological pathways.[61] A CSIRO study into the pathways through which debris reaches and moves into the marine environment found that:

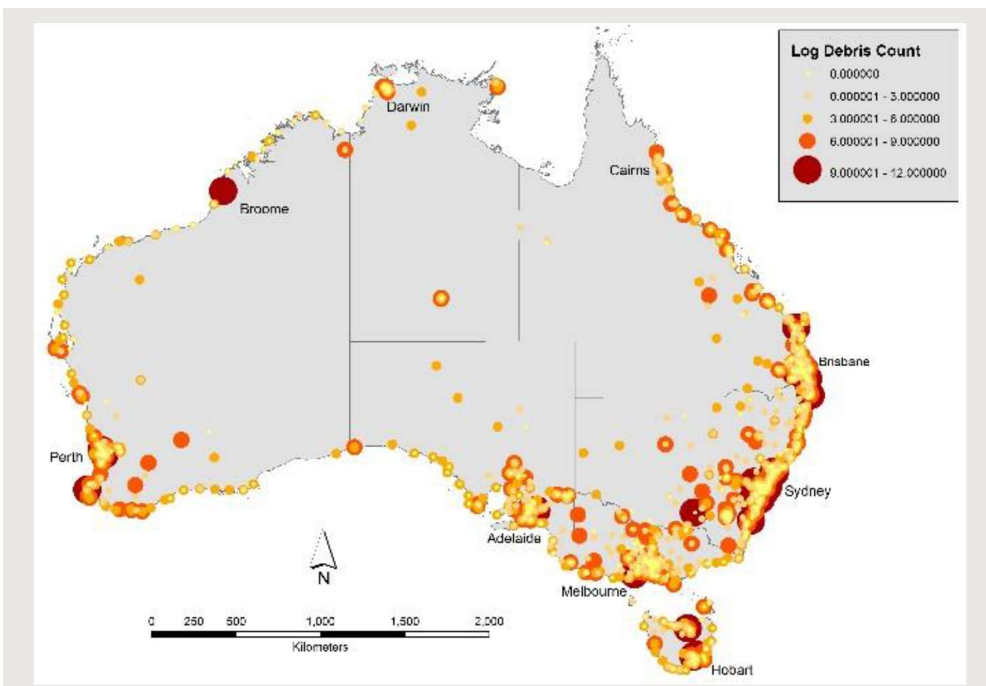
- Human deposition was by far the most important factor determining the debris load at a particular site.
- Transport via water was the second most important factor.
- Wind transport made a smaller (but discernible) contribution to the debris load.[62]

Other key findings from CSIRO's research in terms of pathways to the marine environment include:

- most of the rubbish along the Australian coast is from Australian sources, not from overseas
- debris is concentrated around major cities and urban centres which suggests local sources (see chart 4.2).

In the case of debris movement by wind and water, although wind has an effect, by far the majority of pollution occurs from stormwater runoff into rivers and streams which subsequently make their way into marine waters. [63]

4.2 Debris hotspots based on survey data



Data source: CSIRO, *Identifying and understanding the sources of marine debris,* https://www.csiro.au/-/media/OnA/Files/CSIRO_APC_Factsheet.pdf

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61 Queensland Department of Environment and Science, *Litter and illegal dumping: Pathways,* https://wetlandinfo.des.qld.gov.au/wetlands/management/pressures/litter-illegal-dumping/pathways/index.html, Accessed 10 November 2021.

62 CSIRO, *Identifying and understanding the sources of marine debris,* Fact sheet.

63 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

Sea or ocean based marine debris

Sea or ocean-based sources of marine debris include discarded or lost material from vessels. These vessels include merchant ships, fishing trawlers as well as offshore oil and gas platforms.[64] Until the International Convention for the Prevention of Pollution from Ships was enacted, ship-sourced rubbish was traditionally disposed of at sea. The maritime industry is thought to be responsible for 20 per cent of all marine debris.[65]

Fishing line and nets make up a large proportion of sea-based marine debris especially around areas where there is more fishing activity.

Marine debris composition in the Australian environment

The Australian Marine Debris Initiative collected information on the top 10 items found during beach and water clean-up by Tangaroa Blue volunteers across Australia. Table 4.3 shows the amount of each item collected between 2019 to 2021. Plastics have now surpassed cigarette filters as the most often removed product group during clean-ups.[66] The majority of the top 10 items are plastic or are usually made of plastic.

Estimates on the concentration and presence of marine debris (particularly plastics) in the Australian marine environment are in table A.2.

4.3 Top 10 items from clean-up of Australian beaches and waterways collected between 2019 to 2021

Item	Total number of items
Plastic bits & pieces hard & solid	1 574 344
Lids & tops, pump spray, flow restrictor & similar	377 433
Cigarette butts & filters	272 258
Plastic film remnants (bits of plastic bag, wrap etc)	259 422
Foam insulation & packaging (whole and remnants)	238 825
Plastic packaging food (wrap, packets, containers)	181 566
Plastic drink bottles (water, juice, milk, soft drink)	102 649
Glass or ceramic broken	96 484
Rope & net scraps less than 1 metre	79 609
Straws, confection sticks, cups, plates & cutlery	75 748

Note: Data collected between December 2019 to December 2021

Source: Australian Marine Debris Initiative

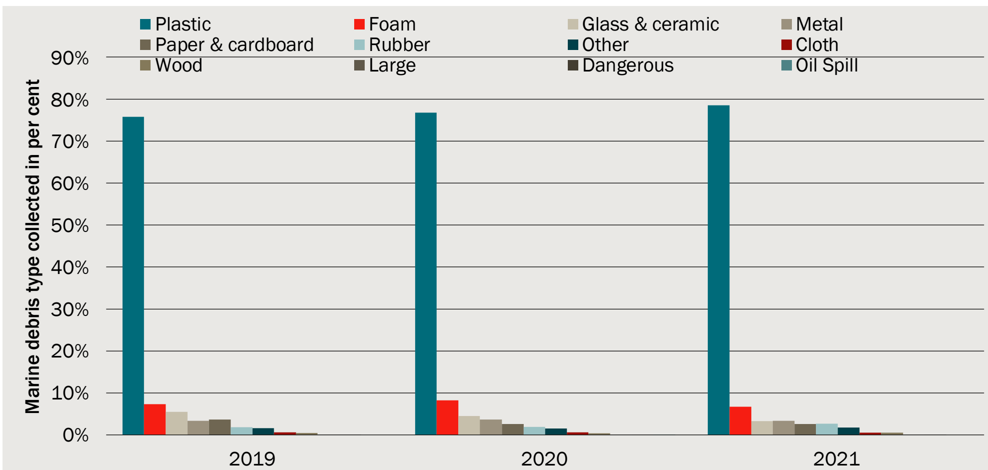
64 Vegter, AC, et al., 2014, 'Global research priorities to mitigate plastic pollution impacts on marine wildlife', Endangered Species Research, 25: 225–247 http://www.int-res.com/articles/esr_oa/n025p225.pdf, p. 233

65 Commonwealth Government of Australia, 2016, The threat of marine plastic pollution in Australia. Accessed from https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Marine_plastics

66 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

Chart 4.4 identifies the yearly proportion of each type of material collected from the marine environment by volunteers. Plastic overwhelmingly constitutes the highest proportion of debris material encountered during clean-up initiatives across Australia. Between 2019-2021, plastic made up around 75 per cent of all waste product encountered by volunteers. This is consistent with global estimates of proportion of plastic in marine debris.[67] The next most common type of debris material was foam (6 to 8 per cent) which is a plastic, followed by glass or ceramics (3 to 5 per cent).

4.4 Type of material collected by year of Clean up initiative across Australia



Data source: Australian Marine Debris Initiative

Environmental impacts

There is a distinct focus on the environmental impacts of plastic marine debris. Plastic is the most mobile and persistent of all debris types. These characteristics of plastic debris are driving concerns of associated environmental impacts and research efforts. In addition, it has been noted that these characteristics distinguish plastics from other debris, particularly in the marine environments where plastic can spread throughout water columns, on the seabed, through the deep sea[68], and along coastal shorelines and remain in the environment for decades or more.[69] Professor Tony Underwood noted in the Senate Inquiry in marine plastic pollution that:

> I think the focus on plastic might be justified because it is persistent in ways that metal, wood and other materials are not. Plastic just gets smaller and smaller, but it does not go away. That

67 Sherrington, C. et al., (2014). Report I: Migratory Species, Marine Debris and its Management. Accessed from https://www.cms.int/sites/default/files/document/COP11_Inf_27_Report_I_Marine_Debris_Management_Eonly.pdf

68 Barrett, J., Chase, Z., Zhang, J., Banaszak Holl, M., Willis, K., Williams, A., Hardesty, B., and Wilcox, C., 2020, *Microplastic Pollution in Deep-Sea Sediments from the Great Australian Bight.*

69 Senate Environment and Communications References Committee, Toxic tide: the threat of marine plastic pollution in Australia, April 2016.

> is different from metal which eventually, when you throw it in the sea, will be gone. I think there is a good reason why the focus on plastic keeps coming up compared with other debris[70]

Research efforts are also focusing on the impacts of microplastics. Microplastics are plastic items that are smaller than 5mm and generally divided up into:

- Primary microplastics – manufactured as small plastics, such as microbeads in face wash and toothpaste
- Secondary microplastics – derived from the breakdown of large items such as fragments from plastic bags or fibres from textiles.[71]

Common environmental impacts from plastic debris, including microplastics, in the marine environment are entanglement, ingestion, smothering, chemical contamination, transport of non-native and invasive species, and human health impacts from incidental consumption through the food chain. Entanglement and ingestion are the most frequently reported environmental impacts of plastic debris on marine life.

Table 4.5 outlines the key marine debris types causing entanglement and ingestion.

4.5 Debris types causing entanglement and ingestion

Debris most frequently associated with entanglement	Debris most frequently associated with ingestion
▪ Net fragments (including ghost nets) ▪ Rope and line (e.g. gill nets, trawl nets, discarded line) ▪ Monofilament line ▪ Packing bands ▪ Plastic circular rings and packaging such as multipack can rings	▪ Small plastic fragments of sufficient small size to be ingested by birds and turtles ▪ Plastic bags ▪ Plastic bags and plastic waste (including net fragments)

Source: Butterworth, A., and Clegg, I., 2012, *Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions,* World Society for the Protection of Animals.

Entanglement

Marine species that are killed and maimed through entanglement include seabirds, turtles, whales, dolphins, dugongs, sea snakes, sharks, fish, crabs and crocodiles.[72] Sublethal and lethal impacts include:

- restricted movement leading to exhaustion or preventing animal from surfacing to breathe
- restricted feeding and subsequent starvation
- smothering and wounding (e.g. lacerations and ulcers), and subsequent infections
- inhibit natural growth of limbs leading to deformation

70 Senate Environment and Communications References Committee, Toxic tide: the threat of marine plastic pollution in Australia, April 2016, p. 5.

71 Australian Institute of Marine Science, 2018, *Marine plastic pollution,* https://www.aims.gov.au/water-quality/plastics

72 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

- reduced reproductive output
- reduced ability to avoid predators.

Derelict fishing gear, including ghost nets, entangle marine turtles, dugong, crocodiles, sawfish, hammerhead sharks, sea snakes and invertebrates. CSIRO estimates 6 per cent of all fishing nets, 9 per cent of all traps and 29 per cent of all lines are lost or discarded into the ocean each year.[73]

Ghost nets are a particular problem in the Gulf of Carpentaria where scientists have found ghost nets are increasing despite more than a decade of illegal fishing countermeasures and clean-up efforts.[74] The following are estimates of the proportion of ghost nets attributable to Australia:

- it is estimated that the vast majority (85 per cent) of ghost nets found along the Gulf coastline originate from outside of Australia's Exclusive Economic Zone.[75]
- of the ghost nets removed from beaches and estuaries (more than 13 000) only 4 per cent of those that could be identified as originating from Australian fisheries (although only around 50 per cent could be identified).[76]
- approximately 12 per cent of fishing debris recorded in Northern Territory was manufactured in Australia (table 4.6).

4.6 Origin of fishing debris recorded at Cape Arnhem, Northern Territory, Australia

Country of manufacture	Net type	Number of nets	Proportion of total nets
		Number	Per cent
Taiwan	Trawl	108	26
	Gill (drift net)	94	
	Sub-total	**202**	
Indonesia	Trawl	131	7
	Gill (drift net)	6	
	Sub-total	**137**	
Taiwan/Korea	Trawl	99	13
Japan	Trawl	63	8
Philippines	Trawl	52	7
Japan/Korea	Trawl	25	3
Thailand	Trawl	23	3
Republic of Korea	Trawl	19	3

73 CSIRO, 2019, *How much fishing gear is lost at sea?,* https://www.csiro.au/en/news/news-releases/2019/how-much-fishing-gear-is-lost-at-sea, Accessed 10 November 2021.

74 Hardesty, B. D., Roman, L., Duke, N. C., and Mackenzie, J. R., 2021, *Abandoned, lost and discarded fishing gear 'ghost nets' are increasing through time in Northern Australia,* Marine Pollution Bulletin 173 (2021) 112959.

75 Hardesty, B. D., Roman, L., Duke, N. C., and Mackenzie, J. R., 2021, *Abandoned, lost and discarded fishing gear 'ghost nets' are increasing through time in Northern Australia,* Marine Pollution Bulletin 173 (2021) 112959.

76 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

Country of manufacture	Net type	Number of nets	Proportion of total nets
		Number	Per cent
	Gill (drift net)	1	
	Sub-total	**20**	
Australia	Trawl	68	12
	Gill (drift net)	26	
	Sub-total	**94**	
Unknown	Trawl	7	9
	Gill (drift net)	3	
	Unknown	59	
	Sub-total	**69**	
Total		**784**	**100**

Source: Macfadyen, G., Huntington, T, and Cappell, R., 2009, *Abandoned, lost or otherwise discarded fishing gear,* UNEP Regional Seas Report and Studies 185, FAO Fisheries and Aquaculture Technical Paper 523.

Incidence data is reported in a variety of forms, including number of individual incidence cases, proportion of species that have at least one individual with a case, and proportion of individuals within a species with a reported case.

Evidence of entanglement at the species level

Some studies report impact at the species level, framed as a species being impacted based on at least one record of an individual being impacted. Table 4.7 presents data on entanglement incidence for key species groups from three studies.

This data at the species level is based on at least one documented case of plastic ingestion. Kühn and Franeker (2020) note that information presented at the species level can incorrectly present the extent of the problem.[77]

4.7 Number of species with document records of entanglement in marine debris

Species group	Laist (1997 study)			Kuhn et al (2015)			Kuhn et al (2020)		
	Spp. total	Entanglement		Spp. total	Entanglement		Spp. total	Entanglement	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Seabirds	312	51	16	406	103	25.4	409	112	27.4
Marine mammals	115	32	28	123	51	41.5	123	49	39.8
Turtles	7	6	86	7	7	100	7	7	100
Sea Snakes	-	-	-	62	2	3.2	62	2	3.2
Fishes	-	34	-	32554	89	nr	31243	101	nr
Invertebrates	-	8	-	159000	92	nr	159000	83	nr

77 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Species group	Laist (1997 study)			Kuhn et al (2015)			Kuhn et al (2020)		
	Spp. total	Entanglement		Spp. total	Entanglement		Spp. total	Entanglement	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Total marine birds, mammals and turtles	**434**	**89**	**20.5**	**536**	**161**	**30.0**	539	168	31.2
All species		**136**			**344**			354	

Note: "nr" represents not reported. Kuhn and van Franeker (2020) note the percentage of affected species is not a useful statistic for reptiles, fish and invertebrates because there are many thousands of species which have not been properly investigated.

Source: Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life,* Marine Anthropogenic Litter, pp 75-116 and Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

Evidence of entanglement at the individual level

Evidence of entanglement at the individual level is based on recorded sightings of entangled animals alive (or recently deceased), often opportunistic in nature or from heavily visited coastal regions. [78] Therefore estimates do not capture unseen cases, such as those which take place in the high seas and it is likely observations of entangled or injured wildlife greatly underestimate total rates of wildlife entanglement.[79] It is estimated the recorded cases of entanglement account for between 3 and 10 per cent of total entanglement cases.[80]

Table 4.8 outlines data on frequency of entanglement by individuals of selected species but does not list the responsible marine debris type. It has been noted that entanglement of marine animals in discarded fishing nets is of particular concern in northern Australian waters.[81]

4.8 Frequency of entanglement for selected species

Species	Size of sample	Individuals with recorded entanglement	Geography
	Number	Per cent	
Leach's storm petrel	151	11	Equatorial Pacific
White-faced storm petrel	13	6.9	Equatorial Pacific
Brown pelican	557	63	California
Northern Gannet (dead)	28	29	North Sea Helgoland
Northern Gannet (fly off cliff)	313	2.6	North Sea Helgoland

78 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

79 Ibid.

80 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for World Society for the Protection of Animals.

81 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

Species	Size of sample	Individuals with recorded entanglement	Geography
	Number	Per cent	
Northern Gannet (entangled in nest)	656 684	2.6 (2014) 3.5 (2015)	North Sea Helgoland
Northern Fulmar	67	1.8	North Sea Helgoland
Guillemot	2880 3381	1.1 1.0	North Sea Helgoland
Grey seal	58	3.6-5	Cornwall, UK
Common minke whale	11	9.1	UK
California/Galapagos/Japanese Sea Lion	3574	3.7	California, USA
Guadalupe fur seal	13	15.4	California, USA
Harbour seal	1072	1.2	California, USA
Northern elephant seal	1484	0.4	California, USA
Common bottlenose dolphin	302	3.9	South Carolina, USA
Green turtle	5347	9	Florida, USA
Loggerhead turtle	9950	4.2	Florida, USA
Leatherback turtle	304	14.1	Florida, USA
Hawksbill turtle	362	8.3	Florida, USA
Kemp's Ridley turtle	1346	5.1	Florida, USA
Olive Ridley turtle	3	33.3	Florida, USA
Loggerhead turtle (live)	948	4.6	Italy
Loggerhead turtle (dead)	307	6.6	Italy

Source: Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

Additional information on entanglement is presented in Appendix A.

Ingestion

Animals may intentionally or accidently ingest marine debris. Ingestion can physically block an animal's digestive tract, alter feeding behaviour and dietary inputs, lacerate the mouth and digestive tract causing serious injury, and influence the buoyancy of species. These can lead to greater susceptibility to predators and diseases and decreased ability to bread and rear young.

Ingestion of plastic can lead to mortality through:

- gastrointestinal obstruction or perforation, which may be caused by either a single or multiple debris items, or
- multiple large plastic items which remain and accumulate in the stomachs of marine animals, reducing the volume available for nutrition food, eventually causing starvation
- in the case of turtles, decomposition of plastic inside a turtle's stomach can produce gas which remains trapped inside causing a turtle to float on the surface of water,

possibly leading to starvation, increased likelihood of injury (e.g. boat strikes) and inability to hide from predators[82]

Certain marine organisms are more at risk of ingestion due to feeding methods, age, lacking an ability to regurgitate or due to activity:

- feeding methods — marine species which feed as filter feeders, deposit feeders and detritivores are most at risk of ingestion of plastics. [83] Foraging by seabirds increases risk of ingestion, and accidental ingestion can occur by filter-feeding marine organisms or through secondary ingestion when animals feed on prey which has already ingested debris. Baleen whales can ingest marine debris as they feed.[84]
- age — younger animals in a range of species are more at risk of ingestion of marine debris, for example, sea turtles are at a higher risk of ingestion during the juvenile and pelagic stages.
- ability to regurgitate — sea turtles don't have the ability to regurgitate so ingested plastic particles may be swallowed and accumulate in the gut.
- activity — toothed whales and dolphins can ingest plastic and other waste either in play or exploration[85]

Various sizes of plastics, including microplastics, can be ingested by species of different sizes. There is evidence that marine invertebrates such as amphipods, lugworms, barnacles, mussels, lobster and squid ingest microplastics.[86] One estimate is 10 per cent of encounters with marine debris are microplastics.[87] There remain uncertainties about the full effect of microplastics on the species ingesting them,[88] and also impacts further up the food chain as well as ecosystem level effects.[89]

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82 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

83 Thompson, R., Moore, C., vom Saal, F., Swan, S., 2009, *Plastics, the environment and human health: current consensus and future trends*, Phil. Trans. R. Soc. B (2009) 364, 2153-2166.

84 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for World Society for the Protection of Animals, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

85 Ibid.

86 Ivar do Sul, J.A., and Costa, M.F. (2014) The present and future of microplastic pollution in the marine environment, *Environmental Pollution* referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

87 AP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012 referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

88 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

89 Ibid.

Evidence of ingestion at the species level

Not surprising, there is more information available for plastic ingestion related to larger marine species and larger plastic particles. Information on plastic ingestion declines with the size of animal and size of the plastic particles.[90] For the smaller taxa, records of ingestion exist for benthic worms, shrimps, shellfish, small zooplankton and goose-barnacles.

Estimates of ingestion impacts at the **species** level include a compilation of records by Kuhn et al. (2015) which found 331 species were impacted by marine debris.[91] An updated literature review of 747 studies by Kuhn and van Franeker (2020) found marine debris affected 701 species through ingestion (table 4.9).[92]

4.9 Number of species with document records of ingestion in marine debris

Species group	Laist (1997 study)			Kuhn et al (2015)			Kuhn et al (2020)		
	Spp. total	Ingestion		Spp. total	Ingestion		Spp. total	Ingestion	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Seabirds	312	111	36	406	164	40.4	409	180	44.0
Marine mammals	115	26	23	123	62	50.4	123	69	56.1
Turtles	7	6	86	7	7	100	7	7	100
Sea Snakes	-	-	-	62	0	0.0	62	0	0.0
Fishes	-	33	-	32 554	92	nr	31 243	363	nr
Invertebrates	-	1	-	159000	6	nr	159 000	82	nr
Total marine birds, mammals and turtles	**434**	**143**	**32.9**	**536**	**233**	**43.5**	**539**	**256**	**47.5**
All species		**177**			**331**			**701**	

Note: "nr" represents not reported. Kuhn and van Franeker (2020) note the percentage of affected species is not a useful statistic for reptiles, fish and invertebrates because there are many thousands of species which have not been properly investigated.

Source: Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life,* and Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Evidence of ingestion at the individual level

Based on the data in table 4.9, there is evidence that 44 per cent of seabird species, 56 per cent of marine mammals and 100 per cent of turtle species have been impacted through ingestion of plastic debris. As noted above, Kühn and Franeker (2020) note that

90 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

91 Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, Deleterious Effects of Litter on Marine Life

92 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

information presented at the species level can incorrectly present the extent of the problem because it is based on at least one documented case of plastic ingestion.[93] Kühn and van Franeker (2020) examined ingestion impacts at the individual level and found the following proportion of individuals had plastic in their stomachs:

- less than 30 per cent of individual seabirds
- 4.4 per cent of mammals
- 32 per cent of turtles (table 4.10).

4.10 Frequency of ingestion by individuals by taxon

Taxon	Species	Species studied	Individuals studied	Individuals with plastic	Frequency of occurrence
	no.	per cent	no.	no.	per cent
All seabirds	409	55.3	43525	12065	27.7
All carnivores	34	23.53	9 784	93	0.95
All baleen whales	14	42.86	96	16	16.67
All toothed whales	72	50.00	5 002	480	9.40
All cetaceans	86	48.84	5 098	486	9.53
All sirenia	3	33.33	4 604	281	6.10
All marine mammals	123	41.46	19 486	860	4.41
All turtles	7	100	7879	2536	32.00

Note: The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available.

Source: Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Werner et al. (2016) compiled information on the proportion of individuals with recorded ingestion (table A.18 in Appendix A). Based on this information, Werner et al. (2016) comment that:

- ingestion is a regular and widespread occurrence for all groups of marine wildlife,
- impacts for lower tropic levels and small-sized organisms are harder to document
- it is extremely difficult to quantify sublethal effects, yet understanding of sublethal effects is important to understand impacts at the population level.[94]

Evidence of ingestion by sea turtles

Sea turtles commonly ingest plastic bags, cling film, food wrappers and balloons, in some cases mistaking plastic bags and other similar plastic film debris as jellyfish prey. [95] Plastics are by far the most concerning type of marine debris for sea turtles, with one

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93 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

94 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

95 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

report noting plastics make up to 90 per cent of the marine debris ingested by marine turtles in Queensland.[96]

Sea turtles are at particular risk from plastics in the oceans because the seven species of marine turtles are already categorised as vulnerable to critically engendered. [97]

Table 4.11 outlines the frequency of ingestion by individual turtles for the seven turtle species.

4.11 Frequency of ingestion by individuals by turtle species

Taxon	Species	Species studied	Individuals studied	Individuals with plastic	Frequency of occurrence
	no.	per cent	no.	no.	per cent
Loggerhead turtle	1	100	3919	843	22
Kemp's ridley turtle	1	100	304	106	35
Olive ridley turtle	1	100	179	81	45
Green turtle	1	100	2720	1275	47
Hawksbill turtle	1	100	86	31	36
Flatback turtle	1	100	2	2	100
Leatherback turtle	1	100	669	198	30
All turtles	**7**	**100**	**7879**	**2536**	**32**

Source: Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Other impacts from marine debris

Marine debris, most notable plastics and microplastics, cause additional impacts in the marine environment of chemical contamination, migration of non-native species and human health impacts.

There is ad—hoc evidence of these impacts from marine debris, however currently there is insufficient evidence to establish:

- incidence of population level impacts
- attribution to marine debris
- final outcomes from these impacts.

The available evidence for these impacts is presented in Appendix A.

96 Great Barrier Reef Marine Park, *Submission 29*, p. 1. referenced in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

97 Australian Institute of Marine Science, 2018, *Tiny plastics are potentially dangerous for turtles too,* https://www.aims.gov.au/docs/media/latest-releases/-/asset_publisher/8Kfw/content/tiny-plastics-are-potentially-dangerous-for-turtles-too

Value of environmental impacts

Based on the above review of the evidence, the main quantifiable environmental impacts of litter and illegal dumping in the marine environment relates to the impact of plastic ingestion by marine animals and entanglement of marine animals in active and derelict fishing gear. [98]

There is evidence that ingestion of plastics and entanglement in fishing gear is having population level impacts on around 20 threatened or endangered species.

Valuing species preservation

There is a significant literature estimating the willingness to pay for species preservation, mostly in the context of endangered or threatened species. Two approaches are estimating the:

- value of avoided extinction of threatened and endangered species
- willingness to pay for a change in status.

The available literature on these approaches is discussed in Appendix A.

The estimated values for species preservation in table 4.12 have been used to value the ingestion and entanglement impacts for twenty endangered and threatened marine species.

4.12 Estimated annual willingness to pay for species preservation

	Household WTP per species	Aggregate WTP per species All Australian households	Aggregate WTP per species NSW, VIC, QLD households
	$ per household	$ million	$ million
Endangered species			
Turtles	71	708	550
Whales	98	972	754
Seabirds	130	1 292	1 003
Vulnerable species			
Turtle	68	673	522
Whale	93	924	717
Seabird	123	1 228	953
Shark	56	560	434

Note: Aggregate WTP is based on 7.2 million households in NSW, Victoria and Queensland.

Source: Amuakwa-Mensah, F. Barenbold, R. and Riemer, O. 2018, Deriving a Benefit Transfer Function for Threatened and Endangered Species in Interaction with Their Level of Charisma, environments, p. 10; ABS; CIE.

98 Ritchie, J. and Roser, M., 2018, *Plastic Pollution,* Our World in Data, https://ourworldindata.org/plastic-pollution#plastic-trade-impact-of-china-s-import-ban. Accessed September 2021.

Cost of entanglement impacts

The cost of entanglement of threatened marine species in Australian fishing gear is estimated to be $363.6 million per year (table 4.13). This estimate is based on the following assumptions:

- 71 per cent of entanglement is due to fishing gear[99] (entanglement due to other debris items (excl. fishing gear) is not included in this cost estimate)
- the incidence rates for entanglement by species outlined in table 4.13. Authors note the difficulty in distinguishing between entanglements in active fishing gear and marine debris.[100],[101] The focus of the studies from which the incidence rates are sourced was marine debris including derelict fishing gear. As such it is assumed the incidence rates below relate only to derelict fishing gear and not active fishing gear (i.e. bycatch).
- willingness to pay per threatened species outlined in table 4.12
- 4 per cent of derelict fishing gear originates from Australian fisheries[102], [103]
- mortality rate of 80 per cent[104] for all species except whales for which mortality rates in table A.15 are applied.

4.13 Estimated cost of fishing gear entanglement for threatened species

Species	Population	Entanglement incidence	Total WTP per species per year	Attribution to Australian water	Total cost attributed to Australian fishing gear
	number	per cent	$ billion per year	per cent	$ million per year
Endangered species					
Loggerhead Turtle	45 000	4.2	0.71	4.0	8.4
Southern Right Whale	3 500	1.4	0.97	4.0	1.1
Blue Whale	17 500	0.0	0.97	4.0	-
Tristan Albatross	11 000	6.6	1.29	4.0	23.9

99 Gall, 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179

100 National Oceanic and Atmospheric Administration, 2014, *Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States,* 2014 NOAA Marine Debris Program Report, page 1.

101 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

102 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

103 Data on incidence of entanglement in active fishing gear in Australia and elsewhere has not been compiled. Nor has the share of entanglements in active versus derelict fishing gear. As such 4 per cent of all entanglements, whether in active or derelict fishing gear are assumed to be attributable to Australia for the species listed.

104 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

Species	Population	Entanglement incidence	Total WTP per species per year	Attribution to Australian water	Total cost attributed to Australian fishing gear
	number	per cent	$ billion per year	per cent	$ million per year
Northern Royal Albatross	20 000	6.6	1.29	4.0	23.9
Gould's Petrel[a]	2 500	6.6	1.29	4.0	23.9
Vulnerable species				4.0	-
Leatherback Turtle	35 000	14.1	0.67	4.0	26.7
Hawksbill Turtle	21 500	8.3	0.67	4.0	15.7
Flatback Turtle[b]	20 500	10.7	0.67	4.0	20.2
Green Turtle	87 500	9.0	0.67	4.0	17.1
Wandering Albatross	55 000	6.6	1.23	4.0	22.7
Humpback Whale	60 000	7.2	0.92	4.0	4.2
Antipodean Albatross	25 260	6.6	1.23	4.0	22.7
Gibson's Albatross	40 000	6.6	1.23	4.0	22.7
Southern Royal Albatross	27 000	6.6	1.23	4.0	22.7
Indian Yellow-nosed Albatross	170 000	6.6	1.23	4.0	22.7
Grey Nurse Shark	1 950	NA	0.56	4.0	-
Grey-headed Albatross	90 000	6.6	1.23	4.0	22.7
Blue Petrel[c]	80 000	9.0	1.23	4.0	31.0
Northern Giant Petrel[c]	7 425	9.0	1.23	4.0	31.0
Total					**363.6**

[a] Rate of entanglement not available for Gould’s Petrel. Estimate based on average rate for other petrel and fulmar species.
[b] Rate of entanglement not available for flatback turtle. Estimate based on average rate for other turtle species.
[c] Rate of entanglement not available for Blue Petrel and Northern Giant Petrel. Estimate based on average rate for Leach’s storm petrel and white-faced storm petrel.

Note: Entanglement incidence data not available for Grey Nurse Share, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Cost of ingestion impacts

The following information was used to value the impact of ingestion of marine debris:

- ingestion incidence data for key taxa and individual turtles species in table 4.10 and table 4.11
- mortality rate of approximately 5 per cent following ingestion[105]
- estimated share of marine plastic from Australia relative to other countries which key species inhabit or migrate through (see Appendix A)
- estimated annual willingness to pay for species preservation in table 4.12.

The cost of ingestion of plastic litter from Australia entering the ocean per year is estimated to be $104 million per year. This reflects the impact on threatened species from mortality following plastic ingestion. In particular, two thirds of this estimated cost is due

105 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

to impacts to Gibson's Albatross. This species predominantly inhabits Australian and New Zealand coastlines, so a higher proportion of the impact (32 per cent) is attributable to Australia. This is in strong contrast to other species for which minimal impact (e.g. 0.003 per cent for a variety of turtle species) is attributable to Australia.

The total cost ranges between $803 and $3 994 dollars per tonne of plastic entering the ocean (approximately between $0.008 and $0.04 per empty 10 gram plastic bottle), depending on the estimated tonnes of plastic litter entering Australian waters per year:

- low estimate of debris — based on estimated 26 150 tonnes of plastic mismanaged in Australia per year [106]
- high estimate of debris — based on estimated 130 000 tonnes of plastic litter entering Australian waters per year (table 4.14).

4.14 Estimated cost of marine plastic litter from Australia for threatened species

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed to Australian litter	Cost per tonne of plastic litter per year
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low	$/t/yr high
Endangered species							
Loggerhead Turtle	45 000	22	0.71	0.003	0.0	0.1	0.0
Southern Right Whale	3 500	16.67	0.97	0.118	0.1	4.5	0.9
Blue Whale	17 500	16.67	0.97	0.003	0.0	0.1	0.0
Tristan Albatross	11 000	27.7	1.29	0.067	0.1	5.7	1.2
Northern Royal Albatross	20 000	27.7	1.29	0.352	0.8	29.9	6.0
Gould's Petrel	2 500	27.7	1.29	6.882	15.3	584.8	117.6
Vulnerable species							
Leatherback Turtle	35 000	30	0.67	0.003	0.0	0.2	0.0
Hawksbill Turtle	21 500	36	0.67	0.003	0.0	0.2	0.0
Flatback Turtle	20 500	100	0.67	0.003	0.0	0.5	0.1
Green Turtle	87 500	47	0.67	0.003	0.0	0.2	0.0
Wandering Albatross	55 000	27.7	1.23	0.166	0.4	13.4	2.7
Humpback Whale	60 000	16.67	0.92	0.003	0.0	0.1	0.0
Antipodean Albatross	25 260	27.7	1.23	7.583	16.0	612.4	123.1
Gibson's Albatross	40 000	27.7	1.23	32.000	67.5	2584.2	519.6
Southern Royal Albatross	27 000	27.7	1.23	0.317	0.7	25.6	5.2

106 Based on global estimate of 8 million tonnes of plastics entering ocean (see https://www.marineconservation.org.au/ocean-plastic-pollution) and Australia's share of plastics emitted to the ocean, estimated as 0.003 per cent.

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed to Australian litter	Cost per tonne of plastic litter per year	
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low	$/t/yr high
Indian Yellow-nosed Albatross	170 000	27.7	1.23	0.416	0.9	33.6	6.8
Grey Nurse Shark	1 950	NA	0.56	#N/A	0.0	0.0	0.0
Grey-headed Albatross	90 000	27.7	1.23	0.326	0.7	26.3	5.3
Blue Petrel	80 000	27.7	1.23	0.576	1.2	46.5	9.3
Northern Giant Petrel	7 425	27.7	1.23	0.317	0.7	25.6	5.2
Total					**104.4**	**3994.2**	**803.0**

Note: Ingestion incidence data was not available for Grey Nurse Shark, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Valuing the cost of microplastics in the marine environment

There have been several recent studies that have directly valued the community's willingness to pay to reduce microplastic pollution in the marine environment. Of most relevance is a forthcoming Australian paper that seeks to value the community's willingness to pay to reduce microplastics in the marine environment using a stated preference survey.[107]

The study reports households' willingness to pay to reduce microplastics in a range as follows.[108]

- A lower bound estimate of $46.25 per household per year over 10 years, implying an aggregate national willingness to pay of around $460.4 million per year (extrapolated across 9.96 million households across Australia)
- An upper bound estimate of $133.75 per household per year, implying an aggregate national willingness to pay of $1.38 billion per year.

Although this study implies that the community's willingness to pay to reduce microplastics is significant, we have not included these estimates of the costs of microplastics in our overall estimates of the environmental costs of litter and illegal dumping for several reasons.

In particular, the framework set out in chapter 2 focuses on the causal linkages, including from the presence of material in the environment to environmental impacts (defined as identifiable impacts on animal and plant species and the functioning of the ecosystem). This is consistent with advice from the Productivity Commission on the use of stated preference studies:

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107 See Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", *Marine Policy*, 135.

108 Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", Marine Policy, 135, p. 7.

> "Environmental goods or attributes in the survey [should be] expressed in terms of endpoints that people directly value. For example, people should be asked about willingness to pay for the environmental improvements brought about by increases in environmental water flows, rather than for increases in environmental water flows themselves."[109]

By contrast, the attributes included in the study (including: pieces per sq km of ocean, number of seabirds affected, average number of microplastics digested per fish and average number of pieces of microplastics per sqm of beach) are mostly measures of the presence of microplastics in the environment, as the environmental impacts are still not well understood. As further noted by the Productivity Commission, where policy outcomes are not expressed in terms that are directly valued by participants, but are instead proxies for the ultimate environmental outcomes that they care about, survey respondents are more likely to draw on prior knowledge or make erroneous assumptions to make relevant connections.[110]

Although the study does not directly measure the environmental outcomes as a result of microplastics, these estimates nevertheless indicate a significant level of community concern and an appetite for action to reduce microplastics in the marine environment.

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[109] Productivity Commission, *Environmental Policy Analysis: A Guide to Non-Market Valuation*, Productivity Commission Staff Working Paper, January 2014, p. 45.

[110] Productivity Commission, *Environmental Policy Analysis: A Guide to Non-Market Valuation*, Productivity Commission Staff Working Paper, January 2014, p. 37.

5 *Impacts on inland waterways*

The key impacts from litter and illegal dumping in inland waterways are entanglement, ingestion, chemical contamination (including human health), and pollution of recreational waters. Chart 5.1 outlines the evidence base for these key impacts (blue shading represents information available for valuation step). Based on the available evidence, an economic value can be estimated for lost recreational use value from stormwater pollution, however there is a lack of information to attribute the impact to dog faeces relative to other contributors (e.g. sewage). There is insufficient evidence to value the other identified impacts.

5.1 Steps to identify and value environmental impacts from litter/illegally dumped debris — inland waterways

Steps /impact categories	Entanglement	Ingestion	Chemical contamination	Stormwater pollution of recreational water
Evidence of debris in environment causing impact				
Evidence on incidence of impact				
Identify population level impacts				
Attribute population level impacts to debris				
Apply economic values to population level impacts				

Note: Hashed shading shows that an economic value/cost has been estimated for the impact, however there is insufficient information to attribute the impact to litter and/or illegal dumping.

Data source: CIE.

This chapter summaries the information on:

- evidence of material in inland waterways
- environmental impacts
- valuation of environmental impacts.

More detailed information regarding impacts in inland waterways is available in Appendix B.

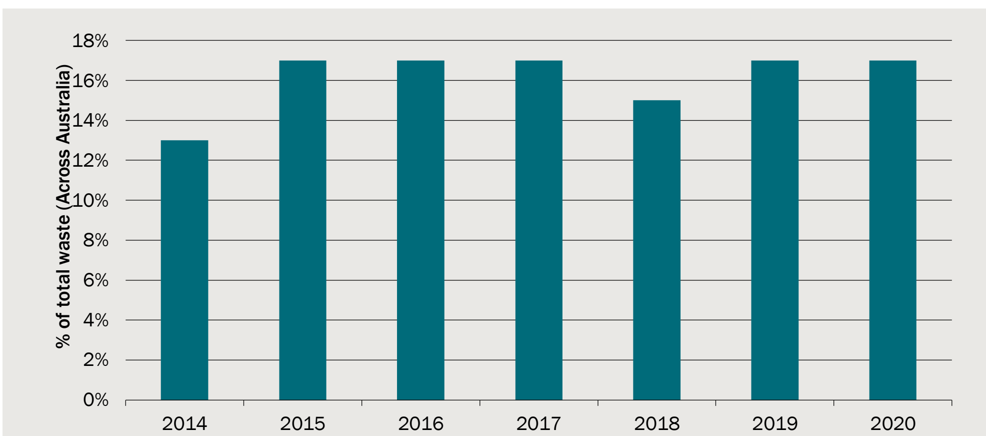
Evidence of material in inland waterways

Many studies focus on litter in inland waterways to understand the extent to which inland waterways are a key source of marine debris, rather than focus on inland waterways themselves. Van Emmerik and Schwarz (2019) state that the fate of macroplastics in freshwater systems is unknown, and the general assumption is that plastics in rivers end up in the ocean.[111]

There is limited systematic data on the extent to which littered or dumped material **accumulates** in Australian inland waterways. Understanding how much material remains in inland waterways following clean-up efforts is important to determine the extent of environmental impacts in inland waterways before the material eventually makes its way onto the marine environment.

There is data available on the quantity and type of litter cleaned up in creeks, rivers and other inland waterways from Clean Up Australia reports. This data shows that litter as a proportion of total waste collected has remained relatively stable over recent years (chart 5.2) and plastics are the most commonly reported rubbish type from waterways, representing 31.7 per cent of total rubbish (chart 5.3). Clean Up Australia data is useful to understand how much litter and debris enters inland waterways, how much is cleaned-up and associated clean-up costs.

