The distribution and abundance of two endangered fish species in the NSW Upper Murray Catchment

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This research was undertaken with the approval of the NSW Fisheries Animal Care & Ethics Committee under permit No. 05/06.

NON-TECHNICAL SUMMARY

The distribution and abundance of two endangered fish species in the NSW Upper Murray Catchment

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EXECUTIVE SUMMARY:

Important populations of two threatened fish species, Macquarie perch and southern pygmy perch, exist within the Upper Murray Catchment. Populations of both species are believed to have been abundant within the Upper Murray, but had declined substantially in both abundance and distribution. However, no information was available on the current extent or relative abundance of the isolated remnant populations of either species. Surveys were done in two key waterways (Coppabella Creek for southern pygmy perch and Mannus Creek for Macquarie perch) to define the range and relative abundance of these species.

Only a single adult Macquarie perch was collected from the nine sites sampled in Mannus Creek, at the downstream boundary of Bogandyera Nature Reserve. However, the aquatic habitat conditions observed throughout the lower portion of Bogandyera Nature Reserve remain relatively undisturbed and generally match the habitat requirements of the species. It is probable that Macquarie perch are present in low abundance throughout this reach, with the population's distribution bounded by a substantial waterfall as the upstream limit and agricultural land downstream of Bogandyera Nature Reserve as the downstream limit. The total distribution of the population is likely to be limited to a 9 km stretch of Mannus Creek. The condition of the co-existing fish community was very poor with alien pest species dominating the fish community at all sites. This population of Macquarie perch is in need of urgent conservation action including; habitat rehabilitation activities to allow for expansion of the populations distribution, pest fish control, provision of targeted environmental flows to encourage recruitment and the introduction of genetically compatible individuals to effect 'genetic rescue' of the population.

In contrast, southern pygmy perch were much more abundant and widespread, being found in all remnant pools in Coppabella Creek upstream of the Horse Creek junction and 56% of the remnant pools between Horse Creek and the Sandy Waterhole Creek junction. Southern pygmy perch made

up 89.5% of the total sample of fish from the ten sites. At the time of sampling, southern pygmy perch occupied a 23 km stretch of Coppabella Creek. However, under typical flow conditions (non-drought), the population's total distribution could be in the order of 73 km of waterway. Two natural and two artificial fish passage barriers on Coppabella Creek provide the important service of excluding common carp, redfin perch and eastern gambusia from a large proportion of the waterway that is occupied by southern pygmy perch.

Since 2006, I&I NSW has been aware that the reaches of Coppabella Creek occupied by southern pygmy perch have been substantially drought affected, with the creek drying to isolated small and shallow pools where southern pygmy perch became increasingly exposed to predation by birds and inevitable death as the shallow pools evaporated. I&I NSW undertook an emergency fish rescue of southern pygmy perch from Coppabella Creek in January/February 2007, removing 122 individuals from three drying pools. Persistent low rainfall throughout 2008 and 2009 resulted in even drier conditions in Coppabella Creek by February 2009. Several small pools known to support thousands of individuals had dried out completely between February and March 2009. Therefore, a second emergency response action was required to safe-guard the population. Approximately 2,000 southern pygmy perch where removed and transferred to the Narrandera Fisheries Centre and a facility at Tumut. Follow up surveillance determined that these pools dried shortly after the fish were rescued.

In an effort to better understand the system and aid in the development of a longer-term drought management strategy for the population, the location and depth of remnant pools within Coppabella Creek were mapped. Mapping of the remnant pools and determining the extent of the population allows for a greater understanding of the risk and security of the population and for more informed planning on how to best manage this population during future drought events. A large number of small shallow (< 0.5 m) pools (40%) within Coppabella Creek means that large portions of the habitat of southern pygmy perch in this system are prone to drought. However, because a reasonable number of pools greater than 1 m deep are also present (21%), sufficient drought refugia should be available to ensure the persistence of the remnant population during drought periods. Although many individuals will perish as the shallow remnant pools dry out, the population as a whole is not as prone to drought impacts as was perceived. To ensure the long-term persistence of the population, ongoing management should protect the habitat quality of the deepest, and therefore most permanent, remnant pools and maintain the exclusion of alien pest fish at the natural and artificial barriers in the stream. Conservation actions required to conserve the Coppabella Creek population of southern pygmy perch include: maintaining or enhancing an existing weir (barrier # 2) to maintain ongoing exclusion of common carp, redfin perch and eastern gambusia, promoting the retention and rehabilitation of aquatic macrophytes through the exclusion of cattle, re-planting of aquatic macrophytes in those remnant pools where macrophyte beds are absent, willow removal and controlled re-establishment of native riparian vegetation.

Given that our findings suggest that the Coppabella Creek population is resilient to drought, it is not a necessity that the captive fish be returned to their point of capture now that drought conditions have eased. An alternative course of action is to locate an independent release location elsewhere in the upper Murray catchment that provides suitable habitat conditions. Therefore, in addition to the recommended on-ground works to conserve the critical drought refuge pools within Coppabella Creek, we also recommend that a short list of waterways that may be suitable for establishment of additional southern pygmy perch populations within the Murray CMA area be developed. Establishment of additional independent populations will provide insurance against the catastrophic loss of the remnant one in Coppabella Creek.

KEYWORDS:

Macquarie perch, *Macquaria australasica*, Southern pygmy perch, *Nannoperca australis*, upper Murray Catchment, drought.

1. INTRODUCTION

The natural fish community of the upper Murray catchment (the catchment upstream of Hume Weir) includes 16 fish species (Table 1). Of these, seven (44%) are listed as threatened in NSW under the *Fisheries Management Act 1994* or federally under the *EPBC Act 1999*:

Critically endangered:	Flat-headed galaxias (*Galaxias rostratus*)
Endangered:	Macquarie perch (*Macquaria australasica*) Trout cod (*Maccullochella macquariensis*) Southern pygmy perch (*Nannoperca australis*) Freshwater catfish (*Tandanus tandanus*)
Vulnerable:	Silver perch (*Bidyanus bidyanus*) Murray cod (*Maccullochella peelii*).

Three of these; flat-headed galaxias, freshwater catfish and silver perch are likely to have naturally been uncommon in the upper Murray catchment, as the slopes zone is thought to represent the upper limit of their distribution in the Murray River (Table 1). Both trout cod and Murray cod are likely to have been more common in the slopes zone and their distributions would have extended into the uplands zone to an altitude of about 500 m above sea level (ASL), but more abundant populations of both these species currently exist in the lower reaches of the Murray River downstream of Lake Mulwala. In contrast, the remaining two threatened fish species, Macquarie perch and southern pygmy perch, are either absent (Macquarie perch) or uncommon (southern pygmy perch) in the lowland reaches of the Murray River and the existing remnant populations of both these species within the upper Murray catchment are very significant to the biodiversity of the Murray catchment overall.

