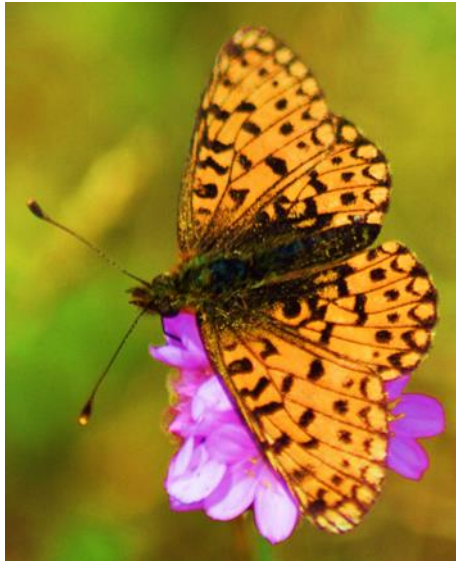


Small Pearl-bordered Fritillary: An analysis of the first and second broods

Small Pearl-bordered Fritillary
An analysis of the first and second broods



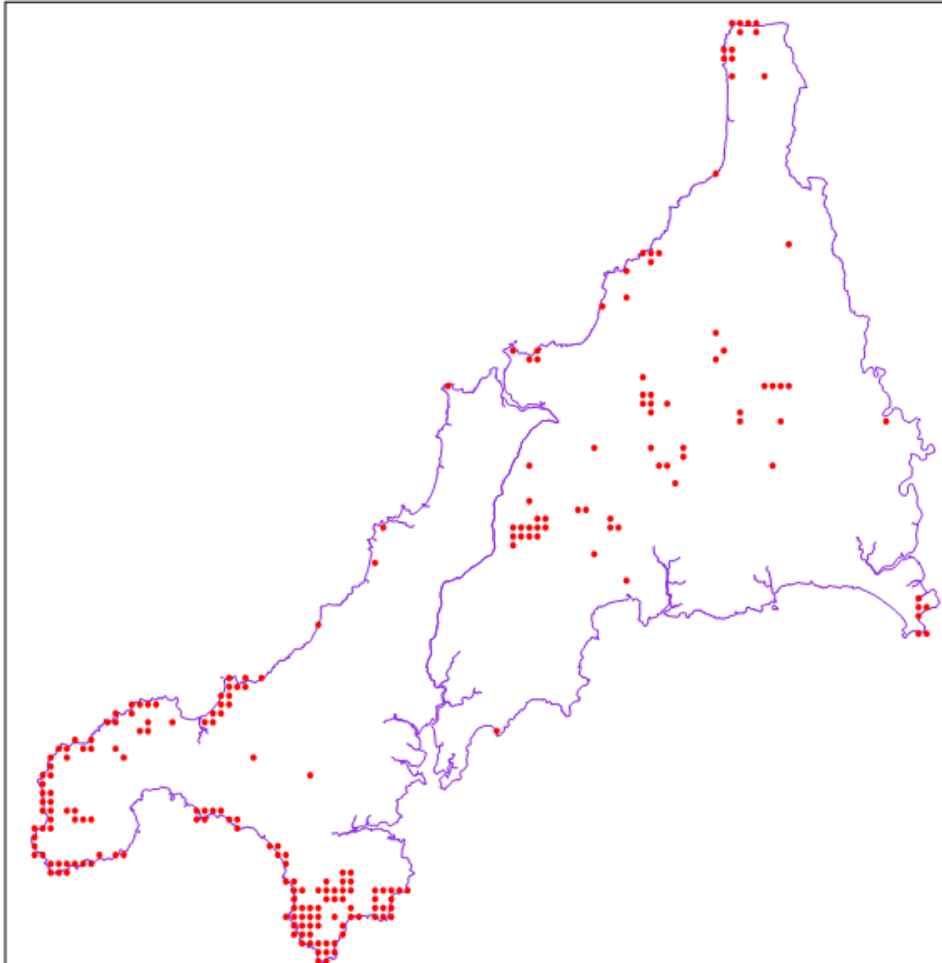
Written by Jerry Dennis
Grayling & Small Pearl-bordered Fritillary Species Champion
January 2021

Small Pearl-bordered Fritillary: An analysis of the first and second broods

1. Introduction

The Small Pearl-bordered Fritillary is well represented in Cornwall and there are 23,705 sightings documented in 423 different kilometre squares.

Total sightings for the last 12 years are 13,817 in 233 kilometre squares and these are shown on the map below (source: ERICA).



Following the 2020 Fritillary Action Group meeting on 9 September 2020, a short investigation has been carried out into the relationship between the first and second broods of the butterfly. The investigation objectives were:

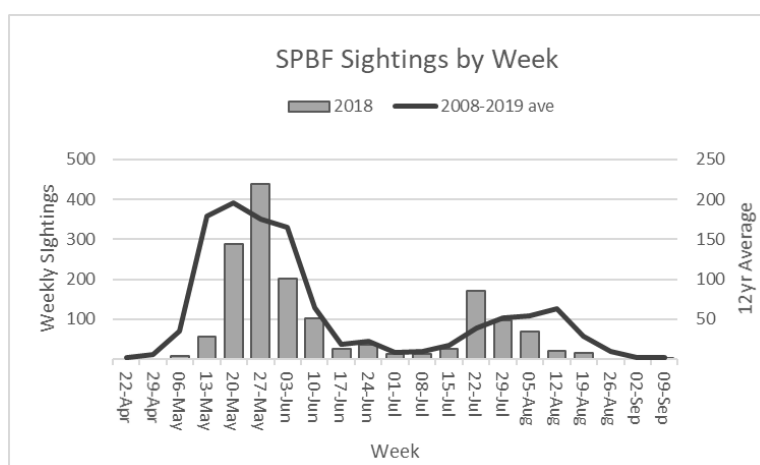
- To establish how the timings of the broods compared from year to year using cumulative frequency analysis,
- To better understand the relationship between the first and second broods, in terms of when the second brood is developed and the timing relative to the first brood,
- To investigate where the second brood is developed and how it compares to the size of the first brood in different areas.

Small Pearl-bordered Fritillary: An analysis of the first and second broods

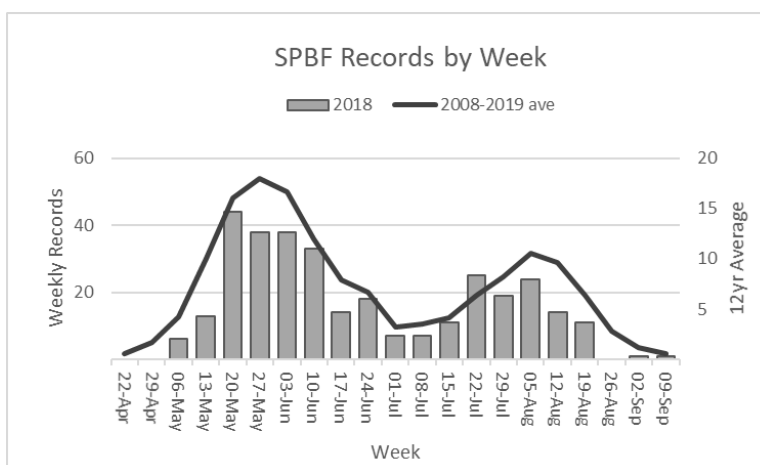
2. Methodology

All records for Small Pearl-bordered Fritillary were downloaded from ERICA and processed to allocate the UKBMS week (Week 1 commences on 1 April each year) and a 'UKBMS day' (Day 1 is 1 April each year).

