occurred within the 100 to 200m² range (Fig 5.1(a)(i)); in unimproved grassland 100 to 200m² (smooth newt) and 200 to 400m² (palmate newt) (Fig 5.1(b)(i)); in woodland, 200 to 400m² (smooth) and 90 to 200m² (palmate) (Fig 5.1(d)(i)). Smooth newts reached maximum frequency of occupation in smaller sites in arable land - between 50 and 75m² (Fig 5.1(c)) (Palmate newts occurred in only two sites in arable land in this sample.) In gardens, maximum occupation frequency was attained in sites over about 7m² for both species, the percentage thereafter levelling off rather than decreasing (Fig 5.1(e)(i)).

Similar pond size maxima of about 100m² were indicated for crested newts in unimproved grassland and woodland, (Figs 5.1(b)(ii) and (d)(ii)). In improved grassland, a distinct optimum peak between 50 and 100m², followed by a significant decrease was recorded (Fig 5.1(a)(ii)). Maximum percentage occupation frequencies in garden ponds occurred when the cumulative mean area just exceed 10m² (Fig 5.1(e)(ii)). Too few arable ponds (4) were occupied by crested newts for size analysis.

Thus, each species exhibited a range of optimum breeding pond sizes in each land-use type. Although the pond *areas* corresponding to maximum occupancy rates for each species were similar between the land-use types, the maximum *percentage occupancies* varied considerably. For example, the toad maximum in improved grassland was approximately 14%, compared to about 29% in the rough grassland; the optimum pond size in both habitats was around 1,000m². Section 5.4.1.2 (i) indicated that a similar range of pond sizes was available in most of the land-use types, and this section suggests that most of the species do have a preferred range of breeding site sizes. If sizes within each species' preferred range are available within most of the habitats, then other factor or factors may be preventing their colonisation.

5.4.1.2.(ii) Pond characteristics other than size

Comparisons between ponds in different land-use types revealed little difference in the extent to which they were shaded, or vegetated with aquatic plants (Table 5.4). The exceptions were garden ponds which suffered excessively from both less frequently ($p<0.001$), and woodland ponds which were heavily shaded significantly more commonly ($p<0.001$). Garden and woodland ponds were also less prone to desiccation than those in the other categories ($p<0.001$ and $p<0.01$ respectively). A greater than expected proportion of ponds in improved grassland than expected had a tendency to dry up ($p<0.001$).

Thus, in terms of shading and emergent and submerged vegetation cover, water-bodies in grassland, arable land and built-up areas varied little. Woodland ponds differed from the rest only in respect of shading and desiccation tendency, but garden ponds differed in every respect.

5.4.2 Terrestrial habitats

5.4.2.1 Approach

The approach adopted in this section was to compare the relative frequencies of occupation of sites by each species within common land-use types - improved grassland, unimproved or rough grassland, arable land, woodland, gardens and built-up areas. Then, using the scoring system described in Table 5.1, the effects of the "influence" of different habitats and landscape features on ponds, on the relative abundance of each species, within each base land-use type, was investigated.

Gardens were treated in two ways - the presence of garden habitats around non-garden ponds was analyzed as any other component of the landscape, but ponds within gardens were investigated separately with respect to surrounding habitats. Finally, the value of the variables found to be important during the above procedures as predictors of the species' presence, was tested using multi-variate analyses.

Table 5.4

Characteristics of water-bodies (other than "area") in different base land-use types. Data are presented as the percentage of ponds within each category (%), with the actual number of sites which this represents (n).

