FINAL REPORT

Project 1.16

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Research needs for the assessment and monitoring of nutrients, chemicals and antimicrobials in the marine environment

Scoping study

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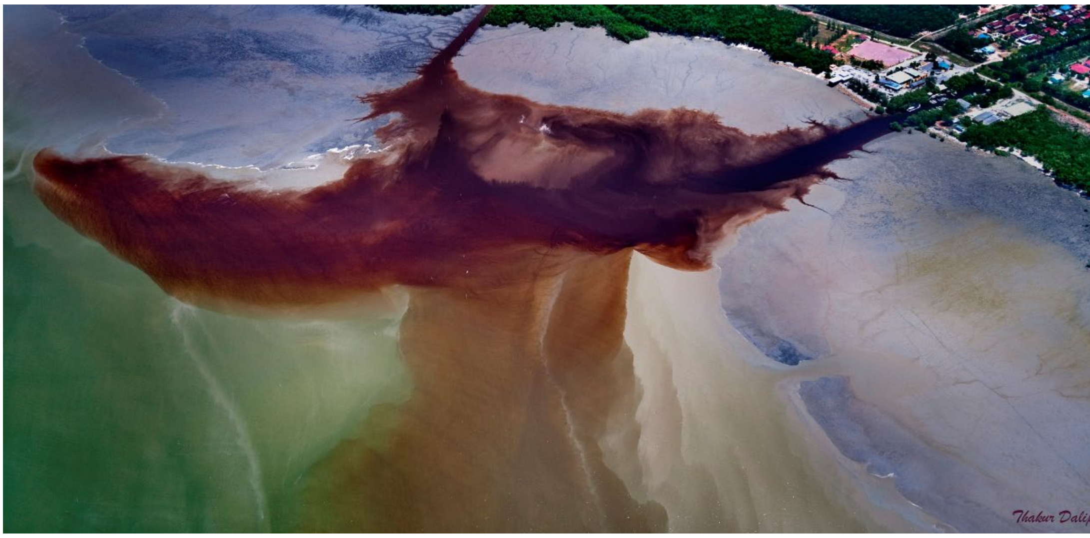

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Executive summary

Healthy and productive marine ecosystems are underpinned by good water quality. Many anthropogenic activities can affect water quality, including activities that release chemical contaminants into the environment. As new chemicals are constantly being produced and used in our daily lives, a plethora of chemical contaminants are being detected in marine waters, sediments, and biota, yet the impacts of many of these chemicals on marine organisms and ecosystems are not yet defined.

Contaminants of Emerging Concern (CECs) are chemicals which have been flagged as potentially hazardous due to new toxicity information (Water Research Australia, 2021). Generally, CECs are poorly understood: there is limited data about their environmental occurrence and biological effects, but emerging research suggests they have the capacity to be toxic. Hence, the concern around the environmental effects of these contaminants is emerging as more scientific evidence comes to light.

The scientific uncertainty surrounding CECs makes regulating these contaminants challenging. In Australia, a range of stakeholders contribute to CEC management. This includes the Commonwealth government, which establishes national CEC policies and objectives, and state and territory governments which regulate environmental CEC emissions in their respective jurisdictions. Government policy makers and regulators are supported by researchers and academics, who generate the scientific evidence to inform government actions.

With an increasing list of CECs detected in the environment, important questions remain unanswered around which contaminants and scientific knowledge gaps should be prioritised in order to achieve optimal environmental outcomes. To address this gap, this project engaged an array of CEC stakeholders from academic research, government, water utilities, and non-government organisations to collaboratively identify priority CEC issues in Australia's marine ecosystems. The results of this process are presented in this report, which should be read in conjunction with the corresponding literature review presented in a separate document.

The project found that stakeholders typically deal with mixtures of several CECs, including antimicrobial compounds, per- and poly-fluoroalkyl substances (PFAS), microplastics, nutrients and heavy metals. The exact nature of CEC mixtures in the environment is likely to vary seasonally and regionally, according to local human activities. Although CECs are, by their nature, poorly understood, information is particularly sparse about the ecological effects of CECs in marine environments, as online CEC databases primarily focus on the effects of CECs in freshwater ecosystems.

Stakeholders identified four knowledge gap themes for CEC management in marine environments. These knowledge gaps are the:

1. Identification of CEC sources, fates and behaviours, and how these may affect CEC exposure pathways for marine organisms.

2. Development of analytical methods to quantify CECs in the environment, and the establishment of environmental CEC baselines which consider regional and seasonal variation.

3. Determination of the ecological effects of CECs, with a focus on understanding the effects of chronic CEC exposures and environmentally-relevant CEC mixtures.

4. Development of toxicity thresholds and consistent risk assessment methodologies that enable stakeholders to prioritise CECs.

We propose that these knowledge gaps can be addressed through a combination of desktop and laboratory studies, and field work. Namely:

- Desktop studies should be used to adapt existing databases to incorporate marine environments, and to identify empirical data needs to enable CEC stakeholders to leverage existing risk prioritisation methodologies.

- Laboratory studies are required to develop standard biomarker protocols, which can assess the effects of CECs, and their mixtures, at the individual, population and ecological levels.

- Field studies are needed to establish standard CEC sampling and analytical methodologies, which will then be used to establish environmental CEC baselines that incorporate regional and seasonal fluctuations. These baselines will then feed into enhancing CEC databases and facilitating CEC risk assessments.

- Field studies are also required to assess ecological effects of CECs in estuarine and marine environments with different receiving water contexts.

1 Water quality in Australia’s coastal environments

Australia’s marine estate is a unique and valuable commodity, accounts for 4% of the world’s oceans and is expected to contribute $100 billion per annum to the Australian economy by 2025 (National Marine Science Plan, 2015-2025).

Coastal areas, including the waterways within the headlands of estuaries and bays, are the key interface between Australia’s oceans and terrestrial landscapes. These coastal areas provide key habitats for aquatic species, drive nutrient cycles, and are sometimes used as receiving waters for anthropogenic waste (Clark et al., 2021). Coastal areas are also the centre of many recreational and industrial activities, which expose these regions to numerous pressures that can deteriorate their long-term water quality.

Coastal water quality is threatened by the ever-increasing list of novel chemicals produced and used in our modern lives (Binetti et al., 2008). These chemicals are commonly incorporated into pharmaceuticals and household items, and are subsequently discharged into coastal areas from a broad range of point sources, such as sewage and industrial wastes. For many of these chemicals, our understanding of their environmental concentrations and biological effects is limited; when new scientific information emerges to suggest that a particular contaminant may harm the environment, we then refer to this as a contaminant of emerging concern (CEC).

CECs can degrade water quality and pose ecotoxicological risks to coastal ecosystems (for examples, see Fonseca & Reis-Santos, 2019, Howarth et al., 2000, and Palmer & Herat, 2021). Subsequently, this can reduce ecosystem health and productivity, and alter the visual amenity and social values associated with coastal areas. Evaluating the ecological effects of CECs is difficult because of the limited scientific understanding about their environmental concentrations, persistence, physiological or ecological effects on marine biota. This paucity of knowledge can hinder the identification of CECs for regulatory control, which may be further complicated if CECs compete for regulatory attention with well-studied ‘legacy’ contaminants, such as heavy metals. As a final complicating factor, the lack of long-term monitoring and inconsistent monitoring approaches – as identified in the Commonwealth’s *State of the Environment Report 2021* (Clark et al., 2021) – makes it difficult to determine how coastal water quality has changed geographically and temporarily.

1.1 Project rationale

CECs threaten the environmental, economic, and social values of Australia’s coastal areas (Diamond et al., 2015; Xabadia et al., 2021). This risk can be managed through regulation and monitoring, yet little has been done to identify which CECs are important in the Australian marine environment, or to document their potential environmental effects.

This project is a scoping study that acts as an initial screening assessment to broadly rank CEC threats and associated uncertainties so that the highest priority threats and knowledge gaps can be targeted for further investigation. The project used stakeholder engagement to identify which CECs are considered to pose the largest threat, and what knowledge gaps should be prioritised to facilitate their regulation.

1.2 Project outputs

This project delivers two outputs:

1. This research report, which presents the results of the stakeholder engagement.
2. A separate literature review that synthesises the scientific knowledge of the key CEC categories identified by stakeholders in this report.

2 Project methodology

2.1 Project scope

The scope for this project was developed iteratively with input from the Department of Climate Change, Energy, the Environment and Water (DCCEEW[1]). The Project Leads presented the initial findings of the project during an online workshop held on 03 February 2022, which was attended by:

- DCCEEW end-users from the:
    - Policy Advice and Integration Section of the Chemicals Management Branch
    - Environmental Contamination, Advice and Standards Section of the Chemicals Management Branch
    - Plastics and Packaging Section of the Waste Policy and Planning Branch
- The National Environmental Science Program (NESP) Marine and Coastal Hub Leader
- The NESP Marine and Coastal Hub Knowledge Broker
- The DCCEEW NESP Liaison Officer

Information received from DCCEEW stakeholders during the workshop was used to refine the project scope.

2.1.1 Sources of CECs

CECs can enter the marine environment from many sources. This project considered CEC pollution only from terrestrial activities, which are:

- Outfalls and point discharges, such as sewage and storm water outfalls and effluents
- Ground and surface water runoff

Water-based sources of CECs, such as aquaculture and recreational fishing and boating, were beyond the scope of the project.

[1] Prior to 1 July 2022, DCCEEW was called the Department of Agriculture, Water and the Environment.

2.1.2 Effects of CECs

This project focussed only on CECs with the potential to affect the marine environment.

Whilst there is public concern around the potential for some CECs to directly affect human health, such as plastic pollution (Davison et al., 2021), this aspect lay outside the project's scope. However, we note that the environmental effects of CECs can indirectly affect humans by altering animal and plant populations, ecosystem services, and economic and recreational amenity.

2.2 Stakeholder identification

We used an iterative method to identify and engage with Australian CEC stakeholders. We first identified sectors in which key CEC stakeholders were likely to operate. Then, we identified specific stakeholder organisations within each sector, and solicited feedback from these stakeholders to identify additional key organisations or individuals.

2.3 Stakeholder engagement methods

The themes discussed in this report are the culmination of in-depth stakeholder engagement over the course of the project. The project used multiple modes of engagement, including:

- The scoping workshop with DCCEEW end-users
- Meetings with representatives from key stakeholder organisations (see Appendix A for a list of organisations)
- An online stakeholder webinar (section 2.3.1)
- An online stakeholder survey (section 2.3.2)

2.3.1 Stakeholder webinar

To understand the needs and priorities of CEC stakeholders outside of DCCEEW, an online workshop (webinar) was held on 22 July 2022. Among the 84 webinar attendees were stakeholders from across state and local governments, Environment Protection Agencies, research institutions, the water industry, and non-government organisations (NGOs).

