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Surveys of EU Habitats Directive *Vertigo* species in England: *Vertigo angustior* at Flordon Common SAC, Norfolk and Fritton Marshes pSSSI, Suffolk

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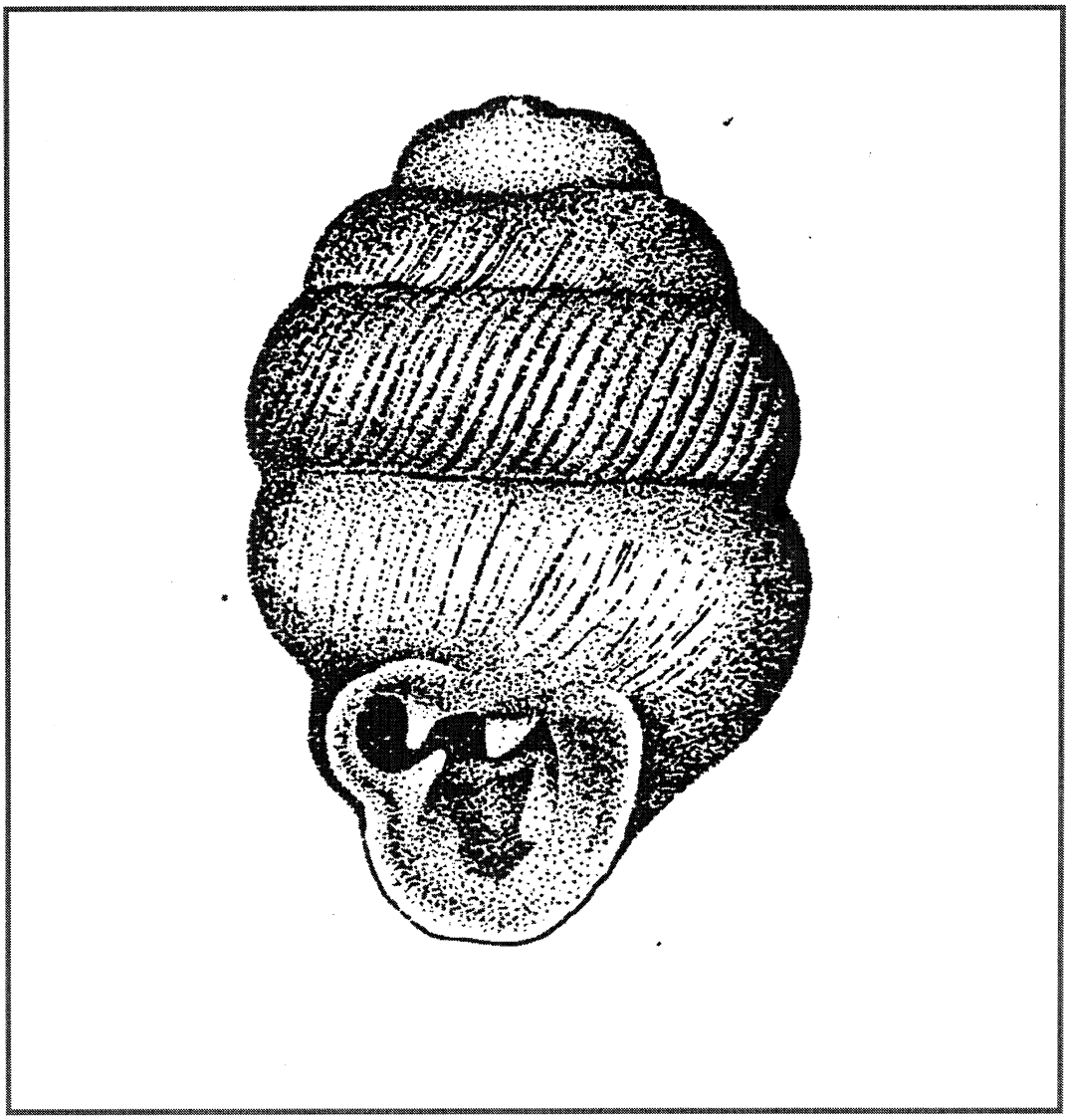

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Surveys of EU Habitats Directive *Vertigo* species in England: 2. *Vertigo angustior* at Flordon Common SAC, Norfolk and Fritton Marshes pSSSI, Suffolk

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Summary

Four species of the snails in the genus *Vertigo* are listed on the Habitats and Species Directive. This places an obligation on the British government to maintain the species in favourable conservation status and to report on this. To this end, several Special Areas of Conservation (SAC) have been proposed. The responsibilities are expanded in the UK Biodiversity Action Plan which requires additional survey to establish the species' status and further studies on the ecological requirements to help form decisions about management. The BAP steering group for terrestrial snails has identified a number of outstanding projects needed to take forward important actions in the Species Action Plans, and those for England are combined in this contract.

This report describes the survey work on *Vertigo angustior* at Flordon Common SAC, Norfolk and Fritton Marshes pSSSI, Suffolk. The principal objectives of this study are:

Flordon Common SAC

1. To provide an accurate distribution of *Vertigo angustior* across the site.
2. To determine the snail's abundance, population structure and habitat requirements.
3. To assess sampling methods.
4. To provide advice for conservation and management
5. To devise a protocol for monitoring.

Fritton Marshes pSSSI

1. To provide an accurate distribution of *Vertigo angustior* across the site.
2. To determine the snail's abundance, population structure and habitat requirements.
3. To provide advice for conservation and management

The survey has shown that *V. angustior* is more widely distributed at Flordon Common than was previously known. It occurs in two main areas at the north-west and south-east parts of the site. The distribution of the snail coincides with the distribution and extent of suitable habitat, occurring mainly in damp, herb-rich fen particularly with *Iris*, *Eupatorium*, *Pulicaria* and mosses. It is absent from the wetter areas and open, grazed grassland. The mean number of *V. angustior* individuals per sample in the favourable habitat was 68.1, which is equivalent to a density of approximately $340m^{-2}$. However, the distribution and abundance was uneven with densities ranging from 5-1100 individuals m^{-2}. The variation is believed to be an effect of small-scale difference in ground moisture and topography, soil and vegetation structure and composition.

Semi-quantitative and quantitative methods have been assessed. The semi-quantitative method is suitable for obtaining reliable data on the species' presence/absence, relative abundance and population structure. Quantitative methods provide more precise information on the distribution within the smaller areas of habitat although they are more prone to error or misinterpretation. Therefore, semi-quantitative sampling is recommended

as being the more simple to carry out and as providing the most reliable data. The Monitoring Protocol is designed on this basis.

The results of the present study have shown that Flordon Common supports a healthy, recruiting population of *Vertigo angustior*. However, the area occupied by the snail is small, less than two hectares, and is, therefore, vulnerable. Although the *V. angustior* population appears to be stable there are 3 potential threats:

1. Increases in grazing levels and changes to current grazing practice
2. Changes in hydrology particularly from ditch deepening or abstraction
3. Scrub encroachment

To provide further advice for management, a project is suggested to validate the observations on the relationship between *Vertigo angustior*, ground moisture levels, and soil texture and composition with actual measurements.

At Fritton Marshes pSSSI *Vertigo angustior* occurred throughout the entire length of an embayment which is unprotected by sea defences and which supports transition zone habitat of damp grassland with low growing herbs, and occasional patches of taller vegetation with *Iris* and *Carex* species. *V. angustior* was the second most frequently occurring snail species, and by far the most dominant numerically (67.8% of the total number of individual snails). The mean number of *V. angustior* per sample was 69.7, which is equivalent to an approximate density of $349m^{-2}$. However, the distribution and abundance was uneven with densities in the positive samples ranging from 5-1860 individuals m^{-2}.

Vertigo angustior is apparently thriving at Fritton and given the location of the site and character of the habitat, there appear to be few threats. Encroachment by scrub and the conifer forest may eventually cause the habitat to become too dry and shaded. At one part of the site footpaths run along the top of the transition zone and therefore human trampling may have a detrimental effect on the habitat. The following management is suggested:

1. Removal of invasive marginal scrub of rhododendron, small birch and oak.
2. Cutting back of *Rosa rugosa*
3. Occasional cutting back (strimming) of rank grass to open the vegetation and reduce the dense thatch of litter on a 2-3 yearly basis.
4. Fencing off the transition zone near the open footpaths to prevent disturbance by trampling

1. Background and objectives

The whorl snail *Vertigo angustior* is in serious decline throughout its European range (Killeen 1996). It is classified in the British Red Data Book (Bratton 1991) as RDB1 (Endangered), is listed on Annex II of the European Habitats & Species Directive, and is a priority species on the UK Biodiversity Action Plan (HMSO 1996).

Vertigo angustior is an inhabitant of moist, usually calcareous places which are affected neither by periodic desiccation nor by regular flooding (Kerney 1999). In Britain, it is known only from 8 sites: Whiteford Burrows and Oxwich Bay, south Wales; Gait Barrows, Cumbria; Flordon and Smockmill Commons, Norfolk; single sites on the Deben and Waveney estuaries, Suffolk; and White Port on the Solway coast in Scotland. The snail inhabits short vegetation with grasses, mosses and low herbs in wet, grazed meadows, coastal marshes and dune slacks, maritime turf, and depressions in limestone pavement. *V. angustior* was common in open landscapes of lowland Britain during the early Postglacial but its habitats were largely suppressed by mid-Postglacial afforestation. Some of the remaining sites may be regarded as chance survivals in places where hydrology and vegetational cover have remained largely unchanged from earlier times (Kerney 1999).

The principal objectives of this study are:

Flordon Common SAC

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2. Flordon Common

Vertigo angustior was first discovered living at Flordon Common in 1972 (Norris & Colville 1974), although examples of dead shells had been recorded before ((Burrell & Clarke 1910; Ellis 1951). Norris & Colville (1974) reported the species as common in marshy grassland in a low-lying area adjacent to the road hedgebank. A survey in 1996 confirmed that the species survived at the site but no attempt was made to determine the precise distribution across the Common. A further survey in 1998 added no new information (Baker *et al* 1998).

