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*Exit Cave and Mystery Creek Cave - Tasmania*

Michael Driessen

Nature Conservation Report 09/02

Department of
Primary Industries and Water

Tasmania
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**SUMMARY**
Exit Cave and Mystery Creek Cave in the Ida Bay karst system in south-east Tasmania contain a diverse and significant cave fauna. The most superlative faunal feature of these caves is the light displays by the Tasmanian Glow-worm *Arachnocampa tasmaniensis.* These displays have been recognised as a world heritage value under the criterion relating to outstanding natural phenomena. The caves also provide habitat for several species listed as rare under the Tasmanian *Threatened Species Protection Act 1995*; the Blind Cave Beetle *Goedotrechus mendumae*, the Ida Bay Cave Beetle *Idacarabus troglodytes*, and the Ida Bay Cave Harvestman, *Hickmanoxyomma cavaticum.*

Although the two caves are protected within the Southwest National Park and are largely undisturbed by human impacts, the tourism potential of Mystery Creek Cave has been recognised and ways to improve visitor access have been suggested. Any changes to the management of these caves need to take into account the ecology of the glow-worms, and other cave fauna, to avoid the major decline that occurred in a glow-worm population in New Zealand following changes to the cave entrance for the benefit of tourists.

The present study aimed to establish baseline monitoring data on the Tasmanian Glow-worm, and other cave fauna, in Exit and Mystery Creek caves that will be useful in determining changes to their populations as a result of changes in cave management or other potential threats. The present study also aimed to obtain, for the first time, information on the ecology of the Tasmanian Glow-worm.

Cave fauna were monitored monthly for 24 months in both Exit and Mystery Creek Cave. In the Tasmania Glow-worm, a strong seasonal pattern was found, with pupae and adults most common in spring and summer. The increase in numbers of pupae and adults coincided with an increase in the number of prey caught in silk threads produced by the larvae. Larvae were present throughout the year but the number glowing varied both seasonally and spatially. In Mystery Creek Cave, the number of larvae glowing was generally highest during summer and autumn and lowest in winter and early spring. In Exit Cave, there was no consistent seasonal pattern in the number of larvae glowing among sites, and overall there was less variation between monthly counts than at Mystery Creek Cave. This difference in seasonal patterns between the two caves may be due to a difference in climate, with Mystery Creek Cave possibly experiencing a greater drying out of the cave air in winter than Exit Cave.

The life cycle of the Tasmanian Glow-worm differs to some extent from that reported for another species of glow-worm, *A. luminosa*, in Waitomo Cave, New Zealand. In *A. luminosa* most life stages of the glow-worm are present throughout the year although there is an underlying annual cycle. Pupae and adults are most common during winter and larvae are most common during spring and summer and this is when the glow-worm display is at its best. The differences between the life cycles of the two species of glow-worm probably result from differences in latitude and climate between the two study locations.

Monthly counts of cave crickets and other cave fauna, which were common in Exit Cave and uncommon in Mystery Creek Cave, revealed few interpretable patterns. The

only consistent pattern observed was in the part of Exit Cave known as the 'wind tunnel' where cave cricket and cave beetle numbers were high during the warmer months and low during the cooler months. This is likely to be a response to the winter effect in that part of Exit Cave.

This study established baseline monitoring data for the Tasmanian Glow-worm in Exit Cave and Mystery Creek Cave that could be used to compare with any future monitoring that may be required. On-going monitoring of glow-worms is a low priority unless a potential threat is identified. Some low level monitoring of glow-worms in Mystery Creek Cave, which has unrestricted visitor access, may be prudent. The current extent of the glow-worm colonies in Exit Cave and Mystery Creek Cave should be mapped in both summer and winter to establish baseline data on their distribution.

Because of the low numbers of beetles, spiders and harvestman recorded during the present study, a more targeted monitoring program is required for these species to improve the detection of changes in abundance. This would require a significant increase in survey effort and is probably not justified at present given the current low level of threat to these species.

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## INTRODUCTION

Tasmania has a rich and diverse cave fauna (Eberhard *et al*. 1991; Hamilton-Smith and Eberhard 2000) and the Ida Bay karst system in the southeast of the state contains one of the most diverse and significant cave faunas in Australia's temperate zone (Eberhard 2001). The most superlative faunal feature of the Ida Bay karst system is the light displays by the Tasmanian glow-worm *Arachnocampa tasmaniensis* Ferguson (Diptera: Keroplatidae) in Mystery Creek and Exit caves. These displays have world heritage value under the criterion relating to outstanding natural phenomena (Anon 1982, 1989). The only other place in the world where glow-worm displays are known to occur on a similar scale is in Waitomo Cave, New Zealand, which attracts over 450,000 visitors annually (Mason 2003). However, in contrast to Waitomo Cave, Mystery Creek and Exit caves and their surface environment are largely undisturbed, have not been modified for tourism development and receive relatively few visitors. The glow-worm display in Mystery Creek Cave has tourist potential, and ways to improve visitor access have been suggested (Merritt 2001). However, any changes to the management of Mystery Creek and Exit caves need to take into account the ecology of the glow-worms, and other cave fauna, to avoid the major decline that occurred in the Waitomo glow-worm population following changes to the cave entrance for the benefit of tourists (Pugsley 1984).

Although the glow-worm display in Mystery Creek Cave has been recognised for more than one hundred years (Anon 1895), the ecology of this species has not previously been studied. The ecology of the New Zealand glow-worm *A. luminosa* (Skuse) has been well studied (eg Richards 1960; Pugsley 1984), and recently the life-cycle of an Australian glow-worm, *A. flava* Harrison, held in captivity was reported (Baker and Merritt 2003). The distribution and phylogenetic relationships of the eight species of Australian glow-worms has recently been defined (Baker et al. 2008).

In addition to glow-worms, the Ida Bay karst system provides the only known habitat for several rare species listed under the Tasmanian *Threatened Species Protection Act 1995*; the Blind Cave Beetle *Goedotrechus mendumae* Moore, the Ida Bay Cave Beetle *Idacarabus troglodytes* Lea, and the Ida Bay Cave Harvestman, *Hickmanoxyomma cavaticum* Hickman

In a review of cave fauna management, Eberhard (1999) recommended that a cave fauna monitoring program be undertaken at Ida Bay to; (1) expand our knowledge of the cave biological resources, (2) identify environmental seasons, cycles, changes and trends, and (3) provide a baseline upon which to assess the impact of future human activity in the cave. Eberhard (1999) identified several potential monitoring sites for glow-worms and other cave fauna and piloted a number of potential monitoring techniques.

The primary aim of this study is to establish baseline monitoring data for the Tasmanian Glow-worm and other cave fauna in Mystery Creek Cave and Exit Cave. To facilitate the relocation of all monitoring sites, comprehensive details on the sites and viewing locations are provided in the appendices of this report together with all raw data.

## THE CAVE FAUNA

The main cave species monitored in this study were the Tasmanian Glow-worm and the Tasmanian Cave Cricket *Micropathus tasmaniensis* Richards. Other cave species recorded in this study were the Ida Bay Cave Harvestman, the Ida Bay Cave Beetle and the Tasmanian Cave Spider *Hickmania troglodytes* (Higgins and Petterd). Another resident of the Ida Bay cave system, the Blind Cave Beetle is difficult to monitor because it is extremely rare and cryptic and was not surveyed. The cave harvestman and cave beetles are troglobytes, meaning they are unable to exist outside the cave environment. The glow-worm, the cave cricket and the cave spider are troglophiles and also occur outside of caves.

A brief description of the distribution and life history of the Tasmanian glow-worm and the Tasmanian cave cricket is given below.

### Glow-worms

Glow-worms referred to in this study are the larval stage of a fly belonging to the genus *Arachnocampa* (Order Dipera, Family Keroplatidae). In addition to the Tasmanian Glow-worm, which only occurs in Tasmania, eight other species of *Arachnocampa* have been described. Seven occur in eastern Australia (Queensland, New South Wales and Victoria), including five recently described species (Baker in press), and one from New Zealand *A. luminosa*. The seven Australian species are; *A. tropica* Baker, *A. flava*, *A. girraweenensis* Baker, *A. richardsae* Harrison, *A. otwayensis* Baker, *A. gippslandensis* Baker and *A. buffaloensis* Baker. Phylogenetic analyses places *A. tasmaniensis* with *A. buffaloensis* (from Mt Buffalo in the Australian Alps, Victoria) in the subgenus *Lucifera*. The remaining Australian species occur in the subgenus *Campara* and *A. luminosa* occurs in the subgenus *Arachnocampa* (Baker *et al.* 2008).

The life history of glow-worms has four stages: egg, larva, pupa and adult fly. The eggs are laid in large numbers directly onto the cave walls. The average number of eggs laid by *A. flava* and *A. luminosa* is about 130 (Baker and Merritt 2003; Richards 1960). *A. luminosa* eggs hatch after 22-24 days (Richards 1960) whereas those of *A. flava* hatch after 7-9 days (Baker and Merritt 2003). The difference in hatching time recorded in the two studies may reflect differences between the two species or differences in temperatures between the two studies with *A. flava* held at 23°C and *A. luminosa* at 15°C. Most *A. luminosa* larvae hatch in spring and summer (Pugsley 1984). The larvae immediately emit their bright blue lights, spread out over the cave, and commence building nests and letting down silk threads coated with droplets of sticky mucus to snare prey. Their main food is insects that are carried in by streams as larvae; adults emerge from the stream, fly towards the glow-worm lights and become entangled in the threads.

The duration of the larval stage is not precisely known because of difficulty tracking larvae over long periods of time, but estimates range from five to twelve months depending on environmental conditions (Richards 1960; Meyer-Rochow 1990; Baker and Merritt 2003). Meyer-Rochow (1990) reported an extreme example of a larval stage lasting up to 18 months due to limited food resources. When the larvae reach a length of about 40mm they pupate (Richards 1960). The pupal stage lasts for about twelve days for *A. luminosa* and six to seven days for *A. flava* held in captivity at higher temperatures. In *A. luminosa* both male and female pupae glow (Richards 1960). The adult fly stage is very short-lived with females living for one to three days and males up to four days (Richards 1960; Baker and Merritt 2003). Unmated male *A. flava* live up to six days (Baker and Merritt 2003). The primary functions of the adult stage are to reproduce and disperse, although as they are weak fliers their dispersal capability is limited. In *A. luminosa*, the main period of adult emergence is during winter but adults can occur at any time of year (Richards 1960; Pugsley 1984). The main predator of *A. luminosa* is harvestman (Richards 1960). Cannibalism also occurs among glow-worms (Richards 1960).

**Cave Crickets**

Crickets are known from caves from many parts of the world (Vandel 1965). The Tasmanian Cave Cricket is one of 14 species in four genera of Rhaphidophoridae known to occur in Tasmania. Virtually all of the Tasmanian species have been recorded from caves and most have also been recorded from surface habitats. The Tasmanian Cave Cricket occurs throughout southern Tasmania where suitable habitats such as caves and wet forest exist. The life histories of cave crickets in Tasmania have not been studied. Very limited observations have been made on the Tasmanian Cave Cricket and on another cave cricket *M. cavernicola* Richards that occurs in the north of Tasmania (Richards 1967). During a limited field survey in November 1966, Richards (1967) found that for both cave cricket species, all seven instars were present in the populations and two generations were present. Female crickets were more common than males in caves at a ratio of 2:1. Examination of gut contents revealed that both the Tasmanian cave cricket and *M. cavernicola* are scavengers and feed on both plant and animal tissues. Cave spiders prey upon Tasmanian cave crickets (Richards and Ollier 1976). Most species of cave crickets are known to leave caves during the night to search for food (Richards 1962; Mohr and Poulson 1966).

Richards (1961) studied the life history of two Rhaphidophoridae species, *Pachyrhamma waitomoenis* Richards and *Pallidoplectron turneri* Richards in New Zealand. In *P. waitomoenis* the life cycle takes a little over two years; about seven months being required for the development of the egg, 15 to 16 months for the nymphal instars, and between five and ten months for the adults. Most nymphs hatch in November and December and adults mature in January. *P. turneri*, unlike *P. waitomoensis*, continues to breed and mature throughout the year. About eight months are required between laying and hatching of the eggs. The length of nymphal and adult life was not determined. In both species females were more common than males.

## METHODS

**Study Area**

Cave fauna were monitored in Mystery Creek Cave and Exit Cave in the Ida Bay karst system, south-east Tasmania (Figs 1–3). Most of the karst system is protected within Southwest National Park, and is part of the Tasmanian Wilderness World Heritage Area. The Ida Bay karst system is developed in Ordovician limestones (Goede 1969) and most of the karst retains native vegetation cover of wet sclerophyll forest and rainforest. The area has been subject to selective logging and quarrying for limestone in the past (Eberhard 2001). Mystery Creek enters Mystery Creek Cave at an altitude of 115 m above sea level flowing underground into Exit Cave — although no connection passable by cavers has been found — where it is joined by a subterranean anabranch of the D'Entrecasteaux River and emerges from Exit Cave at an altitude of 61 m above sea level (Goede 1969). Exit Cave is one of the largest caves known in Australia, with an estimated length of over 20 km, whereas Mystery Creek Cave is significantly smaller (Fig. 1). There are multiple entrances to the caves, including vertical shafts, some more than 200 m above the main stream passage. These shafts have an important "chimney effect" (Tuttle and Stevenson 1977) on air circulation in the caves with cave air generally exiting through the upper entrances and cooler outside air entering lower entrances during winter and the reverse occurring during warmer months.

In Exit Cave where the glow-worms were monitored the creek bed has a gentle slope (falls approximately 1 in 30 m) and contains sand and coarser-grained particles. In Mystery Creek Cave the creek bed also has a gentle slope, but steeper than in Exit Cave (falls approximately 1 in 20 m), and is covered with much coarser sediments (in particular, large boulders and cobbles) and there are no large sand banks.

The nearest meteorological station is at Hastings, 6km north east of the Ida Bay karst system. Rainfall monitoring at Benders Quarry from April 1989 to June 1990 found that rainfall events were highly correlated between Benders Quarry and Hastings but that Benders Quarry received only 0.8 to 0.9 times the rainfall of Hastings (Houshold and Spate 1990). Mean annual rainfall at Hastings is 1374 mm, with rainfall averaging higher in winter than in summer (Fig. 4). Rainfall during the monitoring period (August 1998 to July 2002) was 77% of the long-term average. Most months (17 out of 24) received below average rainfall, and only three months received above average rainfall (Fig. 4). The period from April 1999 to April 2000 experienced particularly low rainfall, with only 59% of the average rainfall occurring during this period. Mean annual minimum and maximum temperatures are 6.1°C and 16°C respectively. Mean maximum temperatures for July and February are 11.2°C and 20.6°C respectively and mean minimum temperatures for the same two months are 2.6°C and 9.2°C respectively. Temperatures were on average slightly warmer in autumn than in spring (Fig. 5).

Locked gates restrict access to Exit Cave and a permit, issued by the Tasmanian Parks and Wildlife Service, is required to enter the cave. Permit records show that less than 100 people per year enter Exit Cave. Access to Mystery Creek Cave is unrestricted, and logbook entry records managed by the Tasmanian Parks and Wildlife Service indicate that less than 1000 people per year visit the cave.

**Cave Fauna Monitoring**

Cave fauna monitoring was conducted once a month for 24 months starting in August 1998. Monitoring each month was limited to a one-day field trip from Hobart to both Exit and Mystery Creek caves. The field trip comprised a two-hour drive from Hobart to Bender's Quarry, 1.25-hour walk to Exit Cave, monitoring at Exit Cave, return walk to Benders Quarry, 0.5-hour walk to Mystery Creek Cave, monitoring at Mystery Creek Cave, a return walk to Benders Quarry, and return to Hobart.

*Tasmanian Glow-worm Counts*

Eberhard (1999) trialed counting glow-worm lights in the caves directly by eye and indirectly from photographs and recommended counting directly by eye. Monitoring sites were selected on the basis that they were clearly defined clusters that were not too numerous to count by eye (ie clusters of <500). Few clusters of glow-worms met this requirement which restricted the total number of monitoring sites. Twelve monitoring sites, six each in Mystery Creek Cave and Exit Cave, were established. These locations tended to be on the edges of the main glow-worm colony (ie. the ceiling of main glow-worm chambers above the rivers) and potentially in positions more susceptible to changing environmental conditions. Glow-worm monitoring sites were located between 65 and 230 m from Exit Cave Entrance and between 45 and 110 m from Mystery Creek Cave entrance (Figs 2 and 3). The area of the sites ranged from 1 to 70 $m^2$. Detailed descriptions of the monitoring sites are given in Appendix I. Most sites were monitored for 24 months, starting in August 1998; sites MC6, EC2 and EC5, which were added in July 1999, were monitored monthly for 12 months.

When counting, each site was viewed from a defined location (see Appendix I for detailed descriptions) to minimise variation in counts due to different observer positions. Lights were counted in the following order: Exit Cave sites 1–6 and Mystery Creek Cave sites 1–6. To minimise disturbance to glow-worms, the observer approached sites carefully and avoided shining lights directly onto the site or making loud noises. Once at the viewing spot, the observer turned off the lights and only began counting after five minutes, to allow for the observer's eyes to adjust to the darkness. The number of larval lights at the site was counted several times, until consistent counts were obtained. Initially, a minimum of five counts was obtained per site but after several months of monitoring this was reduced to a minimum of three. Throughout the survey all glow-worms were counted by the same observer (the author) to minimise observer bias. However, when a second observer was present they also counted the number of glow-worm lights while standing next to the first observer. This gave an opportunity to investigate how repeatable the counts were between observers.

