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Human leishmaniasis in Morocco: a systematic review and meta-analysis — I. Species distribution

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Abstract

Purpose

Three Leishmania species cause human disease in Morocco and differ in reservoir, vector and control measures. We asked how they are distributed among human isolates identified to species by laboratory method, and how far that distribution varies between settings.

Methods

We searched MEDLINE/PubMed, Scopus, ScienceDirect, the national thesis repository and a faculty library catalogue to September 2026; the review was registered before screening (OSF, 10.17605/OSF.IO/JKUB2). Records were routed to full-text assessment by a deterministic rule; duplicate screening of 150 randomly drawn records gave a Cohen's kappa of 0.79. Studies whose design restricted identification to a single species were excluded. Proportions were pooled on the logit scale with random-effects estimation, Hartung-Knapp adjustment and prediction intervals.

Results

Of 557 unique records, 169 were assessed in full text and 16 studies reported species identification on 870 human isolates from 22 provinces. Pooled proportions were 56.8% for L. tropica (95% CI 31.1-79.3), 21.8% for L. major (7.2-49.8) and 9.4% for L. infantum (3.0-25.7), with I^2 of 88.7-92.2% and a prediction interval for L. tropica of 7.6-95.4%. Composition was near-uniform within a focus and radically different between foci: entirely L. major in Zagora, entirely L. tropica in Chichaoua, 85% L. infantum in the seven northern provinces.

Conclusion

These pooled values summarise published typed series and are not an estimate of species distribution among Moroccan cases. Species distribution is a property of the focus rather than of the country, and the molecular evidence base is far thinner than the volume of Moroccan leishmaniasis literature suggests.

Introduction

Leishmaniasis has been notifiable in Morocco since 1995 and remains endemic across a wide range of bioclimatic settings, from the pre-Saharan south to the Mediterranean north. Three species are responsible for human disease, and they are not interchangeable. *L. major* causes zoonotic cutaneous leishmaniasis in arid and pre-Saharan zones, with *Phlebotomus papatasi* as vector and rodents as reservoir. *L. tropica* causes anthroponotic cutaneous leishmaniasis in semi-arid and mountainous areas, transmitted by *P. sergenti*. *L. infantum* causes visceral leishmaniasis, mainly in children in the north, with the dog as principal reservoir, and also produces sporadic cutaneous forms [1,2].

Because reservoir and vector differ, so does control: rodent management and environmental measures for *L. major*, case detection and treatment for *L. tropica*, canine surveillance for *L. infantum*. A control programme therefore needs to know which species circulates in which province — and the answer is not obtainable from case notifications, which record clinical form, not parasite species.

The broad geography is not in question and has been described since the 1990s: *L. major* in the pre-Saharan south, *L. tropica* in the central and northern highlands, *L. infantum* in the north. Three narrative accounts have summarised the Moroccan situation, in 2017, 2018 and 2020 [1–3]. What none of them provides — and what no systematic review has yet attempted for human leishmaniasis in Morocco — is a quantitative synthesis: how many isolates have actually been identified to species, with what methods, in which provinces, and with what uncertainty around the resulting proportions. The systematic reviews that do exist for Morocco concern dogs [4] and sandflies, not human cases.

The distinction matters because a qualitative map and a quantitative one support different decisions. Knowing that *L. tropica* predominates in the centre does not tell a control programme how confident to be about a given province, nor whether a national figure means anything at all. This review therefore asks a deliberately narrow question: among human *Leishmania isolates* identified to species in Morocco by laboratory method, how are the three species distributed, and how much does that distribution vary between settings?

Methods

The review was registered on OSF Registries (https://osf.io/jkub2, DOI 10.17605/OSF.IO/JKUB2) before screening began, and is reported according to PRISMA 2020 [6], the search according to PRISMA-S [7].

The registration specifies three outcomes: the proportion of confirmed cases among those tested (O1), the distribution of clinical forms (O2), and the distribution of *Leishmania species* (O3). This paper reports O3. Outcomes O1 and O2 are reported in a companion paper drawing on the same registration, the same corpus and the same eligibility criteria; the two papers cite each other. No study was excluded on account of this division: studies bearing only on O1 or O2 were deferred to the companion paper, not dropped, and are counted as such in the flow diagram. The decision to report the registered outcomes in two papers was taken before any data extraction and is recorded, dated, in amendment 04 deposited with the registration. The registered title covers all three outcomes; the title of this paper names the outcome it reports.

Four amendments were filed during the review, each dated and deposited with the registration. Amendment 01 settled three eligibility questions raised at screening; amendment 02 revised the rule for resolving overlapping populations; amendment 03 declared the addition of a grey-literature source and the withdrawal of the pre-registered author-contact procedure; amendment 04 is described above. Each is cited at the relevant point below.

Eligibility

Studies were eligible if they reported, for human cases in Morocco, the number of *Leishmania isolates* identified to species and their distribution by species. Identification had to be by laboratory method — isoenzyme electrophoresis, PCR-RFLP, sequencing or an equivalent — applied to the study's own material. Attribution of species from the geographical focus or from lesion appearance was not accepted as identification; this rule excluded several large provincial series and is discussed below.

A study contributed to the pooled analysis only if species identification had not been restricted by design to a single species. Population-genetics studies, which start from a collection already characterised as one species and examine its internal variability, report a proportion of 100% by construction; including them would add a block of that species that measures nothing. Such studies were read and are described narratively, but contribute no proportion.

Isolates of non-human origin were excluded from denominators. Several studies typed human, sandfly and canine material in a single table; where the human subset could not be separated, the study did not contribute.

