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Update to the catalogue of South Australian freshwater fishes (Petromyzontida & Actinopterygii)

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Abstract

South Australia is a large Australian state (~1,000,000 km^2) with diverse aquatic habitats spread across temperate to arid environments. The knowledge of freshwater fishes in this jurisdiction has advanced considerably since the last detailed catalogue of native and alien species was published in 2004 owing to significant survey and research effort, spatial analysis of museum data, and incidental records. The updated list includes 60 native and 35 alien species. New additions to the native fauna include cryptic species of *Retropinna semoni* s.l. (Weber) and *Galaxias olidus* s.l. (Günther). Two others have been rediscovered after long absences, namely *Neochanna cleaveri* (Scott) and *Mogurnda adspersa* (Castelnau). Range extensions are reported for native populations of *Galaxias brevipinnis* Günther, *Leiopotherapon unicolour* (Günther), *Hypseleotris* spp. (hybridogenetic forms) and *Philypnodon macrostomus* Hoese and Reader. There are five new alien species records (all aquarium species) including *Phalloceros caudimaculatus* (Hensel), *Poecilia reticulata* Peters, *Xiphophorus hellerii* Heckel, *Astronotus ocellatus* (Agassiz) and *Paratilapia polleni* Bleeker, with confirmation of *Misgurnus anguillicaudatus* (Cantor). Other range extensions for alien (exotic or translocated native) species in different drainage divisions (various modes of human-mediated dispersal) include *Nematalosa erebi* (Günther), *Cyprinus carpio* Linnaeus, *Oncorhynchus mykiss* (Walbaum), *Salmo salar* Linnaeus, *Salvelinus fontinalis* (Mitchell), *Melanotaenia fluviatilis* (Castelnau), *Atherinosoma microstoma* (Günther), *Macquaria novemaculeata* (Steindachner), *Nannoperca australis* Günther, *Pseudaphritis urvillii* (Valenciennes), and *Hypseleotris* spp. (hybridogenetic forms). New records are a combination of greater available information and new incursions, highlighting the need for ongoing detailed surveys and reporting to detect rare native and alien species.

Key words: conservation, management, taxonomy

Introduction

Up-to-date regional species lists help to inform researchers and managers on the extent of local biodiversity, plus provide a contemporary perspective on the correct taxonomy, conservation targets and potential control issues that relate to the organismal group concerned. More than ever, freshwater fishes are seen as a key part of natural resource management due to their diversity in number and form, intriguing life history and adaptations, links within food-chains, value as bio-indicators, role in human culture and use, and as icons for aquatic conservation and environmental awareness (Berra 2001; Bunn & Arthington 2002; Kennard *et al.* 2006; Hammer *et al.* 2009). The Australian state of South Australia has a diversity of aquatic habitats and a corresponding relatively high richness in freshwater fishes (Allen *et al.* 2002). This update documents advances in knowledge on the presence and distribution of freshwater fishes in South Australia since a previous catalogue published in 2004 (Hammer & Walker 2004).

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Methods

South Australia is a large state in the southern half of Australia (~1,000,000 km^2), which envelopes distinct geological, climatic, hydrological and biogeographic features. The spatial extent includes moderately well-watered and cool Mediterranean type climates in the south east, through to harsh arid conditions in the west and north. Minor topographic relief occurs in the Mount Lofty, Flinders and Musgrave ranges. Hydrological connectivity is organised by five primary drainage divisions (AWRC 1976), namely South East Coast (SEC), Murray–Darling (MD), South Australian Gulf (SAG), Lake Eyre (LE), and Western Plateau (WP) (Figure 1). Aquatic habitats include artesian mound springs, karst rising springs, swamps, lakes, seasonal to perennial streams, episodic desert rivers, and the River Murray and associated wetlands (Hammer *et al.* 2009).

