CHAPTER 5

AMPHIBIAN HABITAT CHARACTERISTICS

5.1 Introduction

An important objective of the Herptile Sites project is to derive habitat management guidelines for each of the five species. Requests for such information now come from many quarters: eg, conservation bodies involved in nature reserve and SSSI management, farming and forestry organisations attempting more environmentally sensitive land husbandry, industrial companies restoring derelict land, and, not least, garden pond owners.

The task of identifying essential habitat components may be approached by detailed population studies, or by comparing habitat variables associated with the presence or absence of each species. The first approach is being adopted, for example, in a NERC/AFRC/SSRC Joint Agriculture and Environment Programme project, based at De Montfort University, in which the utilisation of farmland habitats by toads and crested newts is being investigated using trapping programmes and radio-tracking techniques. Due to their labour-intensive nature however, few such studies can be undertaken. The National Survey provides information from throughout mainland Britain, and the descriptive data supplied by the volunteer recorders allows the second approach to be applied.

5.2 Aims and objectives

The aim of the data analysis was to identify habitat features associated with presence or absence of each species in different land-use types. The overall objective was to provide guidelines for the management of both aquatic and terrestrial landscape components, for amphibians.

5.3 Methods

5.3.1 Data preparation

5.3.1.1 Data selection

The data presented in this chapter were obtained from amphibian survey pond questionnaires (Swan and Oldham 1989); style "A" (Appendix 21) requested data on aquatic characteristics only, while style "B" (Appendix 7) requested pond-type identification, and surrounding terrestrial habitat descriptions.

Analysis was restricted to static water-bodies whose length and width were recorded, and where susceptibility to desiccation and the presence or absence of fish were known. For crested newts, sites in counties known to be outside the normal range of the species (see Chapter 3) were excluded. This did not apply to the smooth or palmate newts, whose national distribution ranges are not so clearly defined.

In this chapter, only species presence or absence are considered, rather than count data, for three reasons:- firstly, the range of recorder ability was probably so wide that count data could not be regarded as representing population size accurately over the whole sample; secondly, counts made by inexperienced recorders surveying at inappropriate parts of the breeding season or in poor climatic conditions could provide data which poorly reflected population sizes. The use of invalid indicators of population sizes could obscure true habitat relationships or create false ones. The possibility still exists with simple presence/absence data when false negatives are presented, but at least the significance of unrepresentative low counts will be reduced. Thirdly, simplifying the data to "presence" or "absence" allows the use of information from tadpole observation, spawn searches and netting, maximising sample size.

5.3.1.2 Water-body description

The water-body descriptions comprise site dimensions, (length and width) and a range of options with which to describe depth, shading, the amount of emergent and submerged vegetation coverage, tendency to desiccate and the presence or absence of fish.

A total sample size of 2,987 pond descriptions were analyzed, combining data from both questionnaire styles. Because of the probability of artificial introduction and maintenance of amphibians in garden ponds, these were regarded as a special category and excluded from some of the analyses. In order to deselect garden ponds, samples were limited to the later pond questionnaires (Appendix 7) in which garden ponds could readily be recognised. The resultant non-garden sample size was 1,503. The set of water-bodies excluding gardens will hereafter be referred to as "field" sites.

5.3.1.3 Terrestrial habitat description

The land-use descriptive section of type "B" questionnaires (Appendix 7) gives a selection of 14 land-uses from which the recorders identified those predominant within each of a range of four distances from sites. Recorders were also asked to choose from seven landscape features potentially affecting amphibians (hedges, roads etc), again at each of a range of four distances from each pond. Land uses or features listed under the "other" category were either entered into existing categories or allocated new ones. The complete list of amended land use categories and habitat features can be found in Appendix 22. For the purpose of the following analysis some categories were combined (Appendix 23).

The range of distances delimiting the terrestrial habitat "bands" around ponds were 0-10 (band 4), 10-100 (band 3), 100-500 (band 2) and 500-1000 (band 1) metres from sites. However, in practice, few surveyors attempted to record the habitats and features present over 500m from ponds. Therefore analysis was restricted to habitat bands within 500m.

In order to derive a data set amenable to analysis, the terrestrial habitat categories were given numerical values relating to their extent and proximity. A ranking system was devised, based on assumptions of increasing influence of each land-use type or habitat feature on sites. It was assumed that the larger the area of coverage by a particular land-use type and the closer it was to the pond, the greater its influence. The scoring system and habitat "bands" are illustrated in Table 5.1.

Some categories, such as "scrub" were presented as options in both the "land use" and "habitat features" sections (Appendix 7), in which case extra "scores" differentiate between the different extent of coverage implied by the terms "predominant land use" and "habitat feature". For example, a "predominant land use" in band 3 will have a higher score than a"habitat feature" at the same distance.

5.3.2 Data analysis

The samples were analyzed initially using the Chi^2 test (Siegel 1956), where the actual frequency of occurrence of each species in the presence of particular land-use types or habitat features was compared to that expected overall. For example, the overall percentage occurrence of frogs at ponds in all habitats was 58%, but when the sample was divided into several land use types, frog frequency ranged from 39% of ponds in arable land to 82% in gardens. To test the significance of these apparently substantial deviations, the expected frequencies were calculated as 58% of the total number of arable and garden sites. Subsequently, the sample was divided still further in order to examine the effects of particular features within specific land-uses. For example, in predominantly arable landscapes, frog pond frequency overall was 39%, but in the sub-set of "arable" ponds where woodland was present within 500 metres, the species was found in 58% of

Table 5.1

System devised for allocating numerical values to terrestrial habitat variables, incorporating the relative extent of each listed category and its proximity to sites.

<table>
<tr><th colspan="4">DISTANCE FROM SITE (metres)</th><th colspan="2">SCORE</th></tr>
<tr><th>0 - 10 (band 4)</th><th>10 - 100 (band 3)</th><th>100 - 500 (band 2)</th><th>500 - 1000 (band 1)*</th><th colspan="2">category listed in pond questionnaire in:-</th></tr>
<tr><th></th><th></th><th></th><th></th><th>both land-use and feature sections</th><th>either land-use or feature sections</th></tr>
<tr><td>- -</td><td>- -</td><td>- -</td><td></td><td>1</td><td>1</td></tr>
<tr><td>- -</td><td>- -</td><td>- hf</td><td></td><td>2</td><td rowspan="2">2</td></tr>
<tr><td>- -</td><td>- -</td><td>LU</td><td></td><td>3</td></tr>
<tr><td>- -</td><td>- hf</td><td></td><td></td><td>4</td><td rowspan="2">3</td></tr>
<tr><td>- -</td><td>LU</td><td></td><td></td><td>5</td></tr>
<tr><td>LU hf</td><td>- -</td><td></td><td></td><td>6</td><td>4</td></tr>
<tr><td>LU hf</td><td>- hf</td><td></td><td></td><td>7</td><td rowspan="2">5</td></tr>
<tr><td>LU hf</td><td>LU</td><td></td><td></td><td>8</td></tr>
<tr><td>LU</td><td>LU</td><td>LU</td><td></td><td></td><td>6</td></tr>
</table>

LU - land-use (assumes extensive coverage)
hf - habitat feature

* data inconsistent so not used

sites. Chi^2 was used to test whether the association between woodland presence and the above average incidence of frog populations was significant. The overall "arable" percentage occurrence figure of 39% was used to calculate the expected frequency of frog populations - ie, 0.39 X total number of ponds which had woodland within 500m.

