Navigating climate change in North-East Landscapes
Swamps, Rivers & Ranges with NRCLP
27 August 2021

Wetlands as a signal of climate change

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Main messages

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1. Wetlands very likely to be greatly affected by climate change, from increased temperatures, decreased rainfall and runoff, changes in evaporation, shifts in seasonal patterns – could be (are?) signals of climate change in our environment

2. Have sufficient scientific knowledge and practical experience to manage wetlands, and turn around past loss and degradation, including through adaptation to climate change if we take notice of these signals

3. Following from that is the apparent problem we have with ensuring the signals are noticed and acted on - knowledge is shared and resources (including through incentives) made available for effective responses (monitoring, adaptation)

What are wetlands?

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Wetlands have been defined and classified in many different ways, and a lot of people have seemingly perished in the battles to establish the dominance of one definition and scheme over another …. that's academic, literarily…

Except we do mix terms – swamps (forested) v marshes (non-forested); or redundant terms (lake & mere) – consistency would help communication, but not today's point

In the context of NE Victoria we have – swamps, marshes, lakes, streams, soaks, turkey nest dams, waterlogged depressions, runoff & drainage zones, waste water ponds, whether artificial or (semi)natural, permanent or ephemeral, rain-filled or by stream or overland flow, organic (peat) based or mineral, whether cropped/grazed …..

What are wetlands?

Systems strongly influenced by the presence of surface water (and its periodic absence) and ground water; support aquatic and semi-aquatic species

What are wetlands?

Cane grass wetlands

Blackbox wetlands

Lignum wetland

Lake / marsh

What are wetlands?

Depressions or sumps in cropland

Grazed depressions or channel overspills

Cleared and grazed channels

What are wetlands?

Reed beds

Streams – riparian vegetation removed

Cumbungi beds

Red gum forest & sedge marshes

Wetlands - Farm dams

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There are a lot of them across the rural landscape and they provide watering holes for many organisms – water birds very obvious, yabbies, turtles, snakes, frog … mosquitoes …

They have variable water depth which can influence their value for biodiversity – if they retain water in drier months then they can be a valuable refuge. If they draw down they could still be valuable dry refuges for many species

They can complement the value of natural wetlands, unlikely to replace these values in their entirety

Wetlands - Farm dams

NB: Farm dams have properties that make them a hotspot for methane emissions—a greenhouse gas that is 34 times more potent than carbon dioxide

Malerba et al 2021. https://doi.org/10.3390/rs13020319

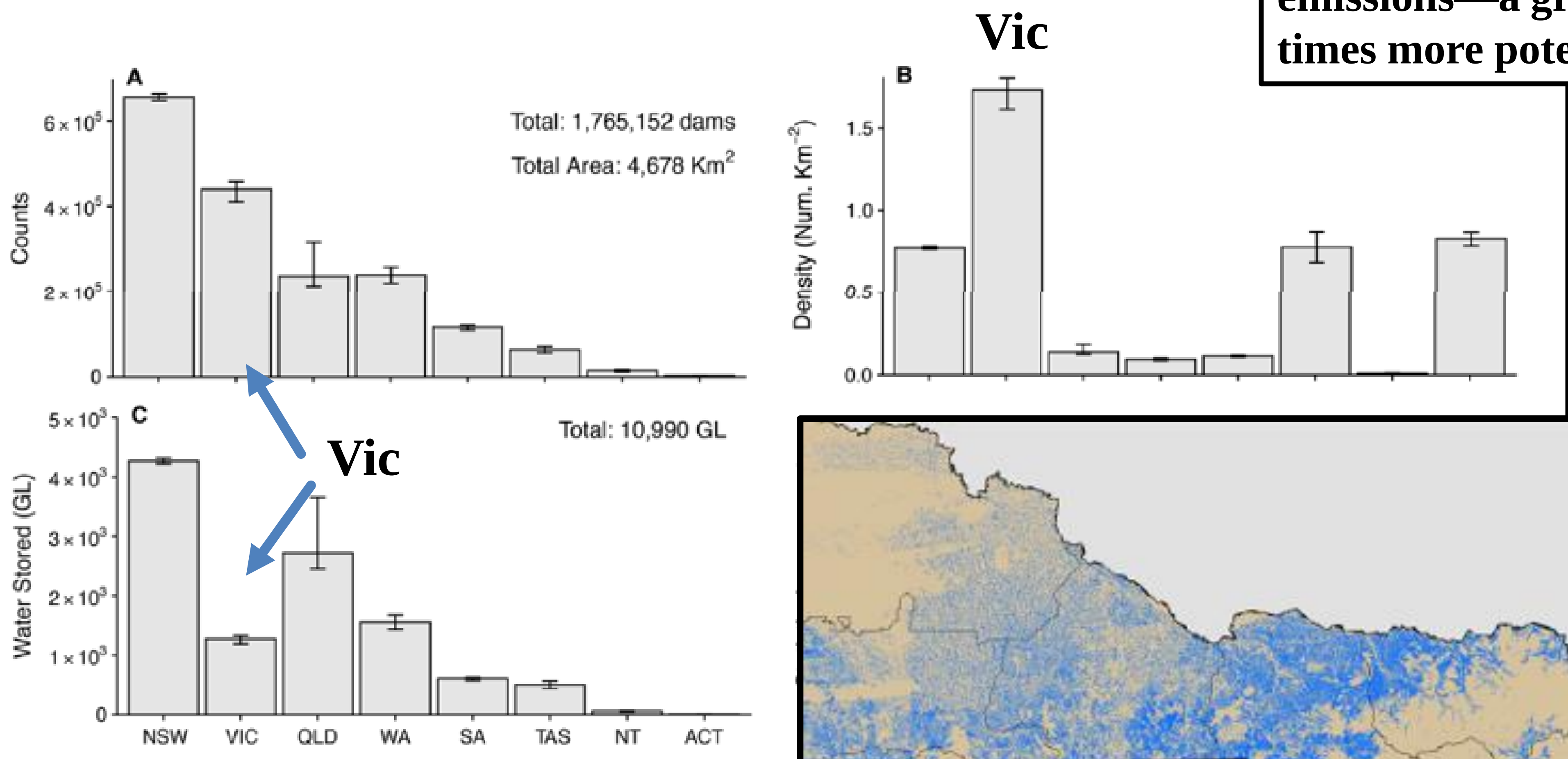
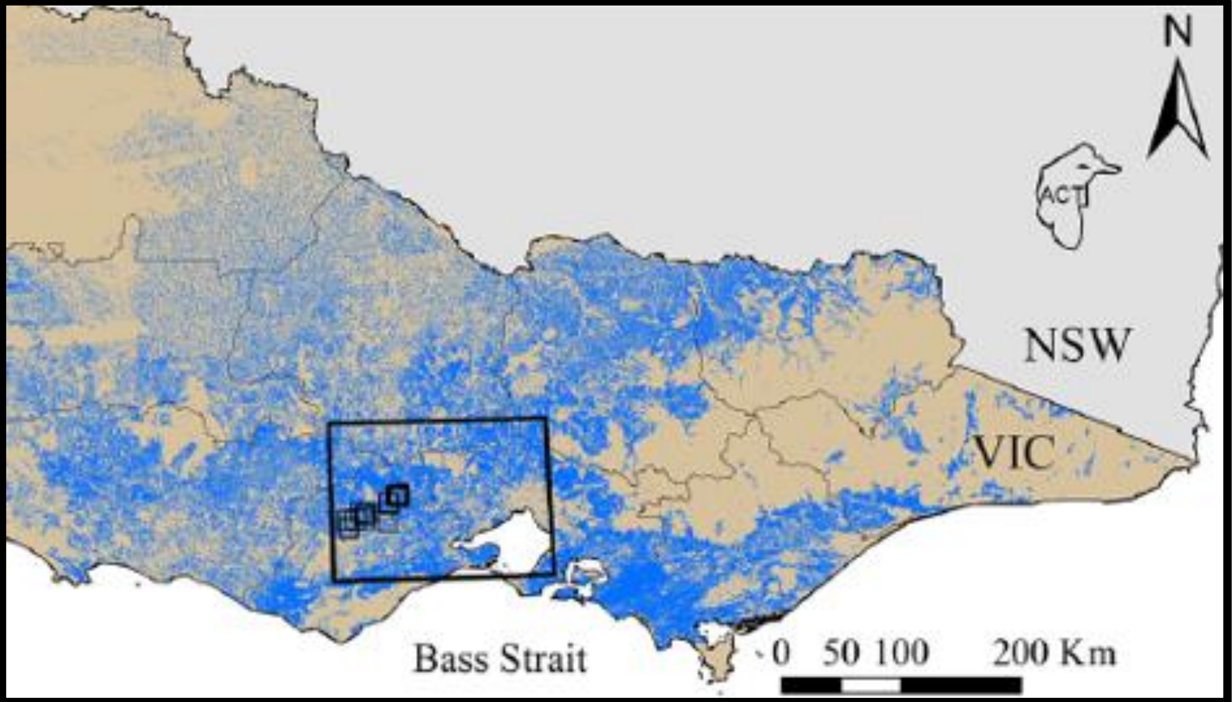


