Juvenile *Astacopsis gouldi* in headwater streams – relative abundance and habitat.

Report to the Forest Practices Board.

April 2004.

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Executive Summary

Two surveys were conducted of juvenile *Astacopsis gouldi* in headwater streams. Repeated sampling of Class 4 and 2 streams in two drainage suggested that a string seasonal pattern in abundance was absent, and that use of Class 4 streams (as defined in the Forest Practices Code) was relatively low at all times of the year compared to Class 2 streams. A survey of a large number of relatively undisturbed stream sites indicated that:

- Class 4 streams are used by juvenile *A. gouldi*, but at significantly lower densities than Class 2 streams;
- juvenile *A. gouldi* numbers are highly spatially variable;
- juvenile *A. gouldi* are more abundant in Class 2 streams of moderate catchment size, and wider channels.

Macro-habitat features favoured by juvenile *A. gouldi* include:

- wide streams with catchment areas typically 2 to 30 km^2; < 2% area of substrate as silt; 10% high proportions of moss cover; moderate to high proportions (10 – 30%) of substrate as boulders; channel slopes < 15%;

  or
- small streams of 0.4 to 2 km^2 catchment area and with significant and sustained groundwater (spring) input leading to elevated perennial baseflows.

Meso-habitat features favoured by juvenile *A. gouldi* include large rocks or logs that are big enough not to be easily dislodged, not embedded in finer substrates, that overly coarser substrates and/or with a distinct cavity underneath.

The maintenance of current prescriptions for the protection of headwater *A. gouldi* populations is recommended.

Juvenile *Astacopsis gouldi* in headwater streams – relative abundance and habitat

Introduction

The giant freshwater lobster, *Astacopsis gouldi, is* listed as 'vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the Tasmanian *Threatened Species Protection Act 1995.* Much recent debate has centred on the effects of forest harvesting operations on headwater streams, particularly small streams classified as 'Class 4' under the Tasmanian Forest Practices Code (2003). In particular claims have been made that such streams may be of particular significance to A. gouldi. especially as areas for reproduction, juvenile rearing and subsequent recruitment into mainstream populations. This follows in part from observations made by Growns (1995) in a survey of *A. gouldi* populations in the Gog Range of the presence of mature females in tributary streams. As a result of this, there has been concern that harvesting operations adjacent to and around Class 4 stream channels may be having significant negative impact on *A. gouldi* populations both in the headwaters and across river catchments as a whole.

Other than the observation made by Growns (1995), there have been no other published reports of the presence of A.gouldi in Class 4 streams. *A. gouldi* surveys reported by Horwitz (1991, 1994), Hamr (1990), Webb (2001), Walsh and Nash (2002) and others have largely focussed on main stem populations and relationships with impacts from previously poorly controlled fishing and landuse change. Some evidence was presented on the effects of fishing on population size/age structure by Horwitz (1991), and this was a significant contributor to the change in fishing regulations pertaining to the species in the 1990's. Recent surveys have implicated sedimentation from agricultural and/or forestry related land use in low numbers of *A. gouldi* (Walsh and Nash 2002).

Hamr (1990) provides the only formal attempt at an assessment of *A. gouldi* population size and structure, though limited to one river. No other surveys have been conducted specifically to look at the issue of recruitment, and use of habitats by juveniles.

This study was initiated to assess the occurrence of juvenile *A. gouldi* in Class 4 streams and to identify the characteristics of habitat where they occurred. In particular, the study attempted to assess the following questions:

- To what extent do juvenile A. *gouldi* occur in Class 4 streams?
- Does Class 4 stream habitat support a significant proportion of juvenile *A. gouldi* population in stream drainages?
- Is there a particular time of the year in which juvenile *A. gouldi* numbers are higher in headwater streams?
- What are the habitat preferences/associations of juvenile *A. gouldi*, assessed across a range of stream sizes?

This document reports on the methodology and results of a survey for juvenile *A. gouldi* conducted between 2000 and 2003 in headwater streams across a range of stream sizes ('classes') and habitat types. The survey was conducted in two parts – a repeated 'temporal' survey of selected sites over an 18 month period; and a 'spatial' survey of a range of sites, each sampled once. Differences in catch per unit effort of juvenile *A. gouldi* between stream classes are examined, as well as relationships between CPUE and habitat variables.

Methods

Survey study sites

Temporal survey

12 sites in two drainages were surveyed every 2 - 4 months over a 14 month period between March 2002 and April 2003 to assess the presence of any significant seasonal peak in juvenile *A. gouldi* abundance. The two drainages were known to have substantial populations of *A. gouldi* in their mainstems (Class 2 stream reaches) and were not substantially disturbed. In each of the Chellis Ck-Flowerdale River and Repulse Ck drainages, one downstream Class 2 reach was sampled along with 5 Class 4 streams (with the exception of the Chellis-Flowerdale drainage for which a 5th Class 4 could not be found). Sampling was conducted using the visual search method, with a 2 hr search effort on every sampling occasion. All adult (> 40 mm carapace length) and juvenile *A. gouldi* (< 40 mm CL) caught were measured, counted and replaced in the location of capture. Site details are shown in Table 1.

Table 1. Sites sampled during temporal survey.

Catchment	Site	Easting	Northing	Catchment area (km^2)	Stream Class
Chellis Ck - Flowerdale R	Chellis Ck	375700	5446300	4.51	2
	Chellis Ck Trib 1 - 1st u/s	375500	5446200	0.23	4
	Chellis Ck Trib 2 - 2nd u/s	375500	5446150	0.41	4
	Flowerdale Trib1 - 200m u/s bridge	375800	5446500	0.7	3
	Flowerdale Trib 2 - 1st d/s of bridge	376400	5447200	0.15	4
	Flowerdale Trib 3 - 3rd d/s of bridge	376350	5447700	0.32	4
Relapse Ck	Relapse Ck	368600	5442150	9.93	2
	Relapse Ck Trib 1 - 250m u/s Arthur R.	368100	5442100	0.18	4
	Relapse Ck Trib 2 - 10m u/s bridge	368650	5442100	0.125	4
	Relapse Ck Trib 3 - 200m u/s bridge	368700	5442200	0.07	4
	Relapse Ck Trib 4 - 400m u/s bridge	368900	5442250	0.144	4
	Arthur R. Trib - at Champion Rd	367800	5443300	0.31	4

Spatial survey

A total of 72 sites were visited as part of a spatial survey between late 2001 and early 2004, 28 of which were Class 4 streams. Sites were deliberately selected to avoid recent disturbance by land clearing including clearfell harvesting. 66 sites were surveyed in detail once each, between spring and late autumn (October to April). 40, 8 and 18 of these sites were in Class 2, 3 and 4 streams respectively. For each Class 4 stream surveyed, a survey was also conducted in a Class 3 and/or Class 2 reach within 1 km downstream of the Class 4 site. Site locations are mapped in Figure 1, and details are provided in Appendix 1.

Early sampling had indicated that juveniles were consistently absent in Class 4 stream sections upstream of Class 2 stream reaches where juveniles were also absent. A significant number (20) of Class 2 stream sites visited either did not contain adult or juvenile *A. gouldi* (with a number of these containing other crayfish species) or were significantly disturbed by recent riparian and catchment vegetation clearance. From 2001, sampling of Class 4 streams within the adjacent drainage was therefore not conducted for these locations. Difficulty was experienced in finding a set of sites with a range of stream sizes and conditions in NE Tasmania at which juveniles were present in any significant number. In addition, the manual searching technique was limited in its applicability when used in granitic sand streams. Attempts to assess juveniles using electrofishing also failed to produce juveniles consistently in these streams. Data from only four sites from NE Tasmania were included in the analysis of results from this survey.

