NSW GOVERNMENT

Department of Planning and Environment

Marine Debris Threat and Risk Assessment Supplementary Material Report

Additional information and resources to supplement the NSW Marine Debris Threat and Risk Assessment (MDTARA) Summary Report

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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, Energy and Science enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
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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)

The MDTARA is a study of the risks posed by marine debris to the marine estate in New South Wales. The assessment is documented in the MDTARA Summary Report (DPE 2022b) to which this document is a supplement.

The statewide threat and risk assessment of the NSW Marine Estate (NSW TARA) identified marine debris as posing a significant threat to its environmental, social and economic values of the NSW marine estate. When assessing these threats, the Marine Estate Management Strategy (MEMS) prioritised the risks posed by marine debris to the NSW marine estate. The MDTARA is the next step towards addressing this significant threat.

1. MDTARA objectives

The major objectives of the MDTARA are to:

- review existing and emerging knowledge regarding marine debris and its impacts on environmental assets and socio-economic values, particularly in New South Wales
- examine the risk posed by marine debris items to the marine estate
- identify priority threats (debris items) that pose the greatest risks to environmental assets (fauna groups) and social values in New South Wales.

2. Background literature

The first of the 3 stages in the MDTARA involved a literature review. Subsequently, relevant entries were included in background documents for experts within an elicitation process (DPIE 2019), and supplementary references, provided by these experts, were added to the overall review. A summary of the key findings from the literature can be found in the MDTARA literature review analysis and summary document (DPE 2022a). It also includes an assessment of the types of information available as well as areas of deficit that are lacking substantial knowledge and data that was undertaken by the University of New South Wales (UNSW) for the MDTARA.

3. Defining priority social values in New South Wales

In a study investigating the perceptions and values of coastal users along Australia's Great Southern Reef (Turnbull et al. 2021), respondents were asked, unprompted, about the social and ecological values of their site. These refer to values targeting benefit to humans (social), and those about conserving and valuing nature (ecological). Focusing on the responses from NSW users and on values that can be impacted by the presence of marine debris, 6 priority social values were identified for the marine estate: aesthetics, recreation, health and wellbeing, environment and biodiversity, the intrinsic value of nature, and economics and business.

The impacts that marine debris can have on social values are expressed differently to those in an environmental analysis. In the MDTARA social analysis the consequences of impacts are defined with respect to the level of concern they would incite in the people of New South Wales, and how this would subsequently lead to management action. Full definitions of levels of concern in the MDTARA are in Section 9 of this report.

4. Knowledge gaps

Through all 3 stages of the MDTARA it was evident that some information was not available or not accessible. With careful consideration of the status of information, and the scope of the assessment, some significant knowledge gaps persist (outlined below). These should continue to be considered in the application and extension of the MDTARA findings.

4.1 Indigenous cultural value

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 Ocean Office 2002). To gain insight about the impacts of marine debris on cultural values directly from Indigenous knowledge-holders, best practice methods of engagement and knowledge sharing in Australia are Indigenous-led (Woodward et al. 2020). Cultural values and stewardship of Sea Country should be considered respectfully and potentially 'through informed, direct engagement' (Hedge et al. 2020).

Future work applying the MDTARA method to Indigenous cultural values should be driven by Indigenous communities and consider ethical research standards to 'increase the contribution of Indigenous knowledge to Australian research, to ensure research has a positive impact for Aboriginal and Torres Strait Islander peoples, and to continuously improve the quality and standards of research in this area' (AIATSIS 2020). 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. Direct engagement should be considered, increasing the contribution of Indigenous knowledge to research and to make sure the research creates positive outcomes for Indigenous Australians.

In summary, using the MDTARA as a tool to assess threats to Indigenous cultural values will require an inclusive co-designed process, led by community or communities, to garner information leading to genuine outcomes for all.

4.2 Fauna groups

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

4.2.1 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 including rope, fishing line and nets. The ingestion of microplastics by pinnipeds was also noted.

The NSW National Parks and Wildlife Service (NPWS) Elements database records wildlife incidents and encounters across NSW lands, coasts and seas. A preliminary assessment of pinniped-related incidents in the database (2012–21) revealed 10% of all debris encounters are pinnipeds. Also:

- 100% of the pinniped incidents reported are entanglements
- 80% of those entanglements were estimated to cause a significant impact
- 50% of all pinniped entanglements involved fishing-related items
- 43% were from plastic rope
- reported entanglement was predominantly around the neck of the animals, which is known to pose significant risk and can lead to suffocation, starvation and death (Franco Trecu et al. 2017).

It is important to acknowledge this is a preliminary assessment and needs further consideration of data quality and the process of analysis. That said, this suggests pinnipeds are susceptible to entanglement in the marine estate. Without being able to quantify risk, it must be conservatively assessed as high in the absence of more information, i.e. applying the precautionary principle in situations of uncertainty and information gaps (MEMA 2013). Initiatives such as lost fishing gear recovery and effective fishing line disposal options will serve to remove or reduce the debris and has been proven to have an impact by reducing the incidents of entanglement in some cases (Kalpan Dau et al. 2009).

4.2.2 Rays

A risk level was unable to be estimated for rays from the MDTARA due to insufficient expert responses in the engagement process, so rays are not included in the environmental risk matrix. The risks from debris should be considered in future work, although in the interim, risk should be conservatively assessed as high, again applying the precautionary principle in the presence of knowledge gaps (MEMA 2013).

4.3 Marine debris spatial data

Currently, in New South Wales, the spatial coverage of macrodebris and microdebris data is unevenly distributed. Marine debris items that were unable to be mapped due to insufficient or incompatible spatial data are: aluminium cans; aquaculture items; cigarette butts; drink cartons; foil wrappers, packets and alfoil; glass and ceramic scrap; glass bottles; hard plastic containers; medical waste (including syringes); metal lids and bottle tops; microplastic (< 5 mm); paper packaging; paper stubs (tickets, receipts etc); plastic food and beverage lids; plastic takeaway utensils; processed timber; rubber footwear; sanitary items; straws and synthetic cardboard.

5. Detailed methods

5.1 Three-stage method

The method for the MDTARA was developed by UNSW for the Department of Planning, Industry and Environment (now the Department of Planning and Environment) in 2019 (Clarke 2019). It has 3 major stages essential for risk assessment, summarised in Figure 1.

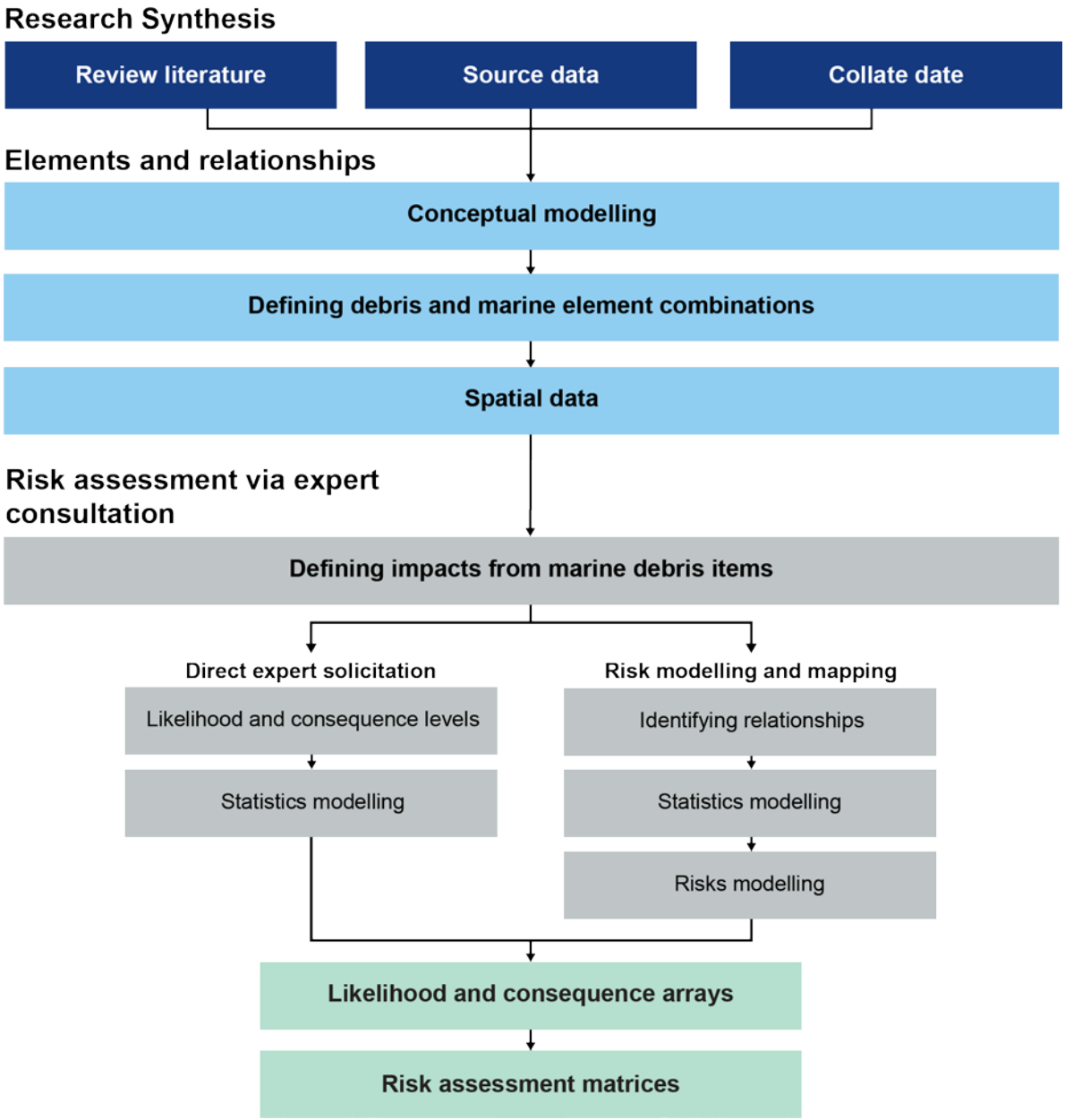


Figure 1 Three stages of the MDTARA method developed by UNSW

5.1.1 Stage 1 – Research synthesis

The research synthesis (literature review) identified stressors and threats related to marine debris on environmental assets and socio-economic values in New South Wales. This included sourcing and collating data relevant to these identified components.

