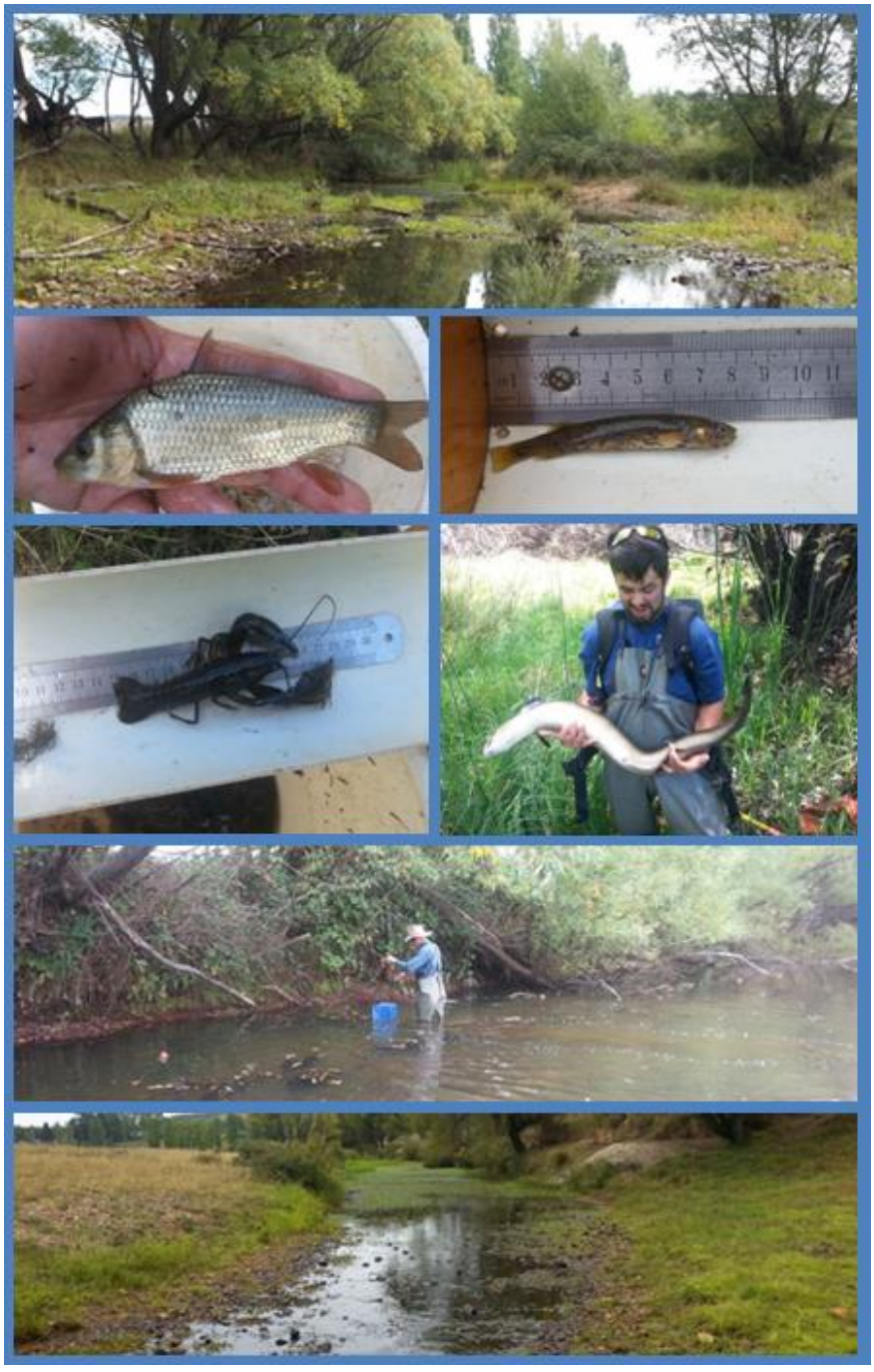
Mulloon Creek Baseline Fish Survey

Autumn 2016



Final report to the Mulloon Institute
Institute for Applied Ecology
University of Canberra

The Mulloon Institute
for Environment, Farming and Society

NSW GOVERNMENT Local Land Services South East

UNIVERSITY OF CANBERRA | INSTITUTE FOR APPLIED ECOLOGY

Acknowledgements

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Introduction

Mulloon Creek is in the upper Shoalhaven River catchment, southeastern NSW. Arising in the Tallaganda State Forest, Mulloon Creek flows in a northerly direction before joining Reedy Creek, which flows into the Shoalhaven River north of Braidwood. The lower half of the Mulloon Creek catchment has been cleared and current land use consists of extensive grazing of sheep and cattle, along with a range of smaller artisanal enterprises. The upper catchment is heavily vegetated with native Eucalypt forest.

The fish fauna of Mulloon Creek should largely comprise species expected to occur in the upper reaches of streams in the coastal catchments of southeastern NSW. Being connected to the Pacific Ocean, a range of diadromous (fish that migrate between freshwater and marine environments) could be expected to occur. However, the construction of Tallowa dam on the Shoalhaven River in 1976 to provide a water supply for Nowra has impeded the upstream and downstream movement of multiple species, leading to extirpations of numerous species upstream of the dam (Bishop and Bell 1978; Gerhke *et al*. 2002). Of note is the apparent extinction of Australian grayling (*Prototroctes maraena*) following the construction of Tallowa dam, and the loss of 10 species of diadromous fish that were predicted to occur upstream of the dam prior to its construction (Gehrke *et al*. 2002). A fish passage structure retro-fitted to the dam wall appears to provide minimal passage for native fish past Tallowa dam. As such, the only diadromous species expected to be upstream of Tallowa dam are the Anguillid eels (Short-finned eel, *Anguilla australis*, and Long-finned eel, *Anguilla reinhardtii*) and two additional species: Climbing galaxias (*Galaxias brevipinnis*) and Australian bass (*Percalates novemaculeata*). Stocking of Australian bass has occurred upstream of Tallowa dam, which theoretically enables them to enter the Mulloon Creek catchment. While they are unlikely to be present now, historically it is plausible that Australian bass occurred in this catchment. To what extent Australian bass may have been present in Mulloon Creek historically is unknown, but it is considered unlikely given that Mulloon Creek is a relatively small, shallow stream very high up in the Shoalhaven River catchment. Climbing galaxias may have been present in the uplands of the Shoalhaven catchment historically, as this species can occur in small streams quite distant from the ocean. Non-diadromous fish that may have occurred upstream of Tallowa Dam include Flat-headed gudgeon *Philypnodon grandiceps*, Dwarf flatheaded gudgeon (*Philypnodon macrostomus*) Empire gudgeon (*Hypseleotris compressa*) and Cox's gudgeon (*Gobiomorphus coxii*).