Since many stakeholders have experience in both CECs and microplastics, we conducted this webinar in conjunction with the research team of the NESP 1.18 project. This collaboration enabled us to explore the interconnectedness of CEC and microplastics management, whilst minimising engagement fatigue for our stakeholders. The online nature of the forum enabled us to facilitate conversations with participants across several Australian jurisdictions, which would otherwise have been difficult due to geographic barriers.

The webinar elicited stakeholders' opinions about critical knowledge gaps and research needs that must be addressed to support evidence-based CEC policy, regulation and management in Australia. The webinar also provided a cross-sector forum for knowledge transfer to identify solutions, lessen barriers and identify opportunities to ameliorate, mitigate and manage CEC-related issues.

A record was made of attendees' written comments in the webinar chat box. The major comments and key themes raised in the webinar were identified, and integrated with the results of meetings and the stakeholder survey (see section 2.3.1). The combined themes are presented in section 3.

2.3.2 Stakeholder survey

The reach of the project was broadened through the development of an online survey. Stakeholders who attended the webinar (section 2.3.1) were encouraged to complete the survey, as were stakeholders identified through the combined professional networks of the NESP 1.16 and NESP 1.18 project teams. Stakeholders referred to the project teams through existing networks were also invited to complete the survey.

Given the integrated nature of CECs and microplastics, the survey was created in collaboration with the research team conducting the NESP 1.18 project, and stakeholders were asked questions related to both microplastics and CECs.

The survey was a mix of multiple choice and open-ended questions (provided in Appendix B) which sought to understand the experience and concerns of CEC stakeholders. The survey was anonymous, to encourage stakeholders to provide honest answers. The survey was approved by the Human Research Ethics Committee at the University of Technology Sydney (approval number: ETH22-7298) and the University of Adelaide (approval number: H-2022-079).

As of 17 August 2022, a total of 56 stakeholders had completed the survey. Of these 56 respondents, 28 people self-identified as having some level of CEC knowledge and experience. The survey results collated from these 28 people are presented in section 3.4.4; responses related specifically to microplastics are presented in NESP 1.18 final report (Reis-Santos et al., 2022).

3 Results

3.1 Marine water quality: foci for the Commonwealth Government

Whilst a host of CECs regularly enter coastal environments, resource restrictions mean that only a portion of these CECs can receive policy attention. At the Commonwealth government level, the focus for marine water quality issues is guided by a range of policies and international obligations. These documents identify water quality as a key priority across a variety of sectors and contaminants, and describe initiatives for management of CEC sources, pathways and impacts in marine contexts and the environment more broadly.

In this section, we describe the overarching CEC-policy context in which the government operates, and identify key areas of interest related to CEC management. This section draws on our literature review of Commonwealth policy documents and feedback gathered from the DCCEEW scoping workshop and one-to-one meetings (described in section 2.3).

3.1.1 Establishing environmental baselines

Two Commonwealth policy documents highlight the need to establish baselines for CECs in the marine environment. The first document, the *National Marine Science Plan 2015-2025* (National Marine Science Committee, 2015), has been created to drive the development of Australia's blue economy. The Plan identifies that establishing marine chemical baseline data, such as those related to CECs, can act as a leverage point for effective management of Australia's marine estate.

The second Commonwealth document to refer to chemical baselines is the *State of the Environment Report 2021*. This report states that water quality fundamentally underpins healthy aquatic ecosystems (Clark et al., 2021), but that many CECs remain unmanaged and large proportions of estuaries are largely unmonitored for CEC presence, fate or ecological impacts.

The theme of establishing CEC environmental baselines, raised in both these documents, is reiterated in CEC-specific Commonwealth documents, discussed below.

3.1.2 Antimicrobials

Antimicrobials are a group of active agents that kill or stop the growth of microbes, such as bacteria, fungi, algae, viruses and parasites (Department of Health, 2019). These chemicals are used widely and globally, in both medicine and agriculture, to treat or prevent microbial infections in humans and animals. Antimicrobials, or biologically active components of these chemicals, enter the environment through run off, or they are excreted in urine and faeces and enter the environment in wastewater. In some regions, antimicrobials are likely to co-occur with other contaminants. For example, antimicrobials and heavy metals are likely to co-occur in agricultural regions as these chemicals are regularly administered together in livestock production (Seiler & Berendonk, 2012).

Antimicrobials act as a selection pressure in the environment, and lead to the evolution of organisms possessing antimicrobial resistant genes. Antimicrobial resistance is emerging as a significant international issue. Key international agencies are collaborating to address risks of antimicrobial resistance across animal, human and environmental health, including: the World Organisation for Animal Health, the Food and Agriculture Organization of the United Nations and the World Health Organization (WHO), and the and UN environment program (UNEP; Department of Health, 2019; World Health Organization, 2015).

Much of the regulatory and scientific focus around antimicrobials is related to antimicrobial resistant genes and organisms, and this is reflected in international and Australian policy documents. However, one opinion expressed by DCCEEW end-users during the scoping workshop was that environmental end-users are concerned with antimicrobials *per se* – rather than antibiotic resistance – because it is the antimicrobials that drive the environmental impacts. In other words, end-users care about the direct effects of antimicrobials on microbes, animals, algae and aquatic plants that form the foundation of aquatic food webs.

The *State of the Environment Report 2021* (Clark et al., 2021) notes that antimicrobials are largely unmanaged but have the potential to affect ecosystems. They are also the focus of Australia’s *National Antimicrobial Resistance Strategy – 2020 and beyond* (Department of Health, 2019), which establishes the problem of antimicrobial resistance as a national priority. This document specifies that combating antimicrobial resistance nationally and globally needs:

- an integrated surveillance and response to resistance and usage (Objective 5)
- strong collaborative research agenda across all sectors (Objective 6)

Both these Objectives can be partially addressed by determining the concentrations of antimicrobials in coastal environments and assessing their associated ecological impacts.

To further support effective management of antimicrobials, the Commonwealth has created the *One Health Master Action Plan for Australia's National Antimicrobial Resistance Strategy* (Department of Health, 2021). This Plan identifies that the environmental sector is fundamental to achieving several goals, including:

- Developing a national surveillance plan, including the potential use of genomics (focus area 5.1.1)
- Developing and continuing to improve mechanisms to provide and analyse data on antimicrobial resistance and usage (focus area 5.1.2)
- Developing, promoting, harmonising and monitoring national consistency in antimicrobial susceptibility testing and reporting (focus area 5.3.1)

3.1.3 Per- and poly-fluoroalkyl substances

Per- and poly-fluoroalkyl substances (PFAS) are a group of chemicals manufactured for household and industrial purposes that have a chain of carbon atoms bonded to fluorine atoms (Heads of EPAs Australia and New Zealand, 2020). Their high solubility means PFAS readily leach into surface and groundwater, are highly mobile in the environment, and bioaccumulate in aquatic food webs.

PFAS are identified in the *Hazardous Waste in Australia 2021* report (Latimer, 2021) and the *PFAS National Environmental Management Plan 2.0* (Heads of EPAs Australia and New Zealand, 2020) as high priority CECs that can threaten marine environmental health. Since PFAS are a component of fire-fighting foam, there is also some concern that PFAS could become a legacy chemical of Australia's bushfire events.

The *PFAS National Environmental Management Plan 2.0* has been endorsed by the Heads of Environment Protection Agencies and Environment Ministers, and has been implemented by the Commonwealth government, and nearly all state and territory jurisdictions. The Management Plan clearly outlines the following knowledge gaps:

- ambient monitoring of PFAS in the environment (Theme 2)
- the empirical establishment of thresholds at which PFAS concentrations impact the broader environment and on water specifically (Theme 3)

In addition to this national focus on PFAS, Australia is involved in PFAS management internationally. In 2012, Australia joined the Organisation for Economic Co-operation and Development (OECD)/United Nations Environment Programme (UNEP) Global Perfluorinated Chemicals Group, which works to reduce PFAS emissions, with the aim of global elimination where possible (Australian Government PFAS Taskforce, 2019).

Internationally, PFAS use and waste management is guided by the Stockholm Convention on Persistent Organic Pollutants (section 3.1.5), of which Australia is a signatory. However, Australia has not ratified the listing of PFAS under the Convention because it currently cannot meet the management obligations that would be required (Australian Government PFAS Taskforce, 2019).

3.1.4 Plastics: debris and microplastics

Discarded plastic items are lightweight and highly mobile in the environment, resulting in large amounts of plastic pollution entering coastal environments. These large plastic debris items reduce the visual amenity of coastal areas, and pose a significant risk to large marine fauna, such as seabirds and marine mammals.

In addition to large plastic items, 'microplastics' measuring ≤ 5 mm in diameter also pollute coastal waterways. Many marine microplastics fragment off large plastic items already polluting the environment (described above), as environmental conditions make the plastic brittle and likely to shatter. Other marine microplastics originate in household and industrial products, and can be discharged from wastewater treatment plants into coastal areas. Microplastics pose an environmental hazard in their own right, but also have the capability to transport and release hydrophobic CECs, such as PFAS (see section 3.1.3, above), into new areas.

Large plastic debris and microplastics are incorporated into several national policies. In 2003, 'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' was listed as a key threatening process under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*, and the resultant *Threat abatement plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans* (Department of the Environment & Energy, 2018) highlights the need to understand the impacts of plastics and microplastics on marine ecological communities (Objective 2).

Government policy has continued to reiterate the need to reduce the effects of plastic pollution on Australia's marine environments, through the *National Waste Policy 2018* (Strategy 10 of Commonwealth of Australia, 2018) and the *National Plastics Plan 2021* (Department of Agriculture Water & the Environment, 2021), which outlines the Commonwealth's commitment to reducing plastic waste and microplastics from entering marine waters.

Whilst most government policies focus on the physical risks plastics and microplastics pose to animals, the *Hazardous Waste in Australia 2021* report (Latimer, 2021) highlights the chemical threat of these CECs. The report notes that a range of chemical additives, such as PFAS and phthalates, are used in plastic manufacturing and that these chemicals can be environmentally hazardous. In January 2021, changes were introduced to the Basel Convention (see section 3.1.5, below) which classified some waste plastic as 'presumed to be hazardous' (Latimer, 2021).

3.1.5 CECs covered by international Conventions

Australia has ratified several UNEP international conventions that restrict, prohibit, or manage the manufacture, use, transport and/or release of specific CECs into the environment. Table 1 summarises the Conventions Australia has ratified. The CECs covered by these Conventions are mercury and mercury-containing compounds, persistent organic pollutants, pesticides and industrial chemicals, and chemically hazardous waste. The scale and global partnership of nations in these UNEP treaties is testament to the significance of the impact of these contaminants on the environment and human health.

As a signatory to these Conventions, Australia has committed to managing the elimination or restriction of these CECs, including waste management requirements and emissions into the environment. For each Convention, Australia must regularly report national progress against the measures; monitoring of these CECs in marine environments will provide tangible information to facilitate Australia's international reporting requirements.

Table 1 United Nations Environment Programme international conventions that Australia has ratified.