5.1.2 Stage 2 – Relationships between stressors, threats and marine debris

Relationships between MDTARA components were defined using collated data, conceptual models and expert advice from the Marine Debris Working Group (working group). Stage 2 also involved defining the types of marine debris and assets and values to be considered in the risk assessments, and collating and creating spatial data for all MDTARA components.

5.1.3 Stage 3 – Risk assessment matrices based on expert elicitation and risk modelling

Risk assessment matrices were determined through the development of likelihood and consequence arrays for impacts of marine debris on ecological and socio-economic assets. The arrays were devised using an expert elicitation process as well as an indirect one using expert input and risk modelling and mapping. The final risk assessment matrices were populated in consultation with the working group using both sources of information.

5.2 Defining components in the MDTARA

The MDTARA considered the assets and values associated with the marine estate (**fauna groups and social values**) and the marine debris items that can negatively impact them (**threats**). Given an encounter, the ways in which the **threats** can affect the **assets,** and have an impact, are called **stressors**.

Figure 2 provides a graphical representation of the major components used in the MDTARA analysis: common marine debris items in New South Wales (**threats**) coinciding with environmental **assets** or socio-economic **values,** resulting in negative impacts (**stressors**) and posing a level of **risk** that can be used to quantify impacts and prioritise threats.

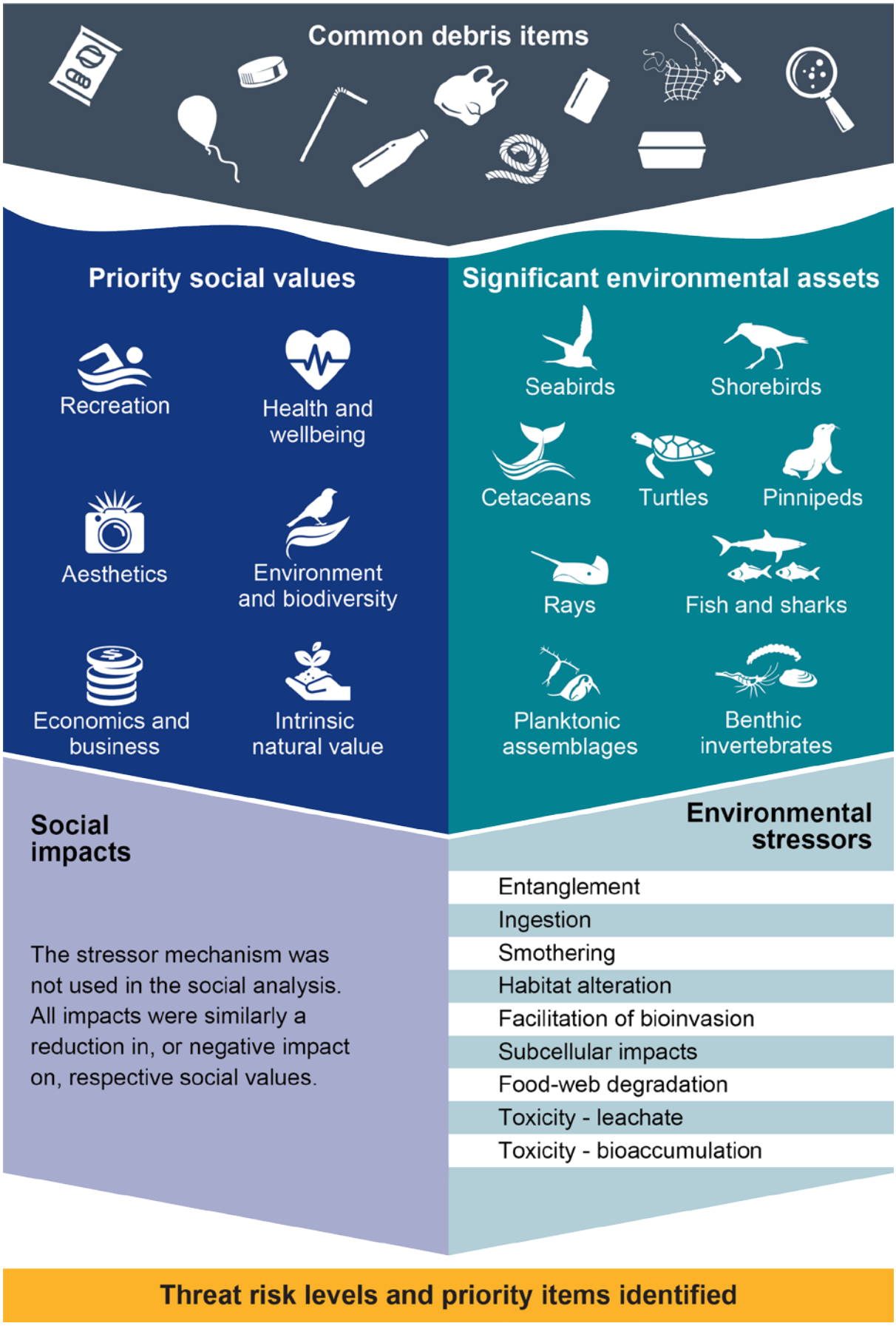


Figure 2 A summary of the primary components included in the MDTARA analysis

5.2.1 Environmental assets (fauna groups) and impact pathways (stressors)

The literature review (DPE 2022a) defined the 'stressors' (e.g. ingestion, entanglement and bioaccumulation) by which debris may impact assets within the marine estate. The review identified the assets known to interact with debris items, and stressors that describe the pathway by which debris may cause impacts. See Section 9 of this report for precise definitions of these stressors.

The working group used the outputs of the literature review (Stage 1) and investigation of the relationships between components (Stage 2) to group organisms into assets according to how they may interact with debris within the marine estate. The group also refined the lists of stressors, merging or disaggregating stressors for relevance. The fauna groups (or environmental assets) included in the MDTARA are identified in Figure 2, which also lists the suite of potential stressors acting upon the assets.

5.2.2 Social values and stressors

Six priority social values were identified from research by Turnbull et al. (2021) investigating the values and perceptions of coastal users. The study asked coastal users, unprompted, about the social and ecological values of their current location. The quantified responses of the NSW users were reduced to priority social values that can be threatened by the presence of marine debris displayed in Figure 2. The concept of stressors or impact pathways was not used in the social analysis. This is because impacts were all, similarly, negative – expressed as a reduction or total loss of these priority social values. The values are further defined in Section 9.

5.2.3 Threats – marine debris items

The complete suite of debris items included in the MDTARA analysis is shown in Table 1.

Table 1 Debris items considered in the environmental and social analyses in the MDTARA

Debris items in analysis		Environmental	Social
Microplastic	Plastic <5 mm	Y	Y
Hard plastic	Fishing line	Y	Y
	Plastic bottles	Y	Y
	Straws	Y	Y
	Fishing nets	Y	Y (other hard plastic item)
	Plastic containers	Y	
	Plastic food & beverage lids	Y	
	Plastic fragments (hard/solid)	Y	
	Plastic rope & fragments	Y	
	Synthetic cardboard	Y	
	Takeaway utensils	Y	
Soft plastic	Plastic bags	Y	Y
	Cigarette butts	Y	Y
	Drink packaging (plastic)	Y	Y (other soft plastic)
	Food packaging (plastic)	Y	
	Plastic film remnants	Y	

Debris items in analysis		Environmental	Social
	Foam packaging & fragments	Y	Y (all foam)
	Foam cups, food packs & trays	Y	
Rubber	Balloons	Y	Y
	Rubber footwear	Y	N
Metal	Aluminium cans	Y	Y
	Metal lids / bottle tops	Y	Y (other metal)
	Foil wrappers, packets & alfoil	Y	
Paper	Drink cartons	Y	N
	Paper packaging	Y	N
	Paper stubs (tickets, receipts etc.)	Y	N
Glass	Glass bottles	Y	Y (All glass & ceramics)
	Glass & ceramic scrap	Y	
Wood	Processed timber	Y	Y
Other	Medical waste (including syringes)	N	Y
	Sanitary items	Y	Y
	Aquaculture items	Y	N
	Fishing traps & pots	Y	N
	Other (specified)	Y	Y

5.2.4 Risk components

In the environmental analysis, risk variables were derived from those in the TARA framework (MEMA 2015) including consequence, likelihood (of the consequence) and the confidence in response. The definitions have been aligned to the focus on marine debris. The consequence variable for social analysis was converted to better reflect the social context. As such, the **level of concern of people in New South Wales** was assessed, which refers to both human interactions with debris as well as the impacts of debris on human places (Creswell 2004). The levels of concern (low, moderate and high) reflect how a situation would prompt management action to reduce the impact of debris items on social values. Both assessments used standard confidence ratings. Table 2 summarises the variable risk components across the analyses. Specific definitions for the terms used are in Section 9.