Flordon Common SSSI is approximately 12ha in area and lies to the west of Flordon village, Norfolk (Grid Ref TM182973). The site lies on Upper Chalk overlain with Glacial drift deposits (sands, chalky boulder clay and loam). From the gate at the northern end, the land slopes gently towards the south and is intersected by a series of parallel ditches which in a NW/SE direction to a small tributary of the River Tas at the southern boundary.

The site has a long history of management. In the last 30 years it has been maintained by light, mixed livestock grazing (ponies, donkeys, geese and ducks). In more recent years this has been supplemented with 4-5 cattle. Management from 1998 has also included removal of trees and scrub from some of the wetter areas.

2.1 Methodology

The sampling strategy and recording procedure were designed to provide detailed information on the distribution, abundance and ecology of *Vertigo angustior* at Flordon Common. In order to provide baseline data and enable comparisons to be made, the methods used are similar to previous surveys and current monitoring projects (e.g. Killeen 1997; Sharland 2000).

Field searching is time consuming and sieving is generally ineffective owing to the high water content of the vegetation. In any case, such information merely indicates a species presence within a site and provides no details of species' abundance or population structure. This method was not considered to have any useful application for sampling within the SAC and was not pursued.

2.1.1 Semi-quantitative samples

Samples were collected from a range of suitable *V. angustior* habitat across the Common to determine the snail's distribution at the site. At each selected site, a sample of live and dead plant material was collected from an area of approximately 3m x 3m. Moss and dead vegetation, and loose soil at the interface were collected from the base of plants such as *Iris* and *Eupatorium*. In areas dominated by sward, vegetation was cut at ground level using a sharp knife with a serrated blade and by plucking material from the tussocks and turf. This yielded a sample from suitable *V. angustior* habitat of approximately 4 litres loose volume, which is estimated to represent material collected from a total area equivalent to 0.2 m^2.

Forty seven samples were collected. The locations are shown on the map Figure 1. General descriptions of the flora and environment for each principal habitat type are given in Section 3.

2.1.2 Quantitative samples

Once the distribution of *V. angustior* had been determined by the semi-quantitative sampling, the area with the core of the population was selected for a quantitative study to determine more precisely the species' distribution and to provide baseline data for future monitoring.

A transect line was measured out along the entire length of the *Iris* transition zone adjacent to the hedgebank along the north-west boundary of the Common, and marked at 10m intervals with garden canes. Samples were taken by collecting al loose plant material, moss and dead leaves (plus associated friable soil) from a quadrat area measuring 25cm x 25cm ($0.0625\ m^2$).

At some of the measured sample points there was no suitable habitat or the ground was too heavily trampled and therefore the marker was moved up to 1m to allow the most suitable habitat to be sampled. At each location 2 replicate samples were taken.

Seventeen locations labelled A-Q were sampled (34 individual samples) along a linear transect. In addition, three further locations (N1-N3) were samples across the habitat zone at 90° from location N. Locations of the sample points are shown on the map Figure 2. The habitat throughout the zone is generally similar and was not detailed for individual sample points.

2.1.3 Soil moisture and characterisation

The results from the semi-quantitative sampling revealed that *Vertigo angustior* occurred most frequently in areas of damp, rather than permanently wet habitat. To substantiate this observation, samples of soil were collected at each of the quantitative sample on points in the transect area. A core of soil was collected to a depth of approximately 10cm using a narrow trowel. This resulted in a sample of approximately 200g wet weight. Each sample was weighed wet, then broken up and spread on kitchen foil and oven dried at 105°C to constant weight. The moisture levels expressed as %wt/wt wet basis are shown in Table 8. A visual assessment of the texture and composition of each soil sample was also made.

Figure 1 Flordon Common - Location of semi-quantitative samples

Figure 2 Flordon Common - Location of quantitative samples

2.1.4 Sample analysis

The resultant samples of vegetation collected by the above methods were subjected to the same treatment. The vegetative material was teased apart and spread on sheets of newspaper to dry. This was then shaken over a 5 mm sieve to remove the bulk of the plant material but to allow all molluscs to pass through. The residue was passed over a graded stack of sieves. and examined microscopically. All molluscs retained by a 0.5 mm sieve were picked out and counted. Specimens of *Vertigo angustior* with a developed lip and/or apertural teeth were recorded as adults and all others as juveniles. All other mollusc species were also picked out and counted.

2.1.5 Timing

The work was carried out in two phases during June and September 2000:

10-12 June: Wide-ranging survey using semi-quantitative sampling method
13-14 September: Quantitative transect

2.1.6 Voucher material

All molluscan material has been retained in the collections of I.J. Killeen until completion of the project. It is proposed to deposit the specimens of *Vertigo angustior* collected during this survey in the collections of the National Museum of Wales, Cardiff.

2.2 Site selection and habitat

Flordon Common supports a range of wetland habitats: *Iris* marsh, open grassland, spring-fed fen, and areas of scrub and woodland. The sampling focused principally on habitat which was considered suitable for *Vertigo angustior;* however, to obtain an accurate picture of the snail's distribution on the Common, some areas with less suitable habitat were also sampled. Areas supporting only woodland or dense scrub were excluded.

Following the NVC classification map for the site (English Nature, Norwich 1993), samples for *Vertigo angustior* were taken from the principal habitat types described in Table 1.

Table 1 Description of habitat types

Habitat	NVC type	Description
A	M27b *Filipendula ulmaria - Angelica sylvestris* tall herb fen. *Urtica dioica - Vicia cracca* sub-comm. M22a *Juncus subnodulosus - Cirsium palustre* fen meadow. M22a/M27b Transition and Mosaic.	More or less continuous zone of damp to wet, tall herb fen, running parallel with the road hedgebank. The vegetation is dominated by *Iris pseudacorus* with *Pulicaria dysenterica, Ranunculus repens & acris,* grasses, *Mentha aquatica, Plantago lanceolata, Trifolium pratense, Lotus uliginosus, Potentilla anserina* etc. Mosses include *Brachythecium rutubulum, Calliergonella cuspidata.* Wetter depressions with *Filipendula ulmaria* and *Juncus subnodulosus. Eupatorium cannabinum* on higher ground. Ground trampled by livestock.
B	Transition and mosaic M27b/M22a/M24b/M24a	Mostly wet, grazed grassland with small patches of *Iris* and associated plants listed above. Mosses include *Brachythecium rutubulum, Calliergonella cuspidata.*
C	Mostly 24a *Eupatorium cannabinum* sub comm. with patchy mosaic of M24b/M22a/M27b.	Generally higher ground than for Habitat A. Dominated by *Eupatorium* with occasional shading from trees and scrub. Mosses include *Brachythecium rutubulum, Calliergonella cuspidata* & *Eurhynchium praelongum..* Samples sites 35 & 40 lie in an area from where trees and scrub have only been recently cleared.
D	M13c *Schoenus nigricans - Juncus subnodulosus* mire, *Caltha palustris - Galium uliginosum* sub-comm.	Permanently wet area with springs (some tufa depositing) and pools of standing water throughout. Sward, mostly <0.3m high with *Schoenus, Juncus,* sedges (*Carex viridula, C. panicea*), mosses including Mosses include *B. rutubulum, C. cuspidata, Campylium stellatum, Ctenidium molluscum, Fissidens adiantoides.* Occasional drier mounds with scrub, *Iris, Eupatorium.*
E	M24b *Molinia caerulea - Cirsium dissectum* fen meadow.	Very heavily grazed grassland sward, mostly <0.1m tall.
F	-	Shaded sites. Site 22 under hawthorn hedge with mosses *Brachythecium rutubulum* & *Eurhynchium praelongum.* Site 45 along path in woodland glade with grasses and *Iris.*

2.3 Results

2.3.1 Distribution in the SAC

The results of the molluscan analysis of the 47 semi-quantitative samples are shown in Tables 2 and 3. Table 2 gives the results grouped into habitat types and Table 3 gives them in numerical site order.

Table 2 Flordon Common - Results from semi-quantitative samples

	Habitat A														Habitat B						
Sample No.	8	9	10	47	11	12	39	14	16	17	18	19	20	21	3	4	5	6	7	27	38
Mollusc species																					
Vertigo angustior ADULT	45	65	119	31	80	59	16	40	87	14	3	62	1	16	4				7	5	
Vertigo angustior JUVENILE	35	30	101	17	28	17	7	8	30	3		31		9						1	
Carychium minimum		4					29		10	3	1	17	22		7	37	8	1	1	1	
Carychium tridentatum	130	122	175	98	153	58	119	98	185	26	10	131	3	116	1			1	16	17	
Succinea putris		2	4	6	2	3	7	1				3	1	3		2		1	3		
Cochlicopa lubrica	1	15	9	16	12	6	6	4	17	6		6	6	2	5	17	8	6	8	3	4
Cochlicopa lubricella																					
Columella edentula		8	11	3	31	2		6	6	1											
Vertigo substriata	5	18	15	8	2	4	4	1													
Vertigo pygmaea	6		6	2	7	2		9	5	1		3	2	4	9	5	3		2	1	1
Vertigo antivertigo							2														
Lauria cylindracea	1	2	10	6		7													2		
Vallonia costata	6	9	13	14	19	4	1	7	42	4		10	1	34				1			3
Vallonia pulchella/excentrica											1			2			2		10		2
Acanthinula aculeata		1	3	2	5			1		1				1							
Punctum pygmaeum	6	5	6	9	8	1	12	10	7	4		8	1	42						1	
Discus rotundatus				3									4								
Vitrina pellucida																					
Vitrea contracta					3										1						
Vitrea crystallina	1	3		2	2			2				1				4	1	4	2		
Nesovitrea hammonis	2	2		1	3	1	5	3		1			12			2		3	1	2	
Aegopinella pura		1	1	1	4				1				2			1					
Aegopinella nitidula																					
Oxychilus alliarius																					
Zonitoides nitidus																3					
Euconulus alderi		4	4	6	10	5	21			5		1	12		3	13			1	3	
Clausilia bidentata			1	2			1														
Trichia plebeia		1	5	9	3	2	8	5	1	1	1	1		3	2			3	2		4
Arianta arbustorum																					
Cepaea nemoralis				1									1								
No of species	10	16	15	19	16	13	13	13	10	12	5	11	13	10	8	9	5	8	12	8	5
Total No of snails	238	292	704	237	372	171	228	195	391	70	16	274	68	230	32	84	22	20	55	34	14