Finally, aquatic and terrestrial variables thus identified as being associated with variations in percentage occupancy of ponds by amphibians were then entered into Discriminant Analysis (Manly 1986). This procedure was used to investigate further the relevance of selected habitat features as predictors of species presence, and to ascertain their relative importance.

5.4 Results

5.4.1 Water-body characteristics

5.4.1.1 Distributions of amphibians with respect to water-body characteristics

5.4.1.1.(i) Amphibians in general

Overall, amphibians were found in water-bodies encompassing a wide range of sizes, from 0.5 to 2×10^6 m^2 in this sample. There was no significant relationship between percentage occupancy by "amphibians" in general and pond area, probably because opposite trends exhibited by different species cancelled each other out (Table 5.2), (eg toads were recorded at low frequency in small ponds whereas frogs occupied a high proportion of them). Overall, however, animals were found less frequently in ponds less than 0.5m deep ($p<0.01$, Chi^2 test, 1df) and percentage occupancy decreased with increasing shade, ($p<0.005$). Amphibians also avoided extremes of vegetation coverage, occurring significantly less frequently in ponds containing either no emergent vegetation at all, or over 75% surface coverage ($p<0.01$). A complete lack of submerged vegetation also was correlated with lowered population frequency ($p<0.001$), although amphibians appear not to be averse to complete substrate coverage; ponds in the over-75% submerged cover range were not associated with lower than expected frequencies. In the complete sample, fish presence was associated with higher than expected amphibian frequencies ($p<0.01$), but when garden ponds were excluded, fish had no effect on amphibian presence overall. Amphibians were found in lower than expected frequency in ponds which desiccated annually ($p<0.001$).

Animals were recorded in 77% of all surveyed sites, and 74% of field ponds. It must, however, be remembered that most of these sites did not form part of a systematically surveyed sample in which all water-bodies within a given area are investigated. Many were recorded as single sites, probably selected as containing, or being likely to contain, animals; therefore percentage figures are not representative of the actual status of each species; there is a tendency to over estimate species percentage occurrence, as indicated by reference to Chapter 4 in which the systematic data sets were reviewed. For example, frogs were found in 47% of systematically surveyed ponds (section 4.4) but in 58% in the present sample.

5.4.1.1.(ii) Frog

In the total sample, frogs were found in greater than expected frequency in ponds $\leq 25m^2$ in area ($p<0.001$), but for the field ponds alone, water-body area had no effect on percentage occupation ($p>0.05$) (Table 5.2). Percentage occupancy was significantly reduced in ponds with over 25% surface shading, the species preferring completely unshaded sites ($p<0.001$). Frequency of occurrence was also significantly reduced in the complete absence of emergent or submerged vegetation ($p<0.01$ and $p<0.001$ respectively). In the all-inclusive data set, ponds containing fish were preferred ($p<0.005$), whereas in the field sample no such preference was exhibited. Ponds desiccating every year were avoided ($p<0.005$) but in the field

Table 5.2

Percentage occupancy of ponds with respect to size, structure and vegetation characteristics. (Rt-frog; Bb-toad; Tv-smooth newt; Th-palmate newt; Tc-crested newt; ANY- any amphibian species; N-total sample size; n-crested newt sample size, excluding sites outside species range)

POND CHARACTERISTICS	PERCENTAGE OCCUPANCY															
	including gardens								**excluding gardens**							
	ANY	Rt	Bb	Tv	Th	N	Tc	n	ANY	Rt	Bb	Tv	Th	N	Tc	n
area (m^2)																
<26	88	77	25	30	13	697	6	680	73	56	14	16	14	147	7	132
26-100	73	55	19	25	15	445	13	432	70	55	13	23	13	245	14	232
101-250	72	54	18	28	14	529	14	511	74	56	19	30	14	255	15	228
251-500	75	58	23	25	15	269	15	257	74	57	22	27	14	212	15	191
501-750	70	51	34	29	17	187	22	111	69	52	34	28	16	112	23	104
751-1000	74	65	39	21	9	145	8	83	80	65	38	22	9	89	9	79
1001-1500	77	63	36	20	10	145	9	136	77	64	39	24	10	80	11	65
1501-2000	69	60	38	17	10	99	12	91	63	59	41	15	10	59	17	46
2001-5000	81	66	49	22	7	215	7	194	77	63	48	19	6	134	7	109
5001-10,000	81	58	50	24	14	88	8	83	74	57	42	21	19	47	10	40
>10,000	74	60	49	11	7	168	3	149	74	61	49	10	8	123	4	96
depth (m)																
<0.5	72	60	18	19	11	1102	6	1058	66	55	16	16	9	538	7	469
0.5-2.0	81	63	32	31	14	1492	14	1436	78	61	31	28	16	742	17	656
>2.0	77	60	43	21	9	393	10	360	72	55	45	21	8	233	11	197
shade (%)																
0	83	68	26	24	15	1068	8	1017	79	65	28	20	14	501	10	409
1-25	80	62	32	30	11	836	13	799	77	59	31	30	10	406	16	369
25-50	74	60	30	29	13	470	11	451	68	54	28	23	16	229	13	208
51-75	70	54	28	23	9	266	13	259	69	53	30	27	11	138	16	129
76-100	64	48	23	13	10	347	9	328	60	44	21	12	10	229	8	207
south shade																
YES	72	58	28	25	13	678	11	635	67	61	30	24	12	529	13	841
NO	79	63	28	25	12	2309	10	2219	76	52	25	21	13	974	12	481
emergent vegetation (%)																
0	67	54	19	15	11	600	7	577	58	49	18	11	9	304	6	276
1-25	80	63	32	27	13	1413	11	1350	75	58	34	23	13	674	13	584
26-50	82	67	31	31	12	488	12	470	84	67	31	33	15	233	18	204
51-75	82	67	28	31	16	276	12	258	78	62	24	30	16	147	14	129
76-100	72	57	19	22	9	210	11	199	72	54	19	20	8	145	13	129
submerged vegetation (%)																
0	61	49	19	14	8	736	5	703	57	45	18	13	9	447	6	405
1-25	81	65	30	27	11	1136	10	1082	76	60	31	25	12	568	12	502
26-50	85	64	36	34	15	478	12	461	86	66	38	31	19	204	17	184
51-75	86	70	33	33	18	328	18	315	86	70	32	37	14	136	27	123
76-100	83	67	27	24	20	309	12	293	78	65	27	17	15	148	15	108
fish presence																
YES	83	67	43	26	9	1193	6	1146	79	64	50	23	12	455	7	396
NO	74	58	18	25	14	1794	14	1708	71	55	19	23	13	1048	15	926
desiccation																
NEVER	80	63	33	28	12	2078	10	1980	75	59	36	23	14	902	11	788
DROUGHT	80	61	22	29	14	375	18	355	78	59	23	30	13	341	18	314
EVERY YEAR	64	55	13	13	12	534	7	519	60	51	7	11	7	260	8	220
TOTAL						**2,987**		**2,854**						**1,503**		**1,322**

sample, this observed tendency was not significant ($p>0.05$). Thus, frogs appear to be catholic in choice of ponds, breeding in water-bodies exhibiting a wide range of sizes and successional stages. Sites devoid of either emergent or submerged vegetation are avoided as are those for which over a quarter of their water surfaces are shaded. Preference for ponds with fish in the sample which included garden ponds may reflect the species' prevalence in gardens where a high proportion of available water-bodies are stocked.