Convention	Chemical/s	Purpose	Date ratified by Australia
Minamata Convention on Mercury	Mercury and mercury-containing compounds	To protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.	December 2021
Stockholm Convention on Persistent Organic Pollutants	Persistent organic pollutants, including PFAS	To protect human health and the environment from persistent organic pollutants.	May 2004[2]
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Chemicals and pesticides (>50 chemicals)	To promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use.	May 2004
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	A wide range of hazardous wastes, based on origin, composition, and characteristics	To protect human health and the environment against the adverse effects of hazardous wastes.	February 1992

3.2 Identification of existing CEC databases

We searched the scientific and 'grey' literature, and used stakeholder engagement, to identify Australian and international CEC databases. Our search found four current databases (sections 3.2.1 to 3.2.4) that collate information which stakeholders can use to manage CECs.

We identified that CEC databases use several definitions for CECs which may be at odds with government and research organisations. This issue is notable for the ECHIDNA Database, which restricts its definition of CECs to only include chemicals that do *not* have an

[2] Australia is yet to ratify the addition of PFAS to the Convention (Australian Government PFAS Taskforce, 2019).

associated toxicity guideline value (Melvin et al., 2021). Using this definition, chemicals with well-known high environmental impacts may be excluded from the ECHIDNA database, regardless of the reliability of its toxicity guideline value.

3.2.1 NORMAN Network

Established in 2005, the NORMAN network is an international collaboration of CEC stakeholders, including research laboratories and government institutions (NORMAN, 2022). The Network compiles chemical and ecotoxicity data for a range of CEC categories.

The Network encourages the validation and harmonisation of common measurement methods and monitoring tools so that the requirements of risk assessors and risk managers can be better met. Using the NORMAN Prioritisation Framework, the database ranks CECs according to risk (NORMAN, 2022a).

3.2.2 ECHINDA Database

The Emerging Chemicals Database for National Awareness (ECHIDNA) Database developed by Water Research Australia collates the chemical properties, bioaccumulation and ecotoxicity of a range of CECs (*ECHIDNA Database*, 2022). Similar to the NORMAN network, the ECHIDNA database offers a risk prioritisation tool to rank CECs (detailed in section 3.3.1). Additionally, the database collates links to information on management options to address CEC-related risks to the environment and human health.

The ECHIDNA Database is available to members of Water Research Australia. However, access may, by request, be extended to other CEC stakeholders: in this way, several attendees at the stakeholder webinar were able to gain access to ECHIDNA.

The Database contains little to no information about CECs in marine environments. According to the Database research team, approximately 85% of the ECHIDNA content focuses on freshwater, with some data also representing surface run off; this skew reflects the research that was available when the ECHIDNA Database was collated. The ECHIDNA Database has the capacity to be expanded to incorporate marine CECs, with the research team advising that this would be best achieved using acute toxicity assays and biomarkers to generate data that can be compared across marine and freshwaters.

3.2.3 National Outfalls Database

This National Outfalls Database was created as part of the NESP Marine Biodiversity Hub C4 project, and is a joint initiative between the Commonwealth government, the NESP, and the Clean Ocean Foundation (National Outfalls Database, n.d.). This freely accessible, online database maps the quality of water discharged from wastewater treatment plants at 193 coastal outfalls[3] across the country. A cluster analysis conducted on the information in the database identified clusters of outfalls with high pollutant levels that include locations in Tasmania, the Northern Territory, and Western Australia (Rohmana et al., 2020).

The Database reports on the measured concentrations of nutrients, such as nitrogen and phosphorus, but does not contain data for novel chemicals that stakeholders would typically consider to be CECs. Furthermore, the water quality parameters presented for each outfall in the Database varies by state because monitoring efforts for wastewater treatments plants ultimately depend on Environment Protection Agency (EPA) requirements, and hence vary between states (Gemmill et al., 2021). Whilst Australia lacks nationally consistent reporting requirements, this is not the situation in other countries (discussed in Rohmana et al., 2020).

3.2.4 ToMEx database

The Toxicity of Microplastics Explorer: Aquatic Animals (ToMEx Database) is a free, international database that enables users to search and visualise microplastics toxicity data to aquatic organisms (Thornton Hampton et al., 2022). A version of ToMEx also exists to catalogue the effects of microplastics to human health, but this lies outside the scope of this project (see section 2.1.2).

ToMEx is the only microplastics toxicity database available, but it is far from complete as it relies on researchers to voluntarily submit their datasets for compilation. The ToMEx database allows users to filter and compile information for different aquatic taxa, as well as by plastic types and shapes. Importantly, ToMEx allows users to discern between the physical effects of microplastics and the effects of chemicals that leach from the microplastics polymer.

In addition to enabling users to search the database for the toxicity data of specific aquatic biota, ToMEx compiles the data into a Species Sensitivity Distribution, a metric often used for setting risk-based thresholds that protect a specified proportion of species (typically 5%). In this way, the Database allows users to model the ecosystem-specific risks of microplastics and their associated chemical leachates.

3.3 CEC risk assessment methodologies

Our search of the literature identified several risk-based approaches for prioritising CECs that account for the paucity of scientific information.

[3] Number as of 23 August 2022.

3.3.1 Risk assessments for CECs with a chemical-only presence

The ECHIDNA Database offers a risk assessment tool to prioritise CECs. The risk assessment focusses on available data and, where data is unavailable, extrapolating from existing data using robust models. The ECHIDNA Database risk assessment can be divided into a two-tiered assessment (Melvin et al., 2021):

- In the tier 1 assessment, CECs are categorised based on their known or predicted persistence, bioaccumulation, and toxicity. CECs that trigger two or more toxicity characteristics are retained for further assessment in tier 2. CECs are also retained for tier 2 assessment if they do not trigger two toxicity characteristics but are either mutagenic or endocrine active.

- In the tier 2 assessment, CECs are further prioritised by compiling (and, where unavailable, modelling) occurrence, toxicity, and removal data to calculate risk quotients. Missing occurrence values are generated using validated predictive models (e.g., fugacity and removal via sewage treatment) and missing toxicity values are generated from models of acute toxicity.

The result of this multi-tiered approach is that the best available evidence is used, despite knowledge gaps, to conduct a preliminary risk assessment and categorise CECs into groups based on their environmental risk. Given the risk-assessment methodology developed for ECHIDNA is already established and has been applied to a range of CECs, adopting this method for other, marine CECs would maintain a level of national consistency.

3.3.2 Risk assessments for CECs with a chemical & physical presence

Plastics and microplastics, which have both a physical and chemical presence in the environment, may require unique risk assessment methodologies.

As part of the New South Wales Marine Estate Management Strategy (Marine Estate Management Authority, 2018), state government scientists and researchers are undertaking a marine debris threat and risk assessment. This risk assessment aims to identify what types of marine debris, which includes microplastics, are the greatest threats to our marine wildlife and to the values that society derives from the marine estate (NSW Department of Planning and Environment, 2022). The risk assessment will examine the likelihood and consequences of impacts to ecological receptors, and will ultimately assist in prioritising actions to help tackle the most important marine debris issues in New South Wales.

3.4 Stakeholders' identification of CEC knowledge gaps

This section draws on the knowledge shared by CEC stakeholders through meetings, the webinar, and the stakeholder survey (see section 2 for a description of engagement methods) to:

1) Ascertain which CECs are a priority for stakeholders

2) Identify potential sources of these CECs
3) Conduct a gap analysis to prioritise research needed to support CEC policy development and management in Australia

3.4.1 Who are Australia's CEC stakeholders?

Australian CEC stakeholders work across many sectors and jurisdictions; understanding the demographics of these stakeholders provides an insight into the effectiveness and ongoing challenges of engaging this diverse group. Using the demographic data captured by the stakeholder survey, we can describe the skills and knowledge of the people who make up Australia's CEC stakeholders.

As of 17 August 2022, a total of 56 stakeholders had responded to the online survey. The survey results suggest that the survey engaged a broad cross section of CEC stakeholders. Of the total 56 respondents, 30 respondents said they had some level of CEC knowledge or experience[4]: 4 respondents said they had extensive knowledge, 14 respondents said they had general knowledge, and 10 respondents said they had 'some' knowledge (Figure 1). An additional two respondents felt they had 'little or no knowledge' of CECs and had been working in their current role for less than 2 years (Figure 1). The survey results presented in section 3 are the responses given by these 30 respondents.

Thirteen respondents had, in addition to their CEC knowledge, expertise and knowledge in microplastics (survey Question 6). These respondents answered questions related to CECs and microplastics (see Appendix B for survey questions). We include their CEC-related responses in this section, and a detailed analysis of their responses to microplastics-related survey questions is provided in NESP 1.18 final report (Reis-Santos et al., 2022).

Survey respondents worked in a variety of sectors and professional roles (Figure 2). Most respondents worked in State government agencies (11 respondents) and Industry (7 respondents), and represented a mix of policy officers, managers, and water services. The survey engaged CEC stakeholders across several jurisdictions (Figure 3). Nearly 22% of stakeholders said that their CEC work was relevant to the whole of Australia, or internationally. This emphasises the universal challenge of managing CECs.

The survey failed to capture responses from stakeholders in the ACT, Northern Territory, Tasmania, and Western Australia (Figure 2). Whilst the NESP 1.16 and NESP 1.18 project teams did reach out to these regions, one potential explanation for their lack of engagement is that stakeholders in these jurisdictions are more difficult to engage, perhaps due to geographical distances and time zone differences. Hence, these stakeholders may be operating in relative isolation compared to CEC stakeholders in eastern Australian states. To

[4] In response to Question 7 "*Please indicate what best describes your knowledge and experience in other emerging contaminants*".

account for this possibility, future stakeholder engagement should pay particular attention to this.

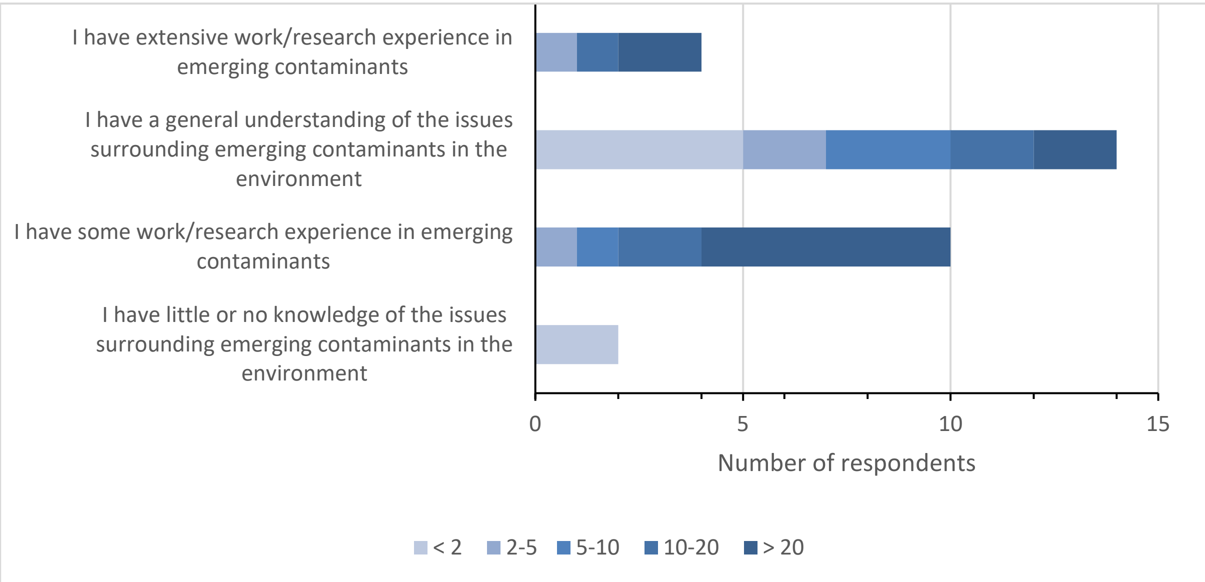

Figure 1 Stakeholders' self-assessed levels of CEC knowledge and experience (survey Question 7), and their number of years' experience dealing with water quality issues (survey Question 3). *n* = 30 respondents.

