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Securing the Future of the Gippsland Lakes

Report from the Royal Society of Victoria's Roundtable, 26 May 2023

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Contents

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Front page image*: The Outer Barrier of the Gippsland Lakes, Ninety Mile Beach, looking across to Raymond Island on the Lakes' side. Source: Shutterstock*

Securing the Future of the Gippsland Lakes

Australia possesses a variety of estuary types, each facing threats to their health and ecological assets. Historical instances of fish kills due to reduced freshwater flows and unregulated pesticide use highlight the longstanding challenges in balancing public and private interests in estuarine management. Sydney Harbour, for example, continues to grapple with the consequences of industrial pollution, impacting commercial fishing. As climate change intensifies, these challenges will multiply, endangering significant estuaries like the Gippsland Lakes.

The Gippsland Lakes comprise the largest estuarine lagoon system on the Australian continent and the largest coastal wetland complex in southeastern Australia, encompassing linked and isolated lagoons, swamps, active and abandoned river and tidal channels within the Gippsland Basin. The Lakes are one of 12 wetland systems in Victoria currently listed under the Ramsar Convention on Wetlands, an international agreement for the conservation of wetlands. The Lakes have been listed as a Ramsar site since 1982, covering over 600 square kilometres. Once the entire terrestrial catchment area is taken into consideration, the area of concern takes in 20,000 square kilometres.

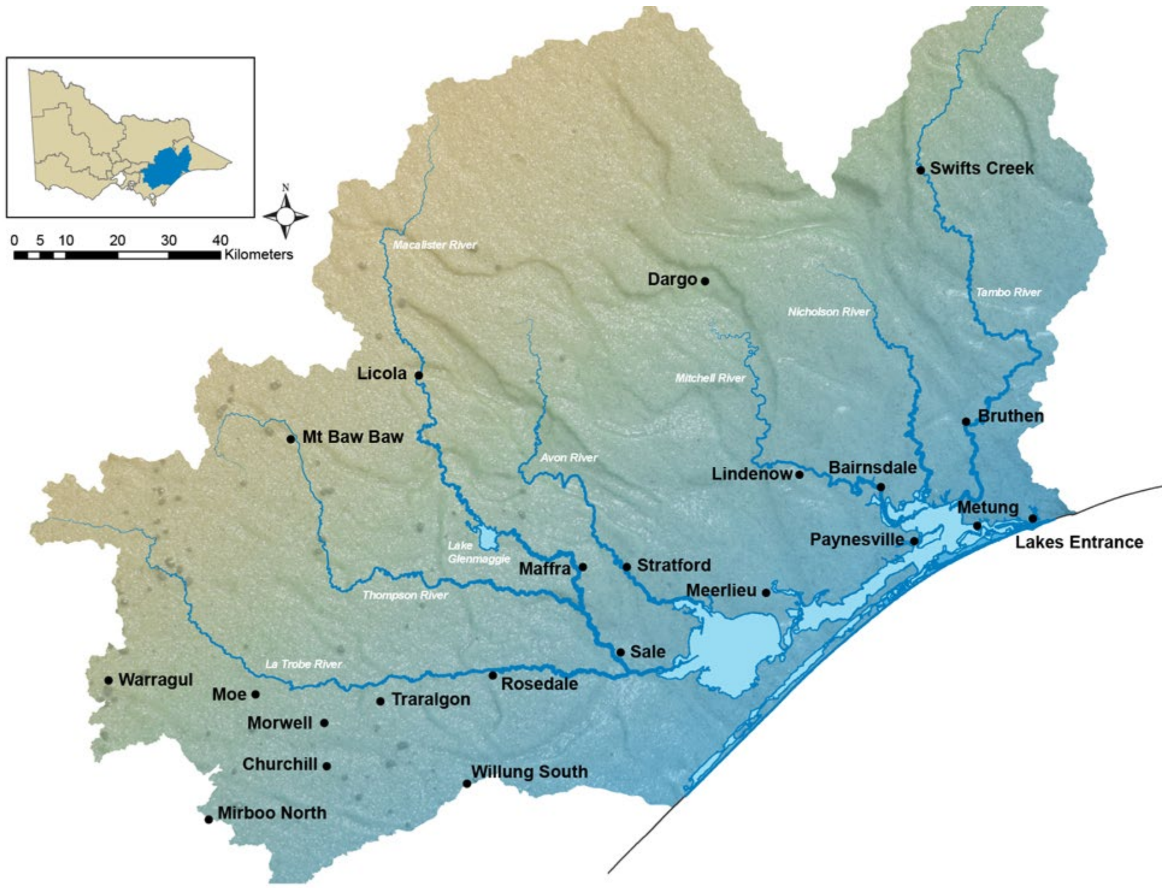

Figure 1 – The Gippsland Lakes are, in large measure, contingent on freshwater inflows, especially from the La Trobe, Avon, Mitchell, Nicholson and Tambo Rivers. Source: https://www.loveourlakes.net.au/lakes-waterways/

Roundtable on the Future of the Gippsland Lakes

In light of the Victorian Government's review of the Gippsland Lakes Ramsar Site Management Plan over the course of 2023-4, the Royal Society of Victoria convened a roundtable discussion of scholars and catchment managers on 26 May 2023 to understand the various concerns held, the evidence base provided in support of these concerns, and convey these for consideration of informed actions by decision makers. This resulted in the compilation of a presentation program and a series of abstracts (provided as Attachment A) with further papers commissioned for a forthcoming edition (Vol. 136) of the *Proceedings of the Royal Society of Victoria* in 2024.

Roundtable presenters and participants, from Left: Dr David Low, Professor Bruce Thom AM, Mr Duncan Malcolm AM, Dr Michael Spencer, Professor Jamie Pittock, Dr Kathleen McInnes, Mr Neville Rosengren (on screen), Professor David Kennedy, Professor Peter Gell, Professor Perran Cook (obscured), Dr Birgita Hansen, Dr Jason Alexandra (obscured), Professor Max Finlayson, Mr Michael Vanderzee, Mr Rob Gell, Mr Sean Phillipson (obscured). Not pictured: Mr Mike Flattley.

Presentations and abstracts were provided by:

Dr Jason Alexandra (Alexandra & Associates)
Professor Perran Cook (Monash University)
Professor Max Finlayson (Charles Sturt University)
Professor Peter Gell (Federation University)
Dr Birgita Hansen (Federation University)
Professor David Kennedy (University of Melbourne)
Dr David Low (Australian Pesticide Reduction Network)
Mr Duncan Malcolm AM (Australian Landscape Trust)
Dr Kathleen McInnes (CSIRO Environment)
Mr Sean Phillipson (Gunaikurnai Land and Waters Aboriginal Corporation)
Professor Jamie Pittock (Australian National University)
Mr Neville Rosengren (La Trobe University)
Dr Michael Spencer (Monash University)
Professor Bruce Thom AM (University of Sydney)

The Gippsland Lakes Estuarine Lagoon System – Terrestrial and Marine Interactions

The Gippsland Lakes have two catchments: the terrestrial catchment, with a history of uplift and denudation contributing fresh water and sediment, and the marine catchment, with fuzzy offshore boundaries contributing salt water, energy and sediments via waves and currents.

The Lakes System features varied water bodies and wetlands enclosed by Pleistocene and Holocene wave-deposited, shore-attached and island barriers, including the Ninety Mile Beach, the outermost expression of three generations of coastal dune barrier formation.

The Formation of the Barrier System

There are three principal periods of dune and beach development in the Gippsland Lakes - each occurred during higher sea level periods. These are:

(a) Prior Barrier (c. 220,000 years in age)

(b) Inner Barrier (80,000 - 125,000 years in age)

(c) Outer Barrier (<8,000 years in age).

Figure 2 - Aerial oblique photo of the Gippsland Lakes, Feb 2023. Source: Neville Rosengren

During each phase of sea level rise, sand is swept off the continental shelf to be deposited as a new barrier sequence, seaward of the previous one.

The beach barriers of the contemporary coast were initially built from sediment transported from the inner continental shelf. However, this source appears to have been exhausted by the late Holocene. The current sediment supply to Ninety Mile Beach is primarily sourced longshore from Corner Inlet, northeast of Wilson's Promontory at the Beach's southernmost extent.

The Outer Barrier and Ninety Mile Beach are part of a continuous littoral drift system that extends from the entrance to Corner Inlet all the way to Mallacoota, near the New South Wales border. Between 2,500 and 2,000 years ago, sand moved quickly from Corner Inlet along 90-Mile Beach, infilling an entrance at Loch Grange and forming another barrier seaward of Rotomah Island, leading to the creation of the Bunga Arm. This resulted in a natural entrance forming cyclically near where Lakes Entrance is today as the only connection between the Gippsland Lakes and the open ocean. (Kennedy, Thom, Gell, & Rosengren, 2024)

Changes to the Barrier System

The Outer Barrier and Ninety Mile Beach are highly dynamic environments, with major phases of reworking occurring in the past 200 years. Fresh sand is observed to bury older soil surfaces along the entire front section of the Outer Barrier. The timing of this phase of high mobility -

the last 200 years - suggests it is a result of changed land management from 1850s up to the 1980s. These areas have been broadly stable due to the removal of stock and introduction of Marram grass *(Ammophila sp.)* as well as changed fire patterns.

However, in the past few decades, it appears that the system is now trending towards erosion, with instances of wave overwash and landward dune rollover becoming more apparent. Significant accretion is only occurring around the engineered mouth to Lakes Entrance and on the islands that mark the seaward boundary of Corner Inlet.

Ninety-Mile Beach and the dune systems of the Outer Barrier are at significant risk of major change, including beach-dune erosion and landward retreat of the shoreline. This retreat is current, ongoing and supported by all indicators. (Kennedy, Thom, Gell, & Rosengren, 2024)

Climate Change and Other Human Impacts

The construction of a permanent entrance at Lakes Entrance in 1889 has led to a significant ecological shift, lowering average water levels by approximately 500cm and increasing salt levels in the lower lakes from tidal ingress. There is now a continuous input of seawater through a dredged entrance.

Figure 3 – Lakes Entrance

Fresh water is becoming scarcer in the region. Reservoir inflows from rainfall in the highly-monitored, neighbouring basin of central Victoria have declined by 21% since 1975. Extraction of groundwater is leading to areas of declining levels in the Red Gum Plains west of Bairnsdale. (Pittock, et al., 2023) Environmental audits in 1998 and subsequent studies identified the need to reduce nutrient inputs from regional agriculture, leading to funded programs for on-farm works and water monitoring, showing some improvements. However, extensive catchment-clearing, mining, agriculture, power generation, and urbanisation have decreased freshwater inflows and increased sediment loads, with associated elevation in nutrient and pollution levels. (EGCMA, 2008)

The population of Gippsland is increasing, along with water demand. New irrigation areas in support of regional agriculture are proposed in the lower Latrobe Valley and the Macalister and Avon systems, placing greater pressure on river systems.

Multiple upstream factors affect the Lakes' futures, including the cumulative impacts of all water diversions, including the inter basin transfer from the Thompson Dam to Melbourne's water supply). There are many impacts and risks from nutrients and pesticides draining from farmland, plus industrial pollutants from the industries in the catchments of which brown coal fired electricity generation is significant. These risks do not stop with the end of mining and generation from brown coal but leave a significant legacy.

In this context, the recovered water formerly allocated to open-cut coal mines and power stations in the Latrobe Valley is currently being considered for reallocation to fill three vast, decommissioned mining pits over a 30-year period. (Pittock, et al., 2023) The Hazelwood Concept Master Plan developed by Arup for mine owner ENGIE proposes to fill a deep, 1281-hectare mine void at Hazelwood from "a number of sources" to fill a 740 gigalitre lake (Arup, 2019).

Leaving aside the high risk of significant pollutants leaching from the mining bed into the Latrobe system without appropriate amelioration, the proposition to fill up to three major coal pit lakes would alter the hydrology of the entire system, both during filling and after, due to increased evapotranspiration. This must be considered in balance with other anticipated impacts on the system.