POND CHARACTERISTICS	GRASSLAND IMPROVED		GRASSLAND UNIMPROVED		ARABLE		WOODLAND		BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	%	n	%	n	%	n	%	n	%	n	%	n	%	n
depth(m)														
<0.5	47	112	37	117	31	16	29	68	32	16	38	162	35	523
0.5-2.0	42	101	48	149	59	30	57	131	50	25	58	246	49	740
>2.0	11	27	15	46	10	5	13	30	18	9	4	17	16	240
shade(%)														
0	36	87	38	118	25	13	15	34	34	17	45	191	33	501
1-25	27	66	27	86	23	12	14	33	28	14	32	138	27	406
25-50	16	38	13	41	16	8	23	52	16	8	18	77	15	229
51-75	6	14	7	23	10	5	15	35	10	5	2	11	9	138
76-100	14	35	14	44	25	13	33	76	12	6	2	8	15	229
south shade														
YES	67	162	68	214	70	36	43	98	56	28	67	286	65	974
NO	32	78	31	98	29	15	57	132	44	22	33	139	35	529
emergent vegetation (%)														
0	24	58	18	57	21	11	22	51	32	16	15	65	20	304
1-25	37	89	41	128	27	14	45	104	44	22	5	201	45	674
26-50	17	40	16	51	18	9	16	37	14	7	23	100	15	233
51-75	9	21	12	38	18	9	8	18	4	2	11	48	10	147
76-100	13	32	12	38	16	8	9	20	6	3	2	11	10	145
submerged vegetation (%)														
0	35	83	30	95	35	18	33	75	32	16	11	47	30	447
1-25	29	71	37	116	39	20	37	86	26	13	46	197	38	568
26-50	18	43	11	36	12	6	9	22	20	10	21	91	13	204
51-75	8	19	10	30	4	2	9	22	8	4	15	64	9	136
76-100	10	24	11	35	10	5	11	25	14	7	6	26	10	148
fish presence														
YES	22	52	26	80	29	15	24	55	36	19	58	247	30	455
NO	78	188	74	232	70	36	76	175	62	31	42	178	70	1048
desiccation														
NEVER	48	116	56	175	65	33	70	161	66	33	93	397	60	905
DROUGHT	24	58	23	71	21	11	17	39	16	8	6	27	23	340
EVERY YEAR	28	66	21	66	14	7	13	30	18	9	0.2	1	17	258
TOTAL		240		312		51		230		50		425		1503

5.4.2.2 Terrestrial habitat associations of the five species

5.4.2.2.(i) Frog

Within the non-garden sample overall, frogs were found in 58% of ponds. Table 5.5(a) shows that percentage occupancy differed little between sites in the vicinity of five out of seven land-use types, ranging from 57% of ponds where improved grassland or built-up areas were present to 62% with woodland within 500m. Frog breeding site frequency was, however, lower in the vicinity of arable land (45%), and higher in the presence of moorland (80%). The absence of either unimproved grassland or woodland habitats was also associated with reduced frequency of frog sites, (53% in both cases). Although frog occupancy was slightly elevated in the set of ponds with gardens within 500m (61%), the percentage of actual garden ponds containing the species was much higher - 82%. Whether this was due to the diverse, and generally hospitable nature of the recorded gardens, or the maintenance of populations by the artificial introduction and subsequent replenishment of frog spawn by householders is unknown.

Considering the "influence" of land-uses on amphibians, the relative abundance of frog populations was lower where improved grassland and arable occurred in band 4 (at the edge of the water-body), (Table 5.5(b)). Where they were beyond 100m (bands 1 and 2), "influence" was minimal. Unimproved grassland on the other hand apparently increased the likelihood of pond occupation when present within 100m, but blanket coverage (ie occurrence in all three bands 2, 3 and 4) was associated with decreased frog frequency. The effect of woodland within the landscape was positive overall but nearness to the pond did not increase the effect. (NB The heathland/moorland sample size was too small for subdivision.) Gardens and built-up areas had a relatively neutral effect, but there was a tendency towards reduced occupancy with blanket coverage of built-up areas.

Table 5.5

(a) Percentage occupancy of recorded sites by each species with respect to the presence or absence of each base land-use type anywhere within 500m.