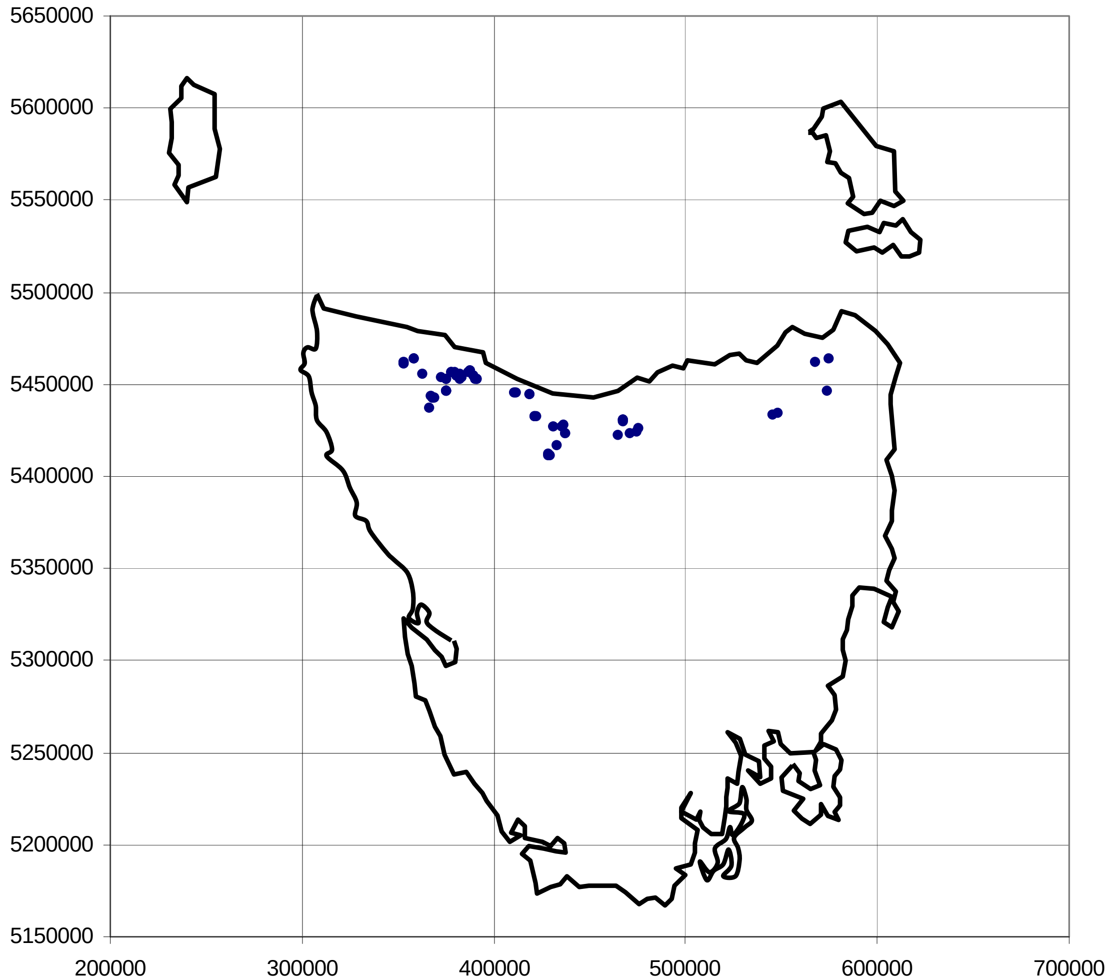

Figure 1. Location of sites surveyed for juveniles *Astacopsis* gouldi.

Stream Classes

The stream 'Class' system used in this report is that used within the Tasmanian Forest Practices Code (2000). This classification is used primarily to define prescriptions for forest operations at or adjacent to stream channels of different catchment areas. The classification in the Code is as follows:

Class 1. *Rivers, lakes and storages (other than farm dams) and tidal waters – generally those named on 1: 100,000 topographical series maps.*

Class 2. *Creeks, streams and other watercourses from the point where their catchment exceeds 100 ha.*

Class 3. *Watercourses carrying running water most of the year between the points where their catchment is 50 and 100 ha.*

Class 4. *All other watercourses carrying water for part or all of the year for most years. depression or drainage line which may only carry surface water during or shortly after rainfall.**

** A Class 4 watercourse is differentiated from a drainage depression by having at least one of the following features:*

- *a gravelly, pebbly, rocky or sandy bed, indicative of flowing water*
- *an obvious gully.*
- *a short steep section of streambank adjacent to the watercourse bed.*

A Class 4 watercourse will often have a change in understorey vegetation from the streambank to the surrounding forest e.g. riparian/moist vegetation on streambanks – ferns, mosses, sedges.

Class 4 streams correspond to first order streams (*sensu* Strahler) and are frequently seasonal or unpredictably ephemeral in flow. They are also highly heterogeneous geomorphologically, due both to local geomorphological context, variation in stream control by local elements (boulders, bedrock, logs etc), variability in groundwater-surface water interactions and local variations in riparian and catchment soils and vegetation.

Class 3 streams are typically second to third order streams with a higher frequency of perennial flow, but still fairly heterogeneous. Class 2 (which for this study includes the subset of Class 1) streams comprise all remaining, and larger stream channels and includes Strahler stream orders ranging from 3 to 9. The vast majority of Class 2 streams are perennial, named creeks and rivers and frequently contain habitat elements dictated by the interaction of stream power with hydraulic controls over a range of scales – generally significantly larger than for Class 4 streams.

Sampling methods

An active searching method was used. A pilot study conducted by Davies and Cook (1999) assessed a variety of methods for surveying juvenile *A. gouldi*. Trapping, electrofishing and baiting all had a low and variable success rate. Active searching across all instream habitats, standardised by time and/or distance, was the most consistent method with the highest capture rate. A capture-mark-recapture study of marked juveniles indicated that this method had a low success rate (of the order of 10% of the juvenile population being caught in a single search event). With consistent search effort and method, and experienced field personnel, the method was deemed suitable for comparative assessments of juvenile population status across stream types and a range of habitat conditions (land use etc).

A study site of 100 - 250 m length was identified. A two person team, working closely together, searched actively for juvenile *A. gouldi*, by a combination of visual scanning and lifting of all major substrate and wood debris elements across the entire the stream channel within the searched area. Searching was continued for ca. 1.5 to 2 hr, with the search time, length of stream and channel area searched recorded. A suite of 28 environmental variables was collected for each site, either measured on-site or derived from maps (Table 2).

Table 2. List of all environmental variables measured for each survey site.

Variable	Description	Unit
Carea	Catchment area	km2
Altitude m	Site altitude	m
Algal %	% cover of riffle substrate by filamentous algae	%
Silt %	% cover of riffle substrate by superficial silt	%
Detritus %	% cover of riffle substrate by organic detritus (leaves etc)	%
Moss %	% cover of riffle substrate by moss	%
Bedrock	% of site substrate as bedrock	%
Boulder	% of site substrate as boulder	%
Cobble	% of site substrate as cobble	%
Pebble	% of site substrate as pebble	%
Gravel	% of site substrate as gravel	%
Sand	% of site substrate as sand	%
Silt	% of site substrate as silt	%
Depth	Mean depth over site	cm
Overhang veg	Cover by overhanging/shading vegetation	Rank
Trailing veg	Cover by vegetation trailing in channel	Rank
LH Rip veg	Width of riparian vegetation, left bank (facing upstream)	Rank
RH Rip veg	Width of riparian vegetation, right bank (facing upstream)	Rank
Temp	Water temperature at time of sampling	Deg C
Conductivity	Measured on date of sampling	uS/cm
WWidth	Mean width of wetted channel	m
BNWidth	Mean width of channel, bank to bank	m
Flow	Flow	Rank
Clarity	Water clarity,	Rank
Riffle %	% of site as riffle habitat	%
Run %	% of site as run habitat	%
Pool %	% of site as pool habitat	%
Snag %	% of site as snag (wood debris) habitat	%

Channel slope was also measured in the field at all sites sampled from Jan 2003 onward.

Data on total cumulative length of Class 4, 3 and 2 streams for all river catchments within the existing distribution of *A. gouldi* were prepared by the Planning Branch of Forestry Tasmania. Streamlines defined by a statewide digital elevation model (DEM) developed by FT were used, providing a more accurate assessment of Class 4 stream drainage location and density than the existing LIST (Tasmap) stream drainage layer.

Data analysis

All juvenile capture data was converted to catch per unit effort (CPUE). Two CPUE figures were derived - catch per unit distance (CPUD, as n per 100 m of stream length surveyed), and catch per unit area (CPUA, as n per 100 m^2 of stream channel area). All CPUE and environmental data were entered into SYSTAT (version 10) and analysed as follows:

- plotting of CPUD and CPUA vs environmental variables.
- correlation (Pearson and Spearman rank) of CPUD and CPUA with environmental variables.
- principle components analysis (using the data reduction routine in SYSTAT) of environmental variables to evaluate redundancy in the environmental data, and generate principal component factors.
- multiple linear regression analysis (interactive, forward stepwise in the SYSTAT GLM routine) with CPUD and CPUD as dependent variables and the environmental variables as independent variables. Model performance was assessed using the adjusted r^2 statistic, and ANOVA F statistic. Only variables with high tolerance values were included in models, and residual plots were examined in each case for homogeneity of variance and outliers.
- logistic regression analysis (interactive, forward stepwise and complete in the SYSTAT regression routine) with presence/absence of juveniles as the dependent variable and environmental variables as independent variables. Model suitability was assessed by examining the 95% bounds of parameter odds ratios, a Chi-squared test based on log likelihood, and McFadden's rho-squared (Wilkinson 2000, Quinn and Keough 2002). Relative model performance was assessed using the G statistic based on differences between model log likelihood ratios, assessed as a Chi-square statistic. In addition, models were evaluated by classifying all sites in the data set as having either presence/absence of juveniles.