Figure 5. Final statistics for Australian farm dams in each State



Ollivier et al 218. DOI: 10.1111/gcb.14477

Where were our wetlands?

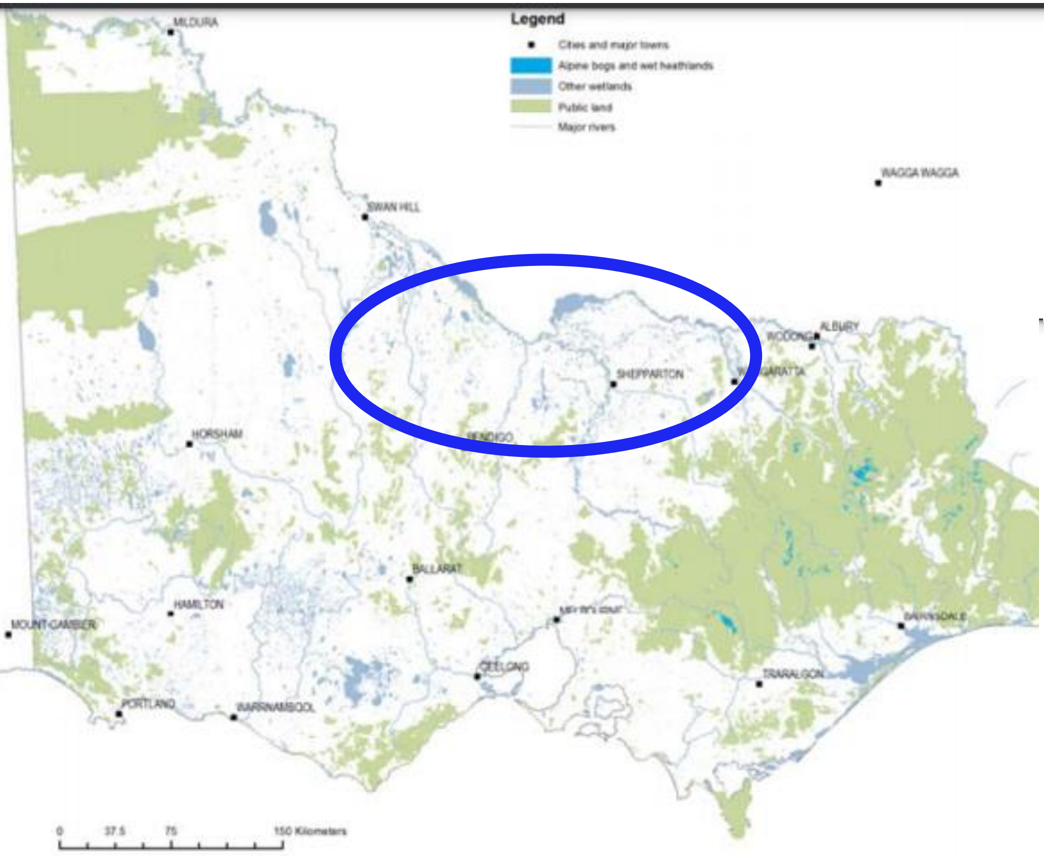


Figure 1. Present-day wetlands in Victoria, based on the Wetland 1994 inventory (DSE 2007a heathland inventory (DSE 2010).

