



Department of Planning and Environment

# Marine Debris Threat and Risk Assessment Summary Report

Funded by the NSW Government as part of the  
NSW Marine Estate Management Strategy



© 2023 State of NSW and Department of Planning and Environment

With the exception of photographs, the State of NSW and Department of Planning and Environment are pleased to allow this material to be reproduced in whole or in part for educational and non-commercial use, provided the meaning is unchanged and its source, publisher and authorship are acknowledged. Specific permission is required for the reproduction of photographs.

The Department of Planning and Environment (DPE) has compiled this report in good faith, exercising all due care and attention. No representation is made about the accuracy, completeness or suitability of the information in this publication for any particular purpose. DPE shall not be liable for any damage which may occur to any person or organisation taking action or not on the basis of this publication. Readers should seek appropriate advice when applying the information to their specific needs.

All content in this publication is owned by DPE and is protected by Crown Copyright, unless credited otherwise. It is licensed under the [Creative Commons Attribution 4.0 International \(CC BY 4.0\)](#), subject to the exemptions contained in the licence. The legal code for the licence is available at [Creative Commons](#).

DPE asserts the right to be attributed as author of the original material in the following manner: © State of New South Wales and Department of Planning and Environment 2023.

Cover photo: Edwina Foulsham/DPE

Published by:

Environment and Heritage  
Department of Planning and Environment  
Locked Bag 5022, Parramatta NSW 2124  
Phone: +61 2 9995 5000 (switchboard)  
Phone: 1300 361 967 (Environment and Heritage enquiries)  
TTY users: phone 133 677, then ask for 1300 361 967  
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967  
Email: [info@environment.nsw.gov.au](mailto:info@environment.nsw.gov.au)  
Website: [www.environment.nsw.gov.au](http://www.environment.nsw.gov.au)

Report pollution and environmental incidents  
Environment Line: 131 555 (NSW only) or [info@environment.nsw.gov.au](mailto:info@environment.nsw.gov.au)  
See also [www.environment.nsw.gov.au](http://www.environment.nsw.gov.au)

ISBN 978-1-922899-43-9  
EHG2023/0110  
October 2022, table 4 error corrected March 2023

Find out more about your environment at:

**[www.environment.nsw.gov.au](http://www.environment.nsw.gov.au)**

# Contents

Acknowledgment of Country	1
NSW Marine Debris Threat and Risk Assessment (MDTARA)	2
Key findings	2
Key terms	5
MDTARA summary report	5
Introduction	6
Marine debris	6
Impacts	6
NSW Marine Estate	6
Marine debris in New South Wales	7
Approach	7
Three stages of the MDTARA	9
Spatial risk mapping	10
Spatial threat prioritisation	10
External reporting to supplement the MDTARA	11
Results	11
Risk matrices	11
Priority debris items	16
Peer review of results by working group members	17
Spatial risk mapping	17
Spatial threat prioritisation	21
External report summary: current management settings in New South Wales	21
Key limitations	23
Key recommendations	23
Conclusion	27
Acknowledgments	28
References	29

## List of tables

Table 1	Key element definitions	5
Table 2	Debris risk matrix for environmental assets (green indicates minimal risk level)	13
Table 3	Stressor risk matrix for environmental assets (green indicates minimal risk level)	14
Table 4	Risk matrix for social values (minimal risk level not considered in analysis)	15
Table 5	Summary of peer review of expert elicitation results for a) fauna groups and b) social values	17
Table 6	Statewide and regional-scale priority threats for mapped debris items	21

## List of figures

Figure 1	MDTARA key findings	3
Figure 2	Summary of debris items in New South Wales from a 2018 review (Smith and Edgar 2018)	7
Figure 3	Main elements in the MDTARA	8
Figure 4	An example of the elements in the MDTARA process	9
Figure 5	Priority marine debris items posing the greatest threats to the marine estate	16
Figure 6	Spatial risk posed by debris items, aggregated across environmental assets	20
Figure 7	Scale and number of programs and policies addressing MDTARA priority items	22

## **Acknowledgment of Country**

The Department of Planning and Environment acknowledges the Traditional Owners and Custodians of the land and seas on which we live and work, and pays respect to Elders past, present and emerging. It also recognises and respects the strong connection and custodial relationship Indigenous peoples have with Sea Country.

# **NSW Marine Debris Threat and Risk Assessment (MDTARA)**

This study assessed the risks posed by marine debris to the marine estate in New South Wales. Commonly found debris items and their impacts on 7 fauna groups (environmental assets) and 6 social values were investigated. Impacts were assessed through an expert elicitation process and used to determine risk levels of identified item and asset/value combinations. Results were mapped with debris location and density to show how risk is spread over the NSW marine estate. Greater understanding of the risks posed by marine debris will assist in tackling the problem now and in the future.

## **Key findings**

The MDTARA has identified the types of marine debris that pose the greatest threats to the marine estate and prioritised them for future research and action. Mapping using debris data highlighted hotspot areas at highest risk from the impacts of debris and knowledge gaps to investigate further. The infographic in Figure 1 summarises the key findings of the MDTARA.

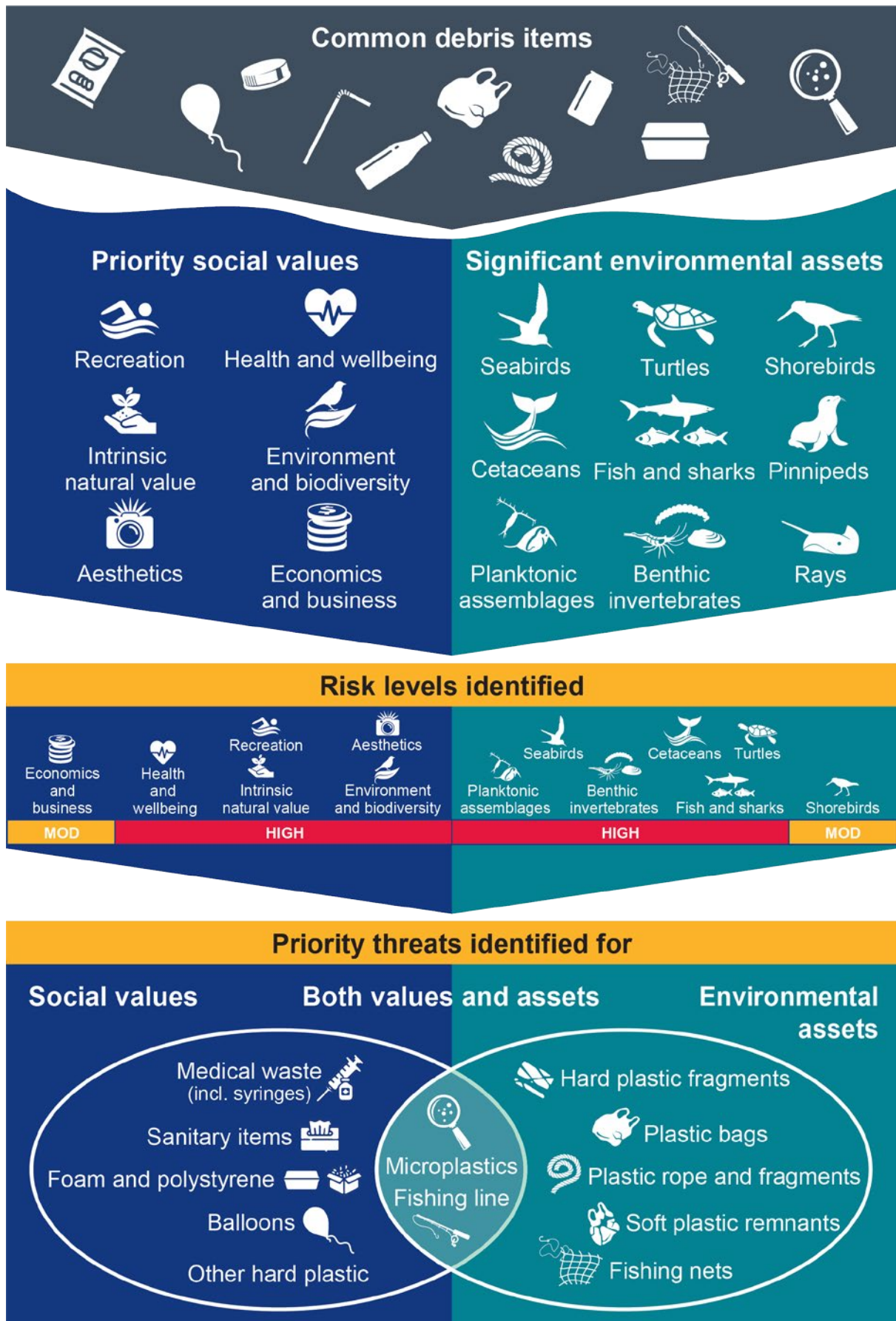


Figure 1 MDTARA key findings

## Fauna groups

- **6 fauna groups are at a high-risk level (red)** from marine debris and one group is at a moderate level (orange).
- 11 items pose a high risk to animals in the marine estate including **microplastics, plastic bags and hard plastic fragments**.
- **Entanglement and ingestion** are the impacts of debris that pose the highest risk level to fauna and impact the most groups.

