

**Supplementary material**

**A commentary on ‘Long-term ecological trends of flow-dependent ecosystems in a major regulated river basin’, by Matthew J. Colloff, Peter Caley, Neil Saintilan, Carmel A. Pollino and Neville D. Crossman**

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**Table S1. Timeline of documented historical changes of Murray–Darling River flow-dependent ecosystems**

See below for numbers matching supporting references

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
1820–1900	Catchment and riparian vegetation extensively cleared, contributing to high erosion <sup>15</sup>	Decline in wetland aquatic plants <sup>1–5</sup>	Decline in plant-associated wetland invertebrates <sup>2, 3, 5, 6</sup>	Decline in Murray cod abundance and distribution. <sup>7–10</sup>			Hunting impacts on some waterbird species <sup>11</sup>	Changes in wetland diatom assemblages, and increased salinity, nutrients, sedimentation and turbidity <sup>1, 3–5, 12–14</sup>
	Grazing livestock, rabbits and foxes introduced			European perch, tench, common carp, brown trout and rainbow trout become established <sup>16</sup>				
	Alien fish species introduced							
	Commercial fishing, hunting of waterbirds and water diversions began							

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
1900–1950	Commercial fishing and hunting of waterbirds increased	Decline in wetland aquatic plants <sup>17</sup>	Decline in plant-associated wetland invertebrates <sup>17</sup>	Decline in populations of native fish species. Rise of alien species <sup>9, 10, 18–20</sup>			Hunting impacts on egret populations and some duck species	Reduced platypus populations <sup>21</sup>
	Dams and weirs constructed, flows regulated, and water diversions increased	Wetland plants invade margins of Lower Murray weir pools <sup>22, 23</sup>	Wetland species – freshwater mussel ( <i>Velesunio ambiguus</i> ); yabbie ( <i>Cherax destructor</i> ) – become common in Lower Murray weir pools <sup>24</sup>					
<i>Gambusia</i> introduced								
1950–2000	Dam and weir construction and floodplain development continued; water diversions continued to grow and peaked	Changes in composition and condition of vegetation communities, alteration of structure, including favouring invasive species <sup>25–31</sup>	Loss or decline of aquatic snail species in the lower Murray River <sup>32</sup>	Reduced range, abundance and breeding of many native species <sup>33–42</sup>	Reduced range and abundance of several species <sup>43–47</sup>		Decline in populations and breeding <sup>48–56</sup>	Increasing salinity, <sup>57</sup> increasing fragmentation of floodplains <sup>58</sup>
	Boolarra strain of common carp introduced to Murray–Darling Basin and rapidly dispersed and became abundant	Decline of <i>Ruppia</i> spp. in Coorong	Decline in distribution and abundance of Murray crayfish ( <i>Eustacus armatus</i> ) <sup>59</sup>					

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
	Chytrid fungus accidentally introduced		Change in composition of Murray River fauna after about 1970 <sup>60</sup>					Increasing occurrence of planktonic algae and cyanobacterial blooms <sup>13, 61</sup>
			<i>Artemia</i> replaces <i>Parartemia</i> in Coorong, South Lagoon					
2000– 2010	Millennium Drought	Widespread canopy loss and dieback of floodplain eucalypts <sup>62–67</sup>	Reduced occurrence of drought-sensitive species <sup>68, 69</sup>	Reduced populations of drought-sensitive species <sup>44, 70–74</sup>	Reduced populations and recruitment of many species. Severe decline of summer-breeding floodplain specialists due to loss of refuge habitats <sup>53, 75, 76</sup>	Reduced populations of long-necked turtles <sup>77</sup>	Decline in populations and breeding <sup>37, 50, 78–80</sup>	Decline in water levels, salinisation and acidification of Lower Lakes <sup>81</sup>  Changes to bird fauna with declines and partial recovery <sup>82–85</sup>
		Increased salinities and major water level recessions in Lower Murray, Lower Lakes and Coorong; riverbank collapse.						

Period	Pressures	Plants	Invertebrates	Fish	Frogs	Turtles	Waterbirds	Other
			Saltwater species, including tubeworm ( <i>Ficopomatus enigmaticus</i> ), invade Lower Lakes. Loss of freshwater mussel ( <i>Velesunio ambiguus</i> ) population in Lake Alexandrina <sup>81</sup>	Several small native species approached extinction and became conservation-reliant <sup>86, 87</sup>		Salinity in Lower Lakes caused short-neck turtle ( <i>Emydura macquarii</i> ) deaths from tubeworm infestation <sup>81</sup>		
2010–2015	Continuing water diversions, persistent alien species, anthropogenic climate change	Floodplain eucalypts partly recovered <sup>88</sup>	Some species that declined during Millennium Drought recovered but others did not <sup>9, 69, 89</sup>	Some species that declined during Millennium Drought recovered, but most did not <sup>90–94</sup>	Some species that declined during Millennium Drought recovered, but others did not <sup>53</sup>			

## Description of state-space modelling of waterbird abundances in the Murray–Darling Basin

We used an exponential growth state–space model (Humbert *et al.*<sup>95</sup>) to model waterbird population growth without density dependence:

$$N_t = N_0 \lambda^t$$

$N_t$  and  $N_0$  were the population abundance at time  $t$  and zero respectively and  $\lambda$  was the population growth rate. We used the log-transformed abundances ( $\ln(N_t + 1)$ ).