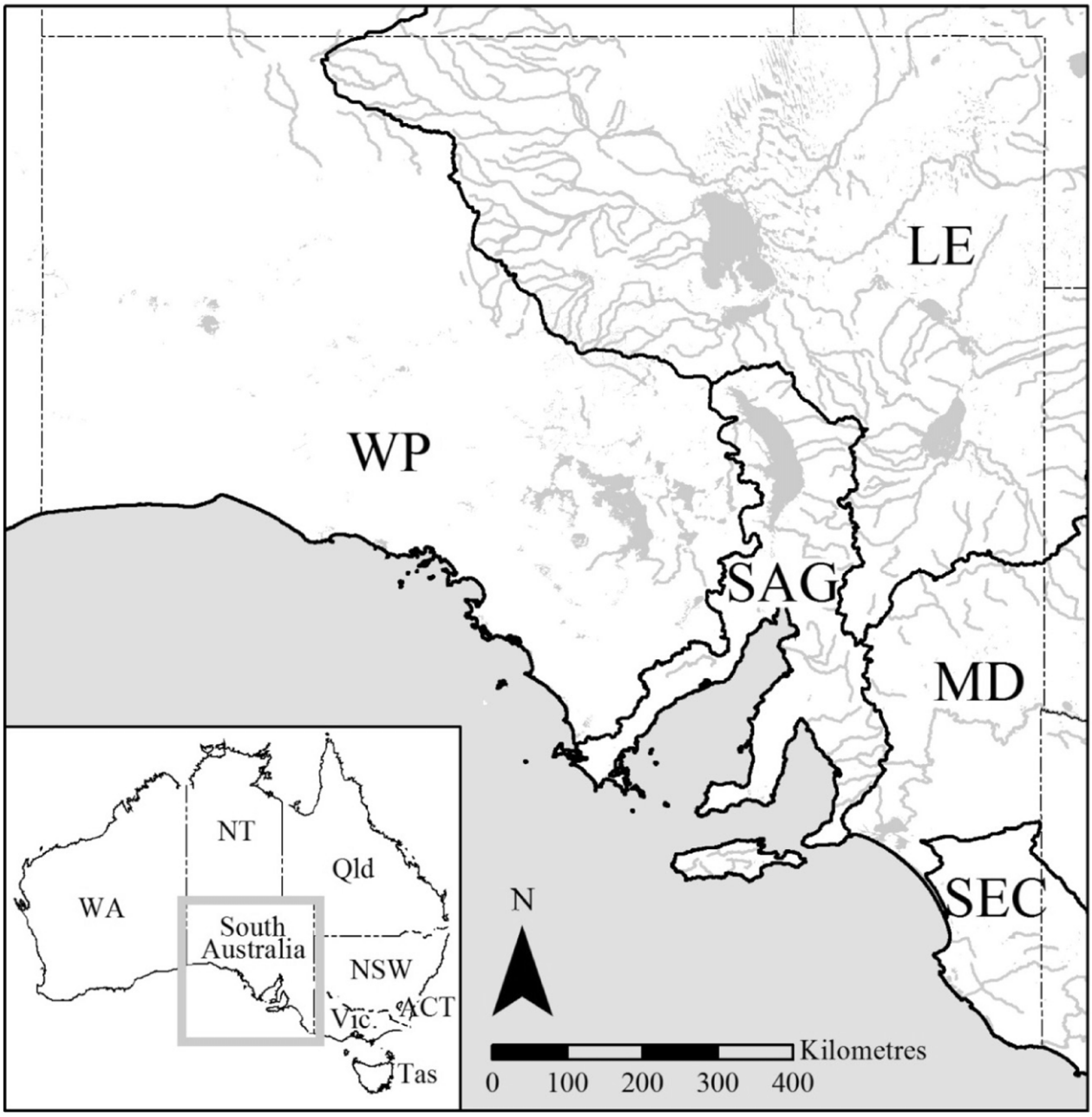

FIGURE 1. Location map of South Australia indicating larger watercourses arranged within drainage divisions (AWRC 1976): South East Coast (SEC), Murray–Darling (MD), South Australian Gulf (SAG), Lake Eyre (LE), and Western Plateau (WP).

Following Hammer & Walker (2004) the term "fresh water" is inclusive of inland saline waters (≥3000 mg L^{-1}). A "freshwater" species includes obligate freshwater and diadromous species, and select euryhaline taxa known to facultatively complete their lifecycle inland (McDowall 1996). "Alien" species include exotic species (not native to Australia) and native Australian species translocated outside their natural range. Alien fishes in natural waterways are regarded as *established* if their populations are self-sustaining or if they are continually stocked, and as *introduced* if records are few and isolated or confined to artificial waterbodies (i.e. the species could potentially become established). Species patterns are explored by drainage division.

The systematic order and nomenclature from the 2004 catalogue (Eschmeyer 1998; Eshmeyer 2012) are maintained, with the exception of: adoption of subspecific status for Australian shortfinned eel populations as *Anguilla australis australis* Richardson (Watanabe *et al.* 2006; Shen & Tzeng 2007); adoption of *Maccullochella peelii* (Mitchell) for Murray Cod in the Murray–Darling Basin following recognition of the previously diagnosed subspecies *Maccullochella peelii mariensis* Rowland as a valid sibling species (Nock *et al.* 2010); placement of *Lates calcarifer* (Bloch) into a new family Latidae from Centropomidae (Otero 2004); and a formal name for the long recognised dwarf flathead gudgeon (*sensu* Hoese & Larson 1980) as *Philypnodon macrostomus* Hoese & Reader, 2006. Other previously listed (2004 catalogue) informal taxa that remain undescribed are Lake Eyre golden perch *Macquaria* sp. (*sensu* Musyl & Keenan 1992) and north-west glassfish *Ambassis* sp. (*sensu* Allen *et al.* 2002). The possible placement of two members of the Percichthyidae, *Macquaria colonorum* (Günther) and *M. novemaculeata* (Steindachner), into the genus *Percalates* (Jerry *et al.* 2001; Near *et al.* 2012) was considered but awaits morphological re-evaluation.

Considerable new information was available to assess updates. Namely, a range of surveys and monitoring included within a detailed appraisal of some 4000 museum and grey literature records using GIS software to map and interrogate distribution information (Hammer *et al.* 2009), and incidental records by the public and natural resource managers. A strong emphasis was placed on sourcing and lodging specimens for new records as significant historic voucher specimens with the South Australian Museum, Adelaide (SAMA), either as registered specimens and/or frozen material lodged in the Australian Biological Tissues Collection (ABTC). Relevant SAMA and ABTC specimen lot numbers are provided in the text when available (e.g. SAMA F1160) and additional information is provided for grey literature records, not supported with vouchers, that may otherwise be difficult to source.