Mulloon Creek exists near the top of the Shoalhaven catchment, is relatively small, and extensive land-clearing in the lower sections all act to reduce the expected abundance and diversity of fish species likely to be present. Small-bodied native freshwater species that could be expected to occur include Mountain galaxias (*Galaxias olidus*) and possibly carp gudgeons (probably Western carp gudgeon *Hypseleotris klunzingeri*). Additional native freshwater species that have been reported from the Shoalhaven River catchment upstream of Tallowa dam include Firetail gudgeon (*Hypseleotris galii*), Western carp gudgeon (*Hypseleotris klunzingeri*), Macquarie perch (*Macquaria australasica*) and Australian smelt (*Retropinna semoni*) (Gehrke *et al*. 2002; Lintermans 2008). The taxonomy and field identification of *Hypseleotris* in southeastern Australia is problematic, with recent genetic studies showing that at least four sexual species of carp gudegeon are present in NSW, (Western, Lakes, Midgleys and Murray-Darling) as well as multiple hemi-clonal unisexual lineages of hybrid origin between the latter three species (Bertozzi *et al*. 2000; Schmidt *et al.* 2011). In addition to this, misidentification of male carp gudgeons (in reproductive colouration i.e. with red fins) as Firetail gudgeons (*Hypseleotris galii*) is possible, and the records of *H. galii* from the Shoalhaven catchment upstream of Tallowa Dam may be unreliable.

Additionally, a range of introduced species exist in nearby catchments that are likely to exist in the Mulloon catchment. Carp (*Cyprinus carpio*) are present in the Shoalhaven River upstream of Tallowa dam, and the lower-mid reaches of the Mongarlowe River (Lintermans 2008). Likewise, Goldfish (*Carassius auratus*) have been recorded in the Shoalhaven River catchment (Bishop and Bell 1978). Rainbow trout (*Oncorhyncus mykiss*) and Brown trout (*Salmo trutta*) exist in the Upper Shoalhaven River catchment and may occur in Mulloon Creek. Finally, the Eastern gambusia (*Gambusia holbrooki*) has a wide distribution throughout southeastern Australia and likely occurs in Mulloon Creek, as it has been recorded in the upper Shoalhaven River catchment (Gehrke *et al.* 2002; Lintermans 2008). However, no data previously exists that describes the fish fauna in Mulloon Creek.

This study aims to document the fish fauna present in the Mulloon Creek catchment, with particular focus on the Mulloon Farm area, and immediate vicinity of the constructed leaky weirs. To contextualise the findings, and to provide a reference for change in fish community in Mulloon Creek over time, three reference sites were identified and surveyed. This study provides a baseline to compare potential future changes in the fish fauna of Mulloon Creek as additional leaky weirs are installed.

Methods

Study sites

Nine sampling sites were pre-selected at the initiation of this study in order to explore the fish distribution and abundance within the Mulloon Creek catchment, and surrounding region to provide context.

Six sites on the Mulloon Creek (Figure 1) and three reference sites on streams outside the Mulloon Creek catchment were selected for sampling. Site descriptions and a wider scale map showing the reference sites in relation to Mulloon Creek are provided in Appendix I. Sites are numbered in an upstream to downstream manner, with Site 1 occurring upstream of the leaky weirs on the Mulloon Institute properties. Site 2 and 3 are situated between leaky weirs, and site 4 is at the downstream-most leaky weir. Sites 5 and 6 are approximately 5.7 and 7.3 km downstream of the lowermost leaky weir respectively, but in areas that are proposed to have leaky weirs installed. Sandhills Creek flows into Mulloon Creek at Site 5. Site 6 occurs just downstream of the Sandhills Creek confluence, near where Mulloon Creek is renamed becoming Reedy Creek.

The three reference sites were sampled to provide context to the Mulloon Creek fish sample. Firstly, a site on Reedy Creek downstream of Mulloon Creek was sampled, which is in the same catchment. Additional sites were sampled on tributaries of the upper Shoalhaven River in Bombay Creek, and Jembaicumbene Creek (Figure A1).

Figure 1. Map showing the position of the 6 sampling sites and existing leaky weirs along Mulloon Creek.

Fish sampling - Electrofishing

Backpack electrofishing was conducted in March 2016 at the 9 sites identified below (Table 1). Two operators using a Smith and Root LR20 backpack electrofisher with a single anode pole (with net) and rat tail cathode performed all electrofishing operations. Electrofishing was conducted in accordance with the A*ustralian Code of Electrofishing Practice* (NSW Fisheries 1997). The first operator carried the backpack electrofisher with anode pole. The second operator carried a 20L plastic bucket and long-handled dipnet with fine mesh for collecting stunned fish. All electrofishing operations were conducted by wading through the stream in a downstream to upstream direction. Both operators used polarising sunglasses to facilitate fish collection.

Table 1. Summary of surveys conducted in Autumn 2016 on Mulloon creek and three nearby reference sites.

Location	Date	Latitude:Longitude	# E-fishing shots	Distance surveyed (m)	Bait-trap set time (hr:min)
Mulloon Creek Site 1	10/03/2016	149.5915E, 35.2964S	5	225m	3:00
Mulloon Creek Site 2	10/03/2016	149.5916E, 35.2705S	3	NA	1:30
Mulloon Creek Site 3	11/03/2016	149.6029E, 35.2638E	3	115m	2:30
Mulloon Creek Site 4	11/03/2016	149.6205E, 35.2262S	4	170m	2:50
Mulloon Creek Site 5	17/03/2016	149.6316E, 35.2012S	3	110m	2:25
Mulloon Creek Site 6	17/03/2016	149.6361E, 35.2042S	3	100m	2:15
Bombay Creek	18/03/2016	149.6973E, 35.4216 S	4	170m	1:10
Jembaicumbene Creek	18/03/2016	149.7102E, 35.5019S	3	170m	1:45
Reedy Creek	24/03/2016	149.7637E, 35.3113S	4	190m	2:35

Electrofishing operations were conducted in accordance with Sustainable River Audit procedures, where practical. A 150 second ‘shot’ was conducted, determined from the duration of electrical discharge recorded by the electrofishing unit (i.e. ‘on time’ rather than elapsed time). In addition, a visual estimate agreed on by both operators of the number of metres traversed along the stream was recorded for each shot. The entire width of the stream was surveyed in a zig-zag pattern where stream width was less than 10m wide. Attempts were made to survey all major microhabitat features, including around patches of emergent and submerged macrophytes, large woody debris and rocks, cobble and boulder habitats. Between 3 and 5 shots were conducted at each site. After each 150 second shot fish were counted and measured, and then released. Fish that were observed during

electrofishing shots but not captured (escaped) were counted as 'observed'. Each fish captured was measured from the tip of the snout to the rear of the centre of the tail to the nearest mm in either total length (TL) or fork length (FL), where appropriate. Yabbies (*Cherax destructor*) were not measured. Total length of eels was estimated. A maximum of 50 fish of each species were measured for length at each shot, if more than 50 were captured. Once 50 were measured, all remaining individuals were counted and released.

