2022 Scientific Consensus Statement | Conclusions

Land-based impacts on Great Barrier Reef water quality and ecosystem condition

Waterhouse J, Pineda M-C, Sambrook K, Newlands M, McKenzie L, Davis A, Pearson R, Fabricius K, Lewis S, Uthicke S, Bainbridge Z, Collier C, Adame F, Prosser I, Wilkinson S, Bartley R, Brooks A, Robson B, Diaz-Pulido G, Reyes C, Caballes C, Burford M, Thorburn P, Weber T, Waltham N, Star M, Negri A, Warne M St J, Templeman S, Silburn M, Chariton A, Coggan A, Murray-Prior R, Schultz T, Espinoza T, Burns C, Gordon I, Devlin M

Citation

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(Authors ordered based on Question number within the 2022 Scientific Consensus Statement)

The 2022 Scientific Consensus Statement was led and coordinated by C_2O Consulting coasts | climate | oceans.

Report design: Katie Sambrook

Cover image: Mulgrave-Russell River in flood, North Queensland.
Photo credit: Dieter Tracey

Yunbenun (Magnetic Island)
Photo: Matt Curnock

Australia's Chief Scientist | Statement of Assurance

Dr Cathy Foley, Australia's Chief Scientist, was tasked in 2021 by the Prime Minister to provide quality assurance and oversight for the development of the *2022 Scientific Consensus Statement on Land-Based Impacts on Great Barrier Reef Water Quality and Ecosystem Condition* (2021–2024).

The role of the Chief Scientist was to identify, recommend and support process enhancements that would increase transparency, accountability and confidence in the findings and conclusions of the 2022 Scientific Consensus Statement, to build on the continuous improvements applied to successive Scientific Consensus Statements since their commencement in 2002.

Australia's Chief Scientist provided advice and made several recommendations to enhance the 2022 Scientific Consensus Statement process, through strengthened processes to manage conflicts of interest through the engagement of an external probity advisor and providing guidance on the development of the peer review process including appointment of Editorial Board members and eminent reviewers. For the five major process steps in the development of the 2022 Scientific Consensus Statement, Australia's Chief Scientist concluded:

- **Question Setting:** The approach to question-setting was iterative and inclusive. The consultation process involved more than 70 stakeholders, Traditional Owner groups and end users from a range of organisations and industries. This ensured the final list of questions was broadly supported and as a result was relevant to non-government stakeholders, experts, policy makers and managers.
- **Author Selection:** The approach to author selection was transparent and robust and achieved the objectives of minimising bias and avoiding real or perceived conflicts of interest.
- **Methods Development:** The approach to the methods development was objective and transparent and took account of multiple lines of evidence and the best available science. There was adequate oversight to evaluate and review the validity and quality of the methods for all stages of the process.
- **Peer Review:** The peer review process was comprehensive and fully transparent, including the process for managing conflicts of interest. An Editorial Board was established to manage the review process. The editorial process involved contributions from 69 external reviewers from Australia and overseas to ensure the outputs were rigorous and credible.
- **Consensus Process:** Best practice methods were used for the consensus process and developed in an objective and transparent manner, taking account of multiple lines of evidence and including the best available science which contributed to the quality and integrity of the process. There was adequate oversight to evaluate and review the validity and quality of the 2022 Scientific Consensus Statement.

The *2022 Scientific Consensus Statement on Land-Based impacts on Great Barrier Reef Water Quality and Ecosystem Condition* is an exemplar of the academic methods for reaching scientific consensus. The public can trust the processes used to develop the 2022 Scientific Consensus Statement, and the conclusions can be relied upon and trusted to inform decision-making.

Reef Water Quality Independent Science Panel Remarks

The Independent Science Panel was established in 2009 to provide multidisciplinary scientific advice to the Australian and Queensland governments on the implementation of the Reef Water Quality Protection Plan. In this role, the Independent Science Panel has reviewed the 2013, 2017 and 2022 Scientific Consensus Statements.

The 2022 Scientific Consensus Statement is currently the best and most authoritative source of information to support evidence-based decisions for better water quality in the Great Barrier Reef World Heritage Area. The Independent Science Panel endorses the process, findings and conclusions of the updated statement.

The process used to develop the 2022 Scientific Consensus Statement was much more formalised compared to previous iterations. To meet the needs of end users, issues were categorised into 30 questions across eight major themes, with teams of expert authors enlisted to address each question. Structured templates, formal evidence appraisal methods and multiple review processes were used to ensure rigour, quality, transparency, independence and convergence in the outputs. The systematic approach used to assess the literature is novel in the field of environmental management and has proved to be a very effective strategy.

