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Australian Swiftlet *Aerodramus terraereginae* colony stability between 2012 and 2021 and new behaviour patterns at Chillagoe and Finch Hatton, Queensland

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Abstract. Surveys of Australian Swiftlets *Aerodramus terraereginae* at Chillagoe and Dooloomai Falls, Finch Hatton, Queensland, were conducted between 2012 and 2021, building on surveys conducted between 1972 and 2011. At Chillagoe, 57 colonies were located during the period 2012–2021: four colonies went extinct during this time, 19 declined, 24 increased and we located eight newly discovered colonies, resulting in a total of 8065 birds counted in 2021. The extinctions were probably caused by increased flooding, as were most of the declines, but the extermination of feral Cats *Felis catus* reduced Australian Swiftlet losses from predation. In 1 year (2017–2018), three pairs in one colony raised three fledglings, an event not previously recorded at Chillagoe. Most pairs raised only one or two fledglings per year. The two colonies at Dooloomai Falls were stable until 2021, when feral cat predation drastically reduced both colonies.

Introduction

Across the Pacific, swiftlets *Aerodramus* spp. use different breeding strategies adapted to the rainfall regime and subsequent supply of insects. Outside of the nest-farming industry in Asia, wild swiftlets breed in caves or, where there are no caves, they use rock overhangs. The close relatives of the Australian Swiftlet *A. terraereginae* that inhabit the Solomon Islands, Vanuatu, New Caledonia, Fiji, Tonga (White-rumped Swiftlet *A. spodiopygius*), Cook Islands (Atiu Swiftlet *A. sawtelli*), Tahiti and the Marquesas (Tahiti Swiftlet *A. leucophaeus*) all live on small tropical islands that have year-round rainfall (Tarburton 1987a, 2009). This allows these species to all raise two young at a time, and so they do not need to breed all year to maintain a stable population. The swiftlets in Samoa (White-rumped Swiftlet) and the Mariana Islands (Mariana Swiftlet *A. bartschi*) have another strategy: they lay only one egg in a clutch, but breed all year in Samoa (Tarburton 2009) and for most of the year in the Mariana Islands (Johnson 2015; Johnson *et al.* 2017). The Australian Swiftlet, however, lives both along the coast and on small tropical islands and also in savanna, where a long dry season reduces the supply of insects. It has been shown that, in both the savanna and the coastal forests, this species uses a third strategy, called sibling incubation, where once the first egg hatches the nestling is given an egg to incubate (Tarburton 1993). This is so well timed that in most cases the adults take on feeding the second nestling the day after the first one fledges. However, with the cave flooding that has increased in the last 20 years (MT pers. obs.), has the Australian Swiftlet been able to cope or has it varied its strategy in order to try to cope?

Building upon our last study of these colonies from 1972 to 2011 (Tarburton & Tarburton 2013), the present paper concentrates on the Australian Swiftlets that nest in the savanna of the Chillagoe–Mungana area of Queensland (*A. t. chillagoensis*), but also compares two colonies at Dooloomai Falls (coastal subspecies *A. t. terraereginae*). Although nesting in caves can provide some extra protection compared with nesting in the open, it can also present different factors that limit successful breeding (Tarburton 2011, 2012; Tarburton & Tarburton 2013). We have found, for example, that, by breeding earlier in wetter years, some Swiftlet colonies at Chillagoe appear to be able to predict which years will have early heavy rainfall. In addition, some colonies there moved nest sites within the same cave after the old site was washed away or flooded. By using these two strategies the Australian Swiftlet can reduce the negative effects of flooding from La Niña summers in tropical Queensland. This study, in 2012–2021, after the La Niña floodings in the period 2007–2012, aimed to determine the long-term effects of flooding, and is reported here. Another aim was to determine whether the Australian Swiftlet ever raises a third nestling to help recover from losses caused by heavy rainfall or predation by feral Cats *Felis catus*.

Methods

Between 2012 and 2021, we completed five long-term census trips to Chillagoe–Mungana, making observations at all the cave entrances that were known at the time. In addition, four trips were made to obtain census data from just some of the known caves.