In addition, mean CPUD and CPUA for Class 4, 3 and 2 streams were compared by one-way analyses of variance, for those stream systems containing juvenile *A. gouldi* (ie streams where no *A. gouldi* were found were excluded). Both variables were ln(x+1) transformed prior to this analysis to ensure homogeneity of variance. Post-hoc comparisons between stream classes were conducted using Tukey's Honest Significant Difference test (HSD).

Mean CPUD of juvenile *A. gouldi* for each stream class were applied to the total length of each stream class in catchments within the *A. gouldi* distribution to provide an index of the relative total abundance of juvenile *A. gouldi* across the stream classes.

Results

Temporal survey

Repeated sampling of two Class 2 and 10 Class 3-4 streams in the two drainages failed to identify a marked seasonal pattern in the abundance of juvenile *A. gouldi*.

A total of 134 captures of A. gouldi were made as follows:

- Class 2 stream sites (n = 2, 6 sampling occasions): 37 adults, 93 juveniles;
- Class 3-4 streams (n = 9 Class 4 + 1 Class 3 stream, 6 sampling occasions): 3 adults, 1 juvenile.

Numbers of juveniles captured were consistent through the year in the Class 2 sites, with the exception of the final sampling visit in April 2003 (Figure 2). There was no substantial seasonal pattern to capture rates of juveniles.

Numbers of adults captured in the Class 2 sites (Figure 2) were higher in March to October (autumn-winter) than in December and February (spring-summer). Very few individuals were captured in the Class 3-4 streams, with all three adult captures being in the lower reaches of two streams. Only one juvenile was caught in the Class 4 streams, in December, over 72 sampling occasions.

Spatial survey

72 stream sites were visited during the spatial survey, covering a range of catchment areas (0.12 to 124 km^2), elevations (18 to 252 m above sea level) and channel dimensions (1 to 20 m bankfull width). 66 sites were surveyed in detail: 40 Class 2, 8 Class 3 and 18 Class 4 streams. Of these, a total of 54 sites were located within drainage sections where juvenile *A. gouldi* were observed and recorded.

A number of sites surveyed did not contain *A. gouldi*, but contained *Astacopsis tricornis*, *A. franklinii* or a species of burrowing crayfish from the genus *Engaeus* or the former genus *Parastacoides*. *A. tricornis* was occasionally observed in the upper reaches of drainages of the coastal river catchments at higher altitudes, while *A. franklinii* was also observed at two sites at higher altitudes (200 – 250m) in the north east. *Engaeus* and *Parastacoides* species were observed in more ephemeral smaller streams with small baseflows, suggesting that they occupy habitats which are not sufficiently frequently flowing to support *A. gouldi*.

A total of 259 juvenile *A. gouldi* were caught during the spatial survey, of which 242, 7 and 10 were caught in Class 2, 3 and 4 streams respectively. Nine juveniles were caught in one Class 4 stream alone (a tributary of Coopers Creek). In stream sites found to contain juvenile *A. gouldi*, the CPUE ranged between 0.28 and 27.5 individuals per 100 m stream length (CPUD), and between 0.18 and 18.3 individuals per 100 m^2 of stream bed area (CPUA).

The pattern of mean CPUE (CPUD and CPUA) by stream class is shown in Figure 3. The derived variables for *A. gouldi* catches are shown by stream class in Table 3 for all sites, as well as for Class 4 streams excluding the Coopers Creek tributary site which was an unusual site (an outlier with high juvenile abundance, believed to be related to spring-fed baseflows, see below). Mean total catch, mean CPUD and CPUA were substantially higher in Class 2 streams than in Class 3 and Class 4 streams.

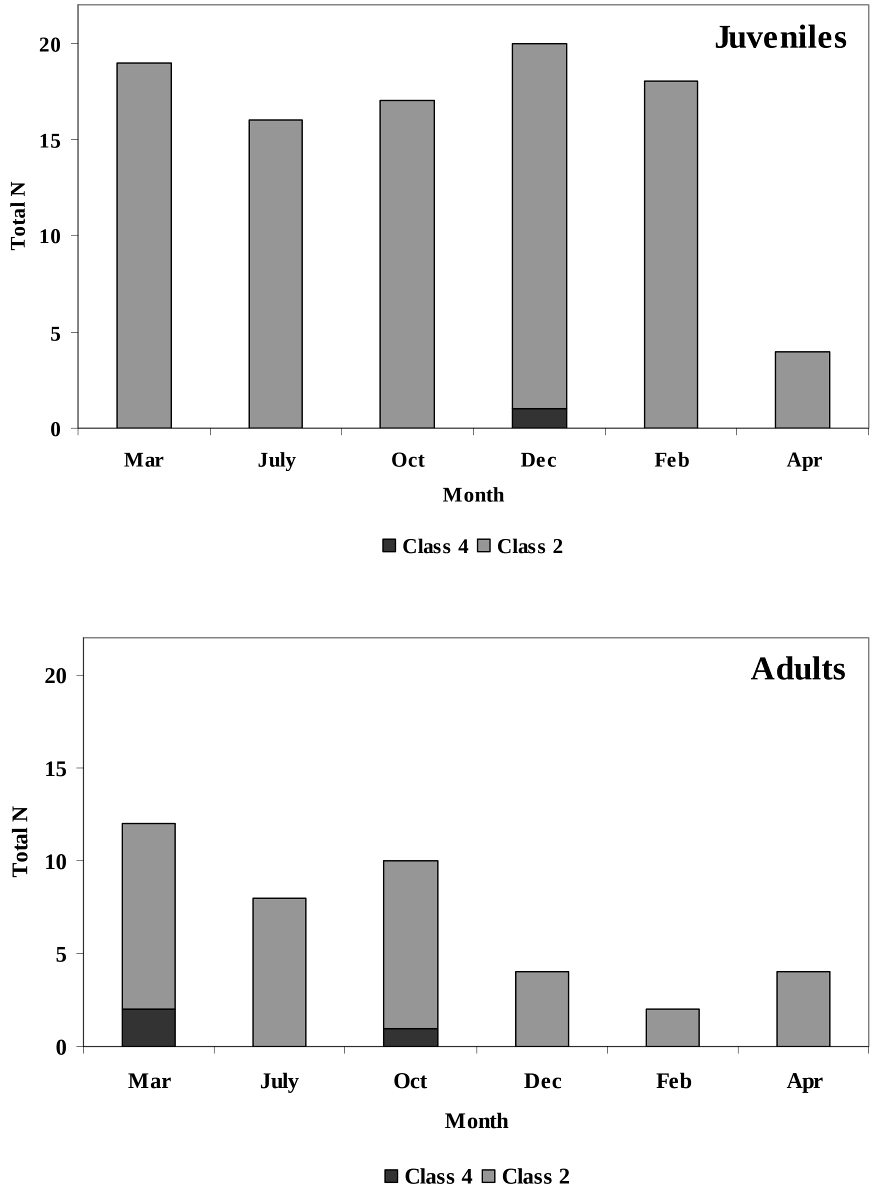

Figure 2. Total abundance of all *A. gouldi* juveniles and adults captured at Class 2 and Class 4 sites in the Chellis Ck – Flowerdale river and repulse Ck drainages between March 2002 and April 2003.

Table 3. Summary statistics for *Astacopsis gouldi* catches (all sizes and juveniles only) during spatial survey. CPUD = catch per unit distance (n per 100 m); CPUA = catch per unit area (n per 100 m^2). * indicates values for Class 4 streams excluding the Coopers Creek tributary 'outlier'.

Class	N sites	Sum		Mean N		Median N		CPUD		CPUA	
		All	Juvs	All	Juvs	All	Juvs	Mean	Median	Mean	Median
2	40	246	242	6.150	6.050	4.00	3.50	3.82	2.47	1.79	0.80
3	8	8	7	1.000	0.880	0	0	0.64	0	0.39	0
4	18	14	10	0.780	0.560	0	0	0.26	0	0.52	0
4*	17	4	1	0.059	0.059	0	0	0.039	0	0.069	0

Analysis of variance indicated that both CPUD and CPUA were statistically significantly different between stream classes ($p < 0.0001$), even when including the Coopers Creek tributary site. The ANOVA tables are as follows:

Dependent Variable: CPUD (ln(x+1) transformed)

N: 66 Multiple R: 0.5180 Squared multiple R: 0.2683

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
CLASS	14.39745	2	7.19872	11.54941	0.00005
Error	39.26776	63	0.62330		

Dependent Variable: CPUA (ln(x+1) transformed)

N: 66 Multiple R: 0.57145 Squared multiple R: 0.32656

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
CLASS	37.63910	2	18.81955	15.27463	< 0.0000005
Error	77.62098	63	1.23208		

Both CPUD and CPUA were significantly and substantially higher in Class 2 than in Class 3 streams (p = 0.024 and 0.006, respectively by Tukey HSD test) and in Class 4 streams (p = 0.0001 and 0.00002, respectively). No significant differences were observed between Class 3 and Class 4 streams.

