

## CHAPTER 6. MONITORING AND ASSESSMENT OF THE WIDER ECOLOGICAL IMPACT ON INVERTEBRATES ON ST AGNES AND GUGH AS PART OF THE ISLES OF SCILLY SEABIRD RECOVERY PROJECT

### SUMMARY

- The pitfall trap surveys were carried out in 2013 and 2014 and repeated in 2016.
- Differences between results in 2013 and 2016 show longer term trends and are perhaps more useful than trends between successive years.
- Bryher is used as a control. If trends are similar on Gugh and St Agnes, but different on Bryher, it is possible that rat removal is one of the causes of the difference. Broad trends between 2013 and 2016 are similar for St Agnes and Gugh but different for Bryher for Devil's Coach Horse and (less clearly) Lawn Hoppers.
- It is interesting to note that patterns between 2013 and 2016 were similar between Gugh and Bryher and dissimilar for St Agnes for six different groups (brown rove beetles, Black Marram Weevil, spiders, millipedes, woodlice and mites). The reasons for this are not clear, but for these species changes in abundance cannot be attributed solely to the removal of rats from St Agnes and Gugh.
- There was a decline in the total number of invertebrates on St Agnes and Gugh between 2014 and 2016, compared with an increase on Bryher; this could be due to an increase in shrew numbers. However, the total number of invertebrates caught increased between 2013 and 2016 on all three islands.
- Changes in the abundance of Lawn Hoppers might be due in part to changes in the abundance of shrews which feed on this species. Between 2013 and 2016 Lawn Hoppers number declined on St Agnes and remained stable on Gugh; in contrast they increased on Bryher. (Numbers of shrews increased during this period on Gugh (a large increase) and St Agnes (a small increase), but decreased on Bryher).
- Broad trends between 2013 and 2016 for St Agnes and Gugh are dissimilar for a range of species such as millipedes, slugs and mites, so that rat removal may not be the major cause of varying trends in the abundance of these species.
- The numbers of sandhoppers increased on all three islands between 2014 and 2016. This may be due the partial recovery of the foreshore habitat after winter storms of 2013/2014, but also the absence of predation by rats. The increase in sandhoppers across all three islands may obscure the effect of rat removal on Gugh.
- *Psyche casta* larvae may form a good food resource for rats. There were large increases in numbers on St Agnes and Gugh, which may be due to the absence of rats; however the huge increase in numbers in scrub on Bryher is difficult to explain.
- In both St Agnes and Gugh there were increases in numbers of red and black ants, flies and springtails – in all these cases the increases were replicated on Bryher indicating that rat removal may not be the major cause of varying trends in the abundance of these species.
- There are a number of different variables which may contribute to changes in the numbers of key invertebrate species and species groups:
  - The large increase in black ants in 2014 followed by a decline in 2016 may be partly attributable to the exceptionally damp weather in early 2014.
  - The winter storms of early 2014 led to considerable loss of foreshore habitat, with a resulting reduction in numbers of the Black Marram Weevil, the Brown Beetle *Calathus mollis* and the Darkling Beetle. These declines continued in

2016, although landscape photos indicate that the foreshore habitat had started regenerate by 2016.

- Large numbers of slugs were found to have been poisoned during the rat baiting programme and were removed to avoid the risk of secondary poisoning; despite this, the number of slugs increased on St Agnes in 2014 and continued to increase in 2016. The number of slugs on Gugh and Bryher decreased between 2013 and 2016.
- The record of *Philopodon plagiatus* in 2014 is possibly the first record for this weevil for Scilly.
- The following beetles (recorded in 2014) are likely to be new records for St Agnes, Gugh and Bryher: *Cassida nobilis*, *Nalassus laevioctostriatus*, *Otiorhynchus atroapterus*, *Phaleria cadaverina*, *Psylliodes marcida* and *Rhagonycha fulva*.
- 33 species of spider were identified in 2016 by Dr Peter Smithers (Table 6.25). These included the first record for Gugh of the Red Data Book species *Clubiona genevensis* (which has previously been found on St Mary's, Bryher, Arthur, Samson and Ganilly) and the first records for Scilly of three species: the nationally scarce spider *Pardosa agrestis*, *Argenna subnigra* and *Silometopus ambiguus*. All of the other species are widespread in the UK.
- It is suggested that future invertebrate monitoring could be centred on ant baiting, butterfly transects and key species such as Devil's Coach Horse and Lawn Hopper.

**Table 6.1. Change in numbers of individual species found within the pitfall traps on St Agnes, Gugh and Bryher between 2013, 2014 and 2016**

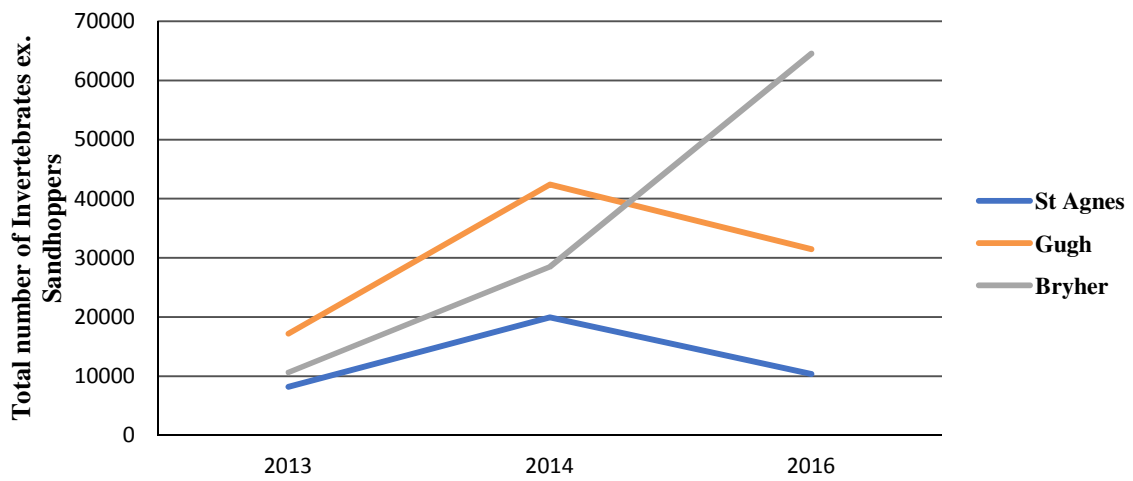
	2013 - 2014			2014 - 2016			2013 - 2016		
	St Agnes	Gugh	Bryher	St Agnes	Gugh	Bryher	St Agnes	Gugh	Bryher
<b>Lawn Hoppers</b>	↓	↔	↑	↓	↔	↓	↓	↔	↑
<b>Brown rove beetles</b>	↑	↑	↔	↓	↑	↑	↔	↑	↑
<b>Black Marram Weevil</b>	↔	↓	↓	↔	↔	↑	↔	↓	↓
<b>Brown Beetle</b>	↔	↓	↔	↔	↔	↔	↓	↓	↓
<b>Devil's Coach Horse</b>	↓	↓	↔	↓	↔	↑	↓	↓	↑
<i>Psyche casta</i>	↔	↑	↓	↑	↔	↑	↑	↑	↑
<b>Spiders</b>	↑	↔	↑	↓	↔	↔	↔	↑	↑
<b>Millipedes</b>	↑	↑	↔	↓	↔	↑	↓	↑	↑
<b>Red ants</b>	↑	↔	↓	↑	↑	↑	↑	↑	↑
<b>Black ants</b>	↑	↑	↑	↓	↓	↓	↑	↑	↑
<b>Slugs</b>	↑	↓	↓	↑	↑	↑	↑	↓	↓
<b>Woodlice</b>	↑	↑	↑	↓	↓	↑	↔	↑	↑
<b>Mites</b>	↓	↑	↑	↓	↓	↑	↓	↑	↑
<b>Flies</b>	↔	↑	↓	↑	↓	↑	↑	↑	↑
<b>Springtails</b>	↑	↑	↔	↔	↔	↑	↑	↑	↑
<b>Sandhoppers</b>	-	-	-	↑	↑	↑	-	-	-
<b>Total number of invertebrates ex S/H</b>	↑	↑	↑	↓	↓	↑	↑	↑	↑

>-25% change declining ↓

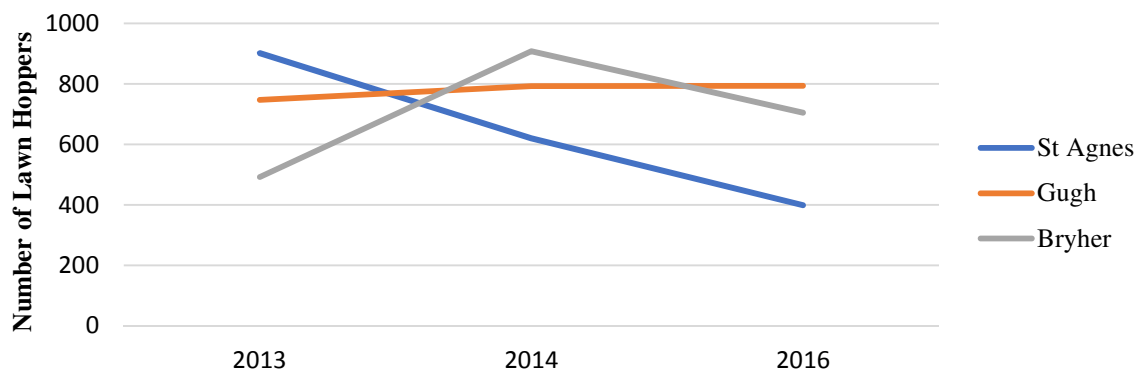
+ or - 25% change stable ↔

>25% change increasing ↑

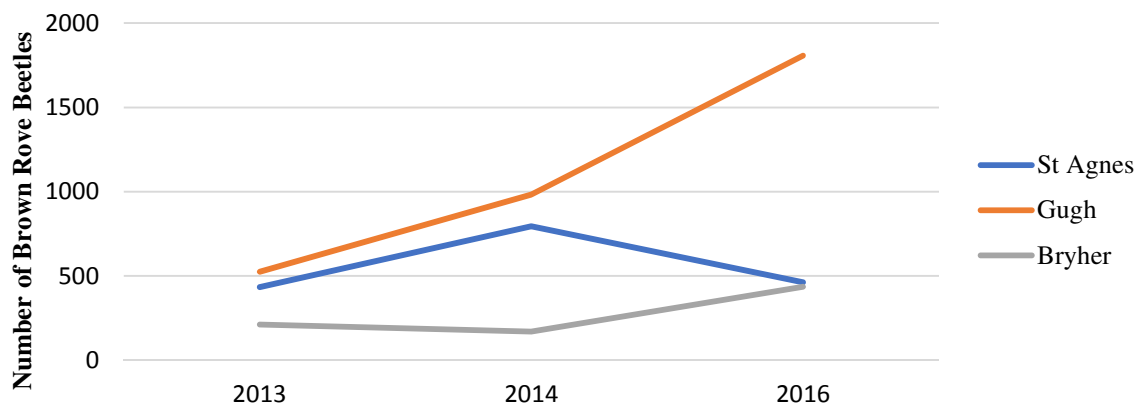
**Fig 6.1. Numbers of Invertebrates recorded on each island each year**



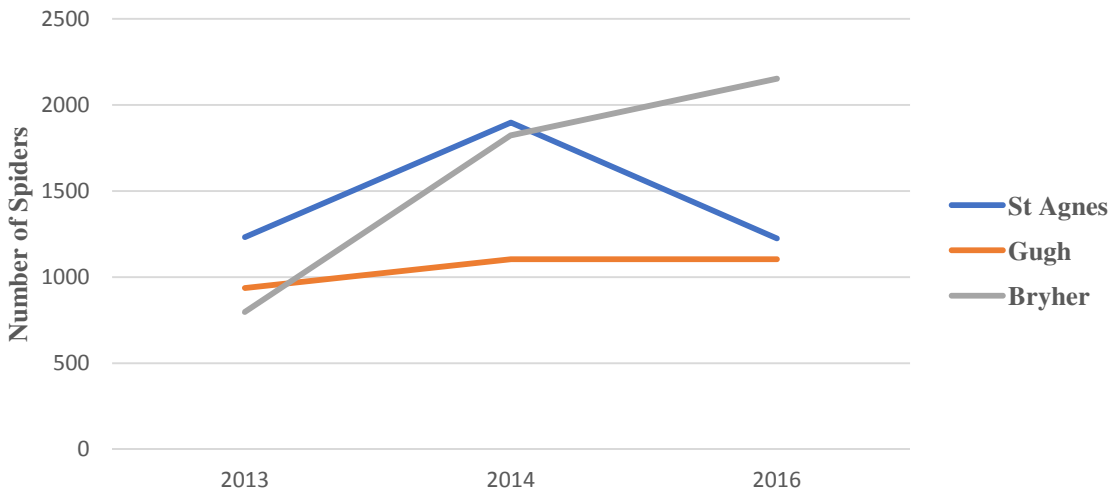
**Fig 6.2. Numbers of Lawn Hopper recorded on each island each year**