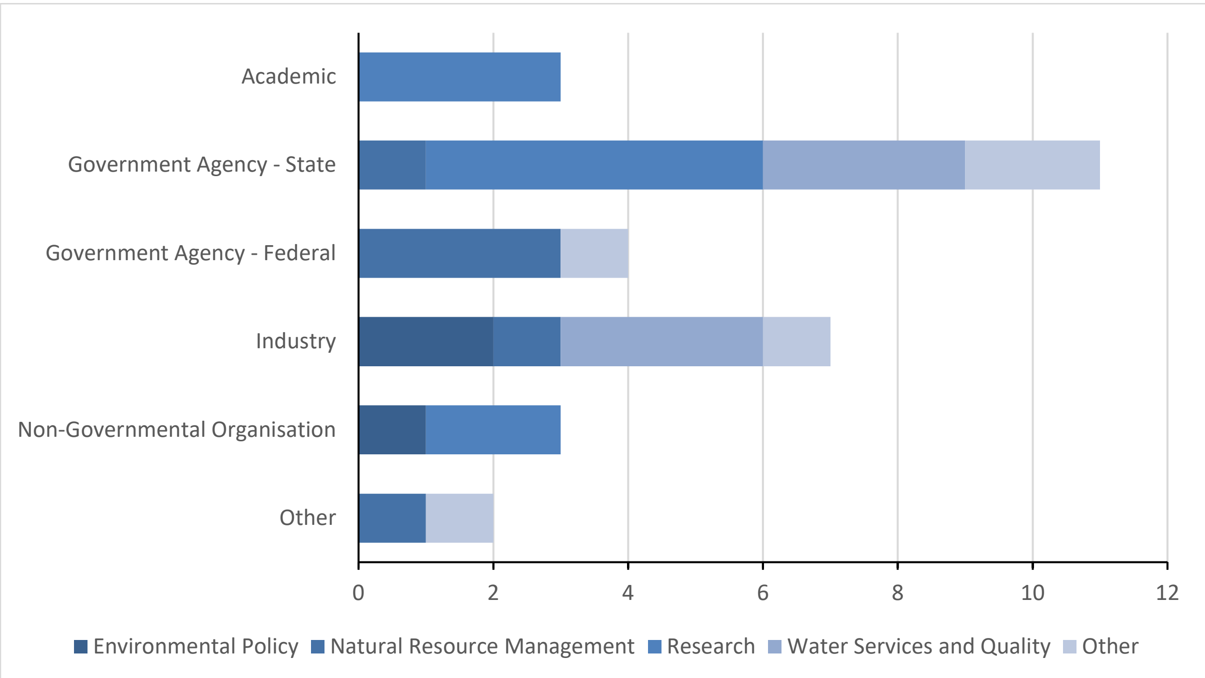

Figure 2 Stakeholders' self-identified sectors (survey Question 1) and professional roles (survey Question 2). *n* = 30 respondents.

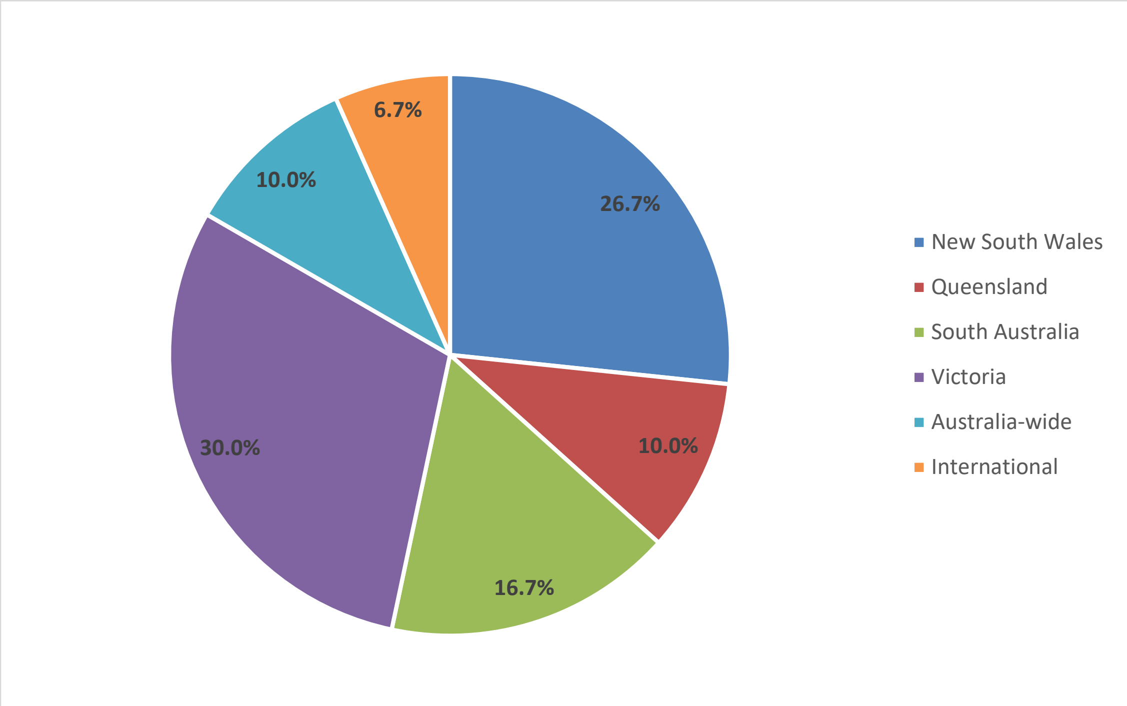

Figure 3 Stakeholders' responses to the question "*What geographic regions does your role or research cover*?" (survey Question 4). Two respondents selected both 'Australia-wide' and 'International'; their answers have been displayed under 'International' only, since this category also includes Australia. Numbers represent the percentage of respondents selecting each category (*n* = 30 respondents). There were no respondents for ACT, Northern Territory, Tasmania, or Western Australia.

3.4.2 Which CECs are important to stakeholders?

Survey Question 17 asked stakeholders:

> "*What are the contaminants you are concerned about or managing with respect to water quality*?"

Respondents were asked to select a single category of CEC from a list provided (categories depicted in Figure 4 and listed in Appendix B). Respondents who selected 'Other' from the list had the opportunity to elaborate on their answer by providing written text.

All 30 CEC stakeholders answered this question. Of the respondents that selected a CEC category from the response options provided, most were concerned with, or managed, 'PFAS and related chemicals' (20% of respondents), and nutrients (14% of respondents; Figure 4). Smaller proportions of respondents were concerned with, or managed, industrial wastes (7% of respondents), antimicrobials (4% of respondents), pharmaceuticals, legacy metals in sediment, or suspended sediment (3% of respondents per category). These responses likely reflect the status quo of CEC management: since CECs are largely unregulated, few respondents are likely to be in professional roles that are concerned with, or manage, CECs like antimicrobials. Therefore, the results presented in Figure 4 may not necessarily reflect respondents' prioritisation of CECs.

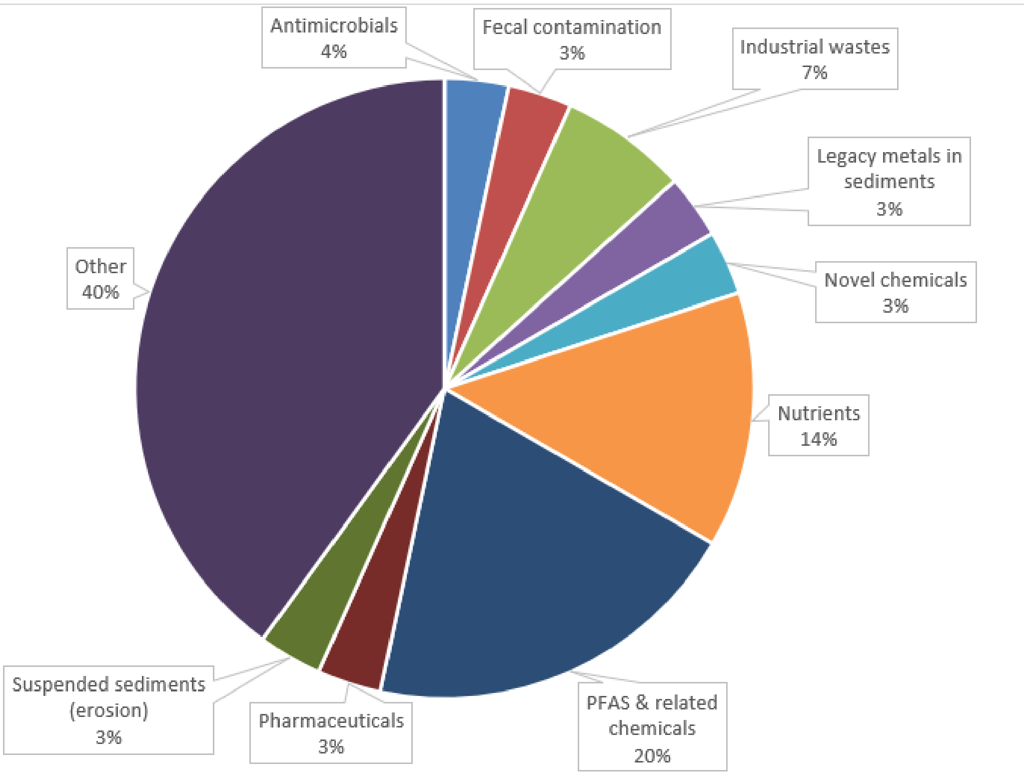

Figure 4 Stakeholders' responses to survey Question 17 "*What are the contaminants you are concerned about or managing with respect to water quality*?". *n* = 30 respondents.