Table 2 Threat and risk variables used within the MDTARA environmental assessment (*), social assessment (#) or both (*#)

Threat & risk variables in the MDTARA				
Consequence	**Likelihood**	**Confidence**	**Level of risk**	**Level of concern**
Insignificant	Rare	Uncertain	Low	Low
Minor	Unlikely	Inferred	Moderate	Moderate
Moderate	Possible	Limited	High	High
Major	Likely	Adequate	Minimal (env only)	*#Soc*
Catastrophic	Almost certain	*#Env/Soc	*#Env/Soc	
* *Env*	* *Env*			

5.3 Expert elicitation (environmental assets / fauna groups)

A comprehensive summary of the application of the method and the technical details of the expert elicitation process can be found in Gacutan et al. (in press). The main components of the expert engagement are summarised here for context and greater understanding.

5.3.1 Key elicitation questions

The main questions addressed in this expert elicitation were:

1. Which stressors (e.g. entanglement, ingestion, smothering, etc.) may affect this taxonomic group via debris?
2. For each relevant stressor, which debris items are most important?
3. For each stressor and debris item, what are the consequences and likelihoods of a negative interaction should the biota encounter debris?

The 2-part structure of the survey is shown in Figure 3 parts a) and b).

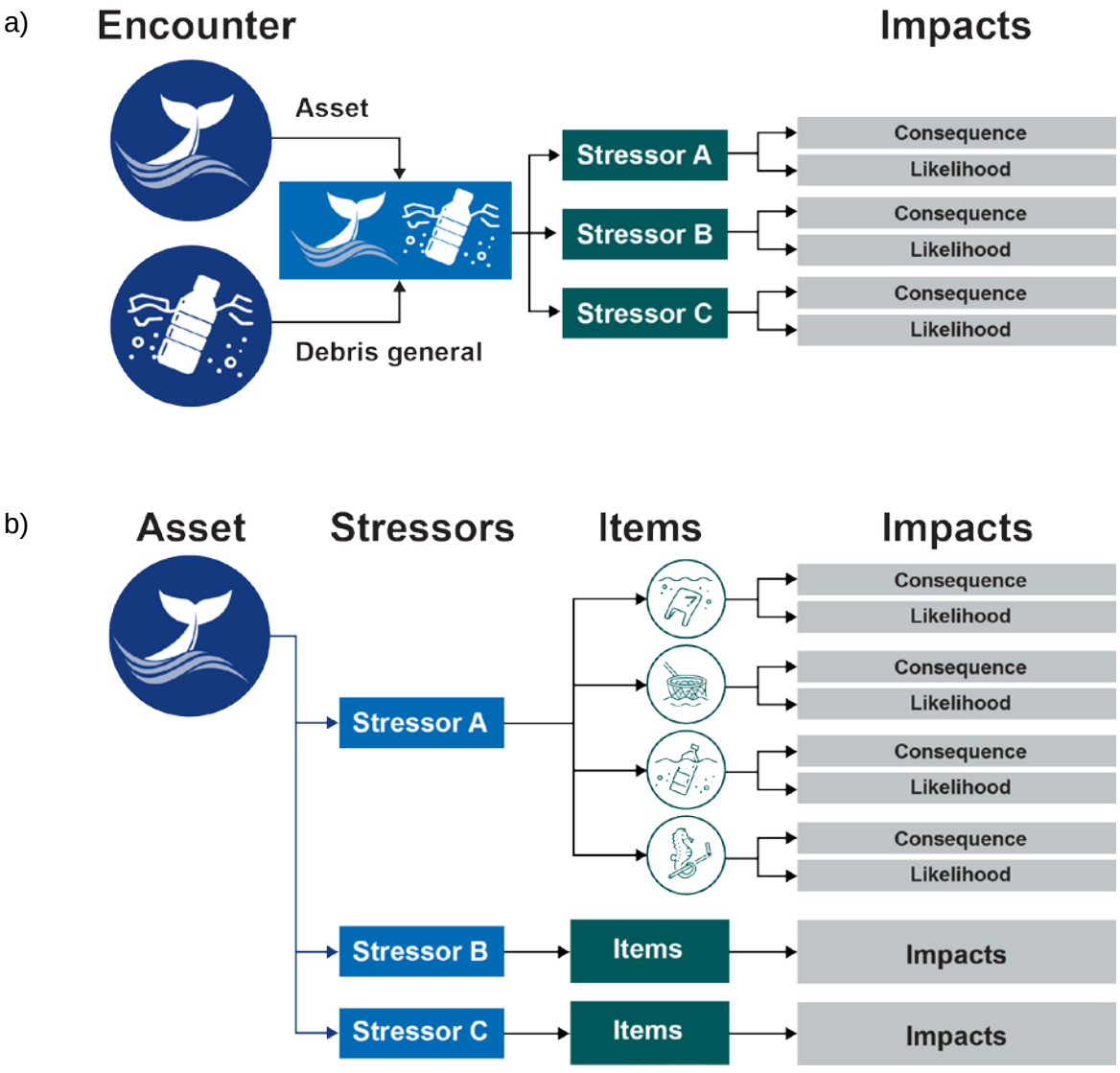


Figure 3 The survey parts within the expert elicitation process for identifying: (top) stressors and impacts from marine debris on environmental assets, and (bottom) risk values from specific debris items on environmental assets

5.3.2 Consequence and likelihood arrays

The primary result of the expert elicitation process for environmental assets is a series of consequence and likelihood arrays that quantify expert responses. The arrays demonstrate the average of the responses given by experts in discrete values for each threat/stressor/asset combination and also depict confidence of experts in their responses.

5.3.3 Risk matrices

The consequence and likelihood values in each array were converted to categories by rounding to the nearest integer and then defined as in Table 3. These metrics were then translated into a risk level using the risk assessment matrix from the NSW TARA, Table 4, where the consequence level and likelihood value for each combination determines the level of risk.

Table 3 Consequence and likelihood levels and equivalent numeric values

Component	Levels	Values
Consequence	Insignificant	1
Consequence	Minor	2
Consequence	Moderate	3
Consequence	Major	4
Consequence	Catastrophic	5
Likelihood	Rare	1
Likelihood	Unlikely	2
Likelihood	Possible	3
Likelihood	Likely	4
Likelihood	Almost certain	5

Table 4 Risk assessment matrix (MEMA 2015)

Likelihood	Level of risk				
Almost certain	Minimal	Low	Moderate	High	High
Likely	Minimal	Low	Moderate	High	High
Possible	Minimal	Minimal	Low	Moderate	High
Unlikely	Minimal	Minimal	Minimal	Low	Moderate
Rare	Minimal	Minimal	Minimal	Minimal	Low
Consequence	Insignificant	Minor	Moderate	Major	Catastrophic

5.4 Expert elicitation (social values)

5.4.1 Key elicitation questions

The main question addressed in this expert elicitation is: for each debris item, what is the level of concern among people in New South Wales, in regard to an impacted priority social value?

The structure of the survey is shown in Figure 4.

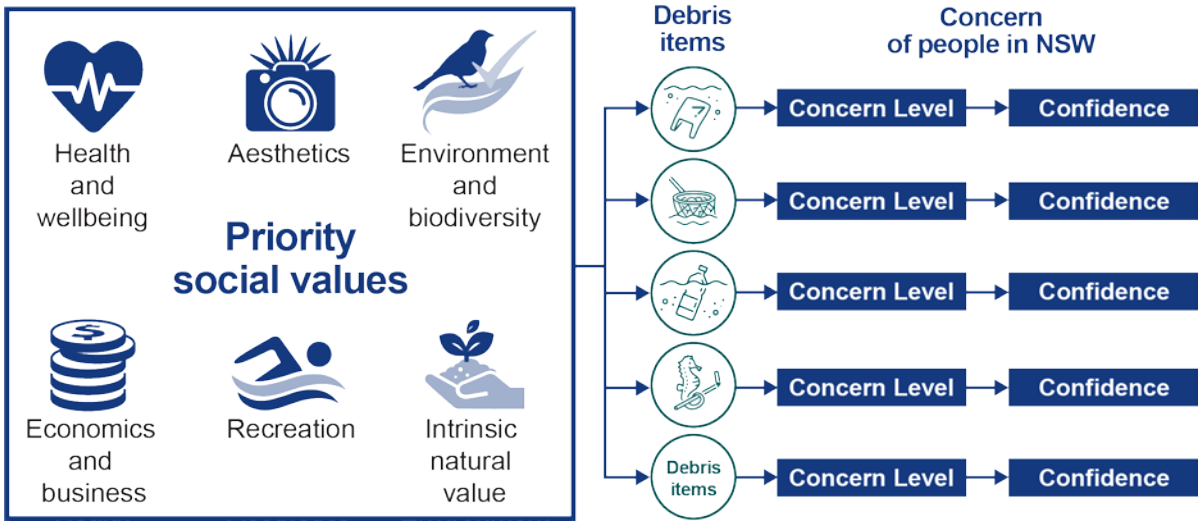


Figure 4 The expert elicitation process for identifying the levels of concern of the people of New South Wales regarding marine debris impacts on social values

5.4.2 Consequence and likelihood arrays

The primary result of the expert elicitation process for social values is a series of modified arrays of the level of concern of people in New South Wales in regard to an impacted priority social value, and depicts confidence of experts in their responses. The arrays demonstrate the average of the responses given by experts for each threat/stressor combination, noting that each social value is directly related to an individual stressor.