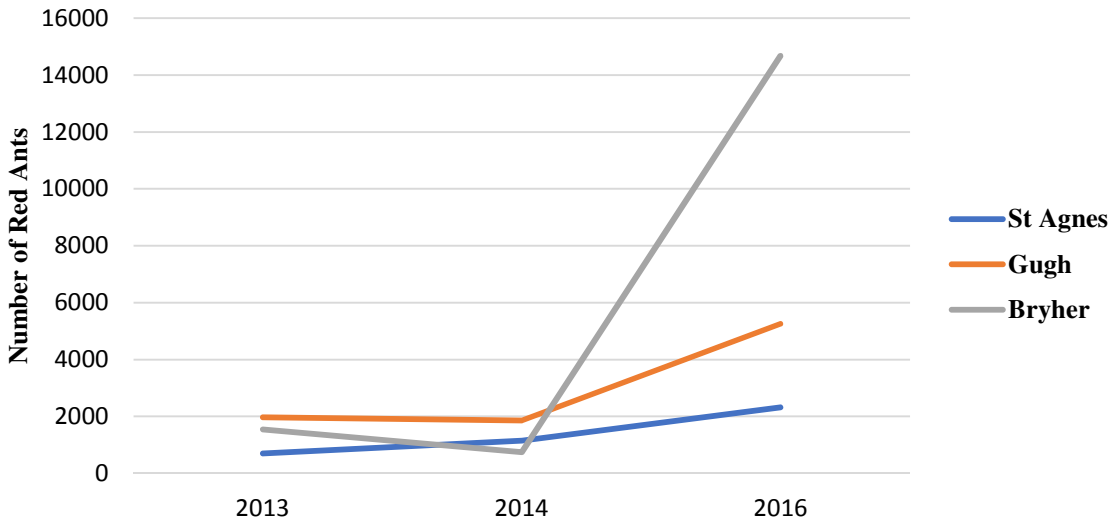
**Fig 6.3. Numbers of Brown Rove Beetles recorded on each island each year**



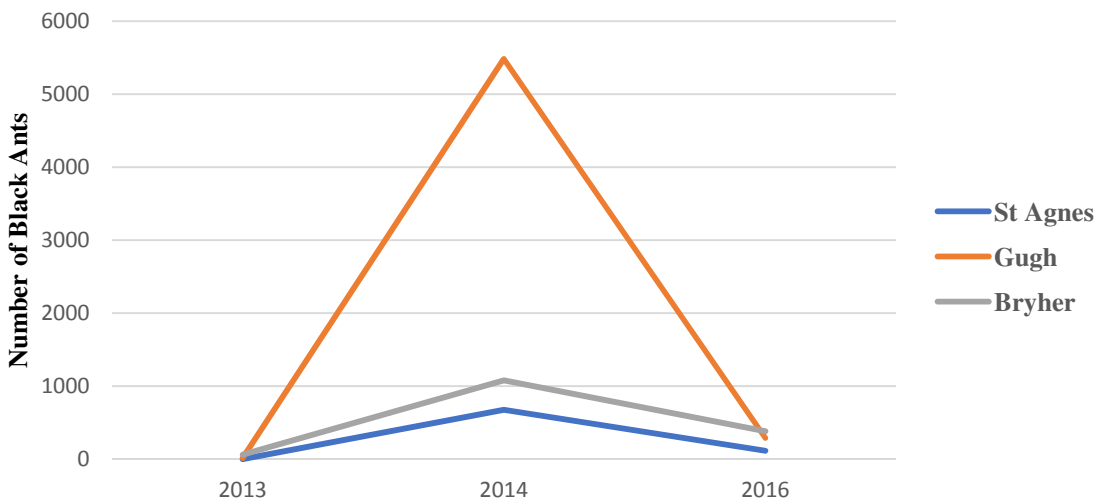
**Fig 6.4. Numbers of Spiders recorded on each island each year**



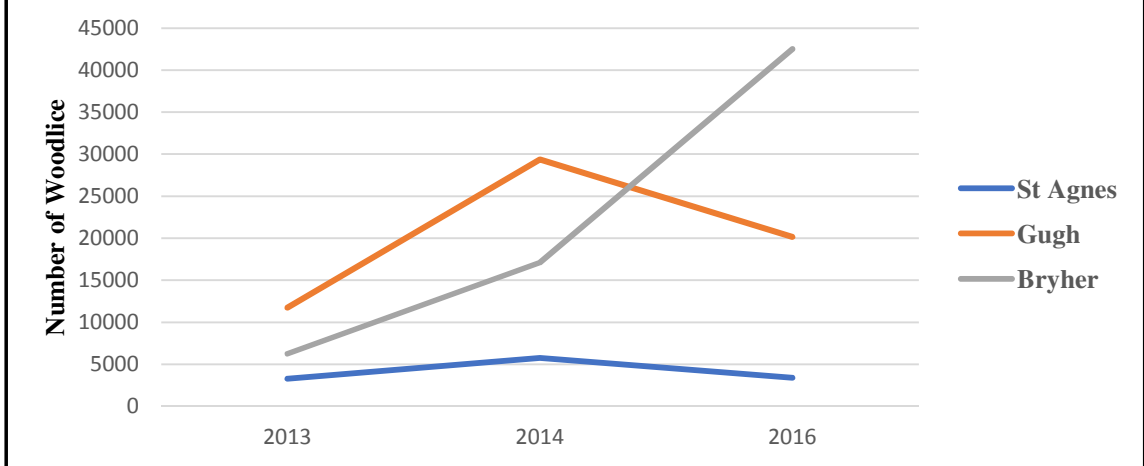
**Fig 6.5. Numbers of Red Ants recorded on each island each year**



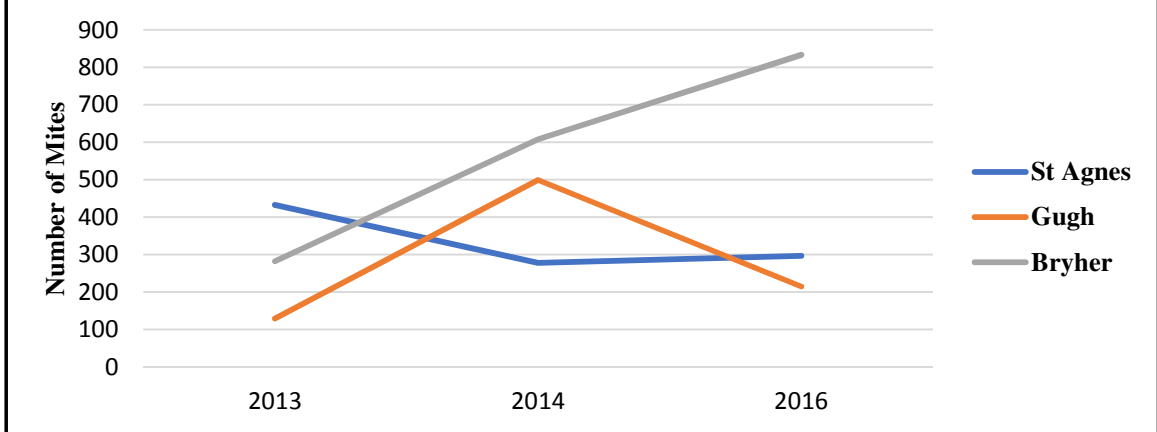
**Fig 6.6. Numbers of Black Ants recorded on each island each year**



**Fig 6.7. Numbers of Woodlice recorded on each island each year**



**Fig 6.8. Numbers of Mites recorded on each island each year**



**Fig 6.9. Numbers of Flies recorded on each island each year**

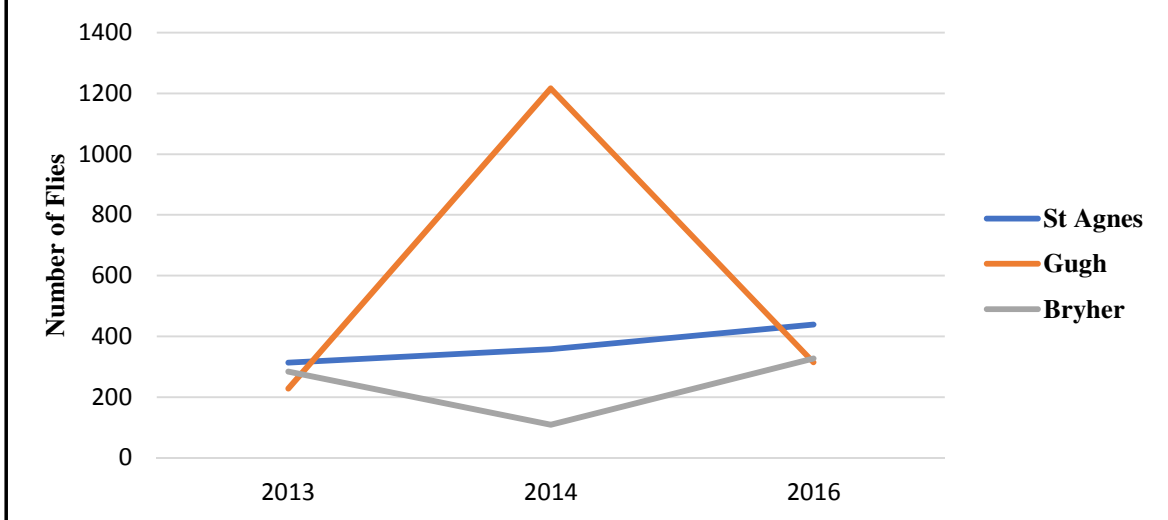


Fig 6.10. Numbers of *Psyche casta* recorded on each island each year

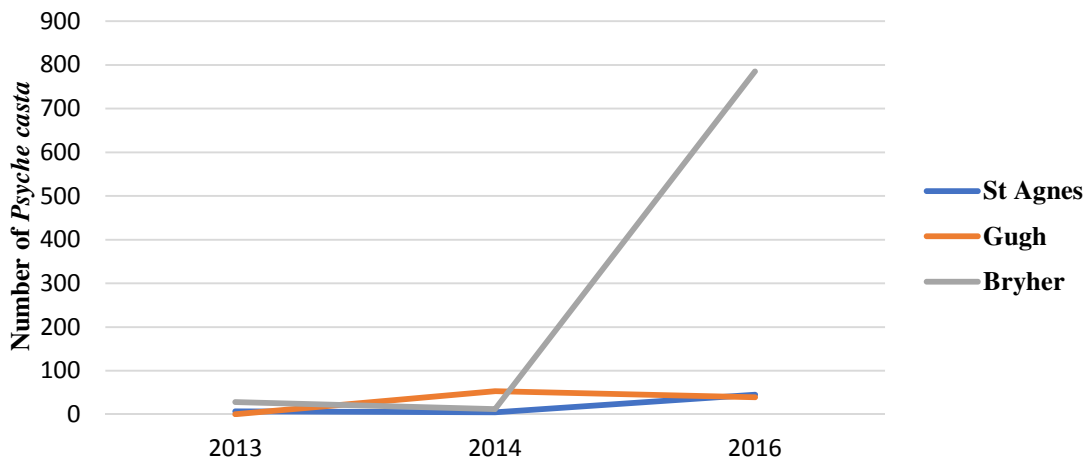


Fig 6.11. Numbers of Devil's Coach Horse recorded on each island each year

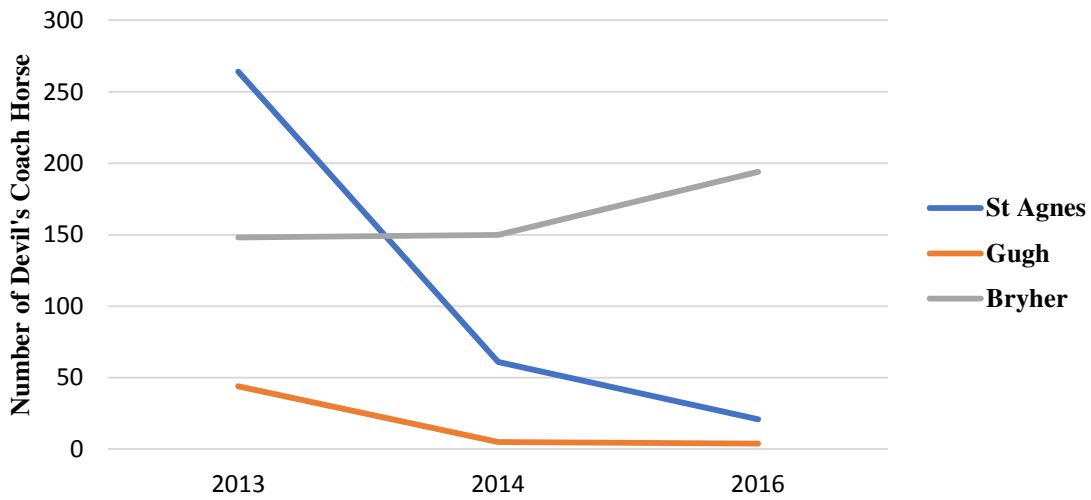
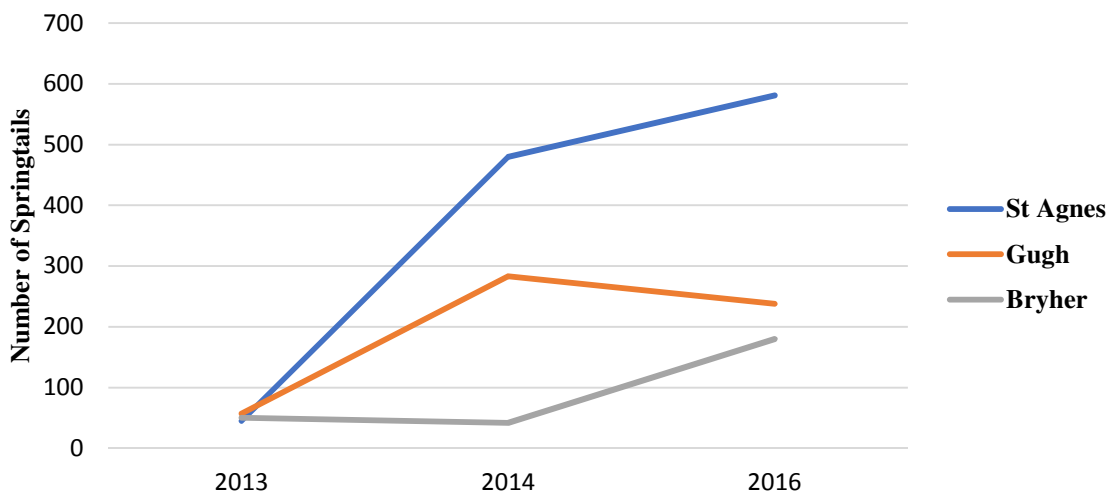


Fig 6.12. Numbers of Springtails recorded on each island each year



## 6.1. AIM OF SURVEYS

To monitor the change in abundance of invertebrates between 2013 and 2016 on St Agnes and Gugh, using Bryher as a control, after the removal of rats on St Agnes and Gugh as part of the Isles of Scilly Seabird Recovery Project.