We used multivariate autoregressive state–space modelling (MARSS), with Gaussian errors:

$$X_t = BX_{t-1} + u_t + w_t$$

where  $w_t \sim \text{MVN}(0, Q_t)$

$$y_t = ZX_t + v_t$$

where  $v_t \sim \text{MVN}(0, R_t)$

$$x_0 \sim \text{MVN}(\pi, \Lambda)$$

The first and second equation, respectively, represented the state and observation processes.  $w_t$  are the process errors at time  $t$  and were multivariate normal (MVN), with mean 0 and covariance  $Q_t$ .  $v_t$  are the observation errors at time  $t$  and were multivariate normal (MVN), with mean 0 and covariance  $R_t$ .  $B$  is the density-dependence element (set to 1, no effect).  $u_t$  was the intrinsic population growth rate.  $Z$  associated observations to unobserved state processes (set to 1, no effect). The initial state vector was specified at  $t = 0$  (i.e.  $x_0$ ), where  $\pi$  was the mean of the initial state distribution and  $\Lambda$  specified the variance of the initial states. We modelled waterbird abundances (1983–2014) using the MARSS R-package (Holmes *et al.*<sup>96</sup>).

## References

1. Gell, P., Tibby, J., Little, F., Baldwin, D., and Hancock, G. (2007). The impact of regulation and salinisation on floodplain lakes: the lower River Murray, Australia. *Hydrobiologia* **591**, 135–146. [doi:10.1007/s10750-007-0806-3](https://doi.org/10.1007/s10750-007-0806-3)
2. Ogden, R. W. (1997). The effects of European settlement on the biodiversity of chydorid Cladocera in billabongs of the south-east Murray basin. *Memoirs of the Museum of Victoria* **56**, 505–511.
3. Ogden, R. W. (2000). Modern and historical variation in aquatic macrophyte cover of billabongs associated with catchment development. *Regulated Rivers: Research and Management* **16**, 497–512. [doi:10.1002/1099-1646\(200009/10\)16:5<497::AID-RRR600>3.0.CO;2-Y](https://doi.org/10.1002/1099-1646(200009/10)16:5<497::AID-RRR600>3.0.CO;2-Y)
4. Reid, M. A., Sayer, C. D., Kershaw, A. P., and Heijnis, H. (2007). Palaeolimnological evidence for submerged plant loss in a floodplain lake associated with accelerated catchment soil erosion (Murray River, Australia). *Journal of Paleolimnology* **38**, 191–208. [doi:10.1007/s10933-006-9067-9](https://doi.org/10.1007/s10933-006-9067-9)