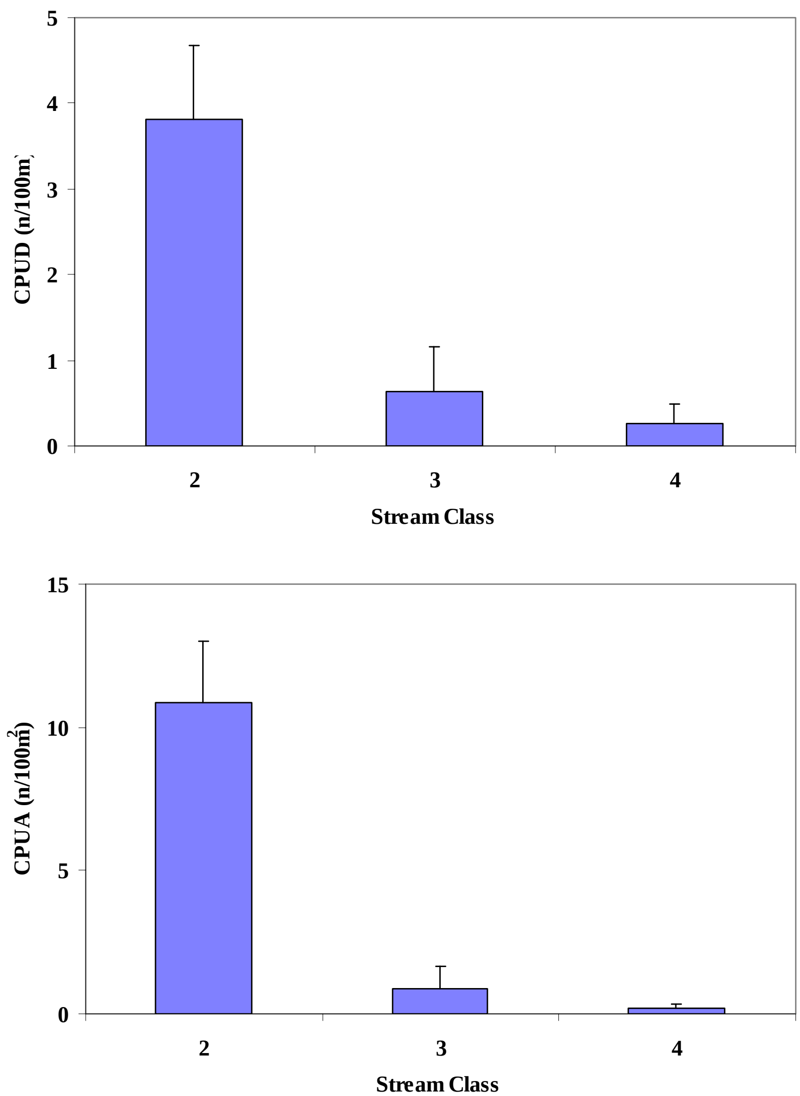

Figure 3. Mean CPUD and CPUA for Class 2, 3 and 4 streams sampled during the spatial survey. Bars indicate standard error.

Environmental relationships

All streams

The following results are for analyses conducted on data collected for all streams (n = 66) including those with no *A. gouldi* recorded in this survey (but which are located within river catchments containing *A. gouldi*).

Juvenile *A. gouldi* density as CPUD was positively correlated (by Spearman rank correlation) with the following variables:

- catchment area, channel width (wetted and bankfull) - all with $p < 0.0001$; and
- % algal cover and % boulder substrate – all with $p < 0.01$.

CPUA was also positively correlated with channel width (wetted and bankfull, both $p < 0.001$).

A significant negative correlation was observed for both CPUD and CPUA with % silt substrate (both $p < 0.01$). CPUE was very low or zero when % silt was ≥ 5% (Figure 3). In addition, no juvenile *A. gouldi* were recorded at sites with channel slopes >10% (Figure 3).

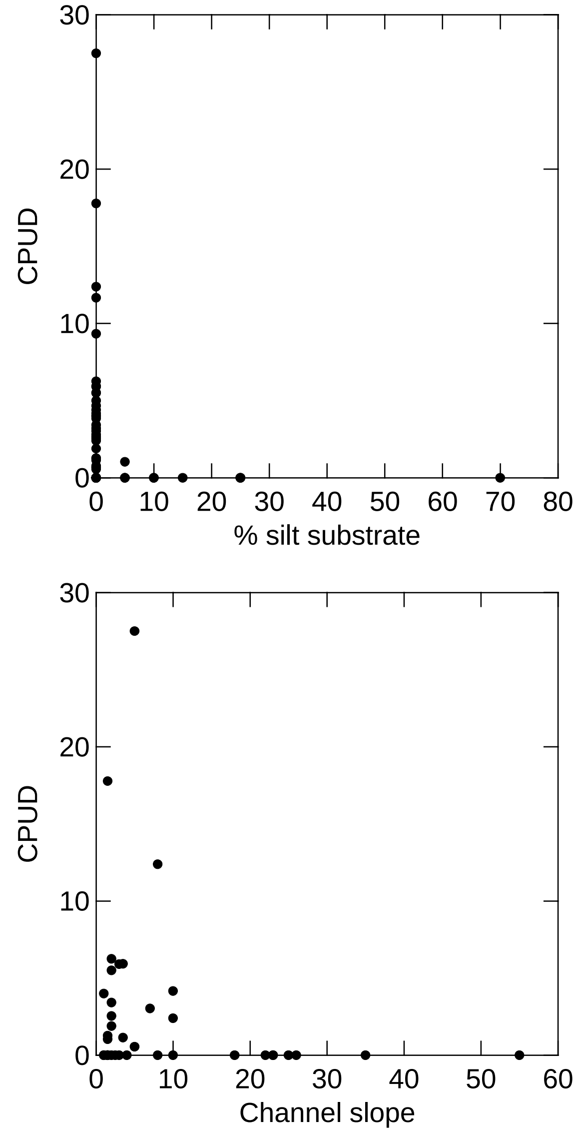

Figure 3. Relationships between CPUD and % silt substrate and channel slope.

Principal components analysis (PCA) conducted on the environmental variables resulted in two factors which accounted for 35.8% of the variance in the environmental data (22.5 and 13.3 % for Factors 1 and 2, respectively). PCA Factor 1 was positively correlated with catchment area, % algal cover, % boulder, % cobble, wetted width, bankfull width, flow rating, water clarity rating, % stream reach as run, % as pool. PCA Factor 1 was negatively correlated with stream class, % organic detritus, % moss cover, % pebble, % gravel, % silt, overhanging vegetation score, trailing vegetation score, % as riffle.

CPUD and CPUA were both significantly correlated with PCA Factor 1, with $r = 0.291$ and 0.245, respectively ($p = 0.01865$ and 0.0490), but not with PCA Factor 2 or any of the remaining PCA factors.

Multiple linear regression of CPUD against the environmental variables resulted in a regression model with only three variables - catchment area, % moss cover, wetted width - and with an adjusted r^2 of only 0.345. Inspection of residuals suggested log transformation of CPUD was necessary, but overall model performance was not significantly improved (adjusted $r^2 = 0.37$).

A consistent outlier was identified in both model runs – the tributary of Coopers Creek. The analyses were repeated with this outlier site removed, but resulted in models with only marginally improved adjusted r^2 values (0.39 and 0.45).

CPUD data was recoded as CPUDR to allow for inclusion of outliers, in an attempt to control for the high degree of noise in the data as follows:
CPUD = 0, CPUDR = 0; CPUD >0 and < 2, CPUDR = 1; CPUD >2 and <5, CPUDR = 2; CPUD > 5, CPUDR = 3.

Multiple linear regression of CPUDR produced a model with an adjusted r^2 of 0.52, using the following variables – catchment area, % bedrock, % moss, wetted width. All variables had low tolerance (ie were not intercorrelated), and plots of residuals showed no trends.

Analysis of CPUA data either recoded in a similar way to CPUA or log transformed, did not result in multiple linear regression models with adjusted r^2 greater than 0.25. Multiple linear regression results for CPUDR are summarised as follows:

Dependent Variable: CPUDR

N: 66 , multiple R: 0.7400, squared multiple R: 0.5475.

Adjusted squared multiple R: 0.5179. Standard error of estimate: 0.7846.

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
Constant	-0.71114	0.27846	0.00000	.	-2.55382	0.01317
Catchment area	-0.01777	0.00410	-0.46606	0.64057	-4.33105	0.00006
% moss cover*	1.33950	0.53262	0.23345	0.86085	2.51493	0.01456
Wetted width **	1.90662	0.22372	0.94592	0.60210	8.52231	0.00000

* = arcsin(sqrt) transformed; ** = ln (x+1) transformed

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	45.43635	4	11.35909	18.45358	< 0.0000005
Residual	37.54850	61	0.61555		

Data on presence/absence of juvenile *A. gouldi* was analysed by logistic regression. Complete stepwise model development was conducted initially, resulting in a model with four variables. Models were then developed sequentially, with decreasing numbers of these four variables, comparing each model with all others using the G statistic. A model was successfully developed with a significant log-likelihood ratio using four variables – catchment area, % moss, wetted width and stream class (see box). There was thus an increased probability of presence of juvenile *A. gouldi* with decreasing catchment area, increased wetted width, increased moss and decreasing stream class). The increased probability of presence at smaller catchment areas and in larger, wider streams appears contradictory, but is a product of decreasing density at large catchment areas (see discussion below).