## 6.2. INTRODUCTION

The distribution and abundance of invertebrates in a particular area depends on a range of factors, e.g. larval foodplant availability, nectar sources for flying insects, temperature and humidity regimes, habitat structure, plant architecture and phenology, soil structure and chemistry, topography etc, in addition to habitat connectivity and historic continuity and, especially for islands, rates of colonisation and survival. Invertebrate communities on Scilly are likely to be impoverished due to island isolation but they represent key components of the island ecologies. Invertebrate communities may respond rapidly to changes in habitat since many species have high fecundity and in some cases may produce several generations per year. They may therefore be excellent indicators of habitat change; for example changes in habitat structure leading to changes in temperature may induce large fluctuations in the abundance of a particular species.

Invertebrates were noted in 35% of rat stomachs on St Agnes and Gugh, in particular slugs, larvae, earthworms, spiders and “insects” (Bell, 2011) and so form an important part of the rat diet on these islands. After rat removal, it is possible that these species may increase.

As a side product of rat removal, numbers of Scilly Shrew appear to be increasing (Chapter 2). The Scilly Shrew feeds predominantly on crustaceans especially the Lawnhopper which is found all over the islands, as well as millipedes, flies, beetles, spiders and mites (Harris & Yalden (2008)). As the numbers of Scilly Shrew increase on St Agnes and Gugh, it may be that numbers of these invertebrates will decrease.

## 6.3. METHODOLOGY

Pitfall trapping was carried out along 18m transects, with one pitfall trap every 2m (= 10 traps) as recommended by Natural England (2007) with a total of 4 transects (= 40 traps) per habitat type (foreshore, coastal grassland, heathland and scrub) giving 160 traps in total for each island. In some cases, the transects led on from each other, depending on the topography and available habitat. (The scrub habitat was the most difficult in which to lay pitfall traps, both because of the difficulty of finding suitable scrub near to other sampled habitats on Gugh and Bryher and problems with digging into the soil in these locations). Holes were dug for each trap using a gardener’s bulb planter and traps inserted into each one. On the foreshore, a pit was dug, the trap inserted, and the sand back-filled around it. The lip of each trap was slightly below, rather than above, the surrounding soil surface, so that small invertebrates would not be dissuaded from falling into the trap.

The transects were mapped in 2013 using a hand-held GPS (Maps 1.1, 1.2, 1.3). The traps comprised two 300ml clear polypropylene cups – 7.5cm (rim diameter) and 10cm





(height). The inner one was removed when emptying the catch into the collection bottle, and replaced into the outer cup, thus ensuring easy replacement without disturbing the surrounding soil. Red plastic circular planting trays were propped over the top of each cup supported by matchsticks (to prevent rain water flowing into the trap) and weighted down with stones). Each trap was filled with about 50ml 50/50 mix of propylene glycol and water (= about 2cm). The planting tray 'lids' were firmly pushed over the permanent cup at the end of each survey so as to aid finding and reusing the traps during future surveys, and to ensure no invertebrates were inadvertently trapped between surveys. All pitfall traps were kept in position for the summer except the foreshore traps, which were collected in after the first survey and which were then reset for each of the subsequent surveys (if left in situ they were likely to be buried under wind-blown sand).



We cut out small wire grids from sheets of 13 mm mesh chicken wire, using a bench mounted wire cutter. These were pushed into the top of the inner cup in order to prevent small vertebrates (most especially Scilly Shrew) falling into the traps.

Overly livestock-grazed and publicly accessible areas were avoided as far as possible to reduce the chances of interference (deliberate or otherwise) with the traps. There was no deliberate interference with the traps, although cattle disturbed and crushed some of the traps especially on St Agnes.



The contents of each trap were decanted into plastic bottles, labelled both inside with waterproof pens on waterproof paper and outside with permanent markers to ensure that the identity of each sample was assured. One bottle was used for every 10 pitfall traps, except for the foreshore traps which were amalgamated. Extra propylene glycol was added to each bottle to ensure that the invertebrates would be preserved for a longer period during transit prior to identification.

Pitfall traps were left day and night to catch nocturnal and diurnal species. They were left in place for 7 nights during the first survey period in 2013, both for logistical reasons but also because it was initially felt that invertebrate numbers might be too low after just 3 nights. However, initial catches were very high and subsequent catches over 3 nights were high enough to provide meaningful results. Results from the first set of catches were adjusted so as to be comparable with the subsequent 3 night results. There were so many woodlice in the first set of catches that some of the smaller invertebrates might have been overlooked.





The contents of each bottle were emptied into a white tray for sorting. In some cases, where the bottles were full, the catch was split into two samples for easier examination. The invertebrates caught were divided into species and groups.

Easily identified invertebrates (e.g. Rose Chafer) were counted individually; otherwise species were grouped into easily identifiable groups (e.g. spiders, woodlice etc). Due to the large numbers of invertebrates caught, and the requirement to use volunteers, the groupings were made as simple as possible. No microscopic identification will be required to repeat these surveys.



Some limited training was provided in identification and a list of the more abundant and easily identified species has been created to be used during subsequent surveys. Easily identifiable species groups such as the Devil's Coach Horse were counted, even though in May they were very scarce; they became abundant in autumn. It is expected that long-living species such as ants and beetles will form a key part of the data analysis. All individual animals were counted except woodlice which were counted in estimated groups of 10, as there were too many to count individually.

Sandhoppers on the beaches were not counted in 2013 as the pitfall traps were completely full and the measurement would simply have been of the capacity of the pitfall traps. These traps were also the most likely to be lost, covered in and or blown away.



Sorting into size classes for species groups was considered but not implemented as it would be impractical to sort each species into size; for example there were 32,369 woodlice recorded in 2013 alone.

Pitfall traps were set up on all islands (40 in each habitat type) in May, June, July and September in 2013, 2014 and 2016 (Table 6.2).

**Table 6.2. Trapping dates for 2016 compared with 2013 and 2014**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
St Agnes	21-28	13-16	10-13	17-20	17-20	3-6	16-19	8-11	12-15	16-19	8-11	6-9
Gugh	22-29	20-23	11-14	17-20	16-19	7-10	16-19	9-12	11-14	16-19	9-9	8-11
Bryher	23-30	16-19	14-17	18-21	14-17	6-9	15-18	10-13	15-18	17-20	6-9	9-12

The methodology for 2014 and 2016 was the same as for 2013 with two exceptions.

The number of pitfall traps on the foreshore was reduced from 40 in 2013 to 10 in 2014 and 2016, as there was concern that the numbers of sandhoppers being killed within the pitfall cups would have a significant effect on sandhopper populations, especially since some of the beaches are small and isolated from other beaches. Sandhoppers were not counted in 2013 as the pitfall traps were completely full and the measurement would simply have been of the capacity of the pitfall traps, but they were counted in 2014 and 2016, so for the first time we

can analyse Sandhoppers results. All other species groups were counted for all years; the results for the foreshore for 2014 and 2016 have been adjusted to take account of this so that comparisons can be made between results for 2013 (with 40 cups) and 2014, 2016 (with 10 cups).

In 2013 we used small wire grids made from sheets of 13 mm mesh chicken wire pushed into the top of the inner cup in order to prevent small vertebrates (most especially Scilly Shrew) falling into the traps. Smaller grids would reduce the catch of larger invertebrates. Three dead Scilly Shrews were caught over the 2013 season (one on each island), representing three captures in a total of 1920 pitfall traps (40 per habitat in 4 habitats per island per survey visit in 4 visits), which equals 1 in 640 traps. The shrews were probably following prey items and forced their way into the traps. We would expect greater numbers of shrews to be caught if populations recovered in 2014 and subsequent years after rat removal so smaller grids were prepared using an 8mm mesh to be used immediately if large numbers of shrews were caught. It was agreed that the trigger for changing to a smaller mesh grid would be the capture of 5 shrews in any one transect in a single habitat. On Bryher in 2016, some shrews were living under the lids in nests on top of the wire grids on the closed pitfalls during August and 4 were disturbed when setting them back up. In the event, 5 shrews were caught in different transects on St Agnes and Gugh, 5 on St Agnes, Gugh and Bryher in 2015 and 8 in total on all 3 islands in 2106 (Table 6.3). The most in a single transect was 2 and the change to 8mm grids was not required.

<b>Table 6.3. Numbers of Scilly Shrew caught in the pitfall traps</b>				
<b>2014</b>				
<b>Island</b>	<b>Month</b>	<b>Habitat</b>	<b>No caught</b>	<b>Total caught</b>
St Agnes	May	Scrub	1	5
St Agnes	July	Heath	1	
St Agnes	September	Heath	1	
Gugh	June	Scrub	1	
Gugh	September	Heath	1	
<b>2015</b>				
Gugh	May	Heath	2	5
Bryher	June	scrub	1	
St Agnes	June	Heath	1	
Gugh	September	Grass	1	
<b>2016</b>				
Gugh	May	Grass	1	8
Bryher	June	Grass	1	
St Agnes	June	Grass	2	
St Agnes	July	Heath	1	
Gugh	July	Grass	1	
Bryher	Sep	Heath	1	
Bryher	Sep	Scrub	1	

Some of the Myriapods were collected and sent to Tony Barber the national recorder for centipedes and author of two key books on centipedes (Barber, A.D. *Key to the identification of British centipedes*, Field Studies Council; Barber, A.D. *Centipedes. Synopses of the British Fauna (New Series) No. 58*. Linnean Society / Field Studies Council).

Some of the spiders were sent to Dr Peter Smithers of Plymouth University for identification.

## 6.4. RESULTS

**Table 6.4. Summary table of the total number of invertebrates and key groups for each island**

	St Agnes			Gugh			Bryher		
	2013	2014	2016	2013	2014	2016	2013	2014	2016
<b>Lawn Hoppers</b>	902	620	399	747	793	794	492	908	705
<b>Brown rove beetles</b>	434	794	462	525	982	1806	212	169	436
<b>Spiders</b>	1232	1899	1225	937	1105	1252	797	1823	2153
<b>Red ants</b>	694	1149	2317	1973	1854	5258	1539	738	14671
<b>Black Ants</b>	5	676	117	18	5481	294	63	1083	384
<b>Woodlice</b>	3288	5756	3390	11719	29379	20169	6251	17117	42498
<b>Mites</b>	433	278	297	129	499	215	282	608	834
<b>Flies</b>	313	358	439	228	1217	314	284	109	327
<i>Psyche casta</i>	7	5	45	0	53	59	28	12	785
<b>Devil's Coach Horse</b>	264	61	21	44	5	4	148	150	194
<b>Springtails</b>	45	480	581	57	283	238	50	42	180
<b>Total no of invertebrates ex Sandhoppers</b>	8195	19959	10368	17168	42389	31486	10649	28497	64563

### 6.4.1. Key species

#### **Black Marram Weevil** *Otiorhynchus atroapterus*

**Table 6.5. Black Marram Weevil on the foreshore 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	2	27	22
2014	0	0	6
2016	0	0	10



There appear to be no recent records of Black Marram Weevil from Scilly, with no known records since 1904 until this project started in 2013. The records from St Agnes, Bryher and Gugh appear to be new records for these islands. It is a large distinctive species found in large numbers on the foreshore associated with Marram grass *Ammophila arenaria*. Numbers on Gugh and Bryher crashed between 2013 and 2014 – on Gugh totals went down from 27 (adjusted from 109 in 30 traps) to 0 (in 10 traps) and on Bryher from 22 (adjusted from 86 in 30 traps) to 6 in 10 traps. The foreshore habitat at Gugh changed radically during 2014 but had started to recover by 2016, although no Black Marram Weevils were recorded. On Bryher, the foreshore habitat was largely destroyed in the 2014 winter storms, and the decline in Black Marram Weevil is almost certainly due to this; Black Marram Weevil changes on St Agnes were slight, as it was not commonly found there.

#### **Darkling Beetle** *Phaleria cadaverina*

There appear to be no recent records of Darkling Beetle from Scilly until this project started in 2013 and it has apparently only been previously recorded from St

**Table 6.6. Darkling Beetle on the foreshore 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	0	9	3
2014	1	1	0
2016	1	3	1



Mary's. It is a distinctive species on sandy coasts found under seaweed, among decaying vegetation and in carrion. One was found for the first time on St Agnes in 2014 and again in 2016. It declined on Gugh from 9 (adjusted from 36 for 30 traps) to 1 (2014) and 3 (2016), and on Bryher from 3 to 0 (2014) with 1 in 2016, in both cases the loss of foreshore habitat would have had a major effect on this species.

**Brown Beetle *Calathus mollis***

**Table 6.7. Brown Beetle *Calathus mollis* 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	1	25	1
2014	0	2	2
2016	0	0	0

This is a small brown beetle. It has been recorded before on the main islands but apparently not on Gugh



and apparently not anywhere on Scilly since 1931. In 2013 there were large numbers on the foreshore on Gugh and small numbers on Bryher. Numbers have declined from 25 on Gugh in 2013 (adjusted from 98 for 30 traps) to 2 in 10 traps, but increased slightly from 1 in 2013 (adjusted from 4 for 30 traps) to 2 for 10 traps on Bryher. None were seen anywhere in 2016, possibly a result of loss of foreshore habitat in 2014 and the slow recovery since then.

**Devil's Coach Horse *Ocypus olens***



This is a distinctive beetle when fully grown (about 25mm long) but can be confused with other black rove beetles

**Table 6.8. Devil's Coach Horse 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	264	44	148
2014	61	5	150
2016	21	4	194

when small. It predates other invertebrates and might be expected to increase in numbers if populations of other

invertebrates increase, unless predated itself. Numbers have reduced on St Agnes (from 264 to 61 to 21) and Gugh (from 43 to 5 to 4), but increased on Bryher. It is most abundant in the autumn; 90% of the specimens found on Bryher over the 3 years' survey were in September. The changes at these levels on Gugh and St Agnes, compared with Bryher, are likely to represent real changes in the ecology of the islands and it would interesting to know if Devil's Coach Horse forms a major constituent part of the diet of Scilly Shrew.

