The Speckled Livebearer *(Phalloceros caudimaculatus)*: A New Alien Fish for South Australia.

A report to PIRSA Fisheries

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EXECUTIVE SUMMARY

This report outlines the initial ground truthing survey of a reported population of alien speckled livebearers, *Phalloceros caudimaculatus*, in the Willunga region, the far southern suburbs of the greater Adelaide region in South Australia. The survey was conducted on behalf of the South Australian Department of Primary Industries and Resources (PIRSA) Fisheries Section by the South Australian Research and Development Institute Aquatic Sciences (SARDI, also a part of PIRSA) on the 18th of September 2008.

The aim of the survey was to follow up public reports of the infestation of speckled livebearers and to:

(1) Verify these reports and positively identify that the species in Willunga Creek was in fact *P. caudimaculatus*.

(2) Determine the extent of their distribution in this creek and surrounding waterbodies.

(3) Establish baseline knowledge of the population regarding their abundance and recruitment to determine if the population is self-sustaining.

(4) Determine the presence of native fish in the area that might be impacted by the species, or by subsequent control activities.

The survey found a large, well established and self sustaining population of *P. caudimaculatus* in Willunga Creek within the township of Willunga, the area of the initial sightings. In addition, the survey found that the population extended upstream and downstream where flow was present. The creek was completely dry both upstream and downstream of the township, isolating the population in the permanently flowing reach around the Willunga Township.

The majority of the catchment including tributaries and connecting streams was completely dry at the time of sampling. *P. caudimaculatus* was not found in any adjacent waterways but the species may still be present in un-surveyed reaches downstream of the survey area. There were no native fish present in Willunga Creek, however a good population of native mountain galaxias (*Galaxias olidus)* were present in an adjacent creek (Wirra Creek) where there were no *P. caudimaculatus*.

The results of this survey highlight this population of *P. caudimaculatus* as an ideal target for a dedicated pest eradication program due to their apparent isolation and the lack of other fish species in the creek.

It is recommended that PIRSA engage with other South Australian government agencies and Natural Resource Management (NRM) groups to develop and implement a plan for eradicating this population. This plan will need to made in conjunction with the community and will require a detailed risk assessment to avoid any subsequent negative impacts of pest control activities.

Follow-up surveys should be included in the management plan to monitor and evaluate the success of the chosen control option. This will ensure that if the population recovers it is quickly identified and addressed. Where possible the management and control of this population should be linked with Pest Fish Response Plans that are currently being developed under the Murray-Darling Basin Commission and the Invasive Animals Co-Operative Research Centre.

1. INTRODUCTION

Phalloceros caudimaculatus (Hensel, 1868) is a freshwater and brackish-water fish native to eastern South America (Brazil from Rio de Janeiro southwards) belonging to a family of livebearers (Trendall and Johnson 1981, McDowall 1999, Allen *et al.* 2002, Wolff *et al.* 2007). It is known by a range of common names including 'caudo', 'dusky millionsfish', 'one-spot livebearer' and 'speckled mosquitofish' (McDowall 1999, Morgan *et al.* 2004). It is considered, however, that the name 'mosquitofish' is misleading and should be avoided for alien poeciliids (Lloyd 1990). Additionally, the highly speckled form of *P. caudimaculatus* present in Australia makes the 'one-spot' title misleading and can also cause confusion and false identification with a closely related pest species, *Gambusia holbrooki*, which actually has one spot. The common name of speckled livebearers will therefore be used in this report.

P. caudimaculatus is a small stocky fish with large eyes that is compressed towards the tail (McDowall 1999) (Figure 1). It has variable coloration depending on its location but is generally mottled yellow with black spots (Rowley *et al.* 2005). The identification of *P. caudimaculatus* has been confused with *G. holbrooki* in the past due to their similar appearance and the variable colouration between individuals. Examination of the gonopodium can be used to distinguish between the two species (Trendall and Johnson 1981).

The livebearer has a broad diet being an omnivore (mainly algae) or a carnivore (small aquatic invertebrates) in still or gentle-flowing waters (McDowall 1999, Morgan *et al.* 2004, Wolff *et al.* 2007). Both male and female *P.caudimaculatus* reach sexual maturity at a standard length (SL) of 18 mm (Morgan *et al.* 2004). It is capable of gestating more than one brood of young at a time and can produce litters of 20-80 young at intervals of 5-6 weeks (McDowall 1999). Its breeding season may be longer than the breeding season of *G. holbrooki* and it may be able to tolerate more variable hydrological regimes (Morgan *et al.* 2004, Rowley *et al.* 2005, Wolff *et al.* 2007). *P. caudimaculatus* is known to tolerate temperatures as low as 5ºC and as high as 38ºC and it may also tolerate low oxygen concentrations due to its morphological adaptation of an upturned mouth in a similar way to *G. holbrooki* (Rowley *et al.* 2005, McNeil and Closs 2007).

Figure 1. The speckled livebearer, *Phalloceros caudimaculatus* (Hensel, 1868), from Willunga Creek in Willunga.

In 1963 *P. caudimaculatus* was permitted import into Australia for the aquarium trade, however, in 1998, due to information on their biology, behaviour, or capacity to become feral in other countries, importation was no longer permitted (McKay 1984). Six species of poeciliid have established non-indigenous populations in Australia, primarily due transportation around the world by the aquarium trade. To date only one of these species, *G. holbrooki*, is widespread and abundant in Australia. *P. caudimaculatus* has one of the most restricted distributions of the six species of Poeciliidae in Australia (Rowley *et al.* 2005).