5. Thoms, M. C., Ogden, R. W., and Reid, M. A. (1999). Establishing the condition of lowland floodplain rivers: a palaeo-ecological approach. *Freshwater Biology* **41**, 407–423. [doi:10.1046/j.1365-2427.1999.00439.x](https://doi.org/10.1046/j.1365-2427.1999.00439.x)
6. Reid, D. D., Harris, J. H., and Chapman, D. J. (1997). NSW inland commercial fishery data analysis. New South Wales Fisheries, Sydney.
7. Humphries, P. (2007). Historical indigenous use of aquatic resources in Australia's Murray–Darling Basin, and its implications for river management. *Ecological Management & Restoration* **8**, 106–113. [doi:10.1111/j.1442-8903.2007.00347.x](https://doi.org/10.1111/j.1442-8903.2007.00347.x)
8. Humphries, P., and Winemiller, K. O. (2009). Impacts on river fauna, shifting baselines and challenges for restoration. *Bioscience* **59**, 673–684. [doi:10.1525/bio.2009.59.8.9](https://doi.org/10.1525/bio.2009.59.8.9)
9. Roberts, D. T., Duivenvoorden, L. J., and Stuart, I. G. (2008). Factors influencing recruitment patterns of golden perch (*Macquaria ambigua oriens*) within a hydrologically variable and regulated Australian tropical river system. *Ecology Freshwater Fish* **17**, 577–589. [doi:10.1111/j.1600-0633.2008.00308.x](https://doi.org/10.1111/j.1600-0633.2008.00308.x)
10. Rowland, S. J. (1989). Aspects of the history and fishery of the Murray cod, *Maccullochella peelii* (Mitchell) (Percichthyidae). *Proceedings of the Linnean Society of New South Wales* **111**, 201–213.
11. Norman, F. I., and Young, A. D. (1980). Short-sighted and doubly short-sighted are they ... Game Laws of Victoria, 1858–1958. *Journal of Australian Studies* **4**, 2–24. [doi:10.1080/14443058009386814](https://doi.org/10.1080/14443058009386814)
12. Gell, P., Fluin, J., Tibby, J., Hancock, G., Harrison, J., Zawadzki, A., Haynes, D., Khanum, S., Little, F., and Walsh, B. (2009). Anthropogenic acceleration of sediment accretion in lowland floodplain wetlands, Murray–Darling Basin, Australia. *Geomorphology* **108**, 122–126. [doi:10.1016/j.geomorph.2007.12.020](https://doi.org/10.1016/j.geomorph.2007.12.020)
13. Gell, P., and Little, F. (2007). Water quality history of Murrumbidgee River floodplain wetlands. Murrumbidgee Catchment Management Authority, Wagga Wagga.
14. Gell, P. A., Bulpin, P., Wallbrink, P., Hancock, G., and Bickford, S. (2005). Tareena Billabong – a palaeolimnological history of an ever-changing wetland, Chowilla floodplain, Murray–Darling Basin, Australia. *Marine and Freshwater Research* **56**, 441–456. [doi:10.1071/MF04107](https://doi.org/10.1071/MF04107)
15. Olley, J. M., and Wasson, R. J. (2003). Changes in the flux of sediment in the upper Murrumbidgee catchment, southeastern Australia, since European settlement. *Hydrological Processes* **17**, 3307–3320. [doi:10.1002/hyp.1388](https://doi.org/10.1002/hyp.1388)
16. Davey, H. W. (1917). Upsetting the balance of nature. *Victorian Naturalist* **33**, 151–154.
17. Kattel, G., Gell, P., Perga, M.-E., Jeppesen, E., Grundell, R., Weller, S., Zawadzki, A., and Barry, L. (2015). Tracking a century of change in trophic structure and dynamics in a floodplain wetland: integrating palaeoecological and palaeoisotopic evidence. *Freshwater Biology* **60**, 711–723. [doi:10.1111/fwb.12521](https://doi.org/10.1111/fwb.12521)
18. Cadwallader, P. L. (1977). 'J.O. Langtry's 1949–50 Murray River Investigations.' (Ministry for Conservation Fisheries and Wildlife Division: Melbourne.)