The change from censusing the colonies by counting active nests (with eggs or nestlings: ‘nest counts’) previously to counting birds leaving or entering the cave at the beginning or end of their feeding day in the non-breeding season (evening arrival/morning emergence surveys) has proven to be less intrusive. However, it does mean that fewer colonies are censused each day. We have continued to use this method to reduce disturbance to the Swiftlets.

We have learnt that not all Australian Swiftlets leave the cave in the same hour, so morning counts used in surveys previously were discontinued, and only evening surveys (after 1600 h) (Tarburton 2013) were used, to increase the accuracy of our results. On a cool day, we observed no Swiftlets overhead, so entered the nearest nesting cave and found the birds in deep sleep distributed throughout the cave roof, at and near their nest sites. Only two birds flew when we approached so it appeared that they were in short-term hibernation, as once recorded in a large clump of young Atiu Swiftlets on a cool day in the Cook Islands (Tarburton 1990). Since 2010 we have therefore conducted only evening censuses, similar to those in the previous decade, and on days that were not cool (Tarburton & Tarburton 2013). Censuses were usually carried out 10–50 m from the cave entrance(s) used by the birds but there was one exception – access to CH312 Project 31 Cave is no longer permitted so the two entrances were censused from Burke Developmental Road, with no apparent loss in accuracy. Both cave entrances are fairly high on the limestone (karst) tower so birds entering are readily observed even though they are about 200 m distant.

We also investigated if Australian Swiftlets are capable of raising a third nestling (they typically raise two per year), to increase the rate of return to normal population levels after extreme weather or predation events have significantly reduced colony size. They might be more likely to achieve this strategy along the coast or on coastal islands where they feed over rainforests, and where the longer wet season provides a high level of insect prey for a longer period, rather than in savanna. We therefore planned to check both subspecies (coastal *A. t. terraereginae* and Chillagoe *A. t. chillagoensis*). Dermot Smyth (pers. comm.) found that on the offshore islands the Swiftlets often raise a third nestling to the fledgling stage, so in the present study we looked at this possibility in three colonies at Chillagoe. Our method was to take monthly photographs of all the nests in three of the smaller colonies, number the nests on paper for each colony and determine if any nests produced a third nestling in one season. We completed this in two caves outside the Chillagoe–Mungana National Park in 2017–2018, and in these two caves plus an additional cave in 2019–2020 and 2020–2021.

Two colonies at Dooloomai Falls (Finch Hatton Gorge) have been censused using the nest count method because of the huge effort required to reach, and return from, their isolated locations. This means that the number of adult Swiftlets there was derived from the number of active nests counted during a daytime visit in the breeding season. These two colonies in the Upper Finch Hatton Gorge, west of Mackay, were censused six times – in 2011, 2015, 2016, 2017, 2018 and 2021.

Results and discussion

At the commencement of this study, we knew of 32 extant and four recently extinct Australian Swiftlet colonies at Chillagoe (*A. t. chillagoensis*) (Tarburton & Tarburton 2013). In this study, by counting flying Swiftlets (Figure 1) leaving or entering caves, we documented 66 Swiftlet colonies or former colony sites, 64 at Chillagoe and two at Dooloomai Falls (*A. t. terraereginae*) (Table 1). At Chillagoe–Mungana, between 2012 and 2021, we found eight colonies that had declined to zero birds in the previous decade, and remained at zero: CH5 Front, Middle and Rear, CH9 Swiss Cottage,

Figure 1. Flying Australian Swiftlet, Squeeze Pot cave CH169, Chillagoe. Photo: Graham Anderson

Table 1. Australian Swiftlet populations at Chillagoe and Dooloomai Falls, Queensland, in years 2011–2021. Cells with no data indicate that no surveys were undertaken in that year.