Information sources and search

MEDLINE/PubMed, Scopus and ScienceDirect were searched on 5 September 2026 with terms combining leishmaniasis and Morocco, without language or date limits. Grey literature was sought in the national thesis repository Toubkal/IMIST and, from 7 September 2026, in the online catalogue of the library of the Faculty of Medicine and Pharmacy of Rabat. The faculty catalogue was added after the recognised discovery that Toubkal does not cover theses defended before the mid-2000s; that addition, and its consequences, are declared in amendment 03. Its pagination does not return pages beyond the first, so nine query variants were run to maximise coverage; exhaustiveness of that source cannot be guaranteed. Web of Science and Embase were not searchable with the available institutional access.

Searches returned 942 records, of which 385 were duplicates, leaving 557 unique records.

Selection

Records were routed to full-text assessment by a deterministic rule applied to titles and abstracts: a record was retained if it lacked an abstract and its title mentioned leishmaniasis, if a *Leishmania species* or MON zymodeme was named, or if a species-identification method was named. Of 557 records, 352 met at least one condition. The rule is scripted and deposited with the review materials; re-running it reproduces the same 352 records. Eligibility was not decided at this stage. It was decided at full text, on two extracted fields — the origin of the isolates and the number of human isolates typed — both of which are verifiable against the source tables.

The rule is deliberately permissive, and asymmetric on purpose: a record wrongly discarded at title stage is lost, whereas a record wrongly retained costs only a reading. Entomological studies naming a species therefore passed the filter, and two of them proved to contain typed human isolates.

Screening and inter-rater agreement

Duplicate screening was performed on a random sample of 150 records drawn from the 557 with fixed seeds, so that the draw is reproducible. It was built in two stages: 50 records first, as a calibration exercise, then 100 further records drawn from the 507 not already selected, after the instruction sheet had been amended. The sample contains 127 journal articles and 23 theses or dissertations, 49 of them without an abstract — 15% grey literature and 33% without an abstract, against 15% and 29% in the corpus as a whole. Each reviewer recorded a decision, an exclusion reason where applicable, and a written justification specific to that record, working from their own file without sight of the other's. Cohen's kappa [9] was computed on the three-level label before any reconciliation.

Agreement was 90.0% (135/150) and Cohen's kappa 0.79 (95% CI 0.69–0.88), substantial, with the lower bound of the interval above the threshold of 0.60 set in the reviewer instructions. Agreement improved between the two stages, from 0.70 (95% CI 0.48–0.92) on the first 50 to 0.82 (0.72–0.92) on the 100 drawn after the instruction sheet was amended; the amendment is dated and deposited with the registration. It states explicitly that a title which does not identify the country or the study population is grounds for 'uncertain' and not for exclusion, a rule prompted by the six disagreements observed at calibration, all of which had that same structure. Every one of the fifteen disagreements over the 150 involved the 'uncertain' label on one side: seven where one reviewer excluded and the other was uncertain, one the reverse, and seven where one included and the other was uncertain. There was no single record that one reviewer included and the other excluded. Since uncertain and included records both proceed to full text, the two reviewers disagreed on whether a record should be read in full in eight cases out of 150, and the kappa for that binary decision was 0.87 (0.79–0.96).

The remaining 407 records were screened by one reviewer. All records proceeding to full text were then assessed against the extraction fields described below. This is a departure from full duplicate screening and is declared as such.

Data extraction and appraisal

For each study we extracted the province or region, the collection period, the origin of the isolates, the identification method, the number of human isolates typed and the distribution by species. Every species count was checked against the study's own tables and had to sum to the stated denominator; discrepancies are recorded in the extraction sheet. Methodological quality was appraised with the JBI checklist for studies reporting prevalence data. The pre-registered procedures for requesting texts from authors and faculties were not carried out; this deviation and its consequences for missing data are declared in amendment 03.

Use of a large language model. A large language model (Claude, Anthropic) was used under the authors' direction to write the record-routing script, the extraction workbooks, the analysis code and the figure code, and to assist in drafting the manuscript. It was not used to decide eligibility, to generate data, or to produce any reported figure without recomputation. Every species count reported here was verified by an

author against the table of the source publication, and the routing script, extraction sheet and analysis code are deposited with the registration so that every number can be recomputed. The model does not meet authorship criteria and is not listed as an author; the authors take full responsibility for the content.

Synthesis

Proportions were pooled on the logit scale with DerSimonian–Laird estimation of between-study variance [12] and the Hartung–Knapp adjustment to the confidence interval [13], and prediction intervals were computed [15]. A continuity correction of 0.5 was applied to the variance of the transformation for studies with a proportion of 0 or 1. Heterogeneity is reported as I^2 [16], τ^2 and Cochran's Q. Subgroup analyses compared single-province with multi-province series. Sensitivity analyses excluded the smallest series and the single urban referral hospital. The analysis code is deposited with the review.

The logit transformation was preferred to the Freeman–Tukey double arcsine [10], which is unstable to back-transform when study sizes differ as widely as they do here, from 4 to 106 isolates [11]. Because DerSimonian–Laird is known to understate between-study variance when heterogeneity is high, the analysis was repeated with Paule–Mandel [14] and restricted maximum likelihood estimation of that variance, and the pooled proportions and prediction intervals compared across the three.

Methodological quality was appraised with the JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data (nine items) [8]. To keep the appraisal reproducible, each item was answered from recorded extraction fields rather than from a global impression: the sampling frame (item 1) from whether the series was population-based in a named province or hospital-referral; the sampling method (item 2) from whether consecutive or exhaustive recruitment was stated; sample size (item 3) from a threshold of 30 typed isolates; description of subjects and setting (item 4) from whether both province and collection period were reported; coverage (item 5) and non-response (item 9) from whether the number typed could be reconciled with the number of confirmed cases; and items 6 to 8 from the identification method, which eligibility already required to be a laboratory technique applied uniformly to all isolates.