19. Cadwallader, P. L. (1978). Some causes of the decline in range and abundance of native fish in the Murray–Darling river system. *Proceedings of the Royal Society of Victoria* **90**, 211–224.
20. Sheldon, F., Thoms, M. C., Berry, O., and Puckridge, J. T. (2000). Using disaster to prevent catastrophe: referencing the impacts of flow changes in large dryland rivers. *Regulated Rivers: Research and Management* **16**, 403–420. [doi:10.1002/1099-1646\(200009/10\)16:5<403::AID-RRR593>3.0.CO;2-3](https://doi.org/10.1002/1099-1646(200009/10)16:5<403::AID-RRR593>3.0.CO;2-3)
21. Grant, T. R. (1993). The past and present freshwater fishery in New South Wales and the distribution and status of the platypus *Omithorhynchus anatinus*. *Australian Zoologist* **29**, 105–113.  
[doi:10.7882/AZ.1993.012](https://doi.org/10.7882/AZ.1993.012)
22. Blanch, S. J., Ganf, G. G., and Walker, K. F. (1999). Tolerance of riverine plants to flooding and exposure indicated by water regime. *Regulated Rivers: Research and Management* **15**, 43–62.  
[doi:10.1002/\(SICI\)1099-1646\(199901/06\)15:1/3<43::AID-RRR535>3.0.CO;2-Q](https://doi.org/10.1002/(SICI)1099-1646(199901/06)15:1/3<43::AID-RRR535>3.0.CO;2-Q)
23. Blanch, S. J., Walker, K. F., and Ganf, G. G. (2000). Water regime preferences of plants in four weir pools of the River Murray, Australia. *Regulated Rivers: Research and Management* **16**, 445–456.  
[doi:10.1002/1099-1646\(200009/10\)16:5<445::AID-RRR596>3.0.CO;2-L](https://doi.org/10.1002/1099-1646(200009/10)16:5<445::AID-RRR596>3.0.CO;2-L)
24. Walker, K. F. (1985). A review of the ecological effects of river regulation in Australia. *Hydrobiologia* **125**, 111–129. [doi:10.1007/BF00045929](https://doi.org/10.1007/BF00045929)
25. Bren, L. J. (2005). The changing hydrology of the Barmah–Millewa forests and its effects on vegetation. *Proceedings of the Royal Society of Victoria* **117**, 61–76.
26. Catford, J. A., Downes, B. J., Gippel, C. J., and Vesk, P. A. (2011). Flow regulation reduces native plant cover and facilitates exotic invasion in riparian wetlands. *Journal of Applied Ecology* **48**, 432–442.  
[doi:10.1111/j.1365-2664.2010.01945.x](https://doi.org/10.1111/j.1365-2664.2010.01945.x)
27. Catford, J. A., Morris, W. K., Vesk, P. A., Gippel, C. J., and Downes, B. J. (2014). Species and environmental characteristics point to flow regulation and drought as drivers of riparian plant invasion. *Diversity & Distributions* **20**, 1084–1096. [doi:10.1111/ddi.12225](https://doi.org/10.1111/ddi.12225)
28. Chesterfield, E. A. (1986). Changes in vegetation of the river red gum forest at Barmah, Victoria. *Australian Forestry* **49**, 4–15. [doi:10.1080/00049158.1986.10674458](https://doi.org/10.1080/00049158.1986.10674458)
29. Dexter, B. D., Rose, H. J., and Davies, N. (1986). River regulation and associated forest management problems in the River Murray red gum forests. *Australian Forestry* **49**, 16–27.  
[doi:10.1080/00049158.1986.10674459](https://doi.org/10.1080/00049158.1986.10674459)
30. Mac Nally, R., Cunningham, S. C., Baker, P. J., Horner, G. J., and Thomson, J. R. (2011). Dynamics of Murray–Darling floodplain forests under multiple stressors: the past, present, and future of an Australian icon. *Water Resources Research* **47**, W00G05. [doi:10.1029/2011WR010383](https://doi.org/10.1029/2011WR010383)
31. Walker, K. F., Boulton, A. J., Thoms, M. C., and Sheldon, F. (1994). Effects of water-level changes induced by weirs on the distribution of littoral plants along the River Murray, South Australia. *Australian Journal of Marine and Freshwater Research* **45**, 1421–1438. [doi:10.1071/MF9941421](https://doi.org/10.1071/MF9941421)

32. Sheldon, F., and Walker, K. F. (1997). Changes in biofilms induced by flow regulation could explain extinctions of aquatic snails in the lower River Murray, Australia. *Hydrobiologia* **347**, 97–108.  
[doi:10.1023/A:1003019302094](https://doi.org/10.1023/A:1003019302094)
33. Brumley, A. R. (1987). Past and present distributions of golden perch *Macquaria ambigua* (Pisces: Percichthyidae) in Victoria, with reference to releases of hatchery-produced fry. *Proceedings of the Royal Society of Victoria* **99**, 111–116.
34. Cadwallader, P. L., and Rogan, P. L. (1977). The Macquarie perch, *Macquaria australasica* (Pisces: Percichthyidae), of Lake Eildon, Victoria. *Australian Journal of Ecology* **2**, 409–418. [doi:10.1111/j.1442-9993.1977.tb01156.x](https://doi.org/10.1111/j.1442-9993.1977.tb01156.x)
35. Ferguson, G. J., Ward, T. M., Ye, Q., Geddes, M. C., and Gillanders, B. M. (2010). Impacts of drought, flow regime and fishing on the fish assemblage in southern Australia's largest temperate estuary. South Australian Research and Development Institute, Adelaide. Research report series 498.
36. Humphries, P., Brown, P., Douglas, J., Pickworth, A., Strongman, R., Hall, K., and Serafini, L. (2008). Flow-related patterns in abundance and composition of the fish fauna of a degraded Australian lowland river. *Freshwater Biology* **53**, 789–813. [doi:10.1111/j.1365-2427.2007.01904.x](https://doi.org/10.1111/j.1365-2427.2007.01904.x)
37. Paton, D. C., Rogers, D. J., Hill, B. M., Bailey, C. P., and Ziembicki, M. (2009). Temporal changes to spatially stratified waterbird communities of the Coorong, South Australia: implications for the management of heterogenous wetlands. *Animal Conservation* **12**, 408–417. [doi:10.1111/j.1469-1795.2009.00264.x](https://doi.org/10.1111/j.1469-1795.2009.00264.x)
38. Roughley, T. C. (1951). 'Fish and Fisheries of Australia.' (Angus and Robertson: Sydney.)
39. Sinclair Knight Mertz Pty Ltd (2008). Collation and analysis of Murray–Darling native fish datasets. Sinclair Knight Merz, Melbourne.
40. Todd, C. R., Ryan, T., Nicol, S. J., and Bearlin, A. R. (2005). The impact of cold water releases on the critical period of post-spawning survival and its implications for Murray cod (*Maccullochella peelii peelii*): a case study of the Mitta Mitta River, southeastern Australia. *River Research and Applications* **21**, 1035–1052. [doi:10.1002/rra.873](https://doi.org/10.1002/rra.873)
41. Tonkin, Z., King, A. J., and Mahoney, J. (2008). Effects of flooding on recruitment and dispersal of the southern pygmy perch (*Nannoperca australis*) at a Murray River floodplain wetland. *Ecological Management & Restoration* **9**, 196–201. [doi:10.1111/j.1442-8903.2008.00418.x](https://doi.org/10.1111/j.1442-8903.2008.00418.x)
42. Zampatti, B., and Leigh, S. (2013). Effects of flooding on recruitment and abundance of golden perch (*Macquaria ambigua ambigua*) in the lower River Murray. *Ecological Management & Restoration* **14**, 135–143. [doi:10.1111/emr.12050](https://doi.org/10.1111/emr.12050)
43. Campbell, A. (Ed.) (1999). 'Declines and Disappearances of Australian Frogs.' (Environment Australia: Canberra.)
44. Walker, K. F. (2006). Serial weirs, cumulative effects: the Lower River Murray, Australia. In 'The Ecology of Desert Rivers' (Ed. R. T. Kingsford.) pp. 248–279. (Cambridge University Press: Cambridge, UK.)