This model successfully classified 74% of sites by presence or absence of juvenile *A. gouldi*.

```
Binary LOGIT Analysis.

Dependent variable: JVPA
Input records:           66
Records for analysis:           66
Sample split

Category choices
   0   (REFERENCE)        33
   1   (RESPONSE)         33
Total      :              66

L-L at iteration 1 is    -45.74771
L-L at iteration 2 is    -29.02322
L-L at iteration 3 is    -27.82911
L-L at iteration 4 is    -27.77457
L-L at iteration 5 is    -27.77437
L-L at iteration 6 is    -27.77437
Log Likelihood:    -27.77437

    Parameter                Estimate        S.E.      t-ratio      p-value
  1 CONSTANT                 -0.78758      2.13246     -0.36933      0.71188
  2 Ln Catchment area        -1.55481      0.68712     -2.26279      0.02365
  3 Ln Wetted width           5.31399      1.65733      3.20636      0.00134
  4 %Moss(arcsin sqrt)        3.92909      2.01739      1.94761      0.05146
  5 Stream Class             -1.06702      0.55557     -1.92057      0.05479

                                                    95.0 % bounds
    Parameter              Odds Ratio        Upper        Lower
  2 Ln Catchment area         0.21123      0.81215      0.05494
  3 Ln Wetted width         203.15899   5230.65987      7.89070
  4 %Moss(arcsin sqrt)       50.86057   2652.10106      0.97538
  5 Stream Class              0.34403      1.02213      0.11580
Log Likelihood of constants only model = LL(0) =    -45.74771
2*[LL(N)-LL(0)] =     35.94668 with 4 df Chi-sq p-value < 0.0000005
McFadden's Rho-Squared =      0.39288



Model Prediction Success Table

      Actual  Predicted Choice                Actual
      Choice     Response    Reference         Total

     Response     24.34943      8.65057     33.00000
    Reference      8.65057     24.34943     33.00000

Pred. Tot.        33.00000     33.00000     66.00000
Correct            0.73786      0.73786
Success Ind.       0.23786      0.23786
Tot. Correct       0.73786
```

Stream drainages containing juvenile *A. gouldi*

The following results are for analyses conducted on data collected from 54 streams in which juvenile *A. gouldi* were recorded in at least the Class 2 (downstream) reach. Thus these data are for stream drainage sections in which juvenile *A. gouldi* are known to occur.

Juvenile *A. gouldi* density, as CPUD and CPUA, was positively correlated (by Spearman rank correlation) with the following variables:

- catchment area, channel width (wetted and bankfull) - all with $p < 0.0001$; and
- % algal cover, % boulder substrate and % of reach as run habitat – all with $p < 0.01$.

CPUD was also negatively correlated with % of reach as riffle habitat and cover of overhanging and trailing vegetation (both $p < 0.01$). A significant negative correlation was observed for both CPUD and CPUA with % silt substrate (both $p < 0.01$).

Principal components analysis (PCA) conducted on the environmental variables resulted in two factors (1a and 2a) which accounted for 39% of the variance in the environmental data (24.5 and 14.5 % for Factors 1a and 2a respectively). PCA Factor 1a was positively correlated with the same variables as PCA Factor 1: catchment area, % algal cover, % boulder, % cobble, wetted width, bankfull width, flow rating, water clarity rating, % stream reach as run, % as pool. PCA Factor 1a was also negatively correlated with stream class, % organic detritus, % moss cover, % pebble, % gravel, % silt, overhanging vegetation score, trailing vegetation cover score, % as riffle.

CPUD and CPUA were both significantly positively correlated with PCA Factor 1a (both $p = < 0.001$ by Spearman rank correlation), but not with PCA Factor 2a or any of the remaining factors from this PCA.

Multiple linear regression of CPUD, after ln(x+1) transformation, against the environmental variables resulted in a regression model with only two independent variables, and with an adjusted r^2 of 0.55. The two variables were bankfull width and % boulder substrate, for which the partial correlations with CPUD were both positive. The results of this analysis are summarized below. Removal of the case with large leverage had a minor effect on the overall model, and was therefore left in. Results of the regression analysis are shown here:

Dependent Variable: CPUD (ln(x+1) transformed)

N = 54   Multiple R: 0.749   Squared multiple R: 0.5609

Adjusted squared multiple R: 0.5437   Standard error of estimate: 0.6253

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
Constant	-1.05347	0.25853	0.00000	.	-4.07487	0.00016
% boulder*	1.15246	0.45155	0.25155	0.88636	2.55222	0.01374
Bankfull width**	1.03952	0.16375	0.62569	0.88636	6.34823	< 0.0000005

* = arcsin(sqrt) transformed; ** = ln (x+1) transformed

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	25.47070	2	12.73535	32.57018	< 0.0000005
Residual	19.94164	51	0.39101		

Case 26 has large leverage (Leverage = 0.26454)

Durbin-Watson D Statistic 1.60009

First Order Autocorrelation 0.18942

Multiple linear regression of CPUA, after ln(x+1) transformation, against the environmental variables resulted in a regression model with only two independent variables, and with an adjusted r^2 of 0.76. The two variables were wetted width and %

wetted width, for which the partial correlations with CPUA were both positive. Results are shown here:

Dependent Variable: CPUA (ln(x+1) transformed)

N = 54 Multiple R: 0.87660 Squared multiple R: 0.7684

Adjusted squared multiple R: 0.7593 Standard error of estimate: 0.6654

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
Constant	-1.03903	0.25629	0.00000	.	-4.05414	0.00017
Moss*	1.39568	0.51965	0.19353	0.87453	2.68580	0.00974
Wetted width**	2.25800	0.17566	0.92626	0.87453	12.85464	< 0.0000005

* = arcsin(sqrt) transformed; ** = ln (x+1) transformed

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	74.93429	2	37.46715	84.61511	< 0.0000005
Residual	22.58254	51	0.44279		

Durbin-Watson D Statistic 1.93907

First Order Autocorrelation 0.02438

Relationships between CPUA and selected variables for streams with juvenile *A. gouldi* are shown in Figure 4, with CPUA recoded to CPUAR as follows:

CPUA = 0, CPUAR = 0; CPUA >0 and < 1, CPUAR = 1; CPUA >1 and <2, CPUAR = 2; CPUA >2 and <5, CPUAR = 3; CPUA > 5, CPUAR = 4.