Current wetland distribution

Pre-European wetland distribution

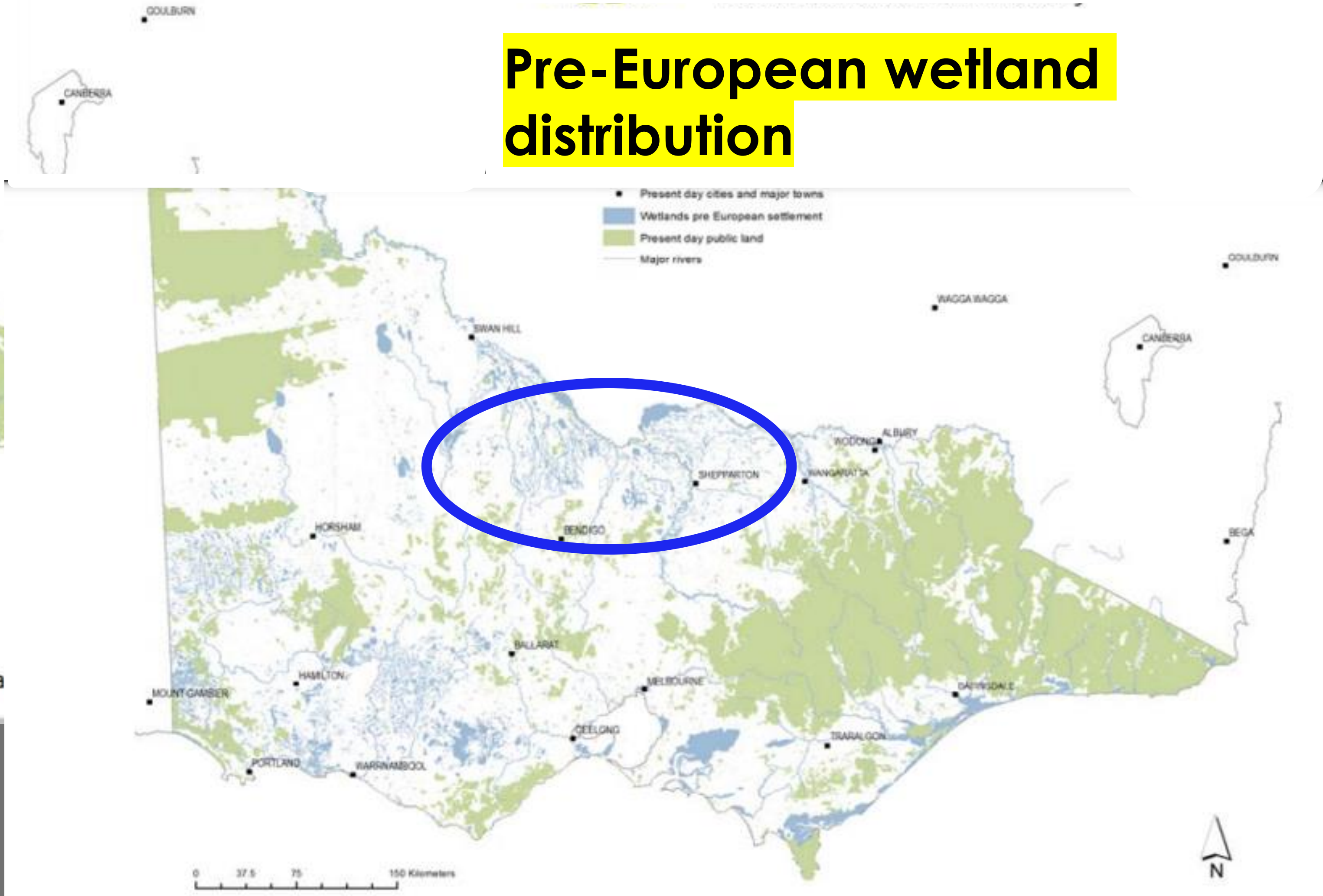


Figure 2. Wetlands in Victoria before European settlement (DSE 2007b).A pre-European map of alpine wetlands is not available.

Vic DSE 2007 & 2010

What condition are they in?

Victoria State of the Environment 2008

Table 1. Broad wetland types in Victoria, with their land tenure and loss since European settlement.

Wetland type	Current number and area (% of total)		% of current wetland numbers by tenure (average area)		Number and area lost since European settlement (% lost)	
	Number	Area (ha)	Public land	Private land	Number	Area (ha)
Shallow freshwater wetlands	9140 (71%)	168 077 (32%)	19% (53 ha)	81% (10 ha)	3532 (28%)	95 443 (31%)
Deep freshwater wetlands	2303 (18%)	141 126 (26%)	55% (102 ha)	45% (12 ha)	349 (12%)	91 055 (37%)
Saline wetlands	1373 (11%)	221 210 (42%)	44% (349 ha)	56% (14 ha)	44 (3%)	14 676 (7%)
Total	12816	530 413	28% (120 ha)	72% (11 ha)	3925 (23%)	201 175 (26%)

Wetlands

By 1994 37% of naturally occurring wetland area had been lost, over 90% of this was on private land.

Victorian wetlands include coastal marshes such as Western Port, Corner Inlet, and the Gippsland Lakes. The Statewide condition of remnant naturally occurring wetlands is not available in detail. An Index of Wetland Condition assessment technique has been developed and is currently being finalised.

Deep freshwater marshes (70% of area lost), shallow freshwater marshes (60% of area lost) and natural freshwater meadows (43% of area lost) are the three types of wetland that have lost the greatest proportion of their original area.