45. Wassens, S. (2008). Review of the past distribution and decline of the southern bell frog *Litoria raniformis* in New South Wales. *Australian Zoologist* **34**, 446–452. [doi:10.7882/AZ.2008.022](https://doi.org/10.7882/AZ.2008.022)
46. Wassens, S., Watts, R. J., Jansen, A., and Rosheir, D. (2008a). Movement patterns of southern bell frogs (*Litoria raniformis*) in response to flooding. *Wildlife Research* **35**, 50–58. [doi:10.1071/WR07095](https://doi.org/10.1071/WR07095)
47. Wassens, S. (2010). Flooding regimes for frogs in lowland rivers of the Murray–Darling Basin. In ‘Ecosystem Response Modelling in the Murray–Darling Basin’. (Eds N. Saintilan and I. C. Overton.) pp. 213–228. (CSIRO Publishing: Melbourne.)
48. Arthur, A. D., Reid, J. R. W., Kingsford, R. T., McGinness, H. M., Ward, K. A., and Harper, M. J. (2012). Breeding flow thresholds of colonial breeding waterbirds in the Murray–Darling Basin, Australia. *Wetlands* **32**, 257–265. [doi:10.1007/s13157-011-0235-y](https://doi.org/10.1007/s13157-011-0235-y)
49. Kingsford, R. T., and Johnson, W. (1998). Impact of water diversions on colonially nesting waterbirds in the Macquarie Marshes in arid Australia. *Colonial Waterbirds* **21**, 159–170. [doi:10.2307/1521903](https://doi.org/10.2307/1521903)
50. Kingsford, R. T., and Thomas, R. F. (2004). Destruction of wetlands and waterbird populations by dams and irrigation on the Murrumbidgee River in arid Australia. *Environmental Management* **34**, 383–396. [doi:10.1007/s00267-004-0250-3](https://doi.org/10.1007/s00267-004-0250-3)
51. Kingsford, R. T., and Auld, K. M. (2005). Waterbird breeding and environmental flow management in the Macquarie Marshes, Arid Australia. *River Research and Applications* **21**, 187–200. [doi:10.1002/rra.840](https://doi.org/10.1002/rra.840)
52. Leslie, D. J. (2001). Effect of river management on colonially-nesting waterbirds in the Barmah–Millewa forest, south-eastern Australia. *Regulated Rivers: Research and Management* **17**, 21–36. [doi:10.1002/1099-1646\(200101/02\)17:1<21::AID-RRR589>3.0.CO;2-V](https://doi.org/10.1002/1099-1646(200101/02)17:1<21::AID-RRR589>3.0.CO;2-V)
53. Mac Nally, R., Nerenberg, S., Thomson, J. R., Lada, H., and Clarke, R. H. (2014). Do frogs bounce, and if so, by how much? Responses to the ‘Big Wet’ following the ‘Big Dry’ in south-eastern Australia. *Global Ecology and Biogeography* **23**, 223–234. [doi:10.1111/geb.12104](https://doi.org/10.1111/geb.12104)
54. Nebel, S., Porter, J. L., and Kingsford, R. T. (2008). Long-term trends of shorebird populations in eastern Australia and impacts of freshwater extraction. *Biological Conservation* **141**, 971–980. [doi:10.1016/j.biocon.2008.01.017](https://doi.org/10.1016/j.biocon.2008.01.017)
55. Reid, J. R. W., Colloff, M. J., Arthur, A. D., and McGinness, H. M. (2013). Influence of catchment condition and water resource development on waterbird assemblages in the Murray–Darling Basin, Australia. *Biological Conservation* **165**, 25–34. [doi:10.1016/j.biocon.2013.05.009](https://doi.org/10.1016/j.biocon.2013.05.009)
56. Kingsford, R. T., and Thomas, R. F. (1995). The Macquarie Marshes in arid Australia and their waterbirds: a 50-year history of decline. *Environmental Management* **19**, 867–878. [doi:10.1007/BF02471938](https://doi.org/10.1007/BF02471938)
57. Jolly, I. D., Williamson, D. R., Gilfedder, M., Walker, G. R., Morton, R., Robinson, G., Jone, H., Zhang, L., Dowling, T. I., Dyce, P., Nathan, R. J., Nandakumar, N., Clarke, R., and McNeill, V. (2001). Historical stream salinity trends and catchment salt balances in the Murray–Darling Basin, Australia. *Marine and Freshwater Research* **52**, 53–63. [doi:10.1071/MF00018](https://doi.org/10.1071/MF00018)