5.4.3 Risk levels

The level of concern values in each array are converted to the 3 categories using the classification defined in Table 5. Given that each level of concern directly translates to a risk level, a matrix is not needed.

Table 5 Levels of concern of the people of New South Wales, their equivalent numeric values and corresponding risk level

Level of concern			
	Low	**Moderate**	**High**
Min value	1	1.68	2.34
Max value	1.67	2.33	3
Risk level	**Low**	**Moderate**	**High**

5.5 Aggregation of risk

The risk values produced from the arrays are aggregated into risk matrices and used to define overall risk levels. The MDTARA used a decision-rule approach which is consistent with the NSW TARA and appropriate to the focus on marine debris (MEMA 2015).

The specific rules applied to the MDTARA matrices for both environmental assets and social values 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 value posed by that threat
- the highest risk value posed to any asset (environmental asset or social value) is the overall risk value for that threat.

The decision rules in the MDTARA approach echo the precautionary principle and hence are more conservative than in the statewide TARA. This is in keeping with the current limitations of knowledge of NSW-specific sources, distribution and impacts of marine debris. It also reflects that a ‘low’ level might still warrant management action from the MDTARA, contrary to the statewide TARA in which ‘low’ risk is likely to be acceptable with monitoring, and ‘high’ or ‘moderate’ risk levels are not acceptable and trigger further examination of a threat.

5.6 Prioritisation of debris items from Stage 3 risk levels

The method used to prioritise debris items is the same as that used in the statewide TARA with the additional consideration of the low risk levels. As the statewide analysis focused on the moderate and high risk levels to provoke threat management, the low risk values were not considered. The MDTARA environmental analysis is interested in all risk levels, so low was included in the prioritisation. The social analysis prioritisation did not include a low level of concern as this is defined as not prompting any management action.

The prioritisation of threats used a scoring system that assigns values for each risk level across a debris item. 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 these values across environmental assets for each item becomes its priority score, with the largest values presenting the highest risk and subsequently the highest priority. The sum of the high and moderate risk levels across social values creates the priority score. Items are ranked using these scores. To determine the list of priority items the top 7 ranked items for each of the analyses were combined and consolidated to form the priority list of 12 items.

5.7 Peer-review process

Members of the working group were given the opportunity to provide peer-review feedback on the results of the expert elicitation. The reviewing comments serve as supplementary information to the quantitative results to maintain the integrity of the elicitation process and to ensure its independence.

5.8 Spatial application methods

5.8.1 Collating available debris databases

Four anthropogenic debris databases were identified, with coverage of key debris items across the NSW marine estate:

- the Australian Marine Debris Initiative (AMDI) database (Tangaroa Blue Foundation 2020)

- the Key Littered Items Study (KLIS) (DPIE 2020)
- Sea Shepherd data (Sea Shepherd 2020)
- subtidal data from Smith and Edgar (2014).

Details of each dataset are provided in Table 6. The method of sampling varied between the datasets, where AMDI, Sea Shepherd and KLIS data (coastal and estuarine clean-ups) events were conducted with the aim of the exhaustive removal of all debris greater than 5 mm. The KLIS data was sampled using transects, while AMDI and Sea Shepherd data cleaned an area from the vegetation to the water line. See Smith and Edgar (2014) for methods specific to subtidal debris.

As the KLIS and Sea Shepherd datasets were aligned with the AMDI categories, all databases were harmonised to the categories used within the AMDI database. The AMDI database, which contained the largest amount of spatial and temporal coverage of the NSW marine estate, was filtered for accuracy and reliability using methods described in Gacutan et al. (2022). To maximise coherence between datasets, counts were standardised to the length of the site (or transect), to debris items per metre. To address differences in temporal resolution, average counts were taken across all events for a given site within each database.

Table 6 Description and data sources for anthropogenic debris databases within the NSW marine estate

Data source	Australian Marine Debris Initiative (AMDI)	Key Littered Items Study (KLIS)	Subtidal data	Sea Shepherd data
Author	Tangaroa Blue Foundation	NSW Government	Smith SDA., Edgar RJ	Sea Shepherd Australia
Relevant literature	Gacutan et al. (2022)	NA	Smith and Edgar (2014)	NA
Timescale	2004 – present	March 2017 – January 2020	2012–2013	2017 – 2019
Categories	12 materials, 59 item types, 140 items	222 items (aligned with AMDI)	94 items	54 items (aligned with AMDI)
Site types	Estuary / coast (beaches)	Estuary	Coast (subtidal)	Coast (beaches)
No. of sites	876	12 (estuaries only)	112	44
No. of events	3593	212	112	62

The distribution for each dataset is presented in Figure 5. Expert elicitation identified 17 items that posed risks to assets within the marine estate, of which 11 items could be related to items found within the debris databases, namely balloons, fishing line, fishing traps and pots, foam packaging, food packaging, hard plastic remnants, soft plastic remnants, plastic bags, plastic drink packaging, food lids and plastic rope (and fragments).