5.4.1.1.(iii) Toad

Toads were seldom encountered in the smaller ponds; they were found in less than expected frequency in sites smaller than $500m^2$ and shallower than 0.5m, ($p<0.001$ in both cases) (Table 5.2). They occurred in lower than expected frequency in completely unshaded ponds but also in those where over 75% of the water-surface was shaded ($p<0.05$). This indicates perhaps the necessity for pond-edge cover which incidentally casts shadows, but avoidance by toads of heavily shaded sites. An absence of either emergent or submerged vegetation coincided with lower than expected frequencies of toad occupancy ($p<0.001$ in both cases). In the field ponds, emergent vegetation covering over 50% of the water-surface was also associated with a lowered frequency ($p<0.001$). Toads were found in much higher than expected frequencies in sites containing fish ($p<0.001$) and occurrence of populations was reduced in ponds known to dry out either every year or only in drought ($p<0.001$).

Thus, pond size and permanence (fish presence would indicate a water-body which dries out very infrequently) are important determinants of toad presence. Aquatic vegetation cover is also necessary but ponds should not be excessively overgrown.

5.4.1.1.(iv) Smooth newt

In the all-inclusive data set, smooth newts occurred at higher than expected frequency in sites less than $750m^2$ ($p<0.001$), but this relationship was not significant in the field pond sample ($p>0.05$) (Table 5.2). In both data sets, though, newts were found at reduced frequency in ponds less than 0.5m deep ($p<0.01$). Sites with no shading at all, or where it extended over 75% or more of the surface were associated with reduced frequency of smooth newt occupation ($p<0.001$). Those which also exhibited extremes of emergent and submerged vegetation cover (none at all or over 75% coverage) were less likely to contain the species ($p<0.001$ in both cases). Permanent water-bodies and those which desiccated only during drought had higher than expected frequencies of newt occupancy ($p<0.001$).

Smooth newts therefore occupy the full range of pond sizes, but are able to utilise smaller sites in gardens. Aquatic and pond edge vegetation cover is required, but excessive terrestrial shading or aquatic plant growth are inimical. Fish presence does not appear to affect species presence. Occasional site desiccation does not prevent species persistence.

5.4.1.1.(v) Palmate newt

As with the smooth newts, palmates were found in higher than expected frequencies in smaller ponds (up to 750m^2) in the garden inclusive sample ($p<0.05$), but not in the field-only data-set ($p>0.05$) (Table 5.2). They also occurred less frequently in sites less than 0.5m deep ($p<0.005$) and in those with no submerged vegetation ($p<0.001$). In the all-inclusive data set, they were found in greater than expected frequency in sites without fish ($p<0.001$), but without the garden data no such relationship persisted. Conversely, site desiccation apparently had no effect on newt distribution within the garden-inclusive data-set but excluding gardens, newts were found more frequently in sites which never dried out ($p<0.01$).

Palmate newts therefore inhabit a wide range of pond sizes, but like the smooths are able to utilise smaller ones in gardens. Relatively unshaded ponds are preferred, with some submerged vegetation, but emergent vegetation apparently has little effect, possibly reflecting its paucity in many of the oligotrophic water-bodies in which the species is found. Ponds which desiccate annually are seldom populated, but the species' relationship to fish is ambivalent, newts preferring non-fish sites in the total sample, but fish presence apparently not affecting their distribution in the field.

5.4.1.1.(vi) Crested newt

Crested newts tended not to breed either in very small or very large ponds, (Table 5.2). They were found in lower than expected frequencies in sites less than $26m^2$ and larger than $750m^2$ in both data-sets ($p<0.001$ and $p<0.005$ respectively). Sites less than 0.5m deep were also unlikely to support populations ($p<0.01$). Ponds with up to 25% shading were preferred to those with either none, or with over 75% of the surface affected ($p<0.025$), suggesting the need for some, but not excessive pond edge cover. Frequencies of occupation were less where either emergent or submerged vegetation cover was zero ($p<0.025$ and $p<0.001$ respectively); in the field sample, the frequency of occupation was greatly elevated where submerged vegetation covered from 50 to 75% of the bottom substrate ($p<0.001$). Frequencies of occurrence were lower in sites containing fish ($p<0.001$) but higher at those which desiccated during drought ($p<0.001$), which two factors may have been related.

Crested newts therefore occupy the size range "small" to "medium", encompassing ponds approximately between $25m^2$ to $750m^2$. They do not generally populate very small sites, even in gardens. A modicum of terrestrial shade is apparently necessary, although this perhaps simply indicates the presence of pond edge vegetation cover, the actual determinant of newt presence. Ponds without emergent or submerged vegetation are avoided, and those with high levels of the latter seem particularly preferred. Fish presence is inimical, possibly reflected in the species preference for sites which desiccate occasionally, thus preventing fish persistence.

5.4.1.2 Comparisons of water-body characteristics between land-use types

Before investigating the effects of broad land-use types, it is necessary to compare the aquatic characteristics of the water-bodies they contain. If ponds vary greatly between different landscapes, aquatic rather than terrestrial factors may be responsible for observed differences.

5.4.1.2.(i) Water-body sizes

The median areas of all ponds in different habitats, and those used as breeding sites by each species are presented in Table 5.3. Water-bodies did not differ significantly in size between any of the land-use types ($p>0.05$, Mann-Whitney U-test), except garden ponds which were significantly smaller than those in each of the other categories ($p<0.001$ in each case). The areas of the breeding sites of each species were also smaller in gardens than in the other habitats ($p<0.001$ in each case), between which they did not vary significantly ($p>0.05$).

To test whether breeding ponds were selected on the basis of size, breeding and non-breeding pond areas were compared within each land-use type.

In most land-use types, the sizes of frog breeding ponds did not vary significantly from those from which they were absent ($p>0.05$); except in gardens, where breeding sites were smaller than non-breeding ponds ($p<0.0003$), and rough grassland where breeding ponds were larger ($p<0.05$). Smooth newts exhibited no differences at all. For toads, palmate and crested newts, garden ponds used as breeding sites were larger than those not supporting the species ($p<0.05$, $p<0.02$ and $p<0.01$ respectively). In the non-garden habitats, crested newt breeding sites did not differ significantly in area from non-newt sites. Palmates apparently occupied the smaller ponds, breeding sites being significantly smaller than non-breeding sites in improved grassland and built-up areas ($p<0.02$ and $p<0.03$ respectively). Toads however were highly selective,

Table 5.3

Areas of water-bodies in different predominant land-use types.