At a subset of sites it was possible to access glow-worms up close to record the number of adult glow-worms, the number of pupae, the number and the type of prey in silk threads, and the presence of other cave fauna. The areas of the subsites ranged from 0.25 to 2 $m^2$, and were clearly defined so that the same area was surveyed each month. Examination for the presence of adults, pupae and number of prey in threads was completed within about 5 minutes. Glow-worm threads hung free at the sites surveyed and rarely stuck to the walls. Detailed descriptions of sub-sites are given in Appendix I. Access to glow-worms below a height of 1.5 m severely restricted the number of sub-sites that could be monitored. Three sub-sites were monitored in Exit Cave (EC3, EC4 and EC6) and five sub-sites were monitored in Mystery Creek Cave (MC1, MC3, MC4, MC5, and MC6). From November 1999 and to April 2000, small numbers of prey trapped in threads were removed for the purposes of identification.

*Stream Fauna*

Samples of freshwater invertebrates were collected to compare between caves and to compare with prey found in glow-worm threads. Invertebrates were kick-sampled, using a standard Freshwater Biological Association net, along a 10 m transect following the centreline of the cave stream. Three kick-samples were taken in Mystery Creek Cave and in each of the two glow-worm caves in Exit Cave in October 1999 and January 2000. Samples were preserved in 70% ethanol. Apart from earthworms, all invertebrates were identified to at least family level and further where possible. The different stream substrates in each cave (see above) may have influenced the sampling technique; as a result, only general comparisons of the stream fauna were made.

*Tasmanian Cave Cricket Counts*
Cave crickets were monitored only in Exit Cave because they were relatively rare in Mystery Creek Cave. Six sites were established in Exit Cave (Fig. 2), three in the ‘Wind Tunnel’, which is the most common access route for people visiting the cave, and three in side caverns that are not normally accessed by visitors. Monitoring commenced at all sites in August 1998 except site F, which was added in August 1999. All cave crickets within each site were counted with the aid of a head torch. When another observer was present the second observer would also count the crickets while walking behind the first observer. Detailed descriptions of the monitoring sites and instructions on counting are given in Appendix I. The order sites were surveyed was E, A, B, D, C and F.

*Other Cave Fauna*
All other fauna species that were observed in monitoring sites and sub-sites were counted. Spiders were classified into size classes of small (head and abdomen length less than 10 mm); medium (head and abdomen length between 10 and 15 mm); and large (head and abdomen length greater than 15 mm). The sex of large spiders was recorded where the spider could be easily observed for sexual characters.

**Environmental Variables**
*Stream Stage*
For each survey, stream stage was recorded at the D’Entrecasteaux River by measuring the distance between the top of a large wooden peg driven into the bank and the water level (Stream Stage A). The peg was approximately 20 m outside of the Exit Cave entrance. In February 1999, a more permanent measure of stream stage (Stream Stage B) was recorded at just inside the Exit Cave entrance using the large metal grill that restricts access to the cave. The total number of horizontal bars exposed above the water was recorded.

*Air Temperature*
Air temperature was recorded inside the caves to the nearest tenth of a degree Celsius using a TempTec™ thermometer for the first 12 months and then a Vaisala HM34C thermometer was used for the second 12 months. Before the Templec thermometer was discarded, both thermometers were used simultaneously for two months to ensure they recorded the same temperatures. Inside cave air temperatures were recorded immediately adjacent to the six glow-worm sites in each cave and averaged for each cave.

*Air Current Direction*
The direction of air movement into and out of the caves was recorded at each cave entrance. At Exit Cave air movement was recorded at the gated entrance to the cave. The entrance is small and it is easy to detect air movement on exposed face or hands. At Mystery Creek Cave, air movement was recorded at the entrance by observing the movement of glow-worm threads when present or delicate plants. Detecting air movement was more difficult at Mystery Creek Cave because of the larger entrance.

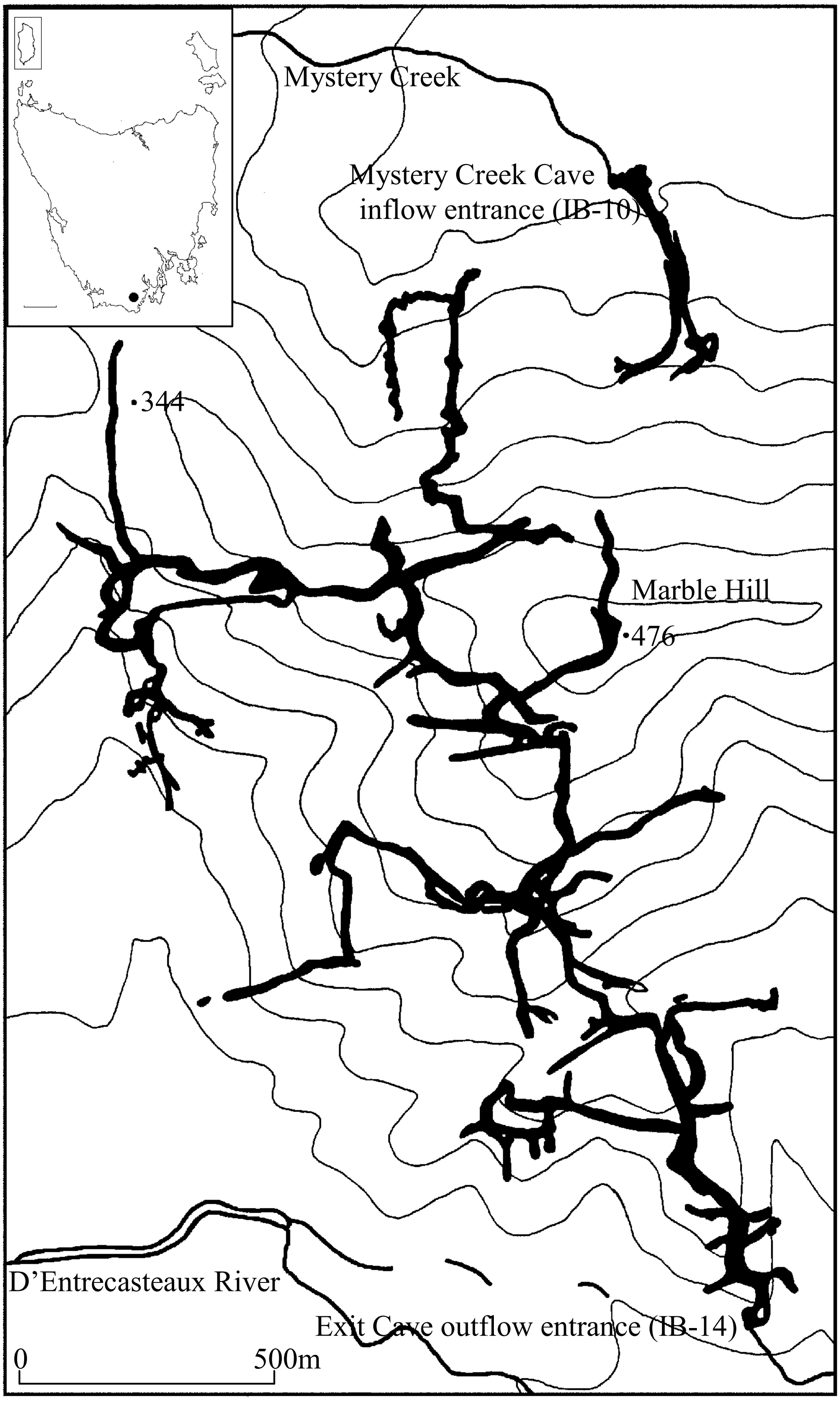



**Fig. 1.** Location of Exit and Mystery Creek Caves. 50 m contour lines shown. Creeks and rivers shown with bold lines. Note an anabranch of D'Entrcasteaux River enters Exit Cave underground north of outflow entrance. Length of scale bar for inset map of Tasmania is 50 km.

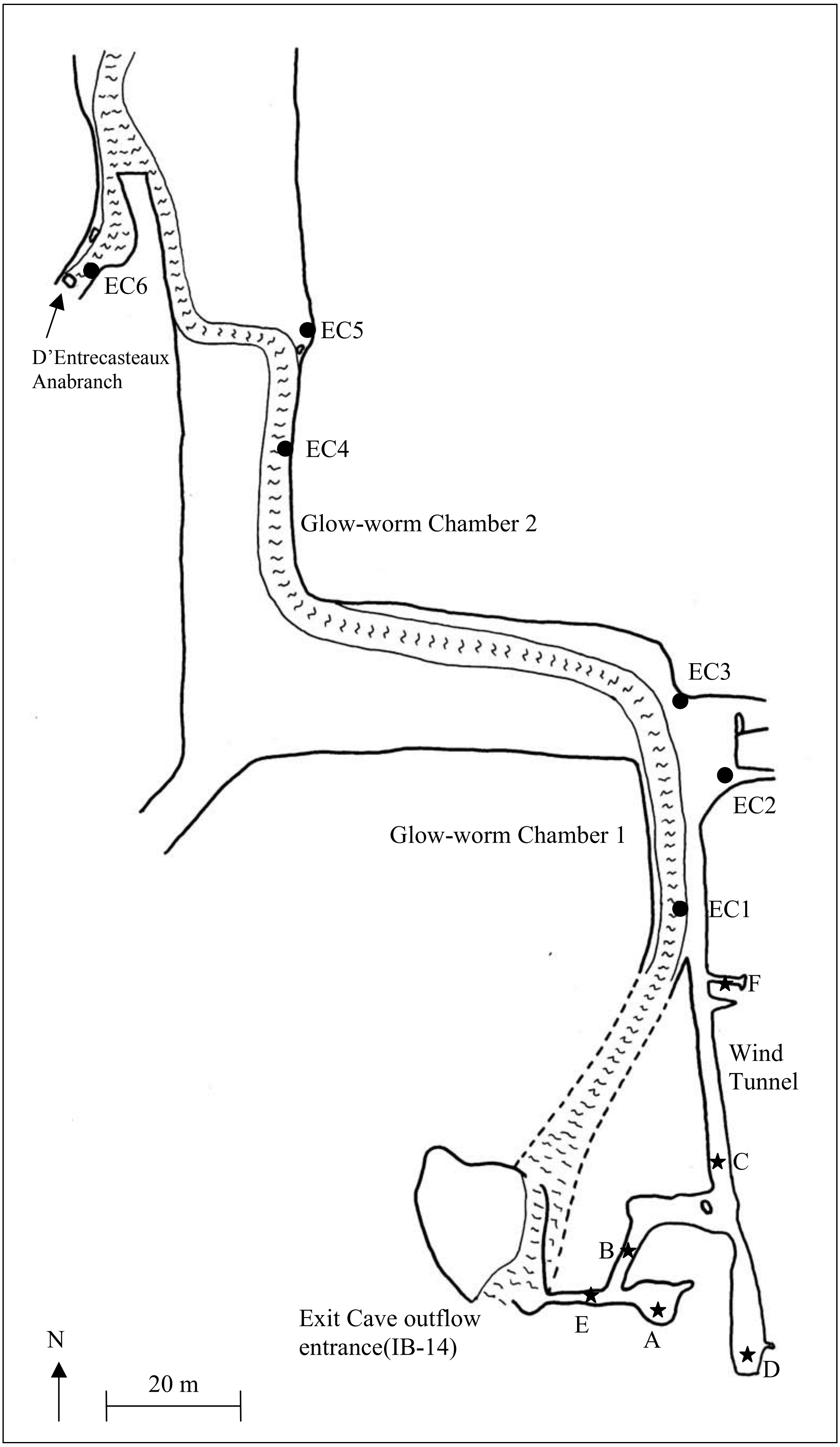



**Fig. 2.** Map of part of Exit Cave showing locations of glow-worm monitoring sites (EC1–6) and cave cricket monitoring sites (A–E).

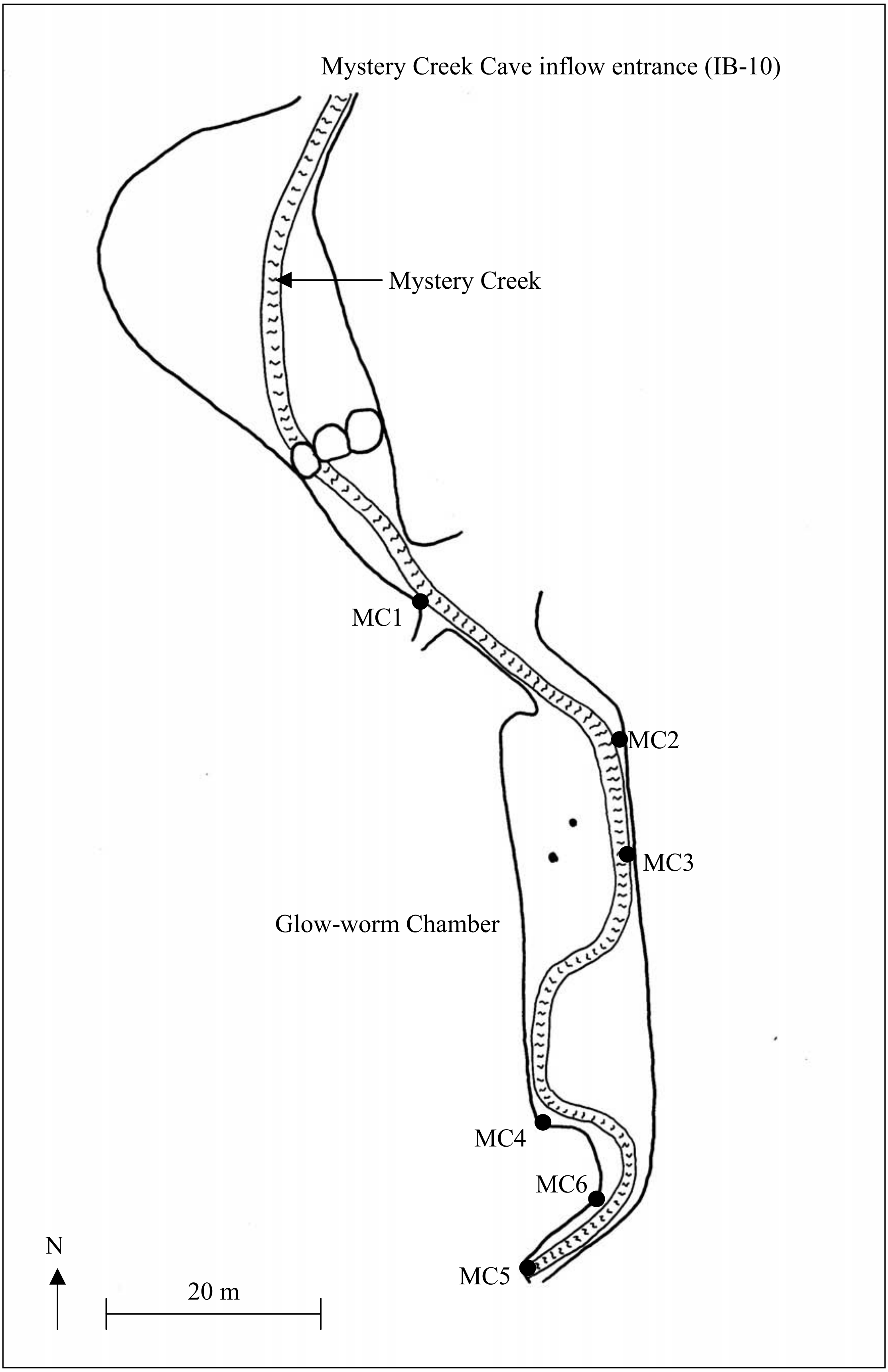



**Fig. 3.** Map of part of Mystery Creek Cave showing locations of glow-worm monitoring sites (MC1-6).

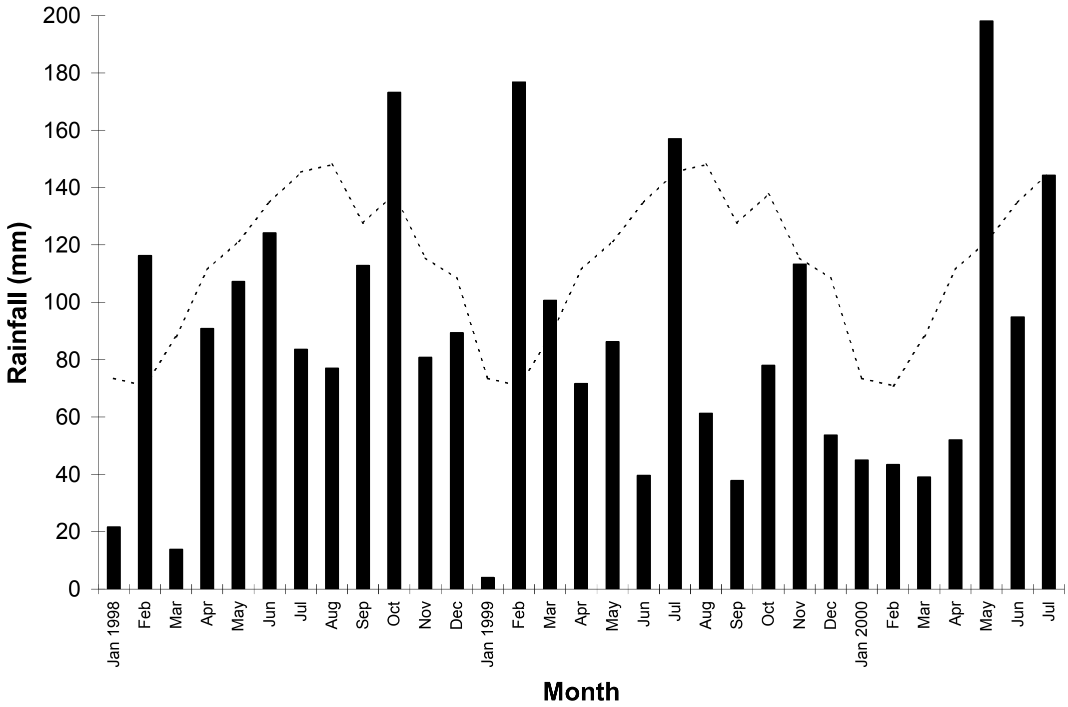



**Fig. 4.** Monthly rainfall totals at Hastings from January 1998 to July 2000. Mean monthly rainfall, collected between 1957 and 1987, shown by dotted line. Data from Australian Bureau of Meteorology.