Ecological Values

Lake Chemistry and Algal Blooms

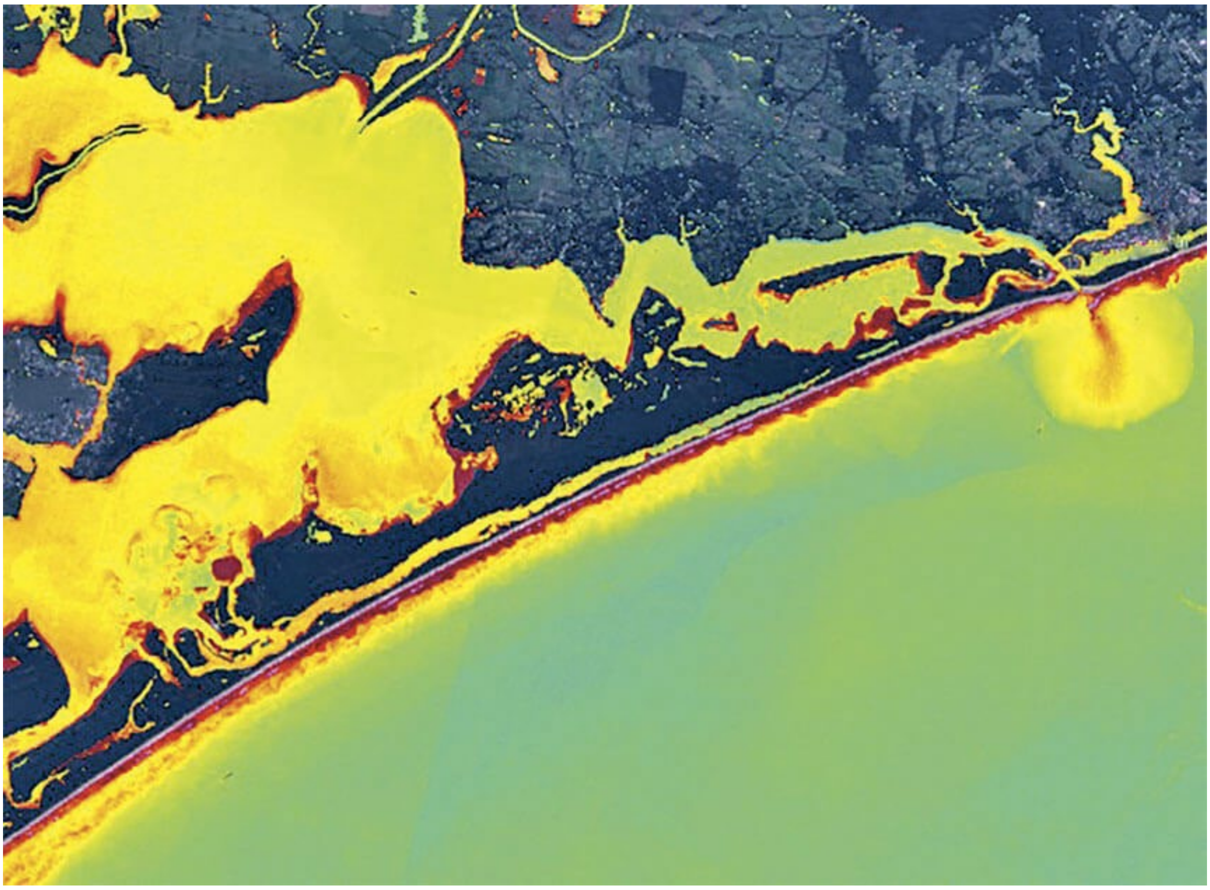

Figure 4 – In May and June of 2022, Victoria's Department of Environment, Land, Water and Planning (DELWP, now DEECA) cautioned that prawns caught in the Gippsland lakes and five nautical miles off the Gippsland coast between McLoughlins Beach to the New South Wales (NSW) border were not suitable for human consumption due to the production of the hepatoxin nodularin from an extensive bloom of the cyanobacterium Nodularia spumigena*. This*

satellite image shows the contemporary chlorophyll levels in the Gippsland Lakes. The red area indicates where the algae bloom is most concentrated while the green indicates more diluted areas. Photo: DELWP/DEECA

The Lakes' hydrological regime, crucial for water levels and lake chemistry, has been significantly altered by human activities, including changes in stream flows and sediment load.

The Lakes experience periodic blooms of toxic cyanobacteria (mostly comprised of *Nodularia spumigena*) that close the waterway for recreation and commercial fishing. The blooms result from a complex interaction between river flows, nutrient biogeochemistry and phytoplankton succession.

The occurrence of blooms is closely linked to the amount of nutrient inputs (particularly phosphorus and nitrogen) from the rivers entering the Gippsland Lakes, highlighting the close link between the catchments and the Lakes' system productivity. During cold months, higher rainfall and snowmelt in the catchments create high river flows into the Lakes. Phytoplankton, including various species such as diatoms, ciliates, and flagellates, build up in response to increased nutrient loads.

In warmer months with lower rainfall, the Lakes' water column stratifies based on differences in temperature, density and salinity. This creates low oxygen conditions in the bottom waters, leading to a reliance upon and competition over nitrogen resources by an enlarged phytoplankton community, which feeds on and grows from phosphorus released from sediments by biological activity. The loss of nitrogen from the water column occurs during nutrient recycling, giving select phytoplankton species such as *Nodularia spumigena* a competitive advantage, as they have the ability to float to the surface and absorb nitrogen from the air while other species die back and release further nutrients through decomposition.

Nodularia produces the hepatotoxin nodularin which results in the Gippsland Lakes being closed for recreational purposes during blooms. In addition, it has been found nodularin makes its way into fish and crustaceans both within the Gippsland Lakes as well as in Bass Strait, with impacts on both commercial fisheries and recreational fishing. (Cook & Smith, 2024)

High nutrient loads contributing to toxic algal blooms are not exclusively from agricultural runoff and are expected to increase with the more regular occurrence of extreme weather events anticipated during climate change. Extensive regional fires followed by floods in 2007 led to record nitrogen and phosphorus loads in rivers and streams, resulting in a major bloom of the *Synechococcus* cyanobacterium in the Gippsland Lakes for the first time on record. This disrupted the food chain at the level of animals foraging on seagrasses and seaweeds starved of sunlight during the bloom. (Cook & Smith, 2024)

Waterbirds

The Lakes have traditionally been one of the most well-known water and migratory shorebird sites in Victoria, with waterbirds a major contributing factor towards the Lakes' nomination as a Ramsar site. At the time of nomination (1982), records of 40,000 – 50,000 waterbirds (Criterion 5) and at least six waterbird species were made in internationally significant numbers (Criterion 6).

There are four main monitoring programs in the Gippsland Lakes that monitor waterbirds, conducted alongside various shorter projects targeting particular species and/or regions. The shorebird survey area covers around 115,000 hectares, surveyed twice a year by BirdLife Australia volunteers.

The Victorian Government funded an extensive multi-agency sand renourishment program to improve habitat for shorebirds and beach nesting birds at Pelican and Crescent Islands in the Gippsland Lakes. Following completion in 2016, there was an immediate increase in breeding success of fairy tern (*Sterna nereis*) and little terns (*Sterna albifrons*), target species in the Ramsar management plan, as well as an increase in foraging habitat for shorebirds. Based on the success of this project, it will be repeated in 2024. (Hansen, Healey, Sullivan, & Weller, 2024)

Several decades of waterbird monitoring by BirdLife Australia volunteers has revealed decreases in abundance across many species, including several listed species, noting a large amount of variation in annual and seasonal abundance (Hansen, Healey, Sullivan, & Weller, 2024) Species once relatively common, such as the common greenshank (*Tringa nebularia*) and red knot (*Calidris canutus*), are now rarely recorded.

Since the 2010 Ecological Character Description, numbers of the red-necked stint (*Calidris ruficollis*) and sharp-tailed sandpiper (*Calidris acuminata*) have fallen from maximum count numbers of 8000 and 3187 individuals respectively to between 150 – 200 of each in 2023.

From the winter following the 2019-2020 fires in Eastern Victoria, the formally large feeding concentrations (up to 10,000) of Eurasian coot (*Fulica atra*) and black swan (*Cygnus atratus*) have plummeted in Jones Bay; this correlates with both the La Niña climate cycle, which would have resulted in many species shifting inland. However, there may also have been a concurrent impact on food resources due to sediment inputs to the bay by the heavy rains following the fires.

Key habitats such as the barrier islands are underrepresented in the survey efforts of the Gippsland Lakes Important Bird and Biodiversity Area (GLIBA) Monitoring Project, a component of the Lakes system vulnerable to climate change. (Hansen, Healey, Sullivan, & Weller, 2024)

Biocultural Values

The cultural significance of the Gippsland Lakes region to the Gunaikurnai peoples relates to a holistic view of Country that encompasses land, waters, air, and all living things. The Lakes region holds traditional hunting, fishing, camping, and gathering places for the Gunaikurnai people. The area includes major base camp locations, shell middens, burial places, and culturally modified trees.

> "Our culture is embedded in our Country, which is vital to our identity. Our stories and songlines link us to our ancestors, who travelled across the Country practicing the customs that make us Gunaikurnai. They moved throughout the landscape to harvest and protect natural resources, to seek refuge from the seasons, and to trade and mix with neighbouring groups." (GLaWAC, 2015)

More than 80% of recorded archaeological sites relating to the 30,000+ year occupation of the region by the GunaiKurnai peoples are directly impacted by the changes associated with a warming climate. (Kennedy, Thom, Gell, & Rosengren, 2024)

From colonisation until very recently, Traditional Owners have had limited ownership, access or opportunities to manage fresh water on Country. Happily, this is now changing with 2gL from the Mitchell Reiver allocated in 2020 and two new licenses in 2023 for 200 mL at Buchan Munji, and for 500mL from the Tambo River. (ABC News, 2023)

Socioeconomic Values

Regional tourism contributes an estimated $1.57 billion for the local economy from 5.63 million visitors annually. Regional agribusiness produces $1.16 billion in commodities per annum, occupying 1.64 million ha, accounting for 19% of Australia's dairy production, along with significant grazing industry based on beef, wool and prime lamb production, vegetable growing and commercial fisheries. (Kennedy, Thom, Gell, & Rosengren, 2024)

Governance

The governing institutions for the Gippsland Lakes and their catchments, overseeing an area of 20,000 square kilometres, have historical foundations shaped by British colonization and 20th-century economic development paradigms. (Cleaver & de Koning, 2015) Governance structures have evolved with population growth, the amalgamation of entities, and changes in government resources and policies.

Governance challenges are increasing due to the complexities and uncertainties arising from the non-linear relationship between climatic and environmental changes, as well as the anticipated yet substantively unpredictable impacts of extreme weather events (e.g., droughts, floods, fires, sea levels and storm surges).

Marshall and Alexandra consider that Victoria's governing institutions exhibit "institutional lock-in," with governing orthodoxies influenced by water resources management, civil engineering, public administration, hydro-developmentalism, and more recent paradigms like neo-liberalism, conservation, and environmentalism. While important enablers of skilled action, these orthodoxies can also frustrate adaptive action based situational awareness in fluid decision-making conditions. (Marshall & Alexandra, 2016)

Recent initiatives, including the influence of Indigenous entities and efforts related to climate change, have reshaped governance priorities and structures. The Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) emphasizes a self-determined approach for achieving outcomes for Healthy Country, focusing on decision-making that benefits the Gunaikurnai people and their long-term relationship with the land.

GLaWAC has entered into agreements with the State of Victoria, recognising Traditional Owner rights and establishing joint management arrangements over specific areas, including those around the Gippsland Lakes. This includes co-management of the estate managed by Parks Victoria in the region.

