Distribution and habitats of the snail *Lymnaea truncatula,* intermediate host of the liver fluke *Fasciola hepatica,* in South Africa

K N de Kock[a], C T Wolmarans[a] and M Bornman[a]

ABSTRACT

This paper focuses on the geographical distribution and habitats of *Lymnaea truncatula,* the intermediate, snail host of the liver fluke, *Fasciola hepatica,* as reflected by the 723 samples in the database of the National Freshwater Snail Collection, Potchefstroom, South Africa. The 221 different loci (1/16-degree squares) on record reflect an extensive but discontinuous distribution, except in Lesotho and in parts of the Mpumalanga, Gauteng and North West provinces of South Africa. Although recorded from 12 different types of waterbody, it was mostly (42.0 %) recovered from swamps. Most samples (45.8 %) were collected in habitats with slow-flowing water. A muddy substratum was recorded for 62.5 % of the samples. Most samples (86.3 %) were collected in habitats with a mean annual air temperature of 10–20 °C, and more than 69 % came from localities with a mean annual rainfall of 600–900 mm. An integrated decision tree constructed from the data indicated that temperature and types of waterbody play a decisive role in determining the presence of *L. truncatula* in a given area. A temperature index calculated for all mollusc species ranked *L. truncatula* second in a total of 53 species according to its association with low temperatures. It remains to be established whether its distribution is indeed discontinuous, and whether its preference for a particular habitat, amphibious habits and ability to aestivate could have resulted in some populations having been overlooked during surveys.

Key words: *Fasciola hepatica,* geographical distribution, habitat types, *Lymnaea truncatula,* temperature.

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INTRODUCTION

Lymnaea (Galba) truncatula (Müller, 1874) is well known as the intermediate host of the liver fluke, *Fasciola hepatica,* in Europe[4] and it is of major importance in transmitting fasciolosis in Lesotho,[11] but no reference could be found with regard to its role in transmission of the disease in South Africa. The oldest record of *L. truncatula* in the National Freshwater Snail Collection (NFSC) is one from Lesotho that dates back to 1956. This paper focuses on the geographical distribution and habitats of *L. truncatula* as reflected by the 723 samples on record in the NFSC. Habitat details, as provided by collectors at the time of collection, and the influence of mean altitude, mean annual rainfall and temperature in the different 'loci' (1/16-degree squares) are discussed. As *L. truncatula* is the preferred host of *Fasciola hepatica*[4], the economic implications of its presence in South Africa are briefly discussed.

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MATERIALS AND METHODS

Data on the geographical distribution and habitats of *L. truncatula* were extracted from the database of the NFSC, which dates from 1956 to the present. Only those samples were included in the analysis for which the collection sites could be located on 1:250 000 topocadastral maps. The 723 samples were grouped into 211 different 'loci' (1/16-degree squares) (Fig. 1) and ranked in intervals according to mean annual rainfall, air temperature and altitude (Table 1). Rainfall, temperature and altitude data were obtained from the Computing Centre for Water Research, University of Natal. All species in the database were ranked according to a temperature index based on their frequencies in the temperature intervals. This was achieved by allocating numeric values, ranging from 1 for the coolest to 5 for the warmest of the 5 temperature intervals. The proportion of the total number of loci falling in a particular temperature interval for each species was then multiplied by the value allocated to that specific temperature interval. This was done for each temperature interval in which the species was recorded and the sum of these scores was then taken as the temperature index for that particular species (D S Brown,The Natural History Museum, London, pers. comm., 2002). Chi-square values were calculated to determine the significance of differences between the frequency of occurrence in, on, or at the different options for each variable, such as waterbody, substratum or temperature.

In addition, the effect size[6] was calculated for each variable to evaluate its importance in determining the distribution of this species. The effect size is an index that measures the degree of discrepancy between the frequency distribution of a given species in the set of alternatives of a given variable such as waterbody, compared with the frequency distribution of all other mollusc species in the database in the set of alternatives of the same variable[6]. The data in the database were also used to construct an integrated decision tree[1]. This is a statistical model that enables the selection and ranking of those variables that maximally discriminate between the frequency of occurrence of a given species under specific conditions compared to all other species in the database. This was done with SAS Enterprise Miner for Windows NT and *Decision Tree Modelling Course Notes*[10].