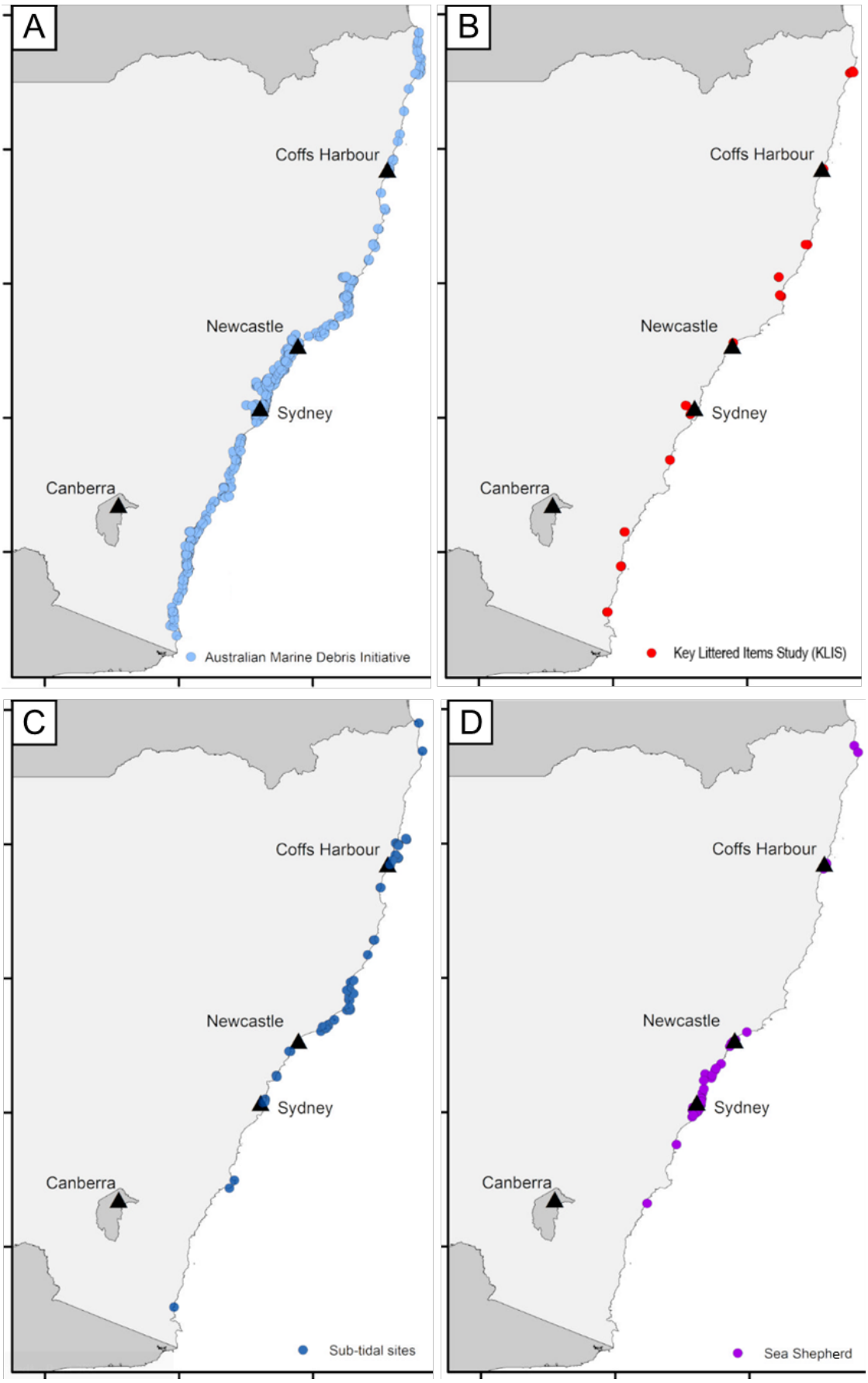


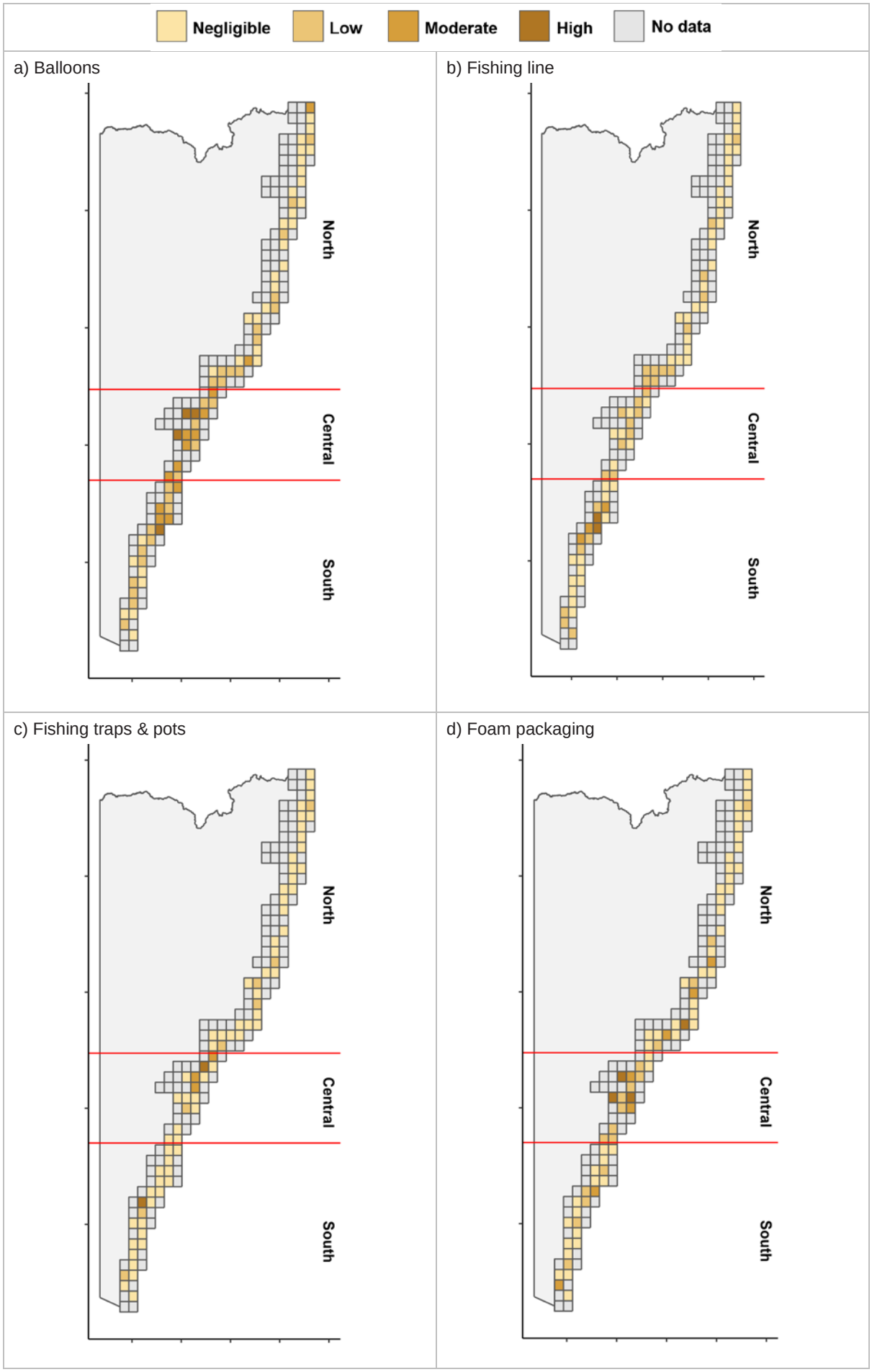
Figure 5 Sampling sites from the (A) Australian Marine Debris Initiative (AMDI), (B) Key Littered Items Study (KLIS), (C) Subtidal data and (D) Sea Shepherd data

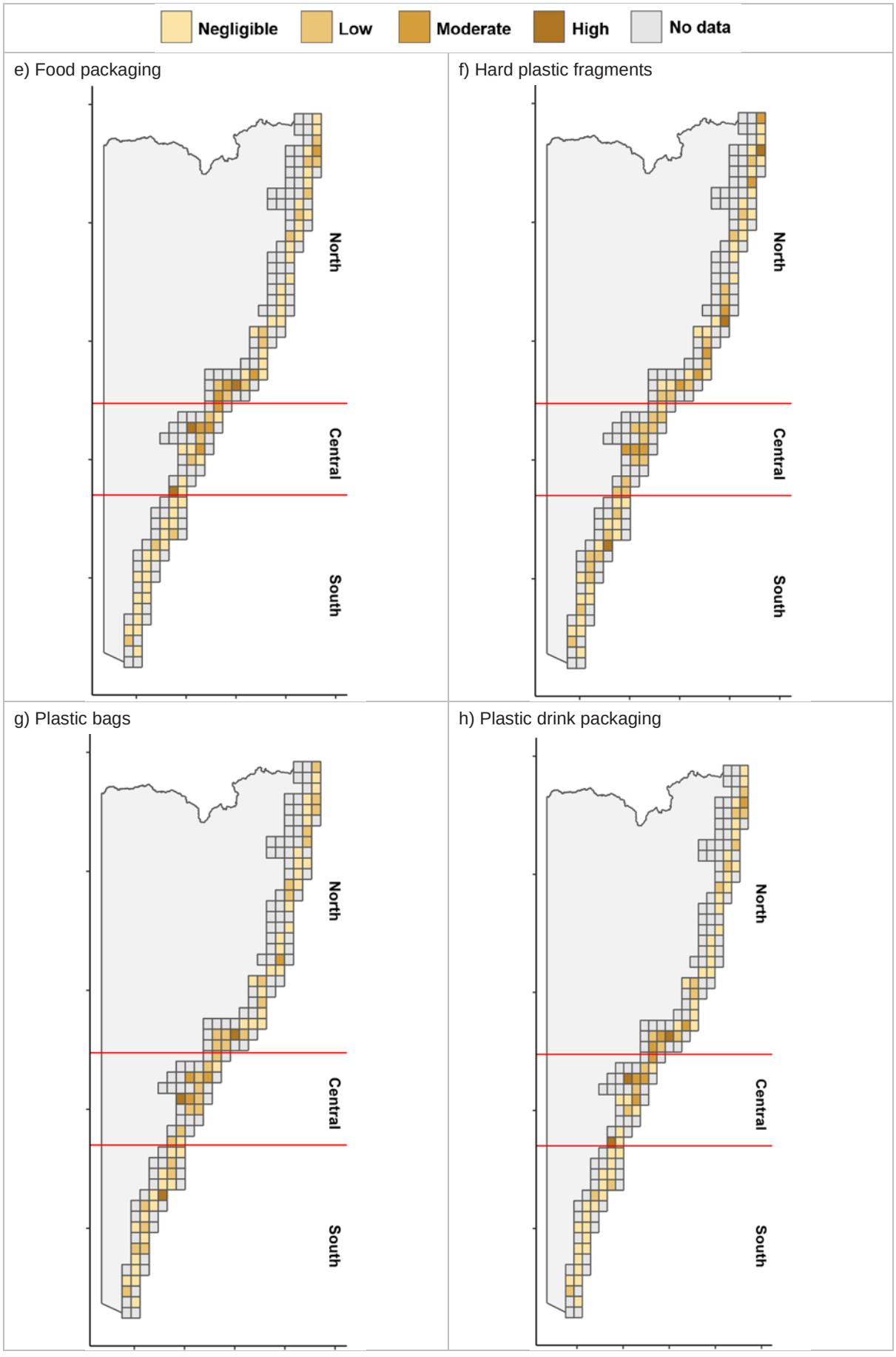
5.8.2 Discretising the NSW marine estate

To enable a spatial analysis of perceived risk to assets by debris items across the NSW marine estate, a 20-km^2 'fishnet' grid was generated, separated into estuary, coastal and marine grids. Coastal grids were defined as those which contained the NSW coastline, while estuary and marine grids were landward and seaward of the coastline vector, respectively. Grids were further classified into the north, central and south regions used within the NSW TARA.

5.8.3 Debris abundance

Debris data was joined to each grid, and the average count per metre was calculated across sites present within the same grid, for each item. K-means clustering was used to discretise average item counts into 4 levels (i.e. minimal, low, moderate and high), shown for each of the mapped items in Figure 6 a) to k).