Table 2 continued: Flordon Common - Results from semi-quantitative samples

	Habitat C										Habitat D								Habitat E					Hab F	
Sample No.	1	2	15	24	30	35	40	43	44	46	13	29	31	32	33	34	36	41	23	26	28	37	42	22	45
Mollusc species																									
Vertigo angustior ADULT	4	1	4	7	8	72	19			3						4	1								
Vertigo angustior JUVENILE	10		2	2	3	31	6			1							1								
Carychium minimum	24	1	17			4	11		2		1	33	17		3	3	17	5			4	2	3		
Carychium tridentatum	104	81	10	58	17	91	13	4	3	76	19	6	4	1	2	9	6							9	59
Succinea putris	4	4		1			3		2	15			1	1				2					2		4
Cochlicopa lubrica	10	3		6	3	24	3	3	4	10	2	2			1	4	10			1	1	7	1	8	16
Cochlicopa lubricella																			1					2	
Columella edentula	5	2										1	3	1		2									
Vertigo substriata			1			11	2									1									1
Vertigo pygmaea	2	1	9	4	10	10	8		2	4	6		11		6	2	13	7	2	1	5	10	4		
Vertigo antivertigo																						1			
Lauria cylindracea	15	4						2		7															13
Vallonia costata		3		9		6		1		21														1	
Vallonia pulchella/ excentrica		1					1										11	4	4	4	4	28	13	9	
Acanthinula aculeata						3					2														4
Punctum pygmaeum	5	2				2	1	3	3	4	3	2	2	2		1		3	1		2		1		6
Discus rotundatus	7	7			2				2			1	1	1		5									9
Vitrina pellucida		2																							
Vitrea contracta		1																						1	
Vitrea crystallina	11	4		10	2	3		2	4		3	4	9	4	1	4		3					3		
Nesovitrea hammonis	3	1	2	2	2	2	2		3	7	1	3	2	1		4	1	1			1			3	2
Aegopinella pura	1	1		4				2	1		2								1					1	
Aegopinella nitidula																									1
Oxychilus alliarius																1								1	
Zonitoides nitidus												2													
Euconulus alderi	2		6		1		4			3		6	3			2		2							
Clausilia bidentata	3							2		4						1									8
Trichia plebeia	3			7		2	1		1	18							1					4	2		12
Arianta arbustorum	1									3															
Cepaea nemoralis				2								1		2											
No of species	17	17	7	12	8	12	12	8	11	13	9	11	10	8	5	14	8	8	5	3	6	6	8	9	12
Total No of snails	214	120	51	112	48	261	74	19	27	177	39	61	53	13	13	43	61	27	9	6	17	52	27	35	135

Table 3 Flordon Common - Results from quantitative samples (in numerical sample order)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Vertigo angustior ADULT	4	1	4				7	45	65	119	80	59		40	4	87	14	3	62	1	16	
Vertigo angustior JUVENILE	10							35	30	101	28	17		8	2	30	3		31		9	
Carychium minimum	54	1	7	37	8	1	1		4				1		17	10	3	1	17	22		
Carychium tridentatum	74	81	1			1	16	130	122	175	153	58	19	98	10	185	26	10	131	3	116	9
Succinea putris	4	4		2		1	3		2	4	2	3		1					3	1	3	
Cochlicopa lubrica	10	3	5	17	8	6	8	1	15	9	12	6	2	4		17	6		6	6	2	8
Cochlicopa lubricella																						2
Columella edentula	5	2							8	11	31	2		6		6	1					
Vertigo substriata								5	18	15	2	4		1	1							
Vertigo pygmaea	2	1	9	5	3		2	6		6	7	2	6	9	9	5	1		3	2	4	
Vertigo antivertigo																						
Lauria cylindracea	15	4					2	1	2	10		7										
Vallonia costata		3				1		6	9	13	19	4		7		42	4		10	1	34	1
Vallonia pulchella/excentrica		1			2		10											1			2	9
Acanthinula aculeata									1	3	5		2	1			1				1	
Punctum pygmaeum	5	2						6	5	6	8	1	3	10		7	4		8	1	42	
Discus rotundatus	7	7																		4		
Vitrina pellucida		2																				
Vitrea contracta		1	1								3											1
Vitrea crystallina	11	4		4	1	4	2	1	3		2		3	2					1			
Nesovitrea hammonis	3	1		2		3	1	2	2		3	1	1	3	2		1			12		3
Aegopinella pura	1	1		1					1	1	4		2			1				2		1
Aegopinella nitidula																						
Oxychilus alliarius																						1
Zonitoides nitidus				3																		
Euconulus alderi	2		3	13			1		4	4	10	5			6		5		1	12		
Clausilia bidentata	3									1												
Trichia plebeia	3		2			3	2		1	5	3	2		5		1	1	1	1		3	
Arianta arbustorum	1																					
Cepaea nemoralis																				1		
No of species	17	17	8	9	5	8	12	10	16	15	16	13	9	13	7	10	12	5	11	13	10	9
Total No of snails	214	120	32	84	22	20	55	238	292	704	372	171	39	195	51	391	70	16	274	68	230	35

Previous studies of Flordon Common suggested that *Vertigo angustior* was confined to the area of *Iris* marsh at the northern end of the site. The results of this survey show that it is more widely distributed. The distribution categorised by areas of high moderate to low density, or individual sites is shown in Figure 3. *V. angustior* occurs more or less continuously in a wide zone along the entire length of the site adjacent to the road hedgebank forming the north-west boundary of the site, and for some distance down the gladed path on the southern boundary. It was also found in a zone along the fence/ditch line towards the south-eastern part of the site, and occasionally from samples elsewhere. The distribution of the snail coincides with the distribution and extent of favourable habitat. A summary of the results from each habitat type is shown in Table 4 below:

Table 4 Results from semi-quantitative samples grouped by habitat

Area	A	B	C	D	E	F
No. of samples	14	7	10	8	5	2
Vertigo angustior						
No of positive samples	14	3	8	2	0	0
Total No. of individuals	954	17	173	6	-	-
Mean No./sample	68.1	2.43	17.3	0.75	-	-
Range	1-220	0-7	0-103	0-4	-	-
All snails						
Total No. of individuals	3486	261	1103	310	111	170
Mean No./sample	249	37.3	110	38.7	22.2	85
Range	16-704	14-84	19-261	13-61	6-52	35-135
Total No. of snail species	22	17	24	21	12	18
Mean No./sample	12.6	7.86	11.7	9.12	5.6	10.5
Range	5-19	5-12	8-17	5-11	3-8	9-12

Specimens of *V. angustior* were retrieved from 27 of the 47 samples. Fourteen of these (52%) were from sites within Habitat Type A - damp, *Iris* dominated marsh. The mean number of individuals per sample was 68.1, which is equivalent to a density of approximately $340m^{-2}$. However, the distribution and abundance was uneven with densities ranging from 5-1100 individuals m^{-2}. The high values compare well with previous results from Flordon (Killeen 1997) or at Whiteford Burrows (Sharland 2000). Habitat A also supported a high diversity of other snail species and the highest numbers of all snails per sample.

Habitat B is mainly wet, grazed grassland with only small, fragmented patches of *Iris* and herb vegetation. *V. angustior* was found in only 3 of the 7 samples and occurred in very low numbers, the richest sample containing 7 individuals (equivalent to $35m^{-2}$). *V. angustior* was found in 8 of the 10 samples from Habitat C - damp grassland dominated by herbs, particularly *Eupatorium*. The mean number of individuals per sample was 17.3, equivalent to a density of approximately $86m^{-2}$. However, the means are elevated by sample 35 which contained 103 individuals (equivalent to $515m^{-2}$).