Molecular genetics was employed to investigate two particular taxonomic issues. The carp gudgeon complex from the Murray–Darling Basin contains genetically distinct and morphologically partially diagnosed (informal) species, namely *Hypseleotris klunzingeri* s.s. (Ogilby), *Hypseleotris* sp. 1 (Midgley's carp gudgeon: *sensu* Larson & Hoese 1996) and *Hypseleotris* sp. 3 (Murray–Darling carp gudgeon: *sensu* Allen *et al.* 2002), and unisexual hybridogenetic forms (Bertozzi *et al.* 2000; Unmack 2000; Schmidt *et al.* 2011) that include the Lake's carp gudgeon morphotype (*sensu* Larson & Hoese 1996) and hence were collectively assigned to a taxa as *Hypseleotris* spp. Nuclear genetic data (allozyme electrophoresis) was utilised to assign selected samples to a taxon or hybrid form following the methodology employed in Bertozzi *et al.* (2000). The 2004 catalogue reported on a possible new grunter species/hybrid form from LEB known as "fat grunter". Samples of this form were available as frozen tissue (ABTC) with matching SAMA voucher specimens collected during the ARIDFLO research project (Costello *et al.* 2003), and were assessed against comparative *Scortum barcoo* (McCulloch & Waite) and *Bidyanus welchi* (McCulloch & Waite) material at a suite of allozyme loci following the "overview study" methodology of Hammer *et al.* (2007). Detailed methodology and results will be reported within a broader study of the Terapontidae elsewhere (Adams *et al*. in prep.).

Results

An updated list of species recorded in South Australia is provided in Tables 1–2, with detailed supporting information for new records in Table 3.

The total number of native fish species for South Australia is now 60 (Table 1). An increase arises with two currently-defined single species acknowledged to contain cryptic taxa following systematic review. *Retropinna semoni* (Weber) has been identified by nuclear genetic data as a complex of at least five species, including two which have parts of their range in South Australia, one candidate taxa from LEB (*Retropinna* sp.) and another from

MD/SEC (designated as *Retropinna semoni* s.l. here for stability, but name likely to change with formal review) (Hammer *et al.* 2007). Combined molecular/morphological review of *Galaxias olidus* Günther has revealed a complex of 15 species, including two in South Australia (Raadik 2011; Raadik and Adams unpublished data) that both occur extralimitally. In South Australia they appear to be allopatric with a roughly east-west split at the Mount Lofty Ranges: *Galaxias olidus* s.s. from the Gawler to Yankalilla catchments (SAG) and Finniss/Tookayerta catchments (MD) (e.g. SAMA F1160); and *Galaxias* sp. (obscure galaxias) from Mosquito Creek (SEC), Hindmarsh Catchment (SAG) (e.g. SAMA F12529) and Marne to Currency catchments (MD) (Raadik 2011).

Nuclear and matrilineal genetic review of species boundaries in *Galaxiella pusilla* (Mack) indicates two species occur east and west of the Otway Ranges, Victoria respectively (Coleman *et al.* 2010; Unmack *et al.* 2012). The western form which spans into South Australia appears to represent an undescribed cryptic species; *G. pusilla* is retained in the current context pending formal taxonomic treatment since this is simply a name change for the local form. Other matrilineal lineages observed in *Galaxias brevipinnis* Günther (New Zealand *v.* Australia) and *Hypseleotris klunzingeri* and *Hypseleotris* sp. 1 (LEB *v.* MD) flag likely future additional species/nomenclature changes (Waters & Wallis 2001; Thacker *et al.* 2007). Genetic analysis of individuals fitting the description of "fat grunter" proved to have a genotype matching *Scortum barcoo* at 50 nuclear loci with no indication of hybrids, and thus appear to be a rare phenotypic variant only (e.g. SAMA F12468 from Warburton River).

Two species believed lost to the state through regional extirpation were rediscovered. *Mogurnda adspersa* (Castelnau), presumed extinct after extensive searches failed to locate any records since the early 1970s (Lloyd & Walker 1986; Pierce 1997; Lintermans 2007; Smith *et al.* 2009), was located at a single wetland on the River Murray (Hammer 2008a; SAMA F11770). *Neochanna cleaveri* (Scott), known only from a single museum specimen from 1974 at Bool Lagoon (SEC), was located as remnant populations in nearby coastal habitat between Beachport and Robe (Hammer *et al.* 2009; Hammer & Tucker 2011; SAMA F12412).