	BASE LAND-USE TYPE														
	grassland								heath		built-up		garden		
	improved		unimproved		arable		woodland		/moor		area		habitats		%
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	overall
frog	57	58	61	53	45	62	62	53	80	56	57	58	61	57	58
toad	24	33	29	26	29	27	34	21	26	28	27	28	32	27	28
smooth	24	21	26	18	23	23	20	26	10	23	29	19	31	21	23
palmate	10	16	11	14	6	14	15	9	24	12	10	14	13	12	12
crested	12	14	14	10	13	12	13	12	2	13	15	11	13	12	13
N	842	661	914	589	399	1104	813	690	83	1420	544	959	316	1187	1503
Tc n	777	545	827	495	374	940	671	651	56	1266	505	817	299	1023	1322

(b) Percentage occupancy of recorded sites by each species with respect to the proximity of each base land-use type. (see Table 5.1 for explanation of "scores")

		LAND-USE "SCORE"				
land-use	species	2	3	4	5	6
imp. grassland	frog	59	60	56	55	52
	toad	24	29	28	17	13
	smooth newt	25	28	27	19	19
	palmate newt	10	10	9	9	8
	crested newt	21	10	9	10	10
N (crested newt n)		*141(129)*	*255(239)*	*168(160)*	*278(249)*	*240(10)*
unimp. grassland	frog	51	61	67	60	58
	toad	26	33	26	30	29
	smooth newt	19	26	21	30	29
	palmate newt	9	13	12	11	10
	crested newt	10	14	14	16	14
N (crested newt n)		*128(495)*	*170(118)*	*208(159)*	*408(367)*	*312(281)*
arable	frog	48	49	34	36	39
	toad	31	31	19	28	27
	smooth newt	27	26	2	19	22
	palmate newt	9	5	2	5	4
	crested newt	19	13	2	7	8
N (crested newt n)		*147(134)*	*147(141)*	*41(40)*	*64(59)*	*51(47)*
woodland	frog	68	61	58	61	61
	toad	29	39	31	34	32
	smooth newt	16	19	29	17	16
	palmate newt	14	17	11	17	19
	crested newt	7	10	21	13	11
N (crested newt n)		*146(116)*	*221(179)*	*149(128)*	*297(248)*	*230(192)*
built-up area	frog	57	57	58	52	50
	toad	25	30	27	24	20
	smooth newt	32	31	20	30	26
	palmate newt	8	6	14	17	24
	crested newt	17	15	13	13	12
N (crested newt n)		*154(149)*	*188(175)*	*118(111)*	*84(70)*	*50(43)*
garden habitats	frog	56	68	56	59	57
	toad	28	36	30	33	24
	smooth newt	28	33	36	26	27
	palmate newt	9	17	14	10	8
	crested newt	11	15	15	13	20
N (crested newt n)		*93(89)*	*115(108)*	*50(47)*	*58(55)*	*37(35)*

In order to identify other land uses and habitat features promoting species survival in relatively non-diverse landscapes, samples of sites were selected whose "score" for particular land-uses was 6. Ie, the particular land-use was predominant from the pond edge throughout the whole 500m radius extending out from the site.

The overall percentage occupancy of sites by frogs within improved grassland was 52%. Where arable land was present within 500m occupancy dropped to 34%; but the presence of non-flowing wetlands (ponds and marshes), moorland, built-up areas or woodland were each associated with an increase of at least 5% (Table 5.6(a)). The effects of particular features at different distances from ponds were investigated using the scoring system illustrated in Table 5.1. For frogs in improved grassland, ditches, although not having an effect within the 500m radius as a whole, were associated with a frequency of frog populations significantly above the expected value when they were within 100m of ponds ($p<0.025$).

Features associated with increased frequencies of frog occupancy of sites in unimproved grassland dominated landscapes were moorland, mineral extraction sites and woodland. No significant influences of proximity were identified.

Within the arable landscape, frogs were found in 39% of ponds overall, but in the presence of hedges, roads and gardens in only 26, 23 and 14% respectively. Features with apparent positive effects were flowing water (rivers, streams, canals etc), non-flowing wetlands, rough grassland and woodland (Table 5.6(a)). More specifically, frogs were found in greater than expected frequency in sites with rough grassland or woodland present anywhere within 100m.

The overall percentage occupancy in woodlands was 61%, positive features being hedges, roads and railway lines, ditches and flowing water (Table 5.6(a)).

