Department of
Sustainability and
Environment

The Impacts of Drought on River Blackfish (*Gadopsis marmoratus*) in Tullaroop and McCallum Creeks

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2010

Arthur Rylah Institute for Environmental Research

Confidential Client Report

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The Impacts of Drought on River Blackfish (*Gadopsis marmoratus*) in Tullaroop and McCallum Creeks

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August 2010

In partnership with:

NORTH CENTRAL
Catchment Management Authority

Arthur Rylah Institute for Environmental Research
Department of Sustainability and Environment
Heidelberg, Victoria

Report produced by: Arthur Rylah Institute for Environmental Research
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Citation: Cable, A. and Saddlier, S. (2010). The impacts of drought on River Blackfish *(Gadopsis marmoratus*) in Tullaroop and McCallum Creeks. Arthur Rylah Institute for Environmental Research. Confidential client report. Department of Sustainability and Environment, Heidelberg, Victoria.

Front cover photo: (Top) River Blackfish *Gadopsis marmoratus* (Renae Ayres), (Bottom left) Site T1 2005 (K. Pitman) and (Bottom right) Site T1 2010 (S. Saddlier).

Authorised by: Victorian Government, Melbourne

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Acknowledgements

The authors would like to thank and acknowledge those who provided assistance with this report including Lauren Dodd (ARI) for assistance with the fieldwork, Jason Lieschke (ARI) for comments on the draft and Jon Leevers, Emma Wolters and Glen Merrick (NCCMA) for project initiation and guidance.

Summary

The North Central Catchment Management Authority (NCCMA) commissioned members of the Arthur Rylah Institute (ARI), Department of Sustainability and Environment (DSE) to assess the impacts of drought on River Blackfish (*Gadopsis marmoratus*) populations in Tullaroop and McCallum Creeks. This report will be used to assist in the decision making processes regarding the management and long term security of these populations.

This assessment follows a study conducted by Pitman and Tinkler (2005) that reported on the distribution and habitat of River Blackfish in McCallum and Tullaroop Creeks during July 2005. Data collected during this survey was used as baseline information for the current assessment with the same sites being replicated for this report.

In the 2005 sampling event, a backpack electrofishing unit was used; however, due to the consistently elevated electrical conductivity levels encountered throughout the study area during the 2010 sampling event, a bankmounted electrofishing unit was employed. Sampling followed a standard fish sampling design, while a range of water quality and habitat characteristics were collected. Water quality parameters represent a snapshot taken at the time of sampling and as such were combined with a range of water quality readings from previous years (provided by NCCMA) for comparative purposes. These readings were used to ascertain the levels of dissolved oxygen and electrical conductivity that River Blackfish in Tullaroop and McCallum Creeks have been subjected to over the recent drought period.

This study found only one River Blackfish in Tullaroop Creek (site T-4), while no River Blackfish were captured (or observed) in McCallum Creek (compared to 22 individuals captured during the 2005 survey). The substantially reduced blackfish catch was observed despite the use of electrofishing equipment which has a far greater output and electrical field, thus providing an increased efficiency compared to the backpack electrofisher used in the previous 2005 sampling event (Pitman and Tinkler, 2005). Fyke nets were also used as a supplementary method to verify the reduced River Blackfish electrofishing catch rates. Results of this method support the very low River Blackfish catch rates observed during electrofishing sampling events.

The poor catch rates of River Blackfish at all sites clearly indicates a downward trend in population density from Tullaroop Creek, downstream of Tullaroop Reservoir to the confluence with the Loddon Reservoir. This supports conclusions made by the Loddon River Environmental Flows Scientific Panel (2002) and Pitman and Tinkler (2005) that River Blackfish populations in Tullaroop Creek are in poor condition.

Recommendations to provide conditions that are likely to benefit the extant population of River Blackfish in this system include adherence to flow regulation guidelines outlined by the Loddon River Environmental Flows Scientific Panel (LREFSP, 2002) to reduce EC and silt levels, and augmenting instream habitat through the restoration of riparian vegetation. Further assessment of additional waters within the Tullaroop Catchment that are known to support River Blackfish populations are recommended, to gauge the extent of wider population decline to assist future management within the NCCMA.

1 INTRODUCTION

Populations of River blackfish *Gadopsis marmoratus* within the Loddon River system are considered regionally significant by the North Central Catchment Management Authority. This status is largely a result of the continuing decline of this species in many northern river basins (including the Loddon River system), as well as their often restricted distribution within this region.

Historical distribution of River Blackfish within the Loddon River system is largely centred around the Tullaroop Creek system and its major tributaries including Birches, McCallum and Creswick Creeks. Lesser tributaries of these creeks have also been recorded to support populations of this species, with small numbers being recorded in Slattery, Coghills, Kilkenny, Glendonald Bullarook and Bet Bet Creeks in 1977 (Hume 1979). More recent surveys have also recorded small numbers in Bet Bet and Bullarook Creeks in 1999 and 2002 respectively (DSE 2010).

This report represents an assessment of the impacts of the prolonged drought period on River Blackfish populations (as well as other fish fauna) in Tullaroop Creek downstream of Tullaroop Reservoir and its tributary McCallum Creek. The findings of this study will aid management decisions regarding the long-term security of these populations. This assessment follows a study conducted by Pittman and Tinkler (2005) that reported on the distribution and habitat of River Blackfish in McCallum and Tullaroop Creeks during July 2005. Data collected during the 2005 survey was used as baseline information for the current assessment with the same sites being replicated for this report. Blackfish abundance and distribution as well as habitat characteristics recorded at each site were compared to characterise variation in the River Blackfish populations during and after the prolonged drought period. Results of historic fish surveys are also discussed to clarify long-term trends in fish population structure.

While the initial report by Pitman and Tinkler (2005) focused on habitat structure and availability, additional emphasis was placed on benthic composition and the effects of water quality during this study, particularly the effects of sedimentation and salinity. Information gained from these surveys was used in conjunction with current literature to identify factors that restrict the persistence of River Blackfish in these waterways. Recommendations for securing the future of River Blackfish in Tullaroop and McCallum Creeks are discussed.

2 METHODS

2.1 Study Sites

The same study sites used in the 2005 survey of McCallum and Tullaroop Creeks by Pitman and Tinkler (2005) were used in the current study. Site locations were determined using 1:50 000 topographic maps, using Map Grid of Australia references (MGA) as well as written descriptions contained within the 2005 report. Site locations details, descriptions and map coordinates are shown in Table 1 and Figure 1.