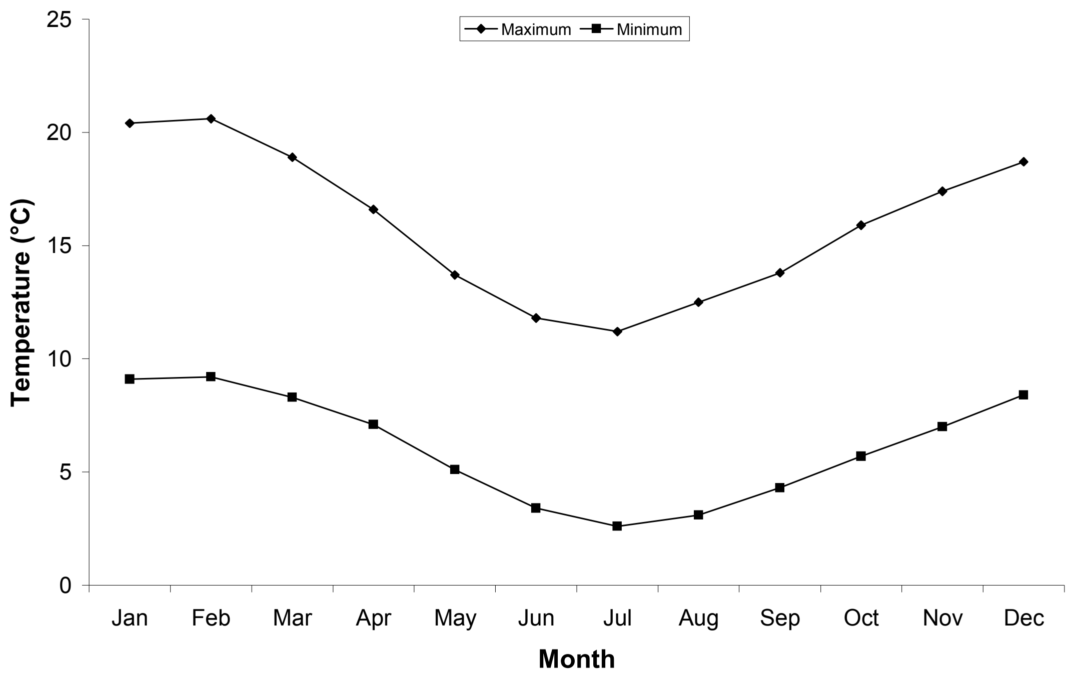



**Fig. 5.** Mean monthly minimum and maximum temperatures at Hastings based on data collected between 1957 and 1987. Data from Australian Bureau of Meteorology.

*Air Moisture*
An index of the amount of moisture in the air and on the cave walls within Exit Cave was obtained by estimating the percentage of walls covered by water drops at cave cricket monitoring sites B and C.

**Data Analysis**
Ordination was used to summarise the relationships between monthly cave fauna counts at all sites monitored for 24 months. The dominant patterns extracted were then related to the following variables; mean monthly rainfall, mean monthly maximum temperature, and mean monthly minimum temperature and year of survey. Non-metric multidimensional scaling was used to ordinate the data using the program PC-ORD (McCune and Mefford 1999). The distance measure used was Sørenson (Bray–Curtis).

## RESULTS

### Environmental Variables
*Stream Stage*
Variation in stream stage during the survey period is shown in Fig. 6. The two methods used to measure stream stage were highly positively correlated (R = 0.83). Stream stage was positively correlated with monthly rainfall (Index A: R = 0.50, Index B: R = 0.63).

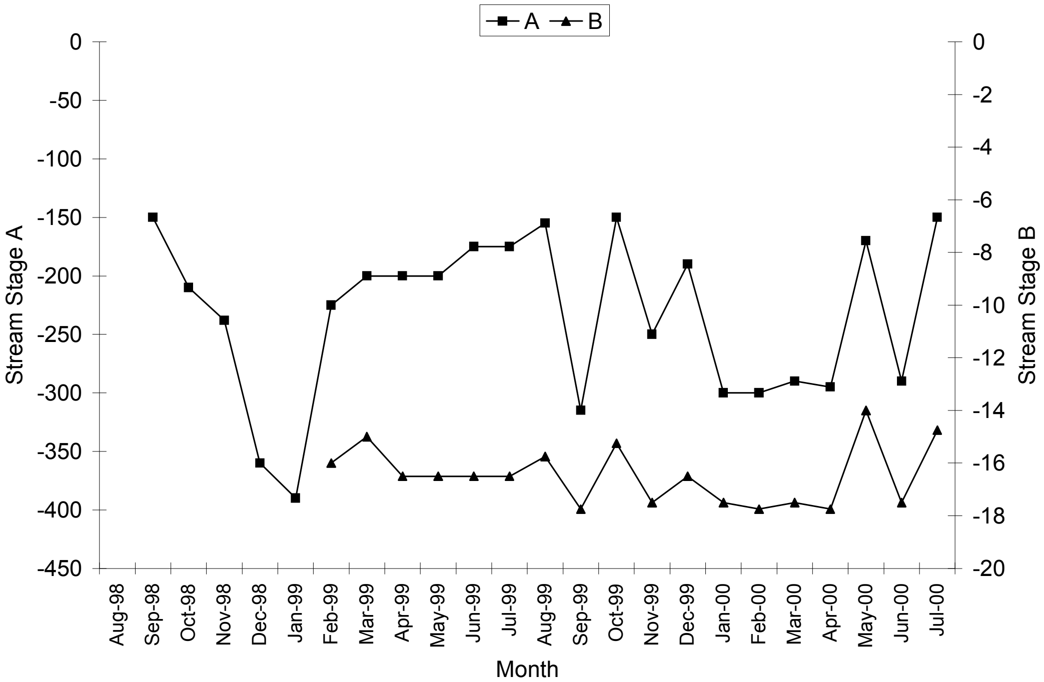



**Fig. 6.** Variation in stream stage in D'Entrecasteaux River from September 1998 to July 2000 using two correlated stream stage measures (see text). Both measures are expressed as negative numbers so that an increase in a measure means an increase in stream stage.

*Air Temperature*

Mean air temperatures in Mystery Creek Cave and Exit Cave ranged between 6.5 and 10.1°C and between 6.7 and 10.0 °C respectively (Fig.7). Mean air temperature, averaged over 24 months, inside Mystery Creek Cave (mean ± standard error: 8.2 ± 0.2°C) was 0.5°C cooler than in Exit Cave (8.7 ± 0.2°C) (paired t-test, $t = 5.869$, $df = 23$, $p = 0.000$).

*Air Current Direction*

At both caves, at the times of day measured, air tended to move into the cave during winter and generally moved out of the cave during other seasons (Fig. 8).

*Air Moisture*

During summer in the wind tunnel in Exit Cave, the walls were mostly covered in water droplets whereas during winter water droplets were virtually absent from the cave walls (Fig. 9).

**Cave Fauna**

*Tasmanian Glow-worm*

Monthly counts of the number of larval lights in Mystery Creek Cave and Exit Cave are given in Figs 10–15. An ordination of larval light counts at sites between months is given in Fig. 16. Axis 1 accounted for 82% of the variation between monthly counts and was positively correlated with mean monthly temperatures and negatively correlated with mean monthly rainfall totals. Axis 2 accounted for only 10% of the variation and is related to differences between the two years of survey.

Trends in the number of larval lights were similar for the different sites in Mystery Creek Cave, with counts generally highest from mid-summer through to autumn and lowest from June through to September (Figs 10–12). High counts of larvae glowing were sometimes recorded in spring, especially during the first year of survey. Counts at site MC2 were lower overall during the second year of monitoring compared with the first year (Fig.10), whereas counts at MC5 were higher during the second year (Fig. 12).

There was no consistent pattern in the monthly counts of larval lights at sites in Exit Cave (Figs 13–15). Furthermore, there was less variation in monthly counts of lights in Exit Cave (mean coefficient of variation = 29%) than in Mystery Creek Cave (mean coefficient of variation = 40%) (Table 1). Four sites (EC1, EC2, EC5 and EC6) in Exit Cave showed no consistent seasonal pattern (Figs 13 and 15). At site EC3, the variation in counts was consistent during both years of survey, but the trend was opposite to sites in Mystery Creek Cave, with counts highest in winter and lowest in summer (Fig. 14). Site EC4 had a similar but less distinct seasonal pattern to those shown by the sites in Mystery Creek Cave (Fig. 14). During the second year of the survey, counts of glow-worm lights increased at EC4 and decreased at EC1 and EC6 (Figs 13-15).

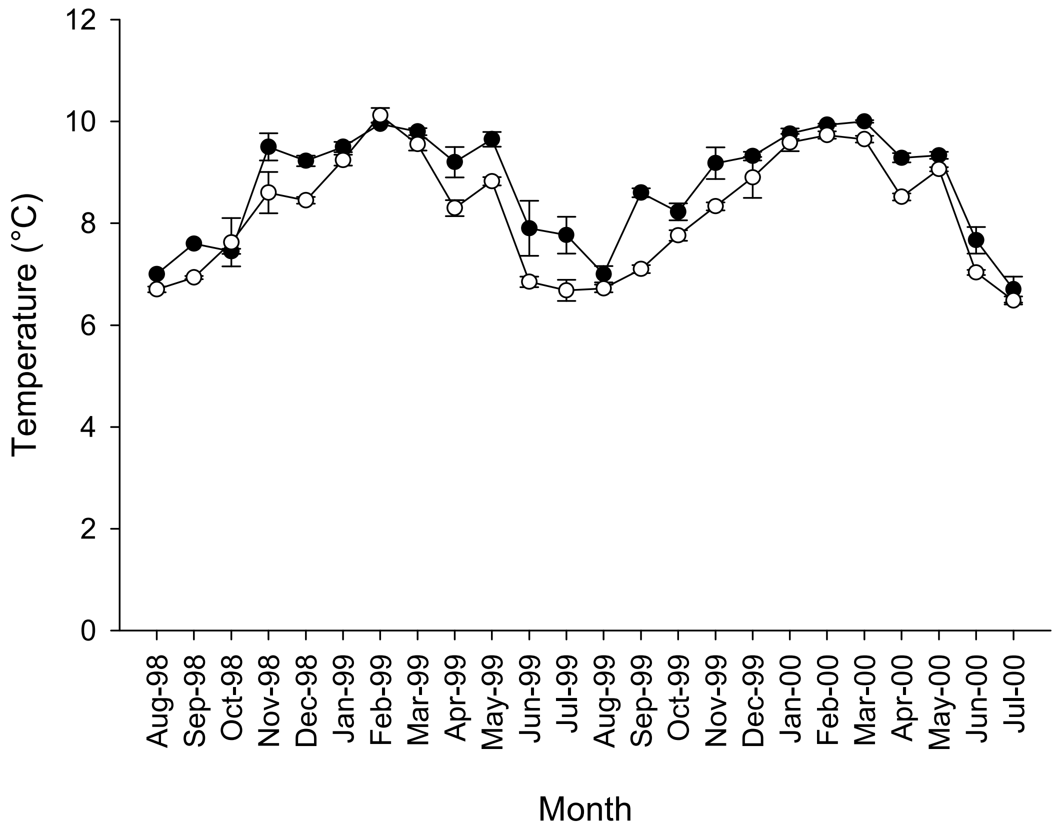



**Fig. 7.** Variation in mean (± standard error) air temperature inside Exit Cave (black circles) and Mystery Creek Cave (white circles).

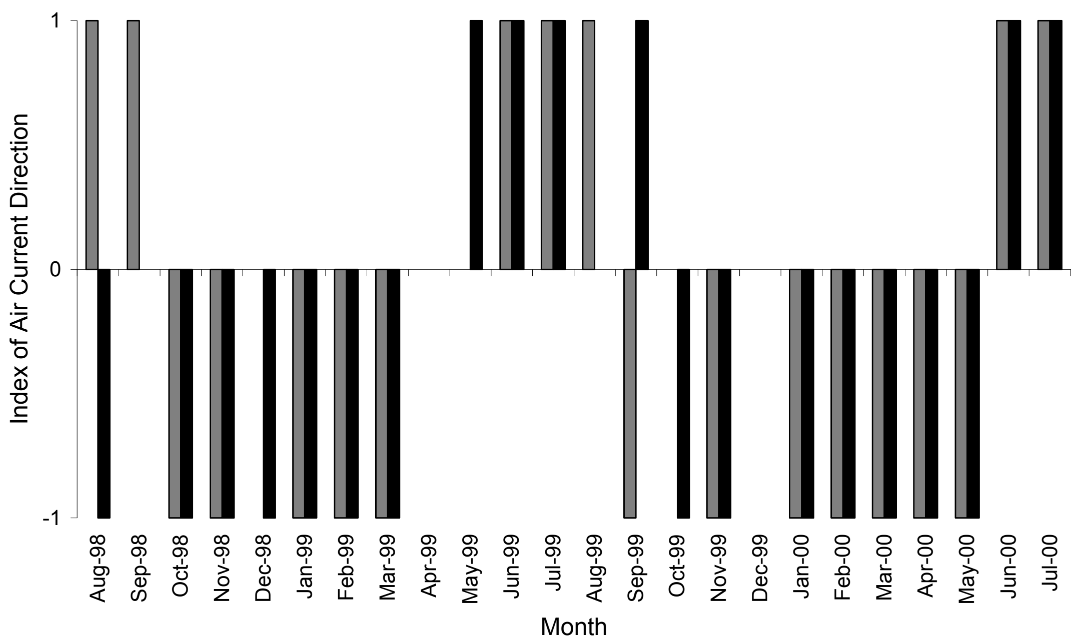



**Fig. 8.** Variation in direction of air current into (+1) and out of (-1) the entrances to Exit Cave (grey bars) and Mystery Creek Cave (black bars).

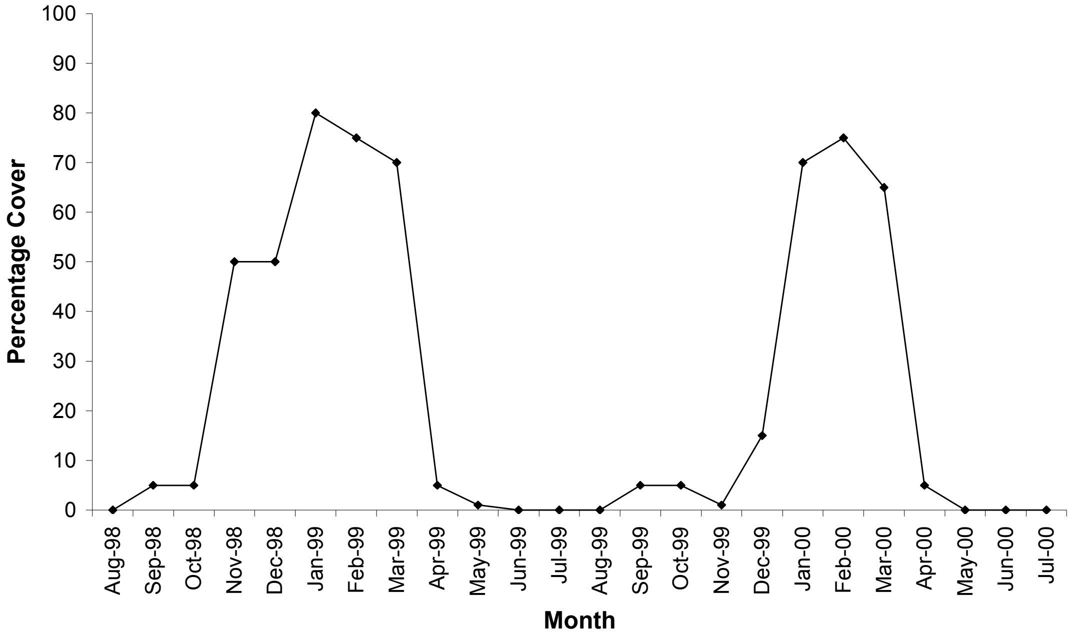



**Fig. 9.** Variation in percentage cover of water droplets on walls in the wind tunnel in Exit Cave.

Counts of larval lights undertaken by the author were highly positively correlated with counts undertaken by second observers who counted the same group of lights while standing next to the author (R = 0.95, Fig. 17). The y-intercept of the regression line did not pass through the origin as would be expected from a one-one relationship; instead other observers generally counted slightly more lights than the author ($t_{0.05\ (2),\ 65} = 2.21$, $p = 0.03$).

Glow-worm pupae began to appear in July and August and increased in abundance during spring, peaking in November and December before declining in abundance during late summer (Fig 18). Pupae were not observed during autumn and most of winter. The appearance of adults largely coincided with the appearance of pupae (Fig. 19). The increased number of adults and pupae observed during the second year of monitoring was due to the addition of a productive monitoring site at Mystery Creek Cave (MC6). Adults were directly observed emerging from pupae in January, October, November and December and mating in October, November and December. No eggs were observed during the monitoring program.