The results show that there is considerable and strong foundational evidence that has not changed since the previous Scientific Consensus Statement, including clear evidence of the impact of anthropogenic land-based runoff on water quality and freshwater, estuarine, coastal and inshore marine ecosystems. This provides greater confidence for managers in the strength of the evidence that underpins the Reef 2050 Water Quality Improvement Plan.

Notable advances from previous Scientific Consensus Statements are greater emphasis on climate change as a pressure and threat, increased analysis of management actions and their potential impacts, and much more focus on social and economic aspects of management as well as factors of success for engaging Traditional Owners in water quality issues. Improving water quality will bolster the resilience of ecosystems against climate change pressures, but scaling up remediation actions and implementing changes to management practices remains challenging.

Knowledge gaps still exist, in particular around potential co-benefits, the economics of changing different management practices, the social drivers that will help adoption of practice changes to improve water quality, and the role that wetlands can play as both an ecosystem asset and a regulating mechanism. While there has been more emphasis on the role of non-agricultural contaminants, this is still a notable data gap.

In summary, the use of a systematic approach to assess literature in the field of environmental management establishes new standards for knowledge synthesis and enhances confidence in the quality of the findings. This Scientific Consensus Statement updates the peer-reviewed knowledge about water quality issues and management options in the Great Barrier Reef and establishes a new reference point for subsequent governance, program design and investment.

Introduction and Process Overview

The 2022 Scientific Consensus Statement on land-based impacts to Great Barrier Reef water quality and ecosystem condition brings together the latest scientific evidence to understand how land-based activities can influence water quality in the Great Barrier Reef, and how these influences can be managed. The Scientific Consensus Statement is used by policymakers as a key evidence-based document for making decisions about managing Great Barrier Reef water quality. In particular, the Scientific Consensus Statement is one of several projects that provides supporting information for the design, delivery and implementation of the Australian and Queensland government's Reef 2050 Water Quality Improvement Plan. The Plan defines objectives and targets related to water quality improvement, identifies spatial management priorities and describes actions for improving the quality of the water that enters the Great Barrier Reef from the adjacent catchment area.

Following stakeholder feedback, the 2022 Scientific Consensus Statement was developed between 2022 and 2024 and included several process changes compared to previous iterations. These changes included demonstrated independence from decision makers in the synthesis and review of the evidence, increased transparency and rigour in the approach to synthesise the evidence base, an assessment of the level of confidence in the findings, greater engagement with end users, stakeholders and other audiences, and more accessible outputs, all underpinned by a set of guiding principles.

The 2022 Scientific Consensus Statement addresses **30 priority questions** that were developed in consultation with scientific experts, policy and management teams and other key stakeholders including representatives from agricultural, tourism, conservation and research organisations, and Traditional Owner groups[1]. The questions are organised into eight Themes: values, condition and drivers of health of the Great Barrier Reef, sediments and particulate nutrients, dissolved nutrients, pesticides, other pollutants, human dimensions of water quality improvements, and emerging science, and cover topics including pollutant distribution and impacts, delivery and source, and management options. The 2022 Scientific Consensus Statement adopted a formal evidence review and synthesis method (covering evidence typically from 1990 until December 2022), with each question led by expert authors and contributors and independently peer reviewed. These syntheses provide the supporting evidence base for the **2022 Scientific Consensus Statement Summary** and **2022 Scientific Consensus Statement Conclusions** (Figure 1).

1 Additional information on question setting, synthesis methods and individual outputs is available from the 2022 Scientific Consensus Statement website.