Twelve respondents (40% of respondents) answered 'Other' (Figure 4). Having selected this option, these respondents then had the opportunity to elaborate on their answer by providing written text. Eleven respondents used the written text to list multiple CECs from the categories already provided in the question. This suggests that for some stakeholders, several CECs have equal priority ranking in terms of professional concern or importance to their roles. It also suggests that the survey had identified CECs of most interest to stakeholders and that end users are dealing with mixtures of chemicals in their jurisdictions, with currently unknown interactive, additive or multiplicative effects.

Some of the 12 respondents who answered 'Other' used the opportunity to provide written text to identify the following new CEC categories:

- Litter
- Pathogens
- EDCs[5]
- Dissolved and particulate metals. Note that this is different to the 'Legacy metals in sediments' response option that the respondent could have selected
- PPCPs[6]. Note that this is different to the more restricted 'Pharmaceuticals' response option that the respondent could have selected

Survey Question 22 asked stakeholders to indicate the load levels of different CEC categories entering waterways, from high load (1) to low load (4), with (5) for 'unsure/don't know'. Note that this question was not asking respondents to *compare* the loads of different CECs, but rather to indicate *how much* of each CEC they felt was entering the environment.

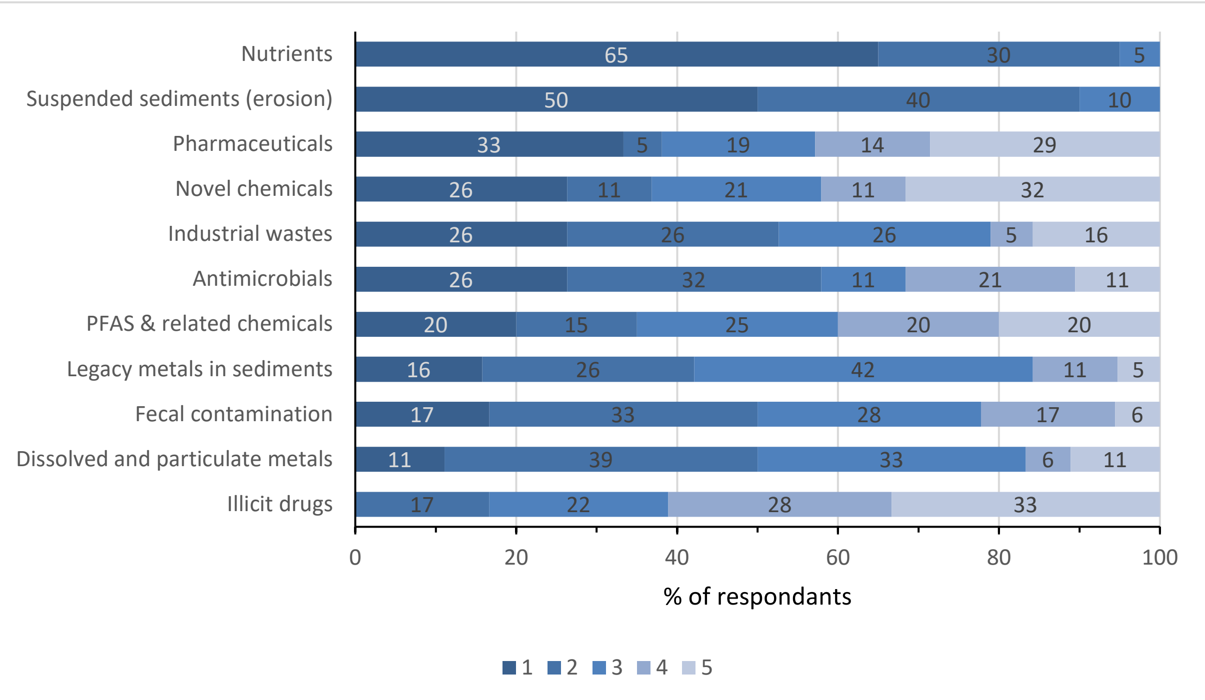

Figure 5 Stakeholders' assessment of CEC loads to waterways (Question 22). Ranks were from 1 (high load) to 4 (lowest load), with a score of 5 for 'unsure/don't know'. Numbers indicate the percentage of respondents that chose a particular load ranking for each CEC category. *n* = 18-21 respondents depending on CEC category, as some respondents did not assess all CECs.

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[5] We understand this to refer to Endocrine Disrupting Chemicals.

[6] We understand this to refer to Pharmaceuticals and Personal Care Products.

Of the stakeholders who answered Question 22, a respective 65% and 50% of respondents felt that nutrients and suspended sediments had high loads (rank 1; Figure 5). The same proportion of respondents identified that these CECs posed high levels of risk to marine environments (Figure 6). These responses likely reflect the fact that these CECs are relatively well studied, and that a large body of literature exists regarding their sources and effects on biological systems.

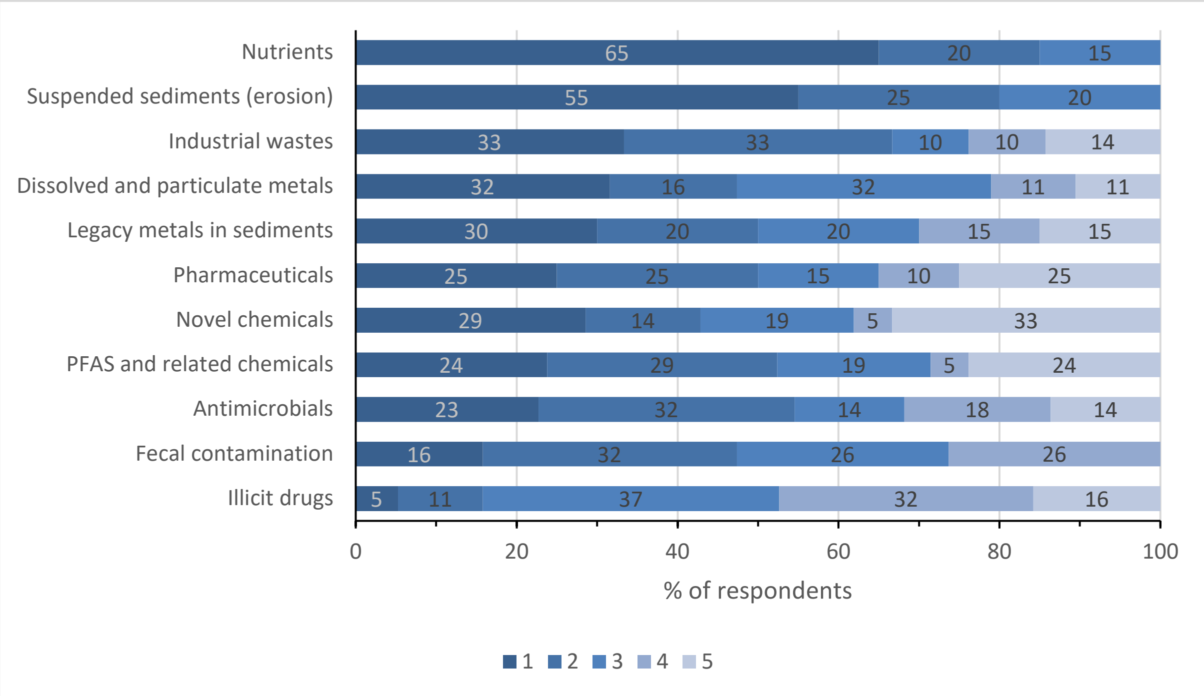

Figure 6 Stakeholders' assessment of the ecological threat posed by CEC categories (survey Question 23). Ranks were from 1 (high threat) to 4 (low threat), with a rank of 5 for 'unsure/don't know'. Numbers indicate the percentage of respondents that chose a particular threat ranking for each CEC category. *n* = 19-22 respondents depending on CEC category, as some respondents did not assess all CECs.

Conversely, approximately 30% of respondents were uncertain (rank 5; Figure 5) about the loads of pharmaceuticals and novel chemicals entering marine environments. Despite this, 25-59% of respondents felt that these CECs posed a high level (rank 1; Figure 6) of ecological risk.

3.4.3 Which CEC sources are important to stakeholders?

There are many sources of CECs to the marine environment, and these may vary across regions. As a reflection of this, one DCCEEW stakeholder advised that comprehensive environmental sampling of CECs should gather a cross-section of types of land-use catchments.

To further identify CEC sources, Question 19 of the stakeholder survey asked respondents to identify sources of the CECs that they were concerned about, or managing in their professional roles. This was an open-ended question that required respondents to type their responses. For stakeholders that listed a single CEC that they were concerned about or managing for Question 17 (see Section 3.4.2), the point sources they listed in Question 19 could clearly be linked to a specific CEC category. This enabled us to summarise the stakeholder-identified point sources for specific CECs in Table 2.

Since the 12 stakeholders who selected 'Other' in Question 17 (see Section 3.4.2) listed multiple CECs, we are unable to link the point sources they identified in Question 19 to a specific CEC. Instead, we have visually presented their responses in Figure 7. Their responses aligned with those presented in Table 2, and emphasised the following point sources:

- Water from treatment plants, including wastewater treatment plants and 'CWMs[7]', desalination plants, and sewage and septic tanks
- Surface water runoff, particularly from agricultural activities (mentioned by 2 stakeholders)

One stakeholder identified aquaculture as a point source. However, as noted in section 2.1.1, water-based activities related to aquaculture lie outside the scope of this Project.

Regarding surface runoff, some stakeholders consider plastic debris and litter to be indicative of other CECs, and refer to debris and litter as a 'gateway contaminant'. Question 18 of the survey asked respondents whether plastic debris can be used as such an indicator: an overwhelming 75% of respondents agreed.

Despite survey respondents listing several point sources, five stakeholders identified later in the survey that CEC sources are a key knowledge gap (see section 3.4.4). This discrepancy could indicate that stakeholders have difficulty identifying all point sources, or the relative importance of several point sources, for a particular CEC.

[7] We understand this to refer to Community Management Wastewater systems.

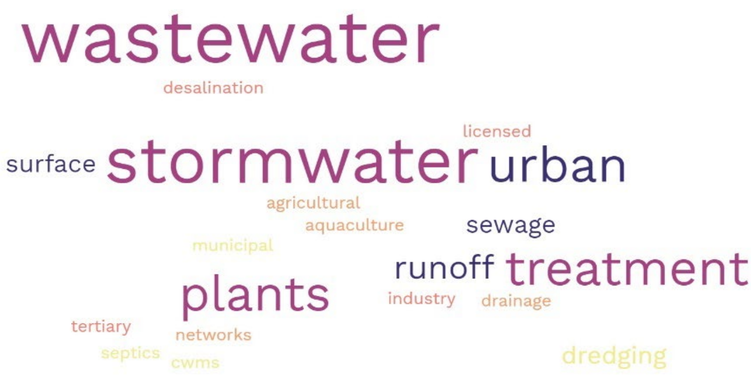

Figure 7 A word cloud generated from the responses of stakeholders who listed general point sources for CECs.