Previous analysis had determined that 9 July was a reasonable common cut-off date to separate the end of the first brood from any second brood butterflies. This judgement arises because there is usually an overlap between the latest first brood and the earliest second brood butterflies. The plot below illustrates how this date is derived. The curve is the average number of sightings per UKBMS week in the last 12 years, reaching a minimum between broods in the UKBMS week commencing 8 July (Week 15). Data for a single year, 2018 is also shown. This had a late first broods after a cold spring and one of the earliest second broods after high temperatures in June and July. Sensitivities using different cut-off dates to +/- 10 days were trialed and did not materially affect the conclusions of the analysis.



A second method for data analysis was to use number of records as opposed to number of sightings in each week and the equivalent plot for records is shown below.



Using the common cut-off date, the total numbers in each brood was calculated. Cumulative frequency was calculated for each brood in each year using the UKBMS Day.

Small Pearl-bordered Fritillary: An analysis of the first and second broods

An excerpt from the results of allocating sightings to UKBMS days for May and early June for the last 10 years is tabulated below and clearly there are many surveys in the database from many places in Cornwall.

Day	UKBMS Day	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total	
01-May	31	2										4	
02-May	32			5					4		12	22	
03-May	33										8	29	
04-May	34										6	6	
05-May	35								3		1	4	
06-May	36		2							3	13	29	
07-May	37			4		6	7		13		10	50	
08-May	38		24						35			63	
09-May	39										3	3	
10-May	40	2	100					4	21	4	15	147	
11-May	41		3		1				100	1	6	111	
12-May	42	5	10	2			12	10			16	80	
13-May	43		80	15		30		30	34	1	20	321	
14-May	44		147	14					11	8	30	386	
15-May	45	400	114	36		203	46	20			36	855	
16-May	46		13	67	4	10	28	3			158	283	
17-May	47				9	29				8	2	58	
18-May	48					1		5	9	18		189	
19-May	49				13	4	11	19	3	21	1	78	
20-May	50		1	152			14	20		1	24	4	238
21-May	51	13		252		2	4		25	23	72	397	
22-May	52	3				1	4	5	2	42	66	138	
23-May	53	14		1			11	6		97	3	135	
24-May	54	42	5	688		4		69	151	6	14	1,009	
25-May	55		1	100	4		2	1	19	93	14	234	
26-May	56			1	134	43	19	4	5	2		209	
27-May	57	22	17	3		26	5			5	5	87	
28-May	58	30		3		2	6	1		49	56	157	
29-May	59	8		12	100			60	20	24		255	
30-May	60		6		4	70		19	12	10	22	242	
31-May	61	12	50		7	82	6		32	48	14	431	

For each brood, the 10%, 50% and 90% population timings were derived from the cumulative frequency data. Specifically, these timings were calculated from the first UKBMS day on which the cumulative population exceeded 10%, 50% (median) or 90% in each brood and were then back-converted to partial UKBMS weeks for convention.

The resultant data are tabulated below.

Small Pearl-bordered Fritillary: An analysis of the first and second broods

Year	Sightings	1st P10	1st P50	1st P90	Sightings	2nd P10	2nd P50	2nd P90
1990	315	5.1	7.4	10.7	44	17.0	19.3	19.7
1991	254	7.3	9.3	13.0	22	14.4	20.4	21.4
1992	127	7.9	9.3	10.9	13	17.0	20.0	20.0
1993	154	7.0	9.3	10.6	2	18.1	21.6	21.6
1994	154	9.7	11.0	13.4	49	14.6	19.4	21.1
1995	218	7.6	9.6	12.4	19	15.6	15.6	18.7
1996	76	9.9	11.3	11.9	11	16.0	19.1	21.1
1997	609	7.7	8.7	13.6	119	18.6	19.4	19.4
1998	426	6.9	10.4	11.4	77	18.6	19.6	19.6
1999	363	8.9	11.0	12.1	52	17.4	17.4	27.7
2000	291	6.4	10.1	11.1	78	18.4	19.0	22.1
2001	522	7.6	8.3	11.4	57	17.1	18.9	19.4
2002	94	5.6	9.3	12.3	74	19.1	19.1	19.7
2003	115	8.6	10.6	11.6	25	17.7	18.6	20.3
2004	384	7.7	10.3	10.6	13	18.3	18.3	19.9
2005	323	8.6	10.4	11.7	20	16.7	17.7	19.1
2006	523	9.0	9.7	10.9	74	16.7	19.1	22.0
2007	405	6.7	8.9	10.0	54	16.6	18.7	19.0
2008	1076	6.1	8.7	10.0	157	17.0	19.4	20.6
2009	698	6.9	9.0	10.7	174	17.3	19.3	20.0
2010	866	4.4	7.6	10.4	547	17.3	17.7	19.6
2011	1000	5.7	6.6	9.3	179	16.9	19.4	19.4
2012	1470	7.1	7.7	7.9	194	18.7	19.1	22.3
2013	1355	8.0	9.6	12.1	718	16.1	19.0	20.4
2014	832	6.4	8.6	10.6	182	15.9	17.9	20.3
2015	453	6.4	9.3	11.4	184	17.1	18.6	21.3
2016	386	6.1	8.0	11.0	260	17.0	19.1	20.9
2017	670	5.7	7.7	9.3	172	16.3	18.3	20.6
2018	1171	7.4	9.0	10.6	413	16.3	16.7	18.6
2019	762	6.0	7.3	10.7	305	15.1	17.0	19.1

The numbers of first and particularly second broods for the first decade are barely adequate to support this type of analysis. Data recorded in the last decade are impressive.

In order to investigate differences in the characteristics of the second brood, the sightings were also analysed by hectads (10km squares) for a county-wide perspective.

Numbers of first brood and second brood Small Pearl-bordered Fritillary in each of Cornwall's 62 hectads were allocated for every year from 2000 onwards. Excerpts from the results are tabulated below for the total in hectads SS10 to SW72 from 2000 to 2019. The first table is for the first brood and the second table is for the second brood.