**Green Tiger beetle *Cicindela campestris***

**Table 6.9. Green Tiger Beetle 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	4	0	2
2014	2	0	0
2016	0	0	2

This distinctive beetle is carnivorous and hunts other small insects. It is associated with warm open heathlands and coastal habitats, especially





where the substrate is firm. In 2013 only 6 were seen (4 on St Agnes and 2 on Bryher), in 2014 2 were seen on St Agnes, and in 2016 only 2 were seen, both on Bryher. Numbers are too low for comparisons to be made between years.

**Minotaur Beetle *Typhaeus typhoeus***

**Table 6.10. Minotaur Beetle 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	0	0	0
2014	0	0	0
2016	0	0	0

The Minotaur Beetle is a distinctive dung beetle found in sandy grassland and heathland, where it feeds on rabbit



droppings and other dung, mainly at night. The males have 3 horns (the central one is short) on the thorax; the females are more difficult to identify but have clear sculpture markings on the front edge of the thorax. It is expected to increase in numbers if rabbit populations increase. In fact rabbit populations increased on both Gugh and St Agnes between 2013 and 2016. However no Minotaur Beetles were seen in the pitfall traps on any of the three islands during the survey and only one was seen (on St Agnes) in 2103.

**Rose Chafer *Cetonia aurata***

**Table 6.11. Rose Chafer 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	30	4	2
2014	34	5	3
2016	3	1	2

The Rose Chafer is a distinctive beetle found relatively commonly on Scilly. There is a distinctive black form



occasionally seen. They can be seen feeding on flowers in summer. The larvae feed on decaying vegetable matter. Numbers were similar between 2013 and 2014, with 34 seen on St Agnes in 2014 compared with 30 in 2013, and 3 on Bryher in 2014 compared with 2 in 2013. However numbers were much lower on St Agnes in 2016, with only 3 seen, mainly on the heathland. One each was seen on Gugh and Bryher in 2016, and numbers are too low to draw any conclusions.

***Psyche casta* larvae**

The caterpillars of the bagworm moth *Psyche casta* make a small case out of grass stems which they carry around. There were many of these on all the islands. They did well on all 3 islands in 2016, but especially well on Bryher with 785 (701 in scrub in July). It is possible that they could be a good food resource for rats, as they form a juicy sandwich with meat surrounded by grass stems, and their increase on Gugh and St Agnes may be partly due to the absence of rats. This does not explain the large increase on Bryher.

**Table 6.12. *Psyche casta* 2013, 2014, 2016**

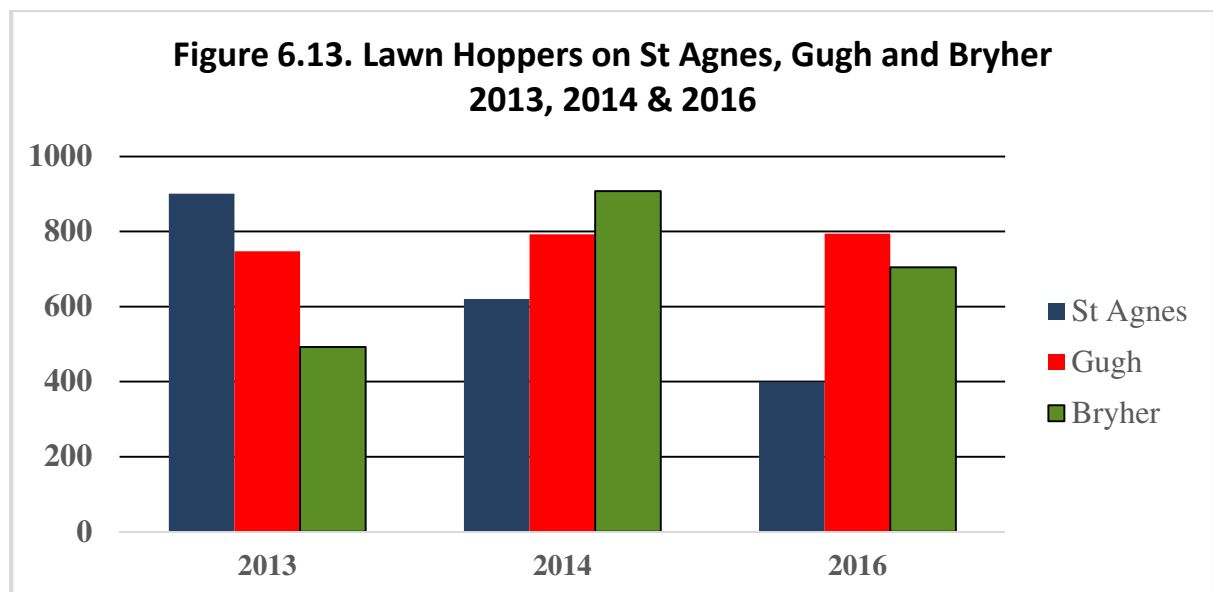
	St Agnes	Gugh	Bryher
2013	7	0	28
2014	5	53	12
2016	45	59	785

## Lawn Hopper, Lawn Shrimp *Arcitalitrus dorrieni*

The Lawn Hopper or Lawn Shrimp *Arcitalitrus dorrieni* occurs almost everywhere in leaf litter and under stones and was found in all trap sessions. It appears to be common everywhere except on the foreshore, although it occasionally occurred in pitfall traps here. Richardson (1980) reported 2,500 per square metre in *Dicksonia antarctica* tree fern litter on the Scillies. It is not known what predares them but it is suggested (Tony Barber GB Non-natives Factsheet Editor [http://www.brc.ac.uk/gbnn\\_admin/index.php?q=node/192](http://www.brc.ac.uk/gbnn_admin/index.php?q=node/192)) that they are probably eaten by carabid beetles, centipedes, birds, etc. It is one of the main food sources for Scilly Shrew and would therefore be expected to decrease in numbers as shrew numbers increase.



**Figure 6.13. Lawn Hoppers on St Agnes, Gugh and Bryher 2013, 2014 & 2016**



The numbers of Lawnhoppers on St Agnes have declined between 2013, 2014 and 2016 (Fig. 6.14; Table 6.9). The largest decline was in coastal grassland, possibly due to increased predation by shrews (Fig. 6.17), although in 2016 the largest numbers of shrews were found on the foreshore. Numbers in heathland went up even though numbers of shrews increased in this habitat.

**Table 6.13. Lawn Hoppers at Gugh 2013, 2014, 2016**

	heath	scrub	Coastal grassland	foreshore	total
<b>2013</b>	67	168	472	39	746
<b>2014</b>	135	295	363	0	793
<b>2016</b>	260	345	101	88	794
<b>totals</b>	<b>462</b>	<b>808</b>	<b>936</b>	<b>127</b>	<b>2333</b>

The numbers of Lawnhoppers on Gugh have remained fairly constant over the years Fig 6.15; Table 10), increasing in heathland and scrub but declining in coastal grassland (Fig 6.18). The numbers of shrews has

**Table 6.14. Lawn Hoppers at Bryher 2013, 2014, 2016**

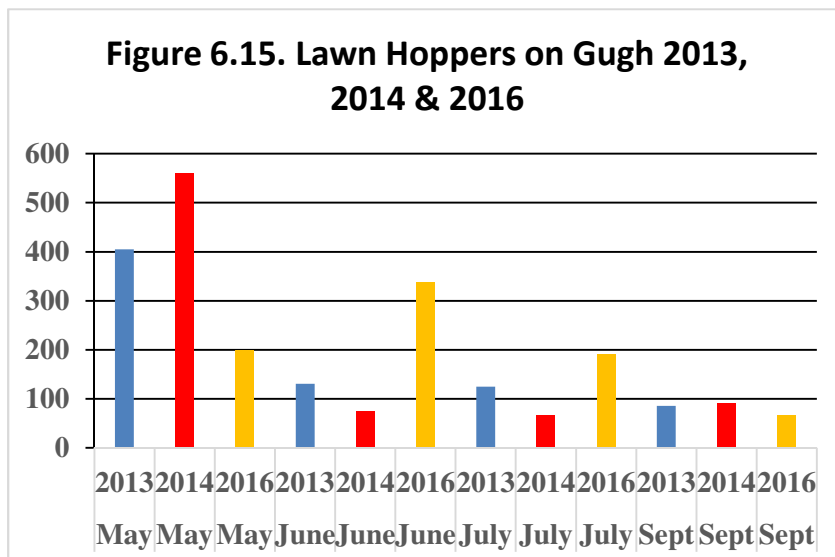
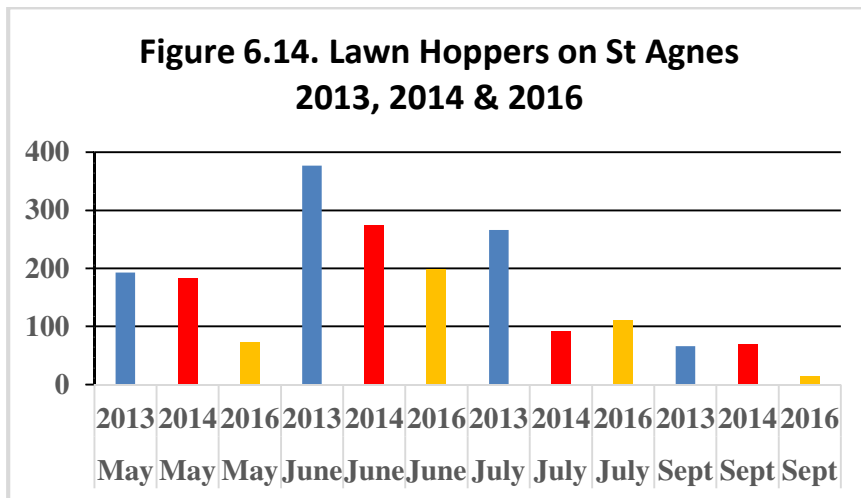
	heath	scrub	Coastal grassland	foreshore	total
<b>2013</b>	68	170	253	1	492
<b>2014</b>	133	82	424	285	924
<b>2016</b>	127	387	163	28	705
<b>totals</b>	<b>328</b>	<b>639</b>	<b>840</b>	<b>314</b>	<b>2121</b>

increased significantly in all habitats over the survey period.

There is no clear trend in numbers of Lawnhoppers on Bryher over the years (Fig 6.16; Table 6.11). Numbers of shrews on Bryher have decreased since 2013, although this may partly be due to the loss of foreshore in 2014. Comparisons are made between the numbers of Lawn Hopper and the numbers shrews in Chapter 2. It is too early to say whether there is any causal relationship between numbers of shrews and Lawn Hoppers.

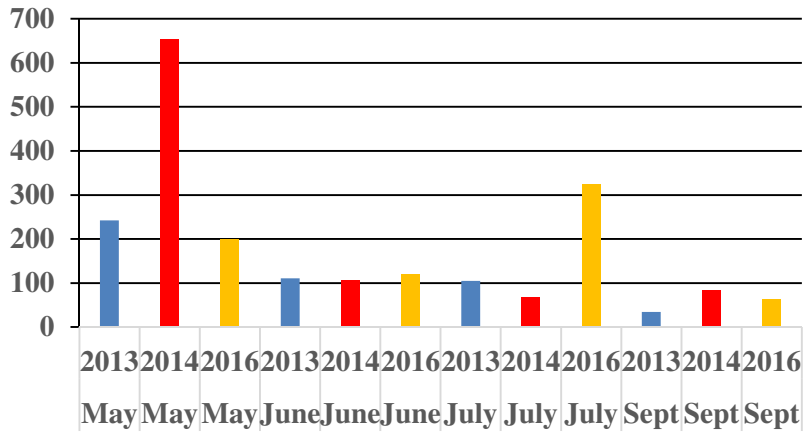
**Table 6.15. Lawn Hoppers at St Agnes 2013, 2014, 2016**

	heath	scrub	Coastal grassland	foreshore	total
<b>2013</b>	250	136	517	0	903
<b>2014</b>	161	61	387	11	620
<b>2016</b>	326	52	16	5	399
<b>totals</b>	<b>737</b>	<b>249</b>	<b>920</b>	<b>16</b>	<b>1922</b>

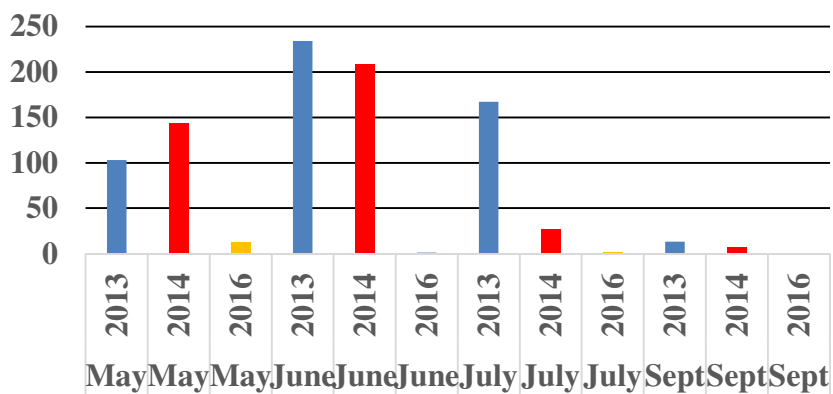




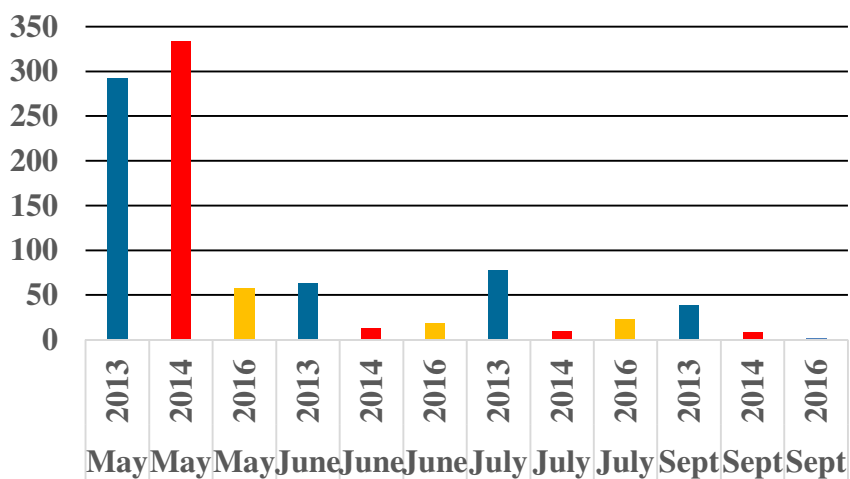
**Figure 6.16. Lawn Hoppers on Bryher  
2013, 2014 & 2016**



**Figure 6.17. Lawn Hoppers in coastal  
grassland on St Agnes 2013, 2014 & 2016**



**Figure 6.18. Lawn Hoppers in Coastal  
Grassland on Gugh 2013, 2014 & 2016**



### Sandhoppers *Talitrus saltator*

The Sandhopper is found abundantly on the beaches of Scilly. They can be found beneath debris washed up on the shore or buried during the day within the sand. They emerge at night (and can be attracted to lights) to feed on rotting seaweed. Their daily activity pattern is strongly linked to the tides, and they migrate up and down the beach, following the falling tides. They are an important food source for shore birds, Scilly Shrews and rats. They were not counted individually in 2013 as the pitfall traps were completely full to overflowing but were counted in 2014 and 2016, when only 10 pitfall traps were used instead of 40. This means that comparisons could not be made between 2013 and 2014 as we would be comparing the carrying capacity of the traps for Sandhoppers in 2013 with actual counts in 2014. Comparisons have been made between 2014 and 2016. In 2014 foreshore habitat had been severely affected by winter storms, especially on Gugh and Bryher, so that sandhopper numbers were probably much lower than normal.