(a) total sample (including amphibian-free sites)

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	360	278	245	345	228	310	6
max	$1.3x10^7$	$2.0x10^6$	$2.0x10^6$	$1.2x10^5$	$4.0x10^5$	$2.0x10^6$	$5.4x10^4$
min	0.75	0.75	3.00	1.00	1.00	2.25	0.50
N	1,503	240	312	51	230	50	425

(b) frog

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	400	262.5	300	427	250	225	6
max	$1.2x10^6$	$6.5x10^4$	$8.2x10^5$	$1.2x10^5$	$2.9x10^5$	$1.3x10^4$	$5.4x10^4$
min	1.00	2.50	3.00	6.00	4.00	9.00	0.50
N	869	126	182	20	141	25	349

(c) toad

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	900	1,000	1,000	600	1,150	600	8
max	$2.0x10^6$	$2.0x10^6$	$2.0x10^6$	$4.5x10^3$	$4.0x10^5$	$2.0x10^6$	$4.0x10^3$
min	1.00	16.00	20.00	24.00	1.00	12.00	0.50
N	421	31	91	14	74	10	144

(d) smooth newt

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	300	225	210	102	150	238	6
max	$1.0x10^5$	$1.4x10^4$	$1.0x10^5$	$4.5x10^3$	$1.0x10^5$	$1.3x10^4$	$2.2x10^3$
min	1.00	15.00	8.00	6.00	22.50	12.00	0.50
N	342	45	91	11	36	13	163

(e) palmate newt

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	300	150	200	-	200	162	12
max	$1.2x10^5$	$7.6x10^3$	$6.7x10^5$	-	$1.2x10^5$	$5.6x10^3$	$1.0x10^3$
min	1.00	1.00	15.00	-	16.00	2.25	0.75
N	186	19	31	2	43	12	47

(f) crested newt

	all (non-garden)	grassland improved	grassland unimproved	arable	woodland	built-up area	garden pond
med(m^2)	300	144	242.5	176	212.5	201	12.5
max	$6.0x10^4$	$6.0x10^4$	$6.0x10^4$	$4.5x10^3$	$4.5x10^3$	$8.0x10^3$	$2.2x10^3$
min	6.30	20.00	12.00	48.00	24.00	56.00	0.75
N	168	23	40	4	22	5	37

breeding sites being larger than non-breeding sites in all habitats ($p<0.001$ in all cases) except for arable land ($p>0.05$). This suggests that factors other than pond size may be important determinants in arable land.

Figures 5.1 (a) to (e) show the relationships between amphibian percentage frequencies of occupation and cumulative mean pond areas within five land-use types. Each of the five species was found more frequently in very small ponds (less than $10m^2$) in gardens than in the other habitats, apart from the palmate newt which also inhabited small ponds in improved grassland.

In both improved and unimproved grassland, and in woodland, the maximum percentage occupancy of ponds by frogs was approached when the cumulative mean pond area was approximately $75m^2$, (Figs 5.1(a)(i), (b)(i) and (d)(i)). In improved grassland, there was no further increase in frequency of occupation with the mean area, whereas in the other two habitats it rose gradually to a maximum at about $1,000m^2$. In arable land (Fig 5.1(c)), maximum occupation frequencies occurred between means of 25 and $75m^2$, decreasing to a minimum in the range 250 to $750m^2$, then rising again until the cumulative mean approached $1,000m^2$. Thus, no clear relationship between occupation frequency and pond size was apparent in arable land.

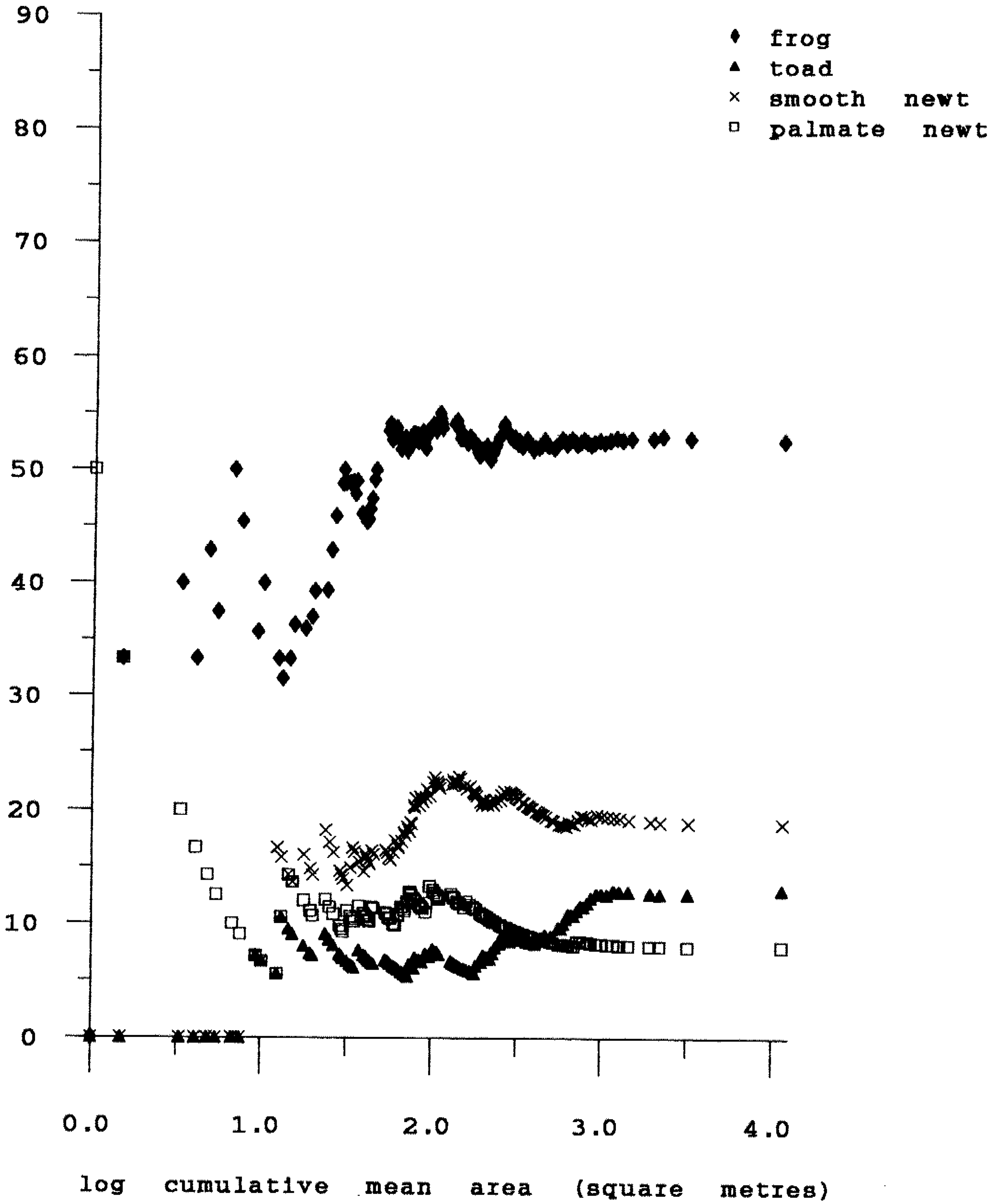
Toads were found very infrequently in ponds below $100m^2$ except in woodland and gardens. In all but arable land and gardens, maximum occupation frequency was attained when the average pond size reached $1,000m^2$, (Figs 5.1(a)(i), (b)(i) and (d)(i)). Within arable land, as with the frogs, maximum occupancy rates occurred in ponds averaging areas of between 250 and $750m^2$ and at $1,000m^2$ (Fig 5.1(c)). In gardens, toads were found relatively frequently in ponds between seven and $10m^2$ (Fig 5.1(e)(i)).