Minor range extensions representing natural distributions are recorded for several species. In SEC *Retropinna semoni* s.l. was documented from the small section of the Glenelg River in South Australia (Hammer *et al.* 2007; SAMA F12451), and *Galaxias brevipinnis* from a small section of fast flowing stream habitat at Piccaninnie Ponds (Hammer 2008b; SAMA F12395). An area on the Southern Fleurieu Peninsular (Hindmarsh and Inman rivers) shares at least four other species in common with the abutting MD, and hence a new record of *Philypnodon macrostomus* from the Hindmarsh River (Hammer 2006; SAMA F12395) represents a confirmed additional native species for SAG, given other populations in the Onkaparinga and Torrens rivers are likely introduced (Hammer & Walker 2004). Genetic data identified the presence of hybridogenetic *Hypseleotris* spp. in the Inman river as a further new record for SAG (ABTC FISHLAB:MA-1107). Mapping of museum records identified a population of *Leiopotherapon unicolor* (Günther) from an endoreic system in WP (The Twins Watercourse), just to the south of LEB (SAMA F7781).

There are nine new records of alien species in South Australia, bringing the tally to 35 (Tables 2–3). Five of the new records were exotic species of the Poeciliidae and Cichlidae. An established population of *Phalloceros caudimaculatus* (Hensel) was discovered at Willunga Creek in SAG (McNeil & Wilson 2008; SAMA F12530). *Poecilia reticulata* Peters and *Xiphophorus hellerii* Heckel were recorded as reproducing populations in an artesian (thermal) fed dam within a natural wetland, Rushy Swamp, in SEC (S. Slater pers. comm. 2010; SAMA F12375 & F12376). Anecdotal evidence from the landholder of *Poecilia latipinna* (Lesueur) released into and later observed from the same location could not be confirmed by the collection of specimens (and is not included in the update). More reliable evidence (photo of angling catch viewed by fish expert) was found for the introduction of *Astronotus ocellatus* (Agassiz) to the Onkaparinga River in SAG (Table 3), and *Paratilapia polleni* Bleeker to SEC as a specimen found on walking track on the edge of the Blue Lake (SAMA F12377). Both records appear to be isolated occurrences of single fish. There were five new records for different drainage divisions, including confirmation of an established population of *Cyprinus carpio* L. in Valley Lake in SEC (SAMA F12581), an individual *Salmo salar* L. at Fowlers Bay (WC) in marine habitat (Table 3), and various grey literature reports for additional stocking locations/records of two other salmonids: *Oncorhynchus mykiss* (Walbaum) to LEB and WP and *Salvelinus fontinalis* (Mitchell) to MD (Table 3). *Misgurnus anguillicaudatus* (Cantor) previously thought to occur in MD based on unverified records (Hammer & Walker 2004), is now confirmed with specimens (L. Suitor, pers. comm. 2011; SAMA F12532).

TABLE 1. Native freshwater fishes in drainage divisions of South Australia. [X = recorded; E = presumed extinct; ? = uncertain status], Recent updates are indicated with **bold** font, # Endemic to South Australia, * Species complex, † See text.

Family	Taxon	Common name	Division				
			SEC	MD	SAG	LE	WP
Geotriidae	*Geotria australis* Gray, 1851	Pouched lamprey	X	X	X		
Mordaciidae	*Mordacia mordax* (Richardson, 1846)	Shortheaded lamprey	X	X	X		
Anguillidae	*Anguilla australis australis* Richardson, 1841	Shortfinned eel	X	X	X		
Clupeidae	*Nematalosa erebi* (Günther, 1868)	Bony herring		X	?	X	
Plotosidae	*Neosiluroides cooperensis* Allen & Feinberg, 1998	Cooper catfish				X	
	Neosilurus gloveri Allen & Feinberg, 1998#	Dalhousie catfish				X	
	Neosilurus hyrtlii Steindachner, 1867	Hyrtl's catfish				X	
	Porochilus argenteus (Zietz, 1896)	Silver tandan				X	
	Tandanus tandanus (Mitchell, 1838)	Freshwater catfish		X			
Retropinnidae	*Prototroctes maraena* Günther, 1864	Australian grayling	X				
	Retropinna semoni (Weber, 1895)*	Australian smelt	**X**	X			
	Retropinna sp. (undescribed) †	Lake Eyre smelt				**X**	
Galaxiidae	*Galaxias brevipinnis* Günther, 1866	Climbing galaxias	**X**	X	X		
	Galaxias maculatus (Jenyns, 1842)	Common galaxias	X	X	X		
	Galaxias olidus Günther 1866*	Mountain galaxias		X	X		
	Galaxias sp. (undescribed)	Obscure galaxias	**X**	**X**	**X**		
	Galaxias rostratus Klunzinger, 1872	Flathead galaxias		E			
	Galaxias truttaceus Valenciennes, 1846	Spotted galaxias	X				
	Galaxiella pusilla (Mack, 1936)	Dwarf galaxias	X				
	Neochanna cleaveri (Scott, 1934)	Australian mudfish	X				

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TABLE 1. (Continued.)