Macquarie perch (*Macquaria australasica* Cuvier 1830) are a moderately sized (maximum total length (TL) = 495 mm, Douglas *et al.* 2002) freshwater percichthyid fish native to the Murray-Darling Basin. Macquarie perch were formerly present from the lower reaches of the Murray River ~ 30 m ASL (Reid *et al.* 1997; Hammer *et al.* 2009), were common in reaches from ~ 100 m (Cadwallader 1982) and abundant above ~ 200 m (Lake 1967; Trueman 2007). They have been collected up to a maximum altitude of 1,100 m ASL in the neighbouring Murrumbidgee River (I&I NSW unpublished data). Historically, Macquarie perch were present in the Macquarie, Lachlan, Murrumbidgee, Murray, Mitta Mitta, Kiewa, Ovens, Broken, Goulburn, Campaspe and Loddon catchments (Cadwallader 1982). However, populations in the Murray-Darling Basin have declined substantially in range and abundance since the mid 1900s (Lake 1971; Pratt 1979; Cadwallader 1982; Ingram *et al.* 2000; Trueman 2007). By the 1970s, Macquarie perch were considered to be seriously threatened with extinction (Lake 1971; Cadwallader 1978). Lake (1971) considered them one of the four most seriously threatened Australian freshwater fish. The species has continued to decline since the 1970s, with populations considered viable as recently as 2005 having declined or disappeared.

Macquarie perch were formerly abundant in the upper Murray River and its tributaries (Trueman 2007). A small but self sustaining population remains within Dartmouth Dam in the Victorian portion of the upper Murray catchment (Douglas *et al.* 2002, Tonkin *et al.* 2009), with the lower Mitta Mitta River population reported to have disappeared following construction of the dam in 1979 (Koehn *et al*. 1995). Only a single Macquarie perch has been collected during scientific surveys undertaken in the NSW portion of the upper Murray catchment since 1990 (86 samples collected from 57 sites: I&I NSW Freshwater Fish Research Database). Despite follow-up

sampling, no additional Macquarie perch have been detected in the Tooma River at Possum Point where a single individual was collected in March 1999 (Harris *et al.* 2006). However, unsubstantiated reports of the capture of Macquarie perch by recreational fishers in Mannus Creek have been circulating over the last few years. In October 2006, one of the authors (Luke Pearce) confirmed their presence when he caught and photographed one whilst angling in Mannus Creek within the Bogandyera Nature Reserve. Therefore, a remnant population of Macquarie perch, of unknown abundance and distribution exists within Mannus Creek.

Table 1. Fish species present within the Upper Murray catchment (upstream of Hume Weir). The abundance ratings within altitude zones reflect the Reference Condition for Fish (RC-F) score developed for the Sustainable Rivers Audit (Murray-Darling Basin Authority, unpublished data).

	Altitude zone			
Species	**Slopes (201 – 400 m)**	**Uplands (401–700 m)**	**Highlands (701–1200 m)**	**Alpine (>1201 m)**
Native fishes	Predicted pre-European status			
Flat-headed galaxias (*Galaxias rostratus*)	Uncommon			
Freshwater catfish (*Tandanus tandanus*)	Uncommon			
Silver perch (*Bidyanus bidyanus*)	Uncommon			
Carp-gudgeon species complex (*Hypseleotris* spp.)	Common			
Golden perch (*Macquaria ambigua*)	Common			
Obscure galaxias (*Galaxias* sp.1)	Common			
Southern pygmy perch (*Nannoperca australis*)	Common			
Northern river blackfish (*Gadopsis marmoratus*)	Common	Uncommon		
Murray cod (*Maccullochella peelii*)	Common	Uncommon		
Flat-headed gudgeon (*Philypnodon grandiceps*)	Common	Uncommon		
Australian smelt (*Retropinna semoni*)	Common	Uncommon		
Trout cod (*Maccullochella macquariensis*)	Common	Common		
Two-spined blackfish (*Gadopsis bispinosus*)	Common	Abundant	Abundant	
Mountain galaxias (*Galaxias olidus*)	Common	Abundant	Abundant	Common
Macquarie perch (*Macquaria australasica*)	Abundant	Common	Uncommon	
Riffle galaxias (*Galaxias* sp. 2)	Abundant	Common	Common	
Alien fishes				
Common carp (*Cyprinus carpio*)				
Goldfish (*Carassius auratus*)				
Climbing galaxias* (*Galaxias brevipinnis*)				
Redfin perch (*Perca fluviatilis*)				
Eastern gambusia (*Gambusia holbrooki*)				
Rainbow trout (*Oncorhynchus mykiss*)				
Brown trout (*Salmo trutta*)				

** These fish are native to coastal catchments but have been introduced to the Upper Murray Catchment via water transfers through the Snowy Hydro Scheme.*

Southern pygmy perch (*Nannoperca australis* Günther 1861) are a small (average total length (TL) = 38 ± 12 mm (max = 85 mm), I&I NSW unpublished data) freshwater percichthyid fish native to the Lachlan, Murrumbidgee and Murray catchments in NSW, all Victorian tributaries of the Murray River and the lower River Murray in South Australia. They are also present in coastal

catchments between the Murray River in South Australia and the Genoa River in Victoria/NSW and in northern Tasmania. In 1949–50, Colonel J.O. Langtry observed that "Pigmy perch (sic), which move in shoals, appear to abound throughout the whole Murray system" (Cadwallader 1977). Lake (1967) and Llewellyn (1974) later reported that they were still abundant although patchily distributed within the Murray-Darling Basin during the late 1960s. However, since that time the species has suffered a severe decline and by the late 1980s to early 1990s they were considered threatened in both NSW and South Australia (Lloyd and Walker 1986, Kuiter *et al*. 1996, Morris et al. 2001, Hammer 2009). Only six isolated remnant populations have been found in NSW since 2000. Two of these have since been lost and a third constituted just a single individual fish. As of 2009, just three remnant populations remain in NSW, one in the upper Lachlan catchment and two in the Murray catchment; Coppabella Creek and upper Billabong Creek. A fourth translocated population was created in Pudman Creek in the upper Lachlan catchment using fish sourced from the neighbouring Blakney Creek.

Figure 1. Macquarie perch. Photo: Gunther Schmida.

Figure 2. Southern pygmy perch (male). Photo: Gunther Schmida.

Coppabella Creek is a small tributary (38 km long) of the upper Murray River near Jingellic, New South Wales. Southern pygmy perch were first collected there in 1992 and again in 1999, with specimens lodged with Museum Victoria. I&I NSW sampling in December 2006 confirmed that they were still present (and abundant) at the original collection site. At the time, Coppabella Creek was heavily drought affected and as an emergency drought response, 122 fish were removed from shallow remnant pools in January/February 2007. The rescued fish were held in an outdoor pond at the Narrandera Fisheries Centre until flows in the creek returned. In February 2008, the 69 fish that remained in the hatchery pond were returned to Coppabella Creek. Subsequent Sustainable Rivers Audit (Davies *et al.* 2008) sampling at a site approximately 5 km downstream in April 2008, and I&I NSW sampling at the rescue/release site in November 2008 indicated that the population had persisted and that southern pygmy perch were abundant at both these sites. However, the full distribution of the remnant population within Coppabella Creek remained unknown.