RESULTS

Although *L. truncatula* was collected in a wide variety of waterbodies, the highest numbers were recovered from swamps (Table 1) and its frequency in this type of waterbody differed significantly from that of all other waterbodies (ranging from $\chi^2 = 11.7$. df = 1, $P < 0.05$, for irrigation furrows to $\chi^2 = 572.39$, df = 1, $P < 0.05$ for streams). The 304 samples recovered from swamps represented 14.0 % of the total number of samples (2179) of all mollusc species (Table 1). Aquatic vegetation was recorded at 91.6 % of the *L. truncatula* collection sites, and the effect size value for this factor was $w = 0.2$ (Table 2).

Most samples (81.3 %) were collected in habitats described as perennial and this differed significantly ($\chi^2 = 33.57$, df = 1,

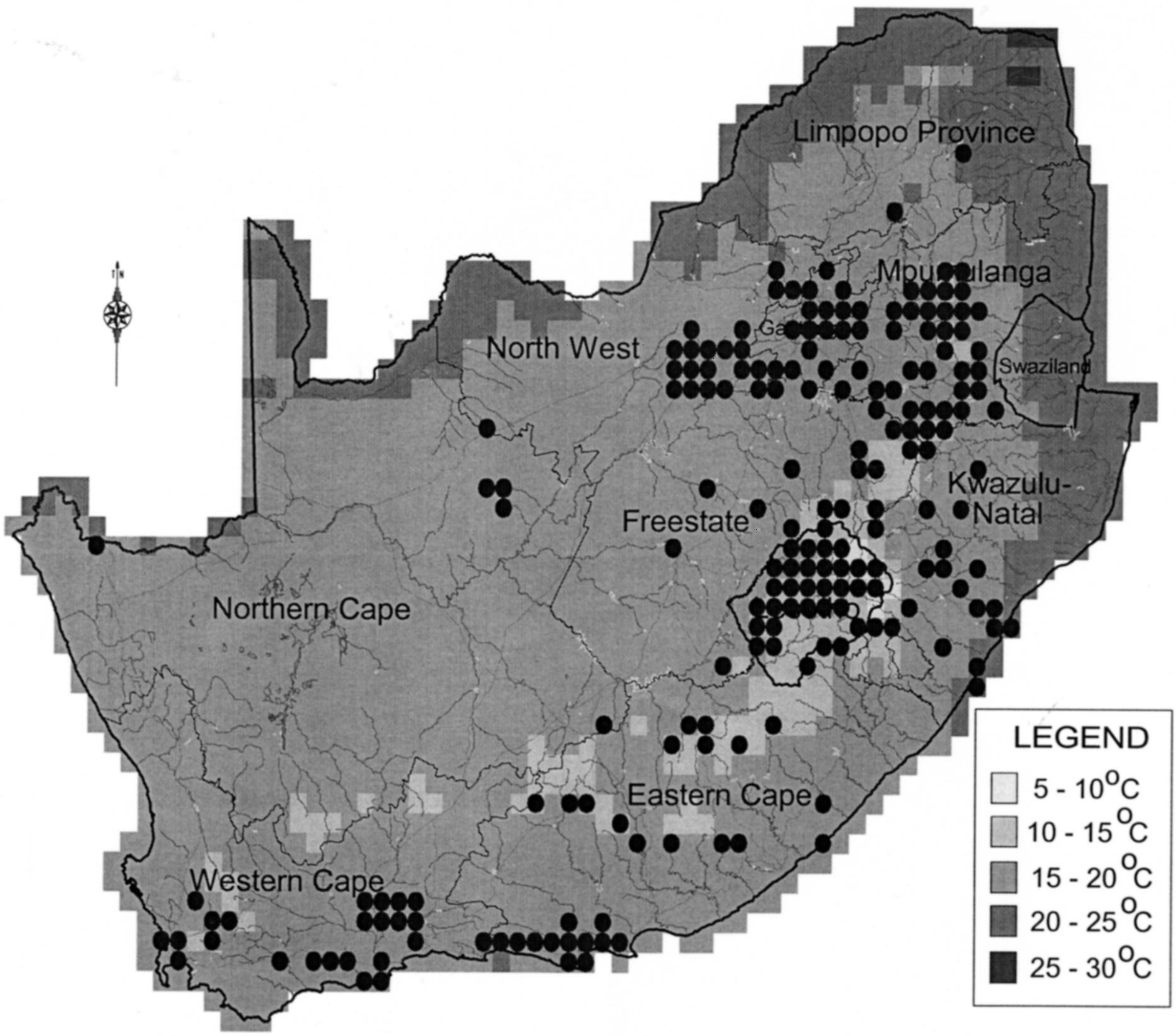

Fig. 1. **The geographical distribution of *Lymnaea truncatula* in 1⁄16- degree square loci and mean annual air temperature in South Africa.**

$P < 0.05$) from the number of samples recovered from seasonal habitats (Table 3).