5.2 Trend in the proportion of total litter found in Rivers/Creeks/Waterways across Australia

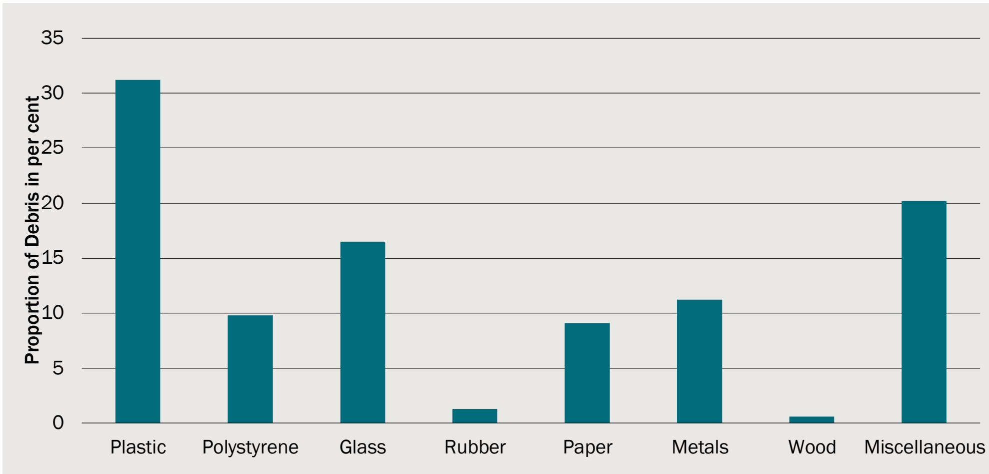


Note: 3,278 sites nationally. Of these, 748 recorded valid data for analysis across 1,274 locations

Data source: Clean Up Australia.

111 Van Emmerik, T. and Schwarz, A., 2019, *Plastic debris in rivers,* https://wires.onlinelibrary.wiley.com/doi/epdf/10.1002/wat2.1398. Accessed September 2021.

5.3 Litter composition in waterways across Australia in 2020



Data source: Clean Up Australia report 2020.

Environmental impacts

Similar to marine environments, various types of litter or dumped materials can negatively impact inland water environments such as inland rivers, lakes and wetlands. Negative impacts from debris could include:

- harm to aquatic fauna through entanglement, ingestion or chemical contamination
- broader impacts to ecosystems through harm to aquatic flora, habitats and ecosystems, or spread of diseases[112]
- water, land or soil pollution, including water-borne diseases and algal blooms
- risk to human health through fish and water consumption[113]

It is widely acknowledged by researchers that the vast majority of research on environmental impacts from litter and dumped material, but in particular plastic debris, has been focused on the marine environment.[114],[115],[116] Many authors have commented

112 See https://www.texasdisposal.com/blog/the-real-cost-of-littering/

113 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

114 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

115 Hoellein, T., Rojas, M., Pink, A., Gasior, J., and Kelly, J., 2014, Anthropogenic litter in urban freshwater ecosystems: distribution and microbial interactions, *PLOS ONE June 23, 2104.*

116 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

that more work is needed to examine the negative impacts of litter and dumped material, in particular plastics, in terrestrial and freshwater habitats.[117,118] For instance,

- 87 per cent (440 papers) of plastic pollution studies are related to the marine environment, compared to only 13 per cent (64 papers) to freshwater systems
- the annual growth rate was approximately 41 to 7 papers per year for marine and freshwater environments, respectively.[119]

Entanglement

In stark contrast to the marine debris literature, Blettler et al. (2018) found there were no studies evaluating entanglement impacts from macroplastics on freshwater fauna and noted that most studies to date have focused on ingestion of plastics.[120]

Serena and Williams (2021) collated evidence of entanglement impacts on platypus in four river basins in the Greater Melbourne area and 13 river basins in regional Victoria (table 5.4). The incidence of entanglement was higher in river basins in the Greater Melbourne area (4 per cent) compared to regional river basins (0.5 per cent). The authors noted the 8-fold increase was likely due to higher amounts of litter and debris in urban waterways.

5.4 Entanglement incidence in platypus in Victorian river basins

Basin	Number of platypus in live-trapping survey	Number of live-trapped platypus with evidence of entanglement	Proportion entangled
	Number	Number	Per cent
Greater Melbourne area (recorded between 1989-2011)			
Werribee Basin	27	4	15
Maribyrnong Basin	94		0
Yarra Basin	778		5
Bunyip Basin	367		1
Sub-total for Greater Melbourne area	1266	51	4
Regional Victoria (recorded between 1997 to 2019)			
13 river basins in regional Victoria[a]	580	3	0.5

[a] Upper Murray River, Broken, Goulburn, Campaspe, Loddon, Wimmera, Hopkins, Barwon, Moorabool, Mitchell, Thomson, Tambo, Snowy.

Source: Serena, M. and Williams, G.A., 2021, *Factors affecting the frequency and outcome of platypus entanglement by human rubbish*, Australian Mammalogy.

117 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

118 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

119 Ibid.

120 Ibid.

Ingestion

Globally, ingestion by freshwater species has been reported in natural, semi-natural and laboratory conditions. In freshwater environments, the group with the highest records of plastic ingestion is fish, with 158 species identified as ingesting plastic in natural conditions and 2 in semi-natural conditions. The second highest group is birds with 20 reported incidences of plastic ingestion in natural conditions and 1 in semi-natural conditions (table 5.5).

5.5 Number of freshwater species that ingested plastic in natural, semi-natural or laboratorial conditions

Group	Natural	Semi-natural	Laboratory	Total
	no.	no.	no.	no.
Crustaceans	1	1	7	9
Other invertebrates	6	0	10	16
Fishes	158	2	0	160
Amphibians	15	0	3	18
Birds	20	1	0	21
Mammals	2	0	0	2
Total	**202**	**4**	**20**	**226**

Source: Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Azevedo-Santos et al. (2021) examined the impacts of plastic ingestion on freshwater organisms, predominantly in laboratory conditions. Nine observations had sub-lethal impacts and four observations had lethal impacts (table 5.6).

5.6 Examples of freshwater organisms negatively affected by plastic ingestion in laboratory or natural conditions

Group	Condition	Sub-lethal	Lethal
		no.	no.
Crustacean	Laboratory	3	2
Mollusk	Laboratory	2	0
Cnidarian	Laboratory	1	0
Fish	Laboratory	2	0
Amphibian	Laboratory	1	1
Mammal	Natural	0	1
Total		**9**	**4**

Source: Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Chemical contamination and microplastics

Degrading plastic litter (including cigarette filters) can release chemicals and microplastics into the environment. These chemicals can leach into waterways potentially impacting plants, animals and humans. There is minimal information on the extent of and final outcomes of impacts from chemical contamination and microplastics in inland waterway environments.

Limited evidence includes:

- birds and aquatic animals can ingest cigarette filters, mistaking them as food. This can lead to serious digestive problems and possibly death.[121]
- chemicals leaching from cigarette filters can be toxic to non-vertebrate aquatic organisms[122]

Overall, there is a lack of evidence that population level impacts are occurring in inland waterways due to chemical contamination and microplastics from litter and illegally dumped debris.

Stormwater pollution of recreational waters

Litter and illegally dumped materials can pollute waterways by directly entering waterways or indirectly entering waterways and beaches through stormwater. Table 5.7 outlines the key stormwater pollution impacts for in-scope waste types.

Victoria EPA noted that dog faeces is one of the most common sources of beach water contamination around Port Phillip Bay.[123]

5.7 Environmental impacts of stormwater pollution

Littered or illegally dumped	Environmental impacts
Animal waste	▪ Increased nutrient levels in stormwater which lead to an increase in algal blooms ▪ Introduced disease causing micro-organisms like bacteria, protozoans and viruses, which can cause gastroenteritis, eye, ear, skin and upper respiratory tract infections, skin irritations and other health problems for humans. ▪ Certain groups of users may be more vulnerable to microbial infection, including, children, the elderly, people with compromised immune systems.
Cigarettes	▪ Source of heavy metal contamination, which can harm local organisms

121 Healthy Land and Water, *Litter in our waterways,* https://hlw.org.au/download-topic/waterways/litter-in-our-waterways/. Accessed September 2021.

122 Slaughter, E., Gersberg, R., Watanabe, K., Rudolph, J., Stransky, C., Novotny, T., 2011, *Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish,* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3088407/pdf/tobaccocontrol40170.pdf. Accessed September 2021.

123 VIC EPA, 2020,*Pick up your doggie doo or you could wind up swimming in it,* 21 January 2020, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/news-and-updates/pick-up-your-doggie-doo-or-you-could-wind-up-swimming-in-it

Littered or illegally dumped material	Environmental impacts
	▪ Organic compounds (such as nicotine, pesticide residues and metal) seep from cigarette filters into aquatic ecosystems, which is toxic to fish and microorganisms. ▪ Evidence that chemicals in cigarette filters seep into soils when littered. Where some hydrocarbons found in cigarettes are carcinogenic.
Illegally dumped oil and grease	▪ Forms a film over water and makes it difficult for aquatic animals and plants to breath. ▪ Can be toxic to plants and animals
Illegally dumped vegetation and	▪ Promotes unwanted weed growth

Source: SA EPA, *Stormwater Pollution,* EPA 491/03, https://www.epa.sa.gov.au/files/8514_water_general.pdf and VIC EPA, 2020,*Pic up your doggie doo or you could wind up swimming in it,* 21 January 2020, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/news-and-updates/pick-up-your-doggie-doo-or-you-could-wind-up-swimming-in-it

Pollutant concentrations of waterways and beaches are often exacerbated during and shortly after storm and flood events. In some cases, stormwater pollution forces the closure of beaches and rivers to swimmers. For example, the Victorian EPA advises people not to swim near stormwater or river outlets for 24-48 hours after heavy rain due to high concentration of animal faeces and other contaminants that are washed into the bay. [124]

Some beaches, baths or lagoons in Greater Sydney are not suitable for swimming following rainfall events due to pollution from faecal contamination. For these water bodies the following warning is provided:

> Water quality is suitable for swimming for most of the time, but due to the presence of several potential sources of faecal contamination, swimming should be avoided following rainfall.[125]

Across Greater Sydney approximately 60 per cent of beaches, baths or lagoons are subject to poor water quality following rainfall events (table B.10).

The Ocean Microbiology Group of the University of Technology Sydney used microbial source-tracking to assess water quality issues in Central Coast Lagoons and at Rose Bay to identify causes of poor water quality. In particular to determine when and where periodically poor water quality is caused by sewage or animal sources (dog or bird) of faecal contamination.[126] Across the study sites, the common findings were:

- dog faeces have a negligible impact on water quality during dry weather conditions
- dog faeces contribute to poor water quality during rainfall events, with material brought in by stormwater from the surrounding catchment or within the sewage system
- sewage inputs played a larger role than dog faeces in reducing water quality.

124 Ibid.

125 NSW Office of Environment and Heritage, *Beaches,* https://www.environment.nsw.gov.au/topics/water/beaches updated and accessed 13 October 2021.

126 University of Technology Sydney, 2020, *Microbial source-tracking to assess water quality in Central Coast Lagoons,* Climate Change Cluster, Faculty of Science, UTS.

See Table B.11 in Appendix B for information on key findings for each coastal area studied.

Value of environmental impacts

Based on the above review of the evidence, the main quantifiable environmental impact of litter and illegal dumping in the inland waterways is stormwater pollution of recreation waters from dog faeces.

There is insufficient information to value the impact of entanglement, ingestion and chemical contamination in inland waterways. The key evidence gaps are:

- incidence data in the natural environment
- identification of final outcomes following interaction with debris
- information to attribute impact to debris.

Value of lost recreational use value due to stormwater pollution at beaches

Stormwater pollution can cause human health impacts if people swim in poor quality water, or a loss of recreational use value if people are prevented from swimming due to poor water quality.

Deloitte Access Economics (2016) estimated there are 36 million visits to Sydney per year with an average value of $38 per person per visit.[127] This information coupled with estimated days of closure based on average high rainfall events (table B.12) per year is used to estimate the lost recreational use value of $37 million per year due to closure of beaches, baths and lagoons in Greater Sydney due to stormwater pollution.

As noted, there is a lack of evidence on the contribution dog faeces makes to poor water quality following heavy rainfall events. In the absence of a sound basis to attribute lost recreation value associated with stormwater pollution to littered dog faeces, table 5.8 shows indicative estimates under various attribution assumptions (ranging from 2.5 per cent to 10 per cent). These estimates provide an order of magnitude in absence of information required for attribution.

5.8 Estimated lost recreational value from dog faeces in stormwater — Sydney

Item	Unit	Value
Number of visits to Sydney's beaches per year	million	38
Average visits per day (not accounting for seasonal effects)	no.	98 630
Average high rainfall events per year (based on daily rainfall > 30mm)	no.	8
Estimated days per closure	Days per closure	2
Total number of closure days per year	Days per year	16
Proportion of beaches, baths, lagoons closed following heavy rainfall events		58

127 Deloitte Access Economics, 2016, *Economic and social value of improved water quality at Sydney's coastal beaches.*

Item	Unit	Value
Estimated number of lost visits to Sydney's beach per year		974 309
Value per beach visit	$ per person per visit	38
Estimated total lost recreational use value	$m per year	37.0
Proportion attributable to litter dog faeces	per cent	
Estimated lost recreation use value due to dog faeces		
Based on 2.5 per cent attribution	$m per year	0.9
Based on 5 per cent attribution	$m per year	1.9
Based on 7.5 per cent attribution	$m per year	2.8
Based on 10 per cent attribution	$m per year	3.7

Source: CIE based on various source.

6 Impacts on terrestrial environments

Littered and illegally dumped material (including unwanted household items) in many urban environments (including around retail areas, streets and highways and industrial areas) can impose significant amenity costs (i.e. likely to be visible to many people) and are therefore more likely to be removed from the environment through regular clean-up activities (this includes regular and frequent clean-up activities, such as council activities, as well as any regular clean-up activities by land owners or managers). As such, the environmental costs are likely to be limited. An exception is asbestos which can have immediate human health impacts when illegally dumped.

Environmental impacts are more likely in terrestrial environments where it is less visible and therefore the littered and/or dumped material persists in the environment for a longer period. These include remote areas of national parks, nature reserves, bushland and beaches. These are environments of concern because they have higher environmental impacts given the proximity to flora and fauna that might be affected by the introduction and persistence of litter.

The key impacts from litter and illegal dumping in terrestrial environments are:

- invasive plants or pests from illegally dumped green waste
- chemical contamination to plants, animals and humans from cigarette filters
- human health impacts from asbestos
- fire risk.

Chart 6.1 outlines the evidence base for these key impacts (blue shading represents information available for valuation step). Based on the available evidence, an economic value can be estimated for invasive weeds and pests, however there is a lack of information to attribute the impact to illegally dumped garden/green waste. There is insufficient evidence to value the other identified impacts.

Dog faeces is also a commonly littered item. The is insufficient information on the impacts of dog faeces in terrestrial environments. The environmental impact of dog faeces in inland waterways is discussed in chapter 5.

6.1 Steps to identify and value environmental impacts from litter/illegally dumped debris — terrestrial environments

Steps /impact categories	Invasive plants	Invasive pests	Chemical contamination	Human health impacts (asbestos)	Fire risk
Evidence of debris in environment causing impact					
Evidence on incidence of impact					
Identify population level impacts					
Attribute population level impacts to debris					
Apply economic values to population level impacts					

Data source: CIE.

This chapter summaries the information on:

- evidence of material in terrestrial environments
- environmental impacts
- valuation of environmental impacts.

More detailed information regarding impacts in terrestrial environments is available in Appendix C.

Evidence of material in terrestrial environments

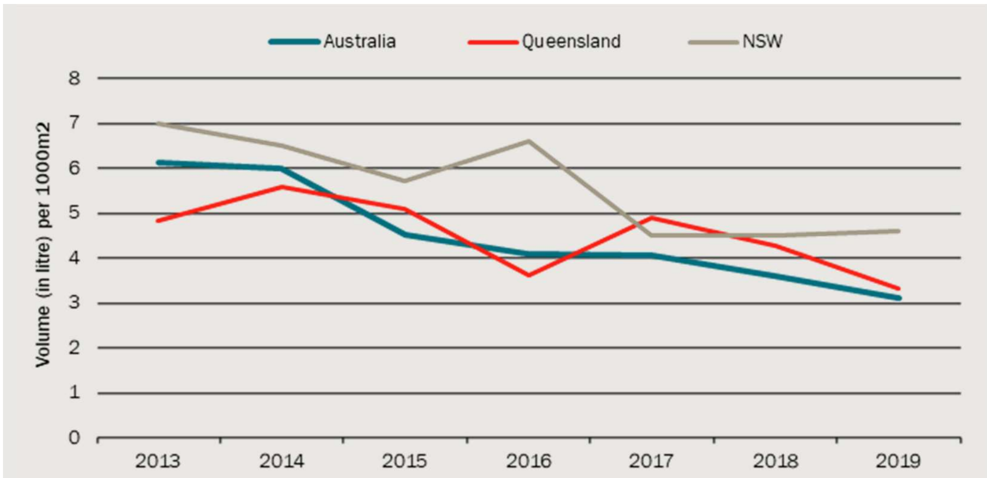
There is limited systematic data on the extent to which littered or dumped material accumulates in terrestrial environments. Where littered and/or dumped material is identified in terrestrial environments, it is often removed and cleaned-up, where possible.

That said, some sources of data that provide an indication of the extent of littered and dumped material in terrestrial environments include the following.

- Clean up Australia data (although the material gathered through Clean Up Australia day is removed from the environment, this may provide an indicator of the sorts of materials that are not being collected through more regular clean-up activities.
- NSW EPA illegal dumping reports — these reports provide an indicator of the types of material that is illegally dumped in NSW.
- Keep Australia Beautiful National Litter Index (KAB NLI) — Annual measure for the presence of litter items at sites within broadly comparable regions across Australian states and territories

A key consideration is whether there is any evidence of material accumulating in terrestrial environments over time. In terms of material entering the terrestrial environment, there has been an overall declining trend in litter across Australia, Queensland and NSW (chart 6.2). Victoria has also recorded a reduction in overall litter count of 1.3 per cent from 2016 to 2017 (not pictured due to date limitations).[128]

6.2 Volume of litter (in litre per 1000m2) in Australia, NSW and Queensland



Data source: Keep Australia Beautiful National Litter Index, The CIE

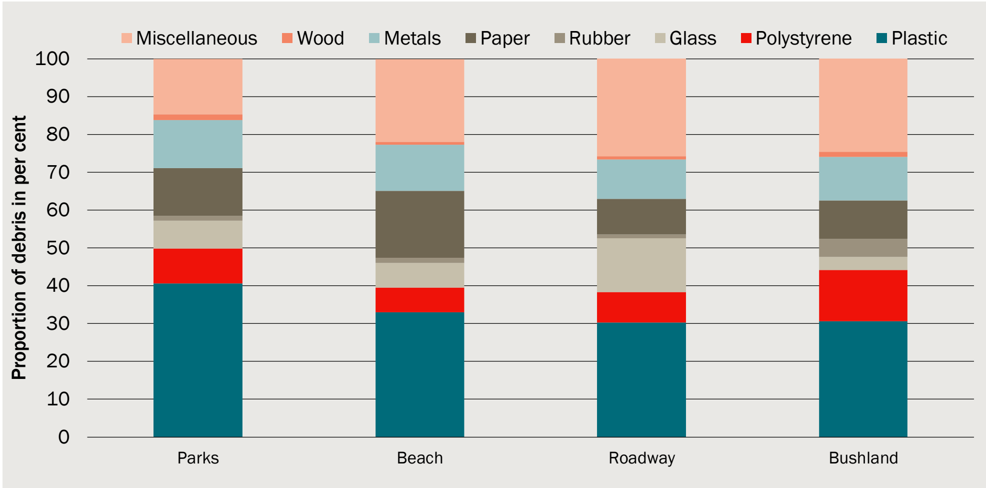
The falling trend highlights the changing behaviours and growing understanding in the community of litter and waste issues as well as the impact of interventions and campaigns led by the national and state government

Key items littered

Figure 6.3 shows the composition of litter in high impact terrestrial environments across Australia based on Clean Up Australia data. Plastic makes up the highest proportion of litter across all the sites. Miscellaneous category of litter also constitutes a significant portion of the litter composition across the high impact sites. This category includes cigarette filters.

128 See, https://ksenvironmental.com.au/national-litter-index-victoria/

6.3 Litter or Debris composition in high environmental impact sites in Australia



Data source: Clean Up Australia 2020 Report, The CIE.

The three most common littered items are cigarette filters, plastic and paper. We identify that the retention of plastic and cigarette filters in the environment have a higher environmental impact than paper. Plastic in its multitude of forms, once introduced into the environment never biodegrade and can be hazardous for animals that come into contact with it through entanglement or ingestion. Moreover, cigarette filters can leech toxins into the environment that cause contamination and threaten the native flora and fauna as well as human health. There is also potential for cigarette filters littered in the environment to increase the risk of bushfires causing loss of property, loss of life and the loss of native habitat for many plants and animals.

Plastic

According to Clean Up Australia report, plastic was the most common rubbish type, representing 36 per cent in 2020 and 31 per cent in 2019 of all rubbish items removed.

Beverage container counts continue to decline – reflective of the impact of container refund schemes. In 2020 they reflected 15.5 per cent of counted rubbish. In 2019 they accounted for 17.9 per cent.[129]

Cigarette filters

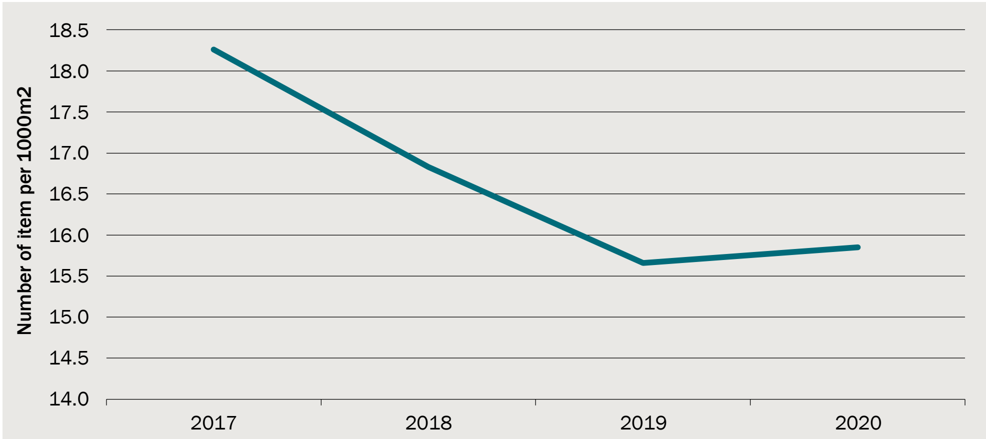
Although cigarette filters contribute the smallest amount to the litter volume (not litter count), among individual items, cigarettes are among the most commonly littered individual item across Australia. In 2020 they represented 16.2 percent of all reported rubbish which is a decrease of 5.8 per cent from 2019.[130]

Figure 6.4 shows a decline in the number of cigarette filters in the NSW environment per 1000m^2.

129 ibid

130 Clean Up Australia 2020 report. See, https://www.cleanup.org.au/rubbish-report

6.4 Estimated number of cigarette filters and packaging per 1,000 m2 in NSW, 2016–20



Data source: NSW Litter report 2016-2020, The CIE.

Cigarette filters used to be the most common littered item in Queensland until 2018-19. Although they are one of the most common single litter items, they only constitute 1 per cent of the volume of litter in Queensland. In 2018–19, plastic items replaced cigarette filters as the most common littered items in Queensland.[131]

Despite contributing a very small fraction to litter volume, cigarette filters continue to be a significant litter load in the environment.[132]

Key items illegally dumped

Garden waste

Householders, small businesses and large businesses are all identified as dumping waste illegally. Illegal dumping occurs most often in locations that are not easily visible by the public. Among these illegally dumped waste, 66 per cent of household respondents and 33 per cent businesses claimed to have disposed of garden waste illegally into the environment.[133]

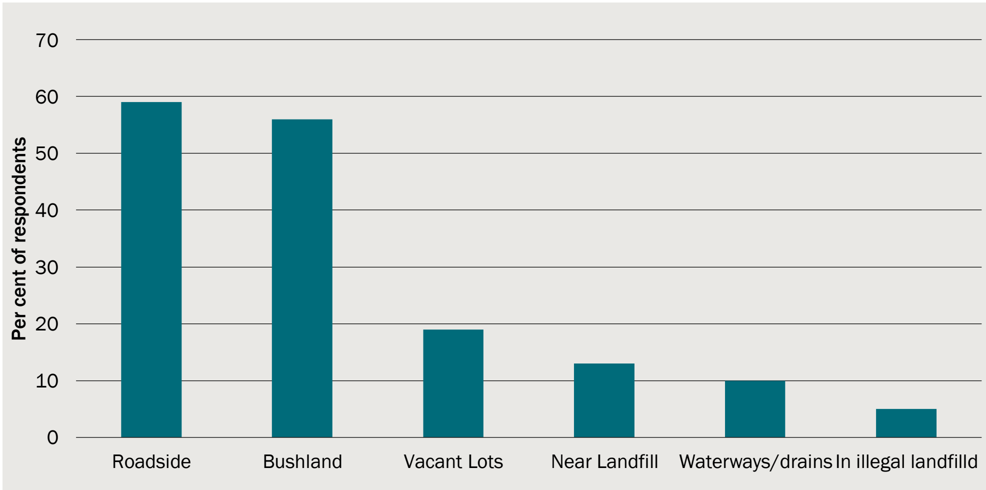
Roadside and bushland sites are the most common sites for illegally dumped waste including green/garden waste (chart 6.5).

131 See, https://www.stateoftheenvironment.des.qld.gov.au/pollution/waste/main-material-types-littered

132 Ibid.

133 NSW EPA. Illegal Dumping research 2019. See, https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/ipsos-report-illegal-dumping-research-2019.pdf?la=en&hash=EF79879EBCCF1DF76306C16AE260D61C1EBF8E94

6.5 Location of illegally dumped waste including green/garden waste in the Illegal Dumping Report 2015



Data source: Illegal Dumping Research Report 2015, NSW EPA

Environmental impacts

The environmental impacts of litter and illegal dumping on terrestrial environments are set out below.

Damage to native vegetation at dumping site

A defining characteristic of illegal dumping (compared to littering) is the volume of material. Dumping large volumes of material in bushland damages native vegetation on the site, directly through smothering current vegetation, limiting opportunities for seedlings as well as potentially changing the soil chemistry due to dumped material.

Invasive plants from illegally dumped green waste

Dumping of green waste is generally perceived as a low-level aesthetic concern, however dumping of green waste causes significant environmental impacts in terrestrial environments. Invasive plants (partly as a result of dumped garden waste) is listed as a key threatening process under the EPBC Act and was also identified in the State of the Environment report as an environmental pressure (see chapter 3).

Potential environmental impacts from illegal dumping of garden waste are:

- introduction of invasive weeds from our gardens into the bushland,
- increase in the amount of soil nutrients that encourage growth of exotic plants and weeds that would compete with native plants preventing natural regeneration of native plants
- increased risk of bushfire from dry garden waste
- introduction of disease, and pests into areas of native bush.

Experts consider illegal green waste dumping is a critical avenue of spreading weeds into natural environments, especially species that would otherwise have trouble growing in bushland. In many cases, residential suburbs near wilderness regions are the biggest perpetrators.[134] The dumping activity can go on for a long time before rangers notice it, and it could take a long time to fix the harm from introduction of weed and invasive plants into the environment.

Garden plants have been, and remain, a significant source of invasive plants. About 400 of the naturalised exotic plant species are identified as harmful or as priority weeds at a region, State or Territory, and National level.[135]

Invasive plants can have a detrimental impact on the biodiversity of various Australian vegetation types, ranging from tropical wetlands to desert riverine vegetation, in natural environments. Weed competition was recognised as the principal cause of the extinction of at least four native plant species, and another 57 species were threatened or would become so in the future due to weed competition. By a wide extent, these estimates most probably understate the current problem.[136]

Many garden plants in Australia become invasive because they are transferred into places where their natural pests and predators, which would normally play an important regulatory role, are absent. In the absence of natural predators and pests, these plants can develop extraordinarily quickly, giving them a competitive advantage over native vegetation.[137]

The environmental impact on Crown land, National Parks, State Forests and the Catchment Authority, was noted to be larger than that on Council land. This is due to factors such as lack of funding, staff resources and time preventing rapid clean up. Illegal green waste dumps are also harder to spot than general waste dumped in these environments. Therefore, they can be overlooked and not reported. This is a key contributing factor to environmental damage.[138]

Invasive pests from illegally dumped green waste

The yellow crazy ant is a highly invasive, non-native species of ant and is listed as one of the top 100 worst invasive species by the IUCN and Global Invasive Species Database. They are a category three restricted pest under the *Biosecurity Act 2014.* The invasive

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134 Coleman, M. J., Sindel, B. M., van der Meulen, A. W., & Reeve, I. J. (2011). The risks associated with weed spread in Australia and implications for natural areas. Natural Areas Journal, 31(4), 368-376.

135 Coleman, M. J., Sindel, B. M., van der Meulen, A. W., & Reeve, I. J. (2011). The risks associated with weed spread in Australia and implications for natural areas. Natural Areas Journal, 31(4), 368-376.

136 ibid

137 ibid

138 NSW EPA. NSW Illegal dumping research. See, https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/ipsos-report-illegal-dumping-research-2019.pdf?la=en&hash=EF79879EBCCF1DF76306C16AE260D61C1EBF8E94

nesting and foraging habits of the yellow crazy ant enable colonies to achieve high densities in a variety of habitats. Suitable nesting grounds include wood debris, rocky substrates, tree bases, leaf litter, mulch, rock walls, pot plants, carports, pool filters and even electrical appliances. Therefore, the illegal dumping of green waste and also other items such as appliances, provides habitat and means of transportation for yellow crazy ants.

Environmental impacts caused by yellow crazy ants include:

- swarming in great numbers and killing larger animals including lizards, frogs, small mammals, turtle hatchlings and bird chicks
- spraying formic acid to blind and kill their prey, this can include spraying acid on people and domestic pets resulting in injury
- large populations of yellow crazy ants can impact on native wildlife and plants, and ecosystems, including invertebrate species inhabiting the Wet Tropics World Heritage Area (WTWHA).
- yellow crazy ants also have a strong mutualism with other invasive species including aphids and scales, thereby enabling other invasive pests to flourish[139]
- damage to household electrical appliances and wiring.

Yellow crazy ant can spread through natural processes, human assisted movements, farming practices and transportation via water. Spring et al (2019) note yellow crazy ant spread relatively slowly in the absence of jump events (e.g. human assisted movements).[140] Human assisted 'jump events' which relate to litter and illegal dumping include the illegal dumping of household green waste.

The proportion of yellow crazy ant spread which is attributable to litter and illegal dumping (primarily household green waste) is not known. This is partly due to the ad-hoc nature of illegal dumping, as opposed to a systemic cause.

Chemical contamination cigarette filters

Impacts to vegetation

One study conducted a greenhouse experiment to examine the impacts of cigarette filters on the growth and development of vegetation (perennial ryegrass and white clover). The results indicated the potential for cigarette filters to reduce growth of terrestrial plants.[141] These results are evidence of impact; however further information is required to establish the extent of these impacts in the natural environment.

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139 Wet Tropics Management Authority, *Impacts of YCA,* https://www.wettropics.gov.au/why-do-we-care, Accessed 8 November 2021.

140 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

141 Green, D., Boots, B., Carvalho, J., Starkey, T., 2019, *Cigarette butts have adverse effects on initial growth of perennial ryegrass (Gramineae: Lolium perene L.) and white clover (Leguminosae: Trifolium repes L.)*, Ecotoxicology and Environmental Safety 182 (1): 109418, July 2019.

Impacts to animal and human health

There is a risk that land based animals and also human infants could ingest littered cigarette filters. Novotny et al. 2011, found that there have been tens of thousands of reported incidences of human and animal exposure to cigarette filters, yet severe toxic outcomes due to ingestion of filters is rare.[142] Novotny (2011) note the following impacts from ingestion of cigarette filters:

- 1-2mg/kg of nicotine in young children may be toxic, causing nausea and vomiting in low doses, and more extensive neurological symptoms with higher doses.
- an oral minimum lethal dose of nicotine in dogs is reported to be 9.2mg/kg, with clinical signs reported at doses as low as 1 mg/kg. In small dogs, ingestion of one cigarette can cause signs
- pet birds are particularly sensitive to the chemicals from ingesting cigarette filters, with reports that pet birds have died after ingesting filters left in household trays.

Based on available reports in the literature, ingestion does occur by small children and domestic animals. However severe poisoning by cigarette filters among children and domestic animals is rare.[143]

Novotny et al. (2011) noted that whilst there was minimal reporting of cigarette filter consumption by wildlife, it did not necessarily mean that ingestion by wildlife does not occur.[144]

Human health impacts from illegally dumped asbestos

Illegally dumped asbestos is a risk to human health. Asbestos fibres can be inhaled and can cause a range of life-threatening illnesses, including: cancers (including mesothelioma and cancers of the lung, ovary and larynx); asbestosis and pleural plaques. These asbestos--related diseases contribute around 4000 deaths in Australia each year. [145]

Illegally dumped asbestos is a contributing factor to the broader problem of human health impacts from asbestos. In general, it is difficult to link cases of asbestos-related disease to exposure to illegally dumped material for several reasons, including:

- people exposed to asbestos fibres through illegally dumped material may not be aware they have been exposed
- the lag between exposure and the onset of symptoms of asbestos-related disease is generally several decades.

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142 Novotny, T., Hardin, S., Hovda, L, Novotny, D, McLean, M. K., and Khan, S., 2011, *Tobacco and cigarette butt consumption in humans and animals,* Research Paper, Tobacco Control 2011; 20, https://tobaccocontrol.bmj.com/content/tobaccocontrol/20/Suppl_1/i17.full.pdf. Accessed September 2021.

143 Ibid.

144 Ibid.

145 Asbestos Safety and Eradication Agency website, https://www.asbestossafety.gov.au/asbestos-health-risks-and-exposure/asbestos-health-risks, accessed 12 October 2021.

As such, there is currently insufficient information to attribute the impact from illegally dumped asbestos, as opposed to other exposure avenues including construction.

Fire risk

Litter and illegally dumped material have potential to contribute to fire risks. Fire related impacts can occur where:

- The littered or dumped item is the ignition point (e.g. where lit cigarettes or glass causes a bushfire) as in those cases the fire would not have occurred without the littered/dumped material
- The littered or dumped material causes specific problems that would not otherwise have occurred — the main example here relates to tyre fires

Whilst there are instances of littered/dumped material, such as cigarettes and tyres, contributing to fires, it is difficult to assess the overall extent to which littered/dumped material contributes to fire risk and fires that have occurred.

Value of environmental impacts

Invasive plants

By far the greatest impact of green waste is the impact on biodiversity brought on by invasive plants introduced into the environment as evidenced by the multitude of studies that have looked into the cost of weed propagation in natural environments. Estimates include the following (although it is not clear how some of these estimates were arrived at).

- Weeds reportedly cost the Victorian economy over $900 million each year.[146]
- Weeds reportedly cost the NSW economy $1.8 billion each year in lost agricultural production and management costs.[147]
- The recent Centre for Invasive Species report estimates the economic costs of weeds to Australia of $5 billion annually (approximately $14 million a day). Ninety per cent of this cost is borne by agriculture, representing a high burden on that sector.[148]
- A Queensland study estimated the community's willingness to pay (using the contingent valuation method) to control the impacts of exotic plants (such as Lantana and Singapore Daisy) on areas of high conservation significance.[149] The management

146 See, https://www.environment.vic.gov.au/invasive-plants-and-animals/invasive-species-on-public-land

147 See, https://www.soe.epa.nsw.gov.au/all-themes/biodiversity/invasive-species

148 Mcleod, R. (2018). Annual Cost of Weed in Australia. Centre for Invasive Species Solution. See, https://invasives.com.au/wp-content/uploads/2019/01/Cost-of-weeds-report.pdf

149 Tumaneng-Diete, T. Page, A. and Binney, J. 2005, Assessing the economic values of exotic invasive plants on areas of conservation significance in Queensland, Paper presented at the

scenarios examined were: stopping and preventing expansion of the environmental weed; and stopping weed expansion and reducing the area of infestation.

– The study estimated the community's willing to pay was around $70-$80 per household (converted to 2020 dollar terms using the national CPI) (table 6.6)
– This equates to around $144-$162 million per year (based on an estimated 1.98 million households in Queensland).

6.6 Estimated willingness to pay for environmental weed control

	Estimated household WTP (2004)[a]	Estimated household WTP (2020)[b]	Aggregate for Queensland[c]
	$	$	$ million
Lantana - stop the spread	56.88	81.7	162.0
Lantana - reduce area infested	53.08	76.3	151.2
Singapore Daisy - stop the spread	52.69	75.7	150.1
Singapore Daisy - reduce area infested	50.56	72.6	144.0

[a] Tumaneng-Diete, Page and Binney (2005, p. 11). [b] Inflated to 2020 dollar terms using the national CPI. [c] Based on an estimated 1.98 million households in Queensland.

Note: Uses estimates from logit model.

Source: Tumaneng-Diete, T. Page, A. and Binney, J. 2005, Assessing the economic values of exotic invasive plants on areas of conservation significance in Queensland, Paper presented at the Australian Agricultural and Resource Economics Society, 49th Annual Conference, 9-11 February 2005, p. 11, ABS, CIE.

Some of the studies that estimate the cost of weeds tend to focus mostly on the impacts on the agriculture industry. The estimated costs of 'environmental weeds' are based on public spending on weed control. Although 'defensive expenditure' is sometimes used as a proxy for environmental costs, there is rarely a close link between defensive expenditure and intrinsic economic value. As such, this approach is rarely suitable for quantifying economic value.[150]

Using an alternative approach, we estimate an aggregate willingness to pay across NSW, Victorian and Queensland households to stop the spread of invasive garden species of around $3.1 billion per year. This is based on the following assumptions.

- Based on the information in table C.16 above, there are:[151]
  – 6 invasive garden species that are threatening a native plant species in NSW (Bitou Bush, Bridal Creeper, Lantana, English Broom, Blackberry and Dutchman's Pipe)
  – 5 invasive garden species that are threatening a native plant species in Victoria (English Broom, Blackberry, Cape Broom, Radiata Pine, Quaking Grass)
  – 5 invasive garden species that are threatening a native plant species in Queensland (Dutchman's Pipe, Para Grass, Lantana, Pink Periwinkle, Rubbervine).

Australian Agricultural and Resource Economics Society, 49th Annual Conference, 9-11 February 2005.

150 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 34.

151 Note that some species are double-counted across multiple states. This is appropriate in this case.

- Each household is assumed to be willing to pay $74.46 to control each invasive garden species that is threatening a native plant species in their state. This is based on the average estimate to reduce areas infested (which is the management strategy most closely aligned to the impacts of dumping garden waste) averaged across Lantana and Singapore Daisy (see table 6.6 above)
- These estimates are aggregated across all households and species.

6.7 Estimated aggregate willingness to pay to control environmental weeds

	Number of invasive garden species	Number of households	Aggregate WTP per species[a]	Annual WTP to reduce area infested by invasive garden species
	No.	Million	$ million	$ billion per year
NSW	6	3.13	233.14	1.40
Victoria	5	2.61	194.67	0.97
Queensland	5	1.98	147.62	0.74
Total			**575.42**	**3.11**

[a] Assumes each household is willing to pay $74.46 to reduce the infestation area for each invasive garden species that is threatening at least one native species in their state.

Source: CIE estimates.

Illegally dumped garden waste contributes to the broader problem of invasive plants. In order to value the environmental impact of illegally dumped garden waste, data is required on its contribution to the broader problem. Currently there is no systematic data on the quantity of illegally dumped green waste, nor the incidence of invasive plants spreading and damaging native species to attribute impact to illegally dumped green waste.

A New Zealand study estimated that:[152]

- garden dumping can greatly enhance the spread of weed species with limited natural dispersal (indicating a high share of the impacts of these weeds could be attributed to illegal dumping).
- garden dumping makes little difference to the time taken to reach a reserve for those weeds that already disperse long distances, by wind or birds (indicating that for these species, the marginal impact of illegal dumping would be low).

However, in the absence of a sound basis to attribute the environmental costs associated with escaped garden plants to illegal dumping, table 6.8 shows indicative estimates under various attribution assumptions.

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152 Timmins, S.T. James, A. Stover, J. and Plank, M. 2010, Is garden waste dumping really a problem?, Conference Paper, Seventeenth Australasian Weeds Conference, 26-30 September 2010.

6.8 Indicative estimates of the costs attributable to illegal dumping under various attribution assumptions

	10% attributed to illegal dumping	20% attributed to illegal dumping	30% attributed to illegal dumping	40% attributed to illegal dumping	50% attributed to illegal dumping
	$ million	$ million	$ million	$ million	$ million
NSW	139.9	279.8	419.6	559.5	699.4
Victoria	97.3	194.7	292.0	389.3	486.7
Queensland	73.8	147.6	221.4	295.2	369.1
Total	**311.0**	**622.1**	**933.1**	**1 244.1**	**1 555.1**

Source: CIE estimates.

Invasive pests

The total cost incurred due to the spread of yellow crazy ants is dependent on whether current eradication efforts are successful at suppressing or completely eradicating the ants. In the absence of a successful eradication program, costs are incurred by the:

- agricultural sector through use cost of treatment sprays and/or loss of production value
- tourism sector through damage to infrastructure and/or declining tourism trade
- local community through social dis-amenity impacts and damages to domestic infrastructure
- loss of species and ecosystem services in natural areas.

A study estimated the socio-economic costs of yellow crazy ants in the absence of a successful eradication program would exceed $700 million over the seven years.[153]

Eradication efforts are ongoing in the wet tropics region of Queensland involving numerous rounds of treatment (aerial and on-ground) and surveys. The total treatment area is approximately 2000 hectares including 133 hectares within the Wet Tropics World Heritage Area.[154] The eradication program is on track to achieve eradication within a ten-year timeframe.[155]

With the current eradication program is place, the predominant impact category for yellow crazy ants is 'clean-up cost'. The Wet Tropics Management Authority (WTMA)

153 Invasive Species Council, *Yellow crazy ant eradication program,* https://invasives.org.au/our-work/invasive-insects/ants/yellow-crazy-ants/ Accessed 8 November 2021.