Because the Coppabella Creek population was one of only three confirmed remnant populations in New South Wales, I&I NSW regional conservation management staff maintained surveillance of water levels within the creek. Persistent low rainfall throughout 2008 and 2009 resulted in even drier conditions in Coppabella Creek than were observed in 2007, with those pools that remained drying rapidly. Several small pools known to support thousands of individuals had dried out completely between February and March 2009. Therefore, a second emergency response action was urgently required to safe-guard the important remnant population.

A decision was made to map the location and depth of remnant pools within Coppabella Creek, undertake rapid assessment fish surveys in remnant pools to establish whether southern pygmy perch were present or absent, and to undertake standard fish community surveys throughout Coppabella Creek to assess the status and distribution of fish species. Mapping of the remnant pools and determining the extent of the population will allow for a greater understanding of the risk and security of the population and allow for more informed planning on how to best manage it during the present and future drought events. In addition, standard fish community surveys of Mannus Creek were done in order to aid the effective management of the potentially last remnant population of Macquarie perch in the NSW portion of the Murray River catchment.

2. METHODS

2.1. Mapping of remnant pools and rapid assessment of the presence/absence of southern pygmy perch in Coppabella Creek

A continuous 29 km length of Coppabella Creek was hiked from 24 – 26 March 2009. Mapping commenced seven kilometres upstream from the Coppabella Road bridge (-35.6860S, 147.7250E) at a point where the modelled streamflow is 5 ML day^{-1} (Stein 2009). Trimble Nomad™ 800LC units installed with Terrasync™ mapping software were used to map the location, size (m^2) and maximum depth (m) of each individual remnant pool along the reach. Each pool was sampled for fish using a dip net to determine presence/absence of southern pygmy perch within each pool. Mapping and rapid assessment sampling continued in a downstream direction until isolated pools became both larger and deeper, there was perceptible flow between pools and the rapid assessment dip net methodology was rendered in-effective. Data collection ceased at the junction of Coppabella Creek and Sandy Waterhole Creek (-35. 8390S 147.7090E). Data were uploaded into a GIS, visually assessed and the variables collated using ArcView® mapping software.

2.2. Standardised fish assemblage sampling

Ten sites were surveyed for southern pygmy perch, with eight sites in Coppabella Creek and two in Jingellic Creek from 3 – 8 April 2009 (Figure 3, Table2). The uppermost site was located at the Coppabella Road bridge and the most downstream site located at Jingellic, approximately 1 km from the confluence of Jingellic Creek and the Murray River. Sites were dispersed roughly equidistantly within this reach.

Nine sites were surveyed for Macquarie perch in Mannus Creek from 31 March – 4 April 2009 (Figure 4, Table 2). The uppermost site was approximately 2.5 km downstream of the Walteela Road crossing and the lower site approximately 7 km upstream of the confluence with Tumbarumba Creek. Sites were dispersed roughly equidistantly within this reach.

Fish sampling protocols used were those developed for the Murray-Darling Basin Authority's Sustainable River Audit – Fish theme (Davies *et al.* 2008, MDBC 2008). These are based on standardised backpack electrofishing in addition to 10 un-baited concertina-type shrimp traps. At three of the sites (Site No. 885, 888 and 890), sampling of deeper pools was undertaken with the aid of float-tubes.

At the completion of each electrofishing operation (electrofishing or shrimp traps), captured individuals were identified, counted, measured and observed for externally visible parasites, wounds and diseases before being released. Rapid habitat assessment of each operation included recording characteristics of riparian and instream vegetation, substratum, in-stream cover and meso-habitat (e.g., pool, run, riffle). Water quality data including temperature (°C), dissolved oxygen (mg L^{-1}), pH, conductivity (µS cm^{-1}) and turbidity (NTU) were recorded using a Horiba® U10 water quality meter.

3. RESULTS

3.1. The distribution of remnant pools and southern pygmy perch within Coppabella Creek

A total of 143 remnant pools were located and recorded along the 29 kilometre reach that was mapped (Figure 5). Pools ranged in size from 1 m^2 to 3,494 m^2 and averaged 381 m^2. Depth of pools varied from 0.1 m to 1.8 m and averaged 0.7 m. Southern pygmy perch were found to occupy 58% of the pools mapped. A summary of mapped variables per 1 km reach is presented in Table 3.

The locations of four barriers to fish passage were also recorded (Figure 5). Fish passage barrier # 1 (-35.77930S 147.70271E) is a small and # 3 (-35.82770S 147.70310E) is a large natural rock bar that are impassable to fish at base flows. Fish passage barriers # 2 (-35.79412S 147.69676E) and # 4 (-35.84177S 147.70541E) are a weir and causeway respectively, that also prevent upstream fish passage.

The bed of Coppabella Creek was totally dry for a distance of 4 km from the point where mapping commenced. A total of 34 remnant pools were recorded within the 7 km of streambed upstream of Horse Creek Junction (average depth 0.5 m and average size 68 m^2) and every remnant pool within this section of the creek contained southern pygmy perch (Figure 5). Twenty-two (65%) of these remnant pools were less than 0.5 m deep. Of the 12 pools providing better drought refuge, nine were 0.5 – 1 m deep and only three were > 1 m deep.

Between Horse Creek and Sandy Waterhole Creek, there were 109 remnant pools, 45% of which were occupied by southern pygmy perch. Of these, 16 (15%) were less than 0.5 m deep and 28 (26%) were more than 1 m deep. Presence/absence of southern pygmy perch was equally likely in remnant pools less than 1 m deep (40 absences versus 41 presences). In contrast, they were substantially more likely to be present in remnant pools greater than 1 m deep (8 absences versus 20 presences). The most downstream location where the presence of southern pygmy perch was confirmed was 2 km from the bottom of the mapped reach.

Additional fish species sampled or observed during the rapid assessment were a northern river blackfish sampled downstream of the Horse Creek junction, a brown trout observed below barrier 2 (Figure 5), eastern gambusia sampled in pools below fish barrier 3 and common carp observed below fish passage barrier 4.

Table 2. Details of the study sites surveyed using standardised fish community survey protocols (Datum = GDA94).