Condition of instream habitat

Victoria State of the Environment 2008

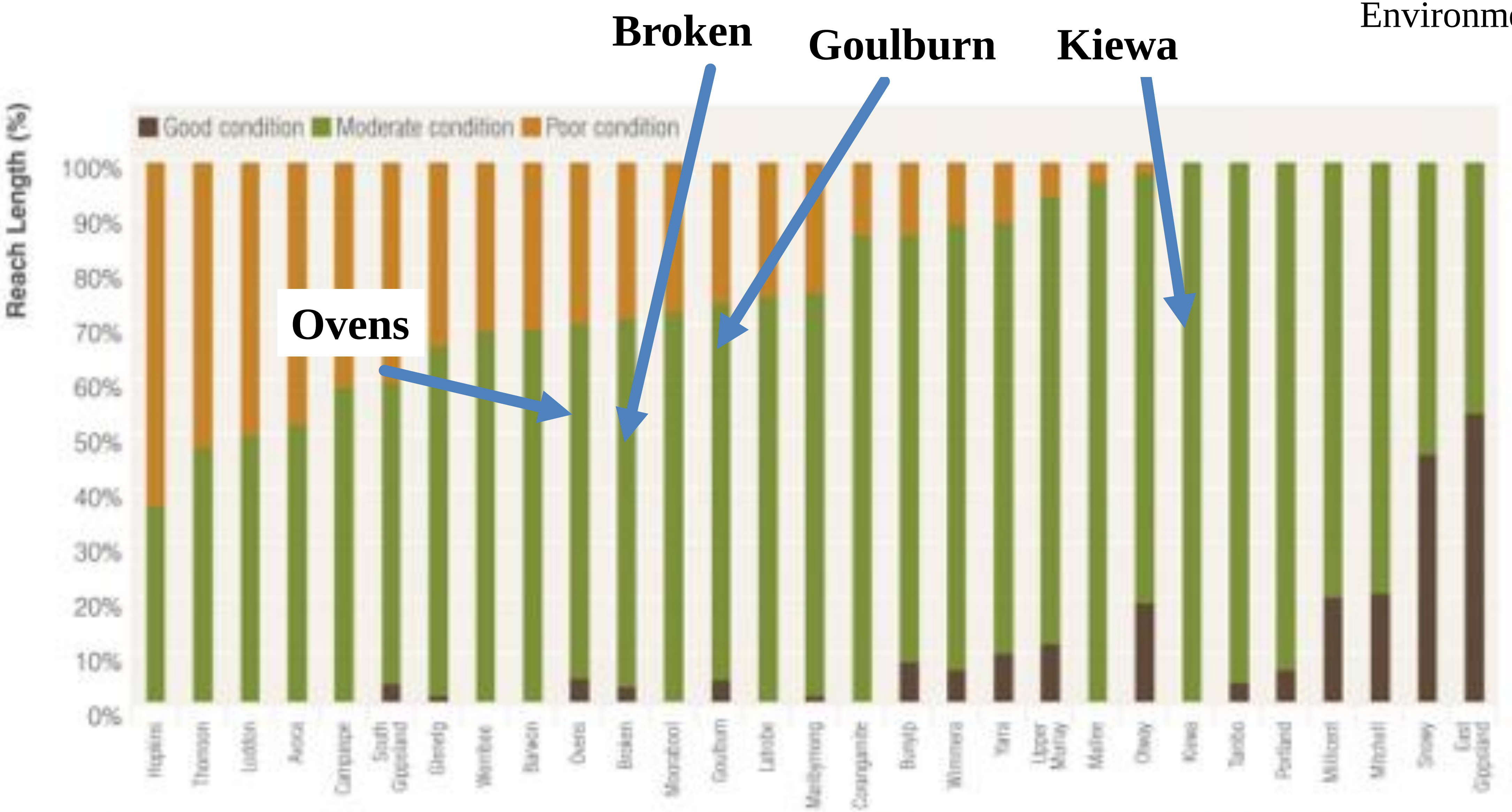


Figure 1. Condition of in-stream habitat, by basin Source: DSE (2008)

Sustainability

Wetland loss and degradation continues globally

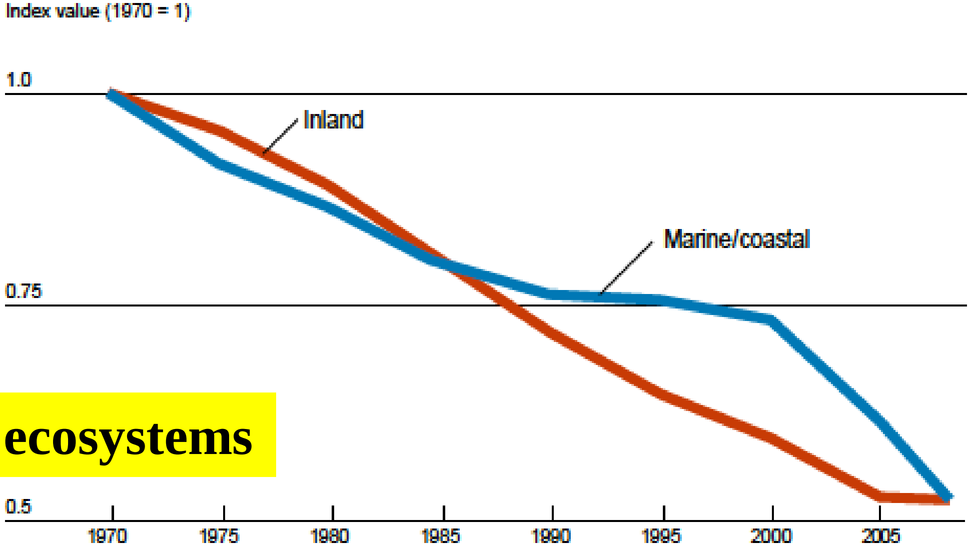
Global Wetland Outlook 2018

Wetlands throughout the world have long been subject to high levels of degradation and loss due to human activities, and this is continuing

Figure 1

Wetland Global Extent Index

adapted from Leadley et al. (2014)



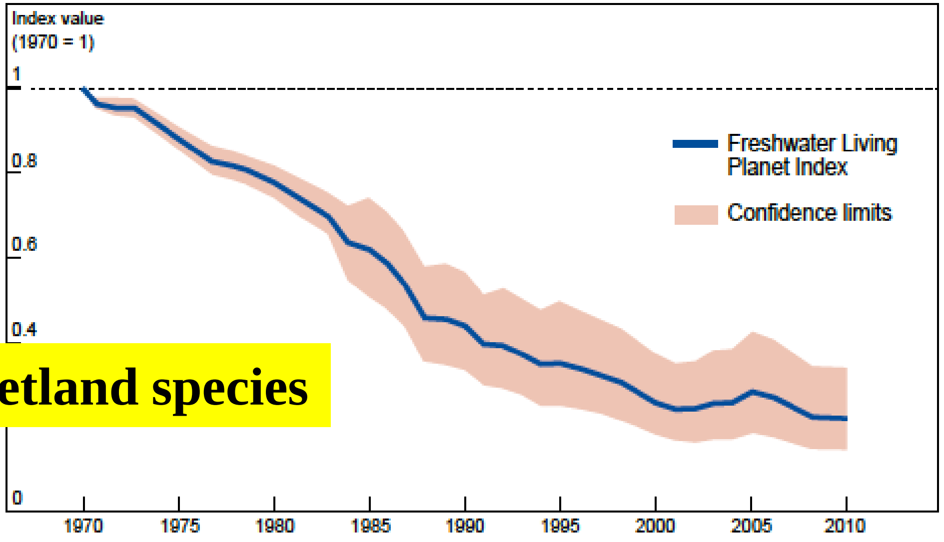
The global average marine/coastal and inland wetland extent trends relative to extent in 1970 and up to 2008 as estimated by the Wetland Extent Index.

Wetland ecosystems

Figure 2

Freshwater Living Planet Index

adapted from WWF (2014)



The Freshwater Living Planet Index shows a decline of 76% between 1970 and 2010 based on trends in 3,066 populations of 757 mammal, bird, reptile, amphibian and fish species.