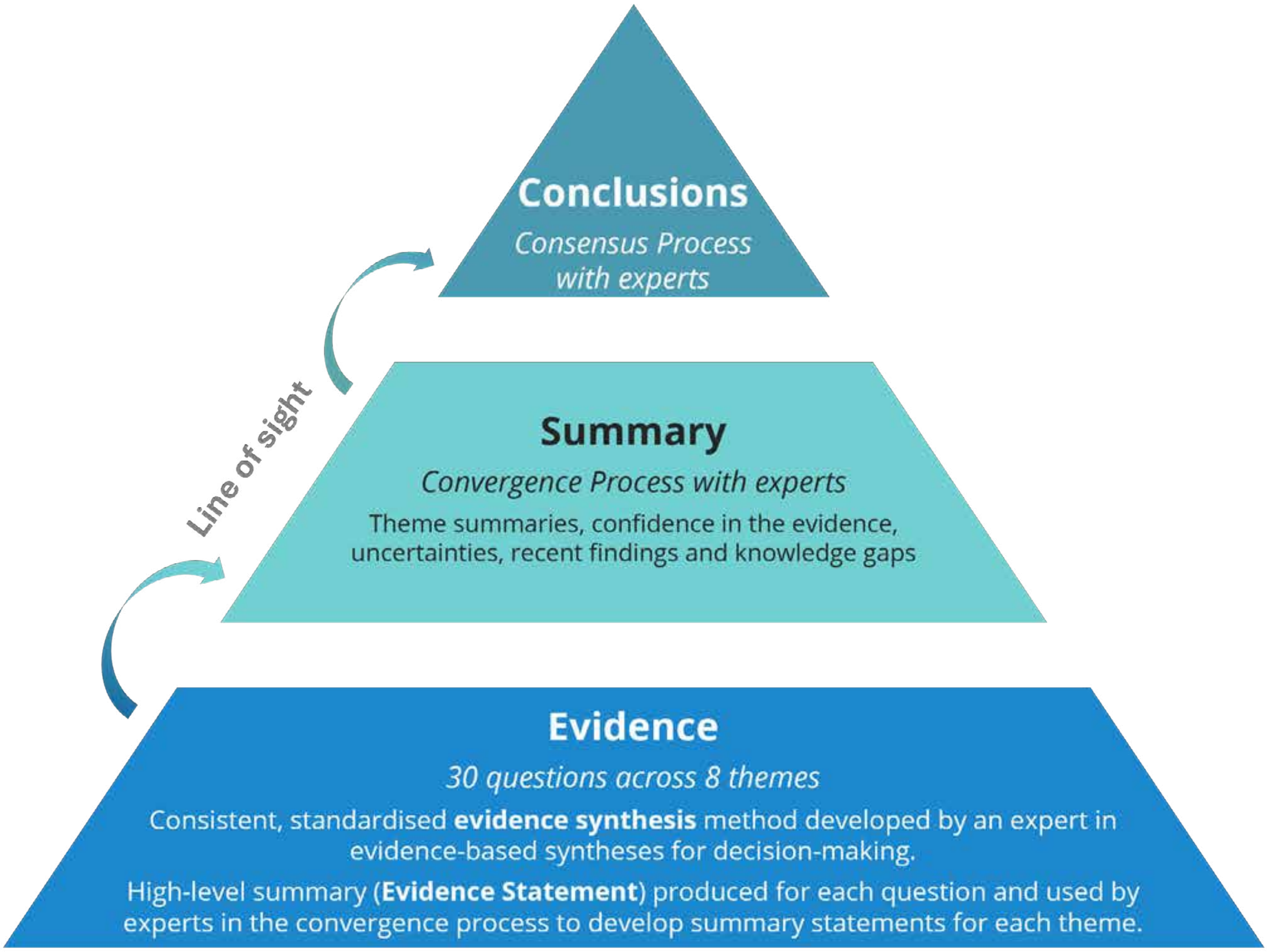


Figure 1. Main outputs and hierarchy of the 2022 Scientific Consensus Statement.

Scientific consensus[2] among experts from multiple research fields and disciplines is extremely important for building confidence in the findings of the 2022 Scientific Consensus Statement for the broad community of policy makers, managers, delivery partners and a wider audience that all hold an interest in water quality outcomes for the Great Barrier Reef. **The Overarching Conclusions and Concluding Statements presented in this document were agreed by 35 experts involved in the 2022 Scientific Consensus Statement consensus process, endorsed by the Reef Water Quality Independent Science Panel (ISP), and reviewed by three independent eminent experts.**

2 The definition of consensus applied for the 2022 Scientific Consensus Statement is: 'A public statement on scientific knowledge on Great Barrier Reef water quality and ecosystem condition, drawn from multiple lines of evidence, that is generally agreed by a representative group of experts. The consensus does not necessarily imply unanimity.'

C2O Consulting coasts|climate|oceans was engaged by the Australian and Queensland governments to coordinate and deliver the 2022 Scientific Consensus Statement. Oversight and assurance was provided by Australia's Chief Scientist. The Reef Water Quality Independent Science Panel (ISP) and the Reef 2050 Independent Expert Panel (IEP) had technical advisory (ISP and IEP) and review roles (ISP only) for specific steps in the process. Policy and management representatives, and stakeholders including the Reef 2050 Advisory Committee (RAC), were kept informed throughout the process.

2022 Scientific Consensus Statement | Overarching Conclusions

1 Historical and continuing land management and catchment modification impair Great Barrier Reef water quality through extensive vegetation degradation, changed hydrology, increased erosion, and expansion of fertilised land uses, urban centres and coastal developments.