With regard to water velocity, no significant difference was found between frequency of occurrence in habitats with fast-flowing or standing water. Most samples were, however, collected in habitats with slow-flowing water (Table 3), which differed significantly from fast-flowing water ($\chi^2 = 14.02$, df = 1, $P < 0.05$) and standing water ($\chi^2 = 83.14$, df = 1, $P < 0.05$). More than 80 % of the samples were collected in habitats with clear and fresh water (Table 3).

More than 60 % of the samples came from habitats with a muddy substratum (Table 4) and the frequency of occurrence in habitats with this type of substratum differed significantly from habitats with a substratum of decomposing plant material ($\chi^2 = 15.36$, df = 1, $P < 0.05$), a sandy substratum ($\chi^2 = 60.68$, df = 1, $P < 0.05$) and a stony substratum ($\chi^2 = 93.2$, df = 1, $P < 0.05$).

Although the largest number of samples fell in temperature intervals covering the range 10–20 °C, the 95 samples from the 5–10 °C interval represented 26.8 % of the total number of collections in this interval (345) for all mollusc species (Table 5). Almost 70 % of the samples came from sites with a mean annual rainfall of 600–900 mm (Table 5).

The number of samples (31.7 %) from sites in the altitude interval 1500–2000 m differed significantly from all other intervals (ranging from $\chi^2 = 85.31$, df = 1, $P < 0.05$, for the 500–1000 m interval, to $\chi^2 = 629.36$; df = 1, $P < 0.05$, for the 1500–2000 m interval). However, the frequency of occurrence in 2 intervals (2000–2500 and 2500–3000 m) in each case represented more than 25 % of the total number of collections for all mollusc species in these intervals (Table 5).

The frequency of occurrence in habitats falling in the 5 selected temperature intervals and the temperature indexes calculated from these data, as well as the ranking of the species in order of their association with low to high temperatures, are presented in Table 6. These results show that only the small clam *Pisidium viridarium* Kuiper, which is widely distributed in Lesotho, is more closely associated with cooler climatic conditions than *L. truncatula*.

The effect size values for each factor are also listed in Tables 1–5. Values in the order of 0.1 and 0.3 indicate small and medium effects, respectively, whereas values of 0.5 and higher indicate significantly large effects[6]. The results suggest that temperature, altitude, type of waterbody and, to a lesser extent, type of substratum, are important factors that could influence the geographical distribution of *L. truncatula* significantly. The effect size values listed in Table 5 indicate that the temperature index of *L. truncatula* differs significantly from that of all other species apart from *Pisidium casertanum* (0.347), *P. langleyanum* (0.454) and *P. costulosum* (0.460) (difference in effect values <0.5) (Table 6).

Temperature was singled out by the decision tree analysis as the most important factor affecting the distribution of this species, followed by type of waterbody (Fig. 2). The 376 (95 + 281) times that *L. truncatula* was collected in habitats falling in the 2 temperature intervals spanning 5–15 °C, represented 7.9 % of the total number of 4758 (354 + 4404) collections in these intervals (Table 5; Fig. 2). By contrast, the 343 times that this species was collected in habitats in the 15–20 °C interval represented just 1.4 % of the total number of collections for the interval (Table 5; Fig. 2). Swamps and springs were selected as the most important waterbodies affecting the distribution of this species in the 5–15 °C temperature intervals (Fig. 2).

DISCUSSION

The geographic range of *L. truncatula* is mainly Holarctic[4]. Although its extensive but scattered distribution in Africa was attributed to migratory birds[9], it could be long-established as subfossil shells are known from the Sahara as well as 2 localities in Namibia[4]. This species has also been reported from the Near East and southwestern Arabia[5]. The occurrence of *L. truncatula* in southeastern Africa has been described as remarkably sporadic and could, to some extent, be attributed to it not being strictly aquatic and therefore not found during surveys that focused exclusively on water[15]. A contributing factor is that it is also a good aestivator[4] and it would therefore not easily be found in surveys conducted during the dry season.