Wetland species

Why are they signals for climate change? Taking into account so much has already been lost or degraded

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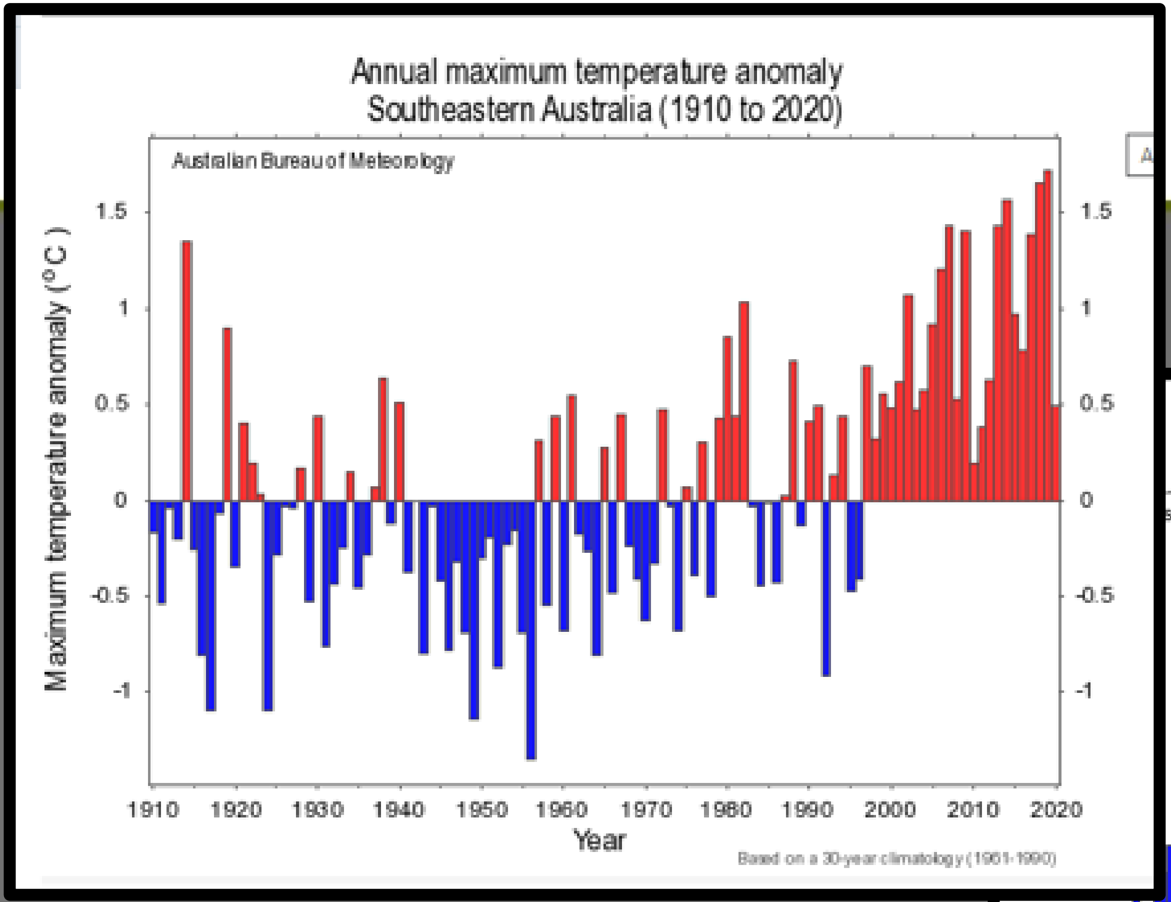
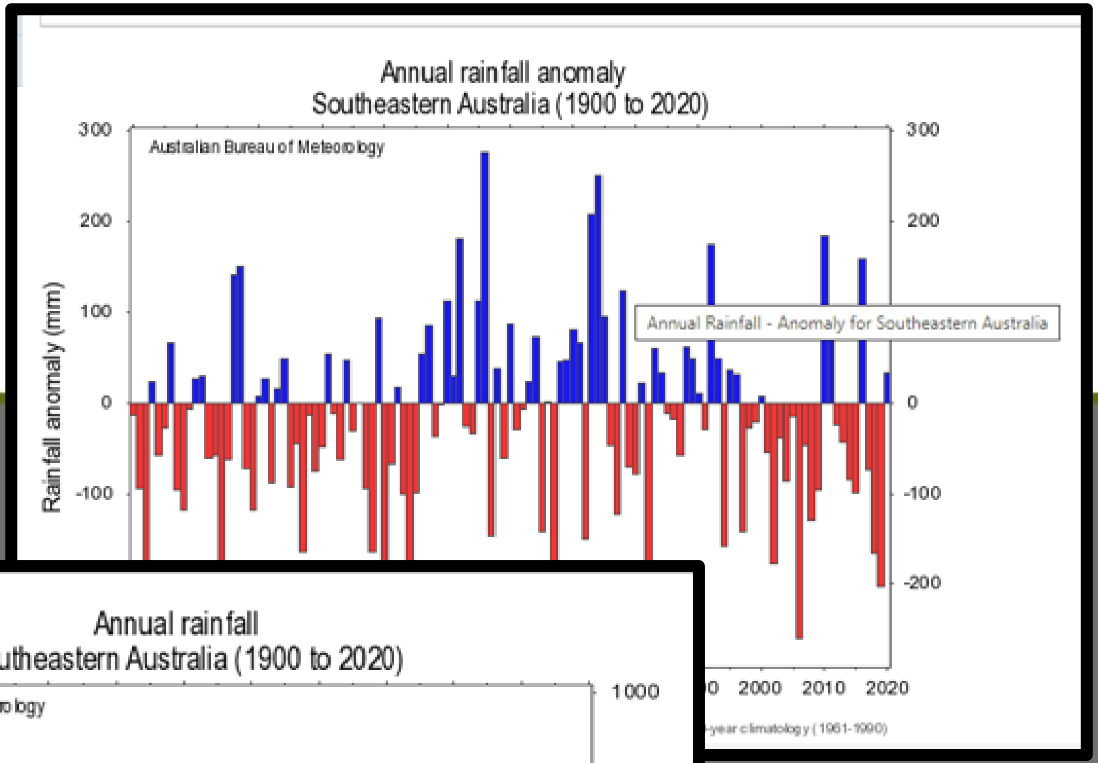
Wetlands very likely to be greatly affected by climate change, from increased temperatures, decreased rainfall and runoff, changes in evaporation, shifts in seasonal patterns, coupled with the human activities and responses (including maladaptation).