Table 5.6

Percentage occupancy of water-bodies in six base land-use types in the presence, or absence, of terrestrial habitat features within 500m. The percentages are not presented where n was less than five.

(a) frog

HABITAT FEATURES	GRASSLAND						WOODLAND		BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	IMPROVED		UNIMPROVED		ARABLE									
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs
hedge/stone-wall	48	59	57	60	26	60	72	57	47	52	80	84	57	58
road/r'way line	56	51	51	62	23	47	70	57	59	38	84	79	56	59
ditch	55	51	61	56	41	36	70	57	50	50	91	80	59	57
flowing water	50	53	60	58	46	37	71	56	50	50	76	84	68	53
still wetlands	57	47	57	62	45	32	61	62	54	46	81	83	58	58
heath/moor	-	52	75	57	-	39	44	59	-	49	-	82	80	56
duneland	-	52	37	59	-	39	-	61	-	51	-	82	53	58
min extract'n	-	52	67	58	-	39	-	62	-	51	-	82	44	42
gardens	56	52	53	60	14	43	59	62	48	53	83	74	61	57
built-up areas	57	51	48	65	15	47	65	60			81	84	57	58
scrub	52	53	58	60	41	35	39	55	49	54	79	84	58	58
imp grassland			60	57	35	42	58	63	53	42	84	77	57	58
unimp grassland	50	54			52	27	62	60	55	47	80	83	61	53
arable	34	57	50	60			61	61	27	56	83	82	45	62
woodland	62	53	64	54	58	22			57	45	59	84	62	53
% (N)	52(240)		58(312)		39(51)		61(230)		50(50)		82(425)		58(1503)	

(b) toad

HABITAT FEATURES	GRASSLAND						WOODLAND		BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	IMPROVED		UNIMPROVED		ARABLE									
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs
hedge/stone-wall	9	19	21	38	13	45	35	31	10	26	36	32	20	34
road/r'way line	14	12	37	25	23	29	26	35	24	14	37	30	29	27
ditch	10	14	25	32	24	32	27	34	17	22	44	32	25	30
flowing water	12	13	40	24	46	21	42	27	8	24	43	21	34	25
still wetlands	10	17	27	33	31	23	30	34	29	11	41	28	28	28
heath/moor	25	13	33	29	-	27	35	32	-	20	-	34	26	28
duneland	-	13	50	29	-	27	-	32	-	20	-	34	47	28
min extract'n	-	13	60	28	-	27	-	32	-	20	-	34	34	28
gardens	18	12	30	29	14	29	31	32	26	10	35	27	32	27
built-up areas	15	12	31	28	0	37	23	35			34	33	27	28
scrub	15	10	33	18	29	23	34	24	16	31	39	30	31	22
imp grassland			22	34	15	35	28	35	21	17	34	32	24	33
unimp grassland	11	14			24	31	36	28	20	20	40	30	29	26
arable	12	13	39	27			38	30	9	23	41	32	29	27
woodland	21	9	35	25	37	18			24	17	42	30	34	21
% (N)	13(240)		29(312)		27(51)		32(230)		20(50)		34(425)		28(1503)	

(c) smooth newt

HABITAT FEATURES	GRASSLAND						WOODLAND		BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	IMPROVED		UNIMPROVED		ARABLE									
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs
hedge/stone-wall	18	19	30	28	19	25	16	13	26	26	38	38	25	21
road/r'way line	20	18	35	26	12	26	16	15	31	19	38	38	25	21
ditch	20	18	31	28	21	23	18	14	39	19	45	37	24	22
flowing water	14	20	22	32	8	26	15	16	17	29	27	41	18	25
still wetlands	16	23	30	26	24	18	17	14	29	23	42	35	24	21
heath/moor	-	19	8	30	-	21	5	17	-	26	-	38	10	23
duneland	-	18	13	30	-	21	-	16	-	24	-	38	26	23
min extract'n	-	18	73	27	-	21	-	15	-	24	-	38	63	22
gardens	23	18	33	28	57	16	31	13	32	16	38	41	31	21
built-up areas	33	13	36	25	23	21	17	15			38	40	29	19
scrub	22	14	28	31	26	12	18	8	27	23	33	42	24	20
imp grassland			29	29	20	13	17	14	29	17	39	35	24	21
unimp grassland	21	17			16	27	18	13	25	27	38	39	26	18
arable	24	17	37	28			19	15	36	23	37	39	23	23
woodland	12	22	26	31	37	7			28	24	33	41	20	26
% (N)	19(240)		29(312)		22(51)		16(230)		26(50)		38(425)		23(1503)	