Results

Study selection

The searches yielded 942 records; 385 duplicates were removed, leaving 557 unique records. The routing rule retained 352 for full-text assessment, of which 169 have been assessed to date, including all 36 theses available in full text from the national repository. Sixteen studies met the contribution criteria and reported species identification on 870 human isolates. One hundred and fifty-three assessed records did not contribute, each for a stated reason: no laboratory identification of species on the study’s own material (48 theses and 74 further reports), species identification reported without the number of isolates typed (8), species restricted by design (7), no separable human denominator (6), method-

development studies on reference strains (8), a narrative review (1), and overlap with a series already included (1). The flow of records is shown in Figure 1.

Characteristics of contributing studies

The sixteen contributing studies were published between 2004 and 2022 and covered 22 provinces. Identification was by ITS1 PCR-RFLP in thirteen studies, with sequencing confirmation in one of them, by ITS1 sequencing alone in one, by nested kDNA PCR in one, and by isoenzyme electrophoresis in one. Denominators ranged from 4 to 106 isolates; seven studies reported on a single named province, five on several provinces or on a national referral series, and four did not name the province precisely. Study characteristics are given in Table 1 and the species counts in Table 2.

Study	Province or region	Period	Form	Confirmation	Species identification	Typed
Baghad B 2020 [17]	Casablanca	2010–2016	CL	PCR	ITS1 PCR-RFLP	106
El Hamouchi A 2019 [18]	Zagora	2017–2018	CL	Microscopy + PCR	ITS1 sequencing	103
Hakkour M 2019 [19]	Seven northern provinces	Not stated	CL, VL	Microscopy	ITS1 PCR-RFLP	89
Bennis I 2018 [20]	Errachidia, Ouarzazate, Tinghir, Sefrou, Sidi Kacem	Not stated	CL	Microscopy + PCR	ITS1 PCR-RFLP	87
Amahmid O 2021 [21]	Central Morocco (province not stated)	Not stated	CL	Microscopy + PCR	ITS1 PCR-RFLP	82
Hakkour M 2016 [22]	Taza	2014	CL, VL	Microscopy	ITS1 PCR-RFLP	66
Ait Kbaich M 2017 [23]	Ouarzazate and Zagora	2015–2016	CL	Microscopy + PCR	ITS1 PCR-RFLP + sequencing	66
Daoui O 2022 [24]	Azilal, Chichaoua, Ouazzane	Not stated	CL	PCR	kDNA nested PCR	63
Rhajaoui M 2012 [25]	Chichaoua	2006–2009	CL	Microscopy + culture	ITS1 PCR-RFLP	62
Mouttaki T 2014 [26]	L. tropica and L. major foci (not stated)	Not stated	CL	PCR	ITS1 PCR-RFLP	44
Hmamouch A 2017 [27]	Boulemane	2015	CL	Microscopy	ITS1 PCR-RFLP	28
Rhajaoui M 2007 [28]	Taroudant, Beni Mellal, Boulemane, Ouarzazate, Errachidia, Sidi Kacem	Not stated	CL	Microscopy + PCR	ITS1 PCR-RFLP	27
Mohamed Mahmoud EA 2016 [29]	Errachidia	2010–2014	CL	Microscopy	ITS1 PCR-RFLP	18
Rhajaoui M 2004 [30]	Zouagha My Yacoub (Fes)	2002	CL	Microscopy + culture	Isoenzymes	16
Mhaidi I 2018 [31]	Not stated	Not stated	CL	Microscopy + PCR	ITS1 PCR-RFLP	9

Study	Province or region	Period	Form	Confirmation	Species identification	Typed
Ajaoud M 2013 [32]	Emerging focus (not stated)	2011	CL	Microscopy	ITS1 PCR-RFLP	4

Table 1. Characteristics of the sixteen contributing studies. CL = cutaneous leishmaniasis, VL = visceral leishmaniasis. All series report human isolates only, an eligibility requirement.

Series (province or region)	Typed	*L. major*	*L. tropica*	*L. infantum*
Casablanca (Ibn Rochd Hospital) [17]	106	38 (36%)	61 (58%)	7 (7%)
Zagora [18]	103	103 (100%)	0 (0%)	0 (0%)
Northern Morocco (7 provinces) [19]	89	0 (0%)	13 (15%)	76 (85%)
Errachidia, Ouarzazate, Tinghir, Sefrou, Sidi Kacem [20]	87	35 (40%)	40 (46%)	12 (14%)
Central Morocco [21]	82	9 (11%)	73 (89%)	0 (0%)
Taza [22]	66	0 (0%)	37 (56%)	29 (44%)
Ouarzazate and Zagora (pre-Saharan) [23]	66	52 (79%)	12 (18%)	2 (3%)
Foum Jemaa, Imintanout, Ouazzane [24]	63	0 (0%)	58 (92%)	5 (8%)
Chichaoua [25]	62	0 (0%)	62 (100%)	0 (0%)
L. tropica and L. major foci [26]	44	19 (43%)	25 (57%)	0 (0%)
Boulemane [27]	28	5 (18%)	23 (82%)	0 (0%)
Six provinces [28]	27	6 (22%)	13 (48%)	8 (30%)
Errachidia [29]	18	11 (61%)	7 (39%)	0 (0%)
Zouagha My Yacoub (Fes) [30]	16	0 (0%)	16 (100%)	0 (0%)
L. infantum focus [31]	9	0 (0%)	1 (11%)	8 (89%)
Emerging focus (Fes) [32]	4	0 (0%)	4 (100%)	0 (0%)
Total	**870**	**278 (32%)**	**445 (51%)**	**147 (17%)**

Table 2. Human *Leishmania isolates* identified to species in Morocco, by study. Percentages are of the isolates typed in that study.

The appraisal is summarised in Table 3. All sixteen studies met the three items concerning the identification method, its uniform application and the statistical treatment of the counts, which is

expected since eligibility required a laboratory method. The corpus is weak on exactly two points. Sampling was documented as consecutive or exhaustive in only four series and was unclear in eleven: isolates generally reach the reference laboratory because a clinician decided to send them, which is a convenience process and the recurrent weakness of this literature. Non-response was unclear in eleven series, most reports giving the number of isolates typed without stating how many confirmed cases were not typed, or why. Six series fell below thirty typed isolates. No study was excluded on the basis of the appraisal; scores range from four to nine items met, with a median of six.