On St Agnes total numbers went up from 7020 in 2014 to 10716 in 2016, a 400% increase. On Gugh, total numbers increased dramatically from 53 in 2014 to 2310 in 2016. On

**Table 6.16. Sandhoppers on St Agnes, Gugh and Bryher 2013, 2014, 2016**

	May 2014	May 2016	June 2014	June 2016	July 2014	July 2016	Sept 2014	Sept 2016
<b>St Agnes</b>	3000	4855	217	3560	94	1	3709	2300
<b>Gugh</b>	50	62	2	2200	0	2	1	46
<b>Bryher</b>	3180	186	317	3385	40	396	1410	5600

Bryher, total numbers almost doubled from 4947 in 2014 to 9567 in 2016. The increase across all three islands indicates that the change in numbers is not solely due to rat removal from St Agnes and Gugh, as otherwise numbers on Bryher would not have increased as well.

### Millipedes and centipedes

**Table 6.17. Millipedes 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	129	132	159
2014	189	171	140
2016	67	176	260

**Table 6.18. Centipedes 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	84	42	32
2014	53	53	25
2016	10	10	38

These were found in low but regular numbers in all sampled habitats. Overall, numbers of millipedes went up between 2013 (129) and 2014 (189) but down in 2016 (67) on St Agnes, but steadily up on Gugh (132 to 171 to 176). On Bryher numbers went down, then up (159 to 140 to 260). The pattern is hard to attribute to rat removal as we would expect millipede numbers to fall as shrew numbers increase (shrews feed on millipedes). The number of centipedes was generally very low.

Five species of centipede and three species of millipede were identified (Table 6.19). All are generally common and widespread on Scilly.

**Table 6.19. Centipedes and Millipedes on St Agnes, Gugh and Bryher 2016**

	Name	St. Agnes	Gugh	Bryher
Centipede	<i>Schendyla nemorensis</i>	x		x
Centipede	<i>Strigamia maritima</i>	x		
Centipede	<i>Geophilus carpophagus</i> sl		x	
Centipede	<i>Lithobius melanops</i>		x	x
Centipede	<i>Lithobius variegatus</i>	x	x	x
Millipede	<i>Proteroiulus fuscus</i>	x	x	x
Millipede	<i>Cylindroiulus latestriatus</i>	x	x	x
Millipede	<i>Cylindroiulus punctatus</i>	x		

**Mites**

**Table 6.20. Mites 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	433	129	282
2014	278	499	608
2016	279	215	834

These can be distinguished by having 8 legs. The majority recorded here were red but a large proportion



were dark brown/black. They are plant pests and parasitic on animals. The mites of Scilly are well recorded (Hyatt, 1993).

Overall, numbers of mites went down between 2013 (433) and 2014 (278) and up slightly in 2016 (297) on St Agnes but up on Gugh at first (129 to 499) and then down in 2016 (215). The pattern on Bryher was different and number continued to rise (282 to 608 to 834). The pattern cannot be attributed to rat removal as otherwise trends on St Agnes and Gugh would be the same.

**Woodlice**

**Table 6.21. Woodlice 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	3288	11719	6251
2014	5756	29379	17117
2016	3390	20169	42498

Woodlice are well known to everyone and are very distinctive. Being hard-bodied they



preserve well in the pitfall traps. Overall, numbers of woodlice went up on all islands between 2013 and 2014: 3288 to 5756 on St Agnes, 11719 to 29376 on Gugh and 9831 to 17117 on Bryher. However in 2016 numbers were down on both St Agnes (3390) and Gugh (20169) compared to Bryher, where numbers went up to 42498. Longer term trends between 2013 and 2016 showed increased on both Gugh and Bryher and stable numbers on St Agnes, so it would be difficult to attribute any changes to rat removal.

## Ants

**Table 6.22. Red Ants 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	694	1973	1539
2014	1149	1854	738
2016	2317	5258	14671

Ants are well known to everyone and are very distinctive. For the purpose of these surveys, they were



divided into red and black ants; the Yellow Meadow Ant *Lasius flavus* was grouped with the red ants.

**Table 6.23. Black Ants 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	5	18	63
2014	676	5481	1083
2016	117	294	384

There were major differences in 2013, 2014 and 2016 between the number of black and red ants found. On St Agnes numbers of red ants nearly doubled each year, increasing from 694 to 1149 to 2317. Black ants increased then decreased (5 to 676 to 117). Results from Gugh and Bryher were similar, with red ants decreasing and then increasing, whereas black ants increased and then decreased.

The pattern cannot be attributed to rat removal as otherwise trends on St Agnes and Gugh would be the same. The increase in the number of black ants in 2014 may be attributed the exceptionally wet weather; black ants (depending on the particular species) generally do better in cooler damper conditions and in longer ranker vegetation.

## Spiders

Spiders were one of the largest groups and likely to form part of the diet of rats. Overall, numbers of spiders went up on Gugh and Bryher between 2013 and 2016 (937 to 1105 to 1252 on Gugh and 797 to 1823 to 2153 on Bryher). However on St Agnes numbers went up then down (1232 to 1899 to 1225).



**Table 6.24. Spiders 2013, 2014, 2016**

	St Agnes	Gugh	Bryher
2013	1232	937	797
2014	1899	1105	1823
2016	1225	1252	2153

The pattern cannot be attributed solely to rat removal as otherwise trends on St Agnes and Gugh would be different from those on Bryher.

33 species were identified in 2016 by Dr Peter Smithers (Table 6.25). These included the first record for Gugh of the Red Data Book species *Clubiona genevensis* (which has previously been found on St Mary's, Bryher, Arthur, Samson and Ganilly) and the first records for Scilly of three species: the nationally scarce spider *Pardosa agrestis*, *Argenna subnigra* and *Silometopus ambiguus*. The common spider *Dysdera crocata* feeds primarily on woodlice, of which there are huge numbers on Scilly. All of the other species are widespread in the UK.

Species	Family	Bryher	Gugh	St Agnes
<i>Clubiona genevensis</i>	Clubionidae		✓	
<i>Dysdera crocata</i>	Dysderidae	✓	✓	
<i>Harpactea hombergii</i>	Dysderidae		✓	
<i>Drassodes lapidosus</i>	Gnaphosidae			✓
<i>Haplodrassus</i> sp.	Gnaphosidae			✓
<i>Micaria pulicaria</i>	Gnaphosidae	✓		
<i>Zelotes latreillei</i>	Gnaphosidae			✓
<i>Zelotes pusillus</i>	Gnaphosidae	✓		
<i>Agroeca</i> sp.	Liocranidae		✓	
<i>Phrurolithus festivus</i>	Liocranidae		✓	
<i>Pardosa agrestis</i>	Lycosidae		✓	✓
<i>Pardosa nigriceps</i>	Lycosidae		✓	✓
<i>Pardosa pullata</i>	Lycosidae		✓	✓
<i>Pardosa palustris</i>	Lycosidae			✓
<i>Trochosa ruricola</i>	Lycosidae		✓	✓
<i>Trochosa terricola</i>	Lycosidae	✓	✓	✓
<i>Argena subnigra</i>	Dictynidae			✓
<i>Centromerita concina</i>	Lynyphiidae		✓	
<i>Ceratinella brevipes</i>	Lynyphiidae		✓	✓
<i>Lepthyphantes tenuis</i>	Lynyphiidae		✓	
<i>Oedothorax fuscus</i>	Lynyphiidae			✓
<i>Peponocranium ludicrum</i>	Lynyphiidae		✓	✓
<i>Silometopus ambiguus</i>	Lynyphiidae		✓	
<i>Tiso vagans</i>	Lynyphiidae		✓	✓
<i>Walckenaeria atrotibialis</i>	Lynyphiidae		✓	
<i>Walckenaeria antica</i>	Lynyphiidae		✓	✓
<i>Walckenaeria nudipalpis</i>	Lynyphiidae		✓	
<i>Ero fulcrata</i>	Mimetidae		✓	
<i>Euophrys frontalis</i>	Salticidae	✓		
<i>Pachygnatha clerki</i>	Tetragnathidae			✓
<i>Pachygnatha degeri</i>	Tetragnathidae		✓	✓
<i>Xysticus cristatus</i>	Thomisidae		✓	
<i>Zora</i> sp.	Zorinae			✓
<b>Total species</b>	<b>33</b>	<b>5</b>	<b>22</b>	<b>18</b>

## Slugs

	St Agnes	Gugh	Bryher
2013	39	21	138
2014	66	3	4
2016	86	23	35

Slugs are easily identified and form one of the foods eaten by rats. They are unlikely to be eaten by shrews. The number of slugs on St Agnes increased from 39 in 2013 to 66 in 2014 to 86. Trends on Gugh and Bryher were similar. On Gugh numbers on declined from 21 in 2013 to 3 in 2014 then up to 23 in 2016; numbers on Bryher declined in this period from 138 to 4 then up to 35. Large numbers of slugs were found to have been poisoned during the rat baiting programme and were removed to avoid the risk of secondary

poisoning. However, the number of slugs increased on St Agnes so there was no obvious effect from poison; numbers declined and then increased on both Gugh and Bryher so this pattern cannot be attributed to poisoning as otherwise trends on Bryher and Gugh would be the different.

### Lesser Cockroach

Lesser Cockroach was found in greater numbers in 2016, especially in coastal grassland in Gugh. However, numbers went up on Bryher as well so this is unlikely to have anything to do with rat removal.

	St Agnes	Gugh	Bryher
<b>2013</b>	0	0	0
<b>2014</b>	7	2	0
<b>2016</b>	5	29	17
	<b>12</b>	<b>31</b>	<b>17</b>

### 6.4.2. Results: St Agnes

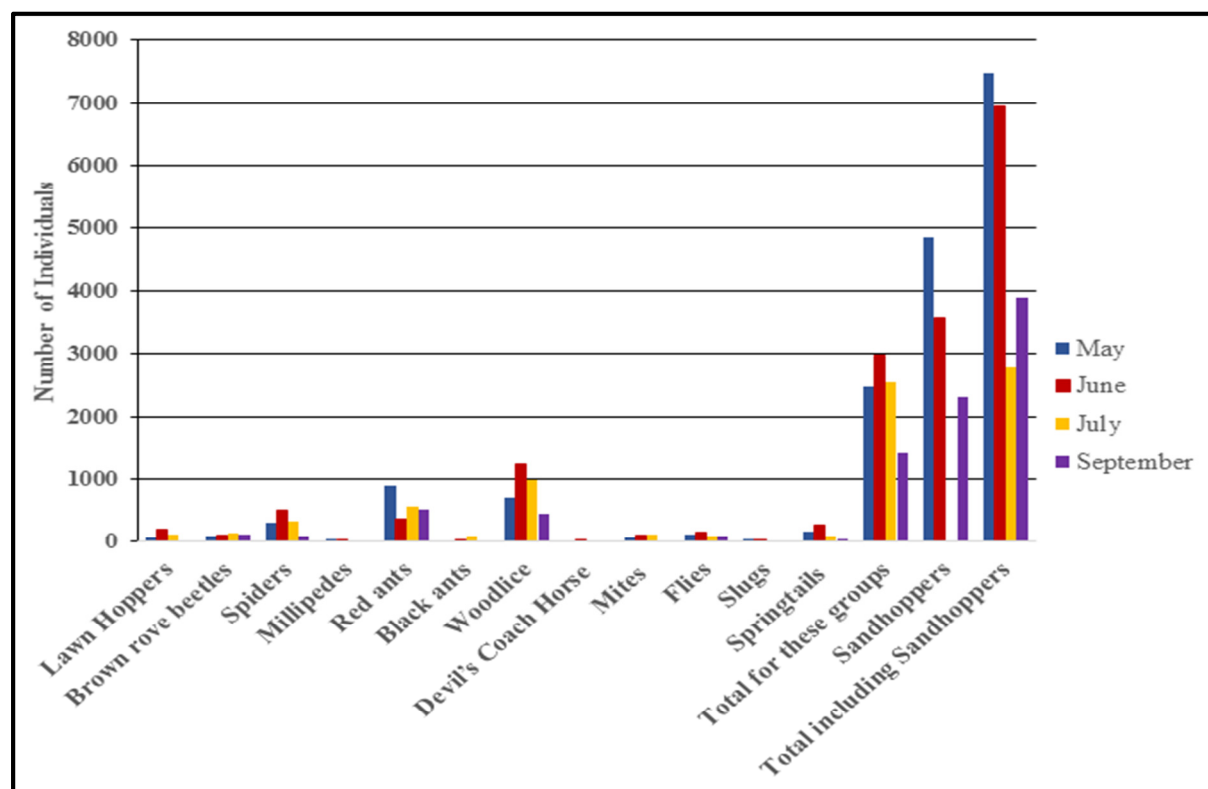
The key species on St Agnes are listed in Table 6.15. Woodlice were the most abundant invertebrates in 2016 followed by ants, spiders and brown rove beetles. There were seasonal differences, with numbers generally peaking in June and declining in July and September (Figure 6.19), as in 2014. Seasonal differences were pronounced in mites (with a large increase in numbers in July) and the Devil's Coach Horse (with a large increase in numbers in September), as in 2013.