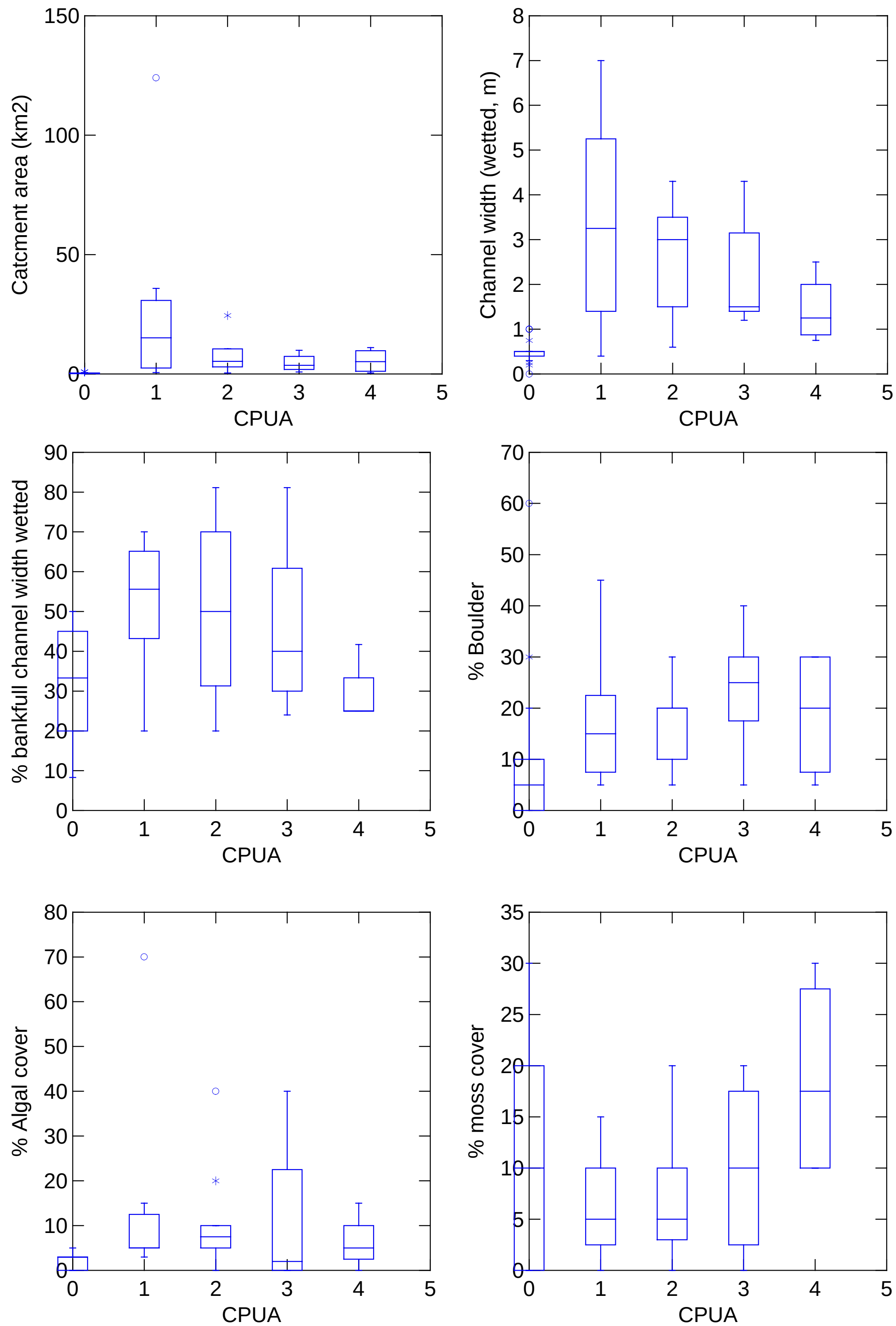

Figure 4. Box plots of the distribution of key environmental variables for four categories of juvenile *A. gouldi* density (n per 100m^2) for stream drainages containing *A. gouldi*.

Overall abundance by stream class

Cumulative lengths of streams of class 2, 3 and 4 calculated from stream drainages mapped by Forestry Tasmania, for all river catchments for which *A. gouldi* is known, both in north west and north east Tasmania are shown in Tables 4 and 5. The proportion of total stream drainage represented by Class 4 streams is remarkably consistent across catchments in both the north west and north east of the state – ranging from 40.2 to 55.6%.

We have used our 'global' means of CPUD for juvenile *A. gouldi* to estimate the relative proportions of juvenile populations at the catchment scale that are resident within the various stream Classes. Overall, this index indicates that juveniles resident within Class 4 streams represent around 7 – 8% of the total abundance within river catchments Tables 4 and 5, Figure 5). It should be noted that if the single 'outlier' case (tributary of Cooper Creek) is removed prior to estimating mean CPUD, then the index falls to 1 – 2 % of the total.

Table 4. Total stream length of various stream classes for NW Tasmania, and estimates of mean proportions (as %) of juvenile *A. gouldi* population by stream class. (Note Class 1 = inadequately differentiated from and pooled with Class 2 streams).

NW Catchments	Class 1 (km)	Class 2 (km)	Class 3 (km)	Class 4 (km)	Grand Total	Class 4 (%)
Black-Detention River		627	159	898	1,685	53.3
Montagu River		160	43	221	424	52.2
Duck River		473	105	598	1,176	50.9
Inglis River		612	118	783	1,513	51.7
Arthur River		1,851	480	2,763	5,095	54.2
Cam River		236	50	243	529	45.9
Emu River		140	33	132	306	43.2
Blythe River		268	64	328	660	49.7
Leven River	1	661	134	710	1,507	47.1
Fourth-Wilmot River	1	383	109	489	982	49.8
Mersey River		986	241	852	2,079	41.0
Rubicon	5	541	131	624	1,301	47.9
Grand Total	7	6,940	1,668	8,641	17,257	Mean = 50.1
Mean JAG popn	3.82		0.640	0.26 (0.039)		
Relative %'s	**88.90**		**3.58**	**7.53 (1.13)**		

Table 5. Total stream length of various stream classes for NE Tasmania, and estimates of mean proportions (as %) of juvenile *A. gouldi* population by stream class.

NE Catchments	Class 2 (km)	Class 3 (km)	Class 4 (km)	Grand Total	Class 4 (%)
Ringarooma River	825	196	687	1,708	40.2
Boobyalla-Tomahawk	625	135	508	1,268	40.1
Pipers River	641	160	715	1,516	47.1
Little-Forester River	371	97	586	1,053	55.6
Great-Forester River	831	199	991	2,022	49.0
North-Esk River	435	117	474	1,026	46.2
Grand Total	3,728	904	3,961	8,593	Mean = 46.1
Mean JAG popn	3.82	0.640	0.26 (0.039)		
Relative %'s	**89.85**	**3.65**	**6.50 (2.11)**		

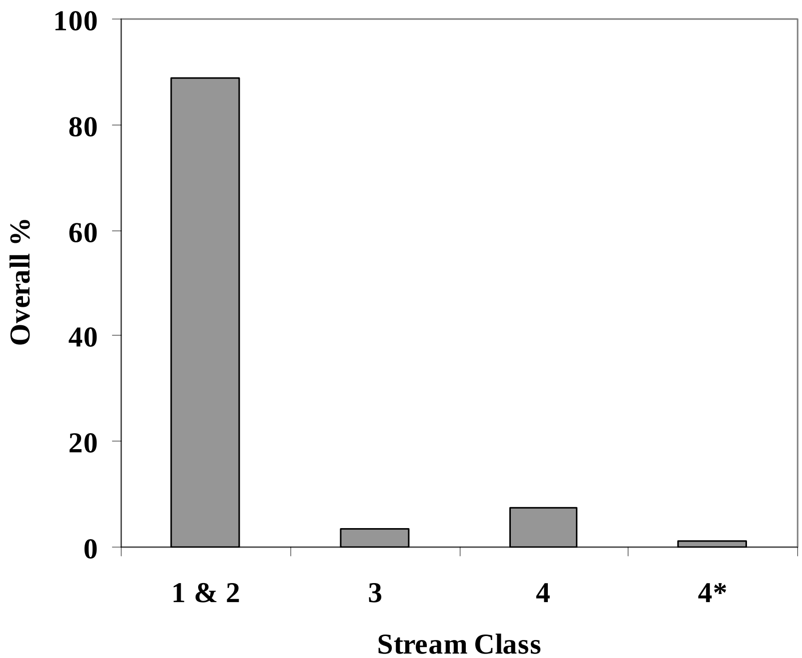

Figure 5. Relative proportions of juvenile *A. gouldi* population occurring in Class 1& 2, Class 3 and Class 4 streams in NW Tasmania. 4* = estimate for Class 4 streams derived when excluding 'outlier' stream – tributary of Coopers Ck - from data set(see text).

Discussion and Conclusions

Significance of Class 4 streams for juvenile *A. gouldi*

This study confirms that juvenile A. gouldi do occur in headwater streams (Class 3 and 4) as observed by Davies and Cook (1999). Comparison of densities of juvenile *A. gouldi* between the three stream classes surveyed indicates that linear and areal densities are substantially and statistically significantly lower in headwater streams (Classes 3 and 4 streams) than in the larger Class 2 streams.

The limited capture success and relatively low density of juvenile *A. gould*i found in Class 4 streams in this study does not mean that they are absent from Class 4 streams. Although captures in Class 4 streams were limited, capture success rates for all methods previously trialled were low, and for the visual search method is ≤ 10%. More prolonged searching, or the use of a more effective search method, would undoubtedly result in higher capture rates. However, we are confident that search effectiveness is reasonably similar across a range of stream channel sizes and types, with the exception of sand bed or highly complex channels (e.g. with significant underground or cryptic channel sections). It is also important that searches are not conducted during periods of high or turbid flow (when juveniles are harder to see and may be more cryptic) or of low water temperature (when juveniles are less active and may be more cryptic). Searches were not conducted under such conditions for this work.

We believe that the magnitude of the differences in observed densities between stream classes are broadly representative of the real situation. We combined mean density (per stream length) figures for each stream class with the cumulative length of all sections of stream drainage in catchments within the range of *A. gouldi* in the northwest and northeast of the state (Table 4 and 5). This gives a relative index of the total population of juveniles in each stream class, and indicates that overall, Class 4 streams would contain only a small proportion (< 8%) of the total abundance of juveniles in these drainages. The density estimates for juvenile *A. gouldi* could be made more precise by sampling a greater number and range of sites. Densities in the more developed (cleared and intensively managed) lower end of stream catchments are also likely to be lower than in less developed catchments (e.g. see Horwitz 1991, 1994, Walsh and Nash 2002). This is partly reflected in our data by the decline in median CPUA with catchment area at higher catchment areas (see Figure 4), where survey sites were unavoidably downstream of a degree of land clearing. The latter may cause the representation of juveniles in larger Class 2 streams to be partly overestimated in these calculations. However, the estimate of the relative contribution of Class 4 stream populations to the overall level of recruitment is unlikely to change substantially.