Table 3. JBI appraisal of the contributing studies.

Series	**n**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Casablanca (referral)	106	N	N	Y	Y	Y	Y	Y	Y	?
Zagora	103	Y	Y	Y	Y	Y	Y	Y	Y	?
Northern Morocco	89	Y	Y	Y	?	?	Y	Y	Y	?
Five provinces (2018)	87	Y	Y	Y	?	Y	Y	Y	Y	Y
Central Morocco	82	?	?	Y	?	Y	Y	Y	Y	?
Taza	66	Y	?	Y	Y	Y	Y	Y	Y	?
Ouarzazate–Zagora	66	Y	Y	Y	Y	Y	Y	Y	Y	Y
Foum Jemaa and 2 others	63	Y	?	Y	?	Y	Y	Y	Y	Y
Chichaoua	62	Y	?	Y	Y	Y	Y	Y	Y	?
L. tropica / L. major foci	44	?	?	Y	?	?	Y	Y	Y	?
Boulemane	28	Y	?	N	Y	Y	Y	Y	Y	?
Six provinces (2007)	27	Y	?	N	?	Y	Y	Y	Y	?
Errachidia	18	Y	?	N	Y	?	Y	Y	Y	?
Zouagha My Yacoub	16	Y	?	N	Y	Y	Y	Y	Y	Y
L. infantum focus	9	?	?	N	?	Y	Y	Y	Y	Y
Emerging focus (Fes)	4	?	?	N	?	Y	Y	Y	Y	?
Items met (of 16)		**11**	**4**	**10**	**8**	**13**	**16**	**16**	**16**	**5**

Y = yes, N = no, ? = unclear. Items: 1 sampling frame, 2 sampling method, 3 sample size, 4 description of subjects and setting, 5 coverage of the identified sample, 6 valid identification method, 7 uniform measurement, 8 statistical analysis, 9 non-response.

Species distribution

Across the sixteen studies, 445 of 870 isolates were *L. tropica*, 278 were *L. major* and 147 were *L. infantum*. Pooled random-effects proportions were 56.8% for *L. tropica* (95% CI 31.1–79.3), 21.8% for *L. major* (7.2–49.8) and 9.4% for *L. infantum* (3.0–25.7).

These pooled values should be read with the heterogeneity that accompanies them, which was extreme: I^2 was 91.3% for *L. tropica* ($\tau^2 = 1.41$, $Q = 171.8$, df 15, $p < 0.001$), 88.7% for *L. major* and 92.2% for *L. infantum*. The 95% prediction interval for *L. tropica* ran from 7.6% to 95.4% — that is, a new Moroccan series could plausibly report almost any composition. Figure 3 shows the forest plot.

The distribution of that heterogeneity is not random, and it is the substantive finding of this review. Composition was near-uniform within a focus and radically different between foci (Figure 2). All 103 isolates typed during the Zagora outbreak were *L. major* [18], and all 62 isolates from Chichaoua were *L. tropica* [25]. In northern Morocco, 76 of 89 isolates (85%) were *L. infantum* [19], including 68 from cutaneous lesions — a form long considered exceptional for that species. In Foum Jemaa, Imintanout and Ouazzane, 58 of 63 were *L. tropica*. Casablanca was the only setting in which all three species occurred in comparable proportions, and it is an urban referral hospital whose patients come from different foci. In the pre-Saharan provinces of Ouarzazate and Zagora, 52 of 66 isolates (79%) were *L. major* in 2015–2016, with *L. tropica* in 18% and *L. infantum* in 3%, so even the most strongly *L. major* focus is not exclusive.

Errachidia province was typed twice by the same team [29]: in 2010 all 11 isolates were *L. major*, and in 2014 seven of the eight cases typed were *L. tropica*. Whether this reflects a true replacement or a change in sampling cannot be settled from the published data, but it is the only within-province time series in the corpus.

Mapping the series province by province (Figure 4) makes the same point geographically. Of the 870 typed isolates, 731 could be placed: 576 in a single named province, and 155 in two series that name several provinces without breaking their counts down. L. major accounts for all 103 isolates from Zagora, all 17 from Ouarzazate and 33 of 40 from Errachidia; L. tropica for all isolates typed in Chichaoua, Azilal, Beni Mellal and Fes; and L. infantum for 76 of 89 isolates from the seven northern provinces and 29 of 66 from Taza. Fifteen provinces have contributed typed isolates; the rest of the country has none.

Subgroup and sensitivity analyses

Restricting the analysis to series from a single named province (k = 7, 399 isolates) gave a pooled *L. tropica* proportion of 62.8% (95% CI 15.6–93.9) with I^2 85%; multi-province and referral series (k = 5, 332 isolates) gave 43.9% (9.2–85.8) with I^2 94%. Neither subgroup was homogeneous, so the split does not explain the variance. Excluding the two smallest series moved the pooled *L. tropica* proportion from 56.8% to 58.0%; excluding the Casablanca referral series moved it to 57.0%; and excluding the two series whose counts were available only from the published abstract moved it to 57.6%. The estimate is therefore stable, and its instability is not the issue; its irrelevance to any particular focus is.

Five provinces were sampled by more than one independent series, which allows the consistency of a local composition to be checked directly rather than inferred. Chichaoua was typed twice, 62 and 16 isolates, both entirely L. tropica. Ouarzazate was typed twice, 14 and 3 isolates, both entirely L. major. Sidi Kacem was typed twice, 1 and 8 isolates, both entirely L. infantum. Boulemane was typed twice, 23 of 28 and 7 of 7 L. tropica. Errachidia was typed three times: 19 of 19 and 3 of 3 L. major, and a third series in which the 11 isolates collected in 2010 were L. major and the 7 collected in 2014 were L. tropica. Within a province, independent series agree; between provinces they do not. That is the meta-analytic result again, reached without pooling anything.