**Table 6.28: Total numbers for key species/species groups on St Agnes**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	193	183	73	377	275	199	266	92	112	66	70	15
<b>Brown rove beetles</b>	44	170	96	234	132	103	95	166	141	61	326	122
<b>Spiders</b>	510	670	306	376	647	500	250	301	324	96	281	95
<b>Millipedes</b>	39	66	35	44	20	13	30	87	14	16	16	5
<b>Red ants</b>	116	25	885	320	247	356	109	683	554	149	194	522
<b>Black ants</b>	5	489	5	0	53	16	0	2	92	0	132	4
<b>Woodlice</b>	524	1305	699	1481	1770	1246	874	1768	993	409	913	452
<b>Devil's Coach Horse</b>	0	0	0	2	11	3	14	12	4	246	38	14
<b>Mites</b>	6	29	61	36	66	96	370	118	109	21	65	31
<b>Flies</b>	11	24	126	98	56	142	36	82	87	30	196	84
<b>Slugs</b>	4	3	37	25	25	21	10	17	6	0	21	22
<b>Springtails</b>	0	385	160	0	62	281	18	10	100	49	24	40
<b>Total for these groups</b>	1452	3349	2483	2993	3364	2976	2072	3338	2536	1143	2276	1406
<b>Total no of invertebrates ex S/H</b>	1554	6476	2618	3192	3844	3374	2217	3518	2782	1232	6121	1594
<b>Sandhoppers</b>	-	3000	4855	-	217	3560	-	94	1	-	3709	2300
<b>Total incl Sandhoppers</b>	-	9476	7473	-	4061	6934	-	3612	2783	-	9830	3894

Note: Sandhoppers were not counted in 2013

**Figure 6.19. Key species and species groups on St Agnes May to September**



#### 6.4.2.1. Heathland (St Agnes)

The most abundant species in the heathland in 2016 were ants, with woodlice being proportionately less common than in the other habitats (Table 6.16). There were large numbers of Devil's Coach Horse.

**Table 6.29: Total numbers for key species/species groups in heathland on St Agnes**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
Lawn Hoppers	48	26	44	94	39	172	63	53	99	45	43	11
Brown rove beetles	2	16	15	45	84	34	25	64	70	14	213	62
Spiders	175	210	93	151	183	144	63	178	141	23	156	32
Millipedes	4	8	7	13	3	4	11	2	3	4	3	1
Red ants	2	0	89	42	33	73	28	106	195	30	47	287
Black ants	0	73	0	0	6	0	0	0	0	0	126	0
Woodlice	20	106	133	121	120	80	111	76	37	56	174	67
Devil's Coach Horse	0	1	0	0	0	3	5	8	3	152	31	7
Mites	4	13	10	16	19	25	13	6	31	1	24	6
Flies	2	5	21	11	10	8	23	5	27	5	66	13
Slugs	0	0	30	0	1	13	0	0	0	0	0	0
Springtails	0	52	28	0	23	37	7	4	25	22	18	14
Total no of invertebrates	276	538	492	535	609	672	415	535	706	366	960	529



#### 6.4.2.2. Scrub (St Agnes)

The most abundant species in the scrub in 2016, as in 2013 and 2014, were woodlice, with red ants, spiders and the brown rove beetle also abundant (Table 6.17).

**Table 6.30: Total numbers for key species/species groups in scrub on St Agnes**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
Lawn Hoppers	43	7	13	49	25	24	36	12	11	8	17	4
Brown rove beetles	34	154	62	189	47	64	68	102	68	47	113	57
Spiders	121	155	125	78	169	164	46	55	73	44	53	33
Millipedes	31	55	23	15	15	8	5	60	10	3	9	4
Red ants	113	0	767	221	198	244	48	526	355	117	131	213
Black ants	0	404	0	0	23	16	0	2	92	0	6	4
Woodlice	399	1081	405	1090	1293	1012	550	1521	748	299	609	326
Devil's Coach Horse	0	0	0	2	11	0	5	4	0	34	1	2
Mites	0	1	22	2	13	55	17	45	42	5	32	9
Flies	4	7	52	67	21	32	8	13	30	4	39	1
Slugs	4	3	6	23	23	8	5	17	6	0	21	22
Springtails	0	37	49	0	38	2	0	5	50	5	6	21
Total no of invertebrates	777	1957	1595	1807	1982	1747	826	2389	1545	623	1086	743

#### 6.4.2.3. Coastal grassland (St Agnes)

The most abundant species in the coastal grassland in 2016, as in 2013, were woodlice and spiders (Table 6.18). Lawn Hopper numbers had declined noticeably in 2016. There were very few brown rove beetles. There were large numbers of springtails in May.

**Table 6.31: Total numbers for key species/species groups in coastal grassland on St Agnes**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
Lawn Hoppers	103	144	13	234	209	1	167	27	2	13	7	0
Brown rove beetles	5	0	19	0	1	3	2	0	2	0	0	1
Spiders	174	292	72	123	277	181	132	67	107	29	68	26
Millipedes	4	3	5	14	2	1	14	25	1	9	4	0
Red ants	1	25	29	52	16	13	13	25	3	2	16	12
Black Ants	5	10	0	0	5	0	0	0	0	0	0	0
Woodlice	102	118	131	262	330	154	212	161	204	54	123	59
Devil's Coach Horse	0	1	0	0	0	0	3	0	1	60	5	5
Mites	2	15	29	18	26	16	340	67	36	15	9	12
Flies	1	7	52	9	11	21	5	21	27	2	13	8
Slugs	0	0	1	2	1	0	5	0	0	0	0	0
Springtails	0	296	83	0	0	188	4	1	25	0	0	0
Total no of invertebrates	425	954	509	775	931	870	954	419	510	221	268	217

#### 6.4.2.4. Foreshore (St Agnes)

The fauna of the foreshore was dominated by sandhoppers (Table 6.19). Spiders and flies were the most abundant other species present. For comparison purposes with 2013, the results need to be divided by 4 as in 2014 and 2016 only 10 pitfall traps were set out compared with 40 in 2013.

**Table 6.32: Total numbers for key species/species groups on the foreshore on St Agnes**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>S/hoppers</b>	1000 <sup>2</sup>	3000	4849	1000 <sup>2</sup>	217	3555	1000 <sup>2</sup>	94	1	1000 <sup>2</sup>	3709	2300
<b>Lawn Hoppers</b>	0	6	3	0	2	2	0	0	0	0	3	0
<b>Black Marram Weevil</b>	0	0	0	1	0	0	1	0	0	0	0	0
<b>Darkling Beetle</b>	0	0	0	0	1	0	0	0	0	0	0	0
<b>Spiders</b>	40	13	16	24	18	11	9	1	3	0	4	4
<b>Flies</b>	4	5	1	11	14	41	0	43	3	19	78	62
<b>Woodlice</b>	3	0	0	8	27	0	1	10	4	0	7	0

<sup>2</sup> estimated numbers

#### 6.4.3. Results: Gugh

The key species on Gugh are listed in Table 6.20. There were exceptionally large numbers of woodlice present here, with over 11000 in the pitfall traps in May and June. There were seasonal differences, with numbers peaking in May and declining steadily through June, July and September (Figure 6.20); the same pattern was observed in 2013. There were large numbers of ants, spiders and brown rove beetles.

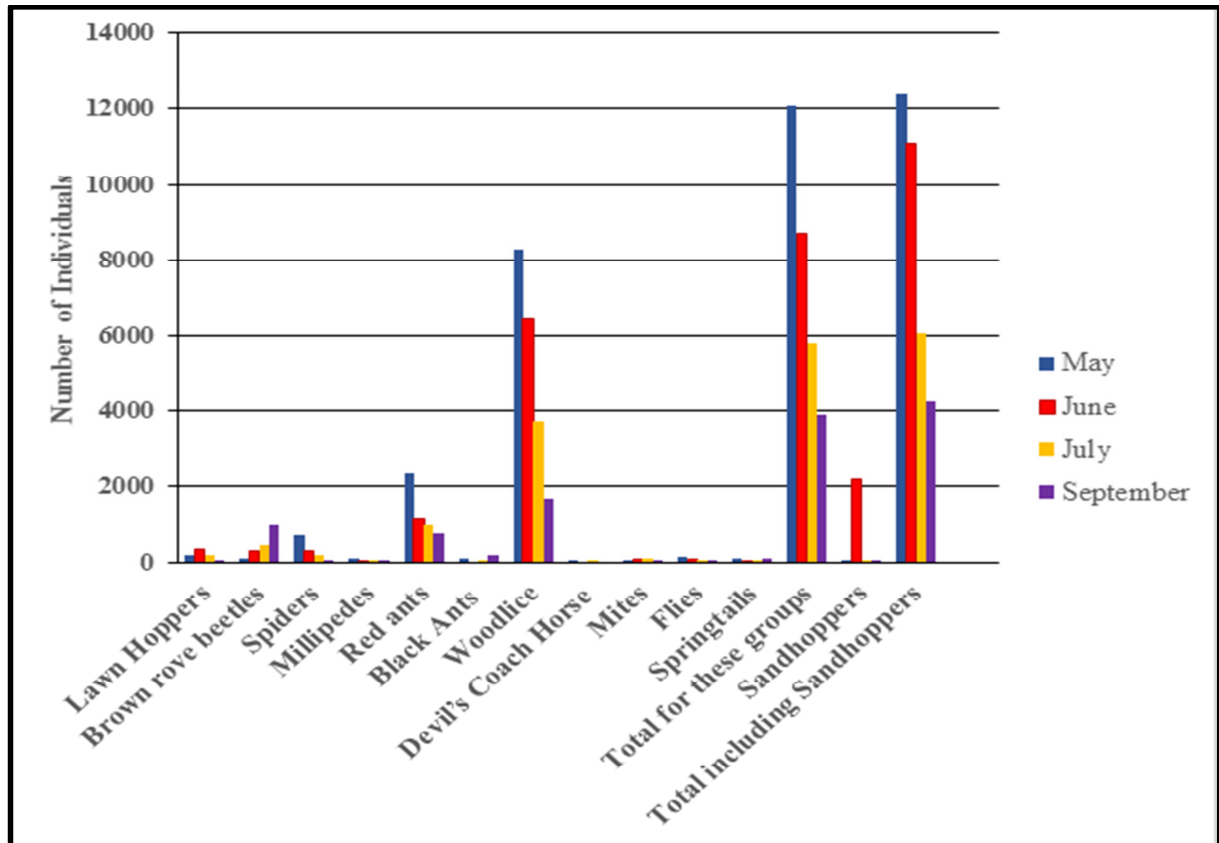
**Table 6.33: Total numbers for key species/species groups on Gugh (excluding sandhoppers)**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	405	560	200	131	75	338	125	67	190	86	91	66
<b>Brown rove beetles</b>	39	71	110	266	296	275	122	434	444	98	181	977
<b>Spiders</b>	390	375	697	316	324	298	171	293	193	60	113	64
<b>Millipedes</b>	41	98	84	46	22	22	26	34	43	19	17	27
<b>Red ants</b>	533	15	2364	595	209	1145	412	1042	994	433	588	755
<b>Black Ants</b>	73	1951	78	2	2074	0	14	1451	32	2	5	184
<b>Woodlice</b>	5817	11046	8295	2420	11397	6461	1776	4797	3720	1706	2139	1693
<b>Devil's Coach Horse</b>	0	0	1	2	0	0	17	1	3	24	4	0
<b>Mites</b>	3	37	52	23	222	66	80	169	84	19	71	13
<b>Flies</b>	14	12	150	96	26	74	46	41	58	56	1138	32
<b>Springtails</b>	0	235	75	0	13	34	5	3	59	25	32	70
<b>Total for these groups</b>	7225	14400	12106	3776	14658	8713	2649	8332	5820	2426	4379	3881
<b>Total no of</b>	7430	14572	12313	4159	14754	8885	2913	8520	6079	2666	4543	4209

<b>invertebrates ex S/H</b>												
<b>Sandhoppers</b>	-	50	62	-	2	2200	-	0	2	-	1	46
<b>Total incl Sandhoppers</b>	-	14622	12375	-	14756	11085	-	8520	6081	-	4543	4255

Note: Sandhoppers were not counted in 2013

**Figure 6.20. Key species and species groups on Gugh May to September**



**6.4.3.1. Heathland (Gugh)**

The most abundant species in the heathland were woodlice, with numbers peaking in June and declining to September (Table 6211). There were large numbers of red ants but no black ants.

**Table 6.34: Total numbers for key species/species groups in heathland on Gugh**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	33	69	81	12	20	68	7	14	105	15	32	6
<b>Brown rove beetles</b>	7	33	22	47	155	81	36	69	125	28	41	198
<b>Spiders</b>	255	116	222	108	106	96	68	96	47	24	53	31
<b>Millipedes</b>	17	12	43	2	13	15	8	11	28	6	6	11
<b>Red ants</b>	522	0	1378	434	162	992	351	780	758	383	385	406
<b>Black Ants</b>	0	1637	0	0	1810	0	2	1	0	0	0	0
<b>Woodlice</b>	1232	1575	1511	715	2455	2563	630	1133	1782	282	298	223
<b>Devil's Coach Horse</b>	0	0	0	0	0	0	1	1	1	0	3	0
<b>Flies</b>	2	2	24	3	4	10	9	1	11	6	714	2
<b>Total no of invertebrates</b>	2073	3686	3369	1340	4759	3896	1121	2123	2918	785	1602	1393

#### 6.4.3.2. Scrub (Gugh)

The most abundant species in the scrub were woodlice, with ants, spiders and the brown rove beetle also abundant (Table 6.22).