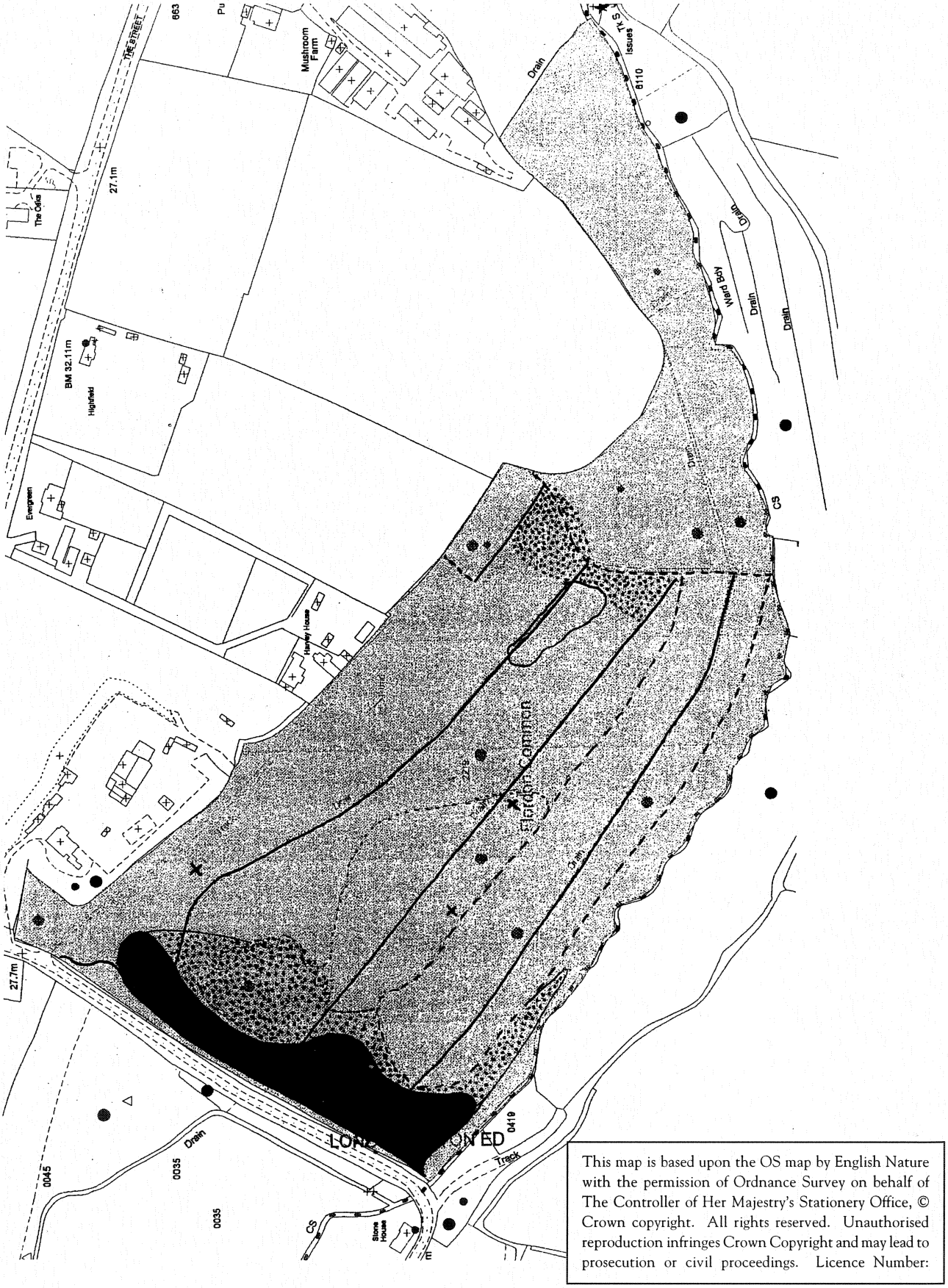

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Figure 3 Flordon Common - Density of *Vertigo angustior* population

V. *angustior* was either very rare or absent from the two open habitats of wet fen or fen meadow (D and E). Habitat C comprises permanently wet, spring fed fen and sward, and V. *angustior* was found only in very low numbers (total 6) from two small areas where there were slightly higher mounds with *Iris/Eupatorium*/herb vegetation. The snail was absent in the fen meadow Habitat E which is heavily grazed and provides no suitable habitat. It was also absent from the 2 samples in drier, heavily shaded sites (Habitat F).

2.3.2 Molluscan composition

Examination of the molluscan species composition and abundance in each habitat type shows a strong correlation between the presence/absence of *V. angustior* and some other snail species (Table 5).

Table 5 Molluscan composition of samples grouped by Habitat Type

(s-q = semi-quantitative samples, q = quantitative samples)

	Species composition %						
Habitat Type	**A s-q**	**A q**	**C**	**B**	**D**	**E**	**F**
Vertigo angustior	27.3	17.4	17.3	6.5	0.75	0	0
Carychium tridentatum	40.8	40.2	41.4	13.4	15.2	0	40.0
Vallonia costata	4.70	5.65	3.63	1.53	0	0	0.59
Vertigo substriata	1.63	2.85	1.27	0	0.32	0	0.59
Carychium minimum	2.47	5.94	5.35	21.1	25.5	8.1	0
Vallonia excentrica/pulchella	0.09	0.64	0.18	5.36	4.84	47.7	5.30
Vertigo pygmaea	1.35	0.70	4.53	8.05	14.5	19.8	0
Vitrea crystallina	0.31	0.41	3.26	4.21	9.03	2.70	0
Other species	21.35	26.21	23.08	39.85	29.86	21.70	53.52
	100	100	100	100	100	100	100

In the most favourable habitat *V. angustior* is a significant component of the molluscan fauna in terms of numbers of individuals. In Flordon Habitat A, *V. angustior* comprised 27.3% and 17.4% of the fauna, although in some individual samples e.g. sample P, this was as high as 40%. A value of 39.4% was obtained in sample 35 from Habitat C. These high component % compare well with other *V. angustior* sites (e.g. Fritton, Gait Barrows, White Port and Whiteford Burrows).

The most dominant snail numerically in the richest *V. angustior* habitat (A and C) is *Carychium tridentatum*, which comprises approximately 40% of the individual snails. The other significant associate, although occurring in much lower numbers, is *Vallonia costata*. *C. tridentatum* is found typically in moist, well-drained, well-vegetated habitats usually on calcareous soils (Kerney 1999). *V. costata* also favours calcareous, well-drained soils but usually occurs in less shaded habitats. At Flordon *Vertigo substriata* also appears to be a coincidental associate. *V. pygmaea* also occurs in low numbers in many samples, but generally the habitat is too shaded.

The molluscan fauna of less favourable *V. angustior* Habitats B and D show a transition from damp to wetland species composition. *Carychium tridentatum* is replaced by *C. minimum* and *Vallonia costata* replaced by *V. pulchella*. *Vertigo substriata* disappears whereas *V. pygmaea*

increases significantly, along with *Vitrea crystallina*. In Habitat E, the fauna is dominated by the species typical of open, damp grassland, *Vertigo pygmaea* and *Vallonia pulchella*.

2.3.3 Transects

The results of the molluscan analysis of the Transect samples are shown in Tables 6 and 7. Table 6 gives the combined results from the 2 replicate quadrat samples at each site, and Table 7 shows the results of the individual replicates.

Although *Vertigo angustior* was found at every sample site, the distribution and abundance varies considerably. The numbers of individuals from the 2 combined replicate samples along the transect from NE to SW is shown in Figure 4 (note - Site N3 has been excluded as it lies on the very wet *Schoenus* fen transition):

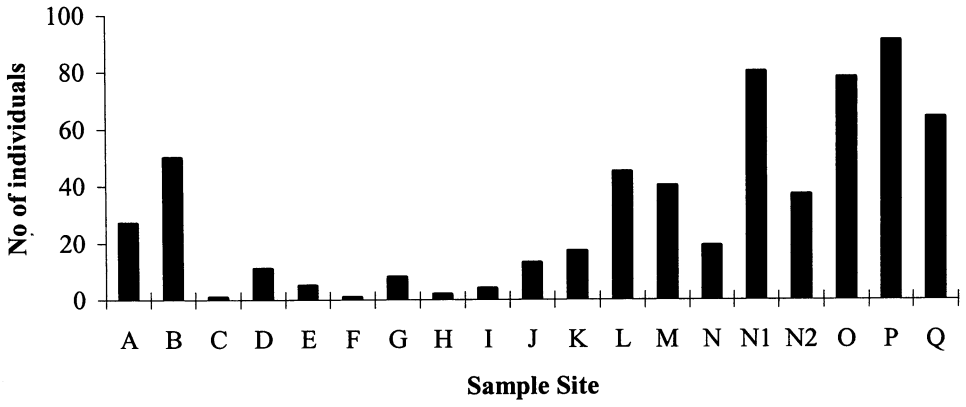

Figure 4 Distribution of V. *angustior* along the transect

Table 6 Flordon Common - Results from quantitative samples (2 replicates combined)

Sample No.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	N1	N2	N3	O	P	Q
Mollusc species																				
Vertigo angustior ADULT	16	37	1	7	3		3	1	3	6	10	30	21	14	39	33	3	45	61	35
Vertigo angustior JUVENILE	11	13	-	4	2	1	5	1	1	7	7	15	19	5	41	4	-	33	30	29
Carychium minimum	14	18	2		23	44	52		13	14						5	12	1	2	5
Carychium tridentatum	205	192	83	86	3	4	30	24	59	46	31	35	55	55	98	44	1	84	158	88
Succinea putris	26	33		6	11	8	28	3	18	26	3	18	29	12	26	13	5	9	24	9
Cochlicopa lubrica	8	16	16	19	18	7	13	4	7	13	8	15	11	10	14	8	5	8	8	15
Columella edentula							1	4	1	1	4	9			5	1		2	1	3
Vertigo substriata				1	2		9		4	6	1	16	4	2	11	4	2		26	10
Vertigo pygmaea				3		2			1	3	3		1	2				9		
Vertigo antivertigo					7	2	1													
Lauria cylindracea							3	3					4	1	3	1			11	2
Vallonia costata	30	18	7	18	1	2	8	2	3		2	4	7	8	5	8		15	36	20
Vallonia pulchella/excentrica				2	3	17														
Acanthinula aculeata				5						1	2		1	1		1				
Punctum pygmaeum	4	5	2	11	1	1	11		7	2		7	6	1	8			9	1	3
Discus rotundatus								2	1											
Vitrea crystallina				2								1		1	1	2	2		1	4
Nesovitrea hammonis	1	1	10	1	2	3		1	1	1	4	3		2	6	2	4	1	4	4
Aegopinella pura	2	1	2				1	2		1					2				5	
Aegopinella nitidula			1																	
Zonitoides nitidus																			4	
Euconulus alderi	8	10	3	5	11	13	21		11	13	7	5	1	3	10	5	1	8	13	9
Clausilia bidentata							2			1				1						
Trichia plebeia	9	6	1	2	2	1	10	1	10	4	8	9	4	3	4	4		3	2	2
Cepaea nemoralis		1		2			1												2	1
No of species	11	12	11	15	13	13	16	11	14	15	12	12	12	15	14	14	9	12	17	16
Total No. of snails	334	351	128	174	89	105	199	48	140	145	90	167	163	121	253	135	35	227	289	239