2 Pollutant loads from the catchment area to the Great Barrier Reef have increased from pre-development loads by 1.4 to 5 times for fine sediments, and 1.5 to 3 times for dissolved inorganic nitrogen (with variations depending on basins).

3 Poor water quality, particularly elevated levels of fine sediments, nutrients and pesticides, continues to have detrimental impacts on Great Barrier Reef ecosystems. The greatest impacts are on freshwater, estuarine, coastal and inshore marine ecosystems.

4 Human-induced climate change is the primary threat to the Great Barrier Reef and poor water quality can exacerbate climate-related impacts. Good water quality is critical for healthy and resilient ecosystems and supports recovery from disturbances such as mass bleaching and extreme weather events. Meeting water quality improvement targets[3] within the next ten years is imperative.

5 While several land management practices and remediation actions are proven to be cost-effective in improving water quality, translating these into more substantial pollutant reductions will require significant scaling up of the adoption of these actions, prioritisation of pollutant hotspots, and greater knowledge of the costs and potential co-benefits of practice adoption.

6 Greater focus on locally effective management solutions can encourage faster adoption, especially when designed and delivered using collaborative approaches involving landholders, Indigenous communities, the broader community, policy makers and scientists.

7 World-leading monitoring, modelling and reporting programs underpin the Great Barrier Reef ecosystems and provide essential knowledge to inform water quality improvement strategies. These programs could be strengthened and refined by increasing their spatial and temporal coverage to capture regional and local differences, provide more balanced coverage across land uses and ecosystems, improve trend analysis and quantify uncertainties.

8 Expanded research effort and more consistent methods are urgently needed to adequately assess 1) the co-benefits and efficiency (including costs) of management solutions across different landscape and climate conditions, 2) the effectiveness of water quality improvement programs and instruments including assessment beyond the life of programs, and 3) ecosystem risks from a wider range of pollutants.

3 The 2025 targets defined in the Reef 2050 Water Quality Improvement Plan [currently under review] require a 25% reduction in the 2009 anthropogenic end-of-catchment fine sediment loads, 20% reduction of particulate nutrients, and a 60% reduction of dissolved inorganic nitrogen loads. The target for pesticides is to protect at least 99% of aquatic species at end-of-catchments by 2025.

Inshore coral reef at Yunbenun (Magnetic Island), Queensland
Photo: Matt Curnock

Concluding Statements

This section contains high-level concluding statements for the Themes covered in the 2022 Scientific Consensus Statement. The 2022 Scientific Consensus Statement Summary contains more detailed information for each Theme.

Values, condition and drivers of health of the Great Barrier Reef

The Great Barrier Reef is one of the world's most complex natural systems, recognised for its considerable ecological, social, economic, and cultural values. Human-induced climate change is the overriding threat to the Great Barrier Reef, and the ability of ecosystems to recover from climate impacts and acute disturbances continues to be compromised by poor water quality.

- The Great Barrier Reef is a highly connected system, and the movement of water, matter and organisms is critical for many ecosystems from the catchment and floodplains to the outer reef. [Q1.4]

- Since the 2017 Scientific Consensus Statement, the condition of inshore coral reef ecosystems has declined, while coral cover on shallow mid- and outer shelf reefs has shown clear recovery following repeated mass bleaching, tropical cyclones and/or crown-of-thorns starfish outbreaks. Partial recovery has been observed in inshore seagrass meadows. Historical loss of some wetland types has been substantial, but condition trends for mangroves and wetlands have stabilised. [Q1.2/1.3/2.1]

- The primary threat to the Great Barrier Reef is climate change. Poor water quality is also a major threat, especially for freshwater, coastal and inshore marine ecosystems, reducing the ability of marine ecosystems to recover from climate-related disturbances. It is therefore imperative that water quality improvement targets are met within the next ten years for Great Barrier Reef ecosystems to persist. [Q2.2, Q2.4]

- Climate change is increasing the intensity of extreme rainfall events and changing the frequency and intensity of droughts, adding challenges to effective water quality management. Other stressors including tropical storms and crown-of-thorns starfish outbreaks and the combined effects of multiple stressors can negatively affect the health of Great Barrier Reef ecosystems. [Q1.2/1.3/2.1, Q2.2, Q2.3, Q2.4]

- The influence of land-based pollutants, particularly fine sediments, nutrients and pesticides, is spatially and temporally variable between pollutants and locations, and is most pronounced in freshwater, estuarine, coastal and inshore marine environments. These environments provide critical ecosystem services across the Great Barrier Reef and maintain high tourism, aesthetic, spiritual, recreational and economic values. [Q1.1, Q1.4, Q2.3, Q3.1, Q4.1, Q5.1]