Table 1. Location of sampling sites in Tullaroop and McCallum Creek
1:50 000 topographic maps – 7624-S and 7623-N

Site	Date surveyed	Description	Co-ordinates (MGA)		
			Zone	Northing	Easting
Mc1	Not surveyed	McCallum Creek on private property above confluence with Tullaroop Creek (DRY)	54	750600	5894900
Mc2	Not surveyed	McCallum Creek at Rodborough Road (unsuitable for sampling)	54	748900	5891250
Mc3	20/07/2010	McCallum Creek at McCallum Bridge	54	746270	5887420
Mc4	19/07/2010	McCallum Creek at Talbot-Majorca Road	54	743600	5883280
Mc5	19/07/2010	McCallum Creek downstream of bridge on Ballarat-Maryborough Road	54	742200	5878020
Mc6	19/07/2010	McCallum Creek downstream of Old Ballarat Road crossing	54	738730	5873810
T1	21/07/2010	Tullaroop Creek at Forbes Road	54	755350	5912360
T2	21/07/2010	Tullaroop Creek at Mullins Bridge	54	754250	5909900
T3	21/07/2010	Tullaroop Creek at Hoopers Bridge	54	752500	5904700
T4	20/07/2010	Tullaroop Creek at Carisbrook	54	750600	5896380
T5	20/07/2010	Tullaroop Creek upstream of Doran Road Quarry	54	753700	5894300
T6	20/07/2010	Tullaroop Creek on private property downstream of Reservoir	54	754810	5891670

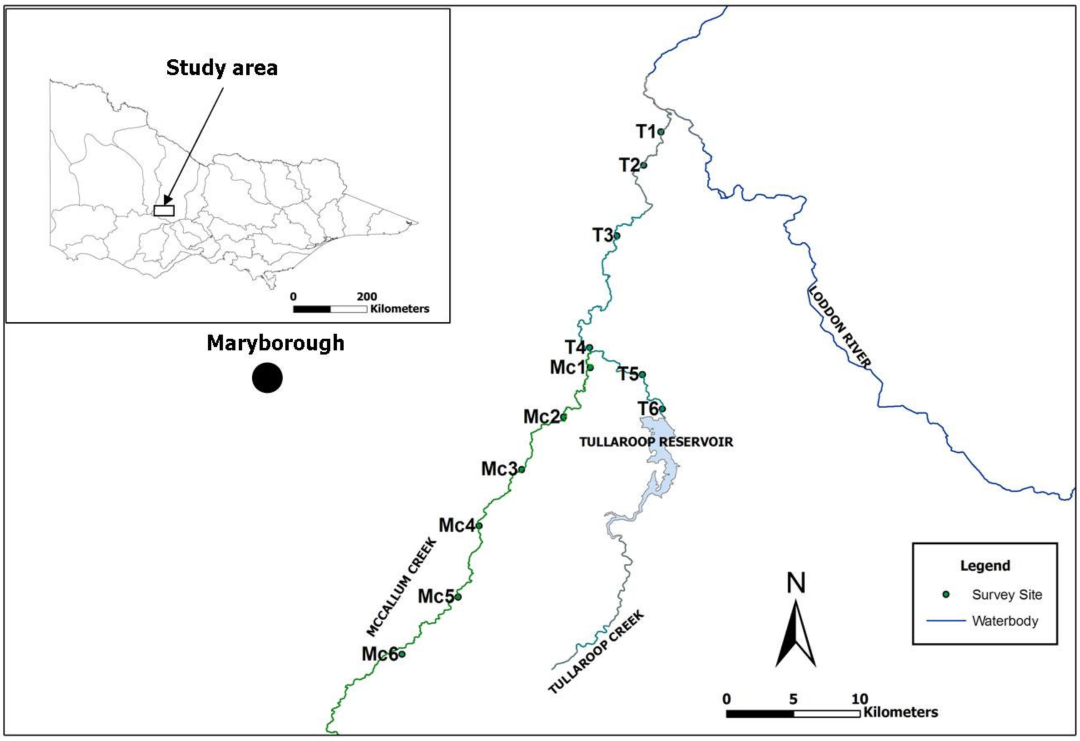

Figure 1. Map of study area displaying survey sites, water bodies and location within Loddon Catchment and Victoria.

2.2 Fish Collection Methods

To determine the abundance of River Blackfish and other fish species within the 12 sites, a Smith-Root® bank mounted electrofishing unit was utilised. Previous surveys had been conducted using a Smith-Root® backpack electrofisher; however this was not possible due to the marked increase in water electrical conductivity which was well outside the operating range of the backpack electrofisher. The Bankmounted electrofisher has a superior electrical output field to the method used in 2005 by Pitman and Tinkler, thus having the potential to increase the number of individuals detected. The use of a backpack electrofisher by Pitman and Tinkler in 2005 was deemed appropriate at the time due to the substantially lower levels of electrical conductivity present during this period.

As in the 2005 sampling even, a standard reach length of 100 metres was electrofished and where possible these 100 m reaches were repeated using the same single-pass approach with an attempt to keep the fishing effort (expressed in electrofishing seconds) consistent with the 2005 effort. Limiting factors were the availability of water and impenetrable patches of Phragmites (*Phragmites australis*) which had increased in density and abundance since the 2005 surveys. Sections that lacked suitable water or were impassable were missed and the measurement of the 100 m was recommenced to maintain a standard sampling effort. The bank mounted electrofisher settings ranged from 340-1000 volts, 120 pulses per second and with an output of 4-13 amps (depending upon waterbody depth, electrical conductivity and area). All fish that were collected were identified, measured (caudal or fork length used depending upon species) to the nearest millimetre and weighed to the nearest gram. Fish that could not be collected and could be positively identified were recorded as observed.

To verify electrofishing catches, single wing fyke nets (25-30 mm mesh size) were set at a sub-sample of sites with suitable depth and width for their deployment. Fyke nets were set at sites T-3 and T-5 as these presented suitable conditions for deployment.

2.3 Habitat

During this assessment, habitat parameters were recorded to monitor the variation in available habitat and detect variation in the environmental factors present at the site which are known to affect the fish biota.

The parameters that were recorded were

- Flow characteristics including
  - Flow type
  - Relative velocity
- Disturbance characteristics including
  - Disturbance rating eg. Extreme – Very Low
  - Disturbance type
- Landuse and riparian vegetation
- Instream cover including
  - Instream cover eg. Logs, aquatic vegetation, bank overhang etc.
  - Substrate
  - Aquatic vegetation type (if present)

It should be noted that habitat assessments of this nature are subjective, and as such only substantial variations between the current and previous surveys were discussed, as fine scale variation may be due subjective variation between personnel.

2.4 Water Quality

As this assessment is focused on the impacts of drought on the Tullaroop and McCallum Creeks River Blackfish populations, water quality data was collected to gauge the suitability of the system to allow blackfish to persist and complete their lifecycle. Water quality parameters including temperature (°C), dissolved oxygen (mg/L), pH, electrical conductivity ($\mu s\ cm^{-1}$) and turbidity (NTU) were recorded prior to sampling. Water quality readings were taken 20 cm from the surface (where possible).

Water quality and flow data for the previous two years (mid 2008- mid 2010) was also provided by the NCCMA (this data was collected by Thiess), and historical data from the late 1970s to 1988 are also discussed provided by the NCCMA (collected by GMW). Data provided by Thiess contained records of the electrical conductivity and dissolved oxygen, with the historical data providing electrical conductivity only. Flow data (recorded in ML/day) contained records from the previous six years and was provided by Goulburn-Murray Water (GMW).

2.5 Historical Data

To supplement the data acquired by Pitman and Tinkler (2005), historical records of aquatic fauna surveys including those recorded in the DSE Aquatic Fauna Database (AFD) were also investigated These records also include attempted translocations, which will be discussed further (see section 3.1).