## Social values

- **5 of 6 social values have a high overall risk level** from debris.
- 10 debris items pose a high level of risk such as **medical waste, foam and polystyrene**.
- The lack of variation in overall risk levels highlights the need for additional analysis to prioritise threats.

## Priority debris items

- **12 debris items** have been identified as priority threats to the marine estate (balloons, foam and polystyrene, medical waste (incl. syringes), other hard plastic, sanitary items, fishing line, fishing nets, hard plastic fragments, microplastics, plastic bags, plastic rope and fragments, soft plastic remnants).
- 3 of the top 7 priority items from the fauna groups are **fishing related**.
- **Microplastics and fishing line** are high-priority threats to address in both the **fauna group** and **social values** assessments.

## Where are the highest risk areas?

Debris items with sufficient data on their distribution and density were mapped with their relative risk rating across the marine estate. Regional and state priorities were then established based on the debris item risk level.

- **'Hotspots'** of spatial risk were found for food packaging, and fishing traps and pots.
- Some debris items are classified as **statewide priorities**. These are **balloons, plastic rope and fragments, fishing line, plastic bags, and plastic fragments (both hard and soft)**.
- The central and south regions of New South Wales are mostly moderate to high-risk areas for balloons and plastic bags.
- **Foam packaging and fishing traps and pots** are **regional priorities** in the central region of New South Wales.



## Key terms

Key terms used in this report and in the MDTARA are in Table 1.

**Table 1 Key element definitions**

Component	Definition	Example
Threat	A marine debris item posing risk	Plastic bag
Asset (environmental)	A fauna group at risk of impact from marine debris	Seabirds
Social values	Standards or qualities that people deem important	Intrinsic natural value
Encounter	The situation in which marine debris can interact with fauna or affect social values	Balloons being released and ingested by a turtle
Impact	An effect or outcome	Death
Stressor	Impact pathways through which debris can affect fauna groups	Entanglement
Consequence	The strength of an impact of an encounter	Major
Likelihood	The likelihood of an impact occurring, given an encounter	Possible
Risk	The chance of something happening that will have an impact	Minimal/low/moderate/high
Risk level	The magnitude of a risk or combination of risks (a function of consequence and likelihood)	Minimal/low/moderate/high
Level of concern	The consequence debris has on a social value (refers to the speed and prioritisation of a call to management action)	Low/ moderate/high
Confidence	The certainty of an expert in their response during the elicitation process, based upon available evidence	Inferred, adequate

## MDTARA summary report

This report summarises the MDTARA approach, results, limitations, and recommendations for considerations when planning strategic research and management associated with the impact of marine debris on the NSW marine estate. It serves as an overview to provide information to stakeholders, practitioners and government. It aims to encourage us to apply the MDTARA findings to managing the marine estate at various scales, using the risk-based approach the assessment has been built upon.

This summary report is supplemented by the following resources:

- supplementary documentation of the MDTARA methods, findings and key concepts: *MDTARA Supplementary Material Report* (DPE 2022b)
- information and analysis of the literature review within the MDTARA: *MDTARA Literature Review Summary* (DPE 2022a)
- a peer-reviewed scientific article (in review) documenting the MDTARA application to New South Wales: Gacutan J, Foulsham E, Turnbull JW, Smith SDA and Clark GF

(in review), 'Mapping marine debris risk using expert elicitation, empirical data, and spatial modelling', *Environmental Science and Policy*

- the background document series used in the threat and risk assessment expert elicitation process: NSW Marine Debris Threat and Risk Assessment (Stage 3) expert elicitation background documents (DPIE 2019)
- an external review to fill the knowledge gap: Review of Programs and Initiatives in Managing Litter and Marine Debris within New South Wales, conducted in 2021 by Tangaroa Blue Foundation for the NSW Department of Planning, Industry and Environment.

## Introduction

The statewide threat and risk assessment of the NSW marine estate (NSW TARA), overseen by the Marine Estate Management Authority (MEMA), prioritised marine debris as a significant threat (MEMA 2017). Previously, the direct impacts of marine debris in New South Wales had not been well studied. Even so, strategic management is needed, using the best available data and knowledge, to reduce the negative impacts of marine debris. Key concepts that provide the context for the MDTARA are how we have defined marine debris and its impacts, and the marine estate, as well as an assessment of the status of marine debris in New South Wales.

## Marine debris

In the MDTARA we have defined marine debris as anthropologically manufactured or processed materials that have been deliberately or accidentally disposed of in, abandoned in, or transported to estuarine, coastal and marine environments. Pollution by debris, particularly plastics, has been documented in scientific literature since the 1970s (Jambeck et al. 2015). It has been found that the vast majority of debris originates from land: up to 80% (US Dept Commerce 1999).

## Impacts

Debris has wide-ranging negative impacts on the environment and on socio-economic values. The environment can be affected in many ways such as the entanglement of fauna in debris, the ingestion of debris, or the changing of habitats. Our social values can be affected by debris, leading to things like a reduction in recreation or a decrease in our appreciation of nature.

## NSW Marine Estate

The marine estate is defined as the coastal and marine areas (including open coast beaches and foreshores), waters and habitats and their associated flora and fauna assemblages existent between the mean high-water mark to the 3 nautical mile (nm) limit of State jurisdiction. Estuarine areas include waters, beaches and foreshores, estuarine habitats and assemblages, and extend from estuary mouth to the upstream tidal limit (adapted from MEMA 2017). In New South Wales, the 3 regions considered are the north (from Tweed Heads to Stockton), central (from Stockton to Shellharbour) and south region (from Shellharbour to the New South Wales/Victoria border)(MEMA 2017).

## Marine debris in New South Wales

A 2018 review assessed marine debris in New South Wales in various habitats as well as reviewing impacts (Smith and Edgar 2018). Figure 2 highlights key debris items reported in these environments.