154 Queensland Government, 2020, *Wet Tropics Management Authority's Yellow Crazy Ant Eradication Program:* August Report Card 2020 https://www.wettropics.gov.au/site/user-assets/AugustReportCard2020FinalLR.pdf Accessed 28 October 2021.

155 Invasive species council, *Yellow Crazy Ants,* https://invasives.org.au/our-work/invasive-insects/ants/yellow-crazy-ants/

estimates the annual cost of the eradication program is $6 million per year for 7 years, equivalent to a present value of $34.6 million.[156]

However, where the eradication program is yet to be effective, or in the absence of an eradication program all together there would be costs to industry and environmental impacts:

- Spring et al (2019) estimated the avoided control costs (e.g. pesticide expenditure, treatment costs) and avoided damages (e.g. crop losses) due to eradication program at $548 million (present value applying 7 per cent discount rate).
- Spring et al (2019) also estimated the environmental benefits of eradicating yellow crazy ants. This was based on an estimated willingness to pay by Australian households of $47 per household to avoid the extinction of seven native species.[157] The total avoided costs from the eradication program, including the avoided environmental costs, was estimated at $6.1 billion (present value applying 7 per cent discount rate).[158]

Illegal dumping has contributed to the spread of yellow crazy ants and the associated costs. However, there is currently a lack of information to attribute these costs to the spread caused by illegal dumping (primarily green/garden waste).

Damage to native vegetation at illegal dumping sites

Although the volume of illegally dumped material and the area of native vegetation damaged through illegal dumping is unknown, the associated environmental costs are likely to be small, compared to other environmental costs, as well as clean-up and amenity costs.

156 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

157 Akter, S., Kompas, T. and Ward, M.B., 2015. Application of portfolio theory to assetbased biosecurity decision analysis. Ecological Economics, 117, pp.73-85 sourced in Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

158 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

PART II

Appendices

A Literature review of environmental impacts in marine environments

Evidence of material in marine environments

Marine debris includes "*any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment*".[159]

A CSIRO study into the pathways through which debris reaches and moves into the marine environment found that:

- human deposition was by far the most important factor determining the debris load at a particular site.
- transport via water was the second most important factor.
- wind transport made a smaller (but discernible) contribution to the debris load.[160]

Land-based marine pollution originates from urban and industrial waste sites, sewage outlets, stormwater, litter transported by systems, and litter discarded by beach users. The Ocean Conservancy (2015) investigated the key sources of plastic leakage into the ocean and found at least 80 per cent of ocean plastic comes from land-based sources. [161]

Sea or ocean-based source of marine debris include discarded or lost material from vessels. These vessels include merchant ships, fishing trawlers as well as offshore oil and gas platforms.[162] Until the International Convention for the Prevention of Pollution from Ships was enacted, ship-sourced rubbish was traditionally disposed of at sea. The maritime industry is thought to be responsible for 20 per cent of all marine debris.[163]

Operating under the paradigm that 80 per cent of marine debris comes from terrestrial sources with only 20 per cent from activities at sea has been contested in many recent studies suggesting a greater proportion should be attributed to marine activities. The actual ratio is likely to be location dependent and it can change significantly over short

159 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica, page 7.

160 CSIRO, *Identifying and understanding the sources of marine debris,* Fact sheet.

161 Ocean Conservancy, 2015, *Stemming the Tide: Land-based strategies for a plastic-free ocean.*

162 Vegter, AC, et al., 2014, 'Global research priorities to mitigate plastic pollution impacts on marine wildlife', Endangered Species Research, 25: 225–247 http://www.int-res.com/articles/esr_oa/n025p225.pdf, p. 233

163 Commonwealth Government of Australia, 2016, The threat of marine plastic pollution in Australia. Accessed from https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Marine_plastics

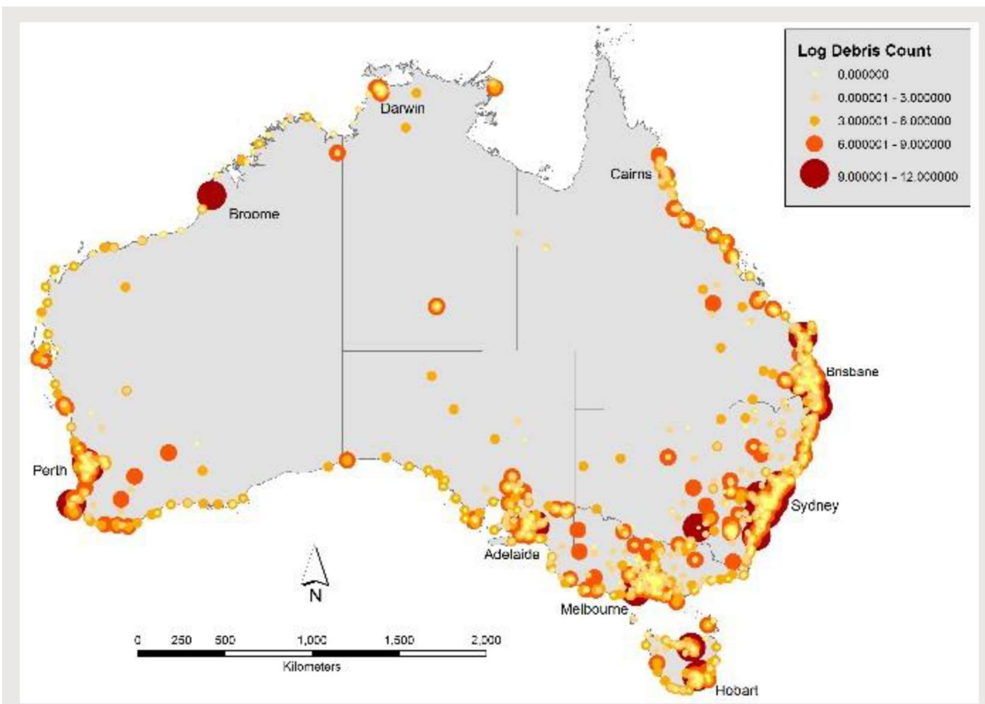
spatial scales depending on characteristics including aspect and proximity to key, local delivery mechanisms.[164] Based on data collected through the Australian Marine Debris Initiative, 52 per cent was related to sea activity and 48 per cent came from land-based sources between 2019 to 2021.[165]

Other key findings from CSIRO's research in terms of pathways to the marine environment include:

- most of the rubbish along the Australian coast is from Australian sources, not from overseas
- debris is concentrated around major cities and urban centres which suggests local sources (see chart A.1).

In the case of debris movement by wind and water, by far the majority of pollution occurs from stormwater runoff into rivers and streams which subsequently make their way into marine waters. [166]

A.1 Debris hotspots based on survey data



Data source: CSIRO, *Identifying and understanding the sources of marine debris,* https://www.csiro.au/-/media/OnA/Files/CSIRO_APC_Factsheet.pdf

164 Smith, Stephen & Banister, Kelsey & Fraser, Nicola & Edgar, Robert. (2018). Tracing the source of marine debris on the beaches of northern New South Wales, Australia: The Bottles on Beaches program. *Marine Pollution Bulletin*. 126. 304-307. 10.1016/j.marpolbul.2017.11.022.

165 Tangora Blue, 2021, Australian Marine Debris Initiative. Accessed from https://amdi.tangaroablue.org/dashboard

166 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

In 2010, coasts adjacent to urban centres and remote areas of north-western Cape York, Groote Eylandt, north-east Arnhem Land, the far north Great Barrier Reef, parts of South Australia, including Anxious Bay, parts of Western Australia, south-west Tasmania, and Australia's sub-Antarctic Islands were identified as areas where debris was reported at comparatively high densities.[167] According to RCA surveys, subtidal marine debris abundance was relatively low over Queensland reefs, but increased on reefs adjacent to high-use recreational regions like Brisbane, the Gold Coast, Magnetic Island, and the Palm Islands. Marine debris assessments in New South Wales, Queensland's adjacent state, found lower levels of debris in offshore reefs but higher densities closer to estuaries and nearshore reefs.[168] In 2016, the greatest concentrations of debris were found along Australia's southwestern margin.[169]

Land-based coastal surveys have provided the majority of the information and data on the sources, magnitude, and impacts of marine debris in Australia. Because debris can sink, become buried below, or become entangled underwater on rocky outcrops and reefs, this data likely underestimates the true concentration of marine debris in Australia's marine and coastal habitats. Some localised instances of snorkelling and diving surveys were also considered. Volunteer diving programmes, however, frequently visit recognised debris-prone locations, therefore their data cannot be used to assess overall patterns of subtidal debris abundance.

Existing estimates of debris and plastic concentration in the Australian marine environment is limited by the sampling locations considered. Many studies have looked into various localised estimates, aggregate estimates from clean-up initiatives, as well as employing novel monitoring tools such as measuring the presence of ingested plastic in marine birds and animals.

Table A.2 highlights some of the literature on evidence of marine debris in and around Australia, especially the level of plastic concentrations in the Australian marine environment.

167 Department of the Environment, Water, Heritage and the Arts, Background Paper for the Threat Abatement Plan for the impacts of marine debris on vertebrate marine life, May 2009, p. 2; see also Australian Institute of Marine Science, Submission 11, p. 3.

168 Using citizen science data to assess the difference in marine debris loads on reefs in Queensland, Australia

169 Hardesty, B., van der Velde, T., Lawson, TJ., Wilcox, C., 2016, *Estimating quantities and sources of marine debris at a continental scale,* Frontiers in Ecology and the Environment, December 2016.

A.2 Range of estimates of marine debris and plastic found in Australia

Source	Year	Key findings
National Plastics Plan (2021)	2021	▪ In Australia approximately 130 000 tonnes of plastic leaks into the marine environment each year
Hajbane, S. et al. (2021) Coastal Garbage Patches: Fronts Accumulate Plastic Films at Ashmore Reef Marine Park (Pulau Pasir), Australia	2021	▪ Mean plastic concentrations of 523 146 pieces per kilometre square for plastics > 500 micrometre comparable to the largest known accumulation zone (Great Pacific garbage patch), greater than surrounding waters that contained 16 561 pieces per kilometre square ▪ Plastics accumulated in fronts encountered within the Ashmore Reef marine park, northern Australia and surrounding waters were sampled using Manta trawls, drone, and snorkel surveys conducted in October 2018.
Barrett et al. (2020) “Microplastic pollution in Deep-Sea Sediments from the great Australian Bight”	2020	▪ Great Australian Bight sediment samples with microplastic range from 0 to 13.6 fragments per g of dry sediment ▪ Concentration ranges from 0 to 105 438.6 microplastic pieces per square km (median 4 363.7, mean 8 966.3, SD 1 330.75)
Hitchcock, J. N. (2020) “Storm events as key moments of microplastic contamination in aquatic ecosystems”	2020	▪ Microplastic abundance increased during two days of heavy rain from 400 particles metre cube before storm event to up to 17,383 particles metre cube after flooding in the Cooks River estuary, Australia
AusMap Microplastic Assessment project	2019	▪ Burdekin Dry Tropics region near Townsville had 27 microplastics per square metre - made up of mostly hard plastic fragments and polystyrene foam. ▪ Other estimates: Cape York = 8-9, Wet Tropics = 2-3, Mckay-Whitsundays = 6-7 and Fitzroy = 16-17 (microplastics per square metre) ▪ South Australia is home to two microplastic hotspots with the highest loads found in Australia, Port Adelaide and West Lakes. – Values from West Lakes Adelaide were between 5500 and 9500 microplastics per square metre ▪ Approximately 1600 microplastics per square metre collected from Sydney Harbour beach ▪ Amount of plastics in Manly went down from 1200 plastics per square metre to less than 200 pieces per square metre after the volunteer beach clean-up drive
Bauer-Civiello, A et al. (2018). “Using citizen science data to assess the difference in marine debris loads on reefs in Queensland, Australia”	2018	▪ Highest debris loads were recorded in SEQ near cities and high use areas. ▪ Overall, debris abundance across reefs was relatively low (average 0.5–3.3 items per survey ~400 square metre), but not absent on remote reefs surveyed in the Great Barrier Reef region
Hajbane and Pattiaratchi (2017) “Plastic Pollution Patterns in Offshore, Nearshore and Estuarine Waters: A Case Study from Perth, Western Australia”	2017	▪ Plastic Pollution ranged from 950 to 60 000 pieces per kilometre square and was dominated by fishing line ▪ Mean offshore concentration of 4 957 pieces per kilometre square comparable to previously recorded concentrations of 4256.4 pieces per kilometre square in 2013

Source	Year	Key findings
Wilson and Verlis (2017) “The ugly face of tourism: Marine debris pollution linked to visitation in the southern Great Barrier Reef, Australia”	2017	▪ The greatest accumulation occurred on the windward side of Wreck Island with 4.7 items accumulating per day on average and amounts equating to 0.1 items per square metre of beach; On leeward side – 0.5 items per day and levels of 0.02 items per square metre ▪ The lowest accumulation was on the leeward side of Northwest Island at 0.3 items/day and levels equal to 0.01 items per square metre of beach. On the wind ward side 1.2 items/day and levels equal to 0.05 items per square metre of beach ▪ Tyron Island (windward) – 0.9 items per day and 0.03 items per square metre ▪ Heron Island (windward) – 0.9 items per day and 0.04 items per square metre; For the leeward side –0.07 items per square metre
Ling, S. D. et al (2017) “Ubiquity of microplastics in coastal seafloor sediments”	2017	▪ 9 552 individual microplastics from 2.84 litres of sediment across all samples (a regional average of 3.4 microplastics per ml sediment) from 42 coastal sites spanning pollution gradients across south-eastern Australia.
Clark and Johnston, (2016) “Australia State of the environment 2016”	2016	▪ Survey data from beach-based clean ups indicates that Queensland beaches can accumulate between 439 and 2806 plastic items per km per year
Smith, S. D. A (2014) “Documenting the Density of Subtidal Marine Debris across Multiple Marine and Coastal Habitats”	2014	▪ Surveys of 120 sites along 1 000 km of the coast of eastern Australia recorded a total of 2 986 items of marine debris. ▪ Debris loads (items per transect) ranged from 0 (210 of the 470 transects contained no debris) to 218
Verlis, K. M. et al. (2014). “Marine debris is selected as nesting material by the brown booby (Sula leucogaster) within the Swain Reefs, Great Barrier Reef, Australia”	2014	▪ Marine debris used in nest material of the brown in the Great Barrier Reef, Australia, was investigated to find 58.3 per cent of surveyed Sula leucogaster nests contained marine debris. ▪ An average of 0.01 marine debris items per square metre were found on surveyed beaches.

Source: CIE.

Plastic in marine debris is a primary source of concern because of its widespread dispersion in the water column, on the seabed, and along coastal shorelines. The majority of this marine debris is plastic, which due to its chemical makeup is a long-lasting material. Around 75 per cent of beach rubbish is made of plastic.[170] Plastics, once released into the environment, never biodegrade, instead photodegrading breaking into smaller and smaller pieces (as microplastics), they remain in the marine ecosystem for decades causing possible entanglement of marine life or in the case of microplastic resulting in plastic ingestion.

There are an estimated 14 million tonnes of microplastic that reside on the ocean floor as part of sediment globally.[171] Among 90 per cent of all debris items ingested across

170 Hardesty, B.D. et al., 2015, A biochemical approach for identifying plastics exposure in live wildlife. *Methods Ecol Evol*, 6: 92-98. https://doi.org/10.1111/2041-210X.12277

171 Microplastic pollution in Deep-Sea Sediments from the great Australian Bight, October 2020

species fall within a narrow "danger zone" range of 2–10 mm, overlapping with the most abundant oceanic debris size.[172]

Wootton et al. (2021) determined the microplastic abundance in nine commercially important, wild-caught fish species purchased from seafood markets across Australia in Western Australia, South Australia, Victoria, Tasmania, New South Wales. Microplastic was found in 35.5 percent of the fish (249 of the 702 analysed), with an average of 0.96 (0.08) piece of microplastic per fish. The bulk of microplastic bits (66 percent) were larger than 1 mm in diameter, with the rest falling between 38 m and 1 mm.[173]

All shearwater boluses sampled from Lord Howe Island between 2002 to 2020 contained plastic. On average, boluses contained 21.8 plastic items weighing a total of 4.0 g. [174] From 2002 to 2015, the amount of plastic in shearwater boluses decreased, then increased again until 2020.[175] Analysis of the stomach contents of seabirds and coastal birds of South-eastern Australia, both migratory and native, demonstrated 30 per cent of all birds sampled containing plastic. The median mass of plastic per bird was 41.7 mg and median number of pieces was 3.0. Shearwaters Puffinus had significantly higher plastic mass and number of pieces than other species, and the most common type of plastic was manufactured fragments.[176]

The interrelationship of microplastic pollution in sediments and oysters in an eastern Australian seaport environment revealed a significant abundance of microplastic particles in both sediments and oysters in all of the studied seaports, with 83–350 particles/kg dry weight in sediments and 0.15–0.83 particles/g wet weight in oysters.[177]

Roman et al. (2016), investigated the gastrointestinal contents of 378 birds across 61 species, collected dead across Eastern Australia among which thirty percent had ingested debris, though ingestion did not occur uniformly within the orders of birds surveyed. Debris ingestion was discovered in the orders Procellariiformes, Suliformes, Charadriiformes, and Pelecaniformes, as well as in all examined habitats and among birds that foraged via surface feeding, pursuit diving, and sight search. The most debris

172 Roman, L., Paterson, H., Townsend, K. A., Wilcox, C., Hardesty, B. D., & Hindell, M. A. (2019). Size of marine debris items ingested and retained by petrels. Marine pollution bulletin, 142, 569–575. https://doi.org/10.1016/j.marpolbul.2019.04.021

173 Wootton, N., Reis-Santos, P., Dowsett, N., Turnbull, A., & Gillanders, B. M. (2021). Low abundance of microplastics in commercially caught fish across southern Australia. Environmental Pollution, 290, 118030.

174 Bond, A. L., Hutton, I., & Lavers, J. L. (2021). Plastics in regurgitated Flesh-footed Shearwater (Ardenna carneipes) boluses as a monitoring tool. Marine Pollution Bulletin, 168, 112428.

175 ibid

176 Gilbert, J. M., Reichelt-Brushett, A. J., Bowling, A. C., & Christidis, L. (2016). Plastic ingestion in marine and coastal bird species of southeastern Australia. *Marine Ornithology*, *44*, 21-26.

177 Jahan, S., Strezov, V., Weldekidan, H., Kumar, R., Kan, T., Sarkodie, S. A., ... & Wilson, S. P. (2019). Interrelationship of microplastic pollution in sediments and oysters in a seaport environment of the eastern coast of Australia. *Science of the Total Environment*, *695*, 133924.

was eaten by Procellariiformes, birds in pelagic areas, and surface feeding marine birds.[178]

Fig A.3 and Fig A.4 shows the microplastic mapping of AusMap Microplastic Assessment project results along the Queensland coast and Sydney that show the microplastic load encountered during the study.

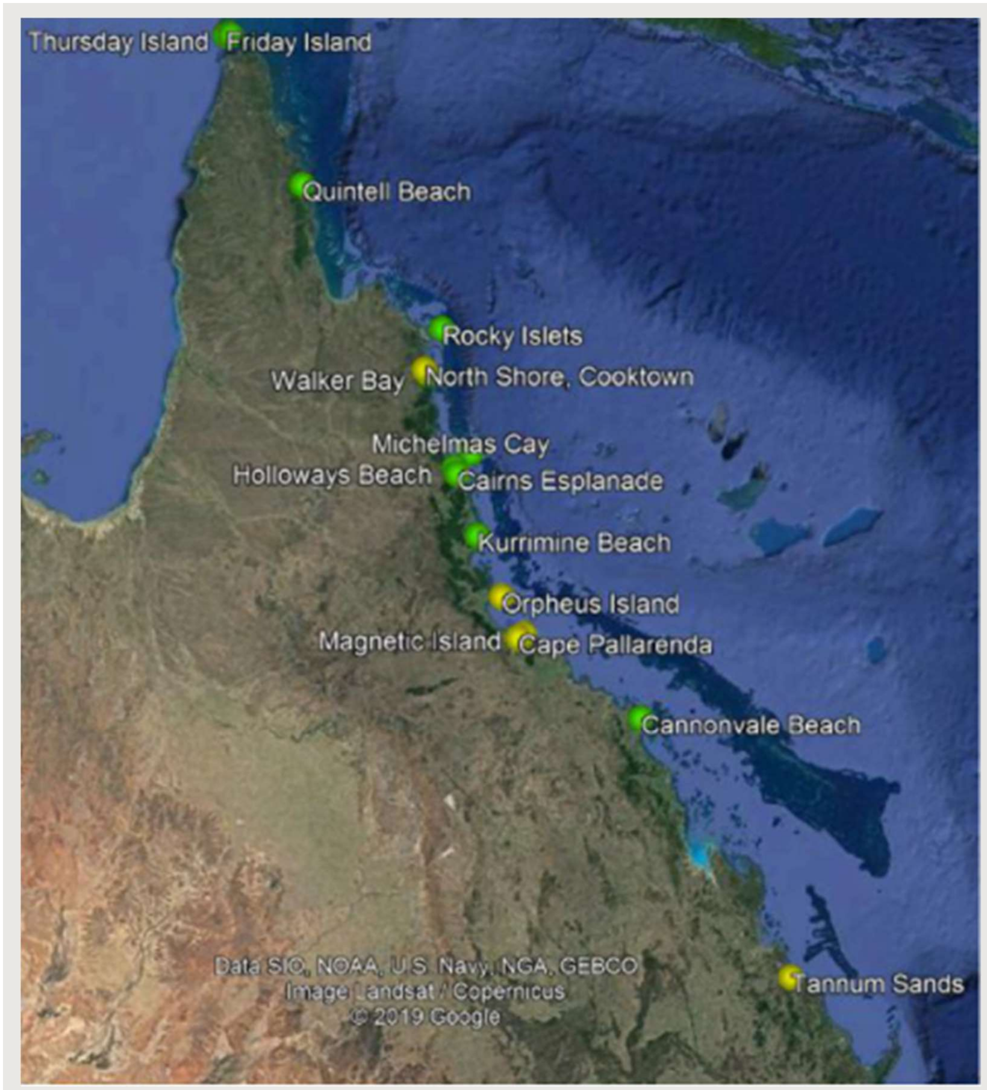
A.3 Microplastic loads collected during sampling in 2019 around Sydney

Data source: AusMap Microplastic Assessment Project

Sydney data shows the variable nature of the microplastics in the region with loads ranging from low to very high. Harbour sites were found to consistently have moderate to high microplastic loads pointing to this catchment as a major source to the nearby coast.

178 Roman, L., Schuyler, Q. A., Hardesty, B. D., & Townsend, K. A. (2016). Anthropogenic debris ingestion by avifauna in eastern Australia. PLoS One, 11(8), e0158343.

A.4 Map of microplastic loads along Queensland Coast



Note: Green points indicate very low levels (<10mps/m2) and yellow points low levels (10-50mps/m2)
Data source: AusMap Microplastic Assessment Project.

Marine debris composition in the Australian environment

The Australian Marine Debris Initiative collected information on the top 10 items found during beach and water clean-up by Tangaroa Blue volunteers across Australia. Table A.5 shows the amount of each item collected between 2019 to 2021. Plastics have now surpassed cigarette filters[179] as the most often removed product group during clean-ups.[180] The majority of the top 10 items are plastic or are usually made of plastic.

179 It is noted that cigarette filters contain plastics.

180 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

A.5 Top 10 items from clean-up of Australian beaches and waterways collected between 2019 to 2021

Item	Total number of items
Plastic bits & pieces hard & solid	1 574 344
Lids & tops, pump spray, flow restrictor & similar	377 433
Cigarette butts & filters	272 258
Plastic film remnants (bits of plastic bag, wrap etc)	259 422
Foam insulation & packaging (whole and remnants)	238 825
Plastic packaging food (wrap, packets, containers)	181 566
Plastic drink bottles (water, juice, milk, soft drink)	102 649
Glass or ceramic broken	96 484
Rope & net scraps less than 1 metre	79 609
Straws, confection sticks, cups, plates & cutlery	75 748

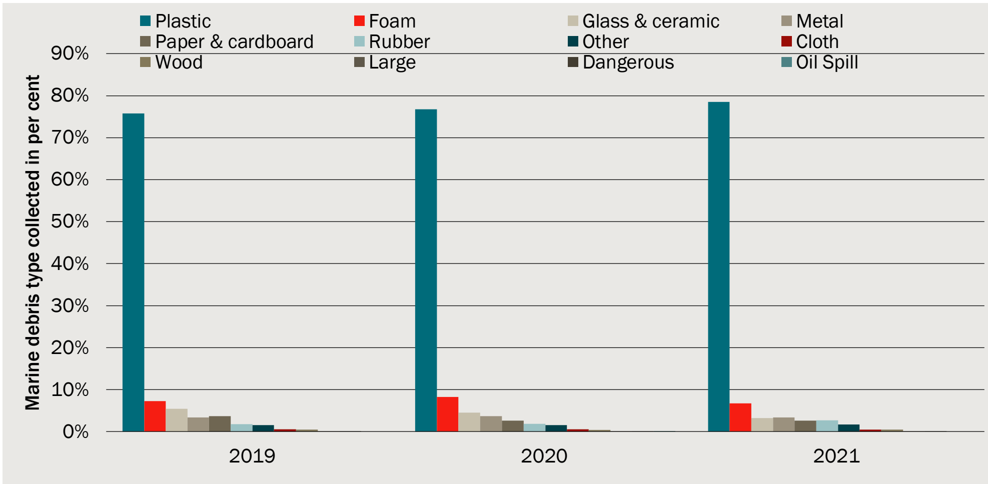
Note: Data collected between December 2019 to December 2021

Source: Australian Marine Debris Initiative

Chart A.6 and A.7 identifies the yearly proportion and quantities, respectively, of each type of material collected from the marine environment by volunteers. Plastic overwhelmingly constitutes the highest proportion of debris material encountered during clean-up initiatives across Australia. Between 2019-2021, plastic made up around 75 per cent of all waste product encountered by volunteers. This is consistent with global estimates of proportion of plastic in marine debris.[181] The next most common type of debris material was foam (a plastic) (6 to 8 per cent), followed by glass or ceramics (3 to 5 per cent). From 2019 to 2021, the composition of marine debris collected has remained fairly consistent over the three years.

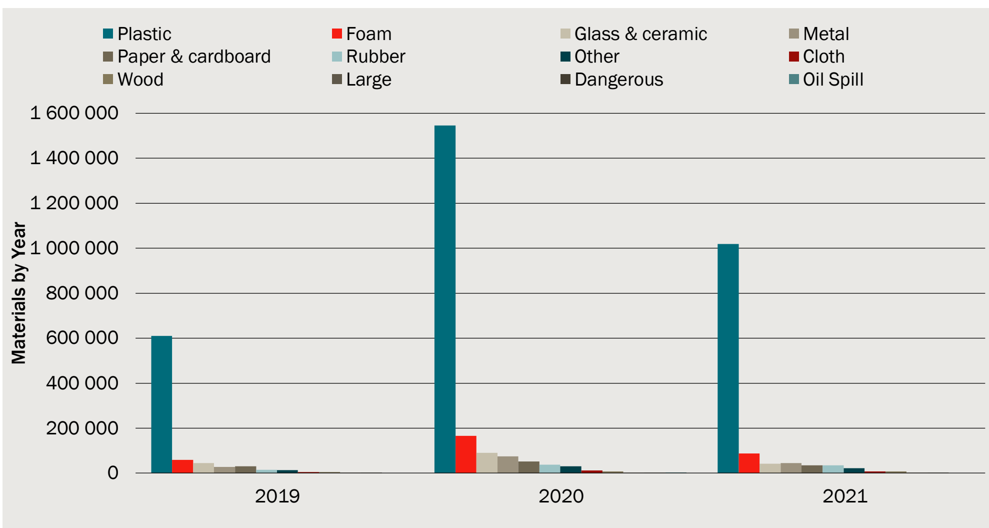
181 Sherrington, C. et al., (2014). Report I: Migratory Species, Marine Debris and its Management. Accessed from https://www.cms.int/sites/default/files/document/COP11_Inf_27_Report_I_Marine_Debris_Management_Eonly.pdf

A.6 Type of material collected by year of Clean up initiative across Australia



Data source: Australian Marine Debris Initiative

A.7 Total collected marine debris by material type and year



Data source: Australian Marine Debris Initiative

Table A.8 highlights some existing literature available on the debris composition in the Australian marine environment. Fishing line and nets make up a huge proportion of sea-based marine debris especially around areas where there is more fishing activity. Highest debris loads were found near areas of more human activity such as coastal cities or urban centres, tourist locations and other high use areas. The majority of these would include plastics or plastic products, food litter, packaging materials, cigarette etc. Therefore, marine debris composition will vary from location to location and region to region based on the most common activity conducted.

A.8 Most common type of Marine debris and Plastic in Australian Marine environment

Source	Year	Key findings
Coastal Garbage Patches: Fronts Accumulate Plastic Films at Ashmore Reef Marine Park (Pulau Pasir), Australia,2021	2021	▪ FTIR spectroscopy found 73.3% were Polyethylene (PE) and 23.3% were Polypropylene (PP) in the coastal garbage patch (CGP). These findings are comparable with proportions found in the Great Pacific Garbage Patch, with 63.6% PE and 20.5% PP. ▪ Other plastics included 5.7% hard/rigid, and 0.4% foam fragments ▪ Identifiable plastic objects found in the CGP were predominantly single use packaging films, followed by Styrofoam cups and bottle lids
AusMap Microplastic Assessment project		▪ Type of microplastic at West Lakes Adelaide 14% Pellet, Hard Fragment 15%, Foam 71% ▪ Type of microplastic in Manly Cove in December 2018 was 50% hard fragment, 40% foam, ~10% pellet
Using citizen science data to assess the difference in marine debris loads on reefs in Queensland, Australia	2018	▪ Fishing line and net made up over half of the debris items (72% and 7% respectively) in South-east Queensland, ▪ 17% of the items recorded in the Great Barrier Reef were made up of fishing net and line (9% fishing line, 8% fishing net) ▪ In the Great Barrier Reef 82% of the items were recorded as 'general rubbish
Plastic Pollution Patterns in Offshore, Nearshore and Estuarine Waters: A Case Study from Perth, Western Australia,	2017	▪ The most common type of plastic overall was fishing line (38%), especially in the nearshore and estuarine areas, closely followed by hard plastic fragments (35%), which dominated in the offshore. ▪ Primary microplastics in the form of cosmetic microbeads made up 6% ▪ Smallest fragments of plastic products were found in the offshore, and the largest in the estuary
Wilson and Verlis (2017) "The ugly face of tourism: Marine debris pollution linked to visitation in the southern Great Barrier Reef, Australia"	2017	▪ When analysing the types of debris found on islands in southern GBR, plastics were by far the most common material recovered at all sites (68 to 92%) for both windward and leeward beaches ▪ More non-plastic related items recovered on leeward beaches than windward beaches ▪ Northwest Island with human visitation more focused on its leeward side, had higher amounts of sheet (i.e. wrappers) and fibrous plastic (i.e. cigarette butts), metal (i.e. aluminium cans) and glass-ceramic items (i.e. bottles) compared to the windward side
Ling, S. D. et al. (2017) "Ubiquity of microplastics in coastal seafloor sediments"	2017	▪ In marine sediments from 42 coastal sites spanning pollution gradients across south-eastern Australia, microplastics occurred as filament and particle forms, constituting 84% and 16% respectively
Hardesty (2016)	2016	▪ 68% of surveyed debris was plastic, 17% glass, 6% paper, 2% wood, 2% cigarettes and 1% fishing line
Lawson, T. J. et al. (2015)	2015	Marine debris that entangle fur seals across South Australia: ▪ 50% were made of plastic twine or rope (including trawl nets),

Source	Year	Key findings
Characteristics of marine debris that entangle Australian fur seals (Arctocephalus pusillus doriferus) in southern Australia		▪ 20% were made of other plastics such as plastic bags, packing straps, and balloon ribbon, ▪ 17% were monofilament line, including gill nets and ▪ 8% were comprised of rubber ▪ The remaining 5% consisted of metal items (such as hooks and lures) and cotton (a baseball cap that resulted in a neck constriction).
Smith, S. D. A. (2014) “Documenting the Density of Subtidal Marine Debris across Multiple Marine and Coastal Habitats”	2014	Type of debris in 6 prominent coastal and marine habitat types along the coast of eastern Australia: ▪ Plastic items were the most abundant (33% of the total), and mostly comprised of fishing monofilament (82% of plastic items and 27% of the total debris) which primarily originated from recreational fishing activities. ▪ Plastic fragments comprised the majority of the remainder of plastic items (10% of total debris) with plastic bags contributing a further 4% to total loads. ▪ Glass items contributed 20% of the total items and mainly comprised entire bottles (13% of total debris) and broken fragments (6% of total debris). ▪ A range of metal objects (18%), and items with mixed construction (18%), made up the majority of other items. ▪ Fishing was the primary source of most debris items (38% of the total), with food and drink accounting for a further 27% of the total.
Verlis, K. M. et al. (2014) “Marine debris is selected as nesting material by the brown booby (Sula leucogaster) within the Swain Reefs, Great Barrier Reef, Australia”	2014	▪ Hard plastic items dominated both in brown booby nests at 56.8% and surveyed beaches (72.8%),

Source: The CIE

There also seems to be a seasonal trend with hard plastics dominating the warmer months and polystyrene foams found more often in cooler months suggesting weather and catchment or water-based activities as influencing factors.[182]

International Origin of Marine debris

CSIRO analysis suggests most marine debris in Australian region is domestic, since debris in marine environment increases with local population, this is suggestive of local sources outweighing input from abroad[183]

Subsequently most sources of plastic pollution are local as well. Most common items are associated with consumers (single-use containers). A significant contribution to this is made from illegal dumping of domestic rubbish around urban margins in Australia.[184]

182 AusMap Microplastic Assessment project 2019

183 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

184 Ibid

Asia accounts for more than 80 per cent of the total leakage of plastic into the ocean. The CSIRO also noted that China and Indonesia were significant sources of plastic pollution.

Transport of international plastic pollutants to Western Australian waters is facilitated through entrainment of Indian Ocean surface waters and the Indonesian Through-flow (ITF), which extends into the Holloway and then Leeuwin Current, capable of transporting water down the coast from Asia.[185] Importantly, the three countries with the highest estimated influx of mismanaged plastic waste to the ocean—namely China, Indonesia and the Philippines—are directly connected to Western Australia by these surface currents. It is hypothesized that the highest concentrations of plastic pollution in the offshore occur during the strongest Leeuwin current flow in May.[186]

Additionally, the CSIRO study found that there is a contribution from international sources in other areas of Australia, particularly the north-eastern Coral Sea, Arafura Sea, southern Indian Ocean and Southern Ocean.[187]

Some estimates of overseas plastic reaching Australia are 70.5 per cent from Indonesia, 8 per cent from Fiji, 4 per cent from Vanuatu, 3 per cent from Papua New Guinea, 2.5 per cent from Philippines, 2.5 per cent from Vietnam, 2 per cent from East Timor, 2 per cent from South Africa, and 1.5 per cent from China.[188]

Some debris collected during snorkelling surveys conducted at Ashmore Reef Marine Park included production or expiry dates and geographical origin evidence. Expiry dates of 2012, 2016, 2018, and 2019 were among some of the debris collected. Hundred percent of those either stated that the object was “Made in Indonesia” (54 per cent) or had other inscriptions in Indonesian language (46 per cent).[189]

In a study, evaluating the Bottles on the Beaches program, plastic bottles were surveyed on the beaches of northern NSW (30 km of beach along a 200-km section of the north coast of New South Wales, Australia).[190] Country of origin and product type could be determined for two-thirds of the 694 bottles found. Just over half (51 per cent) of these were of domestic origin with the remainder dominated by bottles from China (24 per cent) and south-east Asian countries (21 per cent).[191] As most of the foreign bottles

185 ibid

186 ibid

187 CSIRO Submission 15, Inquiry into the threat of marine plastic pollution in Australia and Australian waters, September 2015

188 Galaiduk, R., Lebreton, L., Techera, E., & Reisser, J. (2020). Transnational plastics: an australian case for global action. Frontiers in Environmental Science, 8, 115.

189 Hajbane, S., Calmanovici, B., Reisser, J., Jolly, A., Summers, V., Ferrari, F., ... & Pattiaratchi, C. (2021). Coastal Garbage Patches: Fronts Accumulate Plastic Films at Ashmore Reef Marine Park (Pulau Pasir), Australia. Frontiers in Marine Science, 8, 379.

190 Smith, S. D., Banister, K., Fraser, N., & Edgar, R. J. (2018). Tracing the source of marine debris on the beaches of northern New South Wales, Australia: The bottles on beaches program. Marine pollution bulletin, 126, 304-307.

191 ibid

lacked marine growth, and are unavailable for purchase in the region, passing ships are hypothesised as the primary source.[192]

Given Australian waters are polluted from debris drifting in from overseas, the same is the case when domestic sources of plastics that leak into marine environments to be transported by currents, winds, and waves leading to transnational pollution of other nations' exclusive economic zones.

Environmental impacts

Various types of littered or dumped material could potentially have detrimental impacts on the marine environment. There is a current focus on the impacts of plastics in the marine environment. This is driven by the:

- persistence of plastics within the ocean with effects on wildlife and potentially humans,[193]
- prevalence of plastics, it is estimated that 60-80 per cent of marine debris is comprised of plastic,[194]
- most of the data on impacts on marine wildlife is from plastic marine debris,[195] and
- a finding that 80 per cent of the species impacts were associated with plastic debris, while paper, glass and metal together accounted for less than 2 per cent.[196]

It is considered that plastics break up over time into micro-plastics and do not decompose.[197] The lack of decomposition of plastics causes impacts to the marine environment, and is what distinguishes plastic from other waste types such as paper and cardboard. Glass bottles are also found in marine environments, but seem to have minimal impacts on animals, possibly because it is an inert material and generally sinks.[198]

There is a distinct focus on the environmental impacts of marine debris, with much less research on impacts in inland water and terrestrial environments. A key feature which distinguishes the marine environment from inland waterways and terrestrial

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192 ibid

193 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

194 Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

195 Kühn, S. and van Freneker, J.A., 2020, *Quantitative overview of marine debris ingested by marine megafauna*, Marine Pollution Bulletin 151 (2020) 110858.

196 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

197 APEC, 2020, *Update of 2009 APEC Report on Economic Costs of Marine Debris to APEC Economics.*

198 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

environments is the mobility of the debris once it has entered an environment, and its subsequent persistence.

Plastic is the most mobile and persistent of all debris types. These characteristics of plastic debris are driving concerns of associated environmental impacts and research efforts. In addition, it has been noted that these characteristics distinguish plastics from other debris, particularly in the marine environments where plastic can spread throughout water columns, on the seabed, through the deep sea[199], and along coastal shorelines and remain in the environment for decades or more.[200] Professor Tony Underwood noted in the Senate Inquiry in marine plastic pollution that:

> I think the focus on plastic might be justified because it is persistent in ways that metal, wood and other materials are not. Plastic just gets smaller and smaller, but it does not go away. That is different from metal which eventually, when you throw it in the sea, will be gone. I think there is a good reason why the focus on plastic keeps coming up compared with other debris[201]

The mobility of debris influences the effectiveness of clean-up efforts and subsequent environmental impacts. In marine environments, debris spreads quickly which increases the area impacted and reduces the effectiveness of clean-up efforts. Conversely where debris is littered or illegally dumped on land, impacts are relatively contained to the site and provided there is sufficient access and knowledge of the debris, clean-up efforts are highly successful at removing the debris and minimising environmental impacts.

Environmental impacts from plastic debris

Plastic debris in the marine environment can impact marine fauna and flora, degrade the marine environment and ecological communities, and impact on human health. Research efforts are also focusing on the impacts of microplastics. Microplastics are plastic items that are smaller than 5mm and generally divided up into:

- Primary microplastics — manufactured as small plastics, such as microbeads in face wash and toothpaste
- Secondary microplastics — derived from the breakdown of large items such as fragments from plastic bags or fibres from textiles.[202]

Common environmental impacts from plastic debris, including microplastics, in the marine environment are entanglement, ingestion, smothering, chemical contamination, transport of non-native and invasive species, and human health impacts from incidental consumption through the food chain.

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199 Barrett, J., Chase, Z., Zhang, J., Banaszak Holl, M., Willis, K., Williams, A., Hardesty, B., and Wilcox, C., 2020, *Microplastic Pollution in Deep-Sea Sediments from the Great Australian Bight.*

200 Senate Environment and Communications References Committee, Toxic tide: the threat of marine plastic pollution in Australia, April 2016.

201 Senate Environment and Communications References Committee, Toxic tide: the threat of marine plastic pollution in Australia, April 2016, p. 5.

202 Australian Institute of Marine Science, 2018, *Marine plastic pollution,* https://www.aims.gov.au/water-quality/plastics

Entanglement and ingestion are the most frequently reported environmental impacts of plastic debris on marine life. Sherrington et al (2014) noted that:

> Entanglement is more likely to kill or injure than ingestion, with direct harm or death reported in 80 per cent of reports of entanglement and in only 5 per cent of ingestion reports.[203]

However, it is likely that incidence of ingestion is underreported relative to ingestion given difficulties with observation,[204] primarily that not all dead animals are necropsied or ingested plastic debris may not be recorded where it is not considered as the primary cause of death.[205]

As noted by Kühn and van Franeker (2020) the number of reported cases of ingestion or entanglement by marine species has increased over the past few decades, with the increase more likely due to increasing research efforts in this area rather than just increases in affected individuals or species.[206]

Table A.9 outlines the key marine debris types causing entanglement and ingestion.

