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Supplementary material

Effects of fish kills on fish consumers and other water-dependent fauna: exploring the potential effect of mass mortality of carp in Australia

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Table S1. Aquatic fauna components of the diets of birds that consume freshwater fish in the Murray–Darling Basin, Australia

Primary sources for all species are the published compilations of data by Barker and Vestjens (1989); and Marchant and Higgins (1990). Other species-specific sources are listed in the table. Parentheses indicate components not listed by name in sources but likely to be consumed considering other known food items, feeding techniques, foraging habitats, and gape size

Family common name	Taxon name	Taxon scientific name	Fish	Cyprinidae	Tadpoles	Frogs	Invertebrates	Crustaceans	Molluscs	Turtles	References
Pelican	Australian Pelican	*Pelecanus conspicillatus*	Y	Y	Y	(Y)		Y			Vestjens (1977)
Darter	Australasian Darter	*Anhinga novaehollandiae*	Y	Y	(Y)	(Y)	Y	(Y)	Y	Y	Morton (1988)
Cormorants and Shags	Little Pied Cormorant	*Microcarbo melanoleucos*	Y	Y	Y	Y	Y	Y	Y		Miller (1979)
	Great Cormorant	*Phalacrocorax carbo*	Y	Y	Y	Y	Y	Y			
	Little Black Cormorant	*Phalacrocorax sulcirostris*	Y	Y	Y	(Y)	Y	Y	Y		Miller (1979)
	Pied Cormorant	*Phalacrocorax varius*	Y	(Y)	(Y)	(Y)	(Y)	Y	Y		
Ibis and Spoonbills	Yellow-billed Spoonbill	*Platalea flavipes*	Y	Y	(Y)	(Y)	Y	Y	Y		
	Royal Spoonbill	*Platalea regia*	Y	Y	(Y)	(Y)	Y	Y	Y		Dorn *et al.* (2011)
	Australian White Ibis	*Threskiornis moluccus*	Y	(Y)	(Y)	Y	Y	Y	Y		Carrick (1959)
	Straw-necked Ibis	*Threskiornis spinicollis*	Y	(Y)	(Y)	Y	Y	Y	Y		Carrick (1959)
Herons, Egrets and Bitterns	Australasian Bittern	*Botaurus poiciloptilus*	Y	(Y)	(Y)	Y	(Y)	(Y)			Menkhorst (2012)
	Great Egret	*Ardea alba*	Y	Y	Y	Y	Y	Y	Y		Taylor and Schultz (2008)
	Intermediate Egret	*Ardea intermedia*	Y	Y	Y	Y	Y	(Y)			Taylor and Schultz (2008)
	White-necked Heron	*Ardea pacifica*	Y	Y	(Y)	(Y)	Y	Y			
	Little Egret	*Egretta garzetta*	Y	(Y)	(Y)	(Y)	Y	Y			
	White-faced Heron	*Egretta novaehollandiae*	Y	Y	Y	Y	Y	Y	Y		
	Pied Heron	*Egretta picata*	Y	(Y)	(Y)	(Y)	Y	Y	Y		
	Australian Little Bittern	*Ixobrychus dubius*	Y	(Y)	Y	(Y)	Y	Y			
	Nankeen Night-Heron	*Nycticorax caledonicus*	Y	Y	Y	Y	Y	Y	Y		