Cave no.	*Cave name*	*2011*	*2012*	*2014*	*2015*	*2016*	*2017*	*2018*	*2020*	*2021*
Chillagoe										
CH5	Tower of London Cave & Tower: front site	0						0		0
CH5	Tower of London Cave & Tower: middle site	0						0		0
CH5	Tower of London Cave & Tower: rear site	0						0		0
CH9	Royal Arch Cave: Swiftlet Cavern, Royal Arch Tower	44	37	14		9	20	37		27
CH9	Royal Arch Cave: Swiss Cottage, Royal Arch Tower	0								0
CH24	Keef's Cavern, Ryan Imperial Tower	43	85	74	162			66		254
CH26	Clam Cavern, Walkunder Tower	74	63	130				135		308
CH30	Stop Press Cave, Piano Tower	15	29	8				6		3
CH52	Swiftlet Cave, Royal Arch Tower	206	250	288				211		122
CH81a	New Southlander Cave, Queenslander Tower		36	126				102		107
CH124	Flow Cavern, Royal Arch Tower	44	17	7				22		27
CH133	But Good Cave, Royal Arch Tower		0							
CH144	Christmas Pot Upper Entrance, Suicide Tower	72	144	181				284		414
CH146	Guano Pot, Suicide Tower	116	51	163		120		187		346
CH147	Crocodile Pot, Suicide Tower		253	119		35		83		202+
CH149	Christmas Pot Lower Entrance, Suicide Tower		40	59				160		227
CH167	Crack Pot, Suicide Tower		481	403				303		259
CH169	Squeeze Pot, Suicide Tower	118	236	251				180		142
CH187	Gordale Scar Pot, Spring Tower	322	287	234				307		300
CH192	Wallabadori Cave Entrance 1, Twin Tower			2		6				3
CH221	September Cave, Walkunder Tower	216	108	68				217		184
CH252	Good Black Friday Cave, Spring Tower	247	248	201				284		157
CH306	Mudlark Cave, Spring Tower	0		16		2		2		7
CH309	Barramundi Eyes Cave, Spring Tower							312		206
CH312	Project 31 Cave West Moffatt Tower					109		12		71
CH312	Project 31 Cave East Moffatt Tower					115		195		247
CH322	Swiftlet Scallops Cave 1, Markham Tower	0								0
CH362	Hercules Cave: Rear, Markham Tower	66						40		0
CH362	Hercules Cave: Front, Markham Tower	0								0
CH362	Hercules Cave Combined, Markham Tower	66		22						0
CH374	Swiftlet Scallops Cave 2, Markham Tower	2	5	20	8			67		123
CH379	Tarby's Pot, Spring Tower	168	230	167				258		370
CH380	Golgotha Cave: Side Colony, Tower of London	190								
CH380	Golgotha Cave: Bottom Colony, Tower of London	2	0							
CH380	Golgotha Cave: Combined, Tower of London	192	211	82	79		64	38		92
CH381	Swiftrimlet Cave combined, Royal Arch Tower	38	66	89		123		80		44
CH397	Shirl's Triple Twirl Cave, Royal Arch Tower	28	36	10				0		0
CH398	Swiftlet Swallet Cave, Markham Tower	193	380	314	404			504		363
CH412	Vertical Terraces Cave, Ryan Imperial Tower		70	76				30		149
CH427	Real Eclipse Cave, Eclipse Tower			317						388
CH459	Swiftlet Surprise Cave, Ramparts Tower		447	359	550	297		626		420
CH496	Satu Lagi Cave, Markham Tower	0					64	12		73
CH499	Cactus Cleft Cave, Markham Tower	15	43	43				117		110
CH501	Bottle Cave, Wallaroo Tower	88	141	73				113		106
CH511	Western Pit			0						
CH530	Glory to God Cave, Markham Tower			90				46		137
CH531	Balas Cave, Pinnacle Ridge							277		265
CH532	Kerrin's Dilemma Combined, Royal Arch Tower		193	56		199		278		144