Table 2 A summary of stakeholder-identified point sources of waterborne CECs. To link stakeholder-identified sources with a specific CEC, only the results from respondents that selected a specific CEC category in Question 17 are presented here. *n* = 14 respondents. Note that respondents did not identify any point sources for faecal contamination.

CEC Category[8]	Stakeholder-identified Point Sources						
	Urban waste streams	Moving & extractive industries	Disturbance of bottom sediments	Drinking water catchments	WWTPs	Surface run off	Biosolids
Antimicrobials	□ 1 respondent						
Faecal contamination							
Industrial wastes		□ 1 respondent					
Legacy metals in sediment			□ 1 respondent				
Novel chemicals				□ 1 respondent			

[8] Possible response categories provided in Question 17 of the stakeholder survey.

Nutrients					□ 1 respondent	□ 3 respondents	
PFAS & related chemicals	□ 1 respondent					□ 2 respondents	□ 1 respondent
Pharmaceuticals					□ 1 respondent		
Suspended Sediments						□ 1 respondent	

3.4.4 Gap analysis of CEC knowledge in Australia

The stakeholder survey asked respondents to prioritise a selection of research topics by indicating how critical each topic is to underpin:

- CEC policy and management (survey Question 24), and
- CEC risk assessments (survey Question 25)

Note that these questions asked stakeholders to indicate the importance of each research topic, rather than ranking the topics against each other. Between 17 – 21 stakeholders answered the questions, and the results are presented in Figure 8 and Figure 9.

Additionally, 25 stakeholders answered the open-ended survey Question 20:

"*In your opinion, what are the main gaps in our understanding of the impacts of contaminants in the environment?*"

Respondents' open-ended answers were qualitatively assessed and combined with the results in Figure 8 and Figure 9. We grouped the main themes for knowledge gaps, and discuss these in the subsections, below.

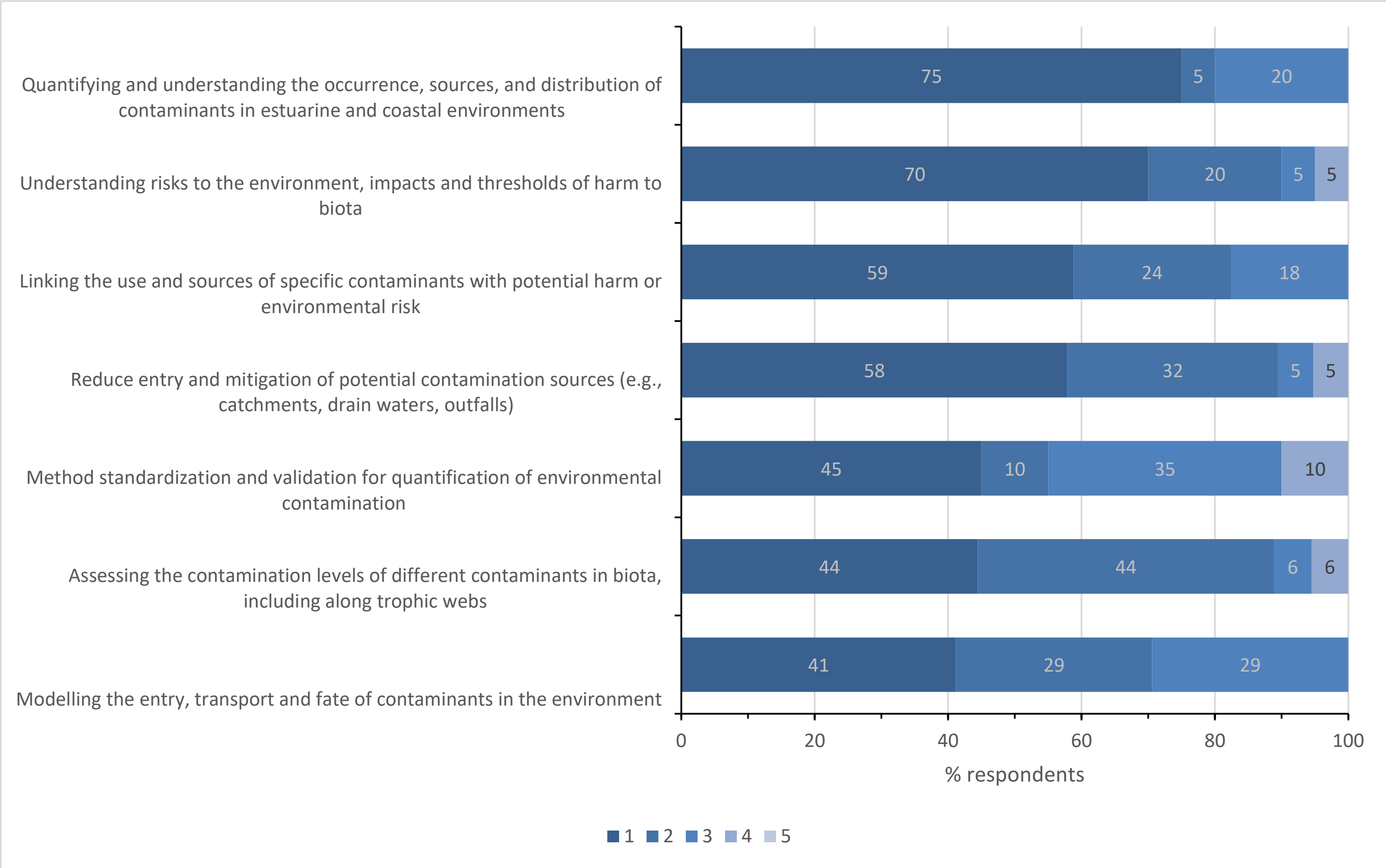

Figure 8 Stakeholders' prioritisation of research topics critical for CEC policy and management. Ranks were from 1 (highest priority) to 4 (lowest priority), with 5 for 'unsure/don't know'. Numbers indicate the percentage of respondents that chose a particular ranking for each topic. *n* = 17-21 respondents depending on research topic, as some respondents did not assess all topics.

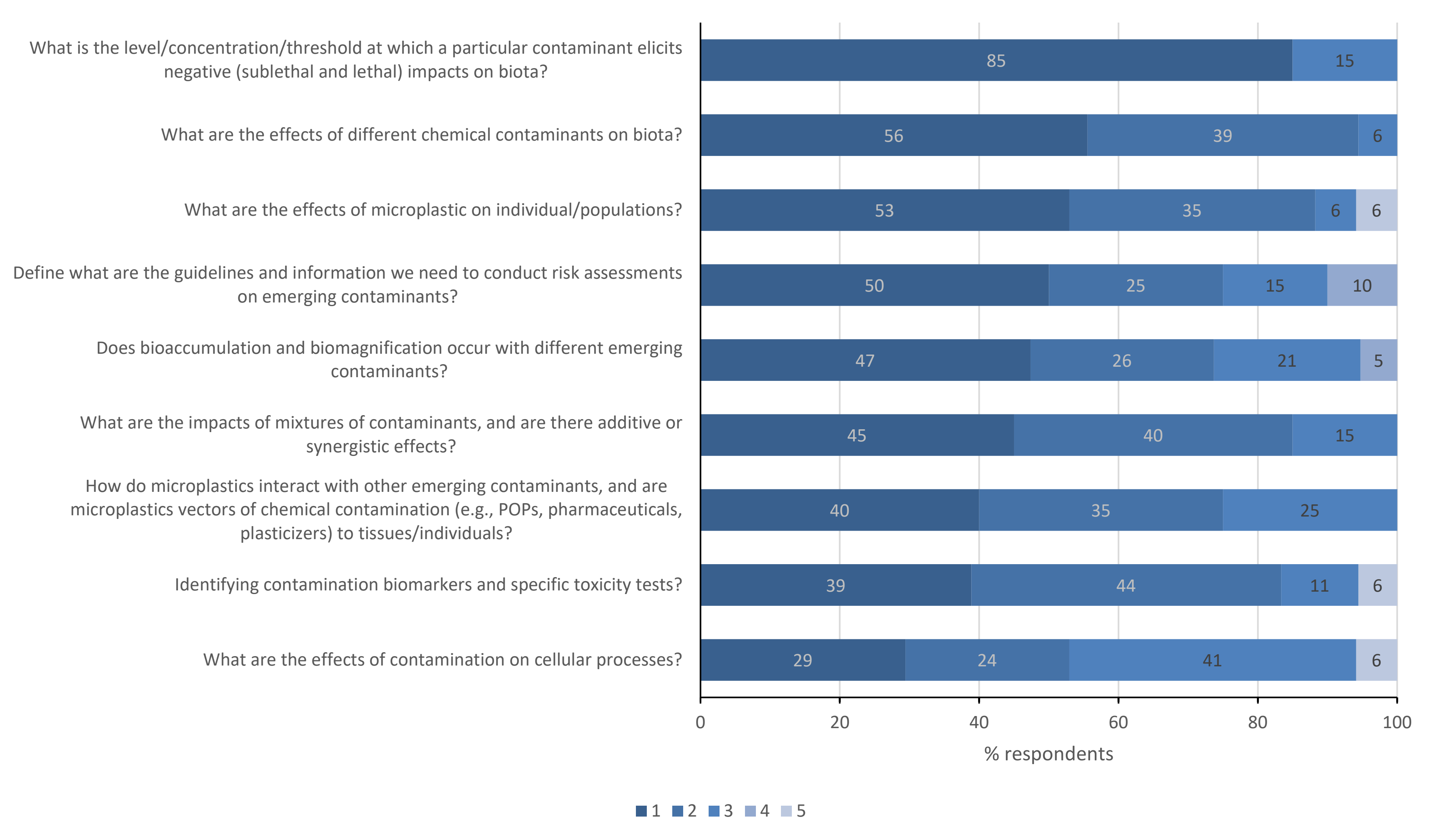

Figure 9 Stakeholders' prioritisation of research topics critical for CEC risk assessments. Ranks were from 1 (highest priority) to 4 (lowest priority), with a score of 5 for 'unsure/don't know'. Numbers indicate the percentage of respondents that chose a particular ranking for each topic. *n* = 17-20 respondents depending on research topics, as some respondents did not assess all topics

Knowledge gap 1 – Identify CEC sources and fate in marine environments

Seventy-five per cent of respondents identified that quantifying the occurrence, sources and distribution of CECs was of the highest research priority (rank 1; Figure 8). This research need was also reflected in the open-ended Question 20, where five stakeholders advised that there was little information about the sources of CECs. One respondent's answer related specifically to reefs, stating "*We have little understanding of how they* [CECs] *enter the Reef, how they disperse*…"

In addition to identifying sources, stakeholders felt that there was little understanding of how CECs behave in the environment. One stakeholder specified that a key knowledge gap was "*mechanisms for their* [CECs] *movement between mediums (between air, soil, biota, groundwater, and surface water)*", and how biotic and abiotic conditions "…*effect rate of movement, concentration and speciation of contaminants.*"

Another stakeholder specified that the "*actual pathways from source to sensitive receptors*…" is a knowledge gap for CECs. This ties in closely with concepts of CEC movement and bioavailability in the environment, whilst also emphasising the need to link such scientific knowledge to the hazard the CEC poses to sensitive species or ecosystems (receptors).