Family common name	Taxon name	Taxon scientific name	Fish	Cyprinidae	Tadpoles	Frogs	Invertebrates	Crustaceans	Molluscs	Turtles	References
Gulls, Terns and Noddies	Whiskered Tern	*Chlidonias hybrida*	Y	(Y)	Y	Y	Y	Y			Dostine and Morton (1989)
	White-winged Black Tern	*Chlidonias leucopterus*	Y	(Y)			Y				
	Silver Gull	*Chroicocephalus novaehollandiae*	Y	Y	Y	Y	Y	Y	Y		
	Common Gull-billed Tern	*Gelochelidon nilotica*	Y	(Y)			Y	Y			
	Caspian Tern	*Hydroprogne caspia*	Y	Y							
Grebes	Great Crested Grebe	*Podiceps cristatus*	Y	(Y)	(Y)		Y	Y			
	Hoary-headed Grebe	*Poliocephalus poliocephalus*	Y	(Y)	(Y)		Y	Y	Y		
	Australasian Grebe	*Tachybaptus novaehollandiae*	Y	(Y)	(Y)		Y	Y	Y		
Ducks, Geese and Swans	Grey Teal	*Anas gracilis*	Y				Y	Y	Y		Briggs (1982)
	Pacific Black Duck	*Anas superciliosa*	Y				Y	Y	Y		
	Musk Duck	*Biziura lobata*	Y	(Y)	Y	Y	Y	Y	Y		
	Freckled Duck	*Stictonetta naevosa*	Y				Y	Y	Y		Briggs (1982)
Storks	Black-necked Stork	*Ephippiorhynchus asiaticus*	Y	(Y)	(Y)	Y	Y	Y		Y	Clancy (2011)
Kingfishers	Azure Kingfisher	*Ceyx azureus*	Y				Y	Y			
	Blue-winged Kookaburra	*Dacelo leachii*	Y	(Y)	(Y)	Y					
	Laughing Kookaburra	*Dacelo novaeguineae*	Y	(Y)	(Y)	Y	Y	Y			
	Red-backed Kingfisher	*Todiramphus pyrrhopygius*	Y	(Y)	(Y)	Y	Y	Y			
	Sacred Kingfisher	*Todiramphus sanctus*	Y	Y	Y	(Y)	Y	Y			
Falcons	Brown Falcon	*Falco berigora*	Y			Y					
Eagles, Kites, Goshawks	Swamp Harrier	*Circus approximans*	Y								
	White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Y	Y							Olsen *et al.* (2013)
	Whistling Kite	*Haliastur sphenurus*	Y				Y	Y		Y	Olsen *et al.* (2013)
	Black Kite	*Milvus migrans*	Y (c)	Y		Y					

Table S2. Literature filtering and compilation steps

Step	Description	Details
1	Drafting of detailed search strings	Searches with high relevance while remaining broad enough to try to capture all sources that might possibly be relevant. Each search string consisted of Boolean operators together with impact terms, subject terms, outcomes terms, subject-area terms, and a set of NOT terms to exclude irrelevant studies commonly identified using the previous sets of terms. Search strings required articles to mention terms related to mortality, fish (of any species), food webs, and carp, as well as terms related to ecological themes and processes.
2	Testing of search results and search string modifications	Searches for known articles to ensure that search strings found relevant literature without greatly expanding the number of irrelevant sources found.
3	Final searches	Using a range of sources including: Web of Science Core Collection; Web of Science All Databases; NRM Knowledge Online; Trove; Google and Google Scholar. Searches covered literature published up to 22 December 2017.
4	Filtering based on titles	PICO filtering of the titles of the first 400 results from Web of Science and the first 50 results from online databases (ordered by relevance). The number of results checked was set based on diminishing chances of relevance.
5	Filtering of abstracts	PICO filtering of the abstracts of articles that satisfied the title filtering.
6	Filtering of full text	PICO filtering of all articles that satisfied the abstract filtering.
7	Reference library compilation, tagging and sorting	The final EndNote library consisted of three internal categories of relevant literature: (1) 'fish mortality (higher trophic level response)'; (2) 'fish mortality (lower trophic level response)'; and (3) 'fish disease/death' (general). For the purposes of our review, 'higher trophic level responses' referred to responses of consumers of any fish or fish-eating species whereas 'lower trophic level responses' referred to animals or plants consumed by fish. Additional internal categories were created for supporting information, including 'carp effects', 'carp specific mortality', 'ecological theory', 'trophic models', and 'water quality'. References and citations of full text articles were scrutinized to identify additional material of relevance.
8	Construction of knowledge status tables	Tables summarising the context, the nominal cause of mortality, the fish taxon involved, primary, secondary and tertiary impacts on predators or prey, and long-term impacts (if known).

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Table S3. Literature reviewed in full text and used to inform conceptual models: by topic, environment, context and design

Only 18 of the 122 articles reviewed in full text met the specified PICO inclusion and exclusion criteria (eligible studies)

Topic	Number of articles	(%)
MFM events	21	17
Trophic models	3	2
Water quality	3	2
Carp effects	25	20
Carp specific mortality	6	5
Ecological theory	13	11
Knowledge of fish species	2	2
Knowledge of consumers	8	7
Higher trophic level impacts	14	11
Lower trophic level impacts	4	3
Ecological Methods	2	2
Cyprinid herpes virus knowledge	21	17
Total	*122*	*100*
Environment		
Marine	25	20
Estuarine	1	1
Freshwater	51	42
Aquaculture	8	7
Laboratory based	3	2
Not applicable	34	28
Total	*122*	*100*
Context		
Theoretically based	35	29
Empirical (academic)	82	67
Pragmatic (management)	5	4
Total	*122*	*100*
Design		
Experimental	13	11
Observational	66	54
Other (review)	43	35
Total	*122*	*100*