The two small newt species both showed clear peaks of optimum pond size ranges. Within improved grassland, these both

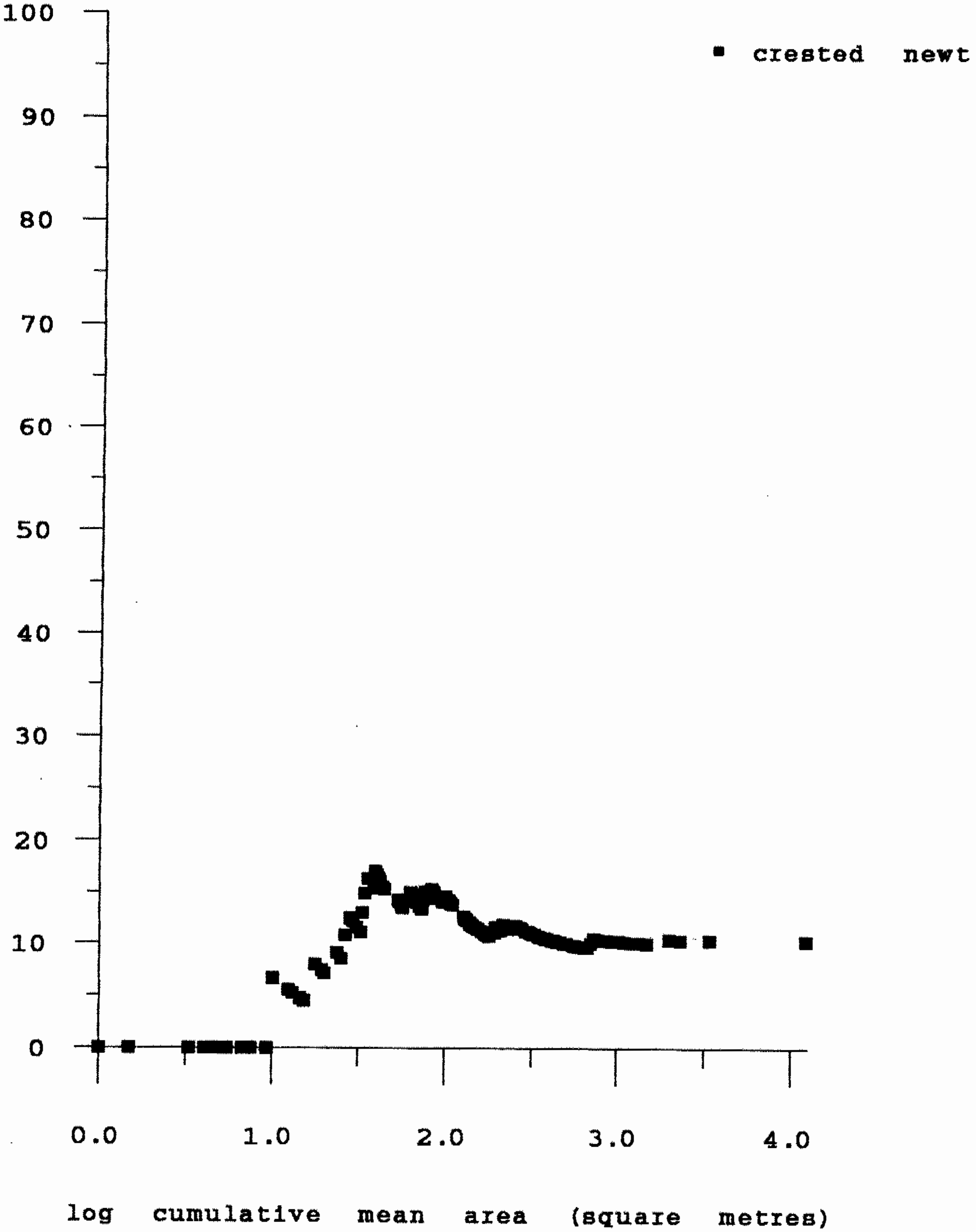
Fig 5.1

Percentages of ponds occupied by amphibians with increasing cumulative mean water-body areas, in different base land-use types.

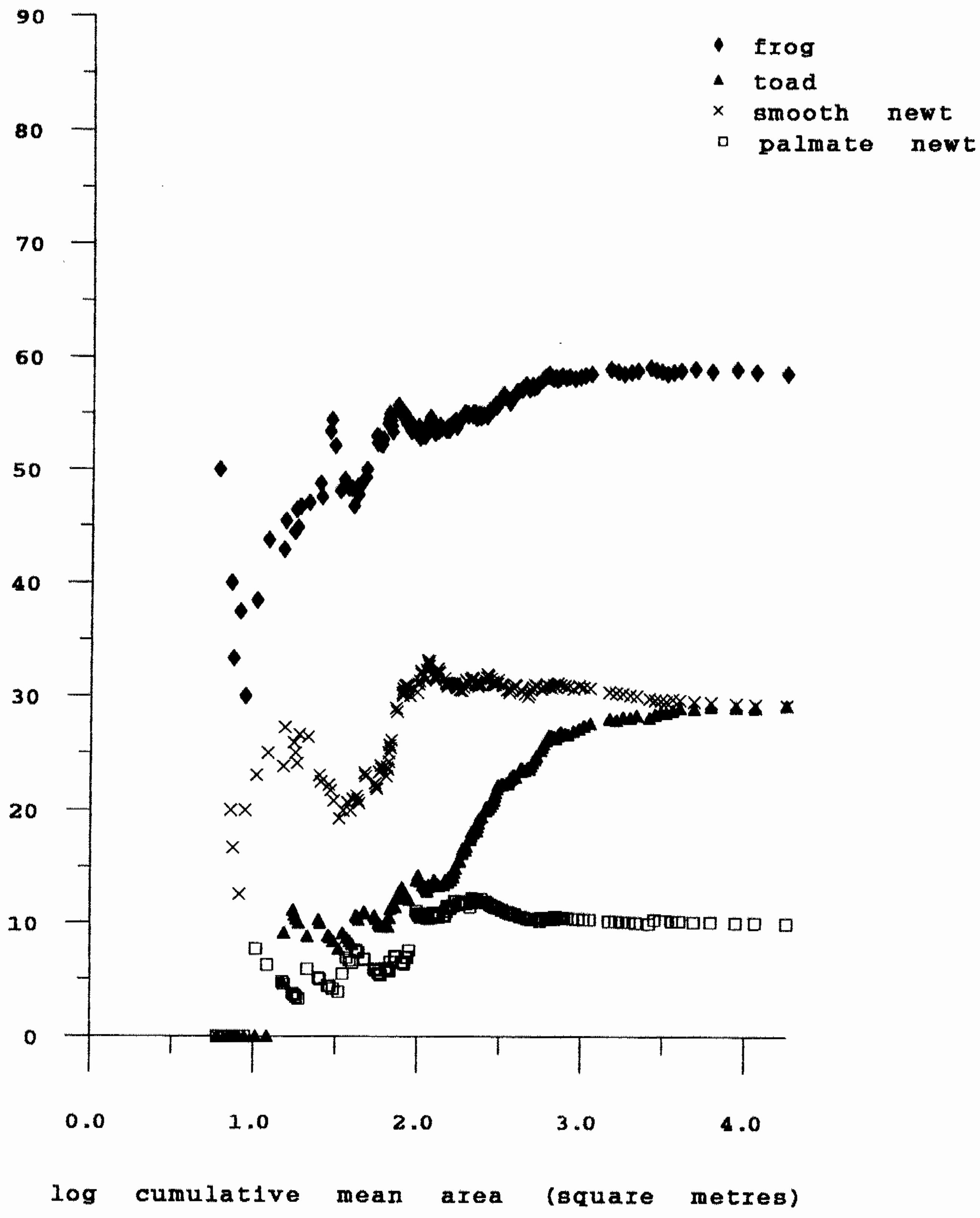
(a) IMPROVED GRASSLAND
(i) frog, toad, smooth newt, palmate newt