It should also be noted that no mapping or modelling resources currently available (through LIST or vis DEM modelled drainage) provide a complete inventory of Class 4 streams for Tasmania. Traditional mapping underestimates the presence of Class 4 stream lines due to difficulties in observing drainage through forest cover, and when drainage is not associated with 'gully' features or is partially underground. DEM-based drainage identification assumes that topography dictates location of streamlines, which while generally true for larger streams of sufficient gradient, is not realistic for many Class 4 streams. Class 4 streamlines are often influenced by local, small scale variations in geology, vegetation, groundwater accession and topography, which are beyond the resolution or scope of DEM models. Thus, the estimates in Tables 4 and 5 are likely to be an underestimate of Class 4 drainage lengths, though probably by only a relatively small factor.

Removal of the one 'outlier' case prior to estimating mean CPUD results in a significantly lower (1-2%) proportion of the total catchment-wide abundance of juveniles being resident in Class 4 streams. This stream represents a particular case of very high juvenile densities for a stream with a small catchment area (40 ha). It is not clear how common streams like the tributary of Cooper Creek are throughout the range of *A. gouldi* (based on our field observations they probably represent < 5% of Class 4 streams). This stream has its headwaters at a contact between quartzites (in the mid and lower catchment) and erosional relict surfaces of basaltic origin. These are two fluvial geomorphological types described as "northern quartzite ridges hills and valleys" and "northern relict surfaces" in the fluvial geomorphological analysis conducted for Tasmania by Jerie et al. (2003). These two types are restricted to the area SW to SE of Rocky Cape, and include parts of the catchments of the Flowerdale, lower Inglis and upper Detention Rivers. The contact between them is, however, restricted to the lower Flowerdale River catchment.

More streams of this type are to be expected within the Flowerdale-Hebe River catchment. Observations in a stream claimed to support high densities of juvenile *A. gouldi* by Walsh (Todd Walsh, pers. comm.) support the suggestion that other streams of similar type are to be found in the Flowerdale-Hebe River catchment. Of course suitable spring-fed streams may occur at other contacts between geologies/lithologies which produce significant groundwater contribution to Class 4 stream baseflows.

Overall, the data indicates that headwater streams:

- may contain suitable habitat for juvenile *A. gouldi*;
- generally support low densities of juvenile *A. gouldi*;
- support densities that are consistently and substantially lower than in Class 2 streams within the same drainage;
- do not support a substantial component of the overall population of juveniles in a catchment;

A subset of Class 4 streams may support juvenile *A. gouldi* at densities close to those observed in Class 2 streams. These are ones in which baseflows are strongly supplemented by groundwater inputs

Habitat preferences of juvenile *A. gouldi*

Macro-habitat features

Juvenile *A. gouldi* were found in streams at all elevations surveyed (18 – 250 m above sea level), and in channels of all widths encountered (1 to 20 m bankfull width). Juveniles were observed in catchment areas ranging between 0.4 and 124 km^2. Juveniles were not found at any site with catchment areas ranging between 0.12 and 0.4 km^2.

Analysis of relationships between measures of juvenile *A. gouldi* density and environmental variables indicates that densities are higher in:

- wider streams at intermediate catchment sizes, typically 2 to 30 km^2;
- streams with low levels of silt substrate (< 2%);
- streams with high proportions of moss cover (> 10%);
- streams with higher proportions of boulder substrate.

No juvenile *A. gouldi* were observed in streams with channel slopes > 10%, with % silt substrate > 5%, or with baseflow conductivities > 160 microS/cm. These conditions are therefore associated with very low true densities of juveniles (ie less than 10 times the lowest densities recorded in our survey ie 3 per 100m stream length, or 2 per 100 m^2 area).

A single Class 4 (tributary of Cooper Creek) contained an unusually high density of juveniles. The Class 2 stream reach immediately downstream also contained a high density of juveniles. There was, however, no significant correlation between Class 4 densities and densities in downstream stream reaches, when assessed over all sites (Pearson correlation, $p > 0.4$). This stream was unusual in having a high baseflow, whose magnitude was distinctly higher than that expected from the catchment area and behaviour of other streams in the area. The high baseflow was due to groundwater input from springs. The density of juveniles in this stream was highly likely to be related to the large baseflow and perennial nature of the stream, resulting in similar habitat characteristics to larger, Class 2 streams in the area.

Logistic regression indicated that presence/absence of juveniles could be reasonably well predicted using four variables – stream class, wetted width, % moss cover and catchment area. 74% of stream sites were successfully classified with presence/absence of juveniles using this model. The negative parameters for stream class and catchment area accounted for the opposite trends of decreasing density at higher stream classes and at large catchment areas. The sensitivity of odds of the presence of juveniles to the variables was in the order: stream width > % moss cover > stream class > catchment area. Overall, presence of juveniles is dictated primarily by stream dimensions and catchment area, and then by the presence of moss – a factor probably related to the presence of larger, stable instream rocks which form suitable shelter sites.

Optimal macro-habitats for juvenile *A. gouldi* are:

- wide streams with:
    - catchment size typically 2 to 30 km^2;
    - < 2% area of substrate as silt;
        - 10% high proportions of moss cover;
    - moderate to high proportions (10 – 30%) of substrate as boulders;
    - channel slopes < 15%;

or

- small streams of:
    - 0.4 to 2 km^2 catchment area; and with
    - significant and sustained groundwater (spring) input leading to elevated perennial baseflows.

Meso-habitat features

The positive relationship between the presence and density of juvenile *A. gouldi* and elevated levels of moss cover and boulder substrate is, we believe, a result of higher densities in streams containing large, stable rocks (and occasionally logs) overlying small refuge cavities. These microhabitats are key features favoured by juveniles. The difficulty experienced by us in capturing juveniles in sandy granitic streams in north-eastern Tasmania is probably related to the absence of such features.

Optimal instream meso-habitat features for juvenile *A. gouldi* are as follows:

- large rocks
  - big enough not to be easily dislodged by high flows or by platypus;
  - overlying coarser substrates (boulder, cobble or pebble);
  - 40 cm in diameter or greater and flat in profile with a distinct cavity underneath;
  - in riffles, runs and pools;
  - in mid-channel and channel edges;
  - not embedded in finer substrates (gravel, sand or clay).
- cavities
  - associated with overlying or underlying rocks but not excavated;
- logs
  - well lodged in the stream bed with a suitable underlying cavity.

Other factors

This survey was limited to a subset of Class 4 streams primarily in the NW of the state. A larger sample set would result in estimates of densities and habitat relationships more accurate and comprehensive. A wide range of streams are being sampled in an ongoing study to evaluate the downstream effects of logging in Class 4 stream catchments on abundance of juvenile *A. gouldi* and macroinvertebrates and stream habitat. These data will be incorporated with this data set and the analyses reported here repeated.

One key factor that determines juvenile *A. gouldi* densities was not studied in this survey – the density of adults, and particularly reproductive females. Resource and time constraints prevented us from conducting surveys of adults. Estimation of densities of adults is difficult, and must be based on catch per unit trapping effort or capture-mark-recapture sampling. Trapping efficacy of adult lobsters is difficult to quantify and highly variable (Hamr 1990 and pers. comm.). Even crude estimates of adult density may explain some of the variation in density of juveniles, although the relationship between juvenile and adult density may be confounded by:

- variable movement of adults into or away from juvenile habitats;
- spatial and temporal variability in mortality of juveniles after release;
- coincident habitat selection by adults and juveniles at the reach scale.

It is known that meso-habitats selected by juveniles and adults differ, with adults favouring deeper pools often associated with snags (Webb 2001) and juveniles favouring shallower areas (Hamr 1990, Davies and Cook 1999). This separation of occupied habitat may also be partly influenced by predation by adults on juveniles.

Management Considerations

The results of this study indicate that although headwater streams (Class 4 and 3) provide some habitat for juvenile *A. gouldi,* they do not represent a significant component of juvenile *A. gouldi* habitat within a river catchment. To assist the recovery of the species, management for the protection of recruitment to *A. gouldi* populations must focus on the catchment as a whole. The emphasis should be on protection of mainstream populations from the cumulative pressures associated with landuse activities (eg., forestry and agriculture), point source pollution and illegal fishing. In particular, measures should be taken to minimise downstream impact on areas of optimal habitat for both adult and juvenile *A. gouldi*.

Current management prescriptions for *A. gouldi* in areas subject to forestry activities (developed in 1999 and revised in 2000/01), take into account the characteristics of habitat utilised by adult *A. gouldi*, indicated by previous studies, (Lynch 1967, Growns 1995, Lynch and Bluhdorn 1997, Webb 2001) and expert opinion. These prescriptions are currently delivered to forest planners via a decision support system (Threatened Fauna Advisor, Forest Practices Board 2002). The details of the prescriptions vary depending on the class of stream, type of operation, and known occurrence of the species or suitable habitat, within the operation area.