These knowledge gaps can potentially be addressed with models, and 41% of respondents said that modelling the entry, transport and fate of CECs in the environment ranked as a high research priority (rank 1; Figure 8).

Summary

Under this knowledge gap theme, stakeholders discussed the need to:

- Identify CEC sources and movement in the environment,
- Understand influences on CEC behaviour and bioavailability, and
- Identify CEC exposure pathways.

Knowledge gap 2 – Quantifying & monitoring CECs in the marine environment

Of the respondents that answered survey Question 23, 55% said that validating and standardising methods for the quantification of CECs in environmental samples ranked as a first or second tier research priority (Figure 8). This theme was echoed in the open-ended Question 20, where stakeholders articulated the need for "…*accurate quantification of concentration and abundance*" of CECs in the environment.

Additionally, stakeholders noted a "*lack of consistent monitoring*" of CECs in the environment and articulated the need for a "…*reliable monitoring method*". Whilst these comments relate to CEC monitoring in a general sense, issues of consistency and reliability were raised during the stakeholder webinar in relation to the use of citizen science to quantify CECs (discussed below).

Stakeholders identified that monitoring CECs in the environment is the preliminary step to understanding their ecological effects. One survey respondent said that CEC monitoring would facilitate the assessment of "*(a)ctual impact at environmentally relevant levels*" (mentioned by 1 stakeholder) and CEC bioaccumulation (mentioned by 1 stakeholder). Additionally, quantifying CECs in the environment may help address what one stakeholder described as "…*a lot of hysteria around these new* emerging contaminates".

Summary

Under this knowledge gap theme, stakeholders discussed the need to:

- Develop methods to quantify CECs in environmental samples, and
- Reliably quantify and monitor CECs in the environment.

Citizen science & the importance of reliability

During the stakeholder webinar, a debate ensued about whether citizen science projects can assist scientists and policy quantifying CECs in the environment. This discussion centred around quantifying microplastics, but we feel the learnings from this discussion are applicable to a range of CECs.

A representative of the Port Phillip Bay EcoCentre felt that citizen science projects are a critical precursor to securing investment for subsequent, detailed scientific CEC quantification. In response, an academic researcher debated whether citizen science projects create reliable data, and highlighted that citizens need to be trained in, and apply, appropriate methodologies to generate reliable data. This debate reflects a wider discourse about the utility of citizen science projects. Whilst each citizen science project will differ depending on the nature of the project, applying guiding principles (Kelly et al., 2020) may enhance the quality of data these projects generate.

Knowledge gap 3 – Determine the ecological effects of CECs

Three stakeholders raised the need to understand the effects of chronic, long-term CEC exposures. Several stakeholders also mentioned that "…*cumulative impacts to oceans, waterways and wetlands*" should be researched. These cumulative impacts refer to the "…*impacts of* [chemical] *mixtures*…", as well as the cumulative impacts of CECs and abiotic stresses. Regarding cumulative impacts, one stakeholder asked:

"how do contaminants influence resilience and capacity of marine communities to tolerate other stressors"?

Whilst a second stakeholder suggested a potential solution:

> "*We don't have an integrated systems approach/understanding for how contaminant mixtures impact biota at all levels of biological organisation*".

We note here that in their articulation of knowledge gaps around cumulative impacts, both stakeholders are inherently focussed on understanding how CECs in real environments affect higher levels of biological organisation.

The need to understand how CECs affect higher levels of biological organisation was expressed by several other stakeholders. One stakeholder described the knowledge gap as:

"…*whole of ecosystem impacts vs individual sp*."

- NGO Researcher, 10-20 years' experience

Summary

Under this knowledge gap theme, stakeholders discussed the need to understand:

- Chronic and cumulative effects of CECs,
- The effects of CEC mixtures, and
- Responses at higher levels of biological organisation.

Knowledge gap 4 – Quantifying the risk of CECs

Stakeholders identified that it is currently difficult to prioritise CECs, with one researcher stating that there is a:

"*Near infinite number of organic contaminants (considering both the larger number of chemicals in use, and all of their transformation products) - how do we prioritise the ones we need to look at?*"

- Academic researcher, >20 years' experience; extensive CEC knowledge.

One way in which CECs can be prioritised is through using toxicity thresholds, which can help managers identify and target CECs that have the potential to cause most harm. However, since such thresholds do not exist, it is unsurprising that 85% of survey respondents ranked the development of lethal and sub-lethal CEC thresholds as a high priority (rank 1; Figure 9). This theme was articulated in the open-ended responses, with stakeholders calling for "*clearly articulated limits*", and "*[t]hresholds which if exceeded are a concern*."

Finally, stakeholders identified that there are no guidelines to assist them to quantify the risk CECs pose. One policy officer suggested there is a:

"*Lack of a consistent methodological approach to quantifying the risk…*"

- Environmental Policy officer, Industry, 2-5 years' experience; extensive CEC knowledge

Summary

Under this knowledge gap theme, stakeholders discussed the need to:

- Prioritise CECs,
- Develop toxicity thresholds, and
- Create a consistent approach to quantifying risk.

4 Conclusions & recommendations

Several Commonwealth policy documents, including the *One Health Master Action Plan for Australia's National Antimicrobial Resistance Strategy* and the *PFAS National Environmental Management Plan 2.0,* refer to the need to establish environmental CECs baselines to support CEC polices and management.

Whilst some Australian and international CEC databases exist, they are often incomplete and focus primarily on CECs in freshwater environments. These databases can, however, be adapted to incorporate marine CEC data when it becomes available.

Wastewater treatment plants are seen as a major source of CECs to the marine environment. The National Outfalls Database collates water quality information for an extensive number of Australian wastewater treatment plants; however, it contains data for only a limited number of contaminants. Further, there are inconsistent CEC reporting requirements between Australian jurisdictions.

There is limited data on the occurrence and ecotoxicity of many CECs. Scientific studies have documented the effects of CECs at the physiological and organism levels, however there are few studies that translate these effects to the ecological or ecosystem level. This knowledge gap hampers CEC risk assessments and reduces stakeholders' abilities to prioritise CEC management efforts.

There is a clear and consistent need to generate more data related to the environmental concentrations of CECs, and an assessment of their ecological impacts. We recommend that these knowledge gaps be addressed through a combination of desktop, laboratory and field-based studies (summarised in Table 3).

Desktop research could be used to:

1) Conduct a CEC prioritisation process for Australian regions. This may include chemicals identified by stakeholders in this project, such as antimicrobials and PFAS

2) Adapt existing freshwater databases, such as the ECHIDNA Database and the National Outfalls Database, for application to marine environments

3) Leverage existing methods for risk ranking CECs by identifying what empirical data is needed to facilitate the application of existing risk methods for CECs and CEC mixtures

Laboratory studies could be used to:

4) Developing standards for biomarker approaches which allow CEC effects to be assessed on marine organisms at various levels of biological organisation, including individual, population, and community levels

5) Use standard biomarker approaches to bridge the gap between laboratory studies and natural ecosystems

Recommendations 1 – 4 (above) should be supported by field work that:

6) Develops standardised sampling and analytical methodology for CECs in diverse marine environments alongside ecological assessments

7) Generates empirical data to establish CEC baselines in marine environments, which will then contribute to enhancing CEC databases (recommendation 1) and conducting risk assessments (recommendation 2)

Table 3 Summary of recommendations to address the identified knowledge gaps in Australia's management of marine CECs.

Research method	Recommendation	Contaminant of Emerging Concern			
		Nutrients	Chemicals	Antimicrobials	Microplastics
Desktop	(1) Conduct a CEC prioritisation process for Australian regions.	☐	☐	☐	☐
	(2) Adapt existing freshwater databases for marine environments.		☐	☐	☐
	(3) Identify empirical data gaps preventing the adoption of existing risk ranking methods for CECs and CEC mixtures.		☐	☐	
Laboratory	(4) Develop standard for biomarkers to assess effects on marine individuals, populations, and communities.		☐	☐	☐
	(5) Bridge the gap between laboratory studies vs natural ecosystems.	☐	☐	☐	☐
Field work	(6) Develop standardised CEC sampling and analytical methodology.	☐	☐	☐	☐
	(7) Generate CEC baselines for marine environments, with a focus on regional and seasonal differences.	☐	☐	☐	☐

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Appendix A

The following organisations were engaged during the project through direct contact, one-to-one meetings, and the DCCEEW scoping workshop.

SECTOR	ORGANISATION ENGAGED
GOVERNMENT	• DCCEEW – Policy Advice and Integration Section of the Chemicals Management Branch. • DCCEEW – Environmental Contamination, Advice and Standards Section of the Chemicals Management Branch. • DCCEEW - Plastics and Packaging Section of the Waste Policy and Planning Branch • Plastics and Packaging Section of the Waste Policy and Planning Branch. • DCCEEW NESP Liaison Officer. • Marine Parks (Norfolk Island) • NSW Department of Planning, Industry & Environment – Science, Economics, & Insights Division. • NSW Department of Planning, Industry & Environment – Marine Debris Threat and Risk Assessment project team
RESEARCH	• NESP Marine and Coastal Hub Leader • NESP Marine and Coastal Hub Knowledge Broker • Water Research Australia • Clean Ocean Foundation • NESP 1.18 Microplastics project team • ECHIDNA Database researchers • Aquatic Animal Health Subcommittee (Fisheries Research & Development Corporation)
SYMPOSIA	• ECHIDNA webinar • Antimicrobial resistance summit

Appendix B

This Appendix contains the questions and response options of the online stakeholder survey.

SECTION 1 - Demographics

Question 1 – Type of Position [Multiple choice]:

- Academic;
- Consultant;
- Government Agency - Federal;
- Government Agency - State;
- Industry,
- Non-Governmental Organisation,
- Other________________

Question 2 – Primary role [Multiple choice]:

- Consultant;
- Environmental Policy;
- Natural Resource Management;
- Research;
- Water Services and Quality;
- Other________________

Question 3 – How many years of experience do you have dealing with microplastics and other water quality issues including other contaminants (e.g., antimicrobials, pharmaceuticals, industrial chemicals) [Multiple choice]:

- Less than 2 years;
- 2 to 5 years;
- 5 to 10 years;
- 10 to 20 years;
- more than 20 years

Question 4 – What geographic regions does your role or research cover [Multiple choice]:

- ACT;
- Australia-wide;
- International;
- New South Wales;
- Northern Territory;
- Queensland;
- South Australia;
- Tasmania;
- Victoria;
- Western Australia

Question 5 – Which area are you most interested and/or have expertise on [Multiple choice]:

- Microplastics
- Water quality and other emerging contaminants (e.g., antimicrobials, industrial chemicals)
- Both

[The next question, and sections on Major Issues and Ranking for Microplastics (in blue) and other emerging contaminants (in grey), will appear according to the answer to the above question]

Question 6 – Please indicate what best describes your knowledge and experience in microplastics [Multiple choice]:

- I have extensive work/research experience in microplastics;
- I have some work/research experience in microplastics;
- I have a general understanding of the issues surrounding microplastics in the environment,
- I have little or no knowledge of the issues surrounding microplastics in the environment;
- Other________________

Question 7 – Please indicate what best describes your knowledge and experience in other emerging contaminants (e.g., chemicals, pharmaceuticals, antimicrobials, pesticides) [Multiple choice]:

- I have extensive work/research experience in emerging contaminants;
- I have some work/research experience in emerging contaminants;
- I have a general understanding of the issues surrounding emerging contaminants in the environment,
- I have little or no knowledge of the issues surrounding emerging contaminants in the environment;
- Other________________

SECTION 2 [Microplastics] – Identifying major issues

Question 8 – Please indicate up to 5 main sources you think are contributing to the presence of microplastics in coastal environments?