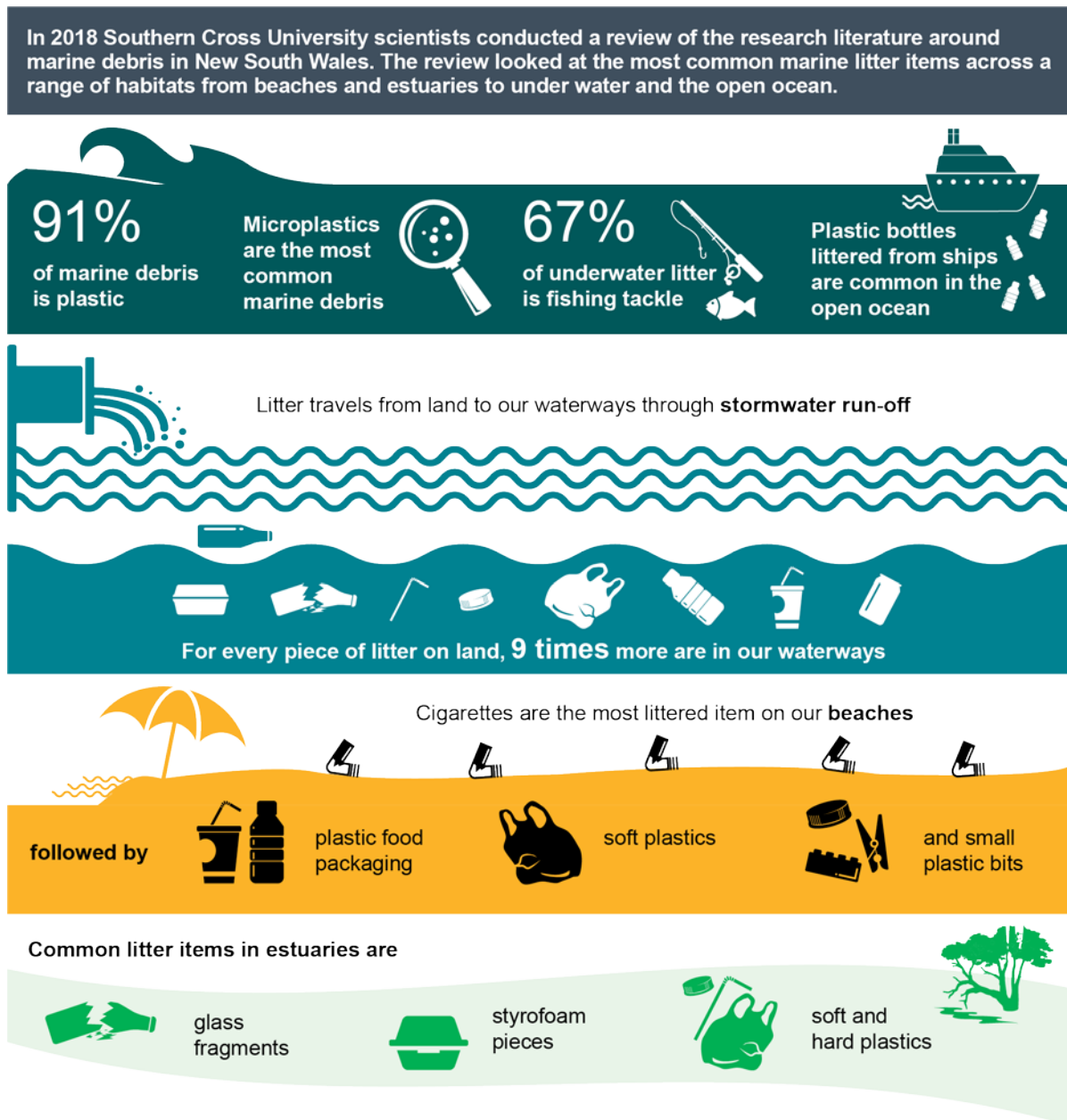


Figure 2 Summary of debris items in New South Wales from a 2018 review (Smith and Edgar 2018)

## Approach

Systematic monitoring and scientific assessment of debris and its impacts across the marine estate is challenging and would require large, long-term studies. As this is not feasible within the bounds of this assessment, the MDTARA has used a risk-based approach to estimate risk levels, applying the NSW TARA framework (MEMA 2015) in a manner consistent with the NSW TARA (MEMA 2017). This includes estimating a level of risk that results from the

impacts of a debris item on fauna groups (environmental assets), as well as the impacts on social values. The MDTARA used information about the distribution of debris to map how risk changes spatially.

A 3-stage method was devised by the University of New South Wales (UNSW) (Clarke GF 2019) and applied to New South Wales (Gacutan et al. in review). Using a combination of expert elicitation and statistical analysis to estimate risk values, this approach considered the following:

- 40 common marine debris items in New South Wales
- 7 fauna groups (environmental assets) (Figure 3); 2 groups were unable to be assessed due to insufficient expert engagement
- 6 priority social values (Figure 3)
- 3 broad environmental divisions (estuarine, coastal, and marine)
- 3 geographical regions of New South Wales (north, central and south)
- NSW TARA framework (MEMA 2015)
- applying similar methods, where appropriate, to those used in the NSW TARA (MEMA 2017)
- the insight and input of a Marine Debris Working Group (working group) convened under the NSW Marine Estate Management Strategy (MEMS).

In situations with a large degree of uncertainty and with limited knowledge, the Delphi technique (using expert elicitation to quantify responses into results) was used (Mukherjee et al. 2015).



Figure 3 Main elements in the MDTARA

## Three stages of the MDTARA

The 3 major stages of the risk assessment were the research synthesis, defining the elements and their relationships, and estimating risk using expert elicitation, risk modelling, and mapping.

### Stage 1 – Research synthesis

In the first stage of the MDTARA, the elements to be considered were defined by reviewing published and unpublished literature, and available data. This included finding and collating data for these elements in New South Wales. Many of the identified elements are key to the MDTARA process shown in Figure 4, an example of the elements and the process of finding risk levels.

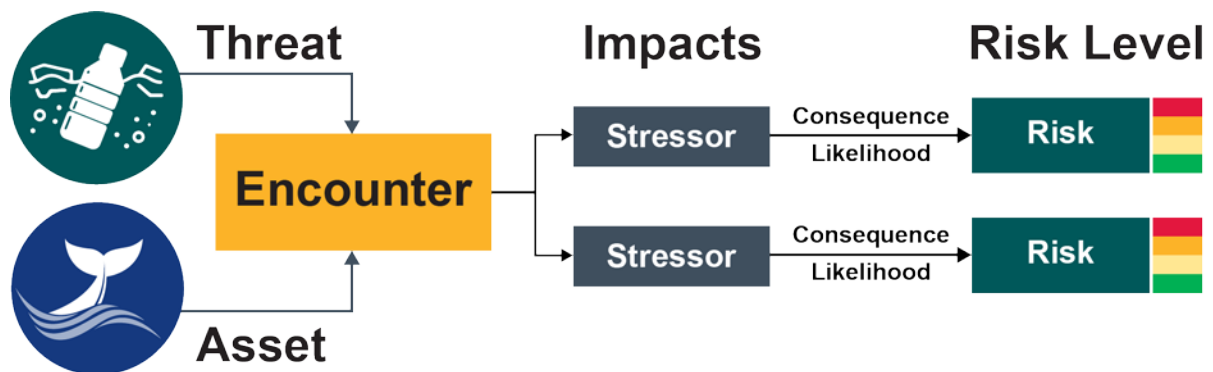


Figure 4 An example of the elements in the MDTARA process

In this part of the MDTARA, a thorough literature review was undertaken to summarise current knowledge about marine debris and its impacts both in New South Wales and further afield. Analysis and review of sources in the literature review process is contained in the literature review summary (DPE 2022a).

### Stage 2 – Defining the relationships between elements in the risk assessment

In Stage 2, risk assessment definitions were made for:

- relationships between elements considered in Stage 1
- marine debris items identified as threats
- fauna groups
- social values.

Collated data, conceptual models, and expert advice from the working group were used to create the definitions. Spatial data relevant to assessment was gathered in this stage.

### Stage 3 – Risk levels from expert elicitation and risk modelling

The final risk assessment was undertaken via expert consultation, risk modelling from responses, and risk mapping. The expert elicitation process estimated risk through consequence and likelihood values given by experts across a variety of debris items (threats) and across impact pathways (stressors).

For fauna groups the main questions addressed in this expert elicitation were:

1. Which debris-related stressors (e.g. entanglement) may affect the group?
2. For each of the debris-related stressors:
  - Which items are most important?
  - What are the consequences of each impact and item combination?
  - What is the likelihood of that consequence occurring in an encounter?

For priority social values, the main questions addressed in this expert elicitation were:

1. Which priority values may be impacted by debris?
2. For each of those:
  - Which debris items are most important?
  - What is the level of concern of people in New South Wales about an impact on each social value and item combination?

### Spatial risk mapping

Spatial risk is a combination of the debris risk level and the exposure of assets to debris. Estimates used best available spatial data for marine debris density, broad environmental ranges for assets (estuarine, coastal, marine) and geographical regions from the NSW TARA (north, central and south).

When adequate debris density data was available for an item, spatial risk levels were mapped for:

- all identified item and asset pairs
- aggregated risk for an item across all assets.

The aggregated values provided spatial distribution of risk, and exposed hotspots of potential impact from debris items. Full and detailed results are provided in the supplementary material report (DPE 2022b) and Gacutan et al. (in review) for finer detail.

### Spatial threat prioritisation

Using the NSW TARA classifications for regional and state priorities, regional risk values were used to prioritise threats and define the scale at which items pose greater risk. For all grid cells with data in a region, the proportion of cells of each risk level was used to calculate a regional risk level. Statewide priorities are defined as items that pose high or moderate risk in all 3 regions. When these high or moderate risk levels occur in only some regions, the item is considered a regional priority where this is the case (MEMA 2017).

## External reporting to supplement the MDTARA

To supplement the stages of the MDTARA, the NSW Department of Planning and Environment contracted consultants to review current management policy and settings around marine debris in New South Wales (Tangaroa Blue Foundation 2021).

## Results

The 3 stages of the MDTARA led to the estimation of risks posed by item types to environmental assets and social values in New South Wales. These risk levels have been used to identify items that are priority threats and locate areas of higher risk in the marine estate. Additional detail of the method used to assign overall risk ratings is included in the supplementary report (DPE 2022b).

### Risk matrices

Overall risk levels across assets, stressors, values and items are aggregated from risk matrices. This used a decision-rule approach consistent with the NSW TARA (MEMA 2015) and appropriate for both environmental and social analyses. The specific rules are:

- all assets and values are considered to be of equal value
- the highest risk assigned to any threat (debris item) is the overall risk level posed by that threat
- the highest risk value posed to any asset or value is the overall risk level for that threat.

### Environmental debris risk

The environmental risk matrix resulting from the expert elicitation identified 17 debris items that pose risk to environmental assets in New South Wales (Table 2). Key findings from the environmental risk matrix include:

- 6 of 7 assets have a high overall risk level from marine debris
- the number of items posing risks to assets varies greatly (1 – plankton to 16 – cetaceans)
- 11 of 17 items posing a risk to environmental assets are at the high level
- 16 debris items are not identified as posing any significant threat to environmental assets.