Table 7 Flordon Common - Results from quantitative samples - Individual replicate analysis

Site	A		B		C		D		E		F		G		H		I		J	
Replicate	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Species																				
Vertigo angustior ADULT	13	3	12	25	1		3	4	3				2	1		1	2	1	4	2
Vertigo angustior JUVENILES	4	7	6	7				4	2			1	5			1	1		6	1
Carychium minimum	2	12	12	6		2			1	22	30	14	14	38			2	11	3	11
Carychium tridentatum	140	65	94	98	59	24	21	65	3			4	24	6	4	20	38	21	36	10
Succinea putris	10	16	21	12			3	3	4	7	1	7	19	9	3		12	6	14	12
Cochlicopa lubrica	6	2	11	5	13	3	6	13	9	9	1	6	6	7		4	2	5	8	5
Columella edentula													1			4	1			1
Vertigo substriata								1		2			8	1			2	2	5	1
Vertigo pygmaea								3			2							1		3
Vertigo antivertigo										7	2			1						
Lauria cylindracea													3			3				
Vallonia costata	21	9	7	11	7		5	13	1			2	6	2		2	3			
Vallonia pulchella/excentrica							2			3	14	3								
Acanthinula aculeata								5											1	
Punctum pygmaeum	2	2	4	1		2	8	3		1	1		2	9			5	2	2	
Discus rotundatus															2			1		
Vitrea crystallina							2													
Nesovitrea hammonis		1	1		2	8	1			2	1	2			1			1		1
Aegopinella pura	2			1	2								1		2				1	
Aegopinella nitidula					1															
Zonitoides nitidus																				
Euconulus alderi	3	5	7	3	1	2	4	1	2	9	9	4	8	13			3	8	4	9
Clausilia bidentata													2						1	
Trichia plebeia	7	2		6	1			2	2			1	9	1		1	8	2	4	
Cepaea nemoralis				1			2						1							
No of species	10	10	9	11	9	6	11	11	8	9	9	10	15	11	5	7	11	12	12	10
Total No. of snails	210	124	175	176	87	41	57	117	27	62	61	44	111	89	12	36	79	61	89	56

Table 7 continued: Flordon Common - Results from quantitative samples - Individual replicate analysis

Site	K		L		M		N		N1		N2		N3		O		P		Q	
Replicate	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Species																				
Vertigo angustior ADULT	5	5	20	10	16	5	2	12	18	21	29	4	3		30	15	24	37	20	15
Vertigo angustior JUVENILES	6	1	6	9	8	11		5	28	13	4				12	21	6	24	22	7
Carychium minimum												5	1	11		1	2			5
Carychium tridentatum	18	13	19	16	33	22	14	41	63	35	33	11	1		50	34	60	98	60	28
Succinea putris		3	10	8	13	16	3	9	13	13	3	10	1	4	6	3	9	15	4	5
Cochlicopa lubrica	2	6	5	10	4	7	8	2	9	5	6	2	1	4	4	4	6	2	12	3
Columella edentula	1	3	3	6					5		1					2		1	3	
Vertigo substriata	1		12	4	4			2	9	2	3	1	2				8	17	8	2
Vertigo pygmaea		3				1		2							2	7				
Vertigo antivertigo																				
Lauria cylindracea					3	1		1	3		1						7	4	2	
Vallonia costata	2		4		5	2		8	4	1	8				6	9	20	16	16	4
Vallonia pulchella/excentrica																				
Acanthinula aculeata	2					1		1			1									
Punctum pygmaeum			1	6	5	1	1		6	2					6	3		1		3
Discus rotundatus																				
Vitrea crystallina				1			1		1			2		2				1	1	3
Nesovitrea hammonis	1	3	1	2				2	5	1		2	1	3		1	2	2		4
Aegopinella pura									2									5		
Aegopinella nitidula																	4			
Zonitoides nitidus																				
Euconulus alderi	5	2	1	4		1	3		3	7		5		1	2	6	9	5	3	6
Clausilia bidentata								1												
Trichia plebeia	6	2	7	2	4			3	4		4				3			2	2	
Cepaea nemoralis																		2	1	
No of species	10	9	11	11	9	10	7	12	14	9	10	9	7	6	9	11	11	15	12	11
Total No. of snails	49	41	89	78	95	68	32	89	173	80	93	42	10	25	121	106	157	232	154	85

This graph indicates that *V. angustior* is more abundant at the northern and southern ends of the zone. This to some extent follows the differences in topography along the transect line. The ground slopes gently from the north end from site A down to the ditch at site C. Between the 2 main ditches (sites D to J) the ground is relatively flat, but then gently rises again from site K to Q. This suggests there are differences in soil moistures or drainage which affects the distribution of *V. angustior* within habitat, which on the basis of its vegetation, appears suitable. The associated mollusc fauna also indicates a wetter environment with the lower lying area supporting a higher proportion of wetland species (*Carychium minimum, Vertigo antivertigo, Vallonia pulchella*). However, these inferred differences are not revealed by the measured soil moisture levels (Table 8).

Samples with high *V. angustior* numbers had a mean moisture of 63.4% (range 50 - 70.6) and those with low numbers (excluding site H) a mean of 64.9% (range 54.9 - 81). The samples were taken following a period of moderate rainfall which may have given higher and/or more similar values. In any case, measurements over a longer period of time would be required to detect any significant differences. The visual assessments of the soil shows differences in texture and composition . The soils on the slopes at the north and south areas have a higher content of grit or chalky pellets and coincide with high *V. angustior* numbers, whereas the soils in the central part appear muddier with a higher humus content and coincide with lower *V. angustior* numbers. These grittier soils are likely to drain more freely and would be less susceptible to inundation during periods of high rainfall.

Table 8 Soil moisture levels and composition

Sample	Moisture %wt/wt wet basis	Soil type
A	62.7	Loam with grit
B	68.9	Loam with grit
C	55.4	Muddy, gritty, humus-rich
D	54.9	Muddy, gritty, humus-rich
E	66.3	Muddy, humus-rich
F	71.3	Muddy, humus-rich
G	66.4	Loam with grit
H	44.6	Loam with high grit content
I	68.9	Muddy, humus-rich
J	55.1	Muddy, humus-rich
K	64.6	Loam with humus, grit and chalk pellets
L	62.8	Loam with humus, grit and chalk pellets
M	56.7	Loam with humus, grit and chalk pellets
N	50.0	Loam with humus, grit and chalk pellets
N1	70.3	Loam with humus, grit and chalk pellets
N2	67.3	Loam with humus, grit and chalk pellets
N3	81.0	Mud
O	57.5	Loam with grit and chalk pellets
P	66.5	Loam with grit and chalk pellets
Q	70.6	Loam with high grit and chalk pellet content

2.3.4 Evaluation of methods

A summary of the molluscan analysis from the semi-quantitative (sq) and quantitative (q) samples from habitat A is shown in Table 9. The numbers from the combined replicates need to be multiplied by 1.6 (shown in parentheses) to allow a comparison with the semi-quantitative samples.:

Table 9 Comparison of Habitat A samples

(s-q = semi-quantitative, q = quantitative 2 replicates combined, qr = individual replicates)

Area	A s-q ($0.2m^2$)	A q ($0.125m^2$)	A qr ($0.0625m^2$)
No. of samples	14	20	40
Vertigo angustior			
No of positive samples	14	20	35
Total No. of individuals	954	596 (954)	596
Mean No./sample	109	29.8 (47.7)	14.9
Range	1-220	1-91 (2-146)	0-61
All snails			
Total No. of individuals	3486	3432 (5491)	3432
Mean No./sample	249	172 (275)	86
Range	16-704	35-351 (56-562)	10-232
Total No. of snail species	22	24	24
Mean No./sample	12.6	13.2	10.0
Range	5-19	9-17	5-15

A direct comparison of these data is not possible as the sample size of the semi-quantitative samples is only estimated to be $0.2m^2$ and there is a greater likelihood that only the most suitable material will be collected. However, in general terms, average numbers of *V. angustior* were higher (double) in the semi-quantitative samples but mean numbers of all snails were very similar. Mollusc species composition and mean number of species per sample were also similar.

Relatively larger differences occur in the quantitative samples between individual replicates at some sample sites (see Table 7), although this may in part be due to differences in the amount of moss and litter within the chosen quadrat area. Numbers of *V. angustior* and all snails, and species composition in some replicates compare well (e.g. B and L). In general the higher the *V. angustior* component, the more similarity between replicates. However, even in these samples, there are differences in composition and numbers of individuals of other snail species (e.g. N1, P and Q). The differences between some samples with very low numbers of *V. angustior* (e.g. E and H) could lead to the conclusion that they came from different habitats (although not the case).

Both methods are minimally destructive and are considered suitable for monitoring *Vertigo angustior* at Flordon Common. The semi-quantitative method is suitable for obtaining reliable data on the species' presence/absence, relative abundance and population structure. It also allows a wide area to be covered and the most suitable habitat to be sampled.

Quantitative methods provide more precise information on the distribution within the smaller areas of habitat. However, there are a number of potential problems. More samples need to be taken, a greater selectivity is required to avoid choosing unsuitable or sparse habitat, their small size may yield results which are unreliable or more open to misinterpretation. Therefore, semi-quantitative sampling is recommended as being the more simple to carry out and as providing the most reliable data. The Monitoring Protocol (Section 2.5) is designed on this basis.