3 Results

3.1 Historical data

3.1.1 Tullaroop Creek

A number of fish surveys have been conducted in Tullaroop Creek between 1978 – 2010 (Hume, 1979; Tunbridge *et al*. 1981; Baxter, 1985; Baxter, *et al*, 1988; Saddlier, unpub. 1990;; McGuckin, 1995; DSE, 2004; Pitman and Tinkler, 2005; and DSE. 2007). A summary of these surveys is outlined in Table 2. The majority of the fish surveys occurred above Tullaroop Reservoir with limited records below the reservoir. There have also been translocations of three recreational native fish species including Macquarie Perch (*Macquaria australasica*), Golden Perch (*Macquaria ambigua*) and Murray Cod (*Maccullochella peelii peelii*), however the long-term viability of these populations appear to be doubtful as there have been no further records of their occurrence since the initial stocking.

River Blackfish have been recorded in Tullaroop Creek since 1978 albeit in low densities with the highest recorded number of individuals occurring below the reservoir where 14 individuals were recorded (DSE, 2005). By comparison, a similar reach, situated in Birches Creek, in the Loddon Catchment, recorded up to 129 individuals at one 100 metre site (Pitman and Saddlier, 2006).

Seven alien fish species have been recorded in Tullaroop Creek with only five of these being recorded to occur downstream of the reservoir (Hume, 1979; Tunbridge *et al*. 1981; McGuckin, 1995; DSE, 2005 and AFD 2010). A list of alien fish species is presented in table 2.

3.1.2 McCallum Creek

There is limited historical data available for McCallum Creek with only three previous fish surveys documented (AFD, 2010 and Pitman and Tinkler 2005). Three native fish species have been recorded during these surveys with no alien species recorded. Surveys conducted by DSE in 1999 and 2005 (AFD, 2010) were undertaken at the same site which coincides, fortuitously, with site Mc-5 for this assessment. At this site River Blackfish were detected on each occasion (see figure 2). Unfortunately, the decline shown in figure 2 continues, with no River Blackfish sampled in 2010. A complete list of fish species captured in McCallum Creek are presented in table 3.

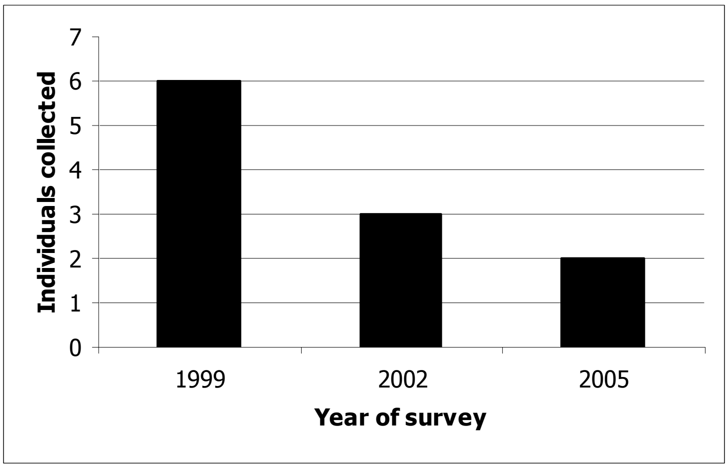

Figure 2. River Blackfish caught at site Mc-5.

Table 2. Fish and decapod crustaceans recorded from Tullaroop Creek.

Species	Common Name (Code)	Reference
Native Fish Species		
Gadopsis marmoratus	River Blackfish (GAD MAR)	Hume 1979; Tunbridge *et al.* 1981; Baxter 1985; McGuckin 1995; Pitman and Tinkler, 2005 and DSE 2007
Galaxias sp. 1	Obscure Galaxias (GAL SP.1)	DSE, 2005 and DSE, 2007
Philypnodon grandiceps	Flat-headed Gudgeon (PHI GRA)	Baxter, 1985 and DSE, 2005
Macquaria ambigua	Golden Perch (translocated) (MAC AMB)	AFD 2010
Macquaria australasica	Macquarie Perch (translocated) (MAC AUS)	Cadwallader 1981; Cadwallader *et al.* 1984 and AFD 2010
Maccullochella peelii peelii	Murray Cod (translocated) (MAC PEE)	Cadwallader *et al.* 1984 and Barnham, 1990
Retropinna semoni	Australian Smelt (RET SEM)	Baxter, 1985; Baxter *et al*. 1988; Saddlier, 1990 and DSE, 2005
Alien Fish Species		
Carassius auratus	Goldfish (CAR AUR)	Tunbridge *et al*. 1981 and Pitman and Tinkler, 2005
Cyprinus carpio	European Carp (CYP CAR)	DSE, 2010
Gambusia holbrooki	Gambusia (GAM HOL)	DSE 2004 and Pitman and Tinkler, 2005
Perca fluviatilis	Redfin (PER FLU)	Hume, 1979; McGuckin1995; DSE 2005 and AFD 2010
Salmo trutta	Brown Trout (SAL TRU)	Hume, 1979; Baxter 1985 and AFD, 2010
Oncorhynchus mykiss	Rainbow Trout (ONC MYK)	Hume, 1979
Tinca tinca	Tench (TIN TIN)	DSE 2004; Pitman and Tinkler, 2005
Native Decapod Crustaceans		
Cherax destructor	Common Yabby	DSE, 2004 and Pitman and Tinkler, 2005
Macrobrachium australiense	Freshwater Prawn	DSE, 2004
Paratya australiensis	Freshwater Shrimp	DSE, 2004

Table 3. Fish and decapod crustaceans recorded from McCallum Creek.

Species	Common Name (Code)	Reference
Native Fish Species		
Gadopsis marmoratus	River Blackfish (GAD MAR)	AFD 2010**;** Pitman and Tinkler, 2005
Galaxias sp.1	Obscure Galaxias (GAL SP.1)	AFD 2010; Pitman and Tinkler, 2005
Philypnodon grandiceps	Flat-headed Gudgeon (PHI GRA)	AFD 2010; Pitman and Tinkler, 2005
Retropinna semoni	Australian Smelt (RET SEM)	Pitman and Tinkler, 2005
Native Decapod Crustaceans		
Cherax destructor	Common Yabby	AFD 2010
Paratya australiensis	Freshwater Shrimp	AFD 2010

3.2 Site Characteristics

Site T-1 – Tullaroop Creek at Forbes Road

This survey extended from 80 metres downstream to 20 metres upstream of the bridge on Forbes Road. The mean width and depth were 10 metres and 0.6 metres respectively. Hydraulic habitat consisted of pool (still water) (100%) while the benthic composition was 80% sand and 20% silt. Instream habitat available to aquatic fauna was dominated by emergent macrophytes, in particular Phragmites (70%), and branch piles. A high level of disturbance was noted at the site which was predominantly bank erosion, from stock access, instability, and clearing of vegetation within the riparian zone. Electrofishing effort = 1676 seconds.