The current distribution and the date of introduction of *P. caudimaculatus* into Australia are not known (Trendall and Johnson 1981), however it has been recorded at Lesmurdie Falls on the Swan-Avon Rivers system, Western Australia, Sydney, Northern Territory (Rowley *et al.* 2005), the Todd River Catchment in the Lake Eyre Region (Wager and Unmack 2000), and at five

locations near Perth (Allen *et al.* 2002; Morgan *et al.* 2004). There is an unpublished report that this species has been found in outdoor ponds in South Australia (Arthington *et al.* 1999) however the South Australian Museum and the Fisheries Department in South Australia (South Australian Department of Primary Industries or PIRSA) have no record of this. *P. caudimaculatus* was listed as a noxious species under the Fisheries Management Act 1994 (NSW) in November 2002, after its first sighting in NSW in March 2002 (Rayner and Creese 2006). Similarly, in Queensland it is unlawful to possess this species (Wager and Unmack 2000).

In captivity this species is reported to behave in a relatively non-aggressive manner, which may partially alleviate its potential impacts on native fish (McDowall 1999, Morgan *et al.* 2004), however its ecological impacts remain unknown (Rowley *et al.* 2005). The invasive ability of *P. caudimaculatus* is similar to that of *G. holbrooki* as it encompasses a similar range of latitude and elevation, and there is some evidence to suggest that *P. caudimaculatus* may be capable of displacing *G. holbrooki* (Rowley *et al.* 2005). Further research is required to determine the ecological impacts of *P. caudimaculatus*, and to also explore the possibility of this species displacing *G. holbrooki*. Due to its wide temperature tolerances and prolonged breeding season, allowing rapid colonisation, the impacts of this species could result in the displacement of native fishes (Morgan *et al.* 2004).

Historically, *P. caudimaculatus* is not known to have been collected or to have become established in the Adelaide region, or anywhere else in South Australia (Hammer and Walker 2004, McNeil and Hammer 2007). In 2008, two independent reports were made regarding the presence of this species within a small suburban creek in the Greater Adelaide Region in South Australia. The first report came from community member Mr Bill Round who had collected the species from a tributary of Willunga Creek in Willunga for over three years and had bred them in aquaria at Hallett Cove Secondary School where he taught. The second report came from an aquarist, Mr Matthew Handf, who contacted PIRSA Fisheries in Autumn 2008 following his discovery of the fish whilst bait trapping for yabbies in the same creek.

PIRSA Fisheries subsequently commissioned a baseline survey of the area. The aims of this survey were to:

(1) Verify these reports and positively identify that the species in Willunga Creek was in fact *P. caudimaculatus*.

(2) Determine the extent of their distribution in this creek and surrounding waterbodies.

(3) Establish baseline knowledge of the population regarding their abundance and recruitment to determine if the population is self-sustaining.

(4) Determine the presence of native fish in the area that might be impacted by the species, or by subsequent control activities.

The results of this survey will then be used to develop recommendations for management and for further research on this species and will address potential options for controlling the population to prevent its spread into other areas.

2. METHODS

2.1 Survey area and approach

The survey was targeted towards the site of the reported collections, which centred on a tributary of Willunga Creek where it transects Methodist Street until it runs under Aldinga Road a few hundred metres downstream. According to the Natural Resources Management Board and the Willunga Council this creek hasn't yet been named and it is an eastern tributary of Willunga Creek. In this report it is named as Willunga Creek however it should be noted that the study area is an unnamed tributary of this creek. This section of the creek has been modified in the past and runs in a straight line along the front of properties in both Methodist Street and Giles Road (Sites 5 and 6, Figure 2). This area was netted most comprehensively with nets places every 20-30 metres over a distance of approximately 1.2 kilometres.

Downstream distribution

To investigate the downstream distribution of the population, nets were placed in lower densities at four additional sites; 1) downstream of the Aldinga Rd culvert along Norman Street (Site 7); 2) in the creek as it runs through the Peacock Farm Bed and Breakfast (Site 8); 3) through Potter's Clay vineyard (Site 9); 4) a public reserve before re-entering private land through the old sewage

settlement ponds towards the Victor Harbour Road Culvert (Figure 2). Downstream of this culvert all standing water was electrofished extensively until the creek became totally dry (Sites 12-14, Figure 2). Downstream from these sites Willunga Creek was dry for several kilometres, as was Willunga Creek, both upstream and downstream of it's junction with Willunga Creek.

The survey downstream was stopped upstream of Main South Road where no standing water was observed. It was decided that the creek was completely dry downstream of the Victor Harbour Road (Site 11) and that the population was most likely restricted upstream of this road (Figure 2). It should be noted that permanent pools downstream of Main South Road may hold this pest fish but were not surveyed. Off channel dams were also present along this reach with the Potters Clay vineyard dam (Site 10) and the Willunga sewage works on Little Road holding water. The vineyard dam was included in the netting survey whilst access was not available to the water treatment works. This site should also be noted as a possible site for the species but was not sampled in this survey.

Upstream distribution

To determine the upstream distribution of the population, an electrofishing survey was conducted upstream of the pipeline through which the creek passes downstream under Victor Harbour Road and into the Willunga township at Giles Road. The survey was conducted through the Ross Roses property and was taken up again further upstream where the creek intersects St. Johns Terrace (Site 3) and then Quarry Road (Site2) (Figure 2). Upstream of the Quarry Road culvert the creek was dry; however two large dams were present. The lower dam was electrofished (Site 1) however further sampling, which was outside the scope of this short survey, is required to determine if they are sites where the species may persist (Figure 2).