2.3.5 *Vertigo angustior* Population Structure

On both sampling occasions (June and September 2000) the *V. angustior* population at Flordon comprised higher numbers of adults than juveniles. In June the ratio was 2.08:1 and by September had increased to 2.61:1. In November 1996 the ratio was 1.98:1 (Killeen 1997). In contrast, the population from Fritton Marshes in June 2000 comprised a higher number of juveniles (ratio 0.68:1). Although no attempt was made the measure the juveniles, the higher proportion of juveniles at both sites in June suggests that breeding occurs in spring/early summer. However, these limited data should be interpreted with caution. Adult/juvenile ratios from other recently studied British *V. angustior* populations are shown in Table 10:

Table 10 Adult/juvenile ratios in British *V. angustior* populations

Site	Date	Ratio Adult:Juvenile	Reference
Flordon	June 2000	2.08	
Flordon	Sept 2000	2.61	
Flordon	November 1996	1.98	Killeen 1997
Fritton	June 2000	0.68	
Gait Barrows	Oct 1996	5.68	Killeen 1998
Gait Barrows	Oct 1998	0.58	Killeen 1998
White Port (Solway)	November 1999	2.40	Killeen & Colville 2000
Whiteford	June 1998	3.76	Sharland 2000
Whiteford	November 1998	0.47	Sharland 2000
Whiteford	June 1999	1.70	Sharland 2000
Whiteford	October 1999	0.64	Sharland 2000

Whilst it should not be expected that populations which cover a wide geographical area should have a similar life cycle, these data show variation between sites and significant differences at the same site between years (e.g Gait Barrows in October 1996 and 1998). Sharland (2000) has provided the most detailed information on the snail's life cycle by monthly monitoring the *V. angustior* population at Whiteford Burrows on the Gower. She found a broadly similar pattern over a 2 year period from 1998-99 with high proportions of adults in June and July 1998 and higher numbers of juveniles from August through to March 1999. From April through to August 1999 adults outnumbered juveniles. Based upon this information it appears that the snail's life cycle at Flordon (and Fritton) is different from that at Whiteford although a longer term study would be required to substantiate this inference.

2.4 Conservation and Management

The results of the present study have shown that Flordon Common supports a healthy, recruiting population of *Vertigo angustior*. However, the area occupied by the snail is small, less than two hectares, and is, therefore, vulnerable.

Although the *V. angustior* population appears to be stable there are 3 potential threats:

1. Increases in grazing levels and changes to current grazing practice
2. Changes in hydrology particularly from ditch deepening or abstraction
3. Scrub encroachment

It is strongly recommended that the present low level of mixed grazing is not altered. Within the area of highest snail density (along the north-west margin), the vegetation does not appear to be over-grazed, however, there is considerable damage to the ground structure by trampling. The effect is to create deeper holes and depressions which are wetter and possibly less favourable to *V. angustior*. A possible option is to exclude livestock by electric fencing for a part of the year, particularly when the snail is most active and breeding (?May to August).

Altering the hydrological conditions by deepening the ditches or abstraction is to be avoided. Whilst this may result in some parts of the site becoming drier and possibly more favourable for *V. angustior*, it would have a knock-on effect of over-draining the currently richest areas for the snail.

Over the last few years a programme of scrub clearance from the north-western part of the site has been instigated and continuation of the clearance programme is recommended. This opens up habitat which may be too shaded or dry for *V. angustior* and should allow more suitable habitat to develop and the snail population to expand. Ideally the change in vegetational composition of the cleared areas, and any expansion of *V. angustior* should be monitored. A new NVC botanical survey may prove useful.

This survey has not identified a clear relationship between *Vertigo angustior*, ground moisture levels, and soil texture and composition. It is suggested that a project is initiated to explore these possible relationships with more detailed measurements which may provide further advice for management. An MSc project at the University of East Anglia may be a possibility. The transect line of the present survey would provide the ideal study area. The work could include monthly measurements of groundwater levels by installation of dip-wells, monthly measurements of surface moistures by coring, characterisation of soil (humus content, particle size analysis, pH etc), and possibly water chemistry. This would need to be supported by a one-off molluscan analysis at each sample site.

2.5 Monitoring Protocol for *Vertigo angustior* at Flordon Common

This section has been written to act as an instruction manual for monitoring the population of *Vertigo angustior* at Flordon Common. It has been designed to enable English Nature personnel and skilled volunteer biologists to carry out the sampling and analysis. A training course will need to be provided prior to monitoring.

1. Sample locations and number of sites to be sampled

The number of sites to be sampled should be at the discretion of EN but will inevitably depend on time and manpower available. However, to obtain adequate data for monitoring *Vertigo angustior* at Flordon, five sites are recommended. The sampling should be semi-quantitative within plot areas. The plot areas should be 10m x 10m and cover representative habitats with a range of *V. angustior* population densities.

1. Locate near sample sites A/B at northern end of the site (Habitat A, moderate to high density)
2. Locate near sample sites O/P/Q near south-west corner (Habitat A, high density)
3. Locate near sample sites N2/N3 at transition between Habitats A and D (moderate to low density) to determine whether *V.angustior* population expands following scrub clearance
4. Locate near sample site 35 (Habitat C, moderate density)
5. Locate near sample sites 3/4 (Habitat B, low density)

It is recommended that all of the sites should be clearly identified with permanent markers such as sturdy wooden stakes.

2. Timing and Frequency

Monitoring should be carried out at 6-yearly intervals (although ideally every 3 years). It is recommended that a more detailed survey is carried out by an independent specialist every 10-15 years. To enable comparison with the present baseline study, the samples should either be collected in June or September.

3. Sampling

Within each 10m x 10m plot, collect a sample of moss, dead vegetation, and loose soil from the base of plants such as *Iris* and *Eupatorium*. It is not necessary to collect the bottom layer of compacted soil. Collect handfuls of material from suitable habitat throughout the plot area into a tray or large plastic box until a quantity of approximately 4 litres loose volume is obtained (half a carrier bagful). Avoid collecting from places with pools of standing water of deep hoofprints. In areas with denser sward, cut the vegetation at ground level with a sharp knife with a serrated blade and/or pluck material from the tussocks and turf. Transfer the sample to a clearly labelled polythene bag (it is advisable to have a separate label inside the bag). It is also useful to record the nature of the material collected (e.g. moss and dead leaves) and take photographs of the sites.

4. Sample preparation

Spread the samples and their labels on sheets of newspaper to dry in a warm, ventilated room. Periodically tease the moss and leaf litter apart to allow faster drying and any adhering snails to drop out. When completely dry, vigorously shake the sample over a coarse mesh (c.5mm) sieve to remove most of the leaves and moss but to allow all snails to pass through. Pass the fine residue over a 0.5mm sieve to remove dust and fine soil. The sample is then ready for analysis although the material will be easier to sort if it is graded by passing it over a 2mm sieve.

5. Sample sorting

Snails may be recovered from the samples by sorting under a stereo microscope at x10 magnification. Place a small quantity of the sample in a c. 10cm diameter petri dish and spread evenly over the surface (Note: if too large a quantity is taken, the juvenile snails may be obscured by larger pieces of leaf debris). Systematically search the dish picking out ALL snails using fine, soft-touch storksbill forceps. Shake the dish and re-search before discarding. Continue this process until the sample is completely picked.

6. Mollusc identification

The best identification guide for terrestrial molluscs is: *A field guide to the land snails of Britain and north-west Europe* by M.P. Kerney & R.A.D. Cameron, Harper Collins 1979. High quality line drawings of all *Vertigo* species are given in: Pokryszko, B.M., 1990. The Vertiginidae of Poland (Gastropoda: Pulmonata: Pupilloidea) - a systematic monograph. *Annales Zoologici, Warsaw.*, 43: 134-257.

Vertigo angustior is instantly recognisable by its sinistrally coiled shell (with the aperture on the left) and the presence of apertural teeth in adults (juveniles do not have apertural teeth). However, another sinistrally coiled snail, *Clausilia bidentata*, also occurs in the same habitat. Adult *Clausilia* are very distinctive, however, juveniles may appear similar to *Vertigo angustior* but may be recognised by their relatively large protoconch (apex of the shell).

Vertigo angustior specimens should be separated into adults (i.e. those with a developed lip and apertural teeth) and the remainder as juveniles. Only live-collected snails should be counted. This may present some difficulties as many of the adult *V. angustior* become bleached with age. Usually these specimens retain a slight pink colouration and there will be traces of dried mucus in the aperture. Dead shells are usually white and are often fragmented. The animals in juveniles tend to dehydrate very quickly and retract to the apex, thus giving the appearance of being empty. However, any snails retaining some degree of translucence should be scored as live.

It is not crucial to record and count the other species of molluscs present in the samples although it would provide useful additional information. Until familiarity and confidence with identification is achieved, English Nature may choose to send the specimens to a specialist for confirmation.

7. Monitoring report

A short annual report should be produced comprising the tables of results along with comparisons of those for all previous years. Until there is information for at least the next 10 years it is unlikely that there will be enough data to detect any trends or changes in the *Vertigo angustior* population.

8. Retention of specimens

The specimens collected during the monitoring surveys are a scientifically valuable resource and should not be discarded following the counting. They may be required, for example, for future biometric analyses to determine population structure. It is strongly recommended that the snails from each individual sample are retained and stored in labelled and dated glass tubes or plastic boxes. Ideally this material should be housed in a (preferably local) museum collection.

9. Equipment suppliers

Sieves	Fisher Scientific Ltd, Bishops Meadow Road, Loughborough LE11 5RG Tel: 01509 231166
Plastic boxes	Daco Marketing Ltd, 7 Christchurch Rd, Folkestone CT20 2SJ Tel: 01303 226137
Gelatine capsules	Davcaps, PO Box 48, Hitchin SG4 9BT Tel: 01462 433210
Forceps	D.J. Henshaw, 34 Rounton Road, Waltham Abbey EN9 3AR Tel: 01992 717663

10. Habitat monitoring

In addition to monitoring the snail populations, it would also be useful to monitor the habitat. To monitor relatively subtle habitat change on a large-scale would require a detailed baseline survey to map out the boundaries, topography and hydrology, botanical community and vegetation structure. Such a proposal is unrealistic and impractical. Therefore, it is suggested that this is restricted to the 5 plot areas selected for snail monitoring.