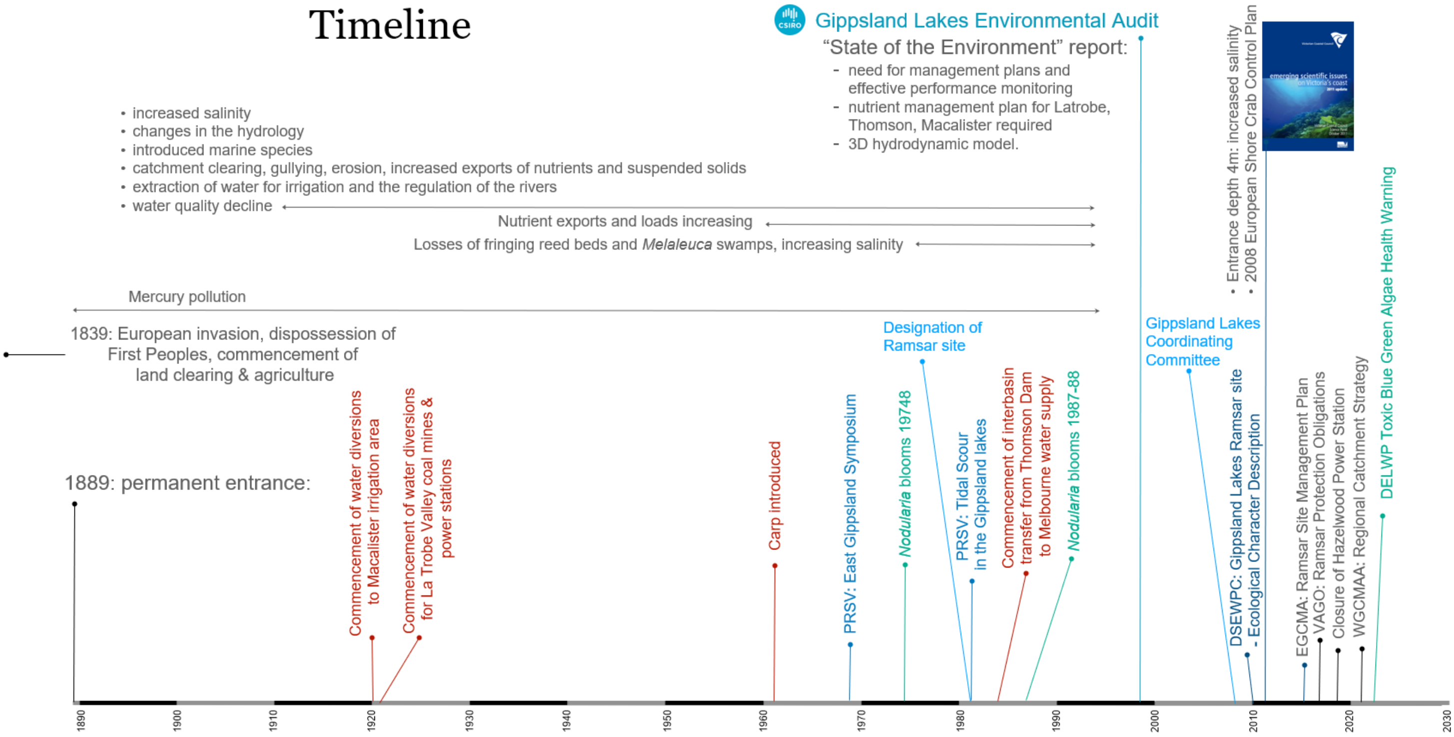

Figure 5 – A timeline representation of the ecological impacts of human activities in the Lakes since the opening of the permanent entrance in 1889, with concurrent scholarly and governance efforts. Source: Rob Gell AM

Ramsar Site Management

There are concerns expressed for current efforts to monitor and maintain the ecological character of the Gippsland Lakes through a period of rapid change, which will require more frequent reassessments of the Ecological Character Description that provides the baseline for Ramsar site management. It appears there is insufficient information on how the Lakes currently meet certain criteria to be listed as a Ramsar site. (Finlayson M. , 2020)

The establishment of a more coordinated management approach to addressing threats to estuary health is sought, with awareness of concurrent efforts from other sites across the Australian continent to establish processes that formulate pathways for recovery and sustainability.

There are collective concerns for the current regulation of pesticides, both generally and in the Lakes catchments, noting that regulatory entities generally perceive the existing system as satisfactory despite growing evidence of considerable ecological harm. Pesticide use in Australia has more than doubled in the past decade and is projected to double again by 2030. With irrigation and agriculture set to increase in the next decade, the flow-on effects of increased pesticide use can be anticipated along with the rising nutrient levels in waterways from fertiliser run-off.

Recommendations

Based on these inputs, the Royal Society of Victoria provides the following recommendations, grouped under categories for different modes of action.

1. Share Knowledge for Collective Understanding

Major stakeholders, in consultation with local communities, need to recognize the current degrading trajectory of estuaries like the Gippsland Lakes, and the importance of addressing this degradation. Community consultation, awareness, and participatory approaches will be essential to ensuring widespread understanding and ownership of the challenges facing the region, which will be vital to sustaining public investment in both mitigation and adaptation to the anticipated ecological impacts on the Lakes and their catchment.

2. Address Knowledge Gaps to Enable Adaptive Decision Making

The region has significant natural resilience due to the relatively low level of urban development on the coast. To properly manage human population growth in the current dynamic landform zone and properly care for Country, a thorough understanding of the current and future landform dynamics is essential.

Quantification of the presence, extent, and height of sea level within the Holocene remains an unanswered yet fundamentally critical question to be solved for understanding the response of Victoria's coast to global warming. Detailed numerical modelling using hybrid-numerical models such as ShoreTrans (McCarroll, et al., 2021) are seen as a critical next stage in understanding the future trajectories of shoreline movement in the region. (Kennedy, Thom, Gell, & Rosengren, 2024)

Further research should concentrate on understanding and mitigating threats posed by sea-level rise, sedimentation, and human interventions. Given the altered hydrological regime and ongoing challenges, comprehensive research to understand and mitigate the impacts of reduced stream flows, increased sediment load, and continuous seawater input on the Gippsland Lakes is required.

Work to date on the region's geomorphic uniqueness has established the broad principles of change; the next stage is to refine our knowledge to the spatial (e.g. midden sites and individual towns) and temporal (e.g. individual storms to decades) scales, which land and water managers of all types can use to effectively manage the coastal estate for the future.

There are gaps in survey coverage for waterbird monitoring in the Gippsland Lakes and a comprehensive analysis of waterbird distribution and abundance in relation to key habitats is urgently required. This should include assessment of current management actions (e.g. sand nourishment for shorebird habitat augmentation) and identification of complementary actions for maintaining ecological character. (Hansen, Healey, Sullivan, & Weller, 2024)

Given our challenges in identifying contemporary research related to the monitoring of fish species in the Lakes, we recommend a program either be established or amplified to better understand the diversity of marine and freshwater species, the status of various introduced species, the interactions of aquatic animals with the dynamic nature of the estuarine system, and the impacts of current and anticipated conditions on species distribution, health and persistence. The Arthur Rylah Institute collaborates with the Victorian Fisheries Authority to produce Native Fish Report Cards annually, and we recommend resourcing be allocated for a concerted focus on the Lakes as a priority waterway.

3. Establish and Maintain an Adaptive, Collaborative Governance Regime

The current governance of the Gippsland Lakes is described as fragmented and disaggregated. The adoption of adaptive and inclusive governance models, including the use of dynamic adaptive policy pathways, to guide decision making and resource allocation is recommended. These are more suitable for addressing the deep uncertainties and evolving societal preferences and perspectives that further complicate the complex challenges and uncertainties faced by the Gippsland Lakes. (Hassnoot, Kwakkel, Walker, & ter Maat, 2013)

An integrated approach would involve diverse stakeholders, who would consider ecological, cultural, and climatic factors. Transparency and understanding can be maintained through establishing an integrated inventory and conducting regular reassessment of the Ramsar site's ecological character to assert a reasonable baseline for targeted improvements. (Finlayson & Pollard, 2009)

Given the compound effect of sea-level rise and changing weather patterns, proactive measures are crucial for coastal hazard mitigation. (McInnes, 2024) Adaptation strategies that ensure holistic, ongoing improvement need to be developed considering fluctuating seasonal conditions, local wave climate changes, vertical land movement, and socioeconomic impacts.

4. Intervene and Invest for Ecological and Cultural Resilience

> "Although they are very different environments, the land and marine environments are interconnected. Some plants and animals rely on both onshore and offshore areas for different life cycle stages and the marine parks and reserves are susceptible to influences from land, making the focus of many programs reducing erosion and nutrient runoff. Managing the landscape as a system and considering the connections between these systems is a core principle in our approach to managing Country." (GLaWAC, 2015)

Sites in areas with sandy sediments or unconsolidated alluvium are particularly susceptible to erosion, with predicted storm surges to impact a larger proportion of known sites than rising lake levels alone over the same period. Of the sites under threat, a significant proportion are in locations where ecologically appropriate vegetation growth could help mitigate the impacts of this erosion.

In keeping with the principles of social justice, and on the basis of First Peoples holding valuable cultural knowledge of lands and waters, and custodial responsibilities for cultural sites of considerable antiquity and significance, the recent positive momentum in seeking active involvement of and collaboration with representatives of the Gunaikurnai Lands and Waters Aboriginal Corporation must be maintained. This extends to improving community wellbeing through training, education and economic development opportunities for the First Peoples of the region, aiming for holistic management principles that address the anticipated impacts of climate change and human development on cultural sites in particular.

We must protect the few remaining free flowing rivers in the Lakes' catchments. This involves setting pre-eminent downstream environmental flow targets linked to thresholds needed to conserve key environmental and cultural assets. We can build on existing Catchment Management Authority programs to systematically restore riparian zones, including the removal of barriers to fish passage, fencing out livestock and restoring native vegetation. (WGCMA, 2016) (EGCMA, 2016)

We must reduce and better balance consumptive water allocations with environmental uses as availability diminishes in the region. Efficiency, recycling and desalination will be key to supporting both a growing human population and competing efforts to mitigate climate change, such as large-scale tree planting for carbon sequestration. (DELWP, 2022) Monitoring and regulation of risks to shared water resources, such as water storage on farms, must be implemented. (Pittock, et al., 2023)

We recommend an active claim on the allocation currently or formerly claimed by brown coal mining and electricity generation activities to regional CMAs and First Peoples for the benefit of the Lakes' catchment system and the persistence of its freshwater ecology during a time of climate change, the further anticipated incursion of marine conditions, population growth and intensification of agricultural activity.

Given the active consideration of reallocating water resources from power stations and mining operations to fill the open-cut pit in the Latrobe Valley, we recommend reference to international research on lignite mine remediation as a demonstrable way to collaborate on accelerating adoptions of solutions, while engaging in the social and technical restitution of the polluted and damaged sites from the fossil fuel era. Mine site rehabilitation is far more than a technical water quality or quantity exercise. It is part of the transition to a low carbon future with recognition of the full range of the consequences of the 20th century's fossil fuel technologies. These technologies created common problems, including the well-recognised carbon pollution problems, but also many smaller, local, and regional impacts. (Alexandra, 2017)

Work on policies and legislation concerned with overcoming the institutionalised use of harmful pesticides in agriculture must begin. Related efforts to prevent cyanobacteria blooms in the Lakes have focused on catchment nutrient reduction efforts and we consider this remains the most sensible approach to the use of both fertilisers and pesticides, acknowledging the cost of sustaining a long-term program and the impacts on local primary production methods.

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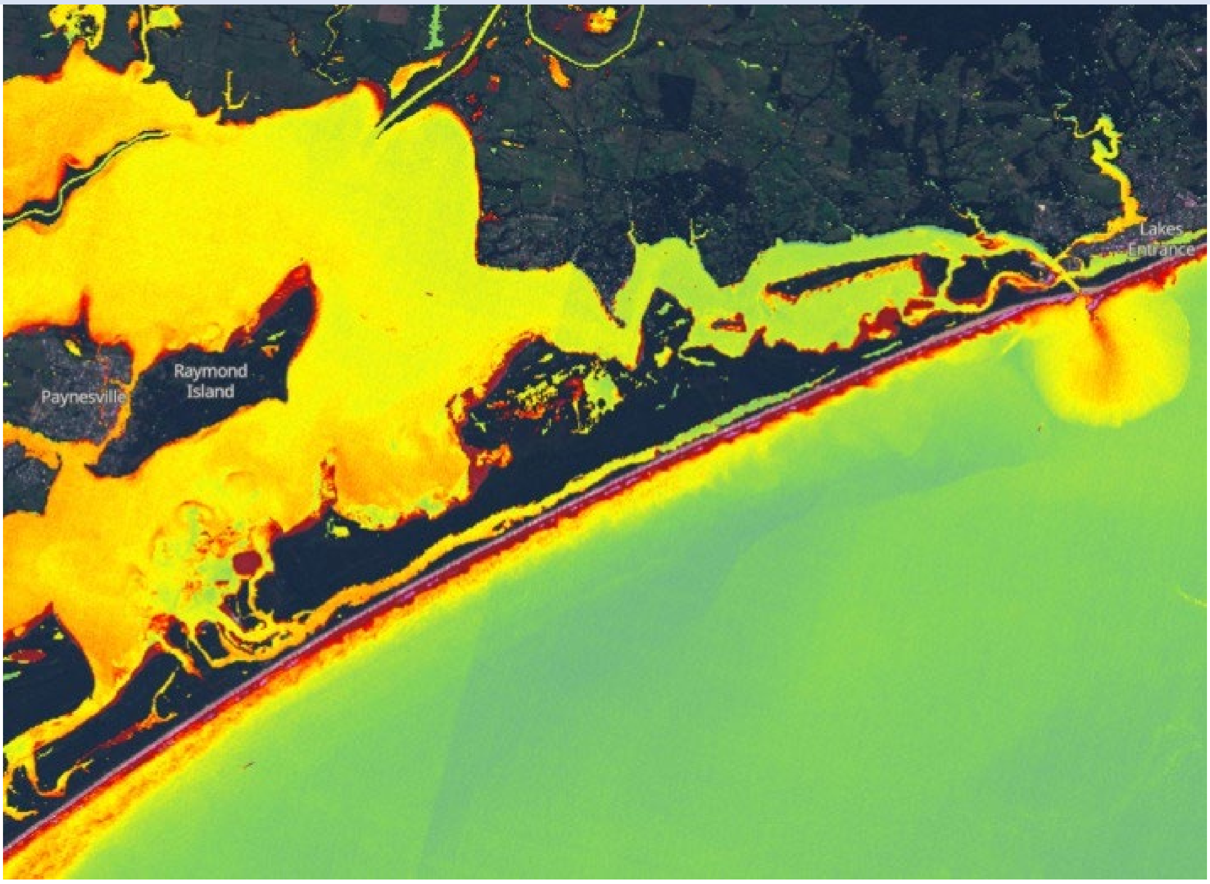
RSV Roundtable: The Future of the Gippsland Lakes

8:30AM – 5:00PM, 26th May, 2023

Cudmore Library, The Royal Society of Victoria
8 La Trobe Street, Melbourne, VIC 3000

Agenda and Abstracts



A satellite image providing a visual representation of the chlorophyll levels in the Gippsland Lakes on 25th May 2022, caused by a widespread, toxic blue green algae bloom. The red areas indicate where the algae bloom is most concentrated, the green indicating more diluted areas. Note a clear release of the bloom into the ocean at Lakes Entrance.