Following each shot, a rapid assessment of instream conditions were made and recorded. Main attributes examined were water depth, substrate composition and extent of submerged and emergent macrophytes and the presence of large woody debris and other structure.

Fish sampling - Bait trapping

At each site, 10 fine-mesh concertina bait traps were deployed, as per Sustainable River Audit procedures. Traps were deployed unbaited into pools. Traps were placed 2-3m apart, with entrances facing in an upstream-downstream orientation. Traps were deployed whilst electrofishing operations were being conducted, and had a soak time of 70-180 minutes, before being retrieved and cleared of fish. Each fish caught was identified, measured for length then released.

Data analysis

Data was compiled in Microsoft Excel 2007 for presentation and analysis. Catch per unit effort was calculated as the number of fish captured and observed, divided by the number of minutes of electrofishing conducted in each shot. Shots were averaged for each site to produce mean and standard deviations. CPUE was calculated for *Galaxias olidus* and *Gambusia holbrooki*, due to their numerical dominance of catches.

Finally, length frequency histograms were produced for captured *Galaxias olidus* and *Gambusia holbrooki* at each site. No figures are present for Sites 1 and 2 on Mulloon Creek for *Gambusia holbrooki*, as they were not sampled at these sites. Figures were prepared in SigmaPlot Version 10.

Results

A grand total of 1,170 fish were captured over the 9 sites, with 941 fish being captured from Mulloon Creek. *Gambusia holbrooki* was the most abundant species, comprising 958 of the total catch, with 715 from Mulloon Creek. However, the distribution of this species was restricted to Sites 3-6, and the three reference sites. *Galaxias olidus* was the next most abundant species, with 203 caught in total, and 179 from Mulloon Creek. *Galaxias olidus* was captured at all sites, however, it was most abundant at Site 5. Small numbers of other species were captured. Five *Cyprinus carpio* were captured at Reedy Creek, while a single *Hypseleotris klunzingeri* was captured at Site 6 and Reedy Creek. Two eels were captured – one *Anguilla australis* at Site 1, and one *A. reinhardtii* at Jembaicumbene Creek (Table 2). A total of 59 yabbies (*Cherax destructor*) were captured across all sites, mostly from Mulloon Creek, and mostly from Site 4. (Table 2). All captures were made via back-pack electrofishing, with the exception of a single *Hypseleotris klunzingeri* captured in a bait trap at Reedy Creek.

Table 2. Summary of number of fish and yabbies captured at each location. Sub-total is presented for Mulloon Creek, and the grand total is the summation across all locations. Empty cells indicate that no fish were captured at that location.

Location	*G. olidus*	*G. holbrooki*	*A. australis*	*A. reinhardti*	*C. carpio*	*H. klunzingeri*	*C. destructor*
Site 1	36		1				1
Site 2	53						7
Site 3	7	165					1
Site 4	11	165					30
Site 5	62	294					3
Site 6	10	91				1	3
Sub total	**179**	**715**	**1**	**0**	**0**	**1**	**45**
Reedy Creek	8	180			5	1	4
Bombay Creek	4	10					3
Jembaicumbene Creek	12	53		1			7
Grand Total	**203**	**958**	**1**	**1**	**5**	**2**	**59**

Where present in Mulloon Creek, *Gambusia holbrooki* tended to dominate the catch (Figure 2). *Gambusia holbrooki* catch rates were highest at Site 5. Likewise, *Gambusia holbrooki* were numerically dominant in Reedy Creek and Jembaicumbene Creek. The catch rates of *Gambusia holbrooki* and *Galaxias olidus* were equal in Bombay Creek (Figure 2). *Galaxias olidus* catch rates were highest at Site 5, followed by Site 2 and Site 1 (Figure 2).

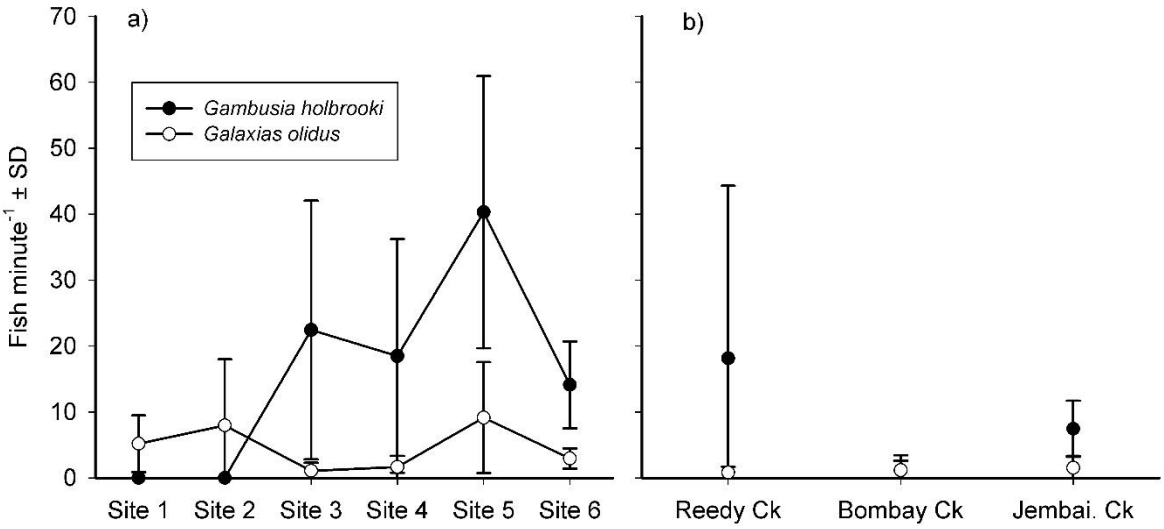

Figure 2. Catch per unit effort (number of fish caught and observed per minute of electrofishing) ± standard deviation of *Gambusia holbrooki* and *Galaxias olidus* at a) sites 1-6 on Mulloon Creek and b) Reedy Creek, Bombay Creek and Jembaicumbene Creek.