Negligible
Low
Moderate
High
No data
a) Balloons
North
Central
South
b) Fishing line
North
Central
South
c) Fishing traps & pots
North
Central
South
d) Foam packaging
North
Central
South


Negligible
Low
Moderate
High
No data
e) Food packaging
North
Central
South
f) Hard plastic fragments
North
Central
South
g) Plastic bags
North
Central
South
h) Plastic drink packaging
North
Central
South

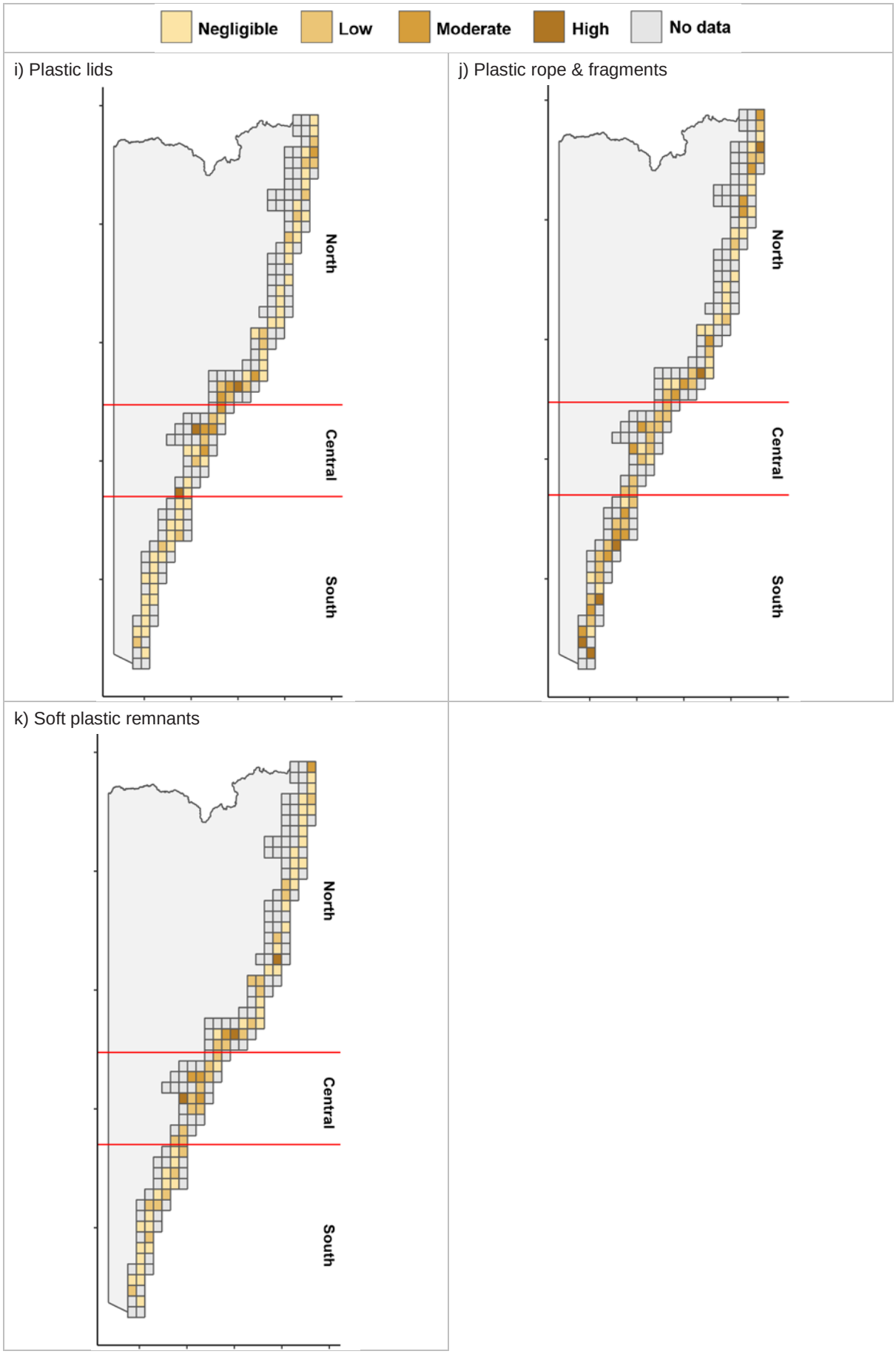


Figure 6 Debris abundance across the NSW marine estate for mappable items

5.8.4 Environmental asset distribution

The 7 biological assets assessed via expert elicitation are aggregates of different biological groups (e.g. benthic assemblages, cetaceans, seabirds) which contain the distributions of species that range from sessile to highly migratory. The distribution of assets within the marine estate were assumed based on grid type. For example, while cetaceans can be found within estuaries in New South Wales, most species are found predominantly in coastal and marine areas. Therefore, analyses of the risks of marine debris to cetaceans were restricted to coastal and marine grids. Table 7 defines the grid types analysed per asset.

Table 7 Grid types analysed per asset

(Note that pinnipeds and rays were not analysed due to the low number of returned expert surveys.)

Asset	Estuarine grid	Coastal grid	Marine grid
Benthic invertebrates	Yes	Yes	Yes
Fish and sharks	Yes	Yes	Yes
Planktonic assemblages	Yes	Yes	Yes
Turtles	No	Yes	Yes
Cetaceans	No	Yes	Yes
Shorebirds	Yes	Yes	No
Seabirds	Yes	Yes	Yes

5.8.5 Social value spatial distribution

Given their nature, social values are not well suited to spatial discretisation. The spatial analysis of risk for social values assumes that social values are distributed evenly across the marine estate. As such, debris distribution is the only spatial variable and can be used directly as a spatial indicator.

5.8.6 Spatial analysis

Local analysis

The expert elicitation process estimated risk values per asset and item, which were joined with the discretised abundance of each debris item using the matrix presented in Table 8. Only items identified as posing a level of risk to the asset were mapped. The spatial risk value per (1) asset and item, and (2) aggregated to item (across all assets) were mapped.

Table 8 Matrix for the calculation of risk spatially from estimated risk values and debris item abundance

		Risk values per asset and item			
		Negligible	Low	Moderate	High
Debris item abundance	Negligible	Negligible	Negligible	Negligible	Negligible
	Low	Negligible	Negligible	Low	Moderate
	Moderate	Negligible	Low	Moderate	High
	High	Negligible	Low	Moderate	High

Regional analysis

Using decision rules, a final aggregation of risk was performed to determine risk per region for each item. Risks were combined spatially using decision rules described in Table 9.

Table 9 Decision-rules for defining spatial risk by region from 20 square km grid cells of spatial risk of an item across all assets

Rule	Resulting risk
If more than 20% of grids with data were categorised as high risk for a debris item, the region was considered high risk.	High
If more than 25% of grids with data were categorised as moderate or high risk for a debris item, the region was considered moderate risk.	Moderate
If more than 30% of grids with data were categorised as low, moderate, or high risk for a debris item, the region was considered low risk.	Low
Considering the previous rules, and if less than 40% of grids with data were categorised as low, moderate, or high risk for a debris item, the region was considered minimal risk.	Minimal

5.8.7 Spatial prioritisation of regional debris item threats

The spatial prioritisation of the MDTARA across the 3 regions used the same criteria as the NSW TARA. Statewide priorities are defined as items that have high or moderate risk values in all 3 regions, while items with only one or 2 regions with high or moderate risk defines the item as a regional priority (MEMA 2017)

6. Defining key outputs of the MDTARA

The major outputs of the MDTARA can be grouped into 2 categories:

1. Risk levels associated with an encounter between marine debris **(threats)** and components of the marine estate **(assets, stressors and values)**

Threats are marine debris items that can negatively impact environmental assets and social values.

Assets are environmental assets (e.g. cetaceans or seabirds) associated with the NSW marine estate.

Stressors are the avenues by which threats can impact environmental assets.

Values are social values (e.g. aesthetics or recreation) associated with the NSW marine estate.

2. Spatial estimations of the risk of debris within the marine estate from a combination of **risk levels** and **exposure**

Debris risk level is a function of the impact of an encounter between an asset or value and a debris item.

Stressor risk level is a function of the impact of debris along numerous impact pathways on an environmental asset.

Exposure is the amount of debris in an area co-incident with an asset, and is an indication of the potential exposure of an environmental asset to that item.

Risk levels posed by marine debris to environmental assets

Expert elicitation was used in the MDTARA to quantify risk posed by marine debris to assets by calculating:

1. **debris risk level**: risk level between each identified item and asset combination given an encounter
2. **stressor risk level**: risk level from all identified items across a nominated risk pathways (stressors e.g. ingestion, entanglement).

Experts were asked to identify the pathways of potential impact by debris (stressors) and corresponding debris items. For each pathway and item pairing, experts estimated the consequence of the interaction, and the likelihood of that consequence occurring given an encounter. A level of confidence was required from the experts for each response.

Using the risk assessment matrix from the NSW TARA framework (MEMA 2015) consequence and likelihood values were converted to risk values.

Risk levels posed by marine debris to social values

The expert elicitation to quantify risk posed by marine debris to social values was modified to reflect the nature of social values and restrict its calculations to **debris risk level**: risk level between each identified item and social value given the incidence of debris and how it incites a level of concern of people in New South Wales. This concern level directly correlates to a risk level.

In this analysis, the stressor mechanism was not used, as the impact ‘pathways’ were consistently a reduction in, or negative effect on, the social value in question.

7. Extended results

7.1 Expert elicitation results

7.1.1 Environmental analysis

Detailed tabulated results from the expert elicitation process in the MDTARA forms the supplementary material supporting the peer-reviewed scientific article documenting the MDTARA application to New South Wales (Gacutan et al. [in review]).

7.1.2 Social values analysis

The expert elicitation process to assess the impacts of debris on priority social values involved 3 responses from experts, 2 of which attended the secondary consensus meeting. Table 10 details the numbers of debris items identified by experts as inciting any level of concern in people in NSW, with respect to their impact on priority social values.