(d) palmate newt

HABITAT FEATURES	GRASSLAND						WOODLAND		BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	IMPROVED		UNIMPROVED		ARABLE									
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs
hedge/stone-wall	5	13	10	10	0	10	14	20	31	19	14	9	10	14
road/r'way line	4	9	5	12	6	3	19	18	14	38	10	12	11	13
ditch	8	8	7	11	3	4	16	20	22	25	13	10	10	14
flowing water	12	6	16	7	8	3	16	20	33	21	11	11	12	12
still wetlands	8	7	10	11	7	0	13	24	25	23	13	9	10	15
heath/moor	-	8	25	9	-	4	30	18	-	24	-	12	24	12
duneland	-	0	0	10	-	4	-	17	-	24	-	11	37	12
min extract'n	-	8	0	10	-	4	-	18	-	24	-	11	13	12
gardens	9	8	11	10	0	4	10	20	26	21	11	10	13	12
built-up areas	7	8	9	11	0	5	14	20			10	13	10	14
scrub	10	5	11	7	0	12	19	22	30	8	12	10	13	10
imp grassland			11	9	0	6	14	21	29	8	12	9	10	16
unimp grassland	3	11			4	4	16	21	40	13	15	9	11	14
arable	4	9	6	10			8	22	9	28	8	12	6	14
woodland	11	6	12	8	4	4			9	34	16	8	15	9
% (N)	8(240)		10(312)		4(51)		19(230)		24(50)		11(425)		12(1503)	

(e) crested newt

HABITAT FEATURES	GRASSLAND								BUILT-UP AREA		GARDEN POND		ALL (NON-GARDEN)	
	IMPROVED		UNIMPROVED		ARABLE		WOODLAND							
	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs	pres	abs
hedge/stone-wall	7	15	16	11	7	11	11	11	12	11	11	8	13	12
road/r'way line	8	11	17	12	0	13	14	10	12	11	7	11	12	13
ditch	14	8	14	13	7	10	8	10	12	11	15	8	13	12
flowing water	9	11	6	17	0	12	10	12	0	14	6	10	6	15
still wetlands	7	15	13	17	7	11	15	8	14	9	12	7	12	13
heath/moor	-	10	0	14	-	8	6	12	-	12	-	9	2	13
duneland	-	10	0	14	-	8	67	10	-	12	-	9	27	50
min extract'n	-	10	60	11	-	8	50	11	-	12	-	9	61	11
gardens	10	10	15	14	28	5	11	11	15	6	9	8	13	12
built-up areas	19	7	22	8	9	8	17	10			7	14	15	11
scrub	9	11	13	16	9	7	11	11	12	9	8	10	11	15
imp grassland			10	16	17	3	17	9	12	11	9	9	12	14
unimp grassland	9	11			9	8	13	9	5	16	9	9	14	10
arable	16	9	19	13			20	9	11	12	5	10	13	12
woodland	11	10	15	13	17	0			23	4	8	10	13	12
% (N)	**10(215)**		**14(281)**		**8(47)**		**11(192)**		**12(43)**		**9(402)**		**13(1322)**	

Frogs were found in 82% of garden ponds.

Percentages of sites occupied by each species associated with land-uses and habitat features at different distances are presented in Appendix 24.