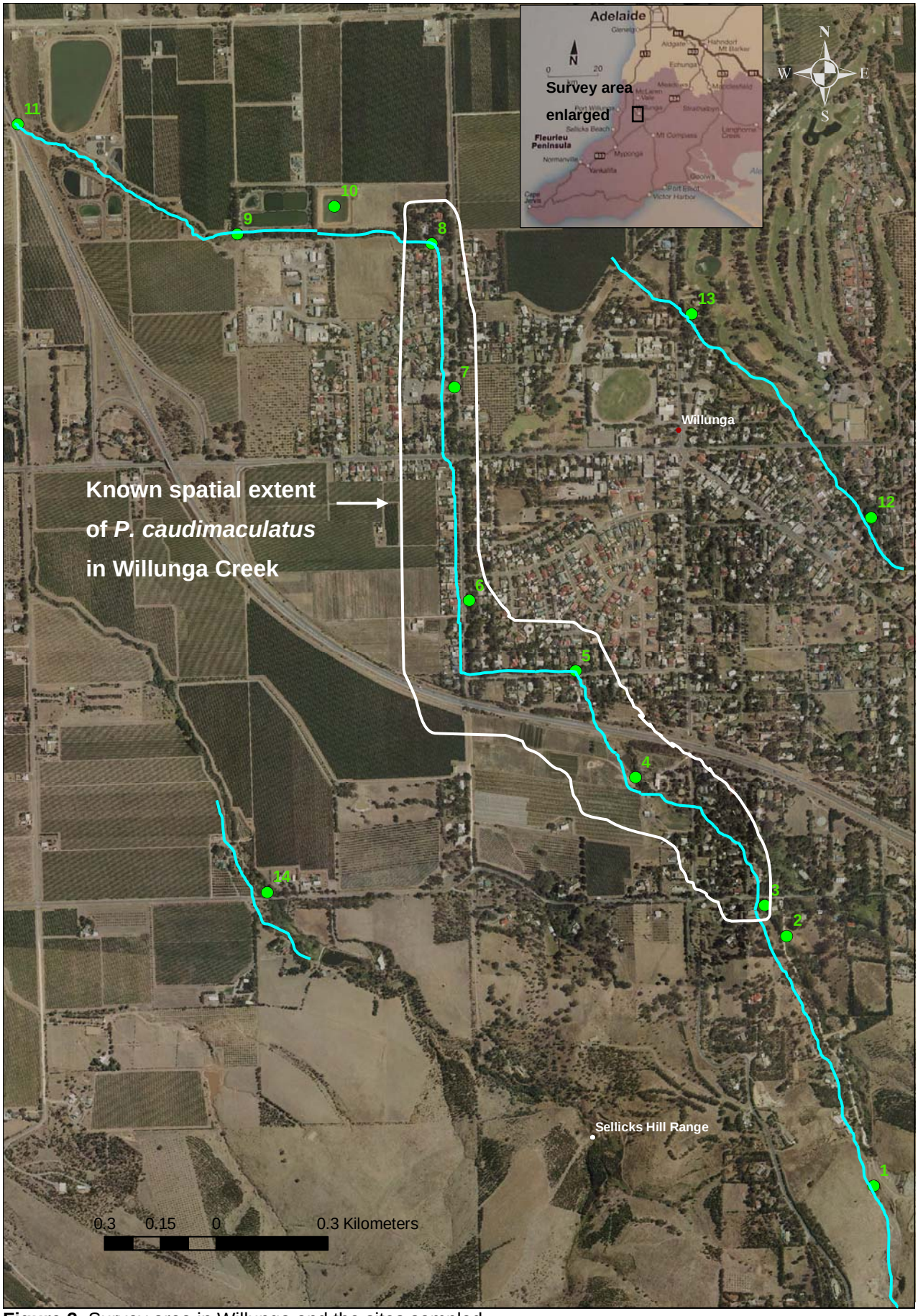

Figure 2. Survey area in Willunga and the sites sampled.

A wider survey found that all adjacent creeks were completely dry with two exceptions, a small amount of water was present in upper Willunga Creek at the Colville Road Bridge (Site 14) and flowing water was present in Wirra Creek, which intersects the Willunga Golf Course on the North Eastern corner of Willunga Township. Wirra Creek was surveyed upstream of the Main Road Culvert (Site 13) and further upstream at St. James Street (Site 12) where the creek passes under the old slate bridge a few hundred metres downstream of where the creek springs amongst private property. The GPS locations of all sites are listed below (Table 1) and are located on the regional map (Figure 2).

Table 1. Survey sites and sampling methods. Note sites that were dry are not included in this table.

Site No.	Site Name	Stream Name	Survey Method*
1	Slate Quarry dam	Willunga Ck	EF
2	Quarry Rd	Willunga Ck	EF
3	St Johns Terrace	Willunga Ck	EF
4	Ross Roses	Willunga Ck	EF
5	Giles Road	Willunga Ck	F, B, EF
6	Methodist Street	Willunga Ck	F, B
7	DTEI	Willunga Ck	F, B
8	Peacock Farm	Willunga Ck	F, B
9	Vineyard (old sewage ponds)	Willunga Ck	F
10	Potters Clay Vineyard Dam	Willunga Ck	F
11	Victor Harbour Road culvert	Willunga Ck	EF
12	St. James Road	Wirra Ck	EF
13	Main Road	Wirra Ck	EF
14	Colville Rd	Willunga Ck	EF

*Survey methods: F = Fyke netting, B = Box traps, EF = Electrofishing

2.2 Fish survey

To determine the abundance of *P. caudimaculatus* in Willunga Creek small fyke nets (wing length 3 m, mesh size 3 mm) and unbaited box traps were set at 6 different sites (Site No. 5-10, Table 1, Figure 2) along the creek on the 18th of September 2008 (Figure 3). Additionally, surrounding waterbodies and adjoining creeks were surveyed using backpack electrofishing.

Figure 3. Survey sites a) Giles Road, b) Methodist Street, c) Peacock farm in Willunga, d) Vineyard downstream of the peacock farm, e) Potter's Clay vineyard dam and f) electrofishing on Giles Road. Note that a, b and c all had very strong populations of *Phalloceros caudimaculatus*, and in site d and site e *P. caudimaculatus* were absent.

Fyke nets and box traps were set overnight for one night at each site on the 18th of September 2008. Equipment was retrieved within approximately 24 hours of the nets and traps being set to account for potential diurnal movement of fish. The lengths of all *P. caudimaculatus* captured (or a subsample per species at each site, n=100) were measured to the nearest millimetre and then immediately destroyed. The size distribution of *P. caudimaculatus* was plotted using combined data from all of the sites.