While this species of algae cannot survive in the ocean and is actively breaking down due to the saltwater, prawns caught from the Gippsland Lakes and up to 5 nautical miles off the Gippsland coast between McLoughlin's Beach and the NSW border may have travelled from bloom affected water and were not suitable for human consumption. Ingesting these toxins by consuming affected seafood can lead to serious illness.

Source: DELWP Gippsland

Roundtable Agenda

8:30am	Registration
8:45	Welcome
	Mr Rob Gell AM, President, The Royal Society of Victoria

Session One: Situational Awareness

8:50	A Short History of Lakes Science, Policy & Governance
	Mr Duncan Malcolm AM, Director, Australian Landscape Trust & Gippsland Medicare Local
9:05	Indigenous Management & Culture on the Lakes
	Mr Sean Phillipson, Policy & Program Manager, Gunaikurnai Land & Waters Aboriginal Corporation (GLaWAC)
9:20	A National Overview of Issues Facing Integrated Coastal Management
	Professor Bruce Thom AM, Professor Emeritus, The University of Sydney
9:35	Between the Mountains and the Sea: the Lakes' Terrestrial-Marine Interface
	Mr Neville Rosengren, Honorary Research Associate, La Trobe University
9:50	The Ramsar Convention on Wetlands & Australia's International Obligations
	Professor Max Finlayson, Adjunct Professor, Institute of Land, Water & Society, Charles Sturt University
10:05	Table Discussion
	*Led by **Professor Peter Gell**, Professor of Environmental Management, Institute of Innovation, Science & Sustainability*
10:35	Break for Morning Tea

Session Two: Global Change, Local Impacts

Part One: Climate Change & Sea Level Rise

10:55	The Water Cycle & Climate Change Impacts
	Professor Jamie Pittock, Fenner School of Environment and Society, ANU College of Science
11:10	Sea Level Rise & the Gippsland Shoreline
	Dr Kathleen McInnes, Group Leader, High Resolution Climate, Oceans and Extremes, CSIRO Environment
11:25	Table Discussion
	*Led by **Professor David Kennedy**, Director, Office for Environmental Programs, The University of Melbourne*
12:00pm	Break for Lunch

Part Two: Changing Ecology

12:50 Water Quality, Agricultural Chemicals & Fisheries

Dr David Low, Founder, Australian Pesticide Reduction Network

1:05 Ramsar Values & Migratory Birds

Dr Birgita Hansen, Senior Research Fellow, Centre for eResearch and Digital Innovation, Federation University

1:20 Floods, fires and phytoplankton: Some perspectives on water quality in the Gippsland Lakes

Professor Perran Cook, Water Studies, School of Chemistry, Monash University

1:35 Table Discussion

Led by Professor Max Finlayson

Session Three: Future Directions – The Way Forward

2:00 Adaptive Governance of Large, Complex Ecosystems

Dr Michael Spencer, Lecturer, Department of Business Law & Taxation, Monash University
Dr Jason Alexandra, Managing Director, Alexandra & Associates

2:15 Table Discussion

Led by Professor Bruce Thom AM

3:00 Break for Afternoon Tea

Session Four: Next Steps

3:20 Table Discussion

Consideration of recommendations, actions, partnerships. Led by Mr Rob Gell AM.

4:50 Acknowledgements & Close of Proceedings

Mr Rob Gell AM

Roundtable Attendees:

Joining these speakers and discussion leaders will be:

- *Mr Mike Flattley, CEO, The Royal Society of Victoria*
- *Mr Michael Vanderzee, Project Lead – Healthy Floodplains, Wentworth Group of Concerned Scientists*
- *Dr Athol Whitten, Director, Advanced Analytics & Data Science, Nous Group*

Abstracts

Situational Awareness

A Short History of Lakes Science, Policy and Governance

History

Since the early days of Gippsland's non-Indigenous human incursions, the Lakes have been a focus for commerce, settlement and recreation.

Following the construction and opening of a permanent navigable entrance in 1889 near what is now called Lakes Entrance, the ecology of the system was fundamentally altered, as the average water levels within the system lowered by an estimated 500cm and salt levels increased due to the twice daily tidal ingress. These impacts have been further exacerbated by extensive catchment-clearing and developments, which have included; mining, destruction of wetlands, intensive agriculture, forestry, brown coal fuelled power-generation, commercial and recreational fishing, the establishment and growth of shoreline townships, and the diversion of natural stream flows for irrigation, industry, domestic uses and Metropolitan Melbourne consumption. As a result of these factors, overall, tributary freshwater inflows have decreased, sediment loads have increased, especially after major bushfire and flood events, and nutrient and pollution loads have also increased.

Mr Duncan Malcolm AM

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Duncan was the inaugural Chair of the Gippsland Lakes and Coast Regional Coastal Board and a member of the Victorian Coastal Council. Other roles have included, Chair of the Rural Water Corporation of Victoria, Commissioner, East Gippsland Shire Council, Chair of the Victorian Environmental Assessment Council, national Chair of both the Irrigation Association of Australia and the National Irrigation Science Network, Chair, Western Port Biosphere Reserve Foundation and he is currently a Director of the Australian Landscape Trust. Duncan is a Monash University Honorary Fellow.

Governance

Governance of the Lakes and within the hinterland and the total catchment area of approx. 20,000 square kilometres has also evolved and changed over time and as population has increased, there has been a rationalisation of utility services in some areas such as, the amalgamation of local government entities and water authorities, and reductions in some State government resources e g. Forestry, Fisheries and agriculture. The legislated powers of organisations such as, the Victorian EPA, Gippsland Ports, Fisheries, Parks Victoria, the application of International agreements (Ramsar listing 1982), Federal policies and legislation (EPBC Act), and various State policy initiatives around coastal planning and development, has also shaped governance structures. From time to time the dedication and drive of committed volunteer or commercial organisations with diverse agendas and interests, have influenced policy direction and planning. More recently, the increased and long-overdue involvement and influence of indigenous entities and the gradual implementation of initiatives related to climate change predictions and mitigation, have reprioritised governance, advocacy and funding. Various structures and committees have been initiated by the Victorian Government – the Gippsland Lakes Management Council, The Gippsland Lakes and Coast Regional Coastal Board, the current Gippsland Lakes Coordinating Committee, the Gunaikurnai Land and Waters Aboriginal Cooperative, and the East and West Gippsland Catchment Management Authorities to name a few. Ambitious calls for a Gippsland Lakes Authority with over-riding jurisdiction over the Lakes and their catchment has unsurprisingly, never eventuated. Today there are approximately twenty organisations, plus sundry associated committees, across the catchment and the Lakes, which have a finger in the Gippsland Lakes governance pie.

Research

The Gippsland Lakes, their fringing shorelines, wetlands, rivers and catchments, have been the focus for much research and observation since early white settlement. Dr Eric Bird in his paper 'The River Deltas of the Gippsland Lakes' (Bird 1961) notes observations by Skene and Smyth (1874) and Howitt (1879) and provides a remarkable understanding of the geomorphology of the system, the impacts from the 1889 opening of the permanent entrance and a very prescient warning of the conditions that still prevail today. Some recent research focussed on the symptoms of declining system health evidenced through vegetation indicators (Boon, Rosengren et al 2014) highlighted the decline forecast by Bird. A major initiative to audit the Lakes in 1998 following previous widespread Nodularia spumigena outbreaks led to the Gippsland Lakes Environmental Audit (Harris, Bately, Webster et al) followed by the final report 'Gippsland Lakes Environmental Study. Assessing Options for Improving Water Quality and Ecological Function' (CSIRO 2001), which identified the need to significantly reduce nutrient inputs to the Lakes from upstream sources within the catchment. Significant funding from the Victorian Government of $22 million to subsidise a program of on-farm works and practices in the Macalister Irrigation District to reduce nutrient loads, along with a coordinated water monitoring program has indicated some improvements. But fluctuating seasonal conditions make overall quantification of improvements difficult. Dr Bird stated that, "it is clear that, in terms of the geological time scale, the Gippsland Lakes will not exist much longer: sedimentation will convert them into a depositional coastal plain, or marine erosion will destroy all trace of them" (Bird 1961). Since 1961, the Blue Rock Dam and Thomson Dam have been constructed and have diverted more fresh water away from the system. Predictions of sea level rise of .5 -1.0 metre must surely exacerbate the current threats to the system.

Where should our research be focussed from here?

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Indigenous Management & Culture on the Lakes

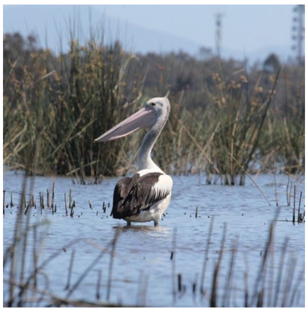
The Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) wishes to pursue outcomes for Healthy Country in a self-determined way, which means 'our people are making decision to benefit the Gunaikurnai and their future'. The Gunaikurnai people have the longest history here and will make decisions to care for Country for the long term.

The story of our creation speaks of Borun, the Pelican, and Tuk, the Musk Duck and how they became the mother and father of the five clans, the creators of Gunaikurnai. This story is linked to the waterways and wetlands across Gunaikurnai Country, including the Gippsland Lakes.

GLaWAC wishes to see principles of holistic management of Country pursued.

> *"As Gunaikurnai, we see our land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing as one. All things come from Wurruk, Yarnda and Watpootjan and they are the spiritual life-giving resources, providing us with resources and forming the basis of our cultural practices. We have a cultural responsibility to ensure that all of it is looked after."*

> *"For many thousands of years Gunaikurnai have lived in the valleys, on the fertile plains and up in the mountains of our traditional Country. Our Country was created by the spirits – the ancestors who link us to the land and bestow on us identity, rights and responsibilities. They defined our relationship with the land – how it should be used, how to move through it safely and how to care for it. In return, Country provided physical and spiritual nourishment for our people, with plentiful food, medicine, water and natural resources for survival."*



Mr Sean Phillipson

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Sean Phillipson is responsible for the development of a strategic Country planning framework for GLaWAC to help coordinate and advance the priorities for land and waterway management across Gunaikurnai Country. He has worked across Gippsland for over 18 years at the EGCMA, Parks Victoria, and as an environmental consultant. Sean has qualifications in environmental science and river health management, and work experience across a range of fields in eastern Victoria including river health improvement, coastal and estuarine management, and the management of wetlands.

Most recently Sean has fulfilled the role of Ramsar Site Coordinator for the Gippsland Lakes Ramsar site. Working together with Traditional Owners, community, and land and waterway managers the EGCMA has coordinated a program aiming to improve the health of the Gippsland Lakes through improved collaborative approaches.

Current arrangements in natural resource management and planning in Victoria often divide parts of the landscape to inform management. The holistic view of Country held by Gunaikurnai is guiding our approach.

> *"Our Country is the land, the rivers and the ocean, the people and the stories, the past and the future. All of it is connected. All of it is important to us. Country heals us and connects us to our ancestors, our culture and history. We are sustained by our Country – through the water, food, medicines and materials that it provides us."*[1]

The Gippsland Lakes are principally within the territories of the Tatungalung and Krauatungalung clans, bordered by the Brataualung, Brayakaulung and Brabralung clan areas. The Lakes region includes the locations of important story places that relate to all aspects of Gunaikurnai life and world views, both past and present.

[1] Gunaikurnai Whole of Country Plan (2015)

Alongside the consent determination and as part of our negotiated settlement package under the Traditional Owner Settlement Act 2010 (Vic), the Gunaikurnai entered into an Indigenous Land Use Agreement and a number of other agreements with the State of Victoria. These agreements build on our rights as Traditional Owners and included:

- the recognition of Traditional Owner rights over all public land within the external boundary of the consent determination
- a grant of Aboriginal Title over 10 areas of land totalling approximately 46,000 hectares
- joint management arrangements over those 10 areas of land.