### Environmental stressor risk

The stressor risk matrix identified 8 stressors that, individually, pose a level of risk to environmental assets (Table 3). Key findings from the environmental stressor matrix include:

- entanglement and ingestion pose the highest risk level and impact the most environmental assets
- bioaccumulation impacts most assets (5) although at a lower risk level than entanglement or ingestion
- the cumulative effect of multiple stressors is an additional consideration when assessing the matrix. Multiple impact pathways can reveal the true risk of harm to assets from any one threat. Using benthic assemblages as an example, although an overall moderate risk level for the asset, 7 of 8 stressors present some level of risk so can equate to a greater risk of impact.

## Social value risk matrix

The social value risk matrix resulting from the expert elicitation described 3 risk levels. These were low, moderate, and high, corresponding to levels of concern of the people in New South Wales (Table 4). The levels of concern relate to both human interactions with debris as well as its impacts on human places. Key findings from the social value risk matrix include:

- 5 of 6 social values have a high overall risk level from debris
- 10 of 16 debris items pose a high level of risk to social values
- the lack of variation in overall risk levels highlights the need for additional analysis to prioritise between the individual items as threats.



**Table 2 Debris risk matrix for environmental assets (green indicates minimal risk level)**

Threats (items)	Benefits/ assets							Overall risk level
	Benthic assemblages	Cetaceans	Fish & sharks	Plankton	Seabirds	Shorebirds	Turtles	
Microplastics	High	Moderate	Low	High	High	Low	High	High
Hard plastic fragments	Moderate	High	Low		High		Moderate	High
Plastic bag		High	Low		Moderate	Low	High	High
Plastic rope (& fragments)	Moderate	High	Low		Low	Low	Low	High
Fishing line		Moderate	Low		High	Moderate	Low	High
Soft plastic remnants	Low	Moderate	Low		Moderate		High	High
Fishing nets		High	High		Low	Moderate		High
Fishing traps & pots		High	Moderate				High	High
Foam packaging (& fragments)	Low	Moderate	Moderate		Moderate		Low	Moderate
Balloons		Low			Moderate		High	High
Drink packaging (plastic)		High						High
Processed timber	High							High
Food packaging (plastic)		Moderate					Low	Moderate
Foam takeaway		Moderate						Moderate
Aquaculture items		Low						Low

Marine Debris Threat and Risk Assessment Summary Report

Benefits/ assets								
Threats (items)	Benthic assemblages	Cetaceans	Fish & sharks	Plankton	Seabirds	Shorebirds	Turtles	Overall risk level
Plastic food/drink lids		Low						Low
Straws		Low						Low
<b>Overall risk level</b>	High	High	High	High	High	Moderate	High	

**Table 3** Stressor risk matrix for environmental assets (green indicates minimal risk level)

Benefits/ assets								
Stressors	Benthic assemblages	Cetaceans	Fish & sharks	Plankton	Seabirds	Shorebirds	Turtles	Overall risk level
Ingestion	Moderate	Moderate	Low	High	Moderate	Moderate	High	High
Entanglement		High	Moderate		Low	Moderate	High	High
Bioaccumulation	Low	Low	Low	Moderate	Low			Moderate
Leachate	Low	Low		Low	Low			Low
Food-web degradation	Low	Low		Moderate				Moderate
Subcellular impacts	Low			Moderate	Low			Moderate
Habitat alteration	Low		Low			Low		Low
Bioinvasion	Low							Low
Smothering								
<b>Overall risk level</b>	Moderate	High	Moderate	High	Moderate	Moderate	High	

**Table 4 Risk matrix for social values (minimal risk level not considered in analysis)**

Threats (items)	Social values						Overall risk level
	Aesthetics	Rights of nature	Human wellbeing	Quality of nature	Reduction of business	Reduction of recreation	
Medical waste (incl. syringes)	High	High	High	High	Moderate	High	High
Sanitary items	High	Moderate	High	High	Low	High	High
Foam & polystyrene	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Balloons	High	Low	High	Moderate	Low	High	High
Microplastics	High	Low	High	High	Low	Moderate	High
Other hard plastic	High	Moderate	Moderate	Low	Moderate	Moderate	High
Fishing line	High	Low	Moderate	Moderate	Low	Moderate	High
Plastic bottle	Moderate	Moderate	Moderate	Low	Low	Moderate	Moderate
Other soft plastics	High	Moderate	Low	Low	Low	Moderate	High
Straws	High	Low	Moderate	Low	Low	Moderate	High
Processed timber	Low	Moderate	Moderate	Low	Low	Moderate	Moderate
Aluminium cans	Low	Moderate	High	Low	Low	Low	High
Glass & ceramics	Low	Low	High	Low	Low	Moderate	High
Cigarette butts	Moderate	Moderate	Low	Low	Low	Low	Moderate
Other metal	Moderate	Moderate	Low	Low	Low	Low	Moderate
Plastic bag	Moderate	Low	Moderate	Low	Low	Low	Moderate
<b>Overall risk level</b>	High	High	High	High	Moderate	High	

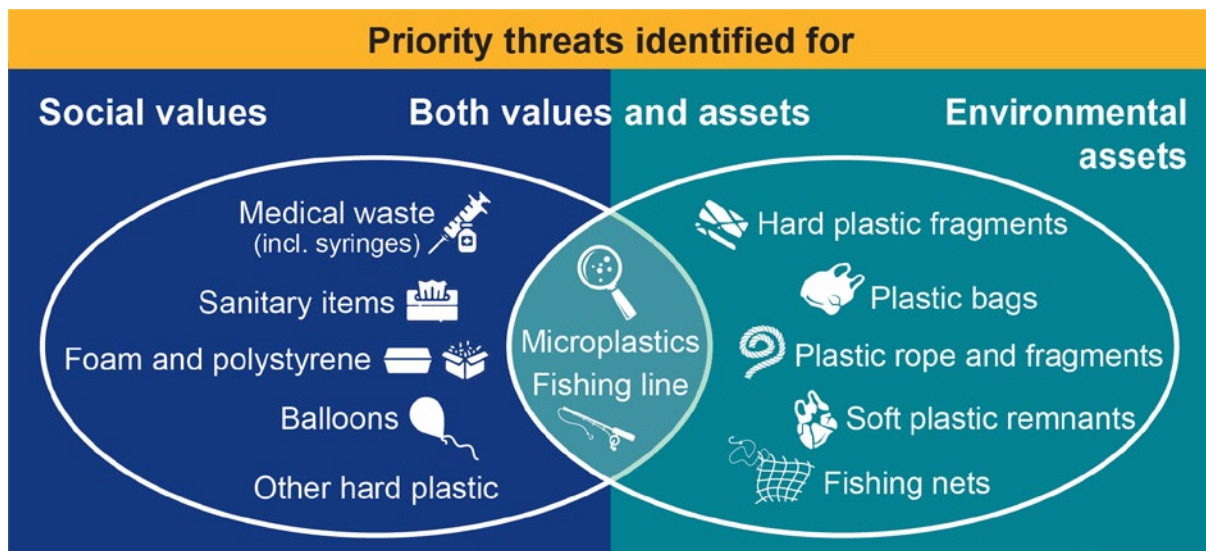
## Priority debris items

Twelve prominent debris items were identified as priority threats to the marine estate. This includes the top 5 items for environmental assets and for social values and 2 items that are a priority for both. The prioritisation process was adapted, for marine debris, from the NSW TARA.

By identifying specific items of concern, the MDTARA is very well placed to recommend management and policy applications, at all scales. This aims to maximise the efficiency of resources and increase the positive impact of risk reduction. The priority items are depicted in Figure 5.

**Key findings** from the priority item analysis from the environmental asset analysis (E), the social value analysis (S) and from a combination of both (E/S) include:

- microplastics are ranked the highest priority threat to the marine estate, with a significant impact on most assets (E)
- 3 of the top 7 items are fishing related (E)
- syringes and medical waste are ranked as the highest priorities, while not featuring in the environmental analysis (S)
- microplastics and fishing line are high priorities in both analyses (E/S).



**Figure 5 Priority marine debris items posing the greatest threats to the marine estate**

The prioritisation of debris items used a scoring system that assigned values for each risk level. A high risk has a value of 3, a moderate risk a value of 2 and a low risk a value of 1. The sum of risk values posed by an item across all environmental assets becomes its priority score, with the largest values presenting the highest risk and subsequently the highest priority. Threats to environmental assets sum all risk values and threats to social values use the high and moderate values only. This was consistent with the statewide TARA but additionally considered low risk levels in the environmental analysis to distinguish between similarly ranked items.

## Peer review of results by working group members

Members of the working group were asked to assess the expert elicitation results. Table 5 summarises these insights which should be considered, with the risk results, in the application of the MDTARA.