Family	Taxon	Common name	Division				
			SEC	MD	SAG	LE	WP
Melanotaeniidae	*Melanotaenia fluviatilis* (Castelnau, 1878)	Murray rainbowfish	?	X			
	Melanotaenia splendida tatei (Zietz, 1896)	Desert rainbowfish				X	
Atherinidae	*Atherinosoma microstoma* (Günther, 1861)	Small-mouthed hardyhead	X	X	X		X
	Craterocephalus dalhousiensis Ivantsoff & Glover, 1974[#]	Dalhousie hardyhead				X	
	Craterocephalus eyresii (Steindachner, 1883)[#]	Lake Eyre hardyhead			X	X	?
	Craterocephalus fluviatilis McCulloch, 1912	Murray hardyhead		X			
	Craterocephalus gloveri Crowley & Ivantsoff 1990[#]	Glover's hardyhead				X	
	Craterocephalus stercusmuscarum fulvus Ivantsoff, Crowley & Allen, 1987	Unspecked hardyhead		X			
	Craterocephalus stercusmuscarum ?*stercusmuscarum* (Günther, 1867)	Fly-specked hardyhead				X	
Ambassidae	*Ambassis agassizii* Steindachner, 1867	Agassizi's glassfish		E			
	Ambassis sp. (undescribed)[†]	Northwest glassfish				X	
Percichthyidae	*Gadopsis marmoratus* Richardson, 1848	River blackfish	X	X	E		
	Maccullochella macquariensis (Cuvier, 1829)	Trout cod		E			
	Maccullochella peelii (Mitchell, 1838)	Murray cod		X			
	Macquaria ambigua ambigua (Richardson, 1845)	Murray–Darling golden perch		X			
	Macquaria australasica Cuvier, 1830	Macquarie perch		E			
	Macquaria sp. (undescribed)[†]	Lake Eyre golden perch				X	
	Nannoperca australis Günther, 1861	Southern pygmy perch	X	X	X		
	Nannoperca obscura (Klunzinger, 1872)	Yarra pygmy perch	X	X			
	Nannoperca variegata Kuiter & Allen, 1986	Variegated pygmy perch	X				
	Macquaria colonorum (Günther, 1863)	Estuary perch	X	X			

……*to be continued on next page*

TABLE 1. (Continued.)

Family	Taxon	Common name	Division				
			SEC	MD	SAG	LE	WP
Terapontidae	*Amniataba percoides* (Günther, 1864)	Banded grunter				X	
	Bidyanus bidyanus (Mitchell, 1838)	Silver perch		X			
	Bidyanus welchi (McCulloch & Waite, 1917)	Welch's grunter				X	
	Leiopotherapon unicolor (Günther, 1859)	Spangled grunter		X	?	X	**X**
	Scortum barcoo (McCulloch & Waite, 1917)	Barcoo grunter				X	
Pseudaphritidae	*Pseudaphritis urvillii* (Valenciennes, 1832)	Congolli	X	X	X		X
Eleotridae	*Hypseleotris klunzingeri* (Ogilby, 1898)	Western carp gudgeon		X		X	
	Hypseleotris sp. 1 (undescribed)†	Midgley's carp gudgeon		X		X	
	Hypseleotris sp. 3 (undescribed)†	Murray–Darling carp gudgeon	?	X	X		
	Hypseleotris spp. (hybridogenetic forms)*†	e.g. Lake's carp gudgeon	?	X	**X**	X	
	Mogurnda adspersa (Castelnau, 1878)	Southern purple-spotted gudgeon		**X**	E		
	Mogurnda clivicola Allen & Jenkins, 1999	Flinders Ranges purple-spotted gudgeon				X	
	Mogurnda thermophila Allen & Jenkins, 1999#	Dalhousie purple-spotted gudgeon				X	
	Philypnodon grandiceps (Krefft, 1864)	Flathead gudgeon	X	X	X		
	Philypnodon macrostomus Hoese & Reader, 2006	Dwarf flathead gudgeon		X	**X**		
Gobiidae	*Chlamydogobius eremius* (Zietz, 1896)#	Desert goby				X	
	Chlamydogobius gloveri Larson, 1995 #	Dalhousie goby				X	
	Pseudogobius olorum (Sauvage, 1880)	Western bluespot goby	X	X	X		X
	Tasmanogobius lasti Hoese, 1991	Lagoon goby	X	X	X		
Totals (Grand Total 60)			**21**	**36**	**19**	**24**	**4**

TABLE 2. Alien fishes in fresh water environments in drainage divisions of South Australia. [X = continually introduced and/or established; I = introduced, few records or not established; A = introduced to artificial habitats (e.g. farm dams, stormwater wetlands); ? = uncertain status], Recent updates are indicated with **bold** font.

Family	Taxon	Common name	Division				
			SEC	MD	SAG	LE	WP
Exotic species							
Cyprinidae	*Carassius auratus* (Linnaeus, 1758)	Goldfish	X	X	X	X	A
	Cyprinus carpio Linnaeus, 1758	Common carp	**X**	X	X	A	
	Tinca tinca (Linnaeus, 1758)	Tench	X	X	X		
Cobitidae	*Misgurnus anguillicaudatus* (Cantor, 1842)	Oriental weatherloach		**X**			
Salmonidae	*Oncorhynchus mykiss* (Walbaum, 1792)	Rainbow trout	I	X	X	**A**	**I**
	Salmo salar Linnaeus, 1758	Atlantic salmon		I			**I**
	Salmo trutta Linnaeus, 1758	Brown trout	I	X	X		
	Salvelinus fontinalis (Mitchell, 1814)	Brook trout		**I**	I		
Poeciliidae	*Gambusia holbrooki* Girard, 1859	Eastern Gambusia	X	X	X	X	I
	Phalloceros caudimaculatus (Hensel, 1868)	Spotted livebearer			**X**		
	Poecilia reticulata Peters, 1859	Guppy	**I**				
	Xiphophorus hellerii Heckel, 1848	Green swordtail	**I**				
Percidae	*Perca fluviatilis* Linnaeus, 1758	Redfin perch	X	X	X	I	
Cichlidae	*Astronotus ocellatus* (Agassiz, 1831)	Oscar			**I**		
	Paratilapia polleni Bleeker, 1868	Black diamond cichlid	**I**				
Translocated Australian native species							
Clupeidae	*Nematalosa erebi* (Günther, 1868)	Bonny herring			**I**		
Plotosidae	*Tandanus tandanus* (Mitchell, 1838)	Freshwater catfish	I	A	X		