Sampling by backpacking electrofishing was conducted on the same day that the nets were retrieved. All electrofishing sites were less than 25m in length with electrofishing time varying between 62 and 324 seconds depending on site characteristics. The entire stream at each site was sampled, including banks and the mid-stream, as well as any small backwaters or connecting ponds. The electrofishing catch includes the number of fish stunned, captured and observed. The electrofishing catch per unit effort (CPUE) was standardised as the number of fish per 100 seconds of electrofishing time.

2.3 Species identification

Identification of *P. caudimaculatus* was conducted using the key to poeciliid species presented in McDowall (1999). Ray counts from the dorsal and pectoral fins, black blotches, and the presence and size of the hooked gonopodium were used to positively identify a subsample of fish (n=10) from Willunga Creek during the survey. These specimens will be lodged with the South Australian Museum as type specimens.

3. RESULTS

All ten individuals of the target species keyed out for taxonomic identification were clearly classified as *Phalloceros caudimaculatus* (Hensel, 1868). All of the fish had black blotches and all of the males (n=4) had a hooked gonopodium that were longer than their heads (Figure 4). *Gambusia affinis* and *G. holbrooki* never have hooked gonopodium (Lloyd 1990). Dorsal and fin ray counts were either 8 or 9 for all specimens, fitting within the description for *P. caudimaculatus* (Lucinda 2008). Alternatively, *G. affinis* possess 6 dorsal rays (McDowall 1999) and *G. holbrooki* 7 dorsal rays (Lloyd and Tomasov 1985, Lloyd 1990). Additionally, *G. affinis* has more than 12 pectoral rays whilst all of our specimens possessed either 8 or 9. The individual characteristics used for classification are presented in Table 2.

Figure 4. Specimens used for the taxonomic identification of livebearers from Willunga Creek. Note the variation in pigmentation, size and morphology between individuals.

Table 2. Results of the taxonomic identification for the 10 fish sub-sample from Willunga Creek including the criteria used for their classification.

Sample No.	Presence of black blotches	Gonopodium longer than head	Gonopodium hooked	Dorsal ray count	Pectoral ray count
1	Yes	Female	Female	8	8
2	Yes	Female	Female	9	9
3	Yes	Female	Female	8	8
4	Yes	Yes	Yes	9	9
5	Yes	Yes	Yes	8	8
6	Yes	Yes	Yes	9	9
7	Yes	Yes	Yes		9
8	Yes (few)	Female	Female		9
9	Yes (few)	Female	Female		9
10	Yes (few)	Female	Female		9
*Phalloceros caudimaculatus**	Yes	Yes	Yes	7-9	9-10
*Gambusia affinis**	No	No	No		12+

** As described in McDowall (1999)*

3.1 General fish community

Netting

A total of 1,009 fish were captured from all sites in Willunga Creek using fyke nets and box traps. Of these 1,009 fish, 99.5% of the total catch (TC) was *P. caudimaculatus*; the remainder 0.5 % (TC) was *G. holbrooki*. The only species of fish caught using fyke nets and box traps was *P. caudimaculatus* (Figure 5) at sites 5-9. *P. caudimaculatus* was absent from sites 10 and 11. At site 10, the vineyard dam, only five *G. holbrooki* were captured making up 100% of the total catch at that site.

Figure 5. Typical catch of *Phalloceros caudimaculatus* from a box trap at Willunga Creek.

Electrofishing

A total of 1,727 fish were caught or observed during the backpack electrofishing survey in Willunga Creek. Apart from *P. caudimaculatus* (99.9% TC), the only other species caught in Willunga Ck was common carp (*Cyprinus carpio*) of which a single pair (0.1%TC), male and female, were captured in spawning condition at Giles St (Table 3). Whilst *P. caudimaculatus* was electrofished across sites 3-6, the extreme upper (sites 1-2) and lower (from site 11 – downstream) reaches either possessed no fish at all or were completely dry. In the adjacent catchments, the Wirra Creek sites possessed a single species, the native mountain galaxias (*Galaxias olidus*) (0.6% TC) (Table 3). Sites in Willunga Creek (west branch) and other adjacent streams had no fish (site 14) or were completely dry. No *P. caudimaculatus* were captured outside of the Willunga Creek catchment and no native fishes were captured in Willunga Creek.

Table 3. Results of the netting and electrofishing surveys for *P. caudimaculatus*. Netting catches are standardised to catch per unit effort (CPUE) by dividing the total catch by the number of nets/traps set. Similarly electrofishing catches are standardised by dividing the total catch per 100 seconds of electrofishing time.

Site No.	Site Name	Stream Name	Box Traps CPUE (Total traps in brackets)	Fyke nets CPUE (Total nets in brackets)	Electrofishing CPUE (Total seconds in brackets)	Non Target catch (Species and number)
1	Slate Quarry dam	Willunga Ck	-	-	0 (52)	
2	Quarry Rd	Willunga Ck	-	-	0 (65)	
3	St Johns Terrace	Willunga Ck	-	-	28.6 (213)	
4	Ross Roses	Willunga Ck	-	-	136.6 (527)	
5	Giles Road	Willunga Ck	9.1 (15)	75.5 (8)	130.1 (630)	*C. carpio* (n=2)
6	Methodist Street	Willunga Ck	0 (5)	56.3 (4)	28.6 (384)	
7	DTEI	Willunga Ck	-	24 (1)	-	
8	Peacock Farm	Willunga Ck	0.4 (9)	5 (2)	-	
9	Vineyard (old sewage ponds)	Willunga Ck	0 (1)	0 (4)	-	
10	Potters Clay Vineyard Dam	Willunga Ck	-	0 (5)	-	*G. holbrooki* (n=5)
11	Victor Harbour Road	Willunga Ck	-	-	0 (105)	
12	Main Rd	Wirra Ck	-	-	0 (440)	*G. olidus* (n=2)
13	St. James Rd.	Wirra Ck	-	-	0 (278)	*G. olidus* (n=8)
14	Colville Rd (west branch)	Willunga Ck	-	-	0 (161)	

3.2 Population structure of P. caudimaculatus

P. caudimaculatus comprised over 99% of the total catch in both the netting and electrofishing surveys. Of the 280 fish measured, over 75% had most likely reached maturity (Figure 6), as this species is known to reach maturity at a length of 18 mm (SL) (Morgan *et al.* 2004). More than half of the population that we measured (>65%) ranged between 17-31 mm TL (Figure 6). Both male and female specimens were collected although sex ratios and sex specific traits were not measured in this survey.