Captured *Galaxias olidus* ranged in size from 25-78 mm FL (Figure 3). *Galaxias olidus* captured at Site 4 and Site 6 tended to represent the smaller size classes, with no individuals over 49 mm FL captured at these sites. *Galaxias olidus* of 35-50mm FL tended to dominate the catches overall.

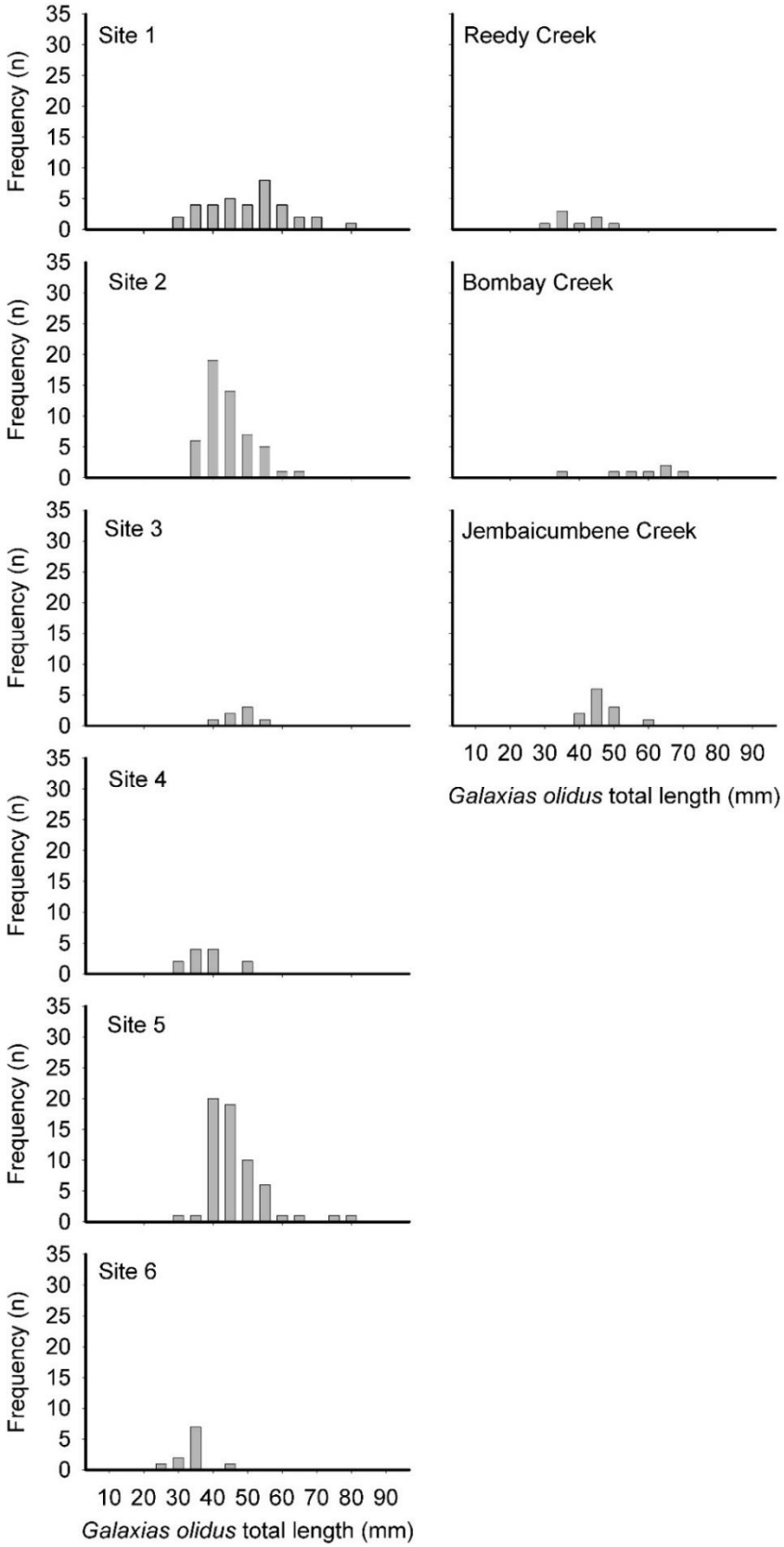

Figure 3. Length frequency histograms of *Galaxias olidus* caught at sites on Mulloon Creek (Sites 1-6) and reference sites (Reedy Creek, Bombay Creek and Jembaicumbene Creek).

Captured *Gambusia holbrooki* ranged between 12-55 TL (Figure 4). The most abundant size classes were between 20-30mm TL. The few individuals captured at Bombay Creek were restricted to 15-23 mm TL (Figure 4).