**Table 5 Summary of peer review of expert elicitation results for a) fauna groups and b) social values**

a) Fauna groups	TARA Component(s)	Review results
Fish & sharks	Entanglement & items	Support results
Benthic invertebrates	Ingestion & bioaccumulation are major stressors	Support results
	Key items: microplastics and all plastic fragments for ingestion & bioaccumulation (major stressors)	Support results
	Smothering and habitat alteration stressors	Should be added
	Plastic bags key items	Should have MINOR to MODERATE consequences
	Entanglement stressor	Suggested addition with MODERATE consequences
	Entanglement in plastic bags	Possible likelihood
	Entanglement in fishing line and rope items	Possible likelihood and for corals likely
b) Social values	Comments	Discussion
Aesthetics	Value is rated very highly but often very dependent on world views	Need a larger set of responses to derive more information
Medical waste & sanitary items	High risk values due to impact on human health and safety	Departs from expectations given known impacts on marine life rated lower than medical waste by participants
All social values	There have been limited studies of social values in NSW and even fewer regarding perceptions of marine debris	The MDTARA uses expert knowledge as a proxy for community perceptions as the best available knowledge source. A more rigorous process is required in future whereby communities are engaged directly

## Spatial risk mapping

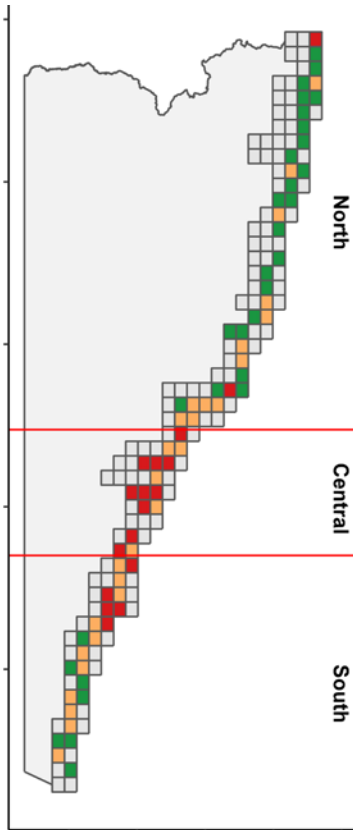
Spatial risk was assessed for all fauna groups and the following debris items: balloons, fishing line, fishing traps and pots, foam packaging, plastic food packaging, hard plastic remnants, plastic bags, and soft plastic fragments.

This produced 60 maps of spatial risk from stressor/asset/threat combinations and 11 maps of aggregated spatial risk levels for the debris items able to be mapped. Figure 6 a) to k) demonstrates how the aggregated risk values expose hotspots of potential impact from debris items. Clear hotspots are observed for food packaging, and traps and pots, while balloons and plastic bags have areas dominated by moderate to high risk levels in the central and south regions. The comprehensive map series is included in the MDTARA supplementary material report (DPE 2022b).

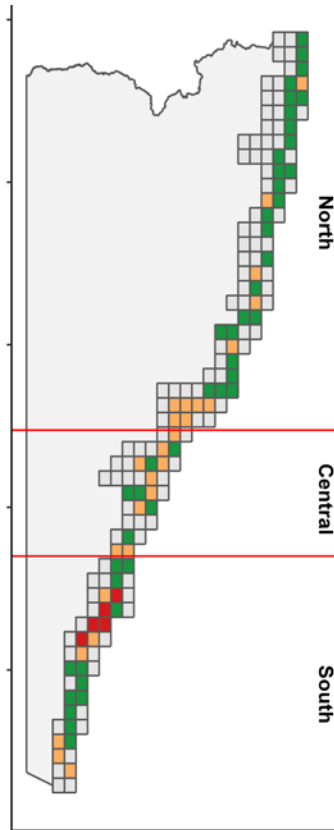
Marine Debris Threat and Risk Assessment Summary Report



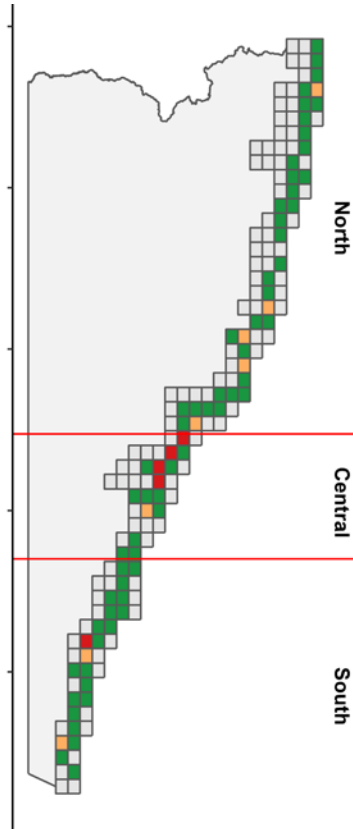
a) Balloons



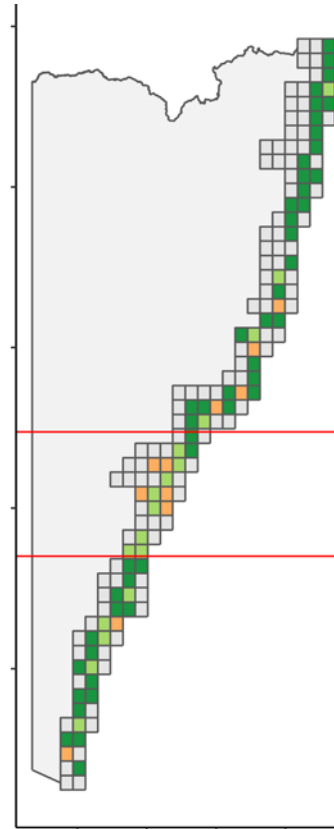
b) Fishing line



c) Fishing traps & pots



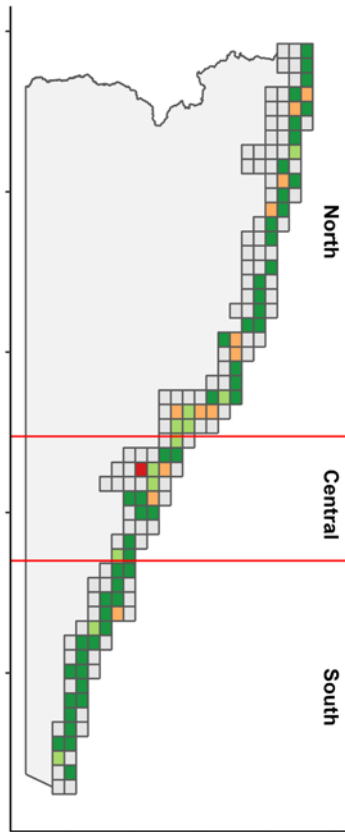
d) Foam packaging & fragments



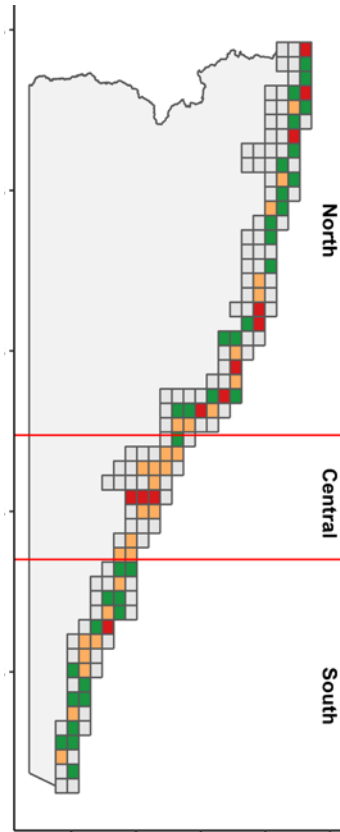
Marine Debris Threat and Risk Assessment Summary Report