These prescriptions should be revised to incorporate the results of this study. In particular, the identified characteristics of optimal macro and meso habitat, can be used to identify key areas (whole catchments or stream reaches) that require local or upstream protection measures for juvenile *A. gouldi*.

Evaluation of the extent to which forestry operations in Class 4 stream catchments affect *A. gouldi* populations in headwater streams was precluded in this study due to the low abundance of juveniles observed in Class 4 streams. Therefore, the extent to which forestry operations in the headwaters impact on juvenile *A. gouldi* habitat, and the effectiveness of the current management prescriptions, remains unclear. This question is to be assessed in a new study (now underway) focussing on the effects on juvenile populations in downstream Class 3 and 2 stream reaches of forest harvest operations in headwater catchments. We recommend that existing protection measures for Class 4 streams delivered by the TFA should continue to be implemented, throughout the range of the species, particularly in areas upstream of optimal habitat for juvenile *A. gouldi*.

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Appendix. Site locations and Astacopsis capture data for intensively surveyed stream sites in spatial survey.

Site	Easting	Northing	Stream Class	Catchment area km^2	Elevation m ASL	Survey time hr	Survey distance m	Juveniles captured n	CPUD n/100m	CPUA $n/100m^2$
Big Ck in plantation	390900	5452300	2	11	100	0.75	150	4	2.67	0.76
Big Ck u/s plantation	391200	5452200	2	10.5	100	2	200	11	5.50	1.57
Dowlings Ck	389600	5454500	2	19.3	70	1	80	1	1.25	0.42
Big Ck u/s plantation	391200	5452200	2	10.5	100	2	200	8	4.00	1.14
Chellis Ck	375700	5446300	2	4.51	240	1.75	250	8	3.20	1.07
Chellis Ck	375700	5446300	2	4.51	240	1.67	250	11	4.40	1.47
Relapse Ck	368600	5442200	2	9.93	130	2	150	14	9.33	2.17
Chellis Ck	375700	5446300	2	4.51	240	2	250	7	2.80	0.93
Relapse Ck	368600	5442200	2	9.93	130	2	150	7	4.67	1.09
Ten Foot Rd Ck 1	382200	5455200	4	0.29	100	1.5	150	0	0.00	0.00
Ten Foot Rd Ck 2	382300	5454800	4	0.21	100	1.5	90	0	0.00	0.00
Zig Zag Trib 1	382500	5452700	4	0.24	95	1.5	90	0	0.00	0.00
Zig Zag Trib 2	382900	5453200	3	0.88	70	1.5	150	0	0.00	0.00
Chellis Ck Trib 1	375500	5446200	4	0.23	250	1.5	150	0	0.00	0.00
Chellis Ck Trib 2	375500	5446150	4	0.41	250	1.5	150	1	0.67	1.11
Chellis Ck Trib 3	375800	5446500	3	0.7	230	1.5	150	1	0.67	0.67
Groove Ck	431000	5426700	3	0.62	250	1.5	240	0	0.00	0.00
Zig Zag Rd Ck	383100	5453500	2	1.025	60	1.5	130	5	3.85	2.96
Hebe R.	372600	5453900	2	4.18	220	1.5	150	0	0.00	0.00

Site	Easting	Northing	Stream Class	Catchment area km^2	Elevation m ASL	Survey time hr	Survey distance m	Juveniles captured n	CPUD n/100m	CPUA n/100m^2
Ingram Ck	436200	5426700	2	2.39	60	1.5	105	0	0.00	0.00
Barrington Ck	436400	5427800	2	2.28	60	1.5	150	0	0.00	0.00
Relapse Ck Trib 1	368900	5442300	4	0.144	150	1.5	210	0	0.00	0.00
Relapse Ck Trib 2	368100	5442200	4	0.18	130	1.5	140	0	0.00	0.00
Zig Zag Rd Ck	383100	5453500	2	1.025	60	1.5	130	1	0.77	0.59
Relapse Ck	368600	5442200	2	9.93	130	1	60	7	11.67	2.71
Puzzle Ck	367100	5437300	3	0.93	250	0.75	100	0	0.00	0.00
Champion Rd Ck	367700	5443100	2	2.4	130	1	150	0	0.00	0.00
Dip R. at Falls	363400	5455800	2	35.9	200	1	80	4	5.00	0.83
Brand's Ck at Dolerite Rd	475456	5425422	2	31.2	160	1.5	193	2	1.04	0.21
Brand's Ck at Brushy Rd	475094	5424002	4	0.42	252	1.5	180	0	0.00	0.00
Rubicon R at Dolerite Rd	464884	5422370	2	203.5	135	1.5	476	0	0.00	0.00
Parrot Ck tributary	471569	5422741	2	2.88	170	1.5	165	0	0.00	0.00
Franklin Rt tributary	467389	5429378	2	2.99	50	0.4	53	1	1.89	1.89
Franklin Rt	468093	5430678	2	124	18	1.5	157	2	1.27	0.18
Franklin Rt tributary	468098	5430729	3	0.927	18	1.5	257	0	0.00	0.00
Radford's Ck	422101	5431965	2	1.412	55	1.5	132	2	1.52	1.01
Radford's Ck	421915	5432123	3	0.826	108	1.5	120	5	4.17	2.78
Radford's Ck tributary	421915	5432123	4	0.215	108	1.5	120	0	0.00	0.00
McBride's Ck at Ferndene Picnic Ground	418750	5444678	2	3.62	65	1.5	135	8	5.93	2.96

Site	Easting	Northing	Stream Class	Catchment area km^2	Elevation m ASL	Survey time hr	Survey distance m	Juveniles captured n	CPUD n/100m	CPUA n/100m^2
McBride's Ck tributary	418843	5443851	4	0.116	100	1.5	221	0	0.00	0.00
Natone Ck at Iron Mine Rd	411450	5445190	2	4.05	35	1.5	263	3	1.14	0.76
Natone Ck tributary	411350	5445170	4	0.149	38	1.5	382	0	0.00	0.00
Weld R. At Frome Rd	573873	5445909	2	43.7	130	1.5	350	0	0.00	0.00
Sandy Ck.	567704	5461386	2	2.52	120	0.75	200	0	0.00	0.00
Bonser Ck.	574904	5463527	2	7.85	60	0.75	200	0	0.00	0.00
Mackenzie Rt.	546028	5433328	2	8.16	255	0.75	100	0	0.00	0.00
Little Mackenzie Rt.	548221	5434419	2	3.29	250	0.75	100	0	0.00	0.00
Unnamed stream near Devil's Gate Dam	437263	5423476	2	2.75	70	1.5	125	3	2.40	2.00
Unnamed stream trib near Devil's Gate Dam	437910	5423190	4	0.27	150	0.2	150	0	0.00	0.00
Blackfish Ck	387749	5457340	2	30.5	40	1.5	380	13	3.42	0.68
Blackfish Ck tributary 1	387720	5457350	4	0.26	40	0.75	144	0	0.00	0.00
"Todd's" Ck	380187	5456403	4	0.477	95	1.5	435	0	0.00	0.00
Unnamed stream, eastern shore LB	433497	5416217	2	1.702	125	1.5	405	0	0.00	0.00
Unnamed stream, western shore LB	429301	5411412	2	8.49	125	1.5	80	22	27.50	18.33
Trib 1 unnamed stream, western shore LB	429075	5411475	2	1.87	135	1.5	105	13	12.38	12.38

Site	Easting	Northing	Stream Class	Catchment area km^2	Elevation m ASL	Survey time hr	Survey distance m	Juveniles captured n	CPUD n/100m	CPUA n/100m^2
Trib 2 unnamed stream, western shore LB	428875	5411550	4	0.415	160	0.85	185	0	0.00	0.00
Hebe River	375643	5452373	2	24.5	130	1.5	352	22	6.25	1.56
Hebe River tributary	375643	5452373	4	0.229	135	1.5	435	0	0.00	0.00
Blackfish Ck tributary 2	387345	5456531	3	0.636	49	1	360	1	0.28	0.69
Cooper's Ck	381100	5454252	2	4.8	125	1.5	218	10	4.59	3.06
Cooper's Ck tributary	380818	5454036	4	0.408	140	1.5	220	9	4.09	5.45
Gibson Ck	353057	5461256	2	11.04	112	1.5	180	32	17.78	7.11
Gibson Ck tributary	353094	5461355	4	0.275	108	1	410	0	0.00	0.00
Melin Rt	358301	5463346	2	27.08	68	1.5	250	10	4.00	0.73
Melin Rt tributary	358550	5463255	4	0.269	75	0.75	150	0	0.00	0.00
Maynes Ck	378350	5456200	2	6.12	117	1.5	432	11	2.55	1.02
Maynes Ck tributary	378350	5456200	3	0.52	117	1.25	780	0	0.00	0.00