Table 10 Debris items in the social values expert elicitation process identified as causing a level of concern in people in New South Wales

Item	Health & wellbeing	Aesthetic values	Natural environment	Reduction in business	Recreation	Rights of nature	Total
Aluminium cans		Y					1
Balloons	Y		Y		Y	Y	4
Cigarette butts	Y	Y	Y		Y		4
Fishing line						Y	1
Foam & Polystyrene		Y	Y	Y		Y	4
Glass & ceramics	Y						1
Medical waste (incl. syringes)	Y	Y	Y	Y	Y	Y	6
Microplastics			Y			Y	2
Other hard plastic		Y	Y	Y			3
Other soft plastics			Y				1
Plastic bag		Y	Y		Y	Y	4
Plastic bottle		Y	Y				2
Processed timber		Y	Y				2
Sanitary items	Y	Y	Y	Y	Y	Y	6
Straws		Y	Y			Y	3
Total	5	10	12	4	5	8	**44**

7.2 Spatial risk results: debris item and fauna group combinations

Spatial risk analysis in the MDTARA considered all combinations of fauna groups and debris items, as long as the debris data had sufficient coverage across the marine estate.

Spatial distribution of risk was estimated (1) for each pathway (stressor) impacting all asset - item pairs and (2) by aggregating the risk across all assets for each of the mappable items. The 11 spatial outputs for aggregated risk can be found in the MDTARA summary report (DPE 2022b). Table 11 summarises the spatial risk across all significant stressor/item/asset groupings by reporting the percentage of area at each risk level by region, for each combination. These percentages quantify the spatial risk levels across the area that could be mapped for each debris item, highlighting areas with known risk levels due to each of the threats.

Table 11 Spatial risk associated with stressor, item and asset combinations as a percentage of the area in each region with marine debris data

The stressors are ingestion (ING), leachate (LCH), entanglement (ENT) and bioaccumulation (BIO).

		North region				Central region				Southern region			
Stressors	**Debris item**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**
Benthic assemblages													
ING	Foam pieces	0	0	10	90	0	0	33	67	0	0	7.8	92
ING	Hard plastic pieces	0	20	28	53	0	20.9	72	7	0	3.9	35	61
ING	Soft plastic pieces	0	10	30	60	0	25.6	67	7	0	0	31	69
LCH	Foam pieces	0	0	10	90	0	0	33	67	0	0	7.8	92
LCH	Food packaging	0	0	13	88	0	0	40	61	0	0	0	100
LCH	Hard plastic pieces	0	0	20	80	0	0	21	79	0	0	3.9	96
LCH	Plastic bags	0	0	5	95	0	0	26	74	0	0	3.9	96
LCH	Plastic rope	0	0	23	78	0	0	14	86	0	0	43	57
LCH	Soft plastic pieces	0	0	10	90	0	0	26	74	0	0	0	100
BIO	Foam pieces	0	10	10	80	0	32.6	54	14	0	7.8	22	71
BIO	Hard plastic pieces	0	0	20	80	0	0	21	79	0	0	3.9	96
Cetaceans													
ENT	Fishing line	2.5	15	15	68	2.4	26.2	24	48	13.7	25.5	14	47
ENT	Traps & pots	0	12.5	0	88	25.6	7	0	67	4	8	0	88
ENT	Plastic bags	5	37.5	0	58	7	60.5	0	33	3.9	52.9	0	43
ENT	Balloons	0	0	0	100	0	0	26	74	0	0	22	78
ING	Fishing line	0	0	2.5	98	0	0	7	93	0	0	26	75
ING	Foam pieces	0	10	10	80	0	20.9	40	40	0	7.8	22	71
ING	Food packaging	7.5	15	10	68	14	23.3	9.3	54	0	6	6	88

		North region				Central region				Southern region			
Stressors	**Debris item**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**
ING	Hard plastic pieces	10.3	12.8	10	67	2.4	31	2.4	64	2	17.6	2	78
ING	Plastic rope	0	0	23	78	0	0	0	100	0	0	43	57
ING	Soft plastic pieces	0	10	28	63	0	14	54	33	0	0	31	69
BIO	Hard plastic pieces	20	27.5	0	53	7	60.5	0	33	3.9	35.3	0	61
Fish/sharks													
ENT	Fishing line	2.5	15	2.5	80	2.4	31	2.4	64	13.5	13.5	14	60
ENT	Traps & pots	0	0	13	88	0	25.6	7	67	0	4	8	88
ENT	Plastic bags	0	0	5	95	0	0	26	74	0	0	3.9	96
ING	Foam pieces	0	10	10	80	0	32.6	54	14	0	7.8	22	71
ING	Hard plastic pieces	0	0	20	80	0	0	21	79	0	0	3.9	96
BIO	Foam pieces	0	0	10	90	0	0	33	67	0	0	7.8	92
BIO	Hard plastic pieces	0	0	20	80	0	0	21	79	0	0	3.9	96
BIO	Soft plastic pieces	0	0	10	90	0	0	26	74	0	0	0	100
Seabirds													
ENT	Balloons	0	0	0	100	0	0	26	74	0	0	22	78
ENT	Fishing line	0	0	2.5	98	0	0	7	93	0	0	26	75
ENT	Plastic bags	0	0	5	95	0	0	7	93	0	0	3.9	96
ING	Balloons	0	0	28	73	0	26.2	33	41	0	21.6	35	43
ING	Fishing line	2.5	30	0	68	7	46.5	0	47	26	26	0	48
ING	Foam pieces	0	0	10	90	0	0	21	79	0	0	7.8	92
ING	Hard plastic pieces	0	20	28	53	0	7	61	33	0	3.9	35	61
ING	Soft plastic pieces	0	10	28	63	0	14	54	33	0	0	31	69
BIO	Foam pieces	0	10	10	80	0	20.9	40	40	0	7.8	22	71

		North region				Central region				Southern region			
Stressors	**Debris item**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**	**High**	**Mod**	**Low**	**Min**
BIO	Hard plastic pieces	20	27.5	0	53	7	60.5	0	33	3.9	35.3	0	61
Shorebirds													
ENT	Fishing line	0	5	30	65	0	7	61	33	0	26	26	48
ENT	Hard plastic pieces	0	0	20	80	0	0	21	79	0	0	3.9	96
ENT	Plastic bags	0	0	5	95	0	0	26	74	0	0	3.9	96
Turtles													
ENT	Traps & pots	0	12.5	0	88	25.6	7	0	67	4	8	0	88
ING	Balloons	0	27.5	0	73	26.2	33.3	0	41	21.6	35.3	0	43
ING	Fishing line	0	0	2.5	98	0	0	7	93	0	0	26	75
ING	Foam pieces	0	0	10	90	0	0	21	79	0	0	7.8	92
ING	Food packaging	0	0	13	88	0	0	26	74	0	0	0	100
ING	Hard plastic pieces	10.3	23.1	13	54	2.4	33.3	31	33	2	19.6	18	61
ING	Plastic bags	0	0	5	95	0	0	7	93	0	0	3.9	96
ING	Soft plastic pieces	10	27.5	0	63	14	53.5	0	33	0	30.8	0	69

7.3 Current marine debris policy and management settings in New South Wales

The review of programs and initiatives in managing litter and marine debris identified characteristics of programs acting within New South Wales. Table 12 provides a general summary of the characteristics of the management and policy programs assessed.

Table 12 Characteristics of management and policy programs in and around New South Wales assessed for the MDTARA (Tangaroa Blue Foundation 2021)

Program features	
Numbers	45 exclusively within NSW 84 within NSW but also at various scales (incl. Australia-wide and multi-state)
Lead organisation	23 government-led 19 not-for-profits (NFPs) or non-government organisations (NGOs)
Focus	Most have more than one focus 62% – awareness building and advocacy 40% – capacity building
Characteristics	33 have a data component 25 considered for pollution reduction

8. Implications for marine estate management in New South Wales

The results of the MDTARA are an element of the overarching decision-making process for marine estate management in New South Wales. Marine debris was identified as a priority threat by the NSW TARA in the first step in the decision-making process for marine estate management in New South Wales (Figure 7). The MDTARA has estimated risk levels from debris items (threats) where possible, prioritised items and begun to assess current management conditions. This covers elements of Steps 2 and 3 of the process, while still highlighting additional knowledge needed before all of Steps 4 and 5 can be undertaken comprehensively (i.e. develop and implement management strategies, monitoring and evaluation).