Five of these jointly managed areas join the waterways of the Gippsland Lakes and Lake Tyers (see Figure 1).

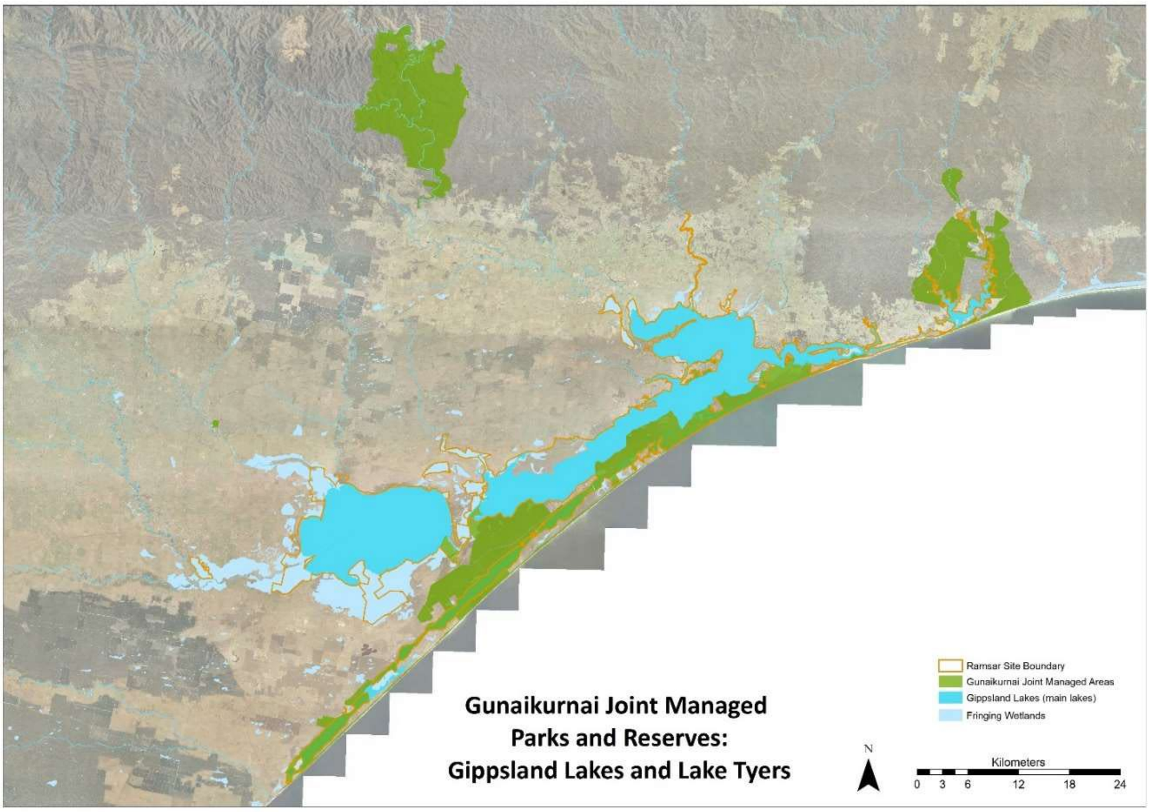

Figure 1: Location of parks and reserves under Joint Management between GLaWAC and Parks Victoria or DEECA (The Knob Reserve only)

The lands and waters of the lakes and associated wetlands comprise traditional hunting, fishing, camping and gathering places of the Old People. Major base camp locations can be found along the dunes between the lakes and the ocean, with many shell accumulations or “middens” still evident as archaeological sites. Burial places are also located within the dunes.

Many “artefact scatters”, consisting mainly of the stone implements made and used by the Old People, are present around the lake shores and the wetland margins, highlighting the selective use of all parts of this landscape. Culturally modified trees (“scarred trees”) are found primarily on the lake shores and riverbanks. This is a sensitive, culturally important area as well as a rich and dynamic environment.

Some recent work completed by GLaWAC in partnership with Monash University covering the Gippsland Lakes region of Gunaikurnai Country, including the Gippsland Lakes Coastal Park and the Lakes National Park has shown that this culturally important area is at risk from the impacts of a changing climate.

Modelling and analysis has shown that a portion of cultural sites (sites can contain one or more site "components", such that a site can be both an Artefact Scatter and a Shell Midden, for example) will be impacted by rising sea levels by 2030.

Sites in areas with sandy sediments or unconsolidated alluvium are particularly susceptible to erosion, with predicted storm surges to impact a larger proportion of known sites than rising lake levels alone over the same period. Of the sites under threat a significant proportion are in locations where vegetation growth could help mitigate the impacts of this erosion.

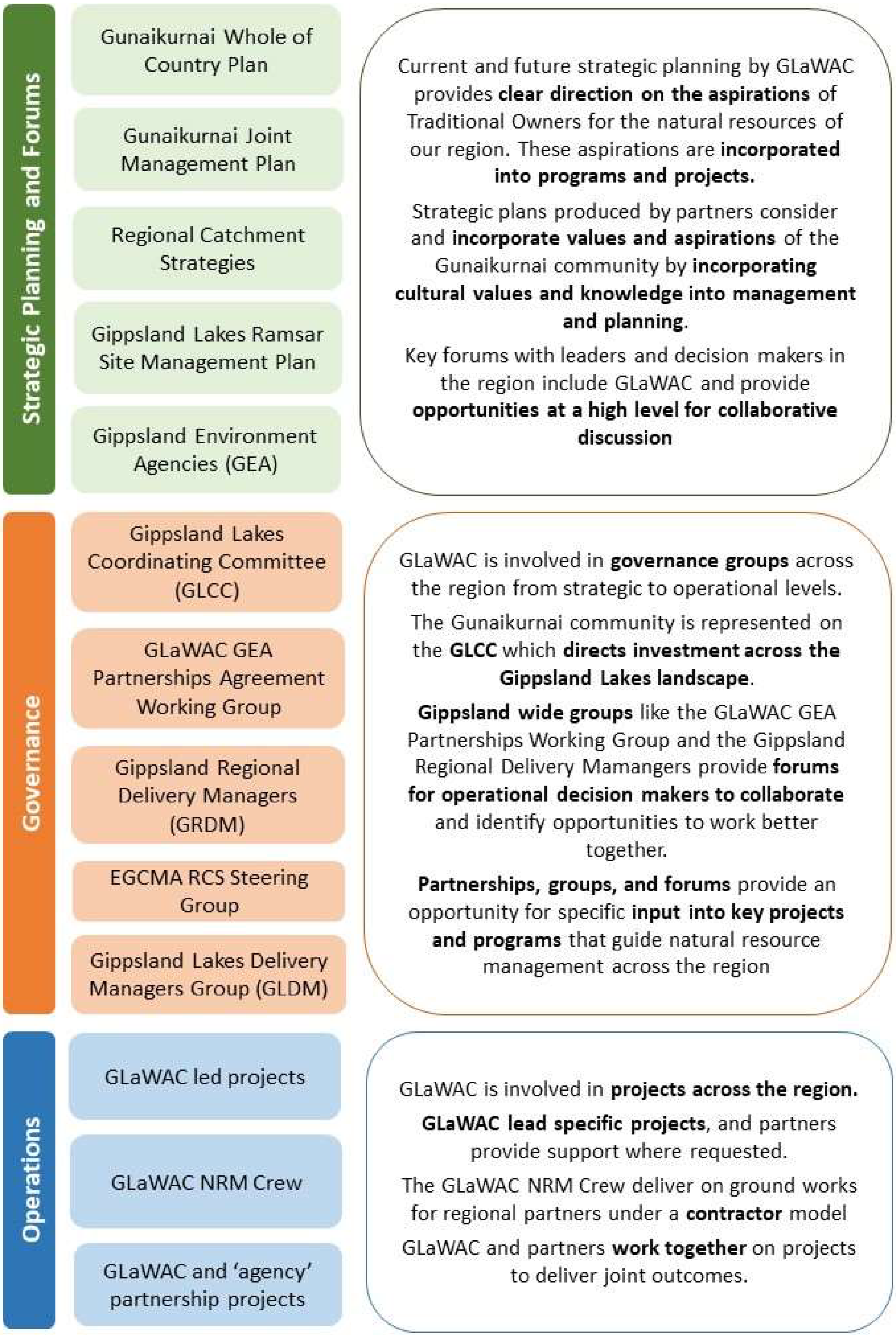

Figure 2: Existing involvement of GLaWAC in planning, governance and operations related to the Gippsland Lakes

Overall, by 2030, under the “best-case” scenario modelled in this work, over 80% of the identified sites assessed by GLaWAC and its partners - Monash University, Australian Research Council Centre of Excellence for Australian Biodiversity and Heritage, Memorial University of Newfoundland, and the University of Melbourne - will be impacted by one or more of the predicted environmental changes under a climate change future.

GLaWAC seeks to influence, and be genuinely involved in healing Country, protecting our cultural sites and traditions on Country, and enhancing community wellbeing, through training, education and economic development opportunities that arise from these aspirations.

Around the Gippsland Lakes and the region more broadly, GLaWAC is involved through a variety of operational programs and partnerships. The level of involvement, number of programs, and their interconnected nature is complex.

The current integration between GLaWAC and our regional partners includes three key themes: Strategic Planning; Governance; Operations and Implementation (see Figure 2).

Issues Facing Integrated Coastal Management

Australia is blessed with a great array of estuary types. From tropical high-tidal to those in southern regions where we encounter coastal lakes, it is apparent that threats exist to the health of estuary waters and ecological assets. These threats are not new. There are some like the Ord in Western Australia that have experienced fish kill from input of pesticides used in farming. Others like the Lower Lakes and Coorong in South Australia are subject to reduced freshwater flows due to over-extraction by irrigation. Sydney Harbour suffers from the legacy of industrial pollution that has long prevented commercial fishing. The list goes on and on as we struggle to balance various public and private interests. But the threats will multiply as climate change impacts take effect, placing those estuaries such as the Gippsland Lakes in danger as those different interests seek to gain advantage of changing environmental conditions.

Gippsland Lakes represent a range of environmental conditions along a salinity gradient that can and has been disturbed. Eric Bird back in the 1960s made this very clear in documenting impacts of the artificial entrance at Lakes Entrance. What was once a system with limited marine input was expanded, and this process continues as dredging continues to even greater depths. Meanwhile more freshwater inputs are not just being diverted for agriculture, there are also threats of farm (and perhaps mine) products being added to flows to pollute lake waters. Climate change in the form of drier periods and sea level rise will contribute further to all that threaten the future of Gippsland Lakes.

A way forward is for major stakeholders in consultation with local communities to first recognise that the current degrading trajectory must stop. Then there should be a collective recognition for the establishment of a process that will formulate pathways to recovery and sustainability. No such process exists for this to happen here at the moment. Elsewhere in Australia different levels of coordinated management of threats to estuary health are being explored. It is time now to start the journey for a sustainable and healthy future for these precious estuary areas of Victoria.

Professor Bruce Thom AM

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Professor Bruce Thom is an Australian geoscientist and educator. He is a founding member of the Wentworth Group of Concerned Scientists, Emeritus Professor at the University of Sydney in Australia and founding President of the Australian Coastal Society. He served as Professor of Geography and Pro-Vice Chancellor (Research) at the University of Sydney, was a Vice-Chancellor of the University of New England and a former Chair of the Australian State of the Environment Committee. Professor Thom has written widely in the areas of physical geography, coastal management, coastal policy, coastal geology, and geomorphology.

Between the Mountains and the Sea: the Lakes' Terrestrial-Marine Interface

Mr Neville Rosengren

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Neville Rosengren is a geomorphologist with 40 years' experience in research, teaching and consultancy in Australia, New Zealand, Indonesia, India, China, UK and USA. He has been engaged as a consultant by State and Commonwealth Government agencies, by major private sector environmental consulting firms and for several years was senior environmental consultant to the United Nations University programme on coastal resources management in Indonesia.

His publications in geomorphology cover aspects of coastal, volcanic and mountain environments. He has long had an active interest in the conservation of geological sites and has published major inventories of sites on a regional (e.g. catchment of the Gippsland Lakes), and thematic (e.g. Box-Ironbark Special Investigation, Newer Volcanic eruption points) scale.

The Gippsland Lakes (GL) comprise the largest coastal wetland complex in southeast Australia. The GL has two catchments: the terrestrial catchment with a long history of uplift and denudation contributing water and sediment and the marine catchment with fuzzy offshore boundaries contributing energy and sediments via waves and currents.