A.9 Debris types causing entanglement and ingestion

Debris most frequently associated with entanglement	Debris most frequently associated with ingestion
▪ Net fragments (including ghost nets) ▪ Rope and line (e.g. gill nets, trawl nets, discarded line) ▪ Monofilament line ▪ Packing bands ▪ Plastic circular rings and packaging such as multipack can rings	▪ Small plastic fragments of sufficient small size to be ingested by birds and turtles ▪ Plastic bags ▪ Plastic bags and plastic waste (including net fragments)

Source: Butterworth, A., and Clegg, I., 2012, *Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions,* World Society for the Protection of Animals.

Key species at risk

Marine debris can impact a variety of species, including protected species of birds, sharks, turtles and marine mammals. Overall, there is more information in the literature relating to ingestion and entanglement for marine birds and mammals, compared to lower taxonomic groups.

Risk factors for ingestion and entanglement by marine species include:

- feeding type – filter feeders are more likely to ingest plastic

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203 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species, page 46

204 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

205 CRC Consulting, 2009, *Impacts of plastic debris on Australian marine wildlife,* Final Report for The Department of the Environment, Water, Heritage and the Arts.

206 Kühn, S. and van Freneker, J.A., 2020, *Quantitative overview of marine debris ingested by marine megafauna*, Marine Pollution Bulletin 151 (2020) 110858.

- age of animal – juvenile turtles are more likely to ingest plastic, with evidence that a disproportionate rate (55 per cent) of incidences were young, pelagic feeding turtles, relative to 25 per cent for older turtles
- type of plastic – turtles are more likely to ingest plastic that resemble natural food sources (for example plastic bags look similar to jellyfish)
- location of habitat and feeding – turtles which feed along coastlines are more likely to ingest larger plastics,[207] and coastal species of cetaceans appear particularly vulnerable as their habitats are affected by human activities, notably fisheries.[208]

Impacts from entanglement or ingestion at the species level have been recorded for:

- over half of seabird species
- all known species of sea turtles
- almost 70 per cent of known marine mammal species
- one-fifth of sea birds (table A.10).[209]

A.10 Overview of plastic ingestion and entanglement in the main animal taxa

Taxa	Species in taxon	Affected species	Affected species within taxon
	No.	No.	Per cent
Seabirds	409	226	55.3
Marine mammals	123	86	69.9
All turtles	7	7	100.0
All sea snakes	62	2	3.2
All fish	31 243	430	nr
All invertebrates	159 000	163	nr

Note: “nr” represents not reported. Kuhn and van Franeker (2020) note the percentage of affected species is not a useful statistic for reptiles, fish and invertebrates because there are many thousands of species which have not been properly investigated.

Source: Kühn, S. and van Franeker, J.A., 2020, *Quantitative overview of marine debris ingested by marine megafauna*, Marine Pollution Bulletin 151 (2020) 110858.

Werner et al. (2016) notes that many species impacted by marine debris through ingestion or entanglement are protected species, with:

- 45 per cent of the 120 marine mammals species listed on the IUCN Red List of Threatened Species have interacted with marine litter through entanglement and/or ingestion.[210]

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207 Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, A quantitative analysis linking sea turtle mortality and plastic debris ingestion, CSIRO.

208 Butterworth, A. and Clegg, I., 2012, *Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions,* World Society for the Protection of Animals.

209 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

210 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

- 15 per cent of marine mammals species affected through entanglement and ingestion are on the IUCN Red List.

Sherrington et al (2014) noted six species identified as experiencing the greatest impacts from entanglement or ingestion of marine debris are migratory.[211] Despite over half of marine mammals, all marine turtles, and a significant proportion of birds known to be migratory[212], Sherrington et. al. (2014) noted that there were no studies systematically examining whether and how migratory species are more vulnerable to marine debris than resident species.[213]

CRC Consulting (2009) examined impacts of plastic debris on Australian marine wildlife with a geographic extent of all Australian waters, including offshore and sub-Antarctic islands and Australian Antarctic Territories. Key findings from this study:

- 77 species of marine wildlife found in Australian waters have been impacted by entanglement in, or ingestion of, plastic debris between 1974-2008
- Affected species include:
  - 6 species of marine turtles
  - 12 species of cetaceans
  - at least 34 species of seabirds, dugongs
  - 6 species of pinnipeds
  - 10 species of sharks and rays
  - and at least 8 other species groups.
- Most records of impacts of plastic debris on wildlife relate to entanglement, rather than ingestion.
- Species dominating existing entanglement and ingestion records are turtles and humpback whales. Australian pelicans and a number of cormorant species are also frequently reported.[214]

Entanglement

Marine species that are killed and maimed through entanglement include seabirds, turtles, whales, dolphins, dugongs, sea snakes, sharks, fish, crabs and crocodiles.[215] Sublethal and lethal impacts include:

- restricted movement leading to exhaustion or preventing animal from surfacing to breathe

211 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

212 Ibid.

213 Ibid.

214 CRC Consulting, 2009, *Impacts of plastic debris on Australian marine wildlife,* Final Report for The Department of the Environment, Water, Heritage and the Arts.

215 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

- restricted feeding and subsequent starvation
- smothering and wounding (e.g. lacerations and ulcers), and subsequent infections
- inhibit natural growth of limbs leading to deformation
- reduced reproductive output
- reduced ability to avoided predators.

Derelict fishing gear, including ghost nets, entangle marine turtles, dugong, crocodiles, sawfish, hammerhead sharks ,sea snakes and invertebrates. CSIRO estimate 6 per cent of all fishing nets, 9 per cent of all traps and 29 per cent of all lines are lost or discarded into the ocean each year.[216]

Ghost nets are a particular problem in the Gulf of Carpentaria where scientists have found ghost nets are increasing despite more than a decade of illegal fishing countermeasures and cleanup efforts.[217] The following are estimates of the proportion of ghost nets attributable to Australia:

- it is estimated that the vast majority (85 per cent) of ghost nets found along the Gulf coastline originate from outside of Australia's Exclusive Economic Zone.[218]
- of the ghost nets removed from beaches and estuaries (more than 13 000) only 4 per cent of those that could be identified originated from Australian fisheries (although only around 50 per cent could be identified).[219]
- approximately 12 per cent of fishing debris recorded in Northern Territory was manufactured in Australia (table A.11).

A.11 Origin of fishing debris recorded at Cape Arnhem, Northern Territory, Australia

Country of manufacture	Net type	Number of nets	Proportion of total nets
		Number	Per cent
Taiwan	Trawl	108	26
	Gill (drift net)	94	
	Sub-total	**202**	
Indonesia	Trawl	131	7
	Gill (drift net)	6	
	Sub-total	**137**	
Taiwan/Korea	Trawl	99	13
Japan	Trawl	63	8

216 CSIRO, 2019, *How much fishing gear is lost at sea?,* https://www.csiro.au/en/news/news-releases/2019/how-much-fishing-gear-is-lost-at-sea, Accessed 10 November 2021.

217 Hardesty, B. D., Roman, L., Duke, N. C., and Mackenzie, J. R., 2021, *Abandoned, lost and discarded fishing gear 'ghost nets' are increasing through time in Northern Australia,* Marine Pollution Bulletin 173 (2021) 112959.

218 Hardesty, B. D., Roman, L., Duke, N. C., and Mackenzie, J. R., 2021, *Abandoned, lost and discarded fishing gear 'ghost nets' are increasing through time in Northern Australia,* Marine Pollution Bulletin 173 (2021) 112959.

219 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

Country of manufacture	Net type	Number of nets	Proportion of total nets
		Number	Per cent
Philippines	Trawl	52	7
Japan/Korea	Trawl	25	3
Thailand	Trawl	23	3
Republic of Korea	Trawl	19	3
	Gill (drift net)	1	
	Sub-total	**20**	
Australia	Trawl	68	12
	Gill (drift net)	26	
	Sub-total	**94**	
Unknown	Trawl	7	9
	Gill (drift net)	3	
	Unknown	59	
	Sub-total	**69**	
Total		**784**	**100**

Source: Macfadyen, G., Huntington, T, and Cappell, R., 2009, *Abandoned, lost or otherwise discarded fishing gear,* UNEP Regional Seas Rerpot and Studies 185, FAO Fisheries and Aquaculture Technical Paper 523.

Evidence of entanglement impacts

Incidence data is reported in a variety of forms, including number of individual incidence cases, proportion of species that have at least one individual with a case, and proportion of individuals within a species with a reported case.

Evidence of entanglement from the literature at the species level and individual level is presented below.

Evidence of entanglement at the species level

Some studies report impact at the species level, framed as a species being impacted based on at least one record of an individual being impacted.

Estimates of entanglement impacts at the **species level** include:

- Kühn et al. (2015) found 344 species were impacted through entanglement in marine debris.[220] An updated study by Kühn and van Franeker (2020) found marine debris affected 354 species through entanglement (table A.12).[221]
- Worldwide, at least 143 species of marine animals have been entangled in marine debris, including most of the world's sea turtles. [222]

220 Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life,* Marine Anthropogenic Litter, pp 75-116.

221 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

222 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

- In Moreton Bay, it was estimated that between six and seven per cent of the animals are being entangled in marine debris. With plastic marine debris sourced primarily from the fishing industry, both commercial and recreational. [223]
- All major classes of marine migratory species (i.e. pinnipeds, cetaceans, turtles, sharks, Sirenia, fish and birds) comprising 192 species are impacted by entanglement. This equates to about 45 per cent of all marine mammals (including 58 per cent of all seals), 0.39 per cent of all fish, 21 per cent of all seabirds, and all sea turtles.[224]
- Animals most frequently reported with cases of entanglement are pinnipeds, humpback and right whales, birds and turtles, though this is as likely to reflect reporting bias as prevalence of this type of impact within different classes.[225]
- Entanglement is the most common known source of mortality to marine turtles in Australia, and the primary cause of mortality for turtles reported in the Gulf of Carpentaria region of Australia.[226]

A.12 Number of species with document records of entanglement in marine debris

Species group	Laist (1997 study)			Kühn et al (2015)			Kühn et al (2020)		
	Spp. total	Entanglement		Spp. total	Entanglement		Spp. total	Entanglement	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Seabirds	312	51	16	406	103	25.4	409	112	27.4
Marine mammals	115	32	28	123	51	41.5	123	49	39.8
Turtles	7	6	86	7	7	100	7	7	100
Sea Snakes	-	-	-	62	2	3.2	62	2	3.2
Fishes	-	34	-	32554	89	nr	31243	101	nr
Invertebrates	-	8	-	159000	92	nr	159000	83	nr
Total marine birds, mammals and turtles	**434**	**89**	**20.5**	**536**	**161**	**30.0**	**539**	**168**	**31.2**
All species		**136**			**344**			**354**	

Note: "nr" represents not reported. Kuhn and van Franeker (2020) note the percentage of affected species is not a useful statistic for reptiles, fish and invertebrates because there are many thousands of species which have not been properly investigated.

Source: Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life,* Marine Anthropogenic Litter, pp 75-116 and Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

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223 Ibid.

224 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

225 Ibid.

226 Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013), Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

Evidence of impact at the individual level

Evidence of entanglement at the individual level are based on recorded sightings of entanglement animals alive (or recently deceased), often opportunistic in nature or from heavily visited coastal regions.[227] Therefore estimates do not capture unseen cases, such as those which take place in the high seas and it is likely observations of entangled or injured wildlife greatly underestimate total rates of wildlife entanglement.[228] It is estimated the recorded cases of entanglement account for between 3 and 10 per cent of total entanglement cases.[229]

Estimates of entanglement impacts at the **individual level** include:

- Butterworth and Clegg (2012) estimate that globally, between 57 000 and 135 000 pinnipeds and baleen whales are entangled each year.[230]
- CSIRO estimates that between 5,000 and 15,000 turtles have been killed in the Gulf of Carpentaria after becoming ensnared by derelict fishing nets, mostly originating from overseas.[231]

Table A.13 outlines data on frequency of entanglement by individuals of selected species but does not list the responsible marine debris type. It has been noted that entanglement of marine animals in discarded fishing nets is of particular concern in northern Australian waters.[232] Tables A.14 and A.15 outline the global entanglement incidence rate for pinnipeds and cetaceans. The type of debris and the mortality rate is also listed in some cases.

A.13 Frequency of entanglement for selected species

Species	Size of sample	Individuals with recorded entanglement	Geography
	Number	Per cent	
Leach's storm petrel	151	11	Equatorial Pacific
White-faced storm petrel	13	6.9	Equatorial Pacific
Brown pelican	557	63	California

227 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

228 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

229 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for World Society for the Protection of Animals.

230 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for World Society for the Protection of Animals, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

231 CSIRO, *Tackling plastic waste,* https://www.csiro.au/en/research/environmental-impacts/recycling/plastics. Accessed September 2021.

232 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

Species	Size of sample	Individuals with recorded entanglement	Geography
	Number	Per cent	
Northern Gannet (dead)	28	29	North Sea Helgoland
Northern Gannet (fly off cliff)	313	2.6	North Sea Helgoland
Northern Gannet (entangled in nest)	656 684	2.6 (2014) 3.5 (2015)	North Sea Helgoland
Northern Fulmar	67	1.8	North Sea Helgoland
Guillemot	2880 3381	1.1 1.0	North Sea Helgoland
Grey seal	58	3.6-5	Cornwall, UK
Common minke whale	11	9.1	UK
California/Galapagos/Japanese Sea Lion	3574	3.7	California, USA
Guadalupe fur seal	13	15.4	California, USA
Harbour seal	1072	1.2	California, USA
Northern elephant seal	1484	0.4	California, USA
Common bottlenose dolphin	302	3.9	South Carolina, USA
Green turtle	5347	9	Florida, USA
Loggerhead turtle	9950	4.2	Florida, USA
Leatherback turtle	304	14.1	Florida, USA
Hawksbill turtle	362	8.3	Florida, USA
Kemp's Ridley turtle	1346	5.1	Florida, USA
Olive Ridley turtle	3	33.3	Florida, USA
Loggerhead turtle (live)	948	4.6	Italy
Loggerhead turtle (dead)	307	6.6	Italy

Source: Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

A.14 Overview of literature containing data on the entanglement of pinnipeds

Species/sub-species	Region[a]	Entanglement rate (incidence in population)	Types of debris			Mortality estimate
			Plastic	Net	Fishing	
		Per cent	Per cent	Per cent	Per cent	Per cent
Kaikoura fur seal	South West Pacific	0.6 – 2.8	31	42		
Australian fur seal	Eastern Indian Ocean	1.9	30	40		73
New Zealand fur seal	Eastern Indian Ocean	0.9	30	29	3	57
Australian sea lion	Eastern Indian Ocean	1.3	11	66	6	44
Antarctic & Sub-Antarctic fur seal	Western Indian Ocean	0.24	D41	17	c. 10	
Antarctic fur seal	South East Atlantic	0.024-0.059	18	48		50
Antarctic fur seal	South West Atlantic	0.4	46-52			80
Cape fur seal	South East Atlantic	0.1-0.6	50			
Californian sea lion	Eastern Central Pacific	3.9-7.9		50	33	

Species/sub-species	Region[a]	Entanglement rate (incidence in population)	Types of debris			Mortality estimate
			Plastic	Net	Fishing line	
		Per cent	Per cent	Per cent	Per cent	Per cent
Hawaiian monk seal	Eastern Central Pacific	0.7	8	32	28	16
Steller sea lion	North East Pacific	0.26	54	7	2	
California sea lion	Eastern Central Pacific	0.08-0.22	25	19	14	
Northern elephant seal	Eastern Central Pacific	0.15	36	19	33	
Harbour seal	Eastern Central Pacific	0.09	33			
Northern fur seal	Eastern Central Pacific	0.24		50		
Stellar sea lion	Eastern Central Pacific		0	4	4	23
Northern fur seal	North East Pacific	0.40	19	65		61
Northern fur seal	North East Pacific	0.08-0.35	37	39	9	
Grey seal	North West Atlantic	3.1 – 5				64
Southern elephant seal	South West Atlantic	0.001-0.002	c.36		c.64	28

[a] Based on FAO 2012

Source: Various sources outlined in Butterworth, A. and Clegg, I., 2012, *Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions,* World Society for the Protection of Animals.

Reported population entanglement rates for Baleen whales[233] range between 5 per cent to 65 per cent, across at least 7 different species (all of which are migratory). The average mortality estimate is 23 percent with a range of 1 per cent to 44 per cent for different species (table A.15).

A.15 Overview of literature containing data on the entanglement of cetaceans

Species/sub-species	Region[a]	Entanglement rate (% become entangled each year	Entanglement rate (by animal or by % of population observed with entanglement scars)	Types of debris (%)		Mortality estimate[b]
				Net	Fishing	
		Per cent	Per cent	Per cent	Per cent	Per cent
Humpback whale	Western Central Atlantic			41	50	10
Humpback whale	North West Atlantic	2.4	17 whales become entangled each year			26
Humpback whale	North West Atlantic	8-10.4	48-57			

233 Baleen and toothed are the two types of whales. Species of baleen whales include blue whale, right whale, fin whale, humpback whale, minke whale, and grey whales.

Species/sub-species	Region[a]	Entanglement rate (% become entangled each year	Entanglement rate (by animal or by % of population observed with entanglement scars)	Types of debris (%) Net	Fishing line	Mortality estimate[b]
		Per cent	Per cent	Per cent	Per cent	Per cent
Humpback whale	North East Pacific	8	52-78			
Western grey whale	North West Pacific		18.7			
Minke whale	North East Atlantic		5-22			
Minke whale	North West Pacific			31	69	0.9
Minke whale	North West Atlantic	2.6	7 whales per year			37
North Atlantic right whale	North West Atlantic		57	25	67	12
North Atlantic right whale	North & Central West Atlantic	1.6 (2 from IWC 2010 population estimate of 300)	6 whales per year			27
North Atlantic right whale	North & Central West Atlantic	1.15 (ICW 2010 population estimate: 300)		71	14	29
Fin whale	North East Atlantic		5			
Fin whale	North West Atlantic	0.8	2 whales per year			44
Blue whale	North West Atlantic		<1 whale per year			
Bryde's whale	North West Atlantic	0.2	<1 whale per year			

[a] Based on FAO Statistical Areas 2012.

[b] Percentage of entangled animals estimated to be killed by their entanglement

Source: Various sources outlined in Butterworth, A. and Clegg, I., 2012, *Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions,* World Society for the Protection of Animals.

Ingestion

Animals may intentionally or accidently ingest marine debris. Ingestion can physically block an animal's digestive tract, alter feeding behaviour and dietary inputs, lacerate the mouth and digestive tract causing serious injury, and influence the buoyancy of species. These can lead to greater susceptibility to predators and diseases and decreased ability to bread and rear young.

Ingestion of plastic can lead to mortality through:

- gastrointestinal obstruction or perforation, which may be caused by either a single or multiple debris items, or

- multiple large plastic items which remain and accumulate in the stomachs of marine animals, reducing the volume available for nutrition food, eventually causing starvation
- in the case of turtles, decomposition of plastic inside a turtle's stomach can produce gas which remains trapped inside causing a turtle to float on the surface of water, possibly leading to starvation and inability to hide from predators[234]

Certain marine organisms are more at risk of ingestion due to feeding methods, age, lacking an ability to regurgitate or due to activity:

- feeding methods — marine species which feed as filter feeders, deposit feeders and detritivores are most at risk of ingestion of plastics. [235] Foraging by seabirds increases risk of ingestion, and accidental ingestion can occur by filter-feeding marine organisms or through secondary ingestion when animals feed on prey which has already ingested debris. Baleen whales can ingest marine debris as they feed.[236]
- age — younger animals in a range of species are more at risk of ingestion of marine debris, for example, sea turtles are at a higher risk of ingestion during the juvenile and pelagic stages.
- ability to regurgitate — sea turtles don't have the ability to regurgitate so ingested plastic particles may be swallowed and accumulate in the gut.
- activity — toothed whales and dolphins can ingest plastic and other waste either in play or exploration[237]

Various sizes of plastics, including microplastics, can be ingested by species of difference sizes. There is evidence that marine invertebrates such as amphipods, lugworms, barnacles, mussels, lobster and squid ingest microplastics.[238] One estimate is 10 per cent of encounters with marine debris are microplastics.[239] There remain uncertainties about

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234 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

235 Thompson, R., Moore, C., vom Saal, F., Swan, S., 2009, *Plastics, the environment and human health: current consensus and future trends*, Phil. Trans. R. Soc. B (2009) 364, 2153-2166.

236 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for World Society for the Protection of Animals, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

237 Ibid.

238 Ivar do Sul, J.A., and Costa, M.F. (2014) The present and future of microplastic pollution in the marine environment, *Environmental Pollution* referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

239 AP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012 referenced in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

the full effect of microplastics on the species ingesting them,[240] and also impacts further up the food chain as well as ecosystem level effects.[241]

The Australian State of the Environment 2016 report noted significant quantities of plastics have been found in digestive tracts of several species of marine vertebrates in Australian waters.[242]

Evidence of ingestion impacts at the species level

Not surprising, there is more information available for plastic ingestion related to larger marine species and larger plastic particles. Information on plastic ingestion declines with the size of animal and size of the plastic particles.[243] For the smaller taxa, records of ingestion exist for benthic worms, shrimps, shellfish, small zooplankton and goose-barnacles.

Estimates of ingestion impacts at the **species** level include a compilated of records by Kühn et al. (2015) which found 331 species were impacted by marine debris.[244] An updated literature review of 747 studies by Kühn and van Franeker (2020) found marine debris affected 701 species through ingestion (table A.16).[245]

A.16 Number of species with document records of ingestion in marine debris

Species group	Laist (1997 study)			Kuhn et al (2015)			Kuhn et al (2020)		
	Spp. total	Ingestion		Spp. total	Ingestion		Spp. total	Ingestion	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Seabirds	312	111	36	406	164	40.4	409	180	44.0
Marine mammals	115	26	23	123	62	50.4	123	69	56.1
Turtles	7	6	86	7	7	100	7	7	100
Sea Snakes	-	-	-	62	0	0.0	62	0	0.0
Fishes	-	33	-	32 554	92	nr	31 243	363	nr
Invertebrates	-	1	-	159000	6	nr	159 000	82	nr

240 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

241 Ibid.

242 Australian Government, *Marine debris: Marine environment (2016) State of the Environment,* https://soe.environment.gov.au/theme/marine-environment/topic/2016/marine-debris, Accessed 23 September 2021.

243 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

244 Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, Deleterious Effects of Litter on Marine Life

245 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Species group	Laist (1997 study)			Kuhn et al (2015)			Kuhn et al (2020)		
	Spp. total	Ingestion		Spp. total	Ingestion		Spp. total	Ingestion	
	no.	no.	per cent	no.	no.	per cent	no.	no.	per cent
Total marine birds, mammals and turtles	**434**	**143**	**32.9**	**536**	**233**	**43.5**	539	256	47.5
All species		**177**			**331**			701	

Note: "nr" represents not reported. Kuhn and van Franeker (2020) note the percentage of affected species is not a useful statistic for reptiles, fish and invertebrates because there are many thousands of species which have not been properly investigated.

Source: Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life,* and Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Evidence of ingestion impacts at the individual level

Based on the data in table A.16, there is evidence that 44 per cent of seabird species, 56 per cent of marine mammals and 100 per cent of turtle species have been impacted through ingestion of plastic debris. This data at the species level is based on at least one documented case of plastic ingestion. Kühn and Franeker (2020) note that information presented at the species level can incorrectly present the extent of the problem.[246] Kühn and van Franeker (2020) examined ingestion impacts at the individual level and found the following proportion of individuals had plastic in their stomachs:

- less than 30 per cent of individual seabirds
- 4.4 per cent of mammals
- 32 per cent of turtles (table A.17).

A.17 Frequency of ingestion by individuals by taxon

Taxon	Species	Species studied	Individuals studied	Individuals with plastic	Frequency of occurrence
	no.	per cent	no.	no.	per cent
All seabirds	409	55.3	43525	12065	27.7
All carnivores	34	23.53	9 784	93	0.95
All baleen whales	14	42.86	96	16	16.67
All toothed whales	72	50.00	5 002	480	9.40
All cetaceans	86	48.84	5 098	486	9.53
All sirenia	3	33.33	4 604	281	6.10
All marine mammals	123	41.46	19 486	860	4.41
All turtles	7	100	7879	2536	32.00

Note: The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available.

Source: Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

246 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Werner et al. (2016) compiled information on the proportion of individuals with recorded ingestion (table A.18). Based on this information, Werner et al. (2016) comment that:

- ingestion is a regular and widespread occurrence for all groups of marine wildlife,
- impacts for lower tropic levels and small-sized organisms are harder to document
- it is extremely difficult to quantify sublethal effects, yet understanding of sublethal effects is important to understand impacts at the population level.[247]

A.18 Frequency of plastic ingestion for selected species

Species	Size of sample	Individuals with ingestion	Geography	Sources
	Number	Per cent		Q
Norway lobster	120	83	Clyde Estuary, Scotland	Murray and Cowie 2011
Atlantic herring	566	2	North Sea	Foekema et al. 2013
Whiting	105	6	North Sea	Foekema et al. 2013
Horse mackerel	100	1	North Sea	Foekema et al. 2013
Haddock	97	6	North Sea	Foekema et al. 2013
Atlantic cod	80	13	North Sea	Foekema et al. 2013
Northern fulmar	1295	95	North Atlantic	Van Franeker et al., 2011
Common Murre	220	2.3	Wales, UK	Weir et al. 1997
Razorbill	81	1	Wales, UK	Weir et al. 1997
Red-throated Loon	19	5	Wales, UK	Weir et al. 1997
Black-headed Gull	18	11	Germany	Schwemmer et al., 2012
Cory's Shearwater	49	96	Mediterranean Sea	Codina-Garcia et al., 2013
Harbour seal	107	11.2	North Sea	Tonay et al. 2007
True's Beaked Whale	3	66.6	Ireland	Lusher et al. 2015
Sperm Whale	22	40.9	North Sea	Unger et al. 2016
Loggerhead Turtle	121	14	Mediterranean Sea, Sardinia	Camedda et al, 2014
	31	71	Mediterranean Sea, Italy	Campani et al., 2013
	54	79.6	Mediterranean Sea, Spain	Tomãs et al. 2002
	2214	40.4	Mediterranean NW	Darmon et al., 2014
Marine turtles (all species)	153	35.4	NE Atlantic	Darmon et al., 2014

Source: Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

247 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

Evidence of ingestion for key species

Sea turtles

Sea turtles commonly ingest plastic bags, cling film, food wrappers and balloons, in some cases mistaking plastic bags and other similar plastic film debris as jellyfish prey. [248] Plastics are by far the most concerning type of marine debris for sea turtles, with one report noting plastics make up to 90 per cent of the marine debris ingested by marine turtles in Queensland.[249]

Sea turtles are particularly at risk of ingesting plastic debris because turtles don't have the capacity to regurgitate, so plastic particles tend to be swallowed and accumulate in the gut.[250] Sea turtles are at risk of ingestion at all stages of their life cycle, with higher risks at the juvenile and pelagic stages (table A.19).[251]

A.19 Risk of ingestion at different life cycle stages

Life cycle stage	Proportion of necropsied turtles which ingested plastic
	Per cent
Post-hatching stage	54
Juveniles	23
Sub-adults	15
Adults	16

Source: Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, A quantitative analysis linking sea turtle mortality and plastic debris ingestion, CSIRO.

Certain turtle species are more likely to ingest debris, including:

- Smaller, oceanic-stage turtles more likely to ingest debris that coastal foragers[252]
- Carnivorous species were less likely to ingest debris than herbivores or gelatinovores[253]
- Oceanic leatherback turtles and green turtles are at the greatest risk of both lethal and sublethal effects from ingested marine litter. Leatherback turtles feed exclusively on

248 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

249 Great Barrier Reef Marine Park, *Submission 29*, p. 1. referenced in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

250 Australian Institute of Marine Science, 2018, *Tiny plastics are potentially dangerous for turtles too,* https://www.aims.gov.au/docs/media/latest-releases/-/asset_publisher/8Kfw/content/tiny-plastics-are-potentially-dangerous-for-turtles-too

251 Schuyler, Q. A., Hardesty, B. D., Wilcox, C. & Townsend, K. A., 2012, To Eat or Not to Eat? Debris Selectivity by Marine Turtles referenced in Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, *A quantitative analysis linking sea turtle mortality and plastic debris ingestion.*

252 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

253 Ibid

jellyfish and other gelatinous organisms, so are at the greatest risk of both lethal and sublethal effects from ingested marine debris such as plastic bags.[254]

Sea turtles are at particular risk from plastics in the oceans because the seven species of marine turtles are already categorised as vulnerable to critically engendered. [255]

Sea turtles were among the first taxa recorded to ingest plastic debris[256], occurring in all regions of the world[257] in all 7 marine turtle species.[258] Table A.20 outlines the frequency of ingestion by individual turtles for the seven turtle species. Based on this data:

- almost one-third of all turtles having ingested plastic, which is consistent with CSIRO's estimate that approximately one-third of global marine turtles have likely ingested debris[259] however slightly lower than an estimate in Schulyer et al. (2015) that 340 000 individuals or up to 52 per cent of sea turtles may have ingested plastic debris[260]
- ingestion rates range from 22 per cent for loggerhead turtles to 100 per cent for flatback turtles (noting that the sample size for flatback turtles is only 2), with the exception of flatback turtles, this range is consistent with the range noted by Werner et. al. (2016) of 15 per cent to almost 50 per cent incidence of debris in investigated individual turtles.[261]

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254 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica, page 54.

255 Australian Institute of Marine Science, 2018, *Tiny plastics are potentially dangerous for turtles too,* https://www.aims.gov.au/docs/media/latest-releases/-/asset_publisher/8Kfw/content/tiny-plastics-are-potentially-dangerous-for-turtles-too

256 Cornelius, S. E. Marine Turtle mortalities along the Pacific Coast of Costa Rica. Copeia 1, 186–187 (1975) and Fritts, T. H. Plastic bags in the intestinal tracts of leatherback marine turtles. Herpetol. Review 13, 72–73 (1982) included in Wilcox, C., et al. 2018, A quantitative analysis linking sea turtle mortality and plastic debris ingestion, CSIRO.

257 Schuyler, Q. A., Hardesty, B. D., Wilcox, C. & Townsend, K. A. Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles. Conserv. Biol. 28, 129–139 (2014a). sourced in Wilcox, C., et al. 2018, A quantitative analysis linking sea turtle mortality and plastic debris ingestion, CSIRO.

258 Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, A quantitative analysis linking sea turtle mortality and plastic debris ingestion, CSIRO.

259 CSIRO, *Tackling plastic waste*, https://www.csiro.au/en/research/environmental-impacts/recycling/plastics, accessed 23rd September 2021.

260 Schuyler, Q. A., Wilcox, C., Townsend, K., and Wedemeyer-Strombel, K., Balazs, G., Sebille, E. V., and Hardestry, B., D., Risk analysis reveals global hotspots for marine debris ingestion by sea turtles, Global Change Biology. 22(2) as cited in Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, *A quantitative analysis linking sea turtle mortality and plastic debris ingestion.*

261 Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

A.20 Frequency of ingestion by individuals by turtle species

Taxon	Species	Species studied	Individuals studied	Individuals with plastic	Frequency of occurrence
	no.	per cent	no.	no.	per cent
Loggerhead turtle	1	100	3919	843	22
Kemp’s ridley turtle	1	100	304	106	35
Olive ridley turtle	1	100	179	81	45
Green turtle	1	100	2720	1275	47
Hawksbill turtle	1	100	86	31	36
Flatback turtle	1	100	2	2	100
Leatherback turtle	1	100	669	198	30
All turtles	**7**	**100**	**7879**	**2536**	**32**

Source: Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, *Marine Pollution Bulletin 151 (2020) 110858.*

Once ingested, plastic debris can lead to mortality in sea turtles. For example, approximately 30 per cent of sea turtle deaths in Moreton Bay can be attributed to ingestion of plastic pollution.[262]

The quantity of ingested plastic influences the probability of mortality, with Wilcox et al. (2018) finding that a sea turtle has a 50 per cent probability of mortality once it has 14 or more pieces of plastic in its gut. The study found strong support for a positive relationship between concentration of plastic in the gut and probability of mortality, demonstrating that higher concentrations of plastic items in the gut lead to a higher probability of mortality.[263]

Data linking plastic to mortality in sea turtles in Australian waters was provided to the Senate Inquiry: Toxic Tide: the threat of marine plastic pollution in Australia:

- over 70 per cent of loggerhead turtles found dead in QLD waters had ingested plastic
- 30 per cent of sea turtle deaths in Moreton Bay can be attributed to the ingestion of plastic pollution
- 33 per cent of sea turtles necropsied from the Brisbane and Sunshine coast areas had ingested plastic debris.[264]

Seabirds and shorebirds

Seabirds commonly ingest degraded hard plastics sourced from take away containers, single-use plastics, discarded consumer products, balloons, hard bits of plastic, foam, metal hooks and fishing line.[265] There are also concerns that ingestion of microplastics

262 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

263 Wilcox, C., Puckridge, M., Schuykerm Q., Townsend, K., and Hardestry, B. D., 2018, *A quantitative analysis linking sea turtle mortality and plastic debris ingestion.*

264 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

265 Ibid.

by shorebirds and the associated absorbed chemicals is an unrecognised threat to resident and migratory shorebirds in Australia and elsewhere.[266]

Juvenile birds are more at risk than adults of ingestion, with ingestion leading to growth and development issues in juvenile birds.

Reported incidences include:

- CSIRO estimate 90 per cent of all seabirds have already ingested plastics. CSIRO has suggested that by 2050, 95 per cent of sea birds will have plastics in the gut[267]
- 95 per cent of deceased Northern Fulmars washed ashore were found to have plastic debris in their digestion system[268]
- 98 per cent of Laysan albatross chicks from Midway Atoll National Wildlife Refuge contained marine plastic debris in their stomachs[269]
- 79 per cent of flesh-footed shearwater chicks contained some ingested plastic, fed to them by their parents who picked this debris up while foraging over the Tasman Sea[270]
- CSIRO identified 67 per cent of short-tailed shearwaters were found to have ingested marine plastic pollution, and that young birds were more likely to ingest plastic than adults, and also consume large amounts[271]
- in one instance, 274 plastic pieces were retrieved from a deceased bird, equivalent to 14 per cent of its body weight[272]

In a case study of beach-cast albatrosses, approximately 6 per cent of albatrosses examined had ingested plastic, with an associated 50 per cent mortality rate after ingestion (table A.21).

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266 Dr Eric Woehler, Birdlife Tasmania, *Committee Hansard*, 26 February 2016, p. 33 in Senate Inquiry, 2016, Toxic tide: the threat of marine plastic pollution in Australia, Environment and Communications References Committee.

267 Boomerang Alliance, 2016, *Turn back the toxic tide – a threat abatement plan for marine plastic pollution.* November 2016.

268 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species

269 Dr Heidi Auman, *Submission 190*, p. 1 referenced in Senate Inquiry, 2016, Toxic tide: the threat of marine plastic pollution in Australia, Environment and Communications References Committee.

270 Mr Ian Hutton, *Submission 69*, p. 1 referenced in Senate Inquiry, 2016, Toxic tide: the threat of marine plastic pollution in Australia, Environment and Communications References Committee.

271 CSIRO, Submission 7, Appendix 2, 'Executive Summary "Understanding the effects of marine debris on wildlife: Final report to Earthwatch Australia"', p. 11., referenced in Senate Inquiry, 2016, Toxic tide: the threat of marine plastic pollution in Australia, Environment and Communications References Committee.

272 Mr Ian Hutton, *Committee Hansard*, 18 February 2016, p. 21, referenced in Senate Inquiry, 2016, Toxic tide: the threat of marine plastic pollution in Australia, Environment and Communications References Committee.

A.21 Case study of 107 beach-cast albatrosses

	Number	Proportion
		Per cent
Number of individuals examined	107	NA
Individuals with ingested plastic	6	5.6
Individuals with gastrointestinal obstruction from plastic that was considered cause of death	3	2.8

Source: Roman. L., Butcher, R.G., Stewart, D., Hunter, S., Jolly., M., Kowalski, P., Hardesty, B.D., Lenting, B., 2020, *Plastic ingestion is an underestimated cause of death for southern hemisphere albatrosses*, CSIRO.

Coral and zooplankton

A recent study by the Australian Research Council Centre of Excellence for Coral Reef Studies found that corals digest microbeads at about the same rate as normal food. Large amounts of plastic were found in the digestive systems of corals demonstrating they are unable to expel the plastic fragments. Accumulation of plastics will cause corals to starve and die when their stomachs become filled with plastic.[273]

Studies have found microplastics present in planktivorous fish, the fish that feed on zooplankton.[274]

Chemical contamination

Plastics contain chemical substances added during manufacture and can also adsorb chemicals at sea. Thereby marine plastic debris can act as both a transport mechanism for chemicals in the ocean and also a source of toxic chemicals contained within.[275] According to the National Toxics Network, toxicity associated with plastics can be attributed to one or more of the following factors:

- residual monomers from the manufacturing process present in the plastic or toxic additives used in the compounding of plastic, leaching out of the plastic
- partial degradation of certain plastics
- persistent organic pollutants (POPs) present in seawater being absorbed and concentrated in microplastic fragments.[276]

Persistent organic pollutants are present in low concentrations in marine environments. Plastic debris, including microplastics, can adsorb POPs, including pollutants such as the banned insecticide DDT, polychlorinated biphenyl (PCBs) phthalates and bisphenol A

273 James Cook University, 'Great Barrier Reef corals eat plastic', Media release, 2015, https://www.jcu.edu.au/news/releases/news-archive2/news-and-media1111111111111111115

274 Birdlife Australia, *Submission 76*, p. 11. referenced in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

275 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

276 Ibid.

(BPA). The adsorption rate differs across plastic polymers, with plastic polymers considered to have lower levels of toxicity in their base having a higher adsorption rate (e.g. HDPE and LDPE).

Contaminants found on plastics can be at a much higher concentration found in surrounding seawater, for example, scientists found polypropylene pellets with up to one million times more concentrated levels of POPs than the surrounding seawater.[277] Hence ingestion of these items substantially increases an animal's exposure to these chemicals.

Chemical contamination impacts discussed in the literature relate primarily to ingestion of plastic debris and include:

- impacts on reproduction and genetic aberrations from phthalates and BPA[278]
- health impacts from ingestion of pellets with low concentrations of POPs. [279]
- chronic dietary exposure to low-density polyethylene by fish causing bioaccumulation of potentially hazardous potentially affecting the health of the liver, compromising immunity and causing infertility.[280]
- some plastics and the chemicals that are adsorbed can act as 'hormone mimics', interfering with hormonal signalling pathways[281] with potential for intergenerational transfer of chemicals occurring.[282]
- toxic chemicals can be transferred into 'the tissues of marine worms and freshwater fish reducing functions'
- ingestion of microplastics can compromise the immune system of animals.[283]

277 Ibid.

278 Oehlmann, J., U Schulte-Oehlmann, W Kloas, O Jagnytsch, I Lutz, K. Kusk, L Wollenberger, E. Santos, G. Paull, K. Van Look and C. Tyler (2009). A critical analysis of the biological impacts of plasticizers on wildlife. Phil. Trans. R. Soc. 364: 2047-2062 as cited in Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm Caused by Marine Litter. JRC Technica.

279 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

280 Ibid.

281 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

282 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

283 Ibid.

- plastics can leach toxic chemicals once ingested by marine animals.[284] The chemicals can transfer into the blood and tissues of individuals causing sublethal health effects in wildlife, even at very low contamination levels.[285]

Researchers and scientists acknowledge that the consequences for marine species of long-term and chronic exposure to plastics and accumulated pollutants, primarily through ingestion, is poorly understood. Research is ongoing and developing in this space.[286]

Evidence of chemical contamination for key species

Fish

An investigation into the impacts of chemical contamination was conducted by comparing fish which ingested clean plastic pellets compared to fish which ingested plastic pellets which had been immersed in the water in San Diego Bay, California for three months. The fish ingesting the immersed pellets accumulated some of the chemicals, including PAHs, PCBs, and PBDE. Effects observed included glycogen depletion and cellular changes.[287]

Seabirds

Evidence of chemical contamination from plastic debris in seabirds includes:

- plasticizer polychlorinated biphenyl (PCB) has been shown to accumulate in (migratory) seabirds such as the Great Shearwater. This impact was positively correlated with the birds' ingestion of plastic particles.[288]
- reduced reproductive success in birds from PCBs[289]

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284 Lavers JL, Bond AL & Hutton I (2014). Plastic ingestion by flesh-footed shearwaters (Puffinus carneipes): implications for fledgling body condition and the accumulation of plastic derived chemicals. Environmental Pollution 187:124–129 as cited in Australian Government, *Marine debris: Marine environment (2016) State of the Environment,* https://soe.environment.gov.au/theme/marine-environment/topic/2016/marine-debris, Accessed 23 September 2021.

285 Tanaka K, Takada H, Yamashita R, Mizukawa K, Fukuwaka M & Watanuki Y (2013). Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Marine Pollution Bulletin 6:219–222 as cited in Australian Government, *Marine debris: Marine environment (2016) State of the Environment,* https://soe.environment.gov.au/theme/marine-environment/topic/2016/marine-debris, Accessed 23 September 2021.

286 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

287 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

288 Ibid.

289 Ibid.

- indications that chemicals associated with plastics can compromise immune functions in birds.[290]
- seabirds have also been shown to accumulate PBDEs (a family of flame-retardant chemicals) in proportion to the quantity of plastic ingested.[291]

Seals

- PCBs are linked to reduced reproductive ability in Baltic Grey and Ringed Seals resulting in population declines[292]
- High body burdens of PCBs in Baltic grey and ringed seals are linked to impairment of immune function and mass mortalities due to morbillivirus infection.[293]

Turtles

- Possible toxicological impact affecting nutrient absorption and metabolism.[294]

Migration of non-native species

Settlement of non-native species can alter natural habitats, impact on native species' habitats and populations through competition for food and shelter, and/or transmit disease.