Prey was observed in silk threads produced by the larvae from August through to May and was not recorded in June or July (Fig 20). Prey identified while in threads was predominantly Ephemeroptera and small Diptera (Table 2). Prey items removed from webs for further identification are shown in Table 3. Most mayflies belonged to the family Leptophlebiidae and most Diptera belonged to the family Chironomidae. Several Trichopera adults were identified in prey removed from threads but not in prey observed in threads suggesting that some Ephemeroptera observed in threads may have been incorrectly identified. The high proportion of Chironomidae and

Leptophlebiidae reflects the high proportion of these taxa recorded from kick samples taken from the streams. In addition to the adult glow-worm removed from threads for identification (Table 3), adults were also observed in threads in November 1999 and March 2000. An adult glow-worm was also observed in a cave spider's web.

**Table 1.** Coefficients of variation (CV) in glow-worm light counts for monitoring sites in Mystery Creek Cave and Exit Cave.

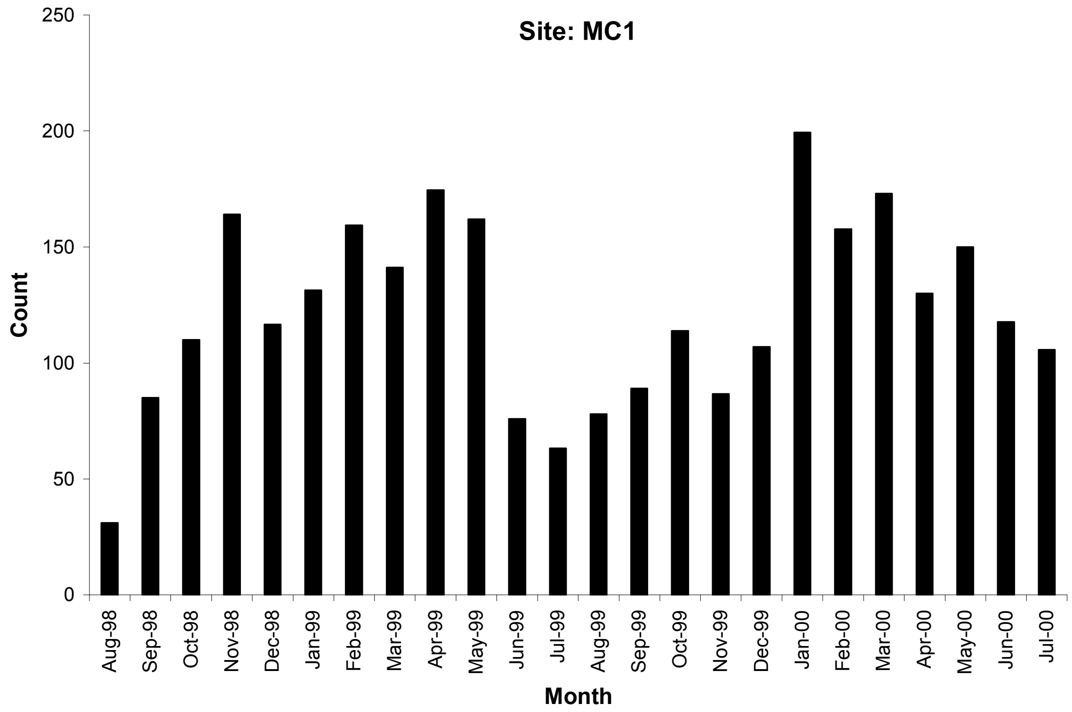
| Mystery Creek Cave | | Exit Cave | |
|---|---|---|---|
| **Sites** | **CV** | **Sites** | **CV** |
| MC1 | 34 | EC1 | 18 |
| MC2 | 48 | EC2 | 22 |
| MC3 | 48 | EC3 | 27 |
| MC4 | 39 | EC4 | 58 |
| MC5 | 40 | EC5 | 28 |
| MC6 | 29 | EC6 | 24 |
| | | | |
| Average | 40 | Average | 29 |

**Table 2.** Types and numbers of prey observed in silk threads produced by glow-worms. Data pooled over all sites.

| Prey Type | Mystery Creek Cave | Exit Cave |
|---|---|---|
| Ephemeroptera | 51 | 30 |
| Small Diptera | 34 | 8 |
| Lepidoptera | 3 | 2 |
| Tiplulidae | 1 | 1 |
| Plecoptera | 1 | 1 |
| *Micropathus tasmaniensis* | 0 | 1 |
| Unidentified | 4 | 13 |

**Table 3.** Prey removed from silk threads produced by glow-worms for further identification. Prey from Mystery Creek Cave and Exit Cave combined.

| Order | Family/other | Number |
|---|---|---|
| Diptera | Chironomidae | 16 |
| | Tanyderidae | 2 |
| | Tipulidae | 2 |
| | *Arachnocampa tasmaniensis* (adult) | 1 |
| Ephemeroptera | Leptophlebiidae | 6 |
| | Unidentified | 3 |
| Trichoptera | Atriplectrididae | 1 |
| | Hydrobiosidae | 3 |
| | Philorheithridae | 2 |
| | Unidentified | 1 |



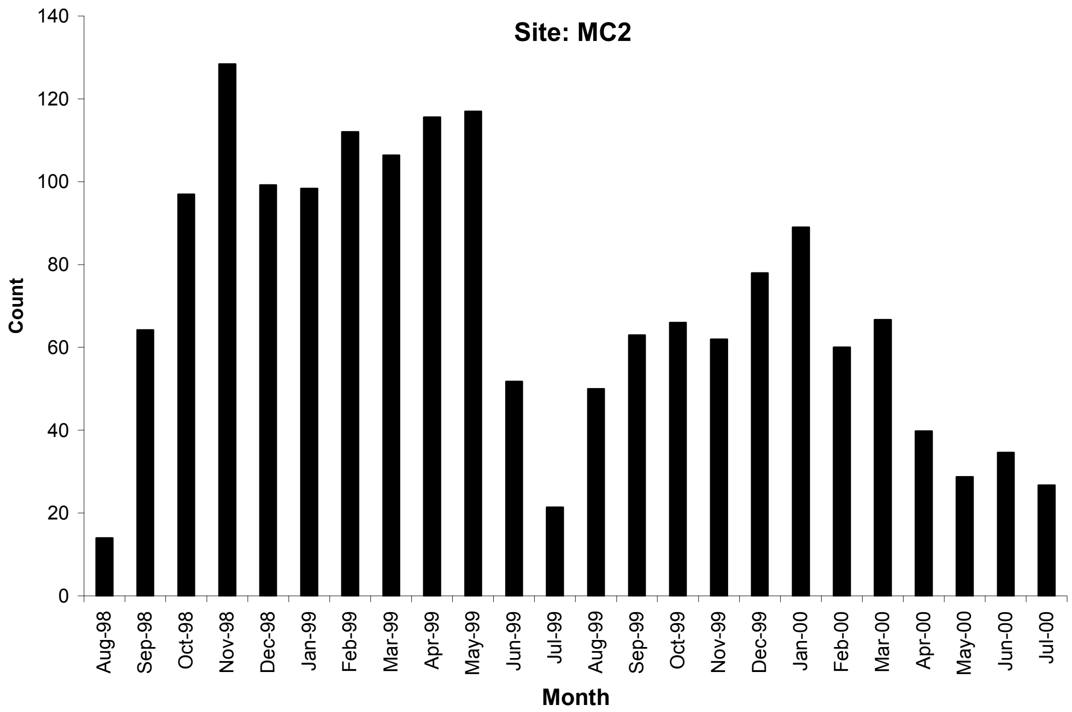
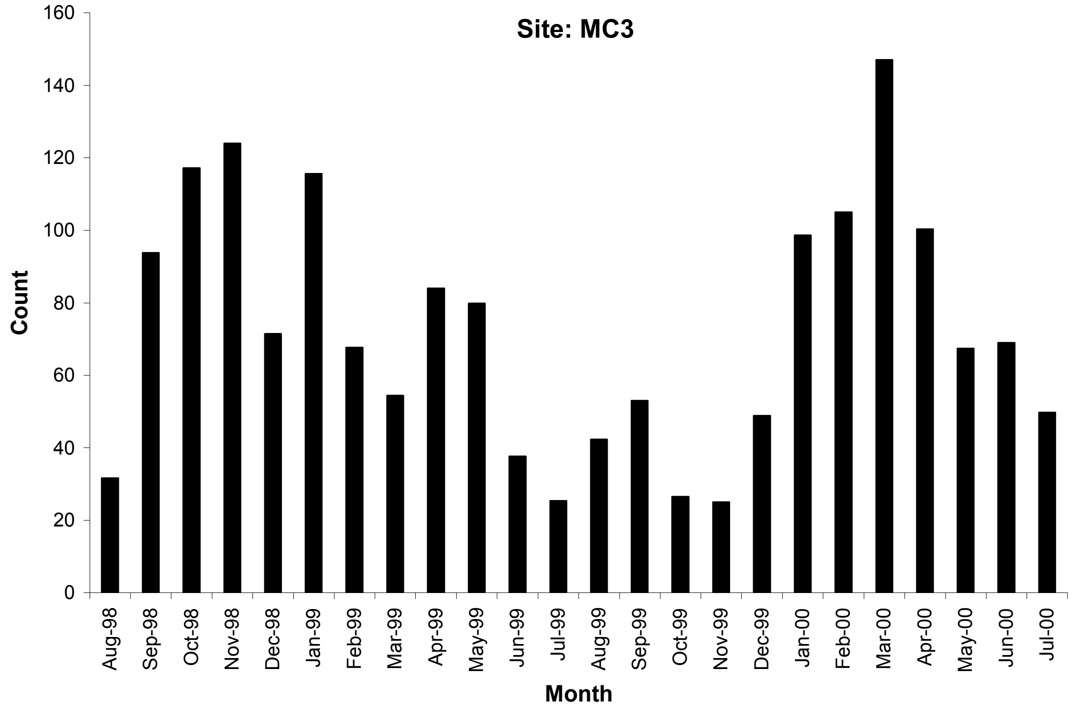




**Fig. 10.** Monthly counts of the number of glow-worm lights at sites MC1 and MC2, Mystery Creek Cave.



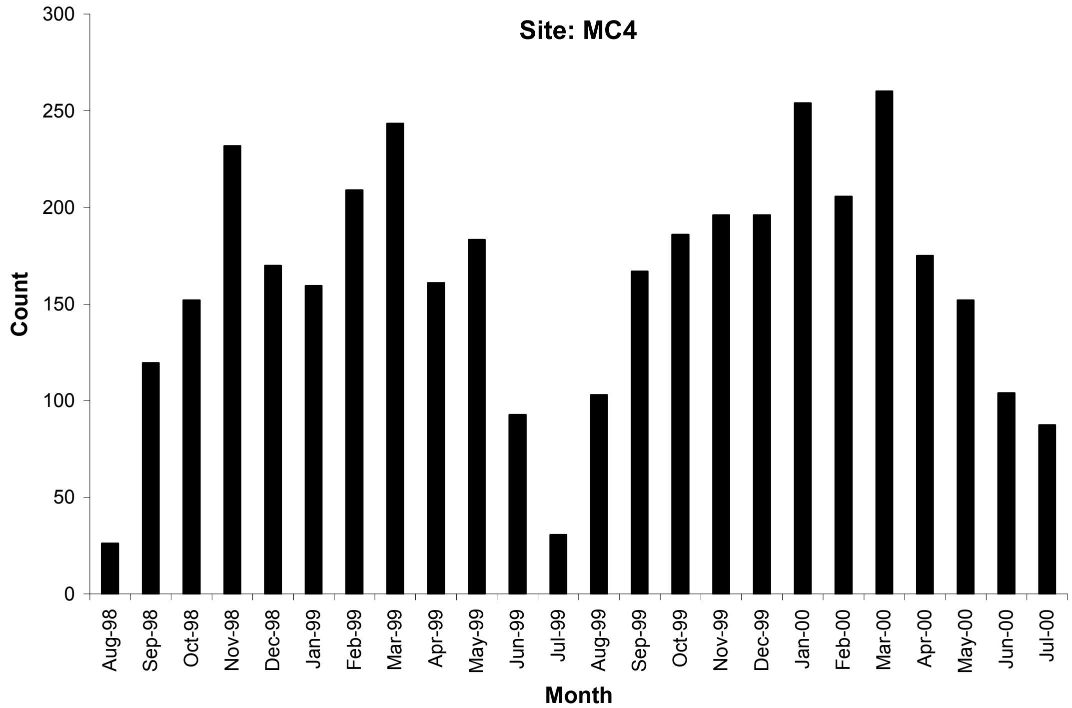
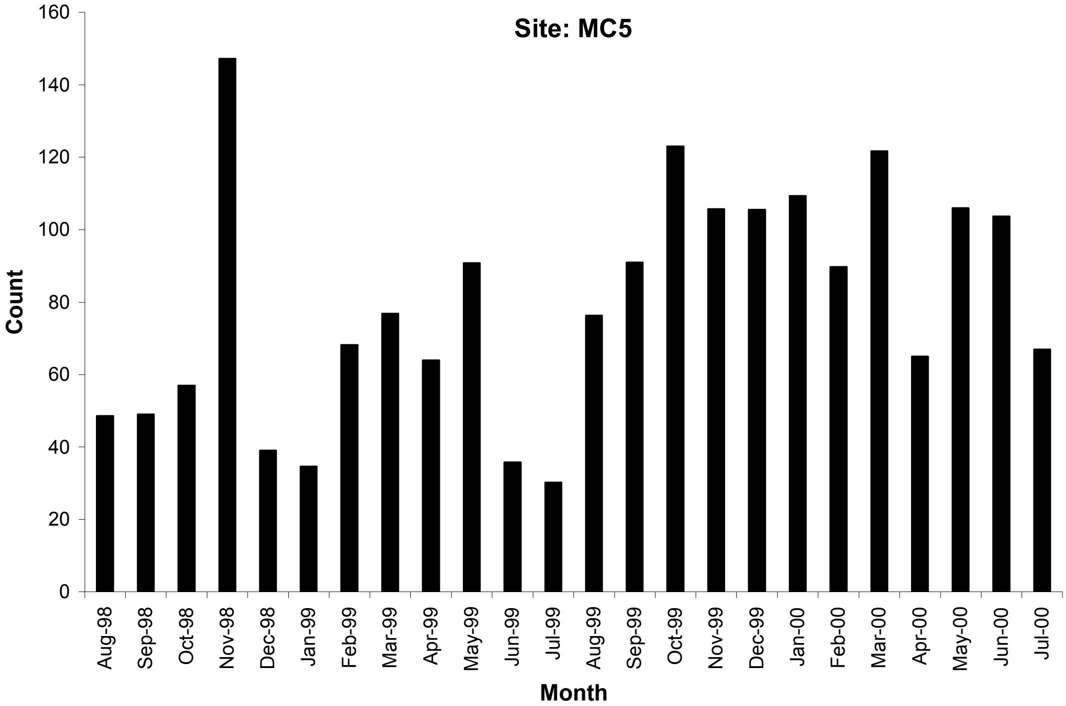