Table 1 continued

Cave no.	*Cave name*	*2011*	*2012*	*2014*	*2015*	*2016*	*2017*	*2018*	*2020*	*2021*
CH533	Krystelle's Delight Cave, Royal Arch Tower		97	60		50		82		106
CH535	Dirk's Back Yard combined, Spring Tower	22	22	49		29		30		35
CH536	Lisette's Art Shoppe Cave, Spring Tower	24	53	38				55		65
CH537	Vertical Mums Cave, Ryan Imperial Tower		25				49			19
CH542	Ella Bella Cave, Kurrajong Tower		21	28		10		19	53	49
CH543	Beefeater Cave, Queenslander Tower		97	9				106		91
CH544	Gruntagrike Cave SE, Ryan Imperial Tower		226	155				76		57
CH547	Mikael's Drop In, Kurrajong Tower		15	14		47		120	110	89
CH550	Cam's Shaft, Kurrajong Tower		52	15		86		87	148	89
CH552	Telicia's Twin, Kurrajong Tower		5	7		3		8	7	15
CH553	First Prussik Cave 2, Royal Arch Tower		23	34		57		61		38
CH554	Joseph's Pit, Markham Tower		38	47	29			71		8
CH556	Keith's Offer Cave, combined, Spring Tower			549		717		588		577
CH557	Shirl's Swirl Cave, Spring Tower			26		65		25		31
CH558	Creation's Speedsters Cave, Royal Arch Tower			60		261		312		226
CH569	Bag End Cave, Ryan Imperial Tower									138
CH572	Swan Song Cave, Royal Arch Tower									89
CHMH3	Metal Hills 3 (combined entrances)		352	398				264		148
Total		**2611**	**5213**	**5551**	**1232**	**2340**	**197**	**7495**	**318**	**8065**
Dooloomai Falls										
Dooloomai Falls Upper		336			48	172	254	168		0
Dooloomai Falls Lower		320			50	188	216	424		20

CH133, CH322, CH362 Front and CH 511 (Table 1). Two colonies declined to zero in 2012–2021 but then recovered: CH306 and CH496. However, two other colonies declined to zero during 2012–2021 but did not recover: CH362 Rear and CH397. Although 19 colonies declined between 2012 and 2021, 24 increased, expanding the total known Australian Swiftlet population in the Chillagoe–Mungana district.

In addition, between 2012 and 2021, we located 21 colonies of Australian Swiftlets in separate caves that were new to us. They were usually located by searching for Swiftlets diving towards the rock surface in areas where we did not know of a cave entrance. These colonies all had reasonably deep black guano deposits (bats produce brown guano) below the nests so they were not newly established colonies, just previously undocumented. They have also added to the total known population and, in 2021, for the first time we counted >8000 Swiftlets in the census at Chillagoe–Mungana. This number comprised the population of 53 current colonies. In comparison, in Fiji, where fewer caves are available (though the caves are much larger), >20,000 White-rumped Swiftlets have been censused in just one cave (Tarburton 1987b), and in Niah Cave System, Borneo, 1.5 million Black-nest Swiftlets *A. maximus* and 300,000 Mossy-nest Swiftlets *A. salangana* have been counted (Lord Medway 1962). Sadly, nest harvesting of the Black-nest Swiftlets in The Great Niah Cave System has reduced the numbers to ~100,000 (Borneo Post: https://www.theborneopost.com/2012/03/17/swiftlet-numbers-dwindling-in-niah-caves/).

Twenty-four of the colonies at Chillagoe caves increased during the present study. One factor that might have contributed to this there was the reduction in predation by feral cats. In 2012–2021, we did not observe any sign of predation at the caves previously affected, although some predation was indicated at CH530 (which had not been predated before 2014) and at the newly discovered cave CH537 in 2021 (Figure 2). Several times, MT observed feral cats stalking in Kangaroo Grass *Themeda triandra* near caves occupied by Swiftlets and, in an attempt to eliminate cats, Queensland National Parks and Wildlife Service rangers set traps at the entrances to caves where piles of Swiftlet feathers had been located in 2010–2020. They captured several cats and the Swiftlet colonies at those caves recovered. Piles of Swiftlet primary feathers always occurred at an entrance to a Swiftlet colony where the ceiling was lower than ~1.5 m above the cave floor, and a cat was usually caught in a trap set near these feathers.

Predation by rats *Rattus* spp. of Australian Swiftlet nests on the high Chillagoe cave roofs was unlikely although rats took nestlings that fell to the cave floor. On Oahu, Hawaiian Islands, however, where Mariana Swiftlets nest on lower cave roofs, trapping of rats resulted in increased reproductive activity and nest success of that species (Johnson *et al.* 2017).