Figure 3. Site T-1 photo (2010)

Figure 4. Site T-1photo (2005) Pitman and Tinkler

Site T-2 – Tullaroop Creek at bridge on Mullins Road

The survey extended from the bridge on Mullins Road to 100 metres upstream. The mean width and depth was 5 metres and 0.3 metres respectively. Hydraulic habitat consisted of pool (90%) and glide (10%), with the benthic composition of sand (90%) and silt (10%). Available instream habitat consisted primarily of aquatic vegetation (80%) of which 75% was Phragmites and Cumbungi (*Typha* sp.). Disturbance rating at the site was high with the most notable disturbance being cleared riparian vegetation. Electrofishing effort = 1465 seconds.

Figure 5. Site T-2 photo (2010)

Figure 6. Site T-2 photo (2005) Pitman and Tinkler

Site T-3 – Tullaroop Creek at Hoopers Bridge

This site extended from Hoopers Bridge to 120 metres downstream with a 20 metre section missed due to impenetrable vegetation. Replication of the reach sampled by Pitman and Tinkler (2005) was not possible due to impenetrable aquatic vegetation, with the current survey including only half of their reach. The mean width and depth were 4 metres and 0.9 metres respectively. Hydraulic habitat consisted entirely of pool or still water, with the benthic composition was sand (50%0 and silt (50%). Available instream habitat consisted primarily of aquatic vegetation (90%) of which almost all (99%) was Phragmites. In the open water surveyed woody debris was abundant. The disturbance rating for this site was very high with considerable bank erosion and riparian vegetation at ground level dominated by Oxalis (*Oxalis pes-caprae*) which formed 90% of the groundcover. Electrofishing effort = 1201 seconds.

Figure 7. Site T-3 photo (2010)

Site

Figure 8. Site T-3 photo (2005) Pitman and Tinkler

T-4 – Tullaroop Creek at Carisbrook

The survey was conducted from 50 metres downstream to 25 metres upstream of confluence with McCallum Creek. Replication of the reach sampled by Pitman and Tinkler (2005) was not possible due to limitations in range of the Bankmounted electrofisher and completion of a 100 metre reach was not possible due to impenetrable aquatic vegetation. The mean width and depth was 8 metres and 0.5 metres respectively, with a benthic composition of sand (25%) and silt (75%). Hydraulic habitat consisted entirely of pools or still water. Available instream habitat consisted of aquatic vegetation (50%), of which 95% was Phragmites, and exposed stream bed (48%). This site had a very high disturbance rating due to cleared riparian vegetation, a large bridge, urban rubbish, sedimentation and exotic vegetation. Electrofishing effort = 985 seconds.

Figure 9. Site T-4 photo (2010)

Figure 10. Site T-4 photo (2005) Pitman and Tinkler

Site T-5 – Tullaroop Creek at Doran Road

This site extended from 60 metres upstream of pump on private property adjacent to Doran Road to 40 metres downstream. The mean width and depth was 6 metres and 0.3 metres respectively, with a benthic composition of silt (80%), sand (15%) and boulders (5%). Hydraulic habitat consisted entirely of pools or still water. Available instream habitat consisted of aquatic vegetation (60%), bare substrate (20%) and some branch piles (10%). Aquatic vegetation was predominantly Phragmites (90%). This site had a very high disturbance rating due to sedimentation, bank erosion and cleared riparian vegetation. Sedimentation at this site is quite pronounced changing from 10% when surveyed in 2005 by Pitman and Tinkler silt presented only 10% of the benthos compared to 80% during the current assessment. Electrofishing effort = 1056 seconds.

Figure 11. Site T-5 photo (2010)

Figure 12. Site T-5 photo (2005) Pitman and Tinkler

Site T-6 – Tullaroop Creek downstream of Tullaroop Reservoir

The site surveyed was a 100 metre section situated approximately 1 kilometre downstream of Tullaroop reservoir. The mean width and depth was 6 metres and 0.8 metres with a benthic composition of silt (80%) and sand (20%). Hydraulic habitat consisted of pools (95%) and a riffle (5%). Available instream habitat present was aquatic vegetation (50%) and branches (5%). Site disturbance rating was very high due to cleared riparian vegetation, culvert, pump inlet, sedimentation and exotic vegetation. Electrofishing effort = 960 seconds.

Figure 13. Site T-6 photo (2010)

Figure 14. Site T-6 photo (2005) Pitman and Tinkler

Site Mc-1 – McCallum Creek upstream of confluence with Tullaroop Creek

Site was not able to be sampled as it was dry.

Figure 15. Site Mc-1 photo (2010)

Figure 16. Site Mc-1 photo (2005) Pitman and Tinkler

Site Mc-2 – McCallum Creek at Rodborough Road

This site was not sampled as the turbidity at this site was uncharacteristically high which would have led to a substantial decrease in electrofishing efficiency.

Site Mc-3 – McCallum Creek at Dunach-Eddington Road

This site extended from 50 metres downstream to 50 metres upstream of the bridge on Dunach-Eddington Road. The mean width and depth was 5.5 metres and 0.6 metres respectively, with a benthic composition of sand (75%), silt (20%) and bed rock (5%). Hydraulic habitat was comprised of pools (70%) and glides (30%). Available instream habitat consisted of bare substrate (70%), aquatic vegetation (20%) and woody debris (10%). This site had a very high disturbance rating due to cleared riparian vegetation, bridge structure and exotic vegetation.

Figure 17. Site Mc-3 photo (2010)

Figure 18. Site Mc-3 photo (2005) Pitman and Tinkler

Site Mc-4 – McCallum Creek at Talbot-Majorca Road

The site surveyed was a 100 metre section at Talbot-Majorca Road. The mean width and depth was 8 metres and 0.2 metres respectively, with a benthic composition of gravel (60%), boulder (20%), sand (10%) and pebble (10%). Hydraulic habitat included a pool (80%) and a riffle (20%). Available instream habitat was comprised of aquatic vegetation (60%), woody debris (15%), rocks (10%) and organic debris (5%). This site had a high disturbance rating due to bank erosion, cleared riparian vegetation and a ford as an artificial barrier. Electrofishing effort = 888 seconds.

Figure 19. Site Mc-4 photo (2010)

Figure 20. Site Mc-4 photo (2005) Pitman and Tinkler

Site Mc-5 – McCallum Creek downstream of Ballarat-Maryborough Road

The survey site was located from 200 metres downstream to 118 metres downstream of bridge on Ballarat-Maryborough Road, with a 100 metre reach unable to be sampled due to impenetrable aquatic vegetation. The mean width and depth was 2 metres and 0.6 metres respectively, with a benthic composition of silt (55%) and sand (45%). Available aquatic habitat was poor at this site with only 35% of instream cover provided by aquatic vegetation, with the remainder being bare substrate. This site had a very high disturbance rating due to bank erosion, cleared riparian vegetation, sedimentation and exotic vegetation. Electrofishing effort = 566 seconds.

Figure 21. Site Mc-5 photo (2010)

Figure 22. Site Mc-5 photo (2005) Pitman and Tinkler

Site Mc-6 – McCallum Creek adjacent to Old Ballarat Road

The site surveyed was located from 200 metres downstream to 100 metres downstream of bridge on Old Ballarat Road. Mean width and depth was 3.5 metres and 0.8 metres respectively, with a benthic composition of silt (90%) and boulder (10%). Hydraulic habitat consisted entirely of pools or still water. Available instream habitat was primarily comprised of leaves and organic debris (80%) and some aquatic vegetation and woody debris. This site had a moderate disturbance rating as there was some clearing of riparian vegetation and bank erosion. Water was hypoxic and algal blooms were visible in the shallower pools. Electrofishing effort = 909 seconds.