**Table 6.35: Total numbers for key species/species groups in scrub on Gugh**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	76	158	46	20	42	181	40	44	60	32	51	58
<b>Brown rove beetles</b>	28	33	74	186	138	185	79	362	312	62	138	748
<b>Spiders</b>	42	142	267	86	104	112	51	92	63	15	26	13
<b>Millipedes</b>	15	17	10	9	6	4	4	6	0	5	6	3
<b>Red ants</b>	11	7	741	147	47	66	52	188	97	0	195	314
<b>Black ants</b>	7	131	0	1	96	0	5	774	32	2	0	181
<b>Woodlice</b>	2408	5560	1832	820	5400	1764	630	1891	556	1070	1032	300
<b>Flies</b>	3	4	31	85	5	27	22	8	19	5	394	6
<b>Total no of invertebrates</b>	6060	6125	3094	1389	5878	2422	936	3467	1268	1280	1941	1813

#### 6.4.3.3. Coastal grassland (Gugh)

The most abundant species in the coastal grassland were woodlice, spiders, ants and mites (Table 6.23). Lawn Hopper numbers had declined noticeably since 2014.

**Table 6.36: Totals numbers for key species/species groups in coastal grassland on Gugh**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	292	333	58	63	13	18	78	9	23	39	8	2
<b>Brown rove beetles</b>	3	5	10	31	1	9	7	3	6	8	1	31
<b>Spiders</b>	76	113	199	41	87	79	41	96	54	21	32	19
<b>Millipedes</b>	9	56	31	31	4	2	14	17	12	8	5	12
<b>Mites</b>	0	28	6	13	220	39	65	157	60	10	38	6
<b>Red ants</b>	0	8	245	14	0	73	7	60	134	31	5	35
<b>Black ants</b>	63	167	78	1	112	20	7	676	0	0	4	3
<b>Woodlice</b>	2165	3900	4945	831	3499	2113	510	1767	1380	350	763	693
<b>Total no of invertebrates</b>	2642	4657	5821	1093	3960	2431	785	2848	1836	556	914	882

#### 6.4.3.4. Foreshore (Gugh)

Sandhopper numbers had declined dramatically in 2014, even though the habitats looked relatively unchanged, but they were abundant in June 2106 (Table 6.24). Woodlice, spiders and flies were the most abundant other species present. For comparison purposes with 2013, the results need to be divided by 4 as in 2014 and 2016 only 10 pitfall traps were set out compared with 40 in 2013.

**Table 6.37: Total numbers for key species/species groups on the foreshore on Gugh**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Sandhopper</b>	1000 <sub>2</sub>	50	20	1000 <sub>2</sub>	2	2200	1000 <sub>2</sub>	0	0	1000 <sup>2</sup>	1	0
<b>Lawn Hoppers</b>	3	0	15	36	0	71	0	0	2	0	0	0
<b>Black Marram Weevil</b>	41	0	2	41	0	2	22	0	0	5	0	0
<b>Darkling Beetle</b>	24	0	0	8	0	0	0	0	1	4	1	2
<b>Brown Beetle</b>	0	0	0	96	0	0	0	2	0	0	5	0
<b>Spiders</b>	17	4	9	81	27	11	11	9	29	0	2	1
<b>Flies</b>	9	0	6	3	13	7	9	26	7	30	5	6
<b>Woodlice</b>	13	11	7	54	43	21	6	6	2	4	46	5

<sup>2</sup> estimated numbers

#### 6.4.4. Results: Bryher

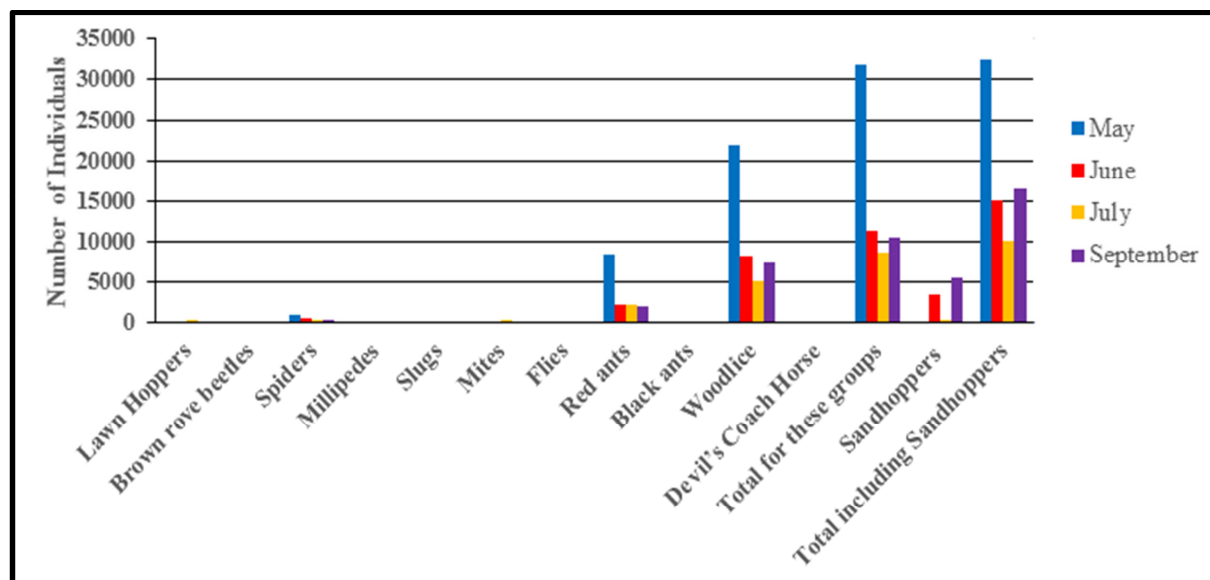
The key species on Bryher are listed in Table 6.25. Woodlice were the most abundant invertebrates in the terrestrial habitats followed by ants, spiders and Lawn Hoppers, as in 2013 and 2014. There were seasonal differences, with numbers peaking in May and steadily declining in June and July before rising in September (Figs 6.21, 6.22). Seasonal differences were pronounced in Lawn Hoppers and black ants.

**Table 6.38: Total numbers for key species/species groups on Bryher**

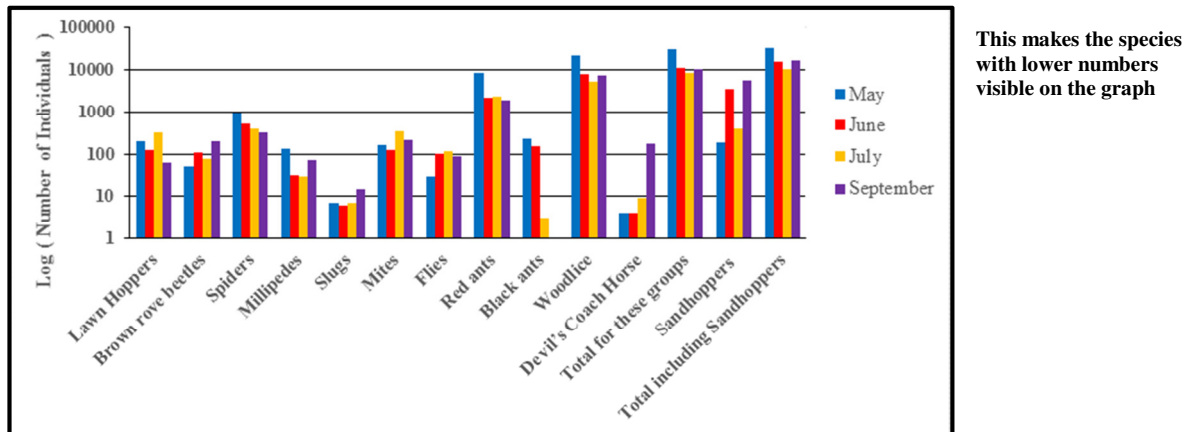
	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	242	654	198	111	106	120	105	66	324	34	82	63
<b>Brown rove beetles</b>	32	60	50	142	49	107	22	48	75	16	12	204
<b>Spiders</b>	232	680	950	306	600	511	167	390	382	92	153	310
<b>Millipedes</b>	26	30	128	77	9	32	21	26	30	35	75	70
<b>Slugs</b>	28	1	7	44	3	6	42	0	7	24	0	15
<b>Mites</b>	18	54	158	46	295	127	146	113	338	72	146	211
<b>Flies</b>	13	18	29	16	31	98	88	11	114	30	49	86
<b>Red ants</b>	281	128	8319	499	296	2115	411	213	2295	348	101	1942
<b>Black ants</b>	47	708	225	6	200	156	6	139	3	4	36	0
<b>Woodlice</b>	1990	4363	21861	1862	3580	8136	1338	5171	5075	1061	4003	7426
<b>Devil's Coach Horse</b>	2	3	4	1	5	4	10	4	9	135	138	177
<b>Total for these groups</b>	2805	6699	31929	3104	5174	11412	2350	6181	8652	1847	4795	10504
<b>Total no of invertebrates ex S/H</b>	2940	10119	32223	3315	5641	11722	2453	6370	9727	1941	6367	10891
<b>Sandhoppers</b>	-	3180	186	-	317	3385	-	40	396	-	1410	5600
<b>Total inc Sandhoppers</b>	-	13299	32409	-	5958	15107	-	6410	10123	-	7777	16491

Note: Sandhoppers were not counted in 2013

**Figure 6.21. Key species and species groups on Bryher May to September**



**Figure 6.22. Key species and species groups on Bryher May to September, adjusted to log scale**



#### 6.4.4.1. Heathland (Bryher)

The most abundant species in the heathland were woodlice (although proportionately less common than in the other habitats), spiders and mites (Table 6.26).

**Table 6.39: Total numbers for key species/species groups in heathland on Bryher**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Lawn Hoppers</b>	53	38	53	10	17	34	2	38	25	3	40	15
<b>Brown rove beetles</b>	3	15	2	8	9	0	0	10	2	0	0	50
<b>Spiders</b>	85	149	279	93	81	194	69	138	149	22	60	128
<b>Millipedes</b>	2	4	37	28	5	4	16	12	11	10	69	25
<b>Mites</b>	5	11	76	30	28	43	45	35	25	11	52	73
<b>Red ants</b>	23	16	29	70	3	10	18	12	5	6	23	122
<b>Black ants</b>	0	0	9	1	2	18	1	1	1	1	1	0
<b>Woodlice</b>	231	634	1271	378	416	451	216	614	205	217	540	1248
<b>Devil's Coach Horse</b>	1	2	1	1	0	0	2	0	2	25	35	83
<b>Total no of invertebrates</b>	430	954	1942	658	603	1058	441	909	591	322	864	1913

#### 6.4.4.2. Scrub (Bryher)

The most abundant species in the scrub were woodlice, with large numbers of red ants (Table 6.27).



**Table 6.40: Total numbers for key species/species groups in scrub on Bryher**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
Lawn Hoppers	46	38	58	20	12	30	89	11	267	15	21	32
Brown rove beetles	24	34	7	125	20	41	11	38	41	14	11	104
Spiders	61	206	163	63	100	92	38	61	82	25	29	54
Millipedes	12	22	60	13	3	20	3	13	15	9	4	20
Mites	15	40	73	16	28	41	81	59	124	9	68	65
Red ants	182	104	7775	358	0	1763	311	199	1795	232	38	1698
Black ants	4	452	0	2	62	0	1	10	2	0	15	0
Woodlice	849	1654	14230	898	1709	6541	680	2677	2940	620	2807	4928
Devil's Coach Horse	1	0	1	0	2	0	4	1	2	57	26	11
Total no of invertebrates	1190	2634	22398	1546	1976	8638	1257	3095	6182	1106	3064	5644

1 adjusted for 3 nights

#### 6.4.4.3. Coastal grassland (Bryher)

The most abundant species in the coastal grassland were woodlice, spiders and ants, as in 2013 and 2014 (although black ants decreased and red ants increased in 2016) (Table 6.28). Lawn Hopper numbers had declined noticeably by September. The predatory Devil's Coach Horse was abundant in September in all years. No slugs were recorded in 2014, although they were common in 2013 and increased in 2016.

**Table 6.41: Total numbers for key species/species groups in coastal grassland on Bryher**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
Lawn Hoppers	143	344	60	80	55	56	14	12	32	16	13	15
Brown rove beetles	5	9	41	9	19	64	6	0	32	2	1	50
Spiders	84	312	507	85	366	221	52	170	115	43	56	128
Millipedes	10	4	31	26	1	7	2	1	4	16	2	25
Mites	0	3	9	0	237	36	20	18	186	9	26	73
Red ants	76	8	515	70	293	337	82	0	489	19	40	122
Black ants	43	256	216	3	134	138	1	128	0	1	18	0
Woodlice	911	1985	6360	569	1402	1135	425	1836	1925	223	633	1248
Slugs	27	0	7	43	0	5	41	0	7	24	0	7
Devil's Coach Horse	0	1	2	0	3	4	4	3	5	53	77	83
Total no of invertebrates	1247	2994	7827	926	2571	2153	679	2208	2884	454	980	1913

#### 6.4.4.4. Foreshore (Bryher)

The fauna of the foreshore was dominated by sandhoppers in all years, although numbers were lower in 2016 until September (Table 6.29). The foreshore transect on Bryher was heavily affected by winter storms so that the numbers recorded in 2014 were likely to reflect loss of foreshore habitat; by 2016 the Marram Weevil appeared to have disappeared completely. Lawn Hoppers were sparse.