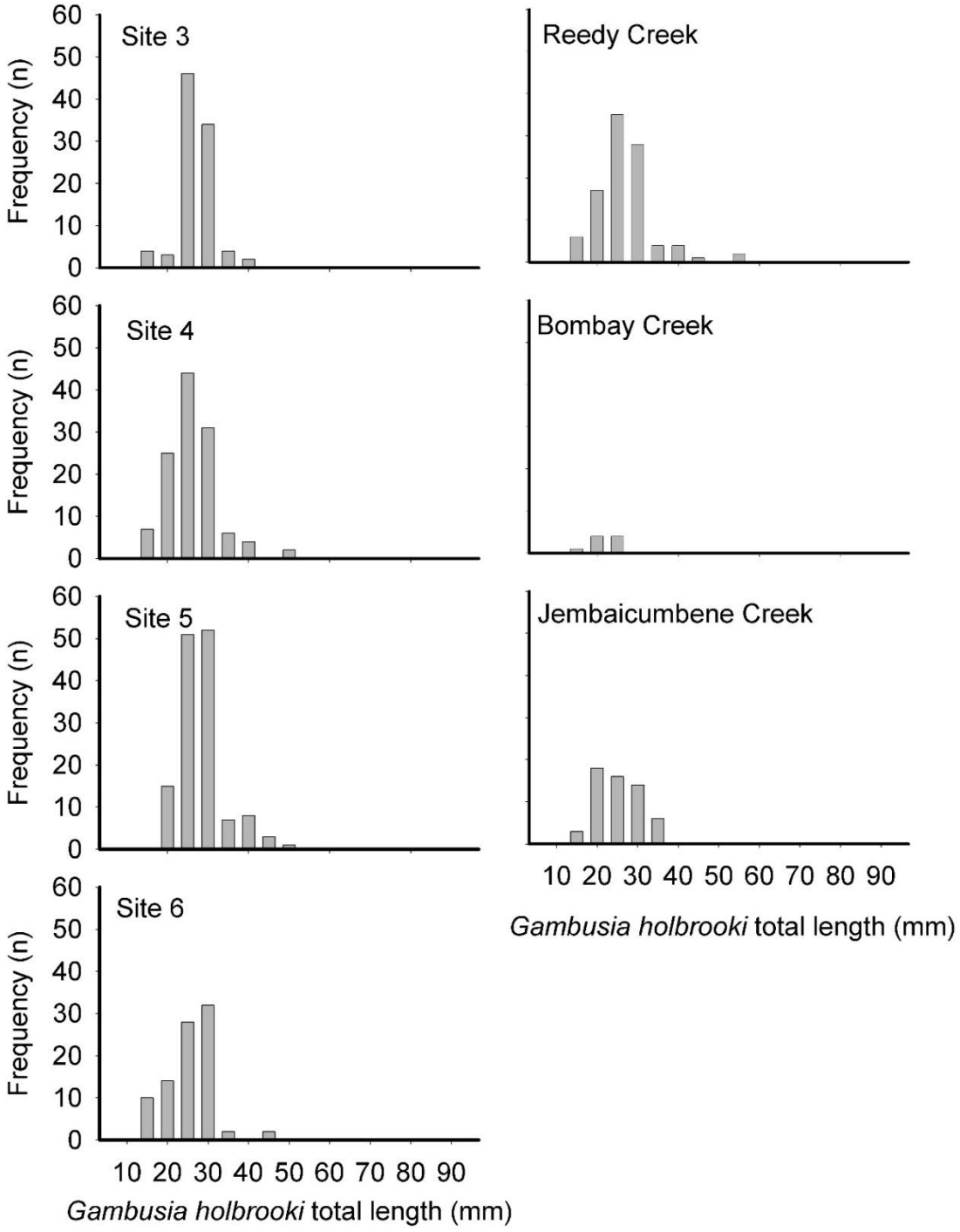

Figure 4. Length frequency histograms of *Gambusia holbrooki* caught sites on Mulloon Creek (Sites 3-6) and reference sites (Reedy Creek, Bombay Creek and Jembaicumbene Creek).

Discussion

A total of 1170 fish were sampled across the 9 sites, with 941 sampled from the Mulloon Creek sites. Additionally, 59 yabbies were sampled, with 45 sampled from the Mulloon Creek sites. It is interesting to note that only *Galaxias olidus* and a single *Anguilla australis* were captured at site 1, and only *G. olidus* at site 2. No introduced species were caught at these sites. Additional eels (of undetermined species) were observed at sites 1 and 2, but not captured. Site 1 is in a deeply incised channel but appears to have minimal impacts from land use, compared to the other sites on Mulloon Creek. It appears to have the steepest gradient, with considerable length of riffle sections and cobble substrate. These habitat features may tend to suit galaxias, while higher water velocities tend not to suit the invasive *Gambusia holbrooki* (Pyke 2005; Lintermans 2007), which occurs from site 3 downstream.

Where present, *Gambusia holbrooki* dominated the catch. This is not surprising, as where present, this species commonly reaches high densities (Pyke 2005; Rowe *et al*. 2008). By late summer, *G. holbrooki* numbers tend to reach their maximum yet undergo a decline through the cooler winter months (Kahn *et al*. 2013). Indeed, a large number of juvenile *G. holbrooki* (~10mm TL) were seen, but tend to be under-sampled by the electrofishing equipment. The flatter gradient and resulting reduction in flow and extensive emergent and submerged macrophytes creates habitat that greatly favours this species (Rowe *et al*. 2008). The construction of leaky weirs that partially impound the creek and slow water velocities will tend to create further habitat that is highly suitable for this species.

While *G. holbrooki* dominated the catch, *Galaxias olidus* were the most widespread species, being captured at every site sampled. This species has a very widespread distribution throughout south eastern Australia (Raadik 2014), and is one of 15 newly described species, although it is likely that numerous undescribed species exist. We noted that from sites 3 and further downstream, most *G. olidus* showed high infestations of endo-parasites, visible externally as black spots. These are most likely metacercaria of digenean trematodes embedded in the skin (Figure 5) (Drayson 1989; Lintermans 2007). Despite some heavy infestations, many of the fish appeared to be in reasonable condition, however some smaller individuals were clearly in poor condition, possibly due their higher parasite loads. This parasite is widespread and considered natural in galaxias populations (Lintermans 2007).

Figure 5. A Mountain galaxias (*Galaxias olidus*) captured at Mulloon Creek site 5 with a severe infestation of the metacercaria of digenean trematodes (black spots). Photo: Danswell Starrs.

A total of two eels were captured, although several others were directly observed, or believed to be disturbed by the electrofisher but otherwise not seen. A single *Anguilla australis* was captured at site 1, but 3, believed to be *A. australis* were disturbed at site 2. Eels can successfully occupy small headwater streams for an extended period of time, and are usually the largest fauna that occur in these habitats. Eels of both species encountered here can be resident in freshwaters for many years (up to 20) but do not breed in freshwaters, migrating downstream to marine habitats to spawn and die (Tsukomoto *et al.* 2002; Lintermans 2007). The large number of yabbies captured suggests that food resources may be abundant for eels in this creek system. Eels were not detected below site 2, however the reason for this is unknown. Our inability to sample the deepest pools may have limited our ability to detect this species in these habitats.

A single *Anguilla reinhardtii* was captured in Jembaicumbene Creek. At ~1.2m TL, it was an impressive animal (Figure 6). An additional eel (*A. reinhardtii*) was seen at this site, but not captured. Lintermans (2008) reports capturing Long-finned eels in the nearby Mongarlowe River. Despite the construction of Tallowa Dam, eels are expected to be present in upstream catchments due

to the ability of juvenile eels to climb large structures such as dams. Whether *A. reinhardtii* occur in sympatry with *A. australis* in Mulloon Creek is unknown, but it is suggested that long-finned eels tend to occur lower down in river catchments than short-finned eels with almost all the eels recorded in the upper reaches of the Snowy Mountains being *A. australis* (see Lintermans 1998).

Figure 6. A large Long-finned eel captured at Jembaicumbene Creek.