Figure 23. Site Mc-6 photo (2010)

Figure 24. Site Mc-6 photo (2005) Pitman and Tinkler

3.3 Water Quality

A comparison of the water quality data between the current survey and those obtained by Pitman and Tinkler (2005) showed a marked difference in electrical conductivity (EC) levels. The mean EC reading across all sites in 2005 was 1150 µs cm^{-1} whereas in 2010 the mean was 2049 µs cm^{-1} at water temperature (see table 4). Long term water quality readings were obtained from NCCMA via Theiss Services for the previous two years and other EC data was obtained by NCCMA for Tullaroop and McCallum Creeks from the late 1970s to 1988 (see figure 26). Maximum and minimum electrical conductivity readings from 1970s to 1988 show fluctuations at both creeks from >500 µs cm^{-1} to ~3 000 µs cm^{-1}. Salinity data obtained by Theiss Services for NCCMA across 8 sites on Tullaroop Creek for the two years preceding the current survey record values exceeding 10 000 µs/cm^{-1} at one site with an average of 4 000 µs/cm^{-1} across all sites. See figure 25 for graphed results and tolerances of River Blackfish highlighting early life stages at which they are most susceptible (Dunlop *et al*. 2005).

Table 4. Water quality at survey sites at time of sampling 2005 and 2010.

Site	EC at water temp (µs cm^{-1})		Temp (ºC)		DO (mg L^{-1})		Turbidity (NTU)		pH	
	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005
Mc1	N/A	1122	0	7.3	0	10.2	0	4.3	0	7.6
Mc2	N/A	1044	0	7.6	0	10.6	0	10	0	7.8
Mc3	1487	1078	6	7.8	9.56	9.3	13.4	2	7.81	7.8
Mc4	1616	766	13	8.2	8.7	7.6	29.2	13.7	8	7.1
Mc5	1399	1010	12	7.8	9.69	10.9	34.8	19	8.08	7.9
Mc6	2759	934	15	8.2	4.73	11.3	N/A	10.1	7.65	8.2
T1	3211	901	8	7	6.24	1.8	27	5	8.04	7.4
T2	1913	1300	8	7.4	10.15	6.4	25	11.6	7.82	7.4
T3	2512	1496	7	7.1	8.6	8.8	8.8	5.3	8.27	7.5
T4	2365	1459	7	7.5	12.29	10.4	11	4.7	8.2	7.5
T5	1888	1310	7	7.6	11.54	10.6	7.5	14.3	8.24	7.7
T6	1343	1383	10	7.9	13.01	10.7	30	3.3	8.85	7.7

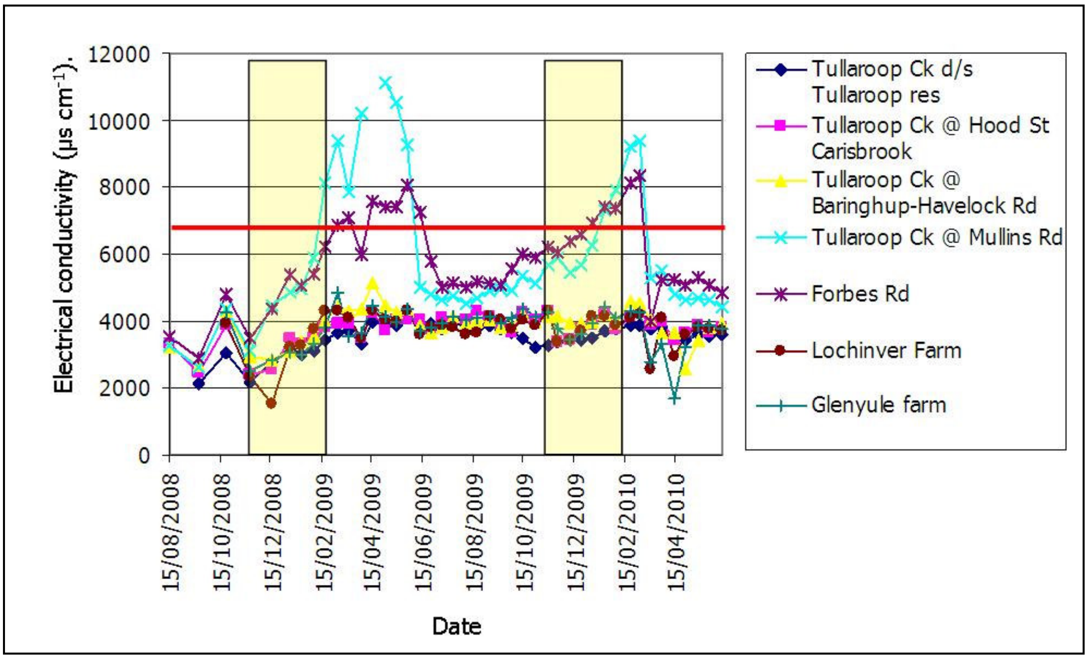

Figure 25. Electrical conductivity at sites in Tullaroop Creek. Shaded yellow areas show time when early life stages of River Blackfish are expected to be present and red line showing acute LC50 for River Blackfish. (data provided by NCCMA collected by Theiss Pty. Ltd.)