The choice of variance estimator does not move the pooled proportions but does move the heterogeneity. For L. tropica the pooled value was 56.8% under DerSimonian–Laird, 58.0% under Paule–Mandel and 57.8% under REML; for L. major, 21.8%, 17.4% and 17.7%; for L. infantum, 9.4%, 9.0% and 9.0%. The between-study variance, however, was two to four times larger under the two likelihood-based estimators than under DerSimonian–Laird (for L. tropica, $\tau^2 = 4.48$ and 3.58 against 1.41), and the prediction interval for L. tropica widened from 7.6–95.4% to 1.3–99.3%. The pooled figure is therefore stable, and the case against using it is stronger under the estimators that handle high heterogeneity better, not weaker.

What the grey literature does not contain

Thirty-six theses were retrieved in full text from the national repository and read in their entirety. Each was searched systematically for the co-occurrence of a typing method — PCR-RFLP, ITS1, isoenzymes, zymodeme, hsp70 — with a count of Moroccan strains. There were no such occurrences. Where a species is named in these theses, it is attributed from the geographical focus or from lesion appearance: one thesis reporting 429 cases states that all were due to *L. major* "according to epidemiological data and lesion types"; another describes its cases as *L. tropica* "as classically described" for the province. These series are substantial and valuable for incidence and clinical description, and they are the subject of a companion report; they carry no species-identification data.

Discussion

This review assembled every published Moroccan series in which human *Leishmania isolates* were identified to species by laboratory method. Sixteen studies met that condition, covering 870 isolates over eighteen years and 22 provinces. The pooled proportions — about 57% *L. tropica*, 22% *L. major*, 9% *L. infantum* — are reported because the protocol specified them, but the honest reading of this corpus is that they should not be used.

The reason is in the prediction interval. With I^2 above 90% and a prediction interval running from 8% to 95%, the pooled proportion of *L. tropica* does not describe any Moroccan setting. It is the average of foci that have nothing in common, and averaging them destroys precisely the information a control programme needs. A single figure for Morocco would suggest that a given case has a certain chance of

being one species or another; in reality, in Zagora that chance was 100% for *L. major*, and in Chichaoua 100% for *L. tropica*.

This is not a defect of the studies or of the analysis. It is a property of the disease. Each species has its own vector and its own reservoir, and both are constrained by bioclimate: *P. papatasi* and rodent reservoirs in pre-Saharan zones, *P. sergenti* in semi-arid highlands, *P. perniciosus* and the dog in the humid north. The parasite follows them. What the meta-analysis measures, when it reports $\tau^2 = 1.27$, is the strength of that geographical determination.

The finding with the most immediate consequence is the northern one. Seventy-six of 89 isolates from seven northern provinces were *L. infantum* [19], and 68 of those came from cutaneous lesions. *L. infantum* has long been treated in Morocco as the agent of visceral disease, with cutaneous presentations regarded as sporadic. In the northern series typed here, it accounted for the large majority of identified isolates, most of them from cutaneous lesions — a pattern that no longer reads as sporadic, although 89 isolates from seven provinces cannot establish how common it is among northern cases in general. That has practical implications: a cutaneous lesion in Larache or Chefchaouen carries a different reservoir — the dog — and therefore a different control response from a lesion in Errachidia.

The thinness of the molecular evidence

The second finding is one of absence. Morocco notifies several thousand cases of leishmaniasis a year. This review identified 870 human isolates typed to species in the entire published literature since 2002. Of the 36 provincial theses we could retrieve in full text and read in their entirety, not one reported laboratory species identification on its own series. Theses form a large part of the Moroccan writing on the disease, and the catalogue records we could not obtain may behave differently, so this is a statement about what we could read, not about every thesis written. The molecular picture of Moroccan leishmaniasis rests on a small number of laboratory studies, most from two or three centres, and the map they support has large blank areas.

This matters for how existing distribution maps should be read. Maps that assign a species to a province on the basis of the focus type reproduce an assumption rather than a measurement, and the Errachidia sequence — *L. major* in 2010, *L. tropica* in 2014 — shows that the assumption can go out of date within four years.

The remedy does not require a research programme. Leishmaniasis is already notifiable, and the reference laboratory already receives isolates; what is missing is that species identification is not part of the notification. Two measures would close the gap. Recording the identified species, or its absence, as a field of the routine notification would turn an existing flow into a national dataset. And typing a fixed annual quota of consecutive confirmed cases in a small number of sentinel provinces, chosen to span the pre-Saharan, highland and northern settings, would give each of those provinces a denominator that the present literature cannot supply. Neither measure needs a new sampling frame; both need the counts to be written down.

Strengths and limitations

The main strength is that eligibility for the pooled analysis was decided on two verifiable fields rather than on judgement, and that every species count was reconciled against the source table. The routing rule from title/abstract to full text is deterministic and scripted, so the selection can be reproduced exactly. The decision to exclude studies whose species was fixed by design removed 63 isolates that would otherwise have inflated the *L. infantum* proportion by construction.

The limitations are substantial and they run in the same direction. Duplicate screening was performed on a random sample of 150 records, 27% of the corpus, rather than on the whole of it; the reviewers' agreement on the sample cannot be assumed to hold exactly on the remainder. Web of Science and Embase could not be searched. The catalogue of the Rabat faculty could not be paged beyond its first page of results, so grey-literature coverage cannot be claimed as exhaustive. The pre-registered procedures for obtaining texts from authors and faculties were withdrawn during the review, so reports that were identified but not available online are counted as not retrieved rather than assessed; 28 catalogue records fall into this category, together with theses deposited as metadata only. Assessment was closed on 7 September 2026; reports identified but not obtainable by that date are counted as not retrieved, as the flow diagram shows, and the estimates reported here are final for this review. Two contributing series could be read only through the publisher's abstract, the full text not being available to us; their species counts and denominators are stated explicitly in those abstracts and were checked for internal consistency, and removing both moves the pooled *L. tropica* proportion by less than one percentage point.