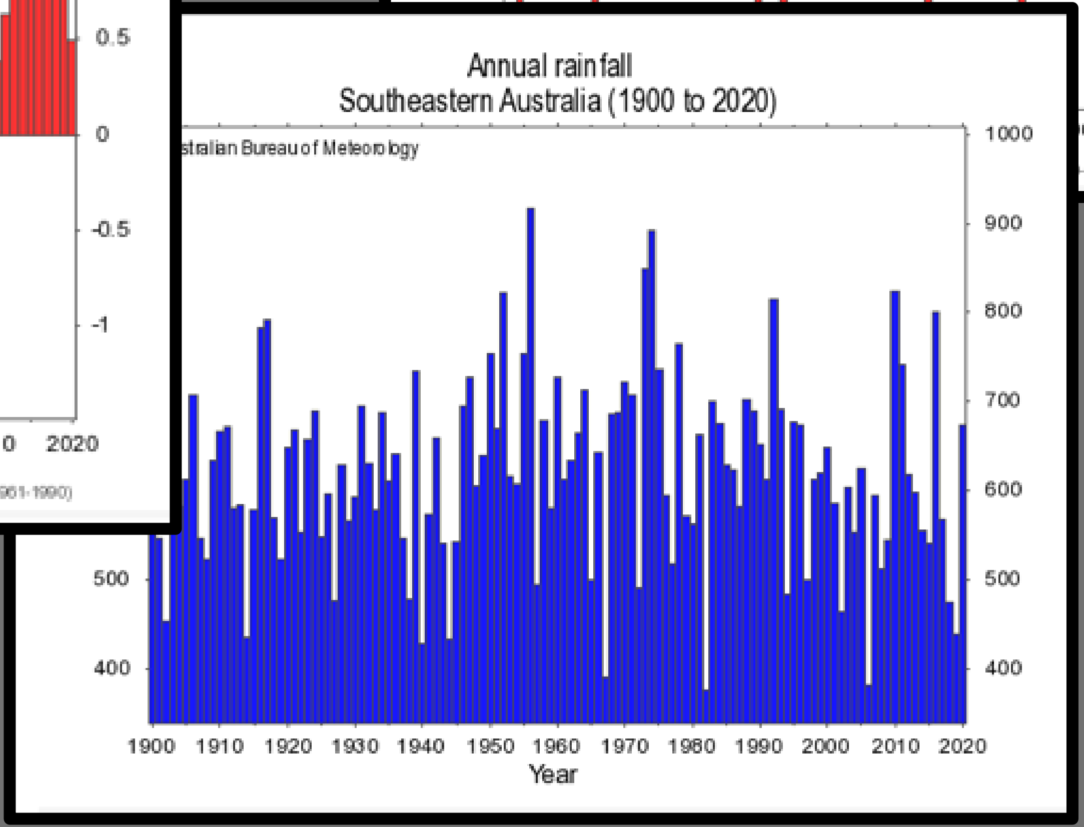
Signals – wetlands of all types are dependent on water / whether permanent or ephemeral the ecological processes that support the biodiversity are connected to the water regime.

In this part of the world we are expecting warmer & drier conditions and changes in seasonality. The signals will be there – the question is more whether we will be watching them (monitoring, and with the best indicators), and if we are able to respond (governance and adaptation, and avoidance of maladaptation).

Climate







Aust Bureau of Meteorology

Consequences - runoff

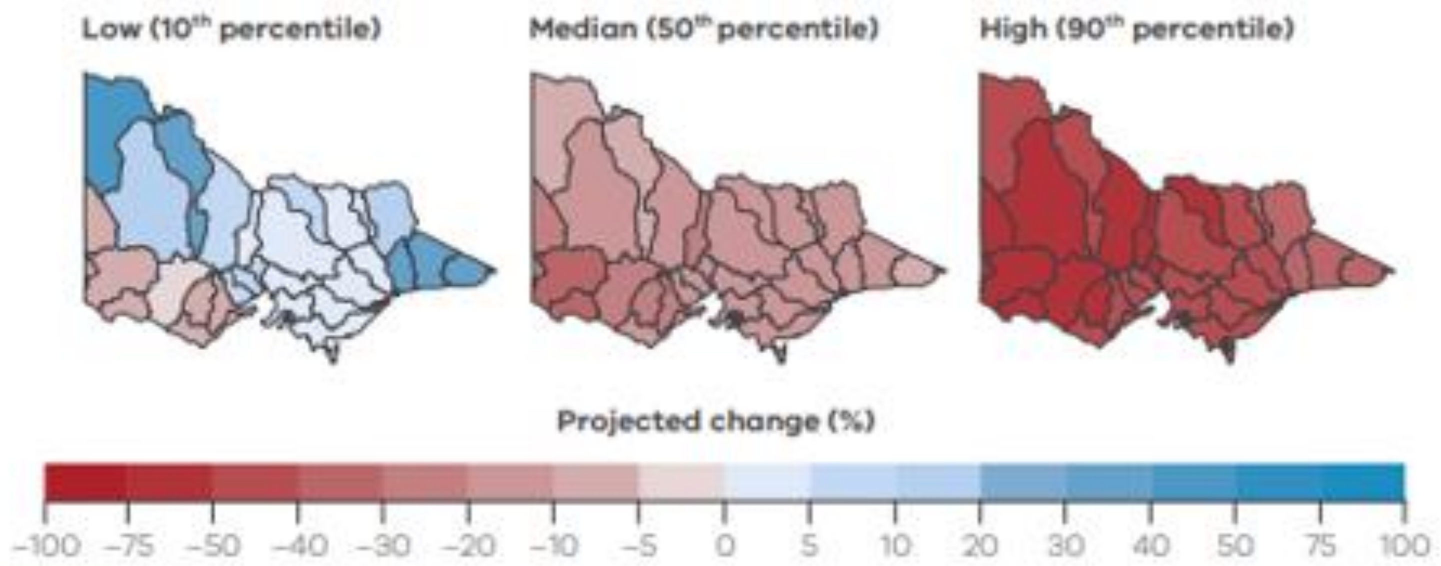
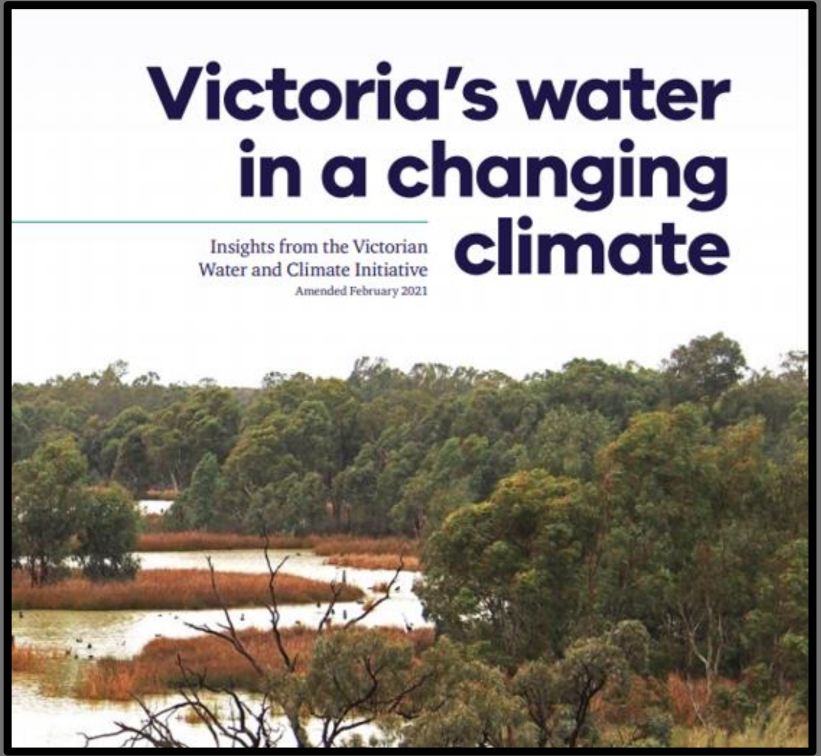


FIGURE 4.1 Median and range of projected percentage changes to basin mean annual runoff centred on 2065 relative to post-1975 average for a high emissions scenario (RCP8.5). (Source: Potter et al. 2016).