Our results show *L. truncatula* occurs most extensively in the cooler areas of South Africa and Lesotho (Fig. 1), and this is in agreement with an earlier report[4]. Studies on its population dynamics under natural conditions in Lesotho suggested a distinct preference for lower temperatures, optimally between 10 and 20 °C[13]. It is therefore not surprising that 719 (95 + 281 + 343) of 723 (99.4 %) samples of *L. truncatula* in the NFSC fell in the 5–20 °C interval range (Table 5). This preference for lower temperatures is also reflected by the temperature index for this species (Table 6). The results of both the decision tree (Fig. 2) and the effect size analyses (Table 5) indicated that temperature is an important determinant of its geographical distribution. Its occurrence in the warmer regions of South Africa can possi-

Table 1: **Types of waterbody in which the 723 samples of *Lymnaea truncatula* were collected during surveys.**

Waterbody	A	B (%)	C	D (%)
Stream	139	19.2	7211	1.9
Channel*	2	0.3	169	1.2
Concrete dam	1	0.1	221	0.5
Dam	69	9.5	8400	0.8
Ditch**	19	2.6	636	3.0
Irrigation furrow***	4	0.6	113	3.5
Pond+	12	1.7	1566	0.8
River	88	12.2	7507	1.2
Spring	18	2.5	301	6.0
Swamp++	304	42.0	2179	14.0
Waterhole+++	2	0.3	225	0.9
Not indicated	65			
Effect size		*w* = 1.5 (large effect)		

A: number of times collected in the waterbody.
B: percentage of the total number of collections (723) on record for *L. truncatula*.
C: number of times any mollusc was collected in the waterbody.
D: percentage occurrence of *L. truncatula* in the total number of collections in a specific type of waterbody.
*Large, man-made watercourse for irrigation purposes, usually lined by concrete.
**Narrow, man-made furrows to drain rainwater from the side of roads, usually associated with culverts or a low-level bridges.
***Narrow, dug-out furrows, usually not lined by concrete, to conduct water from a channel, or small water impoundments for irrigation of fields, orchards, etc.
+Small, man-made, water impoundments usually for ornamental purposes.
++An area of waterlogged ground, usually with dense vegetation.
+++Bodies of seasonal water closely associated with rivers, filled with rainwater when rivers overflow their banks, but usually isolated from main river during the dry season.

Table 2: **Occurrence of aquatic vegetation in waterbodies from which *Lymnaea truncatula* was recorded during surveys covering 723 collection sites.**

	Yes	No	Not indicated
A	662	12	49
B (%)	91.6	1.7	6.8
C		*w* = 0.2 (small effect)	

A: number of times recorded from a waterbody.
B: percentage of total number of collections (723) on record for *L. truncatula.*
C: effect size value for aquatic vegetation.

Table 3: **Water conditions in habitats of *Lymnaea truncatula* as recorded by collectors during surveys.**

	Type		Velocity			Clearness		Salinity	
	Perennial	Seasonal	Standing	Fast	Slow	Clear	Muddy	Fresh	Brackish
A	588	66	283	42	331	593	57	626	3
B (%)	81.3	9.0	39.1	5.8	45.8	82.0	7.9	86.6	0.4
C	22 432	5350	16 147	2229	9501	20 408	6438	24 089	657
D (%)	2.6	1.2	1.8	1.8	3.5	2.9	0.9	2.6	0.5
E	*w* = 0.2 (small effect)			*w* = 0 (medium effect)		*w* = 0.4 (medium effect)		*w* = 0.1 (small effect)	

A: number of times collected in a specific water condition.
B: percentage of the total number of collections (723).
C: number of times any mollusc was collected in a specific water condition.
D: percentage occurrence of *Lymnaea truncatula* in the total number of collections in a specific water condition.
E: effect size values for each water condition.