Burdekin River following heavy rainfall in 2019
Photo: Matt Curnock

Sediments and particulate nutrients

Exports of fine sediment and particulate nutrients from catchments to the Great Barrier Reef are 1.4 to 5 times higher than pre-development rates. Increased delivery of land-based fine sediment and particulate nutrients reduces the quality and quantity of light in Great Barrier Reef ecosystems, with impacts on inshore seagrass meadows and coral reefs. Management is most effective when targeted to sediment and particulate nutrient hotspots which can occur in all land uses from gully, streambank or hillslope erosion.

- Flood plumes carrying fine sediment and particulate nutrients elevate turbidity, with the influence decreasing with distance from river mouths. Some particulate nutrients become bioavailable in the marine environment and promote algal growth but these processes are poorly understood. Reduced water clarity can persist for up to six months due to frequent resuspension of the newly delivered sediment following large floods. Ecosystem responses include changes to the abundance, diversity, spatial extent and recovery rates of inshore seagrass meadow and coral reef ecosystems, and their associated communities including fish and dugongs. [Q3.1, Q3.2]

- Land used for grazing is the largest contributor of fine sediments, because it is by far the biggest land use by area (73%). Other intensive land uses can generate large amounts of fine sediment locally but cover a smaller area. The main drivers of anthropogenic sediment and particulate nutrient exports are overgrazing, land clearing, tillage and other soil disturbances. Modelling and observations show that about half of the sediment exported comes from gully erosion, with hillslope and streambank erosion accounting almost equally for the other half. Much of the export comes from a relatively small area. For example, in the Bowen catchment, 30% of the sediment from gully erosion comes from just 2% of the gullies. [Q3.3, Q3.4, Q3.6]

- Land management and remediation are most cost-effective when targeted at hotspots of fine sediment and particulate nutrient export. Large-scale remediation of gullies can reduce sediment exports by more than 90% in restored gullies within 1 to 2 years. Maximising revegetation of streambanks and channels is expected to reduce erosion, but the water quality benefits have not been quantified in the Great Barrier Reef catchment area. To reduce hillslope erosion, management should aim to maintain more than 70% ground cover. Retention and protection of existing vegetation is important for reducing erosion. [Q3.4, Q3.5, Q3.6]

Satellite image of the Central Great Barrier Reef showing extent of land-based runoff
Photo: TropWATER

Dissolved nutrients

Agricultural development, especially sugarcane, and landscape modification have substantially increased nitrogen and phosphorus (nutrient) exports to the Great Barrier Reef, with dissolved inorganic nitrogen exports 1.5 to 3 times pre-development rates. Excess nutrients can have a negative impact on the health of Great Barrier Reef ecosystems, particularly on inshore coral reefs, and this may be exacerbated further when combined with climate change impacts. Reducing fertiliser application to industry recommended rates is the most effective and profitable practice for reducing nutrient exports. Natural and near-natural wetlands, and healthy rivers have the potential to support water quality improvements but are understudied in the Great Barrier Reef.

- The highest concentrations of nitrogen and phosphorus in the Great Barrier Reef are found in inshore areas. Upwelling and nitrogen fixation can also contribute to nutrient inputs. Excess amounts of dissolved nutrients are detrimental to coral health, recruitment, calcification, and reproduction, and may increase coral susceptibility to bleaching. Excess nutrients can lead to phytoplankton blooms that can increase the food supply for crown-of-thorns starfish larvae, possibly contributing to outbreaks. Other factors such as inherent life history traits and the removal of starfish predators can also influence outbreaks. Combining evidence from these different factors will contribute to a more complete understanding about when, where and how population outbreaks will occur. [Q4.1, Q4.2, Q4.3]

- Basins dominated by sugarcane make the greatest contribution to dissolved inorganic nitrogen exports (42% of total). Grazing lands contribute 22%, and although other land uses contribute smaller amounts, they can be locally important. Increased erosion from grazing and other land uses can contribute to nutrient export, with transformation of particulate nutrients to dissolved form (termed bioavailable nutrients) during transport. The primary drivers of anthropogenic nitrogen and phosphorus export are fertiliser application, changed catchment hydrology and erosion. [Q4.4, Q4.5]