I&I NSW Site No.	Waterway	Latitude	Longitude	Altitude (m)
Southern pygmy perch survey sites				
6282	Jingellic Creek	-35.92983	147.69299	220
6281	Jingellic Creek	-35.89275	147.69157	222
6288	Coppabella Creek	-35.88203	147.70337	247
6284	Coppabella Creek	-35.85081	147.70799	255
6285	Coppabella Creek	-35.83488	147.70300	279
6283	Coppabella Creek	-35.80697	147.69600	295
6287	Coppabella Creek	-35.79173	147.69673	310
68606	Coppabella Creek	-35.76791	147.71036	342
6286	Coppabella Creek	-35.75689	147.71606	350
8008	Coppabella Creek	-35.74057	147.72560	360
Macquarie perch survey sites				
893	Mannus Creek	-35.94230	148.03149	247
892	Mannus Creek	-35.94469	148.01288	300
891	Mannus Creek	-35.94473	147.99956	305
890	Mannus Creek	-35.93802	147.99078	330
889	Mannus Creek	-35.92500	147.98431	350
888	Mannus Creek	-35.91900	147.98720	400
886	Mannus Creek	-35.90080	147.98199	415
887	Mannus Creek	-35.88700	147.98840	435
885	Mannus Creek	-35.87530	147.98421	445

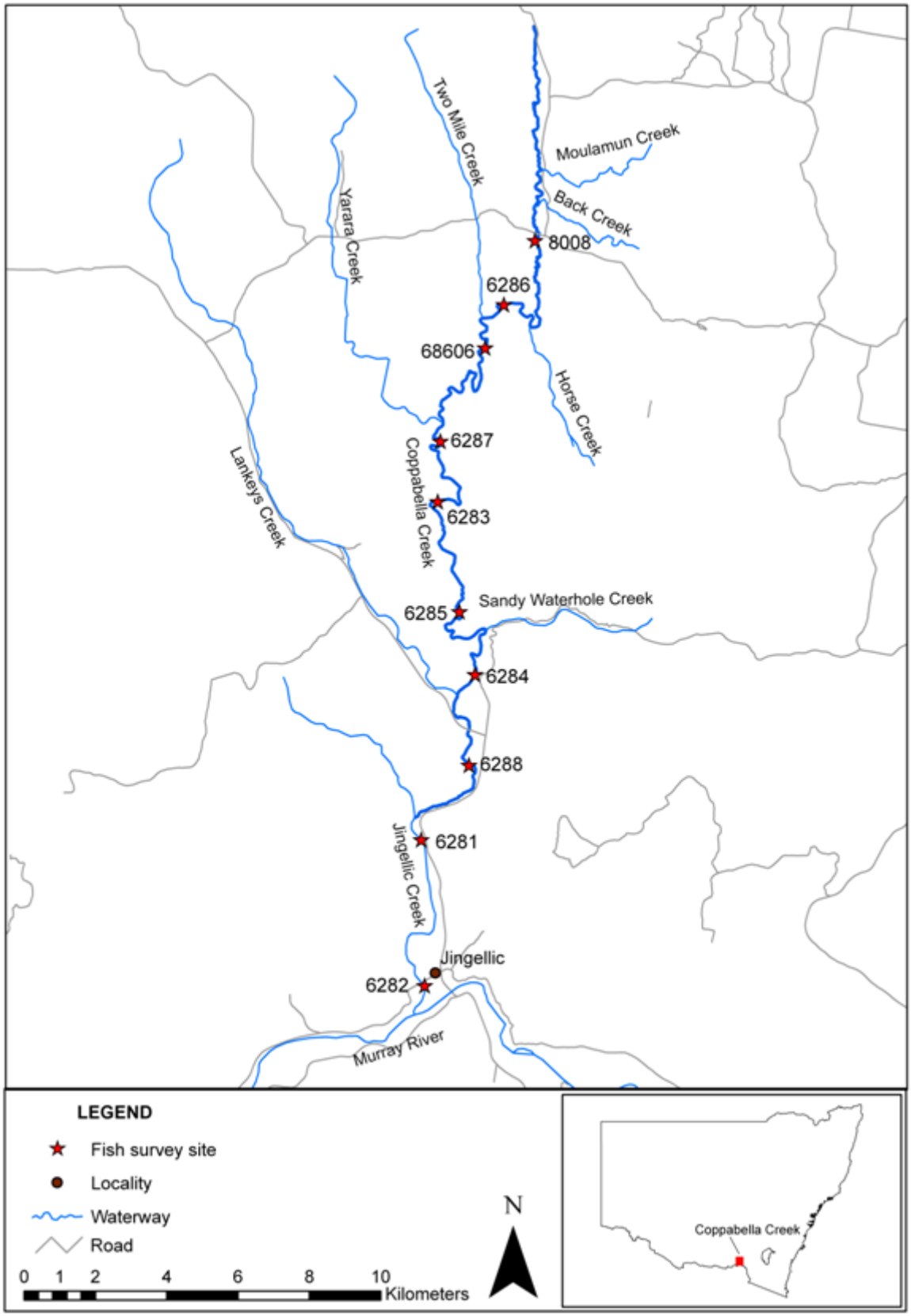

Figure 3. Locations of fish survey sites along Coppabella and Jingellic Creeks sampled by I&I NSW in April 2009.