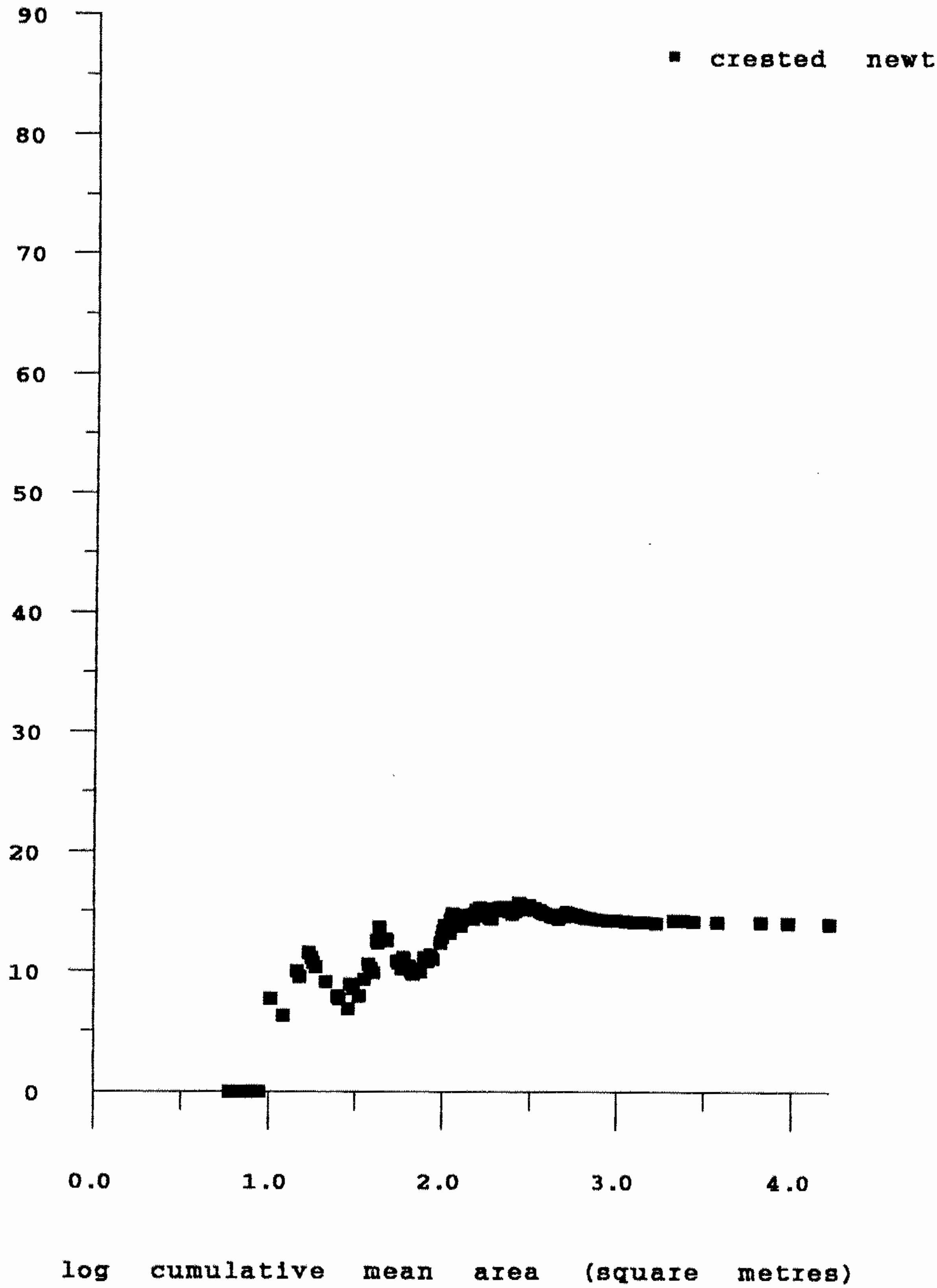
(a) IMPROVED GRASSLAND
(ii) crested newt