A total of 5 juvenile *Cyprinus carpio* (65-131mm FL) were captured from Reedy Creek (Figure 7). *Cyprinus carpio* is common in the Shoalhaven River, and the lower-mid reaches of the Mongarlowe River (Lintermans 2008), hence it was not surprising to capture them in Reedy Creek. No adult *Cyprinus carpio* were observed or captured, yet the presence of juveniles indicates that adults are present and are breeding in Reedy Creek. Whether Carp enter the upper reaches of Mulloon Creek remains to be seen, and will be dependent on flow conditions and instream barriers to fish movement. Provided flow connectivity occurs, and impassable instream barriers are either absent, or drown-out under higher flows, it would seem inevitable that Carp will invade Mulloon Creek eventually. Intermittency of flows in summer may help to slow or prevent their upstream dispersal,

however. Use of satellite imagery such as Google Earth or LIDAR may be useful to identify whether potential barriers to upstream invasion are present, with ground-truthing then able to identify whether such barriers may be able to be augmented or modified to prevent *Cyprinus carpio* invasion. As eels are the only other fish species present in the current survey which make large-scale migrations, and as eels can successfully negotiate even large barriers, the augmentation or installation of barriers will not adversely impact other native fish species present.

Figure 7. Juvenile Carp captured in Reedy Creek.

Throughout our surveys, just 2 *Hypseleotris klunzingeri* were captured. However, large numbers were observed at Site 6, in a very large, deep pool, and were readily observed at Reedy Creek, again in a large pool. Despite setting bait-traps in these pools, only a single individual was captured by bait trap, possibly a result of the relatively short soak times employed for bait traps. Future surveys looking to target this species should consider different sampling tactics to adequately sample this species (e.g. longer soak times for bait traps). Coupled with our inability to survey large, deep (>1m depth) pools with backpack electrofishing, there is the possibility that some fish species may remain

undetected. Whether *Hypseleotris klunzingeri* is native to the Shoalhaven river catchment is unknown, with a suggestion that it may have been translocated into the catchment from the Murray-Darling Basin (P. Unmack, pers comm.)

Although no fish surveys were conducted prior to the installation of the existing leaky weirs, the current survey does suggest that the weirs are unlikely to have had significant impacts on native fish distribution. Eels are expected to be highly mobile, and will not be impeded by these structures. *Galaxias olidus* is known to be a sedentary, non-migratory species with a home range of < 25 m (Berra 1973; Lintermans 2007), but have considerable ability to climb wet rocks if required (Green 2008), so the weirs are likely inconsequential to movement of this species. Conversely, species such as *Gambusia holbrooki* could be expected to be easily impeded by instream structures. Whether the creation of impounded pools has affected the abundance of the alien *Gambusia holbrooki* remains unknown, as the weir pools present ideal habitat for this flow-avoiding species. How *Gambusia holbrooki* came to be present in Mulloon Creek is unknown, and where they initially established is also unknown. The species is commonly moved by people in the mistaken belief that they are a native species, and whether this has happened previously in the Mulloon catchment is unknown. Whether the absence of *Gambusia holbrooki* at sites 1 and 2 is a direct result of a barrier formed by leaky weirs, or simply reflects that they have not invaded this habitat, or it is unsuitable is unknown. Future monitoring around the weirs may reveal if the movement of *G. holbrooki* is being restricted by these structures. Additional investigation of the presence of *G. holbrooki* in farm dams in the Mulloon Creek catchment would be worthwhile, as such dam populations may serve as refugia for *G. holbrooki* to overwinter and then reinvade when high rainfall causes dams to spill.

In summary, the fish fauna in Mulloon Creek is relatively depauperate, but not unexpected, given the landuse history, habitat quality and the potential impacts of Tallowa Dam downstream on the Shoalhaven River. The possible invasion by *Cyprinus carpio* seems to be the most likely change to the fish fauna that could be reasonably predicted, and even this is speculative. The construction of additional leaky weirs would produce additional habitat that would greatly suit *Gambusia holbrooki* and *C. carpio* if they were to successfully invade this upper catchment.