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Question 9 – Please indicate if, in your opinion, if microplastics in coastal environments are primarily

- from breakdown of larger plastic debris in the environment
- from direct entry of primary forms of microplastics (e.g., microbeads, tyre dust, nurdles, fibres)

Question 10 – In your opinion, which are the main gaps/limitations in our understanding of the impacts of microplastics in the environment?

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Question 11 – In your opinion, what are the short-term (next 5 years) scientific information and research priority needs regarding microplastics in coastal environments to inform management and policy development?

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Section 3 [Microplastics] – Ranking and scoring main issues

In this section, please rank each of options using the 1 to 4 scale below, where 1 is the highest importance and 4 the lowest importance. Use 5 for unsure/don't know or not applicable.

RANKING ORDER

1 – Highly important, OR highly important, critical research priority, OR critical need/gap to inform management and policy development.

2 – Important, OR important but not crucial primary research priority, OR important need/gap but not the top priority needed to inform management and policy development

3 – Relevant, OR interesting research foci but not a priority, OR interesting need/gap to address but not key to inform management and policy development

4 – Unimportant, OR trivial and not relevant research foci, OR not an important need/gap to inform management and policy development

5 – Unsure/don't know

Question 12 – How would you rank the importance of these potential sources and pathways in terms of microplastic loads entering coastal environments:

[from highest (1) to lowest (4), with (5) for unsure/don't know]

- Derelict fishing gear
- Degradation and breakdown of land based plastic debris
- Microfibres from synthetic textiles
- Personal care, cosmetic and domestic products
- Tyre wear
- Waste water outflows (Primary/secondary treatment)
- Waste water outflows (Tertiary treatment)
- Biosolids
- Stormwater, drainwater and untreated outflows
- Industrial primary plastics (e.g., Pellets, nurdles)
- Runoff and input from catchments
- Others (Please specify) _________

Question 13 – How would you rank theses potential sources and pathways with respect to their threat to ecological communities?

[from highest (1) to lowest (4), with (5) for unsure/don't know]

- Derelict fishing gear
- Degradation and breakdown of land based plastic debris
- Microfibres from synthetic textiles
- Personal care, cosmetic and domestic products
- Tyre wear
- Waste water outflows (Primary/secondary treatment)
- Waste water outflows (Tertiary treatment)
- Biosolids
- Stormwater, Drainwater and untreated outflows
- Industrial primary plastics (e.g., Pellets, nurdles)
- Runoff and input from catchments
- Others (Please specify) _________

Question 14 – Of the broad research areas indicated below, which in your opinion are most critical to be undertaken to underpin management and policy options?

[from highest (1) to lowest (4) priority, with (5) for unsure/don't know]

- Quantifying and understanding the occurrence, sources, and distribution of microplastics in coastal environments
- Assessing the occurrence or ingestion of microplastic in biota, including along trophic webs
- Understanding risks to the environment, impacts and thresholds of harm to biota
- Modelling the entry, transport and distribution of microplastics in the environment
- Linking the use and sources of specific microplastics with potential harm or environmental risk
- Method standardization and validation for microplastic assessments
- Reduce entry and capture of microplastics in potential sources (e.g., catchments, drainwaters, outfalls)

Question 15 – Regarding methodological procedures, which in your opinion are the most critical issues and needs for development?

[from highest (1) to lowest (4) priority, with (5) for unsure/don't know]

- Identifying the best methods for sampling and reporting of microplastics in different environmental compartments and biota?
- Defining a standardised and validated method for the assessment of microplastics in coastal and marine environments, including validation, quality assurance and control?
- Developing high-throughput methods for separation, quantification and characterization of microplastics
- Improve the validation of polymers, and respective microplastic libraries, for the effective characterisation of microplastics and reconstructing contamination sources and pathways
- Harmonising citizen science tools to contribute to broad scale data collection
- Identifying and quantifying chemical compounds in microplastics

Question 16 – Regarding risks to the environment and scale of harm of microplastics, which in your opinion are the most critical questions and needs for development?

[from highest (1) to lowest (4) priority, with (5) for unsure/don't know]

- What are the effects of different polymer types on biota?
- What are the effects of fibres from synthetic textiles to biota?
- What is the level/concentration/threshold at which a particular type of microplastic elicits negative physical (sublethal and lethal) impacts on biota?
- What is the level/concentration/threshold at which a particular type of microplastic elicits negative chemical (sublethal and lethal) impacts on biota?
- Identifying microplastic contamination biomarkers and specific toxicity tests
- What are the physical effects of microplastic on cellular processes?
- What are the chemical effects of microplastic on cellular processes?
- What are the physical effects of microplastic on individual/populations?
- What are the physical effects of microplastic on individual/populations?
- Does bioaccumulation and biomagnification occur and potentially exacerbate impacts of microplastics?
- Are microplastics key vectors of chemical contamination (e.g., POPs, pharmaceuticals, plasticizers) to tissues/individuals?
- Can we disentangle effects of plastic versus secondary effects of chemicals leaching out of them?
- How do gut residence/excretion processes influence potential negative impacts on biota?
- Are microplastics translocating through physiological barriers?
- Define what are the guidelines and information we need to conduct risk assessments on microplastics
- Move primary focus from microplastics to nanoplastics.
- What are the impacts of microplastics on microbial communities, and are microplastics vectors for the introduction of pathogens or invasive species
- How do microplastics interact with other emerging contaminants in the environment?

SECTION 2 [Water Quality & Emerging Contaminants] – Identifying major issues

Question 17 – What are the contaminants you are concerned about or managing with respect to water quality? [Multiple choice]:

- Nutrients
- Suspended sediments (erosion)
- Fecal contamination
- Antimicrobials
- Legacy metals in sediments
- Dissolved and particulate metals
- Pharmaceuticals
- Illicit drugs
- Industrial wastes
- Novel chemicals
- PFAS and related chemicals
- Other (please name)

Question 18 – Plastic/debris/litter is being described as a 'gateway' contaminant to estuaries and coastal waters. In other words, its entry into waterways via stormwater (surface runoff) is considered an indicator of the presence of other contaminants. Do you agree?

- Yes
- No
- Don't know.

Question 19 – For each contaminant, please indicate if contaminants are primarily from

- Surface runoff from catchments
- Urban stormwater
- Water treatment plants (primary treatment)
- Water treatment plants (secondary treatment)
- Water treatment plants (tertiary treatment)
- Regulated discharges
- Spills from ships
- All of the above
- Other (please elaborate)

Question 20 – In your opinion, what are the main gaps in our understanding of the impacts of contaminants in the environment?

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Question 21 – In your opinion, what are the information and research needs regarding contaminants, to inform policy and management?

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Section 3 [Water Quality & Emerging Contaminants] – Ranking and scoring main issues

In this section, please rank each of options using the 1 to 4 scale below, where 1 is the highest importance and 4 the lowest importance. Use 5 for unsure/don't know or not applicable.

RANKING ORDER

1 – Highly important, OR highly important, critical research priority, OR critical need/gap to inform management and policy development.

2 – Important, OR important but not crucial primary research priority, OR important need/gap but not the top priority needed to inform management and policy development

3 – Relevant, OR interesting research foci but not a priority, OR interesting need/gap to address but not key to inform management and policy development

4 – Unimportant, OR trivial and not relevant research foci, OR not an important need/gap to inform management and policy development

5 – Unsure/don't know

Question 22 – How would you rank these contaminants in terms of their load entering aquatic waterways? [from highest (1) to lowest (4), with (5) for unsure/don't know]

- -Nutrients
- Suspended sediments (erosion)
- Fecal contamination
- Antimicrobials
- Legacy metals in sediments
- Dissolved and particulate metals
- Pharmaceuticals
- Illicit drugs
- Industrial wastes
- Novel chemicals
- PFAS and related chemicals
- Others (Please specify) _________

Question 23 – How would you rank these contaminants with respect to their threat to ecological communities?

[from highest (1) to lowest (4), with (5) for unsure/don’t know]

- -Nutrients
- Suspended sediments (erosion)
- Faecal contamination
- Antimicrobials
- Legacy metals in sediments
- Dissolved and particulate metals
- Pharmaceuticals
- Illicit drugs
- Industrial wastes
- Novel chemicals
- PFAS and related chemicals
- Others (Please specify) _________

Question 24 – Of the broad research areas indicated below, which in your opinion are most critical to be undertaken to underpin management and policy options?

[from highest (1) to lowest (4) priority, with (5) for unsure/don’t know]

- Quantifying and understanding the occurrence, sources, and distribution of contaminants in estuarine and coastal environments
- Assessing the contamination levels of different contaminants in biota, including along trophic webs
- Understanding risks to the environment, impacts and thresholds of harm to biota
- Modelling the entry, transport and fate of contaminants in the environment
- Linking the use and sources of specific contaminants with potential harm or environmental risk
- Method standardization and validation for quantification of environmental contamination
- Reduce entry and mitigation of potential contamination sources (e.g., catchments, drain waters, outfalls)

Question 25 – Regarding risks to the environment and scale of harm of chemical contaminants, which in your opinion are the most critical questions and needs for development?

[from highest (1) to lowest (4) priority, with (5) for unsure/don’t know]

- What are the effects of different chemical contaminants on biota?
- What is the level/concentration/threshold at which a particular contaminant elicits negative (sublethal and lethal) impacts on biota?
- Identifying contamination biomarkers and specific toxicity tests?
- What are the effects of contamination on cellular processes?
- What are the effects of microplastic on individual/populations?
- Does bioaccumulation and biomagnification occur with different emerging contaminants?
- How do microplastics interact with other emerging contaminants, and are microplastics vectors of chemical contamination (e.g., POPs, pharmaceuticals, plasticizers) to tissues/individuals?
- Define what are the guidelines and information we need to conduct risk assessments on emerging contaminants?
- What are the impacts of mixtures of contaminants, and are there additive or synergistic effects

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