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	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	TOTAL	
SS10																					6	6
SS11												3					4	4	2	11		24
SS20																						
SS21						3			895	309	479	277	1,306	864	479	145	217	177	173	372	5,696	
SW32	1	10	9	1	72	59	4	21	2	2	34	14	15	25	23	34	71	18	59	43	517	
SW33	7	3		6	6	5	4	1	20	24		8	21	5	3	5	4	23	22	11	178	
SW42									2		21					6			5	15	49	
SW43	24	1	10		5	6	1	4	3	12	5		1		2	24				3	101	
SW44						1					4						1	2	41	20	69	
SW52	22	72				2	5	1		4	2	21		4		2	3	6	44	8	196	
SW53	7	4	2	1	1	2		10	1		3	14	5	26	12	14	4	43	37	3	189	
SW54	20	7	15		1			8			28	20	9	9	15	11	8	17	10	10	188	
SW61				4	69	20	4	1	6	65	7	11	17	51	47	32	37	29	86	37	524	
SW62	60	308		1						16			4					175	14	2	580	
SW63	16		2									2	2								22	
SW64		1	1	10					1									31	28	67	139	
SW65																						
SW71		2			2	13	1	7	4	99	4		61	81	77	22		14	116	24	527	
SW72						2	2		3	2		1			4				3	1	18	

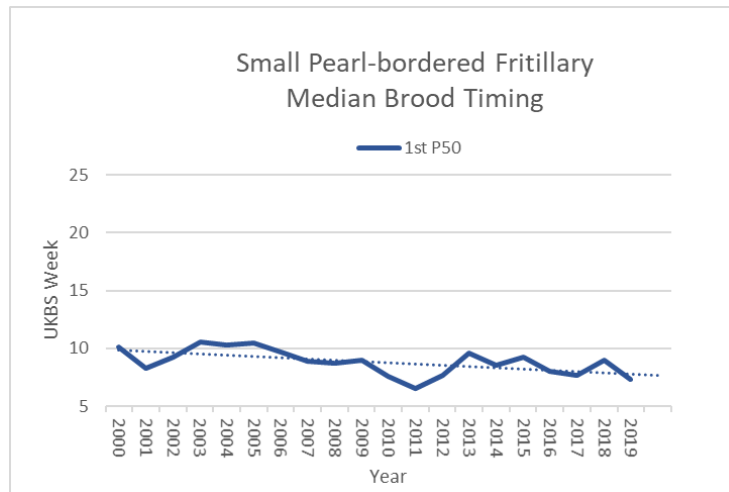
Second Brood	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
SS10																					
SS11												1				2	1	5	9	61	79
SS20																					
SS21						1			133	41	288	33	107	356	49	33	78	33	37	58	1,247
SW32	6	2	3	16	11	16	11	37	6	80	145	91	7	136	35	75	32	19	33	46	807
SW33		1					8		2	21		1	8	15	14	10	38	13	18	42	191
SW42								1				1		4			8			3	17
SW43								1							2					2	5
SW44																			17		17
SW52		6			2		1				4				5			1	43	35	97
SW53	44	5		9			2	1			2			24		3		9	21		120
SW54	22	15	7					1			14	5	1	41	28	10	19	10	10	16	199
SW61		22	2			1	26			30	76	38	67	45	35	30	34	37	80	4	527
SW62		1	61				6	1						46		12	30	18	16	1	192
SW63																			2		2
SW64								1									6	24	103	23	157
SW65																					
SW71	6		1						10	1	6	1		50	1	3	6	2	17	1	105
SW72																					

Small Pearl-bordered Fritillary: An analysis of the first and second broods

3. Results and Discussion

3.1 Phenology of first and second broods

A plot of the timings in UKBS weeks of the median (50%) occurrence of the first broods between 2000 and 2019 is shown below.

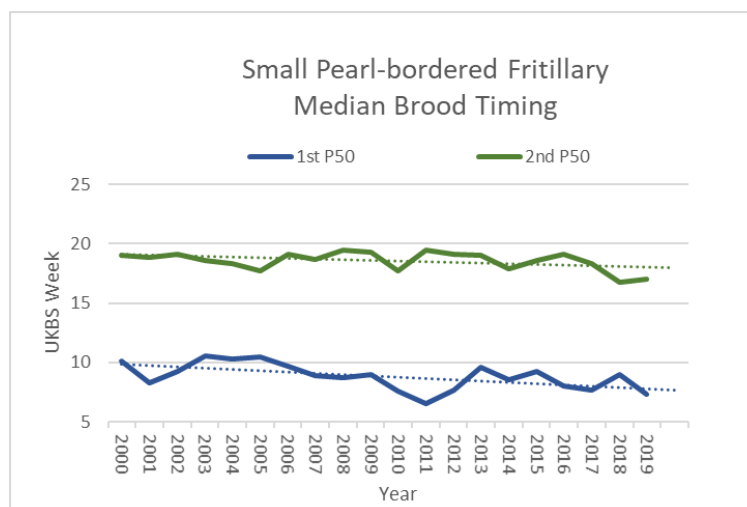


Two trends can be observed:

- The median population timing varies from year to year by up to 2 weeks,
- There is an overall long-term trend for earlier occurrence as characterised by the best fit line shown on the graph.

The equation of this trend line enables an estimate of long-term trend, equating to 15 days. Previous studies by the author have shown that the yearly variation of this timing can be correlated to the average temperatures in late larval and pupal stages where the warmer the temperature, the earlier the butterflies emerge.

To build on this finding, the timing of the median occurrence of the second broods are added to the plot as shown below.



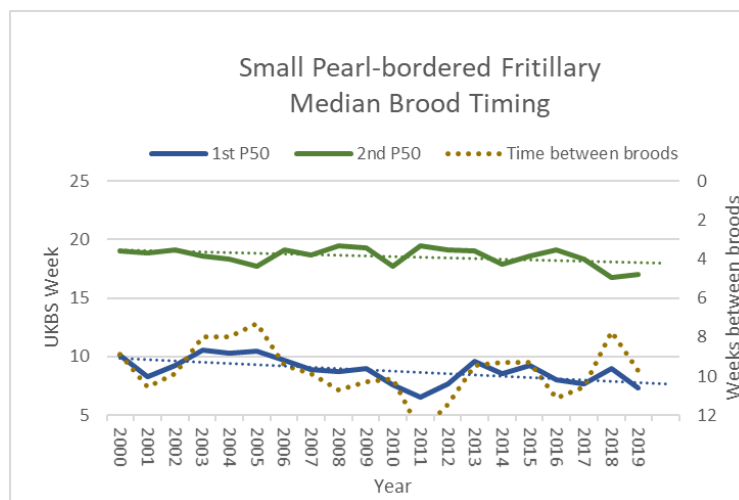
Again, the two observations noted above can be seen in the second broods, although the magnitude of year-to-year differences is less. Using the equation of a best-fit trend line, this indicates the

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median of the second brood getting earlier by 8 days over the last 20 years. This is about half of the progression calculated for the first brood.

What is also apparent is that the second brood timing is independent of the first brood within a framework where both first and second broods have a similar long term trend of getting earlier. The relative earliness/lateness of the first brood is not reflected in the relative timing of the second brood.

This is illustrated by adding the timing between broods to the plot shown below, but using an inverted y-axis scale (right-hand side). This, as best as can be arranged, overlies the timing of the first brood to show the inverse correlation of later first brood with shorter time between broods, and vice versa.



Discussion

The yearly variation of brood timings reiterated here for the Small Pearl-bordered Fritillary has been observed in many univoltine species and the first broods of bivoltine species analysed in the same way and the correlation between ambient temperature during late larval and pupal stages has been established as a working principle for all species analysed. What is concluded here for both first and second broods is that they are showing a phenological response to the average warming of the local climate in the last 20 years.

There appears to be a reset mechanism for the timing of the second brood emergence that is independent of the first brood. In a year when the first brood is relatively early, the gap between the median timings of the first and second broods is longer and, in a year when the first brood is late, the gap time is shorter. A potential causal factor is day length and its possible influence on the development of the early butterfly stages, effectively slowing down oval stage and early larval instars when second brood eggs are laid early and speeding these stages up when they are late. On top of this 'correction', there is additional variation in the timing of the median of the second brood due to climatic factors as described above.