Table 5: **Frequency distribution of the 723 collection sites of *Lymnaea truncatula* in selected intervals of mean annual air temperature and rainfall and mean altitude in South Africa.**

	Temperature interval (°C)				Rainfall interval (mm)				Altitude interval (m)					
	5–10	10–15	15–20	20–25	0–300	300–600	600–900	900–1200	0–500	500–1000	1000–1500	1500–2000	2000–2500	2500–3000
A	95	281	343	4	7	210	500	6	45	30	195	229	158	66
B (%)	13.1	38.9	47.4	0.6	1.0	29.0	69.2	0.8	6.2	4.1	27.0	31.7	22.9	9.1
C	354	4404	24928	4276	975	11994	19799	1203	6747	4491	14918	6998	586	259
D (%)	26.8	6.3	1.4	0.1	0.7	1.8	2.5	0.5	0.7	0.7	1.3	3.3	27.0	25.5
E	*w* = 1.5 (large effect)				*w* = 0.2 (small to medium effect)				*w* = 1.9 (large effect)					

A: number of times collected at a locality falling in a specific interval.
B: percentage of the total number of collections (723) on record for *L. truncatula*.
C: number of times any mollusc was collected at a locality falling within a specific interval.
D: percentage occurrence of *L. truncatula* in the total number of collections within a specific interval.
E: effect size values for each factor.

Table 4: **Substratum types in the habitats of *Lymnaea truncatula* as described by collectors during surveys.**

	Substratum type			
	Muddy	Stony	Sandy	Decomposing material
A	452	103	101	4
B (%)	62.5	4.3	14.0	0.6
C	12835	7934	6523	632
D (%)	3.5	1.3	1.5	0.6
E	*w* = 0.5 (medium to large effect)			

A: number of times collected on a specific substratum.
B: percentage of the total number of collections (723) on record for *L. truncatula*.
C: number of times any mollusc was collected in a waterbody with a specific substratum.
D: percentage occurrence of *L. truncatula* in the total number of collections in a waterbody with a specific substratum.
E: effect size calculated for substratum types.

bly be attributed to an increased reproduction rate during the colder months and the production of sufficient offspring to see the population through the unfavourable summer months[13].

The decision tree and effect size analyses also indicated that habitat type could play a decisive role in the geographical distribution of *L. truncatula.* Swamps were reported as the preferred habitat of this species in Lesotho[12], substantiated by the finding that 42.0 % of the samples of this species in the NFSC was collected in swamps (Table 1). Of interest is that this species is semi-amphibious throughout its geographic range and seems to thrive on almost permanently moist, poorly drained ground[2]. The swamps in Lesotho are exceptionally favourable habitats and the snail occurs there in greater densities than in other parts of Africa[2]. Although aquatic vegetation was recorded at 91.6 % of the collection sites, the effect size value (w = 0.2) of this factor (Table 2) suggests that it is relatively unimportant in determining the presence of this species in a particular habitat.

Although the invader species *Lymnaea (Pseudosuccinea) columella* (Say) is more widely distributed in South Africa than *L. truncatula,*[7] and is reported as an intermediate host of *F. hepatica* elsewhere in the world, its contribution to transmission of fasciolosis in South Africa has not yet been evaluated[4]. As mentioned above, *L. truncatula* is of major importance in transmitting fasciolosis in Lesotho[11] and was also reported as an intermediate host of *F. hepatica* elsewhere in South Africa[14].

Variations in the epidemiology of fasciolosis transmission are primarily related to the availability of the snail host[4]. In the central highlands of Ethiopia, active populations of *L. truncatula* that were present for only about 40 days during the rainy season, were responsible for maintaining the life cycle of *F. hepatica*[8]. Snails emerging from aestivation immediately started shedding cercariae from infections carried over from the previous rainy season. This suggests that at least some of the transmission foci in a given area could be overlooked when surveys are conducted during the dry season. No recent data on the geographical distribution of fasciolosis in South Africa are available. However, a recent serological survey of *Fasciola* species in South Africa revealed that the geographical distribution of the disease is considerably more extensive than reported in literature (A Wellington, Merial South Africa, pers. comm., 2002; J Boomker, Department of Veterinary Tropical Diseases, University of Pretoria, pers. comm., 2002).