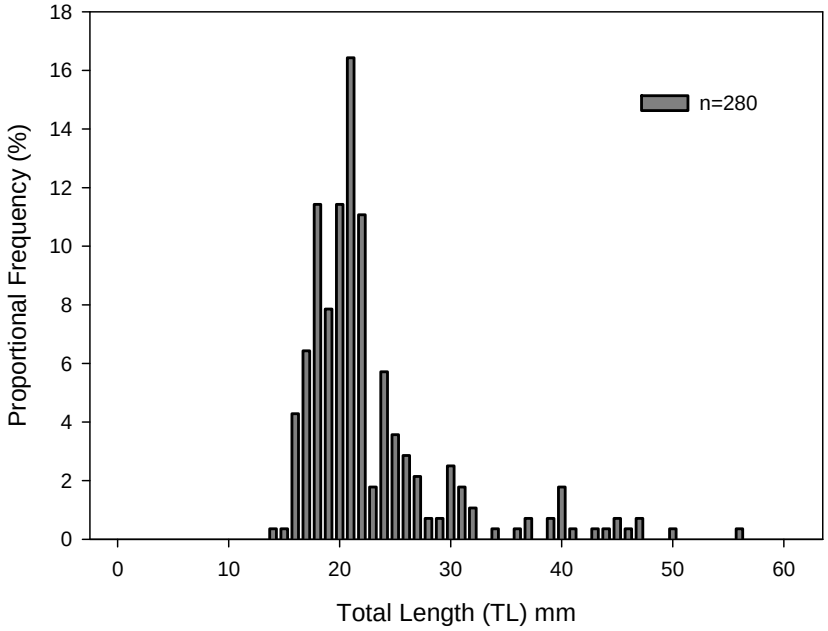

Figure 6. Length-frequency distribution of speckled livebearers (*Phalloceros caudimaculatus*) collected in September 2008 from all sites in Willunga Creek, Willunga.

4. DISCUSSION

4.1 Identification of P. caudimaculatus

The presence of this species in outdoor ponds within South Australia has been referred to in the past (Arthington *et al.* 1999); however there has been no official report of its release into the wild prior to 2008. We have positively identified the Willunga population as *Phalloceros caudimaculatus* (McDowall 1999) and as such it is a new invasive species for South Australia (Hammer and Walker 2004). This adds to infestations in Western Australia and Sydney and emphasises that the species is an extremely well adapted invader that is a high risk for infesting all types of watercourse all over Australia (Morgan *et al.* 2004; Rayner and Creese 2006). As such, it should be reconsidered as to whether the species should be allowed to be kept in Australia at all circumstances like in Queensland (Wager and Unmack 2000) and reiterates the importance of controlling all known populations as soon as possible to prevent its spread across the continent.

4.2 Spatial extent of P. caudimaculatus

The survey discovered a strong population of *P. caudimaculatus* within permanent reaches of upper Willunga Creek. The population was present in the area of the original report, the township of Willunga, but was found also to extend upstream to Quarry Road.

The population was also present downstream of the original reported site along Norman Road and through the Peacock Farm B&B. The population did not appear to extend further downstream from this property. The reach downstream of this site (adjacent to the reserve and Potters Clay Vineyard and continuing through to the Victor Harbour Road) had very low or no surface flow. As such it appeared that the population was restricted to the section of flowing water between Quarry Rd and the back of Peacock Farm. Local landholders and residents stated that this section represents the extent of permanent flow in this creek and that it dries completely downstream of Peacock Farm in most or all years.

All adjacent waterways were completely disconnected from this reach, and almost all other streams in the catchment were completely dry at the time of the survey. *P. caudimaculatus* was not present in off-stream storages at the Potters Clay Vineyard and upstream at the slate quarry, even though some Gambusia was present at the vineyard. Whilst this suggests that *P. caudimaculatus* may prefer mainstream channel habitats, it should not be assumed absent from any other off-channel habitats that were not sampled. As such, the wastewater dams at Little Road and Victor

Harbour Road should be surveyed, as should the dams upstream of the slate quarry gate. Importantly, the downstream extent of this survey does not necessarily represent the downstream extent of the population. The survey was limited to the area upstream of Main South Road and did not cover dams or tributaries coming into the creek downstream of Victor Harbour Road. Further surveys will be required to seek out any permanent water bodies within these areas before any control efforts begin as recolonisation of pest fish from adjacent areas can undermine often expensive pest removal programs (McNeil *et al.* 2001). However, recolonisation of *P. caudimaculatus* in the Willunga reach from downstream is unlikely due to a 4m high concrete wall in the stream channel at the Victor Harbour Road culvert. This barrier would prevent any upstream movement of fish into the area, including desirable native fishes.

4.3 Temporal extent of P. caudimaculatus

The original report of the species from Mr Bill Round outlined that he had collected the species from Willunga Creek for over three years and had also bred them in aquaria where they reproduced multiple times per year. This observation fits well with the protracted spawning period observed within the species' natural habitat in Brazil (Wolff *et al.* 2007). This study found young *P. caudimaculatus* and pregnant females were present almost all year round and suggested multiple spawning and recruitment events that peak in late summer/autumn and spring. Similarly, in Western Australia, established populations are able to spawn all year round (Morgan *et al.* 2004).