**Fig. 11.** Monthly counts of the number of glow-worm lights at site MC3 and MC4, Mystery Creek Cave.



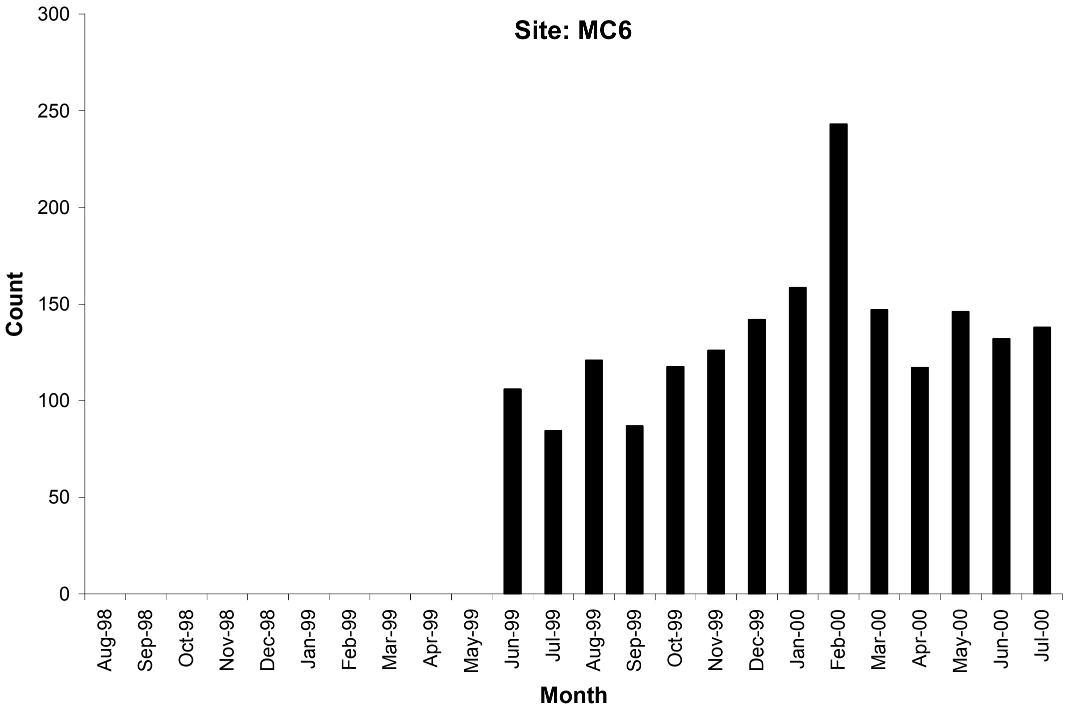




**Fig. 12.** Monthly counts of the number of glow-worm lights at site MC5 and MC6, Mystery Creek Cave.

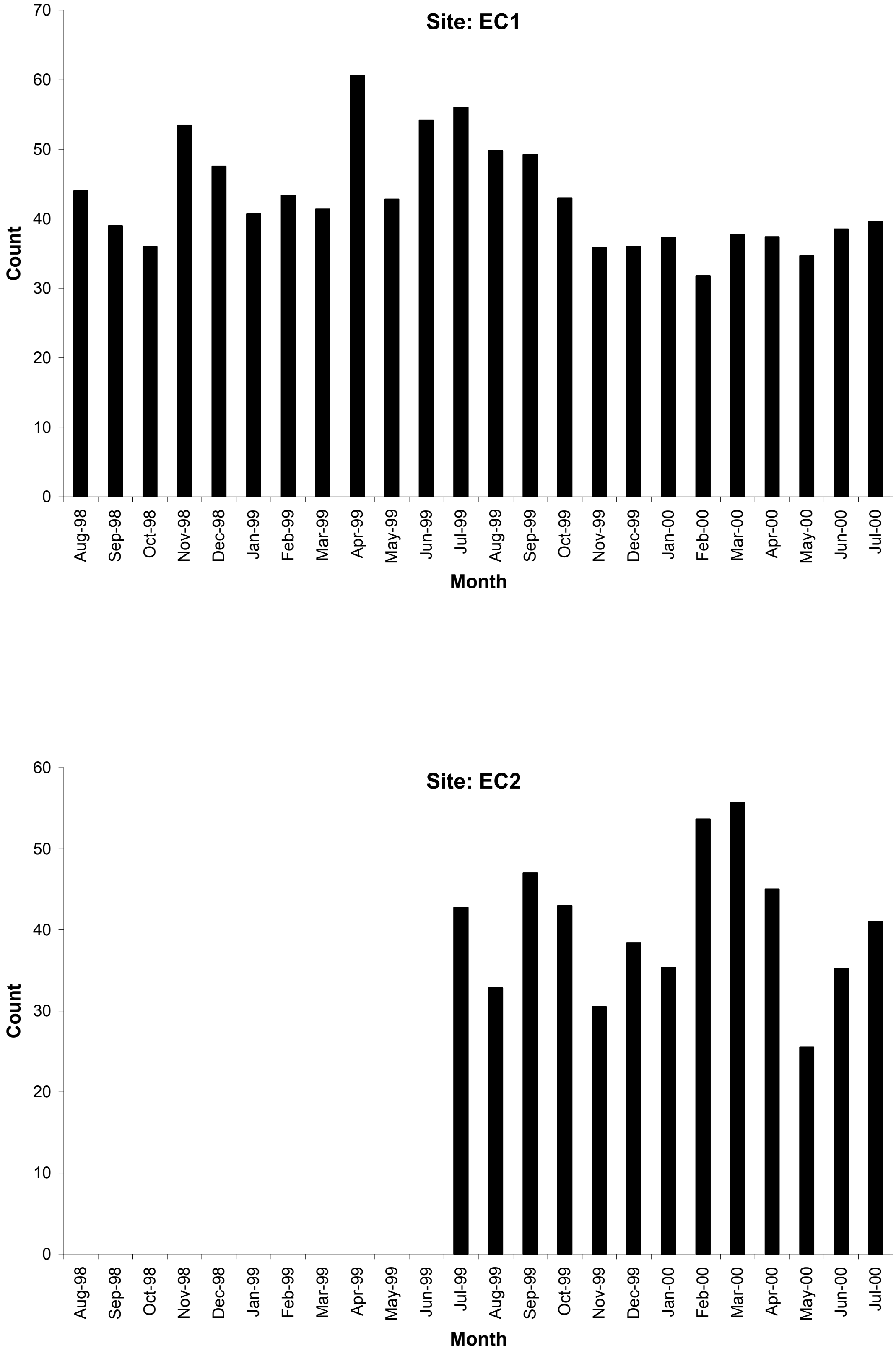
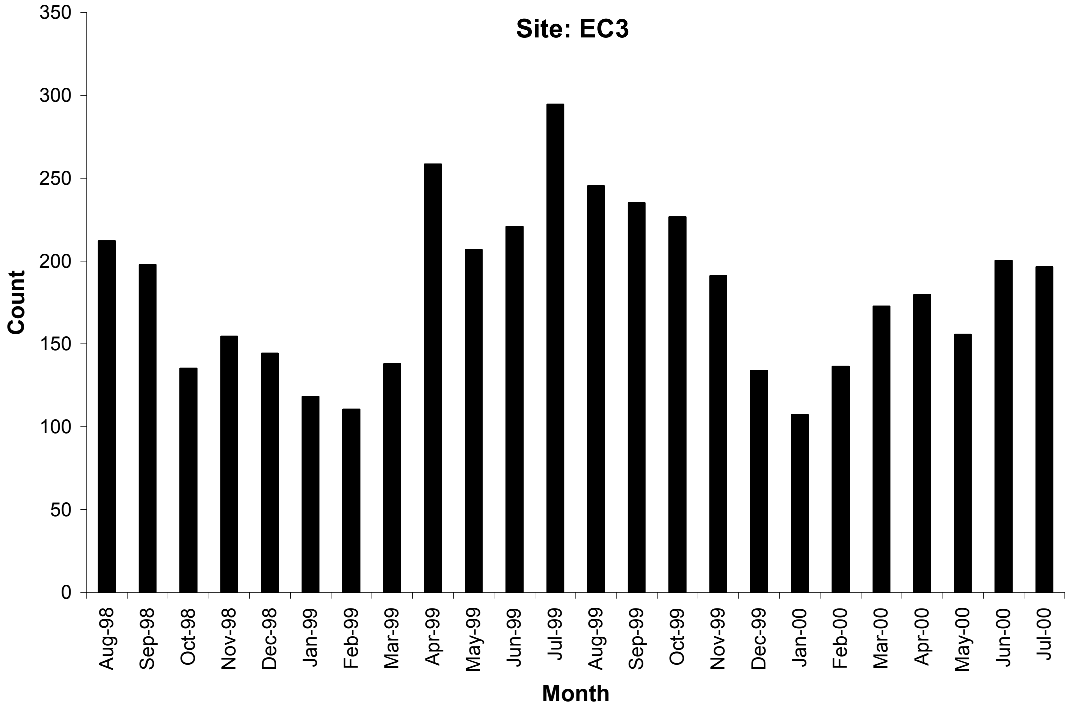



**Fig. 13.** Monthly counts of the number of glow-worm lights at site EC1 and EC2, Exit Cave.



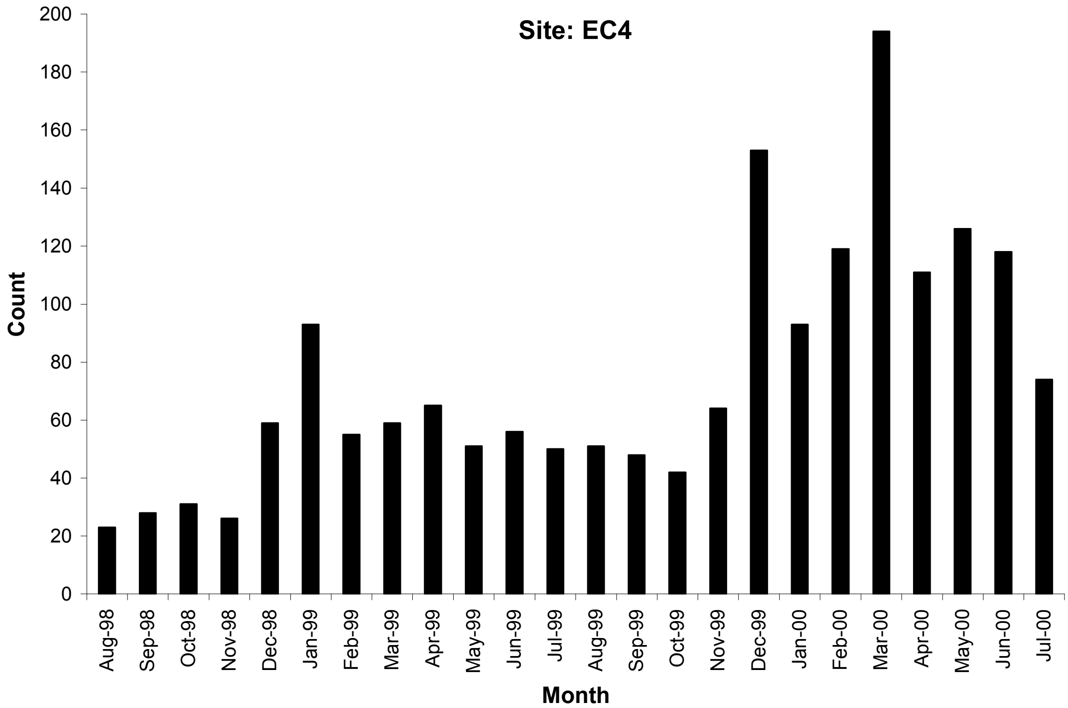
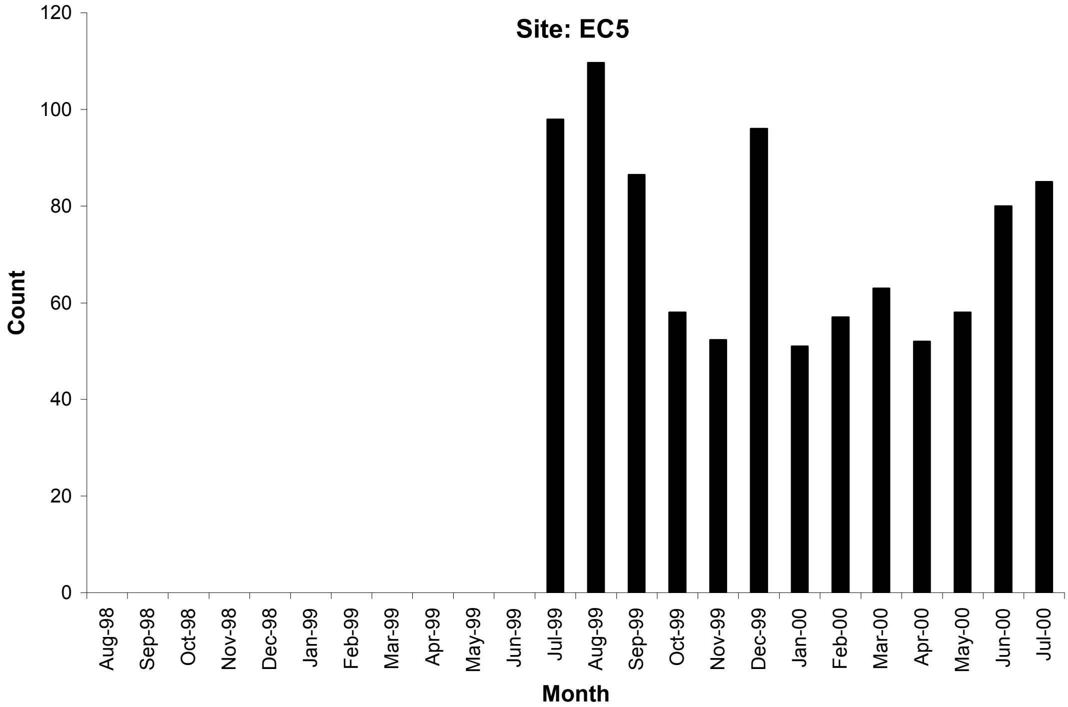




**Fig. 14.** Monthly counts of the number of glow-worm lights at site EC3 and EC4, Exit Cave.



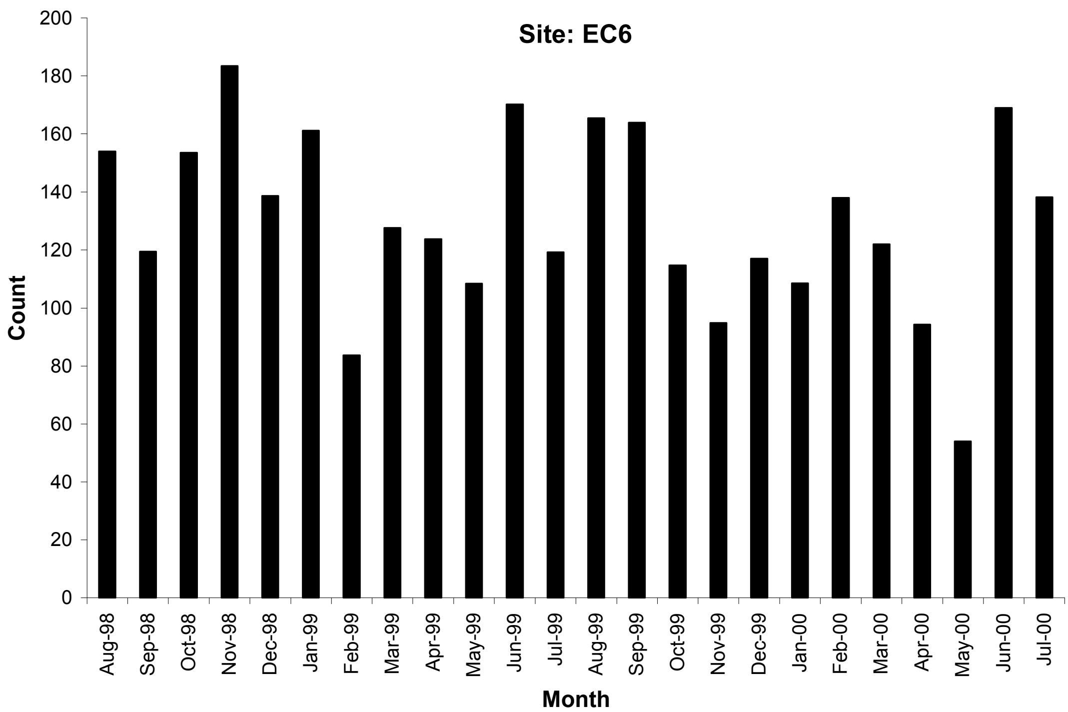




**Fig. 15.** Monthly counts of the number of glow-worm lights at site EC5 and EC6, Exit Cave.

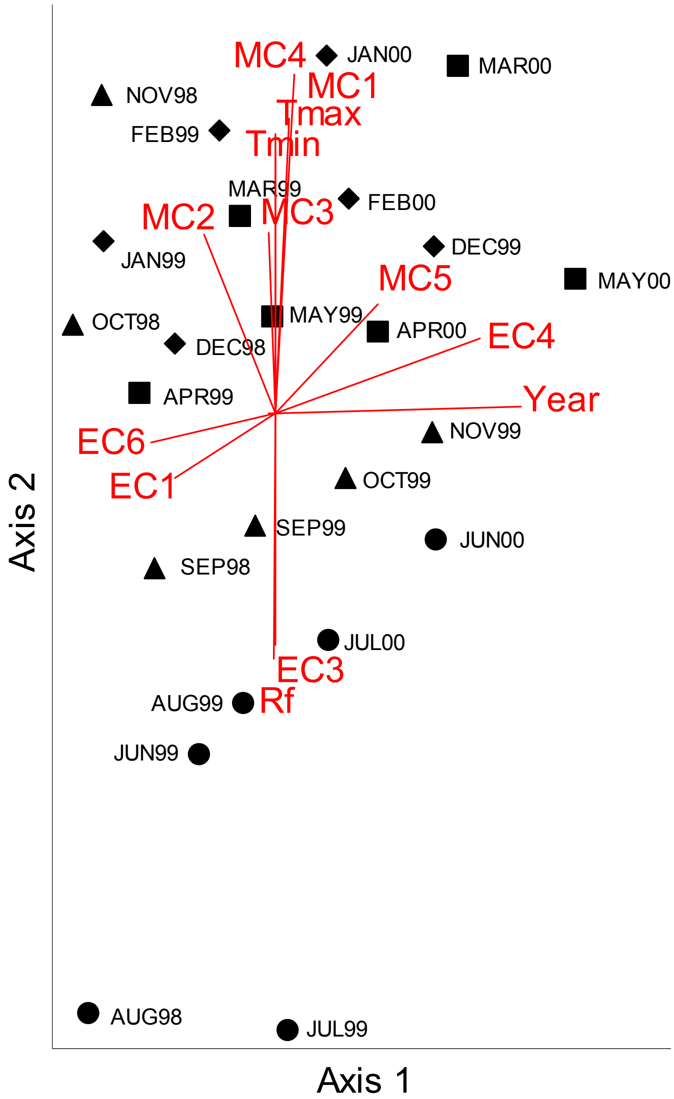



**Fig. 16.** Ordination of similarity in site glow-worm counts between months in Mystery Creek and Exit Cave using Nonmetric Multidimensional Scaling (2 dimensional solution, final stress = 11.625, final instability = 0.00464, Axis 1 $r^2$ = 0.82, Axis 2 $r^2$ = 0.10). Only sites sampled in all 24 months were used. Circles = winter months, triangles = spring months, squares = autumn months, diamonds = summer months. EC = Exit Cave. MC = Mystery Creek Cave. Rf = average monthly rainfall. Tmin = mean monthly minimum temperature. Tmax = mean monthly maximum temperature.