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Appendix I

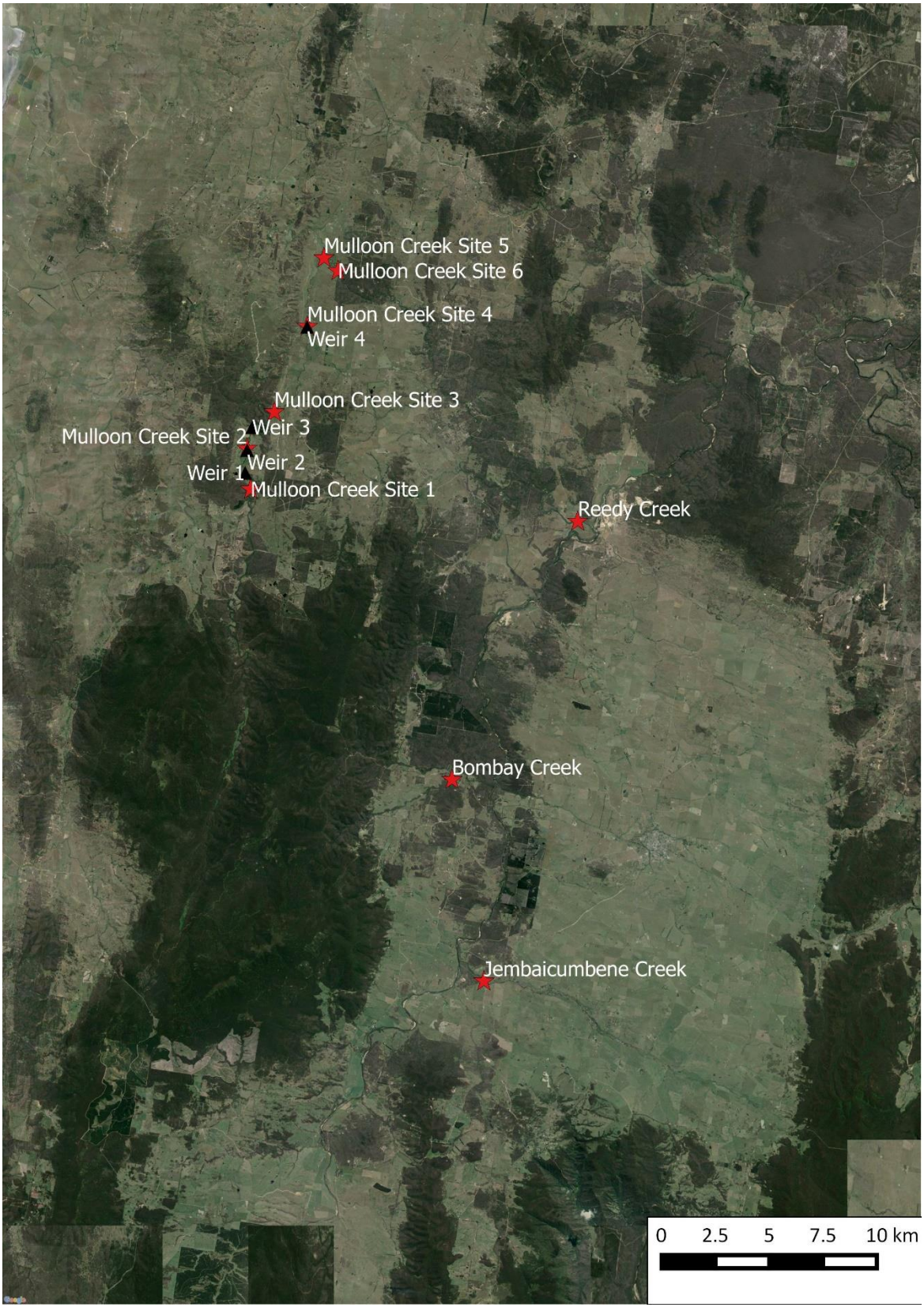


Figure A1. Map showing the reference sampling sites in relation to the 6 sites on Mulloon Creek.

Mulloon Creek Site 1

Description: The upstream-most site sampled on Mulloon Creek. This site occurs at the downstream end of a large tract of gorge country. At this point the creek is in a deeply (~15-20m) incised channel. Blackberries are the dominant riparian vegetation along this reach. Stream consisted of long shallow pools, and short riffle sequences.

Elevation: 745m asl

Stream Width: 2-5m wide

Average Stream Depth: 0.75-1m

Substrate Composition: Approximately 50% cobble, 25% sediment and 25% submerged vegetation. Small proportion was bedrock

Emergent Macrophytes: No significant emergent vegetation in this reach

Submergent Macrophytes: Considerable proportion contained submerged vegetation.

Other Structure: Large amounts of drowned timber and large boulders and bedrock structures.

Mulloon Creek Site 1.

Mulloon Creek Site 2

Description: The second site sampled on Mulloon Creek. This site occurs just downstream of the homestead, and is situated downstream of the first leaky weir in the system. The weir pool was sampled with the bait traps. Consisted of very long pools and runs, with very minimal riffle habitat. Willows are the dominant riparian vegetation. Considerable stands of tall emergent macrophytes present, and very dense submerged vegetation throughout this reach.

Elevation: 735m asl

Stream Width: ~3-5m wide

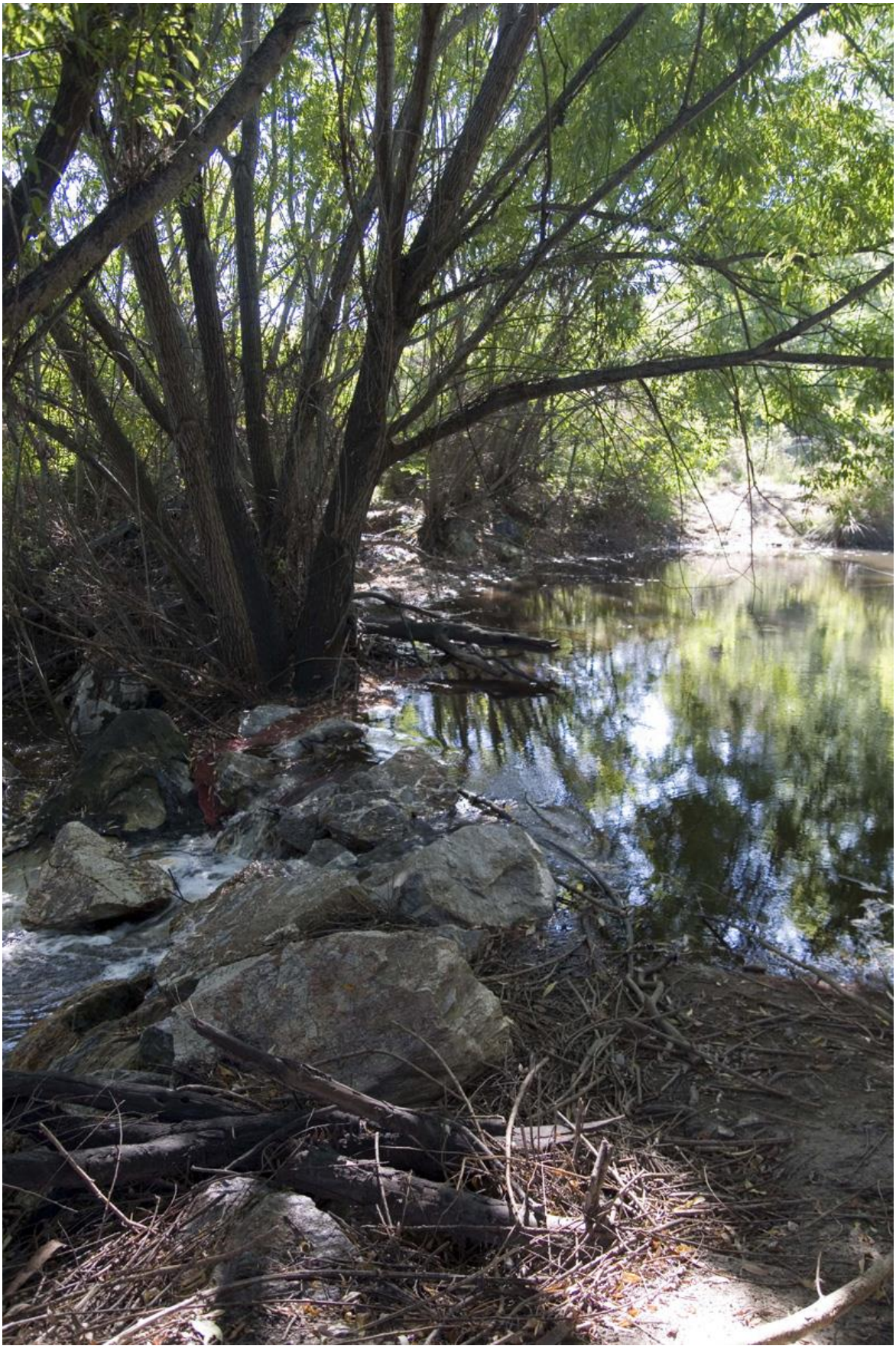
Average Stream Depth: 0.5-0.75m

Substrate Composition: Primarily sediment and submerged vegetation. Very small amounts of cobble, with proportionally more cobble in the upstream riffle section of this reach.

Emergent Macrophytes: Large stands greater than 2m wide. Height of the emergent vegetation is greater than 1m.