No assessment of the financial losses due to fasciolosis in South Africa has yet been made. However, in other parts of Africa, financial losses due to fasciolosis are high enough to necessitate regular dosing of animals[3]. Prevalence in livestock and assessments of financial losses elsewhere in Africa have been reported in several papers[3,4,11]. As the availability of the snail intermediate hosts is essential in the epidemiology of fasciolosis, it is of great importance to update the geographical distribution of *L. truncatula* in view of our results. In planning such surveys, special attention should be given to the preferred habitats of *L. truncatula.* Its amphibious habits and ability to aestivate should also be taken into account. The results of such surveys should confirm whether its distribution is indeed as discontinuous as reflected by the data currently at our disposal.

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Table 6: **Frequency distribution in temperature intervals and temperature index of *Lymnaea truncatula* compared to all mollusc species in the database of the National Freshwater Snail Collection.**

Mollusc species	Number of samples	5–10 ºC	10–15 ºC	15–20 ºC	20–25 ºC	25–30 ºC	Index*	SD**	CV***	Effect size value
Pisidium viridarium	636	201	270	163	2		1.947	0.764	39.225	-0.534
Lymnaea truncatula	723	95	281	343	4		2.354	0.709	30.135	0.000
Pisidium casertanum	5		2	3			2.600	0.548	21.066	0.347
Pisidium langleyanum	627	18	173	430	6		2.676	0.544	20.328	0.454
Pisidium costulosum	425	1	138	282	4		2.680	0.492	18.344	0.460
Bulinus tropicus	8448	32	2326	5860	230		2.744	0.502	18.305	0.551
Gyraulus connollyi	969		185	777	7		2.816	0.406	14.404	0.652
Ceratophallus natalensis	1797		299	1430	68		2.871	0.433	15.092	0.730
Burnupia (all species)	2778	7	287	2384	100		2.928	0.380	12.971	0.809
Ferrissia (all species)	540		72	420	47	1	2.957	0.476	16.088	0.851
Bulinus reticulatus	296		6	287	3		2.990	0.174	5.832	0.897
Assiminea umlaasiana	2			2			3.000	0.000	0.000	0.911
Tomichia cawstoni	4			4			3.000	0.000	0.000	0.911
Tomichia differens	10			10			3.000	0.000	0.000	0.911
Tomichia lirata	2			2			3.000	0.000	0.000	0.911
Tomichia ventricosa	89			89			3.000	0.000	0.000	0.911
Tomichia tristis	81			79	2		3.025	0.156	5.162	0.946
Unio caffer	76		6	63	6	1	3.026	0.461	15.237	0.948
Physa acuta	755			719	36		3.048	0.213	6.997	0.978
Bulinus depressus	552			519	33		3.060	0.237	7.755	0.995
Arcuatula capensis	15			14	1		3.067	0.258	8.420	1.005
Lymnaea columella	2302		81	1977	243	1	3.071	0.371	12.072	1.012
Lymnaea natalensis	4721		205	3802	713	1	3.108	0.429	13.789	1.064
Assiminea bifasciata	17			15	2		3.118	0.332	10.652	1.077
Gyraulus costulatus	736		20	580	135	1	3.159	0.437	13.836	1.135
Bulinus forskalii	1209		17	985	204	3	3.160	0.409	12.948	1.136
Pisidium ovampicum	6			5	1		3.167	0.408	12.892	1.146
Sphaerium capense	25		1	17	7		3.240	0.523	16.136	1.250
Bulinus africanus sp. group	2930		9	2155	760	6	3.260	0.450	13.816	1.278
Corbicula fluminalis	389		1	291	94	4	3.267	0.437	13.384	1.288
Tomichia natalensis	23			16	7		3.304	0.470	14.238	1.340
Thiara amarula	10			6	4		3.400	0.516	15.188	1.475
Assiminea ovata	5			3	2		3.400	0.548	16.109	1.475
Melanoides victoriae	49			29	19	1	3.429	0.540	15.752	1.516
Biomphalaria pfeifferi	1639		5	880	751	3	3.459	0.508	14.692	1.558
Septaria tessellaria	2			1	1		3.500	0.707	20.203	1.616
Coelatura framesi	6			3	3		3.500	0.548	15.649	1.616
Neritina natalensis	16			8	8		3.500	0.516	14.754	1.616
Bulinus natalensis	245		2	97	146		3.588	0.510	14.204	1.740
Segmentorbis planodiscus	27			9	18		3.667	0.480	13.101	1.851
Segmentorbis angustus	32			7	25		3.781	0.420	11.108	2.013
Melanoides tuberculata	305			64	237	4	3.803	0.430	11.305	2.044
Pisidium pirothi	23			4	19		3.826	0.388	10.129	2.076
Spathopsis petersi	44			5	37	2	3.932	0.398	10.111	2.225
Aplexa marmorata	9				9		4.000	0.000	0.000	2.322
Bellamya capillata	31				31		4.000	0.000	0.000	2.322
Eupera ferruginea	171			6	157	6	4.000	0.258	6.455	2.322
Lentorbis carringtoni	8				8		4.000	0.000	0.000	2.322
Lentorbis junodi	12				12		4.000	0.000	0.000	2.322
Segmentorbis kanisaensis	9				9		4.000	0.000	0.000	2.322
Spathopsis wahlbergi	28			1	26	1	4.000	0.272	6.804	2.322
Cleopatra ferruginea	73				71	2	4.027	0.164	4.081	2.360
Lanistes ovum	41				38	3	4.073	0.264	6.473	2.425