Two further limitations concern the studies themselves. Sampling is a convenience process in almost every series: isolates reach the national reference laboratory when a clinician chooses to send them, and the JBI appraisal marks this as the recurrent weakness of the corpus. And several series are hospital-based, so their denominators reflect referral patterns rather than the population of a province.

Conclusion

Among human *Leishmania isolates* identified to species in Morocco, *L. tropica* is the most frequently reported, followed by *L. major* and *L. infantum*. But the pooled figures should not be carried into practice: between-study variance dominates, and species composition is determined by the focus rather than by the country. Control planning requires provincial data, and for much of Morocco those data do not yet exist. The most useful conclusion this review can offer is a map of where identification has been done and where it has not — and a caution against the practice, widespread in the national literature, of naming a species from the geography rather than from the laboratory.

Declarations

Funding. No funding was received for conducting this study.

Competing interests. The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval. This is a systematic review of published aggregate data. No ethics approval and no informed consent were required; no new data were collected from human participants or animals.

Data availability. The extraction sheet, the deterministic routing script, the analysis code and the full list of assessed records with reasons for non-contribution are deposited with the OSF registration (https://osf.io/jkub2).

Author contributions. AE conceived the review, wrote and registered the protocol, ran the searches, screened records, extracted and checked the data, performed the analysis and drafted the manuscript. SEEK performed the independent duplicate screening of the random sample and contributed to the resolution of disagreements. MC contributed to the statistical analysis and its interpretation. All authors read and approved the final manuscript.

Registration: OSF Registries, DOI 10.17605/OSF.IO/JKUB2, registered before screening; amendments 01–04 filed during the review and deposited with the registration.

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Figures

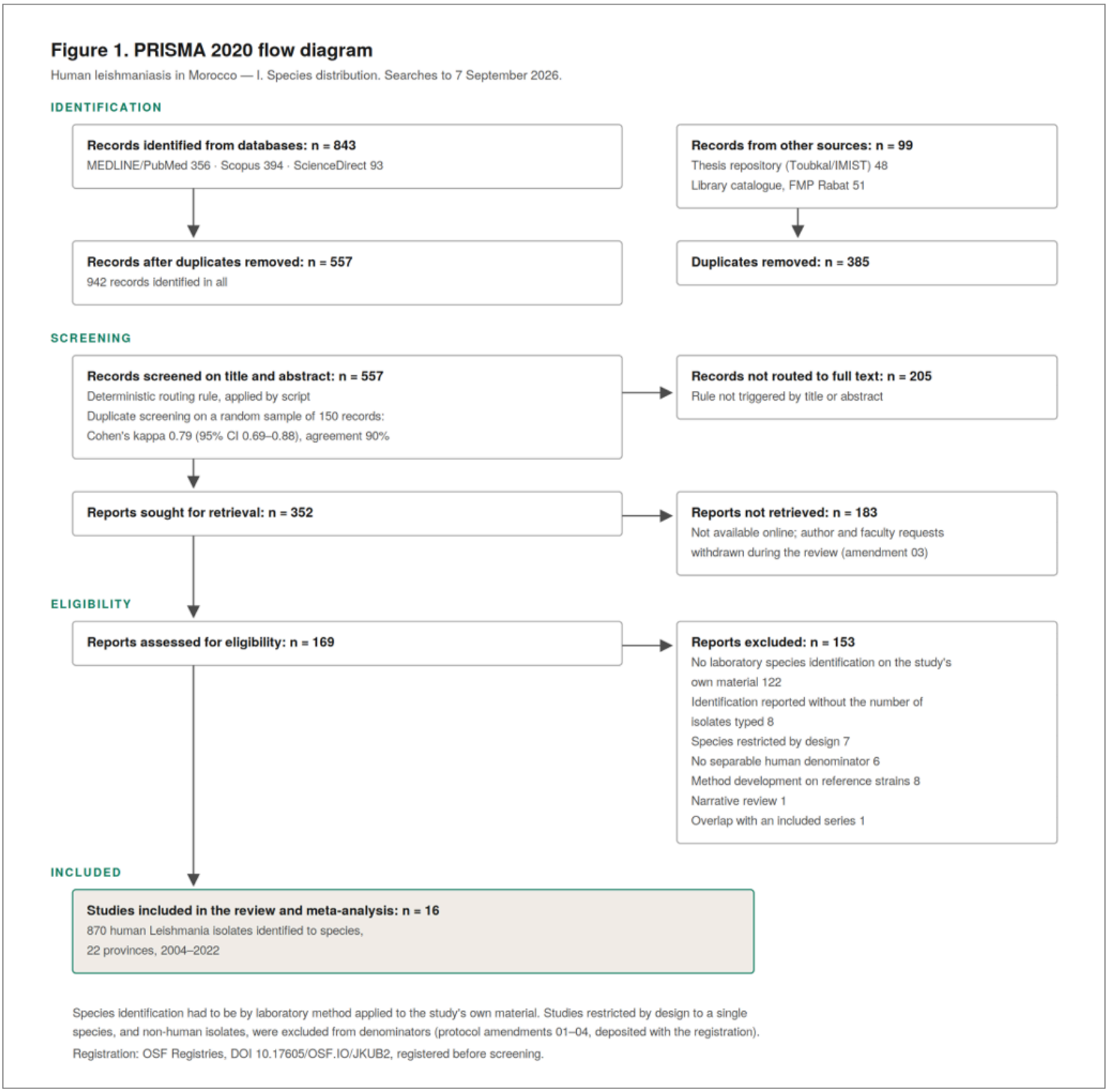


Figure 1

PRISMA 2020 flow of records.