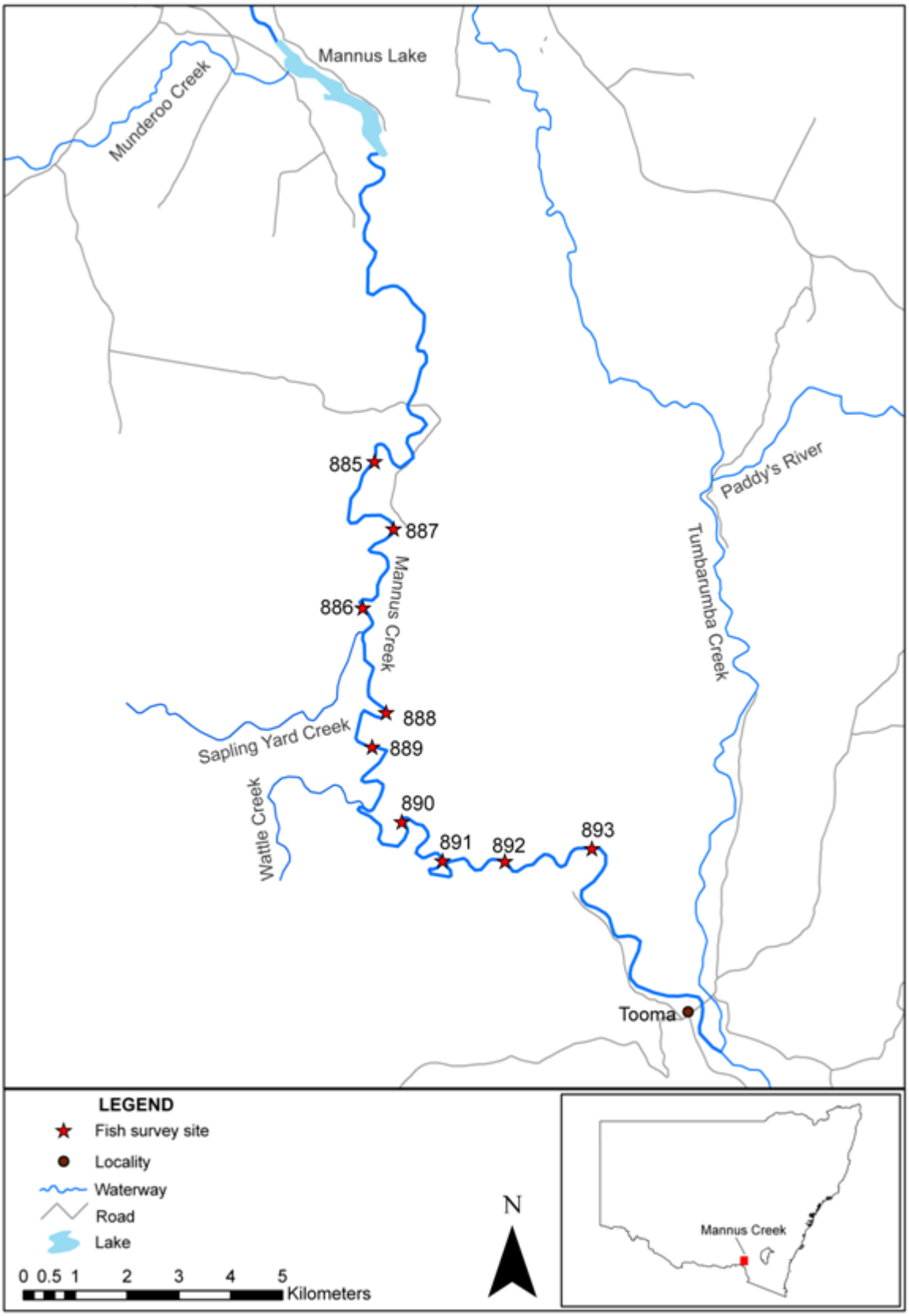

Figure 4. Locations of fish survey sites along Mannus Creek sampled by I&I NSW in March/April 2009.

Table 3. Summary table of each 1 km reach mapped along Coppabella Creek.

Reach No.	Number of pools	Mean pool size (m^2)	Mean depth (m)	Maximum depth (m)	Pools > 0.5 m	Pools > 1 m	% of pools with pygmy perch present
1	0 (dry)	0	0	0	0	0	0
2	0 (dry)	0	0	0	0	0	0
3	0 (dry)	0	0	0	0	0	0
4	0 (dry)	0	0	0	0	0	0
5	3	22.3	0.47	0.6	2	0	100
6	2	8.7	0.30	0.3	0	0	100
7	7	16.8	0.29	0.6	1	0	100
8	9	33.9	0.50	1.5	4	1	100
9	8	74.0	0.61	0.1	3	0	100
10	3	154.4	0.73	1.2	3	1	100
11	3	375.2	0.87	1.5	2	1	67
12	2	186.6	0.95	1.6	1	1	0
13	10	135.7	0.56	1.2	6	1	40
14	8	288.1	0.84	1.5	7	3	63
15	7	651.8	1.03	1.7	7	3	71
16	8	489.7	0.81	1.4	8	2	63
17	4	283.0	0.53	0.6	3	0	100
18	7	335.9	0.81	1.2	7	2	100
19	2	112.5	0.45	0.5	1	0	100
20	8	340.5	0.80	1.1	8	2	75
21	6	486.8	0.60	1.0	3	1	83
22	6	451.7	0.93	1.5	6	3	67
23	6	629.2	0.90	1.7	6	2	33
24	5	1050.2	0.85	1.3	6	2	60
25	6	847.8	0.73	1.2	3	3	50
26	7	564.6	1.03	1.8	7	2	29
27	6	858.6	0.80	1.6	5	1	33
28	5	473.1	0.68	0.9	5	0	0
29	5	324.1	0.56	0.9	4	0	0

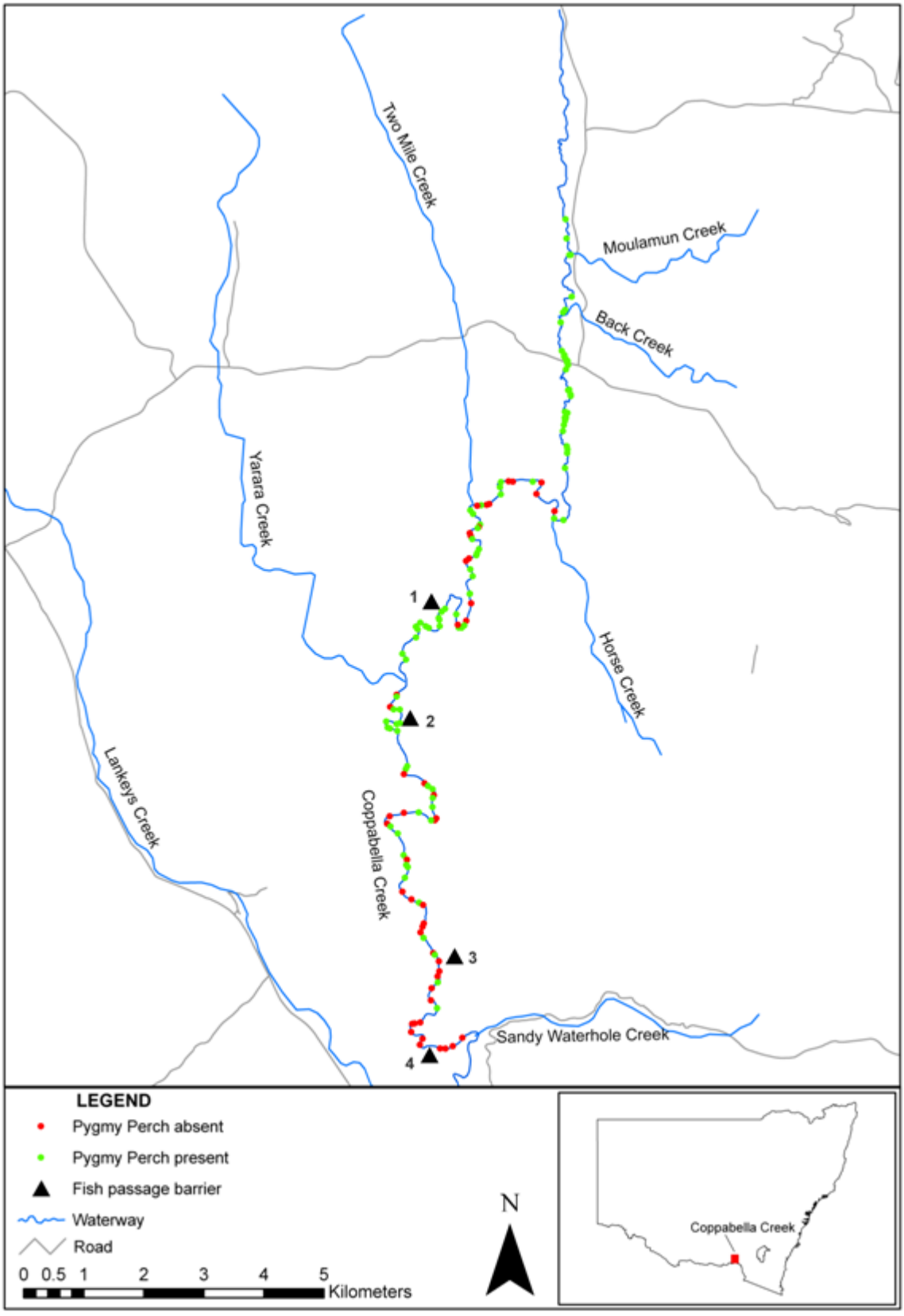

Figure 5. Mapped area of Coppabella Creek showing southern pygmy perch present (green circles) or absent (red circles) within remnant pools. Fish passage barriers are shown as black triangles.