5.4.2.2.(ii) Toad

In the total non-garden sample, toads were present in 28% of surveyed ponds. Their percentage frequency in sites with particular land use types anywhere within 500m varied between 24%, in the presence of improved grassland, and 34% with woodland in the vicinity (Table 5.5 (a)). The highest percentage occupancy of sites by toads in association with the presence of "beneficial" habitats occurred where the particular land use was in band 3, ie neither extending up to the pond edge nor located over 100m distant (Table 5.5 (b)). A trend of increasing percentages of occupied sites was discernable between those where improved and rough grassland, woodland, gardens and built-up areas were at least 100m away and those where they were within 100m. With arable land, though, there was no such increase. There was a sharp decline in the proportion of toad ponds between sites for which improved grassland occurred in band 4 only (immediately surrounding the pond) and those for which it was the predominant habitat in bands 2 and 3 also (28% occupancy cf 17%). Gardens and built-up areas were associated with opposite trends, the former coinciding with increasing toad frequency of occupation, and the latter with decreases.

Toads were recorded in 13% of ponds within landscapes dominated by improved grassland, but, with moorland, gardens or woodland present within 500m, the percentage occupancies of sites rose to 25,18,and 21% respectively (Table 5.6(b)). The effects of some features, as well as major land use types, may be positive or negative depending on their location relative to water-bodies; these positive and negative effects may cancel each other out if the entire 500m radius is taken as a whole. For example, the presence of flowing and still water-

bodies within 100m of ponds was associated with toad frequencies above the expected value, but where they were at least 100m distant, the percentages were less than expected, ($p<0.05$ in both cases). In improved grassland habitats, the presence of woodland and built-up areas within 100m, were also both associated with above expected toad occupancy values, $p<0.05$ in both cases.

Twenty nine percent of surveyed ponds in habitats dominated by unimproved grassland contained toads, higher frequencies of occupation being associated with the presence of roads and railway lines, flowing water, sand dunes, mineral extraction sites, arable land and woodland anywhere within 500m (Table 5.6(b)). The presence of several features which appeared to increase the likelihood of toad occupancy suggests that landscape diversity is a salient feature. With regard to proximity, flowing water, still water-bodies, mineral extraction sites, scrub, and woodland were all features associated with higher than expected toad frequencies when located within 100m of ponds ($p<0.005$, $p<0.025$, $p<0.025$, $p<0.005$ and $p<0.05$ respectively). Improved grassland extending right from the pond edge up to 100m distant was associated with lower than expected toad frequencies, $p<0.05$.

Toads were found in a larger percentage of ponds in arable than improved grassland landscapes - 27 cf 13% (Table 5.6(b)). Features associated with increased levels of occupancy in arable land were flowing water (46%) and woodland (37%). However, on closer inspection of the data, other factors also appear to have had some effect. Although overall the presence of ditches within 500m had no significant effect, their presence within 100m was associated with an elevated frequency of occupation ($p<0.025$). A complete absence of scrub within 100m may have had a negative effect on toad percentage occupancy, but presence of the feature from 100m and extending up to the pond edge was associated with increased toad frequency, ($p<0.05$). The effect of woodlands also was most strongly positive when they were within 100m of ponds ($p<0.05$).

Toads occurred in a higher percentage of sites in woodland dominated landscapes than in any other overall land-use type (32%). Still higher frequencies were found in the presence of flowing water and arable land (42 and 38% respectively) Table 5.6(b)). Within woodlands, toads were found more frequently in ponds with hedges or flowing water within 100m ($p<0.01$ and $p<0.005$ respectively).

Toads were recorded in 34% of garden ponds.

5.4.2.2.(iii) Smooth newt

Smooth newts were recorded in 23% of the total sample, their frequencies of occurrence in association with different land use types ranging from 20% with woodland present to 31% in the vicinity of gardens (Table 5.5(a)). Frequencies of occupation dropped with the presence of arable land at pond edges (scores 4, 5 and 6), and with improved grassland, woodland and built-up areas present anywhere within 500m (Table 5.5(b)).

Within predominantly improved grassland habitats smooth newts were present in 19% of sites, but in the presence of built-up areas and arable land, the percentages were 33 and 24% respectively (Table 5.6(c)). However, built-up areas were not associated with above expected frequencies when within 100m of sites ($p<0.001$).