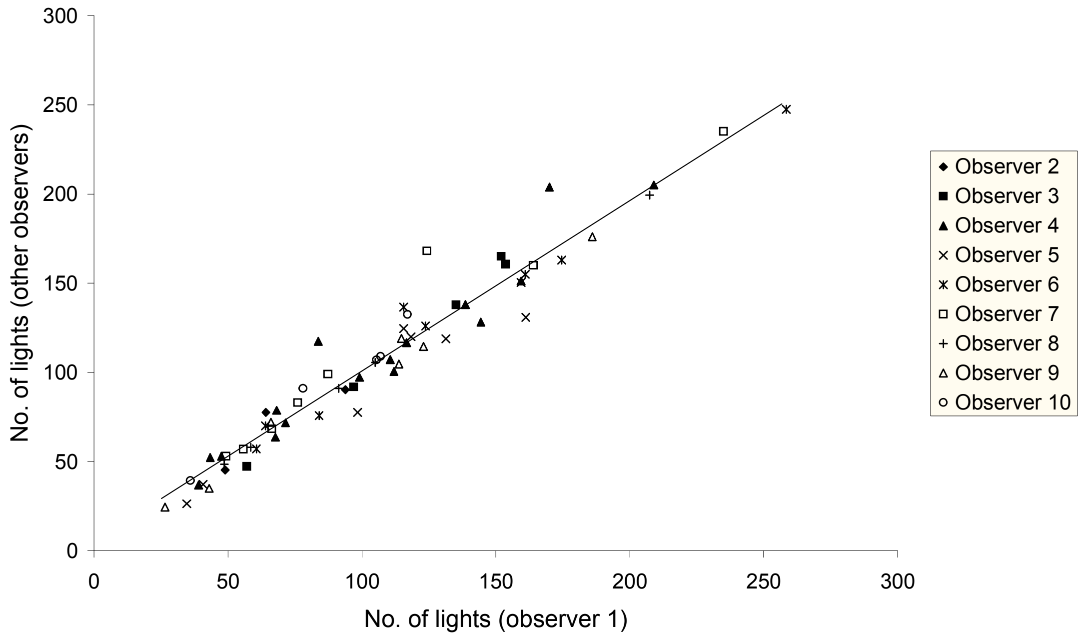



**Fig. 17.** Comparison of counts of glow-worm lights by the author (observer 1) with counts of glow-worm lights at same locations at the same time by one of nine other observers. R = 0.95.

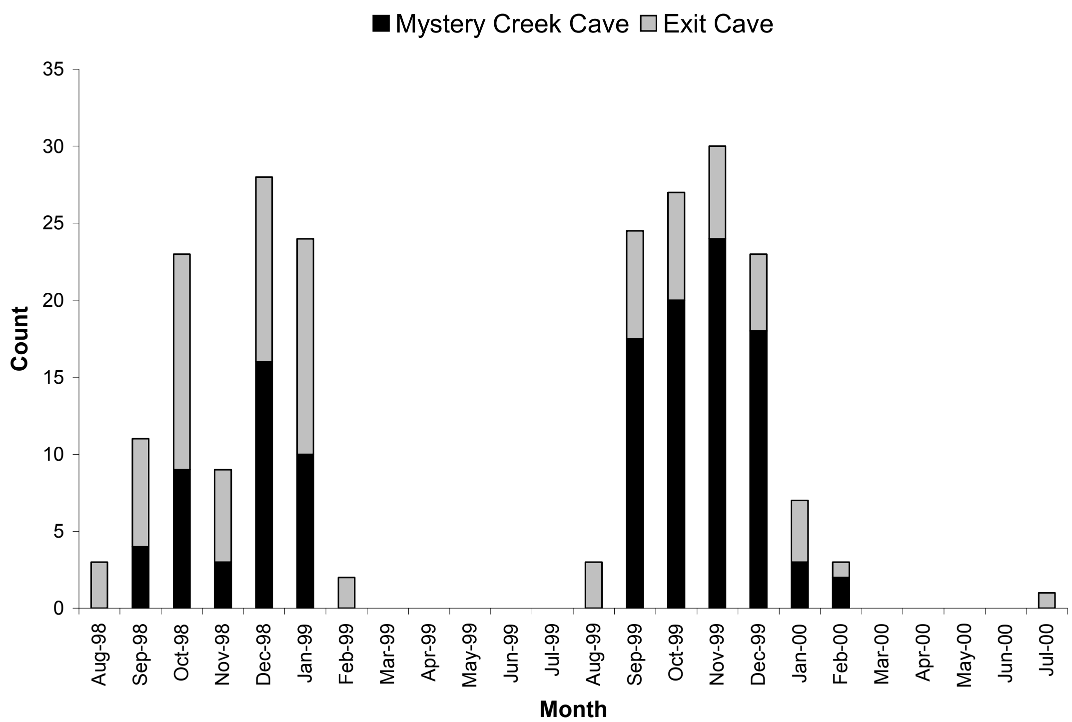



**Fig. 18.** Monthly variation in number of glow-worm pupae. Counts pooled over all glow-worm sub-sites in Mystery Creek and Exit caves.

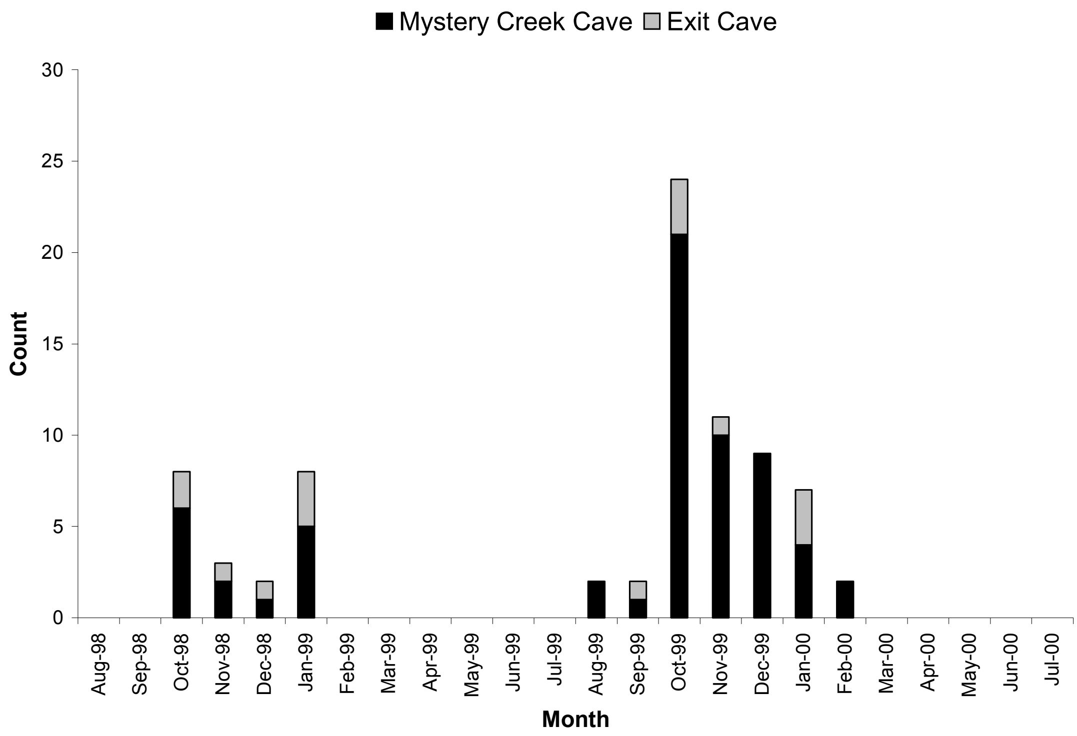



**Fig. 19.** Monthly variation in number of adult glow-worms. Counts pooled over all glow-worm sub-sites in Mystery Creek and Exit caves.

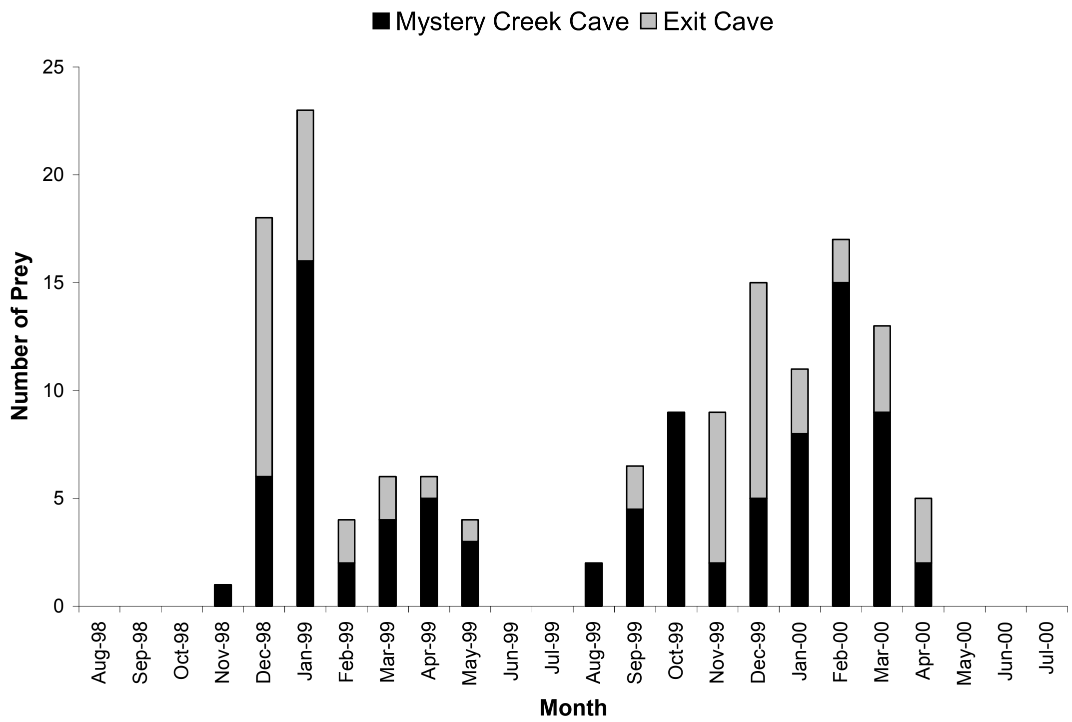



**Fig. 20.** Monthly variation in number of prey recorded in glow-worms threads. Counts pooled over all glow-worm sub-sites in Mystery Creek and Exit caves. Prey not recorded from August 1998 to October 1998.

*Stream Fauna*

A total of 470 freshwater invertebrates were collected in kick samples from the streams in Mystery Creek Cave and Exit Cave comprising 22 families and 44 species/morphospecies. A complete list of all invertebrates identified from each kick sample is given in Appendix II and summarised in Fig. 21. The most commonly captured families were the midges, Chironomidae (predominantly the subfamily Chironominae) and the mayflies, Leptophlebiidae (predominantly *Nousia* spp.). At the family level of identification, there were few differences between stream faunas of the two caves or between the October and January samples (Fig 21). The fly family Simulidae and the beetle family Elmidae were caught only in Exit Cave and the Eustheniidae appeared to be more common in the samples taken from Mystery Creek Cave than in Exit Cave.

*Tasmanian Cave Cricket*

There were few interpretable patterns in monthly cave cricket counts at Exit Cave and a useful ordination was not found. A visual examination of the monthly counts at each site (Figs 22–24) indicates that counts at site B in the wind tunnel were higher in summer than in winter. Cave cricket counts at site C, also in the wind tunnel, showed a similar pattern, although counts were much lower and the seasonal differences less marked than at site B. Monthly counts at sites B and C were highly correlated (R = 0.70). At site F, which was only sampled during the second year of the survey, the trend was the opposite of sites B and C, with counts higher in winter and lower in summer. No clear seasonal pattern was observed at sites A, D or E.

Counts of cave crickets undertaken by the author were highly positively correlated with counts undertaken by other observers who counted the same group of crickets (R = 0.93, Fig 25). The y-intercept of the regression line did not differ significantly from zero ($t_{0.05\ (2),\ 38} = 1.11$, $p = 0.27$) indicating a one-to-one relationship between observer counts.

Mating was observed in March, April and July. Moulting was observed in February, March, April, June and July. A cricket was observed ovipositing in August. Small cave crickets were present in the population throughout the year indicating an overlap of generations and that cave crickets can hatch at any time of the year

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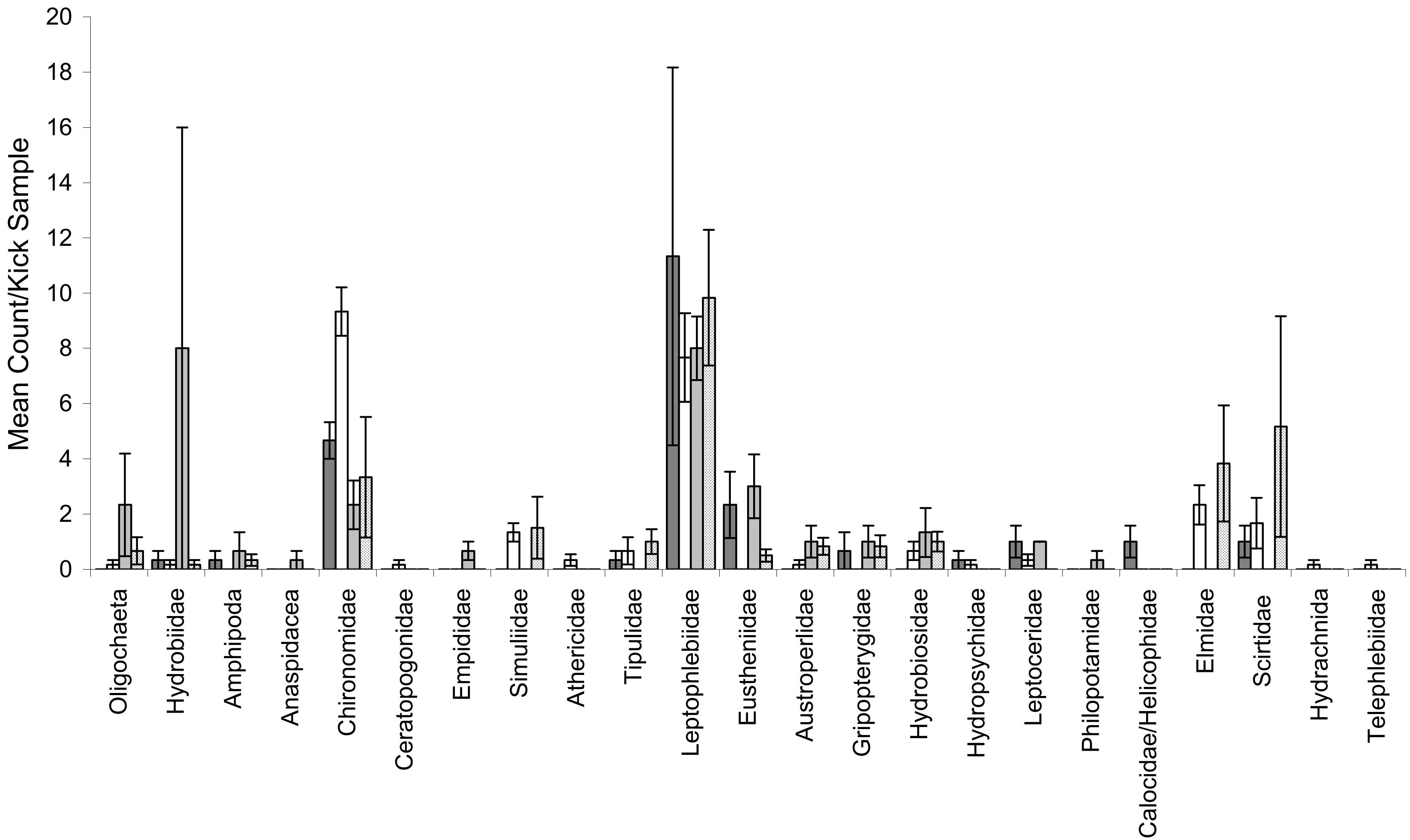
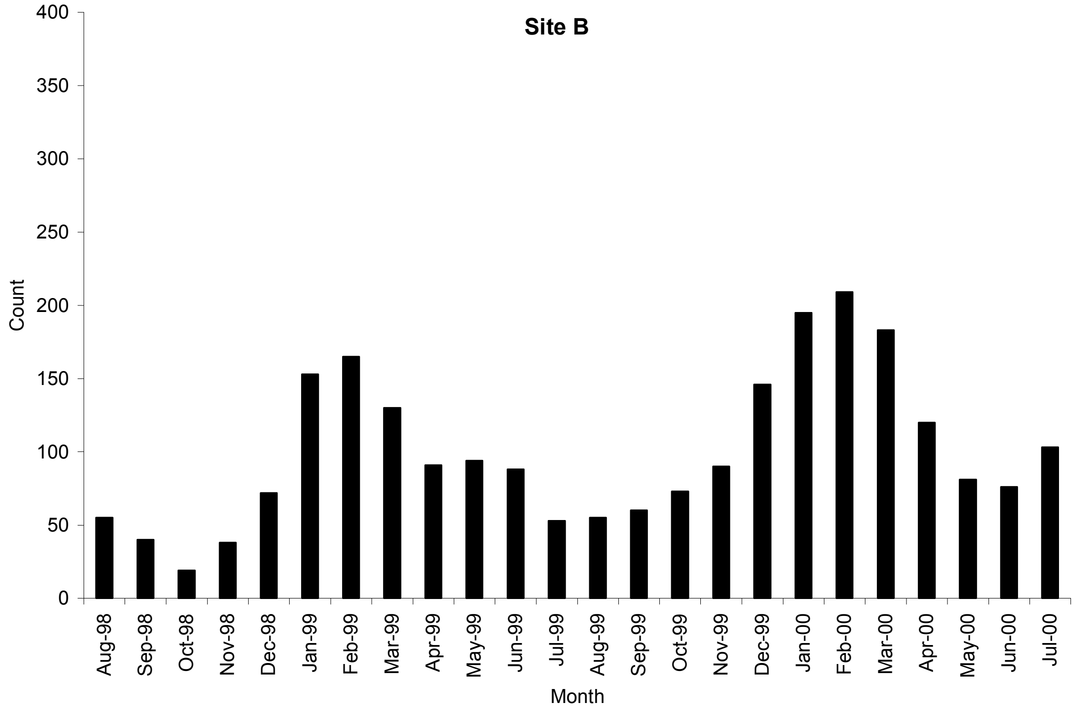



**Fig. 21.** Mean Count (± standard error) of invertebrate taxa per 10 m kick sample in Mystery Creek Cave (n = 3) and Exit Cave (n = 6). Dark grey and light grey bars are for October and January in Mystery Creek Cave, respectively. Clear and speckled bars are for October and January in Exit Cave respectively.