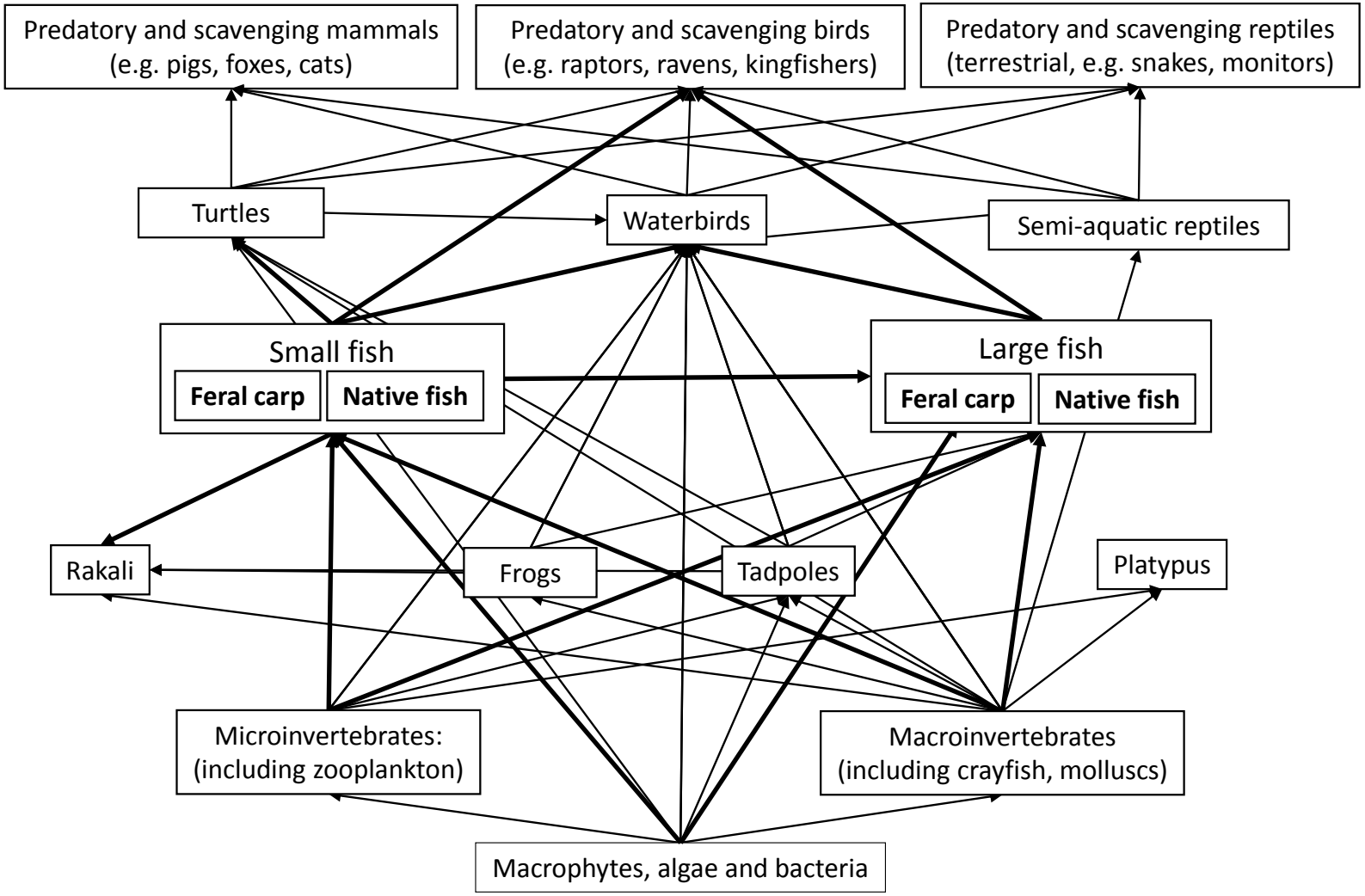

Fig. S1. Conceptual model of feral carp in a simplified Australian freshwater food web. Arrows move from food sources to consumers. Dark heavy arrows indicate primary links between carp and other food web components; light arrows indicate links in the food web that are not dominated by carp but may be affected by carp presence or absence.

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