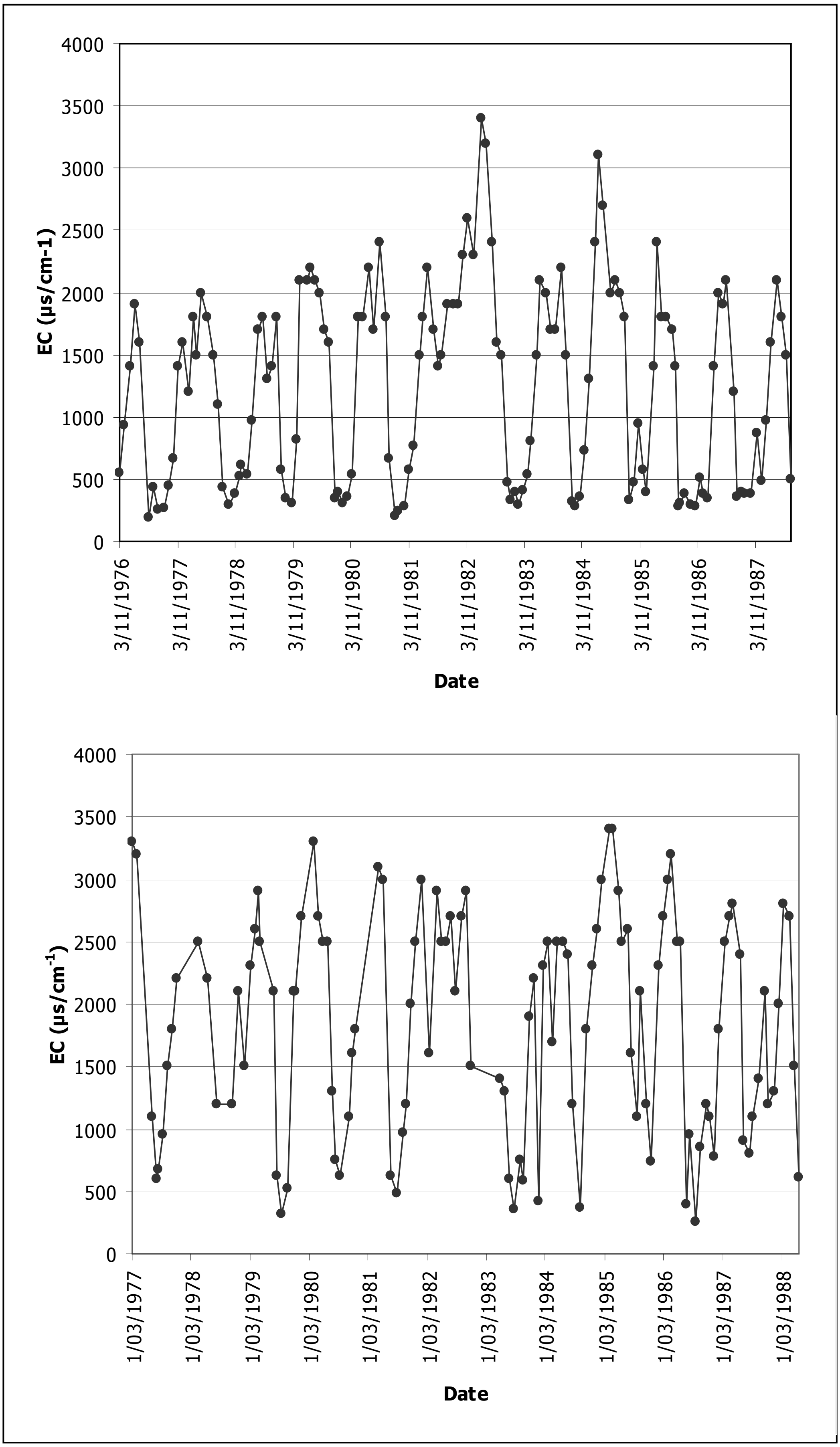

Figure 26. Electrical conductivity at Tullaroop Creek between 1976 and 1987 (top) and McCallum Creek between 1977 and 1988 (bottom). Data provided by NCCMA.

3.4 Fish Surveys

A total of 125 individual fish were caught of which nine different species were identified with the most abundant being Obscure Galaxias (*Galaxias* sp.1) with 35 individuals captured and an additional 32 observed. Flat-headed Gudgeon (*Philypnodon grandiceps*) was the next most frequently detected (36 individuals), followed closely by the introduced Mosquito Fish (*Gambusia holbrooki*) with 35 individuals. Tench (*Tinca tinca*) was recorded in 2005, but were not recorded during the 2010 survey. Two species, European Carp (*Cyprinus carpio*) and Roach (*Rutilus rutilis*), not recorded in 2005 were collected in 2010. European Carp were represented by two individuals captured at the site situated furthest downstream (T-1), and the most upstream site below Tullaroop Reservoir (T-6) where one large individual (685 mm) was captured.

The proportion of alien fish species was higher in 2010 comprising 41% of individuals caught whereas in 2005 only 9% of the catch was represented by alien species. For the current survey native species comprised 24% of the fish biomass whereas alien species represented the remaining 76% (excluding one large carp which exceeded 7 kg and 18 Mosquito Fish weighing <0.1 gram).

One River Blackfish was collected during this survey, recorded at site T-4. This shows a marked reduction in their occurrence across the sites when compared with the survey of the same sites, conducted by Pitman and Tinkler in 2005 when 22 River Blackfish were recorded.

In McCallum Creek there was a distinct reduction in the total number of all fish species captured (native and exotic species) compared to the 2005 survey, with only 14 fish captured during 2010 compared to 248 individuals in 2005 (Pitman and Tinkler). Redfin (*Perca fluviatilis*) comprised a significant proportion of the total catch in 2010 (comprising 11 of the 14 individuals captured), whereas this species was not detected in the 2005 surveys. The most significant change to the distribution and abundance of fish species in McCallum Creek was represented by Obscure Galaxias which were captured in relatively high abundance at five of the six sites during the 2005 surveys, compared to the 2010 survey where only two individuals were recorded from one site (site Mc-4). Flatheaded Gudgeon was found in low abundance at site Mc-3 (where one individual was captured) compared to six individuals recorded at site Mc-5 in 2005 .

One Flatheaded Gudgeon was collected using the fyke nets at T-3 (measuring 105 mm), with no other fish species being detected with this method.

Table 5. Fish species caught across survey sites during 2010 electrofishing surveys. Figures in brackets represent individuals caught during 2005 survey.

Site	GAD MAR	GAL SP.1	PHI GRA	RET SEM	GAM HOL*	PER FLU*	CAR AUR*	CYP CAR*	RUT RUT*	TIN TIN*	Total
T-1			**24** (2)	**1**	**2**	(11)	(4)	**2**			**29** (17)
T-2					**16** (2)	(11)	(2)				**16** (15)
T-3	(14)	(13)	**1**								**1** (27)
T-4	**1** (1)	**22** (28)	**2**		**14** (1)		**2**		**1**		**42** (30)
T-5	(1)	**10** (7)	(1)		**1**					(2)	**11** (9)
T-6	(2)	**1** (2)	**8** (12)		**2**	(1)		**1**			**12** (17)
Mc-1		(1)		(1)							**0** (2)
Mc-2											**0** (0)
Mc-3	(1)	(21)	**1**	(65)		**5**					**6** (87)
Mc-4		**2** (96)				**1**					**3** (96)
Mc-5	(2)	(33)	(6)			**5**					**5** (41)
Mc-6	(1)	(21)									**0** (22)
Total	**1** (22)	**35** (222)	**36** (21)	**1** (66)	**35** (3)	**11** (23)	**2** (6)	**3** (0)	**1** (0)	**0** (2)	**125** (363)

* **Denotes alien species.**

3.5 River Blackfish Habitat

Apart from aquatic vegetation levels, there was little variation in the structural habitat available to River Blackfish between the current surveys and those conducted in 2005 (Pitman and Tinkler). Structural habitat levels at the majority of sites are considered suitable for River Blackfish, with structural woody habitat, aquatic vegetation and rocks recorded at all sites, in varying quantities. Aquatic vegetation was detected in greater abundance than in the previous survey with photographic comparisons of the sites outlining variations (see site photographs figure 3 -24).

Distinct differences in the streambed silt levels were detected between survey events particularly in Tullaroop Creek where an increase in silt of up to 70% was observed (see figure 26). No discernible differences were observed in McCallum Creek.