**Table 6.42: Total numbers for key species/species groups on the foreshore on Bryher**

	May 2013	May 2014	May 2016	June 2013	June 2014	June 2016	July 2013	July 2014	July 2016	Sept 2013	Sept 2014	Sept 2016
<b>Sandhopper</b>	1000 <sup>2</sup>	3180	186	1000 <sup>2</sup>	317	3200	1000 <sup>2</sup>	40	396	1000 <sup>2</sup>	1410	5600
<b>Lawn Hoppers</b>	0	234	27	1	22	0	0	21	0	0	8	1
<b>Black Marram Weevil</b>	1	1	0	73	2	0	2	3	0	10	0	0
<b>Darkling Beetle</b>	3	0	0	0	0	1	5	0	0	3	0	0
<b>Brown Beetle</b>	1	2	0	3	0	0	0	0	0	0	0	0
<b>Spiders</b>	1	13	1	65	53	4	8	21	36	2	8	0
<b>Flies</b>	6	2	7	6	12	20	42	2	6	43	1	16
<b>Woodlice</b>	0	90	0	17	53	9	17	44	5	1	23	2

<sup>2</sup> estimated numbers

## 6.5. DISCUSSION

### 6.5.1. Variables

There are a number of different variables which may contribute to changes in the numbers of key invertebrate species and species groups. The distribution and abundance of invertebrates in a particular area depends on a range of factors, e.g. predator numbers, larval foodplant availability, nectar sources for flying insects, temperature and humidity regimes, habitat structure, plant architecture and phenology, topography, soil structure and chemistry. In particular, many invertebrates exhibit rapid responses to changes in climate, especially those species which have several generations per year. Changes in temperature may induce large fluctuations in the abundance of a particular species. Changes in humidity, especially during winter when many invertebrates are hibernating, may cause increased mortality levels. In addition, direct habitat loss may lead to smaller local populations and local extinctions.

The total number of invertebrates increased between 2013 and 2016. However, there was a decline in the total number of invertebrates on St Agnes and Gugh between 2014 and 2016, compared with an increase on Bryher. It is possible that this could be due to an increase in predation by shrews.

One of the possible effects of the rat removal was the increase in shrew numbers, which could cause a secondary effect on their prey of small invertebrates. Changes in the abundance of Lawn Hoppers on St Agnes might be due at least in part to changes in the abundance of shrews. There was little change in the abundance of Lawn Hoppers on Gugh despite a considerable increase in shrew activity, so here there seemed to be little casual connection between the abundance of these two species. The numbers of millipedes increased on St Agnes and Gugh even though shrew numbers increased; in fact, millipede numbers would be expected to fall as shrews feed on these species.

The larvae of the moth *Psyche casta* increased dramatically between 2013 and 2016. These case-bearing larvae are probably eaten by rats and the upward trend on St Agnes and Gugh may be due at least partly to rat removal; but the trend was also upwards on Bryher and this is difficult to explain. Shrews, which are insectivorous, are unlikely to eat these larvae as they are surrounded by grass stems as a form of camouflage and protection.

The numbers of Sandhoppers increased between 2014 and 2016. This may be due the partial recovery of the foreshore habitat after winter storms of 2013/2014, but also the absence of predation by rats. The increase in Sandhoppers across all three islands may obscure the effect of rat removal on Gugh and St Agnes.

The winter storms of early 2014 led to considerable loss of foreshore habitat. Numbers of the Black Marram Weevil and the Brown Beetle *Calathus mollis*, which are restricted to the foreshore, either remained roughly constant or declined on the three islands over the three years of sampling; this is unlikely to be a response to the removal of rats. The Darkling Beetle declined on Gugh and disappeared from Bryher directly due to loss of habitat.

The number of black ants decreased on all three islands between 2014 and 2016 but increased overall between 2013 and 2016. The species were not identified but are likely to be *Formica fusca* and/or *Lasius niger*. These ants are generally more likely than red ants to be found in longer ranker vegetation and generally do better in cooler damper conditions (depending on

the particular species). The increase in black ants may therefore be attributable at least partly to the exceptionally damp winter and spring of early 2014 and is unlikely to be a response to the removal of rats.

Other potential variables include changes in grazing by cattle and salt spray burn on vegetation. Salt spray burn is visible in the landscape photos taken on Gugh and Bryher in 2014. There was no grazing on Bryher after early 2014, when the ponies were taken off the island.

Rodenticides may have had an effect as large numbers of slugs were found to have been poisoned during the rat baiting programme and were removed to avoid the risk of secondary poisoning; however, the number of slugs increased on St Agnes despite poisoning. Numbers declined on both Gugh and Bryher between 2013 and 2016 and so this pattern cannot be attributed to poisoning as otherwise trends on Bryher and Gugh would be different.

### **6.5.2. The use of Bryher as a control**

The survey methodology on Gugh and St Agnes was repeated on Bryher so that trends in the numbers of key species and species groups here can be compared to trends on Gugh and St Agnes where rats have been removed. If trends are similar on Gugh and St Agnes, but different on Bryher, then it is possible that rat removal is one of the causes of the difference. If the trends are the same across all three islands, or if trends are different between St Agnes and Gugh, then it is more likely that trends are independent of rat removal.

No simple story emerges from the data. Broad trends between 2013 and 2014 were similar for St Agnes and Gugh but different for Bryher for the following species: brown rove beetles, Devil's Coach Horse, spiders, millipedes and springtails. Trends between 2014 and 2016 were similar for St Agnes and Gugh but different for Bryher for the following species: Black Marram Weevil, woodlice, mites and springtails; the total number of invertebrates went down on St Agnes and Gugh but up on Bryher over this period. However, between 2013 and 2016 trends were similar for St Agnes and Gugh but different for Bryher only for the Devil's Coach Horse and (less clearly) for the Lawn Hopper.

It is interesting to note that patterns between 2013 and 2016 were similar between Gugh and Bryher and dissimilar for St Agnes for six different groups (brown rove beetles, Black Marram Weevil, spiders, millipedes, woodlice and mites). The reasons for this are not clear, but for these species changes in abundance cannot be attributed solely to the removal of rats from St Agnes and Gugh

- Devil's Coach Horse - the decline in numbers on St Agnes and Gugh may be at least partly attributable to the removal of rats from these islands and possible increased predation by shrews. However, these beetles predate other invertebrates and might be expected to increase in numbers as the overall numbers of invertebrates increased. Numbers increased on Bryher.
- Brown rove beetles – these are very common and may have been an important food resource for rats. The increase in numbers in 2014 on St Agnes and Gugh may be at least partly attributable to the removal of rats from these islands. Numbers remained broadly stable on Bryher. However in 2016 numbers increased on Gugh and Bryher decreasing on St Agnes.

- Spiders – these are very common and may have been an important food resource for rats. Numbers on St Agnes remained broadly stable but increased on Gugh and Bryher between 2013 and 2016. Spiders might form an important food source for shrews.
- Millipedes – these are known to be predated by Scilly Shrews. In 2014 numbers increased on St Agnes and Gugh but remained broadly stable on Bryher but in 2016 numbers declined on St Agnes but increased on Gugh and Bryher. The pattern is hard to attribute to rat removal as shrew numbers increased in 2014 in which case millipede numbers would be expected to fall as shrews feed on these species.
- Springtails – the numbers recorded on St Agnes, Gugh and Bryher have considerably increased between 2013 and 2016. There is no obvious reason for this but it is known that springtails occasionally form huge swarms (a huge swarm in a road in Austria was once mistaken for a chemical spill). The pattern is difficult to attribute to rat removal.

Broad trends between 2013 and 2016 for St Agnes and Gugh are dissimilar for a range of species. These patterns cannot be easily attributed to rat removal as otherwise trends on St Agnes and Gugh would be likely to be same. Further monitoring may give greater credibility to these trends. The use of Bryher as a control indicates that changes in trends for the following species cannot be attributed directly to rat removal: *Psyche casta*, mites, woodlice, red ants, slugs and flies. The only species where there is a clear difference in trends between 2013 and 2016 are Devils' Coach Horse and (less clearly) Lawn Hopper. There was however a decline in the total number of invertebrates on St Agnes and Gugh between 2014 and 2016, compared with an increase on Bryher; this could be due to an increase in shrew numbers.

### 6.5.3. Discussion on Methodology

There are a range of methods for surveying invertebrates including pitfall traps, light traps, malaise traps and suction traps, and sweeping, beating, pond netting and netting of flying of insects, as well as searching on the ground, under stones, in leaf litter and in vegetation. Particular methods are suited to particular invertebrates. The easiest method for amateur volunteers is probably the transect method, e.g. for butterflies, but this method only samples small groups of insects and is unlikely to show trends resulting from rat removal. Pitfall traps have the advantage of collecting large numbers of individuals across many invertebrate groups, but the disadvantage that many species are very difficult to identify, even for experts – especially the flies, rove beetles and spiders. Pitfall traps also are only effective for certain invertebrate groups – mainly ground dwelling (although in scrub some species will fall into the pitfalls from above) and slow moving species. They are particular effective for beetles (Coleoptera), woodlice, spiders, harvestmen and bugs (Hemiptera) but less effective for flies (Diptera), grasshoppers (Orthoptera), Hymenoptera (apart from ants) and Molluscs (slugs and snails); they are ineffective for Lepidoptera and Odonata. The method used here – identifying distinctive animals to species level and combining all others into easily identifiable groups – appeared to work well.

The main problems are twofold. Firstly, there were some apparent errors in identification by the volunteers in 2016, particularly with the Lesser Cockroach, and if this exercise is to be repeated it would be useful to have a check on identifications mid-way through the summer season. Secondly, some of the individual invertebrates are very small and can be overlooked. For example, many of the flies and weevils were tiny and hard to see, and in one case there

were many tiny baby spiders. It may also be feasible to omit some of the groups in future recording where there were so few individuals recorded e.g. the Hemiptera and Aculeates (apart from ants).

For longer-lived species such as woodlice and sandhoppers, it is important that the pit-fall traps do not significantly affect the populations supported by the habitats sampled. Any effect was most likely to show after the first survey in 2013, when the traps were kept out for 7 nights. In fact, the results for June 2013 showed that there were drops in numbers for some species/species groups but there are also some increases (invertebrate numbers were adjusted for the number of trap nights). For example, a small brown Staphylinid showed increases in numbers between May and June 2013; this is likely to be due to their natural life cycle. Red ants also showed increases in numbers in spring 2013; this may show increased foraging activity or increased activity in warmer weather – and ant populations generally suffered nationally in the spring of 2013 due to the exceptionally cold weather. Otherwise, Lawn Hoppers, spiders and woodlice showed decreases in some catches but increases in others. Millipedes generally showed neither increase nor decrease. In the longer term, mites showed a dramatic increase in July and Devil's Coach Horse in September in most years, due to seasonal changes. Generally, the scrub, grassland and heathlands habitats are large and robust enough so that pitfall traps run for 3 nights are unlikely to have an effect on invertebrate populations. The traps represent a tiny proportion of the habitat available on each island.

The sandhoppers were not counted in 2013 as the pitfall traps were full to overflowing. These traps were also the most likely of all the traps to be lost, covered by sand and or blown away by wind. Statistically significant sampling of sandhoppers on the beaches would involve using enough traps to ensure that some traps at least were not full, but this would be a large number, so large that the populations on these small beaches with narrow linear foreshores might be significantly damaged. Alternative sampling methods could be considered, such as counting numbers in random grid squares across the foreshore at dusk which would provide comparable data, or even using lights (they are attracted to light). The biology of the sandhopper should also be considered; since they occupy different beach zones at different states of the tide, these different beach zones would need to be sampled at different times.

No data on temperature and humidity were collected. The logistics of setting out and collecting pitfall traps on the three islands is such that it would not be possible to abort trapping sessions or change sessions at the last minute; trap sessions over 3 nights are likely to involve a range of weather patterns that cannot be accurately predicted. Trapping on all islands at a similar time will ensure that results can be compared, i.e. weather patterns are likely to affect the 3 islands in similar ways at the same time.

Biomass has not been measured. Sorting into size classes for species groups was considered but not implemented as it would be impractical to sort each species into size. Weighing specimens in propylene glycol would be impractical and specimens cannot easily be dried out. It would be possible to estimate biomass for some groups e.g. woodlice by multiplying the number of specimens by the mass of the average individual, but this would not be an accurate measure.

Pitfall trapping is a labour intensive methodology. Identification by volunteers can be difficult. For many of the species groups little is known about their ecology and population trends are unknown elsewhere in the UK. Large numbers of particular species are killed, although this is unlikely to have much effect on the population survival (see above).

However, invertebrates are good indicators of habitat change. Alternative methods would include targeting key species – rather than species groups – where their ecology is known and which are either good indicators of habitat change (e.g. ants, butterflies and beetles) or have been shown during the course of this study to respond to rat removal (e.g. Devil's Coach Horse and Lawn Hopper).

Ants are good indicators of habitats and respond very rapidly to environmental changes, especially changes in vegetation height. Ant baiting techniques could be carried out. These surveys are easy to carry out and produce identification to species level. They can be fun for volunteers and easy to teach, especially on the Isles of Scilly where there are a limited number of possible species. Future ant-baiting surveys could be easily carried out if volunteers were found to do this, although the first tranche of surveys would have to be carried out in early spring to provide baseline data.

Beetles such as the Rose Chafer, Minotaur and Green Tiger Beetle are easily identifiable by volunteers and the ecology is known. However these species were found in relatively low numbers and the effect of rat removal on their populations is unknown. Butterflies are good indicators of habitat change. They respond quickly to habitat changes, e.g. scrub encroachment of removal, but they may only show an indirect response to rat removal.

Lawn Hoppers are known to be a food resource for Scilly Shrew and changes in the abundance of Lawn Hoppers might be due in part to changes in the abundance of shrews. They are distinctive and can be easy to monitor, e.g. turning over stones and looking through leaf litter. They come out at night, when they can travel tens of metres in search of food and mates. However, this would be secondary monitoring whereas direct monitoring of shrews would be easier.

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