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TABLE 2. (Continued)

Family	Taxon	Common name	Division				
			SEC	MD	SAG	LE	WP
Galaxiidae	*Galaxiella pusilla* (Mack, 1936)	Dwarf galaxias			I?		
Melanotaeniidae	*Melanotaenia fluviatilis* (Castelnau, 1878)	Murray rainbowfish	I?	**I**	X		
Atherinidae	*Atherinosoma microstoma* (Günther, 1861)	Smallmouthed hardyhead	**X**	**I?**			
Ambassidae	*Ambassis agassizii* Steindachner, 1867	Agassizi's glassfish		A			
Percichthyidae	*Gadopsis marmoratus* Richardson, 1848	River blackfish			A		
	Maccullochella peelii (Mitchell, 1838)	Murray cod	I	A	X	I	
	Macquaria ambigua ambigua (Richardson, 1845)	Murray–Darling golden perch	I	A	X	A	
	Nannoperca australis Günther, 1861	Southern pygmy perch		**I**	A		
	Macquaria novemaculeata (Steindachner, 1866)	Australian bass		I	**I**		
Latidae	*Lates calcarifer* (Bloch, 1790)	Barramundi			I		
Terapontidae	*Bidyanus bidyanus* (Mitchell, 1838)	Silver perch	I	A	A	A	
Pseudaphritidae	*Pseudaphritis urvillii* (Valenciennes, 1832)	Congolli	**I**				
Eleotridae	*Hypseleotris* sp. 1 (undescribed)	Midgley's carp gudgeon			X		
	Hypseleotris sp. 3 (undescribed)	Murray–Darling carp gudgeon	X?				
	Hypseleotris spp. (undescribed)	Hybridogenetic carp gudgeon forms	**X**		**X**		
	Mogurnda adspersa (Castelnau, 1878)	Southern purple-spotted gudgeon		A	A		
	Philypnodon macrostomus Hoese and Reader, 2006	Dwarf flathead gudgeon			X?		
	Oxyeleotris lineolata (Steindachner, 1867)	Sleepy cod		I			
Totals (Grand Total 35)			**19**	**21**	**25**	**8**	**4**
Total established (Grand Total 18)			**8**	**8**	**15**	**2**	**0**

TABLE 3. Notes on the geographic distribution of selected freshwater fishes in South Australia (in support of Tables 1–2). [Record types: 1 = range extension or new state record; 2 = restricted presence; 3 = established alien species; 4 = introduced; 5 = erroneous report], SAMA = South Australian Museum, Adelaide.

Species	Record Type	Details	Source
South East Coast Drainage Division			
Retropinna semoni	1	Identified in the small section of the Glenelg River flowing through SA.	Hammer *et al.* (2007); SAMA F12451 (2004)
Galaxias brevipinnis	1	Lower south east SA, Piccanninnie Ponds outflow creek.	Hammer (2008b); SAMA F12395 (2007)
Mordacia mordax	2	Record from freshwater in the region verified at Ewens Ponds.	SAMA F11930 (2008)
Galaxias truttaceus	2	Originally reported from Ewens Ponds/Eight Mile Creek. Recorded from additional localities in Lower SE SA (Cress Creek, Deep Creek and Piccaninnie systems).	Hammer (2008b); SAMA F12463 (2007, whitebait); SAMA F12562 (2011)
Neochanna cleaveri	2	Previously known from a single specimen at Bool Lagoon (1974), rediscovered in the Beachport and Robe area.	SAMA F12499 (2008, whitebait), SAMA F12412 (2010); Hammer (2009b); Hammer and Tucker (2011)
Coorong fishes	3/4	Artificial surface water connection between the Upper South East and Salt Creek at the southern end of the Coorong allows fish movement. Field observations and distributional records confirmed for *Atherinosoma microstoma* and *Pseudaphritis urvillii* (photo). Likely to also include *Pseudogobius olorum* occurring in Salt Creek (and other diadromous species).	Hammer (2002, 2010)
Cyprinus carpio	3	Previously one record from Bool Lagoon (1995), reproducing population now confirmed in Valley Lake.	S. Slater, unpublished data; F12581 (2011)
Tandanus tandanus	4	Originally reported from Lucindale. Additional anecdotal evidence provides locality details as Bakers Range Drain, Katani Park, where it persisted to at least the 1970s.	SAMA F1918 (1936)
Maccullochella peelii	4	Additional information regarding introductions of wild fish from MD to SEC (1913–1926): Lake Bonney, Valley Lake, Robe Lakes and Mosquito Creek.	Trueman (2011)
Poecilia reticulata & *Xiphophorus hellerii*	4	Thermal spring fed dam within Rushy Swamp, north of Drain L. Source population eradicated via spring capping and infilling of dam.	SAMA F12375 & F12376 (2010); S. Slater pers. comm. (2010)
Paratilapia polleni	4?	Individual found on the walking track around Blue Lake, Mt Gambier.	SAMA F12377 (2009)
Hypseleotris spp.	4?	Genotyping indicated the presence of hybridogens (MD x X).	SAMA F12457 (2005) *sensu* Bertozzi *et al.* (2001)