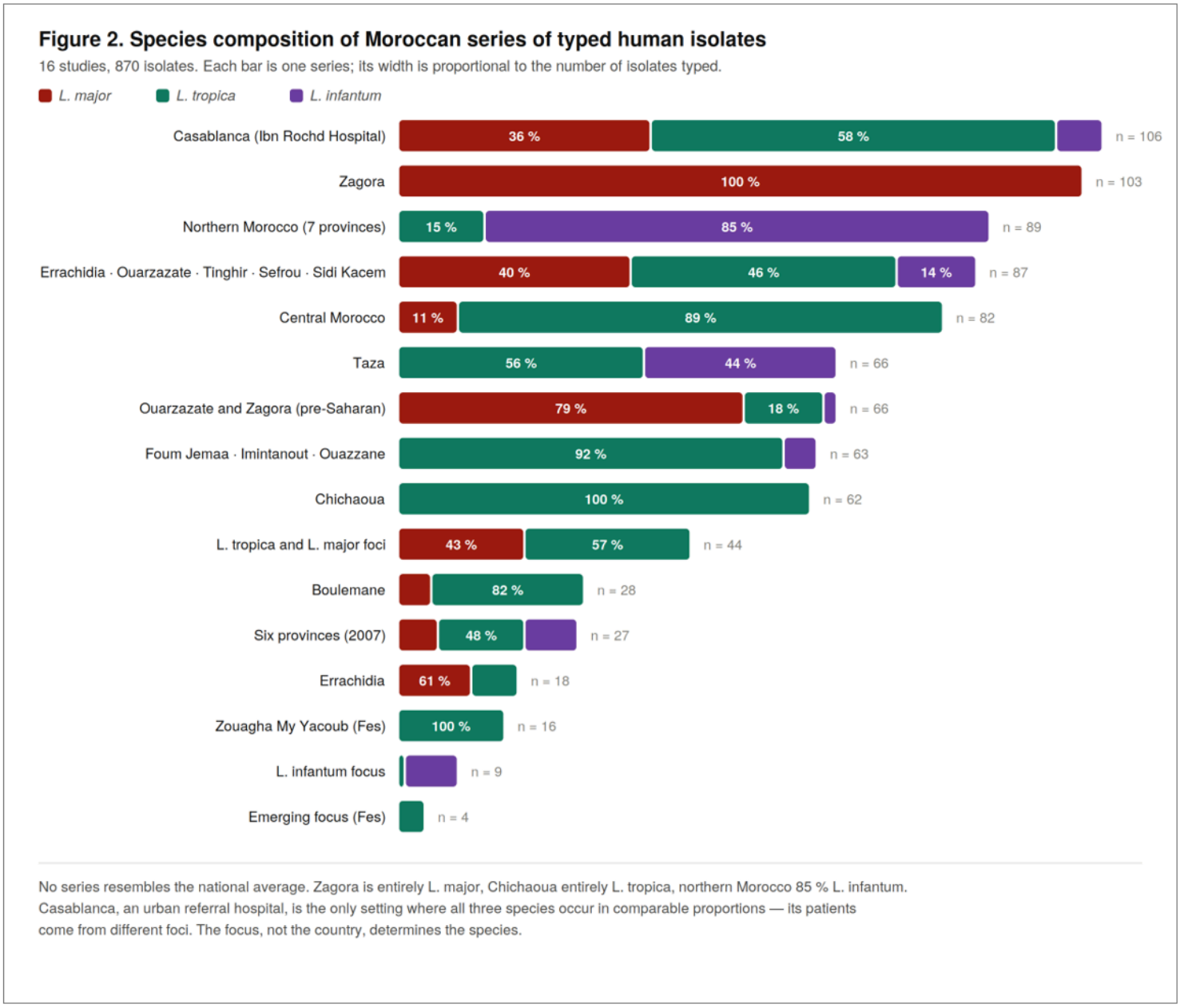


Figure 2

Species composition of Moroccan series of typed human isolates.