The results of the present survey revealed that the Willunga population of *P. caudimaculatus* consisted of individuals from a wide range of sizes. Of most interest is the clear peak in smaller sized individuals (0-20 mm TL) that represent recent recruitment (Wolff *et al.* 2007). The dominance of this size range in the population suggests that there has been strong recruitment in recent times. This is likely to include spawning in late winter 2008 as juveniles of the familial *G. holbrooki* appear to be born at around 15mm in length (McNeil 2004). The results support the observation of the species in Western Australia, re-emphasising the fact that the species can tolerate and indeed reproduce successfully in cold-water habitats (Morgan *et al.* 2004). This is of particular concern as it means the species could potentially survive within almost any habitat in Southern Australia once introduced.

The presence of adult fish from a wide range of sizes, especially the existence of very large adults over 50mm in length, supports the anecdotal evidence that the population has been present and recruiting for a number of years. However, a dedicated ageing study using known aged fish and counts of daily growth rings in the otolith (ear stones) of wild caught fish is required before fish

ages can be confidently estimated (McNeil *et al.* 2008). This aging approach is inexpensive and could be conducted at SARDI in a relatively short time frame. It is quite clear however, that the population is well-naturalised and self-sustaining. If eradication is successful however, the requirement for biological studies on this species' becomes less urgent.

4.4 Potential impacts

No other native fish (only alien carp, n=2) were collected at any site where *P. caudimaculatus* was found. The reasons for this are not clear, however it cannot be ruled out that the stream was fishless prior to the introduction of livebearers, as no data exists for this catchment prior to the current survey. The presence of *G. olidus* in nearby Wirra Creek suggests that this species was likely to have inhabited Willunga Creek historically.

It has been noted that *P. caudimaculatus* can exclude *G. holbrooki* from areas where it has been introduced (Morgan *et al.* 2004). Indeed, the only site where *G. holbrooki* were present in the current survey was in an off-channel dam where there were no *P. caudimaculatus*. This could be the result of aggressive interactions, competition for resources, or predation of small age classes of *G. holbrooki*, but there is no data to elucidate the mechanisms of this result.

Another potential explanation that should not be ruled out is that *P. caudimaculatus* may carry some disease that has impacted heavily on other species of fish, leading to their decline. This is unfounded, but perhaps should be investigated in assessing the potential impacts of this species on other fish as a cautionary measure. An investigation into aquarium industry records and literature would be useful in outlining the diseases or parasites that inflict or are spread by this species.

4.4 Native fauna

The impact of this pest fish on other fishes including South Australian natives is unknown, but it appeared to be less aggressive than *G. holbrooki* when placed into tanks with native western pygmy perch (*Edelia vittata*) (Morgan *et al.* 2004). Research into the potential impacts on other fauna and on ecological systems should be promoted to and taken up by research institutions such as universities, state and federal research agencies.

A project conducted under the Murray-Darling-Basin Commission is currently being undertaken through the Victorian Department of Sustainability and Natural Resources (DSE) to quantify the

impact of *G. holbrook*i on native fish species and explore control options for this species. This highlights the need to collect information on the potential impacts of alien livebearers and a similar study should be pertinent for *P. caudimaculatus*. Assuming that the impacts of *P. caudimaculatus* may be similar to those of *G. holbrooki*, this study should be considered during the planning for future management of the *P. caudimaculatus* in South Australia.

The presence of *G. olidus* in nearby Wirra Creek suggests that this native species could have been displaced from Willunga Creek by the alien Livebearers. Regardless, the introduction of *G. olidus* into Willunga Creek could provide competition for the livebearers and may be an option in the future control of the pest population. No other native fish were present in the region, but highly threatened species such as the southern purple spotted gudgeon (*Mogurnda adspersa*), which is extinct from the region but present in the Murray River, may be used as a replacement for livebearers if they are removed.

Frogs (tadpoles), turtles, yabbies and other invertebrates were observed and collected during the survey. Any control effort aimed at eradicating the livebearer must take into consideration the impact of control actions on these fauna.

4.5 Management context

As a new invasive species the management of the population comes under a range of policy and legislative areas. The release of alien fish, including aquarium fish is an offence under the *Fisheries Management Act 2007* (South Australia). This act also provides the power to make regulations for the control of alien fish and the control of disease in fish (FMA 2007). The responsibility under this act sits with the Director of Fisheries within PIRSA Fisheries. Various other State Government Agencies and Regional Boards work under a policy framework that explicitly address the control of alien biota and the prevention of new invasions. The need for a common rapid management response to new invasions by alien freshwater fish has been acknowledged by government and research institutions (Koehn and McDowall 2004; Ansell and Jackson 2007). It is recommended that a comprehensive action plan for chemical application should be developed, including risk analysis and consultation with relevant stakeholders (i.e. landholders and water users) for the control of the P. *caudimaculatus* population under this legislative and policy framework.

The Invasive Animals Co-Operative Research Centre (IACRC) is currently developing a rapid response framework for responding to freshwater fish invasions. This project is also being conducted by Victoria's DSE but is at such an early stage that there are no guidelines available to

assist in the present case. It is most likely however, that the response guidelines will follow the Australian Emergency Marine Pest Response Plan (NHT 2005), which was developed for dealing with new invasions in marine environments (Renae Ayres, Victorian DSE, *pers. comm.*).

4.6 Community consultation and consideration

The site of infestation is dominated by suburban properties. According to landholders in Giles and Methodist Streets, the centre of the creek forms the property boundaries, with half of the creek being owned by the Onkaparinga City Council, and the inside half owned by the landholders. Both upstream and downstream of the township, the creek flows through private freehold property. As a result, any management plan and subsequent actions must incorporate close and careful strategic consultation with the community and in particular with the owners of the creek frontage properties.

Sampling conducted during this survey was only carried out with the explicit verbal consent of the residents and where residents could not be contacted, sampling was not conducted at their address. This approach must be carried into the planning and control phases of future management operations. Almost all residents expressed concern for the ecological integrity of the creek, were equally concerned about possible impacts of our sampling techniques and were wary of negative impacts of any control actions.