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TABLE 3. (Continued.)

Species	Record Type	Details	Source
Murray–Darling Drainage Division			
Mogurnda adspersa	2	Rediscovered in a small wetland near Murray Bridge on the River Murray (2003), last records from 1973.	Hammer (2008a); SAMA F11770 (2007), F3272 (1973)
Upper South East fish community	3/4	Artificial surface water connection (as above) provides a dispersal pathway for the *Atherinosoma microstoma* (if not introduced from MD originally) and a distinct SE genetic population of *Nannoperca australis*, possibly also *Philypnodon grandiceps*.	Hammer (2002; 2010)
Misgurnus anguillicaudatus	4	Previous unverified records, numerous specimens recorded near Berri and Renmark following 2010/2011 floods along the River Murray.	L. Suitor, unpublished data; SAMA F12532 (2011)
Salvelinus fontinalis	4	Record of stocking into the Finniss River in 1975.	Clements (1988), p. 301
Melanotaenia fluviatilis	4	Native in region, but individual recorded in isolated stream habitat in Meadows Creek, Mount Lofty Ranges.	Hammer (2009a); SAMA F2527 (2006)
South Australian Gulf Division			
Philypnodon macrostomus	1	Hindmarsh R. Presumed native as part of a distinct local faunal assemblage with ties to the Murray (*Galaxias* sp., *Nannoperca australis*, *P. grandiceps, Hypseleotris* sp. 3).	Hammer (2006; 2008a); SAMA F12528 (2006)
Anguilla australis australis	2	Previously reported from Kangaroo Island, additional recent records from the mainland; (1) Inman R., (2) Onkaparinga R, (3) Salisbury wetlands (photo), (4) Bolivar, Port R. System (photo).	(1 & 4) D. Hicks, Australian Water Quality Centre, unpublished data; (2) McNeil & Hammer (2007); SAMAF10411 (2006), (3) C. Burgess, Waterwatch, pers. comm. 2005
Hypseleotris spp.	2 & 4	Genotyping indicated the presence of native hybridogens (MD x X) in the Inman River (genotype only) and introduced hybridogens (Midg x X) in the R. Torrens.	ABTC FISHLAB:MA-1107, SAMAF12546 (2011) *sensu* Bertozzi *et al.* (2001)

……to be continued on the next page

TABLE 3. (Continued.)

Species	Record Type	Details	Source
Phalloceros caudimaculatus	3	Established population discovered in a spring fed creek at Willunga (2008).	McNeil and Wilson (2008); SAMA F12530 (2008)
Nematalosa erebi	4	Single unverified report of a live fish in the upper River Torrens (2008), collected by researchers familiar with the species (D. McNeil, pers. comm. 2011). Record from the Port R. system (Bone Is.), regurgitated by a pelican chick.	McNeil *et al.* (2011); SAMA F7168 (1990)
Macquaria novemaculeata	4	Fish angled from Broughton R. (2004, photo).	A. Ivey pers. comm. (2010)
Astronotus ocellatus	4?	Unverified report of a fish angled from Onkaparinga R. based on photo viewed by magazine editor (undated). Included due to high degree of confidence by reporter and due to distinctive appearance of a well known aquarium species.	Modern Fishing article 1996–2003, S. Mensforth pers. comm. (2010)
Lake Eyre Drainage Division			
Oncorhynchus mykiss	4	Reports of stocking into dams of the region.	Glover (1988)
Poecilia reticulata	5	Literature report from Cooper Creek near Innamincka (Policemans Waterhole), no physical or photo voucher. Subsequent sampling has yielded no additional evidence.	Bleher (2006) cf. McNeil *et al.* (2008); SAMA unpublished field data (2007)
Western Province Drainage Division			
Leiopotherapon unicolor	1	Minor range extension, just south of LEB drainage divide (White Nob Dam, The Twins Watercourse).	SAMA F7781 (1995)
Salmo salar	4	Photo in magazine of an adult fish angled from Fowlers Bay jetty (2005).	Hunt (2005)
Oncorhynchus mykiss	4	Reports of stocking into “Sheringa Dam (Eyre Pen.)” in 1934.	Morrissy (1967)