Due to the very small size and shallow depth of five remnant pools within reaches 5 and 6 (Figure 6), and a perceived likelihood of prolonged dry conditions, dip nets were used to remove an estimated 1,000 fish. Approximately 600 of these were transferred to the Narrandera Fisheries Centre and the remainder to a facility at Tumut. The fish transferred to Narrandera were housed along with ~1,000 individuals already rescued from drying pools on 13 February 2009. Follow-up surveillance determined that these pools, along with many others within the mapped reaches, dried shortly after the fish were rescued.

Figure 6. Two of the remnant pools within reaches 5 and 6 from which ~1,000 southern pygmy perch were rescued and transferred to the Narrandera Fisheries Centre and a holding facility at Tumut.

3.2. The distribution and abundance of fish species within Coppabella Creek

Eight species of fish were sampled from the 10 sites surveyed in Coppabella and Jingellic Creeks (Table 4). This included two native species (mountain galaxias and Australian smelt) and two alien species (goldfish and redfin perch) which were not collected or observed during the rapid assessment surveys. However, one species which was observed during rapid assessment surveys, alien brown trout, was not sampled at any of the 10 fully surveyed sites. Overall, a total of nine fish species are known to exist within the Coppabella-Jingellic Creek system.

Standardised sampling yielded a catch of 2,618 fish and an estimated additional 472 individuals were observed from the 10 sites. Southern pygmy perch made up 89.5% of the total sample. Pygmy perch were collected at all six sites upstream of the Sandy Waterhole Creek junction and fish passage barrier # 4. The next most abundant species was the alien eastern gambusia, which only constituted 7.6% of the catch. This alien species was collected at all 5 sites downstream of fish passage barrier # 3 and only co-occurred with southern pygmy perch at site No. 6285. Redfin perch were collected at 5 of the 6 sites downstream of fish passage barrier # 2 and co-occurred with southern pygmy perch at two sites (No. 6285 and 6283). Common carp were collected at three of the four sites downstream of fish passage barrier # 4 and were observed but not captured at the fourth. Apart from the less common goldfish and Australian smelt, common carp are the only species that had a mutually exclusive distribution with southern pygmy perch.

There was a distinct difference in the length-frequency distribution of those southern pygmy perch co-occurring with eastern gambusia and/or redfin perch and those occurring as mono-specific populations (Figure 7). No individuals < 40 mm TL occurred at sites occupied by alien species whereas a much broader range of size classes and individuals as small as 15 mm TL occurred in those reaches where southern pygmy perch were the sole species present.

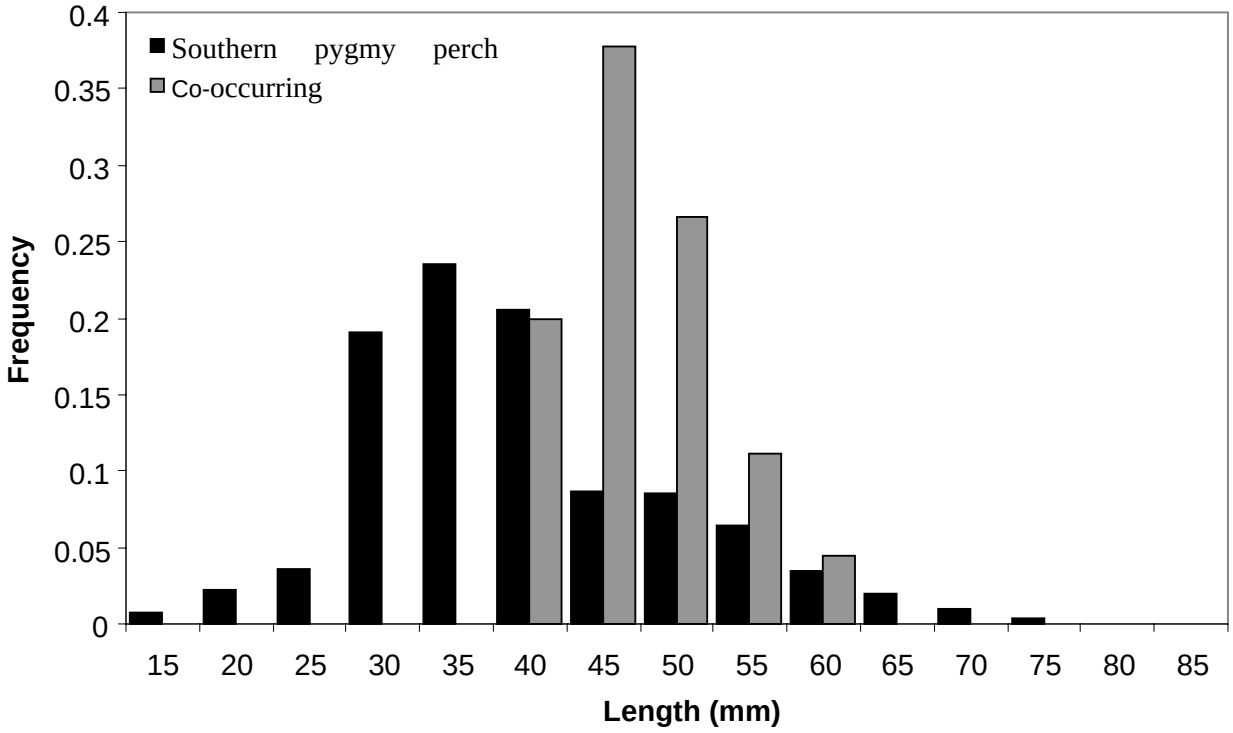

Figure 7. The length-frequency distributions of southern pygmy perch co-occurring in remnant pools with redfin, eastern gambusia and mountain galaxias (grey bars) versus those existing as monospecific populations (black bars).

Table 4. Abundance of fish recorded at fish survey sites in Coppabella Creek and Jingellic Creek. Values in parentheses are the number of individuals observed but not collected during sampling.

Common Name	Sampling sites										
	6282	**6281**	**6288**	**6284**	**6285**	**6283**	**6287**	**68606**	**6286**	**8008**	**Total catch**
Southern pygmy perch					10 (2)	35 (7)	770 (35)	272 (40)	86 (14)	1,202 (292)	2,375 (390)
Eastern gambusia	121 (2)	1 (0)	8 (12)	62 (50)	8 (0)						200 (64)
Common carp	0 (1)	10 (3)	2 (4)	2 (0)							14 (8)
Redfin perch	2 (0)	5 (3)	1 (0)		1 (0)	4 (0)					13 (3)
Australian smelt	9 (6)										9 (6)
Goldfish	6 (0)										6 (0)
Mountain galaxias						1 (0)					1 (0)
Northern river blackfish				0 (1)							0 (1)
Brown trout											0

Table 5. Abundance of fish recorded at fish survey sites in Mannus Creek. Values in parentheses are the number of individuals observed but not collected during sampling.