Migration of non-native marine species can occur through rafting, whereby species hitch-hike into new marine and coastal environments. Natural debris such as driftwood and timber are used by marine life as rafts. Plastic debris, constituting between 61-87 per cent of all types of marine debris[295], provides an alternative raft. The durability,

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[290] Grasman, K.A., and Fox, G.A. (2001) Associations between altered immune function and organochlorine contamination in young Caspian terns (Sterna caspia) from Lake Huron, 1997-1999, *Ecotoxicology (London, England)*, Vol.10, No.2, pp.101–114 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[291] Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., and Watanuki, Y. (2013) Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.219–222 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[292] Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[293] Vos, J.G., Dybing, E., Greim, H.A., et al. (2008) *Health Effects of Endocrine-Disrupting Chemicals on Wildlife, with Special Reference to the European Situation*, accessed 13 December 2013, http://informahealthcare.com/doi/abs/10.1080/10408440091159176%20 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[294] Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

[295] Garcia-Gómez, J. C., Garrigós, M., and Garrigós, J., 2021, *Plastic as a vector of dispersion for marine species with invasive potential. A review,* Frontiers in Ecology and Evolution.

longevity, buoyancy and surface of plastic debris makes it a viable raft[296] and in some cases a more efficient raft for certain species, including Arthropoda, Annelida and Mollusca.[297] Organisms also can colonise non-degradable material and be transported by currents and winds.[298]

Observations of rafting noted in the literature include:

- organisms ranging from algae to iguanas have been observed to raft on rubbish in the marine environment
- plastic encrusted with marine organisms have been found in the Pacific, Atlantic, Caribbean and Mediterranean Seas
- over 250 marine pests have invaded Australian waters – many hitching a ride via shipping, floating rafts of debris, and more recently plastics
- a total of 387 taxa, including pro- and eukaryotic microorganisms, seaweeds and invertebrates, have been found rafting on floating litter in all major oceanic regions.[299]

Evidence of impacts

The full impact pathway to establish a causal relationship requires evidence of:

- organisms rafting on plastic debris, as opposed to natural debris such as driftwood
- tracking of the raft to a new environment
- monitoring of organisms to determine whether successful settlement occurs
- monitoring to identifying impacts on native fauna and flora .0

One study predicted that diversity of global marine species might decrease by as much as 58 per cent if worldwide biotic mixing occurs.[300] However there is no information available to attribute this loss of diversity to litter and illegally dumped debris.

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296 Ibid.

297 Ibid.

298 Ibid.

299 Kiessling, K., L. Gutow and M. Thiel (2015). *Marine Litter as Habitat and Dispersal Vector.* In M. Bergmann et al., (eds.), Marine Anthropogenic Litter, Chapter 6, 141-181 as cited in Werner, S., Budziak, A., van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. *Harm Caused by Marine Litter*. JRC Technica.

300 Mckinney, M.L. (1998) On predicting biotic homogenization: species-area patterns in marine biota, *Global Ecology & Biogeography Letters*, Vol.7, No.3, pp.297–301 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species..

Microplastics

Impact on aquatic organisms

Microplastics is defined as plastics less than 5 millimetres in diameter. Ingestion of microplastics has been documented for marine life as small as planktonic organisms and larvae at the bottom of the food chain, in small and large invertebrates, and in fish.[301] Ingestion can occur through uptake by filter-feeders, swallowing surrounding water or consumption of organisms that have previously ingested microplastics.[302]

Impacts from ingestion of microplastics noted in the literature include:

- decreased feeding because of ingestion, and reduced mobility because of adherence to the external carapace and appendages of exposed zooplankton.[303]
- degradation of molecular, cellular, physiology and, ultimately, ecological processes within the marine environment.[304]
- movement of microplastics into the circulatory system of animals can include inflammation, fibrosis, breaks in DNA, sometimes mortality and sometimes reduction in feeding behaviour[305]
- laboratory experiments involving fish being fed microplastics found there were 'cellular and tissue level disruptions'.[306]

Ritchie and Roser (2018) note that microplastics 'rarely cause mortality in any organisms', and that feeding habits for many aquatic organisms remain unchanged

301 Smith, M., Love, D., Rochman, C. M., Neff, R. A., (2018), *Microplastics in Seafood and the Implications for Human Health,* Current Environmental Health Reports (2018) 5:375-386.

302 Ritchie, J. and Roser, M., 2018, *Plastic Polluion,* Our World in Data, https://ourworldindata.org/plastic-pollution#plastic-trade-impact-of-china-s-import-ban. Accessed September 2021.

303 Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J & Galloway TS (2013). Microplastic ingestion by zooplankton. Environmental Science and Technology 47:6646–6655 as cited in Australian Government, Marine debris: Marine environment (2016) State of the Environment, https://soe.environment.gov.au/theme/marine-environment/topic/2016/marine-debris, Accessed 23 September 2021.

304 Browne MA, Underwood AJ, Chapman MG, Williams R, Thompson RC & van Franeker JA (2015). Linking effects of anthropogenic debris to ecological impact. Proceedings of the Royal Society B: Biological Sciences 282(1807):20142929 as cited in Australian Government, Marine debris: Marine environment (2016) State of the Environment, https://soe.environment.gov.au/theme/marine-environment/topic/2016/marine-debris, Accessed 23 September 2021.

305 Dr Mark Browne, Committee Hansard, 18 February 2016, p. 6 as cited in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

306 Dr Britta Denise Hardesty, CSIRO, *Committee Hansard*, 26 February 2016, p. 4. As cited in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

following ingestion of microplastics. Yet for others, microplastics in the gut can occupy space where food should be and therefore have negative biological impacts.[307]

The extent of ingestion and transfer of microplastics through the food chain, as well as a full list of potential impacts from microplastics has not been well established at either the individual, population or ecosystem levels. Sherrington et al. (2014) note it will be difficult to establish impacts at the population and ecosystem levels because it is likely many of the impacts from microplastics will be 'sublethal, subtle and extremely complex to unravel the influence of different factors'.[308]

Human health impacts from microplastics and chemical contamination

The risks to human health from ingestion of microplastics and chemical contamination through plastic adsorption are not well understood but are the subject of ongoing research. Particles as small as 0.16μm to 150μm have been found to translocate through the intestinal wall, mainly through lymphatic tissue.[309]

Further research is required to establish the extent of plastic ingestion by humans through the food chain, followed by identifying causal relationships to health impacts, for example, cancers, thyroid disorders, reproductive issues. This includes identifying impacts from:

- the plastic itself, and
- the toxic chemicals contained within the plastics and the chemicals absorbed by the plastic while in the ocean.

Quantity of plastics ingested by humans

Humans can ingest plastics through seafood. For example, in one study it would found that approximately 300 plastic particles (or 1.5ug) would be consumed in a 300 gram

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307 Ritchie, J. and Roser, M., 2018, *Plastic Polluion,* Our World in Data, https://ourworldindata.org/plastic-pollution#plastic-trade-impact-of-china-s-import-ban. Accessed September 2021.

308 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

309 Hussain N, Jaitley V, and Florence AT, 'Recent advances in the understanding of uptake of microparticulates across the gastrointestinal lymphatics', *Advanced Drug Delivery Reviews*, 50, 2001, pp. 107–142 in Van Cauwenberghe L and Janssen CR, 'Microplastics in bivalves cultured for human consumption', *Environmental Pollution*, 193, 2014, pp. 65-70 as cited in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

serving of mussels.[310] Another study found that 50 particles of plastic would be consumed in a 100 gram serving of oysters.[311]

Rochman et al. (2015) [312] explored how marine debris may be affecting humans, by assessing whether anthropogenic debris was present in marine animals sold for human consumption. The study examined fish sold at fish markets or from fisherman selling their catch for human consumption in Indonesia and USA (table A.22). Debris types included in the study were plastic fragments, plastic monofilament, plastic film, plastic foam and fibres.

The occurrence of anthropogenic debris in individual animals was slightly greater in Indonesia (28 per cent) than USA (26 per cent). Overall, the frequency of occurrence of plastic debris in seafood was similar between locations. However there was a trend for individual Indonesian fish to contain a higher number of particles.

A.22 Incidence of debris in fish and shellfish purchased from Indonesia and USA

Common name	Number collected	Number with debris	Debris pieces per animal (average)	Debris pieces per animal (range)	Type of debris
Fish purchased from Indonesia					
Tilapia	5	0	0	0	N/A
Skipjack tuna	9	0	0	0	N/A
Indian Mackerel	9	5	1	0-3	Fragment, film, monofilament
Shortfin scad	17	5	2.5	0-21	Styrofoam, fragments
Herring	10	4	1.1	0-5	Fragments
Family Carangidae	7	5	5.9	0-14	Fragments
Rabbitfish (Siganus argenteus)	2	1	0.5	0-1	Fragment
Rabbitfish (Siganus canaliculatus)	3	1	0.3	0-1	Monofilament
Humpback red snapper	5	0	0	0	N/A
Oxeye scad	7	0	0	0	N/A
Fish and shellfish purchased from the USA					
Pacific oyster	12	4	0.6	0-2	Fibres

310 Bouwmeester H, Hollman PCH, Peters RJB, 'Potential Health Impact of Environmentally Released Micro- and Nanoplastics in the Human Food Production Chain: Experiences from Nanotoxicology', *Environmental science and technology*, 49(15), 2015, pp. 8932–9847 referenced in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

311 Van Cauwenberghe L and Janssen CR, 'Microplastics in bivalves cultured for human consumption', *Environmental Pollution,* 193, 2014, pp. 65–70 referenced in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

312 Rochman, C., Tahir., Williams, S., Baxa, D., Lam, R., Miller, J., The, F., Werorilangi, S., The, S., (2015), Anthropogenic debris in seafood: Plastic debris and fibres from textiles in fish and bivalves sold for human consumption, Scientific Reports, 5:14340.

Common name	Number collected	Number with debris	Debris pieces per animal (average)	Debris pieces per animal (range)	Type of debris
Jacksmelt	7	3	1.6	0-10	Fibres, fragment
Pacific anchovy	10	3	0.3	0-1	Fibre, film, monofilament
Pacific mackerel	1	0	0	0	N/A
Yellowtail rockfish	3	1	0.3	0-1	N/A
Striped bass	7	2	0.9	0-3	Fiber, film, foam
Chinook salmon	4	1	0.25	0-1	Fiber
Albacore tuna	2	0	0	0	N/A
Blue rockfish	10	2	0.2	0-1	Fibers
Pacific sanddab	5	3	1	0-3	Fiber, film
Lingcod	11	1	0	0-1	Film
Copper rockfish	1	0	0	0	N/A
Vermilion rockfish	3	0	0	0	N/A

Source: Rochman, C., Tahir., Williams, S., Baxa, D., Lam, R., Miller, J., The, F., Werorilangi, S., The, S., (2015), *Anthropogenic debris in seafood: Plastic debris and fibres from textiles in fish and bivalves sold for human consumption,* Scientific Reports, 5:14340.

Broader impacts on ecosystems

Marine debris can impact on ecosystems through changes in habitat and species assemblages, dispersal of marine organisms, introduction of invasive species and pathogens, and alteration of marine food webs.[313] Examples of impacts from marine debris on coral reefs, seagrass beds and the associated bottom-dwelling species include:

- fish nets get caught and damage coral
- debris can smother benthic habitats, for example large quantities of litter in Papua New Guinea was suggested to be smothering seedlings planted to rehabilitate depleted mangrove forests[314]
- accumulation of debris on the sea floor might inhibit gas exchange between water within the sediment and the overlying water, altering the composition of life on the sea floor[315]

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313 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

314 Smith, S. D. A. (2012). Marine debris: A proximate threat to marine sustainability in Bootless Bay, Papua New Guinea. *Marine Pollution Bulletin, 64*, 1880–1883 as cited in Kühn, S., Bravo Rebolledo, E., and van Franeker, J., 2015, *Deleterious Effects of Litter on Marine Life*

315 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

- Richards (2011) found a significant negative relationship between marine debris cover and coral cover, with coral cover and species diversity decreasing with increasing debris abundance[316]
- Lamb et al (2018) examined impacts of plastic waste on coral reefs and found the likelihood of disease in coral reefs increases from 4 per cent to 89 per cent when corals are in contact with plastic[317]

Research into the broader impacts of marine debris on ecosystems has been undertaken in key Australian areas of the Great Barrier Reef and the Gulf of Carpentaria with the following findings:

- The Great Barrier Reef Outlook Report 2014 and the Great Barrier Reef Long Term Sustainability Report 2015 have identified marine debris as a major threatening process to the long-term health and sustainability of the reef.[318]
- The Australian Institute of Marine Science (AIMS) conducted a qualitative risk assessment of nine different categories of emerging contaminants, including marine plastic pollution, for the Great Barrier Reef and Torres Strait marine ecosystems. A key finding was that:

  …as far as the overall outcomes of the risk assessment are concerned, marine plastics and microplastics pose one of the highest risks, if not the highest, depending on the region, of all nine different categories of emerging contaminants assessed.[319]

Whilst research is ongoing, the scale and long-term effects of these impacts on marine ecosystems is still uncertain.[320]

Valuing the environmental impacts

Based on the above review of the evidence, the main quantifiable environmental impacts of litter and illegal dumping in the marine environment relate to:

- marine animals which ingest littered or illegally dumped plastics, which remain in the stomach of marine animals causing direct damage and/or accumulating and eventually causing starvation.

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316 Richards, Z. & Beger, M. (2011). A quantification of the standing stock of macro-debris in Majuro lagoon and its effect on hard coral communities. Marine Pollution Bulletin, 62, 1693-1701 as cited in Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

317 Lamb, J.B., Willis, B.L., Fiorenza, E.A., Couch, C.S, Howard, R., Rader, D.N., True, J.D., Kelly, L.A., Ahmad, A., Jompa, J., Harvell, C.D., 2018, *Plastic waste associated with disease on coral reefs,* Science 359, 460-462 26 January 2018.

318 Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

319 Dr Frederieke Kroon, Australian Institute of Marine Science, *Committee Hansard*, 10 March 2016, p. 15 as cited in Senate Standing Committee on Environment and Communications, 2016, *Toxic tide: the threat of marine plastic pollution in Australia,* Senate Inquiry April 2016.

320 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

- marine animals which become entanglement in derelict fishing gear, causing severe injuries or fatality.

There is evidence that ingestion of plastics and entanglement in derelict fishing gear may be having population-level impacts on around 20 threatened or endangered species.

Valuing species preservation

There is a significant literature estimating the willingness to pay for species preservation, mostly in the context of endangered or threatened species. There are various ways that species preservation has been valued in the literature.

Estimated value of avoiding extinction of threatened and endangered species

One way species preservation is conceptualised in the literature is as the community's WTP to avoid a species population dropping below the minimum viable level and thus becoming extinct (at least in the wild). However, Lew (2015) notes that most stated preference studies are valuing actions to improve populations of endangered or threatened species, rather than the species themselves.

According to Johnson et. al. (2015) function transfers typically outperform unit value transfers in terms of accuracy, although not always (refer to appendix D).[321] There are several meta-analyses that provide an opportunity to use the function transfer approach to valuing threatened and endangered species.

In particular, Amuakwa-Mensah et. al. (2018) conducts a meta-analysis regression to explain variation in willingness to pay for threatened and endangered species and derive a benefit transfer function that can be used to value TEVs for threatened and endangered species. The meta-analysis covered 56 surveys (45 in developed countries and 11 in developing countries) covering 92 values species (including 37 marine or terrestrial mammals, 19 bird, 19 fishes, four invertebrates and 13 reptiles).[322]

A number of models were estimated, including various combinations of the following variables.

- Study methodology variables, including: response rate, sample size, study year, method (contingent valuation, choice experiment or hybrid), survey format (face-to-face or other)
- Developed or developing country
- Payment vehicle (tax, bill, membership fee, Trust fund or unspecified) and frequency (monthly, one-off or per visit)
- Taxa (bird, fish, marine mammal, terrestrial mammal or reptile)

321 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, pp. 21-22.

322 Amuakwa-Mensah, F. Barenbold, R. and Riemer, O. 2018, Deriving a Benefit Transfer Function for Threatened and Endngered Species in Interaction with Their Level of Charisma, environments, p. 7.

- Level of threat and charisma (endangered with low charisma, endangered with high charisma, threatened with low charisma or threatened with high charisma)
- Resident or visitor.

Of the models reported in the paper, Model (4) provides the best fit and is therefore used to estimate WTP for this study (see table A.23).

A.23 Willingness to pay model

	Coeff	se
Ln Response rate	-0.526**	0.242
Ln Sample size	0.352***	0.079
Level of threat & charisma (ref=threatened with low charisma)		
Endangered with low charisma	1.106***	0.401
Endangered with high charisma	0.709**	0.336
Threatened with high charisma	0.658*	0.341
Country (ref = developed country)		
Developing country	-0.816**	0.368
Payment vehicle (ref=tax)		
Bill	-1.496***	0.455
Membership fee	-0.434	0.373
Trust fund	-0.351*	0.2
Unspecified	-0.507	0.576
Payment frequency (ref=annual)		
Monthly	-1.409***	0.401
Once	0.068	0.258
Per visit	-0.478	0.54
Class (ref = bird)		
Fish	-0.786***	0.246
Invertebrate	-0.765	0.476
Mammal (marine)	-0.285	0.231
Mammal (terrestrial)	-0.578**	0.272
Reptile	-0.602*	0.309
Respondents (ref=visitor)		
Residents	-0.904***	0.248
Constant	4.19***	1.046
R-squared	0.784	
Adjusted R-squared	0.716	

Note: *** statistically significant at the 99 per cent level of significance. ** statistically significant at the 95 per cent level of significance. * statistically significant at the 90 per cent level of significance.

Source: Amuakwa-Mensah, F. Barenbold, R. and Riemer, O. 2018, Deriving a Benefit Transfer Function for Threatened and Endangered Species in Interaction with Their Level of Charisma, environments, p. 10.

Based on the above model, willingness to pay estimates (converted from 2015 US dollars to 2020 Australian dollars, using the average PPP exchange rate over the period since

2000 and inflated using the Australian CPI) are shown in table C.2. These estimates are also based on:

- a hypothetical sample size of 1713 and response rate of 61 per cent based on averages across the studies
- all species have high charisma
- the payment vehicle is an annual tax (as this is likely to be most closely aligned with how litter reduction programs would be funded)
- the estimated willingness to pay reflects the preferences of residents (rather than visitors).

The aggregate willingness to pay for all Australian households is shown in table A.24. In 2021, there are an estimated 7.2 million households in NSW, Victoria and Queensland. Across these households, the aggregate willingness to pay to preserve these species is also shown.

A.24 Estimated annual willingness to pay for species preservation

	Household WTP per species	Aggregate WTP per species All Australian households	Aggregate WTP per species NSW, VIC, QLD households
	$ per household	$ million	$ million
Endangered species			
Turtles	71	708	550
Whales	98	972	754
Seabirds	130	1 292	1 003
Vulnerable species			
Turtle	68	673	522
Whale	93	924	717
Seabird	123	1 228	953
Shark	56	560	434

Note: Aggregate WTP is based on 7.2 million households in NSW, Victoria and Queensland.

Source: Amuakwa-Mensah, F. Barenbold, R. and Riemer, O. 2018, Deriving a Benefit Transfer Function for Threatened and Endangered Species in Interaction with Their Level of Charisma, environments, p. 10; ABS; CIE.

Willingness to pay for a change in status

An alternative approach to valuing 'species preservation' that has been used in a series of related studies is to estimate the community's willingness to pay for a change in a species 'status' under the US Endangered Species Act. In an Australian context, this could be considered analogous to a change in status under the EPBC Act.

Table A.25 shows the average WTP across various species types (converted to 2020 Australian dollars).

A.25 WTP estimates for change of species status

	Low	Average	High
	$A (2020)	$A (2020)	$A (2020)
Mammals	84.64	105.10	125.56
Fish	74.31	83.14	91.97
Turtles	94.56	105.33	116.10
Invertebrates	119.43	126.67	133.92

Source:

The specific estimates reported in each of these studies is shown in table A.26.

A.26 Studies estimating WTP for change in status

Species	References	Valuation method	Mean /Median WTP range	Frequency of payment	Units	Survey year	Good valued	Country
Mammals								
Hawaiian monk seal	Lew and Wallmo 2011	CE	$47.47–92.68	Annual	H	2008	Improved status	U.S.
Hawaiian monk seal	Wallmo and Lew 2011	CE	$47.47–73.97	Annual	H	2008	Improved status	U.S.
Hawaiian monk seal	Wallmo and Lew 2012	CE	$39.37–72.00	Annual	H	2009	Improved status	U.S.
North Pacific right whale	Wallmo and Lew 2012	CE	$45.30–79.44	Annual	H	2009	Improved status	U.S.
North Atlantic right whale	Wallmo and Lew 2012	CE	$42.12–77.77	Annual	H	2009	Improved status	U.S.
Humpback whale	Wallmo and Lew 2015	CE	$65.14–67.46	Annual	H	2010	Improved status	U.S.
Southern resident killer whale	Wallmo and Lew 2015	CE	$90.14–95.97	Annual	H	2010	Improved status	U.S.
Fish								
Puget Sound Chinook salmon	Wallmo and Lew 2011	CE	$50.98	Annual	H	2008	Improved status	U.S.
Puget Sound Chinook salmon	Wallmo and Lew 2012	CE	$43.97	Annual	H	2009	Improved status	U.S.
Upper Willamette River Chinook salmon	Wallmo and Lew 2012	CE	$44.14	Annual	H	2009	Improved status	U.S.
Central California coast coho salmon	Wallmo and Lew 2015	CE	$54.55–62.13	Annual	H	2010	Improved status	U.S.

Species	References	Valuation method	Mean /Median WTP range	Frequency of payment	Units	Survey year	Good valued	Country
Southern California steelhead	Wallmo and Lew 2015	CE	$75.91–82.86	Annual	H	2010	Improved status	U.S.
Smalltooth sawfish	Lew and Wallmo 2011	CE	$36.74–69.79	Annual	H	2008	Improved status	U.S
Smalltooth sawfish	Wallmo and Lew 2011	CE	$36.74–57.97	Annual	H	2008	Improved status	U.S.
Smalltooth sawfish	Wallmo and Lew 2012	CE	$35.24–56.35	Annual	H	2009	Improved status	U.S.
Turtles								
Loggerhead sea turtle	Wallmo and Lew 2012	CE	$47.47	Annual	H	2009	Improved status	U.S.
Hawksbill sea turtle	Wallmo and Lew 2015	CE	$91.82–100.36	Annual	H	2010	Improved status	U.S.
Leatherback sea turtle	Wallmo and Lew 2012	CE	$41.22–73.81	Annual	H	2009	Improved status	U.S
Invertebrates								
Elkhorn coral	Wallmo and Lew 2015	CE	$76.68–85.40	Annual	H	2010	Improved status	U.S.
Black abalone	Wallmo and Lew 2015	CE	$75.32–85.03	Annual	H	2010	Improved status	U.S.
Plants								
Johnson's seagrass	Wallmo and Lew 2015	CE	$44.18–46.82	Annual	H	2010	Improved status	U.S.

Source: Lew,D.K. 2015, Willingness to pay for threatened and endangered marine species: a review of the literature and prospects for policy use, Frontiers in Marine Science, p. 8.

Valuation of entanglement impacts

The largest evidence base in the literature is impacts through entanglement and ingestion. The majority of entanglement impacts are due to active or derelict fishing gear.[323] Gall et al (2015) found entanglement incidents were predominantly due to plastic rope and netting (71 per cent).[324]

323 Ritchie, J. and Roser, M., 2018, *Plastic Pollution,* Our World in Data, https://ourworldindata.org/plastic-pollution#plastic-trade-impact-of-china-s-import-ban. Accessed September 2021.

324 Gall, 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179

Incidence rates of entanglement for key marine species are shown in table A.13, A.14 and A.15. It is assumed 80 per cent of entanglement cases have reported mortality[325] unless otherwise specified in table A.15.

Based on the willingness to pay for species preservation above (table A.24), the aggregate willingness (across households in NSW, Victoria and Queensland) to pay to preserve the 20 endangered and threatened species identified in the EPBC Act listing is estimated at around $20.5 billion per year (table A.27).

A.27 Estimated willingness to pay for species preservation

	Household WTP per species	Number of species	Aggregate WTP per species per year	Total
	$ per household	No.	$ billion per year	$ billion per year
Endangered species				
Turtles	71	1	0.71	0.71
Whales	98	2	0.97	1.94
Seabirds	130	3	1.29	3.88
Vulnerable species				
Turtle	68	4	0.67	2.69
Whale	93	1	0.92	0.92
Seabird	123	8	1.23	9.83
Shark	56	1	0.56	0.56
Total		**20**	**6.36**	**20.53**

Source: Amuakwa-Mensah, F. Barenbold, R. and Riemer, O. 2018, Deriving a Benefit Transfer Function for Threatened and Endangered Species in Interaction with Their Level of Charisma, environments, p. 10; ABS; CIE.

The cost of entanglement of threatened marine species in Australian fishing gear is estimated to be $363.6 million per year (table A.28). This estimate is based on the following assumptions:

- 71 per cent of entanglement is due to fishing gear[326] (entanglement due to other debris items (excl. fishing gear) is not included in this cost estimate)
- the incidence rates for entanglement by species outlined in table A.28. Authors note the difficulty in distinguishing between entanglements in active fishing gear and marine debris.[327],[328] The focus of the studies from which the incidence rates are sourced was marine debris including derelict fishing gear. As such it is assumed the

325 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

326 Gall, 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179

327 National Oceanic and Atmospheric Administration, 2014, *Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States,* 2014 NOAA Marine Debris Program Report, page 1.

328 Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

incidence rates below relate only to derelict fishing gear and not active fishing gear (i.e. bycatch).

- willingness to pay per threatened species outlined in table A.27 and A.28
- 4 per cent of derelict fishing gear originates from Australian fisheries[329],[330]
- mortality rate of 80 per cent[331] for all species except whales for which mortality rates in table A.15 are applied.

A.28 Estimated cost of fishing gear entanglement for threatened species

Species	Population	Entanglement incidence	Total WTP per species per year	Attribution to Australian water	Total cost attributed to Australian fishing gear
	number	per cent	$ billion per year	per cent	$ million per year
Endangered species					
Loggerhead Turtle	45 000	4.2	0.71	4.0	8.4
Southern Right Whale	3 500	1.4	0.97	4.0	1.1
Blue Whale	17 500	0.0	0.97	4.0	-
Tristan Albatross	11 000	6.6	1.29	4.0	23.9
Northern Royal Albatross	20 000	6.6	1.29	4.0	23.9
Gould's Petrel	2 500	6.6	1.29	4.0	23.9
Vulnerable species				4.0	-
Leatherback Turtle	35 000	14.1	0.67	4.0	26.7
Hawksbill Turtle	21 500	8.3	0.67	4.0	15.7
Flatback Turtle	20 500	10.7	0.67	4.0	20.2
Green Turtle	87 500	9.0	0.67	4.0	17.1
Wandering Albatross	55 000	6.6	1.23	4.0	22.7
Humpback Whale	60 000	7.2	0.92	4.0	4.2
Antipodean Albatross	25 260	6.6	1.23	4.0	22.7
Gibson's Albatross	40 000	6.6	1.23	4.0	22.7
Southern Royal Albatross	27 000	6.6	1.23	4.0	22.7
Indian Yellow-nosed Albatross	170 000	6.6	1.23	4.0	22.7
Grey Nurse Shark	1 950	NA	0.56	4.0	-
Grey-headed Albatross	90 000	6.6	1.23	4.0	22.7
Blue Petrel	80 000	9.0	1.23	4.0	31.0

329 Evans, K. Bax, N. and Smith, D.C. 2017, "Marine Environment", Australia State of the Environment 2016, p. 58

330 Data on incidence of entanglement in active fishing gear in Australia and elsewhere has not been compiled. Nor has the share of entanglements in active versus derelict fishing gear. As such 4 per cent of all entanglements, whether in active or derelict fishing gear are assumed to be attributable to Australia for the species listed.

331 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

Northern Giant Petrel	7 425	9.0	1.23	4.0	31.0
Total					**363.6**

Note: Entanglement incidence data not available for Grey Nurse Share, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Valuation of ingestion impacts

Gall et al (2015) found ingestion incidents predominantly involved plastic fragments.[332]

Table A.29 outlines the ingestion incidence for key taxa impacted by plastic ingestion. These ingestion rates, along with ingestion rates for individual turtle species from table A.20 were used to estimate the number of individuals which ingested plastic. Approximately 5 per cent of ingestion cases have reported mortality.[333]

The ingestion incidence data is based on global populations. Australia's contribution to these global impacts was estimated as follows:

- identifying the key countries which species inhabit and migrate through — identified separately for each of the 20 species identified as endangered or vulnerable in Australia, and
- estimating Australia's share of global plastics emitted to the ocean as a proportion of all countries identified as relevant for a given species (see tables A.30 and A.31).

A.29 Ingestion incidence for key taxa

Taxon	Species	Species studied	Individuals studied	Individuals with plastic	Frequency of occurrence
	no.	per cent	no.	no.	per cent
All seabirds	409	55.3	43525	12065	27.7
All carnivores	34	23.53	9 784	93	0.95
All baleen whales	14	42.86	96	16	16.67
All toothed whales	72	50	5 002	480	9.4
All cetaceans	86	48.84	5 098	486	9.53
All sirenia	3	33.33	4 604	281	6.1
All marine mammals	123	41.46	19 486	860	4.41
All turtles	7	100	7879	2536	32

Note: The total number of species in the taxon is given with the percentage of species within the taxon for which ingestion studies are available.

Source: Kühn, S. and van Franeker, J., A. (2020), Quantitative overview of marine debris ingested by marine megafauna, Marine Pollution Bulletin 151 (2020) 110858.

332 Gall, 2015, *The impact of debris on marine life,* Marine Pollution Bulletin 92 (2015) 170-179

333 Sherrington, C., Darrah, C., Cole, G., and Hogg, D., 2014, Report 1: Migratory species, marine debris and its management. Convention on Migratory Species.

A.30 Countries from which marine plastic debris impacts threatened seabirds

Country	Share of global plastic waste emitted to the ocean, 2019 (per cent)	Tristan Albatross	Wandering Albatross	Northern Royal Albatross	Gould's Petrel	Antipodean Albatross	Southern Royal Albatross	Indian Yellow-nosed Albatross	Grey-headed albatross	Blue Petrel	Northern Giant Petrel	Gibson's albatross
Angola	0.088	■										
Argentina	0.422	■	■	■			■		■	■	■	
Australia	0.003	■	■	■	■	■	■	■	■	■	■	■
Brazil	3.859	■	■									
Chile	0.033	■	■	■		■	■		■	■	■	
Fiji	0.037				■							
Madagascar	0.079							■				
Mozambique	0.260							■				
Namibia	0.000	■	■					■			■	
New Caledonia					■							
New Zealand	0.007		■	■	■	■	■	■	■	■	■	■
Peru	0.026			■			■				■	
South Africa	0.436	■	■	■			■	■	■		■	
Uruguay	0.102		■				■		■	■	■	
Estimated share for Australia (per cent)		**0.1**	**0.2**	**0.4**	**6.9**	**7.6**	**0.3**	**0.4**	**0.3**	**0.6**	**0.3**	**32.0**

a

Note: Highlighted brown box represents country which species inhabits/migrates through.

Source: CIE based on Oiseaux.net https://www.oiseaux.net/ for Tristan Albatross, Antipodean Albatross, and Indian Yellow-nosed Albatross; eBird, https://ebird.org/species/goupet1/ for Wandering Albatross, Northern Royal Albatross, Gould's Petrel, Southern Royal Albatross, Grey-headed albatross, Blue Petrel, Northern Giant Petrel and Gibson's albatross.

A.31 Continents from which marine plastic debris impacts threatened whale and turtle species

Continent	Share of global plastic waste emitted to the ocean, 2019 (per cent)	Southern right whale[a]	Blue whale	Humpback whale	Loggerhead turtle[a]	Leatherback turtle[a]	Hawksbill turtle[a]	Flatback turtle[b]	Green turtle[a]
Asia	80.994		■	■	■	■	■		■
Africa	7.989		■	■	■	■	■		■
Australia	0.003	■	■	■	■	■	■		■
North America	4.499		■	■	■	■	■		■
South America	5.513	■	■	■	■	■	■		■

Continent	Share of global plastic waste emitted to the ocean, 2019 (per cent)	Southern right whale[a]	Blue whale	Humpback whale	Loggerhead turtle[a]	Leatherback turtle[a]	Hawksbill turtle[a]	Flatback turtle[b]	Green turtle[a]
Europe	0.595								
Estimated share for Australia (per cent)		**0.118**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**	**0.003**

[a] Only certain countries on continent included. Southern right whale: countries included are Argentina, Australia, Brazil, Chile, Madagascar, Mozambique, New Zealand and Uruguay. Loggerhead turtle includes all continents but excludes some key countries including Argentina, Canada, Norway, Russia and part of Chile, New Zealand and United States. Leatherback turtle includes all continents but excludes Argentina. Hawksbill turtle: countries excluded from selected continents include Argentina, Canada, Chile, Russia, Spain. Green turtle includes all continents (excluding Antarctica) with the following countries excluded, Argentina, Canada, northern European countries, and Russia.

[b] Data on geographic range wasn't available for flatback turtle, applied average of leatherback, hawksbill and green turtle.

Note: Highlighted brown box represents country which species inhabits/migrates through.

Source: CIE based on Ladatco Tours, *About Southern Right Wales,* https://www.ladatco.com/VALDES%20-%20about%20Southern%20right%20whales.htm; Blue Whale Range, https://sites.google.com/site/leslielab23/range; International Whaling Commission, *Humpback Whale,* https://wwhandbook.iwc.int/en/species/humpback-whale; National Oceanic and Atmospheric Administration Fishers, *Loggerhead Turtle,* https://www.fisheries.noaa.gov/species/loggerhead-turtle; National Oceanic and Atmospheric Administration Fishers, *Leatherback Turtle,* https://www.fisheries.noaa.gov/species/leatherback-turtle; National Oceanic and Atmospheric Administration Fishers, *Hawksbill Turtle,* https://www.fisheries.noaa.gov/species/hawksbill-turtle; National Oceanic and Atmospheric Administration Fishers, *Green Turtle,* https://www.fisheries.noaa.gov/species/green-turtle.

The cost of ingestion of plastic litter from Australia entering the ocean per year is estimated to be $104 million per year. This reflects the impact on threatened species from mortality following plastic ingestion. In particular, two thirds of this estimated cost is due to impacts to Gibson's Albatross. This species predominantly inhabits Australian and New Zealand coastlines, so a higher proportion of the impact (32 per cent) is attributable to Australia. This is in strong contrast to other species for which minimal impact (e.g. 0.003 per cent for a variety of turtle species) is attributable to Australia.

The total cost ranges between $803 and $3 994 dollars per tonne of plastic entering the ocean (approximately between $0.008 and $0.04 per empty 10 gram plastic bottle), depending on the estimated tonnes of plastic litter entering Australian waters per year:

- low estimate of debris — based on estimated 26 150 tonnes of plastic entering Australia waters per year [334]
- high estimate of debris — based on estimated 130 000 tonnes of plastic litter entering Australian waters per year (table A.32).

334 Based on global estimate of 8 million tonnes of plastics entering ocean (see https://www.marineconservation.org.au/ocean-plastic-pollution) and Australia's share of plastics emitted to the ocean, estimated as 0.003 per cent.

A.32 Estimated cost of marine plastic litter from Australia for threatened species

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed Australian litter	Cost per tonne of plastic litter per year	
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low	$/t/yr high
Endangered species							
Loggerhead Turtle	45 000	22.0	0.71	0.003	0.0	0.1	0.0
Southern Right Whale	3 500	16.7	0.97	0.118	0.1	4.5	0.9
Blue Whale	17 500	16.7	0.97	0.003	0.0	0.1	0.0
Tristan Albatross	11 000	27.7	1.29	0.067	0.1	5.7	1.2
Northern Royal Albatross	20 000	27.7	1.29	0.352	0.8	29.9	6.0
Gould's Petrel	2 500	27.7	1.29	6.882	15.3	584.8	117.6
							Vulnerable species
Leatherback Turtle	35 000	30	0.67	0.003	0.0	0.2	0.0
Hawksbill Turtle	21 500	36	0.67	0.003	0.0	0.2	0.0
Flatback Turtle	20 500	100	0.67	0.003	0.0	0.5	0.1
Green Turtle	87 500	47	0.67	0.003	0.0	0.2	0.0
Wandering Albatross	55 000	27.7	1.23	0.166	0.4	13.4	2.7
Humpback Whale	60 000	16.7	0.92	0.003	0.0	0.1	0.0
Antipodean Albatross	25 260	27.7	1.23	7.583	16.0	612.4	123.1
Gibson's Albatross	40 000	27.7	1.23	32.000	67.5	2584.2	519.6
Southern Royal Albatross	27 000	27.7	1.23	0.317	0.7	25.6	5.2
Indian Yellow-nosed Albatross	170 000	27.7	1.23	0.416	0.9	33.6	6.8
Grey Nurse Shark	1 950	NA	0.56	NA	0.0	0.0	0.0
Grey-headed Albatross	90 000	27.7	1.23	0.326	0.7	26.3	5.3
Blue Petrel	80 000	27.7	1.23	0.576	1.2	46.5	9.3

Species	Estimated population	Ingestion incidence	Total WTP per species per year	Attribution to Australian waters	Total cost attributed Australian litter	Cost per tonne of plastic litter per year	
	no.	per cent	$b/yr	per cent	$m/yr	$/t/yr low	$/t/yr high
Northern Giant Petrel	7 425	27.7	1.23	0.317	0.7	25.6	5.2
Total					**104.4**	**3994.2**	**803.0**

Note: Ingestion incidence data was not available for Grey Nurse Shark, so impacts have not been valued.

Source: CIE based on various sources outlined throughout report.

Valuing the impacts of microplastics in the ocean

There have been several recent studies that have directly valued the community's willingness to pay to reduce microplastic pollution in the marine environment. Of most relevance is a forthcoming Australian paper that seeks to value the community's willingness to pay to reduce microplastics in the marine environment using a stated preference survey.[335] The attributes and levels in the stated preference experiment are summarised in table A.33.

A.33 Attributes and levels of the stated preference experiment

Attribute	Level 1	Level 2	Level 3	Level 4	Level 5
Ocean: pieces per square km of ocean	2 500	3 000	3 500	4 000	4 500
Seabird: number of birds impacted	75%	80%	85%	90%	95%
Marine life: number of animal deaths per year	70 000	80 000	90 000	100 000	110 000
Fish: average number of microplastics digested per fish	1.5	2	2.5	3	3.5
Beach: average number of microplastics per sqm	95	115	135	155	175
Household levy: yearly amount for 10 years ($)	$0	$30	$60	$90	$120

Source: Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", *Marine Policy*, 135, p. 3.

The study reports households' willingness to pay to reduce microplastics range between:

- $46.25 per year over 10 years (based on reducing all non-price attributes shown in table A.33 from Level 4 to Level 3)
- $138.75 per household (based on reducing all non-price attributes shown in table A.33 from Level 4 to Level 1).[336]

Extrapolating these estimates across all Australian households (note that the study extrapolates across NSW residents only), provides an indicative estimate of the aggregate willingness to pay to reduce microplastics in a range between (table A.34):

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335 See Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", *Marine Policy*, 135.

336 Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", Marine Policy, 135, p. 7.

- $460.4 million per year; and
- $1.38 billion per year.

A.34 Indicative willingness to pay to reduce microplastics

	Annual WTP per household	Aggregate annual WTP[a]
	$ per year	$ million per year
Lower bound (Level 3)	46.25	460.4
Upper bound (Level 1)	138.75	1 381.3

[a] Based on 9.96 million households.

Source: Borriello, A. and Rose, J. M. 2022, "The issue of microplastics in the oceans: Preferences and willingness to pay to tackle the issue in Australia", Marine Policy, 135, p. 3; ABS, CIE.

Although this study implies that the community's willingness to pay to reduce microplastics is significant, we have not included these estimates of the costs of microplastics in our overall estimates of the environmental costs of litter and illegal dumping for several reasons.

In particular, the framework set out in chapter 2 focuses on the causal linkages, including from the presence of material in the environment to environmental impacts (defined as identifiable impacts on animal and plant species and the functioning of the ecosystem). This is consistent with advice from the Productivity Commission on the use of stated preference studies:

> "Environmental goods or attributes in the survey [should be] expressed in terms of endpoints that people directly value. For example, people should be asked about willingness to pay for the environmental improvements brought about by increases in environmental water flows, rather than for increases in environmental water flows themselves."[337]

By contrast, the attributes included in the study are mostly measures of the presence of microplastics in the environment, as the environmental impacts are still not well understood. As further noted by the Productivity Commission, where policy outcomes are not expressed in terms that are directly valued by participants, but are instead proxies for the ultimate environmental outcomes that they care about, survey respondents are more likely to draw on prior knowledge or make erroneous assumptions to make relevant connections.[338]

Although the study does not directly measure the environmental outcomes as a result of microplastics, these estimates nevertheless indicate a significant level of community concern and an appetite for action to reduce microplastics in the marine environment.

337 Productivity Commission, *Environmental Policy Analysis: A Guide to Non-Market Valuation*, Productivity Commission Staff Working Paper, January 2014, p. 45.

338 Productivity Commission, *Environmental Policy Analysis: A Guide to Non-Market Valuation*, Productivity Commission Staff Working Paper, January 2014, p. 37.