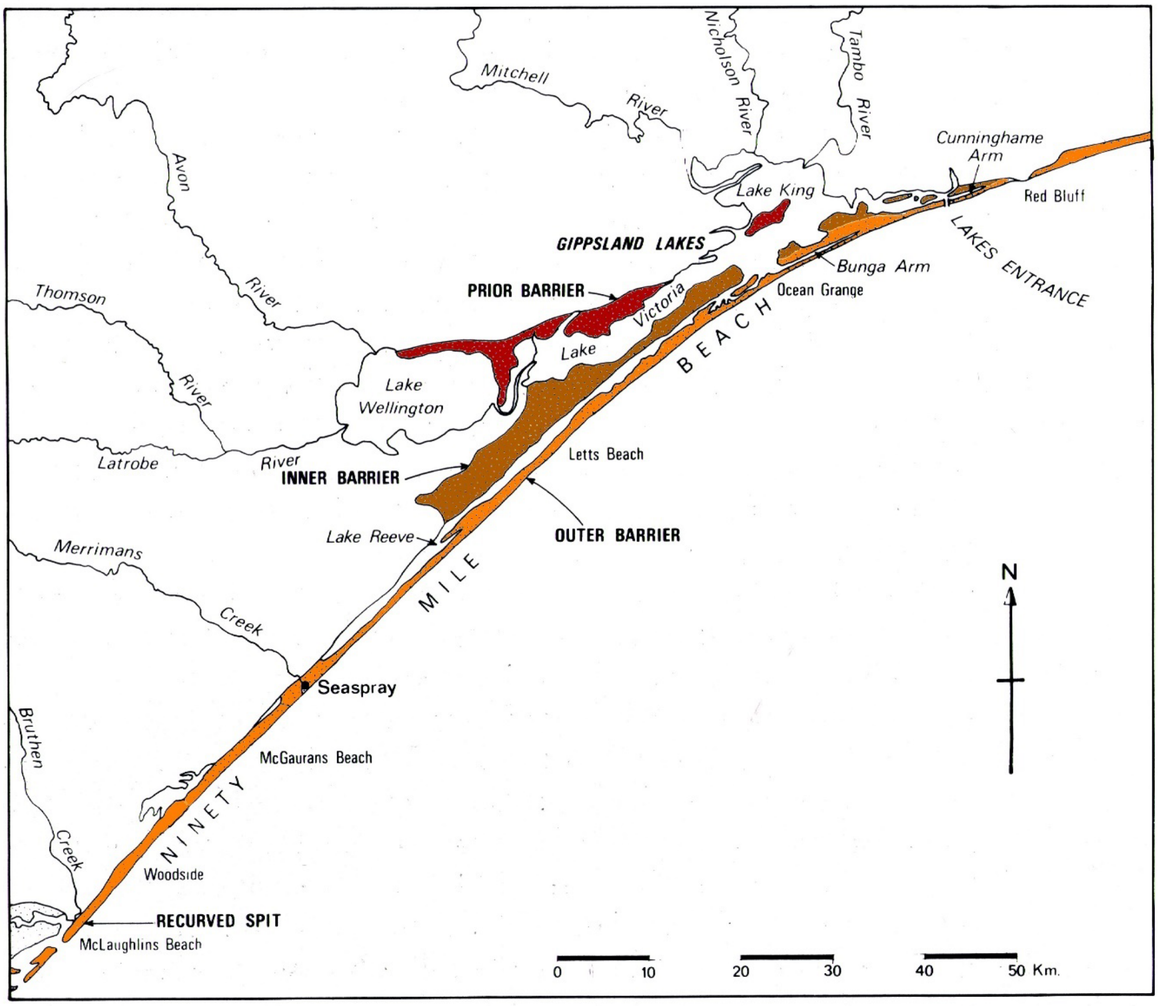

Figure 1. Barrier systems of the Gippsland Lakes.

The linked and isolated lagoons, swamps, active and abandoned river and tidal channels occupy the present surface of the elongate and largely offshore Gippsland (tectonic) Basin. The basin has a basement of Palaeozoic metasediment, volcanic and intrusive rocks and depression and a thick cover of Mesozoic and Cenozoic marine and terrestrial sediments. Structures in the younger basin rocks record a history of post-Mesozoic deformation including significant Neogene tectonics resulting in uplift and denudation of much of the earlier Cenozoic cover.

The varied water bodies and wetlands of the GL are enclosed by a complex of Pleistocene and Holocene wave-deposited shore-attached and island barriers capped by aeolian sand bodies. Eric Bird in multiple publications since 1963 recognised three generations of coastal barrier formation termed outer, inner and prior (Figure 1, Figure 2). The Ninety Mile Beach (NMB)—one of the longest beach systems in Australia extending 140km from Red Bluff to the easternmost entrance to Shoal (Corner) Inlet—is the present outermost expression of these. The present configuration of the NMB reflects the most recent exposure and subsequent submergence of the 100+km wide shallow gently sloping shelf of eastern Bass Strait.

Figure 2. Aerial oblique Gippsland Lakes, Feb 2023.

The principal drivers of shoreline change on the NMB are the direction and strength of wave and wind and associated sediment movement in the shore zone and proximal backshore and the influence of introduced plant species on dune accumulation. Inside the GL wider area river discharge into the shallow lakes has built a variety of delta systems shaped by the volume and type of sediment and interaction with aquatic vegetation. The pre-European hydrological regime that governed the water levels and lake chemistry has been substantially altered by changes in stream flows (reduction) and sediment load (increase), and the continuous input of seawater and marine sediment by the permanently maintained dredged entrance. Determining the associated changes in fringing and aquatic vegetation—a key component of the geomorphological system dynamics—is an ongoing research challenge.

The Ramsar Convention on Wetlands and Australia's International Obligations

The Ramsar Convention on Wetlands is an international agreement between governments (contracting parties) to ensure the wise use and conservation of wetlands. The Convention was agreed in 1971 in the city of Ramsar, Iran, and came into effect in 1975. There are 172 contracting parties with ca. 2500 sites, listed as internationally important (known as Ramsar sites) with Australia having 67 listed sites. Obligations for Contracting Parties are derived from the text of the Convention (Stroud et al. 2021) and on occasions modified by decisions taken at triennial meetings. These provide guidance for meeting the obligations, and recommendations that seem to be constructed to avoid specific commitments.

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Professor Max Finlayson is a wetland ecologist with extensive experience internationally in water pollution, mining and agricultural impacts, invasive species, climate change, and human well-being and wetlands. He has participated in global assessments such as those for biodiversity and ecosystem services, climate change, environment and wetland outlooks, and water management in agriculture.

Since the early 1990s he has been a technical adviser to the Ramsar Convention on Wetlands and has written extensively on wetland ecology and management and contributed to the development of concepts and methods for wetland inventory, assessment and monitoring, and undertaken site-based assessments in many countries.

He has also been actively involved in national and international scientific societies and environmental non-governmental organisations.

He has been recognised for his research, education, and policy work by:

- *The Ramsar Convention on Wetlands*
- *Wetlands International*
- *Society of Wetland Scientists*
- *Australian Freshwater Science Society*
- *And most recently, in 2022 awarded a Chinese Government Friendship Award*

Listing of Ramsar sites is the best-known feature of the Convention, but is only one overarching obligation, and is the one that is addressed here given that the Lakes are a listed site. The site covers an area of 60,015 ha, was listed in 1982, and meets 6 of the 9 criteria that can be used for listing. An analysis of how the site meets all criteria indicates that there is insufficient information to determine if it meets the other 3 – this illustrates an information deficit and raises question about how the site is monitored, and whether the ecological character is being maintained. Once a site is listed the contracting party is required to maintain the ecological character of the site, with provisions to improve or restore this as appropriate, and report any likely or actual change to the Convention (Pritchard et al. 2022).

The latter implies that the ecological character is being monitored – without such activity is hard to see how any reporting could occur. There is an ecological character description of the site that complements and extends the information on the site contained in the formal Ramsar Information Sheet that is required for a listed site, and which should be updated at 6 yearly intervals, if not sooner. The sheet on the Ramsar website is dated 1999. There have been several retorts from officials in the past that the sheet is being updated, and even if currently held in a file awaiting uploading, the failure to hitherto maintain this rather straightforward requirement further suggests an unwillingness to do this. The Victorian authorities are responsible for the site with Commonwealth responsible for reporting.

Returning to the maintenance of the ecological character. The practice in Australia has been to assess changes against the condition of the site when it was listed; this is a valid option, but not the only one, especially when the site was degraded when listing (Finlayson et al. 2021). Sticking to the condition at the time of listing could be used to excuse past sins and avoid restoration (Gell et al. 2016). In the past when claims of adverse changes in the Lakes have been raised, especially related to changes in salinity, they have been met with retorts that the site is on a trajectory of changing salinity following the opening of the entrance in 1889. That may be the case and would benefit from an assessment of all causes of increasing salinity. It also negates the position of maintaining Ramsar sites in the condition at the time of listing. It also does not take into account the reports of unprecedented algal blooms, reports of marine species, and the decline of fringing vegetation. Further, in terms of ecological character, any such assessments and reporting should consider more than the biodiversity, including changes in ecological processes (such as salinity, nutrients, or other pollutants) and ecosystem services (such as loss of amenity and recreational values). The banning of commercial fishing in order to maintain fish stocks suggests there was a case for reporting likely change in the ecological character.

As a finale when addressing ecological character there is a need to consider the impacts of climate change and sea level rise. The decision in 2008 to allow ongoing deeper dredging of the entrance was assessed under the EPBC Act but not for its likely impact on the Ramsar site. This in itself would warrant a reappraisal, although the Convention has hitherto not provided effective guidance (Finlayson et al. 2017). There have also, over the past decade or more, been statements that the site would become saline under climate change. Belatedly a vulnerability assessment may be underway.

The following steps could help meet our obligations (including for migratory waterbirds) for the Gippsland Lakes, aware that implementation of Ramsar in Victoria has been previously criticised:

- Ongoing community consultation, awareness, involvement – participatory not top-down
- Integrated inventory, assessment & monitoring of all parts of ecological character – improved transparency and close the information gaps (cut the excuses; some have been there too long)
- Identify likely scenarios of change through participatory approaches and confirm likely ecological states and their acceptability (for ecological and social reasons)
- Report likely changes in the ecological character as well as actual adverse change.

An alternative could be to shed any pretence and delist the site – purportedly no one has done that for any sites and the process is torturous (Pittock et al 2010) but could be done unilaterally even if contentiously. But even that would not avoid the issues if Australia fully implemented the Convention (that is another story).

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Global Change, Local Impacts

The Water Cycle and Climate Change Impacts

The state of the ecosystems in the Gippsland Lakes is in large measure contingent on freshwater inflows (especially from the LaTrobe, Avon, Thompson, Mitchell, Nicholson and Tambo rivers) that establish the salinity gradient across the lakes system from rivers to the sea (EGCMA, 2016). The location of the catchment of the Gippsland Lakes in the difficult mid-latitudes means that large climate change impacts that diminish water quantity and quality are likely. Further, there is a need to assess not only the direct climate change impacts on water but also the consequences of how society chooses to manage water differently in response. In this synthesis, some scientific information is drawn from the better researched Murray-Darling basin immediately north of the Gippsland Lakes catchment.

1. Water volumes and flow timing will change.

Rainfall in southern Victoria is projected to decline with climate change. Inflows into reservoirs in central Victoria have already fallen by 21% since 1975 (DELWP, 2022). Percentage changes to river-basin aggregated annual runoff for East Gippsland for 2065 under emissions pathway RCP8.5 (relative to 1975–2014) range from a +21% for low impact, to -18% in the median and -39% in the high impact scenarios (Potter et al., 2016). These declines are anticipated to be greater in autumn and spring. Further, greater extremes of floods and droughts are expected. In all, there is a high probability of declines of freshwater inflows into the Lakes. In extreme droughts saline waters could be expected to flow a long way inland with consequent negative impacts on populations of freshwater flora and fauna.

2. Water quality will decline.

Unfortunately, there are many ways in which water quality will decline in a changing climate (Baldwin, 2021, DELWP, 2022, Pittock, 2009). Higher average temperatures will impact on freshwater ecosystems (Potter et al., 2016). Greater climatic extremes and more frequent severe fires would see more sediments, nutrients and other pollutants washed into the rivers and ultimately the lakes. Cyannobacteria blooms are likely to increase in frequency. Potential acid sulphate soils may desiccate and oxidize in severe droughts (Agriculture Victoria, 2019).

Professor Jamie Pittock

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Professor Jamie Pittock teaches courses on environment and society and climate change vulnerability and adaptation. He co-convenes ANU's Masters of Climate Change program. Jamie's research focusses on environmental governance, climate change adaptation, energy and sustainable management of water. Jamie manages research projects on irrigation in Africa (Mozambique, Tanzania and Zimbabwe) and on energy and food in the Mekong region.

Jamie's PhD examined integration between management of freshwater ecosystems and responses to climate change, involving case studies from nine countries.