FIG. 4.1 KEY TAKEAWAY:
Runoff is likely to decline across Victoria towards the middle of this century, but there is a large range of uncertainty.



Climate change and wetlands – observed changes (IPCC 6AR – water chapter in press)

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Increasing temperatures affect wetlands through influencing biophysical processes, which affects feeding and breeding habits and species' distribution ranges, including their ability to compete with others. Increased temperatures can also cause deoxygenation in the lower depths of the water columns and throughout the entire water column if heating destabilizes the water column. Under extreme heat, often associated with minimal rainfall or water flows, drying of shallower areas and the migration or death of individual organisms can occur.

Climate change and wetlands – observed changes (IPCC 6AR – water chapter in press)

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Decreases in water availability and changes in flow regimes could reduce both habitat size and heterogeneity and increase the probability of species extinctions. Changes in the seasonality of flow regimes and variability and more intermittent flows are also projected and could result in decreased food chain lengths through the loss of large-bodied top predators and changes in nutrient loadings and water quality.

The situation for freshwater systems in drylands is expected to be severe. Changes to snow melt are projected to reduce water availability and cause declines in biodiversity.

Climate change and wetlands – observed changes (IPCC 6AR – water chapter in press)

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Climate change is a direct driver of change impacting freshwater ecosystems through increasing temperatures or declining rainfall, for example, by causing physiological stress or death (thermal stress, dehydration or desiccation), limiting food supplies, or resulting in migration of animals to other feeding or breeding areas, and possibly increased competition with animals already present in those migrating locations.

Ample evidence that such changes are occurring – have been observed. In NE Victoria?

Generalised hypotheses

1. Increasing temperatures – increased production of biodiversity in wetlands versus increase physiological stress

2. Decreasing rainfall – reduced production of biodiversity in wetlands plus increased physiological stress

Can we measures these changes as signals of climate change?

Certainly can …. need baseline conditions for selected ecosystems and species, account for daily/seasonal variability. Sentinel species and sites needed.

Measure and assess trends in biophysical variables – we know how to do this, and with increasingly sophisticated techniques (remote sensing, audiometrics, genomics, …). BUT can we identify early warning indicators that will enable managers to respond to mitigate (avert or reduce impacts) or adapt to impacts?

Early warning signals

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Enable managers sufficient time to take effective action – some thought needed here as existing biophysical or ecological monitoring may not do this; too late monitoring … early warning capability may not come with normal ecological monitoring…

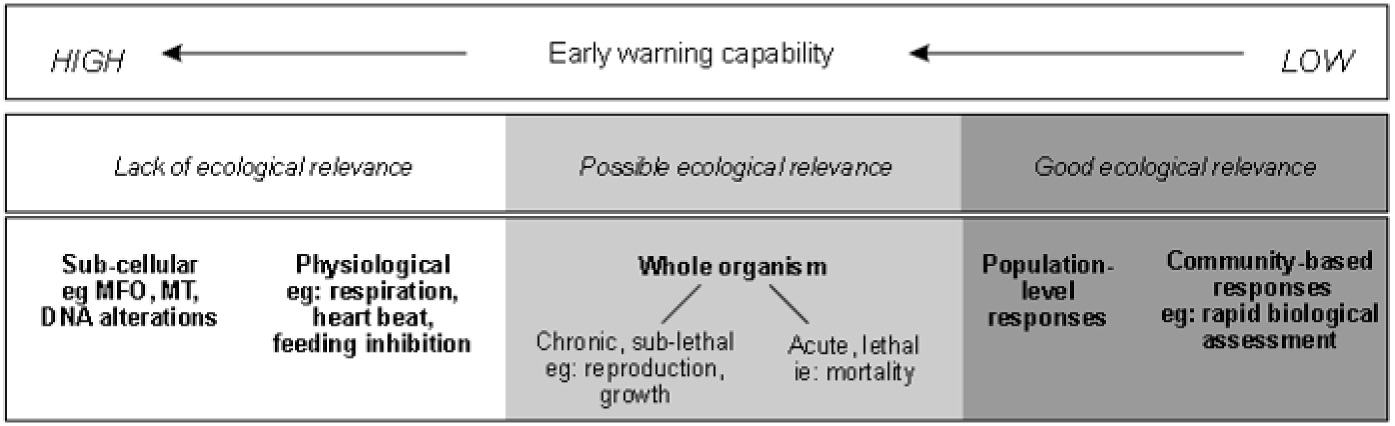

Figure 2 Relationship of ecological relevance and early warning capability to measurable biological responses

Can we elaborate a set of early warning indicators to inform climate change adaptation for wetlands?

Van Dam et al 1999

Early warning signals

Enable managers to respond or adapt with sufficient time to take effective action, such as:

- **relocate breeding populations of vulnerable or iconic species**
- **re-establish / re-introduce preferred species**
- **intervene in water management decisions (establish eflows, engineering works to move water around)**
- **reduce water temperatures through riparian plantings**
- **sustain groundwater connections to surface water**
- **manage water temperatures using water releases from dams**
- **…**
- **reduce other pressures that interact with climate drivers**