The key characteristics and indicators of the most favourable *Vertigo angustior* habitat at Flordon Common may be summarised:

- permanently damp (not waterlogged), relatively open fen meadow;
- *Iris* beds with *Eupatorium*, *Pulicaria* and interstitial mosses;
- relatively tall vegetation structure (mostly 0.4 - 0.8m) maintained by light to moderate grazing by ponies and cattle.

It is considered that any change detected on a small scale would be an indicator for the site as a whole, so it is recommended that habitat monitoring is carried out only in the snail monitoring plots.

Within each 10m x 10m plot, randomly select ten 1x1m quadrats. Within each, record the following:

- **Percentage cover of bare ground**

The most favourable *Vertigo angustior* habitat comprises very little unvegetated ground. Such as there is results from livestock trampling. If the area of bare/unvegetated ground starts to increase beyond say 10%, the habitat is becoming less favourable for the snail. Such increase may arise from a change in hydrology (either increase or decrease in water levels), but may also result from a significant increase in grazing/trampling.

- **Wetness**

Most of the *Vertigo angustior* habitat is permanently damp such that the ground is 'spongy', but not so wet that water rises under light pressure on the surface, or has pools of standing water. However, the level of wetness will vary naturally throughout the year according to local weather, particularly during periods of high rainfall or drought. During monitoring the moisture levels in the plots should be recorded using a simple scale:

1. Ground dry, possibly with cracks, and no footprint impression is left.

2. Ground damp and 'spongy'. Footprint impression is left on the surface but water does not rise under light pressure.

3. Ground wet. No surface veneer, but water rises under light (foot) pressure.

4. Ground wet. Surface veneer of water less than 1-2cm deep.

5. Ground very wet. Water depth greater than 2cm. May form pools.

On an overall annual basis, levels of 2 (-3) are the most ideal for *V. angustior*. Wetness needs to be interpreted with caution as levels of 1 or 4-5 may be a short-term result of drought or high rainfall. To detect unacceptable change in ground wetness may require an assessment more frequently than once in 6 years. However, if during monitoring, a wetness level of 1 is recorded when there has been no preceding period of drought, the site should ideally be revisited after a period of 3-6 months. If the site remains dry, then changes in hydrology should be considered as a possible cause. Similarly *V. angustior* will not tolerate prolonged waterlogged conditions.

- **Vegetation type and structure**

At Flordon Common *Vertigo angustior* lives principally in moss and litter at the base of relatively tall vegetation dominated by *Iris* or *Eupatorium* in generally unshaded locations. It is also found in grassland/*Potentilla anserina* sward with an open structure.

The following plants and mosses are characteristic of the most favourable *V. angustior* habitat:

Most frequent plant associates

Iris pseudacorus
Cirsium palustre
Eupatorium cannabinum
Filipendula ulmaria
Grasses
Juncus subnodulosus
Lotus uliginosus
Mentha aquatica
Plantago lanceolata
Potentilla anserina
Pulicaria dysenterica
Ranunculus acris
Ranunculus repens
Trifolium pratense

Mosses

Brachythecium rutubulum
Calliergonella cuspidata
Eurhynchium praelongum

Record:

- The % cover of most abundant positive indicators (*Iris*, *Eupatorium* and mosses) and indicators of less favourable conditions (*Filipendula*, *Juncus subnodulosus*, *Mentha aquatica*, and plants of drier conditions).

- Vegetation height using a 200g drop disk in the centre of each quadrat, following the recommendation for monitoring lowland grassland (Robertson *et al.*, 2000).

Mean percentage cover of *Iris* and *Eupatorium* should together remain at least 30%. A decrease in the suitability of the habitat may be evident from an increase to more than a mean percentage cover of 20% in species such as *Filipendula*, *Juncus subnodulosus* and to a lesser extent, *Mentha aquatica*, which may indicate the site is becoming too wet. A similar increase in nettles, tall grasses, or other more catholic species may indicate the site is becoming drier. An increase in scrub (willow, ash or hawthorn saplings) may eventually result in over shading and/or drying, and these should be removed.

11. Evaluating change

The objective of any monitoring programme is to allow any change to be detected and to ensure that favourable condition is maintained. The *Vertigo angustior* populations are very likely to have good and bad years according to local weather, especially during periods of drought. Fluctuations in abundance are naturally occurring phenomena and therefore a year with very low numbers recorded should not necessarily be interpreted as a long-term population decline. This does, however, present problems with monitoring intervals of 6 years.

In the area recommended for monitoring (Habitat A), the mean number of *V. angustior* individuals per semi-quantitative sample was 68. If significantly lower numbers of

individuals (say less than a mean of 15-20 per sample) are recorded in a year where there are no long periods of drought, then the monitoring should be repeated the following year. If the low numbers persist then there may be cause for concern.

Provided that there are no changes to the grazing regime or hydrology of the site (see Section 2.4) then there should be no change in favourable condition. Recommended management proposals should prevent such occurrences. With our present knowledge it is unclear what measures could be taken if favourable condition is maintained but the *V. angustior* population does decline.

~

It should be stressed that any differences from the present baseline survey recorded during monitoring may not necessarily indicate long-term change. If significant changes in the key habitat characteristics are noted, they should be confirmed by subsequent more frequent visits.

If the results are confirmed and cannot be attributed to short-term effects of weather or grazing, then the habitat may be in serious decline. The reasons should be sought and measures taken to alleviate the problem and to restore the habitat to favourable condition.

3. Fritton Marshes

Vertigo angustior was first discovered at Fritton in 1988 in a small area of transition marsh (2-5m wide) lying between River Waveney saltmarsh and Waveney Forest at Grid Reference TG458012 (Killeen 1992). A brief survey carried for JNCC in 1991 showed that *V. angustior* was restricted to a relatively short (<500m) stretch of river but in places was locally abundant (Killeen 1991). A survey in 1998 confirmed the species' survival at the site but added no further distributional information (Baker *et al* 1998).

The results of the 1991 survey indicated that the transition zone habitat (and *V. angustior*) was restricted to an embayment area where the land is unprotected by sea defences. At this point the River Waveney is tidal with brackish water, and is flanked by a broad zone of *Phragmites australis* up to 150m wide in places, and is backed by Waveney Forest. The forest lies on Glacial sands and comprises mainly conifers planted in the 1950s with a curtain of small oak trees. Prior to planting, the area had been open heathland. Transition zone habitat comprising mainly grassland with herbs, and occasional patches of sedge and *Iris*, occurs on the lower slopes at the saltmarsh/forest interface. Drift lines of flood detritus (dead stems) occur within the transition zone indicating that the habitat is subject to periodic submergence by high spring tides. Beyond the embayment at the north-east and south-west ends the a high grass-covered bank separates the saltmarsh from reclaimed grazing marshes and transition zone habitat is absent.

3.1 Methodology

To determine the snail's distribution at the site, samples were collected from a range of potentially suitable *V. angustior* habitat along the entire length of the transition zone lying between the saltmarsh and heathland/woodland.. At each selected site, a sample of live and dead plant material was collected from an area of approximately 3m x 3m. Moss and dead vegetation, and loose soil at the interface were collected from the base of tall herbs and sedges. In areas with only grassland/*Potentilla* sward, vegetation was cut at ground level using a sharp knife with a serrated blade and by plucking material from the tussocks and turf. This yielded a sample from suitable *V. angustior* habitat of approximately 4 litres loose volume, which is estimated to represent material collected from a total area equivalent to 0.2 m^2.

The vegetative material was teased apart and spread on sheets of newspaper to dry. This was then shaken over a 5 mm sieve to remove the bulk of the plant material but to allow all molluscs to pass through. The residue was passed over a graded stack of sieves and examined microscopically. All molluscs retained by a 0.5 mm sieve were picked out and counted. Specimens of *Vertigo angustior* with a developed lip and/or apertural teeth were recorded as adults and all others as juveniles. All other mollusc species were also picked out and counted.

The work was carried out on 3 & 4 June 2000.

Samples were collected from 25 individual sites. The locations are shown on the map Figure 5. General descriptions of the flora and environment for each are given in Section 3.2.

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Figure 5 Fritton Marshes - location of sample sites

3.2 Site selection and habitat

Sites were selected at intervals within the transition zone habitat of the embayment area, plus two on the seawall bank at the south-western end (Table 11).

Table 11 Descriptions of sample locations

Sample	Description
1	Landward side of grassy bank/sea wall between reclaimed grazing marsh and saltmarsh
2	Landward side of grassy bank/sea wall between reclaimed grazing marsh and saltmarsh. Base of slope with small patches of grasses and *Potentilla anserina*.
3	Slope of ditch on landward side of bank - grasses with occasional *Potentilla anserina*.
4	Wet grassland amongst scrub.
5	Bank sloping down to *Phragmites* bed. Base of bank sampled - grasses and occasional *Rumex*, *Urtica*, *Carex riparia*, umbellifers, bracken.
6	As above but sampled near top of bank, lots of moss (*Brachythecium rutubulum*).
7	Top of bank with bracken, *Plantago lanceolata*, grasses, umbellifers, mosses (*B. rutubulum*)
8	Lower slope of bank with small patch of *Iris*, *Carex* cf *acutiformis* and grasses.
9	Flat grassland (mainly *Festuca rubra*) with *Potentilla anserina*
10	*Festuca/Potentilla* grassland with patchy *Iris* and *Carex*.
11	*Festuca/Potentilla* grassland with patchy *Iris* and *Carex*.
12	Grassland at heath margin.
13	Mosses at base of tall herbs (*Althaea officinalis*, *Oenanthe aquatica*, *Carex* sp.).
14	*Festuca/Potentilla* grassland.
15	*Festuca/Potentilla* grassland and tall herbs (*Althaea officinalis*, *Oenanthe aquatica*).
16	Grassy bank beneath oak scrub.
17	10m long grassy hollow beneath oak trees, with *Carex* cf *riparia* and *Iris*.
18	Bank beneath oak trees with grasses, herbs and *Lonicera*.
19	Bank with grasses, *Carex* and mosses, beneath *Rhododendron* and *Lonicera*.
20	Grasses, herbs and mosses amongst *Rosa rugosa*.
21	Short grassland with herbs on landward side of hedge. Moss includes *Eurhynchium praelongum*.
22	Grasses, herbs and mosses amongst *Rosa rugosa*.
23	Grasses, herbs and mosses amongst *Rosa rugosa*.
24	Extensive grassland area (including *Phalaris*) with patchy *Carex*, *Potentilla* etc.
25	Extensive grassland area (including *Phalaris*) with patchy *Carex*, *Potentilla* etc.