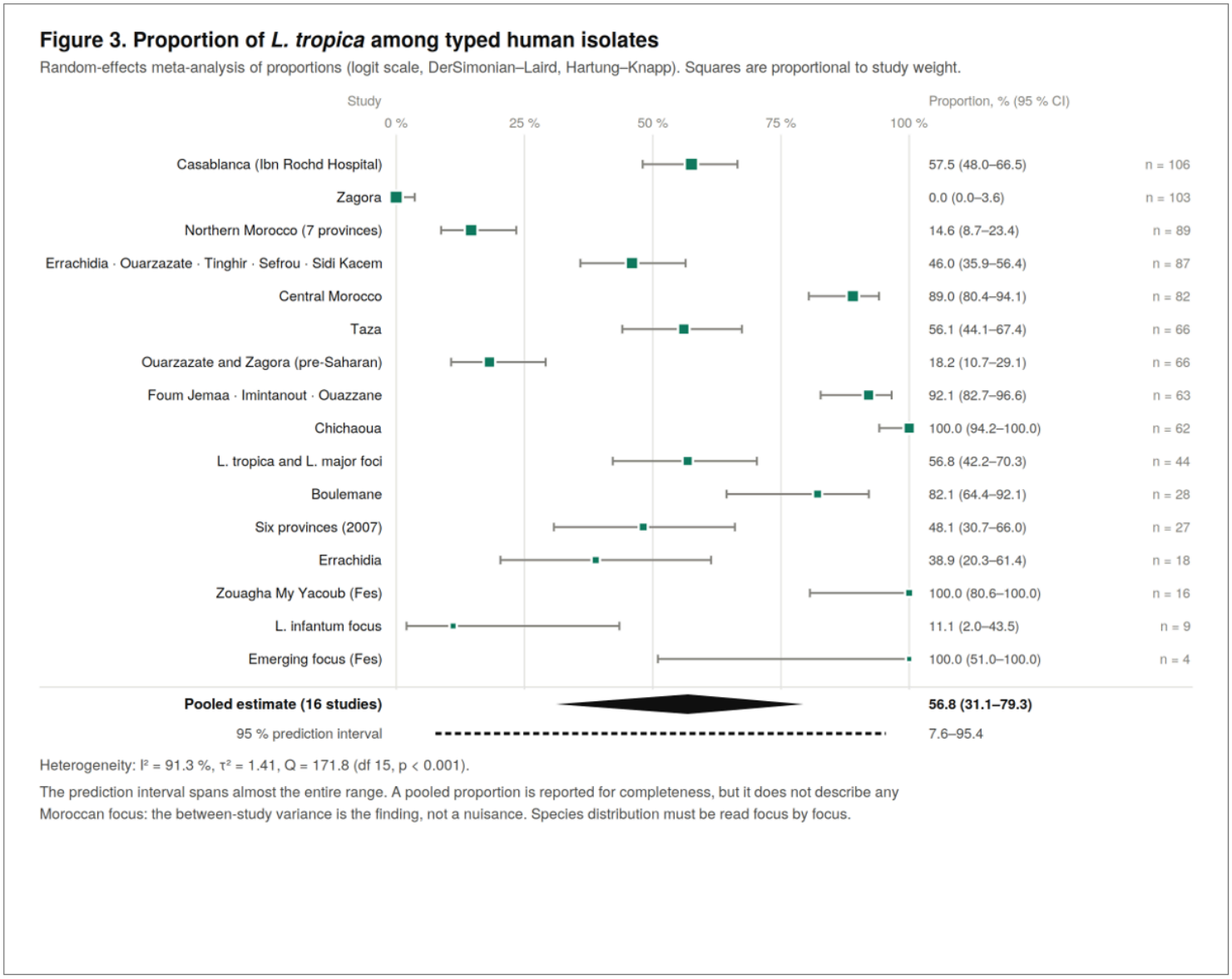


Figure 3

Proportion of *L. tropica* among typed human isolates, with 95% confidence and prediction intervals.

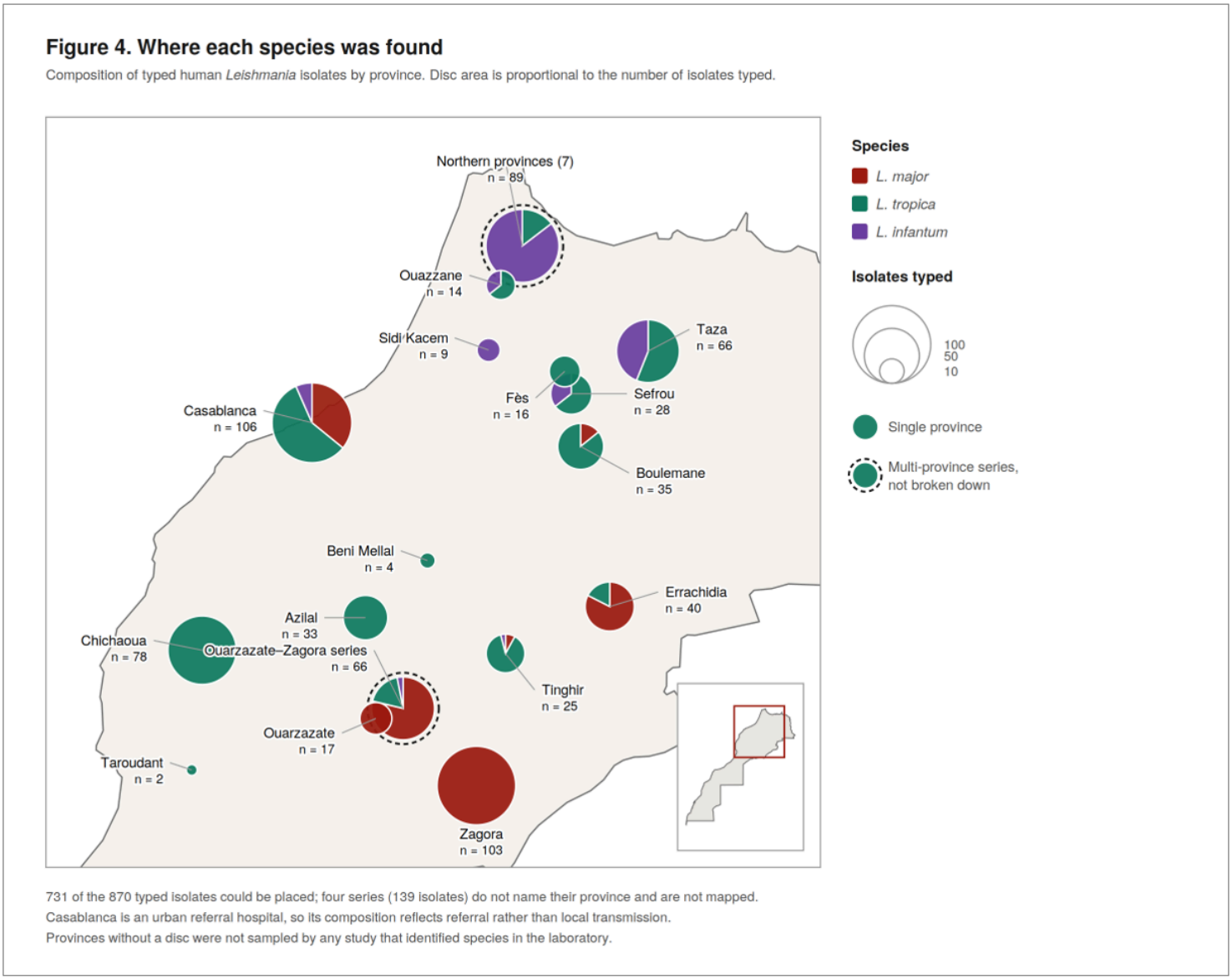


Figure 4

Composition of typed human isolates by province.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementaryextractiondata.xlsx
- PRISMA2020checklist.docx