In unimproved grassland, in which smooth newts were found in 29% of ponds, road and railway lines, mineral extraction sites, built-up areas and arable land within 500m were all associated with elevated frequencies of the species' occurrence, (Table 5.6(c)). Newts were found at higher than expected frequencies where mineral extraction sites were present within 100m and where built-up areas were present in, but not closer than band 2.

Twenty-two percent of ponds in arable habitats contained smooth newts, but higher frequencies of occupation were

observed where gardens and woodland were present within 500m (Table 5.6(c)).

Smooth newts exhibited a relatively low frequency of occupation within predominantly woodland habitats (16%), which was higher in ponds with gardens present within 500m (31%) (Table 5.6(c)). Ponds with improved (or grazed) grassland present within, but not beyond, 10m of the water's edge also had a higher frequency of occupation, $p<0.001$.

Smooth newts were found in 38% of garden ponds.

5.4.2.2.(iv) Palmate newt

Palmate newts were recorded in 12% of the total sample, percentage frequencies ranging from six percent in ponds with arable land present to 15% of those with woodland within 500m (Table 5.5(a)). However, lower percentage presence in sites associated with arable is likely simply to reflect the national distribution of the species; it is generally not found in the agricultural lowlands. From Table 5.5(b), no clear trend of either increasing or decreasing percentage occupancy with "influence" of any land-use type was discernable except for built-up areas in which the effect was positive.

In landscapes dominated by improved grassland, palmate newts were present in 8% of ponds. A slightly higher frequency (12%) was observed for ponds in which flowing water was present within 500m (Table 5.6(d)). Examining the effects of distances on the influence of habitat features, more ponds contained palmate newts than expected where flowing or still water-bodies were present in bands 2 and 3 ($p<0.05$ and $p<0.025$ respectively). Higher than expected frequencies were also found where scrub was present within 100m.

Ten percent of rough grassland ponds contained palmate newts, but those within 500m of flowing water, heath or moorland, were more likely to support them (16 and 25% frequencies of

occupation respectively) (Table 5.6(d)). Considering proximity, increased frequencies of occupation were observed where flowing water was present in band 2 only ($p<0.001$), and where heathland/moorland habitats were within 100m ($p<0.05$).

Palmate newts were recorded in only two of the ponds in predominantly arable landscapes.

The species was present in 19% of woodland dominated habitats, and with heathland/moorland and sand dune features present within 500m the percentage occupancy figures were higher - 30 and 100% respectively (Table 5.6(d)). More specifically, higher than expected newt frequencies were observed with heathland/moorland vegetation close to the pond (within 10m) or sand dunes anywhere within 500m ($p<0.005$ and $p<0.001$ respectively).

Palmate newts were found in 11% of the garden ponds in this sample.

5.4.2.2.(v) crested newt

The total sample size of potential crested newt sites, excluding counties outside of their national distribution range, was 1,322, of which 13% contained the species (Table 5.5(a)). There was little difference in their observed frequencies of occupation between sites associated with the different land use types. Frequencies ranged from 12% in ponds with improved grassland within 500m to 15% for those associated with built-up areas. Improved grassland within 100m of the site coincided with lowered occupation frequencies, the opposite trend to that observed for rough grassland (Table 5.5(b)). Sites with arable land within 10m had much lower frequencies of occupancy than those where the ploughed area did not impinge on band 4, the area immediately around the pond. The occupation frequency was higher in sites with woodland present, close to the water's edge, but not extending further than 10m beyond (21%), than where woodland coverage was more extensive (11 and 13%). Although the overall

percentage frequency of the newt sites associated with built-up areas was relatively high (15%), it decreased with proximity. This may therefore not indicate a habitat preference, but merely signify that crested newts are found most frequently in landscapes also populated by human beings.

In predominantly improved grassland habitats, only ten percent of ponds contained crested newts, but the presence of built-up areas and arable land was associated with increased frequencies of occupation - 19 and 16% respectively (Table 5.6(e)).