Although there was no evidence of predation of Australian Swiftlets by pythons at either of the Dooloomai Falls colonies, at Chillagoe, we have watched Children's Pythons *Antaresia childreni* fall to the ground trying to reach Swiftlet nests. MT observed a Children's Python

Figure 2. Evidence of likely feral cat predation on Australian Swiftlets at CH26 cave, Chillagoe, Queensland. Photo: Michael Tarburton

and python scats (which contained Swiftlet flight-feathers: Figure 3) on five consecutive visits (1985–2001: Tarburton & Tarburton 2013) to the upper colony at CH380 Golgotha Cave (where the entrance passage is so narrow that it was easy to locate the individual python on each visit). However, python predation there appeared insignificant as that colony increased in size during this study. Also, because pythons are poikilothermic, they consume less than homeothermic predators such as feral cats, and they

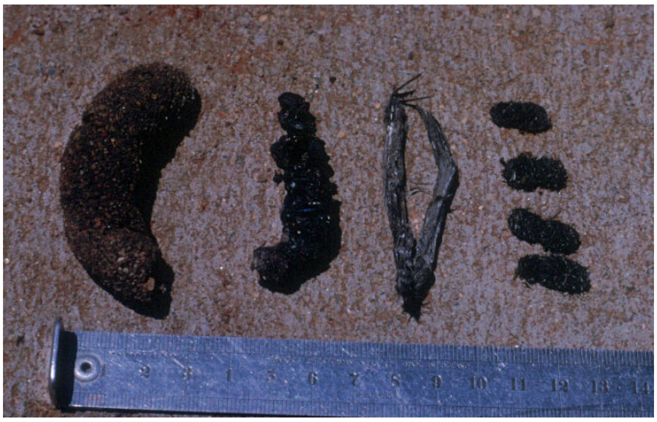

Figure 3. Children's Python faecal pellets from Golgotha Cave, 25 December 2000. The third pellet from the left contains Australian Swiftlet flight-feathers. Photo: Michael Tarburton

Figure 4. Jaw of Northern Quoll, located in low part of entrance to the top colony of Golgotha Cave CH 380. Photo: Courtesy Queensland Museum

Table 2. Monthly and annual rainfall (mm) for Chillagoe during the study period 2011–2021.

Year	*Month*												*Total for year*
	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	
2011	379	195	413	11	0	20	0	0	0	14	13	98	1143
2012	175	108	269	9	13	33	10	0	0	0	58	48	723
2013	438	87	124	51	5	0	0	0	0	28	187	15	935
2014	28	130	19	57	5	8	0	7	0	9	1	74	338
2015	136	118	26	5	1	5	4	0	0	3	52	156	506
2016	158	129	134	3	9	0	0	2	0	2	30	73	538
2017	285	183	134	0	5	4	1	1	3	37	116	20	788
2018	72	31	86	0	0	0	0	0	0	0	30	59	288
2019	317	168	119	12	7	6	0	0	0	0	0	40	665
2020	315	196	89	10	33	0	0	1	2	6	10	199	860
2021	389	329	52	50	0	0	2	0	0	10	79	249	1251
2022	193	233	36	39	158								
Mean	228	215	134	29	14	11	4	4	5	15	57	138	853
No. years greater than mean	6	1	2	3	2	2	1	1	0	2	4	3	3

Table 3. Number of pairs of Australian Swiftlets breeding at three colonies at Chillagoe, and the results of their attempts.

Colony	*Year*	*No. pairs attempting to breed*	*Average no. fledgings/nest*	*No. pairs with 3 fledglings*
Satu Lagi	2017–18	39	1.3	3
Satu Lagi	2019–20	30	0.7	0
Satu Lagi	2020–21	39	0.9	0
Swiftlet Scallops 2	2017–18	29	1	0
Swiftlet Scallops 2	2019–20	41	0.9	0
Swiftlet Scallops 2	2020–21	52	1	0
Newsouthlander	2019–20	35	1.1	0
Newsouthlander	2020–21	27	0.8	0

Figure 5. Australian Swiftlet wing-feathers from a massive (likely) feral cat-kill at the upper colony at Dooloomai Falls, 23 January 2021. Photo: Aaron Bean

appear to be territorial as MT never observed more than one python in a cave. It was also in the low entrance to Golgotha Cave that, in 1985, MT found the jaw of a Northern Quoll *Dasyurus hallucatus* (identified at the Queensland Museum: Figure 4). Quolls might have occupied this food niche before cats and Cane Toads *Rhinella marina* drastically reduced the number of Quolls.