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3.2 Regional Variations in Second Brood Development

Using the analysed data described in section 2, a table of first and second brood comparisons by hectad was constructed and these results are shown below using colour-coding (see key). Principal places where Small Pearls occur are given for each hectad.

HECTAD	Location / Site	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
SS11	Tidna Valley									15%	13%	60%	12%	8%	41%	11%	23%	36%	19%	21%	17%	55%
SS21	Marsland								176%			426%	650%	47%	544%	152%	221%	45%	106%	59%	107%	
SW32	Porthgwarra		20%			15%	29%			10%	88%			93%					57%	82%	382%	
SW33	Cape Cornwall - Pendeen																					
SW42	Lamorna - Penberth																					20%
SW43	Zennor - Porthmeor																					
SW44	Treveal																				41%	
SW52	Cudden Point - Rinsey		8%																		98%	
SW53	Upton Towans							10%							92%		21%		21%	57%		
SW54	Upton Towans	110%		47%								50%	25%			187%	91%		59%	100%	160%	
SW61	Poldu - Kynance					5%				46%			345%	394%	88%	78%	94%	92%	128%	93%	11%	
SW62	Pothleven - Loe Bar		0%																	10%	114%	
SW64	Hudder Down - Hell's Mouth																			77%	368%	34%
SW71	Erisey Barton									1%					62%	1%	47%		14%	15%	14%	
SW95	Goss Moor																					
SW96	Goss Moor - Demelza Bog																					
SX05	Treskilling Downs							1%														
SX06	Breney Common		4%					3%				1%	1%		1%				9%			
SX07	Pendrift - De Lank																					
SX08	Backways Cove, POW Quarry							5%			9%	33%	28%									
SX16	Bunny's Hill - Cabilla							1%		14%												
SX17	Pendrift Down - S Penquite																					
SX19	Valency Valley - Milllook																					
SX27	North Hill, Cheesewring																	58%				
SX45	Minadew Brakes								31%													

	First brood below threshold
	No second brood
15%	2nd / 1st brood ratio (<25%)
85%	2nd / 1st brood ratio (<100%)
100%	Second brood >100%

For those years where there are at least 10 first brood sightings the ratio of any second brood sightings are used to create a 2nd / 1st ratio and these are shown as percentages and colour-coded as in the key.

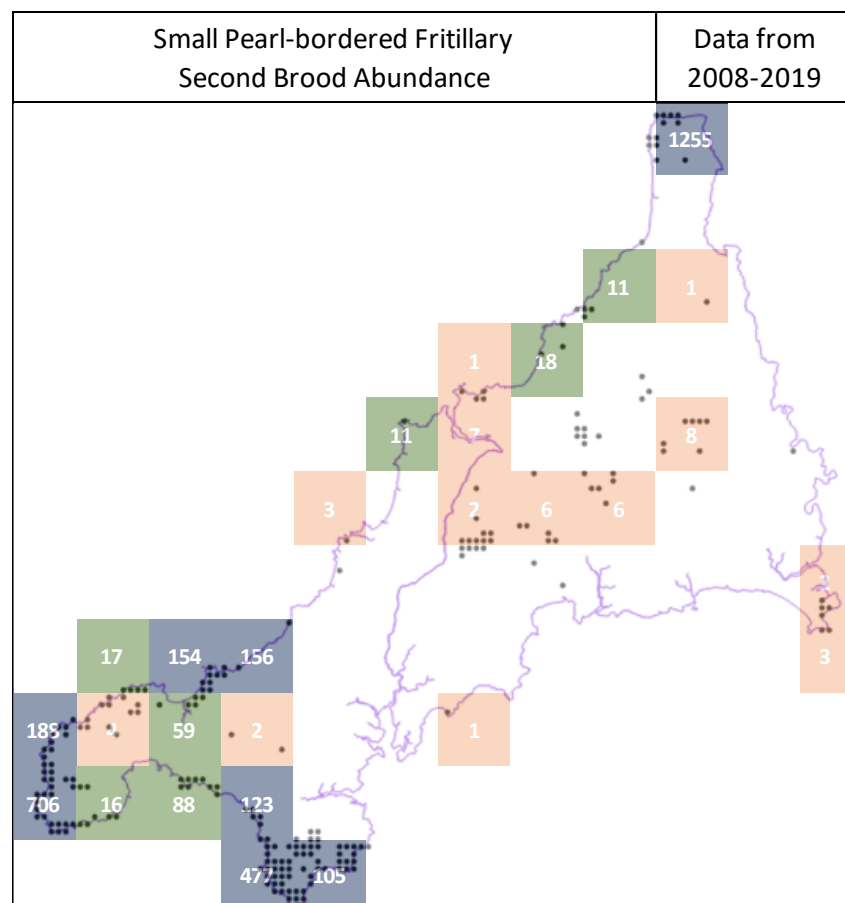
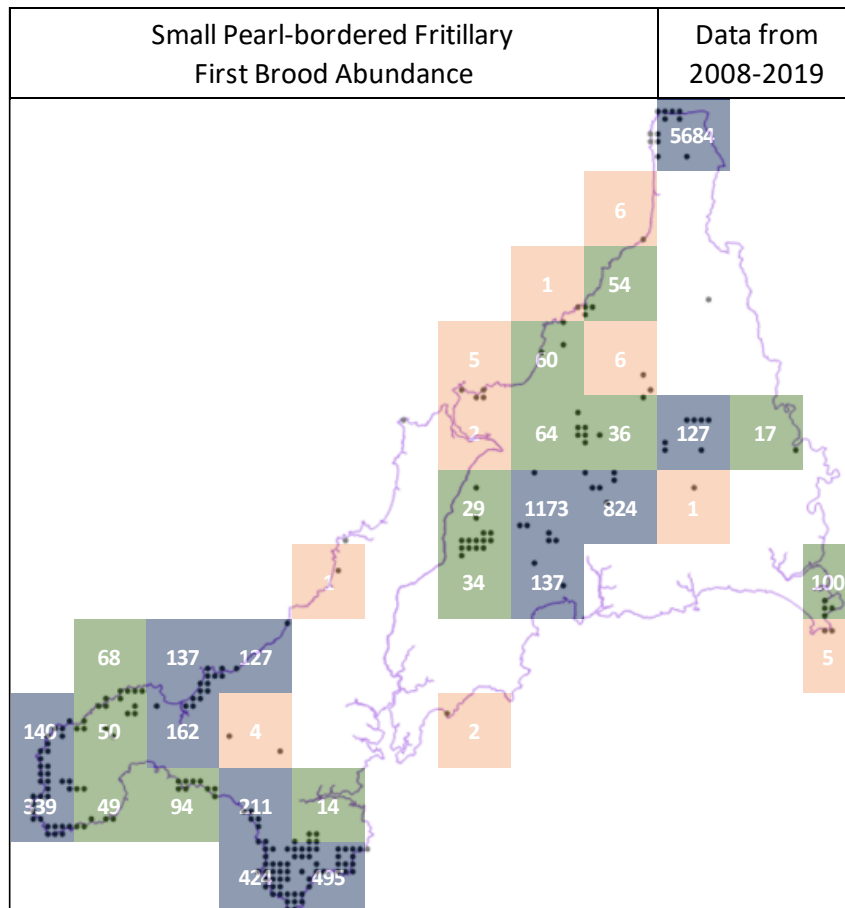
The data is filtered with a first brood threshold of at least 10 in any year at the hectad. Those years for those hectads that fail this test are shown in white. The list of hectads summarised is also filtered to remove those hectads that have less than 10 Small Pearl-bordered Fritillary sightings overall.