Submergent Macrophytes: Considerable proportion contained submerged vegetation. Often narrow channel in the middle that was not vegetated.

Other Structure: Minimal structure in-stream. At upstream end larger cobble and boulders were present.



Leaky weir upstream of Mulloon Creek Site 2.

Mulloon Creek Site 3.

Description: The third site sampled on Mulloon Creek. This reach occurs on the downstream side of Mulloon Road. The bait traps were set in the large pool on the upstream side of the road crossing. This particular reach is wide with considerable shallow sections. Native vegetation dominates in this reach.

Elevation: 724m asl

Stream Width: ~5-10m wide

Average Stream Depth: 0.75-1m at the downstream end, but shallower (< 0.5m) closer to the road crossing.

Substrate Composition: Sediment and sand dominated in this reach. Some submerged vegetation in places, and cobble up near the road crossing.

Emergent Macrophytes: No emergent vegetation throughout this reach.

Submergent Macrophytes: Variable in the extent of channel coverage. In some places complete width of channel, while in places restricted to <1m in width.

Other Structure: Small amounts of wood debris in this reach.

Mulloon Creek Site 3.

Mulloon Creek Site 4

Description: The fourth site sampled on Mulloon Creek. This site is on the north side of the Kings Highway, off Hazeldell Road on Palarang crossing near homestead. The reach is immediately downstream of a leaky weir, with the bait traps set in the weir pool at the upstream end of the reach. This reach was shallow and slow-flowing with very dense submerged vegetation and large numbers of yabbies. Riparian zone greatly depleted, consisting of willows and blackberries where present.

Elevation: 701m asl

Stream Width: ~3-8m wide

Average Stream Depth: Varied between 0.5-1m at the downstream end, but shallower (< 0.5m) closer to the road crossing.

Substrate Composition: Sediment, cobble and sand dominated in this reach.

Emergent Macrophytes: No emergent vegetation throughout this reach.

Submergent Macrophytes: Nearly consistently extended across the entire width of the channel. Very dense. Yabbies and *Gambusia holbrooki* found to be sitting on the surface throughout this reach.

Other Structure: No meaningful additional structure found in this reach.

Mulloon Creek Site 4.

Mulloon Creek Site 5

Description: The fifth site sampled on Mulloon Creek. This reach occurs near the confluence of Mulloon Creek and Sandhills Creek. The creek had ceased flowing though this reach, and consisted of long, stagnant pools. The bait traps were set in a long shallow pool at the downstream end of this reach. Willows, blackberries and large stands of emergent vegetation dominated the riparian zone. Water quality may have been compromised by large amounts of inputs from cattle feeding in the stream corridor.

Elevation: 698m asl

Stream Width: ~3-10m wide

Average Stream Depth: 0.5-0.75m.

Substrate Composition: Substrate highly variable. Cobble present in the previously riffle sections, while pools consisted of sediment, sand and submerged vegetation.

Emergent Macrophytes: Highly variable. Absent in some areas, and extensive (>2m wide) in places.

Submergent Macrophytes: Variable. Absent in places, and extensive in others. Larger pools that were deep tended to have cobble or sand substrates and minimal submerged vegetation.

Other Structure: Minimal large structure. One large pool had undercut bank and large tree roots.

Mulloon Creek Site 5.

Mulloon Creek Site 6

Description: The downstream-most site sampled on Mulloon Creek. This reach occurs downstream of the confluence of Mulloon Creek and Sandhills Creek. The bait traps were set in a long, wide and deep pool at the downstream end of this reach. Large schools of Western carp gudgeons were present in this pool. Willows and large stands of emergent vegetation dominated the riparian zone. Water quality may have been compromised by large amounts of inputs from cattle feeding in the stream corridor upstream.

Elevation: 694m asl

Stream Width: ~5-10m wide

Average Stream Depth: 0.75 to >1m.

Substrate Composition: Consisted primarily of cobble and submerged vegetation.

Emergent Macrophytes: Variable. Minimal in some areas where deeply incised banks occurred, and extensive (>2m wide) in places.

Submergent Macrophytes: Variable but generally extensive. Larger pools that were deep tended to have submerged vegetation around the margin only.

Other Structure: A few boulders and fallen trees present in this reach.

Mulloon Creek Site 6.

Reedy Creek at Mayfield Road crossing

Description: This site occurs on the downstream side of the Mayfield Road crossing of Reedy Creek. This reach is heavily overgrown with native understorey and willows. Channel is quite wide in places, but stream greatly restricted within this region. Flow was low, and numerous isolated pools existed alongside the flowing creek.

Elevation: 581m asl

Stream Width: ~5-10m wide

Average Stream Depth: Tended to be quite deep, >1m throughout.

Substrate Composition: Consisted primarily of cobble and sediment.

Emergent Macrophytes: Variable. Minimal in some areas where deeply incised banks occurred, and extensive (>2m wide) in places.

Submergent Macrophytes: Highly variable. Non-existent in places, but covering entire stream width in others.

Other Structure: Large amounts of fallen timber in this reach.

Reedy Creek at Mayfield Road crossing.

Bombay Creek at Hoskinstown Road crossing

Description: This site occurs on the downstream side of the Hoskinstown Road crossing of Bombay Creek. This reach has a dense native canopy and thick blackberry understorey.

Elevation: 663m asl

Stream Width: ~5-10m wide

Average Stream Depth: 0.75-1m

Substrate Composition: Primarily sediment, with small amounts of cobble and submerged vegetation.

Emergent Macrophytes: Small amounts of emergent vegetation, tending to be <1m wide, and <1m high.

Submergent Macrophytes: Tended to be minimal, and made up primarily of clumps within the stream.

Other Structure: Large amounts of fallen timber in this reach.

Bombay Creek at Hoskinstown Road crossing.

Jembaicumbene Creek at Cooma Road crossing

Description: This site occurs on the downstream side of the Cooma Road crossing of Jembaicumbene Creek. The bait traps were set on the upstream side of the road crossing. This reach has a Willow canopy and numerous Willows instream and thick blackberry understorey.

Elevation: 655m asl

Stream Width: ~5-10m wide

Average Stream Depth: Deep, >1m.

Substrate Composition: Downstream end consisted primarily of sediment, while upstream end made up of sediment, cobble and submerged vegetation.

Emergent Macrophytes: Narrow band <1m in width and >1m tall.

Submergent Macrophytes: Tended to be narrow and restricted to small patches.

Other Structure: Willow roots and trunks extensive in this reach.

Jembaicumbene Creek at Cooma Road crossing.