The remaining four additions to the list of alien species in the state were translocated Australian native species. A single *Nematalosa erebi* (Günther) was captured during monitoring in the upper River Torrens (SAG) (McNeil *et al.* 2011; Table 3). The only other record for the species in this drainage division was on an island in the Port River system, where individuals were apparently transported across a drainage divide (likely from MD) by piscivorous birds to feed chicks (SAMA F7168). Artificial surface water connection (drains) between the Upper South East and Salt Creek at the southern end of the Coorong was documented (physical observations and distributional data) to allow artificial fish movement (translocation) between MD and SEC for *Atherinosoma microstoma* (Günther) and *Pseudaphritis urvillii* (Valenciennes), and others species may also be involved (Hammer 2002, 2010; Table 3). Introduced populations of hybridogenetic *Hypseleotris* spp. were recorded from SAG (River Torrens; SAMA F12546) and SEC (Henry Creek; SAMA F12457) (Table 3). New records for drainage divisions include *Melanotaenia fluviatilis* (Castelnau) from isolated habitat in MD and *Macquaria novemaculeata* recorded from the Broughton River in SAG (Table 3).

In recent years aquatic environments in South Australia have seen unprecedented change as a result of over-allocation of water and extended drought conditions. The status of several species as extant in the wild is unknown with likely extirpation of *Nannoperca obscura* (Klunzinger) and, soon after rediscovery, *Mogurnda adspersa* as part of wide felt fish declines in MD and SEC (Hammer *et al.* 2009; Zampatti *et al.* 2010; Wedderburn *et al.* 2012). Nonetheless, programs exist aiming to re-establish or supplement wild populations of these species, particularly in the MD (Bice *et al.* 2012; Hammer *et al.* 2012), but the success of these actions is uncertain.

Discussion

Review of South Australian freshwater fishes is timely given the high number of new records since the previous catalogue (some 30 in ~8 years) (Hammer & Walker 2004). The positive outcome of research and observation to better document aquatic diversity in the state greatly improves the quality of informed decision making and local awareness of conservation goals and management issues (Hammer *et al.* 2009). Such new knowledge however, is tempered by detailed observations of species decline and habitats under threat (e.g. Wedderburn *et al.* 2012). A key lesson in the case of rediscovery is that a second chance for conserving these imperilled species should be taken before it is once again too late (i.e. major threats to viability of *Mogurnda adspersa*). Moreover these examples and ongoing new finds argue that other species (presumed extinct, cryptic or novel) may still be found with ongoing and intensive effort and complete taxonomic evaluations.

Twenty new records for alien species (state and or drainage division) are a combination of greater available information and new incursions and also highlight the need for ongoing detailed surveys and reporting. Lintermans (2004) lists 12 mechanisms for the human assisted dispersal of alien fishes in Australia, and many of these are clearly evident in new records documented herein. "Deliberate legal and deliberate illegal stocking" of fish for angling purposes has contributed to new records such as *Macquaria novemaculeata* in SAG and salmonid records in MD, SAG, LE and WP. Most of the later records, unearthed during ongoing review, reflect historic releases, and highlight the systemic introduction of salmonids to most surface waters of the state. Indeed many millions of fish have been stocked since the early 1900s (Morrissy 1967; Fulton 2004), with legal releases continuing under permit in several waterways of SAG and MD, and other illegal releases documented such as in Baldina Creek in MD (Hammer *et al.* 2005). Trueman (2011) collated historic information (newspaper articles) that indicate the timing of introduction or establishment of several other alien species of angling interest by the early-mid 1800s including *Carassius auratus* L., *Maccullochella peelii* and *Perca fluviatilis* L. One salmonid report, *Salmo salar* at Fowlers Bay, could be an example of the mechanism "escape from aquaculture facilities". *Melanotaenia fluviatilis* occur in many farm dams and backyard ponds in the Mount Lofty Ranges, and the record in a local stream likely signals another of the listed introduction pathways "escape from outside ponds and dams".

The new state records of poeciliids and cichlids are all likely to have arrived via "discarding of aquarium fish". Most are unlikely to be viable introductions due to low winter temperatures in the southern half of the state, but could still transmit potentially deleterious disease and parasites to native biota. Control efforts were immediately instigated for *Phalloceros caudimaculatus* at Willunga Creek (McNeil *et al.* 2010; PIRSA Biosecurity, unpublished data) and poeciliids at Rushy Swamp (Department for Environment and Natural Resources, unpublished data), and these efforts benefited from the localised and contained nature of the outbreaks. The establishment of *Cyprinus*

carpio in a third drainage division (MD, SAG and now SEC) is cause for concern. Although within a confined lake environment, the large size and depth of the area will make control difficult and this population could act as a source vector for further human assisted dispersal (e.g. "deliberate illegal stocking", "bait bucket introductions" and "deliberate release for cultural reasons"). A final likely mechanism for ongoing introductions between different drainage divisions is "transfers via water diversions" (Lintermans 2004). *Nematalosa erebi* is one of several species likely to have arrived from the River Murray to the Onkaparinga and Torrens rivers via water pipeline, and the artificial connection between the Coorong and Upper South East allows movement between drainage divisions that otherwise appear to have been separated by marine barriers and geography for considerable periods of evolutionary time (Hammer 2001; Unmack 2001; Hammer *et al.* 2010).

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