58. Thoms, M. C. (2003). Floodplain–river ecosystems: lateral connections and the implications of human interference. *Geomorphology* **56**, 335–349. [doi:10.1016/S0169-555X\(03\)00160-0](https://doi.org/10.1016/S0169-555X(03)00160-0)
59. Gilligan, D., Rolls, R., Merrick, J., Lintermans, M., Duncan, P., and Kohen, J. (2007). Scoping the knowledge requirements for Murray crayfish (*Euastacus armatus*). Department of Primary Industries, Narrandera. Fisheries final report series 89.
60. Cook, R., Paul, W., Hawking, J., Davey, C., and Suter, P. (2011). River Murray Biological Monitoring Program. Review of monitoring 1980 to 2009. The Murray–Darling Freshwater Research Centre, Wodonga.
61. Croome, R., Wheaton, L., Henderson, B., Oliver, R., Vilizzi, L., Paul, W., and McInerney, P. (2011). River Murray water quality monitoring program: phytoplankton data 27, trend analysis 1980–2008. Murray–Darling Freshwater Research Centre, Wodonga. Publication 06/2011.
62. Armstrong, J. L., Kingsford, R. T., and Jenkins, K. M. (2009). The effect of regulating the Lachlan River on the Booligal Wetlands – the floodplain red gum swamps. Report from the University of New South Wales, Sydney.
63. Catelotti, K., Kingsford, R. T., Bino, G., and Bacon, P. (2015). Inundation requirements for persistence and recovery of river red gums (*Eucalyptus camaldulensis*) in semi-arid Australia. *Biological Conservation* **184**, 346–356. [doi:10.1016/j.biocon.2015.02.014](https://doi.org/10.1016/j.biocon.2015.02.014)
64. Cunningham, S. C., Mac Nally, R., Read, J., Baker, P. J., White, M., Thomson, J. R., and Griffioen, P. (2009). A robust technique for mapping vegetation condition across a major river system. *Ecosystems* **12**, 207–219. [doi:10.1007/s10021-008-9218-0](https://doi.org/10.1007/s10021-008-9218-0)
65. Cunningham, S. C., Thomson, J. R., MacNally, R., Read, J., and Baker, P. J. (2011). Groundwater change forecasts widespread forest dieback across an extensive floodplain system. *Freshwater Biology* **56**, 1494–1508. [doi:10.1111/j.1365-2427.2011.02585.x](https://doi.org/10.1111/j.1365-2427.2011.02585.x)
66. George, A. K., Walker, K. F., and Lewis, M. (2005). Population status of eucalypt trees on the River Murray floodplain, South Australia. *River Research and Applications* **21**, 271–282. [doi:10.1002/rra.846](https://doi.org/10.1002/rra.846)
67. Horner, G. J., Baker, P. J., Mac Nally, R., Cunningham, S. C., Thomson, J. R., and Hamilton, F. (2009). Mortality of developing floodplain forests subjected to a drying climate and water extraction. *Global Change Biology* **15**, 2176–2186. [doi:10.1111/j.1365-2486.2009.01915.x](https://doi.org/10.1111/j.1365-2486.2009.01915.x)
68. Chessman, B. C. (2009). Climatic changes and 13-year trends in stream macroinvertebrate assemblages in New South Wales, Australia. *Global Change Biology* **15**, 2791–2802. [doi:10.1111/j.1365-2486.2008.01840.x](https://doi.org/10.1111/j.1365-2486.2008.01840.x)
69. Chessman, B. C. (2015). Relationships between lotic macroinvertebrate traits and responses to extreme drought. *Freshwater Biology* **60**, 50–63. [doi:10.1111/fwb.12466](https://doi.org/10.1111/fwb.12466)
70. Lintermans, M. (2013). The rise and fall of a translocated population of the endangered Macquarie perch, *Macquaria australasica*, in south-eastern Australia. *Marine and Freshwater Research* **64**, 838–850. [doi:10.1071/MF12270](https://doi.org/10.1071/MF12270)