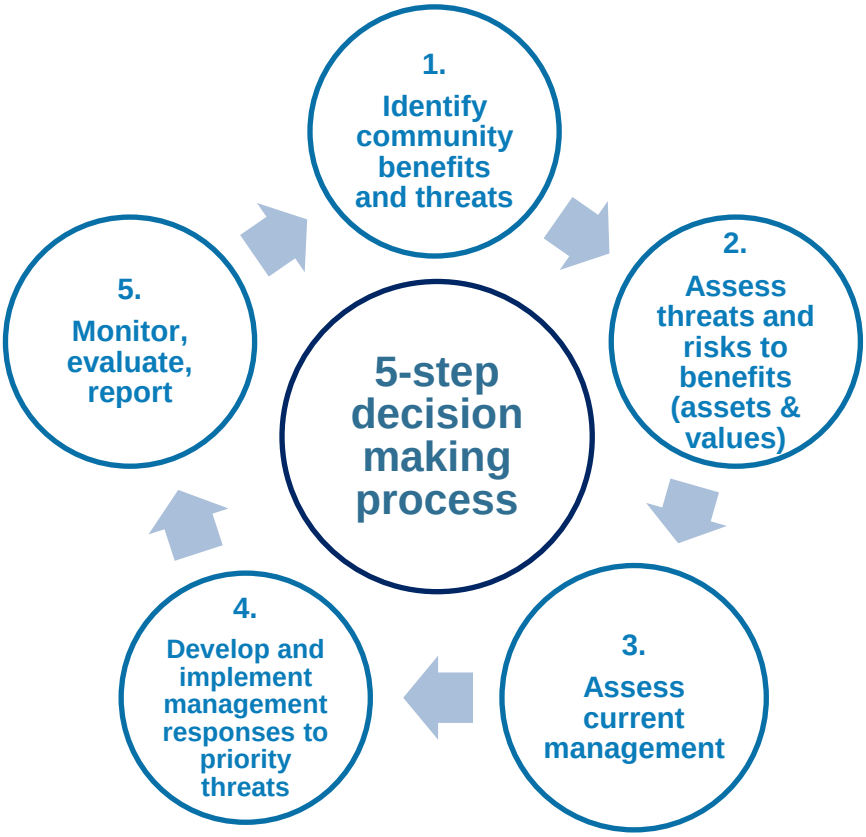


Figure 7 Five-step decision making process for marine estate management in New South Wales (MEMA 2017)

An element of Step 3, assessing current management, has been covered in the MDTARA, highlighting programs in New South Wales dominated by focusing on awareness building, advocacy and capacity building. The need to assess how these programs perform in reducing risk is a topic for future work. This is also true of Step 4, development and implementation of management responses to priority threats, to make sure potential risk reduction options are analysed for their effectiveness.

Assessing the characteristics of priority items will add value to both Steps 2 and 3. A closer look at debris sources, transport and sinks will help us understand the risks better and where, when and how they can be mitigated the most effectively.

9. Definition of terms

9.1 MDTARA components

Table 13 Impact pathways (stressors)

Stressors	Definition
Toxicity – bioaccumulation	The amount of toxins magnified between trophic levels due to the ingestion of debris; can increase the uptake of trace metals, persistent organic pollutants (POPs), poly- and perfluoroalkyl substances (PFAS) in marine food webs.
Entanglement	Marine debris may entangle marine species, causing injury, restricted mobility and drowning. Debris can cause starvation, infection, amputation and smothering. Impaired movement can impact the efficiency of swimming, feeding and breeding.
Facilitation of bio-invasion	Debris items may be sufficiently buoyant and disperse far from their source. The debris item may facilitate the recruitment and dispersion of species to new areas, especially for areas limited in natural debris. Some of these introduced species may become invasive.
Food-web degradation	Debris may alter interactions between trophic levels, impacting the flow of energy through the local ecosystem.
Habitat alteration or destruction	Debris items may alter or destroy the benthic cover of habitat-forming species, impacting the local ecosystem.
Ingestion	Marine species may consume marine debris inadvertently, by confusing it with prey items, or through bioaccumulation, predating on species that have ingested debris. This may lead to physical blockage of the digestive system, leading to internal injuries and pain. Ingestion of debris can lead to reduced or inefficient feeding, nutritional deficiencies, and eventual starvation may occur.
Toxicity – leachate	Debris items can leach toxic substances (e.g. plasticisers) into the aquatic environment as well as into the tissues and digestive tissues of species that have ingested debris. This can cause toxic impacts on various levels.
Smothering	Debris items may cover the asset, where the blanketing effect could lead to anoxia and hypoxia induced by inhibition of gas exchange. Debris may also limit the access of organisms to nutrient flow and light.
Subcellular impacts	Nano and micro-sized debris, once ingested, may interact and impact an organism's normal cellular function.

Table 14 Consequence of an interaction between environmental assets and debris

Value	Consequence	Description
1	**Insignificant**	**No measurable negative impacts** on total species abundance and/or biotic assemblages are, or will be, evident against natural variations.
2	**Minor**	**Barely measurable negative impacts** on total species abundance and/or biotic assemblages are, or will be, evident compared to total abundance of biota and/or biotic assemblages against natural variations.
3	**Moderate**	**Measurable and ongoing negative impacts** on total species abundance and/or biotic assemblages are, or will be, evident in one or more locations. Nevertheless, both the level and the percentage of total species abundance and/or biotic assemblages affected have not or **will**

Value	Consequence	Description
		not influence their overall recovery capacity. A change in the overall trophic/community structure is not and will not be evident.
4	Major	**Substantial measurable and ongoing negative impacts** on total species abundance and/or biotic assemblages are, or will be, evident in one or more locations. The proportion of total species abundance and/or biotic assemblages affected **will influence the recovery capacity of the total species abundance** and/or biotic assemblages, with some clear shifts in the overall trophic/community structure and function.
5	Catastrophic	The level of total species abundance and/or biotic assemblages negatively affected, **endangers their long-term survival**. It will result in **extreme changes to the region's trophic/community structure** as well as the function of the remaining total species abundance and/or biotic assemblages.

Table 15 Additional definitions of consequence specific to an interaction between fish/sharks and debris

Value	Consequence	Description
1	Insignificant	**No measurable negative impacts** on threatened or protected species are or will be evident against natural variations.
2	Minor	**Barely measurable negative impacts** on threatened or protected species are or will be evident against natural variations.
3	Moderate	Many individuals of a threatened or protected species will be **measurably negatively affected**. Nevertheless, no ongoing impact on local dynamics or overall number of individuals is or will be evident, and the impact has not or **will not significantly affect population status of protected species or recovery of already threatened species.**
4	Major	**Substantial measurable and ongoing negative impacts** have or will **affect the number of individuals of protected species and recovery of already threatened species.**
5	Catastrophic	The ongoing level of mortality has or will generate **significant additional declines to already threatened or protected species leading to potential local extinction in New South Wales.**

Table 16 Likelihood of an impact, given an encounter, between fauna and debris

Value	Label	Description
1	Rare	**Never reported** for this situation, **but still plausible** in the event of an encounter (< 5%).
2	Unlikely	Uncommon, but has been known to occur elsewhere. Expected to occur here only in **specific circumstances** in the event of an encounter (5–30%).
3	Possible	Some clear evidence exists to suggest this is **possible** in the event of an encounter (30–50%).
4	Likely	**Expected to occur** in the event of an encounter (50–90%).
5	Almost certain	A very **large certainty** that this will occur in the event of an encounter (>90%).

Table 17 Confidence of the responses based on available evidence

Value	Label	Description
1	**Uncertain**	There is **no evidence** available.
2	**Inferred**	There is **very limited evidence**, often from local-scale studies in other regions and/or overseas.
3	**Limited**	There is limited evidence, often from **studies in other regions** or at a local scale in the NSW marine estate.
4	**Adequate**	There is adequate high-quality evidence, often available **specifically from the NSW marine estate**.

Table 18 Definition of the priority social values

Value	Definitions
Aesthetics	Sensory enjoyment; sights, sounds, smells; including beauty, scenery, tidiness, peace and quiet.
Recreation	Enjoying human activities including walking, sightseeing, socialising, eating, relaxing, swimming, diving, surfing, snorkelling, fishing, collecting, boating and photography.
Health and wellbeing	Enhancing human wellbeing; physical and mental health; including safety, shelter, cleanliness (no pollution), avoidance of user conflict, relaxation, stress release and serenity.
Biodiversity and ecosystems	Diversity and abundance of plants and animals, and their natural interactions, including richness, variety, growth, size, ecosystem health and integrity.
Natural environment	Nature free from human impacts; natural, unspoilt, remote, wild and pristine places.
Intrinsic value of nature	Respect and consideration for nature; plants and animals, and their right to exist free from human interference; 'their place'.
Economics and business	Provision for commercial outcomes including tourism, commercial fishing and supporting local businesses.

Table 19 Level of concern people in New South Wales have towards the impact of debris items on social values

Value	Concern level	Description
1	**Low**	The impact is undesirable but would not prompt a call to management action.
2	**Moderate**	The impact would prompt a call to management action, if practical to do so.
3	**High**	The impact is not socially acceptable and would prompt a call for immediate and prioritised management action.

9.2 General terms

Term	Definition
NSW TARA	A statewide threat and risk assessment commissioned by the Marine Estate Management Authority to assess all threats posing risk to the NSW Marine Estate (MEMA 2017).
NSW Marine Estate	Coastal and marine areas include open coast beaches and foreshores, waters and marine habitats and associated flora and fauna assemblages 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). It is otherwise referred to as 'marine estate' in this document.
MDTARA	The marine debris threat and risk assessment, funded by the NSW Government as part of the NSW Marine Estate Management Strategy.
MDWG	Marine Debris Working Group is a group of scientists, environmental management and policy professionals, wildlife hospital and rescue practitioners, and debris or litter management practitioners convened as part of the part of the Marine Estate Management Strategy. It is otherwise referred to as 'working group' in this document.
DPE	NSW Department of Planning and Environment (previously NSW DPIE).
DPIE	Department of Planning, Industry and Environment (DPIE), now the Department of Planning and Environment.
Place	A meaningful location (Cresswell 2004). Place is what gives a space meaning, 'personality' and a connection to a cultural or personal identity. It is the culturally ascribed meaning given to a space (Fletcher 2019).

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