Some clear patterns emerge. Some hectads, such as SW32 (Porthgwarra) tend to record bigger second broods than first broods. Others, such as SS21 (Marsland) have second broods that are 25% or less than the size of the first broods. Hectads such as XS06 (Breney Common) have rare occurrences of small numbers of second brood butterflies.

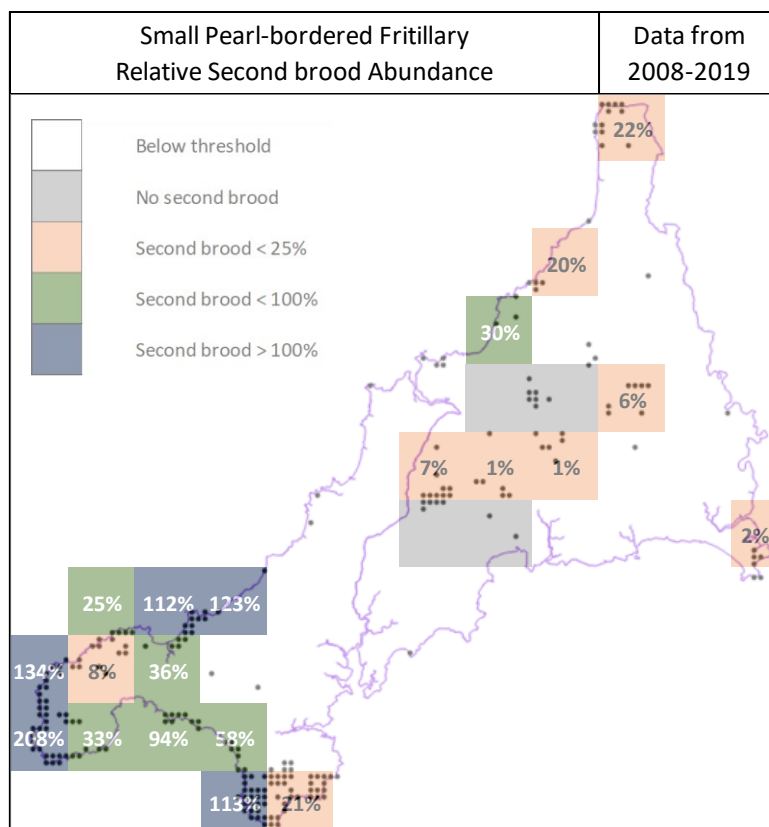
The two plats overpage show the distribution of first and second broods sightings over the last 12 years by hectad with the sightings from ERICA the same period (black dots). Any hectads with less than 10 sightings in the last 10 years were not plotted. Numbers in each hectad are shown in white.

The highest number of sightings in both broods are in SS21 at and around the reserve at Marsland. Breney Common has high first brood numbers in SX06. The second brood sightings are high in the west of Cornwall, such as at Gwennap Head to Gwynver in SW32.

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Small Pearl-bordered Fritillary: An analysis of the first and second broods



The third plat shows the relative abundance (No. of 2nd brood / No. 1st brood). A clear pattern emerges.

The colonies in locations at the extreme west of Cornwall (SW32, SW33) have recorded the most substantial second broods in the last 10 years, averaging more than 100% bigger than the first broods. There are three other coastal hectads that have second broods larger than first broods: along the towans at Hayle to Hudder Down (SW54, SW64) and SW61 from Poldhu Cove to Kynance Cove.

Elsewhere in west Cornwall most hectads with sufficient sightings have significant second broods that average more than 25% of the first broods. Interestingly, the results from Upton Towans transect, lying in two separate hectads SW53 and SW54 show slightly different behaviours. There are two exceptions, SW54 that includes the West Penwith hills and south-east Lizard SW71 that includes the transect at Erisey Barton, Goonhilly Downs and the coastal section.

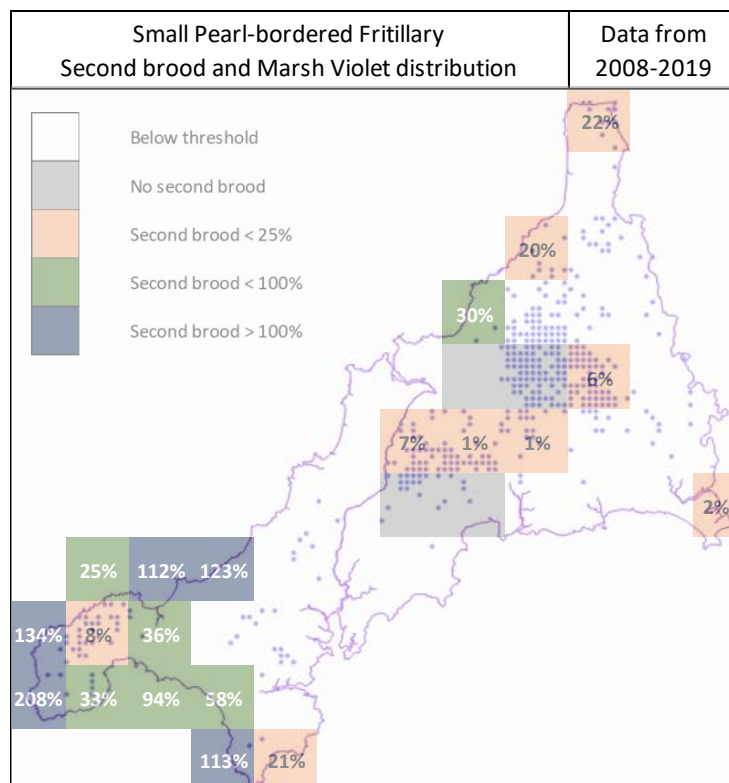
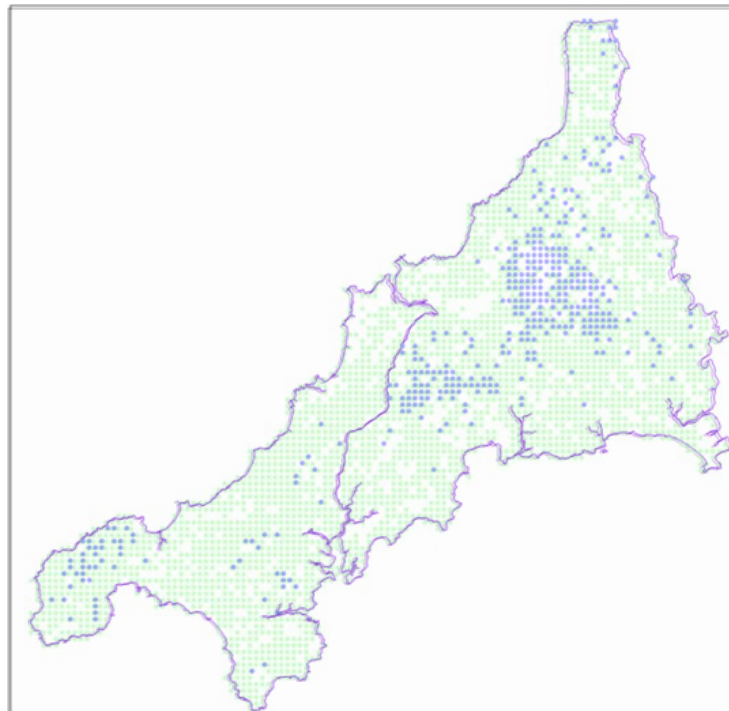
The sites in the east of the county have mixed characteristics. Along the north coast, second broods are recorded at sites near Tintagel and Valency Valley, averaging more than 25% of the first broods. At Marsland (SS21) the second broods are smaller than this, and inland from the coast and in the Bodmin area, the sites are characterised by having either no or very small second broods.