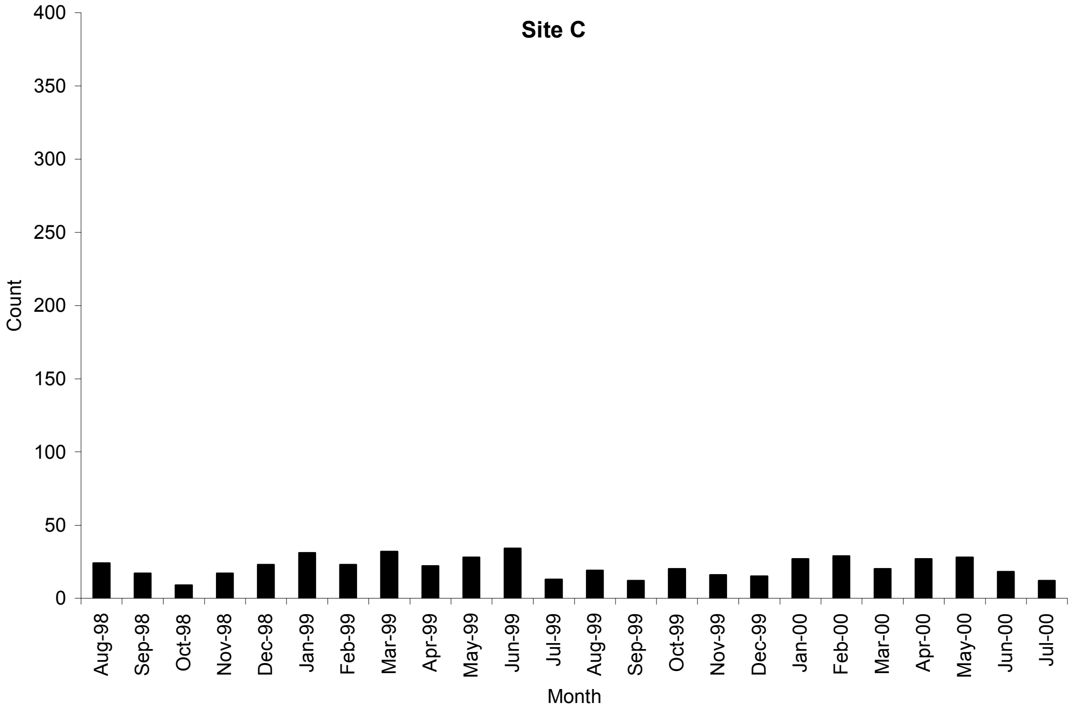




**Fig. 22.** Monthly counts of cave crickets at sites B and C, Exit Cave.

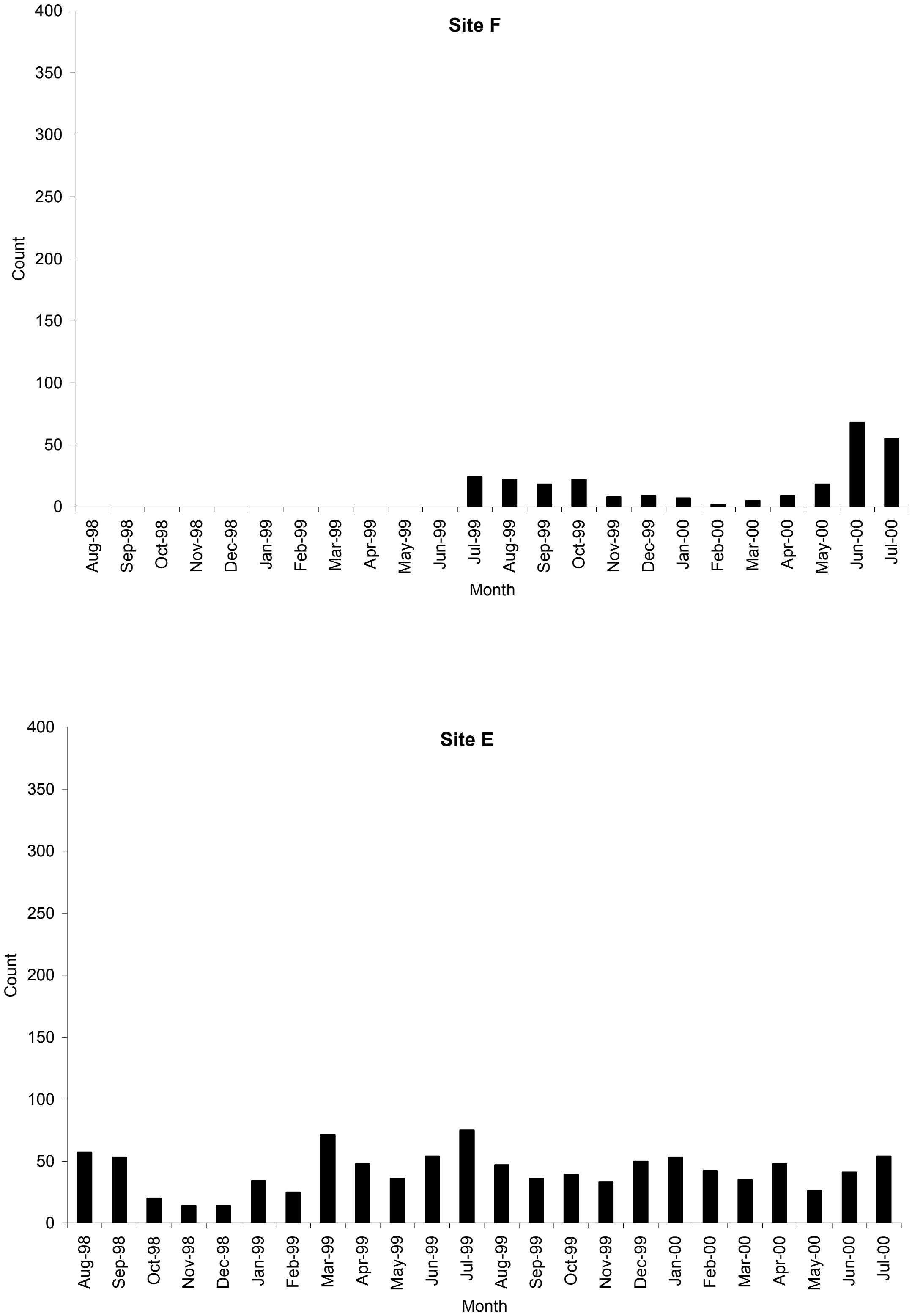



**Fig. 23.** Monthly counts of cave crickets at sites F and E, Exit Cave.

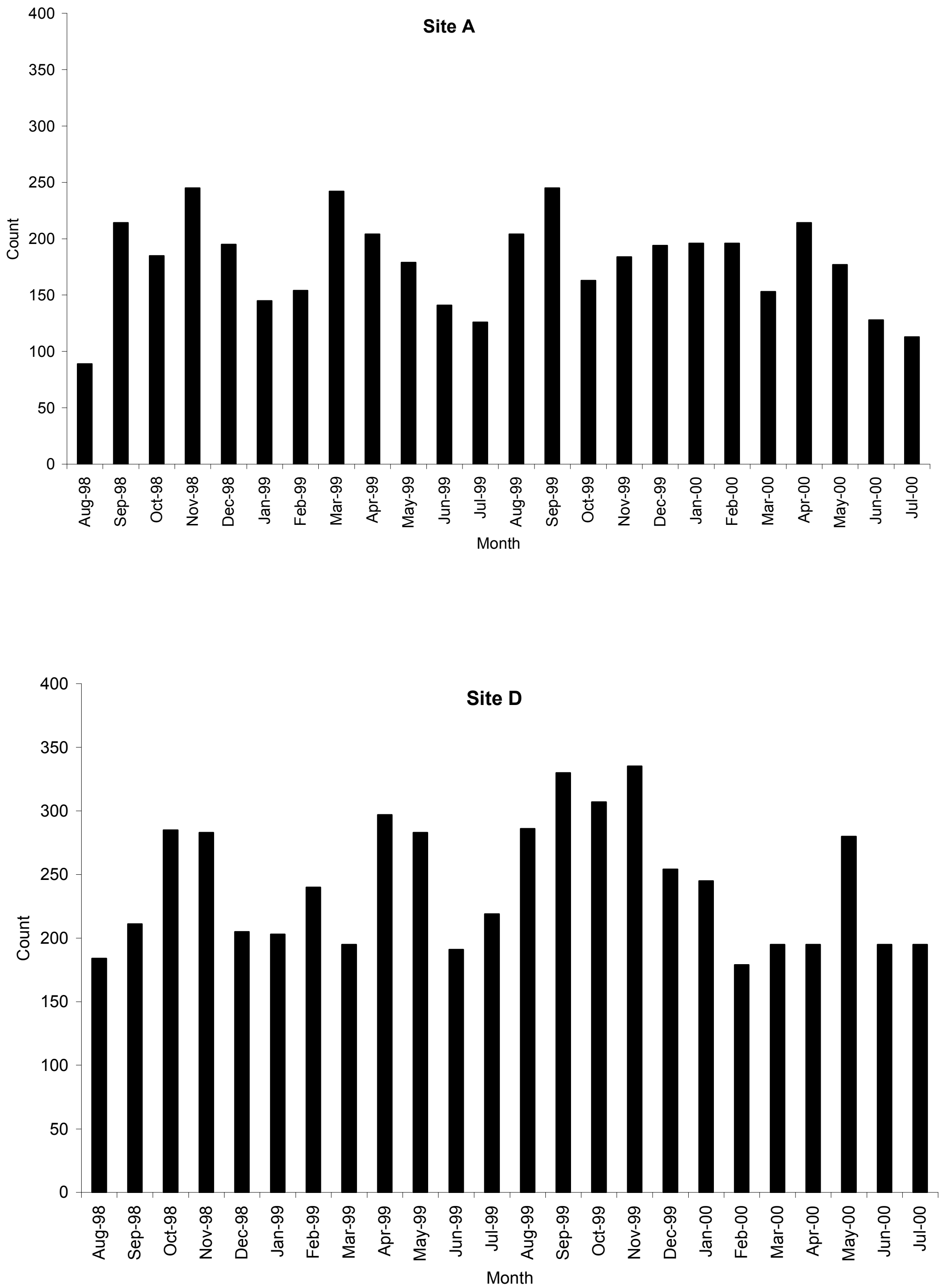



**Fig. 24.** Monthly counts of cave crickets at sites A and D, Exit Cave.

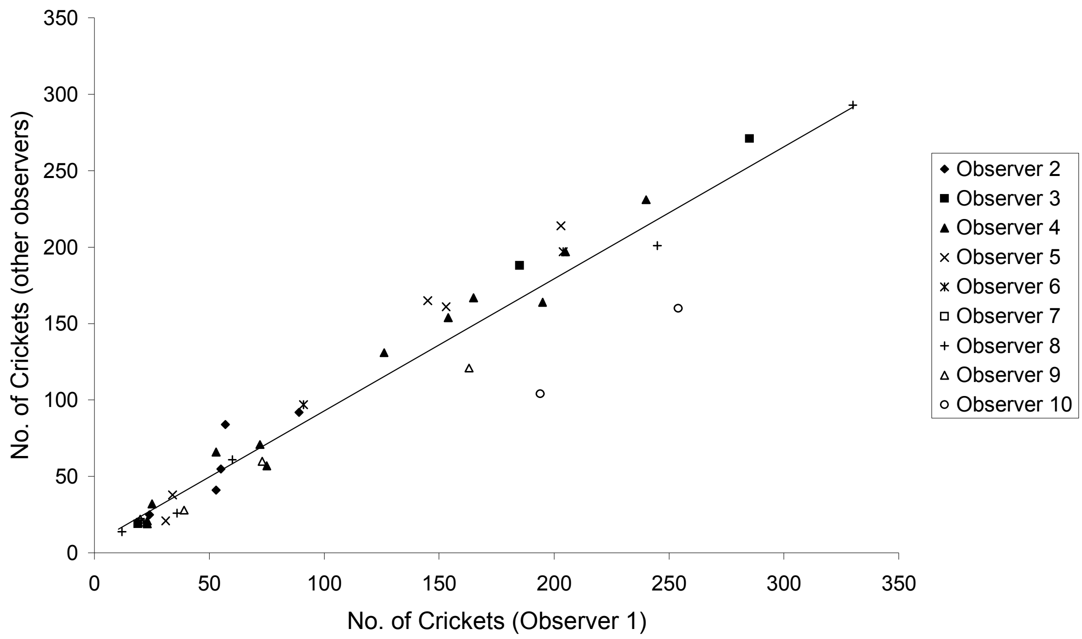



**Fig. 25.** Comparison of counts of crickets by author (observer 1) with counts of crickets at same locations at the same time by one of nine other observers. R = 0.96.

*Other Cave Fauna*

Counts from monitoring plots, as well as general observations in the two caves, suggest that fewer cave spiders and cave crickets were recorded in Mystery Creek Cave than in Exit Cave — within the parts of the caves surveyed (Table 4). No cave beetles or Amaurobiidae spiders were recorded at the monitoring sites in Mystery Creek Cave. The Ida Bay Cave Harvestman was regularly observed in both caves, usually near glow-worms.

Ida Bay Cave Beetle

All Ida Bay Cave Beetles except one were observed at the cave cricket monitoring sites A-F (Table 4) partly reflecting that cave beetles are known to prey on cave cricket eggs (Mohr and Poulson 1966). An Ida Bay Cave Beetle was observed feeding on a Tasmanian Cave Cricket egg in April 1999. The majority of cave beetles were observed at sites E (70% of total beetle observations), B (19%) and C (8%). These three sites had good viewing areas to observe beetles compared with sites A and D and they also had significant areas of soft substrates suitable for crickets to oviposit their eggs. In the wind tunnel (sites B and C) the numbers of cave beetles observed was higher during summer than during winter (Fig. 26), similar to that observed for cave crickets (Fig. 22). At site E, beetles were present all year round with counts lowest in autumn (Fig. 26). Ida Bay Cave Beetles were observed mating in the months of January, April, May and September.

Tasmanian Cave Spider

Tasmanian Cave Spiders were observed in association with both glow-worm and cave cricket monitoring sites (Table 4). Cave spiders prey on cave crickets (Doran *et al.* 1997) and presumably place their webs to intercept prey that are attracted to glow-worm lights. Very low numbers of spiders were observed at the glow-worm sub-sites in Mystery Creek Cave (35 observations over 24 months) and Exit Cave (17 observation over 24 months) and as a result little can be said about seasonal patterns and no graphs of monthly counts are shown. The majority of spiders were recorded at sites A and D (67%, total count = 392) and monthly counts at these two sites were highly correlated (R = 0.80). No consistent seasonal pattern was observed at sites A and D or at the other sites (Fig. 27). There was, however, a significant increase in the number of spiders in August 1999 and this was due to a large increase in the number of small spiders (Fig. 28).

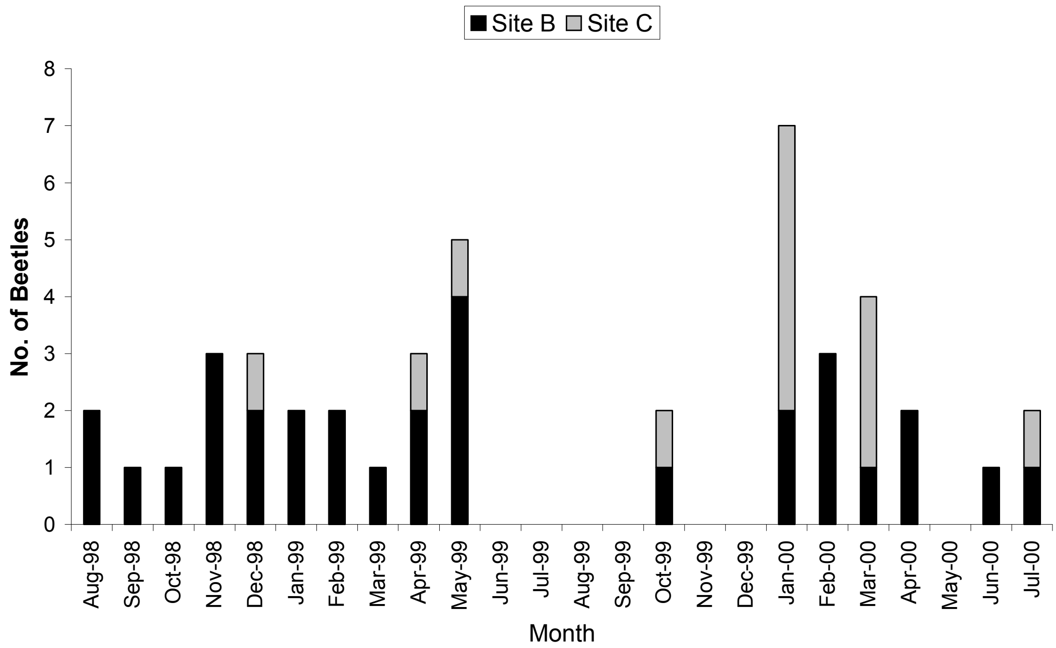
Large adult female spiders were observed more frequently than large adult males throughout the year (Fig. 29) at an average sex ratio of 4:1. At site E, a spider egg sac, not present in August 1998 was observed in September 1998. Nine months later, in June 1999, spiders had hatched and 53 spiderlings were observed on the spider egg sac.