71. Ning, N. S. P., Gawne, B., Cook, R. A., and Nielsen, D. L. (2013). Zooplankton dynamics in response to the transition from drought to flooding in four Murray–Darling Basin rivers affected by differing levels of flow regulation. *Hydrobiologia* **702**, 45–62. [doi:10.1007/s10750-012-1306-7](https://doi.org/10.1007/s10750-012-1306-7)
72. Saddlier, S., Koehn, J. D., and Hammer, M. P. (2013). Let's not forget the small fishes – conservation of two threatened species of pygmy perch in south-eastern Australia. *Marine and Freshwater Research* **64**, 874–886. [doi:10.1071/MF12260](https://doi.org/10.1071/MF12260)
73. Wedderburn, S. D., Barnes, T. C., and Hillyard, K. A. (2014). Shifts in fish assemblages indicate failed recovery of threatened species following prolonged drought in terminating lakes of the Murray–Darling Basin, Australia. *Hydrobiologia* **730**, 179–190. [doi:10.1007/s10750-014-1836-2](https://doi.org/10.1007/s10750-014-1836-2)
74. Noell, C. J., Ye, Q., Short, D. A., Bucater, L. B., and Wellman, N. R. (2009). Fish assemblages of the Murray mouth and Coorong region, South Australia, during an extended drought period. South Australian Research and Development Institute, Adelaide.
75. Wassens, S., Arnaiz, O.L., Healy, S., Watts, R.J., and Maguire, J. (2008b). Hydrological and habitat requirements to maintain viable southern bell frog (*Litoria raniformis*) populations on the Lowbidgee floodplain – Phase 1. Department of Environment and Climate Change, Queanbeyan.
76. Wassens, S., and Maher, M. (2011). River regulation influences the composition and distribution of inland frog communities. *River Research and Applications* **27**, 238–246. [doi:10.1002/rra.1347](https://doi.org/10.1002/rra.1347)
77. Chessman, B. C. (2011). Declines of freshwater turtles associated with climatic drying in Australia's Murray–Darling Basin. *Wildlife Research* **38**, 664–671. [doi:10.1071/WR11108](https://doi.org/10.1071/WR11108)
78. Bino, G., Sisson, S. A., Kingsford, R. T., Thomas, R. F., and Bowen, S. (2015). Developing state and transition models of floodplain vegetation dynamics as a tool for conservation decision-making: a case study of the Macquarie Marshes Ramsar wetland. *Journal of Applied Ecology* **52**, 654–664. [doi:10.1111/1365-2664.12410](https://doi.org/10.1111/1365-2664.12410)
79. Selwood, K. E., Clarke, R. H., Cunningham, S. C., Lada, H., McGeoch, M. A., and Mac Nally, R. (in press). A bust but no boom: responses of floodplain bird assemblages during and after prolonged drought. *Journal of Animal Ecology*
80. Wen, L., Rogers, K., Saintilan, N., and Ling, J. (2011). The influences of climate and hydrology on population dynamics of waterbirds in the lower Murrumbidgee River floodplains in southeast Australia: implications for environmental water management. *Ecological Modelling* **222**, 154–163. [doi:10.1016/j.ecolmodel.2010.09.016](https://doi.org/10.1016/j.ecolmodel.2010.09.016)
81. Kingsford, R. T., Walker, K. F., Lester, R. E., Young, W. J., Fairweather, P. G., Sammut, J., and Geddes, M. C. (2011). A Ramsar wetland in crisis – the Coorong, Lower Lakes and Murray Mouth, Australia. *Marine and Freshwater Research* **62**, 255–265. [doi:10.1071/MF09315](https://doi.org/10.1071/MF09315)
82. Bennett, J. M., Nimmo, D. G., Clarke, R. H., Hall, M., Thomson, J. R., Radford, J. Q., Bennett, A. F., and Mac Nally, R. (2014). Resistance and resilience to pressures: can the abrupt end of extreme drought reverse the collapse of an avifauna? *Diversity & Distributions* **20**, 1321–1332. [doi:10.1111/ddi.12230](https://doi.org/10.1111/ddi.12230)