Availability of larval foodplants has also been investigated. The principal foodplant, Common Dog-Violet *Viola riviniana*, is widespread and common in Cornwall but is more limited in inland areas and on moorland. In these circumstances, the butterfly can use the Marsh Violet *Viola palustris* that is much more localised but present in the higher places and on moors.

The figure below is a superimposition of the distribution of Common Dog (light green) and Marsh Violet (purple) recorded in ERICA since 2008. Light green squares are where there is only Common

Small Pearl-bordered Fritillary: An analysis of the first and second broods

Dog-Violet recorded, both are recorded in dark green squares and purple squares show where there is only Marsh Violet.



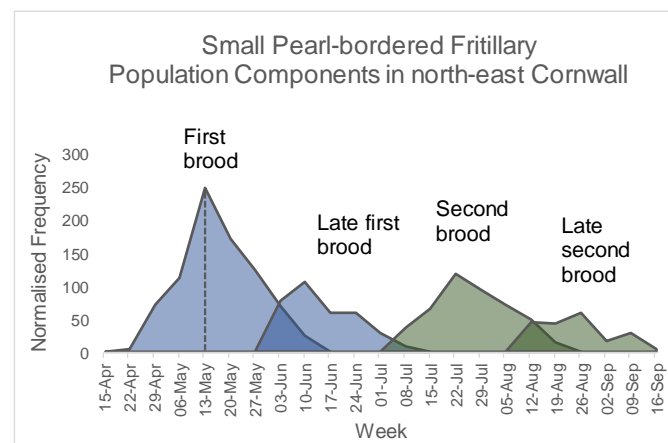
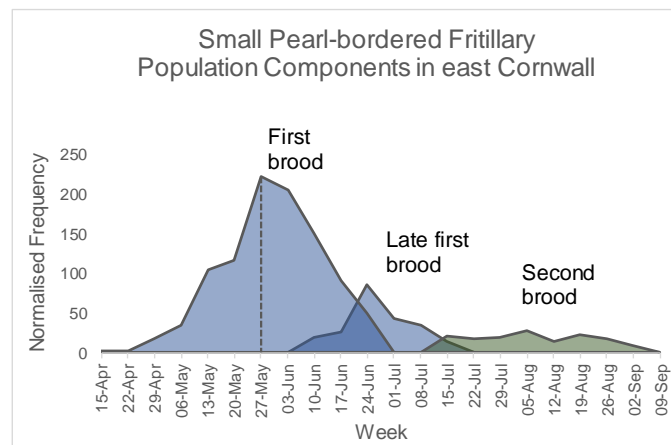
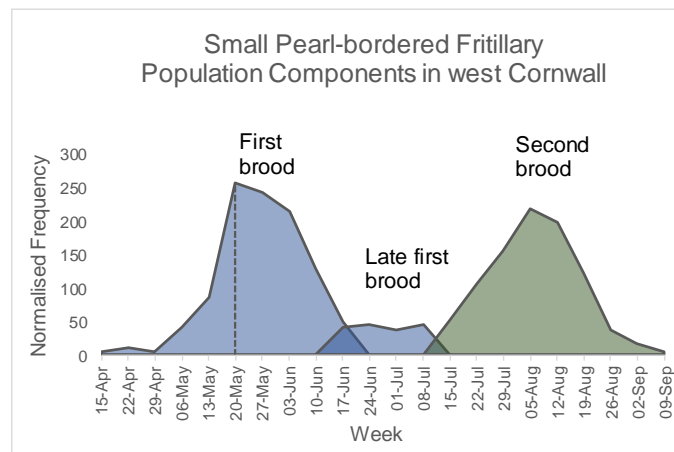
The plot above combines relative second brood abundance and Marsh Violet locations. The places where second broods are poorly and intermittently developed, less than 10% of the first brood, are in the areas where Marsh Violets are present and more prevalent than Common Dog-Violet.

Small Pearl-bordered Fritillary: An analysis of the first and second broods

3.3 Regional variations in brood timing

Variations in Small Pearl-bordered Fritillary emergence in areas of the county were investigated. Three areas were selected: West Cornwall (west of SW71), East Cornwall (east of SW61) and SS hectads in the north-east. Deconvolution models were generated for each area based on weekly records from 2008-2019. This encompasses all of the Cornish sightings. Totals are normalised for comparison purposes based on overall first brood abundance. Two sets of models were created.

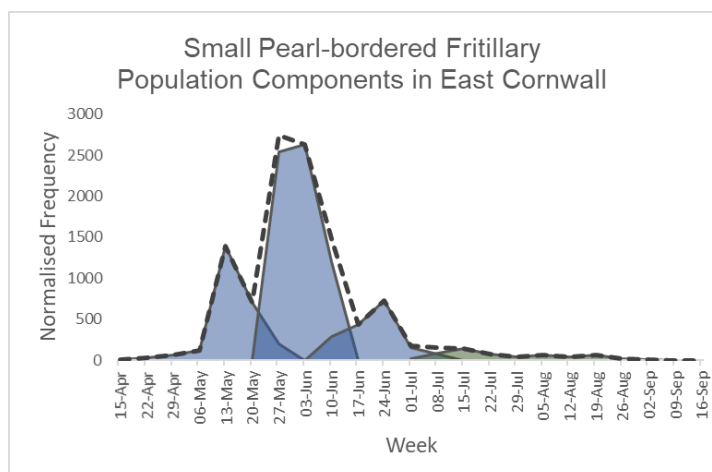
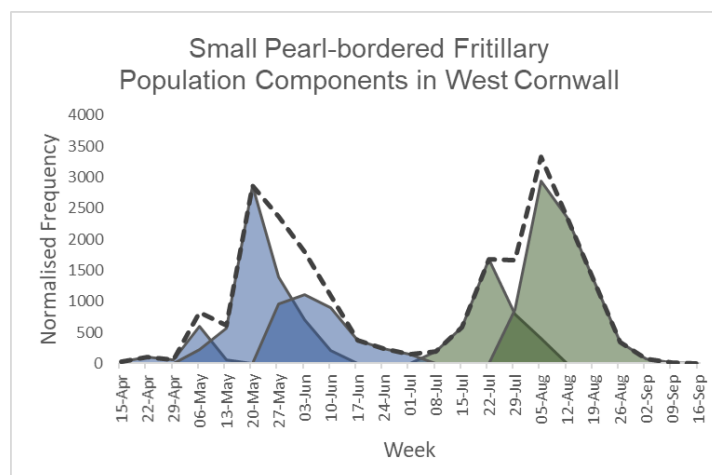
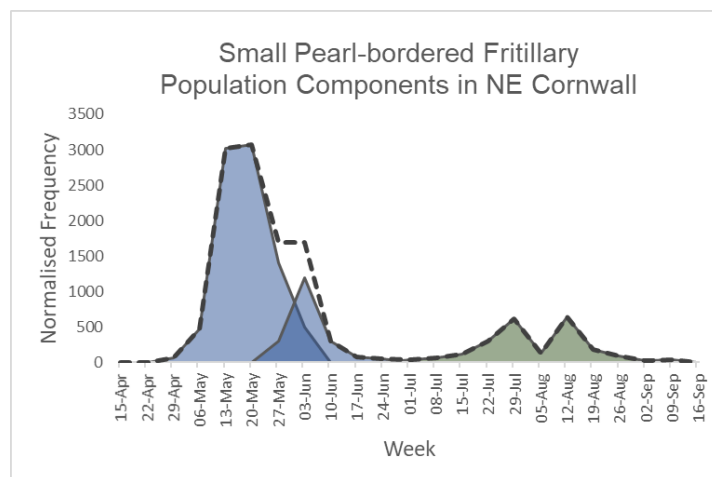
The first set of models are based on the number of records in each week. They are displayed below.