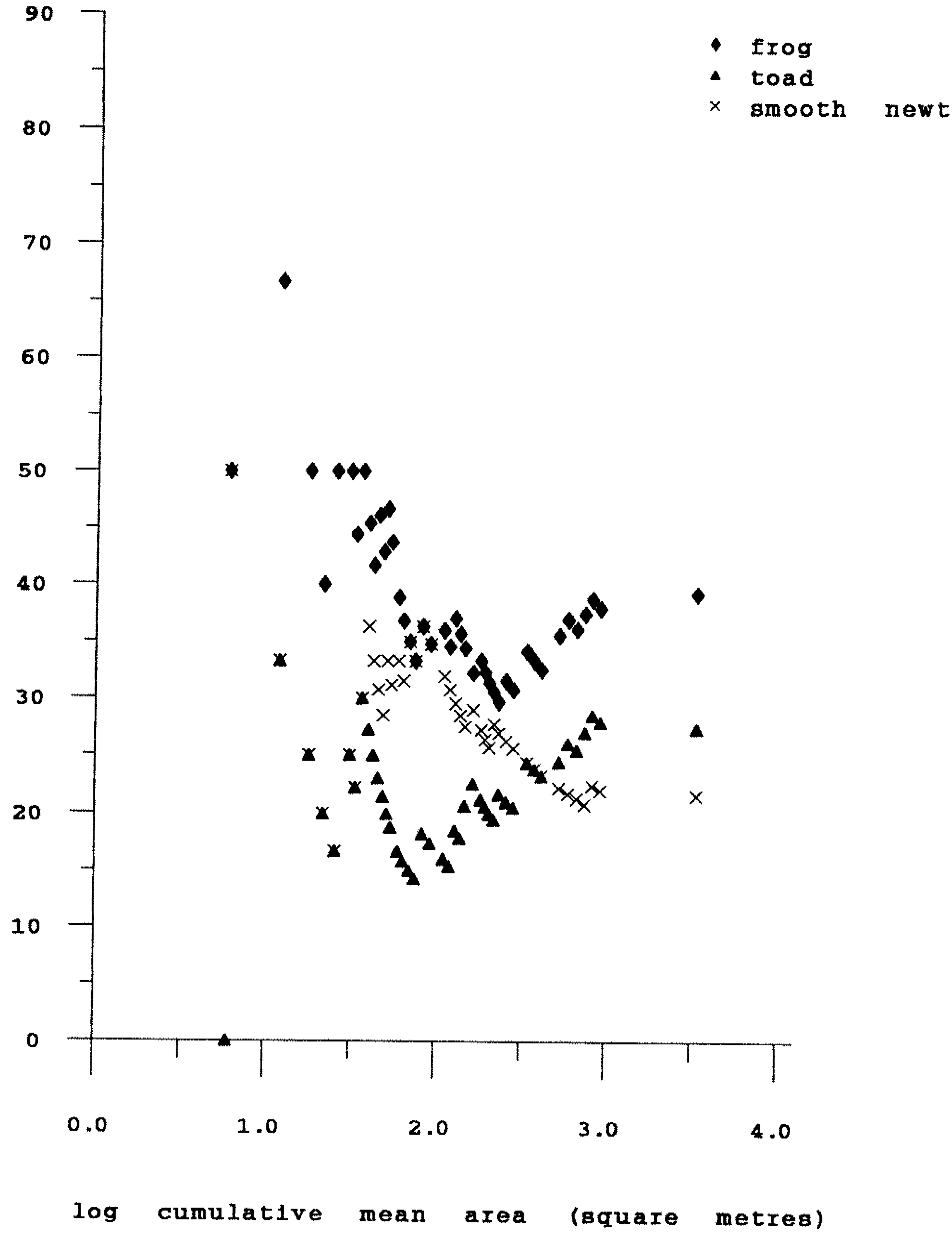
(b) UNIMPROVED GRASSLAND
(i) frog, toad, smooth newt, palmate newt



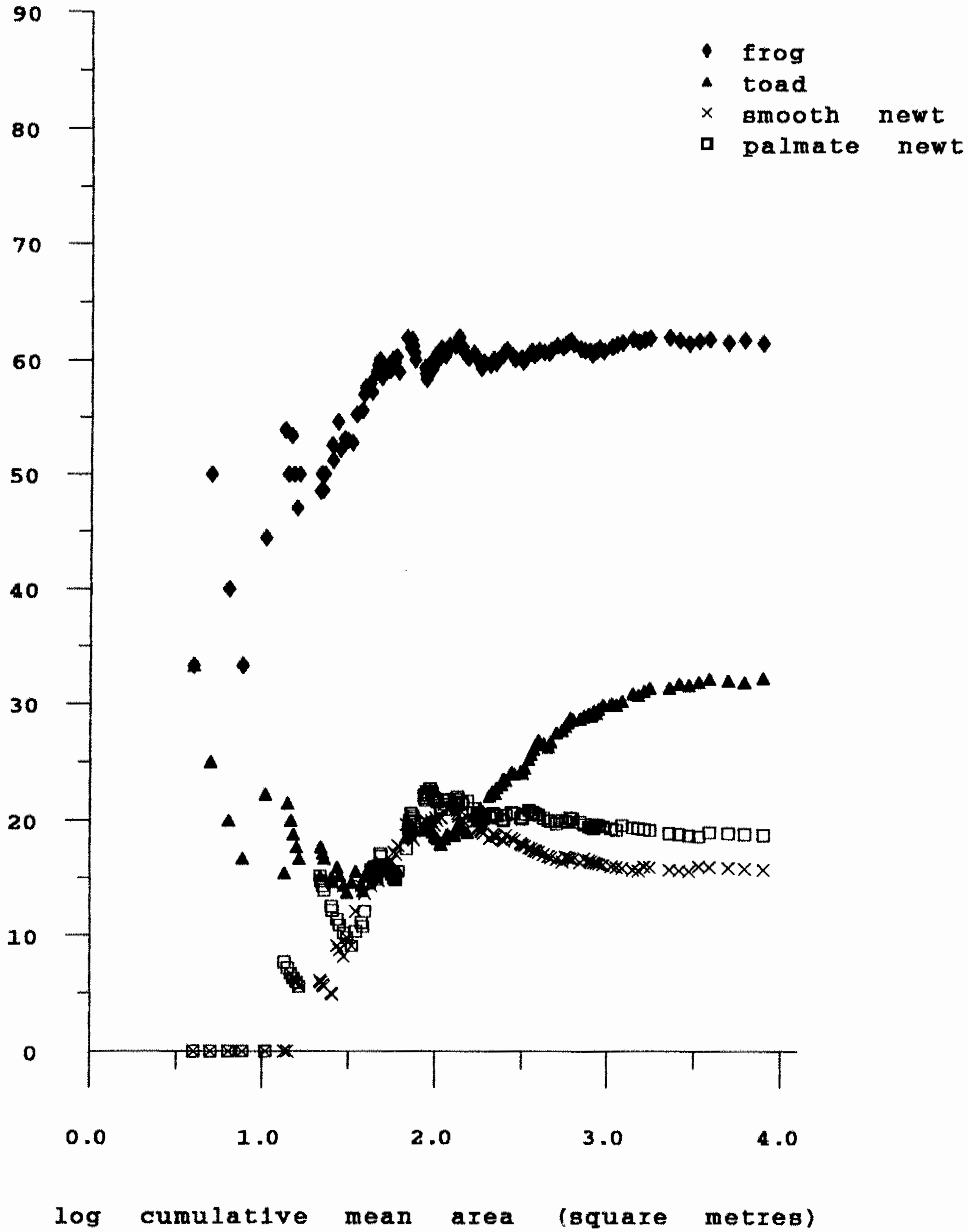
(b) UNIMPROVED GRASSLAND
(ii) crested newt