Ida Bay Cave Harvestman

The Ida Bay Cave Harvestman was found at both glow-worm and cave cricket monitoring sites (Table 4). Cave harvestmen are known to prey on glow-worms in New Zealand (Richards 1960). Although harvestmen were regularly observed, numbers were very low and no clear pattern in monthly counts was observed (Figs 30–31). Amongst sites A–F in Exit Cave nearly half (49%) of all harvestmen were observed at site E, and this may be due to the small glow-worm colony that occurs on the roof in this part of the cave.

**Table 4.** Total counts of fauna recorded in glow-worm and cave cricket monitoring plots in Exit and Mystery Creek caves during 24 months of monthly monitoring.

| Taxa | Mystery Creek Cave glow-worm sub-sites (n = 5, approx. area = 7m$^2$) | Exit Cave glow-worm sub-sites (n = 5, approx. area = 5m$^2$) | Exit Cave cricket sites (n = 6, approx. area = 325m$^2$) |
|---|---|---|---|
| Tasmanian Cave Spider | 17 | 35 | 340 |
| Ida Bay Cave Harvestman | 30 | 34 | 41 |
| Tasmanian Cave Cricket | 12 | 22 | 14,255 |
| Ida Bay Cave Beetle | 0 | 1 | 161 |
| Amaurobiidae | 0 | 2 | 4 |



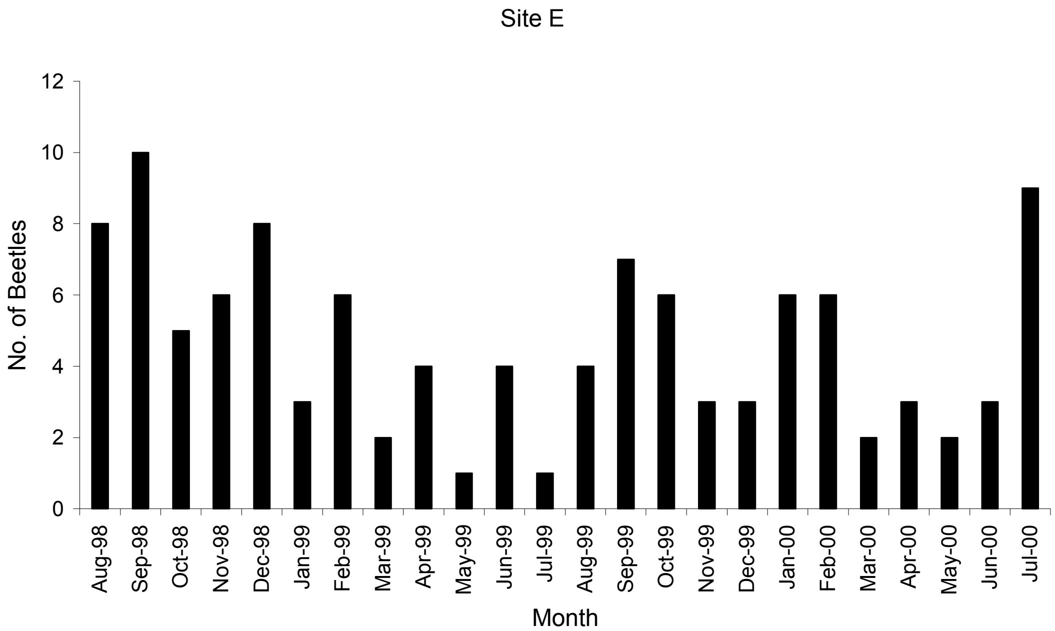
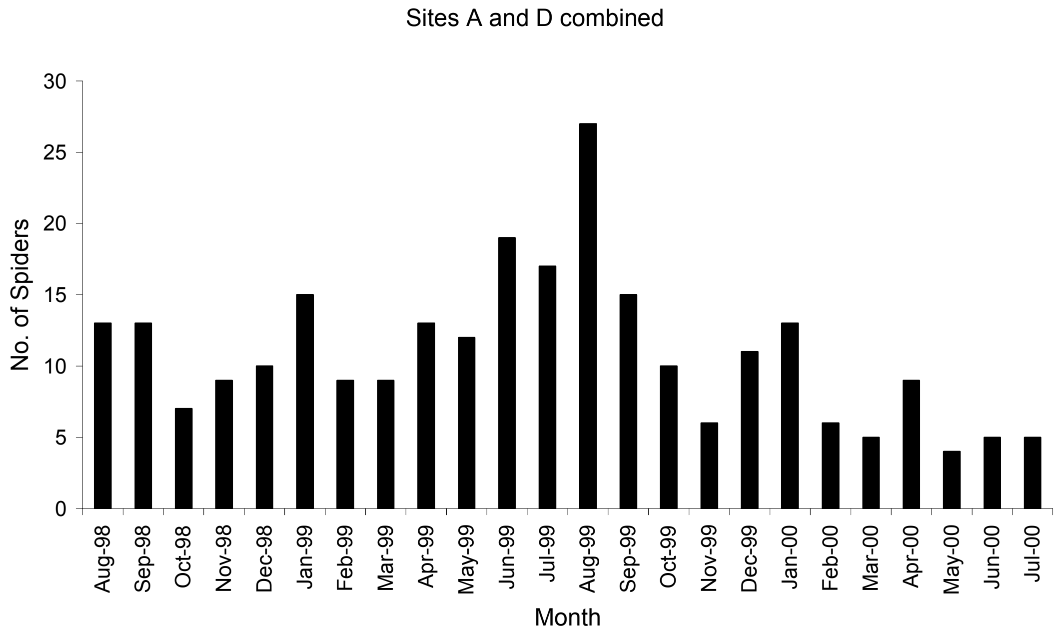




**Fig. 26.** Monthly counts of Ida Bay Cave Beetles in Exit Cave at sites and B and C (combined) and site E. Graphs not shown for sites A and D because few beetles were recorded.



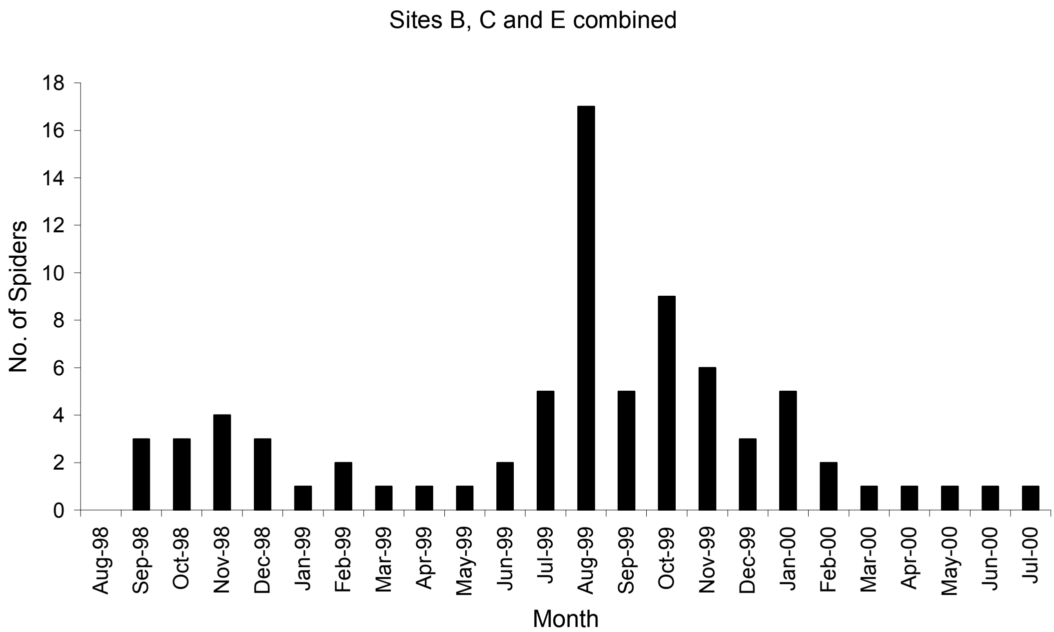




**Fig 27.** Monthly counts of the Tasmanian Cave Spiders in Exit Cave.

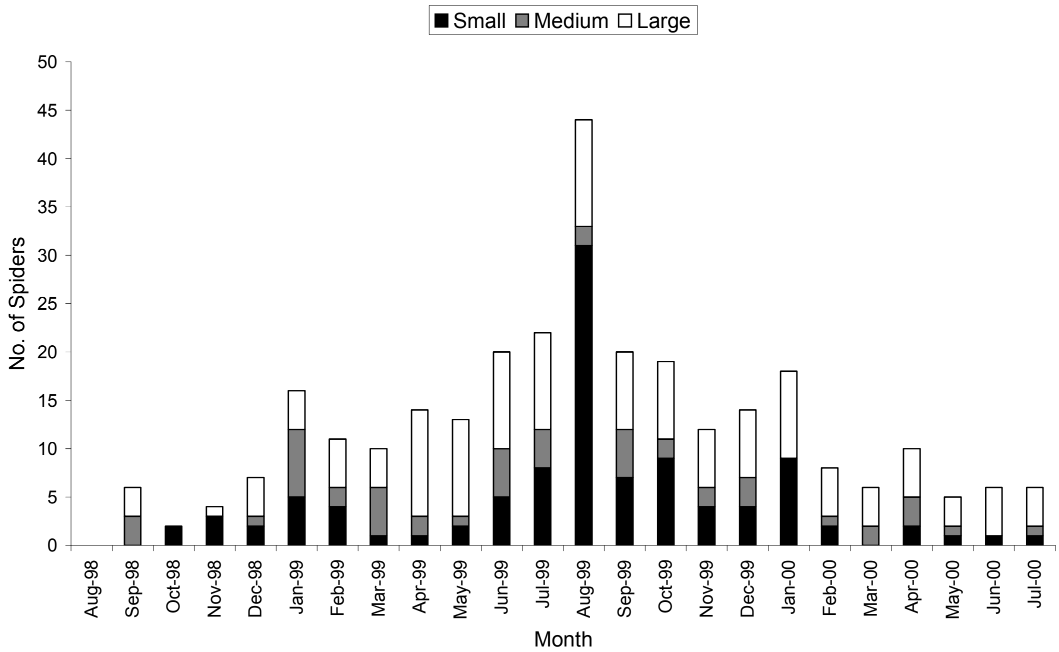



**Fig. 28.** Monthly counts of different size classes of the Tasmanian Cave Spider in Exit Cave. Counts pooled over sites A-E.

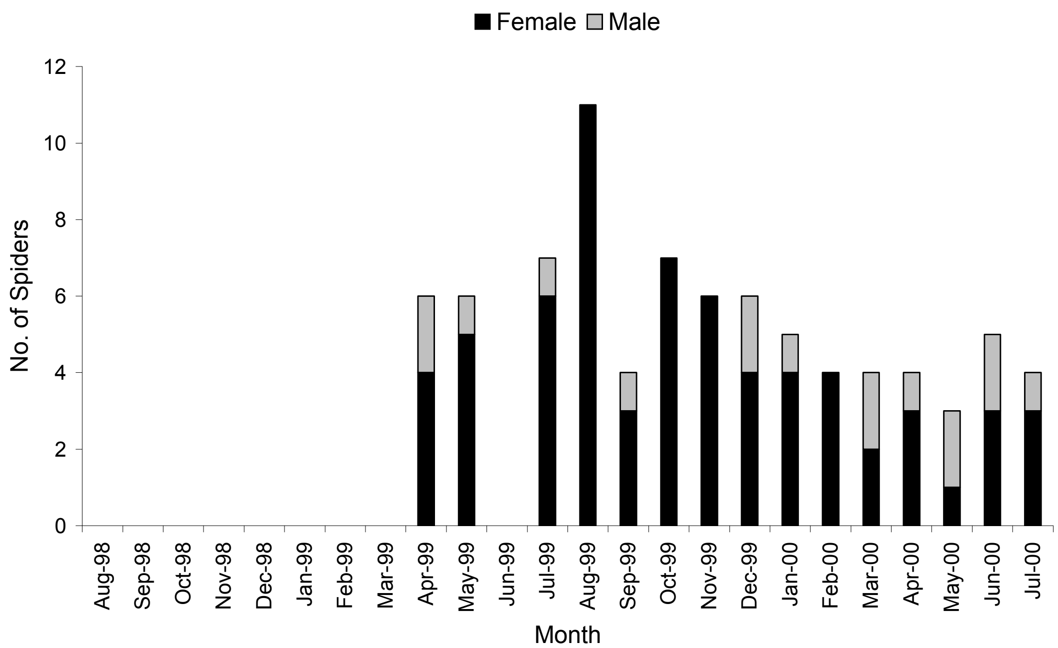



**Fig. 29.** Monthly counts of male and female Tasmanian Cave Spiders in Exit Cave. Counts pooled over sites A-E. No data on sex ratio collected between Aug 1998 and March 1999.

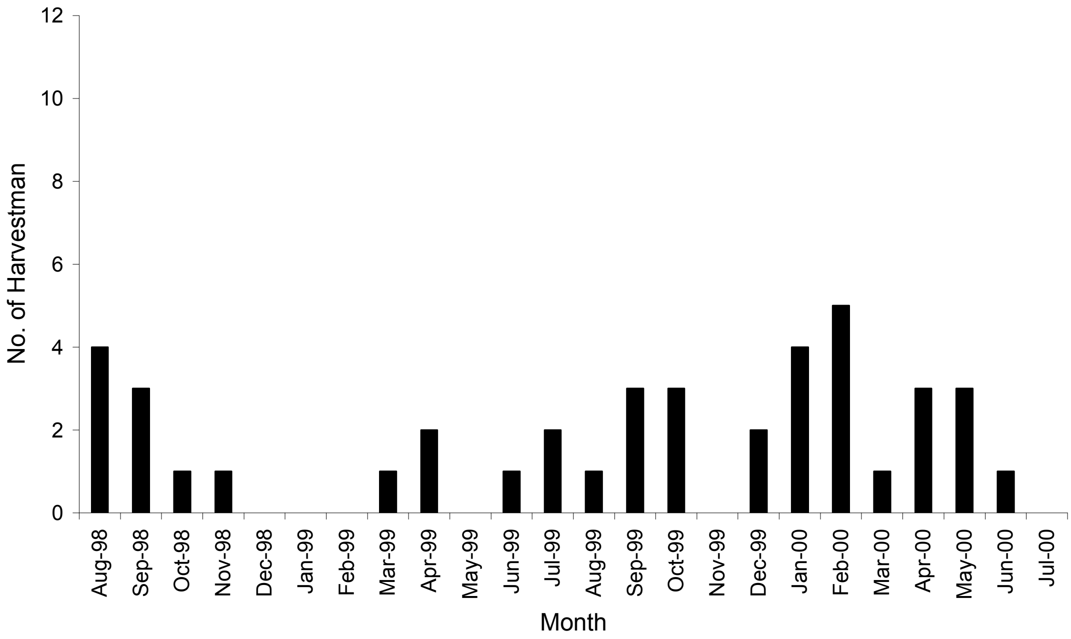



**Fig. 30.** Monthly counts of Ida Bay Cave Harvestman. Data pooled over monitoring sites A-F in Exit Cave.

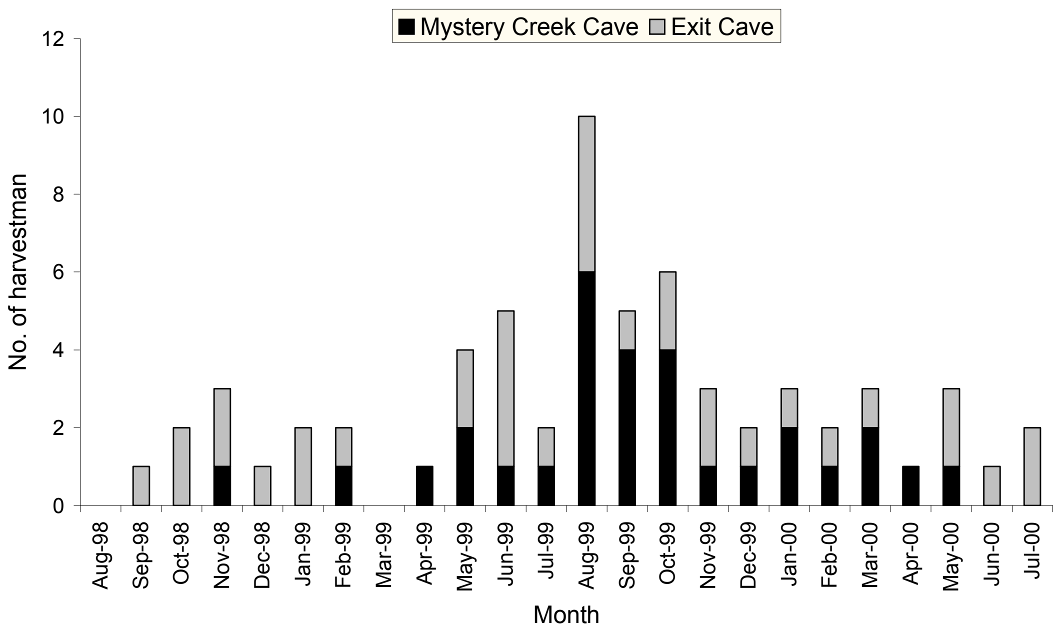



**Fig. 31.** Monthly counts of Ida Bay Cave Harvestman. Data pooled over glow-worm monitoring sub-sites in Exit Cave and Mystery Creek caves.