Common Name	Sampling sites									
	893	**892**	**891**	**890**	**889**	**888**	**886**	**887**	**885**	**Total catch**
Eastern gambusia	8 (0)	5 (0)		1 (0)	4 (17)	1 (0)	30 (4)	31 (5)	10 (0)	90 (26)
Redfin perch	2 (0)	5 (0)	17 (0)	3 (0)	11 (2)	6 (1)			1 (0)	45 (3)
Common carp	1 (0)	2 (0)	2 (0)	1 (0)	3 (0)					9 (0)
Goldfish							7 (1)		1 (0)	8 (1)
Rainbow trout								2 (0)		2 (0)
River blackfish								1 (0)		1 (0)
Macquarie perch		1 (0)								1 (0)

3.3. The distribution and abundance of fish species within Mannus Creek

Seven species of fish were sampled from the nine sites surveyed in Mannus Creek (Table 5). These consisted of five alien species and only two native species. The four alien pest species; eastern gambusia, redfin perch, common carp and goldfish were the most widespread and abundant fish present. Seven of the nine sites were only occupied by one or more of these alien pests. Overall, alien fish comprised 98.7% of the total fish abundance within Mannus Creek. Introduced rainbow trout and the two native species, northern river blackfish and Macquarie perch, were only sampled from a single site each.

The single Macquarie perch collected was an adult individual 382 mm TL which was sampled from site No. 892, ~ 500 m downstream of the boundary of Bogandyera Nature Reserve and pastoral land.

4. DISCUSSION

Standardised fish community sampling provided data on the distribution and abundance of the important populations of endangered Macquarie perch in Mannus Creek and the endangered southern pygmy perch in Coppabella Creek.

4.1. Macquarie perch in Mannus Creek

The single adult Macquarie perch collected in Mannus Creek, at the downstream boundary of Bogandyera Nature Reserve (site No. 892), is only the second specimen collected by scientific sampling since standardised fish community sampling commenced in the NSW portion of the upper Murray catchment in the 1990s. Its capture substantiates recent reports of the angling of Macquarie perch by recreational fishers in Mannus Creek (Wayne Dubois, pers. comm.). The specimen we collected was 4.3 km (river distance) downstream of the location where one of the authors (Luke Pearce) captured one whilst angling within Bogandyera Nature Reserve (site No. 890) in October 2006 (although no Macquarie perch were collected at this site during our survey). Therefore, there are now two confirmed records of Macquarie perch within Mannus Creek, each within about 4.3 km of one another and both in or just downstream of the Nature Reserve. However, the aquatic habitat conditions recorded at other sites within the reserve (site No. 892 to 889) also remain relatively undisturbed and generally match the habitat requirements of the species (Gilligan *et al.* 2010). Therefore, it is possible that Macquarie perch are present in low abundance throughout this reach. However, with a substantial waterfall immediately upstream of site 889 (Figure 8) and agricultural land immediately downstream of site 892, in all probability, the total distribution of the population is likely to be limited to a 9 km stretch of Mannus Creek.

Given that the habitat quality throughout this 9 km reach appears acceptable, the population would benefit most from habitat rehabilitation works at the upstream and downstream limits in order to increase the amount of habitat available to the population. The falls at the upstream limit of the reach (Figure 8) prevent upstream expansion of the population even if habitat conditions were restored, so habitat rehabilitation works should be focused on the instream and riparian rehabilitation of the waterway downstream of Bogandyera Nature Reserve. However, because of the predominance of alien pest fish and the rarity and low diversity of native fishes, habitat rehabilitation alone is unlikely to result in substantial improvement in the status of the local Macquarie perch population. Pest fish management actions are likely to benefit the native fish community, including the remnant Macquarie perch population; especially those that reduce the abundance of predatory redfin perch. Environmental flow releases from Lake Mannus leading up to and during the spawning season (at water temperatures of 16^{o}C, Douglas 2002, Tonkin *et al.* 2009) may promote recruitment by triggering spawning and enhancing the availability of flowing water mesohabitats. And lastly, given the small population size and long period of low abundance, the remnant population is likely to be suffering from loss of genetic diversity and inbreeding depression (Frankham *et al.* 2002). Therefore, consideration should be given to translocating Macquarie perch from another genetically appropriate population (e.g., from Dartmouth Dam or Cataract Dam (Faulks *et al.* 2009)) into Mannus Creek in order to insure against any further genetic deterioration of the population and to promote their rate of population recovery.

Figure 8. A waterfall on Mannus Creek immediately upstream of site 889 (-35.925S 147.98431E). This fall probably represents the upstream limit of the local Macquarie perch population.

4.2. Southern pygmy perch in Coppabella Creek

Southern pygmy perch were found in all remnant pools in Coppabella Creek upstream of the Horse Creek junction and 56% of the remnant pools between Horse Creek and the Sandy Waterhole Creek junction. The most downstream specimen was collected from a pool 2 km upstream of the junction of Sandy Waterhole and Coppabella Creeks. Therefore, at the time of sampling, southern pygmy perch occupied a 23 km stretch of Coppabella Creek. However, the upstream limit was affected by the drought conditions existing at the time of sampling. Under normal flow conditions, the population's distribution is likely to extend a further 4 km upstream along Coppabella Creek. There are also an additional 43 km of waterways in unmapped and unsampled tributary streams which have a modelled natural flow of greater than 5 ML day $^{-1}$ (Stein *et al.* 2009) which are also potentially occupied by southern pygmy perch (assuming no fish passage barriers exist); Horse Creek, Yarara/Vyners Creeks, Two Mile Creek, Back Creek, and Moulamun Creek. Therefore, the total range of the Coppabella population of southern pygmy perch could be in the order of 73 km of waterway.

Southern pygmy perch were found at all sites upstream of the Horse Creek junction irrespective of maximum depth, pool size or habitat features. Although still widespread between Horse Creek and the downstream limit of their distribution within Coppabella Creek, pygmy perch present within pools in this reach were both less abundant and lacked the smaller size classes found within those remnant pools where southern pygmy perch were the only species present (Table 4 and Figure 7). It is possible that the presence of redfin perch and brown trout downstream of the artificial barrier # 2 and eastern gambusia downstream of natural fish passage barrier # 3 may be biotic factors

impacting on the persistence and recruitment of southern pygmy perch. Woodward and Malone (2002) report a similar pattern in a southern Victorian population where southern pygmy perch abundance was lower at a site with a greater abundance of redfin perch and short-finned eel (*Anguilla australis*) and both redfin perch and brown trout have been reported to prey heavily on southern pygmy perch (Cadwallader 1977, Humphries 1995, Woodward and Malone 2002). However, in Coppabella Creek, the exclusion of carp at barrier # 4 appears most critical, as no pygmy perch where found at any site downstream of this point. We are not able to identify the causative nature of this negative relationship without undertaking detailed manipulative experiments, but speculate that the impacts of carp on southern pygmy perch are perhaps a response to carp's impacts on the environment and principally on aquatic macrophyte cover.