Fourteen percent of ponds in habitats dominated by rough grassland supported crested newts. The presence of mineral extraction sites, built-up areas and arable land were all associated with elevated occupation frequencies (60, 22 and 19% respectively) (Table 5.6(e)). Crested newts were found with higher than expected frequency in sites with ditches present in band 2, but less frequently than expected where they were recorded within bands 3 and 4 ($p<0.05$). They were also found in higher than expected frequency where still water-bodies were not present within 500m ($p<0.001$). Higher frequencies also occurred within 500m of built-up areas and within 100m of woodland ($p<0.001$ and $p<0.025$ respectively).

Crested newts occurred in only eight percent of ponds in arable dominated habitats, all four occupied sites being within 500m of gardens, improved grassland and woodland. The low number of populations sites in itself illustrates the unsuitability of this type of landscape for the species.

Predominantly woodland habitats supported crested newts in 11% of ponds. In the presence of sand dunes, built-up areas, improved grassland or arable land however, crested newt occupation frequencies were 67, 17, 17 and 20% respectively (Table 5.6(e)). Crested newts were found at higher than expected frequencies where ditches were present between 10 and 500m from sites, and where improved grassland was present even

further away - between 100 and 500m, ($p<0.05$ and $p<0.025$ respectively).

Crested newts were found in 9% of garden ponds.

5.4.2.2.(vi) Limitations of procedure

In this section, aquatic and terrestrial habitat variables associated with significant variations in percentage occupancy of sites by each species, were identified. Using Chi^2, it has also been possible to test whether the probability of sites supporting each species varied according to the distance of particular habitats or landscape features from them, within a maximum radius of 500m from each pond. However, the chi^2 test did not allow relative effects of features to be compared, nor did it reveal inter-variable correlations.

In the following section, Discriminant Analysis was applied to the data in order to find out whether the combinations of variables identified above adequately separate breeding from non-breeding ponds of each species. The technique also allowed the relative importance of variables as determinants of species presence to be compared.

5.4.3 Discriminant analysis incorporating aquatic and terrestrial variables

5.4.3.1 Procedure

Important aquatic and terrestrial habitat variables identified in the previous sections were entered into the multi-variate analysis procedure "Discriminant Analysis", (Manly 1986). In this procedure, a discriminant function coefficient (DFC) was calculated for each habitat variable, from which the overall discriminant function for each pond was derived. The greater the difference between the discriminant functions calculated for ponds with animals present, and those from which they were absent, the more significant was the separation of the two groups based upon the given variables. The significance of the

degree of separation was indicated by a Chi^2 statistic with associated probability value. The best separation of the data categories, in this case "presence" or "absence" of each species, was obtained by the combination of variables resulting in the lowest Wilks Lambda value.

The size of the DFC for a particular variable should indicate its relative importance as a determinant of species are presence. The accuracy of the discriminant functions in predicting whether sites contained each species was tested at the end of the procedure where, based on the discriminant scores alone, ponds within each sample were separated into two groups. The separation point was the score midway between the averages of the predicted "species present" and "species absent" sites. The percentage of sites correctly predicted to contain each species was used to assess the value of the variables and their DFCs, in identifying habitat criteria important to amphibians. Discriminant analysis also calculated inter-variable correlations, which were important to recognise in the interpretation of the results.

5.4.3.2 Methods

Each terrestrial habitat variable was allocated a "score" based on its assumed influence on the pond to which it related, (see Table 5.1). Values were assigned to aquatic parameters to represent their relative values. For example, percentage emergent cover equal to 0 was given the value 1; the range 1-25%, 2; 26-50%, 3; 51-75%, 4; and 76-100%, 5.

The variables entered into the analysis were chosen under two criteria. Firstly, for each overall land-use type (improved grassland, arable etc) features whose presence within 500m was associated with a difference in percentage occupancy by the species of +/- 5% from the average for that land-use, were selected. For example, frogs were found in 39% of all "arable" ponds, but this increased to 45% of those with ponds or other still water-bodies within 500m. Therefore, "wetlands" was entered as a variable in the discriminant analysis. Secondly,