- The most effective management practice to reduce dissolved inorganic nitrogen exports from sugarcane is reducing fertiliser applications. However, optimum application rates are uncertain, and large reductions may impact on productivity and profitability, which impedes adoption of reduced rates. The effectiveness of other management practices for nitrogen in sugarcane is variable and/or not clearly demonstrated. The evidence for improving water quality through the management of phosphorus in crop production, and nitrogen in the production of crops other than sugarcane, is limited. The same is true for cost-effectiveness of most practices. Reducing erosion reduces both particulate and dissolved nutrients, although the transformation processes from particulate to dissolved forms are poorly understood. [Q4.4, Q4.5, Q4.6, Q3.3, Q3.4, Q3.5, Q3.6]

- The global evidence indicates that tropical wetland systems can retain, process and, at times, export nutrients. It also shows that natural and near-natural wetlands are typically more effective at removing some forms of nutrients than constructed or restored wetlands. Hydrology, maintenance and presence of vegetation are important factors for maximising nutrient removal efficiency. There are few studies from the Great Barrier Reef that measure or model the efficacy or cost of wetlands as a water quality improvement tool. The historical loss of natural wetlands, particularly in floodplains, the degradation of those remaining, the presence of vegetation, hydrological characteristics, and the need for ongoing and long-term maintenance of restored wetlands are important considerations for maximising nutrient removal efficiency and determining future protection and management opportunities for Great Barrier Reef wetlands. [Q4.7, Q4.8, Q4.9]

Precision application of pesticides using a shielded sprayer
Photo: Rob Milla

Pesticides and other pollutants

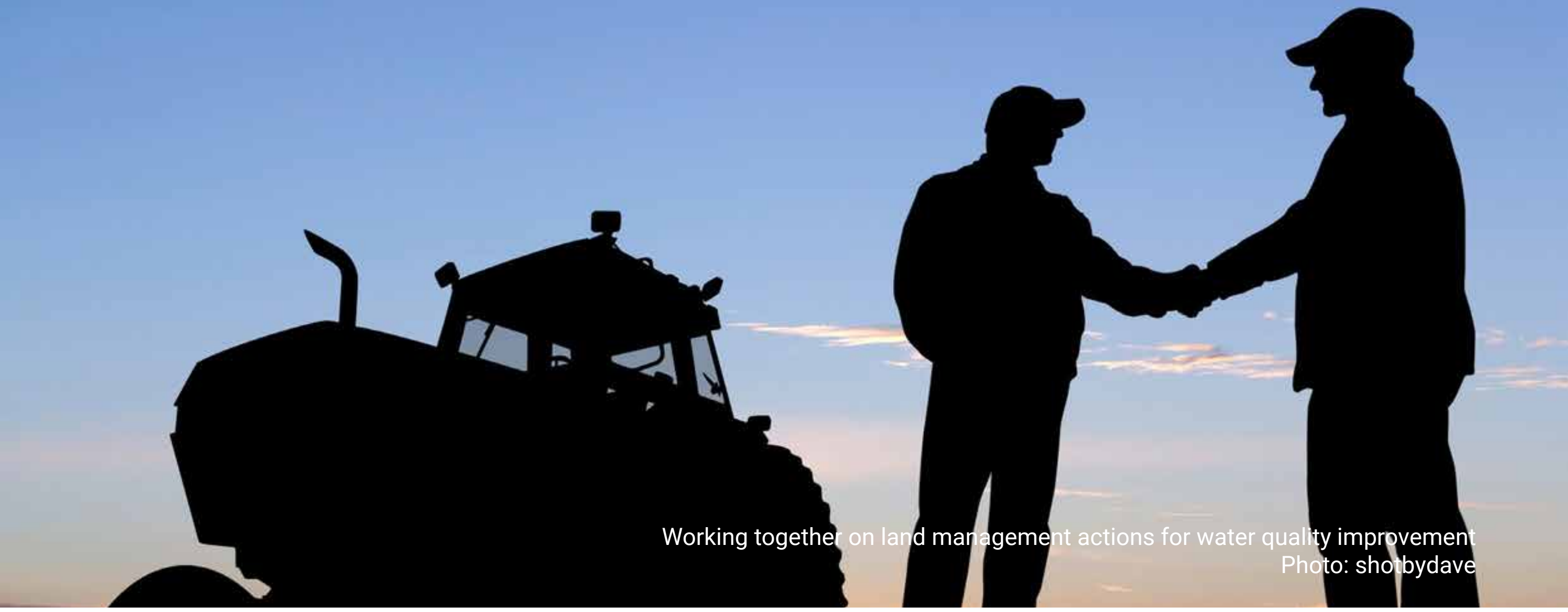
Pesticides frequently occur at concentrations that exceed protection guidelines for freshwater ecosystems of the Great Barrier Reef, particularly during the first flush of each wet season. Exceedances also occur in inshore marine waters but are less frequent and typically associated with flood plumes. The risk that pesticides pose to aquatic organisms reduces with distance from their source. Management practices have been shown to reduce pesticide losses. Much less is known about the distribution, concentrations and impacts of other pollutants on the Great Barrier Reef. For most pollutants, including some pesticides, there is insufficient monitoring and toxicity data to comprehensively assess environmental risk.