It is therefore clear that residents and landholders must be closely involved in any control efforts and have input into deciding on the best control options or management path. The Willunga Environment Centre distributes a fortnightly newsletter to all properties and some of these identified this as a good vehicle for informing and communication progress to the local residents. Community and resident meetings are recommended to keep the locals informed and take on their concerns and ideas.

Furthermore, the non-residential landholders are predominantly agricultural with three vineyards and a rose farm using creek water for their businesses. It is essential that any control plans and actions involve good communication and work with these landholders (Ansell and Jackson 2007), but that any impacts on water quality and chemistry stemming from control options are thoroughly researched and minimised. Some of these enterprises are governed by strict water quality regulations under the South Australian Department of Water, Land and Biodiversity Conservation (DWLBC) and it must be ensured that control actions (especially chemical control options such as rotenone) do not impact adversely on their businesses.

The incorporation of the Adelaide and Mount Lofty Ranges Natural Resource Management Board (AMLRNRMB) in the ongoing control planning and actions will be crucial in creating and maintaining these linkages between state agency policy and actions and the community members and landholders. It is suggested that representatives of this agency be involved closely in any steering committees associated with control projects, as should representatives from DWLBC, the SA Department for Environment and Heritage (DEH), SA Water and possibly the SA Environment Protection Agency (EPA) to ensure that all regulatory and statutory requirements are being met.

4.7 Conclusions

The results of the survey suggest that this site is suitable for significant control actions and has the potential to remove all *P. caudimaculatus* permanently; therefore implementing a successful pest control program is encouraged. The isolated nature of the infested reach, the absence of any native fishes in the pilot survey and the good accessibility to all reaches of the stream (implying landholder consent) mean that control efforts would have a good chance of success.

It is therefore suggested that control of the Willunga population of *P. caudimaculatus* be used as a test case for applying South Australia's emergency response capacity using existing and developmental guidelines and criteria (currently being developed by DEH, the IACRC in conjunction with state and federal government). The principal method for controlling pest fish populations is through the use of rotenone fish toxin (Finlayson et. al. 2000) it's use may be subject to restrictions and controls in Australian States (Rayner and Creese 2006).

Rotenone is a useful tool for sampling and controlling freshwater fish populations around the world and in Australia (Rayner and Creese 2006). It has been successfully used to dramatically reduce populations of *P. caudimaculatus* to less than 0.05% of their pre-treatment abundance in New South Wales (Rayner and Creese 2006). Rotenone, a natural toxin produced by many tropical plants, is highly toxic to fish and other aquatic life, but has a low toxicity to birds and mammals. It is a highly specific poison that works by affecting cellular aerobic respiration, blocking the uptake of oxygen in fish (Ling 2003). Rotenone can be applied by using hand-pumped pesticide sprayers or drippers to ensure that desired concentrations are reached. It neutralises downstream so rotenone can be applied to sections of a reach at a time (Finlayson *et al.* 2000).

If rotenone were to be applied in Willunga Creek there would be a high chance of success in eradicating *P. caudimaculatus* due to the isolated nature of the reach, the relatively low levels of

dense aquatic vegetation, good mixing flows and easy access for application (Rayner and Creese 2006). This option, however, has the potential to impact on other stream fauna. As a result, ecological and biodiversity impacts must be assessed and considered before control works begin. It is likely that repeated applications of rotenone would be required (Rayner and Creese 2006) but a single application during summer, when water temperatures are high and flows are low, may be all that is necessary (Lintermans 2000).

If eradication using rotenone is not feasible or desirable, then physical removal actions may be required. This approach is not rapid and requires a high level of effort, financial support and commitment. Regular removal of fish using electrofishing and netting will be effective in removing large numbers of *P. caudimaculatus* but there are no records of successfully eradicating small fish using these techniques. As stated earlier, the translocation of native fishes into the creek in conjunction with the removal of *P. caudimaculatus* may increase the control value of this type of approach due to increased competition.

It is recommended that the most effective approach should combine all of these techniques and must be assessed with ongoing monitoring and assessment to determine the success of the efforts. Marking of *P. caudimaculatus* prior to commencing control actions is strongly recommended, as it is an excellent tool for assessing the success of various control methods and determining the effective population size. An effective monitoring program is an essential component of any pest fish management program (Ansell and Jackson 2007).

As the species is an aquarium escapee, it would also be prudent to conduct a survey of aquarium and pet retailers in the area to quantify the nature of the livebearer trade in the Adelaide region and to determine other potential sources of infestation. It is also recommended that the status of the species in South Australia be addressed and that action be taken to prevent the species being sold in the state, if these measures are not already included under the current legislation.

4.7 Recommendations

1. Develop a 'Pest Fish Control Plan' for the Willunga population of *P. caudimaculatus* addressing control options, outlining possible impacts of control activities and incorporating community and ecological concerns and values.
2. Form a project steering committee represented by PIRSA, AMLRNRMB, DEH, SARDI Aquatic Sciences and DWLBC and Onkaparinga City Council to oversee the control program.
3. Conduct further field assessments of the distribution of *P. caudimaculatus*, particularly downstream of Main South Road and in streams, dams and lagoons

that may at some time be connected to Willunga Creek or may contain infestation of *P. caudimaculatus*.

4 Conduct community education and consultation activities utilising existing extension programs where possible.

5 Collect additional biological and ecological information regarding the species and their potential impacts linking with research agencies, the IACRC and Universities.

6 Implement appropriate control actions considering the use of rotenone, netting and electrofishing.

7 Consider the translocation of appropriate native fishes into the creek following control actions.

8 Develop an ongoing monitoring and assessment program to determine the effectiveness of the control program and to pick up any re-infestation or resilience of the *P. caudimaculatus* population following control actions

9 Respond to any *P. caudimaculatus* population recovery appropriately with further actions.

10 Ensure that all of the above incorporate and link to State and Federal Freshwater Pest Fish Emergency Response Plans, currently being developed.