The large number of small shallow pools (40%) within Coppabella Creek means that large portions of the habitat of southern pygmy perch in this system are prone to drought impacts. However, because a reasonable number of pools greater than 1 m deep are also present (21%), sufficient drought refugia should be available to ensure the persistence of the remnant population during most drought periods. Although many individuals will perish as the number of shallow remnant pools dry out, the population as a whole is not as prone to drought impacts as was perceived. However, the recent establishment of pine plantations in the catchment between the existing Carabost State Forest and around the vicinity of the Yarara Creek junction is likely to have impacts on the drought resilience and long-term viability of the remnant population in Coppabella Creek. Replacement of largely un-forested grazing land with plantation forests is known to reduce runoff into waterways within affected catchments (Zhang *et al.* 2001; DeFries and Eshleman 2004). Therefore, as the new pine plantation matures, reduced runoff into Coppabella Creek will place greater stress on refugia within Coppabella Creek during future drought cycles. Further, climate change impacts may result in further reductions in runoff in the catchment and further exacerbate the drought risk to the population.

To ensure the long-term persistence of the population, ongoing management should protect the habitat quality of the deepest, and therefore most permanent, remnant pools and maintain the exclusion of alien pest fish at the natural and artificial barriers in the stream. There are 15 pools within Coppabella Creek greater than 1 m deep where high priority on-ground works should be implemented (Table 6). The first step in the conservation strategy requires that the existing artificial barrier in reach 20, barrier # 2 (Figure 9), should be maintained and or enhanced to prevent redfin perch and other pest fish from invading southern pygmy perch habitat. Secondly, as it has been demonstrated previously that southern pygmy perch have a close association with aquatic vegetation (Llewellyn 1974, Cadwallader 1979, Humphries 1995, Woodward and Malone 2002), habitat works that promote the retention and rehabilitation of aquatic macrophytes will be an important component of a management regime to conserve and enhance southern pygmy perch populations. On-ground works required to achieve this include:

- Exclusion of livestock from the riparian zone of each refuge pool.
- Planting of aquatic macrophytes in those remnant pools where macrophyte beds are absent (using locally collected cuttings and/or seed-stock).
- Willow removal.
- Re-establishment of native riparian vegetation. However, revegetation should be controlled in order to limit the amount of shading of the stream. Too dense a canopy resulting from intensive re-planting or uncontrolled re-growth could inhibit the beneficial growth of aquatic macrophyte beds (Maridet *et al.* 1998; Lyons *et al.* 2000, Growns *et al.* 2003).

Water levels within these 15 priority sites should be monitored frequently during subsequent drought events to ensure the persistence of the remnant population of pygmy perch into the future in the face of current changes in land-use in the catchment and longer term impacts of climate

change. If total drying of priority refuge sites is considered likely, action should be taken to rescue those southern pygmy perch present.

Those southern pygmy perch rescued from drying pools in Coppabella Creek in February and March 2009 and housed in an outdoor earthen pond at the Narrandera Fisheries Centre recruited over the spring/summer period whilst in captivity. It is anticipated that around 5,000 individuals are now in captivity. Given that our findings suggest that the Coppabella Creek population is somewhat resilient to drought, it is not a necessity that the captive fish be returned to their point of capture now that drought conditions have eased. An alternative course of action would be to identify an independent release location elsewhere in the Murray catchment that provides suitable habitat conditions. If a waterway with a limited population of alien pest species (perhaps with a fish passage barrier excluding their colonisation) and an abundance of aquatic macrophyte growth can be located, this strategy has the advantage that an additional population can be established that is independent of those already existing in Coppabella Creek and Billabong Creek. In the event of the unfortunate loss of either of these two remnant populations, the newly created population could ensure the continued presence of southern pygmy perch in the catchment.

Therefore, in addition to the recommended on-ground works to conserve the 15 critical drought refuge pools within Coppabella Creek, we also recommend that the local knowledge of the CMA's catchment officers, and the communication networks established by the CMA be utilised to identify a short list of waterways within the Murray CMA area that may be suitable for establishment of additional southern pygmy perch populations. I&I NSW can then review the list, identify the best potential release locations based on habitat characteristics and undertake releases. These reaches can be populated with those fish rescued from Coppabella Creek in 2009 and subsequently bred at the Narrandera Fisheries Centre or with fish rescued from shallow remnant pools in Coppabella Creek during future drought events.

Table 6. The location of critical drought refugia (those greater than 1 m deep) within Coppabella Creek.

Reach No.	Latitude	Longitude	Mean pool size (m^2)	Maximum depth (m)
8	-35.743187	147.726910	99	1.5
10	-35.752840	147.726818	351	1.2
11	-35.762382	147.724505	1,005	1.5
12	-35.758813	147.721247	270	1.6
13	-35.760524	147.710381	168	1.2
14	-35.761148	147.708920	245	1.1
14	-35.761950	147.709741	227	1.5
14	-35.763463	147.710825	215	1.2
15	-35.766938	147.710730	2,120	1.6
15	-35.769919	147.708973	977	1.3
15	-35.771258	147.709496	754	1.7
16	-35.778855	147.707789	108	1.4
16	-35.777122	147.706634	638	1.4
18	-35.778186	147.703675	1,190	1.2
18	-35.780246	147.699232	181	1.2

Figure 9. An artificial barrier on Coppabella Creek (-35.79412S 147.69676E) which is believed to exclude redfin perch from 73 km of habitat occupied by southern pygmy perch.

4.3. Summary of activities required to conserve populations of Macquarie perch and southern pygmy perch in the upper Murray catchment

4.3.1. Mannus Creek and Macquarie perch

- Instream and riparian habitat rehabilitation works downstream of Bogandyera Nature Reserve to increase the amount of habitat available to the population.
- Explore and implement potential pest fish management actions – especially those that reduce the abundance of predatory redfin perch.
- Negotiate and facilitate environmental flow releases from Lake Mannus leading up to and during the spawning season to promote recruitment of Macquarie perch.
- Prevent/reverse inbreeding depression and loss of genetic diversity by translocating genetically appropriate Macquarie perch from elsewhere (e.g., from Dartmouth or Cataract Dams) into Mannus Creek in order to insure against any further genetic deterioration of the population and to promote their rate of population recovery.

4.3.2. Coppabella Creek and southern pygmy perch

- Protect or enhance the habitat quality of the deepest remnant pools (see Table 6).
- Maintain the exclusion of alien pest fish at the natural and artificial barriers in the stream. Especially the artificial barrier in reach 20 (barrier # 2), which currently prevents redfin perch and other pest fish from invading southern pygmy perch habitat.
- Undertake habitat works that promote the retention and rehabilitation of aquatic macrophytes, including:
    - Exclusion of cattle from the riparian zone of each refuge pool.
    - Planting of aquatic macrophytes in those remnant pools where macrophyte beds are absent (using locally collected cuttings and/or seed-stock).
    - Willow removal.
    - Controlled re-establishment of native riparian vegetation.
- Monitor water levels in priority drought refugia during subsequent drought events to ensure the persistence of the remnant population. If total drying of priority refuge sites is considered likely, action should be taken to rescue those southern pygmy perch present.
- Identify potential independent release locations elsewhere in the Murray catchment that provide suitable habitat conditions for rescued and/or captive bred southern pygmy perch.

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