- Pesticide mixtures are present in the vast majority of all monitored fresh, estuarine and marine waters of the Great Barrier Reef. The Mackay Whitsunday region and Barratta Creek in the Burdekin region, consistently record higher concentrations and risk than elsewhere. Long-term analyses indicate that photosystem II herbicide concentrations have increased in some inshore sites of the Great Barrier Reef between 2005 and 2018. Almost all tested pesticides are reported as harmful to non-target aquatic species of the Great Barrier Reef. Pesticides can increase the vulnerability of local aquatic species to other stressors, including heatwaves. [Q5.1]

- Sugarcane remains the main source of pesticides, with other agricultural and urban sources also contributing. Pesticide export is influenced by the timing and rate of application, rainfall, irrigation regimes, and pesticide and soil properties. [Q5.2]

- The most effective management practices to reduce pesticide risk from agricultural land uses include: reducing the total amount of pesticide applied (within label recommendations); optimising application methods; timing application to coincide with periods with a low chance of rainfall runoff; choosing pesticides with lower environmental risk; reducing soil erosion; and improving irrigation efficiency. [Q5.3]

- Other pollutants present in the Great Barrier Reef include: metals; persistent organic pollutants; per- and poly-fluoroalkyl substances; plastics; pharmaceutical, veterinary and personal health care products; and coal dust. There were no local studies on sunscreens, but international studies suggest that they are likely to be present. Limited data indicate that metal concentrations are highest near more industrial and developed areas, although concentrations above national water quality guideline values are rarely found. There is insufficient monitoring data to determine the spatial range, concentrations, temporal trends and the risk that most of these pollutants pose to Great Barrier Reef ecosystems. [Q6.1]



Working together on land management actions for water quality improvement
Photo: shotbydave

Human dimensions of water quality improvement and emerging science

Trust building and collaborative processes with landholders, stakeholders, scientists, Traditional Owners and policy makers are key factors for enhancing the adoption and impact of land management change for water quality improvements. There is a lack of published information on the effectiveness and efficiency of policies, programs and instruments designed to motivate adoption of land management approaches for improved water quality, the conditions that engender practice change and enable scalability, as well as the broader co-benefits for people and the environment.

- Empowerment of Traditional Owners for decision making and management of the Great Barrier Reef, and its connected catchment area, can be strengthened through better understanding by all partners of Indigenous culture and connection to Country. Integration of Indigenous knowledge and input also requires support for increased capacity and improved capability to become engaged and involved in policy and program design, planning and delivery. [Q7.3]

- Methodologies to assess the effectiveness of programs and instruments to improve water quality through land management change are inconsistent, and usually only refer to estimated pollutant load reductions. There is a need for greater consideration of the broader co-benefits of improved land management, taking into account interconnected social, economic, cultural and human health factors that influence adoption, especially in the context of future climate scenarios. [Q7.1, Q7.2, Q8.1, Q8.2]

- Numerous factors, from high-level elements like program and policy direction to more granular influences such as landholder relationships and characteristics of the practices, influence the implementation and effectiveness of water quality improvement programs, including the adoption of various management practices. Distrust of government, researchers and program delivery providers significantly hinders the adoption of land management practices. Overcoming this barrier through the development, testing, and scaling of management practices via collaborative processes is crucial for accelerating water quality improvements. [Q7.2, Q7.3]

Flooded wetlands
Photo: Matt Curnock

Strength of evidence

A total of **4,480** studies were used to address the **30 questions** that form the 2022 Scientific Consensus Statement. The strength of the evidence was assessed taking into account the confidence rating (based on the overall relevance and consistency of the evidence), quantity of evidence items, and diversity of study types.

The strength of the evidence is considered to be **high** for the topics covering the value and connectivity of Great Barrier Reef ecosystems, the spatial and temporal distribution of sediments, nutrients and pesticides, their drivers and sources, and the impacts on most Great Barrier Reef ecosystems (with some exceptions related to wetlands, where there is less evidence available).