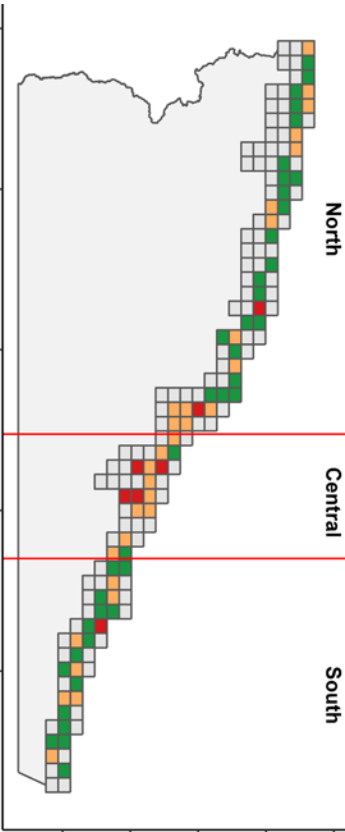
e) Food packaging



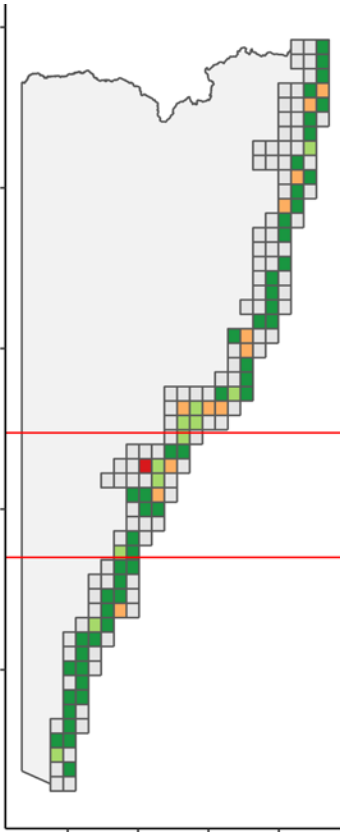
f) Hard plastic fragments



g) Plastic bags



h) Plastic drink packaging



Marine Debris Threat and Risk Assessment Summary Report

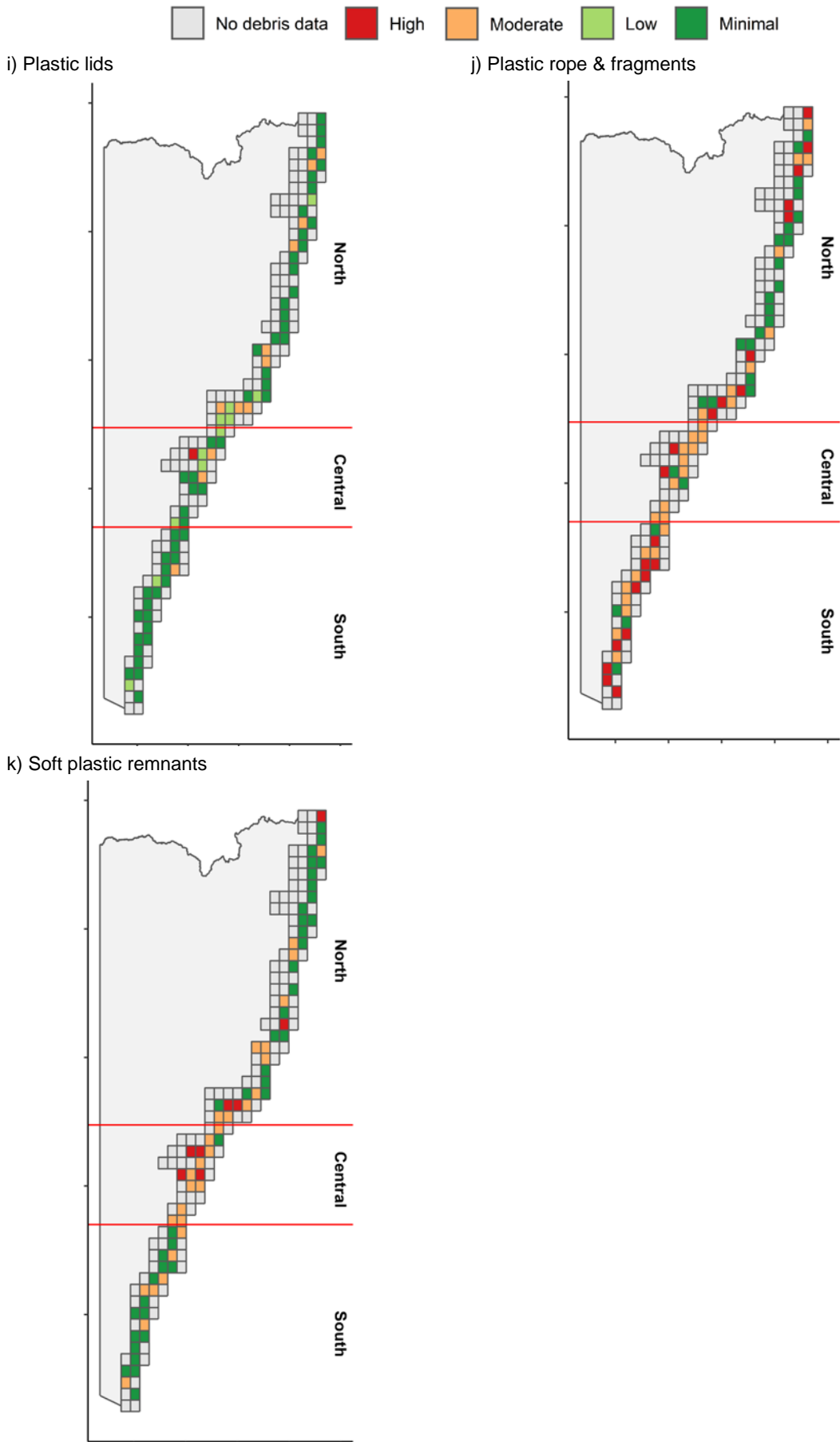


Figure 6 Spatial risk posed by debris items, aggregated across environmental assets



## Spatial threat prioritisation

Using the spatial risk maps, 6 statewide and 2 regional priority items were identified. As shown in Table 3, balloons, fishing line, hard and soft plastic fragments, plastics bags as well as plastic rope (and pieces) are geographically statewide priorities. Fishing pots & traps and foam packaging are regional priorities in various areas. Plastic food/drink packaging and lids do not pose a moderate or high exposure risk across any region to be considered a regional risk.

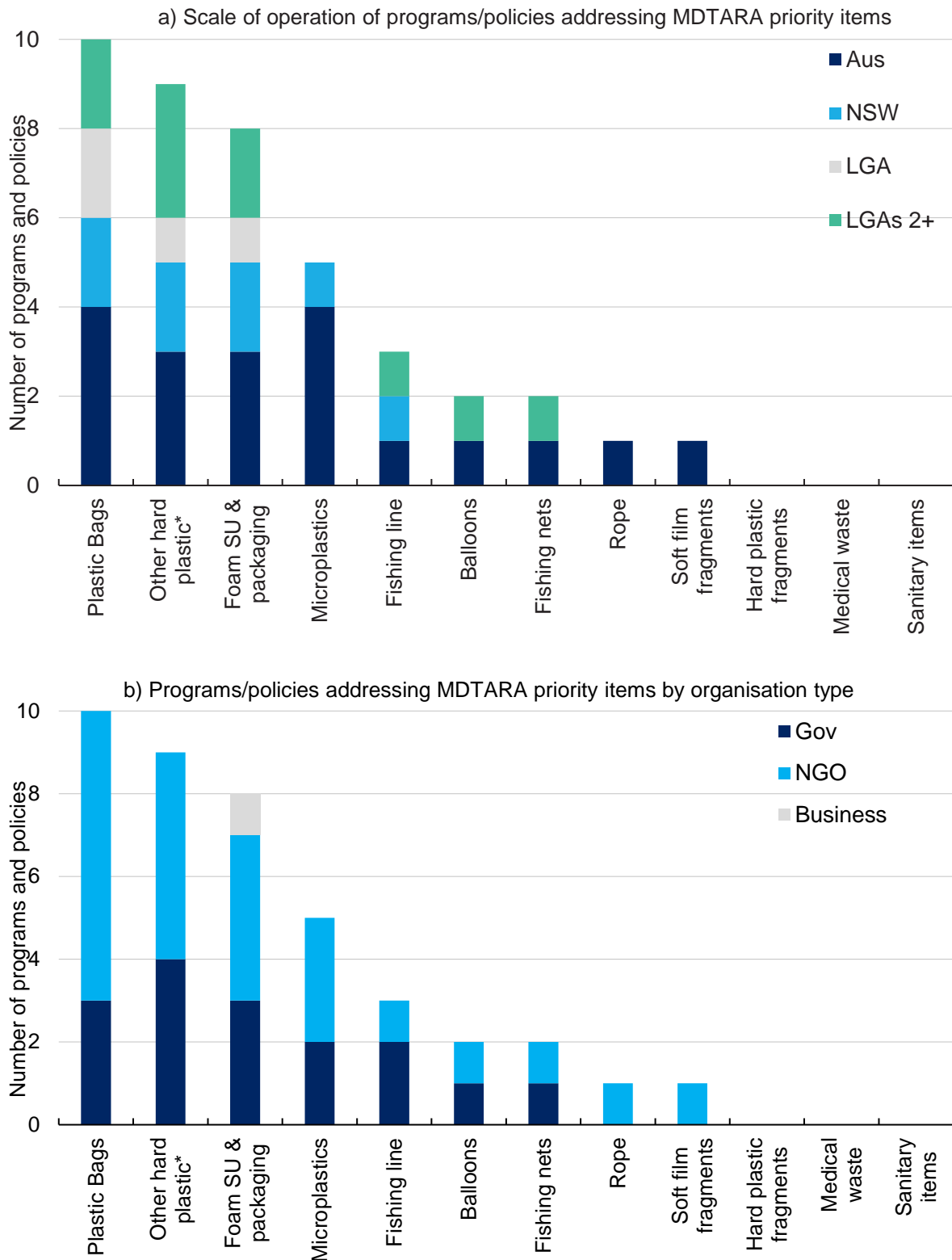
**Table 6 Statewide and regional-scale priority threats for mapped debris items**