Prior to joining ANU, Jamie worked for WWF International as Director of their Global Freshwater Program on conservation of wetlands, water use in agriculture, and river basin management. He worked for WWF Australia on: national environmental laws; conservation of threatened biodiversity; management of invasive species; and measures to support Indigenous and private conservation land managers. He also worked in the Northern Territory and in Victoria.

Jamie is a fellow of the Higher Education Academy (FHEA) and a graduate of the Australian Institute of Company Directors. He is a member of the Wentworth Group of Concerned Scientists and the World Commission on Protected Areas, serves on the Advisory Board of The Nature Conservancy Australia and the public fund of Water Stewardship Asia-Pacific, and chairs the Eminent Scientists Group of WWF Australia. Jamie is an editor of Regional Environmental Change, Frontiers - Freshwater Science, and Ecosystem Services.

3. Changes in water management in the catchment may further diminish inflows.

A number of changes in the way that the water is managed in the catchment of the Gippsland Lakes may exacerbate or lessen the impacts on water availability. The population of the region and urban water demand is increasing (DELWP, 2022). The closure of coal mines and power stations in the LaTrobe Valley brings the opportunity to reallocate the large volumes of water allocated for cooling power stations to environmental flows and Traditional Owners (DELWP, 2022). However, the proposals to flood the former mining voids may take vast volumes of water over 30 years (Whittaker, 2020). Despite increasing scarcity, the Victorian Government also proposes new irrigation areas in the lower Latrobe region and in the Macalister and Avon systems (DELWP, 2022).

As direct climate change impacts worsen it is likely that societal responses will further diminish river inflows, for example, with measures to maximise rainwater harvesting on farm lands, or increased transpiration from tree planting for carbon sequestration (Pittock et al., 2023). Thorough regulation of groundwater will be required to prevent switching to and over extraction of groundwater, for instance, there are areas of declining groundwater levels on the Red Gum Plains (west of Bairnsdale) (EGCMA, 2022).

Some societal response options.

There is an urgent need to step up considerations of options for managing water in a changing climate to conserve the Ramsar wetlands of the Gippsland Lakes. Among those options are:

a) Deciding to reduce water allocations and the balance of water allocation between consumptive and environmental uses as water availability diminishes (Lindsay, 2021);
b) More water use efficiency, recycling and desalination (DELWP, 2022);
c) Setting pre-eminent downstream environmental flow targets linked to thresholds needed to conserve key environmental and cultural assets (Baldwin, 2021), and protecting the few remaining free flowing rivers (Pittock and Finlayson, 2011).
d) Monitoring and regulating risks to shared water resources, such as water storage on farms and tree planting (Pittock et al., 2023); and
e) Building on Catchment Management Authority programs to systematically restore riparian zones, including removing barriers to fish passage, fencing out livestock and restoring native vegetation (WGCMA, 2016, EGCMA, 2016).

Finally, the limited current ownership (2 GL/yr entitlement) and management opportunities for Traditional Owners of their fresh waters is unjust (GLaWAC, 2023). Funding Traditional Owners would be one way of implementing a number of these response options, for example, through more investment in Indigenous land and water management programs.

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Sea Level Rise and the Gippsland Shoreline.

Sea-level rise as a consequence of global warming is a major concern for low-lying coastal communities. Coastal environments are increasingly likely to experience hazards such as coastal inundation and erosion over coming decades driven by sea-level rise. Additionally, severe weather events, which cause storm surges, high waves and heavy rainfall totals will likely be affected by climate change and this will have a compound effect on coastal hazards associated with sea-level rise.

Factors that affect global mean sea level are primarily governed by ocean mass changes due to addition of meltwater from land-based sources such as glaciers and the major ice sheets of Greenland and Antarctica and ocean density changes which are driven largely by temperature changes. Regional variations in sea level are caused by large scale atmospheric weather patterns, ocean currents and circulation and changes in the Earth's rotation and gravity related to mass changes such as melting of polar Ice Sheets. Local vertical land movement also affects relative sea level rise along coastal margins.

With each IPCC assessment cycle, advances in sea level science are compiled, assessed and sea-level rise projections are updated accordingly. In the latest IPCC 6th assessment report, the emission scenarios that underpin sea-level rise scenarios are the shared socio-economic pathways. A major source of uncertainty in sea-level rise scenarios is the contribution from the major ice sheets, particularly Antarctica. Other uncertainties arise from local factors such as vertical land movement which affects relative sea level rise.

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Kathleen McInnes leads the High Resolution Climate, Ocean and Extremes group of the Climate Science Centre in CSIRO's Environment business unit. Her work deals with how climate change will affect severe weather and coastal extreme sea levels with a focus on Australia and small islands. She has developed climate projections for impact and adaptation assessments to assist local government manage and adapt to climate change. Her contribution to this work was awarded Eureka awards in 2003 and 2009. She has published over 200 refereed publications, reports and articles and has been a lead author on several reports of the Intergovernmental Panel on Climate Change in the area of sea level, extreme weather and compound events. She also served as a co-chair of the World Climate Research Program Grand Challenge on Regional Sea Level Changes and Coastal Impacts. In 2017 she became a Fellow of the Australian Meteorological and Oceanographic Society and in 2020 she was awarded the CSIRO Medal for

Global warming is causing tropical expansion and a southward shift in major weather systems. This is associated with an enhancement of wind speeds in the westerly wind belt south of Australia, which in turn is changing the ocean wave climate. A continuation of this trend is projected for future decades. This may further affect the drivers of coastal hazards in the Gippsland Lakes region through changes in local wave climate (wave height, period and direction) and weather systems that are largely responsible for coastal hazards in this region. These changes have the potential to further compound the coastal hazards associated with sea-level rise.

Changing Ecology

Pesticide Pollution Lock-ins and the Gippsland Lakes

From a semiotic perspective (i.e., from the perspective of the special study of signs and how signs function to create meaning) our special ecological sciences are socially constructed. We group our observations together to make sense of what we sense in the world, correcting and refining as we go. This is a social activity (think of why we use peer review for example). Just as important for my purpose, we do this grouping and classifying within social institutions. I will focus on the role of institutions in the social construction of pesticide pollution in the Gippsland Lakes.

Pesticide use in Australia has more than doubled in the last ten years and is set to double again by 2030 (APVMA 2023). We have no figures for the Gippsland system, however, it is safe to assume there has been a similar increase in use. There is now considerable evidence emerging that shows our increased use of pesticides is severely affecting our biodiversity (e.g., Sigmund *et al.* 2023). Despite this emerging scientific knowledge of ecological harm, nearly all relevant government actors at all levels consider Australia's existing pesticide regulatory system to be generally satisfactory. Given this, my presentation will focus on the role that public institutions play in upholding and defending the occlusion of harms caused by pesticide pollution. In terms of a policy recommendation for the forum, I will argue that we need to focus more of our efforts on finding ways to overcome institutionalised pesticide use lock-in to create an ecological improvement for the Gippsland Lakes.

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David Low is qualified with a PhD in Scientific Communication (Australian National University, 2003) and is a Master of Environmental Science (Monash University, 1992). He became interested in the environmental issues related to weeding while working for Monsanto and talking with people who were concerned with the health and environmental effects of the chemicals Monsanto were selling. He realised that, instead of killing weeds with chemicals, weeds can instead be used as a resource, for example, many weeds can be used as silage to feed stock or as a living tool to revitalise soil. While studying for his environmental science degree, he also noticed that where there is biodiversity, there is decreased weed problems. So began David's work to learn about and advocate for the environmental benefits of working with nature instead of 'waging war' through the use of toxic, synthetic pesticides.

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Ramsar Values and Migratory Birds of Gippsland Lakes

The Gippsland Lakes Ramsar site was listed in 1982 on the basis of four criteria of which two, Criteria 5 and 6, are wholly focused on waterbirds (Hansen et al. 2021). At the time of nomination, Gippsland Lakes had records of 40,000-50,000 waterbirds (Criterion 5) and at least six waterbird species recorded in internationally significant numbers, that is, representing 1% or more of their population (Criterion 6) (Gippsland Lakes RIS 1999).

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Birgita is a senior research fellow in the Centre for eResearch and Digital Innovation at Federation University, where she manages research projects relating to citizen science, natural resource management and digital agriculture.

Her primary research focuses on the conservation of shorebirds, waterbirds and their wetland habitats, with a growing emphasis on achieving conservation outcomes through technology-enablement. She has previously undertaken research on responses of woodland birds to riparian restoration.

Birgita is a long-term member of the Victorian Wader Study Group, and an executive committee member of the Australasian Wader Studies Group and International Wader Study Group. She is also a member of the BirdLife Australia Research and Conservation Committee, and the IUCN Woodcock and Snipe Specialist Group.

Birgita is leading The Latham's Snipe Project, a national citizen science project investigating the movement patterns and habitat use by Latham's Snipe.

Gippsland Lakes have supported substantial congregations of migratory shorebirds in the past and it was traditionally one of the most well-known sites for migratory shorebirds in Victoria (Watkins 1993). It has been part of the national shorebird monitoring program since the program commenced in the 1980s by the Australasian Wader Studies Group (Hansen et al. 2019). The program is ongoing and coordinated by BirdLife Australia, with additional surveys of the Gippsland Lakes Important Bird Area being conducted by BirdLife East Gippsland.

The 2010 Ecological Character Description listed Red-necked Stint and Sharp-tailed Sandpiper based on maximum counts exceeding 2% of the East Asian-Australasian Flyway population (8000 and 3187, respectively) (BMT WBM. 2011). Since that time, shorebird numbers have decreased and populations of these two species are around 150-200 individuals (Van Swinderen et al. 2023). Other species like Common Greenshank and Red Knot are recorded relatively rarely compared with past surveys.

Decreases in recorded numbers of many migratory shorebirds is likely to reflect both changes in habitat suitability and survey effort. Locations like Lake Reeve and Jones Bay support shorebirds depending on hydrological and climate conditions. For example, Lake Reeve has supported significant populations of Sharp-tailed Sandpiper and Red Knot, but in drought periods the habitat is unsuitable for shorebirds due to drying of the mudflats. Jones Bay will often support migratory shorebirds dependent on outflows from the Mitchell River. Areas like the western morasses and fringing wetland habitat on the southern side of Lake Wellington contain suitable habitat for shorebirds but the southern shores are largely unsurveyed due to difficulties with access.

Small-scale management activities such as dredge-spoil habitat augmentation may provide opportunities for reinstating local populations of threatened species like great knot and red knot. However, insufficient survey coverage due to difficulties in access prevents a robust assessment of shorebird population size and distribution across the lakes system. This will be important to determine if changes in shorebird populations reflect broader changes in ecological character (as has occurred in the Coorong Ramsar wetlands).

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Floods, fires and phytoplankton: Some perspectives on water quality in the Gippsland Lakes

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Research Interests

Biogeochemistry of permeable sediments

Influence of cable bacteria on sediment geochemical processes

Current projects:

Coastal permeable sediments as a novel source of greenhouse gases

Untangling the mechanisms of nutrient export from agricultural catchments

Resolving nanoscale structure-activity for rational electrocatalyst design

The Gippsland Lakes are well known for their recurring blooms of cyanobacteria, which mostly comprise of Nodularia spumigena*. Underlying these blooms, however, is a complex interaction between river flows, nutrient biogeochemistry and phytoplankton succession that supports the productivity of the Gippsland Lakes.*

Nodularia blooms typically take place in years of above average river flow, which typically occur over the winter months and into lake spring (Cook and Holland 2012). These flows bring nitrogen and phosphorus into the lakes as well as lowering the salinity leading to stratification. Over the winter months this stimulates blooms of dinoflagellates such as *Prorocentrum cordatum* and *Gymnodinium sp*., as well as ciliates such as *Favella spp* and diatoms such as *Skeletonema sp* (Jonathan Smith, First Algal Alert Monitoring program). The size of these blooms is closely linked to the amount of nutrient inputs from the rivers entering the Gippsland Lakes, highlighting the close link between the catchments and system productivity (Cook and Holland 2012). These phytoplankton are rapidly grazed by zooplankton and have turnover times of ~0.5 to 2d-1 (Holland et al. 2012). Additionally, recent work has highlighted the importance of flagellates in juvenile fish nutrition (McNaughton et al. 2022). It is therefore logical to assume that these winter and spring blooms of diatoms, ciliates and flagellates play a critical role in supporting the food webs of the Gippsland Lakes.