B Literature review of environmental impacts in inland waterways

Evidence of the presence of littered and dumped material in the environment

Many studies focus on litter in inland waterways to understand the extent to which inland waterways are a key source of marine debris. Van Emmerik and Schwarz (2019) state that the fate of macroplastics in freshwater systems is unknown, and the general assumption is that plastics in rivers end up in the ocean.[339]

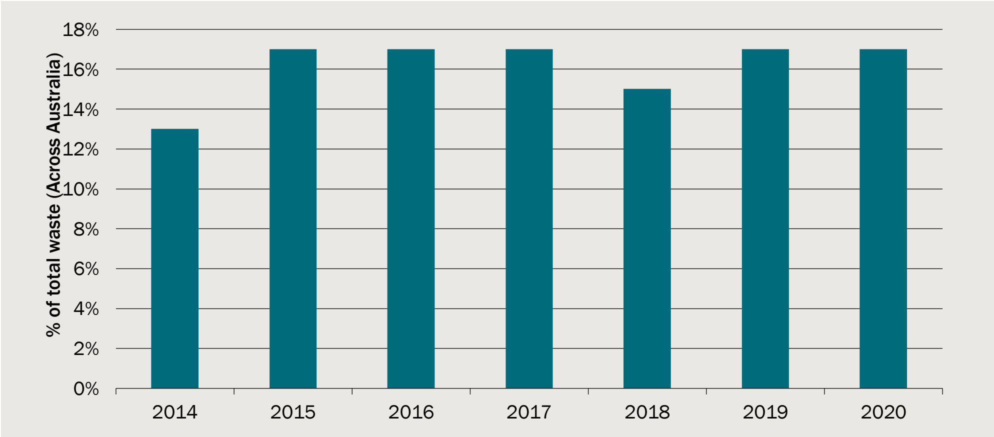
There is limited systematic data on the extent to which littered or dumped material **accumulates** in Australian inland waterways. The latter is important, because littered and illegally dumped material can have environmental impacts on these fresh and brackish waterways environments before they eventually make their way onto the marine environment. In a 2010 Healthy Waterways' community survey, residents of South East Queensland highlighted rubbish and litter as the most crucial factor damaging the waterways.[340]

Clean Up Australia Rubbish report data on the proportion of total litter collected across Australian waterways such as creeks, river and other bodies of in land water. Figure B.1 highlights the litter cleaned up from rivers, creeks and waterways, as the percentage of total waste collected across a multitude of environments from 2014 to 2020 across Australia. In recent years the proportion of total litter found in the Australian waterways have remained fairly stable at 14 to 15 per cent. This data is useful to understand how much litter and debris enters inland waterways and is subsequently cleaned up. However it does not identify how much remains in inland waterways causing subsequent environmental impacts.

339 Van Emmerik, T. and Schwarz, A., 2019, *Plastic debris in rivers,* https://wires.onlinelibrary.wiley.com/doi/epdf/10.1002/wat2.1398. Accessed September 2021.

340 See, https://hlw.org.au/download-topic/waterways/litter-in-our-waterways/

B.1 Trend in the proportion of total litter found in Rivers/Creeks/Waterways across Australia

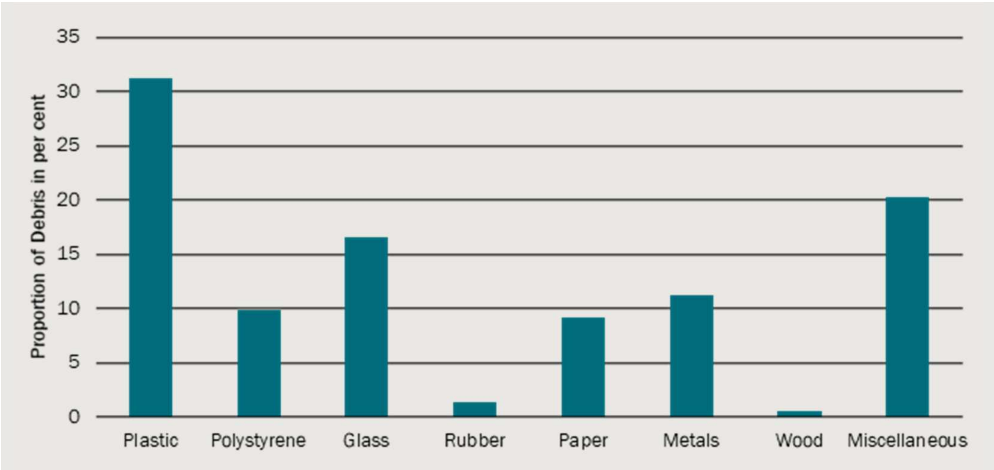


Note: 3,278 sites nationally. Of these, 748 recorded valid data for analysis across 1,274 locations
Data source: Clean Up Australia

Litter Composition

Plastics were the rubbish type most commonly reported from waterways, representing 31.7 per cent of the total rubbish (chart B.2). The Clean Up Rubbish Report survey lists a total of 94 specific waste items grouped by source material, with an 'other' or 'miscellaneous' category for those items which do not fit easily within the list. Cigarette filters found in these environments are categorised under 'miscellaneous'. Glass items was also a common litter item to be found alongside riverbeds. Beverage bottle counts were the dominant group within items of glass material in the environment.

B.2 Litter composition in waterways across Australia in 2020



Data source: Clean Up Australia report 2020

A study used freshwater shrimp in Victoria to measure presence of microplastic in the sampled rural freshwater sites. In the 30 water samples and 100 shrimp analysed, a total of 36 per cent of shrimp contained microplastics with an average of 24 ± 31 items/g.

Microplastics were present in the surface waters of all sites, with an average abundance of 0.40 ± 0.27 items/L.[341] The dominant plastic types were polyester in water samples, and rayon in shrimp samples. Despite the fact that the results of this study demonstrate a comparatively low concentration of microplastics in water samples when compared to global studies, it is worth noting that microplastics have been found in fresh waterbodies in Victoria on a regular basis.[342]

In South East Queensland, The Healthy Waterways Clean Up Program has recorded a 50 per cent increase in the number of plastic water bottles collected from local waterways.[343] Brisbane City Council has identified that cigarette filters make up more than 50 per cent of all littered items but discarded chewing gum is emerging as a major issue.

There are also instances of illegal dumping of garden waste in waterways however to a much lesser amount than that happens in bushland as evidenced by community response to the survey assessing attitude towards illegal dumping in the NSW EPA illegal dumping research report.[344]

Environmental impacts

Similar to marine environments, various types of litter or dumped materials can negatively impact inland water environments such as inland rivers, lakes and wetlands. Negative impacts from debris could include:

- harm to aquatic fauna through entanglement, ingestion or chemical contamination
- broader impacts to ecosystems through harm to aquatic flora, habitats and ecosystems, or spread of diseases[345]
- water, land or soil pollution, including water-borne diseases and algal blooms
- risk to human health through fish and water consumption[346]

Evidence of environmental impacts

It is widely acknowledged by researchers that the vast majority of research on environmental impacts from litter and dumped material, but in particular plastic debris,

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341 Nan, B., Su, L., Kellar, C., Craig, N. J., Keough, M. J., & Pettigrove, V. (2020). Identification of microplastics in surface water and Australian freshwater shrimp Paratya australiensis in Victoria, Australia. Environmental Pollution, 259, 113865.

342 Ibid

343 See, https://hlw.org.au/download-topic/waterways/litter-in-our-waterways/

344 NSW EPA (2015). NSW Illegal dumping research. See, https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/illegaldumping/150481-illegal-dumping-report.ashx

345 See https://www.texasdisposal.com/blog/the-real-cost-of-littering/

346 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

has been focused on the marine environment.[347],[348],[349] Many authors have commented that more work is needed to examine the negative impacts of litter and dumped material, in particular plastics, in terrestrial and freshwater habitats. [350],[351]

Thompson et. al. (2009) noted there was an absence of information on the quantities and effects of plastic debris in natural terrestrial and freshwater habitats, and on agricultural land.[352] The Queensland government also acknowledge the need for further investigation of the abundance and nature of plastic pollution in freshwater systems. [353]

Blettler, M. et al. (2018) conducted a bibliometric analysis on the topic of freshwater plastic pollution and compared it to the literature on marine environment. The authors found that 87 per cent (440 papers) of plastic pollution studies are related to the marine environment, compared to only 13 per cent (64 papers) to freshwater systems. Furthermore, the annual growth rate was approximately 41 to 7 papers per year for marine and freshwater environments, respectively (chart B.3). Overall, the authors found the research related to plastic debris in freshwater environments presented only fragments of the 'overall picture of freshwater plastic pollution'.[354]

Of the 106 plastic pollution studies recorded in freshwater environments reviewed by Blettler et. al. (2018) only 2 per cent were conducted in Australia.[355]

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347 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

348 Hoellein, T., Rojas, M., Pink, A., Gasior, J., and Kelly, J., 2014, Anthropogenic litter in urban freshwater ecosystems: distribution and microbial interactions, *PLOS ONE June 23, 2104.*

349 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

350 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

351 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

352 Thompson, R., Moore, C., vom Saal, F., and Swan, S., 2009, Plastics, the environment and human health: current consensus and future trends, *Phil. Trans. R. Soc. B (2009) 364, 2153-2166.*

353 https://wetlandinfo.des.qld.gov.au/wetlands/management/pressures/litter-illegal-dumping/sinks/fresh-water/"

354 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

355 Ibid

B.3 Production of plastic pollution studies for freshwater and marine environments

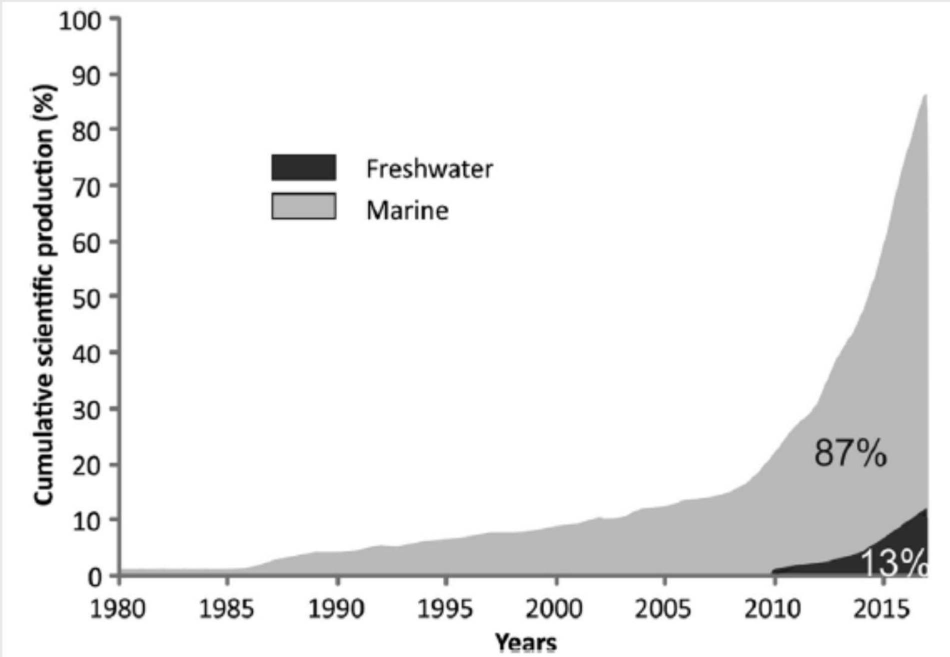


Fig. 1. Comparison between plastic pollution studies performed in marine and fresh-waters, showing total scientific publication and rate of growth in both environments since January 1980 to May 2018.

Data source: Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

The majority of studies examining impacts and interactions between plastics and organisms were conducted for marine environments (178 studies) compared to 39 studies in freshwater environments (table B.4). Key biotic groups examined in freshwater environments were fish, bird, zoobenthos, zooplankton and bacteria.

B.4 Number of studies considering impact and interactions between plastics and organisms in marine and freshwater environments

Biotic groups	Marine	Freshwater	
		Developed countries	Developing countries
	no.	no.	no.
Fish	35	10	7
Bird	59	3	1
Mammal	11	0	0
Turtle	17	0	0
Zoobenthos	15	3	1
Zooplankton	7	7	0
Mollusk	10	1	0
Decapods	4	0	0

Biotic groups	Marine	Freshwater	
		Developed countries	Developing countries
	no.	no.	no.
Bacteria	13	3	0
Fungi	1	0	0
Alga	6	2	0
Moss	0	1	0
Total studies	**178**	**30**	**9**

Source: Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

Literature on plastics in freshwater environments is dominated by a focus on microplastic. Bletter et al (2018) note there is no reason to assume freshwater ecosystems are unaffected by macro-debris and suggest the following reasons for a focus on microplastics rather than macroplastics:

- microplastics have been identified as one of the top 10 emerging issues by the United Nations Environment Programme (UNEP) in the 2005, 2014 and 2016 Year Books
- microplastics can impact freshwater fish
- small plastic fragments may possibly have higher leaching rates of exogenous chemicals than those given by macroplastics, due to their proportionally greater surface area
- microplastics are possibly more widespread than macroplastics.[356]

Despite the relative lack of information on environmental impacts from plastic and other debris in freshwater environments, from the limited evidence available authors note that plastics and other anthropogenic debris are a concern for the health of freshwater ecosystems.[357] Azevedo-Santos et al (2021) state that although more studies on the extent of plastic pollution in river networks are required, that plastic pollution in freshwater ecosystems is likely to be as detrimental as seen in marine environments.[358]

Entanglement and ingestion

In stark contrast to the marine debris literature, Blettler et al. (2018) found there were no studies evaluating entanglement impacts from macroplastics on freshwater fauna and

356 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

357 Holland, E. R., Mallory, M., and Shutler, D., 2016, *Plastics and other anthropogenic debris in freshwater birds from Canada,* Science of The Total Environment, Volume 571, 15 November 2016, Pages 251-258.

358 Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

noted that most studies to date have focused on ingestion of plastics.[359] The available evidence of ingestion impacts is presented below.

Blettler et al. (2018) note that the abundance of microplastics in freshwater environments is likely comparable to marine contamination levels.[360] Globally, ingestion by freshwater species has been reported in natural, semi-natural and laboratory conditions. In freshwater environments, the group with the highest records of plastic ingestion is fish, with 158 species identified as ingesting plastic in natural conditions and 2 in semi-natural conditions. The second highest group is birds with 20 reported incidences of plastic ingestion in natural conditions and 1 in semi-natural conditions (table B.5).

B.5 Number of freshwater species that ingested plastic in natural, semi-natural or laboratorial conditions

Group	Natural	Semi-natural	Laboratory	Total
	no.	no.	no.	no.
Crustaceans	1	1	7	9
Other invertebrates	6	0	10	16
Fishes	158	2	0	160
Amphibians	15	0	3	18
Birds	20	1	0	21
Mammals	2	0	0	2
Total	**202**	**4**	**20**	**226**

Source: Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Effects of ingestion

Azevedo-Santos et al. (2021) examined the impacts of plastic ingestion on freshwater organisms, predominantly in laboratory conditions. Nine observations had sub-lethal impacts and four observations had lethal impacts (table B.6).

B.6 Examples of freshwater organisms negatively affected by plastic ingestion in laboratory or natural conditions

Group	Condition	Sub-lethal	Lethal
		no.	no.
Crustacean	Laboratory	3	2
Mollusk	Laboratory	2	0
Cnidarian	Laboratory	1	0
Fish	Laboratory	2	0

359 Blettler, M., Abrial, E., Khan, R., Sivri, N., Espinola, L., 2018, Freshwater plastic pollution: recognizing research biases and identifying knowledge gaps, *Water Research 143 (2018) 416-424.*

360 Ibid.

Group	Condition	Sub-lethal	Lethal
		no.	no.
Amphibian	Laboratory	1	1
Mammal	Natural	0	1
Total		**9**	**4**

Source: Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Table B.7 outlines potential or identified impacts noted in the literature for different biotic groups within freshwater environments. Potential impacts have been investigated from laboratory studies and in some cases inferred from evidence of impacts to counterpart biota in the marine environment.

B.7 Scope of potential impacts to different biotic groups

Biotic group	Potential or recorded impacts
Algae and plants	▪ Laboratory studies show that plastics may cause negative impacts including – Decreased photosynthetic production in algae – Affect root development – Aquatic algae or plants may absorb small-sized particles – Field studies are lacking, but algae and plants in natural ecosystems are likely to respond in a similar way.[361]
Freshwater crustaceans	▪ Some crustacean groups have the potential to ingest plastic particles ▪ The negative effects include decreased survival to changes in the ability to reproduce ▪ Entanglement in ghost nets affects freshwater decapod crustaceans
Invertebrates	▪ Evidence that macroinvertebrates are able to ingest plastic, potentially leading to input to plastic material into aquatic food chains.
Fishes	▪ Freshwater fishes are the group with most records of plastic ingestion ▪ Increasing trend indicates that plastic ingestion by freshwater fish is more common than currently reported ▪ Evidence of negative effects of plastic ingestion on fishes, but in laboratory conditions, including: – inflammatory processes in the digestive tract from exposure to polystyrene – various plastics caused damage to intestine of fishes – ingestion of large amounts of polyethylene may cause gut distension and abnormal swimming behaviour, which in natural conditions may lead to secondary effects (e.g. vulnerability to predation). – Synthetic polymers may adhere to fish gills, and may clog or harm the gills – Entanglement in plastic rings or ghost fishing nets

361 Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Biotic group	Potential or recorded impacts
Amphibians	▪ plastic ingestion has been reported for 18 freshwater species (see table B.5) ▪ microplastic may adhere to the gill of amphibians (based on laboratorial studies) ▪ plastics can causal external morphological, mutagenic and cytotoxic changes in tadpoles
Reptiles	▪ Evidence of impacts for reptiles is limited to the marine environment, but considered to be similarly relevant for reptiles in freshwater environments.
Birds	▪ Evidence of freshwater birds ingesting plastic directly or indirectly. ▪ The impact of ingestion by freshwater birds has not been well documented, however Azevedo-Santos et al. (2021) consider the impacts to be similar to those of marine species, namely obstruction of the digestive tract, with risk of starvation. ▪ Evidence of entanglement is available for freshwater birds, leading to sublethal to lethal effects, or potentially minor consequences if birds escape entanglement. ▪ It is noted that construction of nests using synthetic polymers by freshwater birds may lead to risk of contamination, ingestion and entanglement for adults and offspring. ▪ A Canadian study examined ingestion of plastic and other debris in 350 individuals of 17 freshwater and 1 marine bird species and estimated ingestion rates to be 11.1 per cent across all freshwater species studies.[362]
Mammals	▪ Reported incidence of ingestion by two freshwater mammal species ▪ Entanglement in fishing nets (bycatch and ghost nets) considered a problem for freshwater mammals, with a reported entanglement of a freshwater dolphin ▪ It is noted that construction of holts using synthetic polymers may expose animals to the risks of plastic ingestion and entanglement.

Source: Azevedo-Santos VM, Brito MFG, Manoel PS, Perroca JF, Rodrigues-Filho JL, Paschoal LRP, Gonçalves GRL, Wolf MR, Blettler MCM, Andrade MC, Nobile AB, Lima FP, Ruocco AMC, Silva CV, Perbiche-Neves G, Portinho JL, Giarrizzo T, Arcifa MS, Pelicice FM., 2021, Plastic pollution: a focus on freshwater biodiversity, AMBIO A Journal of the Human Environment, February 2021.

Entanglement of platypus

Serena and Williams (2021) collated evidence of entanglement impacts on platypus in four river basins in the Greater Melbourne area and 13 river basins in regional Victoria (table B.8). The incidence of entanglement was higher in river basins in the Greater Melbourne area (4 per cent) compared to regional river basins (0.5 per cent). The authors noted the 8-fold increase was likely due to higher amounts of litter and debris in urban waterways.

The frequency of entanglement was higher (over double) in first-year juveniles (11 per cent) compares to adults and subadults (5 per cent). Potential explanations for this are:

- juvenile platypus may be more playful or inquisitive
- the smaller necks and torsos of juveniles may pass through a wider range of debris items
- juveniles would have less strength compared to adults to remove entangling items

362 Holland, E. R., Mallory, M., and Shutler, D., 2016, *Plastics and other anthropogenic debris in freshwater birds from Canada,* Science of The Total Environment, Volume 571, 15 November 2016, Pages 251-258.

Platypus can become entangled in rubbish looped around the neck and torso regions. Debris items causing entanglement were:

- 62 per cent of cases were caused by relatively narrow (up to 3-mm wide) elastic/rubber bands as routinely used in households and offices
- 13 per cent caused by loops of nylon fishing line.
- 16 per cent caused by bangle-type bracelets, cable-ties, food jar seals, part of a six-pack holder and various rings and bands on unknown origin
- remaining 9 per cent caused by miscellaneous items.

Debris items can cause entanglement around the neck, torso or bandolier-style (from in front of one foreleg to behind the opposite foreleg). The authors found that the outcome of entanglement for platypus can range from relatively innocuous to serious injury or death, depending on how the body is entangled and also the extent of skin abrasions.[363] For instance, narrow household- or office-type elastic/rubber bands were consistently associated with (at most) minor abrasions.

The authors noted reports that entanglement was highly likely to have been the primary cause of death for 11 cases and a further 2 cases where entangled animals were found in a debilitated state and may have died without human intervention.[364]

Overall the authors noted that:

- up to 1.5 per cent of the platypus residing across the greater Melbourne area, and 0.5 per cent of those living in regional Victoria are estimated to be at risk of entanglement-related injuries or death at any point in time.
- adverse population consequences of entanglement could increase under circumstances of reduced transport of litter downstream
- impacts can be heightened at the localised level as demonstrated by the higher incidence rate at Werribee Basin.

B.8 Entanglement incidence in platypus in Victorian river basins

Basin	Number of platypus in live-trapping survey	Number of live-trapped platypus with evidence of entanglement	Proportion entangled
	Number	Number	Per cent
Greater Melbourne area (recorded between 1989-2011)			
Werribee Basin	27	4	15
Maribyrnong Basin	94		0
Yarra Basin	778		5
Bunyip Basin	367		1
Sub-total for Greater Melbourne area	1266	51	4

363 Serena, M. and Williams, G.A., 2021, *Factors affecting the frequency and outcome of platypus entanglement by human rubbish*, Australian Mammalogy.

364 Ibid.

Basin	Number of platypus in live-trapping survey	Number of live-trapped platypus with evidence of entanglement	Proportion entangled
	Number	Number	Per cent
Regional Victoria (recorded between 1997 to 2019)			
13 river basins in regional Victoria[a]	580	3	0.5

[a] Upper Murray River, Broken, Goulburn, Campaspe, Loddon, Wimmera, Hopkins, Barwon, Moorabool, Mitchell, Thomson, Tambo, Snowy.

Source: Serena, M. and Williams, G.A., 2021, *Factors affecting the frequency and outcome of platypus entanglement by human rubbish*, Australian Mammalogy.

Chemical contamination

Degrading plastic litter can release chemicals and microplastics into the environment. These chemicals can leach into soil, land and waterways potentially impacting plants, animals and humans. There is minimal information on the extent and outcomes of chemical contamination and microplastics in inland waterway environments.

Cigarette filters

In terms of number of items, cigarette filters are one of the largest sources of plastic litter. In NSW, cigarette filters are consistently the most littered item in NSW with 1.32 billion cigarette filters littered each year.

Cigarette filters can contain chemicals such as arsenic and formaldehyde and cellulose acetate which is a form of plastic that does not readily biodegrade. Cigarette filters are readily transported by stormwater runoff to local streams, rivers and waterways.[365] Moerman and Potts (2010) found that cigarette litter was found to be a point source for metal contamination.[366]

Birds and aquatic animals can ingest cigarette filters, mistaking them as food. This can lead to serious digestive problems and possibly death.[367]

Previous studies have found that chemicals leaching from cigarette filters can be toxic to non-vertebrate aquatic organisms. Slaughter et al (2011) studied the toxicity of cigarette butt leachate to selected fish species and found that ‘fish were less sensitive to cigarette

365 NSW EPA, 2021, *Reducing cigarette butt litter,* https://www.epa.nsw.gov.au/your-environment/litter-and-illegal-dumping/epa-work-prevent-litter/reducing-cigarette-butt-litter. Accessed September 2021.

366 Moerman, J.W. and Potts, G.E., 2010, *Analysis of metals leached from smoked cigarette litter,* https://tobaccocontrol.bmj.com/content/tobaccocontrol/20/Suppl_1/i30.full.pdf. Accessed September 2021.

367 Healthy Land and Water, *Litter in our waterways,* https://hlw.org.au/download-topic/waterways/litter-in-our-waterways/. Accessed September 2021.

butt leachate than daphnids (water fleas) previously tested, but have a similar sensitivity as marine bacteria.[368]

There is a lack of information on the concentration level of cigarette filters that causes environmental impact through chemical contamination in waterways.

Human health impacts from microplastics

As noted above, the risks to human health from ingestion of microplastics and chemical contamination through plastic adsorption are not well understood but are the subject of ongoing research. Similar human health impacts could potentially occur through the consumption of fish and seafood sourced from inland waterways.

Stormwater pollution of recreational waters

Litter and illegally dumped materials can pollute waterways by directly entering waterways or indirectly entering waterways and beaches through stormwater. Table B.9 outlines the key stormwater pollution impacts for in-scope waste types.

Victoria EPA note that dog faeces is one of the most common sources of beach water contamination around Port Phillip Bay.[369]

B.9 Environmental impacts of stormwater pollution

Littered or illegally dumped material	Environmental impacts
Animal waste	▪ Increased nutrient levels in stormwater which lead to an increase in algal blooms ▪ Introduced disease causing micro-organisms like bacteria, protozoans and viruses, which can cause gastroenteritis, eye, ear, skin and upper respiratory tract infections, skin irritations and other health problems for humans. ▪ Certain groups of users may be more vulnerable to microbial infection, including, children, the elderly, people with compromised immune systems.
Cigarettes	▪ Source of heavy metal contamination, which can harm local organisms ▪ Organic compounds (such as nicotine, pesticide residues and metal) seep from cigarette filters into aquatic ecosystems, which is toxic to fish and microorganisms. ▪ Evidence that chemicals in cigarette filters seep into soils when littered. Where some hydrocarbons found in cigarettes are carcinogenic.

368 Slaughter, E., Gersberg, R., Watanabe, K., Rudolph, J., Stransky, C., Novotny, T., 2011, *Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish,* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3088407/pdf/tobaccocontrol40170.pdf. Accessed September 2021.

369 VIC EPA, 2020,*Pick up your doggie doo or you could wind up swimming in it,* 21 January 2020, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/news-and-updates/pick-up-your-doggie-doo-or-you-could-wind-up-swimming-in-it

Littered or illegally dumped material	Environmental impacts
Illegally dumped oil and grease	▪ Forms a film over water and makes it difficult for aquatic animals and plants to breath. ▪ Can be toxic to plants and animals
Illegally dumped vegetation and green waste	▪ Promotes unwanted weed growth

Source: SA EPA, *Stormwater Pollution,* EPA 491/03, https://www.epa.sa.gov.au/files/8514_water_general.pdf and VIC EPA, 2020,*Pic up your doggie doo or you could wind up swimming in it,* 21 January 2020, https://www.epa.vic.gov.au/about-epa/news-media-and-updates/news-and-updates/pick-up-your-doggie-doo-or-you-could-wind-up-swimming-in-it

Pollutant concentrations of waterways and beaches are often exacerbated during and shortly after storm and flood events. In some cases, stormwater pollution forces the closure of beaches and rivers to swimmers. For example, the Victorian EPA advises people not to swim near stormwater or river outlets for 24-48 hours after heavy rain due to high concentration of animal faeces and other contaminants that are washed into the bay. [370]

Some beaches, baths or lagoons in Greater Sydney are not suitable for swimming following rainfall events due to pollution from faecal contamination. For these water bodies the following warning is provided:

> Water quality is suitable for swimming for most of the time, but due to the presence of several potential sources of faecal contamination, swimming should be avoided following rainfall.[371]

Table B.10 outlines the proportion of beaches, baths or lagoons in Greater Sydney that are likely to have poor water quality following rainfall due to faecal contamination through stormwater. All beaches, baths or lagoons are subject to poor water quality following rainfall in the following regions — Lane Cover River, Parramatta River, Botany Bay, and Lower Georges River.

B.10 Greater Sydney coastal water bodies subject to poor water quality after rainfall

Region	Number of beaches, baths or lagoons	Number of beaches, baths or lagoons with potential faecal contamination following rainfall	Proportion of beaches, baths or lagoons subject to poor water quality following rainfall
	no.	no.	per cent
Sydney ocean beaches			
Northern	21	13	62
City	9	8	89
Southern	8	1	12.5
Pittwater beaches			
Pittwater	10	7	70

370 Ibid.

371 NSW Office of Environment and Heritage, *Beaches,* https://www.environment.nsw.gov.au/topics/water/beaches updated and accessed 13 October 2021.

Region	Number of beaches, baths or lagoons	Number of beaches, baths or lagoons with potential faecal contamination following rainfall	Proportion of beaches, baths or lagoons subject to poor water quality following rainfall
	no.	no.	per cent
Sydney Harbour beaches			
Middle Harbour, North Harbour, Port Jackson	18	16	89
Lane Cover River, Parramatta River	7	7	100
Southern Harbour beaches			
Botany Bay	11	11	100
Lower Georges River	4	4	100
Port Hacking	5	4	80
Hunter beaches			
Port Stephens Council	4	0	0
Newcastle City Council	7	0	0
Lake Macquarie City Council	6	1	17
Central Coast beaches			
Wyong	18	6	33.3
Gosford	11	8	73
Illawarra beaches			
Wollongong	13	6	46
Shellharbour	2	0	0
Kiama	5	1	20
Total	**159**	**93**	**58**

Source: NSW Office of Environment and Heritage, *Beaches,* https://www.environment.nsw.gov.au/topics/water/beaches updated and accessed 13 October 2021.

The Ocean Microbiology Group of the University of Technology Sydney used microbial source-tracking to assess water quality issues in Central Coast Lagoons and at Rose Bay to identify causes of poor water quality. In particular to determine when and where periodically poor water quality is caused by sewage or animal sources (dog or bird) of faecal contamination.[372] Table B.11 outlines the key findings for each coastal area. Across the study sites, the common findings were:

- dog faeces have a negligible impact on water quality during dry weather conditions
- dog faeces contribute to poor water quality during rainfall events, with material brought in by stormwater from the surrounding catchment or within the sewage system
- overall, sewage inputs played a larger role than dog faeces in reducing water quality.

372 University of Technology Sydney, 2020, *Microbial source-tracking to assess water quality in Central Coast Lagoons,* Climate Change Cluster, Faculty of Science, UTS.

B.11 Contribution of dog faeces to water quality in five coastal areas

Coastal area	Rainfall events
Rose Bay	Dry weather conditions: ▪ Animal faeces have a negligible impact on water quality during dry weather conditions, with 22 per cent of samples detecting markers for dog faecal material Rainfall events: ▪ Increase in go faeces co-occurred with human faecal markers ▪ Source of dog faeces likely from the catchment serviced by stormwater rather than Rose Bay Beach ▪ Contribution of dog faecal contamination was up to an order of magnitude lower than the human faecal markers, implying small contribution to poor water quality from dog faeces.
Cockrone Lagoon	Dry weather conditions: ▪ Dog faecal material undetectable or at very low levels Rainfall events: ▪ Dog and bird faecal material elevated during significant rainfall. ▪ Results imply that dog and bird faecal material was washed into the lagoon from the surrounding environment during the rainfall event. ▪ During the February 2020 rainfall event, the dog marker was below detection limits in all samples, implying a negligible impact of dog faeces.
Avoca Lagoon	Rainfall events: ▪ In addition to sewage inputs, dog and bird faeces are washed into Avoca Lagoon from the surrounding environment during rainfall. ▪ Dog faeces were possibly introduced to the lagoon with sewage.
Wamberal Lagoon	Rainfall events: ▪ Results indicate the bird and dog faeces contribute to poor water quality, however the impact was highly localised in both space and time ▪ About 10 per cent of samples exhibited high levels of bird and dog faecal material
Terrigal Lagoon	Dry weather conditions: ▪ Low levels of marker for dog-faeces were detected on Terrigal Beach Rainfall events: ▪ During a high rainfall event, high levels of dog faeces markers were present, either due to stormwater bringing dog faeces in from the surrounding environment, or the presence of dog faeces within sewage. ▪ During a small rainfall event, dog faeces markers were undetectable. Indicating that dog faeces is not responsible for poor water quality during periods of low rainfall. ▪ Microbial source tracking results indicate that sewage is the predominant cause of contamination.

Source: University of Technology Sydney, 2020, *Microbial source-tracking to assess water quality in Central Coast Lagoons,* Climate Change Cluster, Faculty of Science, UTS and University of Technology Sydney, 2020, *Microbial source-tracking to assess water quality issues at Rose Bay,* Climate Change Cluster, Faculty of Science, UTS.

Broader impacts on ecosystems

Litter and illegally dumped material can be a breeding ground for bacteria and diseases, with potential to spread diseases, viruses and parasites through two methods:

- Direct — germs can be transmitted by direct contact with litter (e.g. picking up, touching or accidentally injuring themselves)

- Indirect — bacteria and parasites can also be transmitted to humans indirectly through an affected vector. Vectors are animals or insects that come in contact with contaminated litter and then transmit those contaminates to humans.[373]

Valuing the environmental impacts

Valuing impacts from stormwater pollution

Stormwater pollution can cause human health impacts if people swim in poor quality water, or a loss of recreational use value if people are prevented from swimming due to poor water quality.

Almost 60 per cent of beaches, baths and lagoons in Greater Sydney are subject to poor water quality from potential sources of faecal contamination following rainfall events (table B.10). Dog faeces are one contributing element of this faecal contamination. Based on results of microbial source-tracking to assess water quality (outlined in table B.11), dog faeces contribute to poor water quality during rainfall events but to a lesser extent compared to sewage inputs. There is insufficient evidence to apportion the total impact to dog faeces relative to other sewage inputs.

Historical data on the annual number of closures of beaches, baths and lagoons in Greater Sydney is not available. Based on daily rainfall data at Sydney (Observatory Hill), the average number of days per year with daily rainfall greater than 10mm, 20mm and 30mm is 32, 14 and 8, respectively (table B.12).

B.12 Number of days with daily rainfall greater than 10mm and 20mm — Sydney

Year	Number of days with daily rainfall > 10mm	Number of days with daily rainfall > 20mm	Number of days with daily rainfall > 30mm
	no.	no.	no.
2018	29	13	6
2019	28	12	6
2020	40	18	11
Average	**32**	**14**	**8**

Note: Based on daily rainfall data at Sydney (Observatory Hill)

Source: Bureau of Meteorology, *Daily Rainfall: Sydney (Observatory Hill)*, http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_stn_num=066214&p_startYear=

Deloitte Access Economics (2016) estimated there are 36 million visits to Sydney's coastal beaches per year with an average value of $38 per person per visit.[374] This information coupled with estimated days of closure based on average high rainfall events (table B.12) per year is used to estimate the lost recreational use value of $37 million per

373 See https://www.texasdisposal.com/blog/the-real-cost-of-littering/

374 Deloitte Access Economics, 2016, *Economic and social value of improved water quality at Sydney's coastal beaches.*

year due to closure of beaches, baths and lagoons in Greater Sydney due to stormwater pollution.

As noted, there is a lack of evidence on the contribution dog faeces adds to poor water quality following heavy rainfall events. In the absence of a sound basis to attribute lost recreation value associated with stormwater pollution to littered dog faeces, table B.13 shows indicative estimates under various attribution assumptions (ranging from 2.5 per cent to 10 per cent). These estimates are provided as an order of magnitude in the absence of information to attribute the total impact to littered dog faeces.

B.13 Estimated lost recreational value from dog faeces in stormwater — Sydney

Item	Unit	Value
Number of visits to Sydney's beaches per year	million	36
Average visits per day (not accounting for seasonal effects)	no.	98630
Average high rainfall events per year (based on daily rainfall > 30mm)	no.	8
Estimated days per closure	Days per closure	2
Total number of closure days per year	Days per year	16
Proportion of beaches, baths, lagoons closed following heavy rainfall events		58
Estimated number of lost visits to Sydney's beach per year		974 309
Value per beach visit	$ per person per visit	38
Estimated total lost recreational use value	$m per year	37.0
Proportion attributable to litter dog faeces	per cent	
Estimated lost recreation use value due to dog faeces		
Based on 2.5 per cent attribution	$m per year	0.9
Based on 5 per cent attribution	$m per year	1.9
Based on 7.5 per cent attribution	$m per year	2.8
Based on 10 per cent attribution	$m per year	3.7

Source: CIE based on various source.

C Literature review of environmental impacts in terrestrial environments

Littered and dumped material (including unwanted household items) in many urban environments (including around retail areas, streets and highways and industrial areas) may impose significant amenity costs (i.e. likely to be visible to many people) and are therefore more likely to be removed from the environment through regular clean-up activities (this includes regular and frequent clean-up activities, such as council activities, as well as any regular clean-up activities by land owners or managers. As such, the environmental costs are likely to be limited. An exception is asbestos which can have human health impacts when dumped illegally.

Environmental impacts are more likely in terrestrial environments where it is less visible and therefore the littered and/or dumped material persists in the environment for a longer period. These include remote areas of national parks, nature reserves, bushland and beaches. These are environments of concern because they have higher environmental impacts given the proximity to flora and fauna that might be affected by the introduction and persistence of litter.

Evidence of material in terrestrial environments

There is limited systematic data on the extent to which littered or dumped material accumulates in terrestrial environments. Where littered and/or dumped material is identified in terrestrial environments, it is often removed and cleaned-up, where possible.

That said, some sources of data that may provide some indicators of the extent of littered and dumped material in terrestrial environments include the following.

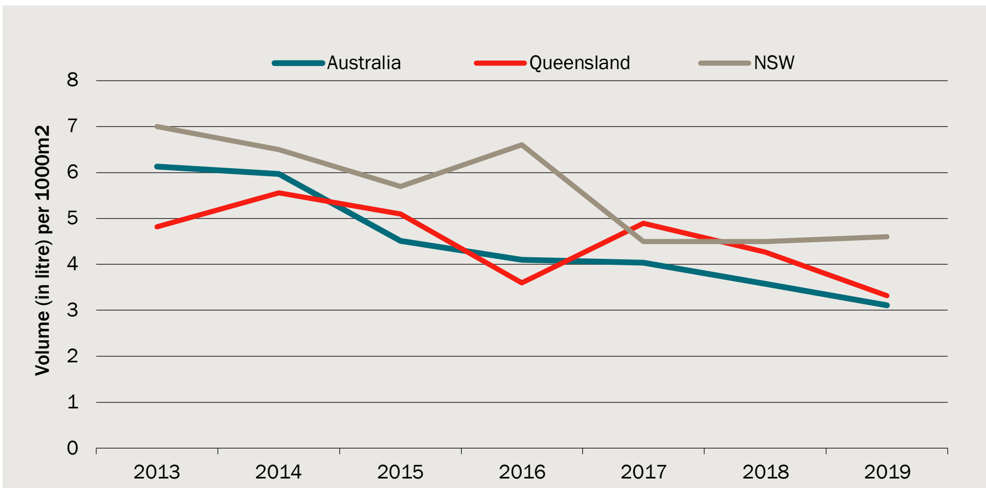
- Clean up Australia data (although the material gathered through Clean Up Australia day is removed from the environment, this may provide an indicator of the sorts of materials that are not being collected through more regular clean-up activities.
- NSW EPA illegal dumping reports — these reports provide an indicator of the types of material that is illegally dumped in NSW.
- Keep Australia Beautiful National Litter Index (KAB NLI) — Annual measure for the presence of litter items at sites within broadly comparable regions across Australian states and territories

A key consideration is whether there is any evidence of material accumulating in terrestrial environments over time.

The National Litter Index (NLI) is Australia's annual set of quantitative measures for measuring the presence of litter, (identifying the type, location and volume) across the country. Litter counts are carried out twice annually across 983 sites nationally to create an annual report on litter. They also report individually on the different states and territories litter status such as key trends in the quantities and locations of litter as well as and achievements of litter reduction targets.[375]

There was an overall falling trend in litter across Australia from 8.86 litre per 1000m^2 in 2005-2006 to 3.11 litre per 1000m^2 in 2018-2019 identified by the NLI. These falling trends are also mirrored across the states and territory. Pictured in Figure C.1 is the national trend alongside litter trends in NSW and Queensland. Victoria has also recorded a reduction in overall litter count of 1.3 per cent from 2016 to 2017 (not pictured).[376]

C.1 Volume of litter (in litre per 1000m^2) in Australia, NSW and Queensland



Data source: Keep Australia Beautiful National Litter Index, The CIE

The falling trend highlights the changing behaviours and growing understanding in the community of litter and waste issues as well as the impact of interventions and campaigns led by the national and state government

However, sites surveyed within the National Litter Index were sampled primarily from urban and near-urban areas. Therefore, most of the sites measured in the estimate pertain to industrial sites, retail precincts and residential areas with high litter activity but low environmental impact. These are locations that have high amenity value and are regularly cleaned up. Hence, generalisation of findings to high environmental impact locations must be made with caution.