Threats (items)	Spatial risk by region			Priority
	North	Central	South	
Balloons	Moderate	High	High	State
Fishing line	Moderate	Moderate	High	State
Fishing traps & pots		High		Regional
Foam packaging		Moderate	Low	Regional
Food packaging (plastic)	Low	Low		
Hard plastic fragments	High	Moderate	Moderate	State
Plastic bag	Moderate	High	<b>Moderate</b>	State
Drink packaging (plastic)	Low	Low		
Plastic food/drink lids	Low	Low		
Plastic rope (& fragments)	High	Moderate	High	State
Soft plastic remnants	Moderate	High	Moderate	State

## External report summary: current management settings in New South Wales

The review of current management policy and settings around marine debris in New South Wales (Tangaroa Blue Foundation 2021) summarised current programs and their characteristics. Of the programs identified, 45 were operating exclusively within New South Wales (84 in Australia). There was a variety in type of organisation, foci and how they act to reduce debris impact. Significantly, the report highlighted the analysis of the efficacy of programs in addressing risks posed by debris is important in future research and management.

Characteristics of the current programs that consider MDTARA priority items are summarised in Figure 7 a) and b). Plastic bags are addressed in the most programs, mostly in Australia wide programs and predominantly run by non-government organisations (NGOs). Some priority items are not covered well, if at all, notably those items that are, or include, fragments (hard plastic, soft plastic and rope and fragments). This highlights an area for consideration in future risk reduction.



**Figure 7 Scale and number of programs and policies addressing MDTARA priority items**

a) Their scale of operation and b) the type of organisation responsible for them. \*The 'other hard plastic' priority item from the social analysis includes a combination of numerous individual items considered in the environmental analysis so is covered by a multitude of current programs that are divided between other priority items.

## Key limitations

A multitude of interactions between debris and the environment, people and places of New South Wales is evident. Despite this evidence, the quantification of these impacts in New South Wales, and elsewhere, is limited. Even with this incomplete equation, and in spite of the significant uncertainties, the need for management of debris, and the significant risks that it poses, is evident.

Key limitations that impacted the MDTARA are described below.

The **statewide scale of the analysis** required the amalgamation of species to be grouped by fauna type. Similarly, some specific items were grouped together. As such, the resolution of the results that can be used in decision-making are coarse.

The **resolution of the spatial risk mapped** in the MDTARA is limited by the resolution of the statewide animal distribution and debris density data. New or higher resolution data may improve these limitations as they become available in future.

The **engagement of experts** is a key component of the MDTARA and can limit the assessment if too few experts are involved in the elicitation process. In this assessment, that was the case for the pinniped and ray fauna groups therefore the analysis of risk levels for these was not possible.

The **uncertainties and knowledge gaps regarding the debris–fauna impacts** identified in the literature review are acknowledged. For the purposes of the risk assessment, and subsequent management applications, they have been remediated using expert elicitation. This is a recognised technique used in situations where primary data is lacking or inaccessible (Mukherjee et al. 2015).

**The need for risk assessment to inform management exists in the absence of empirical data**, so expert elicitation was used in the MDTARA to estimate risk levels to highlight future areas for research, identify priority threats and threatened areas and reduce ongoing uncertainty.

The assessment of current marine debris programs and initiatives summarises the current situation in and around New South Wales but it identified it was important to assess how they 'enable and advance marine debris management' (Tangaroa Blue Foundation 2021). **An evaluation of the current effectiveness of current programs in reducing the risks posed by marine debris** will be beneficial in New South Wales.

As the scope of the MDTARA has a focus on debris items and the risk levels they pose, it narrows its direct application to risk reduction strategies that are focused on items. To increase the effectiveness of applying the MDTARA, **more knowledge about the sources, transport pathways and accumulation patterns of priority items should be explored**.

## Key recommendations

A primary objective of the MDTARA was to determine risk levels posed by various threats (debris items) by gathering existing information, using the best of this available information and applying this knowledge to understand the threats. As a result of this understanding, a wide variety of stakeholders will have a better ability to assess and manage threats. The key recommendations from the MDTARA are:

- stakeholder engagement and communication
- considerations for strategic research and management planning
- the application of the MDTARA findings to the ongoing NSW Litter Prevention Strategy and other marine debris management strategies and programs.

## Stakeholder engagement and communication

A clear plan for the communication of the MDTARA and its outcomes to stakeholders is a key recommendation. Successful knowledge-sharing with a variety of stakeholders will enable the risks posed by marine debris to be better addressed at all scales, local to statewide. Future research and assessment should continue to be shared to improve outcomes and continue to minimise uncertainty.

Sharing the knowledge from the MDTARA widely will enable stakeholders to align the information with existing policies and strategies for maximum benefit.

## Strategic research and management planning

A key recommendation of the MDTARA is to consider 4 primary factors when developing any subsequent strategic research and management plans. The factors, aligning strongly with MDTARA outcomes, are:

- 1 risk levels and priority marine debris items
- 2 spatial distribution of risk in New South Wales
- 3 knowledge gaps
- 4 management strategies for debris items.

These factors will inform measures that reduce the risks posed by marine debris in an efficient and cost-effective way, to achieve outcomes, as highlighted in the underpinning principles for managing the marine estate (MEMA 2013). In addition they will continue to reduce uncertainty in areas where knowledge is limited.

### Factor 1: Risk levels and priority Items

Priority items and those that pose high risk across a wide spatial range are a primary factor to consider in the application of the MDTARA. It is important to prioritise research and management actions that are relevant to these highest risks to focus knowledge gathering, efficient and effective management, and remediation.

In addition, the impact pathways by which items impact different fauna groups should be considered. A focus on these pathways can maximise the benefits of any strategic management. Entanglement and ingestion stressors pose the highest risks and also impact the most assets. Considering management that addresses items across multiple impact pathways can increase the benefits of strategic management.

Both priority items and priority impact pathways can direct attention to research and management options with multiple benefits. The added context serves to maximise their impact in reducing risk.

The definition of priority and high risk level threats in the MDTARA needs to be complemented with knowledge-gathering and research into the specific items. Factors such as source, transport pathways and current or potential management strategies are significant considerations in strategic planning.

### Factor 2: Spatial distribution of risk

The prioritisation of mapped areas of highest risk in New South Wales can help to maximise the benefits of research and management in the same way as defining priority threat items. 'Hotspot' areas and regional priority threats can be preferentially targeted for research and management to increase the efficacy and efficiency of risk reduction.

However, the absence of data for spatial risk mapping in the MDTARA is a key knowledge gap, a significant example being microplastics.

By considering the risk maps in strategic planning we could assess mapped risk for fauna groups against current evidence. We also may be able to infer the location of debris incidents with fauna. By investigating the significance of relationships between the risk and the incidents we can assess the use of the maps as surrogates or indicators to direct management. The NSW National Parks and Wildlife Services (NPWS) Elements Marine Wildlife Dashboard (NPWS 2021) includes documented seabird incidents with debris and is a significant dataset to consider for this application.

### **Factor 3: Knowledge gaps**

Although using the best available information is an underpinning principle for managing the marine estate (MEMA 2013), in all 3 stages of the MDTARA, relevant data did not exist, was not available or was not accessible. With careful consideration of the status of information and the scope of the assessment, some knowledge gaps persist. These should be significant considerations in strategic research and management planning to add value to future management actions. Detailed assessment of these knowledge gaps is included in the supplementary material associated with this report (DPE 2022b: Section 4).

#### **3.1 Source, transport and sink distribution for priority items**

The MDTARA has identified both items posing significant risk to the marine estate and areas at the highest risk of impacts from marine debris. To apply these results to decisions on management actions, additional information is needed to establish the debris source, pathways of transport and other sinks (areas of deposition) for debris, particularly for priority items. The knowledge gained will be instrumental in planning management strategies at all scales (local to statewide) to reduce risk in New South Wales.

#### **3.2 Indigenous cultural values**

Current knowledge regarding the impacts of marine debris on Indigenous cultural values and stewardship of Sea Country is limited, and refers to pollution more broadly (National Oceans Office 2002). To engage in a TARA process for Indigenous cultural values in New South Wales, we require knowledge about the impacts debris has on these values and options for culturally appropriate management. 'Indigenous knowledge is so important to fixing some of the issues that we see in in modern Australia ... in their relationship with Country, Indigenous people are best placed to give advice because having that value of Country and water and the knowledge that comes with that – and the laws that protect that – is key to the way we fix the problem' (Woodward et al. 2020). We need to consider direct engagement, increasing the contribution of Indigenous knowledge to research and to make sure the research creates positive outcomes for Indigenous Australians.