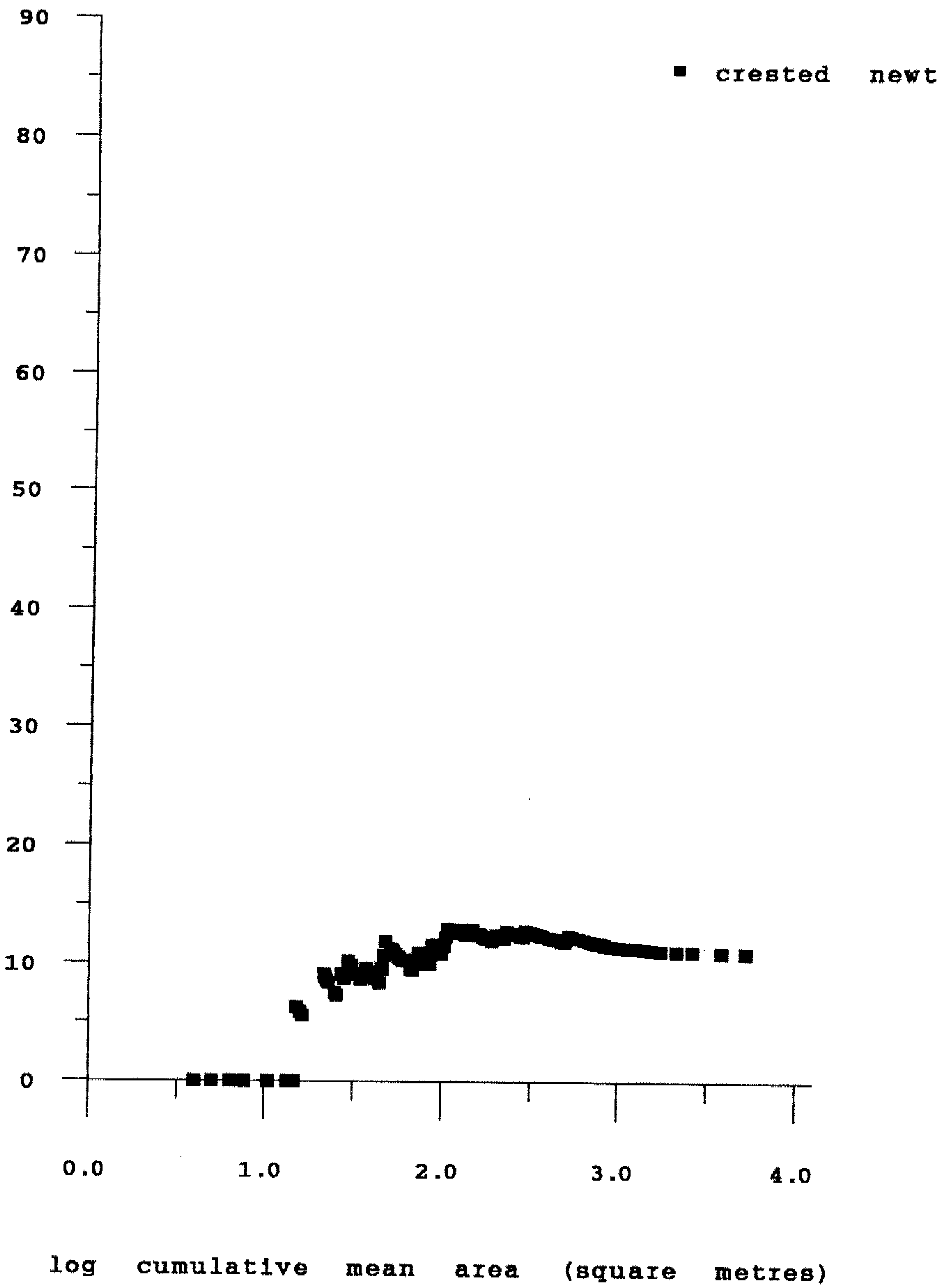
(c) ARABLE


90
80
70
60
50
40
30
20
10
0
frog
toad
smooth newt
0.0
1.0
2.0
3.0
4.0
log cumulative mean area (square metres)

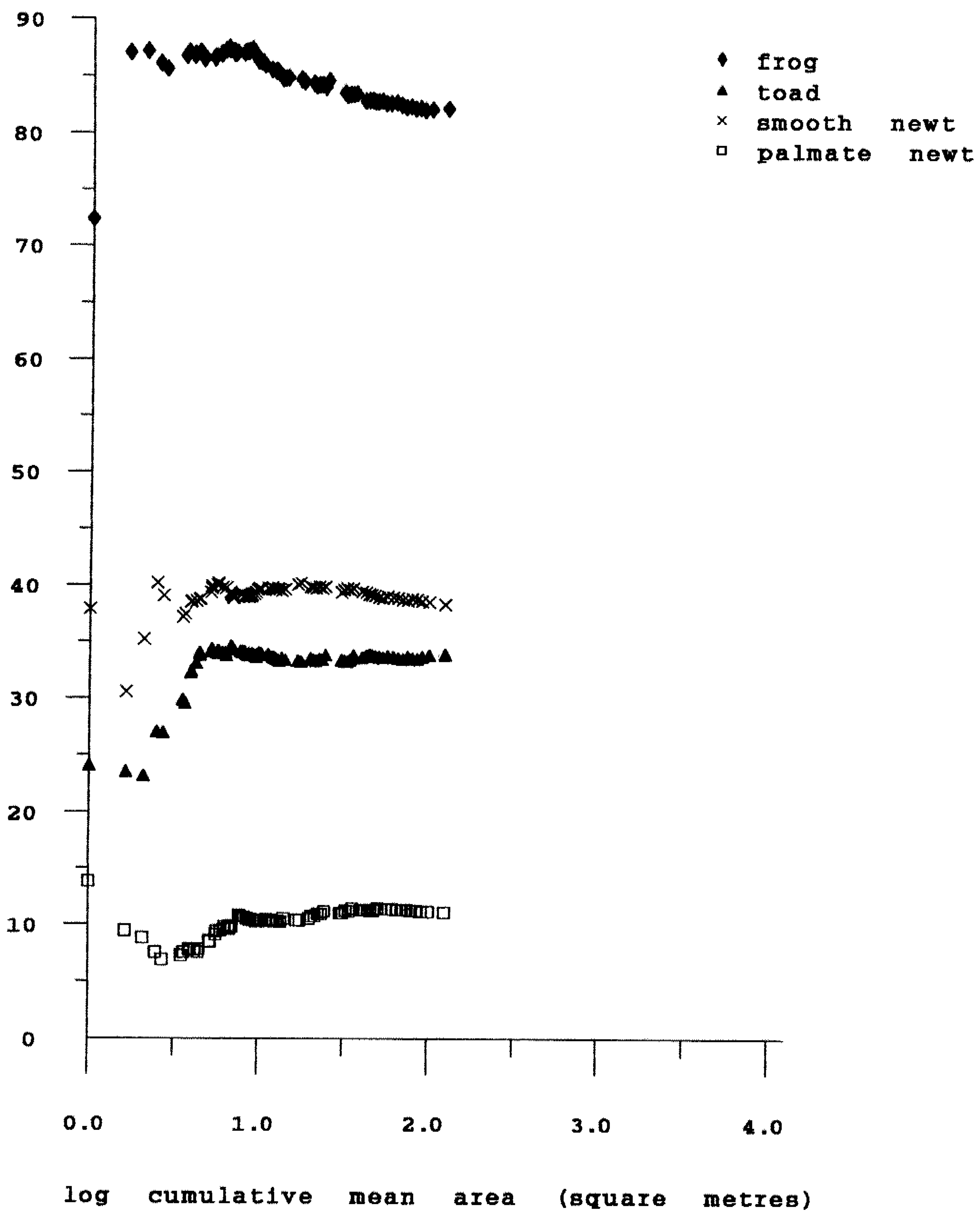
(d) WOODLAND
(i) frog, toad, smooth newt, palmate newt



(d) WOODLAND
(ii) crested newt



(e) GARDEN PONDS
(i) frog, toad, smooth newt, palmate newt



(e) GARDEN PONDS
(ii) crested newt