Small Pearl-bordered Fritillary: An analysis of the first and second broods

For the first brood, each records model shows a main population but peaking at different times, being earliest in the north-east (w./c 13 May), second in the west (w/c 20 May) and latest in the east (27 May). There is a later, smaller component of records that extend through June and July, across the first-second divide. These are from years when late populations developed, in particular 2013. The second broods show contrasting components, most significant in the west, smaller and bimodal in the north-east and even smaller and possibly bimodal in the east.

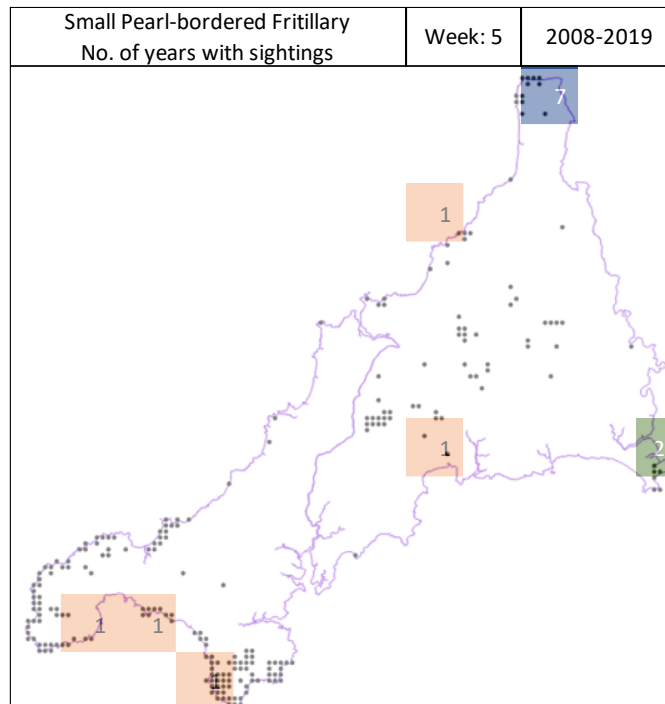
A set of three deconvolution models based on sightings between 2008 and 2019 were also created as summarised below. The total weekly numbers are shown with the dotted grey lines, first brood in blue and second brood in green as for the records models.



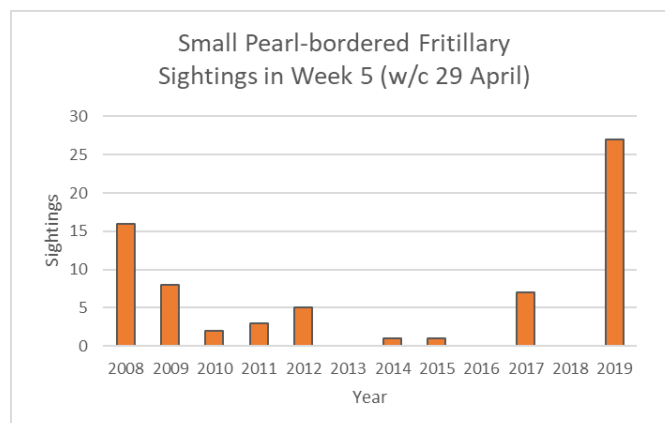
Small Pearl-bordered Fritillary: An analysis of the first and second broods

These models show considerably more character than the records models. The first broods in each area can be divided into two or three population components – early (small) in north-east and east only, mid (significant) and late (small). There is no known difference in the overwintering strategy of the butterflies in these components. The relative timings of the mid peaks are similar to those of the records models.

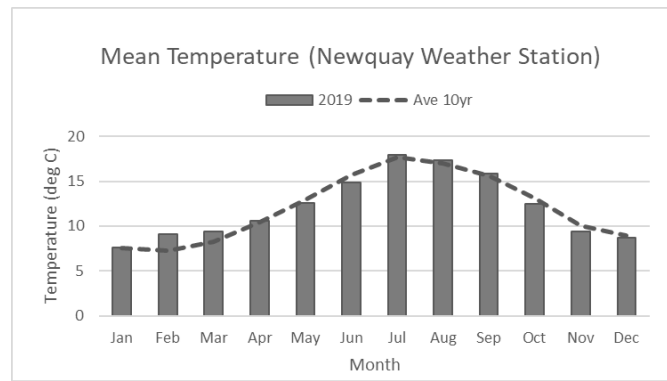
Examination of the distribution of sightings in Week 5 (w/c 29 April) illustrates where the early component occurs. The plot below shows the number of years in which hectads with sightings in Week 5. The most significant is at the Marsland reserve and environs with sightings from 7 out of the 12 years.



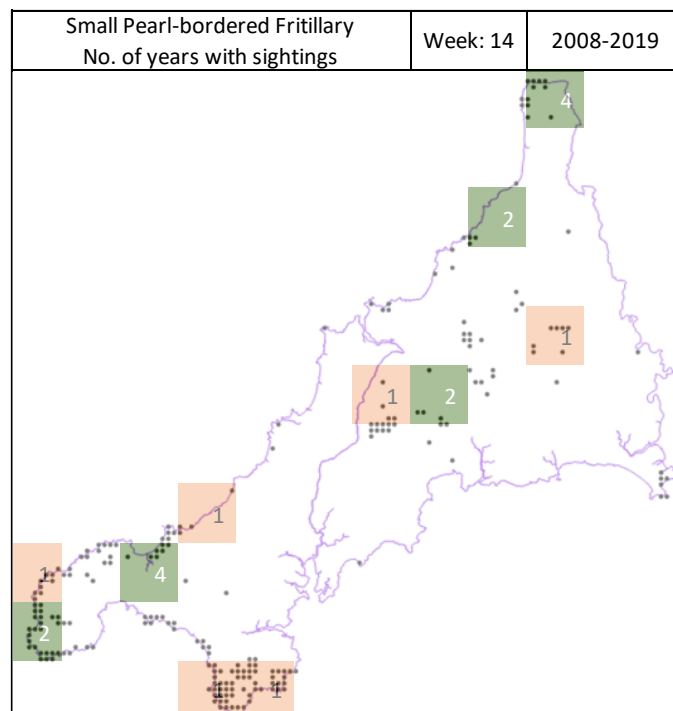
On a yearly basis, the graph below shows how many sightings occurred in Week 5 with 2019 being the most significant year. This has the warmest February mean temperature in the 12 years and a warmer-than-average March (see plot below)