83. Mac Nally, R., Lada, H., Cunningham, S. C., Thomson, J. R., and Fleishman, E. (2014). Climate-change-driven deterioration of the condition of floodplain forest and the future for the avifauna. *Global Ecology and Biogeography* **23**, 191–202. [doi:10.1111/geb.12091](https://doi.org/10.1111/geb.12091)
84. McGinness, H. M., Arthur, A. D., and Reid, J. R. W. (2013). Woodland bird declines in the Murray–Darling Basin: are there links with floodplain change? *The Rangeland Journal* **32**, 315–327. [doi:10.1071/RJ10016](https://doi.org/10.1071/RJ10016)
85. Selwood, K. E., Thomson, J. R., Clarke, R. H., McGeoch, M. A., and Mac Nally, R. (2015). The potential of floodplains as drought refugia for terrestrial birds in drying climates. *Global Ecology and Biogeography* **24**, 838–848 [doi:10.1111/geb.12305](https://doi.org/10.1111/geb.12305).
86. Hammer, M. P., Bice, C. M., Hall, A., Frears, A., Watt, A., Whiterod, N. S., Beheregaray, L. B., Harris, J. O., and Zampatti, B. P. (2013). Freshwater fish conservation in the face of critical water shortages in the southern Murray–Darling Basin, Australia. *Marine and Freshwater Research* **64**, 807–821. [doi:10.1071/MF12258](https://doi.org/10.1071/MF12258)
87. Rowland, S. J. (2004). Overview of the history, fishery, biology and aquaculture of Murray cod (*Maccullochella peelii peelii*). Management of Murray cod in the Murray–Darling Basin: statement, recommendations and supporting papers. Proceedings of a Workshop held in Canberra, 2004.
88. Doody, T. M., Benger, S. N., Pritchard, J. L., and Overton, I. C. (2014). Ecological response of *Eucalyptus camaldulensis* (river red gum) to extended drought and flooding along the River Murray, South Australia (1997–2011) and implications for environmental flow management. *Marine and Freshwater Research* **65**, 1082–1093. [doi:10.1071/MF13247](https://doi.org/10.1071/MF13247)
89. Dittmann, S., Brown, E., Navong, N., Beyer, K., Silvester, L., Baggalley, S., and Keuning, J. (2012). Benthic macroinvertebrate survey 2011–12: Lower Lakes, Coorong and Murray Mouth icon site. Report for the Department for Water and Murray–Darling Basin Authority. Flinders University, Adelaide.
90. Bice, C. M., Gehrig, S. L., Zampatti, B. P., Nicol, J. M., Wilson, P., Leigh, S. L., and Marsland, K. (2014). Flow-induced alterations to fish assemblages, habitat and fish–habitat associations in a regulated lowland river. *Hydrobiologia* **722**, 205–222. [doi:10.1007/s10750-013-1701-8](https://doi.org/10.1007/s10750-013-1701-8)
91. Cheshire, K. J. M., Ye, Q., Wilson, P., and Bucater, L. (2012). From drought to flood: annual variation in larval fish assemblages in larval fish assemblages in a heavily regulated lowland temperate river. Goyder Institute for Water Research Technical Report Series 12/6.
92. Wassens, S., Walcott, A., Wilson, A., and Freire, R. (2013). Frog breeding in rain-fed wetlands after a period of severe drought: implications for predicting the impacts of climate change. *Hydrobiologia* **708**, 69–80. [doi:10.1007/s10750-011-0955-2](https://doi.org/10.1007/s10750-011-0955-2)
93. Wedderburn, S. D., Hammer, M. P., and Bice, C. M. (2012). Shifts in small-bodied fish assemblages resulting from drought-induced water level recession in terminating lakes of the Murray–Darling Basin, Australia. *Hydrobiologia* **691**, 35–46. [doi:10.1007/s10750-011-0993-9](https://doi.org/10.1007/s10750-011-0993-9)

94. Ye, Q., Bucater, L., Short, D., and Livore, J. (2012). Fish response to barrage releases in 2011/12, and recovery following the recent drought in the Coorong. South Australian Research and Development Institute, Adelaide. Research Report Series 665.
95. Humbert, J.-Y., Scott Mills, L., Horne, J. S., and Dennis, B. (2009). A better way to estimate population trends. *Oikos* **118**, 1940–1946. doi:[10.1111/j.1600-0706.2009.17839.x](https://doi.org/10.1111/j.1600-0706.2009.17839.x)
96. Holmes, E. E., Ward, E. J., and Wills, K. (2012). MARSS: multivariate autoregressive state–space models for analyzing time-series data. *The R Journal* **4**, 11–19.