As the season progresses from spring into summer, river flows typically decline, which means that nutrient recycling is the dominant source of nitrogen and phosphorus for phytoplankton. Stratified conditions lead to low oxygen in the bottom waters of the Gippsland Lakes, stimulating phosphorus release into the water from the sediment (Cook et al. 2010). This is a critical process in the Gippsland Lakes and our own research, as well as that of CSIRO suggests that P releases can at times, be more rapid than might be expected from diffusion alone (Webster et al. 2001; Zhu et al. 2016). We believe that this process can be enhanced by the presence of benthic fauna such as *capitellid* worms. The burrowing action of these organisms greatly enhances oxygenation of the sediment leading to the accumulation of iron oxide and phosphorus associated with this during oxic periods in the water column. Upon the onset of low oxygen or anoxic conditions, these large pools of phosphorus are released into the water column (Scicluna et al. 2015; Zhu et al. 2016). Nitrogen recycling processes in contrast, lead to a loss of nitrogen through the process of denitrification. This in turn leads to the depletion of nitrogen relative to phosphorus well below the critical ‘Redfield Ratio’ of 16N:1P required for phytoplankton growth (Cook et al. 2010). Stratified and nitrogen limited conditions are highly conducive to *Nodularia* blooms because these organisms are capable of fixing nitrogen from the atmosphere alleviating nitrogen limitation. In addition, these organisms can control their buoyancy, accumulating at the surface to meet their light requirements and sinking to the bottom to meet their phosphorus requirements. The exact trigger for the bloom initiation (and akinete spore germination) is unclear, however, blooms seem occur during periods of prolonged warm and calm weather.

Once initiated, the size and duration of *Nodularia* blooms is most likely controlled by the period of favourable weather conditions. The size of the bloom appears unrelated to catchment nutrient inputs reflecting the importance of internal recycling (Cook and Holland 2012). *Nodularia* produces the hepatotoxin nodularin which results in the Gippsland Lakes being closed for recreational purposes during blooms. In addition, it has been found nodularin makes its way into fish and crustaceans both within the Gippsland Lakes as well as in Bass Strait (Craig Ingram pers comm). The exact mechanism of this transfer remains unclear, however both passive uptake from the water column and via the food web are possible. Although cyanobacteria are generally unpalatable to grazing organisms, we have found that nitrogen from *Nodularia* can make its way into the food web. Nitrogen that has been newly 'fixed' by *Nodularia* has a unique isotope signature that allows us to trace the progression of this nitrogen into other phytoplankton and fish such as bream. While making these isotope measurements, we simultaneously conducted grazing experiments that showed *Nodularia* were not directly grazed by zooplankton. Instead, it seems likely that zooplankton such as *Oncaea sp*. were scraping epibiont bacteria off the surface of *Nodularia* (Woodland et al. 2013). It is unclear if this mechanism could be a vector for nodularin transfer. Further work is required to understand the movement of nodularin through the food web of the Gippsland Lakes.

Not all high flow years follow the above progression with some wet years having no blooms of *Nodularia*. Of particular note, were the years 2007-2008, which experienced extensive fires in the catchment during the summer of 2007. In June, a flood led to the highest loads of nitrogen and phosphorus into the lakes ever recorded. Nitrate loads were particularly high and high concentrations of the nitrogen and chlorophyll persisted in the water column over the summer and into the winter of 2008. This was associated with a bloom of the pico-cyanobacteria *Synechococcus* sp. (Cook and Holland 2012). The small size of this cyanobacteria means that it does not settle to the sediment, and it also appears to be a poor food source for grazers, resulting in its long persistence.

While reports of *Nodularia* blooms in the Gippsland Lakes have existed since the 1960s, it is less clear whether these are a modern phenomenon or have a longer history. Anecdotes from the 1880s of fisherman being poisoned by toxic water exist in fisherman Jock Carstairs diary (Synan 1989). To explore this, we explored paleo-proxies in cores retrieved from Lake King. This work suggested that prior to the opening of the entrance in 1880, the lakes were fresher as, expected, but that they were also in a more eutrophic state as indicated by higher sediment organic carbon content, and the presence of cyanobacteria pigments. Nitrogen isotopes also suggest more nitrogen fixation by cyanobacteria. The fresher state of the Gippsland Lakes is likely a key factor that promoted the apparently higher abundance of cyanobacteria during this period. In addition, we observed much higher levels of charcoal in the sediment prior to the 1880s. As noted previously, bushfires can lead to increased nutrient loads to the lakes, and it is possible that the lakes were maintained in a eutrophic state by cultural burning practices (or possibly a response to colonisation). After the opening of the entrance, there was a period of relative oligotrophy with lower sediment organic carbon contents and cyanobacteria pigments. From the 1950s onwards, proxies of eutrophication began to increase, coincident with a rapid increase of urbanisation and agricultural intensity in the catchment (Cook et al. 2016).

Given the severe socio-economic impacts of *Nodularia* blooms, there has been much interest in ways to prevent them. In the Peel-Harvey Estuary, the magnitude of blooms has been greatly reduced by the construction of a second artificial entrance. This raised salinities above the threshold suitable for *Nodularia*. This approach has also been explored using models, but these studies have concluded that a second entrance is unlikely to have a significant impact on blooms size (Webster et al. 2001). Other engineering approaches such as destratification have been discussed, but the size of the Gippsland Lakes means the costs are most likely prohibitive. At present, the major focus is on reducing loads of nitrogen and phosphorus to the Gippsland Lakes through catchment revegetation and farm nutrient management strategies. Although this is an expensive and long-term program, the numerous other water quality, and ecological co-benefits mean this is probably the most prudent approach.

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Future Directions

Adaptive Governance of Large, Complex Ecosystems – such as the Gippsland Lakes

The current conditions of the Gippsland Lakes are a result of multiple pressures. These pressures will combine to drive their future condition. Governance challenges are increasing as a result of climate change interacting with these other pressures. These interactions result in complex uncertainties and compound and systemic risks that challenge simple risk assessment methods[1]. There are not linear relationships between warming and environmental challenges. Rather, change may be sudden, disruptive, unexpected and move the system to new states, driven by extreme events (like droughts, floods, fire) and changes in underlying processes[2].

Many of the risks facing the lake systems and their catchments are poorly understood, and management cannot rely on simple risk assessment models or predictable outcomes from management interventions. All ecosystem and water resources management must deal with non-stationarity and changing

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Michael established the Forest Stewardship Council Ltd. in Australia and was the foundation chair for the first decade of the international Alliance for Water Stewardship. He is currently Chair of the Fitzroy Residents Association and is retained as an advisor by two leading PR firms on communication and issues management.

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Jason's PhD focused on climate risk assessment and adaptive governance of the Murray Darling Basin. In the past, he held senior roles in government including as a Senior Executive at the Murray Darling Basin Commission and the MDB Authority, where he had responsibility for natural resource management programs including native fish conservation, ecological assessments of riverine ecosystems, and risk assessment and climate R&D.

Jason's consultancy work spans many aspects of natural resources management. Jason's policy work is grounded in practical and business experience in agriculture, forestry and horticulture. In 1989 Jason was awarded the inaugural Banksia Award for work in promoting revegetation.

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climatic and geochemical cycles[3] The post-normal world is characterised by *"irreducible complexity, deep uncertainties, multiple legitimate perspectives, value dissent, high stakes, and urgency of decision-making"* with science unable to provide absolute truths and confident solutions.[4]

These conditions have many profound implications for governance and research including the well-recognised need for interdisciplinary, participatory and trans-disciplinary approaches. Dealing with these challenges will require forms of governance that are inclusive, integrative, adaptive and transformative.[5]

This paper set out some ideas about the characteristics of governance models that are appropriate for the social-ecological system of the Gippsland Lakes.

Governance processes determine how change is understood, decisions made, resources allocated, and outcomes evaluated[6]. Governance involves formal and informal structures and institutions, processes and practices, including those of large bureaucracies, smaller units, businesses, non-government organisations, or informal networks. These institutions operate in accordance with rules, norms and practices codified formally as laws, regulations and standards or informally as accepted practices and organisational or social cultures. Governance institutions determine how large complex systems, like lakes and river basins, are understood, managed and governed[7]. A sizable body of literature argues that institutions become locked-in to ways of thinking and acting that constrains their ability to adapt to change, new expectations or new circumstances (institutional lock-in) and that path dependence is critical in fashioning and constraining options for change[8].

Victoria's governing institutions, including those for the Gippsland Lakes and their catchments, emerged from British colonisation, and the state-sponsored economic development of the 20th century. These historical foundations shape contemporary governing practice, with certain paradigms and disciplinary traditions become sedimented into the systems of governing.[9] For the Lakes these combine water resources management, civil engineering, public administration, hydro-developmentalism, and more recently, neo-liberalism, conservation and environmentalism. Together these form governing orthodoxies with considerable inertia and produce governing techniques and policy logics that can limit capacity for adaptation.

Impacts of climate change are unpredictable given non-linear relationship between warming and change (sudden events) and, uncertainty[10]. Climate risk analysis needs to account for potential

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state-shifts in socio-ecological systems[11]. Combined with other human-induced environmental changes, climate change can contribute to tipping points beyond which impacts may amount to a state-shift of unknown dimensions[12]. Climate change risk increase and uncertainty escalates at the regional scales with changes in precipitation, wind speeds, seasonal variations and weather extremes magnified through catchment and ecological processes and socio-ecological feedbacks.[13][14] Improved climate risk assessment techniques are emerging, but these typically adopt administratively rational models of problem solving.[15] Techniques used to support adaptation decisions under various degrees of uncertainly, include cost-benefit analysis where uncertainly is less profound (for example sea level rise), adaptation pathways where there are prospects uncertainty can be resolved (e.g. flood protection) to robust decision-making for solutions that can work under a range of scenarios where the information base is insufficient.

Stanley et al. identify a complex layering of climate risks.[16] Their *1st-to-4th order impact framework* illustrates the flow-through of risks from immediate and direct impacts to ecosystem and livelihood impacts. The framework shows, for example, linkages between climate changes (1st order) and ongoing viability of food production (2nd order), rising in food, water and energy prices (3rd order) and a consequent increases in poverty (4th order). They emphasise feedbacks between the four orders. Rising et al.[17] argue current risk management models, including those based on scenario analysis, suffer from five deficiencies; (1) biophysical impacts are either outdated or unavailable; (2) poor handling of extremes; (3) or impacts magnified through feedback loops and interactions; (4) deep uncertainties for which probabilities do not exist, and (5) unknown, poorly quantified or unidentified risks.

Adaptive governance models and the use of dynamic adaptive policy pathways, seek to address the problems of these deep uncertainties when combined with evolving societal preferences and perspectives.[18] These adaptive approaches extend and revise analysis over time monitoring

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critical developments and tipping points that could render policy responses inappropriate.[19] Hassnoot et al. contrasts this approach with traditional static "predict and plan' approaches that "assume the future can be predicted" planned for and managed (p. 485).[20] These approaches focus on the capacities of the decision-making process rather than specific outcomes, emphasising adaptive decision-making "in the face of high uncertainty and inter-temporal uncertainty."[21] The use of adaptation pathways addresses the need for societal transformations, where the goal of adaptation is not specific "risk reduction per se but rather addressing the systemic drivers of vulnerability in dynamic systems".[22] There are few examples of fully developed and broad adaption strategies because most strategies focus on incremental change that supports the status quo, rather than transformative change[23]. While recognising there are different contexts for adaptation, the task of enabling decision-making "requires understanding the interdependencies between institutions, values and knowledge and how to change these."[24]

Adaptive governance is good governance in periods of rapid change and therefore needs to be:

- Adaptive and flexible rather than based on static or stationary views of the world in order to anticipate and accommodate unpredictable futures;
- Integrative rather than siloed or narrow and responsive to emerging understanding of social, ecological and economic systems;
- Capable of transformative change that can accommodate the new normals that are emerging due to climate change
- Inclusive; create space for relevant stakeholders to have a voice and share ownership of transformative change

Governance needs to bring together stakeholders to encourage them to develop their capabilities, engage in productive deliberations about joint decision-making, and develop informed positions about risks and appropriate responses[25]. The need for open ended, transparent, participatory planning approaches is axiomatic in adaptive governance. Conservation approaches suited to post-normal conditions require scientists and practitioners to implement approaches unconstrained by disciplines and sectoral boundaries, geopolitical polarities, or technical problematisation. Instead, governance practice suited to a "post-normal world" requires a stronger focus on inclusive creation of knowledge and the interaction of this knowledge with societal values and rules[26].

We hope that the ideas outlined above about adaptive governance can help guide thinking about what is needed for governing the Gippsland Lakes. At present, the Gippsland Lakes governance

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is fragmented, and disaggregated with numerous specialist agencies responsible for components of the system. Successive strategies have attempted to guide and coordinate management efforts. We are not advocating for a specific governance model – such as the creation of single new authority – or of specific forms of oversight, such a co-governance model with lead responsibilities for actions allocated across different agencies, with other agencies monitoring their performance. What we are arguing for is that we need to assess governance capacities in light of the complex challenges we face, and explore, design and deliberate on the models that will provide adaptive capacities. The decisions on which models and the reforms needed will be guided by the democratic deliberations.