Wetlands - Farm dams can contribute to greenhouse gases

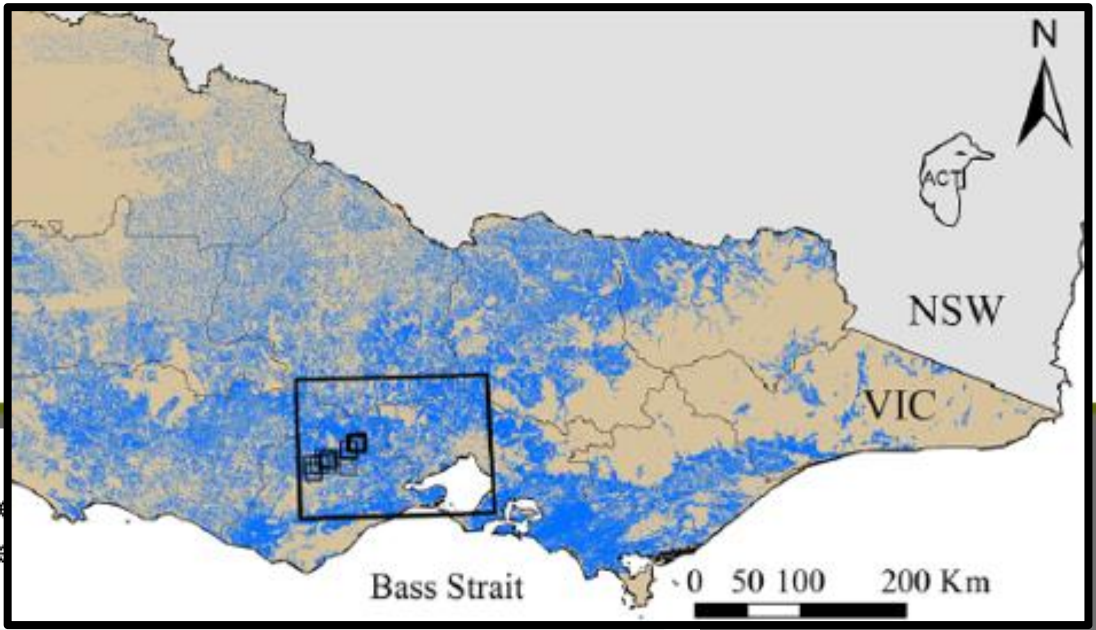

TABLE 1 CO_2 and CH_4 emissions from inland freshwater ecosystems. Carbon dioxide equivale
warming potential of CH_4 from Neubauer and Megonigal (2015). Flux type D represents diffusive
derived from the sum of both diffusive and ebullitive emissions

Ecosystem type	CO_2 (mmol m^2 d^{-1})	CH_4 (mmol m^2 d^{-1})	CO_2-e (g CO_2 m^2/day)	Flux type	References
Natural					
Lakes	15.9–17.91	0.56–3.33	1.48–5.54	D + E	St. Louis et al. (2000); Deemer et al. (2016)
Wetlands	–	1.29–5.25	1.8–7.33	D + E	Stanley et al. (2016); Deemer et al. (2016)
Ponds (<0.001 km^2)	35.18 ± 5.21	2.28 ± 0.51	4.73 ± 0.94	D	Holgerson and Raymond (2016)
Human-built					
Tropical reservoirs	68.17	6.23	11.7	D + E	St. Louis et al. (2000)
Temperate reservoirs	34.08	1.25	3.24	D + E	St. Louis et al. (2000)
Temperate farm dams	24.4 ± 3.56	7.2 ± 1.74	11.12 ± 2.59	D	This study

Notes. Values presented are means and were sourced, and converted to mmol m^2 d^{-1}, from the studies listed in the final column and the references therein (specifically, see Deemer et al. (2016) Table 1, and St. Louis et al. (2000) Table 2). – indicates the range of sourced mean values. The CO_2 values reported for temperate farm dams are the mean ± standard error of data acquired within this study and are inclusive of farm dams that showed net uptake of CO_2.

Ollivier et al 218. DOI: 10.1111/gcb.14477

Farm dams can contribute to greenhouse gases – influenced by land uses

Land use has a significant effect on emissions, largely **higher methane flux in livestock rearing compared with cropping.**

Reducing nutrient inputs to farm dams could reduce emissions (25% nutrient reduction would half emissions).

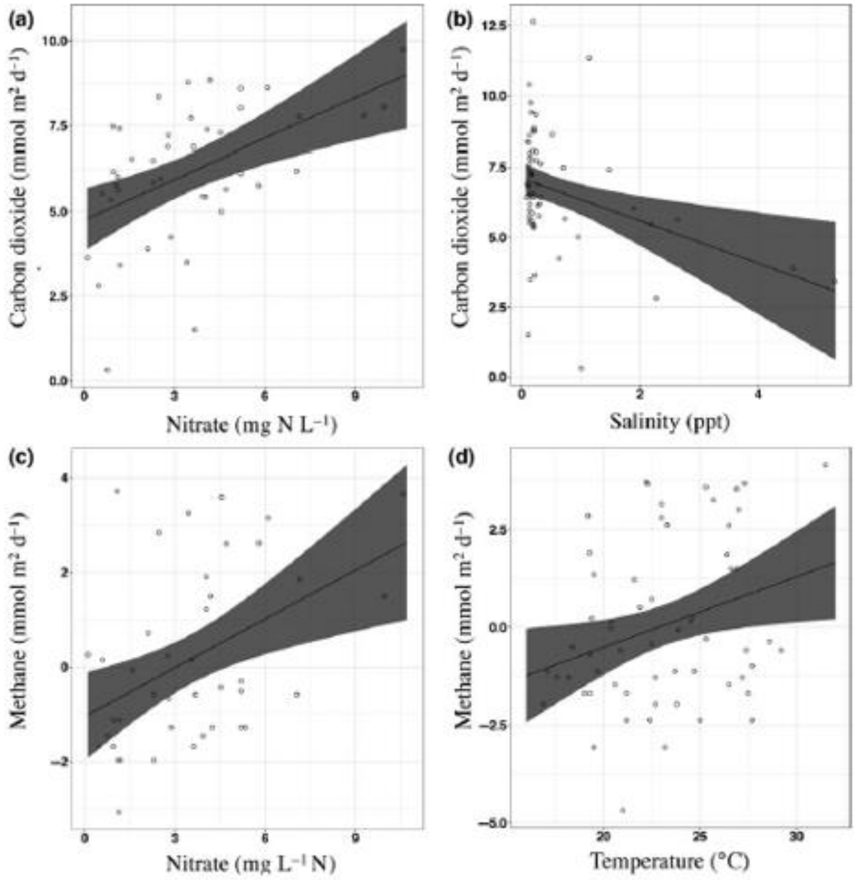

FIGURE 4 Linear mixed-effects models showing the relationship between diffusive greenhouse gas emissions from farm dams and environmental conditions. Farm location was treated as a random factor to account for between-farm dissimilarity. Data points represent the transformed data (CO_2: square root, CH_4: natural log) inclusive of farm dams with net uptake of GHG (see methods, Equation 3). Solid lines indicate the predicted model fit, and shaded areas represent 95% confidence interval

Ollivier et al 218. DOI: 10.1111/gcb.14477

Suggest inclusion of small agricultural water bodies into global carbon budgets; relatively large emissions is potential large gap in climate change mitigation policy.

Wetlands are highly vulnerable to climate change – impacts are occurring; they are a signal for climate change ….at times mixed with other signals

Wetlands are highly vulnerable to anthropogenic climate change and this is likely to have significant consequences for their ecological character. Effective assessment & monitoring are needed and is very feasible if supported …. resources to support the expertise

Climate change can affect (is affecting) wetlands directly (via the effects of a warming climate and changes in rainfall) and indirectly (through interaction with other pressures)

Wetlands are under pressure – high level of loss and degradation; responses are needed anyway and more so given additional pressure from climate (e.g. for secure refugia)

Can multiple small wetlands contribute to mitigating climate change by storing carbon? Will poor management of small wetlands release more "greenhouse" gases?