*Index = temperature index.
**SD = standard deviation.
***CV = coefficient of variation.

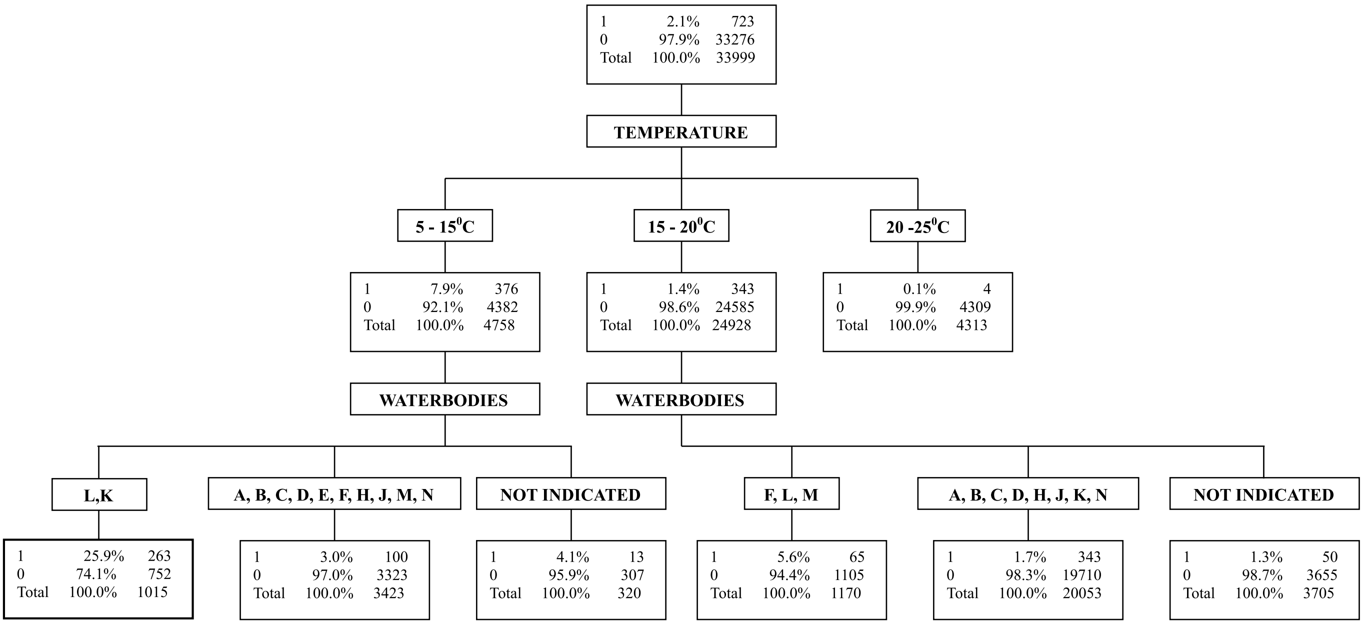

Fig. 2: **Decision tree of the frequency of occurrence of *Lymnaea truncatula* for each variable compared to the frequency of occurrence of all other species in the database of the NFSC. 0 = percentages and frequencies of all other species, 1 = percentages and frequencies of *L. truncatula.* Waterbodies: A = stream, B = channel, C = concrete dam, D = dam, E = ditch, F = irrigation furrow, H = pond, J = river, K = spring, L = swamp, N = waterhole.**

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