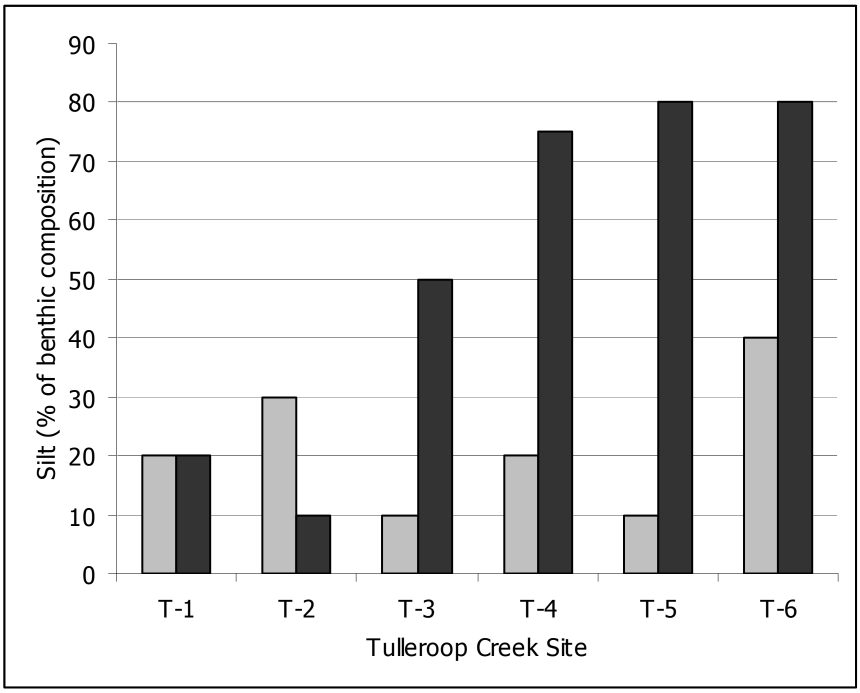

Figure 26. Comparison of streambed silt at sites on Tullaroop Creek. Grey bars 2005 and black bars 2010.

4 Discussion

This study found only one River Blackfish, at site T-4 on Tullaroop Creek, compared to 22 individuals captured at seven of the 12 sites surveyed during 2005. Although different electrofishing gear types were used in each survey, the substantial decrease in River Blackfish captured during 2010 should not be attributed to this factor. In contrast, the electrofishing equipment used during the current survey has a far greater output and electrical field range, resulting in greater electrofishing efficiency, compared to the backpack electrofisher used in the previous 2005 sampling event (Pitman and Tinkler). Fyke nets were used at a subset of the sites sampled to verify that the density of river blackfish was very low rather than being due to sampling inefficiency. No River Blackfish were caught in the fyke nets supporting the data collected using the bankmounted electrofisher.

The poor catch rates of River Blackfish at all sites clearly indicates a downward trend in population density from Tullaroop Creek between Tullaroop Reservoir and the confluence with the Loddon River. This supports conclusions made by the Loddon River Environmental Flows Scientific Panel (2002) that River Blackfish populations in Tullaroop Creek are in poor condition.

No River Blackfish were detected at the sites surveyed on McCallum Creek. Of the 22 fish recorded in 2005, four were from McCallum Creek. The absence of River Blackfish in this survey also highlights a decline in the McCallum Creek population. Additional data from site Mc-5 on McCallum Creek which has been surveyed on four separate occasions since 1999, also highlights the decline of River Blackfish populations, gradually falling from six individuals in 1999 to no individuals captured in 2010. This decline may be representative of conditions throughout the McCallum Creek system where large sections had dried completely over the recent drought period. In the isolated pools that remained, it is questionable as to whether enough oxygen remained in the water or if the electrical conductivity was within tolerable limits for River Blackfish. Fish species that were collected during the surveys, including Flatheaded Gudgeon, Obscure Galaxias, and Redfin, are species that are able to tolerate high levels of salinity (James *et al*, 2003).

A greater diversity of alien species was detected across all sites surveyed in 2010 with two species, Roach (*Rutilis rutilis*) and European Carp (*Cyprinus carpio*) recorded for the first time during fish surveys. Both these species are known to be tolerant of elevated salinity levels and are reported to be able to tolerate ‘brackish’ water conditions (Cadwallader and Backhouse 1983).

4.1 Factors influencing the distribution and abundance of River Blackfish

This study is focused on the impacts of a prolonged drought period on River Blackfish populations in Tullaroop and McCallum Creeks. Obvious impacts include a marked reduction in the availability of surface water in Tullaroop Creek, with the creek being reduced to unconnected pools over summer months (A. Teese., pers comms. 2010). Very low water levels would also result in a reduction in available habitat for fish species as snags and aquatic vegetation became exposed. Water quality data provided by NCCMA show levels of dissolved oxygen reaching zero at a number of sites. Unless refuge pools containing suitable water quality conditions were available at these sites, it is extremely doubtful that native fish species would persist at these locations.

River Blackfish have been noted to be in decline throughout the majority of its pre-European range in Victoria with numerous factors being identified as the causes of the decline (Cadwallader and Backhouse, 1983: Koehn and O’Connor, 1990: Jackson *et al*. 1996; Bond and Lake, 2003 and Bond and Lake, 2005). Of the factors known to impede the persistence of River Blackfish, most were present in Tullaroop Creek over the drought period. These include (but are not limited to) reduced available habitat, clearing of riparian vegetation, sedimentation, predation from alien fishes, low dissolved oxygen, high electrical conductivity, resource competition with alien species and water security. All of these conditions are known to impact River Blackfish and have the potential to be exacerbated by the extended drought period that has occurred in the North Central Catchment from 1999-2010.

In addition to these documented factors, aquatic vegetation and in particular Phragmites and Cumbungi were recorded at substantially greater densities than in 2005 (Pitman and Tinkler). While emergent vegetation such as Phragmites and Cumbungi may provide some habitat for River Blackfish, dense stands constrict the main channel and reduce available pool habitat which are often used as refuges during low flow conditions. The reduced flow regime downstream of Tullaroop Reservoir during drought conditions has provided favourable conditions for these two plant species. Phragmites also produces large quantities of vegetative material that, during times of stress, will decompose in the waterway resulting in anoxic water (Asaeda and Karunartne, 2000).

Increasing stream salinity levels is an increasing concern in Australia, particularly over the current drought period where they pose a severe threat to aquatic ecosystems. These conditions result in the mortality of fish species when levels increase to the point where species are unable to regulate their osmotic processes (Schofield and Ruprecht, 1989; Jolly *et al*. 2001; Clunie *et al*. 2002 and Kefford *et al*. 2004; Dunlop *et al*. 2005). Electrical conductivity of the water in Tullaroop Creek and McCallum Creek display a marked increase since the 2005 surveys conducted by Pitman and Tinkler, with conductivities ranging from between 901 – 1,496 $\mu s/cm^{-1}$ in 2005 and 1,343 – 3,211 $\mu s/cm^{-1}$ in 2010. The electrical conductivity readings taken at the time of the surveys are lower than readings taken earlier in the year by Thiess (see Figure 25) where electrical conductivity levels exceed 10,000 $\mu s/cm^{-1}$. The tolerance of River Blackfish to elevated electrical conductivity levels are much lower than many other native species with osmoregulatory processes beginning to break down at approximately 7,500 $\mu s/cm^{-1}$ (Tunbridge, 1988; James *et al,* 2003; Kefford *et al*. 2004 and Dunlop *et al*. 2005). Factors exacerbating salinity levels in Tullaroop Creek include the accumulation of salts through the evaporation of Tullaroop Reservoir which are subsequently released downstream, potential run-off from irrigated bore water used on crops and pasture, and influx of groundwater to streams (Jolly *et al*. 2001).