REFERENCES

Allen GR, Midgley SH, Allen M (2002) Introduced families. In 'Field Guide to the Freshwater Fishes of Australia'. (Eds J Knight and W Bulgin) pp.355-371. (CSIRO Publishing: Collingwood, Victoria).

Ansell D, Jackson P (2007) Emerging Issues in Alien Fish Management in the Murray-Darling Basin: Statement, recommendations and supporting papers. Proceedings of a workshop held in Brisbane QLD 30-31 May 2006. Murray-Darling Basin Commission, Canberra. MDBC Publication No: 16/07.

Arthington AH, Kailola PJ, Woodland DJ, Zalucki JM (1999) Baseline environmental data relevant to an evaluation of quarantine risk potentially associated with the importation to Australia of ornamental finfish. Final report to the Australian Quarantine and Inspection Service (AQIS). Griffith University, Centre for Catchment and In-stream Research.

Finlayson BJ, Schnick RA, Cailteux RL, DeMong L, Horton WD, McClay W, Thompson CW, Tichacek GJ (2000) Rotenone use in fisheries management. American Fisheries Society, USA.

FMA (2007) Miscellaneous Offences. In 'Fisheries Management Act South Australia 2007' pp 47-48.

Hammer MP, Walker KF (2004) A catalogue of South Australian freshwater fishes, including new records, range extensions and translocations. *Transactions of the Royal Society of South Australia*. **128** (2), 85-97.

Higham J (2007) Summary of existing alien fish management (control) mechanisms in MDB jurisdictions. In: Ansell D and Jackson P (2007) Emerging Issues in Alien Fish Management in the Murray-Darling Basin: Statement, recommendations and supporting papers. Proceedings of a workshop held in Brisbane QLD 30-31 May 2006. Murray-Darling Basin Commission, Canberra. MDBC Publication No: 16/07.

Ling N (2003) Rotenone – a review of its toxicity and use for fisheries management. *Science for Conservation*, **211**, 5-40.

Lintermans M (2000) Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout *Oncorhynchus mykiss*. *Marine and Freshwater Research*, **51**, 799-804.

Lloyd LN, Tomasov JF (1985) Taxonomic status of the mosquitofish, *Gambusia affinis* (Poeciliidae), in Australia. *Australian Journal of Marine and Freshwater Research*, **36**, 447-451.

Lloyd L (1990) Taxanomic update: species control using taxonomy *Gambusia affinis* no longer exists in Australia. *Australian Society for Fish Biology Newsletter*, **20**.

Lucinda PHF (2008) Systematics and biogeography of the genus *Phalloceros* Eigenmann, 1907 (Cyprinodontiformes: Poeciliidae: Poeciliinae), with the description of twenty-one new species. *Neotropical Ichthyology*, **6**, 113-158.

McDowall RM (1999) Further feral Poeciliid fish in New Zealand fresh waters, with a key to species. *New Zealand Journal of Marine and Freshwater Research*, **33**, 673-682.

McKay RJ (1984) Introduction of alien fishes in Australia. In 'Distribution, Biology, and Management of Alien Fishes' pp.177-199. (The John Hopkins University Press, London).

McNeil DG, Wilson PJ, Hartwell D and Pellizzari M (2008). Olive Perchlet in the Lachlan River: Population Status and Sustainability in the Lake Brewster Region. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.

McNeil DG, Closs GP (2007). Behavioural responses of a south-east Australian floodplain fish community to gradual hypoxia. *Freshwater Biology* **52**, 412-420.

McNeil DG, Hammer M (2007) 'Biological review of the freshwater fishes of the Mount Lofty Ranges.' South Australian Research and Development Institute (Aquatic Sciences), F2006/000335, Adelaide.

McNeil DG (2004) Ecophysiology and behaviour of Ovens River floodplain fish: hypoxia tolerance and the role of the physicochemical environment in structuring Australian billabong fish communities. Ph.D thesis, La Trobe University.

McNeil DG, Kusmierski RK, and Edney GA (2001). Carp control and native fish enhancement in an urban Murray River Billabong; Horseshoe Lagoon, Albury, NSW. Report to the Albury City Council, Albury, NSW.

Morgan DL, Gill HS, Maddern MG, Beatty SJ (2004) Distribution and impacts of introduced freshwater fishes in Western Australia. *New Zealand Journal of Marine and Freshwater Research*, **38**, 511-523.

NHT (2005) Australian Emergency Marine Pest Plan (EMPPlan) Control Centre Management Manual (Draft report). Natural Heritage Trust, Canberra, ACT.

Rayner TS, Creese RG (2006) A review of rotenone use for the control of non-indigenous fish in Australian fresh waters, and an attempted eradication of the noxious fish, *Phalloceros caudimaculatus*. *New Zealand Journal of Marine and Freshwater Research*, **40**, 477-486.

Rowley JJL, Rayner TS, Pyke GH (2005) New records and invasion potential of the poeciliid fish *Phalloceros caudimaculatus*. *New Zealand Journal of Marine and Freshwater Research*. **39**, 1013-1022.

Trendall JP, Johnson MS (1981) Identification by anatomy and gel electrophoresis of *Phalloceros caudimaculatus* (Poeciliidae), previously mistaken for *Gambusia affinis holbrooki* (Poeciliidae). *Australian Journal of Marine and Freshwater Research,* **32**, 993-996.

Wagner R, Unmack PJ (2000) Fishes of the Lake Eyre Catchment of Central Australia. Department of Primary Industries and Queensland Fisheries Service, Queensland.

Wolff LL, Hreciuk ER, Viana D, Zaleski T, Donatti L (2007) Population structure of *Phalloceros caudimaculatus* (Hensel, 1868) (Cyprinodontiformes, Poeciliidae) collected in a brook in Guarapuava, PR. *Brazilian Archives of Biology and Technology*, **50**, 417-423.