3.3 Results

The results of the molluscan analysis of each sample are shown in Table 12. The results for *V. angustior* are summarised in Table 13.

Vertigo angustior occurred throughout the entire length of the embayment area and in a single site on the bank just beyond at the south-west end. It was not found further along the banks at either end and therefore appears to be restricted to the embayment which is unprotected by sea defences and which supports the transition zone habitat.

Table 12 Fritton Marshes - Results from semi-quantitative samples

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Mollusc species																									
Vertigo angustior ADULT		8			22	76	6	91	28	35	82	1	4	16	13	48	137	3	7	60	37	3	8	18	
Vertigo angustior JUV		2			45	40	1	158	11	51	80		17	17	24	116	235	3		180	30	6	7	16	
Carychium minimum			1		23	2	3																		
Cochlicopa lubrica	1		5		2	3	2	20	5	6	16	2	1	7	4	7	3	3	16	12	9	3	9		2
Cochlicopa lubricella						10	13	3		1											2				
Columella aspera																2	1	1	1				6		
Vertigo pusilla									2	2	7					2	12		1	1	3		1	3	
Vertigo substriata					2	10	3	23	2						1	3	7	1	16	1	5	5	11		
Vertigo pygmaea	2	21	25		1	2		37	13	7	16	1	1	7			3			5	24				3
Lauria cylindracea																1		5		1		2	2		
Vallonia costata		2	1		1	17	5										1				1				
Vallonia excentrica	2	10	5		11	7	1			11	15		9							4	10				5
Punctum pygmaeum	1		1	3												1			5	3	1	4			
Vitrina pellucida				2	7					1									1	1					2
Vitrea contracta					1	8	9			2					2										
Nesovitrea hammonis			1	3	1	11	7	2				2	1		5	4					2	1	1		
Aegopinella pura						1																			
Oxychilus alliarius				5		18	4	1							1	2	2		3	1					1
Oxychilus cellarius	2	1	2																						
Euconulus fulvus				1		1		1							1		3		3			1	2		
Trichia hispida	2	9			6	21	4	2																	
Cepaea nemoralis		1			1	4																			
No of terrestrial species	6	7	8	5	12	15	11	9	5	7	5	4	5	3	7	9	9	5	9	10	10	7	8	2	5
Total No of snails	10	54	41	14	123	306	58	338	61	116	216	6	33	47	51	186	404	16	53	269	123	25	47	37	13

Table 13 Summary of results for *Vertigo angustiorr*

Total No. of samples	25
No. of samples with *V. angustior*	21
Total No. of *V. angustior* (adult and juvenile)	1742
Range	0-362
Mean No. of *V. angustior* per sample	69.7
No. of samples with adult *V. angustior*	21
Total No. of adult *V. angustior*	703
Range	0-137
Mean No. of adult *V. angustior* per sample (n=25)	28.1
No. of samples with juvenile *V. angustior*	19
Total No. of juvenile *V. angustior*	1039
Range	0-235
Mean No. of juvenile *V. angustior* per sample (n=25)	41.6

Vertigo angustior was the second most frequently occurring snail species, being found in 21 of the 25 samples, and by far the most dominant numerically (Table 14). A total of 1742 specimens were found, representing 67.8% of the total number of individual snails. The mean number of *V. angustior* per sample was 69.7, which is equivalent to an approximate density of 349m^{-2}. his almost identical with the most favourable habitat at Flordon Common (Section 2.3.2). However, the distribution and abundance was uneven with densities in the positive samples ranging from 5-1860 individuals m^{-2}. The high value is considerably in excess of that from any of the Flordon samples. Densities in excess of 1500 m^{-2} have been recorded from Whiteford Burrows (Sharland 2000) and at Gait Barrows (Killeen 1998). In most samples juveniles outnumbered juveniles with an overall adult to juvenile ratio of 0.68:1, although in some samples (e.g 20) the ratio was as high as 0.25. This is rather different from Flordon at the same time of year where adults outnumbered juveniles by 2:1. This suggests that the species may breed earlier in the drier coastal environment.

The transition zone habitat at Fritton is different from Flordon in that it is much drier, and is predominantly grassland turf with a low herb diversity (*Potentilla anserina* is the commonest), and only a few small patches with *Iris* or *Carex* species. In terms of its location, it is similar to the site at Martlesham Creek in Suffolk (Killeen 1983), although the ground is wetter at Martlesham and *V. angustior* is much rarer.

Table 14 Mollusc species in Fritton semi-quantitative samples (n=25) ranked by frequency of occurrence and frequency of individuals

Rank Order by frequency of occurrence

Rank	Species	No of sites
1	*Cochlicopa lubrica*	22
2	*Vertigo angustior*	21
3	*Vertigo pygmaea*	16
4	*Vertigo substriata*	14
5	*Nesovitrea hammonis*	13
6	*Vallonia excentrica*	12
7	*Vertigo pusilla*	10
7	*Oxychilus alliarius*	10
9	*Euconulus fulvus*	8
9	*Punctum pygmaeum*	8
11	*Vallonia costata*	7
12	*Vitrina pellucida*	6
12	*Trichia hispida*	6
14	*Cochlicopa lubricella*	5
14	*Columella aspera*	5
14	*Lauria cylindracea*	5
14	*Vitrea contracta*	5
18	*Carychium minimum*	4
19	*Oxychilus cellarius*	3
19	*Cepaea nemoralis*	3
21	*Aegopinella pura*	1

Rank Order by frequency of individuals

Rank	Species	No of individuals	%
1	*Vertigo angustior*	1742	67.8
2	*Vertigo pygmaea*	168	6.53
3	*Cochlicopa lubrica*	138	5.37
4	*Vertigo substriata*	90	3.5
4	*Vallonia excentrica*	90	3.5
6	*Trichia hispida*	44	1.71
7	*Nesovitrea hammonis*	41	1.59
8	*Oxychilus alliarius*	38	1.48
9	*Vertigo pusilla*	34	1.32
10	*Carychium minimum*	29	1.13
11	*Vallonia costata*	28	1.09
12	*Cochlicopa lubricella*	27	1.05
13	*Vitrea contracta*	22	0.86
14	*Punctum pygmaeum*	19	0.74
15	*Vitrina pellucida*	14	0.54
16	*Euconulus fulvus*	13	0.51
17	*Columella aspera*	11	0.43
17	*Lauria cylindracea*	11	0.43
19	*Cepaea nemoralis*	6	0.23
20	*Oxychilus cellarius*	5	0.19
21	*Aegopinella pura*	1	0.04

Twenty other mollusc species were found associated with *V. angustior* at Fritton of which there are 13 species in common with Flordon. The fauna is comprised of species characteristic of a range of habitats. Species of damp, open grassland habitats (e.g. *Vertigo pygmaea, Vallonia excentrica*) are amongst the most frequently occurring (Table 14), whereas *Cochlicopa lubricella* is typical of drier grassland. The top ranked species also include *Cochlicopa lubrica, Nesovitrea hammonis and Oxychilus alliarius*, which are tolerant of damp to dry habitats and base poor conditions. The frequent occurrence (10 samples) of *Vertigo pusilla* shows the influence of the dry heathland. In East Anglia this species is uncommon but is most usually found in litter in the dry open margins of mixed woodland on sandy soil. It coexists with *V. angustior* at Martlesham Creek. Truly wetland elements are virtually absent, *Carychium minimum* is the only species present, yet that only occurred in 4 samples.

There are other differences between the molluscan composition at Fritton compared with Flordon. Most significant is the absence of *Carychium tridentatum* which comprised 40% of the individual snails in the most favourable *V. angustior* habitat at Flordon. The numerical composition of the samples (Table 14) shows a dominance by *V. angustior* (67.8% of all snail specimens). The next commonest were *Vertigo pygmaea* and *Cochlicopa lubrica* with 6.53% and 5.37% of individuals respectively. The remaining 18 species all comprised 3.5% or less of all snail individuals, nine of which comprised less than 1%.

3.4 Conservation and Management

The Fritton *Vertigo angustior* site is included within Waveney Ronds pSSSI. Within this area there no definite physical boundaries and although the pSSSI boundary has been set at Mean High Water Mark, it is open to interpretation as to how much of the transition zone habitat would be included. Most of the *V. angustior* population would be encompassed if the boundary was set at the top of the banks, and/or the forest and heathland edge. It may be necessary to mark these boundaries with fences or stakes so that it is clear where future management may impact the population.

Vertigo angustior is apparently thriving at Fritton and given the location of the site and character of the habitat, there appear to be few threats. Encroachment by scrub and the conifer forest may eventually cause the habitat to become too dry and shaded. At one part of the site (TG45750100) footpaths run along the top of the transition zone and therefore human trampling may have a detrimental effect on the habitat.

A site meeting to discuss management issues was held on site in December 1998 (Drake, English Nature memo). The management suggestions arising from the meeting remain unchanged:

1. Removal of invasive marginal scrub of rhododendron, small birch and oak.
2. Cutting back of *Rosa rugosa*
3. Occasional cutting back (strimming) of rank grass to open the vegetation and reduce the dense thatch of litter on a 2-3 yearly basis.
4. Fencing off the transition zone near the open footpaths to prevent disturbance by trampling.

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