#### **3.3 Social values directly related to marine debris**

The MDTARA social analysis was enabled using priority values extracted from Turnbull et al. (2021). This research was directed across all elements of environmental stewardship pertaining to the Great Southern Reef in Australia without a marine debris focus. Research that specifically targets the impacts of marine debris on social values would be of great benefit for New South Wales. Also, given the nature of social values, spatial distribution is not always an appropriate measure to assess impacts and possible risk management. Further research into how specific locations and social settings are related to our social values will enable more informed spatial assessment.

### 3.4 Sources of fishing-related items

Fishing-related items pose threats that are consistent regardless of their source or how they are functioning when they have an impact. The impact is no different but it requires different consideration in management planning i.e. when engaging with stakeholders or deciding on risk management strategies. Further knowledge needs to be gained about appropriate and effective actions to reduce risks. An example is when an encounter occurs between a fauna group, for example seabirds, and a fishing-related item, for example fishing line. We can't establish whether an impact is due to active fishing or from debris (lost/discarded items), but this does not diminish the impact.

### 3.5 Fauna groups

The expert elicitation stage of the MDTARA did not obtain enough responses for analysis for the pinniped and ray fauna groups. As such, a risk level was unable to be estimated and they don't appear in the environmental risk matrix.

#### *Pinnipeds*

The literature review in MDTARA Stage 1 revealed significant impacts of debris items on pinnipeds both in Australia as well as overseas, with no direct reference to New South Wales. With entanglement being the predominant stressor, many of the MDTARA priority items are identified in the literature. These include rope, fishing line, nets and microplastics.

The NPWS Elements Marine Wildlife Dashboard (NPWS 2021) has multiple records of wildlife incidents with marine debris. A preliminary assessment of pinniped-related incidents in the database (2014–21) showed 10% of all debris encounters are entangled pinnipeds and 50% of those entanglements are due to fishing-related items. However, it is important to acknowledge this is a preliminary assessment and further consideration is needed regarding the data quality and conclusions drawn. That said, it suggests pinnipeds are susceptible to entanglement in the marine estate, and without being able to quantify risk, it must be conservatively assessed as high in the absence of more information. Guided by an underpinning principle for the marine estate, in areas of uncertainty and information gaps the precautionary principle should be applied (MEMA 2013).

#### *Rays*

As a risk level was unable to be estimated for rays from the MDTARA, given a lack of responses from experts, rays were not included in the environmental risk matrix. The risks from debris should be considered in future work, although in the interim, the precautionary principle should be applied (MEMA 2013) and risk should be conservatively assessed as high.

### 3.6 Spatial data

Currently the spatial extent of micro debris and microplastic data in New South Wales is not well distributed and is variable between items of interest. Elements with inadequate data present a gap in knowledge that prevents the equitable assessment of threats in strategic planning. Notably, despite a growing number of monitoring and sampling programs, micro debris data, both density and type, is not comprehensive enough to map for the marine estate. Given its prioritisation in both the environmental and social analyses this is a critical knowledge gap to address.

Given that social values have been considered equally distributed across space in the absence of further research (Section 3.3), the distribution of priority threats to social values has not been specifically considered. To enable the equitable consideration of all threats, these gaps in understanding need to be included in strategic planning.

## Factor 4: Risk management strategies

Strategic planning for marine debris risk reduction needs to consider multiple aspects of management and remediation options. Some of these include:

- existing options active in New South Wales
- existing options outside New South Wales
- efficacy of existing options (looking at items reduced, currency, focus, scale, monitoring etc)
- preference for options that reduce risk in multiple ways (source reduction, infrastructure, product design etc).

We recognise that a deeper understanding of the efficacy and sustainability of these programs in managing marine debris is necessary to make any additional assumptions about their impact on risk. We also acknowledge some actions target multiple items, and specific information regarding a program's ability to impact a specific item must be inferred from the broader focus. These factors should be considered in strategic research and management planning to build on the MDTARA outcome.

## Future application in NSW litter prevention and marine debris management strategies and programs

Future development of the NSW Government's Litter Prevention Strategy (NSW Government 2019) should integrate these findings to ensure identified risks are appropriately considered and managed, based on the factors identified above. Similarly, future program responses and funding opportunities supported by the strategy should consider opportunities to support local and regional litter management responses that address these identified risks.

## Conclusion

The MDTARA has analysed the threats and risk levels associated with marine debris in New South Wales and has provided tools and knowledge to enable better risk management in future. This will enable stakeholders and managers, at all scales, to use the best available information when reducing the risks posed by marine debris. Overall this will lead to stakeholders making better, more informed judgements with increased transparency.

In reflecting the key recommendations, desirable next steps principally include:

- developing a communication strategy for the MDTARA
- devising and executing a strategic management plan considering priority and high-risk items, knowledge gaps and existing management
- identifying and connecting with stakeholders and assessing areas for collaboration
- collaborating with other NSW government agencies to apply the MDTARA to programs and strategies, particularly the NSW Litter Prevention Strategy.

## **Acknowledgments**

We would like to acknowledge the working group, convened as an initiative under the MEMS, for oversight and input into the MDTARA; Dr Graeme Clark, Jordan Gacutan and John Turnbull from the Evolution & Ecology Research Centre at UNSW for devising the MDTARA methodology and making significant contributions to its execution and continued support; and, in addition, John Turnbull for experienced facilitation of the expert elicitation consensus meetings.

The NSW Government is acknowledged as the funding body for this work under the Marine Estate Management Strategy water quality initiative 1A.



## References

- Clark GF (2019), *Methodology report for marine debris threat and risk assessment for NSW*, report prepared for NSW Department of Planning, Industry and Environment.
- Jambeck J, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Narayan R and Law KLL (2015), 'Marine pollution. Plastic waste inputs from land into the ocean', *Science* 347(6223): 768–771, doi: 10.1126/science.1260352.
- Gacutan J, Foulsham E, Turnbull JW, Smith SDA and Clark GF (in review), 'Mapping marine debris risk using expert elicitation, empirical data, and spatial modelling', *Environmental Science and Policy*.
- MEMA (2017), *New South Wales Marine Estate Threat and Risk Assessment Report: Final Report*, WBM BMT for the NSW Marine Estate Management Authority.
- MEMA (2015), *Threat and Risk Assessment Framework for the NSW Marine Estate*, NSW Marine Estate Management Authority
- MEMA (2013), *Managing the NSW Marine Estate: Purpose, Underpinning Principles and Priority Setting*, NSW Marine Estate Management Authority.
- Mukherjee N, Hugé J, Sutherland WJ, McNeill J, Van Opstal M, Dahdouh-Guebas F and Koedam N (2015), 'The Delphi technique in ecology and biological conservation: applications and guidelines', *Methods in Ecology and Evolution* 6: 1097–1109, doi: 10.1111/2041-210X.12387.
- National Oceans Office (2002), *Sea Country – an Indigenous perspective, Assessment Report, The South-east Regional Marine Plan*, Commonwealth of Australia.
- NPWS (2021), *Elements Marine Wildlife Dashboard*, NSW National Parks and Wildlife Services, <https://npws-elements.nogginoca.com>, accessed 9/7/2021.
- DPE (2022a), *Marine Debris Threat and Risk Assessment Literature Review Summary*, NSW Department of Planning and Environment.
- DPE (2022b), *Marine Debris Threat and Risk Assessment Supplementary Material Report*, NSW Department of Planning and Environment.
- DPIE (2019), *NSW Marine Debris Threat and Risk Assessment (Stage 3) expert elicitation background documents*, NSW Department of Planning, Industry and Environment.
- NSW Government (2019), *NSW Litter Prevention Strategy 2019–2022*.
- Smith SDA & Edgar RJ (2018), *Review of information on marine debris in NSW*, review prepared for the NSW Environment Protection Authority.
- Tangaroa Blue Foundation (2021), *Review of programs and initiatives in managing litter and marine debris within NSW*, review prepared for NSW Department of Planning, Industry and Environment.
- Turnbull J, Clark G and Johnston E (2021), 'Conceptualising sustainability through environmental stewardship and virtuous cycles – a new empirically-grounded model', *Sustainability Science* 16:1475–1487, <https://doi.org/10.1007/s11625-021-00981-4>.
- US Dept Commerce (1999), *Turning to the Sea: America's Ocean Future*, US Department of Commerce and US Navy, Washington DC.
- Woodward E, Hill R, Harkness P and Archer R (eds.) (2020), *Our Knowledge Our Way in caring for Country: Indigenous-led approaches to strengthening and sharing our knowledge for land and sea management*, Best Practice Guidelines from Australian Experiences, NAILSMA and CSIRO, Cairns, Australia.