For questions related to the effectiveness of management practices in reducing pollutant exports, the strength of evidence is considered to be **moderate**, with limited information on certain land uses (such as bananas/horticulture, urban, and roads) and certain management practices in the Great Barrier Reef context (e.g., streambank rehabilitation, wetland treatment systems).

The strength of evidence is **limited to moderate** for the questions reviewing the effectiveness of programs and instruments aimed at motivating landholders to adopt management practices and the factors influencing adoption of practices that improve water quality due to limited published and peer reviewed information.

The questions with the **lowest** strength of evidence include 'other pollutants' (such as per- and poly-fluoroalkyl substances, pharmaceutical, veterinary, and personal health care products, coal dust and fly ash, and sunscreen), with limited local evidence on many pollutant types particularly with regard to ecological risk, and the factors of success in Indigenous involvement in water quality management and decision making, with limited peer reviewed evidence relevant to the Great Barrier Reef.

Live coral at Bwgcolman (Palm Island), North Queensland
Phot:o: GeoNadir

New knowledge since the 2017 Scientific Consensus Statement

Since the 2017 Scientific Consensus Statement, there has been a shift in the severity of climate-related impacts on Great Barrier Reef ecosystems and associated values, with climate-related impacts projected to intensify rapidly throughout this century. The importance of the role of improved water quality on the health of Great Barrier Reef ecosystems in the context of climate change has become clearer with monitoring data demonstrating the role of good water quality in promoting the recovery of coral reefs and seagrass meadows following disturbance events.

Other concepts have been reinforced through multiple lines of evidence, such as the verification that sediment and nutrient exports are well above pre-development rates, quantification of the contribution of different land uses and biophysical drivers such as vegetation degradation and fertiliser inputs to end-of-catchment pollutant loads, and knowledge of the role of catchment development and the historical and ongoing loss of important ecological functions that contribute to poor water quality. The distribution and impacts of mixtures of pesticides in Great Barrier Reef ecosystems is also now better understood with an increased focus on ecological risk and identification of clear hotspot areas for management. The scope of evidence on 'other pollutants' has been expanded including recent studies on the distribution of per- and poly-fluoroalkyl substances and plastics.

In terms of management options, new evidence has established the effectiveness of the remediation of large-scale gullies in combination with sustainable land management practices to maintain sediment export reduction, as well as further clarification of the potential benefits of Enhanced Efficiency Fertiliser application in sugarcane for reducing dissolved nutrient exports under different conditions. New research has also begun to assess the effectiveness of specific wetland treatment systems for water quality improvement in agricultural areas. Recent scientific findings associated with the human dimensions of water quality management show the need for greater emphasis on social values, the importance of landholder trust in government, scientists and program delivery organisations in engendering management practice change and greater collaboration among everyone involved in water quality management. This should include Indigenous knowledge and greater engagement and involvement of Traditional Owners in management and decision making for the Great Barrier Reef.

TYTO wetlands, Far North Queensland
Photo: Katie Sambrook

Key knowledge gaps

A detailed list of knowledge gaps identified through the 2022 Scientific Consensus Statement process is presented within each synthesis of evidence and collated by Themes within the 2022 Scientific Consensus Statement Summary. Key knowledge gaps and actions identified by experts are listed below. These gaps need to be considered in the context and uncertainties of a changing climate, and include:

- Greater assessment of the impacts of pollutants on some ecosystems such as wetlands.
- Increased knowledge of the combined and cumulative impacts of multiple stressors on a range of ecosystems and species, especially in the context of climate change projections.
- Better understanding of nutrient sources, transformations and fate (especially for particulate nitrogen and phosphorus) and their interaction with other impacts including bleaching and crown-of-thorns starfish outbreaks.
- Additional information on the ecological risk of emerging alternative pesticides.
- Collection of fundamental data and establishment of guideline values for most of the 'other pollutant' groups including coal, per- and poly-fluoroalkyl substances, pharmaceutical, veterinary, and personal health care products, and sunscreens.
- Quantification of water quality improvements from a wider range of management solutions to target effective practices that deliver benefits in shorter timeframes.
- Quantification of the cost-effectiveness of management solutions across projects, programs and instruments using consistent and comparable approaches.
- Approaches to facilitate integration of Indigenous knowledge and Traditional Owners into water quality management.
- Quantification of the co-benefits of land management to improve water quality.
- Development of consistent methods to evaluate the effectiveness of programs and instruments applied to motivate land management change.

Ensuring that research outputs are peer reviewed and publicly available is essential for inclusion in future Scientific Consensus Statements.

Sediment laden river following high rainfall in the Wet Tropics, Far North Queensland
Photo: Dieter Tracey

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2022 Scientific Consensus Statement |
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