Combining our census data for 1972–2011 and 2012–2021 (Tarburton & Tarburton 2013; this study, Table 1), 15% of Australian Swiftlet colonies at Chillagoe have gone extinct but 53% have increased in size. Some smaller details not obvious in Table 1 are that the cave CH9 Swiss Cottage, which for several years had one pair of Swiftlets, now had none. CH133 But Good Cave and CH511 Western Pit were reported by a caving club member to have Swiftlets, but we have never documented any there. CH322 Swiftlet Scallops 1 cave has not had Swiftlets since 1982, when five were recorded there (Chillagoe Caving Club records 1982). CH362 Hercules Cave Front colony was occupied from 1986 until 2006 (Tarburton & Tarburton 2013), when excessive rain washed the nests off the walls (this paper). The rear colony of the same cave suffered a similar fate 11 years later, with 285 mm of rain in January 2017 (Table 2). CH380 Golgotha Cave lost the very deep bottom colony between 2011 and 2012 and, because the birds use the same entrances as the side colony, we cannot determine from entry counts whether that colony has re-established after it was flooded by heavy rainfall in January 2011 (379 mm: Table 2).

In the last few days of our 2021 visit (25–28 July), we noticed a few Swiftlets entering caves during the day, and inspection revealed nests under construction, 4 months earlier than normal. The heavy rainfall in both December 2021 and February 2022 (Table 2) might have been a reason for the early construction of nests. Although we were unable to check whether that season's early breeding was successful, in previous seasons when Swiftlets started breeding early, they could raise their broods before the nests deteriorated and collapsed from excessive water running over them. The Swiftlets in CH374 Swiftlet Scallops 2 Cave bred late during heavy rainfall and, on 4 February 2022, eggs and nestlings were present in nests that were deteriorating prematurely. In four seasons since 2006, some colonies commenced breeding early and, even though not predicted, an unusually wet season (La Niña) occurred. In 2021, the Bureau of Meteorology prediction of an approaching La Niña coincided with early breeding in some Australian Swiftlet colonies.

Table 3 shows that the average number of Swiftlet fledglings per nest per season in the three caves that we examined on a monthly basis at Chillagoe varied from 0.7 to 1.3, and only in 1 year in one cave (2017–2018, Satu Lagi) did any pairs raise three fledglings. This contrasts with subspecies *A. t. terraereginae* nesting on small offshore islands, where most pairs raised three nestlings per season (Dermot Smyth pers. comm.), presumably because of the longer wet season along the coastal areas, which in turn provides abundant insects for a much longer period.

The two Swiftlet colonies at Dooloomai Falls declined (Table 1), again likely caused initially by the more frequent extreme wet La Niña downpours. On several occasions, the nests were observed to be collapsing and washing off the walls because of oversaturation. These colonies have previously recovered from similar events. However, during our 2021 visit (23 January), large piles of Swiftlet wing-feathers were discovered (Figure 5), indicating likely predation by feral cats at both Dooloomai Falls colonies. There were no active nests in the upper colony (though adult Swiftlets might still have roosted there at night), and only five in the lower colony. A similar killing attributed to cats also happened in 1989 and both colonies recovered to hundreds of Swiftlets by 2011 (Tarburton & Tarburton 2013).

In summary, in the savanna region of their range Australian Swiftlets have only one brood per year but rarely attempt to raise three nestlings. In some populations that have declined because of excessive rainfall, subsequent increase in population size occurs, instead, when breeding begins early; by some unknown means, the birds have advance awareness of a season that will be earlier and wetter than normal. Some colonies still experience significant declines caused by heavy rain and predation by feral cats, but most recover from these events, although in 2012–2021 four colonies at Chillagoe declined to zero and remained there.

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