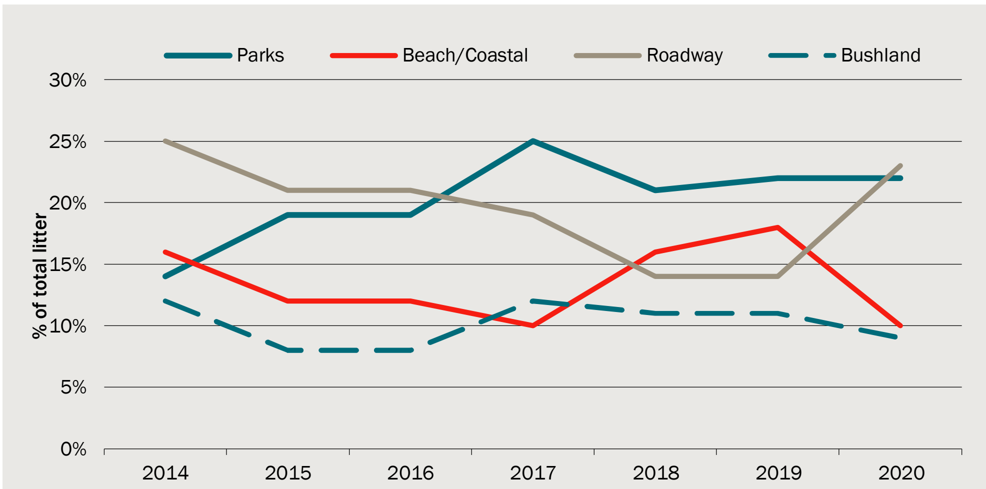
The areas with higher environmental impact are locations and sites where the Australian biome is threatened due to the presence of litter in the environment. With regards to terrestrial environments these are bushland and nature reserves, as well as vegetated lands in proximity to highways and motorways where litter ingestion by wild animals, entrapment, bushfires from lit cigarette filters etc. may result in a loss or destruction of native habitat.

375 This includes 151 sites each across Victoria, Queensland and NSW

376 See, https://ksenvironmental.com.au/national-litter-index-victoria/

Clean Up Australia Rubbish report have data to distinguish the proportion of total waste collected across different type of locations. We have identified the high impact land-based sites from these to include parks, bushland, roadway and beaches. Figure C.2 highlights the high impact sites and measures the percentage of total waste collected from each site from 2014 to 2020. These are based on rubbish that is removed from the environment by Clean Up Australia Volunteers.

C.2 Trend in the proportion of litter found in high impact sites across Australia



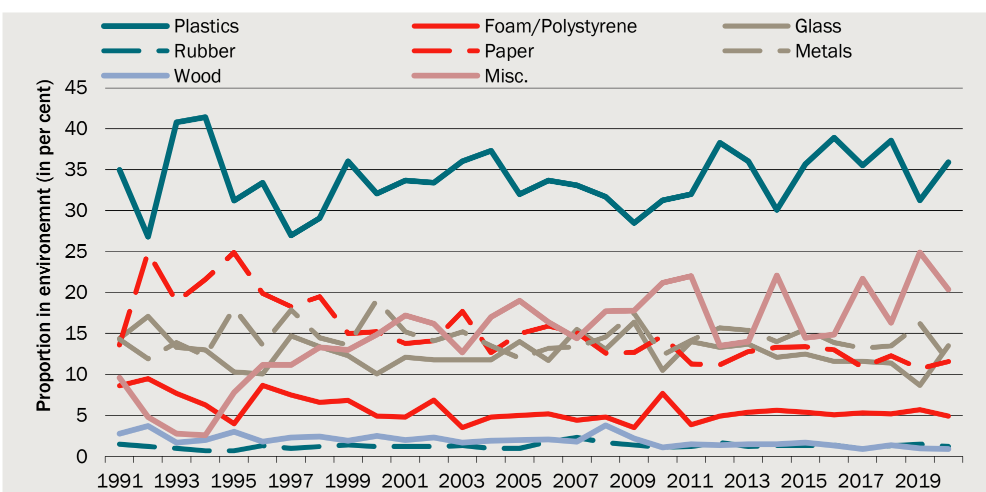
Note: 3,278 sites nationally. Of these, 748 recorded valid data for analysis across 1,274 locations

Data source: Clean Up Australia

Litter composition

Figure C.3 identifies the contribution of objects recognised within established litter categories to the overall litter stream from 1991 to 2020.

C.3 Historical trend of litter items in Australian environment



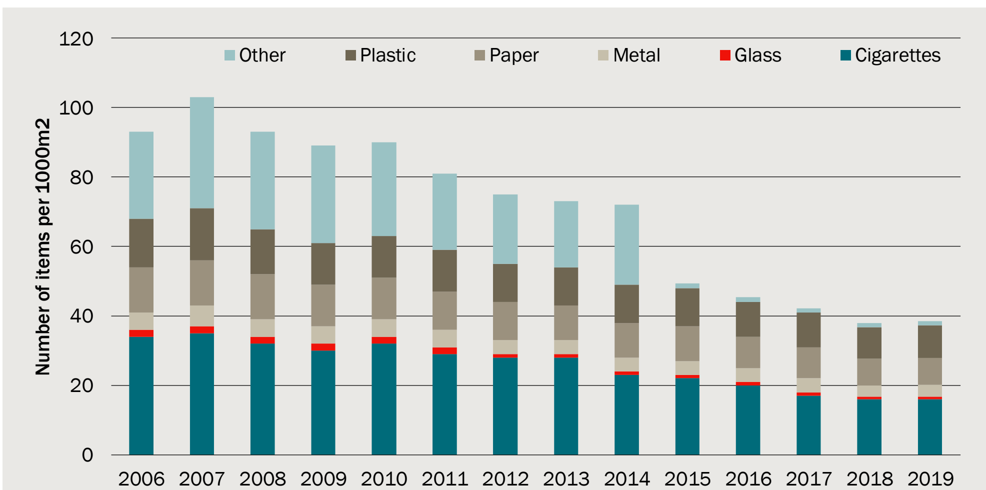
Data source: Clean Up Australia

The composition of litter has remained stable over the 30 years. Paper as a proportion of litter in the environment has dropped from 25 per cent in 1991 to 10 per cent by 2020. This can be attributed to the increased trend of digitisation that has reduced the use of paper over the last 3 decades.

On the other hand, proportion of miscellaneous litter has grown over the years. Cigarette filters dominate the miscellaneous category as reported by the Clean Up Australia Volunteers.

Figure C.4, on the other hand, demonstrates the national composition of litter items per 1000 m^2 evidenced from the National Litter Index survey results. Although, as demonstrated by the data litter items per 1000 m^2 have continued to fall since 2006 from approximately 90 to below 40 items per 1000m^2 in 2019. As single items, cigarette filters dominate the composition of litter however, the trend also sees a decline in the number of cigarette filters over time. The plastic in the litter composition has remained fairly stable over time.

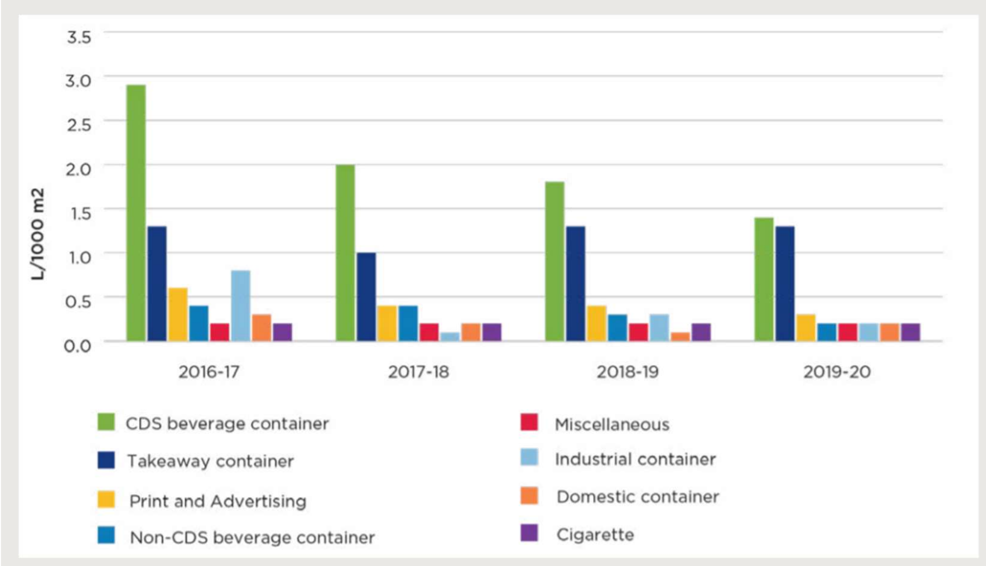
C.4 Litter Item Count Composition per 1000m^2 in Australia from National Litter Index



Data source: National Litter Index, The CIE.

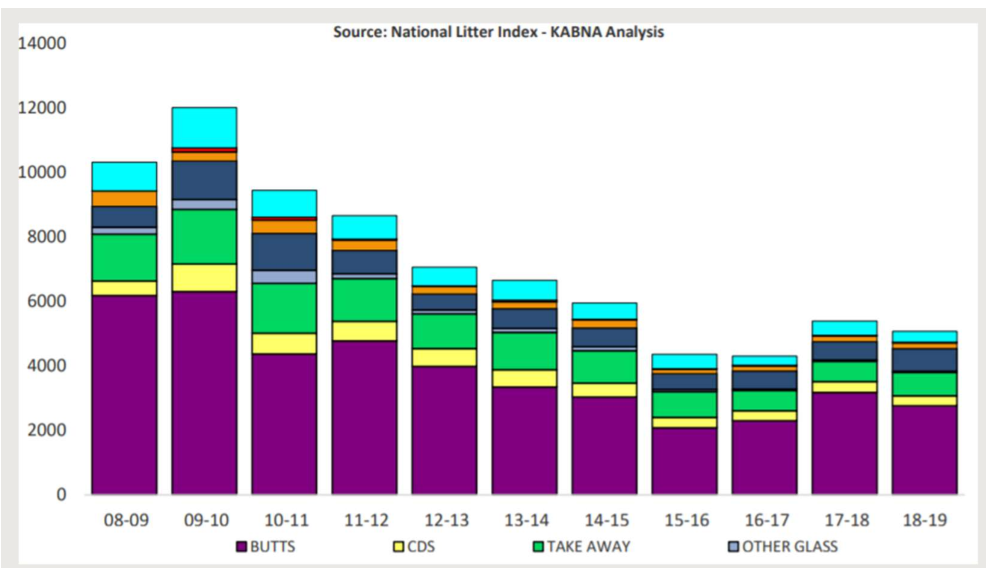
Figure C.5 demonstrates litter composition across NSW (in L per 1000m^2). Figure C.6 and C.7 shows the litter item count composition in Victoria (total item count) and Queensland (item count per 1000m^2).

C.5 Litter Composition in NSW in L/1000m² from National Litter Index Report 2016-2020



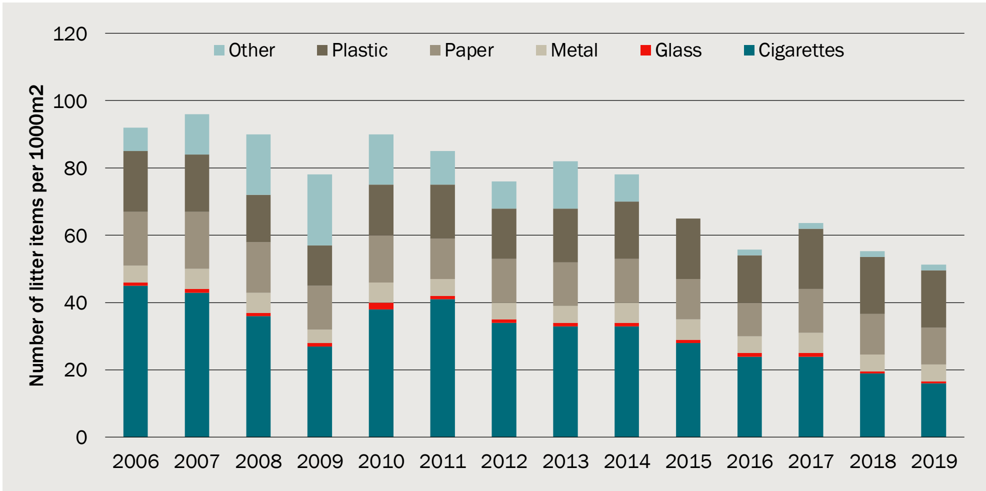
Data source: NSW Litter Report 2016-2020

C.6 Total Litter Item Count Composition in Victoria from National Litter Index 2018-19 Victoria Results



Data source: https://assets.sustainability.vic.gov.au/susvic/Report-National-Litter-Index-2018-19-Victoria-results.pdf

C.7 Litter Item Count Composition per 1000m² in Queensland from National Litter Index

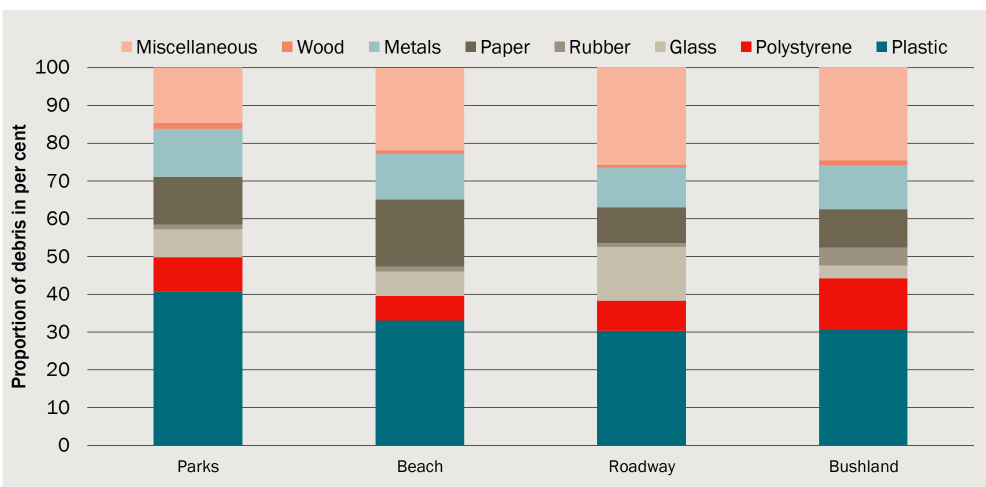


Data source: https://www.stateoftheenvironment.des.qld.gov.au/pollution/waste/main-material-types-littered

As individual item count cigarette filters constitute a higher share of the composition as demonstrated by Victoria and Queensland (Figure C.6 and C.7) however, contributes a small amount to volume estimate of litter as demonstrated by NSW data.

Figure C.8 shows the composition of litter in high impact terrestrial environments across Australia based on Clean Up Australia data. Plastic makes up the highest proportion of litter across all the sites. Miscellaneous category of litter also constitutes a significant portion of the litter composition across the high impact sites. This category includes cigarette filters.

C.8 Litter or Debris composition in high environmental impact sites in Australia



Data source: Clean Up Australia 2020 Report, The CIE.

The three most common litter items are cigarette filters, plastic and paper. We identify that the retention of plastic and cigarette filters in the environment have a higher environmental impact than paper. Plastic in its multitude of forms, once introduced into the environment never biodegrade and can be hazardous for animals that come into contact with it through entanglement or ingestion. Moreover, cigarette filters can leech toxins into the environment that cause contamination and threaten the native flora and fauna as well as human health. There is also potential for cigarette filters dumped in the environment to increase risk of bushfires causing loss of property, loss of life and the loss of native habitat for many plants and animals.

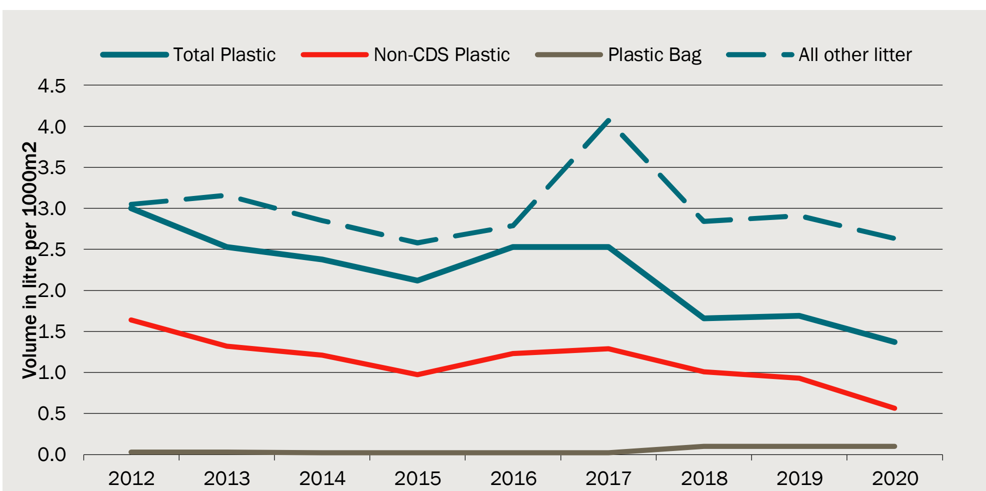
Plastic

According to Clean Up Australia report Plastic was the most common rubbish type, representing 36 per cent in 2020 and 31 per cent in 2019 of all rubbish items removed. There were 33 562 items of soft plastics including plastic food, retail and garbage bags, plastic confectionery wrappers, cling wrap etc. making up 13.7 per cent of all surveyed rubbish and 40.4 per cent of plastics. Within grouped items, packaging dominates the litter counts representing 49.8 per cent of all reported rubbish during the year. This is on-par with 2019, during which packaging represented 50.3 per cent.[377]

Beverage container counts continue to decline – reflective of the impact of container refund schemes. In 2020 they reflected 15.5 per cent of counted rubbish. In 2019 they accounted for 17.9 per cent.[378]

Figure C.9 shows the volume of plastic in NSW based on the National litter index findings.

C.9 Volume of plastics per 1,000m2 in NSW 2012-2020



Data source: NSW Litter Report 2016-2020 and 2012-2017, The CIE.

Between 2016 and 2020, the volume of CDS beverage container litter fell by 52 per cent according to the NSW litter report (not shown in figure C.9). As a result, CDS beverage

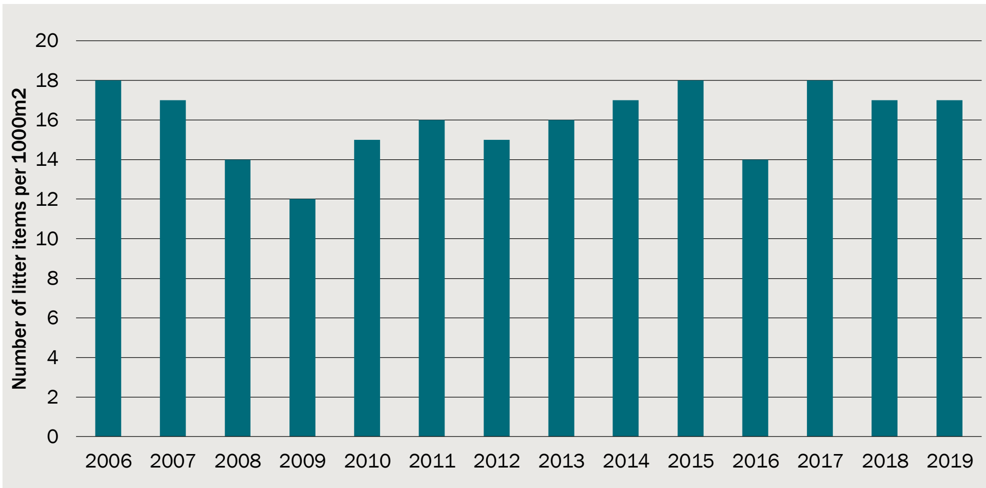
377 Clean Up Australia 2020 report. See, https://www.cleanup.org.au/rubbish-report

378 ibid

containers fell from 44 per cent of the total litter stream (by volume) in 2016 to 35 per cent in 2020.[379]

Plastic litter has remained between 18 to 12 items per 1000m^2 from 2006 to 2019 in Queensland (chart C.10). Plastic accounts for 45 per cent of the total litter volume of material surveyed across Queensland.[380]

C.10 Number of Plastic litter items per 1000m^2 in Queensland 2006-2019



Data source: National Litter Index

Cigarette filters

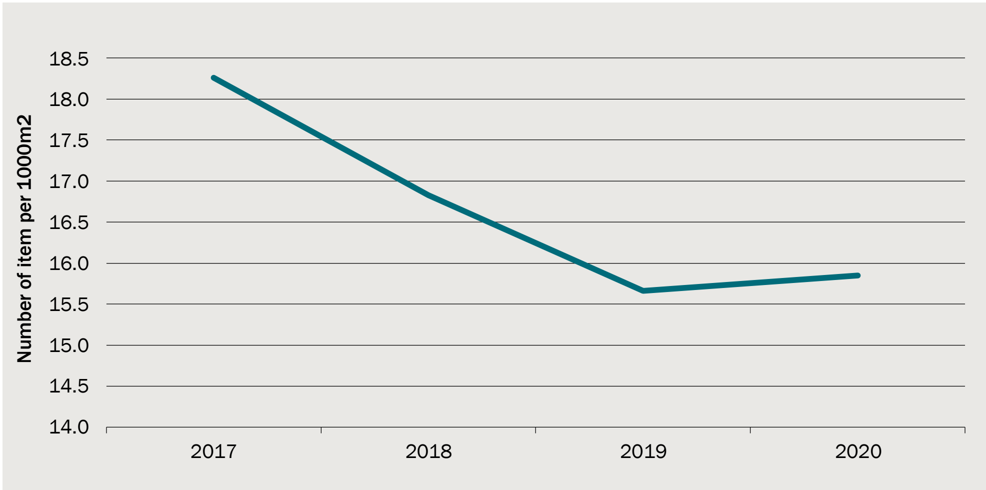
Although cigarette filters contribute the smallest amount to the litter volume (not litter count), among individual item, cigarettes are among the most commonly littered individual item across Australia. In 2020 they represented 16.2 percent of all reported rubbish which is a decrease of 5.8 per cent from the 2019 proportion.[381]

379 NSW Litter report 2016-2020

380 See, https://www.stateoftheenvironment.des.qld.gov.au/pollution/waste/main-material-types-littered

381 Clean Up Australia 2020 report. See, https://www.cleanup.org.au/rubbish-report

C.11 Estimated number of cigarette filters and packaging per 1,000 m2 in NSW, 2016–20



Data source: NSW Litter report 2016-2020, The CIE.

Figure C.11 shows a decline in the number of cigarette filters in the NSW environment per 1000m^2.

Cigarette filters used to be the most common littered item in Queensland until 2018-19. Although they are one of the most common single litter items, they only constitute 1 per cent of the volume of litter in Queensland. In 2018–19, plastic items replaced cigarette filters as the most common littered items in Queensland.[382]

Despite contributing a very small fraction to litter volume, cigarette filters continue to be a significant litter load in the environment.[383]

Illegally dumped material

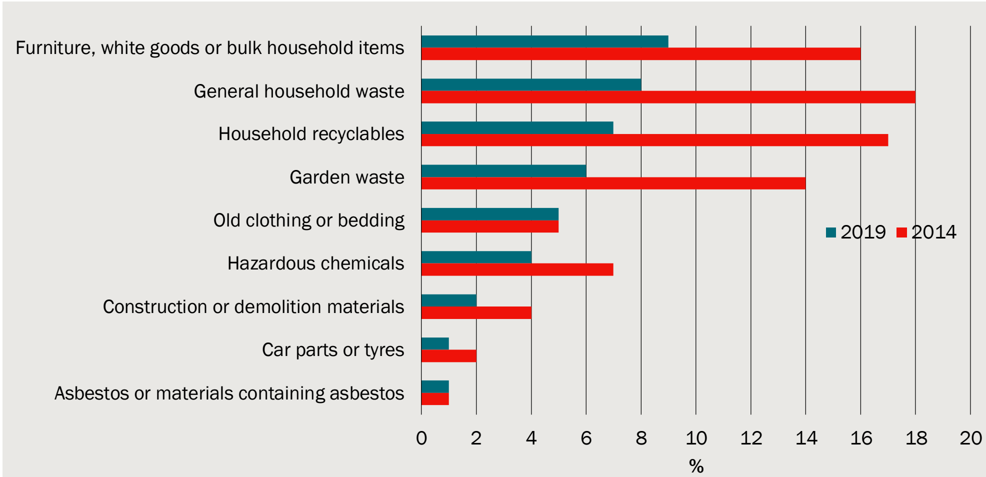
As with litter, there is no comprehensive source of data on the composition of illegally dumped material. One source of information on the types of material illegal dumped is research by Ipsos for the NSW EPA.

As part of broader studies on illegal dumping, Ipsos surveyed both households and businesses in NSW in 2014 and 2019. The 2019 survey indicated that the main types of goods illegally dumped by households are: bulky household items (including furniture and white goods) (9 per cent of households); general household waste (8 per cent of households); household recyclables (7 per cent of households); and garden waste (6 per cent of households). The surveys also indicated a significant decline in the number of households that reported illegally dumping these items, compared with the 2014 survey.

382 See, https://www.stateoftheenvironment.des.qld.gov.au/pollution/waste/main-material-types-littered

383 Ibid.

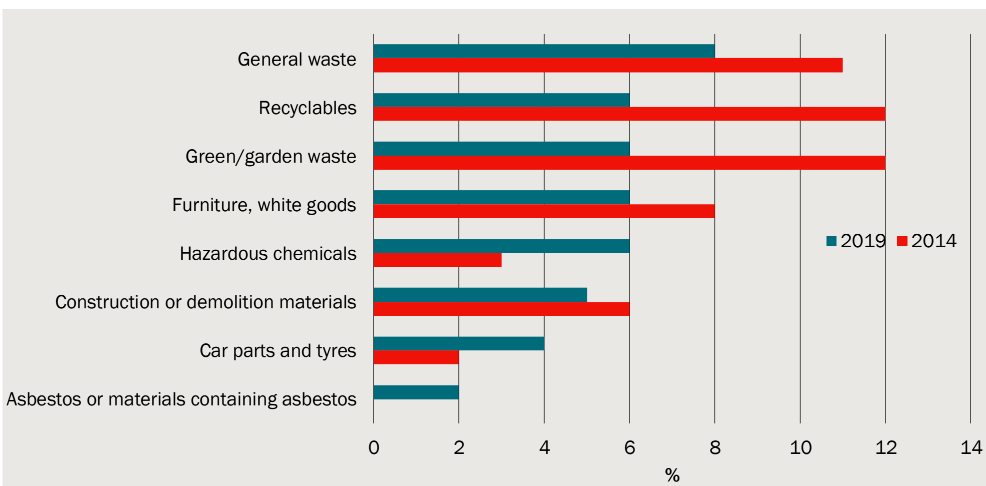
C.12 Types of waste illegally dumped — community



Data source: Ipsos, EPA - Illegal Dumping Research Report, Report prepared for the NSW Environment Protection Authority, July 2020, p. 90.

The business survey indicated that similar types of waste are illegally dumped by businesses (chart C.13). There was also a significant decline in the proportion of businesses reporting illegal dumping of the most prevalent items (general waste, recyclables, green/garden waste and furniture and white goods).

C.13 Types of waste illegally dumped — industry



Data source: Ipsos, *EPA - Illegal Dumping Research Report*, Report prepared for the NSW Environment Protection Authority, July 2020, p. 92.

Other litter/rubbish found with environmental impact

We are also interested in the impact of illegal dumping of garden waste as well as impact of dog faeces on the environment. The evidence for the presence of illegally dumped garden waste in the environment is discussed below.

There does not seem to be data collected on the quantity of dog faeces littered. It is noted in the NSW Litter Report 2012-2017 that organic matter (including food, chewing gum and dog faeces) is not recorded during the litter count.[384]

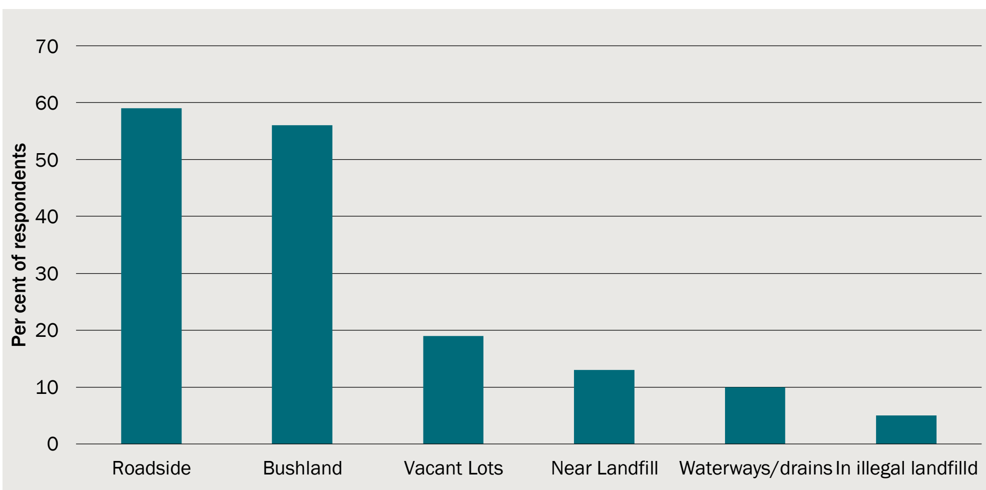
Illegal Dumping of Garden waste

In Australia, the largest importer of exotic plant species is the gardening industry, and most major environmental weeds originally derive from domestic gardens or nurseries. Approximately 28,000 exotic plant species have been introduced into Australia since European settlement. About 66 per cent of the naturalized exotic plant species in Australia originated in nurseries or domestic gardens introduced to the natural environment by means of illegal dumping of weed and garden clippings.[385]

Households, small businesses and large businesses are all identified as dumping waste illegally. Illegal dumping occurs most often in locations that are not easily visible by the public. Among these illegally dumped waste, 66 per cent of household respondents and 33 per cent businesses claimed to have disposed of garden waste illegally into the environment.[386]

Roadside and bushland sites are the most common sites for illegally dumped waste including green/garden waste (chart C.14).

C.14 Location of illegally dumped waste including green/garden waste in the Illegal Dumping Report 2015



Data source: Illegal Dumping Research Report 2015, NSW EPA

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384 NSW Government, 2020, *NSW Litter Report 2012-2017.*

385 Hu, R., & Gill, N. (2016). Garden-related environmental behavior and weed management: An Australian case study. Society & natural resources, 29(2), 148-165.

386 NSW EPA. Illegal Dumping research 2019. See, https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/ipsos-report-illegal-dumping-research-2019.pdf?la=en&hash=EF79879EBCCF1DF76306C16AE260D61C1EBF8E94

Regional residents were more likely to find leaving garden waste in a park more unacceptable than metro residents. Leaving green or garden waste in a park was the least rejected behaviour among businesses.[387]

National parks and bushland continue to be identified as illegal dumping hot spot areas. The majority of LGAs believed green waste is mainly dumped in bushland while other household waste is dumped on the roadside.[388] The choice of dumping of green waste near parks and bushlands are driven by the public's notion that they are merely returning organic waste back into the environment without registering the adverse impact it may have as a result. This was particularly the case because there was a lack of understanding regarding environmental processes and the environmental impact of dumping of green waste into the natural environment.

Moreover, reserves and bushlands are viewed as wild and unkempt, hence people in general do not care for the aesthetic value of this type of setting when they decide to dump garden waste which they consider to be part of nature. Secondly, because the public perceives these areas as council duty, the public may be unwilling to care for or conserve bushland in reserves threatened by weed invasion.[389] It is also difficult to monitor broad swaths of bushland and national parks, with the large number of potential access points for dumpers. When these spots are within a short distance of populous regions there is propensity for more illegal dumping of garden waste.[390]

Weed spread along bushland tracks appears to be a result of garbage disposal activities, as such locations provide a handy and hidden dumping option. Dumping of garden/green waste is a cause for concern as they were not always reported immediately due to being hidden, increasing the likelihood of environmental damage to flora and fauna.

Environmental impacts

Some of the key environmental impacts of litter and illegal dumping on terrestrial environments are set out below.

Impact of litter and illegal dumping on land-based animals

Litter and illegally dumped material could directly impact on land-based animals through ingestion and entanglement. In general, there are few studies that estimate the direct impacts on land-based animals.

387 Ibid.

388 ibid

389 Hu, R., & Gill, N. (2015). Movement of Garden Plants from Market to Bushland: Gardeners' Plant Procurement and Garden-Related Behaviour. Geographical Research, 53(2), 134-144.

390 NSW EPA. Illegal Dumping research 2019. See, https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/ipsos-report-illegal-dumping-research-2019.pdf?la=en&hash=EF79879EBCCF1DF76306C16AE260D61C1EBF8E94

Research in the marine environment indicate that the likelihood of ingestion depends on feeding habits, which means that land-based animals are less likely to ingest plastics and other materials.

Although there may have been instances where land-based animals have ingested plastics or other materials and this has had an adverse impact on the animal, there is little evidence that this is a significant environmental problem that would be having population-level impacts on land-based animals.

Direct damage to the dumping site

One of the defining characteristics of illegal dumping (compared to litter) is the volume of material. Illegal dumping involves illegal disposal of larger items (including: furniture, white goods, beds, cars and car parts, construction and demolition material) or large volumes of smaller items (such as general household waste).

Large volumes of waste which are illegally dumped in natural environments destroy much of the native vegetation on the site. These environmental impacts are in addition to the amenity impacts estimated separately.

Invasive plants

Dumping of green waste is generally perceived as a low-level aesthetic concern, but causes significant environmental impacts in terrestrial environments. Invasive plants (partly as a result of dumped garden waste) is listed as a key threatening process under the EPBC Act and was also identified in the State of the Environment report as an environmental pressure (see chapter 3).

Potential environmental impacts from illegal dumping of garden waste are:

- introduction of invasive weeds from our gardens into the bushland,
- increase in the amount of soil nutrients that encourage growth of exotic plants and weeds that would compete with native plants preventing natural regeneration of native plants
- increased risk of bushfire from dry garden waste
- introduce disease, and pests into areas of native bush.

In Australia, the largest importer of exotic plant species is the gardening industry, and most major environmental weeds originally derive from domestic gardens or nurseries.[391]

Experts consider illegal trash dumping is a critical avenue of spreading weeds into natural environments, especially species that would otherwise have trouble growing in bushland.

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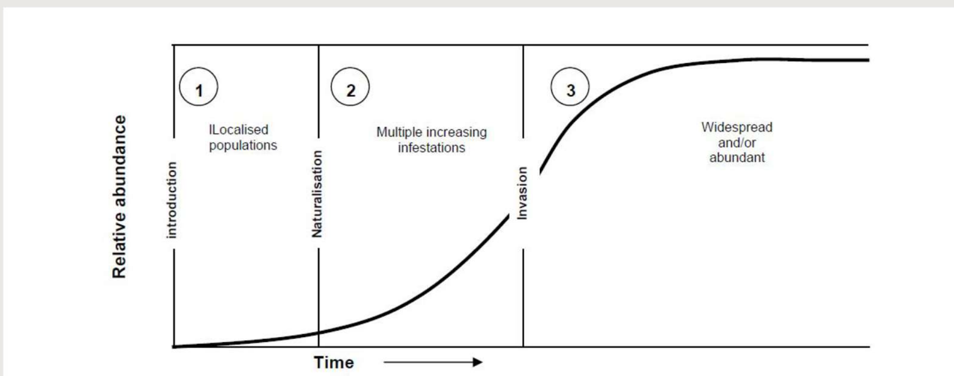
391 Hu, R., & Gill, N. (2015). Movement of Garden Plants from Market to Bushland: Gardeners' Plant Procurement and Garden-Related Behaviour. Geographical Research, 53(2), 134-144.

In many cases, residential suburbs near wilderness regions are the biggest perpetrators.[392] The dumping activity can go on for a long time before rangers notice it, and it could take a long time to fix the harm from introduction of weed and invasive plants into the environment.

Garden plants have been, and remain, a significant source of invasive plants. About 400 of the naturalised exotic plant species are identified as harmful or as priority weeds at a region, State or Territory, and National level.[393]

According to Barker et al. (2006), in terms of the invasion process and the impact on native biodiversity, invasive garden plants are similar to other types of environmental weeds. Plant invasion occurs within a three-stage process and is represented in chart C.15.

C.15 Three stages of weed development (Barker et al. 2006)



Data source: Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

This process comprises of at least three stages:

- The introduction of a 'new' species to a region.
- A stage of naturalisation in which introduced plant species reproduce naturally without the need for human intervention
- An invasive stage in which a naturalised plant species spreads widely and ultimately impacts adversely on native indigenous species

Species that are common garden plants and a nuisance, are more likely to be dumped in garden waste than uncommon or tame plants. Having been dumped, weeds and invasive

392 Coleman, M. J., Sindel, B. M., van der Meulen, A. W., & Reeve, I. J. (2011). The risks associated with weed spread in Australia and implications for natural areas. Natural Areas Journal, 31(4), 368-376.

393 Coleman, M. J., Sindel, B. M., van der Meulen, A. W., & Reeve, I. J. (2011). The risks associated with weed spread in Australia and implications for natural areas. Natural Areas Journal, 31(4), 368-376.

plants that can grow from fragments any time of the year are more likely to establish than species that can only establish from seeds at a specific time of the year.[394]

When more than one species occupies the same niche and have similar requirements for a restricted resource, competition between species is unavoidable. It is well recognised that escaped garden plants compete with native plants for scarce resources including moisture, nutrients, sunlight, pollinators, and space.[395]

Invasive plants can have a detrimental impact on the biodiversity of various Australian vegetation types, ranging from tropical wetlands to desert riverine vegetation, in natural environments. Weed competition was recognised as the principal cause of the extinction of at least four native plant species, and another 57 species were threatened or would become so in the future due to weed competition. By a wide extent, these estimates most probably understate the current problem.[396]

Many garden plants in Australia become invasive because they are transferred into places where their natural pests and predators, which would normally play an important regulatory role, are absent. In the absence of natural predators and pests, these plants can develop extraordinarily quickly, giving them a competitive advantage over native vegetation.[397]

Table C.16 lists native species that are adversely impacted by invasive garden plants (this list is by no means exhaustive).

C.16 Native species under threat from invasive garden plants in Australia

State and Territory	Threatened species	Invasive garden plants*
Tasmania	Tussock Skink (Pseudemoia pagenstecheri)1	Gorse (Ulex europaeus)
NSW	Zieria Prostrata (Zieria prostrata)2 Austral Toad-flax (Thesium australe)2	Bitou Bush (Chrysanthemoides monilifera subsp. rotundata)
NSW	Cumberland Plain Woodland2 Pink Pimelea (Pimelea spicata)2	Bridal Creeper (Asparagus asparagoides)

394 Timmins, S. M., James, A., Stover, J., & Plank, M. (2010). Is garden waste dumping really a problem?. In 17th Australian weeds conference. New frontiers in New Zealand: together we can beat the weeds (pp. 455-458).

395 Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

396 ibid

397 ibid

State and Territory	Threatened species	Invasive garden plants*
NSW	Hairy Quandong (Elaeocarpus williamsianus)2	Lantana (Lantana camara)
NSW and Victoria	Mountain Pygmy Possum (Burramys parvus)2	English Broom (Cytisus scoparius subsp scoparius) Blackberry (Rubus fruticosus aggregate)
Victoria	Eltham Copper Butterfly (Paralucia pyrodiscus lucida)1	Cape Broom (Genista monspessulana) Radiata Pine (Pinus radiata) Quaking Grass (Briza maxima)
SA	Common White Spider Orchid (Caladenia argocalla)2	Topped Lavender (Lavandula stoechas) Soursobs (Oxalis pescaprae) St John's Wort (Hypericum perforatum) Gorse (Ulex europaeus) Hawthorn (Crataegus monogyna) Watsonia (Watsonia meriana var bulbillifera)
Qld and NSW	Richmond Birdwing Butterfly (Troides richmondia)1	Dutchman's Pipe (Aristolochia elegans)
Qld	Aponogeton Queenslandicus (Aponogeton queenslandicus)1	Para Grass (Brachiaria mutica)
Qld	Jabiru (Ephippiorhynchus asiaticus australiensis)1	Para Grass (Brachiaria mutica)
Qld	Brolga Park Zieria (Zieria bifida previously Zieria sp. “Brolga Park”)2	Lantana (Lantana camara)
Qld	Proserpine Rock Wallaby (Petrogale persephone)2	Pink Periwinkle (Catharanthus roseus) Rubbervine (Cryptostegia grandiflora)
WA	Wing-fruited Lasiopetalum (Lasiopetalum pterocarpum)2	Watsonia (Watsonia meriana var bulbillifera) Blackberry (Rubus fruticosus aggregate) Gladioli (Gladiolus undulatus)
NT	Yellow Chat (Alligator Rivers) (Epthianura crocea tunney	Mimosa (Mimosa pigra)

Note: [1] Listed as threatened only under state/territory legislation.
[2] Listed as threatened under both state/territory and national legislation.
Source: State of the environment repot 2006, Beeton et al., 2006

Basket asparagus (Asparagus aethiopicus) has become a naturalised invasive plant in some coastal areas of Australia since its introduction in the late 19th century. It is spread through garden waste dumping as well as avian dispersal of seed.[398] In recent times the list of invasive plants introduced into Australia is expected to have gone up.