There is insufficient data to identify the range of macro-invertebrate species selected as prey by River Blackfish in Tullaroop Creek, as literature documenting the diet of River Blackfish is primarily concerned with populations occupying upland streams. It is known that macro-invertebrates are particularly susceptible to increased salinity levels, with the majority of species suffering adverse or lethal effects at 3, 000 $\mu s/cm^{-1}$ (Dunlop *et al*. 2005). This highlights the indirect effects that increased salinity levels may have on River Blackfish through a reduction in available prey items.

Tullaroop Creek is located in an area which is heavily influenced by agricultural practices, being the primary source of income for the communities in the area. As such the clearing of riparian vegetation and bank erosion resulting from these landuse practices has had a negative impact on Tullaroop Creek. The clearing of streamside vegetation reduces the biodiversity of riparian ecosystems thus reducing the number of interactions that need to occur between species to complete their life cycles (Jansen and Robertson, 2001). Clearing of riparian vegetation and bank erosion was noted at all sites with high levels of both disturbance categories evident at most sites. The removal of riparian vegetation not only removes components of a functioning aquatic ecosystem such as organic input from leaves and small branches, but also removes future instream woody habitat. This habitat component has been identified as a key requirement for River Blackfish as it provides refugia and spawning habitat in the form of hollow logs (Kahn *et al.* 2004). Leaves and detritus also form refuge for juvenile River Blackfish.

Pitman and Tinkler (2005) documented that the site with the highest number of River Blackfish was also the site with the lowest streambed silt composition. The streambed silt composition (sedimentation) at sites surveyed in Tullaroop Creek display a marked increase compared to levels documented in 2005. The impacts of increased sediment loads are known to adversely affect the successful recruitment of River Blackfish as it can smother the adhesive eggs or prevent their attachment to hollow logs (Jackson *et al*, 1996; Koehn and O'Connor, 1990). Sedimentation in Tullaroop Creek is exacerbated by the regulated flow released from Tullaroop Reservoir which reduces the incidence of high flow events which are necessary to mobilise deposited sediments further downstream. The prolonged drought period has had a marked increase in sedimentation levels in Tullaroop Creek due to a reduction in water available for environmental flows (Velik-Lord, B. pers comms. 2010). While low levels of sedimentation are a natural and necessary component of river morphology evolution, human induced erosion in agricultural landscapes is a primary cause of sedimentation of waterways (Bond and Lake, 2005), frequently leading to the infilling of deeper holes and the blanketing of substrate and habitat which is necessary for aquatic species including River Blackfish.

Redfin are an introduced species that is highly piscivorous and is known to prey on many smaller native small bodied fish species, as well as excluding them from prime habitats and food resources (Allen et al, 2002). Redfin were found at four sites in 2005 and three sites in 2010. Juvenile River Blackfish are highly susceptible to predation from Redfin, with larger individuals known to specifically target slower moving benthic fishes (Rowe *et al.* 2008). Two Redfin collected during the electrofishing surveys were dissected and their stomach contents revealed the presence of Flatheaded Gudgeon, a benthic species that shares behaviour similar to juvenile River Blackfish (Jackson, *et al*, 1996). With the low levels of flow present in Tullaroop and McCallum Creeks, native fish species are likely to have been restricted to refuge pools, increasing the likelihood of predation by Redfin. This factor is likely to have a pronounced effect on the ability of River Blackfish to persist in Tullaroop and McCallum Creeks under drought conditions.

4.2 Management recommendations for the persistence of River Blackfish

The aim of this study was to assess the ability of the River Blackfish population to persist in Tullaroop and McCallum Creeks under drought conditions and to identify means of reducing the impacts that adversely affect this ability. This assessment found that River Blackfish have dramatically decreased in abundance, but have been able to persist in Tullaroop Creek through the prolonged drought period, although in very low numbers. River Blackfish take many years to recolonise areas that had been made unsuitable through lack of water or available habitat (Bond and Lake, 2005), thus increasing the importance of securing the remaining population. Further research is required to assess the extent of the population decline across the catchment to ascertain the impact of these effects. Key refugia pools may be identified, which need protecting if drought conditions persist or return in the future.

This study identified several factors adversely affecting the ability of River Blackfish to persist in Tullaroop and McCallum Creek, all of which have been exacerbated by the drought period. Of these factors, water quality is of primary concern, with limited volumes frequently being restricted to isolated pools which are affected by extremely low dissolved oxygen levels, elevated salinity levels and potential algal blooms resulting from elevated nutrient levels as a result of unrestricted stock access. Appropriate water use is a factor that can be managed to reduce surface water salinity, sedimentation and improve overall water quality. The Loddon River Environmental Flows Scientific Panel (LREFSP) (2002) outlined flow recommendations for Tullaroop Creek with the aim of maintaining positive environmental values with a key priority to maintain River Blackfish populations. The limited availability of water in Tullaroop Reservoir has reduced the capacity of NCCMA Environmental Flows Division to meet these recommendations (Velik-Lord, B. pers comms, 2010). Adhering to the recommendations outlined by LREFSP (2002) will provide a waterway with hydraulic characteristics fundamental to the persistence of River Blackfish in Tullaroop Creek. These recommendations will reduce sedimentation and salinity and improve the overall quality of water for all aquatic organisms. Zampatti and Lieschke (1999) and LREFSP (2002) identified that adult River Blackfish require a minimum water depth of 20 centimetres.

While reducing salinisation and sedimentation is of a higher priority, if there is a capacity to maintain this depth throughout the reach, compliance with these guidelines is recommended.

Targeted River Blackfish surveys at sites known to support River Blackfish populations should also be undertaken to investigate the impacts of drought on these larger populations with the aim of identifying remaining healthy populations and key refugia sites.

Further studies are recommended to assess the extent of salinity in Tullaroop Creek Catchment through monitoring of additional sites across a broader geographical area.

Instream structural woody habitat is a key habitat requirement for River Blackfish and is a fundamental component of lowland stream ecosystems, supporting a variety of aquatic organisms (Crook and Robertson, 1999 and Koehn *et al*, 2004). As such, some habitat rehabilitation works have been conducted in Tullaroop Creek and it is recommended that these improvements be augmented with revegetation of riparian zones to restore a level of biodiversity that supports the interactions required for a functioning riparian ecosystem. Other sites for revegetation works should be prioritised on the basis of selecting sites that provide potential habitat for River Blackfish, including deep pools with instream woody habitat. The benefits of riparian revegetation to River Blackfish include; increased suitable habitat for macro-invertebrates, a reduction in run-off of sediments and saline water, reduced bank erosion and provision of instream shading to reduce evaporation of refuge pools over extended dry periods. A secondary outcome of revegetation of the riparian zone will be a reduction in the occurrence of Soursob (*Oxalis pes-caprae*) which has been identified as a cause of large scale soil movement (DPI, 2009).

Redfin have been identified as a threat to River Blackfish in Tullaroop and McCallum Creek, and as such measures need to be taken to prevent further incursions into these systems. It is recommended that the feasibility of the reduction of impacts associated with Redfin and other pest species in Tullaroop and McCallum Creek be assessed.

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