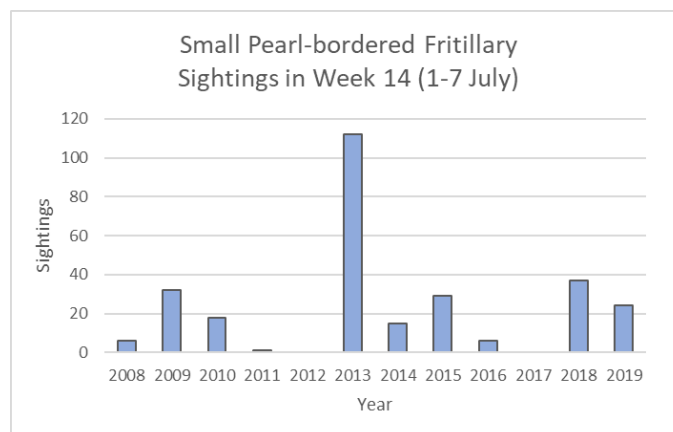
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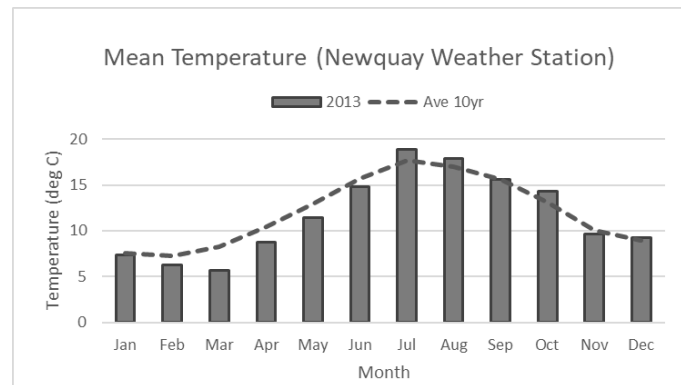
Similarly, examination of the sightings in Week 14 (w/c 1 July) illustrates the locations with sightings in the late first brood component.



These are more widely distributed, with several hectads having records in more than one year in the north-western side of Cornwall. Examination of how many late first brood sightings occurred in Week 14 shows that the only significant year was 2013 that was colder than average between January and July (see plot below).



Small Pearl-bordered Fritillary: An analysis of the first and second broods



Discussion

There are clear regional patterns to the characteristics of the first and second broods of the Small Pearl-bordered Fritillary in Cornwall.

The first brood peaks at different times in different areas. The earliest is seen in the north-east, at Marsland-Hard Hills, peaking c. 13 May. Peaking is approximately 1 week later in the west and a further week later in the central and eastern parts of the county. There are occasional early and late pulses of emergence, driven by unusually warm or cool weather, with subordinate early and late population components evident in the overall first brood distribution.

Areas in the west of the county are places where strong second broods develop in most years and they are often bigger than the first broods. Coastal locations in the north-east of the county (SS hectads) can show significant second broods, although less impressive than in the west. At elevated inland moorland and heathland sites in central Cornwall and north Penwith, the second broods are much smaller and less frequently developed. They are characterised as less than 10% of the first broods or non-existent.

There is a correlation between the habitat where the Marsh Violet is growing, often in proximity to the Dog Violet, and the places where the Small Pearl-bordered Fritillary has no second brood or a very small partial second brood.

Several causations are possible in this relationship between ground elevation, distance from the coast, larval foodplant availability and Small Pearl-bordered Fritillary second brood characteristics. Two are proposed as worthy of follow-up monitoring.

Causation A: Both Marsh Violet and Small Pearl-bordered Fritillary are responding to an environmental difference connected with the inland sites that have higher elevation. This could be a subtle climatic difference in temperature and/or rainfall. The propensity of the offspring of the first brood to enter early diapause and not continue to fully develop into a second brood is strongly related to the environmental factor.

Some evidence for this causation comes from the later emergence of the first brood in the east of the county, dominated by inland sites. This may not leave sufficient time for the butterfly to develop a second brood.

Causation B: The Small Pearl-bordered Fritillary is responding to the larval foodplant that is available at the time that the offspring larvae of the first brood are choosing to fully develop into a second brood, or alternatively, to enter a long diapause. In the upland areas, it is possible that the Common Dog-Violet is less adapted to growing there or less effective with different types of scrub, and it is less viable for sustaining summer larvae to maturity. The Marsh Violet is in its ideal habitat there and

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its viability to sustain a second brood might be much reduced compared to the Common Dog-Violet. Hence, most or all of the larvae decide to enter early diapause based on larval foodplant availability.

Some evidence for this causation comes from the distinctive distribution pattern of the larval foodplants in the areas without second broods.

4. Conclusions and recommendations

- 4.1 The phenology of the two Small Pearl-bordered Fritillary broods has been investigated and there is sufficient data available to characterise these over the last 20 years.
- 4.2 Using the timing of the median population development, the data indicates a considerable amount of variation from year-to-year but with a steady trend of earlier occurrence of both broods over the 20 years, the first brood by 15 days and the second brood by 8 days.
- 4.3 The timing of the butterfly's second brood is independent of the timing of the first brood. Its timing does vary and is likely to be dependent on the climatic conditions during late larval and pupal stages.
- 4.4 The character of the partial second brood, specifically in terms to its size compared to the first brood, varies systematically in the county. By grouping the sightings into hectads, a county-wide view has been established.
- 4.5 In the west, there is a significant second brood, that in coastal areas, can be bigger than the first brood. The second brood is present, but of lesser relative abundance along the northern coast.
- 4.6 In the central parts of the county the second brood is very small compared to the first brood, less than 10%, and is often not recorded at all.
- 4.7 The timing of the first brood is also seen to vary across the county. The earliest timing is in the extreme north-east at Marsland. The latest is the inland areas in the east of the county, where the peak and median of the first brood occur two weeks later than Marsland. The timing of the second brood is similar in all areas of the county.
- 4.8 The reduced development of the second brood in the central and eastern parts of the county may be directly related to a subtle climatic difference at higher elevations, with the first brood being slower to develop in these places. It may also be indirectly related to the effect of a subtle climatic or habitat difference on the butterfly's larval foodplants, Common Dog-Violet and Marsh Violet.
- 4.9 Further monitoring will be useful in better understanding the behaviour of the Small Pearl-bordered Fritillary, particularly with regard to its second brood development in different parts of the county.
- 4.10 Future monitoring at site level of the specific larval foodplants that butterfly is using will be very helpful, especially in those in the places where there are both Common Dog-Violets and Marsh Violets growing.

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- 4.11 Weekly monitoring of significant colonies in the western areas of the county where the butterfly is using Common Dog-Violet should be continued and widened to new sites.
- 4.12 Further insight from the walkers of the UKBMS transects where the butterfly is resident may offer new insights into subtle variations in the habitat being used.