Pathogens (fungi, bacteria, and viruses) that are associated with exotic garden plants in their natural range are frequently introduced as a result of their introduction. Pathogens cause little harm in their natural habitats and hosts. However, in a new environment, these infections might induce illness, which has a negative influence on native vegetation.[399]

The best-well-known example of such a pathogen in Australia is Phytophthora cinnamomi. While there is considerable debate over the origins of P. cinnamomi in Australia, it is thought to be of Asian origin and that it initially arrived in Western Australia shortly after European arrival. It is a soil-borne microorganism that grows on the surface of plant roots and infiltrates the cells of susceptible host plants, feasting on root and basal stem tissue until the host plant is weakened or terminated by a reduction in water and nutrient circulation within the plant.[400]

The environmental impact on Crown land, such as National Parks, State Forests and the Catchment Authority, was noted to be larger than that on Council land. This is due to factors such as lack of funding, staff resources and time preventing rapid clean up. Illegal green waste dumps are also harder to spot than general waste dumped in these environments. Therefore, they can be overlooked and not reported. This is a key contributing factor to environmental damage.[401]

Invasive pests — Yellow Crazy Ant in the Wet Tropics of Queensland

The yellow crazy ant is a highly invasive, non-native species of ant and is listed as one of the top 100 worst invasive species by the IUCN and Global Invasive Species Database. They are a category three restricted pest under the *Biosecurity Act 2014*. The invasive nesting and foraging habits of the yellow crazy ants enable colonies to achieve high densities in a variety of habitats. Suitable nesting grounds include wood debris, rocky substrates, tree bases, leaf litter, mulch, rock walls, pot plants, carports, pool filters and even electrical appliances. Therefore, the illegal dumping of green waste and also other

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398 O'Connor, J. M., Burrows, D. M., Allen, B. L., & Burnett, S. E. (2019). Is the European red fox a vector of the invasive basket asparagus (Asparagus aethiopicus) in eastern Australia?. Australian Mammalogy, 42(2), 204-210. See, https://www.publish.csiro.au/am/am19001

399 Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

400 Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the List of Key Threatening Processes under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

401 NSW EPA. NSW Illegal dumping research. See, https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/illegaldumping/ipsos-report-illegal-dumping-research-2019.pdf?la=en&hash=EF79879EBCCF1DF76306C16AE260D61C1EBF8E94

items such as appliances, provides habitat and means of transportation for yellow crazy ants.

Environmental impacts caused by yellow crazy ants include:

- swarming in great numbers and killing larger animals including lizards, frogs, small mammals, turtle hatchlings and bird chicks
- spraying formic acid to blind and kill their prey, this can include spraying acid on people and domestic pets resulting in injury
- large populations of yellow crazy ants can impact on native wildlife and plants, and ecosystems, including invertebrate species inhabiting the Wet Tropics World Heritage Area.
- yellow crazy ants also have a strong mutualism with other invasive species including aphids and scales, thereby enabling other invasive pests to flourish[402]
- damage to household electrical appliances and wiring.

Yellow crazy ant can spread through natural processes, human assisted movements, farming practices and transportation via water. Spring et al (2019) note yellow crazy ant spread relatively slowly in the absence of jump events (e.g. human assisted movements).[403] Human assisted 'jump events' which relate to litter and illegal dumping include the illegal dumping of household green waste.

The proportion of spread of yellow crazy ants attributable to litter and illegal dumping (primarily household green waste) is not known. This is partly due to the ad-hoc nature of illegal dumping, as opposed to a systemic cause.

Cigarette filters

Impacts to vegetation

One study conducted a greenhouse experiment to examine the impacts of cigarette filters on the growth and development of vegetation (perennial ryegrass and white clover). The results indicated the potential for cigarette filters to reduce growth of terrestrial plants.[404] These results are evidence of impact; however further information is required to establish the extent of these impacts in the natural environment.

Impacts to animal and human health

There is a risk that land based animals and also human infants could ingest littered cigarette filters. Novotny et al. 2011, found that there have been tens of thousands of

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402 Wet Tropics Management Authority, *Impacts of YCA,* https://www.wettropics.gov.au/why-do-we-care, Accessed 8 November 2021.

403 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

404 Green, D., Boots, B., Carvalho, J., Starkey, T., 2019, *Cigarette butts have adverse effects on initial growth of perennial ryegrass (Gramineae: Lolium perene L.) and white clover (Leguminosae: Trifolium repes L.)*, Ecotoxicology and Environmental Safety 182 (1): 109418, July 2019.

reports incidences of human and animal exposure to cigarette filters, yet severe toxic outcomes due to ingestion of filters is rare.[405] Novotny (2011) note the following impacts from ingestion of cigarette filters:

- 1-2mg/kg of nicotine in young children may be toxic, causing nausea and vomiting in low doses, and more extensive neurological symptoms with higher doses.
- an oral minimum lethal dose of nicotine in dogs is reported to be 9.2mg/kg, with clinical signs reported at doses as low as 1 mg/kg. In small dogs, ingestion of one cigarette can cause signs
- pet birds are particularly sensitive to the chemicals from ingesting cigarette filters, with reports that pet birds have died after ingesting filters left in household trays.

Based on available reports in the literature, ingestion does occur by small children and domestic animals. However severe poisoning by cigarette filters among children and domestic animals is rare.[406]

Novotny et al. (2011) noted that whilst there was minimal reporting of cigarette filter consumption by wildlife, it did not necessary mean that ingestion by wildlife did not occur.[407]

Human health impacts from illegally dumped asbestos

Illegal dumping of asbestos containing materials is considered a significant issue from multiple perspectives, including:

- Illegally dumped asbestos is a risk to human health — asbestos fibres can be inhaled and can cause a range of life threatening illnesses, including: cancers (including mesothelioma and cancers of the lung, ovary and larynx); asbestosis and pleural plaques. These asbestos-related diseases contribute around 4000 deaths in Australia each year.[408]
- Illegally dumped asbestos is costly to clean up. Although there is limited data, previous studies have estimated that the cost of cleaning up illegally dumped waste at around $11 million per year.[409]

Clean-up costs are outside the scope of this report. Furthermore, we are not aware of any studies that quantify the incidence of asbestos-related disease with illegally dumped

405 Novotny, T., Hardin, S., Hovda, L, Novotny, D, McLean, M. K., and Khan, S., 2011, *Tobacco and cigarette butt consumption in humans and animals,* Research Paper, Tobacco Control 2011; 20, https://tobaccocontrol.bmj.com/content/tobaccocontrol/20/Suppl_1/i17.full.pdf. Accessed September 2021.

406 Ibid.

407 Ibid.

408 Asbestos Safety and Eradication Agency website, https://www.asbestossafety.gov.au/asbestos-health-risks-and-exposure/asbestos-health-risks, accessed 12 October 2021.

409 Asbestos Safety and Eradication Agency, Illegal asbestos dumping: Review of issues and initiatives, Final Discussion Paper, Prepared by ACIL-Allen Consulting, 16 March 2016, p. 1.

asbestos containing materials. Consequently, there is insufficient information at the present time to quantify these impacts.

Fire risk

Litter and illegally dumped material have potential to contribute to fire risks. Fire-related impacts can occur where:

- The littered or dumped item is the ignition point (e.g. where lit cigarettes or glass causes a bushfire) as in those cases the fire would not have occurred without the littered/dumped material
- The littered or dumped material causes specific problems that would not otherwise have occurred — the main example here relates to tyre fires.

Whilst there are instances of littered/dumped material contributing to fires, it is difficult to assess the overall extent to which littered/dumped material contributes to fire risk and fires that have occurred.

Fire risk from littered cigarettes

One case study is a fire incident in the Gold Coast Hinterland of Queensland where police determined a littered cigarette was the cause. The bushfire destroyed 11 homes and the historic Binna Burra Lodge.[410]

Fire risk from illegally dumped tyres

Tyres which are exposed to excess heat can thermally degrade through a process called pyrolysis. Pyrolysis releases flammable gases and pressure can build up within a type causing it to rupture or explode. A tyre explosion can cause significant environmental damage, or serious injuries or fatalities. Impacts can occur up to 300 metres from the type. Tyre fire explosions can be unpredictable, occurring immediately or up to 24 hours after pyrolysis has initiated.[411]

Tyre fires can burn for extended periods of time. For instance, a tyre fire in Melbourne of 150 000 tyres at a yard in Broadmeadows took days to extinguish. Environmental impacts from the fire include release of toxic black smoke over surrounding areas and potentially harmful runoff into waterways.[412]

There is insufficient information on incidence of tyre fires from illegally dumped tyres.

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410 ABC News, 2019, *Cigarette butt to blame for devastating Binna Burra bushfire,* Wednesday 13 November 2019, https://www.abc.net.au/news/2019-11-13/binna-burra-fire-an-accident-teenagers-discarded-cigarettes/11699474

411 Queensland Resources Safety and Health, 2004, *Tyre fires, pyrolysis and explosions,* Mines safety bulletin no. 47, 30 April 2004, Version 1.

412 ABC News, 2016, *Melbourne tyre blaze under control but may burn for several days, firefighters say,* https://www.abc.net.au/news/2016-01-12/melbourne-tyre-blaze-may-burn-for-another-24-hours-firefighters/7082642?nw=0&r=Gallery

Valuing the environmental impacts

Invasive plants

By far the greatest impact of green waste is the impact on biodiversity brought on by invasive plants introduced into the environment as evidenced by the multitude of studies that have looked into the cost of weed propagation in natural environments. Estimates include the following (although it is not clear how some of these estimates were arrived at).

- Weeds reportedly cost the Victorian economy over $900 million each year.[413]
- Weeds reportedly cost the NSW economy $1.8 billion each year in lost agricultural production and management costs.[414]
- The recent Centre for Invasive Species report estimates the economic costs of weeds to Australia of $5 billion annually (approximately $14 million a day). Ninety per cent of this cost is borne by agriculture, representing a high burden on that sector.[415]
- A Queensland study estimated the community's willingness to pay (using the contingent valuation method) to control the impacts of exotic plants (such as Lantana and Singapore Daisy) on areas of high conservation significance.[416] The management scenarios examined were: stopping and preventing expansion of the environmental weed; and stopping weed expansion and reducing the area of infestation.
  - The study estimated the community's willing to pay was around $70-$80 per household (converted to 2020 dollar terms using the national CPI) (table C.17)
  - This equates to around $144-$162 million per year (based on an estimated 1.98 million households in Queensland).

C.17 Estimated willingness to pay for environmental weed control

	Estimated household WTP (2004)[a]	Estimated household WTP (2020)[b]	Aggregate for Queensland[c]
	$	$	$ million
Lantana - stop the spread	56.88	81.7	162.0
Lantana - reduce area infested	53.08	76.3	151.2
Singapore Daisy - stop the spread	52.69	75.7	150.1
Singapore Daisy - reduce area infested	50.56	72.6	144.0

413 See, https://www.environment.vic.gov.au/invasive-plants-and-animals/invasive-species-on-public-land

414 See, https://www.soe.epa.nsw.gov.au/all-themes/biodiversity/invasive-species

415 Mcleod, R. (2018). Annual Cost of Weed in Australia. Centre for Invasive Species Solution. See, https://invasives.com.au/wp-content/uploads/2019/01/Cost-of-weeds-report.pdf

416 Tumaneng-Diete, T. Page, A. and Binney, J. 2005, Assessing the economic values of exotic invasive plants on areas of conservation significance in Queensland, Paper presented at the Australian Agricultural and Resource Economics Society, 49th Annual Conference, 9-11 February 2005.

[a] Tumaneng-Diete, Page and Binney (2005, p. 11). [b] Inflated to 2020 dollar terms using the national CPI. [c] Based on an estimated 1.98 million households in Queensland.

Note: Uses estimates from logit model.

Source: Tumaneng-Diete, T. Page, A. and Binney, J. 2005, Assessing the economic values of exotic invasive plants on areas of conservation significance in Queensland, Paper presented at the Australian Agricultural and Resource Economics Society, 49th Annual Conference, 9-11 February 2005, p. 11, ABS, CIE.

Some of the studies that estimate the cost of weeds tend to focus mostly on the impacts on the agriculture industry. The estimated costs of 'environmental weeds' are based on public spending on weed control. Although 'defensive expenditure' is sometimes used as a proxy for environmental costs, there is rarely a close link between defensive expenditure and intrinsic economic value. As such, this approach is rarely suitable for quantifying economic value.[417]

Using an alternative approach, we estimate an aggregate willingness to pay across NSW, Victorian and Queensland households to stop the spread of invasive garden species of around $3.1 billion per year. This is based on the following assumptions.

- Based on the information in table C.16 above, there are:[418]
  - 6 invasive garden species that are threatening a native plant species in NSW (Bitou Bush, Bridal Creeper, Lantana, English Broom, Blackberry and Dutchman's Pipe)
  - 5 invasive garden species that are threatening a native plant species in Victoria (English Broom, Blackberry, Cape Broom, Radiata Pine, Quaking Grass)
  - 5 invasive garden species that are threatening a native plant species in Queensland (Dutchman's Pipe, Para Grass, Lantana, Pink Periwinkle, Rubbervine).
- Each household is assumed to be willing to pay $74.46 to control each invasive garden species that is threatening a native plant species in their state. This is based on: the average estimate to reduce areas infested (which is the management strategy most closely aligned to the impacts of dumping garden waste) averaged across Lantana and Singapore Daisy (see table C.17 above)
- These estimates are aggregated across all households and species (table C.18).

C.18 Estimated aggregate willingness to pay to control environmental weeds

	Number of invasive garden species	Number of households	Aggregate WTP per species[a]	Annual WTP to reduce area infested by invasive garden species
	No.	Million	$ million	$ billion per year
NSW	6	3.13	233.14	1.40
Victoria	5	2.61	194.67	0.97
Queensland	5	1.98	147.62	0.74
Total			**575.42**	**3.11**

[a] Assumes each household is willing to pay $74.46 to reduce the infestation area for each invasive garden species that is threatening at least one native species in their state.

Source: CIE estimates.

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417 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 34.

418 Note that some species are double-counted across multiple states. This is appropriate in this case.

Illegally dumped garden waste contributes to the broader problem of invasive plants. In order to value the environmental impact of illegally dumped garden waste, data is required on its contribution to the broader problem. Currently there is no systematic data on the quantity of illegally dumped green waste, nor the incidence of invasive plants spreading and damaging native species to attribute impact to illegally dumped green waste.

A New Zealand study estimated that:[419]

- garden dumping can greatly enhance the spread of weed species with limited natural dispersal (indicating a high share of the impacts of these weeds could be attributed to illegal dumping)
- garden dumping makes little difference to the time taken to reach a reserve for those weeds that already disperse long distances, by wind or birds (indicating that for these species, the marginal impact of illegal dumping would be low).

However, in the absence of a sound basis to attribute the environmental costs associated with escaped garden plants to illegal dumping, table C.19 shows indicative estimates under various attribution assumptions.

C.19 Indicative estimates of the costs attributable to illegal dumping under various attribution assumptions

	10% attributed to illegal dumping	20% attributed to illegal dumping	30% attributed to illegal dumping	40% attributed to illegal dumping	50% attributed to illegal dumping
	$ million	$ million	$ million	$ million	$ million
NSW	139.9	279.8	419.6	559.5	699.4
Victoria	97.3	194.7	292.0	389.3	486.7
Queensland	73.8	147.6	221.4	295.2	369.1
Total	**311.0**	**622.1**	**933.1**	**1 244.1**	**1 555.1**

Source: CIE estimates.

Invasive pests — yellow crazy ants in the Wet Tropics of Queensland

The total cost incurred due to the spread of yellow crazy ants is dependent on whether current eradication efforts are successful at suppressing or completely eradicating the ants. In the absence of a successful eradication program, costs are incurred by the:

- agricultural sector through use cost of treatment sprays and/or loss of production value
- tourism sector through damage to infrastructure and/or declining tourism trade
- local community through social dis-amenity impacts and damages to domestic infrastructure

419 Timmins, S.T. James, A. Stover, J. and Plank, M. 2010, Is garden waste dumping really a problem?, Conference Paper, Seventeenth Australasian Weeds Conference, 26-30 September 2010.

- loss of species and ecosystem services in natural areas.

A study estimated the socio-economic costs of yellow crazy ants in the absence of a successful eradication program would exceed $700 million over the seven years.[420]

Eradication efforts are ongoing in the wet tropics region of Queensland involving numerous rounds of treatment (aerial and on-ground) and surveys. The total treatment area is approximately 2000 hectares including 133 hectares within the Wet Tropics World Heritage Area.[421] The eradication program is on track to achieve eradication within a ten-year timeframe.[422]

With the current eradication program is place, the predominant impact category for yellow crazy ants is 'clean-up cost'. The Wet Tropics Management Authority (WTMA) estimates the annual cost of the eradication program is $6 million per year for 7 years, equivalent to a present value of $34.6 million.[423]

However, where the eradication program is yet to be effective, or in the absence of an eradication program, there would be costs to industry and environmental impacts:

- Spring et al (2019) estimated the avoided control costs (e.g. pesticide expenditure, treatment costs) and avoided damages (e.g. crop losses) due to eradication program at $548 million (present value applying 7 per cent discount rate).
- Spring et al (2019) also estimated the environmental benefits of eradicating yellow crazy. This was based on an estimated willingness to pay by Australian households of $47 per household to avoid the extinction of seven native species.[424] The total avoided costs from the eradication program, including the avoided environmental costs, was estimated at $6.1 billion (present value applying 7 per cent discount rate).[425]

Illegal dumping has contributed to the spread of yellow crazy ant and the associated costs. However, there is currently a lack of information to attribute these costs to the spread caused by illegal dumping (primarily green/garden waste).

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420 Invasive Species Council, *Yellow crazy ant eradication program,* https://invasives.org.au/our-work/invasive-insects/ants/yellow-crazy-ants/ Accessed 8 November 2021.

421 Queensland Government, 2020, *Wet Tropics Management Authority's Yellow Crazy Ant Eradication Program:* August Report Card 2020 https://www.wettropics.gov.au/site/user-assets/AugustReportCard2020FinalLR.pdf Accessed 28 October 2021.

422 Invasive species council, *Yellow Crazy Ants,* https://invasives.org.au/our-work/invasive-insects/ants/yellow-crazy-ants/

423 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

424 Akter, S., Kompas, T. and Ward, M.B., 2015. Application of portfolio theory to assetbased biosecurity decision analysis. Ecological Economics, 117, pp.73-85 sourced in Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

425 Spring, D., Kompas, T., and Bradhurst, R., 2019, *Cost-Benefit Analysis of the Yellow Crazy Ant Eradication Program.* Report prepared for the Wet Tropics Management Authority.

Direct damage to native vegetation at illegal dumping sites

As noted above, the direct environmental damage at an illegal dumping site is in addition to any amenity impacts (which are valued in a separate report). As such, the environmental costs we are seeking to value for the purposes of this study relate to the loss of native vegetation at the site.

Australian studies on the willingness to pay for native vegetation are summarised in table C.20. The impacts tend to vary depending on the type of environment and whether the species or ecological community on the site are endangered.

C.20 Estimated values for native vegetation from literature

Study	Attribute valued	Original WTP value ($ per household per unit)	WTP value in 2021 dollars ($ per household per unit)	Payment frequency	Present value ($2021 per household)
Native vegetation					
Hatton et. al. (2011)[a]	Healthy vegetation (ha)	0.0008	0.00096	Annual payment per household for 10 years	0.007
Mazur & Bennett (2009)[b]	Native vegetation in good condition (ha)	0.0006	0.0008	Annual payment per household for 5 years	0.003
Gillespie Economics (2009a)[c]	Native vegetation protected (ha)	0.3	0.38	Once-off payment	0.38
Endangered Ecological Communities					
Gillespie Economics (2009b)[d]	Avoid EECs from being cleared (ha)	0.41	0.52	Once-off payment	0.52
	EEC planted in the region (ha)	0.10	0.13	Once-off payment	0.13
	Protect existing EEC in the region (ha)	0.28	0.35	Once-off payment	0.35
Iconic native species					
Bennett et. al. (2007)[e]	Healthy River Red Gums (per 1,000 ha)	1.45*	1.95	Annual payment per household for 20 years	$0.02 per hectare ($20.68 per 1,000 hectares)
	Rainforest (per 1,000 ha)	11.16*	15.02	Annual payment per household for 20 years	$0.16 per hectare ($159.14 per 1,000 hectares)
	Old growth forest (per 1,000 ha)	0.65*	0.87	Annual payment per household for 20 years	$0.01 per hectare

Study	Attribute valued	Original WTP value ($ per household per unit)	WTP value in 2021 dollars ($ per household per unit)	Payment frequency	Present value ($2021 per household)
					($9.27 per 1,000 hectares)
Habitat types					
MacDonald & Morrison (2010)	Scrubland (per 1,000 ha)	0.72	0.88	Annual payment per household for 5 years	$0.004 per hectare ($3.61 per 1,000 hectares)
	Grassy woodland (per 1,000 ha)	1.06	1.30	Annual payment per household for 5 years	$0.005 per hectare ($5.32 per 1,000 hectares)

[a] Hatton MacDonald, D., Morrison, M., Rose, J., and Boyle, K., 2011, *Valuing a multistate river: the case of the River Murray,* The Australian Journal of Agricultural and Resources Economics, 55, pp. 374 – 392; [b] Mazur and Bennett 2009, Location differences in communities' preferences for environmental improvements in selected NSW catchments: A Choice Modelling approach; [c] Gillespie Economics 2009a, Bulli Seam Operations Socio-Economic Assessment, prepared for Illawarra Coal Holdings; [d] Gillespie Economics 2009b, Mount Thorley Warkworth Operations Choice Modelling Study of Environmental and SocialImpacts, prepared for Coal & Allied Pty Ltd; [e] Bennett, J., Dumsday, R., Lloyd, C., Kragt, M., (2007) Non-use values of Victorian Public Land: Case Studies of River Red Gum and East Gippsland Forests.

Note: EECs stands for Endangered Ecological Communities.

Source: See table notes.

To provide some indicative estimates on the aggregate cost of the loss of native vegetation as a result of illegal dumping to NSW, Victoria and Queensland, we use the estimates for native vegetation in general (i.e. the first three studies listed) and aggregate across households in the relevant states.

A relevant consideration in the use of benefit transfer relates to scaling of benefits across populations. In particular, it is likely that households are willing to pay more to preserve native vegetation in close proximity to where they live (including within another state). It is therefore questionable whether it is appropriate to aggregate the willingness to pay estimates across all households within each state or across all of the relevant states.

Nevertheless, even when aggregated across all households within each state (or even all household in all of the relevant states, estimates based on Hatton et. al. (2010) and Mazur & Bennett (2009) are in a range of a few thousand dollars per hectare per year (table C.21). Costs based on Gillespie Economics (2009a) are significantly higher, although these estimates relate to a one-off payment, rather than an annual payment. Furthermore, the context of the Gillespie Economics (2009a) study was a mining site which is different to the context used in the other two studies listed.

C.21 Estimated aggregate cost of native vegetation loss

	Households	Aggregate annual WTP based on Hatton et. al. (2010)[a]	Aggregate annual WTP based on Mazur & Bennett (2009)[b]	Aggregate WTP based on Gillespie Economics (2009a)[c]
	million	$ per year	$ per year	$
NSW	3.13	3 006	2 505	1 189 803
Victoria	2.61	2 510	2 092	993 471
Queensland	1.98	1 903	1 586	753 379
Total	**7.73**	**7 419**	**6 182**	**2 936 653**

[a] Based on estimated value of $0.00096 per year per hectare. [b] Based on estimated value of $0.0008 per year per hectare. [c] Based on estimated value of $0.380 per hectare (one-off payment).

Note: Gillespie Economics (2009a) is based on a one-off payment, while the other studies refer to an annual payment.

Source: See table C.20 above.

The persistence of these environmental costs would depend on if (and when) the dumped material is cleaned up and whether there are additional efforts to rehabilitate the site. Once the material has been removed from the site, the site could regenerate over time. This process could potentially happen more quickly if efforts are made to rehabilitate the site.

As most illegal dumping in bushland involves a vehicle (such as a ute),[426] converting these estimates above to environmental costs per ute-load of waste provides a useful perspective. Ute tray dimensions are as follows (based on a Toyota Hilux):

- 3.45 m^2 for a dual cab, implying around 2 892 ute loads of waste per hectare
- 4.82 m^2 for a single cab, implying around 2072 ute loads of waste per hectare.

Based on these estimates, the environmental cost per ute load of waste illegally dumped in the natural environment is shown in table C.22.

- The estimates based on Hatton et. al. (2010) and Mazur & Bennett (2009) are generally less than a couple of dollars per year per ute load. If any environmental impacts persist over several years, the costs could be in the order of $10 per ute load.
- Aggregate environmental costs based on Gillespie Economics (2009a) are in the order of several hundred dollars per ute load (depending on the state), although this estimate implies a permanent impact (which seems unlikely).

C.22 Estimated environmental cost per ute load of waste dumped in the natural environment

	Aggregate Annual WTP (based on Hatton et. al. 2010)[a]	Aggregate Annual WTP based on Mazur & Bennett (2009)[b]	Aggregate WTP based on Gillespie Economics (2009a)[c]
	$ per year	$ per year	$
Double cab ute[d]			
NSW	1.04	0.87	411.43

426 See Ipsos, *EPA - Illegal Dumping Research Report*, Report prepared for the NSW Environment Protection Authority, July 2020, p. 40.

	Aggregate Annual WTP (based on Hatton et. al. 2010)[a]	Aggregate Annual WTP based on Mazur & Bennett (2009)[b]	Aggregate WTP based on Gillespie Economics (2009a)[c]
	$ per year	$ per year	$
Victoria	0.87	0.72	343.54
Queensland	0.66	0.55	260.52
Total	2.57	2.14	1 015.49
Single cab ute[e]			
NSW	1.45	1.21	574.20
Victoria	1.21	1.01	479.45
Queensland	0.92	0.77	363.58
Total	3.58	2.98	1 417.23

[a] Based on estimated value of $0.00096 per year per hectare. [b] Based on estimated value of $0.0008 per year per hectare. [c] Based on estimated value of $0.380 per hectare (one-off payment). [d] Based on ute tray area of 3.45 m². [e] Based on single cab ute tray area of 4.82 m².

Note: Gillespie Economics (2009a) is based on a one-off payment, while the other studies refer to an annual payment.

Source: See table C.21 above.

The number of hectares of native vegetation destroyed by illegal dumping activity is not known. Nevertheless, indicative estimates of the order of magnitude of the cost of illegal dumping are provided in table C.23. These estimates are based on the following assumptions.

- We assume that **4 per cent** of households illegally dump material in bushland. This is based on the Ipsos household survey for the NSW EPA, which reports that:[427]
  - 1 per cent of households disposed of waste on public land; and
  - 3 per cent households disposed of waste on someone else's land.
- Each of these households dumps **one** ute-load of material in bushland per year (ute dimensions are assumed to be 4.82 m^2, based on a single cab Toyota Hilux).
- Households are willing to pay **$0.00096 per hectare** per year for each hectare of healthy vegetation (based on Hatton et. al. 2011). This is aggregated across all households within the state in which the illegal dumping activity occurs.
- The environmental damage persists for 5 years and future costs are discounted, using a 7 per cent discount rate.

Based on these assumptions, the cost of direct damage to native vegetation from illegal dumping ranges between around $320 000 per year in Queensland up to around $800 000 per year in NSW.

427 Ipsos, *EPA - Illegal Dumping Research Report*, Report prepared for the NSW Environment Protection Authority, July 2020, p. 88.

C.23 Indicative estimates of the cost of damage to native vegetation from illegal dumping

	Households	Number of ute loads[a]	Environmental cost[b]
	million	No.	$
NSW	3.13	125 242	797 058
Victoria	2.61	104 576	555 713
Queensland	1.98	79 303	319 570

[a] Assumes: 4 per cent of household illegally dump material in bushland; and each of these household dumps one ute-load of waste per year. b Assumes: households are willing to pay **$0.00096 per hectare** per year for each hectare of healthy vegetation (based on Hatton et. al. 2011) aggregated across all households within the state in which the illegal dumping activity occurs; the environmental damage persists for 5 years and future costs are discounted using a 7 per cent discount rate.

Source: CIE indicative estimates.

Although there is much uncertainty around these estimates, they nevertheless indicate that these costs are likely to be trivial relative to other types of environmental costs (as well as clean-up and amenity costs).

D Valuing environmental costs

Techniques for valuing environmental impacts

The value members of the community place on all goods and services — including environmental goods and services — is reflected in their 'willingness to pay'.

In cost-benefit analysis (CBA), goods and services are typically valued at the market price where possible.[428] However, the benefits from environmental assets are generally not traded in markets and are therefore not directly observable.

There are various techniques economists use to value environmental outcomes in monetary terms, including the following.

- **Replacement cost and damage cost** — this approach infers the value of an environmental asset from the cost of restoring it to its undamaged state. However, the cost of replacing an environmental asset will generally be unrelated to its intrinsic value. Johnson et al (2015) note that except in rare circumstances, neither replacement nor damage cost approaches are suitable for quantifying economic value.[429]
- **Revealed preference approaches** — these studies seek to elicit people's willing to pay for environmental services by observing their behaviour in related markets.[430] A key advantage of revealed preference measures is that values are inferred from actual observed behaviour. The main revealed preference methodologies used to value environmental assets are as follows.
  - **Travel cost method** — this approach can be used to value recreational use values of non-market goods, including outdoor natural areas (such as beaches or bushland areas). Although most natural areas are not directly priced in Australia, travel costs are used as a proxy for the value of accessing the site.[431]
  - **Hedonic pricing method (HPM)** — this approach estimates the value of a non-market good by observing behaviour in the market for a related goods and

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[428] See for example: NSW Government, Guide to Cost Benefit Analysis, Policy and Guidelines Paper TPP 17-03, March 2017, p. 33.

[429] Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 34.

[430] Australian Government Office of Best Practice Regulation, *Research Report: Environmental valuation and uncertainty*, July 2014, p. 13.

[431] OECD, 2018, Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris, https://www.oecd-ilibrary.org/environment/cost-benefit-analysis-and-the-environment_9789264085169-en, p. 66.

services (particularly property markets and labour markets).[432] The underlying rationale is that the price of many market goods reflects a bundle of its characteristics. The HPM uses statistical techniques to isolate the implicit price of each of these characteristics, which in some cases will include environmental services. For example, the amenity (or disamenity) value of aspects of the local environment (such as traffic noise or proximity to green space) can be inferred from analysing property prices, holding all other characteristics that affect price constant.

- **Stated preference approaches** — these approaches typically ask individuals to self-report their preferences through a survey. Survey-based approaches can be susceptible to various biases (such as hypothetical and framing bias). Careful survey design is therefore important to ensure the survey elicits valid results. The main stated preference methods are:
  - **Contingent valuation** — this approach directly asks survey respondents their willingness to pay (or willingness to accept compensation) for a hypothetical change in the provision of a non-market good.[433]
  - **Choice experiment** — this approach involves asking respondents to select from a number of pre-defined options. The options are described in terms of a common set of attributes, but each option is differentiated from the others by a different level of each attribute.[434] A monetary valuation of the various attributes can be estimated through analysis of the trade-offs made by respondents between attributes and price.
- **Benefit transfer method** — this approach involves extrapolating the results from pre-existing studies to another similar situation.[435] It is frequently used in policy analysis where the time and cost prohibits primary research.

Benefit transfer

Cost-benefit analysis (CBA) is an approach to assessing the impacts of government policy decisions. CBA involves quantifying all financial, social and environmental impacts in monetary terms, so that the trade-offs can be understood and weighed up in a common metric. In many contexts, CBA is preferred approach to assessing the impacts of government policy decisions. For example, regulatory impact assessment guidelines

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432 OECD, 2018, Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris, https://www.oecd-ilibrary.org/environment/cost-benefit-analysis-and-the-environment_9789264085169-en, p. 57.

433 OECD, 2018, Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris, https://www.oecd-ilibrary.org/environment/cost-benefit-analysis-and-the-environment_9789264085169-en, p. 85.

434 NSW Government, Guide to Cost Benefit Analysis, Policy and Guidelines Paper TPP 17-03, March 2017, p. 34.

435 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 4.

(including in NSW[436], Victoria[437] and Queensland[438]) typically require the use of CBA (where possible) when assessing the impacts of a regulatory proposal.

Many government decisions will have an impact on environment values. However, given the time and costs associated with primary research, benefit transfer is often the only practical option available to practitioners, where it is necessary to value environmental costs and benefits as part of a CBA. The alternative is that environmental impacts are excluded from CBAs (or dealt with qualitatively) and possibly given insufficient weight in government decisions.

Challenges and pitfalls

Despite the large and growing academic literature on benefit transfer and its widespread use in policy analysis, it remains subject to misuse and misunderstanding. [439] Johnson et. al. (2015) provides a detailed exposition of the key issues in benefit transfer.

A CBA where some costs and benefits are valued using benefit transfer will be reliable only if the benefit transfers are reliable. However, benefit transfers are subject to a variety of potential errors. There are broadly two types of errors associated with benefit transfer:[440]

- Measurement errors — these are errors transferred errors from the original primary studies (i.e. differences between the true underlying value and a primary study estimate). The accuracy of benefit transfer depends on the type and quality of primary studies used to generate transfer estimates.[441] It is crucial that the original primary study estimates represent valid measures of economic value.[442]
- Generalisation errors — these are the errors related to the transfer process itself. Common generalisation errors include:
  - Benefit scaling — a common pitfall of benefit transfer involves the scaling of benefits over populations, affected areas or quantities of change. Per unit values tend to be higher in small local case studies than regional or national ones, due to factors such as distance decay and diminishing marginal utility. Unit values should

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436 NSW Government Guide to Better Regulation, Policy and Guidelines paper TPP 19-01, January 2019, p. 14.

437 Victorian Guide to Regulation: A handbook for policy-makers in Victoria, 2016, p. 37.

438 The Queensland Government Guide to Better Regulation, May 2019, P. 21.

439 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 21.

440 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 41.

441 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 39.

442 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 34.

not therefore be scaled to significantly larger or smaller geographic areas (or scales) without adjustments.[443]

– Lack of site similarity — a key requirements for accurate benefit transfer is similarity between the site, valuation context and populations at the study site and those at the policy site.[444]
– Commodity inconsistency — accurate transfers require an understanding of the welfare-influencing quantities or qualities of goods at affected sites, both in primary studies from which values are estimated and in policy sites for which estimates are needed. Even studies of seemingly similar nonmarket goods may estimate values for differing underlying quantities or qualities.[445]

Types of benefit transfer methods

There are broadly two types of benefit transfer methods:

- Unit value transfers — this involves the transfer of a single number or set of numbers (either 'as is' or adjusted) from pre-existing primary studies.
- Function transfers — this approach involves deriving information using an estimated function derived from original research, such as a meta-analysis that incorporates results from multiple studies.

Function transfers typically outperform unit value transfers in terms of accuracy (although not always). Unit value transfers can perform satisfactorily if the study and policy contexts are very similar.[446]

443 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 34.

444 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, p. 38.

445 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, pp. 38-39.

446 Johnson, R.J. Rolfe, J. Rosenberger, R.S. and Brouwer, R. 2015, *Benefit Transfer of Environmental and Resource Values: A Guide for Researchers and Practitioners*, Springer, pp. 21-22.

E Share of global marine plastic waste

E.1 Share of global plastic waste emitted to the ocean, 2019

Entity	Code	Share of global plastics emitted to ocean	Mismanaged waste emitted to the ocean
		per cent	metric tonnes per year
Africa		7.99	78252
Albania	ALB	0.16	1565
Algeria	DZA	0.59	5774
Angola	AGO	0.09	860
Antigua and Barbuda	ATG	0.00	2
Argentina	ARG	0.42	4137
Asia		80.99	793298
Australia	AUS	0.0033	32
Bahamas	BHS	0.00	20
Bahrain	BHR	0.00	0
Bangladesh	BGD	2.52	24640
Barbados	BRB	0.00	45
Belgium	BEL	0.00	34
Belize	BLZ	0.04	374
Benin	BEN	0.17	1639
Bosnia and Herzegovina	BIH	0.00	6
Brazil	BRA	3.86	37799
Brunei	BRN	0.01	134
Bulgaria	BGR	0.00	7
Burkina Faso	BFA	0.00	0
Cambodia	KHM	0.11	1113
Cameroon	CMR	1.09	10671
Canada	CAN	0.02	238
Cape Verde	CPV	0.00	0
Chile	CHL	0.03	322
China	CHN	7.22	70707
Colombia	COL	0.04	431
Comoros	COM	0.00	0
Congo	COG	0.07	676
Costa Rica	CRI	0.05	450

Entity	Code	Share of global plastics emitted to ocean	Mismanaged waste emitted to the ocean
		per cent	metric tonnes per year
Cote d'Ivoire	CIV	0.49	4784
Croatia	HRV	0.02	224
Cyprus	CYP	0.00	3
Democratic Republic of Congo	COD	0.04	420
Denmark	DNK	0.00	9
Djibouti	DJI	0.00	4
Dominica	DMA	0.01	53
Dominican Republic	DOM	0.64	6276
EU-27		0.22	2157
Ecuador	ECU	0.12	1136
Egypt	EGY	0.25	2471
El Salvador	SLV	0.08	808
Equatorial Guinea	GNQ	0.04	405
Eritrea	ERI	0.00	48
Estonia	EST	0.00	12
Europe		0.60	5832
Fiji	FJI	0.04	365
Finland	FIN	0.00	0
France	FRA	0.02	235
French Guiana	GUF	0.00	7
Gabon	GAB	0.05	445
Gambia	GMB	0.04	421
Georgia	GEO	0.00	3
Germany	DEU	0.01	134
Ghana	GHA	0.43	4185
Greece	GRC	0.02	216
Grenada	GRD	0.01	130
Guadeloupe	GLP	0.00	4
Guatemala	GTM	0.73	7142
Guinea	GIN	0.24	2347
Guinea-Bissau	GNB	0.03	247
Guyana	GUY	0.13	1246
Haiti	HTI	0.71	6929
Honduras	HND	0.25	2436
Hong Kong	HKG	0.01	112
Iceland	ISL	0.00	0
India	IND	12.92	126513
Indonesia	IDN	5.75	56333

Entity	Code	Share of global plastics emitted to ocean	Mismanaged waste emitted to the ocean
		per cent	metric tonnes per year
Iran	IRN	0.09	928
Iraq	IRQ	0.01	67
Ireland	IRL	0.01	115
Israel	ISR	0.00	33
Italy	ITA	0.04	414
Jamaica	JAM	0.24	2334
Japan	JPN	0.19	1835
Jordan	JOR	0.00	1
Kazakhstan	KAZ	0.00	13
Kenya	KEN	0.03	259
Kiribati	KIR	0.00	0
Kuwait	KWT	0.00	7
Latvia	LVA	0.00	9
Lebanon	LBN	0.07	684
Lesotho	LSO	0.00	0
Liberia	LBR	0.27	2638
Libya	LBY	0.09	879
Lithuania	LTU	0.00	7
Macau		0.03	341
Madagascar	MDG	0.08	775
Malaysia	MYS	7.46	73098
Maldives	MDV	0.00	0
Malta	MLT	0.00	0
Marshall Islands	MHL	0.00	0
Martinique	MTQ	0.00	22
Mauritania	MRT	0.01	127
Mauritius	MUS	0.00	0
Mexico	MEX	0.36	3512
Micronesia		0.00	37
Monaco	MCO	0.00	0
Montenegro	MNE	0.00	0
Morocco	MAR	0.18	1800
Mozambique	MOZ	0.26	2544
Myanmar	MMR	0.26	2544
Namibia	NAM	0.00	2
Netherlands	NLD	0.03	271
New Zealand	NZL	0.01	68
Nicaragua	NIC	0.15	1465

Entity	Code	Share of global plastics emitted to ocean	Mismanaged waste emitted to the ocean
		per cent	metric tonnes per year
Nigeria	NGA	1.90	18640
North America		4.50	44067
North Korea	PRK	0.01	50
Norway	NOR	0.00	0
Oceania		0.37	3631
Oman	OMN	0.00	1
Pakistan	PAK	0.09	873
Palau	PLW	0.00	7
Palestine	PSE	0.01	118
Panama	PAN	0.53	5237
Papua New Guinea	PNG	0.31	3059
Peru	PER	0.03	259
Philippines	PHL	36.38	356371
Poland	POL	0.00	29
Portugal	PRT	0.01	76
Puerto Rico	PRI	0.01	71
Qatar	QAT	0.00	0
Reunion	REU	0.00	0
Romania	ROU	0.01	80
Russia	RUS	0.06	542
Saint Kitts and Nevis	KNA	0.00	1
Saint Lucia	LCA	0.05	449
Saint Martin		0.00	0
Saint Vincent and the Grenadines	VCT	0.01	81
Samoa	WSM	0.00	0
Sao Tome and Principe	STP	0.01	77
Saudi Arabia	SAU	0.00	3
Senegal	SEN	0.02	169
Seychelles	SYC	0.00	0
Sierra Leone	SLE	0.37	3624
Singapore	SGP	0.02	164
Sint Maarten		0.00	0
Slovakia	SVK	0.00	0
Slovenia	SVN	0.00	11
Solomon Islands	SLB	0.01	100
Somalia	SOM	0.00	2
South Africa	ZAF	0.44	4266
South America		5.51	54000

Entity	Code	Share of global plastics emitted to ocean	Mismanaged waste emitted to the ocean
		per cent	metric tonnes per year
South Korea	KOR	0.04	387
Spain	ESP	0.02	235
Sri Lanka	LKA	0.99	9654
Sudan	SDN	0.01	106
Suriname	SUR	0.17	1677
Sweden	SWE	0.00	36
Syria	SYR	0.00	44
Taiwan	TWN	0.05	531
Tanzania	TZA	0.59	5785
Thailand	THA	2.33	22806
Timor	TLS	0.07	715
Togo	TGO	0.04	436
Tonga	TON	0.00	0
Trinidad and Tobago	TTO	0.36	3557
Tunisia	TUN	0.07	688
Turkey	TUR	1.46	14329
Ukraine	UKR	0.09	859
United Arab Emirates	ARE	0.00	14
United Kingdom	GBR	0.07	703
United States	USA	0.25	2431
Uruguay	URY	0.10	998
Venezuela	VEN	0.61	5988
Vietnam	VNM	2.88	28221
Western Sahara	ESH	0.00	38
Yemen	YEM	0.03	252
Zimbabwe	ZWE	0.00	0

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